

Pohjois-Suomen Kalatutkimus 1975 (3-4): 41-66  
Ichthyologia Fennica Borealis 1975 (3-4): 41-66

Lind, E.A. & Kaukoranta, E. 1975: The pike, *Esox lucius* L., in the estuary of the Oulujoki river. II. Population. (Yhteenvedo: Oulujoen suiston hauki, *Esox lucius* L. II. Populaatio). - Ichthyol. Fenn. Borealis 1975 (3-4): 41-66.

Oulu 1975

The pike, *Esox lucius* L., in the estuary of the  
Oulujoki river. II. Population

E.A. Lind (ed.), Department of Zoology  
University of Oulu  
90100 Oulu 10  
Finland

E. Kaukoranta, Vesitekniikka Oy  
Fredrikink. 77 A  
00100 Helsinki 10  
Finland

I. Introduction	42
II. Study area and methods	43
III. Population	43
IV. Production	45
v. survival and mortality rates	48
VI. Energy ecology	50
vII. Catch statistics for Finland	52
vIII. Summary	56
IX. Yhteenveto	58
References	59
Figures	63

Oulu 1975

## I. Introduction

The "Synopsis of biological data on the pike, *Esox lucius* (Linnaeus 1758)" published by Toner & Lawler (1969) does not include some excellent population studies published later, e.g. Kipling & Frost (1970) and Backiel (1971). Neither does it include the data available for Finland.

The regional variation in the catch in Finland has been described by Liedes (1954) and Heikkinen (1960), and seasonal variations by Hurme (1959). The Finnish Game and Fisheries Research Institute, Fisheries Division (1974) has collected and published figures for the annual variation in the catch during the period 1962-1973. This material includes catches obtained from both fresh and brackish water. Catch statistics have been also presented for several large lakes (Lagom 1962, Pulkkinen 1965, Snehmeikka 1971, Mikkola 1972, Kaukoranta & Niemelä 1973, Uusimäki 1973, Ollila 1974).

Population densities in ponds have been determined by means of poisoning (Toivonen 1962, Toivonen et al. 1964, Wikgren 1963) and in rivers by means of electric fishing (Kännö 1968, 1971).

Brackish water populations have been studied by Gottberg (1917, 1922) in Åland, by Halme & Hurme (1952) and by Lehtonen (1972) at Helsinki and by Halme (1957, 1958), Halme & Korhonen (1960) and Korhonen (1961) at Tvärminne.

The purpose of this study is to describe the population structure of the species and some population parameters in the estuary of the Oulujoki river. On the basis of the population figures and the food coefficients a calculation for the food consumption is also performed. Some ecological characteristics of the fish are described separately in Part I (Kaukoranta & Lind, manuscript).

## II. Study area and methods

Study area. - The study area comprised the free section of the Oulujoki river ( $65^{\circ}$  N,  $25^{\circ}$  E), length approx. 3 km and area 190 ha, between the sea and the Merikoski power station. The main water and climate characteristics are described in Part I.

Methods. - The population was studied by means of tagging. The fish for tagging were caught during the spawning time in 1971. A total of 110 individuals, or 55 % of the fish tagged, had been recaptured by the end of 1974, the number of fish tagged and released having been 200. The methods of fishing, measurement, weighing and sex determination are described in Part I.

## III. Population

Sex ratio. - The following male-female ratios outside the spawning time have been reported: 47.1:52.9 (Gottberg 1917), 60.0:40.0 (Carbine 1944), 52.0:48.0 (Healy 1956), 46.2:53.8 (Toner & Lawler 1969) and 49.4:50.6 (Hakoköngäs 1971). The ratio in the study area was calculated from the samples caught for tagging. The results are presented in Table 1.

Table 1. Sex ratio by number in samples caught for tagging in 1971 and in the fish recaptured in 1971-1974. - Taulukko 1. Sukupuolijakautuma yksilöluvussa ja % toukokuussa 1971 merkittyjen ja v. 1974 loppuun mennessä merkittynä tavattujen kalojen perusteella.

	Number of fish (Kalojen lukumäärä)	%
Fish tagged in 1971 (Merkitty 1971)		
♂♂	138	69.0
♀♀	27	13.5
??	35	17.5
Total (Yhteensä)	200	100.0
Fish recaptured in 1971- 1974 (Merk. tav. 1971-1974)		
♂♂	73	66.4
♀♀	20	18.1
??	17	15.5
Total (Yhteensä)	110	100.0

The males were more numerous than the females, the male-female ratio by number being 83.6:16.4 in the fish tagged and 78.5:21.5 in the fish recaptured. The corresponding figures by weight were 75.5:24.5 and 71.5:28.5.

This ratio may be explained mainly on the basis of the spawning behaviour of the species. Many reports indicate that the males are predominant in the early run and females in later run (Carbine & Applegate 1946, Clark 1950, Healy 1956, Toner & Lawler 1969). The males remain in the spawning grounds for a longer time than the females (Svärdson 1947), having reached their maturity earlier (Svärdson, Toner & Lawler). Most fish were tagged in the study area in the early run, and the males were smaller than the females. The fish in this sample from 1971 were also smaller than in the total population, since the market price did not permit the purchase of many large individuals for tagging.

Population and population density. - The population by number in the study area was calculated using the formula presented by Robson & Regier (1968), and the population by weight on the basis of the average weight of the fish recaptured. Two separate calculations on the mature fish were made, and the results are presented in Table 2. The fish caught or known to have died before the recapturing periods are not included in the number of fish tagged.

The population thus amounted to an average of about 850 individuals by number and about 1 370 kg by weight, or 4.5 ind./ha and 7.2 kg/ha.

The following population densities have been reported for the species in lakes and ponds: about 120 ind./100 m of shoreline (Svärdson 1945), 9.6 kg/ha in game fish lakes and 6.1 kg/ha in coarse fish waters (Carlander 1955), 80 ind./ha and 5.4 kg/ha in a lake and 110 ind./ha and 23.6 kg/ha in a pond (Munro 1957), 1.5 kg/ha in ponds (Toivonen 1962, Toivonen et al. 1964), 28 ind./ha and 3.3 kg/ha in a pond (Wikgren 1963), 29 ind./ha and 46 ind./ha in two lakes (Seaburg & Moyle 1964), 0.9-3.1 kg/ha for the whole lake and 3.6-9.5 kg/ha and 2.5-8.3 ind./ha for water of depth less than 10 m

Table 2. Estimated size and density by number and weight of the population of adult fish in the study area in 1971-1972. The number of fish tagged amounted to 200 individuals, the average weight of the fish recaptured being 1.6 kg. No attention was paid to the sex ratio. (a)= Fish recaptured by trolling spoon during the period June-August 1971, number of survivors at the beginning of the period 164 individuals. (b)=Fish recaptured by gill nets in May 1972, number of survivors 72 individuals. - Taulukko 2. Sukukypsien kalojen populaation koko ja tiheys yksilöluvussa ja painossa Oulujoen suistossa v. 1971-1972. Merkitettyjen kalojen määrä oli 200 ja niiden keskipaino merkittynä tavattaessa 1.6 kg. Laskelmassa ei ole otettu huomioon sukupuolien lukumääräsuhteita. (a)=Kontrollipyynti uistimella kesä-elokuussa 1971, säilyneiden määrä kauden alussa 164 yks. (b)=Kontrollipyynti verkolla toukokuussa 1972, säilyneiden määrä pyyntikauden alussa 72 yks.

	(a)	(b)	Total (Yht.)
Number of fish caught (Kontr. kalojen määrä)	53	209	262
Number of fish recaptured (Merk. tav. määrä)	10	18	28
Population, ind. (Populaatio, yks.)	269	236	505
S.E.	240	163	202
Ind./ha (Yks./ha)	4.6	4.4	4.5
Population, kg (Populaatio, kg)	1390	1338	1365
S.E.	384	261	323
Kg/ha (Kg/ha)	7.3	7.0	7.2

(Kipling & Frost 1970), 5.3-13.3 kg/ha in a lake (Rudenko 1971, Gulin & Rudenko 1973).

