

Trends in coastal fish stocks of the Baltic Sea

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Coastal fish monitoring with multi-mesh gill nets and gill net series is carried out in eleven areas around the Baltic Sea. The purpose of the monitoring is to reveal population status and elucidate long-term trends of fish population and community development. Time series cover 9–20 years of annual monitoring, the last year being 2002. Significant increasing trends of perch and roach catches were observed in the archipelago region of the Sea of Åland and Archipelago Sea. A possible reason for these trends was ongoing coastal eutrophication. Significant trends with opposite directions appeared in two areas in the Gulf of Bothnia and two areas at the Swedish coast of the Baltic Proper. The Curonian Lagoon is severely affected by anthropogenic impact, structuring the local fish community. Indications of decreased eutrophication were noted in the Gulf of Riga. High fishing pressure during the 1990s in the West-Estonian archipelago and the following collapse of coastal fish stocks was apparent in the monitoring catches.

Introduction

Baltic Sea ecosystems underwent changes during the late 20th century, eutrophication being one of the most noticeable causes to these changes. Total input of nitrogen to the Baltic Sea has increased by a factor of four and phosphorus by a factor of eight since the early 1900s (Larsson *et al.* 1985). Light penetration, recorded as Secchi disc depth, decreased significantly in all Baltic Sea sub-basins during 1903–2004 (*see* www.helcom.fi/environment/indicators2004/secchi). Eutrophication results in increased phyto- and

zooplankton productions, increased sedimentation of organic matter, increased oxygen deficit, and decreased light penetration (Bernes 1988, HELCOM 2002). Eutrophication is also an important factor structuring fish community composition and long-term development, causing increased production of fish biomass (Ryder 1981) and changes in fish community structure and function. Observed changes in fish community composition reported from European lakes due to increased nutrient load are decreased coregonid and increased cyprinid abundance. Some nutrient load may favour abundance of

percid fish species, however, heavy eutrophication usually favours cyprinid species at the expense of percid fish species (Hartmann 1977). Similar observations have been reported from heavily eutrophicated Baltic coastal areas (e.g. Hansson 1987, Bonsdorff *et al.* 1997, Lappalainen 2002).

Fish monitoring was performed annually in a network of areas along the coast of the Baltic Sea with the aim of following the development of coastal fish stocks. The monitoring is coordinated by Coordination Organ for Baltic Reference Areas (COBRA), situated at the Provincial Government of Åland Islands within the framework of HELCOM. The information is used to reveal trends in coastal fish stock development and provide background data for large-scale environmental assessments, for fisheries investigations and studies of local pollution. Six monitoring areas are located in coastal regions lacking significant local environmental disturbances. These areas reflect variations in fish abundance due to natural events more than irregular impact of human influence. Five additional areas, subjected to some anthropogenic impact, are also included into the monitoring network.

The aim of this paper is to assess regional and large-scale trends in the temporal long-term development of abundant coastal Baltic fish communities and populations. We also discuss possible reasons for the observed trends in fish communities in relation to environmental changes.

Material and methods

All monitoring areas are located close to the coast or in archipelagos (Fig. 1). Areas with minor local anthropogenic impact are located in the Archipelago of Gryt at the east coast of Sweden (Kvädöfjärden), West-Estonian archipelago (Hiiumaa), southern Archipelago Sea in Finland (Brunskär), the northwestern archipelago of the Åland Islands (Finbo), Northern Quark (Holmöarna) and to the northernmost archipelago of the Gulf of Bothnia in Sweden (Råneå). The other areas included are subjected to different local impacts. One area is situated in the central and one in the northern part of the Curonian

Lagoon in Lithuania. Here municipal wastewater and run-off from agriculture have had a significant impact on the environment of the lagoon. Daugava is located near the mouths of two large Latvian rivers, Daugava and Lielupe. Run-off from large agricultural areas and wastewater from several large cities affect the area. Muskö is located in the Stockholm Archipelago close to the urban area of Stockholm. Forsmark area, in the southern Gulf of Bothnia, is affected by thermal run-off from a nuclear power plant (Fig. 1). Time series cover 9–20 years of annual monitoring and year 2002 is the last year included in the analysis (Table 1).

The monitoring areas are grouped into larger geographical regions and the monitoring results are discussed as regional fish stock development in the paper. The eastern Baltic Proper comprises the following areas: Curonian Lagoon, Daugava and Hiiumaa. The western Baltic Proper includes Kvädöfjärden and Muskö areas. Brunskär, Finbo and Forsmark areas are located in the Archipelago region between the northern Baltic Proper and the southern Gulf of Bothnia (in the following referred to as “the Archipelago region”) and areas Holmöarna and Råneå belong to the Gulf of Bothnia region.

During the investigation period, fishing was performed annually in August at fixed stations at 2–5 m water depths using multimesh gill nets or gill net series (Thoresson 1993). Fishing was repeated six nights at each station. The gill nets were set between 14:00 and 16:00 and lifted the next day between 07:00 and 10:00. Coastal survey nets, 35 m long, 3 m deep (2.5 m in water) and composed of five 7-m-long panels with mesh sizes 17, 21, 25, 33 and 50 mm knot to knot were used in the archipelago region and Gulf of Bothnia (Brunskär, Finbo, Forsmark, Holmöarna, Råneå). Two linked nets were set at each station with a total net surface of 210 m². In the southern areas (Curonian Lagoon, Daugava, Hiiumaa, Kvädöfjärden, Muskö) gill net series were used. These net series consist of four 30 m long and 1.8 m deep (1.5 m in water) nets. Each net was made up of a single mesh size, 17, 21.5, 25 and 30 mm, respectively. One gill net series was set at each station and the total net surface was 216 m², i.e. close to that of the coastal survey gill nets. The results are presented as an index of

