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Monitoring 0+ perch (*Perca fluviatilis*) abundance in respect to time and habitat

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The episodic acidification of the river Kyrönjoki decreased from 1980 to 1994. During this time 0+ perch (*Perca fluviatilis*) abundance showed a homogeneously increasing trend in the whole estuary. Every year the 0+ perch abundances showed a clear but often uneven decrease throughout July. The decrease was frequently significant in the middle of the month. It was also evident that the habitat affected the abundance pattern. In the beginning of July most 0+ perch were found in shallow waters. In late July 0+ juveniles were more frequent in vegetated than in nonvegetated areas, where perch were also smaller. The homogeneity of sampling stations allows us to reduce the number of sampling stations when monitoring the relative abundance of 0+ perch, but then the time and habitat should be standardised more tightly.

1. Introduction

In the early 1970s the fish populations of the river Kyrönjoki suffered from large mass fish kills (Hildén *et al*. 1982). The fish kills were found to be dependent on episodic acidifications of the river in spring and autumn, due to engineerings in the sulphur rich soils in the catchment area (Hudd *et al*. 1984). Monitoring the effects of the acidification was started in 1980. Although no large mass fish kills on adult fish have occurred since the monitoring started, acidic periods have caused recruitment failures of several spring (Hudd *et al*. 1986, Hudd *et al*. 1994), autumn (Leskelä & Hudd 1993) and winter spawning (Kjellman *et al*. 1994) fish species during the 1980s.

In 1980 an initial phase was set up to determine the time and place for the occurrence of 0+ juveniles. Between 1980–1982 the whole estuary from spring to autumn was searched for juveniles using several types of gear (Hudd *et al*. 1984). Based on this initial mapping the monitoring programme from 1983 onwards consisted of 30 geographical fixed stations using a small beach seine. The stations were set out to cover the different biotops where most 0+ juveniles were obtained in the inner estuary. The time of monitoring was set for July, since the juveniles seemed not to be recruited to the seine before July, and after July most juveniles had started to migrate seawards (Urho *et al*. 1990).

The purpose of this paper was to study how the monitoring of 0+ perch (*Perca fluviatilis*) abundance

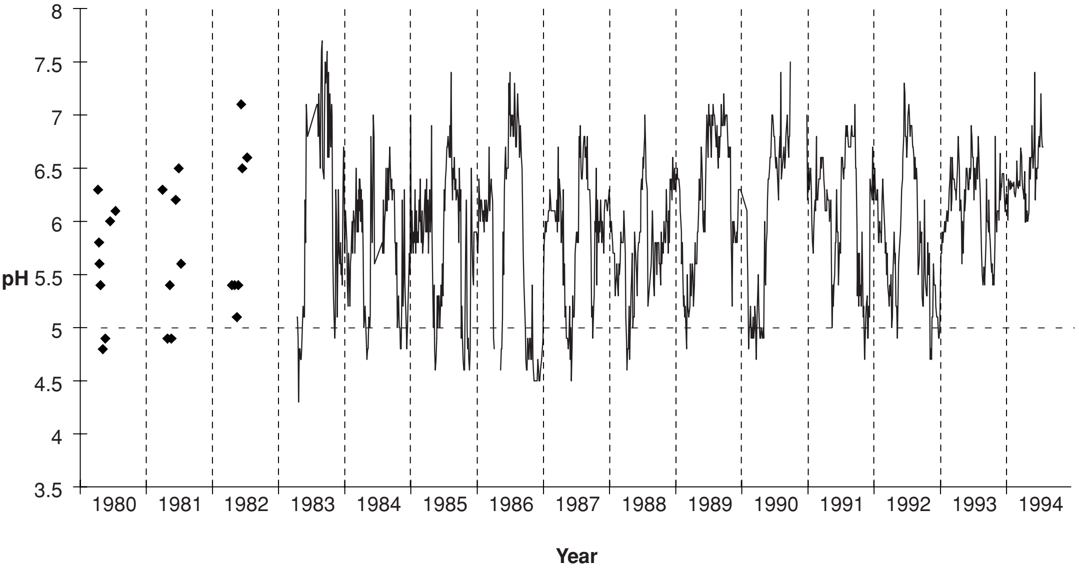

Fig. 1. The episodic acidification of the river Kyrönjoki in years 1980–1994 measured as pH fluctuations in the outer estuary.

could be applied to give annually comparable estimates, and furthermore to study if the sampling could be reduced in time or place without decreasing the precision or accuracy. The need for the study was urged as the annual monitoring programme grew laborious and thus expensive along with the increase of annual juvenile abundance.

