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Variation in the relative year-class strength of pikeperch, *Stizostedion lucioperca* (L.), in two Finnish lakes at different latitudes

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The catch per unit effort (*CPUE*), total catch and growth data of pikeperch, *Stizostedion lucioperca* (L.), from two Finnish lakes, Lake Lohjanjärvi and Lake Pyhäselkä, were gathered between 1979 and 1994. The growth rate of pikeperch in southern Lake Lohjanjärvi was faster than in northern Lake Pyhäselkä. The variation in the year-class index was higher in Lake Lohjanjärvi. We concluded that the shorter growing season and lower temperatures in northern areas weakened the variation in the relative strength of the year-classes.

1. Introduction

Both biotic and abiotic factors cause variation in the year-class strength of fish in lakes (e.g. Miller *et al*. 1988). Intra- and interspecific relations of fish and the productivity of the ecosystem are the main biotic components of population fluctuations (Miller *et al*. 1988, Luecke *et al*. 1990). The most important abiotic factor is generally temperature. Its seasonal variations cause periodicity and regional differences in the production of the fish stocks.

The strength of year-classes of pikeperch, *Stizostedion lucioperca* (L.), vary greatly. It has been demonstrated in numerous studies that the temperature alone is responsible for the success of the embryonal, larval and juvenile development, and for recruitment of pikeperch (e.g. Deelder & Willemsen 1964, Willemsen 1977, Svärdson & Molin 1981, Van Densen & Grimm 1988, Buijse 1992, Colby & Lehtonen 1994, Lappalainen *et al*. 1995, Lehtonen & Lappalainen 1995) and of perch, *Perca fluviatilis* L. (Neuman 1976, Böhling *et al*. 1991, Lehtonen & Lappalainen 1995, Sandström *et al*. 1995). The spawning of pikeperch begins normally at around 14°C and the temperature preference of adult fish ranges between 24 and 29°C (Hokansson 1977). Due to the northern location of Finnish lakes, water temperatures remain normally below the optimum for pikeperch.

We analysed the growth rate and the relative strength of year-classes in pikeperch populations

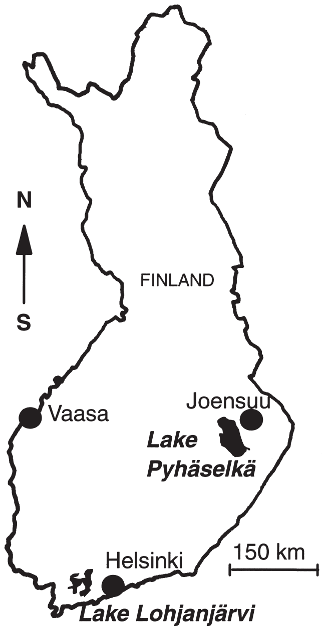

Fig. 1. Location of the study lakes and meteorological stations.

of two Finnish lakes, the southern Lake Lohjanjärvi and the northern Lake Pyhäselkä. We expected to prove that the variation in the year-class strength of pikeperch would be higher in Lake Pyhäselkä, i.e. near the northern edge of the distribution range of this species in Finland. Thus, in a northern lake, fewer strong year-classes are expected, while in a southern lake strong year-classes should occur more frequently.