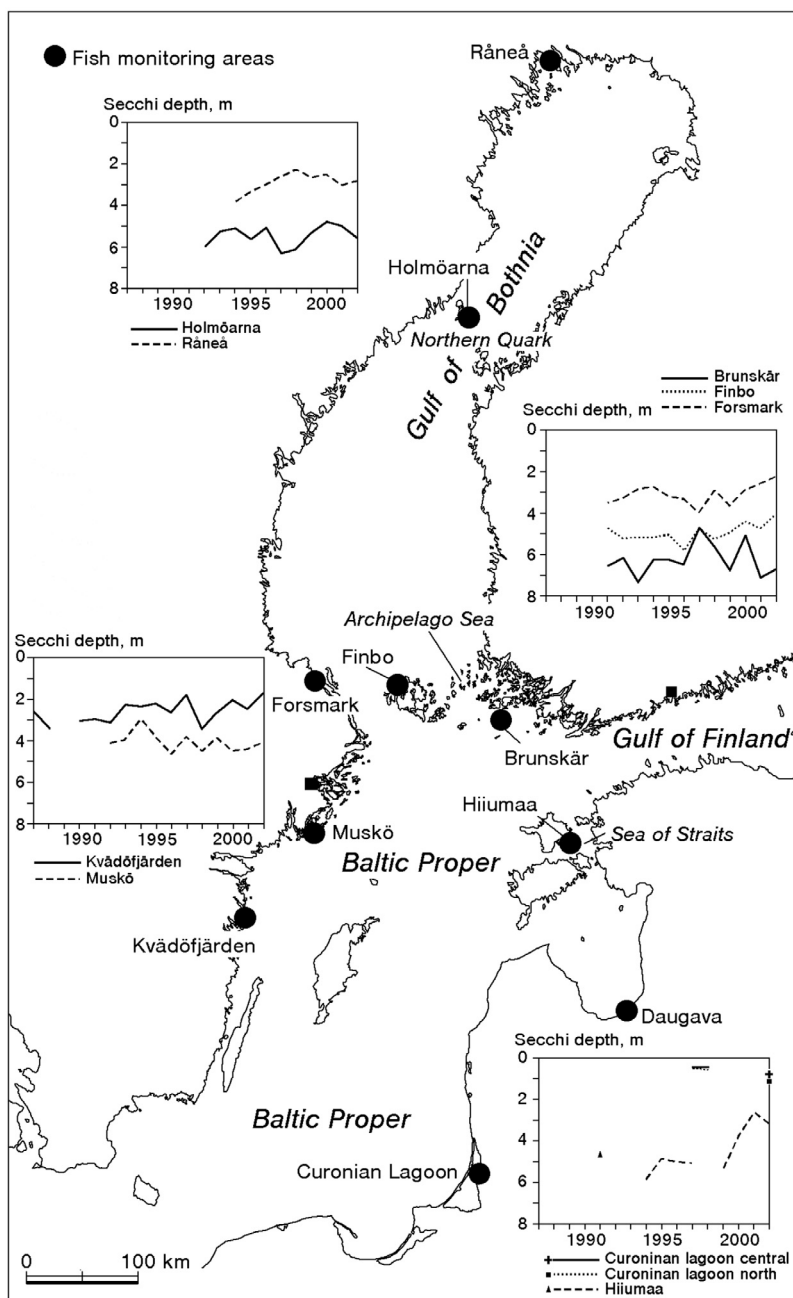


Fig. 1. Fish monitoring areas in the Baltic Sea with Secchi depth development during the monitoring period.

abundance (catch in numbers per station and fishing night; CPUE). Catch per unit effort in terms of weight of demersal community was calculated from the length distribution at all areas, except at Kvädöfjärden, where weights were recorded. As the two sampling methods used comprise similar, although not identical mesh sizes, and as the total net area differed less than 3% between

the two methods, no corrections were performed. However, it cannot exclude that minor, sampling related, differences may occur.

Water transparency was measured as Secchi depth, which was noted when the nets were lifted, giving six recordings per year and area. It was measured with a white plastic disc with a diameter of 25 cm. The disc was lowered into

Table 1. Fish populations tested on homogeneity between stations and on trend significance, Mann-Kendall test for trend $p < 0.05$. Only fish populations found homogeneous between stations were trend tested. + = significant increasing trend, – = significant decreasing trend, nt = no trend, dh = data not homogeneous between stations, blank = not tested.

Species	Curonian Lagoon central		Curonian Lagoon north		Daugava	Hiiumaa	Kvädöfjärden	Muskö	Brunskär	Finbo	Forsmark	Holmöarna	Råneå
	1994	1994	1994	1994	1993	1992	1987	1991	1992	1987	1983	1989	1994
First year included in the trend analyses													
Number of stations													
Demersal fish community	nt	nt	nt	nt	nt	–	dh	–	+	+	+	–	nt
Perch	–	nt	nt	nt	nt	–	+	nt	+	+	+	–	+
Ruffe	nt	+	+	+	dh	dh	nt	dh		nt	dh	nt	dh
Pikeperch	dh	nt	nt	nt	–	–	dh	nt	+	nt	dh	+	dh
Roach	nt	–	–	–	–	–	dh	nt					dh
Bream	nt	nt	nt	nt	nt		dh	dh					dh
Rudd							nt	dh			dh		
White bream	nt	+	+	+	nt			dh					
Vimba bream	dh	nt	nt	nt	nt			dh				dh	dh
Whitefish						dh			dh	dh			
Flounder													
Secchi depth	+	+	+	+		–	–	+	nt	–	–	nt	–

the water and the Secchi depth was noted when it was no longer visible. Other water quality measurements were not made within the programme.

