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Content

Executive Summary

Coastal fish monitoring by using gillnets is performed annually in all Baltic Sea regions, and since 2003 has been coordinated by the HELCOM FISH PRO network. The monitoring programs sample the coastal fish communities in late summer and are typically targeting warm-water species. Data presented in this assessment cover coastal areas of Finland, Estonia, Latvia, Lithuania, Poland and Sweden. Assessments on coastal fish community status are requested for the Baltic Sea Action Plan and the EU Marine Strategy Framework Directive. This assessment consists of three parts: Part I which proposes a method for selecting indicators to assess coastal fish community status, Part II which presents an assessment of the current status of coastal fish communities in the Baltic Sea, and Part III which reviews existing restoration and restocking programmes for threatened and declining coastal fish species in the HELCOM member states.

Part I proposes a multivariate method of data analysis that is generally applicable for all three monitoring methods that exist. The set of indicators selected was to some extent unique for specific gears, accounting for differences among sampling methods and geographic areas in, for example, species composition and gear-specific properties. The relationship between state indicators and pressure variables were generally stronger for variables representing manageable pressures than natural factors such as depth, water temperature, salinity and wave exposure. Given that there was redundancy in the responses of the selected indicators to pressures, and that data on several potential pressure variables was not available for the study, these analyses represent a first important step in developing indicators for coastal fish community status in the Baltic Sea.

The status of monitored coastal fish communities during the period 2005-2009 was assessed using the selected state indicators, relative to 1995-2004. The assessments showed that the development of the fish communities in the Gulf of Bothnia and Baltic Proper have to some extent followed different trajectories over the past 15 years. In the Gulf of Bothnia, there was generally an increase in size-related indicators and in the abundance of Cyprinids. In contrast, the communities assessed in the Baltic Proper generally showed a decrease in size-related indicators, and in some areas the total abundance and abundance of Cyprinids had decreased. The results suggest that communities in different geographic areas are to some extent affected by different environmental stressors.

The findings suggest that continuing long-term monitoring programmes is essential for future assessments of coastal fish community status and that regular meetings between contracting parties are needed to harmonise assessment methods. Future meetings should investigate the potential for incorporating other data sources in the indicator framework, in order to enhance the spatial coverage, and to include additional pressure variables in the analyses. The assessment of relationships between indicators and pressures should be continued, and preferably enhanced by considering the impacts of non-indigenous species, the effects of biological interactions within coastal fish communities, and the interactions between coastal and open sea habitats.

Introduction

Background to the assessment

Coastal fish communities are an important component of Baltic Sea ecosystems. They are also of great importance to human society in the Baltic region, both from a socio-economic and cultural point of view. The composition of these coastal fish communities varies naturally from place to place and broadly reflects the general habitat characteristics of the area in which they occur. These habitat characteristics include natural factors such as salinity level and water temperature and anthropogenic pressures such as nutrient inputs from agriculture and sewage. There have been dramatic changes in these coastal fish communities over the late 20th century, and this has resulted in an increased focus on this component of the Baltic Sea system.

In order to determine the potential effects of human activities on coastal fish communities, a programme of annual monitoring of coastal fish in the Baltic Sea was first initiated in the mid-1980s. The activities of the network of experts on coastal fish monitoring started in 2003 under the umbrella of the World Bank/GEF funded Baltic Sea Regional Project and subsequently continued under the HELCOM FISH Project during 2008-2010 and continues today under the HELCOM FISH-PRO project. The "Coordination Organ for Baltic Reference Areas" (COBRA) coordinated the programme and maintains a database of the results. The coastal fish monitoring is to be conducted according to a specific procedure (HELCOM COMBINE manual) so that the results can be compared among the areas monitored.

Coastal fish monitoring in the Baltic Sea

Coastal fish communities are monitored each year over the entire Baltic Sea. The monitoring network presented here covers areas of Finland,


Test fishing with net series in Mönsterås, southern Swedish Baltic coast in August.

