Examensarbete
i ämnet biologi

Early to late summer fish distribution in a bay of the Gulf of Bothnia

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Abstract

This study examined the fish community in a shallow bay in the Gulf of Bothnia during the summer of 2007. The distribution of several fish species within the bay was investigated. Possible influence on trout is discussed.

Fish was sampled eight times at three different areas of the bay starting 4th of June and ending 7th of September. The fish was sampled with multimesh gillnets and horizontal echosounding.

I found that the bay was dominated by three freshwater species, roach, perch and ruffe with no apparent effect of season on their distribution. However, the abundance of roach in the outer area changed significantly with low abundance early in the summer and high abundance late summer and autumn. The overall high abundance of warm water species in trout feeding areas could potentially have a negative effect on trout through feeding competition.

Keywords: Bothnian Bay ; brackish-water; temporal variation; multimesh gillnet; perch; roach; ruffe; trout.

Sammanfattning

Denna studie undersökte fisksamhället i en grund vik i Bottenviken under sommaren 2007. Förändring av distribution, i både tid och rum, undersöktes för flera fiskarter. Eventuella effekter på öring diskuteras.

Fiske med nordiska översiktsnät utfördes på tre olika områden i viken. Fisket startades fjärde juni och avslutades sjunde september. Vid varje fisketillfälle gjordes en inspelning med ett horisontellt ekolod på varje fiskeplats.

Studien visar att viken domineras av tre sötvattensarter, mört, abborre och gers. Tätheten av mört, i vikens yttre område, förändrades signifikant under studien, från låg i början till hög på slutet. Den höga tätheten av fisk i ytterområdet kan potentiellt ha effekt på öring genom födokonkurens.

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Introduction

The Baltic Sea is a brackish water inland sea with salinity ranging between about 2–7 ‰. There is a gradient in salinity and in the northernmost part of the Gulf of Bothnia, the salinity is very low due to freshwater runoff from large rivers. One result of these circumstances is presence of both freshwater and saltwater species in the Gulf of Bothnia.

Not much is known about the seasonal migration patterns of fish in the northern part of the Baltic Sea. The studies that have been made either focus on long-term trends (Adjers *et al.*, 2006) or study areas in the southern part of the Baltic Sea. In a study of 12 coastal bays in southwestern Finland, Lappalainen and Urho (2006) showed that young-of-the-year fish show a change in dominance from freshwater species in the inner areas to marine species in the outer areas. Seasonal variation in the species composition, abundance and distribution, between inner bay, central bay and outer bay, have been found for most species fish in a shallow bay in the Estonian Archipelago (Vetemaa *et al.*, 2006). The most dynamic period found in that study was in the spring when baltic herring (*Clupea harengus*) and smelt (*Osmerus eperlanus*) enter the bay for spawning.

The use of multimesh gillnets is a common method to estimate abundance of lentic fish communities in the Nordic countries. The method is standardized and gives results that can be compared between studies (Appelberg, 2000). There are however several drawbacks with the method. Different species have different catchability, dependent on size, life stage and activity. The catchability also goes down with high abundances simply because the mesh gets occupied (Olin *et al.*, 2004). The shape of the fish also has an effect on catchability but the combination of twelve various mesh sizes used in Nordic multimesh gillnets aim to minimize this error (Kurkilahti *et al.*, 2002).

There is also an ethical issue of killing the fish for survey purposes. I therefore found it important to find an alternative method and test if sampling the areas with an advanced echo sounder can give an abundance index that correlates to the result from the gill-nets. Using an echosounder is in most cases also less work intensive. Studies where fish abundance estimated with echo sounder correlated with other methods (gillnets and electrofishing) (Kubecka *et al.*, 1994; Bergquist *et al.*, 2007), as well as studies without correlation (Enderlein and Appelberg, 1992; Peltonen *et al.*, 1999) have been published.