2. Material and methods

2.1. Water quality

The pH was measured regularly, twice a week, in the river Kyrönjoki estuary since 1983. Between the years 1980–1982 only sporadic pH measurements from the lower reaches are available[1]. These measurements are not fully comparable to the pH measurements in the estuary, as the pH is at least 0.5 higher in the lower reaches than in the estuary[2]. The water quality, measured as pH-fluctuation, improved from 1980 to 1994 (Fig. 1). Even if few measurements were taken in 1980–1982, it can be concluded that the pH dropped below 5 for several weeks during the springs of 1980 and 1981. The lowest pH, 4.3, was measured on 24th of April 1983. After which it remained below 5.0 until 15th May. From 1983 to 1987, the pH generally dropped well below 5 for several weeks during the spawning time of perch. In 1988 the lowest pH was measured on 13th of April, to reach above 5.0 before the 1st of May. From 1988 onwards the pH minimum generally occurred earlier in the spring, or even reached its minimum during the winter, in contrast to previous years. In 1993 and 1994 (by 31 July) the pH did not drop below 5.5.

2.2. Estimates of 0+ perch abundance

The 0+ perch was collected with a small beach seine in the river Kyrönjoki estuary between the years 1980–1994 (Table 1). In some years with low temperature in early summer or a late pH minimum in spring, larvae were also caught during the first seinings. It is, however, more convenient to speak only about juveniles as the majority of catches were juveniles. Based on a search sampling between 1980–1982 the monitoring was concentrated to the inner estuary on 30 seining stations from 1983 onwards. The seine used had an arm length of 10 m, with a mesh size of 5 mm. The bag was 3.5 m long, with a mesh size of 1 mm, and the depth of the seine was 2.5 m. The seine was pulled to a 5 m long boat by 20 m long ropes. The seining stations were geographically set. The systematic sampling covered some open water areas of the river bed, but mainly vegetation areas dominated by yellow water lily, *Nuphar luteum,* in the estuary. The time of monitoring was set for July, but varied from year to year depending on the occurrence of juveniles. When possible, all stations were hauled during daytime 4 times per year. As the time of monitoring generally covered more than one month and varied from

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1) West Finland Regional Environment Centre, Vaasa. Unpubl.

2) Storberg. K-E. 1983: Kyrönjoen alaosan vedenlaadusta. — West Finland Regional Environment Centre, Vaasa. Duplicate.

year to year, the seining season was divided into four 10-day periods for calculations. The first period stretched from 1st to10th of July, the last period thus ending on the 9th of August. The approximate mean depth and coverage of vegetation (as % of area hauled covered by *Nuphar*-vegetation) were recorded for each haul (Table 1). The vegetation coverage of a station could change between the years and time of year. Therefore a separate experiment was arranged in 1995 to study the effect of vegetation at the stations on catches.

To allow a comparison of the 0+ perch abundance in different vegetation coverage, 9 stations in the vegetation zone were hauled 3 times from 26 to 28 July in 1995. Three of the stations had no surface covering vegetation, forming open areas inside the macrophyte vegetation zone. Three stations had medium vegetation (*Nuphar* coverage 30–70%) and three stations were placed in dense (80–100% *Nuphar*) vegetation. Juveniles caught were conserved in 70–80% ethanol in the field. 150 perch juveniles per haul were measured for total length (mm). The depth at these seining stations was 0.6–1.0 m, and did not differ (Kruskall-Wallis 1.129, $p > 0.5$) between the three vegetation densities.

