INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

C.M. 1983/J : 27
Baltic Fish Committee

ASSESSMENT OF SMELT *(Osmerus eperlanus (L.))* STOCK IN THE VAASA ARCHIPELAGO, GULF OF BOTHNIA

by

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Abstract

According to tagging experiments the smeltfisheries in the Vaasa Archipelago are based on a single population or a number of mixed populations. The schools, when ascending, seem namely to migrate through several fishing areas. In the period of 1978 to 1982 the growth of the recruited age groups has not changed. According to the age composition of the catches, the recruitment to the vulnerable stock varies quite a lot. The total mortality rate has been valued at 0.7 and the natural mortality rate is assumed to be quite low, close to 0.15. The catches in the area have varied a lot and a decline in the catch/unit effort has been the fact during the period studied. The curves of yield/recruit show that the present recruitment age of 4 is suitable in order to maximize the yield per recruit at the present growth rate. The present fishing mortality apparently gives the highest possible yield.

Résumé

D'après les expériences de marquage, les pêches d'éperlans dans l'archipel de Vaasa sont basées sur une seule population ou sur un nombre de populations mélangées. Les bandes semblent migrer à travers plusieurs zones de pêches quand elles remontent. La croissance des groupes d'age recrutés n'a pas changé pendant la période 1978-1982. D'après la composition d'âge des prises le recrutement pour le stock vulnérable a varié très sensiblement. Le taux de mortalité total a été estimé à 0.7 et le taux de mortalité naturelle est estimé assez faible, proche de 0.15. Les prises dans la région ont beaucoup varié et un déclin dans les prises par unité d'effort ont été le point marquant pendant la période étudiée. Les courbes de productivité par recrue montrent que l'âge de recrutement actuel de 4 est convenable afin de maximaliser la productivité par recrue au taux actuel de croissance. La mortalité de pêche actuelle donne apparemment la plus haute productivité possible.

Introduction

Nearly all of the Finnish commercial catch of smelt in the sea is caught in the Northern Quark (LEHTONEN 1978). There are no previous studies on the population dynamics of the smelt in the Northern Quark, nor have there been any studies on the reduction in catch on some of the typical fishing sites (e.g. HÄSTBACKA & HUDD 1980, AXELL & HUDD 1981 and HUDD et al. 1983a). The aim of this work is to describe the geographical distribution, the migrations, the population parameters and the fishery of the smelt in the Northern Quark. Y/R-curves are presented and the basis for the management of the smelt fishery is discussed.

Materials and methods

In 1979, 1980 and 1982, altogether 2940 smelts were tagged; in 1979 and 1980 tagging was done at the beginning of the spawning run, and in 1982 at the end of the run. The tagging took place on typical smelt fishing sites in the inlets of the Vaasan eteläinen kaupunginselkä in Vaasa, in Köklot-fjärden in Korsholm and in the archipelago off of the River Kyrönjoki in Maxmo (Fig. 1-3). 1400 of these were tagged with Lea tags (BAGENAL 1978) and 1540 with a plastic flag tag (GUNDERSEN 1959). The fishes used for tagging were taken from trap nets. They were not anaesthetized although they were held for some hours in capture before being tagged. The tagged fish were released at the same place they were caught.

During the trap net seasons random samples were taken from the catches. The total lengths and weights of 2117 smelts were measured. Ages were determined from otoliths. Larvae and fingerlings have been sampled with a modified Gulf V (SCHNACK 1974), Gulf Olympia (HUDD et al. 1983b) high speed samplers and with purse seine and fingerling trawls (HUDD et al. 1983a).

The growth is described by the von Bertalanffy's equation of growth using a computer program from ABRAMSON (1971). Mortality rates have been estimated from the age compositions in the samples from trap nets. Data on landings and by-catches are collected from interviews with fishermen and foragers and from the papers of HÄSTBACKA & HUDD (1980) and AXELL & HUDD (1981). Information on the catches in the recreational fishing was taken from SEPPONEN & HILDEN (1982), ÖSTERHOLM et al. (1982) and from interviews with sportsfishermen. Yield/recruit curves have been done using JONES' (1957) modification of BEVERTON & HOLT's (1957) method.

Results

1. Distribution area and migrations

Until December 31st, 1982, altogether 119 recaptures from the taggings in 1979 and 1980 and 97 recaptures from the taggings in 1982 were reported. 2.5 % of the smelts tagged with streamer tags were recaptured, while 19.8 % and 24.3 % of those tagged with Lea tags in 1980 and 1982 respectively were reported. Most of the recaptures are from the same fishing season but some occurred up to two years after the tagging. The majority of them are from the Northern Quark but there are recaptures reported from as far as the sea area off Pietarsaari and off Kalajoki (Figure 1-3).

The recaptures done at the same places in successive years after tagging, indicate that the smelt possess homing. Yet there are recaptures done in neighbouring fishing areas in the same tagging year as well as in successive years. This indicates that the ascending schools migrate through archipelagoes and inlets where they are fished upon among the homing part of the population.

The main part of the stock migrates upstream to the spawning areas in late April and in the beginning of May. Some years the ascension is delayed due to climatic factors and there are observations of spawning in the early summer. The migration is most intensive when the temperature reaches 3-4 ^{o}C (Figure 4). The schools ascend at dusk. The spawning takes place in very shallow waters in estuarine areas. After spawning the smelt migrate to deeper sea areas off the archipelago (Figure 3-4). In the summer schools don't appear in the shallow archipelago. Although schools sometimes dwell in the wintertime in the archipelago, the most important wintering areas seem to be the sea areas off the archipelagoes. The wintering areas are probably already reached in the summer.

2. Growth

There are some small differences in the growth rates of the first summer (Figure 5) of different years. Fingerlings caught in a 4 mm trap net in February 1982 had a mean length of 55 mm (min: 49, max: 63 mm, n: 22), which indicates that the growth stopped at the level found in the trawl samples in November 1981. During the first season of growth the smelt in the Northern Quark thus reaches a length of 55-65 mm.

