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European Inland Fisheries
Advisory Commission (EIFAC)

Management of freshwater fisheries

Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May – 3 June 1988

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Preface

The European Inland Fisheries Advisory Commission (EIFAC) is a regional fishery commission of the Food and Agriculture Organization of the United Nations (FAO) and was established in 1957. EIFAC has 3 sub-commissions active in the field of inland fisheries: I. Fishery biology and management. II. Fish culture and diseases. III. Fish and polluted water. One of the activities of sub-commission I is the Cooperative research programme on lake fisheries management (COPLAKE).

In 1984, the working party on COPLAKE recommended to Sub-Commission I that EIFAC consider holding a symposium dealing with the state and prospects of inland fisheries. In 1986, the 14th Session of EIFAC (Bordeaux, France) identified the need for a general review and evaluation of fishery management schemes and recommended that a symposium on this topic be organized in conjunction with the 15th Session.

Over the past 30 years, EIFAC has focused on a broad variety of management-related topics such as the ageing of fish, sampling, the establishment of criteria for water quality, and the effects of habitat modification. A general review and evaluation of fishery management as an organized process in inland waters has not, however, been carried out.

This Symposium was held in Göteborg, Sweden on 31 May-3 June 1988 and was attended by 105 participants from 24 countries. In his opening address, Mr B. Steinmetz, convener of the steering committee, reviewed the broad variety of EIFAC activities preceding the Symposium, and which prepared the ground for it. As fisheries management is becoming part of the overall integrated management of freshwater ecosystems in several EIFAC countries, the symposium focused on all aspects of fishery management, including commercial, recreational and nature conservancy uses. It included a multi-species approach which where possible, took into account the trophic status and the nature of the fish community of the water body concerned. The symposium was run as six consecutive sessions: 1. General aspects of European Inland Fisheries Management. 2. Lakes. 3. Reservoirs. 4. Linear systems (rivers, canals). 5. Estuaries. 6. Recommendations. In the last session, the principal documentation comprised 70 papers, 27 of which were presented. The French contributions were translated by FAO before inclusion in these proceedings.

The Steering Committee for the Symposium consisted of B. Steinmetz (The Netherlands) Convener, W.L.T. van Densen (The Netherlands) Secretary, T. Backiel (Poland), M. Bninska (Poland), K. O'Hara (United Kingdom), E.A. Huisman (The Netherlands), G. Leynaud (France), H. Löffler (Federal Republic of Germany), L. Nyman (Sweden), R.A. Ryder (Canada), P. Tuunainen (Finland), J. Vostradovsky (Czechoslovakia) and R.L. Welcomme (FAO, Rome). The Swedish Organizing Committee comprised B. Holmberg (National Board of Fisheries) and L. Nyman (Institute of Freshwater Research, Drottningholm), whose efforts, together with those of the Swedish Administrative Team, are acknowledged with gratitude.

Wim L.T. van Densen
Secretary to the Steering Committee

Summary of session proceedings and recommendations

1. Introduction

Many aspects of fisheries management in European inland waters have been dealt with during previous symposia organized by EIFAC, during workshops and technical consultations which EIFAC organized or participated in, or in reports published by EIFAC. Some of these were concerned with technical aspects, like sampling methods (Backiel & Welcomme, 1980) and their application in appraising fishery resources (Welcomme, 1975), the application of specific techniques, such as the assessment of pelagic fish stocks by acoustic methods in Lakes Konnevesi, Constance and Tegel, and eel fishing gear and fishing gear intercalibration experiments. Others were concerned with biological and ecological matters, like ageing, the ecological diagnosis of salmon streams, habitat modification (Alabaster 1985) and the decrease of aquatic vegetation. A major concern has been with water quality and its impact on habitat (Alabaster & Lloyd 1980). More recently attention has been paid to problems of introduction and stocking (EIFAC 1984). Also, more integrating aspects such as organization, administration and economic evaluation, and recreational fisheries were dealt with. The objectives of this symposium were:

1. to collect information on the significance of inland fisheries in the member countries of EIFAC;
2. to compare the fisheries management processes whereby decisions are made at different organizational levels for different types of water body, and to discuss the information needed to support them;
3. to indicate constraints on these management processes for inland waters and suggest measures for alleviating them, and;
4. to examine ways in which data on catches, fishing effort and biological research are collected, presented to, and used, by those responsible for fisheries management.

The sessions of the symposium were divided into categories dependent upon the types of waterbody concerned, based on the belief that fisheries management is more closely tied to type of waterbody than anything else. Thus, *e.g.*, the fisheries management of reservoirs has to deal with constraints on the fishery imposed by overall water use patterns, and in linear systems, various types of fish community have to be managed according to the prevailing use and hydrological regime of the system. In the case of estuaries, not only is management involved in seeking a rational exploitation of local resources, but also in protecting the passage of migrant species.

2. General aspects

The session opened with contributors asserting that several aspects of fisheries management are common to both professional and recreational inland fisheries, and to different types of waterbodies such as lakes, reservoirs, rivers and estuaries. It follows that to compare the management of these systems, it is necessary to perceive fisheries management as a decision-making process, with a simple common structure, which can be applied to locally specific situations by relevant responsible organizations.

The first step in the management process is to gather information on the fish stocks and the fishery. Routine surveys and other fishery-independent data are needed to follow trends and fluctuations in the fish stocks, but these are generally expensive, at least in terms of manpower. Savings can be achieved by limiting research effort to the levels required to meet management objectives, and by refining the design of any current research in the light of results already obtained. Standardization and computerization of the collection and processing of routine survey data can save a lot of time (52). Mapping catchments, and discovering the ecological characteristics of their fish stocks and environments, as done in France (18), is a management tool whose potential has yet to be fully exploited.

It was emphasized that decision-making in fisheries management should be based on the evaluation of quantified management objectives (26, 30). These should be realistic and clearly specified, and should identify all data requirements. It was pointed out that the range of objectives has been broadened in recent years to include the use of fish to improve water quality in some water bodies, especially in water supply reservoirs (3, 6, 28, 29).

Fishery-dependent catch-effort data were said to have two functions. They both inform the manager about fish stocks, and they form the basis for evaluating the management programme when the objectives are defined as a desired catch level. The lack of such data makes fisheries management on behalf of recreational and professional fisheries impossible (31). The production of catch/effort data requires a good recording system, and also that recreational and professional fishermen have been educated to a sufficient level in fishery management. Government organizations should endeavour to improve mechanisms for collecting catch/effort data wherever possible. Examples of recording systems for catch-effort data of recreational fisheries came from Lake Geneva (16) and from rivers in England (47) and Wales (49). Good catch data of professional fisheries exist for a number of large waterbodies (4, 16, 21, 22, 25, 27, 40, 41, 42, 55).

Regulations were seen as essential elements of fishery management which should have sufficient flexibility to achieve the management objectives desired (35). With increases in the complexity of regulations, the need for well-educated and informed user groups also increases. This was also recognised as being true for the successful implementation of fishery management schemes, for which the education of decision-makers, user groups and the general public is of major importance (24, 32).

Concerning the organization of management, it was recommended that management responsibilities should be clearly stated in fishery regulations and government acts, where this has not already been done. Special attention to the organizational aspects was given in contributions on Swedish management units (39) and on the fisheries management of Swiss lakes (42) and of Lake Trasimeno, Italy (25). It seems that lakes with internationally managed fisheries have the most thoroughly worked-out organization schemes (4, 16, 55). National reviews of inland fisheries management were presented for Turkey (43) and the USSR (44). Those for Greece (20) and Switzerland (42) contained detailed biological backgrounds. Socio-economic backgrounds were highlighted in other contributions (13, 29).

3. Lakes

It was reported that, both in Europe and North America, the largest and most valuable fisheries resources are over-exploited. Unrestricted access to fishing, leading to competition between commercial fishermen in large productive lakes, such as Lake Erie, Canada (55), and Lake IJssel, The Netherlands (27), encourages over-fishing.

To be effective, fisheries management must allow a flexibility of response, and must involve an appropriate blend of timeliness of application and precision in results. For expansive fishery systems in danger of over-exploitation, the timing of the analysis, and the application of the regulatory device, may be more important than in a closely monitored, contained system, where fine precision is sought. Hence, the scale of the lake system is an important management consideration.

Another matter to become clear during this session was that the perception of the value of different species of fish was subject to regional variation. As a generalization, salmonids are preferred in northern Europe while cyprinids are the fish of choice in Central European and Mediterranean countries. Hence, a unification of management philosophies and ultimate management goals for European countries may be determined only at the most fundamental level.

Under-utilized resources were discussed and it was claimed that detailed management plans may be unnecessary when a resource is not being utilized, or is vastly under utilized, as is the case with vendace in Finland (5, 9, 10, 14). However, a potentially valuable, under-utilized resource, offers an opportunity for future regulation without conflict, by establishing regulation before the resource is heavily exploited. Many of the under-utilized resources of northern Sweden and Canada offer opportunities for planned management without confrontation. Such opportunities are rarely grasped.

It was clear from several contributions that the management approach to severely degraded lake fisheries varies widely. Stocking in this respect is the major management measure applied (11, 36). Some lakes are stocked, virtually to the point where fish can no longer survive, thus extending a fishery beyond the point where it would cease to exist after all natural reproduction failed. However, to make rehabilitation of the environment the prime consideration is a preferred approach. Attempts to retain natural fish communities are in many instances as the most pragmatic approach to the management of inland lake fisheries (54). This approach is strongly favoured by French and Swedish authorities. It attempts to sustain, in perpetuity, yields from naturally reproducing stocks without the need for introducing exotic species. However, this stance is difficult to maintain under the continual pressure exerted by certain user groups, particularly by anglers who are interested in fishing exotic species.

Other papers dealt with future moves toward the integration of resource and environmental management, emphasizing the advantage of this practice to the management of fisheries. A well-conceived ecosystem approach, while not offering a solution to all fisheries problems, would herald the advent of a truly rational approach to most of them.

It became clear that responsibility for fisheries management rests with different authorities in different countries; central governments are responsible in some countries, regional or state governments in others, while in yet others it is individuals who own the water rights and hold responsibility. Further, responsibilities for fisheries often conflict with the responsibilities of other institutions charged with, among other things, preserving water quality. Thus, *e.g.*, which authority should be responsible for mitigating the effects of acid rain on fisheries should be clearly determined in each country. Similarly, there should be clear delegation of authority for special aspects of fisheries management in lakes, such as the protection of rare and endangered species.

4. Reservoirs

Most reservoirs are created and operated principally for purposes other than fisheries, which adversely affects the management of their fishery resources. The effects of reservoir construction and operation, on indigenous and introduced fish species, and the exploitation and management of these resources for commercial or recreational purposes, were the main topics discussed. Inundation of spawning areas and consequent loss of riverine species from impounded areas was a common experience, together with the obstruction of migratory routes. As most fish-spawning occurs in littoral zones, and as they these zones are also sites for the greatest production of fish-food organisms, severe degradation of fisheries occurs in lakes with high annual drawdowns. Stocking is a major management measure taken in reservoirs all over Europe (1, 3, 7, 33). Reservoirs benefit fisheries in Cyprus, since fisheries have been created where none previously existed (1).

It was concluded that the full potential of reservoirs as fishery resources should be recognized, promoted and developed. Fishery and other biological management policies should be included when reservoirs are planned or constructed, and as conflicts may arise between different reservoir users, an integrated and collaborative approach to fisheries management in reservoirs was seen to be essential.

5. Linear systems

Riverine fisheries usually receive low priority compared to other uses of the water resource, but the ecological and aesthetic values of rivers are being increasingly appreciated as pollution and habitat degradation cause fish diversity and fish stocks to decline. (It was reported that some rivers have been modified to a level where they almost cease to be recognizable as rivers (2).

The restoration of fish stocks in formerly polluted rivers, and in those affected by flow regulation, received a great deal of attention. Management situations with conservation objectives were reported, including the re-establishment of migratory trout and salmon in Polish, Finnish, French, and United Kingdom rivers (12, 17, 41, 45). While the objective of such programmes was the establishment of self-sustaining populations, it was recognized that stocking was important in the early stages. In the case of the River Thames (United Kingdom), the demonstration of improved estuarine water quality was an important consideration in planning the project (45).

The complexity of management of linear systems results from their multiple use, especially where the requirements of commercial or recreational freshwater fisheries conflicts with other interests (19, 50). Such programmes have been overcome in England and Wales by the establishment of integrated management bodies (Water Authorities), but changes are currently proposed in their structure and the consequences for fisheries are, as yet, unknown (46, 51).

It was concluded that management of rivers must be evaluated both in ecological and in socio-economic terms, although it was recognized that socio-economic factors are, and will remain, a major constraint on fisheries. Fisheries can serve as a valuable measure of the well-being of a river as concluded for French inland fisheries (15). It was felt that linear systems have several characteristic features which differentiate them from other aquatic systems.

6. Estuaries

Estuaries are extremely important ecosystems which, although of limited extent when compared to the open sea and to rivers, are both important feeding and nursery grounds for fish, and important transitional areas between fresh and salt water for migratory species. They constitute complex habitats which are particularly vulnerable to exploitation by man, and they provide attractive areas for economic development.

It emerged that in northern Europe, fisheries management in estuaries concentrates on the maintenance and improvement of migratory salmonids (12, 34, 45); in France it concentrates on salmonids (17), and also on shad and sturgeon stocks (19); in Italy on mullet and on the use of estuarine lagoons for aquaculture (23); in Romania on sturgeon and cyprinid stocks (38); and in Portugal on migratory fish (37). Declining populations and reduced species diversity have been reported from various investigations, and in these cases there is an urgent need for managerial measures to mitigate these effects. Fishery management for rehabilitation of rare fish species may be a high priority in some countries. Fishery studies have lead to the restoration of sturgeon *(Acipenser sturio)* stocks in the Gironde River (France). Rehabilitation of the River Thames to a point where the quality of the water is adequate for free upstream passage of salmon, is an example of a successful scheme, based on sound fishery and economic commitment.

Demands on estuaries by industrial and other interests, such as water abstraction, cooling water demand, sewage disposal, dredging, navigation, engineering structures, land reclamation, etc., frequently interfere with the maintenance of fish and fisheries. Fishery management of estuaries, like that of reservoirs and linear systems, frequently has to work under constraints placed on aquatic organisms and their environment by other users of the water resource. The responsibility for fishery management in estuaries usually rests with several government organizations since fish stocks are both of marine and riverine character (48). It was concluded that the formulation of policies for the protection and management of estuaries should be closely integrated into plans for the overall development of the river basin and the estuarine area itself.

7. Recommendations

On the basis of the scientific data provided by the symposium, the session made the following recommendations:

- an ecosystem approach to fisheries management should be encouraged. In the long term, effective management of fisheries in inland waters can only be achieved by the integration of all management schemes which affect these waters. As a first step managers of all aspects of the water system should have more opportunities to exchange information and to discuss proposed policies and developments;
- collection of catch and effort data needs to be further improved and governments, through their various organizations, should endeavour to improve the mechanisms for such collection wherever possible. The gathering of fishery-independent data by routine surveys should be organized in such way as to meet the information needs of the fisheries management;

- efforts should be directed toward the standardization and analysis of data collection. The resulting data should be made available in the most appropriate form for various user groups;
- EIFAC should stimulate the distribution and use of computer programs for inland fisheries research and management;
- EIFAC member countries should periodically review and update their inland fisheries management policies to ensure management practices appropriate to current problems;
- education in fisheries management at the levels of decision makers, user groups and the general public is of major importance. EIFAC should stimulate the development of educational activities and materials at all these levels, and;
- governments should encourage the active participation of professional inland fishermen in the management of fisheries and the freshwater environment.

References

Alabaster, J.S., 1985. Habitat modification and freshwater fisheries. FAO, Butterworths, London. 278 pp.

Alabaster, J.S. & Lloyd, R., 1980. Water quality criteria for freshwater fish. Butterworths, London. 297 pp.

Backiel, T. & Welcomme, R.L. (Eds), 1980. Guidelines for sampling fish in inland waters. EIFAC Technical Paper No. 33. 176 pp.

EIFAC, 1984. Documents presented at the Symposium on stock enhancement in the management of freshwater fisheries. EIFAC Technical Paper No. 42. Suppl. 554 pp.

FAO, 1981. Allocation of fishery resources. Ed. Grover, J.H. FAO with the American Fisheries Society. 623 pp.

Welcomme, R.L. (Ed.), 1975. Symposium on the methodology for the survey, monitoring and appraisal of fishery resources in lakes and large rivers. EIFAC Technical Paper No. 23. Suppl. 1. 747 pp.

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Twenty years of experience in managing Cyprus reservoirs for angling

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Abstract

Natural freshwater bodies do not exist in Cyprus and periods of drought are not uncommon. There are no indigenous freshwater fish on the island. The government undertook a major dam building scheme in 1960 which increased the impounded capacity from 6 million tonnes to 273 million tonnes in 1988. The Department of Fisheries has, during the last twenty years, imported suitable fish species for the exploitation of dams for angling. Now 19 species are found in the Cyprus reservoirs.

In this paper information is given on the procedures followed for importing and stocking various species as well as on the fish population present in each dam. The stocking policy, as formulated through twenty years of experience, is cited. The problems faced in managing the fish stocks for angling are discussed. Reference is made to the constraints and problems encountered because of the management and use of the impounded water by different authorities for irrigation and drinking. Statistical data on angling licences are analysed. The main provisions of the angling regulations are given, as well as information on the relevant legislation. The contribution of angling to the promotion of the recreational use of reservoirs is discussed and information is given on the provision of facilities to anglers. The recent utilization of the dams for the cage culture of trout and the mass production of ornamental fish is mentioned. Potential developments are discussed briefly.

1. Introduction

Natural freshwater bodies do not exist in Cyprus, the third largest island in the Mediterranean Sea. The only natural lakes are those of Akrotiri and Larnaka which are salt lakes and dry up during the summer. Drought periods are not uncommon and the increasing need of water had to be met with the construction of dams. For this reason the Government undertook a major dam building scheme which increased reservoir capacity from 6 million tonnes in 1960 to 273 million tonnes in 1988. Twenty reservoirs, which cover 1177 ha in total and have a capacity of 261 million tonnes, were stocked with fish and are used for angling. The island lacked indigenous freshwater fish and all species had to be introduced and acclimatized to the local conditions.

The fish stocks are managed by the Department of Fisheries, while other departments and bodies are involved in the management of the water of the reservoirs for various purposes.

2. Reservoirs

2.1 Their use

The main reasons for constructing the dams were to provide water for irrigation, local industry, and the domestic needs of towns, villages and the flourishing tourist industry (over 1 million tourists in 1987) (Kondeatis 1974). The result has been the construction of dams of ever increasing size. Because of their various uses the quality of the water in the reservoirs is safeguarded by the enforcement of several laws by appropriate Government Departments.

The dams either belong to the Government, as Government Water Works, or to Irrigation Divisions which are formed by the landowners who use the water from the reservoirs. Government reservoirs are managed either by the Water Development Department or by Water Works Committees, while those which belong to Irrigation Divisions are managed by Irrigation Committees, the members of which are elected from among the members of the Irrigation Divisions. The maintenance of the dams of both categories is undertaken by the Water Development Department.

Most of the major dams belonging to the government are designed for over annual storage and no maintenance problems are faced. Water for domestic purposes is supplied only from the Government Water Works, directly through special Water Treatment Plants, or indirectly, by the enrichment of aquifers where boreholes for pumping drinking water exist.

2.2 Physico-chemical characteristics

The dams which are stocked with fish are usually mesotrophic to eutrophic (Ricker 1968). The water has high pH and is hard, especially that of reservoirs lying on the lowland chalks. Highland dams lie on diabase igneous rock. The water temperature of the lowland reservoirs varies between 12-29°C, while that behind the highland dams ranges from 8-27°C. Cyprus dams are built at altitudes ranging from about 30 to 1570 m asl.

The dams which are used for angling are listed in *Table 1,* where detailed information is given on their surface areas, capacities, mean depths and fish species present (Kondeatis 1974).

3. Introduction of fish for angling

Most of the fish species and the more useful ones for angling were introduced during the last 20 years from Canada, U.S.A., Israel, U.K. and Hungary among others. Now 19 species, including game and coarse fish, are found in Cyprus reservoirs. Most of them did not have a Greek name and it was necessary to give them common names which either referred to their most distinctive morphological features or to their habits.

Table 1. Altitude, capacity, area and mean depth of 20 Cyprus dams used for angling and the fish species present in them.

Reservoir	Altitude (m asl)	Capacity ($x 10^3 m^3$)	Area (ha)	Mean depth (m)	Trout	Mosquito fish	Carp	Roach	Bleak	Grey mullet	Cray fish	Eel	Bass	Perch	Catfish	Tilapia	Goldfish	Pikeperch	Tench	Silver bream
Prodhromos	1 570	110	2.6	4.2	*	*														
Palekhori	700	620	11.0	5.6	*	*														
Kalopanayiotis	550	390	4.7	8.3	*	*														
Xyliatos	502	1 220	9.6	12.7	*	*														
Lefkara	290	13 850	65.0	21.3	*	*	*	*	*	*	*									
Kafizes	260	113	2.0	5.6	*	*	*													
Lefka	250	368.45	4.5	8.2	*	*	*					*	*	*						
Lymbia	200	220	8.5	2.6		*	*				*	*	*	*	*	*				
Athalassa	170	20	1.0	2.0		*	*				*					*	*			
Kouris	150	115 000	340.0	33.8		*	*	*										*		
Dhypotamos	131	13 700	96.0	14.3		*													*	
Kalavasos	126	17 100	87.5	19.5		*	*						*							
Ayia Marina	120	320	3.3	9.7		*	*													
Evretou	102	25 800	126.0	20.5		*	*									*				
Polemidhia	100	3 700	11.0	33.6		*	*					*	*	*	*					
Pomos	75	840	8.3	10.1		*	*													
Mavrokolymbos	70	2 180	17.5	12.5		*	*	*												
Argaka	65	1 150	10.7	10.7		*	*	*												
Yermasoyia	60	13 600	110.0	12.4		*	*	*	*	*			*	*						*
Asprokremmos	30	51 000	259.0	19.7		*	*	*												

3.1 Legislation

Aquatic resources are government property. The Department of Fisheries is the appropriate government Department which, in exercise of its powers under the relevant law, is responsible for angling in reservoirs as regards provision, management and allocation (licensing) of stocks. The work is entirely financed by the government. Thus, according to Regulation 8C (a) of 1981 made under the provisions of the Fisheries Law Cap. 135, no legal or physical person can introduce into the country living fish or fish ova, at any stage of development, without prior written authorization by the Head of the Department of Fisheries and subject to any terms he may impose.

3.2 Policy for fish introduction

The policy was formulated during the last two decades on the basis of experience gained, local needs, means available, and the relevant guidelines of the European Inland Fisheries Advisory Commission (EIFAC) and other international organizations such as the International Council for the Exploration of the Seas (ICES) and the Office International des Epizooties (OIE).

The species to be introduced were selected according to the certain criteria (EIFAC 1980, Stephanou 1982). They had to be:

- Fish suited to the physico-chemical characteristics of the chosen reservoir.
- Species attractive for anglers.
- Species with good flesh quality.
- Species which meet other needs of the Fisheries Department, such as the production of ornamental fish, *e.g.* Koi carp.
- Species which fill a vacant niche, *e.g.* crayfish *(Astacus astacus, Pacifastacus leniusculus, Procambarus clarkii)*.

Apart from the above criteria, which are valid for fish intended for stocking the reservoirs, other species, including several species of trout and salmon, *e.g.* coho *(Oncorhynchus kisutch)* and Atlantic salmon *(Salmo salar)*, were introduced to the island and kept for experimental culture in proper installations.

Before each introduction an extensive study of the requirements of each species was carried out and information on relevant experience from other countries was collected. Anglers' views were also taken into consideration. Every effort was made to locate sources of hatchery reared fish (avoiding collection from the wild) and to introduce the fish at an early life stage. For some species this was not feasible.

According to legislation of the Veterinary Services Department a certificate of health, issued by the appropriate authority of the country of origin, must accompany each consignment of live fish to Cyprus. Cyprus is considered free from major fish diseases. The requirements of the Veterinary Services Department are based on the guidelines given by the draft International Convention for the Control of Communicable Fish Diseases of EIFAC/OIE (FAO/OIE 1977, OIE 1986).

In addition to the precautions taken in the country of origin, upon arrival, the fish are kept in quarantine for several weeks and undergo several treatments to eliminate the possibility of introducing fish diseases. Usually they are subsequently stocked in small reservoirs, where fishing is not allowed, to grow and reproduce. The second generation is used for stocking other reservoirs for angling (Kohler & Stanley 1984).

4. Stocking reservoirs for angling

4.1 Legislation

According to the provisions of the Fisheries Law Cap. 135 Regulation 8C (b) of 1981, no fish may be stocked into any inland water without previous written authorization by the Head of the Department of Fisheries, and if authorization is granted, it is subject to any terms he may impose.

4.2 Stocking policy

When deciding on stocking the following points are taken into consideration (Alabaster & Lloyd 1982, Stephanou 1982):

- The physico-chemical characteristics of each reservoir have to meet the requirements of the fish. The water temperature is the main parameter which is considered.
- The qualities of the species from the angling point of view. Good fighters and large-bodied species are greatly appreciated and sought after by anglers, *e.g.* large-mouth bass *(Micropterus salmoides)* and rainbow trout *(Salmo gairdneri irideus)*. Large carp *(Cyprinus carpio)*, and cyprinids generally, are of secondary importance, predators being more popular. The red swamp crayfish *(Procambarus clarkii)* is also very popular, especially with young anglers.
- The quality of the fish flesh, since only the anglers of English origin practice 'catch and release' angling. The rest eat their catches. Indirectly this practice helped the expansion of the local market for farmed trout which represented a new taste for the Cyprus cuisine. Carp are not appreciated for their taste, especially those caught in lowland reservoirs during the hot season.
- The establishment of fish populations of a suitable composition, so that good angling opportunities exist all year round. This is valid mainly for lowland reservoirs.
- The creation of a balanced community, *i.e.* a community which includes a variety of species occupying different niches and having different food requirements. According to current practice the reservoirs are at first enriched with prolific, omnivorous species and later with predators. Other species are added gradually.

The species which are presently found in each Cyprus dam used for angling are listed in *Table 1* (EIFAC 1984). These may change from one year to another. Extinction of unwanted species is effected when the reservoirs are emptied for maintenance purposes, or at the end of the irrigation season, when the water levels decline. This practice is mainly used for small dams, while in large dams this purpose is more efficiently served by predators. There is no need to thin-out fish populations, except those of carp in certain reservoirs. The predators, mainly bass and perch *(Perca fluviatilis)*, serve to control the sizes of the populations of cyprinids and tilapia hybrids *(Tilapia aurea* x *T. nilotica)*. The combination of the two predators helps overcome the problem of too many small sized perch.

Dams above the 300 m asl are stocked annually with trout for angling. Natural reproduction is of no significance. The suitability of various species of trout for stocking in reservoirs, *e.g.* brook trout *(Salvelinus fontinalis)*, brown trout *(Salmo trutta)*, cutthroat trout *(Salmo clarkei)* and rainbow trout, was tested for several years. Rainbow trout was found the most suitable salmonid for still water bodies and the ideal one for stocking reservoirs where angling depends largely on 1-year old fish.

The stocking material is produced at the government Experimental Freshwater Fish Culture Station at Kalopanayiotis and during the last three years it has been mostly 'all female' fish.

During the first years of trout stocking, large numbers of small sized fish (6-10 cm) were stocked in spring and angling was permitted in the succeeding winter-early spring. Soon it was proved that young trout perished, because of high summer temperatures. Also the emptying of the reservoirs in autumn-winter had adverse effects on the survival and growth of the fish. This has led to a change in the trout stocking policy in all but one reservoir. Now, smaller numbers, about 20 000, of larger fish (15-18 cm) are stocked in January. Before stocking new trout the reservoirs are enriched with mosquito fish *(Gambusia affinis)*. Thus the main trout angling season was switched from winter to spring. Trout angling in spring has certain advantages, since the water is offered for open air recreation and most of the trout are fished out before summer. Larger trout withstand the high water temperatures which prevail in the surface layers during the summer better than small specimens. They fast and find refuge below the thermocline, in the cool water layers.

The number of trout which must be stocked in each reservoir so that the fish attain a size acceptable for angling (usually above 20 cm) was found by 'trial and error'. Each reservoir is considered and dealt with as a separate case, and the stocking density is affected very largely by the richness of the natural food supply.

The presence of bleak *(Alburnus alburnus)* and large numbers of young carp in reservoirs which are used for trout angling was found to affect trout growth negatively, being competitors for food. Larger trout also compete with larger carp for food, especially during the warmer months of the year, when trout feed on the bottom fauna. So in recent years highland reservoirs have been stocked only with trout, except for some mosquito fish which serve as forage fish.

The lowland dams are stocked with a variety of warm water and eurythermic species, the most common of these being mirror carp and mosquito fish. The fish community is self-sustaining, although some additional stocking takes place, either to enhance an already existing species or to introduce a new one. The stocking material is collected from large reservoirs using shore seines, from small reservoirs when they dry up or are emptied for irrigation during summer (and which serve as spawning grounds for species which are purposefully introduced there), and by Angling Clubs, with rod and line, during angling competitions which are specially organized for this purpose (Bennett 1962, Gerdeaux & Billard 1985).

According to experience gained, stocking mature fish in new reservoirs is an efficient method for the fast production of fishable populations. This method has been employed for the past five years for stocking large new impoundments. Broodstock, mainly of carp and large-mouth bass, are collected with rod and line and stocked in reservoirs 1-3 months before the reproductive period, in order to give them time to acclimatize to the new environment. In reservoirs where angling is permitted, this period is shorter in order to eliminate the possibilities of fishing out the new broodstock.

5. Angling in reservoirs

The area around the high-water level of the dams, up to a certain level, belongs to the government and no riparian rights exist in Cyprus. Angling in freshwater started in 1969 with the issue of licences by the Department of Fisheries for fishing in the Athalassa Reservoir.

5.1 Licensing

The government owns the fishing rights on the island. From 1969-1981 the licences were issued free of charge. This helped attract the people's interest in the new sport, and experience on the management of fish stocks was gained. The licence was valid for a three-months period and it was not transferable. With the years the necessary steps for the development of this sector were identified and their legal framework was defined with the amendment of the existing law and the formulation of relevant regulations.

The amendment of the Fisheries Law Cap. 135, which was made in late 1981, provided for the collection of fees for the issue of licences and increased the fine imposed on offenders against any provision of Law Cap. 135 from a maximum of 500 C to a maximum of 3000 C (1 C=2.2$US). The relevant Fisheries (revised) Regulations of 1981 include Regulation 8 where it is stated that:

1. No person shall kill, pursue or catch any species of fish from any inland waters or possess or attempt to possess or sell such fish without the prior permission in writing from the Head of the Department of Fisheries or any person duly authorized by the Head of the Department of Fisheries and under such terms and conditions he may think fit. Provided that the Head of the Department of Fisheries may, in his absolute discretion, restrict, suspend or cancel the issue or validity, each case to be examined on its own merits, of fishing licences issued in accordance with the provisions of subsection (1) of the present Regulations.
2. All licences issued under this section shall expire on the 31st day of December of the year in which they were issued.
3. For every licence issued in accordance with the provisions of subsection (1) of the present Regulations the fee shall be 1 C.

'Inland waters' means any river, natural brook, dam, lake or salt lake.

In 1982 licensing was modified in accordance with the provisions of the new legislation and certain conditions were imposed on the fishing licence, which provide, among others things, for the following:

- A bag limit for trout of 15 fish.
- A minimum size for trout and bass of 15 cm.
- Anglers to provide the Director of Fisheries with any information relevant to their angling he may deem necessary.
- The daily angling hours.
- The method of angling.

The enforcement of the law is carried out by the Fisheries Inspectors and the technical staff of the Department of Fisheries who carry out patrols in the areas of the dams.

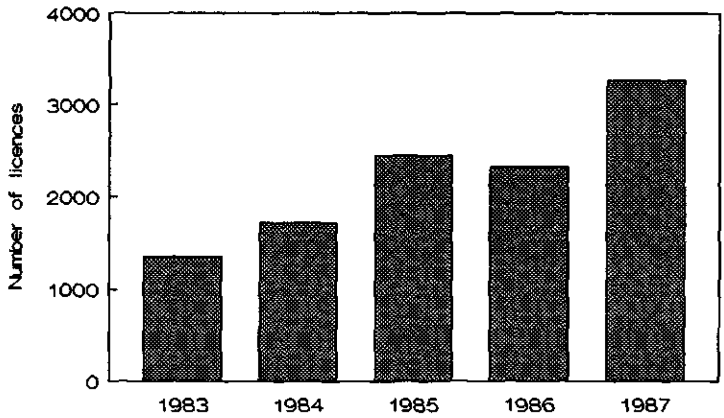

Figure 1. Angling licences issued during the period 1983-1987.

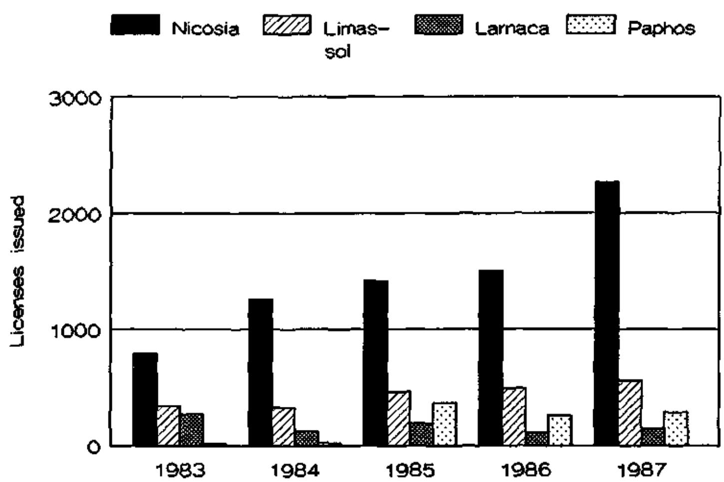

Figure 2. Angling licences issued by district during the period 1983-1987.

Poaching is less common now than 10 years ago. Publicity is given whenever fines are imposed on offenders against the Law.

5.2 Statistics

The licences are issued by the Department of Fisheries and there is an upward trend in their number *(Figure 1)*. It is interesting to note that a largest number of licences is issued for the large urban centre of Nicosia which lies in the central plain *(Figure 2)*. For most of its inhabitants angling represents a new form of open-air leisure activity, while those of the coastal towns of Limassol, Larnaca and Paphos have always been able to fish in the sea.

On the basis of the number of licences issued, a public preference for the highland reservoirs which are stocked with trout is evident. The licences for trout angling represented about 42% of the total in 1986 and 49% in 1987.

A large percentage of the licences is issued to foreigners resident in Cyprus, and to a lesser extent to tourists. The total number of anglers is estimated to be about 3000. Most of the anglers are rather young.

The Angling Clubs of the British Sovereign Base Areas organize angling competitions and collect data referring to their catches, the condition of the fish and fisheries etc., on special forms provided by the Department of Fisheries. *Figure 3* illustrates the catch per rod per hour at Polemidhia Reservoir. Also information on the situation of fish stocks in reservoirs is given by anglers when applying for licences or during patrols in the area of the dams. The return of specially designed questionnaires on fish catches, which were

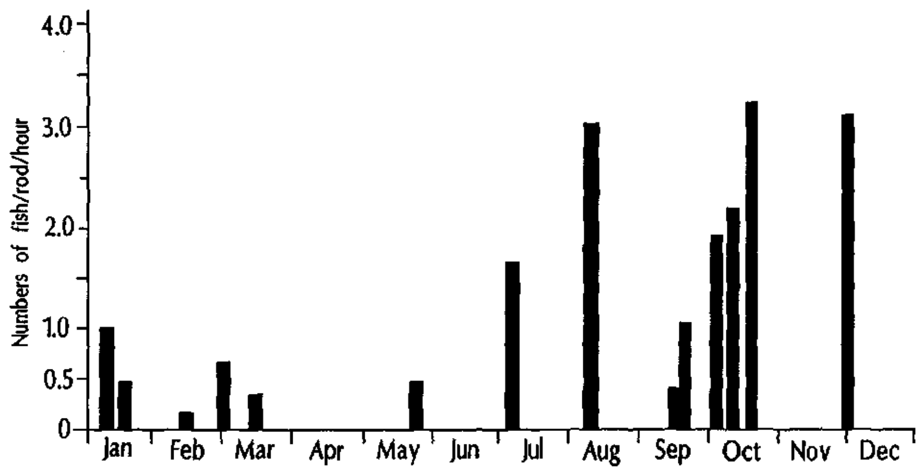

Figure 3. Catch per rod per hour at Polemidhia Dam during 1987.

circulated several times in the past twenty years, was very poor. Generally the issue of licences by the members of the Department of Fisheries facilitates a two-way, continuous flow of information between the fisheries managers and the anglers.

5.3 Constraints and problems

Problems for fisheries management are created because of the use of the water of the reservoirs for irrigation which is considered of primary importance. These are more acute in the small reservoirs. At the end of the irrigation season, especially in years of drought, small dams retain only small water quantities or dry up. In both cases the stocks are fished out and kept in tanks or are transferred to other reservoirs. Also the small reservoirs require frequent maintenance and are emptied from time to time during winter to avoid siltation. The fish stocks are collected below the dams with nets and stored in tanks until the works are over and the dams collect enough water for re-stocking.

Generally there is co-operation between the Government Departments involved (Dept. of Fisheries, Water Development Dept.) and the relevant local authorities, so that conflicts are either eliminated or avoided.

Apart from being an occasional problem, the maintenance practices offer the opportunity to the Department of Fisheries to change the composition of the ichthyofauna by adding or excluding fish species or to simply thin out the fish population. It usually takes 1-2 years for the fish community to recover and become suitable for angling, depending on its composition. Reservoirs which are stocked with trout every year are not that seriously affected by these practices.

The use of dams for the supply of water for domestic use does not interfere with their use for angling, as the dams concerned are large. There are indications that the pumping of compressed air into the hypolimnion during the summer months, which is undertaken for the amelioration of the water quality of these reservoirs, has a beneficial effect on the fish community.

Regulation 8A of the Fisheries (revised) Regulations of 1981 provides that no person is allowed to pollute any water body with any substance which may have direct or indirect detrimental effect on aquatic life. A new revision is expected to be adopted soon which provides for standards for the waters entering inland water bodies (temperature, COD, BOD5, pH, Zn, Cu).

Generally there is no serious water pollution problem. During the last twenty years only one incident occurred and the softdrink company responsible was prosecuted. The water of dams which are near potential sources of pollution are monitored. Some 'die-back' of algae occurs from time to time during the hot season in small rich dams and results in the mass mortality of fish.

The extraction of gravel from dam reservoirs is practiced on a limited scale under licence by the Department of Mines and in accordance with various terms suggested by the Department of Fisheries which safeguard, as far as possible, the destruction of the fish habitats and especially the spawning grounds.

5.4 Public awareness of angling

Publicity proved to be one of the main tools for the promotion of angling in reservoirs and the enforcement of the relevant policy and legislative measures. Since angling in freshwater is a new sport, public understanding, acceptance and co-operation is gradually being built up (EIFAC 1977, 1980, Alabaster 1978). The Department of Fisheries gives publicity to related issues through TV and radio. Articles on angling are often released to the local press. Information on the relevant legislation and fishery publicity material is handed to the anglers and forwarded to the Angling Clubs. Efforts are also made for the building of public awareness on nature conservation issues and relevant conditions are included in the angling licence.

6. Other related uses of reservoirs

6.1 Recreational use of reservoirs

During the last 20 years there has been an increasing public interest in the use of reservoirs for recreation which has also promoted tourism. Angling has gradually become one of the main attractions of the dam areas, which by now are frequented by an increasing number of visitors. Besides angling the landscape quality plays a significant role. It became evident over the years that both had to be protected and improved (Stephanou 1981).

In the early 1980s, in addition to the enforcement of new legislative measures on angling, the Department of Fisheries submitted to the government, suggestions for the recreational use of 6 dams. As a result a technical committee was formed for an integrated approach to the recreational use of reservoirs (EIFAC 1980). The committee consists of a representative of the Cyprus Tourism Organization and a representative of each of the following Departments: Fisheries, Water Development, Town Planning and Housing, and Forestry. The committee formulates projects for the promotion of the recreational use of reservoirs and puts forward to the appropriate Government Departments, suggestions on policy issues for the above task. The projects refer mainly to the provision of facilities to the anglers and the general public (picnic sites, car parking, sanitary facilities etc.). As regards angling, these refer to the provision or expansion of access to the dams and the water level, the provision and improvement of fishing sites, covers (sheds) etc. Planting or reforestation is also undertaken. The projects are funded by the Cyprus Tourism Organization. The maintenance is partly undertaken by the Forestry Department (when the installations are in the forest areas) or the local authorities.

To date, two projects have been completed in the most heavily fished reservoirs of Yermasoyia and Xyliatos. Another one is in its final stages of planning.

Meanwhile the areas around the dams are expected to be declared as areas of exceptional beauty and interest under the auspices of the Town and Country Planning Law 90/1972. Development activities will be restricted to those which are of national interest or cannot be undertaken elsewhere.

6.2 Cage culture of trout in reservoirs

During the last 3 years experiments were undertaken by the Department of Fisheries, in co-operation with the private sector, for the production of trout in floating cages in reservoirs (Stephanou 1986). The experiments were very successful and proved that trout can be produced seasonally (late autumn-early summer). The rational commercial exploitation of the dams for cage culture, at a scale which does not affect its other uses, offers a breakthrough in the development of trout culture in Cyprus. There are also indications that this practice has a beneficial effect on the growth of the trout which are stocked in the reservoirs and are used for angling. This is reflected by the number of angling licences issued during the last two years. The 'wild' trout feed on uneaten food which drops out of the cages, as well as on natural food, the growth of which is enhanced by the wastes of the intensive cage culture. The environmental impact of trout cage culture is being followed by a water monitoring programme.

6.3 Production of ornamental and other fish in dams

Certain small dams are used for the mass production of ornamental fish (goldfish, Koi carp), carp, mosquito fish and other species. The dams are stocked with brood fish in winter-early spring and the offsprings are easily collected by late summer. This management practice takes advantage of the use of dams for irrigation, which in this case is considered as an advantage

7. Conclusion

The building of more and larger dams created opportunities for their exploitation for angling and other uses which were beyond the initial aims of the government.

Suitable freshwater species were imported and acclimatized in the Cyprus reservoirs. The introduction of new species is now slowing down. More attention is being paid to the introduction of species which could contribute to the upgrading of angling.

Some drawbacks hindering the management of reservoirs for angling are becoming evident with the years. The increase in the number of anglers and the resulting fishing pressure on stocks necessitates the intensification of trout stocking. Supplementary stocking of other species, especially of those which are highly esteemed by anglers, is required in certain reservoirs.

Efficient management practices for the fish stocks were established according to experience gained. An overall policy was formulated which aims at establishing and maintaining fish stocks of suitable size and composition for angling in reservoirs and the promotion of angling because of its socio-economic value (EIFAC 1980). The active participation of Cyprus in EIFAC, since its first years of establishment, and in other similar International Organizations, proved very helpful towards this end. Equally useful are the integrated programmes of the technical committee for the recreational use of dams.

Angling has been accepted as a new sport and its legal framework has been defined. The co-operation and assistance of the anglers to the management of the dams for angling has been secured and their organization into Angling Clubs is being promoted. Public support is expanding. Generally the co-operation between all parties involved in the management of the water of the dams has proved indispensable and it is expected to be strengthened, since no fishery project in reservoirs could be successful without it.

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References

Alabaster, J., (Ed.). 1978. Recreational Freshwater Fisheries, their Conservation, Management and Development. W.R.C., Stevenage Lab. U.K.

Alabaster, J. & Lloyd, R., (Eds). 1982. Water quality criteria for freshwater fish. Butterworths, London. 316 pp.

Bennett, W.G., 1962. Management of Artificial Lakes and Ponds. Reinhold, London. 283 pp.

EIFAC, 1977. Economic evaluation of sport and commercial fisheries. EIFAC Tech. Pap. 26. 186 pp.

EIFAC, 1980. Report of the Technical Consultation on the Allocation of Fishery Resources: Conclusions and Recommendations EIFAC/80/6.

EIFAC,1984. Stocking. Introductions and Transplantations. EIFAC Tech. Pap. 42,Suppl. 1: 281, and (42) Suppl. 2: 283-554.

FAO/OIE, 1977. Government Consultation on an International Convention for the Control of the Spread of Major Communicable Fish Diseases. FAO Fish. Rep. No. 192. 44 pp.

Gerdeaux, D. & Billard, R. (Eds). 1985. Gestion piscicole des lacs et retenues artificielles. INRA, Paris. 274 pp.

Kohler, C.C. & Stanley, G., 1984. A suggested protocol for evaluating proposed exotic fish introductions in the United States. In: Courtenay, W.R. & Stauffer, J.R. (Eds). Distribution, biology and management of exotic fishes. Johns Hopkins Press, Baltimore. pp. 387-407.

Kondeatis, G.A., 1974. Dams of Cyprus. Water Development Department, Nicosia. 264 pp.

O.I.E., 1986. Code Zoosanitaire International. Paris.

Ricker, E.W., (Ed.), 1968. Methods for assessment of Fish Production in Fresh Waters. IBP, London No:3. 313 pp.

Stephanou, D., 1981. On the Recreational Use of Dams. Dept. of Fisheries, Nicosia. 53 pp.

Stephanou, D., 1982. Recreational fisheries in Cyprus. In: Grover, J.H., (Ed.). Allocation of fishery resources. FAO/American Fisheries Society. pp. 545-549.

Stephanou, D., 1986. The experimental cage culture of rainbow trout *(Salmo gairdneri irideus)* in Xyliatos dam. Dept. of Fisheries, Nicosia (internal report).

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 14-24.

Effects of hydraulic engineering on habitat and fish community in river anabranches of the middle Danube

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Abstract

The Vojka anabranch system is a part of the inland delta of the Middle Danube in Czechoslovakia. Its right branch, the Zofín arm, was studied prior to, and after, the hydraulic works on the main stream were performed. These involved intensive dredging of the river bed and raising embankments in the 35 km long section of river adjacent to the Vojka system, which was then isolated from the river. The hydrological regime of the anabranch system changed, followed by the subsequent alteration of the habitat and the fish community. Both the Vojka system and the Zofín arm were affected by extensive siltation and shallowing. They gradually transformed from a parapotamon-eupotamon to a plesiopotamon-parapotamon. The Zofín arm changed to a periodic water body during periods of low water in the Danube. The species diversity, ichthyomass and ecologic production of the fish community, decreased after the hydraulic works. The fish community became dominated by phytophils and phytolithophils, and by small sized species or young specimens. The share of lithophils (the economically preferred species) and the fishes of harvestable size fell substantially and the fishery value of this water body became negligible.

I. Introduction

Hydraulic structures in rivers, such as dams, levées or channels alter the morphology of a river system and hence the species diversity, density and composition of the fish communities. Construction of the Gabcíkovo-Nagymaros River Barrage System (GNRBS) in the Middle Danube, which started in 1978, will change a part of river amounting to 172 km in length. Abstraction of water from the main stream into an artificial lateral channel will cut off an extensive floodplain from the river. Most of the floodplain water bodies will be drained, and the remaining ones will be transformed into standing waters, displaying all the features of ageing such as siltation and shallowing (Holcík, Bastl, Ertl & Vranosvsky 1981). Although the overall effect of this process upon the fish and fisheries are well known (Antipa 1912, Rodewald 1952, Balon 1967a, Starret 1972, Dill, Kelley & Frazer 1975, Welcomme 1979, 1983, 1985) the details are poorly documented. This paper supplies information concerning the impact of hydraulic engineering on the hydrology, morphology and fish community in one side-arm of the Vojka anabranch system.

The following information provides the basic data on the fisheries in this 172 km long stretch of the River Danube, delimited by the river kilometres 1880.2 and 1708.2 *(Figure 1)*. Its upper part (7.5 km in length) forms the Czechoslovakian-Austrian frontier, the middle part (measuring 23.7 km) lies within the territory of Czechoslovakia, and the

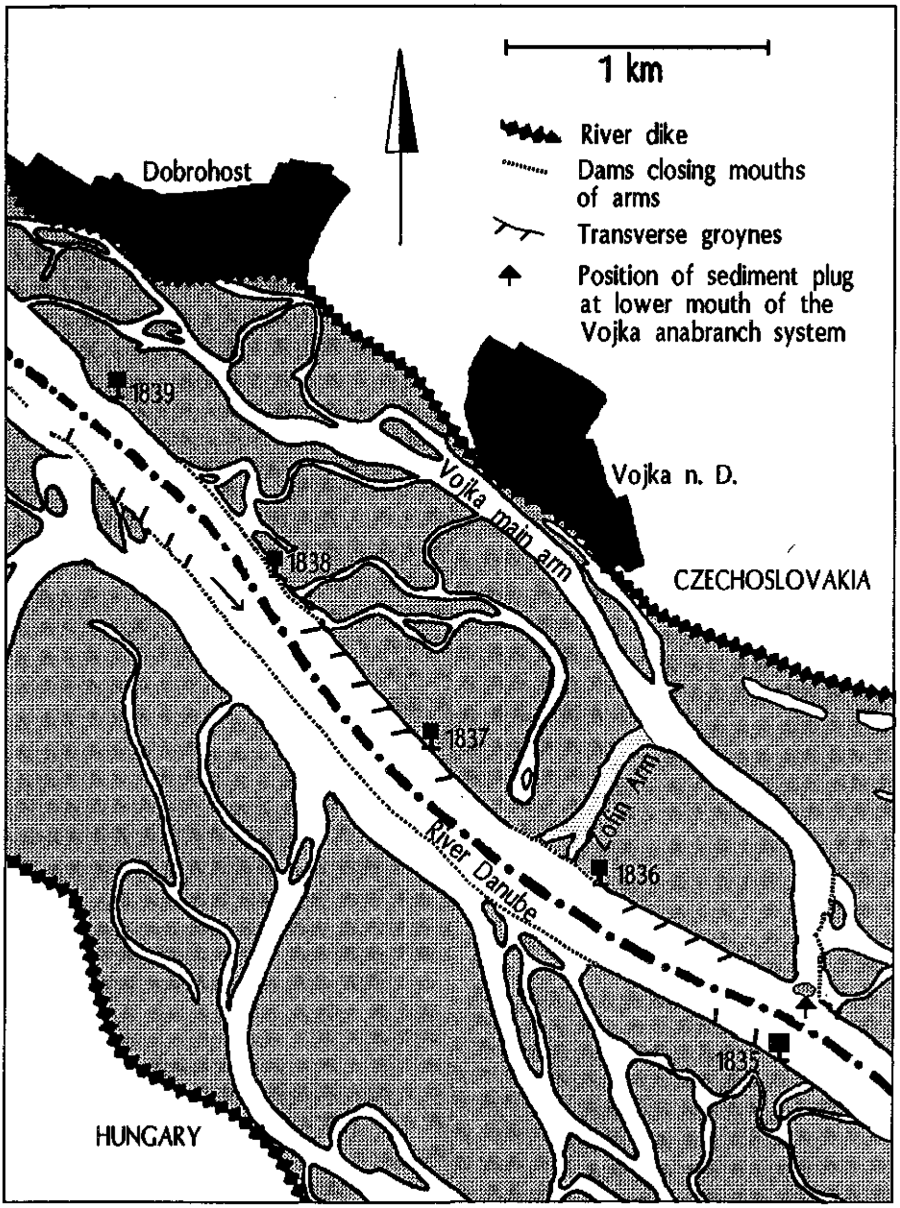

Figure 1. Part of the middle Danube between Czechoslovakia and Hungary showing the Vojka anabranch system and the Zofín arm.

lower part (140.8 km long) is shared both by Hungary (right bank) and Czechoslovakia (left bank).

The Danube is 200-300 m wide in the upper part, but it broadens to 400-700 m before leaving Czechoslovakian territory. The total area of the main channel is 7937 ha, and the area of the Czech anabranches amounts to 1778 ha while the anabranches on the Hungarian bank cover 1336 ha. The fisheries in the Czechoslovakian part of the Danube are managed by the Slovak Anglers Union. In 1961-1972 fishing was carried out by 12-21 professional fishermen organized in 3 groups, and by 5000-7000 anglers. In 1973-1986 the number of professional fishermen fell to 10 operating in 2 groups, but the number of anglers rose to between 10 000 and 13 000. The mean annual catch in 1961-1972 amounted to 206 tonnes, but in 1973-1986 it dropped to 166 tonnes. Due to the increase in the number of anglers their proportion of the catch also changed in these periods. While in 1961-1972 the share of the catch taken by anglers averaged 49% of the total, it rose to 61% in 1973-1986. In 1985 and 1986 the catch landed by professional fishermen decreased to 20% and 24% of the total respectively. The most productive part of this stretch of the Danube is that limited by river kilometres 1842-1811. Here the mean annual yield in the arms in 1961-1986 was about 105 kg/ha, while in the corresponding part of the main channel it averaged 4-5 kg/ha. Due to the lower fish density and difficult fishing conditions in the main channel of the Danube, only about 8% of the catch comes from the main channel, while 82% comes from the anabranches of the inland delta (the current velocity in the main channel, at the mean discharge rate of 2000 m^3/sec., is about 1.4 m/sec., the bottom is unstable and the embankments are mostly artificial). Further details on the fisheries, hydrobiology and ichthyology of this stretch of the Danube, as well as a prediction of changes after the construction of the GNRBS, is given by (Holcík *et al.* 1981).

Table 1. Morphological characteristics of Zofín arm for two different months during Period I (1969-1973) and Period II (1983-1984).

Period	Year	Month	Area (ha)	Volume (m^3)	Mean depth (cm)	Maximum depth (cm)
I.	1969	July	3.8	41 595	109	256
		October	2.1	13 020	62	120
	1970	July	3.2	43 680	136	350
		October	2.0	18 400	92	148
	1971	July	3.1	54 870	177	368
		October	1.5	6 675	44	95
	1972	July	2.0	17 720	88	419
		October	1.2	3 657	30	66
	1973	July	3.0	38 919	129	398
		October	1.5	6 996	46	98
II.	1983	July	2.0	10 378	53	90
		October	1.5	3 936	26	54
	1984	July	3.0	48 471	160	257
		September	3.0	65 081	215	312

2. Materials and Methods

This research was conducted in the Zofín arm *(Figure 1)* in 1983-1984 (Period II). The Zofín arm is a righthand branch of the Vojka arm which forms the axis of the Vojka anabranch system, located on the left bank of the Danube (river km 1835-1840). This locality was chosen for three reasons:

1. The Vojka system is that part of the Danube in which canalisation and the artificial raising of river banks were completed during the past decade.
2. This system is adjacent to the recently constructed lateral channel.
3. The fish community of the Zofín arm, including its species diversity, abundance, ichthyomass and production, is fairly well known from previous research carried out in 1969-1973 (Period I) (Holcík and Bastl 1973, 1976; Holcík 1988).

The Zofín arm is about 620 m long, with a mean width of 64 m. The mean depth varied between 30 and 177 cm in Period I, but between 26 and 215 cm during in Period II, depending on the water levels in the river. Other morphometric data are summarized in *(Table 1)*. Details of its limnological characteristics, including the fish community present in Period I (1969-1973), are given by Holcík and Bastl (1976).

There are no data on the fisheries in the Vojka anabranch system. The fish in this region are taken by anglers, but mostly illegally by peasants from nearby villages, although before 1973, the Vojka anabranch system was also occasionally worked by professional fishermen. Afterwards, however, commercial fishing was abandoned because of the negative effects of the hydraulic works performed in the adjacent section of the main channel, as explained below. Nevertheless, it is estimated that the mean annual yield in 1969-1973 was close to 100 kg/ha.

Sampling methods, examination of material and population estimation methods used in both periods were the same and are described in detail in papers by Holcík and Bastl (1973, 1975, 1976). Production, both total (Ricker 1946, 1975) and available (Balon 1974), was calculated for Period I.

$$\text{Total production } P_T = G\bar{B}$$

where:
G = instantaneous rate of growth
$\bar{B}$ = mean biomass

$$\text{Available production } P_A = N'(\bar{w}_i - \bar{w}_{i-1})$$

where:
N' = abundance at time of annulus formation
$\bar{w}$ = interpolated mean weight of fish
i = single age groups

For more details on the calculation of ecological and available production see Holcík (1974) and Balon (1974).

The production values for Period II were assessed using the relationships between standing stock ($\hat{B}$) in particular seasons and years and corresponding production data in Period I, assuming that the relationships between these variables in Period II are analogous. Relevant regressions are as follows:

$$(1)\ P_T = 1.330\ \hat{B}^{1.016};\ r = 0.819;\ P < 0.01;\ n = 10$$

$$(2)\ P_A = 0.299\ \hat{B}^{1.129};\ r = 0.823;\ P < 0.01;\ n = 10$$

where ranges for $\hat{B}$ varied from 64 to 542 kg/ha.

3. Results

Hydraulic works performed in the Danube river between Vojka and Bratislava (river km 1870-1835) deepened the river bed by about 1 m and raised the river banks by 1 m. Due to this the relationship between the water level (H in cm) and discharge (Q in m³/sec. - water gauge in Bratislava) which had a power regression form in Period I (Q=2.5539 $H^{1.15319}$; r= 0.997; P<0.001) changed into a linear regression in Period II (Q= 26.28 + 7.88H; r= 0.980; P<0.001). This indicates that the discharge of the Danube in Period II became higher and the Vojka system is filled later but emptied sooner than in Period I. Dredging of the river bed caused subsequent siltation of the lower mouth of the Vojka system by gravel and suspended solids. This process began in 1971 but became more profound after 1979. Recently the lower mouth of the Vojka arm, draining the whole system into the main stream, has been almost completely blocked by a plug of sediment *(Figure 1)*.

Table 2. Calculated changes in the Zofín arm volumes (V) dependent on discharge from the Danube (Q) in Period I (1969-1973) and Period II (1983-1984). Particular volumes derived from regression equations based on data of Q and V found during a topographic survey. Period I: V = -29 357 + 33.40 Q (r = 0.08; P < 0.01; n = 10). Period II: V = -48 756 + 41.07 Q (r = 0.99; P < 0.01; n = 4).

Discharge m³/sec	Volume (m³) Period I	Volume (m³) Period II	Difference %
1000	4 042	no water	-100
1200	10 722	527	-95
1400	17 402	8 741	-50
1600	24 082	16 955	-30
1800	30 762	25 169	-18
2000	37 442	33 383	-11
2500	54 142	53 918	1

In Period II the system communicated with the main stream only if the water gauge was higher than 300 cm. If so, water flow to the Vojka system was restored through a depression in its upper mouth embankment, and it emptied back into the Danube through two shallow and narrow channels through the sediment plug in its lower mouth *(Figure 1)* which were made by water during floods. Originally the gravel bottom of both the Vojka system and the Zofín arm became heavily silted. In Period I a muddy bottom was rather rare and in Zofín, it occurred only in the upper part. However, in Period II, the bed of the whole arm was covered by a continuous layer of mud 33 cm in average thickness, and 77 cm thick at maximum. In contrast to Period I, when the water filled the arm all year round, in Period II, Zofín completely dried up if flow in the Danube fell below 1100-1200 m^3/sec. This situation regularly occurs in winter months, and in the low water years, in summer also. Within a period from August to December in both 1983 and 1984, Zofín dried up for 70 and 109 days respectively. Changed hydrology of the Danube, together with siltation of the whole Vojka anabranch system are responsible for the different filling character of Zofín. *Table 2* shows that in Period II the process of arm filling is more rapid and its volume (at comparable Q) lower than it was in Period I.

Table 3. Characteristics of the fish community in Zofín arm in Period I (1969-1973) and Period II (1983-1984). Data are mean (Period I, n= 10; Period II, n = 4. F/C is the ratio between the total weight of forage fish (F) and the total weight of piscivorous fish (C) (Swingle 1950). A_{TG} is the percentage of the weight of the harvestable-sized game fishes on the total weight of their populations (Holcík and Bastl 1973).

Character	Units		Period I (1969-1973)	Period II (1983-1984)
Number of species			22	16
Density	N/ha		12 365	12 172
Ichthyomass	kg/ha		292	189
Production	kg/ha/year	P_T	464	276
		P_A	199	118
Community structure	kg/ha (% of fish biomass)	Phytophils	42 (14)	40 (21)
		Phytolithophils	218 (75)	149 (79)
		Lithophils	32 (11)	0.3 (0.1)
		Piscivores	25 (8)	13 (7)
		Preferred species	24 (8)	13 (7)
		Secondary species	75 (26)	10 (5)
		Accompanying species	194 (66)	166 (88)
		Harvestable sized fish	65 (22)	4 (2)
F/C	ratio		25	19
A_{TG}	% of game fish biomass		40	10

Table 4. Species composition of the Zofín arm fish fauna in Periods I and II.

Ecological group	Species	Period I 1969-1973	Period II 1983-1984	Economic preference:
Phytophils	*Esox lucius*	+	+	Preferred
	Rutilus pigus	+	-	Secondary
	Scardinius erythrophthalmus	+	+	Accompanying
	Tinca tinca	+	-	Preferred
	Blicca bjoerkna	+	+	Accompanying
	Carassius carassius	+	+	Accompanying
	Carassius auratus	-	+	Accompanying
	Cyprinus carpio	+	-	Preferred
	Cobitis taenia	+	+	Accompanying
	Misgurnus fossilis	+	-	Accompanying
	Stizostedion volgense	+	-	Secondary
Phytolithophils	*Rutius rutilus*	+	+	Accompanying
	Leuciscus leuciscus	+	+	Accompanying
	Leuciscus idus	+	+	Secondary
	Alburnus alburnus	+	+	Accompanying
	Abramis brama	+	+	Secondary
	Abramis ballerus	+	+	Secondary
	Vimba vimba	+	+	Secondary
	Stizostedion lucioperca	+	+	Preferred
	Perca fluviatilis	+	+	Accompanying
	Gymnocephalus cernua	+	+	Accompanying
Lithophils	*Coregonus lavaretus*	+	-	Preferred
	Leuciscus cephalus	+	+	Secondary
	Aspius aspius	+	+	Preferred
	Chondrostoma nasus	+	+	Secondary
	Barbus barbus	+	-	Secondary
	Abramis sapa	+	-	Secondary
	Gymnocephalus baloni	+	-	Accompanying
	Gymnocephalus schraetser	+	-	Accompanying
Psammophils	*Gobio gobio*	+	+	Accompanying
	Gobio albipinnatus	+	+	Accompanying
	Orthrias barbatulus	+	-	Accompanying
Ostracophils	*Rhodeus sericeus*	+	+	Accompanying
Speleophils	*Proterorhinus marmoratus*	+	+	Accompanying

Total fish abundance was the same in Period II as it was in Period I *(Table 3)*. However, seasonal abundance (not shown on table) changed, as the summer values in Period II were 21% higher and the autumn ones 25% lower than in Period I. On the other hand, the ichthyomass in kg/ha fell by 36% in Period II (24% in the summer and 49% in the autumn). The fish community structure also underwent considerable changes. The ecological groups given here *(Table 4)* are based on the concept of ecological guilds of Balon (1975, 1981) characterizing the particular fish species according to their spawning substrate. Thus:

Lithophils = rock and gravel spawners with benthic larvae.
Phytolithophils = non obligatory plant spawners, depositing adhesive eggs on submerged objects.
Phytophils = obligatory plant spawners with adhesive eggs stuck to submerged plants, living or dead.
Psammophils = sand spawners, laying adhesive eggs in running water on sand and fine roots above sand.
Ostracophils = eggs deposited in live invertebrates via the female's ovipositor.
Speleophils = hole nesters, sticking eggs in cleaned holes or crevices in rock, shells, tins, etc.

In terms of their percentage contribution to the total fish biomass, shown in *Table 3*, lithophils almost disappeared in Period II, phytophils almost doubled their biomass, while phytolithophils remained unchanged. The small decrease in the biomass of predators shown is more significant than suggested by both the percentage change and the F/C ratio. It is biased by a few large pike *(Esox lucius)*, but the stock of predators was actually dominated by fingerlings and yearlings of pike-perch *(Stizostedion lucioperca)* in Period II. The proportion of harvestable sized fish was also considerably lower in Period II, as

Table 5. Mean individual weight (g) based on the quotient of biomass and abundance in the Zofín arm in Periods I and II.

Species	Period I	Period II
Rutilus rutilus	41	18
Alburnus alburnus	18	12
Abramis brama	96	16
Blicca bjoerkna	39	14
Gymnocephalus cernua	13	11
Perca fluviatilis	25	16
Stizostedion lucioperca	144	80
Esox lucius	421	188
Vimba vimba	88	7
Scardinius erythrophthalmus	27	21
Leuciscus cephalus	230	22
Leuciscus idus	41	15

indicated both by their percentage contribution to the total ichthyomass and the A_{TG} index *(Table 3)*. The differences in numbers and ichthyomass suggest that in Period II the fish community came to be dominated by the small sized species and young specimens. This is further illustrated by the decrease in the mean weight of individuals of particular species *(Table 5)*

The total number of species in the Zofín arm fish community decreased from 33 in Period I to 23 in Period II *(Table 4)*. The number of species fell in all ecological groups except phytolithophils and ostracophils. The 63% decrease in the number of species of lithophils was most dramatic, and as a statistical compensation, although the number of species of phytolithophils remained unchanged, their proportional representation (in terms of numbers of species) increased from 33 to 48% and they became the dominant group.

The classification of fish with respect to commercial importance, used in *Table 4*, is made according to Balon (1967b). The fish are divided into three groups; economically preferred, secondary and accompanying. *Table 4* shows that the economic importance of the fish community in the Zofín arm also declined between the two periods, as the numbers of economically preferred and secondary species decreased from 6 to 3 and 10 to 6 respectively.

4. Discussion and conclusions

Canalization of the Danube, and isolating the floodplain water bodies from the river has had a severe impact on environmental conditions. Breaking off the continuous water flow led to an increase in siltation and the shallowing of both the Vojka anabranch system and the Zofín arm. These factors were responsible for massive alterations in their fish habitats, which became more uniform and also more unstable than before.

For a proper description of the alterations we adopted definitions for habitat categorization in their abbreviated form from Holcík, Banarescu and Evans (1989):

Eupotamon = the main channel of a river and its anabranches (braided belt) with permanent flow.

Parapotamon = the side arms of the braided belt in permanent contiguous connection with the main channel at their downstream ends.

Plesiopotamon = permanent or temporary standing water bodies that were formerly side arms of the braided belt; they may or may not be fed by ground water, and their size increases or decreases according to hydrological conditions in the river.

Generally, the character of both the Vojka anabranch system and the Zofín arm changed from a parapotamon-eupotamon system in Period I to a plesiopotamon-parapotamon system in Period II (*sensu* classification of Roux 1982). Moreover, the periodically repeated abstraction of water changed Zofín from a permanent to an intermittent water body with limited conditions for fish life. The character of the habitat and the structure of the fish community suggest that fish reproduction is restricted to phytophils and phytolithophils. However, spawning of these groups is possible only if the riparian vegetation is flooded. The reproduction of these groups is also adversely affected by the rapid decrease of water level, and its abstraction from the arm, in the period when water levels are low in the Danube. The mortality rate of developing eggs and early developmental stages of hatched juveniles has to be very high. Low water levels and a shortage of shelters has created an environment quite unsuitable for permanent habitation by large-sized species and older age groups. The fish community thus became simpler, consisting of fewer species, and is now dominated by small-sized species and young specimens. Consequently, production and catches from water bodies which underwent these changes are very low. It is likely that most of the apparent fish production in the Zofín arm is created outside the arm and derives from fish migrating into the arm from other parts of the Vojka system, or from fish arriving from the river in high water years (Holcík 1988). There are doubts as to whether the Zofín arm has been genuinely productive during Period II. The fish community now closely resembles those of the intermittent floodplain waterbodies which form in natural or artificial depressions when water levels are high in the Danube, but which may dry up when levels are low (Holcík *et al.* 1981). This type of water body offers little, if any, potential for a fishery.

References

Antipa, G., 1912. Das Überschwemmungsgebiet der unteren Donau. Inst. Geologiei al Romaniei 4: 172 pp.

Balon, E.K., 1967a. Vyvoj ichtyofauny Dunaja, jej súcasny stav a pokus o prognózu dalsích zmien po vystavbe vodnych diel. Biologické prace 13: 7-121.

Balon, E.K. 1967b. Vplyv Zivatného prostredia na rast ryb v Oravskom lpriehradnom jazere. Biologické prace 13: 122-174.

Balon, E.K. 1974. Fish production of a tropical ecosystem. In: Balon, E.K. & Coche, A.G. (Eds). Lake Kariba: a man-made tropical ecosystem in Central Africa. Monogr. Biol. 24: 249-767.

Balon, E.K., 1975. Reproductive guilds of fishes: a proposal and definition. J. Fish. Res. Board Can. 32: 821-864.

Balon, E.K., 1981. Additions and amendments to the classification of reproductive styles in fishes. Env. Biol. Fish 6: 377-389.

Dill, W.A., Kelley, D.W. & Fraser, J.C., 1975. Water and land-use development and the aquatic environment: problems and solutions. FAO Fish. Tech. Pap. 141. 10 pp.

Holcík, J., 1974. The green bream *Sargochromis condringtoni* (Boulenger, 1908.). In: Balon, E.K. & Coche, A.G., (Eds). Lake Kariba: a man-made tropical ecosystem in Central Africa. Monogr. Biol. 24: 280-298.

Holcík, J., 1988. Some aspects of fish production in streams with particular reference to floodplain rivers: an example from the Czechoslovakian Danube. MS.

Holcík, J., Banarescu, P. & Evans, D., 1989. General introduction to fishes. In Holcík, J. (Ed.). The Freshwater Fishes of Europe. Vol. I. Part II. Acipenseriformes. AULA-Verlag, Wiesbaden. 464 pp.

Holcík, J. & Bastl, I., 1973. Ichtyocenózy dvoch dunajskych ramien so zretelom na zneny v ich druhovom zloení a hustote vo vztahu ku kolísaniu hladiny v hlavnom toku. Biologické prace 19. 103 pp.

Holcík, J. & Bastl, I., 1975. Sampling and population estimation with small mesh seine as used during ichthyological research on Danubian backwaters. EIFAC Tech. Pap. 23 (suppl. 1/2): 627-640.

Holcík, J. & Bastl, I., 1976. Ecological effects of water level fluctuation upon the fish populations in the Danube river floodplain in Czechoslovakia. Acta Sci. Nat. Brno. No. 10. 46 pp.

Holcík, J., Bastl, I., Ertl, M. & Vranovsky, M., 1981. Hydrobiology and ichthyology of the Czechoslovak Danube in relation to predicted changes after the construction of the Gabcíkovo-Nagymaros River Barrage System. Prace Laboratória rybarstva a hydrobiologie 3: 19-158.

Ricker, W.E., 1946. Production and utilization of fish populations. Ecol. Monogr. 16: 174-391.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can No. 191. 382 pp.

Rodewald, L., 1952. Beitrag zur Kenntniss des Einfluss der Kanäle auf den Mechanismus der Fischproduktion der Donaudeltaseen. Ann. Inst. Cerc. Piscicol. Rom. 1: 115-186.

Roux, A.L. (Ed.), 1982. Cartographie polythématique appliquée à la gestion écologique des eaux. Etude d'un hydrosystème fluvial: Le Haut-Rhône Français. Ed. du CRNS, Paris. 113 pp.

Starret, W.C., 1972. Man and the Illinois river. In: Oglesby, R.T., Carlson, C.A., & McCann, J.A. (Eds). River ecology and man. Academic Press, New York & London. pp. 131-169.

Swingle, H.S., 1950. Relationships and dynamics of balanced and unbalanced fish populations. Alabama Agricult. Exp. Stat. Bulletin 274. 74 pp.

Welcomme, R.L. 1979. Fisheries ecology of floodplain rivers. Longman, London & New York. 317 pp.

Welcomme, R.L., 1983. River Basins. FAO Fish. Tech. Pap. 202. 60 pp.

Welcomme, R.L., 1985. River fisheries. FAO Fish. Tech.Pap. 262. 330 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 25-37.

Fish production and fisheries management in Eastern European reservoirs

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Abstract

Fisheries on reservoirs in Eastern Europe are either extensive or intensive. Extensive fisheries, based on the natural output of species indigenous to the original water courses, prevail on the largest reservoirs. Intensive fishery management, practised on smaller reservoirs, requires alteration of the fish community, which is best effected from the time the reservoir is first filled. Later interventions, in mature ecosystems, require much more effort and are more costly. Attention is paid to the characteristics of reservoirs used for different types of fishing, to the fishery management of water supply reservoirs, and to the effectiveness of stocking the fry and older stages of both predatory and non-predatory species.

There were over 10 000 reservoirs in Europe in 1970, accounting for more than a third of all inland water areas on the continent. The productivity of reservoir waters is growing as a result of the increasing supply of biogenic substances washed into them and the practice of regular stocking. Additional stocking with species adapted to the pelagic zones, *e.g.* *Coregonus peled* and silver carp *(Hypophthalmichthys molitrix)* can further raise yields. Improvements in stocking technique, both in the timing and siting of releases, can also increase yields. The construction of new dams can include earthworks to prepare the bottoms of prospective reservoirs for netting, both for the capture of marketable fish and the removal of undesirable species.

1. Introduction

This paper surveys findings of importance to fish production in reservoirs. Although European reservoirs are not built primarily for fishery purposes, fisheries have operated on most of them since they were first filled. The intensity of the fishery depends upon local conditions, both natural and economic. There is a tendency to prefer exploitation by recreational fishing on small reservoirs (with areas of several hundreds to several thousands of hectares) in densely populated regions. Large reservoirs on large rivers, *e.g.* in the USSR, are all exploited by commercial fisheries.

2. Characteristics of reservoirs

Reservoirs are man-made lakes which arise from the damming of rivers in their valleys. They are impounded to accumulate water for a variety of uses, such as power production, irrigation, and the provision of domestic water supplies and navigable channels. Fisheries have been practised in almost all European reservoirs since they were created. According to Fortunatov (1963) and Avakjan & Sharapov (1971) there were some 10 000 reservoirs in the world by the late 1960s. In many countries reservoirs comprise a significant part of the total national water resource, *e.g.*, about 33% in the USSR and 45% in Czechoslovakia. More than 70 reservoirs larger than 100 000 ha have been built in Africa, America and Europe. The largest man-made lakes in Europe are the Kuibyshevskoe Reservoir (644 800 ha), the Rybinskoe Reservoir (455 000 ha) and the Volgogradskoe Reservoir (311 700 ha). However, these large reservoirs have specific water regimes, and specific principles of fish production, which cannot be applied to smaller reservoirs.

Reservoirs may be classified in different ways, and classifications in current use depend upon such diverse factors as morphometry or level of fish production. The topography of the flooded landscape determines the physical characteristics of the reservoir. A reservoir can be of 'river' type, having a length at least ten times greater than its maximum width, or 'lake-river' type where wide tributary valleys are flooded as well as the main river valley, or 'lake' type, where broad lowland valleys are inundated.

In width, European reservoirs range from several hundred metres to several tens of kilometres, *e.g.* the Rybinskoe Reservoir is 60 km wide, and in length they vary from several, to several hundred kilometres, *e.g.* the Kuibyshevskoe Reservoir is 450 km long. In maximum depth they range from a few metres, as in lowland reservoirs, to more than 100 m in some mountain reservoirs.

3. Factors influencing fisheries

3.1 Water level fluctuation

This is perhaps the most important area of difference between natural lakes and reservoirs, and it has a major influence on fisheries. Water level in lakes is more stable than in reservoirs. Where a dam is used for power generation, water levels frequently show diurnal fluctuations, and these may reach several metres in some mountain reservoirs. In any case, all reservoirs exhibit seasonal fluctuations occasioned chiefly by seasonal changes in influx. However, the efflux from reservoirs, *e.g.* through the turbines of hydroelectric plants, or for irrigation, also varies, and periods of maximum demand may coincide with those of minimum influx. This situation sometimes leads to huge drawdowns in the latter half of the year.

High water levels in spring are important for the natural reproduction of phytophilous species and the survival of their fry, and land exposed during drawdowns may be overgrown by terrestrial vegetation, depending upon the time of year and the climate. Water level fluctuations can influence the abundance of all hydrobionts, *e.g.* lowering the water level at spawning time can decrease fish stocks and *vice versa* (Heman, Campbell & Redmond 1969, Fraser 1972).

3.2 Temperature patterns

The temperature patterns in reservoirs are associated, not only with geography and climate, but also with the morphometry of the water body and other abiotic factors like the discharge of warm water from nuclear power stations. Temperature differences between the surface and bottom waters can be as large as 15°C, and the gradient can reach 7°C/m. In the trout reservoirs of high altitudes the surface temperatures seldom exceed 20°C during the warmest months, but in some lowland reservoirs, usually stocked with cyprinids, surface temperatures may reach 30°C. Both freezing and thawing begin in the upstream parts of 'river' or 'river-lake' type reservoirs. Temperature stratification in a reservoir influences the spatial distribution of fish, and changing water temperatures influence the onset of migration and reproduction (Poddubnyj & Fortunatov 1961, Poddubnyj 1971, Vostradovsky 1977). Temperature stratification is not important in shallow reservoirs, nor in those with high flow rates. In a cascade of reservoirs the temperature of the upstream water bodies has a considerable influence on the thermal regime of the lower water bodies. Where power production is involved the downstream reservoirs are cooled in summer but warmed in winter.

3.3 Water chemistry

The water chemistry of reservoirs is influenced by a number of factors. The geology of the substratum is the most important of these, but the supply of nutrients from the catchment, the residence time of the water in the reservoir, and factors affecting the oxygenation of the various layers are also important.

Reservoirs pass through several developmental stages, each of differing length. The trophic state of the water varies with each developmental stage, and thus so also does the potential fish production of the reservoir. The conditions which prevail immediately after the reservoir is filled are very different from those which develop later (Baranov 1961, Vostradovsky 1966).

The oxygen content of the water depends upon temperature, depth, season and degree of eutrophication. The concentration of biogenic substances, especially soluble phosphorus and nitrogen, are influenced by the influxes from the catchment. Henderson & Welcomme (1974) tried to show a relationship between fish yield and morpho-edaphic index, based on the conductivity of the water, from which study reservoirs appeared to be more productive than natural lakes. Differences in water chemistry are frequently observed between upstream and downstream parts of a reservoir, and in different strata. If set in agricultural land, undesirable substances can accumulate in the sediments of reservoirs, *e.g.* pesticides and heavy metals. Low pH values can affect fish production adversely.

4. Fish food resources

4.1 Phytoplankton

A phytoplankton develops in a reservoir as soon as it begins to fill. Initially the phytoplankton depends upon nutrients available from the newly-flooded bottom, and as these are usually plentiful, the young reservoir usually has an abundant phytoplankton. However, the early growth phase tails off and, later, the phytoplankton becomes dependent upon the influx of nutrients from the catchment, and of course on water turbidity, pH, temperature and the structure of the fish community. Diatoms generally dominate the flora in early summer, while cyanophytes tend to become ascendent towards the end of summer. Some cyanophytes may produce toxic blooms. The biomass of phytoplankton in reservoirs varies from several kg/ha to several tonnes/ha, but if there is a sudden die-back, fish are endangered by the high consumption of oxygen and the release of toxins. Phytoplankton biomass can be controlled by limiting the supply of biogenic substances, by water turbidity, and by stocking the reservoir with suitable fish species and managing it well. Chemical methods for phytoplankton control are limited for ecological reasons.

4.2 Zooplankton

Zooplankton is a basic food source for fish. It ranges in size from small rotifers to large daphnids. Zooplankton production depends upon a complex interaction of different factors. As a reservoir fills the rheophilous zooplankton species are replaced by limnophilous species. Water temperature, transparency, velocity, residence time, level fluctuations, concentration of food organisms (bacteria and phytoplankton) and the presence of higher aquatic plants are all involved. The size and species composition of the zooplankton also depend upon the composition of the fish community. Zooplankton biomass increases with higher water temperatures, especially in the upstream parts of reservoirs and in shallow bays. Isaev & Karpova (1980) present the summer zooplankton biomass in 34 Soviet reservoirs, as ranging from 0.5-10.9 g/m^3, the average being 3.16 g/m^3. This gives a maximum mass of 109 kg/ha/m depth, and an average mass of 31.6 kg/ha/m depth. Clearly, the deeper the reservoir the greater its zooplankton biomass per hectare. Using these figures, if the distribution were uniform and of maximum density, the biomass in a 20 m deep reservoir would be 2180 kg/ha. In reservoirs of medium depth and greater, zooplankton is the main source of food for fish. This gives rise to the need for the biomanipulation of zooplankton stocks in water-supply reservoirs used for intensive fisheries.

4.3 Zoobenthos

The development of the zoobenthos, the food source for bottom feeding fish, is influenced by the depth of the water column and the nature of the reservoir bottom (Mordukhai-Boltovskoi & Dzuban 1966). The first stage of benthic production occurs just after the reservoir has filled and vegetation has been flooded, but forms fully adapted to the new biotope prevail during the second stage of reservoir development. Chironomid larvae comprise some 80% of the zoobenthos, while the remainder includes oligochaetes and a variety of other organisms. According to Isaev & Karpova (1980) the average biomass of zoobenthos ranged from 3.52-26.21 g/m^2 in 44 reservoirs. New organisms have been successfully introduced to some reservoirs, *e.g. Pontogammurus robustoides, Paramysis kolwalewskii* and *Dreissena* spp. *Dreissena* produced a biomass of up to 5 kg/m^2 in the first few years after its introduction. The type and density of zoobenthos varies with the depth of the bottom, so that biomass ranges of 2.5-150 kg/ha have been recorded on 1 m deep bottoms, 125-750 kg/ha on 5 m deep bottoms, and 250-1500 kg/ha on 10 m deep bottoms.

5. Formation of the ichthyofauna.

When a river is impounded, the conditions for rheophilous fish close to the dam deteriorate rapidly. These species disappear from the reservoir quickly, within 6-24 months. They either die or withdraw to the tributaries. The reservoir is then populated by limnophilous species which multiply amongst the freshly flooded vegetation and utilise zooplankton as their main food source. The development of a reservoir ichthyofauna is entirely dependent upon the spectrum of species present, and their abundance in the river before flooding. In high altitude reservoirs several years usually elapse before new species (other than salmonids) penetrate the new environment. However, conditions tend to stabilize in 5-8 years, and any further changes occur only over long time periods. If planktivorous fish overpopulate, competition for food increases with an adverse effect on the development of the whole community. Fish of little interest, either to anglers or professional fishermen, multiply, so that small roach *(Rutilus rutilus)*, bream *(Abramis brama)* and white bream *(Blicca bjoerkna)* predominate. This also favours predators such as pike *(Esox lucius)* and perch *(Perca fluviatilis)*.

6. Fish production or potential fish yield

According to Baranov (1961), Ioffe (1961) and Tyurin (1961), the largest reservoirs can be placed in one of five categories, using fish production or benthic production levels as criteria *(Table 1)*. They may also be classified by latitude since this is related to fish production *(Table 2)*.

Table 1. Classification of reservoirs by fish production and benthic production.

Trophic state of reservoir	Fish production (kg/ha/year)	Benthic biomass production (kg/ha)
1. Oligotrophic	2-7	<15
2. Oligotrophic-mesohumic	7-15	15-30
3. Mesohumic-mesotrophic	15-30	30-60
4. Mesotrophic-eutrophic	30-60	60-120
5. Eutrophic	>60	>120

Table 2. The relationship of mean fish production or potential fish yield with latitude.

Latitude	Fish production (kg/ha/year)
North of 58°N	5-20
58 - 52°N	20-50
South of 52°N	50-80

In reservoirs used for recreational fisheries the yield can be as high as 200 kg/ha depending upon intensity of stocking. The yields from professional reservoir fisheries, without stocking, range from 15-40 kg/ha. For professional fisheries it is desirable to prepare the fishing grounds before the reservoir is filled, or to do this when water levels are very low.

7. Types of exploitation

7.1 Professional fisheries

Professional fisheries are practised mainly on large reservoirs. General factors limiting professional fisheries are unsuitable bottom form and unsuitable fish faunas, where the predominant species are not in demand at the markets. Reservoir fisheries employ similar fishing techniques to those used on natural lakes, and the use of monofilament gill-nets has increased in recent years. In European reservoirs, the largest fish populations are of cyprinids, *e.g.* bream, silver bream and roach, and percids, *e.g.* perch and ruffe *(Gymnocephalus cernua)*. Fishes of these two families usually comprise 75% of all catches made by the active fishing systems, *i.e.* seining and trawling. Predators, *e.g.* pike, pikeperch *(Stizostedion lucioperca)* and sheatfish *(Silurus glanis)*, constitute the smallest fraction of the catch. Their abundance depends largely, or even entirely, on stocking, because their natural reproduction in reservoirs is adversely affected by changing water levels and temperature regimes.

7.2 Angling

Angling conflicts with professional fisheries on most European inland waters. Professional fishing is being displaced, or is being confined to catching spawners for hatcheries, or to certain species such as eel *(Anguilla anguilla)*. The principles which govern angling in reservoirs vary with socio-economic conditions and with the traditions associated with the consumption of freshwater fish. Introduction of the strict recording of anglers catches is important for future management policies. Professional fishing was abolished in Czechoslovakian reservoirs because anglers wanted to use them exclusively for sport fishing. Subsequent catch trends on three reservoirs are reported by Krupauer & Vostradovsky (1966) and Vostradovsky (1966, 1969).

The combined catches of anglers and professional fishermen *(Figure 1a,b,c)* reached 35.9 kg/ha after 7 years in the Lipno Reservoir ('lake-river' type, 4650 ha), 28.9 kg/ha after 3 years in the Orlik Reservoir ('river' type, 2700 ha) and 72.4 kg/ha after 4 years in the Jessenice Reservoir ('lake' type, 700 ha). The economically important species, predators and carp *(Cyprinus carpio)*, dominated the anglers' catches and reached 15 kg/ha. Bream, roach and perch, among the coarse fish, prevailed in the professional catches, and reached 25 kg/ha *(Figure 2)*. It is worth noting that after professional fishing ceased, no significant increase was recorded in the catches of anglers. The high angling catches at present being recorded in the Orlik Reservoir are due to elevated rates of stocking with carp. The development of the catches of predators *(Figure 3)* and carp *(Figure 4)* confirms the selective effect of angling and suggests that fishing for coarse fish, using nets, should be started again to compensate. In some waters, regulation fishing is

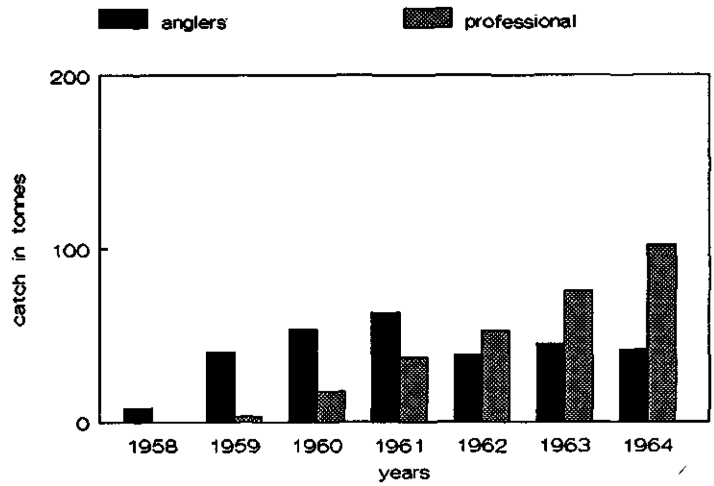

Figure 1a. Fish catches by anglers and professional fishermen in Lipno Reservoir.

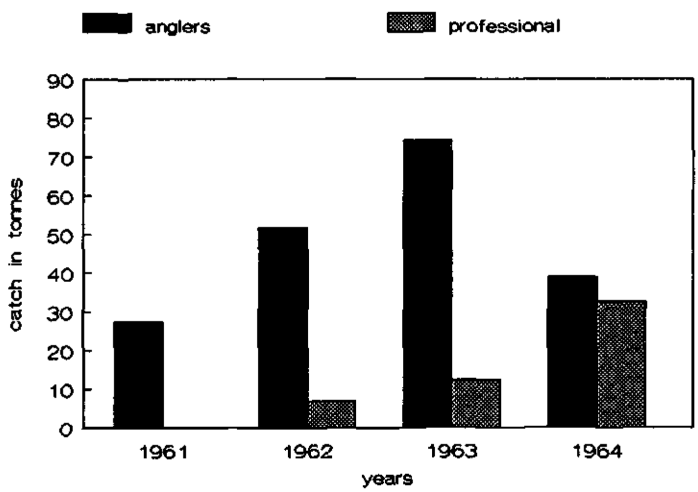

Figure 1b. Fish catches by anglers and professional fishermen in Orlic Reservoir.

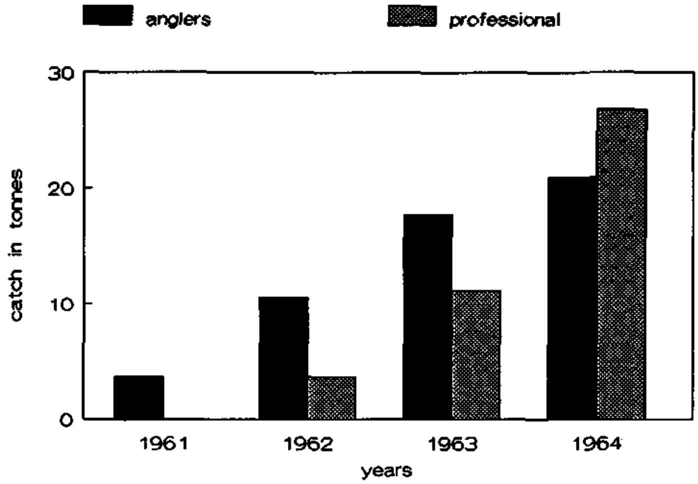

Figure 1c. Fish catches by anglers and professional fishermen in Jessenice Reservoir.

practised to reduce the abundance of coarse fish. Such measures should also be applied to water-supply reservoirs where predators should be protected and planktivores removed by compensatory fishing.

8. Fish stocking

The need for stocking depends primarily upon the intensity of exploitation. In practice, stocking with some species (pike, trout) is so intensive that the need for natural spawning is discounted. If stocking of certain species is interrupted their abundance decreases considerably. These include common carp, grass carp *(Ctenopharyngodon idella)*, silver carp *(Hypophthalmichthys molitrix)*, brown trout *(Salmo trutta)*, rainbow trout *(Salmo gairdneri)* and pike among others. Because of deteriorating conditions in reservoirs, and the occurrence of large predatory fish in them, it is recommended that stocking material of asp *(Aspius aspius)*, pikeperch and sheatfish is not released before it is 1 year old, or 2 years old in the case of common carp, grass carp and silver carp. Pike are stocked as forced fry, 4-10 cm long.

The intensity of stocking depends on the area of the reservoir or on the length of its shoreline. In those reservoirs heavily exploited by anglers, the stocking rate is 100 or more two year old non-predatory species per hectare per year. The stocking rate for predators is determined by the shoreline, using one forced fry individual per 5-10 m stretch, depending on the size of the fry. Where the shore is rugged and overgrown with aquatic

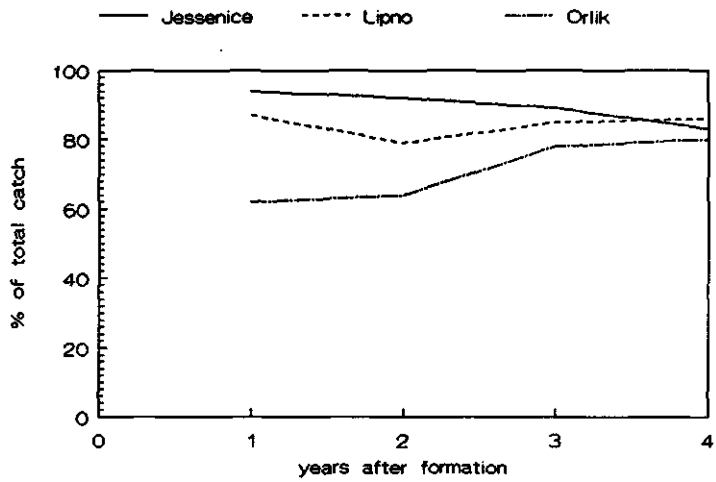

Figure 2a. Lines show the proportion of valuable species in the total catches (all species combined) of anglers on three reservoirs.

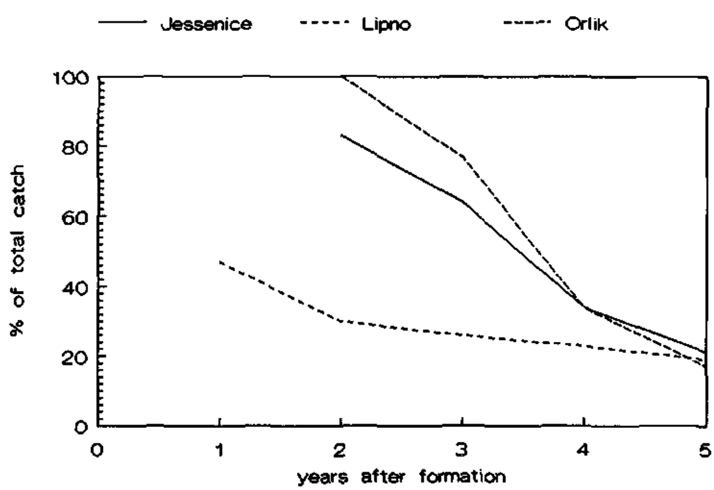

Figure 2b. Lines show the proportion of valuable species in the total catches (all species combined) of professional fishermen on three reservoirs.

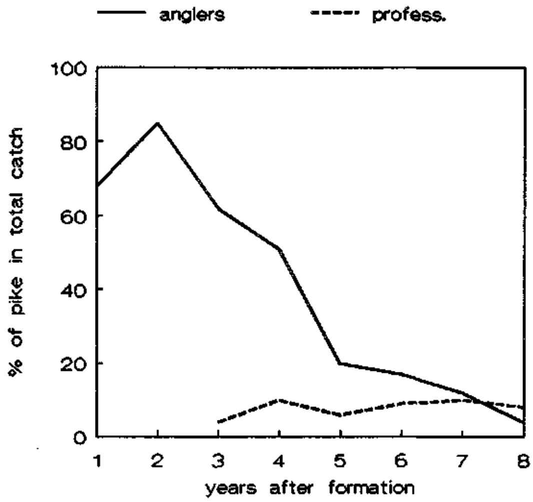

Figure 3. Percentage of pike in the total annual catches from Lipno Reservoir for the first 8 years after formation.

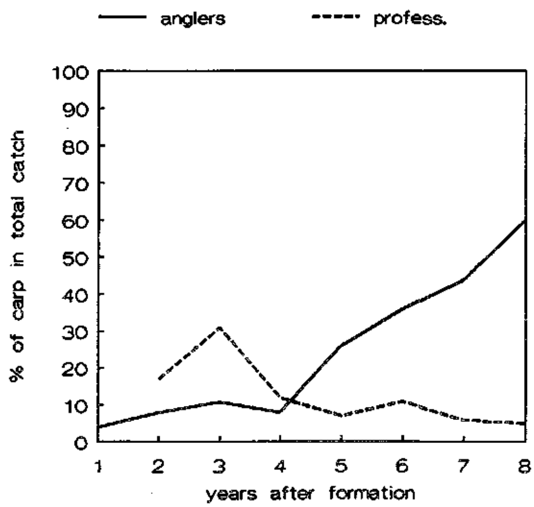

Figure 4. Percentage of carp in the total annual catches from Lipno Reservoir for the first 8 years after formation.

vegetation the stocking rate is higher and *vice versa*. Stocking of the larger non-predatory species is best carried out in spring because mortality is then lower.

A trial using 16 626 individually tagged fish was conducted in the Lipno Reservoir to assess the effectiveness of stocking the reservoir with 1.5 year old carp. Most of the material came from ponds, but a small proportion was netted in the reservoir itself and releases were made in different months. As can be seen from *Table 3*, the recapture rate was highest for fish stocked in the spring and summer months, and lowest for those stocked in autumn. During winter there is a marked reduction of the water level, conditions are harsh, and losses of autumn stocked fish are high. The recapture data suggest a high level of mortality in the fish stock, and also that the fish stocked remain close to their point of release for a long period (Vostradovska 1975). The tagging trial indicated that once anglers are interested in catching carp, stocking practice must be made more effective, both by using fish with better survival qualities, and by improving the stocking technique *per se*.

Table 3. Recapture of tagged 1.5 year old carp per month in the Lipno Reservoir (4650 ha).

	April	May	June	July	August	September	October	November	Total
Number of carp tagged	2487	251	451	2442	1116	705	8342	832	16 626
Number recaptured	398	18	99	440	234	120	1418	50	2 777
% recapture	16	7	22	18	21	17	17	6	16.7

Where reservoirs are stocked with salmonids, 2 year old individuals are used at rates dependent upon the intensity of exploitation. Where fishing intensity is very high it is recommended that still older material is used, *i.e.* a 'put and take' system be implemented. Before a reservoir is filled, or if the water level is drawn down in an existing reservoir, it is useful to consider the possibility of isolating shallow bays for the production of fish for stocking, by building barriers.

It is possible to use species which utilise the food resources of a reservoir more efficiently, *e.g.* by introducing species which feed on plankton in the pelagic zones. Echo sounding shows that most species in reservoirs inhabit the shallower coastal waters. Thus stocking with *Coregonus peled* can permit better exploitation of the pelagic zone and can boost yield from a suitable reservoir when fished in November and December (Vostradovsky, Krizek, Ruzicka & Vostradovska 1988). This species is less sensitive to higher temperatures and reductions in oxygen concentration than other coregonids. In warmer (more eutrophic) reservoirs the available food, phytoplankton and detritus, can be best utilised by species such as silver carp, but fishing for this species is difficult, and so, because of its high fat content, is its utilisation.

9. Fisheries management in water supply reservoirs

Planktivorous fish worsen water quality in reservoirs designed for the storage of drinking water (Hrbacek 1962, Benndorf 1984, Lazzaro 1987). As fish predate the zooplankton, the average size of zooplankters decreases, which leads to a decline in the rate at which the zooplankton consumes phytoplankton. The major practices used to circumvent this include reducing the numbers of planktivorous fish by fishing, lowering the water level during the spawning season, and supporting populations of piscivorous fish. In many cases these practices do improve water clarity, reduce chlorophyll content and improve oxygen content. However, they must be regarded only as part of the general effort aimed at alleviating the effects of eutrophication, and they must be accompanied by measures aimed at reducing the levels of biogenic substances in the water.

References

Avakjan, A.B., & Sharapov, V.A., 1971. Some data about world reservoirs. Gidrotechn.stroit. 8: 48-51 (in Russian).

Baranov, F.I., 1961. Attempt of hydrochemical classification of the European reservoirs in USSR. GOSNIORCH, T. 50: 279-323. (in Russian).

Benndorf, J., 1984. Manipulation of the pelagic food web by stocking with predacious fishes. Int. Rev. Ges. Hydrobiol. 69: 407-428.

Fortunatov, M.A., 1963. Problems of reservoir building and preliminary total sum in different parts of the world. Mater ob izuc. Kuibyshevskoe vodochr., Vyp. 1: 203-211 (in Russian).

Fraser, J.C., 1972. Water levels, fluctuation, and minimum pools in reservoirs for fish and other aquatic resources – an annotated bibliography. FAO Fish.Techn. Pap. 113: 4-42.

Heman, L., Campbell, R.S., & Redmond, G.L. 1969. Manipulation of fish populations through reservoir drawdown. Trans. Amer. Fish. Soc., 98: 293-304.

Henderson, H.F., & Welcomme, R.L., 1974. The relationship of yield to Morpho-Edaphic index and number of fishermen in African inland fisheries. UN/FAO CIFA Occ. Pap. No.1, 19pp.

Hrbacek, J., 1962. Species composition and the amount of zooplankton in relation to the fish stock. Rozpravy CSAV, CZ, 72: 1-114.

IOFFE, C.I., 1961. Forming of benthos fauna in the USSR reservoirs and their classification. GOSNIORCH, T. 50: 341-381 (in Russian).

Isaev, A.I. & Karpova, E.I., 1980. Fisheries management of reservoirs. Handbook. Moscow. pp. 1-299 (in Russian).

Krupauer, V. & Vostradovsky, J., 1966. Economic aspects of the development of management of the Lipno, Orlik and Jessenice Reservoirs. Bul. VURH Vodnany, 3: 1-23 (in Czech with English resumé).

Lazzaro, X., 1987. A review of planktivorous fishes. Their evolution, feeding, behaviour, selectivities and impacts. Hydrobiologia 146: 97-167.

Mordukhai-Boltovskoi, F.D., & Dzuban, N.A., 1966. Forming of benthos fauna in larger reservoirs. Ekol. vod. org., Moscow, pp. 98-103 (in Russian).

Poddubnyj, A.G., 1971. Ecological topography of fish populations in reservoirs. Leningrad, pp. 1-392 (in Russian).

Poddubnyj, A.G., & Fortunatov, M.A., 1961. Problems of fishery utilisation of reservoirs in different geographical zones. Voprosy ichthiologii, T.1, 4/21: 599-611 (in Russian).

Tyurin, P.V., 1961. Influence of water level fluctuation in reservoirs on the forming of the fish stock. GOSNIORCH, T. 50: 395-410 (in Russian).

Vostradovska, M., 1975. The use of fish-tagging for the evaluation of the effectiveness of stock carp releasing in a dam lake. Bul. VURH Vodnany, CZ, 3: 10-31 (in Czech with English resumé).

Vostradovsky, J., 1966. On the biology, profitableness and catching of carp in the Lipno reservoir. Animal Production 34: 715-722 (in Czech with English resumé).

Vostradovsky, J., 1969. The development of catches and the sex ratio of pike in the Lipno dam lake. Bul. VURH Vodnany, CZ, 4: 7-18 (in Czech with English resumé).

Vostradovsky, J., 1977. New knowledge on the management of flowing waters and dam lakes. Bul. VURH Vodnany, 4: 3-11 (in Czech with English resumé).

Vostradovsky, J., Krizek, J., Ruzicka, L. & Vostradovska, M., 1988. Biology of hybrids (*Coregonus lavaraetus maraena* x *C. peled*) in man-made lakes. Finnish Fish. Res. 9: 183-189.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 38-52.

Fisheries management of Lake Constance: an example of international co-operation

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Abstract

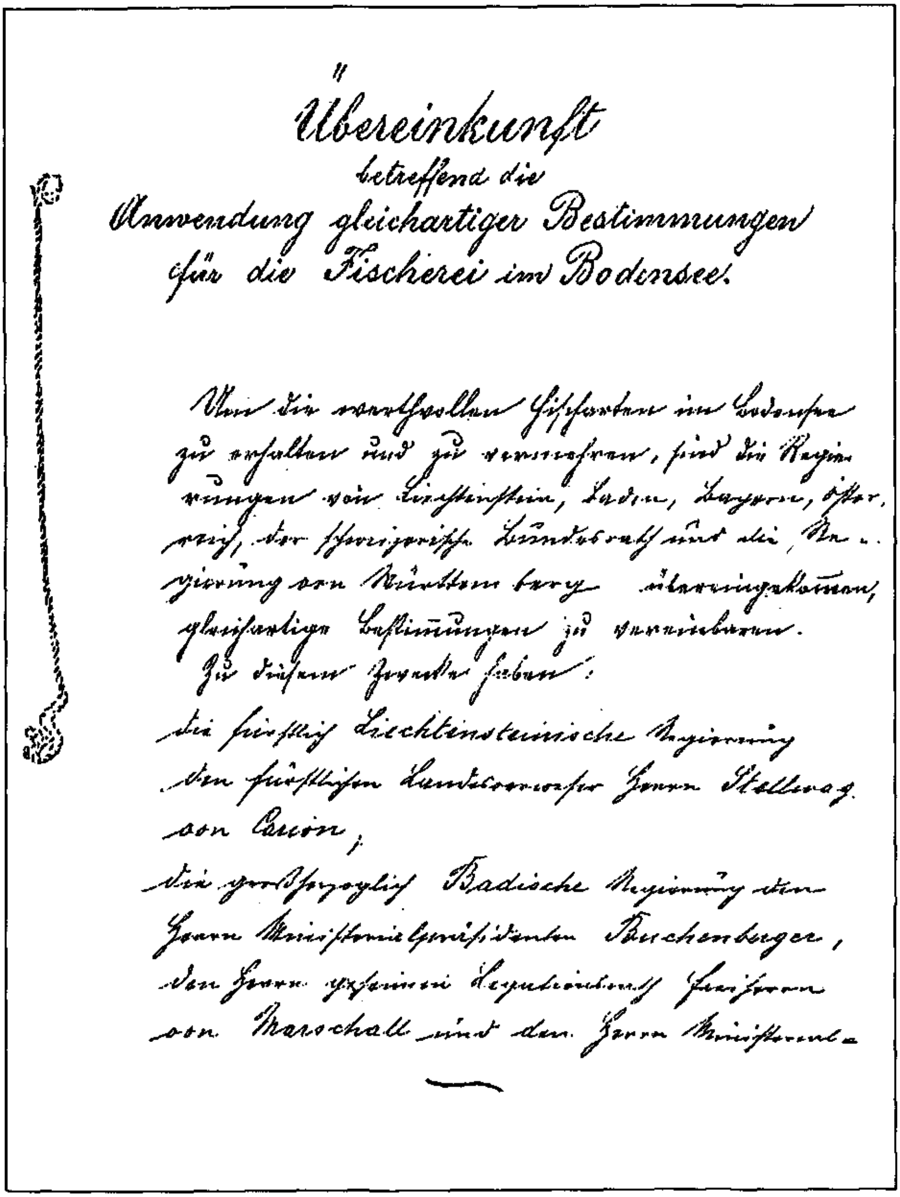
This paper describes the management schemes for the fisheries of Lake Constance. The current regulations originate from the 'Bregenzer Agreement' of 5th July 1893. Present standing orders and regulations concerning fishing methods for commercial and recreational fisheries, and management policies, including a stocking plan, are the devices used by the responsible administrators and biologists from the Federal Republic of Germany (Baden-Württemberg, Bavaria), Austria (Vorarlberg), Switzerland (St. Gallen, Thurgau) and the Principality of Liechtenstein, who work together in the International Deputies' Conference for Lake Constance.

1. Introduction

Since medieval times, laws and regulations have existed which regulate the fisheries and assure the yields from Lake Constance (Kisbert 1978, Kriegsmann 1968). Over 90 years ago, on 5th July 1893, the 'Bregenzer Agreement' for the international management of the Lake Constance fisheries was signed by the Swiss parliament and the governments of Baden, Bavaria, Liechtenstein, Austria-Hungary and Württemberg *(Figure 1)*. It is the oldest known and still operational international fishery treaty (FAO 1983). These countries decided to co-operate to protect and increase the valuable fish stocks and this aim is still unchanged today.

2. Lake Constance

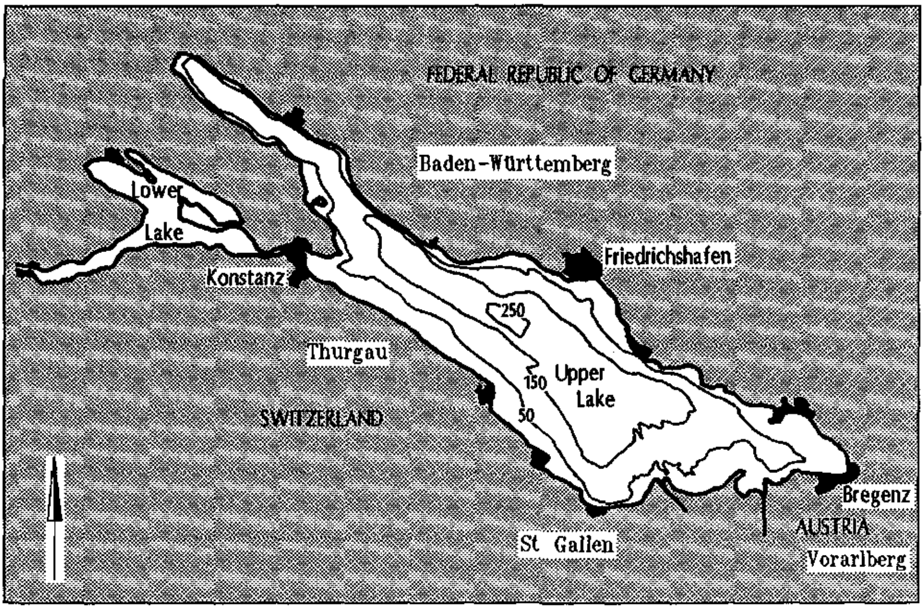
Lake Constance is situated 47°N/09°E north of the Alps. The lake is shared by Austria, the Federal Republic of Germany (the Federal states of Bavaria and Baden-Württemberg) and Switzerland (the Cantons of St. Gallen and Thurgau). It consists of two basins *(Figure 2)*, the Upper Lake (47 600 ha) and the Lower Lake (6300 ha), connected by the River Rhine. For further morphometric and limnological details see Hartmann & Nümann (1977).



Übereinkunft
betreffend die
Anwendung gleichartiger Bestimmungen
für die Fischerei im Bodensee.

Um die werthvollen Fischarten im Bodensee zu erhalten und zu vermehren, sind die Regierungen von Liechtenstein, Baden, Bayern, Österreich, der schweizerische Bundesrath und die Regierung von Württemberg übereingekommen, gleichartige Bestimmungen zu vereinbaren.
Zu diesem Zwecke haben:
die fürstlich Liechtensteinische Regierung den fürstlichen Landesverweser Herrn Stellwag von Carion;
die großherzoglich Badische Regierung den Herrn Ministerialpräsidenten Buchenberger, den Herrn geheimen Legationsrath Freiherrn von Marschall und den Herrn Ministerial-

Figure 1. The Agreement of Bregenz. Copy from part of the contract.



	Upper lake	Lower lake
Area (ha)	47 600	6 300
Area, 0-10 m (ha)	6 660	3 020
Depth, maximum (m)	252	46
Ø (m)	100	13
Length of shoreline (km)	171	90

Figure 2. Lake Constance.

3. Annual catches

Table 1 shows the mean annual catches of the professional fishermen of Lake Constance in the decades 1927-1936 (8.4 kg/ha/yr) and 1977-1986 (26.8 kg/ha/yr). For comparison, the mean yield from Lake Geneva in the period 1960-1974 was 18.6 kg/ha/yr (Lachavanne 1980). As a consequence of eutrophication and increasing fishing effort the overall yield from Lake Constance tripled between 1936 and 1986. This was essentially due to major changes in the catches of 4 species, whitefish *(Coregonus lavaretus)*, perch *(Perca fluviatilis)*, bream *(Abramis brama)* and roach *(Rutilus rutilus)*. The species composition of the fish community also changed over this fifty year period and the catch statistics reflect this *(Figure 3)*. Although catches of coregonids have increased, they initially provided more than 70% of the total annual catch, but now contribute only 40%

Table 1. Mean annual catch (1927-1936 and 1977-1986) in Lake Constance.

	1927-1936		1977-1986	
	kg	%	kg	%
Whitefish (*Coregonus lavaretus*)	289 665	72.5	548 520	43.1
Perch (*Perca fluviatilis*)	40 718	10.2	428 703	33.7
Pike (*Esox lucius*)	15 569	3.9	2 057	0.2
Roach (*Rutilus rutilus*) and other cyprinids	14 186	3.5	146 477	11.5
Bream (*Abramis brama*)	12 068	3.0	117 093	9.2
Trout (*Salmo trutta* f. *lacustris*)	10 410	2.6	2 904	0.2
Burbot (*Lota lota*)	5 788	1.4	5 113	0.4
Tench (*Tinca tinca*)	4 118	1.0	1 354	0.1
Carp (*Cyprinus carpio*)	2 346	0.6	811	0.1
Pikeperch (*Stizostedion lucioperca*)	2 143	0.5	3 007	0.2
Eel (*Anguilla anguilla*)	827	0.2	16 208	1.3
Arctic charr (*Salvelinus alpinus*)	499	0.1	418	0.03
Grayling (*Thymallus thymallus*)	96	0.02	63	0.005
Rainbow trout (*Salmo gairdneri*)	-	-	634	0.05
Other species	1 330	0.3	50	0.004
Total	399 763		1 273 412	

of it. The percentage of perch in the annual total has risen from 10-30%, and the annual catches of bream have have tripled, while those of roach have quadrupled.

Major declines, in absolute and relative terms, have occurred in pike *(Esox lucius)*and brown trout *(Salmo trutta)* yields. This can be explained by changes in water quality and loss of spawning grounds in the littoral area due to technical measures (Löffler 1985, Deufel, Löffler & Wagner 1986). The principal reasons for the decline in catches of lake trout *(Salmo trutta* f. *lacustris)* are the intensive fishery for young immature age classes, the construction of barrages and dams on rivers formerly providing spawning grounds, and the alternative management of rainbow trout *(Salmo gairdneri)* which offered easily applicable, but ultimately ineffective, solutions for the problems of autochthonous trout (Ruhlé *et al.* 1984).

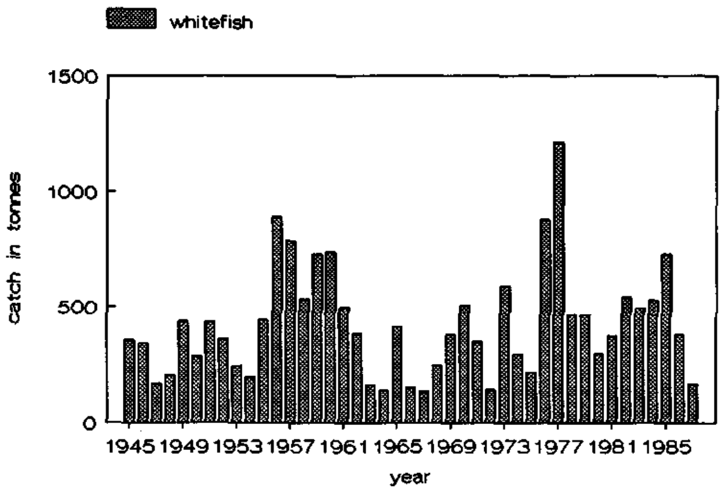


Figure 3a. Lake Constance, yield of whitefish.

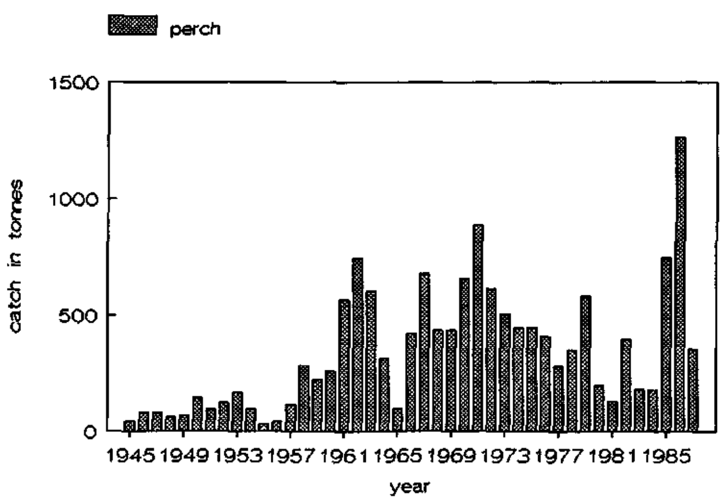


Figure 3b. Lake Constance, yield of perch.

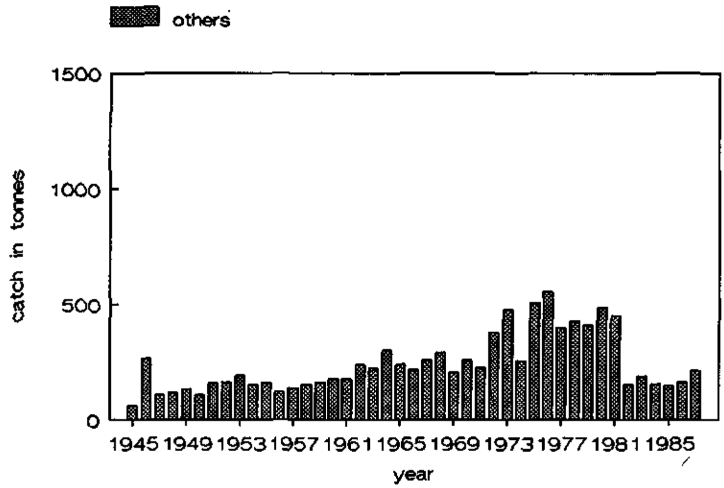


Figure 3c. Lake Constance, yield of other fish.

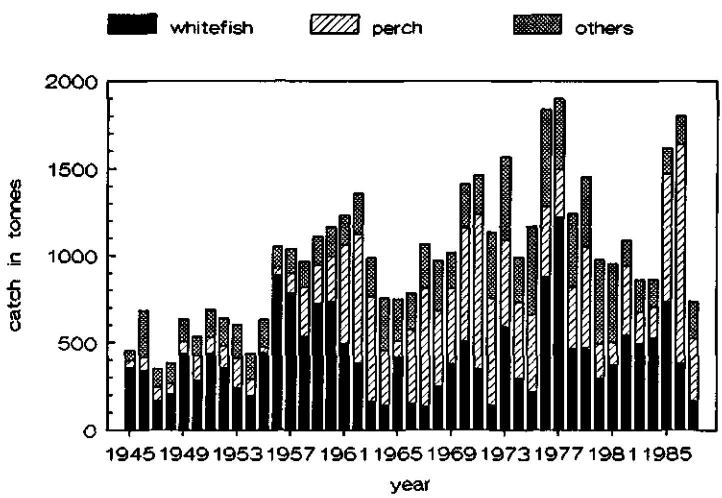


Figure 3d. Lake Constance, total fish yield.

4. The agreement of Bregenz

The first paragraph defines the area of authority. In referring to 'Lake Constance' the Upper Lake is implied. The nearshore region, which remains in national responsibility, is the part up to 25 m water depth. The deeper parts are defined as the offshore region. The following paragraphs describe the then legal gear and the times when it could be used. They also fix legal sizes and closed seasons, and give definitions regarding the spawning season of whitefish. At that time of the agreement it was forbidden to sell fish caught under the legal size or during the closed season. Another two paragraphs are dedicated to the protection of the lake trout in the tributaries with respect to water works and water usage. In paragraph 14 the appointment of Deputies by the individual countries and standing orders is regulated. Paragraph IV of the final minutes has a very high priority. It says, 'It is the desire of the governments to prohibit the introduction of new fish species into Lake Constance and its tributaries without prior information and subsequent permission. This permission shall only be granted after adequate investigations taking into consideration the probable advantages of the introduction and only with the approval of all governments, involved in the agreement, through their deputies.' A far-sighted provision indeed.

Nowadays, in the Conference of International Deputies for the Fisheries of Lake Constance, the German federal states of Baden-Württemberg (BW) and Bavaria (BY), Austria (A) with the federal state of Vorarlberg, Switzerland with the cantons of St. Gallen (SG) and Thurgau (TG) and the Principality of Liechtenstein work together. The latter is involved in the conference because its running waters are important for the spawning and rearing of migrating brown trout. The agreement came into being despite the individual countries holding different opinions about the international status of the lake. Questions about the division of real estate or condominium (common property) were and will be set aside in favour of the superordinate target. Today the original agreement is supplemented by:

- Present standing orders.
- Regulations about fishing methods for commercial and recreational fisheries.
- Fisheries management policy.

The rules which are at present in operation are summarised in those 3 guidelines. In any case the legal principle of positive transcription is valid, which means that only things which are included in the above standing orders and regulations can be done or used. But as the word guidelines indicates, these decisions are no permanent dogma. They grew out of necessities and will always be adapted to the existing situation.

5. Fisheries administration and legislation

Fisheries administration is regulated by standing orders. At present the deputies are appointed by the government of Baden-Württemberg, the Bavarian state government, the government of the Principality of Liechtenstein, the federal government of Austria and the federal council of Switzerland *(Figure 4)*. Every deputy makes an annual report about the fishery (yields, trends during fishing season, incubation of spawning products, stocking, number of licences issued and gear used, etc.) which is circulated among them. The deputies are responsible for all management decisions. During their meetings immediate problems of lake management and consequences of biological research are discussed. The votes must be unanimous to become national law and consequently binding on the 175 professional fishermen or so, and more than 5000 anglers of Lake Constance.

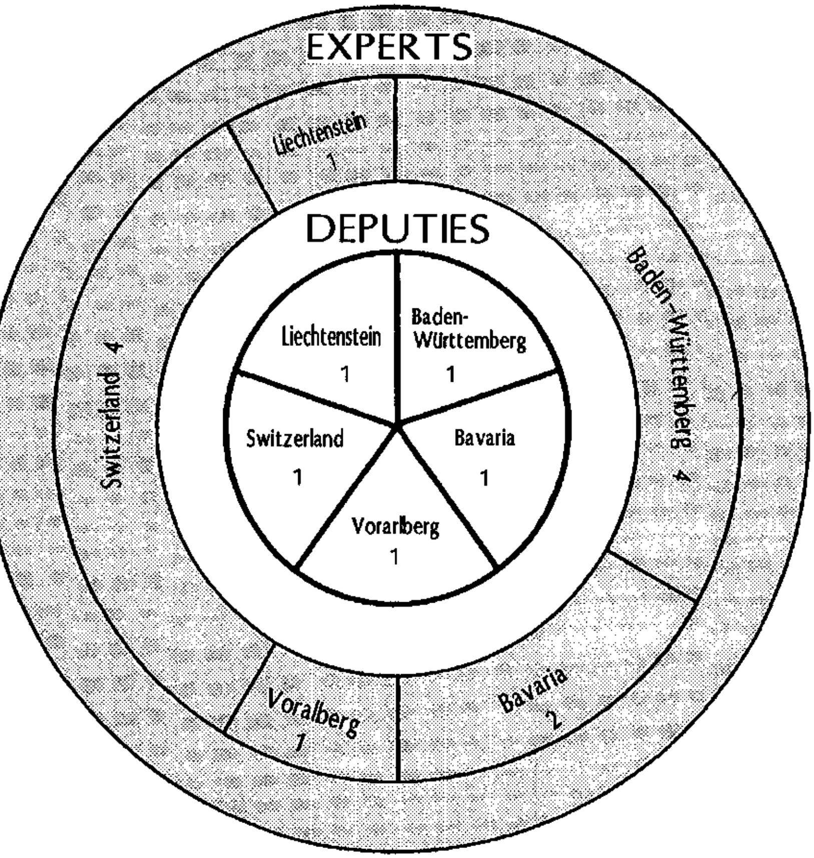


Figure 4. Member countries and numerical composition in the International Deputies' Conference, and the experts' meetings.

The Conference of International Deputies meets once a year in June. During the 94 years of the agreement, 79 meetings have taken place. Usually every state, except the Principality of Liechtenstein, chairs the conference for three years with the chairmanship changing in alphabetical order. The deputies of the countries appoint fisheries experts, research scientists and administrators, to advise them. The chairmanship of the experts' meetings changes in the same way as that of the deputies' conference. The experts meet at least once a year. They deal with scientific questions as well as problems in fishery management, and they prepare reports and proposals for submission to the conference *(Figure 5)*. The bases of their work are regular hauls, scientific investigations of national institutes and since 1914 common catch statistics (15 taxa). In questions of management the jurisdiction of the bordering country ends at the 25 m depth contour, but offshore, all fishermen are subject to the same rules.

Figure 5. Flow-sheet of the International Deputies' Conference.

Participation at the conference is very restricted. Besides the deputies and some experts, only the official representative of the professional and recreational fishermen (International Lake Constance Fisheries Union) is admitted. Proposals to be put on the agenda, as well as reports, must be accepted by the chairman. The conference is preceded by a preparatory meeting of the deputies with the experts, the fisheries wardens and representatives of the union.

6. Fisheries management policy

Since 1986 the management principles have been systematically summarized. In their foreword they develop the agreement of Bregenz to a certain extent: The protection of fish stocks, constant yields and consideration of the natural variety of the autochthonous fish stocks are all equally important objectives. With these additions, as well as the yield orientated aspect of fishery, nature conservation is also taken into account, especially the somewhat neglected aspect of species diversity. Everybody who wants to catch fish within the range of the agreement, that is to say who wants to participate in management, needs a permit according to the laws of one of the border countries.

This permit can refer to fishing from the shore or boat, nearshore or offshore. Permission for professional fishermen is given in the form of a licence, and only one licence is issued per fishery plant. The conditions for licensing are laid down by the border countries. In the federal state of Baden-Württemberg, for example, the licence is given only to master fishermen. In 1914 the participating countries agreed on 435 licences, more or less according to the proportion of their lakeshore border. This figure was halved in 1934 when only 218 licences were granted (BW: 112; BY: 12; A: 19; SG: 22; TG: 53). In 1987, just 193 fishermen were licensed (offshore/nearshore; BW: 77/8; BY: 15/7;A: 20/3; SG: 16; TG: 42/5). A further reduction in the number of licences issued is a management objective of high priority, with a view to reducing the total fishing effort on the lake.

Exceptions to these management principles are only permitted for scientific, epidemiological or special management purposes, or for the preservation of designated fish species or winning spawning products.

Catches of spawning coregonids are particularly well regulated. The beginning of the spawning season (50% of females ripe and ready to spawn) for the pelagic spawning whitefish is ascertained by coordinated trial catches by the Institute for Lake Research and Fisheries at Langenargen, the State Hatchery at Nonnenhorn and the Swiss Game and Fisheries Administration of St. Gallen. The fisheries wardens, and one fisherman representing the union, act in an advisory capacity. To ascertain the onset of spawning in littoral spawning whitefish, coordinated trial catches are made by the fisheries wardens of the respective countries.

Fishing for mature fish therefore starts by special permission. It stands to reason that the spawning products must be treated and fertilised very carefully, and the spawn must be handed over to a hatchery. Spawning catches cease after all hatcheries are filled; spawn is exchanged across national borders and each country has a more or less equal share of the hatchery capacity. In recent years the catching of pelagic whitefish spawners lasted 2-3 days and that of the littoral spawners, 5-8 days. Over the last decade a mean annual volume of 2700 litres of pelagic spawn and 3700 litres of littoral spawn were collected.

A further central point of management policy is the stocking plan which was established as a guideline. Intentionally it does not fix the numbers or sizes of fish to be stocked, as these values depend on the availability of spawning material and the capacity of the hatcheries. Furthermore the countries are able to act flexibly and to respond appropriately to any eventuality within the formulated management goals. The guideline states:

1. The natural reproduction of fish as well as the productivity of the lake are the prerequisites for a natural fish stock and the maintenance of species diversity. Lasting yield and species conservation enjoy equal rights.

2. Stocking is only a part of the management concept. Besides stocking, all the other methods of improving the fish stocks are used with priority, as stocking only controls symptoms and provides no solutions.

3. Fingerlings shall only be stocked when natural regeneration is restricted and stocking promises success. The ecological conditions alone, determine the species composition and thus the stocking requirement, not the wishes of the fishermen.

4. Rare or endangered fish species are supported even if no yield appropriate to expenditure is expected. For such species, research about stock, habitat, etc should be intensified.
5. When stocking occurs quality has to rank as the first priority. Stocking material should originate exclusively from autochthonous parental fish (except eel). To prevent the introduction of parasites or other pathogens the competent fish health services are engaged in stocking measures.
6. A significant check on the success of management measures is inevitable. For that purpose the catch statistics of professional and recreational fishermen should be further improved. Efforts to ascertain the mortality of stocked fish must be undertaken, *e.g.* by tagging experiments.
7. In all cases the International Deputies' Conference has to make decisions as to stocking or naturalising species, or even sub-species, which are not mentioned in the plan. For those species which can be stocked, the management goal, priority of measures and stocking ratios are formulated. At present whitefish, lake trout, arctic charr *(Salvelinus alpinus)*, pike, eel *(Anguilla anguilla)*, carp *(Cyprinus carpio)* and tench *(Tinca tinca)* come into consideration.

7. Fishing methods

The chapter in the agreement about the practices of the professional and recreational fisheries first lists the gear permitted. Bottom gill-nets, fishpots, long lines and angling equipment can be used nearshore as well as offshore. Angling is allowed with hook and line, a small lift net, bait bottle and dip-net. Drifting and anchored gill-nets are restricted to the offshore fishery, as are trout nets. Special whitefish gill-nets (Spannsatz, Sandfelchensatz) and fyke nets are restricted to the nearshore.

Before initial use, all the professional gear must be measured and sealed by the competent fishery warden. Exposed gear must be marked by buoys which bear the identification of the owner. Gear which is ready for use can only be carried alongside or on the lake when it is in accordance with the regulations.

The second paragraph contains special regulations about the individual gear. As far as possible, all catching devices are described as indicated in *Table 2*.

Special regulations about catches of spawning whitefish, closed seasons for 8 taxa, legal minimum size for 10 taxa and the use of bait fish form the contents of the following chapter. It is completed by remarks on supervision of fishery, fish kills and treatment of marked fish. Persons who act contrary to the regulations will incur a penalty. Something out of the ordinary is the fact that the licence can be temporarily withdrawn. If gear is changed or forbidden by decisions of the deputies, the experts work out temporary regulations which allow the fishermen to use up old materials in a certain time to prevent hardship.

The last chapter under the heading 'mass catches of whitefish' needs some special attention as regards management. Mass catches in drifting or anchored whitefish gill-nets are defined as yields of 50 kg/fisherman/day or more, provided that this is not an occasional or isolated event. To judge the situation Baden-Württemberg, Bavaria, Austria and Switzerland each send one representative (fishery warden) to a standing committee. The members of this committee coordinate their statements within their countries before attending the committee meetings. In their decisions they have to weigh up the management of the whole lake against national interests. If such mass catches increase, detailed controls are put into operation. Over a certain limit the members of the committee have to deliberate on measures immediately and make prompt decisions. Decisions are decided by majority and can refer to:

- The reduction of the number of gill-nets from 4 to 3.
- The imposition of additional closed days per week.
- The minimum water depth for the use of the gill-nets.

A combination of these three measures, which have to be limited in time, is possible too. If the yields drop to 5 kg/net/day the restrictions are cancelled. The last such event was in 1985. A large majority of the fishermen approve of this management device.

Table 2. Systematic description of fishing gear.

For a given net the following minima and maxima are valid:	Example: Drifting gill-nets
a. mesh size at least....	44 mm
b. diameter of netting yarn at least....	0.12 mm
c. length of net at most....	120 m
d. height of net at most....	7m
e. number of nets at most....	4
Application time:	
season	31 March (12.00) — 15 October (12.00)
daily	Monday to Thursday
Remarks	No floating headrope

8. Market situation

In the past 15 years the marketing situation has changed. Whereas in former times most of the landings were processed externally, today most fishermen have their own processing plants. They fillet and smoke their own catches and sell them directly to hotels, restaurants and private households. Perch fillets fetch extremely high prices, up to 60 SFr/kg.

9. Problems of fisheries management

One problem which has high priority is the continuing high fishing pressure on the stocks of whitefish and perch (Hartmann 1984). At the moment a group of experts is dealing with the problem of the nearshore fishery. The group has been instructed to

Gear	Month J F M A M J J A S O N D	Height (m)	Length (m)	Mesh size (mm)	Yarn diameter (mm)	Number /fleet	Offshore	Nearshore	Remarks
Drifting gill-net	31/3 12.00h – 15/10 12.00h Set Monday - Thursday Min depth ≥ 5 m	7	120	44	0.12	4	•		No floating headrope All nets as one fleet
Anchored gill-net	10/1 12.00h – 31/3 12.00h No raise on Sundays and festival days	7	120	44	0.12	4	•		Anchored on both sides
Bottom gill-net	5/5; 20/5 – 14/11; 16/12 Raise daily Saturday 12.00 h Days before festival days 18.00 h Control daily	2	100	32	0.12	20	•	•	15.12 to 10.01: only offshore
Bream net	31/3; 21/5	4	100	80	0.20		•	•	Per net omission of one 32 mm net
Anchored nearshore gill-net	10/1 – 31/8 Only for nearshore licenses Not coincidental with drifting or anchored gill-nets	2	100	44	0.12	5		•	No floating headrope nearshore anchored on both sides
Trout net	10/1 12.00h – 15/7 12.00 No raise on Sundays and festival days	5	100	70	0.20	3	•		No monofilamentous yarn, no floating headrope
Trap net	Control every other day	2		32 (wings)		1		•	Cod-end 1x1 *m*
Fyke net	Control every other day	0.6		10			•	•	Leader 6 *m* wings 3 m unlimited number
Long line	Control every other day						•	•	No limitation in hook number

Figure 6. Fishing regulations for professional fishermen in the upper part of Lake Constance.

reform this part of the agreement and to present proposals (number of nets, mesh sizes etc.) to the next Conference of Deputies.

There are critics who believe that questions of fishery biology are not sufficiently taken into account before decisions are made. There are others to whom the work seems too ponderous, or the decision making processes too protracted, or too much influenced by political considerations, as described by Hartmann (1983). Of course sometimes things do move slowly, but the current system probably avoids quick solutions which subsequently prove to be wrong and have to be modified. Another problem that arises from time to time is the question of national borders in the bottom gill-net fishery.

This international co-operation, now lasting over 90 years, has often proved its worth in managing the problems of the lake. For example, the eutrophication which caused accelerated growth of the whitefish (Nümann 1972) called for lake-wide agreements to reduce fishing pressure by enlarging mesh sizes and reducing the number of gill-nets permitted. Further, drastic arrangements were recently put into operation to save the migratory brown trout which was otherwise threatened with local extinction. Even after the two world wars, this common work was quickly taken up again.

The acceptance of biological facts, the responsibility for the common lake, and fair, objective and trusting co-operation have been, until now, the essentials of the work of the International Deputies' Conference. Under these conditions current problems can be solved in a satisfactory way. A lot of things are regulated in a very detailed way *(Figure 6)*, as it became apparent in the past that, in such an expanse of water, a few general regulations are not sufficient to keep things in order. Despite this essential themes such as overfishing, stocking with allocthonous taxa, or effectiveness of stocking, are still far from having ideal solutions.

References

Deufel, J., Löffler, H. & Wagner, B., 1986. Auswirkungen der Eutrophierung und anderer anthropogener Einflüsse auf die Laichplätze einiger Bodensee-Fischarten. Österr. Fisch. 39: 325-336.

FAO, 1983. Activities of regional fisheries bodies and other international organisations concerned with fisheries. Committee on Fisheries (COFI), 83/Inf. 6: 1-28.

Hartmann, J., 1983. Trends bei der Regelung der Bodenseefischerei während 90 Jahren. Österr. Fisch. 36: 278-280.

Hartmann, J., 1984. Zur heutigen Befischungsintensität beim Felchen *(Coregonus lavaretus)* des Bodensees. Fischwirt 34: 44-45.

Hartmann, J., 1986. Besatzerfolge? Fischwirt 36: 33-35.

Hartmann, J. & Nümann, W., 1977. Percids of Lake Constance, a lake undergoing eutrophication. J. Fish. Res. Board Can. 34: 1670-1677.

Kisbert, G., 1978. Vortrag aus Anlass des 85-jährigen Bestandes der Übereinkunft vom 05. Juli 1893 - Betreffend die Anwendung gleichartiger Bestimmungen für die Fischerei im Bodensee kurz - Bregenzer Übereinkunft - genannt. Gehalten auf der Jahreshauptversammlung des Internationalen Bodenseefischereiverbandes (1909) zu Hard am 20. Mai 1978. TS.

Kriegsmann, F., 1968. 75 Jahre internationale Übereinkunft für die Fischerei im Bodensee-Obersee. Fischwirt 18: 277-284.

Lachavanne, J.-B., 1980. Les manifestations de l'eutrophisation des eaux dans un grand lac profond: Le Léman (Suisse). Schweiz. Z. Hydrol. 42: 127-154.

Löffler, H., 1985. Zur Hechtproblematik im Bodensee. TS.

Nümann, W., 1972. The Bodensee: effects of exploitation and eutrophication on the salmonid community. J. Fish. Res. Bd Can. 29: 833-847.

Ruhlé, Ch. *et al.*, 1984. Die Bodensee-Seeforelle. Probleme und Problemlösungen. Österr. Fisch. 37: 271-307.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 53-66.

A plan for fisheries management of the heavily modified Lake Kemijärvi, Northern Finland

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Abstract

Lake Kemijärvi has been affected by substantial water level regulation for hydroelectric power purposes, and by pulp mill effluents, log floating, and two large reservoirs built in the upper reaches of the affluent water course. Economically the most important fish are vendace *(Coregonus albula)* and pike *(Esox lucius)*. The lake is stocked annually with whitefish *(Coregonus lavaretus)* fingerlings and young brown trout *(Salmo trutta lacustris)*, but the results have been poor.

About 1500 people engage in subsistence or recreational fishing in Lake Kemijärvi. Interest in fishing has been reduced by the rather high mercury contents found in predatory fish and the bad flavours caused by pulp mill effluents. Further, fishing gear is easily torn on stumps and wood snags in the regulation zone. At present there is no professional fishing in Lake Kemijärvi, although some fishermen sell part of their catch. Fluctuations in the vendace stock have restricted its commercial utilisation, but in recent years the stock has been strong and interest in seine netting has begun to revive. At the same time, exports of pike and perch to Central Europe have created new possibilities for professional fishing in the lake. The following measures are recommended for fisheries management in Lake Kemijärvi:

- Moderation of water level regulation.
- Thinning of the dense roach, perch and whitefish stocks by intensive fishing with non-selective gear.
- Clearing the shores for seine fishing of vendace.
- Use of exclusively planktivorous dense-gillraker whitefish for stocking.
- Experiments with different brown trout stocks and the use of larger individuals for stocking.
- Stocking with other predatory species, such as pikeperch.
- Information campaigns for eliminating the prejudices concerning mercury contents and bad flavours in fish.

1 Introduction

If artificial reservoirs are excluded, Lake Kemijärvi is the most strongly regulated lake in Finland. The main measure taken to compensate for the damage caused by water level regulation has been stocking with whitefish *(Coregonus lavaretus)* and brown trout *(Salmo trutta lacustris)*.

The fish stocks and fishery of Lake Kemijärvi, before regulation, were studied by Sormunen (1964). In the 1980s an extensive research program was carried out to elucidate the present state of the lake; its water quality, plankton, littoral vegetation, bottom fauna and fish stocks (Nenonen 1987). The goal of the study was to create a basis for planning the fisheries management and to evaluate the effectiveness of the ameliorative measures taken to date. This paper is based on the fisheries section of the Lake Kemijärvi Research Project (Heikinheimo-Schmid & Huusko 1987a).

2. Lake Kemijärvi

Lake Kemijärvi drains into the Gulf of Bothnia through the Kemijoki River. The town of Kemijärvi, with some 13 000 residents, is situated on the lakeshore. The maximum area of the lake is 28 500 ha *(Figure 1)*. The main basin is traversed by a strong current, while the eastern part is more lake-like. Regulation of the lake for hydroelectric power began in 1966. The upper limit of the regulation is more than 2+ m above the mean

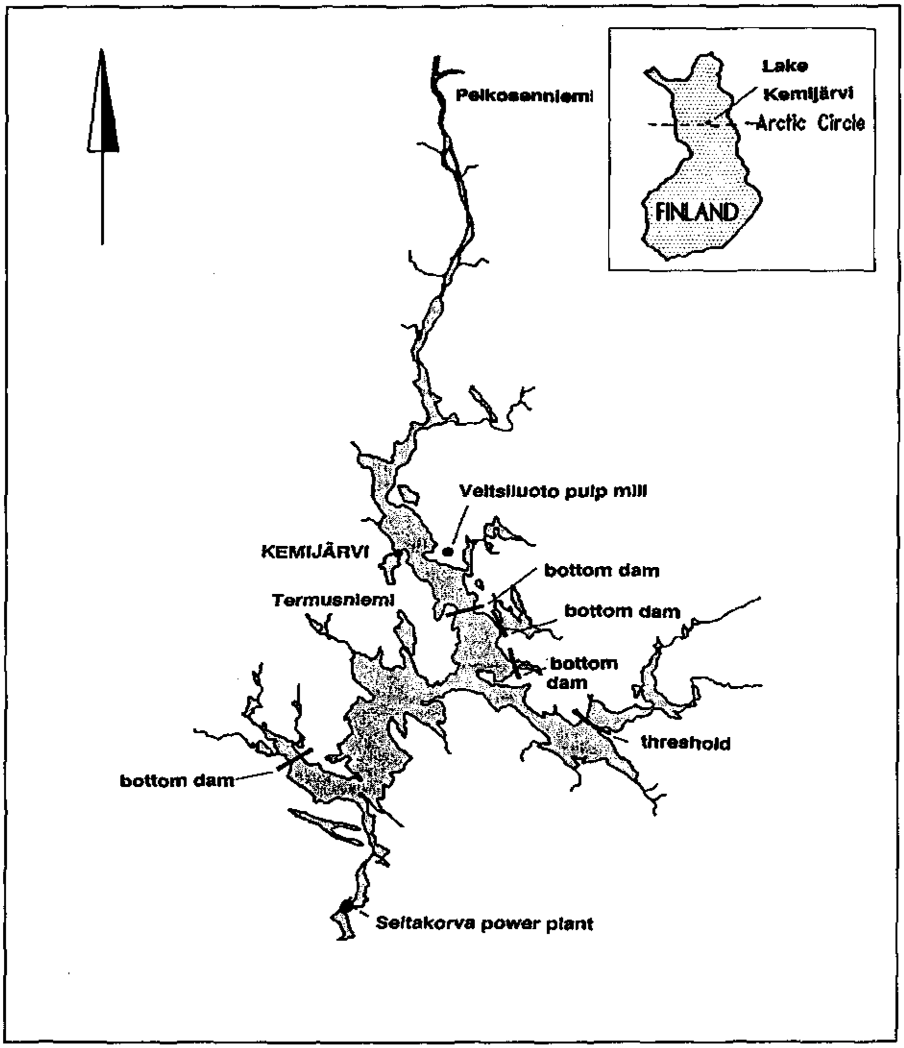

Figure 1. Lake Kemijärvi.

natural water level during summer. In the main basin, the amplitude of water level fluctuation is 7 m, but in the uppermost part of the lake and in some bays, bottom dams or natural barriers restrict this to 3-5 m. The water level is kept fairly constant during summer, but decreases during winter and reaches its minimum in late spring. The flood rises rapidly at the end of May, about two weeks later than in the natural lake. At the same time, the lake is freed from ice cover *(Figure 2)*. Because of the long shoreline with many shallow bays, vast littoral areas are affected by regulation. Thus during late winter, more than half the lake dries, and the water surface contracts to 13 000 ha.

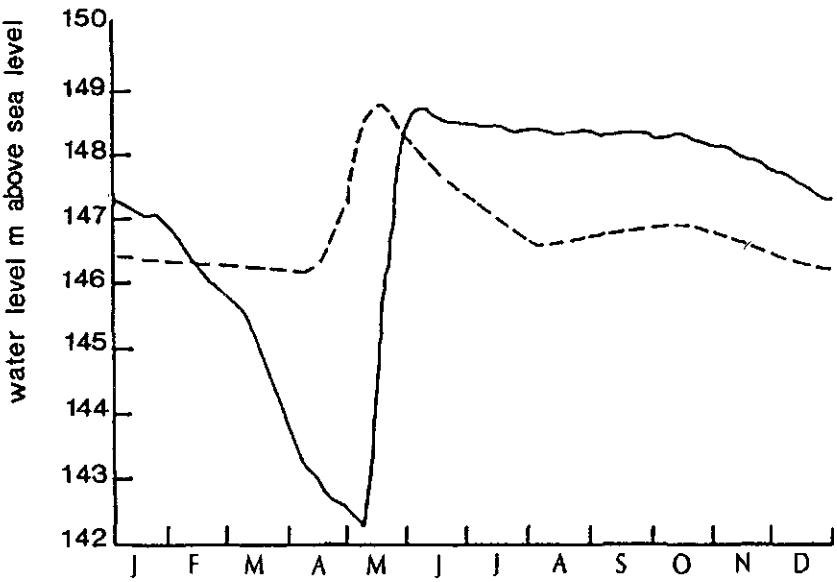

Figure 2. Mean water levels in Lake Kemijärvi according to Reuna (1979). Broken lines represent the natural state 1919-1964. Solid lines represent the regulated state 1965-1975.

Lake Kemijärvi is classified as slightly eutrophic. The effect of pulp mill effluents, noticeable by the higher phosphorus and NaLS contents, is limited mainly to the area extending downstream from the mill to the bottom dam of Termusniemi (Kinnunen 1987). Due to the strong current and dilution of the waste waters, water quality is not a restricting factor for fish stocks elsewhere in the lake.

The humic substances washed out of the Lokka and Porttipahta reservoirs, built in the upper reaches of the watercourse, influence the water quality of Lake Kemijärvi during winter. The mean water colour varies between 60 and 155 mg Pt/litre, the greatest differences occurring in the main basin. The strong flow from the reservoirs in winter largely prevents thermal stratification in the main basin of Lake Kemijärvi, so that an oxygen deficiency very seldom occurs (Kinnunen 1987).

3. Material and methods

In order to plan fisheries management, information was needed concerning:

- The present state of fishing, *i.e.* fishing effort, types of gear used, fish catches, fish marketing.
- Problems caused by habitat modification.
- The present state of fish stocks, the composition of the fish community, spawning grounds and the current level of exploitation of the fish stocks.
- The effectiveness of fish stocking and other ameliorative procedures.

The fishing and catch statistics were collected by postal questionnaire. Catch per unit effort values were calculated yearly from the daily catch books kept by each of 11-15 fishermen. The spawning areas and depths inhabited by the most important fish species were mapped by interviewing local fishermen. The marketing and use of fish from Lake Kemijärvi were studied by Partanen (1987).

For the calculation of growth and mortality rates, more than 7000 fish were sampled during 1982-1985. The species sampled were whitefish *(Coregonus lavaretus)*, vendace *(Coregonus albula)*, pike *(Esox lucius)*, roach *(Rutilus rutilus)* and perch *(Perca fluviatilis)*.

The mortality rates of whitefish, pike, roach and perch were determined by the method of Robson and Chapman (1961). For studying the present level of exploitation of the fish stocks, yield per recruit by different rates of fishing was calculated by a model based on cohort analysis (Gulland 1983), and on the mean weights of the fish in different age groups. The mortality of vendace was determined by using the yearly catches per unit effort of the separate year-classes (Ricker 1975).

4. Fishing and catches in Lake Kemijärvi

As late as the 1960s, seining was the most important form of fishing in Lake Kemijärvi. With the decrease in the importance of professional fishing and the shift to subsistence and recreational fishing, seine fishing almost ceased, the number of gill-nets and fishing rods increased, and cotton nets were replaced by much more effective synthetic fibre nets. A similar development has been common in many other Finnish lakes.

There are at present about 1000 households fishing in Lake Kemijärvi. The most commonly used gear is the gill-net. On average there are about 2 vendace nets and 5 other gill-nets per fishing household, and the mesh size most commonly used is 35-40 mm (knot to knot). According to the inquiry, 4 seine nets were used in 1982.

At present the lake is fished by some 30-60 semi-professional fishermen, who sell part of their catch. The number of these fishermen and the amount of fish sold depends greatly on the strength of the vendace stock.

According to data obtained from the questionnaire, the total annual catch was *c.* 100-200 tonnes (3-6 kg/ha) in 1980-81, but only 67 tonnes (2 kg/ha) in 1982, which is below the mean catch per hectare (3 kg/ha) from the inland waters of Lapland (Lovikka & Alapuranen 1982). The difference between catches is due to a reduction in the numbers of fishermen, and in their fishing efforts, at the beginning of the 1980s. For instance, the number of gill-nets used decreased by nearly 40%, and that of wire traps, trap nets and spinning rods by about 50% from 1980 to 1982.

The main species in the catch are vendace, pike, and perch; but the proportion of vendace depends on the fluctuations in the vendace stock *(Table 1)*. Only 6% (4 tonnes) of the catch from Lake Kemijärvi was sold in 1982. In recent years the export of pike and perch to Central Europe has created new possibilities for professional fishermen in Lake Kemijärvi, and the vendace stock has recovered from its lowest level, reached in 1982. The amount of fish sold in 1984 was more than 20 tonnes. Half of this was pike, and about one quarter vendace (Partanen 1987).

Table 1. Fish catches from Lake Kemijärvi in 1980 and 1982.

Year	1980	1982
Vendace	44 300	8 400
Pike	42 300	22 200
Perch	41 600	16 700
Roach	23 600	6 800
Whitefish	12 400	4 400
Ide	12 100	3 900
Burbot	6 700	2 800
Others	12 200	1 400
Total	195 200	66 600

5. Remedial measures

5.1 Stocking with whitefish

Stocking with 1-summer old whitefish fingerlings began in Lake Kemijärvi in the late 1960s, using the following whitefish forms (the Latin names according to Svärdson 1979):

migratory whitefish	*Coregonus lavaretus*	mean 29 gillrakers
Siberian peled whitefish	*Coregonus peled*	48-69, mean 58 gillrakers
'bottom whitefish'	*Coregonus fera*	mean 21 gillrakers
plankton whitefish	*Coregonus pallasi*	more than 40 gillrakers

The average number of whitefish released annually during the last 10 years has been 10 fingerlings/ha. The real annual mean stocking density may have exceeded 30 fingerlings/ha, because a great many of the fingerlings released in the rivers above the lake are very probably carried downstream into the lake. Most of the planted whitefish have been plankton whitefish, migratory whitefish and peled; but in recent years the migratory whitefish have been replaced by bottom whitefish.

This whitefish stocking has not been profitable. Stocking with migratory whitefish seems to have had no effect. The yield from stocking with planktivorous whitefish was roughly estimated as 10 kg/1000 fingerlings released, and that from stocking with peled whitefish at 20 kg/1000 fingerlings. This compares unfavourably with the mean yield from whitefish stocking in northern Finland which has been about 100 kg/1000 fingerlings (Salojärvi 1986).

5.2 Stocking with brown trout

Brown trout stocking of Lake Kemijärvi, and the waters flowing into it, began in the late 1960s. It was mostly done with 2 year old smolts and by 1986 nearly 200 000 such smolts had been released.

Brown trout stocking has also not been successful. Tagging results for stocking in 1971-1984, and test fishing done in the Kemijoki River, indicate that after release the brown trout tend to migrate downstream (Heikinheimo-Schmid & Huusko 1987b). The yield per 1000 tagged smolts in Lake Kemijärvi was only 2 kg, and 75% of the tag returns were received in the year of stocking. Half of the returns from the following two years were from the Kemijoki River below the lake, or from the sea area *(Table 2)*. Apparently a great many of the fish are destroyed in the turbines of the power plants in the Kemijoki River, or the tags are lost. According to the catch statistics, the yield from 1000 released brown trout was estimated at 10-20 kg.

Table 2. Tag returns by area and year for brown trout released in Lake Kemijärvi during 1971-1984. The total number of trout released was 3489 and the number recovered 44.

	Lake Kemijärvi	Kemijoki River down-stream from the lake	Sea area
Year of stocking	33	-	-
First year after stocking	4	3	3
Second year after stocking	1	-	-

5.3 Other measures

At the onset of regulation, bottom dams were constructed in the upper part of the lake at Termusniemi and in the mouths of three bays, to reduce the damage caused by water level regulation. The amplitude of the water level fluctuation in these areas is 3-4 metres, and in the easternmost part of the lake, separated by a natural threshold, it is 5 metres *(Figure 1)*. The local significance of these areas for fishing is great, especially in winter, when vast areas of the main basin are dry. Due to the bottom dams, some important reproductive areas of vendace, pike and ide, have been preserved.

Fishing restrictions have been applied in only a few areas as a means of fishery management. In some limited areas the minimum mesh size allowed has been 27 or 35 mm (knot to knot). In a few areas fishing has been forbidden in spring to protect the pike during its spawning period.

6. The present state of the fish stocks

6.1 Whitefish

About 40% of the whitefish catch from Lake Kemijärvi consists of sparse-gillraker whitefish (32 gillrakers on average), which most probably belong to the naturally reproducing, river-spawning, migratory whitefish stock *(Coregonus lavaretus* s. str.*)*. Before the onset of regulation there was a lake-spawning whitefish with about the same gillraker number *(C. wartmanni* sensu Svärdson 1979), but almost 90% of its spawning grounds have been destroyed by regulation. The normality of the gillraker distribution suggests that stocking with the migratory whitefish with a lower gillraker number (30 gillrakers on average) has not had any perceptible consequence.

The rest of the whitefish catch consists of dense-gillraker whitefish, *i.e.* released peled whitefish *(C. peled)* and plankton whitefish *(C. pallasi* sensu Svärdson 1979). The river-spawning plankton whitefish belonged to the original fish community of the lake, but is not known to reproduce there at present.

The growth of all forms of whitefish is poor. Most of the whitefish catch is taken with 35-40 mm gill-nets (knot to knot), but the catch per unit effort is higher with *c.* 30 mm gill-nets.

6.2 Vendace

Vendace are mostly caught with gill-nets, but seine netting has begun to revive in the recent good vendace years. The vendace spawns at depths of 2-10+ m, and in spite of regulation, some 60% of the natural spawning grounds remain. Sedimentation caused by erosion of the shoreline spoils the quality of the spawning grounds, which results in a higher mortality of eggs and fry.

The degradation of spawning grounds is not directly reflected in catches. The effect depends on the relationship between the number of eggs laid and the year-class strength, and on the intensity of fishing. Due to density-dependent mortality of the young, maximum recruitment is most probably achieved from a certain intermediate spawning stock (Viljanen 1986, Salojärvi 1987). With the present low fishing effort, the loss of eggs caused by regulation may not affect catches at all. With effective fishing, the size of the spawning stock would decrease to a critical level, and thus the loss of the eggs laid on the regulation zone would restrict the year-class strength.

The reduction of spawning areas and the increased density-independent mortality of eggs also increase the risk of the stock collapsing under unfavourable conditions.

In 1982 the vendace catch was lowest during the study period, since when the stock has shown a steady recovery. This is also indicated by the catch per unit effort *(Figure 3)*. There were no exceptionally strong year-classes in the catch during the study period.

6.3 Brown trout

The existence of naturally spawning brown trout stocks in Lake Kemijärvi is questionable. The brown trout spawning in the small rivers flowing into the lake have apparently been local stocks which only occasionally migrated into the lake. Nowadays most of the reproductive areas have been destroyed by the dredging of the rapids. However, restoration of the dredged areas is in progress.

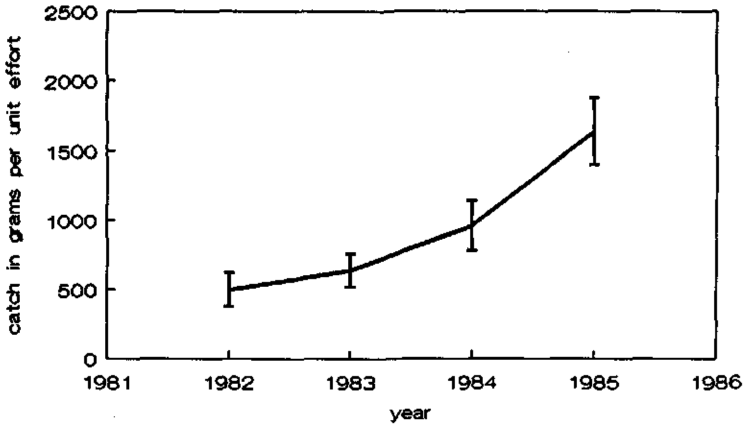

Figure 3. Catch per unit effort (with 95% confidence limits) in gill-net fishing for vendace in Lake Kemijärvi from 1982-1985.

6.4 Pike

The pike is one of the most abundant species in the fish catch from Lake Kemijärvi. The delay of the spring flood, compared with its timing in natural conditions, may disturb the spawning of pike. Erosion, caused by water level regulation, has destroyed the vegetation in many of the flooded areas which are important to pike as spawning and nursery grounds. Nevertheless, reproduction is still likely to be successful in the many sheltered bays which have peaty shores with rich vegetation. The pike also migrates upstream to spawn in the Kemijoki river, which plays an important role in maintaining the pike stock of the lake.

6.5 Roach

There is no active fishing for roach, but it is commonly caught as a bycatch. Dense stocks of small-sized roach are a local nuisance, *e.g.* when fishing for vendace with gill-nets. The high density of the roach stock is most probably due to the vast areas available for its reproduction, although it is commonly believed that roach have migrated downstream to Lake Kemijärvi from the Lokka and Porttipahta reservoirs.

6.6 Perch

Perch form about one third of the catch from Lake Kemijärvi. The reproduction of perch is not disturbed by regulation because its spawning period occurs when the water level is near to the upper limit of regulation. The perch are slow-growing, and the age distribution indicates incomplete recruitment to the gill-net fishery.

6.7 Pikeperch

The pikeperch *(Stizostedion lucioperca)* is one of the original species in the lake, but it is very scarce at present. In Lake Kemijärvi pikeperch is at the northern limit of its range and is therefore sensitive to changes in the environment (Lehtonen *et al.* 1984). Reproduction may fail because of the short growing season, and there may be high mortality among the young during the first winter. Indirect effects of regulation, such as sedimentation, increase the death of eggs and fry, although there is no marked water level fluctuation during the reproductive period of pikeperch.

7. Problems of fisheries management

A schematic presentation of the adverse effects of habitat modification on the fisheries of Lake Kemijärvi is given in *Figure 4*.

7.1 Factors decreasing the interest in fishing

According to the fishermen interviewed, the tearing of fishing gear on stumps and wood snags in the regulation zone is the greatest hindrance to fishing in Lake Kemijärvi. The next, in order of importance, are fouling of fishing gear and fluctuation of the water level. Log floating prevents fishing locally for about one month in early summer.

Badly flavoured fish flesh, due to pulp mill effluents, occurs mainly in predator species in Lake Kemijärvi, *e.g.* pike, perch and burbot *(Lota lota)*, and only occasionally in other species such as vendace (Nenonen 1987). Badly flavoured fish are mostly restricted to the area influenced by the pulp mill effluents, but are also found upstream of the mill in spring, due to the spawning migration of pike. Bad flavours from other causes, such as eutrophication or log depositories, occur locally, *e.g.* in the eastern branch of the lake.

In the beginning of the 1980s mercury concentrations exceeding 0.5 mg/kg were found in pike from Lake Kemijärvi, and in consequence, the public was advised not to eat the fish more than once a week. It is very likely that the news of the high mercury content of fish from Lake Kemijärvi caused the decline in the number of fishermen, the fishing effort, and the catches during the 1980-1982 period. Some fishermen moved their gear to other lakes, although the quality of most of the fish from Lake Kemijärvi was perfectly acceptable. In 1985, mercury concentrations slightly over 0.5 mg/kg were found only in pike from the central area of the lake (Surma-aho & Knuutila 1985). In fact, the mercury content of pike in Lake Kemijärvi was similar to the average values found in pike from other Finnish lakes, and mercury in fish has been found to be connected with high concentrations of humic substances in the water (Verta, Rekolainen & Kinnunen 1986).

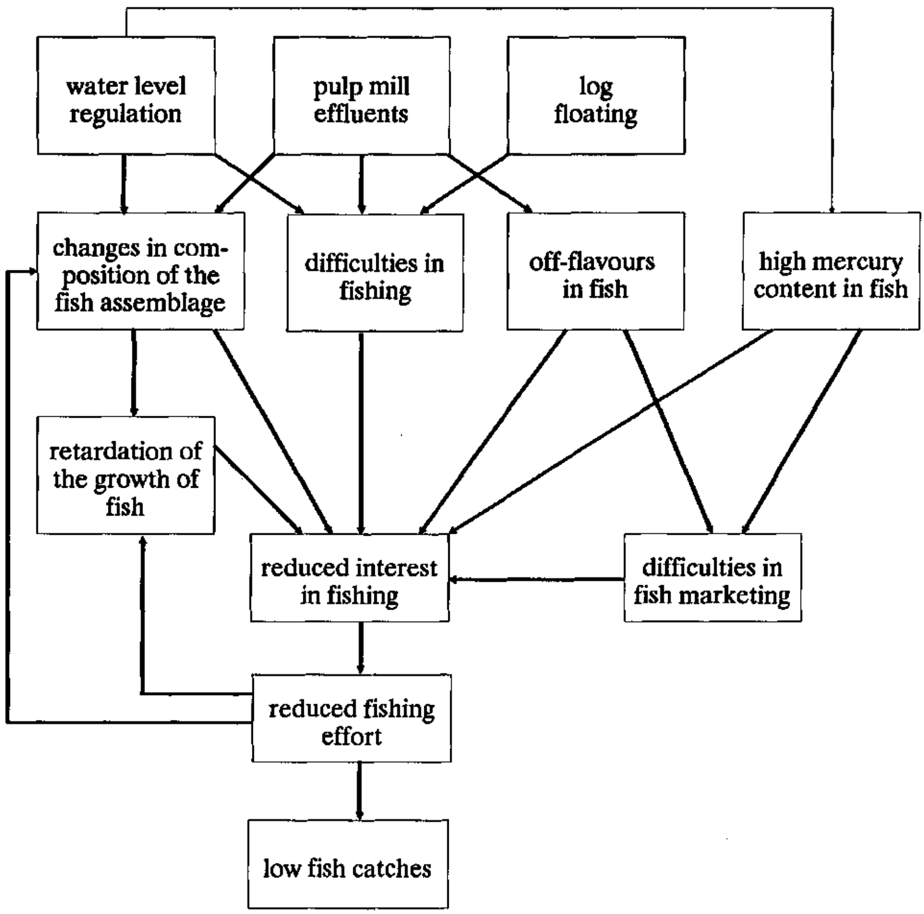

Figure 4. The effect of habitat modifications on the fisheries of Lake Kemijärvi.

The bad reputation of Lake Kemijärvi fish spoiled the market for all species, and hence the fishery, in the early 1980s. However, recently, interest in fishing the lake has begun to recover due to improvement of the vendace stock and the opening of foreign markets for pike and perch.

7.2 Reduction of food resources of fish

The bottom fauna of the littoral zone in Lake Kemijärvi is typical of that of regulated lakes. Important fish food organisms which dominated the littoral in the natural state, such as *Ephemera vulgata, Pontoporeia affinis* and *Pallasea quadrispinosa*, are now rare or missing over vast areas (Tikkanen 1987). Chironomid larvae, which are much less valuable as fish food, are now the most common element of the littoral bottom fauna. The diminution of food resources affects bottom-feeding whitefish most severely, *i.e.* sparse-gillraker forms such as the migratory whitefish, and young brown trout. The diet of all forms of whitefish now consists mainly of chironomids and zooplankton (Huusko 1987).

7.3 Downstream migration of the fish released

In early summer, fish from Lake Kemijärvi have been observed to migrate downstream in large shoals at the time of log floating. Vendace and whitefish are the most common species, together with young brown trout used for stocking (Heikinheimo-Schmid & Huusko 1987b).

The distribution of the gillraker numbers of the migrating whitefish indicates that most of them are introduced migratory whitefish. This supports the hypothesis that the sparse-gillraker whitefish in Lake Kemijärvi are mostly of natural origin. The proportion of planktonivorous whitefish in the group migrating downstream was small while peled whitefish were lacking (Heikinheimo-Schmid & Huusko 1988).

Downstream migration of whitefish and vendace most probably occurs when the density of the stock is too high in relation to food resources, thus being a mechanism of population regulation. If stocking density is suitable, whitefish grow well and remain in the lake (Salojärvi 1986). The migratory whitefish may also have a greater tendency to leave the lake, since littoral food resources are scarce and their sparse gillrakers render them unable to compete successfully for plankton with the other forms of whitefish and vendace.

The downstream migration of introduced brown trout may also be connected with the lack of littoral bottom food, on which this species depends before it becomes piscivorous. The migratory behaviour of different brown trout stocks also varies (Gönczi 1985). The conditions in the main basin of the lake may be unfavourable to brown trout because of the strong current, especially in spring.

7.4 Selective fishing

The great proportion of gill-nets in the fishing effort makes fishing selective, leaving the small-sized fish. In the present situation in Lake Kemijärvi, the dense, slow-growing perch and roach stocks recruit incompletely to the fishery, and the whitefish fishery is also ineffective. The present stocking density of whitefish is apparently too high in relation to the fishing effort, and this has reduced their growth. The biomass of the whitefish stock and the yield per 1000 stocked fingerlings are found to be inversely related, which is due to retarded growth occasioned by high stock densities (Salojärvi 1989).

Yield per recruit curves show that more effective fishing with the types of gear used at present would not increase the catch of any species. Intensive harvesting of the younger age groups by non-selective fishing gear, such as seine nets and traps, would decrease the density and thus stimulate the growth of the fish, and their recruitment to the fishery.

There is increasing evidence of the beneficial effects of intensive fishing on the vendace stocks (Sarvala 1986). Great oscillations in the strength of the year-classes may be a consequence of unbalanced fishing, which leads to strong exploitation of top predators and a too weak exploitation of vendace (Salojärvi 1987). Effective seine netting can prevent the formation of over abundant year-classes and thus dampen the fluctuations of the vendace stocks, increase the catches and make the supply for fish markets more even.

8. Proposals for fisheries management

8.1 Stocking whitefish

The stocking density for whitefish is at present too high, in view of the existence of the natural whitefish and vendace stocks and the downstream migration of the whitefish released in the upper part of the watercourse.

The yearly releases of planktonivorous and peled whitefish should remain at the present level, and stocking with sparse-gillraker whitefish should be stopped. The yearly rate of whitefish stocking would then be 6-7/ha, more than half of which would be planktonivorous whitefish.

The stocking density for whitefish in the upper watercourse should also be reduced to prevent migration to Lake Kemijärvi, or else migration should be taken into account in calculating the stocking numbers for Lake Kemijärvi.

8.2 Stocking brown trout

Stocking with brown trout often fails in regulated lakes (Toivonen *et al.* 1983). Stocking with larger piscivorous young has given better results (Gönczi 1985, FÅK 1986). Experiments should be made with brown trout stocks other than those used at present. The tendency to downstream migration might be diminished by acclimating the young to the stocking lake in net cages before release and avoiding stocking during the log floating time. Brown trout could be both a desirable catch species for local subsistence fishermen and an attraction for sport fishermen from other regions.

8.3 Stocking other species

Reintroduction of pikeperch into Lake Kemijärvi would have a beneficial effect on the composition of the fish assemblage similar to that of non-selective fishing, since it would increase predation on the undesirable fish stocks. Release of 1-summer old fingerlings would allow the fish to reach the critical size for survival over the first winter. Pikeperch fishing is not a traditional form of fishing in Lake Kemijärvi and therefore guidance would be needed. Pikeperch would also be suitable for sport fishing with spinning rods.

Little is known about grayling *(Thymallus thymallus)* in fisheries management. Gönczi (1985) recommended stocking with grayling in river reservoirs because they are fairly stationary and have opportunistic feeding habits. Grayling might also be suitable for Lake Kemijärvi.

8.4 Fishing

Thinning of over abundant roach, perch, and whitefish stocks by intensive, nonselective fishing would relieve competition and improve the growth of more valuable species. The use of gill-nets with a small mesh size (about 30 mm knot to knot) should be increased. Fishing with seine nets, traps and hooks can be recommended. Pound nets have proved successful for whitefish, *e.g.* in Lake Oulujärvi (Salojärvi, pers. comm.), and the use of these nets should be allowed, at least by professional fishermen. The littoral should be cleared, so that the lack of suitable sites does not restrict the use of seines.

Fears concerning mercury contents and off-flavours in fish should be eliminated by information campaigns, and the situation should be regularly monitored. Despite this, subsistence and recreational fishing by the local people will probably remain the most important form of fishing in Lake Kemijärvi. Because of the location of the lake, near Rovaniemi, the largest city in Finnish Lapland, there should be good opportunities for developing a recreational fishery in connection with tourism, for instance by organizing guided fishing trips.

Professional or semi-professional fishing in Lake Kemijärvi could be based on fishing for vendace, pike and perch, if the supply of vendace was more uniform. The maximum mercury concentration in marketable fish in Finland is 1.0 mg/kg, which has never been exceeded in Lake Kemijärvi.

References

FÅK, 1986. Fiskevård i älvmagasin. Slutrapport, del I. Sundsvall. 155 pp.

Gönczi, A.P., 1985. Utsättning av harr i kraftverkmagasin. FÅK informerar. 20: 23-31.

Gulland, J.A., 1983. Fish stock assessment. A manual of basic methods. Volume I. Chichester. John Wiley & Sons. 223 pp.

Heikinheimo-Schmid, O. & Huusko, A., 1987a. Kemijärven kalata- louden nykytila ja ehdotukset kalakantojen hoito- toimenpiteiksi. Helsinki. RKTL, kalantutki-musosasto. Monistettuja julkaisuja. 69: 212 pp.

Heikinheimo-Schmid, O. & Huusko, A., 1987b. Kalojen vaellus Kemijärvestä alavirtaan. Helsinki. RKTL, kalantutki- musosasto. Monistettuja julkaisuja. 68: 223-251.

Heikinheimo-Schmid, O. & Huusko, A., 1988. Management of coregonids in the heavily modified Lake Kemijärvi, northern Finland. International Symposium on the Biology and Management of Coregonids, Joensuu, Finland 1987. Finnish Fish. Res. 9: 435-445.

Huusko, A., 1987. Siian ja ahvenen ravinnosta Kemijärvessä. Helsinki. RKTL, kalantutkimusosasto. Monistettuja julkaisuja. 68: 195-222.

Kinnunen, K., 1987. Kemijärven tilan kehittyminen järven säännös- telyn aikana. Helsinki. Vesi- ja ympäristöhallituksen monistesarja. (in press).

Lehtonen, H., Miina, T. & Frisk, T., 1984. Natural occurrence of pikeperch *(Stizostedion lucioperca* (L.)) and success of introductions in relation to water quality and lake area in Finland. Aqua Fenn. 14: 189-196.

Lovikka, T. & Alapuranen, J., 1982. Lapin läänin alueellinen kalataloussuunnitelma. Osaraportti 1. Lapin kala- talouden nykytila. Rovaniemi. Lapin läänin kala- toimisto. 72 pp.

Nenonen, M. (Ed.), 1987. Kemijärven tila ja kalatalous (English summary: The state and fisheries of Lake Kemijärvi. Final report and proposal for future action). Helsinki. Vesi- ja ympäristöhallinnon julkaisuja. 13: 134 pp.

Partanen, H., 1987. Selvitys Kemijärven kalan markkinoinnista. Helsinki. RKTL, kalantutkimusosasto. Monistettuja julkaisuja. 68: 83-111.

Reuna, M., 1979. Vedenkorkeuden aikakäyriä ja pysyvyyksiä. Helsinki. Vesientutkimuslaitoksen julkaisuja. 33: 85 pp.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 pp.

Robson, D.S. & Chapman, D.G., 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90: 181-189.

Salojärvi, K., 1986. Review of whitefish *(Coregonus lavaretus* L. s.l.*)* fingerling rearing and stocking in Finland. Arch. Hydrobiol. Beih. Ergebn. Limnol. 22: 99-114.

Salojärvi, K., 1987. Why do vendace *(Coregonus albula* L.*)* populations fluctuate? Aqua Fenn. 17: 17-26.

Salojärvi, K., 1989. Population regulation of stocked northern densely-rakered whitefish *(C. pallasi)* in Lake Kallioinen, northern Finland. (Manuscript).

Sarvala, J., 1986. Järven kalatuotantoa säätelevät tekijät. (Factors regulating fish production in lakes). Research contract 09/109 of the Academy of Finland. Final report. Turku. (Mimeo.).

Sormunen, T., 1964. Kemijärven säännöstelyn kalataloudellinen ja limnologinen tutkimus. I. Luonnontila ja ehdotukset. Helsinki. Kalataloussäätiön monistettuja julkaisuja. 8: 91 pp.

Surma-aho, K. & Knuutila, M., 1985. Tutkimusraportti Kemijoen ja Kemijärven kalojen elohopeapitoisuuksista. Jyväskylä. Jyväskylän yliopisto, Ympäristöntutkimuskeskus. 12 pp. (Mimeo.).

Svärdson, G., 1979. Speciation of Scandinavian *Coregonus*. Rep. Inst. Freshw. Res. Drottningholm. 57: 1-95.

Tikkanen, P., 1987. Kemijärven pohjaeläinyhteisöistä litoraalissa ja profundaalissa sekä niitä säätelevistä tekijöistä. Rovaniemi. Kemijoen vesiensuojeluyhdistys ry. 53 pp. (Mimeo.).

Toivonen, J., Ikonen, E., Lindström, A., Alapassi, T. & Kokko, U., 1983. Järvitaimenen merkittyjen poikasten istutukset Suomessa vuosina 1959-1969. Helsinki. RKTL, kalantutkimusosasto. Monistettuja julkaisuja. 15: 226 pp.

Viljanen, M., 1986. Biology, propagation, exploitation and management of vendace *(Coregonus albula* L.*)* in Finland. Arch. Hydrobiol. Beih. Ergebn. Limnol. 22: 73-97.

Verta, M., Rekolainen, S. & Kinnunen, K., 1986. Causes of increased fish mercury levels in Finnish reservoirs. Vesihallitus. Vesientutkimuslaitoksen julkaisuja. 65: 44-58.

Personal communications: Salojärvi, K., MSc, Finnish Game and Fisheries Research Institute, Fisheries Division, Helsinki, Finland.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 67-73.

Propagation and management of the asp, *Aspius aspius* (L.), in Finland

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Abstract

Finland's only self-sustaining asp stock lives in the Kokemenjoki River watershed. The asp (*Aspius aspius*) is ranked at the top of the threatened species list in Finland. Thus, the Finnish Game and Fisheries Research Institute started a project for the artificial propagation of asp. This large cyprinid predator can also be used in the recreational fishery and as a biological ameliorator in eutrophic waters.

Spawners were caught by gill-netting at the beginning of May. Pituitary injections were used to induce ovulation in females. The eggs were incubated in glass incubation jars using modified Soviet techniques. Milk treatment was found to be the best method for eliminating the adhesiveness of the eggs. The incubation period lasted 8-24 days, depending on water temperature during incubation. Fry were reared in natural rearing ponds, and the fingerlings were released into natural waters during September and October. 1-summer old asp reached a mean weight of 1.0-6.0 g and a mean length of 5-9 cm. Some experiments have been carried out on the artificial feeding of young asp. The first summer and winter survival rates in rearing ponds were high, and some evidence of good growth and survival is provided by the preliminary results of stocking in waterbodies where the asp does not naturally occur.

The purpose of the project is to enhance the original population and to re-introduce asp to its former haunts. A legal size of 50 cm and regulation of fishing during the spawning season would help secure natural reproduction. For survival of the species it is necessary to protect the remaining spawning grounds from water level regulation.

1. Introduction

The asp, a large cyprinid predator, lives in southern Finland at the northernmost extent of its range. It has been limited to some lake and river systems with suitable spawning grounds in rapids. It has never been numerous, and only two freshwater populations have supported a fishery. Since the 1950s, one of the two major populations has died out while the other has diminished radically. The main causes for the decline seem to have been pollution, water level regulation for power generation and construction work, and possibly overfishing (Ulvinen 1983, Pennanen 1987). Similar factors have accounted for the decline of asp catches in other countries, *e.g.* eutrophication, pesticides and intensive fishing have reduced stocks in Lake Balaton, Hungary (Biró 1979), and changes in riverine flow regimes and the increasing salinity of the Aral Sea have destroyed stocks in the USSR (Ermahanov & Rasulov 1983).

In order to conserve and enhance the last self-sustaining asp stock in the Kokemenjoki River system and to re-introduce asp to its former haunts, the Finnish Game and Fisheries Research Institute started a project at Porla fish farm in 1984. From the beginning this project was supported by WWF-Finland. Juhani Jokela, a fish farmer from

Vammala, western Finland, has cooperated with us. The study has focused on attempts to induce ovulation of females in captivity, develop incubation techniques, and rear asp fry in ponds with natural food resources. The need to produce asp fingerlings for stocking was also recognized by the Commission for the Protection of Threatened Animals and Plants (Uhanalaisten eläinten ja kasvien suojelutoimikunnan mietintö 1986). The commission ranked the asp as an endangered species in Finland.

Experiences in artificial propagation of asp have been reported earlier by Babaev (1976) and by Vostradovsky & Vasa (1981). The possibility of stocking to create or support a recreational fishery, or to use this species as a biological ameliorator in eutrophic waterbodies makes the asp a fascinating object for fish culture.

2. Propagation

2.1 Trapping and hormonal treatment of spawners

Brood fish were caught by experienced fishermen using gill-nets with 55 to 75 mm mesh-sizes. The fish were captured adjacent to spawning sites before spawning or during spawning, in the first half of May. Spawners were either kept in net cages in running water near the spawning grounds, or were moved immediately to the hatchery for stripping. As early as 1984 it had been noticed that in captivity final maturation of females did not proceed, even if they were caught only a few days prior to spawning. Because of this and the uncertainty of obtaining fully ripe spawners of both sexes at the same time, we decided to use hormonal stimulation of non-ripe female spawners.

Earlier, Babaev (1976) had reported successful hormonal induction of final maturation in the asp. He used acetone dried hypophyses of asp or wild carp to induce ovulation and spermiation, in doses of 3 mg per kilogram live weight for females and 5 mg per individual for males.

In our modification of the technique we used pituitary glands of bream, *Abramis brama*. This species was chosen as a donor species because it is said to be closely related to the asp. It is abundant, large (having large hypophyses), and available at the right time (late winter). Only glands of mature and healthy fish were accepted. Hypophyses were removed from freshly killed bream and dehydrated in acetone for 24 hours. They were stored dry for 1 to 2 months before use. For injections, an extract of pulverized pituitaries was prepared in 0.9 % NaCl solution. The dose we used was 3 mg hypophyses per kilogram live weight of female asp. Injections were administered intramuscularly, usually as two fractions; the first contained 10-30 % of the total dose, while the second (given 24 hours later) contained the rest. For the treatment, as well as for controlling readiness to spawn and for stripping, the fish were anaesthetised with MS222. After hypophysation the fish were kept in net cages or in pools with running water to await ovulation.

From 1985 to 1987 a total of 22 female asp were injected with bream pituitary extract to induce ovulation. In 18 cases ripe eggs could be stripped and fertilized. The stripped eggs of two females could not be fertilised. In these cases there had been a delay of several days from capture to injection. Two females died before ovulation from injuries caused by gill-netting. Without pituitary treatment, females kept in captivity usually failed to ovulate. Especially during the springs of 1985 and 1987, when weather conditions in May were cold and capricious, the chance of getting fertile eggs without hypophysation was only about 50 % *(Table 1)*.

Table 1. Number of female asp captured fully ripe, injected with bream pituitary extract, or kept in captivity without pituitary injections, together with the number of females which gave fertilized eggs, and the number of females which failed to ovulate.

Year	Captured ripe	Pituitary treated			Untreated		
	Number of ripe females	Number of ripe females	Number giving fertilized eggs	Number failing to ovulate	Number of ripe females	Number giving fertilized eggs	Number failing to ovulate
1985	4	4	4	-	16	7	9
1986	8	9	8	1	13	11	2
1987	6	9	6	3	13	6	7
Total	18	22	18	4	42	24	18

The ripening time between the second injection and ovulation was negatively correlated to water temperature and closely followed the relation given by Babaev (1976), requiring about 85 hours at 7°C, 72 hours at 8-9°C and only 45 hours at 10-11°C. Also, eight individuals, given the whole pituitary dose in one injection, responded with ovulation following this schedule.

It may be concluded that one normally succeeds in inducing the final maturation and ovulation of asp eggs using this method, providing that the fish are injected within 1-2 days of capture and that treatment and temperature conditions are adequate. The pituitary treatment also gives the exact timing of stripping. It minimizes handling of the fish and hence increases the chance of securing eggs of good quality. Thus use of the pituitary treatment of female asp can be recommended when the captured fish have not yet ovulated.

Generally, sufficient milt could be stripped easily, from anaesthetised males, and they were used 2 to 3 times during the spawning season. However, not all captured males were fully ripe, and in some instances there was a lack of milt. To guarantee successful fertilization, pituitary treatment of males, as well as freeze-conservation of sperm, could be useful.

After spawning, breeders were released to their native waters. A few individuals were left in the ponds at Porla fish farm in order to examine the possibility of producing eggs and milt in captivity. So far this has not succeeded.

In May 1986, 28 adult asp were released with Carlin tags attached by steel wires around the thickest ray of the dorsal fin. During the year six individuals were recaptured. Three of these were taken during spawning on the same sites as a year earlier. We could strip all three (two females, one male) again, and one of the females was pituitary treated in both years. Thus it appears that the stripping of roe and milt is not harmful to the asp. We have found no evidence that adult asp would not spawn annually.

2.2 Fertilization and incubation

Sperm of two or more males was always used for fertilisation of the eggs of each female. Eggs and sperm were mixed dry in a bowl. For fertilisation and subsequent rinsing of the eggs we used a modified milk treatment recommended by Soin (1977). Milk was diluted with water 1:4-1:5 and 1.0-1.5 g NaCl per litre was added. Fertilisation was accomplished using a small amount of this emulsion, after which 10 litres of emulsion per litre of fertilized eggs was poured on. Continuous stirring for 90 min was necessary to diminish the stickiness of the fertilized eggs for incubation in jars. The swollen eggs were poured into incubation jars (8 or 20 litres).

This method does not totally nullify the adhesiveness of the eggs, which continue to swell for 1 to 2 hours. It is therefore essential that not more than 350 to 450 g of eggs (weighed before fertilization) are placed in each 8 litre jar. The conventional urea-tannin treatment, which we used in our first attempts, gave loose eggs, but the hatching success was considerably lower than with milk treatment.

Above the funnel-shaped bottom part of the jar we usually placed a strainer plate. During the delicate stages before the completion of gastrulation, water flow was kept slow and the eggs were allowed to lie almost stagnant on the plate. After approximately 24 hours the strainer plate was removed, the flow was increased, and the eggs were forced to rotate slowly. For incubation we used river or pond water, which was not always filtered. If fertilization had not been very successful, it was necessary to siphon dead eggs from the jars and use of malachite green treatments to stop the growth of *Saprolegnia*. Hatching success seems to depend mainly on the rate of fertilization, which is very dependent on the timing of stripping.

Because of uncontrolled water temperature, the duration of the incubation period varied greatly. A rapid increase in water temperature from 9°C to 16°C (1°C per day) induced hatching after 8 days of incubation. On the other hand, if water temperature after fertilization remained long at 7-10°C, the incubation increased to 16-24 (max 28) days. If the development had been rapid, the larvae hatched in their early stages about 7 mm long and fully transparent, while a long incubation period yielded 9-10 mm, pigmented larvae, ready to fill their swim-bladders. As Lange *et al.* (1975) noted, larval asp have no adhesive gland and they lie on horizontal surfaces. In incubation jars, every now and then, larvae swim for 3-5 seconds spirally upwards and then falling down again. As soon as the swim-bladders are filled, larvae start to swim horizontally, searching for food. Larvae were carried out of the jar by a water current or were siphoned into collection boxes. The boxes, where the larvae were kept for 1-4 days in running water, had a double bottom made of sifting fabrics (mesh aperture 0.6 mm). Then, the post-larval asps, already shoaling and feeding, were transferred to rearing ponds.

2.3 Production of fingerlings

The rearing ponds had areas of 0.3-10.0 ha and a mean depth of about 1 m. They were filled one week in advance. Fry were grown on the natural food resources of the ponds. In general, first summer survival of the asp fry has been at least 75 %. We have used stocking densities of 0.5-4.0 fry per m^2. In Finland the productivity of ponds with asp fry in monoculture has been 25-50 kg/ha.

Depending on the stocking density and the temperatures during the growing season, fry reached a mean length of 50-92 mm during their first summer *(Table 2)*. This corresponds well with the observed lengths of 1-summer old asp from natural spawn in Finland. At smaller fry densities a mean weight of 4-6 g may be reached. In Czechoslovakia, according to Vostradovsky & Vasa (1981), the mean weight of reared 1 year old asps is 10 to 20 g.

The ponds were emptied during September and October. The captured fingerlings were transported in tanks or polythene bags to stocking sites. Fingerlings were easy to handle, *e.g.* scale losses were slight and mortality was insignificant.

Each year small groups of asp fingerlings have been retained at Porla fish farm. From these fish we hope to get a hatchery brood stock. They have shown very low over-winter mortality. In summer they have been fed dry pellets as additional food. Thus it is possible to produce 1-2 year old asp for stocking. In Finland, however, production of stocking material on a large scale is profitable only when based on pond-rearing of 1-summer old fish.

Table 2. Variation in mean size of 1-summer old asp, from 1984-1987.

	Number of groups	Mean length (mm)		Mean weight (g)	
		min	max	min	max
1984	2	90	92	5.0	6.0
1985	5	54	80	1.2	3.6
1986	6	70	90	2.4	5.0
1987	8	50	73	1.0	2.8

3. Management

3.1 Management and protection of the original population

Data on asp catches from the Kokemenjoki River, and Lakes Kulovesi and Rautavesi which discharge into it, are sparse or totally lacking before the 1950s. During the 1950s, catches of about 1000 to 3000 kg were taken annually from the two lakes, which have a total area of about 6300 ha. Pulp industry wastes then spoiled the water quality and the spawning grounds of the asp. Catches from the lakes fell to 150-200 kg per year in the 1960s. In the 1970s the main spawning grounds of asp inhabiting the lakes were lost because of new dams (Pennanen 1987). In spite of the gradually improving water quality since the 1960s, the asp stock has not recovered.

Our presumption is that the recruitment of asp in Lakes Kulovesi and Rautavesi is very low due to the loss of suitable spawning grounds. Because of the small population size and long generation time (8-9 years), natural recovery of the stock will be slow, if indeed it will recover at all. Implicitly, successful artificial spawning and stocking of fingerlings should help the stock recover.

Pennanen (1987) estimated that, on the basis of data on fecundity, growth and reproductive life-span, and assuming a 1% survival from egg to 1-summer old, one mature female asp of the Kokemenjoki watercourse stock produces an average of 2800 fingerlings during her lifetime. Using artificial propagation, this 'subsistence limit' can easily be exceeded, thanks to high first summer survival.

Our aim is to enhance the asp population by stocking, which is a prerequisite for intensifying the fishery. For the present we have no means of assessing the level of stocking of fingerlings needed to restore catches to their former levels. However, an annual stocking of 0.1 million fingerlings would probably lead to a slight improvement in the catch and provide a rough estimate of stocking success.

Since 1984 less than 200 000 asp fingerlings have been released to this watercourse. Attempts to evaluate the effect of this level of stocking have not been carried out. Under fish farm conditions we have used hot-wire-marking of fingerlings on an experimental scale. The imprint is visible for at least one year, and group marking of reared fingerlings would suffice to distinguish between reared and natural 1 year old (1+) asp. Several factors suggest that stocking with 1-summer old asp should be successful. First, the asp is a native fish of Finland whose fingerlings are adapted to the long winter. Secondly, asp become piscivorous only gradually, largely during their second summer; thus the contribution of a year-class to recruitment is not conditioned by becoming piscivorous during the first growing season. The reared asp fingerlings from each pond are very even-sized. Thirdly, first records of asp, introduced as fingerlings in 1985 to two lakes in southern Finland, were made in the summers of 1986 and 1987. In these new environments the young asp had grown well; their mean weight exceeded 100 g in July 1987.

Within the Kokemenjoki River system asp has traditionally been valued highly by fishermen, and it can be considered a valuable species in the recreational fishery. In addition to its value to the fishery, conservation of the asp stock is of prime importance to nature conservation in the area. The two interests need not conflict. Intensive fishing on spawning grounds using gill-nets, which might be fatal, should be restricted for propagation purposes only. A minimum legal length of 50 cm (total length) should be imposed since smaller individuals are immature. Otherwise, we believe, fishing does not threaten the stock. However, data on fishing mortality and population size are still few, and these should be studied, as well as the success of naturally spawned fish. Regulation of a fishery is often necessary to prevent the depletion of asp stocks. In Lithuania, according to Gajgalas (1977), positive changes in the age-composition of catches, and larger catches, resulted from fishery regulations. According to him, irrational fishing of immature and spawning asp should be discontinued. Biró (1979) stated that in the changed environmental conditions of Lake Balaton the intensity of asp fishing had to be reduced. In various parts of the USSR a minimum legal catch length is imposed for asp.

Dredging a part of the River Kokemenjoki and its tributary, the Loimijoki, as planned by the National Board of Waters and Environment, would destroy some of the last few spawning grounds of the asp. Such efforts should be strongly opposed. On the contrary, the restoration of rapids areas is necessary, together with a reduction of the levels of daily flow regulation.

3.2 Re-introduction of asp and its use for biomanipulation

Re-introduction of the asp to the River Kymijoki was begun with fingerlings in 1987. Establishment of a new population would both lower the chance of extinction of the species and improve the value of the recreational fishery in this river system. In addition, two other lake and river systems in southern Finland have been stocked with asp fingerlings.

In Czechoslovakia, according to Vostradovsky (pers. comm.), water-supply reservoirs have been stocked with asp to control the small planktivorous coarse fish, which when abundant, promote poor water quality. Juvenile and adult asp feed mainly on 2-7 cm long fish; in summer they consume the fry of other cyprinids, very largely (Popova 1978). Unlike pike and pikeperch, asp exhibit no cannibalism within year-classes. It can therefore be stocked in greater densities than other predatory species used for amelioration purposes. This makes it a very promising species for biomanipulation of eutrophied waters in southern Finland and other areas of its range. However, the possible effects of introducing asp to freshwater ecosystems should be carefully investigated. These kinds of studies will be best carried out in small waterbodies.

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References

Babaev, N.S., 1976. Metodiceskie ukazanija po iskusstvennomu razvedeniju aral'skogo zereha. Leningrad, GosNIORH. 15 pp.

Biró, P., 1979. Human impacts on biomass, population size and yield-per-recruits of asp *(Aspius aspius* L.) in Lake Balaton. Symp. Biol. Hung. 19: 125-139.

Ermahanov, Z. & Rasulov. A.H., 1983. Analiz nerestovogo stada i harakteristika proizvoditelej aral'skogo krasnogubogo zereha *Aspius aspius* iblioides (Kessler) (Cyprinidae) nizov'ev reki Syrdar'i. Vopr. Ihtiol. 23: 933-940.

Gajgalas, K.S., 1977. Morfoekologiceskie osobennosti i hozjajstvennoe znacenie zereha *Aspius aspius* (L.) v bassejne zal. Kursju Mares. Vopr. Ihtiol. 17: 1016-1023.

Lange, N.O., Dmitrieva E.N., & Islamgazieva, R.B., 1975. Osobennosti razvitija zereha *Aspius aspius* (L.) niznego tecenija r. Ural. In: Disler, N.N. (Ed.). Osobennosti razvitija ryb v razlicnyh estestvennyh i eksperimental'nyh uslovijah. Moscow, Nauka. pp. 3-33.

Pennanen, J.T., 1987. Kokemenjoen vesistn toutaimen hoito- ja suojeluohjelma. Helsinki, RKTL, kalantutkimusosasto. Monistettuja julkaisuja 60: 56 pp.

Popova, O.A., 1978. The role of predaceous fish in ecosystems. In: Gerking, S.D. (Ed.). Ecology of freshwater fish production. Blackwell, Oxford. pp. 215-249.

Soin, S.G., 1977. O nekotoryh osobennostjah razvitija karpa *Cyprinus carpio* L. v svjazi s inkubaciej ego ikry v zavodskih uslovijah. Vopr. Ihtiol. 17: 900-911.

Uhanalaisten eläinten ja kasvien suojelutoimikunnan mietintö. 2. Suomen uhanalaiset eläimet. Helsinki 1986. Komiteanmietintö 1985: 43. 466 pp.

Ulvinen, A., 1983. Kymenlaakson sisvesien toutaimesta ja sen hvimisest. Suomen Kalastuslehti 90: 191-193.

Vostradovsky, J. & Vasa J., 1981. Bolen dravy *(Aspius aspius* L.) - novy objekt umeleho chovu (Asp *(Aspius aspius* L.) as a new fish species for rearing). Buletin VURH Vodnany 17: 10-13.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 74-81.

On the natural and introduced fish fauna in Finnish reservoirs

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Abstract

Since the 1960s about 20 reservoirs have been constructed in Finland mainly for flood control and hydro power purposes. Typically they are shallow (mean depths 1.5-7 m), small (c. 1000 ha) and built on peat land and coniferous woodland. The water is polyhumous (colour 100-400 mg Pt per l), acid (pH 5-6), and very low in oxygen content during the winter draw down. Macrophyte vegetation is sparse.

The most common fish species are pike, perch, roach, burbot and ruffe and, in addition, in some reservoirs, bream, bleak and crucian carp. In many reservoirs perch is dominant during the first years after impoundment. Bottom fauna is important food for most species. Coregonid and salmonid species have been introduced to almost all reservoirs, in some cases in large numbers.

We studied 13 reservoirs of varying character, e.g. age, situation in the watershed, hydrography and littoral conditions. The number of fish species was lowest in the acid, upper reach reservoirs, where plankton feeders were lacking.

Fish have been introduced into reservoirs regardless of the possibilities of the species surviving there. The factors influencing fish stocking were mostly of social character and the species introduced were those with high economic values, but very little chance of surviving the severe winter conditions in the reservoirs.

1. Introduction

This study is part of a research programme on Finnish reservoirs, and ecological successions in them, and is financed by the National Board of Waters and Environment and the Academy of Finland. The aim of the study is to investigate abiotic and biotic conditions and successions in these waters, which do not seem to have any clear counterpart among reservoirs elsewhere and still less among natural waters. The results can be applied to the development of water quality monitoring programmes, bottom fauna methodology and fishery management in reservoirs.

Fishing rights in the reservoirs are held by local fishing guilds or private land owners. The guilds sell fishing licences and are responsible for the management of the fisheries. In management decisions the guilds are assisted by publicly funded fishery advisers, and management may be financed by public funds.

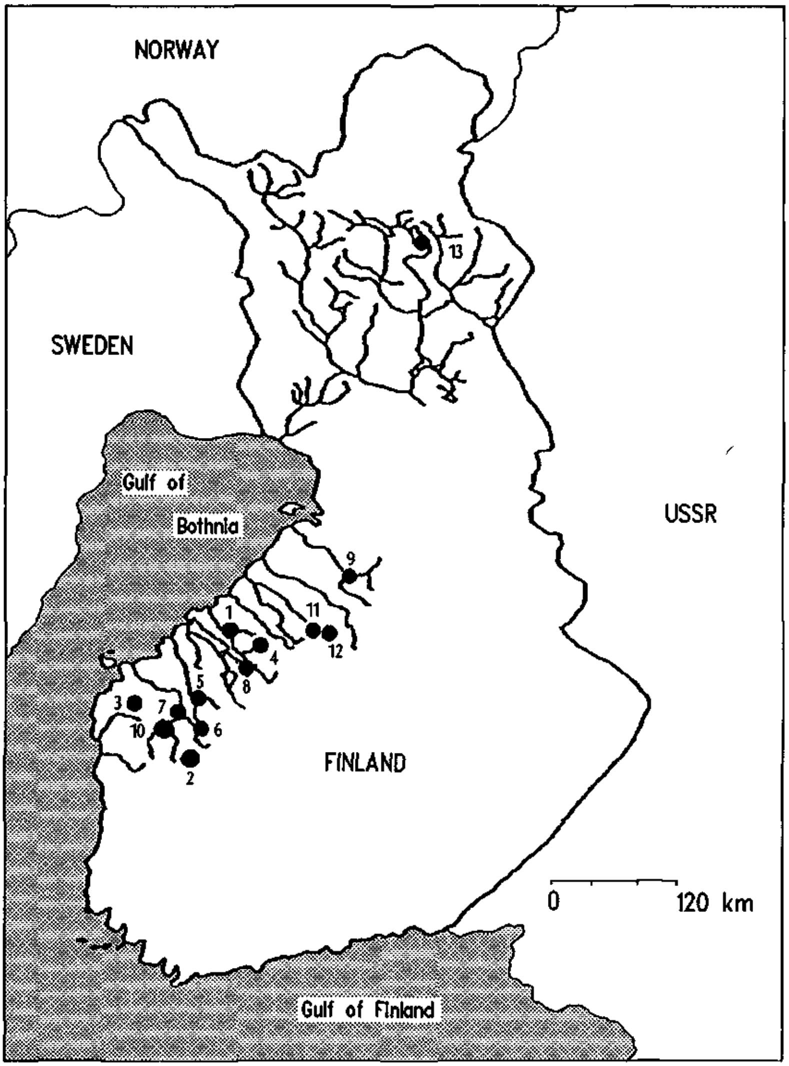

Figure 1. Study area. For names of reservoirs (1-13) see Table 1.

2. Description of the reservoir studies

Most Finnish reservoirs are built near the west coast for flood control and hydro power purposes *(Figure 1)*. The oldest ones are now over 20 years old. Typical features of the reservoirs *(Tables 1 and 2)* are shallowness, small size, inundated bottom areas of peatland and coniferous woodland, polyhumous acid water, severely low oxygen concentrations during the winter draw down and sparse macrophyte vegetation (Vogt 1978). However, aquatic mosses may cover large bottom areas in the more acid reservoirs, which often have very gently sloping shores without any eroding activity (Koskenniemi 1987). In the larger reservoirs, due to erosion, the bottoms of the littoral zones are mainly minerogenic.

Table 1. General characteristics of the reservoirs.

Reservoir	Age in 1988	Area	Mean depth	Theoretical residence *time*	Mean regulation efficiency	Peat soils of the bottom area	Share of different shoreline types (%) of the natural shoreline length			
							Minerogenic	Organogenic shoreline types		
	years	km²	m	days		%		with higher vegetation	water moss	without vegetation
1. Vissavesi	23	3.7	1.8	260	1.27	52	40	0	30	30
2. Liikapuro	21	3.1	1.5	296	0.97	75	50	0	50	0
3. Kivi-ja Levalampi	11	9.7	1.7	140	1.25	62	30	0	0	70
4. Venetjärvi	23	17.5	1.6	200	1.81	58	35	1	60	4
5. Hirvijärvi	15	15.5	2.6	120	1.32	33	65	5	10	20
6. Kalajärvi	11	11.3	3.8	110	1.36	20	75	5	10	10
7. Kyrkösjärvi	8	6.4	2.4	23	0.62	50	40	22	33	5
8. Patana	21	11.0	4.8	190	1.26	32	80	0	5	15
9. Uljua	18	28.0	5.4	150	1.31	48	90	0	0	10
10. Pitkämö	17	1.0	7.0	4	0.99	0	80	20	0	0
11. Hautaperä	13	7.6	6.7	71	1.50	10	90	0	0	10
12. Kuona	20	5.4	1.9	60	1.05	0	80	20	0	0
13. Lokka	20	417.0	3.7	710	0.47	90	-	-	-	-

Table 2. Mean surface (= 1 m depth) water quality of the reservoirs in July-August (Liikapuro in September) and mean oxygen saturation during the winter draw-down in March-April. Colour values measured by comparator.

	% Oxygen saturation		Total phosphorous	Total nitrogen	pH	Colour pigment
	July-August	March-April	µg/l	µg/l		mg Pt/l
1. Vissavesi	60	9	93	910	5.2	270
2. Liikapuro	85	17	41	650	5.3	180
3. Kivi-ja Levalampi	66	24	90	870	5.5	230
4. Venetjärvi	79	15	36	580	5.6	120
5. Hirvijärvi	66	36	167	1620	5.7	200
6. Kalajärvi	68	59	60	960	5.9	210
7. Kyrkösjärvi	64	60	90	780	5.9	240
8. Patana	79	39	47	720	6.0	160
9. Uljua	82	12	58	640	6.4	170
10. Pitkämö	79	61	97	870	6.4	260
11. Hautaperä	77	55	51	810	6.4	170
12. Kuonanjärvi	80	18	76	690	6.4	210
13. Lokka	83	52	66	680	6.7	90

3. Material and methods

The water analyses were made by standard methods of the National Board of Waters and Environment. The data on the natural fish stocks and their food composition were collected for monitoring purposes by experimental gill-net and fyke net fishing during the open water season. These data are mainly published in Finnish by the relevant local authorities. Available data on fish stocks and management in the reservoirs were complemented by interviews with local fishermen and authorities.

The stocking data (species/intensity) were collected from official stocking statistics and the stocking results from the literature and by interviewing local fishing guilds and authorities.

Table 3. The fish fauna of Finnish inland reservoirs (reservoirs ranked according to mean summer pH values; *Table 2*). Section A – natural stocks with proportion of total ichthyomass denoted by numbers: 4=>50%, 3=31-50%, 2=11-30%, 1=1-10% and 0<1%. Section B – age of species when stocked:L= larvae, Y = yearlings, S = spawners. Successfulness of stocking indicated by + or –. Section C – reservoirs stocked with game fish marked with *. Reservoir numbers as for *Tables 1* and *2*.