2.3. Statistical methods

Juvenile abundance was measured as catch per unit effort (*CPUE*) and the effects on the abundance of juveniles from the acidification was tested by a Mann-Kendall trend analysis (Gilbert 1987). In this analysis no concern was taken whether the juveniles were caught in the beginning or at the end of the seining period. Neither depth nor vegetation were included. The abundance dependency on vegetation in the year 1995 was tested by an ANOVA-analysis. Other juvenile abundances were compared by Kruskall-Wallis or Mann-Whitney *U*-test statistics (SYSTAT 1992) using the four 10-day periods into which each year had been divided.

3. Results

3.1. Trends in 0+ perch abundance

The mean catch of 0+ perch per unit effort, on the 30 geographically fixed stations, increased from a mean of 125 juveniles in 1980–1987 to 348 in 1988–1994 (Table 1). The increasing abundances formed a positive trend, that was significant and homogeneous for all stations (Table 2).

Besides a common positive trend in the 0+ perch abundances from 1983 to 1994, there was an obvious seasonality in the abundance readings. In almost all years the abundance was the highest in the first of the four 10-day periods, decreasing to the last of the periods. However, the rate of decrease was not equal in all years or periods. From period 1 to period 2 the abundances decreased significantly in 25% of the years. The abundances decreased significantly in 69% of the years from period 2 to period 3, and the corresponding figure from period 3 to period 4 was 27% (Table 3).

Table 1. Number and characteristics of hauls pulled with a small beach seine in the river Kyrönjoki in years 1980–1994.

Year	Abundance of 0+ perch			Date of seining		Vegetation* in haul (%)		Depth (m)	
	mean	*S.D.*	*n*	first	last	min.	max.	min.	max.
1980	114	357	178	25.6	21.8	–	–	0.3	2.5
1981	206	558	286	14.5	23.9	1	5	0.2	2.5
1982	292	545	135	31.5	11.8	0	5	0.2	3.0
1983	4	18	180	19.7	24.8	0	5	–	–
1984	15	51	76	09.7	30.7	–	–	–	–
1985	8	23	120	02.7	29.7	0	5	0.4	2.2
1986	316	501	151	01.7	01.8	0	80	0.4	1.6
1987	44	109	66	20.7	07.8	0	95	0.4	1.4
1988	114	243	117	13.7	10.8	0	5	0.3	1.6
1989	285	834	124	16.6	28.7	0	60	0.4	1.5
1990	271	443	89	01.7	24.7	0	60	0.4	1.2
1991	99	199	130	02.7	09.8	0	90	0.2	2.0
1992	132	183	117	25.6	03.8	0	70	0.3	1.5
1993	555	987	119	28.6	06.8	10	95	0.3	1.2
1994	978	1393	116	04.7	02.8	10	80	0.2	1.5

* in years 1980–1985 and 1988 on a scale 0–5, where 0 = no vegetation and 5 = dense vegetation

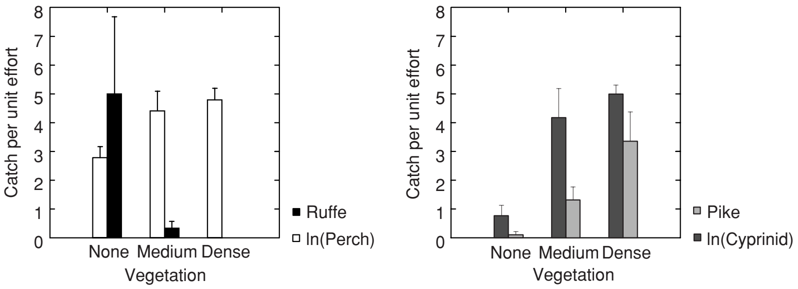

Fig. 2. Abundance (*CPUE* + *S.E.*, *n* = 9) of perch, ruffe, pike and cyprinid 0+ juveniles in three densities of *Nuphar sp.* (none = 0%, medium = 30–70% and dense = 80–100%) in the river Kyrönjoki.