Estonia, Latvia, Lithuania and Sweden (Figure 1). The assessment also reports on structural changes in coastal fish communities in Poland based on available data from this area. Coastal fish communities in the Baltic Sea areas of Denmark, Germany and Russia are also monitored, but are not included in the present assessment. The monitoring of coastal fish communities is coordinated

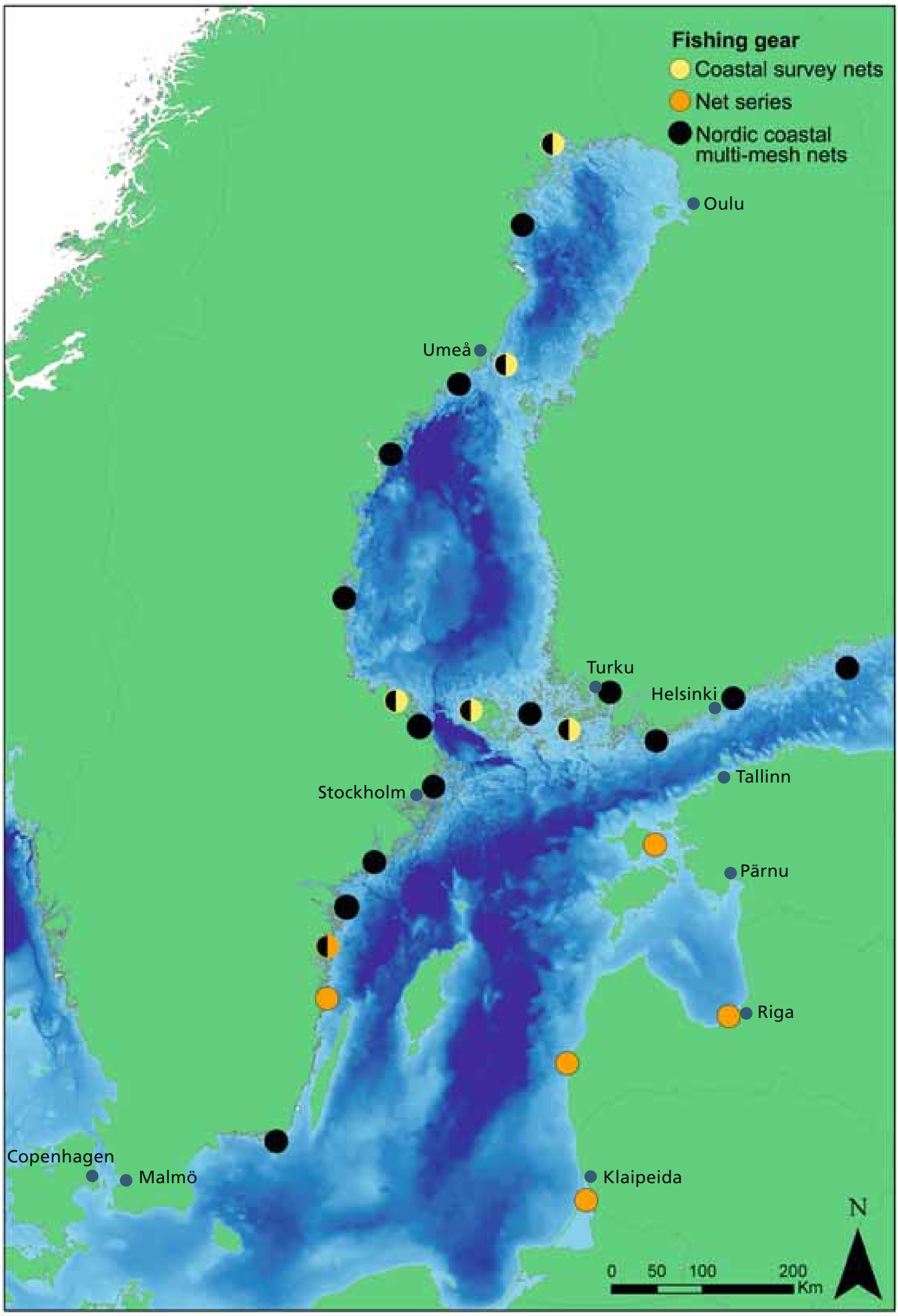


Figure 1. Monitoring areas and gear used in the Baltic Sea referred to in this report.

by the HELCOM FISH project *Expert network on monitoring and protecting of coastal fish and lamprey species*.