The winter mean value of the nutrient pool in the Baltic Proper during 1996–2004 showed high levels of dissolved inorganic nitrogen ($> 10 \mu\text{mol l}^{-1}$) and phosphorus ($> 1 \mu\text{mol l}^{-1}$) in the coastal areas of Lithuania and Latvia (see http://www.helcom.fi/environment2/eutrophication/en_GB/state). In contrast, levels of dissolved inorganic nitrogen were low ($3\text{--}5 \mu\text{mol l}^{-1}$) and dissolved inorganic phosphorus was below $1 \mu\text{mol l}^{-1}$ at the Swedish east coast of the Baltic Proper and at the western part of the Åland Islands. Dissolved inorganic nitrogen was $5\text{--}8 \mu\text{mol l}^{-1}$ and dissolved inorganic phosphorus below $1 \mu\text{mol l}^{-1}$ in the Archipelago Sea. Dissolved inorganic nitrogen was relatively high ($6\text{--}9 \mu\text{mol l}^{-1}$) in the northern Gulf of Bothnia, but dissolved inorganic phosphorus was low, below $0.5 \mu\text{mol l}^{-1}$ (see http://www.helcom.fi/environment2/eutrophication/en_GB/state).

Trends at individual stations were analysed according to the Mann-Kendall test for trends (Kendall 1975). It is a non-parametric test for monotonic trends and zero slopes of time-ordered data versus time. Data does not have to be conformed to normal distribution and missing data is allowed. The basis is a sign test, which tests if a variable is increasing or decreasing with time. The test has a relatively low power, meaning that it might be less efficient to show trends when they in fact exist. This is especially the case when the trend is non-monotonic.

To test for homogeneity of trend direction at multiple stations, a homogeneity χ^2 statistic was used. χ^2_{homog} was calculated as follows:

$$\chi^2_{\text{homog}} = \chi^2_{\text{total}} - \chi^2_{\text{trend}} = \sum_{j=1}^M Z_j^2 - M\bar{Z}^2$$

$$Z_j = \frac{S_j}{\sqrt{\text{VAR}(S_j)}}$$

where S_j is the Mann-Kendall trend statistic for the station and M is the number of stations (Gilbert 1987). If χ^2_{homog} exceeds the critical value of χ^2 distribution with $\text{df} = M - 1$ at 0.05 level the hypothesis of homogeneous station trends is rejected. If stations are not homogeneous no statements are made about area-wide trends. The

stations were considered independent in the sense that the catch at one station was assumed not to affect the catches at other stations. The number of stations sampled in each area is presented in Table 1. Homogeneity tests and trend analyses were performed on the demersal fish community, excluding pelagic species (i.e. Baltic herring (*Clupea harengus*), bleak (*Alburnus alburnus*), smelt (*Osmerus eperlanus*), vendace (*Coregonus albula*), sprat (*Sprattus sprattus*), twaite shad (*Alosa fallax*) and ziege (*Pelecus cultratus*)) and demersal fish species with mean CPUE smaller than 1.0 (limit set by the authors) during the monitoring period. Secchi disc depth was also analysed with the Mann-Kendall test for trends at individual depth levels.

Results

In total 38 fish species were caught in the monitoring programme, 29 freshwater and 9 marine species (Table 2). Freshwater species dominated the fish catches in the coastal areas of the northern Baltic Proper and Gulf of Bothnia. The most common species, which were caught in all areas, were perch (*Perca fluviatilis*), roach (*Rutilus rutilus*) and ruffe (*Gymnocephalus cernuus*). Also ide (*Leuciscus idus*) was found in low numbers in all areas, except in the northern part of the Curonian Lagoon. Pike (*Esox lucius*) was lacking in the Curonian Lagoon and at Daugava, whereas whitefish (*Coregonus lavaretus*) was not caught at Hiiumaa. White bream (*Blicca bjoerkna*) and smelt (*Osmerus eperlanus*) were not caught at Holmöarna and at Råneå. The largest catches of marine species were observed in areas located in the northern Baltic Proper. Eight marine species, Baltic herring, cod (*Gadus morhua*), flounder (*Platichthys flesus*), fourhorned sculpin (*Triglopsis quadricornis*), longspined bullhead (*Taurulus bubalis*), sprat, turbot (*Psetta maxima*) and viviparous blenny (*Zoarces viviparus*) were caught in these areas. Sprat was noted in southern areas up to the Forsmark area and viviparous blenny to the Holmöarna area. Baltic herring, which was the only marine species distributed all over the Baltic Sea, was not caught in the Curonian Lagoon. Freshwater species preferring cold water, such as Arctic char (*Salvelinus alpinus*),

Table 2. Mean fish catches (CPUE) over the monitoring period in fish monitoring areas in the Baltic Sea.

