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Young-of-the-year fish species composition in small coastal bays in the northern Baltic Sea, surveyed with beach seine and small underwater detonations

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The young-of-the-year (YOY) fish species composition of 12 small coastal bays in the Tvärminne region, southwestern Finland, was surveyed in late summer 2003 using a beach seine and underwater detonations. The surface area of the bays varied between 1 and 21 ha, and they were located along a clear exposure gradient reaching from an innermost bay system, where the surface water salinity was 1‰–3‰, to an outer archipelago, where salinity was around 5‰–6‰. The beach seine data demonstrated a change in dominance from freshwater species in the inner areas to marine species in the more exposed outer areas. Using the beach seine, the average number of YOY fish species in a single bay was 6.2 and the total number of YOY fish species caught was 17, while only four species were caught by detonation. Detonation sampling caught effectively only the YOY of some early spawning freshwater species, such as perch and roach. For these two species, both methods gave quite similar abundance patterns in the study bays. The YOY of some other common species, such as bleak and sticklebacks, were too small (8–22 mm) to be caught with the detonation method. The results demonstrated a rather low sampling precision with both methods even for the most abundant freshwater species, the main reason being that YOY fish are usually highly aggregated leading to a high frequency of zero samples.

Introduction

Fish reproduction is a key mechanism controlling fish production. Thus, knowledge of fish reproduction areas is often needed to understand changes in fish stocks and to protect these areas from adverse changes. Small bays are common features in the northern Baltic Sea, especially along the northern coast of the Gulf of Finland and in the Archipelago Sea between Finland and Sweden. Small bays are typically more sheltered than the surrounding areas and often have higher water temperatures during the growth period. Consequently, these habitats are considered valuable spawning and nursery areas for many fish species (e.g. Karås and Hudd 1993).

Beach seining has been the main method for sampling young fish and small-sized littoral species in shallow marine and estuary habitats in the Baltic Sea (e.g. Urho *et al*. 1990, Sundell 1994, Kjellman *et al*. 1996, Rajasilta *et al*. 1999). Seining combines several advantages: no poisons or explosives are needed, the gear is simple and sampling is rapid and active. Seining should capture different species equally, and fish are often alive after capture, enabling an accurate assessment of gut contents (Pierce *et al.* 1989). A beach seine is also large and effective enough to catch less common species, but small enough to be handled by only two persons. However, physical obstructions such as rocks or stones and dense vegetation interfere with the seine, causing it to lift from the bottom and thereby preventing it from passing through the entire water column. At worst, a stony bottom or dense hard-stemmed vegetation can completely prevent the use of a beach seine. It is also ineffective at catching certain bottom-dwelling species (Lyons 1986).

Underwater detonations were first used for fish sampling in streams, but as early as the 1980s they were also used in some canals and small lakes (Metzger and Shaftland 1986, Bayley and Austen 1988). Metzger and Shaftland (1986) used a strong detonation cord in small lakes, which instantaneously killed all fish within 7 m of the explosion. Karås (1996), Sandström and Karås (2002) and Nilsson *et al.* (2004) used detonation to sample young of the year (YOY) fish in coastal areas of the Baltic Sea. In these Swedish studies, the detonations stunned or killed fish within an area of about 50 m^2. In 2003 and 2004, less forceful explosives were used in the Baltic Sea region, and the effective range of the new explosives was less than 10 m^2. Detonation sampling can be performed in almost all shallow habitats and even in dense vegetation. This is the strongest advantage of the method, especially in coastal waters where electrofishing cannot be carried out due to the high conductivity. Detonation sampling with a small charge also enables accurate data to be gathered on the small-scale habitat preferences of YOY fish. Bayley and Austen (1988) compared the detonation method and rotenone for sampling fish in warm-water impoundments, but no other attempts to evaluate the detonation method have been reported in the literature.

