Salmonids and other migratory fish in Lake IJsselmeer

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Summary

Routine fish surveys cannot monitor rare fish efficiently. Therefore, in fall 1994 a research programme started, asking commercial fishermen to deliver migratory fish in return for a premium. This bycatch was to be delivered in freezers placed at fish auctions. From fall 1994 to December 1997, 2065 fish were contributed to the programme. More than half of the catches were sea trout. In this report, catches of salmon (*Salmo salar*, n=65), sea trout (*Salmo trutta*, n=1100), rainbow trout (*Oncorhynchus mykiss*, n=36), twaite shad (*Alosa fallax*, n=65), lamprey (*Petromyzon marinus*, n=283) and lampern (*Lampetra fluviatilis*, n=304) are described.

For salmon up to 17 large individuals (50-100 cm) were caught per year and up to 16 small individuals (10-25 cm). Fish of the smaller cohort mainly occurred in May and June, of the larger cohort mainly in September, October. The largest catch of sea trout was recorded in 1995 (504 individuals), followed by 206 individuals in 1996 and 349 individuals in 1997. Two cohorts could be observed in the catch: one growing from 20 cm in May to 40 cm in December and one ranging in length from 40 cm in March to 60 cm or more in December. The majority of trout (71%) was immature. Rainbow trout occurred mainly in 1995 (22 out of 36 individuals). Length ranges from 20-40 cm indicating one year class was found only. Twaite shad were mostly caught close to the Afsluitdijk at a length of 30-50 cm from September to December. Apparently, these fish enter lake IJsselmeer unintentionally or only for a short period of time. Catches of lamprey occurred mostly in May. Timing and length coincide with upstream migration, suggesting lampreys use lake IJsselmeer to migrate upstream. Lampern were handed in in such large numbers by a few fishermen in November 1994 and 1995. Personal communication revealed that more lamperns were caught in other areas of the lake. From then onwards this species was excluded. Length and timing of the contributed lamperns coincide with upstream migration. Other migratory fish included a sturgeon (5 individuals, most likely originating from culture), whitefish (*Coregonus lavaretus*, 22 individuals) and houting (*Coregonus oxyrhynchus*, 5 individuals).

The origin of salmon and sea trout in lake IJsselmeer is unknown. Fatty acid composition, strontium content in scales, or trimethylamine oxide (TMAO) concentration in muscle tissue were analysed to explore their origin chemically. None of these methods could provide conclusive evidence to either freshwater or a marine origin of the fish although, TMAO analysis gave a strong indication toward marine origin. Analysis of growth data suggests younger sea trout originate from the Waddensea. For the larger ones, it is quite likely many enter the lake from the Waddensea although the existence of resident freshwater populations cannot be ruled out completely. Further upstream migration towards spawning areas might be possible. Alternatively, they might also stay in the lake to return to sea. Smaller salmon (15-25 cm, occurring in May) probably originate from upstream regions of the Rhine were they might have been stocked. Immigration of larger salmon reported later (September and October) coincide with upstream migration behaviour of winter salmon to the spawning grounds reported in literature. The number of individuals is, however, rather small.

To what extent the lake IJsselmeer stocks contribute to the total population of the Rhine tributary is rather uncertain. A programme based on catches by commercial fishermen has been shown to be a reliable source of information. Statistical analysis shows 72% of the total number of salmonids caught as bycatch were delivered. Most fish were caught in fykenets. For fykenets a closed season exists from December to April, therefore a full coverage of the whole year is not achievable. This illustrates the limits of the programme. Overfishing in the lake for many years will have removed a significant part of salmonids entering the lake. Optimisation of the eel-fisheries will, as a side effect, also lower the number of salmonids in the bycatch.The restoration of the river Rhine has been successfully pursued. Local problems in the restoration of salmonid stocks have been solved. So far, however, the coherence of the restoration efforts throughout the catchment area is rather low. Quantitative evaluation, as obtained in the programme described in this report, is crucial to the evaluation of the restoration efforts.

1 Introduction

In 1987 the 'Rhine Action Programme' started aiming at:
- creating conditions for the return of higher species (e.g. salmon),
- safeguarding the use of Rhine water for supply of drinking water,
- eliminating pollution of sediment by hazardous compounds (Van Dijk & Marteijn, 1993).

A direct cause for the start of this programme was a disaster in 1986 at the firm Sandoz in Basel and resulting pollution of the river Rhine. Migratory fish were, however, already seldomly caught in the years before this disaster. Poor water quality combined with construction of physical barriers and destruction of spawning grounds was the main cause for the serious decline of most migratory fish.

Since the start of the research programme 'Ecological Rehabilitation of the River Rhine' in 1988, various topics on migratory fish were published in this series. De Groot (1989 a,b) described the historical situation of Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta trutta*) in the river Rhine. A description of physical barriers for migratory fish has been presented by de Haas (1991) and Vanhemelrijk (1991). The functionality of a fishpass has been described by Lanters (1995). Sonneveldt and Baart (1997) assessed there was little evidence thermal or chemical barriers could possibly hamper re-introduction of salmonids.

Technical measures have been taken to overcome physical barriers as much as possible. Target species to conduct these measures was Atlantic salmon. Restocking programmes of Atlantic salmon and trout have been conducted in the river Sieg, a branch of the river Rhine in Germany (Schmidt, 1991, Steinberg & Lubieniecki, 1991). Other programmes in Denmark, Germany, France and the Netherlands also involved stocking and/or tagging of trout and salmon.

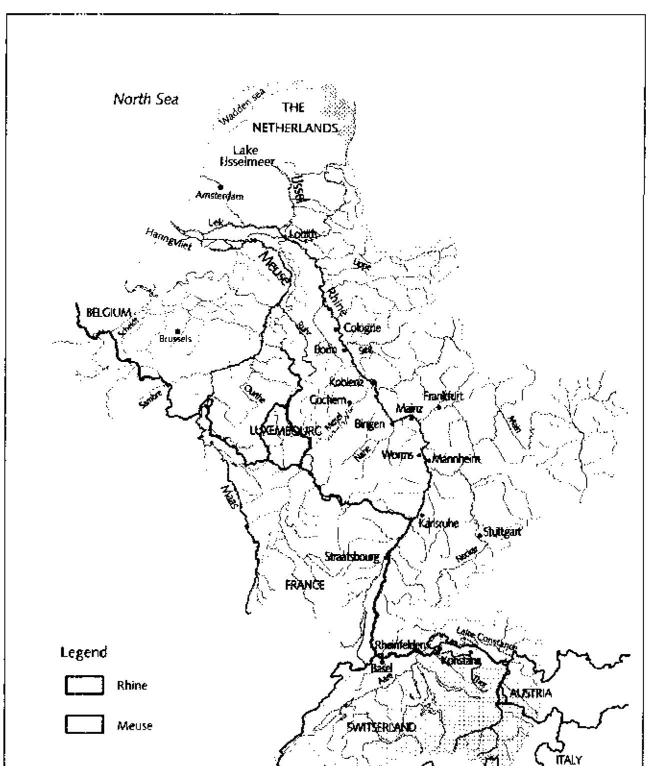


Figure 1.1: Lake IJsselmeer is the most northern downstream part of the Rhine basin.

In this report, an overview of results obtained in a research programme to assess the amount and composition of rare (migratory) fish in lake IJsselmeer, starting in 1994 will be presented. Lake IJsselmeer is part of the Rhine basin (Fig 1.1).

The river Rhine discharges about 10% of its water into the lake via the river IJssel, a branch of the river Rhine. The lake is connected by sluices to the Waddensea. Lake IJsselmeer thus constitutes one of the potential entrances of the river for migratory fish. The observation of migratory fish in lake IJsselmeer could provide information necessary to assess the stock dynamics in the rest of river.

Routine surveys seldomly catch most migratory fish species. Therefore samples of these species were obtained from commercial fishermen fishing in the lake mainly for eel, perch and pikeperch. The fishermen received a premium for each fish contributed to the programme. In 1994 and 1995, effort was made to assess the origin of trout and salmon by means of analysing body tissue on trimethylamine oxide (TMAO) content or fatty acid composition (chapter 5.1).

The programme was initiated by Rijkswaterstaat Directorate IJsselmeergebied (RWS-RDIJ) and conducted by the Netherlands Institute of Fisheries Research (RIVO-DLO). Earlier reports dealing with sections of the programme have been published by Mous & Luten (1995), Mous et al. (1995) and Dekker & van Willigen (1996, 1997, 1998).

2 Description of lake IJsselmeer and fisheries

2.1 Lake IJsselmeer

Lake IJsselmeer is a former estuary, formerly named "Zuiderzee". In 1932 the Zuiderzee was closed off. Tidal movement, formerly reaching to the southern part of the estuary, disappeared. Within two years after closure the newly created lake became completely fresh (salinity dropped from 6 mg/l to ≈ 0.2 mg/l). Land reclamation programmes reduced the area from its original 3.450 km^2 to its present 1.840 km^2 by the creation of three polders. In 1975 the lake was split by a dyke into two parts: Markermeer (the southern part) and IJsselmeer (the northern part) (Fig 2.1).

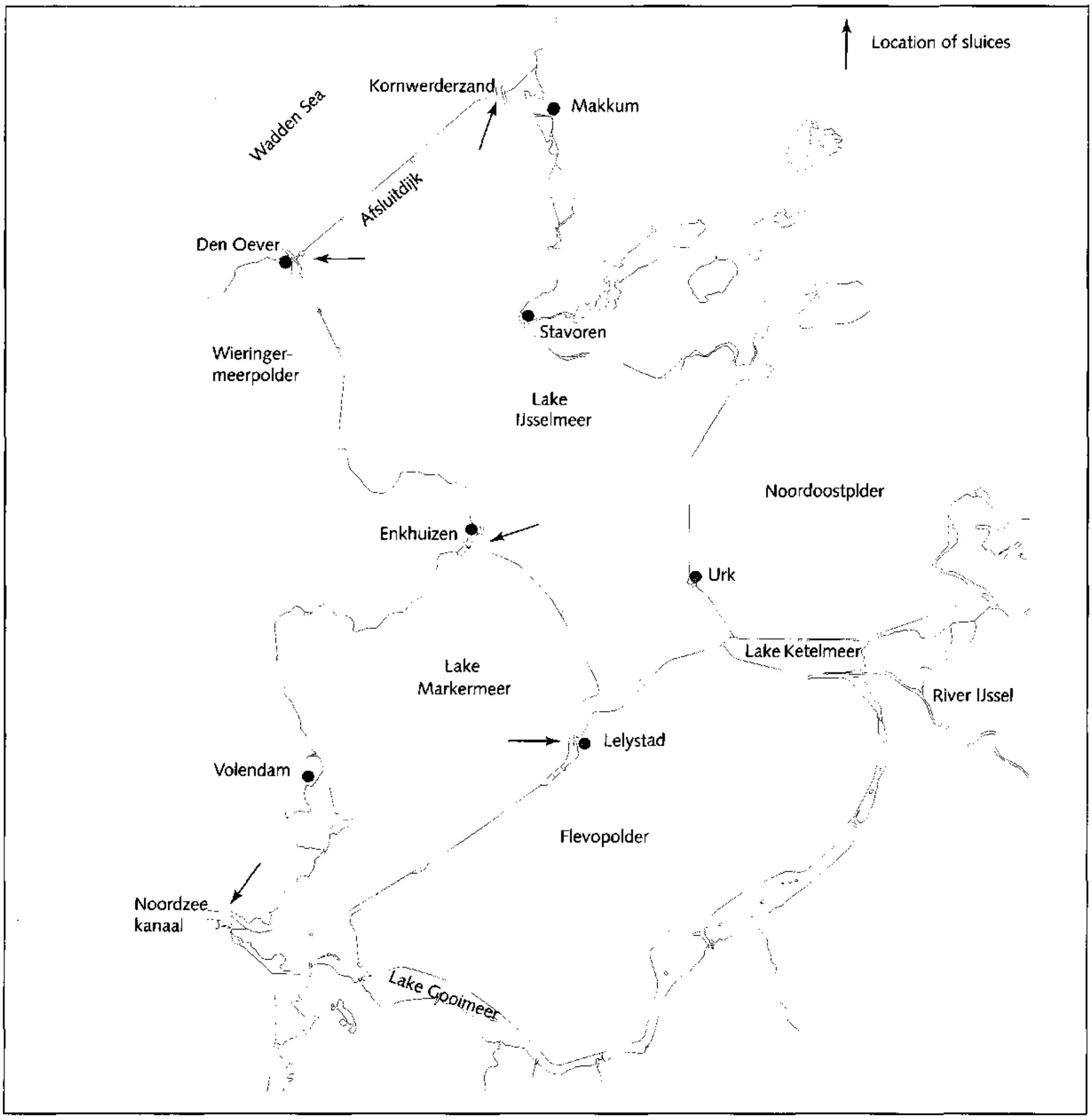


Figure 2.1 : Lake IJsselmeer forms the linkage between the River IJssel and the Wadden Sea. Lake Markermeer is separated from IJsselmeer by a dike which has two sluices.

At present both compartments of the lake are eutrophic, shallow freshwater. The Northern part (confusingly named IJsselmeer) has a surface of 1.140 km^2 and a shoreline of 218 km. The mean depth is 4.5 m, with depressions up to 9 m caused by former tidal movement. The water inlet of the

lake is the river IJssel, a branch of the river Rhine (Fig 1.1). Water outlet is mainly to the Waddensea through 12 m wide discharging sluices in the Afsluitdijk. Fifteen of these sluices are located near Den Oever; ten near Makkum (Fig 2.1). The southern compartment called Markermeer has a surface of 700 km^2 and a shoreline of 160 km. The mean depth is 3.9 m, the maximum depth 6 m. Water inlet of this lake is the Gooimeer. The main water outlet is the Noordzeekanaal that ends in the Northsea. Sluices between the two compartments are located near Enkhuizen and Lelystad (Fig 2.1).
For migratory fish lake IJsselmeer is the most important of the two lakes, forming a direct link between the sea and the river Rhine. Since 1991 the regime of the sluices was adapted to facilitate the migration of fish at times when waterlevel in Waddensea and IJsselmeer levelled. This resulted in increased amounts of flounder in lake IJsselmeer (for example Dekker & Hartgers, 1998). For the actual target organisms (salmonids and other rare migratory fish) the effect of the altered sluice regime is more difficult to assess. Routine fish surveys rarely catch migratory fish while the programme described in this report started only after the change in sluice management.

2.2 Fisheries

In lake IJsselmeer, the following fisheries are practised:

1) Fyke net fishery with fyke nets fixed to poles along the shore and at the edges of sand banks. This fishery catches eel (including silver eel), and a small proportion of marketable perch. Additionally, small fish such as young, undersized perch and pikeperch and all other species are caught and discarded, resulting in a considerable discard mortality.
2) Fyke net fishery with nets set in a train by anchors to the bottom (summer fyke nets). This fishing technique provides the same range of species as the previous one, except that silver eel are less important.
3) Fyke net fishery for smelt. This fishery is executed during the spawning season of smelt in spring.
4) Eel boxes, catching eel only. These wooden boxes (approximately 70 x 10 x 10) resemble baited eel-pots. They are attached to a long rope and are mostly baited with smelt (Deelder, 1971).
5) Long lines fishing for eel, with a bycatch of perch and pikeperch.
6) Gill nets, fishing for perch, pikeperch, bream and roach. Perch and pikeperch are the more valuable species.
7) Seine nets catching bream and roach, mostly for stocking purposes for recreational fisheries.