The corresponding figures presented for rivers were as follows: 66 ind./ha (Solman 1954), 553 ind./ha and 11.5 kg/ha the average weight of the fish being about 20 g (Kännö 1968, 1971) and 6.4-7.3 kg/ha (Backiel 1971).

#### IV. Production

Fish production. - The production of the species in Lake Windermere has been estimated at 1.4-5.1 kg/ha/year

(Johnson 1966) or at about 1.3-3.7 tons/year or about 0.9-2.5 kg/ha/year (Kipling & Frost 1970). In the Vistula River the production of the fish was estimated at 1.2-1.8 kg/ha/year, the production of the gonads being 0.1 kg/ha/year (Backiel 1971), while in the Lake Demenets production amounted to 5.5 kg/ha/year according to Rudenko (1971) and to 3.7 kg/ha/year according to Gulin & Rudenko (1973).

The production in the study area was calculated on the basis of the population and growth rate, as presented by Ricker (1946), Allen (1950) and Chapman (1968). In addition, the production was determined on the basis of the standing crop and mortality rate. The results for production in terms of weight are presented in Table 3.

Some sources of error are worth mentioning. Some fish may lose their tags, and some fishermen do not send in the tags they have found. In addition, the population in the study area was a mixed one (Part I).

Table 3. Production in kg/year and in kg/ha/year in the study area during the growing season of 1971. The absolute growth/year for the males and females was 264 g and 599 g, the growth rates being 0.27 and 0.44 (Part I). The mortality rate was 0.75 (see below). - Taulukko 3. Haukituotanto kg/vuosi ja kg/ha/vuosi tutkimusalueella kasvukautena 1971. ♂: n absoluuttinen kasvu oli 264 g/v. ja ♀♀: n 599 g/v., kasvukertoimien arvot vastaavasti 0.27 ja 0.44 (Part I). Kuolevuus oli 0.75 (lähemmin jäljempänä).

	Kg/study area (Kg/tutkimus- alue)	Kg/ha
Growth rate x population (Kasvukerroin x populaatio)		
Sex ratio 78:22	435	2.3
- " - 50:50	505	2.7
Absolute growth x population (Abs. kasvu x populaatio)		
Sex ratio 78:22	288	1.5
- " - 50:50	368	1.9
Mortality rate x population (Kuolevuus x populaatio)		
First year mortality	996	5.2
Average - " -	1024	5.4

Table 4. Production of milt and roe in the study area in 1971-1972. The average weight of the male gonads was about 3 % of the body weight, and that of the female gonads about 19 %, according to Frost & Kipling (1967). The corresponding figures for Lake Oulujärvi, according to Hakoköngäs (1971), were about 1 % and 9 %. The number of eggs/female kg was about 28 400 (Toner & Lawler 1969). (a)=sex ratio 78:22 and (b)=sex ratio 50:50. - Taulukko 4. Maidin ja mädin tuotanto tutkimusalueella v. 1971-1972. maidin ja mädin paino oli keskimäärin n. 3 % ja n. 19 % kalan painosta (Frost & Kipling 1967). Oulujärvellä maitia oli n. 1 % ja mätiä n. 9 % kalan painosta (Hakoköngäs 1971). Mätimunia määrä/naaras-kg oli n. 28 400 (Toner & Lawler 1969). (a)=♂:♀-suhde 78:22 ja (b)=50:50.

	Kg/study area (Kg/tutkimusalue)		Kg/ha	
	(a)	(b)	(a)	(b)
Milt (Maiti)				
1 %	9.4	5.6	0.05	0.03
3 %	28.2	16.7	0.15	0.09
Roe (Mäti)				
9 %	34.7	72.8	0.18	0.38
19 %	73.3	153.7	0.39	0.81
Number of eggs in mill. (Mätimunia, milj.)	11.0	23.0	0.06	0.12

so that as a result the estimated production varied from 1.5 to 5.4 kg/ha/year, averaging 3.2 kg/ha/year. It is supposed that the figure providing the closest approximation to the true production was 2.7 kg/ha/year (Growth rate x population with sex ratio 50:50). On this basis the relationship production:standing crop amounted to about 0.37.

Production of gonads. - The production of milt and roe was calculated on the basis of the population, sex ratio, gonad weight and number of eggs. The results are presented in Table 4.

The different bases for the calculations resulted in a variation in the combined production of milt and roe from 0.2 to 1.0 kg/ha/year, or from 3.0 to 13.3 % of the standing crop of the mature fish. Correspondingly, The number of eggs spawned varied from about 60 000 to 120 000 eggs/ha/year. In Lake Mälaren the number of eggs spawned was estimated at about 14 Mill./550 m of shoreline (Svärdson 1945).



## V. Survival and mortality rates

Mature fish. - The survival and mortality rates for mature pike were studied by means of tagging, and calculated using the formula presented by Ricker (1958). The numbers of fish tagged and recaptured are presented in Table 5 and Fig. 1. The figure also shows the increase in length and weight during the period 1971-1974. Only combined rates for males, females and those individuals whose sex was unknown were included. The results are presented in Table 6.

In Minnesota the total mortality rate was calculated to be 0.50-0.85 (Toner & Lawler 1969), while the same source states that in a small Wisconsin lake the pike showed a 0.33-0.56 mortality. This implies a survival rate varying from 0.15 to 0.67. At Helsinki in the Gulf of Finland the survival rate was 0.15 and the mortality rate 0.85 (Lehtonen 1972). Most of these fish were transported from a distance of about 50 km, tagged and released at Helsinki. A total of only 7.5 % of the fish released were later recaptured. Thus the fish showed a tendency to "disappear". The survival and mortality rates in the study area were 0.25 and 0.75 respectively.

Table 5. Yearly variation in the number of fish recaptured during one year, from May to May in 1971-1974. The fish were tagged in May 1971, n=200. - Taulukko 5. Merkitynä tavattujen kalojen ajallinen jakautuma yhden vuoden jaksoissa tutkimuskaudella 1971-1974. 1 vuosi = aikaväli toukokuusta seuraavan vuoden toukokuuhun. kalat merkittiin toukokuussa 1971, n=200.

	n	% of fish tagged (% merk. määrästä)	% of fish recaptured (% merk. tav. määrästä)
1971-1972	83	41.5	75.5
1972-1973	22	11.0	20.0
1973-1974	4	2.0	3.6
1974-1975	1	0.5	0.9
Total (Yhteensä)	110	55.0	100.0

Table 6. Survival and mortality rates in mature pike in the study area determined on the basis of tagging. The material is presented in Table 5. - Taulukko 6. Oulujoen suiston hauen säilyvyys ja kuolevuus määritettynä merkin-  
töjen perusteella. Materiaali taulukossa 5.

	Survival rate (Säilyvyys)	Mortality rate (Kuolevuus)
1. year (1. vuosi)	0.27	0.73
2.       (2.       )	0.18	0.82
3.       (3.       )	0.25	0.75
(Average (Keskiarvo))	0.25	0.75
	Rate of ex- ploitation (Kalastuskuo- levuus)	Natural mor- tality rate (Luonnollinen kuolevuus)
1. year (1. vuosi)	0.42	0.31
2.       (2.       )	0.41	0.41
3.       (3.       )	0.44	0.31
Average (Keskiarvo)	0.42	0.33

The rate of exploitation and the natural mortality rate in the study area were 0.42 and 0.33. The last-mentioned figure does not differ from that presented by Kipling & Frost (1970), who calculated the instantaneous mortality rate to be 0.35 for males and 0.30 for females. On the other hand, exploitation at Helsinki was estimated at 0.11 and the natural mortality rate at 0.74. The rate of exploitation in the study area exceeds production. This is mainly due to the fact that several fish were caught soon after tagging. In addition, some fish were caught outside the study area.