The large-scale distribution of marine and freshwater fish species along the salinity gradient of the Baltic Sea is well known (Ojaveer *et al.* 1981). However, the small-scale patterns along local inshore–offshore gradients have little been studied. The bays of this study were located on a clear exposure and salinity gradient extending from the innermost bay areas, subject to considerable freshwater runoff, to the outermost archipelago, where the surface water salinity is around 5‰–6‰. Our first aim was to determine the YOY fish species composition and abundance along this gradient. Adults of marine species can enter waters of very low salinity and most of the freshwater species occur throughout the archipelago zone of the Baltic Sea, but the early life stages are the most sensitive to surrounding conditions. Abiotic factors such as salinity and water temperature have been stated to have a decisive effect on larval and juvenile fish in marine estuaries (Harris *et al.* 2001) and on marine littoral fish assemblages (Thorman 1986), whereas in lake littoral zones and rivers biotic factors, especially the macrophyte abundance and heterogeneity, often play a major role (Weaver *et al.* 1997, Grenouillet *et al.* 2002). Therefore, our hypothesis was that clear changes in YOY composition and abundance along the exposure and salinity gradient would be detected. Another main aim of the present study was to compare the YOY fish catches using beach seining and using detonation in small coastal bays, in a region where the fish fauna consists of a mixture of freshwater and marine species.

Materials and methods

Study area

The sampling sites were located in the western part of the Gulf of Finland, within a geographical range of about 30 km (Fig. 1). The shoreline of the northern coast of the gulf is very irregular, having numerous deeply extended bay areas and a unique archipelago zone off the shoreline. Abiotic conditions vary considerably in the gradient between the innermost bay areas and the open sea, with salinity in the latter being around 5‰–7‰. The period of winter ice cover usually begins in January and the ice breaks up in April. In the innermost areas the ice-cover period is usually 1–2 months longer, salinities are much lower and spring water temperatures are higher than in the open sea.

The 12 bays sampled were small (1–21 ha) and shallow (max. depth 3 m) and located in three archipelago zones: the innermost bay-area,

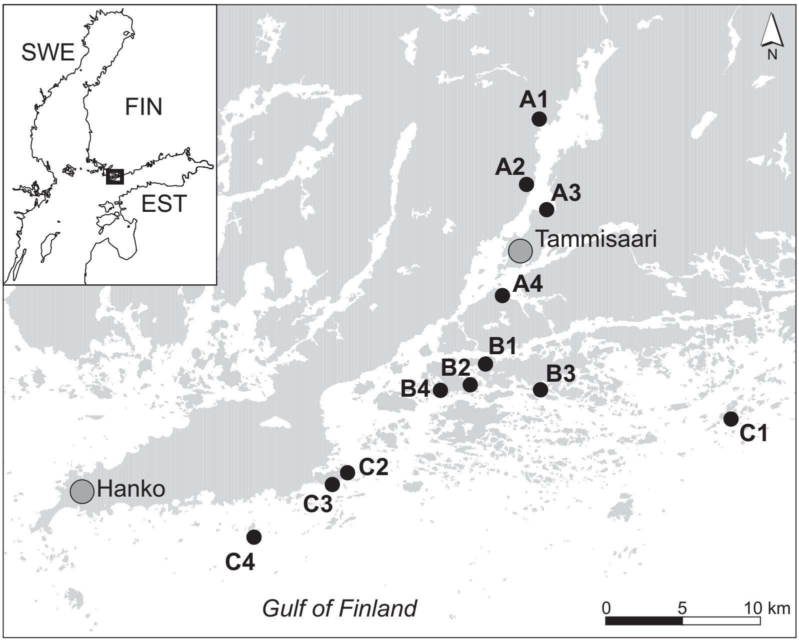

Fig. 1. Location of study areas.

intermediate archipelago and outer archipelago, with four bays in each zone (Fig. 1). The bays were included in a larger study examining the natural value of coastal bays, and thus various background data were available. Bays in the innermost area had soft muddy bottoms, and 60%–80% of the bottoms were in the late summer covered by macrophytes (M. Westerbom unpubl. data). Spring salinities, measured in 2004, varied between 1‰ and 3‰, and spring water temperatures — ranging from 12 to 15 °C — were higher than in outer sites (Table 1). In the intermediate archipelago, the bottoms were mostly muddy, although some sand also occurred in two of the bays. The macrophyte coverage rate varied between 10% and 50%. The bays in the outer archipelago were more exposed to the open sea, as seen in the salinity and temperature values (Table 1). The bottoms in this area were a mixture of mud, sand and stones/rock and the macrophyte coverage rate in the sampled bays varied between 30% and 70%.