3.2. Juveniles and vegetation

The estimate of 0+ fish abundance was affected by vegetation coverage, where the catch per unit effort increased for juveniles of perch, pike (*Esox lucius*) and cyprinids as the vegetation coverage also increased. The only species to decrease by increasing vegetation coverage was ruffe (*Gymnocephalus cernuus*) (Fig. 2). The differences were significant for perch (Table 4), where both the medium (Tukey, $p < 0.05$) and dense (Tukey, $p < 0.01$) areas of vegetation had a significantly higher abundance than the areas of no vegetation. There was a slight difference between the areas of medium and dense vegetation in terms of abundance, but this was not significant (Tukey, $p > 0.50$). The *CPUE* distribution did not differ between these two groups (Kolmogorov-Smirnov two sample test, $p > 0.50$). However, the standard deviation of catch per unit effort at medium densities of vegetation were the highest. None of the distributions were normally distributed (Kolmogorov-Smirnov one sample test, $p < 0.01$), nor did they have the same variances unless ln-transformed.

The length distribution of 0+ perch varied between all three densities of vegetation. In the no vegetation hauls two different length groups were found. One with a mean size of 19 mm and another with a mean size of 34 mm. In the medium vegetation hauls a minor part of the juveniles were of the smaller group, whereas the juveniles, in the dense vegetation hauls, were normally distributed around the mean size of 34 mm (Fig. 3).

Table 2. Trend analysis (Mann-Kendall) of 0+ perch abundance in the river Kyrönjoki estuary in years 1983–1994 on 30 geographically fixed seining stations.

Station	2	*p*	*df*
Homogeneity	11.77	> 0.10	29
Equal trend	276.37	< 0.01	29

3.3. Abundance of 0+ perch and depth

Assuming that there are no differences in the 0+ perch abundance between medium and dense vegetation coverage and that 1st–20th July forms a period generally differing from 21st July to 9th August it was discovered that 0+ perch abundance was also affected by the depth at the seining station in the last 3 years. Common for these years were the high juvenile abundances. In 1992, the year with the highest bioenergetic index (calculated according to Karås

Table 3. Percent (%) significant decrease (Mann-Whitney *U*-test, $p < 0.05$) in 0+ perch abundances during the summer in 1980–1994 in the river Kyrönjoki. The seining period has been divided into four 10-day periods.

Period	11–20 Jul.		21–30 Jul.		31 Jul.–09 Aug.	
	%	*n*	%	*n*	%	*n*
01–10 Jul.	25	12	50	12	62	8
11–20 Jul.	–	69	13	60	10	
21–30 Jul.	–	–	27	11		

Table 4. Effect of vegetation coverage on the ln-transformed abundance of 0+ perch in the vegetation zone in the river Kyrönjoki estuary, where vegetation coverage has been divided into three groups according to densities of *Nuphar sp.* (none = 0%, medium = 30–70% and dense = 80–100%) in haul (ANOVA).

Groups	Sum of squares	*F*-value	*p*	*df*
Between	18.172	3.911	< 0.05	2
Within	55.761			24
Bartlett test		1.646	> 0.10	2

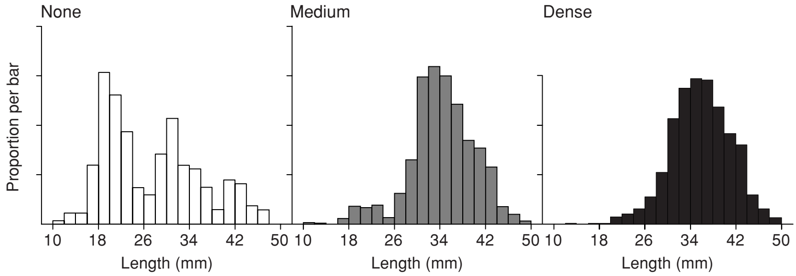

Fig. 3. Length distribution of 0+ perch in three densities of *Nuphar sp.* (none = 0%, medium = 30–70% and dense = 80).

