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Covariation in year-class strength of perch, *Perca fluviatilis* L. and pikeperch, *Stizostedion lucioperca* (L.)

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Covariation in the year-class strengths of perch, *Perca fluviatilis* L., and pikeperch *Stizostedion lucioperca* (L.), were studied among ten populations in Baltic coastal areas and three pikeperch populations in lakes. Within the studied periods in 1974–1981 and 1980–1987 the covariations in the year-class strength were similar between populations of the same species and between species. When the variations in year-class strength in several populations were compared annually between species no statistically significant differences were found during the 16 examined years. Despite the covariations, correlation coefficients in year-class strength between populations were lower for greater distances. About half (18 cases out of 35) of the correlation coefficients were statistically significant when the distance between populations was less than 300 km. Some rather high correlation coefficients were also found at distances between 300 and 900 km, but only one was statistically significant.

1. Introduction

Several abiotic factors are known to affect the year-class strength of perch, *Perca fluviatilis* L., and pikeperch, *Stizostedion lucioperca* (L.), among them temperature, wind velocity and direction, water level and the duration of ice cover (e.g. Woynarovich 1963, Svärdson & Molin 1968, 1973, Koonce *et al*. 1977, Willemsen 1977, Böhling *et al*. 1991, Lehtonen & Lappalainen 1995). Most often the strongest effects are those related to temperature. Because the year-class variations of both species is strongly correlated with air temperature (Lehtonen & Lappalainen 1995), we hypothesized that the year-class strengths should fluctuate in the same manner in different populations. On the other hand, because the correlations between different sites in air temperatures are stronger in places located nearby than those located far away (Malcher & Schönwiese 1987), year-class strengths should differ less in populations situated close to each other than in remote populations.

Fig. 1. Study area. Perch study sites are marked with stars and pikeperch with squares.

The objective of this study was to compare the variations in year-class strength in several perch and pikeperch populations. Another objective was to examine the variation in year-class strength between populations in relation to their distance. Positive effects of temperature on both species have been demonstrated in many studies (e.g. Svärdson & Molin 1973, Willemsen 1977, Craig *et al.* 1979, Böhling *et al.* 1991, Buijse & Houthuijzen 1992, Buijse *et al.* 1992, Lappalainen & Lehtonen 1995, Lehtonen & Lappalainen 1995), and we suggested that the temperature is directly or indirectly the main reason for the variations in year-class strength. In some populations environmental changes may have crucial effects on year-class strength variation (Hudd *et al.* 1994), but such study sites were not included in our analyses.

2. Material and methods

2.1. Study area

The study areas consist of the northern Baltic Sea at latitudes 55–65°N and Lakes Lohjanjärvi (Finland, latitude 60°N), Mälaren and Hjälmaren (Sweden latitude 59–60°N) (Fig. 1). In the northernmost study area the salinity of the surface water is as low as 1–3‰ as compared to 7‰ at the Lithuanian coast (Kurish Haff). Tides are insignificant in the whole Baltic Sea. On average, the nearshore Baltic waters are ice-covered for 6 months in the northernmost parts and there may be years of ice-free winters on the Lithuanian and Estonian coasts.

Lake Lohjanjärvi has an area of 89 km^2, the mean depth is 13 m, and the greatest depth 54 m. The lake is subject to cultural eutrophication from municipal and industrial effluents. Loading has, however, diminished during recent decades. Lake Mälaren is the third largest lake of Sweden having an area of 1 140 km^2. Its mean depth is 11.9 m and maximum depth 61 m. Water level is regulated having a range of 0.5 m. Its water is eutrophicated. Lake Hjälmaren has an area of 478 km^2. Its mean depth is 6.1 m and maximum depth 22 m. Its water level is regulated. The water is eutrophicated (Lake Biwa Res. Inst. & Internat. Lake Environ. Comm. 1989).

2.2. Year-class material

Perch and pikeperch material were collected by our own test-fishing and commercial fishermen. The annual sample size was in most cases 100–300 fish per study site, but they were even higher in some sites. Pikeperch material presented by Svärdson and Molin (1973) from lakes Hjälmaren and Mälaren and Gaygalas and Gyarulaytis (1974) from Lithuanian coast were analysed and used only in the examination of year-class variations between populations in relation to the distance. Populations were assumed to be separate even in the closest situated study sites in Helsinki, because samplings were performed during the spawning season when the stocks are known to be isolated (Böhling & Lehtonen 1984, Lehtonen & Toivonen 1987). All year-class strengths were calculated according to the method of Svärdson (1961) adjusted by Neuman (1974) from up-dated catch data (Böhling *et al.* 1991, Lehtonen & Lappalainen 1995) (Table 1). The year-class strength calculation method is described in detail by Böhling *et al.* (1991) and Lappalainen and Lehtonen (1995). Populations with at least 8 year-classes were included in the analyses.