Fish sampling

Fish samples were taken from 21 July to 7 August 2003. All sites were sampled by both detonation and beach seining, the time lags between the two samplings at single sites varying from a few hours to 5 days. The beach seine used for sampling had an arm length of 10 m, a mesh size of 5 mm and a depth of 2.5 m. The mesh size of the cod end was 1 mm. The lower ropes of both arms carried 16 plummets, each of 225 g. Four similar plummets were fixed to the 1.6-m-long lower rope on the mouth. Before the start of sampling, the behaviour of the seine was checked by a scuba-diver in one of the bays. The seine was hauled perpendicularly to the shoreline with 20 m ropes. The seine was pulled to the shore, except in a few cases when the seine was lifted into a boat. The seining stations were spaced around the bays as widely as possible, the final factor determining the actual location being the suitability of the bottom and the shore. The number of hauls at each site was six, except in one small bay (B4), where only five suitable stations were found. The captured fish were preserved by freezing or in 5% formalin when smaller than 3–4 cm.

The detonation method was based on small (1 g) explosive charges that were detonated underwater at 0.5–1.0 m depth. The detonations were carried out from a boat and using a 4–5-m-long rod. Detonations stunned fish within a radius of 1–3 m. All fish floating to the surface were collected and frozen. The total number of samples (12–34 detonations per bay) was dependent on the area of bay having a suitable depth (> 0.5 m). Accurate location of the detonation sampling points was based on a system originally established for simultaneous vegetation surveys. Lines, directed crossways to the mouth of the bays, were formed at 50 m intervals, starting at the end of the bays. Along each line points were marked at 10 m intervals. The fish sampling stations were finally selected from these points using systematic sampling.

In the laboratory, the preserved fish were identified to species and their length measured to the nearest 1 mm. Sub-samples were used for length measurement in cases where the number of captured fish was high. The length distribution was used to separate YOY individuals from older fish. YOY individuals of common goby (*Pomatoschistus microps*) and sand goby (*Pomatoschistus minutus*) were difficult to distinguish from each other and thus these species were combined as a species group. Neither sampling method allowed absolute quantitative estimations of abundance, but both methods enabled a comparison between sites of relative abundance as catch per unit effort (CPUE). Hierarchical cluster analysis was used to test the consistency of the data and to examine the possible patterns in YOY fish composition along the exposure and salinity gradient. In the first analysis, the most common species were clustered using Pearson's correlation measure and the single linkage method (SYSTAT 1998). In the second analysis, the 12 bays were clustered using standardized data and thereafter Pearson's correlation measure and single linkage.

Results

Species composition along the exposure gradient

During the field work it became evident that sampling with the beach seine gave more diverse data on the YOY fish community than the detonation sampling. Thus, the comparison of YOY species composition here is based on the beach seine data. The average number of YOY fish species in the beach seine catches was 5.5 species/bay in the innermost bays (A1–A4), 6.0 species/bay in the intermediate area (B1–B4), and 7.0 species/bay in the outer archipelago. However, the differences between means were not statistically significant ($p > 0.05$) in this small data set. The total CPUEs (all species combined) of YOY individuals were also slightly higher in the outer archipelago than in the inner areas, but the correlation between mean total CPUEs and species number was weak ($r = 0.34$, $p = 0.2807$, $n = 12$). The lowest total CPUE and species number (only 2) was found in the intermediate archipelago at B3. The macrophyte coverage rate, 10%, was also the lowest in this bay.

Table 1. Characteristics of the study bays. Data on bottom quality and vegetation coverage are from late summer 2003 and were provided by M. Westerbom (unpubl. data).