	Curonian Lagoon central	Curonian Lagoon north	Daugava	Hiiumaa	Kväddöfjärden	Muskö	Brunskär	Finbo	Forsmark	Holmönarna	Råneå
Freshwater species											
Arctic char (<i>Salvelinus alpinus</i>)											< 0.1
Asp (<i>Aspius aspius</i>)	< 0.1	0.2									
Barbel (<i>Barbus barbus</i>)	< 0.1				< 0.1						
Bleak (<i>Alburnus alburnus</i>)	0.8	7.5	0.2	0.7	0.1				< 0.1	0.3	0.1
Bream (<i>Abramis brama</i>)	3.1	1.6	1.5			< 0.1			0.3		2.1
Burbot (<i>Lota lota</i>)	< 0.1	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	< 0.1
Chub (<i>Leuciscus cephalus</i>)	< 0.1										
Crucian carp (<i>Carassius carassius</i>)			0.4	0.3	< 0.1		< 0.1		< 0.1	< 0.1	0.2
Dace (<i>Leuciscus leuciscus</i>)	< 0.1	< 0.1									
Goldfish (<i>Carassius auratus</i>)											
Grayling (<i>Thymallus thymallus</i>)	< 0.1									< 0.1	
Gudgeon (<i>Gobio gobio</i>)	< 0.1	0.9	< 0.1	0.2	0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.3
Ide (<i>Leuciscus idus</i>)		0.1		0.2	24.6	20.7	43.9	64.7	79.6	52.7	26.2
Perch (<i>Perca fluviatilis</i>)	43.0	94.8	41.7	16.6	0.7	0.5	< 0.1	0.2	0.1	< 0.1	0.2
Pike (<i>Esox lucius</i>)				0.2	0.2	0.2	0.2	0.4	0.7		
Pikeperch (<i>Sander lucioperca</i>)	1.9	7.5	7.4	0.2			< 0.1	< 0.1			< 0.1
Rainbow trout (<i>Oncorhynchus mykiss</i>)					37.4	31.2	8.4	13.6	22.2	10.0	60.5
Roach (<i>Rutilus rutilus</i>)	93.7	196.4	28.5	23.7	1.6	2.1	< 0.1	2.5	2.0	5.4	4.0
Ruffe (<i>Gymnocephalus cernuus</i>)	148.3	107.5	28.7	1.1	6.6	1.2	< 0.1	< 0.1	< 0.1		
Rudd (<i>Scardinius erythrophthalmus</i>)											
Salmon (<i>Salmo salar</i>)	138.7	28.9	15.1	0.3	12.0	14.0	< 0.1	< 0.1	3.7		
White bream (<i>Blicca bjoerkna</i>)	0.1	< 0.1	9.3	< 0.1	< 0.1	< 0.1	0.6	0.2	< 0.1		
Smelt (<i>Osmerus eperlanus</i>)		< 0.1			< 0.1	< 0.1					
Tench (<i>Tinca tinca</i>)											
Trout (<i>Salmo trutta</i>)											
Vendace (<i>Coregonus albus</i>)										< 0.1	0.1
Whitefish (<i>Coregonus lavaretus</i>)	< 0.1		< 0.1		< 0.1	< 0.1	0.9	< 0.1	< 0.1	2.0	1.0
Vimba bream (<i>Vimba vimba</i>)	0.5	13.4	3.9	0.6	< 0.1	< 0.1			< 0.1		
Ziege (<i>Pelecus cultratus</i>)	1.1	< 0.1									
Number of species	18	16	12	13	15	14	12	15	14	11	14
Marine species											
Baltic herring (<i>Clupea harengus</i>)											
Cod (<i>Gadus morhua</i>)			8.0	2.5	0.4	2.9	20.3	23.2	8.7	9.3	1.0
Flounder (<i>Platichthys flesus</i>)					< 0.1		2.6	< 0.1			
Fourhorned sculpin (<i>Trigloporus quadricornis</i>)					0.1	0.3		1.5			
Longspined bullhead (<i>Taurogobius baicalis</i>)								0.2			
Turbot (<i>Psetta maxima</i>)			< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1		
Twaited shad (<i>Alosa fallax</i>)		0.1		< 0.1	< 0.1		< 0.1	< 0.1	< 0.1		
Sprat (<i>Sprattus sprattus</i>)		< 0.1		< 0.1			< 0.1	< 0.1	< 0.1		
Viviparous blenny (<i>Zoarces viviparus</i>)			1.3	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	
Number of species	0	3	4	6	4	3	6	8	3	2	1

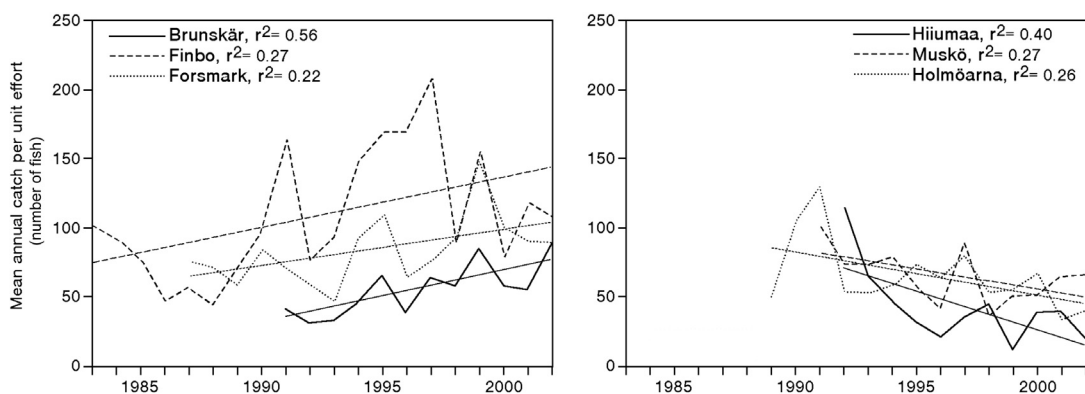


Fig. 2. Development of catches of demersal fish communities in monitoring areas in the Baltic Sea. Only significant ($p < 0.05$) trends are illustrated and directions are indicated with lines of best fit.