The fishing intensity in the lake is high and all commercial fish stocks are heavily over-exploited.

Table 2.1: Fishing gear used in the IJsselmeer fisheries. The total gear number represents the total allowed number. This does not mean that every gear is always used, usage can vary by the season. (from : Dekker & van Willigen, 1996).

Gear type	Total number	Meshsize (mm)	Season
Fyke	1756	24	1/5-1/12
Summer-fyke	18043	24	1/5-15/10
Fyke for smelt	5060	24	≈1/3-1/4
Fyke for cyprinids for restocking	100	40	1/11-15/5
Eel-boxes	21835	≈ 24	11/4-1/11
Gill nets	5940	101	1/7-15/3
Seine net	5	40	1/11-15/3
Trawling for smelt as bait	30	12	15/4-15/10
Long lines	8*500m	hook 10 mm	11/4-1/11

Table 2.1 gives the approximate number of gears used, mesh size, the location in the lake and the open seasons. At present ≈ 70 companies participate in fisheries' activity on the lake. Economically the fishery for eel is most important followed by catches of perch and pikeperch (table 2.2).

Table 2.2: Commercial catches of the most abundant species (weight in tonnes and value in 1000 Dutch fl.) in 1993 in lake IJsselmeer.

Species	weight (in tonnes)	value (in 1000 Dutch fl)
Eel	384	6396
Perch	212	2018
Pikeperch	38	443
Smelt	579	353
Other species	48	125

3 Collection and handling of fish

In fall 1994 small freezers were placed at six fish auctions in lake IJsselmeer area. Posters were put up requesting fishermen to deliver their catches of migratory fish species in the freezer with notes on place, date and geartype of the catch. For each fish a premium was handed over combined with a reimbursement of the market value of the fish. In most cases only a few individuals per species were handed in. Lampern *(Lampetra fluviatilis)* however, was handed in large numbers in November 1994 and 1995. In the following years this species was therefore excluded from the programme. Catches of lampern will be discussed briefly (chapter 4.6).

Every two months the fish were collected from the auction halls. After defrosting in approximately 20 hours, fish were analysed in groups of 200 individuals per day.

Table 3.1: Variables measured and collected for each individual fish.

Variable	Units, remarks
Catch characteristics	
Date	
Vessel	
Fishing gear	
Place	
Morphometric characteristics	
Species	
Length	unit: cm; interval: mm
Weight	unit: g; interval 1 g
Circumference	max. circumference; unit: cm; interval: 1 cm.
Sex	
Maturity stage	scale according to Bagenal (1978); table 2
Stomach	weight (g) and content
Liver	weight (g)
Scales	collection without further analysis
Otolith	collection without further analysis

Table 3.1 presents the variables measured during analysis. Maturity stages have been derived from Bagenal (1978) who is referring to Kesteven (1960). Codes and a short description of these stages are presented in table 3.2. Stages I and II comprise juveniles, which would certainly not be spawning in the spawning season following their capture. Stage III comprises fish preparing for spawning. It is uncertain whether these fish would have spawned in the first upcoming spawning season. From stage IV onwards the fish are more or less developed in maturity and would most certainly have participated in spawning. Stage VI to IX involve actual spawning and are completed in a very short period of time.

Identification of the fish took place on the basis of external morphometric characteristics based on Wheeler (1978) and Nijssen & de Groot (1987). Identification of the sturgeon is, however, uncertain. The fish mentioned in this report do not belong to the species *Acipenser sturio.* Most likely they originate from various cultured varieties of sturgeon (de Nie, 1996).

Table 3.2: Classification of maturity stages in fish according to Bagenal (1978), referring to Kesteven (1960).

Code	Classification	Description
I	Virgin	Very small sexual organs close under the vertebral column. Testes and ovaries transparent, colourless to grey. Eggs invisible to naked eye.
II	Maturating virgin	Testes and ovaries translucent, grey-red. Length half, or slightly more than half, the length of the central cavity. Single eggs can be seen with magnifying glass.
III	Developing	Testes and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye as whitish granular.
IV	Developing	Testes reddish-white. No milt-drops appear under pressure. Ovaries orange reddish. Eggs clearly discernible; opaque. Testes and ovaries occupy about two-thirds of ventral cavity.
V	Gravid	Sexual organs filling ventral cavity. Testes white, drops of milt fall with pressure Eggs completely round, some already translucent and ripe.
VI	Spawning	Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.
VII	Spawning/ spent	Not yet fully empty. No opaque eggs left in ovary.
VIII	Spent	Testes and ovaries empty, red. A few eggs in the state of reabsorption.
IX	Recovering/ spent	Testes and ovaries translucent, grey-red. Length half, or slightly more than half, the length of ventral cavity. Single eggs can be seen with magnifying glass.

4 Species description

4.1 Introduction

From fall 1994 up to December 1997, 2065 fishes have been contributed to the programme by commercial fishermen fishing in lake IJsselmeer and Markermeer.

Table 4.1 provides an overview of the total number of fish per species per quarter. Fig 4.1 presents species composition . Lamperns were excluded from the programme in 1995 because large numbers were landed in single fyke nets during November 1994 and 1995. In this report emphasis is placed on anadromous fish. Atlantic salmon, sea trout, rainbowtrout, twaite shad, lamprey and lampern, the more numerous species within the programme, are discussed in sections 4.2 to 4.7. Section 4.8 deals with sturgeon, whitefish and houting. These species were reported not frequently enough to derive quantitative conclusions. The other species presented in table 4.1 will not be discussed here, see Dekker & van Willigen (1996, 1997 and 1998) for details.

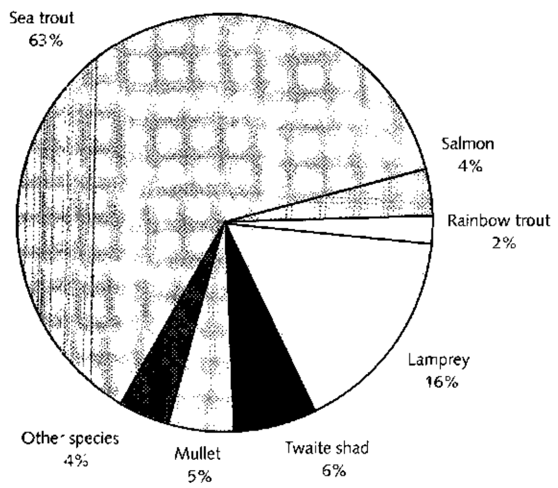
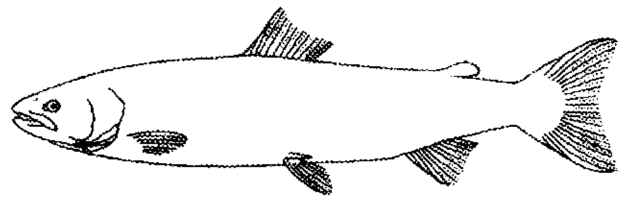


Figure 4.1: Species composition of collected fish (october 1994-december 1997); other species comprises: houting, whitefish, tench, asp, barbel, weatherfish, spined loach, wels, burbot, sturgeon (Lampern is excluded).

For each species, a brief characterisation is given with regard to morphology, migration behaviour and distribution and abundance in Western Europe and in the Rhine tributaries, based on Lelek (1987), McDowall (1988), Nijssen & de Groot (1988) and de Nie (1996) unless stated otherwise. An indication of the abundance of the species on a European scale has been indicated according to the classification presented by Lelek (1987). This scale ranges from intermediate (common now, but likely to become endangered if there is any further deterioration of their biotopes), to rare, vulnerable, endangered and finally extinct. The catches are discussed with respect to their monthly occurrence, year to year variation, length distribution, sex ratio and maturity. Results on salmon and trout are extensively discussed in section 5.2.

4.2 Atlantic salmon

Sc: *Salmo salar*
NL: Zalm
F: Saumon atlantique
D: Lachs



Species characteristics

The Atlantic salmon possesses a distinct adipose fin, abdominal pelvic fins and well developed teeth in the jaws. The extreme end of the upper jaw of salmon just reaches the level of the rear edge of the eye. Spawning takes place in winter (generally November-December). Only 5% of the adult fish spawn a second time . During their stay in freshwater, adult salmon do not feed.
Growth of the juveniles is rapid from mid-April to the end of July. After one winter only the most

Table 4.1: Total number of collected fish (October 1994-December 1997), specified per species and quarter.

		1994		1995				1996				1997				Total
	QUARTER	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
SPECIES																
Lampern	*Lampetra fluviatilis*		152				152									**304**
Lamprey	*Petromyzon marinus*		2	3	100	7			42	5			118	6		**283**
Twaite shad	*Alosa fallax*		4			2	3		2	32	32		12	1	25	**113**
Houting	*Coregonus oxyrhynchus*									1				4		**5**
Whitefish	*Coregonus lavaretus*				1					1			16	4		**22**
Atlantic salmon	*Salmo salar*		2		7	11	5		12	2	5		16	2	3	**65**
Rainbowtrout	*Oncorhynchus mykiss*		5		6	15	1		4	2	2			1		**36**
Sea trout	*Salmo trutta*	1	38	8	149	270	77	34	95	41	38	11	191	114	33	**1100**
Tench	*Tinca tinca*										1					**1**
Asp	*Aspius aspius*			1						1				1	1	**4**
Barbel	*Barbus barbus*		3							1					1	**5**
Weatherfish	*Misgurnus fossilis*									1						**1**
Spined loach	*Cobitis taenia*										1					**1**
Wels	*Silurus glanis*					1				2						**3**
Burbot	*Lota lota*					1				1	1	2				**5**
Thick-lipped grey mullet	*Chelon labrosus*				1	13			5	28	10		2	29	8	**96**
Sea-bass	*Dicentrarchus labrax*					3			1	4			2	1	3	**14**
Sturgeon (?)						1	1	1					1		1	**5**
Total		**1**	**206**	**12**	**266**	**322**	**239**	**35**	**166**	**119**	**90**	**11**	**358**	**163**	**75**	**2063**

rapid growing juveniles (parr) with a length of 10 to 15 cm can start their sea-ward migration. Two year old smolts (seaward going juveniles) average 13 to 16 cm, while 3 year old fish may be 13 to 20 cm long. The length of the adult fish is not as much dependent on age than of the time it has fed at sea. Historically, salmon caught in the Rhine returning in spring after one year at sea were known as grilse or Jacob's salmon (61-67 cm long). Salmon remaining another year at sea (83-91 cm) normally returned in the period May-July. These 'small summer salmon', as they were called, were mostly immature when entering the Netherlands and reached maturity further upstream. Older salmon, winter salmon (103-115 cm), reached the Rhine in September, October. From May onwards these were called large summer salmon. Only a few fish (mostly females) return back to the sea after spawning. These kelts usually occurred in April (de Groot, 1989a).
Atlantic salmon is native to the north Atlantic region. In Europe it occurs from the Mino river in Portugal up to the Pechora in the Northeast. Self sustainable populations are found in England, in the countries north of the Baltic, in Norway and Iceland (Lelek, 1987). The salmon population in the Rhine once was large but the fish stock declined rapidly after the 1920's. Organised salmon fishery stopped in 1933, in the 1940's only a few hundred salmon per year were caught. In recent decades salmon was occasionally encountered in Dutch waters (Fig 4.2).

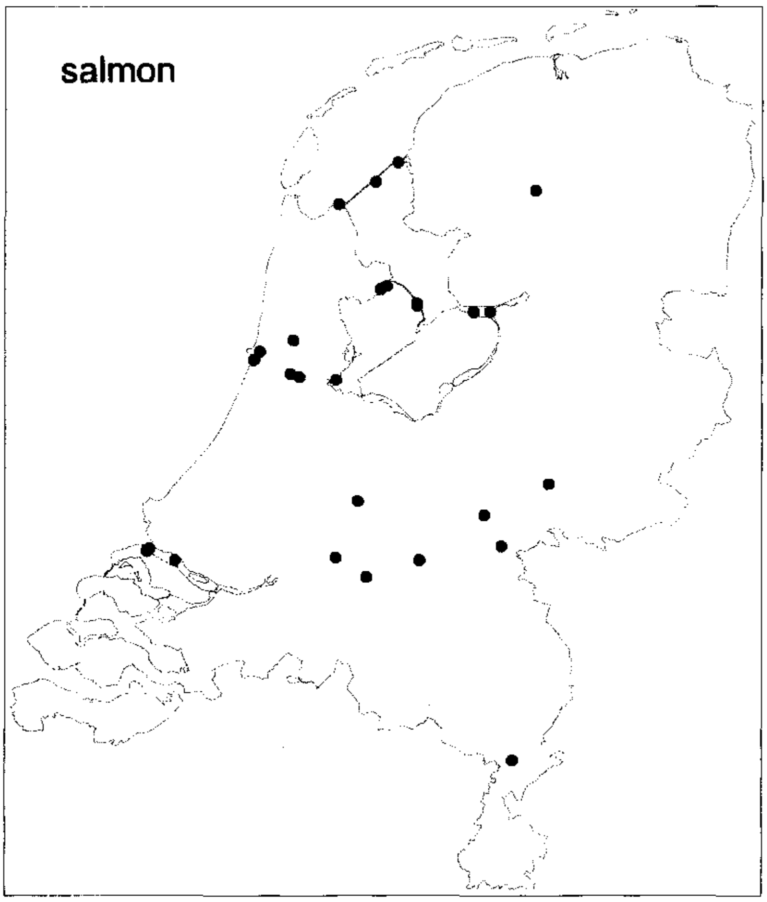


Figure 4.2: Distribution of salmon in the Netherlands (data put at our disposal bij de Nie).

At present main barriers for the salmon seem to be physical barriers hampering upstream migration to the spawning grounds, and the availability of suitable spawning grounds. In Europe the population is classified as endangered, locally threatened or extinct.

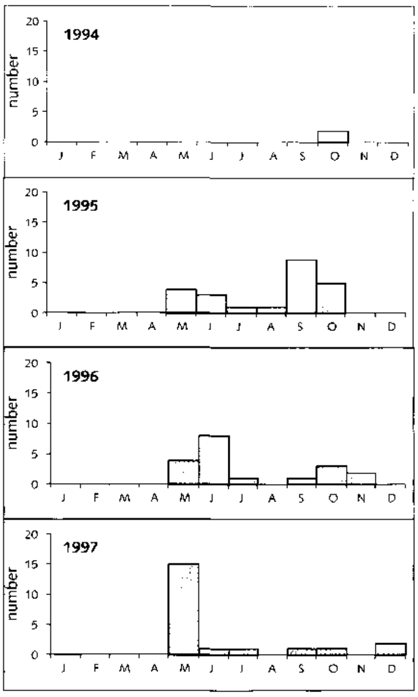


Figure 4.3: Distribution of reported salmon per month.