Reservoir number	1	2	3	4	5	6	7	8	9	10	11	12	13
A – natural stocks													
Esox lucius	4	4	3	3	2	2	2	1	1	2	2	2	3
Perca fluviatilis	1	1	3	3	2	2	3	1	1	2	2	1	2
Gymnocephalus cernua			1	2	1	1	1	1	1	0	1		0
Lota lota				1	0	1	2	2	1	1	1	1	1
Rutilus rutilus					2	2	2	3	3	3	2	3	3
Abramis brama				1	0		2	3			1		
Alburnus alburnus							0	1					0
Carassius carassius			1			1							
Leuciscus idus											0		1
Others													1
B – introduced stocks:													
Esox lucius			L+		L+					L+			
Abramis brama			S-	S-	S+	S+					S+	S-	
Coregonus spp.	Y-			Y-		Y(+)		Y-	LY-		Y-		Y+
Salmo trutta lacustris													YS
C – introduced game fish:													
Salmo gairdneri						*		*	*	*	*		
Salmo trutta lacustris	*		*		*	*		*					
Salvelinus fontinalis			*		*					*			
Thymallus thymallus			*										

4. Results and discussion

The main results are shown in *Table 3*. The reservoirs are ranked according to the pH value of the water *(Table 2)*. Small reservoirs built on peat land *(Table 1)* are the most acid ones. Annual minimum water levels occur in March-April, and maximum levels are reached in May and remain constant during summer. Only in the northern Lokka reservoir does the summer high water level vary from year to year. The following conclusions can be drawn from our data:

1. The fish fauna of the reservoirs usually originates from bog ponds or small forest lakes present in the area before impoundment. Additive species may reach the reservoir through the inlets. Pike *(Esox lucius)*, perch *(Perca fluviatilis)*, roach *(Rutilus rutilus)*, ruffe *(Gymnocephalus cernua)* and crucian carp *(Carassius carassius)* are typical fish

species in small lakes and ponds in Finland. In addition, in streams, burbot *(Lota lota)* and bleak *(Alburnus alburnus)* are common. Bream *(Abramis brama)* inhabit larger lakes and are absent from some moderately acid reservoirs because of invasion barriers.

2. In many reservoirs there is a mass development of perch during the first few years after impoundment. Because of the greater space available to them by contrast with the pre-impoundment period, the fish grow quickly at the beginning. Later on, changes in reservoir fish faunas are mainly determined by other factors.

3. The number of natural fish species is low, particularly in those reservoirs with acid water and low oxygen contents in winter. In these reservoirs pike is a superdominant species. The cyprinids and burbot are common only in reservoirs where pH values exceed 5.5.

4. During the succession in a reservoir the water quality changes very slowly or not at all. The seasonal variations are of much greater significance. During winter, low oxygen content of the water leads to fish kills, which may even result in total fish mortality in the upper reaches reservoirs. Here, near the inlets, fish have limited possibilities of finding oxygen-rich water. Hence, fluctuations in the composition of the fish fauna and biomass of a reservoir may be very large from year to year.

5. Due to the morphology of the reservoirs, zooplankton biomass is small compared to that of the bottom fauna. The bottom fauna plays an important role in providing fish food, even for predatory and semi-predatory fish (pike, perch, burbot). In May-June, just after the thaw, chironomids emerge in huge masses (Koskenniemi & Paasivirta 1987) and are consumed as pupae by the fish. *Asellus aquaticus* is an important food item for predatory fish during the whole open-water period. In autumn, other insect groups (Odonata) are eaten by pike in the most acid reservoirs, and perch yearlings are eaten in great numbers by pike and burbot in the moderately acid reservoirs.

6. Because of their shallowness the reservoirs are extra sensitive to climatic conditions. When the air temperature is low during and after the spawning season (May-June), the spawning success, especially of cyprinids, is low, *e.g.* in 1982 and 1985. Water level regulation practices do not usually limit the reproductive success of the early spring spawning species (especially pike) because the high summer water level is reached during the thaw.

7. The total catch is usually between 5-20 kg/ha/year, although the fish stocks would allow higher yields. However, the reservoirs are not built for fishing purposes, and fishing activity is limited by several factors, *e.g.* unsuitable bottoms for net fishing, rugged shore lines, lack of launching sites for boats and the remoteness of the reservoirs.

8. Especially in the most acid, highly regulated, young (less than 10 years old) reservoirs, the mercury content of fish flesh is high (Verta, Rekolainen & Kinnunen 1986). The highest concentrations are found in predatory species, indicating the enrichment of methyl-mercury compounds up the food chain. In eight of the 13 reservoirs the mean concentration of mercury in at least one fish species exceeded 1.0 mg/kg, which is the highest level allowed in fish for human consumption in Finland. The high mercury content thus restricts the use of the fish as human food and consequently limits management possibilities.

9. Introduction of species able to reproduce in the reservoirs is mainly achieved with spawning bream (100-500 fish per reservoir per year) from nearby waters. The practice has been fairly successful in reservoirs with medium acidity and moderate oxygen conditions during winter *(Table 3)*. Bream stocks may, however, be destroyed by severe conditions during the winter draw down. Coregonids *(Coregonus lavaretus, C. muksun, C. peled)* have also been stocked in most reservoirs (5000-30 000 yearlings per reservoir per year), but only in Lapland (Lokka-Porttipahta reservoir complex; 1.5 million yearlings per year) has it been possible to create stocks large enough to support commercial fishing. There catches of *C. peled*, and increasingly *C. lavaretus*, run at about 3 kg/ha (Mutenia 1987).
10. Several salmonid species and grayling *(Thymallus thymallus)* have been stocked for recreational fishing purposes in the reservoirs (200-2000 fish per reservoir per year; individual weights *c.* 0.5 kg). The numbers stocked varies greatly between reservoirs, and in those reservoirs where the fish are found to die or migrate upstream or downstream, because of severe winter conditions, stocking activity has now decreased. The introduction of game fish species has also led to limitations on the use of effective fishing gear.
11. The choice of species for introduction, and of stocking density, have been quite independent of the chances the species has for survival in the reservoir. Active fishing guilds and proximity to towns seems to influence these management measures far more than biological considerations. In future, fisheries management of reservoirs should be planned by professional administrators.

5. Conclusions and fisheries management proposals

1. Regulation regimes which produce poor water quality during the winter draw downs are the most important factors preventing successful fisheries management in the reservoirs studied (except Lokka, *Table 1*). In some reservoirs there are now plans to decrease the amplitude of water level fluctuations. Shortening the duration of the draw down could be an additional improvement. Attempts to improve the general water quality of reservoirs (*e.g.* by liming) seem to have very limited effect.
2. Efficient fishing of the natural stocks can be generally recommended as a good management measure in the reservoirs. Thus gill-net and fyke net fishing should be allowed on a larger scale, especially during the spawning time in spring. This would increase mean individual fish weight. To improve net fishing possibilities we suggest cleaning limited stretches of shoreline and the developing special areas for net fishing areas where, prior to impoundment, there were ponds or lakes or open peatlands.
3. In addition to bream, pikeperch and ide *(Leuciscus idus)* could be introduced in the larger, only moderately acid reservoirs. Also the introduction of eel *(Anguilla anguilla)* should be considered. In the reservoirs with the poorest water quality, the recommended management measures are efficient fishing of the species already present, or stocking of catch-size game fish.

4. Because of high mercury contents in predatory species, non-predatory species should be favoured, by permitting either the efficient fishing of predators or, even, the emptying of reservoirs before the introduction of new fish.

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References

Koskenniemi, E., 1987. Development of floating peat and macrophyte vegetation in a newly created, polyhumic reservoir, western Finland. Aq. Fenn. 17: 165-173.

Koskenniemi, E. & Paasivirta, L., 1987. The chironomid (Diptera) fauna in a Finnish reservoir during its first four years. Ent. Scand. Suppl. 29: 239-246.

Mutenia, A., 1987 Lokka ja Pottipahta Lapin tärkeimmät kalavedet. (Lokka and Porttipahta The most important fish waters in Lapland; in Finnish). Suomen Lalastuslehti. 94: 347-350.

Verta, M., Rekolainen, S. & Kinnunen, K., 1986. Causes of increased fish mercury levels in Finnish reservoirs. Publ. Water Res. Inst. 65: 44-58.

Vogt, H., 1978. An ecological and environmental survey of the humic man-made lakes in Finland. Aq. Fenn. 8: 12-24.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc, Wageningen. pp. 82-89.

The importance of estuaries for the reproduction of freshwater fish in the Gulf of Bothnia

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Abstract

Estuaries are important spawning and nursery areas for most freshwater fish species of the Baltic Sea. Compared to the sea, they offer warm, nutritious, and often also, vegetated and sheltered areas. The importance of estuaries for freshwater fisheries is elevated in passing northwards up the Gulf of Bothnia because of progressively lower sea water temperatures in this direction. However, environmental changes have led to the deterioration of estuaries all around the gulf, but this is most noticeable in the northern parts, since it is here that catches of freshwater fish, off the estuaries, have diminished most.

1. Introduction

In the Gulf of Bothnia salinity varies between 2‰ in the northern part and 6‰ in the southern part. The mean discharge of Finnish rivers to the Gulf of Bothnia is 2170 m^3 /sec; 78 m^3 to the Archipelago Sea, 340 m^3 to the Bothnian Sea and 1750 m^3 to the Bothnian Bay (Pitkänen 1986). The areas and the location of the rivers are shown in *Figure 1*. Although there were difficulties in classifying the estuaries from the geographical point of view, Rosberg (1895) distinguished four major groups in the Bothnian Bay, mainly on the basis of the area of the archipelagos outside the river mouth. According to this classification, the major estuary formations occur in the southern parts of the Bothnian Bay, where rich archipelagos are present. None of the estuaries in the Bay of Bothnia show true marine protuberances, because the rapid uplift of the coast precludes the formation of classical sedimentary deltas (Winterhalter, Floden, Ignatius, Axberg & Niemistö 1981). No classification of the estuaries in the Bothnian Sea has yet been made, either geographical or ecological.

The number of fish species inhabiting the Gulf of Bothnia is about 30-40, depending upon the area. The fish fauna consists mainly of freshwater species (Andreasson & Petersson 1982, Koli 1984). The proportion of freshwater fish is largest in the northern parts of the gulf, but the total number of fish species is smallest there. According to Koli (1984), when migratory species such as salmon and trout are excluded, the number of freshwater species in the northernmost part of the gulf is 20, and the number of marine species only 8. In the Archipelago Sea the corresponding numbers are 24 freshwater and 22 marine species.

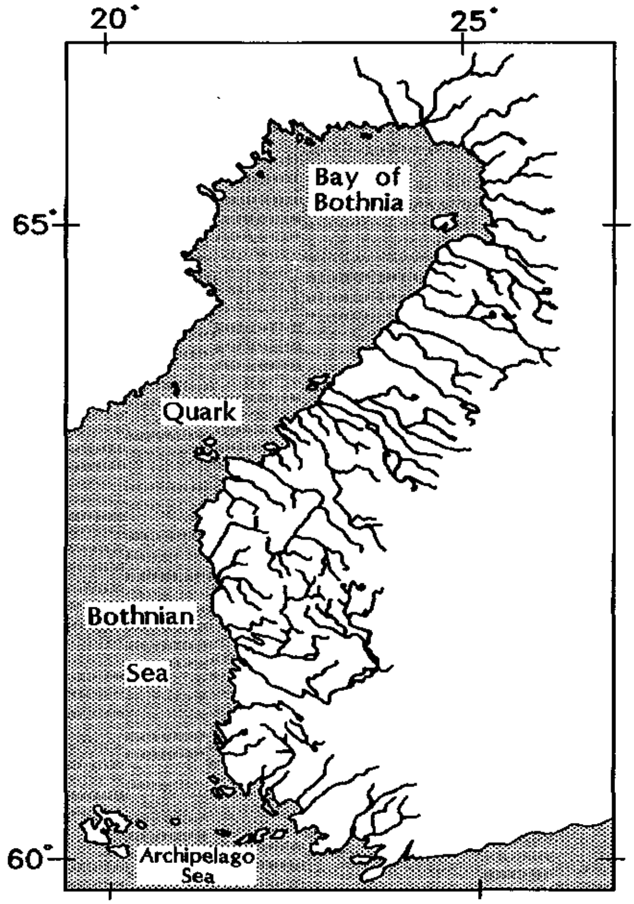

Figure 1. The Finnish coast of the Gulf of Bothnia and the largest rivers discharging into it.

2. Warmth, food resources and shelter

It has been suggested that the relative importance of rivers as areas for reproduction increases from south to north, due to the fact that the rivers warm up earlier in the spring and offer a more suitable thermal environment for eggs and larvae (Eriksson & Müller 1982). The shallowness of the waters, which permits early warming in the spring, also precludes cold upwelling during the growth period of the offspring. Sea temperatures are also raised by the outflow of warmer inland waters. The thermal regime in the estuaries is therefore more stable than in the open sea, thus promoting fast growth and low mortality rates for the larvae.

The waters flowing seaward through the estuaries provide a rich food supply for young fish. The highest zooplankton and benthos biomasses are found in estuaries (Fransz 1986, Pitkänen, Kangas, Miettinen & Ekholm 1987).

Shelter in estuaries is both by turbidity, and by the luxuriance of macrophyte vegetation, both a consequence of the richness of nutrients in the water. Some fish take advantage of the turbidity, *e.g.* pikeperch *(Stizostedion lucioperca)* and smelt *(Osmerus eperlanus)*, while others benefit from the dense macrophyte vegetation, *e.g.* many cyprinids and pike *(Esox lucius)* (Urho, Hilden & Hudd 1988).

3. Warm and cold water fishes — two examples

3.1 Burbot, a cold water fish

The adult burbot *(Lota lota* L.*)* is a cold water stenothermal fish. In the Gulf of Bothnia, burbot spawn in February, when water temperatures are lowest. In the estuary of the Kyrönjoki, feeding larvae are not found in the outer archipelagos beyond the influence of river water (Hudd, Hilden, Urho & Jåfs 1984). Salinity is higher in the archipelagos than the estuaries, but this cannot be the limiting factor, since experiments have shown that the upper limit of the salinity tolerance for eggs and larvae is 12 ‰ (Jäger, Nellen, Schöfer & Shodjai 1981). We suggest that in the northern part of the Gulf of Bothnia only warm and nutritious freshwater outlets can offer a sufficiently high production of suitably small food organisms for the very small burbot larvae. In the more saline and

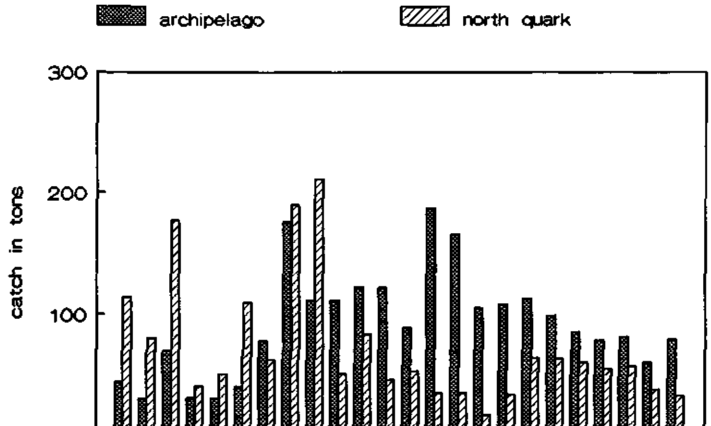

Figure 2. The professional burbot catch in the Archipelago Sea and the Quark from 1963-1986.

warmer environment of the Archipelago Sea, the production and diversity of small food organisms is probably high enough to keep the small first feeders alive. Besides this, the growth period in southern areas is longer, enabling better growth during the first summer.

A similar situation occurs with the perch *(Perca fluviatilis)*, which is a warm water species (Neuman 1976, Karås & Neuman 1981). It also has very small larvae, and in the first stages the spatial distribution of the larvae overlaps that of the burbot. Stocks of burbot and perch have diminished in the Quark area, and if this development was a natural fluctuation, we could expect the development of catches and stocks to be the same all over the northern Baltic. Comparing burbot catches from the Archipelago Sea and the Quark, both of which are rich in archipelagos, reveals different developments *(Figure 2)*. This can be explained by the large scale destruction of reproductive areas in the Quark (Hilden, Hudd & Lehtonen 1982). The destruction is caused by large scale acidification caused by extractions and dredgings in soils rich in heavy metals and sulphur (Purokoski 1959, Björklund 1985). An example of the dependence of year-class strength on water quality is given in *Figure 3.* Whenever the water has been acid (Hudd, Hilden & Urho 1986) there has been a poor year class.

3.2 Bream, a warm water phytophilous fish

Estuaries which possess large belts of macrophytes exhibit high levels of primary production and provide splendid spawning areas for several phytophilous species, such as pike and bream *(Abramis brama* L.*)*. The warm water of the estuaries favour the larvae and fry. The absence of large vegetation belts in the warm waters of the archipelagos makes them unsuitable for these species. Since the vegetated zones in the estuaries offer suitable environments for small cyprinid larvae, they are also important nursery areas for predators like the larvae and juveniles of pike.

Environmental changes in estuaries have influenced the year class strength of bream *e.g.* in the Kyrönjoki Estuary (Hudd *et al.* 1984, Urho *et al.* 1988). Poor year-classes are born in years, *e.g.* 1970 and 1971, when the water has been acid. Almost all estuaries in the Bothnian Bay area are sensitive to acidification due to anthropogenic disturbance of acid soils. Many estuaries have also deteriorated because of the discharge of toxic effluents or because of hydro-engineering works carried out in rivers. Good spawning and nursery areas like estuaries are very limited in the northern parts of the Gulf of Bothnia and small local changes may have serious effects on fishing over much larger areas as shown by Hudd *et al.* (1986). Degraded spawning and nursery areas influenced bream catches adversely, over the entire northern part of the Gulf of Bothnia during the 1970s (Hilden *et al.* 1984). Natural environmental changes generally influence large areas synchronously. For instance, 1972 was a very favourable one for bream and many other freshwater species and strong year-classes were noted in all areas studied along Finnish coast except in those places which were acid that year.

4. Interactions between estuaries and the sea

Populations of fish which reproduce in rivers, river mouths or shallow inlets are very sensitive to environmental changes because their stocks are dependent on small geographical areas. Taggings of pike, perch, burbot, pikeperch, bream, whitefish *(Coregonus*

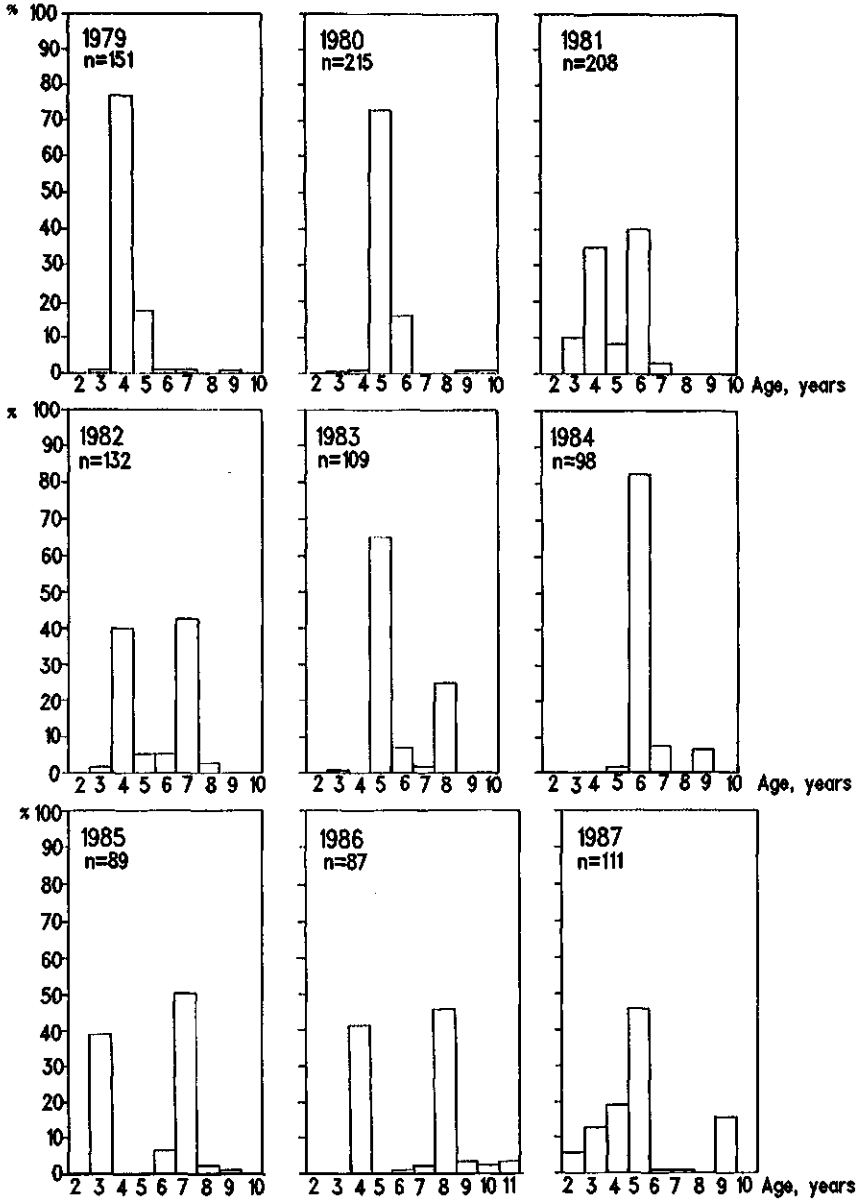

Figure 3. Age composition of burbot catch in the estuary of the River Kyrönjoki, Northern Quark.

lavaretus) and smelt have shown that during their feeding migrations in the Gulf of Bothnia, these freshwater species originate from spawning areas in estuaries or rivers (Kaukoranta & Lind 1975, Lehtonen 1981, Johnson 1982, Hudd *et al.* 1984, Hudd 1985, Hudd & Lehtonen 1987, Lehtonen & Toivonen 1987). *Figure 4*, which illustrates this, shows the spawning and fishing grounds for bream in the estuary of the Kyrönjoki River. The most important fishing areas for these freshwater species are always located off estuaries (Lehtonen 1978).

In much of the Gulf of Bothnia important spawning sites are mostly located in shallow sheltered inlets and fladas, where temperature development in spring, and the abundance of macrophytic vegetation, resembles the situation in estuaries (Blomqvist 1984, Hästbacka 1984, Wistbacka 1986). Thus although spawning and nursery areas for most freshwater species can be found outside estuaries, in the northern part of the gulf, large scale reproduction seems to be confined to estuaries.

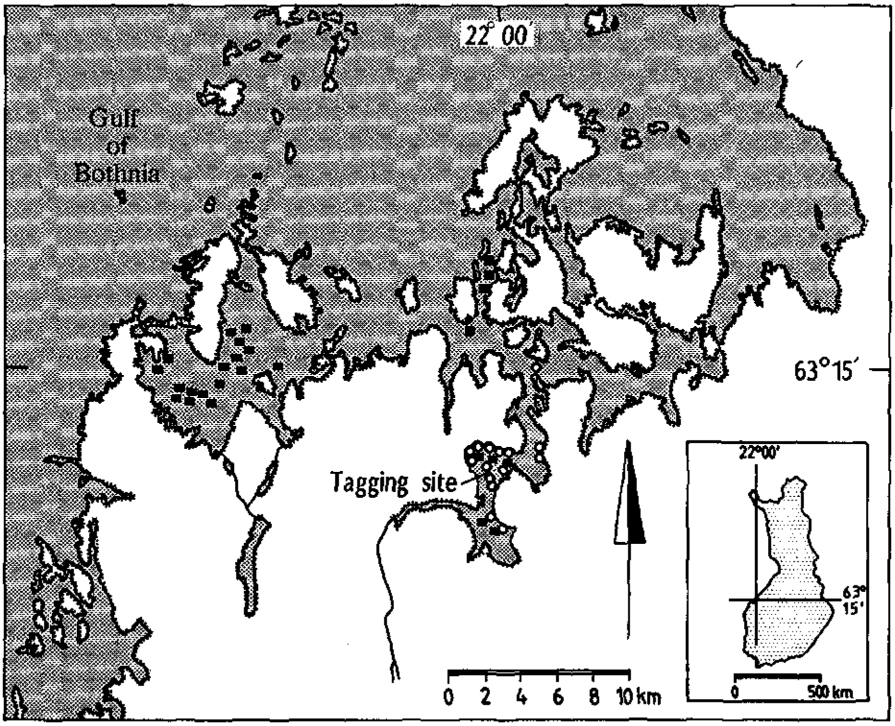

Figure 4. The results of a tagging experiment of bream in the estuary of the Kyrönjoki. The recaptures are divided between the spawning time in late May-June (circles) and the rest of the year (squares).

5. Conclusions

The selection of spawning areas by freshwater fishes in the Gulf of Bothnia is not dependent on low salinity. Most species are known to reproduce successfully in the southernmost parts of the gulf and the Archipelago Sea, where the salinity is 5-6‰. More probable determining factors are high and stable summer temperatures, an abundance of shelter, and of suitable food organisms. The ice cover on the Gulf of Bothnia, especially on the Bothnian Bay and northern Quark, breaks up about 3-5 weeks later than on the seaward flowing rivers. Fishes which are ready to spawn, find warmer water and food rich biotopes in the estuaries and rivers. The temperature regime is more stable in estuaries because they are well protected from upwellings from the sea. These factors explain the importance of estuaries, particularly in the northernmost parts of the gulf, where the sea water is extremely cold at the beginning of the spring spawning of cyprinids and percids.

Paradoxically we have learned about the importance of estuaries and rivers only through completely neglecting them. The catches of some species collapsed and no reason could be found other than large scale environmental changes in rivers and estuaries. The situation is now recognised and environmental planning and management has taken these observations into consideration in many estuaries by *e.g.*, neutralising the waters during the spring flood. However, although we are now aware of the importance of estuaries, we are still far from a proper understanding of the role that they play. Much could probably be gained by investigating the biology of freshwater fish larvae and juveniles in northern waters, and by comparing the thermal regimes, levels of production, and the diversity of food organisms in different areas.

References

Andreasson, S. & Petersson, B., 1982. The fish fauna of the Gulf of Bothnia. In: Müller, K. (Ed.). Coastal Research in the Gulf of Bothnia, Junk. The Hague. pp. 301-315.

Björklund, A., 1985. Moraine contains huge amount of sulphur. Finlands natur. 1: 4-7 (in Swedish).

Blomqvist, E.M., 1984. Changes in fish community structure and migration activity in a brackish bay isolated by land upheaval and reverted by dredging. Ophelia, Suppl. 3: 11-21.

Eriksson, L.O. & Müller, K., 1982. The importance of a small river for recruitment of coastal fish populations. In: Müller, K. (Ed.). Coastal Research in the Gulf of Bothnia. Junk. The Hague. pp. 371-385.

Fransz, H.G., 1986. Effects of fresh water inflow on the distribution, composition and production of plankton in the Dutch coastal waters of the North Sea. NATO ASI Series. G7: 241-249.

Hästbacka, H., 1984. The fladas — fish nurseries in the sea. Vaasa, Österbottens Fiskarförbund. 22 pp. (in Swedish).

Hilden, M., Hudd, R. & Lehtonen, H., 1984. The effects of environmental changes on the fisheries and fish stocks in the Archipelago Sea and the Finnish part of the Gulf of Bothnia. Aqua Fennica. 12: 47-58.

Hudd, R., 1985. Assessment of the smelt *(Osmerus eperlanus* L.) stock in the Northern Quark, Gulf of Bothnia. Finnish Fish. Res. 5: 55-68.

Hudd, R., Hilden, M. & Urho, L., 1986. The effects of anthropogenic acidification on the stocks and fisheries of bream and burbot in the sea area influenced by the river Kyrönjoki in the Gulf of Bothnia. Publ. Wat. Res. Inst. 68: 134-138.

Hudd, R., Hilden, M., Urho, L. & Jåfs, L., 1984. Fishery investigations (in 1980-1982) of the Kyrönjoki River estuary and its area of influence in the northern Quark, Baltic Sea. National Board of Waters, Report 242: 1-275 (in Finnish and Swedish with an English summary).

Hudd, R. & Lehtonen, H. 1987. Migrations and home ranges of natural and transplanted burbot (*Lota lota*) off the coast of Finland. Proc. V Congr. europ. Ichthyol. Stockholm 1985. pp. 201-205.

Jäger, T., Nellen, E., Schöfer, W. & Shodjai, F. 1981. Influence of salinity and temperature on early life stages of *Coregonus albula*, *C. lavaretus*, *Rutilus rutilus* and *Lota lota*. Rapp. P.v. Reun. int. Explor. Mer. 178: 345-348.

Johnson, T., 1982. Seasonal migrations of anadromous fishes in a northern Swedish stream. In: Müller, K. (Ed.). Coastal Research in the Gulf of Bothnia. Junk. The Hague. pp. 353-361.

Karås, P. & Neuman, E., 1981. First-year growth of perch *(Perca fluviatilis* L.) and roach *(Rutilus rutilus* L.) in a heated Baltic bay. Rep. Inst. Freshw. Res. Drottningholm. 59: 48-63.

Kaukoranta, E. & Lind, E.A., 1975. The pike, *Esox lucius* L., in the estuary of the Oulujoki river. I. Ecology. Ichthyol Fenn. Borealis. 1-2: 1-40.

Koli, L., 1984. The fishes and their distribution in Finland. In: Koli, L., (Ed.). Suomen elimet 3, Espoo. Weilin & Göös. pp 10-12 (in Finnish).

Lehtonen, H., 1978. Fishing of freshwater fishes in Finnish Baltic Sea area in 1976. Suomen kalatalous. 48: 25-40 (in Finnish with English summary).

Lehtonen, H., 1981. Biology and stock assessments of coregonids by the Baltic coast of Finland. Finnish Fish. Res. 3: 31-83.

Lehtonen, H. & Toivonen, J., 1987. Migration of pikeperch, *Stizostedion lucioperca* (L.), in different coastal waters in the Baltic Sea. Finnish Fish. Res. 7: 24-30.

Neuman, E., 1976. The growth and year-class strength of perch *(Perca fluviatilis* L.) in some Baltic archipelagos, with special reference to temperature. Rep. Inst. Freshw. Res. Drottningholm. 55: 51-70.

Pitkänen, H., 1986. Discharges of nutrients and organic matter to the Gulf of Bothnia by Finnish rivers in 1968-1983. Publications of the Water Research Institute. 68: 72-83.

Pitkänen, H., Kangas, P., Miettinen, V., & Ekholm, P., 1987. The state of the Finnish coastal waters in 1979-1983. Vesi- ja ympäristöhallituksen julkaisuja. 8: 1-167.

Purokoski, P., 1959. On the sulphuric soils of the coastal areas. Agrologisia julkaisuja. 74:1-27 (in Finnish).

Rosberg, J.E., 1895. The deltas on the Finnish side of the Bothnian Bay. Academic dissertation, Univ. Helsinki. 255 pp. (in Swedish).

Urho, L., Hilden, M. & Hudd, R., 1988. The Kyrönjoki estuary as a reproductive area for fish stocks, and the effects of environmental changes. Manuscript. Finnish Game and Fisheries Research Institute. 21 pp.

Winterhalter, B., Floden, T., Ignatius, H., Axberg, S. & Niemistö, L., 1981. Geology of the Baltic Sea. In: Voipio, A. (Ed.). The Baltic Sea. Elsevier. Amsterdam-Oxford-New York. 1-121.

Wistbacka, R., 1986. The spawning and nursery areas of fresh water fish. Rep. Fish. Distr. Vaasa. 1: 1-176 (in Swedish).

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 90-100.

Management of a weakly exploited population of vendace *(Coregonus albula* L. *)* in Lake Puulavesi (central Finland)

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Abstract

The vendace stock of Lake Puulavesi has been studied since 1984 in order to assess prospects for developing professional fishing in the area. Investigations carried out on the lake include analyses of catch per unit effort, statistics and catch samples, hydroacoustic surveys and studies of vendace larvae. The stock seems to be under exploited and growth of fish and recruitment are both limited by density-dependent factors. There are many semi-professional fishermen in the area. Most of the annual catch is obtained during a short period in autumn, which promotes marketing difficulties. The aim of management is to optimise exploitation of the presently under-utilised stock. This will be carried out by intensifying winter seining and gill-net fishing. Some recent developments and problems associated with professional fishing are described.

1. Introduction

Vendace is the most important species in Finnish lakes, and underpins widespread professional and semi-professional fisheries, as well as being popular with recreational and subsistence fishermen. Stocks vary considerably as to their degree of exploitation. There are lakes with advanced professional fisheries yielding catches in excess of 10 kg/ha/year, but there are many others with good stocks that are still under exploited and these could well support professional fisheries. During the last few years there has been increasing interest in fishing as a livelihood, since traditional forms of agriculture offer fewer and fewer opportunities.

The present research and management scheme for Lake Puulavesi began in 1984. This report describes the results of preliminary research into the vendace stock of Lake Puulavesi, the management scheme for the stock, and the development of professional fishing on the lake.

2. The study area and the fish community

2.1 Morphological characteristics and water quality

Lake Puulavesi covers some 32 500 ha in Central Finland. Research and management have been carried out in a 20 800 ha sector of the lake, which has a mean depth of about 20 m and a maximum depth of 70 m. There are two large and many minor pelagic areas, and also some archipelagic areas with narrow straits. The lake is oligotrophic with a total phosphorus content of 3-7 μg/litre and a total nitrogen content of 400-500 μg/litre. The lake is lightly regulated for hydroelectric purposes.

2.2 The fish community of the pelagic areas

The fish community of the pelagic areas is typical of northern hemisphere oligotrophic lakes. The plankton eating vendace *(Coregonus albula* L.) predominates, and there is an abundant smelt population *(Osmerus eperlanus* L.). The peripheral areas of the pelagic zones are inhabited by lake whitefish *(Coregonus oxyrhynchus* L.) with a mean gillraker number of 40.

The most common pelagic predators are burbot *(Lota lota* L.) and pike *(Esox lucius L.)*, which move to deeper water during winter. In the past there were abundant natural stocks of brown trout *(Salmo trutta* L.) and pikeperch *(Stizostedion lucioperca* L.), but both species now depend on stocking. Brown trout became extinct locally when their spawning grounds, rapids areas, were dredged for hydroelectric and log floating purposes, but some of the rapids are now being restored. The reason for the loss of pikeperch is not known, but it seems to be connected with a slight cooling of the climate recorded since the second World War.

3. Survey methods

The vendace stock of Lake Puulavesi has been monitored by various routine methods since autumn 1984. The survey included:

3.1 Catch and effort statistics

The 18 regular fishermen in the area keep daily records of their catches and fishing effort. In addition an annual inquiry is sent to every seine group, and to a random 10-20% of the recreational and subsistence fishermen. They are asked to estimate their monthly catches and fishing effort.

3.2 Catch samples

Samples have been collected from catches made with different types of gear and from different parts of the lake during the major fishing periods (winter-summer-autumn) in order to monitor the age composition of the vendace population and its growth and recruitment.

3.3 Hydroacoustic surveys

Hydroacoustic surveys were carried out in the pelagic zones in September 1986 and 1987 to estimate fish densities. Further surveys will be carried out annually to study the correlation between hydroacoustic results and catch per unit effort (CPUE).

3.4 Larval studies

The densities of vendace larvae have been monitored in several littoral areas around the lake by means of a miniature seine during the last two spring seasons. Data on larval densities will be used to assess the possible relationship between stock and recruitment.

4. The fishing organization

There are 18 local fishing associations, each comprising the owners of the fishing rights in the villages, mainly farmers and summer cottage owners. The numbers of sets of gear in use is regulated by an agreement that a maximum of one standard gear unit (s.g.u.) is allowed per hectare in each association area (*e.g.* 1 standard gill-net is 1 s.g.u., a vendace seine is 20 s.g.u.s and a vendace trawl is 50 s.g.u.s). Up to 80% of the gear units are allocated to association members in proportion to the area of land they own in the village, while the remaining units are available for sport fishermen and professionals, who do not own land in the village. The owners of fishing rights can also rent their gear units to outsiders.

Association members are responsible for managing the fish stocks in their areas, management decisions (*e.g.* plans for stocking, gear unit prices) being made at annual meetings of the associations. This system means that adjacent association areas can be managed in quite different ways. Under a new fishing law, in force since 1983, the associations of a single lake system are combined to form a fisheries area organization. The management committee for an area is required to produce an overall plan for the management of the fish stocks in its area. Thus, local fishing association areas within single lakes will now be managed more uniformly, although area plans are only guidelines for local associations, and are not binding upon them.

5. The vendace stock and objectives for its management

5.1 Fluctuations in population

Major population fluctuations, which usually render professional fishing difficult, are typical of vendace stocks in Finnish lakes. The fluctuation cycle in Lake Puulavesi seems to be relatively long, about 5 years according to the local fishermen. The same may be seen from the CPUE statistics for the last nine years *(Figure 1)*. The last five years have included one very abundant year class, 1983 *(Figure 2)*, and it is interesting to note that this emerged from the sparse spawning population of 1982. This supports the observation that recruitment of vendace is most successful from intermediate and sparsely spawning populations, whereas reproduction tends to be less successful in the largest stocks (*e.g.* Auvinen 1978, Salojärvi, Valkeajärvi 1983, Viljanen 1988, Valtonen & Marjomäki 1988).

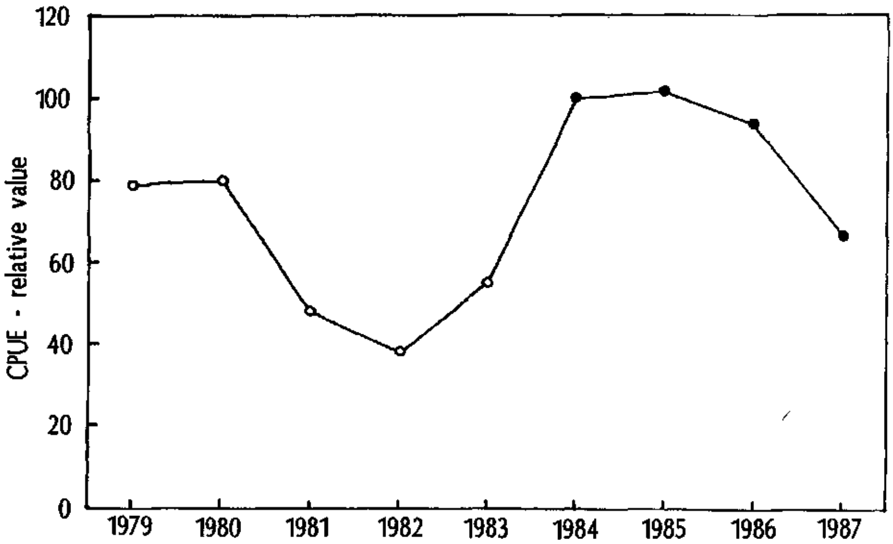


Figure 1. The average catch of vendace per seine haul in relative weight units from Lake Puulavesi in the autumns of 1979-1987. ○ = according to one fisherman, • = average of nine fishermen.

5.2 Growth

Growth rates of vendace in Lake Puulavesi have been rather slow compared with rates in other lakes in central Finland, because of intraspecific competition for food. However, there has been some improvement during the last two years, since the population has become more sparse *(Figure 3)*. The abundant year-class of 1983 reached the profitable gill-netting size of 150 mm in four years and the sparse year-class of 1985 in three years. The average weights of the 1+ and 2+ age groups in autumn 1987 were 50 % greater than they were in 1984.

5.3 Mortality

It seems that total mortality in the stock increases as the fish grow older *(Table 1)*, but there has been an increase in mortality rates in the 1+ to 2+ and 2+ to 3+ year age groups in recent years.

It is impossible to separate total mortality into that due to natural causes and that due to fishing at present, but it is probable that the proportion due to fishing is of minor importance, if the current modest annual catches are considered *(Table 2)*. Further

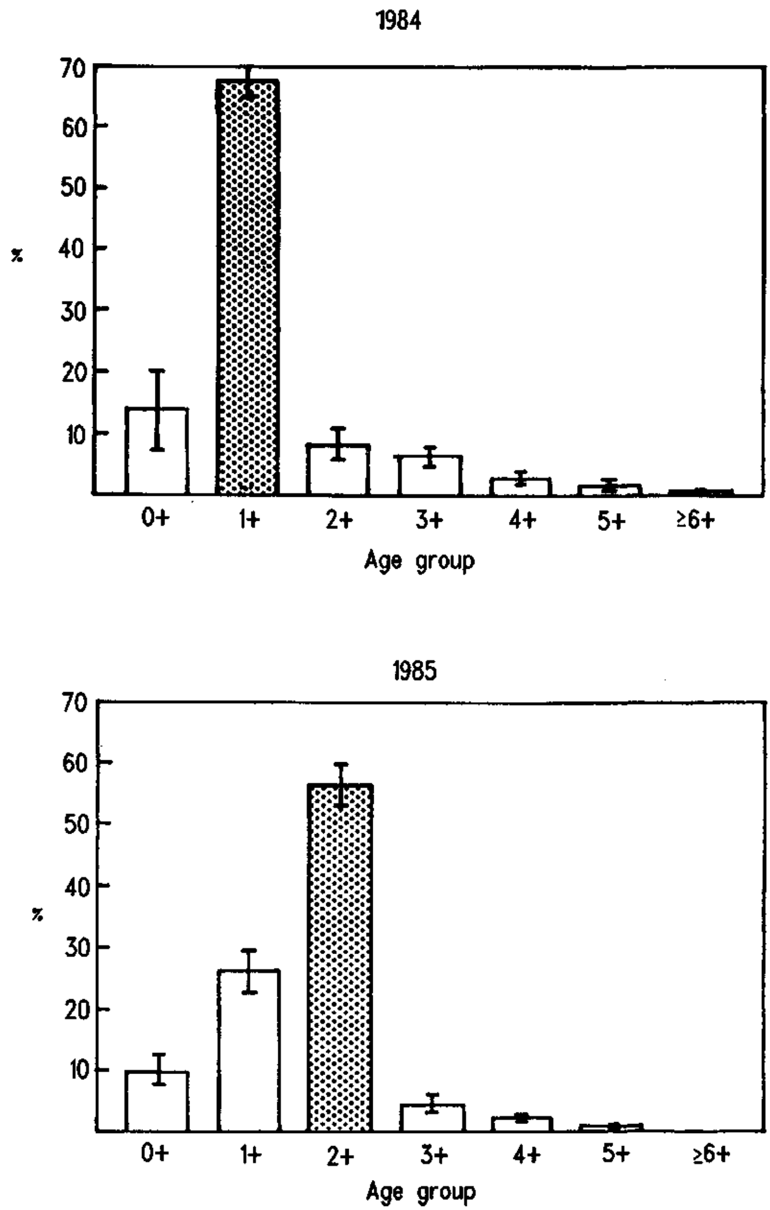
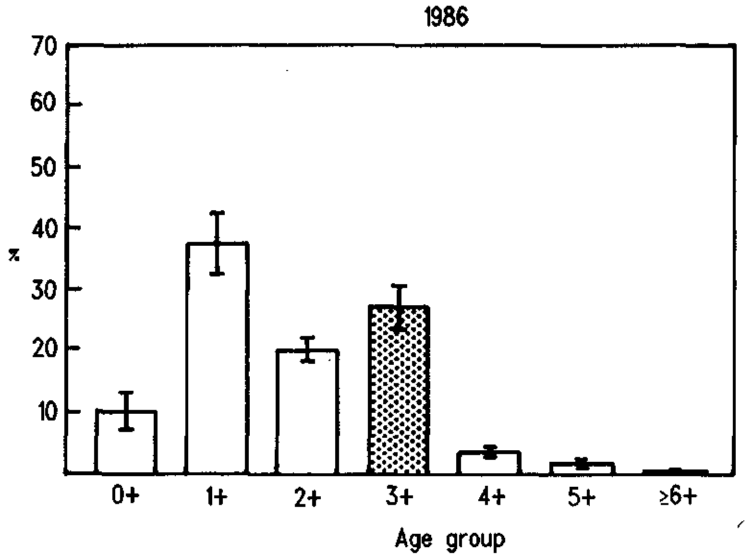


Figure 2. The average age composition in seine catches (with standard errors) in the autumns of 1984-1987. The abundant cohort of 1983 is shaded.



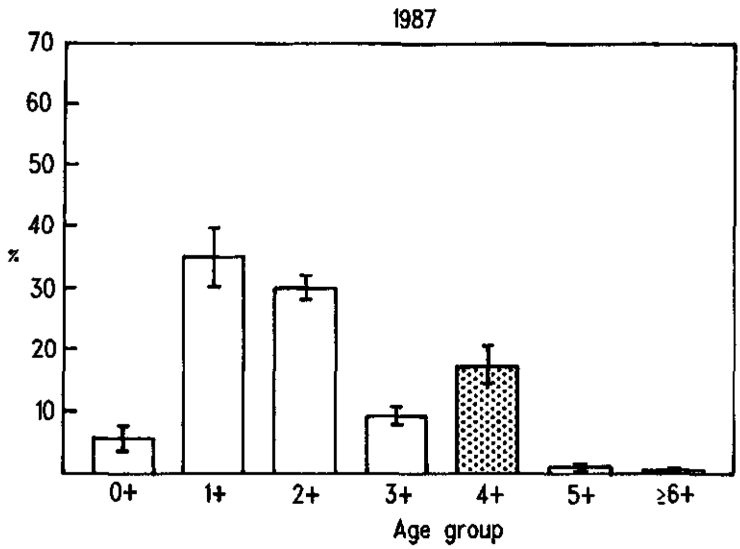


Figure 2. (continued).

information on this matter will be obtained when the population density estimates from the hydroacoustic surveys are compared with subsequent catch statistics.

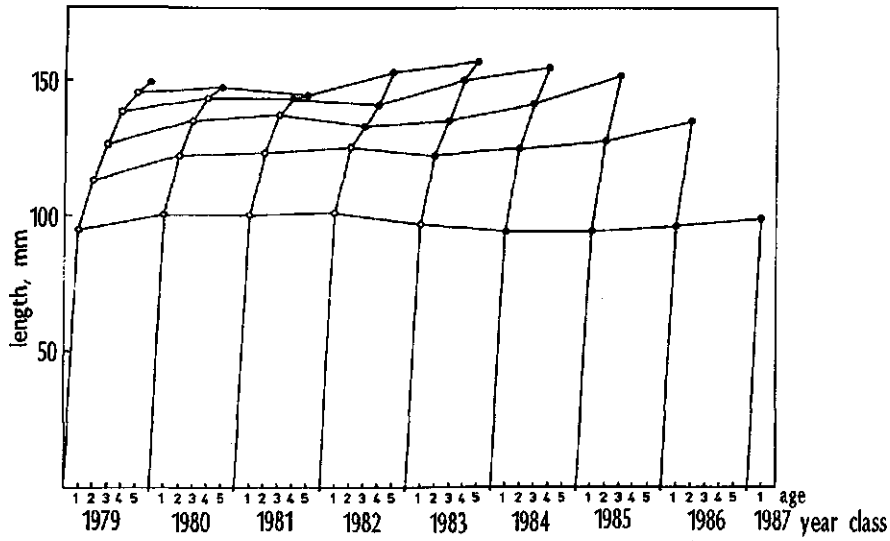


Figure 3. The average length of vendace year classes 1979-1987, ages 1 to 5 years. ° = back calculated value, • = average length in samples.

5.4 General objectives for vendace stock management

It has not been impossible to set quantitative objectives for catch quotas or optimal fishing efforts, because the fluctuating nature of the recruitment of vendace is not properly understood. This is because vendace growth rates depend upon stock sizes, and because of difficulties encountered in distinguishing the relative importance of different factors causing mortality. Thus, only generalised recommendations for management can be offered.

In order to optimise catches the density of the population should be kept at a level where growth rate and recruitment are not severely limited by the density of the stock. This should result in the more frequent emergence of abundant year-classes. Such a level can be achieved by means of effective fishing. The desirable spawning stock density in Lake Puulavesi is obviously less than that which has prevailed in the last few years, and may be somewhere near the level of 1982 *(Figure 1)*.

Effective fishing should be started during the second year of the fishes' lives, at the latest in the second winter after the first spawning. This thinning of the population should lead to the better growth of the rest of the fish so that they reach profitable gill-netting size sooner. Intensified exploitation of old fish is reasonable on the grounds that their natural mortality rates are high and most of them would otherwise be wasted.

Table 1. Instantaneous total mortality coefficient (Z) per year of vendace in Lake Puulavesi in 1984-1987.

Age group	Instantaneous total mortality		
	1984 - 1985	1985 - 1986	1986 - 1987
1+ – 2+	0.34	0.52	0.73
2+ – 3+	0.86	0.99	1.26
3+ – 4+	1.24	0.49	0.93
4+ – 5+	1.30	0.39	1.80
5+ – 6+	-	1.76	1.80

There is a general opinion that recruitment overfishing of vendace is very unlikely to happen unless reproduction is limited by a severe oxygen deficit (Hamrin 1986). In Lake Konnevesi, which is very similar to Lake Puulavesi, the most abundant year-classes have arisen from the most sparse populations (Valkeajärvi 1983).

6. Recent developments in vendace fishing

The annual yield of vendace per hectare in Lake Puulavesi has been close to the average for Finnish lakes *(Table 2)*, but it has been only one half to one third of the yields obtained from areas using more advanced professional fishing.

Table 2. Annual vendace yields in Lake Puulavesi in 1984-1987.

	Yield (metric tons)			
Year	Seine	Gill-nets	Total	kg/ha
1984	52	38	90	4.3
1985	40	34	74	3.6
1986	46	37	83	4.0
1987	45*	43	88	4.2

* includes trawl catch

There were about 50 seine groups (of 2-3 persons each) operating on Lake Puulavesi in 1985. Most of these people were semi-professionals, who fished only during summer weekends, and acquired most of their catch during the October spawning season *(Figure 4)*. Four of the seine groups were professional, although they obtained major portions of their annual incomes from agriculture. Only two of the groups fished during the winter. Winter seining has not been popular because the lake is too deep to catch vendace with summer seines (which are only 15 m high) during the winter. There were only 3 semi-professional gill-net fishermen, and some 600 subsistence and recreational fishermen, who caught vendace on Lake Puulavesi in 1985.

According to inquiries, the greatest impediment to professional fishing in 1984 was marketing. The flesh of the vendace deteriorates rapidly, even at temperatures close to freezing, and in just a few hours at summer temperatures. Thus fishermen have to sell their catches as quickly as possible, which lowers prices and reduces demand for the species. During autumn, when most semi-professionals had some fish to sell, the situation was at its worst.

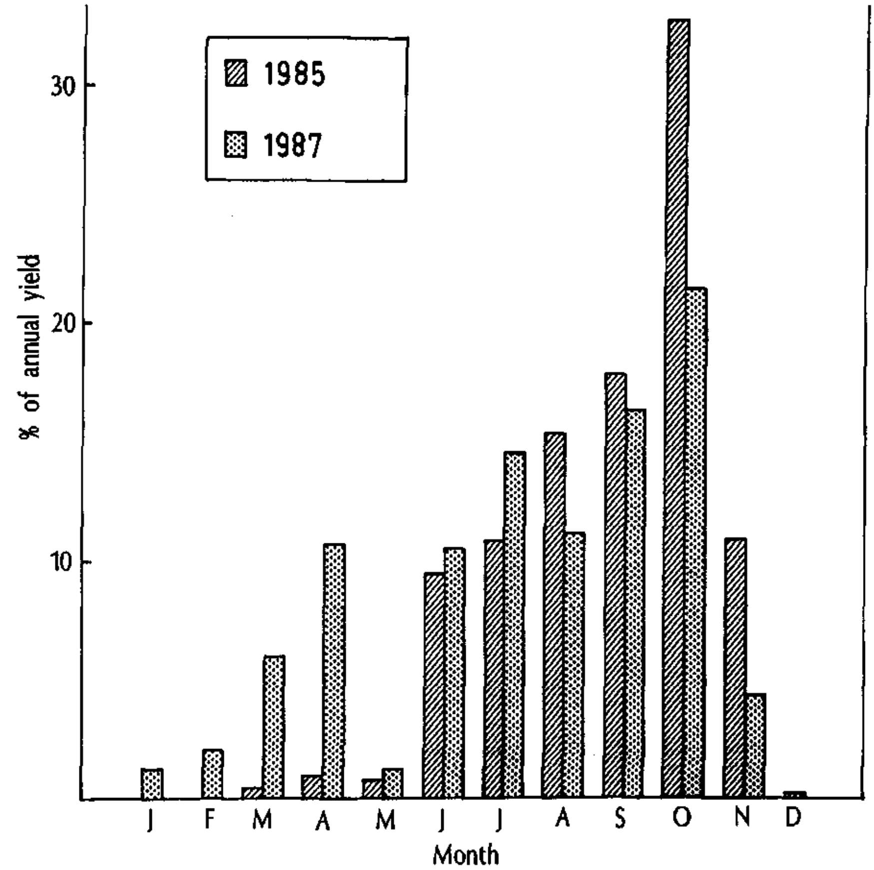


Figure 4. The distribution of the annual yield of vendace using seine nets over different months in 1985 and 1987.

Our management policy was to encourage some of the seine groups to purchase higher seines (25-30 m) and fish in winter, when there were no marketing difficulties, or it was easy to store catches. Two groups began fishing with large seines in the winter of 1987, and two more in 1988. They had profitable catches and became professional. Because of this the annual catch for 1987 was spread more uniformly throughout the year than that of 1985 *(Figure 4)*. Also, the price of vendace was twice as high in winter 1987 as it was in autumn. The number of winter seine groups will probably now increase as fishermen learn winter seining techniques from each other.

The solution to the problems of summer and autumn fishing lies in gill-netting and cooling catches. To this end a consultant fishery technician has been training professional gill-net fishermen to catch large vendace and chill their catches to 0°C in their boats. They use crushed ice and store the fish in cellular plastic boxes. This product has been marketed at three times the price paid for seined, non-chilled vendace. Chilling fish has also been beneficial to the seine groups, who then have more time for marketing, and are no longer forced to sell at low prices.

During autumn the gill-net fishermen take roe from the fish and sell it separately as a variety of caviar, selling the fish in a cleaned state. These modest refining processes have raised the price of vendace to four times that once obtained for seine catches. Socially and economically the most important aspect of this additional processing is that it provides occasional employment opportunities to local people in a region of severe seasonal unemployment.

This more advanced vendace fishing will be better buffered against natural fluctuations of the stock than traditional autumn seining. Gill-net fishermen can now regulate their fishing effort to some degree by changing the number of nets in use and by concentrating at times, on processing their catches. Winter seine groups are usually local farmers who can change to forestry when vendace stocks are low.

One problem which has arisen with the development of professional fishing is that fishermen using winter seines, as well as dozens of gill-nets, have found it difficult to rent gear units from the fishing associations. They need large fishing areas to be able to follow the migrations of the vendace schools in order to get regular catches, so that, although they own fishing rights in some associations, they must rent extra gear units from neighbouring associations. Some of the associations have been unwilling to rent gear units, despite the fact that they only use half of their units themselves, fearing that the brown trout and whitefish they have stocked could be caught by the professionals. It should be possible to solve this problem by determining the composition of catches and offering reasonable rental prices.

Trawling for vendace is spreading rapidly on the inland waters of Finland. One fisherman tested a trawl on Lake Puulavesi in summer 1987, but it is still too early to know whether the technique will become common on this lake. Technically it is possible, but it has met with resistance from other fishermen and fishing corporations.

7. Prospects for the future

The improved exploitation of the vendace stock will be monitored in the future using the survey methods mentioned above, and management recommendations will be given to those responsible for making decisions in the fishing corporations.

It seems that regulation of the developing vendace fishery will be automatic once all the gear units held by the local fishing associations are put to proper use. Ultimately, it is fishing associations who can decide how much and what kind of fishing can be carried out in their areas.

Future research will concentrate on analysing the effects of increased exploitation on vendace productivity and fluctuations of the vendace stock. An effort will be made to model the density-dependent changes in growth, mortality and recruitment. Some research will be devoted to brown trout, because of its appearance as a by-catch in trawling and gill-netting. Other research will be directed towards assessing the potential predators of vendace and their effects on vendace mortality.

References

Auvinen, H., 1978. Muikkukannan suuruuteen ja vaihteluun vaikutta- vista tekijöistä. Kalamies. 8: 1-3.

Hamrin, S.F., 1986. Ecology of vendace, *Coregonus albula*, with special reference to factors important to commercial fishery. Arch. Hydrobiol. 22: 51-72.

Salojärvi, K., Auvinen H. & Ikonen, E., 1981. Oulujoen vesistön kalatalouden hoitosuunnitelma. Riista ja kalatalouden tutkimuslaitos, kalantutkimusosasto, monistettuja julkai suja. 1: 1-277.

Valkeajärvi, P., 1983. On the fishing and fluctuations of vendace stocks *(Coregonus albula* L.) in Lake Konnevesi, Central Finland. Jyväskylän yliopiston biologian laitoksen tie donantoja. 33: 7-38 (with English summary).

Valtonen, T. & Marjomäki, T., 1988. Stock-recruitment relationship in certain Finnish vendace *(Coregonus albula* L.) populations. Finnish Fish. Res. 9: 267-270.

Viljanen, M., 1988. Population dynamics of vendace *(Coregonus albula* L.) in Finland. University of Joensuu. Publications in sciences. 12: 1-19.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 101-111.

Recent changes in the fishery on Lake Inari, Finland

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Abstract

Lake Inari (69°N, 28°E) is situated between the sub-Arctic and temperature zones. It covers 115 300 ha and is among the most northern of the large lakes in Finland, and indeed in the world. The lake has survived to the present day as a clean oligotrophic, barren lake, even if water control measures for power production have tended to alter its natural state. In order to mitigate the effects of regulation, whitefish *(Coregonus albula)*, migratory brown trout *(Salmo trutta lacustris)*, lake trout *(Salvelinus namaycush)* and arctic charr *(Salvelinus alpinus)* have been stocked annually since 1976. Vendace *(Coregonus albula)* was introduced to Lake Inari in the 1960s.

Between 1979-1984 the number of nets used for whitefish were reduced, while the numbers used for trout and charr fishing both doubled. Consequently the whitefish catch has not grown, despite heavy stocking. To improve whitefish catches a new fishing method involving large trap nets was introduced in 1986. By 1987 professional fishermen had 13 such trap nets and catches have since been promising. The present vendace stock is large enough to support professional fishing, but because there was no experience with this species, experiments with winter seines were inaugurated in 1985, and with trawls in 1987. Results have been good and professional fishermen have accepted the new methods. Recent developments in methods of fishing, marketing and financing have increased interest in fishing. Commercial catches have grown over the past few years and it is predicted that this will continue.

1. Introduction

Lake Inari is located at the transition between temperate and sub-arctic zones (69°N, 28°E). Its large surface (115 300 ha) and northern location make it one of the most northern large lakes in Finland, and indeed in the whole world. It is completely covered by ice in winter but is open water during the brief summer *(Figure 1)*. Lake Inari remains unpolluted and oligotrophic; the only anthropogenic factor to have an adverse effect on its ecology is the regulation of the water level for power production. Water level regulation began on the Soviet side of the outlet in 1948, with the building of the Paatsjoki Hydropower Plant. The current amplitude of fluctuations is 2.36 m (Mutenia 1985). The USSR paid Finland a flat sum in 1959 as a comprehensive compensation for any damage caused by the regulation of Lake Inari.

Long-term regulation has caused considerable erosion of the shoreline and the littoral zone of the lake, which has adversely affected fish nutrition and spawning. Compared to pre-regulation years, fishing effort and catch sizes decreased by one-third during the 1960s (Toivonen 1966). It was estimated that 80 % of the reduction in catches was due to regulation and 20 % to other factors (Toivonen 1972). On the basis of these and other studies, the Finnish courts ordered the State of Finland to compensate commercial fishermen, and to clear and restore the shoreline. In addition, annual compensatory stockings were ordered, each to consist of one million 1-summer old whitefish fingerlings, 100 000 migratory brown trout *(Salmo trutta lacustris)* or land-locked salmon *(Salmo salar sebago)*, and 250 000 1-summer old Arctic charr or lake trout *(Salvelinus namaycush)*. The court further ordered that scientific studies were to be made to assess the results of these stockings.

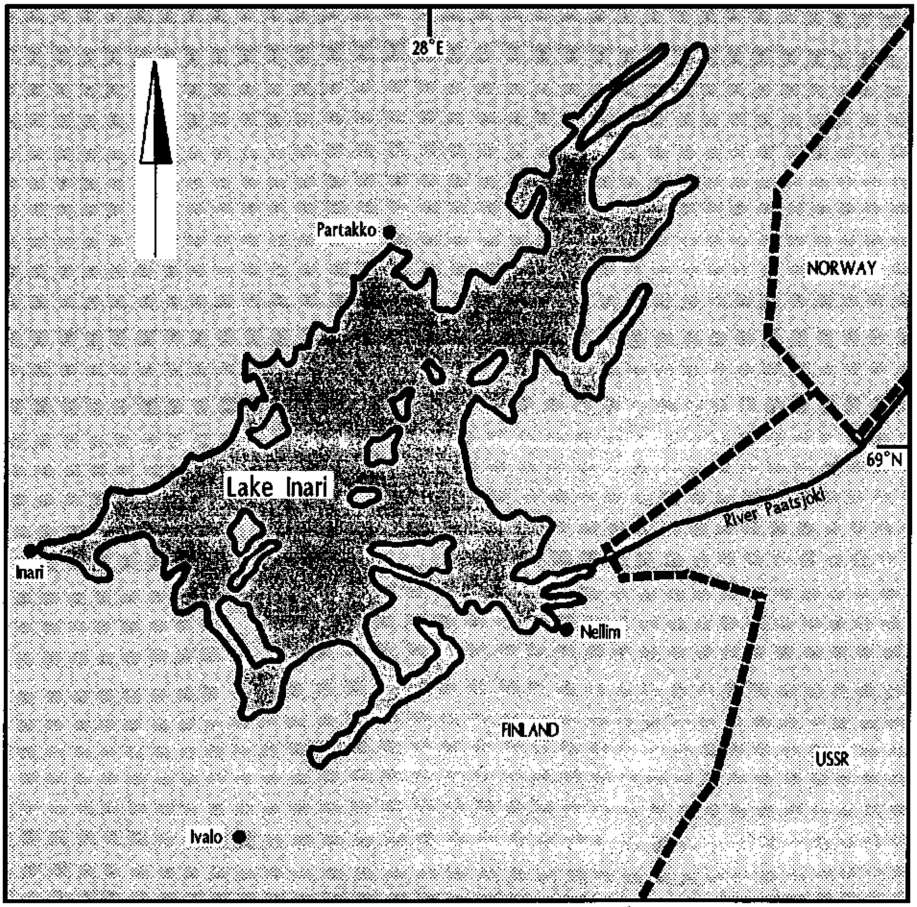

Figure 1. Location of Lake Inari.

The management programme required by the compensatory stockings reached full implementation in the 1980's. When, despite the stockings, the level of catches from Lake Inari failed to rise, it became evident that there was a need to improve the fishing methods used. It was also necessary to organise the chilling and distribution of catches, as the markets for fresh fish, in the urban areas of southern Finland, are distant from the lake.

The development of both the fishery and the marketing programme were made possible by a payment for future water level regulation covering the years 1985-1994, made by the USSR to Finland. The Finnish Ministry of Forestry and Agriculture agreed, in 1985, to the transfer of these funds (*c.* 27 million FIM) to the Commune of Inari, on condition that they were used for the development of fisheries. On this basis the Commune initiated a fisheries development project which, in regard to Lake Inari, has concentrated on the development of fishing techniques and the provision of fisheries prerequisites.

2. The development of the fishery in the 1970s and 1980s

2.1 Fishermen

The major trend in the development of fisheries in Lake Inari, from the time before water level regulation until the mid-1980s, was one of sharp decline (Mutenia 1985). The number of professional fishermen has varied during the 1970s and 1980s between 32 and 78 *(Table 1)*. For most fishermen, fishing is only a sideline. However, following the decline in the early 1980s, the number of professional fishermen increased. In addition 303-385 local subsistence or recreational fishermen used the lake during the years 1977-1987, and a rapid increase in the number of tourists who fish began in the 1980s. To illustrate this the number of fishing permits for Lake Inari increased from 1700 in 1982 to 3800 in 1987 *(Table 1)*. Lake Inari has become one of the most popular recreational fishing waters in Finnish Lapland.

Table 1. Numbers of local and recreational tourist fishermen in Lake Inari from 1977-1987.

Year	Commercial fishermen	Subsistance and local recreational fishermen	Tourist recreational fishermen	Total
1977	78	331	1728	2137
1978	67	343	1803	2213
1979	76	303	1756	2135
1980	64	339	1757	2160
1981	33	317	1847	2197
1982	34	378	1727	2139
1983	32	342	1835	2209
1984	57	307	2203	2567
1985	-	-	2341	-
1986	47	385	3049	3481
1987	-	-	3880	-

2.2 Fishing methods and equipment

Local people fish mainly with gill-nets, 9600 of which (26 per household) were in use in 1984. The number of gill-nets has grown by about 1000 since 1979 and mesh sizes have become larger. The mean length of the nets is 30 m, while mesh sizes vary from 35-70 mm and heights from 1.8-8.0 m. Over the same period, the number of seine nets has doubled. The number of whitefish trap nets has, by contrast, decreased by almost 40 % *(Table 2)*.

During 1986-1987 large fyke nets, winter seine nets and trawlers were introduced and used by professional fishermen in addition to traditional methods.

Table 2. Fishing equipment used on Lake Inari from 1977-1979 (Mutenia 1985) and from 1984-1987.

Type of equipment	Year					
	1977	1978	1979	1984	1986	1987
Seine nets	10	11	12	25		
Trap nets	1656	1392	1584	940		
Gill-nets	8312	8617	8818	9600		
Wire traps	8	5	12	87		
Winter seine nets					2	2
Large fyke nets					2	15
Trawls						3

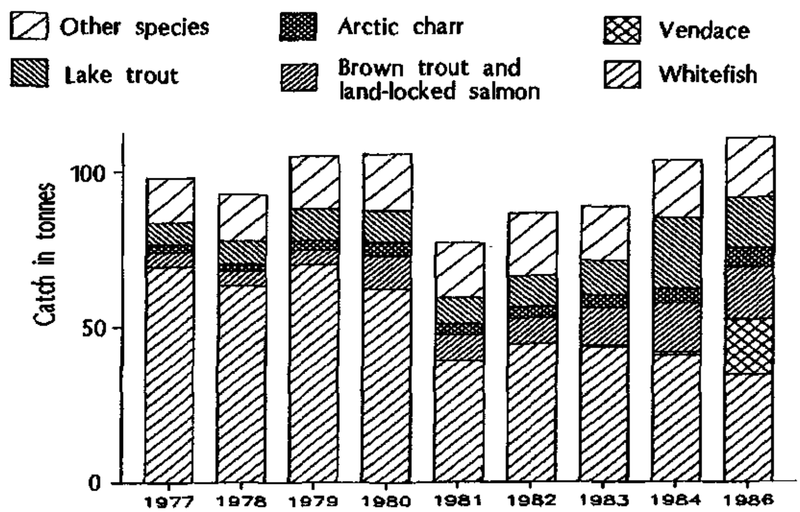

Figure 2. Catches (tonnes) by local fishermen in Lake Inari from 1977-1984, and 1986.

2.3 Catches

The total catch of all local fishermen averaged 100 tonnes/yr during the 1970s and 1980s *(Figure 2)*, but its composition changed. The average annual catch of whitefish declined from 63 tonnes in 1977-1980 to 39 tonnes in 1981-1984, while concurrently, catches of predatory salmonids (brown trout, land-locked salmon, lake trout, char) increased substantially. In 1986 these latter species accounted for 40 % of the total catch *(Figure 2)*. In the same year, professional fishing of vendace *(Coregonus albula)* began in Lake Inari, with an initial annual catch of 17.8 tonnes, but it is estimated that the vendace catch will approach 100 tonnes in 1987 when all data are processed.

Visitors' catches began to increase markedly after 1983 *(Figure 3)*. The tourist catch had been 7.2-9.8 tonnes/yr until this time, but by 1986 it had exceeded 20 tonnes. This

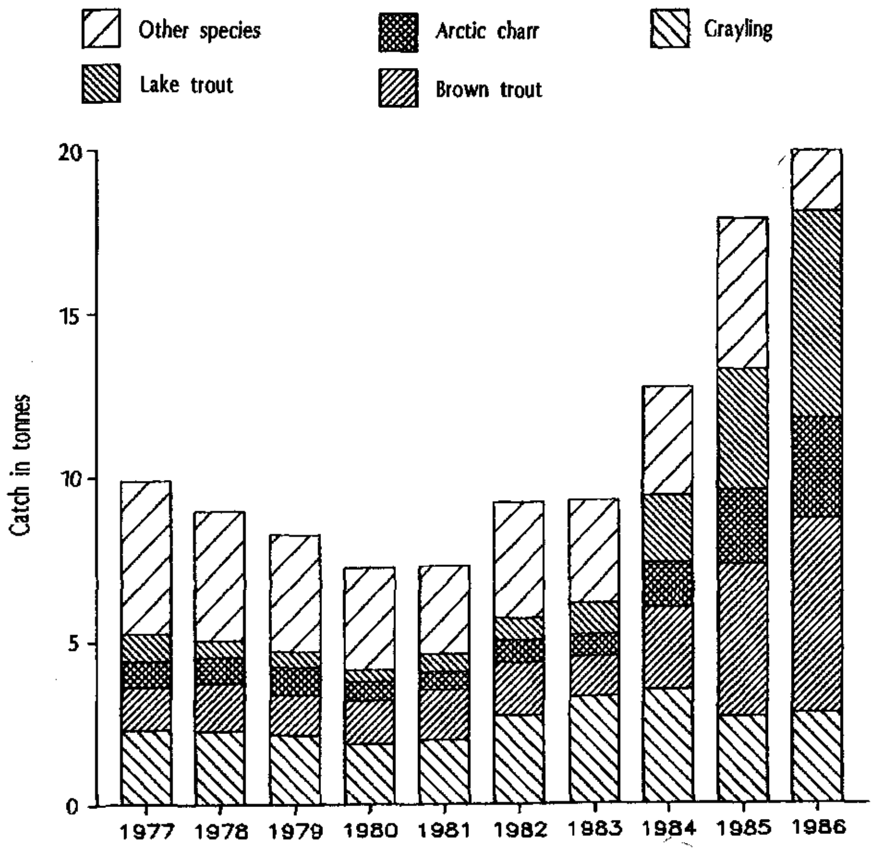

Figure 3. Catches by recreational fishermen resident outside Inari Commune from 1977-1986. Data for the winter catch of 1986 are missing.

increase is largely due to increasing numbers of fishermen; CUE has not changed greatly. However, it is clear that recreational fishermen have benefited directly from the stocking practices, because since these began their catches of brown trout, lake trout and charr have increased at an exceptionally fast rate *(Figure 3)*.

3. The impact of compensation measures on fishery economics in Lake Inari

The measures to compensate for the damage done to Lake Inari by water level regulation began to be implemented in 1976. Compensatory stockings of charr and lake trout were made at this time, while whitefish were stocked in the quantities required by the compensation ruling for the first time in 1979, and brown trout were stocked in 1980. The obligation to stock with whitefish and charr can be met annually, but that for trout was plagued by an annual shortfall that was eliminated only in 1987.

As the result of fish cultivation, trout fishery in Lake Inari has increased. By 1984 the trout catch had quadrupled from its level during the early 1970s, and at present it is approaching the level of 27 tonnes/year which prevailed before water level regulation. In 1981-1986 all trout stocked were marked by clipping the adipose fin. In 1985, cultivated, stocked trout accounted for over half (55%) the registered trout catch. By 1986, 65 % of the commercial trout catch was derived from cultivated fish.

Lake trout were stocked to compensate for the losses of indigenous Inari charr, since it was felt that lake trout would be better able to adapt to the changing conditions caused by water level fluctuation. The results of these stockings have been satisfactory (Mutenia, Simola & Tuunainen 1984). Fishing of charr and lake trout has increased as the market for these species has improved. Their total catch in 1984 was 31 tonnes, which exceeds the charr catch before regulation by 33%. On the basis of fin cutting, 98 % of the commercial lake trout catch in 1986 could be attributed to the 1982-1985 stockings of 2 year old fish. This indicates that lake trout is not reproducing naturally in Lake Inari, or that natural reproduction is insignificant.

Obligatory stocking of whitefish fingerlings reached the projected level in 1979, but since whitefish require 6-9 years to reach catch size, they will not be recruited to fisheries until the late 1980s; indeed whitefish catches actually declined during the first years of stocking. This reduction in catch size may be attributed to a decline in fishing effort as well as to the unfavourable conditions imposed by regulation. Professional fishermen quickly switched to fishing for trout and charr with large mesh (50-70 mm) nets, since netting whitefish is not very profitable and marketing it is difficult. The mesh size for whitefish is 35-45 mm. However, due to the obligatory stocking of predatory salmonids, the profitability of professional fishing began to improve between 1983 and 1985, despite the fact that traditional methods were still used exclusively at that time (Mutenia & Vihervuori 1988).

Vendace is new to the Inari area, having been first introduced in the early 1960s. The species was naturalised by the 1970s and formed a stock in Lake Inari which could be exploited by fisheries in the 1980s (Sergejeff 1987). Primarily because of vendace, Lake Inari has seen the introduction of new professional fishing methods. These are winter seine fishing through the ice, and trawling, methods which are today the most important professional fishing methods in inland waters elsewhere in Finland. Because of the vendace fishery it is expected that the total catch level for Lake Inari will increase substantially in the near future. Vendace has also become an important food source for brown and lake trout (Mutenia, unpublished data).

4. Measures taken to develop the fishery

4.1 Fishing techniques

Fishing with gill-nets is labour intensive and is so selective that when practised exclusively, the greater part of the fish production in the lake, by vendace and whitefish, is under-utilised by commercial fisheries. Because of this, new fishing methods have begun to be introduced on Lake Inari.

Development of fishing techniques began in 1985 with trials of winter seine fishing for vendace. The Inari Commune acquired suitable seines, and courses in the techniques of winter seine fishing were arranged for local fishermen. In 1986, the average winter seine catch was 160 kg/haul. Presently there are a few winter seining groups operating on the lake.

Development of open water fishing for whitefish and vendace began in 1986 when two 12 m high open ended fyke nets were used. In trials these proved efficient in catching whitefish in early summer, and vendace in the autumn when that species approaches the littoral zone prior to spawning.

In 1987, there were 12 professional fishermen using 15 fyke nets in Lake Inari. The combined catch from these was 15.6 tonnes, comprising 10.2 tonnes of whitefish and 4.6 tonnes of vendace. Learning to fish with fyke nets takes time, and the catches from these nets will improve as fishermen become better acquainted with them.

In summer, catch-size vendace move out into the wide expanses of deep open water in Lake Inari, and they are then difficult to catch with nets, either seines or fykes. Thus for the development of a summer fishery, a lightly constructed trawl was acquired in the spring of 1987. This was used in trials conducted in association with commercial fishermen. The effective hauling time of the trawler was 122.5 hours. Average catch was 90.4 kg/hr of which 79.1 kg was vendace and the rest mainly dwarf whitefish (Ahonen & Aikio 1987). This catch rate compares favourably with the average one of 59 kg/hr for vendace from the waters of Southern Finland (Niskanen & Lahti 1986).

In the autumn of 1987, the combined vendace catches of the three trawling groups then operating on Lake Inari was estimated as 40 tonnes, but this will increase as 8-10 trawling pairs are coming to the lake in 1988.

4.2 Marketing of fish

Prior to the 1960s the bulk of the professional catch from Lake Inari was salted and sold outside the municipality. However, subsequently the demand for salt fish fell, as tastes changed and education in nutrition led to a general decrease in the consumption of salted foods. Thus the market for fish from Lake Inari became confined to the immediate vicinity, where, at the beginning of the 1980s, some 15 tonnes a year was sold in local shops. Moreover, some of this came from outside the Inari area (Partanen 1987).

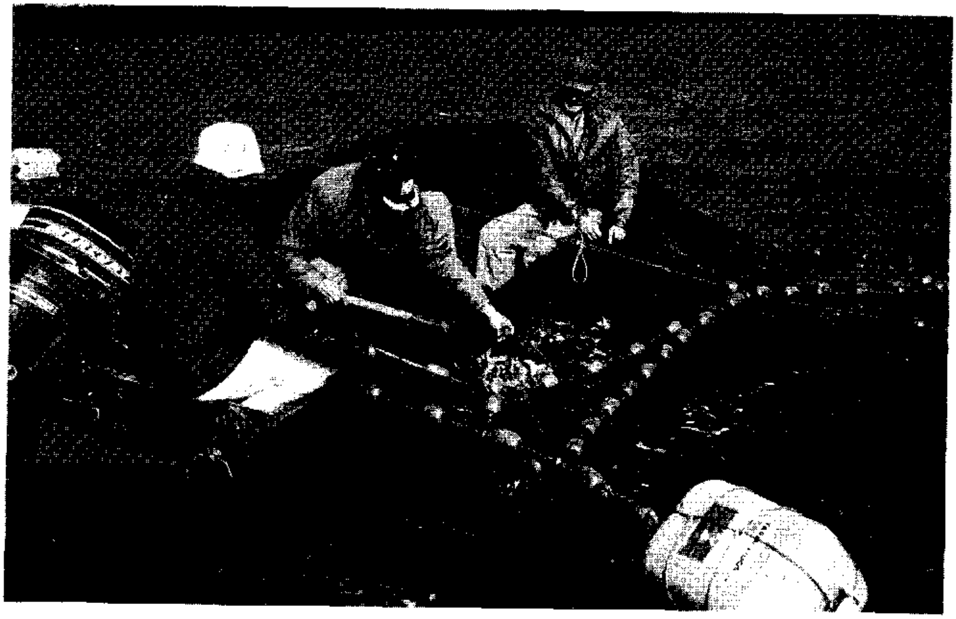

Plate 1. Open ended fyke nets, used to catch vendace and whitefish.

Plate 2. Trout, charr and whitefish are typical species in net fishing in autumn.

(Photographs by M. Ahonen)

A guaranteed market is a prerequisite for the development of a commercial fishery. Since local markets were limited, arrangements had to be made to transport fish beyond the Commune of Inari. Organisation of a new distribution system began in the autumn of 1985 when a collection and transport network was set up around the lake. Initially these activities were supported by funds from the Government of the Province of Lapland, and later, support was provided by the Finnish Ministry of Forestry and Agriculture. The fish are now sold to a concern in the village of Sodankylä, some 200 km south of the lake. Fish are collected three times a week during the open water period, using a van which traverses the perimeter of the lake, and a boat which collects from islands in the lake and directly from some of the fishing boats. Fish are collected from about 150 fishermen. The collecting concern estimated that in 1987 some 90 tonnes were collected from Lake Inari, approximately half of which were vendace. The instigation of the collection service has guaranteed that all fish caught by professional fishermen can be marketed. It has made efficient fisheries possible for small-sized whitefish and vendace, and in addition, has made it possible to exploit other species, such as pike *(Esox lucius)* and perch *(Perca fluviatilis)*, for which there was no previous demand.

From the point of view of maintaining consumer demand for fish, the quality of the fish delivered to the consumer is of the utmost importance. Quality can be kept high if the fish are covered with ice immediately after they are taken from the water (which is in fact required by law in Finland) and kept chilled until sold. To this end the Commune of Inari established crushed ice stations at four points around the lake in 1987. Fishermen obtain ice, free of charge, from these stations, which have a combined ice crushing capacity of about 5300 litres/day. Training courses in the use of this ice were arranged for local fishermen; and according to the logs of the ice stations, fishermen collected some 55 000 litres of ice in 1987.

A joint study by the Commune of Inari and the Fisheries Department of the Finnish Game and Fisheries Research Institute mapped the development and present state of fish marketing in Inari in 1987 (Partanen 1987). This study emphasised the role played by the Commune of Inari in coordinating the development of fish marketing in the area.

5. Forms of economic support for commercial fishermen

One of the main principles of regional policy in Finland is to ensure population growth and rising living standards in more remote parts of the country, such as the archipelago and northern Lapland. For this reason the public sector provides financial support for commercial enterprises in these regions. A law was passed in 1984 intending to support occupations based on natural resources in northernmost Finland. Under this law, practitioners of the traditional nature-based occupations of reindeer herding, hunting and fishing, receive long-term low interest loans and grants, for the acquisition of land and equipment, *e.g.* for fishing nets and trawlers. In Lake Inari, fishermen were granted 17 such loans and grants in 1985-1986.

In addition to the support granted to nature-based occupations, Inari fishermen are also eligible for other forms of support which are open to commercial fishermen throughout Finland. This latter support may take the form of low interest loans to fishermen, investment grants from the Ministry of Trade and Industry, grant aid for small enterprises in the countryside, and start-up funds for people entering fisheries. Fishermen can obtain advice on the different forms of aid available to them from fisheries consultants in local agricultural extension centres, from the municipal secretary for agriculture, and from the commercial secretary. Today Finnish fishermen are well acquainted with the sources of finance available to them, and almost every fisherman avails himself of aid. By combining the different forms of finance it is possible to obtain as much as 75% of the capital needed to set up a small fishery enterprise.

6. Legislation and administration

In 1982, a new Fisheries Act came into force in Finland, emphasising the sensible utilisation of fish stocks and of obtaining the largest possible sustainable yield from the waterways. This Act did not, however, include the northernmost part of Finland, where the old Fisheries Act of 1951 still holds sway. The spirit of the old law is to protect the fish stocks. In addition to the old Fisheries Act, fishing in Lake Inari is governed by numerous special regulations and decisions, as the result of which fisheries legislation for the lake has been confusing. This confusion is relieved to some extent by the fact that the State owns over 98 % of the water surface of the lake. Fishing in State waters is governed by a special Committee, with members from the National Board of Forestry, the Laplanders Association, the statutory local fisheries association, the municipality, and commercial fishermen.

In the 1985 agreement whereby the Commune of Inari was given the compensation fund from the USSR, the Commune was also given responsibility for preparing guidelines for fishing the lake. The draft guidelines were produced in co-operation with all interested parties during 1986-1987, and were then submitted to the Ministry of Forestry and Agriculture for ratification. The draft regulations were simplified from the prevailing regulations, which were complicated and sometimes contradictory, and aimed at providing commercial fisheries with the best possible operating conditions. In particular, all the previous mesh size limits for nets were removed, with the exception of those for surface nets used for taking brown trout and land-locked salmon. In addition, the strict fishing limits previously in force were softened.

Several organisations work within the framework of fisheries in Lake Inari. The owner of the waters, *i.e.* the State, is represented by the National Board of Forestries which oversees fisheries. Compensatory stockings are carried out by the Finnish Game and Fisheries Research Institute, which also follows-up on the results of the stockings.

Courses for fishermen are organised by the Regional Vocational Training Centre of Lapland. The special agreement between the Ministry of Forestry and Agriculture, and the Commune of Inari, gives the municipality the responsibility for co-ordinating fishing operations in Lake Inari.

7. The outlook for fisheries in Lake Inari

Commercial fisheries in Lake Inari are only just coming of age after a trying adolescence. The old type of fishery, based on nets, which was as much a way of life as a source of monetary income, has passed into history. They have been replaced by new fisheries, regular commercial enterprises, which require capital outlays and which use modern techniques. The changes have brought conflict, and it will be some years before the Inari fisheries finally mature and stabilise.

Through the introduction of modern fishing techniques, the catch from Lake Inari will continue to increase. To ensure that the entire catch is sold, marketing of Lake Inari fish will have to be integrated into the national marketing system. This will mean that the quality of the fish will have to remain as high as possible, to make it competitive. In marketing and advertising, emphasis can be placed upon the unpolluted nature of fish from the pure northern waters of Lake Inari, and Inari charr can be treated as a speciality. This will permit setting slightly higher prices for Inari fish than for southern fish, otherwise transport costs will reduce profitability.

Fishing tours to Lake Inari should increase. Trolling has become a very popular method of sport fishing in Finland, and Lake Inari offers unrivalled possibilities for this. The species usually taken by trolling are predatory salmonids, which may necessitate an increase in the rates of stocking these fish. Clear rules will have to be made for recreational fishermen, to avoid conflicts with the commercial fisheries of Lake Inari.

References

Ahonen, M. & Aikio, V., 1987. Muikun Troolikalastuskokeilu Inarijärvellä. Suómen kalastuslehti. 8: 406-408. Helsinki.

Mutenia, A., 1985a. Development of fish stock and fish populations in Lake Inari. In: Alabaster, J.S. (Ed.). Habitat modification and freshwater fisheries. Butterworths, London. pp. 179-185.

Mutenia, A., 1985b. Kalastus Inarijärvellä vuonna 1980 ja kalastuksen ja kalansaaliin kehittyminen. Riista ja kalatalouden tutkimuslaitos, kalantutkimusosasto. Monistettuja julkaisuja. Helsinki. 34: 20-36.

Mutenia, A., Simola, O. & Tuunainen, O., 1982. Results of lake trout stockings in Finland 1957-1981. EIFAC Symposium on stock enhancement in the management of freshwater fisheries. Budapest, 31 May - 3 June 1982. EIFAC Tech.Pap./Doc. Tech. CECPI, 42 Suppl. 2: 381-391.

Mutenia, A. & Vihervuori, A., 1988. Ammattikalastuksen kannattavuuden kehitys Inarijärvellä vuosina 1976-1985. Riista ja kalatalouden tutkimuslaitos, kalantutkimusosasto. Monistettuja julkaisuja. Helsinki. (in press).

Niskanen, J. & Lahti, E., 1986. Sisävesien troolikalastus-III Saaliit. Suomen kalastuslehti. Helsinki. 5: 216-219.

Partanen, H., 1987. Kalan markkinoinnin nykytila ja kehittäminen Inarin kunnan alueella. Riista ja kalatalouden tutkimuslaitos. Monistettuja julkaisuja. 65. Helsinki. p. 110.

Sergejeff, K., 1985. Muikku Inarijärvessä. Suomen kalastuslehti. Helsinki. 2: 50-51.

Toivonen, J., 1966. Lausunto vedensäännöstelyn vaikutuksesta Inarijärven kalakantoihin ja kalastukseen. Helsinki. (mimeo) 73 pp.

Toivonen, J., 1972. Vedensäännöstelyn vaikutus Inarijärven kalakantoihin ja kalastukseen. Täydentävä lausunto. Helsinki. (mimeo) 28 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 112-126.

Predicting the efficiency of whitefish *(Coregonus lavaretus* L. s.l.*)* stocking from pre-stocking catch statistics

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Abstract

Cluster analysis was used to test the possibility of predicting the efficiency of whitefish stocking using pre-stocking catch statistics as source material. The clusters formed by the method were also examined in relation to lake regulation. The grouping of the lakes was meaningful, concerning both the predictability of stocking success and the effects of lake regulation. Results confirm earlier observations on stocking efficiency. However, further research using a larger number of lakes is needed, and the impact of different environmental factors on lake classification should be studied.

1. Introduction

Degradation of the environment, destruction of spawning grounds and overfishing have led to a decline in whitefish catches in many of the inland waters of Finland. Lake regulation has caused many habitat changes which are harmful to whitefish stocks. To compensate for this damage, stocking is frequently performed. Traditionally, large quantities of whitefish larvae and fingerlings are also released in lakes which are still in a natural state. The success of stocking has varied considerably (Salojärvi 1986) and in some cases stocking has been completely unsatisfactory. The causes of the wide variation in stocking results need to be studied, to avoid wasting the limited financial resources available to fisheries management.

Stocking failures can be due to many factors, such as the quality and quantity of stocking material and different fishing practices. On the basis of general ecological knowledge, assemblages of fish species, and species interactions, can also be expected to affect the yield from stocking. The recent development of multivariate techniques has provided the analytical methods required to study these complex patterns.

Fisheries scientists have used multivariate techniques to classify the distribution of fish in larger areas, such as states of the USA (Smith & Fisher 1970, Stevenson, Schnell & Black 1974), to examine fish associations in certain rivers (Echelle & Schnell 1976, Rose & Echelle 1981, Pflieger, Schene & Haverland 1981), and to identify fish assemblages in northern Wisconsin (Tonn & Magnuson 1982). The classification techniques used in these studies varied considerably, having been dependent on the different data available.

A few studies have carried analysis farther and have tried to find environmental variables which characterized the fish ecoregions derived (Tonn, Magnuson & Forbes 1983, Hawkes, Miller & Layher 1986).

The aim of this study was to find out whether it is possible to use pre-stocking catch statistics to predict the efficiency of whitefish stocking. A further aim was to examine the classification of the lakes given by the cluster analysis in relation to lake regulation. Catch statistics are generally available for only one year (or in some cases for a few years) and the effect of this paucity of data was also studied.

2. Description of the lakes studied

2.1 General

Data on the total catches from 32 lakes were collected from seven different studies on lakes in northern Finland *(Figure 1)*.

Some basic characteristics of the study lakes are listed in *Table 1*. The trophic status of the lakes varied from oligotrophic to mesotrophic; none of the lakes was clearly eutrophic, or received significant amounts of industrial or municipal wastes. However, the eastern part of Lake Oulujärvi was exceptional in this respect. The main pollutant loading of the lakes was usually nonpoint loading originating from agriculture and forestry (National Board of Waters 1986). In certain lakes, the organic load from the discharge area was evident from the brown colour of the water *(Table 1)*. Lake Oulujärvi, which is the second largest lake in this study, was divided into three sub-areas. The area near Kajaani was excluded, because it was heavily loaded with effluents from forest industries. Twelve of the study lakes were regulated for hydroelectric purposes. The water level differences allowed in these lakes varied from 2 m, *e.g.* in Lake Kynsijärvi, to 6 m in Lake Vuokkijärvi *(Table 1)*.

2.2 Catch statistics

The average annual catch in the study lakes was 6.6 kg/ha and varied between 1.1 and 15.0 kg/ha *(Table 2)*. There was a slight negative correlation ($r = -0.31$, statistically significant at 90 % level) between lake size and catch in kg/ha, all species combined. In general, the lowest catches were obtained from the lakes in the Iijoki basin and the highest catches from those in the Kemijoki basin *(Table 2)*.

The catches of three to six dominant species comprised over 90 % of the total annual catches *(Table 2)*. All the lakes with vendace catches over 3 kg/ha were unregulated, the only exception being the eastern basin of Lake Oulujärvi. The vendace catches of the small lakes (under 1000 ha) were relatively low, and their contribution to the total catch was usually less than 15 %. No vendace were caught in Lake Iso-Venejärvi and Lake Inarijärvi *(Table 2)*. Whitefish catches were usually higher in unregulated lakes than in regulated ones. All the lakes with whitefish catches over 1 kg/ha were unregulated.

Vendace were dominant in 22 lakes, perch in five (mainly small lakes), whitefish in three, roach in one, and pike in one *(Table 2)*.

11	Inarijärvi
22	Kemijärvi
23	Iso-Venijärvi
24	Unari
25	Sonkajärvi
31	Jerisjärvi
41	Yli-Kitka
42	Ala-Kitka
43	Kiitämä
44	Suininki
51	Kuusamojärvi
52	Kirpistö
53	Muojärvi
54	Joukamojärvi
61	Livojärvi
62	Kynsijärvi
63	Kostonjärvi
64	Iijärvi
65	Kerojärvet
66	Irnijärvi
67	Polojärvi
71	Peranka
72	Saarijärvi
73	Kiantajärvi
74	Vuokkijärvi
81	Änätti
82	Lentua
83	Lammasjärvi
84	Ontojärvi
85	Kiimasjärvi
86	Nuasjärvi
87	Oulujärvi (1)
88	Oulujärvi (2)

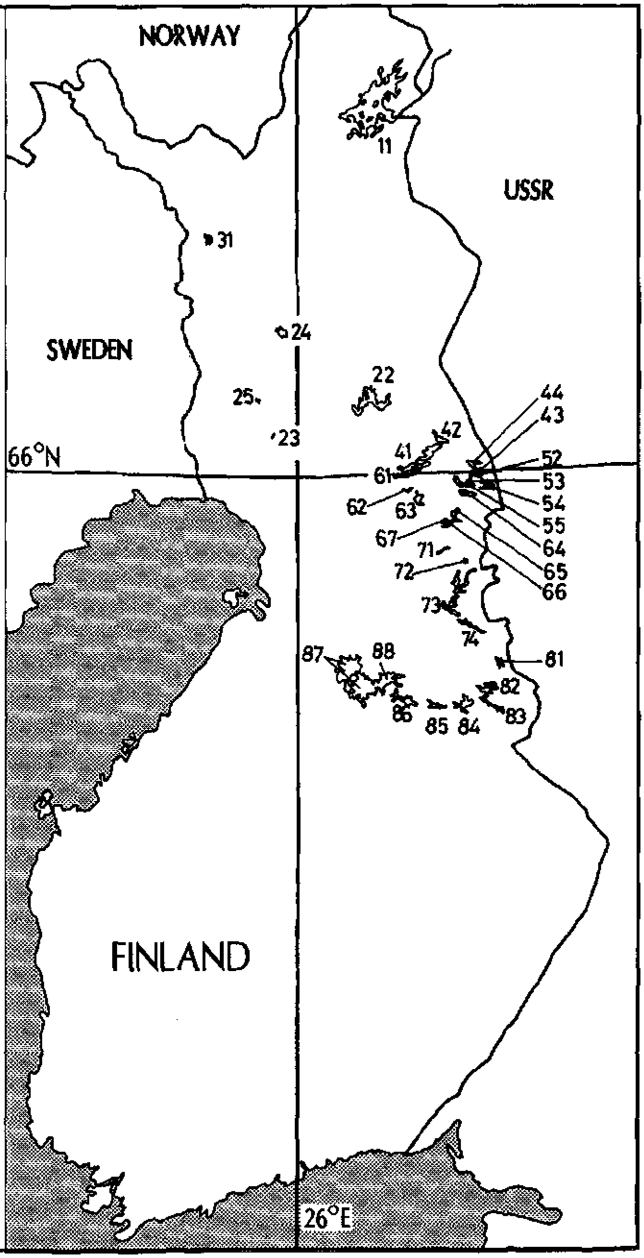

Figure 1. Location of lakes and water courses studied.

Table 1. Study lakes grouped by watercourses and some basic properties of each lake. The area is that measured at mean water level. MW = mean water level, NN = sea water level, W = water level difference allowed in a regulated lake, u = unregulated. Water samples were collected and analysed by the National Board of Waters.

Lake	No.	Area (ha)	MW (NN+m)	W (m)	Depth (m)	Conductivity (mS/cm)	Alkalinity (mval/l)	Colour (mg Pt/l)	Total PO_4 (µg/l)
Inari	11	115300	118	2.4	96	33	0.21	10	10
Kemijärvi	22	20600	146	u	24	54-63	0.30-0.32	98-108	45-54
Iso-Venijärvi	23	200	187	u	15	27-29		20	9-10
Unari	24	2900	180	u	23	20-36	0.09-0.19	50-150	13-37
Sonkajärvi	25	300	102	u	9	22-43		70-120	7-27
Jerisjärvi	31	2400	258	u	10	28-41	0.15-0.20	10-50	9-57
Yli-Kitka	41	20800	240	u	31	35-36	0.26-0.28	10-14	4-6
Ala-Kitka	42	5300	240	u	17	34-39	0.25-0.26	4-13	10
Kiitämä	43	1500	253	u	18	36-39	0.27-0.29	7-15	5-11
Suininki	44	2200	252	u	27	38-40	0.29-0.33	19-36	9-16
Kuusamojärvi	51	5100	253	u	17	43-47	0.33-0.36	16-18	7-11
Kirpistö	52	1300	253	u	17	35-37	0.26-0.30	7-11	6-10
Muojärvi	53	5500	253	u	37	41-47	0.33-0.36	6-19	3-18
Joukamojärvi	54	2500	252	u	13	37-45	0.29-0.30	14-17	8-14
Livojärvi	61	3300	244	u	15	30-34		5-15	4-8
Kynsijärvi	62	1200	232	2.0	9	22-120	0.10-0.63	26-105	6-40
Kostonjärvi	63	4300	232	5.0	17	29-75	0.11-0.24	25-60	6-25
Iijärvi	64	2100	254	u	18	30-44	0.25-0.32	17-38	7-19
Kerojärvet	65	2200	237	4.0	14	30-39	0.18-0.28	29-40	8
Irnijärvi	66	3000	236	4.0	20	28-37	0.16-0.25	30-40	7-19
Polojärvi	67	800	236	4.0	13	25-28	0.14-0.19	22-60	10-32
Peranka	71	400	242	u	34	23-32	0.11-0.36	38-80	6-23
Saarijärvi	72	700	202	u	29	33-54	0.29-0.33	31-50	6-9
Kiantajärvi	73	15500	198	4.0	41	19-27	0.13-0.20	28-74	5-10
Vuokkijärvi	74	4700	188	6.0	19	18-31	0.07-0.19	52-95	18-50
Änätti	81	3400	182	u	43	21-27	0.10-0.18	38-73	8-11
Lentua	82	9100	168	u	52	18-23	0.10-0.18	29-60	5-60
Lammasjärvi	83	4100	163	u	13	21-26	0.04-0.05	80-120	19-20
Ontojärvi	84	10500	158	4.4	29	24-27	0.08-0.10	61-86	9-15
Kiimasjärvi	85	5500	138	2.5	33	20-23	0.08-0.09	61-70	6-10
Nuasjärvi	86	9700	138	2.3	42	20-25	0.07-0.25	54-70	5-50
Oulujärvi (1)	87	73300	122	2.7	36	24-35	0.10-0.17	35-80	5-30
Oulujärvi (2)	88	10100	122	2.7	30	17-28	0.03-0.20	38-80	5-30

Table 2. Classification of the study lakes (Ward's minimum variance method) and the catches of different species expressed as percentages (see caption on opposite page).

Lake No.	Catch (kg/ha)	Whitefish	Vendace	Charr	Brown trout	Grayling	Smelt	Pike	Bream	Ide	Roach	Burbot	Ruff	Pikeperch	Perch	Stocking efficiency	Catch year	Reference
1 Predatory																		
84	4.3	9.6	28.5	-	0.5	-	0.2	16.4	0.8	-	11.2	8.5	-	2.5	21.7	-	1973	1
86	6.0	3.1	29.0	-	0.7	-	0.7	19.3	0.3	-	14.3	11.1	-	0.1	21.5	+	1973	1
88	15.0	2.9	28.6	-	0.4	-	9.3	18.4	0.5	-	9.9	10.6	-	0.1	19.4	+	1973	1
85	8.0	4.0	16.5	-	0.2	-	2.3	22.4	3.2	-	15.0	11.4	-	0.1	25.0	+	1973	1
74	8.1	3.0	27.0	-	0.3	-	-	33.4	-	-	7.7	10.4	-	-	18.2	+	1973	1
2 Cyprinid																		
62	3.5	12.0	39.5	-	0.5	0.0	-	13.6	0.3	2.9	18.6	1.2	2.1	-	9.3	-	1979	2
63	6.5	15.1	35.6	-	0.6	-	-	19.5	0.1	0.3	16.0	3.3	0.3	-	9.3	-	1979	2
22	4.5	4.9	37.0	-	0.2	0.3	1.1	19.6	-	4.4	9.2	2.2	-	1.6	19.6	-	1960	3
73	6.6	5.4	38.1	-	0.7	-	1.1	13.7	0.3	-	18.1	6.5	-	0.0	16.1	+	1973	1
3 Trash fish																		
65	4.3	3.7	41.4	-	0.0	0.3	-	4.3	-	2.1	21.6	2.9	8.6	-	15.1	-	1979	2
66	2.2	2.2	43.5	-	-	-	-	5.6	-	-	19.7	5.0	3.4	-	20.7	-	1979	2
52	9.9	10.4	33.6	-	0.1	-	-	3.5	-	2.4	16.3	4.6	12.8	-	16.2	n	1966	4
67	3.9	5.4	27.5	-	0.3	-	-	3.7	-	0.7	26.9	1.2	10.7	-	23.5	-	1979	2
64	5.4	11.4	19.9	-	0.3	0.2	-	5.3	-	0.1	39.2	3.3	6.4	-	14.0	n	1966	4
4 Whitefish																		
42	6.7	25.1	31.7	-	0.0	0.6	-	9.8	-	0.6	6.4	0.7	0.5	-	24.5	-	1966	4
54	7.2	29.6	21.6	-	1.6	1.3	-	11.9	-	2.4	6.0	5.0	-	-	20.9	n	1966	4
41	5.0	18.3	46.6	-	1.0	0.6	-	7.1	0.1	0.9	5.7	3.1	0.1	-	16.5	-	1966	4
61	2.5	28.7	40.4	-	0.8	-	-	4.1	-	-	0.7	3.1	0.8	-	21.4	n	1966	4
83	9.1	22.5	16.2	-	1.2	-	0.0	13.2	2.4	-	15.8	7.6	-	0.3	21.0	-	1973	1
31	5.2	30.1	33.7	-	0.3	-	-	3.7	-	-	8.2	13.0	-	-	11.0	-	1973	5
5 Vendace																		
81	7.6	7.3	44.0	-	1.3	-	7.2	10.4	0.1	-	8.9	7.6	-	0.0	13.3	-	1973	1
82	8.6	9.8	44.1	-	0.9	-	8.3	6.6	0.0	-	7.1	6.3	-	-	17.0	+	1973	1
51	7.5	6.8	51.8	-	0.3	-	-	7.7	0.0	1.2	17.9	2.4	0.6	-	11.3	n	1966	4
53	10.5	12.9	51.3	-	0.5	0.0	-	3.6	0.0	0.5	14.9	2.3	4.2	-	9.8	n	1966	4
24	6.3	7.3	49.9	-	0.1	0.2	4.1	10.3	-	-	8.7	6.1	4.5	-	8.9	-	1975	6
87	5.0	3.3	57.2	-	0.2	-	4.9	11.1	1.6	-	5.7	6.6	-	0.2	9.3	+	1973	1
43	8.8	8.0	61.6	-	0.0	0.1	-	3.1	-	2.8	8.6	3.3	3.8	-	8.8	n	1966	4
44	10.5	11.2	75.3	-	0.0	0.1	-	1.9	-	0.4	4.6	1.6	0.6	-	4.3	n	1966	4
6 Salmonid																		
11	1.1	65.0	-	10.1	5.6	4.8	-	3.8	-	-	-	4.9	-	-	5.5	-	1977	7
7 Perch																		
71	4.8	8.1	12.7	-	1.0	-	0.1	3.2	-	-	10.5	2.4	-	-	62.2	+	1978	8
72	4.1	8.7	2.4	-	0.7	-	0.6	5.9	-	-	18.7	3.1	-	-	60.1	+	1980	9
8 Perch																		
23	4.7	-	-	-	-	-	-	6.5	-	-	42.6	6.5	1.9	-	42.6	+	1962	10
25	14.2	13.6	3.8	-	2.1	0.2	-	22.5	0.2	0.6	17.2	5.5	0.3	-	33.8	+	1974	11

2.3 Whitefish stocking

Whitefish larvae have been released in almost all the study lakes, and nowadays, the most important stocking method is to release 1 summer old fingerlings in the lakes (Salojärvi 1986). Stocking with whitefish larvae usually fails, if a naturally reproducing population already exists (Christie 1963, Salojärvi 1983). Thus only stocking with fingerlings was considered here.

The efficiency of stocking was assessed by comparing stocking and catch statistics. Stocking was classified as efficient if, following it, the whitefish catch increased at least twofold. Stocking was considered to be inefficient if the catch decreased, or if increases were only minimal. The third category includes lakes where no stocking was performed, or where the scale of stocking was so small that no effect was expected.

In 11 out of the 25 cases stocking was successful *(Table 2)*. In some lakes dramatic changes took place in the catch level. The annual whitefish catch from Lake Oulujärvi increased from less than 20 tonnes to nearly 100 tonnes after stocking, and that from Lake Kiantajärvi from 6 tonnes to over 20 tonnes per year.

3. Clustering of lakes

3.1 Methods

The catches of the 14 most common species were selected for the analysis, these being bream *(Abramis brama)*, burbot *(Lota lota)*, charr *(Salvelinus alpinus)*, grayling *(Thymallus thymallus)*, ide *(Leuciscus idus)*, perch *(Perca fluviatilis)*, pike *(Esox lucius)*, pikeperch *(Stizostedion lucioperca)*, ruffe *(Gymnocephalus cernua)*, roach *(Rutilus rutilus)*, smelt *(Osmerus eperlanus)*, trout *(Salmo trutta)*, vendace *(Coregonus albula)* and whitefish or houting *(Coregonus lavaretus)*.

The classification of the lakes was performed using an agglomerative hierarchical clustering analysis. Agglomerative clustering has two steps. First, from the samples-by-species data matrix, a samples-by-samples dissimilarities matrix is computed using one of many dissimilarity (distance) measures (such as percentage dissimilarity or Euclidean distance). Second, some agglomeration procedure is applied successively to build up a hierarchy of increasingly larger clusters, *i.e.* the most similar sample pair is joined first, and the process continues until a single cluster contains all the samples. The cluster hierarchy obtained is normally presented as a dendrogram.

Table 2. The classification of the study lakes (Ward's minimum variance method) and the catches of different fish species, expressed as percentages. The number of clusters selected is eight. The total catch kg/ha by lakes is also presented. For location and name of lakes see *Table 1* and *Figure1*. Estimated stocking efficiency: − = stocking inefficient, whitefish catch not increased or only slightly changed; + = stocking estimated to be efficient, whitefish catch has increased many times compared with the pre-stocking catch; n = scale of stocking so small, effect negligible. References: 1= Salojärvi et al. (1981), 2= Kauppinen & Taskila (1982), 3= Sormunen (1964), 4= Kalataloussäätiö (unpubl.), 5= Sarjamo (1987), 6= Alapuranen (1981), 7= Mutenia (1985), 8= Salojärvi (1988), 9= Salojärvi (unpubl.), 10= Ruokanen (1979), 11= Salmela (1976).

Multivariate statistical procedures such as classification have several requirements, some of which are difficult to meet. For descriptive studies, however, wide departures from the ideal data structure are tolerable (*e.g.* Green & Vascotto 1978). For classification, the annual catch by species was divided by the area of the lake to give per hectare per year catches. As the sample totals (*i.e.* total annual per hectare catches) varied greatly between lakes (*Table 2*), the data were transformed so that the abundances of the species were expressed as percentages of the total catch for each lake. Gauch (1982) recommends adjusting the abundance values for each sample, so that all samples have the same total. Clustering was performed using both forms of the data (catches/ha and percentages).

The statistical procedure was performed using the SAS data analysis system (SAS 1985). The **cluster** procedure was used for hierarchical clustering and the **tree** procedure was used to draw a dendrogram of the cluster hierarchy and to extract clusters at specific levels of the tree. The cluster procedure offers 11 clustering methods, which differ in computing the distance between two clusters. The samples-by-samples dissimilarities matrix is computed, however, by all methods, using Euclidean distance (in this study squared).

Average linkage and Ward's minimum variance methods were used. Both methods have been widely employed in ecological studies (*e.g.* Balon, Crawford & Lelek 1986, Hawkes *et al.* 1986, Hebert & Hann 1986). In average linkage the distance between two clusters is the average distance between pairs of observations, one in each cluster. Average distance was calculated using the unweighted pair-groups method with arithmetic averages (UPGMA). Ward's minimum variance method merges clusters, provided that the increase in within-group dispersion (variance) is less than it would be if either of the two clusters were joined with any other cluster. Thus the method seeks to minimize within-cluster sums of squares, which are indexed by the semi-partial R-squared (SPR^2) (= between-cluster sums of squares divided by total, corrected sums of squares).

There are no satisfactory methods for determining the number of population clusters for any type of cluster analysis (*e.g.* Everitt 1979, 1980). If the purpose of the study is to summarize the data without trying to uncover 'real' clusters, the squared multiple correlation R^2 (the proportion of variance accounted for by the clusters) may be used (SAS 1985). In this study the number of clusters was selected mainly on the basis of a subjective evaluation of the dendrograms obtained.

3.2 Results of the cluster analysis

With catches per hectare data, the two different clustering methods (average linkage and Ward's minimum variance method) gave similar classification patterns for the lakes. They tended to form clusters containing lakes with roughly the same level of total catches. Thus, catches per hectare data were rather unsatisfactory for revealing different fish species assemblages.

The cluster analysis performed with percentage catches was more successful in this respect. In general, Ward's method produced more uniform clusters than the average distance method with respect to the number of observations in a cluster. However, with this form of data also, the actual classification was based mainly on the variance of the most abundant species (vendace, perch, roach, pike, whitefish, burbot and ruffe). The

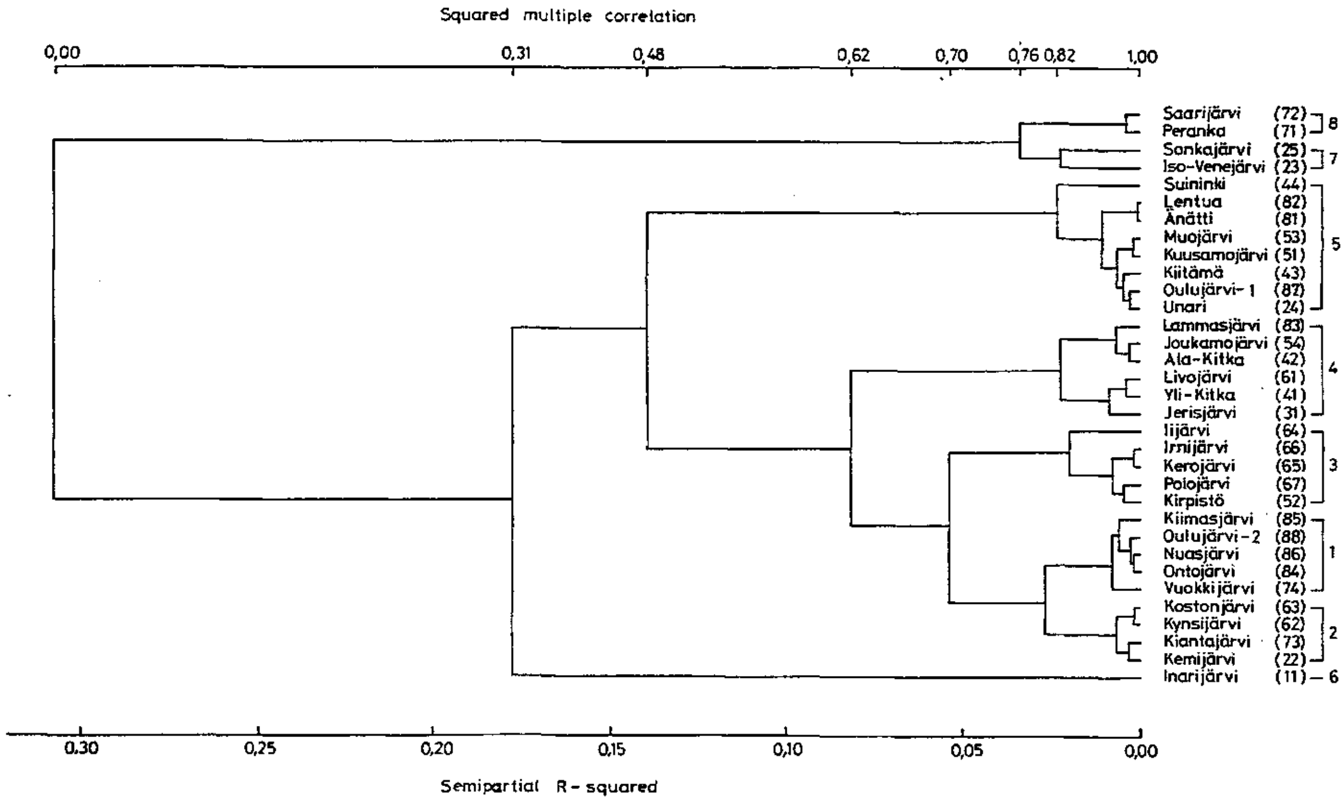

Figure 2. Dendrogram formed by Ward's minimum variance method, using percentage catches.

catches of other species were usually so low, that they did not have any effect on the classification obtained by the cluster analysis.

When the number of clusters was set at eight, the following classification was obtained using percentages data and Ward's method (the squared multiple correlation was 0.82, *Figure 2*):

Cluster 1 (predatory) contained five regulated lakes in the Oulujoki watercourse. The catches contained a fairly high proportion (46.6-62.0 %) of predatory species (perch, pike and burbot). This was due to the high proportion of pike and also fairly high proportion of burbot in the total catches from these lakes *(Table 2)*. Whitefish stocking has been efficient in these lakes. Lake Ontojärvi is the only exception and even there stocking gave good results at first.

Cluster 2 (cyprinid) comprised three regulated lakes and Lake Kemijärvi (nowadays also regulated). This cluster resembled the 'predatory' cluster, but the proportion of predatory fish was lower (24.1-41.3 %) and that of vendace and roach somewhat higher *(Table 2)*. Stocking with whitefish fingerlings has been successful in Lake Kiantajärvi, but in the other lakes in this cluster very poor results have been obtained.

Cluster 3 (trash fish) contained three regulated and one unregulated lake in the River Iijoki drainage basin and Lake Kirpistö on the River Kemijoki watercourse. The feature common to these lakes was a high proportion of roach (16.3-39.2 %) and a fairly high proportion of ruffe (3.3-12.8 %), and a low proportion of pike (3.5-5.6 %). Whitefish fingerling stocking has yielded very poor results in these lakes. From cluster 1 to cluster 3, the proportion of pike decreased and the proportion of roach increased.

Cluster 4 (whitefish) contained six unregulated lakes with a high proportion (18.3-30.1 %) of whitefish in the total catches. In none of these lakes has stocking increased the whitefish catch, although for some, only circumstantial observations on the efficiency of stocking are at present available.

Cluster 5 (vendace) contained seven unregulated and one regulated lake (the western basins of Lake Oulujärvi). Vendace comprised about half (44.0-75.3 %) of the total catches from these lakes. This cluster resembled the 'whitefish' cluster, but the whitefish and perch catches were lower *(Table 2)*. In four of the lakes in this 'vendace' cluster there was a fairly high proportion of smelt (4.1 to 8.3 %), possibly due to the fact that seining of vendace also yields smelt as a by product, if that species is present. In two of these lakes the yield from stocking has been good, while in one lake the whitefish catch has not increased despite large releases of fingerlings.

Cluster 6 (salmonid) contained only one lake, Inarijärvi, with high proportions of whitefish, charr and trout. So far, the whitefish catch has not increased in spite of large-scale stocking with fingerlings.

Clusters 7 and **8** (perch) were closely related, but differed greatly from the other lakes. They formed a branch containing small lakes situated in the upper reaches of individual tributary watercourses with high proportions of perch *(Table 2)*. In all four lakes whitefish stocking has been successful.

3.3 The effect of variation in the annual catch

Due to the shortage of suitable data, the present clustering was based on catch data representing only one year for each lake. This reduces the reliability of the results. For example, the stocks of certain fish species are known to fluctuate (*e.g.* vendace and whitefish). Catch data for a period longer than a year were available for only half of the study lakes. The data used in this study for those lakes were compared with the data for the preceding or following years. The best data for comparison were those of Ollila (1970), who gives the total catches for the years 1964-1968 for lakes 41, 42, 43, 44, 51, 52, 53, 54 and 64 (year 1966 was used in the cluster analysis). Comparative data were available for a shorter period for lakes 11, 23, 24, 62, 63, 71 and 72 (sources the same as for the data in the classification).

The comparison revealed one clear mis-classification, which was due to the fact that the vendace catches from Lake Kirpistö were exceptionally low in 1966 compared with both the preceding and succeeding years. Thus this lake should be in the 'vendace' cluster instead of the 'cyprinid' cluster. According to the same data, the other unregulated lake (Iijärvi) in the 'trash fish' cluster could also be considered to belong to the 'vendace' cluster on the basis of the catches for 1964 and 1965, but not on the basis of the catches for the subsequent three years. The extremely high proportion (75 %) of vendace in the catches from Lake Suininki was also unusual; during the four other years for which data was available the proportion of vendace in the total catches varied from 57 to 66 %. Nevertheless, this lake should still belong to the 'vendace' cluster. Lake Unari in the 'vendace' cluster could instead, have been placed in the 'cyprinid' cluster (between the 'predatory' and 'trash fish' clusters) which already contained another lake in Lapland. The lakes in the 'vendace' and 'whitefish' clusters could quite often have been placed in either cluster, although a few lakes in these clusters seemed to be true vendace (Suininki and Kuusamojärvi) or true whitefish lakes (Joukamojärvi and Jerisjärvi).

In summary, the same type of clustering would have been obtained if there had been data for a period longer than one year. It should be emphasized that the clusters are not separate groups of specific types of lakes, but are hierarchically connected with each other, and that therefore, near clusters will always have features in common.

4. Discussion

4.1 The applicability of the method

Two important prerequisites for the successful application of a multivariate analysis are the data editing and the selection of a multivariate technique which is appropriate for a given data set and purpose (Gauch 1982). Data editing is important, because the form of data used in the multivariate analysis greatly affects the results obtained.

The importance of data editing was also evident from this study. The cluster analysis performed using hectare catches formed rather heterogenous clusters of lakes with roughly equivalent total catches/ha. Thus the use of this form of data did not seem to suit the purpose of revealing different fish species assemblages since the sample totals (the total catches of the lakes) were unequal.

Cluster analysis performed using adjusted (relativised) abundance values (the proportion of each fish species in the total catch of each lake) gave a more meaningful classification of the lakes. However, with this form of data too, the actual classification was based mainly on the variance of the most abundant fish species; vendace, perch, roach, pike, whitefish, burbot and ruffe. The proportion of other species in the total catches were usually so low that they did not have any effect on the classification.

As regards the multivariate analysis method used in this study, the hierarchical cluster analysis performed reasonably well. Hierarchical clustering has been recommended as an essential procedure in ecological community analysis by Green and Vascotto (1978) and Hawkes *et al.* (1986). However, Gauch (1982) recommends ordination in preference to classification methods. The use of both ordination and classification is fairly common in community analysis (Tonn *et al.* 1983, Hawkes *et al.* 1986).

The selection of a clustering method is of secondary importance compared to the choice of the multivariate method. The usual advice given is to use several different methods and to compare the classifications obtained. When an exploratory cluster analysis is done, as in this study, and one has no idea what kinds of clusters to expect, it is advisable to include at least one method based on nonparametric density estimation (such as single linkage and density linkage) (SAS 1985). Nevertheless, such a method was not considered necessary in this study because average linkage and Ward's minimum variance method revealed the 'clusters' in the data set reasonably well.

The two different clustering methods used gave quite similar classification patterns for the lakes. The average linkage method had a tendency to produce clusters in which the number of samples varied widely, including several clusters containing only one or two lakes. By contrast, Ward's method is strongly biased to produce clusters with roughly the same number of observations (Milligan 1980). This was clearly seen in the classification patterns obtained. Ward's method was used as the only clustering method in the study of Hawkes *et al.* (1986).

Fish community analyses are usually based on the results of experimental fishing performed with standardized fish sampling methods (Tonn *et al.* 1983, Hawkes *et al.* 1986). One of the basic assumptions in this study was that the catches obtained by sample survey would reflect the fish community occurring in a particular lake. It is clear that catches do not give a very representative picture of the total fish assemblage in a lake, because fishing is selective. It is also difficult to compare catches from different lakes, because of variation in the fishing methods and efforts.

4.2 The effect of environment on the classification

The classification obtained indicates that the catches from a particular lake reflect the environmental properties of the lake. It seems that one of the most significant environmental variables in this respect is the regulation of lakes.

Regulation of lakes is known to be especially harmful to fish species which spawn in autumn, such as whitefish and vendace. The proportions of these species were higher in unregulated than in regulated lakes. All lakes with vendace catches over 3 kg/ha (the eastern basin of Lake Oulujärvi is the only exception) or whitefish catches over 1 kg/ha were unregulated. It is known that habitat modifications, caused by lake level regulation, water-power works and the dredging of rivers, have considerably reduced suitable whitefish nursery/breeding areas. The deleterious effects of regulation on vendace stocks increases as the difference in water levels increases between spawning and hatching times. If the water level variation is small the effect is probably negligible. This explains, in part, why the unpolluted western basins of Lake Oulujärvi were classified as vendace lakes.

The regulated lakes had a higher proportion of either predatory (chiefly pike) or trash fish (roach and ruffe) in the total catches. The greatest pike catches (over 1.5 kg/ha) usually came from regulated lakes. This was to be expected as regulation is not considered to be very harmful to these species which all spawn in spring.

What factors are responsible for the differences in the catches of the various regulated and unregulated lakes? The potential causes include the regulation procedure employed, the water quality, the size and altitude of the lake, and different fisheries practices. The grouping of the regulated lakes depended on geographical location. The predatory cluster included lakes in the Oulujoki basin, but the lakes with a high proportion of roach and ruffe were mainly located in the Iijoki basin. These lakes also differed in size (the lakes in the Iijoki basin were smaller), altitude (the lakes in the Iijoki basin were on the average 71 m higher than the study lakes in the Oulujoki basin) and water quality. Among the unregulated lakes, no such clear differences were observed between the vendace and whitefish lakes. The perch lakes differed in size from other unregulated lakes, all being small (under 1000 ha) lakes in the upper reaches of watercourses. For this reason the two unregulated lakes in Lapland (Unari and Kemijärvi) could be placed in the intermediate cluster, which otherwise contained only regulated lakes.

4.3 Predictability of stocking efficiency

From the point of view of estimating the efficiency of stocking, the clusters formed seem to be satisfactory. This confirms the hypothesis that the success of whitefish stocking depends on the fish community present.

The good results of stocking in the lakes of cluster 1 (predatory cluster) can be related to the harmful effect of lake regulation on the eggs and larvae of whitefish. Stocking compensates for the damage caused by lake regulation. Strong predation, caused chiefly by pike, ensures that these lakes are seldom overstocked. The poor result of stocking in Lake Ontojärvi can possibly be explained by too high a stocking density and the fact that the lake is connected with others which are still in a natural state.

The reason for the poor result of whitefish stocking in the lakes belonging to cluster 2 (cyprinid cluster) is probably overstocking, especially since the number of predators is lower in these lakes. This is confirmed by research on Lake Kemijärvi (Heikinheimo-Schmid & Huusko 1987) and the good results obtained from Lake Kiantajärvi, which is intensively fished and whose predator catch has increased since the pre-stocking phase.

The number of predators is very low and the stocking density high in the lakes of cluster 3 (trash fish cluster). In these conditions intra- and interspecific competition can be severe and this is probably responsible for the poor results from these lakes. Judging by the total catch level, the fishing effort is low.

The failure of whitefish stocking in the lakes of cluster 4 (whitefish cluster) could be expected in the light of present knowledge. The result of stocking is known to correlate negatively with the density and biomass of the whitefish stock (Salojärvi 1988). Larvae stocking has failed in cases in which a dense, naturally reproducing whitefish population exists (Christie 1963). The poor results in these lakes are thus caused by intraspecific competition for food.

Cluster 5 (vendace cluster) is a close relative of the preceding cluster. All of its lakes also have naturally reproducing whitefish populations. The good results from the western part of Lake Oulujärvi and Lake Lentua can be explained as follows. Lake Oulujärvi is regulated, predator species are abundant, stocking is at a reasonable level and fishing is intense. The whitefish stock in Lake Lentua is overfished and the area of suitable spawning grounds is restricted (Salojärvi, Auvinen & Ikonen 1981). Although the number of fingerlings released in Lake Lentua has so far been low, stocking it has evidently been a cure for overfishing.

Lake Inari (cluster 6) is poorly fished. The catch is composed mainly of whitefish, and the natural reproduction of whitefish is good in spite of the fact that the lake is regulated. In view of the limited fishing effort and good natural reproduction, the level of stocking has been far too high and the practice has been unsuccessful.

Clusters 7 and 8 are close relatives and can be dealt with at the same time. In small lakes with no naturally spawning whitefish, or with a sparse population of local whitefish, stocking is successful in most cases. Small lakes are often rather heavily fished per unit area by contrast with larger lakes.

The clusters obtained thus seem to accord well with the success of whitefish stocking and these preliminary results are promising from the point of view of planning whitefish stocking programmes. There also appears to be some possibility of controlling fishing and preparing the lake in advance to ensure a higher catch from stocking. However, the method used here is very general in nature and cannot give satisfactory answers to questions concerning the optimum stocking rate for different types of water bodies, or the regulation of fishing etc. More detailed studies are needed for these questions.

References

Alapuranen, J., 1981. Unarinjärven kalataloudellinen käyttö-ja hoitosuunnitelma. Rovaniemi, Lapin läänin maatalouskeskus. 78 pp.

Balon, E.K., Crawford, S.S. & Lelek, A., 1986. Fish communities of the upper Danube River (Germany, Austria) prior to the new Rhein-Main-Donau connection. Environmental Biology of Fishes. 15: 243-271.

Christie, W.J., 1963. Effects of artificial propagation and the weather on recruitment in the Lake Ontario whitefish fishery. J. Fish. Res. Bd Can. 20: 597-646.

Echelle, A.A. & Schnell, G.D., 1976. Factor analysis of species associations among fishes of the Kiamichi river, Oklahoma. Trans. Am. Fish. Soc. 105: 17-31.

Everitt, B.S., 1979. Unresolved problems in cluster analysis. Biometrics 35: 169-181.

Everitt, B.S., 1980. Cluster analysis. London, Heineman Educational Books Ltd.

Gauch, H.G., Jr., 1982. Multivariate analysis in community ecology. Cambridge, Cambridge University Press. 298 pp.

Green, R.H. & G.L. Vascotto, G.D., 1978. A method for the analysis of environmental factors controlling patterns of species composition in aquatic communities. Water Research. 12: 583-590.

Hawkes, C.L., Miller, D.L. & Layher, W.G., 1986. Fish ecoregions of Kansas: stream fish assemblage patterns and associated environmental correlates. Environmental Biology of Fishes. 17: 267-279.

Hebert, P.D.N. & Hann, B.J., 1986. Patterns in the composition of arctic tundra pond micro-crustacean communities. Can. J. Fish. Aquat. Sci. 43: 1416-1425.

Heikinheimo-Schmid, O. & Huusko, A., 1987. Kemijärven kalatalouden nykytila ja ehdotukset hoitotoimenpiteiksi. Riista- ja kalatalouden tutkimuslaitos, kalantutkimusosasto. Monistettu-ja julkaisuja 69: 1-212.

Kauppinen, V. & Taskila, E., 1982. Irni-, Kero- ja Polojärven sekä Koston-, Kynsi- ja Tervajärven sekä Unilammen säännöstelyn kalatalousselvitys. Oulu, Pohjois-Suomen Vesitutkimustoimisto. 49 pp.

Milligan, G.W., 1980. An examination of the effect of six types of error perturbation on fifteen clustering algorithms. Psychometrika. 45: 325-342.

Milligan, G.W., 1981. A review of Monte Carlo tests of cluster analysis. Multivariate Behavioural Research. 16: 379-407.

Mutenia, A., 1985. Development of fish stock and fish populations in Lake Inari. In: J.S. Alabaster (Ed.). Habitat modification and freshwater fisheries. pp. 179-185. Butterworths, London.

National Board of Waters, 1986. Integrated water resources development plans for the Oulujoki, Iijoki and Kiiminkijoki river basins and Kuusamo watercourses. Publications of the National Board of Waters. 49: 1-177.

Ollila, A., 1970. Kuusamon vesien kalastus. Helsinki, Kalatalouden Keskusliitto. 46 pp.

Pflieger, W.L., Schene, M.A., Jr. & Haverland, P.L., 1981. Techniques for the classification of stream habitats, with examples of their application in defining the stream habitats of Missouri. In: N.B. Armentrout (Ed.). Acquisition and Utilization of Aquatic Habitat Inventory Information. Proceedings of a Symposium. American Fisheries Society. Bethesda. pp. 362-368.

Rose, D.R. & Echelle, A.A., 1981. Factor analysis of associations of fishes in Little River, central Texas, with an interdrainage comparison. Amer. Mid. Natur. 106: 379-391.

Ruokanen, H., 1979. Kalastuksesta sekä vaellussiian, *Coregonus lavaretus* (L.), ja muikun, *Coregonus albula* (L.), biologiasta eräällä pohjois-suomalaisella järvellä, Iso-Venejärvi (67° N, 26° E). M.Sc. thesis, University of Oulu. 56 pp.

Salmela, R., 1976. Sinetän voimalaitoksen rakentamista ja Sinettäjoen vesistön säännöstelyä koskevaan katselmustoimitukseen liittyvä, vuosia 1974-75 koskeva kalatalousselvitys. Oulu, Pohjois-Suomen vesitutkimustoimisto. 46 pp.

Salojärvi, K., 1983. Siian luonnonravintolammikkoviljely ja kesänvanhojen poikasten istutusten tulokset Pohjois-Suomen sisävesissä. Suomen kalatalous 51: 51-66.

Salojärvi, K., 1986. Review of whitefish (*Coregonus lavaretus* L. s.l.) fingerling rearing and stocking in Finland. Arch. Hydrobiol. Beih. Ergebn. Limnol. 22: 99-114.

Salojärvi, K., 1988. Effect of the stocking density of whitefish (*Coregonus lavaretus* L. s.l.) fingerlings on the fish yield in Lake Peranka, Northern Finland. Finnish Fish. Res. 9: 407-416.

Salojärvi, K., Auvinen, H. & Ikonen, E., 1981. Oulujoen vesistön kalatalouden hoitosuunnitelma. Riista-ja kalatalouden tutkimuslaitos, kalantutkimusosasto. Monistettuja julkaisuja 1: 1-227.

Salojärvi, K. *et al.*, 1985. Oulujrven kalatalouden kehittmissuunnitelma. Riista-ja kalatalouden tutkimuslaitos, kalantutkimusosasto. Monistettuja julkaisuja 40: 1-278.

Sarjamo, H., 1987. Jerisjärven kalastus ja siikakannat vuosina 1978-82. Riista-ja kalatalouden tutkimuslaitos, kalantutkimusosasto. Monistettuja julkaisuja 70: 75-104.

SAS Institute, 1985. SAS User's Guide: Statistics. SAS Inst. Inc. North Carolina.

Smith, G.R. & Fisher, D.R., 1970. Factor analysis of distribution patterns of Kansas fishes. In: Dort, W., Jr. & Jones, J.K., Jr. (Eds). Pleistocene and Recent Environments of the Central Great Plains. University of Kansas, Department of Geology. Special Publication 3, University of Kansas Press, Lawrence. pp. 259-277.

Sormunen, T., 1964. Kemijärven säännöstelyn kalataloudellinen ja limnologinen tutkimus. I Luonnontila ja ehdotukset. Kalataloussäätiön monistettuja julkaisuja 8: 1-91.

Stevenson, M.M., Schnell, G.D. & Black, R., 1974. Factor analysis of fish distribution patterns in western and central Oklahoma. Systematic Zoology. 23: 202-218.

Tonn, W.M. & Magnuson, J.J., 1982. Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. Ecology. 63: 1149-1166.

Tonn, W.M., Magnuson, J.J. & Forbes, A.M., 1983. Community analysis in fishery management: an application with northern Wisconsin lakes. Trans. Am. Fish. Soc. 112: 368-377.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc, Wageningen. pp. 127-136.

Re-introduction of salmon, *Salmo salar* (L.), and sea trout, *Salmo trutta* m. *trutta* (L.), to the Vantaanjoki River, Finland

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Abstract

The Vantaanjoki River flowing into the Gulf of Finland supported a sea trout run until 1872, when the mouth of the river was dammed. In the 1940s the river became heavily loaded with municipal and industrial waste waters. The Vantaanjoki was also used as a source of raw water for the city of Helsinki and, during dry summers, the water intake from the river was so large that the flow to the sea was almost negligible. Since then the effectiveness of the waste water treatment has been increased and the water intake for Helsinki has been changed to another watercourse. Because of the improvement in the river, attempts were made to re-introduce sea trout in 1980. Releases of sea trout, and salmon fry and fingerlings, were successful. Stocking at the rate of 300-700 sea trout alevins per 100 m^2 yielded about 30 1 year old parr per 100 m^2. The optimal stocking density for salmon fry is 600-800 individuals per 100 m^2. Being strong competitors, salmon and trout may replace other species in the nursery areas. The size of the nursery areas for sea trout and salmon in the River Vantaanjoki is about 14 hectares. The growth rate is fast and the smolt stage is reached in two years. This area could produce about 45 000 sea trout or salmon smolts per year. For this number, releases of 0.5-1.1 million alevins would be needed. Numerous brooks flowing to this river might also be suitable nursery grounds for sea trout and salmon, and smolt production could thus be increased. This scale of smolt production does not support a sufficiently large spawning run to the river to allow natural reproduction and fishing in the river. Fishing of these two species is so intense in the Baltic, that about 90% of the catch is taken in the sea. The target is to make a sport fishery possible in the Vantaanjoki. As the potential smolt production is too small for this purpose, releases of hatchery-reared sea trout and salmon smolts are also needed in the river. If the target spawning run is 1000-1500 sea trout and salmon, 1.5 million fingerlings must be released yearly in the nursery areas, and 60 000 sea trout smolts and 150 000 salmon smolts. However, regulation of the fishing effort in the sea would reduce the need for releases.

1. The management area

1.1 Geopolitical situation

The Vantaanjoki River flows through Helsinki, the capital of Finland, and about one million people live in the vicinity of the Vantaanjoki watercourse. The demand for recreational fishing in inland waters is growing with the increase in leisure time which people have, especially in southern Finland, where the area of inland waters is smaller than elsewhere in the country. Fishing has always been one of the most popular pastimes in Finland. Although the Vantaanjoki is small compared with other river systems in Finland, it has an important recreational potential for the people living in the area.

1.2 The Vantaanjoki watershed

The total area of Vantaanjoki watershed is 168-500 ha. The length of the river is about 100 km and the uppermost part lies 111 m above sea level *(Figure 1)*. Lakes occupy 2.3% of the catchment area. Many fields and bogs in the drainage basin have been ditched, because of which the discharge at the mouth varies from 3-4 m^3/sec. in summer to over 200 m^3/sec in spring. Damming of the river was begun in the 16th century and almost all the suitable rapids were harnessed for mills or saw mills. At the end of the 19th century the mouth of the river was dammed to provide the raw water supply for the city of Helsinki.

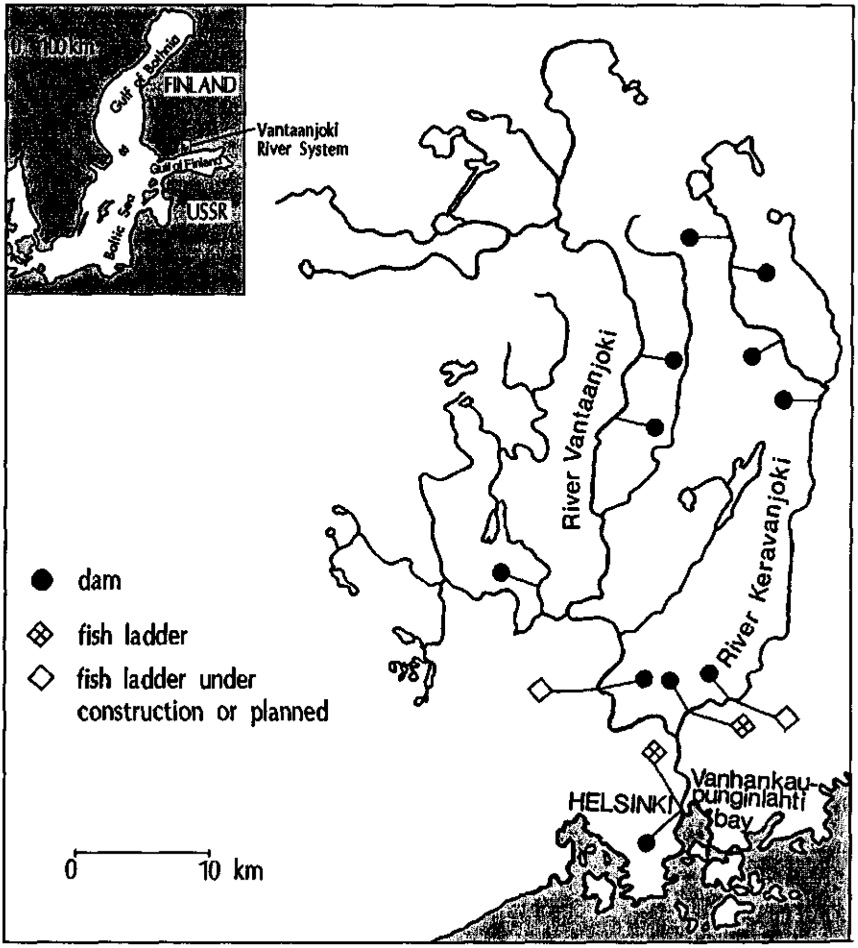

Figure 1. The Vantaanjoki River system.

Rapid pollution of the river began in the late 1940s, mainly by municipal and industrial wastes and by farms in the rural area. During the most disastrous period, in the 1960s, oxygen depletion was common and several parts of the river were completely dead (Jokinen 1983). The need for water in Helsinki was so large that in dry summers almost all the riverine flow was used for drinking water. In the 1970s effective waste water treatment began to improve the water quality. Construction of the 130 km pipeline from Lake Päijänne, to satisfy the demand for raw water in Helsinki, increased the amount of water in the river and thus also its quality.

The water of the Vantaanjoki is clouded by clay particles. The colour of water varies with the volume of the flow; during dry periods in summer and winter it is brownish due to humic substances originating from forests and bogs. The quality of water in the Vantaanjoki and its tributaries has improved markedly since the 1960s, when the situation was worst. As the phosphorus content has decreased, blooms of blue-green algae have become rare. The water quality is however, still poorer than it would be if the river were in a natural state. The nutrient content is still high and there is still an oxygen deficiency in some lakes when they are covered by ice in winter, and also in the head waters where pollution is worst. In other areas the oxygen content is adequate for fish life, especially in the rapids. Because of the clay soil in the catchment and intensive agriculture, the water is well buffered. The pH varies from 6.5-8.0. The growth period in the Vantaanjoki is long compared with that in other areas of Finland. The water temperature is above 10°C for 4.5 months. The total length of rapids suitable as nursery areas for salmonids is about 8 km and their total area 14 ha. The river banks by the rapids are covered with dense vegetation. The number of species of aquatic plants is rather small. In the slow-flowing areas *Nuphar luteum* and *Sparganium* sp. occur with *Fontinalis* sp. abundant in shallow rapids. There are few gravel bottoms in the rapids. In the steepest rapids the bottom is rocky or formed by boulders; in the low rapids it comprises sand and stones.

1.3 History of the fisheries

In the 14th century the Vantaanjoki was known as a good 'salmon' river, yielding an annual catch of 4-6 tonnes of sea trout. Fish were taken in weirs and nets in the lower reaches of the river and the lower courses of the tributaries.

The spawning run of the sea trout into the river was disturbed by the increasing number of mill and saw mill dams and the river was completely closed in 1872, when the city of Helsinki constructed a dam across the river mouth, at the Vanhankaupunginkoski rapids. The sea trout run continued for some years and the catches were about the same as before, but gradually they decreased to some tens of fish per year (Segerstråle 1937). Although small, the sea trout catch was quite valuable. These few fish originated from spawning in the river mouth or from brown trout *(Salmo trutta fario)* stocks in the upper reaches of the tributaries (Levander 1927, Hurme 1952).

After the enclosure of the river, spring-spawning species such as perch *(Perca fluviatilis)*, pike *(Esox lucius)*, bream *(Abramis brama)* and roach *(Rutilus rutilus)* were taken mainly during spawning migration in the recreational and subsistence fishery in the lakes. In the river mouth, in Vanhankaupunginlahti, fishery continued on a larger scale. The gears most commonly used were gill-nets, trap nets, wire nets, lures and rods. Vimba *(Vimba vimba)* and European river lamprey *(Lampetra fluviatilis)* were also caught in the mouth. Other species taken were pikeperch *(Stizostedion lucioperca)*, eel *(Anguilla anguilla)*, burbot *(Lota lota)* and sea trout. A few professional fisherman used trap nets in this area.

In recent years, before the re-introduction of salmonids to the river, the only gear used in the river was the rod and line. In the Vanhankaupunginlahti area the professional fishery was dying out. Subsistence and recreational fishery with gill-nets and lures predominated.

1.4 Research on re-introduction

In the early 1980s, when the water quality had improved, it was decided to see if salmonids could survive in the river. Doubt was expressed about this plan, because salmonids were thought to belong to bright, crystal-clear brooks and rivers, rather than to the turbid clayey Vantaanjoki. One-summer old sea trout fingerlings were released in autumn, in the lowest rapids in the river. In the following summer the fish were recognised in these rapids. The stocking program was continued by releasing alevins in spring, which gave good results. The releases of sea trout smolts which had previously been made in the sea area off Helsinki were then concentrated in the mouth of the Vantaanjoki. Some years later salmon alevins were also released in the rapids. These measures also gave good results. Salmon smolts were at first released in the river mouth, but later more and more smolt releases were made in the upper part of the river, in order to induce spawners to home into the river as well. Homing was studied by releasing tagged salmon smolts.

Nowadays the number of salmon and sea trout smolts released annually is about 160 000 and the number of alevins about 100 000. About 100 000 whitefish *(Coregonus lavaretus)* fingerlings will also be released annually. The results of these studies have been presented by Ikonen, Ahlfors, Mikkola & Saura (1987).

A fish ladder has been constructed in the lowest dam for the scores of homing spawners, and there will be three more ladders which will allow fish to migrate about 40 km up the river. In 1986 a fishery management area was established comprising the Vantaanjoki watercourse and river mouth.

2. Results of research on re-introduction

2.1 Parr densities resulting from stockings

The parr densities in the stocking areas were studied by electrofishing and the successive removal method (Junge & Libosvarsky 1965). The stocking densities for sea trout alevins varied between 100 and 1500 individuals per 100 m^2. These densities created a parr population in which the proportion of the 0+ age group was 75-85% and that of the 1+ age group 15-25%. Older parr made up 0-2%. The densities in these parr populations was 10-150 individuals/100 m^2. The best stocking density for sea trout alevins was found to be 300-700 individuals/100 m^2, which in good conditions can produce about 30 1+ parr/100 m^2. At greater stocking densities, density dependent mortality begins to take effect.

The stocking densities for salmon fry varied from 100-200 individuals/100 m^2 and resulted in 20-40 parr/100 m^2. The best stocking density for salmon fry is perhaps greater, say 600-800 individuals/100 m^2.

2.2 Effects of stocking on the fish community

Before the test releases of sea trout alevins in the rapids the dominant species were bullhead *(Cottus gobio)* and gudgeon *(Gobio gobio)*. Cyprinids, such as roach, bleak *(Alburnus alburnus)* and chub *(Leuciscus cephalus)* were also numerous. Other species in the rapids were perch, pike, ruffe *(Gymnocephalus cernua)*, burbot, the European brook lamprey *(Lampetra planeri)* and crayfish *(Astacus astacus)*.

After the release of sea trout alevins and salmon fry in the small and medium-sized rapids in the upper reaches and tributaries of the river, sea trout and salmon became dominant, replacing other species *(Figure 2)*. In the larger rapids, in the lower part of the river, the change in the fish community was less marked when fry or alevins were used, but when 1 summer old fingerlings were released salmon became dominant in these areas as well.

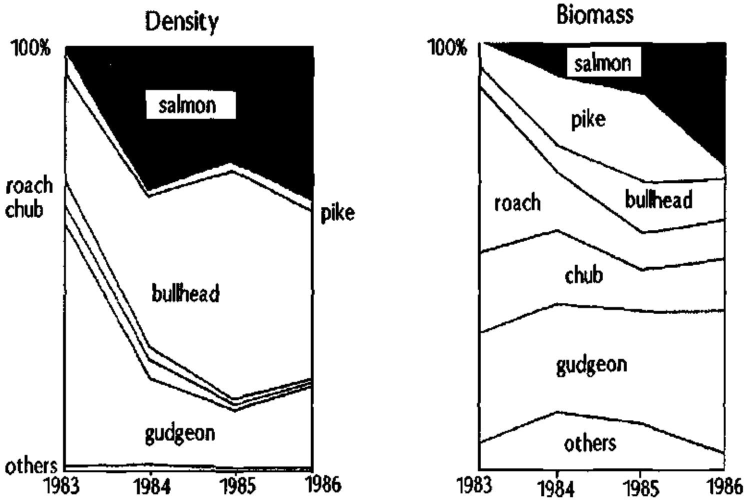

Figure 2. Change in the densities and biomass of the fish populations in the middle part of the Vantaanjoki River. Salmon became one of the most important fish species here after three years of stocking at densities of 11 000 individuals/ha in 1984, 10 400 ind./ha in 1985 and 20 900 ind./ha in 1986.

2.3 Growth, mortality and smolt production of sea trout and salmon

In Finnish rivers sea trout and salmon normally need 3-5 years to smoltify. Because of the southern situation of the Vantaanjoki, the growth rate of salmonids is faster than elsewhere in Finland and salmonids usually smoltify at two years *(Figure 3)*.

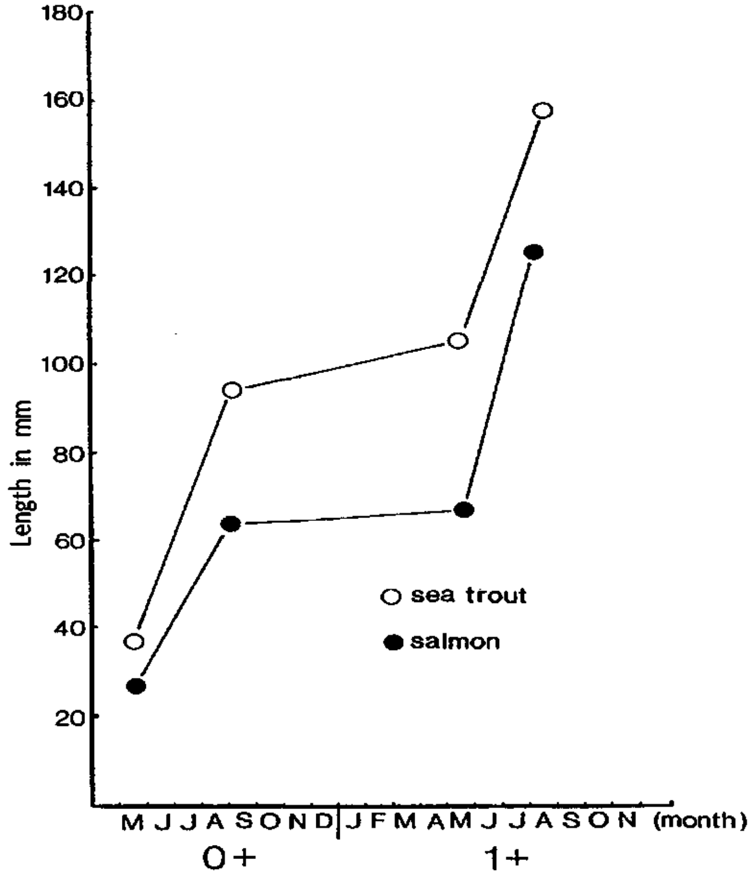

Figure 3. The growth of salmon and sea trout parr originating from the releases of alevins in the Vantaanjoki River.

When fry or alevins are used, losses are greatest during the first two months after stocking and survival varies from 7-26%. Initial mortality is greatest in the large rapids and at high stocking densities *(Table 1)*. Losses include migration from the stocking area.

The river contains 14 hectares of rapids suitable for nursery areas for a total production of about 45 000 sea trout smolts. To achieve this number, 0.5-1.1 million alevins will be needed. If the brooks and ditches were also to be used, production could be greater. The combined production of salmon and sea trout parr could also be greater than the production of either of the two species used separately (Kennedy & Strange 1980).

Table 1. Stationarity of sea trout parr originating from releases of alevins in the Vantaanjoki River.

Part of river	Stocking density (individuals/100 m^2)	Stationarity	
		2 months after stocking	14 months after stocking
Top brook	550	76	20
Middle reach rapid	650	25	6
Large rapid	1500	7	1

2.4 The spawning runs of sea trout and salmon

In 1982-1986, 3300 tagged sea trout and 4500 tagged salmon smolts were released in the Vantaanjoki or its mouth. The sea trout stock originated from the River Isojoki, flowing into the southern part of the Gulf of Bothnia. The salmon stock orginated from the River Neva flowing, into the head of the Gulf of Finland. These stocks feed mainly in the Gulf of Finland *(Figures 4* and *5)*.

The tagging experiments indicated that the sea trout prefer to remain in the archipelago zone (Toivonen & Ikonen 1978). The proportion of tags recovered outside the Gulf of Finland has not normally exceeded 20%. Of the tags recovered from salmon released in the Vantaanjoki in 1983, 66% came from the Gulf of Finland and 34% from the Baltic Main Basin. During their feeding migrations, salmon move farther seaward than sea trout. During their spawning migrations, salmon seem to follow the outer edge of the archipelago while homing to the river.

The profitability of salmon and sea trout smolt stocking was studied on the basis of tag recoveries, stocking figures and catch data. The catches from the releases of salmon and sea trout were comparable with those from releases in the other areas of the Gulf of Finland.

The total annual catch from sea trout releases in the Vantaanjoki in 1982-1986 was estimated at about 29 tonnes. The proportion of the catch in the river mouth was estimated at about 1 tonne on the basis of the tag recoveries. If the mean weight of the sea trout is about 4 kg, the release of 60 000 sea trout smolts could produce 250 sea trout homing to the river mouth.

The total annual catch from salmon releases in 1985-1986 was estimated at about 82 tonnes. The catch of salmon in the river mouth was estimated at 1.4 tonnes on the basis of the tag recoveries. If the mean weight of these homing salmon is taken as 6 kg, it can be deduced that there were 233 of them.

In the 19th century, when the river was still almost undisturbed, all the sea trout were caught in the river or its mouth, during their spawning run. Nowadays more than 90% of the total catch is taken in the sea during feeding or spawning migration. Most of the catch

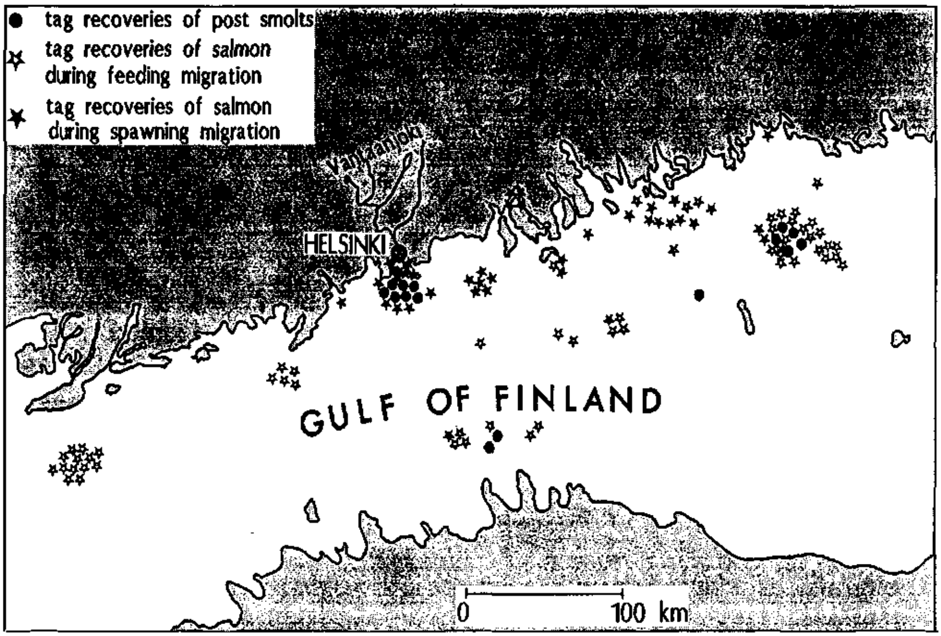

Figure 4. Tag recoveries in the Gulf of Finland from releases of 2000 salmon smolts in the Vantaanjoki River during 1983.

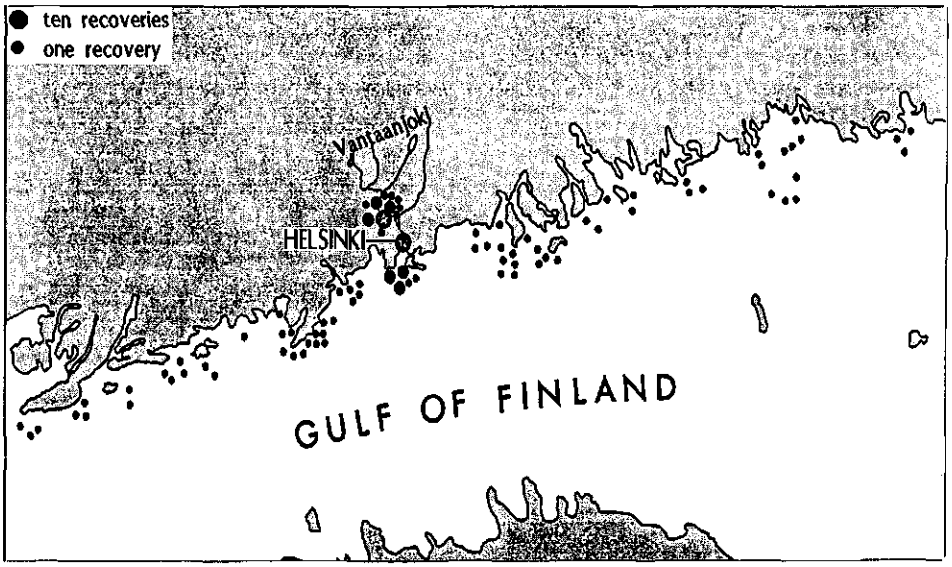

Figure 5. Tag recoveries in the Gulf of Finland from releases of sea trout smolts in theVantaanjoki River in1982 and 1983.

(70%) is taken in the subsistence and recreational fisheries with gill-nets. The rest of the catch is taken with long lines and trap nets as a by-catch of the salmon fishery.

Professional fishermen take about 80% of the total salmon catch with long lines and trap nets. The trap net fishery in the Gulf of Finland has increased remarkably in the 1980s, since Finland began to release salmon smolts in this area. Previously, almost all the salmon catch was taken with long lines, but by 1985 over 50% of the catch was taken in trap nets. Because of the intensive fishery in the sea and coastal waters, the numbers of homing salmon and sea trout are very small despite the large number of smolts released.

The numbers of homing salmon and sea trout were estimated on the basis of tag recoveries and catch samples in the river mouth. Test fishing in the mouth was difficult because of the water quality. Gill-nets became dirty and for that reason this method can lead to underestimates of the numbers of homing salmon and sea trout. Tag recovery data also lead to underestimates because of the declining activity of the fishermen.

3. Plan for fishery management

3.1 The role of the fishery management area

According to the new fishing law of 1983, Finnish water areas are divided on the basis of the fisheries they support, regardless of their ownership. The aim of this law is to achieve maximum sustainable fishing yields. To reach this target, a fishery management plan will be made for each area, which will comprise separate plans for different parts of the area, taking account of local differences. In 1986 the Vantaanjoki watercourse with the Vanhankaupunginlahti bay should form one such fishery management area. The plans for this area should provide for sport and recreational fishery.

3.2 How to obtain 1500 salmon for anglers

If the target is 1500 homing salmon and sea trout, at least one million salmon and sea trout fry or alevins should be released. However the fishing pressure off the city of Helsinki is so strong that releases of alevins are not enough to ensure that sufficient salmon and sea trout home to the river. About 100 000 1-summer old to 1-year old salmon and sea trout fingerlings are also needed, and about 60 000 sea trout and 150 000 salmon smolts should be released in the river. The salmon and sea trout alevins should be released in the nursery areas situated above the lowest dams. If sea trout and salmon parr do well in the same areas, the two species could be released in the same waters. Small brooks or ditches are very suitable for fry, especially when they flow to rapids in the river. Parr releases should be made in the largest rapids. Smolt releases should be divided, one half being made in the river, to ensure that the fish really enter the Vantaanjoki; the other half should be made in the river mouth.

To improve conditions in the river, water should be added from the Päijänne tunnel during dry seasons. This would improve the quantity and quality of the water.

Smolts obtained by releasing alevins would be as expensive, or perhaps twice as expensive, as hatchery-reared smolts, but would be more 'natural' than hatchery fish, having been exposed for longer to natural selection and being better adapted to the river.

Stocking material should be obtained from the eggs and milt of spawners caught in the river mouth.

To bring the river catches up to the level before impoundment, smolt production should be about 20 times as high as it has previously been. The greater smolt production needed to produce the same amount of homing fish as previously is due to the very intensive fishery in the sea whereby only a small proportion of the spawners reach the river mouth. There is a difference in this respect between salmon and sea trout; about twice as many salmon smolts as sea trout smolts are needed to produce the same number of spawners. The numbers of spawners could be increased by regulating the fishery in the sea. The migration route in the river could be lengthened to 40 km by building the 3 fish ladders already designed.

Development of the Vantaanjoki watercourse as a sport fishery area will need to be regulated legally. In the rapids and fast-flowing areas, angling can be allowed, but live bait and rod and line fishing should be forbidden in waters suitable for salmon and sea trout nurseries. Because of the strong local demand for fishing, angling cannot be prohibited in all rapids, but some should be closed to permit the monitoring of natural reproduction and experimental releases.

The effect of fry releases and possible natural reproduction should be monitored by electro-fishing. Smolt releases should be followed up by the regular tagging of a proportion of the fish. All the fish ascending the river should be tagged to follow their migration in the watercourse.

4. References

Hurme, S., 1952. Vantaanjoki taimenvetenä. Metsästys ja Kalastus. 41: 1-3.

Ikonen, E., Ahlfors, P., Mikkola, J. & Saura, A., 1987. Meritaimenen ja lohen elvyttäminen Vantaanjoen vesistössä. Riista- ja kalatalouden tutkimuslaitoksen kalantutkimusosaston julkaisu. Helsinki. 62: 102 pp.

Jokinen, O., 1983. Vesistön esittely. Kirjassa: Vantaanjoki. Vantaanjoen ja Helsingin seudun vesiensuojeluyhdistyksen vuotisjuhlajulkaisu. 20: 35-47.

Junge, C.O. & Libosvarsky, J., 1965. Effects of size selectivity on population estimates based on successive removal with electrical fishing gear. Zool. listy. 14: 171-178.

Kennedy, G.J.A. & Strange, C.D., 1980. Population changes after two years of salmon *(Salmo salar)* stocking in upland trout *(S. trutta)* streams. J. Fish. Biol. 17: 577-586.

Levander, K.M., 1927. Purolohia Vantaanjoessa. Suomen Kalastuslehti. 34: 197.

Segerstråle, C., 1937. Studier rörande havsforellen *(Salmo trutta* L.*)* in Södra Finland, speciellt på karelska näset och i Nyland. Acta Soc. pro Fauna et Flora Fenn. 60: 696-741 (in Swedish).

Toivonen, J. & Ikonen, E., 1978. Meritaimen Suomessa. Suomen Kalastuslehti. 87: 4-10.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 137-144.

The value of recreational fishing in the Province of Central Finland

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Abstract

According to Finnish water rights legislation, the water rights court defines terms for permission to change natural conditions. In this context the value of fisheries resources should always be evaluated to ensure that fisheries interests can be considered. Evaluation of these resources is also prerequisite for appropriate fisheries management in altered situations. The system for managing fisheries on Finnish lakes has some features peculiar to Finnish administrative organisations and institutions. These features influence the outputs of the systems.

An empirical study of the value of recreational fishing to the inhabitants of the Province of Central Finland was carried out by questionnaires mailed to a sample of heads of households which had paid the obligatory statutory fishery fee in 1981. Consumers' surpluses for individual households were assessed by direct questioning and were found to average 1000 Fmk per household, while the aggregate consumers surplus was 5.2 million Fmk. Forty percent of the households questioned were not willing to pay more for their fishing than they already did.

The total benefit received from recreational fishing was calculated as the sum of a household's surplus and its fishing costs. It is suggested that during damage evaluation fishing costs should be interpreted as benefits rather than losses. Total benefit of the population was calculated as 28 million Fmk. On average it was 1000 Fmk per household. The functioning of the fishing market seems unsatisfactory because demand for and supply of fishing opportunities are not equal. Obviously water owners do not have enough information about fishermen's willingness to pay for fishing, in order to develop fishing opportunities and price fishing permits appropriately.

1. Introduction

1.1 Fisheries law and water rights legislation

The existing fisheries law came into force at the beginning of 1983. The aim of the law was thoroughly changed at this time. The previous law was based on conservation, and the new law on the utilization of fish and crayfish stocks. As a result of past long-term emphasis of conservational aspects in the decision making process of the fisheries system, the value of fisheries resources, and the different options for their future use, was considered only partially. Thus many economic and social aspects of fisheries management received scant attention from both the authorities and the owners of the fishing rights.

According to Finnish water rights legislation, the water rights court defines terms for permission to change or affect natural conditions pertaining to waterbodies. In this context the value of any fisheries resources should be evaluated to ensure that fisheries interests are also considered.

The relative importance of fishing as a source of livelihood has decreased in Finland since the 1950s, while its significance as a leisure activity has increased. However, fishery interests are governed by laws relating to the use of water whose targets and values date from the 1950s. When water rights legislation was partly renewed last year, the recreational use of water resources became a protected advantage. Now water rights legislation provides a much stronger tool than fisheries law for maintaining and defending the biological resources of a fisheries system.

The new fisheries law created a new management unit, besides fishing co-operatives, namely the fisheries area. The whole country was divided into 200 fisheries areas, each with its own council. The areas have been delineated according to watercourses and fishing pressures. Every fishing co-operative and organisation of commercial or recreational fishermen in a fishery area has representatives on the area council. This body determines management objectives for its own fishery area. The actions of fisheries areas councils are directed from fisheries district level *(Figure 1)*. There are 11 fisheries districts, each covering a single province, except in northern Finland.

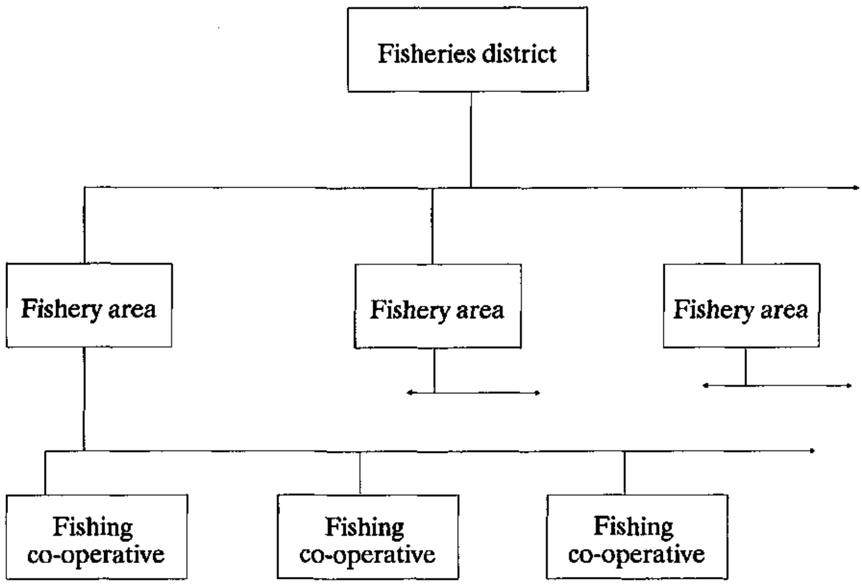

Figure 1. Part of the structure of the Finnish fisheries organisation.

1.2 The fisheries system

The need for a systems approach arises from the fact that the fishery system is not a closed system (Gulland 1978, Harville 1985), but a part of society. Clearly a systems approach can be applied to strengthen the ability of fishery authorities to look after fisheries interests.

Finnish lake fishery systems are open systems, which interact with their environments. They can be divided into three subsystems; biological, socio-economical and politico-administrative *(Figure 2)*. Components of the subsystems can be natural conditions, functional units, action or normative rules. The most important interactions occur between subsystems (Sipponen 1987).

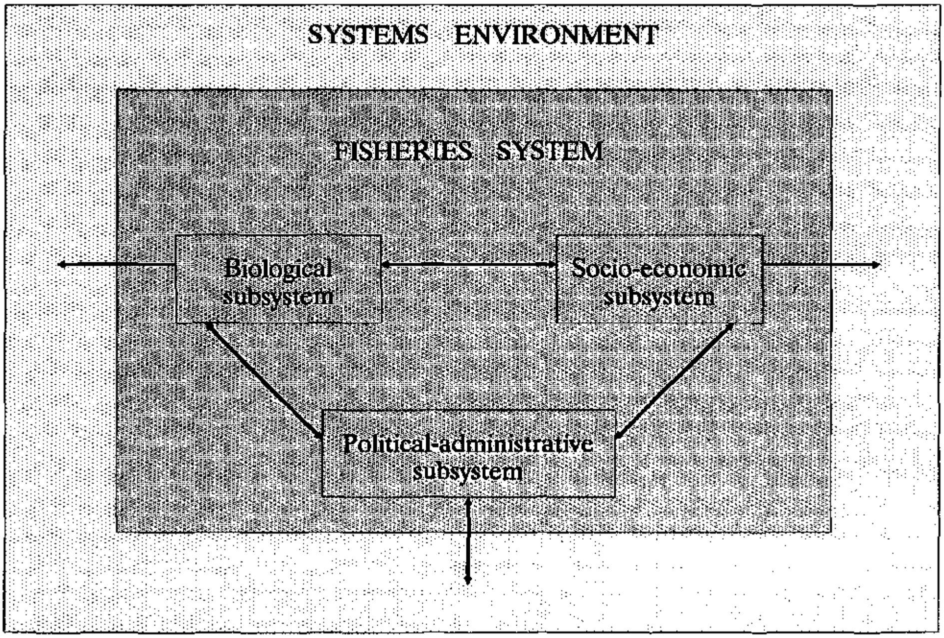

Figure 2. Structure of the fisheries system.

In Finland, the right to fish is connected with land ownership. About 90% of inland waters are owned by fishing co-operatives, which are also the most common management units. In practice, waters owned by fishing co-operatives are in common use for the shareholders.

Social institutions have a profound influence on the Finnish fisheries system. Manners and habits concerning the utilization of fisheries resources have brought a certain rigidity into the fisheries system (Kovanen, Sipponen & Laukkanen 1984). Public rights of access in Finland are similar to those of other Nordic countries (Vilkuna 1981). In Finland these rights include the right to walk in forests, to pick berries and mushrooms and to fish with a hook and line in one's place of residence.

2. Evaluation of the value of recreational fishing

2.1 An empirical study

Research dealing with recreational fishing is relatively uncommon, considering its popularity in Finland, where every fourth citizen is interested in fishing. Although this type of research has become more common in recent years (Lehtonen & Salojärvi 1983, Lehtonen 1983), only a few studies concern the utilities derived from recreational fishing and their usability in decision making. One of the aims of this study was to provide this kind of knowledge.

In the Province of Central Finland there are 250 000 inhabitants, comprising some 100 000 households. The study was carried out by questionnaires mailed to the heads of 2242 households chosen from among those households which had purchased fishing permits in 1981. The sample was taken by stratified sampling from this group of householders. Special consideration was given to the geographic distribution of the households sampled. The usable response was 69.4%. Two different aspects of the value of recreational fishing to inhabitants of the Province were considered, namely consumers' surpluses and total benefit.

2.2 The consumer's surplus

The consumer's surplus per household was assessed by direct questioning. The household was asked whether the value derived from its fishing effort was greater than its fishing costs in 1981. The amount of money exceeding fishing costs was interpreted as a consumer's surplus, *i.e.* the net value of its fishing effort. The evaluation was restricted to fishing that had really occurred. Fishing included all fishing efforts by all members of the household, regardless of their duration. Fishing costs included all costs; capital as well as variable costs. A consumer's surplus greater than 10 000 Fmk was considered unrealistic and was excluded from data.

The mean surplus, of those declared, was 1000 Fmk per household. However, only 16% of the households studied declared and quantified a surplus, although a further 18% said that they made a surplus but were unable to quantify it. The aggregate of consumers surpluses for the provincial population amounted to 5.2 million Fmk.

Forty percent of households questioned were not willing to pay more for their fishing than they already did. Thus the fishing costs of these households are situated on their demand curve for fishing effort, at the point where marginal utility equals the price of fishing. There is therefore no reason for them to increase fishing effort above the prevailing level.

Daily fishing costs have been calculated as a function of annual fishing days. Curve 1 in *Figure 3* is based on actual costs paid, or unit costs.

If the consumers' surpluses were to be included in (added to) the current price of fishing permits, it would mean an increase of 5-8 Fmk/day/household, promoting a new curve (curve 2 in *Figure 3*). This means that the annual increase of fishing costs would be 170 Fmk per household.

If the rise of the cost of the fishing permit concerned only households which made a surplus, the new curve of daily fishing costs would be situated on a much higher level, curve 3 in *Figure 3*. However, in this case these households would have to pay according to their willingness to pay. It would be justifiable to price some fishing permits this way, although some fishermen might switch to other activities.

The maximum net value of recreational fishing by the inhabitants of the Province of Central Finland can be assessed if it is assumed that the surpluses of those households which made surpluses but could not quantify them (18% of the sample), were the same as those of the households which could quantify them (16% of the sample). In this case the total net value would rise to 11.2 million Fmk. However, it is better to use the lower aggregated value of 5.2 million Fmk from the quantified surpluses.

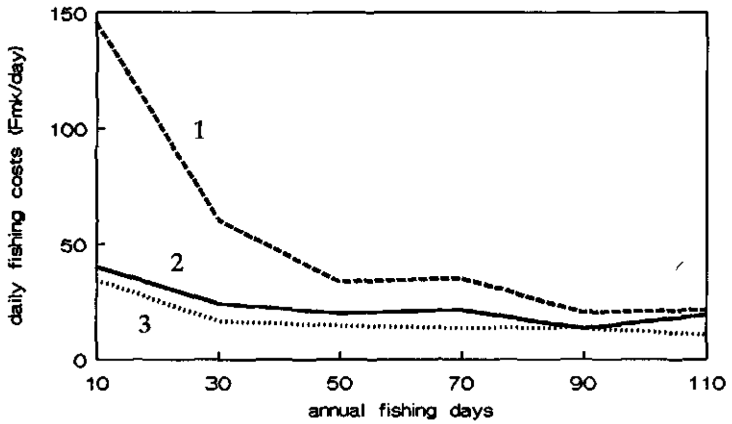

Figure 3. Daily cost of recreational fishing of households in the Province of Central Finland in 1981. 1. realised fishing costs, 2. average consumer's surplus added to the realised costs, 3. consumer's surplus added to realised costs of those households which received net value.

2.3 The total benefit of recreational fishing

The total benefit of recreational fishing to a household has been calculated as the sum of a consumer's surplus and his fishing costs. Where households did not achieve a surplus, their fishing costs alone indicate their total benefit. This is based on the following reasoning: fishing costs can be regarded as beneficial even when they do not lead to any value gained in fishing, because they provide goods (*e.g.* gear) and services (*e.g.* fishing permits).

According to consumer theory, recreational fishermen would not invest in fishing unless the utility they receive from it exceeds that available from other activities. Thus fishing costs include some features of 'opportunity costs' and can thus be regarded as indicators of utility, an interpretation defended by Stabler (1982). Further, Sinden & Worrell (1979) present a wide interpretation of the concept of 'opportunity cost'.

The total benefit derived by the (provincial) population was 28 million Fmk. On average it was 700 Fmk per household not achieving, and 2000 Fmk per household achieving, a consumer's surplus. When divided among all households interested in fishing, total benefit amounted to 1000 Fmk per household.

As far as I can see the treatment of permission applications in the water rights court is strongly supported by this kind of interpretation of utility in spite of the inaccuracy of the utility concept. Treatment is diverse compared with the situation where fishing costs are regarded only as a disutility. As a consequence a much broader variety of management objectives may come into consideration in the fisheries system.

3. Towards a more balanced approach

3.1 Fishing market

The functioning of the fishing market seems to be unsatisfactory, because the supply of fishing opportunities and the demand for them are not always equivalent. Clearly water owners have not had sufficient information about fishermen's willingness to pay for fishing, to allow them to price fishing permits appropriately. Because they lack this information water owners do not have any special incentive to improve the quality of their fishing grounds or strengthen their fish stocks. In addition, the fact that the unit of property ownership is the fishing co-operative influences the pricing of fishing permits. Within a co-operative the influence of a shareholder depends on the area of land he/she owns. In many cases the number of shareholders is so large that individuals have very little opportunity to influence the decision making process. Many shareholders have no interest in improving the economic use of their fisheries resources and the full rent potential may not be realised because of this.

Fishing co-operatives are social institutions in Finland. The confidential posts offered by them are highly appreciated, and the functions of fishing co-operatives regulated by fishing law are only a part of all those they really have in the Finnish fishery system.

The low price of fishing permits is a consequence of the desire to price permits in a socially acceptable way, but also, in part, from an inability to recognize the development potentials of fishery resources. Further, underpricing also owes something to welfare considerations and the wish to provide fishing opportunities for everybody. Pricing should be based on a conscious choice between nominally and properly priced fishing.

If fishery resources are deemed to be underpriced the implication is that demand for fishing opportunities is higher than it would be if fishing permits were more expensive. However, rises in the price of fishing permits may cause the least interested fishermen to turn away from fishing and the recruitment threshold may rise too high for the health of recreational fisheries. On the other hand, nominal prices do not support the preservation of options for diverse future uses. As decision makers at fishery area level are less connected with proprietorial rights than the fishing co-operatives are, and because fisheries areas councils control larger areas, they see the importance of relevant price information more clearly. Fishing area councils offer excellent opportunities for the discussion of management objectives.

3.2 The value of recreational fishing and the water rights court

During the evaluation process in the water rights court the pecuniary amount of compensation is counted as the difference between the value of the catch and the fishing costs. In this connection fishing costs are regarded as a disutility. If this principle had been applied to recreational fishing in the Province of Central Finland it would have meant that all fishermen accrued disutility from their fishing. If this really were the case rational fishermen would have given up fishing for other activities. As this has not happened it can be concluded that recreational fishing yields utility which the methods of the water rights court do not reveal.

As negative utilities are senseless in assessing values in connection with laws regarding the use of waters, the water rights court assumes that fishing costs are 40% of the gross value of a catch. Thus good reasons can be found for interpreting fishing costs as benefits rather than disutilities during damage evaluation.

One can agree with Hollo (1976) about the ideal objectives of fishery policy in value assessment procedure: that the water rights court should use its discretion so that greater damage is prevented. In Finland the level of compensation depends on the annual catch, whereas for agriculture and forestry compensation levels are based on productivity. An essential goal for fishery administration should be to change water rights legislation in this respect so that pecuniary fishery damage can also be compensated according to biological productivity, *viz.* MSY, not only catch. There is some resistance to this change, because MSY has been said to be a too obscure concept for value assessment.

However, the existence of net utility means that attempts to evaluate recreational fishing according to fishing costs and the value of a catch are bound to fail. According to the present study one possibility to evaluate non-market utilities is to multiply the dock price of the catch of recreational fishermen by a factor of 1.6-4.7 or the retail price of the catch by a factor of 1.0-2.5, depending on the fishing group concerned. The broader use of the utility concept is justified, particularly in situations where market information is inadequate.

In future more information concerning the value of recreational fishing will be available to the water rights court. It is desirable that this information has normative effects on authorities. New members of the water rights court, educated in natural sciences, and appointed at the beginning of 1988, bear great responsibilities.

References

Gulland, J.A., 1978. Fishing, fish and food production. In: Gerking, S.D., (Ed.). Ecology of freshwater fish production. pp 378-402. Blackwell, Oxford.

Harville, J.P., 1985. Expanding horizons for fishery management. Fisheries. 10: 14-20.

Hollo, E., 1976. Pilaamiskiellon sisältä vesilain mukaan. Suomalaisen lakimiesyhdistyksen julkaisuja. A-Sarja nro 113. Vammala. 561. (In Finnish with a German summary).

Kovanen, J., Sipponen M. & Laukkanen, T., 1984. The Fishery Management Plan for the Province of Central Finland. Reports of the Hydrobiological Research Centre. 124: 1-253.

Lehtonen, H., 1983. Recreational and subsistence fishery and its importance in Finland. Suomen Kalatalous 51: 67-74.

Lehtonen, H. & Salojärvi, K., 1983. Subsistence and recreational fisheries in Finland in 1978. Suomen Kalatalous. 50: 30-72.

Sinden, J.A. & Worrell, A.C., 1979. Unpriced values. Decisions Without Market Prices. John Wiley & Sons. New York. 511 pp.

Sipponen, M., 1987. Keskisuomalaisten kotitarve- ja virkistyska- lastuksesta ja sen arvosta v. 1981 erityisesti vesioikeudelli- sen intressivertailun kannalta. Jyväskylän ylioppiston biologian laitoksen tiedonantoja 48: 1-143.

Stabler, M.J., 1982. Estimation of the benefits of fishing on U.K. canals: some problems of methods. In: Grover, J.H., (Ed.). Allocation of fishery resources. FAO/American Fisheries Society. pp. 346-355.

Vilkuna K., 1981. Jokamiehenoikeudet maan tapana. Suomen Luonto. 40: 354-359.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 145-150.

Vendace fisheries in Finnish lakes

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Abstract

During the 1962-1983 period, total annual catches of vendace (*Coregonus albula* L.), including non-commercial catches from all Finnish inland waters, ranged from 3084 to 7815 tonnes. Commercial catches over this period ranged from 1446 to 6055 tonnes and averaged 3164 tonnes/yr. At the same time marine vendace catches ranged from 109 to 951 tonnes. In 1983 the combined catch of vendace from both inland and coastal waters was 6279 tonnes. The freshwater part of this amounted to 6007 tonnes, representing a catch rate of about 2 kg/ha, and 65% (4081 tonnes) was caught by commercial fishermen. Nearly 70 % of the total commercial catch of all species from inland waters was vendace and this is now the most important commercial species from inland waters.

Seine nets, gill-nets and trawls are most commonly used for vendace. The profitability of the freshwater vendace fishery is marginally lower than that of the Baltic Sea commercial fishery, but it can be improved, for example by selling vendace roe as a delicacy. To date there has been little need to regulate the vendace fishery, because, so far as is known, the current level of exploitation has not harmed the stocks. The future of the vendace fishery in Finland will depend on natural fluctuations in the stocks and on the ability of the fisheries to adapt to them. No dramatic changes are expected in the near future.

1. Introduction

This report deals with the Finnish vendace *(Coregonus albula* L.*)* fisheries from 1962 to 1983, with special reference to commercial fisheries. Some data concerning subsistence and recreational fisheries for vendace are given too. The information concerning commercial vendace fisheries was gathered by sending an inquiry to every commercial fisherman registered with the Finnish Game and Fisheries Research Institute (*cf.* Rantala 1983, Rantala, Parmanne, Lehtonen, Ikonen & Aro 1986).

2. Fishermen and catches

In 1962-1983 annual commercial freshwater vendace catches ranged from 1446 to 6055 tonnes, with an average of 3164 tonnes. These figures suggest large stock fluctuations *(Figure 1.)*, as does the fact that annual catches have usually been above the cited average during the 1970s and 1980s. The total annual catch of this species from inland waters, including non-commercial catches, ranged from 3084 to 7815 tonnes, while during the same period, the annual commercial vendace catch from the sea ranged from 109 to 951 tonnes.

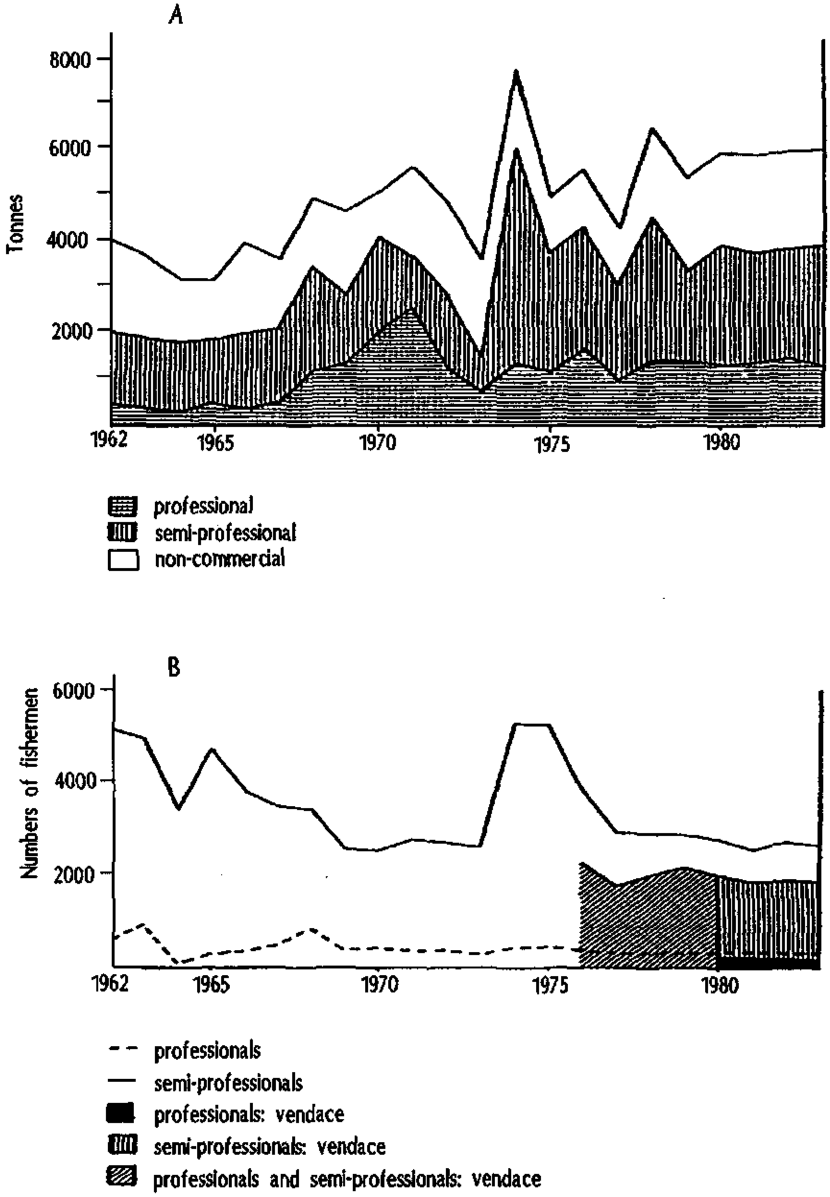


Figure 1. A. The commercial vendace catch from Finnish inland waters from 1962-1983.
B. Numbers of commercial fishermen in the inland area from 1962-1983.

The statistics collected by the Finnish Game and Fisheries Research Institute show that during the past decade about 300 professional and 2500 semi-professional commercial fishermen operated on Finnish inland waters *(Figure 1)* (see also Hintikka 1967). In Finland a fishermen is classed as a professional if he receives at least 50 % of his gross annual income from fishing, and as a semi-professional fishermen if he earns less than 50% from fishing. Over the years professionals have been replacing semi-professionals. In both groups most fishermen catch vendace. In 1983 63 % of professionals and 72 % of semi-professionals, fishing inland waters, caught vendace.

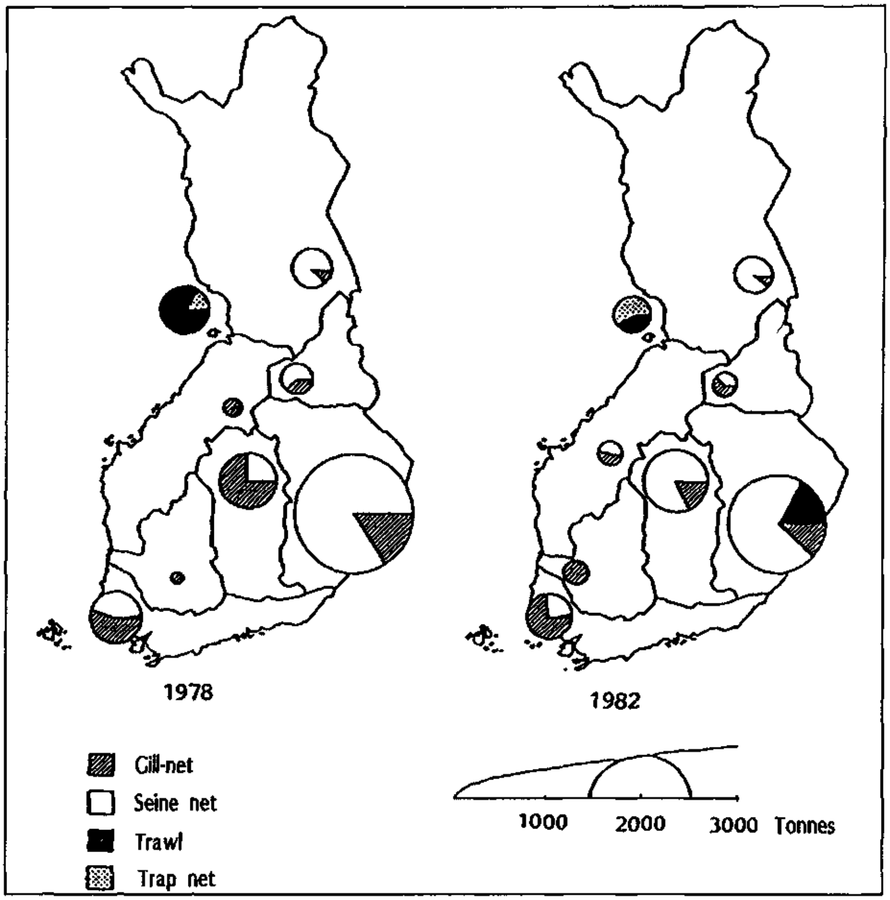


Figure 2. The commercial vendace catch by type of fishing gear in different areas of Finland in 1978 and 1982.

In 1983, a total of 6007 tonnes of vendace was caught in freshwater and 272 tonnes in the sea, the sum (6279 tonnes) representing 4 % of the total Finnish fish catch. The freshwater yield was about 2 kg/ha. Over 90 % of the marine catch was made in the Bay of Bothnia. The commercial vendace catch from inland waters was 65 % of the total freshwater vendace catch. Nearly 70 % of the total commercial fish catch from inland waters consisted of vendace, this being the most important inland species. Measured in Finnish marks, the vendace catch accounted for 64 % of the value of the entire inland commercial fish catch. An inquiry by the Finnish Game and Fisheries Research Institute for 1978, found that about 70 000 families (15 % of all non-commercial fishermen) caught vendace. Their per family catch was about 30 kg/vendace/yr, and their share of the total vendace catch from inland waters was about 30 % (Lehtonen & Salojärvi 1983).

3. Fishing areas

The Vuoksi drainage basin, especially the Saimaa area, is the most important region for freshwater vendace fisheries, but there are many other important lake areas *(Figure 2)*. The geographic distribution of commercial and non-commercial vendace catches are similar, except in SW Finland and the Bothnian Bay area, where commercial catches are proportionally much higher. The introduction of vendace into Lake Inari will make it one of the most important centres for vendace fishing in Finnish Lapland. Pollution has destroyed vendace stocks in some Finnish lakes and watercourses, thereby harming the fishery. This applies in particular to lakes Oulujärvi, Päijänne and Saimaa.

4. Fishing gear

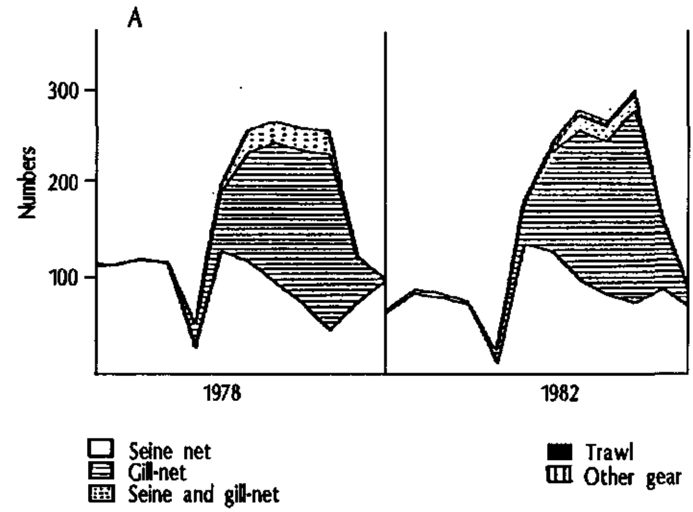
The gear most commonly used by professional fishermen in inland waters for vendace are, in descending order of importance, seine nets, gill-nets and trawls. Pound nets and trap nets have been used too, but their catch has so far been very small *(Figure 3)*. Non-commercial fishermen mainly use gill-nets. Commercial fishermen thus use very efficient gear and techniques for vendace, and efficiency is increasing all the time.

5. Profitability

The profitability of the inland commercial vendace fishery has been slightly lower than that of the Baltic Sea vendace fishery (Viitanen, Salmi & Jäntti-Huhtanen 1986). It has, however, been improved by the introduction of seining in winter, when the demand for fresh fish exceeds the supply in inland areas and prices are high. Another factor to increase the profitability of the vendace fishery is the practice of selling the roe separately as a high priced delicacy.

6. Fishing regulations

So far there has been little need to regulate the vendace fishery. The tendency has been to increase fishing effort by introducing more efficient techniques. This is because levels of exploitation to date appear not to have harmed vendace stocks in any lake investigated. If necessary, Finnish fisheries law will permit regulatory measures.



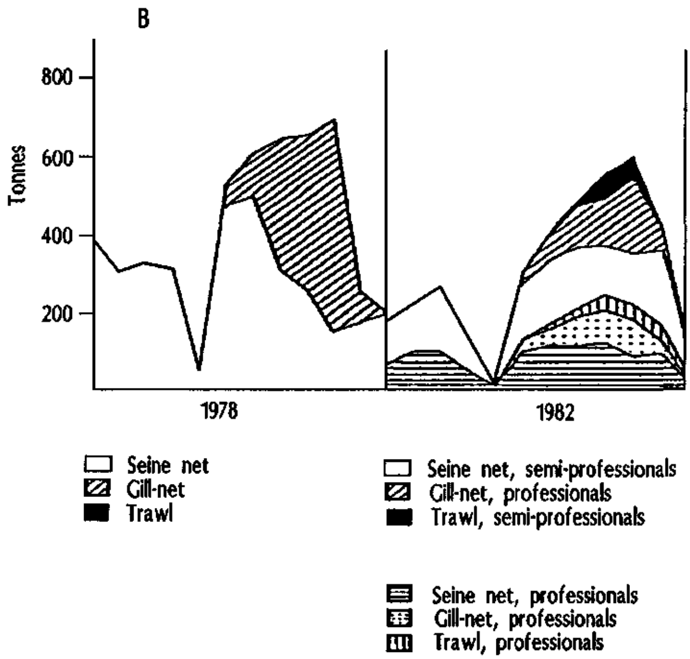


Figure 3. A. The number of commercial fishermen catching vendace in 1978 and 1982.
B. The commercial vendace catch in inland waters by fishing gear in 1978 and 1982. Results for 1978 are combined for professionals and semi-professionals; and for 1982 shown separately.

7. Future

The future of the vendace fishery in Finnish lakes will be influenced by natural fluctuations of vendace stocks and the ability of the fisheries to adapt to these. The growth of the price of vendace on the markets will also be important. No abrupt changes in the overall vendace fishery are anticipated, but local changes can be rapid and dramatic. They are caused by sudden unpredictable fluctuations in the local vendace stock.

References

Hintikka, N., 1967. Catch of fish, fishermen, boats used in fishing and fishing with registered vessels in Finland in the years 1964 and 1965. Suomen Kalatalous 28: 1-28.

Lehtonen, H. and Salojärvi, K., 1983. Subsistence and recreational fisheries in Finland. Suomen Kalatalous 50: 30-72.

Rantala, A., 1983. National fishery statistics on catches in 1979-1981. Suomen Kalatalous 50: 73-83.

Rantala, A., Parmanne, R., Lehtonen, H., Ikonen, E., & Aro, E., 1986. Fishing in Finland in 1983. Suomen Kalatalous 52: 1-15.

Viitanen, M., Salmi, P., and Jäntti-Huhtanen, N., 1986. The profitability of professional fishing in Finland in 1983. Suomen Kalatalous 52: 16-28.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 151-167.

Analysis of the professional fishery in the Loire-Allier and Vilaine Basins, France

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Abstract

Within the scope of the new law on river fishing of June 1984, the Ministry of the Environment commissioned CEMAGREF to make a socio-economic, technical and statutory survey of French inland professional fishery operating under river regulations. After giving our own definition of professional fishermen, to enable all the fishermen of this type to be identified, and after counting them, we submit a tentative typology of their activity in relation to the phenomenon of multiple employment. We effected a virtual census of the professional fishermen in the study area, since out of a total of 110 professional fishermen identified, 94 were investigated either directly or indirectly. Our findings concern demographic characteristics of the different groups of fishermen, the matter of succession in the fisheries when elderly fishermen retire, seasonal fishing, the different types of activities that make up the professional fisheries and the problems that professional fishermen presently experience.

An appreciation of the national situation is proposed on the basis of our studies on these two river basins. Numerous constraints, combined with disputes between individuals, and the difficulties professional fishermen experience in organizing themselves, do not bode well for the future of the professional fisheries. An analysis of the current fishing population and the present condition of the fisheries shows that, despite the intention of young people to join the profession so that the replacement of retiring personnel is assured, a large part of the industry is destined to disappear over the next ten years if nothing is done. Despite this, inland professional fishery is a valuable resource and of considerable economic interest. Its diverse production is worth 50 million FF annually, and it contributes towards a high quality regional gastronomy. The professional fishermen, attached to both their traditional methods and the locality they live in, play an important part in the protection and management of the surface waters. When they have gone there will be no curb, in some areas, on the depredations of polluting industries and developers.

Résumé

Dans le cadre de la nouvelle loi sur la pêche fluviale de Juin 1984, Le Ministère de l'Environnement à chargé le CEMAGREF d'une étude socioéconomique, technique et réglementaire des pêches professionnelles continentales françaises sous réglementation fluviale.

Après avoir donné notre propre définition de travail du pêcheur professionnel qui permet de les dénombrer avec précision, nous présentons une première typologie de l'activité de pêche.

Les résultats de l'application de notre méthode d'enquête à l'étude des pêcheries des bassins Loire-Allier et Vilaine sont ensuite exposés par secteurs: caractéristiques démographiques des groupes de pêcheurs, succession, pratique de la pêche et calendrier, typologie de l'activité, problèmes nombreux et divers auxquels ces pêcheurs sont confrontés.

Nous aboutissons à un véritable recensement puisque sur 110 pêcheurs dénombrés et retenus comme professionnels, 95 ont été directement our indirectement enquêtés.

A partir de l'étude de ces bassins, un constat de la situation nationale est avancé. De nombreux facteurs limitatifs, joints aux querelles de personnes et aux difficultés d'organisation des pêcheurs professionnels, entravent le maintien de l'activité. L'analyse de la démographie et des conditions d'excercice de la pêche montre, malgré l'arrivée des jeunes dans la profession et des relèves assurées ou potentielles, qu'une bonne partie est amenée à disparaître dans les dix années à venir si rien n'est fait. Pourtant la pêche professionnelle continentale est d'un grand intéret économique et patrimonial: sa production diversifiée atteint en première approximation une valeur de 50 millions de francs et participe au maintien d'une gastronomie régionale de qualité. Les pêcheurs professionnels attachés à leur outil de production, à leur "lieu de vie" que son les lacs et les rivières, jouent un rôle important dans la protection et la gestion des milieux aquatiques. Eux partis, dans certaines zones, if n'y aura plus de frein aux tentations des pollueurs et des aménageurs.

1. Introduction

France passed a new law on fishing in fresh waters and the management of fish resources on 29 June 1984 (Law No. 84-512). This law makes clear that the protection of the fishery resources implies a balanced management of the those resources of which fishing, as a social and economic activity, is the major element (Law 401 of the rural code) and that only professional fishermen are authorized to sell their catch (article 416).

The lack of knowledge of professional freshwater fisheries led the Ministry of Environment, which is responsible for fisheries in fresh waters, to commission the Centre National du Machinisme Agricole du Génie Rural des Eaux et des Forêts (CEMAGREF) to make a study of the importance and characteristics of professional fisheries in the freshwaters of France.

Because of the scarcity of studies on inland water fisheries, and the difficulty of using the often highly specialized bibliographic data, we had to elaborate an original method of investigation on the basis of our experience gained during the statistical surveys of catches begun in 1978 among the fishermen of the Gironde estuarine system (who were difficult to approach at the beginning), and of the socio-professional survey launched in 1983-1984 (Castelnaud, Cerezuelle, Guchan & Rochard 1985, Castelnaud, Coutancier, Cerezuelle & Guchan 1985.)

Our method is based on a field inquiry during which each professional fisherman is interrogated using an elaborate questionnaire. An analysis of existing literature was also carried out, together with a re-examination of all information held by interested administrations and fisheries organizations.

This study will be expanded to encompass the whole of France and should allow for the establishment of a reference directory of fisheries for the management of the resources nationally. Only certain river basins have been examined so far, and here we present a tentative classification of the activities of professional fishermen through our analysis of the fisheries of the Loire-Allier and Vilaine basins. These studies already formed the basis of a report on the general situation of professional fishing (Castelnaud & Babin 1987).

2. Typology of the professional fishermen's activities

Neither the old regulations, nor the new law, define professional river fishermen *per se*. Thus to define the group we had been commissioned to investigate, we had to lay down our own criteria of professionality.

We defined a professional fisherman as one who is concerned by the conditions under which fishing is pursued and how the resource is managed, and who contributes to a regime of social protection as a fisherman or an associated activity, for at least six months each year. Finally, he sells fish or draws revenue from the sale of fish. Note that this definition does not consider the time he actually devotes to fishing. We have, additionally, defined three categories of professional fishermen:

- Professional fishermen who have fishing rights.
- Associated professionals who work within the fishery, or with the fish, but who themselves have no *fishing rights.*
- Professional labourers who work within the fishery or with the fish, and are employed by a professional fisherman.

On the basis of these criteria we carried out a census of professional fishermen using lists furnished by the services responsible for management and our field investigations to identify them. We then attempted to categorize different types of professional fishery practice by taking account of the time devoted to fishing and that devoted to associated professional activities, using the information collected *(Table 1).*

Table l. Census of professional fishermen of the Loire-Allier and Vilaine Basins.

	Intensive fishing activity 9-12 months		Medium fishing activity 6-9 months		Small scale, 3-4 months, or secondary activity spread over the year		
Sectors	with other activities	without other activities	with other activities	without other activities	with other activities	without other activities	Total
Grand Lieu	9	2					11
Lower Loire, Vilaine	14	1	22	9	6	3	55
Maine & Loire	8		4	4			16
Mid and upper Loire & Allier	1	3	3	6			13
Total	32	6	29	19	6	3	95

3. Analysis of professional fishermen in the Loire-Allier and Vilaine Basins

3.1 The sectors: geographic and regulatory limitations

In water courses and canals discharging to the sea, fishing is subject to marine regulations downstream of the upper limit of the penetration of saline waters. Professional river fishermen may only fish above this point *(Figure 1)*, where the fishery is subject to river regulations. However, up to the old limit of marine registration upstream of this point, professional sea fishermen can fish in competition with river fishermen under ancestral fishing rights.

This latter category of fishermen is not included in the present study. Above the ancient limit of the marine fishery, only river fishermen can fish professionally. The policing of fishing waters and fisheries is provided by different services outside the Ministry of Environment at the level of each Department and may be the 'Direction Départementale de l'Equipement (DDE), Service de la Navigation (SN)' but more often the 'Direction Départementale de l'Agriculture et de la Forêt (DDAF)'.

We have defined four sectors characterized by the geographical distribution of the fishermen, their numbers, the types of fishery, and the administrative boundaries.

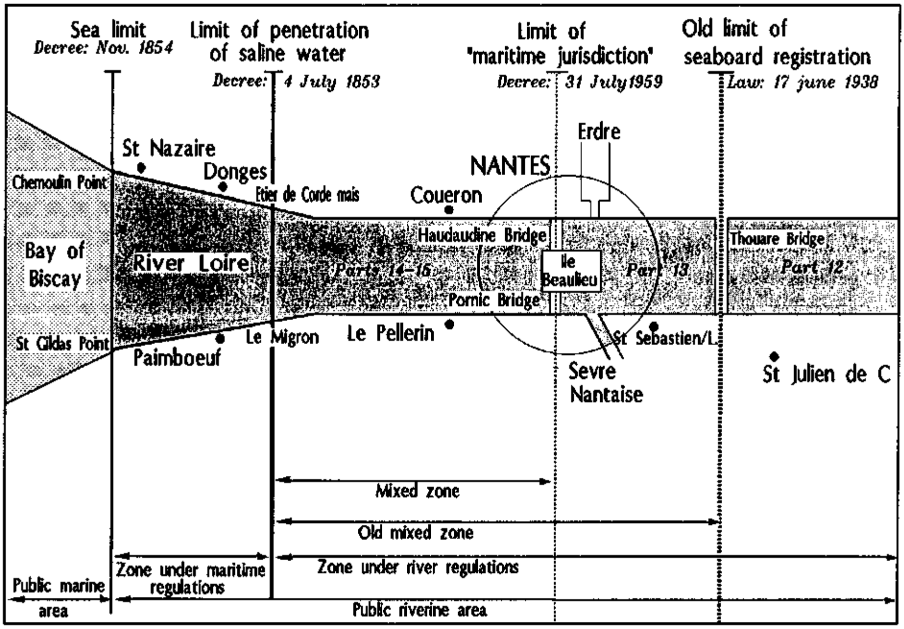

Figure 1. Administrative limits of the Loire estuary.

