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Dynamics of European smelt (Osmerus eperlanus L.) in Lake IJsselmeer during the 1992 spawning period

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Contents

SUMMARY

In 1992 the sampling program of the commercial smelt catches during the spawning season in Lake IJsselmeer was extended with a trawl survey. This survey was designed to sample the area between the open water and the spawning grounds at the shore. The smelt population and catches of the commercial fishery are dominated by the 1 year old animals (approximate 96% of total catch number). The mean length of smelt was a fraction higher in the commercial fishery then in the survey.

Males stay longer at the spawning grounds then the females do and have a higher chance to be caught in the commercial fishery. Because only very few spent animals (males and females) were caught during the spawning season it seems that females can spawn several times.

At one location catch numbers were related with distance to the shore. The spawning activities take place within 1000 metres from the shore.

1. INTRODUCTION

European smelt (*Osmerus eperlanus*), later referred to in this paper as smelt, has a central role in the foodweb of Lake IJsselmeer. Smelt is the largest consumer of zooplankton and serves itself as the main prey-species for piscivorous fish and birds (Buijse et. al., 1991). Since 1980 a commercial fishery developed at the spawning grounds. During 4 to 5 weeks in March and April, fykenets are placed along the shore to catch spawning smelt. The landings of this fishery averaged 8-15 $kg.ha^{-1}$ between 1982 and 1991 (see fig 1.1). Because of the low commercial value of smelt little research has been done on this species in the past. However the policy of an integrated management of fisheries, fish stocks and birds necessitates the understanding of the dynamics of the smelt-population.

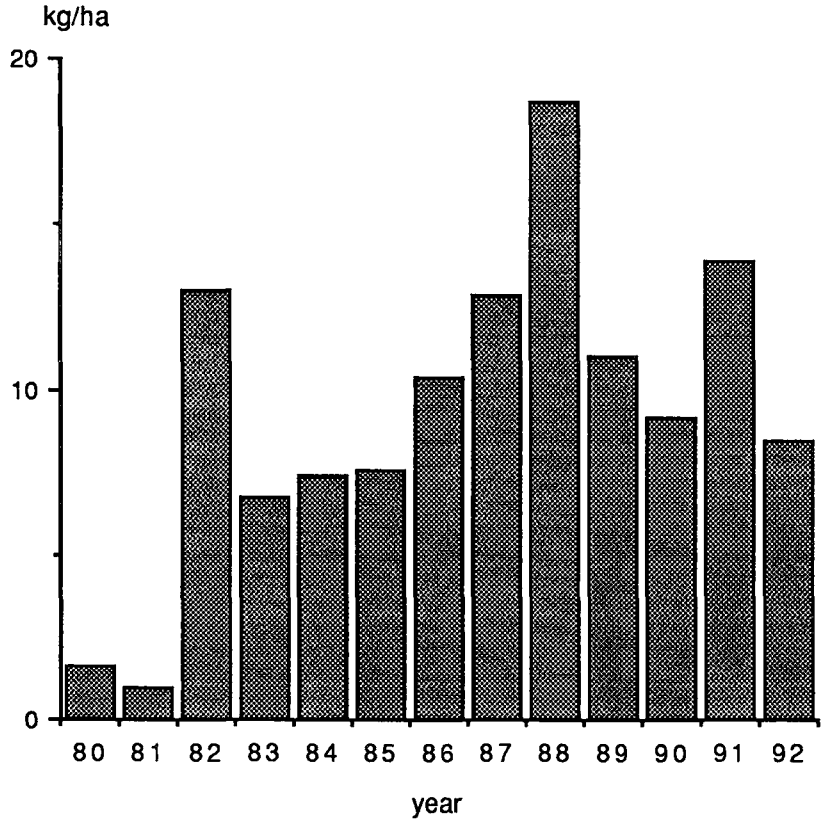

Figure 1.1 Annual catch of smelt by the commercial fishery in Lake IJsselmeer between 1980 and 1992.

In 1988 the Netherlands Institute for Fisheries Research (RIVO), started monitoring the commercial smelt catches. Schaap (1990) and Janss (1992) found a similar development of the catch composition between 1988 and 1991. The catch is totally dominated by the 1+ group, but at the start of the spawning season older age-groups are present in high numbers. Schaap (1990) and Janss (1992) suggest that these older age groups represent migrating smelt from the Waddenzee. Gillraker counts, a method to distinguish sub-populations (Belyanina, 1969; Nellbring, 1989), gave no solution for this hypothesis (van der Schaft, 1984). It is possible that a

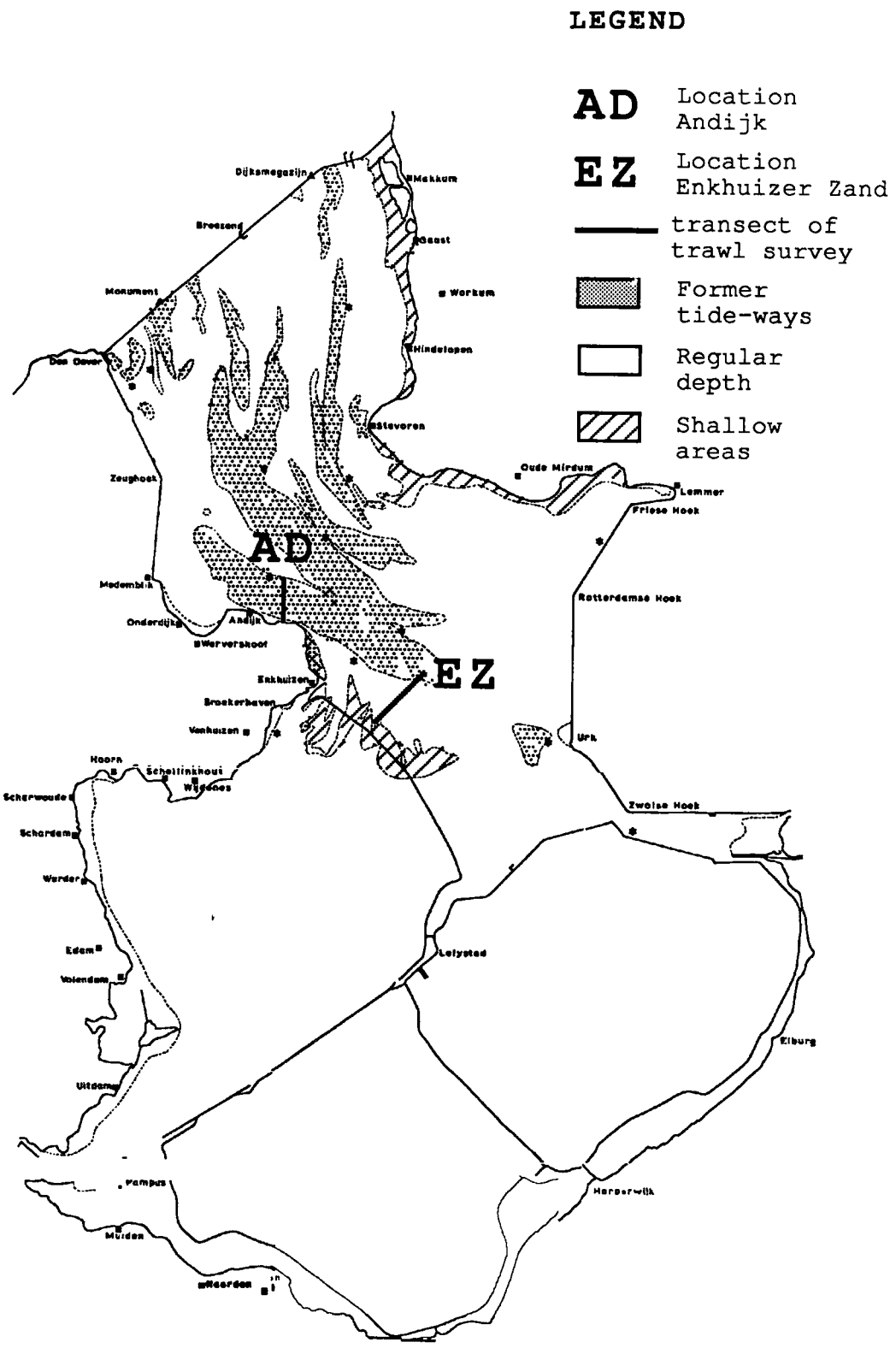

Figure 1.2 Lake IJsselmeer and the position of the transects at location AD and EZ.