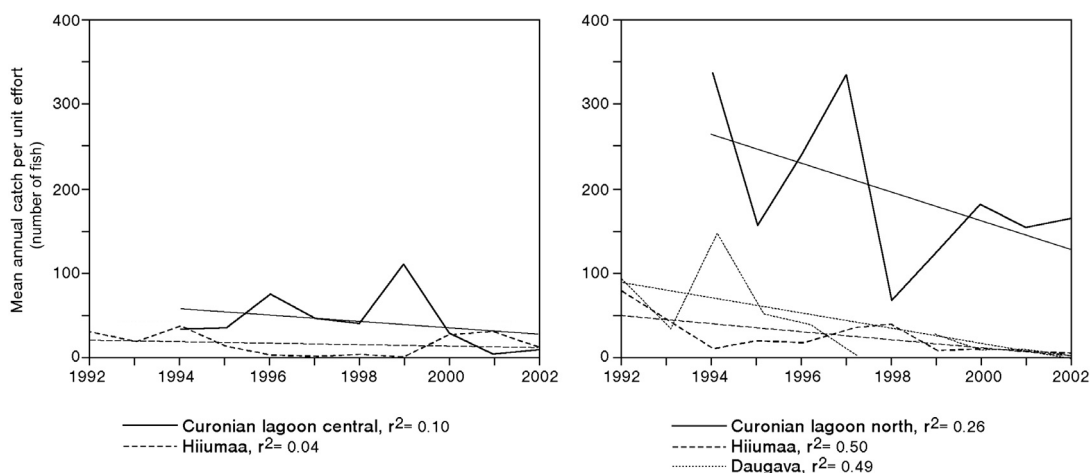


Fig. 3. Development of catches of perch (left-hand side panel) and roach (right-hand side panel) in the eastern Baltic Proper. Only significant trends ($p < 0.05$) are illustrated and directions are indicated with lines of best fit.

grayling (*Thymallus thymallus*) and vendace was mainly caught in the two northernmost areas.

Eastern Baltic Proper

The freshwater fish community consisted of 18 species in the Curonian Lagoon. In this area the four most common species were perch, roach, ruffe and white bream. A few individuals of the marine species flounder, sprat and twaite shad were also caught. Perch, roach and ruffe dominated the catches in Daugava, but white bream and pikeperch (*Sander lucioperca*) were also common. In this area 16 freshwater species and four marine species were caught. Among the 13

freshwater species and six marine species found in Estonian waters at Hiiumaa, perch and roach were the most common (Table 2).

The development of the demersal fish communities showed homogeneity among stations within all four areas (Table 1). The abundance of fish decreased significantly at Hiiumaa, both in terms of numbers (Fig. 2) and weight ($r^2 = 0.22$, $p < 0.05$). No significant trends were detected in the Curonian Lagoon or Daugava.

Perch abundance decreased significantly both in the central Curonian Lagoon and at Hiiumaa. Also roach decreased in the north Curonian Lagoon, at Daugava and at Hiiumaa (Fig. 3). The pikeperch population decreased significantly at Daugava ($r^2 = 0.63$, $p < 0.05$). Catches of ruffe

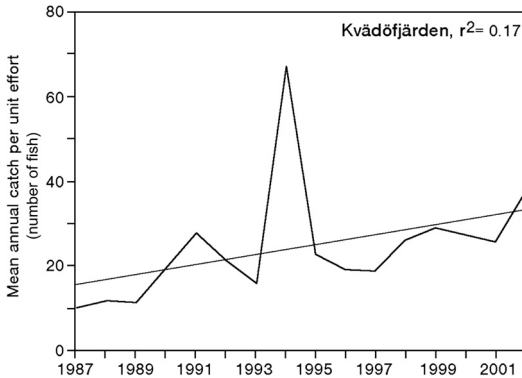


Fig. 4. Development of catches of perch in the western Baltic Proper. Only significant trends ($p < 0.05$) are illustrated and directions are indicated with lines of best fit.

($r^2 = 0.15$, $p < 0.05$) and white bream ($r^2 = 0.55$, $p < 0.05$) increased significantly in the north Curonian Lagoon. Ruffe, roach, bream (*Abramis brama*) and white bream catches in the central Curonian Lagoon did not show any significant trends. Neither were there any significant trends in the development of the perch, pikeperch, bream and vimba bream (*Vimba vimba*) catches in the north Curonian Lagoon, nor the perch, bream, white bream and vimba bream catches at Daugava (Table 1). The development of pikeperch and vimba bream catches was not homogeneous among stations in the central Curonian Lagoon. Neither was the development of ruffe at Daugava, nor the ruffe and flounder development at Hiiumaa homogeneous. In the Curonian Lagoon Secchi disc depth increased significantly from 0.5 m in 1998 to 0.9 m in the central and to 1.1 m in the northern part in 2002 (Student's t -test: $p < 0.0001$). A significant decline of the Secchi depth was noted at Hiiumaa.

Western Baltic Proper

The fish community at Kvädöfjärden consisted of 19 species, comprising 15 freshwater species (Table 2). Perch and roach dominated the catches over the years, but white bream and rudd (*Scardinius erythrophthalmus*) were also abundant. Baltic herring, flounder, sprat and cod represented the marine fish community. The freshwater community consisted of 14 species at

Muskö, perch, roach and white bream being the most abundant ones (Table 2). The marine fish community consisted of Baltic herring, flounder and turbot. The development of the demersal fish community showed homogeneity among stations at Muskö, but not at Kvädöfjärden (Table 1). The catch of demersal fish species decreased significantly at Muskö both in terms of numbers (Fig. 2) and weight ($r^2 = 0.57$, $p < 0.05$).