The growth among the harvestable part of the stock hasn't changed during the period 1978-1982 (Figure 6). The mean lengths and weights of the single age-groups in samples from 1978 to 1982 are presented in Table 1. In general, the females grow a bit faster than the males, and are the biggest specimens. Figure 7 shows the growth of the smelt in the Northern Quark according to v. Bertalanffy's growth equation and Figure 8 the length-weight relationship for the samples taken during the spawning period.

3. Age composition of trap net catches and the age of recruitment of new fish to the vulnerable population

The catches from smelt trap nets that have a mesh size (bar length) of 10 mm, have consisted of the age-groups 2 to 10 (Figure 9). In the samples from Baltic herring trap nets, which have a mesh size (bar length) of 12-13 mm, the mean ages are a little older. In general, the recruitment age in trap net fishing is of 4 years old. From the age-composition (Figure 9) one can see that the mean age in the landings has increased in the period 1978-1982. As can be seen, this is caused by the high variation in the number of recruits.

4. Survival and mortality

According to the age composition in the single samples, the survival rate $(S = \frac{N_{t+1}}{N_t})$ and it's 95 % confidence limits are calculated to be 0.50 ± 0.05 (Table 2). This gives a Z value of 0.7.

Initial analyses using PALOHEIMO's method (RICKER 1975) of estimating the natural mortality, indicate that the mortality is low, close to 0.15. By giving the natural mortality the value of 0.15 or 0.2, one obtains, according to $Z = F + M$, the values 0.55 and 0.5 respectively for the fishing mortality.

5. Fishing and catches

The main part of the smelt fishing is done with trap nets in the inlets of the spawning areas. Important fishing places are the estuary of the River Malaxå, the inlet of Vaasan eteläinen kaupunginselkä, which is an estuary for three smaller rivers, the inlet to Köklotfjärden and the Maxmo archipelago, which is the estuarine area of the River Kyrönjoki. There are also some smelt fishing with trap nets in the estuaries of the River Munsalanjoki and the River Lapuanjoki (Figure 10). The trap net season is very short, usually lasting only two or three weeks (Figure 4).

There are no developed gill net fishing activities of smelt in the Northern Quark. There is quite a lot smelt caught in e.g. whitefish fishing.

In the late fall and also in the spring the trawl catches of smelt can be rather big. There is no smelt trawl fishing. The smelt caught in trawls are by-catches from the Baltic herring trawl fishing. The trawling areas in the Northern Quark are on the smelt's wintering areas.

The main part of the catches is taken from trap net fishing during the spawning run in April and May. Estimates of the total catches in 1979-1982 are presented in Table 3. The catches have varied a lot and so have the catch per unit effort values. As an example of this the catch and catch per unit effort values in the landing in Vaasa are presented in Table 4.

6. The equilibrum yield per recruit

The population parameters used for calculating the Y/R curves are presented in Table 5. Even by increasing the fishing mortality, the yield/recruit would not grow (Figure 11). One can also see that the overall recruitment age of 4 years gives catches that are very close to the top of the catch per recruit curves at present growth rates.

Discussion

PARMANNE and SJÖBLOM (1982) got 3.8 % recaptures when using Lea tags in tagging Baltic herring. They conclude that the Lea tag is more suitable for migration studies than the plastic tag and streamer tag, which gave very few recaptures. In the Northern Quark the recaptures from smelts tagged with Lea tags were 19.8 % and 24.3 % and with streamer tags 2.2 %. Accord-

ingly the Lea tag is the more suitable when studying migrations and distribution areas. The rates of recapture are very low, compared for example with McKENZIE (1964), who got even 79 % recaptures. McKENZIE caught the smelts homing in their spawning creeks and there were recaptures done in fishing areas off the coast as well. In the Northern Quark smelt is caught almost entirely for use in forage and the catch is not sorted. This is probably the reason for the lower rates of recapture.

Although there is evidence for homing among the smelt in the Northern Quark one can postulate, according to the recaptures of tagged smelts, that the smelt fisheries in the area is based on the same smelt resource, which in the management gives the possibility to treat the smelt in the Northern Quark more or less as an unit stock (GULLAND 1969). When the schools ascend they migrate through archipelagoes and inlets that are important fishing places. Homing among smelt has also been proven by McKENZIE (1964). Although MURAWSKI (1980) found that there is spawning in several spawning sites among some males, the small amount of these does not deny homing among the chief part of the population. The recaptures in the estuary of the River Kyrönjoki of smelts tagged in the inlet of Köklotfjärden a year before fortifies the assumption that the ascending schools migrate through several fishing places. The same assumption is further fortified by the recaptures of smelts tagged in one inlet and found in other fishing places in the same fishing season (Fig. 1-3).

The adult smelts are found to migrate out of the archipelagoes in the summer. This is also pointed out by NEUMAN (1982) in the archipelagoes in the southern Bothnian Sea. The reason is the smelts preference for cold waters. The recaptures of smelts tagged late in the spawning season of 1982 show a northward migration in the summer. Yet the majority of the recaptures in the summertime show that all of the smelt do not migrate northward but only move to deeper sea areas off the archipelagoes. According to interviews with trawlers, the catches of smelt are nearly always of equal sizes in the fall and early winter. Fishermen's echograms, that show the smelt schools very close to the bottom, also indicate that the majority of the smelt schools winter there. The large by-catches of smelt in gill net fishing in the wintertime are thus caused by single schools and NEUMAN's (1982) statements claiming that the smelt returns to the archipelago in November and December is not true for all of the population in the Northern Quark.

The smelt is known to show large oscillations in the abundance and the success of single year-classes. This is especially known for populations of the small landlocked forms. The reasons for the large oscillations are

usually natural but there are also observations on remarkable changes in densities due to intense fishing (BELYANINA 1969). The mass mortalities mentioned above perhaps have affected the success of the year-classes.

The life span of the Quarkenian smelt is very similar to the life spans found in several typical migratory smelt populations in the Sovjet Union (BELYANINA 1969). The catches in the Northern Quark have, during the last years, consisted of a remarquably large number of age-groups and there is a remarkably high frequency of older age-groups. The reason for the wry age distribution is probably the variable survival of eggs and larvae and it can easily be postulated that the recruitment is not in steady state.