3.1.1 Sector 1: Grand-Lieu Lake sector

Strictly speaking, Grand-Lieu Lake forms part of the Loire-Allier basin, and its geographical position and certain characteristics of its fishery are close to those of the lower Loire-Vilaine, but the lake does not lie in the public domain. The owners rent the fishing rights on its waters to a co-operative of professional fishermen. One part of the lake was designated a nature reserve in 1980 and the DDAF of the Loire-Atlantique polices the fishery.

3.1.2 Sector 2: Lower Loire-Vilaine sector

As far as professional fishery is concerned, this sector is delimited by the lower Loire from Ingrandes to Coremais and includes parts of the Sèvre Nantaise, Erdre, Oust, Don, and Chère Rivers, the Vilaine upstream of the dam at Arzal, and part of the Nantes to Brest Canal *(Figure 2)*. These water courses extend over several departments and sometimes comprise natural boundaries which delimit them. Some discharge to the sea and are therefore subject to the legal complex described above. All this explains why the division of competence between the different administrative services is complex. The DDE of the Ille and Vilaine and the Loire-Atlantique, the SN of the Loire-Atlantique and Maine-et-Loire, the DDAF of Morbihan and the Loire-Atlantique are often involved, but with different roles on the same river reaches.

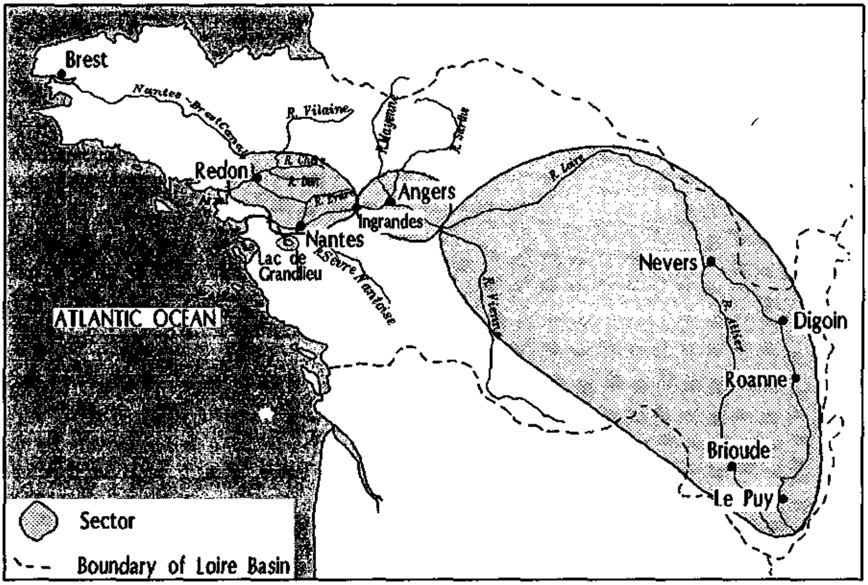

Figure 2. Location of sectors studied.

3.1.3 Sector 3: Maine-et-Loire sector

As its name indicates, this sector lies in the Maine-et-Loire Department and concerns, for professional fishery purposes, parts of the Loire, Maine, Mayenne and Sarthe Rivers *(Figure 2)*. The Maine-et-Loire DDAF assures the policing and management of the Loire fishery, while the Maine-et-Loire DDE provides them on the Maine, Mayenne and Sarthe.

3.1.4 Sector 4: Mid-Loire, Upper Loire and Allier sector

The sector includes the Indre-et-Loire, Loire-et-Cher, Loiret, Nièvre, Saône-et-Loire, Allier, Loire, Puy-de-Dôme, (Haute-Loire) watercourses and concerns, for professional fishery, the Loire between Le Puy and the Bec de Vienne, and the Allier between Brioude and Bec d'Allier (at the level of Nevers). *Figure 2* shows the boundaries of the departments crossed. The management and policing of the fishery of the Loire and its effluents in the sector are assured by the DDAFs; only the canal from Roanne to Digoin comes under the responsibility of the Loire DDE.

3.2 The replies to the 'administrative' questionnaires

The replies of the Financial Agencies of the Basins, of the SRAEs (Service Régional de l'Aménagement des Eaux), of the DRAEs (Direction Régionale de l'Architecture et de l'Environnement), of the CSP Regional Delegations (Conseil Supérieur de la Pêche), and of the AAPP Federations (Association Agrée de Pêche et de Pisciculture) to the questionnaire were either non-existent or incomplete. Exceptions were some of the AAPP federations, the regional delegation of CSP No. 4 of Poitiers, and the Pays-de-Loire DRAE/CETE of the West. On the contrary, we managed to obtain the return of all questionnaires from all the Management Departments concerned (DDAF, DDE). Some departments provided a complete document with precise and exhaustive lists of fishermen, but many over or under estimated the number of professional fishermen, knowing them insufficiently or not all, and being unable to provide details of fishery, production and marketing methods used. Some departments, however, called in the opinion of professionals.

Despite the technical help of the water-bailiffs, the CSP and the AAPP Federations, most of the Management Departments deplored the lack of technical equipment, skilled personnel, training and time available.

3.3 Bibliographic data

A bibliographic inventory was drawn up in 1983, within the framework of the Eel Working Group (Castelnaud & Gascuel 1983). The analysis is based on the eel, but the documents deal also with other species. Without being exhaustive, this inventory gathers most of the works regarding the subject of fishery with nets and fishing gear published up to now. Among these, only those of Ivoy de la Poype (1901), Talhouarne (1975, 1981), and Bellec (1981) contribute sufficiently accurate and comprehensive data on the fishery practices and production of the Loire-Allier basin.

Arrignon (1986a) described the fish species of the Loire and their environment together with the economic and socio-economic aspects of the fisheries and regretted the absence of proper information on catches.

Fleury (1974) has carried out an exhaustive study of the Loire from the Bec du Vienne to the mouth, including the professional fishery (updated with regard to the professional fishery and the impact of the extractions, by the DRA/CETE-Ouest 1987). The problem of aggregate quarrying in the Loire and Allier Basins, and the protection of the milieu, have also been dealt with by Clavel, Cuinat, Hamon & Romaneix (1977), Cuinat (1980b,c), Foucaud (1981), and SEPNMC (1982). A preliminary scheme for the construction of a nuclear power station at Pellerin had led Maillard and Metayer (1976) to draw up a piscicultural and halieutic inventory for this site. Later, the Scientific Committee for the Environment of the Loire Estuary (CSEEL 1984) produced a very complete ecological report of the lower estuary (essentially under maritime regulation), which forms a reference work on the subject. Elie & Rigaud (1984) provide a similar study for the Vilaine in connection with the Arzal dam. A review of the exploitation of Atlantic salmon in France has recently been made by Arrignon (1986b) who analysed every river basin. Salmon and salmon fishing in the Loire-Allier Basin were the subject of short notes by Bureau (1981), Bachelier (1964), Cuinat (1980a), Richard (1980, 1982) Cuinat & Bomassi (1987) and in Brittany and lower Normandy by Prouzet & Touzery (1982). G.O.P. (1986) and Tissier (1987) produced the most recent estimates of the catches. With regard to elvers, reference should be made to Guerault, Desaunay, Eie, Marchand & Gay (1985) and to the Commité Interprofessionel des Poissons Migrateurs (CIPE).

For Grand-Lieu Lake, Linard (1986) drew a very complete scenario of the professional fishery. Less expensive studies by Petit (1982) complement those of Bellec (1981) and AND-GRESA (1985).

Trap and boom-net fishing are described in detail by Robert (1976) and Meriau (1979), while La Sologne (1982), who provides a very instructive history of professional salmon fishery, takes up these two techniques in his introduction.

3.4 The findings of the field investigations

Within the scope of the field investigations we accomplished an almost complete census, since out of 110 fishermen, 94 were investigated either directly or indirectly *(Table 1)*. Of these, 11 were at Grand-Lieu and 83 were on the Loire, Allier and Vilaine Rivers. Other fishermen were encountered, but they did not meet the conditions of professionalism we had laid down. Of the 94 fishermen investigated, no less than 74 come from the Loire-Vilaine, the Grand-Lieu estuary, and the lake system. The Maine and Loire sector had 17 professional fishermen, while over the rest of the Loire-Allier system there were only 1-4 professional fishermen per department crossed.

Grand-Lieu sector

Eleven professional fishermen practise fishery intensively; 4 fishermen are over 55 years old, 4 between 35 and 50 years of ages, and 3 are aged between 25 and 34.

These fishermen fish on private property; they are grouped in a Co-operative Society and share the cost of leasing the fishing rights. A tradition of fishing exists in families and the conditions for entering the profession on the lake are very restrictive, but there seems to be a keen demand to take any places falling vacant. Catches are mainly of non-migrant eel, predatory species and cyprinids *(Table 2)*. All fishermen engage in full-time fishery, but also catch coypu *(Myocastor coypus)*, and two of them have secondary jobs. Members of married couples occasionally both participate in fishing.

Fishing on the Grand-Lieu lake is, in the opinion of all the fishermen, a viable and fairly secure occupation. The Grand-Lieu fishermen are the only ones to be united in an organised structure. They are concerned to put the resource and fishery on a permanent basis, but they encounter difficulties in making their group effective. They have, nevertheless, developed a system for the admission of new fishermen and have established a solidarity fund.

The regulation of the fishing remains fairly vague: semi-official authorization permits the use of 'capetchade' hoop-nets and the fishing of predatory species during the off-season. Environmental (silting) and water management problems arise in connection with the nature reserve and local farmers.

The Loire below Vilaine

Sixty-three professional fishermen, including two married couples, 53 of whom were investigated, were counted in 1987. This is a young population owing to the arrival of new fishermen, especially for elver fishing. No woman holds a professional fishing licence. Fishing is a family affair: more than half have family records in river fishing and nearly 30% have relatives working in the sector. The problem of replacement arises in the strictly river zone (upstream of the mixed zone on the Loire) and on the Vilaine, where many of the fishermen are elderly.

In the mixed zone successions are already confirmed in a predominantly young population. However, the continuation of fishing is linked an elver fishery, which can become problematical. The spectrum of fish caught varies with the zone:

- In the downstream zone of the Loire and in the Sèvre-Nantaise system, elvers and migrant species, *e.g.* shad, lamprey, mullet and salmon, are most important *(Table 2)*.
- In the upstream zone, the seaward-migrating eels are caught by kiddle (4 installations) and lampreys are caught in wicker lamprey baskets *(Table 2)*.
- In the Vilaine (Oust, Don and Chère included) and Erdre Basins, non-migrant eels and predatory fish are sought *(Table 2)*.

At least 25% of the fishermen have another occupation besides fishing, but very few are farmers. Some 70% of fishermen fish at medium to strong intensity. For 26% fishing is a viable activity, while 5% have serious difficulties in supporting themselves. The majority, almost 70%, manage to live by associating their fishing with another trade, or by virtue of their wives' earnings.

Individually the fishermen here make an effort to manage the resources; they are, before all else, professional fishermen and do other jobs out of necessity. Most of them told us that they made realistic reports of their catches to the Management Services and they gave us their production figures.

There are several clans of fishermen, and the situation is not clarified by the Accredited Departmental or Interdepartmental Associations. The complexity of the administrative and regulatory system in the sector leads to additional difficulties, notably:

- Competition between professional river and sea fishermen, with the problem of the membership of the latter in the Accredited Professional Fishermen's Association.
- Competition between the elver fishery and the seaward-migrating eel fishery.
- Poorly defined fishing rights in the Redon region.

Coexistence with anglers, does not appear to cause problems.

The quality of the water and the environment is not a reason for major concern for this group of fishermen, except for those on the Vilaine, who have to contend with the effects of the Arzal dam, and those in the upstream lots of the Loire Atlantique department, who find plastic covers discarded by market gardeners, and shipping movements, an inconvenience.

The Maine et Loire sector

Seventeen professional fishermen, including 4 married couples holding fishing rights, were operating on the Loire, Maine, Mayenne and Sarthe Rivers in 1987. Working together is fairly well developed here, especially between married couples. A small enterprise, consisting of a couple and 2 co-lessees who are not family members, was encountered. The average age is 45 and the oldest fishermen operate in the upstream part of the sector. Succession is little provided for, but the fishermen clearly wished their profession to continue should the future allow it. The chief practice of the sector is catching seaward-migrating eels by kiddle (12 installations). In the upstream part, boom-nets are also used (5 installations) to catch salmon and shad. Lampreys, mullet, predatory fish and non-migrant eels are also caught *(Table 2)*. One fishermen from the upstream sector ceased fishing in 1987, 2 others are also farmers, and 1 couple help the lock-keeper in the summer. Thus 12 fishermen are full-time professionals while 4 combine fishing with other jobs. This is the only sector where so many fishermen made real or 'simplified real' declarations. For two couples and two individual fishermen, fishing does not ensure a sufficient income; for all others it is a viable occupation.

We did not ascertain whether or not there were internal disputes in this group of fishermen, who seem fairly well organized and disciplined. The majority are not affiliated to trade unions. Only one fisherman said he reported his catches. None was hostile toward us and most were inclined to participate in the scientific proceedings and fishery management.

Co-existence with anglers is not easy. It compels the professional fisherman to fish at night and to do little fishing in summer. The anglers catch pikeperch on the spawning grounds during the closed fishing season and sell them. Quarrying, herbicide treatments of the banks, commercial shipping, and dams are some of the harmful factors troubling fishermen in the sector.

The mid-Loire and the Loire upstream of Allier

We counted 13 professional fishermen, including 1 woman, and there were 6 workmen engaged by one of the two fishery enterprises in the sector. We were refused an interview, and only the workmen and 1 assignee were investigated indirectly.

A single professional fisherman was less than 30 years old and the population is, on the whole, fairly elderly. Upstream of Loiret, only 1 fisherman was aged under 50. Half of those holding a professional fishing licence will retire in the coming 5 or 10 years, and despite several possible successions, the future of fishing in this is critical. The basic practices are to catch shad and salmon with boom-nets or traps (7 installations) downstream of Bec d'Allier, and to catch whitebait by cast-net upstream *(Table 2)*. Other species caught are non-migrant eels (exclusively downstream of Bec d'Allier), and lampreys, cyprinids and predatory fish over the whole sector. A fairly large personnel is used, *e.g.* 1 fisherman's mate per operation upstream of Bec d'Allier, 2 or 3 persons to handle boom-nets and even more for seines. Of the 13 professional fishermen, 4 practice fishing intensively, while 9 have more than one job (farmers, pond fish-breeders, fishmongers). Six employees also work in pond fish-breeding in one of the two fishery enterprises *(Table 1)*.

For several of these professional fishermen, it is the work of their wives that ensures the household's basic income and the possibility of keeping the fishing activity going; 4

Table 2. Fishing calendar of the professional fishery in the Loire-Allier and Vilaine Basins. Regions: 1. Lake GrandLieu, 2. Lower Loire, zone 1, 3. Lower Loire, zone 2, 4.Lower Loire, Vilaine and Erdre Basins, zone 3, 5. Maine and Loire 6. Mid-Loire, Upper Loire and Allier.

Species	Zone	Type of gear	J	F	M	A	M	J	J	A	S	O	N	D
Roach, rudd	1	reel												
Carp	1	reel												
Tench	1	reel												
Bream	1	reel												
Other cyprinids	6	gill-net												
	6	basket trap												
Whitebait	6	purse seine												
	6	gill-net												
	6	cast net												
Catfish	1	fyke net												
Pikeperch	1	gill-net												
	3	gill-net												
	4	gill-net												
	5	gill-net												
	5	drift net												
	6	gill-net												
	6	basket trap												
Pike	1	reel												
	4	gill-net												
	5	gill-net												
	5	drift net												
	6	gill-net												
	6	basket trap												
Glass eel	2	scoop net												
	3	scoop net												
	4	scoop net												
Silver eel	3	stow net												
	4	stow net												
	4	small stow net												
	4	winged fyke net												
	5	stow net												

Species	Zone	Gear	J	F	M	A	M	J	J	A	S	O	N	D
Yellow eel	1	ground line			■	■								
	1	eel pots	■	■							■	■	■	■
	1	fyke net			■	■	■	■	■	■	■	■	■	■
	2	eel pots					■	■	■	■	■	░	░	
	2	ground line					■	■	■	■	■	░	░	
	2	square dip net					■	■	■	■	■	░	░	
	3	basket traps			■	■	■	■	■	■	■			
	4	basket traps	░	░	░	■	■	░						■
	5	basket traps			■	■	■	■	░	░				
	6	basket traps	░	░	■	■	■	░	░	░	░	░	░	
Shad	2	drift net			■	■	■	■						
	3	gill-net		■	■	■	■							
	5	barrier with lift net			■	■	■							
	6	barrier with lift net			■	■	■							
	6	small barrier w. lift net			■	■	■							
Sea lamprey	2	drift net			■	■	■	■						
	3	gill-net	■	■	■	■	■							
	3	lamprey basket	■	■	■	■	■							
	5	lamprey basket			■	■	■							
	5	trammel drift net			■	■	■							
	6	small barrier w. lift net			■	■	■							
	6	basket trap			■	■	■							
Salmonids	2	drift net	░	░	░	░	░	░	░			░	░	░
	3	gill-net	░											
	5	barrier with lift net		■	■	■	■	■						
	6	barrier with lift net			■	■	■	░						
	6	small barrier w. lift net			■	■	■	░						
Mullet	2	gill-net					■	■	■	■	■			
	2	drift net					■	■	■	■	■			
	3	gill-net				■	■	■	■	■	■			
	5	gill-net				░	░	■	■	■				
	5	drift net				░	░	■	■	■				
Flounder	2	drift net										■	■	■

■ Intensive fishing ░ Non-intensive fishing are restaurant keepers and 2 are fish merchants; they make the best use they can of the fishery product.

The fishermen located upstream of the Nièvre department do not report their catches because they are not asked to do so, and they have no idea about the management of the resource. By contrast the fishermen located downstream all feel themselves concerned. It seems that the majority report their catches to the DDAF or CSP. They are ready to take part in a follow-up of the catches and in the management of the resources; some of them, besides, take a close interest in the studies conducted on salmon and shad. The professional fishermen state unanimously that the regulations are not suited to local conditions and the restrictions are too numerous and inappropriate. For example, the 10 mm mesh size has been suppressed in the Loiret, while cast-net fishing has been authorized for amateurs in Puy-de-Dôme putting them on par with the professional whitebait fishers.

In all the departments except Nièvre, the professional fishermen reproach the anglers for organizing themselves to fish pikeperch and salmon in the spawning areas, in the reserves near the dam. They are said to be in collusion with restaurant keepers, and to make it impossible to fish with nets and tackle during some periods.

In this sector, causes of deterioration of the aquatic environment are very often reported, *e.g.*, the construction and effects of the Blois dam, nuclear power stations, quarrying, lowering of the water level, difficult access to the river, etc.

4. Conclusions

We have been able to ascertain that professional fishery is an occupation whose financial return varies according to particular situations and its mode of performance. It is often necessary for the titular professional fisher to call on gratuitous, or at times paid help.

About 40% of the professional fishermen fish in an intensive manner and obtain all or the main part of their revenue from fishery. Fifty per cent fish with medium intensity. Half of them have no other occupation, but the other half combines fishing with another job. Finally 10% fish only on a limited scale *(Table 1)*.

Fishermen with additional occupations are criticized by those without such occupations because those with them avoid the seasonal slumps and can afford to subsidize their fishing in various ways, *e.g.* by investing in gear. This makes it easier for them to cling to the profession than would otherwise be the case. Some married fishermen are able to invest in gear using money derived from the wages of their partners.

On the other hand, those who have additional occupations point out that if all fishermen were on the water throughout the year, competition for catches, fishing zones and the sale of products would occur, especially in mixed zones. We are persuaded by this viewpoint. Holding of more than one job enables professional fishery to be maintained in some areas where it might otherwise fail. Most of the fishermen with other jobs in the Seine, Loire-Allier and Vilaine basins have them out of necessity and are, first and foremost, professional fishermen. Unlike what occurred in Gironde (Castelnaud *et al.* 1985b), the multi-job holders have, like the other professional fishermen, a concern for the management of the resource, particularly in the Grand-Lieu Lake. The professional fishermen usually report their catches fairly realistically, or are willing to do so when

Plate 1. Fyke net fishing for eel on the River Loire near Angers.

asked. In any case, few reacted adversely to our enquiries. Fishermen want a simple registration system to be proposed to them, and in return they ask to be advised of the findings.

Finally, several of them have taken part, or are still taking part in piscicultural inventories and in research on certain species, *e.g.* shad, salmon and eel. They are all watchful for any attacks on the quality of the waters and of the environment.

Although a certain concern regarding management, and a desire to participate in it, was ascertained among fishermen taken individually, when the groups and their dynamics were considered, we were dismayed by their inability to find common objectives, to defend their professional interests, or to organize themselves. They are in their majority, powerless *vis-à-vis* the administration, and new technical, judicial or other factors that could probably help them. AND-GRESA (1985) and DRAE/CETE-Ouest (1987) show that the majority of the Loire professional fishermen they investigated are at present incapable of agreeing among themselves as to how to organize their own sales network. Except for the handicaps linked to the scattered distribution of the producers, who are spread over 700 km, and the competition for sea caught fish, the establishment of a co-operative clashes with the contradictory motivations of the producers. Most of them want an organization of this kind, but only for delivering 'poisson blanc'. The solution would be to encourage the development of small processing units, but at the moment no organisation has taken this direction, except for the 'Association pour le Dévelopement de l'Agriculture et de la Pêche en Rhône-Alpes' in its own area.

Disputes, at times violent, occur between some fishermen over matters of competition, rivalry, character, etc., and several anomalies and disagreements have been observed among the groups of fishermen using nets and fishing gear. Clans have been formed and among the leaders it seems there are greater tendencies to divide than to unite. Professional fishermen do not recognize one another, and opposition between river, lake and estuarine fishermen remains alive.

Personal differences and the difficulties in organizing group activities are characteristic of all human communities. However, in the case of professional fishermen these difficulties are, or have been, worsened by certain factors identified during the first part of the national survey (Castelnaud & Babin 1987). These were:

- The lack of an official definition of a professional fisherman (until the law of June 1984), and a general lack of technical assistance to the profession, and of aid for fishermen to 'start up'.
- The fact that all categories of fishermen could sell fish, including anglers (until the law of June 1984).
- The fact that regulations are often arbitrary in nature, and become more and more restrictive.
- The fact that some regulations give professional fishing a 'supplementary character' (until the law of June 1984).
- The fact that recreational fishing is accorded too great an importance, and that the impact of angling on professional fisheries is not appreciated.
- The fact that there has been a marked degradation of rivers, streams and lakes, and the lowering of water levels, which has reduced the possibilities for fishing and diminished fish stocks.

These constraints are interdependent and for some have cumulative effects. For example, both net and tackle fishing were only authorized if the administration judged it necessary, and numerous fishing sites were 'reserved', and denied to the professional fishery, often on application by the Departmental Federations of the AAPP. In the same way, certain FDAAPPs demanded the suppression of both net and tackle fishing in sites damaged by the harnessing of waters or by quarrying.

One has to ask whether these reductions in the working space for professional fishermen, and regulations which complicate and limit professional fishing are justified. There has been no assessment of fish stocks in general, nor of the fishing efforts of the different categories of fishermen, nor of their catches.

All this has led to degradation of professional fishing, and one wonders how it has survived. Our study shows that, despite the intention of young people to fill vacant places in fisheries, a large part of the industry is destined to be lost over the next ten years if no remedial action is taken.

Nevertheless, the economic and patrimonial interests of the professional inland fishery in the present context of agricultural undervaluation is obvious. The river fishing law throws its objectives into relief, it wants 'to inscribe fishery in the economic context by making a clear-cut distinction between amateur and professional fishing, in order to develop the latter and to ensure a better utilization of the economic capital that the French water courses represent.'

Professional fishermen can now help determine the quality of the aquatic environment. Their constant presence on the water, their experience, and their desire to preserve their livelihoods keeps them alert to harmful influences, which they can now report. Should the law be relaxed there will be no curb on the polluters.

The production of the professional freshwater fishery, with a landed catch valued at 50 million francs, plus a further 20 million francs from the sea fishermen's catches in the mixed zones, is registered in a sector where the deficit in the trade balance is very large. For example, since it preserves the genuineness of the regional cuisine the whitebait from French rivers and streams is much better adapted to the preparation of local specialities than frozen imports. This pleads in favour of bolstering a professional fishery, which would be able to:

- Create employment if the professional fishermen became, in fact, the only 'commercial fishermen'.
- Relaunch regional gastronomy.
- Play an appropriate role in managing the resource.

References

AND-GRESA, 1985. Projet d'organisation collective des pêcheurs du Bassin de la Loire (conclusions) Fév. 1985. 51 pp.

Arrignon, J., 1986a. Fish and their environment in large European river ecosystems. The Loire. Science de l'eau 7: 21-34.

Arrignon, J., 1986b. Saumon atlantique: l'exploitation de la resource en France. In 3^{e} Symposium International sur le Saumon Atlantique. 21-23 Octobre 1986. A.S.T and A.I.D.S.A. 20 pp.

Bachelier, R., 1964. L'histoire du saumon en Loire. Bull. Fr. de Pisciculture 213: 121-131.

Bellec, S., 1981. Etude des conditions de pêche sur le domaine public fluvial de la Loire: pêche à la ligne. Pêche aux engins, essai de détermination de la valeur biologique des lots. Neuilly-sur-Seine: Min. Environment: Director de la Protection de la Nature. 232 pp.

Bureau, L., 1891. Le saumon de la Loire dans ses rapports avec la réglementation de la pêche. Bull. Soc. Sci. Nat. de l'Ouest de la France. 1: 7-19.

Castelnaud, G. & Gascuel, D., 1983. Premier Groupe National de réflexion sur l'anguille. Thème 3: Exploitation et suivi de la ressource *Anguilla anguilla*. Inventaire et analyse des travaux français, réflexions et bilan. La Rochelle rapport interministériel (Agriculture, Mer, Environment). 30 pp.

Castelnaud, G. & Babin, D., 1987. La pêche professionnelle aux filets et aux engins dans les eaux continentales françaises 1ere partie: les bassins Seine, Loire-Allier, Vilaine. Bordeaux: CEMAGREF (division ALA)/Ministère de l'Environment. 189 pp.

Castelnaud, G., Coutancier, B., Cerezuelle, D. & Guchan, A., 1985. La pêche des migrateurs en Gironde 1ere partie: Analyse historique du XVIIIe Siècle à nos jours - Bilan et perspectives. Bordeaux: CEMAGREF (division ALA)/M.S.H.A./ Ministère de l'Environnement/Département de la Gironde. 177 pp.

Castelnaud, G., Cerezuelle, D., Guchan, A. & Rochard, E., 1985. La pêche des migrateurs en Gironde 2eme partie: Enquête socio-professionnelle - propositions de gestion. Bordeaux: CEMAGREF (division ALA)/M.S.H.A./Ministère de l'Environnement/Département de la Gironde. 110 pp.

Clavel, P., Cuinat, R., Hamon, Y. & Romaneix, C., 1977. Effets des extractions de matériaux alluvionnaires sur l'environnement aquatique dans les cours supérieurs de la Loire et de l'Allier. Bull. Fr. de Pisciculture. 268: 121-154.

Commité Scientifique pour l'Environnement de l'Estuaire de la Loire, 1984. Rapport final du C.S.E.E.L.- C.N.X.O. Rapports Scientifiques et Techniques No. 55. 158 pp.

Cuinat, R. & Bomassi, P., 1987. Evolution de la situation pour le saumon du bassin Loire-Allier de 1979 à 1985. In: La restauration des rivières à saumons. Paris:INRA. pp. 39-51. pp.

Cuinat, R., 1980a. "Le saumon du Bassin Loire-Allier". Saumons No 34, numéro spéciale Le Saumon de France. 26-32 pp.

Cuinat, R., 1980b. Rejets de matières en suspension par les exploitations de granulats dans la rivière Allier. Effets sur la vie aquatique. CSP. 6ème DR. Coll. FAO. CECPI, Vichy, Avril 1980. Polyc. 24 pp.

Cuinat, R., 1980c. Modification du profil en long de la rivière Allier par suite des extractions intensives de granulats. Conséquences sur la migration du saumon atlantique. CSP. 6ème DR. Coll. FAO. CECPI, Vichy, Avril 1980, Polyc. 1 p.

DRAE Pays de Loire/CETE-Ouest, 1987. La Loire de Nantes au Bec de Vienne des richesses à gérer. Tome III. Activité Pêche - Aspects économiques. Neuilly: Min. Environnement. Taxe Parafiscale sur les Granulats. AFB Loire-Bretagne. Sarelo. FDAAPP 44 et 49. 143 pp.

Elie, P. & Rigaud, C., 1984. Etude de la population d'anguilles de l'esturaire et du bassin versant de la Vilaine: pêche, biologie, écologie. Examen particulier de l'impact du barrange d'Arzal sur la migration anadrome (Civelles). Bordeaux: CEMAGREF - Division ALA/Univ. Rennes I/Union Régionale des Fédérations des Associations Agrées des Pêches et Pisciculture de Bretagne, Maine et Normandie. Tomes I et II.

Fleury, D., 1974. Etudes des sites naturems et des problèmes. Brest: SEPNB/Min. Qualité de la vie. 5 Tomes A.B.C.D.E.

Foucaud, R., 1981. Groupe de travail sur les extractions de matériaux. Approche des problèmes posés par les extractions de matériaux dans les cours d'eau: exemple de la Loire et de l'Allier. - Annales des Mines, Mars-Avril. pp. 179-184.

Gazette Officielle de la Pêche. 1986. Le programme d'Aménagement de la Loire a un peu trop oublié les pêcheurs et les idées qu'ils défendent.No. 889-890. Spécial Saumon de la Loire. 24 pp.

Guerault, P., Desaunay, Y., Elie, P., Marchand, J. & Gay, C., 1985. Variation de l'abondance de civelles (secteurs Loire et Vilaine) de 1976 à 1984. Rapport préliminaire. Nantes: IFREMER. Univ. 5 pp.

Ivoy de la Poype, P., 1901. La question de la pêche dans le bassin de la Loire-Poitiers: Maurice Bousrey. 307 pp.

La Sologne, A., 1982. Les pêcheurs de saumon en Loire. pp. 5-30.

Linard, A., 1986. Les pêcheurs du lac de Grand-Lieu. Le Chasse Marée 2-17.

Maillard, Y. & Metayer, C., 1976. Etude écologique d'avant-projet sur le site du Pellerin. Inventaires biologiques de base et bilan hydroécologique global de la Basse-Loire. Université Nantes. 209 pp.

Meriau, B., 1979. Les pêcheurs de saumons en Loire. Bibliothèque de Travail 871: 1-28.

Petit, R., 1982. Evolution de l'état du marché du bassin de la Loire. In: Colloque sur la production et la commercialisation du poisson d'eau douce de Dijon. Cahiers de l'Association Internationale des Entretiens Ecologiques. Nos. 11/12. pp. 133-137.

Prouzet, P. & Touzery, H., 1982. Le saumon en Bretagne et Basse Normandie. Saumons 34: 19-25.

Richard, R., 1980. La route du saumon sur l'axe Loire-Allier. 20 pp.

Richard, R., 1982. La Loire et le saumon atlantique. La Sologne 22-29 pp.

Robert, B., 1976. Un pêcheur professionnel en Loire. Le Journal de Sologne et ses environs 13: 35-37.

SEPNMC, FRANE, 1982. Rivière Allier. Nature Vivante Special Number. 110 pp.

Talhouarne, R., 1975. Enquête sur la pêche aux engins. Pau: Conseil Supérieur de la pêche. D.R. Pyrénées. 24 pp.

Talhouarne, R., 1981. Exploitation de la pêche sur le Domaine Public Fluvial: préparation des baux 1982-1986. Rapport Min. Environnement. 29 pp.

Tissier, J., 1987. Etat des captures de saumon atlantique dans l'ensemble de la France en 1986. Saumons No. 60. 9 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 168-181.

Fisheries management in an international lake: Lake Geneva

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Abstract

Sixty percent of the area of Lake Geneva lies in Switzerland and forty percent in France. One hundred and fifty professional fishermen exploit salmonids (trout and charr), coregonids and percids (perch). An agreement was recently concluded between the two states to coordinate regulations for both professional and recreational fishing. The regulations govern fishing effort, number of nets, fishing hours, the areas where fishing is permitted and closed periods during the breeding seasons of the species fished. Large-scale stockings are carried out with trout and charr aged between 4 and 6 months, and coregonid larvae. Stocking material is obtained from eggs collected from brood stock taken from the lake. Management policies are increasingly oriented toward put, grow and take fisheries. Catch is recorded daily by both professional and recreational fishermen. Numerous marking experiments with juveniles, carried out jointly by the two countries over the past three years, should provide useful data for improving stocking policies.

Résumé

Le lac Léman (58 240 ha) est à 60% suisse et 40% français. Une pêcherie professionnelle de 150 pêcheurs exploite essentiellement des Salmonidés: truite, omble, corégone et un Percidé, la perche. Un concordat récent entre les deux états harmonise la règlementation de la pêcherie tant professionnelle qu'amateur. Les règlements portent essentiellement sur l'effort de pêche, le nombre de filets, les heures de pêche, les lieux de poses et les périodes d'interdiction pendant la reproduction des espèces pêchées. Un effort important d'empoissonnement est fait avec des poissons âgés de 4 à 6 mois pour la truite et l'omble et des larves de corégone. Les alevins introduits sont issus d'oeufs récoltés sur des géniteurs pêchés au lac. La gestion actuelle s'oriente de plus en plus vers le pacage lacustre. La récolte est l'objet de statistiques journaliès obligatoires pour les professionnels comme pour les amateurs. De nombreux marquages d'alevins, coordonnés depuis maintenant 3 ans, vont fournir des résultats importants pour améliorer l'alevinage.

1. Introduction

Lake Geneva is situated 372 m asl and covers an area of 58 240 ha of which 40% (23 900 ha) belongs to France. It is 72.3 km long with an average width of 8.1 km. The maximum depth is 309.7 m, while the mean depth is 152.7 m. Its volume is 89 km^3 and hence its heat inertia is substantial. Water temperatures never falls below 4°C and the lake never freezes. Its surface water temperature sometimes rises above 24°C in the summer months. The epilimnion is well defined from May-June to September-October. The lake surface is sometimes subject to the action of strong north or westerly winds which give rise to currents capable of de-stratifying the lake before the epilimnion is fully defined.

CIPEL (International Commission for the Protection of Lake Geneva's water) has been monitoring the quality of the lake water since 1957. The threat of eutrophication led the two states to undertake protection measures. These measures are beginning to have an effect in that the quality of the water has not deteriorated further in recent years. At least the rate of discharge of contaminated water into the lake has levelled off (CIPEL 1984).

As a result of eutrophication the rate of growth of fish increased (Laurent 1972, Lang & Lang 1983, Champigneulle, Gerdeaux & Gillet 1983a, Gerdeaux 1985). Fisheries management plans did not take this change in biological characteristics into account quickly enough and overfishing led to very small catches in 1976-1980 *(Figures 1* and *2)*. This was no doubt one of the reasons why the 1980 Franco-Swiss agreement was drawn up.

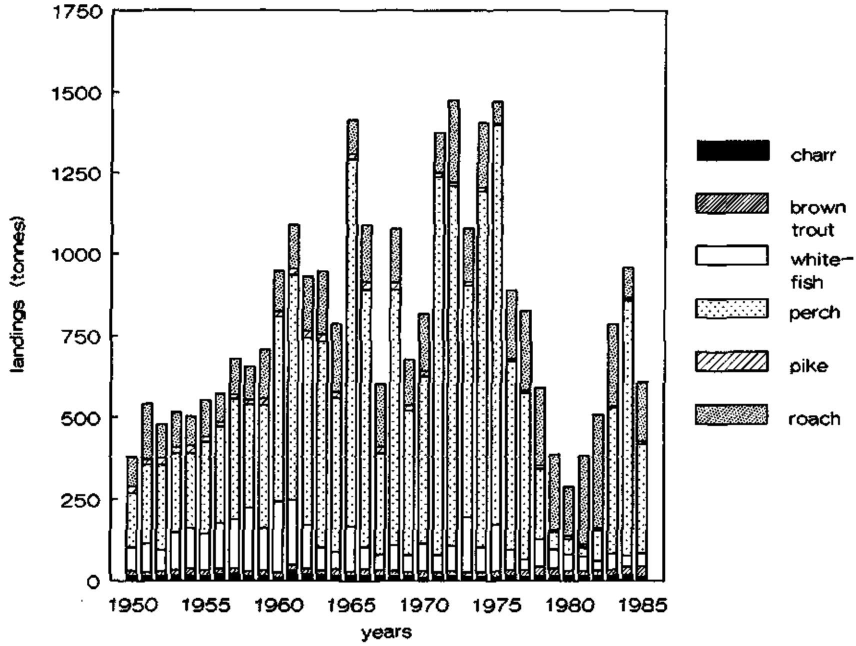

Figure 1. Total catches in Lake Geneva from 1950-1985.

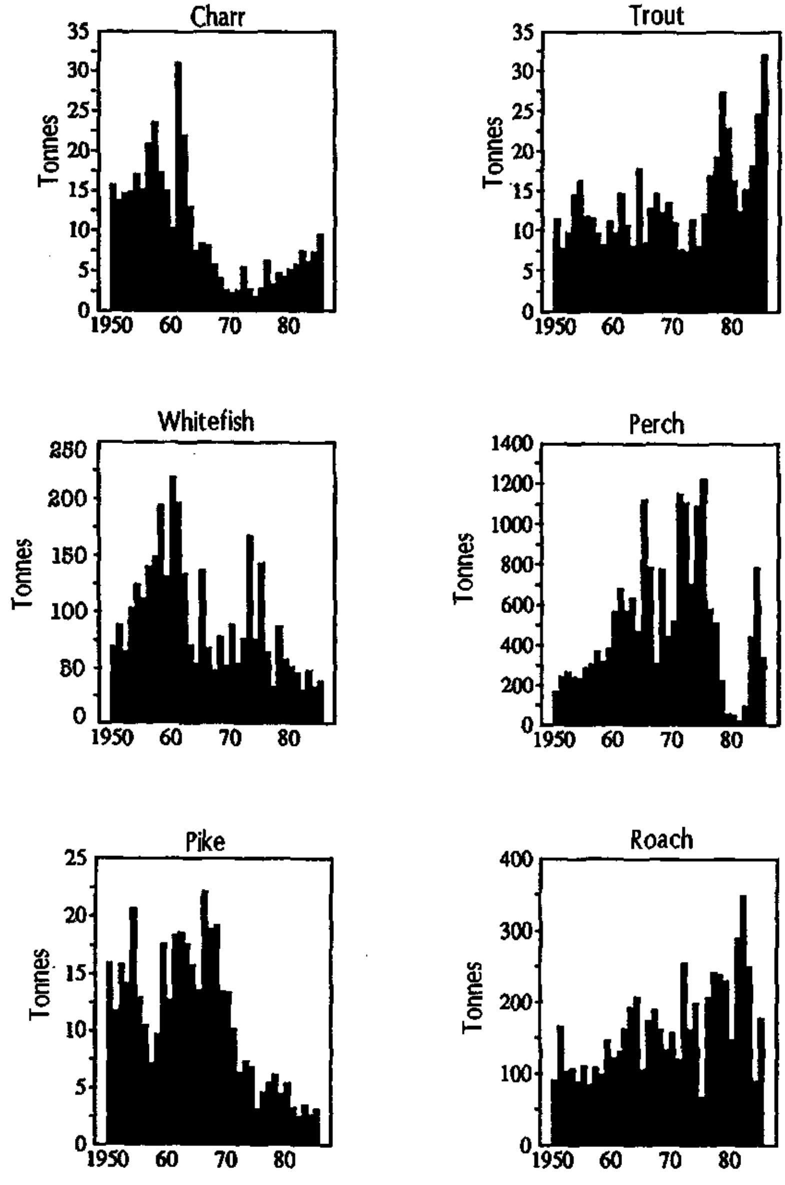

Figure 2. Catches per species in Lake Geneva from 1950-1986.

2. The fish stock of Lake Geneva

Seven of the 23 species currently found in Lake Geneva comprise the bulk of the catches (*Figures 1* and *2*) (Büttiker 1984). Three species of salmonids are fished: lake trout (*Salmo trutta lacustris*), artic charr (*Salvelinus alpinus*) and whitefish (*Coregonus palea*). The first two are indigenous to the lake, while the whitefish were obtained by stocking with Neuchâtel 'palées' in 1923. Roach (*Rutilus rutilus*) is one of the 10 species of cyprinids regularly fished. Bleak (*Alburnus alburnus*), like gudgeon (*Gobio gobio*), is quite sought after in some years. Perch (*Perca fluviatilis*) accounts for more than half the income of Lake Geneva's professional fishermen. Pike (*Esox lucius*) is no longer a sizeable component of present-day catches, although from 1950-1970 more than 10 tonnes were caught annually. Burbot (*Lota lota*) is seldom fished. The other species present in the lake are not actively sought after and represent by-catches only.

3. Fisheries legislation

The first regulations prohibiting the capture of coregonids and perch during spawning seasons, and the capture of fish weighing less than 61 g, were enforced by Geneva magistrates in 1670. These regulations remained in force until the 19th century and it was not until 1880 that the first agreement was signed between Switzerland and France.

3.1 The 1880 agreement

This prescribed size limits measured from the eye to the beginning of the tail, and established closed seasons in order to protect the species during their spawning seasons (*Table 1*). It was amended in 1891, particularly with respect to the provisions concerning closed seasons. In the amended version charr was no longer protected during its spawning season in December!

3.2 The 1904 agreement

This agreement was established in order to correct certain errors contained in the previous one. A simpler method for measuring fish was adopted, the fish being measured from the tip of its snout to the end of its tail fin (*Table 1*). The agreement was denounced by Switzerland in 1910 and terminated in 1912 because of the introduction of a new type of net, the 'pic', or drift net. In 1920 the Swiss government began talks with a view to establishing a new agreement. A joint text was signed by the plenipotentiaries of both states in 1924. The text was ratified by the Federal Chambers that same year, but because of opposition by French professional fishermen, the text was never brought before the French parliament for approval. Thus, between 1912 and 1980, legislation in France and Switzerland developed along different lines. The laws in the two countries did not authorize the same types of net, the same number of nets or the same minimum mesh size for each type. Legal fish sizes differed. The minimum size for salmonids was smaller in Switzerland, and France abolished the minimum size limit for perch in 1960 whilst Switzerland maintained it.

Table 1. Protection methods detailed in the different Franco-Swiss agreements for fishing regulations in Lake Geneva.

Agreement	All species	Trout		Charr		Whitefish		Perch	
	Closed season	Size (cm)	Closed season	Size (cm)	Closed season	Size (cm)	Closed season	Size (cm)	Closed season
1880	15 Apr to 31 May	20	10 Oct to 20 Jan	20	10 Oct to 20 Jan	15	February	15	15 Apr to 31 May
1891		20	1 Aug to 31 Dec	20	15 Feb to 15 Mar	15	15 Feb to 15 Mar	15	May
1904	15 Feb to 5 Mar	25	1 Oct to 31 Dec	20	December	15	15 Feb to 5 Mar	15	15 Feb to 5 Mar
1980		35		27	15 Oct to 15 Jan	30	15 Oct to 15 Jan	15	5 May to 20 May

3.3 The 1980 agreement

Talks which began in 1976, between the federal authorities and the representatives of the French ministries concerned, culminated in the signing of a Franco-Swiss fisheries agreement in 1980. The major provisions of the agreement concerned:

- The expansion of fishing grounds so that recreational fishermen were allowed to fish at any point in the lake.
- The establishment of restocking management plans and steps to control fishing pressure (in particular by limiting the number of fishing permits issued).
- The protection of the fish habitat.
- The monitoring of fishing and the punishment of offences.

Rules provided details regarding:

- Protected areas, where fishing, or any other activity which could endanger the fish habitat, could be prohibited.
- Fishing gear and methods.
- Minimum capture sizes.
- Closed seasons.

A consultative commission was appointed to ensure that the agreement was properly enforced.

3.4 Current regulations

The consultative commission has drawn up an initial five-year plan based on the measures recommended in the agreement. Until 1980, the only fishing data available concerned catches. Fishing effort was not recorded. Fisheries management had no data whatsoever on stock, and very little on the effectiveness of stocking methods. The management principle at the time was to allow the fish to spawn at least once before entering the fishery and to prohibit fishing during the spawning season. A minimum mesh size was set, so that legal capture size would be respected, and fishing gear was prohibited on any site where a species, for which the gear was not designed, was likely to be caught. In order to control fishing pressure, the number of pieces of gear per fisherman and the number of fishermen were limited.

In order to obtain a better assessment of the fishery, efforts have been made to collect data on catches per unit effort. Both professional and recreational fishermen have to record their catches daily. Research is being carried out jointly in order to improve salmonid fry production and to assess stocking efficiency. The consultative commission set up working parties to look into management planning and fishery research. A third working party has been appointed to deal with legal matters.

4. Fishing methods

With very few exceptions, having to do with tradition, the same types of gear are used throughout the lake.

4.1 Nets

4.1.1 Seine-type drag nets

The 'monte' net is 20 m high, with a sweepline 80 m long and a bag 17 m deep. Mesh size must be at least 35 mm and at least 23 mm in the bag. It may be used between the shore and the edge of the shelf, and the bottom of the bag may not be lifted aboard the vessel until some of the fish have been allowed to slip through the netting. This net takes mainly perch.

The 'grand filet' is 40 m high; the sweepline is 120 m long (mesh 40 mm) and the bag is 25 m deep (mesh 35 mm). Its use is prohibited in the in-shore zone during the perch spawning season, and also over the entire lake during the closed season for salmonids. It is currently used by fewer than 10 professional fishermen for the capture of pelagic fish, trout and whitefish.

4.1.2 Floating gill-nets with a single wall of netting

The large 'pic' nets are 20 m high and not more than 120 m long with a 48 mm mesh. Not more than 12 nets may be strung together. The upper strengthening rope must be at least 3 m below the surface of the water. They are used off-shore except during the salmonid closed season. They are set in the evening and hauled early in the morning. They too, like the 'grand filet', take trout and whitefish and, quite often, roach.

4.1.3 Bottom set gill-nets with a single wall of netting

There are five different types, depending on the species to be caught *(Table 2)*.

Table 2. Different types of bottom set gill-nets used in Lake Geneva.

Type	Height (m)	Max length (m)	Minimum mesh size	Prohibited	Target species
Small 'pic' net	4.2-8.0	120	40 mm	Salmonids closed season	Charr, pike
'Redalet'	<4.2	100	32 mm	Salmonids closed season	Charr, whitefish
'Menier' for perch	<2.0	100	23 mm	Bottoms <45 m deep 5-30 May	Perch
Lift net	<3.0	100	48 mm	Authorised 16 Jan-31 Mar	Trout

Table 3. Amount of gear permitted to different types of fishermen on Lake Geneva.

	Professional fishermen		Recreational fishermen	
	Large scale	Small scale	Using gear	Trolling
'Grand filet'	1	-	-	-
'Monte'	1	-	-	-
Large 'pic'	6	3	-	-
Small 'pic'	4	2	1	-
Lift net	3	-	-	-
'Redalet'	10	5	-	-
'Menier' for perch	10	5	1	-
'Sardinière'	10	5	1	-
Trammel	8	4	-	-
Pot	6	3	1	-
Lines	3	3	3	3
Trolling line	4	4	4	4

4.1.4 Bottom set gill-nets with a triple wall of netting

The trammel net is 2 m high and 100 m long (mesh not less than 23 mm). It is sometimes set on bottoms at depths of 150 m or more to capture burbot.

4.2 Traps

The only trap commonly used on Lake Geneva is the pot trap for capturing perch. It is not equipped with wings. The netting mesh size is set at 23 mm. Total pot volume must not exceed 4 m^3 and pots must not be set during the closed season for perch.

4.3 Lines

Bottom fixed lines are not often used on Lake Geneva. Traditional floating lines with up to 6 hooks are allowed. Trolls, shotted or unshotted, are dragged behind vessels. They can have up to 20 lines to which artificial or natural bait is set. Troll lines trailed behind the vessel cannot exceed 200 m in length and must not extend out more than 50 m on either side of the vessel's axis.

4.4 Number of nets, gears and lines allowed

Each category of fisherman is allowed a maximum number of gears and nets *(Table 3)*.

5. Different categories of fishermen on Lake Geneva

5.1 Professional fishermen

Two types of fishing licences are issued, large-scale and small-scale. The former are issued to those actively engaged in fishing, while the latter are issued to retired fishermen, who continue to fish, but only on a small scale. The large-scale fishing licence can only be obtained by the sons of former holders. In France, only professional fishermen are allowed to market their fish (in Switzerland any fisherman can sell his catch). The number of professional fishermen is steadily declining and their average age is increasing since few young people are interested in fishing as a career *(Figure 3)*.

5.2 Recreational fishermen

Recreational fishermen can obtain, either a trolling licence, or a licence to fish using a floating or bottom set line, but not a troll. Capture of certain species is limited: perch up to 80 fish per day, trout up to 8 fish per day and 250 per year, and charr up to 10 per day and 250 per year. There are no restrictions on other species.

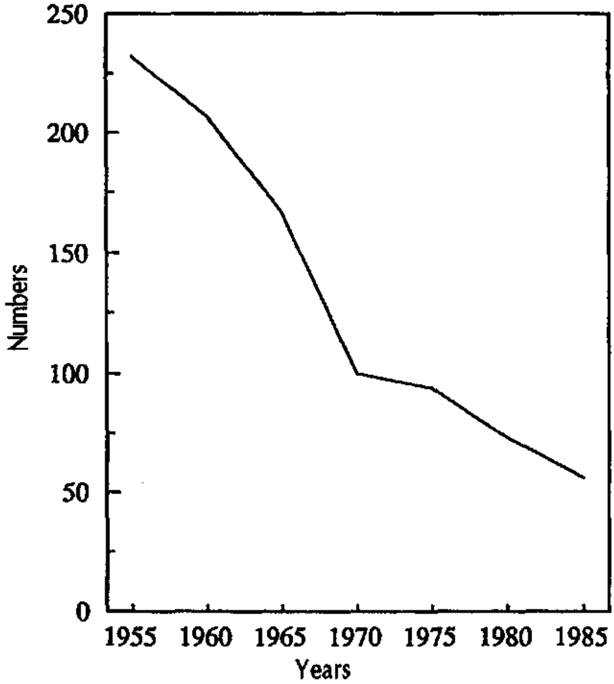

Figure 3. Number of 'large-scale' fishing licences issued on the French side of Lake Geneva from 1955-1985.

6. Fish protection

Since there are regulations governing net and pot mesh sizes, and when and where they may be used, the minimum legal capture sizes and the breeding seasons of fragile species such as salmonids and percids *(Table 1)* are usually respected. Fishing is prohibited during the salmonid and percid breeding seasons. The perch breeding season varies depending on the water temperature, and spawning may not take place during the closed season. When this happens the closed period is altered. A prefectoral order was issued in the past, in France, to take account of the effect of climatic changes on fish biology. Of a total shoreline of 167 km, only a few kilometres are permanently closed to fishing.

7. Estimating catch

All professional and recreational troll fishermen have to record their catches. Professional fishermen have to complete a separate form for each species caught each month.

The forms are issued by Agriculture Department offices and must be returned to that office at the end of each month.

A fishing book is issued to recreational fishermen when they receive their licences. In this book they record the dates of catches and the numbers of fish of protected species (perch, charr or trout) caught. A fisherman may be charged with an offence if he does not record his catches *(Figure 4)*. Fishermen must return their fishing books to the authorities at the end of each year. Failure to provide catch statistics will result in the licence being withheld the following year.

Month:																																		
Days	Perch								Trout								Charr										Total per day in kg							
	numbers								numbers								numbers										Trout	Whitefish	Charr	Burbot	Perch	Roach	Pike	Others
	10	20	30	40	50	60	70	80	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	9	10								
1																																		
2																																		
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5																																		
28																																		
29																																		
30																																		
31																																		
Monthly total																																		

Figure 4. An example of a page from a record book belonging to a recreational fisherman.

From the fisheries management point of view these data are unfortunately far from complete. They are, first of all, a means of monitoring captures of protected species. Fishing effort can only be estimated. Where recreational troll fishing is concerned, mean fishing effort is half a day, bearing in mind the time it takes the vessel to reach the fishing grounds and the time taken to set the troll (drag) net. Daily fishing effort cannot easily be obtained for professional fishing. Perch, for instance, can be fished with 3 different types of gear, 23 or 26 mm mesh 'menier' nets, pots or seines. Fishing effort for salmonids is easier to control. Coregonids are almost always fished by means of 'pic' nets which are always set in groups of 6 and left overnight, so that fishing effort is in this case very constant. Further scientific monitoring, *e.g.* age and size classes of captured fish, should lead to more accurate assessments of stocks, and the use of improved management methods. Stocking and egg collecting are ways of obtaining further data.

8. Stocking methods

Egg incubation and fry rearing establishments, located on the lake shore, are mainly involved in stocking the lake with salmonids *(Table 4)*.

A number of exotic species were introduced to Lake Geneva in the early part of the century, but the authorities are now trying to stock fish from the lake itself. Each year both countries organize captures to collect the eggs from the lake's natural spawners. Lake trout move to the tributaries to spawn and, every year, a trap is set on the Aubonne, a Swiss tributary. The eggs are collected and the fish are tagged and monitored (Büttiker, Matthey, Bel & Durand 1987). Lake trout fry is difficult to raise in fish culture stations and the stock kept is therefore small, despite which it still provides a substantial quantity of eggs. Future efforts will focus on stocking larger quantities of fry obtained from Lake Geneva spawners.

Table 4. Stocking effort (numbers) in Lake Geneva from Switzerland and France 1982-1985.

	1982	1983	1984	1985
Trout				
Rainbow trout (6 months)	221 088	231 629	120 841	111 649
Rainbow trout (1 year)	-	-	20 638	5 000
Brown trout (fry)	10 585	11 285	-	6 100
Brown trout (yearling)	933 979	1 493 957	911 381	916 834
Pike				
Fry	549 007	941 300	828 247	-
Pickerel	-	10 000	5 000	-
Whitefish				
Fry	24 953 744	14 737 422	27 500 787	11 484 636
Yearlings	6 425	31 695	21 300	70 488
Arctic charr				
Fry	19 600	43 800	112 000	-
Yearlings	456 460	453 280	289 434	306 388

Charr spawning grounds are small and well known, and professional fishermen are allowed to set their nets there (Champigneulle, Gerdeaux & Gillet 1983b). The nets are always hauled in the presence of a warden or fish culture technician. The eggs are taken from the mature individuals, and those charr which are not mature when captured are transferred to the fish culture station if their condition permits. The 2164 charr captured on the French side in 1987 provided 829 000 eggs. Of these, 254 150 were taken from females kept in the fish culture station until maturity. Data collected over the past five years has helped to improve the charr fishery. The increase in mesh size improved the sex ratio in favour of females. Also, fewer males are killed even though male mortality exceeds female mortality. Nets can only be left for one night instead of two, and unripe females can be kept in fish culture stations. More eggs are being collected as a result of these measures. Previously the yield was 800-1300 eggs/kg of female captured. It is now 1400-1500 eggs/kg. Scientific monitoring of both charr and coregonid fisheries is made easier by the fact that when these species are captured during the closed season, they must be marked on the operculum or they cannot be sold.

Coregonids spawn over the whole of the littoral zone and broodstock are captured by many fishermen. There are three fish collection points. Fish culture technicians or fishing wardens take the eggs from gravid females (Gerdeaux 1984, 1986). Unripe female coregonids cannot be kept in fish culture stations. Bibliographic data and studies on egg predation by invertebrates and fish (Gillet 1987) show that egg survival rate is low in Lake Geneva. It will not be possible to know how effective these management methods are until it is known whether stocking has been effective with early fry, with 30 or 60 day old fry, or with yearlings 4 to 6 cm long (Gerdeaux & Dewaele 1986). Larvae rearing is beginning to produce good fry (Champigneulle, Boutry, Dewaele & Maufoy 1986).

Fry have been marked, either by cauterization of the adipose fin or by magnetic marking (Champigneulle & Escomel 1984). The working party on fish culture research is co-ordinating these marking operations as well as data collection. Marked fish have now entered the fishery and initial results show that stocked fish account for a large proportion of captures. This is an indication of the poor condition of charr spawning grounds in Lake Geneva. As a result of eutrophication, oxygen concentrations at the surface of the sediments is inadequate and this accounts for the high mortality rate of embryos (Rubin pers. comm.).

9. Discussion

For joint French-Swiss fishing regulations to succeed, both countries must be prepared to make concessions. Certain points of discussion may be difficult because of different traditions and legislation. Perch is sought by Swiss professional fishermen. Burbot is not fished in Switzerland and salmonids are not as sought after there, as they are in France *(Figure 5)*. Switzerland is currently subsidizing the roach fishery. The catch is to be processed under a food aid scheme for developing countries. Coregonids are frequently found in Swiss lakes, but the market for this type of fish is not as open in Switzerland as it is in France.

France does not allow recreational fishermen to market their catch. This is how French law ensures that the sport remains a sport. Swiss recreational fishermen can market their catch, and recreational fishermen can sometimes obtain a reasonable amount of extra income as a result. The daily catch limitations in force are a means of preventing any over zealousness on the part of these fishermen.

The great advantage of joint regulations is that they make management easier. If fishing gear, legal size limits and collection methods are the same in both countries, and stocking

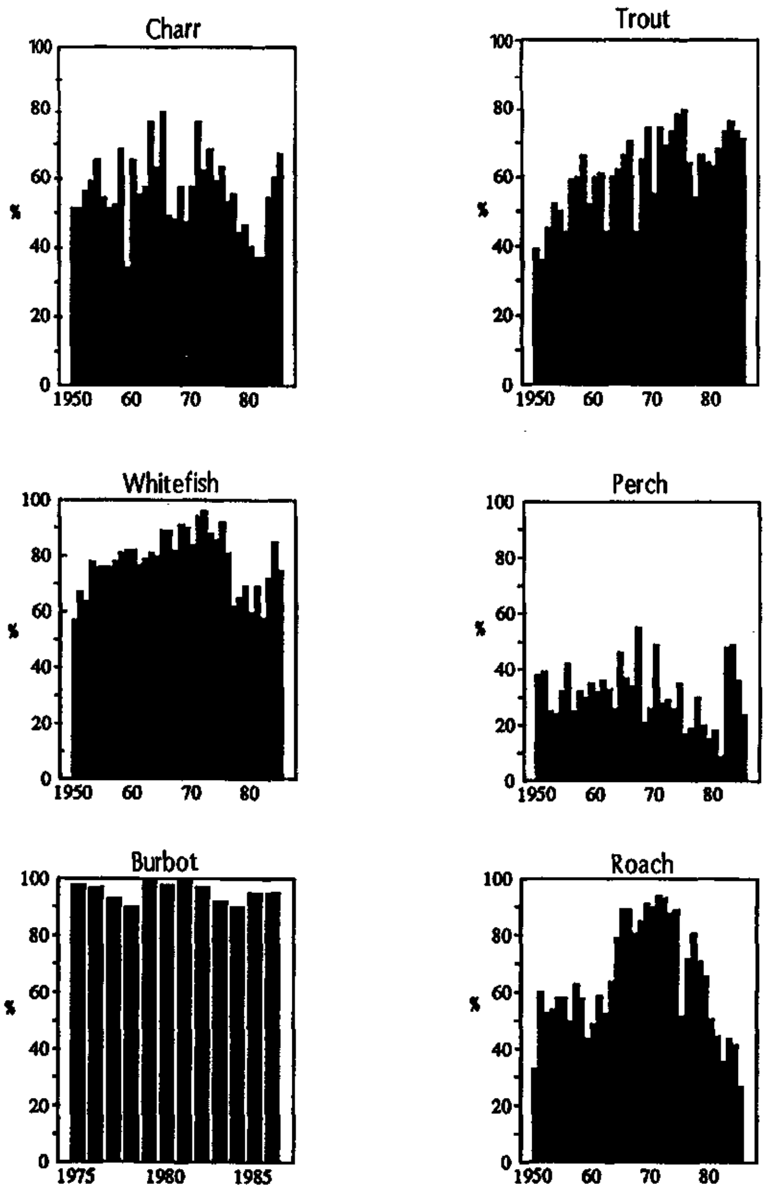

Figure 5. Proportion of the catch caught by French professional fishermen in Lake Geneva from 1950-1986.

is co-ordinated, it will be much easier to assess the fishery. Future five-year management plans could then be based on reliable data.

References

Büttiker, B., 1984. Faune piscicole in CIPEL Le Lac Léman. Synthèse 1957-1982: 315-324.

Büttiker, B., Matthey, G., Bel, J. & Durand, P., 1987. Age et croissance de la truite lacustre *(Salmo trutta lacustris* L.) du Léman. Schweiz. Z. Hydrol. 49: 316-328.

Champigneulle, A., Gerdeaux, D. & Gillet, C., 1983a. Les pêches de géniteurs de corégone dans le Léman français en 1982. Bull. Fr. Piscic. 290: 149-157.

Champigneulle, A., Gerdeaux, D. & Gillet, C., 1983b. Les pêches exceptionnelles d'ombles et de corégones dans les eaux françaises du Léman en 1982. Rapport I.L. 83-6. 15 pp.

Champigneulle, A. & Escomel, J., 1984. Marquage des salmonidés de petite taille par cautérisation de l'adipeuse ou ablaytion des deux pelviennes. Bull. Fr. Piscic. 294: 52-58.

Champigneulle, A., Boutry, E., Dewaele, P. & Maufoy, C., 1986. Rearing larvae of lake coregonid fishes in France. Preliminary data on the production in small ponds, illuminated cages and tanks. Arch. Hydrobio. Beih. Ergebn. Limnol. 22: 241-264.

CIPEL. 1984. Le Léman. Synthèse 1957-1982. 650 pp.

Gerdeaux, D., 1984. Statistiques des pêches exceptionnelles de corégones dans les eaux françaises du Léman en 1983. Rapport I.L. Thonon 16-84. 12 pp.

Gerdeaux, D., 1985. Statistiques des pêches exceptionnelles de corégones dans les eaux françaises du Léman en 1984. Note sur la croissance du corégone. Rapport I.L. Thonon 20-85. 10 pp.

Gerdeaux, D., 1986. Statistiques des pêches exceptionnelles de corégones dans les eaux françaises du Léman. Rapport I.L. Thonon 26-86. 5 pp.

Gerdeaux, D. & Dewaele, P., 1986. Effects of the weather and artificial propagation on the catches in the lake Leman coregonid fishery. Arch. Hydrobiol. Beih. Ergebn. Limnol. 22: 343-352.

Gillet, C., 1987. Etude de la survie des oeufs de corégones dans quelques lacs à différents degrés d'eutrophisation. Rapport I.L. Thonon 87-34. 8 pp.

Lang, B. & Lang, C., 1983. Effets combinés de la pêche et de l'eutrophisation sur la perche *(Perca fluviatilis* L.) dans les eaux vaudoises du Léman. Schweiz. Z. Hydrol. 45: 480-494.

Laurent, P.J., 1972. Lac Léman: Effects of exploitation, eutrophication, and introductions on the salmonid community. J. Fish. Res. Bd Can. 29: 867-875.

Matthey, G., 1975. La pêche dans les eaux vaudoises du lac Léman. Schweiz. Z. Hydrol. 37: 200-212.

Ponton, D. & Gerdeaux, D., 1987. La population de Gardons du lac Léman en 1983-1985. Structure en âge, déterminisme du recrutement, analyse de la croissance. Bull. Fr. Piscic. 305: 43-53.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 182-189.

Stock restoration of migratory salmonids in the River Orne, Lower Normandy, France

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Abstract

Management for the restoration of stocks of migratory salmonids (Atlantic salmon and sea trout) has been carried out on the River Orne since 1981. This coastal river is 175 km long.

The management activities taken to date have sought to re-establish salmonid populations which are able to tolerate an active sport fishery in the river. This is important to the development of tourism. Attempts to enhance the stocks are based on the restoration of the smolt producing capacity of the river basin.

The project was formulated after hearing the requirements of local communities and evaluating the potential of the basin. Facets of the programme implemented to date deal with ecosystem, the migratory populations and the setting up of administrative rules to permit resource development and management. Good public relations are developed through local information and educational campaigns focussing on 'discovering the river'.

Résumé

La restauration du stock de salmonidés migrateurs, saumon atlantique (*Salmo salar* L.) et truite de mer (*Salmo trutta* L.) a été entreprise depuis 1981 sur l'Orne, fleuve côtier long de 175 kilomètres.

L'ensemble des actions développées vise à rétablir sur ce cours d'eau un cheptel pouvant servir de support à une pêche sportive active, dans un objectif touristique. L'accroissement du stock de migrateurs est recherché par un restauration de la capacité de production en smolts du bassin. Après une définition du projet, basée sur la demande formulée par les collectivités locales et sur une évaluation du potentiel du bassin, le programme engagé comprend des opéations en faveur du milieu, des interventions sur le peuplement de migrateurs, ainsi que la mise en place de dispositions réglementaires de nature à garantir le développment et favoriser la gestion de la ressource.

La valorisation de ces actions est également entreprise auprès du public à travers des structures d'information et d'animation locales axées sur la découverte de la rivière.

1. Introduction

Since 1981, the River Orne has been the object of a programme for restoring stocks of Atlantic salmon *(Salmo salar)* and sea trout *(Salmo trutta)* for touristic and recreational purposes. The project, which is being co-ordinated by the Conseil Supérieur de la Pêche, aims to promote sport fishing, but also to make the public and users of the river aware of the richness and vulnerability of the aquatic environment. Fishing in the Orne basin is practised exclusively by amateur anglers, who belong to 17 officially recognised associations (Associations Agrées de Pêche et de Pisciculture). The development plan for the River Orne aims to implement actions which take into consideration the diverse uses made of the river.

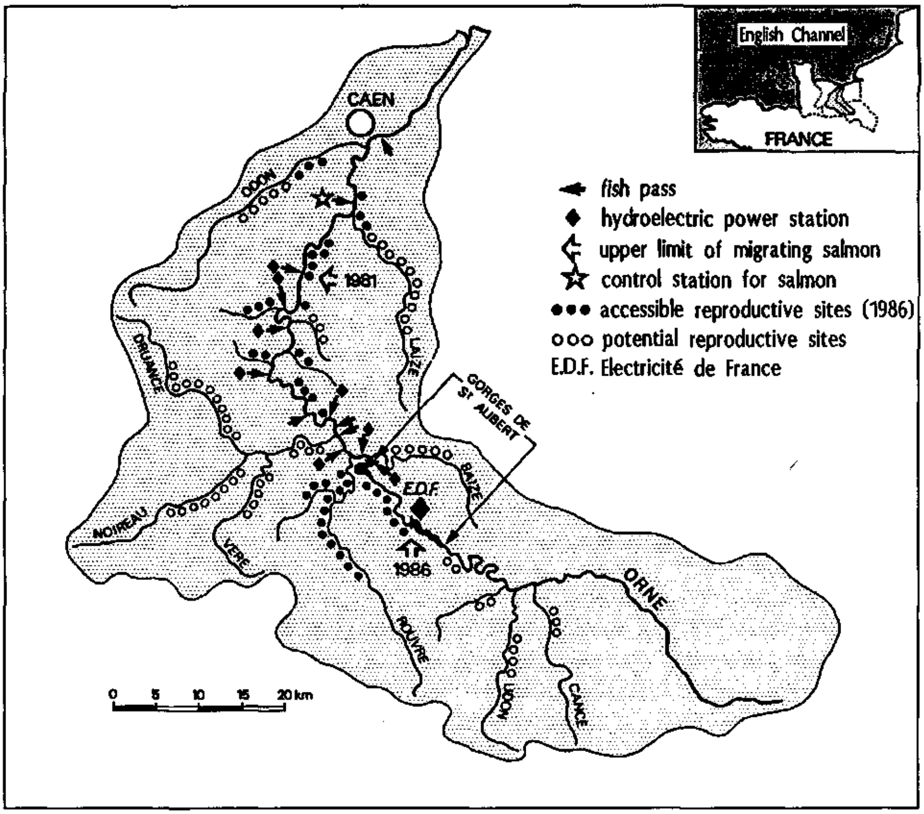

Figure 1. The Orne Basin. Location and recovery of the spawning areas of juvenile migratory salmonids.

2. Description of the environment

The Orne is the most important coastal river of Lower Normandy. It is 175 km long and flows into the Baie de la Seine near Caen. It has a catchment of 2900 km^2 comprising sedimentary (upstream and downstream) and primary formations of predominantly impervious rocks (schist, granite). Because of the stratified nature of the substratum, the middle course of the river is marked by a steep change in the gradient at the Saint-Aubert Gorges *(Figure 1)*. In this granite area, the slope reaches 8%, whereas the average overall slope of the river bed is just 1.1%. The mean annual rate of flow is 22 m^3/sec. This contrasts with a low water flow of only 2-3 m^3/sec.

Atlantic salmon have long frequented the River Orne, but the increasing pressure of human activities on the course of the river led to their disappearance in 1935. Before the nineteenth century, some forty dams and weirs transformed the 80 km downstream reach into a succession of mill ponds. The principal spawning areas for salmonids were therefore located some 100 km from the coast, in the steep areas of the river and its two main tributaries, the Rouvre and Noireau. From the end of the nineteenth century, industrial activity (factories, mills) developed along the valley, as a result of investment to upgrade the infrastructure of the river (building dams, installation of water driven turbines). From 1930-1960 several hydroelectric impoundments have been built on the river, among which the Rabodanges Dam submerged a number of traditional salmonid spawning areas *(Figure 1)*.

In the last few decades there have been new and different uses of the river. Although there is no industrial activity in the downstream area, approaching Caen and the bay, the French Electricity Board (EDF) uses the water in 7 autonomous hydroelectric plants, each producing falls ≤ 4 m in river level, and at the Rabodanges Dam which creates a 49 m fall. These developments influence the flow of the river, even though the majority of the old dams are no longer used.

The Orne has been used for the abstraction of drinking water for urban communities in the downstream area since 1976. In order to preserve this new function, the Water Board for the Seine-Normandy region (l'Agence de l'Eau Seine-Normandie) implemented a 'Quality Objective'. Finally, leisure and tourist activities related to the river have been developing in the Orne valley during the last decade. The expansion and evolution of new uses for the river and its water are thus leading the aquatic environment in a new direction.

3. Programme for development

In 1980, a combination of factors led to the promotion of the migratory salmonid programme for the river Orne. A biological study of the sea trout populations in the area, carried out on behalf of the Ministry of the Environment, revealed the presence of large-sized fish in the river, which prompted the Regional Association for the Orne Valley (Syndicat Intercommunal de la Vallée de l'Orne), to ask for the implementation of a programme to develop a sport fishery for migratory salmonids. This, to enhance the tourist potential of the valley.

Historically, it was known that salmonids were once abundant in the river and that their stocks had been severely depleted by human intervention, and it was clear that they could not be increased until the capacity of the basin for smolt production was restored. An analysis showed quite decisively that only 11% of the potential spawning and nursery areas for juvenile salmon (an estimated total of 57 ha) could be reached by spawners ascending the river because of obstacles barring their way.

3.1 Improving the environment

Three measures have been taken to improve the potential for producing juvenile salmon in the catchment:

1. The free passage of migratory fish has been restored. Between 1981 and 1986 14 fish passes were constructed in the River Orne, restoring access to most of the original reproductive sites up to about 100 km from the coast. Further, guiding systems have been installed which allow both smolts and adults, migrating downstream, to pass hydroelectric power stations safely, avoiding death in the turbines.
2. The influence of hydroelectric power stations has been reduced. The application of statutory regulations of 1980 and 1981 made it possible to constrain the influence of 7 power plants by imposing a complete ban on discharging water through the sluices, by imposing minimum flow rates downstream from power stations, and by occasionally stopping power generation during periods of low water in order to guarantee a continuous minimum flow. For the section of the river located between the dams of the French Electricity Board (EDF), which is presently subject to critical hydraulic conditions (lack of minimum flow), a special enterprise enabled the environment for juvenile salmon to be improved by enabling minimum flows ranging from 0.2 to 3 m^3/sec *(Figure 2)*. The restoration of minimum flows close to optimum should guarantee the passage of salmonids through this 10 km stretch of the river.

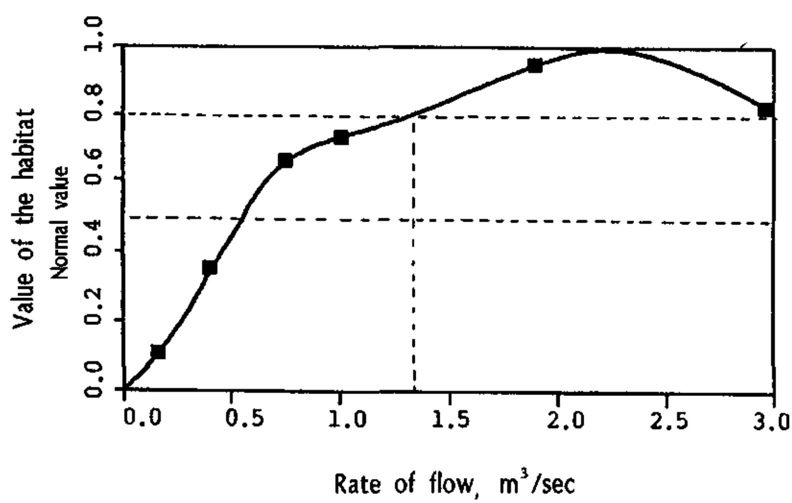

Figure 2. Development of the quality of the habitat for juvenile salmon in the Orne, downstream from the Rabodanges dam of EDF for minimum flows ranging from 0.2 - 3 m^3/sec.
The value of the habitat for juvenile salmon is obtained for a flow rate by balancing the surface areas of the production habitats, expressed in % of the total surface area of the water, against the preferences of this species for each habitat (after Baglinière & Champigneulle 1982, 1986).

3. Spawning grounds and nursery areas for salmon have been developed (recovered) and protected. The quality of spawning grounds has been improved by cleaning and maintenance works. In addition, the planned removal of several disused weirs should lower the water level in the areas with highest natural gradients and produce new spawning areas. Further, in order to preserve the spawning capacity of one of the

principal tributaries, the River Rouvre, a statutory order concerning the protection of the biotope now prohibits all planning activities (notably agricultural hydraulics) in that river. Similar measures are being considered for the principal breeding sites in the main basin.

3.2 Measures concerning the fish stock

Direct measures to influence the population of migratory fish have been taken since the beginning of the 'Orne programme'. The numbers migrating upstream each year are monitored by trapping adult fish at the control station 23 km from the sea. These data enable precise characterisation of the sea trout population by scale analysis and morphological sexing. Currently 600 to 1000 individuals of large average size (60 cm/3 kg) are monitored annually. The biological cycle is short, 85% of 1-year old smolts return after 1 or 2 winters at sea. Their growth is rapid so that they already average 53 cm in length and 2 kg in weight at a 1+ sea age, and perhaps as much as 69 cm in length and 3.7 kg in weight at 2+ sea age *(Figure 3)*.

Young stock have been planted on a number of occasions now. The first experience of re-introducing salmon, limited to a single breeding stream, resulted in an initial return of mature salmon in 1984 (ratio of returns smolt/adult 5.2 %), whereas the release of 200 000 young fish in 1984 resulted in a return of more than a hundred adults in 1986-1987. In order to improve the colonization of the river system a five-year stocking programme is planned for the years 1989-1993. Between 100 000 and 150 000 young fish will be used over 4-6 months each year. To this end it is planned to collect sea trout eggs at the control station.

3.3 Legal measures

These moves to improve both the environment and the population of migratory salmonids are reinforced by legal measures which assist the programme and the management of the natural resource. Because of the results achieved in the Orne, sea trout have been protected by legislation (1985) which prohibits fishing for the vulnerable stages, *i.e.* smolts, immature fish, and adult fish returning to the sea after spawning, and encourages the fishing of adult sea trout. The fishing season is adapted to the upstream migration, 1st May-1st November. The massive catches of sea trout smolts once made in the estuary have also been stopped. Finally, no new hydroelectric plant may be built on the Orne, or its tributary the Rouvre, following a decree of 1984.

4. Financing and perspectives

The measures described are financed jointly by the State (Ministry of the Environment), the local authorities (Region of Basse Normandie and the two departments of Calvados and Orne), the Angling Federations and the Seine-Normandie Water Board. In addition, the proposed development of the fishery resources of the rivers of Basse Normandie, in the period 1989-1993, have been formally agreed between state and regional councils in a plan.

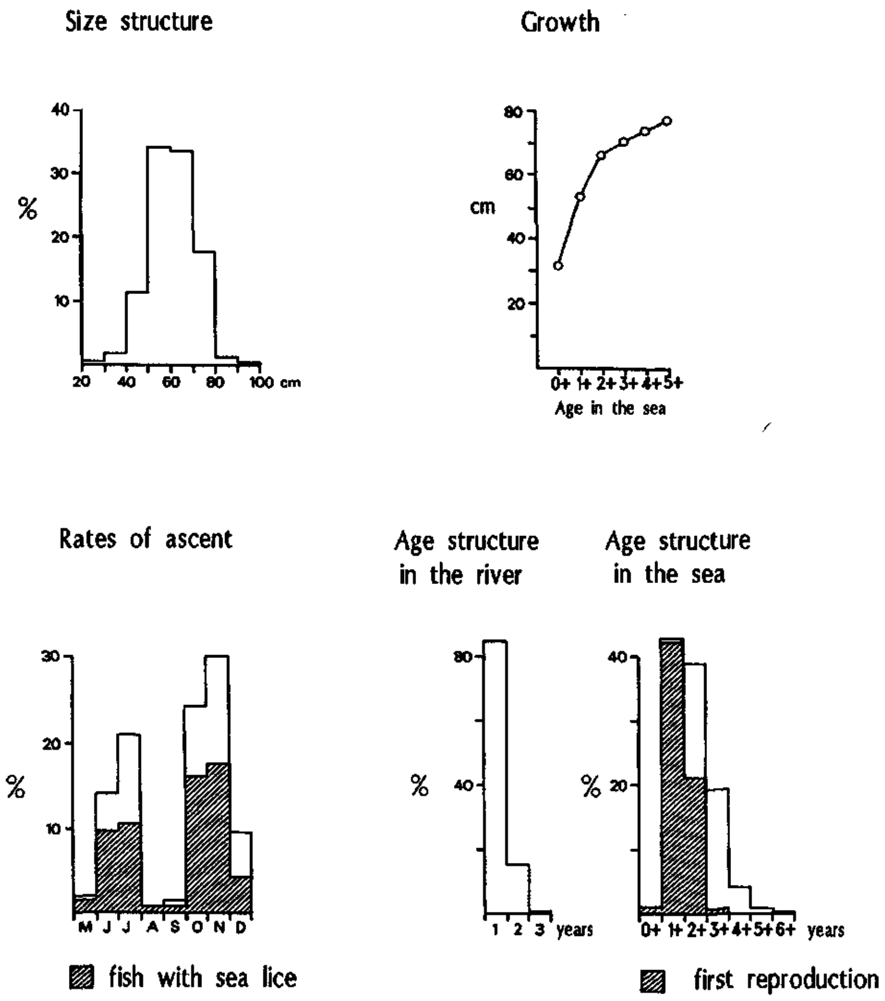

Figure 3. Principal characteristics of Orne River sea trout.

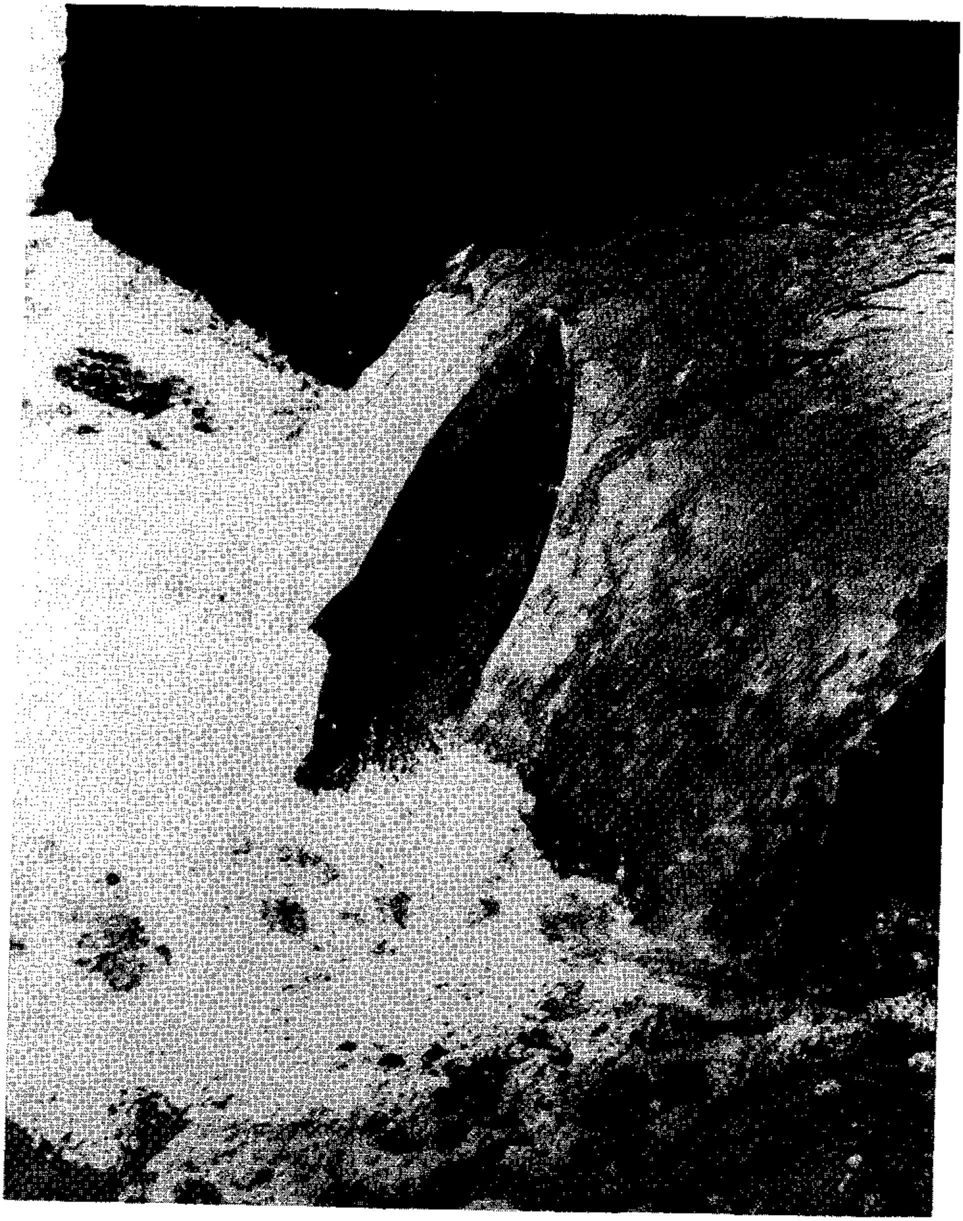

Plate 1. Sea trout (*circa* 5.5 kg) entering fish pass on the River Orne.

The Orne programme is also used to support a broad educational programme which aims to introduce the freshwater aquatic environment to the public. The Permanent Information Centre for the Environment of the Orne (CPIE) has set up an 'itinerary to discover the river' and the public are encouraged to visit the control station for 'upstream migration'. Public support for the return of the migratory salmonids to the river is considered indispensable to the long-term success of the programme.

5. Discussion and perspectives

The programme initiated on the Orne shows the complementarity required between the biological, technical and legislatory domains in the rehabilitation process. On such a watercourse as the Orne, where multiple uses are often contradictory, the success of reintroducing sensitive species such as salmon or sea trout requires the co-operative participation of various parties and the organisations they represent. Without this the programme could not be implemented effectively. The broad consensus developed around the Orne project offered an extremely favourable context in which to pursue the undertaking.

In future, since the restoration of nature is progressing, work will concentrate on optimising the restocking measures, such as improving the quality of the young fish produced, tagging, and monitoring the rate of smoltification in juvenile sea trout. Finally, it is essential that the actions to benefit the migratory salmonids should not be jeopardized by problems typical of the estuary, for instance the mediocre quality of the water or poaching.

References

Baglinière, J.L. & Champigneulle, A., 1982. Densité des populations de truite commune *(Salmo trutta* L.) et de juvéniles de saumon atlantique *(Salmo salar* L.) sur le cours principal du Scorffe (Bretagne): preferendums physiques et variations annuelles (1976-1980). Acta Aecologica/ Oecol. Applic. 3: 241-256.

Baglinière, J.L. & Champigneulle, A., 1986. Population estimates of juvenile Atlantic salmon, *Salmo salar*, as indices of smolt production in the River Scorff, Brittany. J. Fish Biol. 29: 467-482.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 190-214.

Technical aspects of French legislation dealing with freshwater fisheries (June 1984): 'Fisheries orientation schemes' and 'fishery resources management plans'

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Abstract

The latest Freshwater Fisheries Act is based upon three principles, protection of natural freshwater ecosystems, rehabilitation of these systems, and development of fisheries resources with a view to making their recreational and professional exploitation possible. Three administrative levels are involved in meeting these objectives: 1. The river basin level, where a commission coordinates the political and technical decisions. 2. The French 'départe-ment' level, where a working group draws up 'fisheries orientation schemes.' 3. The stream segment level, where 'fisheries resource management plans' are drawn up by the users themselves.

This paper deals with the fisheries orientation schemes and the fisheries resource management plans. The fisheries orientation scheme is the main feature of the system. It comprises; base mapping (1:50 000) of the aquatic ecosystem showing the main constraints and uses of the system and providing basic data on streams and rivers; general thematic mapping (1:250 000 to 1:500 000) based on an analysis of the different components of the aquatic system, including water quality, physical habitat, and fish migration; and mapping of possible objectives to make the work easier for managers and decision-makers.

The management plans include basic data (on stocking practices, captures, trends with respect to the issuing of licenses) provided by the users of the fishery resource. Plan content and complexity will vary depending on the type of ecosystem involved, the quality of the fishery and the objectives defined in the fisheries orientation scheme. These two mechanisms could make better use of data available in different government departments and improve freshwater ecosystem management.

Résumé

La nouvelle loi française relative à la pêche en eau douce pose trois principes: la préservation du patrimoine naturel aquatique, sa réhabilitation, sa mise en valeur par la pêche. Pour satisfaire à ces objectifs, le dispositif administratif prévoit trois niveaux: 1. Bassin fluvial où seront définies les grandes orientations de la politique de gestion. 2. Département où est mise en oeuvre une procédure de 'schéma départemental de vocation pisciole.' 3. Cours d'eau ou tronçon de cours d'eau où seront établis des 'plans de gestion'.

Les deux dernières démarches sont détaillées dans cette communication. Le schéma de vocation piscicole est la clé de voûte de tout le dispositif. Il comprend:

- un biland des informations essentielles souvent dispersées entre plusieurs acteurs: les données de base relatives à la situation administrative et à la connaissance technique et écologique du milieu sont compilées, critiquées, sélectionnées puis cartographiées sur des documents réalisés en noir et blanc à l'échelle du 1/50 000è. Ces cartes constituent le support de base, lien technique des différents échelons gestionnaires et permettent d'apprécier rapidement l'état écologique d'un système aquatique, ses contraintes et son degré de sollicitation.
- une synthèse générale à l'échelle (1/250 000è et 1/500 000è) de chaque département, basée sur un diagnostic écologique et halieutique des différents systèmes aquatiques et representée sur des cartes thématiques.

- une présentation des objectifs de gestion retenus et des actions à mettre en oeuvre.

Le plan de gestion est le document élémentaire établi par le gestionnaire direct de la ressource piscicole. Il droit être conçu pour faciliter la circulartion de l'information entre ce dernier et l'échelon de gestion départmental. Ce titre, il contient l'essentiel des données relatives au peuplement piscicole (état des mouvements), et aux interventions physiques sur le milieu (aménagements de l'habitat). Son contenu et sa complexité seront modulables en fonction des types de cours d'eau et de leur statut, définis dans le schéma de vocation piscicole.

1. Introduction

France's recent Freshwater Fisheries Act No. 84-512 of 29 June 1984 puts forward three basic principles for aquatic ecosystem management (Rural Code, art. 401):

- The protection of natural aquatic systems. This first point is a reiteration of a principle already put forward in the Nature Protection Act (No. 76-629 of 10 July 1976).
- The rehabilation of these systems.
- Their development by means of a well-balanced system of management and the promotion of recreational and professional fishing.

In order to meet these objectives, the Act provided for technical support at 3 levels:

- In each large river basin, a commission will co-ordinate political and technical decisions.
- Fishery orientation schemes will be put into effect in every 'departement'.
- The direct users of the resources will establish fishery management plans for every stream or river.

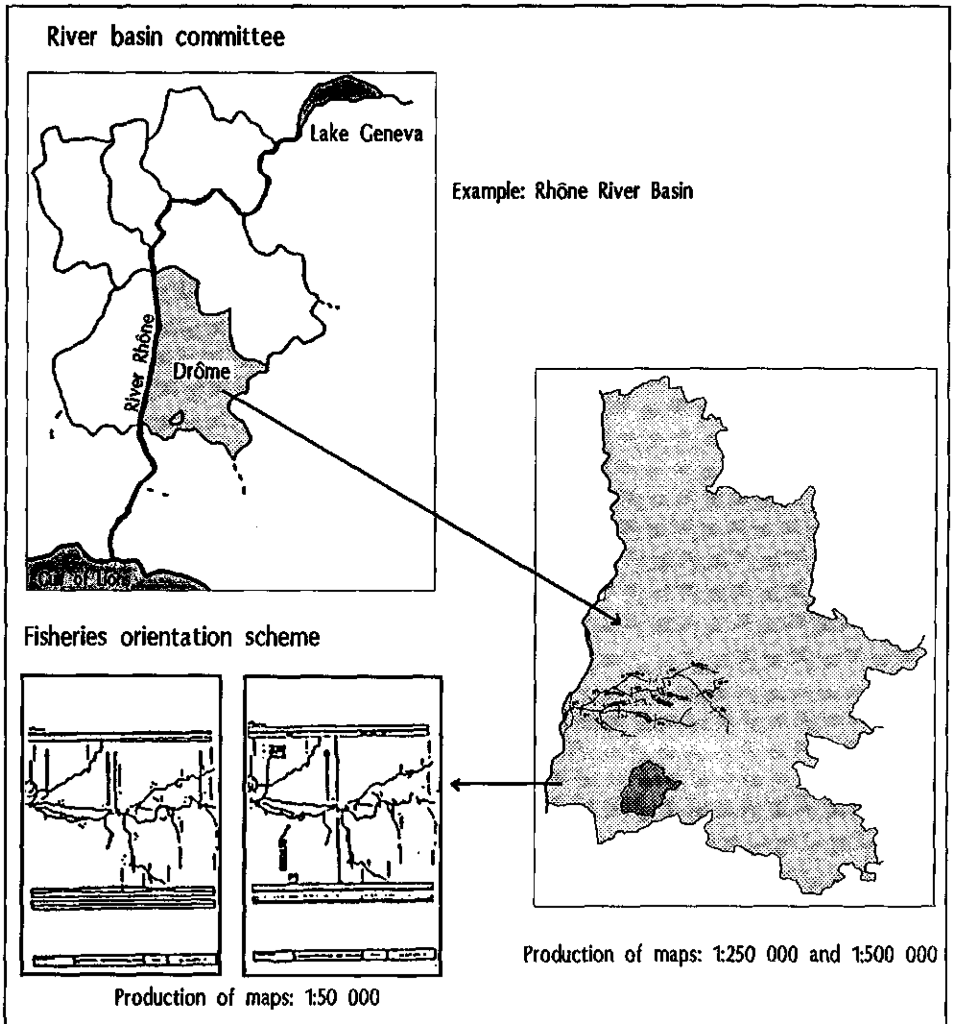
In order to achieve 'balanced management' which is presented as an objective in the Fisheries Act, it is essential to set up methods for analysing aquatic systems throughout France so as to obtain an indication of their 'state of health', and methods for predicting the effect that human activities have on them.

So far, only the first of these mechanisms has been set up. The predictive methods are still being improved and assessed. The findings of the analysis should help the parties concerned to define possible management objectives. The different stages involved are described below. One original aspect of the process is the production of maps. These maps will provide either basic data (scale of 1:50 000) for widespread distribution and use in day-to-day management, or more general data concerning an entire 'département' (scales of 1:250 000 and 1:500 000), which would help in decision making and the definition of objectives *(Figure 1)*.

2. The purpose of the management system

The concept of 'balanced management' in the Act is probably an indication that the legislator wishes to encourage all those involved in aquatic ecosystems management to co-ordinate their actions and respect the systems' potential and sensitivity.

Within the meaning of the Act, the best management method would be one which provides scope for human uses of aquatic resources and at the same time ensures, through a series of decisions and actions, compatibility with the way the system operates, so that the nation's common heritage is maintained.



Management plans

Stream or river	Measures called for
– –	– –
Officer in charge	– –
– –	– –
Presentation	– –
– –	– –

Figure 1. Different levels of French freshwater fisheries management.

Table 1. Principal methods currently used in France to determine the chemical and biological quality of water.

Questions	Ecosystem parameter					Methods and principles	Origin/authors
	Biotope		Biocoenosis				
	Water (chemical)	Physical and spatial parameters (habitat)	Flora	Inverte-brates	Fish		
Chemical quality of water?	*					*Physico-chemical analysis*, interpreted on the basis of the threshold principle	EEC standards National standards
Biological quality?						*Biocoenotic analyses*, comparing the observed stock composition with a theoretical or reference stock composition	
						Qualitative methods	
				*		– Biotic index (mark 1 to 10) BI	Tuffery & Verneaux (1968)
				*		– Overall biological quality index OBQI	Verneaux, Faessel & Malesieux (1976)
				*		– Potential biological quality index PBQI	Verneaux, Faessel & Malesieux (1976)
						Specialised methods	Coste (1976), Desey (1980)
			*	*		– Diatoms, molluscs and oligochaetes	Mouthon (1980), Lafont (1984)
						Fish-based methods	
		Gradient				– Theoretical zonation (gradient rule) qualitative composition of fish population for each zone (trout, charr, burbot, bream)	Huet (1949), Oceanic Europe
	Total hardness	Wetted perimeter				– Theoretical fish stock composition in 10 zones or biocoenoses, and	Verneaux (1977), Doubs River basin (France)
	Tempera-ture	Distance from source			*	– Observed stock compared with theoretical distributions	

Table 2. Some methods for determining standing stock of fish in rivers.

Questions	Ecosystem parameter						Methods and principles	Origin/authors
	Biotope			Biocoenosis				
	Water (chemical)	Temperature	Physical and spatial parameters (habitat)	Flora	Invertebrates	Fish		
Standing stock?							Relations established through regressions between biotopic parameters and fish biomass	
							Methods used with brown trout (*Salmo trutta fario* L.)	
	Calcium		*Gradient*				B (kg/ha = 18.1) I (index of gradient) + 7.3 Ca (calcium index) 3.37	Cuinat (1971) for 50 French rivers (Normandy, Massif-Central, Lower Rhine valley, Basque country)
	* Nitrates	*	*		Food abundance diversity		HQI score (habitat quality index) Index takes into account measured perameters (late summer stream flow, physic- chemical variability cover, water velocity, width) which are then classified arbitrarily	Binns & Eiserman (1979) USA Wyoming (west)
							General models by river	
	Alkalinity	*	Gradient				$B = -295 + 0.19A + 5.72T + 16.8L$ all fish B = absolute biomass of fish community (kg/ha) A = total water alkalinity (mg/l $CaCO_3$) T = mean water temperature, June-July (°C) P = mean gradient (‰) L = mean width (cm)	Philippart (1979) Ourthe, Belgium

Questions	Ecosystem parameter						Methods and principles	Origin/authors
	Biotope			Biocoenosis				
	Water (chemical)	Tem-perature	Physical and spatial parameters (habitat)	Flora	Inverte-brates	Fish		
Productivity?	*		*	*	*	*	**Empirical models** P = BLK P = annual productivity or yield (kg/km) L = mean width of stream B = biogenic capacity (1-10) (expert opinion) K = coefficient of productivity; K_1=f(temperature) K_2=f(acidity) K_3=f(population types) K_4=(age of fish) K_5=characteristic of the impluvium	Léger (1909, Huet (1949), Arrignon (1976)
Carrying capacity ?			*			*	Physical habitat simulation – PHABSIM Instream flow incremental methodology – IFIM – This method combines hydraulic modelling and preferenda functions for fish species – Habitat attributes are analysed over one or several regimes – The method is then put into practice in the stream itself (watershed, anthropisation, physico-chemical factors, thermal limitations?)	Stalnaker (1979) Bovee (1982), Bovee & Milhous (1978)

3. Determining the quality of an aquatic system

This step must precede any other management action. Hubert (1984) rightfully recalls that there is no easy way of determining the quality of aquatic ecosystems. These systems are difficult to analyse, the space and time dynamics operating in them are very complex and the way they work is not always clearly understood since understanding them calls for knowledge of several disciplines (geomorphology, hydrology, hydraulics, biology, ecology, ethology, etc.). Before using existing methods of analysis, it is essential to know how they will respond to different stimuli, how sensitive and how valid they are.

3.1 Methods for determining the quality of aquatic ecosystems

Most currently used methods focus on certain factors such as the suitability of the water for drinking and bathing purposes and as a habitat for fish, and are based on threshold values of certain parameters. Others, including some biocoenotic, floristic and faunistic methods try to provide a more complete view of the influences being exerted on the aquatic system. These methods are particularly useful for measuring pollution. Mention must finally be made of the various theoretical classifications of rivers and streams. These are based on a principle linking abiotic control parameters (geo-morphological and hydrological) with the fauna (invertebrates or fish). Then, in a given case study, physical parameters can be used to predict the theoretical composition and distribution of a fauna, and anomalies in the predictive process can be detected by comparing the actual fauna with the predicted population. These are very general methods, which can only be used in the eco-geographical context for which they were designed. See the work of Huet (1949) and Verneaux (1977).

3.2 Methods for determining standing fish stocks

There are few sufficiently reliable, general methods available. Three methods have been proposed *(Table 2)* using:

1. Simple biomass measurement models, based on linear regressions between physical parameters and biomass observations useable only in the regions where they were tested.
2. Empirical estimates of fish productivity, based mainly on an appreciation of biogenic capacity (Léger 1909, 1945) and an expert opinion.
3. Carrying capacity estimates, this is another method for indirectly estimating fish stocks. It consists of evaluating the spatial or trophic resources of a site on the assumption that habitat and food are the major limiting factors acting on an aquatic system.

The method for estimating the physical carrying capacity of a stream system, described by Bovee (1982) as 'instream flow incremental methodology', is worth mentioning. The habitat is broken down into discrete elements or units at the level of one sample station or biological model and expressed as a measure of habitat preference by species and life stages. By using hydraulic models it is possible to reconstitute habitat parameter distribution at different flows and thus pave the way for retrospective and prospective analyses.

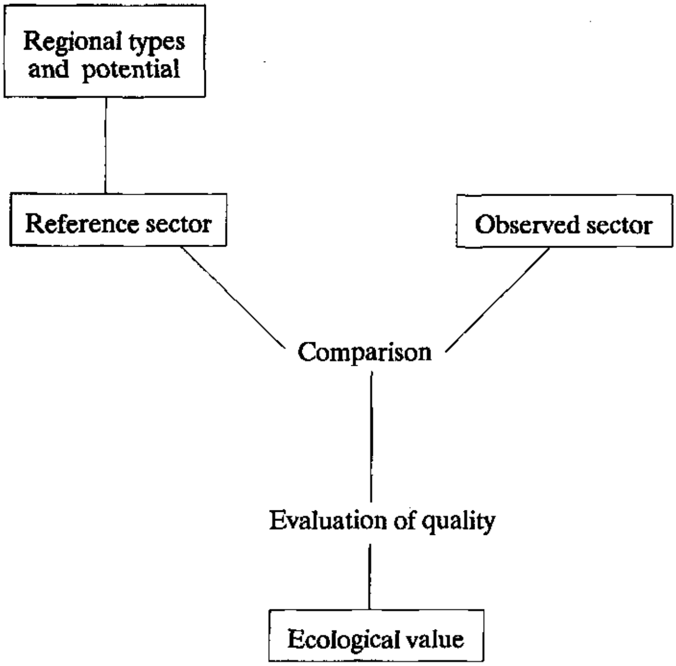


Figure 2. Proposed procedure for assessing ecological value.

3.3 Practical conclusions

In order to comply with the provisions of the Act, answers to two questions must be provided in each case. These concern:

1. Qualitative aspects: Has the ecosystem under consideration preserved its functional integrity. In other words, what is its ecological quality rating? Is it known how this will evolve in time and space?
2. Quantitative aspects: What is its potential as regards fish life and fisheries? Would they be enhanced through fishing?

Given current knowledge of aquatic ecosystems and the methods available, it is not possible to provide satisfactory answers to these questions. Most qualitative methods are not complete in that they focus only on certain components of the ecosystem (*e.g.* water, sediment, fauna). They do not often take account of regional conditions, which are increasingly acknowledged as being important. It is obvious that alpine streams cannot function like streams in the Landes region or in Brittany. It would be useful to try to transpose and adopt the notion of 'ecological region' which exists in terrestrial ecology.

This would enable us to compare a local situation with a regional, reference situation, at the same time taking into account a maximum number of attributes.

The work method recommended in departmental fisheries orientation schemes involves assembling the data available on the different French aquatic ecosystems, assessing them, and collecting fresh data so that it may be possible in the long term to use the procedure shown in *(Figure 2)*.

Since few reference situations are available we recommend proceeding with the help of an expert for each component, to determine the effects which are likely to penalize the sector under observation. Such a procedure would be all the more pertinent since the expert would be experienced in the region and could check his findings against objective measurements of the parameters.

4. Fisheries orientation schemes

4.1 The overall mechanism

The fisheries orientation schemes are co-ordinated at national level by the Ministry of the Environment, the Department for Nature Protection and the Fisheries and Hydrobiology Service. A working party oversees the procedure in every 'département'. The technical side is usually handled by a hydrobiologist who reports to the Agriculture and Forestry Departmental Headquarters (DDAF) and the Federation of Approved Fishery and Fishculture Associations (FDAAPP). Several other bodies also participate, especially services involved in studying the resource, the Regional Water Management Service (SRAE) and the 'Conseil Supérieur de la Pêche' (CSP). *Table 3* shows the overall organization and the role each body plays.

A River Basin Commission will be set up at supra-departmental level to co-ordinate the different measures being carried out on the same ecosystems.

4.2 Major stages in the procedure

Table 4 shows that four major stages are involved.

Stage 1: Current state of aquatic systems

This is the basis of the whole procedure and should provide current data on the aquatic systems and on the demand placed upon them. Since data are dispersed among several partners, they must be assembled and made available to all those involved. A stream map was drawn up for this purpose with the help of the 'Laboratoire de Géologie Rhodanienne' (U.A. CNRS 260) (Souchon, Trocherie, Danière, Bethemont & Martin 1984).

Figure 3 and *4* give examples of the maps (format A4, 21 x 29.7 cm; in black and white) and techniques used. Care has been taken to ensure that the maps are legible and easy to update.

Data are presented on two thematic maps, one dealing with the physical and human constraints relating to the stream (management, administration) and the other with understanding the ecosystem. Each stream is divided into homogeneous segments, which makes defining objectives and actions easier. The information contained in the maps was obtained from archives and verified in the field. Further data were also collected on surmountability of obstacles, spawning grounds, cover, temperatures and electro-fishing. Data which do not appear on the maps are put on card-files which are easy to computerize. The system could be improved by developing a computer programme so that the maps could be prepared directly on the screen. Since all bodies involved in the plan do not possess the same computer equipment, the basic data needed to determine stream

Table 3. Principal bodies involved in the fisheries orientation scheme (see text for abbreviations).

Stage	Principal bodies	Other partners
Co-ordination and monitoring of departmental working party	Agricultural and Forestry departmental Headquarters (Direction Départmentale de l'agriculture et de la forêt – DDAF)	
1. Survey **Status report**		
Management, administration	DDAF DR CSP Regional Water Management service (Service Régional d'Aménagement des Eaux – SRAE) AAPP Departmental Federation AAPP fishing wardens AA professional fishermen	Departmental Headquarters for Equipment (Direction Départementale de l'Equipement) Navigation Service (Service navigation) River Basin Financing Agency (Agence Financière du Bassin) Regional Department of Industry and Research (Direction Régionale Industrie et Recherche).
Environmental information		Universities, National Agronomic Research Institute (Institut National de la Recherche Agronomique – INRA) CEMAGREF
2. Reference systems	DR CSP SRAE	Universities, INRA, CEMAGREF
3. Synthesis	DDAF	
	opinion:	Regional Assembly River Basin Commission Services AAF Federation Nature Protection Associations Chamber of Agriculture Chamber of Commerce and Industry Guild Chamber (Chambre des Métiers)
	deliberation:	Country Council (Conseil général)
	approval:	"Commissaire de la République"
4. Measures and action plan	DDAF FD AAPP AAPP DR CSP	

quality are distributed on paper. Thanks to the maps, by the end of this first stage the working party already has an idea of where the major problems lie.

River police and fishing wardens will also have up-to-date working documents to help them in their daily tasks.

Table 4. Principle stages of the fisheries orientation scheme.

Stage	Documents produced	Comments	Effects
1. Site survey Report on current situation	Maps (scale 1:50 000)	Existing data put to use	First appraisal of major black-spots
		Dispersed data on the aquatic environment assembled and incorporated into maps which are easily accessible and easy to update	
	Files brought up to date		Working tools to help: – river police – fishing wardens
2. Reference systems	Regional typologies	Basis for comparing the observed situation with the theoretical or measured reference situation in terms of degree of disturbance	All theoretical data applicable to local situations Guide to research requirements
3. Assembling data	At departmental level, maps giving an analysis of current situatins: – ecoplogical – fishery	Attention focused on the situation in sectors of the stream	Help with decision-making (categorisation of situations)
	Maps proposing objectives	Options for aquatic ecosystem management	Medium term objectives defined
4. Measures and action plans	May be expressed in map form	Concern: – questions regarding rules and regulations; usually protection measures (bans) – technical questions	Steps taken to meet objectives (order of priority)

Stage 2: Obtaining a better understanding of the system

The fisheries orientation schemes, as mentioned in 3.3, are an opportunity for bringing together all the data available on an entire region for collecting information on aquatic ecosystems about which little or nothing is known. For instance, much less is known about the middle reaches of streams – barbel zone (Huet 1949) – than about the upper reaches – trout zone (Huet 1949).

Stages 3 and 4: Assembling data at departmental level: objectives and actions

Documents assembling the major findings of the aquatic systems analysis at departmental level must be drawn up for submission to the department's elected representatives who will establish the objectives. The data must be organized under the two headings mentioned in the Act, the ecological value and fisheries value, which also includes the value to fish. Thematic maps would show:

- Quality:
  - Ecological quality (degree of disturbance in the system's various components based on factors such as water quality, habitat and fish movements would be shown on a separate map).
  - Fisheries quality: current angling pressure, fish population; biomass of fishable fish.
- Potential:
  - Ecological, when reliable data exist.
  - Fishing, bearing in mind the factors influencing fishing activities: proximity of large towns and river accessibility.
- Objectives:
  - General, demonstrating the will to close the gap between the actual and the potential situation.
  - Specific, focussing on improving water quality and habitat.

Managers have a wide range of measures at their disposal: statutory measures, pursuant to the freshwater fisheries Act or nature conservancy by-laws, direct technical interventions (*e.g.* water purification) or monitoring (knowledge of the resource, angling pressure, catches, etc.).

Only when the initial analysis of the quality of the ecosystem has been properly carried out, *i.e.,* all available data has been compared and assessed, following the logic of the ecology of the river system and distributed to as many partners as possible, can the *fisheries orientation schemes begin to play their true role, i.e. provide the framework for* ecosystem management. The orientation schemes should provide more complete evaluation of the quality of inland aquatic systems than that provided by previously used procedures which focussed only on certain factors such as water quality.

Finally, they should help draw attention to the fact that we need to perfect our understanding of aquatic systems, particularly as regards fish distribution, space-time dynamics and the way the systems operate productivity. They could also serve as a useful framework within which a series of measures (data collection, the monitoring of the effects of actions undertaken) could be drawn up in an attempt to achieve a more objective management system.

5. Fisheries management plan

Fisheries management plans are prepared by the person exploiting the resource. The plans were provided for in the Act, but the administrative authorities must first define exactly what they should comprise. During this preparatory phase some twenty pilot plans will be tested. They have been specially chosen to represent the wide range of existing situations and different types of aquatic ecosystems. We shall deal here with technical factors to be taken into account. The management plan must not be seen as a

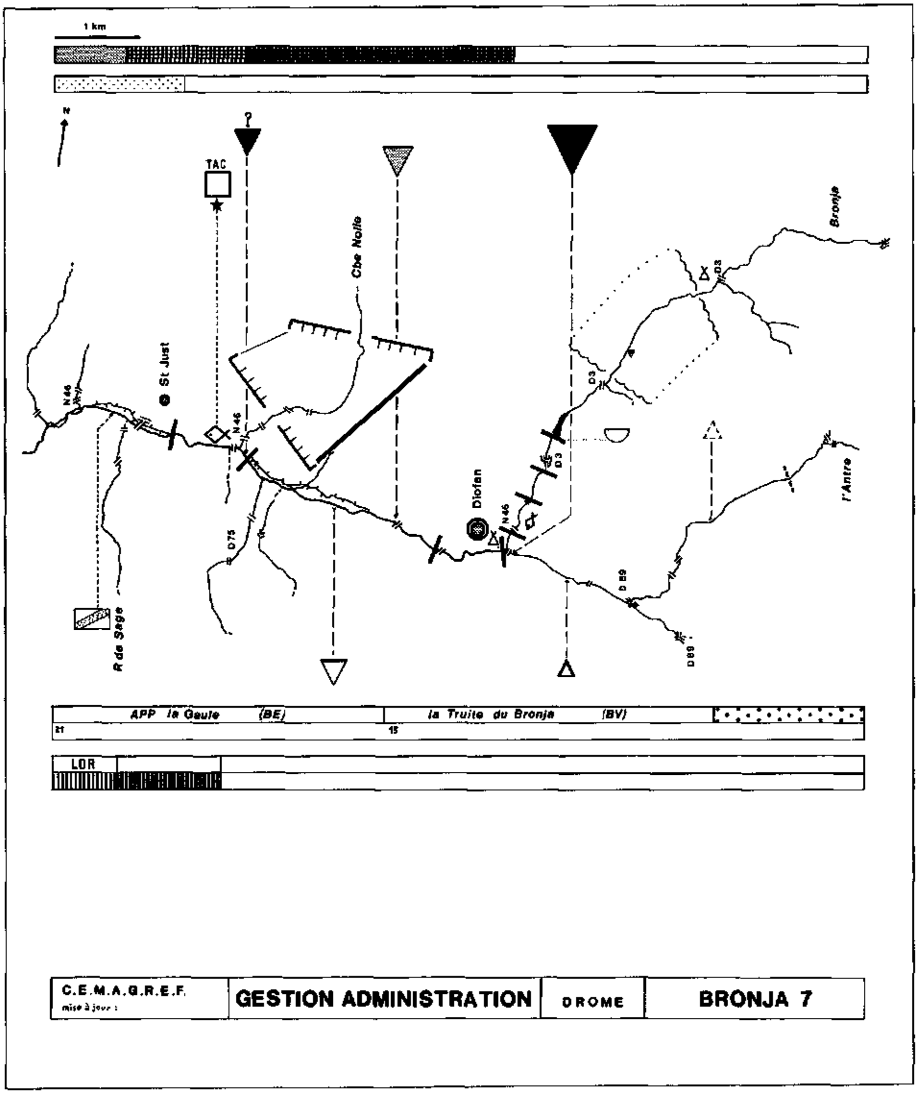


Figure 3. Current management map showing uses and constraints (taken from a 1:50 000 map).

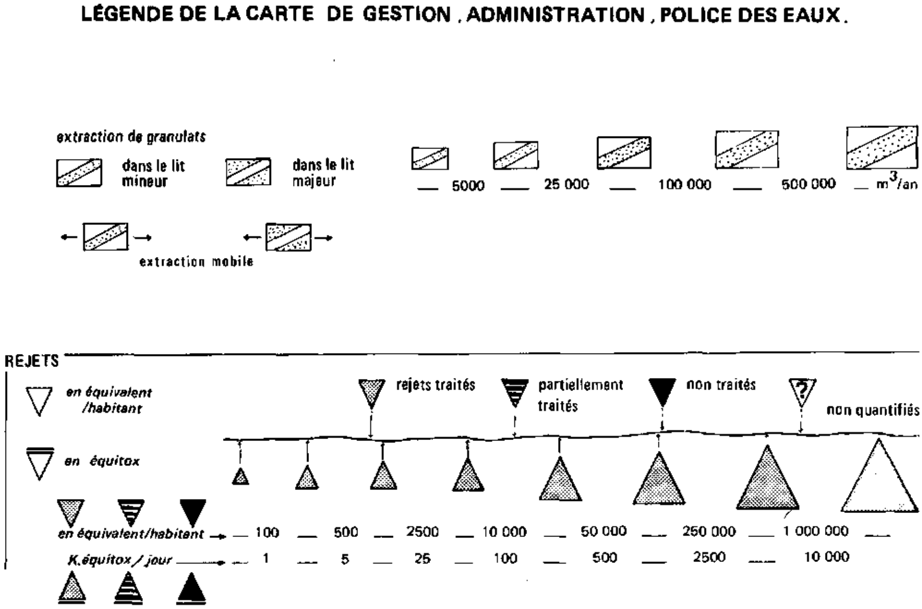


Figure 3. Key to map.

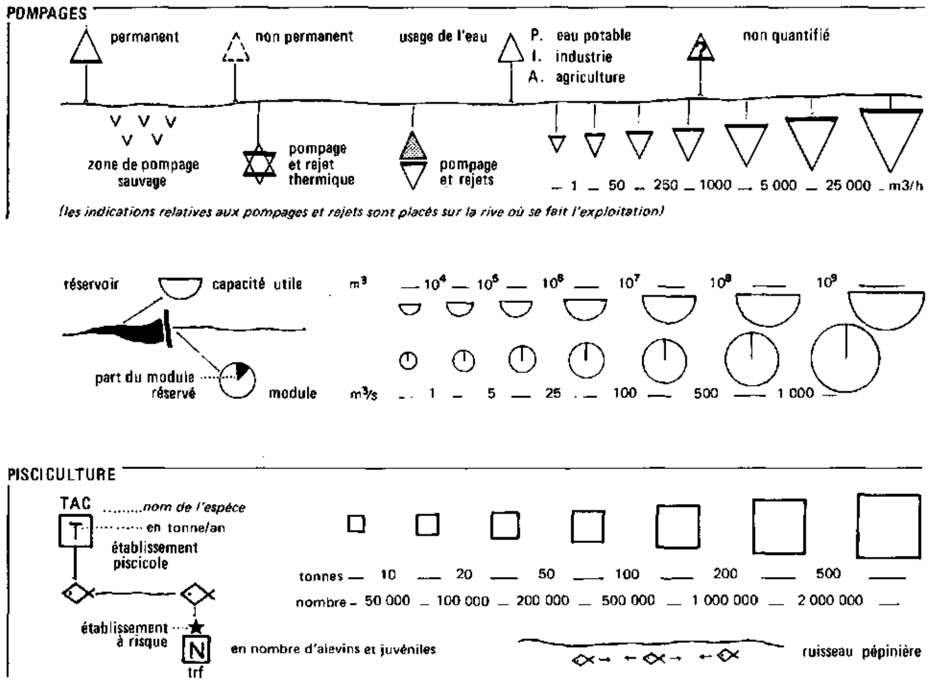


Figure 3. Key to map (contiued).

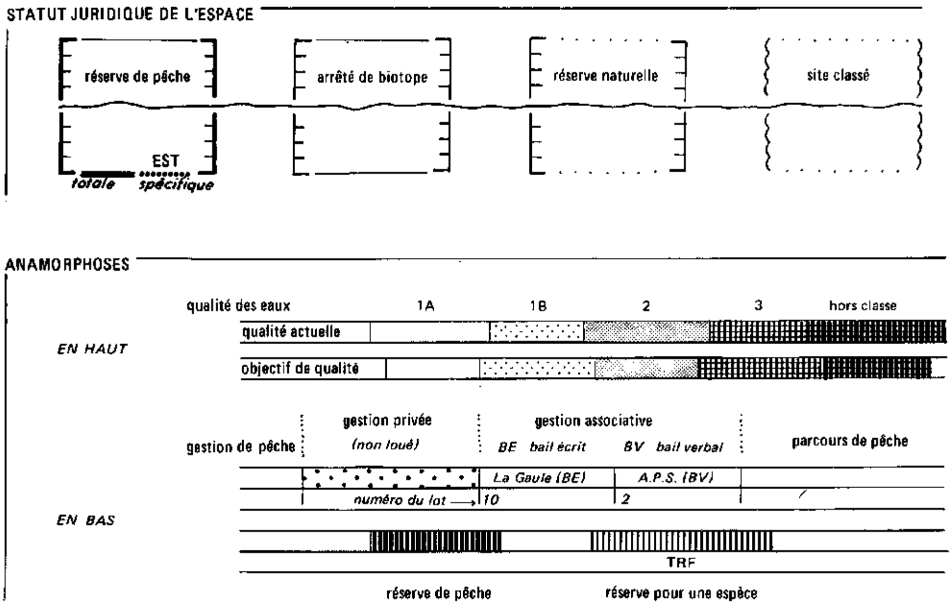


Figure 3. Key to map (contiued).

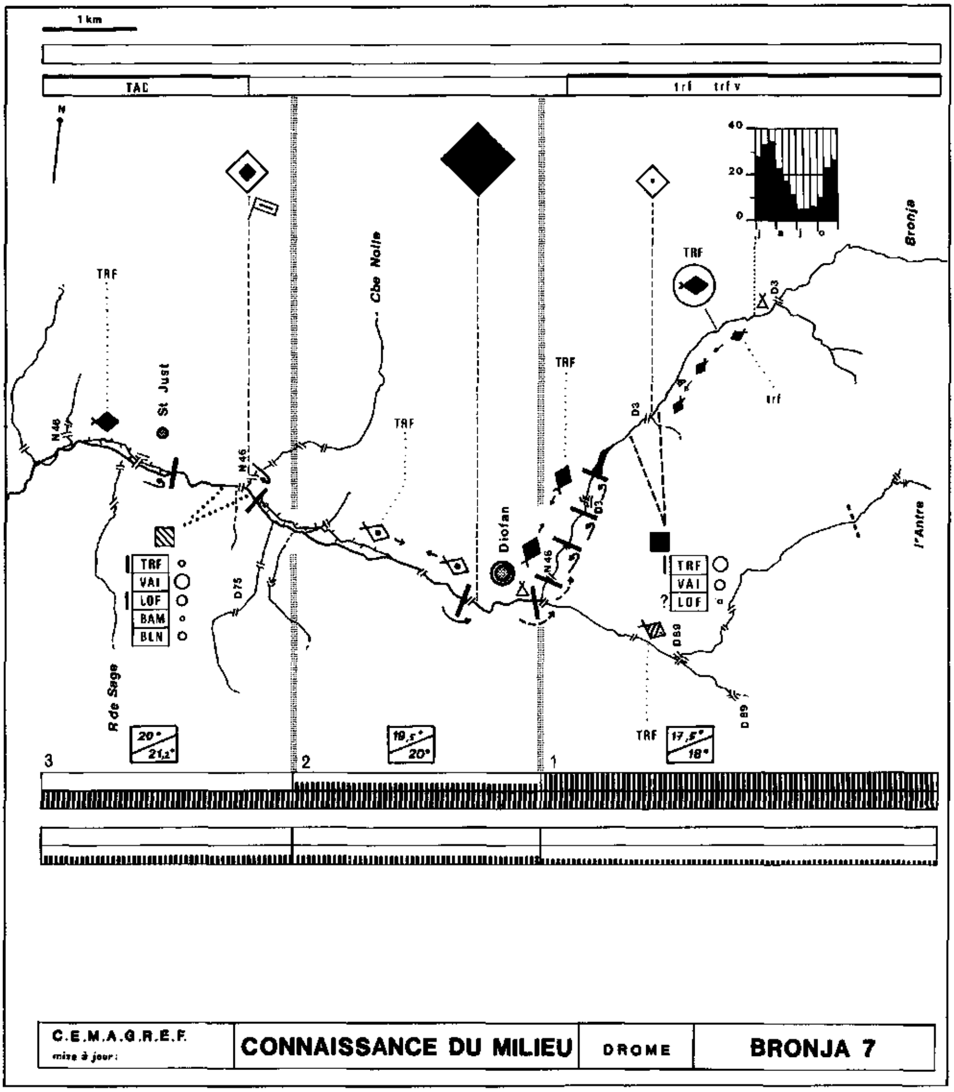


Figure 4. Map showing knowledge of ecosystem (taken from a 1:50 000map).

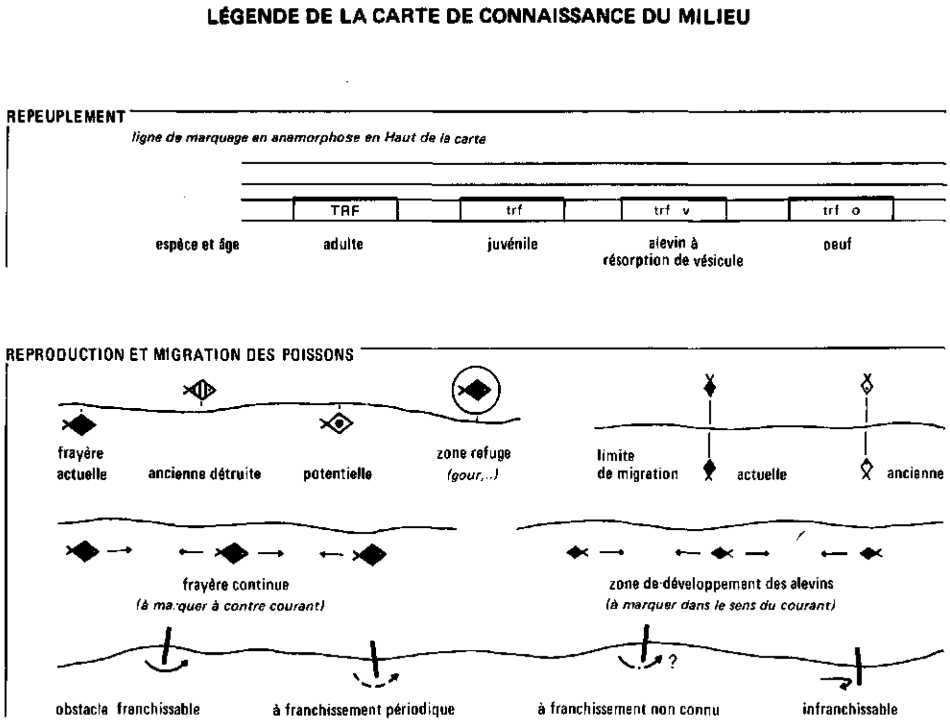


Figure 4. Key to map.

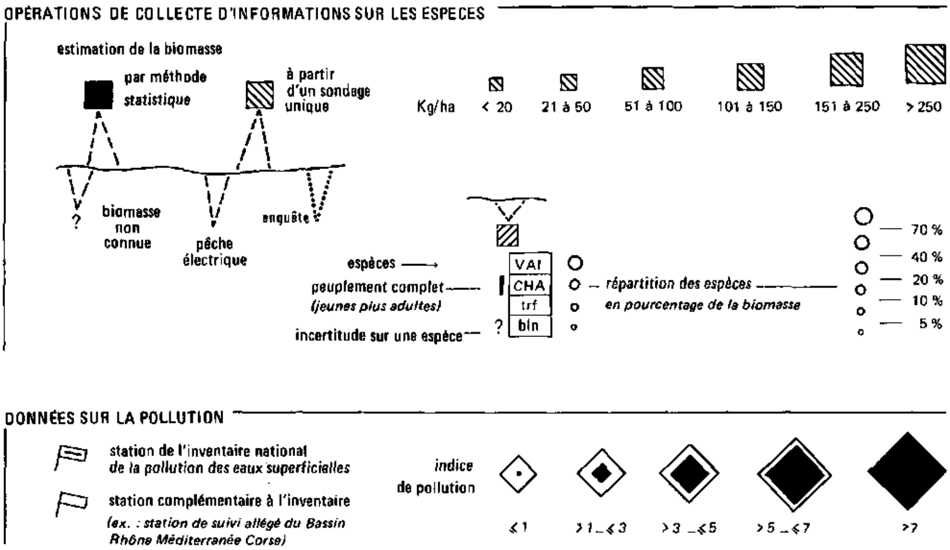


Figure 4. Key to map (continued).

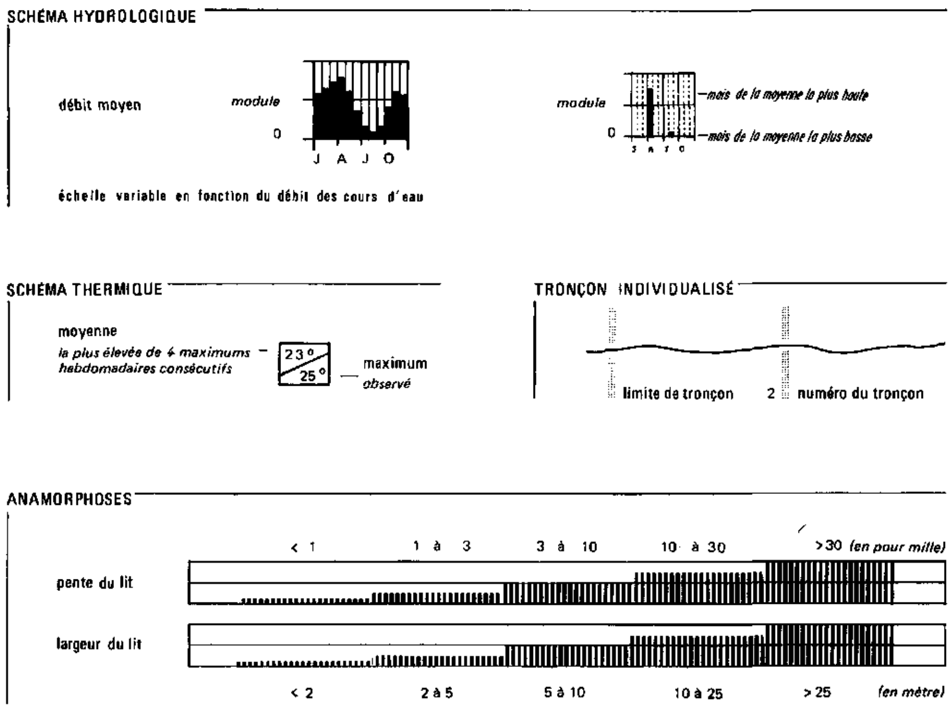


Figure 4. Key to map (continued).

constraint, but rather as a means whereby information can circulate between the user and management at departmental level. The fact that it has been seen fit to introduce this procedure does not mean that fishermen and their organizations have hitherto neglected the rivers and lakes. The procedure was introduced to co-ordinate and simplify fishing practices and regulations and improve fishery exploitation.

So as to respect the logic of the ecology of the river system, users will be strongly encouraged to submit joint plans when the section being exploited is sufficiently long and includes functional hydrographic zones: breeding grounds, juvenile rearing grounds, feeding areas, zones offering summer or winter cover. There should not be more plans than there are sections. Plans will take account of the objectives established under the fisheries orientation scheme which decides on the use to which the stream will be put and determines the level of protection required.

Figure 5 shows how a fisheries management plan is related to the fisheries orientation schemes.

As well as identifying the users and the section of the stream they manage, the plan should also state the objective to be met, which could be one of the following:

- Biotope and fishery protection based on natural recruitment of salmonids or cyprinids.
- Additional stocking, to be motivated.

Special guidelines will be drawn up for long-distance migratory species to take account of the hydrographic system they frequent. The plan could also take account of factors such as:

- Access: to members or open to all.
- Type of fishery: all types encouraged or only certain ones.
- Current fisheries situation:
    - Species fished, fishing methods used.
    - Accessibility of sector, fishability.
    - Special regulations.
    - Number of members, fishing pressure, space-time distribution (surveys carried out?).
    - Captures (surveys?).
    - Report on recent years and future trends.
- Knowledge of the environment in order to correct or add to the data provided through the fisheries orientation scheme. Users can make a useful contribution in this field, particularly through observations on:
    - Spawning grounds, surmountability of obstacles, the trend as regards the physical and chemical quality of the ecosystem.
    - Population dynamics: species captured, length, growth (fishing books, studies?).
    - The disappearance or development of certain species.

Finally, the plans could also make reference to measures taken in the past and indicate through what type of programme the managers expect to fulfil their objectives. They should distinguish between the items which fall within their competence and those which do not (new regulations, protection measures or studies).

Since all sites are not subjected to the same degree of fishing pressure, some plans may not have to be as well-defined as others. In other words, an ecosystem in proximity to a large town is likely to come under strong pressure and fishing and captures may have a

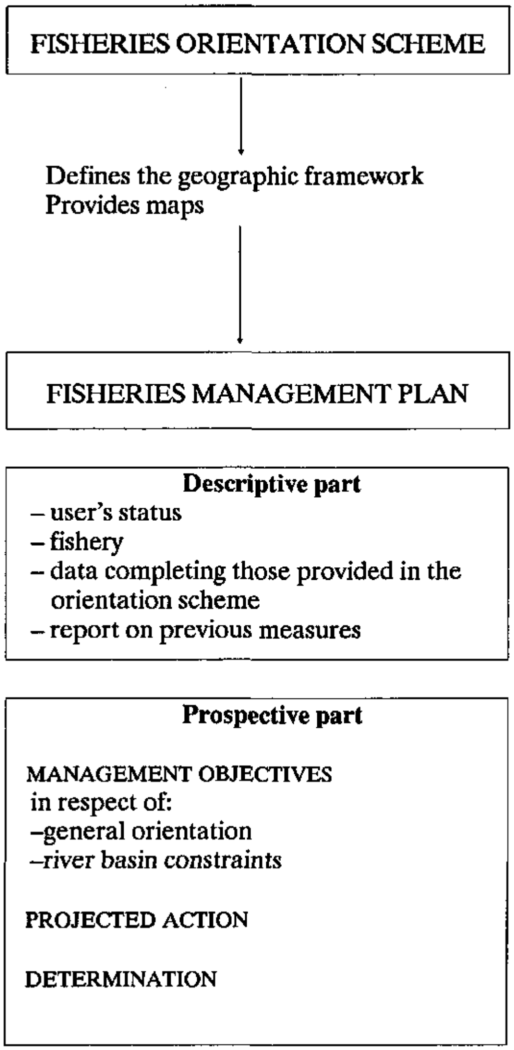


Figure 5. Elements of the fisheries management plan and how it is related to the fisheries management schemes.

strong impact on the structure of the populations fished. An ecosystem which is not easily accessible or which is remote will escape that pressure.

The duration of the schemes will be five years, matching the duration of fishing rights, and their initial effect will be to reduce inconsistencies. To be able to judge the merits of the measures proposed, it will be necessary for us to improve our knowledge of the system. To do this, studies will have to focus on certain reference sites and the effects will have to be analysed using very objective criteria.

Immediate steps could be taken to collect data on the different parameters which influence fish population and production on this type of site. This would mean:

- Checking that the physical and chemical qualities of the site are not unsuitable for any given species or group species.
- Taking physical measurements of the habitat and using hydraulic simulation models to determine the relationship between carrying capacity and flow.
- Making surveys of angling pressure and captures.
- Collecting stocking data.
- Using a population dynamics model to simulate cohort development over time.

When all this data has been obtained it will be possible, by means of a dynamic model, to assess the maximum carrying capacity of the stream for each fish life stage and species and determine fishery potential and the level of exploitation to be allowed.

The establishment of these plans is an important step in the entire scheme since they will:

- provide more complete information on current practices;
- allow for greater continuity in time and space through a system of co-ordinate policies;
- contribute towards a better understanding of traditional practices.

Following a comparative analysis, the different experiences with established fisheries management practices (which are most often based on know-how or empirical methods developed in hydrobiology or fish culture laboratories-Lèger 1909, Vibert 1949), could be assessed and corrected.

6. Conclusion

The passing of the new freshwater fisheries Act of June 1984 led to a considerable amount of reflection on aquatic ecosystems management. The possibility of enhancing these systems through fisheries was considered by the legislators as a bonus for good, overall watershed management, and not the promotion of one of the uses to which water is put. Many problems are involved. For instance, ways have to be found to develop rural tourism to save the countryside from the rural exodus and the success of such a step could depend on the quality of streams and lakes. The two new procedures, fisheries orientation schemes and management plans are designed to comply with the provisions of the Act: protection, rehabilitation and enhancement through fisheries or natural aquatic systems. The fisheries orientation schemes are prepared at department level. They define major policy lines which are put to the representatives of the system's users, for discussion, before being submitted for approval to the Country Council (Conseil Général). At the technical level, existing data, previously dispersed and disparate, are analysed and presented in map form.

The management plans are drawn up by the users of the fishery resources themselves, who then provide others involved in management with data on the quality of the environment where they exercise their fishing rights, the fishing methods used, and the measures envisaged to maintain or develop the activity in keeping with the objectives put forward in the orientation scheme. This mechanism will form the frame within which all the partners involved in aquatic ecosystem management will develop their work.

Scientists must be prepared to answer further questions dealing with methods for describing reference sectors, assessing the fish production potential of aquatic systems, measuring the space-time stability of the most sought-after environments and estimating the fishery and patrimonial value of these environments.

References

Arignon, J., 1976. Aménagement écologique et piscicole des eaux douces. Gauhier-Villars Ed., Paris. 320 pp.

Binns, N.A. & Eiserman, F.M., 1979. Quantification of fluvial trout habitat in Wyoming. Trans. Am. Fish. Soc. 108: 215-228.

Bovee, K.D., 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information paper No. 12. FWS/OBS 82/26, Western Energy and Land Use Team, U.S. Fish & Wildl. Serv. 248 pp.

Bovee, K.D. & Milhous, R.T., 1978. Hydraulic simulation in Instream Flow Studies: theory and techniques. Instream Flow Information paper No. 5. FWS/OBS 78/33, U.S. Fish Wildl. Serv. 130 pp.

Coste, M., 1976. Use of diatom communities for the assessment of water quality. CEC Report 2nd collaborative study concerning methods for assessing river quality. Practical demonstration on the river Trent. 19 pp.

Cuinat, R., 1971. Principaux caractères démographiques observés sur 50 rivières à truites françaises. Influence de la pente et du calcium. Ann. Hydrobiol. 2: 187-207.

Descy, J.P., 1980. Utilisation des algues benthiques comme indicateurs biologiques de la qualité des eaux courantes. In: Pesson. La pollution des eaux continentales. Gauthier-Villars Ed. Paris. pp. 169-194.

Hubert, P., 1984. Eaupuscule. Une introduction à la gestion de l'eau. Ellipse éd. 192 pp.

Huet, M., 1949. Aperçu des relations entre la pente et le populations piscicoles dans les eaux courantes. Schweiz. Z. Hydrol. 11: 332-351.

Lafont, M., 1984. Oligochaete communities as biological descriptors of pollution in the fine sediment of rivers. Hydrobiologia 115: 127-129.

Léger, L., 1909. Principes de la méthode rationnelle du peuplement des cours d'eau à Salmonidés. Trav. Lab. Piscicult. Grenoble. 1: 533-568.

Léger, L., 1945. Economie biologique et productivité de nos rivières à Cyprinidés. Bull. fr. Piscicult. 139: 49-69.

Mouthon, J., 1980. Contribution à l'écologie des Mollusques des eaux courantes - esquisse biotypologique et données écologiques. Thèse 3ème cycle, Univ. Paris VI. 169 pp.

Philippart, J.C., 1979. Evaluation des ressources piscicoles et halieutiques dans les rivières du bassin de la Meuse. Définition d'une méthode d'étude. In: Calembert, L. (Ed.). Problématique et Gestion des Eaux Intérieures, Actes du Colloque de Liège, 16-19 mai, 1978, Ed. Derouaux Liège. pp. 481-495.

Souchon, Y., Trocherie, F., Danière, C., Bethemont, J. & Martin, S., 1984. Schéma départemental de vocation piscicole - Notice cartographique. Min. Piscic. et CNRS, Lab. Géogr. Rhodanienne. 35 pp.

Stalnaker, C.B., 1979. The use of habitat structure preferenda for establishing flow regimes necessary for maintenance of fish habitat. In: Ward & Stanford (Eds). The ecology of regulated streams. Plenum Press, New York. 326-337.

Tuffery, G.& Verneaux, J., 1968. Méthode de détermination de la qualité biologique des eaux courantes: les indices biotiques. Trav. Cerafer Paris. 31 pp.

Verneaux, J., 1977. Biotypologie de l'écosystème 'eau courante'. Déterminisme approché de la structure biotypologique. C.R. Acad. Sci. Paris. 284 D: 77-79.

Verneaux, J., Faessel, B. & Malesieux, G., 1976. Note préliminaire à la proposition de nouvelles méthodes. Détermination de la qualité des eaux courantes. Trav. CTGREF et Cent. Hydrobiol. Univ. Besançon. 14 pp.

Vibert, R., 1949. Du repeuplement en truites et saumons par enfouissement de 'boîtes d'alevinage', garnie d'oeufs, dans les graviers. Bull. fr. Piscicult. 153: 125-150.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 215-229.

An attempt to estimate *Alosa alosa* and *Alosa fallax* juvenile mortality caused by three types of human activity in the Gironde Estuary, 1985-1986

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Abstract

An estimate of the numbers of *Alosa alosa* and *Alosa fallax* juveniles (group 1 and 2) destroyed by three kinds of impact of human origin was made in 1985-1986 in the Gironde Estuary. Two of these impacts were related to fisheries in the estuary, *viz* the *Anguilla anguilla* elver fishery (open season 15 November-30 March) and the *Palaemon longirostris* white shrimp fishery (open all year). The third impact was caused by the continuous industrial activity of the nuclear power station at Blayais (CPNB). Juvenile mortality in both species was caused mainly by mechanical phenomena.

The total impact of these three activities during the period January-December 1986 caused the destruction of 704 710 *Alosa alosa* and 3 203 670 *Alosa fallax* juveniles (1984 and 1986 downstream migrants combined). The CPNB caused the heaviest mortality in the first species, while the white shrimp fishery was responsible for the greatest mortality in the second species. Moreover for both species, only the CPNB affected the three generations of downstream migrants born in 1984, 1985 and 1986. The white shrimp fishery did not affect the 1984 cohorts, while the elver fishery destroyed only the 1985 downstream migrants.

Résumé

L'estimation des quantités de jeunes *Alosa alosa* et *Alosa fallax* (groupes 1 et 2) détruits par trois types d'impacts d'origine humaine est réalisée dans l'estuaire de la Gironde en 1985 et 1986. Deux de ces impacts sont liés à l'exploitation halieutique des eaux estuariennes : le pêche à la civielle d'*Anguilla anguilla* (ouverte du 15 Novembre au 30 Mars) et la pêche à la crevette blanche *Palaemon longirostris* (ouverte toute l'année). Le troisième impact est dû à l'activité industrielle constante du Centre de Production Nucléaire du Blayais (CPNB). La mortalité des juvéniles des deux espèces est provoquée principalement par des phénomènes mécaniques.

L'impact total de ces trois activités sur une période identique (Janvier à Décembre 1986) entraîne une destruction de 704 710 jeunes *Alosa alosa* et 3 203 670 jeunes *Alosa fallax* (dévalants 1984, 1985 et 1986 confondus). Pour la première espèce c'est le CPNB qui provoque la mortalité la plus forte et pour la deuxième espèce is s'agit de la pêche à la crevette blanche. De plus, pour les deux espèces, seul l'impact du CPNB s'exerce sur trois générations d'alosons dévalants nés en 1984, 1985 et 1986. La pression de la pêche à la crevette blanche ne touche pas les cohortes 1984, et, celle de la pêche à la civelle ne détruit que des dévalants 1985.

1. Introduction

At present the Centre National du Machinisme Agricole du Génie Rural (CEMAGREF) is developing a programme to acquire information on the *Alosa* populations of the Dordogne-Garonne-Gironde Estuary system with a view to managing these populations. *Alosa alosa* comprised 40% of the total annual catch (538 tonnes) from the Gironde-Garonne-Dordogne Estuary in 1986. This meant that this species contributed 24% of the landed value of the catch, amounting to 11.7 million FF. The economic importance of the two species in this estuary, which opens to the Bay of Biscay, can be underlined by indicating that their joint value placed them 13th in order of importance of natural resources in the area in 1981.

The activities of the CEMAGREF programme are being conducted along three main lines previously recognized as essential (Elie 1985). These are:

- A study of the biology and ecology of species constituting the base of the inland fisheries.
- An assessment of the impact of fishery activities on the dynamics of the exploited stocks.
- An assessment of the impact of other human activities on the dynamics of the exploited stocks.

The work we have done here concerns the populations of *Alosa alosa* and *Alosa fallax* present in their juvenile stages in the estuary-river system. The aim has been to estimate the magnitude of human pressure on these populations. The human impacts derive from three activities. The first, of an industrial character, is related to the effects of the nuclear power station at Braud-et-Saint-Louis (Gironde). The other two concern the effects of the white shrimp *(Palaemon longirostris)* and the elver fisheries (post-larval stage of *Anguilla anguilla*) since *Alosa* juveniles are by-catches in both these fisheries.

2. Characterization of sources of mortality caused by man

2.1 The industrial sector

The nuclear power station of Blayais (CPNB) is the only large industrial establishment in operation *(Figure 1)* in the area. It consists of four sections each generating 900 MW. Cooling is carried out in an open circuit which pumps estuary water through at a constant rate of 168 m^3/sec. It is the only open circuit nuclear power station installed on an estuary. Its cooling system is similar to those of power stations built on the open coast, but this one exercises its influence on a much smaller and more sensitive area. Water enters the system 400 m from the shore via two submerged intakes and is channelled to two intake tanks. Eight circulation pumps, with capacities of 20 m^3/sec. each, are connected to a rotating filter drum 15 m in diameter and 6.15 m wide. This filter is covered by a 3 mm square mesh metal net equipped with stiffeners. The drums turn continuously. The filtered water is heated in the power station and then discharged 2200 m from the right shore through spray cones. It is not the hot water that causes the mortality of the *Alosa* juveniles, since they are able to avoid areas with temperatures above 30°C (Marcy, Jacobson & Nankee 1972, Moss 1972), but the method of flushing the drums with water jets to clean off adherent rubbish. It was demonstrated that adherent *Alosa* juveniles suffer 100% mortality even when low pressure jets are used (Boigontier, Filipozzi & Taverny 1985).

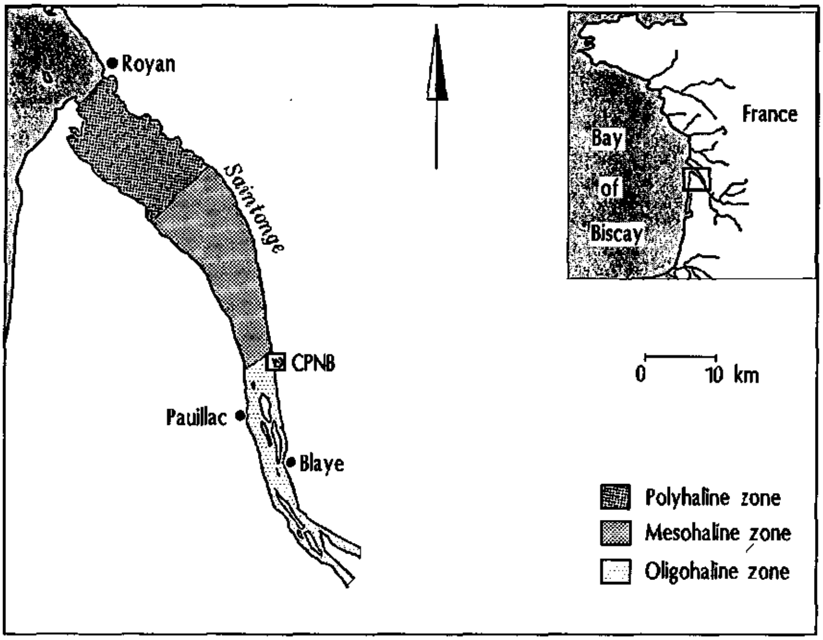


Figure 1. Map of the Gironde Estuary showing the location of the CPNB, and the inner estuary where the samples were taken.

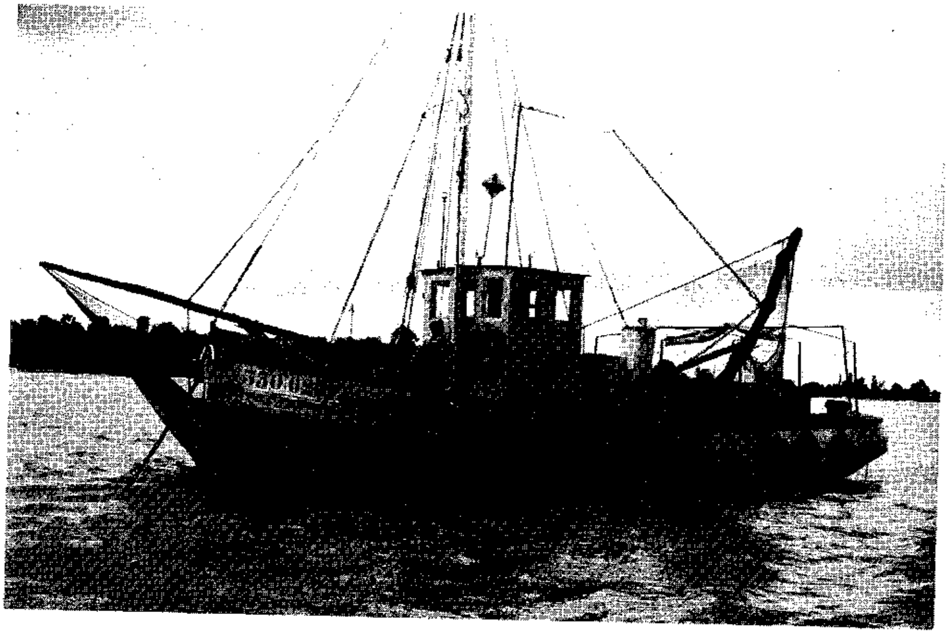
2.2 The fishery sector

Neither of the fisheries, for white shrimp and glass eel, uses selective nets, and together with the target species these capture an associated fauna which includes juvenile shad *(Plate 1)*.

The white shrimp fishery employs nets consisting of two frames, one of which is placed on each side of the boat. The area of their fishing opening varies from 20 to over 30 m^2 with 8 to 9 mm mesh size. It is a static fishery. It is open all year, and operates day and night at all states of the tide. Fishing time varies from one to several hours per period.

The elver fishery uses 'pilabours' (a local term for the net used) which are similar to the shrimping nets, but the areas of their openings are smaller, 7 m^2 maximum, while the net mesh is only 4 mm reducing to 1 mm at the end. This fishery is authorized from 15 November to 1 April. It is practiced mainly at high tide both day and night. Successive net casts vary from 15 minutes to over an hour.

Operation of both types of net can lead to large by-catches. Young *Alosa* which have undergone stress in the nets are heavily covered with scales and cannot tolerate prolonged immersion. They suffer 100% mortality.



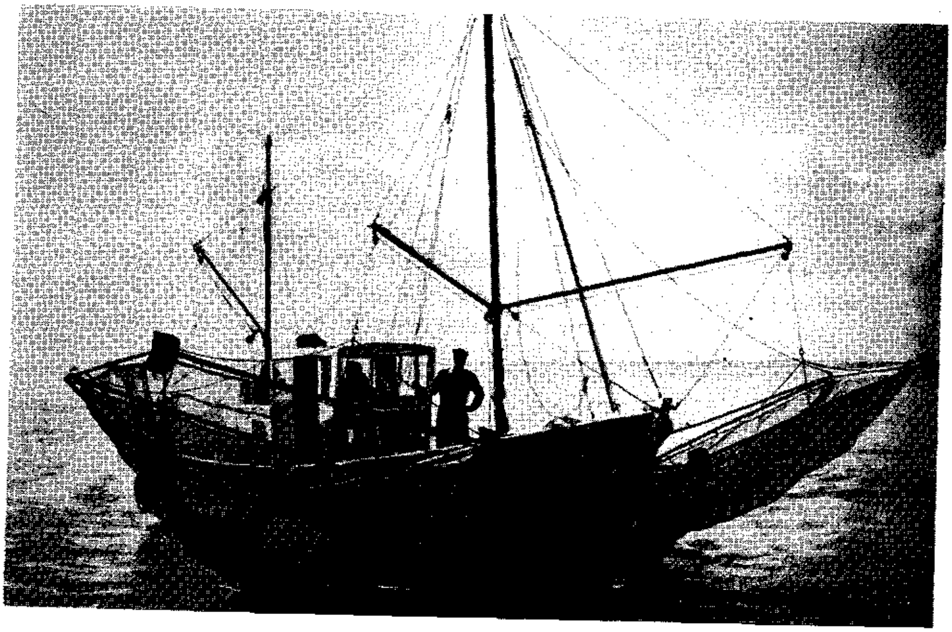


Plate 1. Fishing gear for catching white shrimps and glass eels.

3. Materials and methods

3.1 Survey of impact of the Blayais power station

The survey was made from August 1985 to December 1986. The experimental fishery took place in the washing water outlet channels of the filter drums, using a purse net 4 m long mounted on a metal frame adjusted to the cross sectional profile of the piping. This gear consisted of a 4 mm square mesh net over about 3 m and then a 1 mm square mesh layer at the end part. The frame and net combination was let down along a metal slide attached to the walls of each of the two channels. A system of arms and pulleys enabled it to be raised again *(Figure 2)*. All the young shad were preserved in formalin diluted at 5%.

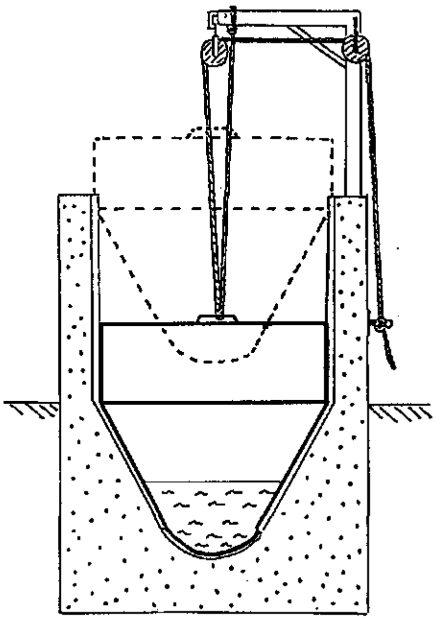


Figure 2. Cross section of washing water conduit from filter drum and front view of the experimental net in its fishing and resting position.

3.2 Survey of impact of the two types of fishery

The elver fishery survey began in December 1985 and was concluded in March 1986. Sampling of the white shrimp fishery began in July 1986, at the time when most fishermen engage in this activity, and was terminated in December of the same year. What made these two surveys original was the fact that they were adjusted to the planning of the fishermen, followed their fishing effort for a given period, and did not alter their fishing habits. Also to avoid bias in the sample results, the characteristics that could cause variability in abundance of by-catches were taken into account. These were the different salinity areas of the inner estuary of the Gironde and the variable area of the shrimping net and 'pilabours' fishing openings. *Alosa alosa* and *Alosa fallax* juveniles which formed part of the by-catches were collected systematically and preserved by freezing.

3.3 Types of analyses and methods adopted

Laboratory examination made it possible to distinguish *Alosa alosa* from *Alosa fallax* by two criteria: the general morphology of the individuals and, as a complement in doubtful cases, a count of the number of branchiospines on the first gill arch. Each individual sampled was measured to the nearest mm and the scales were sampled. By these operations, cohorts of individuals of the same age could be distinguished *(Figure 3)*.

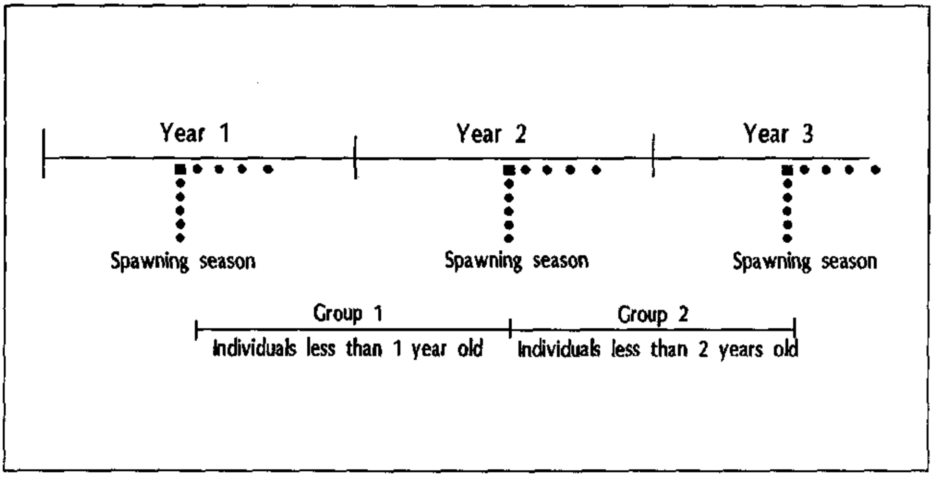


Figure 3. Age classes of *Alosa alosa* and *Alosa fallax* studied.

For the survey conducted at the Blayais nuclear power station the quantities of juveniles of each species collected on a given date were referred to a 24 hour period using the formula (Boigontier & Mounie 1984):

$$N_i = \frac{n_i \times 24 \times 3600}{T}$$

where:

N_i = the estimated number of organisms of species i caught in 24 hours;
n_i = the total numbers of the species for all the samples j;
T = the sum of the duration of the sampling j.

An estimate of the cumulative number between two sampling dates was calculated by the formula (Boignotier & Mounie 1984):

$$N_i = \frac{N_i \ N_{i+1}}{2} \ (n-1) \ + N_{i+1}$$

where:
N_{i+1} = the number of individuals on date $i + 1$
n = the number of days between i and $i + 1$.

In the context of the fishery surveys, the largest possible number of fishermen's calendars were collected in order to determine fishing effort in terms of numbers of trips (where a trip corresponds to a unit fishing activity during either a high or low tide period).

$$J_i = a_{i_t} \ E \qquad E = \sum_{t=d_1}^{t=d_m} \ (\sum_{p=0}^{p=x} \ Sd_p) \ t$$

where:
J_i = the estimate of the number of juveniles of the species caught during period t;
a_i = abundance of individuals of species i per trip captured during a given time t;
E = the sum of trips made by all the fishermen p for the given period t; and
Sd_p = the number of trips on date d for all the fishermen concerned during the period t examined.

In estimating impact we did not find by-catches (of young *Alosa*) significantly different between the mesohaline and oligohaline parts of the estuary, nor between gear with large or small fishing surfaces. Abundance levels seemed to be related much more to the period of intervention than to the technique or place of capture. The impacts of the fisheries were established by dividing the times of activity into periods.

4. Results and discussion

4.1 Abiotic parameters

Within the total duration of the survey the period corresponding to high flow levels was that extending from January to May 1986 (3000 m^3/s at the end of April). The periods of lowest levels (below 500 m^3/s) were, respectively, from mid-July to December 1985, or about six months, and from July to October 1986 or four months. Starting in mid-November the flow rates, which were at their lowest at that time, almost doubled and reached over 1500 m^3/s at the end of December *(Figure 4a)*.

The minimum water temperatures observed were spread from the end of November 1985 to February 1986. The minimum reading was 4°C at the end of November 1985. Starting in March 1986 the water became warmer and its temperature fluctuated around 10°C, then suddenly in May, during one month, it reached 20°C. The maxima were recorded between mid-July and the beginning of August. After that month the temperature dropped and a minimum (4°C) was again recorded in December 1986 *(Figure 4b)*.

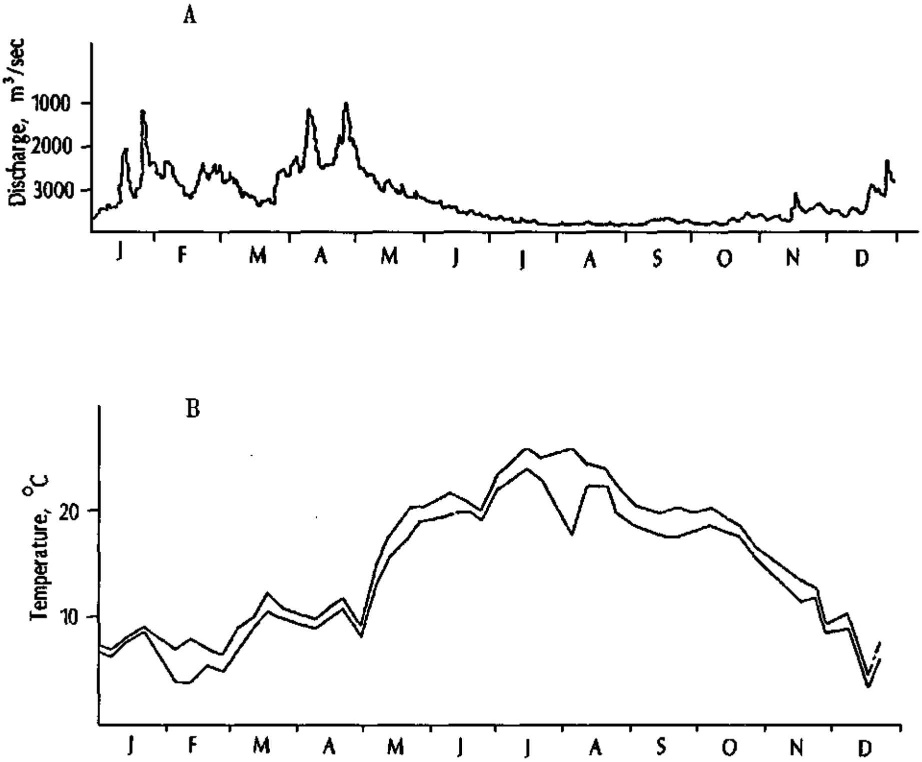


Figure 4. A. Daily discharge from the Gironde Estuary during 1986.
B. Temperature of the Gironde Estuary during 1986.

4.2 Biological characteristics of *Alosa alosa* and *Alosa fallax* juveniles

From August 1985 to June 1986 two size frequency groups were distinguished for *Alosa alosa* juveniles. Group 1 contained specimens 51-122 mm long corresponding to individuals less than 1 year old, while Group 2 comprised specimens 135-230 mm long corresponding to individuals less than 2 years old *(Figure 3)*. A similar observation was made for *Alosa fallax* with size ranges of 20-114 and 130-229 mm for groups 1 and 2 respectively.

The water temperatures of the estuary increase markedly from May to June *(cf Figure 4)* permitting an algal bloom, when, due to an abundance of food, the fish exhibit a second phase of growth. Then the first wintering occurs. Size variability within a cohort is large. To determine it, without the aid of scale readings, we had to take into account both the size of the fish and their date of capture.

4.3 Estimated quantity of young *Alosa* destroyed by the different activities

The white shrimp fishery began in mid-March, in 1986, and the elver fishery towards the end of November, in 1985. The time intervals corresponding to these two fishing seasons were re-examined in the context of Blayais, in order to compare, for the same time interval, the estimate of quantities of *Alosa* juveniles which suffered industrial and fishery type impacts *(Table 1)*.

A comparison of the estimated impacts caused by the two types of activities *(Table 1)* showed that the operation of the CPNB caused greater destruction among group 1 individuals whatever *Alosa* species was considered. In fact for the same interval, the destruction caused by the CPNB was 8 times heavier among *Alosa alosa* juveniles and 36 times heavier among *Alosa fallax* juveniles than that of the fishery activity. Moreover, by contrast with the industrial activity, fishery operations did not capture any juveniles from any species born in 1984 (group 2).

The survey of the white shrimp fishery did not begin until July 1986. To estimate the pressures imposed by the two types of activity and compare them, two periods were considered, taking into account a difference in the level of data obtained during the two intervals:

- **Period 1.** Between March and June the destruction of -1 and -2 *Alosa* juveniles caused by the CPNB was compared to that caused by the estuarine fisheries to all cohorts present in the area. During this period *Alosa alosa* individuals were destroyed by the Blayais power station at a rate 3 times greater than by the white shrimp fishery. With *Alosa fallax* juveniles the quantities netted were practically the same in both the activities considered *(Table 1)*.
- **Period 2.** From July to December 1986 the downstream migrants can be divided into groups 1 and 2. White shrimp exploitation caused 5 times more deaths among *Alosa fallax* juveniles belonging to group 1. It destroyed the same quantity of group 2 juveniles of this species as did the CPNB. For *Alosa alosa* (groups 1 and 2) destruction by the power station proved to be slightly greater than that by the fishery.

Considering the season as a whole (from mid-March to December 1986) for the 1985-1986 downstream migrants of both species, the ratios of destruction are the same as those obtained during the second period. From January to December 1986 the impact of the CPNB operated on the downstream migrant juveniles of both species born in 1984, 1985 and 1986. The white shrimp fishery did not affect the 1984 cohorts, while the elver fishery destroyed only individuals belonging to the 1985 downstream migrants *(cf Table 1)*. During 1986 the main source of man-induced juvenile *Alosa alosa* mortality was the Blayais nuclear power station. For *Alosa fallax* juveniles, in 1986, the white shrimp fishery had the greatest impact.

Table 1. Estimations of the numbers of young *Alosa alosa* and *Alosa fallax* lost through industrial and fisheries activities from January to December 1985 (in millions of individuals).

		Alosa alosa			*Alosa fallax*		
		1984	1985	1986	1984	1985	1986
End November 1985 to end March 1986	Power station	4.3	844.95	0	10.7	394.65	0
			849.25			405.35	
	Elver fishery	0	106.83	0	0	10.88	0
			106.83			10.88	
Mid- March 1986 to June 1986	Power station	0			0		
			18.49			14.27	
	Shrimp fishery	0					
			6.44			12.24	
July 1986 to December 1986	Power station	0	8.55	160.87	0	19.04	456.47
			169.42			475.51	
	Shrimp fishery	0	6.87	152.94	0	19.24	2447.40
			159.81			2466.73	
January 1986 to December 1986	Power station	1.81	272.18	160.87	7.10	250.23	456.47
			734.85			713.80	
	Elver fishery	0	106.83	0	0	10.88	0
	Shrimp fishery	0			0		
			163.02			2478.97	

5. Relations between the impact of human activities and the biology of juvenile shad

On the basis of fishing campaigns conducted by the CEMAGREF, following a cross itinerary 2 km downstream from the Blayais station, it appeared that dummy *Alosa* juveniles were distributed relatively uniformly near the surface and across the whole width of this section of the estuary. However, true *Alosa* juveniles have a marked preference for the Saintonge channel, located along the right hand shore. The installation of the intake heads of the Blayais power station and the concentration of the downstream migrants in the same channel may explain the magnitude of the impact of the CPNB compared to that of the fishery activities.

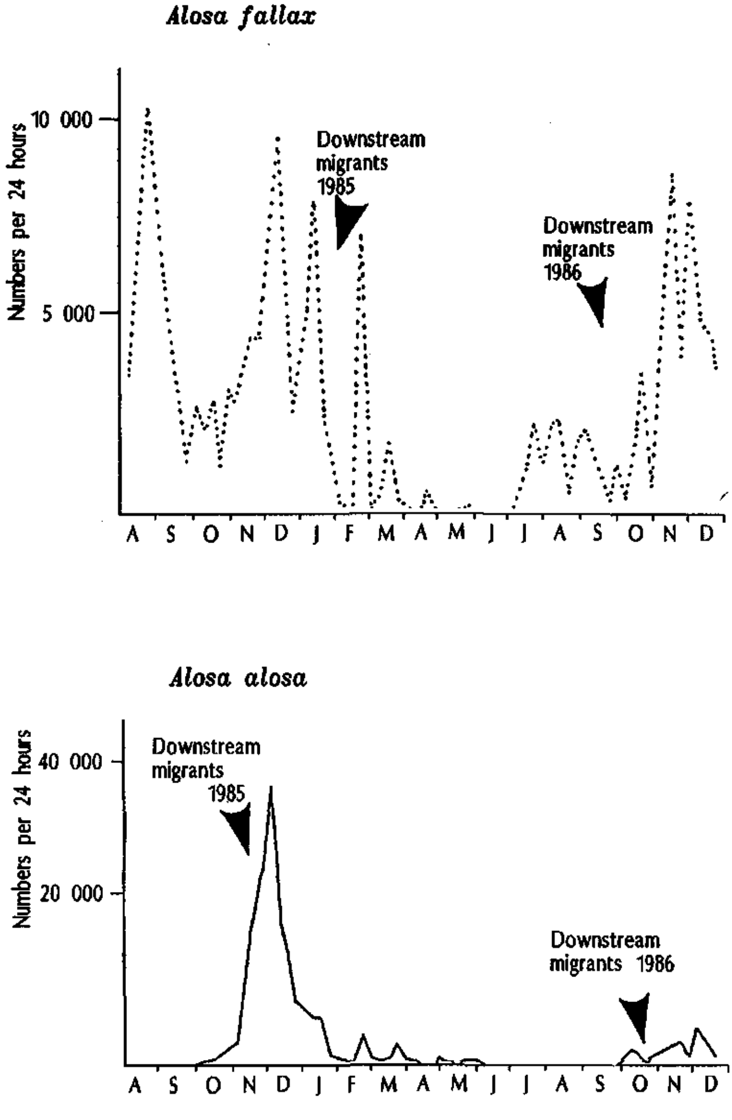


Figure 5. Numbers of −1 *Alosa alosa* and *Alosa fallax* captured each 24 hours from August 1985 to December 1986 at CPNB.

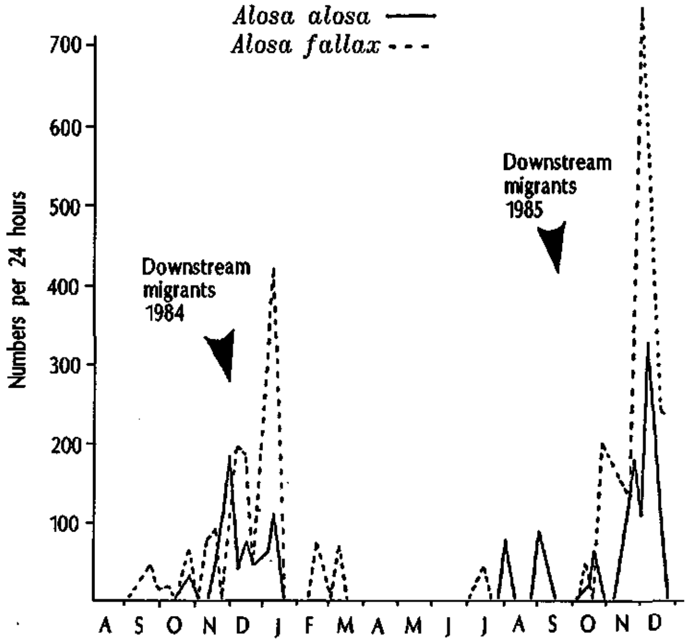


Figure 6. Numbers of ~2 *Alosa alosa* and *Alosa fallax* captured each 24 hours from August 1985 to December 1986 at CPNB.

5.1 The case of the Blayais nuclear power station

The numbers of individuals captured per 24 h period from August 1985 to December 1986 enables us to deduce the abundance of the downstream migration and time its peak. We observed that the 1984 *Alosa alosa* group 2 downstream migrants appeared towards the end of October 1985 and disappeared around mid-January 1986. With *Alosa fallax,* the period when they were present was longer, from September 1985 to March 1986 (*Figures 5* and *6*).

The 1985 group 1 downstream migrants were subject to the impacts mainly from September 1985 to January 1986; 81% of group 1 catches were made during the November-December-January period (with a peak of 36 175 individuals per 24 hr period at the beginning of December).

The plot of capture rate for *Alosa fallax* juveniles in group 1 (1985 downstream migrants) was less marked than that for *Alosa alosa*, but showed more peaks. Contrary to results obtained in the Severn estuary with *Alosa fallax* group 1 individuals (Claridge & Gardner 1978), the drop of temperature alone does not determine downstream migration. In spite of a lowering of average temperature, from over 20°C in August to less than 10°C in January, the presence of that species was observed in the Gironde Estuary from August 1985 to the end of May 1986. A drop in numbers of both species occurred at the end of January-beginning of February 1986 and was accompanied by a sharp drop in water temperature and salinity. This phenonenon can be explained, as can that described by Chittenden (1972) involving *Alosa sapidissima* juveniles, by the tendency of un-acclimated organisms to retreat from extreme environmental conditions.

With 1985 downstream migrants (group 2 *Alosa* juveniles) the highest abundance per 24 h occurred in 1986 during November and December. We do not yet understand their presence at this time, in terms of the understood general behaviour of *Alosa* populations in this part of the estuary.

The 1986 *Alosa alosa* group 1 downstream migrants appeared at the same time as those of the 1985 descent (October). However the numbers caught per 24 h period between October and December were much lower, with the December peak totalling only 5012 individuals per 24 hr period. With *Alosa fallax* the first group 1 individuals were netted in July 1986. The months of November and December showed the highest capture peaks of 8786 and 8000 individuals per 24 hr period respectively.

5.2 The case of the shrimp fishery

This fishery is practiced over the whole width of the estuary at distances greater than 200 m from the shores. It has been established that the spatial preference of dummy *Alosa* juveniles in this sector of the estuary is mainly at the surface and that they become distributed relatively uniformly. This characteristic may possibly explain why the impact provoked by the white shrimp fishery is 5 times heavier than that of the CPNB which, through its intake heads, abstracts water only from deep water in the Saintonge channel. Further, fishing effort in the shrimp fishery increases in summer, coincident with the downstream migration of group 1 *Alosa fallax*. Lastly, depending on the fishermen's persistence, they can make up to four fishing trips per day and they do this most often in summer.

The period from 25th July to 25 November was the most destructive for *Alosa fallax (Table 2)*. At the end of November 1986 mortality dropped, contrary to what happened at the CPNB. In fact, at this time, most fishermen still working were operating in the upstream part of the inner estuary, in the oligohaline area, while the largest proportion of the downstream migrating *Alosa* juveniles were to be found farther downstream.

The *Alosa alosa* juveniles did not really feel the impact of this fishery, except from the beginning of September to the end of November, because there was still a large general fishing effort, rather than a shrimping effort, at the time the group 1 downstream migrants entered the estuary *(Table 2)*.

5.3 The case of the elver fishery

During the winter of 1985-1986 about 70% of the boats equipped for this type of fishing worked along the right (Saintonge) shore. Their fishing effort was very steady. In spite of this the estimated quantity of young group 1 *Alosa* destroyed was low. Since young *Alosa alosa* have a marked spatial distribution near the Saintonge shore, one might have expected to harvest a larger number of juveniles in the by-catches of this fishery.

However, when one examines the specific methods of this fishery, one sees that it is practiced along the shores in a stretch of water about 1 m deep as close as possible to the banks. We can conclude therefore that *Alosa alosa* and *Alosa fallax* juveniles seldom move in these shallow water areas and are not caught by this type of fishery.

Table 2. Estimates of the numbers of *Alosa alosa* and *Alosa fallax* juveniles caught when fishing for white shrimp during 1986 (in millions of individuals).

Alosa alosa				Alosa fallax			
	Industrious fishermen	Average fishermen	Less active fishermen		Industrious fishermen	Average fishermen	Less active fishermen
Mid-March to 10 September	3.76	6.79	1.56	Mid-March to 25 July	9.08	7.87	1.04
		12.10				17.99	
10September to 10 November	75.82	54.19	16.28	25 July to 25 November	1142.42	997.78	292.99
		146.29				2433.19	
10 November to 31 December	3.22	1.41	-	25 November to 31 December	18.26	9.54	-
		4.63				27.79	
Total		163.02				2478.97	

6. Discussion

The three human activities considered in this study brought about the mortality of 704 710 *Alosa alosa* and 3 203 670 *Alosa fallax* (groups 1 and 2) in 1986.

For the two species, 3 successive cohorts were affected by the activity of the CPNB (1984, 1985 and 1986 downstream migrants). This caused the heaviest mortality amongst *Alosa alosa* juveniles (434 850 individuals destroyed). For *Alosa fallax*, the white shrimp fishery, which was particularly intensive at the time of the downstream migration of their group 1, appeared to cause the heaviest mortality. It destroyed some 2 478 970 individuals from the first and second year-classes (1985 and 1986), but it did not appear to affect the third year-class. The elver fishery had only a minor impact on the 1986 year-classes, killing 106 830 *Alosa alosa* and 10 880 *Alosa fallax*.

This estimated non-natural mortality seems to be very high. However a total mortality estimate, from all causes, natural and human, in the full life cycle of the two species would be necessary to permit us to propose management measures for their protection. Only continuous monitoring of the fisheries, and the physical changes in the river, estuary and associated marine ecosystems, will permit the elaboration of a coherent management scheme. The content of this paper contributes in part to our understanding of the biology of these two species.

References

Boigontier, B., Filipozzi, P. & Taverny, C., 1985. Etude de l'efficacité des nouveaux dispositifs de récupération des macro-organismes de la centrale nucléaire du Blayais (Gironde). Bordeaux, E.D.F., CEMAGREF. 81 pp.

Boigontier, B. & Mounié, D., 1984. Contribution à la connaissance de la dynamique de la macro-faune bentho-démersale et pélagique en Gironde, tentative et difficultés pour relativiser l'impact mécanique d'une centrale nucléaire: le Blayais (Gironde), Bordeaux, E.N.S.A.T., CEMAGREF. 491 pp.

Chittenden, M.E., 1972. Responses of young American shad (*Alosa sapidissima*) to low temperature. Trans. Am. Fish. Soc. 101: 680-685.

Claridge, P.N. & Gardner, D.C., 1978. Growth and movements of the twaite shad (*Alosa fallax* L.), in the Severn estuary. J. Fish Biol. 12: 203-211.

Elie, P. & Rigaud, C., 1984. Etude de la population d'anguilles de l'estuaire et du bassin versant de la Vilaine: pêche, biologie, écologie. Examen particulier de l'impact du barrage d'Arzal sur la migration anadrome (civelles), tome 1, CEMAGREF, Bordeaux, Faculté des Sciences de Rennes, U.R.F.D.A.A.P.P. 164 pp.

Elie, P., 1985. Les aloses en France, importance, état des connaissances et proposition d'un cadre pour la gestion de ces ressources, CEMAGREF, Bordeaux. 19 pp.

Elie, P., Boignotier, B. & Rochard, E., 1988. Etude du suivi halieutique de l'estuaire de la Gironde, 1987. E.D.F., CEMAGREF, Bordeaux. 212 pp.

Marcy, B.C., Jr, Jacobson, P.M. & Nankee, R.L., 1972. Observations on the reactions of young American shad to a heated effluent. Trans. Am. Fish. Soc. 4: 740-743.

Moss, S.A., 1972. The responses of young American shad to rapid temperature changes. Trans. Am. Fish. Soc. 2: 381-384.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 230-247.

Fisheries decline in the freshwater lakes of northern Greece with special attention for Lake Mikri Prespa

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Abstract

Greek lakes, and Balkan lakes in general, are unique in Europe due to their great age (Tertiary period), being much older than Glacial (Quarternary) lakes. The majority of these lakes are shallow (less than 10 m deep), alkaline (pH 8.0), eutrophic and warm. Their fish communities are mainly dominated by cyprinids with few or no piscivorous predators (pike, perch, sheatfish). All Greek lakes, small or large, sustain commercial fisheries. Nowadays their yields vary between 6.5 and 79.6 kg/ha/yr. However, in the 1960s their yields were higher, 12.4-222 kg/ha/yr. The observed decline is mainly the result of overfishing, the increase of eutrophication, the introduction of exotic species and the introduction of nylon nets and outboard engines. This is the consequence of the absence of management and/or lack of implementation and enforcement of the few existing fishing regulations The most valuable commercial fish species is the common carp, *Cyprinus carpio* L., which is among the species most affected by the decline. A study of the fish community of Lake Mikri Prespa carried out in 1984 and 1985 provides a case study of a fishery decline. Proposals are made for restoring commercial fisheries to the lakes of northern Greece, and creating an ecological balance between exploitation and the preservation of these unique ecosystems.

Résumé

Les lacs des Balkans, en particulier les lacs grecs, sont uniques en Europe puisqu'ils existent depuis l'ère tertiaire alors que les autres lacs sont d'origine glaciaire. La plupart de ces lacs sont peu profonds (profondeur < 10.0 mètres), alcalins (pH >8), eutrophiques, et leurs eaux sont chaudes. Leurs peuplements de poissons sont dominés par les cyprinidés et on ne recense que peu ou pas de poissons prédateurs (brochets, perches et silures). Sur tous les lacs grecs, grands ou petits, on observe des pêcheries professionnelles. De nos jours la production de ces lacs varie de 6.5 à 79.6 kg par hectare par an alors que dans les années soixante elle variait entre 12.4 et 222.0 kg par hectare par an. L'énorme déclin de la production des pêcheries est attribué à la surexploitation et à d'autres facteurs tels que l'augmentation de l'eutrophisation, les nombreuses introductions d'espèces non-indigènes et l'apparition des filets en nylon et des moteurs hors-bord; ceux-ci sont la conséquence d'une absence de gestion et/ou d'un manque de mise en vigueur des quelques règlements existant actuellement. L'espèce la plus recherchée commercialement est la carpe, *Cyprinus carpio* L. et c'est l'espèce qui a le plus diminué dans les captures des pêcheurs. L'étude scientifique du lac Mikri Prespa constitue un exemple du déclin des pêcheries en Grèce. Des propositions, compatibles avec la protection de ces lacs uniques en Europe, sont faites afin de restaurer les pêcheries professionnelles en Grèce.

1. Introduction

This century scientists in Greece have studied marine and brackish water organisms to the detriment of our knowledge of freshwater organisms, and most of the few studies of freshwater fishes that were made dealt with their taxonomy. Recently, however, some work has been published on the biology and ecology of several freshwater fish species living in the lakes and streams of Greece (Papageorgiou 1979, Daoulas 1985, Neophitou 1987, Crivelli & Dupont 1987). There are few publications concerning the fisheries of Greek lakes (Athanassopoulos 1935, Athanassopoulos 1940, Economidis & Voyadjis 1981).

The aim of this paper is to draw attention to the serious decline of the freshwater fisheries in northern Greece and to propose some means of restoring commercial fisheries whilst maintaining an ecological balance between the exploitation and preservation of these unique ecosystems.

2. Lakes of northern Greece and their fish communities

2.1 The lakes

The origin of the twelve lakes of northern Greece studied *(Figure 1)* is tectonic, and dates from the Miocene and Pliocene (Tertiary) periods. They are, therefore, much older than most other European lakes. Lakes Mikri Prespa and Megali Prespa belong to the Adriatic Basin, the remaining lakes form a group which is linked to the Aegean Sea *(Table 1)*. With the exception of three lakes (Megali Prespa, Veggoritis and Volvi) which have an average depth greater than 10 m, the remaining lakes are all shallow. One of the latter, Lake Kerkini, which was formerly a shallow natural lake, has been transformed into a reservoir for irrigation purposes. Many of them lack both an inlet and an outlet, or the latter alone, and are only temporary. Only one lake (Vistonis Lake) is directly linked with the sea through a channel. Few data concerning the quality of the water in these lakes are available (Mourkides 1978, Ouzonis & Yannakopoulou 1984, Kilikidis 1984). All of these lakes are alkaline (*c.* pH 8), some are dimictic (*e.g.* Mikri Prespa, Kastoria and Doiran) while others are warm monomictic (*e.g.* Volvi, Veggoritis and Megali Prespa) lakes. Transparency (Secchi disk measurements) is less than 1 m in summer in all but the deepest (Volvi, Megali Prespa and Veggoritis) of these lakes. Algal blooms occur on all these lakes and there are dense beds of submerged vegetation. The trophic status of Lakes Megali Prespa and Veggoritis can be considered as oligotrophic to mesotrophic, but the remaining ten are either eutrophic or even hypertrophic (*e.g.* Koronia and Vistonia lakes). However, eutrophication of these lakes cannot be considered a recent happening. Stankovic (1931) studied the trophic status of the lakes of the Aegean basin in 1928 and 1929. He concluded that Veggoritis lake was oligotrophic, and that Doiran, Kastoria, Volvi, Petron, Chimaditis and Zazari lakes were eutrophic judging by their transparencies (less than 0.5 m in summer) and mesotrophic according to their concentrations of N and P. This shows that the phenomenon of ageing of these lakes was under way much before any agricultural development occurred in this region. Since 1981, when Greece entered the EEC, the ageing processes have speeded up due to increased loading

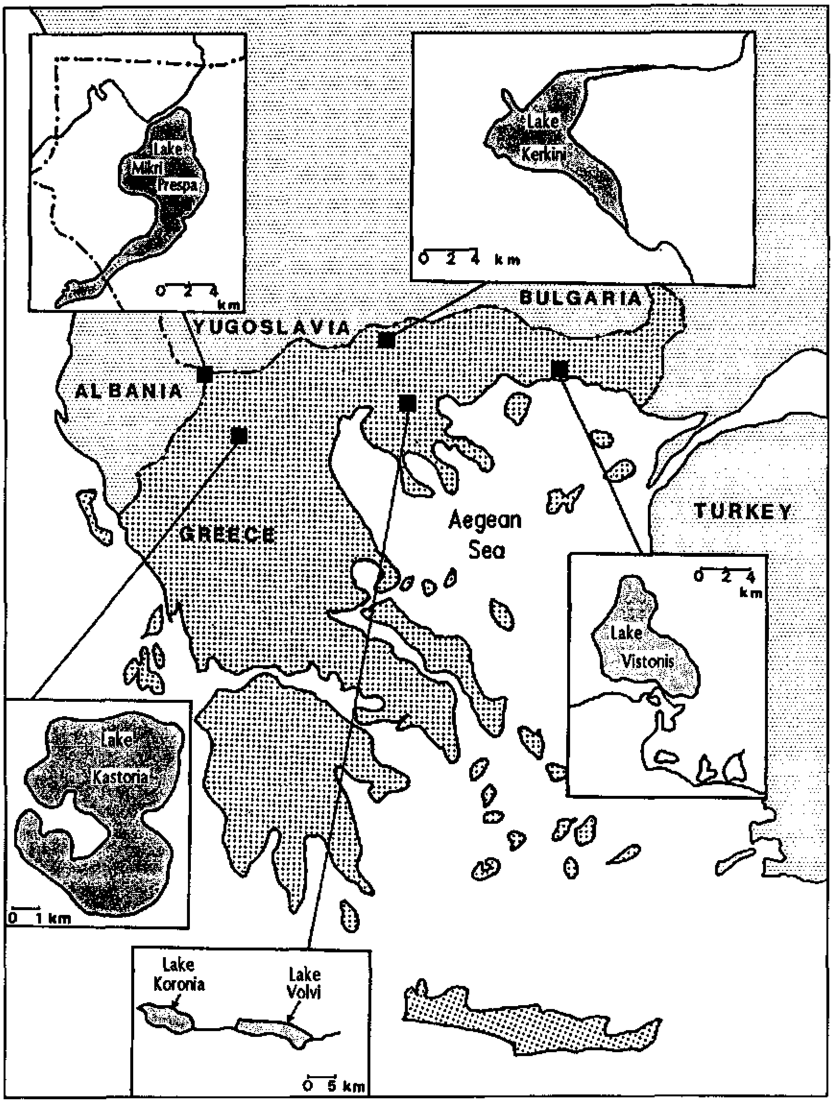

Figure 1. The geographical location of several lakes in northern Greece.

with fertilizers, a consequence of the rapid development of agriculture in the catchments of these lakes. Industrial pollution is also a problem for some of these lakes.

Table 1. Characteristics of lakes in northern Greece.

Lakes	Altitude (m)	Surface area (ha)	Mean depth (m)	Maximum depth (m)	Longitude/ Latitude
Vistonis	15	4 500	2.0	3.5	41°00'N, 25°08'E
Koronia	75	4 200	6.6	8.5	40°40'N, 23°13'E
Volvi	37	6 860	13.5	23.0	40°39'N, 23°15'E
Kerkini	35	6 000	5.0	15.0	41°12'N, 23°09'E
Doiran	148	*1 560	6.5	9.8	41°15'N, 22°50'E
Veggoritis	540	7 000	25.0	46.0	40°45'N, 21°47'E
Petron	572	1 400	2.0	4.0	40°43'N, 21°42'E
Zazari	650	200	3.5	5.0	40°38'N, 21°30'E
Chimaditis	673	400	3.0	4.0	40°36'N, 21°32'E
Kastoria	688	3 237	3.5	9.0	40°31'N, 21°18'E
Mikri Prespa	853	*4 841	6.7	7.9	40°31'N, 21°08'E
Megali Prespa	853	*3 764	18.0	55.0	40°46'N, 21°01'E

* excluding area in another country

2.2 The fish communities

The taxonomy of many genera *(e.g. Barbus, Rutilus, Gobio)* of freshwater fish in Greece is still doubtful. A list of the fish faunas of the lakes of northern Greece will therefore not be given. Cyprinidae *(e.g. Cyprinus carpio, Leuciscus sp., Alburnus sp., Rutilus sp.* etc.) dominate the fish faunas of these lakes in terms of numbers of species. Predators are represented by eel *(Anguilla anguilla)*, sheatfish *(Silurus glanis)*, perch *(Perca fluviatilis)*, pike *(Esox lucius)* and in one case (Lake Megali Prespa) by *Salmo trutta peristericus*. Fish belonging to Cobitidae, Gobiidae, and Clupeidae can also be found in these lakes. In addition, several endemic species are said to occur in these waterbodies. These include species of *Barbus, Rutilus, Alosa* and *Gobio*, however, since their taxonomy is not yet established this remains a controversial issue. The large number of introduced species may be detrimental to one or more of these reputedly endemic species. Gibel carp *(Carassius auratus gibelio)* has been introduced to almost all lakes. The other species, exotic or native, which have been introduced either officially or illegally are: *Perca fluviatilis, Esox lucius, Tinca tinca* (tench), *Parabramis pekinensis, Lepomis gibbosus* (pumpkinseed), *Gambusia affinis* (mosquito fish), *Hypophthalmichthys molitrix* (silver carp) and *Pseudorasbora parva*. Some of these introductions were made in the 1920s and 1930s (*e.g.* to Lake Kastoria).

3. Fisheries

3.1 Organization and existing fishing regulations

All Greek lakes support a commercial fishery. They are all state-owned. In some lakes fishing rights do not exist, and anybody living in the area around the lake can fish without a fishing licence. In other lakes fishing rights are sold by auction, commonly for 5 years, to individuals or to a co-operative of fishermen. There are, however, no statistics on the number of fishermen fishing in a lake for a particular year. This is because fishing licences are not always required. There are two kinds of fishermen, professional fishermen, who earn their total annual income from fishing, and part-time fishermen. These latter people fish less regularly (mainly in the winter) than the professionals, and fishing provides only a secondary income for them. Generally their primary income is from agriculture and/or stock farming. Among the professional fishermen there are few young people. According to interviews that we made around Greek lakes, the number of fishermen has decreased in the last thirty years by at least 50% on each lake. Now there are, on average, 2.5 fishermen/100 ha on Greek lakes (range 1.3-10.5 fishermen/100 ha).

These fishermen use gill-nets, trammel nets with mesh sizes from 10-100 mm (stretched mesh). Each panel is between 40-50 m long by 1.0-3.0 m deep. One fisherman generally sets between 1000 and 2500 m of nets. In addition, but less frequently, they also use fish traps, fyke nets, beach and boat seines, hooks-and-lines and even harpoons. Nylon nets were first introduced at the beginning of the 1960s. Over the same period the fishermen have begun to use outboard engines, from 6-40 horse power. On Greek lakes there is practically no recreational fishing.

Greece is politically divided into 52 counties (Nomos). In each county there is a fishery officer working for the agriculture department, who is in charge of organizing all aspects of fisheries. All the fisheries data collected in the counties are gathered in the Fishery Department of the Ministry of Agriculture in Athens. Fisheries statistics of Greek lakes are collected daily in several landing areas around the lakes. Fishermen weigh their catches by species and pay a tax of 10% of the total value of the fish caught to the state. The statistics are biased in two ways. First, not all of the catches are recorded and second, the fishermen "consciously or unconsciously" misidentify species (because of great differences in the market value among fish species).

There is no limit on fishing effort, and data are not available regarding the number of fishermen fishing per unit time, the length of the nets used at a time, and the mesh size of the nets. The only fishing regulation common to all Greek lakes is the closed season which generally lasts 30 to 40 days. It starts in early or mid-April. In a few lakes (*e.g.* Lake Mikri Prespa) the duration of the closed season was recently extended to two months. Another fishing regulation is the ban on seines, introduced in the 1970s, because of their detrimental effect on the fish fauna. Apart from some temporary and local fishing regulations, *e.g.* a ban on fishing for 'tsironi' in Lake Kastoria in 1982, a ban on catching fish of various species less than 100 mm long to sell to trout farmers as a trout feed, and some mesh size limits, there are no other fishing regulations. Due to a lack of manpower, the closed season is not effectively enforced. Poaching is frequent and widespread.

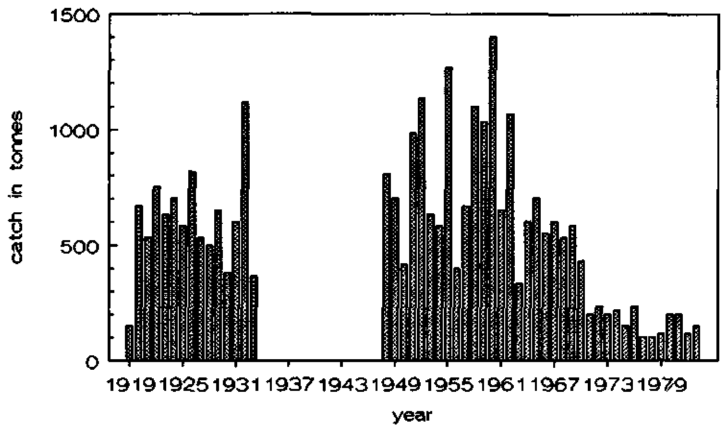

Figure 2a. Annual commercial catches in Lake Koronia.

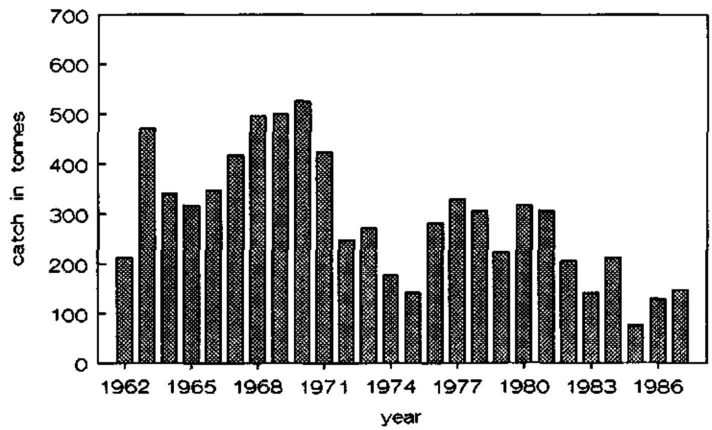

Figure 2b. Annual commercial catches in Lake Vistonis.

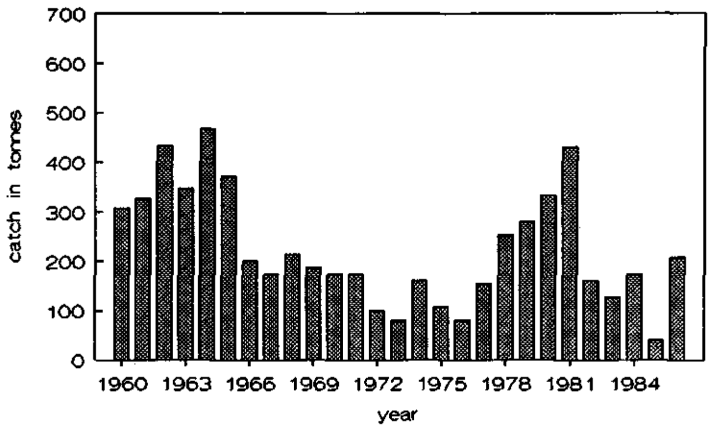

Figure 2c. Annual commercial catches in Lake Kastoria.

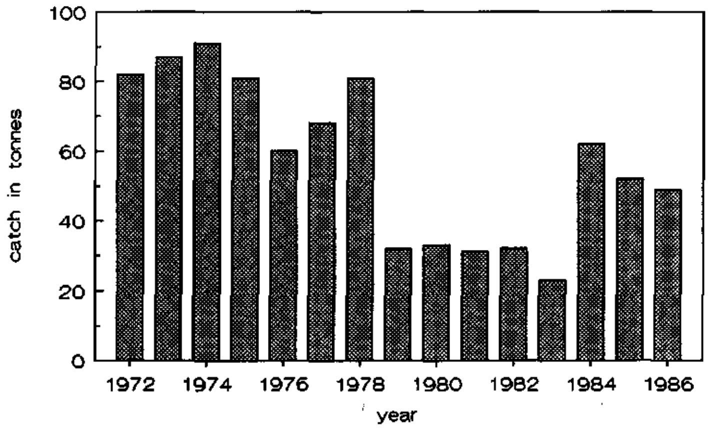

Figure 2d. Annual commerrcial catches in Lake Veggoritis.

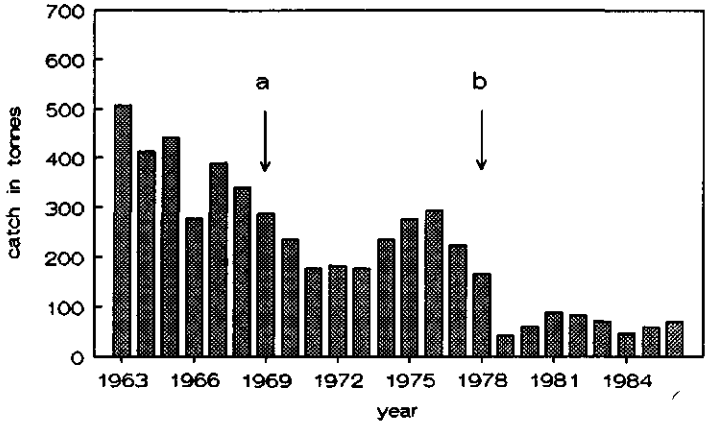

Figure 2e. Annual commercial catches in Lake Mikri Prespa: a. new canal between Lakes Mikri and Megali Prespa. b. irrigation system completed.

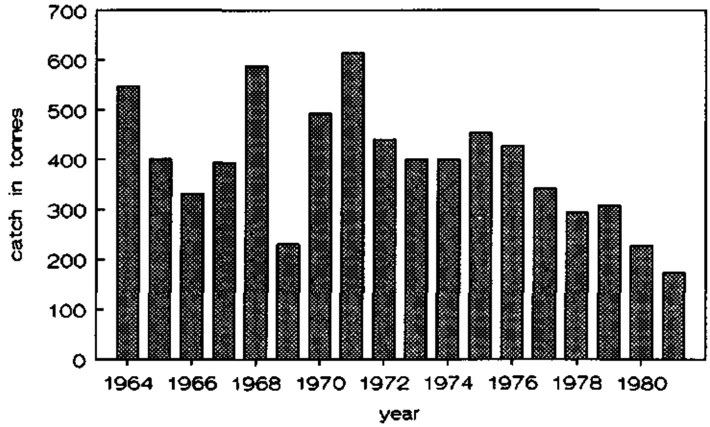

Figure 2f. Annual commercial catches in Lake Volvi.

3.2 Yield of Greek lakes

Fishery statistics have been difficult to obtain because often, in the past, the data on fish catches collected by the Nomarchia were recorded by the tax department and not gathered in the Fisheries Department at the Ministry of Agriculture.

The yield from the lakes fluctuates, but the trend is mostly downwards and in some lakes it is striking *(Figure 2)*. For all lakes the maximum and minimum yield ever recorded and the mean yield for the last ten years are presented in *Table 2*. Athanassopoulos (1940) published the total commercial catches from 1928 to 1935 for all fisheries of Greek freshwater lakes. The mean total yield at that time was 3698 tonnes/yr. The mean total yield of the last ten years of 17 Greek freshwater lakes (= *c.* 95% of all Greek lakes with a commercial fishery) is 1720 tonnes/yr. This represents a decrease of 54% in the catch. The annual yield of Greek lakes has in the past been remarkably high for temperate European freshwater lakes.

Table 2. Total yield and carp yield (kg/ha/year) of lakes of northern Greece.

Lake	Period	All Species			Carp		
		Average yield in the last 10 years	Minimum yield	Maximum yield	Average yield in the last 10 years	Minimum yield	Maximum yield
Megali Prespa	1973-1987	35.6	3.3 (1986)	73.5 (1977)	0.1	0.01 (1977)	1.4 (1973)
Mikri Prespa	1964-1987	13.8	8.4 (1979)	100.9 (1964)	0.8	0.3 (1986)	5,7 (1973)
Veggoritis	1964-1987	6.5	3.2 (1983)	13.0 (1974)	1.4	0.4 (1986)	3.8 (1974)
Petron	1972-1987	14.2	6.6 (1984)	20.1 (1972)	1.0	0.06 (1985)	7.9 (1973)
Zazari	1973-1987	24.0	5.7 (1985)	150.4 (1977)	15.3	0.3 (1986)	116.4 (1976)
Chimaditis	1973-1987	14.5	1.4 (1978)	54.2 (1975)	5.2	0.1 (1981)	53.8 (1975)
Kastoria	1960-1987	68.0	12.5 (1985)	148.3 (1964)	8.1	0.9 (1973)	26.4 (1963)
Koronia	1918-1983	43.3	28.9 (1979)	339.0 (1960)	4.3	0.7 (1983)	203.6 (1955)
Volvi	1964-1982	48.5	26.4 (1982)	91.4 (1971)	1.2	0.4 (1975)	2.3 (1968)
Kerkini	1967-1987	79.6	12.6 (1978)	174.7 (1984)	no data	no data	no data
Vistonis	1961-1987	44.1	18.4 (1983)	111.3 (1970)	13.5	1.4 (1975)	83.8 (1970)

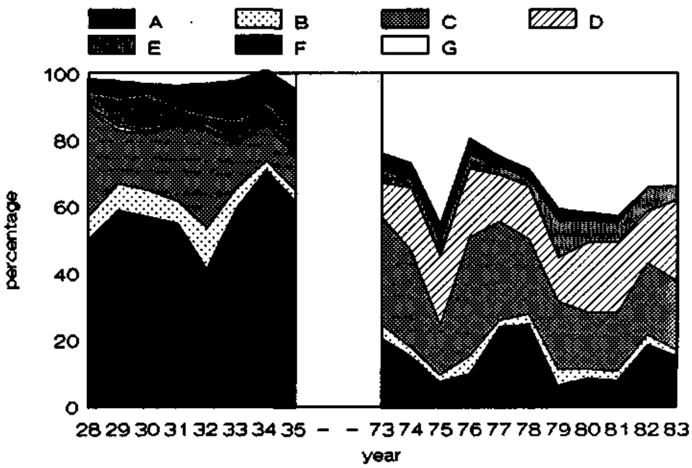

Figure 3. Species composition (%) of annual catches in Greek lakes. A = *Cyprinus carpio*, B = *Silurus glanis*, C = *Scardinius erythrophthalmus*, D = *Alburnus alburnus*, E = *Anguilla anguilla*, F = *Alosa* sp., G = others.

The common carp *(Cyprinus carpio)* is the most economically important freshwater fish species. Its market price is by far the highest of all freshwater fish species in Greece (300-450 drachma/kg according to the region and the time of the year). If the species composition of the commercial catches for 1927-1935 are compared with those of the 1970s and 1980s *(Figure 3)* the decline is even more dramatic. The proportion of common carp is seen to decrease from 56.7% (the mean for 1928-1935) to 14.7% (the mean for 1973-1983), accompanied by similar decreases in the importance of *Silurus glanis, Esox lucius* and *Alosa* sp. At the same time the proportion of less economically important species, *e.g.* roach *(Rutilus* sp.*)*, rudd *(Scardinius erythrophthalmus)* and bleak *(Alburnus alburnus)*, are seen to increase sharply, and these latter species command market prices of only 30-60 drachma/kg. Another consequence of the decline of common carp in the catches is the growing proportion of species of secondary economic importance in the catches; these include *Leuciscus* sp., *Tinca tinca, Carassius* sp., *Barbus* spp., and small fish of various species, 'tsironi'. It seems that some species have already disappeared from certain lakes due to overfishing, *e.g.*, *Silurus glanis* and *Esox lucius* from Lake Koronia (Economidis & Voyadjis 1981), and *Silurus glanis* from Lake Megali Prespa.

As our set of lakes are all similar with regard to certain parameters, *e.g.*, climate, geographic area, fish communities and heavy fishing pressure, it has been possible to investigate the morpho-edaphic index (MEI: total dissolved solid/mean depth) and the total phosphorus concentrations, as predictors of fish yield for all Greek freshwater lakes (Ryder, Kerr, Loftus & Regier 1974, Hanson & Leggett 1982). The morpho-edaphic index was a poor predictor of fish yield ($r=0.21$, $n=14$ lakes) in comparison with the total phosphorus concentrations, which show a significant positive correlation with fish yield (mean fish yield of the last ten years) ($P < 0.03$, $r = 0.61$, $df = 12$, log fish yield=0.534, log total phosphorous concentration + 1.239).