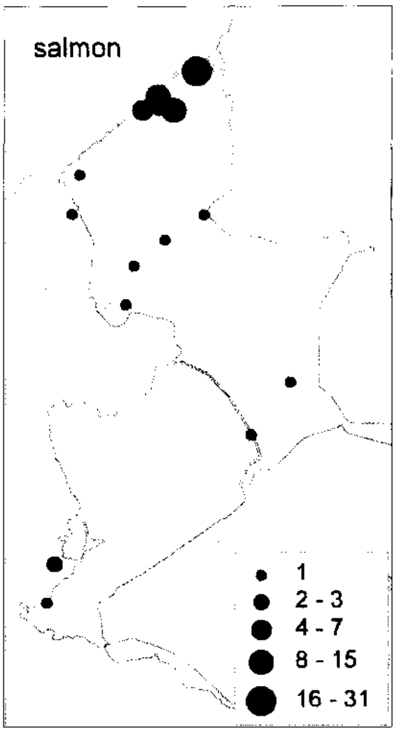


Figure 4.4: Distribution of reported salmon in lake IJsselmeer and Markermeer.

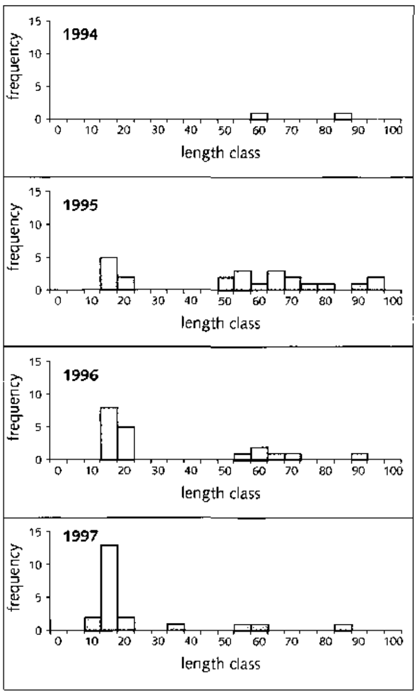


Figure 4.5: Length frequency distribution of reported salmon.

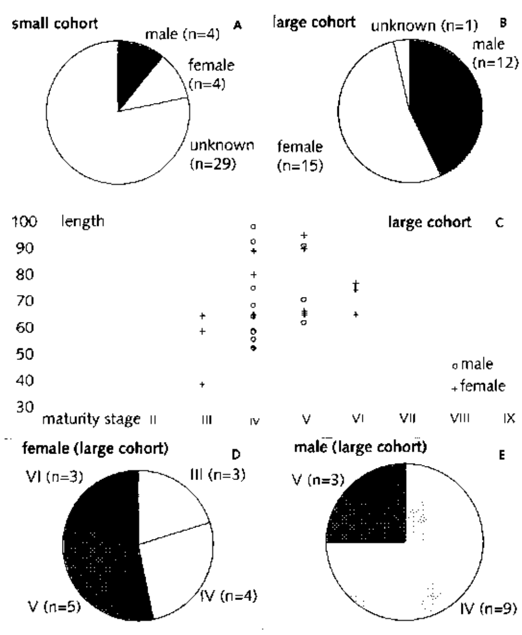


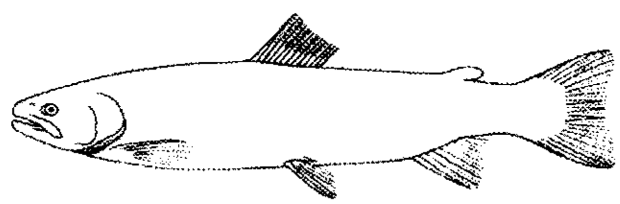
Figure 4.6: Sex ratio of salmon (A-small cohort; B-large cohort), length distribution as a function of maturity stage for large salmon (C) and maturity stage of female (D) and Male (E) large salmon.

Catches in lake IJsselmeer

Sixty-five salmons were caught in total from 1994 until 1997. In 1994 only 2 individuals were caught, in 1995 23 individuals with a peak in September, in 1996 19 individuals with a peak in June and, in 1997, 21 individuals with a peak in May (fig 4.3). Most individuals were caught near the Eastern part of the Afsluitdijk (fig 4.4). In all years up to 17 large individuals (50 - 100 cm) were caught and up to 16 small individuals (10-25 cm). Each year the number of smaller fish seemed to increase compared with previous years whereas the number of larger individuals decreased (fig 4.5). Fish of the smaller cohort were mainly caught in May and June. In most cases the sex of these fish could not be determined as they were still immature (stage I or II). Larger males (12 individuals) occurred from September until December in a developing or occasionally gravid maturity stage (IV or V). Larger females (14 individuals) occurred in September, October and once in December (fig 4.6). Maturity developed with length. However the number of observations is too low to reach final conclusions.

4.3 Sea Trout

Sc: *Salmo trutta*
NL: Zeeforel
F: Truite de mer
D: Meerforelle



Species characteristics

General characteristics of this species are: a brown back with adipose fin and silver coloured flanks . The upper jaw reaches well past the posterior edge of the eye. Coloration of the fish is variable and dependent on habitat and life stage of the fish. According to de Groot (1989b) *Salmo trutta* has resident populations in freshwater (brown trout) and migratory populations (sea trout). The life cycles of salmon and sea trout share many characteristics. For trout the size at maturity is smaller. Spawning run starts in summer, takes place in winter and can occur several times during life. Immature fish also ascend the river at the autumn spawning run of the adults (dummy run). Young trout can stay in the river for 1 to 3 years before migrating to the sea. When at sea, sea trout generally stays closer to the shore (100-350 km) than salmon (de Groot, 1989b) and is known to roam coastal areas and estuaries.

Sea trout has a world wide distribution after introduction in the American continent and other continents with suitable habitats. In Europe it is distributed from the Cheshskaya Bay in the East to

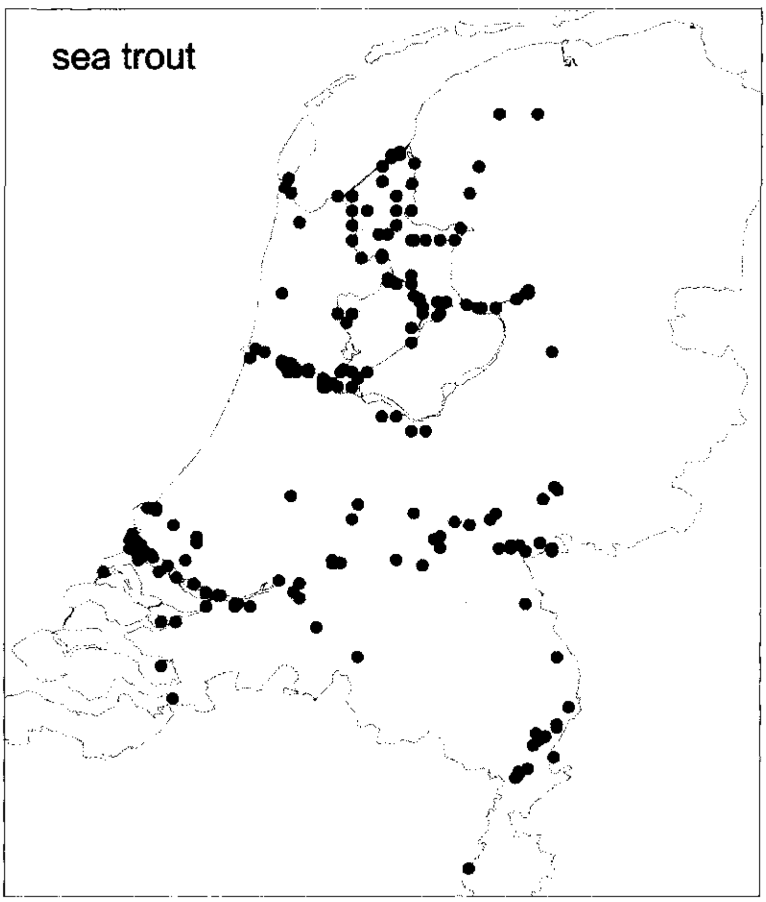


Figure 4.7: Distribution of sea trout in the Netherlands (data put at our disposal by de Nie).

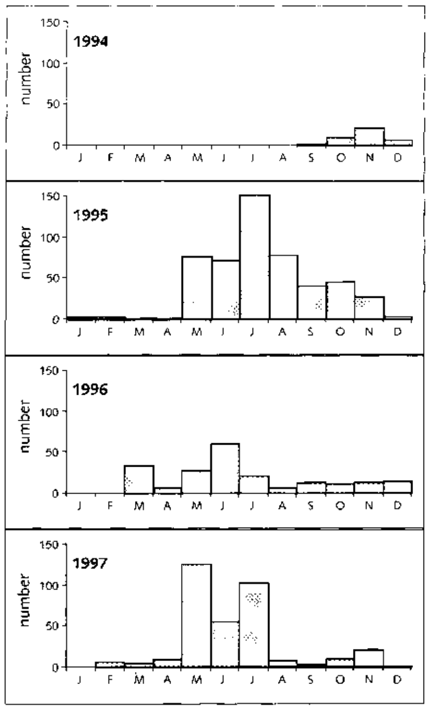


Figure 4.8: Distribution of reported sea trout per month.

the Douro river in Portugal. Sea trout is common in the British Isles, Scandinavia and Iceland. In other rivers it occurs sporadically because of a.o. difficulties with respect to upstream migration. In Europe the population is classified as endangered, locally threatened or extinct. In some rivers the population is maintained artificially by means of stocking. Stocking can only be successful when combined with clear passage ways from sea to suitable spawning areas. As early as 1920-1930 stocking of sea trout in the Netherlands was practised. Nowadays sea trout is frequently stocked throughout the Rhine tributary, and occasionally seen in the Netherlands (fig 4.7).

De Groot (1989b) analysed historical data and publications of catches of sea trout in the Netherlands in the beginning of the century. He concludes that sea trout has never been abundant in the Rhine. Annual catches from 1886 to 1986 vary considerably but no evidence can be found to suggest that there has been a serious decline in numbers. Exact estimations on these fish stocks is difficult because fishing effort also changed notably over the years. There is still too little material to evaluate the development of the trout population in the Netherlands.

Catches in lake IJsselmeer

The majority of the reported fish concerned sea trout in all years of the current programme (fig 4.1). In 1995 the largest catch was recorded with 504 individuals, followed by a smaller catch in 1996 (206 individuals) and again a large catch in 1997 (349 individuals) (fig 4.8).

Fig 4.9 presents the individual length of sea trout by date of catchment. Based on this graph Dekker & van Willigen (1996) concluded that two cohorts of fish were present in the lake. Apparently the youngest cohort, which they tentatively named grilse, ranges from an average length of 20 cm in May

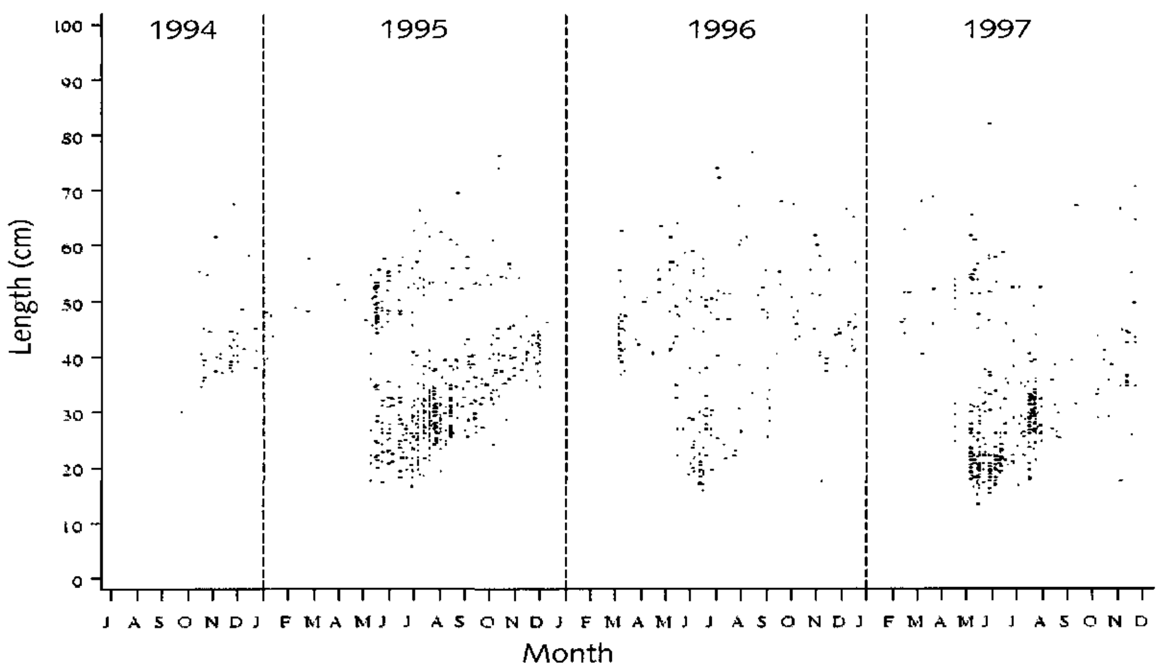


Figure 4.9: Length distribution of reported sea trout as a function of date.

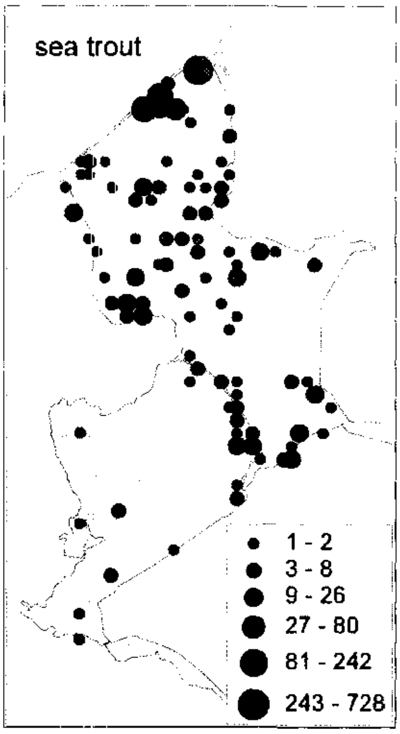


Figure 4.10: Distribution of reported sea trout in lake IJsselmeer and Markermeer.

until an average of 40 cm in December, whereas the older cohort ranges from an average length of 40 cm in March to an average of 60 cm or more at the end of the year. This division into two cohorts was most pronounced in 1995 and 1997, in 1996 the number of fish in the smaller cohort was too small to establish a clear separation. Most trout were caught in lake IJsselmeer and occasionally in lake Markermeer, this holds for both cohorts alike. For both cohorts, there seem to be areas of concentration in lake IJsselmeer near the Afsluitdijk (Kornwerderzand) in the north, a wide range in the central part of the lake and close to the Lake Ketelmeer in the south, where the IJssel enters into the lake. In 1997 catches were predominantly made close to the Afsluitdijk (fig 4.10). The distribution of fish throughout the lake and the fact that only a small number of them had marine prey in their stomachs, makes it likely to believe that the fish spend some time in the lake instead of travelling from the Waddensea to the river as quickly as possible.