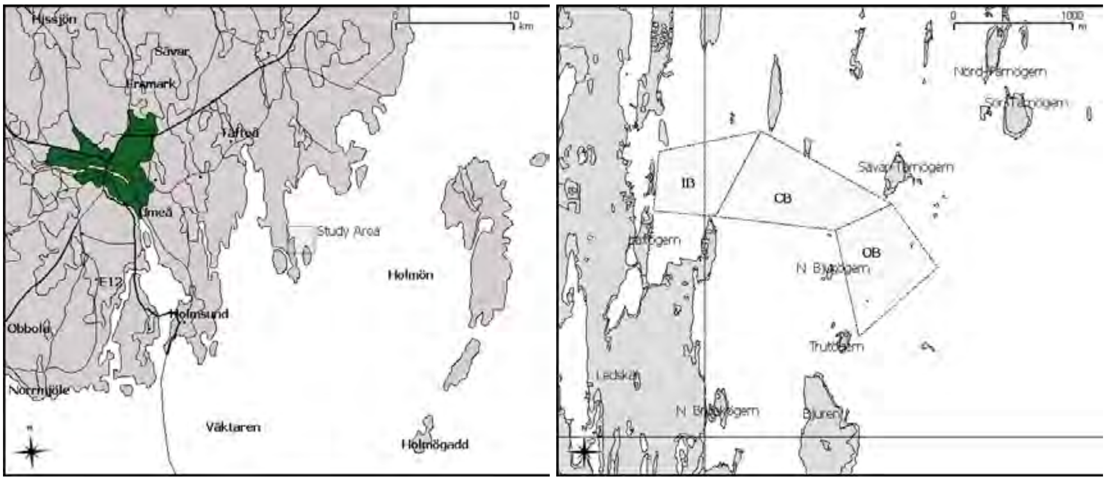
In a ongoing study of the initial sea phase of post smolt brown trout (*Salmo trutta*), Larson and Serrano (pers. comm.) have found that when the smolt leave the river they migrate to the outer part of the archipelago to feed almost immediately. In the middle of the summer, the trout seem to migrate further and leave the bay. During test fishing of the area, where trout resided, high abundance of warm water species like perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*) was found. High densities of these species might outcompete

trout for food resources, that initially feed on similar prey as perch and roach. This exploitative competition might cause trout to leave previously occupied areas.
In this study, I examine how the distribution of fresh water and marine fish species varies in a bay in the Gulf of Bothnia from early summer to late summer. My goal was to find migration patterns both in time and space. I have also tested the use of horizontal echosounding as an alternative method to the multimesh gillnets. Finally I have discussed if fresh water species migration in the bay can have an effect on anadroumous brown trout during their initial sea phase.

Material and methods

Study area

The Sävar Bay is located about 15 km east of the city of Umeå (Fig. 1). The bay is relatively shallow with a maximum depth of <7m. The bay has numerous small islands and a large proportion is less than four meters deep.



(a) Overview (b) Detail

Figure 1: Map of the study area located at 63°46' N 20°36' E.

The aim was to estimate the distribution of the fish fauna both in time and space. I therefore divided the data in three different areas and three time periods.
Inner bay, IB, is near the mainland just outside of the original outlet of river Sävarån (the current main outlet is located ca 5 km north via a man made channel). IB is well protected with shallow water, soft bottoms and some vegetation areas near the shoreline.

Central bay, CB, is semi-protected in the archipelago of the bay and the bottom is a mixture of sediments and rocks. Outer bay, OB, is furthest out with just a few islands before the open sea and has a bottom dominated by rocks and boulders.
Temperature loggers covering all study areas were placed in the bay from the start of June to the end of July. The last two fishing occasions I measured the temperature manually but due to malfunction of the equipment I only got readings for the inner bay and central bay on the 13/8 and only IB 7/9 therefore, I use the same temperatures for CB and OB for 13/8 and same temperature for all areas on the 7/9.
I divided the time of the study to three periods called "Early", "Middle" and "Late". The first three fishing occasions (4/6, 11/6 and 18/6) were defined as period "Early". During this period the water temperature was rising, from 10.3 to 16.8 ℃, and there was a pronounced temperature gradient (4.6 to 5.1 ℃ difference between IB and OB) with cooler water in the outer region of the bay. The next two fishing occasions (25/6 and 2/7) were defined as "Middle" and this period is characterized of higher water temperatures (14.1 to 19.9 ℃) with a diminishing temperature gradient (3 to 4.1 ℃) between IB and OB. During the last three fishings (10/7, 13/8 and 7/9), called "Late", the water started to cool off (17.7 to 11.0 ℃) and there was only a small temperature difference (0 to 1.1 ℃) between IB and OB (Fig. 2).