part of the smelt population in the IJsselmeer does not invest in gonad development but in growth, the so-called survivors (van der Schaft, 1984).
Males are always more abundant in the commercial catches then females because males are able to spawn several nights whereas females usually spawn only during one night (Belyanina, 1969). The declining maturity of the females in the commercial catches found by Janss (1992) was contradicting with this theory.

In 1992 the sampling program of the commercial fishery was extended with a trawl-survey in the IJsselmeer-district during the spawning season. The trawl survey was set up to sample the area between the spawning grounds (shallow areas) at the shore up to the open water region, fig 1.3. The aim of this design is to examine the dynamics of the smelt population during the spawning season. Extra attention is paid to the following questions:

- Does the population structure of smelt in Lake IJsselmeer change due to spawning activities and fishery mortality?
- Does smelt show a typical spatial distribution (with respect to distance to spawning grounds) during the spawning season?
- Is there a part of the smelt population not investing in gonadal development?

Small scale experiments in order to detect an useful substrate for collecting eggs at the spawning grounds and the hatching of hand-incubated eggs in the laboratory are described in additional chapters of this paper.

2. STUDY AREA

Lake IJsselmeer is a 182,000 ha eutrophic lake. It is divided into a northern basin (112,000 ha) and a southern basin (70,000 ha) by the construction of a dyke in 1975 (fig. 1.2). The northern part has an average depth of 4.5 meter. The commercial fishery in both lakes consists of a fishery with fykenets on eel (*Anquilla anquilla*) during the summer-period, a gillnet fishery for pikeperch (*Stizostedion lucioperca*) and perch (*Perca fluviatilis*) during the winter and the already mentioned fishery on smelt in early spring. The smelt-population in Lake IJsselmeer is mainly composed of a landlocked population which attains an average length of 7 cm after one year and of 12 cm after two years (de Groot, 1990). The biomass of smelt at the end of the year was estimated by Buijse et al. (1991) at an average of 66.1 $kg.ha^{-1}$ between 1966 and 1987, assuming a trawl efficiency of 100%.

The two locations sampled during the trawl-survey, Andijk (AD) and Enkhuizer Zand (EZ) are both situated in the northern part of Lake IJsselmeer (fig 2.2). AD has a steep shoreline, quickly dropping to a depth of 4-5 meter. EZ has a very moderate increase in depth and only 4 kilometres off-shore the depth reaches 5 meters. AD has a muddy bottom surface. EZ has a higher sand fraction and the bottom is covered with Zebra mussels (*Dreissena polymorpha*).

3. MATERIAL AND METHODS

The fishing season of the commercial fishery started at the first of March and ended 5 weeks later at April 4. At weekly intervals 2 market samples were taken. One sample from the IJsselmeer and one from the Markermeer. The sample, one fishing-box of 40 kg, was taken direct from the

fishing vessels and examined in the laboratory. Only the data from the northern basin are used in this study because the trawl survey was restricted to this area.

The trawl survey was carried out at two different locations, Andijk (AD) and Enkhuizer Zand (EZ), in Lake IJsselmeer (fig 2.1). Both locations were surveyed during day-time. Spawning activities take place during the night (Rupp, 1959; Murowsky et. al.,1980). Therefore the results of this study will not describe behavioural aspects of spawning smelt. Only the impact of spawning activities and fishing mortality on the population structure can be deduced from the data.

At each location smelt was sampled at different distances from the shore. The hauls were made parallel to the shoreline with a 3 meter beam trawl. During the first sampling day a dual-cod-end-trawl was used to determine the optimum meshsize. This dual-cod-end-trawl is described by van de Hak et al. (1989), and has a 10 and 20 mm cod end. The results of this fishing session led to the decision to sample the smelt population with two different meshsizes, 2 and 17 mm in order to catch both: the very small and the larger smelt with sufficient efficiency. The two beam trawls were used simultaneously (if possible) or alternating. In appendix A a full review is given of the sampling day, location, distance to shore, and meshsize used. Accurate length-frequency distributions in millimetres total length were taken from all samples. 20 to 30 animals per centimetre class were sexed and examined for their maturity (see appendix B). Spent animals were very difficult to sex on a macroscopic level. In order to avoid mistakes no sex was determined when animals were spent.

A small significant difference (Kolmogorov-Smirnov test, $p<0.05$) was detected between the length-frequency distributions in the 2 and 17 mm net. When catch numbers are concerned in further analyses the catches in both nets are treated as separate samples. If length-frequency distributions and sex ratios are discussed the catches in both meshsizes are lumped together. Figure 3.1 shows that the difference in catch-characteristics of both meshsizes is small and will influence catch numbers to a very low extent.

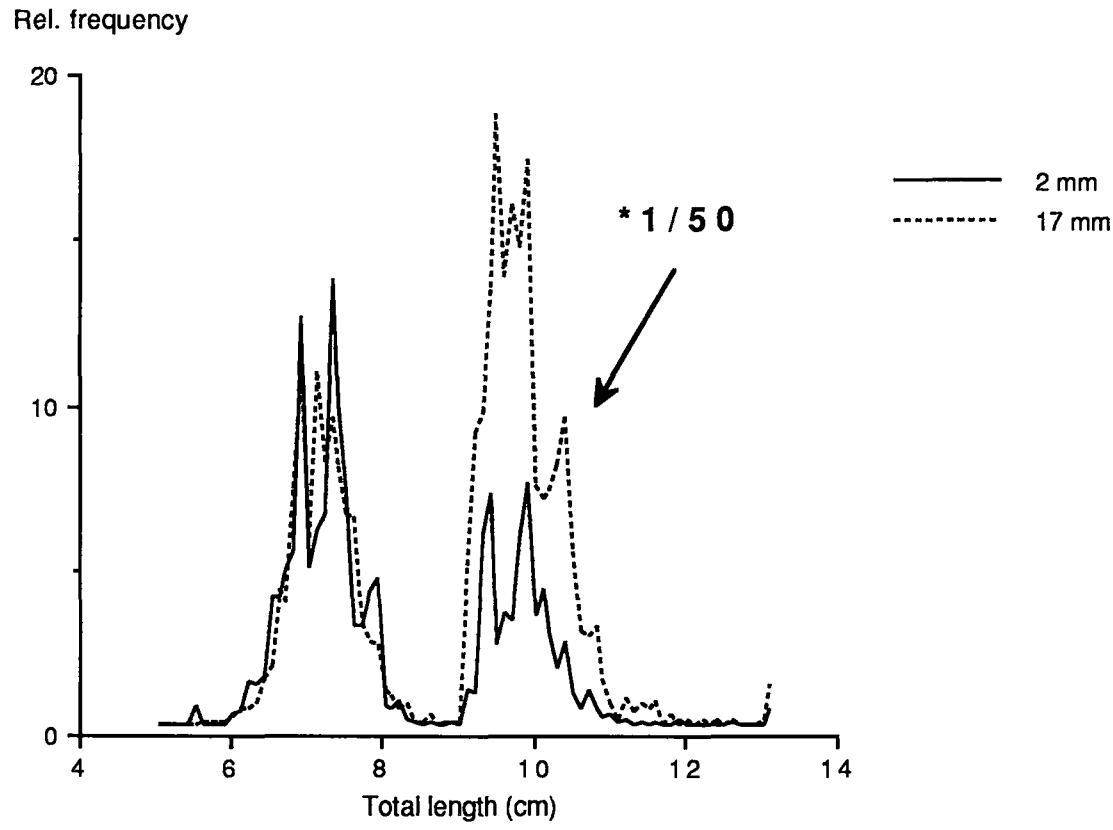

Figure 3.1 The relative length frequency distributions for smelt of the total smelt catches in the 2 and 17 mm nets during the trawl survey in Lake IJsselmeer.