The are several reasons for the decline of the fisheries. The primary cause is that fisheries in Greece are unmanaged, or poorly managed, which leads to overfishing. Detrimental introductions of exotic fish species, water pollution, eutrophication, and decreasing water-level in spring due to pumping for irrigation might also have contributed to the observed decline of fish catches.

4. Lake Mikri Prespa

4.1 Study area and method

The lake is situated mainly in Greece (4841 ha) on the border with Yugoslavia, with a small section stretching into Albania (500 ha). It is linked by a narrow canal with Lake Megali Prespa. It is a typical cyprinid lake with 14 fish species of which 11 belong to Cyprinidae (Crivelli 1984, Crivelli & Dupont 1987). A sampling programme of the fish of Lake Mikri Prespa was carried out in the spring of 1984 (April-June) and in 1985 (March-June) with experimental gill-nets. Two sets of 50 m of monofilament gill-nets were used with 10 mesh sizes from 10-60 mm (stretched mesh). The nets were set at six different sampling stations for two to four consecutive days and were visited daily. Selectivity of the nets has been investigated (Boy & Crivelli 1988). Some 9000 fish were caught in 1984, and 11 600 in 1985, in 144 hauls. They were all measured. Relative abundance and size-class distribution of the fish population were then estimated. Age and growth, length at sexual maturity, length of spawning period and diet have also been studied. Catches per unit effort (CPUE) have been calculated using length-weight relationships (Crivelli 1984).

4.2 Fisheries statistics

Statistics for the fishery of this lake are available from 1964 to 1986 *(Figure 2)* and information on the species composition of the catch is available from 1973 to 1986 *(Figure 4)*. Due to the absence of fishing licences no data are available on the number of fishermen operating on Lake Mikri Prespa. According to interviews with local people, the number of fishermen has decreased by at least 50% since 1945 and today the total number of fishermen in the area is around 100. Fishermen use mainly gill-nets and trammel nets with mesh sizes from 13-80 mm. Until 1982 fishing with two seines was allowed from December to February, mainly to catch *Alburnus alburnus*. Such fishing has been forbidden since 1983. Apart from the ban of the seine in 1983, there is only one fishing regulation: the closed season. The local fishermen's association decides the timing of the spring closed season, to let the fish spawn. Previously, the closed season lasted 30-40 days, and always included the month of May. Since 1983 the fishing has been closed for 40-50 days (*e.g.* 1984: from 20 April to 10 June). The best periods for fishing are from February to April and from September to November.

According to local fishermen the common carp is rare because of a disease. Carp were first observed with this disease in 1969 and its incidence had so increased by 1973 that most carp were dying from it. This disease might be a salmonellosis (Kanellis pers.

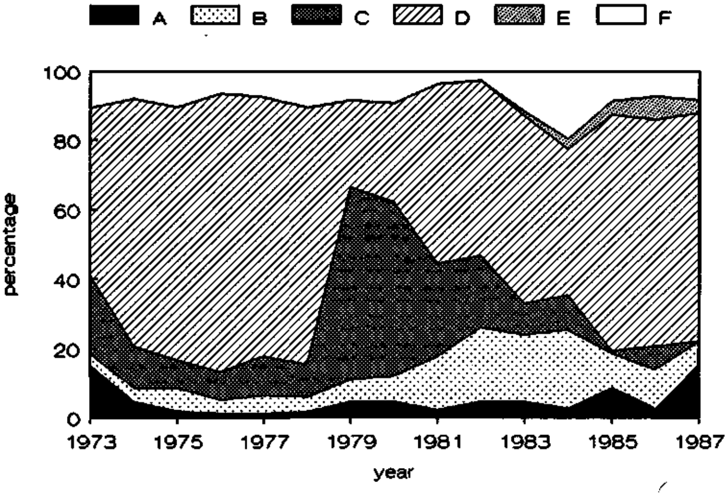

Figure 4. Species composition (%) of annual catches in Lake Mikri Prespa. A = *Cyprinus carpio*, B = *Leuciscus cephalus*, C = *Chondrostoma nasus*, D = *Alburnus alburnus*, E = *Carassius auratus*, F = others.

comm.) and its origin is unknown. Today the few carp which are caught are healthy. Since the carp decline, the fishermen have tried to compensate for their loss of income by catching other species more intensively, *e.g.* chub *(Leuciscus cephalus)*. However, the fishermen cannot guarantee their annual income without an abundant carp population. The fishermen believe that the general decrease in fish abundance at lake Mikri Prespa is due to:

- The carp disease.
- The banning of cutting and burning reeds (which affects the spawning of the fish).
- The introduction of the coypu *(Myocastor coypus)* a destructive aquatic rodent.
- Overfishing.
- The absence of a closed season in the Albanian part of the lake.

For the fishermen the solution to the present decline of the fishery in Lake Mikri Prespa is the enrichment of the lake with carp, and the permission to cut or burn the reeds.

Stock enhancement by the fishermen has been carried out twice. In 1983 small carp, less than 100 mm long, were put into the lake in autumn. This stocking was a complete failure, no released carp were ever caught. In October 1984 the lake was stocked with 9 tonnes of carp from a fish farm in Yugoslavia. The size of carp used was much bigger than in 1983, 320-370 mm long (2-3 years old). During the same month at which the carp were released, the fishermen caught one tonne of this carp. They decided, therefore, to close the fishing until the following June. In June 1985 they caught 7.5 tonnes of the stocked carp. Two conclusions can be drawn from these two attempts at stocking, *viz* restocking with one year old carp results in only minimal survival, but restocking with carp at least two years old gives much better survival, although the vulnerability of farm reared carp is still very high.

4.3 Studies on the fish populations

The relative abundance of each of the different fish species in Lake Mikri Prespa, assessed by experimental sampling, was compared with the species composition of catches (by % biomass) from this lake for the same period *(Table 3)*. Two species, *Alburnus alburnus* and *Rutilus rubilio*, provided 82.4% and 87.0% of the total ichthyomass in 1984 and 1985 respectively. This is characteristic of an unbalanced fish community. In addition, by the end of the 1970s, four exotic fish species, *Carassius auratus gibelio, Parabramis pekinensis, Hypophthalmichthys molitrix* and *Pseudorasbora parva* (Bianco 1988) had been introduced into Lake Mikri Prespa, probably by the Albanian people on the southern part of the lake. Only the introduction of *Carassius auratus* and *Pseudorasbora parva* were successful and today *Carassius auratus* constitutes more than 5% of the total catch. The other two species are caught only rarely.

Table 3. Species composition (% of biomass) of the experimental samples and the annual commercial catches from Lake Mikri Prespa in 1984 and 1985.

	1984		1985	
Fish species	Samples	Annual yield	Samples	Annual yield
Alburnus alburnus	32.4	42.0	40.2	68.8
Rutilus rubilio	50.0	17.4	46.8	7.1
Leuciscus cephalus	10.0	22.5	6.6	9.7
Barbus prespensis	0.9	0.3	0.7	0.06
Chondrostoma nasus	3.8	9.9	1.6	0.08
Cyprinus carpio	-	3.3	1.1	9.3
Albyrnoides bipunctatus	2.9		2.9	
Anguilla anguilla		1.4		0.8
Carassius auratus	0.01	3.1	0.05	4.1

The catch per unit effort (CPUE) has been calculated for each mesh size at the different sampling stations as the gram weight of fish caught per hour per square metre of gill-net *(Table 4)*. The major conclusions to be drawn from the CPUE data is that the larger mesh sizes used (38-60 mm) have poor performance, a consequence of the scarcity of large old fish at Lake Mikri Prespa.

The average length of the fish caught, by species, in the ten mesh sizes used, are presented in *Table 5*. Fish of the following genera: *Alburnus, Carassius, Alburnoides* and *Rutilus*, are all caught, regardless of mesh size, when they have reached maturity. In contrast, of the remaining genera *e.g., Cyprinus, Leuciscus, Chondrostoma* and *Barbus*,

Table 4. Catch per unit effort ($g/hour/m^2$) of experimental gill-nets used in Lake Mikri Prespa

	Number of sampling stations	Mesh size (mm)										Total	Air temperature (°C)	Mean Secchi disk depth (m)
		10	14	18	23	28	32	38	45	52	60			
1984														
April	4	1.17*	2.57	3.54	2.94	0.79	0.31	0.43	0.40	0.48	0	12.63	7.8	1.93
May	1	0.42	3.33	5.58	5.71	4.20	1.94	1.62	1.90	0	0	24.70	15.0	1.61
June	2	27.06	26.65	11.76	6.64	0.90	0.77	0.29	0	0	0	74.07	17.8	1.08
1985														
March	5	0.26	1.05	2.32	1.84	0.32	0	0	0.33	0.49	0	6.61	4.7	2.10
April	2	2.21	6.05	8.55	6.97	0.64	1.44	0.25	0.92	0	1.45	28.48	11.0	1.57
May	5	14.53	19.58	9.22	6.87	1.12	1.03	0.83	0	0.19	0	53.37	16.1	1.38
June	2	25.62	18.78	7.73	5.57	1.22	0.77	1.25	0	0	0	60.94	18.5	0.88

* Mean

immature fish are caught in several mesh sizes. The small number of yearlings and immature fish in our catches, and the small number of age-classes in the populations of several species, seems to indicate that the populations of *Cyprinus carpio, Chondrostoma nasus* (nase) and possibly of *Barbus prespensis* and *Leuciscus cephalus* have reached the critical level of collapse. Already before the last World War, numbers of common carp were decreasing in the fishery catches of Lake Mikri Prespa (Vafiadis Lazaros, Prespa and its beauties, Athens 1940). We believe that overfishing is the main cause of the decline of the fishery of Lake Mikri Prespa. However, we also believe that the building of a concrete canal between Lake Mikri Prespa and Lake Megali Prespa in 1969-1970 lowered the water level of Lake Mikri Prespa (T. Hollis pers. comm.). The diminution of the water-level has markedly reduced, in spring, the surface area of flooded shallow water necessary for the successful spawning of species such as carp. This change in water-level has exacerbated the decline of the fishery. Nevertheless, the only way to restore the stock is to strictly enforce new fishing regulations. Only when these regulations are fully implemented can one envisage that temporary stocking will speed up the recovery of the stock. In addition, reedbed management to favour spawning should be recommended, and the stocking of any non-native fish species should not be advised.

Table 5. Average length of fish caught by different mesh sizes during experimental sampling in Lake Mikri Prespa (N= 21 sampling stations, 1984-1985 combined). Shaded area represents length of fish which are still immature.

	Mesh Size (mm)									
Species	10	14	18	13	18	32	38	45	52	60
Carassius auratus	0	0	96	0	0	163	175	0	0	304
Alburnoides bipunctatus	74	99	0	0	0	0	0	0	0	0
Alburnus alburnus	96	126	151	165	0	0	0	0	0	0
Rutilus rubilio	79	99	124	144	175	188	0	0	0	0
Chondrostoma nasus	80	126	159	179	209	226	283	0	0	0
Leuciscus cephalus	0	118	157	173	225	254	277	338	365	0
Barbus prespensis	100	120	153	168	222	221	248	0	0	0
Cyprinus carpio	0	0	0	0	0	188	205	276	0	351

5. Proposals for restoring the fish stocks

The objective of good management for restoring a self-sustaining fishery is to ensure that the spawning stock does not become so small that there is a danger of recruitment failure. This will require a longer closed season, a minimum landing size, some form of effort or yield control, and an increase in mesh size to reduce the fishing pressure on immature or recently mature fish, and to distribute the catch over a wider range of age groups. If the fishing pressure is relaxed the overfished stock will probably rebuild after several years. The immediate effects of fishing regulations will include an initial loss in catch and earnings before the long-term benefits become apparent. A temporary subsidy to licensed fishermen as compensation for the sacrifice during rebuilding of stock should therefore be recommended. This is a small amount within the framework of regional development, and temporary subsidies in build up phases of new activities are common practice in development aid.

5.1 Fishing regulations

- **Licensing.** Licensing should be restricted solely to professional fishermen. Every professional fisherman should get a free licence allowing him to fish on a specific lake. This licence should be identical for all Greek freshwater lakes and it should be issued on an annual basis. In cases where fishermen have disregarded the fishing regulations, licences should not be renewed the following year.
- **Closed season.** The closed season should be extended to two months for all lakes, either from April-May or from May-June, depending upon the altitude of the lake. A closed season of one month could also be included in winter for a small number of lakes with important populations of *Coregonus* sp. or *Esox lucius.*
- **Mesh size and size limit.** It does not seem practically feasible to edit and enforce a minimum landing size of fish in Greece. A minimum mesh size should therefore be defined. At Lake Mikri Prespa, for example, a minimum mesh size of 45 mm (stretched mesh) would be advisable in order to protect, in order of priority, the spawning stocks of carp, chub, nase and barbel. However, mesh regulations alone are not sufficient and should be applied in conjunction with limitations on effort or yield.
- **Effort or yield limitations.** Quotas or yield limitations do not, to us, seem feasible in Greece, as they are too difficult to implement. Careful regulation of fishing effort is therefore the main procedure which will ensure full stock protection. The most effective and most easily implemented way of controlling fishing effort is to limit the number of fishermen by licensing. The number and the length of the nets set daily per fisherman should also be regulated in order to reduce the fishing effort.

5.2 Implementation and enforcement of fishing regulations

In each Nomarchia there should be a fishery officer and a number of wardens. The duties of the fishery officer should be to strictly enforce the fishing regulations by directing and guiding the work of the wardens. These wardens should be equipped with a boat and a powerful engine in order to be effective in the field. They should check that the fishing regulations are being adhered to by the fishermen and should be authorized to report any unlawful acts to the authorities which may then prosecute fishermen who have not respected the regulations. In addition, the fishery officer should distribute the fishing licence annually, and with the help of the wardens, he should organize and monitor the fishery statistics at landing points. No stock enhancement should be carried out without the agreement of the fishery officer.

5.3 Introduction of exotic species and stock enhancement

Greek lakes are geologically old lakes inhabited by a certain number of endemic fish species. Conservation of these endemic fish species should be an important priority. The introduction of numerous exotic fish species in Greek freshwaters cannot be tolerated, and henceforth should not occur. Holcík (1984) clearly stated the ineffectiveness of such introductions.

Stocking programmes for the purpose of enhancing commercial fisheries are only a temporary management practice, generally carried out to restore the stock of a declining fish species after the cause of its decline has been well defined. Economically, stock enhancement is an expensive management practice, and its benefit is always difficult to assess (cost/benefit analysis). Maintenance stocking, involving fry and small fingerling-size fish to supplement natural reproduction, has seldom been effective and should not be recommended. Put-and-take stocking, the permanent stocking of catchable sized fish, should also be rejected for commercial fishery management because it is not economically feasible. In Greece, if fishing regulations are adopted, and strictly implemented and enforced, and only under these conditions, stock enhancement, for example of common carp, could be envisaged as a solution for restoring the declining stock. However, such stocking programmes should be carefully evaluated and planned in order to maximise the cost/benefit ratios of such management programmes. Only native species should be involved in these programmes.

6. Conclusion

Sound fisheries management in Greece should include a reduction in the fishing pressure, the establishment of fishing regulations, the maintenance of wild stocks and their restoration, especially those of endemic species (genetic conservation), and a ban on the introduction of any exotic fish species. In addition, it should also involve an educational programme directed towards the professional fishermen to make them aware of the reasons for and the absolute necessity of new fishing regulations, and the need for a strict enforcement of these regulations, for their own benefit: a self-sustaining commercial fishery which could bring a reasonable annual income on a long-term basis.

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References

Athanassopoulos, G., 1935. Effets d'abaissement du niveau par dessèchement sur la production piscicole d'un lac Macédonien. Verh. int. Ver. Limnol. 7: 321-325.

Athanassopoulos, G., 1940. Bericht über die Süsswasserfischerei in Griechenland. Int. Rev. Hydrobiol. 39: 628-633.

Bianco, P.G., 1988. Occurence of the Asiatic gobionid *Pseudorasbora parva* (Temminck and Schlegel) in south-eastern Europe. J. Fish Biol. 32: 973-974.

Boy, V. & Crivelli, A.J., 1988. Simultaneous determination of gill-net selectivity and population age class distribution for two cyprinids. Fish. Res. 6: 337-345.

Crivelli, A.J., 1984. Lake fisheries. In: Integrated Environmental Study of Prespa National Park, Greece. Final report. Commission of the European Communities D.G. XII, pp. 49-86 and 144-155.

Crivelli, A.J. & Dupont, F., 1987. Biometrical and biological features of *Alburnus alburnus* x *Rutilus rubilio* natural hybrids from Lake Mikri Prespa, northern Greece. J. Fish Biol. 31: 721-733.

Daoulas, C., 1985. Alimentation de *Rutilus alburnoides hellenicus* Stephanidis (Pisces, Cyprinidae) dans le lac de Trichonis, Grèce. Vie et Milieu 35: 63-68.

Economidis, P.S. & Voyadjis, V.P., 1981. Etude de l'évolution du peuplement ichthyologique du lac Koronia (Macédoine, Grèce) et de sa pêcherie pendant la période 1947-1977. Sci. Annals Fac. Phys. & Mathem., Univ. of Thessaloniki. 21: 17-58.

Hanson, J.M. & Leggett, W.C., 1982. Empirical prediction of fish biomass and yield. Can. J. Fish. Aquat. Sci. 39: 257-263.

Holcík, J., 1984. Some considerations on the role of introduced species of fish in the management of inland fisheries. EIFAC Tech. Pap., (42). Suppl. vol. 2: 488-495.

Kilikidis, S.D., 1984. Ecological study on lakes of northern Greece, Agiou Vassiliou, Doirani and Vistonis. Scientific Annals of the Veterinary School. Univ. Thessaloniki. 22: 271-395 (In Greek).

Mourkides, G.A., 1978. The lakes of northern Greece. I. Trophic status, 1977. Scientific Annals of the School of Agriculture and Forestry, Univ. Thessaloniki. 21: 119-131.

Neophitou, C., 1987. A study of some autoecological parameters of southern barbel *(Barbus meridionalis)* in the Rentina stream, Greece. J. Appl. Ichthyol. 3: 24-29.

Ouzounis, K. & Yannakopoulou, T., 1984. Some physico-chemical characteristics of Vistonis Lake (northern Greece). Thalassographica 7: 61-72.

Papageorgiou, N.K. 1979. The length-weight relationship, age, growth and reproduction of the roach, *Rutilus rutilus*, in Lake Volvi. J. Fish Biol. 14: 529-538.

Ryder, R.A., Kerr, S.R., Loftus, K.H. & Regier, H.A., 1974. The morphoedaphic index, a fish yield estimator-review and evaluation. J. Fish Res. Bd Can. 31: 663-688.

Stankovic, S., 1931. Les particularités limnologiques des lacs égéens. Verh. Int. Ver. Limnol. 5: 158-196.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 248-261.

Population parameters and yield-per-recruit estimates for pikeperch *(Stizostedion lucioperca* L.) in Lake Balaton, Hungary

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Abstract

Due to fluctuations in the stock density of pikeperch in Lake Balaton (59 500 ha) during the period 1975-1985 both productivity and yield changed. The total annual yield of pikeperch by the professional fishery in the period 1975-1985 was between 33.8 and 52.8 tonnes/yr (0.57-0.92 kg/ha). Along the longitudinal axis of the lake from NE to SW, the exploitation rates (E) were 45, 55, and 21%

The fishable life span of pikeperch in the NE basin of the lake is 11 years, in the Central basin, 8 years, and in the SW basin, 6 years. Yield-per-recruit estimates according to dynamic pool models, referring to these three distinct basins of Lake Balaton, revealed up to two-fold differences due to variations in fishing intensity (F) and natural mortality (M) and in growth rates. According to yield isopleths, the maximum yields (MY) in the NE and central basins of the lake are attained at ages of recruitment to the fishery (t_c) of 10-13 years, while in the SW basin the corresponding age is 7-12 years. Lately the regeneration of pikeperch stocks has been studied because of the present rate of exploitation, faster growth rates, higher natural recruitment and artificial stocking.

1. Introduction

The pikeperch, which is top predator in Lake Balaton, formed 5-12% of the commercial catch from the lake for many years (Biró 1977a). Studies of pikeperch in Lake Balaton include those of feeding in early and adult life (Biró 1973, 1977b) dynamics of the local stocks (Biró 1985), early and adult growth rates (Biró 1970) and biological role in the ecosystem (Biró 1977a,b, 1978). The biology of the species is therefore quite well known. However, after the eutrophication of the lake, and the mass fish-kills of 1965, 1975 and 1982, the dynamics of the populations inhabiting different local water areas changed. In particular, growth rates and productivity changed due to fluctuations in population densities. During repeated studies of pikeperch population dynamics, it was established that the annual yields from the local stocks were less than the expected values of 1-3 kg/ha (Biró 1985). Because of their different productivities and sensitivities to environmental impacts, several economically and biologically important fish species respond differently to the variety of environmental conditions provided by Lake Balaton (Biró 1985). After the decreases in the stocks of pikeperch in 1965-1975 and the early 1980s, changes were observed in the dynamics of the local populations. On some eutrophied areas of the lake the growth of pikeperch became faster and independent of stock density (Biró 1985). Recently the stocks have been found to be recovering.

The aim of this work was to make yield-per-recruit estimates for pikeperch and to compare them with those made ten years ago (Biró 1977a), and further to assess the present rate of productivity and exploitation of the pikeperch stocks.

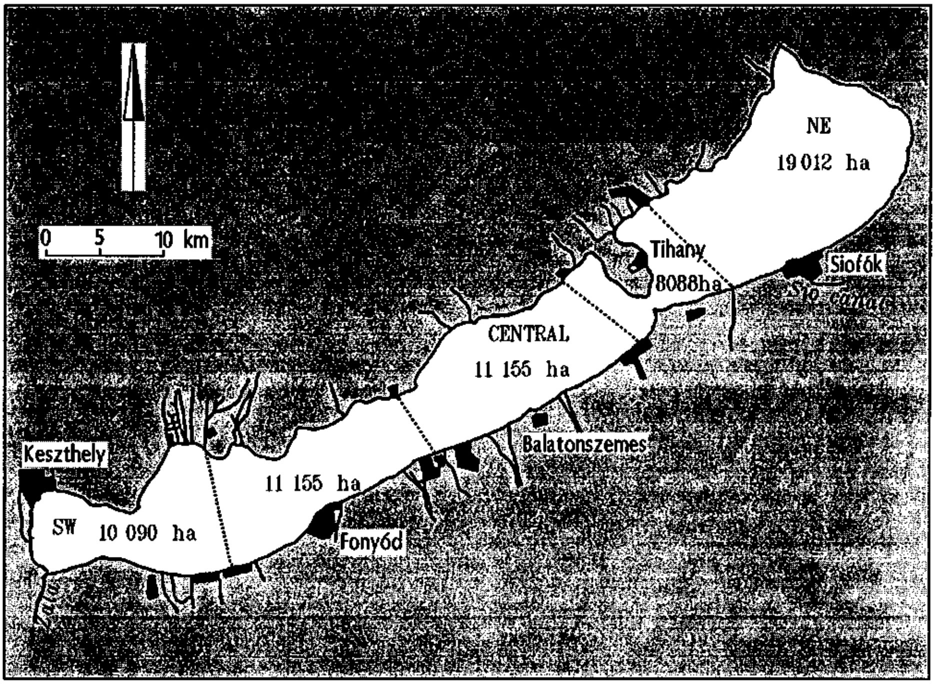


Figure 1. The five fishing areas of Lake Balaton with indication of fishery stations (NE = northeastern, SW = southwestern basin).

2. Material and methods

The material used in this study was caught by professional fishermen (altogether 4246 samples) in three ares, the northeastern (NE), central (C) and southwestern (SW) basins of the lake *(Figure 1)*. For the type of observations made and details of the analyses of the results, refer to Biró (1985). The catch-statistics for 1960-1985 were obtained from the Balaton Fishing Company (Siófok). These comprised annual yield and fishing efforts (f=hours/yr) for the different areas. The density and biomass of the local stocks were estimated by Leslie methods on the basis of monthly catch statistics for 1984-1985 (Ricker 1975). Yield-per-recruit estimates were derived from details of population dynamics and the fishery and according to the 'dynamic pool model' of Beverton & Holt (1957).

Assuming constant mortality and growth rates throughout the fishable life span, we estimated the biomass per recruit (B/R) for different ages at recruitment to the fishery (t_c) and different values of fishing mortality (F). Recruitment (R) was assumed to be constant (R=1). The results were compared with those assessed for the period 1964-1973 (Biró 1977).

3. Results

3.1 The pikeperch yields of the professional fishery in Lake Balaton

Five seine nets are currently used for commercial fisheries in Lake Balaton (length 1000 m, height 4 m, cod-end mesh size 3.5 cm bar mesh). On the five fishing areas of Lake Balaton the total annual fishing efforts (f) varied between 0 and 474 hours/yr in 1975-1985. No seining was practised in the NE basin in 1982, 1984 and 1985. In these years some gill-netting only was used. The total fishing effort for the whole lake was 1009-1945 hours/yr and decreased over the period 1975-1985. In the NE basin the effort per unit surface area was lower and decreased more sharply than in the C and SW basins *(Figure 2)*.

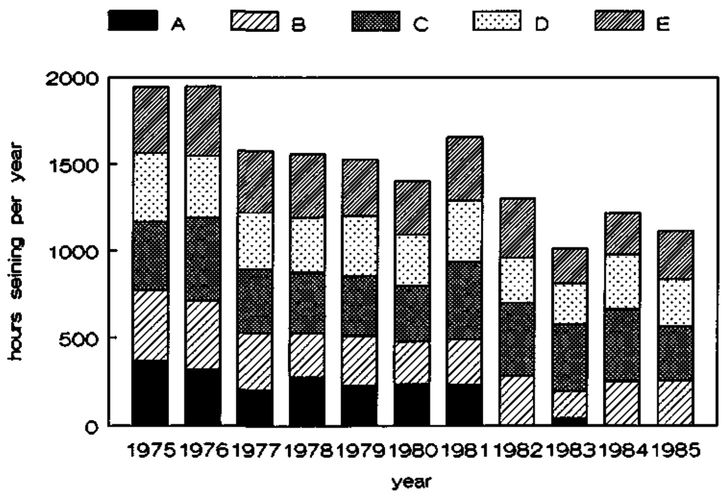


Figure 2. Fishing effort in hours seining per 1000 ha of lake per year, for local areas and the whole lake. A = Siófok, B = Tihany, C = Balatonszemes, D = Fonyód, E = Keszthely (See *Figure 1*).

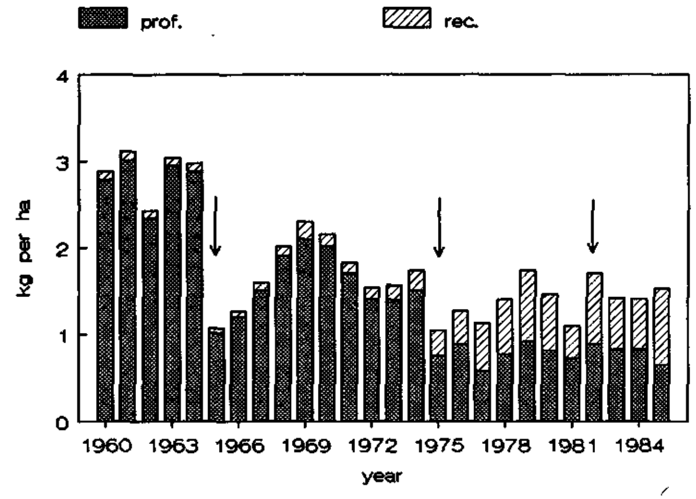


Figure 3. Variation of professional and recreational annual pikeperch catches during 1960-1985. Arrows indicate mass fish kills.

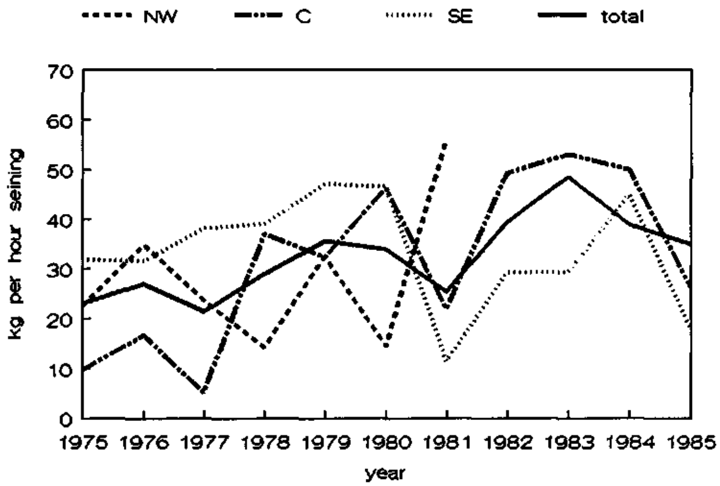


Figure 4. Catch (kg) per unit effort (1 hour seine netting) in the three basins (NE, C, SW) and for the whole of the lake.

Table 1. Estimated population parameters for pikeperch in Lake Balaton for the years 1970-1973 and 1984-1985.

Variable	1970-1973*	1984-1985
Total biomass (t)	578	95.4 - 292
Biomass (kg/ha)	9.7	1.6 - 4.9
Population size (N/ha)	15	2.4 -7.5
Production rate (P/B) (%/year)	50	39 - 63
Annual production (kg/ha)	4.9	0.9 - 2.6
Instantaneous total mortality coeff. (Z) per year	1.0442	0.364 -1.242
Natural mortality coefficient (M) per year	0.373	0.11 - 0.34
Fishing mortality coefficient (F) per year	0.671	0.25 - 0.96
Annual mortality rate (A) (%/year)	65	30 - 71
Survival rate (S) (%/year)	35	29 - 69
Rate of exploitation (E) (%/year)	41	20.8 - 55
Maximum length of fish (L_∞) (cm)**	75.7	75.7 -112.5
Maximum weight of fish (W_∞) (g)***	6429	5577 - 14 230
Coefficient of growth in length (K) per year	0.1376	0.09 - 0.1957
Coefficient of growth in weight (G) per year	0.5051	0.52 - 0.69
Total catch (t/year)	119	33.8 - 52.8
Catch (kg/ha/year)	2	0.63 - 0.96
Catch per unit effort (tonnes/100 hours/year)	3.9	2.14 - 4.86
Age at first capture t_c (year)	2.9	2.6 - 3.1
Maximum age (years)	15	15
Mean length of fish caught (cm)	36	35 - 42.5
Mean weight of fish caught (g)	603	572 - 1019

* After Biró (1978)

** asymptote of curve of growth in length according to Bertalafanny's growth model

*** asymptote of curve of growth in weight

The annual pikeperch harvest depends on the population density, the selectivity of the seine net used and the intensity of fishing. Between 1960-1975 the total annual yield of pikeperch by the professional fishery decreased from 3 kg/ha to less than 1 kg/ha, but stabilized thereafter. The loss of stocks (yield) caused by pikeperch angling increased from the 1970s onwards and in 1985 considerably exceeded the yield of the professional fisheries (0.9-0.7 kg/ha respectively) *(Figure 3)*.

In the period 1975-1985, in the NE basin, the pikeperch catch was between 3453 and 12 205 kg (0.2-0.7 kg/ha), in the central basin between 3823 and 20 689 kg (0.3-1.9 kg/ha), and in the SW basin between 4176 and 15 295 kg (0.4-1.5 kg/ha) *(Table 2)*. Based on these figures, and on the catches per unit effort (CPUE) per hour of seine netting, it was concluded that the density of local stocks varied and that their distribution is not homogeneous *(Figure 4)*.

3.2 Population parameters

Between the periods 1970-1973 and 1978-1985, in all three basins of Lake Balaton, the average biomass ($\bar{B}$) decreased by 33-50% *(Table 1)*. The numerical density of the populations showed similar decreases. Along the longitudinal axis of the lake in a NE-SW direction, the number of age-classes decreases, the growth constant (K) gets higher, and maximum length decreases *(Table 2)*. The P/B ratios in the NE, C and SW basins were 39, 63 and 59% respectively. Annual production per unit area was low (0.9-2.6 kg/ha) and the annual total pikeperch catch decreased to less than half its former value. Other characteristic differences between the basins are given in *Table 2*. The rate of exploitation (E) was calculated as $E = (F/Z)(1-e^{-Z})$.

Table 2. Basic parameters of the population dynamics and the fishery of pikeperch in the three basins of Lake Balaton, during 1984-1985 (avarage value).

	NE basin (Siófok-Tihany)	C basin (Balatonszemes)	SW basin (Keszthely)
Age-groups in the fishery	3+ to 13+	3+ to 10+	3+ to 8+
K (per year)	0.0943	0.0892	0.1957
L_∞ (cm)	112.5	112.2	75.7
t_0 years	0	-0.12	+0.425
Z (per year)	1.08	1.24	0.36
F (per year)	0.74	0.96	0.25
M (per year)	0.34	0.28	0.11
S (per year)	0.34	0.29	0.69
A (per year)	0.66	0.71	0.30
q (per year)	0.0014	0.0027	0.0007
f (hours)	529	349	362
E (per year)	0.4522	0.5497	0.2083

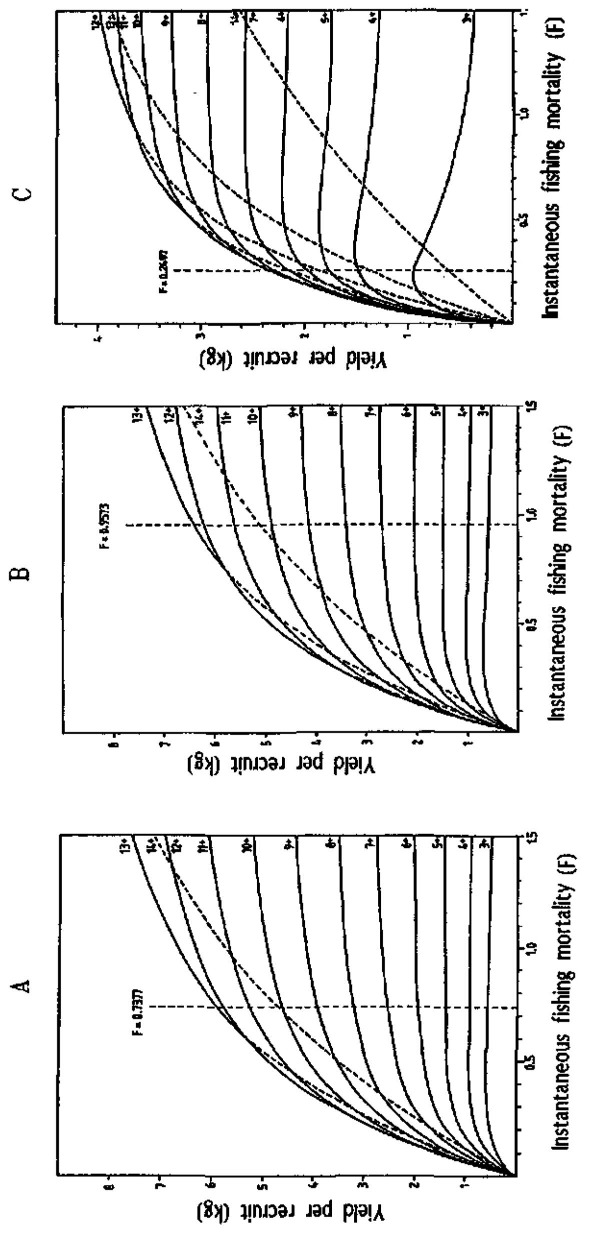
3.3 Yield-per-recruit estimates

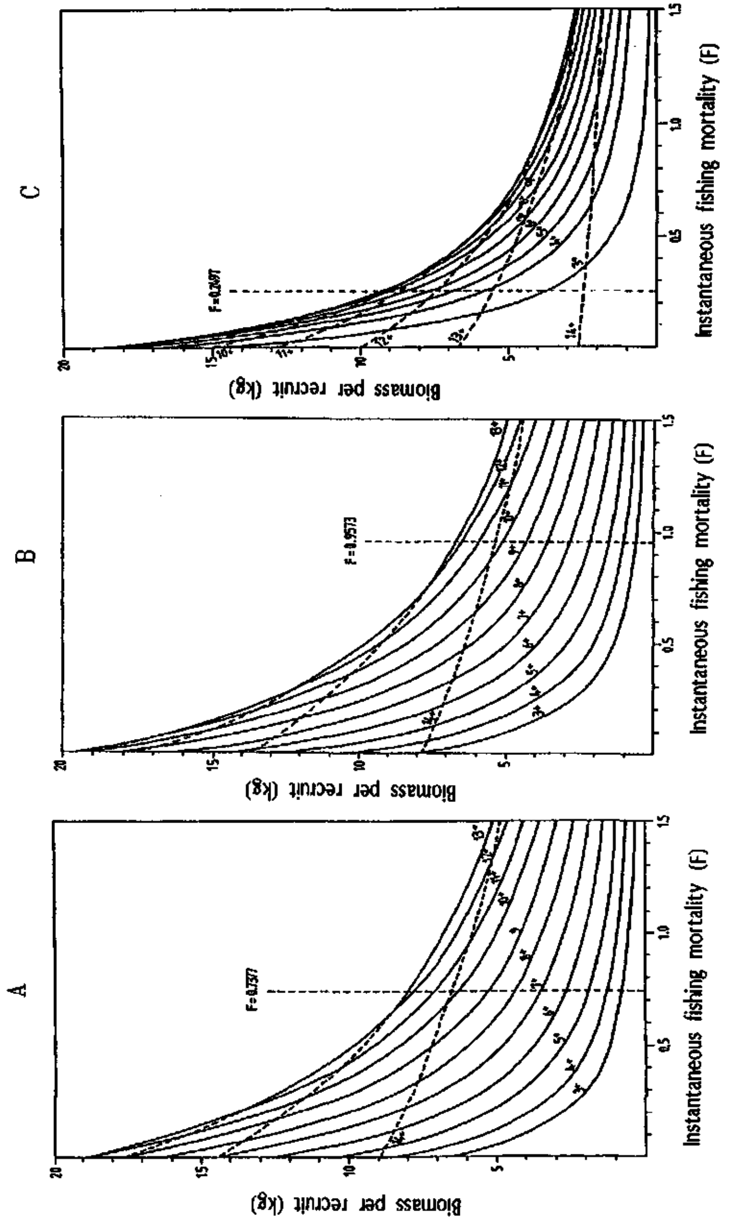
In *Figure 5* the equilibrium yields of pikeperch can be seen as a function of the instantaneous rate of fishing mortality (F). The fishable life-span of pikeperch is 11 years in the NE basin (3+ to 13+), 8 years in the C basin (3+ to 10+) and 6 years in the SW basin (3+ to 8+). Recruitment to the exploited phase begins from 3 years of age in the NE and C basins, and from 2.5 years in the SW basin. In the NE and C basins, due to natural mortality, the isopleth for equilibrium yields shows asymptotic curves. In the NE and C areas the Y/R values *(Figure 5a,b)* are about twice as high as those of the SW basin *(Figure 5c)*. This may be caused by spatial and temporal differences in the survival and growth rates of the exploited year-classes, mainly after the 7-8 year. The yield at present fishing intensity and t_c = 13 years, theoretically, still grows, but decreases above this. In the SW basin of the lake, due to low fishing and natural mortalities, and different growth characteristics, yields show a different form. At t_c = 12 years, the yield, theoretically, increases with increasing fishing mortality, but thereafter decreases.

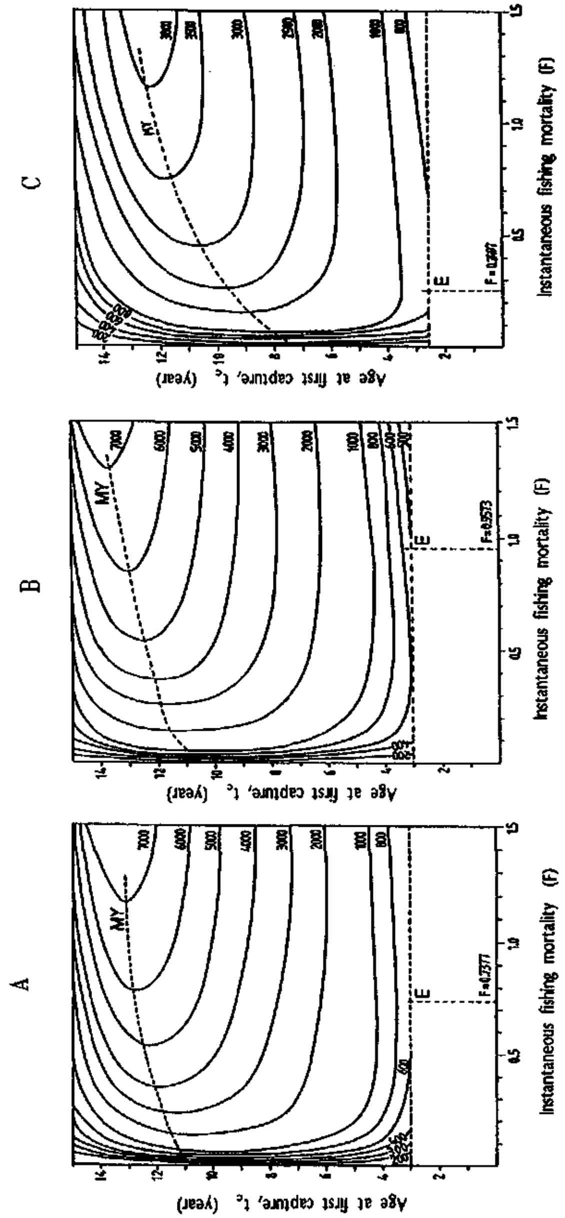
The biomass proportional to recruitment (B/R) changes inversely as a function of instantaneous fishing mortality (F) *(Figure 6)*. In 1970-1973 in the NE basin of the lake, at a fishing mortality of F = 0.76/yr, the rate of exploitation of pikeperch stocks was E = 41%. The yield-per-recruit (Y/R) for F = 0.76/yr at t_c = 3-8 years was 690-1900 g and the biomass-per-recruit (B/R) was 1000-3250 g (Biró 1977a). In the same area in 1984-1985, at F = 0.74/yr fishing mortality, the rate of exploitation of the stock was E = 45%, which essentially did not change. At t_c 3-8 years the yield-per-recruit (Y/R) was now 550-3200 g, the latter figure exceeding the value assessed ten years ago by some 1300 g (68%) *(Figure 5a)*. The biomass proportional to recruitment (B/R) at the given t_c varied from 800-4400 g *(Figure 6a)*. The upper value was therefore 35.4% higher than in 1970-1973. In the C basin of the lake, at F = 0.96/yr, the rate of exploitation was E = 55%, the yield-per-recruit (Y/R) varied from 580-3400 g *(Figure 5b)*, and the biomass-per-recruit (B/R) from 600-3600 g *(Figure 6b)*. In the SW basin at F = 0.25/yr, E proved to be 21%, and the yield-per-recruit (Y/R) ranged from 940-2290 g *(Figure 5c)*, the biomass-per-recruit (B/R) varied from 3700-9000 g *(Figure 6c)*. According to the yield isopleths, the maximum yields (MY) in the NE and in the C basins of the lake can be achieved at fairly high ages at first capture (11-13 yrs) and in the SW basin between 7-12 yrs *(Figure 7)*.

4. Discussion

A considerable decrease in pikeperch stocks in Lake Balaton was observed more than ten years ago (Biró 1985). During the period 1980-1985 the stock density approximated its former value, so they can be considered to have recovered, but they still fluctuate widely. These changes occurred in parallel with changes in the basic population parameters. Earlier the growth of the stocks was density-dependent (Biró 1970), but due to stock depletion and reduced inter-specific competition, it latterly became density-independent. In the early 1970s the standing stock produced 50% of its biomass. The P/B ratio in 1984-1985 ranged from 39 to 63% and the regeneration of the stocks was promoted by the yearly introduction of a large number (1.2 million) of pond reared fry. As the local populations are not separated from one another, and migration occurs between different areas of the lake, the causes of mortality vary. Judging by the weight of the pikeperch caught, both the commercial and recreational fisheries appear to be


A
B
C
Yield per recruit (kg)
Instantaneous fishing mortality (F)


A
B
C
Biomass per recruit (kg)
Instantaneous fishing mortality (F)


A
B
C
MY
E
Instantaneous fishing mortality (F)
Age at first capture, t_c (year)

more effective in the SW basin. There the stocks seem to be more stable than those in the NE and the C basins, where the proportion of 3-4 year old specimens is higher. Pikeperch reach maturity at 3-4 years, and some are therefore caught after the first spawning.

In Lake Balaton the pikeperch populations produce both 'weak' and 'strong' year-classes in haphazard fashion because of the variable temperature and lotic conditions which may prevail during hatching. The numerical decrease of a 'weak' year-class during the first 3-4 years after spawning causes a significant change in the stock structure. The fishing of pikeperch in Lake Balaton is based on a minimum of 5 year-classes. The different size and age structures of the stocks are therefore also influenced by standard net selection which thus has a regulatory effect upon natural recruitment. The yield-per-recruit estimates, from the dynamic pool model, indicate that any increase in the minimum legal size in the NE and C basins of the lake would encourage an increase in the size of spawning stocks, and thus their production and survival rates.

With an increase in fishing intensity the yield from the NE and the C basins cannot be increased. However, in the SW basin a significant increase in yield is possible. All these are connected to trophic status and the amount of food consumed in the different basins (Biró & Vörös 1988). Maximum yields cannot be sustained for long periods (Larkin 1977) in any of the 3 water areas of the lake. Further, fisheries are selective with respect to the year-classes of the local stocks (Lehtonen 1983) and it can be established that the fisheries may bring about changes in the age and size structures of the stocks in Lake Balaton. It is highly probable, that at yields over about 3 kg/ha, the stocks may decline because of over-fishing (Ryder, Kerr, Loftus & Regier 1974).

Several methods can be used to estimate yields. The morpho-edaphic index for Lake Balaton (total dissolved solids of 400 mg/l divided by the mean depth of 3 m) proved to be 133.3 (Biró 1978). This is more than three times higher than the optimal value of 40 (Ryder *et al.* 1974), and this biases estimates of yield which indicate about 11.2 kg/ha for Lake Balaton. For pikeperch, the power function calculated by the morphometric characteristics of the lake, the average annual chlorophyll-a concentration, and the yield values for bream *(Abramis brama)* (Biró & Vörös 1988) is not applicable. This multi-variable power function can be successfully applied to the bream stock, which comprises the bulk of the fish fauna of Lake Balaton, because this stock is more stable than the pikeperch stock. The pikeperch stock is more sensitive to external influences than the bream stock.

Along the longitudinal axis of the lake there were significant (maximum *c.* fourfold) differences in the stock density, P/B ratio, mortality rates and yield values for pikeperch. The present increase of stock density may have been caused by a reduction of fishing intensity during the past few years (1975-1985). The high general fishing intensity can significantly reduce the populations of predatory species, and increased eutrophication can further destabilize them. The fish production capacity of Lake Balaton, including the top predator pikeperch, is very closely related to the intensity of primary productivity and the efficiency of energy transfer to fish (Biró & Vörös 1988).

Exploitation rate can influence the size and stability of fish stocks significantly, during both the pre- and post-recruitment phases. Mortality due to fishing was possibly high during the periods of low stock abundance and *vice versa*. Assuming a relatively constant population with density-dependent natural mortality, there must be a compensatory survival, especially during the pre-recruit phase (Backiel 1966). However, the pikeperch population, due to changing environmental conditions, is rather unstable. The correct estimate of natural mortality is usually critical, especially at a relatively low level of fishing intensity and in case of a fast growing fish-species with a high natural mortality (Backiel 1966) such as the pikeperch in Lake Balaton. The data analysed were obtained from the time when fishing intensity was reduced. On this account the rate of instantaneous total mortality, determined from the catch curve, is more transitional than steady. Considering the changes of stock dynamics in space and time, a better knowledge of the renewal rate of the spawning stocks would be particularly important for registering the annual changes of stock size and alterations of 'strong' and 'weak' year-classes. The separation of the stock controlling effects of the professional fishery from those of angling would also result in more reliable parameters.

In this study, excluding economic aspects, we examined only the biological characteristics of the populations because to achieve maximum economic yields, the average at first capture would be significantly different from the biological optimum (Regier 1966). The relationship between mortality and stock density is influenced by competition and predation. In the past, predation (cannibalism) was occasionally intense among pikeperch in Lake Balaton, and then operated as an important 'self-regulatory measure' (Biró 1977a,b). Now however, cannibalism seems less important than inter- and intraspecific competition in influencing the regeneration of stocks. This competition arises because the larvae and fry of pikeperch inhabit the littoral zones which also provide food for other species. From the point of view of ecology, over-fishing occurs when the stock decreases to such an extent that it can not regain its former density naturally (Regier 1966). It can be stated that the depleted pikeperch stocks which occur in Lake Balaton take a very long time to regenerate after the environment begins to stabilize.

During the recent phase of advanced eutrophication, changes in the dynamics of pikeperch stocks were observed. Parallel with an increase in primary production (Herodek, Istvánovics & Zlinszky 1988) the annual length and weight gain of pikeperch first became slower, and then, following a significant drop in stock density, appeared to become faster, even in the SW hypertrophic areas. The annual rate of growth of year-classes 1-4, especially in the SW basin, exceeded the rates observed in Lake Fertö (Hacker 1979). The accelerated growth probably resulted in higher survival rates and a more rapid regeneration of the stock, and indicates better acclimation to the extreme environmental effects (Hartmann & Nümann 1977, Holcík & Hruska 1966, Leach, Johnson, Kelso, Hartmann, Nümann & Entz 1977). According to Spangler, Payne, Thorpe, Byrne, Regier & Christie (1977) the percids respond to increased exploitation via an accelerated growth rate, thus changing the variability of natural recruitment and shortening the time to sexual maturity. In Lake Balaton, the decrease in fishing intensity and the fluctuation of stock density, coupled with environmental changes, could well produce a similar response. In 1984-1985 the observed differences in the yield-per-recruit and the biomass values proportional to recruitment, compared to the former estimates (1970-1973) along the longitudinal axis of the lake, might be caused by the faster growth and reduced exploitation. These variations are understandable since biological production within a population can be so variable (Craig 1987). The changes in growth and the population size of perch *(Perca fluviatilis)* in Lake Windermere, England, after exploitation had ceased, resulted in a range of adult production from 2 to 15 kg/ha/yr during the period 1961-1972 (Craig 1980). Yields of walleye *(Stizostedion vitreum)* show extensive variation between and within lakes, and it is known that pikeperch usually produce higher yields in brackish water than in fresh water.

Anglers tend to remove smaller walleye than commercial fishermen from lakes in Alberta, Canada, (Craig & Smiley 1986) and many of these smaller walleye are sexually immature. Yields to anglers can also exceed those of commercial fishermen and need to be taken into consideration when management rules are made for a fishery (Craig 1987). This certainly holds for Lake Balaton.

Acknowledgments

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References

Backiel, T., 1966. On the dynamics of an intensively exploited fish population. Verh. Internat. Verein. Limnol. 16: 1237-1244.

Beverton, R.J.H. & Holt, S.J., 1957. On the dynamics of exploited fish populations. London. Her Majesty's Stationery Office. Fish. Invest. Min. Agr. Food Ser. 2, 19: 533 p.

Biró, P., 1970. Investigation of growth of pikeperch *(Lucioperca lucioperca* L.*)* in Lake Balaton. Annal. Biol. Tihany. 37: 145-164.

Biró, P., 1977a. Effects of exploitation, introductions and eutrophication on percids in Lake Balaton. J. Fish. Res. Bd Can. 34: 1678-1683.

Biró, P., 1977b. Food consumption and energy transformation of pikeperch *(Lucioperca lucioperca* L.*)* population in Lake Balaton. Ichthyologia (Yugoslavia) 9: 47-60.

Biró, P., 1978. Exploitation of fishery resources of Lake Balaton. Verh. Internat. Verein. Limnol. 20: 2147-2149.

Biró, P., 1979. A fogassüllö táplálékának, növekedésének és produkciójának vizsgálata a Balatonban. HAKI Szarvas, A halhustermelés fejlesztése 7. 173 pp.

Biró, P., 1985. Dynamics of pikeperch, *Stizostedion lucioperca* (L.), in Lake Balaton. Internat. Revue der Ges. Hydrobiol. (Berlin) 70: 471-490.

Biró, P. & Vörös, L., 1988. Relationship between the yield of bream, *Abramis brama* L., chlorphyll-a concentration and shore-length: water area ratio in Lake Balaton, Hungary. Aquacult. Fish. Man. 19: 53-61.

Craig, J.F., 1980. Growth and production of the 1955 to 1972 cohorts of perch, *Perca fluviatilis* L., in Windermere. J. Anim. Ecol. 49: 291-315.

Craig, J.F., 1987. The biology of perch and related fish. Croom Helm, Beckenham, U.K. 333 pp.

Craig, J.F. & Smiley, K., 1986. Walleye *(Stizostedion vitreum)* and northern pike *(Esox lucius)* populations in three Alberta Lakes. J. Fish Biol. 29: 67-85.

Hacker, R., 1979. Fishes and fishery in Neusiedlersee. In: Löffler, H. (Ed.). The limnology of a shallow lake in central Europe. Junk, The Hague-Boston-London, Monogr. Biol. 37: 423-438.

Hartmann, J. and Nümann, W., 1977. Percids of Lake Constance, a lake undergoing eutrophication. J. Fish. Res. Bd Can. 34: 1670-1677.

Herodek, S., Istvánovics, V. & Zlinszky, J., 1988. Phosphorus metabolism and eutrophication control of Lake Balaton. Verh. Internat. Verein Limnol. 23: 517-521.

Holcík, J. & Hruska, V., 1966. On the spawning substrate of the roach, *Rutilus rutilus* (Linnaeus, 1758), and bream, *Abramis brama* (Linnaeus, 1758), and notes on the ecological characteristics of some European fishes. Vest. Cesk. Spol. Zool. 30: 22-29.

Larkin, P.A., 1977. An epitaph for the concept of maximum sustained yield. Trans. Amer. Fish. Soc. 106: 1-11.

Leach, J.H., Johnson, M.G., Kelso, J.R.M., Hartmann, J., Nümann, W. & Entz, B., 1977. Responses of percid fishes and habitats to eutrophication. J. Fish. Res. Bd Can. 34: 1964-1971.

Lehtonen, H., 1983. Stocks of pikeperch *(Stizostedion lucioperca* L.) and their management in the Archipelago Sea and the Gulf of Finland. Finnish Fish. Res. 5: 1-16.

Regier, H.A., 1966. A perspective on research on the dynamics of fish populations in the Great Lakes. The Progressive Fish Culturist, Jan. 1966 pp. 3-18.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd Can. 119: 1-300.

Ryder, R.A., Kerr, S.R., Loftus, K.H. & Regier, H.A., 1974. The morphoedaphic index, a fish yield estimator-review and evaluation. J. Fish. Res. Bd Can. 31: 663-688.

Spangler, G.R., Payne, N.R., Thorpe, J.E., Byrne, J.M., Regier, H.A. & Christie, W.J., 1977. Responses of percids to exploitation. J. Fish. Res. Bd Can. 34: 1983-1988.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 262-269.

Eel management practice in three lake systems in Ireland

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Abstract

Lough Neagh, 39 626 ha, is the only substantial lake on the River Bann. Fishing rights are owned by the Lough Neagh Eel Fishermen's Co-operative who transport elvers from the tidal boundary and occasionally supplement their stocking programme with imported elvers. Elvers are stocked at a mean rate of 444/ha. Fishing is restricted to members of the co-operative and daily bag limits are imposed. An annual yield varying from 454-926 tonnes has been maintained between 1977 and 1986.

The rivers of the Shannon catchment flow through 10 lakes, each having an area greater than 200 ha, giving a total area of 34 433 ha. Management since 1959 has comprised transport of elvers at a rate of 357/ha and a total ban on fishing for yellow eels, partly rescinded in 1985. Annual yields of 22-59 tonnes have been obtained from 1977 to 1986.

The River Corrib catchment contains three lakes with a total area of 25 430 ha. No regular transport of elvers has taken place. There is no legal limit for the length of a long line, but effort is restricted to the operation of not more than twenty small fyke nets per fisherman. There are 14 fisheries for silver eels. Annual yield has varied from 19-44 tonnes between 1977 and 1986.

It is concluded that a well-managed fishery in mesotrophic freshwater is capable of a sustained yield of a minimum of 16 kg/eel/ha. Yields as low as 0.75 kg/ha are recorded in cases where management is over-restrictive or under-developed. The stocking rate of 444 elvers/ha used in Lough Neagh is the highest known in Europe and is associated with the highest known yield/ha from lakes.

1. Introduction

The management structure for a lake-based eel fishery comprises a stocking phase based on the capture and transportation of elvers from near the mouth of the river draining the lake system, from other rivers or from both. Fishing may be controlled by limiting the effort. Data are presented comparing the catches in three lake systems in Ireland and contrasting the yield attained by three distinct management systems.

The management system required for a fishery for the freshwater eel *(Anguilla anguilla)* is unique insofar as it is impossible to obtain progeny from the breeding stock in the river system. All rivers, and indeed all countries, whose fishery is based on a single species of eel, depend on a single, oceanic breeding stock. There is no evidence that the size of this stock has changed materially in historic times and it is assumed that no practical steps can be taken to enhance breeding success.

Since the beginning of the 20th century, elvers caught close to the mouths of rivers have been transported to river systems believed to be deficient in stocks (Tesch 1977). This practice has been found to be effective and is applied widely in Europe. Other management inputs are the imposition of restrictions on fishing effort. In Ireland, two lake systems, the Corrib and the Shannon, have been studied by the author over a period beginning in 1967. A third, Lough Neagh, has been managed by a co-operative society since 1972. Details of management systems and yield from these three systems are given and the results compared.

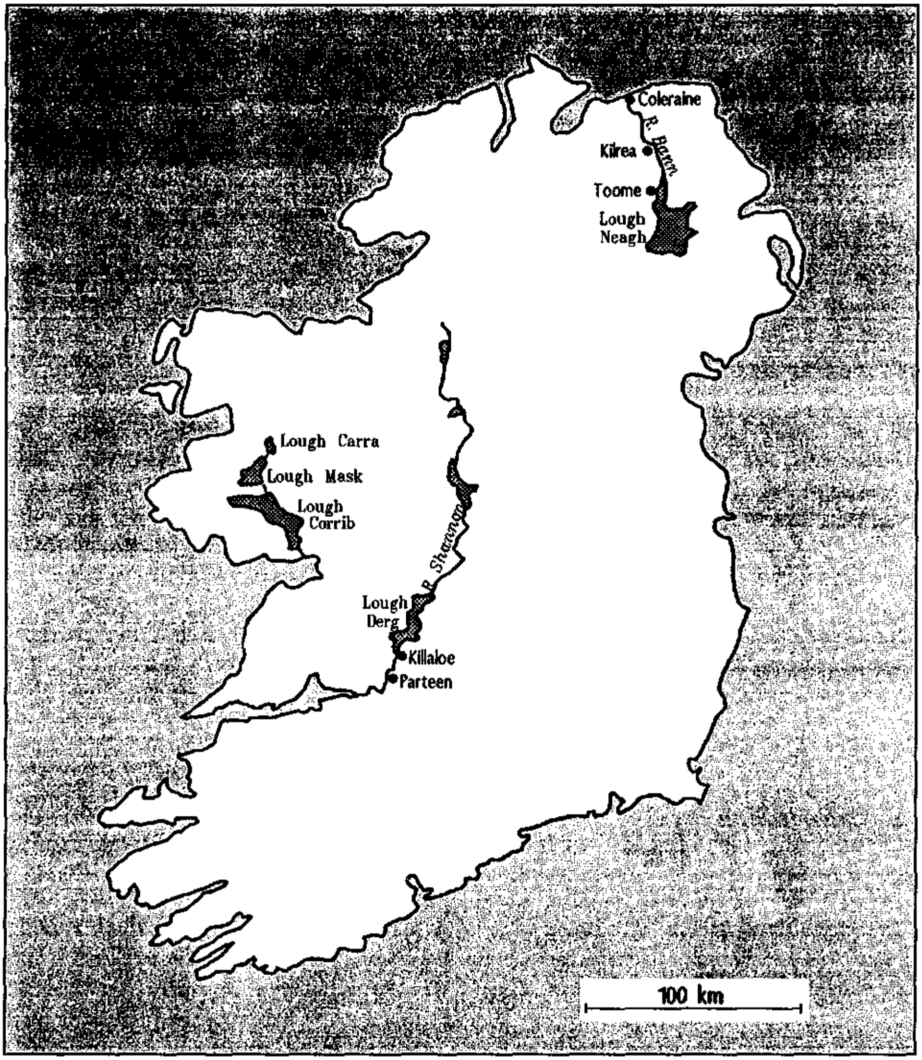

Figure 1. Location of river systems and capture sites.

2. Management systems

2.1 Lough Neagh

With an area of 39 626 ha, Lough Neagh is the largest lake in Ireland. It lies on the River Bann, 21 km upstream of the tidal boundary. The level of the lake is controlled by a barrage situated 1 km upstream of the silver eel fishery at Toome *(Figure 1)*. Extensive excavation of the River Bann has taken place for land drainage purposes and the river enters its estuary at Coleraine by passing over a weir.

It is considered that few elvers, if any, are able to surmount this weir and elver traps are operated. All the elvers captured are taken overland to be released in the lake. The catch is measured volumetrically and may be taken to be equal to the total recruitment.

Fishing for yellow eels is done largely by long line, with a limited amount of draft netting. Fishing is restricted to licence holders, who number 180. A maximum daily catch limit of 51 kg/licensee is enforced. Fyke nets are not permitted.

Silver eels are caught at two points on the River Bann, downstream of the lake: Toome and Kilrea. The gear used comprises a barrage of conical nets which in each case extends over 90% of the width of the river.

2.2 The River Shannon system

The River Shannon *(Figure 1)* is divided into two streams by a dam at Parteen, 18 km upstream of the tidal boundary. The western stream forms the headrace to a dam at the tidal boundary which is impassable to elvers, except on rare occasions when a ship lock is operated. Elver traps operate at this dam. The eastern stream is the natural bed of the river. An unknown number of elvers enter this. Some of these are trapped at Parteen where substantial numbers of older eels are also captured (Moriarty 1986). Elvers and older eels are released in Lough Derg and, to a lesser degree, in lakes farther upstream. Elver transportation has been in progress since 1959.

Fishing for yellow eels has been forbidden throughout the river system from 1959 to 1984. In 1984 however, two crews operating 20 fyke nets each, have operated in Lough Derg, the lowest lake on the system.

Silver eel fishing takes place at a number of installations. The major one is at Killaloe where a barrage of nets extends over 90% of the width of the river. Downstream, at Clonlara, three sets of nets are operated in the headrace canal. Each set of nets extends over 11% of the cross section of the canal. Small sets of nets are operated at three other points. The flow of water in the Shannon is controlled to a great extent by the operations of the power station near its mouth. Flood conditions in rainy weather, which would be expected in an uncontrolled system, from time to time fail to materialise. At other times high floods make the weir at Killaloe unfishable. In recent years an abundance of filamentous algae has, on occasions, clogged the nets and reduced the efficiency of the gear.

2.3 The River Corrib system

As in the case of Lough Neagh, a barrage to control the water level stands close to the tidal boundary on the Corrib system *(Figure 1)*. Elver passes are put in place periodically,

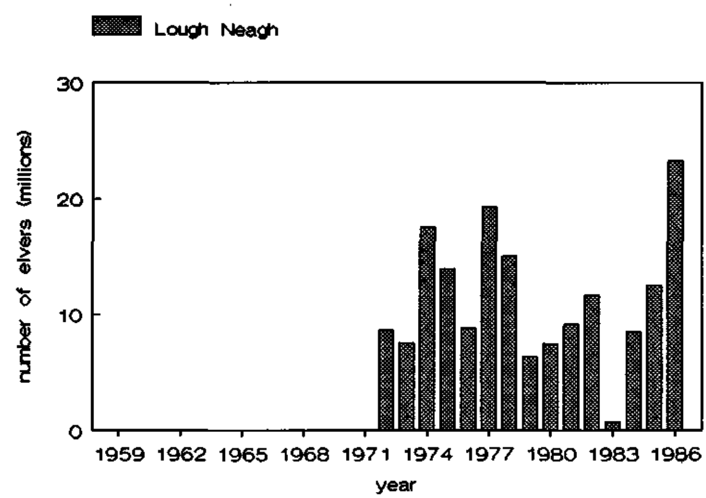

Figure 2a. Numbers of elvers released in Lough Neagh, following overland transportation.

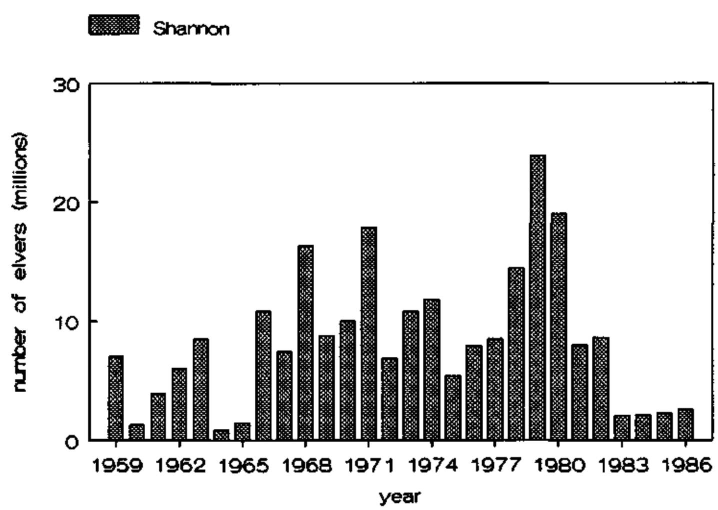

Figure 2b. Numbers of elvers released in the Shannon lakes, following overland transportation.

but there has been no regular scheme for capture or transportation of elvers into the system. Evidently, substantial numbers of elvers are able to surmount the barrage.

Fishing for yellow eels by long line is permitted by licence without restriction, but in fact is practised by very few individuals. Small fyke nets are operated under authorisation. With the exception of long-established fishermen who operate up to 50 nets, a limit of 20 nets per person is imposed.

Silver eel fishing by nets extending over 90% of the width of the River Corrib takes place just upstream of its tidal boundary. Water from Lough Mask flows towards Lough Corrib in a number of streams, some of which run underground. One substantial barrage of nets for silver eels and 14 smaller trapping systems are in use. The net barrage in the River Corrib cannot be operated in high floods.

3. Stocking

The numbers of elvers released into Lough Neagh since 1960 are shown in *Figure 2*. Since 1984, the figure includes numbers between 4 and 17 million imported from the River Severn to supplement the catch from the River Bann. *Figure 2* also shows the annual stocking rate of elvers and young eels in the Shannon lakes. The totals include a number of eels of more than 1 year old, caught at the trap at Parteen. The majority of the eels transported are released in Lough Derg, the lowest lake in the system.

4. Catch

The mean annual catch in Lough Neagh is 855 tonnes. Annual variations are shown in *Figure 3*. The greatest yield on record was made in 1979 when both silver and yellow eel catches reached peak values. The yellow eel catch was sustained at a high level for the next four years, increasing considerably in 1984. The silver eel catch declined after 1976, but has remained higher than the minimum value recorded in 1972.

Record catches of silver eels *(Figure 3)* in the Shannon were made in 1977, 1979 and 1983. After 1979, catches remained greater than any recorded prior to 1977. Yellow eel fishing in the Shannon lakes began after a 20 year interval in 1984, with two crews operating 20 small fyke nets each. Their catch in 1986 amounted to 5.6 tonnes, 10% of the silver eel catch. An unknown quantity of yellow eels is taken by illegal fishing.

In the Corrib system, peak catches of both silver and yellow eels were recorded in 1983. A greater yellow eel catch was made in 1986, but the silver catch was the lowest in the 8 year period *(Figure 3)*.

The relationship between recruitment (number of glass eels entering the system) and catch is easily calculated for Lough Neagh, where virtually all the ascending glass eels are caught and weighed before distribution in the lake. In the Shannon system the only figure for recruitment available is the number of glass eels distributed, since an unknown number enter the system through fish passes and a navigation lock. In this case it is believed that the majority of the glass eels are quantified.

In the Corrib system, the level of recruitment is unknown since none of the glass eels are caught during their migration. This is the situation in many eel fisheries and,

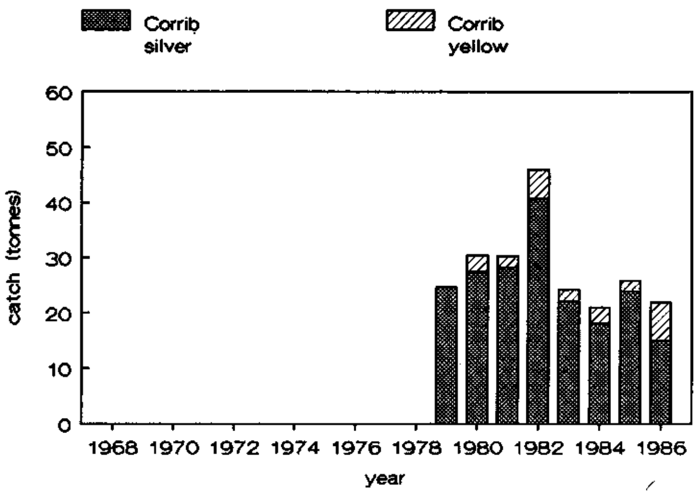

Figure 3a. Reported catches of yellow and silver eels in the Corrib system.

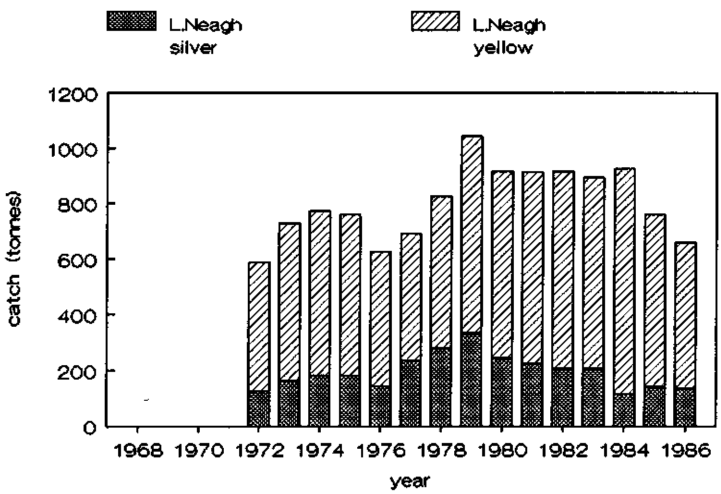

Figure 3b. Reported catches of yellow and silver eels in Lough Neagh.

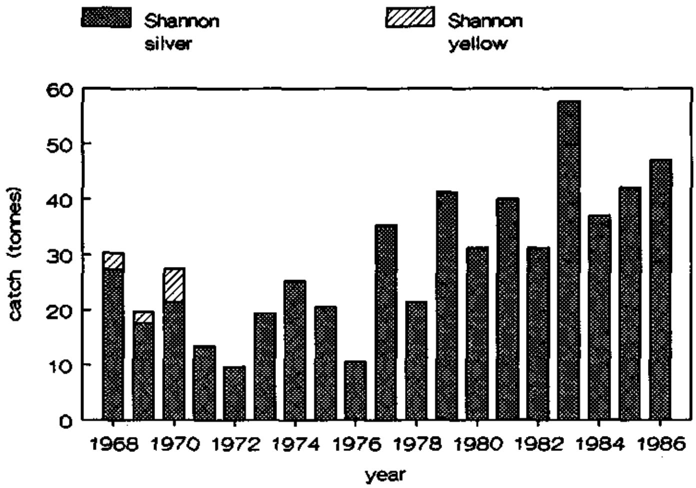

Figure 3c. Reported catches of yellow and silver eels in the Shannon system.

considered with the fact that supplies of glass eels vary greatly between years, makes it very difficult to establish a relationship between recruitment and catch.

Mean annual catches recorded in the ten years 1977-1986 are shown in *Table 1*, together with catch and stocking rate/ha and an estimate of fishing effort. The latter is difficult to quantify, especially in the case of the silver eels. In effect there are two major installations on each of the three systems and a number of minor fisheries.

Moriarty (1987) showed that the stocks of yellow eels in the Shannon were greater than in Lough Neagh. The stocks in the Corrib system have not been assessed since 1969 (Moriarty 1972), but appeared to be smaller than in Lough Neagh. In broad terms, the trophic status of the three lake systems are similar and there are indications of abundant invertebrate food being available in all. The greatest yield by a factor of 12 occurs in Lough Neagh. The silver eel catch there is five times that of the Shannon and it appears that this may be explained by differences in the efficiency of the gear. The yellow eel catch in Lough Neagh is 20 times that of the Shannon lakes and appears to depend entirely on the difference in fishing effort.

The fishing effort for silver eels in the Corrib lakes is similar to that in the Shannon, while the effort for yellow eels is considerably greater. The catches and yield/ha, however, are little more than half the value for the Shannon.

Comparable data from other lake fisheries for Atlantic eel are few. Leopold (1985), however, has published data from lakes in Poland. The highest yield which she quotes, 3.99 kg/ha, is better than that for the Shannon, but very much lower than the Lough Neagh figure of 21.6 kg/ha. The greatest stocking rate in her survey was 96.4 elvers/ha, about one fifth of that used in Lough Neagh.

Table 1. Mean annual catch and stocking rates in three Irish fisheries; effort as number of installations for silver eels, number of licensed boat crews for yellow eels.

Water body		Surface area	Stocking	Effort		Catch (kg/ha)	
		1000 ha	(elvers/ha)	yellow eels	silver eels	yellow eels	silver eels
L. Neagh	1977-1986	40	446	180	2	16.1	5.5
R. Shannon	1977-1986	34	357	2	8	0.7	1.1
L. Corrib	1979-1986	25	0	26	16	0.9	0.1

5. Conclusions

Accepting that commercial catch data are frequently unreliable, and that fishing effort is difficult to quantify, it may be concluded that the Lough Neagh fishery owes its success to the practice of stocking elvers at high density and maintaining a substantial fishing effort. Further, that the Shannon lakes contain a stock which cannot be fully exploited by the current low intensity fishing effort and that the Corrib lakes could provide a greatly increased and sustainable yield, if managed properly with a stocking programme.

The yield from Polish lakes is considerably lower than that from Lough Neagh and is matched by a low stocking rate. The high elver stocking rate used in Lough Neagh appears to be a major factor in producing the high yield and could well be taken as a standard for other European lake systems.

References

Leopold, M., 1985. Problems in analysing the effectiveness of eel stocking in interconnected lakes. EIFAC Working Party on Eel. Perpignan. 4 pp.

Moriarty, C., 1972. Studies of the eel *Anguilla anguilla* in Ireland. 1. in the lakes of the Corrib System. Irish Fisheries Investigations A 10. 39 pp.

Moriarty, C., 1986. Riverine migration of young eels *Anguilla anguilla* (L.). Fisheries Research 4: 43-58.

Moriarty, C., 1987. The eel stocks of the Shannon System and prospects for the development of the fishery. Fishery Leaflet 139. Dublin. mimeo 8 pp.

Tesch, F.-W., 1977. The eel. Chapman and Hall, London. 434 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 270-283.

Thirty-five years of management in the coastal Lagoon of Sabaudia, Italy

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Abstract

Lake Sabaudia is a lagoon of about 390 ha. Its water is brackish; below three meters depth it is practically anoxic. Notwithstanding this some important recovery interventions have taken place, but the impact of human activities on the aquatic environment are still heavy. The 'Azienda Vallicola Lago di Paola' has three major objectives: extensive valliculture, mussel culture and intensive aquaculture. Valliculture yields are based on fisheries using different types of nets, or using a weir, where the catadromous migrating fish are collected. A yield of 150 kg/ha was the historical average, containing a high proportion of sea bass and sea bream, but in 1969 and in 1979 the lake suffered disastrous dystrophic conditions. Now yields are below 80 kg/ha of fish, mainly mullet. The blue mussel plant is designed to produce 1000 tonnes/yr. A plant for the depuration of bivalves is annexed to the Azienda. The intensive aquaculture project is still at a pilot scale, with some earthen ponds and hatcheries for sea bass, sea bream, mullet and cuttlefish. A major restructuring in income distribution is under way, with the creation of a co-operative of workers which will be paid by shares of the revenues, and not by fixed salary. A research institute, the 'Istituto Brunelli', has operated on the lake since 1978. It monitors the environment, supervises the hatcheries, and studies some aquacultural aspects, including restocking and the introduction of new species, such as short-neck clam and penaeid prawns. After an analysis of the production data and of the present structures, interventions in various fields are envisaged, some of which are now in progress.

1. The Lagoon

Lake Sabaudia, or Lago di Paola, is a coastal lagoon with a surface of 390 ha, located 100 km South of Rome *(Figure 1)*. It originated from a Quaternary ria (Anonymous 1983) and extends along the coast for about 7 km and with some finger-shaped indentations called 'bracci', which are relict tributary river beds. Its mean depth is 4 m, with a maximum of 10 m, and its volume is 14 million m^3. The basin is separated from the sea by a narrow sand dune, but has two mouths at the extremities: the small 'Caterattino' at the north end and the Torre Paola Channel at the south end *(Figure 1)*. The latter is more important and was dredged and embanked by the Romans.

The water of Lake Sabaudia is brackish. In 1930 the salinity was below 10‰. However, following marshland reclamation, the opening of the Caterattino Mouth, the reopening of the Torre Paola Channel, the closing of some tributaries, and the intensive abstraction of potential fresh water inflows for irrigation (which probably lowered the water table),

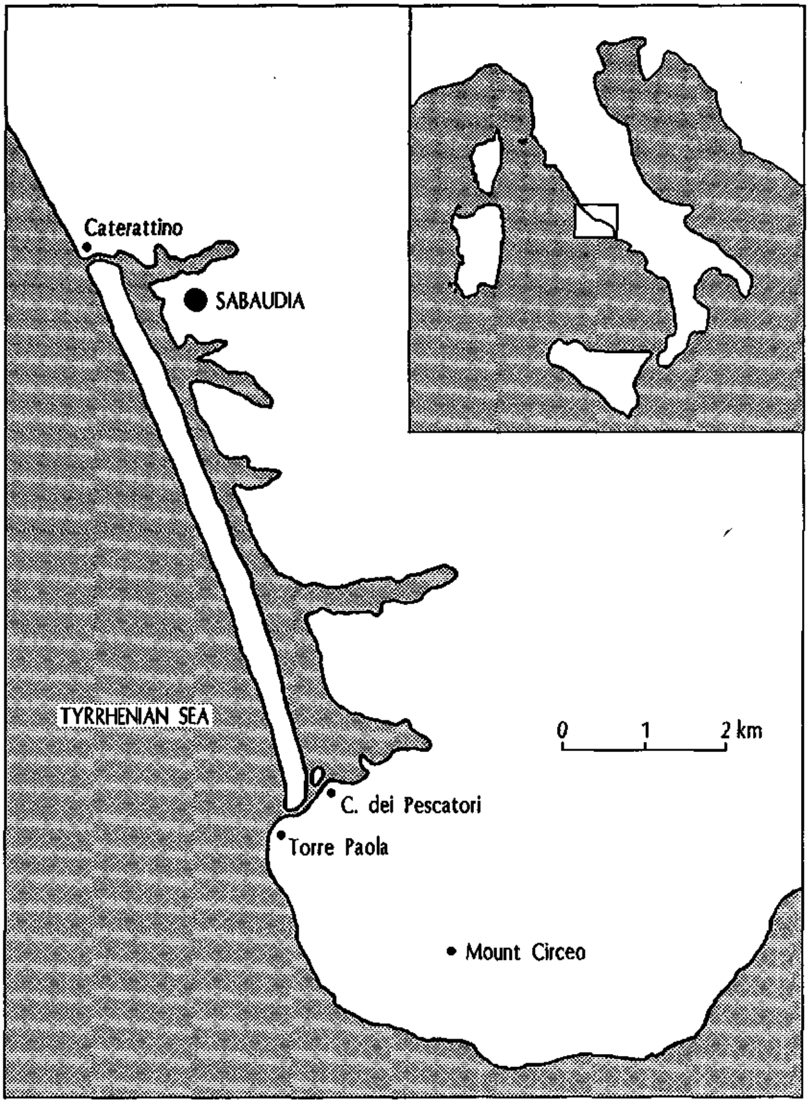

Figure 1. Sabaudia Lagoon.

the average salinity has steadily increased and stabilized in 1980 at a maximum value of 30‰ (Perdicaro 1984).

Theoretically, the lake environment is fully protected, because the whole water body is included in the Circeo National Park. In fact, the lake was used for many years as a dumping site for urban sewage and agricultural and light industrial wastes, particularly its northern part. The subsequent hypertrophia has caused recurrent dystrophic crises, especially in 1969 and 1979, when commercial yields from the lake were completely destroyed. Since then some major interventions have been launched, including the closing down of a pig farm and the interruption of sewage disposal into the lake. Notwithstanding these measures, the impact of human activities on the aquatic environment remains heavy and causes some damage every year. From the point of view of production, the water column, which usually does not mix completely, even under homothermal conditions, is practically anoxic below 2.5 m during the summer months. Luckily, some signs of recovery are already evident, *e.g.*, the gradual disappearance of north-south gradients in the distribution of benthos and plankton species shows that the most polluted area is recovering and reaching the same environmental parameters as the southern part (Costa, Minervini, Lombardi & Bianchini 1985).

Fishing has been going on in the lagoon since Roman times, when some artificial basins were dug near the Torre Paola Channel as holding tanks for the captured fish. While the lake was never abandoned from a production point of view, the mouths closed and were only reopened in 1718, to transform what had been a freshwater lake into a brackish 'valle da pesca'. A 9-year cycle was empirically adopted for the water-exchange management; every nine years the mouths of the lagoon were closed to 'refreshen' the water. Written rules for management date back as far as 1856. A few years later, Gioachino Scalfati, the 'superintendent' of the lake, became owner of the fishing rights and, from then on, the same family has continued to manage the lake. A comprehensive and reliable logbook of the daily landings, including some remarks on the environment and the fishing operations, has been kept since 1952 (Scalfati 1982). A theoretical scheme of the functions of the firm 'Azienda Vallicola Lago di Paola' (AVLP) is drafted in *Figure 2*. The Azienda manages three production branches: extensive valliculture, mussel culture and intensive aquaculture.

2. The production branches

2.1 Valliculture

Valliculture yields are based on two kinds of catching devices; a variety of net types set in the water body, and the 'lavorieri', which are fixed structures on the channels between the lake and the sea.

The type of net set in the waterbody differ depending on the species being fished, the season and the conditions. That most used is a seine, locally called 'cinta', made of very fine nylon mono-filament, of barracuda type, which works to enclose a known school; the fish is thereafter caught as in a gill-net. Its major disadvantages are that sometimes the fish are in water too deep, or that the fish see the fishermen and avoid the gear. A small beach seine, called 'sciabica', is used for yellow eel fishing. It is generally dangerous for fry and is used with extreme caution to avoid to catch young animals. Small fyke nets

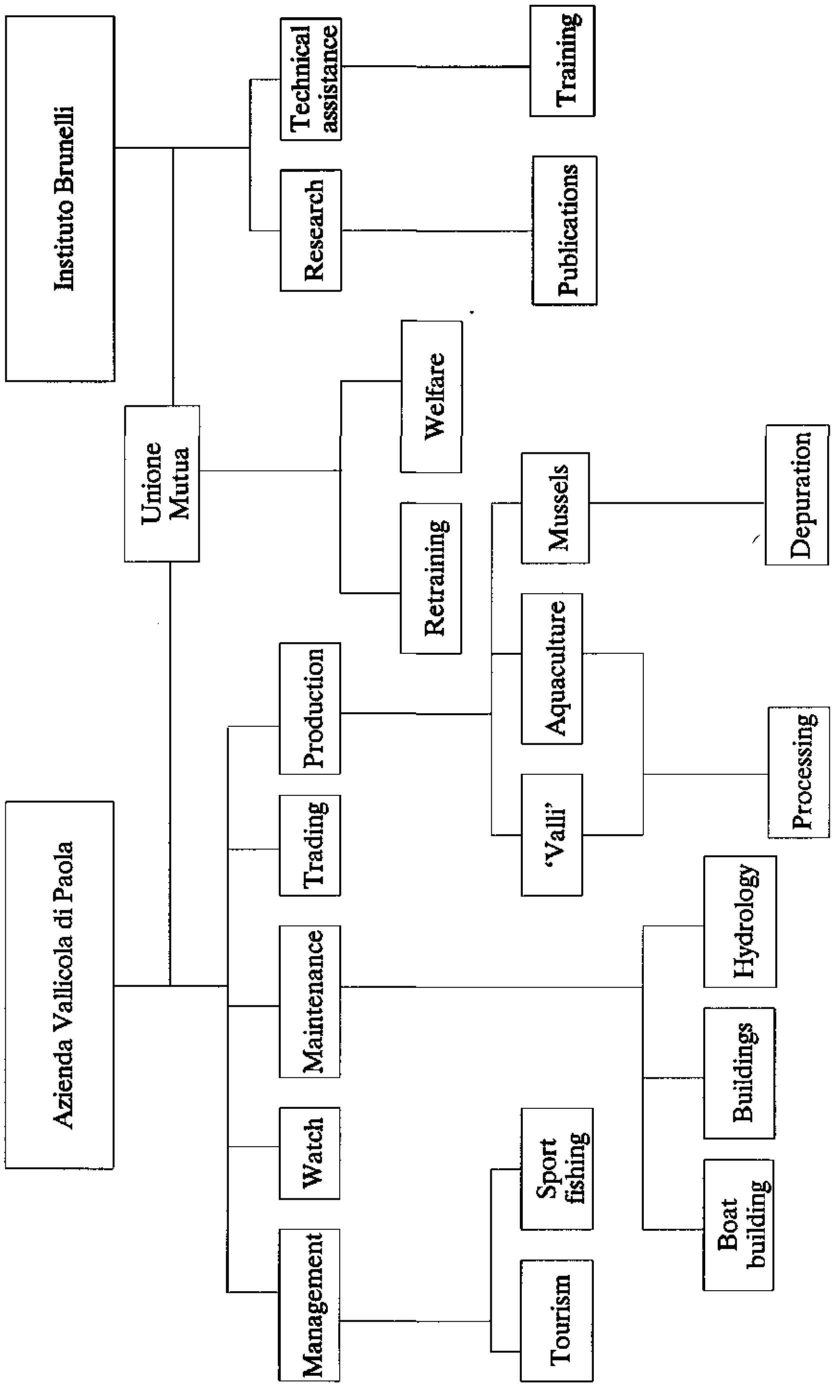

Figure 2. Structure and function of the management of Sabaudia Lagoon.

known as 'bertovelli' are also used for eels, mainly in the silver stage. Sometimes, but rarely, other nets are used, such as regular gill-nets, sweep nets and rakes. About 20 years ago, a very complex gear, called 'chiusarana', was still used. It was set up and moved forward following the fish which were frightened by the noise, until all the fish were herded into a collecting area. It was abandoned because, besides the technique being too labour intensive, the fish are now accustomed to higher noise levels created by leisure boats, and have changed their behaviour.

The 'lavoriero' of Sabaudia is a weir, once made of reeds, but now of aluminium rods set in a concrete bed. It works like a fyke net, having a funnel which permits the entrance of the fish to the 'chamber' while preventing them from escaping. The adult fish migrating to the sea (anadromous) are collected while fry and fingerlings ascending the system pass throughout the mesh. The 'lavorieri' operate in a very selective manner, fishing about 60% of the better quality fish, while having an overall capture rate of 30%.

The fish caught in Lake Sabaudia are divided into classes according to commercial value. The first class comprises sea bream *(Sparus aurata)*, sea bass *(Dicentrarchus labrax)*, sole *(Solea vulgaris)* and white bream *(Diplodus sargus)*. Then there are 4 species of mullet, grey mullet *(Mugil cephalus)*, golden grey mullet *(Liza aurata)*, thin-lipped grey mullet *(Liza ramada)* and thick-lipped grey mullet *(Chelon labrosus)* of differing habits *(Figure 3)*, and eel *(Anguilla anguilla)*. Finally, there are 'others' of lowest value, including silversides *(Atherina boyeri)*, salema *(Sarpa salpa)* and annular bream *(Diplodus annularis)*. For some time the newly introduced and highly priced short-neck clam *(Venerupis semidecussata)* was also collected. Short notes on the more important species follow:

Sea bass: Runs once a year during December-March. Some stay in the lake longer than the optimum period, becoming larger, but causing economic losses because of their heavy predation of forage fish.

Sea bream: Sometimes absent for several consecutive years. Probably the most sensitive fish to environmental conditions in the lake. Caught in the lavorieri in October-November.

Sole: Is collected only by the lavorieri, mainly in May.

White bream: This category contains both *Diplodus sargus* and *Diplodus vulgaris*. White bream sometimes disappears like sea bream.

Eel: Come from the natural entrance and are caught as both yellow and silver eels, chiefly in the lake.

Grey mullet runs once a year during July-September. Only mature specimens are caught in the lavorieri. Their roes, salted and dried, are used to make bottarga.

Golden grey mullet is the dominant mullet species, whose two apparent runs are in fact one long run which lasts from May to October but which flags during the hottest period.

Thin-lipped grey mullet genuinely has two runs, in March-April and October-November. The whole population is caught at the lavorieri.

Thick-lipped grey mullet runs with mature and immature specimens from March to May.

A fifth species, *Oedalechilus labeo*, smaller and more marine, without interest for the Azienda fisheries, is present, at least as fry, in the lake.

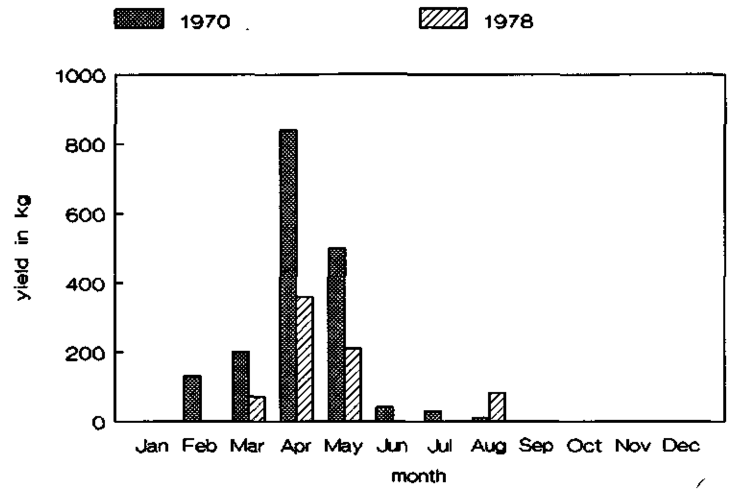

Figure 3a. Monthly catches of *Chelon labrosus* (from Costa & Minervini 1982).

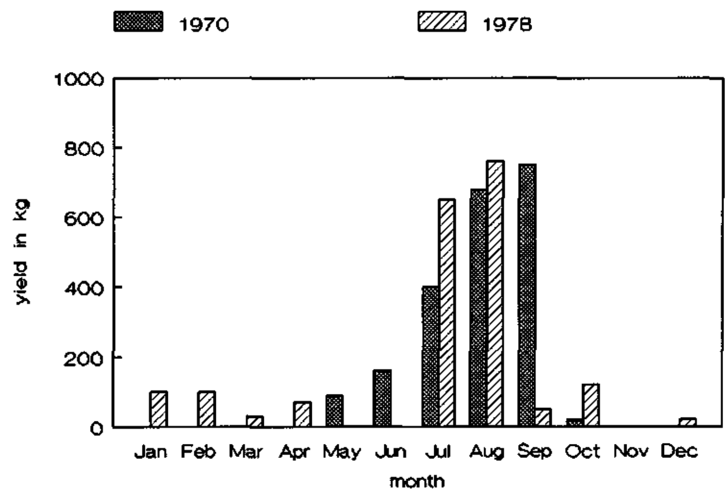

Figure 3b. Monthly catches of *Mugil cephalus* (from Costa & Minervini 1982).

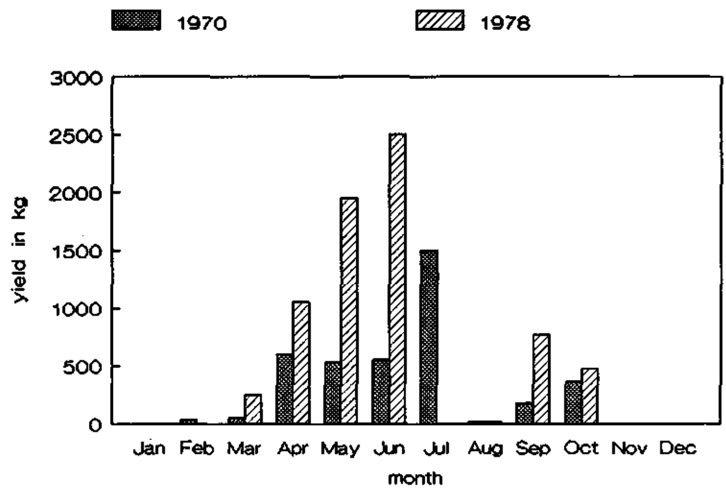

Figure 3c. Monthly catches of *Liza aurata* (from Costa & Minervini 1982).

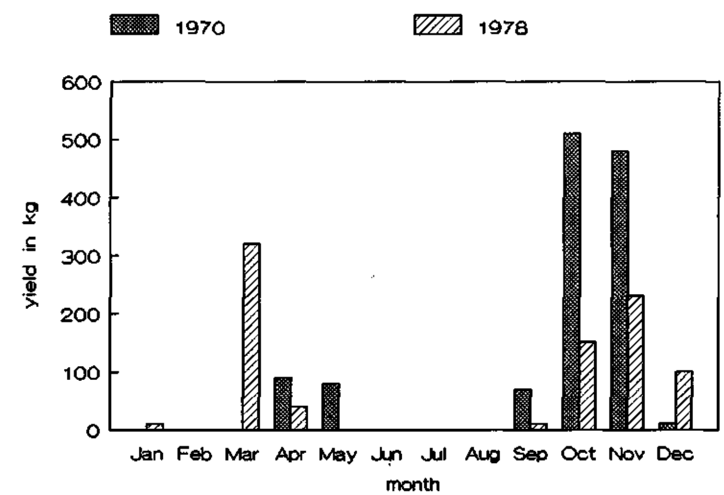

Figure 3d. Monthly catches of *Liza ramada* (from Costa & Minervini 1982.)

Table 1. Annual fishery production of Lake Sabaudia. The first class fish include bass, bream and sole (from Costa and Minervini 1982, and Costa *et al.* 1985).

	Fish yield (weight)		Fish yield (value)		Mussels
	First class fish (tonnes)	Other fish (tonnes)	Total (millions)	lit/kg (mean)	(tonnes)
1963	15.5	46.6	332	5350	698
1964	7.9	74.9	354	4300	1265
1965	11.3	69.8	365	4500	615
1966	11.2	63.3	417	5600	846
1967	9.1	73.5	356	4300	526
1968	9.4	85.1	388	4100	764
1969	4.6	50.5	201	3600	548
1970	3.8	50.1	209	3850	463
1971	1.2	42.6	141	3250	259
1972	1.6	49.6	166	3250	322
1973	2.5	51.8	193	3550	356
1974	0.7	74.5	245	3250	148
1975	1.2	59.3	191	3150	339
1976	1.4	71.4	204	2800	207
1977	0.8	63.3	182	2850	524
1978	1.7	64.4	212	3200	598
1979	1.9	48.7	176	3500	622
1980	0.0	19.3	58	3000	193
1981	0.0	11.3	29	2600	0
1982	0.5	22.0	73	3250	105
1983	1.7	33.6	115	3250	170
1984	2.2	34.6	127	3450	281
1985	2.1	20.4	83	3700	186
1986	2.5	17.0	83	4250	57
1987	0.7	13.7	51	3550	30

Although there have been large annual fluctuations in yields in recent years, an average catch of over 150 kg/ha has maintained, with a high proportion of first class fish in the catch *(Table 1* and *Figure 4)*. However, following the mass mortality of 1969 the situation deteriorated with low biomasses in the lagoon and, worse, lower economic returns. The dystrophic conditions affected the highest priced species most, especially sea bream which all but disappeared from the lagoon for many years, but mullet and eel stocks did not suffer any major set-back. Nevertheless, gross catches were reduced and the price of fish fell concurrently. This trend culminated in 1979 when over 100 tonnes of fish were killed in the single month of July (Costa & Minervini 1982), but some signs of recovery have been observed since 1983. Still, production and yields remain low, around 80 kg/ha, with only a low proportion of first quality fish in the catches *(Figures 4* and *5)*.

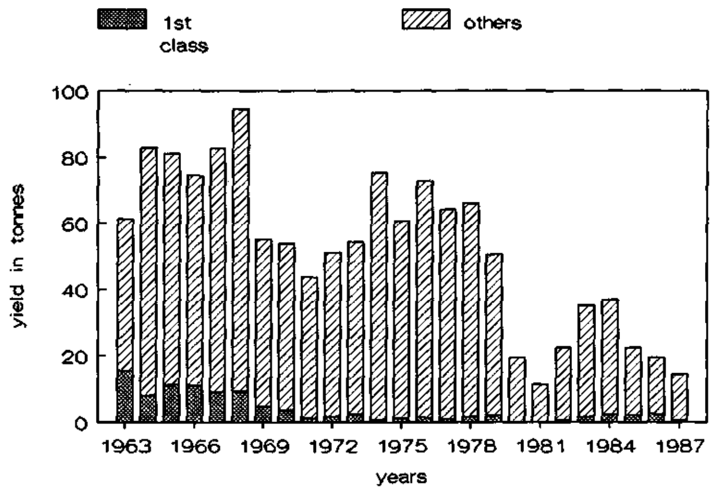

Figure 4. Annual yields of first class and other fish species from Sabaudia Lagoon.

2.2 Mussel culture

Mussel production *(Figure 6)* began in 1958 and is based on two different systems. One, with a very short cycle, uses 'cozze vuote' mussels of commercial size, but low flesh weight, as inputs (about 20-25 g and 6 cm size). These recover in the lake with a weight increase ratio (kg-input:kg-output) of 1.1:1.5 on a six-month cycle from October to May. Using 'seme' mussels of about 5 g and 1-2 cm input size, the production ratio is much higher, of the order of 2.1:3.3, but the time required is longer. Because the temperature is too high and fouling abundant, production is suspended during the summer months. The mussel park is located in the southern part of the lake, and consists of fixed concrete

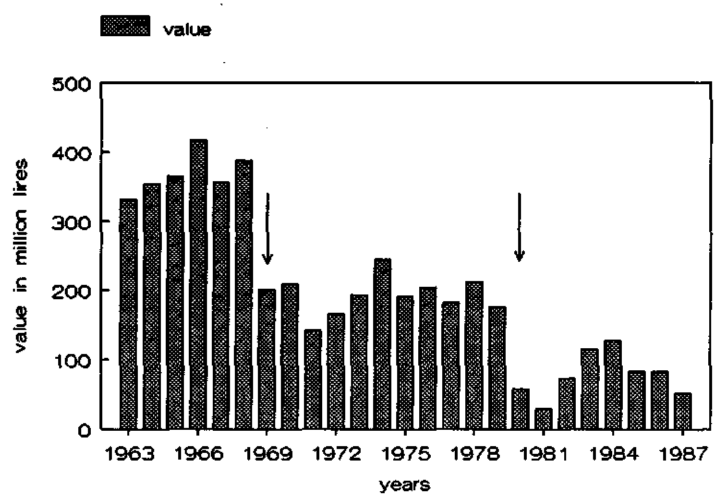

Figure 5. Value of annual catches from Sabaudia Lagoon. Arrows = dystrophic events.

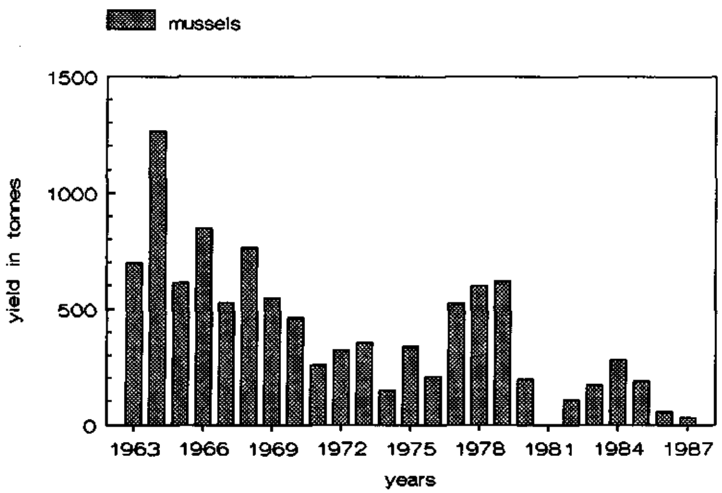

Figure 6. Annual mussel production from Lake Sabaudia.

poles holding suspension steel cables, to which the mussel socks, 'reste' or 'pergolari', are attached. The farm is designed for a production of 1000 tonnes/yr (Scalfati 1970). The mussel presence is also important indirectly, because mussel larvae are a major component of the meroplankton (Costa *et al.* 1985) which provides food for the young stages of several species of fish. Incidentally, the deterioration of the lake environment was reflected by the length of the socks which was reduced from 4 m in the 1960s to 2 m in the 1970s.

The Azienda cleans and bags its own mussel produce; moreover a depuration plant is annexed to the park, and this can also treat the produce of other farms, including different species such as clams and scallops.

2.3 Intensive aquaculture

Some experimental yields came from intensive aquaculture, mainly of fry and fingerlings for restocking. The hatchery produces sea bass, sea bream, mullet and cuttlefish, and has specific expertise on rearing larvae and fry in thermal effluents. The earthen ponds are used for keeping broodstock and for feeding trials.

3. Scientific research

The Azienda has consistently shown an interest in scientific research, both for the sake of the environment and for its potential application in the rational exploitation of resources. While the Azienda has always been hospitable to many researchers, since the beginning of the 1970s it employed two biologists directly, to study the lake ecosystem and new production technologies. Finally, in 1978, it institutionalized this interest by establishing the 'Istituto Idrobiologia ed Acquacoltura G. Brunelli' with other partners (the fishery-research co-operative COIPA, the engineering firm Agrind, the guild of workers and the Chamber of Commerce of Latina). The institute manages an experimental hatchery with annexed laboratory, a specialized library and a fully equipped boat, and it can tap the Azienda's resources if necessary. The institute monitors the environment, supervises the experimental hatchery, and studies some aspects of aquaculture, including the restocking and introduction of new species, such as short-neck clams and penaeid prawns. On the occasion of the mass mortality of 1979, the institute watched the recovery of the environment, step by step, and co-ordinated the multi-disciplinary efforts aimed at healing the lake and finding a permanent solution to the problem of recurring dystrophic crises. The institute carries out studies and consultancies concerning management of the aquatic environment, aquaculture and artisanal fisheries at national and international level. Finally it publishes a quarterly scientific journal, the 'Quaderni', with over 1000 copies diffused by exchange in Italy and abroad.

4. Management

The Lake Sabaudia fishery requires that some major interventions be made if it is to become more effective. Some of these have to be directed at the environment and some at management practices.

4.1 Interventions on the environment

First of all, the input from urban, agricultural and industrial waste has to be reduced. A direct intervention has been made by the Sabaudia County which collects sewage and now dumps it beyond the environment of the lake, and a pig farm has ceased diverting slurry to the lake. Further measures can be taken on a case by case basis. With regard to agricultural run-off containing fertilisers and pesticides, the construction of a channel encircling the whole lake to divert them is hardly feasible and could even damage the lake. As the lake is situated entirely within the Circeo National Park the farmers can be compelled to ensure its protection by using less dangerous products. As regards the healing of the deeper waters, dredging the anoxic sludges could prove disastrous. It is therefore suggested that the bottom water is pumped out of the lake, using a tide-powered device. Also the construction of sluices in the channels will help in setting the environmental parameters at the right level, mainly reducing salinity.

4.2 Intervention on the management

From the point of view of the management of the valliculture, the introduction of modern gear, like the purse seine, can improve yields. Restocking the lake with both indigenous and exotic species could be valuable, starting with a renewed introduction of the short-necked clam. Once the lake starts to be reclaimed, bivalve culture can be increased by establishing a new park in the northern part of the basin. The completion and updating of the mollusc depuration plant will also produce more revenue. Finally, the fish of lower quality can be treated so as to increase their value, through smoking and making cured roe etc.

Intensive aquaculture must be boosted, by creating at least a hectare of ponds, and setting floating pen cages in the lake, near Torre Paola. One fifth of the ponds will be devoted to raising sea bass, the rest to eel farming. In the pen cages, sea bream, sea bass and other fingerlings, from natural or artificial reproduction, will be grown for about one year, up to the market size. With these interventions, aquaculture production can reach 35 tonnes, of which 24 tonnes will be eels.

4.3 Interventions on the structures

The management structure for the lake at the end of 1978 is shown in *Figure 2.* This required 45 persons. Two years later, following the mass mortality, the situation appears very different *(Table 2).* With no more fishery production to manage and protect many functions became redundant. At the same time litigation against the organizations responsible for the disaster became a new interest for the Azienda. Only mussel culture, being seasonal and short term, was unscathed and retained its value. Altogether, only 29 people were employed in 1981, many of whom were part-time, unskilled workers. This figure was lowered steadily over the years, without the Azienda having to replace those who left its service. Despite this, the yields per employee are still too low for a sound economy. Moreover, the personnel are not flexible enough and cannot, or do not switch roles when required. In fact, many preferred to be laid off rather than accept different duties in the restructuring of the Azienda after the 1979 crisis.

This situation will be solved shortly, when the remaining workers join a co-operative and receive shares of the revenues instead of fixed salaries. The Azienda will be protected from persistent running losses, while the workers will be lured by a system that gratifies hard-work and higher individual productivity. Further, the Azienda itself will loose some of its image of 'private ownership', that sometimes damaged its quest for public funding. Finally, a very important role has to be played by the 'Unione Mutua', a workers guild, in recycling and retraining older workers and teaching badly needed new recruits.

Table 2. Personnel employed by the Azienda in administrative and production branches.

			1979	1981
Full time	Trained	Administration	4	3
		Production	5	4
	Skilled	Administration	4	-
		Production	13	9
	Unskilled	Administration	-	-
		Production	3	1
	Total	Administration	8	3
		Production	21	14
Part time	Trained	Administration	1	1
		Production	2	2
	Skilled	Administration	-	-
		Production	2	1
	Unskilled	Administration	2	1
		Production	9	7
	Total	Administration	3	2
		Production	13	10
Overall	Total	Administration	11	5
		Production	34	24

5. Conclusion

It appears that the situation of Lake of Sabaudia after the crisis of 1979 has improved, but without a full recovery to the previous standards, both in environmental quality and quantity of fish produced. Nevertheless, the old level of production could be reached again, and probably passed, with some environmental interventions and management enhancement. While the latter could be implemented with little effort, the former are time and money demanding, and some are beyond the scope of the Azienda. Public funds are therefore necessary. The full recovery of the lake could represent a perfect marriage between fishery needs and natural and cultural benefits.

References

Anonymous, 1983. Le zone umide nei comprensori di bonifica della Toscana, del Lazio, dell'Umbria e della Sardegna. Publ. Ist. Tecnica Propaganda Agraria 54.

Costa, C. & Minervini, R., 1982. Studio finalizzato al recupero produttivo del Lago di Paola (Sabaudia). Quad. Ist. Idrobiol. Acquacolt. 'G. Brunelli' 2: 61-130.

Costa, C., Minervini, R., Lombardi, F. & Bianchini, M.L., 1985. Indaginesulla fauna planctonica, bentonica e sulla vallicoltura del Lago di Sabaudia. Quad. Ist. Idrobiol. Acquacolt. 'G. Brunelli' 5: 3-33.

Perdicaro, R., 1984. Condizioni chimico-fisiche del Lago di Sabaudiao di Paola dal 1933 al 1984. Quad. Ist. Idrobiol. Acquacolt. 'G. Brunelli' 4: 71-139.

Scalfati, G., 1970. La mitilicoltura, il suo ambiente, l'organizzazione tecnico-economica e la disciplina giuridica. Min. Marina Mercantile, Mem. 29: 1-272.

Scalfati,G., 1982. Notizie storiche sul lago di Paola. Quad. Ist. Idrobiol. Acquacolt. 'G. Brunelli' 2: 51-59.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 284-291.

Salmonid management using valley hatcheries in Italy

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Abstract

There are many problems associated with the traditional methods of restocking natural systems with salmonid fry. These include a tendency to reduce the 'wildness' of the population, a tendency to reduce the degree of heterogeneity of the fish, the frequent unsuitability of the fry for the area stocked and the weakening of natural autochtonous populations.

In an attempt to combat these problems the Province of Torino has programmed the building of 11 hatcheries in mountain valleys, to produce stocking material from local strains and adapted to specific stocking sites. These hatcheries will be managed by volunteers from local angling clubs, with expert help from the province. Three of these hatcheries began production in 1986 and 1987, providing 1 000 000 fry and 400 000 troutlings of *Salmo trutta*, and 60 000 fry and 30 000 troutlings of *Salmo trutta marmoratus*. The value of fish produced in 1987 was approximately 70 000 000 Lit, and the profit to the Province of Torino, about 40 000 000 Lit.

1. Introduction

The concepts involved in the best management of fish populations under natural conditions require there to be facilities and techniques for raising large quantities of suitable restocking material (Supino 1934, Bianco 1976, Alessio 1986). However, traditional stock fish farming requires high population densities and maximum levels of stock domestication for economic reasons, but these characteristics are not desirable in material destined for restocking natural systems. To compound this, the heterogeneous nature of the stocking material available, which nowadays comes from all parts of Europe, has reduced, and in the Po Basin completely eliminated, the indigenous populations of salmonids. This is particularly true for *Salmo trutta*, where it always seems more difficult to recognize the form referred to by fishermen as the 'old' or 'local' form than the new stocked form (Tortonese 1970). Within the range of *Salmo trutta marmoratus*, for example, intermediate forms are often present (Tortonese 1970), apparently derived from inter-breedings with the many forms of *S. trutta* that have been introduced. Thus the local subspecies is being weakened and reduced in numbers.

The only cases where the use of traditionally produced stocking material would be acceptable are where, either the fish are stocked into waters from which they were originally derived, and to which they are therefore adapted, or where they are introduced to waters which have been completely depopulated by changes (Philippard, Melard & Poncin 1987). Generally selection acts most strongly upon the youngest age-classes (Arrignon 1976), but it is far cheaper to re-stock with young specimens than old ones, and the fish farmer may find it inconvenient to produce mature stocking material. He tends to want good food conversion, rapid growth of his fish and quick profits.

Another problem related to unsuccessful restocking arises during the transport of the stocking material. In trout, very high levels of lactic acid are produced after even a brief effort (Cuinat 1971, Vibert & Lagler 1961, Werner, Hall, Laughlin, Wagner, Wilsmann & Funk 1977), and reabsorption of this takes 6-12 hrs, which is much slower than in mammals. During transport, the swimming movements necessary to maintain station often cause the development of excessive lactate concentrations and this may kill more than 90% of the fish, even several days after they have been released. This phenomenon, known as 'deferred mortality', may be defined as the percentage loss, not directly attributable to predation, which occurs within seven days of introducing the fish to new waters. Further, fish just released into a natural environment are weak, and they experience an increased risk of predation, and increased competition (Neumann 1956). Competitors, both inter- and intra-specific, are generally better able to find natural food and shelter than the new fish, which are unaccustomed to the environment. Newly introduced fish are frequently forced to remain exposed in the current.

Another problem is that salmonids bred in intensive conditions and released in natural systems frequently have poor reproductive potential. This is because the reproductive phase of a natural population is concentrated and synchronized, for all individuals, into a brief period, often a few days, so that many fish in mating condition can meet. Fish that are out of phase, either too early or too late, tend not to find suitable mates. Fish farming, on the contrary, selects the opposite behaviour, because it is convenient to have the reproductive phase spread out over a long period (Forneris & Alessio 1986).

Finally, logistics dictate that traditional restocking is usually concentrated in brief periods in order to reduce transport costs, without consideration of environmental, biological and climatic factors. The priorities of the supplier and customer tend to be considered, rather than those of the fish. Thus we can summarize the drawbacks of the methods hitherto used for natural restocking as:

- Loss of 'wildness' of fish bred in intensive conditions.
- Inter- and intra-specific competition between native and introduced fish.
- Deferred mortality due to stress induced by transport.
- Reproductive difficulties for fish raised in farms.
- Over-complex and bureaucratic organization of the traditional restocking system.

The solution to these problems requires a complete re-evaluation of the traditional restocking methods, and the adoption of a new management strategy based on the creation of small units producing fish to the first stage of development in valley hatcheries.

For the second stage (the production of 4-6 cm troutlings) our experience is that it is best to use small water bodies of high biological productivity which are able to sustain suitable population densities (50 alevins per m^2) feeding exclusively on natural food.

2. The recovery and increase of native species and populations

Improvement of the status of the native species, vital to good management of our fish fauna, requires the ability to identify the species, grade them, capture reproductive individuals by electrical stunning (Peduzzi & Meng 1976, Regis, Pattee & Lebreton

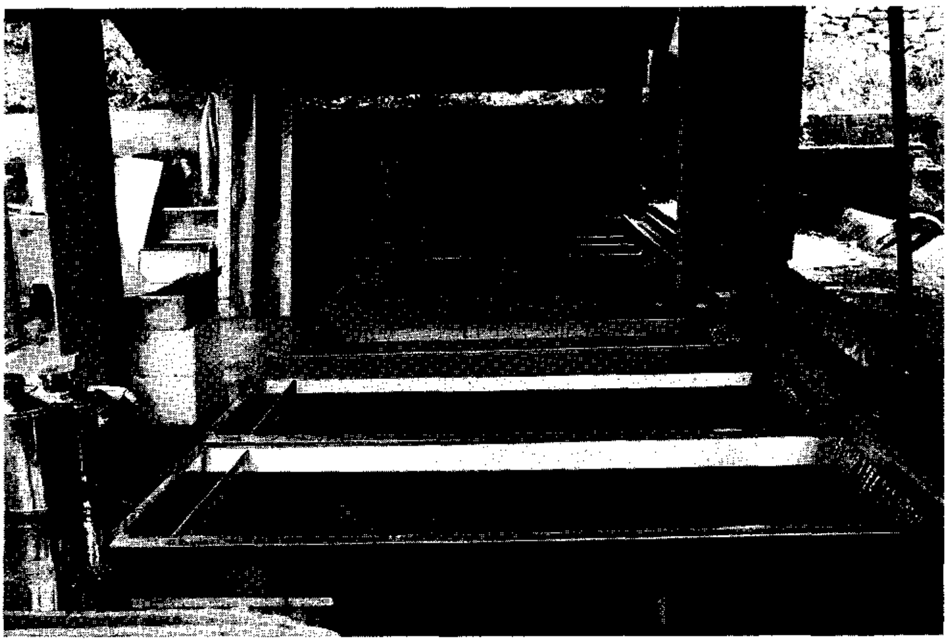

Plate 1. A valley hatchery.

Plate 2. Operator in training at a valley hatchery.

1981), and thereafter to selectively multiply stocks on the basis of their trueness to morphological type. *Salmo trutta marmoratus*, a subspecies of the Po valley, is particularly useful in evaluating this new rationale as it has a regular reproductive cycle and its spawning grounds are easily found. Also its characteristic colouring makes it easy to distinguish from *Salmo trutta trutta* and hybrids.

In the first stage culture of *Salmo trutta marmoratus*, a water flow of 100-300 l/min is necessary, depending upon the temperature. Using water at a constant 10°C, the duration of the various phases of first stage culturing are:

- 18-22 days from fertilization to the appearance of eyes in the embryo.
- 38-42 days from fertilization to hatching.
- 20-30 days from hatching to absorption of the yolk sac.

When absorption of the yolk sac is almost complete, the alevins can be sown in stretches of water that are suitably productive, or can be used directly for restocking fishing waters. The young trout produced in suitable river stretches, having withstood the natural hazards, will be similar to their wild counterparts and will be the best material for restocking. Intensive rearing to the troutling stage (4-10 cm) has been performed in round basins, even in the open with using shade netting. This system, although not ideal because it reduces 'wildness', may be necessary if particular environmental conditions preclude restocking with very young fish, *e.g.* where the entire surface of a lake is frozen until June or July, or where it is impossible to get to the highest reaches of an alpine stream because of snow. From our experience and the literature (Arrignon 1976), the ideal characteristics of waterbodies for the extensive raising of troutlings are pH 7.0, dissolved O_2 not less than 9 mg/l, slope 2-4‰, temperature not exceeding 15°C, width 100-150 cm, depth 15-50 cm, and length not less 500 m. The productive capacity of a system depends not only on the total area available, but also on the presence of shelter, a substrate favourable to bottom fauna and aquatic vegetation and the absence of predators (Burdin 1967).

The number of troutlings which should be introduced depends on many factors, some of which are not always easy to determine, but in every case the number is influenced by the environment and the working cycle of the hatchery. Every case should be treated individually (Arrignon 1976). Purely as an example, an ideal density could be 10-50 alevins per m^2 (Forneris & Alessio 1987). The survival of such troutlings may be as high as 65-80% and they are generally 6-12 cm long after 6 months and 14-18 cm long after 1 year.

3. Valley hatcheries as working models

By a grant of the Province of Torino, it has been possible to organize small producer units known as 'valley hatcheries' *(Plate 1)*. These are run by local angling clubs. The grant project will have two stages. The first will be a sort of 'running in' of plant and operators *(Plate 2)* and will produce fry and troutlings from embryo-stage eggs which will have been obtained from commercial hatcheries. The second stage will be aimed at recovering and boosting populations of both *Salmo trutta trutta* and *S. trutta marmoratus*, once the system is running reliably.

Initially, possible sites for the construction of hatcheries were studied, and 11 areas were chosen, in the larger hydrographic basins. Requirements were a water supply flowing at not less than 150 l/min, either from a spring, or mixed origin, over 500 m^2 of public land and the presence of people capable of managing the operation, perhaps with the help of experts from the fisheries board of the Province.

Construction and running costs are met by the local Councils, using initial grants. Contracts are set up to run the plants for a number of years. In drawing up detailed plans we avoided rigidity, permitting us to take advantage of local conditions and to adapt unused buildings where available.

Table 1 shows the production realized by the valley hatcheries to 1988. *Table 2* gives the 1987 balance sheet for the operative hatcheries. Columns 2 and 3 give the value of fish produced. The Italian market prices are 15 Lit per alevin (column 2) and 170 Lit per troutling (column 3). Column 4 gives the depreciation allowance for each site calculated over ten years. Column 5 gives production and management costs. However, it should be emphasized that manpower is free in all hatcheries, being provided by volunteers from the angling clubs. The eggs for the 1986 and 1987 cycles were purchased from trout farms. The economic benefits take account of the fact that, to date, agreements drawn up stipulate that 40% of the commercial value of the product shall be returned to the society managing project.

Table 1. Numbers of alevins and troutlings of *Salmo trutta* and *Salmo trutta marmoratus* produced by the valley hatcheries now operating.

Sites	Species	Stage of sowing	1986	1987	1988
Luserna S.G.	*S.trutta*	alevins	293 000	350 000	400 000
		troutlings	30 000	150 000	240 000
	S.trutta marmoratus	alevins *			20 000
		troutlings*		20 000	
Quincinetto	*S.trutta*	alevins	131 000	275 000	250 000
		troutlings	18 000	80 000	100 000
		alevins *		30 000	100 000
Praly	*S.trutta*	alevins		30 000	25 000
		troutlings		28 000	20 000
Perosa	*S.trutta*	alevins			300 000
		troutlings			70 000
		alevins *			30 000
Perrero	*S.trutta*	alevins			100 000
		troutlings			30 000

* fry produced by wild parents and sowed in suitable stretches of river for extensive culture.

Table 2. Balance sheet for 1987. The Italian market prices are 15 Lit per alevin and 170 Lit per troutling. The saving for the Province of Torino was about 42 000 000 Lit.

Sites	Value of fish produced		Depreciation allowance	Production and management costs
	alevins	troutlings		
Luserna S.G.	5 200 000	42 500 000	4 600 000	14 000 000
Quincinetto	4 132 000	13 600 000	850 000	5 000 000
Praly	450 000	4 250 000	1 500 000	2 000 000
Total	70 132 000		27 950 000	

4. Conclusions

Ideal restocking, where it can be practiced, must be based on the introduction of selected strains, preferably native to the locality and perfectly adapted to the introduction site. The fish should be in good health and raised in an environment that is as natural as possible.

The valley hatcheries, run by local angling clubs, could provide such material. The stock produced will be under good genetic and sanitary control, aiding the correct management of native fish populations. Entrusting management of the hatcheries to the local fishing societies will tend to make those who benefit from fishing more responsible, and aware of the problems involved in conserving the local fish fauna.

References

Alessio, G.L., 1986. Finalità, criteri e metodi di intervento per la conservazione, la tutela e la valorizzazione dell'ittiofauna. Quaderni E.T.P. Udine. 14: 7-16.

Arrignon, J., 1976. Amenagement écologique et piscicole des eaux douces. Gautiers-Villars, Paris. 322 pp.

Bianco, P.G., 1976. I pesci d'acqua dolce d'Italia: considerazioni e criteri generali sulle semine in natura. Proc. Sem. 'Reintroductions: technique and ethics', WWF, Atti & Studi, Boitani ed., Roma. 2: 243-265.

Burdin, G., 1967. Propos sur les rigoles d'alevinage. Bull. Off. C.S.P. (67), Paris.

Cuinat, R., 1971. Ecologique et repeuplement des course d'eaux à truite. Bull. Franc. Piscic. vols 240, 242, 243.

Forneris, G. & Alessio, G.L., 1986. Cento norme pratiche per allevare trote, carpe e pescigatto. REDA, Milano. 200 pp.

Forneris, G. & Alessio, G.L., 1987. Recupero di popolazioni di *Salmo trutta marmoratus* Cuv.: modello operativo per la gestione dell'ittiofauna. Atti 2 Convegno Nazionale A.I.I.A.D., 5-6 giugno, Torino, 1987. 1: 113-122.

Neumann, M.A., 1956. Social behaviour and interspecific competition in two trout species. Physiol. Zool. 29: 64-81.

Peduzzi, R. & Meng, H., 1976. Introduzione alla pesca elettrica. Riv. It. Piscic. Ittiop. 3: 81-87.

Philippart, J.C., Melard, C.H. & Poncin, P., 1987. Abstract, Conference Aquaculture Europe 1987 International Conference. Amsterdam, 2-5 June.

Regis, J., Pattee, E. & Lebreton, D.J., 1981. A new method for evaluating the efficiency of electric fishing. Arch. Hydrobiol. 93: 68-82.

Supino, F., 1934. Note di pesca. Ripopolamento delle acque dolci. Riv. Sci. Nat. 'Natura' 25: 43-58.

Tortonese, E., 1970. Ostheichthyes, Parte I - Fauna d'Italia Volume X, Bologna, Calderini. No:13. 545 pp.

Vibert, R. & Lagler, K., 1961. Pêches continentales. Dunod, Paris. 720 pp.

Werner, E.E., Hall, D.J., Laughlin, D.R., Wagner, D.J., Wilsmann, L.A. & Funk, F.C., 1977. Habitat partitioning in a freshwater fish community. J. Fish. Res. Bd Can. 34: 360-370.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 292-300.

Management structures in Lake Trasimeno, Central Italy

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Abstract

Lake Trasimeno, Central Italy, has an area of about 12 800 ha, and a maximum depth of 6 m. The annual average yield is approximately 65 kg fish/ha, but this fluctuates substantially. The most sought after species are pike, eel, perch, latterino, tench and carp.

The technical body for managing the lake is an organisation of Perugia Province, the 'Consorzio Pesca Acquacoltura Trasimeno'. This was established in 1918 and shows an ever growing vitality. The Consorzio mediates between fishermen, regulates the fishery and controls restocking. Moreover, it is responsible for fish sales, and experiments with the preparation of added-value products, *e.g.* by smoking, and operates a 'typical' restaurant. The Consorzio owns a large, modern fish farming centre, with laboratories, hatcheries, basins and outdoor ponds.

From 1981 to 1984 the 'Cooperativa Idrobiologia Pesca Acquacoltura' (COIPA) of Rome carried out pilot studies for the centre and after its completion assumed the technical and scientific control of the new plant, and trained the present staff. The centre now produces pike, carp and grass carp fry in bulk, and is studying exotic species such as sturgeon and crayfish, both for aquaculture and restocking purposes. Surplus production is sold outside the Consorzio.

Today several different bodies, with different principal interests, work together on conservation issues, and in maintaining water quality, navigation and recreation in the overall management of the lake.

1. Lake Trasimeno

Lake Trasimeno *(Figure 1)*, situated in Central Italy (Province of Perugia), has an area of 12 800 ha; its catchment extends over another 26 800 ha. The lake, of tectonic formation, originated in the recent Quaternary (Villafranchian) in sedimentary rocks (Anonymous 1983).

The water body is characterised by modest depth, frequent and complete mixing, very low transparency, a substantial concentration of oxidizable material, an average pH of 8.3 (rising to 10.0 in special circumstances) and a macrobenthos containing typical astatic eurytopic components (Tiberi, Taticchi Viganò & Di Giovanni 1971). The monthly average productivity of the phytoplankton (1969) is around 3 000 000 cells/l. The zooplankton density averages 150-200 ind./l in the pelagic area and 500 ind./l in the neritic zone. The macrobenthos comprises mainly chironomids, heteropterans and annelids *(Stylaria, Dero, Tubifex)* and numbers some 2500 individuals/m^2 (Tiberi *et al.* 1971).

Since the emperor Claudius, who is said to have built an artificial emissary with an underground channel 900 m long, man has tried to regulate the surface level of the lake

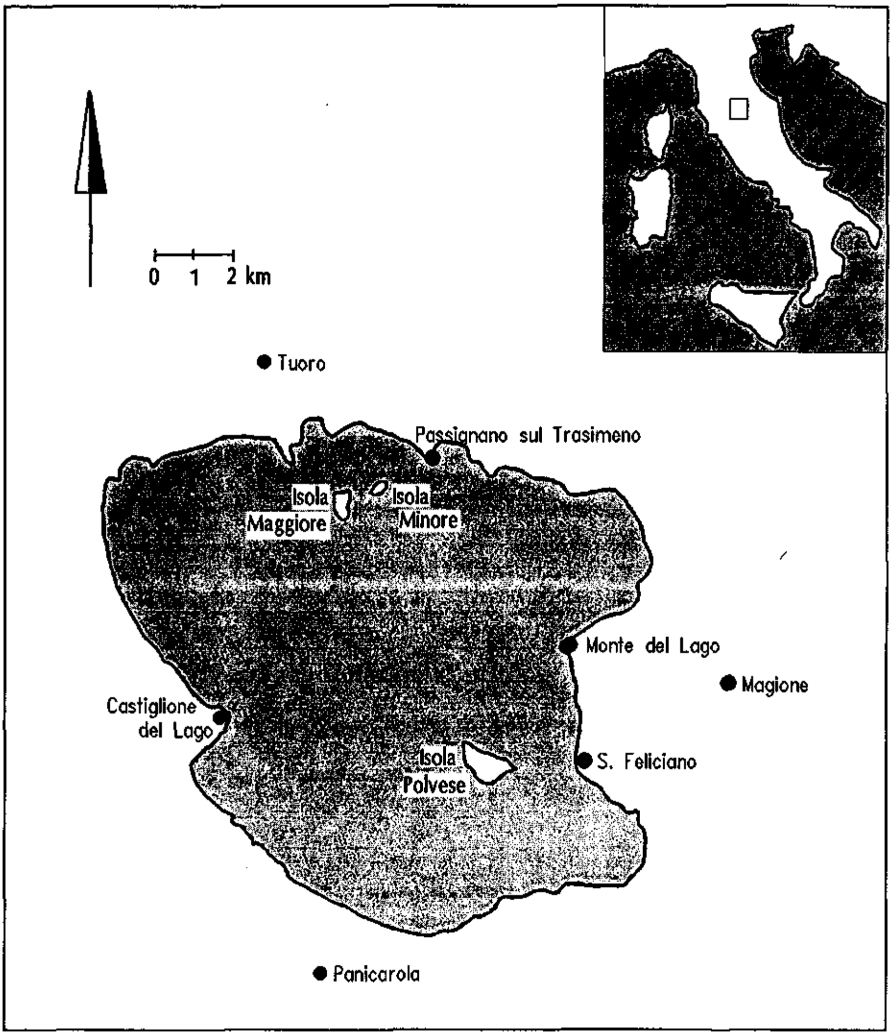

Figure 1. Lake Trasimeno.

(Di Giovanni 1974). It now has a maximum depth of 6 m, but the major part is shallow and swampy, less than 2 m deep. However, in 1958 it had a maximum depth of only 3 m and we may assume that it then had a smaller surface area. Moreover, macrophytes then invaded the whole water body, making fishing and boating impossible, and causing lethal falls in dissolved oxygen concentrations (Castelli 1964).

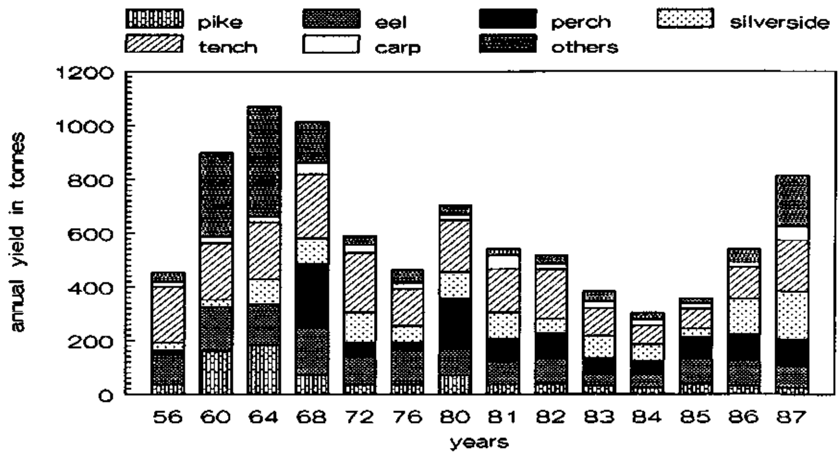

Figure 2. Official landings of fish from Lake Trasimeno. The bars for 1956-1976 are based on 4-yearly averages (1956/1959 – 1976/1979). Official figures tend to underestimate actual landings by as much as 30%. There was a ban on fishing for perch from 1961-1965. The category 'others' did not include sunfish in the period 1956-1959. Data 1956-1975 are from Gianotti & Giovinazzo (1975). Data for 1979-1986 are from Consorzio Pesca Acquacoltura Trasimeno. Data for 1987 are estimated.

2. The fishery

In the last century the fisheries of Lake Trasimeno landed a yearly average of about 800 tonnes *(Figure 2)*, but the actual figure fluctuated widely reflecting even minor environmental changes. Taken together the activities of the fishery gross about 3 billion Lit/yr. In 1986 and 1987 fishermen landed fish worth 2.6 and 3.0 billion Lit respectively, *i.e.* 2.0-2.3 million US$, but in 1984 the catch was worth only 1.4 billion Lit or about 1 million US$.

There are 18 species of fish in the lake. Of these the most sought after are pike *(Esox lucius)*, eel *(Anguilla anguilla)*, perch *(Perca fluviatilis)*, latterino *(Atherina mochon)*, tench *(Tinca tinca)*, carp *(Cyprinus carpio)*, red eye *(Scardinius erythrophthalmus)* and pumpkinseed *(Lepomis gibbosus)*, in descending order of importance. Accidentally, they also catch various mullet (mainly *Mugil cephalus*, but also *Liza ramada*, *Liza aurata*, *Chelon labrosus*), grass carp *(Ctenopharyngodon idella)*, chub *(Leuciscus cephalus)* and roach *(Rutilus rubilio)*. Notes on these species follow:

Pike. This predator is autochthonous, but is also restocked using material from Hungary and from the artificial reproduction of local broodstock, and written records of pike (and eel) restocking date back to the year 1266. Pike are caught with gill-nets, long lines and fyke nets. The pike season is closed from February 15 to March 15, except for catching sexually mature animals for stripping in the local hatchery. The minimum legal size is 35 cm and market price for pike fluctuates around 8000 Lit/kg.

Eel. The majority of the eel population in the lake derives from stocking, presently carried out with medium-to-large specimens. Eels are fished with small unbaited fyke nets ('bertovelli') or long lines and are caught mainly at the yellow stage. The minimum legal size is 35 cm, which means very few males can be fished. The price exceeds 9000 Lit/kg.

Perch. Besides natural reproduction, this species is usually stocked, using material of various origins. It schools when young. It was totally protected from 1961 to 1965. The current legal size is 18 cm and there is a closed season from March 1 to April 15. Prices range from 7000 to 8000 Lit/kg.

Latterino. This small planktophagous fish was accidentally, and luckily, introduced in 1920, and its population is now self-sustaining. Fishing for latterino is forbidden for 6 months, from April to October. Its price is around 3000 Lit/kg.

Tench. Tench is now the most commonly landed species from Lake Trasimeno, and is sometimes restocked. Its legal size is 20 cm, with a closed season during June. While generally considered a better fish than carp, in the Trasimeno area it is priced lower at about 3000 Lit/kg.

Carp. Mirror carp was first introduced in 1921, while common carp ('regina') is probably native, but is sometimes restocked. The minimum legal size is 35 cm, with a closed season during June. Price averages 3500 Lit/kg.

Red eye or rudd. This species feeds mainly on vegetation. It is considered a poor quality fish and has no market value.

Pumpkinseed. Accidentally introduced in 1926 and locally called 'bad perch'. It prefers the neritic zone. A few years ago it was the most common fish caught in the lake and was a pest, but the population has been markedly reduced since it became sought after for fresh feed for aquaculture. Its price is below 1000 Lit/kg.

Mullet. None of the four species introduced to Lake Trasimeno can reproduce in the lake. They are generally bred in short cycles, during spring and summer only, because of their sensitivity to cold weather. The grey mullet has been used since 1923, the other three since 1961. They command a price of 4000 Lit/kg.

Grass carp. This species, which cannot reproduce in the lake, was introduced for the first time in 1986. Large fish, up to 2 kg, are now occasionally caught. This trial, considered a success, will be repeated in the future with larger inputs.

Chub. This is an autochthonous species which is sometimes restocked. It prefers the pelagic zone and is now very rare.

Roach. Before 1958 this was a common fish in the lake, but it is now rare. In times past it was caught with a peculiar type of gear called 'tofo con crini'.

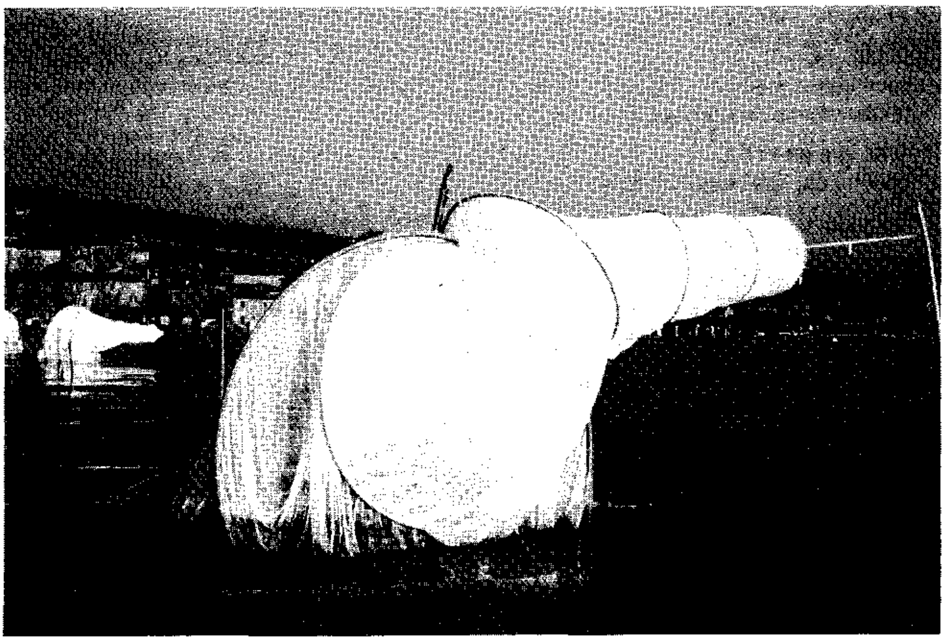

Plate 1. Fyke net on Lake Trasimeno.

3. Fishing gear

Six main types of gear are used in the lake:

- Gill-nets, locally called 'altana', whose mesh and shape are related to the expected prey.
- Fyke nets, with or without wings, of different mesh and size. The smaller ones are called 'bertovello', the larger ones 'tofo' *(Plate 1)*.
- Sweep nets, now uncommon, called 'giacco' or 'sparviero'.
- Dipping nets, sometimes used from a boat, called 'bilancella'.
- Long lines, called 'fila'.
- Barrages, once made of reeds but now of plastic netting, are set to lead the fish into the fyke nets, called 'arella'.

4. Management structures

About 190 commercial fishermen are employed on Lake Trasimeno. They are organized geographically into 7 co-operatives, but the trend has been for the numbers of both fishermen and co-operatives to decline in the last few years *(Table 1)*.

Table 1. Professional fishermen and co-operatives operating on Lake Trasimeno.

	1956	1964	1968	1972	1976	1987
Fishermen	480	470	450	360	290	190
Co-operatives		10	10	8	7	7

The body responsible for the management of the lake is an organisation of Perugia Province, the 'Consorzio Pesca Acquacoltura del Trasimeno' which was established in 1918. It is still a vital body, regulating the fishery, supervising restocking and proposing new ways of exploiting the resources of the lake. The Consorzio mediates between parties with conflicting needs including both commercial and recreational users of the lake. Moreover, after asking for technical advice, it evaluates the usefulness and potential risks of introducing new species. The Consorzio operates in a political environment encompassing more than lake management alone, and thus has to compromise and accommodate many different interests.

Recently, the Consorzio has decided to buy all the catches and now markets all the products of the fishery. In this way, competition between co-operatives is buffered, and the prices paid by the fish brokers are generally higher than can otherwise be obtained. This is certainly true for the most valuable species, pike, eel and perch, but not always so for lower quality species, such as carp and tench. These latter species constitute the bulk of the landings, but are not appreciated even when filleted. The Consorzio is thus experimenting to upgrade the product through intensive processing, *e.g.*, the fish is smoked or ground up to make hamburgers and sausages. These products are still very cheap and seem to be well received by canteens and community caterers. The success of this operation will influence the whole fishery policy of the Trasimeno Lake. To attract more discerning consumers as well, the Consorzio owns a restaurant where lake fish is served in traditional local dishes and where new recipes are developed.

In addition the Consorzio manages sport fishing and is involved in regulating fowl hunting, and the cutting of reeds (*Phragmites* sp.), which are used in horticulture, and for thatching and other products.

Table 2. Numbers restocked in Lake Trasimeno.

		Mean 1950-1966	Mean 1967-1976	Mean 1977-1980	1984	1985	1986
Eel	small yellow	150	175	650	1 000	-	300
	elvers	200	800	330	-	-	-
	glass eels	-	5000	5000	-	-	-
Pike	fingerlings	200	-	-	-	32	420
	fry	-	10 000	9 000	1 000	3 200	13
Perch	fingerlings	55	?	60	-	-	2
	fry	-	1 600	1 500	-	-	-
Carp	fingerlings	-	-	-	160	26	450
	fry	-	-	-	4 500	-	10 000
Grass carp	fingerlings	-	-	-	-	-	100
	fry	-	-	-	-	-	5 100
Mullet		30	500	55	450	-	-
Roach		20	-	-	-	-	-
Tench		8	35	-	-	-	7
Chub		1	-	-	-	-	-
Sea bass		-	4	-	-	-	-

5. The fish farm and hatchery centre

The Consorzio owns a large, modern fish farm and hatchery, the 'Centro Ittiogenico del Trasimeno' (CIT). This was established in 1984 in S. Arcangelo, with funding from the Italian Government, the Umbria Region, Perugia Province, and the European Economic Community.

The CIT aims to exploit freshwater products through a more modern and rational management of the lake. Therefore, its major objectives are:

- To make better use of Lake Trasimeno for the production of the most valuable species of fish, including eel and grey mullet.

- To rationalize professional fishing in the lake.
- To carry out research on the reproduction and farming of freshwater fish and shellfish (feeding, ichthyopathology, production techniques).
- To make the centre available for public and private research and for training courses at all levels.

The centre comprises a hatchery building with a laboratory annexe, 36 earthen ponds each of 150 m^2 surface for breeding fry, and some large earthen basins for holding broodstock. Some pen-cages for fingerling production are set in the terminal decanting ponds.

Water is taken directly from the lake and can be filtered, UV sterilized, heated and thermo-regulated; it serves 40 Zug bottles, 50 bell-shaped containers (for hatching grass carp) and 50 plastic tanks of various dimensions up to 15 m^3.

From 1981 to 1984 COIPA made pilot trials at the old establishment at S. Feliciano, but after the completion of the new centre in S. Arcangelo, COIPA assumed its technical and scientific direction for 3 years and trained the present staff.

The CIT now produces larvae with reabsorbed yolk, fry, and fingerlings. The bulk of the production is pike, carp and grass carp, with a little tench and perch. Most of the production is used in the lake itself, but surpluses are sold outside the Consorzio. The centre is also studying exotic species, such as sturgeon *(Acipenser ruthenus)*, tilapia *(Oreochromis)* hybrids, European catfish *(Silurus glanis)* and crayfish *(Procambarus clarkii, Macrobrachium rosenbergii)*, for both aquaculture and restocking.

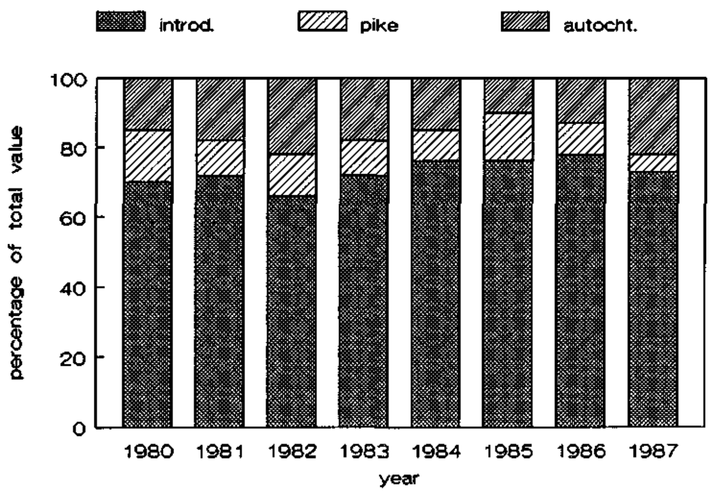

Figure 3. Percentage of introduced species, pike and autochthonous species in the total value of the catch from Lake Trasimeno, 1980-1987.

In addition to material produced in the CIT, fry and fingerlings are sometimes purchased by the Consorzio for restocking the lake. This occurs when interventions are required which are were not planned. Average inputs to the lake are reported in *Table 2.*

While there is no doubt that restocking and introduction programmes play an important role in maintaining and raising the quality of the local fisheries, the biological impact, especially on the autochthonous stocks, is still under study and represents the single major problem in the management of Lake Trasimeno. *Figure 3* shows the relative values of autochthonous species, pike (which is heavily restocked) and introduced species in annual catches from Lake Trasimeno.

6. Interactions between various interests on the lake

A hydrobiological station of the University of Perugia, the Institute 'G.B. Grassi', also operates on the lake. It has been very active in the past when its researchers monitored the lake environment and fishery, and performed many fundamental limnological studies which are still useful to management today.

From a cultural point of view, the Museum of Freshwater Fishery explains the traditional way of life and how younger planners seek to streamline the exploitation of the lake resources.

Several bodies with different interests in the lake are involved in its overall management, and do not always interact harmoniously. Lake Trasimeno is covered by the National Landscapes Act and has been designated as a 'wetland of international importance' for its role in bird migration. Further, the Umbria Region protects the surroundings as a Regional Natural Park. However, there are plans to dyke some areas, to upgrade recreational harbours, to build new tourist marinas and to develop camping sites. The ferry company seeks open navigation lanes in areas where fishing gear is set. When drought is imminent there are clashes between the irrigation needs of local agriculture and the need not to allow drawdown to proceed too far. An agency separate from the Consorzio, the Technical Office, regulates abstraction and inflow, and a recent example of mismanagement was the accidental entrance of the catfish to the lake when water flows were altered in the channel linking Lake Trasimeno with Lake Chiusi.

References

Anonymous, 1983. Le zone umide nei comprensori di bonifica della Toscana, del Lazio, dell'Umbria e della Sardegna. Publ. Ist. Tecnica Propaganda Agr. pp. 19-20.

Castelli, B., 1964. Considerazioni sopra il Lago Trasimeno. Le Scienze 1: 1-2.

Di Giovanni, M.V., 1974. Vicende ecologiche del Lago Trasimeno. Riv. Idrobiol. 13: 57-78.

Gianotti, F.S. & Giovinazzo, G., 1975. Il quadriennio di pesca 1972-1975 nel Lago Trasimeno. Riv. Idrobiol. 14: 283-329.

Tiberi, O., Taticchi Viganò, M.I. & Di Giovanni, M.V., 1971. Ragguagli sulle condizioni fisiche, chimiche, planctonologiche e bentoniche del Lago Trasimeno (febbr. 1969 - febbr. 1970). Riv. Idrobiol. 10: 37-233.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 301-312.

Structure for the decision-making process in inland fisheries management

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Abstract

After comparing inland fisheries management with fisheries management in the marine environment, a generalized management scheme is proposed. The management scheme is confined to fisheries management with quantified biological management objectives. The crucial part of fisheries management, as an objective-oriented, continuous decision-making process, is the evaluation of the information on the fishery and the fish stocks, generated by the research component. The information needs of current fisheries management must form the basis for scaling and partitioning future research efforts and budget allocations. Special attention is given to uncertainties in decision-making and the use of computer models, including their use for extension and education.

1. Introduction

Recommendation 1 (Data and information) of the 1980 Vichy Technical Consultation on the 'Allocation of Fishery Resources' dealt with the need for comprehensive information and data on both the users and resources of the aquatic ecosystems under consideration (Gaudet 1982). This information was regarded as essential for the development of integrated models for use in long-term planning and policy analysis, and for managing specific fisheries efficiently. To be meaningful the data should be based on common definitions and have a high degree of comparability. Maybe it was not appreciated, at that time, that data only become information when they are related to objectives, to decisions to be taken, and only in this way acquire a meaningful content. It was realized that to be instrumental in the management process, fishery scientists should package fishery information in such a manner that the general public, engineers, and trained administrators, can understand and see clearly the trade-offs involved with each proposed alternative. For this, an effective two-way flow of information between fishermen and scientists, as well as between fishery interests and the general public, is necessary (recommendation 1, E5). It was also recommended that the flow of information and the decision-making process within fisheries management and policy-making be studied (recommendation 1, E3).

In the meantime, the growing use of computers has made data storage more easy, but whether these data stores meet the information needs of the decision-makers in the fisheries management process depends on the way these data are gathered and presented by the researchers. To know what kind of information is needed, and when, in the management process, one has to analyse fisheries management as a continuous decision-making process. Rothschild & Heimbuch (1983) put it this way: 'the task of fisheries managers involves the design of fishery management systems, where the kinds and quality of information are carefully specified'.

In this contribution a generalized management scheme is proposed, which has not too much analytical complexity to hamper its additional use in comparing different management situations. The scheme shows the structure of the management process, its interrelating actions, analyses and decisions, and the constraints on them. Which management boards are meeting, and how frequently, how research budgets are allocated, and how extension and education are used to facilitate information transfer and decision-making etc. is a matter of organization.

First, some features specific to inland fisheries, as opposed to marine fisheries, are pointed out, and their possible consequences for fisheries management mentioned. Second, a generalized management scheme is presented. Third, organizational aspects are discussed together with recent developments like the incorporation of the findings of ecological research in monitoring programmes, computer modelling, and the growing emphasis on extension and education.

2. Inland fisheries

Although many concepts and definitions can be used both in marine and freshwater fisheries management, there are a number of characteristics which distinguish freshwater from marine environments, and thus also the fisheries management applied to them:

1. There is great physical, and probably also ecological, diversity among freshwater ecosystems (rivers, lakes, small streams etc.). Also, the low surface area to periphery ratio, and the presence of littoral vegetation, are accompanied by a more structured environment than found in the sea. The specific role of littoral vegetation in the dynamics of fish populations (segregation of feeding habits, shelter from predation) is realized progressively (Grimm 1983, Werner *et al.* 1983).

2. The order of size of freshwater ecosystems is much smaller than that of marine ones, and the number of water bodies is much larger. This implies that management cannot cover all water bodies equally intensively and a selection, either for representative water bodies or extensive management, has to be made. The management organization is influenced by this scale too. For example, for the management of the North Sea stocks of plaice, the EC can rely on a well-organized research body, which co-ordinates international research efforts in a most efficient way. In freshwater environments, managers of river systems may have nothing in common, and no contact, with managers of lacustrine systems close-by.

3. The combined use of freshwater fish stocks by commercial and sport fishermen, and sometimes also by those managing fish stocks to improve water quality (biomanipulation), is further influenced by the use of the water body for purposes other than the fishery (Alabaster 1975, Petr 1985).

3. Translations

In this contribution the management objectives are confined to biologically defined objectives. They are not defined in terms of recreational benefits, economic returns or others. Problems in the formulation and evaluation of sociological, economical or ethical fisheries management objectives are still very large (Talhelm & Libby 1987). Also, in the management of the large-scale North Sea fisheries, management objectives are formulated in biological terms in the first instance (*e.g.* stock conservation), which accounts for economic constraints in the enforcement of management measures. In this marine fishery one is still engaged in tailoring the biological output to the needs of economic analysis (Hoydal 1985). Analysis for comparability of management situations must first focus on management objectives in biological terms. This does not imply that one does not need to pay attention to socio-economical aspects. A lot of them come up in every phase of the management process, such as legal, sociological and economic constraints, and educational problems in advocating management measures, and information handling and transfer in the organization of the management process. But these aspects are omitted from the management objectives dealt with here. It is assumed that sociological or economic objectives can ultimately be translated into biological terms.

4. A generalized management scheme

The scheme clarifies the management of fisheries as a continuous decision-making process (*Figure 1*). Emphasis on decision-making was also given by Welcomme & Henderson (1976) in their elaborated flow chart of decisions in the management of fisheries.

4.1 Inventory of users preferences

In case of commercial fishermen this is a relatively easy phase in the management process. They want a high, sometimes combined with a stable, yield of the most commercially interesting species. For sport fishermen this is a much less easy task. The preferences of sport fishermen can be very dependent on the current availability of sport fish and inquiries are sometimes unable to unmask this. Moreover, when inquiries are used, they should be designed in a way that makes a distinction between angler actions (constrained demand) and stated preferences (unconstrained demand) possible (Harris & Bergersen 1985).

For realistic expectations of commercial and sporting fishermen to be realized from the limited fish and aquatic resource base, one needs effective science transfer within management agencies and effective communication between those agencies and the public (Loftus 1987). Once the biological potential and constraints are realized, it is desirable that the user groups pronounce articulate demands, before fishery scientists provide them with detailed information on the present status of the fish stocks. Otherwise the user groups might be hesitant from the very beginning of the management process onwards.

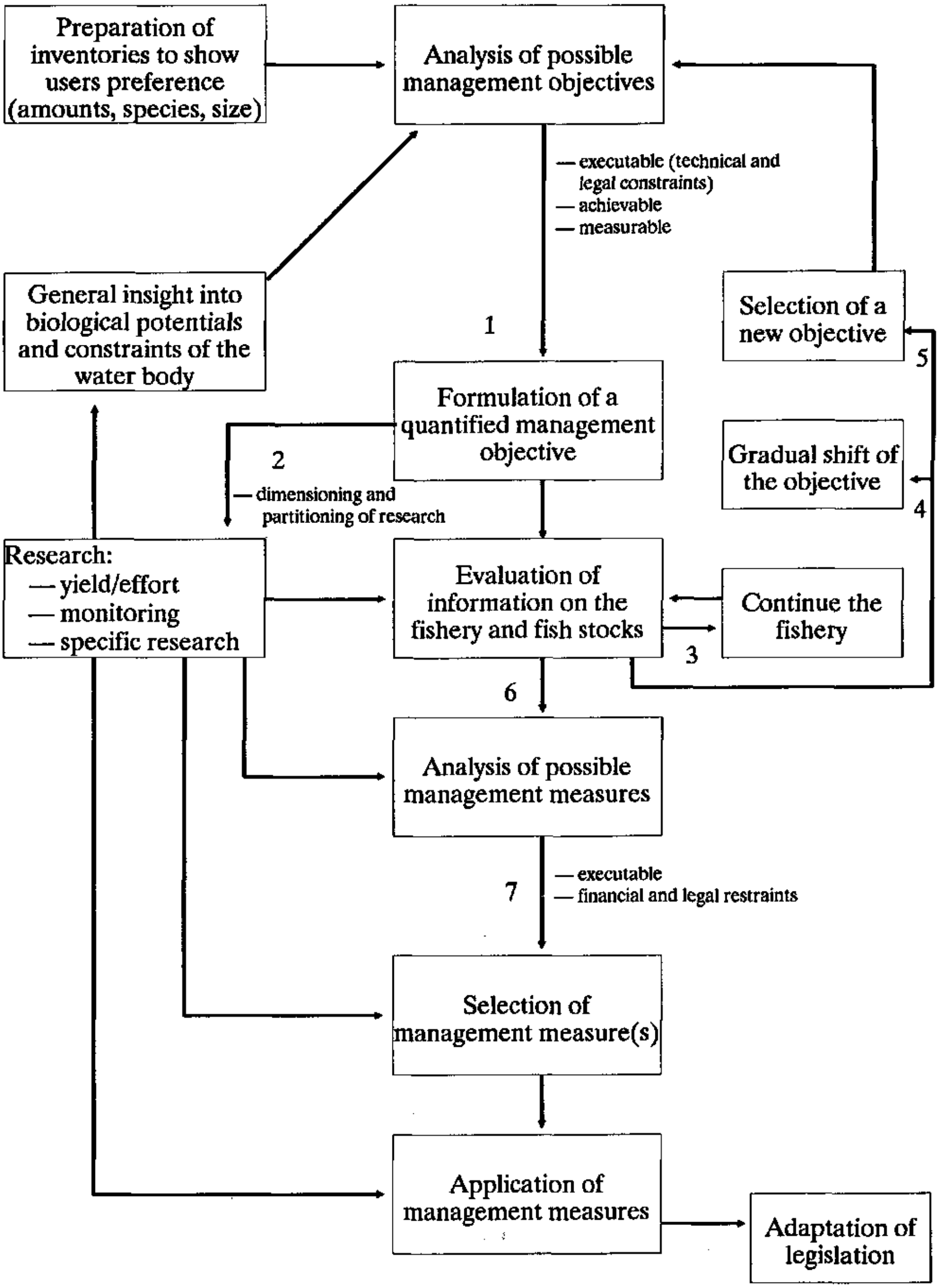

Figure 1. A generalized management scheme. The numbers indicate when main decisions have to be taken.

4.2 Analysis of possible management objectives

In this phase user preferences are combined with a general insight into the biological possibilities of and constraints upon the water body concerned. Some extreme management objectives can be excluded. Already at this phase a data set can be available, containing daily angling catches from similar water bodies, so that sport fishermen can appreciate what range of catches can be expected (this volume, Steinmetz 1990). The same holds for commercial fishermen.

There are a number of situations in which the fish stock is used simultaneously by sport and commercial fishermen. The allocation problem can interfere in this phase of the management process, but this need not necessarily be the case. The analysis/inventory of possible management objectives can act parallel to each other. Integration can happen in a subsequent stage of the management process.

4.3 Formulation of a quantified management objective

A management objective can be formulated after the inventory of the possible management objectives on the basis of their executability, achievability and measurability. There might be all kinds of technical and legal constraints which exclude certain management objectives. Achievability can be related to a feeling for realism in the socio-economic context. A step-by-step policy is an appropriate technique in some instances. However, management cannot be too gradual, otherwise the instructive value of the results of the measures taken may be lost in the 'stochastic noise of nature', *e.g.* variations in year-class strengths.

The management objective must be measurable, otherwise it is difficult to evaluate the fisheries management. In exceptional situations logical answers will do: is an introduced new species for the water body still present five years after its introduction? In most other situations measurability already starts with the present level of say catch/rod/day as a reference. In the most ideal situation one not only aims for a quantified management objective, but also defines acceptable levels of variation in the yield, the spawning stock etc.

4.4 Scaling and partitioning of research

Research on the fish stock or the fishery in its most wide sense serves to enlarge the general insight in the functioning of the water bodies, and more specifically, it has to support the fisheries management. The basic three research categories in fisheries management distinguished here are:

1. Gathering yield and effort data on the fishery to describe trends and to follow stock size from the catch per unit effort (CPUE). Wherever possible detailed information is gathered on the size and age structure of the catch. The data in this category are fishery-dependent data. In freshwater fisheries there is promising scope for the active participation of motivated user groups in gathering data on the fishery (this volume, Cowx 1990).
2. Monitoring is exclusively the fishery-independent gathering of data on the fish stock. Surveys of larvae and young fish are examples of this.

3. Specific research encompasses every type of research which is limited in time with clearly defined research goals, *e.g.*, investigating net selectivity, distribution patterns, reproductive cycles etc. Research for specific demands or users preferences is omitted from these three categories. Since they may change with time they too have to be monitored, but probably not on an annual basis. The choice for a distinct management objective should have the direct consequence that part of the total research effort is allocated for making the evaluation of the management objective possible.

4.5 Evaluation of the information on the fish stock or the fishery

This phase can be considered as the central part of the management process. A conclusion must always be drawn from it. However, it often happens that the information is inadequate or unavailable, and the success of the fisheries management which has been employed cannot therefore be evaluated. Thus the decision to continue the fishery with the governing management objective is sometimes the consequence of the absence of information. Some information might be a reason for making a gradual shift in the management objective (*e.g.* yield projected) or to select a new objective, for instance because of a distinct change in the ecosystem.

4.6 Analysis, selection and application of management measures

A management objective should always direct research but it does not necessarily lead to the application of management measures. Analogous to the selection of management objectives, one has to select management measures. There might be financial and legal constraints here. The financial constraints can be in the form of a sudden drop in the yield, *e.g.* when the mesh size is enlarged. A research unit can be asked to estimate the size of the drop, its duration, and the length of the period required to 'earn back' the loss. In this way the economic constraint can be quantified. In some situations technical constraints seem to be lesser problems than the enforcement and control of management measures.

4.7 The effect of the management measures

Whether measuring the effect of management measures is easily communicated or not depends on the management objective. It is easier to communicate about projected yields, because of the relevant experience of the user group, than about desired spawning stock biomasses. In the case of larval stocking programmes, there might be direct evidence for a large contribution of stocked individuals to the 0-group fish, and there might be circumstantial evidence that yields increased after the start of the stocking programme, but the final measurement of the effect of larval stocking is by tracing stocked individuals in the catches of the user group (Klein 1987).

5. Decision-making

The moments at which the main decisions in the management process have to be taken are when a definite formulation of the management objective has to be made, when one has to scale and partition research efforts, when action has to be taken after the evaluation of the information on the fishery or fish stocks, and when one has to select a management measure(s) for application *(Figure 1)*. The ideal decision maker *(Homo economicus)* (de Leeuw 1982):

- Knows what he wants.
- Is completely informed about the causal relationships between possible management actions and their outcome.
- Overviews all possible actions.
- Has unlimited capability for processing information.

In fisheries management the objectives are not always (clearly) defined. Also, information can be incomplete and not all possible actions are surveyable. The costs for adequate data acquisition and its processing are sometimes considered too high and managers are 'satisfied' with a situation of 'bounded rationality'. Most problematic in the management of natural resources, however, is the uncertainty the decision-maker has to deal with.

6. Uncertainty

A decision-maker has to deal with different types of uncertainty. There can be uncertainty because of the incompleteness of the information available to the decision-maker, uncertainty because of the possible unreliability of the observations on the fish stock and the fishery (statistical aspects of sampling, methodological problems, selectivity - Backiel & Welcomme 1980), and uncertainty because of variations in the resource itself. Following Hilborn's (1987) taxonomy of the latter type of uncertainty, we have to deal with noise, with uncertain states of nature and with surprise. With noise, *e.g.* due to variations in year-class strength, it is by experience over the long term, that we know how to cope with this uncertainty using statistical decision theory and adaptive control theory (Rothschild & Heimbuch 1983). For uncertain states of nature, we can observe trends, be they explicable or not, and here Hilborn advocates 'active adaptive management'. For example, we cannot anticipate how well a given rehabilitation method, like biomanipulation, might work for a deteriorating environment until we try it. Walters (1986) used a number of management problems in freshwater fisheries as examples for his treatise on adaptive management. Surprise is occasioned by an unanticipated event, one that has never happened before and for which our past experience is largely irrelevant. To some extent the (planned) result of introducing Nile perch to Lake Victoria (East Africa) was a surprise because of its unforeseen ecological consequences (Ribbink 1987).

7. Research

It is usual for inland fisheries that required research is not exclusively carried out by fisheries research institutes. Some research units are built into larger organizations like water authorities, river authorities and limnological institutes etc. General insight into the functioning of freshwater ecosystems is gathered in other branches of the same organization and this makes exchange of information effective.

The potentially productive link between fisheries research and limnology nowadays manifests itself by, for example, the recent development of quick cost-effective survey methods using the species composition and mean size of the larger zooplankton as indicators of the structure of the fish community (Mills, Green & Schiavone 1987). This development is related to the growing knowledge of the impact of planktivorous fish on the structure of the zooplankton community, and in its turn, of the zooplankton on the algal community (Carpenter *et al.* 1985, Scavia *et al.* 1986, Mills, Forney & Wagner 1987). This last matter has aroused the attention of water quality managers, since increasing the stock of planktivorous fish lowers the intensity of zooplankton grazing on algae, which leads to increased algal growth and decreased water quality, and *vice versa*. They may wish to curtail planktivores or enhance piscivore stocks (biomanipulation) (Shapiro & Wright 1984). Recognition of this has broadened the group of scientists motivated to do research on freshwater fish.

In an inventory of all possible methods of surveying and monitoring inland waters (Welcomme 1975), Tiews (1975 p. 537) concludes that there is no inexpensive way of monitoring eggs, larvae and juvenile fish. Further, Henderson (1980) says that sampling programmes for freshwater fish that are statistically efficient as well as economic are not easy to achieve. The large variability in the size of catches is a property of the fish populations themselves and precision can only be gained through intensive sampling and improving the designs of sampling programmes. Also, the sampling methods that evolve in research programmes are determined by constraints that are posed by the characteristics of individual sites (deep Alpine lakes, shallow vegetated lakes, fast-flowing rivers, recreation purposes etc.).

It is becoming better appreciated that fish surveys of inland waters still have to be refined so that developments in fish stocks can be monitored in the most cost-effective way (Hickley & Starkie 1985). The Anglian Water Authority (UK) has developed a survey practice for all its waters which covers species composition, density and biomass, as well as year-class structure and the growth rates of the dominant fish species, but this is done in 3-yearly cycles (Coles, Wortley & Noble 1985). A careful study of the distribution pattern of the fish can indicate the most appropriate time of the year to execute surveys, when fish are most evenly distributed, thus optimising the sampling effort (Jordan & Wortley 1985). An example of a well worked approach for calculating cost-effectiveness in survey sampling is given by Milner *et al.* (1985) who distinguish qualitative, semi-quantitative and quantitative sampling methods. On the basis of the number of sites that could be surveyed in a day, they calculated the effort, accounting for salaries, vehicle use, administrative on-costs, chemical analysis and time required to process the data. Associated with the development of efficient survey methods, there is a growing volume of software capable of treating and analyzing field data as it becomes available. Some programmes make possible, with certain assumptions, a quick analysis and breakdown of LF-distributions into their constituent components (MacDonald 1987, Sparre 1987).

Once gathered, data on fish (stocks) gain a growing information value when incorporated in 'expert systems'. As an example, Marshall *et al.* (1987) used data on the American lake trout (a species used as an indicator of ecosystem quality) to assess ecosystem quality in the Great Lakes Basin of North America. By contrast, Milner *et al.* (1985) used the technique in reverse; starting from a knowledge of the environment they used habitat evaluation techniques to assess the extent of the habitat of the local brown trout. A type of expert system could also be built out of attempts to predict temperate fish assemblages by the analysis of the requirements of individual species (Henderson 1985). A basis for the kind of approach mentioned above was already laid during an earlier attempt to compare different freshwater fisheries (FAO 1980). Whether 'expert systems' become a promising tool in fisheries management depends on our ability to design meaningful information structures.

8. Modelling

Computer models to be used in fisheries management can be in different development stages:

1. They can be complex analytic models, for application in research on, *e.g.*, the dynamics of a certain fish stock. Such programmes are only to be used by specialists.
2. They can be models for investigating the consequences of different management strategies in a specific situation. Their output should be in a form that can be used directly by the decision-makers. People engaged in the management of the particular fish stock can run such programmes.
3. They can be generalized, user-friendly, models, that allow parameters to be changed. These can be used by a wide range of people, from fishery scientists to fishermen, and they are important in research, management and education.

An illustrated description of development from stage 1 to 2 is given by Hilborn *et al.* (1984), dealing with management problems in both sporting and commercial Canadian salmon fisheries. They mention hidden benefits conferred by the model, such as it serving as a common ground for discussion, instead of having all arguments based on intuition and assumption. This benefit is only gained when the assumptions in the model are explicit and are clear to the potential users of the model, or to those who use the output. With the aid of computer models the consequences of possible management strategies can be scanned and this output can direct the formulation of (adjusted) management objectives (Clark & Huang 1985, Jacobson & Taylor 1985, Berkes & Gönenc 1982, Staub, Büttiker & Krämer 1987).

A representative model in stage 3 is that of B.L. Johnson. This demonstrates competition in an open-access gill-net fishery and was designed for class exercise (Johnson & Stein 1986). This model is an age-structured population model which has among its features, exponential curves for numbers and weights at age, a Ricker-type stock/recruit curve with a random component, and an age-defined maturity curve. The population is fished with a number of gill-nets and with mesh sizes which are optional for the users of the program. The exercise can easily be adapted for use with extension groups, management agency workshops or commercial fishermen.

A further development is the FINMAN-programme for microcomputers which simulates decision-making at different levels within the fisheries management institution, including general and research budget allocations (Ault & Fox Jr. 1986).

9. Extension and education

Some people are concerned about the speed with which research findings, ultimately all beneficial to fisheries management, are disseminated. Loftus (1987) emphasized the need to create communication networks for effective information transfer from the research scientist to management organization and, as common sense, to the public. This need was already put into words in the recommendations of the Vichy 1980 Technical Consultation (Gaudet 1982). Extension and education programmes on fish ecology and fisheries management will certainly contribute to more effective science transfer.

Every phase of the fisheries management process will gain from better educated user groups. Stange (1981) cites Eschmeyer (1955) saying that the future of fishing depended on two things: research and education. As representatives of both commercial and sport fishermen participate in management boards in most countries, it is of utmost importance to have them well and efficiently informed about the ecosystem and the fishery. They have to formulate and evaluate management objectives relying for a large part on a general insight in the functioning of ecosystems. It is probable that management measures taken are more easily accepted when the fishermen can foresee the effect of the measure and is also aware of the underlying assumptions. Also, here, education is a functional aspect of the total management process. In the Federal Republic of Germany every angler has to pass an examination before he is allowed to go sport fishing.

In the United States the Magunson Fishery and Conservation Management Act of 1976 requires active public participation throughout the planning and decision-making process. In relation to this, Harville (1985) has mentioned the two diverging pathways in the education of fishery managers as being:

1. A traditional discipline-centred route to a research career;
2. A professional career in fishery management and administration with an understanding of the multiplicity of factors, social as well as technical, that are involved in resource decision-making.

Such a divergence of capabilities between people involved in the management of large scale marine fisheries might be realistic, but in inland fisheries management these capabilities must often be combined as a professional style in one person.

References

Alabaster, J.S. (Ed.)., 1975. Habitat modification and freshwater fisheries. Proceedings of a symposium of the European Inland Fisheries Advisory Commission. Butterworths, London. 278 pp.

Ault, J.S. & Fox Jr., W.W., 1986. FINMAN. A fisheries institution management training simulation model. II. Model description and operations manual. Florida Sea Grant College TP-47-A: 1-127.

Backiel, T. & Welcomme, R.L. (Eds)., 1980. Guidelines for sampling fish in inland waters. EIFAC Technical Paper 33. 176 pp.

Berkes, F. & Gönenc, T., 1982. A mathematical model on the exploitation of northern lake whitefish with gill-nets. North Am. J. Fish. Man. 2: 176-183.

Carpenter, S.R., Kitchell, J.F. & Hodgson, J.R., 1985. Cascading trophic interactions and lake productivity. Fish predation and herbivory can regulate lake ecosystems. Bioscience 35: 634-639.

Clark Jr., R.D. & Huang, B., 1985. Conflict between sport fishing, commercial fishing, and rehabilitation of lake trout in Lake Michigan. North Am. J. Fish. Man. 5: 261-276.

Coles, T.F., Wortley, J.S. & Noble, P., 1985. Survey methodology for fish population assessment within Anglian water. J. Fish Biol. 27 (Supplement A): 175-186.

FAO, 1980. Comparative studies on freshwater fisheries. Report of a workshop held at the Instituto Italiano di Idrobiologia, Pallanza, Italy, 4-8 September 1978. FAO Fisheries Technical Paper No. 198. 46 pp.

Gaudet, J.-L., 1982. Introduction and summary. In: Grover J.H. (Ed.). Allocation of fishery resources. Proceedings of the technical consultation on allocation of fishery resources held in Vichy, France, 20-23 April 1980. FAO/AFS. pp. 1-7.

Grimm, M.P., 1983. Regulation of biomasses of small (41 cm) northern pike (*Esox lucius* L.) with special reference to the contribution of individuals stocked as fingerlings (4-6 cm). Fish. Mangmt. 14: 115-135.

Harris, C.C. & Bergersen, E.P., 1985. Survey on demand for sport fisheries: problems and potentialities for its use in fishery management planning. North Am. J. Fish. Man. 5: 400-410.

Harville, J.P., 1985. Expanding horizons for fishery management. Fisheries 10: 14-20.

Henderson, H.F., 1980. Some statistical consideration in relation to sampling populations of fishes. In: Backiel, T. & Welcomme R.L. (Eds). Guidelines for sampling fish in inland waters. EIFAC Technical Paper 33: 167-176.

Henderson, P.A., 1985. An approach to the prediction of temperate freshwater fish communities. J. Fish Biol. 27 (Supplement A): 279-291.

Hickley, P. & Starkie, A., 1985. Cost effective sampling of fish populations in large water bodies. J. Fish Biol. 27 (Supplement A): 151-161.

Hilborn, R., 1987. Living with uncertainty in resource management. North Am. J. Fish. Man. 7: 1-5.

Hilborn, R., Walters, C.J., Peterman, R.M. & Staley, M.J., 1984. Models and fisheries: a case study in implementation. North Am. J. Fish. Man. 4: 9-14.

Hoydal, K., 1985. ICES procedures in formulating management advice. In: FAO, Papers presented at the expert consultation of fishing effort (fishing mortality). Rome, 17-26 January 1983. FAO Fisheries Report no. 298. Supplement 3: 215-230.

Jacobson, P.C. & Taylor, W.W., 1985. Simulation of harvest strategies for a fluctuating population of lake whitefish. North Am. J. Fish. Man. 5: 537-546.

Johnson, B.L. & Stein, R.A., 1986. Competition for open-access resources: a class exercise that demonstrates the tragedy of the commons. Fisheries 11: 2-6.

Jordan, D.R. & Wortley, J.S., 1985. Sampling strategy related to fish distribution, with particular reference to the Norfolk Broads. J. Fish Biol. 27 (Supplement A): 163-173.

Klein, M., 1987. The significance of stocking measures for stabilising and increasing yields in coregonid fishery in Lake Starnberg. Finnish Fisheries Research (in press).

Leeuw, A.C.J. de, 1982. Organizations: management, analysis, design and change; a system concept. (Organisaties: management, analyse, ontwerp en verandering; een systeemvisie). Van Gorcum, Assen. 336 pp. (in Dutch).

Loftus, K.H., 1987. Inadequate science transfer: an issue basic to effective fisheries management. Trans. Am. Fish. Soc. 116: 314-319.

MacDonald, P.D.M., 1987. Analysis of length-frequency distributions. In: Summerfelt R.C. & Hall G.L. (Eds). Age and growth of fish. Iowa State University Press, Ames, Iowa. pp. 371-384.

Marshall, T.R., Ryder, R.A., Edwards, C.J. & Spangler, G.R., 1987. Using the lake trout as an indicator of ecosystem health - application of the dichotomous key. Great Lakes Fishery Commission. Technical Report No. 49. 35 pp.

Mills, E.L., Forney, J.L. & Wagner, K.J., 1987. Fish predation and its cascading effect on the Oneida Lake food chain. In: Kerfoot, W.C. & Sih, A. (Eds). Predation. Direct and indirect impact on aquatic communities. University Press of New England. Hannover, London. pp. 118-131.

Mills, E.L., Green, D.M. & Schiavone Jr., A., 1987. Use of zooplankton size to assess the community structure of fish populations in freshwater lakes. North Am. J. Fish. Man. 7: 369-378.

Milner, N.J., Hemsworth, R.J. & Jones, B.E., 1985. Habitat evaluation as a fisheries management tool. J. Fish Biol. 27 (Supplement A): 85-108.

Petr, T. (Ed.)., 1985. Inland fisheries in multi-purpose river basin planning and development in tropical Asian countries. Three case studies. FAO Fisheries Technical Paper No. 265. 166 pp.

Ribbink, A.J., 1987. African lakes and their fishes: conservation scenarios and suggestions. Env. Biol. Fish 19: 3-26.

Rothschild, B.J. & Heimbuch, D.G., 1983. Managing variable fishery stocks in an uncertain environment. The design of fishery management systems. In: Sharp, G.D. & Csirke, J. (Eds). Proceedings of the expert consultation to examine changes in abundance and species of neritic fish resources. FAO Fisheries Report 291, 3: 1141-1159.

Scavia, D., Fahnenstiel, G.L., Evans, M.S., Jude, D.J. & Lehman, J.T., 1986. Influence of salmonine predation and weather on long-term water quality trends in Lake Michigan. Can. J. Fish. Aquat. Sci. 43: 435-443.

Shapiro, J. & Wright, D.I., 1984. Lake restoration by biomanipulation - Round Lake, Minnesota. Freshw. Biol. 14: 371-383.

Sparre, P., 1987. Computer programs for fish stock assessment. Length-based fish stock assessment for Apple II computers. FAO Technical Paper No. 101, Supplement 2. 218 pp.

Stange, D., 1981. An open letter to anglers and fisheries professionals. North Am. J. Fish. Man. 1: 193-199.

Staub, E., Büttiker, B. & Krämer, A., 1987. Grundlagen für Modellsimulationen zur Bewirtschaftung des Barsches (*Perca fluviatilis* L.) im Bodensee. Bundesamt für Umweltschutz, Bern. Schriftenreihe Fischerei. Nr. 46. 40 pp.

Talhelm, D.R. & Libby, L.W., 1987. In search of a total value assessment framework: SAFR symposium overview and synthesis. Trans. Am. Fish. Soc. 116: 293-301.

Tiews, K., 1975. Review. Sampling larval and juvenile fish. In: Welcomme R.L. (Ed.). Symposium on the methodology for the survey, monitoring and appraisal of fishery resources in lakes and large rivers. EIFAC Technical Paper 23: 534-537.

Walters, C., 1986. Adaptive management of renewable resources. Macmillan Publishing Company, New York. 374 pp.

Welcomme, R.L. (Ed.), 1975. Symposium on the methodology for the survey, monitoring and appraisal of fishery resources in lakes and large rivers. EIFAC Technical Paper 23, Supplement 1. 747 pp.

Welcomme, R.L. & Henderson, H.F., 1976. Aspects of the management of inland waters for fisheries. FAO Fisheries Technical Paper no. 161. 36 pp.

Werner, E.E., Mittelbach, G.G., Hall, D.J. & Gilliam, J.F., 1983. Experimental tests of optimal habitat use in fish: the role of relative habitat profitability. Ecology 64: 1525-1539.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 313-327

Management of the fish stocks in Lake IJssel, The Netherlands

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Abstract

The development of the commercial fishery of Lake IJssel, a 184 000 ha eutrophic freshwater lake, over the period 1947-1987 has been described. Although by sanitation the number of fishing companies decreased from 906 in 1947 to 100 in 1987, the total effort increased and caused the present over-exploitation of the stocks of eel and pikeperch, caught mainly with fyke nets and gill-nets respectively. Because of this over-exploitation the fishermen have expanded the marginal fisheries on cyprinids, and on spawning smelt. Different management measures were taken, and active gear like two-boat seines and bottom trawls were banned. The total amount of fishing gear was not limited until the total fyke net effort was limited in 1986. The system of data gathering on the fish stocks and the fishery is described, together with the calculation of the research efforts. The absence of a registration system for the fishing effort per company, and for the spatial distribution of the fishing effort, together with the consequential absence of an annual evaluation of the catch per unit effort by the fishermen themselves, hampered the fisheries management process. An effort registration system will be implemented in the near future.

1. Introduction

Following the construction of Lake IJssel in 1932 by damming a brackish water sea bay (Zuiderzee), the ecosystem took some 5 years to stabilize (Havinga 1945). After the Second World War the character of the fishery there changed because of the trade-off between active and passive fishing. At the moment there are about 100 fishing companies, employing some 300 people in the fleet. In addition, about 600 people are employed in associated industries (product processing, making and repairing nets, boat construction etc.). Apparently the management measures taken were not strict enough to avoid over-exploitation of the stocks of eel *(Anguilla anguilla)* and pikeperch *(Stizostedion lucioperca)* with fyke and gill-nets. The management aim of the organizations of commercial fishermen, for the fish stocks in the 184 000 ha Lake IJssel, is a yield which guarantees the viability of the present 100 companies. This aim is not translated into quantified objectives like required yield in terms of weight, or desirable spawning stock biomass and population structure.

In this contribution the development of the fishery is described on the basis of the yield, the fishing gear and the management implemented. Further, the present efforts for monitoring the fishery and the fish stocks are sketched. An method of organizing the management process, using both long- and short-term evaluation of the fishery by the fishermen themselves, is presented as a possible way to prevent the uncontrolled increases in fishing effort which now occur periodically.

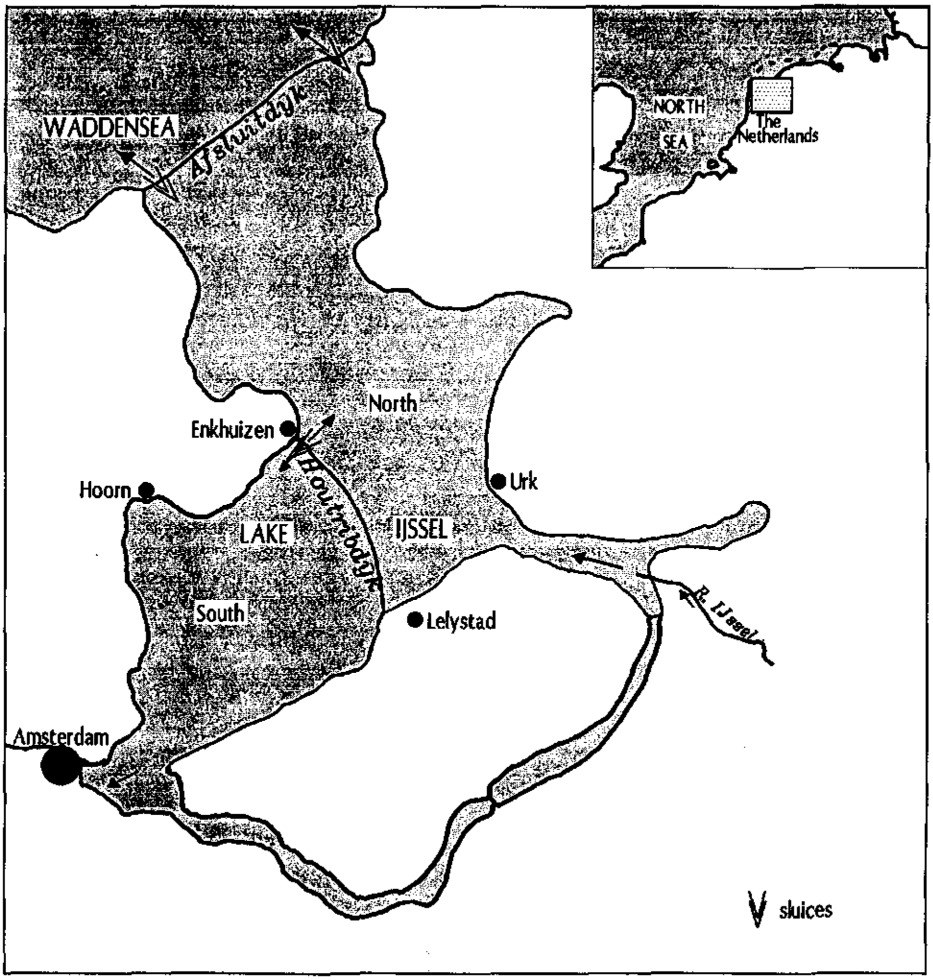
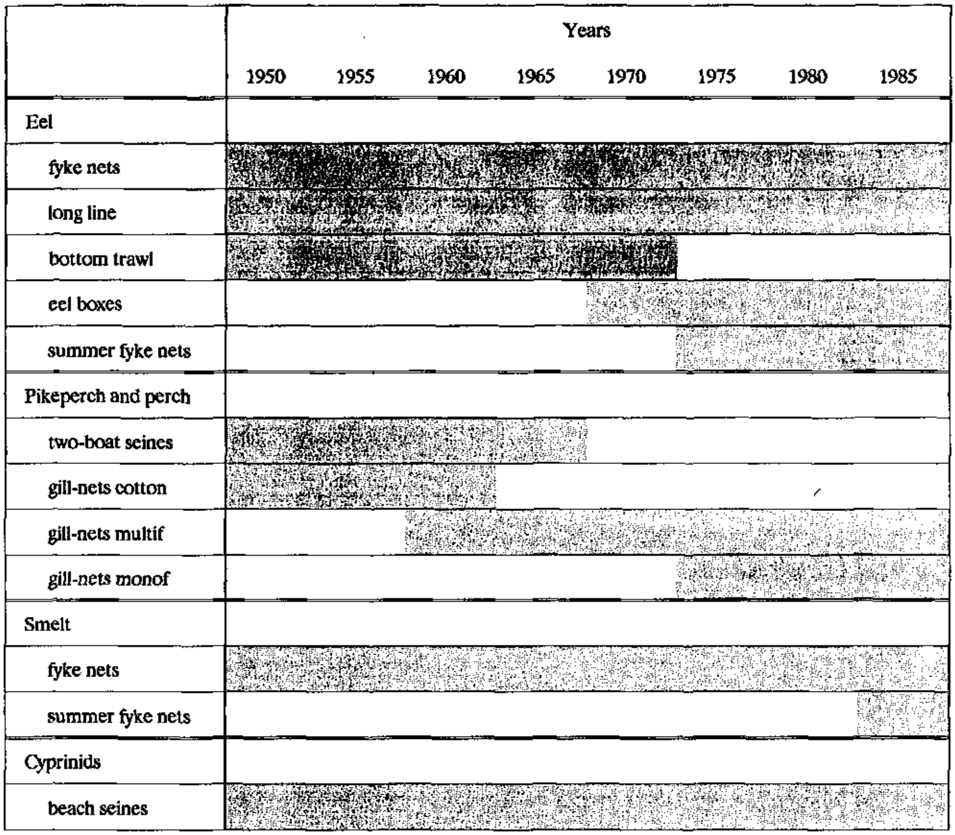


Figure 1. Lake IJssel and its geographical position. The dam dividing the lake into northern and southern parts was constructed in 1975. Since its construction the surface of the lake has been diminished by successive impoundments (1942, 1957, 1968) to 55% of its initial surface area. Arrows = direction of flow.

Table 1. The use of the different types of fishing gear in the Lake IJssel fishery from 1947 onward.



2. Lake IJssel

The mean depth of Lake IJssel, which is eutrophic, is 4.3 m, with some gullies in the middle up to 8 m deep *(Figure 1)*. These gullies were formed by tidal movements in the old Zuiderzee and are now partly filled with fine-grained sediments. The shallowness of the lake and the flatness of the bottom gives potential for the use of boat seines, bottom trawls, (bottom) gill-nets and summer (open water) fyke nets.

The main water supply of Lake IJssel is from the River Rhine (70%), which drains into the lake via the River IJssel. The chloride content of the lake is about 200 mg/l. The main drainage occurs during low tide in the Waddensea via the sluices in the closure dam in the north. The mean retention time of the water in the lake is about 6 months in the northern part and about 12 months in the southern part.

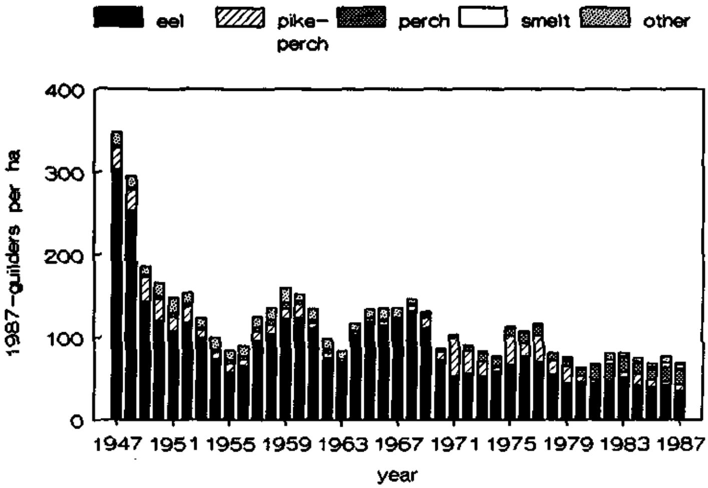


Figure 2. The landings of eel, pikeperch, perch, smelt and other categories from Lake IJssel in terms of their value in Dutch guilders per hectare (1987 prices) in the period 1947-1986.

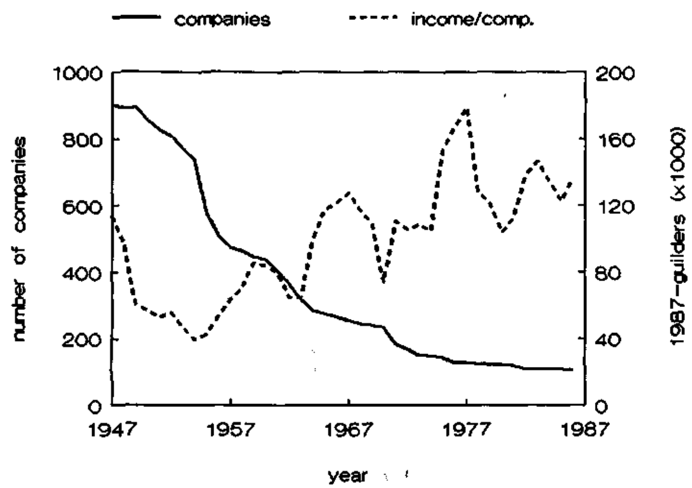


Figure 3. The number of fishing companies and the mean value (1987 prices) of the yield per fishing company from Lake IJssel in the period 1947-1986.

Good estimates of the biological productivity of the lake do not exist. Total P is about 270μg/l in the northern and 130μg/l in the southern parts of the lake. Chlorophyll content is about 70 and 45 μg/l respectively. Eutrophication has caused the dominance of Cyanophyceae *(Aphanizomenon flos-aquae, Microcystis aeruginosa)* in the northern part of the lake. In the southern part green algae *(Scenedesmus* sp.*)* and diatoms are dominant in spring and Cyanophyceae *(M. aeruginosa)* in summer. The main zooplankters are *Daphnia hyalina*, cyclopoid copepods, *Bosmina coregoni, B. longirostris* and *Chydorus sphaericus*, a similar spectrum to that found in other eutrophic lakes in The Netherlands.

The macrofauna comprises *Neomysis integer* (Mysidacea), *Gammarus tigrinus* (Amphipoda) and *Asellus aquaticus* (Isopoda), which are important food items for eel, perch *(Perca fluviatilis)* and ruffe *(Gymnocephalus cernua)*. The bottom fauna is represented by chironomid larvae, Tubificidae and molluscs *(Dreissena polymorpha)* and is important for eel, ruffe, bream *(Abramis brama)* and roach *(Rutilus rutilus)*.

The major fish species present are eel, the percids pikeperch, perch and ruffe, the cyprinids bream and roach, flounder *(Platichthys flesus)* and smelt *(Osmerus eperlanus)*. Recently, increasing but small numbers of sea trout were observed. The population dynamics of pikeperch and perch and the impact of the fishery is described by Willemsen (1977, 1983). The present status of the eel fishery is analysed by Dekker (1987).

3. Description of the fishery

3.1 Landings

Eel has always made the major contribution to the earnings of the fishery, followed by pikeperch and perch *(Figure 2)*. Apart from these species, some income has been derived from the by-catches of the bottom trawl eel fishery, which consist mainly of smelt, ruffe and juveniles of various other species. Recently additional income has also arisen from the by-catches of the fyke net fishery for spawning smelt. However, the total income of the fishery has decreased and this is to be attributed to a decline in total landings, because the price per unit weight of eel, pikeperch and perch showed no decreasing trend throughout the period 1947-1987. Because of the decrease in the number of fishing companies the income per company increased *(Figure 3)*.

The landings, assessed by weight, show the unreliability of the catches of pikeperch, which reflect the combined effects of year-class variation and intensive exploitation by the fishery *(Figure 4)*.

The present seasonal character of the fishery is exemplified by a monthly mean over a five year period (1982-1986) *(Figure 5)*. At the end of the summer, fishermen switch from fyke net fishing for eel, to gill-net fishing for pikeperch and perch. There is no closed season for eel. The closed season for the gill-net fishery is from mid-March to 1st July. The winter gill-net fishery can be interrupted by ice cover.

3.2 Development of the fishery

Traditional methods for catching eel used to employ fyke nets in the littoral zone, baited long lines and bottom trawls *(Table 1)*. Some of these methods were very similar to those used in the old Zuiderzee. The effort in the long line fishery decreased with a decrease

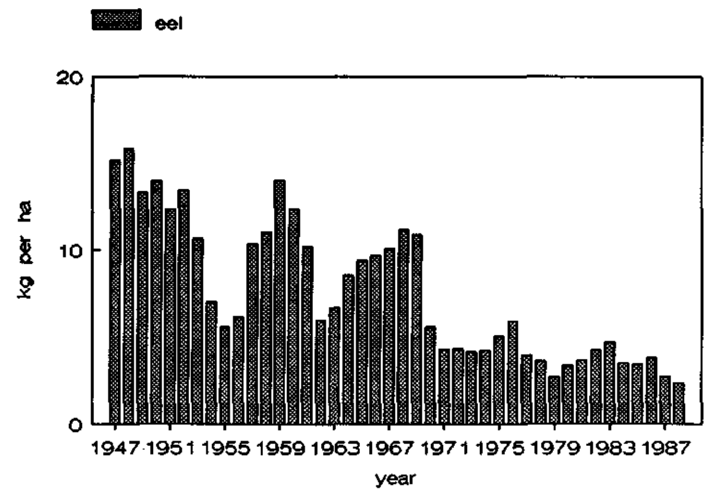


Figure 4a. Landings (kg/ha) of eel from Lake IJssel in the period 1947-1988.

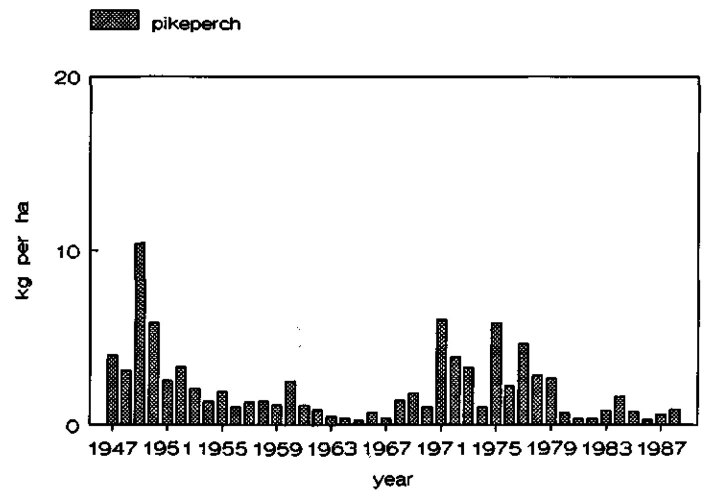


Figure 4b. Landings (kg/ha) of pikeperch from Lake IJssel in the period 1947-1988.

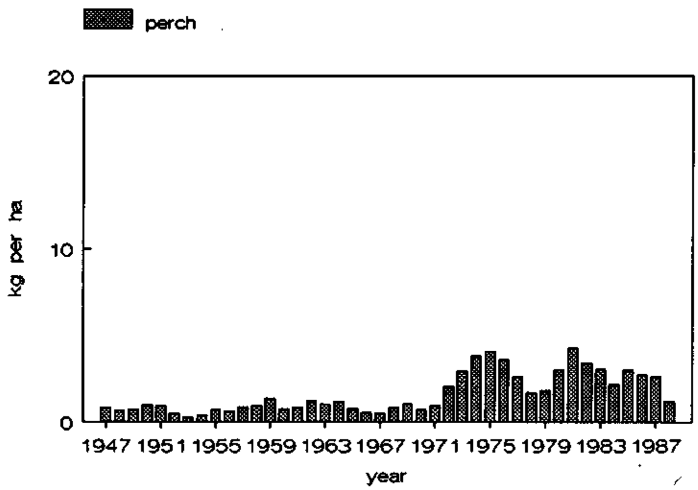


Figure 4c. Landings (kg/ha) of perch from Lake IJssel in the period 1947-1988.

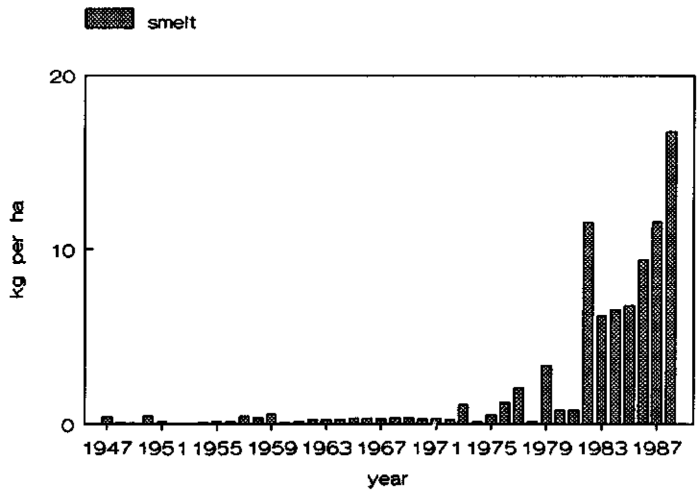


Figure 4d. Landings (kg/ha) of smelt from Lake IJssel in the period 1947-1988.

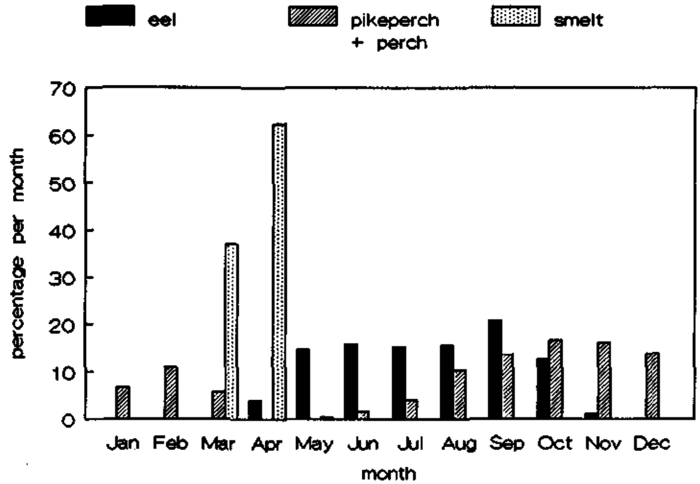


Figure 5. Seasonal pattern of the fishery. Landings per category and per month are a mean for the years 1982-1986.

in the stock of large eels, which was due to intensive bottom trawling and fyke net fishing. Bottom trawling was especially practised in the gullies. Trawling used to be forbidden from Saturday until Monday (16:00 hours), but it was completely banned in 1970 because it took too many juvenile pikeperch and perch in the by-catch. The by-catch had comprised mainly little smelt and ruffe and had been landed as 'industrial fish'.

As the ban on trawling was anticipated by the fishermen, they had already started to use eel boxes in 1967. Eel boxes are a kind of wooden eel pot (Deelder 1971). As with long lines, when baited with smelt, they catch larger and less fatty eel than the better quality eel caught with bottom trawls and fyke nets. Fatty eel can be smoked and the price of smoked eel is twice as high as that of fresh eel. In 1971 the fishermen start setting fyke nets at the edges of sand banks in the open water zone, whereas in 1973 they started to use the smaller summer fyke nets in the open water (Oudelaar 1983). These nets are linked to each other and can be set and anchored as quickly as a gill-net. Their total number has increased tremendously, to 30 000 in 1987. Some fishermen have broadened the base width of these summer fyke nets from 1.4 to 2.0 m. Since 1st June 1987 the maximum width allowed is 1.5 m and the maximum height 1.0 m.

The two-boat seine (length 160-200 m; depth 3 m; mesh size 92 mm) was a very efficient method for catching pikeperch and perch. It was banned in 1963 and the consequence of this was an increasing investment in gill-nets. These were cotton gill-nets until they were replaced by multifilament nylon gill-nets around 1960. At that time 92 mm stretched mesh was used. In 1967 and 1974 the minimum mesh size was enlarged to 96 and 101 mm respectively. After the ban on bottom trawling in 1970 the number of gill-nets in the fishery also increased. The first monofilament gill-nets appeared in 1975 and had substantially replaced multifilament nets by 1987. At present some 70 companies have around 100 gill-net units of 80-85 m length each, totalling nearly 600 km of gill-net.

The spring fyke net fishery for spawning smelt used to be directed to large specimens (over 10 cm) for human consumption, with smaller smelt being landed as industrial fish. However, from 1982, smaller smelt has also been landed for human consumption, since which time the fyke net effort has increased manyfold. The fyke nets used are open water summer fyke nets as well as the traditional littoral fyke nets.

Finally, beach seining is used to catch roach and bream to stock angling waters elsewhere.

4. Organization of the management process

The fishing rights for Lake IJssel are state-owned. Fishermen acquire a permit for fishing. The state has set corporate prescriptions concerning the use of different types of fishing gear, closed seasons, minimum mesh sizes and minimum sizes of fish which may be taken *(Table 2)*.

Table 2. General prescriptions for the commercial fishery in Lake IJssel in 1987.

Category	Specification
Effort limitation	47 500 fyke net units (since 1986) (= 30 000 summer (open water) fyke nets (=1 unit) and 3 500 normal fyke nets (=5 units) in 1986 maximum base width of summer fyke nets 1.5 m; maximum height 1.0 m (since 1987)
Closed periods	closed season for fishing pikeperch and perch 15 March - 1 July no gill-net fishing between Saturday 16.00 hours and Monday 08.00 hours (since 1979)
Minimum mesh size	fyke nets 20 mm stretched mesh or rings of 13 mm inner diameter in the rear end (since 1985) gill- nets 101 mm stretched mesh since 1974

The fisheries management is executed by the state. A distinct management board with full responsibility for fisheries management of the lake has never existed. The government merely installed advisory committees (1955-1956; 1964-1966; 1974-1984) or these were set up by the initiative of the organization of commercial fishermen (from 1987 onwards). In these committees the interests of commercial and sport fishermen, as well as fishery biologists and economists of governmental bodies, are represented. Management recommendations drawn up by these committees are channelled directly, or via the master organization of commercial fishermen (since 1987), to the Ministry of Agriculture and Fisheries for eventual implementation. In general the Ministry awaits a committee recommendation before a management measure is implemented. Nevertheless, a direct political route was followed for the ban on bottom trawling in 1970. This decision was made by the national parliament and implemented directly.

Table 3. The monitoring system for the fish stocks and the fishery in Lake IJssel. Consultations, planning, preparations etc. excluded.