The current assessment considers the status of coastal fish communities within the period 2005–2009, in relation to previous data from the monitoring areas. The length of the available time series varies widely. The longest time series is 22 years (Table 1).

Coastal fish monitoring takes place in August and so reflects trends in species that occur in coastal areas during the warm part of the year. Fishing is undertaken using survey nets that mainly target demersal and benthopelagic species, that is, species that live close to or near the bottom. However, some pelagic species are also captured.

During the assessment period, a total of 44 fish species were recorded. The most commonly occurring species are European perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), ruffe (*Gymnocephalus cernuus*), and Baltic herring (*Clupea harengus*) (Table 2).

Three methods are used for monitoring the coastal fish communities around the Baltic Sea. In the Baltic Proper, the longest time series are from monitoring using Net series, and in the Gulf of Bothnia, from monitoring using Coastal survey nets. Monitoring using Nordic coastal multi-mesh nets was introduced in 2001 (Appelberg et al., 2003) and is used only in Finland and Sweden. It is used here in all areas established after 2001 and in some areas in parallel with monitoring using Net series or Coastal survey nets.

Table 1. Coastal fish monitoring in the Baltic Sea. Areas are listed from north to south. Years show the starting year of each data series and the final year is given in brackets if the programme has ended.

Area	Country	Basin	Nordic coastal multi-mesh net	Coastal survey nets	Net series
Råneå	Sweden	Gulf of Bothnia	2002	1994 (2004)	
Kinnbäcksfjärden	Sweden	Gulf of Bothnia	2004		
Holmön	Sweden	Gulf of Bothnia	2002	1989	
Norrbyn	Sweden	Gulf of Bothnia	2002		
Gaviksfjärden	Sweden	Gulf of Bothnia	2004		
Långvindsfjärden	Sweden	Gulf of Bothnia	2002		
Haapasaaret	Finland	Gulf of Finland	2003 (2008)		
Kaitvesi	Finland	Gulf of Bothnia	2005		
Helsinki	Finland	Gulf of Finland	2005		
Forsmark	Sweden	Gulf of Bothnia	2002	1987	
Finbo	Finland	Gulf of Bothnia	2002	1991 (2008)	
Kumlinge	Finland	Gulf of Bothnia	2003		
Brunskär	Finland	Gulf of Bothnia	2002	1991 (2004)	
Tvärminne	Finland	Gulf of Finland	2005		
Lagnö	Sweden	Baltic Proper	2002		
Hiiumaa	Estonia	Baltic Proper			1991
Asköfjärden	Sweden	Baltic Proper	2005		
Kvädöfjärden	Sweden	Baltic Proper	2001		1987
Vinö	Sweden	Baltic Proper			1995
Daugavgriva	Latvia	Gulf of Riga			1995
Jūrkalne	Latvia	Baltic Proper			1999
Torhamn	Sweden	Baltic Proper	2002		
Curonian lagoon	Lithuania	Baltic Proper			1993

Table 2. **Fish species recorded in the monitored areas during the assessment period, 2005 – 2009. Values show the mean catch per unit effort, estimated as numbers per net and night, by monitoring area and method.**