Of the total catch 71 % was immature (stage ≤ 2). For 114 individuals (10 % of the total catch) sex could not be determined. These fish were all immature and small fish (15-35 cm). Of the other fish 67% of the catch was female. No marked differences in length frequency distribution could be observed between males, females and fish of unknown sex of the smaller cohort. For both male and female sea trout, the individuals belonging to the older cohort were caught throughout the year and grilse occurred

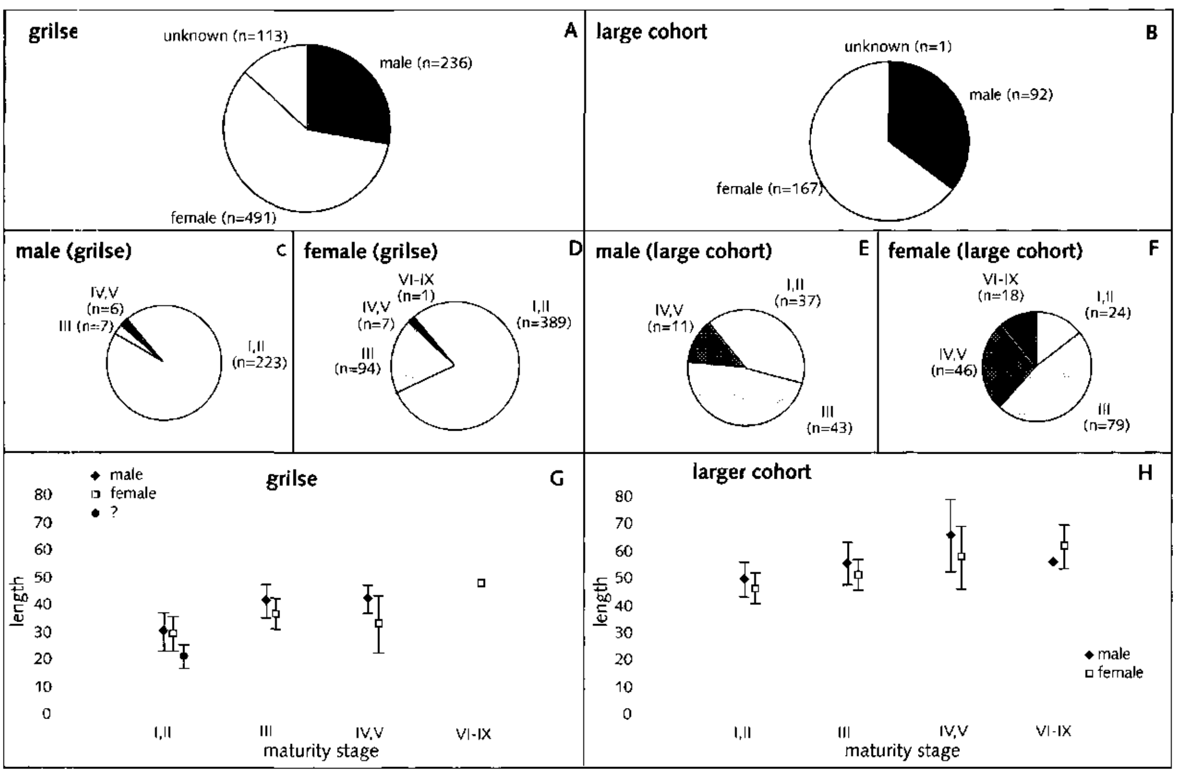
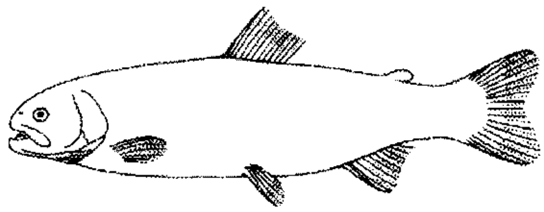


Figure 4.11: Sex ratio of sea trout (A-grilse, B-larger chohort), maturity stage of male and female sea trout (C-male (grilse), D-female (grilse), E-male (larger cohort), F-female (larger cohort), and length distribution (avg ± std) as a function of maturity stage (G-grilse, H-larger cohort).

from May onwards. For both male and female sea trout maturity stage increased with increasing length up to approximately 60 cm (fig 4.11).
Fifty percent of the males from 50 cm onwards showed a developing testes. As length increases a small number of individuals showed a higher grade of maturation (IV or V). No clear relationship between the month of capture and the maturity stage was found for males, which could be caused by the small number of large fish. The 5 male individuals which were gravid or spawning occurred in September until December, fish with maturity stage II to IV occurred year round. Half of the females of 40 cm belonged to a developing maturity stage (III). As time progressed a larger group of female individuals with higher maturity stages (IV to VII) was found than males. Gravid or spawning females occurred more frequently than males (36 female individuals compared to 5 males) and were encountered from August until May. Females with maturity stage II to IV occurred year round.

4.4 Rainbow trout

Sc: *Oncorhynchus mykiss*
NL: Regenboogforel
F: Truite arc-en-ciel
D: Regenbogenforelle



Species characteristics

Rainbow trout has a typical salmonid body shape and a dark greenish back, light sides with a purple band and white belly. Many black pigmentation spots are found on head, body dorsal fin and tail. This species originates from the Western part of the United States. Import of rainbow trout in Europe started in 1874. This species is the easiest of all salmonids to breed. Rainbow trout now occurs on all continents except the South pole. In the Netherlands stocking started in 1898. Water temperature in the Netherlands is unfit for natural reproduction. Large amounts are stocked in inland waters by sports fishery organisations. Distribution of rainbow trout in the Netherlands is presented in fig 4.12

Catches in lake IJsselmeer

In total 36 rainbowtrouts were delivered in the course of the programme, mostly caught from June until October of 1995 (22 individuals). In other years this species was encountered occasionally (fig. 4.13). All observations occurred between June and December (5 individuals in 1994, 8 in 1996 and 1 in 1997).

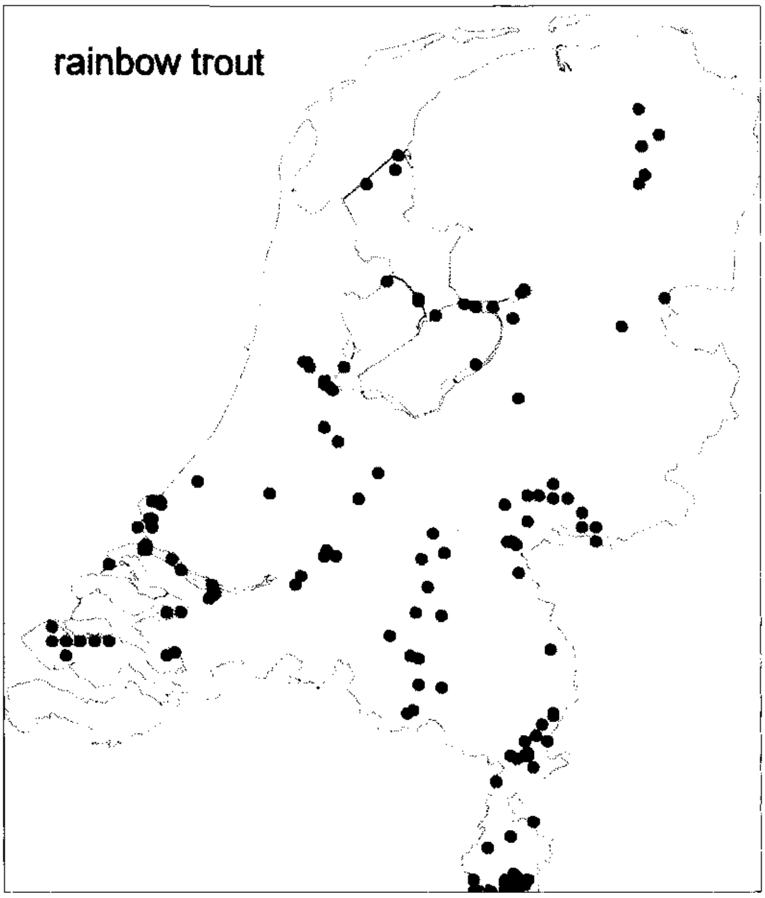


Figure 4.12: Distribution of rainbow trout in the Netherlands (data put at our disposal by de Nie).

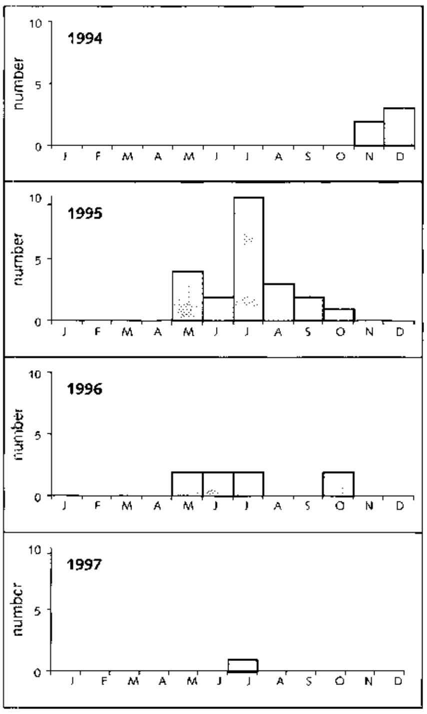


Figure 4.13: Distribution of reported rainbow trout per month.

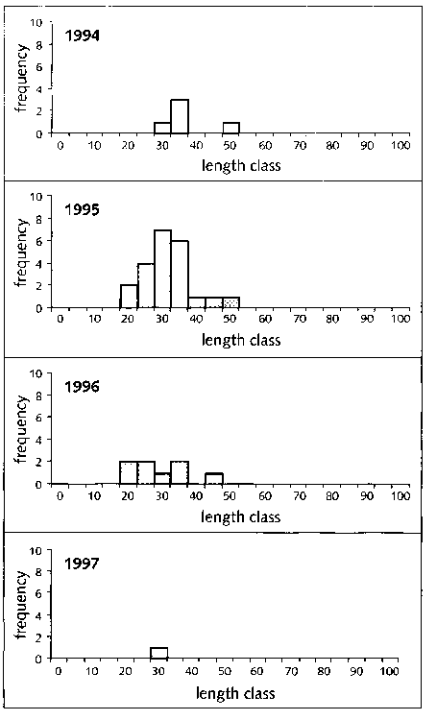


Figure 4.14: Length frequency distribution of reported rainbow trout.

Length ranges from 20 to 40 cm with a few larger female specimens up to 54 cm (fig 4.14). This length range could indicate that only one year class is encountered and that the fish grow from June until October from 20 to 40 cm. Most individuals (both female and male) were immature.

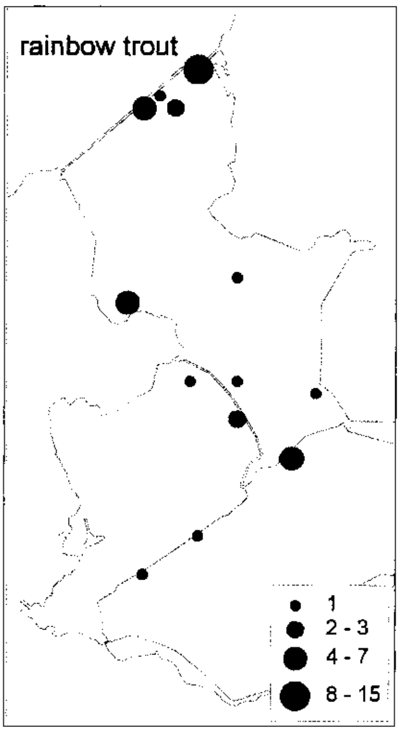
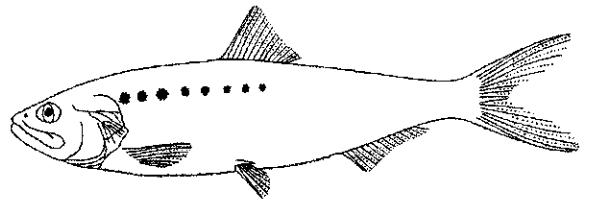


Figure 4.15: Distribution of reported rainbow trout in lake IJsselmeer and Markermeer.

4.5 Twaite shad



Sc: *Alosa fallax*
NL: Fint
F: Alose feinte
D: Finte

Species characteristics

Twaite shad is an anadromous fish of the family Clupeidae, mostly marine species. Twaite shad enters river mouths to spawn in or just above tidal reaches, from May to June. Eggs are demersal and drift over the estuary bottom towards sea. In the year following hatchment young fish migrate to sea. The European population has decreased drastically in the last few years and is classified endangered (although little is known about the population at sea). In rivers in northern Europe it is considered almost extinct. In the Netherlands a fishery for twaite shad existed until 1966. Since tidal movement is essential for development of larvae of twaite shad, closing of many of the river mouths from the sea has been a major cause for the decline of twaite shads in the Netherlands (de Groot, 1992). Chances for recovery of the twaite shad population are not foreseen in lake IJsselmeer, but much more in the south-west of the Netherlands.At this moment the sluicing regime in the Haringvliet is reconsidered in order to allow former tidal movement to some extent. At present twaite shad is observed at several locations, mostly near the coast of the Netherlands (fig 4.16)

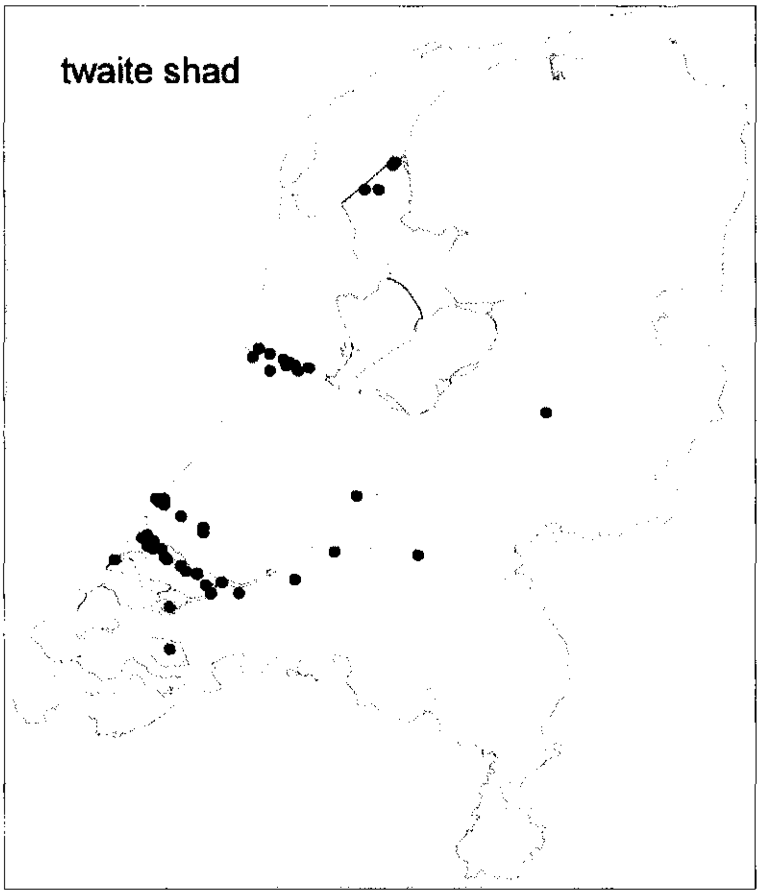


Figure 4.16: Distribution of twaite shad in the Netherlands (data put at our disposal by de Nie).