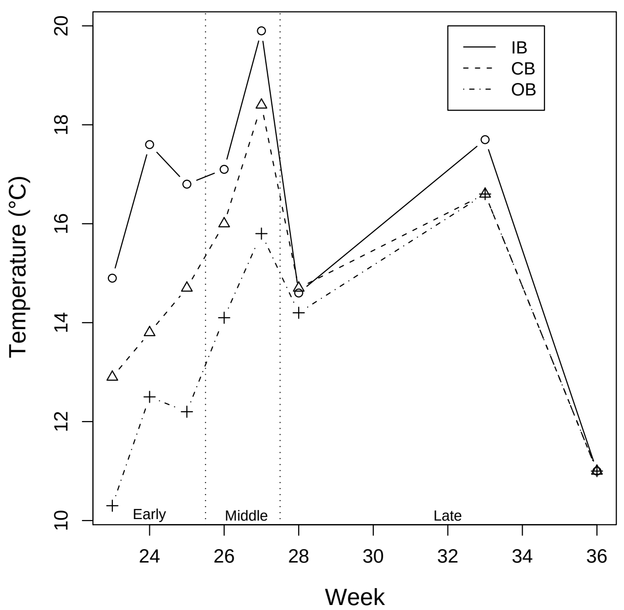


Figure 2: Water temperature (℃) on each fishing occasion for "Inner Bay" (IB), "Central Bay" (CB) and "Outer Bay" (OB). Time periods are indicated by vertical, dotted lines.

Data collection

During the study period, all three areas were fished with Nordic multimesh gillnets (Appelberg, 2000). The Nordic multimesh gillnet was developed to minimize sampling errors and to make data collected in all Nordic countries comparable (Appelberg *et al.*, 1995). I fished each area eight times and used two nets per area and fishing occasion. Each fishing location was chosen randomly by placing points along the three meter curve in each area. A GPS-waypoint was recorded and used to navigate to the point during fishing. The center of each net was placed on the three meter curve and the direction perpendicular to the depth curve. The nets were set between 18:00 and 20:00 in the evening and lifted between 7:00 and 9:00 the morning after. I started the fishing on the 4th of June and stopped 7th of September (Table 1).

Table 1: Date and position for all nets during the whole study period.

Period	**Date**	**Inner Bay**		**Central Bay**		**Outer Bay**	
		Lat 63°	**Lon 20°**	**Lat 63°**	**Lon 20°**	**Lat 63°**	**Lon 20°**
Early	04-jun	46.243	43.310	46.189	34.826	45.924	36.197
		46.178	34.144	46.081	34.600	45.603	36.301
	11-jun	46.234	33.987	46.147	35.397	45.810	35.750
		45.975	34.237	45.867	35.170	45.748	35.663
	18-jun	46.121	33.851	46.023	36.060	45.616	36.250
		45.941	34.050	45.817	35.483	45.390	35.881
Middle	25-jun	46.239	34.042	46.034	36.008	45.652	35.956
		46.230	34.320	46.104	34.730	45.584	35.830
	02-jul	46.018	34.036	45.951	35.658	45.654	35.730
		46.155	34.229	45.996	36.008	45.933	36.155
	10-jul	45.987	34.047	45.930	34.563	45.386	35.881
		46.154	34.229	46.214	35.618	45.893	35.715
Late	13-aug	46.174	33.898	46.215	35.597	45.635	35.757
		46.239	34.103	46.309	35.103	45.692	36.244
	07-sep	45.961	34.049	46.231	34.876	45.929	36.164
		45.910	34.566	46.074	35.359	45.406	35.885

The number of fish of all species was counted, and their length (mm) and the weight (g) was measured. Ten individuals of each species from each net were saved and frozen for possible stomach analyse in the future.
To be able to select subsets of the fish for data analysis I decided to store the data in a database. I choose Sqlite3, an open source database that is available for many platforms and is easy to use. The data analyse was done with R: A Language and Environment for Statistical Computing
(R Development Core Team, 2007).

The result of the fishing is presented as an index of abundance calculated as: catch in numbers per station and fishing night (NPUE). Catch per unit effort in terms of weight is calculated as: sum of weights per station and fishing night (CPUE).

Before the nets were set I made a recording with an advanced sonar, SIMRAD EY60 (GPT 200 kHz Split Beam) at the location of the net. The sonar was connected to a portable computer with the ER60 software that records the signal to hard disc. A GPS receiver (U2 SIRF Star II, WAAS-EGNOS) was also connected to the computer and its signal was recorded together with the sonar data. The transceiver has an opening of 7 degrees and it was set to point 15 degrees down from the horizontal line. On each fishing site, I recorded eight minutes of sonar data by first pointing the transceiver to the north and recording during one minute. I then slowly turned the transceiver clockwise 90 degrees during one minute. The procedure with one minute stationary and one minute turning recording was repeated until the transceiver pointed to the north again, thus recorded a full 360 degrees. This resulted in a total scan time of 384 minutes. The sonar data was analysed with Sonar5-Pro (Balk, 2001) which is a program for advanced analysis of sonar data developed at the Faculty of Mathematics and Natural Science, University of Oslo.