The recaptures of tagged smelt are not reliable enough to calculate mortality rates. It is of course also hazardous to approximate mortality rates from the age compositions in catches from samplings in five years and when it is likely that the recruitment during that period has not been in steady state. The given mortality rate has to be considered as preliminary. Yet the presented survival rate agrees with the rates for the populations in the Soviet lakes Lazmiaden, Ladoga, Onega and the rivers Neva, Yenisey, Lena, Chatanga and Anadyr. In these the survival rates are between 0.4 and 0.58 (calculated from age distributions presented in BELYANINA 1969). The mortality rates seem to deviate from those found in Elbe (LILLELUND 1961) and in Miramichi (McKENZIE 1964) Z = 1.34 and Z = 0.92 respectively (calculated from presented age composition), and also from Z = 1.268 presented by MURAWSKI (1978) for the rainbow smelt in Parker River.

The smelt in Northern Quarken grows slower than the smelt in the Gulf of Finland. The difference between the growth in the Quarkenian smelt and the smelt in the northern Gulf of Bothnia is very little (Table 6). Since one can assume that the smelt during the growth season prefers colder water layers (NEUMAN 1982), which are probably basically the same temperature all over the Baltic, the difference in growth is either due to differences in population densities or to differences in food supply. Since at least some of the smelt migrate northward in the summer, the environment during the growing season does not differ much from the smelt TIMOLA (1977) has studied.

The smelt is often mixed in the statistics with, for example, Baltic herring catches. In gill net fishing the smelt often is thrown away or sold as forage mixed with roach and cottides. This is one of the reasons there are differences between the official statistics made by the Finnish Game and Fisheries Research Institute and those given in this work (Table 7).

The yield per recruit curves indicate that the catches probably wouldn't grow although the fishing mortality would, and that the biggest catches at

present growth are reached, if the recruitment age is kept at 4 years. The catches in Baltic herring trap nets and smelt trap nets are seldom equal size every year, and some years the overall recruitment age is closer to 5 years than to 4 years. Although the catches in smelt trap nets would dominate and the recruitment age would be 3 years, one cannot assume that larger catches in smelt trap nets is the reason for the decline in the total catches seen in the last years (Table 7). The reasons for the variations in catches has to be attributed to variations in recruitment and in the climatic circumstances during the short fishing season.

Engineering and dredging causes acidification over large areas and mass mortalities have disturbed the smelt fisheries several times (e.g. Anon. 1973, HUDD et al. 1983). The mass mortalities among adult fishes are only a visible sign of the problems that the mortalities among eggs and larvae cause several years later (e.g. HUDD 1982).

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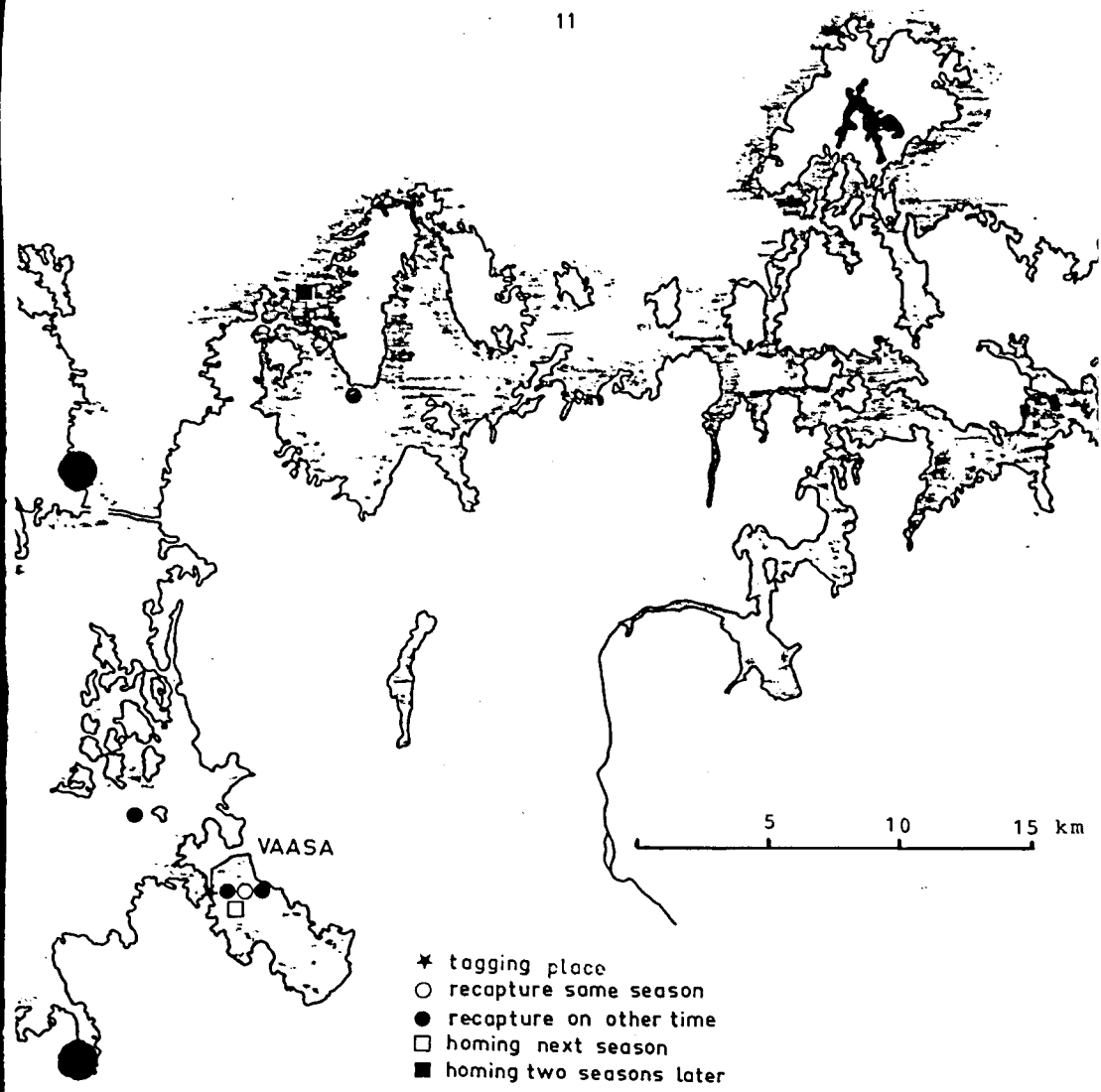

Figure 1. Recaptures of smelt tagged with the plastic flag tag in the inlet to the Vaasan eteläinen kaupunginselkä.