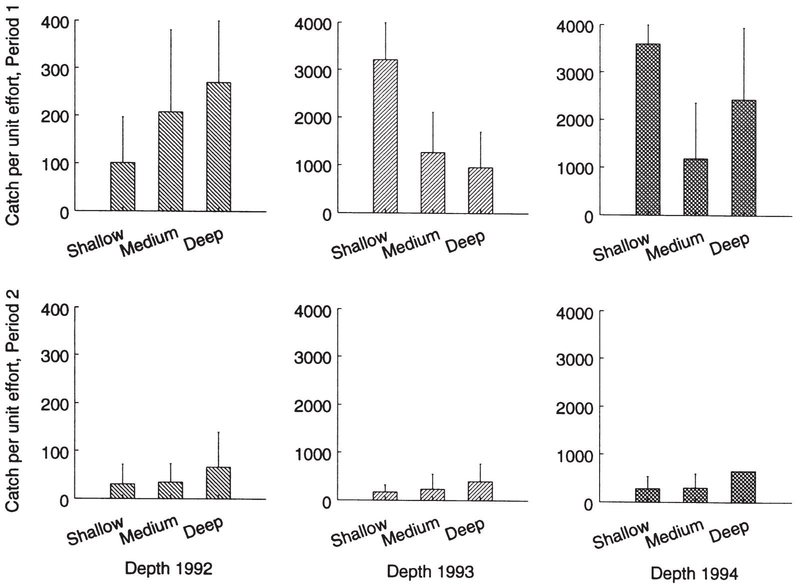

Fig. 4. Abundance (*CPUE*) of 0+ perch at three depths (shallow < 0.5 m, medium = 0.5–1.0 m and deep = 1.0–1.5 m) between 1992–1994 in the river Kyrönjoki. Each year has been divided into two periods 1–20 Jul and 21 Jul.–09 Aug.

(1987)) the abundance rose with depth. In 1993 and 1994 the abundance was the highest in shallow waters (< 0.5 m) in the beginning of July, becoming the lowest by the end of the month (Fig. 4).

4. Discussion

4.1. Yearly 0+ perch abundance and environmental changes

The 0+ perch abundance increased from 1983 to 1994 in the river Kyrönjoki estuary, and the increase was significant throughout the estuary at all seining stations. This general trend overruled the effects of both differences in time of monitoring and habitat selection in the form of varying vegetation and depth at the fixed stations. One of the major changes that have taken place in the river Kyrönjoki from 1980 to 1994 is the reduced acidification. In the beginning of the study period the pH frequently dropped below levels that have been proven as being lethal to the early stages of perch (Beamish *et al.* 1975, Rask 1984). In the 1970s and 1980s Hudd *et al.* (1994) could even link the year class strength of perch to the acidification through the mean juvenile abundance of the summer. It can be concluded that in the river Kyrönjoki estuary the single most important factor for limiting 0+ perch abundance has been the episodic acidification in spring. The acidification has been especially detrimental as it coincides with the most acidification sensitive stages during spawning, hatching and early larvae (Urho *et al.* 1990, Tuunainen *et al.* 1991).

Reduced acidification is, however, not the only change to have taken place from 1980 to 1994. The environment has for instance been exposed to frequent warm summers in the 1990s. To analyse the contribution of these factors to the increasing abundance, some reference data is needed. According to Hudd *et al.* (1996) it seems that the perch year-class strength in the estuary nowadays coincides more closely with the general trend in the Baltic Sea. Whatever the reason for the increased abundance of juveniles in the estuary, for monitoring purposes it is essential that the whole area has developed homogeneously, the same way as the 30 seining stations monitoring the abundance of 0+ perch developed.

The variation in larval and juvenile abundance is, however, large between the samples within a year. The catches may vary from 0 to several thousands juveniles per haul. This is due to the difference in catchability, sampling time and place, all of which are dependent on fish behaviour.

4.2. Efficiency of the seine

There are large differences among species in seine efficiencies. Certain species (midwater fishes) are more vulnerable to capture than others (bentic fishes) (Lyons 1986, Pierce *et al.* 1990). Lyons (1986) presented daytime capture efficiencies of around 50% for yellow perch juveniles ranging from 110 to 145 mm of total length with a 1.8 m high beach seine. This is only slightly higher than is got by seining at night with a 2.4 m high seine (Parsley *et al.* 1989). We have used an even higher seine during daytime since 1981 as we noticed that shallow seines are not efficient enough. We have not actually tested the efficiency of our seine and fish may avoid seines by swimming under or over the net when they are repelled by noise or vibration. We abandoned the seine hauls that snagged obstructions or if the seine was clearly noticed to roll up from the bottom due to macrophytes. We did not use seine in dense *Pragmites*- or *Juncus*-vegetation, but selected areas with *Nuphar*, *Potamogeton* and other softer submerged plants, which are not as efficient in rolling up the seine.