Survival of eggs and fry. - Carpine (1944) has calculated the survival rate from the eggs to size 2-3 cm to be 0.04-0.44 %. Franklin & Smith (1963) did not notice any correlation between the density of the spawning population and the strength of the year-class. In a pond of 0.7 ha area 20 females and 44 males produced about 900 young in 1937, whereas 1 female and 5 males produced about 1 600 young in 1944 (Svärdson 1964). Montén (1948) reports the survival rate of eggs to fry in the spawning grounds to be 2-5 % and survival to a length of 0.9-1.3 cm to be 0.9 %.

The ratio between the adult pike population and the

number of eggs spawned in the study area varied from 0.004 to 0.008 in 1971-1972.

#### vI. Energy ecology

The position of the species in the ecosystem of fish generally is very important. This is true regarding both intraspecies and interspecies relations. This point of view, however, has only been studied in detail in recent years. The pike consumes a high percentage of the fish populations although itself forming a small part of the standing crop.

Literature review. - About 2 600 pike in two small lakes consumed about 112.5 tons of brown trout and a smaller amount of other fish in one year (Toner & Lawler 1969).

In Lake Windermere the species appears to have consumed about 47-63 % of the total fish production (Johnson 1966), though it was observed later that the total production amounted to 1.3-3.7 tons/year and the total food consumption of the adult pike to 6.1-14.7 tons/year (Kipling & Frost 1970).

The standing crop in the Vistula River amounted to 1.8-2.4 kg/ha, the production of fish to 1.2-1.8 kg/ha/year and that of gonads to 0.1 kg/ha/year, while the catch was 0.7 kg/ha/year and the food consumption of the fish 8.7-12.7 kg/ha/year (Backiel 1971).

The catch obtained from fresh water areas in Finland amounts to about 3 500 tons/year, or about 1 kg/ha/year. The consumption of fish by pike has been estimated at about 13.8 kg/ha/year (Lind 1971).

Fish consumed by pike in the study area. - It is known that the adult pike feeds almost exclusively on fish (e.g. Frost 1954, Healy 1956, Seaburg & Moyle 1964), and this is also true in the mouth of the Oulujoki river (Part I). Popova (1967) has calculated the food coefficient for the species in nature to be 8.8. The corresponding figure presented by Backiel (1971) is 6.7.

Table 7. Caloric content in cal./fresh g for muscle, liver, roe and milt in the pike caught from the study area in May 1974. - Taulukko 7. Tutkimusalueelta toukokuussa pyydystetyn hauen (n=5) lihaksen, maksan, mädin ja maidin kalorimäärä tuorepainon g kohti. Kalojen pituus oli 51.5-58.0 cm, keskimäärin 54.3 cm ja paino 0.8-1.3 kg, keskimäärin 1.0 kg. Käytetty laite Gallenkamp Automatic Adiabatic Bomb Calorimeter. Tulokset mittauksista on esitetty myös aikaisemmin kurssimonisteessa (Ellonen et al. 1974).

	n	Variation (Vaihtelu)	Average (Keskiarvo)
Muscle (Lihas)	29	910-1154	1113
Liver (Maksa)	2	1599-1709	1654
Roe (Mäti)	3	1685-1764	1728
Milt (Maiti)	4	587-815	734

On the basis of these coefficients and a production of about 500 kg/year, the food consumption can be calculated to amount to 3 390 - 4 450 kg/year, or 17.8-23.4 kg/ha/year. These figures represent the minimum ones. The following ratios may be presented:

Population : fish consumed	1 : 2.4-3.3
Mortality : - " -	1 : 3.3-4.3
Exploitation : - " -	1 : 5.9-7.8
Production : - " -	1 : 6.6-8.7
Natural mortality : - " -	1 : 7.4-9.8
Survival : - " -	1 : 9.9-13.0

Calorimetric measurements. - Some calorimetric measurements were performed on the pike caught from the study area during the period 21.-31.V.1974 (Gallenkamp Automatic Adiabatic Bomb Calorimeter). The length of the fish varied from 51.5 to 58.0 cm, averaging 54.3 cm, and the weight from 0.8 to 1.3 kg, averaging 1.0 kg. Caloric content was determined for muscle, liver, roe and milt. The results of the measurements are presented in Table 7.

On the basis of these measurements the energy flow on the population level was calculated. The results are presented in Fig. 2. The input and output of energy do not

balance, which is mainly due to the fact that the figures do not include fish reaching their maturity during the study period.

## VII. Catch statistics for Finland

Seasonal variation in catch. - The seasonal variation in catch for the study area is described in part I. It was observed that most fish were caught during the period May-August.

The seasonal variation in catch for the whole country has been described by Hurme (1959) on the basis of the commercial catch. The results are presented in Fig. 3.

There was a clear seasonal variation in the catch. Most fish were caught during the spawning time in April, May and June, when the catch amounted to about 40 % of the year's total. However, the species was caught throughout the year, and good catches were obtained especially in the winter.

Yearly variation in the catch. - The catch obtained from the fresh water areas of Finland amounted to 2 574 tons in 1953 and that from brackish waters to 1 773 tons, total 4 347 tons (Liedes 1954). The corresponding figures in 1959 were 3 841 tons, 1 985 tons and 5 826 tons (Heikkinen 1960). The yearly variation in the catch during the period 1962-1973 is presented in fig. 3 and Table 8.

The catch obtained from fresh water environments shows some decrease during the period 1962-1973. This decrease is not evident over the longer period 1953-1973, however. The rate of exploitation shows a considerable variation in different parts of the country. Thus the material presented by Nissinen (1965) indicates that in some lakes in central Finland the rate of exploitation may be high (about 75 % of the fish tagged were later recaptured) and the size of the fish small (0.1-1.0 kg). There are obvious signs of overexploitation in some fresh water basins.

The catch obtained from brackish water shows neither an increase nor a decrease during the period 1953-1973. The rate of exploitation, however, shows a considerable regional

Table 8. Yearly variation in the catch in tons obtained from the fresh and brackish water areas of Finland during the period 1962-1973 (Finnish Game and Fisheries Research Institute, Fisheries Division 1974). - Taulukko 8. Sisävesien ja meren haukisaaliin sekä kokonaissaaliin vaihtelu Suomessa ajalla 1962-1973 (Riista- ja kalatalouden tutkimuslaitos, Kalantutkimusosasto 1974). Saaliit tonneina.

	Fresh water (Sisävedet)	Brackish water (Meri)	Total (Yhteensä)
1962	5 146	1 854	7 000
1963	3 771	2 267	6 038
1964	3 173	1 969	5 142
1965	2 944	1 771	4 715
1966	2 882	1 668	4 550
1967	3 201	1 817	5 018
1968	4 136	1 842	5 978
1969	3 263	1 987	5 249
1970	3 315	1 645	4 960
1971	3 279	1 756	5 035
1972	3 286	1 988	5 272
1973	3 452	1 674	5 126
%	65.1	34.9	100.0
Min.	2 882	1 645	4 550
Max.	5 146	2 267	7 000
$\bar{x}$	3 490	1 869	5 360
S.E.	190	61	214

variation, from 0.11 at Helsinki (Lehtonen) to 0.42 at Oulu (this study). The number of fish recaptured was 12.6 % of the number tagged at Åland (Gottberg 1922). The corresponding figure at Tvärminne in 1957 was 31.1 % (Halme & Korhonen 1960). No overexploitation can be detected on the basis of these data.

Catch statistics for some large lakes. - Data collected for some large lakes are presented in Table 9.

The total catch obtained from these lakes varied from 5.6 to 75.7 kg/ha/year, averaging 21.4 kg/ha/year. The corresponding figures for the pike were 0.6-2.9 kg/ha/year and 1.8 kg/ha/year. The relative abundance of the pike also showed wide fluctuations, from 2.4 to 31.0 % of the total catch, averaging 15.3 %. It is true that some lakes were preferred by the pike. Those lakes which yielded a high percentage of pike, yielded only poor total catches, and vice versa.