The aim of my analysis of the sonar data was to get a usable index to compare with the catch in the gill-nets. In the Sonar5 program I used the biomass analysis based on echo counting based on SED (single echo detection). One problem with horizontal echo sounding is the variation in the target strength (TS) for the same size of fish due to the aspect of the fish body. Kubecka and Duncan (1998) showed that the target strength for a 110 mm perch varied between -55 and -21 dB (mean TS = -43.1 dB) when the fish was rotated 360 degrees in a 200 kHz sonar beam. There is also a large variation between the TS for different species and both a 40 cm whitefish and a 60 cm salmon have a TS of about -25 dB (Lilja *et al.*, 2000). The 11:th of December 2007 I calibrated the echosounding equipment at the fish hatchery at Norrfors, where I made a recording in a rearing pool with 12900 juvenile salmon with an average weight of 68 g. This resulted in echos with a mean TS of -42.9 dB.

In my analyse, I chose to discard echos with a TS lower than -40 dB. This should filter echos from debris while still including most of the echos from fish. Each file was analysed to include all SED in the range 5 to 35 meters. As index of fish abundance, I used the numbers “Total weight” and “Total number of targets”, as calculated by the Sonar5 program.

Results

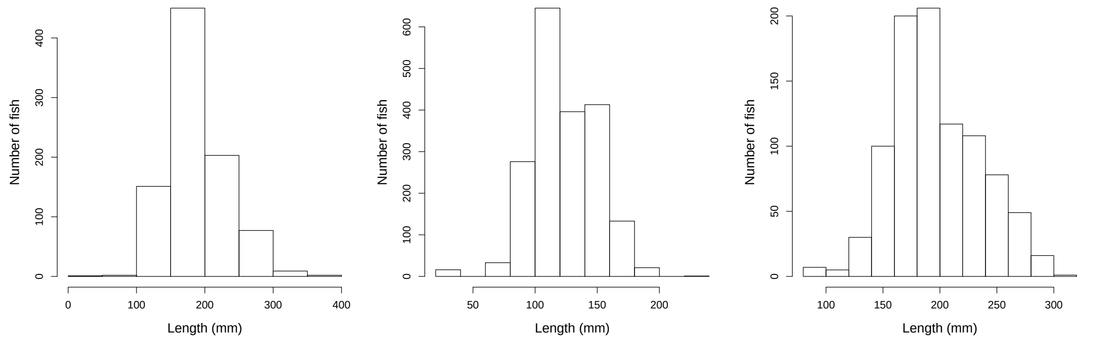
Gillnet

During the whole period, I caught a total of 3976 fishes with a total mass 245 kg. Of the 13 different species caught Baltic herring, European sprat (*Sprattus sprattus*) and Viviparous blenny (*Zoarces viviparus*) were the only true marine species found. The remaining 10 were freshwater species and of these Perch, Ruffe and Roach were dominating in abundance (Table 2).

Table 2: All species caught. Mean NPUE in each area for the whole period. IB = Inner Bay, CB = Central Bay, OB = Outer Bay