2. Material and methods

Total catch, *CPUE* and growth data of pikeperch were collected from two Finnish lakes: the eutrophic and humic Lake Pyhäselkä (Fig. 1) which is located in eastern Finland (62°20´–62°40´N, 29°33´–29°26´E) and Lake Lohjanjärvi (60°09´–60°22´N, 23°44´–24°05´E), a eutrophic lake in southern Finland. The surface area of Lake Pyhäselkä is 246 km^2 and the mean depth 10 m. The area of Lake Lohjanjärvi is 89 km^2 and the mean depth 13 m. The average total phosphorous content in Lake Pyhäselkä and Lake Lohjanjärvi during summer ranged from 11 to 46 mg l^{-1} and from 10 to 47 mg l^{-1}, respectively, and the chlorophyll-*a* concentration from 3 to 14 mg m^{-3} and from 6 to 14 mg m^{-3}, respectively (Karjalainen & Günther 1993, Ranta & Kiiskinen 1995). Pikeperch occurs naturally in these lakes but it has also been stocked during the research period. Of the fish catches, 50–60% were cyprinids (mainly *Rutilus rutilus* (L.) and *Abramis* spp.) and percids (perch, pikeperch), 10–20% coregonids (*Coregonus albula* (L.), *C. lavaretus* L.) and pike (*Esox lucius* L.), and the rest were burbot (*Lota lota* (L.)), brown trout (*Salmo trutta* (L.)) and smelt (*Osmerus eperlanus* (L.)) (Lehtonen & Miina 1988, Karjalainen *et al.* 1993, Knuutinen & Mutilainen 1995, Ranta & Kiiskinen 1995).

Fish samples from Lake Pyhäselkä were collected from the gill net catches of ten local fishermen and from our own test fishing with 1.5 × 30-m gill nets (mesh sizes 10 to 80 mm, knot to knot) annually during 1983–1990 and 1992–1994. From Lake Lohjanjärvi the pikeperch samples were collected with 10 × 60-m gill nets (mesh sizes 40–80 mm) during 1979–1985 and 1989–1993. The sampling took place in winter. Weight (g) and standard length (cm) of the fishes were recorded, and the sex and maturity of fish were ascertained. Age was determined from the scales taken above the lateral line and beneath the spiny dorsal fin. Altogether, scale samples from 977 pikeperch from Lake Pyhäselkä (3–302 per year) and 2 420 from Lake Lohjanjärvi (74–360 per year) were analysed. Growth estimates were based on the observed lengths at age at the time of sampling. We used the monthly average air temperature to describe the thermal conditions in both lakes.

The *CPUE* data of Lake Pyhäselkä were based on the catch statistics of the same ten fishermen which were recorded yearly from 1981 to 1994. The catch of these fishermen was approximately 1% of the total catch in Lake Pyhäselkä (Karjalainen *et al.* 1993). The fish samples included the catches of net fishing with > 50-mm nets in Lake Pyhäselkä and the catches of > 45-mm nets in Lake Lohjanjärvi. The net fishing was mainly targeted at 4–6-year-old fish and the size of recruitment was slightly over 40 cm in both lakes.

The year-class index which describes the relative strength of year-classes was calculated from the data of Lake Lohjanjärvi according to Svärdson (1961), see also Lehtonen and Lappalainen (1995). The index of Lake Pyhäselkä was based on the *CPUE* data and the age distribution of fish. The calculations were restricted to ages 4–7, i.e. to fishes that were old enough to be caught and to age groups that were well represented in the catches. The index of both lakes was scaled between 0 and 500. The year-class strengths were estimated stepwise beginning with the calculation of the percentage age-class distribution in the annual samples. Thereafter, the mean percentage age-class distribution for the whole period was established. In the next step, the different year-classes in different years were expressed as percentages of this mean distribution. Only year-class indices based on at least two years were used. The year-class index is a relative parameter that corresponds to absolute *CPUE* values within a lake. Between the lakes they are not quantitatively comparable.

The annual total catch of pikeperch in both lakes was estimated by a catch-questionnaire collected from randomly selected fishermen at 2–3-year intervals for Lake Pyhäselkä (years 1975, 1978, 1980, 1983, 1986, 1989 and 1992; Karjalainen *et al.* 1993) and in 1983 and 1990 for Lake Lohjanjärvi (Lehtonen & Miina 1988, Knuutinen & Muttilainen 1995, Ranta & Kiiskinen 1995).