Type of monitoring	Method	Time & labour required	Time taken - man hours		
1. Eel					
1.1 Immigration of glass eel	Regular samples in dam inlet in the period Feb-June	100 nights — 1 person, 8 hours per night	800	800	
1.2 Size and sex composition of eel stocks in the lake	Trawling with a 1 mm trawl in the period April-Nov on 10 sites	100 trawl hours in 4 weeks — 5 persons	800	860	
		Data processing	60		
1.3 Density and biomass of bottom fauna	Bottom samples at 30 sites, 3samples per site, mixed for 1 sample	Twice a year (combined with 1.2) extra effort: 4 persons, 0.5 week	160		2 440
		Processing of samples — 3 per day — 1 person	160	380	
		Data processing	60		
1.4 Size and sex composition	Market sampling, 10 samples of 100 eels	Collecting, processing, otolith storage	120	400	
		Data processing (age reading)	280		
2. Other species					
2.1 Larval density	40 hauls with larvae nets perpendicular to the shore	2 weeks — 5 persons	400		
		Determination — 1 person — 3 months	480	940	
		Data processing	60		
2.2 Indexing YCS and growth of 0-group perch and pikeperch	YFS with a 20 mm trawl at 2 sites in a selected area in October	2 weeks — 6 persons	480	520	
		Data processing	40		
2.3 Abundance and size structure of fish of all age groups except eel	25 trawl hauls with 20 mm trawl at 15 sites over all of the lake in October	2 weeks — 6 persons	480		2 370 (without larvae programme and recent expansion of 2.4:1430)
		Scale reading cyprinids 4 weeks — 1 person	160	720	
		Data processing — 2 weeks — 1 person	80		
2.4 Size and age structure of the catch of perch and pikeperch **	Sampling pikeperch and perch landed 10 times per fishing season July-March for measuring and taking scales	2 persons — 4 hours per sampling	80		
		Age reading from scales (n=700), 1 person — 80 scales per day	70	190	
		Data processing including back-calculations	40		

** Recently this category has been expanded to include assessment of length, weight, sex and stage of maturity. Fish are bought at auction for this. Time required 2 persons - 2 days per month = 256 man hours.

5. Data from the fishery and the fish stocks

5.1 Catch and effort data

Following a European Community agreement in June 1975 the fishermen were no longer obliged to auction their fish. The landing statistics available are thought to cover at least 90% of the fish caught, with the *proviso* that for 1975 and 1976 alone, they may not account for more than 60% of eel landings.

At the moment the fishing effort is only known officially in terms of the number of fishing companies and the number of fyke nets used. The number of normal (large) fyke nets is limited by the sites available. The total number of fyke nets was fixed at 3500 in 1986 but their exact increase with time is not known. All fyke nets are now registered using tags supplied by the government *(Table 2)*.

There is no registration of the number of gill-nets in use, neither on the ratio of multi- to monofilament nets. The efficiency of gill-netting increased after 1983-1984, because of the use of electronic fish-finders.

5.2 Monitoring

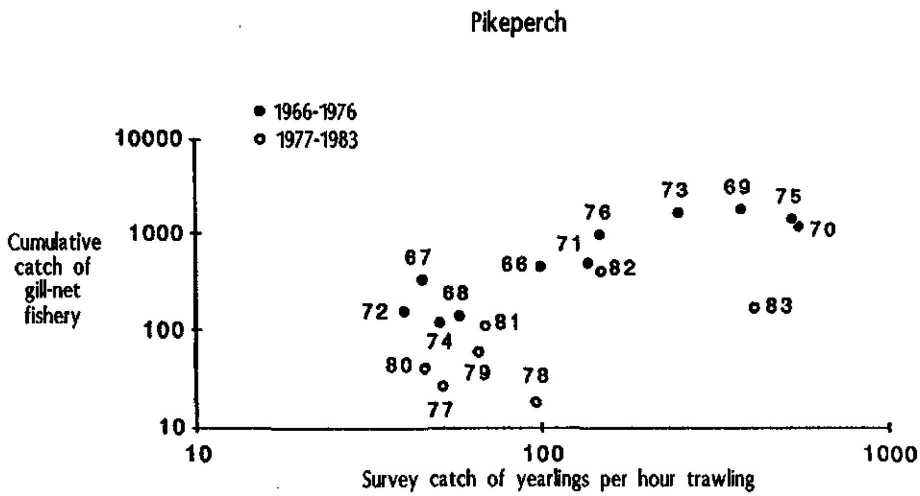
Monitoring the fish stocks, and the composition of the catches of eel, pikeperch and perch now takes about 4700 man-hours/yr or 2 man-years each year *(Table 3)*. Eel monitoring costs the most. Larval surveys for pikeperch and perch took about 1400 man hours (0.7 man/yr) but provided a poor basis for predicting the year-class strength (YCS) of the fish at the time they recruited to the gill-net fishery. By contrast, the autumn young fish surveys (YFS) for 0-group pikeperch and perch (when the fish are about 7 months old) are a good basis for predicting this, and the larval surveys were discontinued as soon as this was appreciated (Willemsen 1977) *(Figure 6)*. Trawl surveys were set up in the 1960s.

5.3 Specific research

In Lake IJssel most specific research deals with standardization of sampling methods, assessing efficiency and selectivity of commercial fishing gear, and the development of alternative commercial fishing gear. Experimental fishing with gill-nets of different mesh sizes (Oudelaar 1976) and different materials (multifilament and monofilament) (Schaap 1987) has been carried out. At the moment specific research is directed towards assessing the impact of summer fyke nets on the survival of 0- and 1-group pikeperch and perch. The extra mortality these nets cause, in the period before recruitment to the gill-net fishery, diminishes the accuracy of the prediction of the year-class strength in gill-net catches made from the autumn survey of 0-group fish. Research has also been carried to see if a beam trawl with an electric field could be selective for eel.

For a more rational exploitation of the eel stocks in the lake, the minimum mesh size of the fyke nets was increased from 18 to 20 mm in 1985. Alternatively, fishermen were allowed to install 2-4 metal rings with inner diameters of 13 mm in the rear-end of the 18 mm netting.

Mortality of juvenile pikeperch and perch caught with fyke nets is very high, up to about 50% of a year-class being taken (Willemsen 1985). Special experiments have been



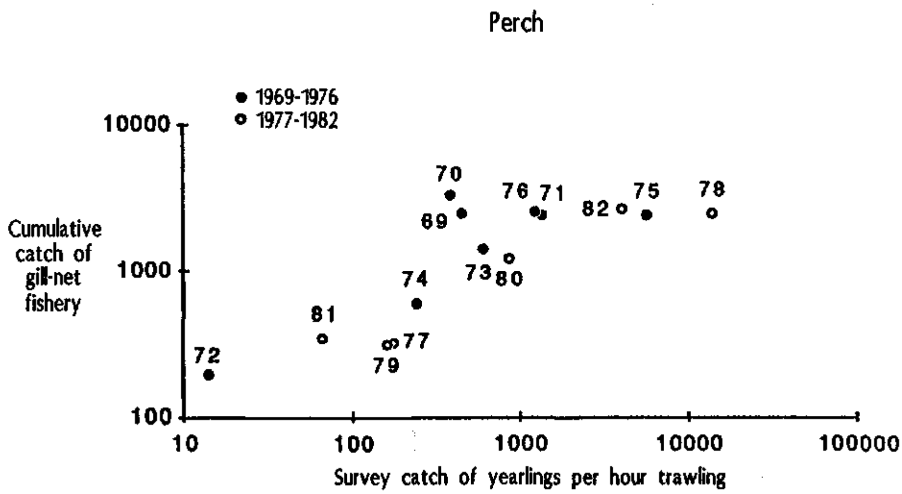


Figure 6. Correlation of survey and commercial catches of pikeperch and perch. Plots show relationship between year-class strength (YCS) as deduced from catches of 0-group fish (yearlings) per hour of trawling during the young fish survey (YFS) in autumn and the cumulative yield in numbers of the same year-class in the gill-net fishery.

carried out to avoid this by-catch. The different forms of net-like barriers in the front hoop of the fykes have been tested to prevent small fish from being caught. These constructions had an unacceptably negative effect on eel catches.

A system for monitoring fishing effort is now on its way. Its development and implementation will cost around 1 man year in time, and it is regarded here as specific research. Every fishing company will be monitored annually with regard to number, type and size of fishing gear used. The information will be collected from the fishermen by inquiries. Once set up at 5 harbours the monitoring programme will entail a time investment of about 180 man-hours/yr (10 evenings of 6 hours by each of 3 persons). Computer input and data processing will cost an extra 60 man-hours.

6. Management

Management goals, as for example, for specific yields, have never been set. The organizations of commercial fishermen still stress the importance of a viable fishery in which the present number of fishing companies (100 in 1987) can survive. The rationalisation of 1932-1976, when the number of companies was reduced from 1600 to 129 was stimulated by state subsidies for fishermen who by their own initiative left the fishery.

The most important management measures taken so far are:

- The ban on two-boat seining for pikeperch and perch (1963).
- The ban on bottom trawling for eel (1970).
- The gradual increase of the minimum mesh size for gill-nets from 92 to 96 to 101 mm stretched mesh.
- The limit on the total number of fyke net units (1986).

Both the ban on trawling and the limit on fyke nets were based principally on the undesirable by-catches of young pikeperch and other species that they made. Remarkably, the effect of these practices on the over-exploited eel stock was only of secondary interest. The decrease in the catches of larger eels made with long lines and eel boxes provided sufficient evidence to warrant limiting the number of summer fyke nets somewhat earlier *(Figure 7)*.

As the ban on bottom trawling (1970) was imposed rather suddenly, there was a strong drive in subsequent years to compensate for what was regarded as a loss of high quality, fatty 'trawl eel'. This also affected the fishery for pikeperch and perch. Here the increase in fishing effort was a combination of more gill-nets, and in the last decade, more monofilament gill-nets. These latter are about twice as efficient as multifilament nets.

The fishery has dwindled as a result of the almost unlimited increase in passive fishing gear per fishing company. At the moment pikeperch is not only severely over-exploited by the gill-net fishery, but its survival in the younger stages might be seriously diminished by the fyke net fishery for eel, which species is also severely over-exploited. It is, however, difficult to estimate the extent to which the fyke net fishery influences the survival of pikeperch. More research on this is required, but it is already clear that the more recent pikeperch year-classes, which were abundant as 0-group fish, did not provide the high recruitment to the gill-net fishery expected *(Figure 6)*. Young perch may have a higher survival rate than pikeperch after being caught in the fyke nets *(Figure 6)*.

The Lake IJssel fishermen are now looking for types of 'escape fisheries'. They want permission to motorize their beach seines for catching bream and roach. They also install

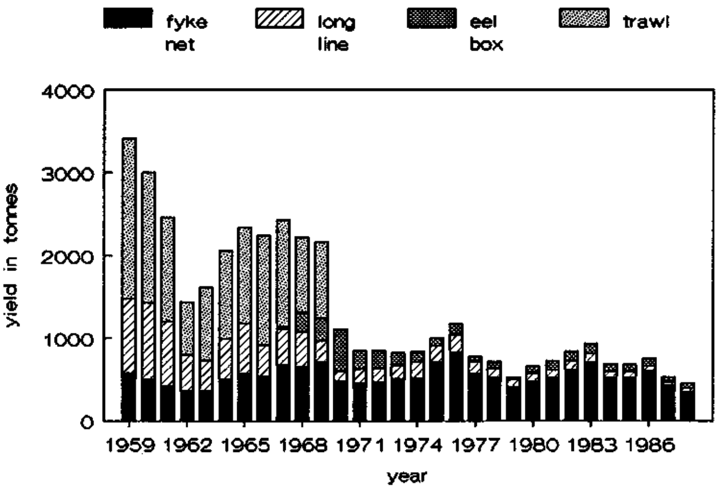


Figure 7. Total landings (tonnes) of eel caught with different types of fishing gear (bottom-trawl, fyke net, long line, eel box) in Lake IJssel in the period 1959-1988.

increasing numbers of fyke nets at the edges of the lake in March when smelt has its spawning run. Specific research has to be directed to the possible adverse effects of this fishery on the stocks of smelt in the lake.

The state could not have foreseen that it had to play an even more active role in the management of the fishery than it already did by rationalisation, bans on fishing gear, and setting minimum mesh sizes for particular types of gear. More specifically, a more endurable long-term type of organization of the fisheries management of Lake IJssel has to be pursued. An important aspect of the management process will be the short-term (annual) evaluation of the state of the fishery by the fishermen themselves. A pre-requisite for this is the dynamic description of the fishery in terms of yield, effort and spatial distribution of the effort, made possible by the registration system for catch and effort data which is to be implemented in the near future.

Once the registration system is implemented, it will require a relatively few man-hours/yr to keep the system working. In the past the fishermen were unwilling to co-operate in setting up the registration system. Maybe the fisheries biologists were not firm enough and did not stress that the evaluation of the fishery was necessary and was seriously hampered by lack of data on the fishing effort. They might not have anticipated the strong warning signal issued by the fishermen themselves in their own short and long-term evaluations of the progress of the CPUE index of the Lake IJssel fisheries.

The implementation of the registration scheme for fishing effort must not endanger the existing core of the monitoring programme, but should run in parallel with it. The monitoring programmes used since the sixties has revealed, among other things, a valuable time series of data on variations in the growth and recruitment of the 0-groups of pikeperch and perch. The variations revealed will be used to help devise future management strategies for perch and pikeperch.

Acknowledgment

Rijkswaterstaat Dienst Binnenwateren supplied the data on the present water quality of Lake IJssel.

References

Deelder, C.L., 1971. A new eel trap, developed in the Netherlands. In: McGrath, C.J. (Ed.). EIFAC consultation on eel fishing gear and techniques. EIFAC Technical Paper. 14: 97-99.

Dekker, W., 1987. De rode-aal-stand van het IJsselmeer (The stock of yellow eel in Lake IJssel). Visserij. 40: 97-102..

Havinga, B., 1945. Rapport betreffende de visscherij en den visstand op het IJsselmeer (Report on the fisheries and fish stocks of Lake IJssel). Generale Commissie Zuiderzeesteunwet. Amsterdam. 114 pp.

Oudelaar, H.G.J., 1976. Resultaten proefvisserijen met staande netten in 1975 (Results of trial fisheries with gill-nets in 1975). Visserij. 29: 173-179.

Oudelaar, H.G.J., 1983. De IJsselmeervisserij (The Lake IJssel Fishery). Visserij. 36: 125-129.

Schaap, L.A., 1987. Vergelijking van de vangsten in mono- en multifilament staande netten in het IJsselmeer (Comparison of catches with mono- and multifilament gill-nets in Lake IJssel). Netherlands Institute for fishery Investigations. IJmuiden. Report BV 87-03. 12 pp.

Willemsen, J., 1977. Population dynamics of percids in Lake IJssel and some smaller lakes in the Netherlands. J. Fish. Res. Bd Can. 34: 1710-1719.

Willemsen, J., 1983. Biology and management of pikeperch. Proc. 3rd Brit. Freshw. Fish. Conf. 1983: pp. 115-125.

Willemsen, J. 1985. De invloed van de visserij met fuiken op de snoekbaars- en baarstand in het IJsselmeer (The impact of fyke net fishery on the stocks of pikeperch and perch in Lake IJssel). Netherlands Institute for Fishery Investigations. IJmuiden. Report BV 85-02. 10 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 328-343.

The role of fish stock management in the control of eutrophication in shallow lakes in The Netherlands

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Abstract

Eutrophication of Dutch shallow lakes (1-3 m deep) has led to a dramatic change in the structure and functioning of the food web. Over the last twenty-five years littoral vegetation has almost disappeared from Dutch shallow lakes as a consequence of eutrophication. Simultaneously the habitat of the important predator fish pike has disappeared. As a result, bream has reached very high biomasses in most shallow lakes. In controlling eutrophication the national policy is aiming at reduction of nutrient loading of lakes. It seems, however, that a wider variety of measures is needed to speed lake recovery. Fish stock management can be of importance in such an integrated approach. Bream may negatively influence the recovery process as a result of its feeding strategy. In the presence of an abundant planktivorous and benthivorous bream stock, zooplankton grazing of algae is low, and the water may become very turbid. This situation may slow down lake recovery even if the external nutrient loading has been severely reduced. Regulation of the bream population may therefore contribute to solving eutrophication problems by lowering the internal resistance of the ecosystem against changes. Biomanipulation experiments have started recently in small lakes in the Netherlands. The experiments are primarily directed at reducing the bream population by fisheries, and introducing predatory fish. Fish stock management in combination with nutrient reduction may thus help in solving the eutrophication problem by initiating a positive feed back process in the food web that may convert ecosystem structure into a socially desirable, *i.e.*, a stable and highly diverse ecosystem.

1. Introduction

Living in the Netherlands one always has water nearby. Ponds, canals, ditches, lakes, streams and rivers are plentiful and cover a surface area which amounts to about 3500 km^2. These aquatic ecosystems are being used for fishery, recreational boating, swimming, boat traffic, industrial use, drinking water supply and agricultural purposes. Each of these functions makes its own specific demands. These demands can not always be complementary. Industrial discharges and drinking water supply obviously won't go together. Water quality management in the Netherlands focuses on the protection of specific functions of surface waters as mentioned above, but also directly on the protection and development of ecosystems. This latter objective has much in common with the general objectives of fish stock management. Water quality management and fish stock management thus share a common interest. In spite of this there is in the Netherlands a situation in which responsibilities for fish stock management and water quality management are separated by law. In this paper attention is paid to fish stock management as a tool in eutrophication control. Results of recent biomanipulation experiments (regulating fisheries) in eutrophic lakes are given. The results show that this type of lake restoration may speed up recovery processes. This integrated approach of lake restoration may turn out profitable both to managers of fish stocks and water quality, and thus emphasises the need for a dialogue between all parties involved.

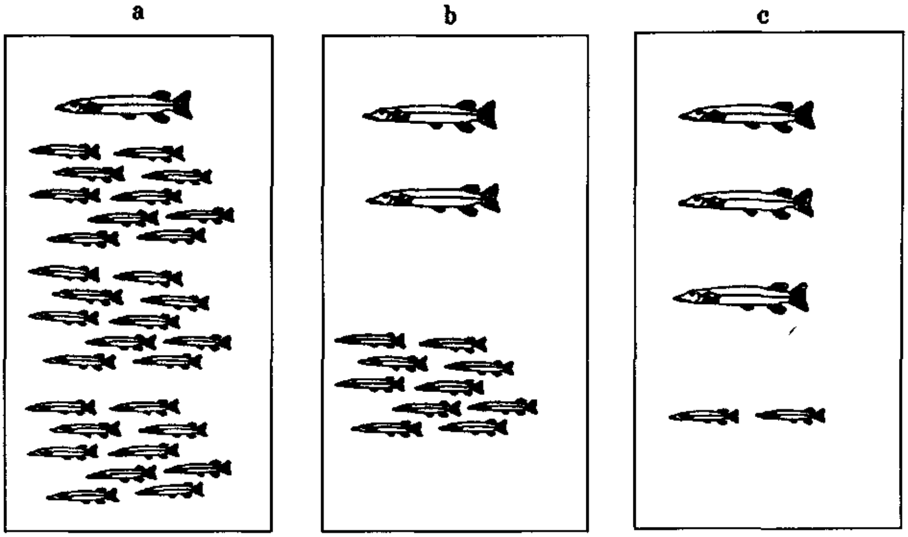

Figure 1. The structure of pike populations in situations where there are decreasing amounts of vegetation. Small pike (<45 cm) protect themselves from cannibalism by hiding among plants. In passing from situation a to situation c, plant growth decreases because of eutrophication, and the structure of the pike population becomes unbalanced (Source: Organisation for the Improvement of Inland Fisheries).

2. Consequences of eutrophication

Eutrophication is a serious problem in Dutch shallow (1-3 m depth) lakes. It has led to a dramatic change in the structure and functioning of the aquatic food chain. In general the eutrophication process can be described as follows. Eutrophication starts with an increase in nutrient load. The water remains clear as the extra nutrients are processed by the abundant littoral vegetation and the lake sediment (ecosystem resistance).

Continuous nutrient loading, however, leads to a prolific growth of filamentous algae upon the higher plants. This results in the disappearance of macrophytes due to a lack of light for growth. This disappearance has drastic consequences for the ecosystem (Van Vierssen, Hootsmans & Vermaat 1985, Carpenter, Stephen & Lodge 1986, Grimm

1985). The most characteristic change is a sharp increase in the abundance of planktonic algae. Persistent nutrient loading eventually leads to permanent bloom of cyanobacteria, which results in a highly stable ecosystem of poor quality.

Over the last twenty-five years, littoral vegetation has almost disappeared from Dutch shallow lakes as a consequence of eutrophication. With the disappearance of submerged vegetation the habitat of the northern pike *(Esox lucius)* was destroyed. The survival of this species has been found to be strongly dependent on the availability of hiding places, which in general are plants or plant remains (Grimm 1981, 1983). Pike hatchlings are attached to plants in the first days of their lives. Pike seek shelter between submerged plants to protect themselves from cannibalism, or to hide themselves when hunting. The relation between hiding places and the structure of a pike population is illustrated in *Figure 1*. In water rich in macrophytes the survival of young pike is relatively high and their large numbers can effectively regulate young bream *(Abramis brama)*. It will be clear that the disappearance of littoral vegetation is an important cause of the decline in numbers of pike, and an increase in those of bream in shallow waters. Bream have found exceptionally good conditions in the algae rich open waters, since these provide an abundant food supply (zooplankton and midge larvae) and greatly reduce the risk of predation. Almost all Dutch shallow lakes are now bream infested (Lammens 1986, van Densen 1985, van Densen, Dijkers & Veerman 1986) with dense populations having biomasses of several hundred kg/ha (Cazemier 1982). This enormous bream stock enhances the algal biomass by reducing the zooplankton density (lowered grazing pressure) and by renewing the supply of nutrients from the lake sediments (bioturbation). Thus, the process of eutrophication has led to a situation in which most Dutch shallow lakes have a life community dominated by algae and bream.

3. Current strategy of eutrophication control

Eutrophication control in the Netherlands aims at reducing the phosphorus load from the environment. Measures are being taken to reduce the phosphorus contents of detergents, to remove phosphate from the effluents of sewage treatment stations, and to lower industrial discharges and the release of phosphorus from agricultural areas. Lowering phosphorus loading should solve the problem of algal blooms by lowering lake productivity. Despite major efforts over the past few years, hardly any recovery can be seen at all. We think that biological feedback mechanisms underlie this lack of recovery. In the process of eutrophication, a critical threshold in nutrient concentrations has to be exceeded before any biological response by the system may be seen *(Figure 2)*. In the same way it might be expected that in lake restoration programmes, nutrient concentrations have to be reduced to a certain threshold value before a response can be expected. In fact, two levels have to be passed before changes can take place. As a first step it is necessary to remove the nutrient store in the lake to make phosphorus or nitrogen a limiting factor for algal growth. A positive biological response of the system may then follow directly, but usually a second step is needed because of the internal resistance of the ecosystem to changes. Large quantities of detritus have been formed on the bottoms of the shallow lakes from the abundant algae. Benthivorous fish, feeding on this, may then increase nutrient concentrations and turbidity, thus lowering the effectiveness of measures aimed at reducing nutrient loadings from external sources. Release of phosphorus from lake sediments is another factor which can frustrate lake recovery. High algal biomass can maintain a big flux of phosphorus from the lake sediment. In summer this internal flux may be as high as the external phosphorus loading of the lake (Boström, Jansson & Forsberg 1987). These feedback mechanisms oblige the water quality manager to put an extra effort into reducing the phosphorus load of the lake before the primary objective of the restoration programme, lowering the algal biomass, can be achieved. When this goal is reached problems still remain to be solved. Ecosystem quality stays rather poor as plant growth is impaired by large quantities of benthivorous bream which turn up plant roots (ten Winkel & Meulemans 1984). Large quantities of new born bream may decimate the zooplankton, thereby reducing the consumption of algae. As bream can live up to an age of 20 years the present heavy infestation of bream in the Dutch shallow lakes may continue to influence water quality for a long time. These biological mechanisms lead to the conclusion that solving the eutrophication problem simply by reducing the (external) phosphorus load will be successful in the long term, but a very time consuming method.

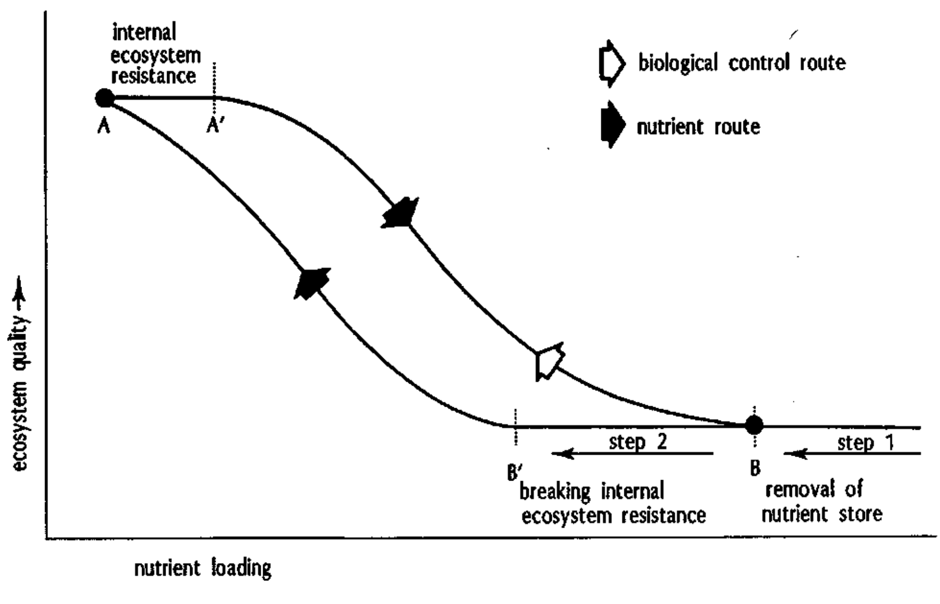

Figure 2. Diagram representing ecosystem quality in response to nutrient loading. Nutrient loading beyond optimal situation A leads to ecosystem decay (A' to B) after a period of internal ecosystem resistance. Beyond point B, ecosystem delay is limited by other factors (e.g. light). Lake restoration by nutrient reduction is a two-step process (dark upward arrow). Biological control methods may speed up lake recovery (light arrow) by altering threshold concentration B' into B (adapted from Hosper, Meijer & Jagtman 1987).

4. Objectives from the viewpoint of fish stock management

In the preceding paragraphs it was recognized that eutrophication leads to ecosystem decay. From the viewpoint of water quality management this is a problem because protection and development of the ecosystem is a general objective. Clearly, from the viewpoint of fish stock management, eutrophication is a problem too. Fish make demands on their environment. Their basic needs are good water quality, a sufficient supply of suitable food, an opportunity to find cover (vegetation), good spawning conditions and migration opportunities. Eutrophication interferes with many of these demands. Individual growth of cyprinids, for instance, is poor in most eutrophic lakes, as a consequence

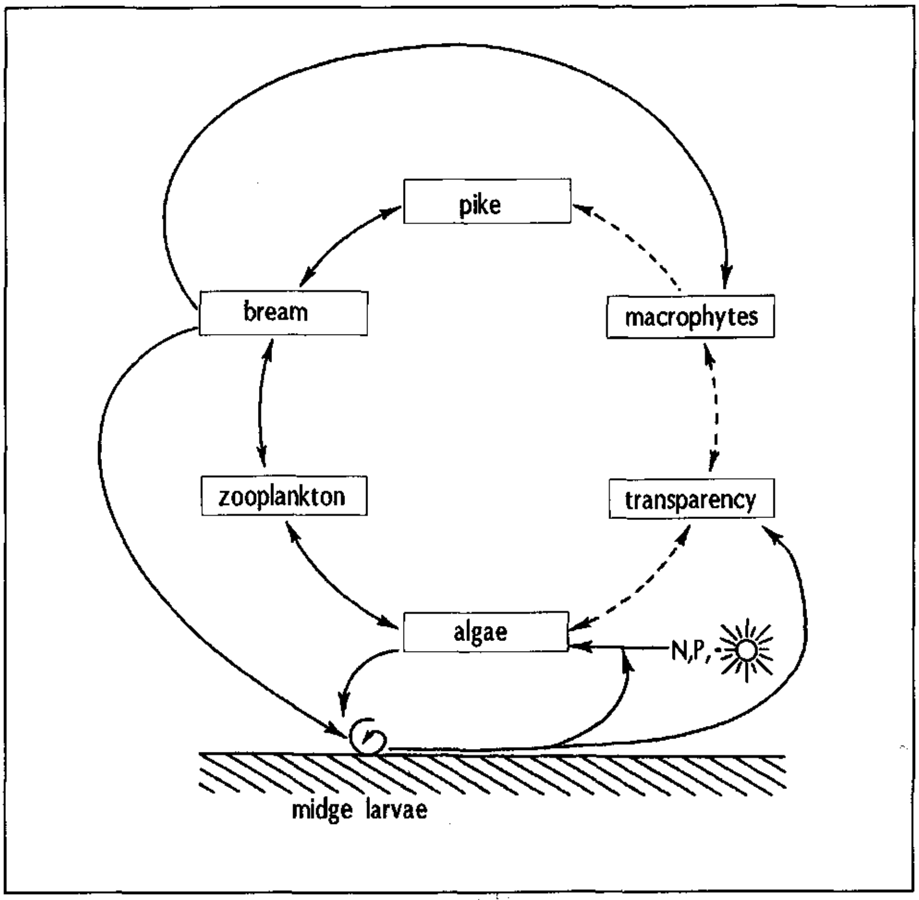

Figure 3. Principal food chain relations in a eutrophic lake. Algae and bream dominate, resulting in turbid water (negative spiral). Zooplankton, pike and macrophytes are few in number (from Hosper *et al.* 1987).

of the density of the stock present. Fishery organizations have determined this and seek remedial measures. The eutrophication of Dutch inland waters has to be reduced (Feith 1982, NVVS 1985). An overcrowded stock of cyprinids is recognized as an effect of eutrophication and although regulating fisheries are considered useful in reducing this stock, it is believed that these measures only take away the symptoms of eutrophication (NVVS 1985). Reduction of nutrient loading has to be the main objective. Without nutrient reduction the eutrophication problem will not be solved. It is important that fisheries regulation does more than 'just take away the symptoms of eutrophication'. By regulating the cyprinid stock in a eutrophic lake, conditions are set which favour a switch to a more diverse ecosystem. Considering the biological feedback mechanisms in an eutrophic lake, it might even be expected that the critical threshold concentration at which lake recovery sets in might be altered in a positive way. Objectives like species diversity, good growth of the fish stock, and the presence of pike and rudd *(Scardinius erythrophthalmus)* (NVVS 1985) thus come within reach. This is a strong argument for using biological measures in parallel with nutrient load reducing measures in eutrophication control.

5. Biological control in practice

How can we get from the situation of turbid, algal-rich, bream-infested water, to one of clear water, a rich littoral vegetation and a strong pike population? This question was raised when we started to think about the possibilities of biological control methods in water quality management. On the basis of preliminary research (Meijer *et al.* 1987), literature reviews (Richter 1985) and interviews with fish scientists, a theory was developed which proved helpful in choosing the key elements in the food chain at which to direct measures (Hosper, Meijer & Jagtman 1987). The principle food chain relations are depicted in *Figure 3* . Reducing the nutrient load is the primary objective to decrease the biomass of algae. When nutrient concentrations start to limit the growth of algae the importance of biological measures grows. Artificial reduction of the bream population may lead to an increase in the number of (large) zooplankton, which causes, through their grazing, a lower algal biomass. In turn this may lead to clearer water, chances for higher plants to grow, the return of pike, an increase in predation of bream and more zooplankton etc. A positive spiral may thus be set in motion. Less re-suspension of sediments as well as the reduced disturbance of rooted macrophytes also brings about positive feedback processes leading to the desired lake conditions.

Pikeperch *(Stizostedion lucioperca)* is known to be able to maintain itself in turbid algal-rich waters. This makes it a suitable predatory species for reducing the large numbers of cyprinids in eutrophic lakes. There is probably little point in releasing young pike in 'bare' waters, due to the strong intraspecific trait of cannibalism. Considering this, pikeperch seemed to be the most attractive species to experiment with. Following successful pond experiments in 1986 (Meijer *et al.* 1987), it was decided to start experiments under natural conditions in 1987. The results of two of these experiments are discussed in the following section.

Table 1. Data on fish removed from the Galgje compartment in the Bleiswijkse Zoom in April 1987 (from Meijer, Raat & Doef 1988).

Species	length (cm)	number	weight (kg)
Stizostedion lucioperca (pikeperch)	<12	200	0.4
	12-22	11	0.7
	22-37	205	55.3
	37-46	101	73.4
	>46	45	96.9
Subtotal:			226.7
Abramis brama (bream)	8-16	33 521	636.5
Blicca bjoerkna (silver bream)	16-24	398	41.3
	24-29	158	45.1
	29-34	219	110.8
	>34	455	353.8
Subtotal:			1 187.5
Cyprinus carpio (carp)		108	550.0
Esox lucius (pike)		5	16.3
Perca fluviatilis (perch)		7	0.8
Rutilus rutilus (roach)		63	1.4
Carassius carassius (crucian carp)		3	1.5
Anguilla anguilla (eel)		62	
Total weight removed:			*circa* 2 000

6. Case studies

6.1 Case 1: Bleiswijkse Zoom (Meijer, Raat & Doef 1988)

The Bleiswijkse Zoom system of three small inter-connected lakes, covering a total of 14.4 ha, was formed in 1970 for recreational purposes. In its first years of existence the system was characterised by high phosphorus concentrations (0.4 mg/l) resulting in peak chlorophyll levels of 300 g/l and a transparency depth of about 0.2 m. In 1986 the question was raised as to whether fish stock management could help in improving water quality. In co-operation with the Organization for the Improvement of Inland Fisheries, which uses the lakes for research purposes, a management scheme was devised which aimed at controlling the rather dense stock of cyprinids. The lake system was divided into two

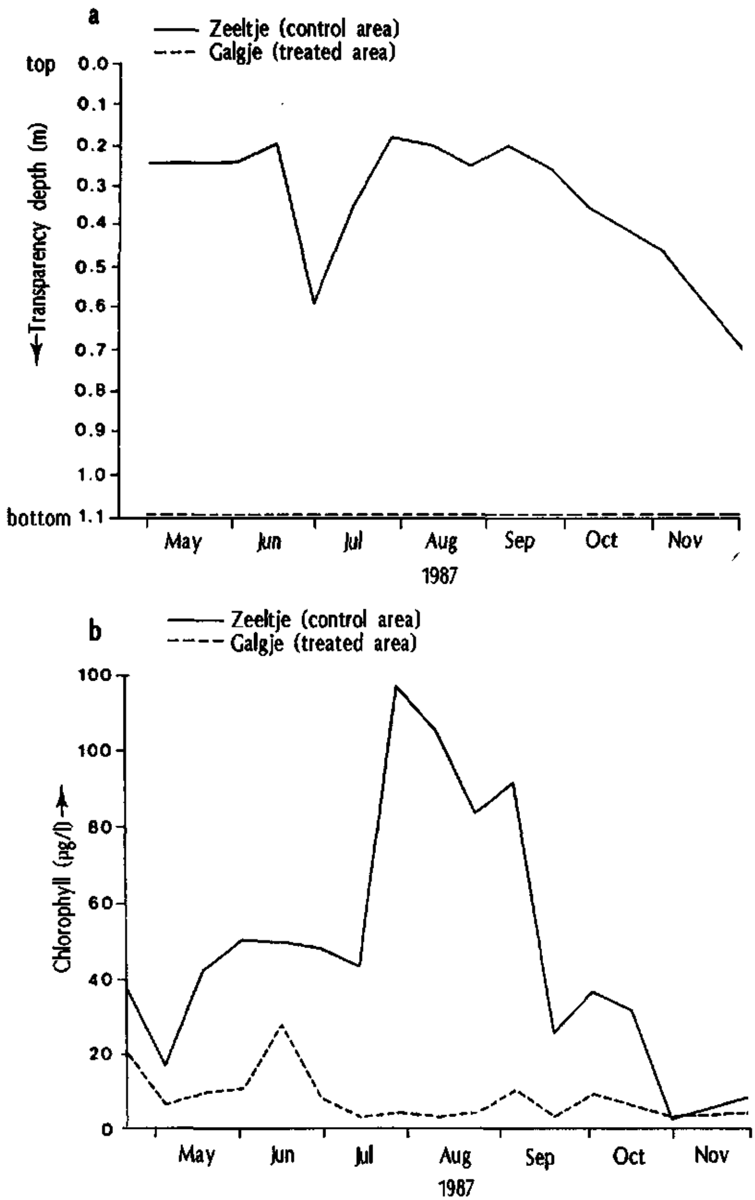

Figure 4. Changes in the Bleiswijkse Zoom following management of the fish stock in April 1987. a. transparency depth. b. chlorophyll concentration (from Meijer *et al.* 1988).

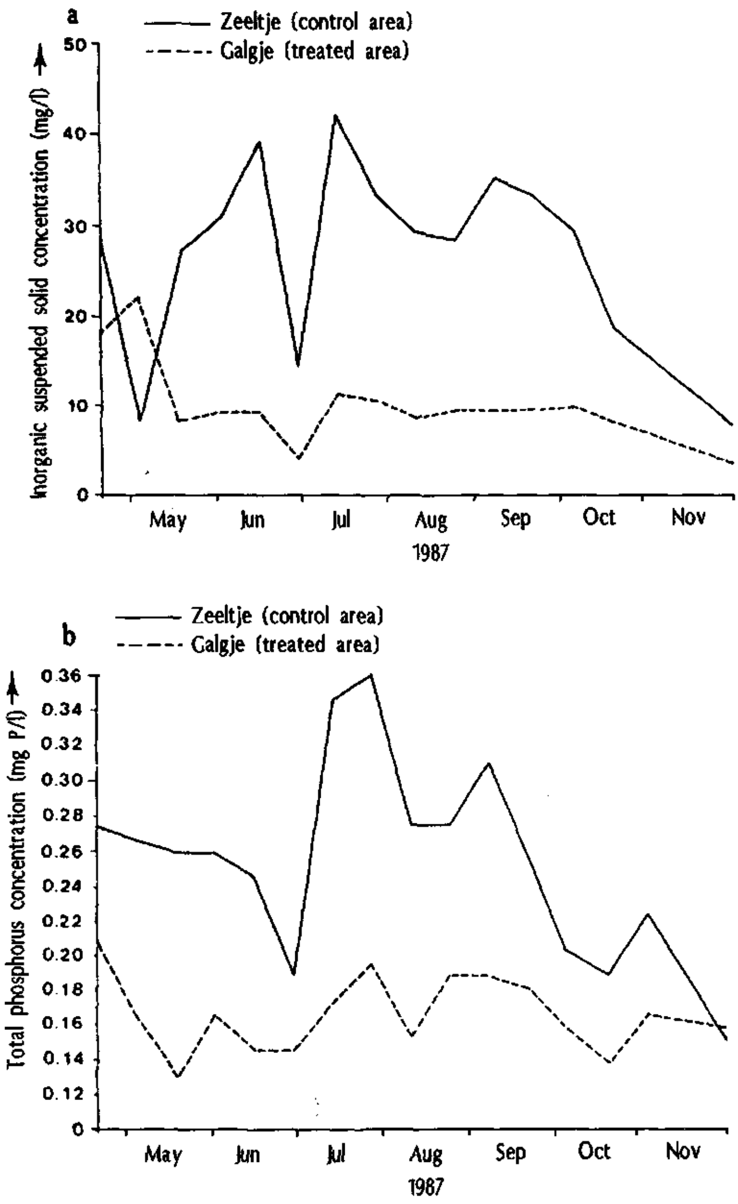

Figure 5. Changes in the Bleiswijkse Zoom following management of the fish stock in April 1987. a. inorganic suspended solid concentration. b. total phosphorus concentration (from Meijer *et al.* 1988).

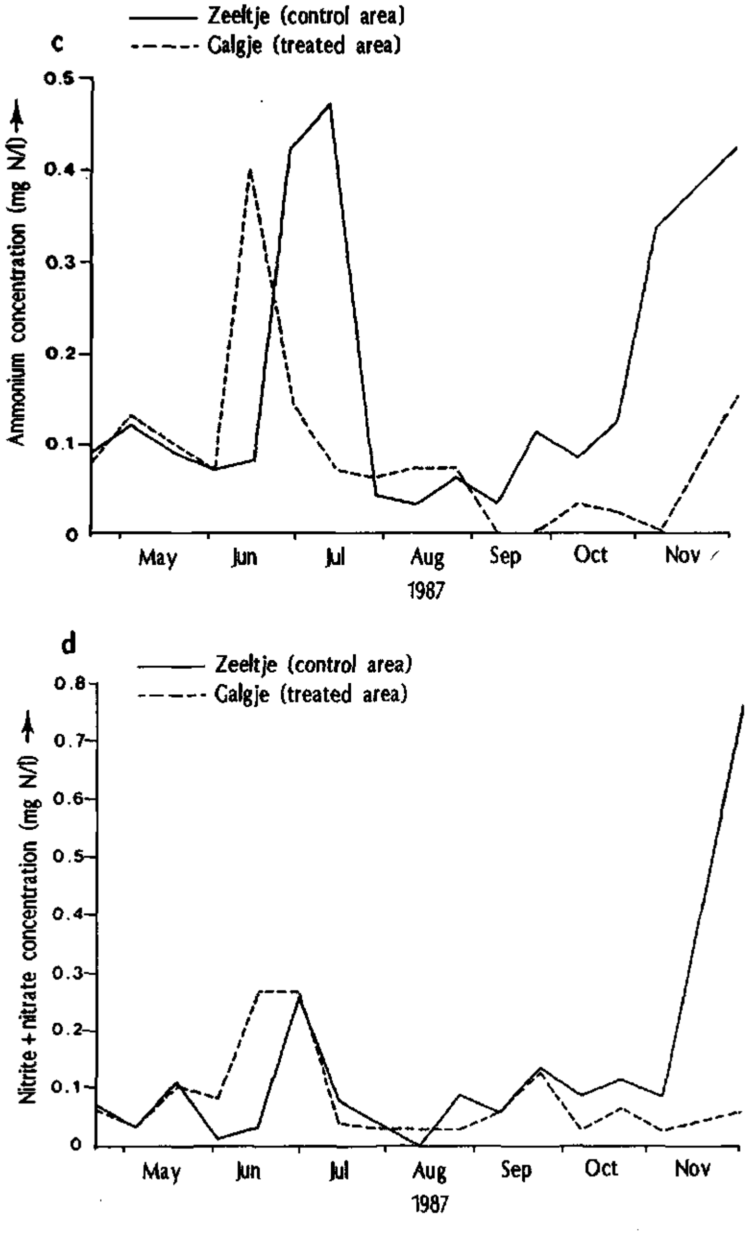

Figure 5. Changes in the Bleiswijkse Zoom following management of the fish stock in April 1987. c. ammonium concentration. d. nitrite and nitrate concentration (from Meijer *et al.* 1988).

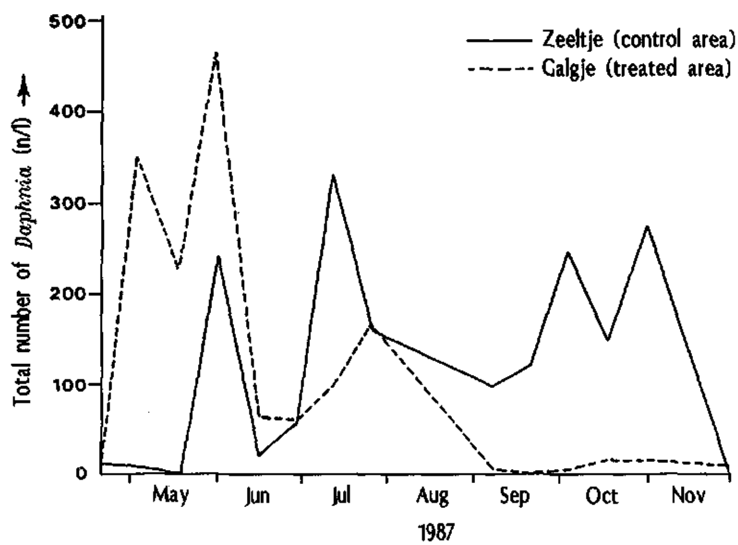

Figure 6. Total number of *Daphnia* in the Bleiswijkse Zoom following fish stock management in April 1987 (from Meijer *et al.* 1988).

compartments called Galgje (3.1 ha; treated area) and Zeeltje (11.3 ha; control area). Water quality in these two compartments was similar before treatment. After being separated by a dam, exchange of fish between the compartments could not occur. The treatment of the Galgje compartment consisted of removing about 2000 kg of fish *(Table 1)*, mainly (1200 kg) bream and silver bream *(Blicca bjoerkna)*, carp *(Cyprinus carpio)* (500 kg) and pikeperch (200 kg). By the end of April 1987 1200 young pikeperch of 2.5 cm length were introduced to regulate newly born bream from the residual bream stock. In the Zeeltje compartment no treatment was undertaken. Within a few weeks of treatment water quality had improved tremendously in the Galgje compartment *(Figures 4a, b, 5a, b, c, d)*. Nutrient and suspended solid concentrations were reduced, chlorophyll levels were extremely low and transparency had increased to 1.1 m (the bottom). Macrophytes, predominantly *Chara vulgaris* var. *longibracteata*, grew rapidly. Large zooplankters like *Daphnia hyalina* first increased rapidly, but their numbers dropped from June onwards *(Figure 6)*. However, algal biomass remained low, despite the reduced grazing by zooplankton. There are indications that the prolific growth of Characeae has something to do with this. Allelopathy may have suppressed the growth of the algae, but it is possible that a lack of nutrients (nitrogen) may have been a limiting factor. By contrast, in the Zeeltje compartment no improvement was seen. However, the growth and survival of the newly introduced pikeperch was poor, presumably due to the dense vegetation (100% cover) which would have hindered them when hunting. In fact, surprisingly, the measures taken resulted in the development of a pike habitat rather than a pikeperch habitat (more open water). Since pike had been almost totally removed from the system, and their numbers are still low, a number of young pike will be re-introduced in 1988.

Measures taken resulted in the fast recovery of the Galgje compartment, with ecosystem alterations being in line with expectations and we anticipate that the presence of macrophytes will now stabilize the ecosystem (Scheffer 1989). Ecosystem monitoring will be continued for the coming three years.

Table 2. Data on fish removed from Lake Zwemlust (March 1987) by seine-netting and electro-fishing (From van Donk, Slim & Grimm, 1988).

Species	length (cm)	number	weight (kg)
Abramis brama (bream)	>20	116	99.4
	10-20	10 005	435.0
	<10	6 208	50.6
Rutilus rutilus (roach)	>10	4 025	64.0
	<10	2 912	24.7
Esox lucius (pike)		44	56.6
Leucaspius delineatus		18 547	30.8
Scardinius erythrophthalmus (rudd)	>20	4	1.0
	10-22	223	5.5
	<10	115	0.6
Blicca bjoerkna (silver bream)		575	9.2
Anguilla anguilla (eel)		24	15.7
Tinca tinca (tench)		7	6.4
Cyprinus carpio (carp)		1	6.4
Perca fluviatilis (perch)	>20	9	3.2
	<20	357	1.7
Stizostedion lucioperca (pikeperch)		1	0.2
Total number and weight removed:		43 173	811.0

6.2 Case 2: Lake Zwemlust (van Donk, Slim & Grimm 1988, van Donk, Gulati & Grimm 1987)

Lake Zwemlust is a shallow (mean depth 1.5 m) hypertrophic lake of 1.5 ha in the centre of The Netherlands. Low transparency depths (0.1-0.3 m) and algal blooms *(Microcystis aeruginosa)* have characterised this lake for years at a stretch. Lake Zwemlust is in use as a natural swimming pool and water quality was not very attractive for recreational activities. The common strategy of reducing the phosphorus loading of the lake to induce

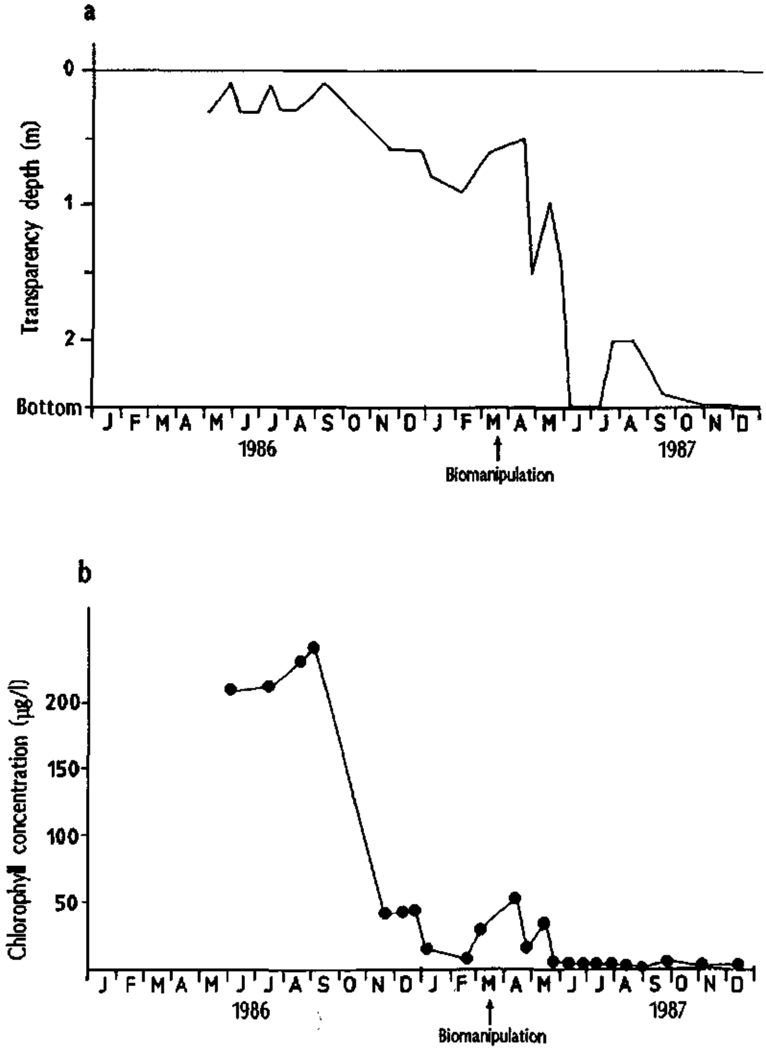

Figure 7. Changes in Lake Zwemlust before and after biomanipulation in March 1987. a. tranparency depth. b. chlorophyll concentration (from van Donk *et al.* 1988).

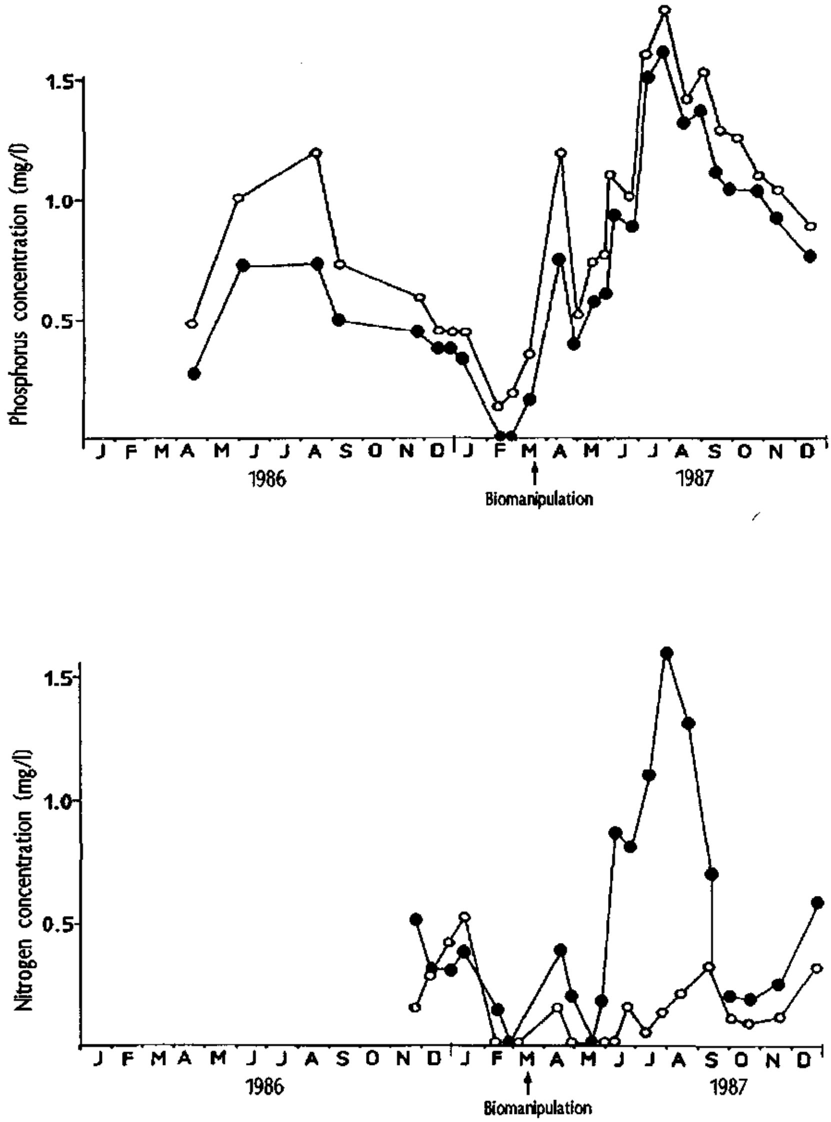

Figure 8. Changes in Lake Zwemlust before and after biomanipulation in March 1987. a. Phosphorus concentration . ● orthophosphate, O total phosphate. b. nitrogen concentration, ● ammonium, O nitrate.

lake recovery proved not to be possible, as this lake only receives seepage water from the nearby nutrient rich River Vecht. The tool of fish stock management was therefore tested. Measures taken consisted of draining the lake by pumping, and eliminating the predominantly planktivorous and benthivorous fish population *(Table 2)* by seine-netting and electro-fishing. The lake was subsequently restocked with 1500 northern pike fingerlings and a low density of rudd as food supply for the pike. Stacks of willow twigs, roots of *Nuphar luteum* and seedlings of *Chara* sp. were brought in as a refuge and spawning place for the pike and as shelter for the zooplankton.

These measures resulted in increased transparencies of 1-2 m *(Figure 7a)*, low chlorophyll levels, below 5μg/l *(Figure 7b)*, and a dense zooplankton population, predominantly *Daphnia* sp. In contrast to the Bleiswijkse Zoom system, nutrient concentrations remained extremely high *(Figures 8a* and *b)*. This is probably due to the dominant effect of seepage, whereas in the Bleiswijkse Zoom system, nutrient concentrations dropped as a result of reduced bioturbation by bream and carp. Growth of rudd was extremely good due to the abundant food supply. Survival of the stocked pike was low, as expected, due to cannibalism and a lack of fish larvae to feed upon. Midge larvae and zooplankton were dominant elements in the diet of the pike. Finally, growth of macrophytes was good, but was hampered by the development of large green algae like *Hydrodyction* sp. and *Enteromorpha* sp. These results are generally in line with expectations. The anticipated decrease in the biomass of cyanophyceae, due to enhanced zooplankton grazing, was confirmed experimentally and led to increased transparency. Growth of macro-algae may however, pose a threat to continued macrophyte development and may eventually affect ecosystem stability. In this way the Zwemlust and Bleiswijkse Zoom systems have exhibited differential development.

7. Concluding remarks

Preliminary results of managing fish stocks to reduce eutrophication in Dutch shallow lakes are hopeful. Expectations of ecosystem development after regulating fisheries are confirmed in general. Even when extremely high nutrient concentrations are present, ecosystem quality seems to be capable of improvement following fish stock management. Subsequent development of macrophytes is a key factor in stabilizing newly recovered ecosystems. Macrophytes may reduce nutrient concentrations, but it seems that, conversely, high nutrient concentrations decrease the chances of continuous macrophyte development. So the basic need to reduce nutrient loadings remains and is crucial. It is however, important to recognize that fish stock management may effect nutrient concentrations as well, either in a positive or a negative way, depending upon the density and composition of the stock present. This is a strong argument for all parties involved discussing the possibilities of integrated lake management, notwithstanding the current situation of responsibilities being separated. Effective fish stock management may speed up lake recovery by reducing eutrophication problems and bringing about the possibility of a new ecosystem equilibrium. The stability of this new ecosystem equilibrium will depend upon the trophic state of the lake. Research will be continued to find out which level of nutrient concentration may be considered 'safe' for retaining a socially desirable, stable and diverse ecosystem.

8. References

Boström, B., Jansson M. & Forsberg, C., 1987. Phosphorus release from lake sediment. Arch. Hydrobiol. 18: 5-59.

Carpenter, R.S. & Lodge, D.M., 1986. Effects of submerged macrophytes on ecosystem processes. Aquatic Botany. 3/4: 341-370.

Cazemier, W., 1982. The growth of bream *(Abramis brama)* in relation to habitat and population density. Hydrobiol. Bull. 16:269-277.

Densen, W.L.T. van, 1985. Bream. In: Pike, pikeperch and bream; biology, population dynamics and management. Report of the working group on evaluation of management methods. LH, OVB, Rivo, S&B. Nieuwegein. pp. 64-87. (In Dutch).

Densen, W.L.T. van, Dijkers, C. & Veerman, R., 1986. The fish community of the Loosdrecht lakes and the perspectives for biomanipulation. Hydrob. Bull. 20: 61-75.

Donk, E. van, Gulati, R.D. & Grimm, M.P., (in press). Restoration by biomanipulation in a small hypertrophic lake: preliminary results. Hydrobiologia.

Donk, E. van, Slim, F.J. & Grimm, M.P., 1988. Herstel van de recreatieplas 'Zwemlust' door toepassing van actief biologisch beheer: eerste resultaten. H_20 13: 338-343. (English summary).

Feith, A.F., 1982. Visstand, visserij en waterkwaliteit. Bijdrage t.b.v. het opstellen van rijks- en provinciale waterkwaliteitsplannen. Directie van de Visserijen, Den Haag. Doc. rapp. nr 24.

Grimm, M.P., 1981. Intraspecific predation as a principal factor controlling the biomass of northern pike *(Esox lucius)*. Fish Mgmt. 12: 77-80.

Grimm, M.P., 1983. Regulation of biomasses of small northern pike *(Esox lucius)*, with special reference to the contribution of individuals stocked as fingerlings (4-6 cm). Fish. Mgmt. 13: 115-134.

Grimm, M.P., 1985. Pike. In: Pike, pikeperch and bream; Report of the working group on evaluation of management methods. LH, OVB, Rivo, S & B. Nieuwegein. pp. 4-28. (in Dutch).

Hosper, S.H., Meijer, M.-L. & Jagtman, E., 1987. Actief biologisch beheer, nieuwe mogelijkheden bij het herstel van meren en plassen. H_2O 12: 274-279 (English summary).

Lammens, E.H.R.R., 1986. Interactions between fishes and the structure of fish communities in Dutch shallow eutrophic lakes. PhD Thesis, Agricultural University, Wageningen. 100 pp.

Meijer, M.-L., Lammens, E.H.R.R., Raat, A.J.P., Grimm, M.P. & Hosper, S.H., (in press). Impact of cyprinids on zooplankton and algae in ten drainable ponds. Preliminary results. Hydrobiologia.

Meijer, M.-L., Raat, A.J.P. & Doef, R.W., 1988. Actief biologisch beheer als herstelmaatregel voor de Bleiswijkse Zoom, eerste resultaten. H_20 21: 344-348. (English summary).

NVVS, 1985. Stek tachtig. Deelnota 2. Visstandbeheer. NVVS, Amersfoort. 48 pp.

Richter, A.F., 1985. Possibilities of biomanipulation for restoring water quality in The Netherlands. Limnologisch Instituut. Oosterzee/Nieuwersluis. Report 1985-08. 109 pp.

Scheffer, M., 1989. Alternative stable states in eutophic shallow freshwater systems: a minimal model. Hydrobiol. Bull. 23:73-83.

Vierssen, W. van, Hootsmans, M.J.M. & Vermaat, J.E., 1985. Waterplanten: bondgenoten bij het waterkwaliteitsbeheer? H_2O 18: 122-126. (English summary).

Winkel, E.H. ten & Meulemans, J. T., 1984. Effects of fish upon submerged vegetation. Hydrobiol. Bull. 18: 157-158.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 344-356.

Fisheries management: a global framework

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Abstract

In the present paper a general framework is developed for the fisheries management process. Fisheries management is a form of human action in the aquatic ecosystem. The process can be structured in a global framework which includes normative thinking, valuation and feedback mechanisms. Three functionally related levels between the environment and the actual implementation of a management plan can be distinguished. The valuation of the aquatic resource is based on different types of values.

This paper further presents a general review of inland fisheries management in The Netherlands in relation to water management. It is shown that a growing interest in ecological valuation of freshwater ecosystems and the biological valuation of fisheries based on empirical evidence is evident. Ecological arguments, together with socio-economic arguments, are increasingly used in allocation and policy making in many countries. Management based solely on biologically rational arguments however, is constrained by existing institutional and non-institutional structures in the society.

1. Introduction

Fisheries management is a term and practice widely in use among fisheries biologists and fisheries related workers. It is a practice with socio-economic objectives, constrained by biological feasibilities. From the point of view of the biologist, fisheries management is synonymous with fish stock management. However, fish stock management is a practice with biological objectives, constrained by socio-economic factors.

Fisheries management has been subject to many detailed case studies dealing with the biological and socio-economic aspects of the process. A comprehensive theory of fisheries management has not been presented until now, although the ingredients for such a theory have been supplied in many studies and textbooks (Williams, Margetts & Elliott 1985, Talhelm & Kennedy 1987, Lackey & Nielsen 1980).

Yarbrough (1987) applied political theory to fisheries management. His study analysed fisheries management at the level of the policy maker. He concluded that public consent and institutional structures offer constraints for resource management. Anderson (1987) broadened the approach to fisheries management with his fisheries management paradigm that included institutional structure and function in the process.

Van Densen (1990) deals with the structures and organization of inland fisheries management at the strategic and the operational levels of the process. His paper presents a view from the perspective of the fisheries biologist. This paper deals with fisheries management mainly at the policy level. A global framework for the management process is presented which structures the socio-economic, political, institutional and biological features of the process. The framework is applied to the actual situation of fisheries management in The Netherlands.

2. Fisheries management

2.1 Fisheries management and human action

Fisheries management takes place in the aquatic environment. It is human action that is, at least partly, based on rational arguments. The literature on policy analysis furnishes models of human action which are suitable for the analysis of the fisheries management process. Jantsch (1972) presented a model *(Figure 1)* that introduces normative thinking, valuation and feedback mechanisms into the planning process. The model has vertical dimensions and distinguishes three functionally related levels between the environment and the actual implementation of a plan.

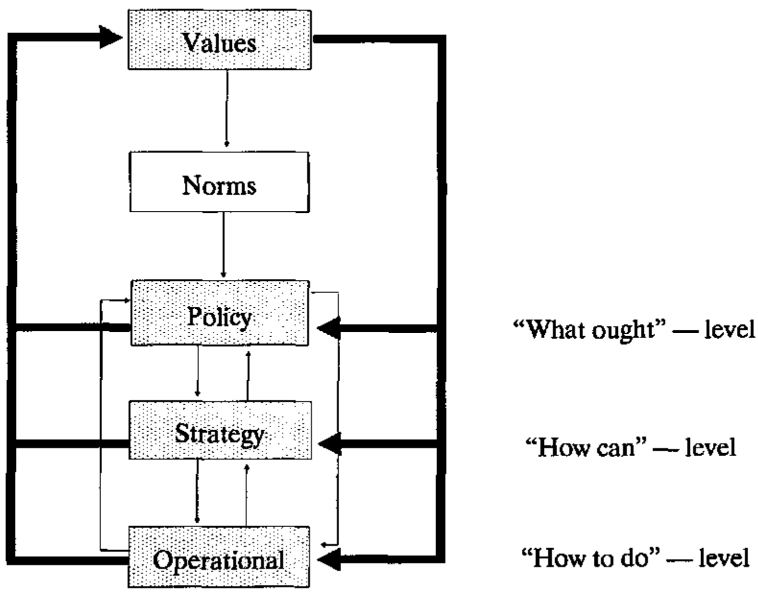

Figure 1. Framework for human action in the environment (modified from Jantsch 1972). Arrows indicate functional relations and feedbacks.

The human action model of fisheries management is looking at the problem as 'how things could be', and 'how things should be' by offering a structured analysis of forecasting, planning and decision-making at three functionally related levels in society. The actual situation differs from the model, and not only by constraints from technocratic approaches embodied in specialized institutions. Yarbrough (1987) concluded from structural theory that the bias in the existing governmental and economic structures (both formal and informal) works against broad management initiatives. The bureaucratic type of action (Jantsch 1972) has its purposes embodied in the institutional structure, which does not correspond with the purposes of the ecosystem perspective (Yarbrough 1987). Existing 'structures' at lower levels in the management process can pose comparable constraints on the implementation of measures.

2.2 Planning in fisheries management

Figure 1 illustrates that the management process takes place at several levels in society. The figure shows the vertical structure of the process. At each level decision making takes place. Jantsch (1972, but see also *Figure 2)* conceptualized the horizontal dimensions of the process by coupling forecasting, planning and decision making. In practice these elements of the decision making process are embodied in various institutional structures of society.

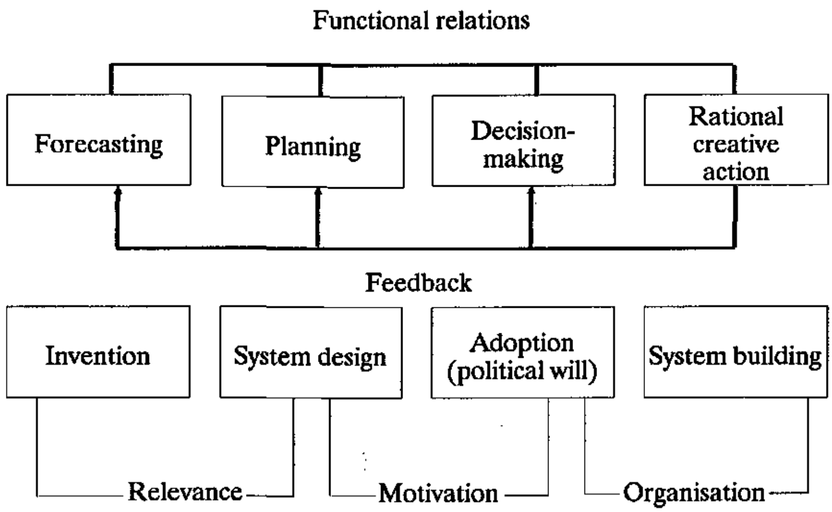

Figure 2. The horizontal framework of the systematic innovation process and key concerns for its phases and the links between them (modified from Jantsch 1972).

Sokoloski (1980) defined planning as a management process carried out prior to implementation and devoted to clearly identifying, defining, and determining the best alternative courses of action necessary to achieve determined goals and objectives. Planning is objective-oriented and precedes the decision making, which finally must result in action. Planning involves forecasting and system design. Decision-making implies the inclusion of the human dimension in the process.

The human dimension introduces a most dynamic and complex component into decision-making (Orbach 1980, Grover 1982, Talhelm & Kennedy 1987). It is an essential element in the process of rational creative action leading to innovation (Jantsch 1972, see also *Figure 2*). The evaluation of the decisions must lead to innovation and optimization of the management. This also implies, in many situations, that management needs an argument that can attach itself to a persisting core of public values. This is sometimes frustrating in terms of scientifically rational problem solving (Yarbrough 1987). Information is needed about the many dimensions of the process. Brown (1987) presented an approach to the need for human dimension research for planning and decision-making in fisheries management. Comparable analyses are needed for broadening the perspectives for the other dimensions of the process.

The approach to fisheries management as a form of human action in the aquatic environment implies that the actual action must be the result of planning and decision-making at various levels in society. Feedback mechanisms must be included in the process, which can have the form of evaluation procedures that can lead to revaluation. Rational planning of fisheries management must have objectives that are based on policy analysis and public consent. In many management situations, however, decision-making takes place without planning and without evaluation.

2.3 Valuation

The valuation of the aquatic resource in socio-economic terms is a topic of current interest in fisheries literature (Grover 1982, Talhelm & Kennedy 1987). Gregory (1987) considered the validity and usefulness of non-monetary approaches to valuing public investments in freshwater fisheries resources. His analysis identified and defined measures of social well-being, psycho-physical measures, attitude measures and multi-attribute choice measures. Higgs (1987) discussed the increasing importance of values in making natural resource decisions. Clear methods for valuation of the environment however, remain obscure. The incorporation of ecological values presents even greater difficulties in that respect.

Talhelm & Libby (1987) considered, in their overview of the Social Assessment of Fisheries Resources (SAFR) Symposium, whether or not a 'total value framework' could be developed to assess all the pros and cons of changes in fishery resources. Their approach was an attempt to reconcile two overlapping value concepts, 'held' values and 'assigned' values, where the last type of values is measurable in monetary units. The authors found that managers need more formal methods to evaluate alternatives and to justify their decisions. A total value framework can organize evaluations from different approaches to resource valuation.

In *Figure 3* a framework of the valuation of the environment is presented. It shows that qualification of the environment is based on choices leading to normation. When applied to the aquatic environment the qualifications can supply the policy maker with tools for allocation and legislation of the aquatic resource.

The concept distinguishes between three types of values:

1. Held values imbed an anthropocentric moral position and perpetuate a relationship of domination between people and nature (Higgs 1987).
2. Assigned values are market prices or their equivalent (observable terms of exchange between goods and services) (Talhelm & Libby 1987).
3. Inherent values are inherent to the environment itself. They are the values that reside in the objects themselves (Hunt 1980). These values are called ecological values by Higgs (1987).

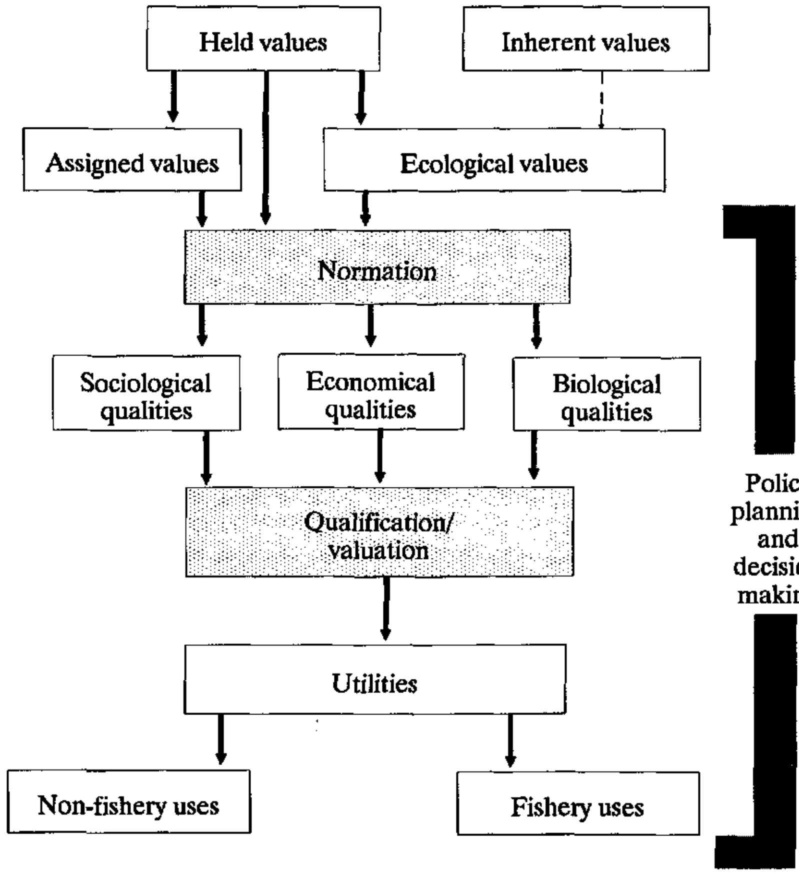

Figure 3. Framework of the normation and valuation process. For the translation of inherent values into ecological values see text.

The held values are complex and difficult to formulate in generally acceptable and operational terms. Nevertheless, held values must be considered in management plans, and the public must believe that the policies are consistent with its values (Yarbrough 1987).

The inherent values of the environment are by definition intangible (Higgs 1987). The biologist can describe the biological objects, the processes and their temporal and spatial variations, and thus he furnishes the measurable characteristics of the objects and processes. The biologist can also furnish data on the controllability of the biological variables. This ecological type of valuation receives increasing interest from ecologists and policy makers. A serious but yet underestimated problem is the variation of interpretation of biological terminology (Parma 1988).

For biologists ecological values are a special type of assigned value. They have a relationship with the inherent values of the environment, but often they are measurable expressions of the held values of biologists.

The ecological qualification aims to present functional information on goods and services that are provided by the natural environment. A functional ecosystem evaluation method for this purpose is described by De Groot (1986). The author distinguishes, besides ecological and socio-economic function valuations, the environmental impact assessment as a basic step in the function evaluation system. This step determines the impact of the human activities on environmental characteristics.

2.4 Fisheries valuation

Rigler (1982a), in his essay on the relation between fisheries management and limnology, pointed out that in fisheries and limnology disparate paradigms can be distinguished. This interferes with the communication between fisheries biologists and limnologists. The same is true for the communication between social scientists, economists and biologists working in the field of fisheries management. Socio-economic theory applied to fisheries management is mistrusted by many biologists, who cannot apply the results of socio-economic surveys in their concepts of fish stock management. On the other hand biologists are sometimes mistrusted by fishermen or not understood by the policy makers.

The concept of fisheries management as a form of human action in the aquatic environment differs from the traditional concept of fisheries management. The first concept is dynamic and is apt to validation in socio-economic and ecological terms. The second concept corresponds to a deterministic attitude and the type of linear planning and action that governs many models in fishery. The concept is designed to solve specific classes of fisheries problems and thus restricted to an aspect of the whole process. It lacks feedbacks to the environment. Thus it does not take into account the constraints from other components in the aquatic environment. It is the technocratic type of approach in the sense of Jantsch (1972).

2.5 Biological valuation

The biological typology of the environment has a long tradition in limnology but not in fisheries biology (Rigler 1982a). Traditionally, many fisheries biologists use simple systems in their approach to fisheries management, comprising only a fish population and fishermen (Rigler 1982a). This approach has been subject to sceptical reviews (Larkin 1977, Gulland 1978). It is increasingly realized that fisheries problems cannot be viewed from a narrow, simplified perspective. The basic system of the fisheries biologist must be enlarged to the aquatic ecosystem in which fish and fishermen are interactive components.

For most fisheries biologists the primary goal in fisheries management is the prediction of the future size and yield of fish stocks. Rigler (1982b) pointed out that in ecology the long-term abundance of a species in an ecosystem is an example of an unpredictable variable. In that perspective, fisheries management based on simple or sophisticated analytical models of the ecosystem does not result in valid predictions of the future state of the components of the system. Therefore Rigler (1982a,b) strongly advocated an empirical approach to ecology, the key characteristic of which is that it only makes predictions. This approach is suitable to fisheries management, in which process the measures are biologically largely based on empirical evidence. Understanding relationships between physico-chemical environmental factors and the biomass and occurrence of fishes is not a simple endeavour because few available data relate fish numbers or biomass to physical or chemical attributes of the environment. Also most descriptions of fish habitat are based on qualitative rather than quantitative measures (Layher, Maughan & Warde 1987).

The morpho-edaphic index (Ryder *et al.* 1974) is a well known example of an empirical correlation on which fisheries management valuations can be made. Another example is Henderson's (1985) analysis based on physico-chemical conditions within the habitat which could be used for the prediction of fish assemblages. A recent development in this area is the programme based on the Habitat Evaluation Procedure of the U.S. Fish and Wildlife Service (Terrell *et.al.* 1982), which method attempts to relate fish biomass or occurrence with physical, chemical and hydrological habitat variables. According to Layher, Maughan & Warde (1987) the basic assumption in such an approach is that once these relationships are known they can be used to predict changes either in fish distribution, occurrence or biomass that may accompany changes in the habitat. Inherent in this basic assumption are four other assumptions:

1. Fish populations respond to physical and chemical characteristics of habitats.
2. Fish populations are at the habitat's carrying capacity.
3. Relationships between fish occurrence or biomass and physical/chemical characteristics can be evaluated.
4. Man-induced changes in physical or chemical attributes of the habitat can be predicted.

3. Management of the freshwater ecosystem in The Netherlands

3.1 Freshwater resource

The inland waters of The Netherlands cover 3370 km^2, which is 9.0% of the total area of the country (CBS 1986). The major part of the water area consists of the former Zuiderzee, since 1932 a large freshwater reservoir, nowadays formed by Lakes IJssel and Marken (in total 1850 km^2). In these waters and in the Rivers Rhine and Meuse the management of the fisheries is the responsibility of the State. The total area of available inland waters larger than 0.5 ha and wider than 6 m is 1510 km^2. The fishing rights of 936 km^2 are in the hands of organizations of sport fishermen and professional fishermen. Here the fisheries management is the responsibility of both sport fishermen and professional fishermen (Van Haasteren & De Groot 1982).

3.2 Water management

3.2.1 General aspects

From 1980 onwards, Dutch governmental policy with regard to the inland water resource, has developed towards the integration of the legislation on environmental protection, pollution and water quality (Waterhuishouding 1985). The policy related to the aquatic resource involves biological qualification and normation. The Legislation on Surface Water Pollution (Wet Verontreiniging Oppervlaktewateren) regulates the production of long-term water quality plans (IMP 1985-1989). These include three scales of ecological quality targets, for 15 major water types that are distinguished by human uses and physical, chemical, hydrobiological, morphological and hydrological characteristics (Parma 1988). This policy must be implemented at provincial level.

The actual management of the surface water (sewage treatment, water quality management, water quantity management) is for most inland waters the responsibility of local, regional or provincial water authorities. The water management of the rivers and Lake IJssel and Lake Marken is the responsibility of the State.

3.2.2 Institutional support for water management

Water management is supported by various institutions at diverse organizational levels. At policy level, two Ministries are involved in legislation on environmental protection, pollution, and the quality of the water of the freshwater resource (Ministry of Transport and Public Works and Ministry of Housing, Physical Planning and Environment). Cramer & Hagendijk (1983) presented an overview of aquatic ecology in The Netherlands, which summarizes the research support at the policy and strategic level of water management.

Cramer (1987) gave a description of the approach of Dutch freshwater ecologists to applied research on the aquatic environment in the last 25 years. Her analysis discussed only part of the efforts that are nowadays spent, by provincial and regional/local water authorities, on studies for ecological valuation of the environment. Cramer (1987) concluded that separate networks among Dutch freshwater ecologists have been established. The social settings of Dutch freshwater ecology conform to the traditional dichotomy of academic *versus* bureaucratic orientation to research.

Most of the ecological research is done by limnologists, so the biological normation and valuation of the water resources represent part of their ideas. Fisheries research in The Netherlands is mostly aimed at strategical and operational problems in fisheries management. The institutional and methodological gap between limnologists and fisheries biologists as described by Rigler (1982a) is still relevant in the Dutch situation. Co-operative studies between limnologists and fisheries biologists formed part of the IBP-programme of the late 1960s in the Tjeukemeer (Cramer 1987). In 1986 a co-operative study on the feasibilities of fish stock management in water quality management was started which co-ordinates the research efforts of fisheries biologists, limnologists and water quality managers (Jagtman *et al.* 1990 - this volume).

3.3 Fisheries management

3.3.1 General aspects

More than 50 fish species are found in Dutch freshwaters. Forty species are protected by the Fisheries Law, by measures related to the size of the fish, the type of the fishery and the fishery period. Ten fish species are protected by the Nature Conservation Law and thus do not fall under the jurisdiction of the Fisheries Law. No fishery for these species is permitted. It is also forbidden to keep these species in captivity without the special permission of the Minister of Agriculture and Fisheries. The Dutch Fisheries Legislation relates to all canals, rivers, ponds and lakes. In these waters the owners, or those who have obtained the right to fish in the water, can take measures to improve the fish stock (Steinmetz 1982). Since 1985 the Dutch Fisheries Law explicitly states that measures to improve the fisheries must take into account the interests of nature conservation.

Management of the fish stock, by those who have the legal right to exploit the fish, is usually primarily aimed at optimising the catch and is therefore not primarily directed to the optimization of the fish stock for the benefit of the fish stock itself. In many management situations this is only a slight difference because catch and fish stock are related.

Fisheries management is usually dependent on the management of the water authority, which sometimes gives rise to conflicting situations. In most management situations there is no structured communication between water authorities and fisheries managers. The role of the fish in the ecology of the freshwater ecosystem is a topic of recent interest among fisheries managers and water quality managers in The Netherlands (Hosper, Meijer & Jagtman 1987, Jagtman *et al.* 1990). The efforts of biomanipulation initiated by water authorities partly interfere with the responsibilities of fisheries managers.

3.3.2 Institutional support of fisheries management

Fisheries management is supported at diverse organizational levels by various institutions (see Steinmetz 1982 for additional information). A difference may be seen between public and private institutions. At policy level, the Ministry of Agriculture and Fisheries is responsible for the legislation of inland fisheries. Decision-making at this level is supported by an Inland Fisheries Advisory Council (Raad voor de Binnenvisserij) that represents the private and public interests in inland fisheries. The Rijksinstituut voor Visserijonderzoek (RIVO; Netherlands Institute for Fisheries Investigations) furnishes technical and biological research data on fish and fisheries. Economic support comes from the Landbouw Economisch Institute (LEI; Institute for Agricultural Economics).

At the strategic level various institutions contribute directly or indirectly to forecasting, planning and decision-making. Data on the biological feasibilities of fish stock management and fisheries management are furnished by the RIVO, the Organization for Improvement of Inland Fisheries (OVB), the Limnological Institute and the Agricultural University. Various aspects of the planning of fisheries management are furnished by extension service and the educational programs of private organizations (NVVS, CNHV: sport fishery organizations; Combinatie van Binnenvissers, OVRIJ: commercial fisheries organizations), a public organization (OVB) (Walder & Van der Spiegel 1990), the Agricultural University (Van Densen 1990) and the State. The Ministry of Agriculture and Fisheries and the Inland Fisheries Advisory Council co-ordinate fisheries research at strategic level, although most of the institutions have a responsibility for their research programmes.

At the operational level, the owner of the fishing rights is responsible for the management of the fish stock. The transfer of fishing rights is possible by lease or permit. According to the Fisheries Law each agreement with regard to the transfer of fishing rights must be approved by the Kamer voor de Binnenvisserij (Chamber for Inland Fisheries). The re-allocation of the task of the Chamber of Inland Fisheries to the Ministry is under consideration. The re-organization of the Ministry of Agriculture and Fisheries has recently resulted in a withdrawal of the advisory and technical support of the State at the operational level. At the moment the advisory and technical support of fisheries managers is re-allocated among the private fishery organizations and the OVB.

In 1952 the Organisatie ter Verbetering van de Binnenvisserij (OVB; Organization for the Improvement of Inland Fisheries) was established by Fisheries Law. The OVB has public tasks in the field of fisheries management. The organization has the legal task to raise, buy and sell fish for stocking purposes. The OVB is financed by the fishery licence fee that is raised by Fisheries Law from all those who practise fishery in inland waters.

The owners and leaseholders are, as fisheries managers, responsible for stocking their waters. Since its foundation the OVB has dealt with more than 33 000 demands for fish for stocking purposes from fisheries managers. In total 3000 tonnes of fish were cultivated by the OVB in that period. The Organization gave subsidiary support to 4700 tonnes of fish transfers, mainly roach *(Rutilus rutilus)*, in the period 1952-1985. From 1952 to 1987 900 tonnes of undersized eels *(Anguilla anguilla)* and elvers were transferred to Dutch inland waters by the intermediance of the OVB.

4. Conclusion

Fisheries management is an activity which is, in many cases, the responsibility of those who exploit the fish stock. Thus the management is usually aimed at measures to improve the catch. Traditionally, the use of freshwater fish is not based on biological values but on a socio-economic valuation of the water resource. However, the importance of ecological valuation of the aquatic resource is increasingly realized. This gives rise to a growing integration of knowledge about the ecology and management of the ecosystem. Fisheries management becomes an element of ecosystem management and is thus in interaction with a broader environment than the traditional approach.

In this concept the goals in fisheries management are no longer defined from the perspective of exploitation, but are directed to the maintenance and optimization of the fish stock. The broadened approach to fish management also implies constraints presented by other users of the resource. Institutional structures on the diverse levels of the management process can interfere with management based on a biological rationale. In this respect Schouten *et al.* (1988) and Rang & Schouten (1988) introduced the concepts hydro-schizophrenia and hydro-inertia for the problems of effective water quality management in The Netherlands. The division of water resources management between a large number of public bodies and the slow responses of hydrological systems to certain environmental changes, hamper effective water quality management.

The management of water quality and fisheries operate from separate networks. A trend towards institutional co-operation is evident, although the different objectives of water management and fisheries management pose problems at policy level about responsibilities.

However, the growing interest in biological valuation of the ecosystem and its management has a positive influence on management strategies. A need for biological and socio-economic valuation is evident and can be supplied by research. Besides that, co-operation between water managers and fisheries managers is important. For the actual management of the water, the fish stock and the fisheries, information and education of fisheries managers and water managers is necessary to improve the quality of the management (van Densen 1990).

References

Anderson, L.G., 1987. Expansion of the fisheries management paradigm to include institutional structure and function. Trans. Am. Fish. Soc. 116: 396-404.

Brown, T.L., 1987. Typology of human dimensions information needed for Great Lakes sportfisheries management. Trans. Am. Fish. Soc. 116: 320-324.

Centraal Bureau voor de statistiek (CBS), 1986. Statistisch zakboek 1986.'s-Gravenhage, Staatsuitgeverij, CBS publicaties. 413 pp.

Cramer, J., 1987. The scope of mission-orientation in Dutch fresh-water ecology. Hydrobiological Bull. 21: 223-234.

Cramer, J. & Hagendijk, R., 1983. Aquatic ecology in The Netherlands: What is being done by whom? Hydrobiological Bull. 17: 77-85.

Densen, W.L.T. van, 1990. Structure for the decision-making process in inland fisheries management. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries, Pudoc, Wageningen, The Netherlands. pp. 301-312.

Gregory, R., 1987. Non-monetary measures of non-market fishery resource benefits. Trans. Am. Fish. Soc. 116: 374-380.

Groot, R.S. de, 1986. A functional ecosystem evaluation method as a tool in environmental planning and decision-making. Wageningen, Nature Conservation Department. 38 pp.

Grover, J.H. (Ed.), 1982. Allocation of fishery resources. Proceedings of the technical consultation on allocation of fishery resources held in Vichy, France, 20-23 April 1980. FAO in cooperation with American Fisheries Society. 623 pp.

Gulland, J.A., 1978. Fishery management: new strategies for new conditions. Trans. Am. Fish. Soc. 107: 1-11.

Haasteren, L.M. van & Groot, A.T. de, 1982. Summary of the provincial analyses of the demand for and the supply of facilities for sport fishing. In: Grover, J.H. (Ed.). Allocation of fisheries resources. FAO in cooperation with American Fisheries Society. pp. 468-479.

Henderson, P.A., 1985. An approach to the prediction of temperate freshwater fish communities. J. Fish Biol. 27: 279-291.

Higgs, E.S., 1987. Changing value perspectives in natural resource allocation: from market to ecosystem. Trans. Am. Fish. Soc. 116: 525-531.

Hosper, S.H., Meijer, M.-L. & Jagtman, E., 1987. Actief biologisch beheer, nieuwe mogelijkheden bij het herstel van meren en plassen. [Biomanipulation a new perspective for restoring lakes in The Netherlands]. H_2O 20: 274-279 (English summary).

Hunt, W.M., 1980. Are mere things morally considerable? Environmental Ethics 2: 59-65.

Indicatief Meerjaren Plan (IMP) Water 1985-1989, 1985. [Water management plan 1985-1989]. Ministerie van Verkeer en Waterstaat, 's-Gravenhage, Staatsuitgeverij. 193 pp.

Jagtman, E., Hosper, S.H., Meijer, M.-L. & Van Donk, E., 1990. The role of fish stock management in the control of eutrophication in shallow lakes in The Netherlands. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries, Pudoc, Wageningen, The Netherlands. pp. 328-343.

Jantsch, E., 1972. Forecasting, planning and policy formation. In: Jantsch, E. (Ed.). Technology, planning and social futures. London, Cassell Assoc. pp. 11-26.

Lackey, R.T. & Nielsen L.A. (Eds), 1980. Fisheries management. Blackwell, Oxford. 422 pp.

Larkin, P.A., 1977. An epitaph for the concept of maximum sustained yield. Trans. Am. Fish. Soc. 106: 1-11.

Layher, W.G., Maughan, O.E. & Warde, W.D., 1987. Spotted bass habitat suitability related to fish occurrence and biomass and measures of physico-chemical variables. North Am. J. Fish. Man. 7: 238-251.

Orbach, M.K., 1980. The human dimension. In: Lackey, R.T. & Nielsen, L.A. (Eds). Fisheries Management. pp. 149-163.

Parma, S., 1988. Management of water quality in surface waters of The Netherlands. Verh. Internat. Verein. Limnol. 23: 1465-1470.

Rang, M.C. & Schouten, C.J.J., 1988. Major obstacles to water quality management Part 2: Hydro-inertia. Verh. Internat. Verein. Limnol. 23: 1482-1487.

Rigler, F.H., 1982a. The relation between fisheries management and limnology. Trans. Am. Fish. Soc. 111: 121-132.

Rigler, F.H., 1982b. Recognition of the possible: An advantage of empiricism in ecology. Can. J. Fish. Aquat. Sci. 39: 1323-1331.

Ryder, R.A. *et al.*, 1974. The morpho-edaphic index, a fish yield estimator - review and evaluation. J. Fish. Res. Bd Can. 31: 663-688.

Schouten, C.J.J., Rang, M.C. & Kleijn, C.E., 1988. Major obstacles to water quality management Part 1: Hydro-schizophrenia. Verh. Internat. Verein. Limnol. 23: 1476-1481.

Sokoloski, A.A., 1980. Planning and policy analysis. In: Lackey, R.T. & Nielsen, L.A. (Eds). Fisheries Management. Blackwell, Oxford. pp. 185-195.

Steinmetz, B., 1982. The Netherlands country review. In: Grover, J.H. (Ed.). Allocation of fisheries resources. FAO in cooperation with American Fisheries Society. pp. 591-597.

Talhelm, D.R. & Libby, L.W., 1987. In search of a total value assessment framework: SAFR symposium overview and synthesis. Trans. Am. Fish. Soc. 116: 293-301.

Talhelm, D.R. & Kennedy, V.S., 1987. Social assessment of fisheries resources. Trans. Am. Fish. Soc. 116: 289-540.

Terrell, J.W. *et al.*, 1982. Habitat suitability index models: Appendix A. Guidelines for riverine and lacustrine applications of fish HSI models with the Habitat Evaluation Procedures. U.S. Dept. Int., Fish Wildl. Service FWS/OBS- 82/10A. 54 pp.

Walder, J. & Spiegel, A. van der, 1990. Education for fisheries managers in The Netherlands. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries, Pudoc, Wageningen, The Netherlands. pp. 372-381.

Waterhuishouding van Nederland 1984, 1985. [Water management in The Netherlands 1984]. Ministerie van Verkeer en Waterstaat. 's-Gravenhage, Staatsuitgeverij. 253 pp.

Williams, R., Margetts, A.R. & Elliott, J.M. (Eds), 1985. The scientific basis of inland fisheries management. J. Fish Biol. 27 (suppl. A). 300 pp.

Yarbrough, C.J., 1987. Using political theory in fishery management. Trans. Am. Fish. Soc. 116: 532-5.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 357-364.

Fisheries management of the Twenthe Canals, The Netherlands

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Abstract

In The Netherlands, the government is responsible for issuing fishing rights and sub-dividing these rights into two categories: eel *(Anguilla anguilla)* and tench *(Tinca tinca)* rights for commercial fishermen, and coarse fish (other than eel) rights for angling associations. In this context it is important to note that all freshwater fish species, except eel, are referred to as coarse fish in The Netherlands.

Fisheries management of the Twenthe Canals is an example of management by an angling association. Management objectives for different sections of the canals were formulated in 1981-1982, based on enquiries regarding preferences for, and catches of, particular species, and inventories of canal habitats. Over the same period the Dutch fisheries extension service developed general criteria for catches in different types of inland water bodies. After four years the different management objectives were evaluated with special reference to angling catches. A major tagging programme for carp, one of the species of interest to anglers, was implemented to evaluate future stocking policy.

1. Introduction

In The Netherlands, government fishery policy is focussed on the management of fish stocks by the users of those stocks. This means that in essence, fishing rights on state owned waters are issued to fishermen. The right to fish for eel *(Anguilla anguilla)*, and sometimes tench *(Tinca tinca)*, is issued to commercial fishermen, and the right to fish for coarse fish (bream, roach, pike etc.) to angling associations.

Over the past few decades the Ministry of Agriculture and Fisheries, which is responsible for implementing government fisheries policies, has supported both the managers of angling associations and commercial fishermen in several ways, for example by:

- Extension with regard to fishery management in specific situations. For instance giving an angling club advice on how to manage a local fish stock following a sampling programme conducted by a survey group from the Ministry.
- The development of criteria for the evaluation of this management, *e.g.* by assessing the growth of different species and the size and nature of catches.
- Extension with regard to the theory and practice of fisheries management, *i.e.* educational extension generally applicable and not related to any specific situation. This expertise is provided by the Organisation for the Improvement of Inland Fisheries (OVB) (Walder & van der Spiegel 1990 - this volume).

The fishery management of the Twenthe Canals, a state owned water body, is an example of the combined efforts of the associated angling clubs which manage the fish stocks, the government extension service and the educational branch of the OVB.

2. The Twenthe Canals

The Twenthe Canals were dug in the 1930s. They connect the industrial areas of Hengelo and Almelo, in the central eastern part of the country, with the IJssel waterway and thus with the large waterways leading to Amsterdam and Rotterdam. The canals are 63 km long, 50 m wide, 3.5-4.0 m deep and have a surface area of 315 ha. They are lined very largely by steel embankments, include three shipping locks, and have sandy bottoms. Their principal functions are to provide a navigable waterway on which there are some 15 000 shipping movements a year, to supply water and provide drainage. Net drainage through the system amounts to 200-400 million m^3/yr. They also provide a recreational area and angling grounds, and in the latter context receive some 80 000 visits/yr. The indigenous fish stock comprises primarily bream *(Abramis brama)*, roach *(Rutilus rutilus)*, pikeperch *(Stizostedion lucioperca)* and white bream *(Blicca bjoerkna)*, while common carp *(Cyprinus carpio)* are stocked.

3. Development of the management plan

The need for a management plan had become evident by the end of the 1970s. Stocking was undertaken at that time, but a coherent plan was lacking, and increasing recreational uses of the water were affecting the fishery. Complaints about declining catches led to the fish stock being sampled for management advice in 1978, at a cost of about 3000 Dutch guilders. As a consequence catches were limited but no problem with the stocks could be clearly identified. Pikeperch were present in all length classes up to 74 cm and large numbers of bream between 30 and 45 cm could be caught. Growth of roach and bream was judged to be acceptable for Dutch conditions (Hofstede 1974).

As an initial step towards formulating a management plan, the angling association decided to ascertain the regional importance of the canals for anglers. Accordingly a list of addresses of those who fished the canals was compiled. To this end members of local angling clubs obtained details from all anglers visiting their parts of the canals on 14 days between 31st May (the opening of the season) and the end of October. An angler's times of arrival and departure, his catches and some personal socio-economic details were requested. From this survey it became clear that close to 80 000 angling visits were made to the canals each year, and that about 40% of these visits were made at weekends.

The results of the survey were presented at the next annual meeting of the association when it was evident that such data are easy for laymen to gather and understand, and in consequence a general management plan was inaugurated. Ten thousand guilders, about 15% of the association's total budget, were earmarked for the project in 1981, with a further 7500 Dfl for conventional stocking with roach and carp.

4. The management plan

Information for a data base was gathered. Attention was paid to:

- The surfaces and morphometry of the canals.
- The quality of the water and water volumes in the canals.
- The fish stocks present locally.
- The possibilities for fishing, whether from bank or boat.
- The wishes and complaints of the users, anglers and commercial fishermen.
- The current management practices, stocking rates, catch limits, minimum allowable sizes etc.
- The current fishing intensity by both anglers and commercial fishermen.

Much of the information required proved to be already available from various authorities, such as those responsible for water management. The extension service of the Ministry of Agriculture and Fisheries then set up guidelines for management plans and criteria for evaluating catches (Steinmetz 1982). Of necessity the management goals had to be measurable by the angling association in order to evaluate the plans.

A data base was set up by the angling association in 1981, for the preparation of which catches were studied on 5 weekend days between June and October 1981. A questionnaire with stamped and addressed return envelope was handed to all anglers in the field on these days. Of 1672 questionnaires issued, 1337 (80%) were returned. The results provided an insight into fishing frequency, preferred species, species caught, fishing techniques, handling of catches, and anglers desires and complaints.

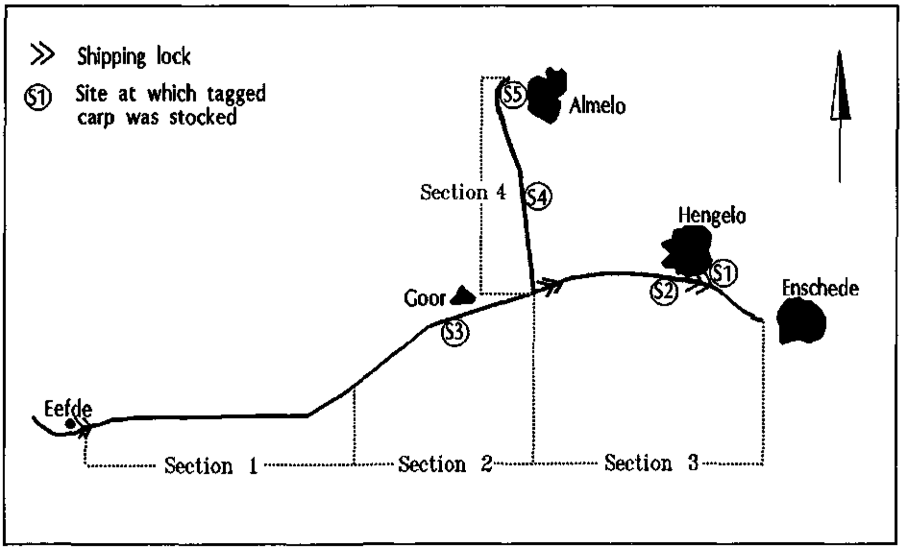

Figure 1. The Twenthe Canals.

Based on the evaluated data a management plan was drafted by the extension service of the Ministry of Agriculture and Fisheries and discussed with the angling association as users of the fish stock. The canals were divided into 4 sections with separate management goals for each *(Figure 1)*.

General problems were also considered, such as heavy boat traffic, limited access to the banks, problems with water quality (*e.g.* pollution), scarcity of vegetation (a natural reed bank was present only in section 4) and the fact that fish have limited access to the canals because of the shipping locks and the presence of weirs on tributary streams.

The draft report was sent to those other interested authorities who were responsible for the general problems cited, with invitations to participate in a discussion of the full draft fishery management plan. This provided for the ongoing assessment of the numbers of visits by anglers, the species preferred by anglers, the percentage of anglers successful in fishing for a certain species and their catches per hour, the percentage of fish landed over the minimum size, the composition of seine catches and the growth of certain species.

General target levels were developed for catch criteria, based on data from a number of other comparable Dutch inland water bodies. These data are given in *Table 1.*

Table 1. Target catches of three main species for anglers in The Netherlands.

Species	% of anglers catching at least 1 fish/visit	Mean catch (fish/hour)
Roach	60-80	1-3
Bream	40-80	0.4-1.1
Carp (ponds)	20-70	0.1-0.4
Carp (open waters)	5-30	pm-0.3

pm = small, but not equal to 0.

However, these catch criteria are only rough and the statistical basis has to be further developed. It is not clear as to which of the two categories is the more important, since often the percentage of successful anglers increases while their catch per hour decreases. Moreover, it is well known that factors such as angling technique and 'hook avoidance' have a marked influence on catches (Beukema 1970).

From a consideration of the data available, especially those concerning catch levels in 1981 *(Table 2)*, a principal goal was formulated as 'the maintenance or improvement of present catch levels of the main species fished for'. Measures to be taken were as follows:

- To improve the immigration of adult bream and roach through the weir and lock near Eefde in spring.
- To limit the population of small cyprinids by stocking with pikeperch fingerlings at a density of 100 individuals/ha/yr.
- To stock the canals with carp of about 30 cm length, at a rate of 25 kg/ha/yr, to compensate for natural and fishing mortalities.
- To study the migrations of carp stocked.
- To maintain the reed vegetation along the banks in section 4.

Table 2. Anglers' preferences and wishes, and catch statistics for four sections of the Twenthe Canals, recorded in 1981 and 1985.

	Number of questionnaires		Visits June-November		% anglers prefer-ring one species		% anglers successful		Numbers caught/hour		% above minimum size *		%anglers wishing to catch more	
	1981	1985	1981	1985	1981	1985	1981	1985	1981	1985	1981	1985	1981	1985
Section 1	287	109	10 000	12 000										
Roach					56	51	74	57	2.2	2.6	75	85	18	29
Bream					12	20	88	53	1.1	1.4	55	39	17	9
Carp					13	14	6	pm	pm	pm	-	-	22	16
Section 2	102	66	6 000	6 000										
Roach					45	44	45	60	1.2	1.0	90	55	17	30
Bream					13	21	69	63	1.2	1.2	60	44	8	9
Carp					20	14	-	-	-	-	-	-	12	28
Section 3	521	349	39 000	43 000										
Roach					46	35	70	73	1.8	1.9	80	76	13	13
Bream					12	24	60	78	0.8	1.5	50	44	18	18
Carp					30	35	29	24	0.3	0.3	65	80	24	32
Section 4	416	178	19 000	11 000										
Roach					35	26	51	45	1.0	1.0	70	73	23	20
Bream					11	21	41	49	0.9	1.2	30	34	20	7
Carp					36	35	14	36	0.3	0.4	50	79	32	30

* roach 15 cm, bream 30 cm, carp 45 cm
pm = small, but not equal to 0

As previously indicated, the first and last of these measures involve the water and traffic management authorities as well as the local fishery manager. All these measures were undertaken, as far as possible, with the exception that stocking with carp was delayed until 1985 at which time a tagging experiment was initiated.

5. Evaluation

The early years of management were evaluated in 1985-1986. Counts of anglers present were again made on 5 weekend days from a light aircraft, and questionnaires of the same type as those used previously were again distributed, this time with an 85% response. A tagging programme, using 2000 carp, was used to study catch levels and fish movements. In *Table 2* the first four criteria for evaluating the management of the fish stock are given separately for each section of the canals. An analysis of the data in *Table 2* shows that:

In Section 1

- The frequency of visits increased while the total number of anglers in the country declined.
- Roach was the preferred species. Catches were in agreement with targets despite a decrease in the numbers of successful anglers because of higher catches per hour.
- Bream increased in popularity, but fewer anglers were successful with this species. However, the catches of those who were successful increased. There was a trend for the numbers of bream less than 30 cm long in catches to increase.
- Carp were of interest only to a small group of specialists.
- From a management point of view the situation in section 1 was satisfactory so current policies could continue.

In Section 2

- The unfavourable situation had not improved. Catches of roach stayed below those from section 1, but there was a slight increase in interest in bream.
- From an overall management point of view the situation could be better, but catches remained satisfactory.
- From the stocking experiment it later became clear (see next section) that introduced carp left sections 1 and 2 to stay in quieter water.

In Section 3

- A large number of visits were made and the trend was for the numbers of visits to increase.
- The popularity of the section reflected the good catch levels attained there, and also certain positive developments for the species caught.
- The carp fishery was successful there, even without stocking (see next section).

In Section 4

- The number of visits declined from 19 000 to 11 000 per year. This was due to the reconstruction and widening of this part of the canal.
- The goal of improving carp catches was realised. Carp catches became attractive.
- The goal of improving roach catches was not realised.

- Interest in bream increased.

Thus the overall results of managing the fish stock in the years 1981-1986 were positive since catch levels remained stable, or even improved, without stocking. However, it became clear that two other matters should be investigated, *viz* the composition of the fish community of the entire canal system and the migration of the carp stocked in the period between the two enquiries. The percentage of carp over 40 cm increased, indicating that the canals were not over-stocked.

6. The fish stock

The fish stock was sampled in December 1978 and April 1987, which revealed that bream, white bream and roach were the main non-predatory species present, with pikeperch as the chief predator. Other species, including eel, perch *(Perca fluviatilis)*, pike *(Esox lucius)*, ruffe *(Gymnocephalus cernua)*, ide *(Leuciscus idus)* and tench were scarce. During the 1987 sampling, large numbers of 1 year old roach and bream were found in the vegetated section 4 and in the unvegetated section 1. Growth of roach and bream generally met the criteria set by Hofstede (1974). No clear changes in the composition of the fish community were discovered.

Table 3 shows the stocking rate and catch data for tagged carp. No tagged specimens were recovered after one year, in fact almost all returns were obtained within 6 months. This experiment yielded very useful management information. Thus it became clear that stocked carp migrated to the quieter parts of the canals and passed the shipping locks in large numbers. Also, nearly 50% of the stocked and tagged carp put into the 60 ha section 3 were caught, mostly between December, when they were released, and the following July. The estimated number of visits by anglers to section 3 was 43 000/yr and 35% of these fished for carp during their visit which amounts to some 15 000 angler/carp days/yr. A quarter of these anglers were successful and caught one carp per 3 hours, so that 4000-5000 carp were landed.

Table 3. Stocking and catch data for tagged carp. For stocking sites (S) see *Figure 1*.

Stocking site	Number stocked	Recaptured in section:					Total
		1	2	3	4	unknown	
S1	400	1	-	100	2	3	106
S2	400	-	-	182	2	5	189
S3	400	5	23	37	48	11	124
S4	400	1	1	26	126	11	165
S5	400	1	16	33	74	15	139

7. Conclusion

The procedure followed for drafting a management plan was satisfactory despite the statistical imperfections of the enquiries. The general data needed concerning the canal ecosystem could be obtained from existing sources with little difficulty. The aerial survey of anglers proved useful and inexpensive. The distribution and processing of questionnaires was labour intensive but necessary for good management. It proved useful to know that catches could improve without stocking and had the advantage that the fishery manager made contact with the anglers. Cowx (1990 - this volume), using catch data from anglers in a different way, drew similar conclusions.

References

Beukema, J.J., 1970. Acquired hook-avoidance in the pike, *Esox lucius* L., fished with artificial and natural baits. J. Fish Biol. 2: 155-160.

Cowx, I.G., 1990. Application of creel census data for the management of fish stocks in large rivers in the United Kingdom. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries, Pudoc, Wageningen, The Netherlands. pp. 526-534.

Hofstede, A.E., 1974. The application of age determination in fishing management. In: Bagenal, T.B. (Ed.). Ageing of fish. Unwin, Woking, U.K. pp. 206-220.

Steinmetz, B., 1982. Management of fish stocks in The Netherlands and the need for planning. In: Grover, J.H. (Ed.). Allocation of fishery resources. FAO/AFS pp. 384-396.

Walder, J.E. & Spiegel A. van der, 1990. Education for fisheries managers in The Netherlands. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries, Pudoc, Wageningen, The Netherlands. pp. 372-381.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp.365-371.

Management problems with the differential allocation of fishing rights to sport and commercial fishermen in the Frisian lakes, The Netherlands

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Abstract

The Frisian lakes in the north of The Netherlands, with surface areas up to 2000 ha each, cover a total area of 16 000 ha. They are all shallow eutrophic lakes, interconnected, and having a retention time of 3-6 months. The fish stocks in the lakes are dominated by pikeperch *(Stizostedion lucioperca)*, bream *(Abramis brama)*, perch *(Perca fluviatilis)*, roach *(Rutilus rutilus)*, ruffe *(Gymnocephalus cernua)*, smelt *(Osmerus eperlanus)* and eel *(Anguilla anguilla)*. Since 1977 the fishing rights for eel have been allocated to commercial fishermen while those for all other species are allocated to sport fishermen. The discontinuation of the gill-net fishery for pikeperch and perch has caused a shift in the population structure of pikeperch and bream to older individuals. Although the fish stocks should be managed as a unit, the administrative organization and the rules applied were not strict enough to ensure this.

1. Introduction

The growing number of anglers in The Netherlands in the 1950s and 1960s provoked changes in the Fishery Act, and led to the political decision in 1972, that sport fishermen should be accorded priority in the acquisition of fishing rights, but that at the same time the interests of commercial fishermen should be considered. It was decided to re-allocate the fishing rights over inland waters. Commercial fishermen can now acquire the fishing rights for eel *(Anguilla anguilla)*, and the organizations of sport fishermen can acquire the fishing rights for all other freshwater fish species. The major fish species in the latter category (coarse fish) are bream *(Abramis brama)*, white bream *(Blicca bjoerkna)*, pikeperch *(Stizostedion lucioperca)*, roach *(Rutilus rutilus)*, perch *(Perca fluviatilis)*, pike *(Esox lucius)*, rudd *(Scardinius erythrophthalmus)* and carp *(Cyprinus carpio)*.

In The Netherlands the allocation of fishing rights to fishermen is a normal procedure and covers some 120 000 ha of inland waters. The major exception is Lake IJssel (180 000 ha). The most important rights acquired by individuals or organization are:

- To fish, within the restrictions of the National Fishery Act (closed seasons, minimum sizes etc.).

- To stock, within the prescription of the National Fishery Act.

Co-ordination of management has been stimulated by way of governmental extension to fishery managers. In some state-owned waters the organization that rents the fishing right is obliged to set up a management committee with representatives of both sport and commercial fishermen who become responsible for a management plan that must be approved by the State. The implementation of the re-allocation of fishing rights has been stimulated by the Ministry of Agriculture and Fisheries by means of a financial compensation to those commercial fishermen who have voluntarily discontinued their fishery for coarse fish. In Friesland, a province in the north of The Netherlands, with 16 000 ha of inland waters, the Frisian Organization of Commercial Fishermen and the Frisian Association of Angling Clubs agreed on the re-allocation of fishing rights in 1975. This agreement was reached in 1977. The Ministry contributed 2 300 000 Dfl and the Frisian Association of Angling Clubs 700 000 Dfl. The main points of the agreement are:

- The installation of a management advisory committee which is to co-ordinate the management of eel and coarse fish, and which would draft a management plan.
- The contracting parties agree to take no management measures which may harm the interest of the other party.
- The parties are obliged to manage the fish stock according to the views of the management advisory committee.
- In case of serious disputes an independent committee with representatives of the State as the owner of the fishing rights, the Province of Friesland and the Association of Dutch Municipalities must be instituted. The judgements of this committee are to be absolute.

In 1977 the Ministry of Agriculture and Fisheries started annual trawl surveys to gain insight into the dynamics of the fish stocks in the lakes, and to provide the management advisory committee with information on the stocks. Until 1977, coarse fish were exploited by commercial fishermen with gill-nets (101 mm stretched mesh) and seines (Goldspink & Banks 1975), and there was an intensive fishery for the two valuable species, perch and pikeperch, which today, are also sought by anglers. It was anticipated that the sudden end to commercial exploitation would lead to an increase in the density of pikeperch and perch stocks, but how the stocks would develop in the long-term could not be foreseen, nor the degree of stability that would be reached.

This contribution discusses critically, the fisheries management of the Frisian Lakes since 1977. A stricter organization of the management process than that hitherto employed, with an adequate supply of fisheries-dependent research data, is suggested.

2. Management objectives and measures

Until 1988 the management advisory committee did not succeed in drafting a management plan with management objectives. From the beginning the discussions were frustrated by the strongly conflicting views of the commercial and sport fishermen regarding the future management of the fisheries. The commercial fishermen stated that the (now) increasing stock of bream had detrimental effects on the fyke net catches of eel, both directly and indirectly. Directly, because of too large a by-catch of low-valued bream in the fyke nets set to catch eel. Indirectly, because of the competition for benthic food organisms between bream and eel. Therefore the commercial fishermen advocated a periodic removal of a large part of the bream stock by seining in winter. The sport fishermen strongly opposed this because they feared a gradual re-introduction of the commercial fishery for pikeperch and perch. The Association of Angling Clubs stated that their catches were satisfactory and that, if the development of the bream stock had an adverse effect on the catches of eel, this had to be proven by scientific research. Specific research into this question was carried out in 1982-1984 (see section 3).

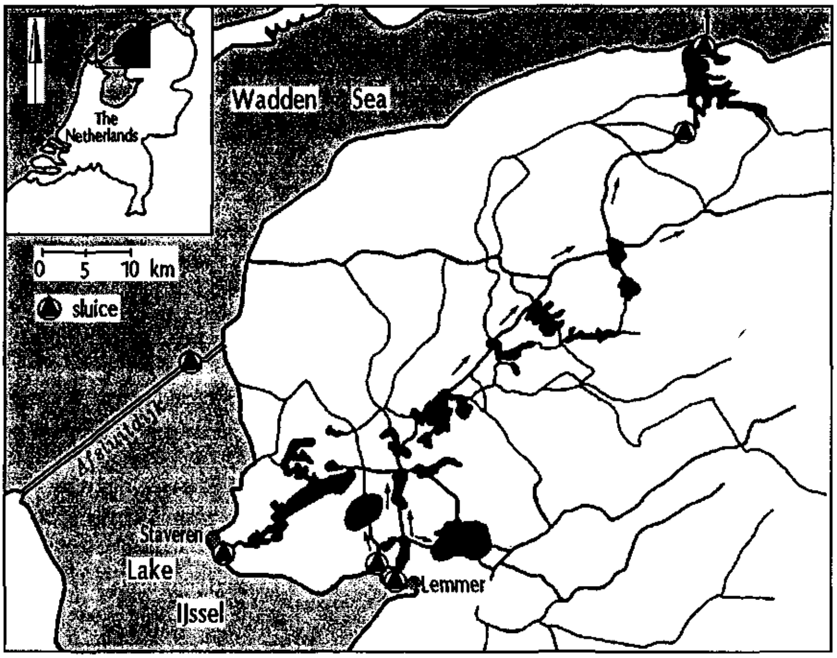

Figure 1. The location of the Frisian lake district. The arrows indicate the major water flow from the freshwater Lake IJssel through the lakes region into the Wadden Sea.

There are no catch statistics available, neither from commercial fishermen, nor from sport fishermen. One reason why there are no landing statistics concerning the catches of the *c.* 40 full-time and 40 part-time commercial fishermen, is the dispersed nature of the fishery in Friesland. There are some 20 lakes *(Figure 1)* of which the largest is about 2000 ha (Tjeukemeer) and there are only 3 fishermen per lake at maximum. There is no central place for wholesale trading. Recording of catch-effort data would thus only be done on the initiative of the fishermen themselves. On the basis of an economical study of the Frisian fishery, in the years 1966-1970, the annual yield of eel was estimated at 8.6 kg/ha and that of pikeperch at 7.2 kg/ha (van Densen 1983). These figures were in the same order of magnitude for Tjeukemeer, the only lake for which detailed catch statistics were analysed over the period 1964-1970. Catch rates were 6.6 kg eel/ha and 3.7-10.4 kg pikeperch/ha (Goldspink & Banks 1975).

Sport fishing is popular among the inhabitants of the province of Friesland. The number of licenses issued per unit number of inhabitants is roughly twice as high in Friesland as the national average (van Densen 1983). Some 50 000 licences were issued in the province in 1986, of which 24 000 were issued to people in angling clubs. About 40% of the people angling in Friesland come from elsewhere (de Groot & van Haasteren 1979). In The Netherlands, anglers fish some 25 times a year. The conservative estimate of angling pressure in Friesland is 1 300 000/rod days/yr (80 rod days/ha/yr).

In addition to national regulations, the management measures taken by the commercial fishermen in Friesland are:

- Stocking of glass eel and young eel.
- Limitation of fishing effort to prevent the over-exploitation of the eel stocks.

Their effort is limited by the maximum number of 50-60 fyke nets/fisherman allowed. These have to be littoral fyke nets of 150-300 meshes, set at fixed sites. Summer, open water, fyke nets, longlines and eel boxes, as used in Lake IJssel (van Densen *et al.* 1990) are forbidden.

The Association of Angling Clubs in Friesland has changed the minimum allowable size of pike to 50 cm (national 45 cm) and has set catch limits of 10 pikeperch/day and 1 pike/day. The catch limit has been set to prevent, among other things, the sale of valuable pikeperch to fish traders.

3. Research

Catch-effort data are lacking. Since the discontinuation of the gill-net fishery, in 1977, a monitoring programme for fish other than eel has been performed by the Fisheries Department. Every autumn about five 10 minute trawl hauls per lake are taken in 7 selected lakes. The total weight and the LF-distributions per species are recorded. By comparing these catches with the more frequent and detailed sampling carried out in the Frisian lakes (especially Tjeukemeer) by the Dutch Limnological Institute, the value of the annual monitoring programme can be established (van Densen & Klein Breteler 1985). The mean length of 0-group fish can be recorded unbiased. However, the estimate of their relative abundance (numbers/10 minute trawl haul) is influenced by the changing patterns of distribution of the younger age groups at the end of the summer, especially those of young bream and roach. For this reason the monitoring programme must not be executed later than in September.

On the basis of the research by the Limnological Institute (Ministry of Education) into the dynamics of fish populations and food organisms, future monitoring programmes can be considerably improved by investing marginal extra time. The condition of the fish is easily recorded and proves to be a sensitive indicator for the well-being of the populations of pikeperch and bream (Lammens 1982, van Densen & Vijverberg 1982). The impact of planktivorous fish on the large *Daphnia hyalina* was so great that the mean size of *D. hyalina* could be used as an indicator of the biomass of 0-group fish, and of the availability of the zooplankton for the facultatively planktivorous older bream (Lammens 1982, Vijverberg & van Densen 1984, van Densen 1985). The zooplankton, and certainly the abundance and mean size of the key organism *D. hyalina*, is easily monitored. A lumped zooplankton sample (0.125 mm gauze) for the whole of the lake gives a reliable average picture of zooplankton density and composition (de Nie, Bromley & Vijverberg 1978, de Nie & Vijverberg 1985). Wind induced water circulation in the shallow lake prevents the clumping of the zooplankton. The analysis of the lumped sample will take about 4 hours per lake, including data processing.

The major food organisms for fish in the Frisian lakes are zooplankton and chironomids. Sampling of chironomids is most time-consuming. Because of their heterogeneous spatial distribution at least 15-20 samples have to be taken over several transects in each lake (Beattie 1982). The samples have to be separated from the bottom sediments (peat, sand, clay) by laborious sieving. The incorporation of this type of observations into a monitoring programme must be done selectively.

Specific research was done by the Fisheries Department and The Netherlands Institute for Fishery Investigations to study the effect of a cropping programme for bream in part (3000 ha) of the lake district during 3 consecutive winters (1981/1982 - 1983/1984). Parameters recorded were the condition of the bream, the fat content of the eels and the abundance of the zoobenthos. Because all lakes are interconnected 10 000 bream and 570 pikeperch were tagged to study their migrations in the area concerned. The cropping by winter seining was done by the commercial fishermen. Only 50% of the target for cropping (100 kg/ha/year) was realized. The evaluation of this large-scale research programme has not yet been completed, but it can already be concluded that this type of research would have been better started on a much smaller scale.

The Limnological Institute was able to follow the development of the fish stocks in Tjeukemeer after the re-allocation of the fishing rights in 1977. There was a shift in the bream and pikeperch populations to the larger size classes which were formerly caught by the intensive gill-net fishery of the commercial fishermen (Lammens 1986, Lammens 1987, Goldspink & Banks 1975). An indirect effect of the re-allocation was the decrease of the roach and the perch populations, which almost disappeared from the open water area as a result of the increased predation pressure by large pikeperch. The latter can prey upon almost all length classes of these species. Within the zooplankton, only the large *Daphnia hyalina* showed a significant increase after 1977 and made the growth of the bream population possible. Only in years with very successful recruitment of smelt *(Osmerus eperlanus)* and perch, did *Daphnia hyalina* stocks collapse and cause deterioration in the condition of bream (van Densen & Vijverberg 1982, Lammens, de Nie, Vijverberg & van Densen 1985).

4. Conclusions

The re-allocation of fishing rights in the Frisian lakes in 1977 brought about a situation in the management of the fish stocks which was difficult to handle. The administrative organization was not strict enough, nor were the rules obligatory. Therefore the management of the eel stocks and the stocks of other freshwater fish as a total unit could not be ensured. The latter aspect is necessary because of the strong interaction between both categories of fish (Lammens *et al.* 1985).

Other constraints on the management of the fish stocks result from the physical character of the lake district. There are many small lakes, which form a typical Dutch polder (reservoir) system, together with the surrounding pasture land. All lakes are interconnected, water has a short retention time (3-6 months) and the system as a whole is open to the immigration of large numbers of larval and juvenile fish from the nearby Lake IJssel (van Densen & Vijverberg 1982).

The dispersed character of the lakes hampers the introduction of an official system for recording commercial eel catches. This is even more difficult for the catches of sport fishermen. They fish chiefly for recreational purposes and put the major part of their catch (bream, roach) back into the lake. There is a specific group of anglers, both from Friesland and from elsewhere, who fish more selectively for pikeperch for consumption. Poachers are expected to take a considerable part of the pikeperch stock.

The openness of the lake district for immigrating larvae and juveniles causes fast and unpredictable shifts in the ratio of predator to prey species. These strong variations have been superimposed on the main trend since 1977, *i.e.* the ageing of the populations of pikeperch and bream. It is difficult for the fisheries managers to distinguish both dynamic aspects.

The monitoring programme can be up-graded by investing just a little extra time. However, the set-up of a catch and effort registration system for both commercial and sport fishermen seems even more urgent. Such a system has not been imposed by the government and, preferably, it should be developed on a voluntary basis. The efforts of fisheries administrators and extension officers must be directed to the development of such a system, before intensive specific research is done. The combination of catch statistics and an efficient and up-graded monitoring programme is a pre-requisite for the future management of the fisheries, including the essential evaluation of management objectives which has still to be formulated.

References

Beattie, D.M., 1982. Distribution and production of the larval chironomids populations in Tjeukemeer. Hydrobiologia. 95: 287-306.

Densen, W.L.T. van, 1983. Fish ecological studies in Tjeukemeer and fishery management. Hydrobiol. Bull. 17: 59-65.

Densen, W.L.T. van, 1985. Feeding behaviour of major 0+ fish species in a shallow, eutrophic lake (Tjeukemeer, The Netherlands). Z. f. angew. Ichthyol. 1: 49-70.

Densen, W.L.T. van, 1990. Structure for the decision-making process in inland fisheries management. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries, Pudoc, Wageningen, The Netherlands. pp. 301-312.

Densen, W.L.T. van & Klein Breteler, P.H.M., 1985. De stand aan 0+ vis in het Friese merengebied. Visserij. 38: 306-313.

Densen, W.L.T. van & Vijverberg, J., 1982. The relations between 0+ fish density, zooplankton size and the vulnerability of pikeperch, *Stizostedion lucioperca*, to angling in the Frisian lakes. Hydrobiologia. 95: 321-336.

Goldspink, C.R. & Banks, J.W., 1975. A description of the Tjeukemeer fishery together with a note upon the yield statistics between 1964 and 1970. J. Fish Biol. 7: 687-708.

Groot A.T. de & Haasteren, L.M. van, 1979. Samenvatting provinciale informatienota's sportvisserij. Direktie van de Visserijen. Ministerie van Landbouw en Visserij. Den Haag. 40 pp.

Lammens, E.H.R.R., 1986. Interactions between fishes and the structure of fish communities in Dutch shallow, eutrophic lakes. PhD thesis. Agricultural University Wageningen. 100 pp.

Lammens, E.H.R.R., 1987. The change in the fish stock in Tjeukemeer after the re-allocation of fishing rights in 1977. Onze Zoetwatervisserij 1987. 3: A1-A7. (in Dutch).

Lammens, E.H.R.R., Nie, H.W. de, Vijverberg, J. & Densen, W.L.T. van, 1985. Resource partitioning and niche shifts of bream (*Abramis brama*) and eel (*Anguilla anguilla*) mediated by predation of smelt (*Osmerus eperlanus*) on *Daphnia hyalina.* Can. J. Fish. Aquat. Sci. 42: 1342-1351.

Nie, H.W. de, Bromley, H.J. & Vijverberg, J., 1978. Distribution patterns of zooplankton in Tjeukemeer, The Netherlands. J. Plankt. Res. 2: 317-334.

Nie, H.W. de & Vijverberg, J., 1985. The accuracy of population density estimates of copepods and cladocerans, using data from Tjeukemeer (The Netherlands) as an example. Hydrobiologia. 124: 3-11.

Vijverberg, J. & Densen, W.L.T. van, 1984. The role of the fish in the foodweb of Tjeukemeer. Verh. Int. Ver. Limnol. 22: 891-896.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp.372-381.

Education for fisheries managers in The Netherlands

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Abstract

The number of people actively involved in fisheries management in The Netherlands is approximately 7000. Most of them are working on a volunteer basis in charge of organizations of sport fishermen, but in addition some 300 commercial fishermen and a few hundred staff-members of governmental agencies and organizations for nature conservation are involved in managing fish stocks.

Until 1978 no structural education was available for fisheries managers. In that year the OVB founded its education department. Since then an educational programme on different topics in fisheries management was developed.

This paper presents a survey of the educational programme for fisheries managers in The Netherlands. Further, the results achieved with this education and a short outlook for the future are discussed.

1. Introduction

The Organization for the Improvement of Inland Fisheries (OVB) was founded in 1952 by Dutch Fisheries Law. The OVB is a target-organization, which means that the organization works for those who pay their annual 'contribution for the improvement of inland fisheries'. Every angler above the age of 14 and every commercial fisherman is obliged by law to pay this contribution. The number of recreational fishermen who paid their annual contribution was over 1 million in 1978 and 605 000 in 1987. The number of professional fishermen is about 600.

The aim of the OVB is to improve the prospects for both recreational and professional fisheries in all inland waters. This is done by educational activities, fisheries research and the production of fish for stocking purposes.

The total surface of inland fishing waters is approximately 350 000 ha (van Haasteren & de Groot 1982), and individual water bodies range from very small (0.5 ha, mainly in the southern part of the country) to very large (Lake IJssel, 200 000 ha). The number of fishery management units in The Netherlands is estimated at 5000.

Since 1973 government policy has been to divide fishing rights so that the right to fish for predator species (pike, perch and pikeperch) and coarse fish, except eel and tench, is reserved for anglers. The right to fish for eel and tench is reserved for commercial fisherman (Steinmetz 1990). However, all fishing rights in Lake IJssel are allocated to professional fishermen.

Apart from Lake IJssel, the total surface of inland waters amounts some 150 000 ha. On these waters, sport fisheries management is performed by about 800 boards and management committees of organizations of sport fishermen (angling clubs and federations). They have fishing rights on 93 000 ha of inland waters (van Haasteren & de Groot 1982). The surface area over which commercial fishermen (about 300 persons; mainly working in 1 or 2 man companies) practise fisheries management is estimated as 100 000 ha, excluding Lake IJssel. In addition, a few hundred staff members in water authorities and organizations for nature conservation are involved in the management of fish stocks. The water area which they are concerned with, in a management capacity, is not known.

Until 1978 information and education on the management of fishing waters was provided by the Ministry of Agriculture and Fisheries. In that year these information tasks were divided into:

1. Supply of specific information concerning concrete management problems of separate fishing waters. This information task was continued by the Ministry of Agriculture and Fisheries.
2. Education of fisheries managers concerning the general theories and principles of fisheries management. This educational task was appointed to the OVB.

This paper surveys the educational programme set up for fisheries managers in The Netherlands, together with the results it has achieved and a short outlook for the future.

2. Theoretical basis for education

In designing the educational programme for fisheries managers some general principles were observed, notably:

1. The educational needs of fisheries managers were surveyed. This principle, originating from marketing theories (Kotler 1975) most certainly applies to education in fisheries. Using the educational needs, information can be offered in terms of solutions to problems that already exist among fisheries managers. This increases the uptake of information (Berlo, Lemert & Mertz 1969, Atkin 1973). Data on this issue were collected by a questionnaire circulated in 1978 and to keep it up-to-date questionnaires are now circulated every 5 years. In addition, further data on educational needs are provided by an advisory committee with representatives of the national organizations of sport and commercial fishermen.
2. The objective for fisheries management education is directed to practical fish stock management. So this education must ultimately lead to changes in behaviour.
3. The effect of education can be substantially increased by using a combination of information techniques (Bouchet 1973). This multi-media approach requires understanding of the objectives that can be achieved with each separate information technique (Schramm 1977).
4. The total group of fisheries managers in The Netherlands amounts to some 7000 people. Total coverage of this group is only possible by using mass media. These information techniques have the disadvantage that their effects are mostly limited to the transfer of knowledge. When changes in attitude and behaviour are required, more persuasive information techniques are needed (Fishbein 1977, van der Vlist 1981). To achieve this, interactive processes in small groups are essential (Lewin 1943) as well as learning by doing (Westmaas-Jes 1977).

5. Fisheries managers in the boards and managing committees of angling clubs must obtain approval for their management plans from their club members. In order to obtain this approval, club members must be persuaded that the plans are good. Thus fisheries managers must be trained to inform, explain, and persuade (Fazio & Gilbert 1982).

3. Social aspects of fisheries management

With respect to the theoretical basis mentioned above, the educational programme for fisheries managers is arranged as shown in *Table 1*. As can be seen from this table it is not only fisheries managers who must be informed, but also the ordinary people in their social environment. If not, then education can lead to an increase of knowledge, without changes in attitude and practical management behaviour, because of rejection in the social environment (Rogers 1982). So the members of angling clubs, being the social environment of sport fisheries managers, must be informed about management plans. After all it is the opinion of the club members that ultimately decides the management possibilities.

Table 1. Objectives, information methods and target groups in education for fisheries management.

Objective	Information methods	Target groups
Transfer of knowledge	Magazine 'OVB-Bericht'	Fisheries managers Government agencies (water authorities)
	Leaflets (15 subjects)	Fisheries managers Angling club members General public
	Paper clippings (for children)	
	Circulation of audio-visual aids film/video panel boards slide series	
	Copy for newspapers and sport fishing magazines	
Change in attitude	Courses for small groups (15-20 persons)	Fisheries managers
Change in behaviour	Courses for small groups (15-20 persons)	Fisheries managers

Also the opinions of the general public influence what fisheries managers can and cannot do. This applies, for instance, to the use of piscicides. These could be very useful in fisheries management, but in The Netherlands the general public is universally against it. Thus, educational information on fisheries management should be mainly directed to fisheries managers (using specialist magazines such as 'OVB-BERICHT', and courses), but the basic points of this information should also be directed to club members (using information leaflets and notices) and the general public (using newspapers, sport fisheries magazines and films/videos).

In the social environment of fisheries managers, staff of governmental agencies, *e.g.* water authorities, are becoming increasingly important. This is mainly caused by the results of recent research concerning the relationships between fish stocks and water quality. This has lead to the development of bio-manipulation techniques in water quality management. The use of these techniques may have far reaching consequences for decision making in fisheries management, because non-fisheries interests will possibly intervene with the freedom of decision making for fisheries managers. So in fisheries management education attention must be paid to water authorities and other governmental agencies (Raat 1990).

4. Separate modules

Let us now consider the separate modules of the OVB educational programme for fisheries managers (see also *Table 1)*.

The magazine 'OVB-BERICHT'

This magazine gives practical information about fish, water and fish stock management in The Netherlands. It is issued four times a year and has a total circulation of 7000 copies.

Information leaflets

At this time the OVB has 15 different information leaflets available, mostly dealing with different fish species, *e.g.* pike *(Esox lucius)*, carp *(Cyprinus carpio)*, grass carp *(Ctenopharyngodon idella)*, perch *(Perca fluviatilis)*, rudd *(Scardinius erythrophthalmus)*, roach *(Rutilus rutilus)*, eel *(Anguilla anguilla)*, rainbow trout *(Salmo gairdneri)* and ide *(Leuciscus idus)*. Fisheries managers can request these leaflets to distribute among angling club members or the general public, in order to get approval for their management plans.

A special kind of information leaflet is made for children. These are 'clipping papers' for use in the last forms of comprehensive schools and the lower forms of secondary schools. Material concerning fish species, fish growth and development, and fish anatomy, has already been developed for this purpose. A complete educational set, enclosing materials and instructions for several lessons, will be presented during the autumn of 1988.

Notice boards and posters

For circulation to fisheries managers the OVB designed posters (panel boards) dealing with different inland fisheries topics *e.g.* lake and river restoration, fish species recognition, salmonid enhancement in The Netherlands, fish habitat improvement and the use and importance of aquatic plants in fisheries management.

Films

The OVB has produced three educational films on fisheries management. These films are lent to fisheries managers to show to club members.

Courses on fisheries management

This is the most important part of the OVB educational programme. A survey of these courses is given in *Figure 1*. The courses are held at the OVB fish farm at Lelystad, with exception of the practical courses. These are held at different locations over the country. OVB courses on fisheries management are held in small groups, *e.g.* 15 to 20 persons. This size of group has proved most effective for the transfer of knowledge and for promoting changes of attitude and behaviour. Practical demonstrations are given on every course and involve the class members.

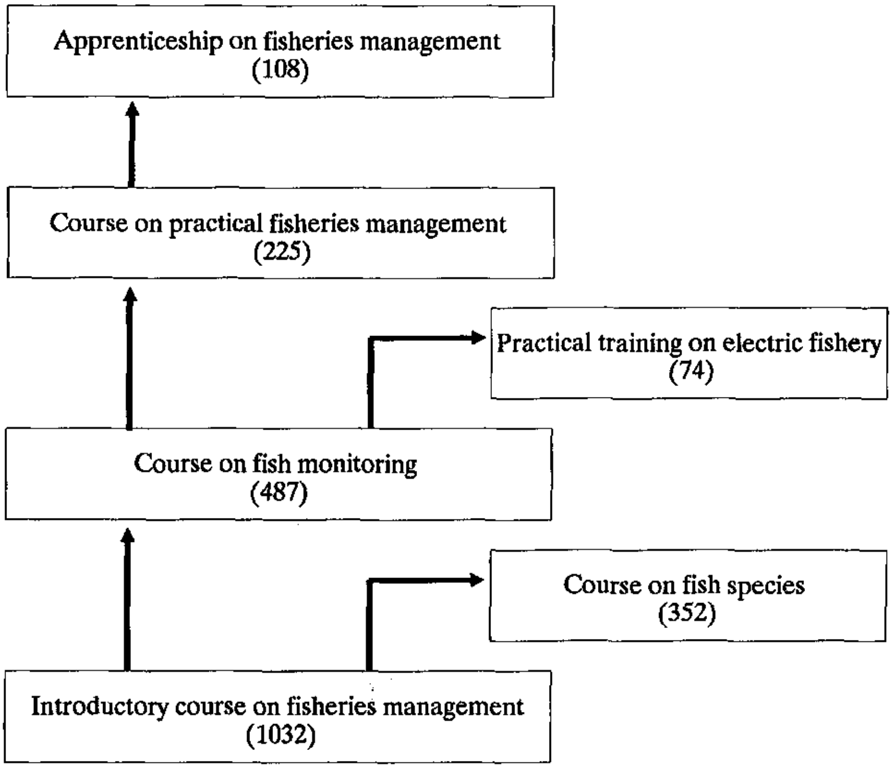

Figure 1. OVB courses on fisheries management. Number of participants in each course given in brackets.

5. Course programmes

The courses shown in *Figure 1* have the following programmes:

Introductory course (since 1980)

This course provides a first acquaintance with fisheries management and simply illustrates the scope of the subject. Attention is paid to the relationship between the densities of fish stocks and the possibilities for their growth. Also the social context of fisheries management is illustrated.

After the Introductory course, continuation courses provide opportunities to obtain qualifications in separate subjects. However, participation in the introductory course is a pre-requisite for these other courses.

Course on fish monitoring (since 1983)

This course surveys monitoring techniques (seine, trawl, fyke nets, anglers survey, electric fishery and mark and recapture techniques). It clearly shows that different kinds of waters and fish species have to be monitored with different types of fishing gear. Also, directions are given for passing information on monitoring to club members and the general public.

Course on fish species (since 1984)

Participants are taught to recognize indigenous Dutch freshwater fish species. In addition, the management of the fish species that are important for inland fisheries is discussed. Participants are trained to inform members of angling clubs about fish recognition and fish behaviour. For this purpose a field guide and a slide series covering all Dutch inland fish species is available.

Practical training on electric fishing (since 1987)

In The Netherlands electric fishing is bound by several legal regulations. The use of this method is restricted to properly trained fishermen. The OVB developed a practical training course on electric fishery during which safety rules are taught.

Course on practical fisheries management (since 1987)

The development of plans for fisheries management is the main subject of this course. This is done by the participants answering an extensive series of multiple choice questions. The mechanism of self-programmed instruction is built into these questions. Data on fish stocks have to be translated into management plans, and environmental parameters have to be incorporated. In this course, directions for transferring information to club members and the general public are also given. Participation on this course is only permitted after the course on fish monitoring has been completed.

Apprenticeship on fisheries management (since 1988)

This is the ultimate step in the OVB course programme. Here fisheries managers have to deal with the problems of how to collect facts and figures concerning the management of fishery waters and fish stocks. Therefore the OVB has selected three fishery waters, spread over the country, as training areas for fisheries managers. Here they can practice under the supervision of OVB staff members. These apprenticeships take one year. Afterwards fisheries managers can turn to support teams with questions which may have arisen during their apprenticeship. In these teams OVB staff members co-operate with staff members of the national organizations of sport and commercial fishermen.

6. Results

A thorough evaluation of educational activities is a major principle for the OVB. In this context regular evaluation enquiries are held, mostly by questionnaires. The results of these evaluations give rise to the following conclusions:

Magazine

- The magazine 'OVB-BERICHT' has been published for 10 years now. In this time it has become an established information source for fisheries managers.

Information leaflets

- Some 190 000 information leaflets have been distributed on request since 1980. These are mainly used to inform angling club members.
- About 115 000 information leaflets for children have been distributed on request since 1986. They are very much appreciated by teachers for biology lessons.

Posters and films

- The OVB posters and films are widely used by fisheries managers to inform angling club members and the general public.
- The OVB films are shown to about 10 000 people each year. Fisheries managers appreciate the circulation of these items in support of their managerial activities.

Courses

- The number of participants in the OVB courses is shown in *Figure 1*. The majority originate from sport fisheries organizations, but commercial fishermen and staff members of water authorities and organizations for nature conservation also take part. The mixed composition of the groups appears stimulating, and promotes mutual understanding between different groups of water users.
- The average age of fisheries managers who participated in OVB courses is 42. This is much younger than the average age of all Dutch fisheries managers. So it seems that the OVB courses are most attractive to the younger managers.
- To date, some 30% of all sport fisheries managers in The Netherlands have participated in OVB courses. However, this does not fairly reflect the influence of the OVB since the 30% who attended courses in fact manage 70% of all the inland waters where sport fishermen have angling rights.
- Of the participants who undertook the course, 45% obtained many new ideas, 47% a reasonable number of new ideas, while only 8% took just 'a few' new ideas away.

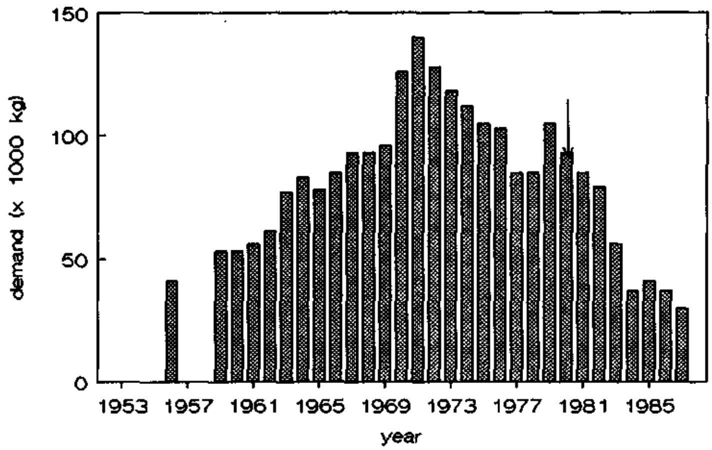

Figure 2. Demand for carp (*Cyprinus carpio*) for stocking purposes in The Netherlands. ↓ First introductory course given in 1980.

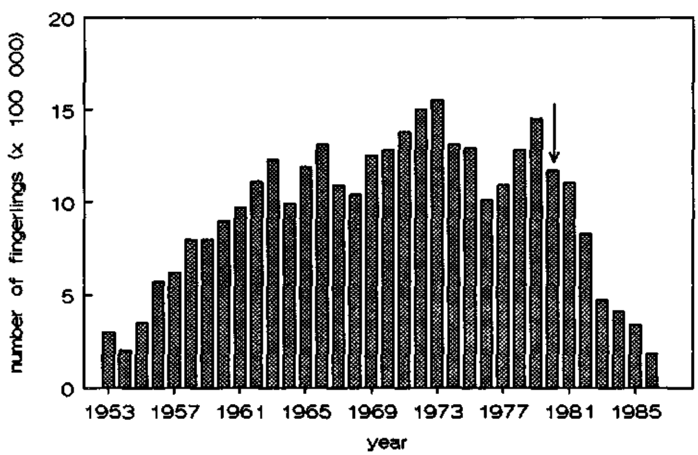

Figure 3. Demand for northern pike fingerlings (*Esox lucius*)for stocking purposes in The Netherlands. ↓ First introductory course given in 1980.

7. Effects

A question which arises is, do the new ideas that fisheries managers get from OVB courses result in new managment practices? To check this, figures for the demand for OVB fish for stocking purposes have been gathered.

In *Figure 2* the demand for carp *(Cyprinus carpio)* for stocking is shown. Note that in 1980 the first introductory course was held. Here in nursery ponds the relation was shown between carp stock densities and the possibilities for the growth of these carp. From that time on fisheries managers became aware of the small growth in dense carp populations and as they mostly prefer large carp, stocking densities of carp fell dramatically.

Figure 3 shows the demand for northern pike fingerlings *(Esox lucius)* for stocking. Note that, in the introductory course (first held in 1980), the results of the OVB research on pike were presented. It was shown that stocking pike fingerlings does not result in denser populations of bigger pike. From that moment onwards a sharp fall in pike stocking figures occurred.

In *Figure 4* the demand for ide *(Leuciscus idus)* for stocking purposes is shown. This species has been produced by the OVB since 1985. It grows much faster than roach *(Rutilus rutilus)* and is also much stronger. So since 1985, ide has been recommended in OVB courses as a good alternative to roach, especially in the heavily fished small ponds of the southern part of the country. As can be seen from *Figure 4*, the amount of ide for stocking purposes has risen considerably.

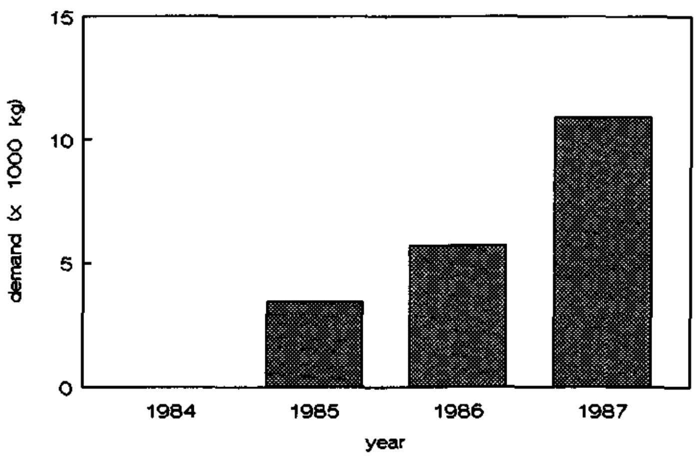

Figure 4. Demand for ide (*Leuciscus idus*) for stocking purposes in The Netherlands.

From the foregoing it can be concluded that the OVB education programmes for fisheries managers have had a substantial impact on practical fisheries management in The Netherlands. With the inception of the apprenticeship scheme for fisheries managers the impact of OVB education can be expected to increase.

References

Atkin, C.K., 1973. Instrumental utilities and information seeking. In Clarke, P. (Ed.). New Models for Mass Communication Research. Sage, Beverly Hills. pp. 205-239.

Berlo, D.K., Lemert J.B. & Mertz R.J., 1969. Dimensions for evaluating the acceptability of message sources. Public Opinion Quarterly. 33: 563-576.

Bouchet, H., 1973. Télépromotion rurale, six années d'expérience (Rural Promotion on Television, Six Years of Experience). Télépromotion Rurale Ouest, Rennes. 53 pp.

Fazio, J.R. & Gilbert,D.L., 1982. Public relations and communications for natural resource managers. Kendall/Hunt, Dubuque, Iowa. 375 pp.

Fishbein, M., 1977. Consumer beliefs and behaviour with respect to cigarette smoking: a critical analysis of the public literature. University of Illinois, Illinois. 113 pp.

Haasteren, L.M. van & Groot, A.T. de, 1982. Summary of the provincial analysis of the demand for and the supply of facilities for sport fishing. In: Grover, J.H. (Ed.). Allocation of fishery resources. FAO. American Fisheries Society. pp. 468-479.

Kotler, P., 1975. Marketing for non profit organizations. Prentice Hall Inc., Englewood Cliffs, N.J. 436 pp.

Lewin, K., 1943. Forces behind food habits and methods of change: the problem of changing food habits. National Research Council Bulletin, Washington. 108: 35-65.

Raat, A.J.P., 1990. Fisheries management: a global framework. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries. Pudoc. Wageningen. pp. 344-356.

Rogers, E.M., 1982. Communications of innovations. The Free Press, New York. 476 pp.

Schramm, W., 1977. Big media, little media. Sage, Beverly Hills. 315 pp.

Steinmetz, B., 1990. Fisheries management of the twenthe canals, The Netherlands. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries. Pudoc. Wageningen. pp. 357-364.

Vlist, E. van der, 1981. De Dynamiek van Sociale Processen. (The Dynamics of Social Processes). Samson, Alphen aan den Rijn.

Westmaas-Jes, M., 1977. Naar Strategieën van Voedingsvoorlichting. (To strategies for food education), Ph.D. thesis Wageningen, Agricultural University Wageningen, Wageningen. 196 pp. (in Dutch).

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 382-389.

Management of Arctic charr *(Salvelinus alpinus* L.*)* and brown trout *(Salmo trutta* L.*)* fisheries in Lake Tunhovdfjord, a Norwegian hydroelectric reservoir

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Abstract

Fishery investigations in Lake Tunhovdfjord commenced in 1917, two years before impoundment. Between 1919 and 1920 the water level rose and the area of the lake increased from 1425 to 2535 ha. In the early years the emphasis of the investigations was on the study of food conditions for fish. Later, interest centred on year class fluctuations, recruitment and migrations, growth rates and yields, and fisheries *per se*. Originally brown trout were the only fish present, but charr and minnow were introduced. Charr is now the most important species constituting 90% of the total catch with annual average yields of some 2.7 kg/ha. Between 47 000 and 158 000 individuals are landed each year, of which approximately 82% are caught in winter by angling through the ice. The total number of visits by anglers varies from 5000-6000 day visits during the winter fishing season, which is high by Norwegian standards. There is a close relationship between hydrology, charr recruitment, migrations and yield.

A combined effect of impoundment and the introduction of charr was a change in the diet of the trout, from one in which benthic organisms were predominant to one in which small charr were predominant. After this the maximum weight of trout increased from 3 to 16 kg. The trout population is largely maintained by natural spawning, but there is some stocking with hatchery-reared juveniles of the local strain. Some 28 500 summerlings are released annually and about one third of the total trout catch derives from fish that have been stocked. In all, 790 000 juveniles have been tagged or fincut. Trout fishing is regulated as to time of year, place of fishing, gear permitted and the size of fish that may be taken, but there are few restrictions on charr fishing.

1. Lake Tunhovdfjord

This lake is situated in southern central Norway in the upper part of River Numedalslågen *(Figure 1)*. The natural catchment is 1809 km^2 providing a mean inflow of 42 m^3/sec. In 1968 three small rivers were diverted to the lake by tunnels, increasing the catchment by 27 100 ha. Originally Lake Tunhovdfjord consisted of three basins, one large and two small, connected by short rapids. In 1919-1920 a dam across the outlet raised the lake level by 18 m and the surface now fluctuates between 718-736 m above sea-level. At the same time, the rapids were canalized forming narrow sounds at low water. In 1946 a dam was erected across the inlet, and the impounded Lake Pålsbufjord, situated immediately above it, was drained into Lake Tunhovdfjord by a tunnel and bottom gates in the dam. Lake Tunhovdfjord's own catchment is small and receives only short streams. The lake is typical of the many Norwegian reservoirs situated just below treeline. The fisheries have been monitored for many years, and the River Numedalslågen, including the lakes Tunhovdfjord and Pålsbufjord, is listed as a research and reference watercourse by the Royal Norwegian Council for Scientific and Industrial Research.

For a long time brown trout *(Salmo trutta* L.) was the only fish present, then, in about 1915, minnows *(Phoxinus phoxinus* L.) were introduced by anglers. In 1910 a mountain lake, 45 km upstream, was stocked with charr fry *(Salvelinus alpinus* L.) and this species established itself in Lake Tunhovdfjord during the early 1920s. Several hundred holiday cabins are scattered between two clusters of small mountain farms bordering the lake. Settlement has not altered the lake's oligotrophic character.

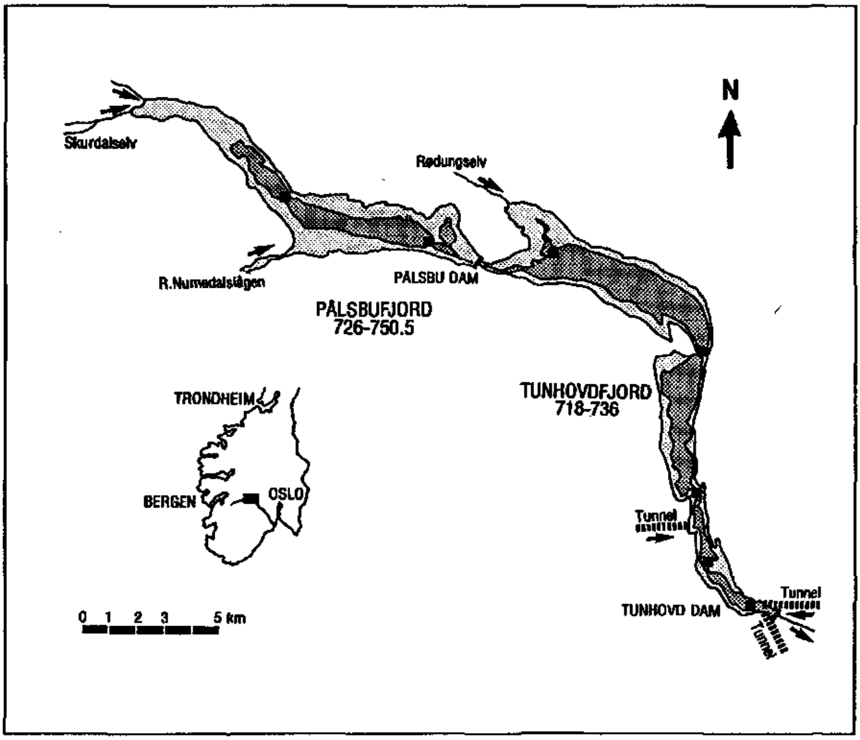

Figure 1. Lakes Tunhovdfjord and Pålsbufjord. Lines indicate areas at maximum and minimum water levels, and rectangles indicate locations for ice-fishing.

2. Fishery investigations

Research was started by Dahl in 1917, two years before the water level rose. Both Dahl (1926) and Huitfeldt-Kaas (1935) were concerned mainly with the fish food situation, and both included the neighbouring Lake Pålsbufjord in their studies for comparison. They found that the yield of trout was substantially reduced after impoundment, apparently due to a reduction in both the numbers of species and individuals of larger benthic organisms. The trout failed to compensate for this lost food source by increasing their intake of plankton.

After 1945 the food studies were resumed. The reduction of available bottom food had continued, although Grimås (1964) found that inundated forest vegetation housed a considerable insect fauna. However, there is now extensive predation of charr by trout (Aass 1973). More recent studies have dealt with the recruitment of charr and its relation to water level fluctuations (Aass 1964), and the importance of migrations on seasonal and total yields of charr (Aass 1970, 1984a). Over the last 30 years, stocking experiments, which involved the use of 790 000 fincut or Carlin-tagged juveniles, were carried out to assess the relative importance of different factors to the fishery. Factors considered included strain of fish, size and age of fish at time of release, stock density achieved and nature of release site. These experiments are still in progress.

3. Charr fisheries

Charr moved downstream to Tunhovdfjord during the first decade (1919-1929) after impoundment. Initially the supply of plankton and semi-planktonic crustaceans was abundant, the charr population was small and thus growth rate was fast. Gradually however, the impounded forest floor was transformed into a barren zone of sand, gravel and stones, with reduced levels of bottom food production. However, this increased the spawning area available to the charr. Thus the charr population increased concomitantly with a decrease in availability of food so that a dense population of stunted charr developed. Spawning charr have averaged just 90-110 g in weight and 20-22 cm in length for some years now.

The small size of the charr has thus become the major management problem, and no obvious solution exists. Except at spawning time the fish is red-fleshed and delicate in flavour, but the local market can only absorb a limited quantity of fresh, frozen or salted charr. Selling the catch outside the district is difficult, because it is a very common species in this part of Norway and production of small-sized charr exceeds demand. Theoretically, an increase in size can be achieved either by reducing recruitment or by increasing exploitation. For the time being, there is no strong case for the latter alternative.

The fluctuating water level has a pronounced effect on recruitment of charr. Eggs and fry in the impounded area may be left dry and frozen by the winter draw-down. The magnitude of the loss increases with the speed and vertical extent of the lowering, and the strength of the year classes varies accordingly. This phenomenon is even more conspicuous in Pålsbufjord (Aass 1984a). However, the present policy of reservoir management is to lower Tunhovdfjord as slowly and as late in the season as possible, thus promoting the hatching success of the charr. Experience shows, however, that a high initial mortality rate has only a small effect on the size of the adult fish.

The situation in Pålsbufjord reservoir (24.5 m regulation height) has been unaltered for many years. In winter the water surface is reduced from 1950 to 525 ha. A new regime of rapid and complete drainage was begun in the 1970s, and now nearly all stony spawning places are laid dry, leaving a central soft-bottomed basin. Recruitment of charr suffers because of the extensive freezing of eggs and the present annual yield is only about one-third of what it is in Tunhovdfjord. Despite this, the average spawning fish is 24-26 cm long and weighs 160-180 g, *i.e.* 60-70 g more than in Lake Tunhovdfjord. Nowadays the charr do not grow to predator size and thus do not reduce the number of recruits directly in either of the lakes, as was the case during the early years of impoundment. For small unimpounded charr lakes, Langeland & Jonsson (1990 - this volume) suggest the use of small-meshed gill-nets as the best management procedure for securing an improved growth rate. It is however, doubtful whether a mainly plankton-producing reservoir will give rise to a fair-sized charr stock.

In most lakes with sympatric charr and brown trout populations, a few trout become predators of charr. The change to a fish diet is more pronounced in reservoirs than lakes because of the effects of reduced benthic production and the increased numbers of small-sized charr. Lake Tunhovdfjord offers perhaps the best example of a brown trout population totally dependant on charr, since in it, trout greater than 25-30 cm in length, feed almost exclusively on charr. Smaller trout consume the juvenile, benthic, 0+ and 1+ charr, while larger trout take adult pelagic charr. Consequently, maximum trout weight has increased from 2-3 to 16 kg over a period of 30 years. A rough estimate indicates that about 3-4 kg charr/ha is consumed yearly. Stocking may contribute to the maintenance of the trout population and thus the predation pressure, but the effect on charr growth seems to be small.

Drowned vegetation renders traditional fishing with bottom nets time-consuming and expensive. Netting areas still have to be cleared of drifting debris and roots, and fishing is concentrated in spawning areas. The use of floating nets for a summer fishery of pelagic charr has started in recent years. The quality of the fish flesh is then at a peak, and the charr are marketed at the right time, *i.e.* when tourists and cabin dwellers are present. Still, floating nets account for only a minor portion of the charr netted, and local fishery authorities need to encourage their use.

Fishing with jigs and baited spoons from the ice has grown to be the most important charr fishing technique on Tunhovdfjord. This technique accounted for 63.8-93.7% of the total number of fish caught between 1961-1980, with an annual average of 81.7% (Aass 1984a). At the same time activity moved from shallow, sheltered bays to deep water. Emptying of the reservoir starts a passive downstream drift of charr, which involves a major part of the adult population. Their movement is however, interrupted in the narrow, canalized sounds when the current becomes perceptible to the fish. The charr then remain in the sounds for the rest of the winter, and are eagerly fished for. The number of visits by anglers used to be 5000-6000 each winter (Aass 1970), but recent observations show a small decline. Both the extent of migration, and exploitation rate, are influenced by the rate of outflow, but in this matter the interests of fishing and power production are not always compatible.

When the water level rises in spring the charr no longer keep to the currents and commence feeding migrations along the shores, mainly towards the dam. Many leave the lake. Most move down the tunnel leading to the power station and are lost from the fishery. In years with a greater than average spring flood the reservoir is also drained by the bottom gates. A small proportion of the migrating fish leave this way and are easily harvested when they stop in the pools below the dam. Because most go through the tunnel it is difficult to assess the number of charr leaving Lake Tunhovdfjord. However, it has been estimated that the annual emigration of charr from Lake Pålsbufjord, in the years 1962-1968, included 11-33% of the adult population. The emigration rate depends upon discharge rate, gate aperture and water level, and it is thus possible to control it (Aass 1973).

For more than 25 years the charr catch in Lake Tunhovdfjord was recorded with the help of local anglers who were paid for the task. Data for effort and harvest were collected on the spot throughout the season from all the main ice-fishing places marked on *Figure 1.* Gill-net catches were reported by the fishermen themselves, but frequent checks were made to validate their figures.

The annual charr catch was estimated as 1.7-4.6 kg/ha during the period 1961-1980, with an average of 2.7 kg/ha *(Table 1).* These figures are based on the water surface at its highest regulated level. If the lowest level is used, the average yield is 4.8 kg/ha. Roughly estimated, the weight of charr removed from Tunhovdfjord by fishing, predation and emigration, is about 9-10 kg/ha/yr (maximum level). Possibly this yield could be increased at the expense of emigration, but this requires collaboration between fishery and power production interests.

Table 1. Estimated annual yield of charr in Lake Tunhovdfjord during 1961-1980 (after Aass 1984a).

Year	Numbers				Yield
	Winter		Summer/ Autumn	Totals	
	Current zones	Still water zones			kg/ha
1961	59 900	7 300	12 500	79 700	3.1
1962	44 650	6 100	10 000	60 750	2.4
1963	34 050	5 050	8 000	47 100	1.7
1964	36 900	7 600	6 900	51 400	1.8
1965	47 700	10 600	9 300	67 600	2.0
1966	73 800	12 500	7 500	93 800	2.5
1967	71 100	14 600	5 800	91 500	2.5
1968	59 250	22 800	10 900	92 950	2.6
1969	65 950	19 100	12 600	97 650	2.8
1970	51 950	11 200	22 600	85 750	2.9
1971	65 300	11 700	21 500	98 500	3.5
1972	37 450	10 300	27 100	74 850	2.9
1973	32 800	13 500	17 100	63 400	2.5
1974	38 950	21 100	9 700	69 750	1.7
1975	45 850	27 200	16 200	89 250	2.2
1976	58 150	27 500	20 350	106 000	2.9
1977	72 800	18 200	26 100	117 100	3.3
1978	101 850	18 400	38 000	158 250	4.6
1979	71 500	14 550	16 100	102 150	2.9
1980	81 750	20 850	29 000	131 600	3.1

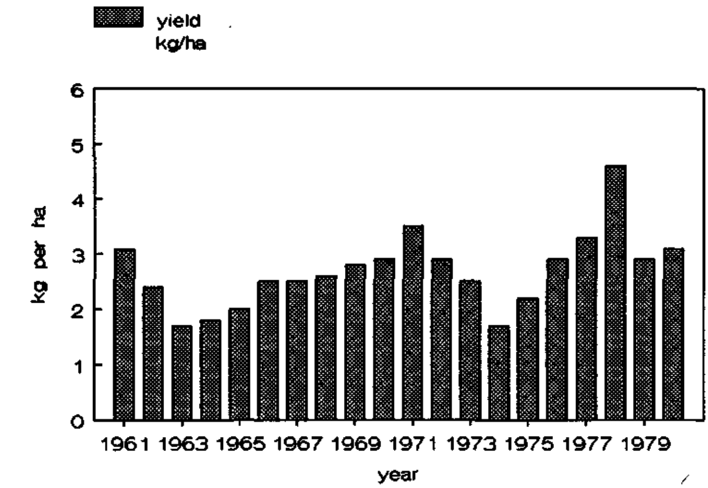

Figure 2a. Estimated annual yield of charr, 1961-1980.

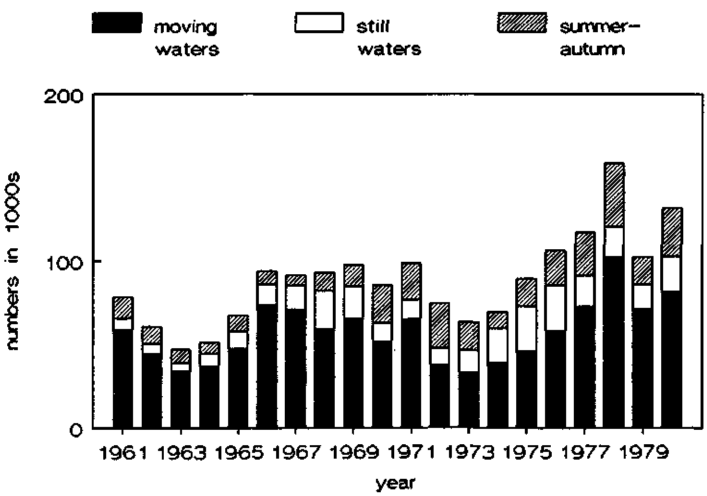

Figure 2b. Estimated annual yield of charr, 1961-1980.

4. Trout fisheries

Trout are harvested mainly by gill-nets set in the littoral zone; only a few are caught by trolling with spoons. The pre-impoundment yield may have been of the order of 2-2.5 kg/ha/yr (Dahl 1926), but after the introduction of charr, the trout yield decreased sharply, although the proportion of large fish increased. In the late 1960s, monofilament salmon nets, with mesh sizes of 60-70 mm, were introduced. Large trout weighing over 3-5 kg were then heavily exploited and their numbers drastically reduced. The annual catch of trout is now estimated to be 0.3 kg/ha.

With the construction of dams in both inlets and outlets, and canalization of the currents between the different basins, the traditional spawning and nursery grounds of trout were reduced almost to nil. To compensate, the power company was instructed to stock the lake with hatchery-reared fingerlings of the local strain. Spawning females are caught while migrating upstream towards the Pålsbufjord dam. Annual stocks amount to 28 500 0+ fingerlings. Occasionally 0+ fish have been replaced by older fish with the intention of compromising between stocking price and survival. Since it seems sensible to try to reduce the period between release and diet change, full-scale stocking experiments with 2 year old fish will be carried out. The current prices of juveniles are approximately 3,7,10 and 15 Norwegian kroner for 0+, 1, 1+ and 2 year old specimens respectively. To this the costs of transport and stocking must be added.

During the years 1959-1987 a total of 790 000 young fish were released, all fincut or Carlin-tagged. In the early years, reared fish provided 33-36% of the trout yield, but more recently the proportion has varied between 25-45%. This is an astonishingly low proportion, considering the possibilities for natural recruitment presumed. Even though the total trout stock is small, it is difficult to explain how wild fish can dominate the population. Downstream migration from the even less productive Pålsbufjord cannot explain this phenomenon.

Food production suitable for young trout is negligible, but for large trout the stunted charr population provides surplus food. Increasing the number of trout in the predatory stage is an important management task. Fry production probably cannot be altered much so the solution is to improve the survival rate of young fish, but it is difficult to see how this can be accomplished in a lake with few resources remaining. It has been suggested that shallow bays should be fertilized and planted with macrophytes which tolerate fluctuating water levels, such as *Ranunculus reptans*. However, even if remedial measures are successful, increased food production will be shared with minnows and small charr, and the extent to which trout will benefit is not clear. More could possibly be achieved by manipulating the stocked fish. At present only 2-4% of the 0+ fingerlings released are recaptured, even if they are scattered in the most shallow and fertile parts of the lake. This utilises about 300-500 kg/juveniles/year. The recapture rate grows with increasing release size, but so do the costs of stocking (Aass 1984b). Taking these into consideration, it appears that 1+ stock may be most cost effective.

5. Fishing regulations

The landowners are organized into two fishery organisations, one for each half of the lake. Only landowners are allowed to use nets. Anglers pay a small licence fee, and the income is used to enhance the fish stock, by supervision, catching spawning females, stocking, collection of fishery statistics and sampling. Angling for charr is allowed year round, and no mesh size regulations exist for fishing with floating or bottom nets at charr spawning sites. While exploitation of charr is encouraged, attempts are made to protect trout stock, aimed at saving both juveniles and the largest of predators. Netting is not allowed in July and there is also a closed season between September 15th and December 1st to protect the spawners. Nets are not allowed closer than 50 m to river and brook outlets. The minimum mesh size of gill-nets for trout is 40 mm measured from knot to knot, and the minimum allowable fish size is 30 cm. Introduction of a maximum mesh size to reduce the fishing pressure on large trout is also being considered. Rod fishing is the only type of fishing permitted in running waters.

References

Aass, P., 1964. Reguleringer og røyerekruttering. Jakt og Fiske. Oslo. 93: 378-381.

Aass, P., 1970. The winter migrations of charr, *Salvelinus alpinus* L., in the hydroelectric reservoirs Tunhovdfjord and Pålsbufjord, Norway. Rep. Inst. Freshw. Res. Drottningholm. 50: 5-44.

Aass, P., 1973. Some effects of lake impoundments on salmonids in Norwegian hydroelectric reservoirs. Acta Univ. Upsaliensis Abstr. Uppsala Diss. Sci. 234: 1-14.

Aass, P., 1984a. Management and utilization of Arctic charr in Norwegian hydroelectric reservoirs. In: Johnson, L. & Burns, B. (Eds). Biology of the Arctic charr. Proceedings of the International Symposium on Arctic charr, 277-291. Univ. of Manitoba Press.

Aass, P., 1984b. Brown trout stocking in Norway. EIFAC Technical Paper no. 42. Suppl. Vol. 1, 123-128.

Dahl, K., 1926. Untersuchungen im Tunhovdfjord über die Nahrungsverhältnisse des Fischbestandes vor und nach der Anstauung. Arch. Hydrobiol. 18: 85-98.

Grimås, U., 1964. Studies on the bottom fauna of impounded lakes in southern Norway (Tunhovdfjord, Pålsbufjord and Rødungen). Rep. Inst. Freshw. Res. Drottningholm. 45: 94-104.

Huitfeldt-Kaas, H., 1935. Der Einfluss der Gewässerregelungen auf den Fischbestand in Binnenseen. Nationaltrykkeriet Oslo. 105 pp.

Langeland, A. & Jonsson B., 1990. Management of stunted populations of Arctic charr *(Salvelinus alpinus)* and brown trout *(Salmo trutta)* in Norway. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries, Pudoc, Wageningen, The Netherlands. pp. 396-405.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 390-395.

Management conflicts arising from stocking brown trout *(Salmo trutta* L.*)* in Oslofjord, Norway

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Abstract

To enhance the game fish supply in Oslofjord, juveniles of sea trout and non-migratory trout have been stocked directly into the fjord without prior adaptation to salt or brackish water. The recapture rate of untagged non-migratory brown trout may exceed 50% but it is slightly less for sea trout. Results indicate that the value of fish meat recovered surpasses the cost of stocking. Economically, the results of stocking Oslofjord rank among the best in Norway, and they also benefit more anglers than any other fish releases. However, the strains used differ in viability, growth rate and migration pattern, and this leads to management problems. The management techniques for pure stocks of sea trout are not satisfactory for mixed populations of wild and reared fish. So far the results of the experimental stocking have not led to any changes in administration or biological approach to the fjord fisheries.

1. Oslofjord

The fjord is 100 km long and covers an area of about 120 000 ha. Of this, the inner basin comprises 20 000 ha and is separated from the outer part by a narrow sound *(Figure 1)*. The districts surrounding the fjord are densely populated. More than a quarter of Norway's total population resides close to the fjord, and thousands of holiday cabins are scattered in between the towns and urbanized areas. The density of leisure boats in the inner fjord is now 400 boats/km^2, and more than 150 000 boats are registered in the whole fjord.

Nowadays, few professional fishermen work in the fjord, but tens of thousands of recreational fishermen use both nets and hooks for gadiform species, herring *(Clupea harengus* L.*)* and migratory salmonids. Attempts have been made to enhance the fjord fisheries by stocking with new hatched cod *(Gadus morhua* L.*)* or small plaice *(Pleuronectes platessa* L.*)*, but without significant consequences. Release of salmon *(Salmo salar* L.*)* and trout juveniles could be a better approach to the problem.

Two large rivers empty into the outer fjord, but only a few small rivers and brooks run into the inner part. Some have been totally destroyed by urbanization and pollution. In the others the capacity for salmonid production is utilized by the local stocks, partly supplemented by hatchery-reared alevins. Thus the chances of increasing natural smolt production are limited. The enhancement of salmonid fisheries in Oslofjord must be based on smolt release either in the river mouths or directly into the fjord. The preliminary results of salmon stocking have been described by Hansen (1986) and those of brown

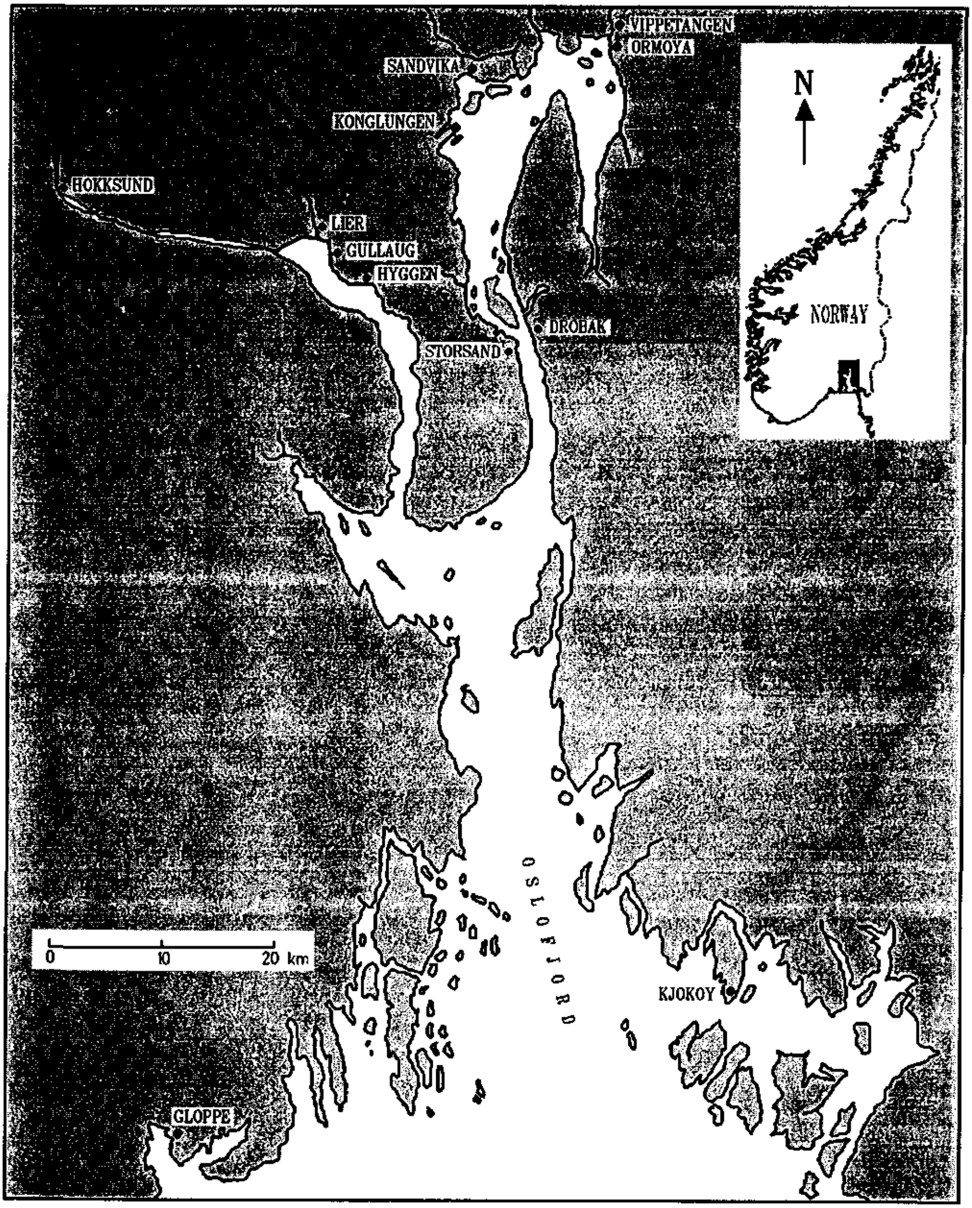

Figure 1. Oslofjord. Release locations are indicated by dots with names.

trout stocking by Aass (1982, 1988). Trout appear to be the best alternative, because most keep to the fjord system and are catchable locally during their whole life. Salmon are harvested mostly by professional fishermen during their return to the spawning river.

2. Results of trout stocking

The experiments include both migratory and non-migratory brown trout, rainbow trout *(Salmo gairdneri* Richardson*)* and brook charr *(Salvelinus fontinalis* Mitchell*)*. Fjord stocking started in 1973. Between this time and the end of 1985, 48 110 juveniles had been released in 86 batches. Of these, 22 355 were non-migratory brown trout, 14 515 were sea trout, 9 545 were rainbow trout, and 1 695 were brook trout. The mean length of the non-migrating species varied between 18.0 and 35.2 cm, while the corresponding figures for sea and rainbow trout were 19.4-28.7 and 15.1-30.5 cm respectively.

The legal fishing size is 30 cm. Juveniles were hatchery reared and Carlin-tagged. Age at stocking varied between 1 and 3 years, but most were two-year-olds. Except for a few control groups, all were released directly into the fjord without any acclimatization to salt or brackish water. The principal results can be summarized as follows:

Non-migratory trout of fish-eating, fast-growing strains, liberated close to the archipelagos in the fjord in spring, gave the best results. Untagged fish can be expected to give a return of 50-60% by number and 700-800 kg/1000 juveniles stocked. These figures are based on the recorded recaptures of tagged fish. To these are added the estimated number of recaptures not reported (40%) and the losses caused by tagging mortality.

On the same assumptions sea trout and rainbow trout give a return of 45-50% by number, but only 350 kg/1000 juveniles. The reasons for this are the slower growth of the sea trout and the short life-span of the rainbow trout.

A two year old brown trout juvenile weighing about 100 g costs 12-14 Norwegian kroner and a one year old rainbow trout of the same size, 7-8 kroner. To be on the safe side, we may put the production costs of the two categories respectively, as 15 and 10 kroner per fish. The value of fish flesh recaptured is about 50 kroner per kilo. Thus a return of 300 kg/1000 juveniles balances the cost of stocking both forms of brown trout, while 200 kg/1000 juveniles covers the cost of stocking rainbow trout. If the production and releasing costs are less than the value of fish caught, then the stocking has been regarded as economically profitable.

The fish-eating strains of non-migratory trout have an annual mean length increase of 10 cm during their first fjord years. The average recapture weights in the third growth season vary between 2.5 and 4.5 kg, depending on the strain and the conditions of stocking. Individual recapture weights of 6.5 and 6.7 kg, in the second growth season, have been recorded in the fjord.

After release the mean annual length increase in sea trout is 8 cm, and the mean recapture weights in the third growth season in the fjord vary between 1.5 and 2.5 kg. The initial growth rate of the sea trout stocked is faster than that of wild fish after they have left the rivers. However, over the years the difference disappears.

The growth rate of rainbow trout is high, but the species is short-lived. Thus, neither the maximum weight, nor the average return weight reaches the level of that of the non-migratory brown trout.

The migrations can be divided into four types: a return journey to freshwater, overwintering, feeding and spawning migrations. The various species and strains differ in their migration patterns. The majority of brook charr, and small stunted brown trout, return quickly to freshwater by ascending the rivers, as do some young rainbow trout. Both sea trout and rainbow trout may overwinter in the rivers at river mouths, but very few in either group ascend the rivers to spawn.

The fastest growing and most viable strains of both forms of brown trout also migrate the farthest. Migrations of up to 2500 km have been recorded, but most of the fish remain in the fjord, especially when released in the inner part. About 70% of the fish stocked close to Oslo were recaptured within 25 km of the release place, *i.e.* within the Strait of Drøbak, and 95% within 100 km.

Approximately equal numbers are recaptured by hooks (spinning, trolling) and nets (gill-nets, seines).

3. Administrative management problems

Although the release of salmonid juveniles in Oslofjord may be regarded as a success, the results have been received with little enthusiasm. The reasons for this are administrative and biological, mixed with a touch of local prejudice.

Release of juvenile trout on a large scale can only be financed by the county or local councils. However, for the time being they have no opportunity to get their money back by selling fishing licenses. Angling in the fjord is free, as long as the state permit is paid. It is unlikely that a local authority will subsidise fish migrating into other parts of the fjord to be caught there. Prior to stocking, some kind of collaboration across the local borders needs to be established. This has been done with good results for the recreational fishery in the forests surrounding the fjord towns of Oslo and Drammen. However, a fjord fishery authority still remains to be constituted, and due to diverging local interest this may be a time-consuming process.

If the authorities are going to support a fjord programme economically, the increased trout stock should be managed in such a way that it is fully exploited. The present legal fishing season in the Oslofjord stretches from June 1st to August 5th. This coincides with the period when the trout leave the littoral in search of sprats *(Sprattus sprattus* L.) and are consequently difficult to catch. For years anglers have argued for a longer open season, but so far in vain. The results of the stocking programme have however, increased public discussion about future regulations.

An expanded trout fishery may conflict with the commercial harvesting of sprat and herring, which is mostly carried out using surface illumination at night. Amateur fishermen complain that all game fish are disturbed and displaced, that forage fish are removed and cod and trout stocks are reduced.

4. Biological management problems

While most anglers agree that the natural production of trout smolts in the rivers emptying into Oslofjord should be increased, many object to the release of trout juveniles directly into the fjord. There are several reasons for this self-contradictory view. Some fear an increased influx of anglers from other districts. Others think it is unnatural to enhance the trout stock in this way, and picture the fjord becoming a 'put and take' water body containing trout of inferior quality. However, to transform a fjord of 200 or 1200 km^2 to such a 'put and take' water body demands larger resources than can be provided in the foreseeable future. The juveniles released measure 20-25 cm and stay in the fjord for some months before attaining the legal size of 30 cm. Although the recapture rate is high, both length and weight increases are too large to consider stocking as producing such a 'put and take' situation.

It is a common belief that an increased trout population will reduce the variety of other species present and will be especially detrimental to the stock of cod. However, due to their different demands for food and habitat, competition between these two species is insignificant. The larger cod are migratory and leave the fjord in the spring for deeper and colder water. The two species share a common littoral habitat only for a few weeks each year.

Cod feed mainly on benthic organisms, while pelagic sprat and herring are the staple food of the fjord trout. Enhancement of the trout stock would only recreate the situation when all streams running into the Oslofjord produced trout smolts. The main competitors with trout are commercial fishermen capturing sprat and herring. Sprat do not spawn in the fjord, but the larvae drift in from the nearby Kattegat and Skagerak. The trout mostly exploit 0+ fish, while the commercial fishery concentrates on 1+. The mortality rate of sprat is high, and the exploitation by trout has only a negligible effect on sprat recruitment.

An objection to fjord stocking is that the trout released may mix with the local spawning stocks and induce unfavourable genetic changes. This concern is general, and the official view is that it is more important to protect the natural strains than to increase the yield. This could lead to the prohibition of fjord stocking.

The possible genetic effects of hybridization between wild populations of Atlantic salmon and farmed or reared individuals have been discussed by Hansen, Lund & Hindar (1987) and Ståhl & Hindar (1988). So far, little reliable information exists. The sea trout has not yet been regarded as a problem because it is not farmed, and the stocking of sea trout rivers has been moderate. It is, however, possible that in future only local strains may be used for stocking. Because of local prejudice it will be difficult to choose between the strains from the several rivers emptying in the fjord. The results so far indicate that fish-eating trout released directly into the fjord are little inclined to enter freshwater, and their genetic impact is possibly small. It should also be remembered that the number of strays from most natural sea trout populations is considerable and thus there is always a degree of mixing.

If the fjord is to be stocked with trout, it is necessary to select a species, form and strain, for the purpose. Rainbow trout have many advantages. The species is robust, fast-growing, cheap and not self-recruiting in Norway. It is more stationary than brown trout and thus well suited to form the basis of a local fishery. For instance, rainbow trout have been released in Oslo harbour and fished from the piers. Nevertheless, both anglers and fishery authorities dislike the species. It is difficult to explain their dislike, but it may be that rainbows are foreign and that farmed rainbows were once of inferior quality. Another drawback is that rainbows tend to enter freshwater where they compete with the local brown trout populations for food and habitat.

Of the two forms of brown trout, the non-migratory one is a newcomer to the fjord. Nevertheless, the best results have been obtained with fast-growing, non-anadromous strains. The choice of strain is not very important, as all the fast-growing ones will do well. Very few enter freshwater as spawners. If they spawn successfully the inclination of the young fish to stay in freshwater could be more pronounced.

The Sandvikselva is the most important sea trout river in the Oslo region. The local fishery authority and the angling club demand that only this strain should be used for enhancement of fjord fishing. This could increase the dominance of the strain and make the total population of the inner fjord more uniform. The other strains also have their distinctive characters, which are well worth protecting. Finally, the Sandvika River strain is not outstanding in either return or growth rate. If this strain is used to avoid local criticism, one must accept a smaller return than if non-migratory trout or other sea trout strains are chosen. The difference in weight return between non-migratory strains and the Sandvika sea trout may be as pronounced as 2:1.

Salmonid farming and stocking have led to the outbreak and spread of fish diseases and parasites. The monogenean *Gyrodactylus salaris* Malmberg, a deadly parasite of salmon in Norway, has recently been tracked in one of the Oslofjord rivers from fish farms. Although this parasite cannot tolerate a salinity in excess of 10-15‰, it is feared that stocked trout could spread the parasites even further. However, several hundred fish farms, with a 1988 production of 80 000 tonnes of salmon and 8000 tonnes of rainbow trout, are located around the coast. It is impossible to prevent the escape of great numbers of salmon and rainbow trout and it is estimated that in 1987 between 5000-10 000 farmed salmon participated in the spawning run in Norwegian salmon rivers. For 1990 it is estimated that farmed salmon will constitute 10-20% of the total spawning run (Ståhl & Hindar 1988). They may then be as much of a risk to the natural populations as reared juveniles released in the fjord.

References

Aass, P., 1982. Fjord stockings of non-anadromous brown trout, *Salmo trutta* L. ICES, C.M. 1982/M:33.

Aass, P., 1988. Sea trout and brown trout *Salmo trutta* L., stocking in the Oslofjord, Norway. Sea trout in Scotland Symposium. (in press).

Hansen, L.P., 1986. Introduction of Atlantic salmon *Salmo salar* L. to the river Akerselv, Oslo. Fauna norv. Ser. A 7: 27-32.

Hansen, L.P., Lund, R.A. & Hindar, K., 1987. Possible interaction between wild and reared Atlantic salmon in Norway. ICES, C.M. 1987/M:14.

Ståhl, G. & Hindar, K., 1988. Genetisk struktur hos Norsk laks: status og perspektiver. Fiske forsk ningen. Rapp. 1.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 396-405.

Management of stunted populations of Arctic charr *(Salvelinus alpinus)* and brown trout *(Salmo trutta)* in Norway

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Abstract

In two harvesting experiments with stunted populations of Arctic charr and brown trout, we compared the effects of fishing with gill-nets of different mesh sizes on the distribution of sizes within stocks. In one experiment, performed over 6 years, we used gill-nets with 16-26 mm bar mesh sizes, and found that the size distribution of a resident allopatric population of Arctic charr changed towards larger fish. Originally the population consisted of charr attaining maturity at a size of about 70-80 g. The fishing caused a ten-fold increase in catch per unit effort in terms of numbers, and a fourteen-fold increase in catch per unit effort in terms of the weight of individuals weighing more than 125 g. In another experiment, a charr-trout lake was fished for 17 years using gill-nets of mesh sizes larger than 22 mm. This procedure did not increase the individual size of the fish. Both populations of Arctic charr and brown trout in this lake consist of small-sized fish of about 100 and 130 g respectively. It is assumed that the general management procedure for Norwegian charr-trout lakes, of fishing with large meshed gill-nets regulated by a lower permissible limit commonly set at a 30 mm mesh size, may be one of several reasons why dense stunted stocks of Arctic charr are maintained. It is proposed that a proper management programme for charr-trout lakes should include an upper mesh size limit of 29 mm for gill-nets.

1. Introduction

Many Norwegian lakes contain populations of stunted Arctic charr *(Salvelinus alpinus)* and brown trout *(Salmo trutta)*, as these species have a high natural recruitment capacity. The fish in these lakes are hardly harvested at all, as the fish seldom exceed 100 g in weight. The question arises as to how one should manage these stunted populations so as to increase the weight of individual fish, and so stimulate fisherman to harvest them. Further, what regulatory measures are required to maintain a desirable length, or age frequency distribution in Arctic charr and brown trout populations in such lakes?

In a harvesting experiment with a resident allopatric Arctic charr population, the size distribution changed towards larger fish. This experiment, on Lake Øvre Stavåtjønn, lasted for 6 years, and the results have already been published (Langeland 1986). In another experiment, carried out over 17 years, using gill-nets with larger mesh sizes, the size distributions of fish in sympatric populations of Arctic charr and brown trout changed towards smaller fish. Using these two experiments, we compared the effect of selective gill-net fishing upon the size distribution of fish in the stocks.

2. The lakes and their fish populations

Lake Øvre Stavåtjønn, which has a resident allopatric population of Arctic charr, is situated 824 m above sea level. It has an area of 4 ha and a maximum depth of 7 m. The other lake, Lake Songsjøen, which contains sympatric populations of Arctic charr and brown trout, is situated 261 m above sea level and has an area of 70 ha with a maximum depth of 32 m.

In Lake Øvre Stavåtjønn the allopatric Arctic charr tend to segregate by habitat and age. In summer the adults are mainly confined to benthic areas, the immature fish (1-3 years) to pelagic water, while the young of the year are restricted to shallow stony areas in the eastern part of the lake. Thus the Arctic charr in this lake may occupy the same type of habitat as brown trout in Lake Songsjøen. In Lake Songsjøen, brown trout live mainly in shallow benthic areas, down to a depth of about 15 m, but also occur in near surface water in the pelagic zone. In summer, adult Arctic charr occur mainly in pelagic water, while juveniles are confined to benthic zones at depths of 15-20 m. The difference in spatial distribution between the allopatric Arctic charr in Lake Stavåtjønn and the sympatric Arctic charr in Lake Songsjøen may be caused by interspecific competition with brown trout in the latter lake (Nilsson 1965, 1967, Hindar, Jonsson, Andrew & Northcote 1988).

Mark and recapture experiments in 1985-1986 indicated a ratio of population sizes of 2:1 between brown trout and Arctic charr in Lake Songsjøen. However, in previous experiments in the same lake, in 1968-1984, bottom-set gill-nets were used exclusively, predominantly catching brown trout (69-88 %) and biasing the results towards brown trout in the dominance ratio between the species.

3. Methods

Arctic charr in Lake Øvre Stavåtjønn were caught with bottom-set and floating gill-nets from 1979 to 1984. Bar mesh sizes of 15.7, 19.6, 22.4 and 26.1 mm were used in equal numbers in both types of nets which were distributed randomly in the lake. The lengths of the fish caught were measured from the tips of the snouts to the ends of the tail fins while the lobes were compressed.

In Lake Songsjøen the fish were caught with bottom-set gill-nets, with bar mesh sizes of 22.4, 24.1, 26.1, 28.5, 31.4. 34.9, 39.2 and 44.8 mm. The numbers of these deployed were 1, 9, 8, 6, 7, 7, 7 and 7 respectively, and they were distributed randomly in shallow benthic areas. Here, fish length was measured as natural tip length (Ricker 1979). This technique led to smaller lengths being obtained, by comparison with those obtained from Lake Songsjøen, but the average differences were less than 1 cm and did not influence the conclusions.

According to the calculations of gill-net selectivity for brown trout (Jensen 1977) and Arctic charr (Jensen 1986) the gill-net series used was expected to catch fish from 15 to 29 cm in Øvre Stavåtjønn and 22 to 50 cm in Lake Songsjøen.

Condition was estimated with Fulton's coefficient of condition:

$$K = 10^2 \times \frac{W}{L^3}$$

where: W = weight (g) and L = length (cm).

4. Results

Lake Øvre Stavåtjønn

The total yield of Arctic charr in Lake Øvre Stavåtjønn during the period 1979-1984 decreased consistently from 18.0 kg/ha in 1979 to 3.0 kg/ha in 1984 *(Table 1)*. The mean weight of the fish varied from 67 g in 1979 to 91 g in 1983. In 1982 and 1984, the mean weight was low due to the high density of young fish.

Table 1. Catches of Arctic charr larger than 15 cm in gill-nets of mesh sizes 15.7, 19.6, 22.4 and 26.1 mm in Lake Øvre Stavåtjønn, 1979-1984.

Year	Effort (net nights)	Number caught	Number/ night	Total weight (kg)	Weight /ha (kg)	Mean fish weight (g)
1979	58	1 065	18.4	71.8	18.0	67
1980	106	899	8.5	68.3	17.1	76
1981	128	583	4.6	51.6	12.9	89
1982	35	496	14.2	36.9	9.2	74
1983	30	259	8.6	23.7	5.9	91
1984	14	158	11.3	12.1	3.0	76

Table 2. Catches of Arctic charr weighing more than 125 g from Lake Øvre Stavåtjønn, 1979-1984. Effort (f) in net nights, yield (Y) in kg, numbers per night (N/f), weight (W) in g, weight of largest fish caught (W_{max}) in g, mean individual weight (W) in g, with net mesh sizes of 22-35 mm.

Year	Effort f (net nights)	Yield Y (kg)	% of total yield	Numbers per night N/n	Weight per night W/n (g)	Weight of largest fish W_{max} (g)	Mean weight Y/N (g)
1979	11	0.7	1	0.5	65	160	130
1980	16	2.1	3	0.8	131	200	144
1981	50	16.8	33	2.0	337	322	169
1982	8	5.4	15	3.5	668	520	191
1983	22	14.6	63	3.4	665	780	196
1984	10	8.8	73	4.8	879	645	183

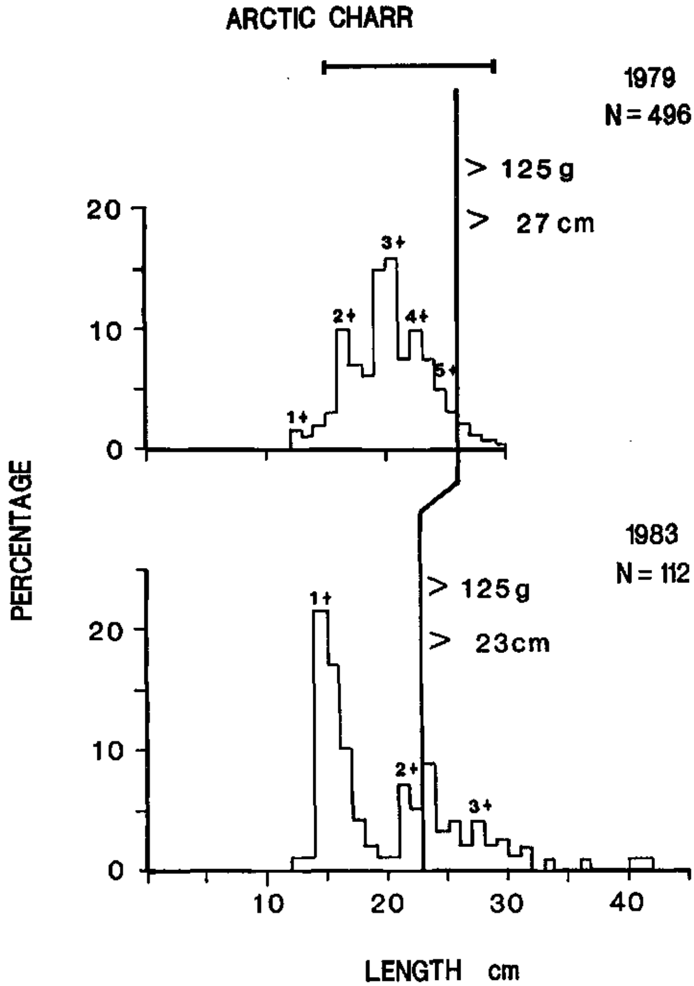

Figure 1. Percentage length frequency distributions (total length in cm) of catches of Arctic charr in Lake Øvre Stavåtjønn 1979 and 1983. Ages (years) are shown above the modes. Fish larger than 125 g shown by a vertical line; horizontal line indicates the effect of gill-net selectivity on fish length. N = number of fish.

The size distribution changed towards larger fish size during the experiment *(Figure 1)*. The size distribution of Arctic charr in Lake Øvre Stavåtjønn exhibited a three-modal pattern where the different age-groups of young fish could be identified. The ageing was verified by analysis of the otholiths. The increase in individual size is shown by the catch per unit effort of Arctic charr over 125 g *(Table 2)*. The yield of such fish increased 9.6

times in number and 13.5 times in weight. Also the maximum individual weight increased as well as mean weight of fish over 125 g *(Table 2)*.

Due to the great fishing effort in 1979-1981 the biomass in Lake Øvre Stavåtjønn declined from 71 kg per ha in 1979 to figures of 40, 24, *c.* 13, 9 and *c.* 20 kg/ha in the years 1980-1984 respectively. Other changes observed were increased growth rate and condition factor *(K)*. For example, 3 year old fish increased from $K=0.78$ in 1979 to $K=0.97$ in 1984. What this means may be better appreciated by saying that 23 cm fish achieved the same weight (125 g) in 1983, as 27 cm fish did in 1979 *(Figure 1)*.

Table 3. Effort (*f*) in net nights, numbers (*N*), mean individual weights (*W*) in grams, total yield (*Y*) in kg and yield in kg/ha of brown trout and Arctic charr caught in bottom-set gill-nets in Lake Songsjøen, 1968-1984.

Year	Effort	Brown trout			Arctic charr			Yield			
	Effort *f* (net nights)	Number *N*	Total yield *Y* (kg)	Individ. weight *W* (g)	Number *N*	Total yield *Y* (g)	Individ. weight *W* (g)	Brown trout (kg/ha)	Brown trout (%)	Arctic charr (kg/ha)	Total (kg/ha)
1968	940	1712	241	141	447	49	109	3.4	83	0.7	4.1
1969	893	1736	253	146	598	74	123	3.6	77	1.1	4.7
1970	674	1180	192	-	572	73	128	2.7	71	1.1	3.8
1971	100	428	65	152	174	22	125	0.9	75	0.3	1.2
1972	900	1298	192	148	382	47	123	2.7	79	0.7	3.4
1973	936	1015	115	113	349	41	116	1.6	73	0.6	2.2
1974	884	1344	141	-	629	60	96	2.0	69	0.9	2.9
1975	676	1173	128	109	271	26	97	1.8	82	0.4	2.2
1976	780	1020	112	110	298	24	82	1.6	84	0.3	1.9
1977	936	1288	157	122	266	23	87	2.2	88	0.3	2.5
1978	1114	1527	188	123	280	28	100	2.7	87	0.4	3.1
1979	862	1020	124	122	387	41	105	1.8	75	0.6	2.4
1980	650	777	100	130	173	17	100	1.4	87	0.2	1.6
1981	832	526	67	128	189	22	115	1.0	77	0.3	1.3
1982	1224	2053	308	-	520	53	102	4.4	85	0.8	5.2
1983	559	1864	242	130	1073	99	92	3.5	71	1.4	4.9
1984	234	601	76	127	346	28	80	1.1	73	0.4	1.5
Mean 17 years				130			105				2.9

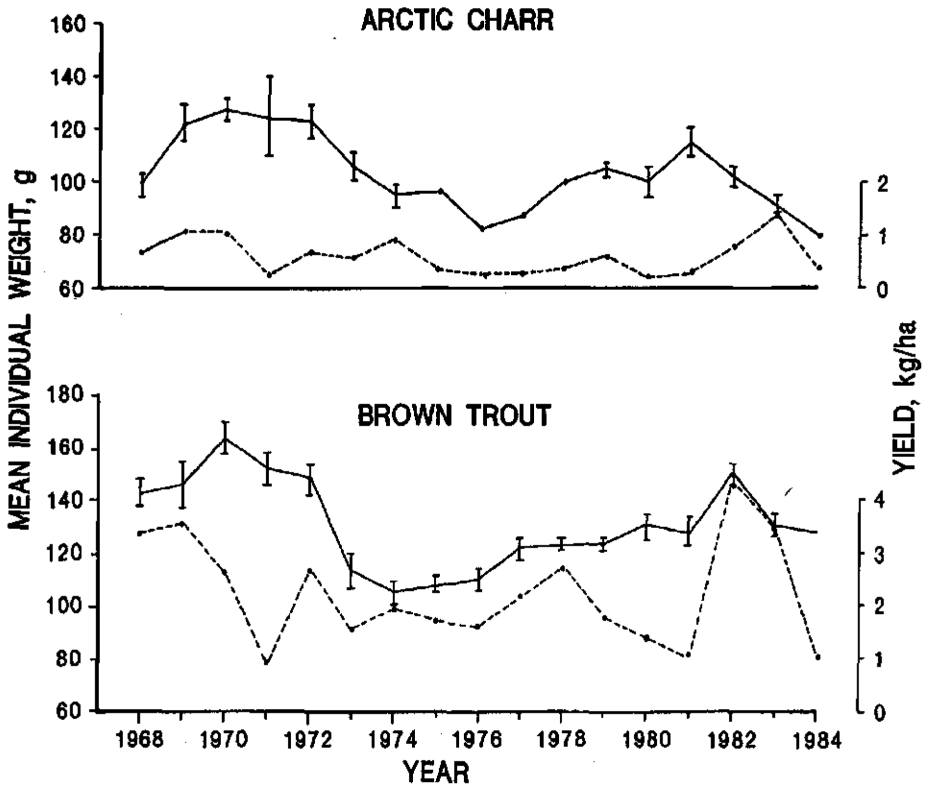

Figure 2. Mean individual weight (continuous line) and yield in kg/ha (broken line) of Arctic charr and brown trout in Lake Songsjøen, 1968-1984. Vertical lines show twice standard error.

Lake Songsjøen

The yield of brown trout and Arctic charr in Lake Songsjøen during the experimental period 1968-1984 varied between 1.2 and 5.2 kg/ha, the mean for all years was 2.9 kg/ha, and brown trout comprised 69-88 % of the catches *(Table 3)*. The change in mean individual weight showed the same pattern for both species. An increase was recorded in the first two years following the start of fishing in 1968 *(Figure 2, Table 3)*.

The mean weight of Arctic charr declined from 128 g to 82 g between 1970 and 1976. Thereafter there was an increase to 115 g in 1981, but this was succeeded by a second decrease, to the lowest mean weight on record (80 g) in 1984. The mean weight of charr over all 17 years was 105 g.

The mean weight of brown trout declined from 163 g in 1970 to 105 g in 1975 *(Figure 2, Table 3)*. The succeeding few years revealed an increase, to 150 g in 1982, but this was also followed by a second decrease, down to 127 g in 1984. The mean weight of brown trout over all 17 years was 130 g.

The hypothesis that the variation in the mean weight of individuals was caused by the intensity of fishing or total catch, was tested by a comparison between yield and mean individual weight. No significant correlation was found, neither for brown trout ($r = 0.43$ $p = 0.05$) nor for Arctic charr ($r = 0.25$ p0.05), which indicates that mean individual weight varied independently of the total weight of fish removed.

The length-frequency distributions of fish in Lake Songsjøen in the years 1968-1969, 1974 and 1983 showed a shift towards smaller fish for both species in later years *(Figure 3)*. Both species exhibited a unimodal pattern of distribution in all years with a more compressed bell shaped distribution for Arctic charr. The modal length of Arctic charr decreased from 24-25 cm in 1968-1969 to 23 cm in 1974 and 22 cm in 1983. A similar shift in modal fish length of about 2 cm was also recorded for brown trout, from 25-26 cm in 1968-1969 to 24 cm in 1983.

Calculations of the condition coefficient *(K)* in 1968, 1974 and 1981-1983 were about the same for all years; 0.86-0.89 for brown trout and 0.81-0.83 for Arctic charr. This indicates that the fishing experiment did not increase the weight:length ratio of the fish.

Numbers of 23 cm brown trout in Lake Songsjøen were estimated as 2842, 2740, 1952, 2010 and 1431 respectively for the years 1968-1972, based on mark and recapture experiments.