The catches are described by four variables: catch number, length, sex ratio and maturity. These four descriptive characteristics of the smelt population will be related with three variables: time, location and distance to shore. The market samples can be related with time only because the other variables are not recorded for these samples. The variable time is used in two forms. In most cases the results of this study will be plotted against day number. Length frequency distributions and sex compositions are presented as the sum of all catches collected in three main periods: pre-spawning (before March 6), spawning (between March 6 and March 31) and post-spawning period (after March 30).

4. RESULTS

4.1 Catch numbers

The catch per unit of effort (CPUE) data in figure 4.1 and 4.2 show the development of the catches throughout the spawning period at respectively location AD and EZ.

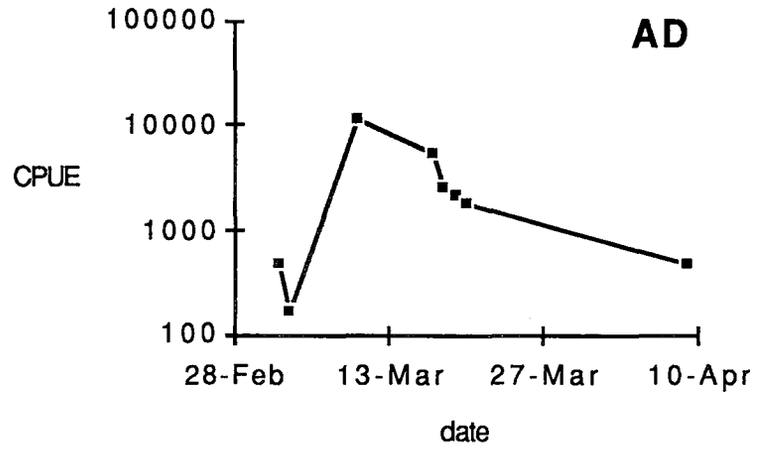

Figure 4.1 Catch number development (per 10 minutes trawling) of smelt at location AD in Lake IJsselmeer during the 1992 spawning period.

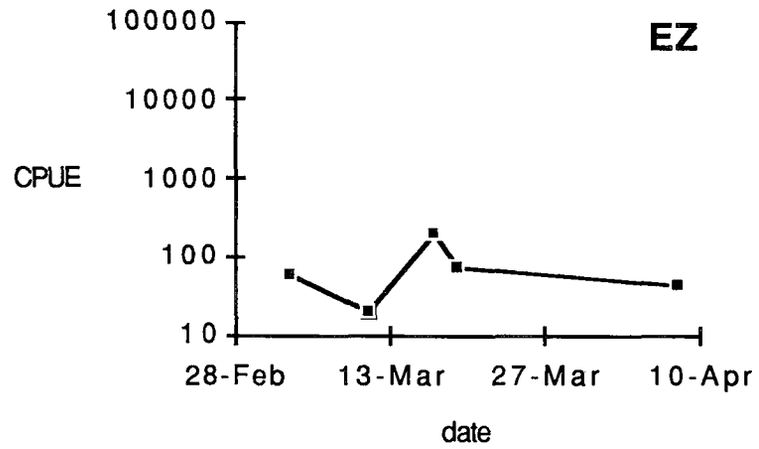

Figure 4.2 Catch number development (per 10 minutes trawling) of smelt at location EZ in Lake IJsselmeer during the 1992 spawning period.

Before the start of spawning catch numbers are low at location AD. Within a week time catch numbers do increase 10 to 20 times (March 10). After the peek level is reached catches decline steadily to the level before the start of the spawning period. Location EZ has a less profound development of the catch numbers. Beside higher catch levels at March 15, the other

observations are fluctuating around a mean of approximate 50 individuals per haul. The smelt densities at location EZ remained low throughout the whole sampling period and are a magnitude lower then catches at AD.

The older animals in the catch account for approximate 4% of the total number at the start of the fishing season. This share decreases rapidly during the spawning season.

Table 4.1 Percentage of >1-group animals in the total catch number.

Type-Period	% >1-group in total catch number
Survey pre	4.1
Survey spawn	1.4
Survey post	1.7
Market spawn	3.6

4.2 Length frequency distributions, sex and maturity

The catch numbers of the older age groups (>8.8 cm) in the figures presented in this chapter are multiplied by 50 in order to visualize the data. The length frequencies are the result of summing the data from both locations.

Table 4.2 Mean length of the two age groups for smelt in Lake IJsselmeer in the pre-spawning (pre), spawning (spawn) and post-spawning (post) period.

age class	period	Survey L_{mean} (cm)	Market L_{mean} (cm)
1-group	pre	6.96	
	spawn	7.07	7.24
	post	6.89	
>1-group	pre	9.92	
	spawn	9.80	10.02
	post	9.77	

The initial population, before fishing mortality occurs, is represented by the length frequency distribution of the pre-spawning period (Fig. 4.1). The length frequency is dominated by the 1-group which ranges between 4.3 and 8.8 cm. The mean length of this group is 7.0 cm. Males and females are equally present in this age group. In the smallest length classes some immature animals are found, 7.2% of the 1-group. The older age-groups (merely 2 year old animals) are all mature and dominated by females.

Table 4.3 Percentage of females, males and unknown (NN) animals in both age-groups of smelt during the three periods in Lake IJsselmeer.

age class		1-group			>1-group		
sex		females	males	NN	females	males	NN
Survey	pre	45	48	7	61	39	0
	spawn	36	63	2	76	22	2
	post	13	3	84	10	0	90
Market	spawn	28	71	2	41	59	0

During the spawning period the older age groups have a smaller share in the total catch (Fig. 4.4) then during the pre-spawning period. The percentage of spent animals in the population is the same for both age-groups The sex ratio has changed, more males occur in the 1-group and more females in the older age groups. The mean length of the 1-group is slightly larger then during the pre-spawning period. The older age groups show a minor decrease in length.

The market samples (Fig. 4.6) do differ from the survey data. The mean lengths of both age groups are significant higher then in the population (T-test, $p<0.001$; Table 4.2). The most distinct difference between the market data and survey data lies within the sex composition of both age classes. The males dominate both age classes in the commercial catches, whereas the smelt population in Lake IJsselmeer has a small dominance of males in the 1-group and a high dominance of females in the older age classes. The share of older age groups in the total catch numbers in the market sample is equal to the initial population structure.