3. Results and discussion

According to the test fishing in Lake Pyhäselkä, the average length of pikeperch caught by the nets with a mesh size of 50 mm was 46 cm (n = 49, $S.D.$ = 4.3). Although the winter fishing restrictions (minimum mesh size 50 mm) should limit the age of caught pikeperch to age 6 or more (average body mass 870 g, average total length 45 cm), 5-year-old fish were also caught (body mass 500–700 g, length 38–42 cm). In Lake Lohjanjärvi, also 4- or 5-year-old pikeperch were harvested (Lehtonen & Miina 1988). In both lakes, the majority of female pikeperch reach maturity at the age of 6 years and, thus, a considerable proportion of fish are harvested before their first reproduction.

The growth rate of pikeperch in Lake Lohjanjärvi was higher than in Lake Pyhäselkä (Fig. 2). Especially, 1–5-year-old fish grew significantly faster in our southern study lake, and thus, the regression coefficients of the LOG(length)–LOG(age) and LOG(weight)–LOG(age) were significantly higher than in the northern Lake Pyhäselkä (t-test between slopes, $p < 0.01$, n = 110 and 353). The trophic level of the lakes was about the same and the difference in growth rate was probably due to the longer growing season in Lake Lohjanjärvi. The average air temperature in April–May and in August–October was approx. 2°C higher at Lake Lohjanjärvi than at Lake Pyhäselkä (Table 1) suggesting a similar difference in water temperature. During our study period, there were 5 years in Lake Pyhäselkä (Joensuu) and 9 years in Lake Lohjanjärvi (Helsinki), when the average air temperature exceeded 10°C in September.

Between 1975 and 1989, 2–3 strong year-classes of pikeperch developed in both lakes. Reproduction of pikeperch and the development of their young were especially successful in 1988. Since 1991 in Lake Lohjanjärvi and since 1993 in Lake Pyhäselkä, the year-class 1988 has prevailed in the pikeperch catches. The years when the strong year-classes appeared were warm, and the warm season continued into September (Table 1).

The coefficient of variation ($c.v.$ %) of the year-class index (Fig. 3) was 112% in Lake Lohjanjärvi and 55% in Lake Pyhäselkä, but after log-transformation of the year-class index our data indicated no significant difference between the lakes (t-test according to Sokal & Brauman 1980, $p > 0.10$, $df = 29$). Log-transformation which was performed in order to normalize the skewed distribution of the year-class index reduced the variation. Furthermore, the ratio between the maximum and minimum values of the year-class index was 29 in Lake Lohjanjärvi and 12 in Lake Pyhäselkä. The original assumption that the variation in the northern lake would be higher than in the southern lake had to be rejected. On the con-

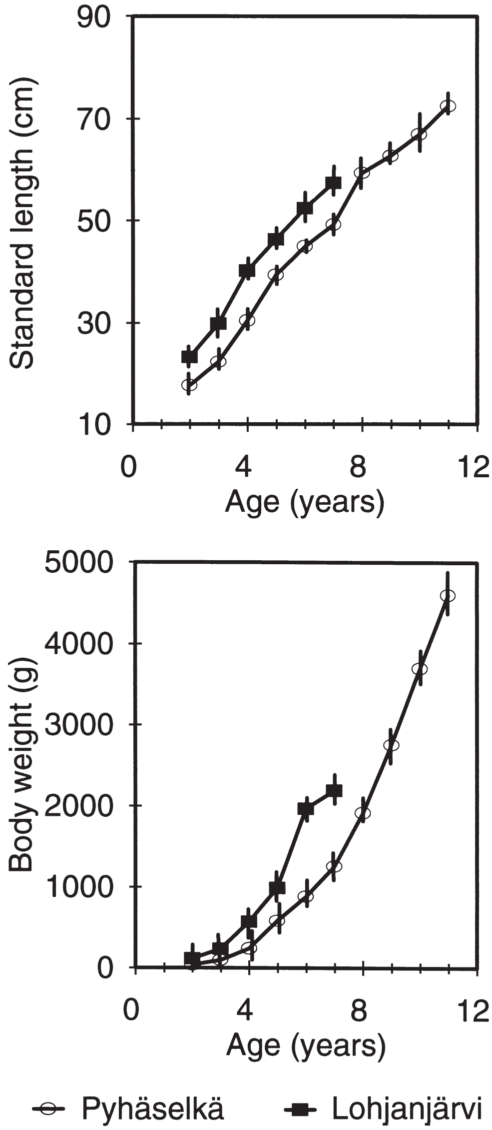

Fig. 2. Mean standard length (cm) and wet weight (g) of pikeperch in Lakes Pyhäselkä and Lohjanjärvi at different ages. The vertical bars represent the 95% confidence limits of the means.

