Ann. Zool. Fennici 33: 553–567 ISSN 0003-455X
Helsinki 28 November 1996

Releases of pikeperch (*Stizostedion lucioperca* (L.)) fingerlings in lakes with no established pikeperch stock

Jukka Ruuhijärvi, Matti Salminen & Tauno Nurmio

Ruuhijärvi, J., Finnish Game and Fisheries Research Institute, Evo Fisheries Research and Aquaculture, Rahtijärventie 291, FIN-16970 Evo, Finland
Salminen, M., Finnish Game and Fisheries Research Institute, P.O. Box 202, FIN-00151 Helsinki, Finland
Nurmio, T., Finnish Game and Fisheries Research Institute, Saimaa Fisheries Research and Aquaculture, Laasalantie 9, FIN-58175 Enonkoski, Finland

Received 21 August 1995, accepted 3 June 1996

One-summer-old pikeperch (*Stizostedion lucioperca* (L.)) fingerlings (4–8 cm) were released in ten small and medium-sized (175–3 600 ha) Finnish lakes with no permanent pikeperch stock in five successive years. Mean stocking density ranged 10–40 fingerlings/ha. In the following 5–7 years, data were collected to estimate the growth and survival rates of the fish and to assess the total yield and profitability of the releases in each lake. Catch samples were obtained from co-operating local fishermen. Fishing statistics were obtained by mailed fishing questionnaires. Reference data on growth and survival were collected from the two parent populations, which belong to the most abundant in Finland. Large annual and between-lake variation was found in the growth and survival rates of the fish released. In most year-classes, the stocked fish were smaller than one-year-old pikeperch in the parent populations. In two lakes, subsequent growth rates were faster than in the parent populations. Similarities in year-class patterns in parent populations and annual survival patterns of stocked fish suggest that common factors contribute to the variation in both cases. Year-class indices for the parent populations were, however, not correlated with summer mean temperatures or with the mean size of one-year-old fish. The yield of the releases varied in different lakes from 0.1 to 34 kg per thousand fingerlings (mean 11.5 kg). In two lakes, the estimated economic output exceeded the direct costs of the releases. An onset of natural reproduction was recorded in two other lakes. In an attempt to explain the variable results, the quality of the stocking material, the limnological features of the lakes, as well as the differences in the fish communities and in the fisheries are considered.

1. Introduction

Efforts to extend the natural occurrence of pikeperch (*Stizostedion lucioperca* (L.)) in Finland began in the late 1800s (Nordqvist 1899). By the 1980s, pikeperch had been successfully introduced into 94 lakes, increasing the number of established lake populations from the original 208 to 302 (Toivonen *et al.* 1981). Introduction failed in 174 lakes. Most introductions were carried out with fertilised eggs and/or adult fish, though a small scale production of pond-reared fingerlings began as early as 1903 (Brofeldt 1920)

During the 1950s and 1960s, the abundance of pikeperch collapsed in numerous lakes in Central Finland (Colby & Lehtonen 1994). As a result, demand for means to augment poor pikeperch populations increased considerably. As transfers of eggs and adult fish were regarded as too unreliable or too expensive, a culture programme was started in 1978 to enhance production of pikeperch fingerlings. New procedures were developed for broodfish catching, artificial spawning and incubation (Salminen & Ruuhijärvi 1991, Salminen *et al.* 1993), as well as for pond-rearing and transport of fingerlings (Forsman *et al.* 1990ab). In the end of the 1980s, annual production of pikeperch fingerlings reached 5–7 million, approximately meeting demand for stocking material. In 1994 the number of stocked pikeperch fingerlings reached 10 million.

In addition to the culture programme, a stocking programme was started in 1983. Its aim was to evaluate fingerling stocking in lakes with different water quality, different fish communities and different fisheries. Initially, only lakes lacking established pikeperch populations were chosen. After the development of a suitable marking method, hot-branding, in 1987 (Saura 1996), stocking experiments were also begun in lakes with fishable, self-sustaining pikeperch populations.

In this paper we assess: 1) the growth and survival rates of stocked pikeperch fingerlings in ten small and medium sized lakes with no previous pikeperch stock, 2) the contribution of the stockings to the fisheries, and 3) the commencement of natural reproduction in these lakes. We then compare these to the growth and survival of pikeperch in the two parent populations, which are among the most abundant in Finland.

Fig. 1. Location of pikeperch stocking lakes, home lakes of the parent populations and temperature stations.

2. Material and methods

2.1. Study areas

Fingerling pikeperch were stocked in five successive years in ten lakes situated in southern and Central Finland (Fig. 1). Before stocking, all lakes lacked a permanent pikeperch population. The surface area of the lakes ranged from 175–3 600 ha (Table 1). The lakes were oligotrophic or mesotrophic, with clear or slightly brownish water colour. Late summer concentrations of total phosphorus in surface water ranged from 4–25 g/l, total nitrogen concentrations 330–690 g/l and water colour 10–70 mg Pt/l.

The fishery of the study lakes is dominated by extensive fishing for household needs. Sport fishing is less important, although most fishers probably include recreation in their motives. Variable mesh gillnets are mainly employed to catch northern pike (*Esox lucius* L.), perch (*Perca fluviatilis* L.), roach (*Rutilus rutilus* (L.)), bream (*Abramis brama* (L.)), burbot (*Lota lota* (L.)), whitefish (*Coregonus lavaretus* ssp), vendace (*Coregonus albula* (L.)) and recently, also pikeperch. Total annual yield varies from 4 to 16 kg/ha across lakes.

2.2. Pikeperch stockings

Pikeperch stockings in the study lakes were begun either in 1983 or 1984 (Table 2). Mean stocking density of the five-year stocking period ranged from 10 to 40 fingerlings/ha and mean length of different stocking groups 35–79 mm. All stockings were carried out between mid-August and the end of September.

Brood fish for the culture programme were captured either from Lake Averia or from Lake Vanajanselkä (Fig. 1, Table 1). The pikeperch populations of these lakes are among the most abundant in Finland. However, in order to compensate for possible adverse effects of the artificial spawning operation on the population, around 10 thousand (70 indiv./ha) pikeperch fingerlings were annually stocked in Lake Averia. In Lake Vanajanselkä, no stockings were made during the study period.

2.3. Age and growth

During the five to six years following stocking, catch samples were collected in each study lake to estimate the growth and survival rates of the stocked fish and to watch for the onset of natural reproduction. Reference data on growth and survival were collected from the two parent populations. Catch samples were obtained from co-operating local fishermen or, in some cases, from our own test fishing (Table 3).

The standard Fraser-Lee method (Fraser 1916, Lee 1920) was applied to back-calculate growth rates. This method assumes a linear regression ($L_c = a + bS_c$) between the total length (L_c) of the fish and scale radius (S_c). To estimate the intercept a, five fish from each 20 mm class with a total length between 40 mm and 500 mm (total 115 fish) were randomly sampled from the pooled scale data of the Finnish Game and Fisheries Research Institute. The aim was to obtain a regression that is valid for back-calculation across the whole range of ages and sizes, including one and two-year-old fish that were lacking from the original data. Parameter S_c was calculated as the mean of the anterior radius of five scales from a standard area between the lateral line and pelvic fin. The equation of the regression line (Fig. 2) was:

$$L_c = 44 \text{ (mm)} + 73.83 S_c \text{ (mm)}, R^2 = 0.98. \quad (1)$$

Length at age i (L_i) was then calculated from the equation:

$$L_i = 44 + (L_c - 44) S_i / S_c, \quad (2)$$

where S_i is the distance between scale focus and annulus i.

