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The pike, *Esox lucius* L., in the estuary of the
Oulujoki river. I. Ecology

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I. Introduction

Toner & Lawler (1969) have published a synopsis of the biological data on the pike, *Esox lucius* L. This synopsis does not include Finnish material on the species, because of language difficulties.

The earliest papers published in Finland include data on age, size and growth rate (Brofeldt 1917, Gottberg 1917, Jääskeläinen 1917, Odenvall 1927, Segerstråle 1948). The growth rate and migration of the species have been studied by means of taggings, both in fresh and brackish waters (Gottberg 1922, Järvi 1931, Segerstråle 1948, Halme 1957, 1958, Halme & Korhonen 1960, Korhonen 1961, Nissinen 1965, A.A. 1970, Lehtonen 1972, 1973). Data on the spawning time in several ponds and small lakes close to the fish breeding establishment at Evo were collected by Brofeldt (1920) and similar data are presented for various parts of Finland by Hakoköngäs (1971). The timing of the spawn in the estuary of the Oulujoki river in 1972 is described by Lind et al. (1973).

The purpose of the present study is to describe some size and ecological characteristics of the species in the population at the mouth of the Oulujoki river, paying special attention to migration.

II. Study area and methods

1. Study area

Study area. - The study area comprised the free section of the Oulujoki river (65° N, 25° E), length approx. 3 km and area 190 ha, between the sea and the Merikoski power station (Fig. 1). The quantity of water running through the power station varied from 200 to 300 m³/s. The variation in the water level was considerable, due partly to fluctuations in the quantity of water running through the power station and partly to variable sea levels.

2. Methods

Fishing. - Fishing with a trolling spoon and hooks is allowed in the study area during the period November-August. Several individuals were also caught with dip nets and gill nets in October, when obtaining examples of the migratory species *Salmo salar*, *S. trutta* and *Coregonus lavaretus* for roe production at the fish breeding establishments at Merikoski and Montta. Fishing in the sea area not subject to any restrictions.

The fish for tagging were caught with gill nets during the period 5.-29.V.1971 when the pike were using the area as a spawning ground (Fig. 3).

Tagging, measurements and weighing of the fish. - On capture the fish were transferred from gill nets into a wood holding cage, and anaesthetized using mS-222 Sandoz.

They were weighed to an accuracy of 10 g, measured to an accuracy of 1 mm and tagged using a plastic tag and steel wire. After tagging, the fish were held in the cages for several hours before release to avoid the release of any unfit fish.

Sex was determined on the basis of flowing milt or roe or of certain morphological characteristics. Some erroneous determinations were later observed.

Recapture. - The fish were recaptured in the study area using gill nets in May 1971-1974, and also at other times of the year by the local fishermen using gill nets, trolling spoon, dip nets and trawl. The number of fish caught by these means is presented in the following list.

	Number of fish (Kalojen määrä)	%
Gill net (verkkko)	75	68.2
Trolling spoon (Uistin)	19	17.3
Dip net (Lippo)	2	1.8
Trawl (Trooli)	1	0.9
Unknown (Tuntematon)	13	11.8
Total (Yhteensä)	110	100.0

A total of 110 individuals, or 55.0 % of the fish released in 1971, had been recaptured by the end of 1974. The number of fish tagged and released was 200.

III. Size and growth rate

1. Size

The species shows a considerable variation in size within its area of distribution (Toner & Lawler 1969). The size variation in fresh water in Finland has been studied by Jääskeläinen (1913), Brofeldt (1917, 1920), Järnefelt (1917), Odenvall (1927), Korhonen (1961), Lagom (1962) and nakoköngäs (1971), and in brackish water by Gottberg (1917). Owing to their faster growth rate, the females are generally longer and heavier than the males.

Table 2. Weight of the males and females and those individuals whose sex was unknown on the basis of the fish tagged in 1971 and recaptured in 1971-1974. - Taulukko 2. $\delta\delta$:n, $\varnothing\varnothing$:n ja sukupuoleltaan määrittämättömien kalojen paino keväällä 1971 merkittyjen ja v. 1971-1974 merkittynä tavattujen yksilöiden perusteella.

Fish tagged in 1971 (Merkitty 1971)	$\delta\delta$	$\varnothing\varnothing$??	Total (Yhteensä)
0.2-0.5 kg	10		7	17
0.6-1.0	108	16	20	144
1.1-1.5	19	9	6	34
1.5-2.0		1		1
Min.	0.3	0.7	0.2	0.2
Max.	1.3	2.0	1.3	2.0
\bar{x}	0.9	1.1	0.8	0.9
S.E.	0.02	0.06	0.03	0.02
n	137	26	33	196
Fish recaptured (Merk. tavattu)				
0.6-1.0 kg	35	3	8	46
1.1-1.5	30	7	2	39
1.6-2.0	2	5	1	8
2.1-2.5		1		1
2.6-3.0		1		1
Min.	0.6	0.7	0.7	0.6
Max.	1.8	3.0	1.9	3.0
\bar{x}	1.1	1.6	1.0	1.1
S.E.	0.04	0.14	0.12	0.05
n	67	17	11	95

Table 3. Length of the males and females and those individuals whose sex was unknown on the basis of the fish tagged in 1971 and recaptured in 1971-1974. - Taulukko 3. ♂♂:n, ♀♀:n ja sukupuoleltaan määrittämättömien kalojen pituus keväällä 1971 merkittyjen ja vuosina 1971-1974 merkittynä tavattujen yksilöiden perusteella.

	♂♂	♀♀	??	Total (Yhteensä)
Fish tagged in 1971 (Merkitty 1971)				
31-35 cm			2	2
36-40	3		2	5
41-45	13		8	21
46-50	51	8	11	70
51-55	55	10	8	73
56-60	15	6	2	23
61-65		1		1
66-70		1		1
Min.	37	46	33	33
Max.	60	67	57	67
\bar{x}	50.3	53.3	47.1	50.2
S.E.	0.35	0.99	0.52	0.28
Fish recaptured in 1971-1974 (Merk. tav. 1971-1974)				
36-40 cm			1	1
46-50	16		4	20
51-55	16	2	5	23
56-60	24	7		31
61-65	2	5	2	9
71-75		2		2
min.	46	53	40	40
max.	65	74	63	74
\bar{x}	54.3	60.6	52.0	55.2
S.E.	0.32	0.98	1.21	0.38
n	58	16	12	86
Fish recaptured on tagging (Merk. tav. merkittäessä)				
36-40 cm			1	1
41-45	5		6	11
46-50	31	7	5	43
51-55	26	6	5	37
56-60	9	4		13
61-65		1		1
66-70		1		1
Min.	43	46	37	37
Max.	60	67	54	67
\bar{x}	50.8	53.2	47.1	50.6
S.E.	0.46	1.15	0.74	0.42
n	71	19	17	107

Size on the basis of taggings. - The size distribution of the fish in the study area is presented on the basis of the fish tagged in 1971 and recaptured during the period 1971-1974. The results are presented in Table 2 and 3 and Figs 4 and 5. The length-weight relationship is presented in Fig. 6.

The females were longer than the males both on tagging and on recapture ($t=2.86$; $p < 0.01$ and $t=6.11$; $p < 0.01$), and were also heavier than the males ($t=5.32$; $p < 0.01$ and $t=3.45$; $p < 0.01$). The difference is due mainly to the difference in growth rate (see below). The females were also heavier than the males even in the same length classes (Fig. 6), due to the difference in gonad weight. The fish in the sample for tagging were admittedly smaller than the average for the population, since the market price did not allow the purchase of many large individuals for tagging.

The average size of the fish tagged (50.2 cm and 0.86 kg) did not differ from the average size on tagging of the fish recaptured (50.6 cm and 0.87 kg). This indicates that the fishing of the mature pike was unselective in regard to size within the study area.

Size in samples obtained by trolling spoon. - The size in the samples obtained by trolling spoon during the period VI.-VIII.1971-1974 was as follows:

	Length in cm (Pituus cm)	Weight in kg (Paino kg)
n	149	159
Variation	40-100	0.4-6.5
Average	65.7	1.9
S.E.	0.44	0.03

The difference in size between the fish recaptured and the fish caught by trolling spoon was statistically significant both regarding length and weight ($t=18.10$; $p < 0.01$ and $t=13.20$; $p < 0.01$).

The largest individual caught in the study area has weighed 16.8 kg (E. Luoto, personal communication).

2. Growth rate

Toner & Lawler have assembled a literature on the growth of the species. Growth varies according to latitude, sex and age of fish. In general, the northern pike is one of the fastest-growing freshwater fish and under ideal conditions is capable of extremely rapid growth.

Some data on the Finnish brackish water populations have been presented. According to Gottberg (1917) the growth of the males in the coastal waters of the Åland Islands varied from 34.9 to 42.6 % of the preceding year's weight. The corresponding figures for the females were from 79.1 to 99.2 %. The growing season lasted from June to October, the growth per growing season being about 10 cm. In the central part of the Gulf of Bothnia the growth in length was not more than about 4 cm/year (Nilsson 1921). Segerstråle (1948) also notes that growth is faster in the females than in the males. In the coastal waters of the Gulf of Finland the growth of the males was about 5 cm/year and that of the females about 7 cm/year (Halme & Korhonen 1960, Korhonen 1961). The average growth in the brackish waters off the city of Helsinki was 7.5 cm/year according to Seppänen (1970) and 3.2 cm/year and 415 g/year according to Lehtonen (1972).

The females similarly achieve larger size and a faster growth rate than the males in fresh waters in Finland (e.g. Odenyall 1927, Hakoköngäs 1971). The growth rate in Lake Ladoga (now U.S.S.R.) varied from 10.1 to 11.2 cm/year at the age of 1-4 years (Jääskeläinen 1917). The average growth in Lake Oulujärvi calculated from a figure presented by Nissinen (1971) was about 250 g/year in weight.

Growing season in the study area. - The growth rate was determined on the basis of the difference between the tagging and recapturing size. The fish were tagged in May 1971 and recaptured during the period May 1971-May 1972. The results for the males and females are presented in Figs 7 and 8 and for the combined material of both sexes in Table 4.