Table 9. Total catch of fish and catch of pike in kg/ha and in percentages obtained from some large lakes in Finland. Material for the Lakes Rautavesi and Liekovesi from Lagom (1962), for Puruvesi from Pulkkinen (1965), for Pyhäjärvi T.P.l. from Shemeikka (1971), for Kallavesi from Mikkola (1972), for Lestijärvi from Uusimäki (1973), for Kiantajärvi from Kaukoranta & Niemelä (1973) and for Joukamojärvi from Ollila (1974). - Taulukko 9. Eräiden Suomen järvien kokonaissaalis ja haukisaalis kg/ha sekä haukisaalis % kokonaissaaliista. Materiaali seuraavista lähteistä: Rautavesi ja Liekovesi (Lagom 1962), Puruvesi (Pulkkinen 1965), Pyhäjärvi T.P.l. (Shemeikka 1971), Kallavesi (Mikkola 1972), Lestijärvi (Uusimäki 1973), Kiantajärvi (Kaukoranta & Niemelä 1973) ja Joukamojärvi (Ollila 1974).

	Total catch (Kokonais- saalis)	Catch of pike (Hauki- saalis)	%
Rautavesi 61° N, 23° E	11.1	2.9	25.9
Liekovesi " "	11.6	3.6	31.0
Puruvesi 62° N, 29° E	25.5	0.6	2.4
Pyhäjärvi T.P.l. 61° N, 22° E	75.7	2.9	3.8
Kallavesi 63° N, 28° E	5.6	1.5	26.8
Lestijärvi 64° N, 25° E	14.8	1.6	10.8
Kiantajärvi 65° N, 29° E	3.7	0.7	18.4
Joukamojärvi 66° N, 30° E	22.8	0.8	3.5
Average (Keskiarvo)	21.4	1.8	15.3

These differences may be explained partly on the basis of differences in carrying capacity, and partly on the basis of the food consumed by the species. The food coefficients are presented above. They mean that the average quantity of small fish consumed by the pike amounts to about 12.2-15.8 kg/ha/year. These figures, however, represent the minimum ones, since the natural mortality rate is excluded (see also Lind 1974).

Regional variation in catch in Finland. - The regional variation in the catch is treated on the basis of the material presented by Heikkinen (1960). The catch of pike in 1959 amounted to 5 826 tons, the distribution of which between the different areas of fresh and brackish water is presented in detail in Tables 10 and 11 and in Fig. 4.

The relative abundance of the species was 20.2 % in fresh water, and 4.2 % in brackish water. This difference was statistically significant ( $t=7.17$ ;  $p < 0.01$ ).

Table 10. Catches obtained from different areas of fresh and brackish water as percentages of the total catch in 1959 (material from Heikkinen 1960). - Taulukko 10. Sisävesien ja meren haukisaaliin alueellinen vaihtelu v. 1959 %:ina kokonaissaaliista Heikkisen (1960) esittämän materiaalin perusteella.

	Fresh water (Sisävedet)	Brackish water (Meri)
n	18	13
Min.	12.6	1.1
Max.	35.0	20.6
$\bar{x}$	20.2	4.2
S.E.	1.68	1.48

The total absolute catch obtained from the fresh water areas was greater than that from the brackish water areas, and similarly the catch/region was greater from the fresh water areas than from the brackish water areas. This difference, however, was not statistically significant. There was also a clear regional variation in the catch, most fish being caught from the southern and central parts of the country.

The average catch obtained from fresh water environments amounted to about 1.2 kg/ha/year in 1959, and to about 1.1 kg/ha/year during the period 1962-1973.

Table 11. Regional variation in the catch in tons obtained from different areas of fresh and brackish water in 1959 (material from Heikkinen 1960). - Taulukko 11. Sisävesien ja meren haukisaaliin alueellinen vaihtelu v. 1959 Heikkisen (1960) esittämän materiaalin perusteella. Saalis- määrät tonneina.

	Fresh water (Sisävedet)	Brackish water (Meri)	Total (Yhteensä)
n	18	13	31
Min.	31	19	19
Max.	558	556	558
$\bar{x}$	213	153	188
S.E.	37	45	30
Total (Yhteensä)	3 841	1 985	5 826



Food consumption. - The quantity of food consumed by the species was calculated on the basis of the food coefficients presented by Popova and Backiel and of the catch figures.

It amounted to about 13 300 - 17 500 tons/year in the brackish waters and to about 25 700 - 33 800 tons/year in the fresh waters, total 39 000 - 51 300 tons/year. The food consumed by the species in fresh water habitats amounted to about 8.0-10.5 kg/ha/year. These figures, as stated above, represent the minimum ones. This means that the pike plays an important role in the ecosystem of fish, especially in fresh waters.

It should be mentioned that the total catch of fish in 1959 amounted to about 66 000 tons, of which the brackish water areas yielded about 47 000 tons and the fresh water areas about 19 000 tons. The average catch/ha obtained from fresh water in 1959 amounted to about 5.9 kg/ha.

#### VIII. Summary

The study area comprised the free section of the Oulujoki river between the sea and a power station (65° N, 25° E). The population was studied by means of tagging. A total of 110 individuals, or 55 % of the 200 fish tagged in May 1971, had been recaptured by the end of 1974. Food consumption was studied by means of food coefficients and production figures. Some calorimetric measurements were performed.

The male-female ratio by number during the spawning time was 83.6:16.4 in the fish tagged and 78.5:21.5 in the fish recaptured. The factors affecting this ratio are discussed. The average population density amounted to about 4.5 ind./ha and 7.2 kg/ha. The estimated total fish production was about 2.7 kg/ha/year, or about 37 % of the standing crop, and the gonad production 0.2-1.0 kg/ha/year, or about 3-13 % of the standing crop.

The number of eggs spawned amounted to about 60 000 - 120 000 eggs/ha/year. The survival of these to mature fish was estimated at about 0.004-0.008 %. The survival and mortality rates for mature fish were 0.25 and 0.75 and the corresponding rates for exploitation and natural mortality were 0.42 and 0.33.

The food consumed by the species in the study area was calculated on the basis of food coefficients and production. This amounted to about 18-23 kg/ha/year, or about 20-26 Mill. Kcal/ha/year. These figures, however, represent the minimum ones.

The annual catch of pike obtained from the brackish water areas of Finland during the period 1962-1973 amounted to 1 900 tons, and that from the fresh water areas to 3 500 tons, or 1.1 kg/ha/year, total 5 400 tons, or about 4 %, 20 % and 9 % of the total catch of fish respectively.

The food consumed by the species amounted to about 13 000 - 18 000 tons in brackish water and to about 26 000 - 34 000 tons in fresh water, or about 8-11 kg/ha/year, total 39 000 - 51 000 tons. These figures for food consumption similarly represent the minimum ones.

Acknowledgements. - We are indebted to Cand. Med. Leena Parkkinen who was responsible for the majority of the recapturing of the fish, and Phil. Cand. Sisko Hyrynkangas for the calorimetric measurements. Mr. Malcolm Hicks, M.A. deserves our grateful thanks for checking the language of this paper. The field work in 1971-1973 was supported by grants from the Oulu Osakeyhtiö cellulose factory and from the National Science Council.

## IX. Yhteenveto

E.A. Lind & E. Kaukoranta: Oulujoen suiston hauki,  
*Esox lucius* L. II. Populaatio.