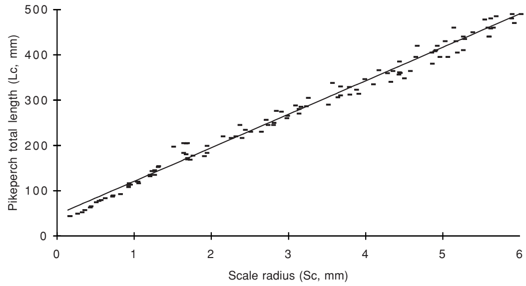

Fig. 2. The relationship between pikeperch total length (L_c, mm) and anterior scale radius (S_c, mm). The equation of the regression line is $L_c = 44 + 73.8\ S_c$, $r^2 = 0.98$.

2.4. Year-class strength and survival

The yearly age distributions of catch samples were used to calculate indices of the relative year-class strength in the study lakes and parent populations. In this context, “yearly” refers to all samples obtained from the beginning of July to the end of the following June. The procedure (Table 4), first presented by Svärdson (1961) and later adjusted by Neuman (1974), begins with the calculation of the percentage age distribution in successive samples. Only ages that were reasonably well (> 3%) represented in the age distribution for the whole period were included in the calculations. In the next step, the different year classes were expressed as percentages of the mean distribution. The index for the strength of each year class was then calculated as the mean of the corresponding percentages in successive samples. Finally, to produce an index for the survival of the stocked fingerlings, the year-class indices for the test lakes were weighted by the number of fish stocked each year.

Table 1. The surface area, depth and water quality in the study lakes. If available, water quality data refer to late summer samples.

	Area (ha)	Depth(m) mean/max	pH	Conduct. mS/m	Colour mgPt/l	Tot-P µg/l	Tot-N µg/l	Sampling date
Home lakes of the parent populations:								
I. Vanajanselkä	10 000	7.0/21	7.2	12.5	45	23	800	VIII/84
II. Averia	140	3.7/7	7.4	12.5	50	84	810	VII/86
Study lakes:								
1. Sulkavanjärvi	942	6.0/25	7.1	5.0	70	25	600	VII/84
2. Suur-Säyneinen	420	?/13	6.5	3.1	70	18	390	VIII/84
3. Hanhijärvi	530	?/18	6.8	4.9	10	4	414	XII/90
4. Ylä-Enonvesi	1 130	?/25	7.1	6.5	30	10	390	XI/90
5. Nerosjärvi	775	4.7/15	6.8	4.7	50	13	320	VIII/88
6. Kuohijärvi	3 600	9.8/30	7.0	5.4	50	11	360	VIII/88
7. Ormajärvi	645	?/29	7.7	14.7	20	15	520	VIII/88
8. Arimaa	175	4.0/18	6.7	6.0	50	11	690	I/84
9. Hormajärvi	510	7.8/22	7.7	8.8	10	14	360	VIII/82
10. Puujärvi	650	8.0/22	7.3	7.4	15	19	330	VIII/91

2.5. Catch and fishing data

Mailed fishing questionnaires were used to assess the annual gear-specific fishing effort and total catches of different fish species. For Lake Ormajärvi, results of annual questionnaires performed by local water authorities were used. In other lakes, three questionnaires were performed, concerning fishing during the first, third and fifth year after stocking period. Questionnaires were mailed to all licensed fishermen, with the exception of ordinary unregistered anglers. After three rounds at intervals of two to three weeks, the return rate usually exceeded 75%. Total annual catch and fishing effort were estimated by assuming that the fishing habits and catches of those fishers who didn't return the questionnaire corresponded to the average. To estimate total yield of pikeperch releases in each lake during the whole five-year period following stocking, catches for the second and fourth years were estimated by linear interpolation.

2.6. Environmental data

Water quality data were obtained from regular measurements by local water authorities. Daily summer temperatures at two field stations (Fig. 1) were taken from a monthly Finnish climate bulletin (Finnish Meteorological Institute).

Table 2. The number and mean size (mm) of pikeperch fingerlings stocked in the study lakes and home lakes of the parent populations from 1983–1988. The corresponding principal parent population for each study lake is indicated in brackets.

	Year						
	1983 No./size	1984 No./size	1985 No./size	1986 No./size	1987 No./size	1988 No./size	Total No.
Home lakes of the parent populations:							
I. Vanajanselkä	0	0	0	0	0	0	0
II. Averia	0	10 000	10 000	10 000	10 000	10 000	50 000
Study lakes:							
1. Sulkavanjärvi(II)	0	22 000/61	22 000/58	21 000/67	0	44 000/68	109 000
2. Suur-Säyneinen(II)	0	14 000/61	14 000/58	14 000/67	14 000/50	14 000/68	70 000
3. Hanhijärvi(II)	0	20 000/71	20 000/56	20 600/53	26 500/54	18 400/72	105 500
4. Ylä-Enonvesi(II)	0	32 900/62	36 000/56	33 800/53	34 500/58	33 800/72	171 000
5. Nerosjärvi(I)	10 000/77	13 000/72	14 500/47	10 000/73	15 000/55	0	62 500
6. Kuohijärvi(I)	6 500/77	56 000/62	60 000/60	49 000/63	9 000/48	0	180 500
7. Ormajärvi(I)	0	13 000/72	13 000/60	13 000/54	13 000/55	13 000/65	65 000
8. Arimaa(II)	3 000/77	4 000/72	3 000/60	3 000/73	6 000/45	0	19 000
9. Hormajärvi(II)	0	10 000/72	6 000/60	9 500/73	37 000/35	8 800/79	71 300
10. Puujärvi(II)	0	11 000/57	8 000/59	11 000/63	12 000/45	8 600/79	50 600
1–10. Total no.	19 500	195 900	196 500	184 900	167 000	140 600	904 400

Table 3. The number of sample fish by year-class.

	Sampling	Year-class														
	period	??	<'79	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	Total
Parent populations:																	
I. Vanajanselkä	86–93	15	2	3	2	8	24	19	0	122	68	13	80	6	3	1	366
II. Averia	84–94	18	32	19	124	4	174	48	6	128	179	14	77	18	2	3	846
Study lakes:																	
1. Sulkavanjärvi	88–92	1							0	0	27	0	41				69
2. Suur-Säyneinen	87–94								6	14	159	24	69				272
3. Hanhijärvi	–								0	0	0	0	0				0
4. Ylä-Enonvesi	88–95	3							126	160	28	89	158	8	44	28	644
5. Nerosjärvi	87–93	3						3	33	96	225	8	1				369
6. Kuohijärvi	88–95	4	8					17	333	190	74	2	1			1	630
7. Ormajärvi	88–94								9	49	52	0	21		6		137
8. Arimaa	86–91							1	4	0	18	0					23
9. Hormajärvi	–							0	0	0	0	0					0
10. Puujärvi	85–93						1		1	0	1	0	19				22
Total number	84–95	44	42	22	126	12	199	88	518	759	831	150	467	32	55	33	3 378

2.7. Statistical tests

ANOVA was applied to test for between-lake and between-year-class differences in the back-calculated length distributions of pikeperch at different ages. Heterogeneity of variances was tested by Cochran's test (Day & Quinn 1989) and normality of the distributions by Lilliefors' test (Sokal & Rohlf 1981). If variances were homogenous, deviations from normal distribution were not regarded as a hindrance to the test. Tukey's HSD test was used for pairwise *post-hoc* comparisons.

The Spearman rank correlation was used to analyse the relationships between summer temperatures, first year growth rates and year-class strengths of pikeperch in the parent populations, and the relationships between some limnological features, fishing effort and yield of stockings in the study lakes. A non-parametric test was chosen because relationships were assumed to be non-linear.

Table 4. An example of the calculation of indices of relative year-class strength and survival. The data are from Lake Ylä-Enonvesi.