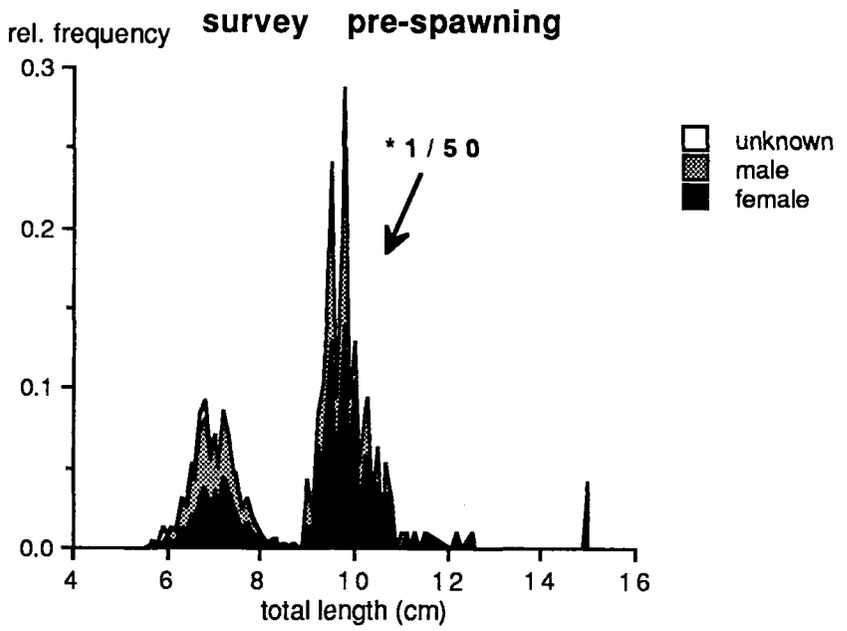

Figure 4.3 Relative length frequency distribution of smelt caught in the trawl survey before March 6, 1992.

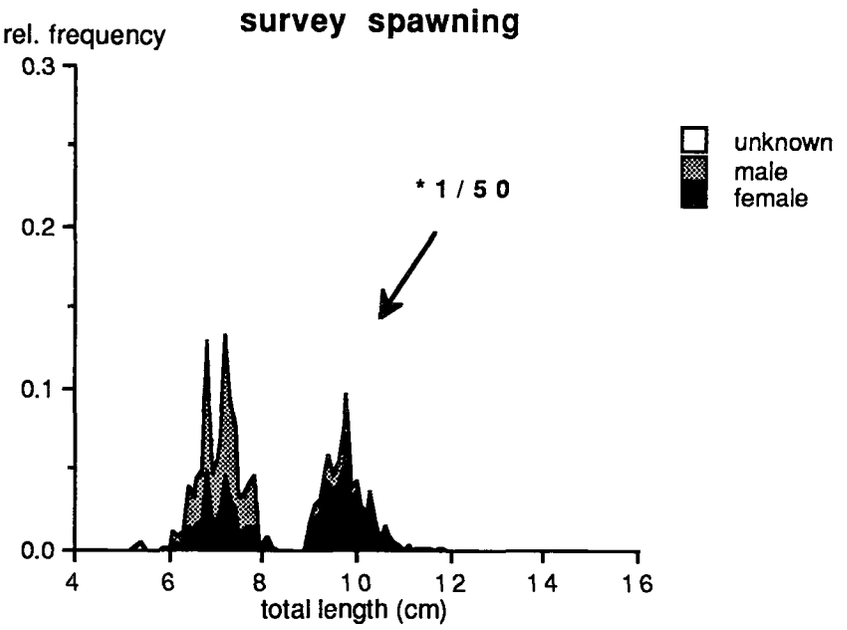

Figure 4.4 Relative length frequency distribution of smelt caught in the trawl survey between March 6 and March 30, 1992 in Lake IJsselmeer.

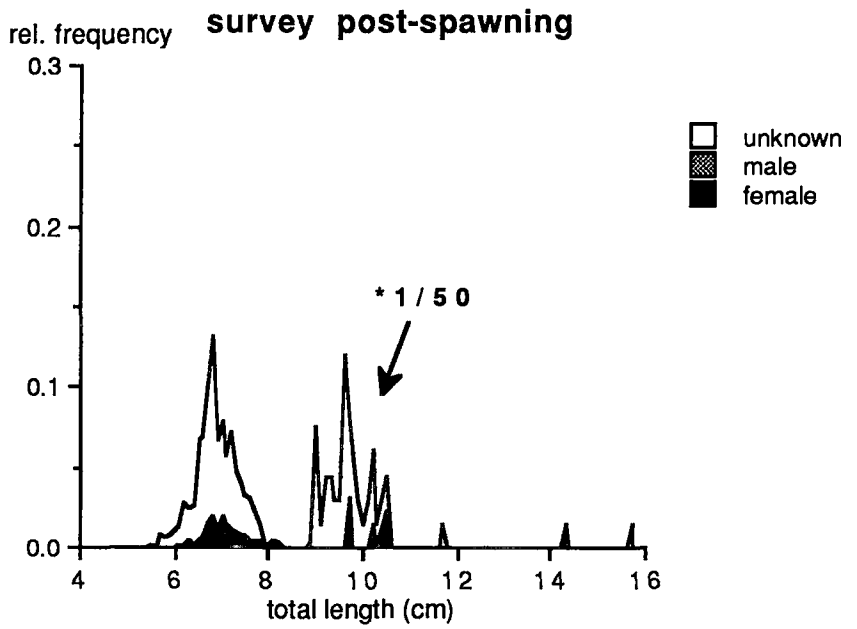

Figure 4.5 Relative length frequency distribution of smelt caught in the trawl survey after March 30, 1992 in Lake IJsselmeer.

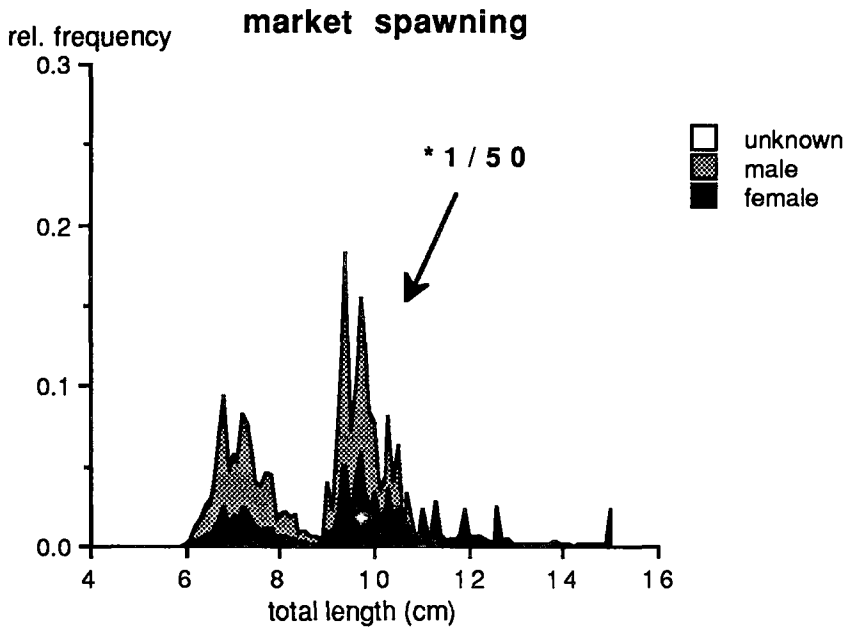

Figure 4.6 Relative length frequency distribution of smelt from the market samples collected between March 6 and March 30,1992 in Lake IJsselmeer.