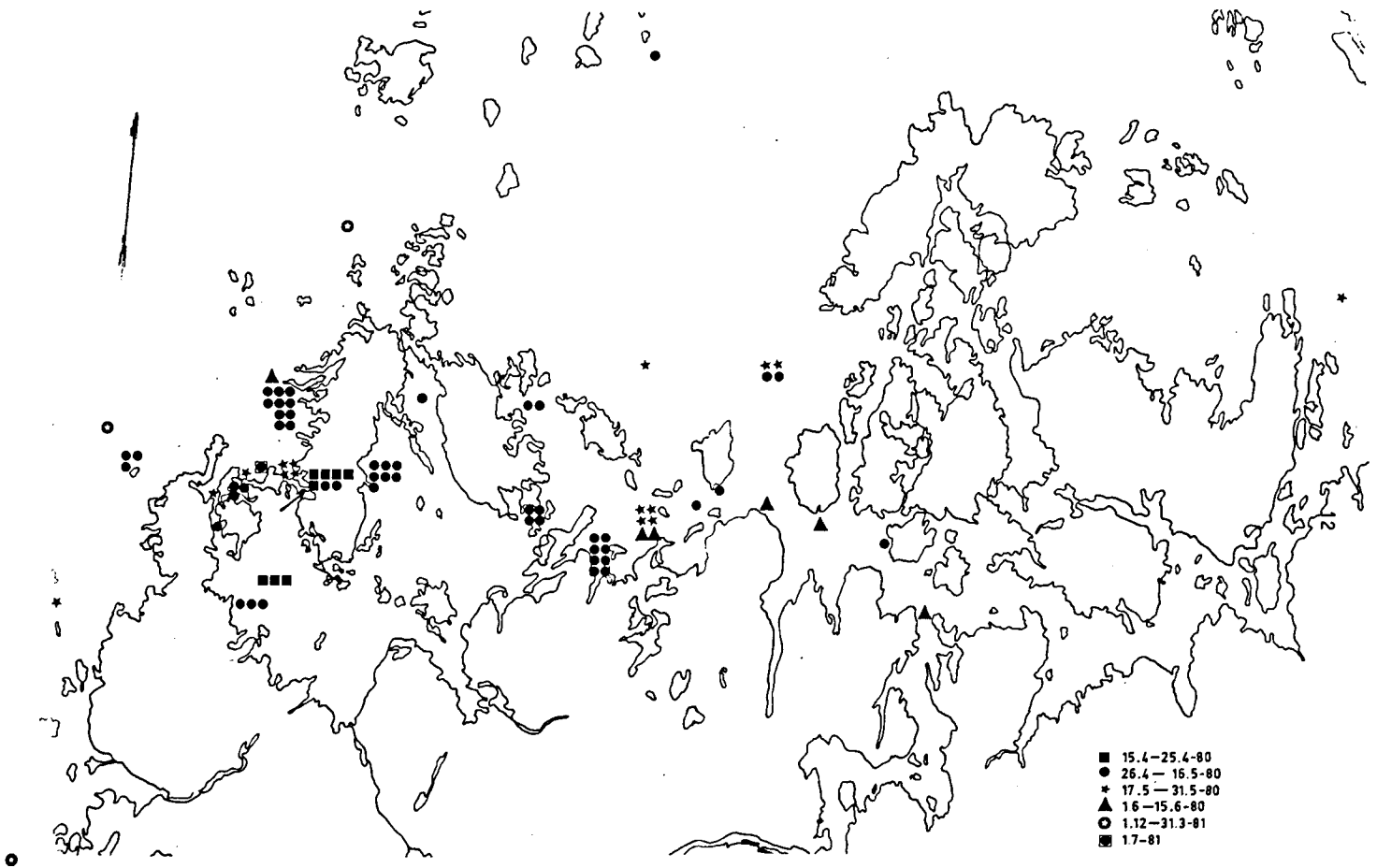

Figure 2. Recaptures of smelt tagged with the Lea tag in the inlet of the Köklotfjärden. The arrow indicates the tagging place.