A. Number of sample fish by age group and sampling season

Age group	Season 89/90	90/91	91/92	92/93	93/94	94/95	All
3+/4	2	47	47	0	21	27	144
4+/5	53	14	17	55	2	22	163
5+/6	5	7	2	13	19	6	52
6+/7	0	2	0	2	1	8	13

B. Percentage age distributions

Age group	Season 89/90	90/91	91/92	92/93	93/94	94/95	Mean
3+/4	3.3	67.1	71.2	0.0	48.8	42.9	38.9
4+/5	88.3	20.0	25.8	78.6	4.7	34.9	42.0
5+/6	8.3	10.0	3.0	18.6	44.2	9.5	15.6
6+/7	0.0	2.9	0.0	2.9	2.3	12.7	3.5

C. Age distributions expressed as percentages of the mean distribution

Age group	Season 89/90	90/91	91/92	92/93	93/94	94/95
3+/4	8.6	172.6	183.1*	0.0	125.6	110.2
4+/5	210.1	47.6	61.3	186.9*	11.1	83.1
5+/6	53.4	64.1	19.4	119.0	283.1*	61.0
6+/7	0.0	82.7	0.0	82.7	67.3	367.4*

D. Year class index (= mean of the values in C for each year-class)

Year-class	1984	1985	1986	1987	1988	1989
Index	68.0	91.4	39.6	105.0	255.1*	24.0

E. Survival index (= year-class index weighted by the number of fish stocked each year)

Year-class	1984	1985	1986	1987	1988	1989
No. stocked	32 900	36 000	33 800	34 500	33 800	0
Index	70.7	86.8	40.0	104.1	258.1	

*Year-class 1988

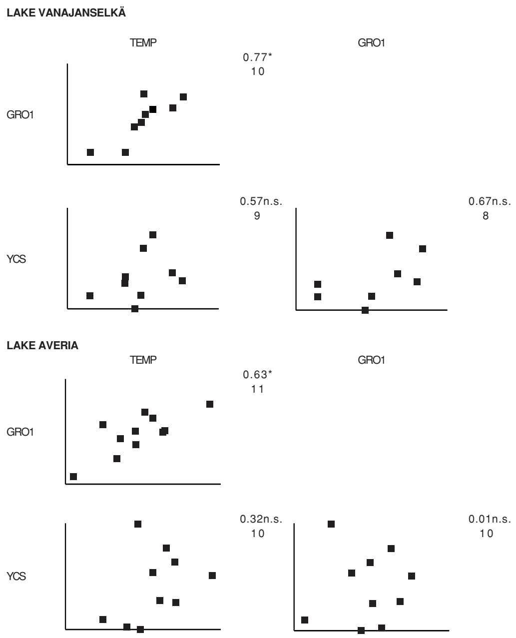

Fig. 3. Spearman rank correlations between relative year-class strengths (YCS), first year growth rates (GRO1) and summer mean temperatures (TEMP). GRO1 = pikeperch mean length after the first growing season (Vanajanselkä 67–102 mm, Averia 63–90 mm). TEMP = mean temperature from June–August at Tampere Pirkkala (for Vanajanselkä 12.9–16.6°C) and at Vihti Maasoja (for Averia 13.2–16.7°C).

3. Results

3.1. The size of one-year-old pikeperch

In parent populations there was significant yearly variation in the back-calculated mean length of pikeperch after the first growing season (Table 5). In Lake Vanajanselkä, the back-calculated mean length of one-year-old pikeperch in 1979–1990 year-classes ranged from 67–102 mm (mean 86 mm) and in Lake Averia 63–90 mm (mean 79 mm). For these populations, the yearly mean lengths were positively correlated with each other ($r_s = 0.87$**, $n = 10$), and with summer temperature conditions (Fig. 3), suggesting that size variation can be mainly attributed to climatic factors.

Within-year-class analyses for the best-sampled year-classes (1985, 1986 and 1988) indicated that wild fish from parent populations were usually larger at age 1 than corresponding year-classes of stocked fish (Tables 6 and 7). In the two cases of apparent onset of natural reproduction (Lake Ylä-Enonvesi and Lake

Ormajärvi), the wild offspring were accordingly larger at age 1 than were their stocked parents.

3.2. Later growth rates

The growth rates and, consequently, the recruitment age of pikeperch varied among year-classes (Table 7). In Lake Vanajanselkä during 1979–1990, the mean length of 4-year-old pikeperch ranged from 276–409 mm and in Lake Averia 284–354 mm (Fig. 4). Despite shorter time series, comparable ranges were found in the study lakes as well, such as in Lake Ylä-Enonvesi (264–389 mm) and in Lake Ormajärvi (278–353 mm). Apparently, the main factor contributing to the wide variation is the irregular pattern of warm and cold summers. Besides first summer growth rates (Fig. 3), growth rates of pikeperch during the second growing season are highly sensitive to summer mean temperatures (Vanajanselkä: Spearman r_s = 0.66*; Averia: Spearman r_s = 0.63*). In Lake Vanajanselkä, the mean length increment from age 1 to age 2 ranged in different year-classes 39–106 mm, and in Lake Averia 52–102 mm.

Size distributions of 4-year-old pikeperch, compared with ANOVA in year-classes 1985, 1986 and 1988, differed significantly across the lakes (Table 5).

Table 5. Results of ANOVA for the lengths of one-year-old (Size 1) and four-year-old (Size 4) pikeperch (Ycl = Year-class).

Criteria	Dependent variable	Factor	Covariate	Source	Sum of squares	*d.f.*	Mean square	*F*-ratio	*p*	r^2
Vanajan-selkä	Size 1	Ycl (81–83, 85–89)	–	Ycl	25 927.9	7	3 703.9	28.65	0.000	0.377
				Error	42 918.9	332	129.3			
Averia	Size 1	Ycl (79–80, 82–89)	–	Ycl	36 064.2	8	4 508.0	37.33	0.000	0.315
				Error	78 357.8	649	120.7			
Ycl 1985	Size 1	Lake (I,II,2,4–7)	–	Lake	41 843.7	6	6 973.9	175.7	0.000	0.606
				Error	27 182.8	685	39.7			
Ycl 1986	Size 1	Lake (I,II,1,2,4–7)	–	Lake	41 493.6	7	5 927.6	103.5	0.000	0.533
				Error	36 308.3	634	57.3			
Ycl 1988	Size 1	Lake (I,II,1,2,4,7,10)	–	Lake	45 324.1	6	7 554.0	49.3	0.000	0.397
				Error	68 753.3	449	153.1			
Vanajan-selkä	Size 4	Ycl (81–83, 85–89)	Size1	Ycl	124 820.4	7	17 831.4	23.3	0.000	0.427
				Size1	36 621.1	1	36 621.1	48.0	0.000	
				Error	211 184.8	277	762.4			
Averia	Size 4	Ycl (79–80, 82–89)	Size1	Ycl	303 718.8	8	37 964.8	63.0	0.000	0.561
				Size1	96 661.4	1	96 661.4	160.4	0.000	
				Error	374 183.5	621	602.6			
Ylä-Enonvesi	Size 4	Ycl (84–91)	Size1	Ycl	224 195.3	7	32 027.9	41.9	0.000	0.617
				Size1	61 853.0	1	61 853.0	80.9	0.000	
				Error	411 961.5	539	764.3			
Ycl 1985	Size 4	Lake (I,II,2,4–7)	Size1	Ycl	187 225.5	6	31 204.2	46.4	0.000	0.347
				Size1	70 333.2	1	70 333.2	104.5	0.000	
				Error	416 502.8	619	672.9			
Ycl 1986	Size 4	Lake (I,II,1,2,4–7)	Size1	Ycl	638 891.9	7	91 270.3	178.4	0.000	0.747
				Size1	24 355.4	1	24 355.4	47.6	0.000	
				Error	267 057.6	522	511.6			
Ycl 1988	Size 4	Lake (I,II,1,2,4,7)	Size1	Ycl	260 077.3	5	52 015.5	74.7	0.000	0.549
				Size1	62 339.2	1	62 339.2	89.5	0.000	
				Error	249 982.7	359	696.3			

To eliminate the impact of differences in stocking sizes, the size of fish at age 1 was used as a covariate in these analyses. Pairwise comparisons show that growth rates were similar in the two parent populations for 1985 and 1986 year-classes, but the 1988 year-class grew significantly better in Lake Vanajanselkä than in Lake Averia (Tukey $p < 0.001$). In comparison with the study lakes, growth rates of pikeperch in Lake Averia and Lake Vanajanselkä fell to the medium category (Table 7). The best growth rates were observed in Lake Sulkavanjärvi and Lake Nerosjärvi and the poorest in Lake Suur-Säyneinen.