Bay	Surface area (ha)	Salinity (‰), 12–21 May 2004	Temp. (°C), 12–21 May 2004	Proportion of muddy bottoms	Tot. vegetation coverage (%)
A1	4	1.3	14.0	100	70
A2	3	1.1	13.3	100	75
A3	10	1.2	15.1	100	62
A4	3	3.1	12.7	100	78
B1	8	5.1	14.8	100	23
B2	21	5.6	8.8	90	72
B3	12	5.2	11.7	100	10
B4	3	5.7	9.3	70	51
C1	3	5.7	9.5	50	28
C2	3	5.9	9.3	100	45
C3	6	6.0	8.9	15	46
C4	1	6.2	9.5	20	71

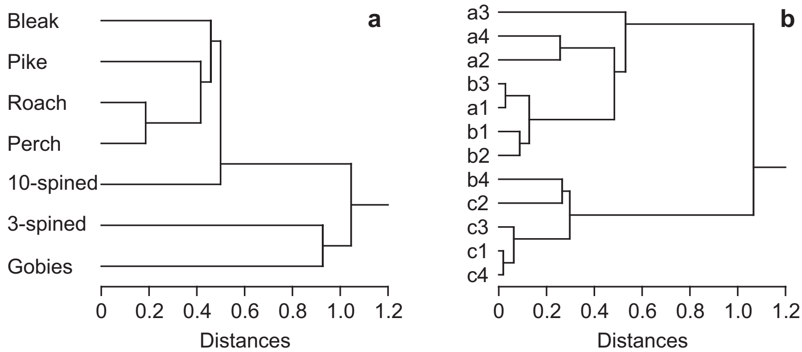

Fig. 2. Dendrograms showing (**a**) the clustering of the most common YOY fish species caught by beach seine, and (**b**) the clustering of the bays based on the YOY fish catches.

YOY roach and perch had maximum abundances in the innermost areas (A3–A4), while bleak (*Alburnus alburnus*) showed a wider distribution and a maximum in the intermediate archipelago (B1–B2). However, three-spined stickleback (*Gasterosteus aculeatus*) and gobies were most common in the outer archipelago (B4, C1–C4) (Table 2). The same pattern was revealed by cluster analysis, where freshwater species such as roach and perch clustered close to each other, and the species with a marine distribution, three-spined stickleback and gobies, were clustered distantly from the other species (Fig. 2a). The cluster analysis of bays (Fig. 2b) also demonstrated a clear structure, suggesting that the YOY fish data does not fully support the original grouping of bays into three classes (A, B and C).

Comparison of catches of the two sampling methods

A total of four YOY fish species were caught in the detonation samples: perch, pike, roach and smelt (Table 2). All were typical freshwater species and no marine species were caught. The average number of YOY fish species caught in one bay by detonation was 1.0. By comparison, beach seine sampling captured a total of 17 YOY fish species, the average number of species in one bay being 6.2. The infrequent species falling into the category 'others' in the seine catches (Table 2) were the black goby (*Gobius niger*), two-spotted goby (*Gobiusculus flavescens*), deep-snouted pipefish (*Syngnathus typhle*), rudd (*Scardinius erythrophthalmus*), Baltic herring (*Clupea harengus*), garfish (*Belone belone*) and bullhead (*Cottus gobio*). By far the most abundant group among the seine catches comprised the approximately 6 to 19 mm long, pelagic YOY of the common goby and sand goby (Tables 2 and 3).

For perch and roach, both sampling methods gave similar patterns for the abundance of YOY in the bays sampled. Perch was most abundant in the inner area (A3 and A4) and roach especially in bay A3, but also in A4 (Fig. 3). Despite the similarity of the general patterns between the two sampling methods, detonation captured relatively more YOY roach than perch. The mean catch of perch per detonation was approximately 1% of that with one seine haul in bays A3 and A4. The respective proportions here for roach were higher, 22% and 4%. For pike (*Esox lucius*), the patterns revealed by the two sampling methods also resembled each other, YOY pike being caught most commonly in the inner sites A1–B2 (Table 2). The numbers of YOY pike caught in a single bay were, however, low for both sampling methods, varying between zero and three individuals.