2.3. Statistical analysis

The variations in year-class strength were compared with a Mann-Whitney *U*-test (SAS Institute 1988). The variations in year-class strength within the two periods of 1974–1981 and 1980–1987 were analyzed with a cluster analysis based on the Pearson correlations between populations (SYSTAT 1992). Furthermore, the covariation in the year-class strengths were studied with a Kendall's coefficient of concordance within these two periods. The periods were chosen to include both cold (1977 and 1981) and warm summers (1980) in the analyses (Lehtonen & Lappalainen 1995) because most of the pikeperch material was from the 1970s and perch material from the 1980s. The effects of distance on year-class strength variations between populations was studied with the correlation analysis. In correlation analyses all year-class strengths were log-transformed, because the distributions were approximately log-normal. Descriptions of all these tests were published by Sokal and Rohlf (1981).

3. Results

3.1. Year-class variations in different populations

The variations in the relative year-class strength of perch and pikeperch were similar when compared annually between species in 1974–1986 (Mann-Whitney *U*-test, Fig. 2). The interrelation in year-class strengths in four perch populations (Kendall's coefficient of concordance, $W = 0.51$, $P < 0.001$), in four pikeperch ($W = 0.72$, $P < 0.001$) and in pooled data ($W = 0.52$, $P < 0.001$) was statistically significant during the period of 1974 –1981. Furthermore there was a strong covariation between perch and pikeperch populations ($Z = 4.49$, $P < 0.001$). During the second studied period of 1980–1987 the corresponding value for perch was 0.76 ($P < 0.001$) and for pooled data 0.64 ($P < 0.001$). Correlation analysis showed that the variations in the year-class strength of pikeperch were also similar ($r = 0.80$, $P = 0.0155$, $n = 8$). Correlation analysis was used because material existed only from two populations. The cluster analysis showed that the variations in year-class strength of perch in Åland during the first period (Åland vs. other study sites, mean correlation coefficient = 0.05, *S.D.* = 0.22, $n = 7$) and in Simo during the second period (mean $r = 0.42$, *S.D.* = 0.23, $n = 6$) were different when compared with the other study sites (Fig. 3).

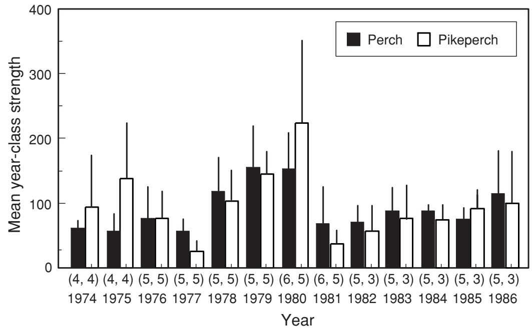

Fig. 2. Relative year-class strength (mean + *S.D*) of perch and pikeperch. In parentheses are the number of populations, first perch and then pikeperch.

Table 1. Perch and pikeperch material.

Species	Population	Sampling years	Gear	Age-groups	Year-classes	*n*
Perch	Simo	1987–1992	Trap net	2–9	1980–1988	1 171
	Pori	1981–1993	Wire trap	3–10	1973–1988	3 171
	Taivassalo	1978–1994	Pound net	3–9	1971–1989	4 508
	Åland	1986–1990	Wire trap	3–10	1978–1985	2 057
	Vanhankaupunginlahti Bay, Helsinki	1980–1994	Wire trap	3–10	1976–1989	3 122
	Vartiokylänlahti Bay, Helsinki	1978–1994	Wire trap	3–9	1978–1989	4 963
Pikeperch	Taivassalo	1977–1994	Gill net	5–10	1969–1987	4 072
	Vanhankaupunginlahti Bay, Helsinki	1977–1994	Gill net	2–8	1971–1990	4 080
	Pärnu Bay	1958–1994	Trap net	5–8	1953–1986	24 180
	L. Lohjanjärvi[1)]	1979–1985	Gill net	2–7	1974–1981	1 690
	L. Lohjanjärvi[1)]	1989, 1991–1993	Gill net	2–6	1986–1989	606
	L. Mälaren[2)]	1955–1972	Gill net	2–5	1952–1968	2 297
	L. Hjälmaren[2)]	1955–1972	Gill net	2–6	1952–1968	1 421
	Kurish Haff[3)]	1966–1972	Gill net	3–8	1954–1969	5 184