Mean CPUE 2005-2009	Nordic survey nets												
	Råneå	Kinnbäcksfjärden	Holmön	Norrbyn	Gaviksfjärden	Långvindsfjärden	Forsmark	Finbo	Kumlinge	Brunskär	Kaitvesi	Tvärminne	Helsinki
Last year included	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009
Freshwater species													
European perch (*Perca fluviatilis*)	34.2	8.5	30.3	15.3	8.0	29.4	26.3	34.5	24.5	54.8	8.2	30.8	26.0
Roach (*Rutilus rutilus*)	17.4	0.03	8.5	2.4	18.4	13.3	5.6	23.0	0.14	4.4	7.9	27.5	25.4
Ruffe (Gymnocephalus cernuus)	7.3	5.3	6.3	10.1	0.01	9.6	4.8	5.1	0.76	0.04	4.7	16.8	10.2
Bleak (*Alburnus alburnus*)	3.3	0.02	1.5	0.3	0.2	1.0	2.5	2.1	3.4	0.3	4.0	0.9	19.7
Ide (*Leuciscus idus*)	0.02	0.004	0.01	0.5	0.03	0.01	0.02	0.004	0.05	0.3	0.01	0.2	0.01
Northern pike (*Esox lucius*)	0.08	0.004	0.03		0.004	0.04	0.00	0.06	0.00	0.01	0.09	0.01	0.01
White bream (*Blicca bjoerkna*)							2.8	3.1	0.03	0.02	16.8	1.7	9.3
Sander (*Sander lucioperca*)	0.004						0.4	0.5	0.13	0.12	2.8	0.5	1.9
Bream (*Abramis brama*)	8.6					0.01	0.5	0.6		0.15	0.2	3.2	3.4
Vimba bream (*Vimba vimba*)							0.02					0.10	0.3
Rudd (*Scardinius erythrophthalmus*)									2.7		0.3		0.02
Vendace (*Coregonus albula*)	2.0	0.9		0.5	0.01	0.01						0.04	
Bullhead (*Cottus gobio*)				0.03	0.004	0.04					0.005		
Burbot (*Lota lota*)		0.02	0.01	0.00	0.004								
Dace (*Leuciscus leuciscus*)	0.02	0.02		3.0									
Crucian carp (*Carassius carassius*)													0.01
Tench (*Tinca tinca*)											0.02		
Gibel carp (*Carassius gibelio*)													
Gudgeon (*Gobio gobio*)													
Grayling (*Thymallus thymallus*)		0.02											
Marine species													
Baltic herring (*Clupea harengus*)	0.3	2.4	5.0	8.9	12.6	5.5	6.3	11.0	9.1	6.9	0.16	2.3	2.3
Flounder (*Platichthys flesus*)					0.004	0.01	0.004	0.10	0.2	0.8	0.01	0.7	0.12
Sprat (*Sprattus sprattus*)	0.07	0.004		2.5		0.3	0.004	0.3	3.3	0.2	0.01	2.1	1.5
Black goby (*Gobius niger*)			0.01			0.04	0.09	0.03	0.10	0.07	0.005	0.13	0.03
Threespined stickleback (*Gasterosteus aculeatus*)		4.8	25.6	0.7	64.9	0.2	0.04		0.004	0.07		0.01	
Eelpout (*Zoarces viviparus*)		0.004		0.04	0.08	0.12	0.01	0.004	0.02	0.15		0.01	0.01
Fourhorned sculpin (*Triglopsis quadricornis*)		1.5	0.01	0.3	0.13	0.5		0.05	0.02	0.2			
Short-nosed pipefish (*Nerophis ophidion*)					0.01		0.01	0.01	0.01				0.01
Turbot (*Psetta maxima*)								0.004	0.01			0.04	
Greater sandeel (*Hyperoplus lanceolatus*)						0.004				0.03		0.07	0.01
Longspined bullhead (*Taurulus bubalis*)										0.09		0.01	
Shorthorn sculpin (*Myoxocephalus scorpius*)						0.004							
Cod (*Gadus morhua*)													
Small sandeel (*Ammodytes tobianus*)												0.01	
Broadnosed pipefish (*Syngnathus typhle*)													
Migratory species													
Baltic whitefish (*Coregonus lavaretus*)	0.10	2.7	0.3	2.5	0.7	0.5	0.03	0.03	0.3	0.3		0.01	0.01
Smelt (*Osmerus eperlanus*)	0.03	1.3		3.5	0.9	0.2	0.004	0.5	2.1	2.5	0.02	2.6	0.04
Trout (*Salmo trutta*)				0.04	0.01	0.004							
Twaite shad (*Alosa fallax*)													
Ziege (*Pelecus cultratus*)													0.01
Eel (*Anguilla anguilla*)													
Garfish (*Belone belone*)													
Salmon (*Salmo salar*)				0.004									
Non-indigenous species													
Rainbow trout (*Oncorhynchus mykiss*)					0.004								

Abundant > than mean CPUE within each gear
Common, >5% of mean CPUE within each gear
Regular, >0.5% of mean CPUE within each gear
Occasional, <0.5% of mean CPUE within each gear