Table 4. Monthly changes in the length (in cm) and weight (in g) of the fish determined on the basis of the fish tagged in May 1971. Only those individuals are included which were recaptured during a period of 12 months after tagging. The roman numerals indicate the months after tagging. - Taulukko 4. Pituuden cm ja painon g muutokset kuukausittain toukokuussa 1971 merkittyjen ja toukokuuhun 1972 mennessä merkittynä tavattujen kalojen perusteella. Roomalaiset numerot kuvaavat kuukausia. merkintäkooksi on katsottu +0, josta tapaamiskoko on laskettu koon lisäyksenä tai pienentymisenä.

	n	Variation (Vaihtelu)	Average (Keskiarvo)	S.E.
Length (Pituus)				
V.1971	19	-2.0...+2.0	-0.5	0.27
VI.	9	-1.5...+7.5	+1.6	0.97
VII.	5	+1.8...+2.8	+2.2	0.17
VIII.	5	+0.5...+8.8	+3.7	1.37
X.	1	+7.6...+7.6	+7.6	0.00
V.1972	34	+1.3...+11.1	+5.3	0.49
weight (Paino)				
V.1971	21	-200...+150	-12	30
VI.	9	-100...+175	+10	43
VII.	5	+0...+500	+174	65
VIII.	6	-70...+450	+228	82
X.	1	+430...+430	+430	0
V.1972	34	+0...+950	+348	32

In May several individuals had diminished in length and especially in weight, the weight decrease being due mainly to the loss of the gonads. The growing season began late in June and apparently continued into October. It is possible that the increases in length and weight are desynchronized especially in shallow fresh waters. This point of view is supported by the fact that the coefficients of condition in Lake Oulujärvi reached their minimum values during the summer months (Hakoköngäs 1971, Lind 1974).

Annual absolute growth. - The results obtained on the basis of taggings are presented in Figs 7 and 8 and Table 5.

Table 5. Annual absolute growth of the males, females and those individuals whose sex was unknown on the basis of the fish tagged in 1971 and recaptured in 1972-1974. - Taulukko 5. ♂♂:n, ♀♀:n ja sukupuoleltaan määrittämättömien kalojen absoluuttinen kasvu määritettynä toukokuussa 1971 merkittyjen ja myöhemmin merkittynä tavattujen yksilöiden perusteella.

Growing season (Kasvukausi)	1.	2.	3.	Total (Yht.)
Length in cm (Pituus cm)				
♂♂				
n	28	3	1	32
Min.	1.3	7.0	7.8	1.3
Max.	8.5	11.5	7.8	11.5
\bar{x}	4.6	9.3	7.8	5.1
S.E.	0.41	1.53	0.00	0.36
Cm/growing season (Cm/kasvukausi)	4.6	4.7	2.6	4.5
♀♀				
n	9	3		12
Min.	4.0	9.5		4.0
Max.	11.1	20.3		20.3
\bar{x}	8.5	14.3		10.9
S.E.	0.82	2.97		0.68
Cm/growing season (Cm/kasvukausi)	8.5	7.1		7.8
??				
n	4			4
Min.	1.5			1.5
Max.	8.0			8.0
\bar{x}	5.1			5.1
S.E.	1.47			1.47
Cm/growing season (Cm/kasvukausi)	5.1			5.1
Total (Yhteensä)				
n	41	6	1	48
Min.	1.3	7.0	7.8	1.3
Max.	11.1	20.3	7.8	20.3
\bar{x}	5.5	11.8	7.8	6.3
S.E.	0.28	1.81	0.00	0.23
Cm/growing season (Cm/kasvukausi)	5.5	5.9	2.6	5.5

	1.	2.	3.	Total (Yht.)
Weight in g (Paino g)				
♂♂				
n	27	3	1	31
Min.	0	300	680	0
Max.	575	725	680	725
\bar{x}	274	475	680	303
S.E.	32	129	0	41
G/growing season (G/kasvukausi)	274	238	227	264
♀♀				
n	10	3		13
Min.	250	690		250
Max.	950	2030		2030
\bar{x}	587	1240		737
S.E.	77	394		105
G/growing season (G/kasvukausi)	587	620		599
??				
n	4			4
Min.	100			100
Max.	740			740
\bar{x}	335			335
S.E.	150			150
G/growing season (G/kasvukausi)	335			335
Total (Yhteensä)				
n	41	6	1	48
Min.	0	300	680	0
Max.	950	2030	680	2030
\bar{x}	357	691	680	421
S.E.	34	210	0	29
G/growing season (G/kasvukausi)	357	346	227	301

The average growth of the females was 7.8 cm/year and 599 g/year. The corresponding figures for the males were 4.5 cm/year and 264 g/year and for those individuals whose sex was unknown 5.1 cm/year and 335 g/year.

The growth in length of the females was faster than that of the males and of those individuals whose sex was unknown. The difference between the females and the males was statistically significant ($t=4.29$; $p<0.01$). The same is true regarding the growth in weight ($t=3.91$; $p<0.01$).

The growth of the males did not differ statistically from that of those individuals whose sex was unknown. Thus the growth of the mature females in the study area was faster than that of the males, which explains the differences in size.

Relative growth. - Growth was calculated as a percentage of tagging size and also of recapturing size for the males, females and unknown fish separately. The calculations were done according to Chapman (1968). The main results are presented in Table 6.

The trends in relative growth give support to the view that the growth of the females is faster than that of the males. The relative growth in the study area was not as fast as that observed by Gottberg (1917) in the coastal waters of Åland.

Table 6. Average relative growth/year of the pike calculated on the basis of the fish tagged in May 1971. The growth is presented as a percentages both of tagging and of recapturing size. - Taulukko 6. Toukokuussa 1971 merkittyjen ja myöhemmin tavattujen kalojen keskimääräinen kasvu % merkitsemäajan ja merkittynä tavattujen kalojen mitoitusta. Materiaali sama kuin taulukossa 5. Kasvukerroin (growth rate) on määritetty Chapmanin (1968) mukaan.

	♂♂	♀♀	??
Length (Pituus)			
% of tagging length (% merkitsemäpituudesta)	8.8	14.6	10.8
% of recapturing length (% merk. tav. pituudesta)	8.1	12.8	9.8
Growth rate (Kasvukerroin)	0.08	0.14	0.10
Weight (Paino)			
% of tagging weight (% merkitsemäpainosta)	31.5	55.9	44.1
% of recapturing weight (% merk. tav. painosta)	24.0	35.9	30.6
Growth rate (Kasvukerroin)	0.27	0.44	0.36

IV. Some ecological characteristics

1. Seasonal variation in catch

One of the earliest studies on the seasonal variation in catch is that of Vallin (1929), who caught pike and some other freshwater fish throughout the year. The best catches were obtained during the spawning time in March, April and May. The seasonal variation in the catch from the study area is presented in Table 7 (see also Figs 7 and 8).

Most fish were caught during the spawning time in May, when the fishing of the species for this study was most intensive. Catches were also generally high in June, although catching with gill nets for research purposes was no longer carried out.

This seasonal variation in catch may be explained on the basis of high locomotor activity during spawning. At this time of year a phase shift may be noted in the pattern of the diurnal periodicity of activity (Lind 1974), and this season also coincides with the main migration period of the species (Toner & Lawler 1969 and below). The poor catches in the winter may indicate a low rate of activity, and equally a low rate of exploitation.

Table 7. Seasonal variation in the catch obtained from the study area and from the sea off the mouth of the Oulujoki river during the period 1971-1974. Only the fish recaptured are included. - Taulukko 7. Saaliin vuodenaikainen vaihtelu Oulujoen suistossa ja Oulun edustan merialueella tutkimuskaudella 1971-1974. Mukana merkittynä tavatut kalat.

Month (Kuukausi)	Ind. (Yks.)	%
V.	72	65.5
VI.	16	14.5
VII.	10	9.0
VIII.	7	6.4
IX.	1	0.9
X.	3	2.8
XI.	1	0.9
Total (Yhteensä)	110	100.0

2. Spawning time

The spawning season may extent from February to June in all parts of the distribution area. The temperatures at which spawning has been noted vary from 4°C to 14.4°C , their average being about $7-8^{\circ}\text{C}$ (Rawson 1932, Clark 1950, Healy 1956, Frost & Kipling 1967, Toner & Lawler 1969).

Spawning occurred in the small lakes and ponds in the commune of Lammi during the period 21.IV.-27.V.1900-1915, at water temperatures varying from 1°C to 11°C (Brofeldt 1920). In Lake Lappajärvi the species spawned during the period early May-late June (Odenvall 1927) and in the Lake Oulujärvi in late May-early June (Hakoköngäs 1971). The water temperature at which the spawning was noted in the Gulf of Finland usually varied from 8°C to 10°C (Segerstråle 1948).

The data collected from the mouth of the Oulujoki river show that the milt of the males was flowing from the end of April to the beginning of June, whereas flowing roe was observed during the last two weeks of May. The spawning season, as determined on the basis of flowing roe, occurred during the periods 17.-28.V.1971 and 19.-26.V.1972, at water temperatures varying from 4.5°C to 6.0°C in 1971 and from 7.5°C to 9.5°C in 1972 (see also Fig. 3 and Lind et al. 1973).

3. Diurnal periodicity of activity

In southern latitudes spawning takes place during the hours of daylight both in the wild and in captivity (Svärdson 1948, Fabricius & Gustafson 1958). Spawning was observed only between 14.00 hours and 18.00 hours by Franklin & Smith (1963), whereas Clark (1950) states that spawning groups were seen at 06.00 hours and as late as 18.30 hours, but none was noted at night.

In Finland this activity has been studied in several ponds and lakes in the commune of Kuusamo (66°N , 29°E) and at the mouth of the Oulujoki river (65°N , 25°E), by

a method involving catching the fish with cages and gill nets examined every 2 or 3 hours. Some additional fish were caught with a trolling spoon. The catch was composed mainly of mature fish. A summary of the main results has been presented earlier by Lind (1974).

A phase shift was noted in the activity pattern of the species. It was day-active in winter whereas activity in June and July was nonsynchronised, with a weak peak in the middle of the night. The activity pattern in August and September had two peaks, one in the morning and one in the evening. Towards autumn these peaks fused together in the middle of the day, a time which then became the principal period of activity.

Table 8. Stomach contents of 145 mature pike in Lake Oulujärvi (according to Hakoköngäs 1971), Lake Pihlajavesi and the Gulf of Bothnia in 1969-1971. - Taulukko 8. 145 Oulujärven (Hakoköngäs 1971), Pihlajaveden ja Perämeren hauen mahan sisältö v. 1969-1971. kalojen pituus vaihteli 30-105 cm ja paino 0.2-5.5 kg, joten pääosa niistä oli su-
kukypsiä.

