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Spatial variation in size distribution of two freshwater species, European perch (*Perca fluviatilis* L.) and roach (*Rutilus rutilus* L.), in the shallow coastal area of the NE Baltic Sea.

Albert, A., Barkala, M., Eschbaum, R., Jürgens, K., Kesler, M., Saat, T., Verliin, A., Vetemaa, M..

Abstract

Patterns of distribution and abundance of different size groups of European perch (*Perca fluviatilis* L.) and roach (*Rutilus rutilus* L.) in the different zones of shallow elongated brackish-water Matsalu Bay (NE Baltic Sea) were investigated. A horizontal salinity gradient from shallow (1 m) freshwater (0-2 ppt) inner part to deeper (3 m) brackish-water (4-6 ppt) outer part occurs in the bay, and therefore provides diverse environmental conditions for various size groups of fish with different habitat optimum. The study revealed the habitat selection pattern to be quite regular over the study period (mid-summer fish monitoring 1995-2007). Perch was abundant all over the bay, whereas larger and older size classes showed preference for shallower and warmer areas of the inner part. On the contrary to perch, both abundance and size of roach increased significantly towards deeper areas of the outermost zone of the bay. The possible reasons and tendencies behind the spatial variability and gradients are discussed.

Keywords: brackish-water, *Perca fluviatilis* L., perch, roach, *Rutilus rutilus* L., size distribution, spatial variation

Estonian Marine Institute, University of Tartu, Vanemuise 46, 51014 Tartu, Estonia [tel: +372 7375094, fax: +372 7375830, e-mail: anu.albert@ut.ee] .

Introduction

There is long list of biotic and abiotic factors that determine the distribution of a fish species. Of those, water salinity is regarded as the most significant physical factor affecting the abundance and distribution of freshwater fish species in brackish basins like estuaries and inshore areas (Loneragan *et al*. 1986, Henderson 1989), other factors, e.g. water temperature, transparency, nutrient status and food base of fish playing also important roles (Thiel *et al*. 1995, Araújo *et al*. 1999, Psuty-Lipska & Borowski 2003).

Matsalu Bay (Fig. 1) in Väinameri (West-Estonian Archipelago Sea) is a relatively shallow but large bay. In the western coast of Estonia it can be considered one of the most important recruitment areas for fish. According to gillnet surveys, several freshwater species dominate in the bay all year round, e.g. roach *Rutilus rutilus*, pike *Esox lucius*, white bream *Blicca bjoerkna*, perch *Perca fluviatilis* and rudd *Scardinius erythrophthalmus*. Some freshwater and anadromous species are less abundant (vimba bream *Vimba vimba*) or almost lacking in the bay (smelt *Osmerus eperlanus*) outside the spawning period. The only abundant marine species is Baltic herring *Clupea harengus membras*, which spawns mostly in the outer parts of the bay (Fig. 1); this species is almost absent in the area in summer (Erm *et al*. 2002). In European lowland lakes and reservoirs fish assemblages are dominated numerically by roach an perch (Matena 1995, Holmgren & Appelberg 2000, Irz *et al*. 2002), pike being a top fish predator (Eklöv 1997). In that relation the shallow bays of NE Baltic Sea, like Matsalu Bay, are similar in their fish assemblages composition (Saat & Eschbaum 2002).

Vetemaa *et al*. (2006) have analyzed year-round and also between-years mid-summer dynamics in species biodiversity and abundance in Matsalu Bay. Results of that study show, that the most abundant species in the mid-summer period are by far roach, perch and white bream (Vetemaa *et al*. 2006). The aim of the present study was to investigate the size distribution of the two most abundant and important species, perch and roach, in the different parts of Matsalu Bay.