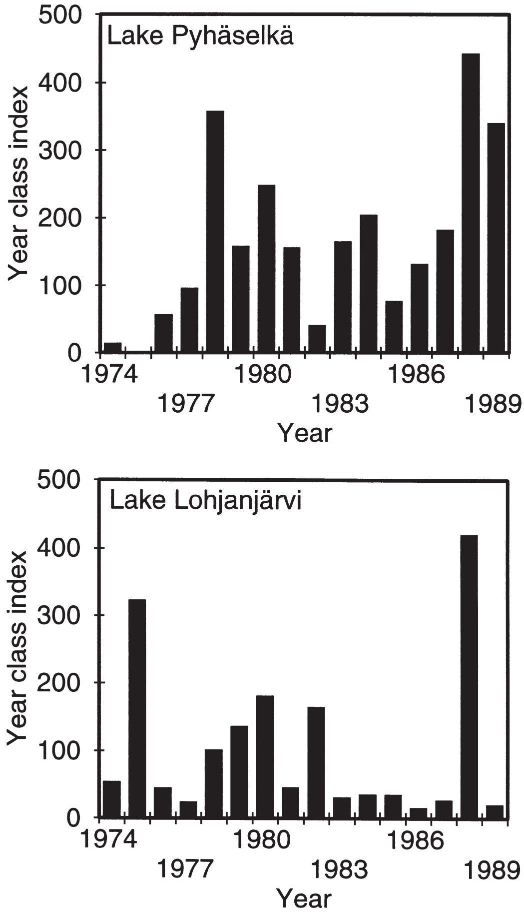

Fig. 3. Relative year-class index of pikeperch in Lakes Pyhäselkä and Lohjanjärvi from 1974 to 1989. Note: Year-class indices between lakes are not in a comparable scale.

trary, the variation in the strength of year-classes appeared to be higher in southern Lake Lohjanjärvi.

In Lake Lohjanjärvi, the catches of pikeperch per hectare were clearly higher than in Lake Pyhäselkä (Fig. 4). The annual catch in Lake Pyhäselkä varied between 0.1 and 0.3 kg ha^{-1} (1975–1992) and in Lake Lohjanjärvi between 1.1 and 1.3 kg ha^{-1} (1983 and 1990) corresponding with the total pikeperch catch in Lake Pyhäselkä (3 000 and 7 000 kg) and in Lake Lohjanjärvi (9 500 and 11 000 kg). We concluded that the shorter growing season and lower temperatures in northern areas of the distribution of pikeperch caused a decrease in the year-class formation even in favourable years, which then weakened the variation in the year-classes. Thus, the year-class strength remained lower in Lake Pyhäselkä even in the favourable years.

The range and the *c.v.* of year-class indices of pikeperch (max./min. ratio > 20) was considerably higher than the range and the *c.v.* of perch (max./min. ratio < 10) in the coastal waters of the

Table 1. The monthly average air temperatures (°C) in Joensuu and Helsinki 1975–1994 (Anonymous 1975–1994).