Five out of ten analysed populations in the region showed homogeneous development among stations (Table 1). The perch catches at Kvädöfjärden increased significantly (Fig. 4), whereas no trends for ruffe and white bream catches could be detected at Kvädöfjärden. Neither were there any trends for the perch and roach catches at Muskö. Catches of roach and rudd at Kvädöfjärden and ruffe, rudd and white bream at Muskö showed no homogenous development between stations. Secchi disc depth significantly decreased in Kvädöfjärden and increased at Muskö.

Archipelago region

At Brunskär the freshwater fish community dominated the catches with 12 species, although the contribution of six marine fish species was notable (Table 2). Perch dominated the catches, followed by Baltic herring. The most diverse fish community among the areas appeared at Finbo with a total of 23 species, 15 freshwater and 8 marine species (Table 2). Perch dominated the catches, followed by Baltic herring and roach. Ruffe and flounder were also abundant. In the Forsmark area 14 freshwater species and three marine species were caught, with perch being the most abundant one, although also roach, white bream and ruffe were frequently caught.

The abundance of demersal fish increased significantly in all three areas both in terms of numbers (Fig. 2) and weight (Brunskär: $r^2 = 0.10$, $p < 0.05$; Finbo: $r^2 = 0.23$, $p < 0.05$; Forsmark: $r^2 = 0.29$, $p < 0.05$). Seven out of 13 tested fish populations showed homogenous development among stations (Table 1). Perch increased significantly in all three areas, and roach increased in Brunskär and Forsmark (Fig. 5). In the beginning of the 1990s roach was rare in the Brunskär area,

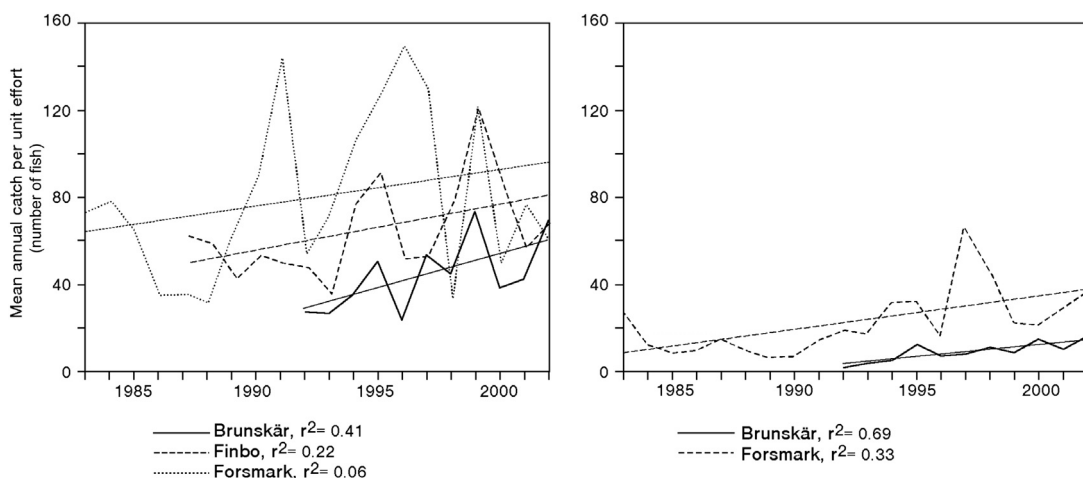


Fig. 5. Development of catches of perch (left-hand side panel) and roach (right-hand side panel) in the archipelago region. Only significant trends ($p < 0.05$) are illustrated and directions are indicated with lines of best fit.

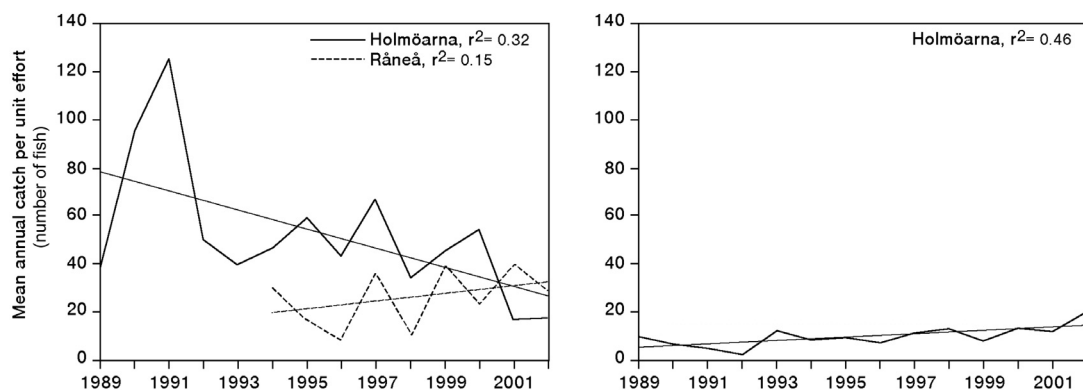


Fig. 6. Development of catches of perch (left-hand side panel) and roach (right-hand side panel) in the Gulf of Bothnia. Only significant trends ($p < 0.05$) are illustrated and directions are indicated with lines of best fit.

but has increased by tenfold during the 11-year period, from 0.81 to 8.0 CPUE. No trends could be detected for ruffe and roach populations in the Finbo area. The development of whitefish and flounder populations did not show homogeneity among stations in the Brunskär area, neither flounder in Finbo, nor ruffe, pikeperch and white bream in the Forsmark area. A significant decrease of the Secchi depth was noted at Finbo and Forsmark whereas no trend was observed at Brunskär.