Tutkimus suoritettiin Oulujoen suistossa alimman voimalaitoksen ja meren välillä ( $65^{\circ}$  N,  $25^{\circ}$  E). Toukokuussa 1971 merkittiin 200 yksilöä, joista 110 yks. eli 55 % merkittyjen määrästä tavattiin v. 1974 loppuun mennessä. Populaatiota ja sen rakennetta tutkittiin näiden tietojen perusteella. Ravinnon kulutus laskettiin ravintokertoimien ja tuotannon perusteella. Lisäksi suoritettiin kalorimetrisiä mittauksia.

merkittyjen kalojen  $\sigma$ : $\sigma$ -suhde oli 83.6:16.4 ja merkittynä tavattujen 78.5:21.5. Jakautumaa pohditaan tekstissä. Populaation tiheys oli n. 4.5 yks./ha ja 7.2 kg/ha. Kalan kokonaistuotannoksi laskettiin n. 2.7 kg/ha/v. eli 37 % massasta. Gonadien tuotanto oli vastaavasti 0.2-1.0 kg/ha/v. ja 3-13 %.

Kudussa vapautettujen mätimunien määräksi saatiin 60000-120000 kpl./ha/v. Näiden säilyvyys sukukypsäksi kalaksi oli 0.004-0.008 %. Täysikasvuisten kalojen säilyvyys oli 0.25 ja kuolevuus 0.75. kalastuskuolevuus nousi arvoon 0.42 ja luonnollinen kuolevuus arvoon 0.33.

Käytetyn ravinnon määräksi laskettiin 18-23 kg/ha/v., mikä vastaa 20-26 milj. Kcal/ha/v. nämä arvot ovat kuitenkin minimiarvoja.

Meren haukisaalis oli keskimäärin 1 900 tonnia v. 1962-1973 ja sisävesien 3 500 t., yhteensä 5 400 t. Luvut tekevät kokonaiskalansaaliista n. 4 %, n. 20 % ja n. 9 % mainittujen ryhmien osalta. Tiheytenä sisävesien haukisaalis oli n. 1.1 kg/ha/v. Käytetyn ravinnon määräksi saatiin 13000-18000 t. meren ja 26000-34000 t. sisävesien osalta, yhteensä 39000-51000 t. Sisävesillä kulutettu ravinto vastaa n. 8-11 kg/ha/v., joten näillä alueilla hauen merkitys kalojen ekosysteemissä on keskeinen. Myös nämä kulutuslukemat edustavat minimiarvoja.

## References

- Allen, K.R. 1950: The computation of production in fish populations. - New Zealand Sci. Rev. 8: 89.
- Backiel, T. 1971: Production and food consumption of predatory fish in the Vistula River. - J. Fish Biol. 3: 369-405.
- Carbine, W. 1944: Egg production of the northern pike, *Esox lucius* L., the percentage survival of eggs and young on the spawning grounds. - Pap. Mich. Acad. Scient. 29: 123-137.
- Carbine, W. & Applegate, V. 1946: The movement and growth of marked pike (*Esox lucius* L.) in Houghton Lake and the Musketon River. - Pap. Mich. Acad. Scient. 32: 215-238.
- Carlander, K.D. 1955: The standing crop of fish in lakes. - J. Fish. Res. Bd Canada 14 (4): 543-570.
- Chapman, D.W. 1968: Production. - In: Ricker, W.E., Methods and assesment of fish production in fresh waters: 182-196 pp. Birkenhead.
- Clark, C.F. 1950: Observations on the spawning habits of the northern pike, *Esox lucius*, in north western Ohio. - Copeia 1950 (4): 285-288.
- Ellonen, T., Hyryn kangas, S., Joensuu, O., Juola, M., Kaukoranta, E., Lind, M.A. & Salmela, R. 1974: Suomen vesieläimistön tuntemisen ja ekologian kenttäkurssi 1974. - Kurssimoniste 107 pp. Oulu.
- Finnish Game and Fisheries Research Institute, Fisheries Division 1974: Kalastus vuonna 1962-1973. (Fishing in 1962-1973). - Suomen Kalatalous 47: 26-49.
- Franklin, D.R. & Smith, L.L. Jr. 1963: Early life history of the northern pike with special reference to the factors influencing the numerical strength of year class. - Trans. Amer. Fish. Soc. 92 (2): 91-110.
- Frost, W.E. 1954: The food of pike, *Esox lucius* L., in windermere. - J. Anim. Ecol. 23: 339-360.
- Frost, W.E. & Kipling, C. 1967: A study of reproduction, early life, weight-length relationship and growth of pike, *Esox lucius* L., in Windermere. - J. Anim. Ecol. 36: 651-693.

- Gottberg, G. 1917: Om gäddans tillväxt i Ålands skärgård.  
- Suomen kalatalous 4: 191-211.
- Gottberg, G. 1922: Om gäddans vandringar i Ålands skärgård. - Fiskeritidskr. Finland 30: 1-6.
- Gulin, V.v. & Rudenko, G.P. 1973: Procedure for assessment of fish production in lakes. - J. Ichthyol. 13: 813-823.
- Hakoköngäs, M. 1971: Hauen, *Esox lucius* L., biologiasta vuoden eri aikoina. - Pro gradu-tutkielma, 50 pp. Oulu.
- Halme, E. 1957: Gäddmärkningar utförda av Timmerö Spinnfiskeklubb r.f. - Fiskeritidskr. Finland 1: 8-15.
- Halme, E. 1958: Timmerö Spinnfiskeklubb RF:n suorittamat hauenmerkinnät. - Suomen Kalastuslehti 65: 35-41.
- Halme, E. & Hurme, S. 1952: Tutkimuksia Helsingin rannikkoalueen kalavesistä, kaloista ja kalastusoloista. - Helsingin Kaup. Julk. 3: 1-157.
- Halme, E. & Korhonen, M. 1960: Haukien vaelluksista rannikkolamme. - Kalamies 1960 (4): 3.
- Healy, A. 1956: Fishes of Lough Rea, co. Galway, Ireland. 2. Pike and rudd with general conclusions. - Salm. Trout. mag. 148: 246-249.
- Heikkinen, J. 1960: Suomen kalansaalistilasto vuodelta 1959. - Maataloush. Kalatal. Tutkimust. Julk. 11: 1-110.
- Hurme, S. 1959: Tutkimus Suomessa kauppaan tulleen kalan kausivaihtelusta. - Maataloush. Kalatal. Tutkimust. Julk. 7: 1-219.
- Johnson, L. 1966: Consumption of food by the resident population of pike, *Esox lucius*, in Lake Windermere. - J. Fish. Res. Bd Canada 23: 1523-1535.
- Kaukoranta, E. & Niemelä, A. 1973: Kiannan reitin nippu-uitoväylän kuntoonpanosuunnitelmaan liittyvä kalatalousselvitys. - Suunnittelukortees Oy, 48 pp. Oulu.
- Kaukoranta, E. & Lind, E.A. manuscript: Pike, *Esox lucius* L., in the mouth of the Oulujoki river. I. Ecology. (Yhteenveto: Oulujoen suiston hauki, *Esox lucius* L. I. Ekologia).
- Kipling, C. & Frost, W.E. 1970: A study of the mortality, population numbers, year class strengths, production and food consumption of pike, *Esox lucius* L., in Windermere from 1944 to 1962. - J. Anim. Ecol. 39: 115-157.
- Korhonen, M. 1961: Hauki, *Esox lucius*. - In: Pitkänen, H.