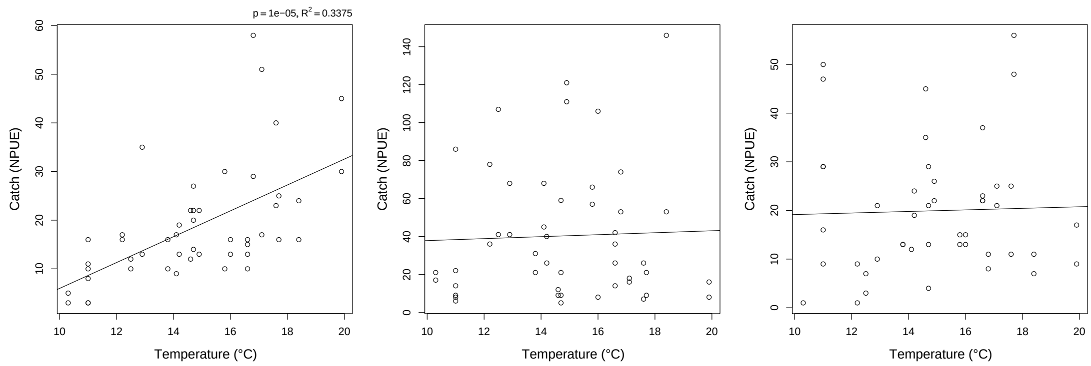
Species	**IB**	**CB**	**OB**
Perch *(Perca fluviatilis)*	28.7	17	11.5
Ruffe *(Gymnocephalus cernuus)*	33.6	39	46.9
Roach *(Rutilus rutilus)*	24	18	14.6
Ide *(Leuciscus idus)*	0.6	0.9	0.6
Whitefish *(Coregonus lavaretus)*	0.5	0.5	0.6
Vendace *(Coregonus albula)*	0.9	$<$0.1	0.1
Smelt *(Osmerus eperlanus)*	$<$0.1	0	0
Stickleback *(Gasterosteus aculeatus)*	0.1	0.6	2.4
Baltic herring *(Clupea harengus)*	1.4	1	2.1
Viviparous blenny *(Zoarces viviparus)*	0	0	$<$0.1
European sprat *(Sprattus sprattus)*	0	$<$0.1	0.8
Burbot *(Lota lota)*	0	0.1	$<$0.1
Bleak *(Alburnus alburnus)*	0.1	0.1	0.1

The three most abundant species were dominant in the total catch and the size distribution (Fig. 3) showed that all size classes were present. Due to the dominance of perch, roach and ruffe I focused all analysis on those three species. The water temperature increased in all areas during the first 4 weeks. During this period there was a clear gradient in temperature with warmer water in the inner bay and colder in the outer bay. In the second week of July there was a summer storm with wind speeds over 20 m/s. The water was stirred and on the 16/7 the temperature was almost the same in all three areas and there was a considerable drop in temperature to less than 15℃ (Fig. 2).
I examined the effect of water temperature on the fish distribution by plotting the number of fish caught per net against the water temperature (Fig. 4). The catches of perch had a positive correlation with water temperature ($p < 0.001$). For roach and ruffe, my data did not show any significant correlation between catch and water temperature.
The catches varied considerably, both spatially and temporally (Table 3 and Figure 5).



(a) Perch (b) Ruffe (c) Roach

Figure 3: The size distribution of the total catch of the three most abundant species. Note the different scale on the y-axis.



(a) Perch*** (b) Ruffe (c) Roach

Figure 4: The effect of temperature on the catches of the three most abundant species. Asterisks indicate significant regression (*** $P < 0.001$). Note the different scale on the y-axis.

An analysis of the catch of the most abundant species in the different areas for the whole period showed that: the catch of perch decreased in all areas over time and that ruffe showed high catches in the beginning of the summer, the catch of roach increased during the study period. The increase of roach was most apparent in the central and outer bay where the catch was low on the first occasions and highest at the end of the summer (Fig. 5). A linear regression of catches per week showed statistically significant relations for roach in the middle bay ($p < 0.01$) and roach in the outer bay ($p < 0.001$).
The relationship between catches of perch and roach changed during the studied period. In the early period the perch dominated the catches in all areas and in the late period the roach dominated in all areas. In the middle period the perch still dominated but the difference was minor.

Table 3: The mean NPUE (±SD) on the different locations for all time periods. A t-test to test for difference is done both for spatial and temporal changes. Asterisks indicate significant p-value (* $P < 0.05$ and *** $P < 0.001$).

	Early		**Middle**		**Late**
Roach IB	17.2 (±8.0)		18 (±6.8)		34.8 (±18.7)
Roach CB	12.3 (±5.5)		11.5 (±3.4)	***	28 (±5.6)
	*				
Roach OB	3.5 (±3.7)		10 (±6.8)	*	30.7 (±13.9)
Perch IB	30.8 (±16.0)		35.8 (±15.3)		16.5 (±6.3)
Perch CB	19.3 (±8.8)		17.2 (±4.7)		15 (±6.2)
Perch OB	10.5 (±5.7)		16.5 (±9.7)		10.7 (±6.7)
Ruffe IB	65.3 (±45.5)	*	14.5 (±4.4)		14.5 (±5.8)
Ruffe CB	40.2 (±19.7)		78.2 (±60.4)		11.8 (±7.5)
Ruffe OB	50 (±35.3)		59 (±10.5)		39.3 (±26.4)

Table 4: Pearson correlation for the catch per net of the three most abundant species.