5. Discussion

The results of the two harvesting experiments were quite different with respect to the size distributions and mean individual weights within the fish populations. Intensive fishing with small meshed gill-nets in Lake Øvre Stavåtjønn clearly increased the individual fish size. On the other hand, the experiment in Lake Songsjøen, where larger mesh sizes were used, reduced the individual sizes of both brown trout and Arctic charr.

Judging from calculations of gill-net selectivity for brown trout (Jensen 1977) and Arctic charr (Jensen 1986), the gill-nets used would have removed fish 15-29 cm long from Lake Øvre Stavåtjønn, and fish 22-50 cm long from Lake Songsjøen. Thus, fish over 29 cm in Lake Øvre Stavåtjønn were less liable to be caught compared with those in Lake Songsjøen. This would certainly have increased the survival of larger fish in Lake Øvre Stavåtjønn. In Lake Øvre Stavåtjønn younger age classes were exposed to higher fishing mortality than those in Lake Songsjøen. In Lake Øvre Stavåtjønn the annual fishing mortality from 1979 to 1982 was calculated to vary between 0.15 and 0.65 based on weight. This caused a change in the population structure towards younger age and increased growth rate. In Lake Songsjøen, mark and recapture experiments have been made in most years. From 1968 to 1972 the population of brown trout 23 cm long declined by 50%, from 2842 to 1431. Based on the rate of removal of brown trout 23 cm long in 1968-1971, we calculated the annual fishing mortality rate as 0.50-0.60, which was about that experienced during the period 1968-1972. As this high fishing mortality was mainly confined to the larger fish, the probability of these surviving was reduced, but smaller individuals, less than 23 cm long, benefited by increased survival in Lake Songsjøen. This

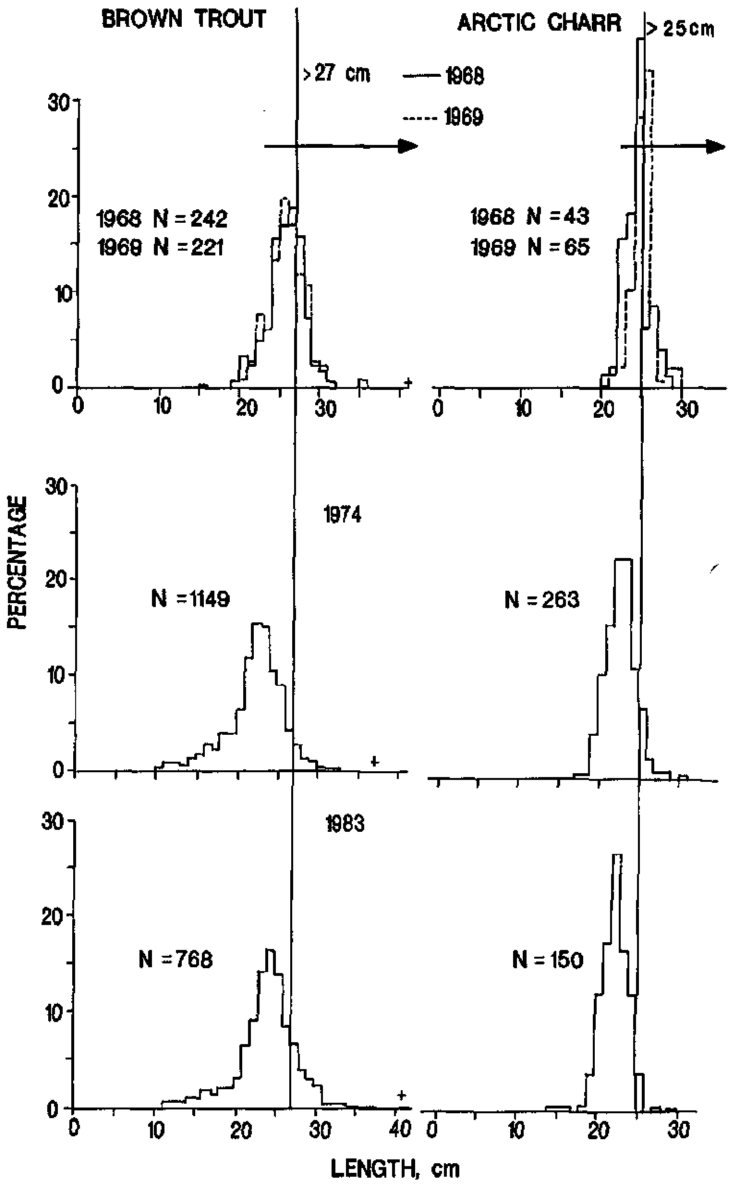

Figure 3. Percentage length frequency distributions (total length in cm) of catches of Arctic charr and brown trout in Lake Songsjøen in 1968, 1969, 1974, 1983. Fish lengths of 27 cm (left) and 25 cm (right) shown by vertical lines. Horizontal lines indicate the effect of gill-net selectivity on fish length. N = number of fish.

permitted smaller and early maturing fish to dominate during the last years of exploitation. Thus, the fishing in Lake Songsjøen from 1968 to 1974 directly increased the mortality of larger fish and indirectly increased survival and density of smaller, younger fish.

The variation in mean individual weight between years in Lake Songsjøen is more difficult to explain. The most reasonable explanation is that the age composition of populations changes with time. In years with a high mean individual weight, the catches of brown trout were dominated by individuals of higher mean age (4.35-5.25 years) than in years when catches had a low mean weight (4.02-4.12 years). Changes towards a younger age distribution due to heavy fishing were typical in Lake Øvre Stavåtjønn (Langeland 1986).

Finally, the improved growth rate of Arctic charr in Lake Øvre Stavåtjønn indicated an increased availability of food. This was supported by an observed increase in the density and individual weight of the larger cladoceran species *Holopedium gibbenum* and *Daphnia galeata* present. However, in Lake Songsjøen there was no indication of improved trophic conditions for individual fish. The continuation studies in 1985 and 1986, using gill-nets of mesh sizes from 12 to 39 mm in all habitats, showed populations of relatively high densities, of the order of 10 000 brown trout and 5000 Arctic charr. Calculations of the condition coefficient support the view that the fishing in Lake Songsjøen failed to increase the growth rates of brown trout and Arctic charr. The decreased size of fish in Lake Songsjøen is caused by a relative increase in numbers of young and small fish in this lake. This may result from a removal of old and large fish and the loss of their competition. In addition, growth rate may have been decreased.

The general management procedure for Norwegian charr-trout lakes is to fish with large-meshed gill-nets regulated by a lower permissible limit commonly set at a 30 mm mesh size. Use of a smaller mesh size is prohibited. This method of highly selective, high-intensity, gill-net fishing, combined with rod and troll fishing (which probably selects active, fast-growing fish) may be the reason for the maintenance of dense stocks of small, sexually mature, brown trout and Arctic charr in the lakes. This hypothesis is supported by the experiment performed in the lakes Øvre Stavåtjønn and Songsjøen. Therefore we propose that the management programme for charr-trout lakes should include an upper mesh size limit of 29 mm for gill-nets as a regulatory measure for populations of Arctic charr and brown trout.

Acknowledgement

We are greatly indebted to the late Dr Kjell W. Jensen who performed the fishing experiment in Lake Songsjøen. Unfortunately, he was not able to complete the study.

References

Hindar, K., Jonsson, B., Andrew J. H. & Northcote, T.G., 1988. Resource utilization of sympatric and experimentally allopatric cutthroat trout and Dolly Varden charr. Oecologia. Berlin. 74: 481-491.

Jensen, K., 1977. On the dynamics and exploitation of the population of brown trout, *Salmo trutta* L., in Lake Øvre Heimdalsvatn, southern Norway. Rep. Inst. Freshwat. Res. Drottningholm. 56: 18-69.

Jensen, J.W., 1986. Gill-net selectivity and the efficiency of alternative combinations of mesh sizes for some freshwater fish. J. Fish Biol. 28: 637-646.

Langeland, A., 1986. Heavy exploitation of a dense resident population of arctic charr in a mountain lake in central Norway. N. Am. J. Fish. Mngmt. 6: 519-525.

Nilsson, N.-A., 1965. Food segregation between salmonid species in North Sweden. Rep. Inst. Freshwat. Res. Drottningholm. 46: 58-78.

Nilsson, N.-A., 1967. Interactive segregation between fish species. In: Gerking S.D. (Ed.). The biological basis of freshwater fish production. Blackwell Scient. Publ. Oxford. pp. 295-313.

Ricker, W.E., 1979. Growth rates and models. In: Hoar, W.S., Randall, D.J. & Brett, J.R. (Eds). Fish physiology, vol. 8. Bioenergetics and growth. Academic Press. New York. pp. 677-743.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 406-436.

Fisheries management in Polish lakes

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Abstract

Management schemes for lake fisheries have been devised by the Department of Fishery Economics of the Inland Fisheries Institute at Olsztyn. They are based on studies of more than 500 lakes with data available for periods of 15-30 years. The fish stocks and the structures of the fish communities in these lakes are influenced most strongly by anthropogenic changes, especially eutrophication of the waters. A method for determining the trophic status of lakes, based upon the analysis of long term data, mostly catch statistics, has been proposed. This depends on time-series and regression analyses. In addition to determining the trophic status of a lake, the method permits an estimate of the effectiveness of the management and stocking practices used, and helps in formulating future procedures. Guidelines are given for general fisheries management in ecologically different lakes. Use of the method, which is now widely used in Poland, is illustrated.

1. Introduction

Commercial fisheries have operated on Polish lakes for many centuries. After the 2nd World War almost all lakes in Poland were used as State Commercial Lake Fish Farms, which were obliged to carry out rational fishery management by law. These farms were required to keep detailed catch statistics and to record management practices. At the beginning of the 1950s, fisheries and biological studies were inaugurated on most (over 2000) lakes in Poland, with a view to developing management schemes for each. In consequence large volumes of data were gathered, from which it emerged that eutrophication of some lakes was so rapid as to invalidate the existing management schemes. Work was therefore begun to develop new principles of lake management, based on analyses of the data which is still continuously coming to hand.

2. Organization

To understand how the data are collected and used it is necessary to know how lake fisheries are organized in Poland. Each State Commercial Lake Farm is economically self-sustaining. Each farm uses specific lakes, but total lake area varies considerably from farm to farm. There are 14 such fish farms in the country, managing a combined lake area of 273 000 ha.

Groups of farms belong to Regional Departments, and the managerial staff of these departments, as well as those of individual farms, are university educated. Each regional department is responsible for the management of its lakes, and management schemes for individual lakes are devised by 'ichthyologists'. Each Regional Department employs at least one ichthyologist who must be a graduate of the Faculty of Inland Fisheries and Water Protection (5 year course) at the Academy of Agriculture and Technology in Olsztyn. On the national level, the interests of inland fisheries are represented by the National Board of Fisheries, whose executive committee includes representatives from each farm. *Figure 1* indicates the organization of inland fisheries in Poland.

Basic management decisions are taken by fish farms, but most often by their Regional Departments. They depend on data gathered as follows.

- Catches are delivered, the same day, to the Regional Department, and the name of the lake, the date, and the details of the catch (weight, species, size-classes) are recorded. In some cases the numbers and types of gear used are also recorded but this is not compulsory. Whether this information is obtained depends upon the managers concerned.
- One copy of the record is given to the fishermen, one to the book-keeper (it constitutes the basis for calculating the earnings of the fishermen) and one to the local managerial unit. Ichthyologists of this unit then enter the data into 'lake-books', one for each lake.
- A 'lake-book' contains details of catches, by species and monthly size-classes, and information on management practices for the lake concerned. Details of all stocking operations are recorded here, including the date, type and origin of the material used, and its quantity and quality. Data regarding methods of exploitation (gear used) are not kept in the lake-books, but may be available from the original catch documents in the archives. These latter may be consulted, but management decisions are usually based on catch statistics alone, since these are most readily available.

3. Development of management schemes

Some years ago it became clear that the procedures for lake management then in use had ceased to be valid. Environmental changes had occurred so rapidly that new management techniques were necessary. The Inland Fisheries Institute was therefore asked to undertake studies aimed at establishing new principles for sensitive lake management which could adapt quickly to changes in individual lakes. Responsibility for these studies then devolved upon the Department of Fishery Economics within the institute.

It was decided that the studies, and thus future management responses, should be based on the data which would be most readily available to ichthyologists in the field, and that moreover, any analyses of data required should be quick and simple. This latter condition is essential if rapid responses are to be made, since a single ichthyologist may be responsible for more than 60 lakes.

Catch statistics, supplemented by details of stocking practices, are readily available in the 'lake-books' of Poland, while data on fishing effort per type of gear used are not easy to obtain. Thus the former data were used exclusively. The studies embraced more than 500 lakes, differing widely in size and trophic status, with statistics going back 15-30 years, available for each lake. Since fishery managers had reported changes in fish stocks, a statistical method involving time-series analysis was used. This method may be used to reveal "the trend of development of a given dynamic series, the trend being expressed by a mathematical function" (*i.e.* a polynomial obtained by the method of least squares) according to Zajac (1982), while Spiegel (1972) says that by using polynomials of

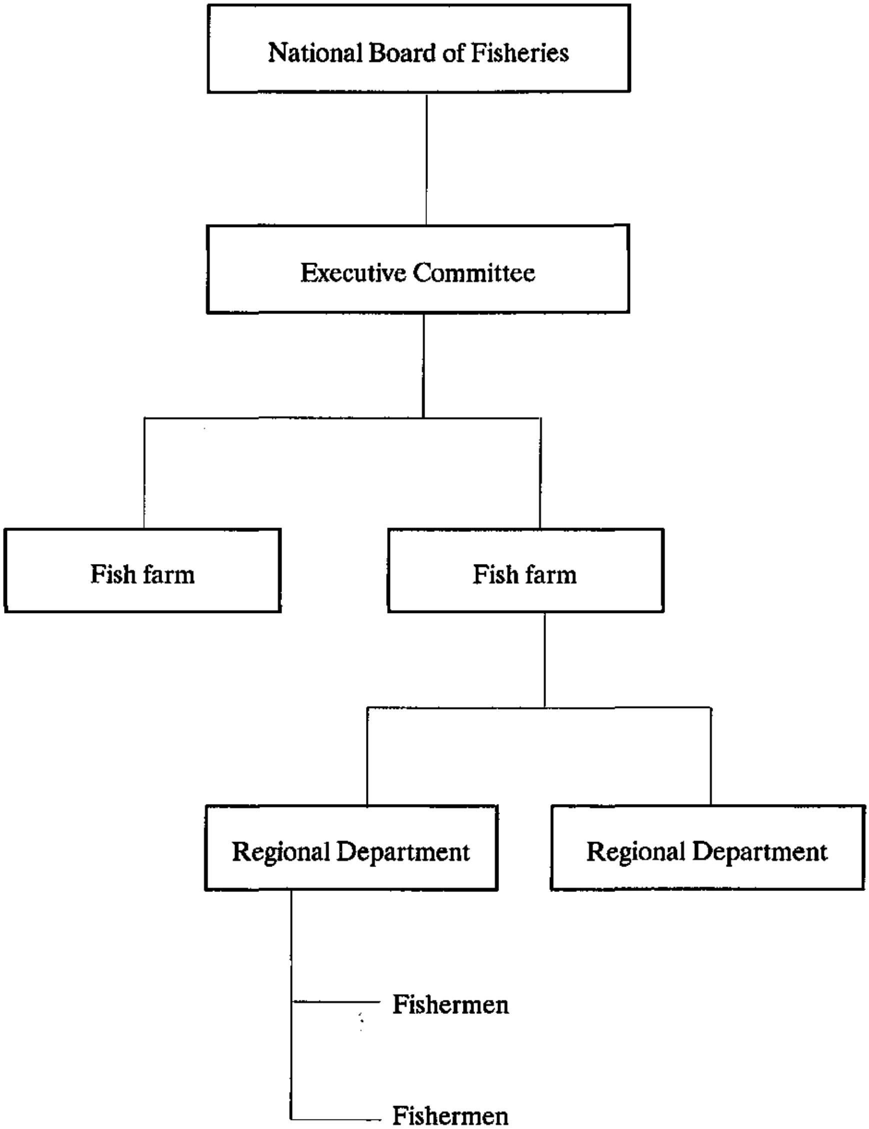


Figure 1. Organization of inland fisheries management in Poland.

"appropriate orders, ... cyclical, seasonal and irregular patterns are eliminated, leaving only the trend movement". The longer the period of time, the more precise are the conclusions on the development of the trend, and it is generally accepted that a period of at least 10 years should be used. Reality of the trend may be determined by calculating correlation coefficients and checking their significance at appropriate degrees of freedom (Spiegel 1972, Frenkel & Kil'dishev 1973, Zajac 1982). In our studies, polynomials up to the 4th order were used, *viz*:

$$y = a + bx$$

$$y = a + bx + cx^2$$

$$y = a + bx + cx^2 + dx^3$$

$$y = a + bx + cx^2 + dx^3 + ex^4$$

where:

y = the variable analysed
x = consecutive years
a,b,c,d = mathematical constants determined by method of least squares.

Since it was assumed that catch statistics would be used for management decisions, attention was first paid to factors which might affect trends in catches. These fall into three groups: environmental quality, exploitation and stocking. Analysis of trends in catches over many years provides an effective method of obtaining knowledge of the quality of an aquatic environment and the structure of its fish community (see Section 4). Obviously, the more additional information available on the lake environment and its fishery management, the more likely it is that future management decisions will be correct. However, analyses of catch statistics alone appeared to be sufficient for decision-making in lake-fishery management provided that the analyses:

- Were based on long term data (so that the trends obtained were reliable).
- Embraced all fish species important to the fishery management programme.
- Included size-classes for all species.
- Ensured that the trends revealed could be compared to models and to each other.

It became clear that long term trends in catches for particular species and size-classes did not mirror fishing effort in a given lake, but were strongly influenced by environmental factors and/or stocking. It was confirmed that eutrophication and pollution were the most significant factors to influence trends in catches in Polish lakes. Changes in the fish stocks of similar lakes showed similar patterns regardless of variable fishing intensity and the use of different gear. The trends were so regular that when deviations were observed it was always possible to relate them to some change in management procedure. For example, in all cases, when the trends for coregonid catches were not consistent with those predicted by the model for catches in lakes subject to eutrophication, it transpired that the lakes concerned had been intensively stocked.

An explanation for the independence of catch and fishing effort in Poland arises from the following:

- The entire fish community of a lake is exploited in Poland. There is no such thing as an eel fishery or a perch fishery. All species present are caught using a variety of types of gear all year round. Exploitation tends to be non-selective, and the entire fish community is managed.

- All Polish fishermen are professionals and must have been educated at one of the basic or elementary schools of inland fisheries. Fishery provides their only source of income. They are all familiar with fish biology and ecology and more concerned with protecting their source of income, *i.e.* the fish stocks, than with immediate profits. They fish on a predetermined set of lakes and the numbers and types of gear used are decided by an ichthyologist in a regional fish farm department. Hence, over the long term, fishing effort is relatively constant and both under- and over-fishing are avoided.

Thus, catch trends for a given lake tend to reflect changes in the fish stocks of that lake rather than changing trends in fishing effort. The influences of environmental quality and stocking mask the effects of variable fishing effort upon catch levels, as is seen in the data from 4 lakes (with surface areas from 140-3000 ha) over periods of 16-25 years, presented in *Figures 3, 5, 6,* and *7.* If any relationship ever did emerge between trends in catches and fishing effort (as in Lake Dargin, *Figure 3*) it was between total catch (all species) and total fishing effort; no relationship between fishing effort and catch for any one species was ever observed.

A method for assessing the trophic status of lakes, and the effectiveness of lake management, was required for formulating future management decisions. This method was based upon calculated statistical trends in the catches of particular species and their size-classes, and then analysing the patterns obtained as explained in the following sections. Data required for this, are catch statistics and information regarding stocking. Details of exploitation were used only when the trends in catches were not easy to interpret. When no statistically significant trends were obtained, *e.g.* if there was a lack of data for some years, the data were smoothed by calculating moving averages, to expose the movement of the trend, and then calculating the trend in the form of a mathematical function (Spiegel 1972) as shown in *Figure 6.*

A theoretical model of the analysis and decision-making process is given in *Figure 17.* The model comprises 5 blocks. The first block represents lake fishery management, the second, data needed for the analysis, the third, analysis of the data, the fourth, the type of conclusions that can be drawn from the analysis, and the fifth represents decision-making. The method can be used regardless of the objectives of the fishery management. As seen from block 4, conclusions from the analysis embrace all possible objectives. The model also shows that lake fishery management involves the need to decide what data are to be collected, how accurately this is to be done, and how they are to be analysed.

4. Trophic status and fish community structures

Knowledge of the structure of the fish community and the trophic status of a lake is essential in making decisions for rational fishery management. Our studies have permitted the development, and more thorough presentation, of models of trends of catches in eutrophying lakes, than those given previously (Colby, Spangler, Hurley & McCombie 1972, Leach, Johnson, Kelso, Hartmann, Numann & Entz 1977, Hartmann 1978), and thus also of the changes taking place in the fish stocks of these lakes (Bninska 1985a, Leopold, Bninska & Nowak 1983, 1986, Leopold *et al.* 1987a,b, Hus 1988, Leopold, Bninska & Wolos 1988). *Figure 18* shows our general model, but since it does not illustrate changes occurring within stocks of particular species, some explanations follow:

- Catches of cyprinids tend to increase until the later stages of eutrophication. They are the last to 'break down'. However, the reactions of different cyprinid species to changes in their environment are not uniform. Where the littoral zone is heavily disturbed, *e.g.* by recreational activities, the resident cyprinids, such as tench *(Tinca tinca)* and crucian carp *(Carassius carassius)*, tend to disappear during the early stages of eutrophication. This is mostly due to impaired reproduction. The rate of growth of most cyprinid species tends to decrease with progressive eutrophication so that the abundance of small specimens increases and of large ones decreases. This is reflected in the size composition of cyprinid catches (Zawisza *et al.* 1979, Bninska 1985a, Leopold, Bninska & Nowak 1986, Leopold 1987, Leopold & Bninska 1987, Leopold *et al.* 1987a,b, Wolos 1988).
- Amongst the predatory species, perch *(Perca fluviatilis)* is usually the first to react to eutrophication, followed by pike *(Esox lucius)*. However, if the littoral zone is subject to additional disturbance, pike tend to disappear before perch. Pikeperch *(Stizostedion lucioperca)* is usually the last to react, and in some lakes its abundance may even increase until a late stage of eutrophication.

Catch statistics reflect the structure of the fish stock in a given lake and comprise several inter-related elements. Analysis is therefore carried out at 4 levels as follows:

Level 1. Total catches. Here the qualitative and quantitative composition of whole catches are analysed. Factors examined include species composition, size-classes and total yields, and their changes in time.

Level 2. Groups of species. Catches of particular groups of species are analysed. The groups are determined by the aim of the analysis. For instance, species occupying the same ecological niche may be analysed, or species of the same family. As before, analyses involve both qualitative and quantitative parameters and trends.

Level 3. Single species. Catches of single species are analysed.

Level 4. Size-classes of single species.

Catch trends permit classification of lakes by trophic state. Classification is based upon an overall picture of the patterns as well as on catch trends for certain indicator species. These latter include coregonids, perch, pike, pikeperch, tench, and the less valuable cyprinids, bream *(Abramis brama)*, white bream *(Blicca bjoerkna)* and roach *(Rutilus rutilus)*. Consideration is also given to catch trends for certain size-classes, *viz* large, medium and small bream, and large and small roach. Where these species are stocked the analyses also embrace data on stocking rates and frequency.

Six categories of lake trophic status have been distinguished and management measures formulated for each (Leopold *et al.* 1987a, Leopold, Bninska & Wolos 1988). Classification of lakes into these categories is based on the following:

- The statistical trends of the catches seen in the light of the general model of lake eutrophication.
- The relationships between these trends.
- The sizes of the catches and their species composition.
- The data on management measures available.
- Information on any anthropogenic disturbances, details of other lake usage, and knowledge of the catchment, local geography, and morphometry of the lake, whenever available.

The six lake categories with their management measures are, in general terms, as follows:

1. Relatively undisturbed lakes. In these lakes self-regulatory ecosystem mechanisms continue to operate normally. Fishery management is limited to exploitation within the productive potential of the lake. Maximum protection is given to the ecosystem and to maintaining the status of its fish stock. The natural reproduction of all species must be protected; no fishing is permitted in the spawning season. Spawning grounds must be protected. In fishing periods, exploitation should be uniform for all species. Stocking is not required, but stocks of the most valuable species may be enhanced in this way.
2. Slightly disturbed lakes. These are also characterised by the normal functioning of ecosystem mechanisms, but natural reproduction of the most sensitive species, *e.g.* coregonids and salmonids, may be disturbed and stocking with these species may be necessary. Exploitation in this type of lake should also be non-selective and forbidden during the spawning season. However, fishing for spawners for artificial reproduction is permitted at this time. Legal sizes must be observed and the spawning grounds protected.
3. Moderately disturbed lakes. Natural regulatory mechanisms are disturbed to some extent, affecting both fish reproduction and stock balance. Management should aim at re-establishing a balanced ecosystem. Exploitation should aim at protecting natural reproduction of the most valuable species, but they may be caught during the spawning season to obtain material for future stocking. The spawning grounds of the valuable species should be protected. Exploitation of the valuable species should be adapted to stocking rates, but may be intensive when stocking rates are high and *vice versa*. Spawning of the less valuable species, mainly cyprinids, need not be protected since in this type of lake they have usually increased their stocks excessively. Exploitation of cyprinids should be intensive.
4. Strongly disturbed lakes. In these lakes self regulatory mechanisms are largely impaired and management should attempt to counteract any further deterioration. Natural reproduction of the most valuable species is highly disturbed and regular stocking at high rates is required. Exploitation of these species during spawning should be limited to obtaining spawners for future stocking. Spawning of less valuable species, bream, white bream and roach, is not protected and exploitation should aim at removing maximal quantities of these. Stocking with these species should be forbidden.
5. Lakes endangered by degradation. Natural regulatory mechanisms are very weak in these lakes. Natural reproduction of the most valuable species is virtually non-existent and their stocks depend upon stocking. However, it is usually necessary to fish for spawners during the reproductive season. Exploitation of these species should be strictly adapted to stocking rates, while that of cyprinids should be very intensive throughout the year. Cyprinids are afforded no protection.
6. Degraded lakes. Management of these lakes seems ineffective. Reproduction of valuable species is virtually non-existent. Spawning is not protected and there are no fishing restrictions. Stocking seems ineffective.

To illustrate this scheme of lake classification, 12 lakes of differing trophic status, with a total area in excess of 12 000 ha, have been selected. Trends for the catches of indicator species from these lakes are given in the several figures described below.

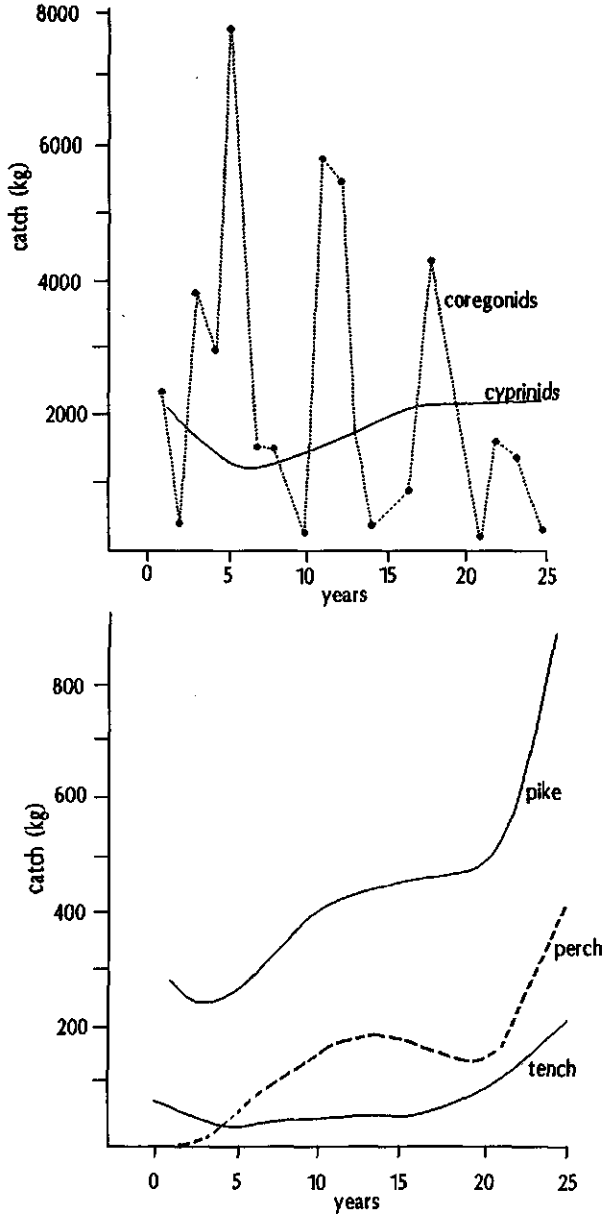


Figure 2. Lake Bobecino: a lake of the first category. Trends in the catches of different species.

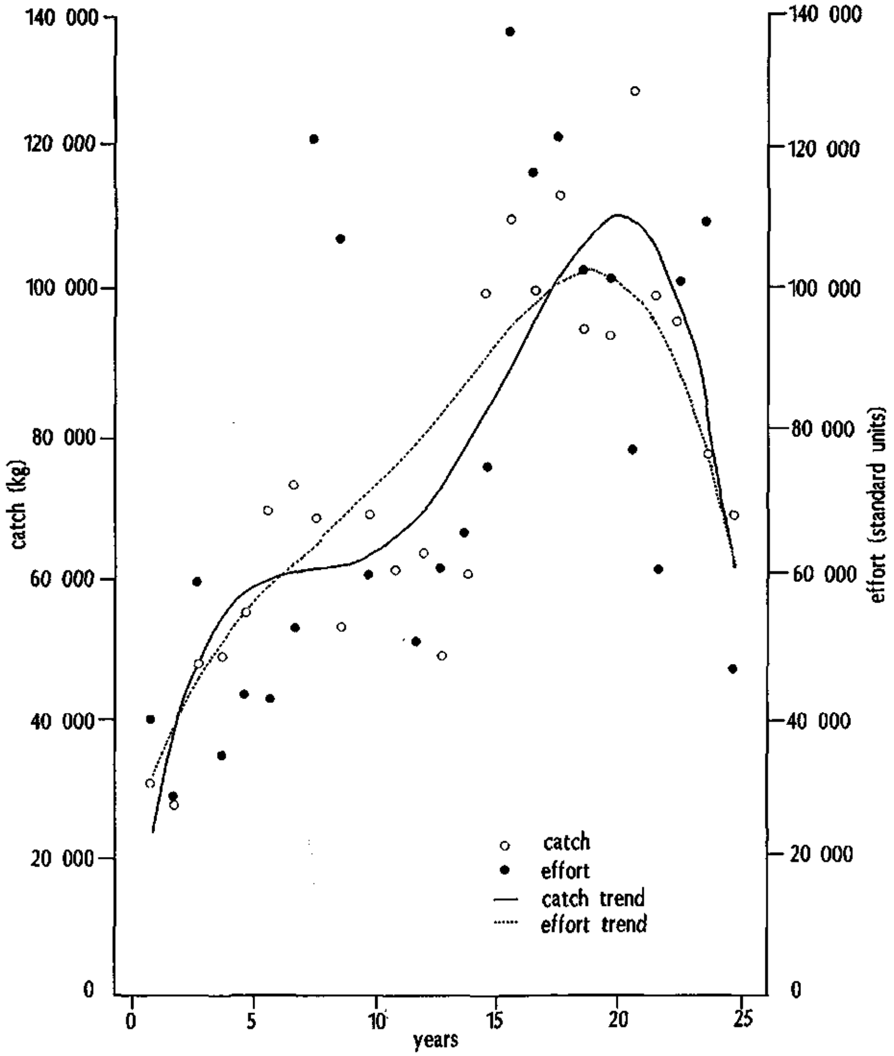


Figure 3-1. Lake Dargin: a lake of the second category. Changes in total catch (kg) and total fishing effort (standard units) over 25 years.

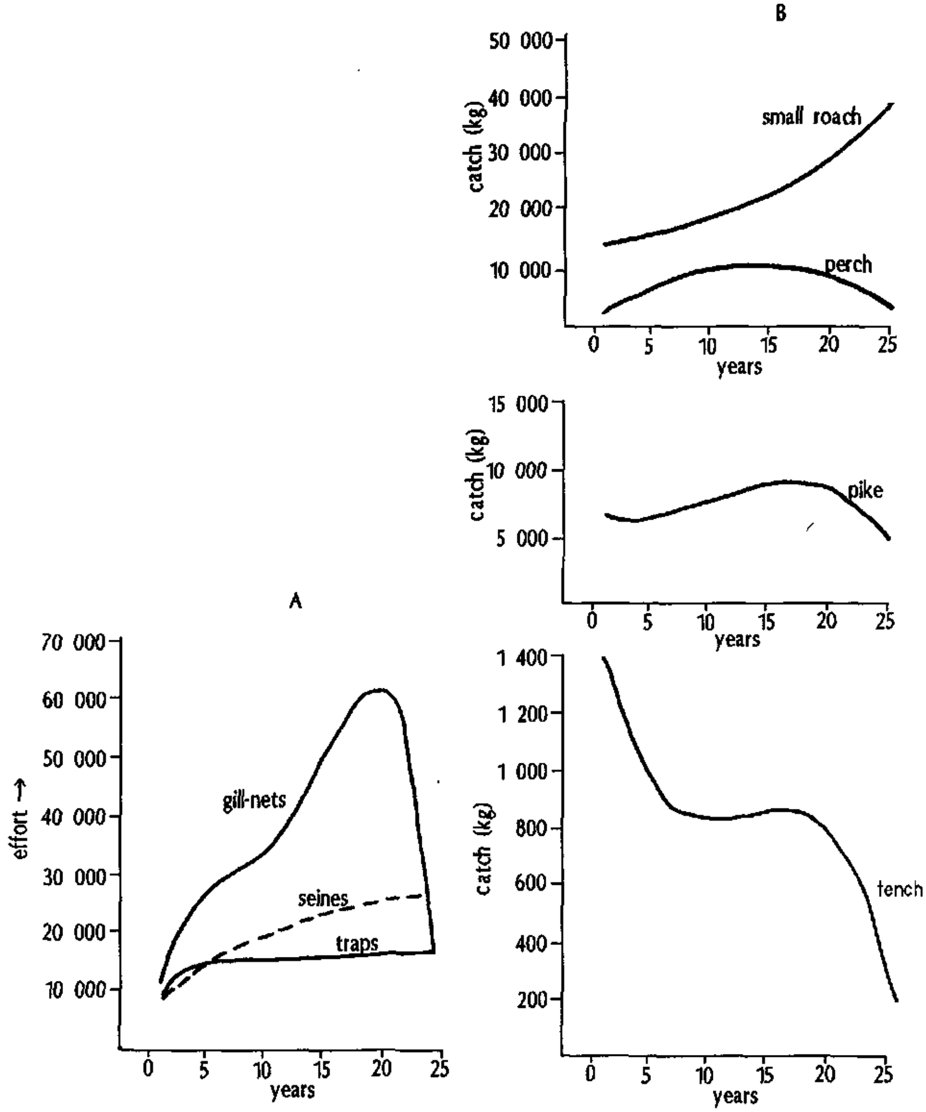


Figure 3-2. Lake Dargin: a lake of the second category. A. Fishing effort per gear type. B. Trends in catches of different species. Pike and tench are not caught in gill-nets.

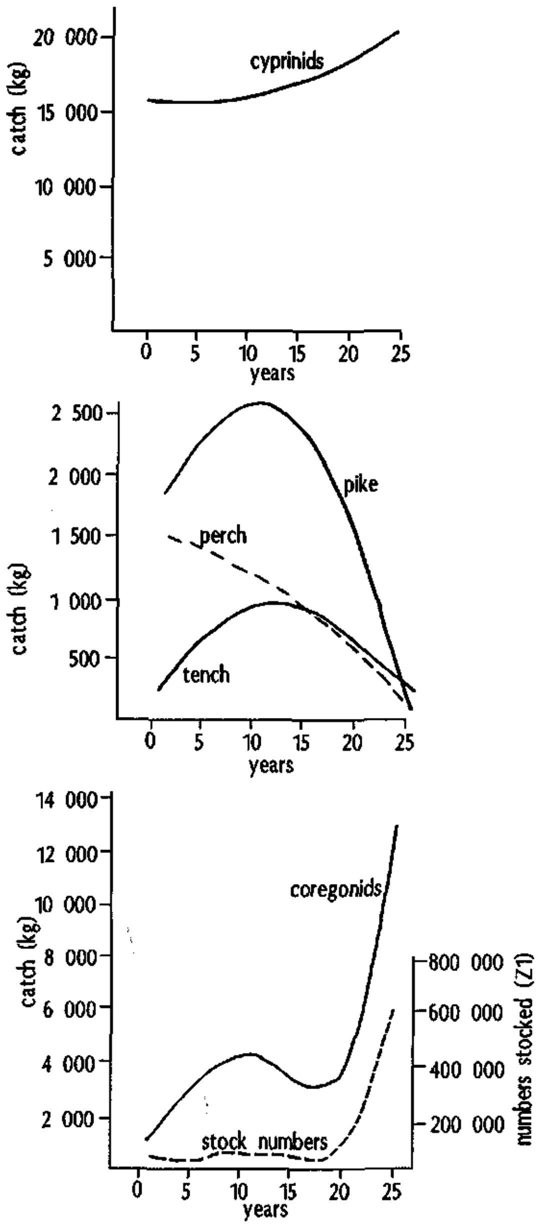


Figure 4. Lake Dabrowa Wielka: a lake of the second category. Trends in catches of different species, together with stocking numbers for coregonids.

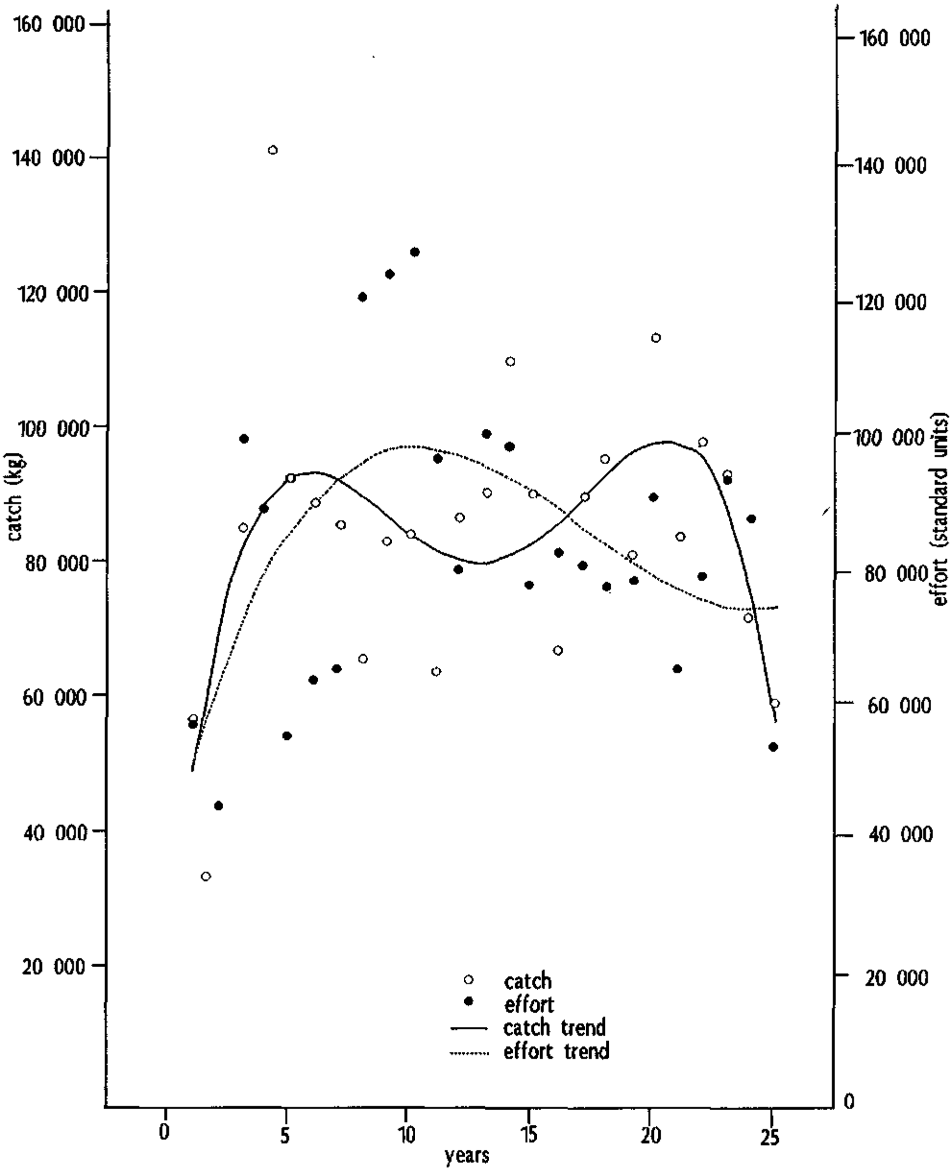


Figure 5-1. Lake Kisajno: a lake between the second and third categories. Total fish catch (kg) and total fishing effort (standard units).

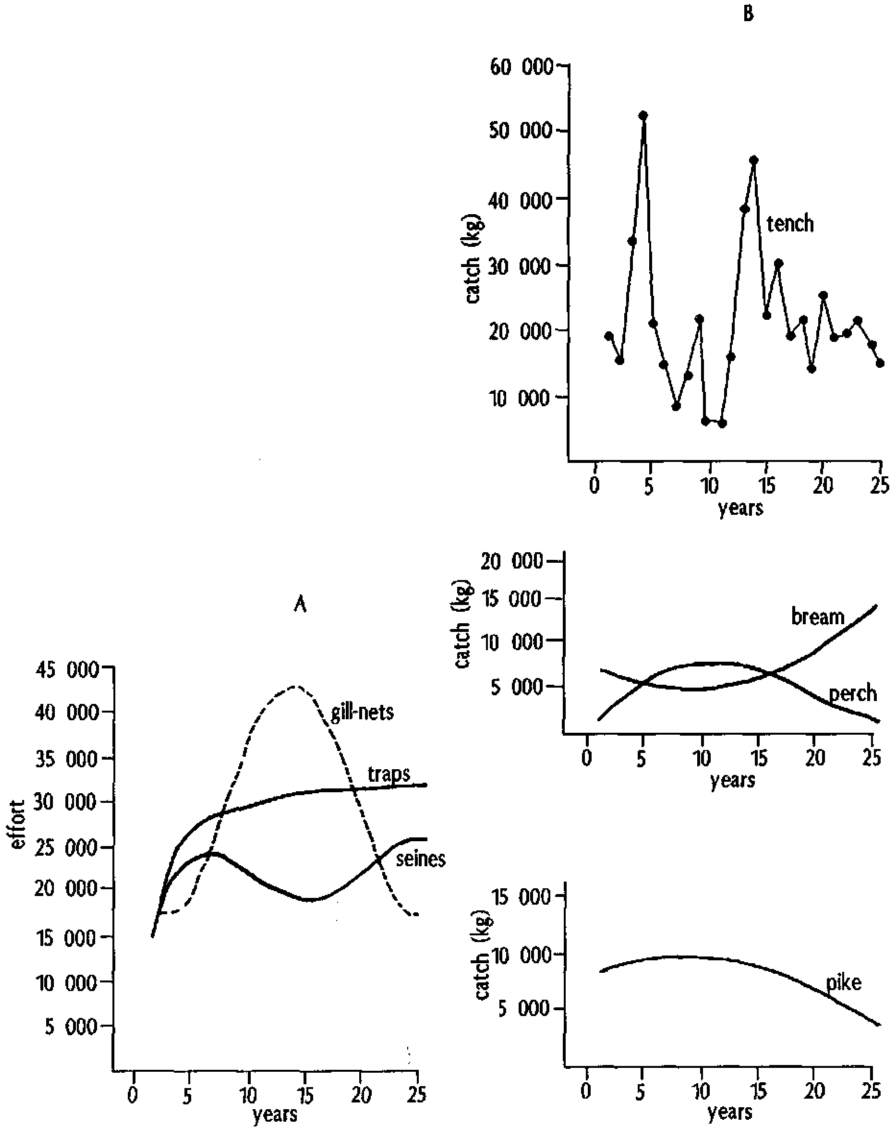


Figure 5-2. Lake Kisajno: a lake in the transition state between the second and third categories. A. Fishing effort for different gear in standard units. B. Catch trends for different species. Pike and tench are not caught in gill-nets.

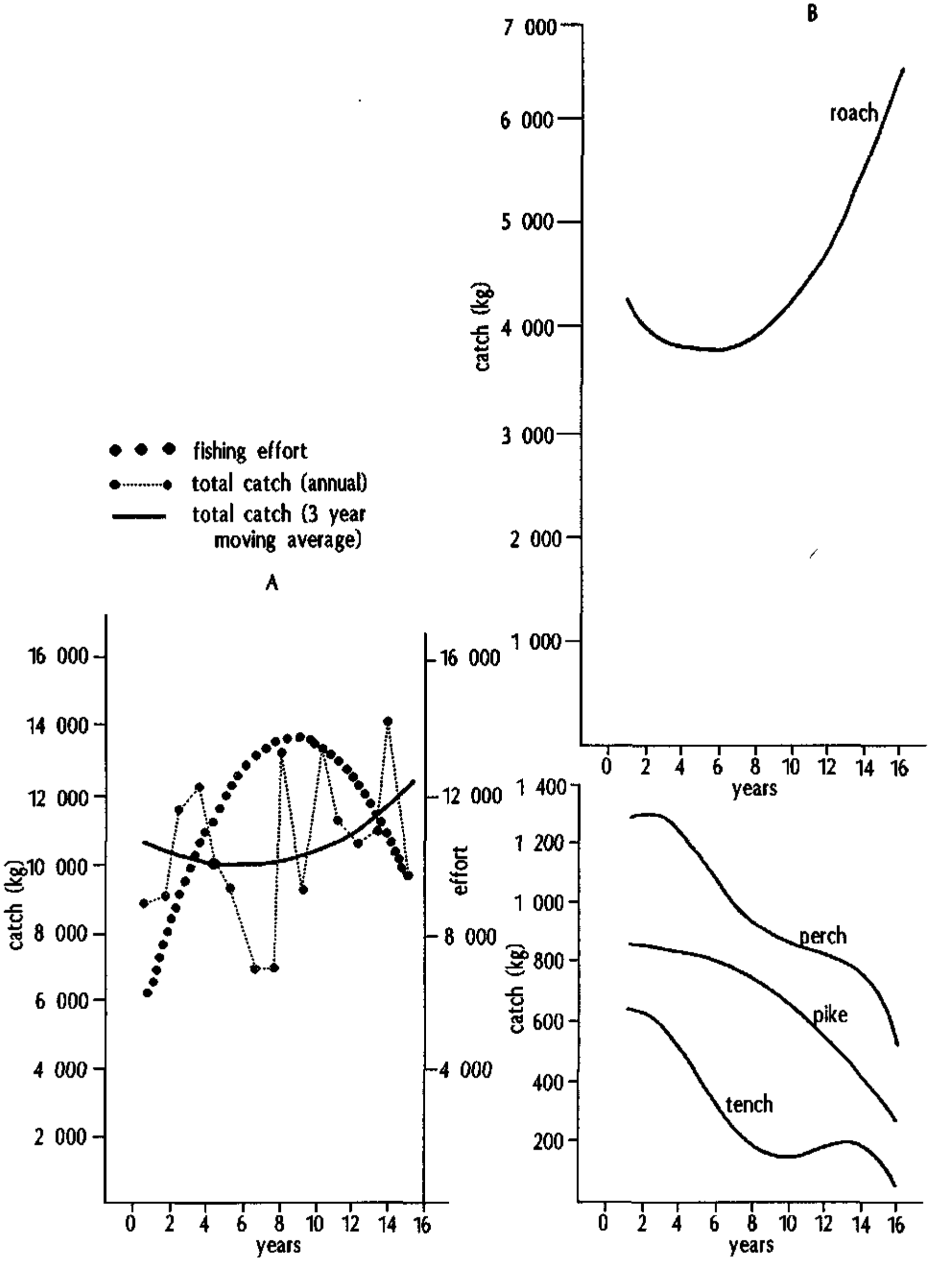


Figure 6. Lake Skarlin: a lake of the third category. A. Fishing effort and total catch as annual and as 3 year running average. B. Trends in catches of different species.

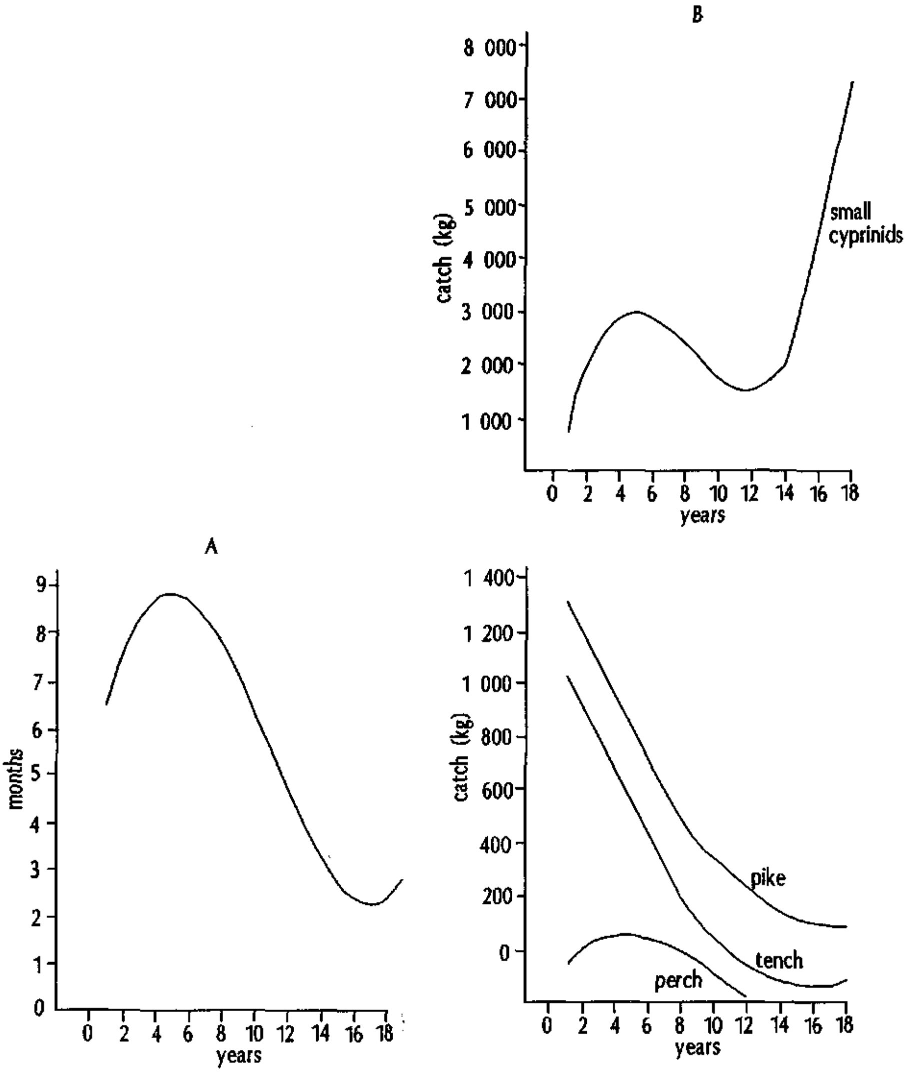
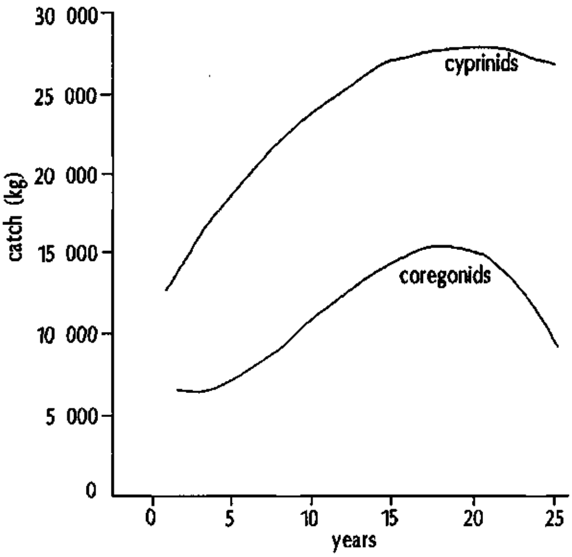


Figure 7. Lake Parszczenica Complex: a lake of the third category. A. Fishing effort in months in different years. B. Trends in annual catches of different species.



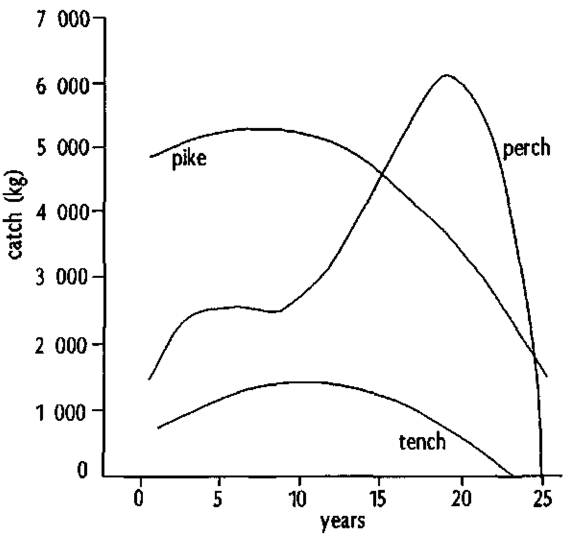


Figure 8. Lake Wigry: a lake of the third category. Trends in catches of different species.

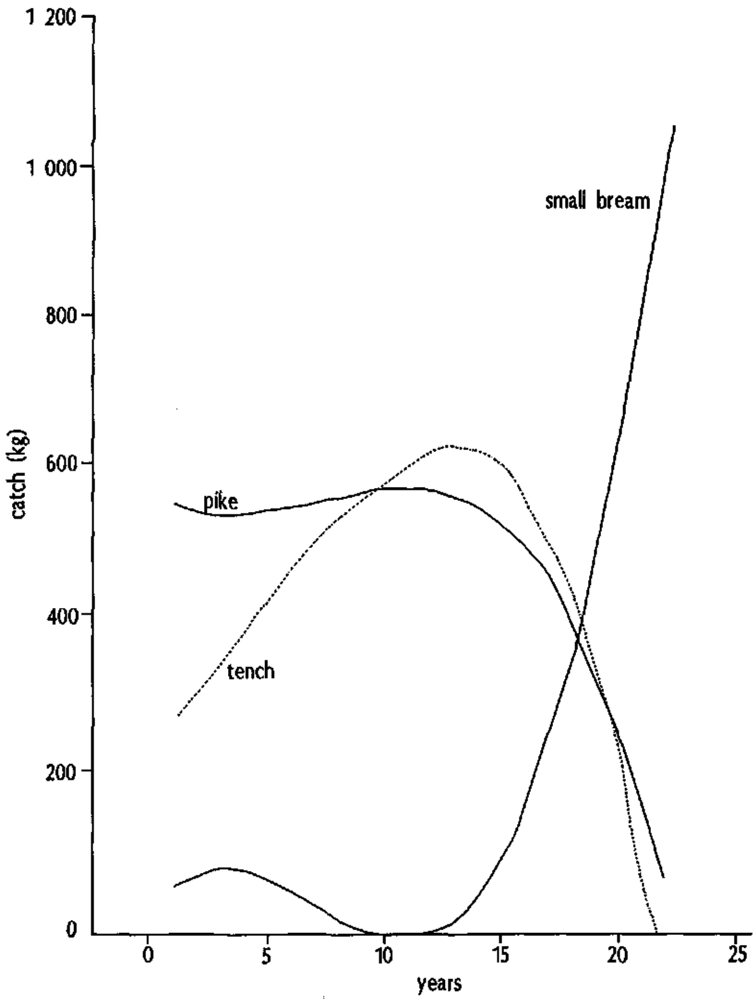


Figure 9. Lake Bachotek: a lake of the third category. Trends in catches of different species.

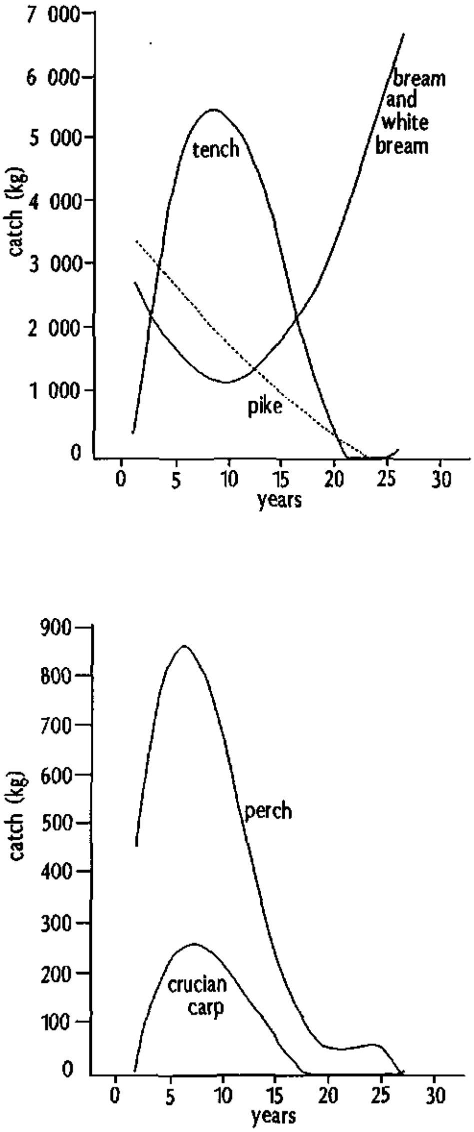


Figure 10. Lake Lubiatowo: a lake of the fourth category. Trends in catch of different species.

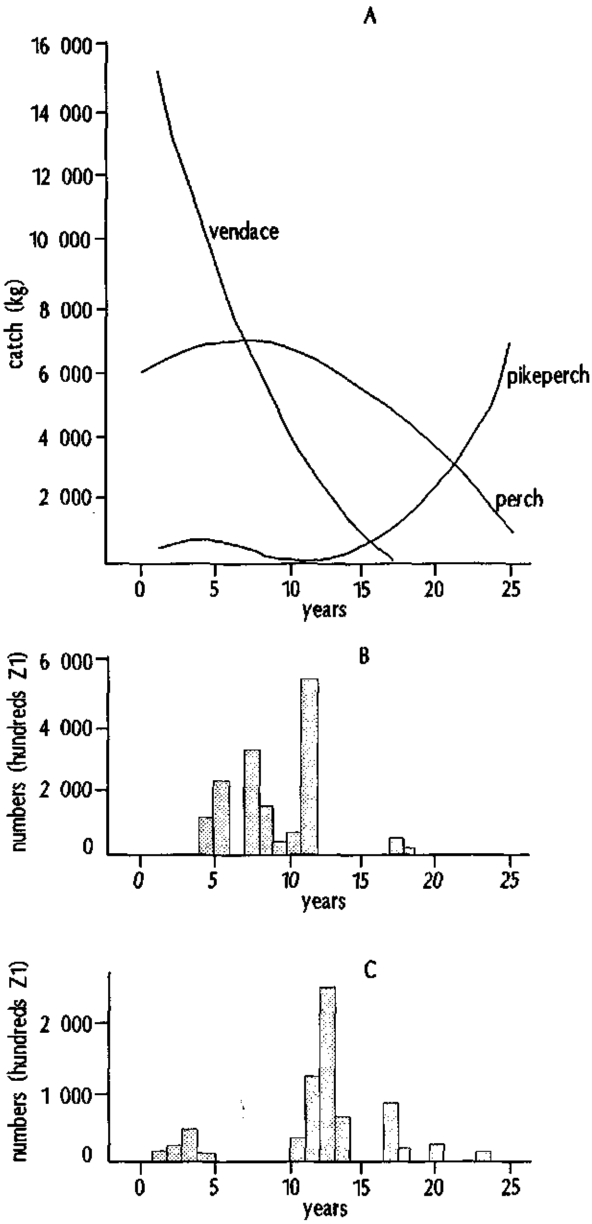


Figure 11. Lake Niegocin Complex: a lake of the fourth category. A. Trends in catches of different species. B. Stocking rates of vendace. C. Stocking rates of pikeperch.

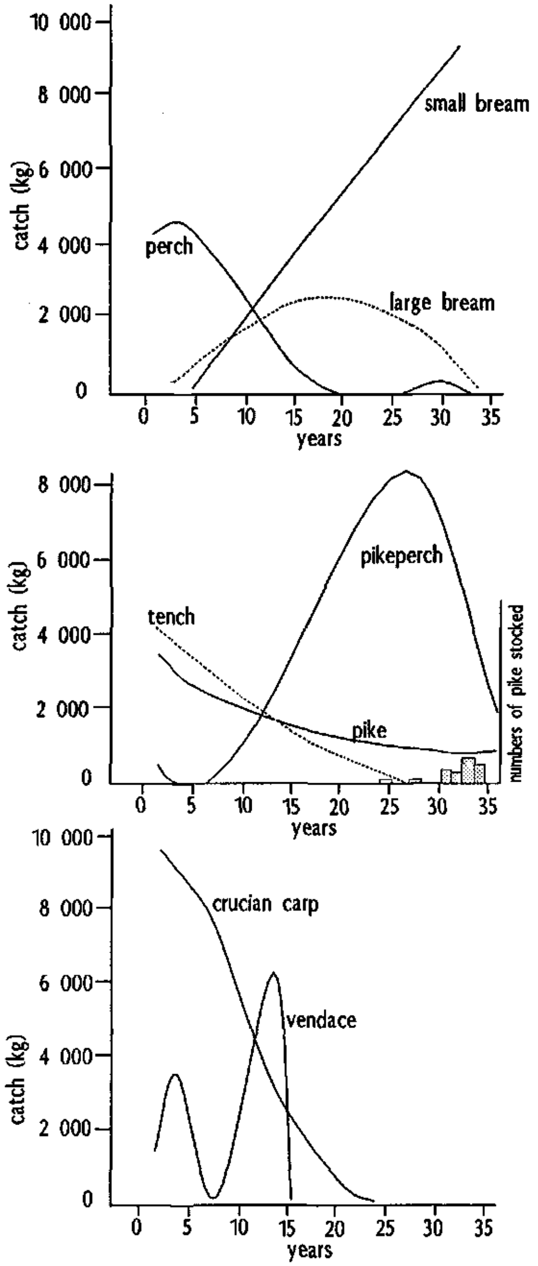


Figure 12. Lake Wielimie: a lake of the fifth category. Trends in catches of different species. The bars in the middle figure represent stocking with pike.

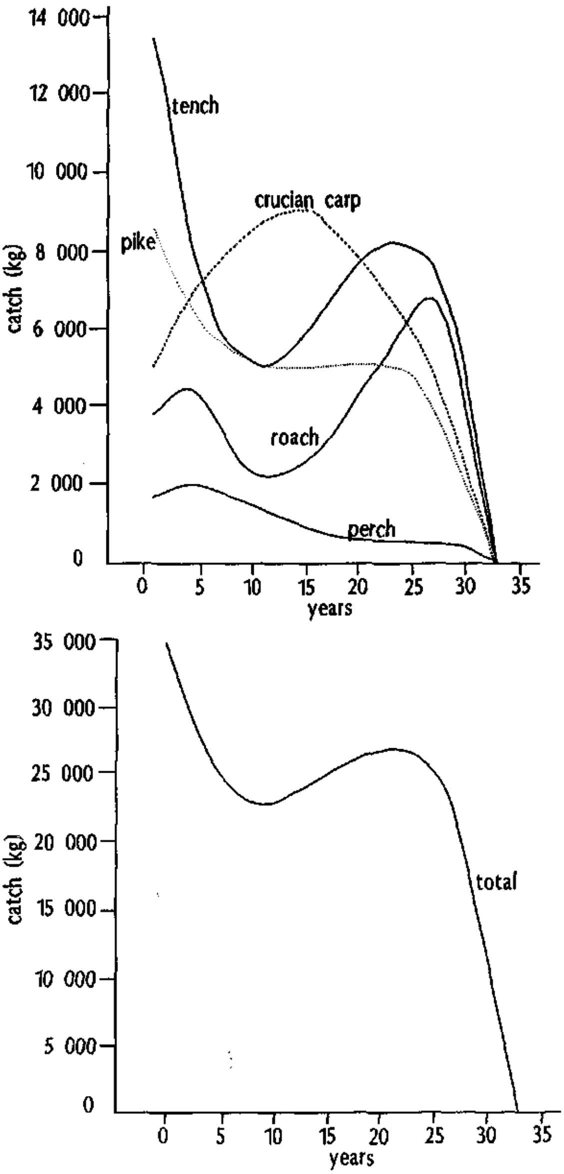


Figure 13. Lake Pogobie: a lake of the sixth category. Trends in catches of different species and in total annual catches.

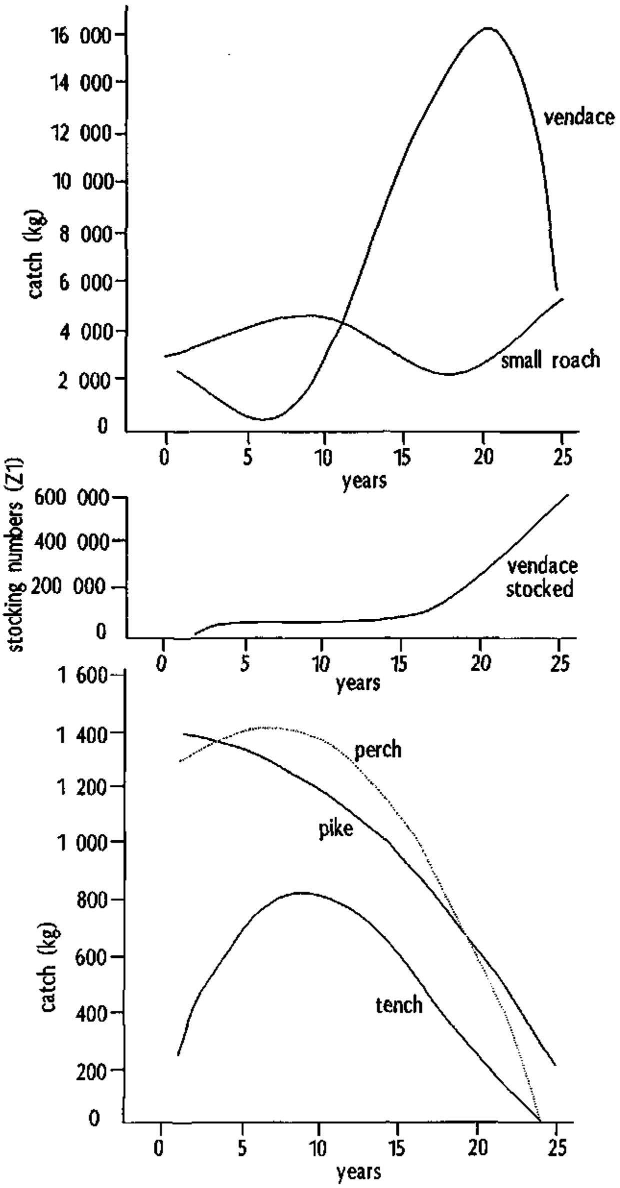


Figure 14. Lake Szelag Duzy: trends in catches of different species, and trend in numbers of Z1 vendace stocked.

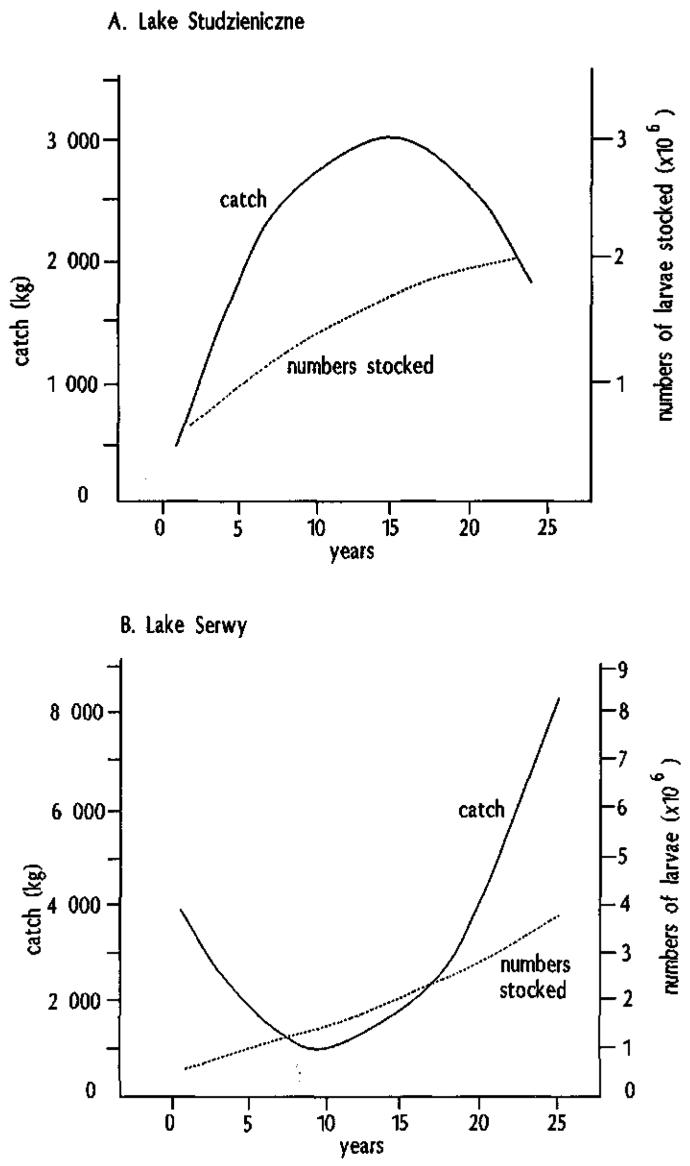


Figure 15. Trends in the catches of vendace (solid line) and the numbers of vendace larvae stocked (broken line) in A. Lake Studzieniczne and B. Lake Serwy.

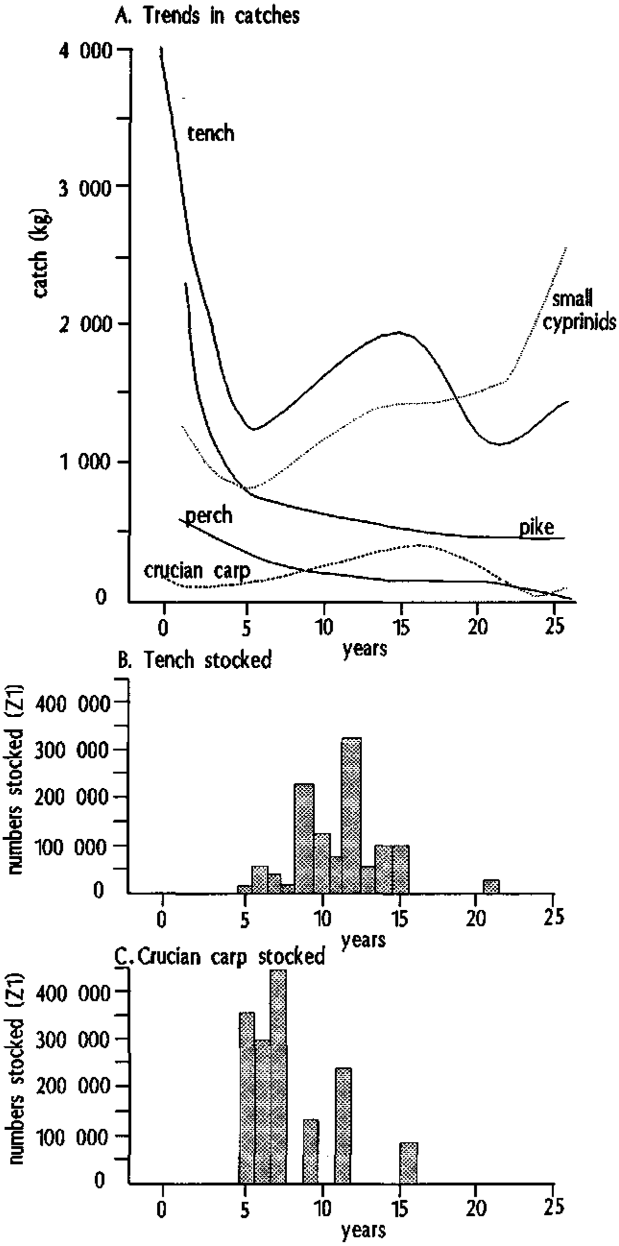


Figure 16. Lake Karnickie: A. Trends in catches of different species. B. Numbers of Z1 tench stocked. C. Numbers of crucian carp stocked.

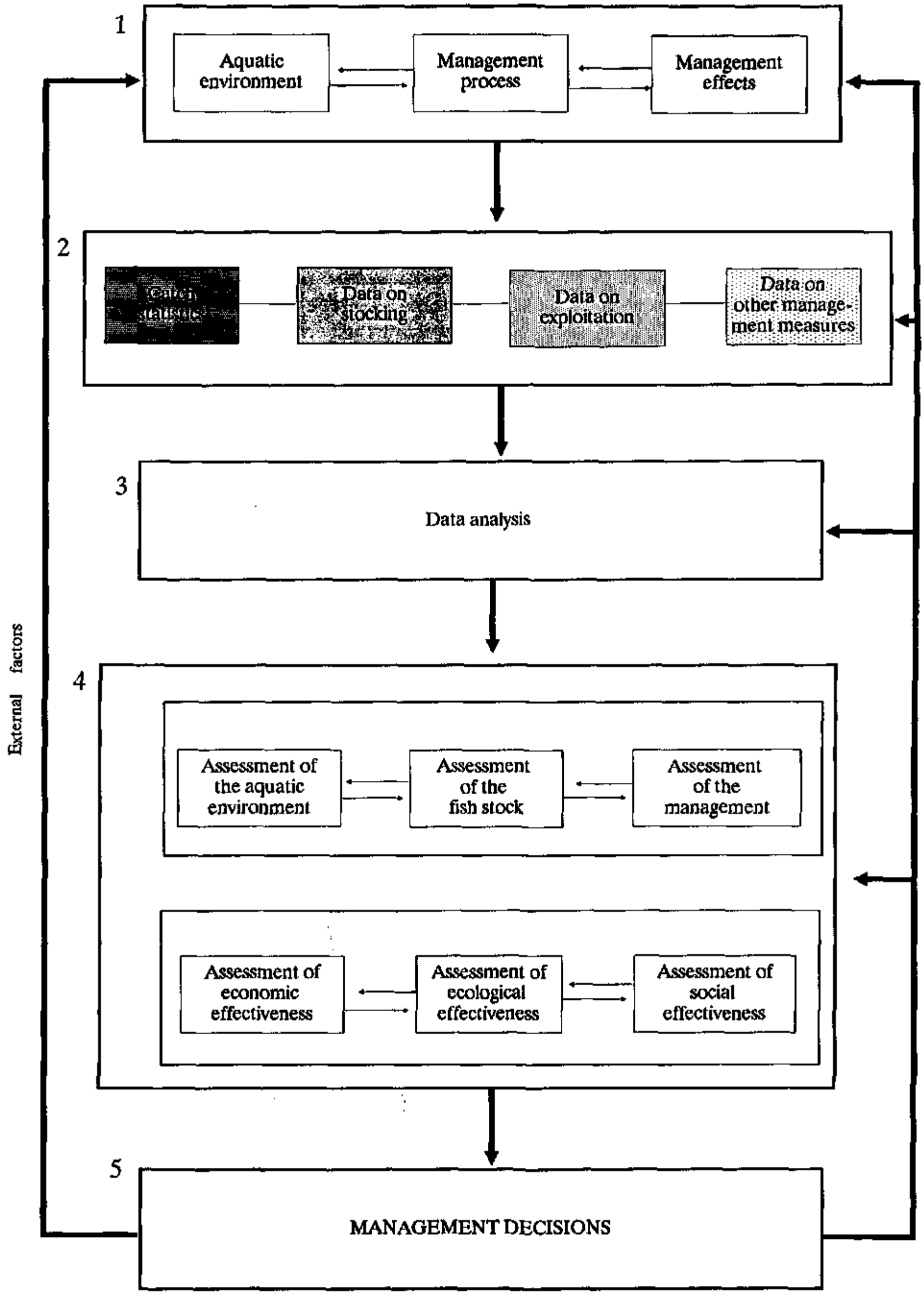


Figure 17. Simplified model of fisheries management.

Lake Bobecino *(Figure 2)* in the 1st category, is the only lake in which coregonid catches show no statistically significant trend and cyprinid catches are more or less stable.

Lakes Dargin and Dabrowa Wielka *(Figures 3* and *4)* are in the 2nd category. Here, catches of pike, perch and tench decrease, while an increase in catches of cyprinids is not very pronounced. Special attention should be paid to Lake Dabrowa Wielka where coregonid catches are entirely dependent upon artificial stocking, and increase, while catches of species less susceptible to eutrophication decrease. This provides an example of the good management of coregonid stocks in a lake of this trophic status.

Lakes Kisajno *(Figure 5)*, Skarlin *(Figure 6)*, Parszczenica *(Figure 7)*, Wigry *(Figure 8)* and Bachotek *(Figure 9)* belong to the 3rd category. In all of them, catches of pike, perch and tench decrease, while less valuable and small-sized cyprinids tend to increase rapidly. Lake Kisajno seems to be in a transition between the 2nd and 3rd categories. It is the only lake in this group in which the littoral seems relatively undisturbed and there is no statistically significant trend for tench catches.

Lake Lubiatowo *(Figure 10)* and the Lake Niegocin complex *(Figure 11)* belong to the 4th category. Lake Niegocin is heavily polluted. Nevertheless, stocking with pikeperch proved effective as seen from the trend of the catches. Again this reflects good management, at least for this species. However, stocking with vendace proved ineffectual indicating that the ecosystem is highly disturbed. Termination of vendace stocking was justified.

Lake Wielimie *(Figure 12)* is in the 5th category. Catch trends are very clear and leave no doubt as to the state of the lake. As stocking with pike slowed the rate at which catches decreased, the lake has not been placed in the final category.

Lake Pogobie *(Figure 13)* is in the 6th category and is no longer of use for a fishery. Even catches of cyprinids broke down here.

5. The decision-making process in lake management

Our studies led us to devise an analytical method for ichthyologists, to use on fish farms. It permits:

- Determination of the trophic state of a lake and its proper categorization.
- Estimation of the effectiveness of past management practices, especially of stocking.
- Use of the results to formulate future management plans for the lake.

An outline of this method, which is now being widely used by ichthyologists is given below. The method provides for three types of action to be taken; protection, exploitation and stocking. In general, with increasing eutrophy and degradation, management responses in these categories should change as follows:

1. Protection. Protective measures cover all activities directed towards enhancing the stocks of the most valuable species, but the most important are those concerned with preserving natural reproduction. Protective measures are of the utmost importance in the least disturbed lakes, and become less important with progressive environmental degradation. Where natural reproduction has broken down, protective measures are useless.
2. Exploitation. In addition to providing the catch, exploitation is an important management tool. The nature and intensity of fishing must be adapted to prevailing

environmental conditions. In general the entire fish community should be uniformly exploited in lakes with low levels of eutrophy, but as eutrophy increases so exploitation should become more selective. It can then be used as a tool to regulate the stocks of less desirable species. At the same time, fishing intensity for valuable species can be adjusted to suit stock sizes and/or stocking practices. Until recently fishing in Poland was non-selective and therefore was not used as a regulatory practice.

3. Artificial stocking. This is of little significance in healthy lakes, but is crucial to the survival of fisheries in highly eutrophic lakes where it is essential to preserve the stocks of valuable species. This has been the most important technique in Polish fishery management for some years now (Bninska 1985b).

These three management techniques differ as to their cost. Protection is least expensive and stocking the most. Moreover, costs of stocking increase as lake conditions deteriorate, thus fishery management becomes more expensive the more eutrophication progresses.

The first two categories of management practices have long term effects and it is impossible to predict their effectiveness in real terms. No reliable input-output model can be constructed for them, despite which, a good ichthyologist can usually judge when the implementation of these measures will prove worthwhile. By contrast, the effects of stocking are usually seen quickly, and input-output models can be constructed for stocking. The practice is the most necessary of the three in view of progressive and widespread lake eutrophication. It usually proves effective if adapted to prevailing environmental conditions (Bninska 1985b, Leopold 1986, 1987, Leopold *et al.* 1987b, 1988, Leopold, Bninska & Szlazynska 1988, Leopold, Bninska & Wolos 1988, Wolos 1988).The objectives of stocking may be:

- To develop a stock not previously present in a lake, and to obtain catches of it.
- To increase the stock of a species under threat in a lake, so that a decrease in catches may be arrested.
- To increase catches of a given species in a lake.

The first and last cases are easily analysed using input-output models, but the second is more complex since the response may be that catches continue to decrease, or they stabilise or increase. Our method involves two steps:

- First, trends of catches and stockings are calculated over a long period using the time-series method. This allows assessment of the rates of changes taking place in the fish community, of relationships between stockings and catches for a single species, and of the current trophic state of the lake in question. Preliminary management decisions can be based on these assessments. Obviously, only statistically significant trends are considered, and these are usually curvilinear.
- Second, statistical correlations between stockings and catches are calculated using regression analysis of real data. This makes it possible to define the most effective stocking rates for any given lake, the minimum and maximum stocking levels, and permits comparisons between different lakes.

Using our method it is possible to allocate stocking material to those lakes where it will prove most effective, *i.e.* to chose lakes and species to be stocked. When no statistically significant trends can be calculated, for instance when stocking has been irregular, or when there has been no significant correlation between stocking and catch, graphic methods can be used with moderately satisfactory results. Some examples of the application of the method follow.

The catch trends for indicator species from Lake Dabrowa Wielka, a 2nd category lake, are given in *Figure 4*. In this category coregonid catches are expected to be stable, or even to decrease slightly, but they are seen to increase rapidly. By comparing catch trends with stocking trends it is evident that catches increase due to stocking. The correlation is highly significant ($r=0.832$ $p<0.001$) and it can be concluded that stocking should continue. Further, the nature of the correlation suggests that stocking rates may be increased.

In Lake Szelag Duzy *(Figure 14)* the conclusions are quite different. Trends of vendace *(Coregonus albula)* catches and stocking show that stocking was effective only in the initial period, but that recently, catches have decreased despite an increase in stocking rates. Clearly the lake is so highly disturbed that coregonids have little chance. The fishery manager should use the stocking material to obtain better results elsewhere. Possibly the lake could be stocked with other species more resistant to the environmental changes than vendace.

An example of how to select which lakes to stock with which species (thus using the available stocking material most effectively), is given in *Figure 15*. Allocation of stocking material between the two lakes in the figure depends upon the amount of material available to the manager. With small quantities, vendace catches will be roughly equivalent in both lakes, but an abundance of material will ensure much better results in Lake Serwy *(Figure 15b)*. High stocking rates in Lake Studzienczne *(Figure 15a)* do not lead to an increase in catches and would waste resources.

Two other lakes, presented in *Figures 11* and *16*, show how data can be used when no statistically significant trends can be calculated. Analysis for Lake Niegocin *(Figure 11)* showed that vendace stockings were no longer effective, so they ceased. This lake has been placed in category 4. However, stocking with pikeperch gave good results and clearly helped to enlarge the stock of this species. Trends for the catches of indicator species in Lake Karnickie *(Figure 16)* show that the lake is moderately eutrophic. The decision to stock with tench was correct, as was the earlier one to stock with crucian carp. Decreasing catches of both species in recent years suggest that stocking should be repeated. It would also be advisable to increase fishing intensity on small cyprinids so as to replace them by the more valuable tench and crucian carp.

6. Conclusion

In appraising the management schemes applied to Polish lake fisheries, and the method used to analyse these fisheries and formulate future management decisions, the following should be borne in mind:

- No management policy can be worked out, and no decisions can be made, without data. Hence it is necessary to have full fishery statistics and supporting information available.
- Environmental conditions vary from lake to lake, so each must be analysed separately. Thus data must be collected accordingly.
- Changes occurring in aquatic ecosystems are often rapid so that analyses must be continuous. This enables managers to respond to changes quickly.
- Trends and correlations are mostly curvilinear. This may explain frequent claims that there is no correlation between stocking and catches, which have so far been based exclusively on linear approaches.

- The analyses required are simple, and quick if computerised. It is imperative that they be made by trained personnel with a sound knowledge of ecology. Only such people are qualified to interpret the results and base rational decisions upon them.

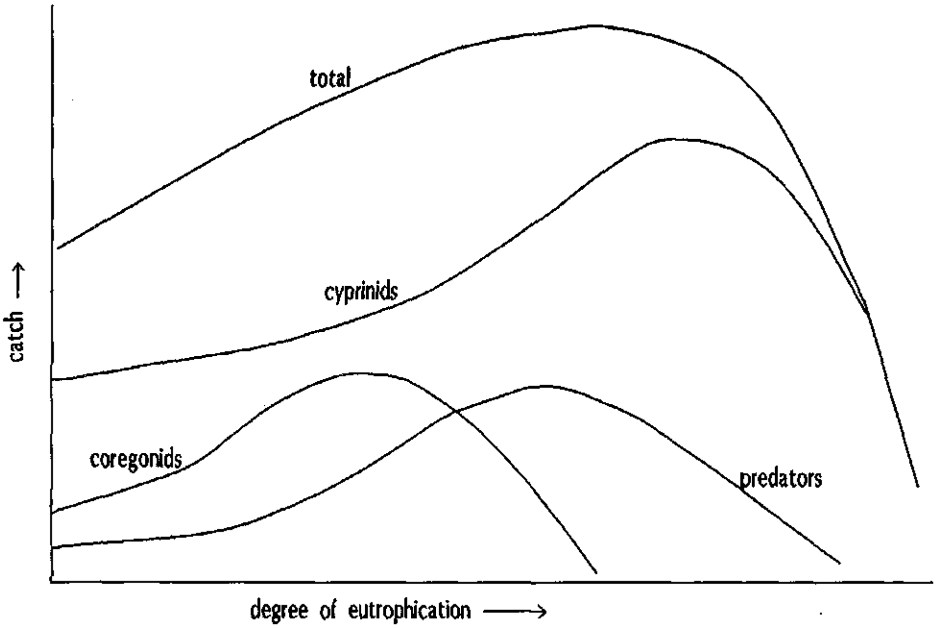


Figure 18. Model of changes in fish communities in lakes subject to eutrophication.

References

Bninska, M., 1985a. The effect of recreational uses upon aquatic ecosystems and fish resources. In: Alabaster J.S. (Ed.). Habitat modification and freshwater fisheries. Butterworth, London. pp. 223-235.

Bninska, M., 1985b. The possibilities of improving catchable fish stocks in lakes undergoing eutrophication. J. Fish. Biol. 27: Suppl.1. pp. 253-261.

Colby, P.J., Spangler, G.R., Hurley, D.A. & McCombie, A.M., 1972. Effects of eutrophication on salmonid communities in lakes. J. Fish. Res. Bd Can. 29: 975-983.

Frenkel', A.A. & Kil'dishev, G.S., 1973. Analiz vremennykh riadov i prognozirovanie (Time series analysis and forecasting). Statistika, Moscow.

Hartmann, J., 1978. Fischereiliche Veränderungen in Kulturbedingten eutrophierenden Seen. Schweiz. Z. Hydrol. 39: 243-254.

Hus, M., 1988. Zwiazki rekreacji i rybactwa na przykladzie jezior Augustowskich (Relationships between recreation and fisheries as exemplified by lakes in the Augustow area). Doctoral dissertation, IRS, Olsztyn. 200 pp.

Leach, J.H., Johnson, M.G., Kelso, J.R.M., Hartmann, J., Numann, W. & Entz, B., 1977. Responses of percid fishes and their habitats to eutrophication. J. Fish. Res. Bd Can. 34: 1964-1971.

Leopold, M. (Ed.), 1986. Stan i perspektywy rybactwa srodladowego w Polsce (Status and prospects of freshwater fisheries in Poland). Expertise for the Ministry of Agriculture, Forestry and Food, IRS, Olsztyn, Poland. 44 pp.

Leopold, M., 1987. Ocena stanu poglowia ryb w jeziorze Zamkowe (Estimation of the state of the fish community in Lake Zamkowe). Report to Sztum Department, Gdansk Fish Farm Dept. Fish. Econom., IRS, Olsztyn, Poland. 4 pp.

Leopold, M. & Bninska, M., 1987. Analiza odlowow i ocena stanu srodowiska oraz perspektywy gospodarki ryabckiej w 4 jeziorach Wielimie, Jamno, Lubiatowo i Lubieszewo (Analysis of fish catches, determination of trophic status and prospects of fishery management in 4 lakes: Wielimie, Jamno, Lubiatowo and Lubieszewo). Report to Koszalin Fish Farm, Dept. Fish. Econom., IRS, Olsztyn, Poland. 14 pp.

Leopold, M., Bninska M. & Nowak, W., 1983. Studium gospodarki rybackiej w Mazurskim Parku Krajobrazowym (Study of the fishery management in the Mazurian Landscape Reserve). Expertise for Olsztyn District authorities. Dept. Fish. Econom., IRS, Olsztyn, Poland. 47 pp..

Leopold, M., Bninska, M. & Nowak, W., 1986. Commercial fish catches as an index of lake eutrophication. Arch. Hydrobiol. 106: 513-524.

Leopold, M., Bninska, M. & Szlazynska, K., 1988. Ocena zarybien koregonidami w Zakładzie Rybackim Augustow (Estimation of the effectiveness of coregonid stockings in Augustow Regional Department). Report to Augustow Department, Gizycko Fish Farm, Dept. Fish. Econom., IRS, Olsztyn, Poland. 7 pp.

Leopold, M., Bninska, M. & Wolos, A., 1988. Gospodarka rybacka w jeziorach Wigierskiego Parku Narodowego (Fishery management in lakes of Wigry National Reserve). Expertise for the reserve. Dept. Fish. Econom., IRS, Olsztyn, Poland. 53 pp.

Leopold, M. *et al.*, 1987a. Ocena stanu troficznosci wybranych jezior woj slupskiego na podstawie analiz wieloletnich odlowow (Determination of the trophic status of selected lakes in Slupsk District on the basis of long-term catch statistics). Expertise for the District authorities, Dept. Fish. Econom., IRS, Olsztyn, Poland. 298 pp.

Leopold, M. *et al.*, 1987b. Gospodarka rybacka w systemie Wielkich Jezior Mazurskich na tle stanu ich srodowiska (Fishery management in the Great Mazurian Lakes on the background of their trophic status). Report to Gizycko Fish Farm. Dept. Fish. Econom., IRS, Olsztyn, Poland. 71 pp.

Leopold, M. *et al.*, 1988. Ocena eksploatacji wedkarskiej wod woj slupskiego na podstawie kart rejestracji polowow. Stan wod PZW i wytyczne ich zagospodarowania (Determination of angling exploitation in waters of Slupsk District on the basis of anglers statistics. State of waters of Polish Anglers Association and guidelines for their management). Expertise for Slupsk Department of the Polish Anglers Association. Dept. Fish. Econom., IRS, Olsztyn, Poland. 298 pp.

Spiegel, M.R., 1972. Theory and problems of Statistics. Shaum's Outline Series, McGraw-Hill, New York. 359 pp.

Wolos A., 1988. Analiza gospodarki rybackiej w jeziorach Laszmiada i Szostak Duzy (Analysis of fishery management in lakes Laszmiada and Szostak Duzy). Report to Elk Department, Gizycko Fish Farm. Dept. Fish. Econom., IRS, Olsztyn, Poland. 18 pp.

Zajac, K., 1982. Zarys metod statystycznych (An outline of statistical methods). PWE, Warsaw, Poland. 504 pp.

Zawisza, J. *et al.*, 1979. Jakie przyjac kierunki rybactwa jeziorowego w Makroregionie Polnocno-Wschodnim na tle istniejacej i spodziewanej eutrofizacji jezior (Policies of lake fishery management in the North-East Macroregion on the background of actual and forecast eutrophication). Expertise for the Polish Academy of Sciences. IRS, Olsztyn, Poland. 69 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp 437-446.

Trout populations in the Lima Basin, North Portugal

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Abstract

Salmonids reach their most southerly distribution in Europe in Portugal. Brown trout *(Salmo trutta)*, Atlantic salmon *(S. salar)* and rainbow trout *(S. gairdneri)* are present in the River Lima. Rainbow trout were introduced before 1900, but the others are native. None of these is fished commercially, but they are taken as by-catches in gear used in other fisheries. They are however, exploited by the sport fishery, especially brown trout.

A sampling programme was carried out in the River Lima and five of its tributaries. The composition of the fish community, the structure of the brown trout population, and its density and annual production are presented and discussed. Suggestions are made for the management of salmonids in the River Lima.

1. Introduction

Only in northern Portugal do conditions permit the establishment of self sustaining fish populations. Native salmonids are represented here by brown trout *(Salmo trutta)* and Atlantic salmon *(S. salar)*, but rainbow trout *(S. gairdneri)* was introduced before 1898 (Soeiro 1954), as self sustaining populations of salmonids.

Apart from rainbow trout, which is cultured in commercial fish-farms, there are no commercial salmonid fisheries. The stock of Atlantic salmon in the River Lima is very small, a maximum of less than 100 fish being caught annually, according to fishermen. Salmon and migratory trout are however, caught as by-catches with the gear used for sea lamprey *(Petromyzon marinus)* and shad *(Alosa alosa, A. fallax)* in estuaries. Legally, salmonids may be caught from inland waters only by angling, but with such small stocks the effort is not worth while from a commercial point of view.

From 1974 to 1981 nearly 270 000 Atlantic salmon juveniles were released in the River Lima (Ramos 1982), but the success of the operation was never estimated as there were no tagging or return control programmes. In addition appreciable numbers of brown trout juveniles were reared in state farms, together with some other freshwater species, and were released in several streams (Soeiro 1954). The results have probably been positive, but unfortunately, again, they were not evaluated quantitatively.

Some official fishery statistics are available, but until recently little attention has been directed to inland fisheries. An appreciable number of professional fishermen are involved, as shown by a mean number of 374 fishing licences issued over the last 10 years in the northwestern region alone *(Figure 1)*. Sport fishing is highly appreciated and a significant number of licences has been requested over the last ten years in this same region. The mean annual number of fishing licences of all types issued is 24 000, which includes national, local, daily and special licences.

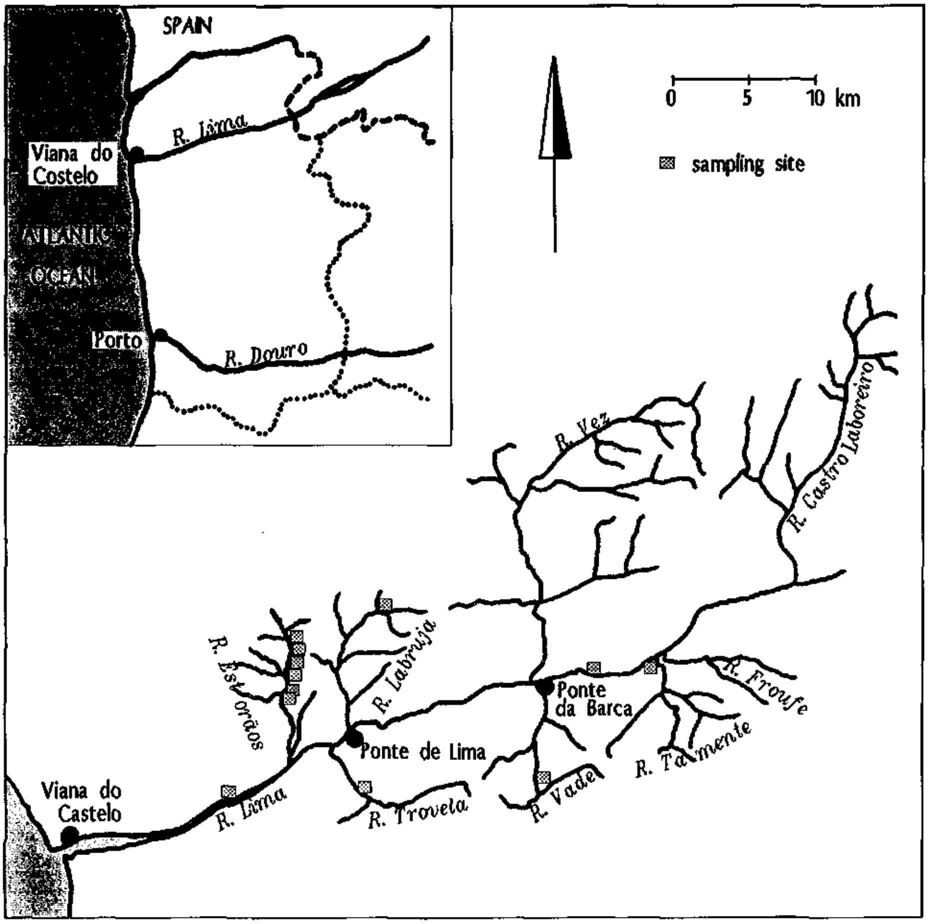

Figure 1. River Lima hydrographic basin and situation of sampling sites. The zone to which the fishery statistics refer is shown in the upper corner of the map.

Information on estuarine commercial yields *(Table 1)* is both scarce and unreliable. Recent studies on the stock of migratory sea lamprey in the Lima River have shown that only 25% of captures are declared. Further, although current legislation makes provision for obtaining details of inland captures, the procedure is rarely adopted. Thus there is a dearth of information regarding professional and sporting fisheries in inland waters, and the fishermen concerned in them.

Portuguese salmonid stocks deserve to be studied for several reasons. Salmonids reach the southern extremity of their European range in Portugal, and thus to study them there may provide information as to critical factors in their biology and ecology. Also the Portuguese fish fauna is peculiar, as a result of geographical isolation (Almaça 1968), so the salmonid populations may reveal important differences from other European populations.

It should be possible to increase the stocks of Atlantic salmon and sea trout in Portuguese rivers, and in consequence of an initiative taken by our Institute, salmonids may become more important to our fisheries in the future. The present brown trout populations already support a thriving sport fishery, particularly in the northwestern region, which brings great economic and touristic advantage. Because of this we must evaluate the stocks, about which we have little information, and obtain biological and ecological data.

Table 1. Annual estuarine catch (in kg) in 1985 in Portuguese rivers (information from the Direcção-Geral das Pescas).

Species	Catch (kg)
Sea lamprey (*Petromyzon marinus*)	2 981.1
Atlantic salmon (*Salmon salar*)	8.0
Shad (*Alosa alosa*)	57 408.2
Twaite Shad (*A. fallax*)	4 511.3
Flounder (*Platichthys flesus*)	93 344.4
Others	29.0
Total	158 282.0

2. The study area

The River Lima rises near Ginzos de Limia in Spain. The main course is 108 km long, the last 65 km being in Portugal. The stream flows southwest before reaching Portugal and then south-southwest to the sea near Viana do Castelo. The river valley is narrow in its upper course in Portugal, becoming broader as it approaches the sea. The catchment is granitic almost to the river mouth, where its bed becomes recent alluvium. The obstacles in the river consist of two hydroelectric dams. The downstream dam was built near the Spanish border in 1922, but is being replaced by a higher dam at the same site, while a third dam is planned 18 km below it. There are about one hundred small dams on the river, for the sea lamprey fishery or to divert water to mills, but these do not constitute obstacles for the migratory species because of their size and special design.

Our study was carried out in five River Lima tributaries as well as the main river (*Figure 1*). The tributaries studied are 10-15 km long and their sources are all at similar altitudes (300-500 m asl). One sampling site was chosen in each tributary, but in different zones of the rivers' courses because of the need to access the sites from the road. Only in the River Estorãos was sampling extended to different zones along its course. In the main river, two points were sampled, one in Touvedo, in the upper part of the river near the projected third dam, and another in Bertiandos, in the lower part of the river near the river mouth.

Table 2. Mean annual water characteristics of the sites sampled in the River Lima hydrographic basin. * Significant differences; ** highly significant differences.

	Labruja	Trovela	Vade	Tamente	Estorãos	Lima	ANOVA
Temperature (°C)	12.70	13.45	12.05	13.15	13.85	11.80	
pH	6.58	6.75	6.49	6.69	6.58	6.61	
Dissolved oxygen(mg/l)	10.36	10.28	10.57	10.73	10.55	11.01	
% saturation of oxygen	101.40	101.64	101.05	104.72	105.39	104.97	
CBO 5(mg/l)	1.45	2.36	1.69	2.15	1.38	1.67	*
Alkalinity (ppm)	7.57	9.90	8.85	7.54	6.48	6.71	**
N-NO_2 (μg/l)	0.09	0.08	0.11	0.07	0.06	0.08	
N-NO_3 (μg/l)	19.61	55.13	36.41	12.17	20.61	17.86	**
N-NH_4 (μg/l)	0.0004	0.0003	0.0011	0.0061	0.0011	0.0001	
P-PO_4 (μg/l)	0.26	9.64	1.54	2.13	0.85	1.79	
Si (mg/l)	1.60	2.37	3.33	1.71	0.84	1.44	**
Hardness (ppm $CaCO_3$)	6.50	10.71	7.57	5.61	6.47	5.56	**
Conductivity (μmhos/cm)	25.17	42.97	29.72	20.69	25.24	19.38	**

3. Materials and methods

Physico-chemical water parameters were determined monthly for one year at all sampling stations. In the tributary rivers, fish were caught using two D.C. electro-fishing sets connected in series. Sampling was carried out for 4 years in the River Estorãos (1983-1986) and for 2 years in all other tributary rivers (1985-1986). The catch-removal method was used twice in each study area on the same day. In the main river, sampling was carried out with gill-nets. Low water conductivity, difficulty of access to the margins, and riverine width were reasons for choosing a different method.

Fork lengths, fresh weights and scale samples were obtained from all captured fish. Age-classes for trout were assessed by scale counting. Estimates of population sizes in the tributary rivers were made by the method of DeLury (1947), while production estimates were calculated by Allen's graphic method (Chapman 1978). In the main river population parameters could not be estimated because of the small numbers of trout captured.

4. Results

The physico-chemical analyses of the waters revealed significant differences between the tributaries studied *(Table 2)*, the Rivers Trovela and Vade for example, having more highly mineralised waters than the others. Electro-fishing efficiency was not always high, partly due to the low conductivity of the water, but also because the abundance of aquatic vegetation in some sites interfered. Efficiency ranged from 56-100% with a mean value of about 90%. Some characteristics of the study areas are shown in *Table 3.*

Table 3. Characteristics of River Lima tributaries.

River	Length (km)	Margins use	Sampling point	Stream bed	Aquatic vegetation	Distance to source (km)
Estorãos	14.3	agriculture & forest	6 along river	rocks to mudd	abundant to scarce	2.4 - 8.0
Labruja	13.2	agriculture	near source	rocks gravel	abundant	2.8
Trovela	15.0	agriculture	middle	gravel	scarce	8.0
Vade	15.5	agriculture	upper	rocks gravel	scarce	7.0
Tamente	10.0	agriculture & forest	near mouth	gravel sand	absent	10.0

There were trout populations in all study areas on the tributary rivers, but their densities varied greatly. In *Table 4* we indicate the age composition of the populations in each study area. The populations showed slow growth rates *(Table 4)*, and their densities and our estimates of instantaneous production are given in *Table 5.* The data from the River Estorãos, for the period 1985-1986, was not considered because illegal fishing in the upper part of the stream altered the population structure.

The ichthyofaunas of the tributaries include chub *(Leuciscus cephalus)*, Iberian nase *(Chondrostoma polylepsis)* and eel *(Anguilla anguilla)*. In the River Tamente, Atlantic salmon juveniles were also present. In the main river 3 additional species were found, Iberian barbel *(Barbus barbus bocagei)*, a roach *(Rutilus arcasi)* and the grey mullet *(Mugil cephalus)*. *Table 6* shows the relative abundances of the species captured in the main river and its tributaries. However, the River Lima fish fauna is also known to include the sea lamprey, two alosids *(Alosa alosa* and *A. fallax)*, flounder *(Platichthys flesus)* and rainbow trout (Albuquerque 1956, Almaça 1965, Daget 1968, Nobre 1932).

5. Discussion

Water quality in the River Lima system is generally good (Fontoura 1984). It has high levels of dissolved oxygen, but is slightly acidic and poor in calcium, reflecting the granitic nature of the hydrographic basin. Water conductivity is low and consequently affected sampling (electro-fishing) efficiency. Some significant differences were observed be-

Table 4. Age group distribution (P in %) and length (L in cm) at age of the trout in the River Lima tributaries studied. For River Estorãos the data refer to the period 1983-1984 and for the others to the period 1985-1986.

Tributary		0+	1+	2+	3+	4+
Estorãos	P (upper zone)	72.8-78.9	12.3-18.7	5.5-5.8	1.5-2.2	
	P (middle zone)	52.1-66.2	22.4-25.7	3.3-9.9	4.6-7.7	2.8-3.3
	P (lower zone)	63.8-69.6	17.5-28.9	5.2-6.7	3.4-4.1	0.5-4.7
	L	6.5-6.7	11.6-12.4	16.1-16.5	18.1-19.4	
Labruja	P	8.6-39.4	37.8-56.2	20.3-29.5	2.4-4.4	1.3
	L	5.53	10.78	13.77	15.00	18.60
Trovela	P	43.9-55.1	26.2-31.4	10.6-11.6	3.7-4.4	0.3-2.0
	L	6.74	12.33	15.79	19.15	21.60
Vade	P	46.9-52.5	33.1-38.7	8.7-10.0	1.7-4.4	0.9
	L	6.92	13.32	17.51	19.25	21.80
Tamente	P	83.3-96.7	3.3-10.0	6.6		
	L	8.45	14.73	18.45		

Table 5. Trout densities and production estimates in the study areas of River Lima tributaries during the study period.

Study area	Density (number/ha)	Production (g/m^2/year)
Estorãos (upper zone)	1 800-2 000	3.3
Estorãos (middle zone)	200-570	1.0
Estorãos (lower zone)	680-1 200	1.1
Labruja	2 800-4 100	6.8
Trovela	2 450-2 500	13.5
Vade	1 960-2 600	7.5
Tamente	220-440	2.0

tween the water chemistries of the tributaries. The Trovela and Vade Rivers had higher productivities than the others and were more highly mineralised.

Although only a small number of trout were captured in the main course of the River Lima *(Table 6)* this does not mean that they are rare. The small number reflects fishing technique and the nature of the sampling points chosen. High water levels and flow rates during the sampling period made it impossible to sample in sites more favourable to salmonids.

Table 6. Relative abundance of the fish taxa in the River Lima and in its tributary rivers.

River		Percentage abundance				
		Salmonidae		Cyprinidae	Anguillidae	Others
		Trout	Salmon			
Estorãos	(upper zone)	21.4-60.8		36.6-77.7	0.9-1.7	
	(middle zone)	19.4-32.4		47.3-58.9	17.6-33.3	
	(lower zone)	22.2-51.2		29.7-58.9	12.2-27.9	
Labruja		99.4-100			0.0-0.6	
Trovela		81.5-90.3		5.7-6.0	3.9-12.5	
Vade		89.1-94.1			5.9-10.9	
Tamente		7.9-17.3	12.6	29.2-42.3	39.9-56.9	
Lima-Trouvedo		0.0-0.6		96.4-100		
Lima-Bertiandos		0.0-2.9		96.2-100		0.0-0.9

The density of the trout populations in the tributaries probably varies between zones, judging from the studies on the River Estorãos. In this river cyprinids are marginally more abundant than trout in the upper zone *(Table 6)* where, in the trout population, juveniles predominate *(Table 5)*. By contrast, trout are less important in the middle and lower zones, where eels become more important although cyprinids remain dominant *(Table 6)*. Moreover, at the middle and lower sampling sites, the trout populations contain higher percentages of older individuals. The confluence of a small stream with the Estorãos near the lower sampling site probably accounts for the increase in trout numbers observed there and also for the small increase in the percentage of juveniles in the trout population. Trout production is higher in the upstream zone of the Estorãos than it is in the middle and lower zones *(Table 5)*; the small increase at the lower zone can be accounted for by the affect of the confluence just mentioned.

The River Tamente sampling site is near the confluence with the River Lima. The fish community is mainly composed of cyprinids and eels *(Table 6)*, but the trout population shows an age-class distribution similar to that observed in the upper zone of the Estorãos, 0+ trout being the most important fraction of the trout population *(Table 4)*. Trout density is comparable with that observed in the middle zone of the Estorãos, but the larger growth rate observed results in better estimated trout production *(Table 5)*. The vicinity of the main river and the presence of good spawning areas explain the presence of Atlantic salmon parr *(Table 6)*.

In the Rivers Trovela and Vade the fish captures were made in the central zone of the rivers. Trout is the dominant fish species *(Table 6)* and we observed similar numbers of 0+ and 1+ individuals in each, and a higher density of 1+ and 2+ fish than in the middle zone of the River Estorãos *(Table 4)*. The sampling points on these two rivers are shallow and the water velocity is high. Although aquatic vegetation is scarce, trees are abundant on the banks. Tree cover probably provides abundant fish food and might explain the higher levels of production found in these areas *(Table 5)*.

The River Labruja is a special case. The sampling point is near its source. It is a very narrow stretch of river which becomes a succession of small pools in the dry season. Space and food are surely the limiting factors that explain the small number of 0+ trout observed *(Table 4)*. Most of these probably drift downstream to escape competition with older fish. The high densities in this stretch *(Table 5)* and the limiting factors referred to, may also explain the slow growth rates observed (McFadden 1969). Trout production is high and reflects the high population density of 200-4100 trout/ha, the lower values being observed in sites where trout was not the dominant fish species (200-2000 trout/ha).

Except for the upper stretch of river Estorãos, where trout and other species are represented in almost equal numbers, these densities are lower than those observed in other more productive Iberian rivers (Lobón-Cerviá & Penczak 1984, Valente in press), but they are higher than the estimates given for two other Iberian rivers (Jalón, Montes, Barceló, Casado & Menes 1988) and for Swedish rivers (Karlstrom 1977, Andersson & Andersson 1984). In the sites where trout is the main species, the densities observed fall within the lower part of the range observed for other European rivers (Horton, Bailey & Wilsdon 1968, LeCren 1969, Egglishaw 1970, Cuinat 1971, Mortensen 1977, Milner, Gee & Hemsworth 1978, Andersson & Andersson 1984, Jalón, Esteban & Alcalde 1986).

Trout growth in all tributaries studied is slow or very slow (Kennedy & Fitzmaurice 1971). Similar growth rates have, however, been observed in other granitic basins (Kennedy & Fitzmaurice 1971) and in unproductive waters with low calcium contents and acidic natures (McFadden & Cooper 1962 cited in McFadden 1969, Timmermans 1966, 1986, Horton *et al.* 1968, Egglishaw 1970, Cuinat 1971, Power 1973), while even slower growth rates have been reported for Norwegian rivers (Power 1973). Nevertheless, other Iberian trout populations in more productive waters show faster growth rates (Lobón-Cerviá & Penczak 1984, Jalón & Serrano 1985, Jalón *et al.* 1986, Jalón *et al.* 1988, Valente in press) as do most other European trout populations studied (Cuinat 1971, Mann 1971, Milner *et al.* 1978).

Annual trout production estimates depend on population densities. In the study sites where trout were outnumbered by other species our estimates are near the lower part of the range observed for trout in other Iberian rivers (Lobón-Cerviá & Penczak 1984, Jalón *et al.* 1988, Valente in press). In all our other sites, where trout were dominant, production ranges from 6.8-13.5 $g/m^2/yr$, which places them in the lower part of the range reported for European rivers in general (LeCren 1969, Egglishaw 1970, Mann 1971, Mortensen 1977, 1979).

6. Conclusions

The River Lima is still an unpolluted river, but some of its water characteristics such as pH, low calcium content and scarce aquatic vegetation are unfavourable for trout. Although the water temperatures observed would favour fast growing populations, other factors such as low calcium content and the scarcity of aquatic vegetation make this river poor in trout food. Thus it cannot sustain dense populations, and growth rate and annual production are low.

Legislation for trout fishing in the River Lima is rather strict. In the salmonid zone of the main river, and in two tributaries, the Tamente and Froufe, only a few restrictions are applied and fishing is possible all year. In another group of tributaries, the Estorãos and Labruja included, angling is only permitted during weekends and holidays. In a final group, including the Rivers Trovela and Vade, a special daily licence is required to fish in reserved sectors. The extension of this last restriction to all tributary rivers might help protect trout stocks.

Measures should be taken to increase the macro-invertebrate fauna, such as protecting bankside vegetation, and increasing aquatic vegetation by creating suitable substrata and building small pools. The increase in shelter brought about would probably increase fish densities. The migratory stock should also be protected during its upstream spawning migrations by constructing a fish pass in the dam to be built in the middle course of the river.

Trout population studies should continue and be extended to correctly evaluate trout stocks, not only in the other tributaries of the Lima, but also in other Portuguese river systems.

References

Albuquerque, R.M., 1956. Peixes de Portugal e ilhas adjacentes (Chaves para a sua determinação). Portugaliae acta biologica, ser. B, Vol. V (Complete volume, 1954-1956).

Almaça, C., 1965. Contribution à la connaissance des poissons des eaux intérieurs du Portugal. Arq. Mus. Boc. 1: 9-39.

Almaça, C., 1968. Os peixes de água docee a zoogeografia da Península Ibérica. Actualidades biológicas 40: 123-148.

Andersson, B. & Andersson, P., 1984. The distribution of trout *(Salmo trutta* L.*)* in relation to pH - an inventory of small streams in Delbso, Central Sweden. Rep. Inst. Freshw. Res. Drott. 61: 28-33.

Chapman, D.W., 1978. Production. In: T.B. Bagenal (Ed.). Methods for assessment of fish production in fresh waters, IBP Handbook No. 3. pp. 202-217.

Cuinat, R., 1971. Principaux caracteres démographiques observées sur 50 rivières a truites françaises. Influence de la pente et du calcium. Ann. Hydrobiol. 2: 187-207.

Daget, J., 1968. Divérsité des faunes de poissons dans les cours d'eaux du Portugal. Arq. Mus. Boc., Notas e Suplementos 15: 21-26.

DeLury, D.B., 1947. On the estimation of biological populations. Biometrics 3: 145-176.

Egglishaw, H.J., 1970. Production of salmon and trout in a stream in Scotland. J. Fish Biol. 2: 117-136.

Fontoura, A.P., 1984. Les communautés de macro-invertebrés du bassin hydrographique du fleuve Lima comme indicateurs de la qualité biologique de l'eau. Publ. Inst. Zool. Dr. "Augusto Nobre" No. 183.

Horton, P.A., Bailey, R.G. & Wilsdon, S.I., 1968. A comparative study of the bionomics of the salmonids of three Devon streams. Arch. Hydrobiol. 65: 187-204.

Jalón, D.G. & Serrano, J., 1985. Las poblaciones de truchas en los rios de la cuenca del Duero. Bol. Est. C. Ecol. 28: 47-56.

Jalón, D.G., Esteban, E.T. & Alcalde, F.R., 1986. Estimacion de algunos parametros poblacionais de la trucha comun *(Salmo trutta fario)* en los rios pirenaicos. Bol. Est. C. Ecol. 29: 51-58.

Jalón, D.G., Montes, C., Barceló, E., Casado, C. & Menes, F., 1988. Effects of hydroelectric scheme on fluvial ecosystems within the Spanish Pyrenees. Regulated Rivers 2: 479-491.

Karlstrom, O., 1977. Habitat selection and population densities of salmon *(Salmo salar* L.*)* and trout *(Salmo trutta* L.*)* parr in Swedish rivers with some reference to human activities. Doc. Thesis, Uppsala University, Sweden.

Kennedy, M. & Fitzmaurice, P., 1971. Growth and food of brown trout *Salmo trutta* (L.) in Irish waters. Proc. R. Ir. Acad. 71 B, n. 18.

LeCren, E.D., 1969. Estimates of fish populations and production in small streams in England. In: T.G. Northcote (Ed.). Salmon and trout in streams, Macmillan, H.R., Lect. Fisheries, Univ. British Columbia, Vancouver. pp. 269-280.

Lobón-Cerviá, J. & Penczak, T., 1984. Fish production in the Jarama River, Central Spain. Hol. Ecol. 7: 128-137.

Mann, R.H.K., 1971. The populations, growth and production of fish in four small streams in southern England. J. Anim. Ecol. 40: 155-190.

McFadden, J.T., 1969. Dynamics and regulation of salmonid populations in streams. In: T.G. Northcote (Ed.). Salmon and trout in streams, Macmillan, H.R., Lect. Fisheries, Univ. British Columbia, Vancouver. pp. 313-329.

Milner, N.J., Gee, A.S. & Hemsworth, R.J., 1978. The production of brown trout, *Salmo trutta*, in tributaries of the Upper Wye, Wales. J. Fish Biol. 13: 599-612.

Mortensen, E., 1977. Fish production in small Danish streams. Folia Limnol. Scandinavica 17: 21-26.

Mortensen, E., 1979. Population dynamics, regulation and production of stream salmonids. In: The use of ecological variables in environmental monitoring. The National Swedish Environment Protection Board, Rep. PM 1151, pp. 220-227.

Nobre, A., 1932. Peixes de água doce de Portugal. Bol. Mins. Agricultura 2: 1-44.

Ramos, M.A., 1982. Atlantic salmon ranching in Portugal. In: Erickson, C. Ferrani, M.P. & Larsson, P.O. (Eds). Sea ranching of Atlantic salmon. Commission of the European Communities, Cost 46/4 Workshop, Lisbon. pp. 109-125.

Soeiro, J.A.S., 1954. Algumas notas sobre o repovoamento piscícola das águas doces em Portugal. Estudos e informação, D.G.S.F.A. No. 40.

Valente, A.C.N., in press. As populações piscícolas do Rio Febros. Observatório 1.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp 447-412.

Fisheries management and the hydraulic regime in the Danube Delta

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Abstract

The Danube Delta, covering more than 500 000 ha, has evolved rapidly and is a comparatively recent geological feature. For 70 years, prior to 1965, both the lower river and delta were exploited for fisheries which were adapted to the hydrology and ecology of the river according to concepts enunciated by Grigore Antipa. Hydraulic management of the river at this time was aimed at fisheries production, and ensured the penetration of fresh river water to all parts of the delta. Subsequently however, a period of dam construction began which adversely affected the fisheries. Major changes to occur were increasing eutrophication of the river, increasing turbidity of the water, silting of the delta and a reduction in the area of seasonally flooded land. Further, the passage of anadromous fish to the middle section of the river was restricted, large spawning areas were lost in consequence, and unwelcome changes occurred in the fish fauna. New fisheries management schemes had therefore to be devised to take account of the changed situation. The current pattern of exploitation for the lower river and delta involves reed-cutting, agriculture, and both extensive and intensive fish culture.

1. Introduction

The Danube is the second longest river in Europe. It is 2857 km long and drains 8% of the continent. It has a catchment of 817 000 km^2 and its delta *(Figure 1)* is the third largest in Europe after those of the Volga and Kuban' Rivers. The delta covers some 500 000 ha and originally comprised well over 300 000 ha of floodplain, 70 000 ha of lake surface and 90 000 ha of lagoons. About 55 000 ha of the delta lies in the USSR, but the major part is in Romania. The delta is multi-lobate with a seaward face of 150 km.

The frontal lagoons have recently been isolated from the Black Sea and are now lakes with controlled hydraulic regimes. In 1986, in the Romanian part of the delta, floodplain and permanent water covered 296 622 ha, dunes and reedswamp covered 4550 ha, forest resources covered 22 872 ha, while 92 596 ha were devoted to agriculture. Of the agricultural land, more than half was rough grazing. The mean height of the delta was 52 cm above sea level, having risen 21 cm since 1951. Between the Kilia branch in the north and the Razelm complex in the south, the network of waterways had a total length of 3463 km, of which 1744 km were canals. The mean density of canals was 0.57km/km^2 (Gistescu, Driga & Anghel 1983). Mean discharge from the delta between 1931 and 1970 was 6550 m^3/sec., minimum discharge was 1970 m^3/sec., and maximum discharge was

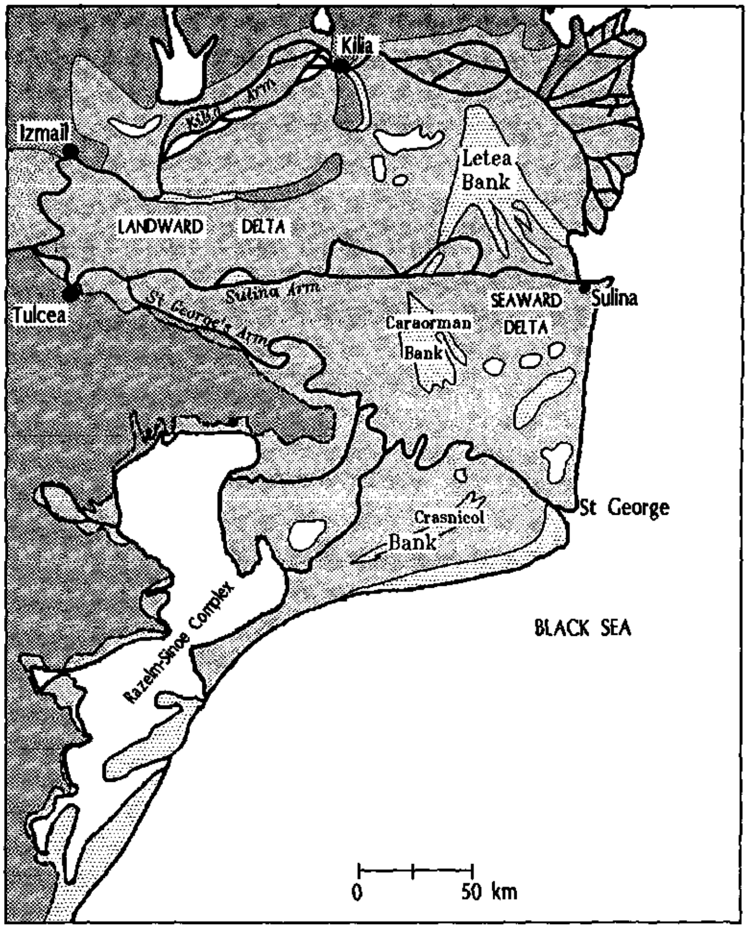

Figure 1. The Danube Delta (colourless areas = open water).

15 540 m^3/sec. Alluvium is now deposited at a mean rate of 58.75 million tonnes/yr (Gistescu *et al.* 1983).

The present delta began to be formed in the Holocene, 8000-10 000 years ago. Currently there are three major distributaries, the northern Kilia branch, the central Sulina branch and the southern St George's branch. In addition, the modern delta is divided into landward and seaward sections by the elevated Letea, Caraorman and Crasnicol bank system which runs parallel to the coast with a NE-SW orientation. The seaward section of the delta, east of the banks, is less than 2500 years old and did not exist in the time of Herodotus. The surface of the Black Sea has been rising by 2-4 mm/yr during the past hundred years, and there is known to have been a light marine transgression during the past 2000 years. The delta face has regressed during the present century, except at the mouths of the most active distributaries, and this trend is expected to continue. There used to be two inland deltas upstream on the floodplain of the lower Danube, but following multiple impoundments, these now form Braila and Calarasi Islands.

Ecologically the delta used to be an essential part of the lower Danube biome. The pioneering work of Antipa (1935) in interpreting ecological relationships in the lower reaches of this river, and of determining base levels for standing stocks of fish under exploitation, underpinned lower Danube fisheries for 60 years. His work will probably continue to be important to good fisheries management in unregulated rivers with deltas elsewhere in Europe. The history of fisheries in the lower Danube can be divided into four periods.

- A fishery based on empirical regulations from the 15th to 19th centuries.
- A period of ecological mis-management due to small hydrotechnical interventions aimed at local short term gains during the years 1879-1894.
- An 'ecological' fishery planned, organized and very largely managed by Grigore Antipa during the period 1895-1956.
- Exploitation of the delta after 1956.

Recent changes in the hydrochemistry of northwestern parts of the Black Sea, and impoundments on the old Danube floodplain, have brought about a considerable change in the species composition of the fish community of the delta. Since the loss of the spawning grounds on the old floodplain, the delta has become more important for the spawning of indigenous species. Fisheries now operate on the branches and frontal delta, on the lakes and lagoons of the delta floodplain, and in the controlled ponds and lakes.

Before 1965, the fisheries concentrated on migratory and semi-migratory species. Among the migratory species, sturgeon *(Acipenser güldenstaedti, A. nudiventris, A. stellatus, Huso huso)* and Black Sea shad *(Alosa pontica pontica)* were most important, with 800-1000 tonnes of sturgeon being caught each year. Among the semi-migratory species, common carp *(Cyprinus carpio)*, pikeperch *(Stizostedion lucioperca)*, sheatfish *(Silurus glanis)*, bream *(Abramis brama)* and ide *(Leuciscus idus)* were most important. All these species, except shad, were reduced in abundance and mean weight after the construction of the barrages on the lower Danube floodplain. Now in the Danube Delta fisheries, carp, roach *(Rutilus rutilus)*, bream and shad are the dominant indigenous species. However, aquaculture has become the most valuable fishery, producing common carp, the far eastern cyprinids, grass carp *(Ctenopharyngodon idella)*, silver carp *(Hypophthalmichthys molitrix)* and bighead carp *(Aristichthys nobilis)*, and North American species of *Ictiobus*.

2. Branches and lower delta

The St George branch, in the south, is the oldest of the branches. It is 109 km long, has many meanders and is undisturbed, at least it was until very recent times. It has a single channel, its mouth is the most seaward point in the delta, and it carries about 20% of the total discharge. The Sulina branch has been altered in recent years so that it is now a dry-walled ship canal, 62.6 km long, with a minimum depth of 7.32 m. Jetties from its mouth project 9 km out into the Black Sea. It too carries 20% of the total discharge. The construction of supplementary canals, oriented southeastwards, is planned to evacuate silt from both the St George and Sulina branches (Rusu 1987). The northern Kilia branch is the most recent branch, having developed only since 1830 (Popp 1985). It is highly ramified, isolating many islands, and transports approximately 60% of the total discharge.

Owing to variations in salinity the different parts of the delta have different fish communities, but these grade into each other. Both fresh and brackish water fishes spawn in the lower delta, and the fry of others (sturgeons, Black Sea shad) shelter and develop there.

The mean parameters for Danube water at Tulcea are, temperature 13°C, Secchi depth 36.8 cm and pH 7.8 (Banu 1967). Total dissolved solids amount to 375 mg/l, while the levels of suspended solids have ranged from 30 to 824 g/m^3 (Timochenko & Therednichenko 1987). Small particles predominate; 89% are between 0.005 and 0.05 mm in diameter. Oxygen concentrations in the main branches are adequate, with slight decreases observed in passing downstream. Most phosphorus is in suspension (80-90%), and ammoniacal nitrogen has increased slightly in recent years.

The phytoplankton is dominated by bacillariophytes; cyanophytes are poorly represented. Among the zooplankton, rotifers are well represented, with 84 species present. Small forms predominate with annual maximum densities close to 100 g/m^3 (Arion 1987). The benthos in the branches is poor, but its density increases tenfold towards the mouths. Seventy five species of fish, from 22 families, have been recorded in the delta. Of these, 44 are freshwater species, the others are migratory, brackish water, euryhaline or salt water species. All species occur in the branches, but not all of them reach the delta lakes. The commercial fishery depends on a few species only.

The fisheries in the distributories of the delta have always been dependent upon species migrating between the lower floodplain and the Black Sea. The purely riverine species have never been very important. The semi-migratory species, carp, pikeperch, ide, bream and sheatfish, used to have spring spawning migrations from the delta to the Grapina, Brates, Boroea and Braila floodplains, but these have now virtually ceased. In consequence the yields for these species are now much reduced, although they are still fished for in the river. The delta river fishery now depends heavily upon several species of sturgeon (Russian, beluga, stellate) and Black Sea shad. These fish reproduce in the Danube where their fry spend several months, but they grow to maturity in the north-west of the Black Sea. The shad fishery still thrives, but that for sturgeon is continuously regressing. There are probably several contributory causes, including deterioration of river water quality, multiple impoundment of the river, loss of spawning grounds and intensity of navigation on the river. However, pollution of the NW Black Sea is of over-riding importance. Reduced oxygen and high hydrogen sulphide concentrations are now manifest in this part of the sea, where they damage the plankton both qualitatively and quantitatively, and frequent kill the algal flora, the benthic fauna and many fish (Bryantsev, Faschuk & Finkelshtejn 1985). Low oxygen concentrations were observed as long ago as 1978. Hypoxia now begins in May and persists through September, with more than half of the water column (23 m) being affected. At the same time the bottom water contains high concentrations of hydrogen sulphide. If high winds blow from the west, bottom water is sucked inshore and H_2S reaches the surface where the sea is less than 5 m deep. This causes massive fish kills (Pshenichnyi & Fashchuk 1987). These phenomena, although then very rare, were described by Antipa (1916), albeit without a scientific explanation. In view of this now common situation it is difficult to understand how sturgeon and other fry can survive, but in some years (*e.g.* 1984) during the last two decades they have been abundant (Kiriliuk & Rovnin 1984). A maximum annual sturgeon catch of 1000 tonnes was recorded by Antipa from the Romanian part of the delta early this century, but over the past 90 years catches have always been in decline. They averaged just 40 tonnes/yr over the past decade *(Figure 2)*.

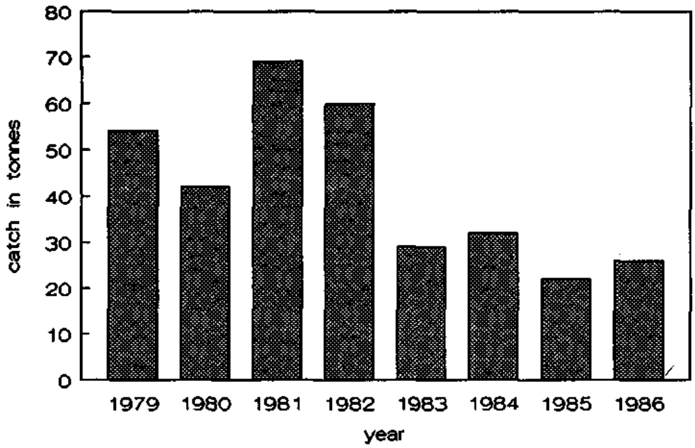

Figure 2. Catches of anadromous sturgeon (Beluga, Russian and stellate sturgeon) in the Romanian part of the Danube Delta, 1979-1986.

Kiriliuk & Rovnin (1984) state that the sturgeon stocks of the NW Black Sea comprise beluga, with lengths of 30-380 cm and ages up to 40 years, stellate sturgeon of 15-184 cm and ages up to 20 years, and Russian sturgeon of 17-190 cm and ages up to 30 years. Spawners represent about 33% of the stellate sturgeon stock and 66% of beluga and Russian sturgeon stocks. Female beluga sturgeons spawn 3-4 times at intervals of 7-8 years. Female Russian sturgeons spawn at 6-7 year intervals and female stellate sturgeons at 6 year intervals. Males make reproductive runs at intervals which are 1-2 years shorter. Beluga sturgeon are known to live for 60-70 years and Russian sturgeon for at least 46 years, but since the specimens caught are all younger than this, it is clear that the fishery is intensive.

The Black Sea shad fishery, although subject to variations in annual yield, is the most important Danube fishery. It operates from March to May and employs some 500 fishermen in Romania and a further 200 in the USSR. Trammel nets are used from a boat, with two men per boat. The most intense fishery occurs in the delta, in the St. George and Kilia branches, but it extends up river for 700 km to certain sites where the species spawns. *Alosa pontica pontica* has a short life span and spawns at 3-4 years of age. There is evidence that conditions for Black Sea shad are now deteriorating during autumn and winter (Mogilchenko 1987), and catches have declined over the past decade *(Figure 3)*.

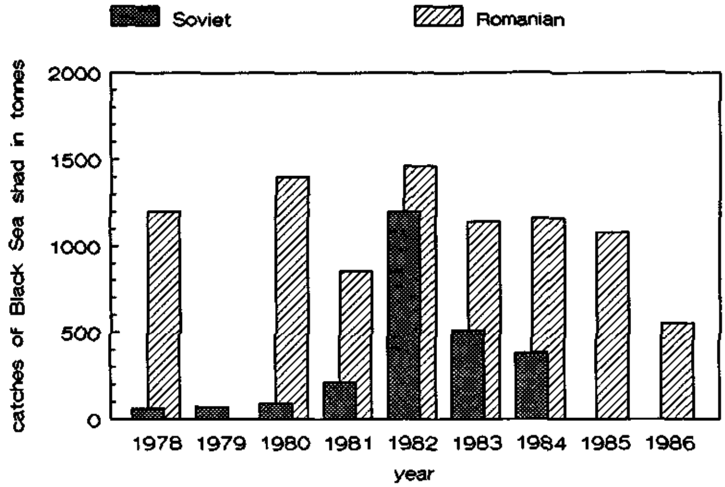

Figure 3. Catches of Black Sea shad in the Romanian and Soviet parts of the Danube Delta (FAO, 1986). Figures are not available for the Romanian part in 1979, nor for the Soviet part in 1985 and 1986.

Among other clupeids fished, catches of green shad *(Alosa caspia nordmanni)* have also decreased, while those of Caspian sprat *(Clupeonella delicatula)* have varied between 2 and 82 tonnes/yr over the last 10 years. This range is similar to that from previous decades. Clupeids are caught with trap nets (Banarescu & Rusu 1972) at the seaward face of the delta, but when the river is in flood, freshwater species are captured with them as these latter fishes tend to enter shallow parts of the sea in the plume of fresh water from the river.

The lower seaward delta and the internal delta of the Kilia branch, where the channel ramifies locally, are important for the growth of fry (Bacescu & Dumitrescu 1958), as also is the sluggish St George branch (Leonte 1965). However, these areas have been affected by anthropogenic impacts in recent years. Most importantly, a port has been constructed in the internal Kilia delta (Levintov 1988), but hydraulic management schemes and the pollution of the Black Sea have affected them all.

3. The delta floodplain, lakes and lagoons

An area of floodplain, with lakes and lagoons subject to inundation, presently occupies about 300 000 ha of the delta, while artificial lakes and ponds have a total surface in excess of 12 000 ha. In addition to the principal channels, the delta is criss-crossed by sections old river bed, with numerous oxbows, all in different stages of silting up, and by longitudinal and transverse connection canals and riverine and maritime banks. Dry land begins to prevail in the landward delta, but most of the seaward delta is flooded regularly and supports a range of swampy vegetational associations. The middle of the floodplain is occupied by lakes of varying salinity. The largest of these are Lakes Fortuna and Isacova-Uzlina, and the Trei-Iezere-Matita-Merhei group in the landward delta, and the Lumina-Puiu-Rosu group in the seaward delta. The frontal lagoons which still remain, Zatonul Mare and Zatonul Mio, are small and economically unimportant.

The delta soils, except the sandy ones, are fertile and will sustain the development of a range of communities (Roman, Roman & Lisandru 1982). The chemistry of the waters of the delta lakes, and the lake sediments, are variable (Hurghisiu 1982), but during the annual flood the waters are replaced and new sediment is brought in. Different lakes are at different stages of eutrophy, as indicated by their variable plankton development (Nicolescu 1981).

The vegetation of the delta is strongly influenced by the quality of the water and the degree to which the soil is flooded, and at present, successions are proceeding rapidly (Klokow 1982). Many areas of *Phragmites* have been replaced by *Typha* in recent years. In the past, the lakes supported a rich submerged vegetation, but this has largely disappeared since 1982, because of a general increase in eutrophy and the consequent overgrowth of algae (Cristofor, Izvoranu & Ciolpan 1985). Phytoplankton productivity in the lakes varies spatially and seasonally, and as might be expected, has an inverse relationship with macrophyte productivity.

The submerged herbivorous communities are also declining under the burgeoning algae (Izvoranu 1982), but those associated with *Typha* stands reach a biomass of 912 kg/ha (Hnidei 1982). Rotifers dominate the zooplankton, but cladocerans are also important, and zooplankton production is very variable; it may be ten times greater in high flood years than in low flood ones (Godeanu & Zinevici 1983). The biomass and productivity of benthic animals changes from lake to lake and place to place within a lake. It also varies seasonally, *e.g.* oligochaetes reach peak biomass in March but decline to a minimum in July-September (Daconu 1981). Patterns of chironomid productivity are closely tied to plant successions in the lakes (Botnariuc, Ignat & Vadineanu 1981). Potential annual benthophagous fish production has been estimated as between 6.5-14.3 kg/ha in Lake Merhei and between 11.8-27.4 kg/ha in Lake Matita (Botnariuc, Vadeanu, Ignat & Diaconu 1985). Crayfish present in these ecosystems are *Pontastacus cubanicus danubialis, P. leptodactylus salinus* and *P. eichwaldi danubialis* (Brodskij 1982), but crayfish catches have declined threefold over the last decade. The delta ecosystems are now degenerating and eutrophying rapidly (Botnariuc, Ignat, Diaconu & Vadineanu 1987).

The Razelm complex of lakes and controlled lagoons (86 000 ha), in the southern delta *(Figure 1)*, is however, different. In 1982 its level of mineralization was less than 500 mg/l, its phytoplankton was dominated by diatoms and its zooplankton by Rotifera followed by Copepoda. Chironomid biomass was 60-100 kg/ha (Staras 1985) while molluscs had an annual average production of about 300 kg/ha. The fish fauna resembles that of the rest of the delta floodplain, and total fish production was estimated as 156 kg/ha in 1982 and 132 kg/ha in 1983 (Munteanu 1984).

4. History of the delta fisheries

The delta has always been an important source of food for Romanian people, and in consequence delta fisheries have long been regulated. The first regulations, empirical ones, derive from the Middle Ages. "The fences of fishermen from the floodplain and Danube Delta were collective hydraulic works, implying complex operations, conducted in the framework of a deep and very old knowledge of the complicated river hydrological mechanisms and of the flooding hydrographical net " (Botzan 1984).

Between 1879-1894 the delta fisheries were exploited through leasing (Antipa 1905) when fishing interests were limited to the term of a lease. At this time small scale hydraulic works were undertaken to bring temporary local advantages, but with disadvantages to other parts of the delta which became deficient in water. Leasing became unpopular and the Romanian State was obliged to legislate and apply its own hydraulic works (dams and reservoirs) to rectify the ecology of the delta.

State administration began in 1895 under the management of Grigore Antipa. Initially schemes were undertaken to improve both water quality and fishery exploitation by the construction of waterways. Canals were built in 4 phases. The first phase (1903-1916) assured a water supply to the Razelm-Sinoe lagoon complex. The second phase (1930-1940) involved fisheries management of St George's Island. In the third phase special transverse canals were constructed to ensure circulation and transport in the landward delta, together with water retention facilities in the inland delta of the Kilia branch. This latter construction retains water after the flood (mid June-mid August) has passed. During the fourth phase (1952-1960) canals were built, mostly in the Dranov zone and the Razelm-Sinoe Complex (Mirica 1958, Nicolau 1969). Following these works mean annual fish yield increased from 5722 tonnes (1902-1906) to 11 542 tonnes (1953-1957), while catch per unit effort increased from 2-3 tonnes/man/yr to 8-10 tonnes/man/yr.

Over the past 25 years the Romanian Delta catch has been about 10 000 tonnes/yr (*Figure 4*). The most productive five year periods each included 2-3 great floods, whereas the poor periods where characterized by low water levels. The reductions in catches in recent times is accounted for by an increase in impoundments, most for agriculture.

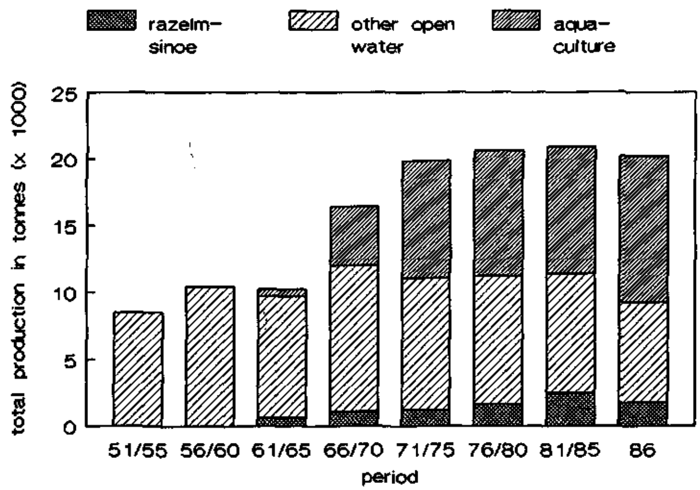

Figure 4. Fish production in the Romanian part of the Danube Delta (tonnes/year).

There has been a change in the species composition of catches over the past 25 years *(Table 1)*. Traditionally common carp were among the most favoured of delta fish, with catches of 700-4500 tonnes/yr, but after the construction of multiple impoundments on the floodplain which began in 1965, the catches fell to 100-300 tonnes/yr. This is due to the fact that, prior to impoundment, carp spawned chiefly on the upstream floodplain where predators were relatively scarce. Now however, they spawn in the delta where predators are common and survival of fry is consequently much reduced.

Table 1. Average percentage of species in catches from the Danube Delta during three characteristic periods - before, during and after impoundments on the floodplain.

Species	1950-1959	1960-1968	1979-1982
Cyprinus carpio	22.1	4.5	2.4
Abramis brama	3.2	2.5	15.0
Rutilus rutilus	17.0	33.1	17.8
Carassius carassius	12.6	8.2	1.3
Carassius auratus	-	-	29.3
Tinca tinca	5.7	5.4	2.4
Other fish	3.3	12.0	8.1
Non-predatory fish: total	63.9	57.5	76.8
Aspius aspius	-	-	0.2
Esox lucius	21.4	21.3	7.2
Perca fluviatilis	5.6	7.5	4.9
Stizostedion lucioperca	1.5	4.3	5.6
Silurus glanis	7.6	12.4	5.0
Predatory fish: total	36.1	42.5	23.2

The three periods shown in *Table 1* are before, during and after the impounding of the floodplain, but are all before agricultural works were undertaken in the delta. The table shows that:

- While the percentage of predators (all species together) in catches has declined by 12.9% (from 36.1 to 23.2%), the trends for individual species depart widely from the overall trend. For example, while the percentage of pike in total catches has fallen by 14.2% (from 21.4 to 7.2%), that of pikeperch has risen by 4.1% (from 1.5 to 5.6%), and that of perch has remained fairly constant.
- Common carp has been replaced by gibel carp *(Carassius auratus)* and common bream as the predominant non-predatory species caught.
- Catches of crucian carp *(Carassius carassius)* have fallen dramatically, to less than a tenth of what they were, while those of tench have halved. Neither of these species is reputed to be affected by the impoundments on the upstream floodplain.

The delta catch statistics include those for the Razelm Complex, but its fishery differs qualitatively and quantitatively from that of the general delta. During the years 1976-1985, when catches from the delta were declining, those from Razelm were increasing *(Figure 4)*. Presently, Razelm and Sinoe have similar fish communities, comprising some 15% predatory and 85% non-predatory species, with gibel carp, bream and roach predominant.

In the delta proper the fishermen catch Black Sea shad from March-May, after which they begin fishing the delta floodplain and its lakes. Here they employ over 5000 trap nets, 30 000 fyke nets, 2000 carp trammel nets and 2000 vimba *(Vimba vimba)* trammel nets. Beginning on the 15th September in the delta, but 1st October in the Razelm Complex, seine nets are permitted on the lakes. About 100 of these are used in total over the entire delta.

Statistics are available only for catches from the several administrative divisions of the greater delta, and the total catch from the entire delta is not certain. Moreover, during flood years, when catches are high, the relationship between catch size and estimated fish production for a given zone is misleading. This is because fish circulate widely during high floods and may be captured anywhere. However, from this point of view, figures from the Razelm Complex are more reliable since the area is isolated by fish fences. Catches from Razelm are 24-30 kg/ha/yr (Staras 1985). Catches for the entire delta, including Razelm and the river branches, are similar, 20-30 kg/ha/yr. During flood years catches reach 35 kg/ha, but fall to 18 kg/ha in drought years.

The Soviet section of the floodplain begins below the port of Reni and extends to the Kilia frontal delta. Most of the floodplain is occupied by lakes. Here catches averaged 27 kg/ha/yr in low to medium flood years, *e.g.* 1946-1950, but 42.5 kg/ha/yr in high flood years, *e.g.* 1954-1956. Impoundments, to isolate sections of river as lakes, began in the Soviet part of the delta in 1952 (Tshernous & Makeev 1959). The lakes so formed were stocked with fry and young fish of commercially valuable species (Klimenko & Mariash 1978).

5. Aquaculture in lakes and ponds

5.1 Lake aquaculture

The lakes in the Soviet part of the delta floodplain are under extensive aquaculture. They are filled during the flood, and in rainy years are supplied by their small tributary streams. Their fish faunas are derived from the Danube with the addition of some exotic Far Eastern species. *Table 2* shows the introductions made in 1983 and *Table 3* the catches of both introduced and indigenous species in 1984.

Most of the fish shown in *Table 3* were caught in lakes. Gibel carp comprises 44% of the catch, while other species of moderate value account for a further 12.5%. This high percentage of medium value fish, compared to that in the Romanian catches, may be explained by the fact that the abundance of predatory fish in the Soviet part of the delta has been much lower than that in the Romanian part over the period 1951-1980 (Voloshkevich 1986). On the basis of his studies Voloshkevich concluded that:

- Predatory species improve the quality of the catches.

- The numbers of predators had fallen and their stocks had grown older because their spawning grounds in the Soviet part of the delta had deteriorated.
- It was necessary to build hatcheries for sheatfish, pike and pikeperch, and to establish a new minimum legal length for sheatfish to prevent immature specimens being caught.

Table 2. Species introduced into the Soviet part of the Danube Delta floodplain in 1983.

Species	Numbers (1000)	Mean weight (g)
Cyprinus carpio	8 313	26.0
Abramis brama	30	2.0
Hypophthalmichthys molitrix and *Aristichthys nobilis*	5 208	30.0
Ctenopharyngodon idella	87	1.5

Table 3. Catches from the Soviet part of the Danube Delta floodplain in 1984.

Species	Catch (tonnes)	% of total catch
Cyprinus carpio	212.3	8.4
Abramis brama	273.4	10.8
Far Eastern species	489.5	19.3
Carassius auratus	1 118.9	44.1
Predatory fish	126.5	5.0
Other species	314.2	12.4
Total	2 534.8	

5.2 Pond aquaculture

The initial idea was to utilize those parts of the delta which could not otherwise be used because their soils were unsuitable, being sandy, peaty, saline or anoxic. The first ponds, of 64 ha, were built at Caraorman on sandy marine soil (Mirica 1965). They entered production in 1966, closely followed by the larger system (3000 ha) at Perisor-Lejai. By 1976, 30 000 ha of hatcheries, rearing farms and complex fish farms had been built *(Figure 5)*. These rely on gravitational water supply, but may use pumped auxillary supplies during periods of low water in the Danube. However, the advent of electricity in the delta made it possible to build ponds at several sites close to the high tension line (*e.g.* Dunavat 1 and 2, Holbina 1 and Periteasca) which relied on pumped supplies. Unfortunately these ponds were established on boggy ground which should have been pre-treated. Also, the water quality on some other farms (*e.g.* Stipoc, Sarinasuf, Iazurile)

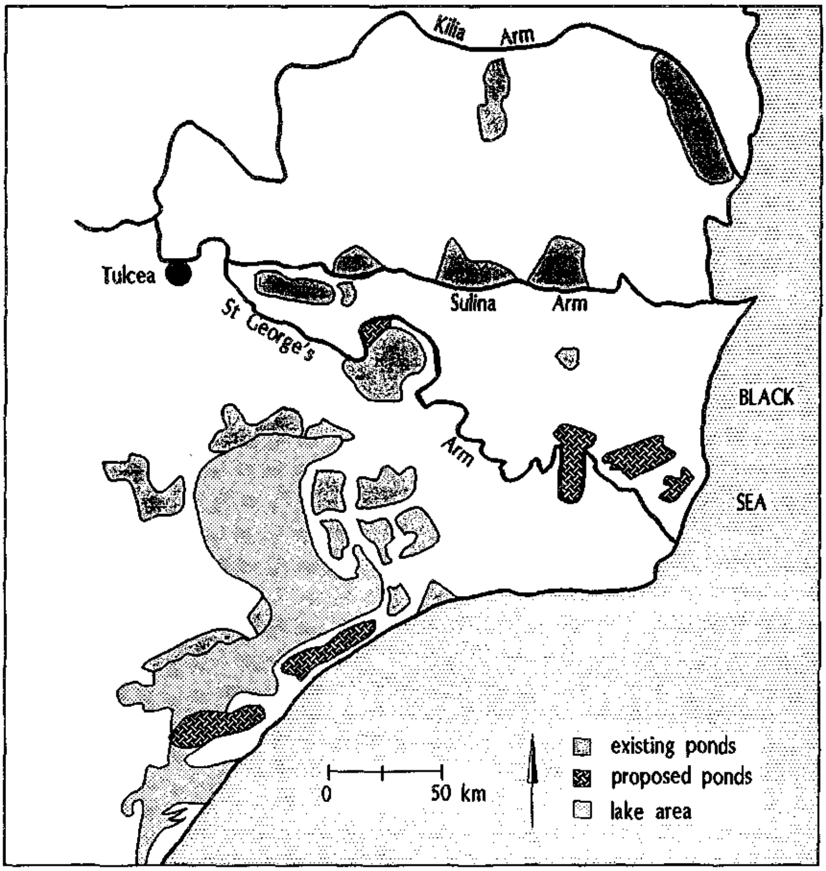

Figure 5. Existing and proposed ponds for the Danube Delta.

gave problems which were only partially resolved by the application of special technology (Banica 1973).

It was necessary to construct the pond walls from materials available locally, chiefly sand and soil containing vegetable debris, and these have settled so that water levels are not maintained. In shallow water, where macrophytes grow in abundance, the fry and young fish come under intense predation by waterfowl, many species of which are protected by law (Bacalbasa 1979).

The best results are now obtained from complex farms with hatcheries and rearing ponds and total surface areas of about 1000 ha. At first the optimum surface area for a pond became a matter of dispute. Most ponds were built to have surfaces of 100-300 ha, for reasons of economy, regardless of the size of fish to be reared. However, for 2+ fish, surfaces of 150-200 ha are acceptable, but with 1+ fish, ponds over 70 ha led to heavy losses. In consequence much pond reconstruction is now in progress. Polyculture is practised over the whole delta. The main species is common carp, with in addition, Far Eastern silver, grass and bighead carp. These last three species now account for 24% of all pond production. The North American species, bigmouth buffalo *(Ictiobus cyprinellus)*, black buffalo *(I. niger)* and smallmouth buffalo *(I. bubalus)* have also now been introduced to some farms.

In 1986, 32 685 ha of ponds were in use and produced 11 038 tonnes of fish, giving an average yield of 338 kg/ha. This is approximately ten times greater than the yield of capture fisheries in the open delta. It has been ascertained that in small polyculture ponds, without supplementary feeding, fish yield can rise to 900 kg/ha. Clearly there are possibilities for increasing yields from the delta still further and it is estimated that with supplementary feeding, delta ponds could achieve yields in excess of 1500 kg/ha.

References

Antipa, G., 1905. Exploataren în Pencarillor Statului. Bucuresti, Imprim. Statului. 26 pp.

Antipa, G., 1916. Pescaria si pescuitul în România. Acad. Rom., Fond. V. Adamáchi 8. 794 pp.

Antipa, G., 1935. L'organisation générale de la vie collective des organismes et du mécanisme de la production dans la biosphère. Acad. roumaine, Études et recherches No 25, extrait. 84 pp.

Arion, E., 1987. Populationsschwankungen der Rotatorien beim Eintritt der Donau in ihr Delta bei Strom-km 80 (Ceatal Izmail) und Strom-km 62 (Ceatal Sf.Gheorghe). Wissensch. Kurzref., 26. Arbeitstag der IAD, Passau/Deutschland. pp. 322-325.

Bacalbasa, N., 1979. La protection des oiseaux aquatiques et la pisciculture dans le Delta du Danube. Bulet.Univ din Galati, Anul II, Fasc.VII Tehn.piscic. 19-28.

Banu, A.C. (coord.), 1967. Limnologia sectorului românesc al Dunarii. Bucuresti, Edit. Acad. R.S.R. 651 pp.

Bacescu, M. & Dumitrescu, H., 1958. Les lagunes en formation aux embouchures du Danube et leur importance pour les poissons migrateurs. Verh. Intern. Limnol. 13: 691-709.

Banarescu, P. & Rusu, C., 1972. Contributii la cunoasterea componentei pe specii a clupeidelor marunte pescuitela gurile Dunarii. Bucuresti, Hidrobiologia 13: 179-188.

Banica, V., 1973. Sisteme ameliorative în lunca si Delta Dunarii pentru sporirea productiei piscicole. Lucr.consf. pe tara a piscicultorilor din R.S.R, 3-4 iulie 1973, Galati pp. 35-41.

Botnariuc, N., Ignat, G. & Vadineanu, A., 1981. Ecological role of some chironomids in Lake Rosu and Porcu Pond in the Danube Delta. Production and productivity in aquatic ecosystems. Edit. Acad. R.S.R., Bucaresti. 214 pp.

Botnariuc, N., Vadineanu, A., Ignat, Gh. & Diaconu, I., 1985. Fauna bentonica ca transportor de energie înghiolurile Matita-Merhei (Delta Dunarii). Delta Dunarii. Studii si comunicari deecologie 1: 231-234.

Botnariuc, N., Ignat, Gh., Diaconu, i. & Vadineanu, a., 1987. La structure et la dynamique de la faune benthonique. Rev. Roum. Biol.-Biol. Anim. 32: 121-127.

Botzan, M., 1984. Apele în viata poporului român. Bucuresti, Edit. Ceres 410 pp.

Brodskij, S., 1982. Über die Krebsfauna der unteren Donauläufen und Klassifikationsfragen der Familie Astacidae. XX Tagung IAD, Kiew, Naukowa Dumka. 223-227.

Bryantsev, W.A., Fashchuk, D. Ya. & Finkelshtein, 1985. Anthropogenic changes in the oceanographic characteristics of the Black Sea (in Russian) Oceanological and fisheries researches of the Black Sea. VNIRO, Moskow. pp. 3-19.

Cristofor, S., Izvoranu, V. & Ciolpan, O., 1985. Date privind distributia, dinamica si productia macrofitelor submerse din ghiolurile Matita si Merhei (Delta Dunarii). Delta Dunarii. Studii si comunicari de ecologie 1: 207-218.

Daconu, I., 1981. Aspects of the structure of aquatic Oligochaeta populations in Lake Rosu and the Porcu Marsh (Danube Delta, 1976). In: Production and productivity in aquatic ecosystems. Edit. Acad. R.S.R., Bucuresti. 214 pp. (in Romanian).

FAO, 1986. Yearbook of fishery statistics: 1984. Volume 58. FAO, Rome. 145 pp.

Gîstescu, P., Driga, B. & Anghel, 1983.Caracteristicile morfohidrografice ale Deltei Dunarii ca rezultat al modificarilor naturale si antropice actuale. Bucaresti, Hidrobiologia 18: 29-42.

Godeanu, S. & Zinevici, V., 1983. Composition, dynamics and production of Rotatoria in the plankton of some lakes of the Danube Delta. Bucuresti, Hydrobiologia 104: 247-257.

Hnidei, L., 1982. Die Rolle der Typhaceen in der Okologie der aquatischen Ökosystemen des Donaudeltas. 23. Arbeitstagung der IAD. Wissenschaft. Kurzref., Wien. pp. 104-106.

Hurghisiu, I., 1982. Untersuchungen über den Gehalt an mineralischen und organischen Stoffen im Wasser und in den Sedimenten der Seen Matita und Merhei (Donaudelta). 23. Arbeitstagung der IAD. Wissenschaft. Kurzref., Wien. pp. 24-26.

Izvoranu, V., 1982. Einige Aspekte der phyophilen Fauna des Porcu- und Rosu-Sees des Donaudelta, 1978. 23. Arbeitstagung der IAD. Wissenschaft. Kurzref., Wien. pp. 145-146.

Kiriliuk, M.M. & Rovnin, A.A., 1984. Soviet information on sturgeon reproducive stock, age composition and spawning conditions. Mater. of the 26th Session of the Mixed Fishery Commission for the Danube River. Plovdiv/Bulgarien. pp. 125-131 (in Russian).

Klimenko, I.P. & Mariash, L.F., 1978. The fish species introduced in the Danube lakes. Rybn. khoz. 9: 27-28 (in Russian).

Klokow, W.M., 1982. Zur Frage der Dynamik der höheren Wasserpflanzen im Kiliadelta der Donau. 20. Arbeitstagung der IAD. Kiew, Naukowa Dumka. 176-179.

Leonte, V., 1965. Cercetari hidroliologice si intiologice pe bratul Sf.Gheorghe. Bulet. Instit. de Cercet. Piscicole. 24: 49-58.

Levintov, A.E., 1988. How will the Danube Delta be ? Priroda 1: 48-53 (in Russian).

Mirica, G., 1958, *Lucrarile hidrotehnice si hidroameliorative executate in Delta Dunarii in ultimii* 80 de ani (1878-1957). Bul. Inst. de Cercet. Piscic. 18: 17-30.

Mirica, G., 1965. Prima pepiniera pentry reproducerea in Delta Dunarii a unor pesti fitofagi, originari din China. Bul Inst. de Cercet. Piscic. 24: 15-18.

Mogilchenko, V.I., 1987. Derzeitiger Verflauf der Laichzeit des Alosa-Herings im Kilia-Delta der Donau. 26. Arbeitstagung der IAD, Passau/Deutschland. Wissenschaft. Kurzref. pp. 293-294.

Munteanu, I., 1984. Die Evolution einiger tropischen Stufen für die Ichthyofauna in einigen Zonen des Donaudeltas und Razelmsees in der Periode 1982-1983. 24. Arbeitstagung der IAD, Szentendre/Ungarn. Wissenschaft. Kurzref. pp. 161-164.

Nicolau, C., 1969. Amenajarea piscicola a zonei fluviale a Deltei Dunarii. I Conceptile de amenajare si amenajarile executate in Delta fluviala. Bul. Inst. de Cercet. Piscic. 28: 5-43.

Nicolescu, D., 1981. The degree of trophicity of some aquatic ecosystems in the Danube Delta as reflected in some bacterioplankton parameters. In: Production and productivity in aquatic ecosystems. Edit. Acad. R.S.R., Bucuresti. pp. 85-92 (in Romanian).

Pshenichnyj, B.P. & Faschuk, D.Ya., 1987. Possibility of protection of the near littoral sea zones against hypoxia. Rybn. Khoz. 2: 15-18 (in Russian).

Roman, T., Roman, L. & Lisandru, F., 1982. Das tropische Potential der Bodenarten des Donaudeltas und die Jahreszeitvariation der Hauptnährungstoffe Stickstoff, Phosphor, Kalium. 23. Arbeitstagung der IAD, Wien. Wissemschaft. Kurzref. pp. 27-29.

Rusu, G., 1987. Evolutia conceptiei do amenajare a Dunarii si a Delta Dunarii. Bucuresti, Hidrotehnica 32: 329-337.

Staras, M., 1985. Situatia actuala si posibilitatile de crestere a productiei piscicole in lacul Razelm. In: Delta Dunarii, Tulcea, Muzeul "Delta Dunarii", 1: 61-70.

Timochenko, W.M. & Tscherednichenko, L.W., 1987. Zusammensetzung der Schwebestoffe in Donauwasser. 26. Arbeitstagung der IAD, Passau/Deutschland, Wussenschaft. Kurzref. pp. 63-64.

Voloshkevich, A.N., 1986. The fishery significance of predatory fishes in the lower reaches of the Danube. J. Ichthyol. 26: 760-766.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 462-465.

6

The organization of fishery management units in Sweden

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Abstract

Fishing rights on Swedish inland waters are private and divided between a large number of owners, which fact has often hindered the successful management of the waters. Recreational fishing is extensive and is increasing. To promote fishery management, and to make more waters accessible for public fishing, the Act of Fishery Management Units was passed in 1960. Later, in 1981, the Act was revised and government subsidies were directed toward the organization of units and the management of fisheries within units. The organization of units is described here, together with a report on progress.

1. Introduction

Fundamental facts for understanding Swedish inland fisheries are that ownership of both water and fishing rights are private, and that there are a great number of lakes (*c.* 100 000) and streams (*c.* 60 000 km). Owners generally have fishing rights only on their own small sections of the water body (divided fishing rights), but in joint ownership, fishing rights over the entire water body are enjoyed by all owners in common (undivided fishing rights). In the first case an owner may use and manage his part of the water however he likes, irrespective of the views of the owners of other parts. If the separate owners do not agree on goals, proper management of the water is not possible. In the second case individual owners have no right to act independently, *e.g.* by stocking with fish. All owners must agree as to the use and management of the water body. Without legal organization, any one of a great number of owners can successfully oppose a proposal by the majority. Conflicts of interests are frequent, both where fishing rights are divided and undivided. This, briefly, is the background which necessitates the organization of fishery management units, and these units are probably exclusive to Sweden.

Professional freshwater fisheries are, in the main, of little importance, but there is extensive recreational fishing and this is increasing all the time. Official reports suggest that out of a total population of 8 million people, 25% fish at least once a year, while 12% fish more than twenty times a year.

Compared to other parts of Europe there are few indigenous fish species (*c.* 40 freshwater species). Of these, only brown trout *(Salmo trutta fario)*, sea trout *(Salmo trutta trutta)*, salmon *(Salmo salar)*, charr *(Salvelinus* spp.*)*, grayling *(Thymallus thymallus)*, rainbow trout *(Salmo gairdneri)*, whitefish *(Coregonus albula)*, pike *(Esox lucius)*, perch *(Perca fluviatilis)*, pikeperch *(Stizostedion lucioperca)*, eel *(Anguilla anguilla)*, and crayfish *(Potamobius fluviatilis, Pacifastacus leniusculus)* are of interest to recreational

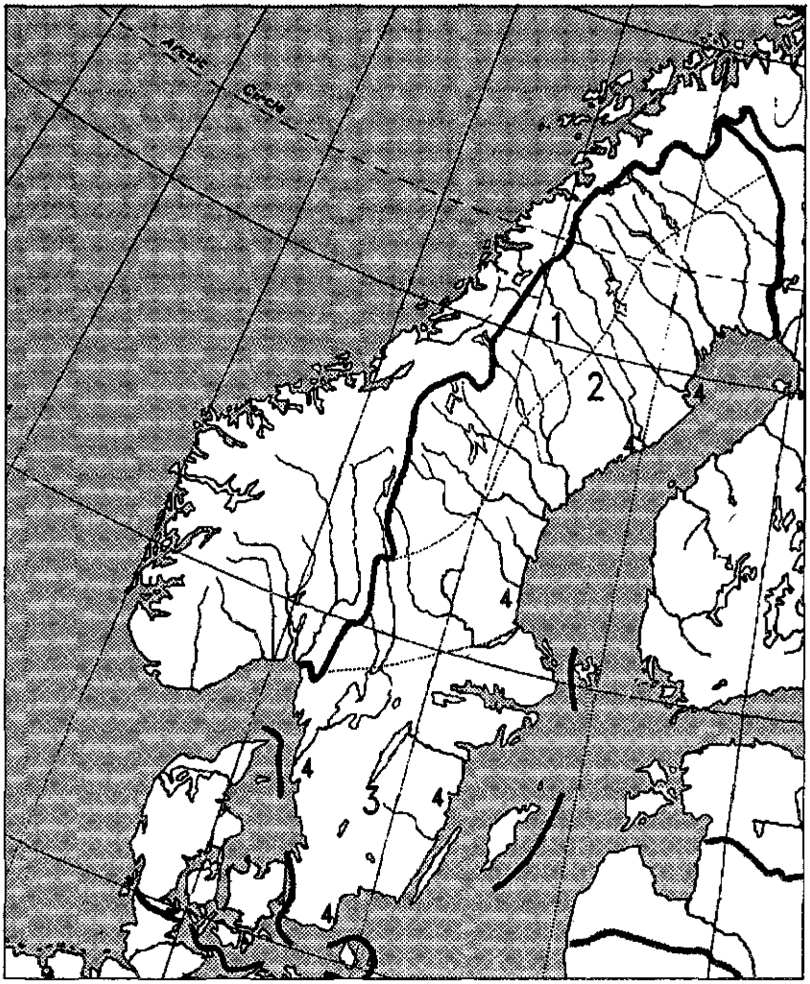

Figure 1. Major biological regions in Sweden with respect to recreational fisheries. Main species managed: 1. Mountain region – charr, grayling, brown trout. 2. Northern inland region – grayling, brown trout, rainbow trout, whitefish. 3. Southern inland region – brown trout, rainbow trout, pike, perch, pikeperch, eel, crayfish. 4. Coastal streams – sea trout, salmon.

fishermen. The major bio-geographical regions, with respect to recreational fisheries, are shown in *Figure 1*.

For several reasons, *e.g.* divided ownership and state-ownership (National Forest Enterprise), many waters are not available for public fishing and real management is lacking over wide areas. To correct this, governmental means have been directed into two fields, namely the organization of fishery management units and management work within these units.

2. Laws and subsidies

The idea of legislating to improve the management of fishing waters has been considered for a long time. Attempts were made to encourage cooperation on waters with divided ownership as long ago as 1896, and these were reinforced in 1950 by the passage of the Fishing Rights Act. The latter has been important in solving local conflicts, but has not, in general, promoted management *per se*.

The Act of Fishery Management Units was passed in 1960. A unit is formed by a decision of the owners of the fishing rights and is established by government authority (the County Council). Within a fishery management unit, the owners make decisions on all matters concerning the fishery and the management of the water (*e.g.* fishing methods, closed seasons, prices of licences and stocking practices) by voting. They also elect a committee which is the counterpart to any authority and this deals with economic and legal issues.

It was hoped that the private owners of water rights would react positively and establish administrations which would cooperate for the management of a lake, a stream or a whole drainage system. Thus the units form the bases for common management of fish stocks and fishing practice. Although some government subsidy was available in connection with the initial organization of units the response was very poor and was limited to the most attractive fishing waters with active fishing clubs.

In order to promote the organization of units, the Act of Fishery Management Units was revised, in 1981. At this time the process of organization was simplified and public interest in getting better opportunities for fishing was stressed. Government funds were allocated for financing most of the costs of organization, and also for fishery management, *e.g.* for environmental improvement and fish stocking. In addition, planning work by the regional fisheries officers was intensified. Within the National Board of Fisheries there are some 40 regional officers whose task is, among other things, to provide advice on fisheries, fishery management, government subsidies, the process of organization of fishery management units, and also, to take an active part in planning the units. As a result of this revised legislation the number of units organized has increased. The Fishing Rights Act provides that the organization of units must be completed by 1990.

3. Size and structure of units

There is no national policy as to the size and structure of the units, except that efforts to join biologically homogeneous areas are advocated. In some counties, with many small lakes, there will be many small units each comprising only one, or a few, lakes. In others the aim has been to include all water courses and lakes within extensive areas. The variation in unit size is therefore wide *(Table 1)*. The number of water owners per unit also varies widely, from less than 10 to several hundreds *(Table 2)*. A total of 580 fishery management units had been established by August 1985, but details of unit size and number of owners per unit are lacking in some cases.

The government subsidies to the organization of units and fishery management, over the last 7 years, was 7 and 20 million Swedish krona respectively. The organization of units is initially promoted by the National Board of Fisheries, and, as far as management is concerned, environmental improvement is considered more urgently in need of support than fish stocking *(Figure 2)*.

Table 1. Range in size of the fishery management units in Sweden organized from 1960-1985.

Unit size (ha)	Number of units	%
<10	11	2
10 - 50	42	8
50 - 100	74	14
100 - 500	202	40
500 - 1000	67	13
>1000	115	23
Total	511	

Table 2. Range in number of water owners of the fishery management units in Sweden organized from 1960-1985.

Number of owners	Number of units	%
<10	36	7
10 - 50	226	42
50 - 100	121	22
>100	159	29
Total	542	

4. Progress

During the 20-year period 1960-1980 some 400 units were established, but the process of organization has been speeded up so that an almost equal number of units was created between 1981 and 1988 *(Table 3)*. Today about 800 units exist and it is estimated the final number will be close to 1650.

Clearly it will be a hard task to fulfill the objective of organizing another 800 units in the few years remaining before 1990. Even to finish the work within 10 years will require substantial increases in government subsidies as well as an increase in the personnel provided by local government and water owners associations.

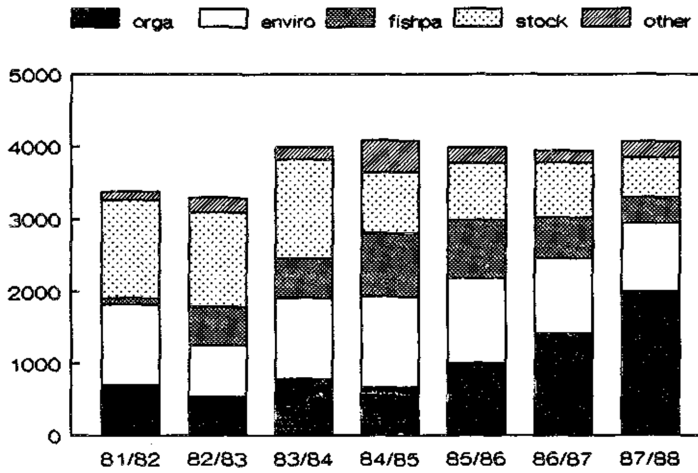

Figure 2. Government subsidies to the organisation of fishery management units and to fishery management in Sweden (SEK in thousands). orga = organisation of fisheries management units, enviro = environmental improvement, fishpa = fish path, stock = fish stocking.

Table 3. Number of fishery management units organized in Sweden from 1981-1988.

Year	Number of units
1981 - 1982	30
1982 - 1983	18
1983 - 1984	36
1984 - 1985	49
1985 - 1986	44
1986 - 1987	44
1987 - 1988	97
Total	318

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp 467-471.

Fish stocks of Lake Vättern: exploitation and fishery management

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Abstract

Lake Vättern is one of the largest lakes of Europe. It is rich in glacial relicts and the fish fauna is of outstanding quality. Charr, whitefish, brown trout and cisco are of great interest to commercial fishermen. Introductions of smolt of land-locked salmon *(Salmo salar)* have been very successful.

1. Introduction

Lake Vättern is the second largest lake in Sweden with an area of about 190 000 ha. It can be characterised as typically oligotrophic with a high oxygen content in deep waters *(Table 1)*.

Table 1. Morphometric and chemical data for Lake Vättern.

Surface area	191 200 ha
Area of precipitation	635 900 ha
Maximum depth	128 m
Mean depth	39 m
Water volume	74×10^9 m^3
Retention time	58 years
Height above sea level	88.5 m
Transparency (Secchi disc)	8-15 m
pH	7.6
Total N	0.5 mg/l
Total P	0.005 mg/l
Chlorophyll a	1-2 mg/m^3

The impact of pollution has decreased during the last decade, but problems are still caused by releases of industrial wastes, such as dioxins from paper mills around the northern part of the lake. There is no evidence of acidification in the basin.

2. The fish fauna

The fish fauna of Lake Vättern comprises 28 species among which the salmonids are of special commercial interest. The food base for pelagic species like smelt *(Osmerus eperlanus)* and cisco *(Coregonus* sp.*)* is rather small, but there is a comparatively good food supply for benthic species. Large relict crustaceans like *Mysis relicta* and *Pallasea quadrispinosa*, with *Gammaracanthus lacustris* at lower depths, are of great importance, especially for the slow-growing Arctic charr *(Salvelinus alpinus)* and whitefish *(Coregonus* spp.*)*. At a length of about 25 cm charr start feeding on smelt, and later on cisco and sticklebacks. Other species of interest in the main basin are brown trout *(Salmo trutta)*, grayling *(Thymallus thymallus)*, burbot *(Lota lota)* and eel *(Anguilla anguilla)*. In the northern basin, which is more eutrophic and shallow than the main basin, the benthic salmonid community is largely replaced by warmer water species like cyprinids. Pike *(Esox lucius)*, perch *(Perca fluviatilis)* and cisco are also more common here.

3. Fisheries and catches

Some 30 fishermen are employed in the commercial fisheries, most of them on a full time basis. They use mainly gill-nets and traps. The fleet is modern, with hydro-acoustic equipment, radar and telecommunications. There are also about 2300 people fishing for recreational purposes, either by gill-netting or trolling. The total catch in 1986 was about 250 tonnes (1.3 kg/ha). *Table 2* shows the catches in 1986. Statistics are available from 1918 and the trends for some of the main species in commercial fisheries are shown in *Figures 1* and *2*.

4. Regulations

In order to prevent over exploitation, especially of Arctic charr, there have been laws regulating fishing in Lake Vättern since the beginning of the century. The use of gill-nets was free in the open parts of the lake until 1984 when restrictions were introduced by the County Administration. Today, the use of gill-nets of more than 180 m is not permitted for recreational purposes. Professional fishermen are given special permission to use nets up to 9000 m long, and to use traps. Trolling or sport fishing with rods from land is free for Swedish citizens. Registration at the County Fishery Administration (Fiskenämnden) is necessary for trolling or net-fishing.

Fishery regulations for Lake Vättern are devised by the National Board of Fisheries or the County Administration and these control closed seasons, minimum mesh sizes, and minimum sizes for charr (40 cm), brown trout (40 cm) and salmon (50 cm). There are also two restricted areas in the main basin where net-fishing is prohibited to protect young Arctic charr. The effects of the regulations will be evaluated in 1989 through studies of

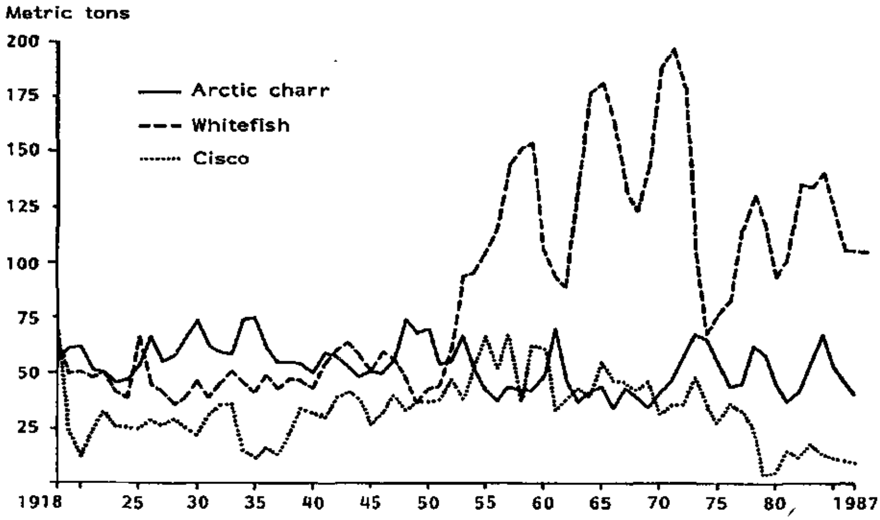

Figure 1. Catches of Arctic charr, whitefish and cisco in Lake Vättern from 1918-1987.

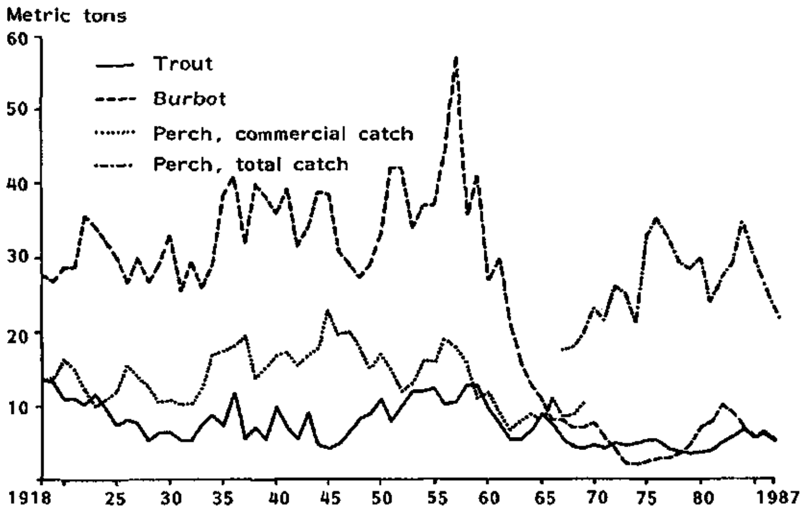

Figure 2. Catches of trout, burbot and perch in Lake Vättern from 1918-1987.

Table 2. Lake Vättern. Total catch of important species in 1986 (tonnes).

Whitefish	104.9
Arctic char	48.1
Salmon (introduced)	12.3
Brown trout	6.2
Cisco	15.5
Perch	26.3
Pike	10.1
Burbor (*Lota lota*)	7.1
Grayling	2.2
Eel (*Anguilla anguilla*)	1.5
Cyprinids	11.6
Total	245.8

mean weights of charr and catch per unit effort in the commercial fisheries. It seems that the intensity of fishing with gill-nets has decreased recently, to the advantage of the slow-growing charr.

5. Introductions and tagging experiments

Artificial propagation of Arctic charr has been going on since the 1920s. Yearly experiments with swim-up fry from 1920 to 1944 did not show any significant contribution to the commercial catches and were interrupted. Tagging experiments with 2 year old charr (about 15-25 cm) have been performed several times since the 1960s, but the recapture of fish above the minimum size is very low and cannot be considered valuable from an economic point of view.

The effect on brown trout, of some planting experiments, is more encouraging. The most appropriate measure to protect and increase the stock of brown trout is to improve breeding and spawning areas in their native rivers, and to this end, some work, including the building of fish-ways, is in progress.

Some exotic species were introduced in the 1960s, *e.g.* splake and kokanee, but results were poor. However, the introduction of smolts of landlocked salmon *(Salmo salar)* from the River Gullspångsälven to Lake Vänern was a great success, and tests with other subpopulations of *Salmo salar*, like 'Klarälven salmon' and 'Baltic salmon', have also been promising.

Yearly releases of 'Gullspångsälven salmon' have been made since 1971 and the yield per 1000 smolts released once reached 1400 kg. Currently, some 25 000 two year old smolts (mean size about 22 cm) are liberated in Lake Vättern each year, during May-June, but yields have fallen in recent years because the techniques employed to catch the fish bring in younger specimens. Yields are now of the order of 700 kg per 1000 smolts released. Nevertheless, the benefits are still very good. *Figure 3* shows the number of smolts released in a given year and the catch in kilograms the subsequent year.

'Gullspångsälven salmon' are very fast-growing. After 18 months in Lake Vättern their mean weights are about 3 kg. They feed on cisco in particular, and cisco resources are used to determine the number of smolts released each year. The salmon stock in Lake Vättern is absolutely dependent on artificial rearing; no spawning has been observed in any of the small rivers which empty into the lake.

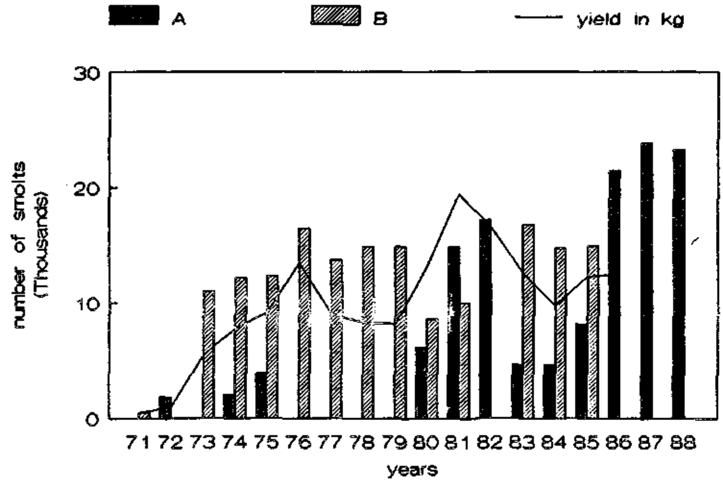

Figure 3. Thousands of smolts released into Lake Vättern and subsequent catches of salmon (x1000 kg) from 1971-1988. A = other stock; B = Gullspångsälven stock.

6. Investigations

Almost all investigations are focused on improving the yield of the species most valuable to the commercial fisheries. However, recently, some inventory work has been carried to assess the possibility of expanding the sport fishery to include brown trout and grayling, and this shows that there is a good stock for sport, *i.e.* fly-fishing. In some places a profitable tourist fishery may therefore be developed. Grayling provides a resource that has not hitherto been considered.

Since knowledge of the food base is important for deciding the size of salmon release each year, investigations using quantitative echo-sounding are now employed to collect information on the distribution and density of prey fish such as cisco, smelt and stickleback. The first results of these investigations will be evaluated in 1989.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp 472-476.

'Salmon Fund Vänern' a project for restoration of salmon stocks in Lake Vänern

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Abstract

There are two stocks of landlocked salmon *(Salmo salar)* and two stocks of brown trout *(Salmo trutta fario)* in Lake Vänern (560 000 ha) in southern Sweden. Salmon and brown trout from one river, the River Gullspångsälven, grow very fast. A project has been inaugurated to increase the annual catch from Lake Vänern to 200 tonnes, which was the yield in former days. The ultimate goals are to build up tourism based on recreational fishing, and to improve commercial fishing. Biological, economic and legal problems, and plans to reach these goals are discussed here.

1. Introduction

Lake Vänern (560 000 ha) in the southern part of Sweden is the largest lake in the country. It contains 34 species of fish. No other lake in Sweden has so many species. *Table 1* shows the mean catches of commercial fishermen at different periods. Vendace *(Coregonus albula)* is the most valuable species because of its roe. There are two stocks of land-locked salmon *(Salmo salar)*, and two stocks of brown trout, *(Salmo trutta)*. These spawn in the Rivers Klarälven and Gullspångsälven. Of special interest are the very fast-growing stocks of salmon and trout from the River Gullspångsälven *(Figure 1)*. When fish of both these stocks return to the river to spawn their mean weight is over 7 kg.

The catch of salmon and trout was once 200 tonnes/yr, but industrial pollution and exploitation of the rivers for hydroelectric power have nearly exterminated the salmon and trout stocks in Lake Vänern. In the early sixties the lake began to be stocked with salmon and trout smolt on a small scale, and in the 1980s reached over 100 000 smolts/yr. At the same time the catch increased from almost nothing to 50 tonnes/yr *(Figure 2)*.

2. Goals of the salmon fund

On the initiative of the county administration a project to restore the salmon and trout stocks was inaugurated in 1985. A project group was set up with members from different local and national interest groups and organisations. The goal is to achieve an annual catch of 200 tonnes, mainly by increased farming and stocking of salmon and trout, and by restoring the natural spawning grounds. It is hoped that equal parts of the annual catch will be taken by recreational and commercial fishermen. Only a small increase can be achieved by improving natural spawning, so farming must go on continuously.

The aim is to develop a recreational fishery that is suited to the market with an all-round service of high quality in different price ranges for both Swedish and foreign tourists.

Table 1. Mean catches (in tonnes/year) taken by commercial fishermen in Lake Vänern.

Species	1914-1923	1934-1940	1962-1971	1972-1981	1982-1984	1985
Vendace	78	86	122	172	337	351
Pike	127	118	94	103	100	102
Burbot	170	145	72	101	123	115
Pikeperch	51	86	75	94	106	81
Whitefish	61	50	32	57	64	63
Perch	116	80	15	28	56	80
Eel	19	10	12	12	12	19
Smelt	32	13	5	11	14	15
Salmon/trout	23	21	3	18	38	45
Other species	118	53	86	171	122	124
Total	795	662	516	767	972	995

3. Biological aspects

The project group has investigated the prerequisites of the project, with regard to biological, economic and legal matters, for two years now. Earlier taggings of salmon and trout smolts have shown that it would require the release of some 500 000 smolts/yr to obtain annual catches of 200 tonnes from Lake Vänern. Most of the smolts would have to originate from the salmon stock in the River Gullspångsälven since this is the quickest growing strain. About 75% of the material will have to be salmon and 70% of this should originate from the river Gullspångsälven. It is estimated that the mean recatch will be of the order of 400 kg/1000 smolts released.

Vendace *(Coregonus albula)* and smelt *(Osmerus eperlanus)* are the most common food items for salmon and trout in Lake Vänern. The lake is more eutrophic today than it was at the beginning of the century and the production of vendace and smelt is therefore assumed to be at least of the same magnitude. The stocks of vendace can fluctuate widely between years, probably depending on intraspecific competition.

One of the greatest problems for the project is to protect natural genetic resources and yet maintain broad genetic variation. Thus all farming should be based on natural spawning stocks, and attempts must be made to prevent too many of the farmed fish

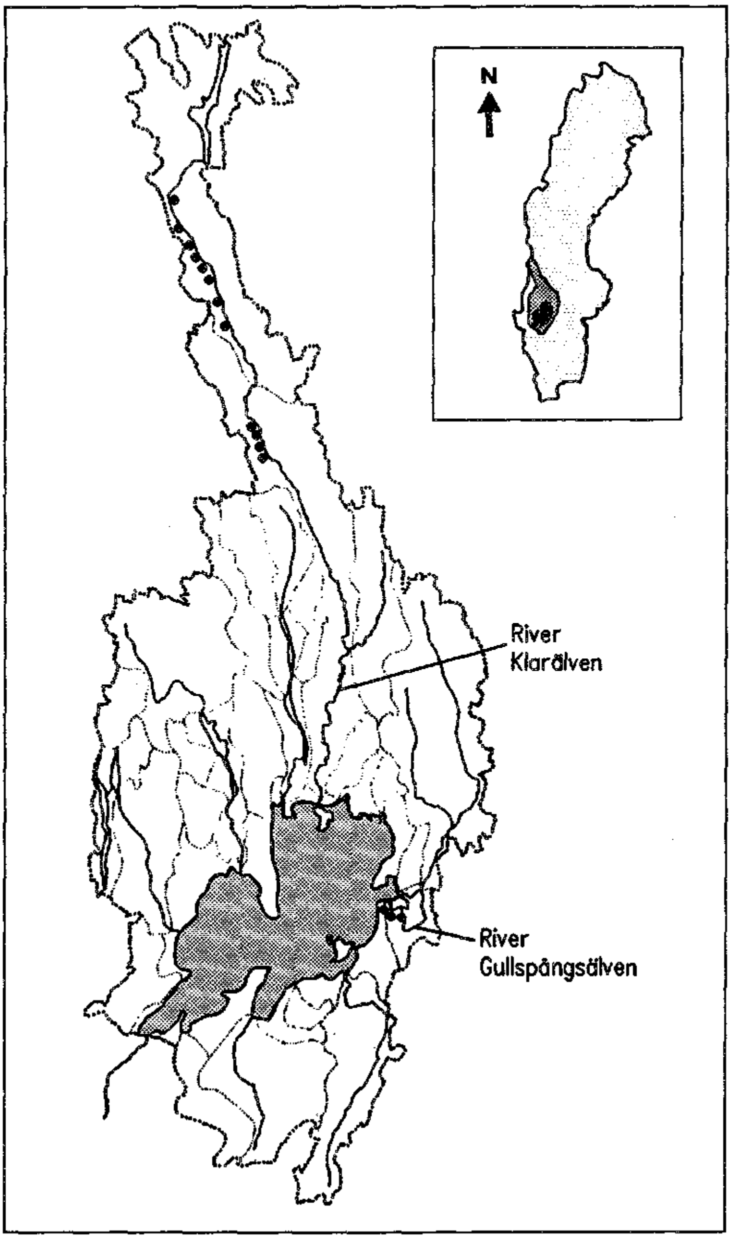

Figure 1. Lake Vänern and its drainage area. Large dots represent the areas which remain for natural spawning.

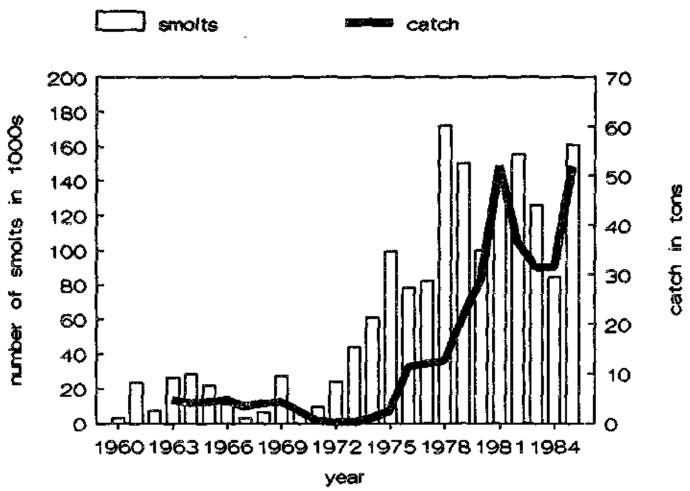

Figure 2. Smolts released in Lake Vänern and the River Klarälven, and catches in Lake Vänern 1960-1985.

reaching the spawning grounds. To this end most smolts are released in the lake, by delayed release, rather than in the rivers.

The plan is to establish a permanent fishing trap in the River Gullspångsälven where all salmon and trout migrating to the spawning areas can be caught. All farmed fish will be tagged by fincutting and only those arising from natural reproduction will be allowed to migrate up to the spawning areas. Fishing will be completely prohibited in the estuaries of all rivers with natural spawning grounds.

4. Legal aspects

In the four largest lakes in Sweden, as along the coast, all Swedes are allowed to fish with sport-fishing equipment. They may fish all over the lakes, and for distances of up to 300 m from the shores with gill-nets. However, this can no longer be permitted in Lake Vänern if the objectives of the project are to be realised. A law has already been passed which restricts the total length of nets to 150 m per person, commercial fishermen excepted. Normally the length of a net is 30 m. Perhaps further restrictions on the use of nets will have to be introduced, and possibly netting will be entirely prohibited in certain parts of the lake. This will improve sport fishing and to some extent licensed commercial fishing. During 1986 about 3900 persons fished in Lake Vänern and used 41 000 nets, and there are some 200 commercial fishermen on the lake, half of whom make fishing their main occupation.

Foreigners are now permitted to fish in Lake Vänern with handheld sport-fishing equipment. However, trolling, on which much tourist fishing must be based, is not yet available to foreigners. The project group has proposed that it will be possible for foreign tourists to purchase licences for trolling.

The old rights allowing Swedes to fish in the largest lakes and around the Swedish coast, even with nets, without any fee, are deeply rooted. But for the Vänern project it will be necessary to be able to regulate the fishing effort both from a biological and an economic point of view.

5. Economic aspects

It has been estimated that the yearly costs will be 8-9 million Swedish krona, mainly for the farming of smolts (6 million krona). Other major costs will be supervision (0.5 million krona), investigations, to follow up and evaluate the results (0.5 million krona), and marketing the tourist aspects of the project (1-2 million krona).

As mentioned previously, there is no licence fee for fishing in Lake Vänern to finance the project. To start the project it will be necessary to obtain state subsidies for the first 4 years.

At present attempts are being made to create a foundation to provide funds for the project. This will include representatives from both county administration and industry, and it is hoped that industry will undertake economic responsibility for the larger part of the project. Initially however, the county administrations and the local authorities will pay the costs. Plans for fish farming and catching spawning fish, and other technical details, will have to be undertaken by the National Board of Fisheries.

As a base for the future funding of the project it has been proposed that a fee of 100 Swedish krona be charged for an annual licence for fishing in Lake Vänern. The National Board of Fisheries has supported this proposal provided that the fee is levied only for the fishing of salmon and trout. However, the imposition of such a fee must be decided by the Swedish parliament.

It is expected that about 5 years after the start of the project 25 000 people will visit Lake Vänern each year, producing an annual income of 100 million krona. It is anticipated that a fishing tourist will spend 600-1000 krona per day on fishing activities, food, hotel and other things, and stay for 4-5 days. The project will create about 300 new jobs.

Trolling will be the most popular form of sport-fishing. For this there will be a demand for charter boats and for boats for leading. This will provide incomes for local fishermen. Most incomes and new jobs will, however, be created within the tourist industry.

The project effectively began with the release of about 150 000 smolts in 1987 and 1988. It is a wide project engaging national and local fishery boards, county administrations, tourism organizations, organizations of sporting and commercial fishermen, and industry. It is the first of its kind in Sweden, but plans are under consideration for similar projects in other parts of the country based on the development of salmon stocks in the northern rivers.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp 477-492.

Management practices for lake fisheries in Switzerland

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Abstract

Lake fishery has a long tradition in Switzerland owing to the abundance of lakes. The species most commonly fished for have been and still are whitefish, perch, charr, pike, and trout. Cyprinids like roach are sometimes caught in large quantities as by-catches but are not particularly esteemed. The fish stocks in the lakes are exploited mainly by commercial fishermen using gill-nets and traps. They account for some 90% of the total yield, while sport fishermen catch the remaining 10%. The yields from lake fisheries reached a maximum in the mid-1970s, due to progressive eutrophication and increased fishing pressure since the 1950s. After a marked decline in the late 1970s they have shown a significant increase in recent years. This paper reviews the organization and practice of fishery management in Swiss lakes. Fisheries management is within the responsibility of the cantonal (state) governments. The federal legislation on fisheries merely sets the frame for the cantonal fishery legislation. Management of the lake fisheries is aimed at achieving a high sustained yield of the commercially important fish species. In practice, management consists of stock enhancement activities, and regulation of the fisheries, applying the principle of allowing most fish to spawn at least once before they are caught. Fishing intensity is regulated by limiting the numbers and sizes of nets, and the number of commercial fishing permits per lake. Perch is exploited without any significant stocking, while whitefishes are regularly stocked as fry in high numbers. Most eel and pikeperch stocks are at rather low levels, in spite of predominant fingerling plantings. This pragmatic approach to fish stock management has apparently met with considerable success in past decades. However, the assessment of the effect of stocking on the fish stocks and yields has not so far been implemented into routine fishery management. The fish populations exploited are surveyed regularly only in a minority of the lakes. Thus important changes in the biological characteristics of fish stocks may go unnoticed, leading to decreases in yields or even population collapses. External experts are then contracted to investigate the situation. A few case-studies illustrate the results of this practice. It seems obvious that an improvement in the management practices could only be achieved by incorporating the new knowledge gradually emerging from research in this field, and by employing more personnel for monitoring basic features of the important fish stocks in a changing environment. Particular efforts are to be made in enhancing rare or threatened species groups such as European (brown) lake trout, charr, shad and certain whitefishes which have already become extinct in some lakes.

1. Organization of lake fishery management

Endowed with an abundance of natural lakes, Switzerland has a long tradition of utilizing the fish stocks in these lakes as an important food resource. Up to the 18th century, most fishing rights were owned by the clergy and the nobility, who bestowed the rights upon individual fishermen or fishery co-operatives. In the surge of the French revolution at the end of the 18th century, came feudalism, and with it all fishery regulations were abolished, leaving the fisheries in chaos. In the course of the 19th century, the cantons (local or state governments) regained their political power and, with this, the fishing rights over rivers and lakes. Since then, the cantonal governments have held sole responsibility for fishery management in Swiss waters. Exceptions to this rule are privately-owned waters, and international waters where the federal government participates in negotiating international fishing regulations. Seventeen cantons have lakes which are exploited commercially today. The federal legislation on fishery merely sets the frame for the cantonal fishery legislations which apply to individual waters.

The traditional goal of fishery management is to achieve a high sustained yield of commercially valuable fish species. These are, in order of importance, perch *(Perca fluviatilis)*, various whitefish *(Coregonus* spp.*)*, cyprinids, mainly roach *(Rutilus rutilus)* and bream *(Abramis brama)*, pike *(Esox lucius)*, charr *(Salvelinus alpinus)*, European lake trout *(Salmo trutta* f. *lacustris)*, burbot *(Lota lota)*, eel *(Anguilla anguilla)* and pikeperch *(Stizostedion lucioperca)*. Roach and bream are often caught in large quantities as by-catches, but are generally disliked by the public. A more recent aspect of fishery management concerns the conservation of threatened species.

Management principles rest on the following two complementary approaches. The first principle is to favour natural reproduction by allowing most fish to spawn once at least before they are caught. This is achieved by regulating mesh sizes of gill-nets and trap nets in the commercial fishery, and through the imposition of minimum size limits for fish caught in the sport fishery. Minimum mesh sizes and size limits are often fixed by a gross estimation of the size of mature fish during the fishery for spawners and not by thorough long-term analysis of age, growth and maturity of the entire fish stock. This may lead to serious problems as will be discussed later. Habitat conservation and rehabilitation of spawning grounds is a partial aim of lake restoration measures especially in eutrophic lakes (Stadelmann 1980) and will eventually help to improve natural reproduction too.

The second principle involves enhancing the fish populations by stocking larvae, fry, older juveniles and fingerlings. Stocking of young fish is subsidized by the federal and cantonal administrations. Examples of stocking efforts are given in the chapter on stock enhancement. In the western part of Switzerland, stocking is done exclusively by the cantons, whereas in a number of lakes in the central and eastern part, commercial and, to a lesser extent, sport fishermen participate in the rearing and stocking programmes run by the cantonal fisheries agencies.

In order to limit fishing intensity and to support the existence of full-time fishermen, the number of commercial fishing permits per lake is closed, their number depending on the size and productivity of the lake. In total, 292 full-time and 193 part-time commercial fishermen (Staub 1987), using mainly gill-nets and traps, share a combined lake area of about 140 000 ha which includes the Swiss parts of international waters. Some 200 000 anglers fish the lakes. Fishing pressure is further limited by the numbers and dimensions of nets, and by closed seasons during the spawning periods of important species. Special permits are issued to commercial fishermen for the 'reproduction fishery', when spawners are caught. In fact, practically all whitefish, charr and pike roe is collected through this fishery which in some lakes contributes significantly to the fishermen's revenue (Roth 1954). The fish caught are not viable and have to be marketed. Roe fishing is stopped when the hatcheries are full. The system of annual catch quotas allotted to individual fishermen for controlling the rate of exploitation has not been adopted for any Swiss lake.

Up till now, evaluation of the efficiency of stock enhancement measures in lakes has hardly been undertaken. The main difficulty here arises from the problems associated with marking fry and juveniles less than three months old. These two categories actually account for 75 to 99% of the fish stocked in lakes, depending on the species (BFS 1987). Due to this lack of information, the number of fish stocked each year depends very largely

Table 1. Average annual yield of commercial and sport fishery from1981-1986 in 20 Swiss lakes. Yield in kg (from Bundesamt für Umweltschutz 1988).

Lake (Excluding foreign parts)	Total	Whitefish	Lake trout	Other trout	Charr	Grayling	Pike	Pikeperch	Perch	Carp	Tench	Bream	Other cyprinids	Burbot	Eel	Catfish	Other
L. Geneva*	404 824	11 119	6 278		3 399		2 504		192 374	229	1 544		162 546	1 174			23 657
L. Neuchâtel	517 221	144 959	8 375		2045	19	5 646	4	135 128	1 501	643	30 258	188 007	388	32	216	
L. Constance	594 025	227 864	2 034	1 364	289	796	4 800	1 081	274 437	309	388	51 883	20 085	1 277	7 152	3	263
L. Lucerne*	379 851	265 447	2 089	44	21 078	184	4 078	87	11 260	28	195	5 737	64 911	3 485	1 186		42
L. Zurich	290 479	85 415	2 744	82	386	70	8 084	102	61 283	550	897	14 617	113 243	2 335	568		103
L. Thun*	43 475	41 250	205		1 198	210	270		146		10	3	135	46			2
L. Maggiore**	172 715	116 737	3 011		101		12 406	444	12 881	25	7 312		17 213	1 080	386		1 119
L. Biel*	117 052	52 920	149				3 084		12 966		157	7 036	39 625	914	134		67
L. Zug	106 174	21 241	444		2 737		1 470		11 375	330	189	6 170	59 709	1 174	1 335		
L. Lugano**	32 421	5	1 517		10	13	247	450	5 716	444	870		20 987	1 122	527		526
L. Brienz*	29 243	28 628	130		143	41	67		16			73	145	99			1
L. Walenstadt	44 003	30 483	1 302	73	1 223		1 032		4 424	3	2	73	2 880	2 450	12		5
L. Murten	60 552	170	881		2		2 847	47	10 563	166	245	13 757	30 207	18	11	1 611	
L. Sempach	77 729	57 586	180	4	30		2 308	3	5 660	92	777	4 117	6 694	186	70		22
L. Hallwil	20 665	16 634	8				1 120	27	1 443	62	143	328	865	14	17		3
L. Joux	21 286	13 303	1 010				2 649		1 861		21		2 177	2			263
L. Sarnen	25 250	14 727	55				840	1	1 228		32		7 906	244	217		
L. Aegeri	9 548	4 090	107		486		1 596		1 450		31		1 697	55	37		
L. Baldegg	11 247	3 538	67	2			549	87	1 939	382	48	1 386	2 878	10	362		
L. Lugern	10 480	7 808	28				548		258				1 815	24			
Total	2 968 240	1 143 924	30 614	1 569	33 127	1 333	56 172	2 333	746 408	4 121	13 504	135 366	743 725	16 097	12 046	1 830	26 073

* without sport fishery

** from 1982 on, without sport fishery

upon the availability of spawners and on the production capacity of the hatcheries. Under these circumstances, lake fisheries management is limited to continuing existing stocking programmes and regulating fishing intensity. Lack of personnel prevents the fisheries agencies from monitoring the age structure of the catches from the majority of lakes. Catches often fluctuate strongly for unknown reasons, and sometimes there may even be a population breakdown. This, in turn, may prompt the appointment of external experts from universities, other fisheries agencies, or private consultants, to analyse the situation and to suggest remedial measures in the management process (see Svarvar & Müller 1982, Kirchhofer & Tschumi 1986).