Material and methods

Study area

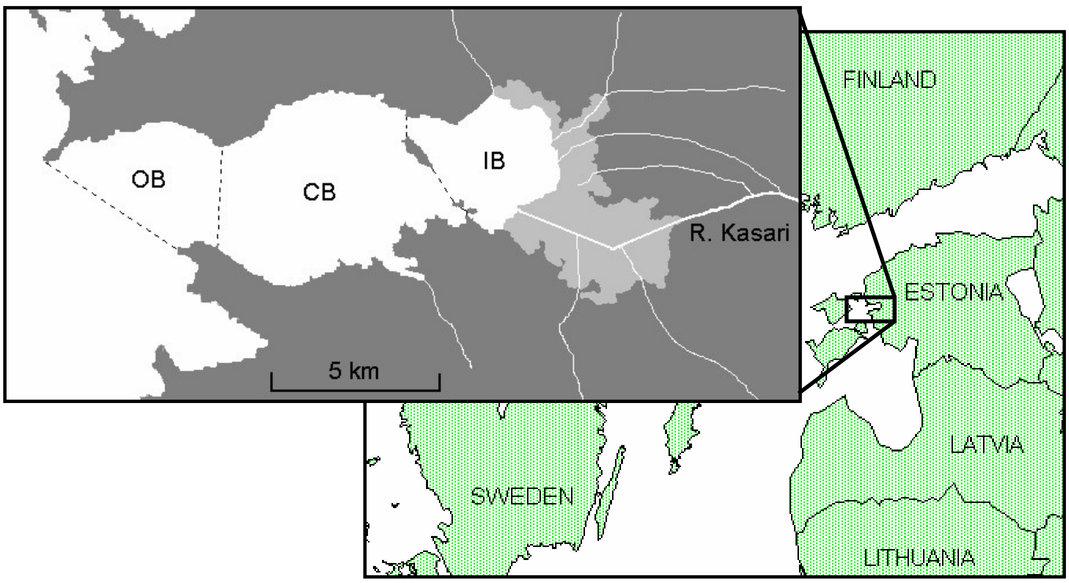

Figure 1. Matsalu Bay. OB – outer bay, CB – central bay, IB – inner bay. Light grey area indicates reed beds (Vetemaa *et al*. 2006).

Matsalu Bay (Fig.1) is one of the largest bays and the only real delta estuary in Estonia. The bay can be divided into three ecologically rather different parts: inner, central and outer bay (IB, CB, OB) (Fig. 1). Its surface area is 67 km^2 and the bay is very shallow – maximum depth is 3.5 m in the OB, ca. 2 m in the CB, and ca. 1 m in the IB. Water chemistry is determined by the mixing of water from Kasari River and Väinameri (shallow sea area between Estonian western islands and the mainland). Salinity is usually 4–6 ppt in OB, 1–4 ppt in CB and 0.5–2 ppt in IB. Ice formation starts typically at the end of November and ice usually thaws in April. Water temperature may reach 25–27 °C in mid-summer. The south-eastern part of the bay is covered with large reed beds. Submersed vegetation forms different communities in OB and CB, while open water part of IB is similar to CB (Trei 1991). Until the early 1990s, fishing was not allowed in CB and IB, while OB was open for fishing. Since 1993, fishing has been allowed in CB as well, while IB remains a closed area. Still, as

Matsalu Bay is considered to be an important recruitment area for fish, the fishing regime is stricter in OB and CB (longer fishing ban in spring–summer and some small closed areas) than in the open areas of Väinameri (Vetemaa *et al*. 2006).

Fish sampling

Standardized coastal fish monitoring routines (Thoresson 1996) for the coastal areas of the northern Baltic Sea were followed, with some modifications. According to this, sampling always took place during a week in late July–early August; data collected in 1995-2007 were used in the present study. Six mesh sizes (17, 21.5, 25, 30, 33 and 38 mm) were used together in line, in a random sequence. Mesh sizes are designed for coastal monitoring considering mainly perch and roach (Thoresson 1996, Saat *et al*. 2003). The net series used gives reliable information about the abundance of length groups larger than 13 cm of perch and roach (Albert & Einarsson 2004).

Only bottom nets (net height 1.8 m) were used. Stations were randomly placed in all three parts of the bay. In each year the total number of stations was around 40, and distribution between sections was roughly equal. Fishing usually took 4-5 days (8-10 stations per night). Only days with wind speed less than 8 m/s were used. The nets were set between 17.00 and 20.00 hours and lifted between 08.00 and 11.00 hours following day. The distance between stations was at least 100 m. Each day water temperature and transparency (Secchi disc depth) were measured. CPUE was calculated as the number of fish per station/night. Fish length was measured as total length (TL) to the nearest mm.

The general pattern of distribution of size classes was calculated using the CPUE of each length group (in 1 cm groups) for each study period (year). To even out the differences between years (i.e. to avoid bigger impact of years with high fish abundance), the CPUEs of each year were converted to proportions and then averaged.

Sampling of fish stomachs (perch and roach) was carried out in 2007 to study the differences in feeding behaviour between the different parts of the bay. The stomach content was indicated as either positive (food items) or negative (empty).