	Oulujärvi 1969-1970 X.-XI.	Pihlajavesi 1970-1971 VI.-VII.	Gulf of Bothnia II.1970	Total (Yht.)
Empty stomachs	64	6	22	92
Undetermined	15		2	17
fish, undetermined	7		3	10
Invertebrate	3	2	2	7
<i>Perca fluviatilis</i>	1	3	3	7
<i>Rutilus rutilus</i>			4	4
<i>Gasterosteus aculeatus</i>			3	3
<i>Coregonus albula</i>	2			2
<i>Gymnocephalus cernua</i>		1		1
<i>Zoarces viviparus</i>			1	1
<i>Esox lucius</i>			1	1
Total (Yhteensä)	92	12	41	145

4. Food

The species can be described as an omnivorous feeder. As a larva its food consists of animal plankton and at 3-20 cm of fish fry, aquatic insects and bottom animals. The adult pike feeds almost exclusively on fish (e.g. Frost 1954, Seaburg & Moyle 1964, Lawler 1965, Toner & Lawler 1959).

Material collected from two lakes in Finland and from the Gulf of Bothnia is presented in Table 8. The length of the fish varied from 30 to 105 cm and the weight from 0.2 to 5.5 kg.

5. Taste abnormalities and mercury content

Taste abnormalities. - Water pollution in the North-Eastern part of the Gulf of Bothnia, which could be detected in the taste and smell of the fish, reached its maximum distribution in 1969-1971. The pike did not show any sign of bad flavour (Lind et al. 1970, Lind & Hytinkoski 1972).

Mercury content. - The mercury content of the water of the Oulujoki river is somewhat higher than that in some other rivers running into the Gulf of Bothnia, and in addition, there is a major source of mercury in the town of Oulu itself. The direction of the dominant water currents in the Gulf of Bothnia is counterclockwise. Thus it is to be expected that the fish would show high mercury contents in the study area, and that the content would decrease towards the south and south-west.

The average mercury content in mg/kg in the pike caught from the study area or from the sea off the study area during the period 1968-1973 were as follows (Alhojärvi 1974):

	Hg mg/kg	n
1968	1.21	5
1969	0.93	15
1970	1.57	7
1971	0.96	12
1972	0.83	7
1973	1.04	2

The regional variation in mercury content in the north-Eastern part of the Gulf of Bothnia is presented in Fig. 9, which shows that the highest figures were observed close to the mercury source. The same material is presented in Table 9.

A positive correlation has been noted between the size of the pike and the mercury content by Fimreite et al. (1971) and by Scott (1974). A corresponding correlation ($r=0.62$; $p < 0.01$) was also observed in the North-Eastern part of the Gulf of Bothnia (Fig. 9). Scott has also noted that relatively heavier fish tended to have lower Hg concentrations. This negative correlation between the coefficient of condition and the Hg concentrations, however, was not observed in the study area.

The fish in the study area and in the sea off the study area, averaging 1.2 kg, were heavier than those in the commune of Ii or at the town of Kemi, which averaged 1.0 kg. This difference, however, was not statistically significant ($t=1.03$; $p < 0.10$). The Hg concentrations were also higher in Oulu than in the sea at a distance of 40-100 km from the mercury source, the averages being 1.2 mg/kg and 0.6 mg/kg respectively. This difference was statistically significant ($t=2.45$; $p < 0.05$).

Table 9. Mercury content in the pike caught from the study area or from the sea close to the Oulujoki river, and from the sea at a distance of about 40-100 km from the study area (Ii and Kemi). - Taulukko 9. Hauen elohöpeapitoisuus mg/kg Oulujoen suistossa ja Oulun edustan merialueella sekä Ii-joen ja Kemin edustalla.

	Weight of pike (Hauen paino)		Hg mg/kg	
	Oulu	Ii-Kemi	Oulu	Ii-Kemi
n	18	5	18	5
Min.	0.36	0.45	0.40	0.45
Max.	2.40	1.48	2.08	0.88
\bar{x}	1.21	0.95	1.16	0.63
S.E.	0.14	0.21	0.18	0.12

The variations in the mg concentrations may be explained on the basis of the migratory behaviour of the pike. The tagged individuals did not move more than 16 km from their tagging place (Fig. 9 and 10). Thus they could not carry mercury in their bodies to a greater distance. The data presented show in addition that the majority of the mercury flowing into the sea sinks to the bottom not far from the Oulujoki river, and that only a small proportion drifts with the sea currents to a greater distance.

V. Movements

1. Literature review

About 61 % of the fish tagged at the islands of Södermanland and Östergötland stayed within a range of about 1 km, the longest migration being 15 km (Ekman 1915). The results presented by Hessler (1934) are almost identical. The fish tagged in the Musketon river were later recaptured in almost every part of the Houghton lake. During the spawning time, however, the pike returned to their earlier spawning grounds. It was also noted that a marked pike travelled 16 km in 22 hours and that the longest migration was 78.5 km (Carbine & Applegate 1946). The pike in Lake Windermere used the same spawning grounds every year and did not move further than 7 km from their tagging place (Frost & Kipling 1967). After spawning the pike becomes solitary and almost territorial (Toner & Lawler 1969). Carlander & Ridenhour (1958) have reported that stocked pike had a tendency to spread to all parts of a lake 1 500 ha in area (see also Toner & Lawler 1969).

This migration pattern has also been shown on the basis of Finnish material obtained from brackish water, around the Åland Island and off Porvoo, where most fish were recaptured within 0.5 km of their tagging place, the longest range of migration being about 5 km (Gottberg 1922, Järvi 1931). The results presented by Lehtonen (1972, 1973) are essentially the same, though the longest migration was about 15 km.

Several pike are reported as migrating from two small lakes to a distance of about 2 km to spawn in brooks and dikes not wider than 0.5 m (Lind 1960).

In Finland, too, stocked pike have a tendency to move, and return to their catching site when transferred a distance of several km (Halme 1957, 1958, Halme & Korhonen 1960, Nissinen 1965, 1971, Lehtonen 1972, 1973).

2. Movements in the study area

Migration area. - The areal distribution of the recapture points is presented in Figs 9-10 and Table 10, which show that most fish were recaptured from the estuary of the Oulujoki river. This may be explained on the basis of the stationary character of the species and seasonal trends in migration.

A total of 84.8 % of the fish recaptured had not moved more than 1 km from their tagging place, the longest migration being about 16 km. A high number of fish migrating no more than 1 km indicates an unusually stationary population. The same is true regarding the average range of movement. It may be supposed that the difference between this and some other materials is due partly to the estuary character of the study area and partly to the high rate of local exploitation during the spawning time.

Table 10. Range of movement of the fish tagged in May 1971 and recaptured by the end of 1974. - Taulukko 10. Keväällä 1971 merkittyjen ja vuoden 1974 loppuun mennessä merkittynä tavattujen kalojen etäisyys merkintäpaikalta.

Extent km (Etäisyys km)	Number of fish (Kalojen määrä)
< 0.5	52
0.6-1.0	32
1.1-2.0	6
2.1-5.0	6
5.1-10.0	1
> 10	2
n	99
min.	0
Max.	16.0
\bar{x}	1.0
S.E.	0.12

Table 11. Seasonal variation in the distance in km from the tagging site to the recapture points of the fish tagged in 1971 and recaptured by the end of 1974. - Taulukko 11. Merkittynä tavattujen kalojen etäisyys merkintäpaikalta eri kuukausina. Kalat merkittiin toukokuussa 1971 ja tavattiin merkittynä ajalla 1971-1974.

Months (Kuukaudet)	n	Variation (Vaihtelu)	Average (Keskiarvo)	S.E.
V.	61	0.0-6.0	0.5	0.09
VI.	18	0.2-15.3	1.5	0.31
VII.	9	0.2-2.8	1.1	0.29
VIII.	7	0.1-4.0	1.8	0.62
IX.	1	2.4-2.4	2.4	0.00
X.	2	0.6-2.3	1.5	0.90
XI.	1	16.0-16.0	16.0	0.00
Total (Yhteensä)	99	0.0-16.0	1.0	0.12

Seasonal trends in migration. - The seasonal variation in the distance of the recapture points is presented in Table 11.

The average distance of the recapture points from the tagging place in May was 0.5 km, whereas that during the period June-November was 1.9 km. This difference was statistically significant ($t=5.69$; $p<0.01$). This indicates that the species performed a seasonal migration. Apparently the migration for most of the fish took place soon after spawning. For example, a specimen (I 9545) was tagged on 11.May 1971 and recaptured five days later (16.V.1971), by which time it had migrated to a distance of 5.3 km from the tagging place.

Return to the spawning ground. - The data presented above show a seasonal variation in habitat selection. The use of the same spawning grounds every year is indicated by Table 12 below.

The differences between the years 1971-1973 were not statistically significant which indicates that the fish returned to the spawning grounds they used in previous years. This result is in accordance with those obtained by Carbine & Applegate (1946) and Frost & Kipling (1967).

Table 12. Range of the recapture points from the tagging place in May 1971-1973. - Taulukko 12. Merkittynä tavattujen kalojen etäisyys merkintäpaikalta toukokuussa 1971-1973.

Year (Vuosi)	n	Variation (Vaihtelu)	Average (Keskiarvo)	S.E.
1971	28	0.0-6.0	0.7	0.22
1972	31	0.0-1.0	0.4	0.14
1973	2	0.4-0.6	0.5	0.10
Total (Yhteensä)	61	0.0-6.0	0.5	0.09

Speed of migration. - The distance between the tagging and recapturing place was divided by the number of days elapsing between tagging and recapturing. The speed of migration of some sample individuals was as follows:

Symbol of fish (Kalan numero)	Time in days (Aika vrk.)	Distance in km (Matka km)	Km/day (Km/vrk.)
I 9545 ♂	5	5.3	1.1
I 9644 ♂	43	2.3	0.5
I 9667 ♂	44	2.3	0.5
I 9680 ♂	1	0.4	0.4
I 9543 ♂	3	0.7	0.2

The swimming speed of most of the individuals, however, was slower. These fish orientated themselves from the spawning grounds to the growing areas. Some other migration records have been reported, for example 16 km in 22 hours (Carbine & Applegate 1946) and 9 km/day (Lehtonen 1972).