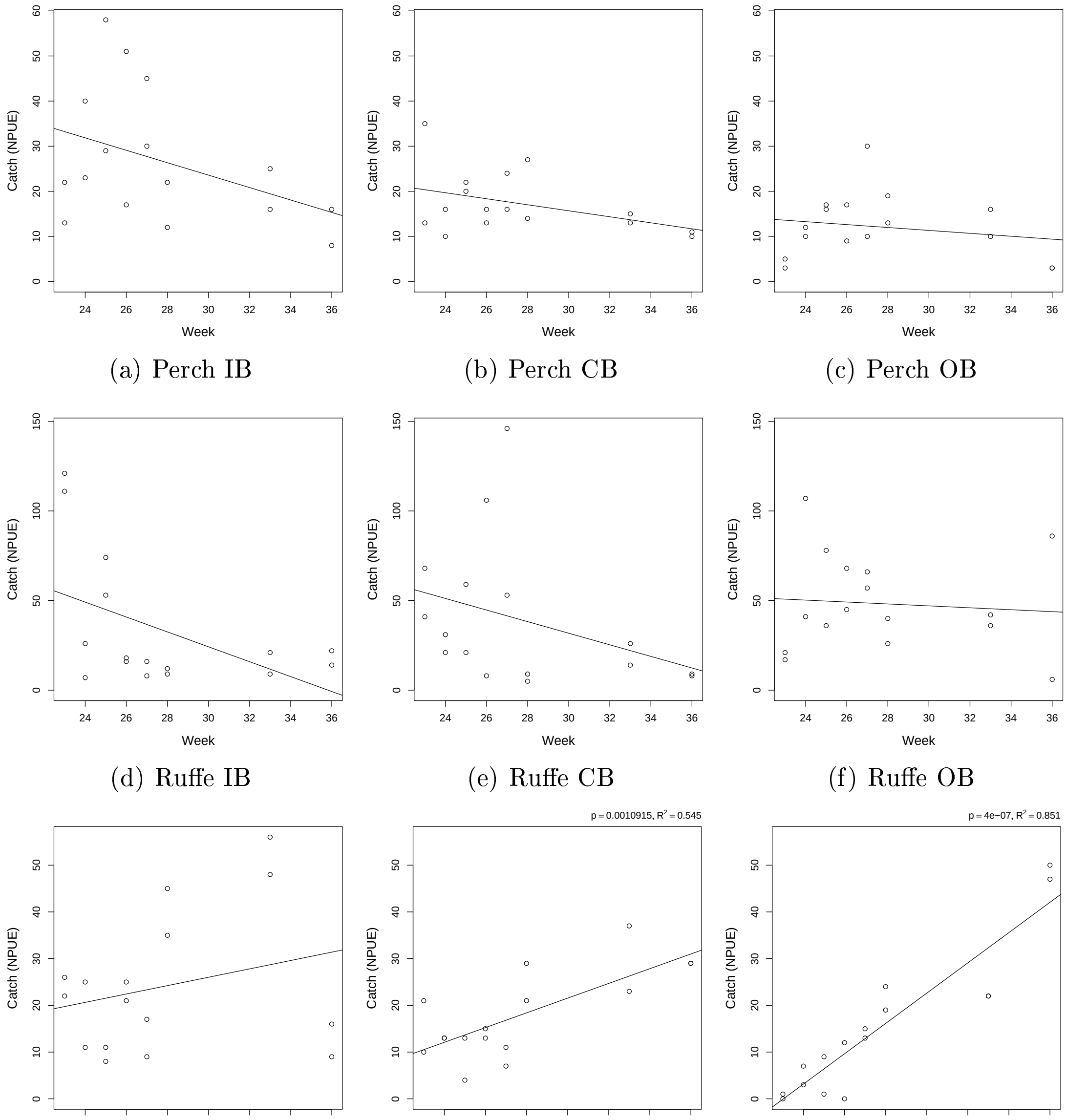
	Perch		**Ruffe**	
	Correlation	P-value	Correlation	P-value
Ruffe	-0.02963	0.8416		
Roach	-0.16008	0.2771	-0.27313	0.06034

To test if the catch of one species had any effect on any of the other species I made a Pearson correlation test between the catch/net of the three most abundant species. Correlation of catches, of different species, would indicate inter-specific influence. However, the result (Table 4) did not show any statistically significant correlation.