The survey data collected after spawning (Fig. 4.5) were very difficult to sex. Just very few males which had some sperm left in their gonads could be examined as mature males. Females which were not fully spent were encountered more often but the overall idea is that all animals took part in the spawning activities, but that some of them were not able to spent all the eggs or the sperm they could. Observation on a macroscopic level showed that some animals had a transparent fluid in their gonads indicating a possible resorption of eggs and sperm. The number of spent animals (immatures were not encountered) in the market and survey data in the spawning period is very low at approximate 2% of the total catch numbers. Within 20 days this share has increased to 85%. Animals above 11 cm were encountered only a few times during the post spawning period. The mean length of the total population decreased in both age groups. Compared with the initial population the mean length of the 1-group dropped with 0.7 mm and of the older age groups with 0.15 mm. This difference in mean length between the pre-spawning and post-spawning population is not significant (T-test) for both age groups.

In Figure 4.7 to 4.9 the development of the mean length (mean of all age groups) per sex is given for location AD and EZ and for the market samples.

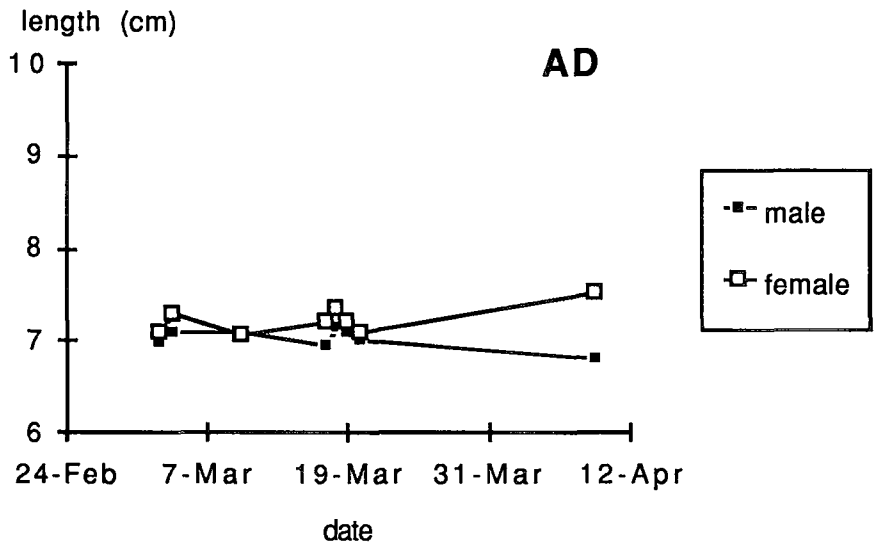

Figure 4.7 Mean length of the mature animals of both sexes of smelt in the trawl survey at location AD in Lake IJsselmeer.

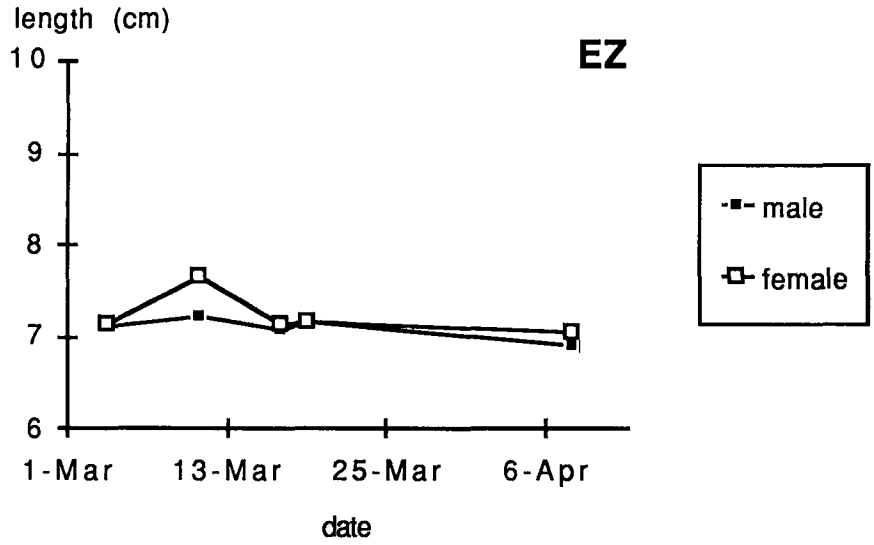

Figure 4.8 Mean length of the mature animals of both sexes of smelt in the trawl survey at location EZ in Lake IJsselmeer.

The mean length of the females is higher then the mean length of the males. This is caused by the dominance of females in the older age classes. At both locations the mean length remains almost constant throughout the spawning period. Only at the last sampling day a small decrease can be detected in mean length for both sexes at EZ and males at AD.

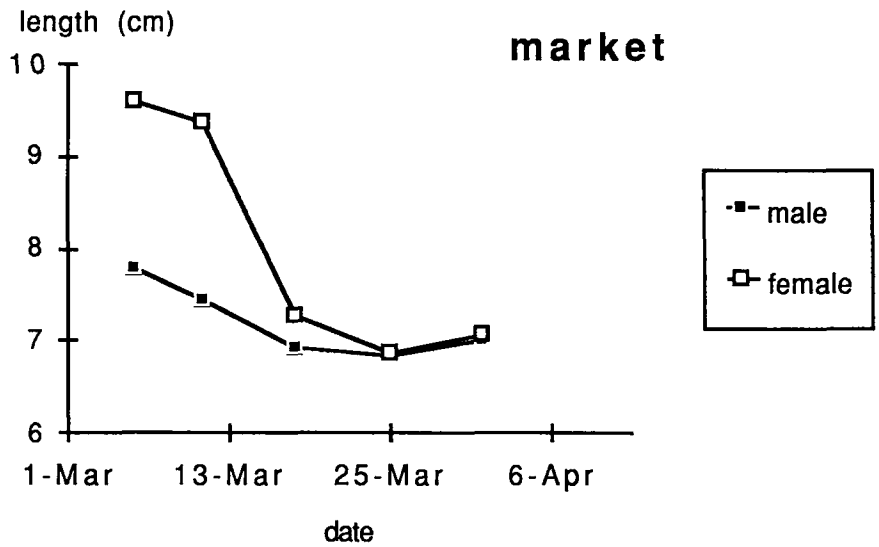

Figure 4.9 Mean length of the mature animals of both sexes of smelt in the market samples.

The development of the mean length in the market sample is a reflection of the share of the older age groups in the total catch. At the start of the fishing season a large part of the catches consists of older animals. Their share decreases throughout the spawning period with a small revival at the end.

4.3 Distance to shore

The distribution of the catch numbers against distance to shore within the spawning period are given in Figure 4.10 for location AD and Figure 4.11 for location EZ.

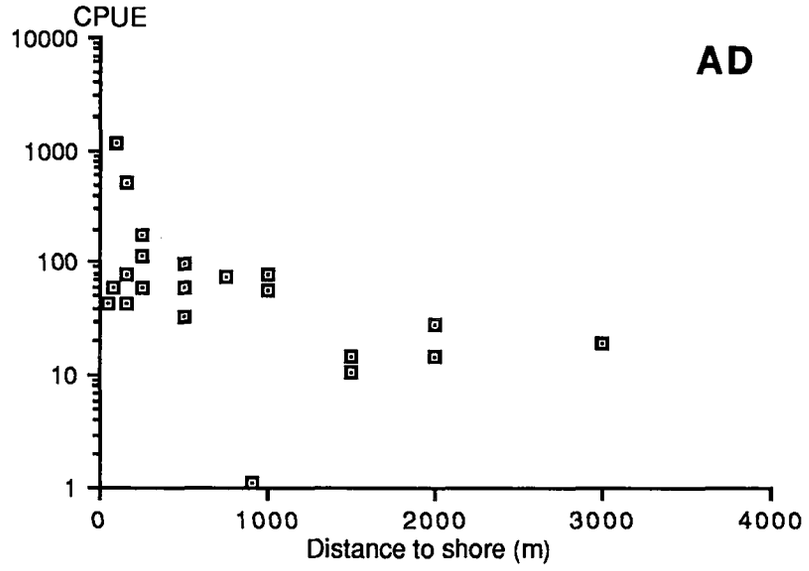

Figure 4.10 Relation between the catch numbers of smelt per 10 minutes trawling (CPUE) and the distance to the shore at location AD in Lake IJsselmeer.