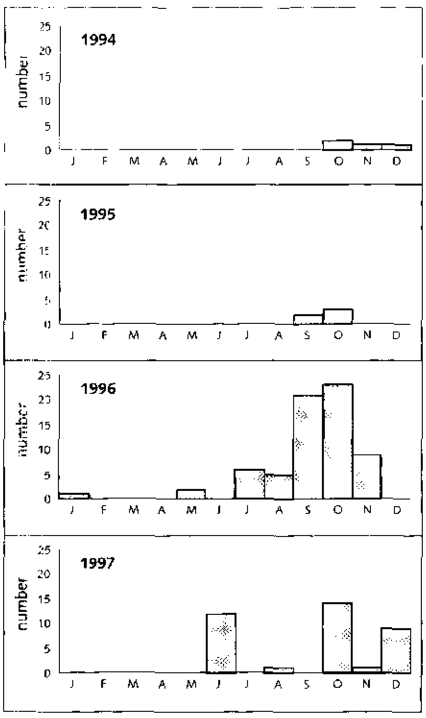


Figure 4.17: Distribution of reported twaite shad per month.

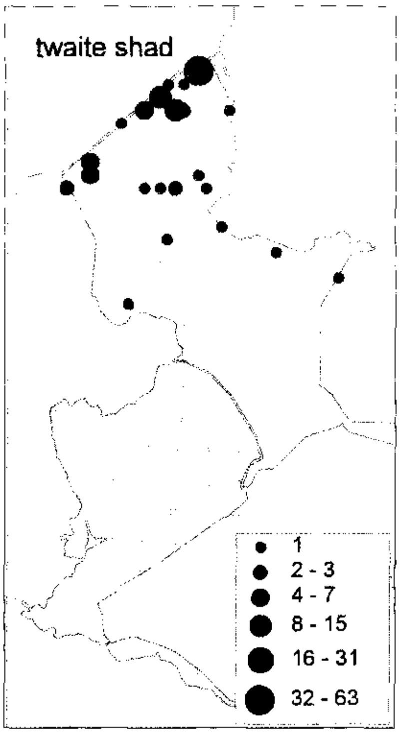


Figure 4.18: Distribution of reported twaite shad in lake IJsselmeer.

Catches in lake IJsselmeer

In the programme 113 twaite shads were entered: 4 in 1994, 5 in 1995, 59 in 1996 and 37 in 1997 (fig 4.17). Personal communication with fishermen revealed that actual catches in 1994 and 1995 were higher. Twaite shad were not handed in consistently because of mis-communication concerning twaite shad from the Waddensea. Most of the fish were caught in large fykes near the Afsluitdijk (fig 4.18) The majority of the catches were fish from 30-50 cm in length landed from September to December (fig 4.19). This period does not coincide with the spawning period and justifies the assumption that the fish enter lake IJsselmeer unintentionally or only for a short period of time.

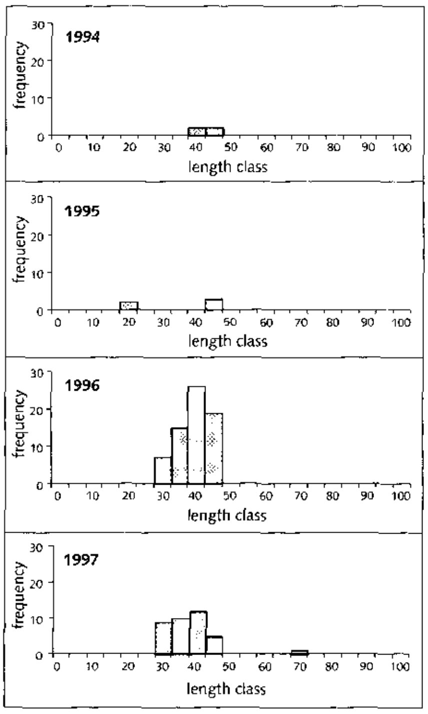
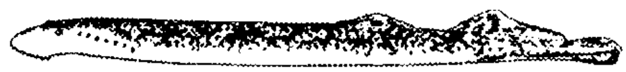


Figure 4.19: Length frequency distribution of reported twaite shad.

4.6 Lamprey



Sc: *Petromyzon marinus*
NL: Zeeprik
F: Lamproie marine
D: Meerneunauge

Species characteristics

Lampreys are elongate and slender in form. The mouth opening is surrounded by a circular sucking disk covered with rows of teeth. Maximal length is 120 cm. Spawning migration occurs in spring, and eggs are laid in primitive nests in gravel. Migrations in excess of 300 km are known, although some spawn only a little above tidal reach. According to de Nie (1996) lampreys never had spawning grounds in the Netherlands. It is generally believed that lampreys die after spawning. The larvae live for several years (usually 3 to 6 years) as filter feeders on aquatic micro-organisms. Metamorphosis takes place during summer and autumn, during which feeding ceases temporarily. Small sub-adults (12.5-15 cm) make their way downstream during autumn. In sea they live as parasites using their sucking disk to penetrate other fish. Here growth can be fast, up to 20 cm a year. After about 28 months they stop feeding, move inshore and migrate back upstream river systems. There is no evidence suggesting homing.

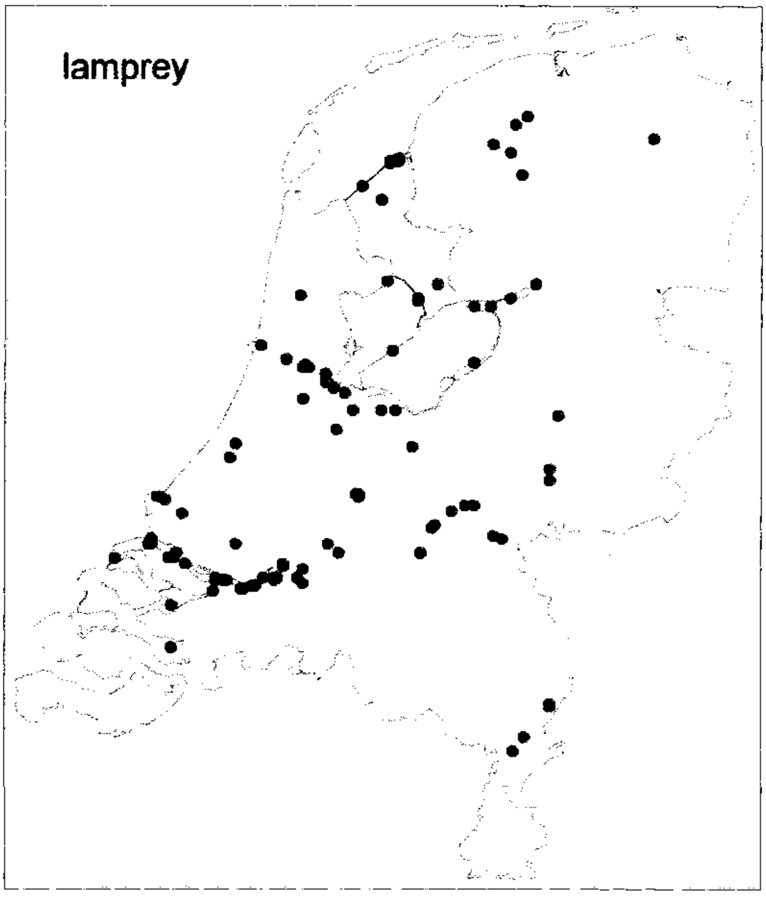


Figure 4.20: Distribution of lamprey in the Netherlands (data put at our disposal by de Nie).

Lampreys enter river systems in Europe from the Norwegian coast down to the Mediterranean . The population size in Europe is classified as vulnerable. Main reasons for decline are water pollution and building of dams and weirs in the river. In the Netherlands the number of lampreys was strongly reduced after 1970. In the river Rhine (and, to a lesser extent, in lake IJsselmeer) lamprey occurred more frequently since the 1980's, possibly because of improved water quality (fig 4.20).

Catches in lake IJsselmeer

In total 283 lampreys were caught in lake IJsselmeer during April to July with a marked peak in May (fig 4.21). The length frequency distribution did not change markedly over the years although catches in 1996 (47 individuals) were less frequent than those of 1995 and 1997 (110 and 124 respectively). Two size classes appeared in the catch: a few individuals had a length of 20 to 45 cm; a larger

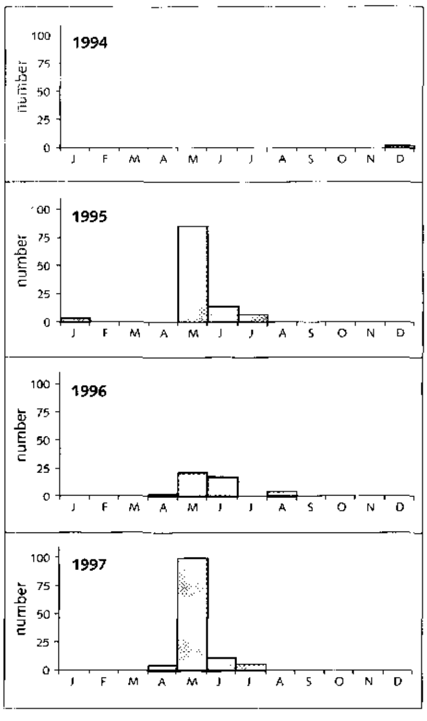


Figure 4.21: Distribution of reported lamprey per month.

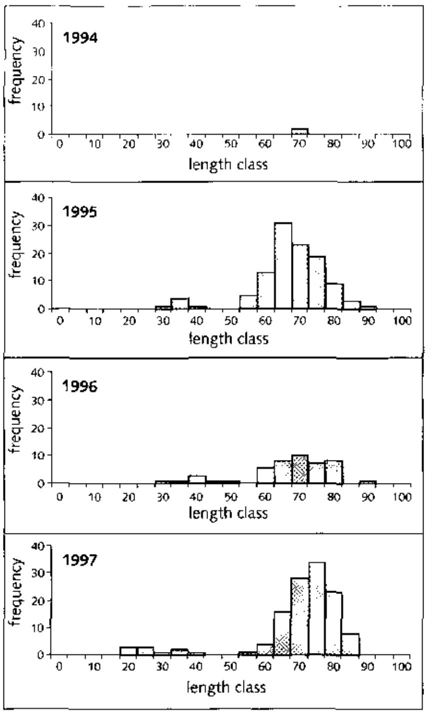


Figure 4.22: Length frequency distribution of reported lamprey.

group ranged in length from 50 to 90 cm with a peak around 70 cm (fig 4.22). This distribution was roughly the same for males and females. It is quite remarkable that females were landed twice as much as males. Maturity of the fish was mostly in a developing stage (females predominantly stage III and IV; males mostly stage III). Comparison with migration patterns of lamprey in Europe reveals that timing and length distribution of all specimens of our catch coincides with upstream migration, which generally takes place during May and early June (Holcík, 1986). Downstream migration of lampreys generally occurs in fall at a length of 12.5 to 15 cm. No specimens with these characteristics were landed in this programme. This could indicate that spawning is unsuccessful or that a different route to sea is followed but it is more likely that these individuals are too small to be caught with the commercial fishing gear in the lake. Distribution of the contributed lampreys is presented in fig 4.23.

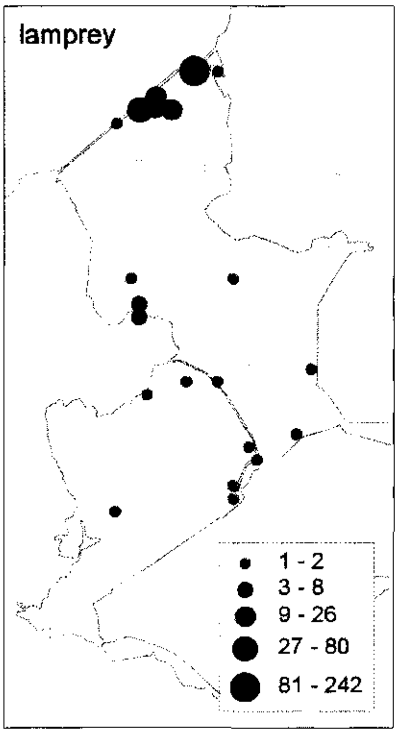
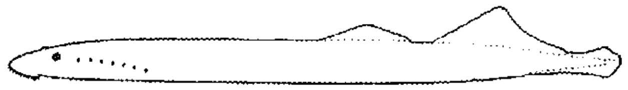


Figure 4.23: Distribution of reported lamprey in lake IJsselmeer and Markermeer.

4.7 Lampern

Sc: *Lampetra fluviatilis*
NL: Rivierprik
F: Lamproie de rivière
D: Flussneunauge



Species characteristics

As lamprey, lampern is an anadromous fish. Maximal length is 50 cm and their sucking disk contains less teeth than that of lamprey. Their life cycle is roughly equal to that of lamprey. Spawning grounds of lamperns are located in middle and upper reaches of the river. Spawning migration takes place in fall. Lampern occurs in coastal waters and river systems in North Western Europe except Iceland. In Europe the population is classified as endangered. Lampern used to be quite common resulting in several fisheries on this species in river systems. Lanzing (1959 in Nijssen & de Groot, 1987) estimated that approximately 250.000 lamperns passed the Meuse near Lith. In the 1960's the abundance of lampern in the Netherlands was significantly reduced caused by physical barriers, destruction of spawning grounds and deteriorating water quality. Since 1980-1990 the number of lamperns increases (fig 4.24). Spawning of lamperns has recently been observed in the catchment area of Rhine and Elbe.

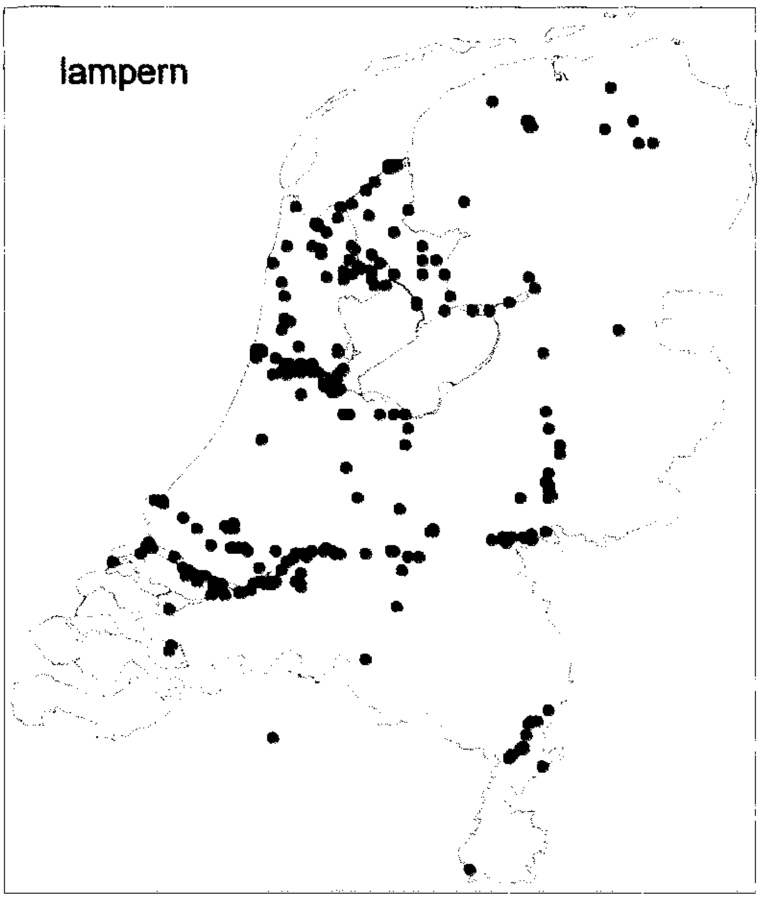


Figure 4.24: Distribution of lampern in the Netherlands (data put at our disposal by de Nie).