Research in lake fishery biology and management in Switzerland is carried out by about a dozen biologists working either for federal and cantonal agencies or for universities. The combination of modern research methods such as dual-beam hydroacoustics (Ehrenberg 1984), mid-water trawling for pelagic fish stock assessment (Geiger, Meng & Müller 1985), efficient gear for sampling fry (Ponton & Müller 1988), micro-tagging (Jefferts, Bergman & Fiscus 1963) with conventional fish biology (age and growth studies, VPA, mortality estimates, food analysis, etc.) is beginning to increase and alter existing knowledge of the population dynamics of fish in lakes. This is true for whitefish, the dominant type of pelagic fish, in particular. Because the study of fish population parameters in a number of lakes is laborious and requires many years, findings which can be incorporated into management practices will only gradually become available in the course of the next five to ten years.

A major aspect of research will deal with the ecological consequences of changes in trophic states. The phenomenon of decreasing nutrient concentrations leading to re-oligotrophication can already be clearly seen in most of the moderately polluted Swiss lakes. Here, fishery research has to assume a leading role in following the effects of the changes on fish community structure, and also in evaluating new strategies on the management side. The scope of research will include both the commercially important and unimportant species, in order to maintain or restore 'harmonic communities' (Ryder & Kerr 1990). Furthermore, important improvements in fish culture, such as rearing fish in illuminated net cages (Brylinski, Radziej & Uryn 1979), are gradually finding their way into the management programmes of cantonal fisheries agencies where they meet with growing success (Egloff 1984, Zaugg & Pedroli 1984).

2. Fishing yield and stock enhancement

2.1 Fishing yield

Statistics on yield by species are compiled annually by the cantonal fisheries agencies. The federal fishery agency collects these data and issues national yield statistics for the 20 major Swiss lakes every two years (BUS 1988). Data on fishing effort are not recorded at all. However, fishing effort is believed to be rather constant in most lakes since the number of commercial fishing permits and nets is kept constant.

Actual data on the average fishing yield in the 20 major Swiss lakes are given in *Table 1*, for the six-year period 1981-1986 (BUS 1988). Sport fishing yield is included for most lakes, its share being roughly 10% of the total yield. Overall the most important categories are whitefish, perch and 'other cyprinids' (mainly roach) which account for 39%, 25%

and 25% of the total yield, respectively, or 89% of it in total. The value of the 1984 yield was estimated at about 17 million Swiss francs (Staub 1987).

The evolution of total annual yield is represented in *Figure 1*. Total yield from lakes seems to have a potential of over 4000 tonnes/yr a value which had been approached by the mid-1970s. Reasons for the rises in yield are increased rates of fishing (due to better gear) and improved marketing, and the increasing productivity of the lakes. The latter phenomenon manifests itself in better (generally) recruitment in perch and cyprinids, and higher growth rates in perch and whitefish. From 1977 on, however, a simultaneous recession of yield in a few very productive 'perch lakes' (*e.g.* Lake Geneva, Lake Neuchâtel) and 'whitefish lakes' (*e.g.* Lake Zug, Lake Thun) caused a temporary decline of total yield to about 2500 tonnes per year. This decline can be largely explained by a short series of years with unfavourable climatic conditions for perch and whitefish reproduction, and overfishing of their stocks with consequent negative feed-back on natural and artificial propagation. In recent years, the situation seems to be improving again *(Figure 1)*.

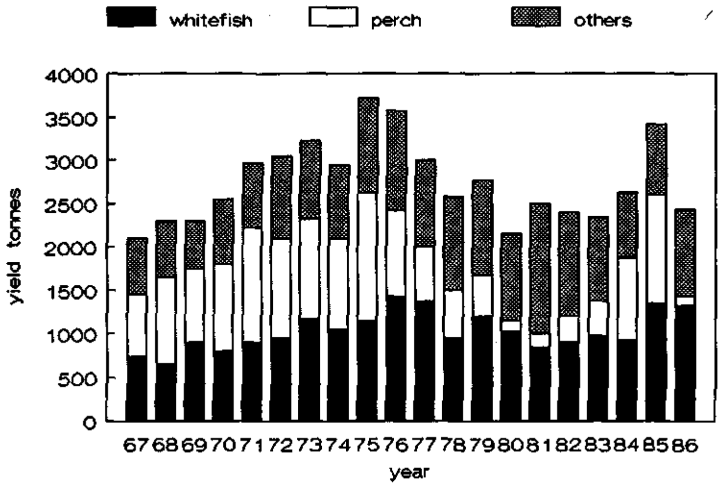

Figure 1. Total annual yield from 20 major Swiss lakes.

The relationship between lake trophic state, yield and fish community structure based on catch data *(Table 2)* is not straightforward. The principal target species in oligotrophic, mesotrophic and eutrophic lakes are whitefish and perch. Yield of the intensively stocked whitefish, see section on stock enhancement, does not show any simple correlation with trophic state. Perch is basically a predator and does not reach yields as high as whitefish. Furthermore, varying year-class strength leads to dramatic yield fluctuations of perch and whitefish, chiefly in eutrophic lakes. The complexity of the situation will warrant a more detailed analysis of time-series data at a later occasion.

Table 2. Trophic state, average annual yield per hectare and important fish species of 20 Swiss lakes from 1981-1986. Data from *Table 1*.

Lake	Trophic state	Area (ha)*	Yield (kg/ha)	Percentage of important species in yield			
				whitefish	perch	cyprinids	pike
L. Geneva	eutrophic	34 745	11.7		48	41	
L. Neuchâtel	mesotrophic	21 581	24.0	28	26	43	
L. Constance	eutrophic/ mesotrophic	17 144	34.6	38	46		
L. Lucerne	mesotrophic/ oligotrophic	11 380	33.4	70		17	
L. Zurich	eutrophic/ mesotrophic	8 852	32.8	29	21	45	
L. Thun	eutrophic/ mesotrophic	4 780	9.1	95			
L. Maggiore	mesotrophic	4 230	40.8	68		14	
L. Biel	eutrophic/ mesotrophic	3 920	29.9	45	11	40	
L. Zug	eutrophic	3 830	27.7	20		63	
L. Lugano	eutrophic	3 070	10.6		18	69	
L. Brienz	oligotrophic	2 918	10.0	98			
L. Walenstadt	mesotrophic/ oligotrophic	2 423	18.2	69	10		
L. Murten	eutrophic	2 282	26.5		17	73	
L. Sempach	eutrophic	1 450	53.6	74		15	
L. Hallwil	eutrophic	1 020	20.3	80			
L. Joux	eutrophic	953	22.3	62		10	12
L. Sarnen	mesotrophic/ oligotrophic	764	33.1	58		31	
L. Aegeri	mesotrophic	716	13.3	43		18	17
L. Baldegg	eutrophic	525	21.4	31	17	42	
L. Lungern	mesotrophic/ oligotrophic	201	52.1	75		17	
Total		126 784	23.4	39	25	30	2

* Excluding foreign parts

2.2 Stock enhancement

In *Table 3*, data on stocking European lake trout, pike and whitefish are summarized for seven selected lakes. Of all commercially important fish species, perch is the only one which is not stocked, with the exception of a few episodic attempts to transplant perch roe and larvae from Lago Maggiore to some other lakes. Thus, the catch of perch relies entirely on natural reproduction.

The term 'juvenile' in *Table 3* has been chosen to designate young-of-the-year which are reared in culture for a period of at least two weeks (pike) and six weeks (trout, whitefish), respectively. Fry are free-swimming and feeding, while fingerlings are juveniles reared for at least three months (pike four months) in culture or in a natural environment.

The figures in *Table 3* are intended to give an idea of the variation in stocking efforts undertaken in different lakes. High stocking densities are reached in medium-sized lakes where the reproduction fishery is successful, *e.g.* pike in Lakes Biel and Sarnen, and whitefish in Lakes Biel, Sempach, Hallwil and Sarnen. The lake trout spawners of Lake Lucerne are mostly caught in the tributaries.

The data on 'stocking efficiency' in *Table 3* contain one important factor which has not been accounted for; natural offspring. Catch of natural origin augments the proportion of fish caught per fish stocked. Natural propagation seems to be important for pike in certain years, in lakes with some littoral vegetation (Lakes Lucerne, Thun, Biel and Sarnen), and for whitefish in oligotrophic and mesotrophic lakes (Lake Lucerne/small form, Lakes Thun and Brienz). The survival rate of whitefish larvae commonly stocked between January and mid-March seems to be consistently lower than 0.5%. Similar data were reported by Roth (1954) and Klein (1987). The thriving charr population in Lake Lucerne also reproduces successfully (Meng & Müller 1988), which explains the high 'stocking efficiency' of 10 adults caught versus 4 fingerling units stocked per hectare. However, the available data *(Table 3)* do not permit any more detailed interpretation with regard to the trophic state of the lakes.

Most pikeperch and eel stocks are at rather low levels, in spite of predominant fingerling/elver planting. Numbers of pikeperch stocked depend entirely on the availability of imported fingerlings. The numbers of elvers stocked have been reduced in recent years because serious negative effects on whitefish, crayfish and other species are suspected as a consequence of stocking eels.

3. Management practices: three case histories

3.1 Lake Sarnen

The total phosphorus concentration in Lake Sarnen increased gradually from 5 mg/m^3 in 1965 to a peak value of 21 mg/m^3 in 1979, followed by a rapid decrease (Müller & Meng 1986) to 5.5 mg/m^3 in 1987. Today, the lake is again considered oligotrophic.

Total fish yield *(Figure 2)* has roughly doubled during the past 20 years. The increase in yield is mainly due to higher roach ('cyprinids') catches in the 1970s, and to a lesser extent, to higher whitefish catches. With the decrease of P-values since 1979, roach

Table 3. Relative stocking densities and their relation to mean annual catch by fish species in some Swiss lakes. 10-year averages: 1972-1981 for Lake Sempach, 1976-1985 for the other lakes. Catch includes unknown proportions of naturally reproduced fish.

	Stocking (number/ha)		Catch (number/ha)	Catch as % of stocking	Source
European lake trout					
Lake Lucerne	36.0	F*	0.26	0.72	Kanton Luzern (1985)
Lake Thun	3.7	F*	0.044	0.72	Kanton Bern(1985)
Lake Brienz	5.3	F*	0.066	1.24	Kanton Bern (1985)
*Fingerlings, juveniles (J) and fry (F) summed as fingerlings: 1F=2J=10L					
Pike					
Lake Lucerne	4.6	F+	0.37	8.00	Kanton Luzern (1985)
Lake Thun	2.9	F+	0.15	5.20	Kanton Bern (1985)
Lake Biel	21.5	F+	0.87	4.00	Kanton Bern (1985)
Lake Brienz	3.4	F+	0.036	1.06	Kanton Bern (1985)
Lake Sarnen	19.1	F+	1.2	6.30	Kanton Obwalden (1985)
+Fingerlings (F), juveniles (J) and fry (L) summed as fingerlings: 1F+10J=100L					
Whitefish					
L. Lucerne (small)	4 662	L	133	2.90	Kanton Luzern (1985)
L. Lucerne (large)	2 718	L**	5.6	0.21	Kanton Luzern (1985)
Lake Thun	3 497	L	85	2.4	Kanton Bern (1985)
Lake Thun	4 166	L**	85	2.00	Kanton Bern (1985)
Lake Biel	10 460	L	65	0.62	Kanton Bern (1985)
Lake Biel	12 390	L**	65	0.52	Kanton Bern (1985)
Lake Brienz	2 370	L	58	2.4	Kanton Bern (1985)
Lake Sempach	39 690	L	238	0.60	Muggli (1983)
Lake Sempach	47 137	L**	238	0.50	Muggli (1983)
Lake Hallwil	9 066	L	35	0.39	Kanton Aargau (1985)
Lake Hallwil	17 396	L**	35	0.20	Kanton Aargau (1985)
Lake Hallwil	833	J	35	4.2	Kanton Aargau (1985)
Lake Sarnen	13 357	L	66	0.49	Kanton Obwalden (1985)
Lake Sarnen	19 014	L**	66	0.35	Kanton Obwalden (1985)
**Larvae and juveniles (J) summed as larvae: 1J=10L					

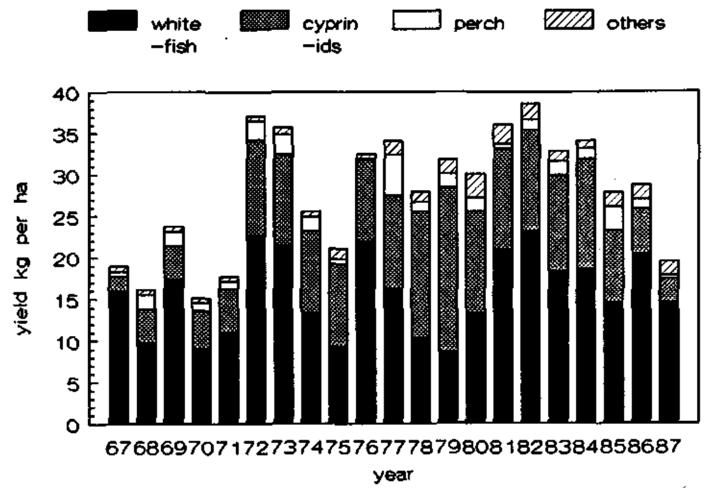

Figure 2. Lake Sarnen. Annual yield of commercial and sport fishery from 1967-1987 (BUS 1988, Kanton Obwalden 1988).

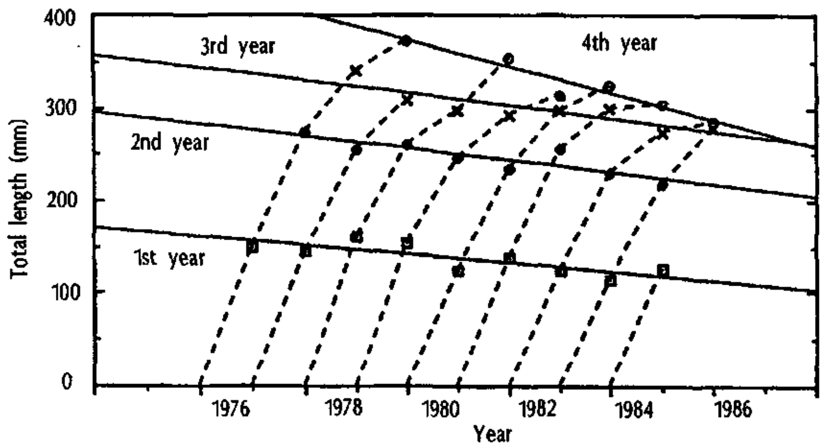

Figure 3. Growth by age-class of whitefish in Lake Sarnen, year classes 1977-1985. The correlations are significant at $p<0.01$.

catches have declined significantly, in spite of the growing interest (since about 1980) in this species for human use, particularly during the spring. Individual growth rates of roach in Lake Sarnen have been demonstrated to depend essentially on the temperature in summer (Müller & Meng 1986) and not on trophic state within the range of P-values observed in this lake. Contrary to yield of roach, whitefish yield is still within the annual variation recorded during the past ten years. However, individual growth rates of whitefish have strongly decreased *(Figure 3)*. In 1981 the age composition of whitefish, which at that time was mostly caught in 38 mm nets (bar mesh size), was 85% age 2 and 15% age 3. By 1987 the fishermen had been forced by necessity to lower the most frequently used mesh size, within the legal limits, to 32 mm for ground nets and 35 mm for drift nets, in order to maintain an acceptable yield. During the same period, the age composition of the commercial whitefish catch changed to 1% age 2, 83% age 3 and 16% age 4, in spite of the lower mesh sizes!

The evolution of the whitefish population had been monitored since 1981 by the nearby Lake Research Laboratory/EAWAG in Kastanienbaum (Lucerne) which runs a long-term fishery research program on this lake. At the request of the cantonal fisheries agency to EAWAG, a recommendation for lowering the legal mesh size of driftnets to 32 mm was given. Possible causes other than reduced lake productivity acting towards growth retardation in whitefish (population density, parasites) will continue to be studied by EAWAG.

Other subjects currently under investigation are mortality factors in juvenile whitefish (Ponton & Müller 1988), and the assessment of the importance of natural offspring. This is done by comparing larval whitefish densities in the lake before and after stocking larvae from cold-incubation. A tentative evaluation of the results obtained so far indicates that natural reproduction accounts for some 5 to 40% of the whitefish juveniles present in late spring, according to the year. Similar results were reported by Klein (1987) from the mesotrophic Lake Starnberg (Bavaria). A first tagging experiment with whitefish fingerlings, using microtags, was started in 1981 (Meng, Müller & Geiger 1986). The resulting final recapture rate as adults has been 10.1%. A second tagging experiment was begun in 1984 and is still under way. Long-term changes in fish stock abundance and community structure are followed by using dual-beam hydroacoustics and pelagic sampling gear, and by interpreting catch statistics. A gill-net selectivity experiment on roach was conducted for EIFAC in 1982/1983 (Dahm, Brenner, Klein & Müller 1988).

It is worth noting, that for whitefish and pike, management activities such as reproduction fishery, egg incubation, rearing of the young, and stocking, are carried out exclusively by the two commercial fishermen of Lake Sarnen.

3.2 Lake Thun

The data presented here are from the work of Kirchhofer & Tschumi (1986) on the whitefish populations of Lake Thun, and from unpublished reports issued by the fisheries agency of Canton Berne (Kanton Bern 1988).

Lake Thun has gradually evolved from oligotrophic to mesotrophic during the past 40 years. Whitefish, as well as lake trout and pike are stocked as larvae and juveniles reared by the cantonal authority in state fish farms. The fishermen do not participate in the rearing and stocking activities. The development of the annual yield (95% whitefish), as represented in *Figure 4*, was characterized by marked fluctuations and a general increase until 1974. From 1975 to 1977, extreme yields of up to 67 kg/ha were achieved, followed by a population collapse. It was not until 1982 that an investigation of the causes of this drastic and persisting drop in yield was begun by the University of Berne, at a request from the cantonal fisheries agency. The investigation revealed that whitefish had continued to accelerate growth since Rufli's (1979) growth studies in 1969-1972. At the same time, fishing pressure had remained high, with the same mesh sizes as in 1970. As a consequence, significant parts of the population had been harvested before the fish could reach sexual maturity. The same sequence of events leading to recruitment overfishing (Gulland 1983) had occurred in the early 1960s in Lake Constance (Nümann 1970).

As in Lake Constance in 1964, the minimum mesh size for drift nets in Lake Thun was eventually raised from 40 to 44 mm in 1985. A further reduction of fishing pressure was achieved by a longer closed season in winter, and by a higher legal size and lower catch limit in sport fishing. Hopefully, these measures will result in a progressive build-up of a large and stable whitefish stock in the coming years. Since 1983, the commercial whitefish catch has been sampled regularly by the fisheries agency. The material is analyzed for age, growth and sexual maturity through a contract with the University of Berne.

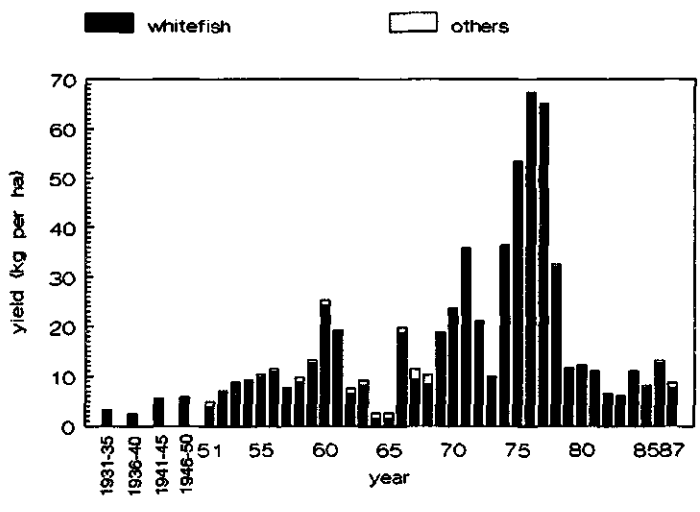

Figure 4. Lake Thun. Annual yield of the commercial fishery from 1931-1987 (Kanton Bern 1988).

3.3 Lake Hallwil

This lake shows how eutrophication and proper management efforts can affect fish populations and yield. Data presented are from Stöckli & Schmid (1987) on trophic state and lake restoration, and from the fisheries agency of Canton Aargau (Kanton Aargau 1988) on fish yield and stocking.

Lake Hallwil has evolved from a mesotrophic to a highly eutrophic lake between 1950 and 1970. Mean total phosphorus concentrations in spring reached their highest values near 240 mg P/m^3 around 1976. However, sewage treatment plants, collector pipes and hypolimnetic oxygenation (from 1985 on) had brought a successive decline of P-values to 160 mg P/m^3 by 1987. In spite of this, the lake remains highly eutrophic and far from the envisaged goal of 30 mg P/m^3. It remains doubtful whether this can be reached under the present situation, with most of the P-input originating from intensive agriculture in the drainage area. Fishery management will have to cope with this disenchanting outlook.

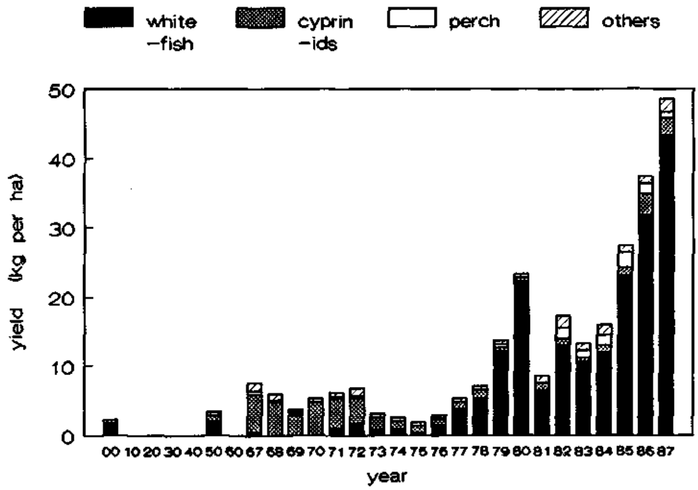

Figure 5. Lake Hallwil. Annual yield of commercial and sport fishery from 1900-1987 (BUS 1988, Kanton Aargau 1987).

Up until about 1950, whitefish was the principal species fished. Relatively high numbers of whitefish larvae were already being regularly stocked to increase yield by the end of the 19th Century (Steinmann 1950, 1951). However, with progressing eutrophication, whitefish yield decreased to insignificance *(Figure 5)*. After 1950, cyprinids became more abundant but decreased to low values again in the mid-1970s. Whitefish catches remained low, in spite of increased planting of larvae from about 1960 onwards. Encouraged by the positive results of rearing whitefish larvae to older juvenile stages on zooplankton in troughs (Roth & Geiger 1968), the fishermen began to install and operate rearing facilities at their own expense. Large scale planting of juveniles reared for at least six weeks started in 1970. The positive reaction of yield to this adjustment in management practice can be seen in *Figure 5*. The correlation between the number of juveniles stocked and the corresponding year-class strength by VPA *(Figure 6)* is significant at $p<0.01$. It seems that stocking juveniles is effective only at a rate higher than 0.4 million per year, possibly indicating some predator effect. Similar regressions on the number of larvae stocked, either weighted 1 or 0.1 and added to juveniles, did not produce any significant correlation, even though natural reproduction can be neglected in this lake. Stocking of whitefish larvae, however, is not always ineffective and can be a useful tool for supplementing natural reproduction (Lake Sarnen), for saving whitefish populations from extinction (Lakes Hallwil, Zug and others) and for restoring populations in lakes from where they have disappeared (Straub 1985).

The Lake Research Laboratory/EAWAG initiated a long-term research program on fish ecology in Lake Hallwil in 1986, after a first survey of the fishery in 1981/1982 (EAWAG 1983). The aim of the project is to understand the mechanisms operating in fish population dynamics in eutrophic lakes, and to explain eventual changes in fish abundance and community structure resulting from restoration measures applied, like hypolimnetic oxygenation and further reduction of P-input (Stöckli & Schmid 1987). The methods employed are the same as in Lake Sarnen.

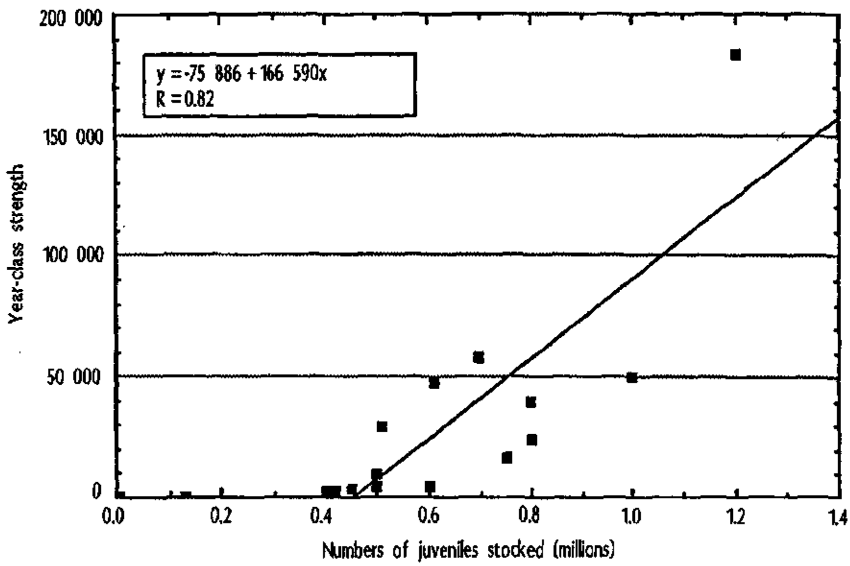

Figure 6. Lake Hallwil. Relationship between virtual year-class strength and number of juveniles stocked, years 1968-1983. The stocking values below 0.4 million have been omitted for calculating the regression line (see text).

4. Discussion and conclusions

In spite of a number of shortcomings, summarized below, the pragmatic approach to fishery management in Swiss lakes outlined above has met with considerable success. It has saved salmonid fish from disappearing from a number of lakes undergoing eutrophication. It has even succeeded in increasing the population sizes of some desired species, and boosting yields in some very productive lakes *(Table 2)* which are no longer suitable for the natural reproduction of salmonids.

In the following paragraphs, existing constraints in lake fishery management are indicated and measures for alleviating them are proposed.

Perch management has to be treated separately because essentially, it consists of regulating the fishery. Most important of all, perch growth has generally increased due to eutrophication during the past few decades (Lang & Lang 1983). Modifications in perch management which have been introduced in recent years, and which consider changes in growth rate, were triggered by severe yield fluctuations arising, at least in part, from overfishing (Lang & Lang 1983). The management model announced by Staub, Büttiker & Krämer (1987) combines biological, technical and climatic aspects and seems to be a most promising approach to perch management. As with other species, biological data on perch need to be elaborated separately for each lake.

Management of whitefish and other species suffers from two major shortcomings. These are:

1. The biological characteristics of exploited fish stocks are being monitored in only a minority of the lakes. Thus, important changes in population structure, *e.g.* due to a changing environment, often go unnoticed, and a decrease in yield or even a collapse of the fishery may result (see section on Lake Thun). Many fisheries agencies are not equipped with enough personnel to conduct a permanent survey of the fisheries. In order to alleviate this problem, a number of biologists should be appointed (permanently or by contracts) by the cantons with important lake fisheries, or by groups of cantons sharing one or several lakes. These biologists would elaborate data on the fish populations and could co-operate in the management process.

2. The effect of stocking on fish stock abundance is a key factor in fisheries management. It ultimately decides on the justification and profitability of fish rearing and stocking programmes. Due to methodological problems, the validation of stocking efforts has hardly ever been tried, except for a gross comparison of stocking versus catch as in *Table 3* (Roth 1954). Direct estimates of the survival rate of larvae, fry and fingerlings in different types of waters are badly needed. The expected results would help to identify, for each species, the most suitable age group for planting at the proper time of the year. The trend is towards older juveniles like fingerlings, with a high survival rate, as our first results on whitefish in Lake Sarnen indicate. On the production side, both delayed planting of cold-hatched fry (Klein 1987) and rearing in illuminated net cages seem to be profitable. Further research in the field of stock enhancement is essential for improving management practices in the future.

To conclude, the need for conserving and enhancing rare and threatened fish species is emphasized. Ecological considerations, apart from economical ones, warrant any additional effort to save species which are bound to disappear or which have already become extinct in some lakes. Examples include salmonids like charr, lake trout and certain whitefishes, and non-salmonids like shad *(Alosa fallax lacustris)* or agone as it is called in Lago di Lugano and Lago Maggiore, and catfish or sheatfish *(Silurus glanis)*.

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References

BFS (Bundesamt für Statistik), 1987. Eidg. Betriebszählung 1985: Fischereibetriebe nach Kantonen. Bern. 41 pp.

Brylinski, E., Radziej, J. & Uryn, B., 1979. Rearing of whitefish *(Coregonus lavaretus* L.*)* larvae and fry in illuminated net cages. Rocz. Nauk. Roln. (Ser. H) 99: 55-77.

BUS (Bundesamt für Umweltschutz), 1988. Fangerträge der schweizerischen Berufs- und Sportfischerei 1967-1986 in 20 Schweizerseen. Bern (unpubl.).

Dahm, E., Brenner, T., Klein, M. & Müller, R., 1988. Experimental investigations on fishing gear selectivity: The Binational Roach Assessment Project (BIRAP) on gill-nets. Report to EIFAC/XV/88, typescript.

EAWAG, 1983. Fischereiliche Abklärungen am Hallwilersee vor Beginn der seeinternen Sanierung, im Auftrag des Kantons Aargau. Auftrag Nr. 4659. 56 pp.

Egloff, K., 1984. Erfahrungsbericht über die Felchenaufzucht in beleuchteten Netzgehegen im Hafen von Steckborn, Bodensee-Untersee. Bundesamt für Umweltschutz, Schriftenreihe Fischerei 43: 12-43.

Ehrenberg, J.E., 1984. Dual-beam target strength system. Acoustic systems for the assessment of fisheries. FAO Fish. Circ. 778: 71-80.

Geiger, W., Meng, H.J. & Müller, R., 1985. Methoden zur fischereibiologischen Erforschung von Seen. Mitteilungen d. EAWAG 19: 1-8.

Gulland, J.A., 1983. Fish stock assessment. Wiley, New York. 223 pp.

Jefferts, K.B., Bergman, P.K. & Fiscus, H., 1963. A coded wire identification system for macro-organisms. Nature 198: 460-462.

Kirchhofer, A. & Tschumi, P.A., 1986. Age structure and growth of coregonid fish populations in Lake Thun. Arch. Hydrobiol. Beih. 22: 303-318.

Klein, M., 1987. Die Bedeutung von Besatzmassnahmen zur Stabilisierung und Steigerung von Renkenerträgen im Starnberger See. Fischer & Teichwirt 38 (12).

Kanton Aargau. Besatz- und Fangstatistik 1968-1988 (unpubl.).

Kanton Bern. Fangstatistik und Jahresberichte 1976-1988 (unpubl.).

Kanton Luzern. Berichte der Geschäftsstelle der Fischereikommission Vierwaldstättersee über die Jahre 1971-1985 (unpubl.).

Kanton Obwalden. Besatz- und Fangstatistik 1967-1988 (unpubl.).

Lang, B. & Lang, C., 1983. Effets combinés de la pêche et de l'eutrophisation sur la perche *(Perca fluviatilis* L.*)* dans les eaux vaudoises du Léman. Schweiz. Z. Hydrol. 45: 480-404.

Meng, H.J. & Müller, R., 1988. Assessment of the functioning of a whitefish *(Coregonus* sp.*)* and charr *(Salvelinus alpinus salvelinus* L.*)* spawning ground modified by gravel extraction. J. Finnish Fish. Res. 9: 477-484.

Meng, H.J., Müller, R. & Geiger, W., 1986. Growth, mortality and yield of stocked coregonid fingerlings identified by microtags. Arch. Hydrobiol. Beih. 22: 319-325.

Muggli, J., 1983. Die aktuellen fischereilichen Verhältnisse des Sempachersees. Bundesamt für Umweltschutz, Schriftenreihe Fischerei 41: 21-45.

Müller, R. & Meng, H.J., 1986. Factors governing the growth rate of roach *Rutilus rutilus* (L.) in pre-alpine Lake Sarnen. Schweiz. Z. Hydrol. 48: 135-144.

Nümann, W., 1970. The 'Blaufelchen' of Lake Constance *(Coregonus wartmanni)* under negative and positive influence of man. In: Lindsey, C.C. & Woods C.S. (Eds). Biology of Coregonid fishes. University of Manitoba Press, Winnipeg. 560 pp.

Ponton, D. & Müller, R., 1988. Distribution and food of larval and juvenile *Coregonus* sp. in Lake Sarnen (Switzerland). J. Finnish Fish. Res. 9:117-125.

Roth, H., 1954. Massnahmen zur Hebung der Felchenbestände in den Seen des Kantons Bern. Schweiz. Fischerei-Z. 62: 94-97/125-127.

Roth, H. & Geiger, W., 1968. Aufzucht von Besatzfischen in Trögen. Veröff. Eidg. Amt für Gewässerschutz/Fischeriinsp. 25: 1-40.

Rufli, H., 1979. Ernährung und Wachstum der Felchenpopulationen (*Coregonus* spp.) des Thuner- und Bielersees. Schweiz. Z. Hydrol. 41: 64-93.

Ryder, R.A. & Kerr, S.R., 1988. Harmonic communities in aquatic ecosystems: A management approach. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries. Pudoc. Wageningen. pp. 594-623.

Stadelmann, P., 1980. Der Zustand des Sempachersees. Wasser, Energie, Luft 72: 311-318.

Staub, E., 1987. Netzfischerei und Fischzucht in der Schweiz. Schweiz. Fischereiwiss. 4: 7-8.

Staub, E., Büttiker, B. & Krämer, A., 1987. Grundlagen für Modellsimulationen zur Bewirtschaftung des Barsches *(Perca fluviatilis* L.) im Bodensee. Bundesamt für Umweltschutz, Schriftenreihe Fischerei 46: 1-40.

Steinmann, P., 1950/51. Monographie der schweizerischen Koregonen. Schweiz. Z. Hydrol. 12 (1/2), 13 (1).

Stöckli, A. & Schmid, M., 1987. Die Sanierung des Hallwilersees. Wasser, Energie, Luft 79: 143-149.

Straub, M., 1985. Felchenbewirtschaftung/Folgerungen aus der Wiederansiedlung der Felchen im Greifensee und Pfäffikersee. Schweiz. Fischereiwiss. 2: 7.

Svarvar, P.O. & Müller, R., 1982. Die Felchen des Alpnachersees. Schweiz. Z. Hydrol. 44: 295-314.

Zaugg, B. & Pedroli, J.-C., 1984. Jungfischaufzucht in natürlichen Gewässern mit Netzkäfigen: Versuche mit einer schwimmenden Fischzucht auf dem Neuenburgersee. Bundesamt für Umweltschutz, Schriftenreihe Fischerei 43: 53-87.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp 493-504.

Inland fisheries of Turkey

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Abstract

Turkey has a rich water resource potential for both marine and inland fisheries with 8333 km of coastlines, 175 000 km of rivers, 1 million ha of natural lakes, 170 000 ha of reservoirs, 70 000 ha of lagoons and 700 small reservoirs used for local needs such as irrigation and the supply of drinking water for animals.

There are 550 species of fish in national marine waters, and 130 species in the inland waters. Turkey's total fish production at present is about 700 000 tonnes/yr of which some 50 000 tonnes comes from inland waters, a mere 8% of the total. Carp comprise 40% of the annual inland catch, and thereafter in descending order of magnitude, bleak comprise 19% of it, crayfish 17%, black fish 3.4%, ide 3.3%, pikeperch 3% and northern pike 1.4%

Scientific studies on inland fisheries began in the 1940s. Limnology, population dynamics and rearing experiments of carp, trout, pike, pikeperch, crayfish, eel, bleak and shellfish have all since been studied. Aquaculture was first practiced in 1969 and there are presently about 250 fish farms operating. The introduction of valuable species of fish to suitable sites has been carried out since 1975. Altogether 150 natural lakes and small dams have been stocked with mirror carp, crayfish and pikeperch.

1. Introduction

Turkey extends over 776 726 km^2 and is situated between Europe and Asia, effectively extending into both continents. The south enjoys a typical Mediterranean climate, the north has a temperate climate, the west experiences a mixed temperate and Mediterranean climate, while central and eastern Anatolia have a continental climate. Thus, 4 different seasons can occur at the same time in Turkey. Accordingly, the vegetation in the different regions varies markedly. There are 7 geographical regions: Black Sea, Marmara, Aegean, Mediterranean, Central Anatolia, Eastern Anatolia and South-East Anatolia *(Figure 1)*. Turkey is a peninsula bounded by the Black Sea, the Aegean Sea and the Mediterranean Sea. It has a long and highly indented coastline, extending for some 8333 km, with numerous bays and mini-peninsulas. There are over 200 natural lakes with a total surface area of nearly 1 000 000 ha, 100 major reservoirs totalling 170 000 ha, 70 000 ha of lagoons, 700 small reservoirs and 175 000 km of rivers. These assets make Turkey one of the richest countries in the world in terms of water resource potential.

There are many different types of inland waters, because of the range of climates, each with different fish faunas. According to the latest research, there are 25 fish families present, comprising 63 genera and 130 species (Acara, Kocatas, Çelikkale, Ongan & Bingle 1982, Çelikkale 1982). Some important species of lakes and reservoirs are summarised in *Table 1*.

Table 1. Some fish species of Turkish inland waters. M = Mediterrannean Region, SEA = Southeast Anatolia

Region	Black Sea		Mamara							Aegean								M	Central Anatolia															Eastern Anatolia							SE A
Reservoir	Almus Dam	Ladik Lake	Abant Lake	Altunyazi Dam	Apolyont Lake	Gala Lake	Iznik Lake	Manyas Lake	Sapanca Lake	Buldan Dam	Demirköprü Dam	Gölcük Lake	Işikli Lake	Kemer Dam	Marmara Lake	Selevir Dam	Seyitler Dam	Amik Lake	Akköy Dam	Akşehir Lake	Apa Lake	Ayranci Dam	Bayindir Dam	Beyşehir Lake	Çavuşlu Lake	Çubuk I Dam	Çubuk II Dam	Eğridir Lake	Hirfanli Dam	Kesikköprü Dam	Kurtboğazi Dam	Porsuk Dam	Sarmisakli Dam	Balik Lake	Çip Dam	Çildir Lake	Hazer Lake	Mamasin Dam	Susuz Dam	Van Lake	Seyhan Dam
Area (km^2)	31.3	2.2	4.0	4.3	150	9.5	300	200	60	3.1	47.7	0.8	7.2	14.8	42.0	5.0	4.9	60.0	0.8	250	12.6	2.0	0.7	600	51.0	0.9	1.2	330	263	6.5	5.0	23.4	2.4	37.0	1.1	115	86	11.7		37.8	67.8
Anguillidae																																									
Anguilla anguilla					*	*			*					*	*			*																							*
Salmonidae																																									
Salmo trutta									*			*																						*							
Salmo trutta abanticus			*									*																													
Esocidae																																									
Esox lucius		*		*	*	*		*					*							*					*																
Cyprinidae																																									
Abramis brama						*		*	*																																*
Acanthorutilus anatolicus																					*			*																	
Alburnus sp.					*			*	*						*			*		*	*			*																	*
Aspius aspius						*			*																																
Barbus meridionalis																																									*
Barbus sp.											*				*														*	*			*				*	*			*
Blicca bjoerkna		*			*			*	*																																
Chalcalburnus chalcoides	*				*		*	*	*			*			*			*	*	*				*					*	*	*						*				*
Chondrostoma sp.											*			*						*			*						*	*											*
Cyprinus carpio					*	*	*	*	*		*	*	*		*	*		*		*	*	*		*	*	*	*	*	*	*		*	*	*		*		*			
Idus sp.																																				*					
Leuciscus cephalus	*				*			*	*	*	*			*		*	*	*		*	*			*	*	*	*		*	*	*	*	*	*	*	*	*	*	*		*

Region	Black Sea		Mamara							Aegean								M
Reservoir	Almus Dam	Ladik Lake	Abant Lake	Altınyazı Dam	Apolyont Lake	Gala Lake	Iznik Lake	Manyas Lake	Sapanca Lake	Buldan Dam	Demirköprü Dam	Gölcük Lake	Işıklı Lake	Kemer Dam	Marmara Lake	Selevir Dam	Seyitler Dam	Amik Lake
Area (km^2)	31.3	2.2	4.0	4.3	150	9.5	300	200	60	3.1	47.7	0.8	7.2	14.8	42.0	5.0	4.9	60.0
Pararhodeus kervillei																		
Rhodeus sp.					*			*										
Rutilus frisii							*											
Rutilus rubilio							*											
Rutilus sp.					*	*		*	*						*			
Scardinius erythrophthalmus					*			*										
Varicorhinus pestai																		
Varicorhinus sp.	*				*			*	*		*			*		*	*	
Vimba vimba					*		*	*	*									
Cobitidae																		
Nemachilus angorae								*	*									
Siluridae																		
Silurus glanis	*			*	*	*	*	*						*				
Clariidae																		
Clarias orontis																		*
Gasterosteidae																		
Gasterosteus aculeatus		*																
Percidae																		
Perca fluviatilis						*			*							*		
Stizostedion lucioperca											*	*			*			
Gobiidae																		
Gobio gobio																		
Gobius laoteus					*			*	*									

Region	Central Anatolia															Eastern Anatolia							SE A
Reservoir	Akköy Dam	Akşehir Lake	Apa Lake	Ayrancı Dam	Bayındır Dam	Beyşehir Lake	Çavuşlu Lake	Çubuk I Dam	Çubuk II Dam	Eğridir Lake	Hirfanlı Dam	Kesikköprü Dam	Kurtboğazı Dam	Porsuk Dam	Sarımsaklı Dam	Balık Lake	Çıp Dam	Çıldır Lake	Hazer Lake	Mamasın Dam	Susuz Dam	Van Lake	Seyhan Dam
Area (km^2)	0.8	250	12.6	2.0	0.7	600	51.0	0.9	1.2	330	263	6.5	5.0	23.4	2.4	37.0	1.1	115	86	11.7		37.8	47.8
Pararhodeus kervillei																				*			
Rhodeus sp.																							
Rutilus frisii																						*	
Rutilus rubilio																							
Rutilus sp.																							
Scardinius erythrophthalmus																							
Varicorhinus pestai										*													
Varicorhinus sp.			*	*		*		*	*		*	*	*		*		*	*	*	*			*
Vimba vimba										*													
Cobitidae																							
Nemachilus angorae		*																					
Siluridae																							
Silurus glanis					*						*	*		*									*
Clariidae																							
Clarias orontis																							
Gasterosteidae																							
Gasterosteus aculeatus																							
Percidae																							
Perca fluviatilis																							
Stizostedion lucioperca			*	*				*	*	*					*					*			
Gobiidae																							
Gobio gobio		*																					
Gobius laoteus																							

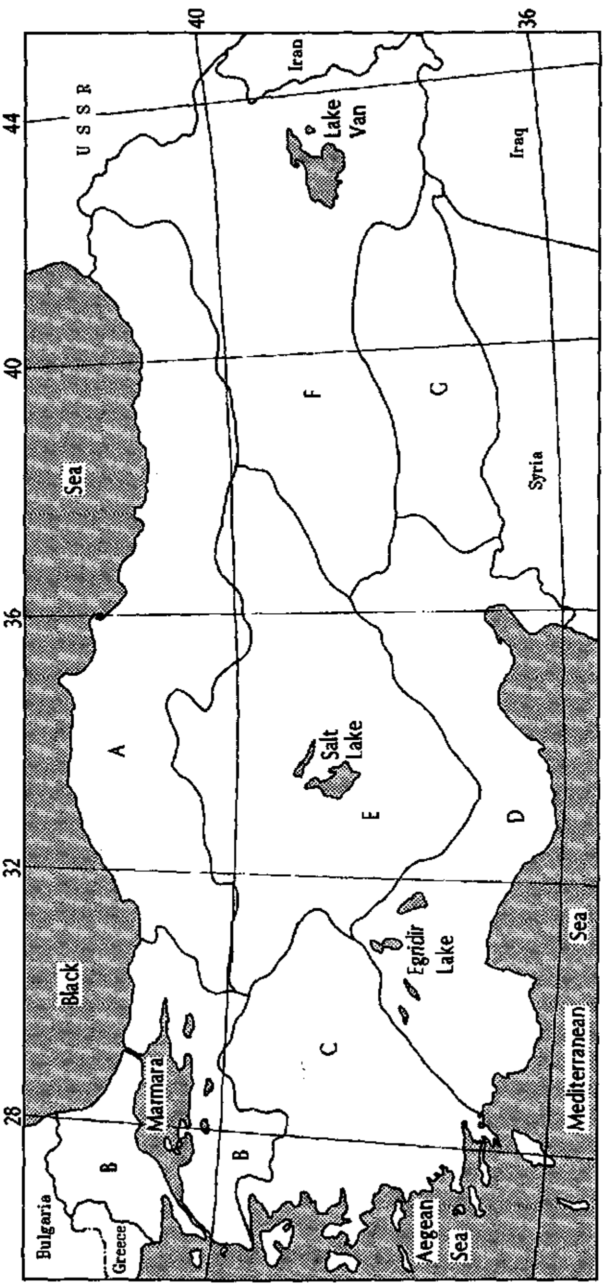

Figure 1. Geographical regions of Turkey. A = Black Sea. B = Marmara. C = Aegean. D = Mediterranean. E = Central Anatolia. F = Eastern Anatolia. G = Southeast Anatolia.

Fishery activities are connected to the Ministry of Agriculture, Forestry and Rural Affairs. Divisions of three general directorates of this Ministry deal with different aspects of fisheries. These are the Directorates of Project and Application, Preservation and Control, and Credit and Support. The directors of agriculture in the 67 provinces of Turkey deal with relevant matters in the provinces in the name of these general directorates. In addition, there are three fishery research institutes directly connected to the Ministry, one in Trabzon (eastern Black Sea region) one in Egridir (Central Anatolia) and one in Bodrum (Mediterranean region). These research institutes are involved in research activities related to both inland and marine fisheries. Fish transplantation and management of lakes and reservoirs are performed respectively by the Ministry of Agriculture, Forestry and Rural Affairs and the general Directorate of State Hydraulic Works of the Ministry of Energy and Natural Resources. Fishing in the lakes and reservoirs is done by fishing co-operatives in the neighbourhood of the waterbodies which buy the fishing rights for 3-5 years. This period can be extended to 15-20 years if, in addition to fishing, the co-operative has a project to increase the fish population.

2. Some studies on inland fisheries in Turkey

Scientific studies on freshwater fish species began 50-60 years ago. Today many investigations are being carried out by both foreign and native scientists. Many new fish species and sub-species have been determined by foreign scientists such as Kosswig, Tortonese, Hanko, Ladiges, Pietschmann and Nordmann. The characteristics of various inland waters and their limnology, and the biology and taxonomy of fish species in many reservoirs have been studied by Turkish researchers.

High altitude lakes are cold and harbour cold water species, those of the coastal regions and plains have temperate or warm water species, and in some waterbodies representatives of different types occur together. The exotic species such as rainbow trout, tilapia, grass carp and mirror carp were introduced a long time ago and they are now transplanted and cultured locally. Total freshwater fish production is presently about 50 000 tonnes/yr. Common carp *(Cyprinus carpio)*, crayfish *(Astacus leptodactylus)* and a native bleak *(Chalcalburnus tarichi = Alburnus tarichi)* provide 75% of the total annual catch *(Table 2)*.

2.1 Common Carp

There are 98 fish species belonging to Cyprinidae in the inland waters of Turkey. Economically the most important of these is the common carp. Common carp is indigenous to Turkey was probably introduced to Europe from Turkey (Meske 1973, Atay & Çelikkale 1983). The mirror carp has been bred from the common carp through prolonged selection. Common carp are found everywhere in Turkey, except in the eastern and south-eastern regions (Ladiges 1960, Kuru 1971, Atay & Çelikkale 1983, Çelikkale 1988). Mirror carp were imported from Europe some 20 years ago and have been cultured in farms. The fry is cultured by state fish farms and used to stock lakes and reservoirs in which mirror carp grows and reproduces well. The studies made on common carp in various inland waters relate to its morphology, reproductive parameters and population dynamics (Çelikkale 1982, Erdem 1983, Sarihan, Tekelioglu & Ercan 1983).

There are some regional differences in form and growth, *e.g.* carp in the lakes of the Aegean and Mediterranean regions show better growth rates and higher condition factors than in lakes of other regions, because of the warmer climate and longer growing season (Hossucu 1970).

Table 2. Inland Fish Production of Turkey (Anonymous, 1984).

Fish species	Production (1000 tonnes)	%
Carp (*Cyprinus carpio*)	18.7	40.0
Bleak (*Chalcalburnus tarichi*)	9.3	19.0
Crayfish (*Astacus leptodactylus*)	7.9	17.0
Catfish (*Clarias gariepinus*)	1.7	3.4
Ide (*Leuciscus cephalus*)	1.6	3.3
Pikeperch (*Stizostedion lucioperca*)	1.5	3.0
Trout (*Salmo trutta* spp.)	1.2	2.4
Northern pike (*Esox lucius*)	0.7	1.4
European eel (*Anguilla anguilla*)	0.6	1.0
Others	3.3	9.5
Total	46.5	

2.2 Bleak *(Chalcalburnus tarichi)*

This species lives mainly in Lake Van and the rivers of the same basin (Kuru 1971). Most of Lake Van (a soda lake) is devoid of fish because of its highly mineralised water. However, this fish lives in parts of the lake near river mouths where fresh water predominates. It migrates downstream to river mouths about mid-April and starts spawning about mid-May. It spawns when the water temperature reaches 17°C and fecundity is about 3750 eggs/individual. The main fishing season commences after April when the fish migrate for spawning. Fishing vessels from the Black Sea are transported by tracks to Lake Van for the commercial fishing season. The catch from Lake Van is consumed fresh or preserved in brine.

2.3 Crayfish

The main studies carried out on crayfish have been on their taxonomy, reproduction and growth. Two subspecies have been determined in Turkey. One of them, *Astacus leptodactylus leptodactylus*, occurs in the Black Sea, Thrace and north of Marmara, while the other, *Astacus leptodactylus salinis*, is found in the south of Marmara, and the Aegean and Middle Anatolian regions (Geldiay & Kocatas 1970). These indigenous species have been transplanted to the other Anatolian lakes and reservoirs. The main crayfish resources of Turkey are now in Lakes Egridir, Apolyont, Manyas, Iznik, Eber, Aksehir, Mogan and Terkos, the reservoirs of Hirfanli and Keban, and the Miliç River (Köksal 1980).

Observations on these reservoirs have shown that the reproductive season varies from place to place. However, hatching has generally started by the beginning of December and incubation is usually complete by the end of June. Males grow faster than females (Erençin & Köksal 1980, Çelikkale 1988).

The mean size of crayfish measured in 8 lakes was 97-115 mm and mean body weight was 21-48 g (Köksal 1980). The mortality rates of cultured crayfish larvae is 52.8% using natural incubation and 56.8% using artificial incubation (Köksal 1985). It has been determined that *A. leptodactylus salinis* adapts well to culture conditions and has high reproductive and survival rates in hatcheries.

Lake Egridir has the largest crayfish population in Turkey and provided 51% of the total crayfish exports in 1980. Generally about 40% of the net income from all fish exports comes from crayfish. The first eggs of crayfish are to be seen in Lake Egridir at the end of December, incubation is completed in this lake in May. Here the maturation of females begins at a weight of about 8 g (Anonymous 1980). The fisheries production from Lake Egridir, for 1976-1981, is given in *Table 3.*

In recent years research has been carried out on crayfish disease because of the high mortality rates observed in some lakes. It is called 'spot disease' or 'crayfish plague'. Mortality rates vary between 8.0-15.7% and 24.3-100.0% per month at selected stations in Mogan Lake.

Table 3. Catches (tonnes) from Lake Egridir in the period 1976-1981.

Species	1976	1977	1978	1979	1980	1981
Crayfish	1 712	2 852	2 116	1 781	2 174	1 573
Pikeperch	315	204	380	482	450	310
Common carp	100	90	120	117	120	128
Vimba spp.	12	20	15	23	15	10
Total	2 139	3 166	2 631	3 403	2 759	2 021

2.4 Pikeperch

There are three representatives of Percidae in the inland waters of Turkey, perch *(Perca fluviatilis)*, pikeperch *(Stizostedion lucioperca)* and ruffe *(Gymnocephalus cernua)*. The most important of these is pikeperch. Perch is probably prey for large carnivorous species in some lakes. Ruffe is found in small numbers in north eastern Thrace. Pikeperch is indigenous to the middle and western Black Sea and Marmara regions. It has been transplanted to some lakes, *e.g.* Lakes Egridir, Marmara and Beysehir, and to the reservoirs at Hirfanli and Seyhan.

The species was introduced to Lake Egridir in 1955 using 10 000 fry. Although there were 10 fish species present in the lake then, only 3 survived until 1970, *Cyprinus carpio, Vimba vimba* and *Vimba cioboldi*. The others were completely wiped out by pikeperch (Sarihan 1970). Pikeperch planted in the Seyhan Reservoir have shown better growth than in Lakes Egridir and Marmara (Sarihan & Toral 1974). In Turkey, pikeperch females generally mature between 1-3 years of age, but in Seyhan Lake they regularly reach maturity by the end of their 1st year. Similar rapid growth was observed in transplanted pikeperch in Lake Beysehir in 1978. Age-length data for pikeperch in some lakes are given in *Table 4*.

Table 4. Growth in length (cm) of pikeperch in some lakes of Turkey, Europe and USSR.

Locality	1 yr	2 yr	3 yr	4 yr	References
Egridir Lake	29.0	37.6	42.1	45.2	Sarihan 1974
Egridir Lake	27.3	32.0	39.9	47.0	Selekoglu 1982
Hirfanli Dam	25.7	41.0	48.8	54.4	Karabatak 1977
Seyhan Dam	38.0	51.5	-	-	Sarihan & Toral 1974
Seyhan Dam	27.4	34.4	47.2	60.5	Gök 1980
Beysehir Lake	31.0	43.0	-	-	Sarihan & Toral 1974
Marmara Lake	23.0	32.0	-	-	Sarihan & Toral 1974
Bafra Lake	17.4	23.4	26.7	29.8	Aral & Büyükhatipoglu 1987
European average	17.0	31.0	43.0	52.0	Schindler 1975
USSR average	16.0	30.0	37.4	42.3	Slastenenko 1955-1956

We have to be careful with pikeperch transplantations. The growth rate is initially high and they adapt very well to their new environment, but when the prey fish have been very largely consumed, their growth rate decreases and cannibalism sets in. The number of fisherman on Lake Egridir has decreased since 1970 and this is attributed to the decrease of the pikeperch yields. A similar phenomenon was observed on Hirfanli and Seyhan Reservoirs.

2.5 Trout

There is only one indigenous species of trout in Turkey, *Salmo trutta*, but there are 5 sub species: *S. t. macrostigma*, *S. t. caspius*, *S. t. labrax*, *S. t. abanticus* and *S. t. fario*. *S. t. macrostigma* is found in the Marmara, Aegean and Mediterranean regions (Balik 1980); *S. t. caspius* in the eastern Anatolian region (Aras 1974) and *S. t. labrax* in the eastern Anatolian and the Black Sea region. *S. t. abanticus* is found only in Lake Abant (Aksiray 1959) and is reputed to be an isolated form of *S. t. fario* (Tortonese 1954, Geldiay 1973, Çelikkale 1982, Çelikkale 1988). This latter sub-species, brook trout *(S. t. fario)*, is found in the Gürün River in Sivas (Baran 1971).

Rainbow trout *(Salmo gairdneri)* is the second species which has been introduced to suitable lakes and rivers in Turkey. Fry of this fish is cultured in state farms and used for introductions, but rainbow trout does not reproduce in Turkish inland waters so the use of native trout sub-species is preferred for transplantation.

Trout have been cultured in Turkey for 20 years. There are more than 200 private and state owned trout farms in Turkey which produce eggs and fry. Earth ponds and raceways are mostly used for the production of older trout. Cage culture is not common, although there are many suitable sites for this type of culture and very good results have been obtained in trials (Çelikkale, Atay & Büyükhatipoglu 1981, Çelikkale 1982).

2.6 Northern pike

Northern pike *(Esox lucius)* is especially good for angling. It occurs naturally in inland waters of the Black Sea, Marmara, Central Anatolia, Aegean and Mediterranean regions, but is most widely distributed in the first two regions (Tanyolaç & Karabatak 1974, Balik 1980, Kuru 1980). The populations are under pressure due to excessive angling pressure. The numbers of pike first decreased in lakes close to the big cities. Then, after legal restrictions were enacted, enrichment projects were carried out with pike in some highly affected lakes.

The length and weight of pike in Lake Mogan (Ankara) is given in *Table 5*. Pike in Lake Aksehir reach sexual maturity at age 2-3 years and reproduction takes place in February and March. Absolute fecundity is 2800-120 200 eggs/female. Maximum growth has been observed in April-June, with minimum growth in summer, in July-August (Karabatak 1982). *Alburnus orontis* and common carp are important food for pike in this lake.

Table 5. Growth in length and weight of Northern Pike in Lake Mogan (Tanyolac & Karabatak 1974).

Age (years)	Length (cm)	Weight (g)
2	36.7	378
3	47.7	764
4	57.3	1 398
5	73.1	2 692
6	92.0	5 755
7	102.0	7957
8	110.0	7960

2.7 Catfish

Catfish *(Clarias gariepinus* - includes *C. lazera)* is a warm water fish found in the southern and south-eastern Mediterranean regions of Turkey. Numerous studies were conducted on this species since it is an export fish (Sarihan & Tekelioglu 1982). The reproductive period is May-June in natural environments. Carp hypophysis and the synthetic hormone 'ostrovet' are used to induce spawning in catfish. Carp hypophysis however, is the more effective. Eggs are hatched in 22-30 hours at a water temperature of 26°C. The hatching rate is 40%. The best food for the fry after the absorption of yolk sacs is a mixture of live and dry food. When feeding with this mixture for three weeks the fry reaches a length of 2 cm and a weight of 0.08 g. The optimal temperature range in the rearing stage is 21.3-29°C, when after 1 year, the fry reach lengths of 20 cm and weights of about 60 g. Growth stops when the water temperature drops below 10°C. It is expected that catfish will play an important role in polyculture in future. Current annual production is 1700-1800 tonnes and the species commands a very high price.

2.8 Other freshwater species

Species of the genus *Leuciscus* are widely distributed all over Turkey. They are *L. cephalus, L. berak, L. borysthenicus, L. cephaloides* and *L. lepidus* (Kuru 1980). The most common of these is *L. cephalus. L. berak* is found in the Aegean and Mediterranean regions; *L. borysthenicus* in the Black Sea, Marmara and Aegean regions; *L. cephaloides* in the Marmara region and *L. lepidus* in the Mediterranean region, and in eastern and south-eastern Anatolia. Consumption and marketing of these species differs from region to region. Together they comprise 3.3% of the total inland fisheries yield, but prices are low because they are full of bones.

Eel is an important species in the lower courses of the rivers of southern and western Turkey, and in the lakes and reservoirs which they reach via the river systems. There are also large eel populations in coastal lagoons in these regions, and the annual eel catch is about 600-700 tonnes. All this is exported to Europe.

Sheatfish or wels *(Silurus glanis)* is another valuable species in Turkey and is found in some lakes and big rivers. Yields have decreased because of overfishing, and stock enhancement using artificially produced fry is planned for the future (Aydin 1980).

Tench *(Tinca tinca)* is another cyprinid living in the Black Sea and the European region of Turkey. It was transplanted to some eutrophic lakes in central Anatolia and has been a dominant species in these lakes, but it has no market value and is used mostly as bait for crayfish baskets. Tench grow to 37 cm with weights up to 910 g. Relative fecundity is 200 eggs/g wt (Göktas 1987).

Varicorhinus capoeta (= *Capoeta capoeta* - Cyprinidae) is consumed regionally. However, because of its extremely boney nature it has no market volume (Özdemir 1982). It is planned to transplant some valuable omnivorous and carnivorous fish species to the lakes where *Capoeta capoeta* lives, in the hope that they may supplant it. Limnological and biological studies are currently being carried out in such lakes.

References

Acara, A., Kocatas, A., Çelikkale, M.S., Ongan, T. & Bingel, F., 1982. Türkiye Su Ürünleri Arastirma ve Gelistirme Faaliyetlerinin Bugünkü Durumu ve Gelecegi Hakkinda Rapor. TÜBITAK, VHAG Komitesi Yürütme Sekreterligi. pp. 1-51.

Aksiray, F., 1959. Abant Gölünde Suni Ilkah Yolu Ile Ilk Alabalik Üretilmesi Hakkinda. Hidrobiyolji Mecmuasi. Seri A. Cilt-V. pp. 1-4.

Anonymous, 1972. DSI Balikçilik Faaliyetleri. Devlet Su Isleri Genel Müd. Yay. No. 733 p. 45.

Anonymous, 1980. Egridir Gölündeki Kerevitlerin Üremerli ve Kerevit Populasyonu Üzerinde Çalismalar. Su Ürünleri Genel Müdürlügü Isparta Su Ürünleri Bölge Müdürlügü Yayinlari, Yay. No. 2.

Aral, O. & Büyükhatipoglu, S., 1987. Bafra Balik Göllerindeki Sudaklarin *(Stizostedion lucioperca* L.*)* Bazi Özellikleri Üzerine Bir Arastirma. Istanbul Üniv. Su Ürünleri Dergisi 1: 157-168.

Aras, S., 1974. Çoruh ve aras Alabaliklari Üzerinde Biyoekolojik Arastirmalar. Atatürk Üniv. Ziraat Fak. Dergisi, 7., Sayi. 1: 17.

Atay, D. & Çelikkale, M.S., 1983. Sazan Üretim Teknigi. San Matbaasi p. 185.

Aydin, F., 1980. Yayin Baliginda *(Silurus glanis* L. 1758) Yari Kontrollü Üretim Olanaklarinin Incelenmesi. Ankara Üniv. Vet. Fak. Doktora Tezi. Basilmamis p. 63.

Balik, S., 1980. Güney Anadolu Bögesi Içsularinda Yasayan Tatlisu Baliklarinin Sistematik ve Zoocografik Yönden Arastirilmasi. Doç. Tezi, Basilmamis. Ege Üniv. Fen Fakültesi, Izmir.

Baran, I., 1971. Gürün-Gökpinar Alasi *(Salmo trutta f. fario* L.*)* Üzerinde Arastirmalar. Ankara Üniv. Vet. Fak. Dergisi, Cilt-XVIII, No. 1.

Çelikkale, M.S., Atay, D. & Büyükhatipoglu, S., 1981. Besgöz Gölünde Ag Kafeslerde Alabalik Yetistiriciliginde Farkli Stok Oranlarinin Gelisme ve Yem Degerlendirme Üzerine Etkisi. Doga Bilim Dergisi, Vet. Hay./Tar. Orm. 5: 147-157.

Çelikkale, M.S., 1982. Kafeslerde Alabalik Yetistiriciliginde Degisik Stok ve Yemeleme Tekniklerinin Karsilastirilmasi. A. Ü. Ziraat Fak. Yay. 820, Bilimsel Arstirma ve Incelmeler No. 484, 64 pp.

Çelikkale, M.S., 1982. Alabalik (*Salmo gairdneri* R.) Üretim Teknigi. Ankara Üniv. Ziraat Fak. Yay. 806, p. 34.

Çelikkale, M.S., 1982. Içsu Ürünleri Avciligi ve Yeristiriciligi. T.C.Ziraat Bankasi Su Ürünleri Kedileri Müdürlügü Yay. 4: 212-225.

Çelikkale, M.S., 1982. Sazan Baligi (*Cyprinus carpio*) Üretim Teknigi. Ankara Üniv. Ziraat Fak. Yay. 805, p. 30.

Çelikkale, M.S., 1988. Içsu Baliklari ve Üretim Teknigi. Cilt-I ve Cilt-II. K.T.Ü. Yayinlari p. 975.

Erdem, Ü., 1983. Egridir, Beysehir ve Çavuscu Göllerindeki Sazan *(Cyprinus carpio)* Populazyonlari Üzerine Karsilastirmali Bir Arastirma. Doga Bilim Dergisi, VHAG, Cilt-7: 167-176.

Erençin, Z. & Köksal, G., 1977. Studies on the Freshwater Crayfish *(Astacus leptodactylus* Esch. 1823) in Anatolia. Ankara Üniv. Vet. Fak. Dergisi Cilt-XXIV, 2: 262-268.

Geldiay, R. & Kocatas, A., 1970. Türkiye'de *Astacus* (Decapoda) Populasyonlarinin Dagilisi ve Taksonomik Tesbiti. Ege Üniv. Fen Fak. Ilmi Raporlar Serisi. No. 94.

Geldiay, R., 1972. Trout *(Salmo trutta)* Populations inhabiting the Streams of Kazdagi Range. Verh. Internat. Verein, Limnol 18: 12-21.

Gök, M., 1980. Seyhan Baraj Gölünde Sudak *(Lucioperca lucioperca* L.*)* 'nin Gelismesi ve Av Kompozisyonu Üzerine Bir Arastirma. C. Ü. Ziraat Fak. (Basilmamis), Adana.

Göktas, M., 1987. Mogan Gölündeki Kadife Baliginin *(Tinca tinca* L.) Boy Agirlik Iliskisindeki Mevsimsel Degisiklikler. Yük. Lisans Tezi. Ankara Üniv. Fen Bilimerli Enst. p. 34.

Hossucu, H., 1970 Göl Marmara Sazani *(Cyprinus carpio* L. var. Royal) Ege Bölgesi Kültür Kosullarinda Verim Özellikleri Üzerinde Arastirmalar. Ege Üniv. Zirkaat Fak. Yay. Izmir.

Karabatak, M., 1982. Aksehir Gölündeki Turna *(Esox lucius* L.) 'nin Büyüme, Üreme ve Beslenmesi. TÜBITAK-VHAG, Proje No. 392, p. 71.

Köksal, G., 1980. Biometric analysis on the feshwater crayfish *(Astacus leptodactylus* Esch. 1823) which is produced in Turkey-Relationship between the major components and meat yield. A. Ü. Vet. Fak. Derg., 26: 93-114.

Köksal, G., 1985. Kültür Kosullarinda Tatlisu Istakozu, *Astacus leptodactylus salinis* (Nordman, 1842) 'in Üreme Randimani Üzerinde Incelemeler. Su Ürünleri Dergisi, Cilt.2, Sayi: 5, pp. 42-56.

Kuru, M., 1971. The fresh water fish fauna of eastern Anatolia. Istanbul Üniv. Fen Fak. Mec. Seri B. 36: 137-147.

Kuru, M., 1980. Türkiye Tatlisu Baliklari Katologu. Hacettepe Üniv. Fen Fak. Zooloji Böl. Ankara. Büro Zelal Matbaasi p. 73.

Ladiges, W., 1960. Süsswasserfische der Türkei, 1. Teil: *Cyprinidae*. Mitt. Hamburg Zool. Mus. Inst. 58: 105-150.

Meske, Ch., 1973. Aquakultur von Warmwasser-Nutzfischen. Verlag Ulmer Stuttgart. p. 160.

Munsuz, N., 1983. Türkiye Sulari. Ankara Üniv. Ziraat Fakültesi Yayinlari, 882, p. 392.

Özdemir, N., 1982. Elazig-Hazar Gölünde Bulunan Capoeta capoeta umbla'nin Ekonomik Degeri ve Yetistirme Olanaklarina Iliskin Biyolojik Özellikleri. Doga Bilim Dergisi, VHAG/Tar. Orm. Cilt-6.

Sarihan, E., 1970. Egridir Gölüne Sudak Baligi *(Lucioperca lucioperca)* Ilave Olduktan Sonra Meydana Gelen Biyolojik ve Ekonomik Degisiklikler. Istanbul Üniv. Fen Fak. Hidrobiyoloji Ars. Enst. Yay., Seri B, Tome VI, Fasc. 3-4, pp. 33-40.

Sarihan, E., & Toral, Ö., 1974. Seyhan Baraj Gölüne Sudak *(Luciperca lucioperca* L. 1758) Yerlestirildikten Sonra Elde Edilen Ilk Sonuçlar. TÜBITAK, IV. Bilim Kongresi Tebligleri, Ankara.

Sarihan, E. & Tekelioglu, N., 1982. Karabalik *(Clarias lazera)* 'in Bazi Vücut Özellikleri ve Çukurova Bölgesinde Yetistirilme Olanaklari. Doga Bilim Dergisi, Vet.Hay./Tar.Orm. Cilt-6.

Sarihan, E., Tekelioglu, N. & Ercan, I., 1983. Aksehir Gölü Sazanlari *(Cyprinus carpio)* Üzerine Bir Arastirma. Çukurova Üniv. Ziraat Fak. Yilligi. 1: 3-11.

Schindler, O., 1975. Unsere Süsswasserfische. Kosmos, Stuttgart. 312 pp.

Slastenenko, E., 1955-1956. The Fishes of the Black Sea Basin (Çeviri: Hanif A. Karadeniz Baliklari). Et ve Balik Kurumu Yay. Istanbul. 711 pp.

Tanyolaç, J. & Karabatak, M., 1974. Mogan Gölünün Biyolojik ve Hidrolojik Özelliklerinin Tesbiti. TÜBITAK-VHAG. Proje-91. Ankara. 49 pp.

Tortonese, E., 1954. The Trouts of Asiatic Turkey. Publ. Hidrobiolog Res. Inst. Univ. Istanbul, Ser. B., Tome-II, pp. 1-25.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 505-510.

Inland Fisheries of the USSR, today and in prospect

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Abstract

Soviet inland fisheries have developed in spite of dramatic hydrological and hydrochemical changes in many major water bodies in recent years. The annual catch from all inland waters now exceeds a million tonnes. To some extent, stock depletion caused by the loss of natural spawning grounds has been compensated for by the construction of hatcheries and the practice of stocking water bodies. In addition the construction of fish-passes on the largest regulated rivers has 'reclaimed' old spawning grounds once considered lost. Some natural lakes have been converted to fish farms, and reservoir fisheries have become important. The utilisation of warm waters from power stations has permitted fish culture in regions too cold for fish farming in natural lakes. Thus fresh fish are now available where once they used not to be. Exotic species have been introduced from the Far East and North America to boost yields by polyculture in reservoirs, and new hybrid strains of carp have been bred. Marketable fish are now produced in culture ponds and very high yields are obtained. A 'fish-feed' industry has grown up to supply feedstuffs to intensive fish farms. A major research programme will be in place by 1990 to support the future development of Soviet inland freshwater fisheries.

1. Introduction

The Soviet Union has extensive inland water resources and ranks high among the nations of the world as to its total area of lakes, rivers and reservoirs. Soviet territory includes some 25 million ha of lakes, 7.5 million ha of reservoirs and 1 million ha of ponds and multi-purpose pools.

Soviet inland fisheries are a well developed part of the national economy. They comprise a fishing fleet, processing facilities, pond, commercial lake and reservoir fish farms, and hatcheries and research institutes. Several organizations are involved in the operation of inland fisheries. These include the Ministry of Fisheries, the Ministry of Energy, several collective and state farms of Gosagroprom (the Soviet Agriculture Ministry), Tsentrosoyuz (the central co-operatives' union) and various other ministries and departments.

In 1987 fisheries run by the Ministry of Fisheries caught 1.165 million tonnes of fish from inland waters, comprising 590 000 tonnes from fresh waters and 575 000 tonnes from inland seas. In addition, annual catches by agricultural enterprises amount to about 125 000 tonnes (half from lakes and rivers/half from ponds), while those of anglers are in the region of 200 000 tonnes. A traditional consumer predilection for freshwater fish of high quality, delivered essentially alive but chilled, has given rise to a special attitude towards advances in both inland fish farming and capture fishing.

2. Environmental changes and fisheries

Inland fisheries have had to face up to radical hydrological and hydrochemical changes in inland waters in recent years. Regulation of rivers, increases in water abstraction, water pollution, riverside timber felling and timber floating, among other things, have influenced fisheries. They have occasioned a decline in the quality of the waters, and reductions in the areas available both for spawning and food production. These in turn have resulted in lowered rates of reproduction, and in reduced stocks and catches of premium fish. For example, reduced riverine influxes to the Aral, Azov and Caspian Seas have had a dramatic adverse effect upon natural reproduction in these water bodies and on yields from them. Because of this situation, while abiding by legislation for the protection of the environment, operations intended to preserve the reproduction of natural populations, and others to develop commercial fish culture, have been accorded top priority.

As opportunities for the natural reproduction of prime species deteriorate, so these species are raised on a large scale on commercial fish farms. However, in addition, substantial reclamation work is carried out whereby young commercial fish are saved from isolation and death in temporarily flooded pools every year. Further, and more importantly, to promote natural reproduction of coregonids, salmonids and sturgeon, thirteen fish passes are now in operation on major watercourses which have been impounded for hydroelectric power. These include the Volga, Don, Kuban' and Tuloma Rivers. Building the fish passes has led to the reclamation of over 240 000 ha of spawning grounds, mainly in the Don, Dnieper and Volga Basins. Further, in the Volga Delta, 16 fish passes have been built and 'dike to water' specially prepared spawning grounds have come into operation.

Currently, in the principal fishery areas, 160 fish farms and 13 acclimatizing stations operate for the breeding of sturgeon, salmonids, coregonids, bream *(Abramis brama)*, pikeperch *(Stizostedion lucioperca)* and common carp *(Cyprinus carpio)*. These release more than 210 billion specimens annually. Despite adverse anthropogenic effects, current programmes maintain the populations of the most important commercial species. These programmes include those for artificial fish breeding, reclaiming waters and breeding grounds, and improving fisheries regulation. Annual catches of fish farmed in natural pools and reservoirs are now of the order of 280 000 tonnes *(Table 1)*.

3. Fish culture

In addition to its role in producing material for stocking lakes and reservoirs, fish culture is used to grow fish directly for the market. This aspect of fish culture is expanding, and the fish farms concerned concentrate on raising common carp, grass carp *(Ctenopharyngodon idella)*, silver carp *(Hypophthalmichthys molitrix)*, buffalo *(Ictiobus* spp.*)*, trout *(Salmo trutta, S. gairdneri)* and channel catfish *(Ictalurus punctatus)*. In 1970, fish raised for the market in Ministry of Fisheries farms, amounted to 63 000 tonnes, or 25.7% of total freshwater catches. By 1987 the proportion had grown to 50.8% and farm raised fish amounted to 299 000 tonnes.

Pond fish culture has become increasingly important over the past 30 years and now produces 84% of all farm-raised marketable fish. Some 14 000 tonnes were produced by

Table 1. Freshwater fish catch and production in inland waters of the USSR – rivers, lakes, reservoirs and estuaries (x1000 tonnes).

	Yield from natural populations in rivers, lakes, reservoirs, estuaries			Yield from fish culture			Total yield		
	1970	1987	2000*	1970	1987	2000*	1970	1987	2000*
Salmonids	5.8	6.0	6.6	-	0.1	5.0	5.8	6.1	11.6
Coregonids	26.2	21.9	23.9	-	0.5	10.0	26.2	22.4	23.9
Eel	0.5	0.4	0.5	-	-	-	0.5	0.5	0.5
Sturgeons	11.4	15.2	19.9	-	-	-	11.4	15.0	19.9
Wild carp	12.6	7.9	10.3	-	0.5	5.0	12.6	8.4	15.3
Bream	43.6	52.9	54.4	-	1.0	2.0	43.6	53.9	56.4
Pikeperch	17.1	16.3	15.8	-	1.0	2.0	17.1	17.3	17.8
Pike	12.4	11.8	12.1	-	0.3	0.5	12.4	12.1	12.6
Smelt	11.6	12.0	12.0	-	-	-	11.6	12.0	12.0
Carp	-	1.2	1.0	40.7	195.5	355.0	40.7	196.7	356.0
Bighead	-	-	4.0	22.0	80.0	150.0	22.0	80.0	154.0
Other large fishes	53.7	48.9	50.2	-	11.2	45.5	53.7	60.1	95.7
Other small fishes	79.3	95.5	96.9	-	10.0	10.0	79.3	105.5	106.9
Total	274.2	290.0	307.6	62.7	300.0	585.0	336.9	578.9	892.6

* estimated figures

this method in 1960. This figure then grew to 62 700 tonnes in 1970, 153 000 tonnes in 1980 and 250 000 tons in 1987 *(Figure 1)*. Growth of commercial fish farming has occurred not only because of the construction of new farms, but largely because of an increased output from fattening ponds. Thus, between 1950 and 1985, total pond area increased by 520% but fish yield per hectare rose by 880%.

Unlike old-fashioned extensive pond fish culture, with outputs of 50-100 kg/ha, modern pond culture uses intensive breeding techniques with dense fry-seeding, and diverse methods to raise the natural forage resources of the ponds. Special mixed pelleted feedstuffs are applied, polyculture is practised (whereby *e.g.*, common carp are bred together with herbivorous species), industrial methods are used for fry production, and the basic fish rearing operations are mechanised. Intensive fish farming, which now utilises about 180 000 ha of fattening ponds, has been accompanied by a consistent growth in yield per hectare. In 1987 it averaged 700 kg/ha throughout the country, while many technologically advanced farms obtain sustained yields of 1250-1500 kg/ha. However, recent research has led to the development of techniques which can take yields to 3000-3500 kg/ha with lower production costs. These are now being introduced.

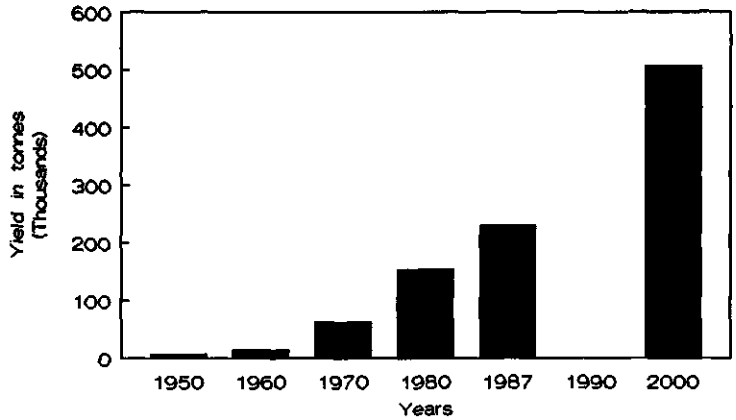

Figure 1. Annual yield from pond fish culture in the USSR.

Research organizations have improved breeding and selection. Promising domestic strains and breeds of common carp have been introduced on a large scale; these include the scaly carp, ramchaty carp, ropshinsky hybrid carp, Middle Russian carp, parsky carp and sarboyansky carp. Highly productive breeds have been imported from Bulgaria, the German Democratic Republic, Hungary, Romania and Viet Nam. High-yield carp are being bred throughout commercial pisciculture, and new 'selection and breeding' farms and 'reproducers' have been completed.

A shortcoming of fish farming in recent years has been the limited range of species available for rearing. Carp accounted for up to 95% of all produce marketed, but Soviet research has been remarkably successful in developing the biotechnology for breeding young herbivorous species, *e.g.* grass carp, silver carp and bighead carp *(Aristichthys nobilis)*. This has made it possible to introduce polyculture which substantially increases pond output, efficiency and profitability.

In addition to traditional pond pisciculture, which currently produces about 90% of all farm-raised marketable fish, new areas have been developing since 1970. These are fish farming in warm water reservoirs and fish farming in hatcheries with closed cycle water supplies.

During the XIth five-year period, fish production from warm water hatcheries and reservoirs increased 400% reaching 24 000 tonnes in 1987. The introduction of warm water culture fisheries, using *e.g.* the cooling waters from power stations, makes a more comprehensive use of water resources possible. Thus live fish can be produced in the north of the country where the climate precludes the profitable farming of traditional ponds. Warm waters from power plants are used to breed large fry (40-50 g) which are subsequently transferred to suitable enclosures where they are grown to marketable size. Production of large-sized fry is increasing every year and over 50 million specimens were produced in 1987.

Fish-breeding operations in facilities with closed-cycle water supplies have also been introduced to the USSR. These have mostly been developed for the production of carp and trout fry in hatcheries with outputs of about 10 tonnes/yr. However, a hatchery with an annual output of 240 tonnes of marketable carp has been commissioned, and another with a capacity of 50 tonnes of carp fry per year is near completion.

Since the practice of fish feeding is crucial to the performance of modern intensive fish farms, an industry specialising in the supply and development of feedstuffs has been set up in the USSR. Four combined feed plants, operating under the Ministry of Fisheries, produce special compound feeds for fry (starter and rearing feeds) for warm water and industrial fish farms.

4. Lake fish farms

Another development in inland fisheries in the USSR since 1970, is the commercial fish farming of specially prepared natural lakes. Lake farms are generally based on small and medium-sized lakes which display ecological conditions suitable for normal fish life, and physiographic conditions conducive to easy fishing. In the north, coregonids are cultured in these lakes, while carp are preferred in the south. In addition such lakes may also be stocked with bream, pike *(Esox lucius)* and pikeperch. Currently the Soviet Ministry of Fisheries has 63 commercial lake farms with a total area of 600 000 ha. Over the XIth five-year period, production from them increased by 240%, reaching 19 600 tonnes in 1985. Fish yield from these lakes has nearly doubled and now stands at 40 kg/ha.

5. Future developments

Taking into account the good flavour and dietary quality of freshwater fish, and the growing domestic market for it, the outlook for the freshwater fish business is one of sustained progress.

Catches of freshwater fish by all industries are planned to rise to about 1.4 million tonnes by the year 2000. Most of this growth is expected to be provided by commercial farms. Freshwater fish catch and production by enterprises of the USSR Ministry of Fisheries will constitute 900 000 tonnes, including 585 000 tonnes of market production; up to 280 000 tonnes will come from fisheries controlled by other ministries, and some 210 000 tonnes will be caught by anglers. This programme will require appropriate capital investment, the refurbishment and modernisation of existing operations by the comprehensive mechanisation of fish-breeding processes, and the introduction of new and highly effective techniques for raising marketable fish. However, above all else, advances in both short and long term programmes, to increase catches of freshwater fish, will depend on the performance of fishery and biological research.

In the USSR the concept of the sustainable utilisation of the fish resources of inland waters is adhered to. By 1990 a complex programme of scientific research is supposed to have been devised for the development of freshwater fisheries. Six priority areas will be considered as follows:

- **Resources.** The assessment of fish resources in reservoirs. The determination of stocks of prospective fish species and of the stocks of fish in specific aquatic ecosystems. The ecological and economic evaluation of the state of fish resources and the prediction of future resources.

- **Fisheries.** The development of methods for the non-exhaustive utilisation of fish resources, and the improvement of conditions for the reproduction of fish populations within specific ecosystems which are being preserved.
- **Fish culture.** The formulation of ecologically sound methods of managing industrial fish culture, the development of ways of reconstructing damaged ichthyofaunas, and the development of methods of production process management for reservoirs in pasture aquaculture.
- **Selection.** The development of effective methods of selection for genetic engineering. The development of highly productive fish breeds and the organization of ecological and genetic monitoring in fish husbandry.
- **Technology.** The development of effective technologies and systems both for fish culture and capture fisheries. The creation of automatic control systems for production processes.
- **Economics.** The development of a rational system of fish culture management, and a territorial and production structure for the country's different regions.

Each of the six priority areas involve three levels of decision: ecological, socio-ecological and aesthetic, in descending order of priority.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 511-519.

Fisheries management in the Thames Basin, England, with special reference to the restoration of a salmon population

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Abstract

The background and main functions of fisheries management are described. One of the major activities of the Thames Water Authority is an attempt to restore a self sustaining population of Atlantic Salmon (*Salmo salar*) to the river system. The history of the development of this project is outlined, emphasising the importance of the investment made in domestic sewage treatment in the estuary, and the significance of a single body, the Thames Water Authority, with control over all aspects of the water cycle and fisheries. The role of the Thames Salmon Trust and its interaction with the Thames Water Authority are briefly discussed. The future of the project described will depend on the views of the new National Rivers Authority and its priorities.

1. Introduction

There are ten Water Authorities in England and Wales. These were established by Act of Parliament (the Water Act 1973) and came into operation on 1st April 1974, replacing a variety of predecessor authorities which were concerned with different aspects of the water cycle.

Amongst the ten new authorities which began life in 1974 the Thames Water Authority was unique in that the Thames Conservancy, from which it had inherited responsibility for the care of the River Thames and its tributaries, had had very much less fishery involvement than the River Authorities in other parts of England and Wales. There was no rod licence and therefore no income. There were fishery bye-laws which governed such matters as size limits of takeable fish, illegal methods of fishing and stocking, but there were no full time staff to enforce them. Such enforcement as there was, was undertaken by a force of volunteers recruited from amongst Thames anglers. It was essentially a low profile and no cost administrative exercise.

All this changed with the formation of the Thames Water Authority. The new authority had the same fishery powers as the other nine authorities, but had not yet seen itself as the instigator of a salmon restoration scheme. The senior fishery staff recruited at the inception intended to attempt to set a new and higher standard of fishery service. A national survey of angling, held a year or so previously, had suggested that there could be close to a million anglers in the area controlled by the Thames Water Authority. These could support a large and well equipped fishery service which could be entirely funded from licence revenue, and not as in the case of some of the other authorities, be heavily dependent on subsidy from general environmental funds.

In the event. the estimates proved to be grossly over optimistic and in the first season only some 129 000 licences were sold for £2 UK each. The service planned was reduced, and even this had to be subsidised from general funds. The failure of anglers to buy the rod licence was partly due to the idea of having to pay for something which they had previously enjoyed for nothing. It required some years of education to convince them of the value of a fishery service. This also needed to be combined with a vigorous enforcement policy in which those fishing without licences were warned and then prosecuted if they still failed to buy one.

The total number of licences sold over the years is shown in *Figure 1*. It is our experience that the evasion rate is about 5-10% of anglers, thus the total number of fishermen is far short of the estimate of potential numbers obtained from the national survey. Thames Water has adopted a policy of increasing the licence charge to cover inflation once every three years. It is noticeable that the increases seem to have little effect on the numbers of licences sold. On the other hand, since a peak in about 1981, numbers have declined steadily, and this is in line with the experience of other Water Authorities where the predominant interest is in cyprinid fisheries.

As originally conceived, the fishery service would have spent a great deal of time assisting fishery clubs and owners with practical fishery management. This has been replaced by providing free advice, but encouraging self-help.

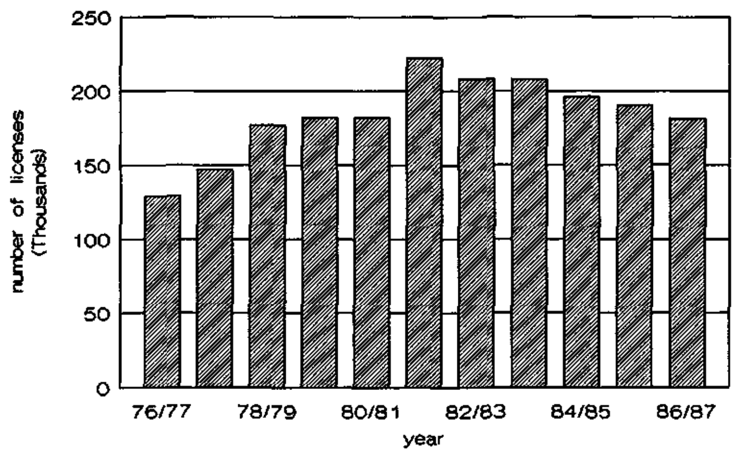

Figure 1. Numbers of licences sold in recent years.

The main activities of the fishery staff are systematic biomass surveys of the major watercourses, together with discussions and the provision of advice to other authority departments concerning ways of avoiding damage to fisheries when carrying out their work. The systematic surveys provided information on population trends and the influences of land drainage schemes or major sewage works. They also provide a basis for loss assessment after a major pollution event or other damage to the fishery. Water authorities are given a specific responsibility by Act of Parliament to maintain, improve and develop fisheries (Salmon and Freshwater Fisheries Act 1975). It is the last two of these three injunctions which cause the most difficulty, no dimensions are set on what should be done, and it is very much up to each authority to respond within its means and on the advice of its Fisheries Advisory Committee. The Thames Water Authority has chosen to put a considerable amount of effort into the development of a run of Atlantic salmon *(Salmo salar)* and sea trout *(Salmo trutta)*, and the remainder of this paper is concerned with the way this has been approached and how it is managed. In fact the effort had its beginnings long before the Authority was formed in 1974.

2. Salmon restoration

2.1 Background to the programme

Up to the end of the 18th century the Thames had a very considerable run of Atlantic salmon which were exploited commercially. Thereafter the rapid growth and industrialisation of London led to a more or less permanent barrier of polluted and deoxygenated water in the estuary. At the same time improvements in the navigability of the river above London led to the building of weirs of a scale which also proved an effective barrier to upstream migration. Between these weirs, channel dredging removed areas of gravel shallows which used to be spawning sites and nursery grounds for salmon. As a result, the run became extinct during the first 30 years of the 19th Century. In the 1860s, and again in the early 1900s, efforts were made to improve the quality of water in the estuary by sewerage and sewage treatment schemes. Both were at least partially successful in at least reducing the grossly offensive state of the river. Both were followed by optimistic, but ill fated efforts to reintroduce salmon. Water quality was inadequate, and indeed for much of the present century the quality of the water again declined, until in the 1950s, the river was effectively dead for a distance of 50 km through London.

During the 1950s the municipal authorities of London decided to find out what was needed to make a radical improvement in the quality of the river. The report which they commissioned (Pippard 1961), identified the major problem as the quality of effluent from the sewage treatment works. By this time industrial effluent was much less important. A programme of massive investment was started which was to last for more than twenty years. It was not long before improvements began to be noticed. Species of marine fish began to re-colonise the outer estuary and were caught in increasing numbers on the screens of power station cooling water intakes. Up-river the freshwater species were able to survive farther and farther downstream towards the centre of London. It was not unnatural therefore, for the thought to arise that migratory species, and particularly salmon, might once again inhabit the River Thames. Re-colonisation of the estuary has been described by Wheeler (1979).

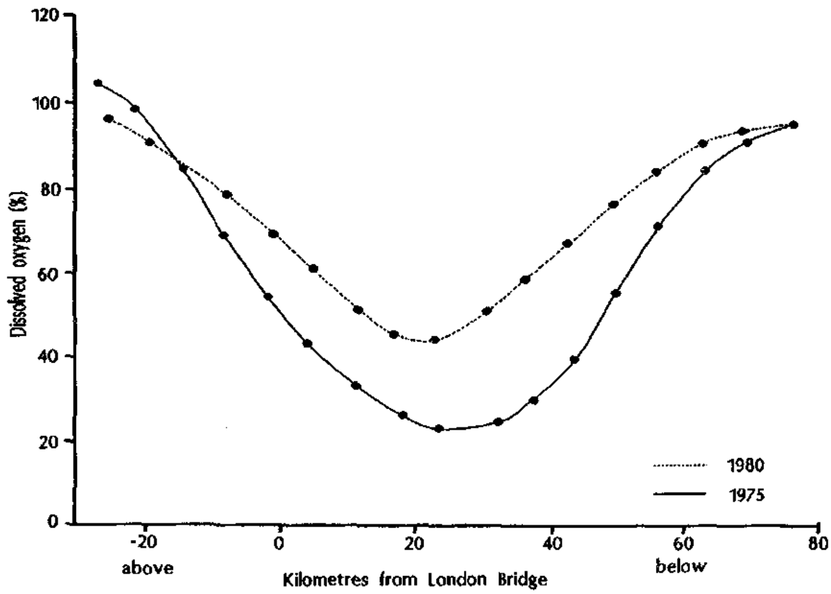

Figure 2. Average dissolved oxygen (expressed as a percentage of the air saturation value) in the Thames Estuary for the third quarters of the two years 1975 and 1980.

The possibility of restoring a salmon run was first considered by the Port of London Authority in conjunction with the Thames Conservancy in 1973, but it was decided that an attempt would be premature. Much more information was required on the prospects for continued improvement in the quality of the tidal water, and on the likelihood that any returning salmon would be able to complete the freshwater phase of their life cycle.

A group of interested bodies got together to form the Thames Migratory Fish Committee. This Committee reported that by 1980 the oxygen concentration in the tideway water would be sufficiently improved, at the critical summer period of low flows, to allow salmon to migrate upstream, but that there would be a measure of risk in some years (Thames Migratory Fish Committee 1977). *Figure 2* shows how the concentration of dissolved oxygen in the crucial third quarter of the year was predicted to improve between 1975 and 1980. The committee also drew attention to the probable shortage of spawning grounds and to the presence of physical barriers to migration in the shape of the weirs in both the main river Thames and its tributaries. However, the overall conclusion was that restoration was possible, but that a decision on whether to go ahead rested with the Thames Water Authority. In retrospect it can be seen that the formation of this authority, with responsibilities for all aspects of the water cycle from head stream to estuary was important for the successful implementation of such a decision. It required a commitment to maintain standards and to work for improvements in a variety of functions for which responsibility had previously been held by several different agencies.

It was recognized that the possibility of a successful restoration could raise considerable fears among anglers and owners of fisheries who had become adapted to quite different interests. The Thames has always been a popular place with coarse fishermen whose clubs pay comparatively low rents for the fishing rights. They feared displacement by a few who were able to afford a high priced salmon fishery. Many of the tributaries which would be suitable for spawning were owned or rented by trout fishermen who saw salmon as unwelcome intruders and potential competitors for space, and likely to attract altogether more persistent and damaging poachers than those they were accustomed to dealing with.

The Thames Water Authority established a working party with representatives of the municipal authorities along the river and the county landowners, to consider the issues. In 1978 this body reported that 'notwithstanding the technical, sociological, legal and financial limiting factors, the rehabilitation of the Thames with its formerly indigenous species, the Atlantic salmon and sea trout, was feasible, and on scientific, social and recreational grounds worthwhile'.

The authority recognized that it would require many years, and a good deal of work, to achieve salmon restoration. Final success could not be guaranteed. A phased programme was drawn up in which the first seven years were to be regarded as the time for pilot studies. If these were successful it was planned to undertake the more costly work, mainly the building of fish passes on the navigation weirs of the main river, and on the many old weirs for water mills which still obstruct the tributaries.

It was recognized that restoration of a salmon population would have an enormous public relations value to the authority, and that a salmon run was tangible proof of the authority's ability to maintain the high quality of the river in a way that pages of statistics could never be. Salmon restoration was therefore to be regarded as a conservation exercise. Angling for salmon would be permitted, but not particularly encouraged. Therefore the necessary funds to run the scheme would come from general environmental funds rather than from angler's licence fees. In 1979 two additional fish biologists were appointed to carry out the work, and at that time the cost of their salaries and running expenses plus the budget for the purchase of young salmon was £30 000 per year.

2.2 The pilot phase

There were four main objectives:

1. Experimental stocking of different life stages of salmon to evaluate their growth and survival.
2. Surveys of potential nursery and spawning areas to evaluate their suitability and carrying capacity.
3. Construction of a trap on a weir just above the head of the tidal reach so that numbers of returning adults could be assessed.
4. Rearing of progeny from adults that returned to the Thames in order to begin the process of establishing a Thames 'race'.

Table 1. Tributaries of the River Thames used for stocking salmon parr.

River	Length (km)	Stocked area (m^2)	Stocking density (parr/m^2)	Capacity (Total number)
(Chalk based)				
Lambourne	11.4	101 000	0.3	30 000
Enborne	18.6	149 000	0.3	45 000
Wey (North)	7.5	30 000	0.2	6 000
Loddon	9.8	75 000	0.3	22 000
Lyde	5.4	30 000	0.3	9 000
Whitewater	8.5	58 000	0.2	12 000
Pang	9.1	57 000	0.3	17 000
Chess	7.9	56 000	0.4	22 000
(Greensand based)				
Wey (South)	10.9	55 000	0.4	22 000
(Limestone based)				
Windrush	5.0	27 000	0.2	5 000
Dikler	4.8	19 000	0.2	4 000
Eye	1.7	6 000	0.2	12 000
	100.6	663 000		195 200

This phase lasted from 1979 to 1986 and the results are summarised below. Objectives 1 and 2 were readily achieved. Detailed evaluations of stocking and survival in many Thames tributaries have been carried out and data on the fully evaluated streams is given in *Table 1*. In addition there are many other streams with some potential as nursery sites with a total area of 57.5 ha and an approximate further carrying capacity of 150 000 parr.

Survival rates have varied greatly from year to year, and from river to river. Despite reasonable water quality and biology, and the relative scarcity of predators, many studies in some streams have shown very poor survival rates for parr. It seems probable that poor physical habitat is the main problem, these streams tend to lack cover and have fine gravelly beds. One research programme is now in progress to investigate the use of instream structures to improve channel cover and diversity.

Survival of parr in the nursery streams has been evaluated by electro-fishing. Overall survival to adult return has also been measured and shows the same wide range of results. Returns from smolts stocked in the lower part of the main river have generally been an order of magnitude better than returns for parr, but are of course only a short term method of sustaining the run. Smolt returns of fish stocked in 1985 and 1986 have been particularly poor. This is a matter of concern because these fish were bought as parr and reared to smolts in cages in our reservoirs. An experiment is in progress this year to remove these fish from the cages in early spring and allow them to complete smoltification in a modified raceway. Survival of these, and a control batch retained in the reservoir until release, will be evaluated in the autumn of 1989 after the bulk of this years smolts will have returned as 1 sea winter adult salmon. The total numbers of juvenile salmon stocked since 1979 are: fry 36 000, parr 590 000, smolts 140 000.

The conclusion from the pilot phase work on stocking and survival is that it will have to continue for many years. It is hoped to gradually change the emphasis from smolt stocking to parr stocking, and that in due course this will be augmented and then overtaken by natural spawning. One interim result is a decision to concentrate on the tributaries arising from the chalk outcrops in the central part of the catchment. The streams arising from the limestone outcrops of the Cotswolds in the western part of the basin have shown lower survival rates of stocked parr. The beds of these streams, being mainly of rather soft Jurassic limestones, have a tendency to concretion which would seriously reduce egg survival. These streams are also much farther from the sea and would require many more fish passes to make them accessible to adults.

For objective 3 a trap was built into the weir at Molesey some 8 km above the head of the tide. Returning adults have been regularly trapped here since 1982. Some have been taken away for hatchery purposes, but the majority are marked and released upstream. It has become clear from the unmarked fish captured in electro-fishing surveys above Molesey, that many fish are by-passing the trap. These surveys thus provided a Lincoln index type of estimate of the run rather than an absolute count as originally planned. This estimate put the number of adults currently returning each year at between 200 and 500. The actual counts of returning adults compiled from various sources are given in *Table 2*.

Objective 4 has proved the most difficult to pursue. It requires expenditure on a hatchery and rearing facilities on a scale which simply could not be met at the present time of financial stringency. We have therefore had to improvise, by begging or hiring space in other people's hatcheries. This could never be done on a large scale, and not surprisingly, has had only limited success. A systematic attempt to rear the progeny of adults returning to the Thames is thus still in the future.

Table 2. Numbers of adult salmon observed in the River Thames in the period 1974-1987.

Method	Year						
	1974-1981	1982	1983	1984	1985	1986	1987
Trap			26	50	37	81	41
Electro-fishing		116	34	43	22	62	2
Angling	0	2	8	6	9	13	4
Other reports	18	10	21	7	7	20	11
Total	18	128	90	106	75	176	58

2.3 Thames salmon restoration, second phase

The pilot studies just described were still incomplete when the authority needed to decide whether to continue its effort or not. The original programme had envisaged a second and third phase devoted to the continuation of stocking policies, but including capital expenditure on fish passes to make more of the main river and tributaries accessible. The decision not to build the hatchery in the first phase had also made reappraisal of this part of the project essential. The limited experience with fish passes in the first phase also suggested that the original cost estimates were much too low. In the seven years since the programme started, the Thames Water Authority had become commercially minded in its attitude to finance, and although willing and indeed anxious to see salmon continuing to return to the Thames, the capital costs, without quantifiable benefits, were considered to be too high.

It was decided that a new organisation, the Thames Salmon Trust, be established as an independent charity. This body was to have the primary objective of raising capital and other resources for the fish passes, hatchery and rearing facilities. Its target was to raise £1 000 000 UK over five years. This would provide money for the building work and a modest level of endowment to assist the running costs. The charity was inaugurated in the summer of 1986 and launched its first appeal in March 1987. The trust also receives from the Thames Water Authority the funds which that authority originally spent on the pilot work on restoration. These Thames Water Authority funds continue to pay the salaries of the two staff members who are involved with the project full time. The trustees receive and monitor the restoration plans and have the ultimate decision on the programme of capital spending. This latter is prepared by the Thames Water Authority staff who service the Trust.

Although there have been some notable contributions, and some significant help from the salmon farming industry in Scotland, the appeal for funds in March 1987 was less successful than hoped. A good many of the companies approached were in sympathy with the objectives, but provided only modest contributions. It is now recognised that a different and more commercial approach is required. The trustees recently employed a person specifically to raise funds. His main target will be commercial sponsorship of individual fish passes and of special events to produce more funds. The trust is also pursuing the idea of holding lotteries to try to produce a regular income.

At present funds are available for about a quarter of the passes needed to give adult salmon access to the major chalk based tributaries, these will be built in the next two years, followed by others as the funds become available. For the hatchery, the Thames Water Authority has decided to expand its general hatchery capacity. Space will be found for salmon rearing, help has been offered from a Scottish salmon producer, and funds will be found for equipment from the Salmon Trust.

Thus the present status of salmon restoration in the Thames is on the basis of a partnership between a charity and an official body, the Thames Water Authority. Reorganisation of the English and Welsh water industries is scheduled for the autumn of 1989. The arrangements by which one authority in each region controls sewage treatment and water supply, sets standards for river quality, and is responsible for fisheries, land drainage and other functions, will be replaced. Broadly, water supply and sewage treatment will be separated and run commercially. The other functions will be the responsibility of a National Rivers Authority. This body will have to reappraise all the initiatives which it inherits. There are certainly other examples of co-operation between water authorities and charities in the general area of conservation, but none, so far as I am aware in which the authority having initiated the formation of the charity then employs staff specifically for the objective of the charity.

3. The future

Much has been resolved, but the future of the Thames salmon restoration scheme is still uncertain. Given the survival rates of parr to adults which we have measured, and the amount of suitable spawning and nursery area which are available, there seems no reason why the Thames should not once again contain a modest self supporting run of salmon. A considerably larger run could be supported if a policy of intensive stocking was undertaken.

So far the majority of the salmon have stayed in the main River Thames until late in the year. They are protected by the closed season after 30 September. They are only vulnerable to legitimate angling in the weir pools, thus the fears of ordinary angling being replaced by expensive salmon fishing are probably groundless. A large run of salmon would undoubtedly attract the attention of poachers, therefore it is safer for the salmon, and for the authority, to have a modest run well distributed in the system. Achievement of this aim is dependent on the capital being found for fish passes.

When the programme was established the element of risk regarding the quality of water in the estuary was recognized. The last eight years have not seen that risk diminish, indeed if anything it has increased through the pressure of cost cutting in sewage treatment. In a large system like the Thames Estuary the search for the right standards for sewage discharges, in order to satisfy desired environmental objectives is complex. The energy costs of raising the oxygen level by even one part per million can be hundreds of thousands of pounds per year, so the price of getting the sums wrong is very high.

The problem of summer storms causing overflow discharges to the river still remains, but is being tackled by commissioning an oxygen bubbling barge, able to inject 30 tonnes of oxygen/day, and able to be moved up and down the estuary to areas of need. This is not seen as an alternative to proper sewage treatment.

The general objective of supporting a salmon population will certainly be within the remit of the NRA. As I have attempted to demonstrate, if this body wishes to continue with a restoration programme it faces two kinds of call upon its resources. The first is a continuing commitment to appropriate water quality standards in the estuary and the second is a continued drive, in co-operation with the Thames Salmon Trust, to fund the hatchery which will be necessary, also the fish passes and general running costs.

References

Pippard, 1961. Pollution of the Tidal Thames. HMSO, London. 609 pp.

Salmon and Freshwater Fisheries Act, 1975. HMSO, London. 43 pp.

The Migratory Fish Committee Report, 1977. The Thames Water Authority, London.

Wheeler, A., 1979. The Tidal Thames. Routledge & Kegan Paul, London. 228 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 520-525.

Integrated catchment management in England and Wales

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Abstract

Systems of fisheries management cannot exist in isolation, but have to take account of other demands made on the environment. The most efficient way of achieving this is by integrated management of the resource as a whole. The benefits of such management were recognised in the formation of 10 Regional Water Authorities in England and Wales in 1974. These bodies are responsible for all aspects of the management of the water cycle in areas defined by natural geographical boundaries, and they can promote optimal solutions to the problems which affect interest groups which might otherwise be in conflict. Activities have been integrated over entire catchment areas, staff have become multi-functional rather than subject specialists and efficiency has been improved with the result that operational costs have been significantly reduced.

The United Kingdom Government now sees regulatory functions as being incompatible with the commercial activities of a privatised industry, and proposes to separate the regulatory functions of Water Authorities from water supply and sewage disposal. Regulatory functions will become the province of a National Rivers Authority (NRA), whilst the service functions will be transferred to Water Service Public Limited Companies (WSPLCs) which will be sold to private investors. The NRA will be a non-departmental public body answerable to the Government, with a small headquarters staff and 10 regions covering the same geographical areas as the existing Water Authorities. It will aim to be financially self-sufficient, recovering its expenditure from water users and from a small Government grant for the provision of environmental services. So far as possible it will reduce its costs by sub-contracting its operations by competitive tenders.

It is proposed that integrated river basin management will be achieved by co-operation and by the NRA regulating the environmental activities of the WSPLCs. Details are not yet available as to how these revolutionary changes will be achieved, but a broad action plan is expected by the autumn of 1988.

1. Introduction

Except in the case of aquaculture, which is a stock rearing exercise governed by market forces, fisheries management is concerned with the manipulation of wild stocks living in their natural environment, modified to a greater or lesser extent by the activities of man.

Natural systems are complex and even when their underlying mechanisms are understood it is seldom possible to control all the factors affecting their performance. As a result, environmental management is as much an art as a science, even when practiced on the basis of scientific principles. Above all, the fisheries manager differs from the investigative scientist in that he is dealing with a system which is being simultaneously managed by others, whose objectives may even be in conflict with his own. To this extent his problems are as much political as scientific and depend on administrative procedures for a solution.

No matter how good, no scheme of management can succeed in the absence of an administrative framework for the resolution of conflicts of interest and, when resources are limited, for the allocation of priorities for investment. Schemes evolved under such a regime may be felt to have suffered from compromise, but they have a better chance of long term success, and in this context compromise should be seen as a positive virtue.

2. Demands on the aquatic environment

The provision of healthy productive fisheries is only one of many demands made on the aquatic environment, all of which must be recognised if the resource is to be used optimally with the minimum of conflict between interests. Other users make demands on both the availability of water and on its quality, and all are inter-related.

2.1 Water resource development

Water is essential to life, without a clean reliable water supply we could not sustain our industrial urbanised culture. In England and Wales 99.2% of the population is connected to the public water supply, creating a total demand in 1987 of 16.85 million m^3/day or nearly three times the mean flow of the River Thames at Teddington. Of this water, 62% is used by industry, the bulk of it as cooling water, with the remainder supplying domestic needs at the rate of 130 litres per person per day to a population of 49.76 million.

The need to regulate the exploitation of water resources is recognised in statute law which requires impoundments and abstractions from aquifers or surface waters to be licensed, although water taken for individual domestic use and for agriculture other than spray irrigation is free from control. All licensed abstractions are subject to limits on the maximum volume, daily rate and season when they are permitted. Large schemes for industry or public water supply are usually governed by complicated operating rules which define the restrictions in great detail. Smaller abstractions from rivers are usually subject to a condition specifying a minimum river flow below which abstraction must cease.

It is these minimum residual flows (MRF) which are most significant for the protection of fisheries. In general, they are not guaranteed flows which will be maintained regardless of the severity of a drought, but are cut-off flows below which abstraction must cease, leaving the whole of the natural flow in the river. Where rivers require a greater level of protection at times of drought, this can only be achieved by storing water for use either as an alternative to river abstraction, or to augment river flows, allowing abstraction to continue further downstream. Surface reservoirs may be used for river regulation, but in some cases the water may be obtained from underground sources, which may be widely spread throughout the catchment. Where they exist, groundwater sources have the added advantage that they can be developed quickly and with the minimum of environmental disruption.

In recent years, improved management of whole catchments has allowed the development of conjunctive use schemes which allow demand to be switched between rivers and groundwater sources to maximise the yield of potable water and minimise the impact on other water users. However, such schemes are only possible where the administrative framework exists to allow quick response and flexibility in decisions.

2.2 Flood control and land drainage

The natural function of rivers is to carry excess rainfall to the sea. Unmanaged systems are capable of dealing with a wide range of flows but include lowland flood plains which are dry for most of the time. However, these marginal lands are attractive for agriculture and urban development, so man has progressively forced the rivers back into their low-flow channels, which are now expected to cope with the whole range of flows. This problem is intensified by the need to drain soils for agriculture and by the provision of urban paved areas which drain rapidly after rain, so that peak flows in managed catchments are greater than they were in the past. These can be accommodated by improved hydraulic design, but the result is a river with very different characteristics from the natural system which it replaces.

Unfortunately the objectives of land drainage and flood protection are at variance with those of water resource development and fisheries. Water drained to the sea in winter is not available for summer use and drainage channels capable of dealing with wide variations in flow are unlikely to sustain productive fisheries. However, by using historic records of rainfall and river flow, drainage schemes can be designed with a predictable risk factor such that they may be expected to be overwhelmed once in 5 or 10 years where this is acceptable, or 50, 500 or a 1000 years where a higher level of protection is required. Elaborate schemes are not only more expensive to build but have greater environmental impact, so care has to be taken to ensure that the level of protection chosen is appropriate to the circumstances.

Maintenance of flood design standards requires management of the river channel by the periodical removal of accumulated silt and other obstructions such as weeds, which are particularly important in summer when channels may be blocked by heavy growths. River capacity can be restored by weed cutting, by the use of herbicides, or biological controls, but good fisheries and the maintenance of ecological diversity demand the presence of a rich flora; when maintenance schemes are designed a balance has to be struck between these interests and the requirements of flood protection.

2.3 Effluent disposal and pollution control

Successful fisheries management rests on the twin foundations of adequate river flow and suitable water quality, but neither can be unconditionally guaranteed. Whilst pollution is universally condemned, we must not lose site of the fact that the capacity of rivers to absorb wastes is a valuable resource. Waste is inseparable from our way of life and cannot be ignored, it is in our own interests to dispose of it safely and at minimum cost, in both financial and environmental terms. Only the most persistent and toxic wastes can be isolated and stored, the rest are far too bulky and contain valuable raw material, including water, that should be recovered and used again.

Complete purification of effluents is not economically possible, so if they are to be re-used we must accept that they will contain substances which the environment has to absorb. The objective is to control the level of impurities so that we maintain an acceptable rather than a pristine environment, at a price we can afford. We all want cleaner rivers, but how much are we prepared to pay?

River quality management in England and Wales is based on a system of 'river quality objectives' which are use-related. Individual discharges are regulated with respect to their volume and chemical composition to ensure that these objectives are met. Where appropriate, rivers are also designated under the European Community (EC) Directives which define water quality for freshwater fisheries, abstraction for potable supply etc., or control the discharge of dangerous substances or the effluents from specific industries. This approach has allowed a steady improvement in water quality over the last 40 years such that our rivers are probably cleaner now than at any time since the first industrial revolution. The return of salmon to the River Thames is well known and similar successes have been achieved on the Rivers Tyne and Tees, albeit at very great cost.

Routine effluent discharges can be planned for and controlled within a framework which recognises the needs of fisheries, nature conservation, water supply and other river uses - accidental pollution is entirely another matter. The unforeseen cannot be prevented by legislation, but we can reduce the frequency of accidents by careful planning. A particular difficulty lies with activities which are potentially dangerous, but where the probability of accidents under normal conditions is low, as is the case with chemical manufacturing or the nuclear power industry. Here it is not sufficient to control only the nature and composition of effluents discharged, safety considerations and environmental objectives need to be taken into account at every stage of planning and management. In the field of water pollution control, the storage of hazardous substances is of particular concern.

3. Integrated management

With so many conflicting interests competing for the resources of the aquatic environment - water supply, flood control, land drainage, fisheries, nature conservation, power generation, navigation, recreation, effluent disposal - it is apparent that a scheme of management for any of them will succeed only if all other interests are taken into account. In England and Wales there has been an evolution towards integration over the last 50 years, culminating in the Water Act of 1973.

By 1987 the water authorities were managing assets with a net value of £28 621 million UK, were investing more than £1000 million in capital expenditure, and had a turnover of £2712 million a year. In their present form the 10 authorities are controlled by Government-appointed Boards of between 9 and 15 members, 2 of whom are appointed by the Minister of Agriculture for their special knowledge of fisheries and land drainage.

The authorities are responsible for managing the whole of the water cycle within geographical rather than political boundaries and have a special duty to further the conservation of natural beauty, fauna and features of special interest in everything they do. In fulfilling their duties to maintain, improve and develop fisheries they spend £8.49 million a year. Of this sum, 56% comes from a direct charge on licensed fishermen, while the remaining 44% is raised as part of the Environmental Services Charge (ESC). The ESC is paid by all customers for services which are of general benefit to the community, and some 6.5% of it is spent on fisheries management. In addition to their direct expenditure on fisheries, the water authorities have regard for fisheries interests in all their other activities. This is especially so in water resource development, where fish passes, fish hatcheries and special compensation flow regimes may be provided, and also in river quality management where, in 1987, they spent more than £554 million to maintain sewage treatment plants and the sewerage system.

Integrated management has ensured that limited resources have been used as efficiently as possible and has allowed the flexibility necessary for a quick response to crises such as pollution and drought. However, there is a price to pay for efficiency. Many people see the water authorities as being remote and arbitrary in their decisions, with no accountability to elected local government bodies (County and District Councils). In particular, in the fields of sewage treatment, river quality management and environmental control, they are seen as being both regulators and potential offenders - the gamekeeper/poacher paradox. Whilst this is more apparent than real, there have been occasions when environmental objectives have had to receive a lower priority than some members of the public would have wished, for instance, government restrictions on finance in recent years have forced the water authorities to delay some low priority sewage treatment schemes, with the result that by 1985 the trend towards an overall improvement in river water quality in England and Wales had been halted, with local deteriorations being reported from some areas. This setback has now been overcome and British rivers are improving once again.

Prior to 1974 the costs of water services were spread between the government and a large number of local authorities, but now that they are separately identified, the public perceives water charges as being too high. Charges have certainly risen (by 22% in real terms since 1974) to provide capital to replace ageing assets which had previously been neglected, but the average domestic customer currently pays only £0.69 UK per head per week for all water services - about the cost of a litre of carbonated mineral water. The industry is constantly striving to improve its efficiency, but the scope for savings from this quarter is diminishing. Better publicity is needed to correct the public misconception regarding prices; if the public truly wants cleaner rivers and better services, it will have to recognise that more money is needed.

4. The future of river basin management

The objective of the current UK Government is to reduce public involvement in the national economy, as a result of which a number of nationalised commercial undertakings have been sold to private investors. Following British Telecom, British Gas and British Airways, the intention is to sell other public utilities, with the Water Industry heading the list. The original proposal was to privatise the industry as a going concern, to be operated as a private monopoly under the eye of a Government watchdog, who would have control over pricing policy and commercial activities. This found little favour with the public, apart from the fact that integrated river basin management would be preserved. It did nothing to solve the poacher/gamekeeper problem and considerable concern was expressed about the prospect of regulatory activities being exercised by a private company operating for profit. In particular, it was doubted whether such a company would be acceptable to the European Community as a 'competent body' for the enforcement of EC Directives.

Following the 1987 general election the Government revised its proposals, suggesting that only the water supply and sewage disposal activities of the Water Authorities should be sold off, leaving water resource development, land drainage, pollution control, river quality planning, fisheries, navigation, environmental conservation and water recreation to be transferred to a new body, the National Rivers Authority (NRA). This was envisaged as a small co-ordinating body responsible for environmental matters, whose operational activities would, so far as possible, be contracted out by competitive tender.

Following consultation, it is now proposed that the main activities of the NRA will be concentrated in 10 regions with the same boundaries as those of the existing water authorities. Each will have a Regional Manager and will be strong enough to carry out the whole range of activities transferred from the water authorities. It is intended that the NRA should be financially self sufficient, recovering its costs from water users and from a small grant, equivalent to the ESC provided by central government.

Integrated river basin management will be maintained by the NRA controlling the activities of all abstractors and effluent dischargers including the WSPLCs, although the mechanics of this has yet to be defined in detail. Given a strong NRA and adequate funds, these proposals have a great deal of merit, and should ensure the efficient management of the aquatic environment enabling fisheries to be developed to their full potential.

Note

I am grateful to the Board and Director of Technical Services of the Southern Water Authority for permission to publish this paper. Any views expressed are my own and are not necessarily those of the Authority.

References

Acts of Parliament:
River Boards Act, 1948
Water Resources Act, 1963
Water Act, 1973
Control of Pollution Act, 1974
Salmon and Freshwater Fisheries Act, 1975
Wildlife and Countryside Act, 1981
Salmon Act, 1986

Government Publications:
CMND 9734. Privatisation of the Water Authorities in England and Wales. H.M.S.O. 1986.
The National River Authority. The Government's proposals for a public regulatory body in a privatised water industry. DoE July 1987.
The National River Authority. The Government's policy for a public regulatory body in a privatised water industry. DoE December 1987.
Water Environment: the next steps. The Government's consultative proposals for environmental protection under a privatised water industry. DoE April 1986.
Water Authorities Association, 1987. Water Facts (annual publication). Water Authorities Association, London.
Natural Environment Research Council, 1985. Hydrological Data UK Yearbook. Institute of Hydrology, Wallingford, England.

Okun, D.A., 1977. Regionalisation of Water Management. A revolution in England and Wales. Applied Science Publishers, London.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc, Wageningen. pp. 526-534.

Application of creel census data for the management of fish stocks in large rivers in the United Kingdom

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Abstract

In the U.K. there is a paucity of information on the fish populations of large rivers, primarily as a result of the difficulties in sampling such water bodies by conventional netting and electric fishing techniques. Consequently, the application and outcome of any fisheries management strategy is based on educated guesswork and has proved difficult to evaluate.

The application of creel census techniques to obtain data on the fish populations of large rivers is described with reference to case studies based on the cyprinid fisheries of the River Trent. The validity of using creel census techniques is discussed, particularly in relation to the accuracy of the data obtained. The implications of species and size selectivity, angler ability, hook avoidance and different environmental conditions on catch rates and composition are described and assessed. The creel census method is a valuable tool to the fisheries manager who requires information on the fish populations of large rivers and lakes where other, more conventional, sampling techniques are not possible.

1. Introduction

Quantitative assessment of fish populations in large waters poses considerable problems for fisheries managers. Conventional sampling techniques, such as electric fishing, netting or poisoning, are often impractical because of river topography, current velocity, submerged obstructions, or the value of the fish resource. Consequently, the application and outcome of any fisheries strategy imposed has often been based on educated guesswork and is difficult to evaluate. Thus an alternative sampling strategy, which overcomes the sampling difficulties but allows enumeration of the fishery, is required. Many workers have attempted to access information on the fisheries of large rivers utilizing anglers' catches (Ayton 1976, Axford 1979, North 1980, Cooper & Wheatley 1981, Hickley & North 1981) but few (Pearce 1983, Cowx & Broughton 1986, Cowx, Fisher & Broughton 1986) have developed the technique to answer the problems of the fisheries manager. This is despite the technique having been used successfully on many put-and-take trout fisheries (*e.g.* North 1983). The present paper demonstrates, using specific case studies from the River Trent catchment (England), how recording and analysing anglers' catch data can be used effectively for management purposes.

The Trent is the principal river catchment of the East Midlands of England *(Figure 1)* and has many of the problems, *e.g.* pollution (industrial, domestic and thermal), poor fisheries and river engineering works, which often confront fisheries managers. It is a

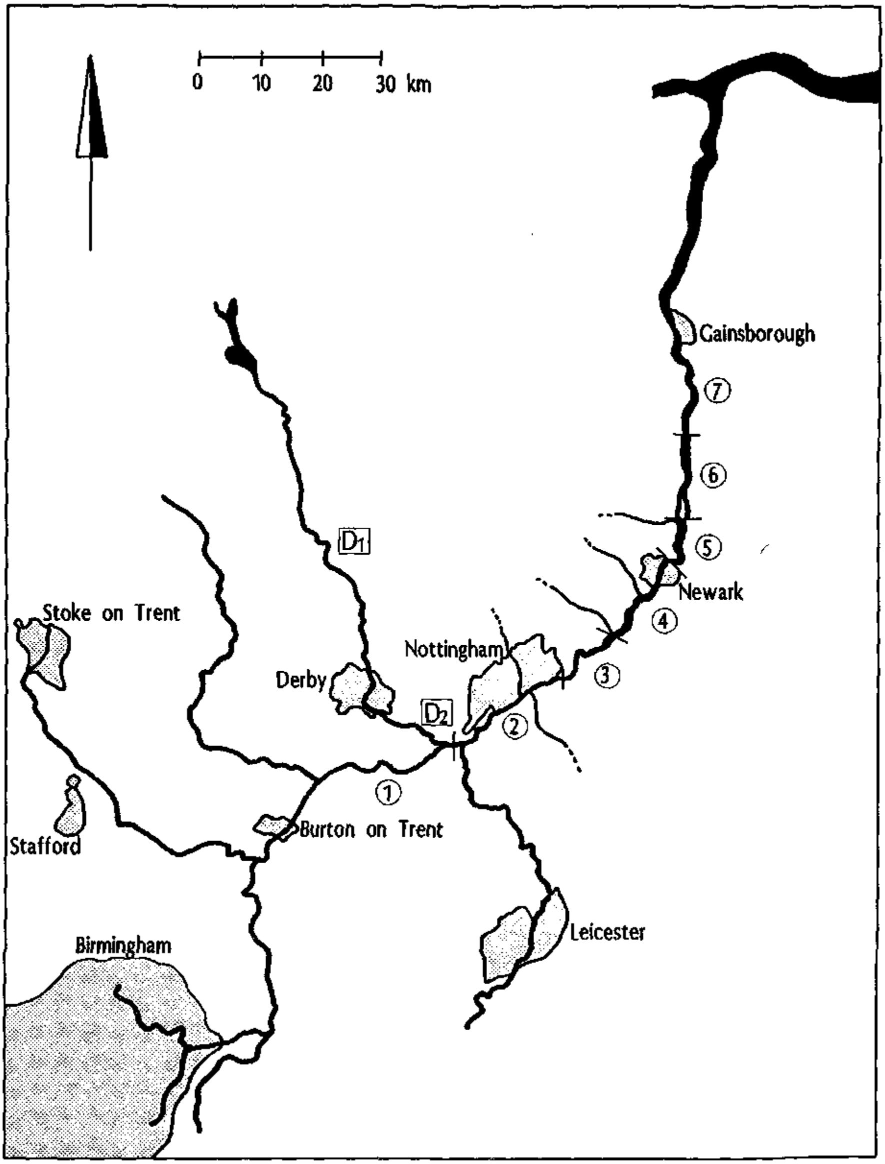

Figure 1. Map of the River Trent showing location of angling census sites. 1–7 = fishery zones in the River Trent. 3 = Nottingham Federation Fishery. D1 = Belper Fishery. D2 = Hoveringham Fishery.

heavily fished waterway under the auspices of the Severn-Trent Water Authority who manage the fishery.

2. Creel census methods

Catches were monitored by distributing postage prepaid catch-return cards to secretaries of angling clubs holding organised competitions, and occasionally to individual anglers. As with most questionnaires, better returns were obtained when the minimum of information was requested. The most important data required are:

- Location, date and number of hours fished.
- Number of anglers fishing.
- Number of anglers catching fish.
- Total weight of fish caught and top three weights.
- Species of fish caught:
  - 1. in greatest numbers.
  - 2. in second greatest numbers.
  - 3. other species.

Other supplementary information may be added for specific studies (see mid-Derwent study).

Two measures of angling success were derived from correctly completed returns, the percentage of anglers that actually catch fish, and the overall catch rate in g/man/hr achieved during the competition or by the individual angler. The species data permit an assessment of the species composition of catches in relation to a specific problem or to long-term trends. The data are analysed using the index proposed by Cowx & Broughton (1986):

$$(\% \text{ abundance} + \% \text{ frequency of occurrence}) \times 0.5$$

The percentage abundance of a species was calculated on a points scale according to its recorded importance in the catches. Thus, when a species was recorded as most common species it was awarded 4 points, next most common 2 points and other captured species 1 point. Abundance was derived by expressing the total points score for each species as a percentage of the total points awarded for all species. Frequency was determined as the percentage of all matches in which a species was represented in the catches.

3. Case studies in the Trent Catchment

3.1 River Trent - Burton to Gainsborough

Since the early 1980s anglers have expressed considerable concern that the River Trent was declining as a fishery and have suggested that prompt action was required to prevent further deterioration. Data on anglers' catches were collected by the Severn-Trent Water Authority for the fishing seasons 1969/70 to 1983/84 using postal questionnaires. These data were analysed and used to evaluate the anglers' complaints.

Angler Success - Contrary to the anglers' perception, the catch rate data (Cowx & Broughton 1986) suggested an improvement in both the percentage of anglers catching fish and the overall catch rate in the post 1978/1979 seasons. These data were not statistically significant. Catch rates were slightly higher in the upper reaches around Burton (Zone 1), and lower in the tidal zone (7) around Gainsborough, than in the intermediate zones (2-6) which constituted the major part of the Trent fishery (Cowx & Broughton 1986).

Species Composition - 22 species of fish were caught during the 15 seasons monitored, but only 10 (Cowx & Broughton 1986) were of importance to anglers. Since the early 1970s there has been a steady decline in the importance of roach *(Rutilus rutilus)* and dace *(Leuciscus leuciscus)*, with a reciprocal increase in the importance of chub *(Leuciscus cephalus)*, bream *(Abramis brama)*, perch *(Perca fluviatilis)*, and latterly barbel *(Barbus barbus)*.

No indication of the alleged deterioration of the fishery was evident from the catch rates, indeed the opposite would appear the case. The quality of the fishery based on a mean annual catch rate of 114 g/man/hr compares favourably with other riverine coarse fisheries, *e.g.* the River Ouse - 58 g/man/hr (Axford 1979), and the River Severn - 82-176 g/man/hr (Hickley & North 1981).

The perceived demise of the fishery stems from the belief of many anglers, that mixed catches based on roach constitute good angling quality. Thus the decline in the importance of roach in the fishery is the cause of the complaints. The mechanism behind the species shift from a roach-dace to a chub-bream-perch fishery is probably linked to an improvement in water quality since the late 1960s (Cowx & Broughton 1986). Roach tend to dominate fish communities in nutrient rich, turbid, eutrophic conditions, and with the improvement in water quality, this domination has lessened allowing previously suppressed species to become established. Chub, bream and perch were the species to take maximum advantage of the reduced competition from roach, probably because abiotic factors (reduced turbidity and elevated oxygen levels) favour these species.

3.2 River Trent - Stoke Bardolph to Gunthorpe

This stretch of river, downstream from Nottingham *(Figure 1)*, under the control of the Nottingham Federation of Anglers, is one of the most popular coarse fishing areas in England. It lends itself to an angling census because fishing stations have been permanently established and marked by a peg number at approximately 10 m intervals. The catch return forms make use of this facility and have recorded individual catches at each peg during all matches held since the 1979/1980 season.

In recent years the anglers have made several allegations about the quality of the fishery including, that there has been an overall decline in the fishing, that certain stretches of the river yield more prolifically than others, that the effluent discharged from a sewage works is detrimental to the fishery, and that there is a decline in catches at weekends because power stations discharging thermal effluent are shut down over this period. All these allegations were investigated through the anglers' catch returns.

As with the previous study on the Trent, mean annual catch rates *(Figure 2)* have improved in recent years. This is also coupled with a change in the status of the fishery from a roach-dace to a chub-bream fishery.

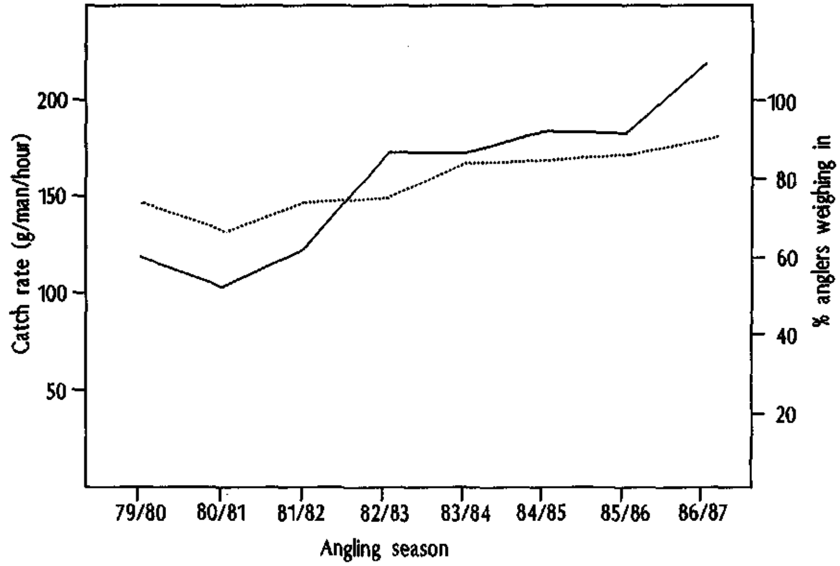

Figure 2. Variation in the percentage of anglers with catch (solid line) and the mean catch rate (broken line) in the Nottingham Federation Fishery in different angling seasons.

Comparison of catch rates for different periods of the week (1986/1987 data) show that weekend catch rates (216.7 g/man/hr) are similar to those of weekdays (229.0 g/man/hr), primarily because angler ability remains constant throughout the week. However, breakdown of the data into months *(Figure 3)* shows that weekend catch rates deteriorate as the season progresses whilst weekday catches remain relatively stable. There is no evidence from temperature records to suggest fluctuating thermal discharge was responsible for these findings; they were more a reflection of cumulative fishing pressure over the season. Over the season there is a reduction in the stock size and declining catchability related to increased hook avoidance (Raat 1985) and angler damage, which is exploited by the anglers. The proportion of the stock remaining accessible is sufficient to satisfy the demands of the small number of weekday anglers (hence their catches were reasonable) but not the large number of weekend anglers. Thus, the reported decline in weekend catches reflects the impact of fishing pressure and not, as suggested, power station activity.

The alleged poor fishing in certain areas, and the effect of the sewage works, was investigated by determining those pegs which consistently produced top weights in competitions. This analysis showed that certain pegs were more productive than others and Stoke Bardolph Sewage Works has a beneficial effect on the fishery. The reasons for poor fishing in certain areas is not always apparent from bankside observations but echo-sounding of the bottom topography shows that quality fishing is associated with underwater features which tend to hold fish.

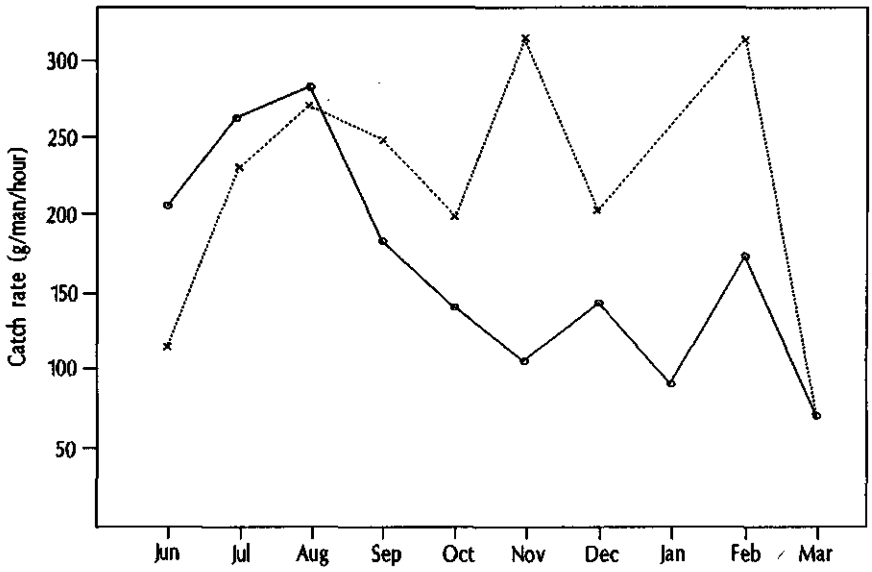

Figure 3. Variation in the catch rate of anglers between weekdays (solid line) and weekends (broken line) at Nottingham Federation Fishery over the 1986/1987 season.

3.3 River Derwent - the Belper fishery (D1)

During the mid 1970s the fish stocks of the middle reaches of the River Derwent (Derbyshire), a major tributary of the River Trent, collapsed due to poor natural recruitment. The fishery showed little evidence of improvement despite repeated stocking by the Severn-Trent Water Authority. In an attempt to evaluate the problem, 589 chub, 804 roach 194 bream and 414 dace were marked with a Panjet and introduced into a 5 km stretch of the middle reaches around Belper between 1979 and 1980. Angler catches were monitored during the 1980/1981 fishing season using a census form which specifically asked for the number of marked and unmarked fish caught. The population size *(N)* of each stocked species was estimated using Bailey's (1951) modification of the Peterson mark-recapture method. The study is described in more detail by Cowx, Fisher & Broughton (1986).

The population estimates *(Table 1)* indicate that the natural fish fauna was extremely poor and that even after stocking the total fish density for the 5 km reach was only 0.35 fish/m^2. This is low by comparison with other rivers, *e.g.* 3.7 and 2.3 fish/m^2 in the Rivers Thames (Williams 1965) and Trent (Cooper & Wheatley 1981) respectively. These data clearly show the poor state of the River Derwent fishery, especially since stocked fish account for almost half of those caught.

Table 1. Details of fish caught in the middle reaches of the River Derwent between 16 June 1980 and 15 March 1981.

Species	No. of marked fish introduced	Total number of fish caught	Number of marked fish caught	Population estimate ± 95% C.L.
Dace	414	142	74	789 ±127
Roach	804	306	124	1975 ±265
Chub	598	913	367	1485 ±115
Bream	194	97	51	371 ±67
Total	1990	1458	616	4706 ±281

3.4 River Derwent - the Hoveringham fishery (D2)

This fishery on the lower reaches of the River Derwent was considered by the controlling angling club, Derbyshire County Council Angling Club, to be overfished. As a result they decided to impose a change in policy towards match fishing in 1979. This involved maintaining a similar seasonal fishing effort but organising monthly rather than weekly matches. The effect of this management strategy was assessed using the anglers' catches monitored between 1973 and 1984.

A dramatic rise in catch rates coincided with the change in management around 1979/1980 and catches have continued to improve *(Table 2)*. Over the study period, chub made an increasingly greater contribution to the catches at the expense of gudgeon *(Gobio gobio)*.

Table 2. Summary of match returns from the River Derwent, Hoveringham Fishery between 1973 and 1984.

Season	Total catch (kg)	Total effort (man hr)	Catch rate (g/man/hr)
1973/74	592.126	2970	199.7
1974/75	722.543	6320	114.3
1975/76	624.905	5495	113.7
1976/77	2393.568	9700	246.8
1977/78	1666.253	5969	279.2
1978/79	3180.794	10608	299.8
1979/80	2260.810	5655	470.5
1980/81	3353.090	7415	452.2
1981/82	3091.650	7550	409.4
1982/83	4391.889	7815	562.0
1983/84	2786.491	5290	526.7

Whilst the change in management policy may have contributed towards the improved catch rates, the primary factor was the change in species composition of catches (Cowx, Fisher & Broughton 1986). The shift was caused by the recruitment of an exceptionally strong 1976 year-class of chub entering the catchable cohort in about 1978. As these chub gained weight with age, their influence was expressed in the catches, both in terms of species composition and weight.

4. Evaluation of the angler census technique

As with other methods of sampling fish populations, angling is undoubtedly selective, *e.g.* hook and bait size often determines the size and species caught (Moore 1973). Indeed, Cooper & Wheatley (1981), in their study on the River Trent, showed that fish < 10 cm long were rarely caught. Particular tackles and techniques are selective against smaller-sized species and the importance of these species in the fauna may therefore be underestimated. However, excluding fish <10 cm long, there is little evidence that angling is more selective than any other sampling technique.

Other factors which have a major impact on the accuracy of the data include environmental factors, *e.g.* water temperature, discharge rate and precipitation, and anglers' ability. North (1980) clearly showed that some species, such as bleak *(Alburnus alburnus)*, bream, dace and eel *(Anguilla anguilla)* make an increasing contribution to catches as temperatures rise, while others, especially roach and chub, predominate at lower temperatures. The mixed ability of anglers is well known and has been clearly demonstrated by Steinmetz (1986) who found considerable differences in the catches of young persons, ladies, and angling officials fishing the same water on the same day.

Despite the inherent errors in the use of the creel census technique, when a thorough investigation is made, the data obtained is no more selective or inaccurate than that obtained by electric fishing (Bohlin & Cowx 1989) or gill-netting (Hamley 1975). In fact in some cases it is considered to be more representative of the fish population (Axford 1979). The errors can be reduced by carrying out the survey over long periods of time (years) and large stretches of river, thus minimising problems created by varying angler ability, and differing environmental factors. Supplementary information on the biology of the species can be easily obtained by sampling the fish in the anglers' keep nets (Cooper & Wheatley 1981) and taking the necessary measurements, scale samples, etc. The technique has the distinct advantage of being cheap (Hickley & Starkie 1985) and does not require many trained personnel. The present paper has demonstrated that creel census can be a valuable tool to the fishery manager who requires information on the fish populations of large rivers and lakes where conventional sampling techniques are not possible.

Note

The opinions expressed are those of the author and not necessarily those of the Severn Trent Water Authority.

Acknowledgments

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References

Axford, S.N., 1979. Angling returns in fisheries biology. Proc. 1st Br. Freshwat. Fish. Conf. Univ. Liverpool. pp 252-271.

Ayton, W.J., 1976. Angling catch and its relation to stock in a Midland canal. Fish. Mgmt. 7: 12-15.

Bailey, N.T.J., 1951. On estimating the size of mobile populations from recapture data. Biometrica. 38: 293-306.

Bohlin, T. & Cowx, I.G., 1989. Implications of unequal probability of capture by electric fishing on the estimation of population size. Proc. Symposium on Fishing with Electricity, HCHE, Hull (in Press).

Cooper, M.J. & Wheatley, G.A., 1981. An examination of the fish populations in the River Trent, Nottinghamshire using angler catches. J. Fish Biol. 19: 539-556.

Cowx, I.G. & Broughton, N.M., 1986. Changes in the species composition of anglers' catches in the River Trent (England) between 1969 and 1984. J. Fish Biol. 28: 625-636.

Cowx, I.G., Fisher, K.A.M. & Broughton, N.M., 1986. The use of anglers' catches to monitor fish populations in large water bodies, with particular reference to the River Derwent, Derbyshire, England. Aquacult. Fish. Mgmt. 17: 95-103.

Hamley, J.M. 1975. Review of gill-net selectivity. J. Fish. Res. Bd Can. 32: 1943-1969.

Hickley, P. & North, E., 1981. An appraisal of anglers' catch composition in the barbel reach of the River Severn. Proc. 2nd Br. Freshwat. Fish. Conf. Univ. Liverpool. pp. 94-100.

Hickley, P. & Starkie, A., 1985. Cost effective sampling of fish populations in large water bodies. J. Fish Biol. 27: (Supplement A) 151-161.

Moore, D.E., 1973. The lower Nene, an exploited fishery? Proc. 1st Br. Coarse Fish. Conf. Univ. Liverpool. pp. 183-190.

North, E., 1980. The effects of water temperature and low upon angling success in the River Severn. Fish. Mgmt. 11: 1-9.

North, E., 1983. Relationships between stocking and anglers' catches in Draycote Water trout fishery. Fish. Mgmt. 8: 86-91.

Pearce, H.G., 1983. Management strategies for British coarse fisheries: the lower Welsh Dee, a case study. Proc. 3rd Br. Freshwat. Fish. Conf. Univ. Liverpool. pp. 262-273.

Raat, A.J.P., 1985. Analysis of angling vulnerability of common carp, *Cyprinus carpio* L., in catch-and-release angling in ponds. Aquacult. Fish. Mgmt. 16: 171-188.

Steinmetz, B., 1986. Bevissing en vangsten. Visserij 39: 58-77.

Williams, W.P., 1965. The population density of four species of freshwater fish, roach (*Rutilus rutilus* (L.)), bleak (*Alburnus alburnus* (L.)), dace (*Leuciscus leuciscus* (L.)) and perch (*Perca fluviatilis* L.) in the River Thames at Reading. J. Fish Biol. 34: 173-185.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 535-539.

The management of fisheries in estuaries frequented by migratory salmonids in England and Wales

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Abstract

Commercial fishing for salmon and migratory trout in estuaries and coastal waters in England and Wales is strictly regulated by the Regional Water Authorities. In these waters there are extensive fisheries for sea fish which are separately regulated by local Sea Fisheries Committees. There have been considerable problems with the illegal taking of large numbers of salmon and migratory trout by persons ostensibly fishing for sea fish. In the past it has been impossible to tackle these problems effectively because neither the Regional Water Authorities nor the local Sea Fisheries Committees has been empowered to make regulations controlling sea fisheries so as to protect salmonids. Recent changes in legislation have altered this position and there is now the opportunity for the different agencies to collaborate in the production of regulations which still permit the effective protection of salmonids whilst allowing *bona-fide* sea fishing activities to continue.

1. Introduction

Commercial fisheries for salmon *(Salmo salar)* and migratory trout *(Salmo trutta)* occur in estuaries and inshore waters round the northwest, southwest and northeast coasts of England, and round almost all of the Welsh coast. The total number of people licensed to fish commercially for salmon and sea trout in England and Wales in 1986 was 1015, and another 1841 persons were endorsed as agents of these licencees. The total reported commercial catch of salmon in 1986 was 190 447 fish weighing 343 tonnes, while that of migratory trout was 162 452 fish weighing 116 tonnes (all figures from Russell & Ducket 1988).

These commercial fisheries are strictly regulated by the Regional Water Authorities with the aim of ensuring enough escapement to freshwater to provide an adequate spawning stock, bearing in mind that further exploitation takes place by sport fishing within the rivers. However, in the same estuarine and coastal waters there are also extensive fisheries for marine species such as mullet *(Mugil* sp.*)*, bass *(Dicentrarchus labrax)*, flounder *(Platichthys flesus)* and cod *(Gadus morhua)*. These fisheries use instruments just as capable of catching migratory salmonids as those officially permitted for that purpose. Regulation of these fisheries is the responsibility of the local Sea Fisheries Committees.

The presence in salmon fishing areas of other fisheries operating under different regulations set by a separate agency has made effective enforcement of the salmon fishing regulations by the Regional Water Authorities almost impossible. This anomalous situation has been recognized by government, and legislation has recently been enacted which permits the different agencies to act together to resolve the problem. This paper explains the problems as they affected the North West Water Authority area (NWWA), and it describes the steps being taken to resolve them.

2. Regulation of fisheries in estuarine and coastal waters of England and Wales

The NWWA has responsibility for enforcing the provisions of the Salmon and Freshwater Fisheries Act 1975, and for protecting salmon and migratory trout stocks throughout an area stretching from the Scottish Border southwards to the Welsh border. The total length of coastline involved is approximately 315 km, and the authority's area of responsibility extends out to 6 nautical miles (approximately 11 km) from the coast. Fishing for salmon and migratory trout is regulated by a system of licensing, and in 1986 the total number of licences issued for commercial fishing was 306, with 77 additional persons endorsed on licences as agents. The number of licences issued for each individual estuary or part of the coast is restricted by Net Limitation Orders which specify the types and numbers of instruments which may be used. These Net Limitation Orders have to be confirmed by the Ministry of Agriculture, Fisheries and Food before the authority can enforce them, and the confirmation procedure involves public consultation. Licences are allocated by the authority each year, and preference has to be given to persons who held a licence in the previous year and who are dependent on fishing for their livelihood. With the exception of a few instruments of ancient usage and historic interest, the use of fixed engines for fishing for salmon and migratory trout is illegal. A fixed engine, broadly speaking, is defined as any fishing instrument which is fixed to the soil or made stationary in any other way, or is fished unattended, and includes fixed nets. The permitted instruments are therefore moveable nets of various types such as seine, drift and haaf nets. The types of nets permitted and the areas in which each may be used are set out in the Authority's Fisheries By-laws and Net Limitation Orders. Localities where fish could be particularly vulnerable to capture, such as the upper part of an estuary, or the area adjacent to the mouth of a river which has no clearly defined estuary, are made prohibited areas. The dimensions and mesh sizes of the nets and the manner in which they may be used are also specified in the by-laws. Nets made of monofilament material are prohibited. There is a statutory closed season of 153 days for fishing for salmon which covers the period between 31st August and 1st February and a closed season of 181 days for migratory trout (between 31st August and 1st March). There is also a statutory weekly closed time of 42 hours (which in most of the NWWA area is extended by by-law to cover the 48 hour period 06:00 hours on Saturday to 06:00 hours on Monday). There are other by-laws also in force, covering matters such as labelling of licensed nets, identification numbers on fishing boats, and a requirement to make a return to the authority detailing all fish caught.

The effect of these various statutes and by-laws is that commercial fishing for salmon and migratory trout is strictly regulated as regards who can fish, when and where they can fish, what type of nets they can use and how they can use them. The primary aim is to prevent over exploitation of stocks. If a decline in stocks in a particular river becomes evident, the Water Authority can apply to the government for confirmation of alteration to Net Limitations Orders and by-laws to further restrict the amount of fishing which may take place.

In contrast, the extensive fishing for marine and estuarine fish which goes on in the same areas as the salmonid fisheries has, up to now, proceeded with very few restrictions. The responsibilities of the local Sea Fisheries Committees, of which there are two in the NWWA area, did not formerly extend beyond the requirement to conserve stocks of these marine species, using powers under the Sea Fisheries Regulation Act 1966. Thus they had no power to impose restrictions for the purpose of protecting salmonids migrating through the areas under their control (basically from the coastline out for 3 nautical miles, but excluding the uppermost parts of estuaries). Similarly the Regional Water Authorities have no powers to restrict sea fishing. The sea fisheries are open entry, with no limits on the numbers fishing and with no closed seasons or weekly closed times. Methods not permitted for salmonids, such as the use of fixed gill-nets and stake nets, have been in widespread use with only minor restrictions on their operation. Unlimited numbers of drift nets have been able to operate in any part of the area.

3. Conflict between protection of migratory salmonids and fisheries for marine species

The existence in the same areas of closely regulated fisheries for salmonids and virtually unrestricted fisheries for sea fish is an obvious recipe for conflict. In the NWWA area the main problems have been persons setting fixed nets, ostensibly for catching sea fish such as flounder, in the migration pathways of adult salmon and migratory trout. In some parts of the region, particularly the Morecambe Bay area and the Ribble Estuary, there have been problems with persons drift netting with monofilament nets, who when challenged claim to be fishing for mullet and bass. Although these fishermen do take fish of the species they are entitled to catch, they also take significant numbers of salmon and migratory trout. If caught with salmon or migratory trout in their possession, they can be prosecuted for taking these fish in an illegal fixed engine or unlicensed net, but they have become very adept at smuggling fish ashore without being apprehended. Courts also often require evidence that the offender intended to take salmon and sea trout and will acquit without such evidence.

With only limited manpower resources it has been impossible for the Water Authority, as the enforcing authority, to police effectively all the areas where salmon may be taken as 'by-catch' to the 'sea fishery' but in the NWWA area it is suspected that in the past it may have equalled at least 50% of the catch taken legally by licensed salmon fishermen. This has obviously made proper management of salmonid fisheries, by regulating exploitation, an impossible task. Elsewhere in England and Wales the problems have been equally acute.

Recently the position was further complicated by an Appeal Court decision that under the Salmon and Freshwater Fisheries Act of 1975 all fixed engines were illegal, regardless of whether or not they were set with the intention of taking salmon or migratory trout. Although this enabled the Water Authorities to deal with the problem of fixed engines which they were satisfied were being set deliberately to catch salmon, it left them with the problem of also having to interfere with those set to catch sea fish in areas where there was no threat to salmonids.

4. Recent changes in legislation

After carrying out a review of salmonid and coastal water fisheries, the government acknowledged that a problem existed which could only be resolved by changes in legislation. The outcome was a new piece of legislation, The Salmon Act 1986. This deals largely with the administration of salmon fisheries in Scotland, but that part of the Act concerning England and Wales gives the Regional Water Authorities and Sea Fisheries Committees powers to act together to resolve the conflict of interests in estuaries and coastal waters. The problem of fixed engines has been met by empowering the Sea Fisheries Committees to make by-laws authorising specified fixed engines, provided that they have consent from the local Water Authority. This will enable a Water Authority to prevent a by-law being made which would authorize the placing and use of a fixed net to take sea fish if they considered that there was an acceptable risk that the net would intercept salmon or migratory trout. Water Authorities also now have the powers to make by-laws to authorize fixed engines in those areas where the Sea Fisheries Committees have no jurisdiction. All unauthorized fixed engines are illegal and can be removed or destroyed by enforcement officers.

The Salmon Act 1986 also empowers Sea Fisheries Committees to make by-laws for the protection of salmon and to prevent interference with their migration. Thus these Committees can now make by-laws regulating sea fishing but with the aim of protecting salmon or migratory trout. These by-laws can only be made with the consent of the Water Authority, and there is nothing to preclude a Water Authority from making the initial approach to a committee to ask them to make such a by-law. Another section of the 1986 act creates an offence of 'handling salmon in suspicious circumstances' which may also have application to the catching of salmon under the guise of fishing for sea fish.

5. Proposed measures to provide protection for migrating salmonids

These changes in legislation provide the opportunity to deal with the problems of the unlawful catching of salmon and migratory trout in estuaries and coastal waters without interfering unnecessarily with the activities of *bona-fide* sea fishermen. Discussions are currently taking place between the NWWA and the two Sea Fisheries Committees as to the new by-laws needed to achieve these objectives. As far as fixed engines are concerned, the intention is to authorize their placing and use for taking sea fish, in such areas and at such times of year, as would present no threat to migrating salmonids. Thus their use would be permitted fairly widely (including in shallow waters and areas adjacent to river mouths) during the winter months when very few salmon are moving along the coasts and through the estuaries. However, at other times of year they will only be permitted in deeper water, where there is 3 metres or more of water above the net at all states of the tide. This will permit the continuance of genuine demersal fisheries for cod, etc. There will also be general conditions relating to the use of fixed engines, the maximum length permitted, exclusion of fixed engines from low water channels, proximity of engines to one another, and proper marking and labelling of engines. It will continue to be an offence to use a fixed engine for taking or facilitating the taking of salmon or migratory trout, and any such fish which are taken accidentally will have to be returned to the water, dead or alive.

By-laws are also under consideration relating to instruments other than fixed engines. Drift and seine netting for sea fish in protective 'boxes' off the mouths of rivers and in estuaries will be prohibited, and also trawling, other than for crustaceans, in low water channels. Drift nets of a mesh size large enough to take salmon or migratory trout will also be prohibited along certain lengths of coast during periods of the year when migratory salmonids are likely to be present there. This is mainly between May and November.

The overall objective is the production of a set of by-laws which will enable the enforcement agencies to deal effectively with the problem of the illegal taking of salmonids, whilst allowing the *bona-fide* sea fisherman to go about his business lawfully and without fear of harassment. Reduction of illegal, and therefore unrecorded taking of salmon and migratory trout will enable the fisheries to be regulated more effectively, and will thus improve the chances of meeting conservation requirements.

To conclude, experience has shown that for proper management of fisheries in estuaries and coastal waters where different stocks mix, it is essential for a collaborative approach to be adopted, and for the interactions of different fisheries to be clearly identified and appropriate management actions taken to prevent one fishery from damaging another.

References

Russell, I.C., & Duckett, L., 1988. Salmon and Migratory trout fisheries statistics for England and Wales, 1986. Fisheries Laboratory, Lowestoft. Data report 12. 17 pp.

Sea Fisheries Regulation Act, 1966. HMSO, London. 12 pp.

Salmon and Freshwater Fisheries Act, 1975. HMSO, London. 43 pp.

Salmon Act 1986. HMSO, London. 46 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 540-546.

Collection of catch data from salmon and sea-trout rod fisheries in Wales

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Abstract

The collection of catch data from rod fisheries for salmon and sea trout in Wales is described. A catch return system based upon licence sales is used to collate information from some 15 000 anglers who buy a licence annually. This is done to quantify long-term changes in the quality of the rod fishery and the fish stocks. A method of data analysis is used which allows an index of catch to be calculated and this is comparable from year to year.

1. Management scheme

Recreational rod fishing is an important activity for a large number of people in Wales. Each year about 85 000 fishing licences are issued to anglers by the regulating body, the Welsh Water Authority. Of these licences, approximately 15 000 are issued for the salmon *(Salmo salar)* and sea trout *(Salmo trutta)* fishery which takes place on some 50 rivers. The fishery is of economic importance locally, through the generation of rents and permit fees paid to water owners and the attraction of visitors into the locality. Management is exercised with the objectives of conserving fish stocks while allowing controlled exploitation to take place in order to generate an economic yield. A number of types of data are therefore collected to enable fisheries managers to:

- Quantify long-term changes in the quality of rod fisheries.
- Identify changes in the fish stocks which support those fisheries, such as weight distribution and the timing of runs.
- Identify the reasons for those changes.
- Estimate the economic and social value of rod fisheries.

2. Catch data collection system

Information on rod caught salmon and sea trout has been collected by the Welsh Water Authority and its predecessor organisations for a number of years. Water bailiffs operating in particular defined areas provided estimates of numbers caught, based on local knowledge, prior to 1976, when a standard method was introduced throughout the authority's area.

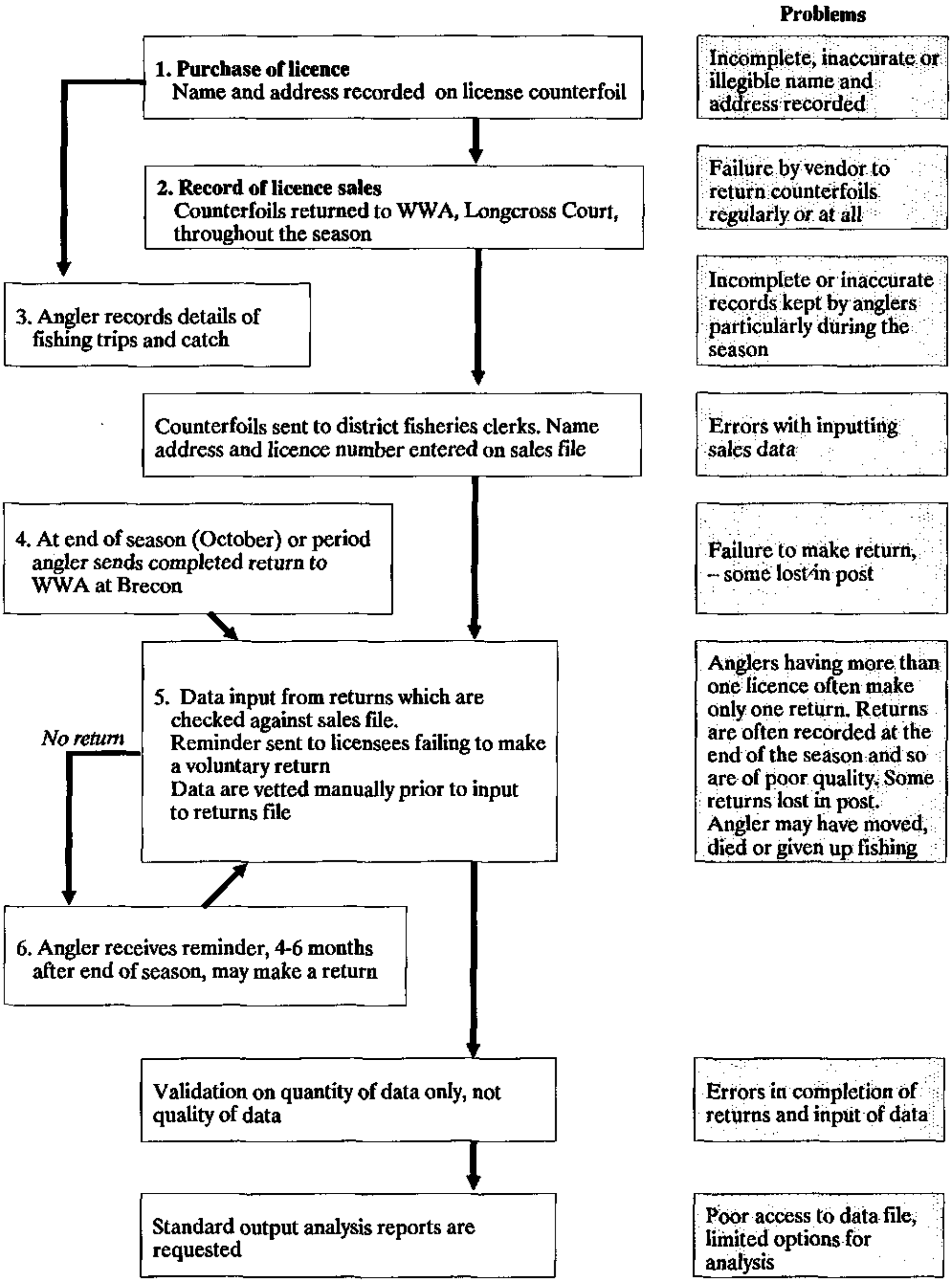

Figure 1. Flow diagram of data system for catch statistics

All anglers fishing for salmon and sea trout are required by law to possess a fishing licence issued by the authority. Each licence records essential angler information in duplicate, and each includes a pre-paid postal catch return form. An authority by-law requires that anglers make a return for each day's fishing whether or not fish are caught. The details requested are date of capture, river, species, weight of individual fish, method of capture and fishing effort in terms of number of days fished.

A computer-based storage system, designed in 1975, and charted in *Figure 1*, holds data from some 15 000 licence counterfoils submitted annually by approximately 400 sales agents. This 'sales' file is updated periodically as returns are received, but as a result of the agent's preferred method of working the majority of counterfoils are received over a two-month period at the end of the year.

2.1 Limitations of the present system

There are a number of problems which constrain both the quantity and quality of data collected:

- Licence agents often fail to record anglers' names and permanent addresses accurately and legibly on sales counterfoils.
- Some agents fail to send in sales counterfoils promptly, if at all, resulting in discrepancies between the number of licences sold and the number on the 'sales' file. These discrepancies amounted to 12.1% in 1983 and 28.4% in 1985.
- Errors can occur with the input of sales data, particularly as a result of incorrect recording of names and addresses by licence sales agents.
- Anglers often complete the catch returns at the end of the season and, therefore, the accuracy of their data is dubious, particularly for effort and fish weights.
- Voluntary returns account for 26-33% of licence sales and it is clear therefore, that the majority of anglers do not make returns unless prompted *(Table 1)*. Total returns, after reminders, range from 55 to 66% of licence sales. Thus there appears to be a fairly constant proportion of anglers who do not make returns.
- Other sources of error include multiple returns, when more than one short-term licence is purchased by the same angler, and from the re-issue of lost licences. A study of anglers in South East Wales (Mawle unpublished) showed that 6.3% of licence counterfoils of all types had replicate names and addresses. As salmon and migratory trout licences tend to consist of a smaller proportion of short-term licences than other types it is suggested that replicate licences would account for a maximum 5% of sales.
- Returns may be lost in the postal system. In November 1986, in a trial, 342 blank returns were posted in various parts of Wales. The median period of return was five days and 90% of returns were received within eight days. A total of nine returns were not received representing 2.7% of the number posted.
- Delay in returning counterfoils, and thus the recording of sales data on the computer, results in reminders being sent out between four and six months after the end of the season. The quality of resulting returns is therefore likely to be poor. In addition, the longer the time period before reminders are sent out, the greater the chance that the licence holder has changed address or died. A survey in South East Wales showed this loss rate to be about 1% per month (Mawle unpublished). The survey also indicated that anglers would be substantially more willing to respond to a reminder received immediately after the end of the season.

Table 1. Analysis of salmon and sea trout catch returns for 1976-1985.

Year	Initial returns			Returns after first reminder			Returns after second reminder			Total returns				
	% returned	Fish/return		% returned	Fish/return		% returned			% returned	Catch numbers		Fish/return	
		Salmon	Sea trout		Salmon	Sea trout		Salmon	Sea trout		Salmon	Sea trout	Salmon	Sea trout
1976	28	0.78	1.30	22	0.20	0.68				30	4947	9579	0.44	0.85
1977	27	1.58	1.60	36	0.16	0.65				63	10371	14207	0.77	1.06
1978	26	1.51	1.93	32	0.14	0.41				58	9822	14209	0.76	1.09
1979	27	0.86	2.15	28	0.22	1.61				55	6503	22647	0.54	1.87
1980	28	1.48	2.80	33	0.17	0.94				61	9672	22446	0.77	1.79
1981	33	1.37	2.19	27	0.17	1.20				60	10742	22485	0.83	1.74
1982	28	0.85	2.17	38	0.20	1.23				66	6287	21632	0.47	1.63
1983	28	0.88	3.15	33	0.30	1.19	5	0.6	2.74	66	6301	23567	0.57	2.14
1984	33	0.60	3.60	26	0.26	1.30				59	3194	18407	0.45	2.60
1985	31	0.99	2.87	31						62	7039	20868	0.98	2.91

2.2 Uses of data

It is important that the data collected are relevant to management needs. For salmon and sea trout fisheries these include:

- Annual, monthly and, in some cases, daily indices of catch.
- The composition, *i.e.* fish size and capture method, of annual and monthly catches.
- An annual index of fishing effort and, hence, catch per unit effort.
- Information on angler origins and distribution of fishing effort between different origins.

The reliability of any conclusions drawn from the catch statistics will depend upon their accuracy. It must be noted that figures relate to in-season runs of fish only, and catches are minimum catches, based upon an average 60% return rate. Therefore, changes in the timing of the runs of fish and/or angler return rates can cause major problems in interpretation of the data. For this reason, catches are unlikely to be directly related to stocks, and data from other sources are required to provide an overall assessment of the status of stocks, *e.g.*, data from juvenile surveys, and trapping and tagging studies.

Since managers are primarily concerned with long-term changes in catches, inaccuracies in catch statistics may not be critical provided that any biases are consistent from year to year. Whilst it is desirable that declared catches should be as close as possible to total catches, since this improves the confidence with which they can be used, for most purposes it is not necessary to obtain an estimate of the total catch. Instead, only a reliable index of catch is required, *e.g.* catch from a fixed proportion of licencees. More detailed and complete data on catches can be obtained via creel surveys, however, these require intensive supervision of fisheries to ensure high return rates.

Catch return rates are estimated from the total number of licence sales within the Welsh Water Authority's area and may vary from river to river. It is therefore important that a cautious approach be adopted when attempting to use this data for management of stocks on any particular river.

3. Improvements to the system

Sales Data: the recording of sales data is often unsatisfactory and may lead to loss of information. Licence issue from one central location may alleviate this problem.

Returns Data: the total proportion of returns received has remained fairly constant at about 60% since 1976 suggesting that a constant proportion of anglers will not make a return. Improvements to the catch return form are indicated but perhaps more importantly the delay in issuing reminders should be reduced. This might be achieved by concentrating effort upon the season licence group who account for 65% of sales and 95% of salmon reported caught. A system presently under consideration involves the sale of licences from a single outlet and the issue of reminders before the end of the fishing season.

4. Data analysis

Details of reported catches by river, species, month, weight group and method of capture, are published annually, together with weight frequency distributions and details of the operation of the reminder system.

More complex analysis depends largely upon the conversion of the computer system to a more readily managed database system and upon confidence in the precision of the data themselves.

The fact that some 40% of anglers fail to make a return suggests that serious inaccuracies may be inherent in the data. *Ad hoc* comparisons of data collected through the catch return system, and other methods, have revealed the potential for under-declaration of catches. For instance, data on catches of salmon collected by water bailiffs on the Rivers Wye and Conway from 1980 to 1986, when compared with data from the catch return system, suggest an under-declaration of 17-35% on the Conway and 44-55% on the Wye.

In an effort to estimate the catch by those not making a return, a second reminder was issued in 1983. A total of 4057 such reminders (25% of licences issued) resulted in 844 returns (5% of licences issued) declaring 505 salmon.

This reminder was not dispatched until 6 months following the close of the fishing season under investigation and cannot therefore be relied upon as giving meaningful information. This exercise has not been repeated.

Table 2. Number of salmon reported to the catch return system. SALMONu = from unprompted returns, SALMONp = from prompted returns, SALMONm = estimated from missing returns. SMu = catch per unprompted return, SMp = catch per prompted return, SMm = catch per missing return. See section 5 for further explanation.

Year	SALMONu	SALMONp	SMu	SMp	SMm	SALMONm	TOTAL
1976	4109	838	0.78	0.14	0.02	187	5134
1977	9108	1262	1.58	0.16	0.02	135	10505
1978	8807	1015	1.51	0.14	0.01	125	9947
1979	5128	1375	0.86	0.22	0.06	571	7074
1980	8509	1163	1.48	0.17	0.02	159	9831
1981	9726	1015	1.37	0.17	0.02	192	10933
1982	4785	1502	0.88	0.20	0.05	311	6598
1983	4123	1673	0.88	0.30	0.10	689	6485
1984	2394	800	0.60	0.26	0.11	827	4021
1985	3585	N/A	0.99	N/A	N/A	N/A	N/A
1986	4819	1585	0.89	0.39	0.17	1178	7582

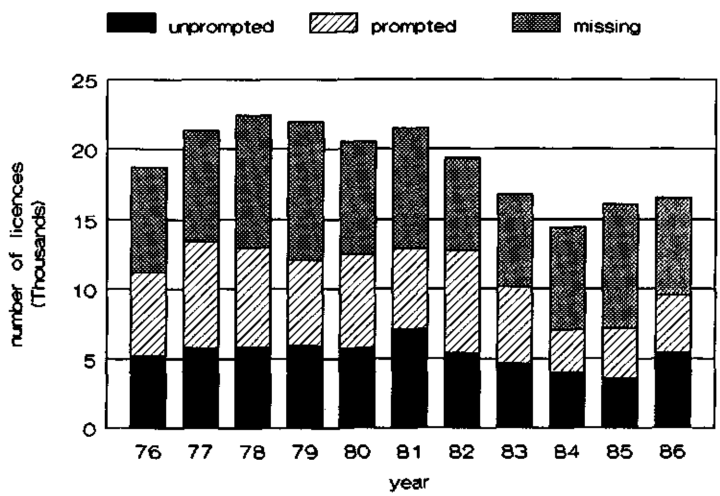

Figure 2. Total number of licences sold, showing the shares of unprompted, prompted, and missing returns.

5. Relationship between prompted and unprompted returns

It was thought that an examination of the relationship between unprompted and prompted returns might give some clues as to the significance of the catch from the group who do not make returns. *Figure 2* and *Table 2* present data relating to annual licence sales, returns, catches and catch rates in which:

SMu = SALMONu/number of unprompted returns = catch per unprompted return.

SMp = SALMONp/number of prompted returns = catch per prompted return.

It is thus possible to estimate catch rates for missing returns based upon assumptions of their probable angling success. *Table 2* gives an estimated value (SMm) based upon the assumption that the relationship between the numbers recorded by prompted and unprompted returns is equal to that between the numbers recorded by the prompted returns and the number caught by the 'missing' group *i.e.* SMp/SMu = SMm/SMp. A total catch can thus be estimated.

In a similar exercise Small & Downham (1985) attempt to demonstrate that this method of estimating total catch is sufficiently robust to be applicable to other rivers and to stillwaters for non-migratory trout. Both analyses use data pooled for a number of rivers and attempt to apply results from these data to estimate total catch from individual rivers based upon unprompted returns alone.

However to achieve this objective the methods require that the number of anglers fishing a given river is known. In the Welsh Water Authority area only the total number of licences sold in the region is known and estimates of total catch will be biased if Pu, the proportion of anglers making an unprompted return, varies significantly from river to river. For those rivers with a greater than average return rate, the catch will be over-estimated whilst it will be under-estimated on those rivers with a less than average return rate.

6. Conclusion

Whilst the total catch of salmon in the Welsh Water Authority's area may be estimated using the method described, sufficient sources of error exist to reject the result so obtained. However, the method does provide an index of catch comparable from year to year provided that equal effort in collecting data is employed each year. An index of catch may be estimated for individual rivers but should be corroborated by independent methods such as creel surveys.

In that the rod catch is only one component of the in-river stock, the method cannot be used as an index of stock abundance, either regionally or for individual rivers, but can be employed as a management tool in conjunction with other measured data such as juvenile population estimates, spawning population estimates and electronic fish counter data.

Reference

Small, I. & Downham D.Y., (1985). The interpretation of anglers' records (trout and sea trout, *Salmo trutta* L. and salmon, *Salmo salar* L.). Aquaculture and Fisheries Management. 16: 151-169.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 547-557.

Fish community structure and management in navigated British canals

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Abstract

The fish communities in four canals of average width 10-14 metres, carrying recreational boat traffic with 500-10 000 movements per year, were sampled in July 1986. Between 5 and 8 sites, each 25 metres long, were selected on each canal and their fish populations were estimated by a catch-removal method, using micromesh seine nets fished between micromesh stop nets. Fish community structure varied according to boat traffic density, with the heavily trafficked, turbid ecosystems having the least species diversity, no piscivorous sight-feeding pike, and large numbers of gudgeon which are barbel feeders. Fish biomass ranged between 99 and 253 kg/ha and was highest in the least trafficked canals. Roach were numerically dominant in all systems but the maximum size achieved in the turbid canals was poor, less than 100 individuals reaching a length of 15 cm per hectare in these waters. Stocked common carp grew well, sometimes reaching specimen size (9 kg) in the presence of heavy boat traffic.

Canals are important sites for recreational angling, especially in areas where river water quality is poor. Heavy recreational boat traffic is perceived by anglers as detrimental to canal fisheries because of adverse habitat effects and physical disturbance to angling. The revenue derived from boats greatly exceeds that from angling, so fisheries enhancement schemes should assume no decline in boat use on the most popular canals. The biomass present in three of the four canals sampled was satisfactory to meet the requirements of a recreational fishery, but the small size of fish, although possibly acceptable to competition anglers, is not adequate for pleasure anglers. Large carp are exploited by specimen anglers, but canals have traditionally been fished by large numbers of anglers and management policies should attempt to meet the requirements of all user groups where this is practicable.

1. Introduction

There are approximately 3100 km of navigable canals and rivers in Britain. These waterways were constructed in the eighteenth and nineteenth centuries for the carriage of freight. Today only 558 km are designated as 'commercial waterways' under the terms of the 1968 Transport Act and are still used mainly for freight transport. Most of the system is designated as 'cruising waterway' (1877 km) and this is used for a variety of recreational purposes of which boating and angling are the most important revenue generators (Hall 1985). The final category is 'remainder waterways' (711 km). These are not necessarily managed for leisure, but nevertheless have considerable recreational usage (Hall 1985).

Whilst boating dominates canal usage in terms of revenue generated, angling is almost as important in terms of numbers of participants, with over 0.75 million adult anglers using the canal system in 1984 (BWB 1986).

The income *per capita* from each angler has been identified as a potential source of increased revenue (Hall 1985). Canals are particularly heavily utilised by anglers in areas where river water quality is poor, such as in the industrialised areas of North West England. Here 40% of anglers regularly fish on canals (NERC 1971). Most of the cruising waterways are relatively narrow artificial canals, being 8-15 m wide, so there is considerable interaction between boats and anglers and multi-user conflict is a potential cause for concern (BWB 1986). Anglers perceive boats as being a nuisance in a number of ways. First their movements can be a direct physical disturbance to the act of fishing (O'Riordan 1978, Owens 1978). Secondly, and more importantly, the reduction in aquatic vegetation with increasing traffic density, documented by Murphy & Eaton (1983), is widely assumed by anglers to be detrimental to fisheries (Murphy & Eaton 1981). Paradoxically, two of the most heavily trafficked waterways, the Shropshire Union and Oxford Canals, are popular in terms of angler usage, at least for competitions (Norman & Cooper 1985). Competition anglers are only a minority of those who fish canals overall (NOP 1980), but they are an important user group on the heavily trafficked waterways.

Heaps & Pearce (1985) have shown that the widely assumed view, that anglers wish to capture large fish (Pitcher & Hart 1982), does not apply to coarse fish competition anglers in Britain. The result of this dichotomy of view means that management objectives are not easy to define for coarse fisheries. In fact the capture of small fishes is an important feature of many prestigious coarse fisheries, such those of the Rivers Nene and Trent, where competitions are common (Moore 1973, Cooper & Wheatley 1981). Observation of catches made during canal competitions suggests that small species and individuals may be even more important than they are in the rivers previously mentioned.

The present study sought to estimate the abundance of all species and sizes of fish in four canals carrying a wide range of boat traffic densities, to give some insight into the availability of the coarse fish present for recreational exploitation and management.

2. Methods

Traffic densities were measured in movements/ha/metre depth of water/year (my) as in Murphy & Eaton (1983). Site details for the four canals chosen for study are listed in *Table 1*. In July 1985 eight sites were sampled on each canal, except for the Rufford Branch. Seine netting with micromesh nets was used with the 'three catch-removals technique' over 25 metres of canal described in detail by Pygott, O'Hara, Cragg-Hine & Newton (in press). All fish, except for large specimens (approximately 15 cm and over) were returned to the laboratory for fork length and weight determination, the larger specimens were weighed, measured and returned alive to the canal. Population densities and biomasses were calculated according to the methods of Zippin (1956) and Mahon, Balon & Noakes (1979) respectively. Data on competition fish catches from the Oxford Canal, a heavily trafficked canal, and the Leeds Liverpool Canal which only carries a light boat traffic, were obtained from the results of two of the national fishing competitions, the results of which are published in the Angling Times with details of the total weight of fish caught by each angler.

Data from routine water authority fish population surveys were collected by writing to individual authorities requesting information. These observations were compared with the results of a questionnaire devised to identify angler's attitudes to the quality of canal fisheries.

Table 1. Canals used for main fisheries sampling in July 1985. Boat traffic density is in movements/ha/ metre depth/year.

Canal	Location: OS National Grid map reference	Number of 25m lengths sampled	Mean width (m)	Mean depth (m)	Boat traffic density	Aquatic vegetation (g/m^2) *
Rufford Branch	SD 465155 to 455130	5	13.1	0.97	500 - 600	117.0
Lancaster	SD 498357 to 9005673	8	13.7	1.03	2500 - 3000	63.2
Macclesfield	SJ 927788 to 905673	8	10.8	0.75	5000 - 5500	0.8
Shropshire Union	SJ 713288 SJ 642483 SJ 672605	8	12.5	0.92	9500 - 10000	0.3

* dry weight of submerged and floating leaved vegetation in July (g/m^2)

3. Results and discussion

The use of small mesh seine nets meant that large numbers of small fish were captured, particularly roach *(Rutilus rutilus)*. In order to indicate the importance of these fish we divided roach caught into those above and below 8 cm in length. This division additionally makes the results more comparable with other canal studies where electro-fishing techniques have generally been used, because electro-fishing biases against the capture of small fish, (Hickley & Starkie 1985). Analysis of these catches *(Table 2)* indicates a general community trend with increasing boat traffic, with a species change away from a tench/pike community, to one that is dominated by gudgeon *(Gobio gobio)* and small roach. The biomass measured by micromesh seine netting techniques revealed a substantial component available below the size of fish usually accounted for by electro-fishing (Pygott *et al.* in press). Total community biomass, may also decline with increasing traffic density in a general way, with the Rufford Branch being greatly superior in total weight of fish to the other three systems. The Shropshire Union Canal contains a slightly higher weight of fish than the Lancaster Canal but this rank order is reversed if the carp stocked in the former canal are excluded. The poor performance of the Macclesfield Canal is considered to relate to both the boat traffic and to the canal profile. Being shallow, the channel appears to be more severely disturbed by boat passages than its traffic density might indicate. Changes in the community status of the canals in relation to boat traffic have been greater in the Macclesfield Canal which, 20 years ago, supported diverse and extensive vegetation, had light boat traffic and was noted in angling periodicals for the quality of its fishery.

Roach were common in all four canals but differences in the abundance of size categories were apparent *(Table 1)*. To interpret these data in a meaningful way in terms of the recreational fishery, rather than on the basis of biological or sampling criteria, roach were numerically assessed in two length categories, greater than 15 cm and

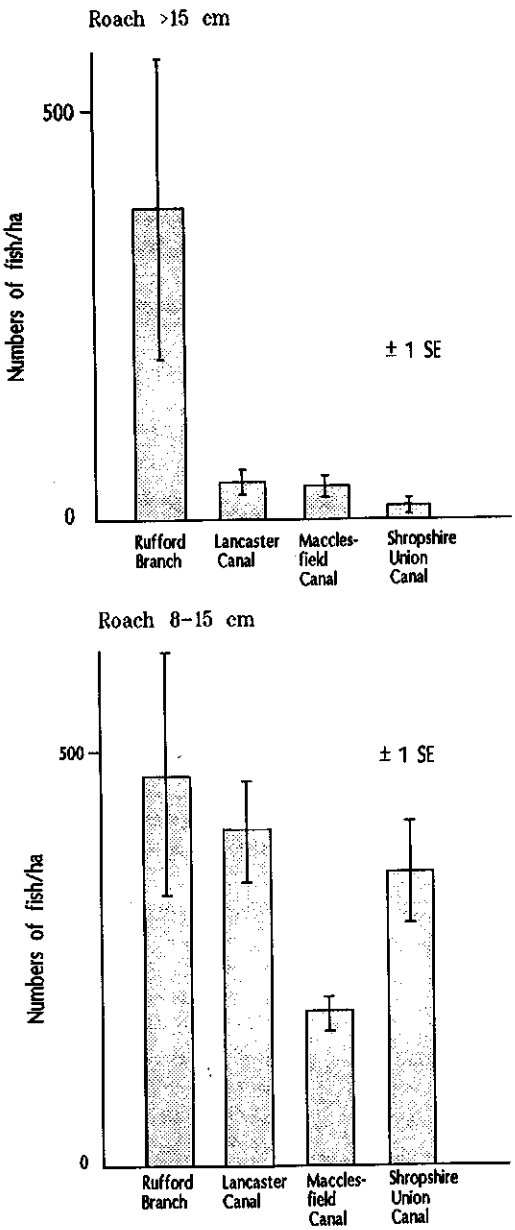


Figure 1. Mean number of roach of two different size categories in four canals.

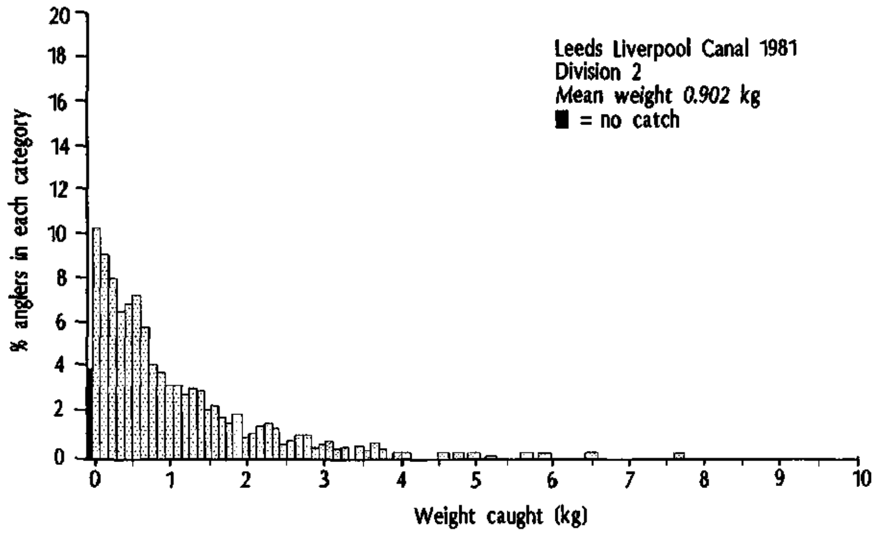
Table 2. Species composition in terms of biomass. All sampling sites combined for each canal.

	Shropshire Union Canal	Macclesfield Canal	Lancaster Canal	Rufford Branch
Species	Percentage of total community biomass			
Roach <8 cm	35.5	46.5	42.6	48.3
Roach >8 cm	28.4	14.1	16.3	18.2
Bream	1.4	6.1	11.8	0.8
Gudgeon	17.0	28.3	4.5	0.8
Eel	5.0		5.9	5.9
Carp	9.2			
Tench			1.4	11.1
Pike			7.3	6.3
Others	3.6	5.1	10.2	8.6
Total biomass (kg/ha)	141	99	136	253

between 8 and 15 cm *(Figure 1)*. These size categories were based on criteria similar to those used in 'proportional stock density estimation' derived by Anderson & Gutreuter (1983) which is used as a measure of the 'quality' of the stock in a fishery. The length of 15 cm is approximately that of a 57 g roach, which we consider to be the canal equivalent of a quality fish captured in angling competitions, as defined by Heaps & Pearce (1985). We also consider a roach of 57 g as being a satisfactory fish for a pleasure angler on a canal, with smaller individuals only being appropriate for competitions. The length of 8 cm is that previously identified as the minimum size caught by anglers in competitions (Moore 1973). However there is no doubt that the modern refinements of tackle, and the use of chironomid larvae (bloodworms) as bait, has led to the ability of anglers to capture smaller fish than reported by Moore (1973). A sample of fish captured for us by an angler included individuals as small as 2.9 cm (D.W. Pool pers. comm.).

The National Angling Competition data for each canal represent the results of 960 anglers fishing over a length of canal of approximately 19 km. Each individual angler's total catch weight was categorised in weight band with 0.1 kg increments *(Figure 2)*. Two features are evident, first very few anglers failed to catch any fish at all, reflecting the general abundance of fish in these canals. This accords with our sampling results. Second, there is a tendency for many anglers to catch more than 1 kg in the Leeds Liverpool Canal, in which tench *(Tinca tinca)* over 0.5 kg are common (Pygott *et al.* in press), whereas this is not the case in the Oxford Canal, which is dominated by small fish particularly gudgeon and roach. Here large fish, mainly chub *(Leuciscus cephalus)* and carp *(Cyprinus carpio)*, are uncommon (Norman & Cooper 1985).

The results from water authorities varied in the quantitative nature of the data and no detailed analysis could be produced, the same was true of results available from our questionnaire. However the information generally accorded with our captures in canals with differing traffic densities, we therefore combined all sources of data to produce a



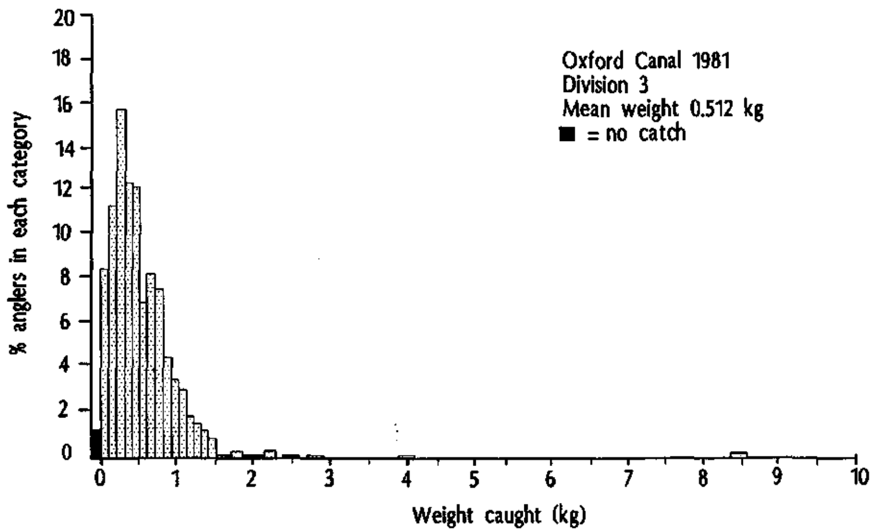


Figure 2. Histograms of weight distribution in two national championships on contrasting canals.

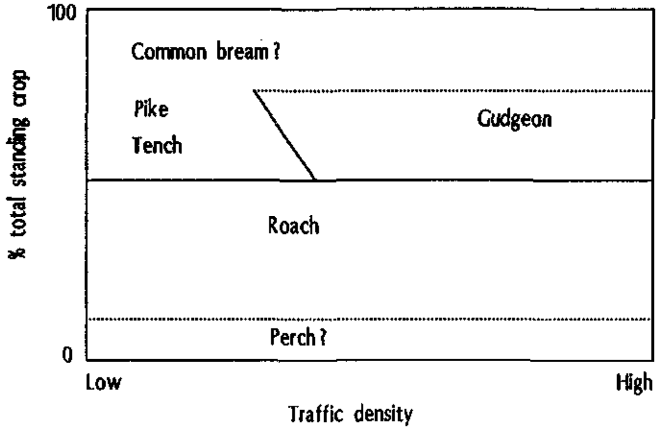


Figure 3. Diagrammatic representation of changes in the composition of fish populations with increasing boat traffic density. See text for further details.

diagrammatic representation of the general trends in fish communities in relation to boat traffic *(Figure 3)*. Further information derived from the questionnaire indicated a general dissatisfaction amongst anglers on canals with high traffic densities.

Murphy & Eaton (1981) similarly report surveys which indicate the dissatisfaction of anglers when boat traffic increases (see also BWB 1986). However care must be exercised in assessing these results because the answers obtained could depend on the categories of anglers surveyed. Briefly, three categories can be identified, namely specimen anglers whose objective is to catch large fish, pleasure anglers whose motive is self-explanatory and match anglers whose objective is to participate in angling competitions and win money. The motivation in the latter category is probably more complex and would require sociological analysis which is beyond the scope of this paper. Clearly there are problems in attempting to reconcile the interests of all of these potential user groups in any given length of canal. For example it is difficult, if not impossible, because of the natural constraints of carrying capacity, to have an adequate number of large fish available for capture if anglers are located at 15 m intervals, the usual distance apart in most competitions. Amongst competition anglers one of the major requirements is for the majority to catch some fish, irrespective of size, this is particularly true where competitions have prizes for team results in addition to those for individuals. Our results indicate the great abundance of small fish in heavily trafficked canals and the data available from a competition on the Oxford Canal demonstrate the ability of anglers to exploit the available fishery resource in a system that, biologically, could be categorised as degraded.

Linfield (1985) has published data on fish biomass in Anglian Water Authority navigations and concludes that boat traffic decreases fish biomass to an average of 50 g/m^2

in heavily used systems. Our data support this finding with regard to the direction of the trend, but they do not record such a steep biomass decline. We attribute this partly to the differences in fish size captured, which depends on the size of the mesh in the net used (Coles, Wortley & Noble 1985). In our study the fine mesh included large numbers of very small fish in the samples. Furthermore the type of fishing existing in Anglian rivers differs from that often exploited in competitions in canals, with bream *(Abramis brama)* catches being a noted feature of the Anglian waters. In addition our sampling technique may have underestimated the biomass of fish which are distributed contagiously in shoals, such as bream and larger roach, and individuals at a low density such as carp. Carp have been recorded at over 9 kg (Douglas pers. comm.) in the Shropshire Union Canal, and in certain sections fish over 2 kg are known to be common (Pygott *et al.* in press). We have also under-estimated the biomass of eels *(Anguilla anguilla)* present.

4. Management implications

Changes in the ecology of canals associated with an increase in boat traffic are to be expected. The impact of traffic on fisheries can be detrimental to certain types of anglers who are in pursuit of particular species. The decline of pike *(Esox lucius)* and tench appeared to be the most noticeable feature as traffic increased. The reduction of pike can possibly be interpreted as having two causes, namely interference with sight feeding by water turbidity and the scarcity of prey fish of adequate size. Possible causes of the decline in tench are discussed below. We have questioned any decline in perch *(Perca fluviatilis)* with increasing traffic *(Figure 3)*, and it is not clear whether any causal relationship exists. The low biomass generally observed could be the result of the perch disease that decimated British perch stocks in the 1970's. Our results tended to indicate the presence of more large perch in the Shropshire Union Canal, where the fish seemed relatively disease free, than in the lightly trafficked Rufford Branch where perch with lesions were still being captured in 1986. Our latest data (Pygott *et al.* in press), from sampling over longer lengths of the Shropshire Union Canal, confirmed that satisfactory numbers of perch, of a size large enough to be piscivorous in habit, were present. These feed on small cyprinids and are evidently succeeding in capturing their prey despite high turbidities.

The presence of large numbers of gudgeon in turbid canals may be something of a surprise to fish biologists, because this is a noted lentic species. However it reproduces well in these waterways. Undoubtedly the presence of barbels allows the efficient capture of prey. The low levels of abundance of larger-sized roach in heavily trafficked canals, and the excellent performance of carp (which are stocked into the canals), is at present the subject of further study, but the differences are believed to be related to the scarcity of macro-invertebrates when boat traffic is high (Murphy & Eaton 1971). Carp are euryphageous and opportunistic (Weatherley & Gill 1987), whereas roach appear to perform poorly in terms of growth when invertebrates are scarce in their diet (Mann 1967). Reasons for the decline in tench in the more heavily navigated waterways may also include inadequate food resources. Management of canal fisheries extends at one extreme from heavily weeded remainder canals, where oxygen sags can be a problem on summer nights, to heavily trafficked canals which, in addition to multi-user demands, are the subject of engineering works requiring periodic water level drawdowns. Both types of canal can provide fisheries that will appeal to particular sectors of the angling community, the former being more valued for the prestigious fish stocks that they may contain, whilst the latter may be more useful to competition anglers.

The demonstrated success of stocking carp in heavily trafficked systems raises complex issues since, although their growth performance exceeds that of the indigenous fishes, and they may appeal to specimen anglers, their presence is often unpopular with competition anglers because of the disproportionate effect the capture of a single individual fish can exert within a competition. The situation is further complicated by the fact that being a eurythermal species, carp feed actively, and are therefore generally only available for capture in the warmer months of the year. This coincides with the periods of maximal boat traffic. The increase in boat traffic, as well as causing community shifts in the heavily trafficked systems, has also resulted in changes in temporal usage, particularly by competition anglers. In summer, competitions start earlier in the morning on heavily navigated waters than on others, before most boats are moving. Also there is a switch to autumn and winter fishing. This latter trend obviously requires the presence of fish that will feed at low temperatures. Gudgeon and roach fulfil this requirement. Other important factors in the increasing popularity of winter angling have been developments in angling technology and the advent of adequate thermal clothing!

5. Management options

The ability to stock with common carp is clearly one possibility that has been successfully exploited. Although carp do not appear to recruit particularly well in Britain, especially in Northern areas, because of climatic conditions, the fact that they grow to a large size, combined with their longevity means only relatively small numbers need to be stocked to reach the carrying capacity of a system (Broughton & Easton 1983). By comparison, short lived, r- selected species like gudgeon are subject to natural wide fluctuations in population density, which are anticipated with this type of life history strategy (Mills & Mann 1985). These fish typically only achieve a maximum age of 2+ years in the Shropshire Union Canal and it is impossible to stock them when weak year-classes occur, simply because of the enormous numbers that would be required. For example we calculate that on this canal, if the 1+ fish were absent, it would require approximately 10 000 fish/km to restock to typical density. In more lightly trafficked systems tench are one of the most important indigenous species. This species, like carp, is readily available from aquaculture sources and since individuals are generally sought at a large size (cf Anderson & Gutreuter 1983), interventionist stocking measures can be implemented. In considering these three species as potential case studies, the longevity and occurrence of successful year-classes are important factors in sustaining the satisfactory performance of a fishery, as emphasised for rivers by Mann (1981). Since roach are the most ubiquitous species in canals and appear to recruit successfully on a regular basis, and because of the large numbers that would be required for any stocking programme, they should be left to natural recruitment. Natural stocks should generally meet management requirements. It is not difficult to manage lightly trafficked canals in normal circumstances. The major problems arise in the heavily trafficked systems. Perhaps one way forward is to utilise the demarcation points provided by navigation locks, to delimit sections that will be managed for different fisheries purposes, in much the same way that still water bodies have been developed. One obvious option is to designate some sections as match areas based mainly on natural fish recruitment and to actively manage other lengths as specimen fisheries based on carp and eels.

Note

The views expressed in this paper are solely those of the authors and should not be construed as representing those of the British Waterways Board.

Acknowledgment

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References

Anderson, R.O. & Gutreuter S.J., 1983. Length, weight and associated structural indices. In: Nielson, L.A. & Johnson, D.L (Eds). Fisheries techniques. Bethesda, American Fisheries Society. pp. 283-300.

BWB, 1986. The British waterways system - leisure and tourism on inland waterways. Leisure Research Paper 23. British Waterways Board, Rickmansworth. 30 pp.

Broughton, N.M. & Easton, K.W., 1983. Longevity in fish, and its management implications. Proc. 3rd British Freshwater Fisheries Conf. Liverpool. pp. 274-280.

Coles, T.F., Wortley, J.S. & Noble P, 1985. Survey methodology for fish population assessment within Anglian water. J. Fish Biol. 27: 175-186.

Cooper, M.J. & Wheatley, G.A., 1981. An examination of the fish populations of the River Trent, Nottinghamshire using angler catches. J. Fish Biol. 19: 539-556.

Hall, R. 1985. Leisure on inland waters. Proc. 4th British Freshwater Fisheries Conf. Liverpool. pp. 107-113.

Heaps, I. & Pearce, H.G., 1985. Match angling and the management of British coarse fisheries for sport. Proc. 4th British Freshwater Fisheries Conf. Liverpool. pp. 71-76.

Hickley, P. & Starkie, A., 1985. Cost effective sampling of fish populations in large water bodies. J. Fish Biol. (Supplement A.). 27: 151-161.

Linfield, R.S.J., 1985. The effect of habitat modification on freshwater fisheries in lowland areas of eastern England. In: Alabaster, J.S. (Ed.). Habitat modification and freshwater fisheries. Butterworths, London. pp. 147-156.

Mahon, R., Balon, E.K. & Noakes, D.L.G., 1979. Distribution, community structure and production of fishes in the upper Speed River, Ontario: a preimpoundment study. Env. Biol. Fish. 4: 219-244.

Mann, K.H. 1967. The cropping of the food supply. In: Gerking, S.D. (Ed.). The biological basis of freshwater fish production. Blackwell, Oxford. pp. 243-257.

Mann, R.H.K., 1981. Natural fluctuations in fish populations. Proc. 1st British Freshwater Fisheries Conf. Liverpool. pp. 146-150.

Mills, C.A. & Mann, R.H.K., 1985. Environmentally-induced fluctuations in year class strength and their implications for management. J. Fish Biol. (Supplement A.) 27: 209-227.

Moore, D.E. 1973. The lower Nene, an exploited fishery? Proc. 6th British Coarse Fisheries Conf. Liverpool. pp. 183-191.

Murphy, K.J, & Eaton, J.W., 1981. Waterplants, boat traffic and angling. Proc. 2nd British Freshwater Fisheries Conf. Liverpool. pp. 173-181.

Murphy, K.J, & Eaton, J.W., 1983. Effects of pleasure-boat traffic on macrophyte growth in canals. J. appl. Ecol. 20: 713-729.

NERC (Natural Environmental Research Council) 1971. National angling survey 1969-7. Main Report. London. NOP Market Research Ltd. 209 pp.

NOP 1980. National angling survey. Summary Report. Medmenham. Water Research Centre. 19 pp.

Norman, S. & Cooper, C., 1985. The ecological status of the fish population in the South Oxford Canal. Proc. 4th British Freshwater Fisheries Conf. Liverpool. pp. 114-120.

O'Riordan, T., 1978. Angling and boating. In: Alabaster, J.S. (Ed.). Recreational freshwater fisheries. Their conservation management and development. Medmenham. Water Research Centre. pp. 117-134.

Owens P.L., 1978. Interaction between fishermen and boat users on the Norfolk Broads. In: Alabaster, J.S. (Ed.). Recreational freshwater fisheries. Their conservation management and development. Medmenham. Water Research Centre. pp.135-147.

Pitcher, T.J. & Hart, P.J.B., 1982. Fisheries ecology. Croom Helm, London. 414 pp.

Pygott, J.R. O'Hara, K. Cragg-Hine, D. & Newton, C., (in press). A comparison of the sampling efficiency of electric fishing and seine netting in two contrasting canal systems.

Weatherley, A.H. & Gill, H.S., 1987. The biology of fish growth. London. Academic Press. 443 pp.

Zippin, C., 1956. An evaluation of the removal method of estimating animal populations. Biometrics 12: 163-189.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 558-568.

Fisheries management practices of the Severn Trent Water Authority in England 1976-1986

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Abstract

Legislation setting up ten Water Authorities of England and Wales in 1974, required them to maintain, improve and develop all salmonid, freshwater fish and eel fisheries in their areas of operation. This paper describes how the Severn Trent Water Authority went about this and how it financed the service.

The Authority's area consists of two distinct river catchments. The River Severn (a relatively clear-water river) contains nationally important commercial salmon, eel and elver fisheries, and various game and coarse fish angling waters. The River Trent, with major industrial towns on its head-waters, contains valuable coarse angling waters with some stillwater game fisheries.

It was clearly established at the outset, in 1975, that in order to achieve its statutory duty the Authority would have to develop an active fisheries management problem-solving service. This would encourage fishery owners and occupiers to manage their waters in the best possible way. How this service was developed and what it achieved is described. Various examples are given illustrating the different types of fisheries management practices applied in both catchments.

1. Introduction

The Severn Trent Water Authority is one of ten Water Authorities in England and Wales legally responsible for maintaining, improving and developing all salmon, trout, freshwater and eel fisheries in their areas of operation. (Section 28, Salmon & Freshwater Fisheries Act 1975). The Act (Section 25) also specifies that a Water Authority shall regulate fishing, and raise income by issuing fishing licences for which a duty is payable. The level of service necessary to achieve this statutory duty was consequently predetermined by finite income. Each water authority has therefore to list priorities. The act required that a water authority should set up and consult a Fisheries Advisory committee about this priority list.

This was against the background that the majority of freshwater fisheries in England and Wales are owned or managed by private individuals, organizations, companies or angling clubs. A few of these employ specialist fishery staff to manage their waters. Many waters are however, controlled by individuals or groups of people without the experience and expertise necessary to develop their own fisheries. It was therefore important that each water authority should have a sufficient number of specialist staff to show fishery occupiers how to look after their fisheries.

This paper describes the fishery resource that the Severn Trent Water Authority has to manage, and how and by whom the resource is used. The policies and fisheries management objectives adopted and applied over the ten year period 1976-1986 are described. The discussion considers whether these objectives were achieved, and if not, what were the constraints, and what modifications are now required.

2. The fishery resource

The Severn Trent Water Authority covers an area of 22 000 km^2 and has two distinct river catchments, those of the Severn and Trent, *Figure 1*.

2.1 The River Severn

The River Severn is the longest river in Great Britain. It is 354 km long with just under 2100 km of tributary streams. The river drains an area of nearly 11 500 km^2, containing a population of about 2 million people. The catchment also contains 450 km of canals and more than 1900 stillwater bodies greater than 0.11 ha, with a total surface area exceeding 4800 ha.

The river provides about 800 million litres of domestic and industrial water per day, for the resident population and for the West Midlands and Bristol. The Clywedog Reservoir, situated at the head-waters is used to augment flows through the greater part of the Severn and in addition, provides a significant measure of flood mitigation in the upper reaches. The average flow of the Severn at the tidal limit is 105 m^3/sec (9100 million litres/day).

The Severn has been described as a salmon river which also supports extensive coarse fisheries (Churchward, Hickley & North 1984, Hickley & North 1981, and Hunt & Jones 1975). As such it supports practically every kind of freshwater fish found in British rivers including salmon *(Salmo salar)*, trout *(Salmo trutta)*, barbel *(Barbus barbus)* and more recently pikeperch *(Stizostedion lucioperca)*. The complete range of British freshwater fish is also found in the stillwaters.

2.2 The River Trent

The River Trent is 280 km long, draining, with its 2200 km of tributaries, an area of 10 550 km^2. The catchment is inhabited by over 5 million people, almost half of whom live in the conurbations of Birmingham, the Black Country and Stoke-on-Trent. Other major urban centres include Nottingham, Derby and Leicester. The average flow of the Trent at Nottingham is 82.5 m^3/sec (7128 m^3 /day).

There are 432 km of canals in the area. The catchment contains 1543 stillwater bodies greater than 0.11 ha with an estimated total surface area of 4460 ha. Of these, 46% are in the size range 0.5-2.5 ha.