3.3. Survival

The relative year-class strength of pikeperch shows considerable variation in both Lake Vanajanselkä and Lake Averia (Fig. 5). For these populations, the pattern of variation is similar ($r_s = 0.76$, $p < 0.05$) suggesting that common factors contribute to the variation in both lakes. However, year-class indices did not correlate with first summer growth rates or summer mean temperatures, which in turn were intercorrelated for both populations (Fig. 3). Apparently, the substantial yearly stockings in Lake Averia have not markedly contributed to the stock, or at least they have not been able to augment the extremely poor year-classes of 1984 and 1987.

Because of insufficient data, relative survival indices of stocked fish could be computed for only five of the ten study lakes (Fig. 5). For three of these lakes, Lake Suur-Säyneinen, Lake Nerosjärvi and Lake Ormajärvi, the survival pattern markedly resembles the corresponding year-class variation in the parent populations. In Lake Kuohijärvi, one year-class

Table 6. Back-calculated mean length (mean, *S.E.*, *n*) of one-year-old pikeperch in the parent populations and study lakes in 1979–1990 year-classes. For stocked year-classes, the mean lengths of corresponding stocking groups are given in brackets.

		Year-class											
		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Parent populations:													
I. Vanajanselkä	mean	88.4		67.2	83.0	101.9		85.1	91.0	67.3	100.1	89.8	89.8
	S.E.	3.7		2.6	1.7	2.7		0.8	1.5	1.6	1.7	6.0	2.9
	n	3		8	24	19		122	68	13	80	6	3
II. Averia	mean	84.4	79.7	77.3	69.7	87.4	82.6	74.9	85.1	62.7	90.4	80.2	
	S.E.	2.3	0.8	6.0	0.4	3.0	7.5	0.6	0.8	1.2	2.5	1.0	
	n	17	110	4	148	42	6	101	136	14	72	18	
Study lakes:													
1. Sulkavanjärvi	mean						– (61)	– (58)	72.1(67)		77.0(68)		
	S.E.								1.0		0.8		
	n								26		40		
2. Suur-Säyneinen	mean						69.5(61)	71.7(58)	73.2(67)	75.1(50)	70.6(68)		
	S.E.						0.9	1.9	0.4	2.6	0.5		
	n							6	14	157	24	68	
3. Hanhijärvi	mean						– (71)	– (56)	– (53)	– (54)	– (72)		
	S.E.												
	n												
4. Ylä-Enonvesi	mean						65.6(62)	64.4(56)	82.0(53)	70.6(58)	92.0(72)	86.3	100.8
	S.E.						0.6	0.4	1.7	1.1	0.8	3.3	2.2
	n						126	160	28	88	158	8	44
5. Nerosjärvi	mean					94.2(77)		81.8(72)	61.3(47)	78.1(73)	64.4(55)		
	S.E.					2.1	1.3	0.6	0.6	3.6			
	n					3	32	72	118	3			
6. Kuohijärvi	mean					75.5(77)		69.9(62)	68.5(60)	67.3(63)	– (48)		
	S.E.					1.6	0.3	0.4	0.6				
	n					17	320	174	57				
7. Ormajärvi	mean						75.7(72)	65.5(60)	62.9(54)	– (55)	71.5(65)		85.5
	S.E.						1.6	0.6	0.5		1.9		2.3
	n						9	49	52		20		6
8. Arimaa	mean					– (77)	81.8(72)	– (60)	81.0(73)	– (45)			
	S.E.						2.4		1.3				
	n						4		18				
9. Hormajärvi	mean						– (72)	– (60)	– (73)	– (35)	– (79)		
	S.E.												
	n												
10. Puujärvi	mean						– (57)	– (59)	– (63)	– (45)	87.3(79)		
	S.E.										2.0		
	n										18		

(1984) deviates from the common pattern, whereas in Lake Ylä-Enonvesi the whole pattern is different.

In two study lakes, Lake Ylä-Enonvesi and Lake Ormajärvi, young pikeperch belonging to post-stocking year-classes were observed, indicating the onset of natural reproduction.

3.4. The yield of stocking

The estimated total pikeperch yield during the five-year period following stocking ranged from 0.1–33.9 kg per thousand fingerlings across lakes (mean 11.4 kg, Fig. 6). In some lakes, best catches were obtained in the first questionnaire (first year) already, whereas in others, a rising trend was observed. In the latter, a considerable proportion of the yield probably remained to be taken later.

The small number of cases (10 lakes) doesn't allow a proper (multivariate) analysis of the numerous factors that may contribute to the large variation in the yields. The plots of yield against growth rates and some important "environmental" factors, such as water colour, total catch, pike catch and fishing effort, don't reveal any clear relationships (Fig. 7). However, the correlation between yield and growth rate was negative, and poorest yields were obtained in lakes with the clearest water.

3.5. The contribution of the stockings to the fishery

Highest catches of pikeperch (> 1 kg/ha) were attained in Lake Suur-Säyneinen, where pikeperch became the most important fish species in the fishery (Table 8). In this lake the number of fishermen was very low and, during the study period almost all learned how to fish pikeperch (Table 9). Special fishing for pikeperch developed also in three other lakes, Lake Ylä-Enonvesi,

Table 7. Pairwise *post-hoc* comparisons of the mean lengths of one-year-old and four-year-old pikeperch in the parent populations and study lakes of year-classes (Ycl) 1985, 1986 and 1988. Table entries are the means (in brackets), the mean differences and the statistical significance of the differences (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, *n.s.* = not significant, Tukey HSD).

Mean size of one-year-old pikeperch (mm)			Sulkavan-järvi	Suur-Säyneinen	Ylä-Enonvesi	Neros-järvi	Kuohi-järvi	Orma-järvi	Puu-järvi
				(71.7)	(64.4)	(61.3)	(68.5)	(65.5)	
Ycl 1985	Vanajanselkä	(85.1)		– 13.3***	– 20.7***	– 23.7***	– 16.5***	– 19.6***	
	Averia	(74.9)		– 3.1*n.s.*	– 10.5***	– 13.6***	– 6.3***	– 9.4***	
			(72.1)	(73.2)	(82.0)	(78.1)	(67.3)	(62.9)	
Ycl 1986	Vanajanselkä	(91.0)	– 18.7***	– 17.8***	– 8.9***	– 12.9***	– 23.7***	– 28.1***	
	Averia	(85.1)	– 12.9***	– 11.9***	– 3.0*n.s.*	– 6.9***	– 17.8***	– 22.2***	
			(77.0)	(70.6)	(91.9)			(71.5)	(87.3)
Ycl 1988	Vanajanselkä	(100.1)	– 23.1***	– 29.5***	– 8.2***			– 28.6***	– 12.8**
	Averia	(90.4)	– 13.4***	– 19.7***	1.6*n.s.*			– 18.9***	– 3.1*n.s.*
Adjusted mean size of four-year-old pikeperch (mm)			**Sulkavan-järvi**	**Suur-Säyneinen**	**Ylä-Enonvesi**	**Neros-järvi**	**Kuohi-järvi**	**Orma-järvi**	**Puu-järvi**
				(279.5)	(301.4)	(356.9)	(317.8)	(299.6)	
Ycl 1985	Vanajanselkä	(291.2)		– 11.7*n.s.*	10.1*n.s.*	65.7***	26.6***	8.4*n.s.*	
	Averia	(298.2)		– 18.7*n.s.*	3.1*n.s.*	58.7***	19.6***	1.4*n.s.*	
			(387.0)	(281.9)	(303.1)	(370.9)	(309.6)	(353.6)	
Ycl 1986	Vanajanselkä	(346.2)	40.8***	– 64.3***	– 43.1***	24.7***	– 36.6***	7.3ns	
	Averia	(344.9)	42.0***	– 63.1***	– 41.8***	25.9***	– 35.4***	8.6*n.s.*	
			(418.5)	(322.4)	(324.5)			(362.1)	
Ycl 1988	Vanajanselkä	(324.5)	93.9***	– 2.1*n.s.*	– 0.1ns			37.6***	
	Averia	(296.9)	121.5***	25.4***	27.5***			65.2***	