Mean CPUE 2005-2009	Nordic survey nets					Coastal SN			Net series					
	Haapasaaret	Lagnö	Asköfjärden	Kvädöfjärden	Torhamn	Holmön	Forsmark	Finbo	Kvädöfjärden	Vinö	Hiiumaa	Daugavgriva	Jürkalne	Curonian lagoon
Last year included	2008	2009	2009	2009	2009	2009	2009	2008	2009	2009	2008	2007	2008	2007
Freshwater species														
European perch (*Perca fluviatilis*)	36.2	24.9	33.6	18.0	18.8	96.6	73.1	104.0	32.6	69.1	8.6	66.4	32.3	48.4
Roach (*Rutilus rutilus*)	19.2	5.4	22.5	18.8	24.9	80.9	21.6	54.4	36.3	50.5	1.4	49.0	0.70	120.3
Ruffe (Gymnocephalus cernuus)	2.1	5.4	5.8	3.0	0.17	3.4	2.8	4.1	1.7	2.9	1.1	21.71		92.8
Bleak (*Alburnus alburnus*)	0.6	0.16	0.4	5.5	4.7	1.5			0.01	0.01	1.4	0.34		2.3
Ide (*Leuciscus idus*)	0.10		0.01	0.13	0.3	0.01	0.08		0.36	1.4	0.05			0.06
Northern pike (*Esox lucius*)		0.07	0.07	0.13	0.4	0.03	0.08	0.19	0.6	1.2	0.10			
White bream (*Blicca bjoerkna*)	0.3	0.6	0.2	2.8	0.5		6.3	1.6	9.1	20.5	0.01	49.4	6.6	72.6
Sander (*Sander lucioperca*)	0.02	0.01	1.1	0.2			1.2	0.6	0.6		0.01	7.3	0.9	3.0
Bream (*Abramis brama*)	0.4		0.06	0.7	0.01		0.9	0.14	1.4			10.6	0.6	2.4
Vimba bream (*Vimba vimba*)	0.4	0.004		0.09	0.02		0.03		0.04		0.03	6.0	8.6	19.3
Rudd (*Scardinius erythrophthalmus*)	0.01	0.01		0.15	0.7		0.10		0.7	0.9	0.7	0.03		
Vendace (*Coregonus albula*)	0.02													
Bullhead (*Cottus gobio*)	0.02	0.01												
Burbot (*Lota lota*)			0.00			0.01								
Dace (*Leuciscus leuciscus*)	0.04					0.01							0.09	
Crucian carp (*Carassius carassius*)						0.01		0.01	0.04	0.01				
Tench (*Tinca tinca*)		0.03		0.23					0.37	0.02				
Gibel carp (*Carassius gibelio*)											0.02			0.06
Gudgeon (*Gobio gobio*)	0.02										0.02			
Grayling (*Thymallus thymallus*)														
Marine species														
Baltic herring (*Clupea harengus*)	5.8	3.8	3.9	3.1	0.5	4.2	8.2	9.1	0.9	1.6	0.10	1.7	35.6	
Flounder (*Platichthys flesus*)	0.11	0.05	0.4	0.6	0.14			0.11	0.39	0.8	0.40	4.4	54.4	
Sprat (*Sprattus sprattus*)	4.2	2.0	4.5	1.8	0.08				0.02	0.02	0.01		0.11	
Black goby (*Gobius niger*)	0.01	0.3	0.3	0.04	0.08		0.01	0.01			0.02			
Threespined stickleback (*Gasterosteus aculeatus*)	0.01	0.01		0.02	0.01	0.11	0.15		0.01	0.01				
Eelpout (*Zoarces viviparus*)	0.07	0.07	0.09	0.004			0.02	0.01						
Fourhorned sculpin (*Triglopsis quadricornis*)		0.2	0.05					0.01						
Short-nosed pipefish (*Nerophis ophidion*)	0.01				0.01		0.03	0.09				0.07		
Turbot (*Psetta maxima*)		0.01	0.01		0.01			0.01				0.03	1.4	
Greater sandeel (*Hyperoplus lanceolatus*)	0.02		0.004	0.004									0.06	
Longspined bullhead (*Taurulus bubalis*)	0.01		0.01											
Shorthorn sculpin (*Myoxocephalus scorpius*)		0.004		0.03					0.01					
Cod (*Gadus morhua*)			0.03		0.13								0.04	
Small sandeel (*Ammodytes tobianus*)			0.05		0.01									
Broadnosed pipefish (*Syngnathus typhle*)								0.01						
Migratory species														
Baltic whitefish (*Coregonus lavaretus*)	0.06	0.9	0.16	0.13	0.06	0.13	0.05	0.03		0.06	0.01			
Smelt (*Osmerus eperlanus*)	0.8	3.1	4.6	0.5			0.08	0.07					1.3	0.06
Trout (*Salmo trutta*)												0.03		
Twaite shad (*Alosa fallax*)													0.15	0.03
Ziege (*Pelecus cultratus*)														0.14
Eel (*Anguilla anguilla*)				0.004	0.01									
Garfish (*Belone belone*)													0.07	
Salmon (*Salmo salar*)														
Non-indigenous species														
Rainbow trout (*Oncorhynchus mykiss*)								0.01					0.04	