Echo sounding

The analyze of the recorded echograms resulted in a total of 12392 targets (TS > -40 dB) with a mean of 309.7 (SD 76.7) per station. The biomass, estimated with Sonar5-Pro from the number of targets and their target strength, was 157 kg with 3.9 kg (SD 2.2) per station.

Figure 6 shows the result from the echo sounding plotted against the result from the gillnet fishing. A linear regression of the relation between the result from the echo sounding and the gillnet fishing showed a negative trend. However, the relation was not statistically significant.

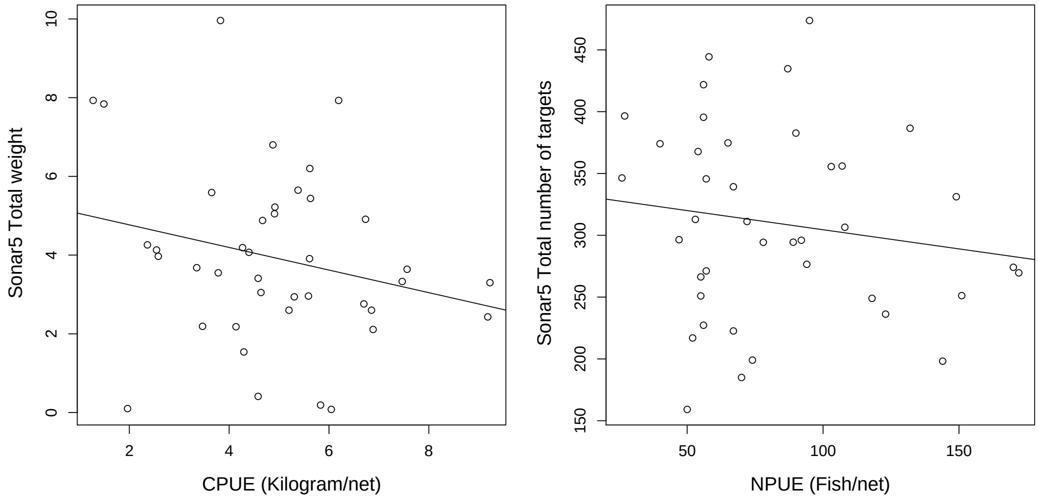


(a) Perch IB (b) Perch CB (c) Perch OB

(d) Ruffe IB (e) Ruffe CB (f) Ruffe OB

(g) Roach IB (h) Roach CB ** (i) Roach OB ***

Figure 5: The catch (NPUE) per area and species on every week of the study period with linear regression trend line. Asterisks indicate significant regressions (** $P < 0.01$ and *** $P < 0.001$).



(a) Mass (b) Counts

Figure 6: Correlation of gillnet fishing result and echo sounding with estimated biomass (a) and estimated number of targets (b). Each point in the plots represents a fishing occasion. The results from the gillnets are on the x-axis and the results from echo sounding are on the y-axis.

Discussion

Gillnets

My result show that the Bay of Sävar has a fish community that is typical for this region. Both the composition of species and the abundance are comparable with other studies in similar areas around the Baltic Sea (Adjers *et al.*, 2006). The catch of ruffe had large variances in the inner bay (IB) during the early period and in central bay (CB) during the middle period. This is probably explained by spawning activity of the ruffe during parts of this period. Brown *et al.* (1998) found that spawning activity of ruffe peaks between 12 and 14 ℃ and I also observed a lot of ruffe with eggs or sperm.
The strongest relation I found was that the catch of roach increased over the study period. Thus the catches increased significantly in the later periods at the central and outer part of the bay. The fact that the catch of roach was not correlated to water temperature was somewhat surprising, as Krause *et al.* (1998) showed that roach preferred warmer water even when the temperature gradient was as low as 1.5 ℃ and the temperature preference for roach is as high as 27℃ according to van Dijk *et al.* (2002).
The change in relationship between catches of roach and perch might be explained by a stronger reaction to water temperature from perch than from roach (Fig. 4) and in the late period the water might already be too cool for the perch to be active. The temperature where perch has its maximum growth rate is 23℃ (Melard *et al.*, 1996). The distribution of perch and roach was somewhat different from what Horppila *et al.* (2000) found in a study in two large lakes in Finland, where the roach always dominated the littoral zone and the perch dominated the open water.
During the summer the water temperature never reached levels that can be considered the optimal for roach and perch (van Dijk *et al.*, 2002; Melard *et al.*, 1996). It has also been shown that even a small temperature difference is enough to make roach choose warmer water (van Dijk *et al.*, 2002). In my study, I observed high abundance of roach in the outer part of the bay from the middle of the summer all through the last fishing occasion. It is likely that the roach and perch segregated to utilize different food resources, such segregation allows the two species to co-exist (Horppila *et al.*, 2000). According to Lappalainen *et al.* (2001) eutrophication, that promotes survival of juvenile roach, can lead to increased intra-specific competition in the inner areas of bays which force older roach to outer areas.
Although the multimesh gillnet method is well developed (Appelberg *et al.*, 1995) and often used in both ecological and fisheries studies (Murphy and Willis, 1996) there are several possible sources of errors in the method. One prerequisite to get data comparable between studies is to fish when the fish behavior isn't disturbed by spawning and the temperature is stable (Appelberg,