VI. Pike population in the study area

The study area comprised the mouth of the Oulujoki river between the sea and the Merikoski power station. This power station formed a barrier against upstream migration, whereas no barriers existed between the study area and the sea.

Consequently, 7.3 % of the mature fish were recaptured

from the sea and 92.7 % from the fresh water area. Apparently migration into the sea was connected with the seasonal movements between the spawning and growing areas. Those individuals performing a seasonal migration into the sea returned to their spawning grounds the next spring.

The average range of movement was about 1 km, the extent of the longest migration being about 16 km. These data show that the mouth of the Oulujoki river with its many islands, bays and sounds is large enough for most of the fish in the population. It is supposed that some pike do inhabit the fresh water area from birth to death without migration to the brackish water area. In any case, the study area is populated by the species the whole year round.

It is also the case that new individuals may migrate to the study area from the sea. This point of view is supported by the fact that the species shows a strong tendency to migrate upstream during the spawning time. The population may also gain some newcomers from above the power station as fish or larvae drift down-river. As a result the study area is inhabited by a mixed population of the species.

VII. Summary

The study area comprised the free section of the Oulujoki river, length approx. 3 km and area 190 ha, between the sea and the Merikoski power station (65° N, 25° E). The quantity of water running through the power station varied from 200 to 300 m³/s. The area was inhabited by about 20 migratory or stationary fish species including *Coregonus lavaretus*, *Salmo salar*, *S. trutta*, *Esox lucius*, *Lota lota*, *Perca fluviatilis* and *Rutilus rutilus*.

The fish for tagging were caught with gill nets during the period 5.-29.V.1971. A total of 200 individuals were caught, measured, weighed, tagged and released. The sex was determined on the basis of flowing milt or roe. Of the fish tagged and released in May 1971, 110 individuals or 55 %, had been recaptured by the end of 1974.

The females were longer on tagging than the males, averaging 53.3 cm and 50.3 cm. They were also heavier than the males, averaging 1.1 kg and 0.9 kg. The corresponding figures for the fish recaptured were as follows: ♀♀ 60.6 cm and 1.6 kg and ♂♂ 54.3 cm and 1.1 kg. The average size of the fish caught by trolling spoon was 65.7 cm and 1.9 kg. The rate of exploitation did not differ in the different size classes. The tagged fish diminished in weight during the spawning time. The growing season began in June and apparently continued into October. The average growth for combined material of males and females was 6.3 cm/year and 421 g/year.

The milt of the males was flowing from the end of April to the end of the study period, and the roe of the females during the periods 17.-28.v.1971 and 19.-26.V.1972. The spawning temperature as measured at the Merikoski power station varied from 4.5°C to 9.5°C. Most fish were recaptured in May or in June, which may be explained on the basis of high locomotor activity during the spawning time and during the seasonal migration after spawning. At the same time a phase shift was observed in the diurnal periodicity of activity.

The pike in the sea off the Oulujoki river showed some increased concentrations of methyl mercury. A positive correlation was noted between mercury concentrations and size of fish. The pike in the sea off the commune of Ii and the town of Kemi had lower concentrations of mercury. The difference is explained on the basis of the stationary character of the species. The difference also shows that a greater part of the mercury released into the sea sinks to the bottom not far from the source.

About 85 % of the fish recaptured did not move more than 1 km from their tagging place, the extent of the longest migration being about 16 km. The pike performed a seasonal migration and returned to their spawning ground of previous years. 7 % of the fish recaptured were caught from the sea off the Oulujoki river, and 93 % from the

study area. This distribution indicated that the study area was inhabited by a mixed population of the species.

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VIII. Yhteenveto

E.A. Lind & E. Kaukoranta: Oulujoen suiston hauki,
Esox lucius L. I. Ekologia.

Tutkimusalue käsitti joen vapaan osuuden Merikosken voimalaitoksen ja meren välillä, pituus n. 3 km ja pinta-ala n. 190 ha (65° N, 25° E). Joen virtaama vaihteli tavallisesti 200-300 m³/s. Alueen kalastoon kuuluu n. 20 vaeltavaa tai paikallista lajia, mm. *Coregonus lavaretus*, *Salmo salar*, *S. trutta*, *Esox lucius*, *Lota lota*, *Perca fluviatilis* ja *Rutilus rutilus*.

Hauen kalastus jokisuistossa on sallittua uistimella ja koukulla marraskuusta syyskuuhun ja lipolla sekä verkolla lokakuussa. Merialueella ei ole rajoituksia. Tutkimusta varten kalat pyydystettiin verkolla 5.-29.V.1971. Ne mitattiin, punnittiin, merkittiin ja vapautettiin pyyntipaikalla. Sukupuoli määritettiin vuotavan maidin ja mädin perusteella. Kaloja merkittiin 200 yksilöä, joista 110 yks. eli 55 % merkittyjen määrästä tavattiin vuoden 1974 loppuun mennessä. Merkittynä tavatuista kaloista 68 % saatiin verkolla ja 17 % uistimella, loput lipolla, troolilla tai muulla pyyntivälineellä.

merkittyjen ♂:n koko oli keskimäärin 50.3 cm ja 0.9 kg sekä ♀:n 53.3 cm ja 1.1 kg. Vastaavat arvot merkittynä tavatuista kaloista olivat ♂ 54.3 cm ja 1.1 kg sekä ♀ 60.6 cm ja 1.6 kg. Uistinsaaliin kalojen koko oli keskimäärin 65.7 cm ja 1.9 kg. Suurin alueelta saatu hauki painoi 16.8 kg. Pyynnin ei havaittu valikoivan kaloja koon perusteella.

Merkityt kalat menettivät toukokuussa painoaan, joka johtuu pääasiassa kudussa vapautetusta mädistä ja maidista. Kasvu alkoi kesäkuussa ja jatkui ilmeisesti lokakuuhun. Keskimääräinen kasvu oli 6.3 cm/vuosi ja 421 g/vuosi. ♂:n kasvu oli hitaampi kuin ♀:n, kasvukertoimien arvot 0.27 ja 0.44.

♂:n maiti oli vuotava huhtikuun lopulta lähtien, ♀:n

mäti ajalla 17.-28.V.1971 ja 19.-26.V.1972. Viimeksi mainittuina aikoina veden lämpötila vaihteli $4.5-9.5^{\circ}\text{C}$, joka katsotaan kutulämpötilaksi. Useimmat merkittynä tavatut kalat saatiin kutuaikana toukokuussa, mutta kesäkuunkin saalis oli huomattava. Jakautuma selittyy suuren liikkumisaktiivisuuden perusteella ja siten, että kudun jälkeen laji suorittaa vuodenaikaisen vaelluksen kutualueelta kasvua-alueelle. Samaan aikaan tapahtuu muutos vuorokausiaktiivisuudessa.

Oulujoen edustan hauki osoittaa kohonnutta elohopeapitoisuutta, joka korreloi positiivisesti kalan kokoon ($r=0.62$; $p < 0.01$). In ja Kemin alueen hauen Hg-pitoisuus oli alempi ($t=2.45$; $p < 0.05$), joka selittyy siten, että lajin vaellus ei ulotu niin pitkälle. Lisäksi se osoittaa, että veden elohopeasta pääosa vaipuu pohjaan lähellä Hg-lähdettä. Perämeren veden päävirtaus tapahtuu vastapäivään.

85 % merkittynä tavatuista kaloista saatiin enintään 1 km etäisyydeltä merkintäpaikalta, pisin vaellusmatka oli 16 km. Lajin todettiin suorittavan vuodenaikaisen vaelluksen, joka alkoi kudun jälkeen. Suurin mitattu vaellusnopeus oli 1.1 km/vrk. Vaelluksen jälkeen kalat palasivat merkintäpaikalle, joten samaa kutualueutta käytettiin vuodesta toiseen. 93 % merkittynä tavatuista kaloista saatiin Oulujoen suiston alueelta ja 7 % mereltä. Täten tutkimusalueen haukikanta koostuu osin sekapopulaatiosta.

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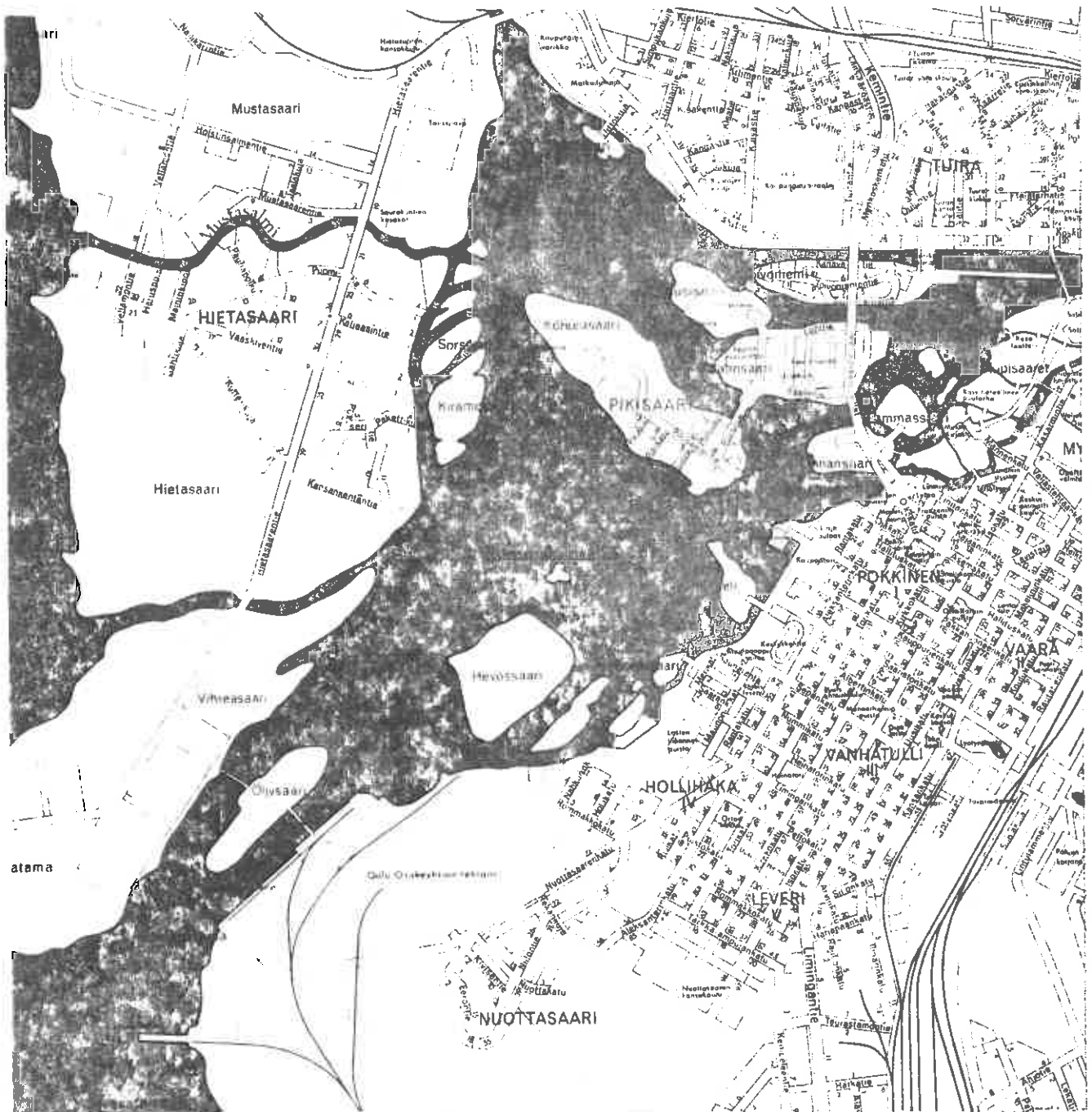
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Scale 1 : 20 000