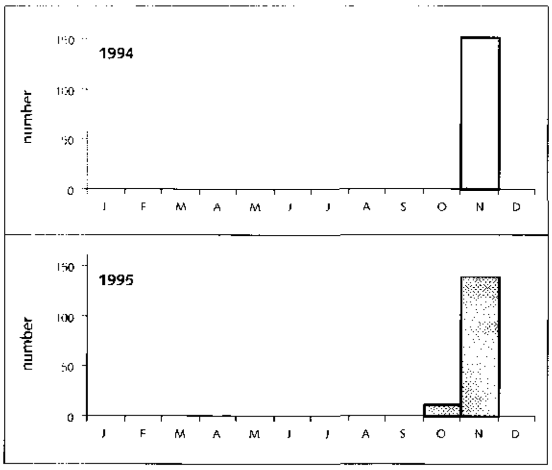


Figure 4.25: Distribution of reported lampern in per month.

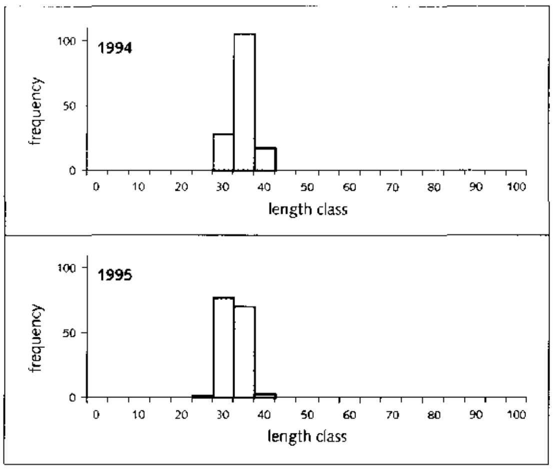


Figure 4.26: Length frequency distribution of reported lampern;

Catches in lake IJsselmeer

In November 1994 and 1995 large numbers of lampern (152 each year) were handed in to the programme on only a few days (fig 4.25). Verbal communication with fishermen revealed that besides these landed individuals more lamperns were caught in other areas of the lake (at least thousands, pers. com. van Willigen). Motivated by cost considerations, lampern was no longer requested. Their occurrence is not as scarce as expected on forehand. The individuals landed were mostly between 35 and 45 cm long (fig 4.26), comparable to the length during upstream migration found in 1959 by Lanzing (in Nijssen & de Groot, 1987). The male-female ratio is approximately 1 with little differences over the size classes. The gonads of all fish were in a developing stage (III (males)or IV (females)) . Distribution of the contributed lampreys is presented in fig 4.27.

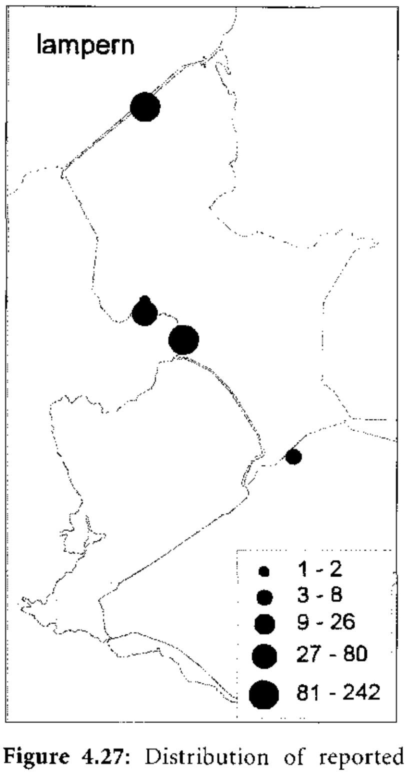
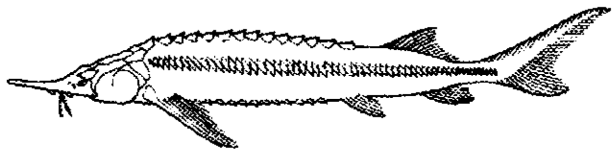


Figure 4.27: Distribution of reported lampern in lake IJsselmeer.

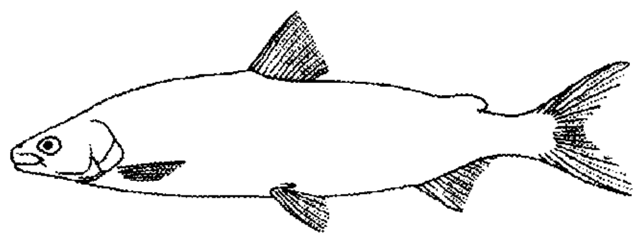
4.8 Other species

Sturgeon



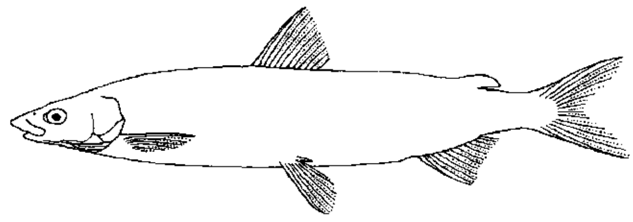
Sturgeon once was found upstream the river Rhine up to Basel. It is now extinct in the Rhine tributary. In the rest of Europe it is classified as endangered, close to extinction. The fish mentioned in this report do **not** belong to the species *Acipenser sturio* but originate most likely from culture. Five individuals were reported: 2 in 1995,1 in 1996 and 2 in 1997 ranging in length from 45 to 82 cm (fig 4.28). Four individuals were male, one was undetermined.

Whitefish



Whitefish *(Coregonus lavaretus)* have an adipose fin and are closely related to the salmonid fishes. Maximal length is 60 cm. Ecological requirements are extremely variable depending on trophic status and accompanying fish species. Whitefish is distributed in the northern part of Europe and alpine lakes. In Europe the population is classified as endangered. Virtually all populations are stocked with fry from hatcheries. In the Netherlands, the North Sea population in the Rhine became extinct in 1940, but the species is still encountered occasionally. Most likely these individuals originate from hatcheries in Germany or Switzerland. In this programme 21 whitefish were contributed: 1 in 1995, 1 in 1996 and 20 in 1997 (fig 4.28). Most fish were caught in fykes in the north-eastern part of the lake. The length ranges 15 to 32 cm. Landing took place from May until the beginning of July.

Houting



Houting *(Coregonus oxyrhynchus)* is much alike whitefish but has a long fleshy snout and a more slender body. Maximal length is 50 cm. It is a migratory species ascending rivers to spawn, usually in November and December. The anadromous population in the Netherlands may be considered as extinct since the 1940's. The decline was caused by increased pollution of estuaries, loss of spawning grounds, overfishing, heavy traffic and physical barriers. From the beginning of this century to the 1940's stocking of houting took place in the Netherlands and other European countries, without much success. The houting population in Europe is classified as endangered. Recently (from 1987 to 1992) young houtings have been stocked in Denmark (Ejby-Ernst & Knudsen, 1998). This stocking was combined with restoration of spawning grounds and improvement of upstream migration routes and water quality. In the Netherlands this species is seldomly encountered.
In this programme 5 individuals were delivered: 1 in 1996 and 4 in 1997 (fig 4.28). The individuals ranged in length from 17 to 29 cm and were caught in large fykes close to the Afsluitdijk and one just north of Marken. These individual caught in 1996 was caught in September, the individuals in 1997 in July. De Groot & Nijssen (1997) conclude that these houtings undoubtedly originate from the stocking programmes in Denmark.

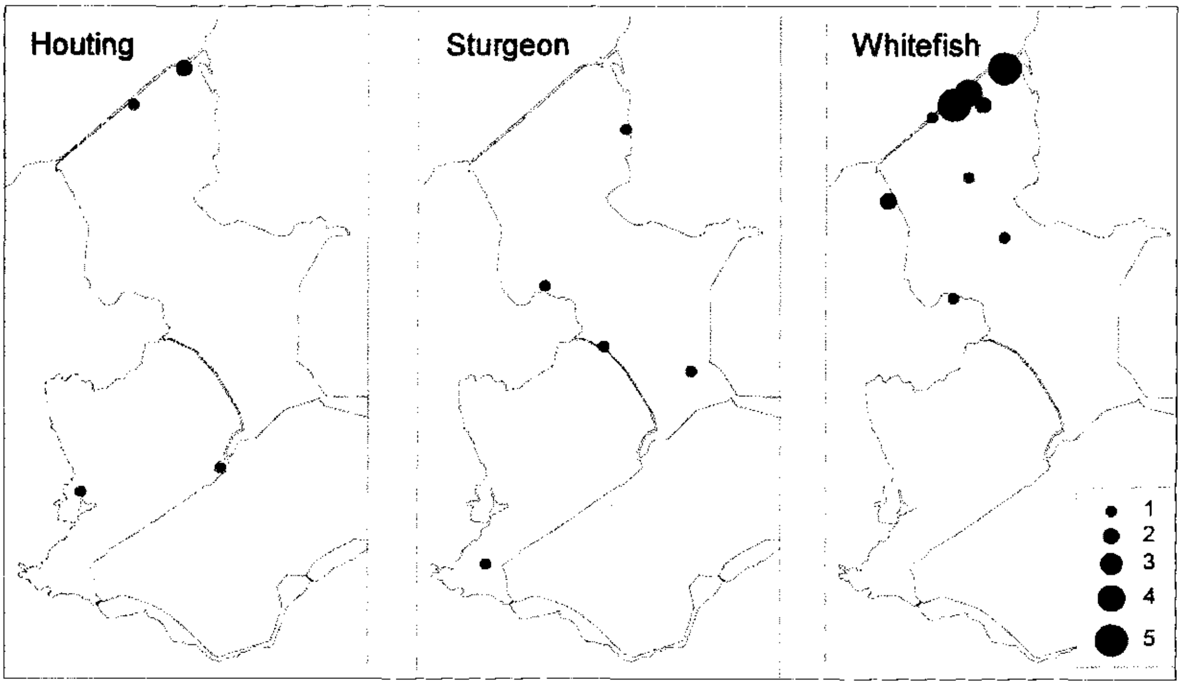


Figure 4.28: Distribution of reported sturgeon, whitefish and houting in lake IJsselmeer and Markermeer.

5 The origin of salmon and trout in IJsselmeer

The origin of salmonids in lake IJsselmeer is important to assess because it provides information on the function of the lake for the populations. Once this is known specific management strategies could be determined in order to support the populations. For the sea trout and salmon caught in lake IJsselmeer the following hypotheses of their origin can be formulated (fig 5.1):

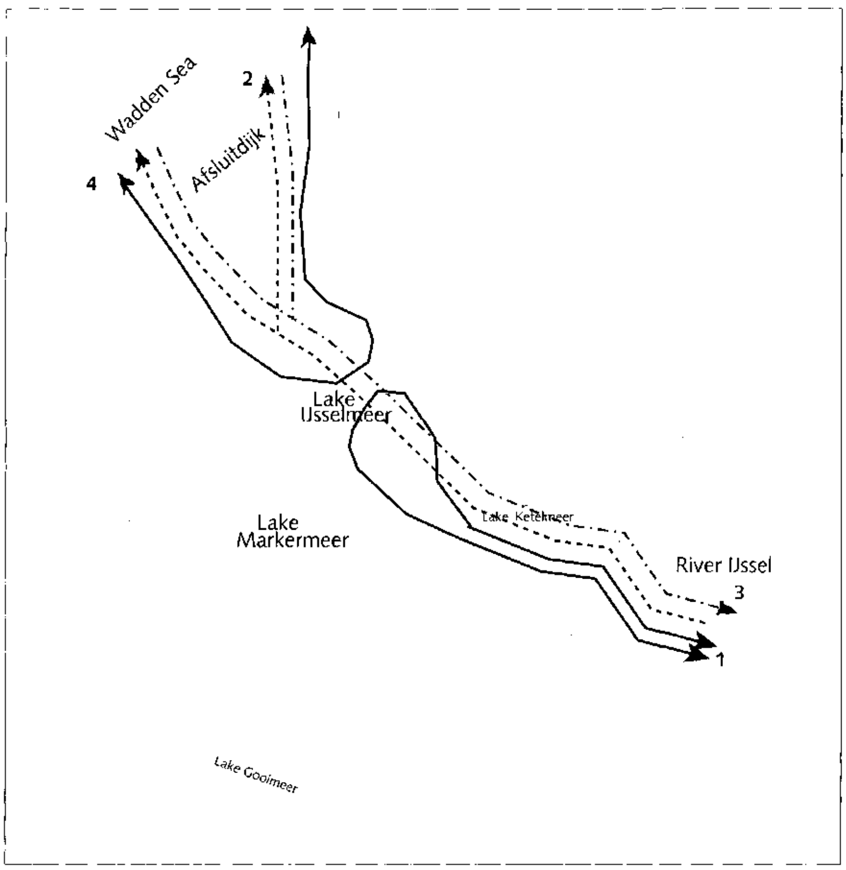


Figure 5.1: Possible migration routes for salmonids in lake IJsselmeer. We do not consider that the whole life cycle is completed within the lake. For explanation of the various routes, see chapter 5.

1) Juvenile salmonids originating from upstream areas enter lake IJsselmeer and stay in the lake. Adult salmonids migrate from the lake via the river IJssel to upstream areas of the river Rhine in order to spawn.
2) Juvenile salmonids originating from upstream areas of the river Rhine migrate towards the sea, amongst other routes, via lake IJsselmeer.
3) Adults originating from the Rhine or other river systems enter the lake via the sluices in the Afsluitdijk and move upstream towards the spawning grounds.
4) Juvenile and adult salmonids originating from nearby estuaries enter lake IJsselmeer after a period at sea. After some time in the lake they move back to sea.
5) Aberrant behaviour of stocked individuals.

Most hypotheses are possible for salmon and sea trout, although salmon exhibits stronger homing behaviour than sea trout. Sea trout is known to stay near the coastal zone than salmon and also uses estuaries as foraging area (hypothesis 4).
In this chapter, an effort will be made to decern between these hypotheses on the basis of chemical analysis of tissue of the salmonids (§ 5.1) and on biological information of the catches e.g. timing, length frequency distribution and stomach contents (§ 5.2).

5.1 Chemical analysis.

Mous and Luten (1995) explored the potentials of detecting substances in fish indicating a time spent in a marine environment. De Groot (1989b) proposed specific marine oils in the fatty tissue. Fatty acid composition of lipids in the tissue of a fish is dependent of the composition of its diet. Fish can also synthesise fatty acids, but this is a species specific process. Although freshwater fish are capable of synthesising poly-unsaturated fatty acids, lipids in marine fish contain a higher amount of these acids since these occur more frequently in their food than in the food of fish living in a freshwater environment. In their literature study Mous and Luten (1995) used published data on the fatty acid composition of 23 freshwater and marine species. Although a difference in fatty acid composition was observed for freshwater and marine fish no distinct threshold value could be established for each group. Therefore the method did not seem very promising as a tool to discriminate between freshwater and marine fish. Furthermore, Sheridan et al. (1985) found that changes in the fatty acid composition in steelhead trout occurred during smoltification before actually entering a marine environment. If this is the case for salmon and sea trout as well, the fatty acid composition cannot help elucidating the origin of the salmonids in lake IJsselmeer.