2000). The recommended time period to do the fishing is from late part of July to the early part of August. My study spanned a much longer period which must be considered when comparing the data to other studies. The ideal solution would be to adjust the catches for the temperature difference. Although Linlokken and Haugen (2006) have studied the effect of temperature on multimesh gillnet CPUE a complete method to adjust the catch is still not developed.
Part of the goal with my study is to highlight a possible competition between the anadromous trout and other fish species in the bay. I wanted to test if there was a migration of fish from the inner part of the bay to the outer part during the course of the summer. If this was to correlate to the time the trout are leaving the area, competition might be the driving force behind the trout migration.
The relative high densities of warm water fish could likely affect other fish species in e.g. food competition. For instance, in a recent study, brown trout have been found to have their feeding areas in the outer part of the bay during the first part of summer. My results showed that increased activity and abundance of roach somewhat coincided with trout leaving their feeding areas. However, this must be confirmed in more studies of for instance prey choice of trout and the species studied within this study.

Echo sounding

Kubecka *et al.* (1994) compared horizontal sonar with gillnet and anglers' yield with positive result for density rankings. A recent report from the Swedish Fishery Board (Bergquist *et al.*, 2007), where they performed a case study of a combination of boat electro-fishing and horizontal echo sounding, found good agreement between electro-fishing and horizontal echo sounding. In contradiction I did not find such a correlation.
A possible explanation can be the different temporal scale of the two methods. The echo sounding takes a snapshot of the area during a very short time period while the gillnets catch fish during a period of 10 to 12 hours. Many fish species show a diel pattern in movement and activity (Zamora and Moreno-Amich, 2002; Baade and Fredrich, 1998), often with peaks at dusk and dawn. This type of activity can increase the catchability of the gillnets and the sonar may miss fish that arrives to the area later. It is also difficult to distinguish stationary fish near the bottom in the interpretation of the sonar data.
The method with a stationary transducer rotated 360 degrees has not been tested before and might not work well. An experimental test of the method should be performed to verify if it is useful. A more traditional echo sounding along a transect might be a better option.
The results from the gillnet fishing should have been corrected for the variation in temperature. Methods for temperature correction is not a part of the

standard method for nordic gillnets (Appelberg, 2000). Linlokken and Haugen (2006) studied the gillnet CPUE dependence of density and temperature for perch and roach. However, to adapt those models to my data was outside the scope of this study.
I chose to base my analyze on single targets automatically detected by the Sonar5-Pro program. In the study made by the Swedish Fishery Board they found that a method based on manual selection of tracks led to be best results (Bergquist *et al.*, 2007). With the number of echos recorded and time available for my study the use of manual tracking was not an option. It is also possible that fish in the area are scared by the boat. However Drastik and Kubecka (2005) found that boat avoidance was not a serious problem in shallow waters.

Conclusions

In this study I have found few statistically significant migration patterns in the bay during the study period. The catch of roach increased during the whole period, especially in the outer part of the bay. The catch of roach remained high in the outer part during the end of the study period when water temerature had dropped. The water temperature was confirmed to have a high influence on the catches of perch. Further studies are needed to examine the factors behind these dynamics. To continue to study the competition between roach and trout I would like to verify the theory that the two species compete for the same type of food resources.
If given more time it would have been interesting to further analyse why the gillnet and echosounding data did not correlate. First I would need a better understanding on how the Sonar5-Pro program works to perhaps be able to choose a better way to estimate the biomass from my data. It would also be valuable to try different ways of recording the data.

Thanks

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