Fig. 1. The mouth of the Oulujoki river in the town of Oulu, where the field work was performed in 1971-1974. Most fish were caught close to the islands of Pikisaari, Kuusisaari and Raatinsaari. They were tagged and released at the catching sites. - Kuva 1. Oulujoen suisto, jossa tutkimuksen maastotyöt suoritettiin vuosina 1971-1974. kalat pyydystettiin pääasiassa Pikisaaren, Kuusisaaren ja Raatinsaaren ympäristöstä. Ne merkittiin ja vapautettiin pyyntipaikalla.

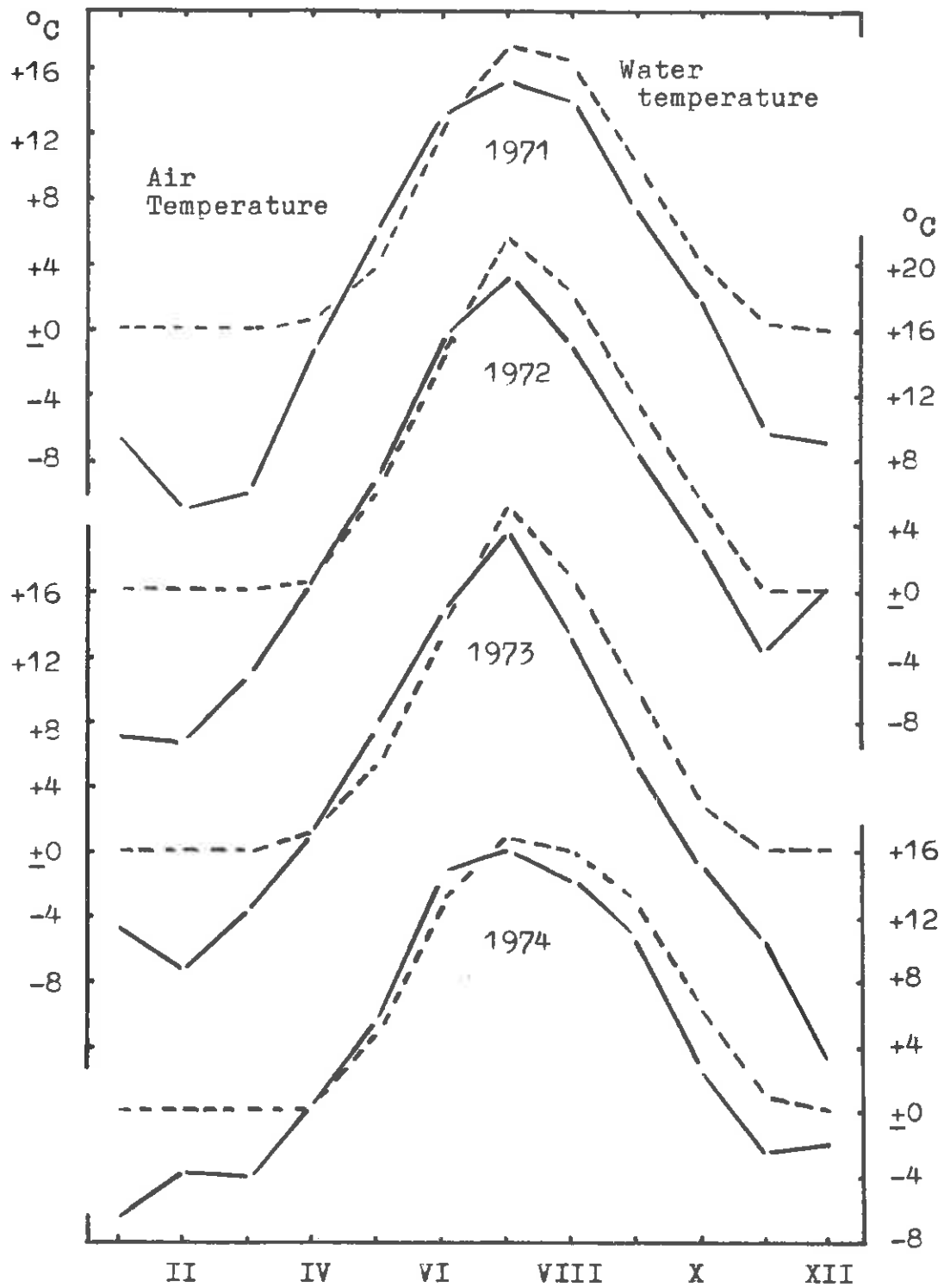


Fig. 2. Variation in air temperature at Oulu (according to Ilmatieteen Laitos 1971-1974) and in water temperature as measured at the Merikoski power station. Horizontally, months, vertically, temperature. - Kuva 2. Ilman lämpötilan vaihtelu Oulussa Ilmatieteen Laitoksen 1971-1974 mukaan (yhtenäinen viiva) ja veden lämpötila mitattuna Merikosken voimalaitoksella (katkoviiva). vaakasuunnassa kuukaudet, pystysuunnassa lämpötila.

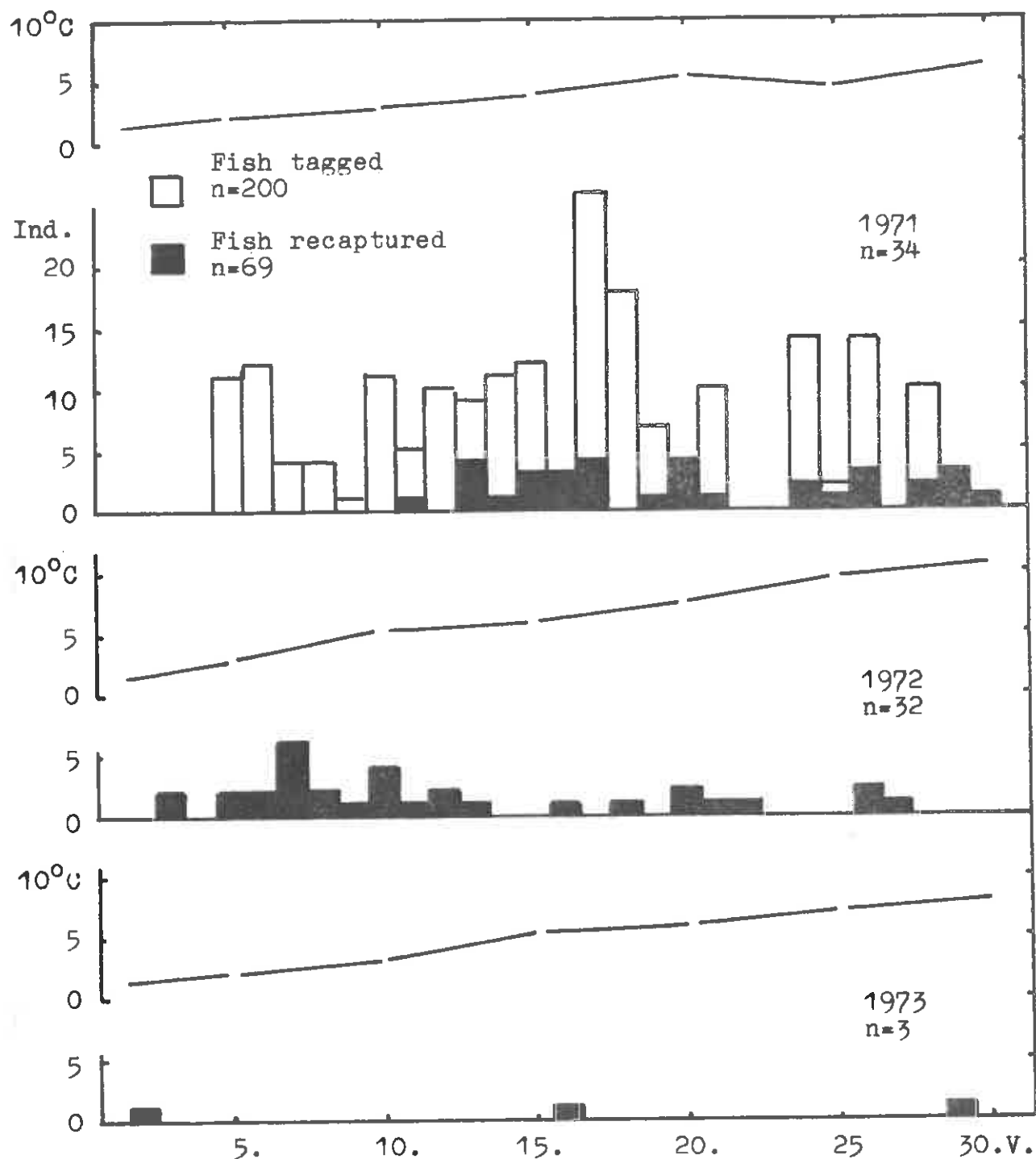


Fig. 3. Daily variation in the number of fish tagged and those recaptured in May 1971-1973 and variation in water temperature at five-day intervals as measured at the Merikoski power station. Horizontally, date, vertically, number of fish and temperature. - Kuva 3. Merkittyjen (valkeat pylväät) ja merkittynä tavattujen (mustat pylväät) kalojen päivittäinen vaihtelu toukokuussa 1971-1973 sekä veden lämpötilan vaihtelu 5 päivänä jaksoina mitattuna Merikosken voimalaitoksella. Vaakasuunnassa päivämäärä, pystysuunnassa kalojen lukumäärä ja lämpötila.