Secondly the possibility to determine strontium (Sr) content in scales of salmonids was explored by Mous & Luten (1995). Some authors (Kalish and Rieman et al. in Mous & Luten, 1995) used the ratio between Sr and Ca in otoliths of salmonids to obtain information on freshwater or marine presence in relation to the Sr/Ca concentrations in the water. Several scales of trout from various Dutch freshwater systems have been analysed. In all cases the Sr concentration was higher than the threshold level. Even fish less than 20 cm, expected to spent no or just a short time in a marine environment, revealed Sr levels above the threshold for marine environments. As with the fatty acid composition this method did not seem very promising as a tool to discriminate between freshwater and marine fish.

The third candidate for discrimination of the origin of salmonids might be the trimethylamine oxide (TMAO). TMAO occurs in the body tissue of marine fish, executing a function in the osmo-regulation (Regenstein et al, 1982). When migrating from salt to freshwater the TMAO concentration drops from 2.9-13.3 mmol/100 g bodytissue in salt water to nearly zero in freshwater conditions (Regenstein et al, 1982). It is not known how fast this transformation process takes place (Mous & Luten, 1995).

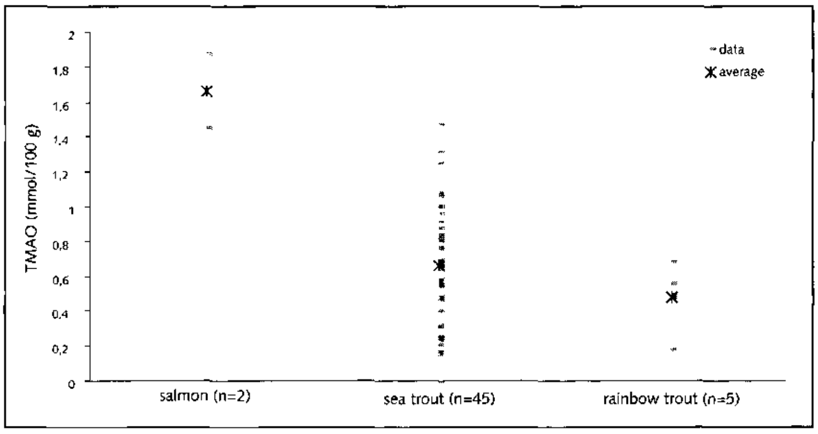


Figure 5.2: TMAO Concentrations of salmon (n=2), sea trout (n=45) and rainbowtrout (n=5).

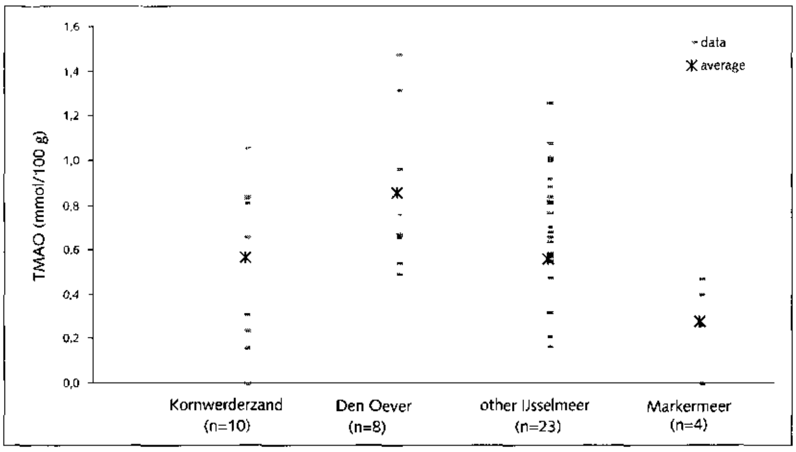


Figure 5.3: *TMAO concentrations of sea trout caught at various locations in lake IJsselmeer*

The TMAO content of salmon (2), rainbowtrout (5) and sea trout (45) caught from September 1994 to April 1995 was assessed (Mous et al.,1995). The TMAO concentration varied from 0 to 1.9 mmol/100 g bodytissue. Analysis of variance revealed that the TMAO concentration in salmon was significantly higher ($p \leq 0.05$) than in rainbowtrout or sea trout (fig 5.2). Sea trout caught near Den Oever contained the highest TMAO concentrations (fig 5.3). Sea trout caught in lake Markermeer had a TMAO concentration which was significant lower than in trout caught at Den Oever (Student-Newman-Keuls, $p \leq 0.01$).

All TMAO concentrations were lower than values obtained for marine fish, indicating that no individual was caught directly after entrance in the lake. The concentrations were however higher than concentrations in fresh water salmonids (Hebard, et al., 1982), which could indicate fish had spent time at sea. The TMAO concentrations in salmon were significantly higher than in sea trout and rainbowtrout. According to McDowall (1988) salmon interrupts the migration less frequently than sea trout. This could corroborate the observation of the higher TMAO content in salmon compared to the concentration in sea trout. The measurements, however, are based on only two observations of salmon (both large females). In sea trout samples, average TMAO concentrations were approximately equal to those of rainbow trout. Sea trout caught close to the Afsluitdijk revealed higher TMAO concentrations than the fish caught in lake Markermeer. This could indicate that sea trout caught in lake Markermeer spent more time in fresh water resulting in a further degradation of TMAO. Based on these results Mous et al. (1995) concluded that there is a strong indication that almost all individuals have been migrating from salt to freshwater.
However, Ruiter (1971) reported TMAO contents in river trout of 1 mmol/100 g. tissue, close to values found in much of the sea trout and rainbow trout samples. Based on its behaviour, it is not necessary for rainbow trout to spent time at sea. Therefore these TMAO concentrations of sea trout and rainbow trout indicate by no means strong marine influence.
The information from the TMAO analysis provided inconclusive information. Further evidence could be obtained by analysing degradation of TMAO and assess TMAO concentrations in freshwater IJsselmeer species. This is essential for a proper evaluation of the concentrations found in the salmonids. Further chemical analysis to the origin of salmonids should include fish caught in all seasons of the year since upstream migration of adults and downstream migration of smolts occurs at different times. In this analysis mainly large individuals ($\approx$ 40 cm) were analysed caught in a period which coincides with upstream migration.

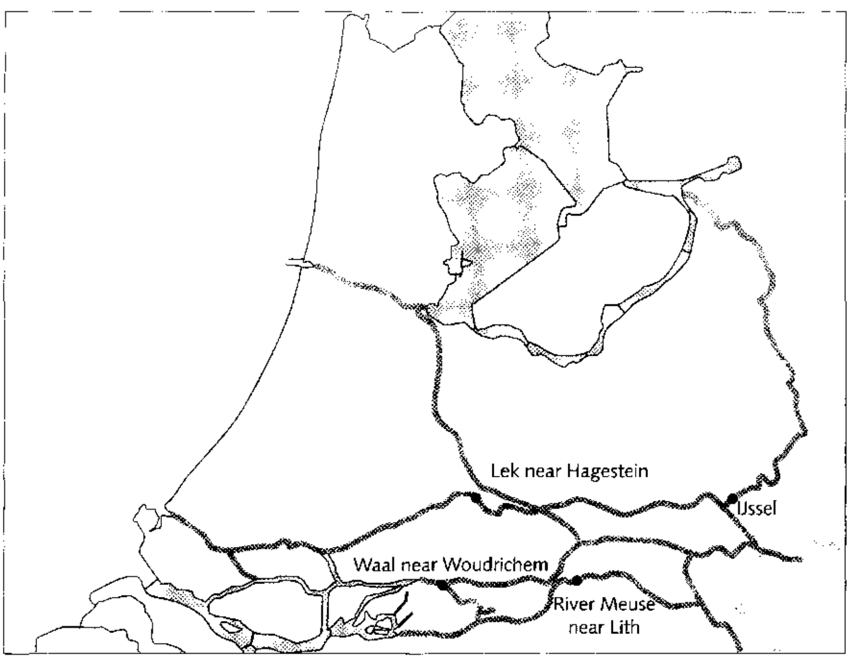


Figure 5.4: Locations of stow nets in the Netherlands are: Lek, Waal, IJssel and River Meuse.

5.2 Biological analysis

In order to discriminate between the different hypotheses regarding the origin of salmon and sea trout catch statistics will be compared with biological behaviour of salmonids. Catches in lake IJsselmeer will be compared with historical catch statistics in the Netherlands and current salmonid research in other parts of the Netherlands.

Sea trout

De Groot (1989b) analysed historical data showing that sea trout has always been present in the catch statistics of the past century, but in relatively low numbers. It is, however, difficult to compare catch statistics of different periods because large differences in e.g. effort or gear type have occurred. Another possibility is naming sea trout as salmon at auctions, and selling brown trout variety as trout. Furthermore, officials noted, as early as 1920, many sea trout were not sold at market and therefore not included in catch statistics (de Groot, 1989b). Catches of sea trout landed at Kralingse Veer (near Rotterdam, the largest outflow of the Rhine) between 1886 and 1891 averaged 594 per annum at an average length of 50 cm. Throughout the year small numbers were caught with a peak from August to October. Catches from 1919 indicate a shift in the period over which the highest trout catches were recorded to the period September to November, with an additional peak in May. The present data in lake IJsselmeer reveal a peak in the catches of the larger cohort of sea trout in May. In the Dutch part of the rivers Meuse, Lek, Waal and IJssel (fig 5.4) large salmonids are caught with stow nets during two six-week periods in June/July and in October/November (e.g. de Jong & Cazemier ,1997; Cazemier & de Jong, 1998 and Hartgers et al.,1998). The catches of sea trout in stow-nets from 1995 to 1997 are comparable with the catches in lake IJsselmeer with respect to length and timing (fig 5.5). Male sea trout in a gravid or spawning stage were found in lake IJsselmeer from September to

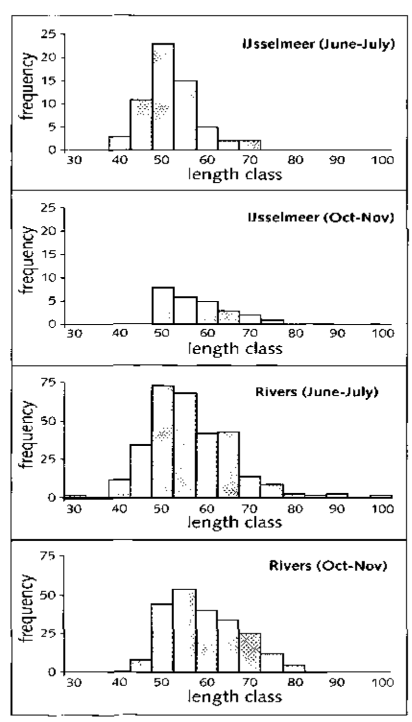


Figure 5.5: Catches of sea trout in stow nets in Dutch rivers in two six-week periods in June and October-November from 1995 to 1997 and contributions in lake IJsselmeer in comparable periods of 1994 - 1997

December, females from August until May. Gravid or spawning individuals caught in fall could be just in time for an upstream migration to the spawning grounds, individuals in May perhaps were too late in finding a suitable upstream passage way. The majority of the larger sea trout occurred year round and were in a developing maturity stage. This might imply upstream migration takes place from May to January and maturation takes place further upstream. On the other hand these fish could also perform a dummy run and only go a little upstream the river before returning to the sea. TMAO analysis did not definitely prove that larger sea trout originates from sea (section 5.1). However the fact that larger sea trout are also caught in river systems in the Netherlands, that sea trout tagged in front of the Dutch coast migrate upstream (Breukelaar et al., 1998) and that spawning of sea trout has been observed in a branch of the river Rhine (river Sieg: Ingendahl & Marmulla, 1996), strongly suggests the population contains a proportion of migratory trout. At this point it is impossible to assess whether all larger sea trout originate from sea going populations or originate from upstream stocking operations. The latter results in resident freshwater populations migrating to the tributary of the river. It is also unclear whether these fish migrate upstream in order to spawn or merely perform dummy runs or use the lake as foraging area.

Smolts migrate seaward in Dutch rivers, at a length of 17 to 20 cm. After 1,2,3 and 4 years at sea, a length of 30-40 cm, 50-60 cm, 60-70 cm and 70-80 cm respectively will have been attained (de Groot, 1989b). The length and appearance of trout varies considerably. In lake IJsselmeer almost no individuals from 17-20 cm have been collected. The youngest cohort consists of fish growing from 20 cm in May up to 40 cm in December. This might indicate that the young trout stay in freshwater for 1 to 3 years before migrating to sea. On the other hand, it might also be possible that these young fish originate from other river systems, e.g. in Denmark. Having smolted at a length of 17 to 20 cm they could stray the next season into the Waddensea, into lake IJsselmeer, to perform a dummy run or use the lake as foraging area. The observation of some smaller trout with marine prey could corroborate this hypothesis. Sea trout caught in June and July 1990 in the coastal area close to the lower part of the river Rhine (Haringvliet estuary) measured 20 to 35 cm (Cazemier , 1991). This is comparable to catches in lake IJsselmeer. Assuming a growth of the younger cohort in lake IJsselmeer ranging from 20 to 40 cm over one year this could hardly be explained as growth in upstream areas. More likely, catches originate from a population roaming coastal waters.

Conclusion

The younger cohort of sea trout found in lake IJsselmeer either originates from upstream areas and migrate to sea after spending more than a year in freshwater or enter lake IJsselmeer from the Waddensea. The fast growth observed through the year and the fact that sea trout with comparable length was found in the coastal area close to the river Rhine (Cazemier, 1991) makes it more probable younger sea trout migrate into the lake from the Waddensea. It is unclear whether these fish originate from the Rhine tributary or from other rivers. For the larger cohort caught in lake IJsselmeer it is quite likely that many enter the lake via the Waddensea although the existence of resident freshwater populations cannot be ruled out completely. It is unknown whether all individuals entering the lake from the sea perform further upstream migration towards spawning areas or stay in the lake to return to the sea, since they all ended in our freezers.

Salmon

The migratory behaviour of salmon is much like sea trout although resident freshwater populations are rare for salmon. Homing to their specific spawning grounds takes place, as is not always the case for sea trout. Spawning takes place in November/December. During the first one or two years of life, salmon generally remain close to their spawning grounds. After one year parr is 10-15 cm long. Two year old smolts leave the river in May and June entering the sea at about 13-16 cm, while three year old smolts may be 13 to 20 cm long. In lake IJsselmeer the smaller fish (15 to 25 cm) occur in May (fig 5.6). It is most likely that these originate from upstream regions of the Rhine where they possibly were stocked.

From 1903 until 1920 the landing of salmon consisted approximately of 10% grilse, 40% small summer salmon and 40% of large winter and summer salmon. Data on monthly supply of salmon between 1911 and 1918 revealed most fish were landed from March until August (de Groot, 1989a). In catches of lake IJsselmeer larger salmon range in length from 50 to 95 cm. They are predominantly found in September and October (fig 5.7). Salmon caught in the stow-net fisheries in the Dutch rivers have a comparable length distribution to the catches in lake IJsselmeer. Salmon were caught in comparable quantities in the rivers in June-July as in October-November. In IJsselmeer, however, only one large salmon was encountered in July (fig 5.7). Based on the period of the year in which the catches of large salmon in lake IJsselmeer were made these could be winter salmon although they are rather small in size compared to the historical catches of winter salmon (103-115 cm).