Results and discussion

It is known that freshwater fish species possess different tolerance limits along abiotic (e.g. temperature, salinity, oxygen) gradients, which are narrower the younger the fish are (Depêche & Billard 1994). In the Baltic Sea, salinity at large scale (i.e. between the different sea areas) and temperature at small scale (i.e locally) are shown to determine the distribution of different freshwater species and their age/size groups (Neuman 1982, Lappalainen *et al*. 2000). At the open coast of NE Baltic at salinity conditions of 6-7 ppt, only larger size classes of perch and roach have been caught with the gillnet series (Albert *et al*. unpublished).

Over the years under investigation, both perch and roach have shown great fluctuation in abundance in the three parts of Matsalu Bay, at the same time roach has been always rather abundant in the OB (Tables 1 & 2).

Table 1. CPUE of perch in Matsalu Bay over the period of 1995-2007 (IB inner bay, CB central bay, OB outer bay).

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
IB	32.33	12.70	7.67	3.43	2.00	6.85	7.43	5.46	19.38	10.30	22.82	5.14	7.69
CB	22.87	6.93	16.53	0.58	3.30	14.93	19.14	14.23	32.14	5.65	16.20	9.62	16.07
OB	23.60	8.82	6.93	2.00	9.92	8.21	20.86	12.57	31.62	15.08	18.00	23.54	21.69

Table 2. CPUE of roach in Matsalu Bay over the period of 1995-2007 (IB inner bay, CB central bay, OB outer bay).

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
IB	3.83	15.40	0.75	2.50	9.80	4.85	3.29	20.23	29.77	20.00	68.82	40.71	7.46
CB	66.22	46.67	8.40	13.63	39.75	28.67	32.29	5.00	18.50	33.94	68.67	35.23	43.64
OB	70.70	44.94	70.79	34.83	128.00	87.64	14.14	20.07	26.85	8.08	37.43	36.00	56.92

Size distribution has been diverse over the years of study, reflecting the variability in strength of different year classes. However, the general pattern shows the tendency of some lenght groups to prefer certain parts of the bay. Perch was abundant all over the bay, whereas larger and older size classes (≥ 25 cm) showed preference for the shallower and warmer inner bay (Fig. 2). On the contrary to perch, both abundance and average size of roach increased significantly towards the deeper outer bay (Fig. 3).

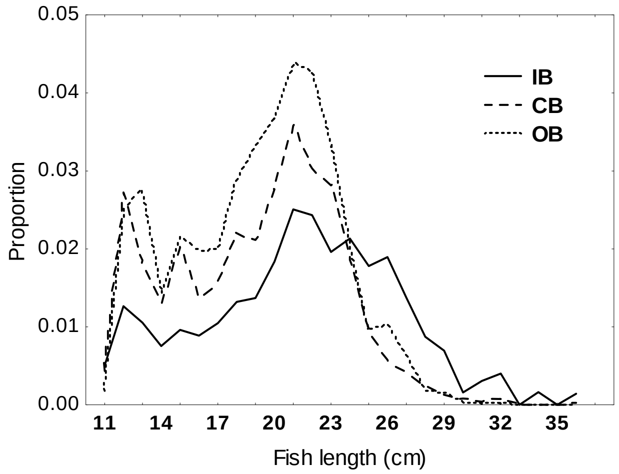

Figure 2. Size distribution of perch in Matsalu Bay (IB inner bay, CB central bay, OB outer bay).

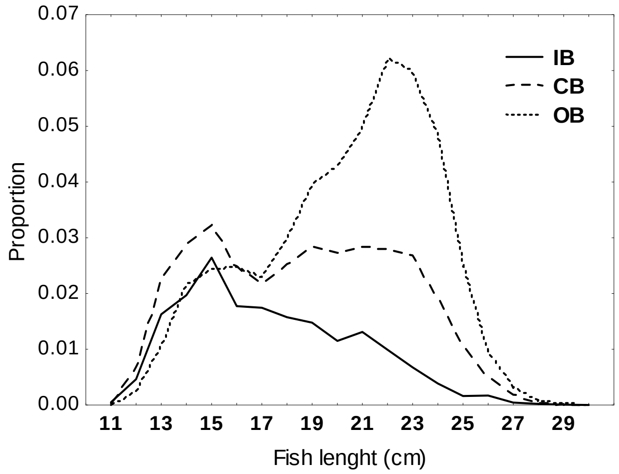

Figure 3. Size distribution of roach in Matsalu Bay (IB inner bay, CB central bay, OB outer bay).