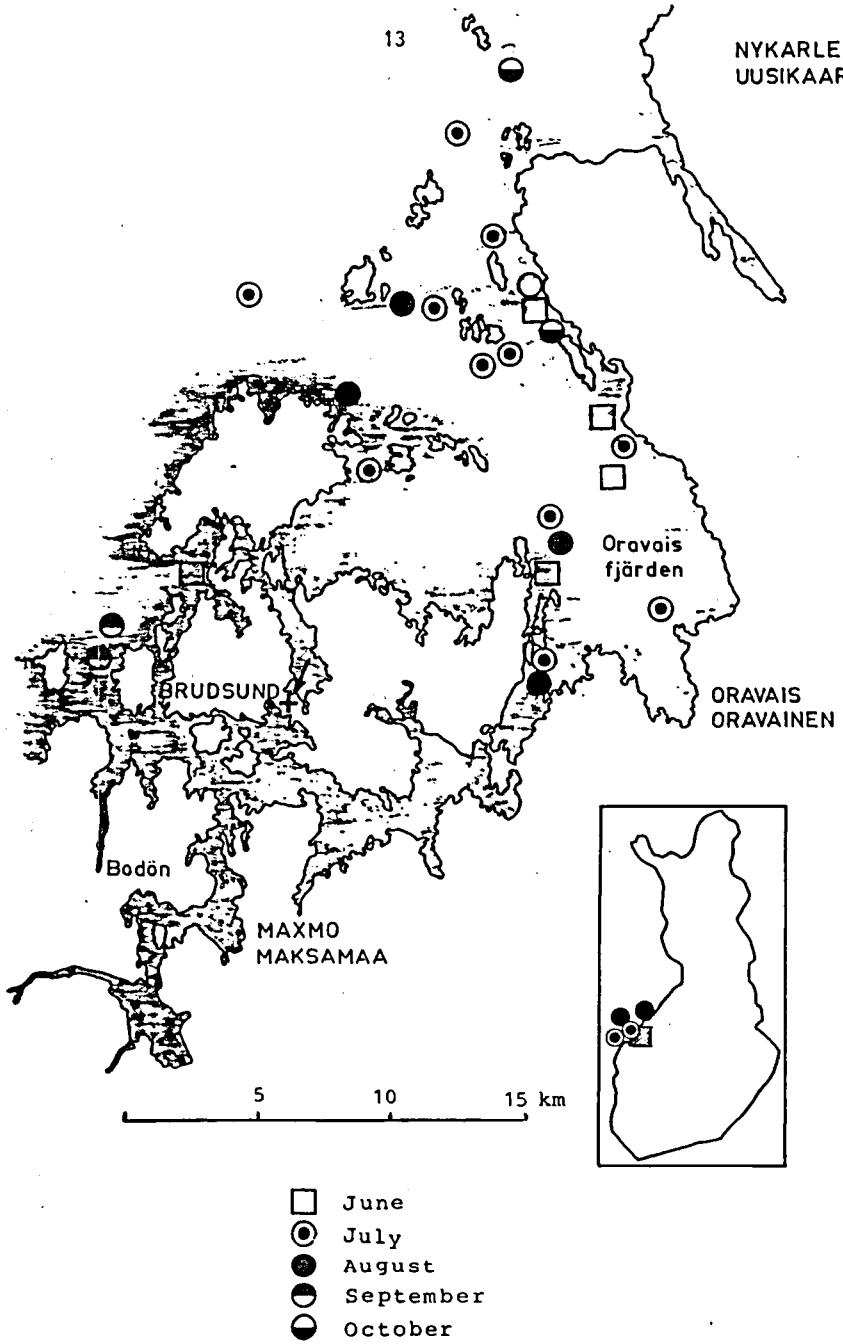

Figure 3. Recaptures of smelt tagged with the Lea tag in Maxmo archipelago off Kyrönjoki river.

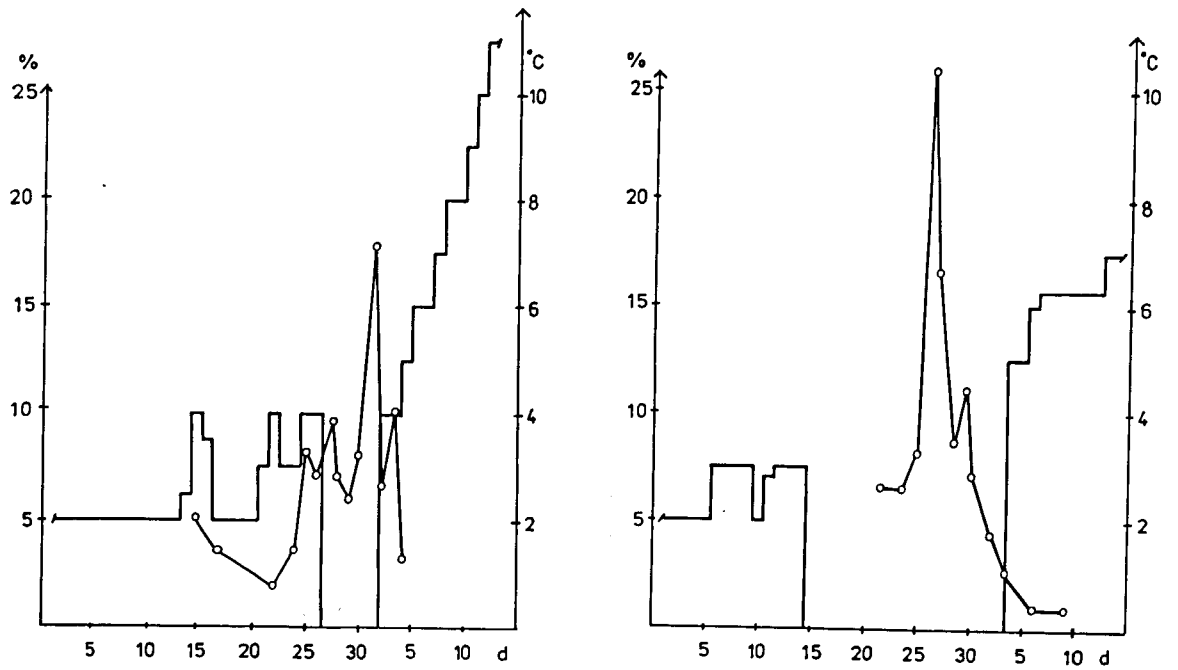

Figure 4. Water temperature (——) and smelt catches (—•—•—) during the upstream migration to the Vaasan etelainen kaupunginselkä for the periods 5.4.1976 - 10.5.1976 and 5.4.1978 - 10.5.1978. The smelt catch is shown as the percentage of the total catch in 3 trap nets.