- Suuri kalakirja: 136-148 pp. Helsinki.
- Kännö, S. 1968: Kalojen runsaussuhteista Paimionjoen koskipaikoissa. - Luonnon Tutkija 72: 88-94.
- Kännö, S. 1971: Piirteitä kalojen ja ympyräsuisten esiintymisestä eri tyyppisissä lounaissuomalaisissa joissa. (Summary: Aspects of the occurrence of fishes and cyclostomates in different types of rivers in southwestern Finland). - Turun Ylioppilas 15: 65-107.
- Lagom, T. 1962: Rauta- ja Liekoveden kaloista. - Maataloush. Kalatal. Tutkimust. Julk. 20: 1-65.
- Lehtonen, H. 1972: Kalanmerkkintätuloksia Helsingin merialueella. (Summary: The results of fish-tagging in Helsinki sea area). - Helsingin Kaup. Rakennusv. vesiensuojelulab. tied. 4 (9): 1-111.
- Liedes, M. 1954: Kalansaalis ja sen arvo vuonna 1953. - Suomen Kalastuslehti 61: 175-180.
- Lind, E.A. 1971: Suomi haukituotannossa maailman kärkipäässä. (Referat: Berechnung über die Produktion der Hechte, *Esox lucius* L., und die Konsumption ihrer Beutefische in den Binnengewässern Finnlands). - Kainuun Sanomat 1971 (6): 4.
- Lind, E.A. 1974: Fish production in some Finnish lakes determined on the basis of catch statistics and food coefficients. (Eräiden suomalaisten järvien kalantuotanto saalistilastojen ja ravintokertoimien perusteella). - Kallottialueen Rauhanpäivät 5.-7.7.1974 Rovaniemi: 8 pp.
- Mikkola, H. 1972: Kallaveden vesistöalueella harjoitettava kalastus ja vesien tila kalatalouden kannalta. - Kuopion vesipiirin Vesitoimisto 1972: 1-43.
- Montén, E. 1948: Undersökningar över gäddynglets biologi och några därmed sammanhängande problem. - Skr. S. Sveriges Fisk. Fören. 1: 3-38.
- Munro, W.R. 1957: The pike of Loch Choin. - Freshw. Salm. Fish. Res. 16: 1-16.
- Nissinen, T. 1965: Hauenmerkkintää pohjois-Savossa. - kalatal. Tutkimust. tied. 1965 (1): 9-45.
- Ollila, A. 1974: Joukamojärven käyttö- ja hoitosuunnitelma. - Oulun Maatalouskeskus, 26 pp. Oulu.
- Popova, O.A. 1967: The "Predator-prey" relationship among

- fishes. - In: Gerking, S.D., The biological basis of freshwater fish production: 359-376 pp. Dorking-Oxford.
- Pulkkinen, V. 1965: Puruveden kalastusoloista. - Suomen Kalastuslehti 72: 184-190.
- Ricker, W.E. 1946: Production and utilization of fish populations. - Ecol. Monog. 16: 373-391.
- Ricker, W.E. 1958: Handbook of computations for biological statistics of fish populations. - Fish. Res. Bd Canada, Bull. 119: 1-300.
- Robson, D.S. & Regier, H.A. 1968: Estimation of population number and mortality rates. - In: Ricker, W.E., Methods and assessment of fish production in fresh waters: 124-158 pp. Birkenhead.
- Rudenko, G.P. 1971: Biomass and abundance in a roach-perch lake. - J. Ichthyol. 11: 524-535.
- Seaburg, K.G. & Moyle, J.B. 1964: Feeding habits, digestion and growth of some Minnesota warm water fishes. - Trans. Amer. Fish. Soc. 93 (3): 269-285.
- Shemeikka, P. 1971: Pyhäjärvi Tl. - eräs kalavesi. - Kalamies 1971 (1): 3.
- Solman, V.E.F. 1954: The ecological relations of pike, *Esox lucius* L., and waterfowl. - Ecology 26: 157-170.
- Svärdson, G. 1945: En gäddlek i siffror. - Svensk. Fisk. Tidskr. 54: 187-192.
- Svärdson, G. 1947: Gäddlekstudier. - Skrift. S. Sveriges Fören. 2: 34-59.
- Svärdson, G. 1964: Gäddan. - Fiske 1864: 8-38.
- Toivonen, J. 1962: Kokemuksia rotenonmyrkytyksistä. - Suomen Kalastuslehti 69: 172-177.
- Toivonen, J., Tuunainen, P. & Peippo, L. 1964: Rotenonmyrkytysten avulla saatuja tietoja eräiden lampien kalakannoista ja niihin vaikuttavista tekijöistä. - Suomen Kalastuslehti 71: 156-164.
- Toner, E.D. & Lawler, G.H. 1969: Synopsis of biological data on the pike, *Esox lucius* (Linnaeus 1758). - FAO Fish Synopsis 30 (1): 1-39.
- Uusimäki, v. 1973: Muistio Lestijärven kalastuksesta v. 1972. Moniste 10 pp. Toholampi.
- Wikgren, B.-O. 1963: Resultaten av rotenonbehandlingen av Strömma Tjejan. - Husö Biol. Stat. Meddel. 6: 1-28.

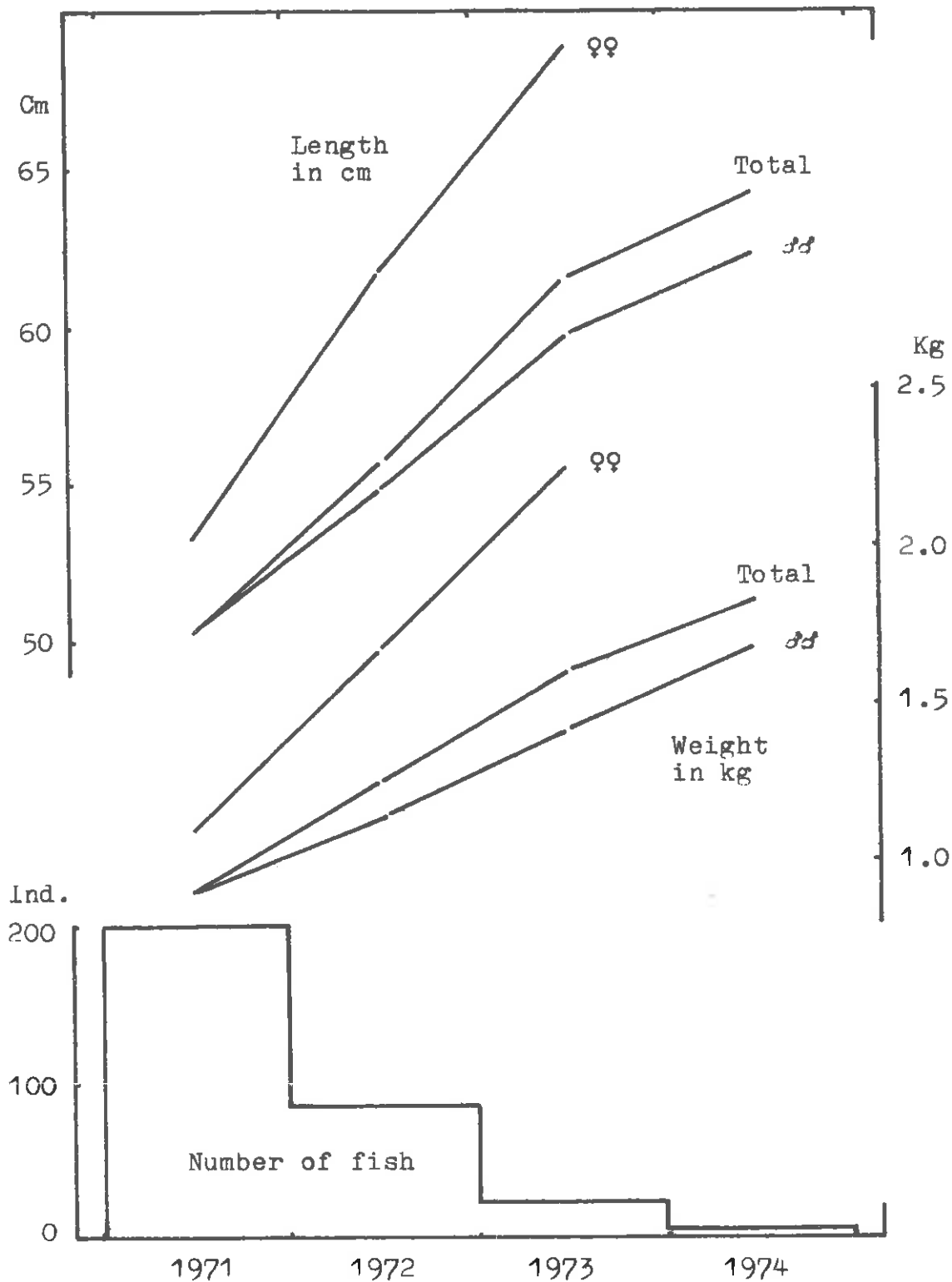


Fig. 1. Above, length of the fish tagged in 1971 and recaptured in 1972-1974. Centre, weight of the same fish. Below, number of fish tagged in 1971 and number of recaptured in 1972-1974. Horizontally, years, vertically, length in cm, weight in kg and number of fish. - Kuva 1. Ylhäällä toukokuussa 1971 merkittyjen ja v. 1972-1974 merkittynä tavattujen kalojen pituus sekä keskellä samojen kalojen paino. Alhaalla v. 1971 merkittyjen ja v. 1972-1974 merkittynä tavattujen kalojen lukumäärä. Vaakasuunnassa vuodet, pystysuunnassa pituus cm ja paino kg sekä kalojen lukumäärä.