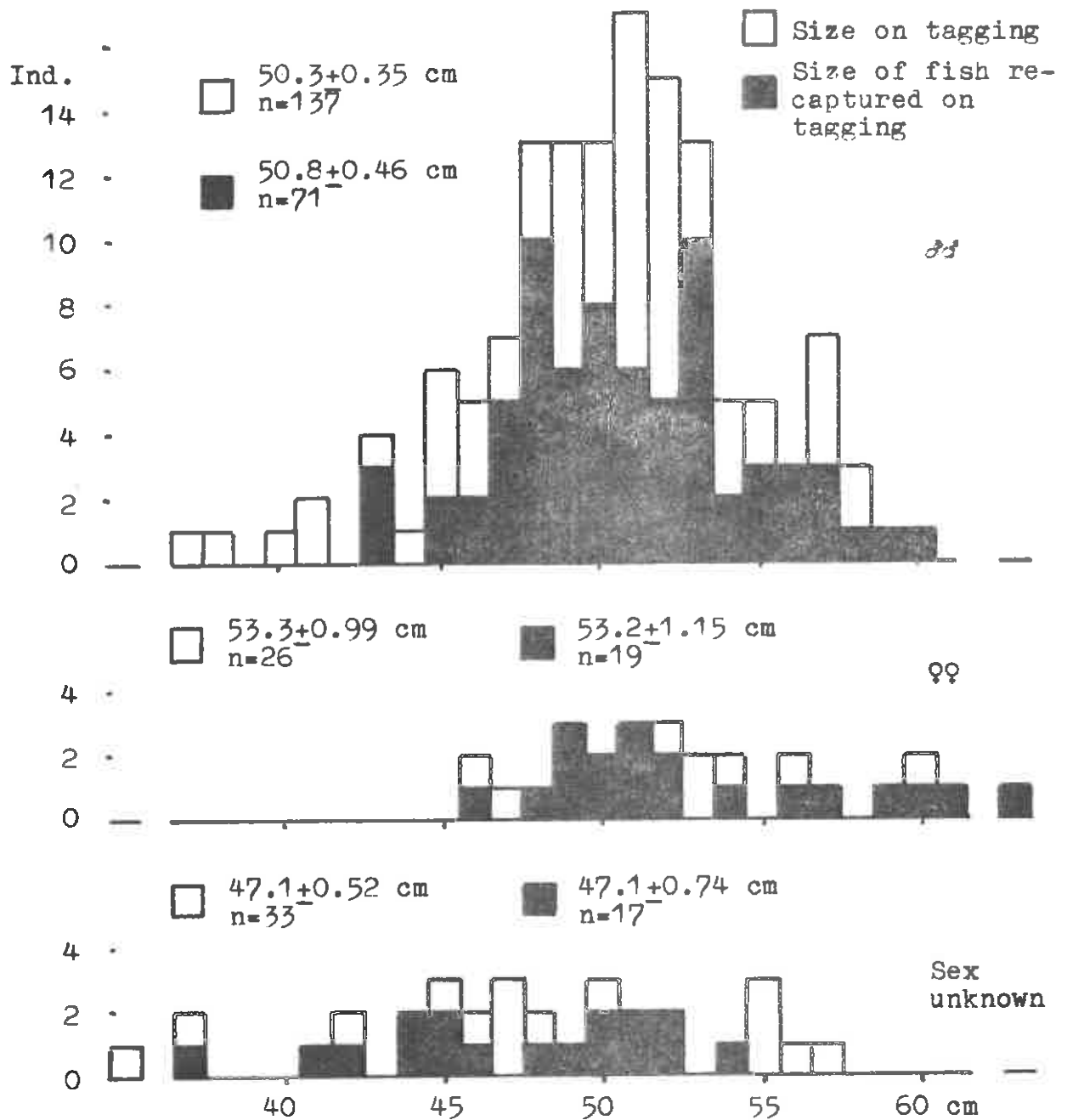
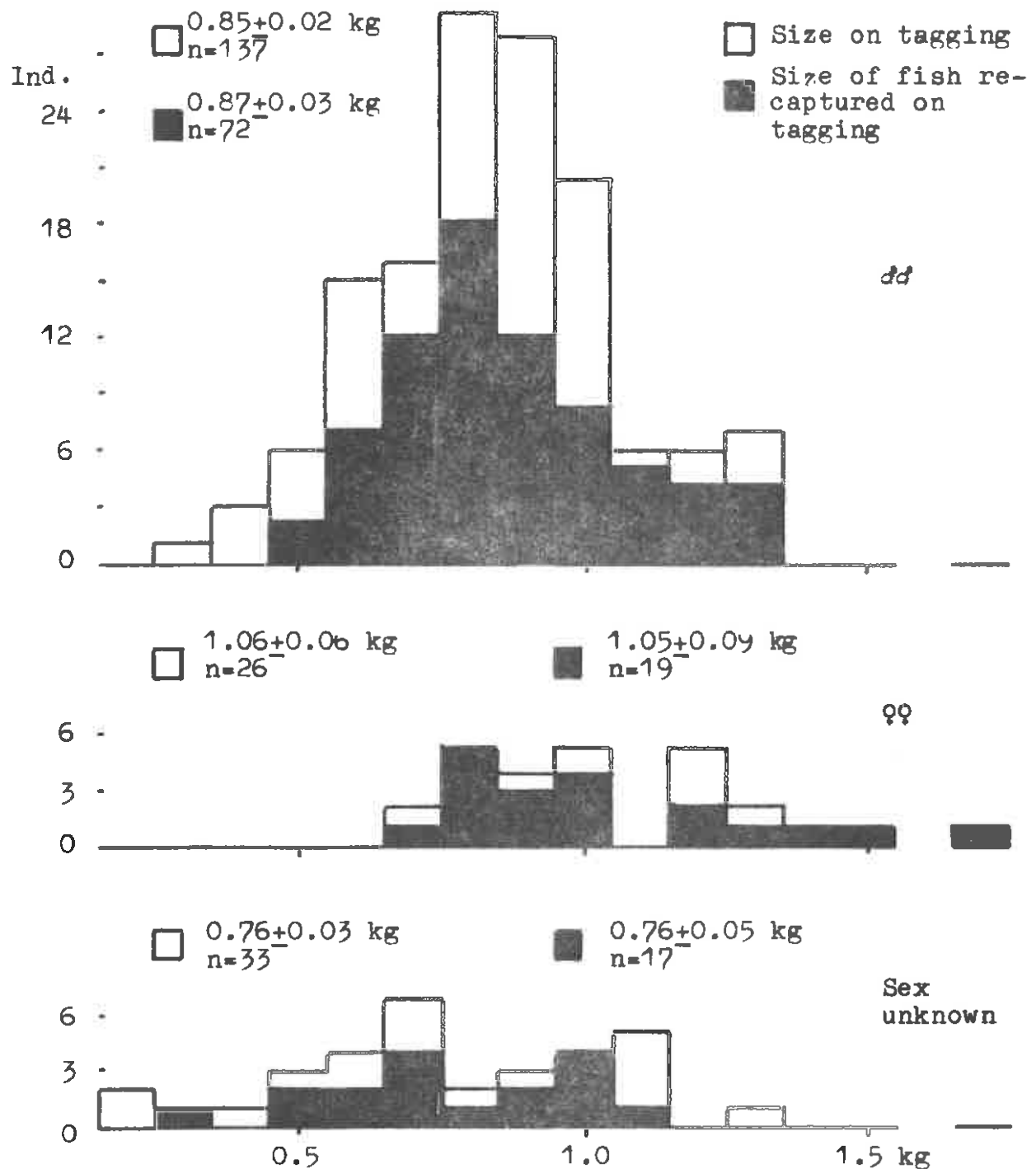


Fig. 4. Distribution by length of the fish tagged and those recaptured in the study area. Horizontally, length in cm, vertically, number of fish. - Kuva 4. Pituusjakautuma merkintäaikana (valkeat pylväät) ja merkittynä tavattujen kalojen pituus merkittäessä (mustat pylväät). Jakautumat osoittavat, että pyynti ei valikoisi saalista koon perusteella. vaakasuunnassa kalojen pituus cm ja pystysuunnassa lukumäärä.



Kuva 5. Distribution by weight of the fish tagged and those recaptured in the study area. horizontally, weight in kg, vertically, number of fish. - Kuva 5. Painojakautuma merkintäaikana (valkeat pylväät) ja merkittynä tavattujen kalojen paino merkittäessä (mustat pylväät). Vaakasuunnassa paino kg ja pystysuunnassa kalojen lukumäärä. Ks. Kuva 4.