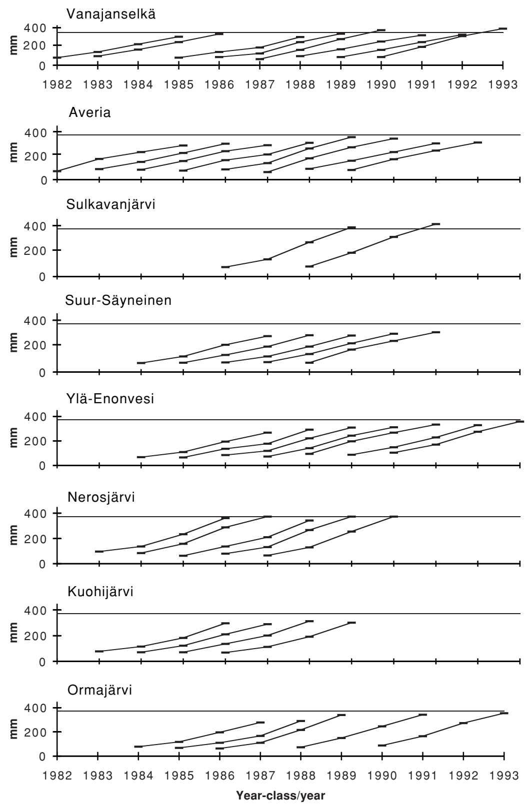

Fig. 4. Back-calculated growth rates of different year-classes of pikeperch during the first four growing seasons across the lakes. Horizontal lines indicate the minimum size limit of pikeperch (370 mm).

Lake Nerosjärvi and Lake Kuohijärvi, in which pikeperch catches reached 0.4–0.5 kg/ha (Table 8). However, the proportion of fishermen involved in pikeperch fishing was comparatively low in these lakes (Table 9).

3.6. Costs vs economical output of releases

The direct costs of stocking programmes in different lakes depend on the number of fingerlings and their size. At present (1995), the market price of a 60 mm fingerling is about FIM 0.7, that of a 70 mm fingerling about FIM 1 and an 80 mm fingerling FIM 1.3. On the basis of these prices, the direct stocking costs per one kg of catch varied in different lakes from FIM 25 to FIM 4 800 (Fig. 8). In two lakes, the present market value of the catch (FIM 30/kg) exceeded estimated stocking costs. Indirect economic effects of pikeperch stockings were not remarkable in the study lakes. The same local fishers who had been fishing

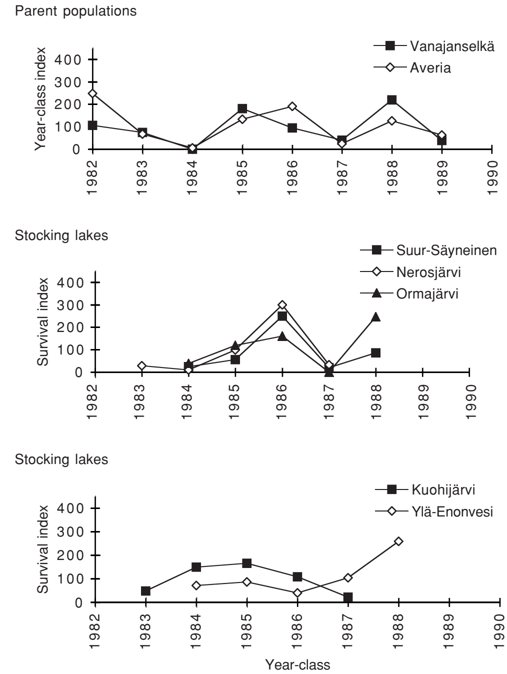

Fig. 5. Pikeperch year-class indices in parent populations and survival indices for different year-classes in stocking lakes.

in the lakes previously, had more valuable catches and used the fish in their own households.

4. Discussion

4.1. Growth and survival

Stocked pikeperch were usually smaller than survivors in parent populations at age 1. Smaller size is probably due to density dependent growth and the lack of suitable food organisms in rearing ponds towards the end of the growing season, leading to early retardation of growth (Forsman *et al*. 1990a). As most rearing ponds are harvested in September, there is usually no time for growth to recover in the stocking lakes before winter. In this study, the back-calculated mean lengths of age 1 pikeperch slightly exceeded the mean lengths of corresponding stocking groups. Scale patterns suggest, however, that in only two cases (Lake Ylä-Enonvesi, 1986 and 1988) can this be partly attributed to post-stocking growth during the first autumn. The fish in question were stocked in mid-August already and corresponding growing seasons were longer