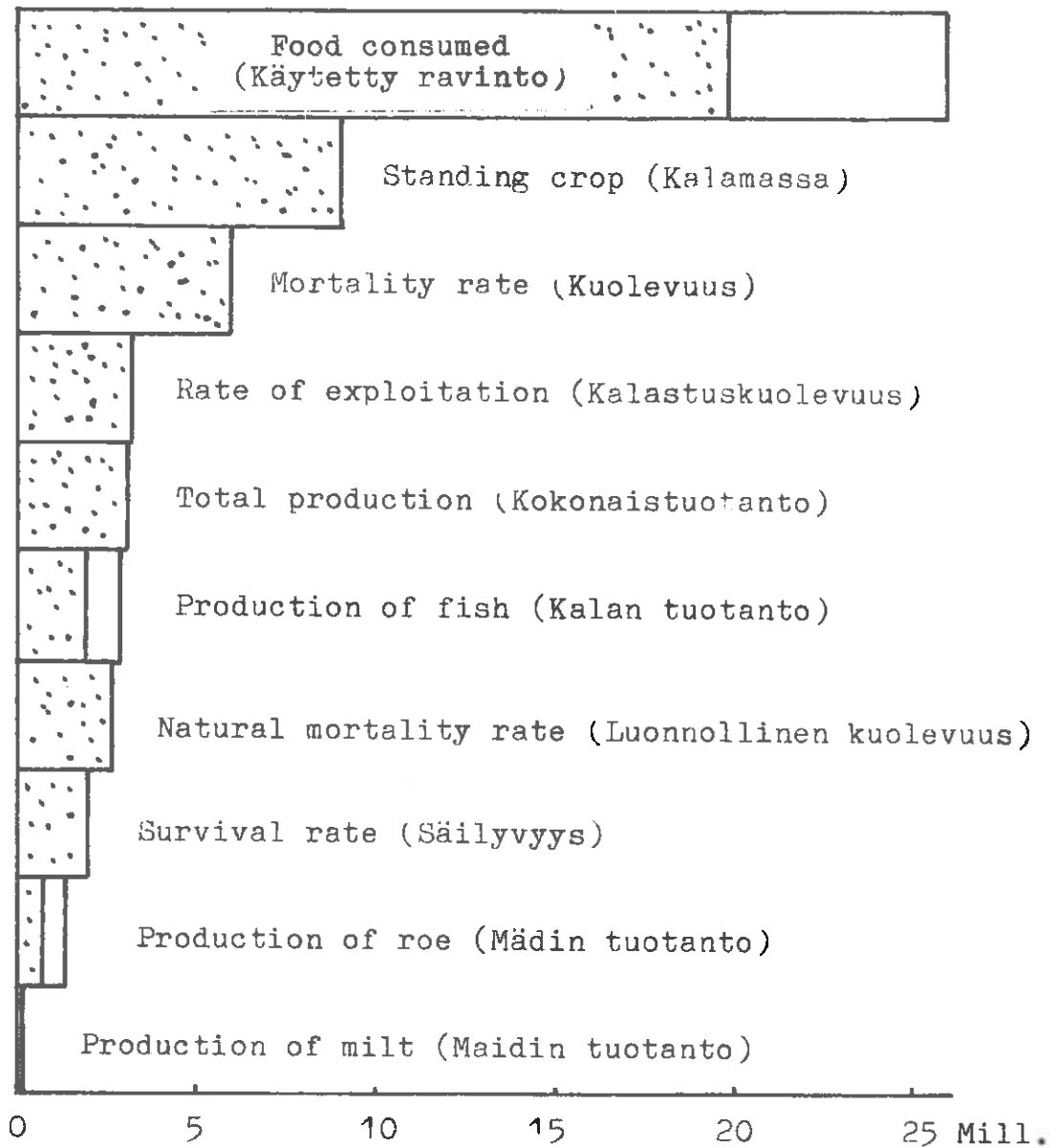


Fig. 2. Energy flow in Mill. Kcal/ha/year in the study area on the population level. The calorimetric measurements were made from five mature individuals caught from the study area in May 1974. The different categories of energy flow are determined on the basis of the fish tagged in 1971 and recaptured during the period 1971-1974. Only mature fish are included. - Kuva 2. Energiavirrat milj. Kcal/ha/vuosi tutkimusalueella populaatiotasolla. Kalorimetriset mittaukset on tehty viidestä alueelta toukokuussa 1974 pyydystetystä hauesta. Energiavirtojen osa-alueiden suuruudet on määritetty toukokuussa 1971 merkittyjen ja myöhemmin merkittynä tavattujen kalojen perusteella. Mukana vain sukukypsät yksilöt, asteikko alhaalla.

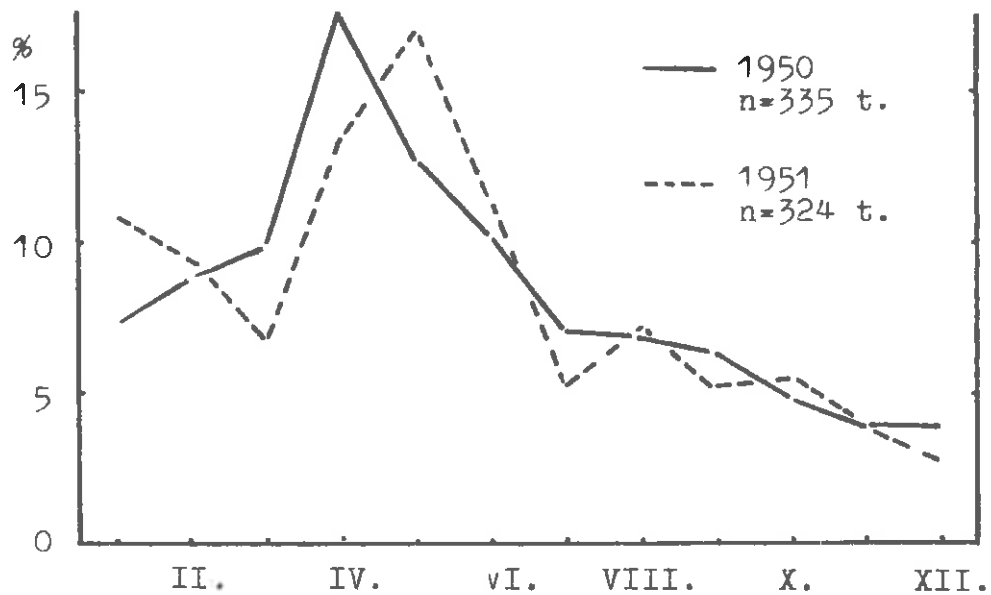
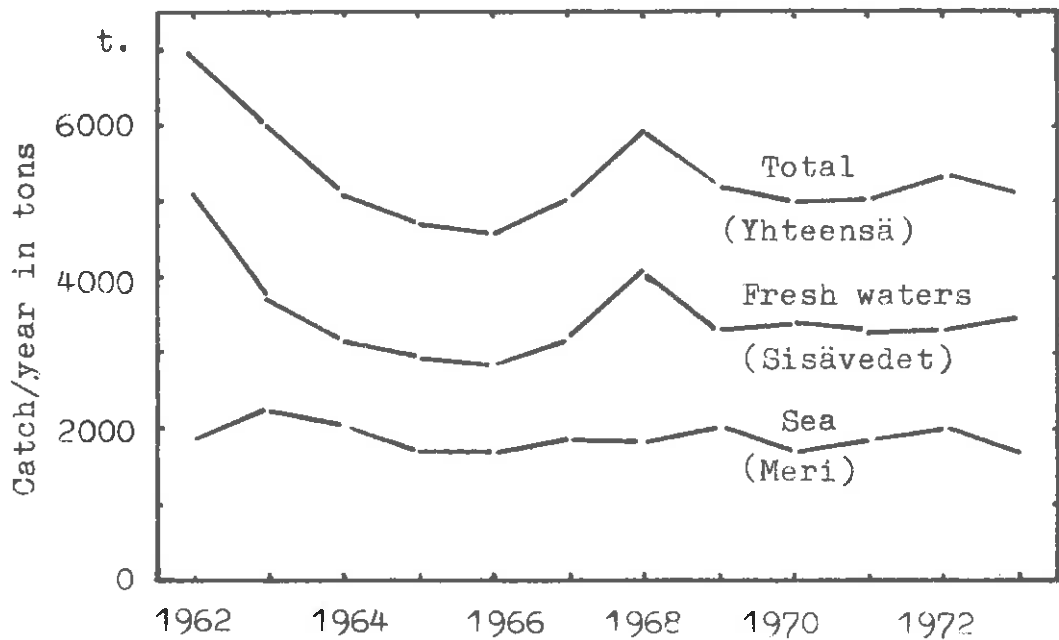