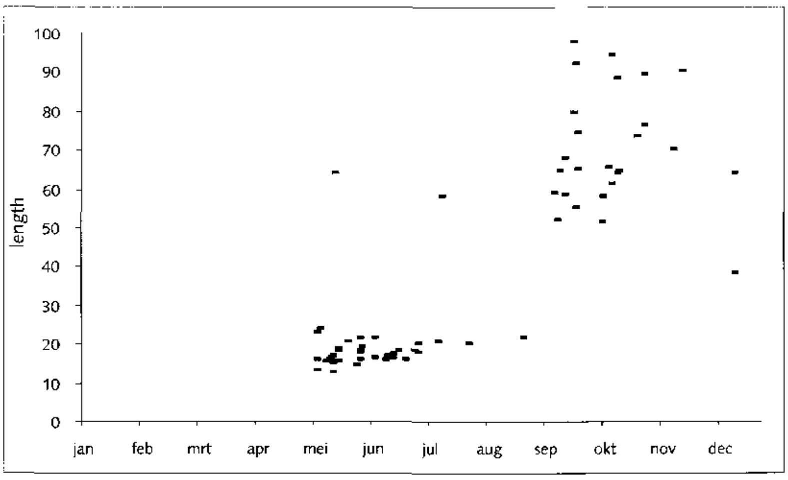


Figure 5.6: Length distribution of reported salmon as a function of date, catches from 1994 to 1997 have been summed

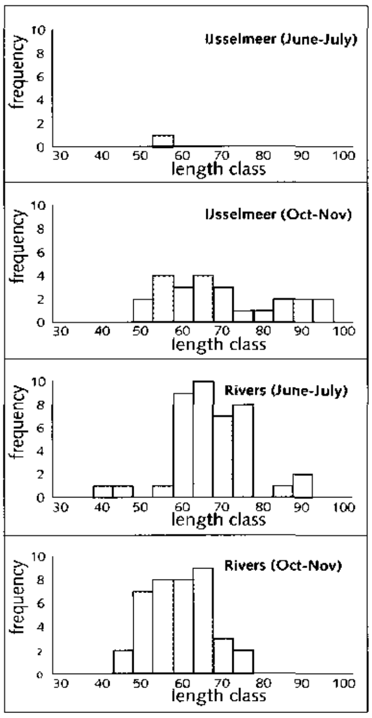


Figure 5.7: Catches of salmon in stow nets in Dutch rivers in two six-weeks periods in June-July and October-November from 1995 to 1997 and contributions in Lake IJsselmeer in comparable periods of 1994-1997.

Conclusion

The smaller salmon (15 to 25 cm) encountered in lake IJsselmeer occur in May. Most likely these originate from upstream regions of the Rhine probably being stocked. Larger salmon were reported in September October, a period which coincides with upstream migration of winter salmon to the spawning grounds. For salmon the number of individuals is too small to draw more detailed conclusions.

6 Catches

6.1 Introduction

In this chapter the migratory fish programme is reviewed. In this section the obtained biological information will be evaluated with respect to the functioning of the lake. In section 6.2 implications of using commercial catch as a source of information are mentioned and section 6.3 explores the reliability and effectiveness of the programme based on statistical analysis.

The number of fish in this programme is ≈ 2000 in three years, which is only a small fraction of the total number of fish in the lake. Assuming that a considerable amount of these rare, migratory fish has been caught because of the high fishing pressure on commercial stocks in the lake, this number is so low that it is impossible to play an important role in the functioning of the ecosystem of the lake. The presence of these fish can be seen as an indication of the suitability of the area for migratory fish combined with the water quality. The fact that only 4% of the catches of sea trout have been found in lake Markermeer most likely indicates that the dyke between the two lakes is a serious barrier for the fish to overcome.

The fish fauna in lake IJsselmeer (partly mentioned in table 4.1) falls apart into 6 categories:

1) *Freshwater species* with a resident population in the lake: pikeperch, perch, ruffe, roach, bream, smelt, ide.
2) *Freshwater species* without a resident population in the lake. These individuals came in the lake by coincidence. This group encloses asp, barbel, tench, wels and burbot, .
3) *Marine species*, which enter freshwater occasionally. Presence in freshwater is , however, not essential to complete their life cycle. Sea-bass and the thick-lipped grey mullet are representatives of this group.
4) *Exotic species*, only occurring in Dutch waters by means of stocking. The sturgeon and the rainbow trout can be mentioned in this group.
5) *Anadromous species*, which enter freshwater in order to spawn. The species discussed in chapter 4.2 up to 4.7 belong to this group with the exception of rainbow trout and sturgeon.
6) *Catadromous species*, spawning in marine water: eel and flounder.

With respect to more abundant anadromous fish the programme revealed information on the population dynamics and the importance of lake IJsselmeer for their life cycle. For all species discussed in section 4.2 to 4.7 information regarding abundance, timing, length frequency distribution etc. has been obtained. Before starting with this programme only fragmentary information on these species was present. More complex questions dealing with quantitative population dynamics of the total stock of migratory fish remain unresolved at the moment, because the number of observations was too low for quantitative analysis.
Lampern and lamprey, which were both caught in reasonable numbers are more frequently found than was expected beforehand. They are found at several places in the North Sea, but spawning grounds in the Rhine tributary are seldomly encountered. However, adult lampern and lamprey in their migrational and reproductive periods were observed in the northern Upper Rhine (Weibel, 1991). Young lamperns were also observed in the Rhine. Timing and length of the larger lamperns and lampreys caught in lake IJsselmeer also largely coincides with natural spawning behaviour.
For salmon, which was caught in small numbers, many questions with respect to their origin and population dynamics remain unresolved (chapter 5). Although for sea trout more data were available it is still unclear where they originate from and what the significance of their stay in lake IJsselmeer is. The fact that numerous stocking procedures take place complicates even more. Stock identity of these salmonids could thus not be resolved. Genetic analysis of the different populations in Europe and of stocked fish could help to unravel population dynamics of sea trout further.

6.2 Commercial catch

This report deals with analysis of voluntary contributions by commercial fishermen. The success of the programme critically hinges on good co-operation of fishermen. Without that, no information on these rare species could have been obtained. To assess the chance of catching a sea trout the following calculation was made on the basis of rough estimates. There are approximately one billion fish in lake IJsselmeer. In the past years more than 1000 sea trout were landed. The chance that a catch is indeed a sea trout is therefore roughly one in a million. In routine surveys on lake IJsselmeer approximately 200.000 fish are caught annually. Since one in a million of these fish is a sea trout only 0.2 individuals per year are expected to be found in these large scale routine surveys. In the past 10 years 3 sea trout have been reported in routine survey, on average 0.3 per year. Thus routine sampling is not unsuitable to collect these species, but simply cannot achieve an effort large enough. Substantial effort can only be obtained by commercial fisheries, at the price of loss of detail, especially details of all non-successful events. Additionally, there can be considerable uncertainty to what extent fishermen co-operate. Personal communication suggests that most fishermen report all their rare fish. However, it is known that some of the larger salmon and sea trout are sometimes taken for personal use. Political issues with respect to other topics in fisheries management in the lake could have created a hostile attitude towards the research institute. The general impression was, however, a positive attitude and a willingness to co-operate.

Other drawbacks of using the commercial fleet to obtain information could be that no lake wide representative sampling can take place, that different gears are used in various periods, and therefore catchability might differ. Fyke nets have a disproportionate share in the observations (fig 6.1). Besides fyke nets, a small portion is caught in gill nets or summer fykes. The closed season for fyke

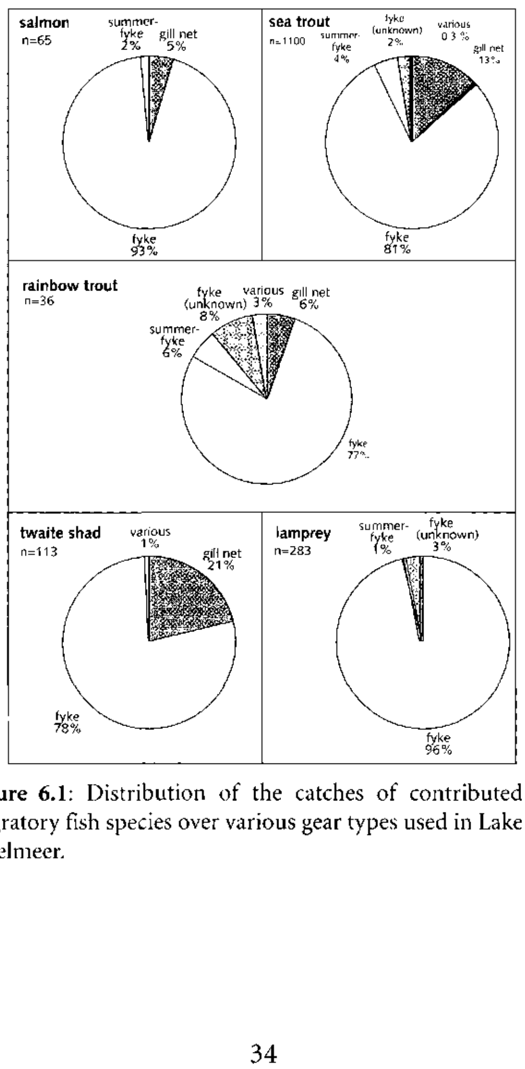


Figure 6.1: Distribution of the catches of contributed migratory fish species over various gear types used in Lake IJsselmeer.

nets (from December to April) resulted in neglectable contribution to this programme during this period. This is a serious problem when interpreting the data and formulate hypotheses on population dynamics because virtually no information can be obtained from January to April, a period in which e.g. downward migration of salmonids could occur.

Finally some notes on the damage of commercial fishery to migratory fish populations. Overfishing in the lake for many years (Dekker, 1991) will have removed a significant part of the salmonids entering the lake. Optimisation of the eel fisheries by reduction of fishing effort will, as a side effect, also lower the number of salmonids in the bycatch.

6.3 Co-operation of commercial fishermen.

Dekker & van Willigen (1997) analysed the reliability of a programme based on voluntary co-operation of the fisherman by means of a statistical model. In this section a brief summary of the model and its findings will be presented. The basis of the model is the fact that co-operation of individual companies is based on two factors: 1) the number of fish caught by a fisherman for the programme and 2) the willingness of this fisherman to co-operate in the programme.

The BP model

The model consists of two submodels:
B-submodel: describes the willingness of individual companies to co-operate in the programme. Starting point is a binomial distribution indicating that a fisherman is either participating or not at all. It will be evident that fishermen without a catch do not deliver any fish, regardless of their willingness. Fishermen who contribute only part of their catch (e.g. only small trout) cannot be discerned in the model and will distort the results.
P-submodel: describes the number of fish caught by an individual company in a certain period. A Poisson distribution is used to describe the catch. An assumption for this model is that willingness of a company to contribute to the programme is known. It is impossible to discern fishermen who were willing but did not catch rare fishes from fishermen who were not willing and might or might not have caught rare fishes. By only including data from companies who did contribute their catches, an analysis of the total catch was possible. The number of fishing gear used by each company was used as an offset variable, assuming a linear relationship between the fishing effort and the catches.

To run the B-submodel, the amount of fish caught by each company must be known. The P-submodel, on the other hand, can only be run if the willingness of a company to contribute to the programme is known. However, the B-submodel results in a prediction of the willingness for all fishermen, regardless of their contributions, while the P-submodel predicts the number caught for all companies, irrespective of their willingness. Combining both submodels results in one model in which each submodel provides information for the other, like a snake eating its own tail. The overall model was applied to the catches of salmon, trout and rainbow trout combined landed in 1995 and 1996.

Results

In the P-submodel the following effects on the catches were analysed: year, quarter, harbour of the reporting vessel, number and type of fishing gear. An analysis of variance shows 75% of the variance could be explained by the full model. Significant factors were: the type of fishing gear combined with quarter (40%) and the harbour of the reporting vessel (32%). The effect of year was significant but explained only 4% of the variance. Most salmonids are landed by ships from Makkum and to a lesser extent by ships from Enkhuizen. Estimates from the catches from Urk show a wide confidence interval. Most salmonids are caught in large fyke nets.

In the B-submodel the following effects on the willingness to co-operate to the programme were analysed: year, quarter, harbour, number and type of fishing gear and the logarithm of the expected catch (derived from the P-model). The latter factor was included to model the potential effect, that fishermen do not take the effort to report small numbers while the premium for large numbers makes the effort worthwhile. This submodel explains only 18% of the total variance. The most important factor (9%) is (the expected) catch of salmonids. A small fraction can be explained by the harbour (2%) and the quarter (1%). The willingness to co-operate varies over the harbours . Fishermen from Urk contribute relatively little. The willingness is high in Makkum and to a lesser extent in Enkhuizen, which is in accordance with the large number of landings. Despite the small number of fish per contribution Volendam co-operated remarkably well. Over and over one or two trout were deposited in the freezers in Volendam. The willingness to co-operate is high in wintertime and low in early spring and summer. This might be explained by the high workload for the fishermen during summer.

The BP model also results in an estimate of the number of salmonids caught in 1995 and 1996 that were not reported. The model estimated the total catch comprised 1049 individuals of which 764 were actually contributed (72%). The system of voluntary contribution for a premium apparently is a remarkably successful and reliable tool to obtain information that could not have been obtained in more traditional ways of sampling fish.

7 Conclusions

- The scope of the research programme starting in fall 1994 was to assess the number and species composition of rare migratory fish in lake IJsselmeer. Involving commercial fishermen to obtain information of these species, based on voluntary contribution combined with a premium per fish, has proven successful. Apart from the quantitative information obtained, the programme has been used for reliable qualitative information. Statistical analysis revealed that 72% of the salmonids caught as bycatch were actually contributed to the programme, resulting in an estimated total catch from 1994 to 1997 of 1500 sea trout and 90 salmon.

- Most deliveries originated from fykenet catches. This limits the programme: during closed seasons no information could be obtained.

- Lake IJsselmeer might still serve as a connection between North Sea and river Rhine for a number of species. Observations of lampern and lamprey for instance, showed timing and length frequency coincide with upstream migration patterns. To what extent migratory fish caught in lake IJsselmeer contribute to the total population of the Rhine tributary is uncertain.

- Regarding sea trout and salmon many questions with respect to population dynamics and origin of the fish are unresolved. Chemical analysis of fatty acid composition and strontium content of scales were inconclusive but the analysis of TMAO concentration gave an indication of a marine origin.

- The cohort of sea trout of smaller length either originates from upstream areas or from the Waddensea. Their fast growth indicates the latter to be the most probable. The cohort of larger fish most likely enters the lake from the Waddensea. Further upstream migration towards spawning areas might be possible. Immigration of immature sea trout (71% of all individuals) must be considered as straying behaviour.

- Smaller salmon (15-25 cm, occurring in May) probably originate from upstream regions of the Rhine where they might have been stocked. Immigration of larger salmon reported later (September and October) coincide with upstream migration behaviour of winter salmon to the spawning grounds reported in literature. The number of individuals is, however, rather small.

- The restoration of the river Rhine has been successfully pursued. Local problems in the restoration of salmonid stocks have been solved. So far, however, the coherence of the restoration efforts throughout the catchment area is rather low. Quantitative evaluation, as obtained in the programme described in this report, is crucial to the evaluation of the restoration efforts.

Acknowledgements

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