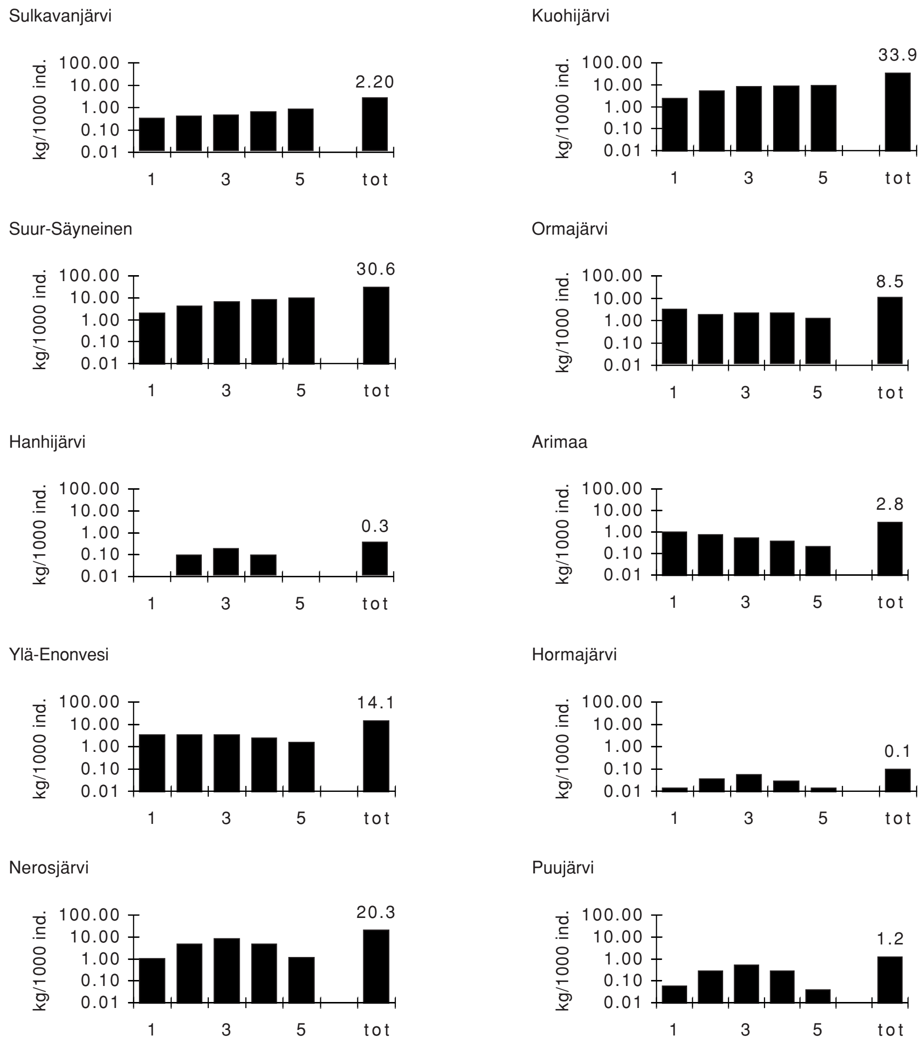

Fig. 6. Estimated yearly pikeperch catches (kg/1 000 fingerlings) in different lakes during the first five-year period following stocking. For Lake Ormajärvi, all yearly estimates are based on fishing questionnaires. For other lakes, only catches for the first, third and fifth years have been estimated from fishing questionnaires, whereas catches for second and fourth years have been estimated by linear interpolation.

and warmer than average. Other possible explanations include size-dependent mortality after stocking and methodological bias. For small fish, data points deviate slightly from the regression line representing the relation between fish length and scale radius (Fig. 2), probably leading to an overestimate of length at age 1. Naturally, this applies to the parent populations, too.

A positive relation between first year growth conditions and recruitment has been demonstrated for many pikeperch populations (Svärdson & Molin 1973, Willemsen 1977, Van Densen 1985, Lappalainen *et al.* 1995). Warm summers enhance growth and reduce size-dependent winter mortality. In Dutch lakes a varying proportion of 0+ pikeperch shift to piscivory and attain faster growth than individuals that remain planktivorous. This produces a bimodal length distribution towards the end of the season. The main contributor to the stock is the larger piscivorous group, the abundance and length distribution of which is sensitive to summer temperatures (Van Densen 1985, Buijse & Houthuijzen 1992).

Present data suggest that the relation between size at age 0 and survival is not as straightforward

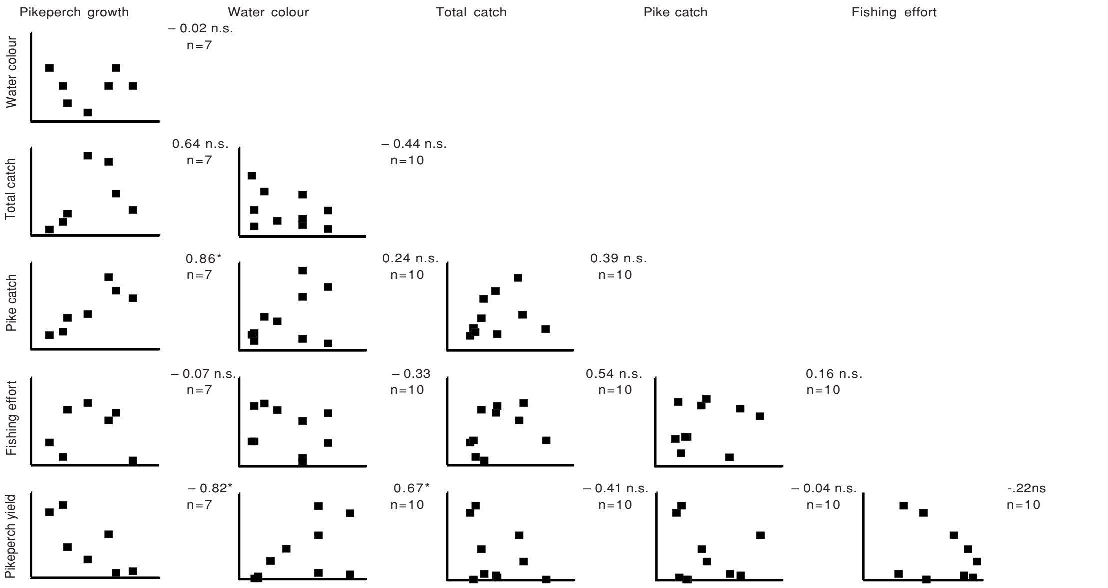

Fig. 7. Spearman rank correlations between pikeperch yield, pikeperch growth rates, water colour, total catch, pike catch and fishing effort in the stocking lakes. Pikeperch yield = total yield of the stockings (kg/1 000 ind.) during the first five-year period (0.1–33.9 kg). Pikeperch growth rates = the mean length of four-year-old pikeperch in the year-class 1986 (279–410 mm). Water colour = water colour value (10–70 mg Pt/l). Total catch = annual total catch of different fish species (mean of 3 questionnaires, 3.6–15.2 kg/ha). Pike catch = annual pike catch (mean of 3 questionnaires, 0.9–4.3 kg/ha). Fishing effort = number of fishing days with gillnets (> 44 mm, knot to knot) (mean of 3 questionnaires, 6.0–18.5 fishing days/ha/a).

Table 8. Estimated annual catch (kg/ha) of different fish species in the study lakes. The values are the means of three successive fishing questionnaires.

Species	Lake									
	Sulkavanjärvi	Suur-Säyneinen	Hanhijärvi	Ylä-Enonvesi	Nerosjärvi	Kuohijärvi	Ormajärvi	Arimaa	Hormajärvi	Puujärvi
Pikeperch (*S. lucioperca*)	0.1	1.0	0.0	0.4	0.3	0.3	0.2	0.1	0.0	0.0
Pike (*E. lucius*)	3.1	0.8	1.3	1.9	4.3	1.1	2.4	2.7	1.4	0.9
Perch (*P. fluviatilis*)	1.1	0.7	1.0	1.2	2.9	1.4	2.4	0.5	2.0	0.9
Roach (*R. rutilus*)	0.6	0.4	0.6	0.5	1.4	0.4	2.6	0.1	4.5	1.2
Burbot (*Lota lota*)	0.4	0.2	0.2	0.2	0.3	0.3	0.6	0.1	0.1	0.1
Bream (*A. brama*)	1.4	0.0	0.0	0.2	1.1	0.1	1.3	2.0	0.2	0.1
Vendace (*C. albula*)	0.0	0.2	0.3	0.3	0.1	0.7	1.2	0.0	5.3	0.9
Whitefish (*C. lavaretus*)	0.1	0.2	0.6	0.6	1.0	0.3	1.9	0.3	1.4	3.2
Trout (*S. trutta*)	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.2	0.2
Others	0.3	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.2	0.0
Total catch	7.1	3.6	4.0	5.5	11.6	4.8	12.9	5.7	15.2	7.7

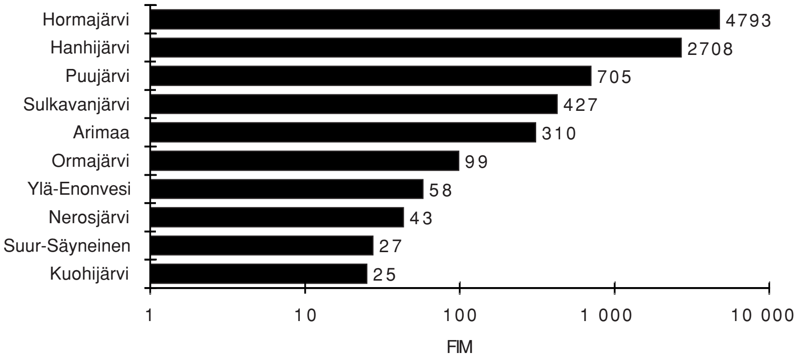

Fig. 8. Stocking costs (FIM) per one kg of pikeperch catch in different lakes.