Fig. 3. Above, yearly variation in the catch of pike obtained from the fresh and brackish water areas of Finland during the period 1962-1973 (Finnish Game and Fisheries Research Institute, Fisheries Division 1974). Horizontally, years, vertically, catch in tons. Below, seasonal variation in the catch according to Hurme (1959). Horizontally, months, vertically, catch as percentages of the year's total. - Kuva 3. Ylhäällä sisävesien ja meren haukisaaliin vuotuinen vaihtelu kaudella 1962-1973 (Riista- ja kalatalouden tutkimuslaitos, Kalantutkimusosasto 1974). Vaakasuunnassa vuodet, pystysuunnassa saalis tonneina. Alhaalla saaliin kausivaihtelu kauppiaan tulleen kalan perusteella (Hurme 1959). Vaakasuunnassa kuukaudet, pystysuunnassa saalis % vuoden saaliista.

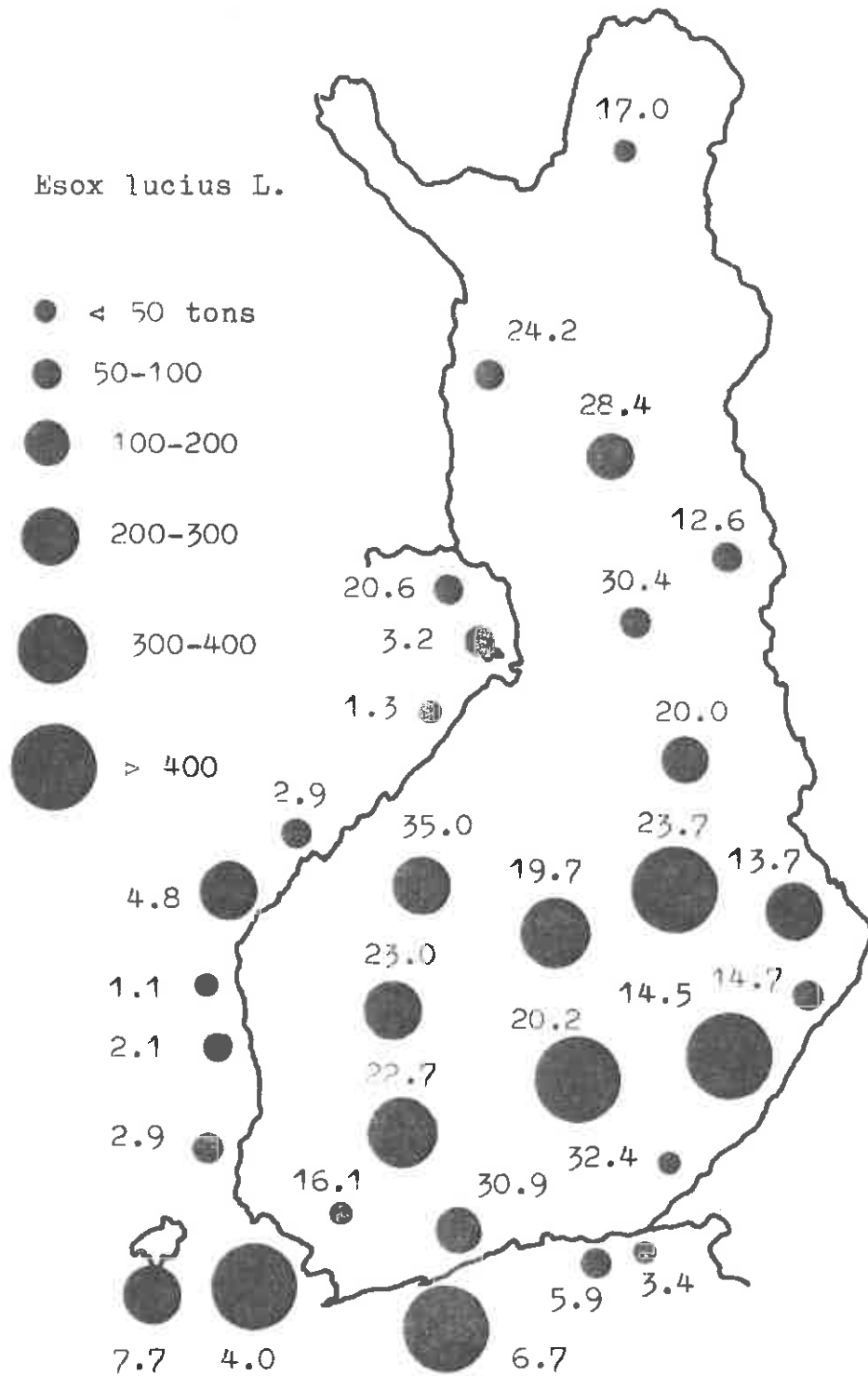


Fig. 4. Regional variation in the catch of pike obtained from the fresh and brackish water areas of Finland in 1959 (material from Heikkinen 1960). The fresh water areas yielded 3 841 tons and the brackish water areas 1 985 tons, total 5 826 tons. The numerals by the dots indicate the catches of pike as percentages of the total catch of fish obtained from the different regions. - Kuva 4. Sisävesien ja meren haukisaaliin alueellinen vaihtelu v. 1959 heikkisen (1960) esittämän materiaalin perusteella. Sisävedet tuottivat 3 841 tonnia ja merialue 1 985 tonnia, yhteensä 5 826 tonnia. Luvut osoittavat haukisaaliin \* kunkin alueen kokonaiskalansaaliista.

Pohjois-Suomen Kalatutkimus 1975  
Ichthyologia Fennica borealis 1975

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

Lind, E.A. & Kaukoranta, E. 1975: The pike, *Esox lucius* L., in the estuary of the Oulujoki river. II. Population. (Yhteenveto: Oulujoen suiston hauki, *Esox lucius* L. II. Populaatio). - Ichthyol. Fenn. Borealis 1975 (3-4): 41-66.