A small pilot experiment carried out earlier in June 2003 demonstrated that very small (length < 15 mm) YOY cyprinids showed no major reactions to the detonations. Thus, length distributions were compared between the catches for the two methods based on the data from A3, where both roach and perch were abundant. The length distributions of roach caught by detonations and seine were approximately similar (Fig. 4), although the median in detonation catch (24 mm) was slightly higher than in seine catch (22 mm). The length distributions of perch were based on smaller data, and no differences between methods were observed (Fig. 4).

Table 2. Catch per unit effort (CPUE) and total number of YOY fish species in the study bays based on detonation and beach seine sampling in July–August 2003. (* < 0.05 for detonations, and < 0.5 for beach seine).

Bay	*n*	Perch	Ruffe	Pike	Smelt	Roach	Tench	Bleak	Minnow	3-spined	10-spined	Gobies	Other species	Tot. number of species
Detonation (ind./det.)														
A1	20	–	–	–	–	–	–	–	–	–	–	–	–	0
A2	20	0.2	–	*	–	–	–	–	–	–	–	–	–	2
A3	25	1.2	–	*	–	81.5	–	–	–	–	–	–	–	3
A4	30	1.1	–	0.1	3.4	1	–	–	–	–	–	–	–	4
B1	25	–	–	–	–	*	–	–	–	–	–	–	–	1
B2	33	–	–	*	–	–	–	–	–	–	–	–	–	1
B3	34	–	–	–	–	–	–	–	–	–	–	–	–	0
B4	18	0.2	–	–	–	–	–	–	–	–	–	–	–	1
C1	12	–	–	–	–	–	–	–	–	–	–	–	–	0
C2	17	–	–	–	–	–	–	–	–	–	–	–	–	0
C3	22	–	–	–	–	–	–	–	–	–	–	–	–	0
C4	15	–	–	–	–	–	–	–	–	–	–	–	–	0
Beach seine (ind./haul)														
A1	6	–	*	*	–	–	–	2	–	1	–	12	–	5
A2	6	*	–	*	–	*	–	*	–	–	1	*	*	7
A3	6	112	–	1	–	370	*	–	–	–	–	–	–	4
A4	6	85	–	*	–	24	1	*	–	–	7	–	–	6
B1	6	1	–	–	–	6	3	49	–	–	–	3	1	6
B2	6	1	–	1	–	4	*	394	–	*	–	40	*	8
B3	6	–	–	–	–	–	–	–	–	–	–	*	*	2
B4	5	5	1	–	–	–	–	3	–	3	*	2870	1	8
C1	6	–	–	–	–	–	–	–	1	26	1	393	1	5
C2	6	2	–	*	–	–	–	*	–	10	*	985	*	7
C3	6	*	*	–	–	–	–	1	*	7	–	174	*	9
C4	6	–	–	*	–	–	–	6	–	19	1	43	1	7

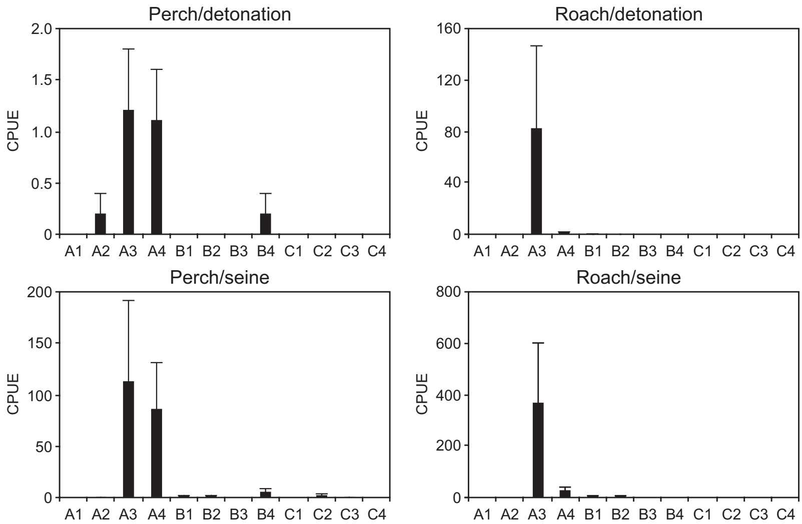

Fig. 3. Mean catch per unit effort (CPUE + SE) of YOY perch and roach caught by detonation and beach seine.