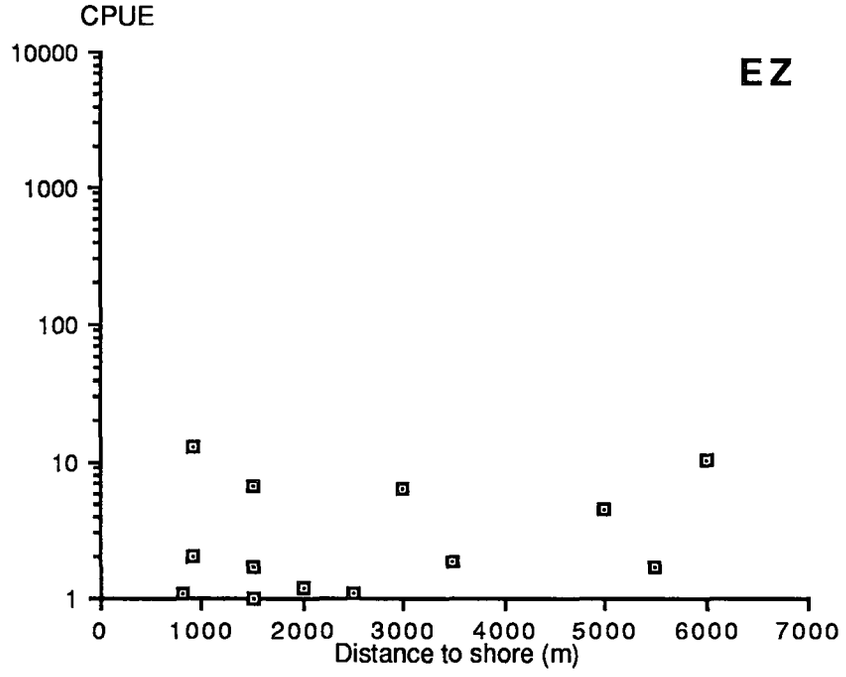

Figure 4.11 Relation between the catch numbers of smelt per 10 minutes trawling (CPUE) and the distance to the shore at location EZ in Lake IJsselmeer.

The catch numbers at AD have a negative relation with distance to shore. Close to the shore (or spawning grounds) higher catch numbers are encountered then in the open water region. At location EZ no relation between catch numbers and distance to shore exists.

The sex ratios at AD (Fig.4.12) and EZ (Fig. 4.14) have no relation with distance to shore during the pre spawning period. At both locations the males and females are encountered in almost the same numbers. During the spawning period a at location AD the males are dominant within 1000 meters of the spawning grounds (Fig. 4.13). Further away from the shore no differences occur when compared with the situation before spawning. An overall male dominance (ca. 60%) was found at location EZ without respect to distance to shore during the spawning period (Fig. 4.15). A smaller share of older animals is responsible for this effect.

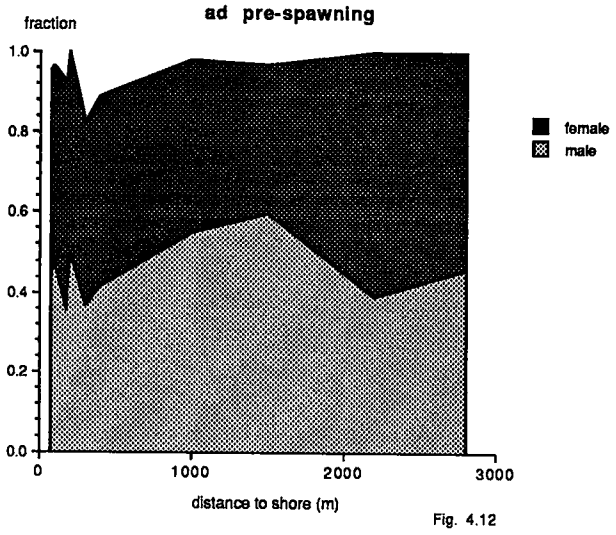

Fig. 4.12

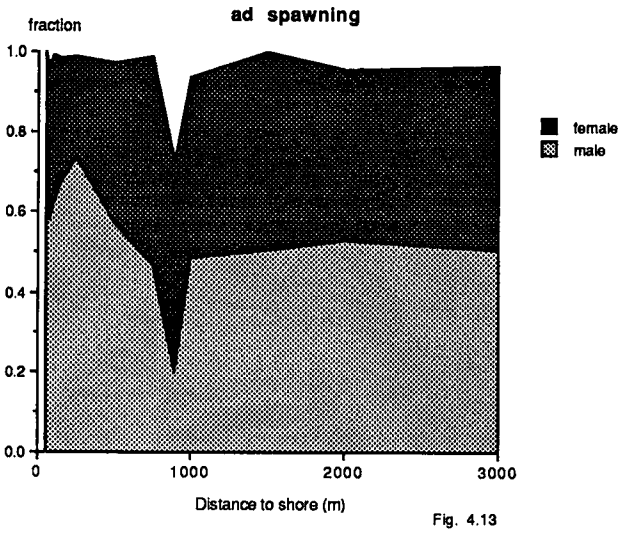

Fig. 4.13

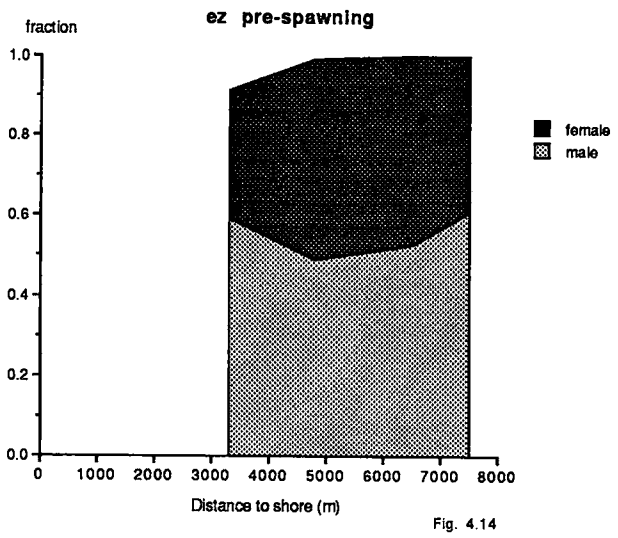

Fig. 4.14

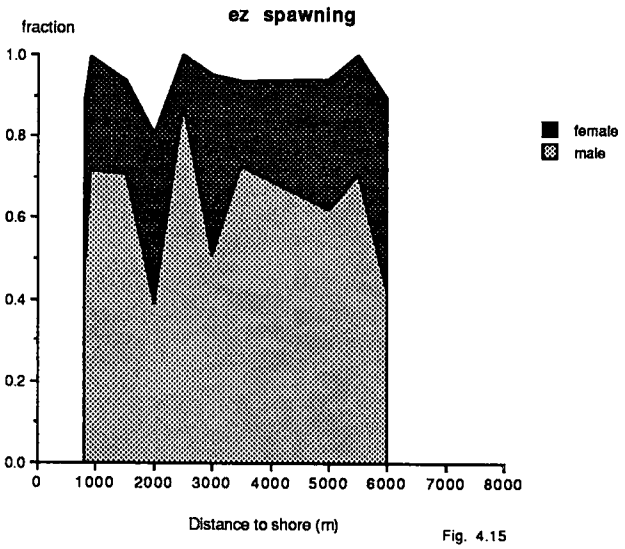

Fig. 4.15

Figure 4.12 to 4.15 Sex ratios of mature males and females in the trawl catches at location AD and EZ in relation with the distance to the nearest shore.