for Finnish pikeperch populations as for Dutch populations. Within the size range (35–79 mm), no clear relationship was found between fingerling size and stocking success. In Lake Averia and Lake Vanajanselkä, first summer growth rates were correlated with summer mean temperatures, but no correlation was found between first summer growth and recruitment. The back-calculated length distributions of one-year-old pikeperch in these lakes were positively skewed and even indicated some extent of bimodality. However, the proportion of larger individuals was very low and the main contributors to the stock are the smaller individuals. Apparently, the recruitment of this mode is influenced by factors that are strong enough to mask the possible effects of first-summer growth conditions. If these factors are climatic, as suggested by the similarities between the year-class patterns for the two parent populations, they must apparently be related to other relevant variables, such as early summer temperatures or temperature minima or maxima. It is also possible that year-class strength is not determined until the sec-

Table 9. The proportion of fishers with pikeperch in their catches in three successive fishing questionnaires during the first five-year period after stocking (first, third and fifth years) in the study lakes. Estimated total number of fishers is given in brackets.

Lake	Questionnaire 1			Questionnaire 2			Questionnaire 3		
	Total No.	Pikeperch in catch No.	%	Total No.	Pikeperch in catch No.	%	Total No.	Pikeperch in catch No.	%
Sulkavanjärvi	60 [80]	14	23.3	58 [76]	8	13.8	47 [69]	17	36.2
Suur-Säyneinen	15 [20]	13	86.7	16 [18]	15	93.8	14 [23]	12	85.7
Hanhijärvi	18 [31]	1	5.6	14 [31]	3	21.4	15 [27]	0	0.0
Ylä-Enonvesi	59 [100]	28	47.5	67 [93]	28	41.8	65 [96]	21	32.3
Nerosjärvi	142 [195]	16	11.3	107 [176]	31	29.0	116 [174]	13	11.2
Kuohijärvi	278 [398]	109	39.2	266 [447]	125	46.9	293 [447]	116	39.6
Ormajärvi	No data available								
Arimaa	42 [52]	9	21.4	37 [47]	3	8.1	33 [45]	1	3.0
Hormajärvi	91 [116]	1	1.1	104 [126]	3	2.9	56 [92]	0	0.0
Puujärvi	66 [95]	2	3.0	94 [109]	11	11.7	94 [121]	2	2.1

ond summer. The small size of one-year-old pikeperch suggests that the critical shift to piscivory mainly occurs during the second summer. The high sensitivity of second summer growth to temperature gives further support to the hypothesis of a prolonged critical period.

According to Buijse and Houthuijzen (1992), a plankton diet provides insufficient basis for the necessary energy stores for winter, which explains the poor contribution of 60–90 mm lower mode pikeperch to the stock in Lake IJssel, The Netherlands. However, the question of whether non-piscivorous pikeperch die of starvation or whether their poor condition results in higher vulnerability to other causes of mortality was not addressed. In this study, 60–70 mm pond-reared fingerlings were able to survive the long Finnish winter. In the parent populations, 70–75 mm fish were able to produce relatively good year-classes. This seems to support the hypothesis of indirect causes of mortality, for example disease and predation. On the other hand, winter in open, shallow and exposed Dutch lakes might be a greater challenge for pikeperch fingerlings than winter in Finnish lakes under the sheltering ice cover. Furthermore, we don't know the exact diet of age 0 fish in Finnish pikeperch populations. In rearing ponds pikeperch eat, besides plankton, bottom fauna (Steffens 1960, Ruuhijärvi, Pennanen, Salminen & Forsman unpublished) which probably provides a much better energy source than plankton. In physiological analyses from four different rearing ponds, total lipid contents of 50–70 mm pikeperch ranged from 0.65–1.3% in August (Forsman *et al*. 1990a). In Lake IJssel, indirectly estimated lipid percentages of 60–90 mm pikeperch ranged from 0.2–0.8% in August (Buijse & Houthuijzen 1992). If real, these differences might show that Finnish pond-reared fingerlings have better energy reserves than pikeperch of comparable size in Lake IJssel.

In Dutch lakes, smelt (*Osmerus eperlanus* (L.)) seems to be the key species that determines the feeding conditions and, thus, the survival and growth rates of pikeperch (e.g. Buijse & Houthuijzen 1992). Data from Lake Vesijärvi indicate that in Finnish lakes young pikeperch may prey on a number of different fish species, especially on perch, even if smelt is present (Peltonen *et al*. 1996). In lake Averia, pikeperch eat mainly bleak (*Alburnus alburnus* (L.)). Smelt is present in most study lakes, but apparently in quite low numbers. Changes in the densities and growth rates of smelt and all other potential prey species probably provide an ever changing complex of feeding conditions affecting growth and survival of young pikeperch.

Pikeperch catches in most Finnish lakes are extremely variable. Traditionally, catch variation has been attributed to variation in year-class strength. The present data give a clear indication that variation in growth rates should also be taken into account. In Lake Vanajanselkä, for instance, the mean length of some year-classes exceeded the minimum size limit of pikeperch (370 mm) during the fourth summer already, whereas others don't attain this limit until the sixth summer. This makes questionable one of the basic assumptions of VPA and the Svärdson-Neuman index applied in this study, the constant age of recruitment. However, in case of large variation, both methods are probably capable of distinguishing between strong and poor year-classes and, consequently, of producing a relatively reliable rank order of year-class sizes.

4.2. Yield of stocking

Stocking success varied considerably across years and lakes. Similarities between the survival pattern of stocked fish and the year-class pattern of parent populations suggest that yearly variation in stocking success may be partly attributed to the same climatic factors that regulate the recruitment of self-sustaining pikeperch populations. Variations in such factors as stocking time and fingerling quality probably add to the variation. In Lake Sulkavanjärvi, for instance, year-classes 1984 and 1985, which originally were of high quality, were exposed to severe handling stress by unprofessional transport personnel. This probably explains the total failure of these year-classes.

In whitefish (*Coregonus lavaretus* ssp.) stockings in northern Finland, the number of recruits is mainly determined by factors intrinsic to the populations (Salojärvi 1992). The possibility of compensatory intrinsic processes in determining the yield cannot be totally excluded in pikeperch stockings either. Stocking densities of pikeperch fingerlings were comparatively high and, furthermore, a negative correlation was found between pikeperch growth rates and pikeperch yield. Comparatively low catch levels suggest, however, that the variation in stocking success and growth can be mainly attributed to density-independent processes.

Across study lakes, stocked pikeperch faced different fish communities, water quality and fisheries. Probably the only thing in common was the lack of a permanent pikeperch population. In a country where fish introductions have a long tradition, this could be taken as an indication that these lakes are totally unsuitable for pikeperch. It is a common belief, for example, that pikeperch eggs and larvae need turbid water to survive. However, different factors probably determine spawning success and the survival and growth of one-summer-old and adult pikeperch. The stocking experiments indicated that fingerling pikeperch could, indeed, survive and grow in all study lakes, even in the clearest ones, though the yields decreased with decreasing water colour.

4.3. Pikeperch introduction and fisheries

No correlation was found between pikeperch yield in different lakes and mean annual fishing effort. This is probably due to the fact that the same gear (45–50 mm gillnets, knot to knot) are employed to catch a number of other fish species besides pikeperch. Only fishing seasons and fishing sites vary, depending on desired catch composition. Because of low catch levels, special fishing for pikeperch developed in only three of the ten study lakes.