Seining in vegetated areas is always exposed to the risk of yielding an inefficient catch, which probably means an increased variation in catches. It is possible that the clearly lower catches of ruffe in the vegetation than in open water may be partly due to escapement from the seine. On the other hand, higher juvenile catches of cyprinids, pike and perch in more vegetated areas undermines the escapement theory. Pierce *et al.* (1990) noticed that fish entrapped in the advancing seine seemed less agitated where macrophyte growth was extensive and thus increased capture efficiency.

We believe that seining is efficient enough to yield comparable information on 0+ fish abundance if the fish are big enough to be caught with the seine. We have not found any information at what precise size perch recruits to the seine. This means that in years with late larval development the first catches may be underestimates and the next ones overestimates compared to other years with larger larvae that have already experienced higher mortality during the same time. Anyway it was noticed that the juveniles of different length are not equally distributed, but instead have some habitat preferences.

4.3. Habitat preferences and changes in 0+ perch abundance

Young-of-the-year perch change habitat during the first summer, first dispersing to the pelagic and then returning to the littoral (Coles 1981, Treasurer 1988). The return back to the littoral area takes place gradually and the size at return depends on the watercourse (Urho 1996). At the end of summer the 0+ perch leave the shallow waters and migrate to the sea (Urho *et al.* 1990). All these changes should be taken into consideration while planning a monitoring programme.

The river Kyrönjoki estuary is a shallow vegetated nursery area. Two thirds of it (12 km^2) is covered by macrophyte belts and thus could mostly be considered as a littoral area. Since vegetation emerges almost all over the estuarine inlets, the larval shift back to near-shore areas within the macrophyte area may not be obvious. Some changes from the more open areas to the vegetation seem to take place, as some smaller 0+ perch still occurred only in vegetation free areas at the end of July in 1995. This may have been due to occurrence of different cohorts. The highest abundance of 0+ perch was then found in areas of dense vegetation, which may be due to them seeking protection in the vegetation (Mittelbach & Chesson 1987) or an increased catchability (Pierce *et al.* 1990). It was also noted that the abundance was higher in deeper waters at the end of the same period, whereas it was higher in shallow waters at the beginning of the month. This shift from shallow to deeper waters is in line with the outward migration of 0+ perch from the inner estuary of the river Kyrönjoki that was shown to start already in the middle of July (Urho *et al.* 1990). In lakes 0+ perch change their diurnal activity pattern and at dusk move offshore by late summer and by late autumn remain in deeper waters (Guma'a 1978, Treasure 1988, Wang & Eckmann 1994).

In the river Kyrönjoki estuary the highest catches of 0+ perch were usually found in the beginning of July, with decreasing abundances throughout the month. A pattern of initially high abundances rapidly declining in seine *CPUE* can be expected (Chapman 1978) and have been found for other species too, where the decline is dependent on migration and mortality of the juveniles (Hudd *et al.* 1988, Urho *et al.* 1990). Due to the difference in the timing of annual temperatures and episodic pH minima (and thus in the size of 0+ perch) the decrease was most often significant in the middle of the sampling period.

4.4. Improving the monitoring of 0+ perch

In monitoring the effects of human activity on a fish community it is important to note that 0+ perch abundance in the beginning of the summer is not comparable to the abundance at the end of summer. From a managemental point of view it is essential to find a period, preferably determined by a predictable parameter, such as time, when annual abundances are comparable. At this time the 0+ fish ought to be entirely recruited to the seine, but not yet migrated away from the nursery area. This may be difficult if different cohorts exist, which is typical to e.g. herring (Urho & Hildén 1990).