5. DISCUSSION

The population structure of smelt at location Enkhuizer Zand does not suggest this area to be an important spawning area. Cath numbers remained low throughout the spawning season. The catch numbers and sex ratios were independent from the distance to the shore. Rupp (1959) showed a preference of smelt for clean gravel or coarse sand. Location Enkhuizer Zand with its shallow character and sandy bottom could therefore be an appropriate spawning area. Other factors are likely to influence the suitability of the spawning grounds. Spawning smelt is usually caught at the lee-shore. Since the the overall wind comes from the south west, location EZ is situated at the unfavoured wind-side. The high densities of zebra mussels can also be responsible for the unsuitability of this site for spawning.

The development of the catch numbers at location AD runs parallel with the landings of the commercial fishery (personal communication with fishermen). At the start of the spawning season around March 7 the smelt catches reach a peak within a week and decrease rapidly afterwards. One week before the official end of the fishing season at the March 3 already many fishermen stopped their fishing activities. The total catch was smaller then in the past four years (figure 1.1). This does not indicate a decrease of smelt densities in Lake IJsselmeer. Spawning activities of smelt also depend on weather conditions and the effort paid by the fishermen is related to the market price for smelt. These two conditions influence the total smelt catch. A storm depression occured in the middle of the spawning season probably disturbing the spawning activities.

Because the commercial fishery with fykenets concentrates on spots where massive runs take place (usually the east side of Lake IJsselmeer) it is not possible to carry out trawl surveys in those areas. Location Andijk is a spawning area without massive runs. The results of the trawl survey at location Andijk show trends which can be linked to spawning activities. The catch numbers close to the shore are higher then off-shore and the fraction of mature males rises in the spawning season. The higher fraction of males close to the spawning grounds is explained by the fact that males remain longer at the spawning grounds then females do. This is also stated by the sex ratio found in the commercial catches. Table 4.2 shows that the fraction of males in the 1-group is higher in the commercial catches then in the trawl survey. For the older age groups this effect is even more severe. In the trawl survey only 22% of the older age groups is male whereas in the commercial catches the males dominate with a fraction of 59%, indicating the longer duration of the males at the spawning grounds. Janss (1992) stated that the declining maturity of the females is contradicting the theory that females only spawn once. Although this statement is based on low catch numbers at the very far end of the spawning season the data of this study do confirm that females can spent more times. In the population (trawl survey) a very low fraction of spent animals (males and females) was found in the surveyed area throughout the spawning season. The higher male fraction in the market samples is caused by the fact that males stay longer or pay more visits to the spawning grounds.

Spent animals were very difficult to sex on a macroscopic level. Spent females were easier to recognize then the males. A method for determine the sex of spent animals would improve the quality of the data.

The immature animals located at the start of the spawning season were not caught later. Probably because they left the spawning grounds. Some of them could be mixed up with spent animals but the length range from the spent animals is different from the immatures caught in

the pre spawning period. The small length of the immatures indicates that maturation is a length related process. Above 5.5 cm all animals are mature, whereas below 5.0 cm no mature animals were found. The strategy of conserving energy by preventing gonadal development and invest in growth is applied by the small specimen. To what extent this immature group contributes to the number of older and larger animal a year later remains unknown. The origin of the older animals is unknown and can come from fully-grown immatures, survivors of the 1+ group or migrating smelt from the Waddenzee.

The commercial landings of smelt at the beginning of the spawning season have a high fraction of older animals which is a common phenomenon (Hutchinton & Mills, 1987). Their numbers drop fast and the mean length of the catches decrease. The influence on the population structure of smelt is low. Although the mean length of the market samples differ significantly from the mean length in the trawl survey, no significant decrease in mean length in the population was detected.

In future it may be worthwhile to survey the smelt population at sites were the massive runs take place. So the catch data from the commercial vessels will be from the same area as the survey. After all it was not necessary to fish with two mesh sizes. The 17 mm is capable of catching small smelt with the same length range as the 2 mm net does. Because the older age-groups are caught with a higher efficiency with the 17 mm net this mesh size can be used best in future surveys during the spawning period.

6. COLLECTION OF SMELT EGGS WITH ARTIFICIAL SUBSTRATES

6.1 Introduction

An artificial substrate capable of collecting eggs of spawning smelt can be an useful tool when the spawning behaviour is studied. Spawning site preferences, egg counts and hatching rates can be determined from such samples. During the spawning period of smelt in Lake IJsselmeer two types of artificial substrates were used. Rothshild (1961) successfully used canvas to collect smelt eggs in a river. This material was selected as a substrate. As a second material transparent perspex plates were used. The advantage of the latter is that they have a defined surface, easy to handle and samples can be taken to the laboratory easily.

6.2 Method and materials

The surface of the canvas tissues and perspex plates was 100 cm^2. Eighteen squares, 9 canvas and 9 perspex, were placed in two iron frames of 1 m^2 each. The iron frames were used to prevent the squares from drifting and to ensure they were positioned horizontally at the bottom. A small boyer was attached to each frame. The frames were placed 100-200 meters off-shore at a depth of 3 meters at location Andijk. They were left overnight and collected the next morning. During three nights both frames were placed at location Andijk.

6.3 Results

During two of the three nights a small number of eggs were deposited on the squares. Three times 1 to 5 eggs were encountered on canvas squares. Four times a small number of eggs (<3) were laid on the perspex plates. Only two perspex plates received a clump of eggs of approximate 30 eggs. These clumps were attached relative firm to the perspex plates.

6.4 Conclusions

Both substrates can serve as an artificial substrate. When eggs are deposited on the perspex plates they are easily located because the perspex is transparent. The surface of the perspex stays the same whereas the canvas squares went bubbling and stretching when they became wet. Experiments with perspex plates are therefore easily reproducible. Eggs deposited above the plates stick to this material. It is unknown what share of the total number of eggs which contacted the perspex plates remained on the plates. Experiments are needed to acquire this information. Perspex should be preferred above canvas in this kind of experiments. The perspex plates should be larger when quantitative data are required in areas where spawning activities are not massive.

7. HATCHING OF HAND INCUBATED SMELT EGGS

7.1 Introduction

Smelt specimen are very vulnerable animals and do not, or very rare, stay alive after they have been caught in a net. An attempt was made to hatch smelt eggs and culture the larvae. Because only a small number of natural eggs were collected with the artificial substrates (see section 5) hand incubated eggs were used in this experiment.

7.2 Material and methods

At the March 20, half-way the spawning period, mature males and females were collected from Lake IJsselmeer. The females were stripped to obtain the mature eggs. The gonads of the males were cut lose and cut into small pieces. The eggs of approximate 30-40 females and the sperm of approximate 50 males were put together in a small amount of water and stirred for 20 minutes in a bowl. After this procedure the remains of the male gonads were removed and the eggs were taken to the laboratory in plastic bags with the addition of 15 litres of water. Because eggs can get mouldy the experiment was done twice. One sample of eggs was incubated and hatched in water taken from Lake IJsselmeer and one sample was incubated and hatched in tap-water. In the laboratory the eggs were put in aquaria with stagnant water. Beside those two aquaria one aquarium was prepared with streaming water in case the eggs would get mouldy.

