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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.

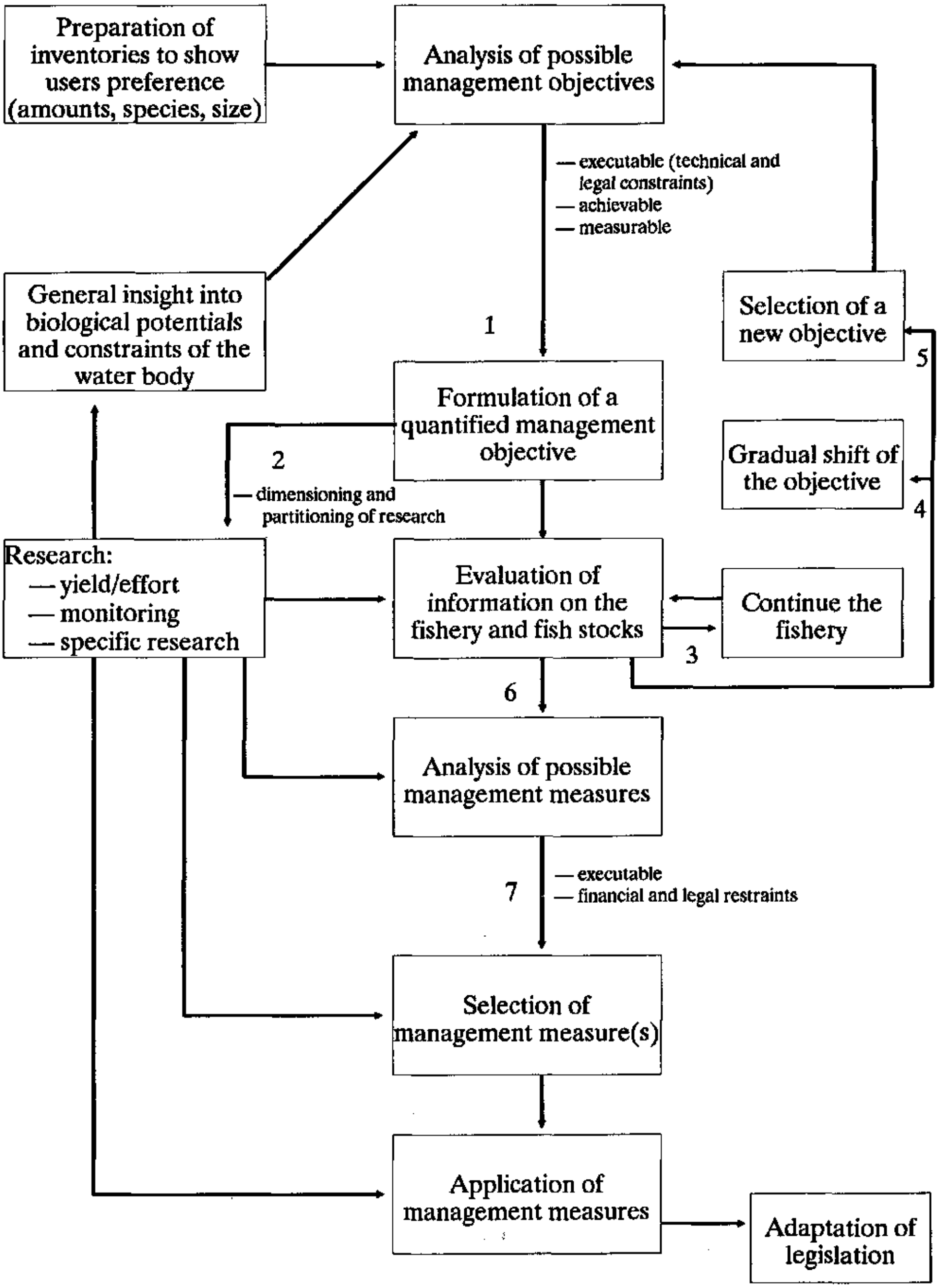

Figure 1. A generalized management scheme. The numbers indicate when main decisions have to be taken.

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.

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