In the river Kyrönjoki estuary significant decreases of juvenile abundances were measured most frequently from the 2nd to the last third of July. The selected ten day periods were, however, too rough to reveal precise dates, or size of juveniles, for the most adequate sampling. If the monitoring extends over both the 2nd and the last third of July the differences in abundance are, at least partly, likely to be dependent on behavioural changes. An alternative is to monitor juveniles as they have just reached the inshore phase. However, this is a more laborious process, as more individuals are obtained when monitoring fish entering this phase. The growth of juveniles has furthermore to be known as the initial high abundance tends to decrease rapidly with time. Too early an effort may also give underestimates if the juveniles have not yet been recruited to the seine. Therefore small differences in time may cause large differences in abundance. By monitoring perch later, i.e. by the end of July or in August, the outwards migration will affect the catches. Furthermore juveniles have a tendency to form bigger schools by the end of summer. *CPUE* thus becomes more variable, with increasing standard deviations of the mean, and so decreasing the statistical power of the material. Anyway, the sampling should be done during a rather short period of time.

After screening the whole estuary during the first years we minimised the sampling to an area where most of the 0+ fish occurred. We were well aware that most surveys are based on too few samples as Cyr *et al.* (1992) have pointed out and therefore we used 30 sampling stations representing different habitats in the area from 1982 to 1994. In addition to the difference in abundance due to the time of sampling there is also a large spatial variation in larval samples (Hildén & Urho 1988). It may be asked how much is lost by monitoring all habitats, if they respond homogeneously to environmental fluctuations, as in this case. Thus abundance shows similar trends over the biotope but may vary depending on the habitat. When habitats are chosen by random, catches tend to be binomially distributed, with peaks at low and high *CPUE*, or at least with an increase in the variance. This may force the data to be treated nonparametrically, decreasing their prognostic value and urge for more samples before significant differences are measurable.

When monitoring 0+ perch the sampling should therefore be concentrated to a relatively short period applying stratified random sampling regarding habitats. If the costs must be even furthermore reduced the habitat monitored should be the one with the highest abundance and the lowest spatial variances during a time when the catches are least affected by mortality, migration and efficiency of the gear. Spatial and temporal variation induced by environmental changes may hamper the precision of estimates, since the number of samples that can be taken is limited. The difference in the means before and after an impact affects the number of samples needed to detect changes in a population (Cyr *et al.* 1992). Although perch is not the most sensitive to acidification, its reproduction strategy and larval distribution, with match and mismatch to the episodic acidification, does make it vulnerable to the soil induced acidification commonly appearing in rivers emptying to the northern Baltic Sea.

References

Beamish, R. J., Lockhart, W. L., van Loon, J. C. & Harvey, H. H. 1975: Long-term acidification of a lake and resulting effects on fishes. — Ambio 4: 98–102.

Chapman, D. W. 1978: Production. — In: Bagenal, T. (ed.), Methods for assessment of fish production in fresh waters, IBP handbook no 3: 202–217. — Blackwell Scientific Publications, Oxford.

Coles, T. F. 1981: The distribution of perch, Perca fluviatilis L. throughout their first year of life in Llyn Tegid, North Wales. — J. Fish Biol. 11: 15–30.

Cyr, H., Downing, J. A., Lalonde, S., Baines, S.B. & Pace, M.L. 1992: Sampling larval fish populations: Choice of sample number and size. — Transactions of the American Fisheries Society 121: 356–368.

Gilbert, R. O. 1987: Statistical methods for environmental pollution monitoring. — Van Nostrand Reinhold, New York.

Guma'a, S. A. 1978: On the early growth of 0+ perch, Perca fluviatilis, in Windermere. — Freshwater Biology 8: 213–220.

Hildén, M. & Urho, L. 1988: Sampling of Larval European Smelt: A Factorial Experiment. — Am. Fish. Soc. Symp. 5: 123–130.

Hildén, M., Hudd, R. & Lehtonen, H. 1982: The effects of environmental changes on the fisheries and fish stocks in the Archipelago Sea and the Finnish part of the Gulf of Bothnia. — Aqua Fennica 12: 47–58.

Hudd, R., Hildén, M., Urho, L., Axell, M-B. & Jåfs, L-A. 1984: Fiskeriundersökning av Kyro älvs mynnings- och influensområde 1980–1982. — Vesihallitus-National board of Waters, Finland, report 242 A.