[1)] Pooled in analyses
[2)] Year-classes calculated according to Svärdson and Molin (1973)
[3)] Year-classes calculated according to Gaygalas and Gyarulaytis (1974)

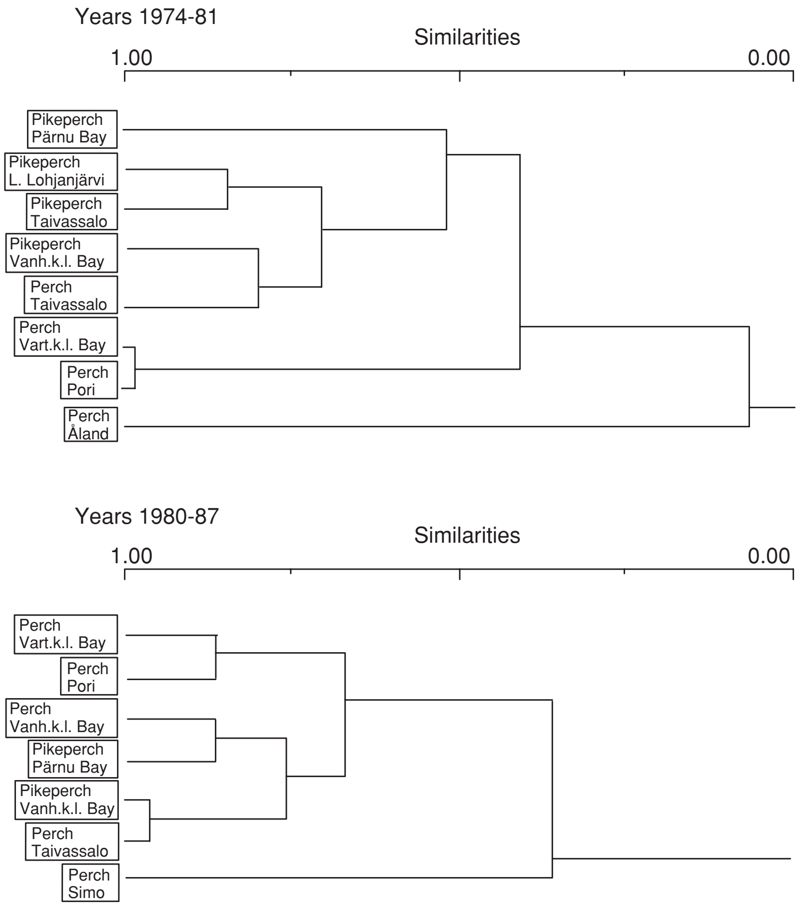

Fig. 3. Variations in year-class strength in 1974–1981 (upper figure) and in 1980–1987 (lower figure).

3.2. Year-class variations between populations in relation to geographic distance

The relationship between the variations in year-class strength between populations and the distance was, as hypothesized, negative ($r = -0.34$, $P = 0.019$, $n = 48$) (Fig. 4). The correlation was strongest among pikeperch populations ($r = -0.72$, $P = 0.0055$, $n = 13$) and negative, but non-significant, among perch ($r = -0.22$, $P = ns$, $n = 13$) and between perch and pikeperch populations ($r = -0.12$, $P = ns$, $n = 22$).

At distances less than 300 km altogether 18 statistically significant correlation coefficients were found (mean $r = 0.54$, $S.D. = 0.18$, $n = 35$), of these 5 were between perch populations ($n = 9$), 5 between pikeperch ($n = 8$) and 8 between perch and pikeperch populations ($n = 18$). The correlation coefficients were highest among perch populations (mean $r = 0.59$, $S.D. = 0.22$), lower among pikeperch (mean $r = 0.58$, $S.D. = 0.19$) and lowest among comparisons between perch and pikeperch populations (mean $r = 0.49$, $S.D. = 0.18$). However, no statistical difference was found in these coefficients between species (Mann-Whitney *U*-test). At distances between 300 and 900 km only the correlation between perch in Simo and perch in Taivassalo was significant ($r = 0.70$, $P = 0.0361$, $n = 9$), even though the correlations between perch in Simo and pikeperch in Vanhankaupunginlahti Bay ($r = 0.65$, $P = 0.0579$, $n = 9$) and in Pärnu Bay ($r = 0.55$, $P = ns$, $n = 8$) were rather high. At these distances the mean correlation coefficient was 0.28 ($S.D. = 0.31$, $n = 13$).