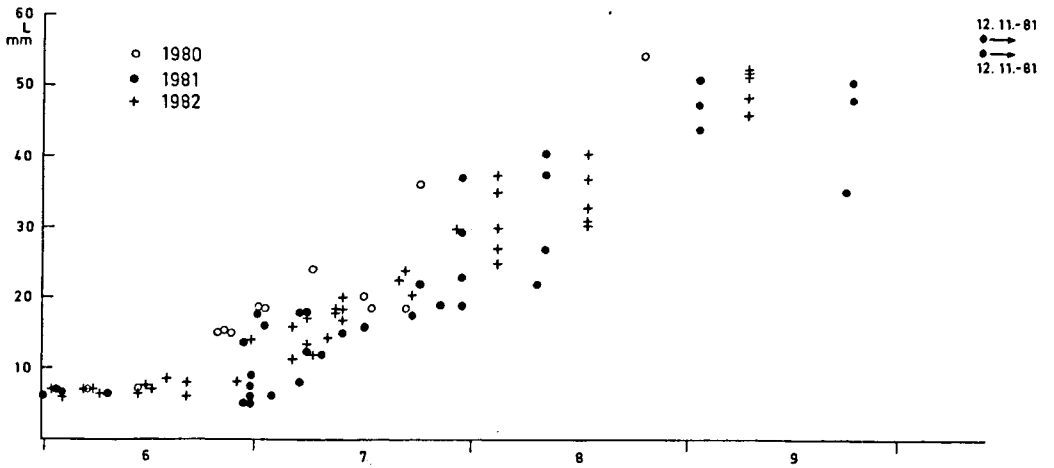

Figure 5. The growth of 0-year smelt in the years 1980-1982.

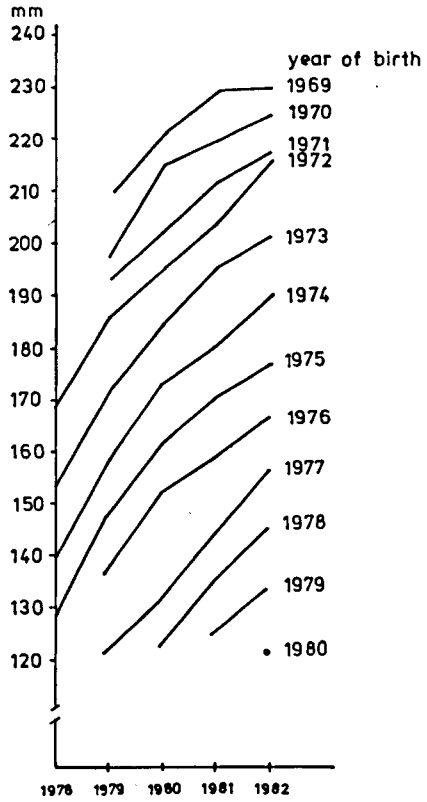

Figure 6. The mean lengths of year classes in samples from 1978 to 1982.

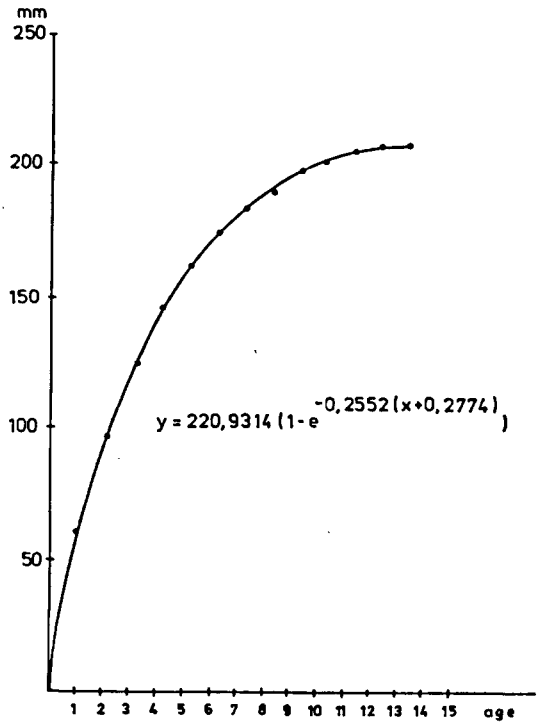

Figure 7. The growth in length according to von Bertalanffy's growth equation.

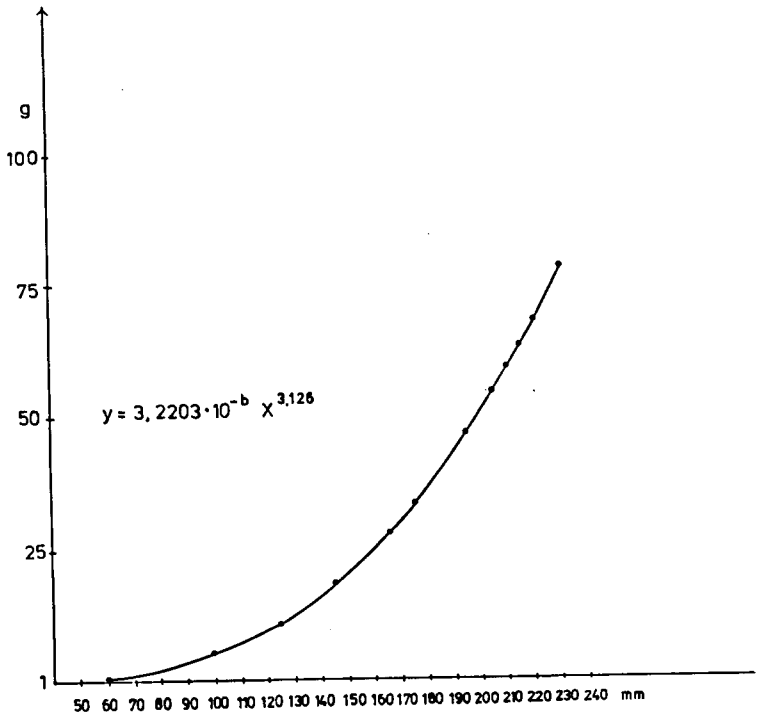

Figure 8. The weigth/length relationship of upstream migrating smelt.