Hudd, R., Hildén, M. & Urho, L. 1986: The effects of anthropogenic acidification on the stocks of bream and burbot in the sea area influenced by the River Kyrönjoki in the Gulf of Bothnia. — Publications of the Water Research Institute 68: 134–138.

Hudd, R., Leskelä, A., Wiik, T. & Lehtonen, H. 1988: Food of European whitefish (Coregonus lavaretus widegreni) larvae and fry in southern Bothnian Bay (Baltic). — Pol. Arch. Hydrobiol. 39: 473–478.

Hudd, R., Leskelä, A., Kjellman, J., Rahikainen, M. & Karås, P. 1994: Effects of episodic acid runoff on the abundance of fish fry of spring spawning fish species and the perch (Perca fluviatilis L.) stock in the estuary of River Kyrönjoki. — In: Müller, R. & Lloyd, R. (eds.), Sublethal and chronic toxic effects of pollutants on freshwater fish: 301–310. — Cambridge.

Hudd, R., Kjellman, J. & Urho, L. 1996: The increase of coincidence in relative year-class strengths of coastal perch (Perca fluviatilis L) stocks in the Baltic Sea. — Ann. Zool. Fennici 33: 383–387.

Karås, P. 1987: Food consumption, growth and recruitment in perch (Perca fluviatilis L.). — Ph.D.- thesis, University of Uppsala, Uppsala.

Kjellman, J., Hudd, R., Leskelä, A., Salmi, J. & Lehtonen, H. 1994: Estimation and prognosis of recruitment failures due to episodic acidifications on burbot (Lota lota L.) of the River Kyrönjoki. — Aqua Fennica 24: 51–57.

Leskelä, A. & Hudd, R. 1993: Anadromous whitefish (Coregonus lavaretus L.) stock in the acidified River Kyrönjoki. — Aqua Fennica 23: 57–62.

Lyons, J. 1986: Capture efficiency of a beach seine for seven freshwater fishes in a north-temperate lake. — North American Journal of Fisheries Management 6: 288–289.

Mittelbach, G. G. & Chesson, P. L. 1987: Predation risk: Indirect effects on fish populations. — In: Keerfoot, W.C. & Sih, A. (eds.), Predation, direct and indirect impacts on aquatic communities: 315–332. — United Press of New England, Hanover.

Parsley, M. J., Palmer, D. E. & Burkhardt, R. W. 1989: Variation in capture efficiency of a beach seine for small fishes. — North American Journal of Fisheries Management 9: 239–244.

Pierce, C. L., Rasmussen, J. B. & Leggett, W. C. 1990: Sampling littoral fish with a seine: Corrections for variable capture efficiency. — Can. J. Fish. Aquat. Sci. 47: 1004–1010.

Rask, M. 1984: The effect of low pH on perch, Perca fluviatilis L. II. The effect of acid stress on different development stages of perch. — Ann. Zool. Fennici 21: 9–13.

SYSTAT. 1992: SYSTAT for Windows: Statistics, version 5th edition. — Evanston, IL.

Treasurer, J. W. 1988: The distribution and growth of lacustrine 0+ perch, Perca fluviatilis. — Env. Biol. Fish. 21: 37–44.

Tuunainen, P., Vuorinen, P. J., Rask, M., Järvenpää, T., Vuorinen, M., Niemelä, E., Lappalainen, A., Peuranen, S. & Raitaniemi, J. 1991: Happaman laskeuman vaikutukset kaloihin ja rapuihin, Loppuraportti. — Suomen Kalatalous 57: 1–44.

Urho, L. & Hildén, M. 1990: Distribution patterns of Baltic herring larvae, Clupea harengus L., in the coastal waters off Helsinki, Finland. — Journal of Plankton Research 12: 41–54.

Urho, L., Hildén, M. & Hudd, R. 1990: Fish reproduction and the impact of acidification in the Kyrönjoki River estuary in the Baltic Sea. — Env. Biol. Fish. 27: 273–283.

Wang, N. & Eckmann, R. 1994: Distribution of perch (Perca fluviatilis L.) during their first year of life in Lake Constance. — Hydrobiologia 277: 135—143.