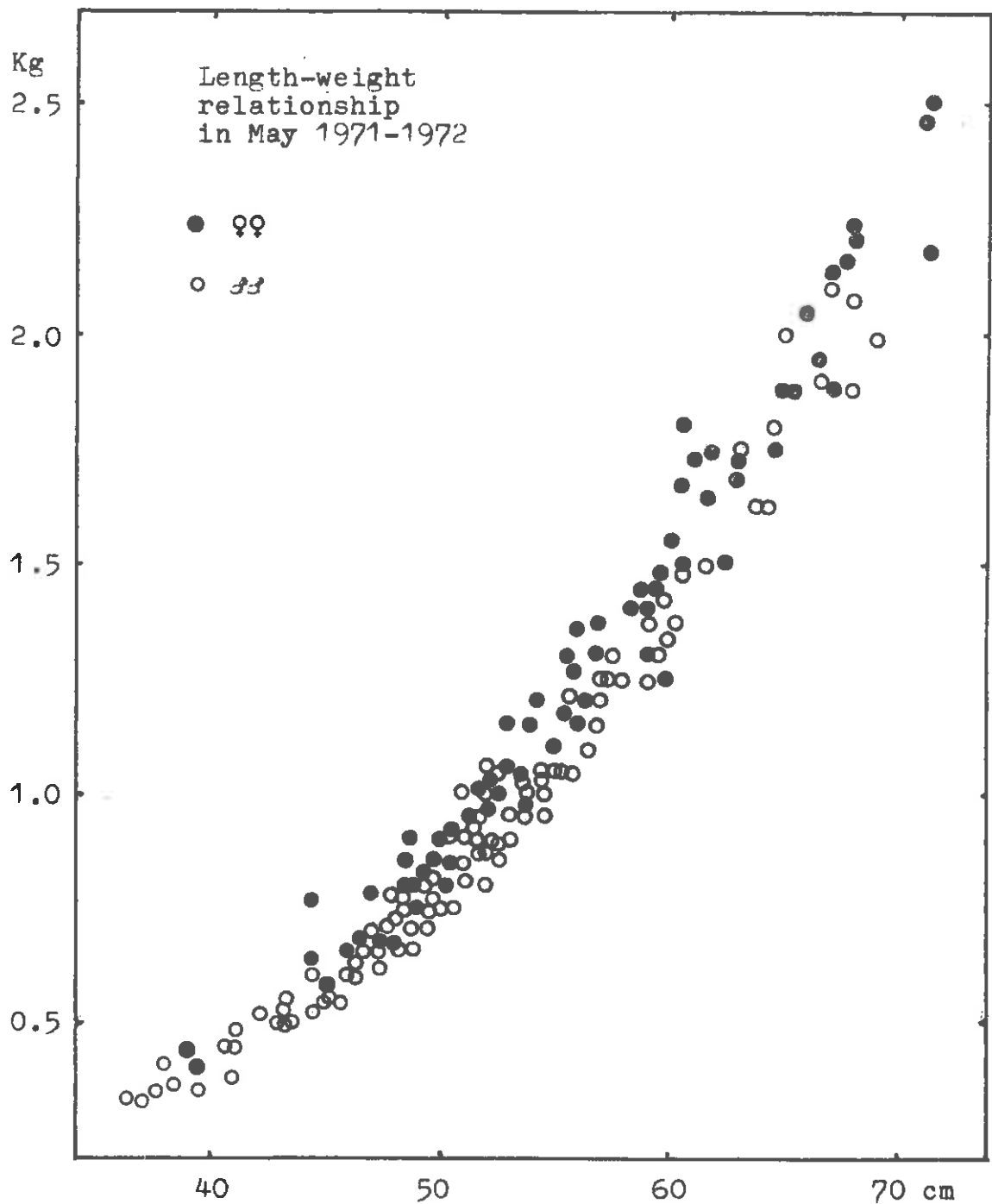


Fig. 6. Length-weight relationship of the males and females in May 1971-1972. horizontally, length in cm, vertically, weight in kg. The differences between the males and females are mainly due to differences in gonad weight.

- Kuva 6. ♂♂:n ja ♀♀:n pituuden ja painon suhde toukokuussa 1971-1972. Vaakasuunnassa kalan pituus cm ja pystysuunnassa paino kg. Sukupuolien väliset erot johtuvat pääasiassa gonadien painoeroista.

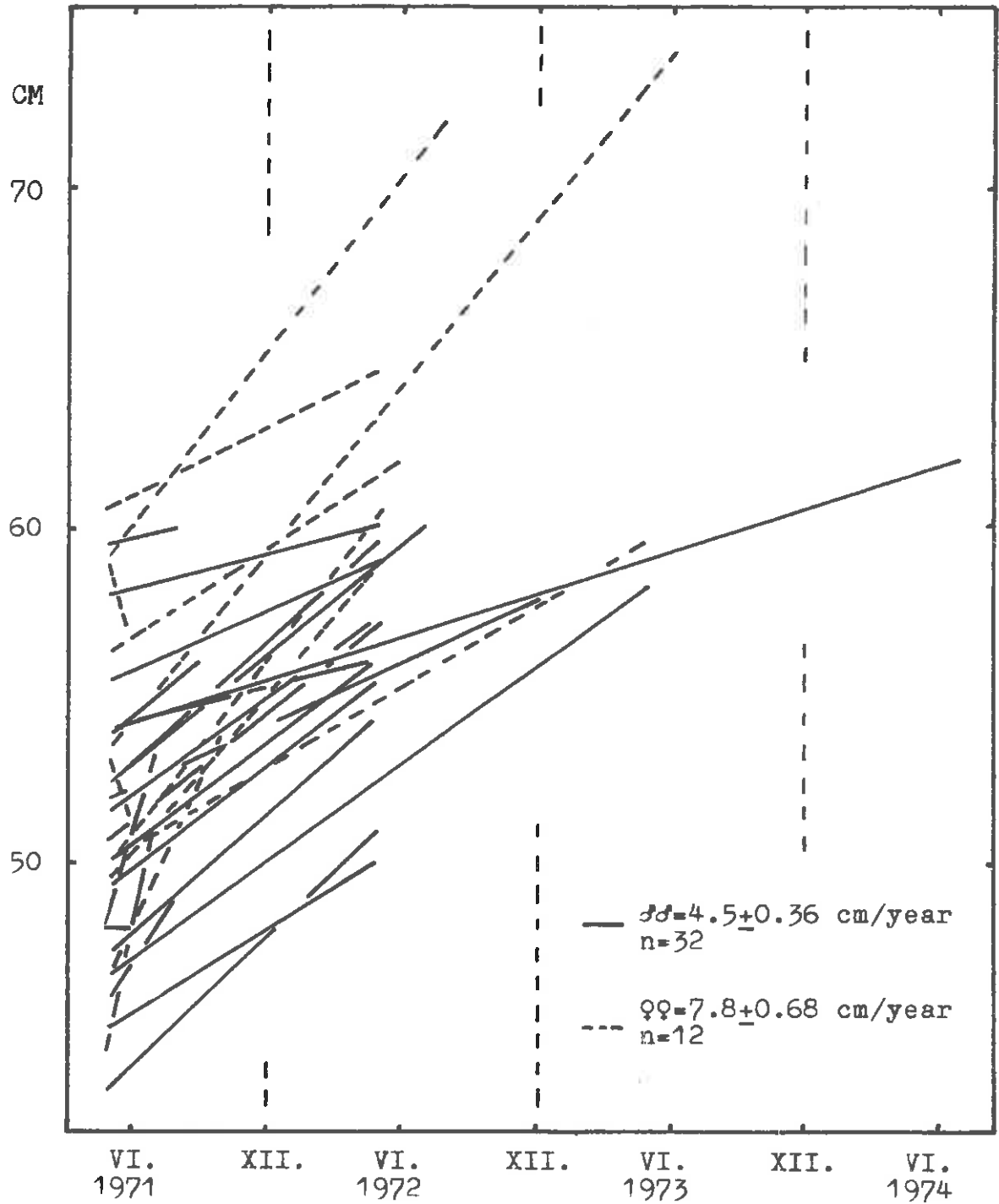


Fig. 7. Yearly and seasonal length changes determined on the basis of the fish tagged in May 1971. Horizontally, the months during the period May 1971 - June 1974, vertically, length in cm. - Kuva 7. Hauen pituuden muutokset toukokuussa 1971 merkittyjen ja myöhemmin merkittynä tavattujen kalojen perusteella. vaakasuunnassa aikaväli toukokuusta 1971 kesäkuuhun 1974, pystysuunnassa kalan pituus cm.

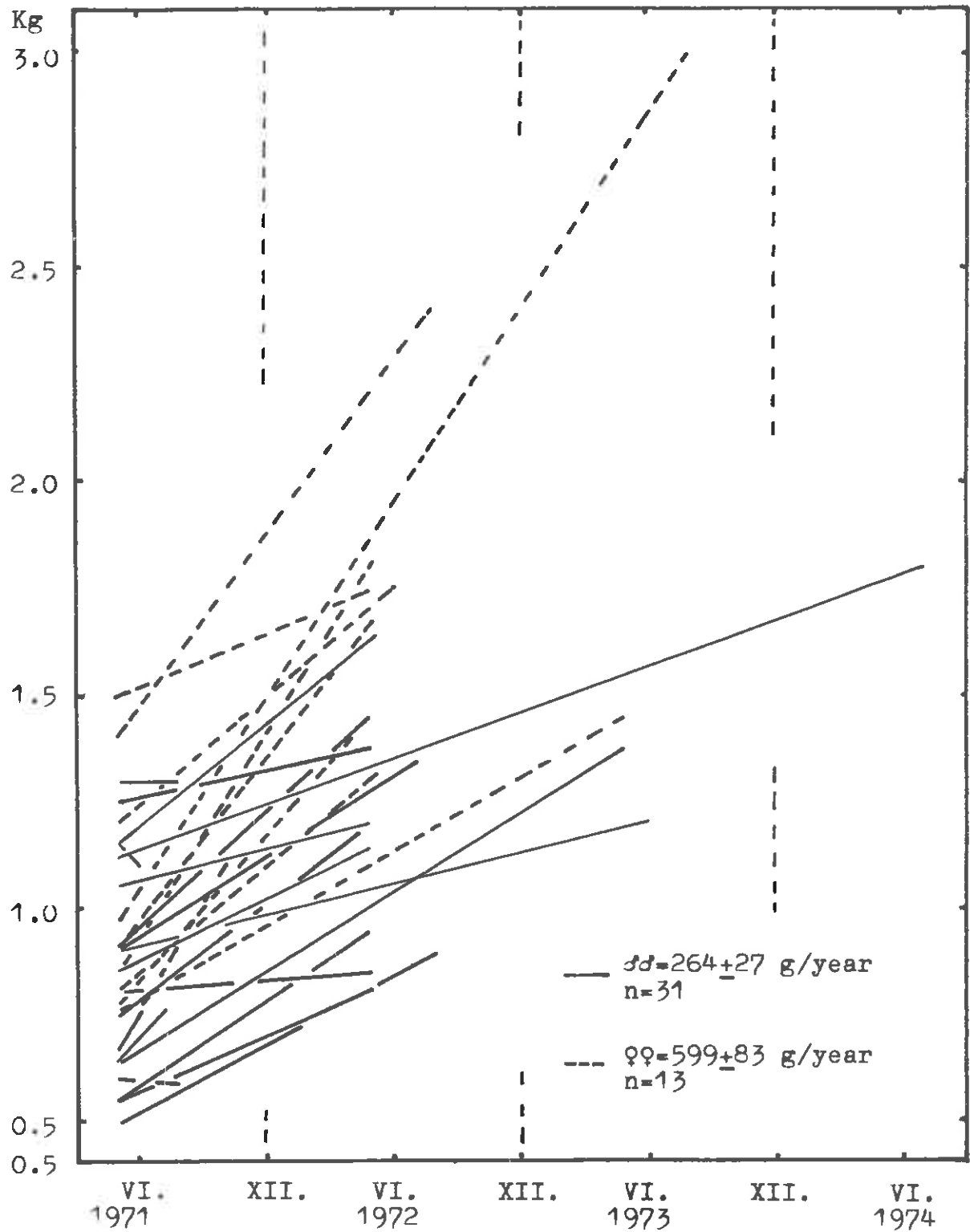


Fig. 8. Yearly and seasonal weight changes determined on the basis of the fish tagged in May 1971. Horizontally, the months during the period May 1971 - June 1974, vertically, weight in kg. - Kuva 8. Hauen painon muutokset toukokuussa 1971 merkittyjen ja myöhemmin merkittynä tavattujen kalojen perusteella. vaakasuunnassa aikaväli toukokuusta 1971 kesäkuuhun 1974, pystysuunnassa kalan paino kg.