There was no correlation between water transparency (2 m on average) and fish abundance in Matsalu Bay during the study periods 1995 – 2007. Effects of water salinity can be considered marginal, because the smaller and more sensitive size classes occured in all parts of the bay throughout the study periods. The results confirm that salinity in the coastal sea of the Väinameri region is definitely not too high for smaller size groups of freshwater fish species.

During the study periods 1995-2007 water temperature in the Matsalu Bay was 17-27° C, as a rule IB being 1-2° C warmer than OB, while CB showed typically intermediate values, The average water temperatures of each study period were tested (Spearman Correlation) against fish abundance (CPUE) in the different parts of the bay to find whether there exists any significant relationship. The results showed, that the abundance of both small (< 17 cm) and large roach in IB correlated positively with temperature (small: $N = 12$, $R = 0.61$, $P = 0.04$; larger: $N = 12$, $R = 0.62$, $P = 0.03$). The proportion of roach caught from inner part of Matsalu Bay was higher in study periods with higher temperature, whereas the share of roach caught from CB and OB was lower than average at the same periods of time.

Lappalainen *et al*. (2000) suggest that the supply for suitable food is an important factor determining the composition of fish communities in the archipelago zone during mid- and late summer. It could also be the key factor behind the horizontal distribution of perch and roach, that were not clearly affected by water temperature in Matsalu Bay.

Investigation of stomachs (2007) showed that in IB larger perch (≥ 24 cm, which preferred that part of the bay in 2007) had empty stomachs only in 15% of the cases, whereas in the CB the share was 39% and in OB 50%. Smaller (< 24 cm) perch showed the same pattern, but differences were not so remarkable: share of empty stomachs was 8% in IB, 17% in CB and 24% in outer part of the bay. So, one reason why larger perch is staying in the inner bay during midsummer period could be the abundance of suitable prey items compared to the outer part of the bay.

Larger roach (≥ 17 cm) in IB had empty stomachs in 28% of the cases, in CB 37% and 70% in OB. Nevertheless, they still preferred the outer bay. Smaller had somewhat different situation: the share of empty stomachs was 32% in IB, 21% in CB and even 78% in OB. As the general pattern (Fig. 3) shows the abundance of smaller-sized roach to be relatively high in the central bay (also in 2007), the food availability there could be one possible explanation, while temperature either directly or indirectly affected the abundance of roach in the inner bay. It is difficult to estimate the particular effects of those factors, as abiotic conditions influence also the abundance and behaviour of suitable prey.

As mentioned above, the inner bay is closed for fishing all year round, but in other parts of the bay and also in the West-Estonian Archipelago Sea perch remains one of the most valuable target species. Consequently the larger and older fish may occur mostly in IB just because there they survive longer. However, Järv and coauthors (2002) have demonstrated that perch migrates out from the Matsalu Bay to overwinter in the deeper areas of Väinameri. So, the fish inhabiting IB can not be considered as protected all year round, which mitigates the possible effect of different fishing regime.

Persson (1997) suggests that abiotic factors affect perch abundance largely through regulating the abundance and behaviour of other species, especially roach. Olin et al. (2002) studied fish community structure in lakes in Southern Finland, and found that abiotic factors explain perch biomass quite poorly, and that dense roach stock has a depressing effect on perch biomass in eutrophic lakes.

Probably the main predator of both perch and roach in Matsalu Bay is the great cormorant, who's largest colony in Estonia is situated 5 km westward from the mouth of Matsalu Bay (Eschbaum *et al*. 2003). But since the cormorants are fishing in all three parts of the bay their impact on spatial distribution of fish is not clear.

In addition to the abovementioned factors like salinity, temperature, water depth, visibility and food base there is also a range of other factors (e.g. vegetation coverage, availability of suitable shelters) that were not quantitatively measured during the test fishing, but which might have its' influence on the spatial variation of perch and roach in the Matsalu Bay.

As size diversity increases as a function of habitat diversity, size distribution of perch and roach in Matsalu Bay varies in its' different parts and reflects the diverse ecological conditions of all three zones of the bay. The shallower, warmer and almost freshwater inner part is preferred by larger size groups of perch. The deeper, more brackish and less warm outer bay and the in-between central bay are suitable habitats for smaller perch as well as for all size groups of roach, whereas larger roach found the outer bay most preferable.

In conclusion, in the large elongated shallow warm-water Matsalu Bay, were water salinity varies between 0.5 and 6 ppt, a list of factors can be found to affect and determine the horizontal variation and abundance of different size/age groups of perch and roach, from which the most evident are water temperature, food availability and fishing pressure

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