According to Colby and Lehtonen (1994), increased fishing pressure combined with slightly decreased mean temperatures were the main reasons for the decline of Finnish pikeperch populations in the 1950s and 1960s. The results of this study give some support to this hypothesis. In Lake Suur-Säyneinen and in Lake Ylä-Enonvesi, comparatively low fishing efforts produced occasionally very high pikeperch catches, especially in the beginning of the autumn season when pikeperch gathered in the deepest areas of the lakes. However, the decline of *CPUE* was usually drastic, indicating that a considerable proportion of catchable pikeperch stock was taken in a few weeks. Apparently, pikeperch stockings should be accompanied by proper regulation of the fishery. Because of the fishing for other important species, a multispecies approach is needed in most cases.

4.4. Economic output of pikeperch stocking

In most study lakes, the yield from pikeperch stocking was low and unpredictable. In economic terms, the results were unsatisfactory. Generalisations based on this study should, however, be made carefully. At present, most stockings are made to restore or augment poor or collapsed populations in old pikeperch lakes, which probably provide more favourable environmental conditions than most of our study lakes, both for the survival of the fingerlings and for the onset of natural reproduction. In such lakes, stocking probably offers managers a useful tool to re-establish lost pikeperch fisheries. Success requires, however, an analysis of the present structure of the fishery and, if necessary, strict management measures should be taken. Another essential prerequisite of success is proper transport and handling of the fingerlings.

The available size range of pikeperch fingerlings in Finland is at present limited to 40–90 mm. The results suggest that pikeperch of this size are still very sensitive to environmental conditions. Stocking larger, possibly already piscivorous, pikeperch might render better results in years of unfavourable climatic conditions, and in lakes where small fish are not able to survive. The development of a low-cost production method of larger 0+ or even 1+ pikeperch for stocking purposes is essential to make this alternative possible.

Acknowledgements. The authors wish to thank the staffs of Evo Fisheries Research and Aquaculture, Porla Aquaculture and Saimaa Fisheries Research and Aquaculture who reared, transported and stocked the pikeperch fingerlings used in this study and helped with field work while pikeperch samples were collected. Many fishers in the study lakes helped us by taking samples of their pikeperch catches. We are also indebted to Mr Tapio Hakaste and Mr Juha Valkama from the Water Protection Association of the River Kokemäenjoki for the data on Lake Vanajanselkä and Lake Ormajärvi.

References

Brofeldt, P. 1920: Evon kalastuskoeasema – 25-vuotinen toiminta ja tulokset (Evo Fisheries Research Station – Results of 25 years of activity). — Suomen kalatalous 6: 1–141. (In Finnish.)

Buijse, A. D. & Houthuijzen, R. P. 1992: Piscivory, growth and size-selective mortality of age 0 pikeperch, Stizostedion lucioperca (L.). — Can. J. Fish. Aquat. Sci. 49: 894–902.

Colby, P. J. & Lehtonen, H. 1994: Suggested causes for the collapse of zander, Stizostedion lucioperca L., populations in northern and central Finland through comparisons with North American walleye, Stizostedion vitreum (Mitchill). — Aqua Fennica 24: 9–20.

Day, R. W. & Quinn, G. P. 1989: Comparisons of treatments after an analysis of variance in ecology. — Ecological Monographs 59: 433–463.

Forsman, L., Salminen, M. & Virtanen, E. 1990a: Physiological condition of one-summer-old pike-perch (Stizostedion lucioperca L.). — In: Berka, R. & Hilge, V. (eds.), Production enhancement in still-water pond culture. Proceedings of FAO-EIFAC symposium on production enhancement in still-water pond culture. Prague, 15–18 May, 1990: 74–83.

Forsman, L., Virtanen, E. & Salminen, M. 1990b: Salt addition decreases transport stress in freshwater pikeperch. — In: Berka, R. & Hilge, V. (eds.), Production enhancement in still-water pond culture. Proceedings of FAO-EIFAC symposium on production enhancement in still-water pond culture. Prague, 15–18 May, 1990: 84–86.

Fraser, C. M. 1917: On the scales of the spring salmon. — Contributions to Canadian Biology, 1915–1916: 29–39.

Lappalainen, J., Erm, V. & Lehtonen, H. 1995: Pikeperch, Stizostedion lucioperca (L.), catch in relation to juvenile density and water temperature in Pärnu Bay, Estonia. — Fisheries Management and Ecology 2: 113–120.

Lee, R. M. 1920: A review of the methods of age and growth determination in fishes by means of scales. — Fishery investigations, Series II, Marine Fisheries Great Britain Ministry of Agriculture and Fisheries and Food 4: 1–32.

Neuman, E. 1974: The effects of temperature on the growth and year-class strength of perch (Perca fluviatilis L.) in some Baltic archipelagos. — Inf. Sötvattenslab. Drottningholm 6: 104.

Nordqvist, O. 1899: Keväällä 1899 Porvoon saaristossa sekä meillä aikaisemmin tehdyt kuhanviljelyskokeet (Pikeperch culture experiments in Finland in 1899 and before). — Suomen Kalastuslehti 8 (7/8/9). 129–131. (In Finnish.)

Peltonen, H., Rita, H. & Ruuhijärvi, J. 1996: Diet and prey selection of pikeperch (Stizostedion lucioperca (L.)) in Lake Vesijärvi analysed with a logit model. — Ann. Zool. Fennici: 33: 481–487.

Salminen, M. & Ruuhijärvi, J. 1991: Production of pikeperch (Stizostedion lucioperca L.) fry, procedure and devices. — In: Lavens, P., Sorgeloos, P., Jaspers, E. & Ollevier, F. (eds.), Larvi '91. Fish and crustacean larviculture symposium. European Aquaculture Society, Special Publication No. 15: 287–289. Gent, Belgium.

Salminen, M., Ruuhijärvi, J. & Ahlfors, P. 1993: Spawning of wild zander (Stizostedion lucioperca (L.)) in cages. — In: Adámek, Z. & Flajšhans, M. (eds.), Proceedings of the scientific conference Fish reproduction '92. Vodňany, Czechoslovakia, 2–4 March, 1992: 42–47. Research Institute of Fish Culture and Hydrobiology Vodňany.

Salojärvi, K. 1992: The role of compensatory processes in determining the yield from whitefish (Coregonus lavaretus L s.l.) stocking in inland waters in Northern Finland. — Finnish Fish. Res. 13: 1–30.

Saura, A. 1996: Use of hot branding in marking one-summer-old pikeperch juveniles. — Ann. Zool. Fennici: 617–620.

Sokal, R. R. & Rohlf, F. J. 1981: Biometry. The principles and practice of statistics in biological research. — Freeman and Co., New York.

Steffens, W. 1960: Ernährung und Wahstum des jungen Zanders (Lucioperca lucioperca (L.)) in Teichen. — Z. Fisch. 9: 161–271.

Svärdson, G. 1961: (No effect of whitefish cultivation in Kalmarsund). — Svensk Fisk. Tidskr. 70: 23–26. (In Swedish.)

Svärdson, G. & Molin, G. 1973: The impact of climate on Scandinavian populations of the Sander, Stizostedion lucioperca (L.). — Rep. Inst. Freshw. Res. Drottningholm 53: 112–139.

Toivonen, J., Antere, I. & Lehtonen, H. 1981: Kuhan esiintyminen Suomessa (The occurrence of pike-perch (Stizostedion lucioperca L.) in Finland). — Finnish Game and Fisheries Research Institute, Fisheries Division. Tiedonantoja 17: 31–50. (In Finnish.)

Van Densen, W. L. T. 1985: Piscivory and the development of bimodality in the size distribution of 0+ pikeperch (Stizostedion lucioperca L.). — Z. angew. Ichthyol. 3: 119–131.

Willemsen, J. 1977: Population dynamics of percids in Lake IJssel and some smaller lakes in the Netherlands. — J. Fish. Res. Board Can. 34. 1710–1719.