Year	Apr	May	Jun	Jul	Aug	Sept	Oct
Joensuu							
1975	1.9	10.5	13.0	16.8	13.7	11.0	2.6
1976	0.1	9.3	10.5	14.5	13.4	6.2	– 1.5
1977	0.8	8.3	13.7	16.0	13.4	6.8	2.0
1978	– 0.9	9.3	13.8	15.4	12.3	7.7	1.6
1979	– 1.0	10.0	14.6	15.8	15.0	8.3	1.2
1980	1.7	6.0	17.3	16.2	13.9	8.6	3.1
1981	– 0.6	9.1	12.8	17.7	13.2	8.5	5.0
1982	1.3	7.9	13.6	16.8	14.2	8.4	2.3
1983	3.1	10.6	13.1	18.0	14.1	10.2	3.5
1984	3.1	12.5	14.0	16.1	13.6	8.6	4.9
1985	– 1.0	7.3	13.1	15.7	15.7	9.2	4.6
1986	0.7	8.4	17.1	17.4	12.4	5.9	3.7
1987	0.1	7.1	13.4	14.6	11.1	7.5	5.5
1988	– 1.1	9.1	16.2	19.4	14.0	10.0	3.2
1989	3.8	10.2	16.7	16.9	14.3	10.0	3.1
1990	1.4	6.7	12.6	15.5	14.6	7.1	3.2
1991	3.9	8.1	13.2	16.6	15.2	8.0	4.9
1992	– 1.0	9.4	15.3	15.2	13.1	11.6	– 1.9
1993	0.5	11.0	10.6	15.6	13.3	4.7	0.8
1994	3.4	6.4	13.4	18.5	14.7	9.3	2.9
Helsinki							
1975	3.3	11.6	13.6	17.8	16.3	12.9	5.5
1976	1.9	10.9	12.8	15.5	15.1	8.0	1.5
1977	1.6	9.4	14.2	14.7	14.4	8.1	3.0
1978	2.0	10.4	14.6	15.3	13.7	8.5	4.0
1979	1.8	10.8	16.0	14.7	16.0	9.7	4.0
1980	4.7	7.2	16.9	16.9	15.2	11.1	5.7
1981	1.9	11.1	13.1	17.0	14.6	10.7	6.7
1982	2.9	9.4	11.9	16.1	17.3	10.6	5.1
1983	5.3	11.8	13.9	18.3	15.8	12.1	6.4
1984	4.7	12.9	14.0	15.2	14.9	9.9	7.2
1985	1.2	9.5	13.6	15.8	16.2	9.3	7.0
1986	3.1	10.9	16.8	17.1	13.8	7.1	5.8
1987	2.6	8.4	12.6	15.3	12.5	9.1	6.9
1988	1.7	12.2	17.3	19.8	14.5	11.3	4.6
1989	5.5	11.1	17.0	17.4	14.3	11.4	5.3
1990	3.7	8.0	12.8	17.7	16.7	9.9	5.9
1991	6.2	9.9	14.3	15.8	15.7	8.7	3.2
1992	2.0	11.4	15.9	16.7	14.9	12.0	0.7
1993	3.7	13.3	12.2	16.0	13.6	6.5	3.7
1994	5.3	8.4	12.9	19.9	15.6	11.1	4.9

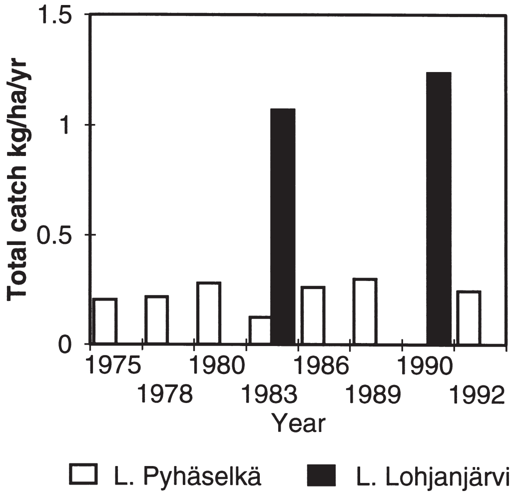

Fig. 4. The annual catch of pikeperch per hectare (kg ha^{-1}) in Lakes Pyhäselkä and Lohjanjärvi in 1975–1992.