The last twenty years have seen a dramatic improvement in the quality of the Trent along its entire length (Lester 1979) and this has led to a corresponding improvement of the fish population. The Trent now supports a good coarse fishery downstream of Stoke-on-Trent and there have been increased numbers of estuarine and migratory fish in the tidal reaches, including the regular return of small numbers of salmon. The River Trent fisheries are described in greater detail by Cooper & Wheatley (1981), Cowx & Broughton (1986) and Easton (1979).

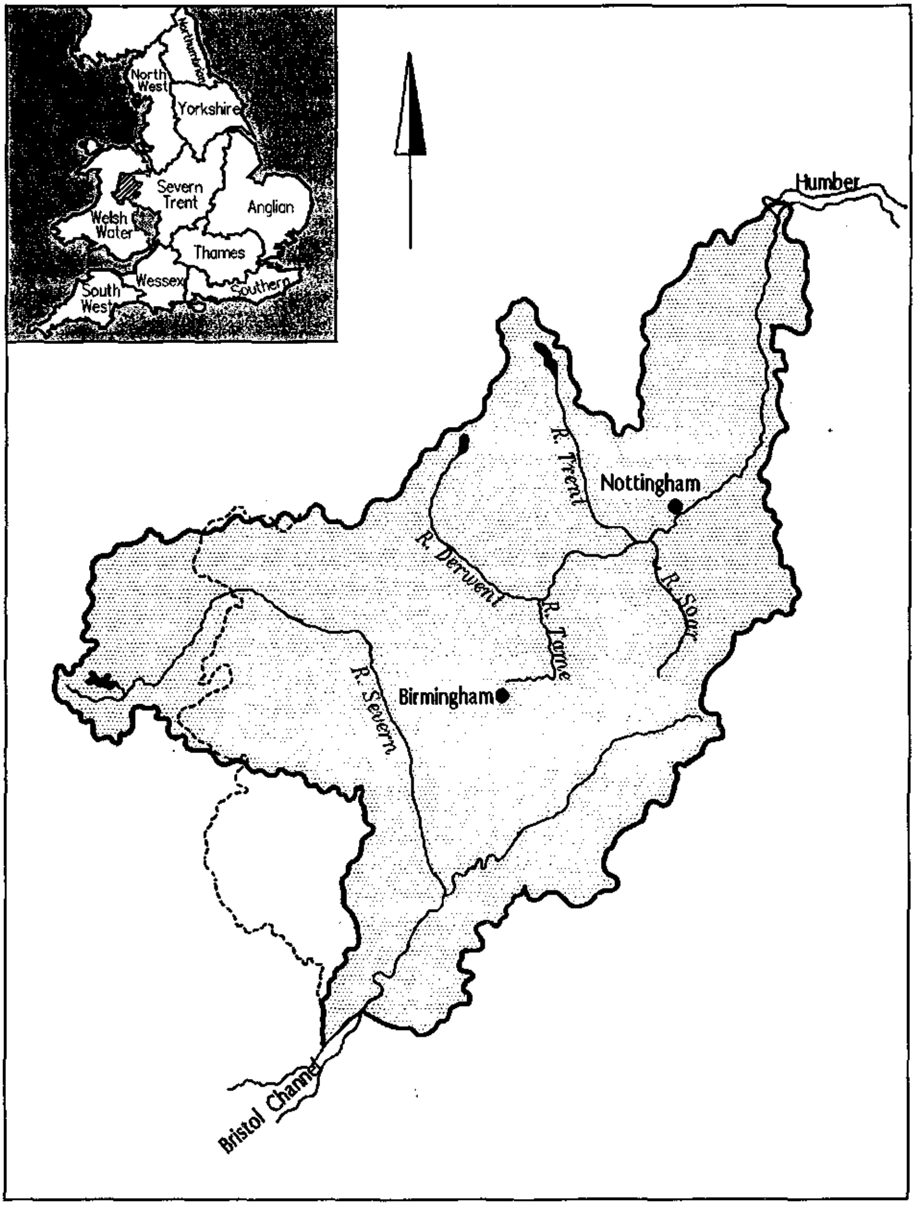

Figure 1. Location of the Severn Trent Water Authority area.

2.3. How the fisheries are used

Fishery areas can be used for all the recreational persuits associated with water and the countryside, such as sailing, water skiing, canoeing, bird watching and informal recreation (Dangerfield 1981). There are some 700 sites of 'special scientific interest' and two national parks, with several areas of outstanding natural beauty, in the Severn Trent Water area.

There is some commercial fishing, but the biggest demand in the Severn Trent Water area is for angling. As an indication of the level of use of waters, a total of £851 000 UK was raised in 1986 from the sale of 265 000 fishing licences. Of this £806 000 originated from the sale of a combined rod and line licence for trout and freshwater fish, £36 000 from a salmon rod and line licence, £5400 from commercial salmon licences and £3700 from commercial eel and elver licences.

The types of commercial salmon, eel *(Anguilla anguilla)*, and elver fisheries practised on the Severn are described by Templeton (1984). Rod and line anglers fish for salmon, trout and all the major coarse fish species. Competition (match) angling for coarse fish is very popular throughout the area, with nationally popular venues on the River Trent.

Table 1. Severn Trent Water Authority policy statement and objectives 1976.

Regulation — to review bye-laws every 5 years	
Conservation — Salmon fisheries	— ensure optimum exploitation of Severn — improve access to spawning areas — assess effect of water quality and barriers — trap and strip adult salmon for parr rearing — review Trent Salmon situation — decide whether to open upper reaches of Teme
Conservation for all other fisheries — general	— offer technical guidance to fishery occupiers — control fish movement for fish disease — designate some river lengths for specific fish
Conservation — trout fisheries — special policies	— develop trout rearing techniques including cages — produce all trout for own stocking
Conservation — freshwater fisheries — special policies	— research into coarse fish rearing techniques — invest in coarse fish holding sites — research cropping methods in large waters — develop NE drains for holding fish — projects to encourage survival of fry
Conservation — eel fisheries — special policies	— greater attention to eel and elver interests — develop as required eel traps — transfer Severn elvers to other sites
Miscellaneous	— install monitoring equipment for upstream salmon — offer fishery improvement grants — controlled experiments on own fishing waters — general awareness of need for effective policy to control spread of fish diseases

3. Policies and management

3.1 Policy making

The Severn Trent Water Authority policy for fisheries was formulated in 1976 after consultation with its Fisheries Advisory Committee. The policy statement divided the main statutory responsibility for maintaining, improving and developing all fisheries into two broad functions of regulation and conservation *(Table 1)*. The statements recognized how these functions interacted with the execution of the other duties of the Authority, including land drainage and channel alterations, changes in run-off patterns following development, the use of reservoirs and canals for fisheries, water resources and the net effects of abstraction, the pattern and size of regulating releases from reservoirs, and changes in water quality resulting from the discharge of effluents and storm sewage overflow. Aspects of integrated catchment management are considered in more detail by Chandler (1990).

The authority recognized the role of regulations (bye-laws) in conserving its fisheries. The various types of regulation and their effect are summarised in *Table 2*. All other policies could be related to the direct conservation or development of the commercial and sport fisheries in both catchments. The need was apparent to collect base line data on the resource, to improve techniques for monitoring it, and to be able to redistribute fish for angling purposes as and when required.

3.2 Management practices

The Severn Trent Water Authority established a staff structure designed to put these policies into management practice *(Figure 2)*. The district fisheries officers and their fisheries inspectors each took responsibility for a subcatchment, with prime responsibility for the regulation and conservation of fisheries. They acted as the main point of contact with, and advisers to, the owners, angling clubs and other participants in the fisheries. Fish biologists had duties related to the special policies on freshwater fisheries. The information collected was used by the district fisheries officers to solve day to day problems. Trout rearing was undertaken by a specialist fish farm manager. A fish pathologist had the role of checking fish health in the area. A catchment fisheries manager co-ordinated all the activities, acting as the link between central policy and its interpretation and implementation.

4. Policy implementation 1976-1986

The Salmon and Freshwater Fisheries Act of 1975 did not suggest any timetable or scale to the authority's activities in maintaining, improving and developing fisheries. It was however, expected to 'effectively execute' its policies and fix its charges with regard to progress. The Authority reviewed and fixed licence charges every two years. Such charges were assessed with due regard to activities proposed. The following activities occurred during 1976-1986 under the policy categories described in *Table 1*.

Table 2. Summary of regulatory methods and their effects.

	Act of Parliament	Water Authority bye-laws	Owner's rules	Main effects	Incidental effects
1. Close seasons		May modify or waive in case of eels or coarse fish	May be extended	To protect fish during breeding	Protects growing crops, nesting birds or, in winter, roosting waterfowl
2. Sanctuaries		Rarely	Occasionally	Restrict the catch of fish	As above
3. Bag limit		Occasionally		Eases pressure on stocks when conditions favour big catches	May be frustrating to anglers on such days
4. Gear limit	Occasionally on commercial methods only	Often	On numbers of permits/ rods	Prevents overcrowding, reduces damage to stocks	Require a balance between quantity and quality
5. Type of gear	Generally restrict permissible methods to rod and line or licensed nets etc. for commercial fishery	Apply mainly to commercial methods	Fine tuning in line with objectives of fishery	Best sport	
6. Size limit	Except in the case of salmon	Occasionally	Can be tailored to the particular fishery	Assist in maintaining breeding stock and optimize quality of sport	

Regulation

The bye-laws were reviewed once. This was achieved by a process of consultation between the Severn Trent Water Authority and the participants in the fisheries. Requests for changes were considered against the rationale 'do such proposals increase by regulation the conservation of the resource'. It was agreed that some bye-laws were no longer required, *e.g.* size limits for coarse fish.

Where possible, subsequent bye-law changes are geared towards a 5-yearly review, although changes can if necessary be made as and when required.

Conservation of salmon fisheries

The statutory declaration of salmon catches has allowed a continuous monitoring of exploitation and has shown a fairly stable fishery (mean annual catch 4278 ±950 salmon). Scale analysis has clearly shown that the principal components of the catch are fish which have spent 1 and 2 winters at sea. Regulation of netting effort through bye-law controls and net limitation orders has continued.

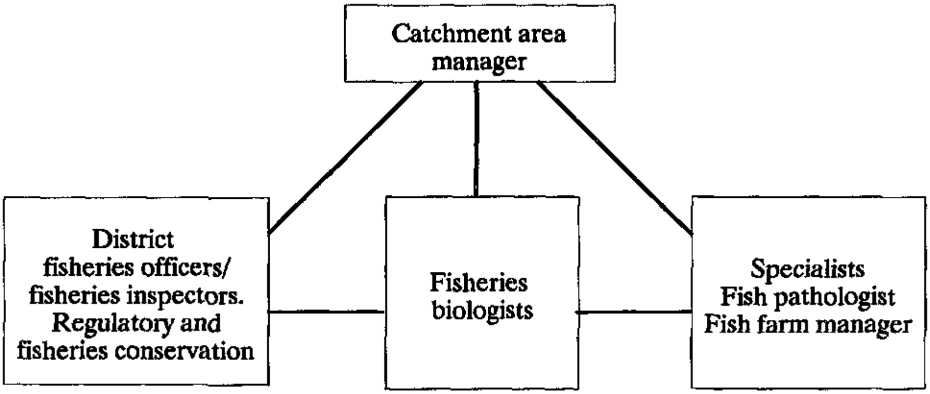

Figure 2. Staff structure of the Severn Trent Water Authority, 1975-1986.

Improved access to spawning areas

The policy of opening up rivers to natural spawning is seen as the most effective management option, where the objective is to improve the fishery. Installation of a major new fish pass with a fish counter at Shrewsbury on the River Severn in 1976, and another at Carreghofa on the River Tanat in 1975 are examples.

Salmon stripping for parr production

There has been a reduction of effort in this sphere, but a small experimental unit has been retained which allows for artificial enhancement of stocks after mass mortalities following pollution.

Assessment of proposals for a barrage in the Severn Estuary

Interest in harnessing the 10 m tidal range in the Severn Estuary for power generation continues. The possibilities were first examined by the Severn Barrage Committee in the early 1980s, and current interest is being shown by the Severn Tidal Power Group. Clearly, with any such barrage there will be a danger of losing fish in the turbines of the generators, and potential promoters have been made aware of this and the relevant research which therefore needs to be undertaken.

Salmon in the Trent

After several years of reports of regular sightings of salmon in the Trent the Fisheries Advisory Committee requested that an investigation be undertaken to establish the numbers coming into the Trent, and the cost of reintroducing salmon to the catchment.

A final report by Bottomley and Jarrams (1985) presented several alternative plans for future development. After discussion and consultation the Authority adopted a policy of opportunistic improvements.

Opening the upper reaches of the River Teme

A review of the effects of introduced salmon on indigenous trout, involving experimental work over a 5 year period, was commissioned by the Fisheries Advisory Committee in 1981. A previous desk study had indicated that if a fish pass were constructed at Ashford near Ludlow, the capacity of the river to attract and support salmon could be doubled (North 1988).

Conservation of all other fisheries - general policies

The main emphasis here was placed on offering a technical problem solving service to water owners, angling clubs, and all other parties concerned with the fisheries. During the period 1977-1986, in the Trent area, the district fisheries officers dealt with an average of 229 (range 167-316) requests for advice each year. The problems encountered ranged from too few to too many fish (Fisher & Broughton 1984) and insufficient to excessive plant life in the waters. Various practical recommendations and techniques were tested at a stillwater demonstration centre. In this way the value of the techniques were tested before implementation (Cooper 1983). Short fisheries management courses were run jointly with the Institute of Fisheries Management for interested parties.

There has also been a small but regular number of applicants for fishery improvement grants. Potential schemes have been assessed on the basis of the additional fishing facilities they would provide.

Section 30 of the Salmon and Freshwater Fisheries Act (1975) requires anyone introducing fish into any waters to obtain the prior written consent of the local water authority. The fish pathologist has been responsible for health checking the sources of supply and for monitoring the distribution of fish parasites (Pocock 1985). There have been no significant fish mortalities attributable to diseases or parasites, other than on fish farms, during the 1976-1986 period.

The designation of certain stretches of river for certain specific types of fishing has always been regarded as a desirable long term policy. However, conflicts may arise, especially on some of the smaller streams which are equally well suited for both trout and coarse fishing. There have been examples where one owner removes coarse fish and introduces trout whilst his neighbour preserves coarse fish. Although no stretches of river have yet been formally designated, river length strategies are upheld by negotiation.

Trout fisheries - special policies

The Severn Trent Water Authority's original policy was to produce sufficient trout for its own needs, comparable in quality and unit price to those from commercial suppliers. The maximum annual rate of production was 40 tonnes, achieved by using land based growing on sites and floating net cages (Jarrams, Easton, Starkie & Templeton 1984). However, trout of good quality and lower unit price have become available on the commercial market and, except in 2 reservoirs, the Authority has ceased to produce trout. It now buys most of its stock fish.

Freshwater fisheries - special policies

Several developments were made by the fish biologists in this field. Experiments began in 1976 to develop techniques for farming coarse fish including roach *(Rutilus rutilus)*, chub *(Leuciscus cephalus)*, dace *(Leuciscus leuciscus)*, barbel, bream *(Abramis brama)* and carp *(Cyprinus carpio)*. All these species are needed to restock angling waters which have suffered losses from pollution. Rearing techniques were successfully developed (Easton & Dolben 1980, Worthington 1983) and a coarse fish production unit has been established on the site of an old trout farm. Experience showed that it was not necessary to invest in sites for holding coarse fish. Inland waters often became available for the removal of excess fish or for growing them on for later removal.

Various techniques have been tried for cropping fish from large rivers and reservoirs. Mini purse seines and seine nets up to 200 metres have been tried in reservoirs. A high powered electric fishing unit has been developed (Hickley & Starkie 1985), and is now in regular use for sampling small and medium-sized rivers. The only technique for monitoring fish populations in large rivers has been to collect data from angling catches (Cooper & Wheatley 1981, Cowx & Broughton 1986). However, recent developments in hydroacoustics in the USA may have application in these situations (Templeton 1987).

The low level drainage system in the northeast of the region has been extensively surveyed using electric fishing equipment and fyke nets (Carpenter 1982). It has not been necessary to develop the area as a source of supply of coarse fish.

There have been no specific projects to encourage the survival of coarse fish fry, but fertilisation techniques used to increase the productivity of some inland waters have achieved this objective in some places.

Eel fisheries - special policies

The eel and elver resource in the River Trent was assessed by Carpenter (1982). Since 1981 the upper reaches of the Rivers Trent and Tame have been regularly stocked with elvers from the River Severn. The objective has been to increase the number of eels in the river for anglers and the few commercial eel fishermen operating in the tidal reaches of the Trent. The Severn has a significant elver fishery in UK terms with an estimated annual catch of 20-80 tonnes. A decline in the catches of both silver and yellow eels has allegedly been caused by over cropping elvers. However, investigations on this subject, initiated in the early 1980s, are not conclusive and are continuing. The elver fishery has been regulated by licensing since 1980. Bye-laws prohibit all fishing methods except the use of hand held nets, thereby excluding trawling. Although the rejuvenation of trapping is still a policy objective, no decisions can be taken until the investigation into the alleged present overcropping of elvers is complete.

A significant quantity of elvers are now restocked at sites throughout the Severn Basin. Survey work has shown that young eels take at least 7 years to migrate to the upper reaches of the Severn. Restocking has resulted in increased turnover and much greater production in certain localised areas. The objective is now to restock at least 300 kg annually in the Severn Basin.

5. Discussion

The Severn Trent Water Authority has shown that the statutory function of maintaining, improving and developing all fisheries in its area can be achieved. It is necessary, however, to have clear policies. Management objectives can then be set. These objectives can only be achieved with the right staffing level of specialists.

The practical approach has been twofold; to persuade fishermen and owners to adopt and follow proper fishery management practices, and to develop new techniques for monitoring fisheries in support of this. Constraints to this approach that are foreseen are that income from licences may decrease, and that central government may change its policy on the control of the expenditure of water authorities.

Note

The views expressed here are those of the authors and not necessarily those of the Severn Trent Water Authority.

References

Bottomley, P.E.B. & Jarrams, P. 1985. Re-introduction of salmon into the River Trent - a preliminary feasibility study. Severn Trent Water Authority. 64pp.

Carpenter, A., 1982. A Study of the biology of the eel, *Anguilla anguilla* L., in the tributaries of the lower River Trent. PhD Thesis, Hull University. 300pp.

Chandler, J.R., 1990. Integrated catchment management. The role of water authorities in England and Wales. In: Densen, W.L.T. van, Steinmetz, B. & Hughes, R.H. (Eds). Management of freshwater fisheries. Pudoc. Wageningen. pp. 520-525.

Churchward, A.S., Hickley, P. & North, E., 1984. The introduction, spread and influence of the barbel, *Barbus barbus*, in the River Severn, Great Britain. EIFAC Tech.Pap.(42), Suppl. 2: 283-554.

Cooper, M., 1983. Restoration and improvement of coarse fisheries. Inst. Fish. Man., Annual Study Course. 14: 53-62.

Cooper, M.J. & Wheatley, G.A., 1981. An examination of the fish population in the River Trent, Nottinghamshire, using angler catches. J. Fish Biol. 19: 539-556.

Cowx, I. & Broughton, N.M., 1986. Changes in the species composition of anglers' catches in the River Trent (England) between 1969 and 1984. J. Fish Biol. 28: 625-636.

Dangerfield, B.J., 1981. Recreation: water and land. IWES Water Practice Manual. Inst. Water Eng. & Scientists. 336pp.

Easton, K.W., 1979. The history of the fisheries in the River Trent. Thesis for Diploma of the Institute of Fisheries Management. 23pp. Severn Trent Water Authority.

Easton, D.W. & Dolben, I.P., 1980. The induced spawning and subsequent survival and growth of roach *Rutilus rutilus* (L). Fish. Mgmt. 11: 59-66.

Fisher, K.A.M. & Broughton, N.M., 1984. The effect of cyprinid introductions on angler success in the River Derwent, Derbyshire. Fish. Mgmt. 15: 35-40.

Hickley, P. & North, E., 1981. An appraisal of anglers' catch composition in the barbel reach of the River Severn. Proc. of 2nd Brit. Freshwater Fish Conf. Liverpool. pp. 94-100.

Hickley, P. & Starkie, A., 1985. Cost effective sampling of fish populations in large water bodies. J. Fish Biol. 27: 151-161.

Hunt, P.C. & Jones, J.W., 1975. A population study of *Barbus barbus* L. in the River Severn, England, 3 Growth. J. Fish Biol. 7: 361-76.

Jarrams, P., Easton, K.W., Starkie, A. & Templeton, R.G., 1980. Salmonid rearing in floating net cages in freshwater reservoirs owned by the Severn Trent Water Authority. Fish. Mgmt. 11: 101-118.

Lester, W.F., 1979. Recovery of the River Trent. Proc. 10th IFM Study Course. Inst. Fish. Mgmt. pp. 63-72.

North, E., 1988. An investigation into the effects of introduced juvenile salmon upon resident brown trout. Severn Trent Water Special Report. 29 pp.

Pocock, I., 1985. Freshwater fish parasite survey. Severn and Trent catchments. Severn Trent Water Report. 100 pp.

Templeton, R.G., 1984. Freshwater fisheries management. Severn Trent Water Authority. Fishing News Books, Farnham, Surrey. 191pp.

Templeton, R.G., 1987. An assessment of freshwater fish stocks by hydroacoustic instrumentation techniques. Severn Trent Water 1987 Travelling Schl. Report. Severn Trent Water Authority.

Worthington, A., 1983. Studies on the reproduction and culture of the roach, *Rutilus rutilus*. PhD Thesis, Trent Polytechnic, Nottingham. 149pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 569-581.

Acquisition and computation of routine fisheries management data by the Anglian Water Authority, England

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Abstract

The Anglian Water Authority has statutory responsibilities for maintaining, improving and developing inland fisheries over five Divisions covering a total land area of 26 795 km^2. Most interest centres on recreational fisheries in rivers and lakes. Quantitative methods for surveying fish populations in these waters have been developed progressively since 1978. Electric fishing, seine netting and trawling are the principal methods used for sampling. Fish populations are quantified mostly using mark-and-recapture techniques, or the catch depletion methods of Seber and Le Cren or Zippin. Biomass estimates are obtained from length-weight regressions or by direct weighing. Surveys are carried out on a three year rolling programme covering every river, and reports for each river present data on species composition, growth rates, survival, year-class strengths, and density and biomass of the dominant species occurring at different sites surveyed. These data form the basis of any remedial management action within fisheries. The transcription, analysis and presentation of survey and other fisheries data previously occupied a large proportion of the survey time. In 1985, the Anglian Water Authority commissioned a project, within a systems analysis context, to identify those aspects of the survey, and other fisheries work, which could be computerised. This identified manual procedures of filing and data analysis as major limitations within the system. Standardised methods of data acquisition and a computerised data processing system based on IBM PC micro-computers were introduced. A series of programmes were developed and coded in advanced BASIC to run under the IBM PC DOS operating system to handle storage, retrieval, statistical analysis, integration and summary presentation of primary data arising from fisheries surveys and other fisheries operations. Mean times for analysis and presentation of single data sets were reduced from 126 to 7 hours.

1. Introduction

Management of inland fisheries is one of the many functions of the ten water authorities in England and Wales *(Figure 1)*. In recent years increasing public interest in fisheries and conservation in the U.K. has resulted in greater emphasis being placed on this function. Moreover, the 1975 Salmon and Freshwater Fisheries Act gave water authorities statutory responsibilities for maintaining, improving and developing inland fisheries within their respective regions. In order to be able to fulfil these obligations, water authorities had to develop methods of assessing fish stocks, and the management techniques necessary to identify problems, and provide solutions, where fisheries were considered to be under performing. Within the Anglian Water Authority region, commercial exploitation of naturally occurring fish stocks is limited to eel *(Anguilla anguilla)*

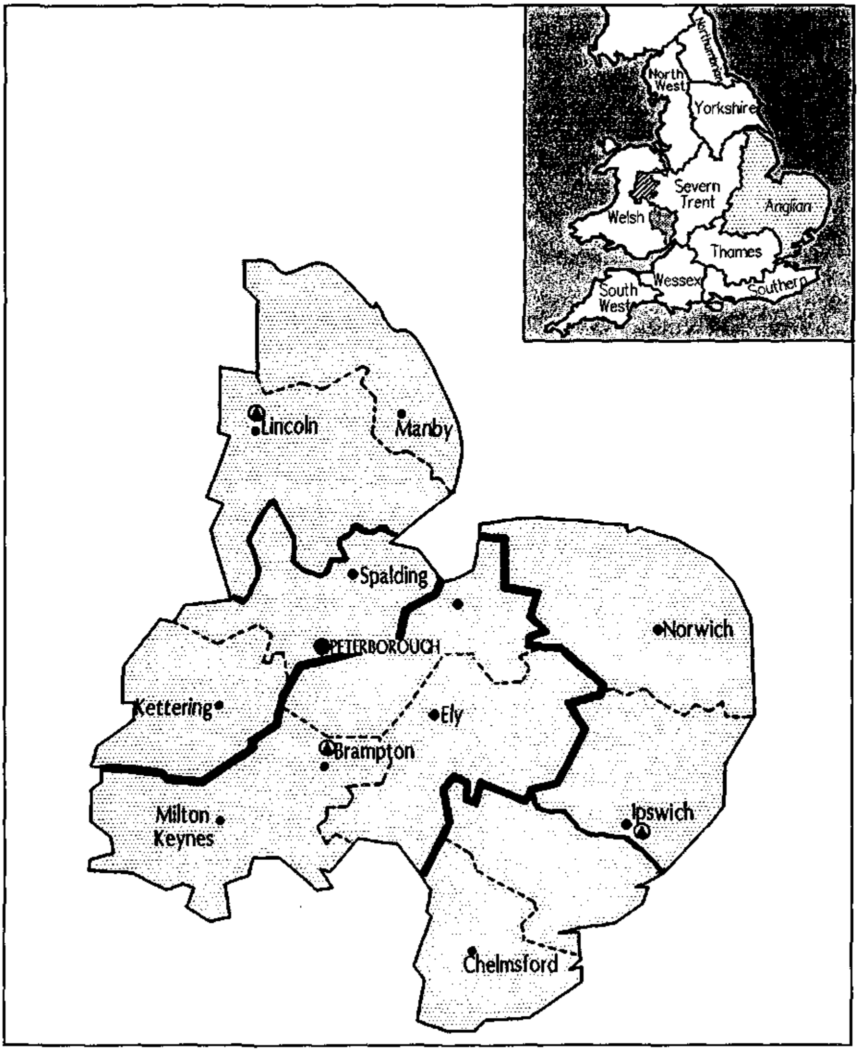

Figure 1. Area covered by the Anglian Water Authority.

fishing on inland waters and the gill-netting of sea trout *(Salmo trutta)* which occurs off-shore during the annual migrations to rivers lying mostly outside the Anglian region. Most interest concerns the recreational fisheries centred on river systems. The initial aim of the Anglian Water Authority's fisheries management programme was to establish appropriate sampling techniques to provide quantitative estimates of fish stocks and to implement a regular monitoring programme for all river systems in the region, including the Norfolk Broads (Linfield 1981). A survey programme was introduced in 1976/1977 with the specific aim of establishing base line data on all fish stocks occurring in major river fisheries areas throughout the Anglian region. Data collected, included species composition, growth rates, survival, the year-class strengths of the dominant species, and the density and biomass of each species occurring at each site surveyed. A classification system based on the results of these surveys was drawn up to provide a means of comparing similar types of fisheries and to provide a measure of the stock of fish present in each water body (Linfield 1981). The acquisition of these data has been repeated on a three year basis so that changes both within and between fisheries can be monitored. This paper describes the results of a major project undertaken between 1985 and 1987, to provide a computer based system of processing the data arising from these fisheries surveys and integrating this with other fisheries management tasks.

2. Fisheries surveys

The Anglian Water Authority region *(Figure 1)* consists of five Divisions each having a fisheries team led by a fisheries scientist. Quantitative sampling techniques for surveying all river habitats in the region, including the Norfolk Broads, have been progressively developed since 1977 (Coles, Wortley & Noble 1985). A three year rolling programme, consisting of 1474 sampling sites covering all the river systems and broads was started in 1978. Data from these surveys are reported to the Fisheries Advisory and Liaison Committees of the Anglian Water Authority in a series of management reports for each river. Seventy one such reports were produced during 1986, and 3333 km of river and 355 ha of the Norfolk Broads was surveyed during the period 1984-86 (Anglian Water Fisheries Annual Report No 4, 1987). Preliminary studies undertaken in 1985 showed that the time taken for analysing and summarising raw data arising from fisheries surveys was disproportionately higher than the time taken to collect data in the field. Further, data were processed in different ways by the five Divisions with resulting difficulties in comparing surveys. The quantity of data generated by the survey programme also led to a backlog which prevented easy access to current stock data for fisheries.

2.1 Systems analysis of fisheries operations

A systems analysis of the activities involved in routine fisheries surveys was conducted to determine how and where a computing system would improve operational efficiency and aid achievement of the management objectives. The flow of information through the fisheries system is shown in *Figure 2,* which contains the following stages:

- Fisheries are sampled using relevant techniques.
- Data are recorded on forms in the field.
- Data are analysed and interpreted.
- Ancillary fisheries activities are carried out, *e.g.* issuing statutory consents to introduce or remove fish from waters, performing health checks on fish, and performing enforcement and advisory duties.
- Production of charts, tables, forms and reports for inclusion in management reports.

The sampling of fisheries was broken down to the data flow processes shown in *Figure 3.* The sampling techniques used routinely in fisheries surveys include electro-fishing (either by wading or from a boat), seine netting between stop nets or within an encircling net,

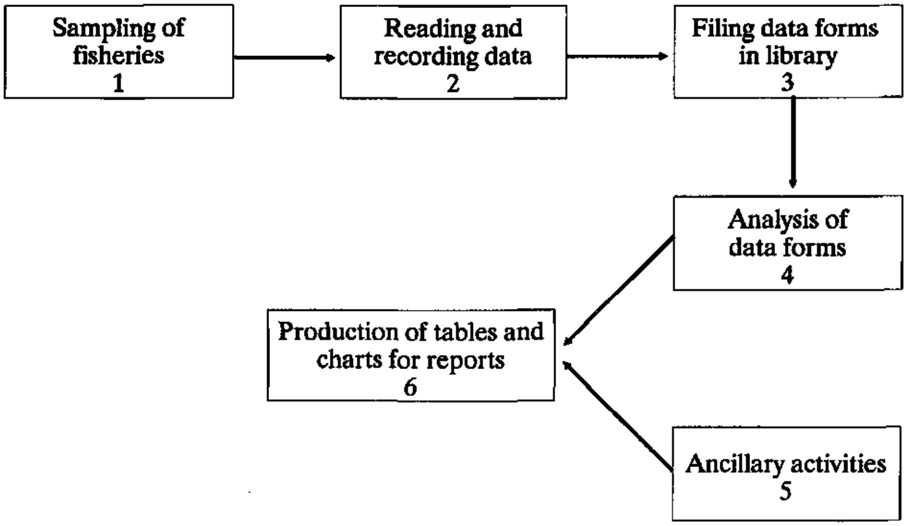

Figure 2. Diagram of data flow through the Anglian Water Authority's fisheries operations.

and trawling. Detailed descriptions of these techniques have been given by Coles, Wortley & Noble (1985).

2.2 Catch efficiency and limitations of the sampling techniques

Throughout the length range of any species of fish there is usually a variation in the efficiency with which the species is caught by these various techniques. For instance, fish larger than a certain size (length) are often caught more efficiently by electric fishing than smaller fish of the same species. Similarly, mesh size and the speed at which different species of fish swim can influence the efficiency of different netting techniques.

In the Anglian Water Authority it is common practice to estimate the numbers of fish of any species in a population in two length groups. The length separating these two length groups is referred to as the 'cut-off length'. Fish longer than the 'cut-off length' are within the size sampled efficiently by the gear while smaller fish are outside this limit. Population estimates for fish larger than the cut-off length, and equal to and smaller than the cut-off length, are computed separately for each species. The dividing length between the two length groups is generally taken as 10 cm for fish sampled by electric fishing and 7 cm for fish taken by the seine nets or trawls used in routine fisheries surveys.

In addition to size selectivity, each fishing technique is also selective for particular species. Seine netting is usually more efficient for species living in mid-water or near surface zones, such as roach *(Rutilus rutilus)* compared with bottom living species such as carp *(Cyprinus carpio)* or tench *(Tinca tinca)*. Electric fishing tends to catch large,

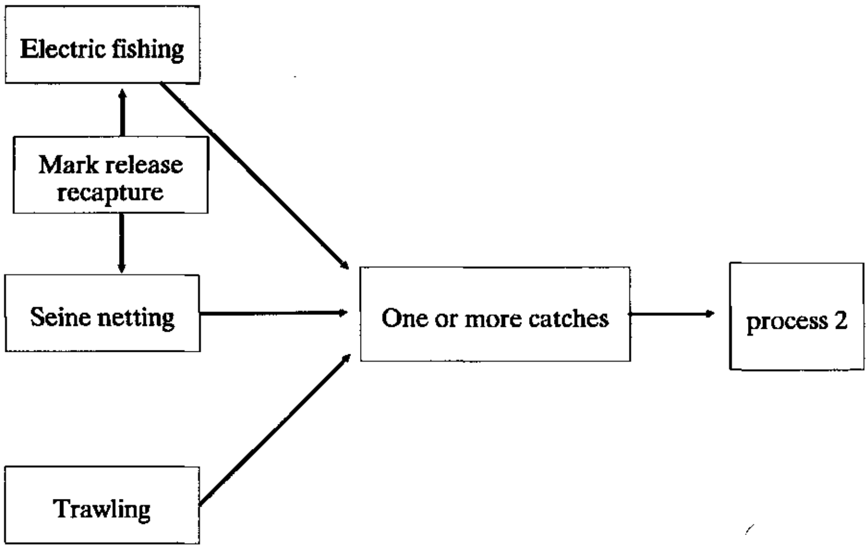

Figure 3. Process 1 - Fisheries sampling techniques.

territorial species such as pike *(Esox lucius)* more efficiently than small, shoaling species, such as minnow *(Phoxinus phoxinus)*. Similarly, trawling may result in a positive selection for bottom dwelling species. Minimum estimates only are used for populations estimated using trawls as the areas sampled by this method are not closed by stop nets to prevent movements of fish into or out of the sampling sites (Coles, Wortley & Noble 1985). Variations in the efficiency with which different sampling methods capture different species had to be taken into account by the computer based information processing system, which was designed to process data for each species separately.

The number of catches carried out at each sampling site in a survey is usually dependent on data derived from the use of the mark-release-recapture method of Lincoln (1930), or the catch depletion models of Seber and Le Cren (1965) and Zippin (1956). Mark-release-recapture is used only for fish larger than 10 cm, and where this type of data is not available the Seber-Le Cren catch depletion model is used for two catches, and the Zippin catch depletion model for three or more catches. Software was developed as follows, to ensure that data from fish smaller than, or equal to, the cut-off length was processed independently of data from larger fish.

For each species, if data from the fish smaller than (or equal to) the cut-off length permit the use of the Zippin or Seber-Le Cren models, the population is estimated using one of them. Where the data do not permit the use of either of these models (and the catch efficiency of fish smaller than the cut-off length is greater than, or equal to, that of fish larger than the cut-off length) the catch efficiency (determined from mark-release-recapture data of fish over the cut-off length) is used to estimate the population below the cut-off length. This provides a better estimate than simply summing the numbers of fish occurring in each catch, but it is nonetheless a minimum estimate and not a true estimate. If the efficiency of capture of fish smaller than the cut-off length is less than that of fish larger than the cut-off length, then a minimum estimate is made by summing the numbers of these species occurring in each catch. The efficiency of capture referred to above is the ratio of the number of fish of each species occurring in the second catch to the number occurring in the first catch.

The data processing software also allows for the catch efficiencies calculated from mark-release-recapture of related species to be combined, if appropriate. For example, if 20 silver bream *(Blicca bjoerkna)* and 100 common bream *(Abramis brama)* were marked and released, and 10 silver bream and 70 common bream were recaptured, the efficiency of capture of silver bream would be 50% whilst that of common bream would be 70%. The relatively small number of silver bream occurring in the two catches may not give a true indication of the efficiency of capture for this species. However, silver bream and common bream show many similarities in behaviour and in this example it could be considered appropriate to combine the mark-release-recapture data for both species so that 120 fish were marked and 80 fish recaptured. This would give an efficiency of capture of 66% which could then be used to estimate the numbers of silver bream in the population. The software allows this option to be used at the discretion of the user.

2.3 Data recording

Processing the catches made during routine fisheries surveys essentially involves the identification of fish species, measurement of the fork length of each fish, removal of suitable scale samples for age determination and simultaneous recording of data, *Figure 4*. Different methods are used in different Divisions of the Anglian Water Authority for recording the weights of measured fish. Length-weight regression equations have been determined for many species from data collected from different populations in rivers at different times of the year. Where these equations are not available, fish are weighed at the time of sampling. Eels and lampreys are counted and weighed only. Where large numbers of fish occur in individual catches random sub-sampling of the most abundant species is used to obtain basic data and the remainder of the catch of these species is counted (counted fish). At all sites the majority of fish caught are returned alive to the water after processing. Small samples of different species may be taken for disease screening. Site data, including the area of water sampled, the map reference, and the site details are also collected at the time of sampling.

Development of the data processing software had to take account of differences in methods of data recording between different survey teams. For instance, data on the weights of fish occurring in different samples could be derived from previously determined length-weight relationships, or weights of individual fish recorded in the field, or the weight of all fish of one species occurring in one catch recorded in the field. Approximately 53 species or hybrids occurred in survey catches and each of these was numerically coded to aid data entry. Length-weight regressions were available for 40 of these species and were incorporated into the data processing system. Facilities were also included to enable variations in these regressions to be made when necessary, and to

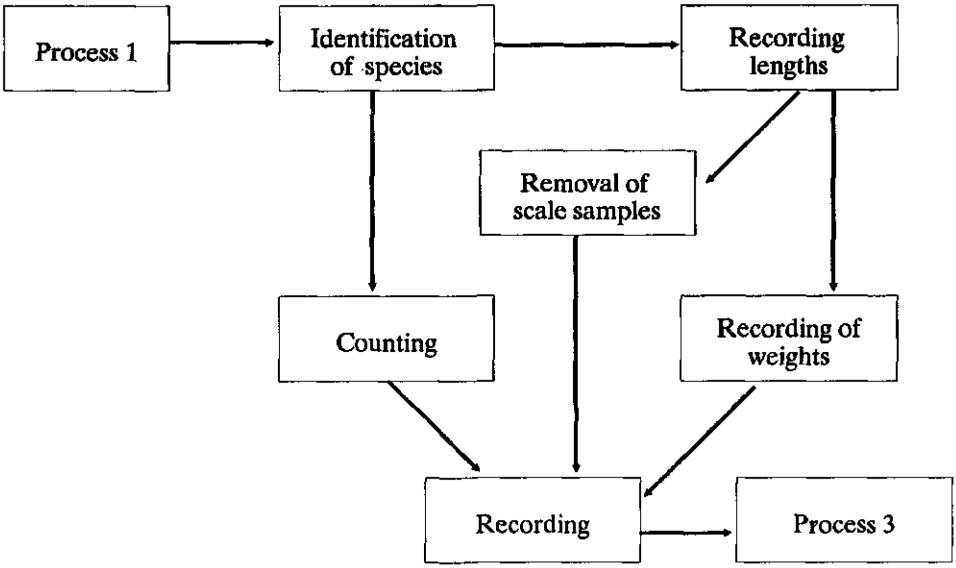

Figure 4. Process 2 - Catch processing and data recording.

input weights of fish for which no equation existed. These facilities enabled the elimination of most weighing of fish in the field, and led to a significant reduction in the time taken to process the catches.

The use of portable computers to log data directly in the field was not found to increase efficiency either in accuracy or in time. Data from 1000 fish of 7 species could be logged in 30 minutes by hand whereas similar data from 500 fish of 4 species took more than one hour to log using a field data logger.

2.4 Data filing

The introduction of a computer based data processing system for routine fisheries surveys involved changes in the way in which the following data for each survey site were filed:

- Number of catches made.
- Catch number.
- Individual lengths of each species occurring in each catch.
- Numbers of counted fish where species had been sub-sampled.
- Total weight of a species in each catch where no length weight regression existed.
- For each species, number of marked fish recaptured in subsequent catches.
- Numbers and weights of eels and each species of lamprey.

2.5 Analysis of fisheries data

Data analysis was recognized as imposing the greatest restrictions on the availability of management data arising from the routine fisheries surveys. Process 4 in the overall context diagram *(Figure 2)* is further sub-divided into the sub-processes shown in *Figure 5*. Data for each species occurring in each catch are treated separately. The number of each

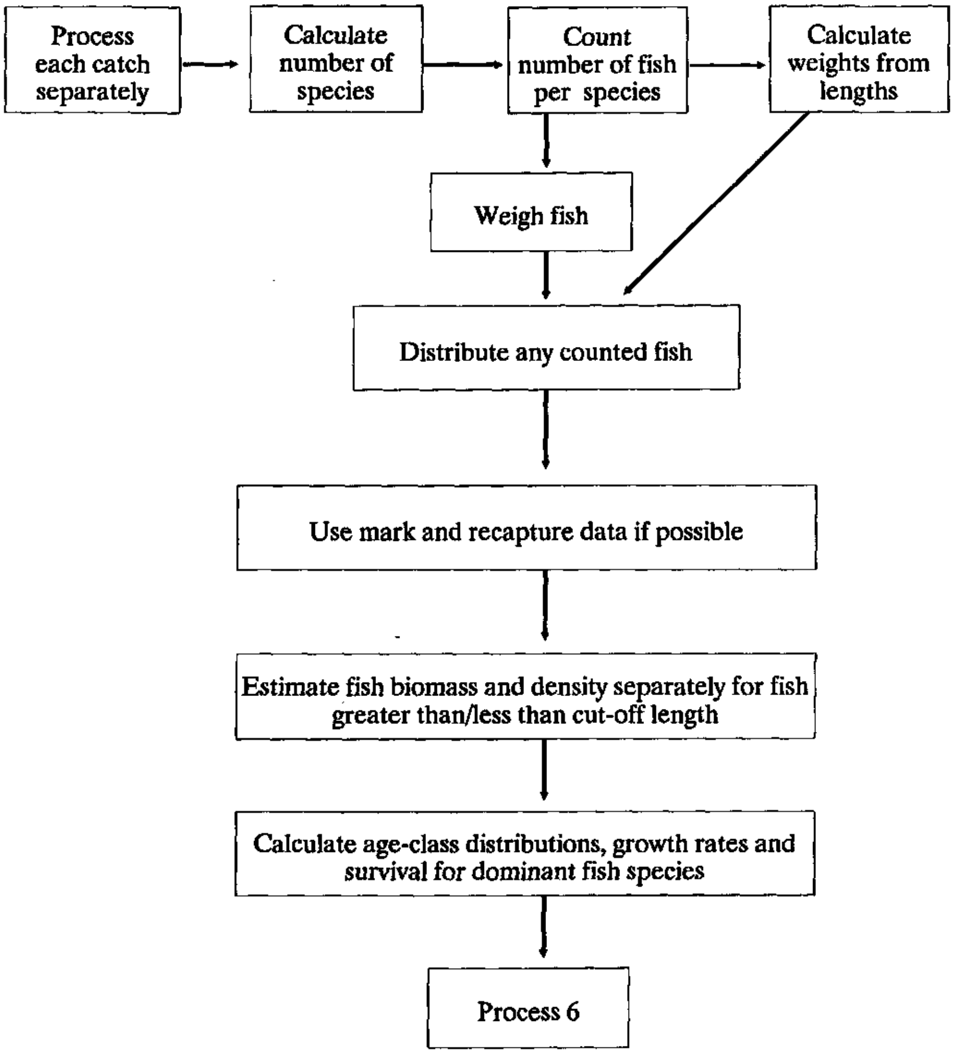

Figure 5. Process 4 - Analysis of fisheries data.

species of fish caught was calculated by noting the number of lengths recorded for that species. If the fish were not weighed then the weights of the fish caught were calculated from their lengths via the length weight regression equations. A length frequency was drawn up and counted fish then distributed accordingly. If mark-release-recapture data were available then the efficiency of capture for the species was calculated. When the numbers and weights of each species in each catch had been determined the biomass and density of each species at that site was estimated using the efficiency of capture derived from mark-release-recapture data or the catch depletion models. The calculations used in the estimation of the population and biomass of each species are given by Vallipuram (1987). In addition to biomass and density estimation, random sub-samples of some species of fish were aged and their survival and growth rates calculated. These aged sub-samples were used to derive year-class structures from the complete length frequency data of each species.

Specific software was developed to carry out all the calculations necessary to produce data on numbers, density and biomass of each species at each site. Routines were incorporated to enable minimum estimates to be obtained where the data did not satisfy the requirements of the catch depletion models. Changes in the times taken for different processes prior to and post computerisation are shown in *Table 1*. Furthermore, the software has been made user friendly so that all members of the survey teams are able to enter field data and extract processed results.

Table 1. Time taken to carry out various divisional, fisheries data processing tasks prior to and after the introduction of a computerised data processing system.

Task	Processing time	
	Manual	Computer
Calculation of biomass and density per site	1 hour	data entry < 30 minutes calculations < 1 minute
Calculation of biomass and density per section (average of 10 sites)	2 days	data entry < half day calculations < 10 minutes
Tabulation of results and preparation of charts per section	3 days	30 minutes
Calculation of length frequency for each species per site	2 hours	calculations < 1 minute data entered in process 1
Estimation of ages of dominant species per section (central service)	1 day	data entry < 30 minutes ageing < 1 minute
Calculation of survival and growth rates (central service)	1 hour	calculations < 1 minute
Retrieval of back data	> 1 week	< 30 minutes

2.6 Ancillary data

In addition to the routine fisheries survey programme each of the five Divisional fisheries teams carry out other duties which generate data used in fisheries management processes, *Figure 2* - Ancillary Functions. The computerised data processing system allows this additional work, shown in *Figure 6*, to be included in the overall software development. Databases have also been developed to provide easy access to other data related to fisheries management, for example: causes, locations, extent and times of fish mortalities and pollution incidents occurring in different fisheries.

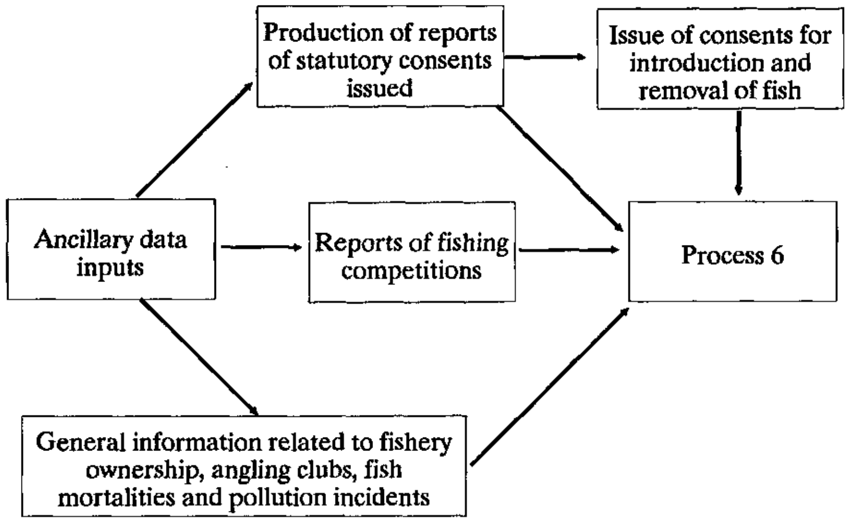

Figure 6. Process 5 - Ancillary fisheries activites.

2.7 Production of tables, charts, and summary sheets

The final process in the context diagram shown in *Figure 2* involves the presentation, in the form of tables, charts, and summary sheets, of all the information derived from data analyses. These form the basis of the fisheries management survey reports. Computer programmes were developed for the production of a series of different tables from the results of computerised data analyses. Examples of typical outputs are shown in *Tables 2, 3* and *4*. It was decided to use a proprietary software package for the production of charts and graphs.

Table 2. Population density (numbers/m^2) of fish more than 10 cm long, of each species, from six sampling sites.

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Mean
Roach	0.1450	0.1228	0.1131	0.0068	0.0044	0.4117	0.1122
Gudgeon	0.0027	0.0014	0	0.0019	0	0	0.0010
Eel	0.0245	0	0	0.0313	0.6600	0.0567	0.0365
Chub	0.0063	0	0	0.0539	0	0.0172	0.0012
Dace	0.0081	0	0	0.5390	0	0.0172	0.0132
Stone loach	<0.0010	0	0	0	0.0377	0	0.0064
Pike	0	0.0628	0.0048	0.0058	0	0.0109	0.0140
Rudd	0	0.0028	0	0	0	0	<0.0010
Tench	0	0	0.0024	0	0	0.0069	0.0015
Perch	0	0	0	0.0049	0	<0.0010	<0.0010
Bullhead	0	0	0	0	0.0022	0	<0.0010
Brown trout	0	0	0	0	0.2088	0	0.3480
Common bream	0	0	0	0	0	0.0065	0.0010
Total	0.0572	0.1900	0.1203	0.1058	0.3600	0.5109	0.2240

Table 3. Biomass (g/m^2) of each species, combining all length categories, at six sampling sites.

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Mean
Roach	0.8154	13.6100	5.9040	0.2745	0.2266	25.6800	7.7526
Gudgeon	0.0500	0.0500	0	0.0300	0	0	0.0200
3 Spined stickleback	0.0040	0	0	0	0.0020	0	<0.0010
Eel	3.1410	0	0	4.2470	14.0300	8.5420	4.9940
Chub	4.3300	0	0	0.1372	0	0	0.7449
Dace	0.8000	0	0	3.4290	0	0.9564	0.8643
Stone loach	0.0200	0	0	0.0070	0.5933	0.0020	0.1039
Brook lamprey	0.0050	0	0	0.0070	0	0	0.0020
Pike	0	6.9770	9.3370	5.0570	0	1.9510	3.8873
Rudd	0	0.1614	0	0	0	0	0.0300
Tench	0	0	0.7190	0	0	2.3960	0.5191
Perch	0	0	0	0.7352	0	0.0200	0.1254
Bullhead	0	0	0	0.0600	0.0800	0	0.0200
Brown trout	0	0	0	0	15.8800	0	2.6133
Common bream	0	0	0	0	0	1.02100	0.1703
Total	9.1700	20.7900	15.9600	13.9800	30.6100	40.5600	21.8490

Table 4. Estimated numbers and biomass for combined species at each site.

Site numbers	Total numbers/m^2	>10 cm numbers/m^2	Total biomass g/m^2	>10 cm biomass g/m^2
1	0.0663	0.0572	9.170	9.146
2	0.2014	0.1900	20.970	20.720
3	0.2825	0.1203	15.960	15.050
4	0.1196	0.1058	13.980	13.890
5	0.4044	0.3600	30.610	30.380
6	0.5307	0.5109	40.560	40.440
Total	1.605	1.344	131.000	129.600

3. Synopsis of the fisheries computing system

The computer programmes developed were coded in advanced BASIC and run on IBM personal computers under the PC DOS operating system in all five Anglian Water Authority Divisions. Following successful evaluation of the system, a central fisheries database is being set up on a Honeywell mainframe computer. The five divisional micro-computers will be linked to this central mainframe via private telecommunication lines so that the central database can be periodically updated. This database will simplify regional correlation of the divisional fisheries data and enable correlation of fisheries data with existing chemical and biological water quality databases.

Acknowledgments

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References

Anglian Water Authority, 1987. Fisheries Annual Report Number 4. Anglian Water, Ambury House, Huntingdon, England. 50 pp.

Coles, T.F., Wortley, J.S. & Noble, P.J., 1985. Survey methodology for fish population assessment within Anglian Water. J. Fish Biol. 27: 175-186.

Lincoln, A.G., 1930. The Lincoln Index for biological applications. OUP, Oxford, U.K.

Linfield, R.S.J.,1981. The development of quantitative sampling methods for assessment of fish stocks in Anglian waters. Assessment of Freshwater Fish Stocks. Seminar Report Water. Space Amenity Commission, London. pp. 16-27.

Seber, G.A.F. & Le Cren, E.D., 1967. Estimating population parameters from catches large relative to the population. J. Anim. Ecol. 36: 631-645.

Vallipuram, S., 1987. Systems analysis and information processing of fisheries data. Thesis submitted to the University of Essex for the Degree of Master of Philosophy. 275 pp.

Zippin, C., 1958. The removal method of population estimation. J. Wildl. Mgmt. 22: 82-90.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 582-593.

Strategies for fish habitat management in estuaries: comparison of estuarine function and fish survival

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Abstract

Research on the use of estuaries by juvenile salmon in British Columbia has emphasized the need to improve our understanding of how various trophic levels support survival at the fry stage. Key indices of functional support, e.g. vegetation production and structure, are now the basis for management schemes, incorporating inference, assumed causal relationships, and semi-quantitative data sets. Recent experimental data on survival (smolt to adult) of chinook salmon, excluded from an estuary, tend to vindicate the inferential information. The experimental work requires more effort before results improve understanding. Experiments can be redesigned to facilitate this. Information on function has been used to make valid decisions for fish habitat management in British Columbian estuaries. Because of the complexity of estuarine ecosystems, inferences from functional data must be used to implement a policy of 'no net loss of productive capacity'. Estimates of productive capacity, which approaches carrying capacity, are difficult to obtain and extrapolations from generic, process-oriented work may therefore be the most efficient method of dealing with the estuarine capacity issue.

1. Introduction

In 1986, the Canadian Department of Fisheries and Oceans (DFO) established a new fish habitat management policy which committed the Department to a guiding principle of 'no net loss of the productive capacity of habitats' (DFO 1986). The implementation of this policy in all fish habitats has created a challenge for managers and scientists, particularly in open and complex systems such as estuaries, coasts, and the open sea. For streams, rivers, and lakes, a few methods exist in the literature for quantifying their carrying capacity, which can approximate productive capacity. Even in those habitats determinations are difficult and are inadequately linked to fish management strategies. In British Columbia, for example, target escapements for spawning salmon are usually set by allocation and conservation policies, and infrequently by some semi-quantitative estimates of spawning habitat capacity, to arrive at 'optimum escapement'. Stocking procedures for fry and smolts being 'outplanted' into rivers and streams are also semi-quantitative, and are usually based on habitats used by wild populations, expressed on a linear or area basis. Habitat evaluation models in freshwater have been found to be highly site-specific and often cannot accurately predict fish population densities from easily measured physical and chemical parameters (Shirvell 1989). In estuaries in British Columbia, the implementation of the policy has proved to be particularly challenging, since these habitats have only recently been recognized as significant fish habitats. In this paper I will review two approaches used in researching salmonid rearing in the estuaries, and evaluate them in terms of their applicability to current strategies of fish habitat management in these important habitats.

Estuaries in British Columbia were first recognized as rearing habitats for juvenile salmonids in the early 1970s, when surveys of the Fraser River estuary and the southern Strait of Georgia began to establish the presence of *Oncorhynchus tshawytscha* (chinook), *O. keta* (chum), *O. kisutch* (coho), *O. gorbuscha* (pink) and *O. nerka* (sockeye) (Hoos & Packmann 1974). Although it had been known that the young salmon had to pass through the estuary on their way to sea, the importance of rearing in the estuary was unknown, relative to riverine habitats. Because of the pressures for industrial development on estuarine wetlands, particularly for forestry and transportation, there arose major concerns about the value of the habitats for salmon production (Dorcey, Northcote & Ward 1978). This stimulated a number of studies on the function of estuarine wetlands with respect to juvenile salmonid life history and ecology. These studies established that an estuary was not simply a conduit which all species traversed on their way to sea: some species and stocks resided in them for considerable periods, fed, and grew in them, before moving seaward. However, the evidence for rearing and feeding in the estuary could be used in a predictive mode, *i.e.*, what decrease in carrying capacity would occur if the estuarine habitats were lost? Pressure to address this question required a partial re-orientation of the types of hypotheses being tested by researchers. Efforts were then made to try to establish survival value of residency in estuaries, in terms of returning spawners and commercial catches.

2. Estuarine function

Research and fish habitat assessment work in the early 1970s involved surveys in a number of estuaries in southern British Columbia, mainly those opening to the Strait of Georgia *(Figure 1)*, and including the Fraser Estuary which is the largest estuary in British Columbia. Management concerns were then related to the filling (loss) of tidal flats, marshes dominated by sedges *(Carex lyngbyei)* and eelgrass beds *(Zostera marina)*, by construction projects such as expansion of the Vancouver International Airport (Fraser Estuary), deep sea docks (Fraser, Squamish, Nanaimo Estuaries), and storage of logs prior to processing in sawmills (Fraser, Squamish, Nanaimo, Cowichan, Campbell, Courtenay Estuaries). These studies established that chum and chinook salmon resided longest in estuaries. Three estuaries received significant attention from researchers between about 1973 and 1983 (Nanaimo, Fraser, Squamish). Data obtained dealt strictly with functional aspects, unravelling food web relationships and trophodynamics in the juvenile phases of the life histories.

3. The Nanaimo River Estuary

Studies by Healey (1980, 1982) established the first British Columbia estimates of estuarine residence times for juvenile chinook and chum salmon using mark-recapture techniques. The 'ocean' life history type for chinook (Healey 1983), where fish move to the estuary soon after emerging as alevins, was shown to be dominant. Fry resided in the

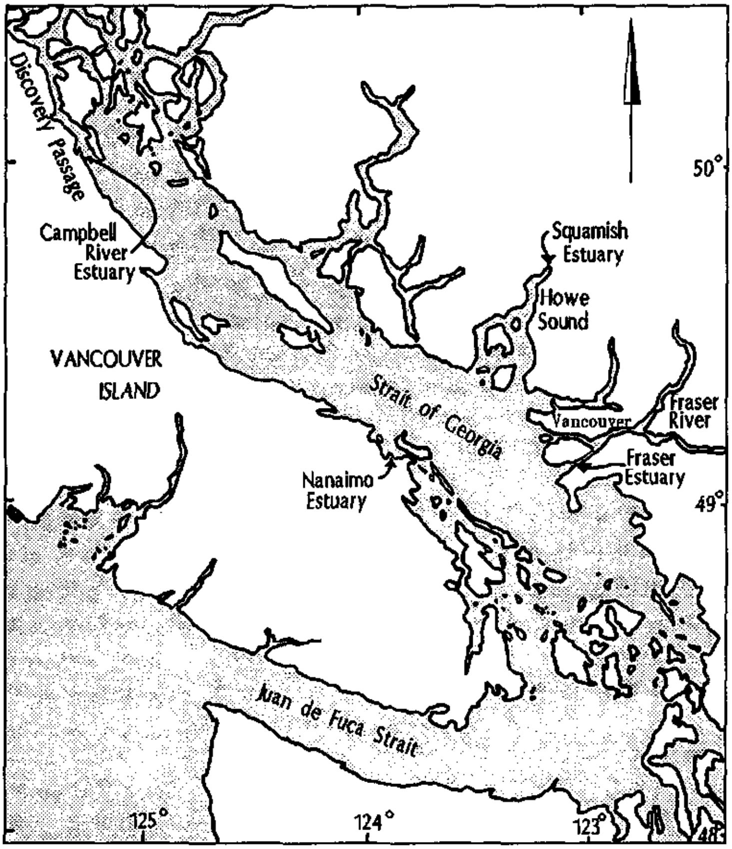

Figure 1. Map of southwestern British Columbia, showing estuaries described in the text.

estuary for 2-3 months before reaching a size of about 70 mm when smolting occurred and the stock moved to sea. Chum salmon fry showed a different pattern. Fry that arrived in the first part of the season resided in the estuary for 2-3 weeks, while later cohorts used the estuary only for 5-6 days. Extensive studies on trophodynamics were conducted at this estuary. Chum fry were found to rely almost exclusively on an harpacticoid copepod *(Harpacticus uniremis)* as a food source, and by analyses of secondary and tertiary production (Sibert 1979, Healey 1979) it was found that prey biomass was almost in balance with the predator's food requirements *(Table 1)*. Healey (1982) documented size-selective mortality in the Nanaimo River chum stock, and the production work showed evidence of food limitation on secondary production of chum fry. This was an important conclusion which reinforced the significance of food sources in the estuary. Earlier researchers at the Nanaimo Estuary had already investigated the carbon flow patterns in the estuary and established the detrital food web in the estuary (Sibert, Brown, Healey, Kask & Naiman 1977). The carbon budget was investigated for the estuary (Naiman & Sibert 1978) and showed that the quantities of detritus from microbenthic algae, sedges, eelgrass, and riparian vegetation from upriver sources were significant, and that the timing of carbon supply was perhaps as significant as the amount produced (Sibert 1982).

Table 1. Summary of abundance, growth, production, and feeding rates of chum fry on the Nanaimo estuary (modified from Healey, 1979).

Year	1975	1976
Downstream migrants	52.4×10^6	$29.6\ 10^6$
Cumulative estuary biomass (kg)[1]	41 000	19 000
Mean daily growth % body wt/d	6.0	6.2
Total production (kg)	2 400	1 100
Daily ingestion rate (%)	15	15
Total food required (kg)	6 200	2 800

[1] Cumulative chum fry biomass from mid-March to early June.

4. The Fraser River Estuary

Intensive studies in this very large estuary have focussed on two habitats within it: brackish marshes about 10 km upstream of the mouth, and some unvegetated tidal flats (14 000 ha) further seaward. Researchers from the University of British Columbia focussed on the use which juvenile chinook made of the brackish marsh areas. The Harrison chinook stock, another 'ocean type' life history form, was found to dominate, and residency time was comparable to that found at the Nanaimo estuary (Levy & Northcote 1982). Research also identified the features of tidal channels cutting through the brackish marsh, and found that deeper channels supported more chinook than shallower habitats (Levy & Northcote 1981). Some thorough studies dealing with sedge production were conducted and below-ground productivity of rhizomes was found to be equivalent or greater than the material above ground (Kistritz, Hall & Yesaki 1983). No detailed work on secondary productivity was done at these study sites, but the diet of chinook was found to be dominated by chironomid larvae and pupae. The linkage between vegetation, invertebrates, and fish production was only presented graphically *(Figure 2)*, but clearly food webs supporting salmon were detritus-based (Northcote, Johnston & Tsumura 1979).

Research on the unvegetated tidal flats showed that juvenile chinook used low tide refuges (Levings 1982) and fed on mysids *(Neomysis mercedis)*, adult chironomids *(Cricotopus* sp.*)*, and gammarid amphipods *(Eogammarus confervicolus)*. Some of these organisms may have been used when chinook were using the marshes at high tide, but invertebrates are also transported to the tidal flats on the ebb flow (Levings 1982).

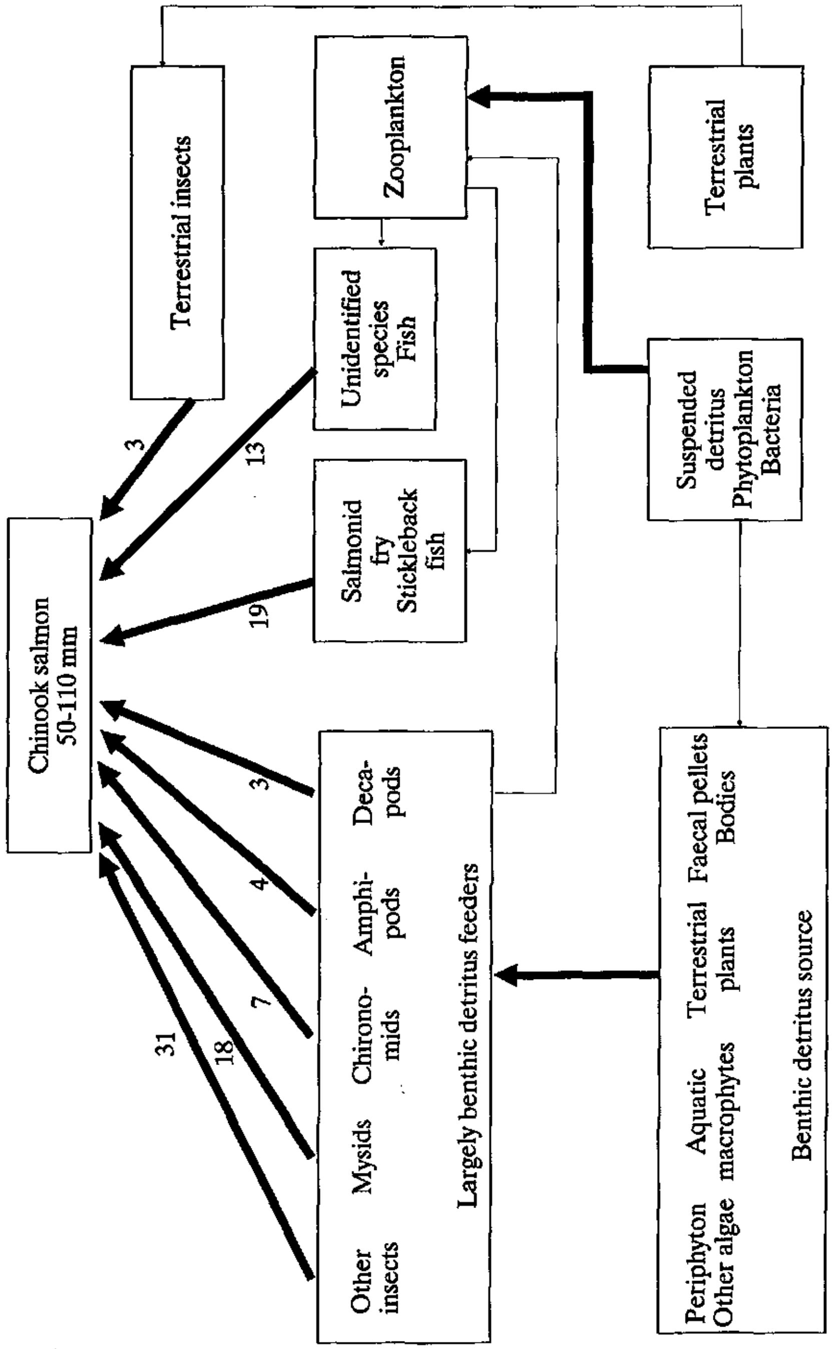

Figure 2. Food web linkages for juvenile chinook salmon in the Fraser River estuary (from Northcote, Johnson & Tsumura 1979).

Harpacticoid copepods in the unvegetated habitat were mainly burrowing species (Harrison 1981) which apparently were not available to the fish. Gammarid amphipods, especially *E. confervicolus*, were found to be preferentially associated with algal detritus on the flats, and grew best on microbenthic algae rather than sedge detritus (Pomeroy & Levings 1980).

5. The Squamish Estuary

This was the first estuary in British Columbia to be examined in detail. Beginning in 1972, a series of studies focussed on the production dynamics of the brackish marsh ecosystem supporting juvenile chinook, coho, and chum fry. In this instance, it was found that chinook smolts and presmolts used the estuary (Levy & Levings 1978). Residency time for chinook in estuaries is inversely related to size (Healey 1980), and therefore these smolts would be expected to spend less time than fry in the estuary. Both chinook and chum used gammarid amphipods *(Eogammarus confervicolus)* extensively. This crustacean was very abundant and productive (Stanhope & Levings 1985) and was also very tightly associated with microhabitats in sedge *(Carex lyngbyei)* rhizomes (Levings 1973). An energy budget was prepared for the estuary and showed that amphipod productivity was highly dependent on energy sources from sedge and microbenthic algae (Pomeroy 1977). Detailed residency studies were not conducted on fish populations at the estuary, except for coho fry which were found to use estuarine channel habitat for up to 10 days (Ryall & Levings 1987).

6. Survival experiments

In 1983, we began a series of experiments to try to test the hypothesis that survival of juvenile salmon to adulthood, when exposed to an estuary, was different from that of salmon excluded from this habitat. The only other work which dealt with the effects of an estuarine life phase on subsequent adult survival was published on chinook salmon in an Oregon, USA, estuary (Reimers 1973). Using scale analyses, this author concluded that a particular form, which used the Sixes River estuary, survived better than forms with life histories which did not. In our experiments, which used hatchery reared chinook, we transported specially marked and coded wire tagged groups (35 000 fry per group) around the Campbell River estuary, and released them into fully marine and transitional sites. We are currently documenting their survival to catch and escapement, relative to that of groups released into the river and the estuary. Experimental procedures are described elsewhere (Macdonald, Levings, McAllister, Fagerlund & McBride 1988) and I present below, preliminary results accounting for data available up to mid-March 1988 (638 returns) *(Table 2)*.

For releases made in 1983 and 1984, there was a significant difference ($p < 0.05$) in returns and fish released to river and estuary sites contributed strongly to catch and escapement. Numbers returned were ranked in the following order: Marine < transition < river <estuary. Results to date indicate that returns from 1985 are not statistically significant ($p > 0.05$). The experiments were accompanied by a sampling program to evaluate dispersion, short-term mortality, feeding, and predation, in an effort to obtain

Table 2. Preliminary results of experimental releases of juvenile chinook salmon at the Campell River Estuary. Observed tag returns in catch and escapement, and total, categorized by release site and year of release (from Levings, McAllister, Macdonald, Brown, Kotyk & Kask 1989).

Release year	Recovery	River	Estuary	Transition	Marine
1983	catch	69	89	22	15
	escapement	73	78	22	12
	total	142	164	44	27
1984	catch	20	36	9	9
	escapement	17	22	6	4
	total	37	58	15	13
1985	catch	28	18	24	29
	escapement	9	11	13	6
	total	37	29	37	35

data on estuarine functioning at the time of the releases. This programme was only partially successful and further work is needed to conclusively identify the causal factors which could have led to the observed differences in survival. It is particularly important to investigate food limitation which is, as explained above, the most significant factor for contemporary estuarine fish habitat management.

7. Development of criteria for estuarine fish habitat management

In the Pacific region of the Department of Fisheries and Oceans, fish habitat management biologists have developed management procedures for minimizing impact on what they infer to be key habitats, accounting for most of the carrying capacity in estuaries. These procedures and criteria have been developed using the above research results, and others, in consultation with local researchers. However, these management criteria have been developed without any data from British Columbia on the quantitative effect of estuarine residency on survival to adult salmon. Management criteria have been mostly based on vegetation and elevation attributes which incorporate the inter-tidal zonation on the estuary shoreline *(Figure 3)*. In brackish estuaries, sedge habitats located at about mid-tide level have been afforded the highest value for fish habitat. In higher salinity areas, eelgrass beds have a similar priority. This is based on our own research results which emphasize the significant role of these plants in detritus production, and on results from elsewhere in the work which have demonstrated the importance of marsh vegetation in predator avoidance (*e.g.* Rozas & Odum 1987), and from observations that show chinook fry to be abundant along shorelines where emergent plant communities occur.

Fish habitat managers have also adapted, with modification, a classification system developed in Oregon (Anonymous 1984) which actually assigns value to various types of estuarine habitat based on salinity, elevation, and vegetation criteria. Habitat managers in British Columbia have not published a numerical rating scheme or guide-line. However, when compensation for habitat loss is permitted, as is possible under the recent DFO policy on Fish Habitat Management (DFO 1986), the most stringent requirements are placed on the vascular plant communities. For example, if sedge meadows are to be replaced, by development of identical habitat through lowering substrate elevation and transplanting supra-tidal areas; safety factors of 2:1 on an area basis have been provisionally recommended to developers. The safety factor is thought to be necessary because it could take as long as 10 years for a developed marsh to function (*i.e.* supply detritus) at rates that are comparable to natural habitats (Race 1985). Riparian fringe habitats (*e.g.* with species of *Salix* and *Alnus*) and unvegetated mud or sandflat habitats, can be replaced provisionally on a 1:1 basis. Although such criteria are based on good ecological principles, they unfortunately do not take into account the loss of shallow water habitat, since the criteria pertain to an **area** rather than a **volumetric** measure of fish habitat. Since estuarine habitat is often lost through filling, to create land for industrial purposes, bookkeeping of fish habitat would be better based on volume.

For the purpose of this paper, however, the most important point is that fish habitat managers are managing these valuable estuarine areas using ecological inference, but backed up by a substantial body of knowledge on food chain dynamics and trophic ecology. A quantitative evaluation or mathematical modelling of the impact of estuarine habitat loss on salmon populations cannot be conducted with present knowledge, but this has not precluded management by inference and development of definitions of habitat for regulatory purposes. For example, under section 31 of Fisheries Act of Canada (see DFO 1986) the Minister of Fisheries and Oceans has the authority to modify, restrict, or prohibit any work or undertaking which is likely to result in the harmful alteration, disruption or destruction of fish habitat where the latter is defined as 'spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes'. Clearly the existing trophodynamic data and the preliminary survival information now available support the idea that estuaries are areas that fish depend on. Using our Campbell River Estuary data for 1983 and 1984 releases (*Table 2*) for example, one can make a crude calculation indicating that if juvenile chinook salmon were denied access to an estuary, survival could decrease by about 68%. If there had been no difference in survival between the release groups and equal fishing mortality, 125 returns from each release group could be expected (*i.e.* 500/4). However, only 40 fish from the marine release were recovered from catch and escapement, a 68% decrease from that theoretically expected.

If the final results of our experimental release work bear out the above conclusion, then management based on inference of estuarine effects on salmonids, trophodynamics, and ecological processes will have been only partially vindicated. This is so because our release experiments considered habitat at the macro scale, *i.e.* the entire estuary. The next level of complexity must be tackled, namely differences in survival value between habitats within the estuary. This is a microhabitat issue for which it will be very difficult to design experiments since juvenile salmon must move with tidal and river currents from one habitat type to another (*e.g.* riparian to marsh to sandflat on an ebbing tide). It will be necessary to continually refine our current understanding and expand the data bases used for fish habitat management in estuaries. This is particularly important in North

ESTUARINE HABITATS

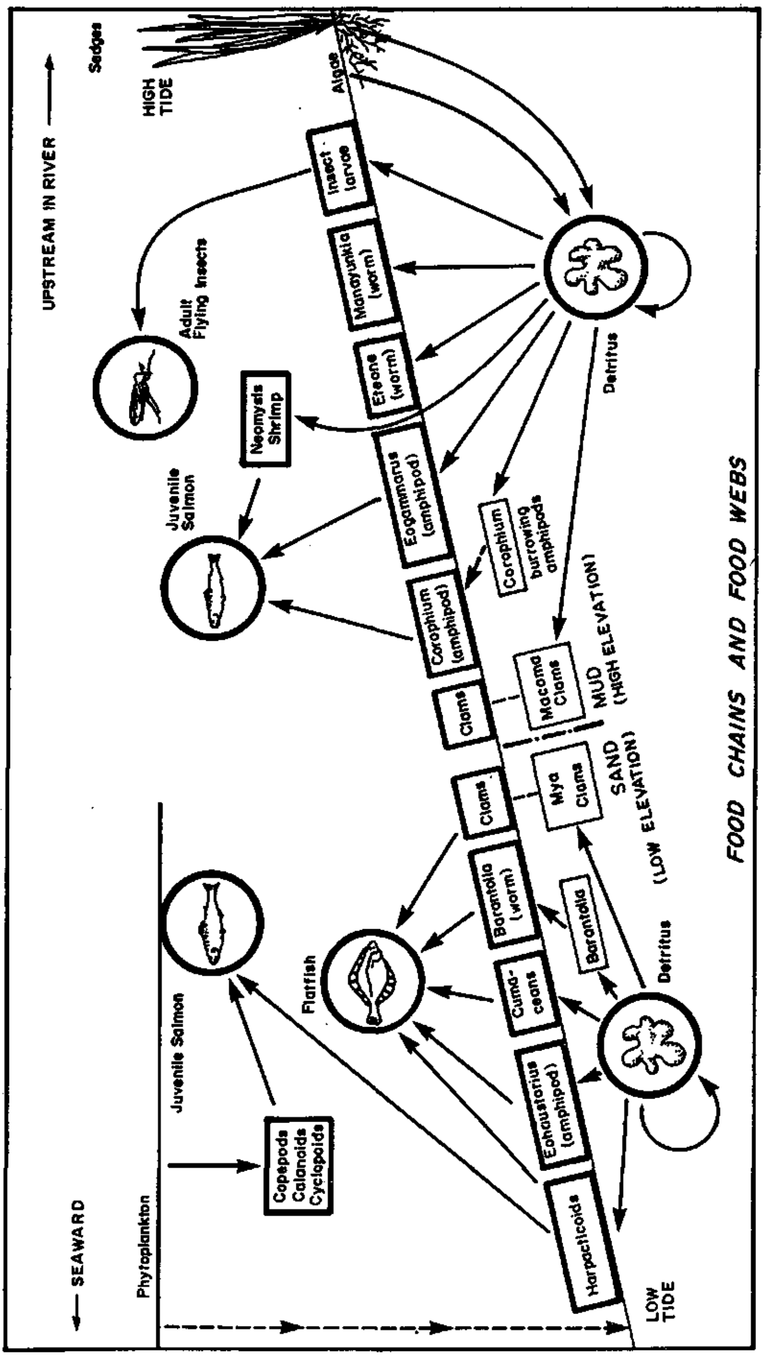

Figure 3. Zonation of biota and food webs at a schematic British Columbia estuary.

America where there is an inexorable shift in human populations towards the coastline, and the competition for space between humans and fish within the estuaries will increase substantially in the next few decades. As well, fish production in estuaries must be meaningfully linked to production upstream in the catchment basin and seaward in the coastal zone. Through an understanding of the complete life history of the stock and habitat effects at various life stages, management strategies can be improved.

References

Anonymous, 1984. Estuarine Mitigation: the Oregon Process. Principal Author, S.F. Hamilton, State of Oregon, Division of State Lands, Salem, Oregon. 60 pp.

DFO (Department of Fisheries and Oceans), 1986. Policy for the Management of Fish Habitat. Department of Fisheries and Oceans, Ottawa, Ontario. Cat. No. Fs 23-98/1986E. 30 pp.

Dorcey, A.H.J., Northcote, T.G. & Ward, D.V., 1978. Are the Fraser marshes essential to salmon? Westwater Lecture Report No. 1 (Given March 9, 1978). Westwater Research Centre, University of B.C., Vancouver. 29 pp.

Harrison, B.J. 1981. The biological determinants of the structure of harpacticoid copepod communities on an estuarine inter-tidal flat (Fraser River Delta, B.C.). Ph.D. Dissertation, University of British Columbia, Vancouver. 350 pp.

Healey, M.C., 1979. Detritus and juvenile salmon production in the Nanaimo estuary. 1. Production and feeding rates of juvenile chum salmon (*Oncorhynchus keta*). J. Fish. Res. Bd Can. 36: 488-496.

Healey, M.C. 1980. Utilisation of the Nanaimo River estuary by juvenile chinook salmon (*Oncorhynchus tshawytscha*). Fish. Bull. (U.S.) 77: 653-668.

Healey, M.C. 1982. Timing and relative intensity of size-selective mortality of juvenile chum salmon (*Oncorhynchus keta*) during early sea life. Can. J. Fish. Aquat. Sci. 39: 952-957.

Healey, M.C., 1983. Coastwide distribution and ocean migration patterns of stream- and ocean-type chinook salmon (*Oncorhynchus tshawytscha*). Canadian Field Naturalist 97: 427-433.

Hoos, L.M. & Packman, G.A., 1974. Fraser River estuary – status of environmental knowledge to 1974. Dept of Environment, Special Estuaries Series Report No. 1. West Vancouver Laboratory, West Vancouver. 518 pp.

Kistritz, R.U., Hall, K.J. & Yesaki, I., 1983. Productivity, detritus flux, and nutrient cycling in a *Carex lyngbyei* tidal marsh. Estuaries 6: 227-236.

Levings, C.D., 1973. Inter-tidal benthos of the Squamish River estuary. Fish. Res. Bd Can., MS Rep. 1218. West Vancouver Laboratory, West Vancouver. 60 pp.

Levings, C.D., 1982. Short term use of a low tide refuge in a sandflat by juvenile chinook (*Oncorhunchus tshawytscha*), Fraser River estuary. Can. Tech. Rep. Fish Aquat. Sci. 1111. 33 pp.

Levings, C.D., McAllister, C.D., Macdonald, J.S., Brown, T.J., Kotyk, M.S. & Kask, B.A., 1989. Chinook salmon and estuarine habitat: a transfer experiment can help evaluate estuary dependency. In: Levings, C.D., Holtby, L.B. & Henderson, M.A. (Eds). Proc. National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Can. Spec. Publ. Fish. Aquat. Sci. 105 (in press). 19 pp.

Levy, D.A. & Levings, C.D., 1978. A description of the fish community of the Squamish River estuary, British Columbia: relative abundance, seasonal changes, and feeding habits of salmonids. Dept of Fisheries and Environment, Fisheries and Marine Service MS Report 1475. West Vancouver Laboratory, West Vancouver. 63 pp.

Levy, D.A. & Northcote, T.G., 1981. The distribution and abundance of juvenile salmon in marsh habitats of the Fraser River estuary. Westwater Research Centre. Tech., Report 25, University of B.C., Vancouver. 117 pp.

Levy, D.A. & Northcote, T.G., 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish. Aquat. Sci. 39: 270-276.

Macdonald, J.S., Levings, C.D., McAllister, C.D., Fagerlund, U.H.M. & McBride, J.R., 1988. A field experiment to test the importance of estuaries for chinook salmon (*Oncorhynchus tshawytscha*) survival: short term results. Can. J. Fish. Aquat. Sci. 145: 1366-1377.

Naiman, R.J. & Sibert, J.R., 1978. Transport of nutrients and carbon from the Nanaimo River to its estuary. Limnol. Oceanogr. 23: 1183-1193.

Northcote, T.G., Johnston, N.T. & Tsumura, K., 1979. Feeding relationships and food web structure of lower Fraser River fishes. Westwater Research Centre, Tech. Report 16. University of B.C., Vancouver. 73 pp.

Pomeroy, W.M., 1977. Benthic algal ecology and primary pathways of energy flow on the Squamish River delta, British Columbia. Ph.D. Dissertation, University of B.C., Vancouver. 175 pp.

Pomeroy, W.M. & Levings, C.D., 1980. Association and feeding relationships between *Eogammarus confervicolus* (Amphipoda, Gammaridae) and benthic algae on Sturgeon and Roberts Bank, Fraser River estuary. Can. J. Fish. Aquat. Sci. 37: 1-10.

Race, M.S., 1985. Critique of present wetlands mitigation policies in the United States based on an analysis of past restoration projects in San Francisco Bay. Environmental Management 9: 71-82.

Reimers, P.E., 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Fish. Comm. Oregon, Res. Rep. 4: 1-43.

Rozas, L.R. & Odum, W.E., 1987. Occupation of submerged aquatic vegetation by fishes: testing the role of food and refuge. Abstract in Proc. Ninth Biennial International Estuarine Research Conference, New Orleans, Louisiana. October 25-29, 1987.

Ryall, R. & Levings, C.D., 1987. Juvenile salmon utilisation of rejuvenated tidal channels in the Squamish River estuary, British Columbia. Can., MS Rep. Fish Aquat. Sci. 1904. West Vancouver Laboratory, West Vancouver. 23 pp.

Shirvell, C.S., 1989. Habitat models and their predictive capability to infer habitat effects on stock size. In: Levings, C.D., Holtby, L.B. & Henderson, M.A. (Eds). Proc. National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Can. Spec. Publ. Fish. Aquat. Sci. 105 (in press).

Sibert, J.R., Brown, T.J., Healey, M.C., Kask, B.A. & Naiman, R.J., 1977. Detritus-based food webs: exploitation by juvenile chum salmon (*Oncorhynchus keta*). Science 196: 649-658.

Sibert, J.R., 1979. Detritus and juvenile salmon production in the Nanaimo estuary II. Meiofauna available as food to juvenile chum salmon (*Oncorhynchus keta*). J. Fish. Res. Bd Can. 36.: 497-503.

Sibert, J.R., 1982. Roles for detritus in complementing productivity of coastal systems. pp. 207-214 in: L.M. Srivastava (Ed.). Synthetic and Degradative Processes in Marine Macrophytes. Walter de Gruyter, New York. 296 pp.

Stanhope, M.J. & Levings, C.D., 1985. Growth and production of *Eogammarus confervicolus* (Amphipoda, Anisogammaridae) at a log storage site and in areas of undisturbed habitat within the Squamish estuary, British Columbia, Can. J. Fish. Aquat. Sci. 42: 1733-1740.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 594-623.

Harmonic communities in aquatic ecosystems: a management perspective

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Abstract

Harmonic communities of fishes, by definition, comprise integral species associations with high levels of niche complementarity. In percid and salmonid assemblages of boreal forest lakes, and also in fish assemblages of marine systems, the harmonic community is dominated by a 'keystone' organism, usually a terminal predator, which is associated with three or four 'key' secondary species. The principal biological outputs of a harmonic community, such as production and yield, are largely dependent on these key species. Harmonic communities are optimized in their species composition through the ecological and evolutionary processes of niche-packing and resource partitioning. Food resources play a major role in this regard. Apposite levels of interspecific structural and behavioural diversity as well as other species linkages, contribute to the resilience and, therefore, the persistence of a harmonic community. Management strategy implies regulation of the terminal predator or other keystone organism, as well as the first three or four 'harmonic' species. Use of weighted mortality coefficients are appropriate targets for regulation, as they allow a disaggregated or astatic assemblage of fishes to regain harmony.

1. Introduction

Management strategies for both freshwater and marine fisheries are often based on the supposition of a sustained harvest of fishes from a finite community with identifiable characteristics. The fish community persists despite moderate to intensive levels of exploitation (Larkin 1976). The management goal of the recent past was to retain the harvestable pool of fishes 'in balance', that is, the predators and their prey would be retained somehow at an appropriate level of dynamic equilibrium. Except perhaps for bass-bluegill farm ponds, or for other simple applications (Swingle 1951), the concept of 'balance' was unquantifiable, unattainable in a complex dynamic system, or even obscure. Essentially, because of the evanescent nature of 'balance', managers had no clear understanding of what their management goal was, and when it was attained, if ever.

As an alternative to 'balance' we offer the hypothesis of the 'harmonic community', with the provisional understanding that our proposal is neither complete nor sufficient.

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1. Contribution No. 85-14 of the Ontario Ministry of Natural Resources, Research Section, Fisheries Branch, Box 50, Maple, Ont., Canada.

2. Bedford Institute of Oceanography Contribution.

Its principal advantage is that it provides a quantifiable and identifiable state or objective for a fisheries manager in a moderately unperturbed, multi-species system.

Harmonic communities of fishes persist over time as recognizable identities, despite the intermittent buffeting of a suite of natural stresses. This persistence is dependent upon the level of species integration which, in turn, is a result of long term co-existence and, perhaps in some instances, co-evolution (Ryder & Kerr 1978, 1984, Ryder, Kerr, Larkin & Taylor 1981, Ryder & Edwards 1985). This innate resilience to natural stresses is related not only to the competitive and predatory inter-dependences of the fishes (Werner 1984), but also to similar inter-relationships within the whole complex of animals and plants comprising the aquatic community (Pimm 1984). Hence, a community which has co-existed (or co-evolved) over eons (Cody & Diamond 1975, Whittaker 1975, Janzen 1980, Futuyma & Slatkin 1983), because of its many discrete pathways for transfer of materials and energy, offers alternative routes for these vital exchanges when confronted with a disruptive stress at a single link or node of the integrated whole (Welch 1967).

A harmonic community of fishes may be viewed as a moderately stable, hierarchic level of an ecosystem, functioning as an integrated unit, rather than as a loose and variable aggregation of weakly associated species. The latter type of fish assemblage, often resulting from the intervention of man, changes rapidly in terms of species composition and topology, and only rarely attains any semblance of predictable steady-state. Because of these ever-changing attributes, we have designated the latter type of fish assemblage, as 'astatic' (Ryder & Kerr 1978). Astatic assemblages have been attributed to cultural eutrophication, over-exploitation, introduction of exotic species (Loftus & Regier 1972), or to any of man's other incursions into the natural environment that directly or indirectly affect the habitat or biota.

While harmonic communities retain their compositional identity when under natural stress, they may be subjected to topological distortion of the whole (Holling 1985). Accordingly, an episodic event such as a forest fire, which may temporarily increase the trophic level of a lake, may simultaneously cause disruption of the biomass spectra, or alter species ratios, or cohort ratios within the community. A fish community stressed naturally in such a manner may be driven towards an earlier successional stage through elastic deformations or topological distortion (Holling 1985), but its overall identity is usually retained in terms of species composition. Hence a percid community (Ryder & Kerr 1978) subjected to stresses emanating from a forest fire, would retain its four key species despite possible internal changes in ratios of cohorts, biomass and size distribution. Yellow perch, which may be favoured initially by eutrophication (Leach, Johnson, Kelso, Hartmann, Numan & Entz 1977), temporarily becomes the predominant species, and mean age and size of the individual cohorts are altered as the young and/or small fishes more efficiently exploit the primitive environment (*i.e.* early successional stage).

Throughout this discussion, we will elaborate on the ecological attributes of two types of harmonic communities found in the north-temperate boreal forests of North America. The first is the percid community found in mesotrophic lakes, consisting of four key species with complementary niche dimensions. These key species of the percid community are the walleye, a terminal predator; the northern pike, an accessory piscivore; the yellow perch, a predator of small food particles which is, in turn, a major prey item; and the white sucker which is a large benthivore and also a prey species during the first year or two of its life.

The salmonid community which is better adapted to oligotrophic lakes, is similarly composed of species playing specific ecological roles. Indeed, some of the components of a harmonic salmonid community may well be the same species to be found in a percid community. Suffice it to say, that regardless of which community is under discussion, the ecological fundamentals will be the same. Accordingly, we will focus most of the remaining discussion on the percid community, drawing examples from the salmonid community as appropriate.

As it is important, from a management point of view, to distinguish an identifiable, integrated and persistent community, from a loose and unstable assemblage of fishes, appropriate descriptive terms were sought. The adjective 'harmonic' was chosen as the term best representing our concept from several points of view. Dictionary definitions of 'harmonic' which are consistent with our intentions are, from the field of electronics, 'a component frequency of a harmonic motion that is an integral multiple of the fundamental frequency'; from mathematics 'the expression of a periodic function as a sum of sines and cosines and specifically by means of a Fourier series'; and from music, 'of or relating to musical harmony; of an integrated nature'.

The noun 'harmony' and adjective 'harmonious' are equally consistent with our intent to convey something other than a haphazard arrangement of community members. Hence 'harmonious' conveys the sense of 'having the parts agreeably related', while 'harmony' suggests 'a pleasing or congruent arrangement of parts'.

We propose that harmonic communities have evolved over time through niche complementarity or 'niche packing' (Werner 1977), an optimization of individual niche scope either through genetic or phenotypic diversification and adaptation (Ryder *et al.* 1981). Hence the concept of harmonic communities may be extended to include different stocks of fishes as well as species, provided that the individual stocks are sufficiently differentiated (either genotypically or phenotypically) to preclude an undue degree of overlap of their realized niches.

Pragmatically, maintenance of harmonic communities provides a benchmark for the efficient management of a fishery (Ryder & Edwards 1985). Purposeful retention of the harmonic condition in the face of multiple cultural stresses requires not only a conceptual insight into the structure and interdependences of the component species of a community, but also a method for the identification of the desirable state from an anthropocentric point of view. Traditional methods for analyses of the internal dynamics of fish stocks (Beverton & Holt 1957, Ricker 1975) aid in the demographic quantification of the individual species constituting harmonic communities. However, a more comprehensive approach requires a new epistemology specific to harmonic communities as persistent and integral subsystems within the larger context of an aquatic ecosystem. Consequently, harmonic communities may be identified according to their observables, but recognition of their prerequisites for persistence requires an ecosystem point of reference. Descriptive scenarios of ecosystem successional stages, provided by Holling (1985), are helpful in circumscribing the environmental boundaries that are conducive to any particular harmonic community. Explicitly, these stages are described by Holling as exploitation, conservation, creative destruction, and mobilization/retention. Accordingly, any aquatic community which transcends one or more of the environmental boundaries may gravitate towards a new dynamic equilibrium (Peterman, Clark & Holling 1979).

Finally, we do not attempt to resolve herein the controversies generated by the failure of previous empirical studies to predict community behaviour (Maurer 1987). Rather, we provide an heuristic community model for evaluation, based in part, on an amalgam of current ecological lore, with the expectation that constructive feedback will enhance and improve its predictive capabilities.

2. Methods

Some of the data relative to species occurrences were based on our own observations, while other data were gleaned from the files of the Ontario Fisheries Information System (OFIS). Many of these data series were derived from 24-hour gill-net catches which integrate species occurrences over time; therefore, they often provide a misleading impression of mutual co-occurrence. To circumvent this problem, the observations relating to the interactions within species assemblages in boreal forest lakes were taken from the SCUBA diving notes of R.A.R. The latter represent over 1000 hours of diving in more than 200 lakes during all seasons of the year, both in the day-time and at night. The derivation of the harmonic community concept is, in part, an intuitive one based on the observed species assemblages while diving (Ryder 1977), and also from emergent patterns of yield derived from the records of long-term commercial fisheries *(Figure 1)*.

3. Epistemology

The level of comprehension of the structure and interdependencies of harmonic communities and astatic fish assemblages in boreal forest lakes is rudimentary. The conceptual literature relating specifically to these ideas is limited (Ryder & Kerr 1978, Ryder *et al.* 1981, Ryder & Kerr 1984). Peterman *et al.* (1979) addressed a similar topic in disparate systems, in which they described multiple equilibrium states in ecological systems. Their terminology differs from that of Ryder & Kerr (1978), but some of their concepts are consistent with our understanding. The 'attractor region' described by Peterman *et al.* (1979) is conceptually similar to our term 'median of central tendency' for fish communities (Ryder & Kerr 1978). In fact, the original notion of discrete zones of relative community stability may be attributed to K. H. Loftus who first observed that when fish yield was plotted against an environmental yield index for a suite of lakes, those with low index values were invariably salmonid communities, while those clustered at higher values were percid, or centrarchid-cyprinid communities (see Colby, Spangler, Hurley & McCombie 1972 for details). This apparent 'cline' of communities was in fact discontiguous, that is, trimodal in distribution, and perhaps attributable to a series of bifurcation processes as described by Kerr (1977). This operational concept removed some of the ambiguity from the notion of a cline of communities which has subsequently been clarified by Ryder & Kerr (1978) and Peterman *et al.* (1979). However, although another school of thought in ecology favours the clinal or continuum concept (Austin 1985), our empirical evidence does not support it, and here it must suffice to say that alternative viewpoints to our hypothesis exist.

Elaboration of the description of harmonic communities by Ryder & Kerr (1984) showed that it was consistent with the concepts of the realized or operational niche of a species (Fry 1947, Hutchinson 1957); interactive segregation between two species (Nilsson 1967); dominance-subordinance between two co-existing species (Svärdson 1976, Skud 1982); and resource partitioning among sympatric species (Schoener 1974, Werner,

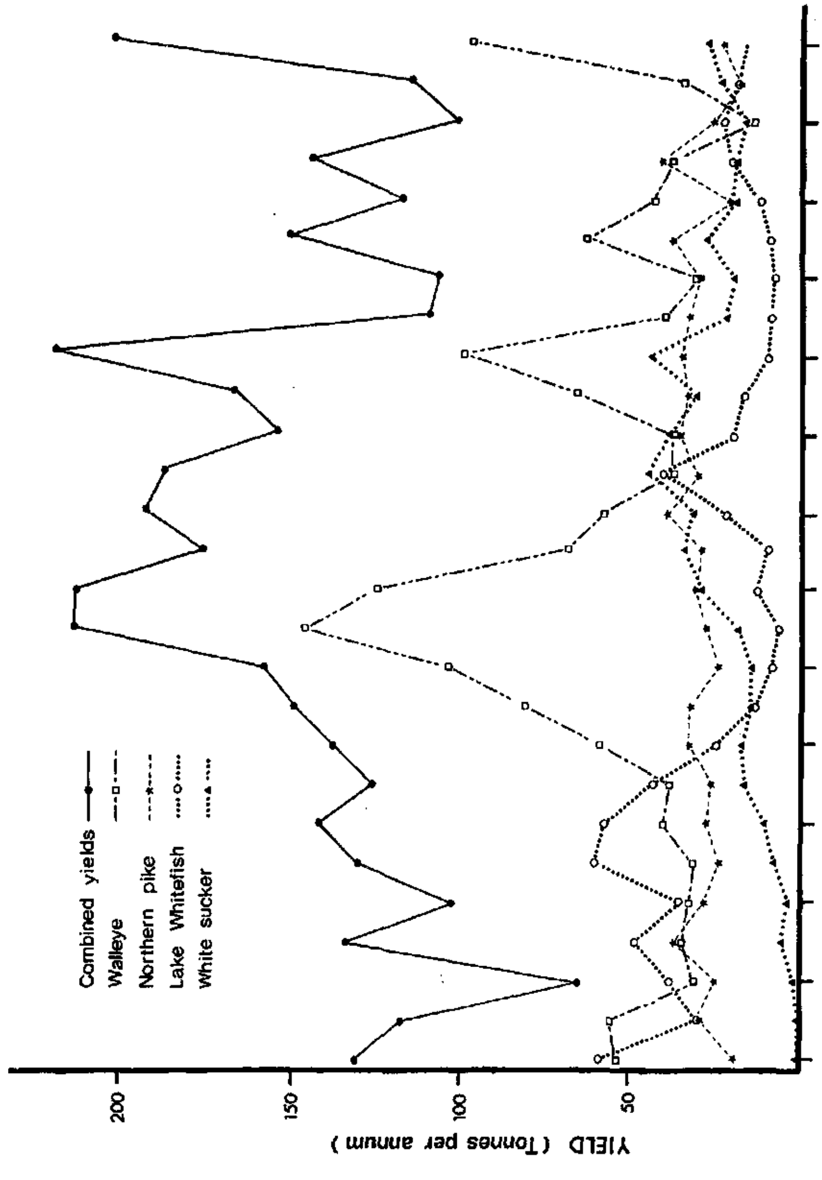

Figure 1. Commercial fishery yields for major species components of a percid community, Shoal Lake, Ontario, 1950-1976. Yellow perch are not normally recorded from this fishery although they occur in abundance within the lake. It is evident that the total yield from this harmonic community is inordinately influenced by the yield of the predominant species, which is a terminal predator, the walleye.

Hall, Laughlin, Wagner, Wilsmann & Funk 1977). Essentially, the harmonic community concept was compatible with some of the most robust and strongly entrenched concepts in ecology.

The significance of harmonic communities within the Laurentian Great Lakes context has been further elaborated by Ryder & Edwards (1985). There, one of the primary obstacles to the application of a community approach is the degree of 'uncertainty' associated with it. We concur that there are major gaps in our knowledge; consequently, there exists a less than perfect accordance of the harmonic community concept with current management perceptions and practices. We have attempted to correct this uncertainty in two recent contributions to the understanding of harmonic communities. The *first* provides a detailed description of how a historic baseline of a harmonic community might be determined through the close monitoring of a single keystone species, in this case, the lake trout *(Salvelinus namaycush)* (Ryder & Edwards 1985). The second contribution, among other things, demonstrates the importance of identifying the effects of human interventions at higher levels of integration than that of the species, in this case-the harmonic community (Kerr, Larkin & Ryder, in prep.)

4. Electronic attributes

While we do not wish to belabour the obvious analogies between electronic and ecological systems, we hasten to point out that an understanding of the behaviour of electronic systems facilitates a comprehension of the more complicated community dynamics. We allude, herein, to some of the fundamental principles without detailed explanation. Later portions of the text will provide further insights into the commonalities shared by electronic and ecological systems. The following is a brief list of analogies which we espouse.

1. Within a harmonic community, in a relatively stable environment, steady-state for the whole community may be maintained through regulation of as few as four or five key species (*i.e.* the first four or five harmonics).
2. Waveform is important in the analysis of a harmonic community. This maxim applies to both the complex output wave (community yield) as well as to the individual harmonics (species yields). Two important properties of waveform are amplitude and frequency, and appropriate analyses should consider both for each key species.
3. Individual species production rates will assume an approximate dynamic proportionality of harmonic waves to one another with minor variance, as well as to community production as long as a modicum of harmony is maintained.
4. Fisheries yields as represented by non-sinsusoidal wave forms, will be predictable only so long as their principal harmonic components retain their conservative, internal, dynamic proportionalities.
5. In a non-sinusoidal wave form, the first harmonic is the most influential in the determination of the shape of the output wave.

This last critical observation may be viewed as analogous to the controlling effect of a terminal predator on the production rates of other species in a harmonic community. In this regard the terminal predator may be considered to be a 'keystone' organism in the sense of Paine (1966). This is explicitly demonstrated in *Figure 1*, where the relative effect of walleye yield on community yield is inordinately large as compared with other single-species effects.

In our further attempt to identify ecological order within seemingly chaotic and unpredictable systems, homeostatic system boundaries must be identified and interactions quantified. Electronic analogues assist this process, but also leave us with both a comprehension and a rhetoric that are neither perfectly apt nor sufficient. The essential factor here is that both the ecological and the electronic systems are specific examples of a common class of situations (Holling 1969). Finally, we point out that an ecological system is not perfectly analogous in form and function to an electronic system. However, the latter provides us with an appropriate orientation, that is, a focal point from which to view community harmonics objectively, and in a systematic and orderly fashion. Quantitative simulation via analogue computer (Denmead 1972) or Fourier series analysis will be left for future endeavours.

While the fundamental principles that we espouse apply to both physical and ecological systems, applications to the latter system are much 'softer' and subject to greater variability or overlap at the stage of quantification. More specifically, ecological regulation is not an additive process, but owes much to both strong and weak non-linear interactions among system components. Despite these differences, the electronic analogy provides a convenient quantitative format for dealing with ecological systems, which often seem inordinately complex and non-quantifiable. In this regard, it is not dissimilar to the application of spectral analysis to ecological systems (Platt & Denman 1975).

5. Concept

We hypothesized that the keystone component of a percid community (Ryder & Kerr 1978) is the walleye *(Stizostedion vitreum)*, which is complemented by other key species, the northern pike *(Esox lucius)*, white sucker *(Catostomus commersonii)* and yellow perch *(Perca flavescens)*. These comprise the four most abundant species within a percid community in a large set (N = 2340) of Ontario lakes *(Table 1)*. The fact that subsequent quantification of the relative importance of these four key species in a percid community (Marshall & Ryan 1987) was substantially retrospective to our initial intuitive observations (Ryder & Kerr 1978), lends a degree of credence to the reliability of the latter approach (Fager & Longhurst 1968). Each of these four species is present in more than 86% of the total set of walleye lakes *(Table 1)*. They are key species, not only by virtue of their relative ubiquity, but also because of their proportionately high abundance in individual walleye lakes (Adams & Olver 1977) and their important ecological roles there.

Lake whitefish *(Coregonus clupeaformis)* and lake herring *(Coregonus artedii)* both occur in only 46% of the lakes. However, these two species are more usually attributed to a salmonid rather than a percid community, and therefore, are more commonly found in the largest and probably deepest lakes of the walleye lake set (Hayes 1957). Here we have one of the apparent ambiguities of the commonly held stereotype of what constitutes a harmonic percid community. We contend that on a purely ecological basis, the lake whitefish and lake herring do not play a critical role in the process of 'harmonizing' within a percid community, despite their important ecological role within a salmonid

Table 1. Species composition of walleye lakes surveyed in Ontario. Percentages express frequency of occurrence within the total lake set (N = 2340). Only species occurring in 20 percent or more of the lakes have been included.

Species	Frequency of Occurrence %
Walleye (*Stizostedion vitreum*)	100
Northern pike (*Esox lucius*)	89
White sucker (*Catostomus commersoni*)	88
Yellow perch (*Perca flavescens*)	86
Lake whitefish (*Coregonus clupeaformis*)	46
Lake herring (*Coregonus artedii*)	46
Spottail shiner (*Notropis hudsonius*)	43
Burbot (*Lota lota*)	31
Johnny darter (*Etheostoma nigrum*)	29
Blacknose shiner (*Notropis heterolepis*)	29
Smallmouth bass (*Micropterus dolomieui*)	26
Iowa darter (*Etheostoma exile*)	25
Rock bass (*Ambloplites rupestris*)	25

community in the large and deep lakes in which they usually occur. Consequently, a stable, harmonic, percid community may exist in the absence of lake whitefish and lake herring, even in large, deep, oligotrophic lakes, but community production will likely decrease even if the four 'key' species modify their realized niche boundaries to partially accommodate the vacant, albeit somewhat hostile habitat within the pelagic and demersal zones. This principle is aptly illustrated upon close examination of fisheries yield data for Lakes Huron and Superior before and following sea lamprey *(Petromyzon marinus)* invasion (Baldwin, Saalfeld, Ross & Buettner 1979). In both instances the terminal predators, lake trout and burbot, of a predominantly salmonid community were effectively eliminated by sea lamprey predation. The large habitat void left in the outer limnetic and demersal zones, which effectively made up roughly 80-90% of the lakes' inhabitable waters, was not utilized by the abundant percid communities, which were restricted to bays, river deltas and the nearshore littoral zone. Subsequent fish yields dropped drastically, of the order of 20-40% of their pre-sea lamprey levels.

The burbot *(Lota lota)* occurs in 31% of the percid lakes and also plays an important ecological role, but is not critical to the existence of a percid community. In southern latitudes, we see progressively more of the salmonid community components, including the burbot, dropping out (Frey 1955). Similarly, at a northern latitude, there are fewer species (*e.g.* pumpkinseed-*Lepomis gibbosus*, smallmouth bass-*Micropterus dolomieu)* which belong more appropriately to a centrarchid-cyprinid community. In general, the four key (species) components remain intact as long as their individual distributional limits are not exceeded. Generally there is no marked extension of walleye distribution within the north-temperate, boreal forest zone (Scott & Crossman 1973) that does not also coincide with the distribution of the other three key species, except for some localized distributional anomalies. The fact that all four species occupied the same refugium during Pleistocene glaciation (Bailey & Smith 1981) lends further credence to the need for long-term coexistence to achieve the harmonic state, and also to a pattern of similarity for post-glacial dispersal.

Because many of the species under discussion *(Tables 1* and *2)* occupied the Mississippi Refugium during the Pleistocene and had approximately similar post-glacial patterns of distribution, their absence from an Ontario lake was probably caused by one of three factors; disruption of normal dispersal routes created by local post-glacial events; changing environmental conditions resulting in gradual extinction; or species incompatibility, often with species from another glacial refugium; *e.g.* the brook trout *(Salvelinus fontinalis)* and walleye are usually mutually exclusive in small to moderate-sized lakes over most of their coincident range.

Table 2. Species composition of lake-trout lakes surveyed in Ontario. Percentages express frequency of occurrence within the total lake set (N = 1633). Only species occurring in 20 percent or more of the lake set have been included.

Species	Frequency of occurrence %
Lake trout *(Salvelinus namaycush)*	100
White sucker (*Catostomus commersoni*)	87
Yellow perch (*Perca flavescens*)	65
Lake whitefish (*Coregonus clupeaformis*)	38
Lake herring (*Coregonus artedii*)	36
Northern pike (*Esox lucius*)	36
Burbot (*Lota lota*)	35
Smallmouth bass (*Micropterus dolomieui*)	29
Iowa darter (*Etheostoma exile*)	22
Pumpkinseed (*Lepomis gibbosus*)	22
Brook Trout (*Salvelinus fontinalis*)	21
Blacknose shiner (*Notropis heterolepis*)	20
Walleye (*Stizostedion vitreum*)	20

Because the Mississippi Refugium was the common origin for both percid and salmonid community components in central North America, we might expect lake trout lakes (salmonid communities) and walleye lakes (percid communities) to contain rather similar faunas *(e.g. Figure 2)*, albeit the relative abundance of individual species would most likely reflect the disparate environments found between salmonid and percid lakes. Certain species with more generalized niches might be successful over a wider range of environments. This would appear to be particularly true for the white sucker and yellow perch, and to a lesser degree for the northern pike *(Figure 2)*. This ability to occupy diverse habitats undoubtedly enhanced survival following post-glacial dispersal for a number of fishes that, of necessity, had to invade rather austere environments. For example, during the Pleistocene, lakes were rapidly changing shape and subject to catastrophic morphological changes due to the creation of new outlets or the damming of old ones (Flint 1957). Also, ice-melt water draining from receding glaciers was extremely cold and laden with turbid clays, creating an inhospitable environment for most invading species.

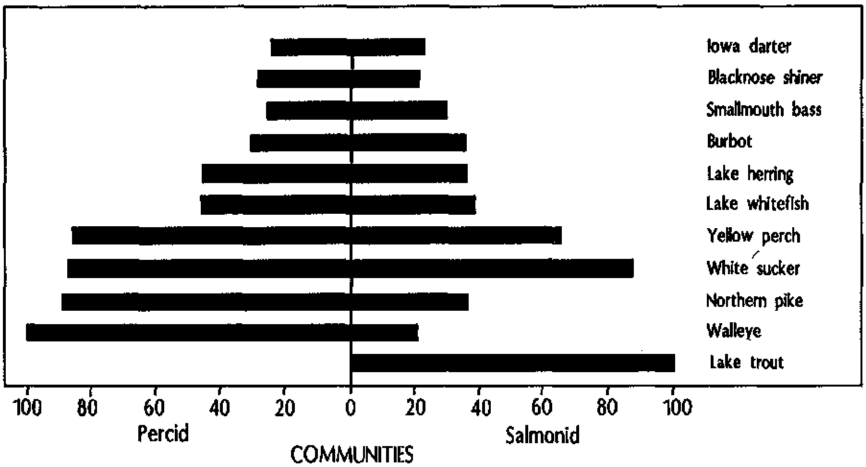

Figure 2. Ten species of fishes common to 20 percent or more of two lake sets consisting of 2340 percid lakes and 1633 salmonid lakes in Ontario. An eleventh species, the lake trout, is included, as it is a 'keystone' species for the salmonid community. It occurs in only 17% of percid communities and as such, remains unrecorded in *Table 1*.

Accordingly, the most readily adaptive species would also be the most widely distributed following post-glacial dispersal. Therefore, to define more precisely the ecological differences between percid and salmonid communities, we analyzed their components on a more rigourous criterion than frequency of occurrence alone. Since salmonid communities normally inhabit oligotrophic lakes while percid communities occupy mesotrophic lakes, it seemed logical to utilize a limiting nutrient such as phosphorus as an environmental index to separate these two types of communities. Indeed, mean phosphorus concentrations of about 10-20μg/l form a demarcation between percid and salmonid communities, with marginal salmonid communities (*i.e.* poor reproduction in lake trout) appearing at about the line of demarcation (Ryan & Marshall in prep.).

Another environmental factor that usually separates oligotrophic lakes from mesotrophic lakes at the same latitude is mean volumetric temperature during the open-water season. Within the boreal forest zone which is underlain by the Precambrian Shield in much of North America, oligotrophic lakes are usually deeper, and consequently colder than mesotrophic lakes, due to differences in physiographic conditions. The species that show marked spatial overlap between percid and salmonid communities *(Figure 2)* are widely separated when classified according to mean temperature preferenda *(Figure 3)*; the latter confer specific metabolic advantages related to growth and reproduction in appropriate environments; that is, mesotrophic lakes for percid communities and oligotrophic lakes for salmonid communities.

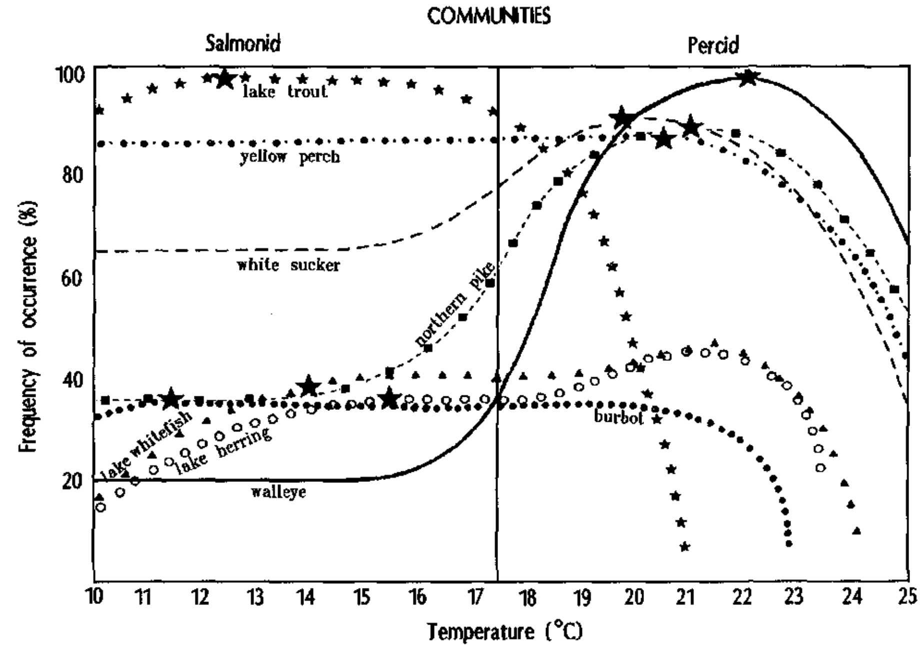

Figure 3. Temperature preferenda and frequency of occurrence of species components occurring in both percid and salmonid communities (20% frequency of occurrence except for lake trout) in the boreal forest zone. Large stars indicate the approximate temperature preferendum for each species. Incipient lethal temperatures are not specifically indicated. Frequency of occurrence is assumed to be highest at the preferred temperature within the 'home' community. Temperature data were interpreted from McCormick *et al.* (1971), Coutant (1977) and Casselman (1978).

Natural lakes that most closely represent the stereotypical salmonid or percid environments respectively, are those that are moderately small and deep if oligotrophic *(Figure 4)*, or large and shallow if mesotrophic *(Figure 5)*. However, many large, shallow lakes have one or more deep bays or basins that may harbour a residual salmonid community (Rawson 1961) in addition to the predominant percid community throughout the remainder of the lake *(Figure 6)*.

Alternatively large deep oligotrophic lakes *(Figure 6)* often have shallow bays, sheltered shorelines or river deltas that provide suitable habitats for percid communities (Ryder 1968). Ontario lakes, for the most part, are distributed over a gradient between

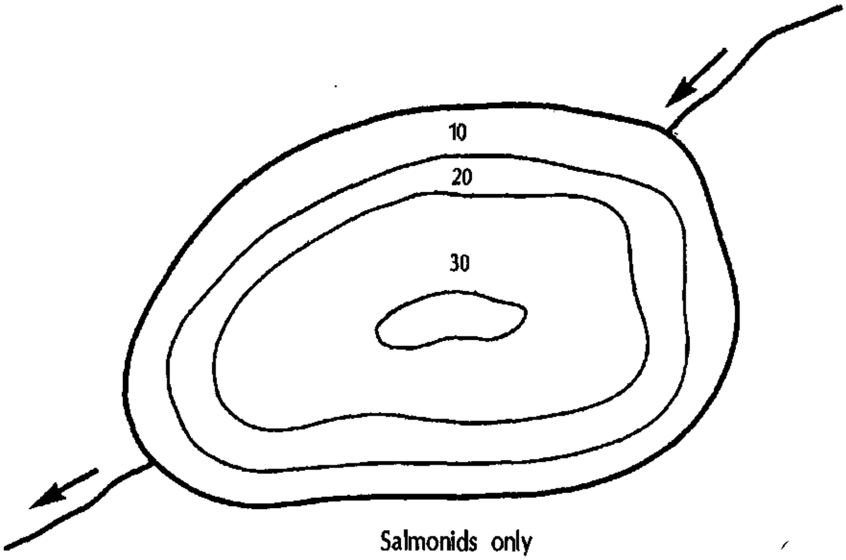

Figure 4. A schematic representation of a small deep oligotrophic lake that typically is dominated by a salmonid community.

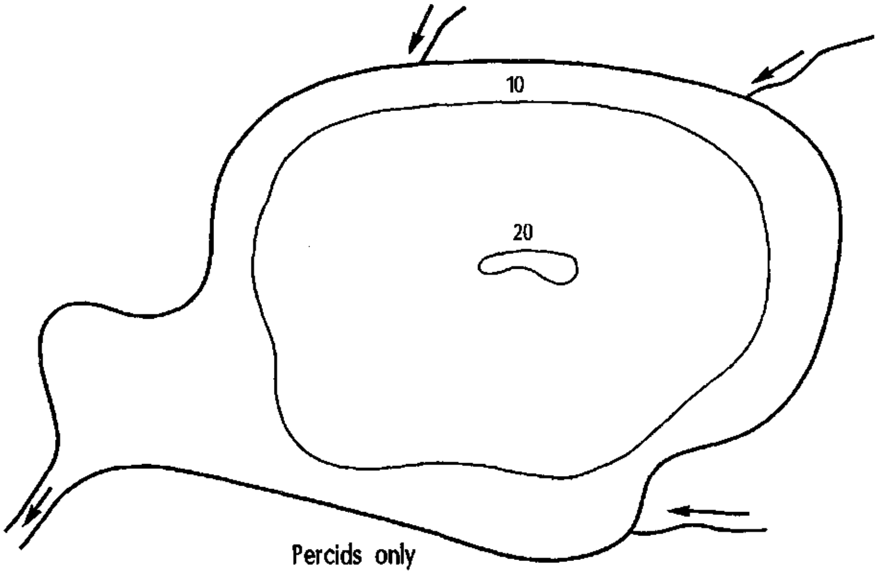

Figure 5. A schematic representation of a large mesotrophic lake that normally contains only members of the percid community.

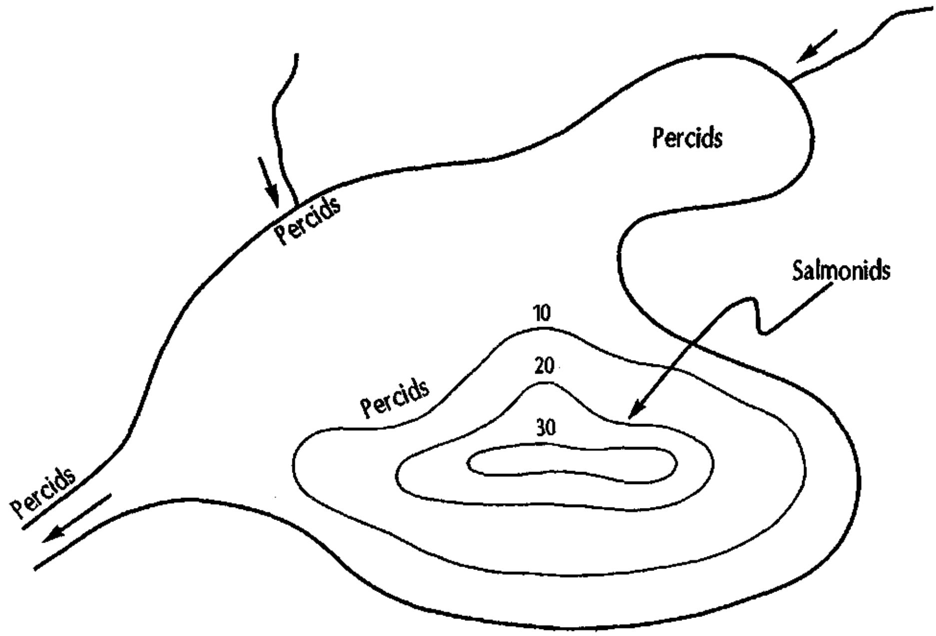

Figure 6. A schematic composite of a large mesotrophic or oligotrophic lake (dependent on nutrient concentrations). These lakes usually contain both percid and salmonid communities, although a degree of ecological segregation is effected along specific environmental dimensions of realized niche (e.g. temperature, nutrients).

the two extremes. This fact, coupled with the common Pleistocene origin for most species in the two communities, makes most classification schemes obscure, or imprecise at best.

6. Marine communities

We have found no major ecological differences (beyond those relating to high levels of salinity) between freshwater and marine fish communities that cannot be accounted for by differences in scale. Indeed, harmony, in the current context, is an essential component of marine communities and has been described in various ways, albeit sometimes in different terminology (Fager & Longhurst 1968, Skud 1982). Scale differences between the Laurentian Great Lakes and the much smaller boreal forest lakes account for differences in both environmental heterogeneity and species diversity, all other things being equal. Hence, in general terms, large lakes have more fish species than do small lakes (Barbour & Brown 1974), and oceanic systems have the most of all.

Because marine ecosystems are often larger, more open-ended, and tend to be bounded by spatially variable ecotones, the community approach is rendered somewhat more tenuous than is the case for most freshwater systems. Correspondingly, because of the large physical scale and generally richer faunal composition of marine communities, the availability of adequate time-series data is also less extensive than for freshwater communities. Moreover, high salinities and the presence of large-scale tidal, frontal, and other similar processes, imposes additional complexities of scale that are generally either less important or completely absent from freshwater systems. Just as the precise identification of fish communities is rendered more difficult by the spatial complexities introduced with increasing lake size, the large scales, relative lack of barriers to movement, and the high level of mobility of many species, further compounds the problem in marine systems. In consequence, the generalizations that can be made regarding community composition, and the harmonic relationships among the various community components, tend to be less rigorous than are similar observations made for discrete freshwater bodies.

Nevertheless, certain marine fish communities have been observed to possess rather well-defined bounds and identities, and are sufficiently integrated to be recognized as relatively discrete entities, although unambiguous community identification is by no means decisive in all instances (McKelvie 1985). Mills (1969) assessed the variable application of community definitions in marine systems, and the report edited by Mahon (1985) contains a number of papers summarizing the latest evidence for fish community structure in the northwest Atlantic. From these papers and comparable evidence from other sources, it is clear that marine production systems can possess similar kinds of community organization, but such patterns are more readily discernible in the generally more robust data sets and sparser faunas of freshwater systems.

Of the differences noted above between marine and freshwater systems, perhaps the most serious, from the point of view of community analysis, stems from the great diversity of the marine fauna. Because of their commercial importance, it is the fishes that comprise the major part of the available data base in freshwater. In marine systems however, large molluscs, crustaceans and mammals often constitute a significant portion of total yield. Even for the relatively depauperate fisheries of the northwest Atlantic (relative to, say, the Gulf of Thailand), the food web comprises very high abundances of largely unsampled fishes (*e.g.* the spiny dogfish, *Squalus acanthias*), invertebrates such as squids and jellyfishes, and birds and mammals. At present it is by no means clear whether these support relatively discrete trophic linkages, or whether strong interactions are the norm; the available data are not adequate to decide the matter, nor is it easy to assess the relative importance of abiotic factors and species interactions in determining species occurrences.

On the other hand, certain marine systems appear to be sufficiently simple in composition, such that the harmonic concept is self-evident. Consider the diversity of mammals, birds, fishes and invertebrates which depend directly upon krill *(Euphausia* sp.*)* for food. In this instance, krill may be a key species, and the dynamic equilibrium maintained between krill and their major predators is likely to be essential for the persistence of the system.

In essence, the time and opportunity for community co-evolution in marine systems has been very great, thereby allowing the generation of extremely complex communities. Nevertheless, the processes reflected in observed organizational patterns are potentially similar to those obtaining in freshwater systems, suggesting that the key to understanding the organization of marine systems may well be found in the study of freshwater communities (Kerr & Ryder 1988).

As marine ecosystems are even more open-ended and less discrete than inland waters, rendering the community approach more difficult, any generalizations made regarding community composition and harmonic relationships among the various components will be less rigorous. However, certain marine fish communities have rather well-defined bounds and identities and are sufficiently aggregated to be recognized as discrete entities (*e.g.* the northwest Atlantic gadoid complex, or the herring-mackerel pelagic complex).

7. Ecological prerequisites

There are several prerequisite conditions for the existence of an harmonic community, that is, one that is sufficiently well-integrated to persist in the foreseeable future as an identifiable and stable entity. Among these prerequisites are appropriately-scaled size ratios for the biota, trophic sufficiency, and complementary niche differentiation among the component species (Lindeman 1942, Kerr 1974, Whittaker & Levin 1975).

We will focus first on one aspect of niche differentiation that is critical to harmonic communities, that of the feeding inter-relationships of fishes in boreal forest lakes. Organisms utilize shared resources, such as energy, materials and space, at a fundamental level. A potential for competition exists whenever food, shelter, or spawning substrate are not present in sufficient abundance (Fraser 1978). Of these, food constitutes a major interactive pathway among organisms as expressed by predator-prey relationships (Stroud & Clepper 1979), grazing rates (Lewis 1979), or nutritional adequacy at the autotrophic level (Vollenweider 1969). Our concern here is with environmental partitioning along a time-space-species-size continuum of finite food resources (Schoener 1974).

Direct interaction of species when food is limiting may be circumvented in several ways (*Table 3*). These include, temporal stratification of resources, spatial partitioning, partitioning by species, and partitioning by size.

Foremost among these is the temporal stratification of food resources, that is, two different predators vying for the same forage base may feed on it at different times. Temporal stratification is most effective when it is mutually exclusive, for example, when one species feeds on a shared resource at night and the other in the day-time, with but little overlap. Certain morphological adaptations enhance the capability of a species to feed at night. These include barbels, a well developed acoustico-lateralis system or the presence of a *tapetum lucidum* behind the retina of the eye. Of the species shown in *Table 3*, the burbot possesses a tactile barbel while the walleye has a *tapetum lucidum* and the capability of occluding it with migrating pigments (Moore 1944). The latter mechanism also contributes to the effective predator-prey relationship between the walleye and yellow perch (Ali, Ryder & Anctil 1977). Temporal stratification of food resources may also occur on a winter-summer basis as in the case of the lake trout and smallmouth bass, the former feeding in littoral areas in winter and the latter species feeding in the same location in summer, thereby avoiding inordinately high levels of interaction (Ryder & Kerr 1984).

Spatial partitioning of food resources allows different predators to feed on similar forage at the same time, but in different locations. This mode of food resource partition-

Table 3. Food and feeding attributes of the 13 principal species comprising percid communities in Ontario. Variability among these attributes is sufficiently great in most cases to preclude direct competition for lengthy periods.

Species	Food type	Food size	Feeding behaviour	Feeding times	Feeding locations
Walleye	forage fishes, yellow perch, *Hexagenia*	medium	opportunistic foraging, schooling	crepuscular periods, nocturnal, bimodal	gravel shoals, macrophytes, water column
Northern pike	forage fishes, white suckers, yellow perch, lake herring	medium to large	passive, stalking, solitary	bimodal, diurnal, intermittent	macrophyte beds, subsurface structure
White sucker	benthic organisms insects, crustaceans	small	unselective vacuuming	diurnal, intermittent	gravel shoals, soft substrates
Yellow perch	forage fishes, benthic organisms, zooplankton	small	active foraging	diurnal, strong bimodal pattern	littoral, macrophyte beds, water column
Lake whitefish	insect larvae, molluscs, amphipods	small	selective benthic feeding	intermittent, day-night	deep, soft substrates
Lake herring	Cladocera, copepods, insects, *Mysis, Pontoporeia*	very small to minute	active foraging	intermittent, diurnal	water column, limnetic
Spottail shiner	Zooplankton, *Daphnia, Bosmina*	minute	active foraging	diurnal	water column
Burbot	crayfish, fishes, molluscs, invertebrates	medium to large	selective benthic foraging	nocturnal	deep, boulder shoals
Johnny darter	midge larvae, mayfly larvae, copepods	very small to minute	selective benthic feeding	diurnal	organic detritus, silt, sand, littoral
Blacknose shiner	Cladocera, insects, green algae	very small to minute	active foraging	diurnal	macrophyte beds, sand or gravel substrate, littoral
Smallmouth bass	crayfish, fishes, insects, amphibians	medium	sedentary, passive, bottom foraging	crepuscular periods, intermittent day-night	gravel and boulder shoals, macrophyte beds
Iowa darter	midge larvae, amphipods, cladocerans, gastropods	very small to minute	selective benthic feeding	diurnal	organic detritus, sand, littoral
Rock bass	aquatic insects, crayfish, amphibians, fishes	medium	active foraging, sedentary, schooling	crepuscular periods, intermittent day-night	boulder and gravel shoals, sunken trees

ing is not as frequent as temporal partitioning in boreal forest lakes although it is by no means uncommon. As an example, both northern pike and lake trout prey upon white suckers, and the latter species is known to be distributed in moderate numbers from the shallow littoral down into the hypolimnion of some lakes (Scott & Crossman 1973). As both lake trout and northern pike are primarily day-time feeders, the white sucker forage base is vulnerable to simultaneous depredation from pike in the shallows and lake trout in the deeper waters. In very large lakes (*e.g.* Lake Superior) a common forage base may be preyed upon by two different predators in discrete bays of the lake. For example, in one bay (Thunder Bay), prior to the invasion of the sea lamprey, the principal predator of lake herring was the lake trout, while in the adjacent Black Bay, the principal predator of the same species was walleye.

Partitioning of the forage base by species or functional group is perhaps the most effective way of stratifying a food resource equitably. Lake trout tend to feed more on lake herring, while walleye feed on yellow perch in general, although there is substantial overlap in each direction as both the walleye and lake trout are, to a certain degree, opportunistic in their feeding habits. Lake whitefish and white suckers feed principally on different segments of the bottom fauna, although again there is often marked overlap. Most fish species inhabiting boreal forest lakes are generalists in the sense that several or many prey species may be appropriate food items. This is in contrast to some of the African cichlids that have highly specialized food preferences (Fryer & Iles 1972), developed perhaps because of extremely long mutual association or even co-evolution.

Partitioning of food particles by size (Kerr 1974) also appears to be effective in precluding direct competition between two species for a common food resource. Adult lake herring, for example, feed on pelagic organisms at least an order of magnitude larger than those preyed upon by the swim-up fry of many fish species that start life as planktivores.

These four methods of stratifying the forage base of a harmonic community do not constitute an exhaustive list, but probably include the most important mechanisms. The key to the food and feeding dimension of realized niche as well as to other ecological prerequisites that we have not explored, is an ecologically equitable partitioning of the resource (Schoener 1974) with moderately little dimensional overlap. Where a high degree of overlap occurs, competition increases, and the system becomes proportionately less efficient in terms of maximized production.

On the other hand, the presence of slight ecological overlap may be particularly advantageous to a moderately austere system if the addition of one or more species allows the system to function along alternative food pathways. Hence, potential overlap along certain niche dimensions, especially that of food resource utilization, enhances survival for the harmonic community through the provision of alternative options upon loss or diminution of a key prey species (see Welch 1967 for an example). The number of fish species occupying a lake or sea has been demonstrated to be a function of its area for any given latitude (Barbour & Brown 1974). Implicitly, in a boreal forest environment which had been previously glaciated, large lakes are likely to have been more accessible (both spatially and temporally) to fish reinvading from glacial refugia. Also, large lakes are likely to be more environmentally heterogeneous than small lakes, and environmental complexity is favourable to greater species numbers (MacArthur 1972), at least up to some optimum level.

Within any given lake, the precise number of species required to produce optimum fish yields is not clear. An appropriate level of species diversity within biotic communities appears to have survival value to the individual stocks or species (Hutchinson 1959) and also to the persistence of the community. Without reviving the old stability-diversity controversy in ecology, we can probably make two general observations that will be ecologically acceptable:

1. Single-species systems rarely persist in nature, except in the most unusual circumstances. Where man has attempted to construct single-species systems they have proven to be very fragile. For example, intensive fish-culture requires the provision of artificial shelter, protection of the stock from predators, parasites and epizootics, the feeding of specialized formulas or fertilization of waters, and often, artificial stripping of eggs and subsequent incubation through several developmental stages. Despite this labour-intensive process consisting of the provision of nurture and shelter, propagation plans often go awry and a cultured stock may be lost because of unpredictable or uncontrollable disasters. Even two- or three-species associations are scarce in nature and are most likely to exist at the polar extremities, on mountain tops or in caverns, where austere or moderately barren environments reduce the probability for colonization by more than a few species (MacArthur 1972). While these relatively depauperate species associations may persist over time, at least some of them tend to be subject to some rather wide, climatically-induced oscillations (Watt 1973) or alternatively, may be extremely fragile, and vulnerable to any marked environmental changes.
2. There appears to be an upper limit to the number of fish species that may co-exist in ecologically equitable numbers. This critical limit is higher in large lakes where opportunities for temporal or spatial distancing are greater due to differences in scale, and where environmental complexity is greater (Barbour & Brown 1974). Increasing species diversity is beneficial for communities up to a level which achieves some kind of persistence over time (Margalef 1972). Also, in natural communities, optimum species numbers interacting in various ways and with appropriate feedback mechanisms, are likely to provide some resistance to invasion by potentially disruptive exotic species (Christie, Fraser & Nepsy 1972), which is one method by which a harmonic community may retain its identity over time.

In essence, then, we hypothesize that harmonic communities function best at some optimum number of species. This number will be greater for large, old lakes than for recently deglaciated, small lakes, and may be seen as related to numbers of ecological opportunities. Unfortunately, a general algorithm for determining optimum diversity within freshwater and marine fish communities has not yet been generated. Such a protocol would consider both the quantitative and qualitative attributes of niche that affect diversity. We have previously noted appropriate species combinations for boreal forest lakes and the northwest Atlantic based on empirical observations of natural, relatively unperturbed systems. The provision of some quantitative estimate of the optimum numbers of species required to ensure enduring, optimum yield levels, is the next logical step.

8. Diversity evaluation

To demonstrate the relationship between a diversity index, key species, and species numbers for boreal forest percid communities we have used the Shannon-Wiener (S-W) index (Shannon & Weaver 1949) in a slightly unconventional manner, and applied it simultaneously to a whole array of percid community lakes (N = 2340) previously selected for analysis *(Table 1)*. We assume that the species combinations occurring in any lake in the set has gelled through co-occurrence, at least since the late Pleistocene,

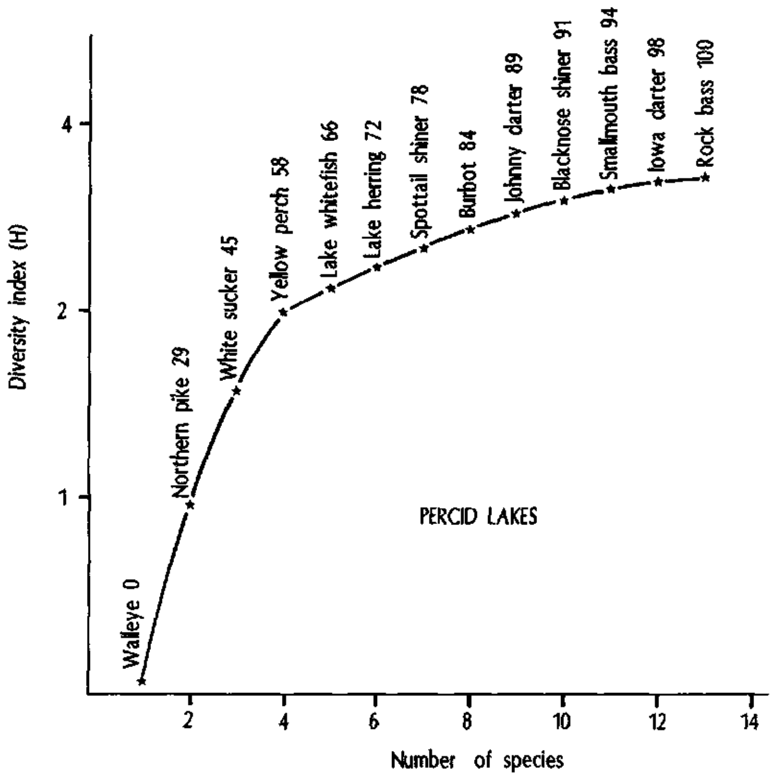

Figure 7. Shannon-Wiener index of diversity as applied to 2340 percid lakes surveyed in Ontario. Walleyes were present in all lakes; other species occurred at lower frequencies down to 20 percent as per *Table 1*. Numbers following species names indicate the percentage of diversity accounted for in a species mix numbering thirteen, by all species included as the curve is ascended. For example, the yellow perch, white sucker, northern pike and walleye alone account for 58% of the diversity within a community consisting of thirteen fish species. The two segments of the curve have markedly different slopes – *i.e.* the slope of the tangent to the curve for the four key species (walleye, northern pike, white sucker and yellow perch) is almost 70° while the slope of the tangent to the remainder of the curve embracing the other nine species is 30°.

into its current species configuration. By application of ergodic theory (Ryder, Kerr, Loftus & Regier 1974), we have sequestered a spatial array of percid community lakes for which the species composition and proportionalities may be considered to be a mean value for the total lake set. The S-W index was then applied to the composite lake set of *Table 1* for species occurring in more than 20% of all walleye lakes, as illustrated in *Figure 7*. This figure may be interpreted in the following manner: if a lake contained only walleyes and northern pike, then 29% of the total diversity as expressed by all 13 species would be expressed by these two species alone. If the white sucker was then added to the previous two species, 45% of the total potential diversity would be achieved. As might be expected, each succeeding species added to the mix would increase the diversity index value, but the incremental increase on average, would decrease as the ascending limb of the curve approached an asymptote at the 100% diversity level.

Examination of the resulting diversity indices, as plotted against species numbers for percid communities, shows a sharp break occurring in the curve *(Figure 7)* after the first four species (walleye, northern pike, white sucker and yellow perch). These four key species had been identified previously as constituting the critical mass or nucleus of a percid community (Ryder & Kerr 1978), and subsequently, were shown to occur in more than 85% of the lake set. This observation has been verified by Marshall & Ryan (1987), who derived their information from a different data set. Consequently, these four species which form the nucleus of a percid community, account for about 60% of the species diversity for a community comprising 13 species *(Figure 7)*. Lake whitefish, lake herring, spottail shiner and burbot increase the diversity index by about 25%, and the last five species contribute only an additional 15%.

9. Community production

Intuitively, the total internal production for a harmonic community would increase as more species were added to the mix, up to some optimum level (Carlander 1955). Once an optimum was reached, the augmentation of additional species might be expected to cause undue 'niche contention' or overlap, that is, too many individual species niches packed into a biotope (community niche) of restrictive and finite dimensions. Appropriately enough, the outcome of increasing niche contention would be likely to be a declining community production efficiency, and subsequent reduction of yields, or perhaps even species extinctions in extreme instances.

Fundamental niche boundaries change with ontogeny over the course of a lifetime for fishes such as the walleye, which may commence life as a non-feeding sac fry submersed in the bottom gravel (Eschmeyer 1950). Later, it becomes a planktivore of the limnetic zone and finally, a terminal piscivore in the nearshore littoral zone. As the multi-dimensional fundamental niche boundaries may be under continual change during this formative period, realized niche boundaries also change as the organism comes into contact with different habitats and experiences new interactions with other species. Ultimately, the fundamental niche of the adult solidifies into a genetically determined envelope with relatively constant dimensions and boundaries. For many individual niche dimensions, there is both an upper and a lower limit (*e.g.* dissolved oxygen concentrations) and the organism might be shown to exhibit the greatest resilience to exogenous stresses when functioning near the optimum of the response surface. Inordinately high niche contention resulting from high numbers of co-existing ecological homologues (*e.g.* a suite of congeners), or as a result of the introduction of an exotic species, might force an indigenous species to function so near to a limiting niche boundary that innate resilience to additional stress is lost.

Unduly high niche contention or overlap, therefore, may tend to reduce community production leading to diminished fish yields. Optimum production from a fish community depends on its relative degree of 'harmony', that is, the degree of compatibility of its integrated component biota. For example, consider the food dimension for the thirteen fish species that are most prevalent in Ontario percid communities *(Table 1)*. Each species plays a particular ecological role within the community with regard to the trophic niche dimension, although its specific function in a given instance may vary depending on the other community components. Differing food habits among several community components of about equal abundance would result in reduced niche contention along the food dimension which, in turn, might contribute to the maintenance of community diversity. Such equitability of a fish community would not be adequately reflected by the S-W diversity index alone. Rather it could be gleaned from a matrix of possible food habits and feeding attributes *(Table 3)*, preferably quantified, depending on the state of our knowledge for a particular species. Non-quantifiable information relating to feeding behaviour may also be quite informative, however.

Table 3 is conservative in the sense that only a minimum number of all possible food habits and feeding attributes are included in each category. No species in the list is highly specialized in food preference, an apparent adaptation for survival in unoccupied, barren or austere environments (Ryder *et al.* 1981). Consequently, the matrix may be seen as a rudimentary representation of the feeding dimension of niche, as reflected by food preference and size, feeding times and locations, and feeding behaviour. *Table 3* shows approximately 25 major food categories (by taxa) which could easily be expanded to a list comprising several hundred species of prey. Five arbitrary food particle sizes were identified (minute to large) covering four orders of magnitude. Seven feeding behaviours are shown, but these may appear in various combinations or variations which would increase the total possibilities by at least a factor of five or six. Various combinations of feeding times would also extend the anticipated number well beyond the six listed. And finally, the range of feeding habitat *(Table 3)* is only an approximation of that available in mesotrophic environments, without taking specific consideration of ecological interface zones (ecotones).

Furthermore, any particular species may feed in other locations, and at different times from those specifically listed in *Table 3*. Our intention is to show that for a single niche dimension, in this case, that of the food resource, a large number of potential strategies exist, all capable of adding complexity to the system, and providing alternative trophic pathways should a major ecological link fail. It can be clearly seen, however, that as the food matrix *(Table 3)* is perused from top to bottom, certain attributes are repeated, and the likelihood for repetition increases with each successive step down the list. Intuitively, there would seem to be an optimum level of complexity at which the environmental resources were used to best advantage for maximum community production; beyond that level, niche contention increases to the extent that community production will be decreased below the maximum potential.

10. Inferences

Evidence has been presented to verify the existence of integrated fish communities with persistent qualities that allow identification over one or more successional stages, despite a modicum of topological distortion. Viewing these communities as 'harmonic' is a useful heuristic approach that focuses on the key elements of the community concept. Measurement of specific community parameters in terms of standing stocks (biomass or numbers) may provide an identifying 'fingerprint' that will allow the separation of one type of community from another within any given suite of communities. A preliminary attempt to clarify the first step of this process has been provided by Marshall and Ryan (1987).

For the remainder of the discussion we will discuss some of the principal attributes of a harmonic community and its ecological requirements. Foremost of these are the levels of connectedness inherent in certain ecological functions such as predation and symbiosis; structural and functional diversity as they are affected by differing ecological roles of harmonic community components; how optimum levels of diversity determine production; habitat requirements that are critical to the existence of a harmonic community, and zoogeographic influences which place restraints on the composition of a harmonic community.

Critical to any discussion of harmonic communities is the inherent connectedness of such communities, that is, the bond that holds them together (Holling 1985). Of necessity, the degree of connectedness will vary from one community to the next and is one of the ecological attributes that will be related to the relative level of harmony achieved. An appropriate level of connectedness may be achieved in many ways, but always binds component parts of communities into closer association.

Species coupling is foremost among a list of connective mechanisms, that is, the functional interdependences that exist between any two species. This pairing is tightest between ecological symbionts (broad sense) which may include symbiosis, commensalism, phoresy, mutualism or parasitism. Contrary to popular opinion, parasitism is a two-way affair, and a particular connection between two community components may have benefits to both the host and the parasite (Lincicome 1971). Hence, 'the goodness of parasitism' in an ecological sense, is often overlooked as an important factor in the level of connectedness of community components.

Similarly, predation links two organisms (Forney 1974, Ali *et al.* 1977), although not as tightly as parasitism, but again, to the ultimate benefit of both populations to which the organisms belong. The predator maintains the prey organisms at an oscillating dynamic equilibrium, consistent with the notion of persistence and retention of appropriate species proportions (Paine 1966), as exemplified by ideal predator/prey ratios. Excessive predation provides compensating feed-back that reduces predator abundance and maintains them in apposite ratios with the prey. The lake trout/lake herring predator/prey relationship exemplifies such an efficiently coupled subsystem (Ryder & Kerr 1984). In Lake Michigan, the predatory presence of lake trout ensured the existence of stock diversity within eight stocks (sometimes called species) of the genus *Coregonus*, which apparently occupied discrete predation refugia (Smith 1964). With the concurrent loss of the two major terminal predators, the lake trout and the burbot, through sea lamprey predation and exploitation, the predation refugia no longer existed and introgression occurred among some of the several stocks of *Coregonus*, ultimately reducing the overall stock diversity (Smith 1964, Paine 1966). Predation in this case, provided the appropriate level of diversity that allowed for the most efficient exploitation of a vast and complex environment by other community components. When the terminal predators were removed from the system, fishery yields declined markedly (Baldwin *et al.* 1979). In a sense, the terminal predator is a major binding force, such that it is difficult to imagine a community persisting at dynamic equilibrium for long without the benefits afforded by predation.

For percid communities, the walleye plays a key role in this regard, supported secondarily by an accessory predator, the northern pike. Within a salmonid community, the lake trout and burbot are 'wired in parallel' (Margalef 1972) and play major predatory roles in providing and maintaining the connectedness of the community.

Many other mechanisms connect the members of a community. These may include recursion, variability of age and size distribution of species cohorts, or the $\log_{10}$ intervals of the biomass spectrum (Kerr 1974). Additional community-binding mechanisms of importance are the linkages made within the trophic-dynamic hierarchy that enhance the exchanges of energy and nutrients, and the presence of other morphologically recursive elements at disparate trophic levels. Each of these connective devices may be vital to the existence of a harmonic community, and in an ecologically persistent system, parallel pathways exist should failure occur within the primary route (Welch 1967).

Both structural diversity and functional interdependencies then, are critical to community integrity, but both appear to have upper limits. That is, dissipative systems (Prigogine 1978) may not persist with too many interlocking elements or too many kinds of relationships (Margalef 1972). Transferring this concept of diversity optimization to marine systems or to lakes of the boreal forest zone, and especially to percid communities, previously noted observations suggest that minimal fish diversity within an harmonic community might consist of an opportunistic terminal predator (walleye), a keystone species in the sense that it retains maximum diversity of its prey (Paine 1966). A secondary or accessory terminal predator (northern pike) provides an alternative energy and nutrient pathway to the fourth trophic level. A broad-based, opportunistic, active foraging predator for small-sized food particles (yellow perch) serves secondarily as a major prey species, at least during its first two years of life. A large benthic-feeding forager (white sucker) also serves as a prey species during its first year or two of life. These four species were originally recognized intuitively, based largely on diving observations (Ryder & Kerr 1978). They were subsequently identified by Legendre & Beauvais (1978) and by Marshall & Ryan (1987) from discrete data sets. They were noted also for 2340 Ontario lakes based on frequency of occurrence *(Table 1)* and comprised the first four most abundant species of a composite diversity index *(Figure 7)*. Accordingly, it seems reasonably conclusive, at least for large, shallow, mesotrophic lakes *(Figure 5)*, that no other species need be present (other than the four key species) for the level of optimum diversity required for near-optimum production levels.

As previously noted for percid communities, optimum production requires a critical mass of at least four or five species present in reasonably equitable and ecologically appropriate numbers. Any sudden increase of the total biomass will be likely to be directed at only one or two species, resulting, subsequently, in uneven partitioning, and diversity will decrease (Margalef 1969). Therefore, in large, deep, mesotrophic lakes *(Figure 6)*, the lake whitefish and lake cisco may be needed for the community to achieve maximum community production rates, despite the fact they are not primary components of a percid community.

Similarly, in large, deep, oligotrophic lakes *(Figure 6)*, shallow bays and the nearshore littoral zone offer ecological conditions best suited to percid community components. The likelihood of one or more percid community species occurring in an oligotrophic lake is directly related to lake area and inversely related to the distance from the source Pleistocene refugium. Therefore, small, northern, oligotrophic lakes *(Figure 4)* are less likely to have percid community components than are large, southern oligotrophic lakes. Since the Ontario oligotrophic lakes we have examined for salmonids *(Table 2)* lie between these two extremes, we expected an intermediate level of percid presence there. In fact, many percid community species occur as frequently in salmonid lakes as in percid lakes *(Figure 2)*, but percid abundance is usually less in salmonid lakes. Only the three terminal predators, the walleye, northern pike and lake trout, appear to favour one type of community over the other *(Figure 2)*. The other eight species common to 20% or more of each lake set were about equally distributed within the two community types. Consequently, the stereotyped image of the particular attributes that constitute a percid or salmonid community in Ontario may be blurred, except for large, shallow, mesotrophic lakes *(Figure 5)* or small, deep, oligotrophic lakes *(Figure 4)* that represent the polar extremes of percid-salmonid habitat. A similar lack of clear definition has been observed

Table 4. Some common ecological properties of harmonic communities. Astatic assemblages of organisms created by cultural interventions have attributes that are generally opposite or unlike those listed for harmonic communities.

Ecological Properties of Harmonic Communities	
1. Coexistence	Long-term species association. Species pairs or communities in some instances may be co-evolved over evolutionary time.
2. Ecological linkages	Moderately tight species couplings or community interdependencies.
3. Integration	Emergent properties of the community (*e.g.* community production) more than the sum of its component parts.
4. Resilience	May be topologically distorted by exogenous natural stresses
5. Key components	The presence of four or five key species are sufficient to retain a harmonic community in dynamic equilibrium and ensure its persistence.
6. Identity	Key species persist under natural stress
7. Predation	Internal species ratios and diversity maintained by predation except for terminal predators which are dependent on abundance of food resource.
8. Biomass spectrum	Harmonic community components retain approximately equivalent standing stocks in terms of biomass when partitioned on a $\log_{10}$ basis over several orders of magnitude.
9. Niche complementarity	Only slight to moderate overlap of adjacent niche hypervolumes.
10. Complexity	Optimum level of species diversity for maximum exploitation of resource base.
11. Resource utilization	Optimum over space and time
12. Fish yields	Maximum
13. Entropy	Relatively low.
14. Epizootics	Moderately resistant to large-scale epidemics.

in European freshwater fish communities (Hartmann 1980). Perhaps the key to understanding this seemingly vague distinction is the recognition that the first four or five most abundant species of a harmonic community determine the character of the emergent properties of the system (*e.g.* community yield), and beyond this, various combinations of co-occuring, indigenous species fill in whatever ecological compartments remain.

Finally, we have compiled a preliminary listing of certain ecological attributes of harmonic communities *(Table 4)*. Either the interpretation of most of these properties is self-evident, or they have been described in detail elsewhere (Kerr & Ryder 1977, Ryder & Kerr 1978, 1984, Ryder *et al.* 1981.). Consequently, we will not elaborate further except to note that for each ecological property of a harmonic community, a similar, but opposite property may be identified for an astatic fish assemblage, thereby underlining a clear distinction between the two states.

11. Anticipated management

Management (by our definition) implies the sustained retention of harmonic fish communities in relatively unperturbed lakes, within the constraints of logistic and economic feasibility. The use of existing data collected by conventional methods would seem to be the initial requirement for effective and inexpensive analyses leading to efficient management.

Accepting that harmonic communities comprise four or five key species, management efforts should be directed at retaining them in appropriate internal production ratios. Also, the production rate of the slowest element (species) of the first four or five harmonics should be retained in some appropriate dynamic proportion to the production rates of the other indigenous species of the community (Holling 1985). Usually, but not always, this requires careful regulation of the principal terminal predator.

Traditionally collected data from extant fisheries have great utility in this regard, especially mortality rates. Since mortality is roughly the inverse of production (sexual products not considered), mortality ratios of the different components of a harmonic community should provide a measure of direction for regulating fish harvests. The perceived consequence is an iterative balancing of the production books through constant feedback and adjustment. Examples of such an approach are provided for U.S. reservoir fish communities (Regier, Cordone & Ryder 1971) and for a tropical fish community (Ryder & Henderson 1975). We recommend further development of this type of management for application to harmonic percid and salmonid communities throughout the boreal forest zone of North America. Ecologically analogous fish communities of north-temperate Eurasia should also be amenable to these techniques.

We also perceive an increasing use of the various Fourier analytical procedures and spectral analyses for the estimation of some of the harmonic community parameters, especially the amplitude and frequency patterns of fish yields, resulting in both improved precision and a higher level of resolution for future yield predictions.

12. Acknowledgements

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References

Adams, G.F. & Olver, C.H., 1977. Yield properties and structure of boreal percid communities in Ontario. J. Fish. Res. Bd Can. 34: 1613-1625.

Ali, M.A., Ryder, R.A. & Anctil, M., 1977. Photoreceptors and visual pigments as related to behavioral responses and preferred habitats of perches (*Perca* spp.) and pikeperches (*Stizostedion* spp.). J. Fish. Res. Bd Can. 34: 1475-1480.

Austin, M.P., 1985. Continuum concept, ordination methods, and niche theory. Ann. Rev. Ecol. Syst. 16: 39-61.

Bailey, R.M. & Smith, G.R., 1981. Origin and geography of the fish fauna of the Laurentian Great Lakes basin. Can. J. Fish. Aquat. Sci. 38: 1539-1561.

Baldwin, N.S., Saalfeld, R.W., Ross, M.A. & Buettner, H.J., 1979. Commercial fish production in the Great Lakes 1867-1977. Great Lakes Fish. Comm., Tech. Rep. No. 3 pp. 1-187.

Barbour, C.D. & Brown, J.H., 1974. Fish species diversity in lakes. Am. Nat. 108: 473-489.

Beverton, R.J.H. & Holt, S.J., 1957. On the dynamics of exploited fish populations. U.K. Min. Agric. Fish., Fish. Invest. (Ser. 2) No.19. 533 pp.

Carlander, K.D., 1955. The standing crop of fish in lakes. J. Fish. Res. Bd Can. 12: 543-570.

Casselman, J.M., 1978. Effects of environmental factors on growth, survival, activity, and exploitation of northern pike. In R.L. Kendall, (Ed.). Selected coolwater fishes of North America. Am. Fish. Soc. Spec. Pub. No. 11. pp. 114-128.

Christie, W.J., Fraser, J.M. & Nepszy, S.J, 1972. Effects of species introductions on salmonid communities in oligotrophic lakes. J. Fish. Res. Bd Can. 29: 969-973.

Cody, M.L. & Diamond, J.M. (Ed.)., 1975. Ecology and evolution of communities. Harvard Univ. Press, Cambridge, Mass.

Colby, P.J., Spangler, G.R., Hurley, D.A. & McCombie, A.M., 1972. Effects of eutrophication on salmonid communities in oligotrophic lakes. J. Fish. Res. Bd Can. 29: 975-983.

Coutant, C.C., 1977. Compilation of temperature preference data. J. Fish. Res. Bd Can. 34: 739-745.

Darlington, P.J. Jr., 1957. Zoogeography: the geographical distribution of animals. John Wiley & Sons, Inc., New York.

Eschmeyer, P.H., 1950. The life history of the walleye, *Stizostedion vitreum vitreum* (Mitchill), in Michigan. Michigan Dept. Cons., Inst. Fish. Res. Bull. No. 3. 99 pp.

Fager, E.W. & A.R. Longhurst. 1968. Recurrent group analysis of species assemblages of demersal fish in the Gulf of Guinea. J. Fish. Res. Bd Can. 25: 1405-1421.

Flint, R.F., 1957. Glacial and Pleistocene geology. John Wiley & Sons, Inc., New York, N.Y. 553 pp.

Forney, J.L., 1974. Interactions between yellow perch abundance, walleye predation, and survival of alternate prey in Oneida Lake, New York. Trans. Am. Fish. Soc. 103: 15-24.

Fraser, J.M., 1978. The effect of competition with yellow perch on the survival and growth of planted brook trout, splake, and rainbow trout in a small Ontario lake. Trans. Am. Fish. Soc. 107: 505-517.

Frey, D.G., 1955. Distributional ecology of the cisco (*Coregonus artedii*) in Indiana. Invest. Indiana Lakes and Streams 4: 177-228.

Fry, F.E.J., 1947. Effects of the environment on animal activity. Univ. Toronto Stud. Biol. Ser. 55, Publ. Ont. Fish. Res. Lab. 68: 1-62.

Fryer, G. & Iles. T.D., 1972. The cichlid fishes of the Great Lakes of Africa. T.F.H. Publications Ltd., Hong Kong. 641 pp.

Futuyma, D.J. & Slatkin, M., (Eds), 1983. Co-evolution. Sinauer Assoc. Inc., Publ., Sunderland, Mass. 555 pp.

Hartmann, J. 1980. Zur Unterscheidung diskreter Fischgesellschaften. Osterreichs Fischerei 5: 93-99.

Hayes, F.R., 1957. On the variation in bottom fauna and fish yield in relation to trophic level and lake dimensions. J. Fish. Res. Bd Can. 14: 1-32.

Holling, C.S., 1969. Stability in ecological and social systems. In: Diversity and stability in ecological systems. Brookhaven National Laboratory, Upton, N.Y. pp. 128-141.

Holling, C.S., 1985. Resilience of ecosystems: local surprise and global change. pp. 228-269. In: Malone, T.F. & Roederer, J.G. (Eds). Global change. Proc. Symp. ICSU, 20th Gen. Assembly. Cambridge University Press, London.

Hutchinson, G.E., 1957. Concluding remarks. Cold Spring Harbor Symp. Quant. Biol. 22: 415-427.

Hutchinson, G.E., 1959. Homage to Santa Rosalia or why are there so many kinds of animals? Amer. Natur. 93: 45-159.

Jansen, D. H., 1981. When is it co-evolution? Evolution 34: 611-612.

Jackson, H.W., 1976. Introduction to electric circuits. Prentice-Hall Inc., Englewood Cliffs, N.J. 673 pp.

Johnson, L., 1972. Keller Lake: Characteristics of a culturally unstressed salmonid community. J. Fish. Res. Bd Can. 29: 731-740.

Kerr, S.R., 1974. Theory of size distribution in ecological communities. J. Fish. Res. Bd Can. 31: 1859-1862.

Kerr, S.R., 1977. Structure and transformation of fish production systems. J. Fish. Res. Bd Can. 34: 1989-1993.

Kerr, S.R. & Ryder, R.A., 1977. Niche theory and percid community structure. J. Fish. Res. Bd Can. 34: 1952-1958.

Kerr, S.R. & Ryder, R.A., 1988. The applicability of fish yield indices in freshwater and marine ecosystems. Limnol. Oceanogr. 33: 973-981.

Kerr, S.R., Larkin, P.A. & Ryder, R.A., (In prep.). Criteria for evaluating the health of aquatic ecosystems. Nat. Res. Council, Ottawa.

Larkin, P.A., 1977. An epitaph for the concept of maximum sustained yield. Trans. Am Fish. Soc. 106: 1-11.

Leach, J.H., Johnson, M.G., Kelso, J.R.M, Hartmann, J., Numan, W. & Entz, B., 1977. Responses of percid fishes and their habitats to eutrophication. J. Fish. Res. Bd Can. 34: 1964-1971.

Legendre, P. & Beauvais, A., 1978. Niches et associations de poissons des lacs de la Radissonie Quebequoise. Naturaliste Can. 105: 137-158.

Lewis, W.M., Jr., 1979. Zooplankton community analysis. Springer-Verlag, New York. 163 pp.

Lincicome, D.R. 1971. The goodness of parasitism: a new hypothesis. In: Cheng, T.C. (Ed.). Aspects of the biology of symbiosis pp. 139-227.

Lindeman, R., 1942. The trophic-dynamic aspect of ecology. Ecology 23: 399-418.

MacArthur, R.H., 1972. Geographical ecology. Harper & Row, New York. 269 pp.

Mahon, R., 1985. (Ed.). Towards the inclusion of fishery interactions in management advice. Proceedings of a Workshop at the Bedford Institute of Oceanography (Oct. 30 - Nov. 1, 1984). Can. Tech. Rept. Fish. Aquat. Sci. No. 47: 221 pp.

Margalef, R., 1969. Diversity and stability: a practical proposal and a model of interdependence. In: Diversity and stability in ecological systems. Brookhaven National Laboratory, Upton, N.Y. pp. 25-37.

Margalef, R., 1972. Homage to Evelyn Hutchinson, or why there is an upper limit to diversity. Trans. Conn. Acad. Arts Sci. 44: 211-235.

Marshall, T.R. & Ryan, P.A., 1987. Abundance patterns and community attributes of fishes relative to environmental gradients. Can. J. Fish. Aquat. Sci. 44: 198-215.

McCormick, J.H., Jones, B.R. & Syrett, R.F., 1971. Temperature requirements for growth and survival of larval ciscos *(Coregonus artedii)*. J. Fish. Res. Bd Can. 28: 924-927.

McKelvie, D.S., 1985. Discreteness of pelagic faunal regions. Marine Biology 88: 125-133.

Mills, E.L., 1969. The community concept in marine zoology, with comments on continua and instability in some marine communities: a review. J. Fish. Res. Bd Can. 26: 1415-1428.

Moore, G.A., 1944. The retinae of two North American teleosts, with special reference to their *tapeta lucida*. J. Comp. Neur. 80: 369-379.

Nilsson, N.A., 1967. Interactive segregation between fish species In: Gerking, S.B. (Ed.). The biological basis of freshwater fish production . Blackwell, Oxford. pp. 295-313.

O'Malley, J.R., 1980. Circuit analysis. Prentice-Hall Inc., Englewood Cliffs, N.J. 543 pp.

Paine, R.T., 1966. Food web complexity and species diversity. Am. Nat. 100: 65-75.

Peterman, R.M., Clark, W.C. & Holling, C.S., 1979. The dynamics of resilience: shifting stability domains in fish and insect ecosystems. In: Population Dynamics. Symposium of British Ecol. Soc. pp. 321-341.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13: 131-144.

Pielou, E.C., 1975. Ecological diversity. Wiley-Interscience Pub., John Wiley & Sons, New York.

Pimm, S.L., 1984. Food chains and return times. In: Strong, D.R., Simberloff, D., Abele, L.G. & Thistle, A.B. (Eds). Ecological communities: Conceptual issues and the evidence. Princeton Univ.Press, Princeton, N.J. pp. 397-412.

Prigogine, I., 1978. Time, structure, and fluctuations. Science 201: 777-785.

Rawson, D.S., 1961. The lake trout of Lac la Ronge, Saskatchewan. J. Fish. Res. Bd Can. 18: 423-462.

Regier, H.A., Cordone, A.J. & Ryder, R.A., 1971. Total fish landings from fresh waters as a function of limnological variables, with special reference to lakes of east-central Africa. FAO Fish Stock Assessment Working Paper No. 3. 13 pp.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations J. Fish. Res. Bd Can. Bull. No. 191. 382 pp.

Robins, C.R. (Chairman), 1980. A list of common and scientific names of fishes from the United States and Canada. Am. Fish. Soc. Spec. Pub. No. 12. 174 pp.

Ryan, P.A. & Marshall, T.R., (in prep.). Towards a definition of the lake trout (*Salvelinus namaycush*) niche through indices of environmental quality.

Ryder, R.A., 1968. Dynamics and exploitation of mature walleyes, *Stizostedion v. vitreum*, in the Nipigon Bay region of Lake Superior. J. Fish. Res. Bd Can. 25: 1347-1376.

Ryder, R.A., 1977. Effects of ambient light variations on behaviour of yearling, subadult, and adult walleyes (*Stizostedion vitreum vitreum*). J. Fish. Res. Bd Can. 34: 1481-1491.

Ryder, R.A., Kerr, S.R., Loftus, K.H. & Regier,.H.A., 1974. The morphoedaphic index, a fish yield estimator-review and evaluation. J. Fish. Res. Bd Can. 31: 663-688.

Ryder, R.A. & Henderson, H.F., 1975. Estimates of potential fish yield for the Nasser Reservoir, Arab Republic of Egypt. J. Fish. Res. Bd Can. 32: 2137-2151.

Ryder, R.A. & Kerr, S.R., 1978. The adult walleye in the percid community - a niche definition based on feeding behaviour and food specificity. In: Kendall, R.L., (Ed.). Selected coolwater fishes of North America. Am. Fish. Soc. Spec. Pub. No. 11. pp. 39-51.

Ryder, R.A., Kerr, S.R., Taylor, W.W & Larkin, P.A., 1981. Community consequences of fish stock diversity. Can. J. Fish. Aquat. Sci. 38: 1856-1866.

Ryder, R.A. & Kerr, S.R., 1984. Reducing the risk of fish introductions: a rational approach to the management of integrated coldwater communities. European Inland Fish Adv. Comm. EIFAC Techn. Pap. 42. Suppl. 2: 510-533.

Ryder, R.A. & Edwards, C.J, (Ed.). 1985. *A conceptual approach for the application of biological* indicators of ecosystem quality in the Great Lakes Basin. Intern. Joint Comm. and Great Lakes Fish. Comm. Windsor, Ont. 169 pp.

Schoener, T.W., 1974. Resource partitioning in ecological communities. Science 185: 27-39.

Scott, W.B. & Crossman, E.J., 1973. Freshwater fishes of Canada. Fish. Res. Bd Can., Bull. No. 184. 966 pp.

Shannon, C.E. & Weaver, W., 1949. The mathematical theory of communication. Univ. Illinois Press, Urbana, USA.

Skud, B.E., 1982. Dominance in fishes: the relation between environment and abundance. Science 216: 144-14.

Smith, S.H., 1964. Status of the deepwater cisco population of Lake Michigan. Trans. Am. Fish. Soc. 93: 155-163.

Stroud, R.H. & Clepper, H., (Ed.) 1979. Predator-prey systems in fisheries management. Sport Fish. Inst., Washington, D.C. 504 pp.

Svardson, G., 1976. Interspecific population dominance in fish communities of Scandinavian Lakes. Inst. Freshw. Res., Drottningholm, Rep. No. 55 pp. 144-171.

Swingle, H.S., 1951. Experiments with various rates of stocking bluegills, *Lepomis macrochirus* Rafinesque, and largemouth bass, *Micropterus salmoides* (Lacepede), in ponds. Trans. Am. Fish. Soc. 80: 218-230.

Vollenweider, R.A., 1969. A manual on methods for measuring primary production in aquatic environments. Intern. Biol. Prog. Handbook No. 12, Blackwell, Oxford. 213 pp.

Watt, K.E.F., 1973. Principles of environmental science. McGraw-Hill, Toronto. 319 pp.

Welch, H., 1967. Energy flow through the major macroscopic components of an aquatic ecosystem. PhD Dissertation, Univ. Georgia, Athens.

Werner, E.E., 1977. Species packing and niche complementarity in three sunfishes. Am. Natur. 111: 553-578.

Werner, E.E., 1984. The mechanisms of species interactions and community organization in fish. In: Strong, D.R., Simberloff, D., Abele, L.G. & Thistle, A.B. (Eds). Ecological communities: Conceptual issues and the evidence. Princeton Univ. Press, Princeton, N.J. pp. 360-382.

Werner, E.E., Hall, D.J., Laughlin D.R., Wagner, D.J., Wilsmann, L.A. & Funk, F.C., 1977. Habitat partitioning in a freshwater community. J. Fish. Res. Bd Can. 34: 360-370.

Whittaker, R.H. & Levin, S.A., (Ed.). 1975. Niche theory and application. Dowden, Hutchinson and Ross, Inc. Halsted Press. 448 pp.

In: W.L.T. van Densen, B. Steinmetz & R.H. Hughes (Eds). 1990. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc. Wageningen. pp. 624-636.

Management of percids in Lake Erie, North America*

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Abstract

Lake Erie's fish populations and their habitats have undergone very substantial changes since 1945. Of the four percid forms originally present, the blue pike *(Stizostedion vitreum glaucum)* is presumed extinct, and the sauger *(S. canadense)* was commercially extinct by the 1950s. The walleye *(S. v. vitreum)* has remained stable in eastern Lake Erie but the highly productive stock of the western basin collapsed in the 1960s. Closure of the walleye fishery from 1970 to 1973, necessitated by mercury contamination, provided an opportunity for development of an international management plan for restoration of the stock. An inter-agency Scientific Protocol Committee evaluated walleye dynamics and recommended management by quota beginning in 1976. Although quotas have been exceeded several times, the walleye stock responded well to limited exploitation, steadily increased, and expanded its range. Landings of yellow perch *(Perca flavescens)* increased during the 1950s, but a steady decline in abundance, beginning in the early 1970s, led to the formation in 1980 of another international inter-agency task group to recommend a basis for quota management. The short-term management recommendation, reported and accepted in 1986, was to reduce fishing effort by 20% by 1990.

Both management schemes evolved when the resource agencies of the five jurisdictions (New York, Pennsylvania, Ohio, Michigan, and Ontario), in the two nations surrounding Lake Erie, perceived a need for the increased and improved management of a shared resource. They sought an international forum in which to develop strategies, appointed inter-agency scientific task groups to develop a basis for management recommendations, and adopted a quota management scheme. Each jurisdiction is responsible for the enforcement and allocation of its portion of the quota between user groups. Reports of catch, effort, and biological observations on stock performance are submitted annually to a standing technical committee charged with updating quotas.

1. Introduction

Lake Erie is the most southerly, most shallow, and most productive of the Laurentian Great Lakes, and is bordered by the states of New York, Pennsylvania, Ohio and Michigan in the USA, and the province of Ontario in Canada *(Figure 1)*. Commercial fish production from the lake has always been high *(Figure 2)*, but the composition of the landings has changed considerably with time because of over exploitation and habitat degradation. We first characterize the habitat and fish resources of Lake Erie, briefly

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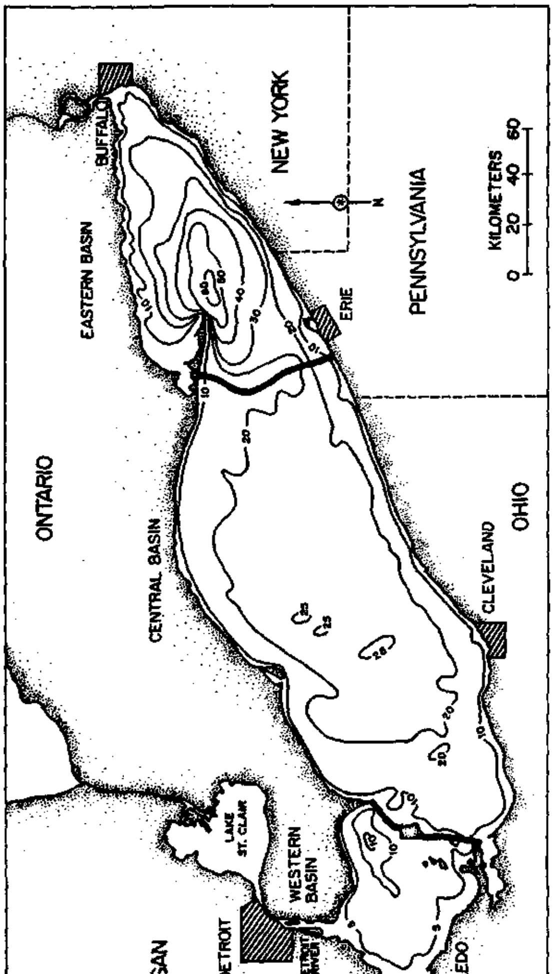

Figure 1. Lake Erie (contours in metres)

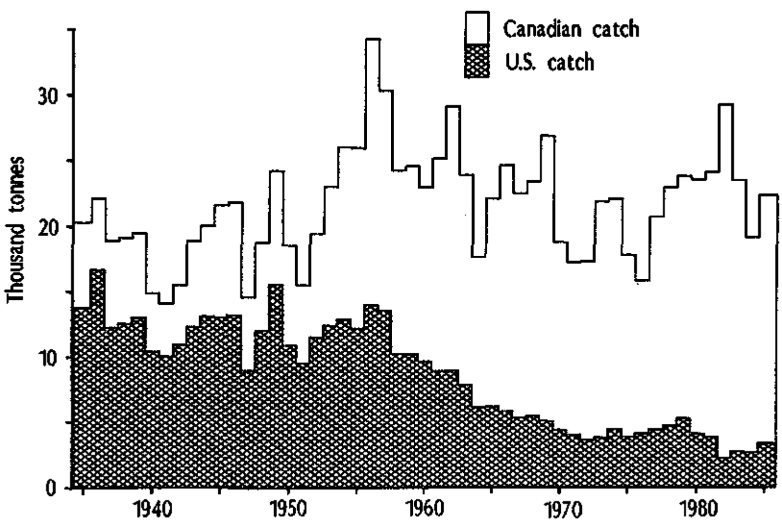

Figure 2. Commercial landings of all species from Lake Erie, 1935-1985.

review past management policies, and then concentrate our discussion on the international inter-agency efforts to manage two species of percids that are presently very important to both recreational and commercial interests.

1.1 Fish habitat

Lake Erie has three distinct basins with differing characteristics *(Table 1)*. The western basin is mostly less than 11 m deep, the central basin is mainly less than 25 m deep, and the eastern basin reaches a depth of 64 m (Sly 1976). Land-use patterns in the watershed include intensive agricultural practice throughout, but a number of large population centres with associated heavy industries are along the southern and western shores *(Figure 1)*. Increasing nutrient loading from these sources resulted in major changes in fish habitat that have been summarized by several workers (Beeton 1961, Hartman 1973, Sly 1976).

The striking changes in the Lake Erie environment during the half century ending about 1970 include a threefold increase in total nitrogen between 1930 and 1958 and a tenfold increase in soluble reactive phosphorus between 1942 and 1967 (Leach & Nepszy 1976). The resulting accelerated eutrophication has been responsible for a widespread decrease in dissolved oxygen. Oxygen-sensitive benthic organisms were virtually eliminated from the western basin whereas the numbers of more tolerant forms increased (Leach & Nepszy 1976). The central basin stratifies regularly and zero oxygen in the hypolimnion has been observed frequently in late summer since 1961. Thermal stratification also

Table 1. Morphometry of Lake Erie (after Hartman 1973).

Characteristic	Western	Central	Eastern	Whole lake
Maximum length (km)	80	213	137	388
Maximum breadth (km)	64	92	76	92
Maximum depth (m)	20	26	64	64
Mean depth (m)	7	18	24	18
Area (km^2)	3 276	16 177	6 237	25 690
Volume (km^3)	24	299	152	475
Shoreline (km)	432	504	424	1 360
Percentage of total area	13	63	24	100
Percentage of total volume	5	63	32	100
Percentage of total shoreline	32	37	31	100

occurs regularly in the deep eastern basin, but critically low concentrations of dissolved oxygen have not been reported (Leach & Nepszy 1976).

In 1970 the governments of Canada and the United States met to consider appropriate methods for preventing and controlling pollution of the Great Lakes. The resulting Great Lakes Water Quality Agreement was concluded and signed in April 1972 and revised and expanded in 1978. Initial efforts under these agreements were directed at reduction of phosphorus loadings from municipal and industrial point sources. Significant decreases in total phosphorus loadings to Lake Erie have resulted in a decrease in phosphorus concentrations in the open lake. It was assumed that these reductions would result in improved hypolimnetic oxygen concentrations in the central basin. To date, this has not occurred; Charlton (1987) estimated a 10-year lag between loading reductions and oxygen response. The western basin is now characterized as eutrophic, the central basin as mesotrophic, and the eastern basin as oligo/mesotrophic (Great Lakes Water Quality Board 1987).

1.2 Fisheries

Yields quoted in this report are from Baldwin, Saalfeld, Ross & Buettner (1979) for the years before 1978, and from agency reports for 1978-1987. Commercial fish production from Lake Erie averaged slightly more than 21 000 tonnes/yr (8 kg/ha) from 1935 to 1985 *(Figure 2)*. Although 19 species have been important to the commercial fishery since about 1800, 6 species have declined from major importance to insignificance or have been completely lost (Hartman 1973). Four non-percid species have become commercially important in this century as a result of over-exploitation and habitat degradation. These are lake sturgeon *(Acipenser fulvescens)* by about 1900, lake trout *(Salvelinus namaycush)* by the 1920s, lake herring *(Coregonus artedii)* by 1926, and lake whitefish *(C. clupeaformis)* by 1960 (Hartman 1973, Leach & Nepszy 1976).

Four forms of percids have also been important constituents of the Lake Erie commercial fishery, but only two remain significant. Landings of sauger *(Stizostedion canadense)* peaked in 1916 and decreased gradually to commercial extinction in 1960. Regier, Applegate & Ryder (1969) suggested that degradation of traditional spawning areas and increasing fishing pressure were important factors in the decline of this species.

The blue pike *(Stizostedion vitreum glaucum)* was abundant in the late 1800s, but landings were fluctuating extensively by 1915. Annual production peaks exceeding 10 000 tonnes and lows under 2500 tonnes were recorded before the fishery collapsed in 1958. The blue pike, now presumed extinct, was subjected to extremely heavy fishing pressure over the entire period 1915-58. Degradation of the oxygen regime in the central basin forced the blue pike into the deeper waters of the eastern basin, where their vulnerability to the fishery increased. Genetic de-segregation may have been responsible for the final disappearance of the remnant stock (Regier *et al.* 1969).

The remaining two percids, walleye *(Stizostedion vitreum vitreum)* and yellow perch *(Perca flavescens)* have been important components of the commercial catches in Lake Erie throughout this century. Annual harvests of walleyes fluctuated between 1915 and 1936, increased sharply to a peak in 1956, and then declined precipitously in 1962. Under intensive management the stock recovered during the 1970s and today yields more than 7000 tonnes/yr (4 kg/ha) to recreational and commercial fisheries. Commercial landings of yellow perch increased during the 1930s as fishermen diverted their efforts to this species after the decline of the lake herring. Annual landings climbed again in the 1950s, when the blue pike and walleye fisheries collapsed, reaching a peak of 15 186 tonnes (6 kg/ha) in 1969. In more recent years, perch landings have declined as strong year-classes have become less frequent.

Recreational fishing has become increasingly important in Lake Erie since about 1970. No lakewide estimates of catch are available, but creel surveys conducted in Ohio and Ontario since 1975 demonstrate the increase in angling pressure. Angling effort rose from 45 846 hours in 1975 to an average of 105 000 hours in 1981-85 in Ontario waters (Hyatt 1986) and from 7.4 million hours in 1975 to 11.2 million hours in 1981-85 in Ohio waters (Ohio Dep. Nat. Resour. 1986). In recent years, the recreational fishery has produced 65-70% of all walleye landings and about 20% of all yellow perch landings.

2. Fishery management in Lake Erie

Jurisdiction over fishery resources in Canada is divided between the federal and provincial governments; in the United States it lies with the states. Ontario fisheries are licensed by the Province, but fishery regulations are enacted by the federal government. The regulations now are drafted by the Ontario Ministry of Natural Resources and passed by the Governor General in Council, usually without revision. Management mechanisms vary somewhat between the various state organizations, but generally a natural resource agency formulates management plans and recommends the necessary regulations to an appointed commission for promulgation; however, action by a legislative body is sometimes necessary.

International response to problems of the Great Lakes fisheries includes a history of study commissions and conferences culminating in 1955, when Canada and the United States joined in the Convention on Great Lakes Fisheries, and thereby established the

Great Lakes Fishery Commission (GLFC). The Convention did not provide for international management of the fisheries, but it charged the Commission with formulating and co-ordinating research to encourage restoration of fish stocks of common concern. Acting through its Lake Committees *(Figure 3)* consisting of senior representatives of the resource agencies surrounding each lake, and by encouraging the formation of inter-agency groups to evaluate particular problems, the Commission has fostered close co-operation among state, provincial, and federal fisheries agencies in the Great Lakes area. The 1981 ratification of 'A Joint Strategic Plan for Management of Great Lakes Fisheries' (developed under the auspices of the Commission) is an outstanding example of this co-operation. First among the strategies is 'consensus must be achieved when management will significantly influence the interests of more than one jurisdiction'.

2.1 Management of commercial fisheries before 1970

Before about 1970, commercial fishery regulations in Lake Erie were mostly those favoured by politically active fishery operators. Minimum size limits on walleyes and yellow perch were in effect in Michigan, Ohio, and Ontario. Minimum gill-net mesh regulations governed the walleye fishery in all Lake Erie states, but not in Ontario, and there were no mesh restrictions affecting yellow perch. Extensive regulations governed trap nets in all jurisdictions. Generally there were no limitations on the number of licenses issued, total effort applied, or quantity of percids landed, though Ontario instituted a lakewide quota for yellow perch in 1969.

Ontario's Lake Erie fishermen were given increasing freedom in the twentieth century, and by 1950 the fishery was generally unregulated. Commercial fishing regulations were rather closely enforced in Michigan and Ohio after 1945 and were conservative with respect to technological innovations.

2.2 Recent management initiatives

Angling became increasingly important in Lake Erie, especially on the United States side, but information on the extent of the recreational catch was not available until after 1975 when Ontario and Ohio instituted comprehensive creel surveys. When walleyes became largely unavailable in the late 1950s, Ohio anglers intensified a campaign to further restrict the commercial fishery. In 1971, following a closure of the walleye fishery necessitated by mercury contamination, Ohio promulgated a 5-year ban on the commercial harvesting of walleyes which later became permanent, and also established a creel limit for walleyes caught by anglers. Michigan developed a policy generally favouring the development of recreational fisheries. Agency actions also resulted in many changes in the yellow perch fishery: Ohio banned the use of gill-nets in 1984 and reduced commercial fishing effort, Pennsylvania increased restrictions, and New York banned gill-nets in 1986.

In 1982, a new management plan was established for Ontario's commercial fisheries after negotiations between the Ministry of Natural Resources and the Ontario Council of Commercial Fisheries, representing the fishing industry. Implementation of this plan began in 1984 with individual quotas for Lake Erie operators. Although government and industry agreed on the principle of individual quotas, problems arose in allocating them between operators. Through negotiation, adaptation, co-management, and co-operation

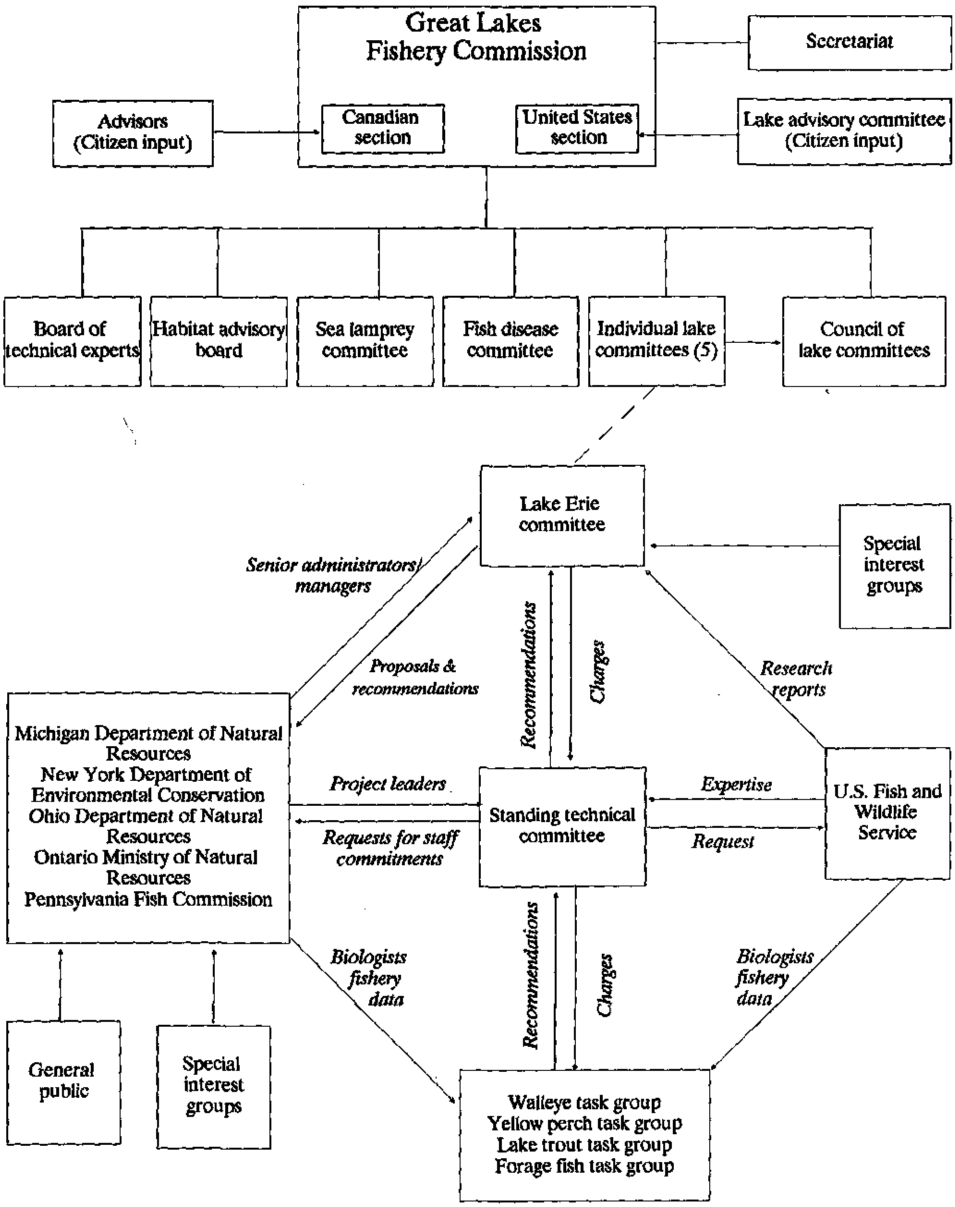

Figure 3. Organization of the Great Lakes Fishery Commission and its Lake Erie Committee. Special interest groups include commercial and sport fishing organizations, environmental organizations and public interest groups.

in enforcement, a workable plan was achieved in 2-3 years and remains in effect today (Berkes & Pocock 1987).

In summary, walleyes are now reserved for recreational harvest in Ohio and Michigan and shared between recreational and commercial interests in other jurisdictions; yellow perch are shared in all jurisdictions except Michigan, where commercial harvest is prohibited. With the resurgency of walleye abundance, discussed later, there has been a considerable shift of angling effort from yellow perch to walleyes.

3. Walleye

The walleye has long been a valuable commercial and sport fish in Lake Erie. At least two discrete populations of walleyes have been distinguished, one confined to the western and central basins, and a smaller one in the eastern basin. Before 1956, the walleye was only an incidental species in the commercial fishery of the eastern basin (Wolfert 1981). After the collapse of the western basin stock in 1957, annual harvest from the eastern basin stock rose in 1958 and ranged from 50-84 tonnes during 1961-1975. After the rebuilding of the western basin stock, commercial landings from the eastern basin decreased in 1976-1983 and then rose again, reaching 158 tonnes in 1985 as the fishery in the Ontario waters of the eastern basin expanded. Little information is available on the extent of recreational harvest from this stock.

3.1 The western basin fishery

The history of the fishery in the western basin before 1970 was reviewed by Regier *et al.* (1969) and Hartman (1973). Our discussion is directed towards understanding more recent events. Commercial harvests fluctuated in 1915-1936, they began to increase slowly in the 1940s, mainly due to increases from Ohio waters, but then increased rapidly in the 1950s *(Figure 4)* as Ontario gill-netters greatly increased the amount and efficiency of their gear (Nepszy 1977). The western basin harvest peaked at over 6000 tonnes in 1956-1957. The stock collapsed and commercial production dropped to 274 tonnes in 1962, rose to 1130 tonnes in 1963, and fell to a record low of 161 tonnes in 1969. Growth rate increased in the remnant stock and these faster growing fish were harvested shortly after recruitment; consequently, few females reached sexual maturity. The environmental degradation mentioned earlier was also implicated in the collapse (Regier *et al.* 1969). River spawning areas were severely reduced through degradation, and oxygen depletion limited the size of the summer habitat.

In 1970, when high levels of mercury were discovered in walleye tissue, the commercial fishery was closed in both the United States and Canadian waters of the western basin, and retention of walleyes caught by anglers was prohibited in Ontario and Michigan. After 1972, as mercury contamination declined due to a reduction in loadings, the walleye fishery in Ontario was reopened to both sport and (limited) commercial users; in Michigan and Ohio, the harvest was still restricted to anglers (Hatch, Nepszy, Muth & Baker 1987).

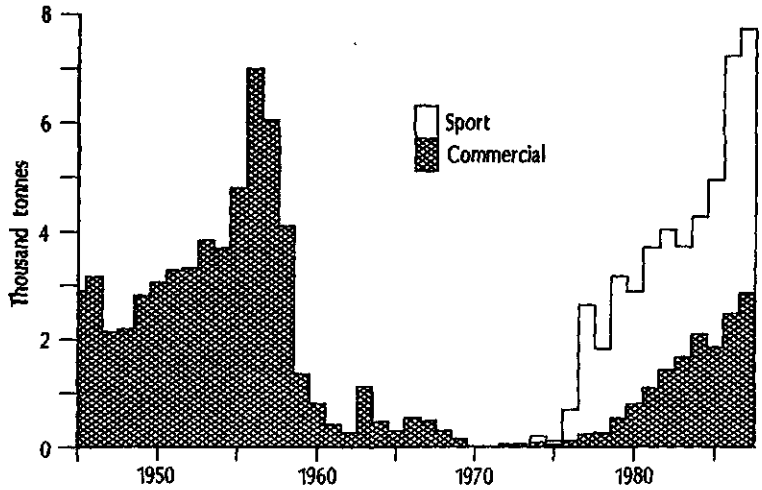

Figure 4. Walleye landings, western and central Lake Erie, 1945-1987.

3.2 Quota management of western basin walleyes

Recognizing the importance of the continued protection of the still depleted resource as the fishery reopened, the GLFC sponsored an international inter-agency meeting in March 1973 to discuss co-ordinated management of walleyes in western Lake Erie. An international plan for conservation and rehabilitation of the walleye resource was formulated, accompanied by a recommendation for an inter-agency Scientific Protocol Committee to evaluate walleye population dynamics and develop forecasts of abundance. The plan was formally endorsed by the commission and forwarded to the respective governments in July 1973.

The Scientific Protocol Committee developed a system of quota management for the walleye fishery involving sequential projection of the fishable stock, conservative exploitation rates to foster recovery of the resource, and the sharing of the quota among the several jurisdictions on the basis of lake surface area. Each jurisdiction was to allocate its portion of the quota among user groups and be responsible for reporting all landings and the enforcement of its portion of the overall quota.

The Scientific Protocol Committee pooled all existing statistical data for western Lake Erie walleyes and concluded that the interval 1963-1969 was the only one for which sufficient data were available to estimate the fishable stock. The second requirement for sequential projection, an index of recruitment, was available as a young-of-the-year index derived from assessment trawling. These data, combined with estimates of mortalities during the 1970-1975 interval, formed a basis for the estimation of the standing stock at the beginning of 1976 (Kutkuhn *et al.* 1976, Hatch *et al.* 1987). The Committee applied a conservative fishing rate to this standing stock to develop the initial quota in 1976, and quota recommendations were submitted annually to the inter-agency GLFC Lake Erie Committee *(Figure 3)* in 1976-1988.

3.3 Stock recovery under management

The innate resiliency of the walleye stock was quickly manifested under the multilateral ban on fishing instituted in 1970 because of mercury contamination. As estimated by sequential projection, the fishable stock increased from about 83 000 walleyes in 1970 to nearly 14 million in 1976. Angler interest expanded rapidly, and increased effort, coupled with a high catch rate, resulted in a marked increase in the estimated sport catch that, in Ohio waters alone, rose from 111 000 walleyes in 1975 to 2.165 million in 1977. The combined harvest of the three jurisdictions exceeded 2500 tonnes in 1977, 4000 tonnes in 1982, and 7000 tonnes in 1986 *(Figure 4)*.

Quotas have been oversubscribed regularly (Hatch *et al.* 1987), due mainly to an inability to fully control the recreational fishery. In 1984, it was the consensus of the Lake Erie Standing Technical Committee *(Figure 3)* that the western basin walleye stock had been rehabilitated and that 20-25% exploitation was appropriate. Abundance of walleyes in Lake Erie's central basin is increasing and the committee must now develop management policies suited to this expanding stock (Hatch *et al.* 1987).

4. Yellow perch

Yellow perch were regularly exploited in the 1930s, but were of secondary importance in the overall fishery before the 1950s because of the popularity of lake herring, whitefish, blue pike, and walleyes (Hartman 1973, Nepszy 1977). Recruitment of several strong year-classes in the 1950s, coupled with increased fishing effort and improved gear efficiency, progressively increased commercial production *(Figure 5)*.

Extremely large year-classes were produced in 1959, 1962, and 1965. Commercial catch rates increased and landings averaged 10 000 tonnes in the mid-1960s, peaking at 15000 tonnes in 1969 *(Figure 5)*. Production was sustained by the 1965 year-class through 1971, but catch rates began to decline, and subsequent production was sustained by increased effort aimed especially at new recruits. Estimated recreational use of the resource, which increased substantially during the early 1970s when walleyes were scarce, has remained near 1000 tonnes in recent years *(Figure 5)*.

4.1 Evolution of management strategies

One year after the record harvest of 1969, the GLFC Lake Erie Committee (LEC) *(Figure 3)* expressed concern over the decreased perch recruitment that was occurring despite apparently adequate spawning stocks. The LEC established an *ad hoc* Perch Subcommittee in 1972 to examine available information and consider management actions. This subcommittee collected available statistics and held an inter-agency workshop in 1973. After noting voids in the data, the group concluded that 'yellow perch populations were suffering from poor recruitment concomitant with heavy exploitation of young fish

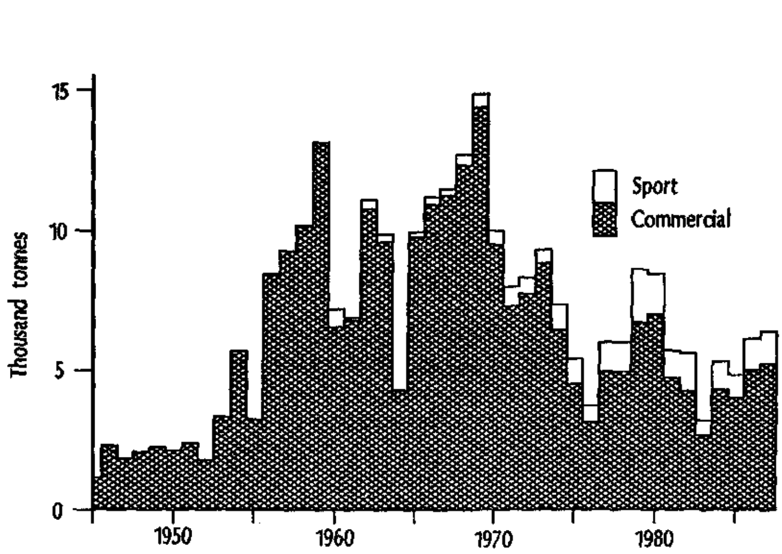

Figure 5. Yellow perch landings, Lake Erie, 1945-1987.

of age groups II and III.' The LEC received the report in 1974 and, although it agreed that sufficient information existed for recommending management measures, decided to await the walleye management plan and then attempt to apply a similar strategy to yellow perch.

Alarmed by reports of greatly reduced commercial production and low recruitment levels, the LEC recommended in 1975, a minimum size limit of 8 to 8.5 inches (203-216 mm), to protect adults through one or more spawnings. It also created a Yellow Perch Technical Committee to:

- Develop the necessary technical information required to consider alternative minimum sizes.
- Submit recommendations for an alternative minimum size.
- Recommend an assessment protocol for evaluating the population's response.

The use of an indirect management strategy for increasing the minimum size, rather than using a direct strategy, *i.e.* a quota system, was based on the urgent need for immediate action. The Yellow Perch Technical Committee Report of 1976 recommended a commercial minimum size between 216-222 mm based on equilibrium models indicating no significant decrease in yield, but a significant increase in reproductive potential (Hartman, Nepszy & Scholl 1980). The LEC unanimously agreed with the recommendation and the need for immediate multilateral action; however, socio-economic and political factors impeded adoption of the lakewide minimum size. Agencies chose instead to enforce the existing 203 mm length limit more rigidly, resulting in severe losses from the dumping of perch of sublegal size and greatly increased enforcement costs. In 1979 the LEC, manifesting rekindled interest in quota management, charged the Standing Technical Committee *(Figure 3)* with selecting a suitable model for establishing yellow perch quotas.

4.2 Development of quota management

The Standing Technical Committee established a Yellow Perch Task Group *(Figure 3)* in 1980 to address development of perch quotas. Data from all agencies were pooled because previous tagging and growth studies did not indicate the existence of separate stocks. The Task Group concluded that equilibrium models were inappropriate for Lake Erie yellow perch because of environmental influences on recruitment - spawning stock biomass appeared to account for only about 50% of the variation in recruitment. Instead the group used cohort analysis to reconstruct virtual populations, and developed a model in which stochastic recruitment was used to evaluate population simulations.

Cohort analysis demonstrated that lower recruitment since 1965, and greatly reduced survival of age groups II and III, were responsible for the decline in yellow perch stocks. Simulations with various fishing rates and ages of recruitment indicated that:

- Fishing mortality prevented expansion of population biomass.
- Optimizing fishing rates would require significant reductions from existing levels.
- Increasing the age at recruitment would aid rehabilitation significantly.

When the preliminary task group report was submitted in 1982, agencies already had begun unilateral actions to reduce fishing effort and increase age at recruitment, and were exploring mechanisms to implement quotas. In 1983 the LEC indicated support for lakewide quota management, but directed the task group to form smaller management units to allow sensitivity to differences in regional fisheries.

4.3 Implementation of quota management

The LEC accepted the Yellow Perch Task Group report for further review in 1985 and began deliberations on harvest strategy; it formally accepted and endorsed the quota methodology in 1986. The committee agreed to a short term policy of a 20% reduction in fishing effort from the 1981 levels by 1990, and a long term policy of reduction to the maximum sustainable yield level by 2000. An interim allocation policy, implemented from 1987 to 1990, provided for allocation of fishing effort between agencies (based on the surface area of each management unit), and agency estimation of its next year's harvest by management unit and re-allocation of estimated available surplus among the remaining agencies within that unit. This interim policy will be re-examined after 1990.

5. Epilogue

The Lake Erie fish community is very unstable. The effects of eutrophication are still stressing the western and central basin stocks and invasions by new species continue. Although the walleye resource appears rehabilitated, it is clear that the harvest policy adopted for yellow perch is a compromise that favours rehabilitation but minimizes disruption in the existing fishery. Yellow perch and walleyes are examples of common stocks exploited in several jurisdictions with differing management objectives. Historic declines in both stocks were related to recruitment. The walleye stock rebounded under limited exploitation and research indicates that the yellow perch stock will be enhanced by a similar reduction in exploitation. Inter-agency management of such trans-boundary stocks depends on a strategy that allows each jurisdiction to control exploitation in concert with its fishery management objectives. The adoption of agency quota allocations from shared stocks has proven to be an acceptable mechanism for agencies to maintain their options for management in their own jurisdictions. Resource agencies on the United States side of Lake Erie have encouraged recreational fishing at the expense of commercial production as a means of improving the economic value of the fishery. Ontario is improving the economic efficiency of its intensive commercial fishery through individual quotas and industry self-policing.

References

Baldwin, N.S., Saalfeld, R.W., Ross, M.A. & Buettner, H. J., 1979. Commercial fish production in the Great Lakes 1867-1977. Great Lakes Fish. Comm. Tech. Rep. 3. 187 pp.

Beeton, A.M., 1961. Environmental changes in Lake Erie. Trans. Am. Fish. Soc. 90: 153-159.

Berkes, F., & Pocock, D., 1987. Quota management and "people problems": a case history of Canadian Lake Erie fisheries. Trans. Am. Fish. Soc. 116: 494-502.

Charlton, M.N., 1987. Lake Erie oxygen revisited. J. Great Lakes Res. 13: 697-708.

Great Lakes Water Quality Board, 1987. 1987 report on Great Lakes water quality. Windsor, Ontario, International Joint Comm. 236 pp.

Hartman, W.L., 1973. Effects of exploitation, environmental changes, and new species on the fish habitats and resources of Lake Erie. Great Lakes Fish. Comm. Tech. Rep. 22. 43 pp.

Hartman, W.L., Nepszy, S.J. & Scholl, R.L., 1980. Minimum size limits for yellow perch (*Perca flavescens*) in western Lake Erie. Great Lakes Fish. Comm. Tech. Rep. 39. 32 pp.

Hatch, R.W., Nepszy, S.J., Muth, K.M. & Baker, C.T., 1987. Dynamics of the recovery of the western Lake Erie walleye (*Stizostedion vitreum vitreum*) stock. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 15-22.

Hyatt, R., 1986. Summer creel census in the Canadian waters of the western basin of Lake Erie. Ont. Min. Nat. Resour., Lake Erie Fish. Assess. Unit Rep. 1986-1. 72 pp.

Kutkuhn, J.H., *et al.*, 1976. First technical report of the GLFC Scientific Protocol Committee on inter-agency management of the walleye resource of western Lake Erie. Great Lakes Fish. Comm. Mtg., Traverse City, MI. June 15, 1976. 31 pp., appendix, and addendum 1. 12 pp.

Leach, J.H., & Nepszy, S. J., 1976. The fish community of Lake Erie. J. Fish. Res. Bd Can. 33: 622-638.

Nepszy, S. J., 1977. Changes in percid populations and species interactions in Lake Erie. J. Fish. Res. Bd Can. 34: 1861-1868.

Ohio Dep. Nat. Resour., 1986. Status and trend highlights, Ohio's Lake Erie fish and fisheries. Ohio Dep. Nat. Res., Lake Erie Fish. Unit. 28 pp.

Regier, H. A., Applegate, V. C. & Ryder, R. A., 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fish. Comm. Tech. Rep. 15. 101 pp.

Sly, P.G., 1976. Lake Erie and its basin. J. Fish. Res. Bd Can. 33: 355-370.

Wolfert, D.R., 1981. The commercial fishery for walleyes in New York waters of Lake Erie, 1959-1978. N. Am. J. Fish. Manage. 1: 112-126.

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