Discussion

Changes in YOY fish species composition along the exposure gradient

A change from freshwater species dominance in the inner areas to a dominance of marine species in the more exposed outer areas was apparent in the beach seine data. This pattern, also revealed by cluster analysis, suggests that salinity is an important factor controlling the YOY fish species richness and composition along the inshore–offshore gradient studied. Seven from the total of 18 YOY species found in this study were marine

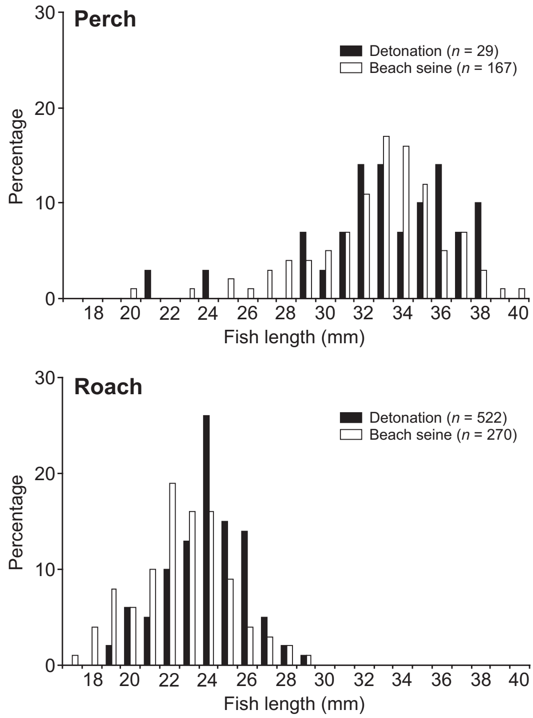

Fig. 4. Length distributions of YOY roach and perch caught by detonation and beach seine in bay C3 during late July 2003.

Table 3. Length ranges of YOY fish in late July to early August 2003 in the beach seine data. *n* = number of fish measured.

Species	Length range (mm)	*n*
Perch	13–52	> 100*
Ruffe	11–24	6
Pikeperch	20–49	5
Pike	60–106	12
Roach	16–48	> 100*
Tench	8–40	24
Bleak	8–27	> 100*
Minnow	9–23	5
3-spined s.b.	10–22	> 100*
10-spined s.b.	11–22	63
Gobies	6–19	> 100*

* Length measurements taken from sub-samples.

or brackish water species. The spring and early summer salinities in the innermost areas, around 1‰, are probably too low for reproduction of some marine species occurring in the area. On the other hand, the salinity in outer areas, 5‰–6‰, is too high or far from optimal for the reproduction of some freshwater species. According to the laboratory experiments of Jäger *et al*. (1981), roach embryos are sensitive to salinity and all eggs died before hatching at the salinity of only 3.5‰. This agrees with the observation that almost all YOY roach were found in the innermost bays. Another important factor affecting the YOY fish species composition is the bottom quality in the bays and in adjacent areas. In the innermost areas only muddy bottoms existed, while the proportion of hard bottoms was greater in the outer archipelago. This could especially affect the occurrence of YOY gobies, as these nest-building fish prefer hard bottoms for breeding. In general, the principle findings here agree with the suggestion of Harris *et al*. (2001) that abiotic factors have a decisive impact on larval and juvenile fish in marine estuaries.

Sundell (1994) carried out beach seine sampling at six sites located very close to areas C2, C3 and C4 of this study. In his data from July and August 1992, the mean CPUE for YOY three-spined stickleback was 94 individuals/haul and for YOY common and sand gobies 1028 individuals/haul. Thus, the catches of these two species were on the same level as in our beach seine results. In 1992, YOY clupeids (*Clupea haremgus*/*Sprattus sprattus*) occurred in high numbers at one sampling site out of six (Sundell 1994), but in our study very few YOY herring were caught. Only a few minnows (*Phoxinux phoxinus*) were caught in both studies. The minnow requires clear water and it has almost disappeared from Finnish coastal waters, because of eutrophication (Koli 1990).