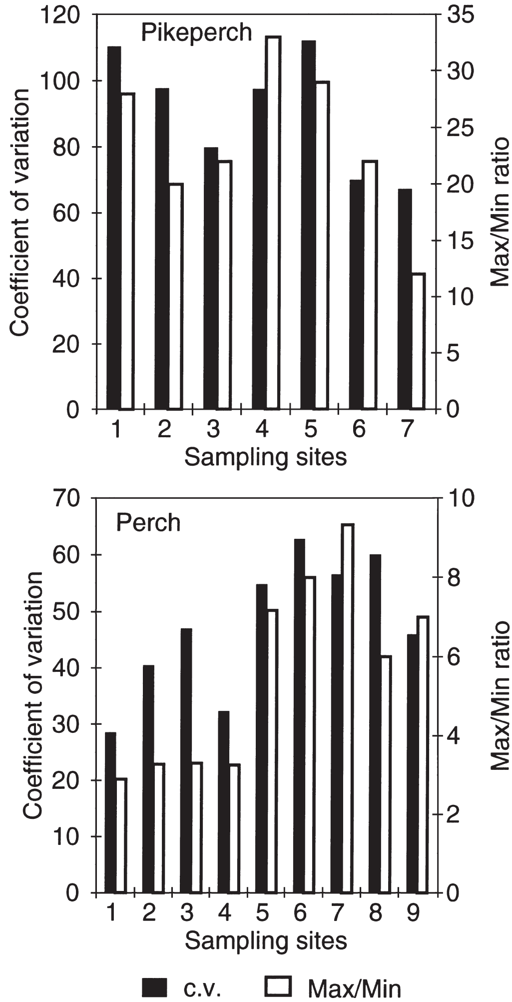

Fig. 5. The coefficient of variation (*c.v.*%) and the relationship between the maximum and minimum year-class indices of pikeperch and perch in the different sampling sites of Baltic coastal waters (data from Böhling *et al.* 1991, Lehtonen & Lappalainen 1995). Sampling sites from south to north for pikeperch: 1 = Åland, 2 = Helsinki, 3 = Hamina, 4 = Taivassalo, 5 = Lohjanjärvi, 6 = Pori and 7 = Pyhäselkä; and for perch: 1 = Hamnefjärden, 2 = Simpevarp, 3 = Fjärdsundet, 4 = Helsinki, 5 = Taivassalo, 6 = Pori, 7 = Söderfjärden, 8 = Luoto, 9 = Kemi.

Baltic Sea (Fig. 5). The reproduction of pikeperch is more sensitive to external disturbances than the reproduction of perch. Spawning areas of pikeperch are more restricted, the spawning period is shorter and probably the eggs of pikeperch are less protected against predators in spite of the nest-guarding behaviour. The duration of the growing season seems also to be more critical for pikeperch than perch. Altogether, the offspring production of pikeperch is more labile than the production of perch.

According to data of Böhling *et al.* (1991) and Lehtonen and Lappalainen (1995), the variation in the year-class index of pikeperch was lower in the northern sampling sites than in the southern. On the contrary, the *c.v.* of the year-class index of perch increased with increasing latitude (Fig. 5). We conclude that, even in favourable years, pikeperch populations near the northern edge of its distribution range are not as capable of producing a strong year-class as those in southern areas. Thus, the temperature sets the upper limit of the year-class production of pikeperch in the north. On the other hand, the success of the production of perch is not so tightly regulated by the temperature. The shorter growing season in the north does not lower the upper limit of the year-class production of perch but it makes the strong year-classes more rare. The variation in the year-class index of perch increased northward as expected according to our original hypothesis for pikeperch.

Fishing pressure and biotic factors such as food availability, parental stock size and interspecific interactions vary between the sampling sites in the Baltic sea (Böhling *et al.* 1991) and also between our study lakes. The differences may produce deviations which weaken the temperature-regulated year-class pattern. However, the climate and temperature synchronize the stock fluctuations (Böhling *et al.* 1991, Lehtonen et al. 1993, Lehtonen & Lappalainen 1995) and regulate the upper limits of the year-class production of percids.

In summary, our findings support several earlier observations that high water temperatures during the first growing season increase the probability of strong year classes of pikeperch, and higher yields once the fish recruit to the fishery.

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