4. Discussion

Both perch and pikeperch have a relative high temperature preference (Hokanson 1977). In warm waters the growth rate of their juveniles is more rapid and the onset of piscivory earlier which reduces predation mortality (Buijse & van Densen 1992, Buijse & Houthuijzen 1992). Thus the length of juveniles and their abundance in their first autumn is usually closely related to the temperature during their first summer and to the year-class strength (Willemsen 1977, Shuter & Post 1990, Böhling *et al*. 1991, Buijse & van Densen 1992, Buijse & Houthuijzen 1992, Lappalainen *et al*. 1995). The length in the first autumn is of crucial importance for the survival during the first winter (Shuter & Post 1990, Johnson & Evans 1991, Conover 1992). Considering the results of Lehtonen and Lappalainen (1995) it is evident, however, that summer temperatures has a greater effect more on the winter mortality of both species than the length of the winter.

Malcher and Schönwiese (1990) showed that the correlation coefficients in mean annual air temperature between Helsinki and other European climatological stations were statistically significant up to distances 2 000 km. It is noteworthy that many significant correlations were found between Helsinki and some North American stations at distances between 6 000 and 8 000 km. In our material the covariation in year-class strength of perch and pikeperch was obvious in populations situated at distances less than 300 km. When the distance between stations exceeded 300 km, only one statistically significant correlation was found. In the study of Malcher and Schönwiese (1990) the correlations were studied during a period of one hundred years (1881–1980) and hence the correlation coefficients of 0.2 were still significant. The lower number of statistically significant correlations in our study could be due to only 8–18 year-classes in our analyses and also due to the fact that in the study of Malcher and Schönwiese (1990) annual temperatures were correlated together instead of summer temperatures. This is important because it is known that the correlation coefficients are lower between summer than annual mean temperatures (Heino 1994) and, on the other hand, summer temperatures have most influence on the variations of year-class strength of both species. Furthermore, the location of the reference climatological station also affects to the correlations between stations, at least in Finland (Heino 1994).

Böhling *et al*. (1991) observed that the variations in year-class strength of perch were similar on the same sides of the Baltic Sea. They suggested that the reason was the predominating south-westerly winds during the summer months, which tend to replace warmer surface water with colder water on the western but not on the eastern side. The variations in year-class strength of perch in Åland during the years 1974–1981 seems to be analogous with this observation. The deviating year-class strength variations in Simo could be due to the longer distance and more severe weather conditions in the northern Gulf of Bothnia. In Simo the mean annual air temperature is 0.9°C and the duration of the ice-cover 190 days compared for example with the corresponding values of 5.2°C and 100 days in Åland (Climatological Statistics in Finland 1991, Lehtonen & Lappalainen 1995).

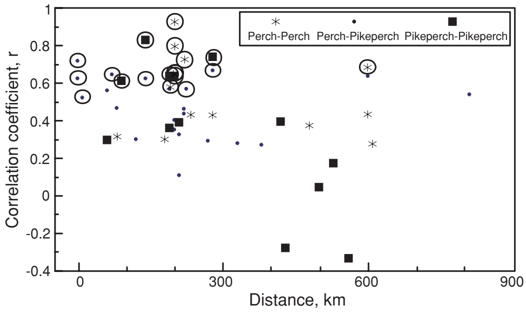

Fig. 4. Correlation coefficients in year-class strength in relation to distance between populations. Stars = correlation coefficient between two perch populations; dots = correlation coefficient between perch and pikeperch populations; squares = correlation coefficients between two pikeperch populations. All correlation coefficients are based on at least 8 year-classes. Significant correlations are encircled ($P < 0.05$).

To conclude, the present data demonstrated that there is clear covariation between the year-class strength variation of perch and pikeperch. The correlations between areas and species as regards year-class strengths were strongest between areas situated nearby. This supports the hypothesis that large-scale weather variations, mainly via water temperature, synchronize variations in year-class strengths. It is difficult to find any alternative biotic or abiotic factor which could act in a uniform manner over large areas.

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