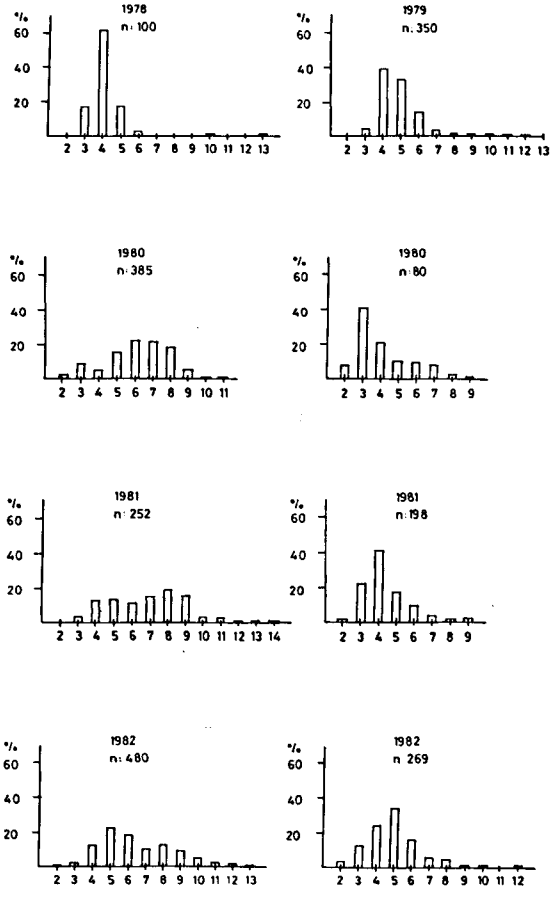

Figure 9. The age composition in the samples from 1978-1982. The left columns are from Baltic herring trap nets and the right columns from smelt trap nets.

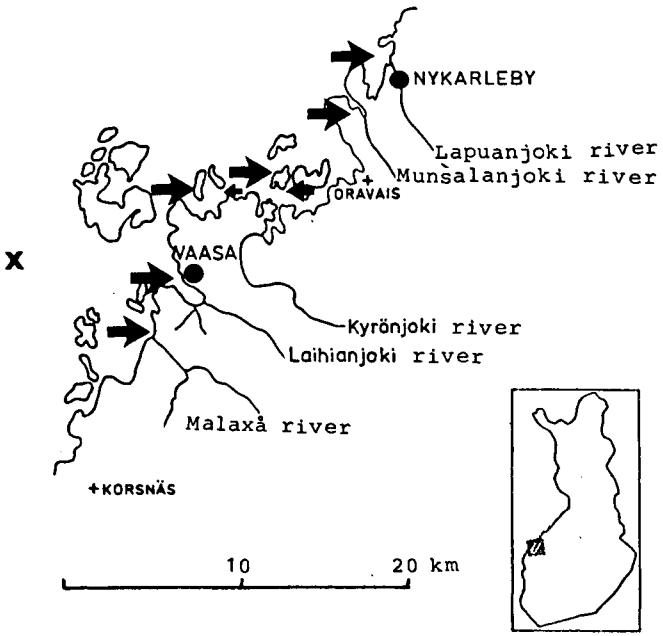

Figure 10. Smelt fishing areas. Arrows show trap net areas and x shows trawling areas. The sizes of arrows do not indicate the magnitude of the fishing nor the catches.

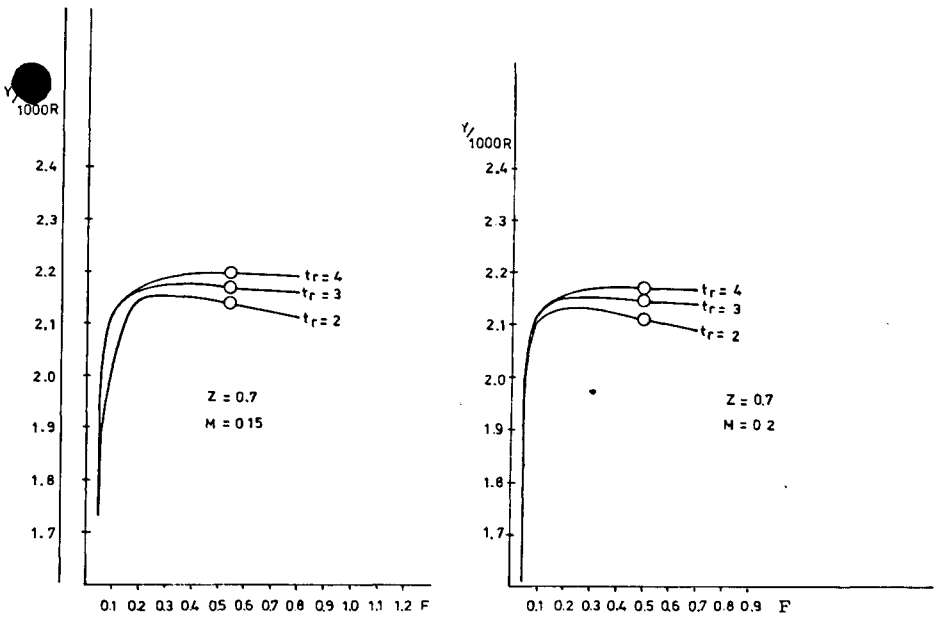

Figure 11. The Y/R-curves at present growth rate of the smelt in the Northern Quarken. The dots indicate the present rate of fishing mortality.

Table 1. The mean lengths and weights of age groups in the samples from 1978-1982.