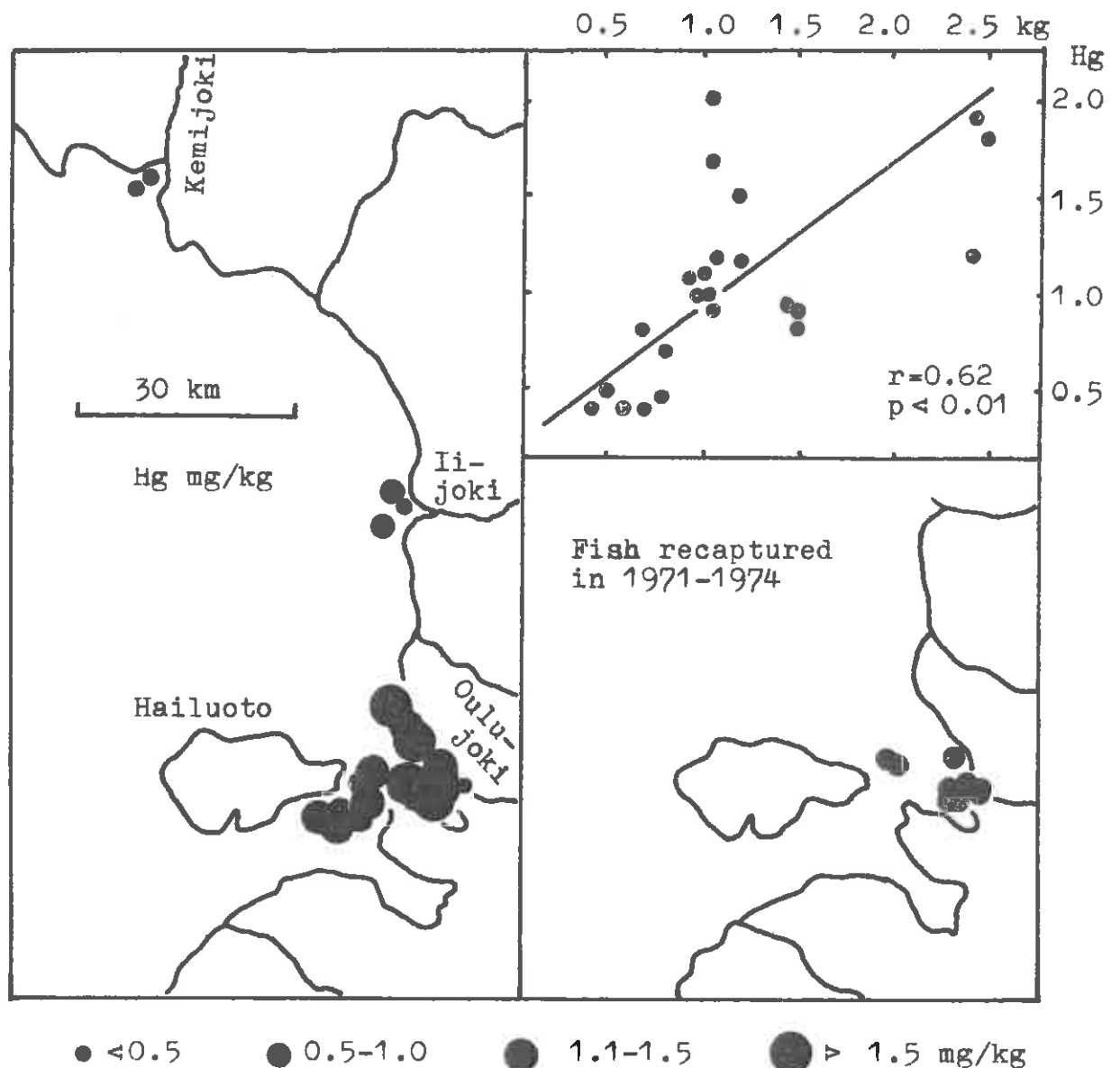


Fig. 9. Left, regional variation in the concentration of mercury in the muscle of the pike, key below. Right above, correlation between mercury content and weight of the pike in 1969-1970 (drawn on the basis of measurements by National Board of waters, Finland). Right below, regional variation in the pike tagged in the mouth of the Oulujoki river in May 1971. - kuva 9. Vasemmalla hauen elohopeapitoisuuden vaihtelu Perämeren NE-osassa, merkkien selitys alhaalla. Oikealla ylhäällä elohopeapitoisuuden ja hauen painon välinen korrelaatio (piirretty Vesihallituksen v. 1969-1970 suorittamien mittaus-ten perusteella). Oikealla alhaalla Oulujoen suistossa touko-kuussa 1971 merkittyjen haukien myöhemmät tapaamispaikat. Liik-kumisalueen laajuus oli keskimäärin 1 km.

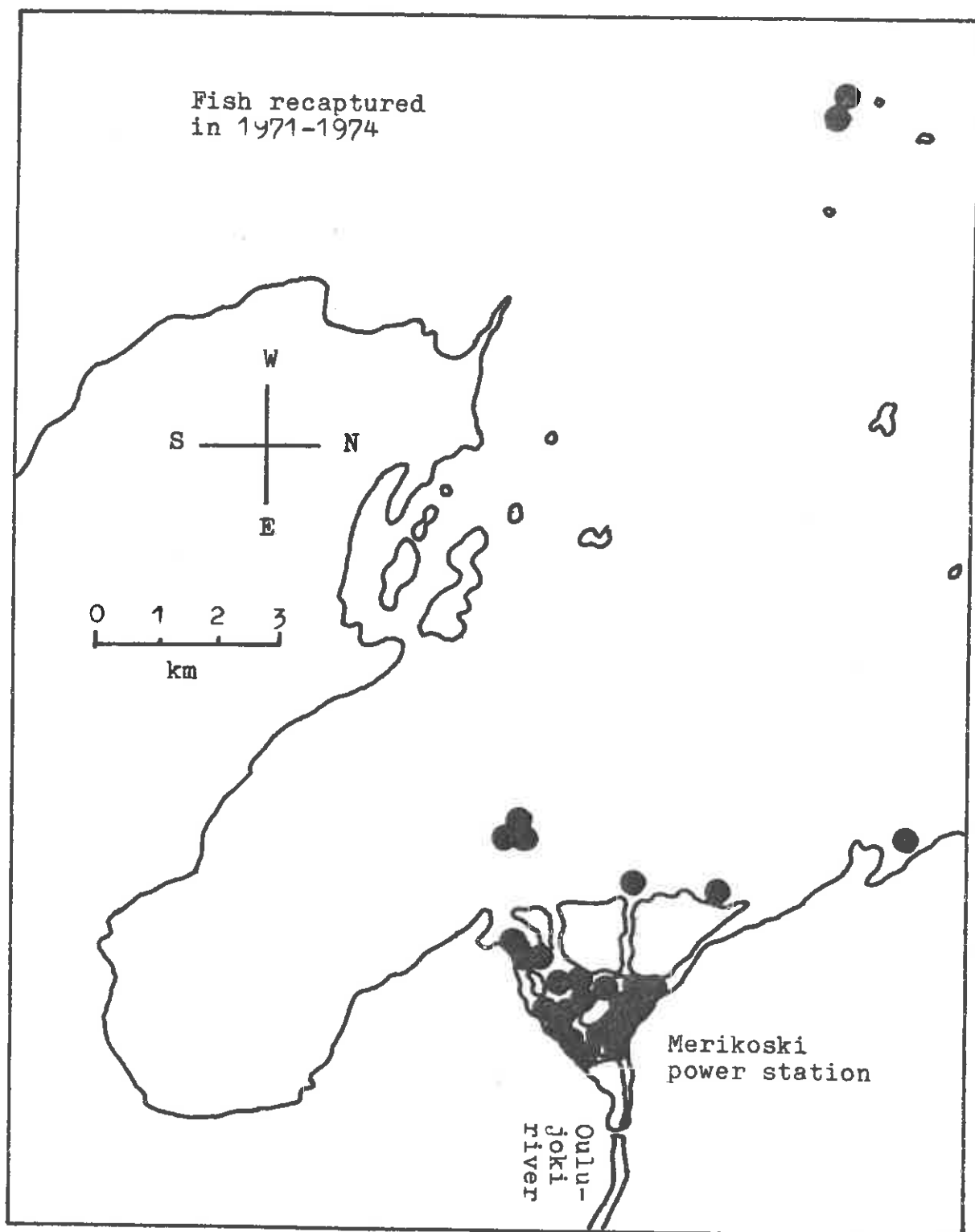


Fig. 10. The dots represent the recapturing sites of the fish tagged in the mouth of the Oulujoki river in 1971. The average extent of the movements amounted to 1.0 ± 0.12 km, the longest migration being 16 km. - Kuva 10. Pisteillä on osoitettu toukokuussa 1971 merkittyjen kalojen myöhemmät tapaamispaikat. Pisin vaellus ulottui 16 km päähän.