Gulf of Bothnia

In the Gulf of Bothnia the fish community consisted almost exclusively of freshwater species in both areas studied (Table 2). Perch was the most

abundant species, followed by roach and ruffe at Holmöarna. Also whitefish was commonly caught. At the most northern area, Råneå, roach and perch dominated the catches, but ruffe and bream were also abundant. Marine species, Baltic herring, appeared in both areas, and the viviparous blenny was also caught in the Holmöarna area.

A significant decrease in abundance of the demersal fish, both in terms of numbers (Fig. 2) and weight ($r^2 = 0.29$, $p < 0.05$), was noted at Holmöarna, whereas no trend was found for total fish abundance at Råneå (Fig. 2). Four out of totally nine tested populations showed homogeneous development of abundance between stations (Table 1). Perch decreased significantly at Holmöarna, and increased significantly at Råneå (Fig. 6). At Holmöarna roach increased sig-

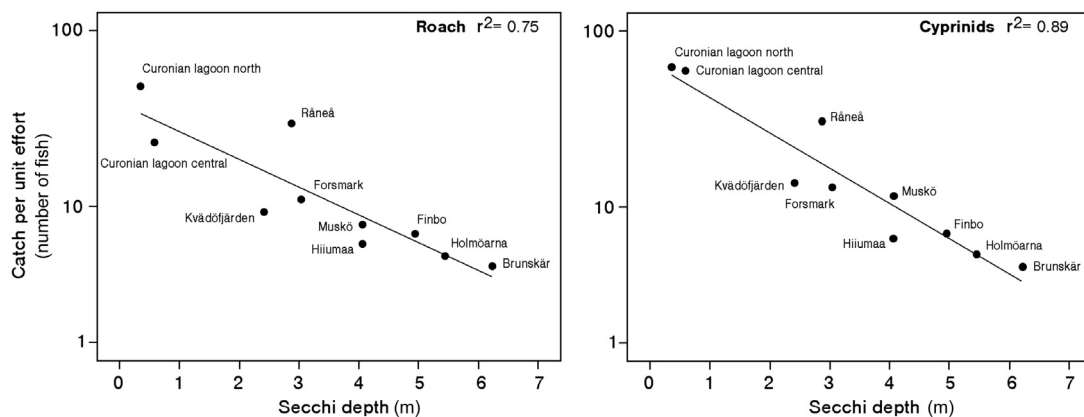


Fig. 7. Secchi depth (mean values) over the monitoring period related to catches of roach ($p < 0.001$) and cyprinids ($p < 0.001$).

nificantly but no trend was noted for ruffe. The whitefish population at Holmöarna and ruffe, roach, bream and whitefish populations at Råneå showed no homogenous development among stations. Secchi depth decreased significantly at Råneå, but showed no trend at Holmöarna.

Water transparency and cyprinid catches

A clear relationship between water transparency, and catches of roach and cyprinid species was found among the monitoring areas (Fig. 7). The mean catches per unit effort (log₁₀-transformed) were negatively correlated with Secchi depths over the monitoring period of roach and cyprinid species. Lowest Secchi depth and largest catches of roach and cyprinids appeared at the Curonian Lagoon, whereas highest Secchi depth and lowest catches of roach and cyprinids appeared at Brunsjär.

Discussion

Noted significant trends of demersal fish communities in terms of numbers were in all cases confirmed by corresponding significant trends in terms of weight. This indicates that the parameters are useful indicators for detecting long-term stock size development of Baltic coastal fish communities.

The most perceivable and consistent trends in the development of fish communities, fish

populations and water transparency, were found in the archipelago region between Sweden and Finland. During the period 1975–1994 an increased nutrient availability, decreased water transparency, and increased biomass of plankton, filamentous algae and zoobenthos as well as an increased proportion of roach in the fish community has been observed in the region (Bonsdorff *et al.* 1997). The nutrients originate from land run-off, airborne depositing and water currents passing through the region. The archipelago, with numerous islands and shallow bottoms connected to a high biological productivity, acts as a nutrient trap that results in continuous eutrophication (Mattila 2000). The slow eutrophication is a possible explanation to the increased roach and perch catches observed in the monitoring areas. Similar development, especially the increase of cyprinid fish species, has been reported from temperate lakes undergoing eutrophication (Svårdson and Molin 1981, Persson *et al.* 1991) as well as from other eutrophicated coastal areas of the Baltic Sea (e.g., Hansson 1987, Lappalainen 2002).

The most important demersal species in the Archipelago region, perch and roach, are both warm-water adapted species with high temperature optima. Temperature is an important factor dimensioning the year-class strength of perch in the Baltic Sea (Böhling *et al.* 1991, Karås and Thoresson 1992), and an increase in temperature can cause strong year-classes (Karås 1996) and thereby enhance the stocks. Measurements of water temperature at five-metre depth at the east-

ern Åland Islands revealed that mean temperature during July–September was 0.8 °C higher in 1990–2002 as compared with that in 1979–1989. The occurrence of warm summers may have contributed to the increase of fish stocks in the area. The significant negative correlation between water transparency and abundance of cyprinid species, however, suggests that also eutrophication possibly contributes to the observed changes in fish communities (Fig. 7).

In the Gulf of Bothnia, few significant trends in the fish community development were detected, and trends were not congruent for the two monitoring areas. Nutrient levels have decreased since the 1980s and phytoplankton biomass has remained unchanged in the Gulf of Bothnia (HELCOM 2002). Increased perch abundance, decreased Secchi depth and high catches of cyprinid fish species in the northernmost Råneå area indicate that run-off water from the Råneälv river may influence the fish community.