	1978					1979					1980					1981					1982				
age	n	$\bar{x}_L$	s_L	$\bar{x}_W$	s_W	n	$\bar{x}_L$	s_L	$\bar{x}_W$	s_W	n	$\bar{x}_L$	s_L	$\bar{x}_W$	s_W	n	$\bar{x}_L$	s_L	$\bar{x}_W$	s_W	n	$\bar{x}_L$	s_L	$\bar{x}_W$	s_W
2	-					1	122.0	0	11.0	0	16	122.4	3.86	7.3	1.21	2	125.5	0	11.0	0	14	121.9		11.1	
3	17	128.4	6.07	12.6	2.10	19	136.9	4.26	13.7	2.69	66	131.6	6.50	12.7	2.04	54	134.8	2.39	14.8	2.48	34	133.9		15.5	
4	61	138.5	5.28	14.5	2.62	136	148.2	4.85	20.0	2.76	39	152.6	4.92	20.6	2.72	116	143.9	3.62	18.9	3.00	132	145.6		18.8	
5	17	153.2	5.07	20.4	3.34	113	159.2	5.34	25.0	3.28	68	162.1	5.03	25.4	3.04	68	159.2	4.16	24.6	3.85	201	157.1		24.1	
6	3	168.7	3.51	26.3	2.08	49	172.2	2.92	32.4	3.45	92	174.2	4.08	32.0	3.89	45	170.9	3.74	30.1	5.35	132	167.0		29.4	
7	-					14	186.6	5.16	41.8	6.42	87	184.8	3.01	38.5	4.17	52	180.7	4.88	36.8	4.86	66	177.6		35.9	
8	-					7	193.6	3.28	45.1	3.79	70	195.4	5.38	47.3	5.60	51	195.5	7.17	46.8	9.01	77	190.2		45.5	
9	-					3	198.3	8.50	32.7	12.12	20	202.5	5.25	54.4	5.61	44	204.7	7.38	54.7	8.11	47	201.5		53.4	
10	1	21.1	0	66.0	0	4	210.0	6.08	61.5	8.72	3	215.7	0	68.3	0	8	212.6	9.07	55.4	7.86	29	216.9		67.2	
11	-					3	224.0	7.07	70.7	12.73	4	222.0	4.51	67.8	6.93	7	220.1	6.17	66.9	8.05	13	218.0		68.1	
12	-					1	203.0	0	65.0	0	-					1	230.0	0	81.0	0	8	225.8		77.4	
13	-					-					-					1	247.0	0	71.0	0	1	230.0		88.0	
14	-					-					-					1	242.0	0	87.0	0	-				

Table 2. Trap net samples from 1978 to 1982 and the S value calculated from the falling part of the age composition.

sample		trap net	n	♀ %	S
Vaasa Sundom	4.5.1978	herring	100	21	0.27
Korsholm Köklot	11.4.1979	herring	100	42	0.46
Vaasa Sundom	30.4.1979	herring	100	28	0.58
Vaasa Sundom	17.4.1979	herring	100	36	0.54
Korsholm Köklot	3.5.1979	herring	50	46	0.54
Maxmo Brudsund	7.5.1980	smelt	80	21	0.55
Vaasa Sundom	10.4.1980	herring	100	61	0.32
Vaasa Sundom	28.4.1980	herring	101	50	0.47
Vaasa Sundom	29.4.1980	herring	102	71	0.57
Korsholm Köklot	15.4.1980	herring	82	54	0.65
Korsholm Köklot	23.4.1981	herring	154	60	0.50
Korsholm Köklot	14.5.1981	herring	98	80	0.31
Maxmo Särkimo	11.5.1981	smelt	100	23	0.54
Maxmo Särkimo	22.4.1981	smelt	98	33	0.38
Korsholm Köklot	11.5.1982	herring	118	85	0.57
Korsholm Köklot	26.4.1982	herring	140	55	0.66
Maxmo Brudsund	13.5.1982	smelt	135	39	0.40
Maxmo Särkimo	12.5.1982	smelt	134	24	0.52
Vaasa Sundom	4.5.1982	herring	106	42	0.58
Vaasa Sundom	10.5.1982	herring	119	45	0.61

Table 3. The total catch (tonnes) in smelt fisheries in the Northern Quark 1979-1982.

	1979	1980	1981	1982
trap net (spawning run)	160	191	56	106
by-catch in herring trap net fishing [1]	32	38	11	21
trawl	20	20	20	20
by-catch in gill net fishing	12	12	12	12
recreational fishing	8	8	8	8
total	232	269	95	155

1) given as 20 % of the catch during spawning run (according to interviews)

Table 4. The smelt catches in the inlet to the Vaasan eteläinen kaupunginselkä 1976-1982. The data on catch for 1976-1980 according to HÄSTBACKA and HUDD (1980) and on catch for 1981 from AXELL and HUDD (1981).

year	catch (kg)	catch/trap net	catch/trap net/day
1976	94 475	5 905 (n: 16)	
1977	18 275	1 828 (n: 10)	
1978	46 200	4 200 (n: 11)	
1979	5 345	1 336 (n: 4)	72
1980	29 465	5 892 (n: 5)	225
1981	4 340	2 170 (n: 2)	145
1982	6 640	1 328 (n: 5)	82

Table 5. The population parameters used for the smelt in the Northern Quark.

Age at recruitment (t_r)	3	4
Max. age in years (t_λ)	14	
Age at zero length (t_0)	- 0,2774	
Exponent of length weight equation (δ)	3,126	
Max. length (L_∞)	220,9	(247 observed)
Max. weight (W_∞)	68	(87 observed)
Growth coefficient (K)	0,2552	
Total mortality (Z)	0,70	
Natural mortality (M)	0,15	0,2
Fishing mortality (F)	0,55	0,5
Annual mortality (A)	0,50	

Table 6. The growth in length of the smelt in the Gulf of Finland (VOIGT 1972), Northern Quark and the northern part of the Bothnian Bay (TIMOLA 1970). The lengths from Northern Quark are 1978-1981 means.

age	VOIGT (1972) Tvärminne	Northern Quarken	TIMOLA (1970) Bothnian Bay
0		57	66,3
2	♂ 142,18 ♀ 140,4	122,7	116,6
3	♂ 157,28 ♀ 159,03	133,6	137,0
4	♂ 173,75 ♀ 180,80	147,1	151,4
5	♂ 185,57 ♀ 195,64	160,0	165,0
6	♂ 194,0 ♀ 230,0	172,9	174,0
7	♂ 230	183,6	
8		195,3	
9		203,8	
10		212,5	
11		221,5	
12		230	
13		247	
14		242	

Table 7. The total catch of smelt in the sea area between Oravainen and Korsnäs according to the statistics of the Finnish Game and Fisheries Research Institute and interviews with foragers and fishermen.

year	statistics tonnes	interviews tonnes
1976	303	
1977	155	
1978	236	
1979	98	232
1980	249	269
1981	74	95
1982		155