The results of the beach seine sampling were generally consistent. The clustering analysis of bays suggested that the YOY fish data does not fully support the original grouping of the study sites into three classes or sub-areas (A, B and C). Instead, a grouping into two classes, outer bays dominated by three-spined sticklebacks and gobies (B4, C1, C2, C3, C4) and inner bays (the remaining bays) could be more appropriate. The results of the beach seine sampling also illustrated that large-scale differences, such as marked changes in YOY fish species composition along the exposure gradient, can be detected even with low or moderate sampling efforts.

Comparison of catches of the two sampling methods

An absolute comparison of CPUEs or species richness in the catches of the two sampling methods was not possible as the exact sampling volumes were unknown and sampling efforts could not be standardised. However, the differences found were clear enough to draw some conclusions. The most pronounced difference was that the majority of species could not be detected by the detonation sampling. It is probable that the pressure wave caused by a detonation particularly affects the swim bladder which, in turn, is the primary reason why stunned fish float to the surface. However, some species, such as gobies, lack a proper swim bladder and the swim bladders of YOY of late-spawning species, such as bleak, minnow and sticklebacks, were probably not well developed in June–August. This is the most likely reason for the complete lack of YOY of these species among the detonation catches. The YOY of these species were either not stunned at all, or they were stunned but sank to the sea floor.

Detonation sampling is generally suitable for sampling other freshwater species, such as pikeperch (*Stizostedion lucioperca*), ruffe (*Gymnocephalus cernuus*) and breams (*Abramis brama* and *Blicca bjoerkna*) if the YOY fish have grown large enough, which on the Baltic coast means sampling in late summer or autumn. This was shown by Sandström and Karås (2002), as they captured YOY of these species in a highly eutrophic bay area on the Swedish Baltic coast in late summer. Perch, roach and pike are early spawners, typically spawning in May in the northern Baltic Sea. The lack of major differences between the length distributions of perch and roach captured with the two sampling methods suggests that the entire cohort of YOY perch and roach had achieved the size required for capture by detonation. The results, however, gave a slight indication that detonation sampling might catch roach relatively more effectively and perch less effectively than seine sampling. This may be a result of YOY roach occupying denser vegetation than perch, observed earlier by Kjellman *et al*. (1996).

Sampling precision

The precision with which fish densities or CPUEs are calculated can be estimated as the coefficient of variation of the mean ($CV_x = SE/x$), low CV_x indicating good precision. If $CV_x \geq 0.5$, the estimates can reliably detect only order-of-magnitude differences among sites or time periods (Cyr *et al*. 1992). As an example here, CV_x values of the mean CPUEs for perch and roach for detonation and seine sampling were calculated for bays A3 and A4 from the data presented in Fig. 2. In these two bays, CV_xs for the two species collected by detonation sampling varied between 0.41 and 0.78, while the respective values for seine sampling varied between 0.53 and 0.79. Hence, similar precision was achieved by 25–30 detonation samples and six seine samples. The main reason for the relatively poor precision is that YOY fish are usually highly aggregated and the frequency of zero samples was high, especially for the detonation method, where over 90% of the samples included no YOY fish.

Effective means to increase precision would be to increase the number of samples. Spring and early summer 2003 were cold in our study region, which most probably depressed YOY fish abundance. The water temperature during spring/summer has a clear effect on the year class strength of perch on the Baltic coast (e.g. Böhling *et al*. 1991), and roach is also a warm-water species. The possibly higher abundance of YOY fish during a 'normal' year could result in higher means and thus also tend to decrease CV_x. Another means to increase numbers of YOY fish in samples is to increase the volume sampled. However, the beach seine used in this study was already large and a bigger one would be difficult for two persons to handle. YOY fish usually appear in a certain zone in the littoral, which means that longer hauls perpendicular to the shoreline would not implicitly increase the number of YOY fish in the catch. The explosive charges used in detonation sampling in earlier investigations on the Swedish Baltic coast were stronger (Sandström and Karås 2002, Nilsson *et al*. 2004) than those in this study (1 g charge). The Swedish surveys performed using larger charges probably gave better precision for a given sample but they were also more laborious and the spatial resolution of the results was poorer.

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