7.3 Results

The egg and larvae development and actions undertaken to hatch the eggs and culture the larvae are discussed in chronological order.

March 20 : Incubation of the eggs at 11:00 hours. At 15:00 hours put into aquaria (one with IJsselmeer water and one filled with tap water) with a water temperature of 15°C.

March 24 : The experiment in the aquarium with tap water is stopped because of moulding of the eggs. The aquarium with IJsselmeer water was smelly (urea) and replaced with tap water.

March 29 : Approximate 7000 eggs are hatched. All eggs and egg tissue removed.

March 31 : Larvae are in good condition and the yolk-sack is still apparent but of decreasing size. 500 Larvae placed in the aquarium with streaming water.

April 1 : Jacked up glasseel food (nippai) added to both aquaria.

April 2 : Larvae haven't been eating the offered food. The yolk-sack has almost disappeared. Larvae are 4.2 mm long and have a head width of 0.4 mm.

April 3 : Decapitated Arthemias added.

April 5 : The stagnant water aquaria is very smelly (urea) and cleaned. Although only three larvae in aquarium with streaming water survived of the initial 500 larvae, 2500 larvae (50% of total

number) replaced from the stagnant aquarium to the aquarium with streaming water. Larvae seem to suffer from underfeeding.

April 8 : 15,000 litres of IJsselmeer water filtered through a 120 µm planktonnet and the collected plankton added to both aquaria. Numbers are decreasing rapidly in both aquaria.

April 9 : Only 50 larvae with empty stomachs left in aquarium with stagnant water. The aquarium with streaming water contains no more live larvae.

April 13 : Experiment is stopped because all larvae died.

7.4 Conclusions

Smelt eggs are easily incubated by hand. The sticky eggs make it necessary to stir the eggs continuously because they tend to attach at available substrate after incubation. Hatching of the smelt eggs took 150 degree-days. The bottle neck of this experiment was to get the larvae to feed themselves. The larvae are very little and require small prey or food items. Because the temperature of the water in Lake IJsselmeer is half of that in the laboratory (7°C) in nature the eggs will hatch 10 days later. That is probably why the zooplankton collected in Lake IJsselmeer did not have the right composition and were not consumed by the larvae. In literature no comparable studies are reported beside Lillelund (1961) which was able to hatch and successfully culture the larvae.

REFERENCES

Belyanina, T.N., 1969. Synopsis on the biological data on smelt, *Osmerus eperlanus* (linnaeus) 1758. FAO Fish. Synopsis 78. 55 p.

Buijse, A.D., M.R. van Eerden, W. Dekker, & W.L.T. van Densen. 1991. A trophic model for IJsselmeer (The Netherlands), a shallow eutrophic lake. p. 000. In: V. Christensen, and D. Pauly [eds.] Trophic models of aquatic ecosystems. ICLARM Conference Proceedings No. 26.

Groot, S.J. de, 1990. Decline of the catches of coregonids and migratory smelt in the lower Rhine, The Netherlands. J. Appl. Ichthyol. 6:247-251.

Hak, H. van der, J. van Willigen, & W. Dekker, 1989. Eel-net selectivity using a dual cod-end beam trawl. ICES paper 1989/B:52 5p.

Hutchinton, P., & D.H. Mills. 1987. Characteristics of spawning-run smelt, *Osmerus eperlanus* (L.), from a Scottish river, with recommendations for their conservation and management. Aquacult. Fish. Mgmt. 18:249-258.

Janss, G.F.E., 1992. Karakteristieken van de spieringaanvoer (*Osmerus eperlanus*) door de beroepsvisserij in het voorjaar op het IJsselmeer. Landbouw Universiteit Wageningen, student-verslag nr. 1369. 36 p.

Lillelund, K., 1961. Untersuchungen über die Biologie und Populationdynamik des Stintes *Osmerus eperlanus* [Linnaeus 1758], der Elbe. Arch. Fish. Wiss. 12:1-128.

Murawski, S.A., G.R. Clayton, R.J. Reed, & C.F. Cole. 1980. Movements of spawning rainbow smelt (*Osmerus mordax*) in a Massachusetts estuary. Estuaries 3:308-314.

Nellbring, S., 1989. The ecology of smelts (Genus *Osmerus*): A literature review. Nordic. J. Freshw. Res. 65:116-145.

Rothshild, B.J., 1961. Production and survival of eggs of the American smelt, *Osmerus mordax* (Mitchill), in Maine. Trans. Amer. Fish. Soc. 90:42-48.

Rupp, R.S., 1959. Variation in the life history of the American smelt in inland waters of Maine. Trans. Amer. Fish. Soc. 88:241-252.

Schaap, L., 1990. IJsselmeer-spieringvisserij. Onze Zoetwatervisserij 83(3):8-10.

Schaft, M. van der, 1984. De paaipopulatie van spiering, *Osmerus eperlanus*, bij Lemmer in het voorjaar van 1983. Limnologisch Instituut studenten verslag 1984-2. 66 p.

Appendix A Review of location, sampling date, gear and distance to the shore.

Location	date	mesh size (mm)	Distance to shore (m)						
AD	3-Mar	2	300	400	1000				
		12	90	180	400	1000			
		20	90	90	180	400	1000		
	4-Mar	17	75	200	1000	1500	2200	2800	
	10-Mar	2	100	500	1000	1500			
		17	100	500	1000	1500			
	17-Mar	2	150	1500	3000				
		17	3000						
	18-Mar	2	50	150	250	500	750	1000	2000
		17	50	150	250	500	750	1000	2000
	19-Mar	2	250						
		17	250	900					
	20-Mar	2	75	150	250	500	1000	2000	
		17	75	150	250	500	1000	2000	
	9-Apr	2	x	x	x	x			
		17	x	x	x	x	x		
EZ	4-Mar	17	2600	3300	4800	6500	7500		
	11-Mar	2	900	1500	2500	5500			
		17	900	1500	2500	5500			
	17-Mar	2	900	1500	3000	5000			
		17	900	1500	3000				
	19-Mar	2	800	1500	2000	3500	6000		
		17	800	1500	2000	3500	6000		
	8-Apr	2	800	1500	3000	7000			
		17	800	1500	2000	3000	5000	7000	
MARKET	6-Mar	213	x						
	11-Mar	213	x						
	18-Mar	213	x						
	25-Mar	213	x						
	1-Apr	213	x						

Appendix B. Possible stages of maturity to be determined on a macro-scopic level.

1 VIRGIN - very small sexual organs close under the vertebral column.Testes and ovaries transparent, colourless to grey. Eggs invisible.

2 MATURING VIRGIN - Testes and ovaries translucent, grey-red. Length half, or slightly more than half, the length of the ventral cavity. Single eggs can be seen with magnifying glass.

3 DEVELOPING - Testes and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye as whitish granular.

4 DEVELOPING, LATER - 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.

5 GRAVID - sexual organs filling ventral cavity. Testes white, drops of milt fall with pressure. Eggs completely round, some already translucent & ripe.

6 RUNNING - Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.

7 PARTLY SPENT - Not yet fully empty. No opaque eggs left in ovary.

8 SPENT - Testes and ovaries empty, red. A few eggs in the state of reabsorption.

9 RECOVERING - 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.