Along the Swedish coast of the Baltic Proper, the only significant catch trends were an increased catch of perch in the Kvädöfjärden area, and a decreasing trend of the demersal fish abundance at Muskö. The Secchi depth showed opposite trends in the two areas. In general, nutrient contents peaked (Hajdu *et al.* 2000) and Secchi depths were at their minimum in the end of the 1980s in the coastal waters in the Swedish Baltic Proper (Larsson *et al.* 1998). Since then, the situation has stabilised and nutrient concentrations have decreased. Reduced perch stocks and recruitment failures of pike, expressed as low abundances of both young-of-the-year and adult fish of most fish species except sticklebacks, have been reported from the Kalmarsund area, south of Kvädöfjärden, as well as in the outer archipelago of the western coast of the Baltic Proper (Andersson *et al.* 2000, Ljunggren *et al.* 2005). Similar development was not seen in the Kvädöfjärden area.

Several significant trends were noted for the coastal fish communities in the Curonian Lagoon, Daugava and Hiiumaa in the Eastern Baltic Proper. The fish communities were, in contrast to other areas, clearly influenced by human impact. The anthropogenic discharges to the Curonian Lagoon have decreased substantially during recent years, resulting in reduced

nutrient load in the area (Kesminas *et al.* 1998). The decreasing trends of perch abundance (central area) and roach abundance (north area) as well as the improved Secchi depth since 1998, indicate decreasing eutrophication. The extensive exploitation of roach in the Curonian Lagoon, with landings that were 3–4 times higher in 1998–2001 as compared with those in 1992–1994 (Repečka 1999), probably contributed to a reduction of the roach population. The significant increasing trends of ruffe and white bream in the northern area to some extent contradict the picture of decreasing eutrophication, however, the development may be an effect of reduced interactions with the dominating species perch and roach. In the Daugava area the decreased roach abundance may indicate reduced nutrient load. The wastewater treatment has improved significantly during the last decade and nitrate concentrations in the Gulf of Riga have decreased (Yurkovskis 2004). According to Ojaveer *et al.* (1999) reduced freshwater run-off and increased water salinity may have influenced the development. The significant decrease of the pikeperch population is probably a result of high fishing pressure. The local pikeperch population is rather small and pikeperch is one of the most important target species for both coastal fisheries and game fishing.

In Estonia, the coastal fishery industry expanded in the beginning of the 1990s. In the middle of the decade, catches in the commercial fishery of perch, pike and pikeperch declined due to overexploitation. The catches of perch in the West-Estonian archipelago in 1999 were about 1% of the average during the last 30 years (Vetemaa *et al.* 2000). The fishing effort decreased during the last 5–7 years, but stocks have improved only slightly. Predation of cormorants is suggested to be one reason for the restrained recovery of the fish stocks (Eschbaum *et al.* 2003). The decline of the perch and roach populations is clearly reflected in the monitoring catches, and the effects of the overexploitation overrule the effects of other possible factors during the monitoring period.

The negative correlation between abundance of cyprinid species/roach and Secchi depth indicates that low water transparency, often caused by increased nutrient load, favours cyprinid species. These species are usually less attractive for

human consumption and the value of the fish community decreases with increased eutrophication. Secchi depth may also be an unsuitable variable for assessment in this respect. Latvian coastal waters are open, shallow and turbulent systems in comparison with archipelagos in the western and northern Baltic. Therefore Secchi depth variation at Daugava depends on wind direction and strength rather than expressing degree of eutrophication.

The multimesh gill nets and gill net series used in the monitoring programme effectively catch only a fraction of the demersal and relatively large-sized fish species. The whole fish community in the Baltic Proper and in the Gulf of Bothnia comprise about 100 fish species (Winkler *et al.* 2000). In the monitoring program 32 demersal species were caught, and only 10 of them were caught in sufficient quantities allowing for statistical analyses to be performed. The monitoring program does not aim at providing data for a complete fish community assessment, and the results certainly indicate that complementary methods have to be used, in case of fish biodiversity monitoring. The ten most frequently caught species analysed in this paper, are common species subjected to human interest. In that sense, these species are good target species for monitoring.

Prevailing water temperature during sampling influences the outcome of the test fishing, as low temperatures reduce swimming activity of several coastal fish species (Neuman 1979). This was clearly observed in 1997 at Daugava. Mean water temperature during fishing was 12.3 °C in 1997, whereas it varied between 16.5–19.2 °C other years. The catch of freshwater species that year was only 21% of the mean for the whole monitoring period. A year with up-welling and low catches of freshwater species may not influence the trend analysis in any significant way. Repeated up-welling for several years may influence the trend analysis to produce decreasing catches. Data from these “coldwater” years could also be excluded from the trend analysis.

Generalisation of monitoring results to wider coastal regions is another difficult question. Due to the survey method, monitoring is focused on “large-sized” species, which are assumed to be relatively stationary. Still, we showed that

results from adjacent stations in the same area sometimes exhibit conflicting trends, indicated by catches whose homogeneity among stations could not be obtained. It is obvious that the two monitoring areas in the Gulf of Bothnia do not represent the entire coastal region of the gulf, and the same is true at least for the two areas in the Swedish coast of the Baltic Proper. The results from smaller regions as the Archipelago region and the Curonian Lagoon were more consistent, and may well represent the fish community development in the region. In addition to this, the observed changes in fish communities in the Archipelago region and western Estonian coast could be logically connected to human induced changes in the areas.

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