Abundant > than mean CPUE within each gear

Common, >5% of mean CPUE within each gear

Regular, >0.5% of mean CPUE within each gear

Occasional, <0.5% of mean CPUE within each gear

Details of the monitoring methods

Three different methods are used for monitoring coastal fish populations around the Baltic Sea. In the Baltic Proper, the longest time series data are from monitoring using Net series, which consists of four 30 m long and 1.8 m deep nets. Each net is made up of a single mesh size, 17, 21.5, 25 and 30 (in Latvia also 38) mm (knot to knot), respectively. In the Gulf of Bothnia, Coastal survey nets are used. These nets are 35 m long, 3 m deep and are composed of five 7 m long panels with mesh sizes of 17, 21, 25, 33 and 50 mm (knot to knot). For both methods, fishing is repeated over three nights at each position.

A new sampling method was introduced in 2001, using Nordic coastal multi-mesh nets (Appelberg et al., 2003). This gear is 45 m long, 1.8 m deep and is composed of nine mesh sizes (10, 12, 15, 19, 24, 30, 38, 48 and 60 mm, knot to knot). A random depth-stratified sampling design is applied. Typically, 45 positions are distributed over four different depth intervals: 0–3 m, 3–6 m, 6–10 m and 10–20 m. Each position is fished with one net for one night. A minimum of ten stations are fished in each depth interval down to 10 m depth, and a minimum of five stations in the deepest depth interval (Söderberg et al., 2004). Monitoring using Nordic coastal multi-mesh nets has in some areas been used in parallel with other net types before 2001 (Figure 1). The method is currently used only in Finland and Sweden, where it is routinely used in all areas established after 2001.

Monitoring by all methods is performed at fixed stations. The gears are set between 14.00 and 16.00 and lifted the next day between 07.00 and 10.00. Catches at each station are registered as numbers per species and length group (2.5 or 1 cm), separately for each mesh size (or net). In addition, wind strength and direction, water temperature, and water transparency measured using a Secchi disc, are routinely monitored during the fishing period (Thoresson, 1992; HELCOM, 2008).

Sampling with all three gear types takes place in August. Thus, the sampling mainly targets fish species that live close to or near the bottom in coastal areas during the warm part of the year. The most commonly occurring species during the assessment period were perch, roach and ruffe. Less stationary cold-water species, such as cod, sculpins, viviparous blenny and whitefish were however also present, predominantly in the deeper depth strata.

The indicator-based assessment

In this report, methods for an indicator-based assessment of coastal fish community state are developed and applied to monitoring data from different areas of the Baltic Sea. The assessment builds on a framework comprising two main steps: the identification of a coherent and representative set of state indicators and the potential relationship of these state indicators to external pressures.

The selection of state indicators was based on an initial evaluation of several metrics. These were evaluated in terms of how well they reflected observed changes in the fish community, and their potential redundancy in contributing to the overall pattern. The aim was to identify a number of metrics suited to indicating the main spatial trends in the fish communities monitored. The evaluation was based on multivariate analyses combined with a series of selection criteria when redundancy occurred. The metrics selected were termed 'state indicators'. The selected state indicators basically represent four different aspects of the fish community: species composition, size structure, trophic structure, and species diversity.

In order to provide advice on management measures to improve the status of fish communities, knowledge about the link between the state indicators and manageable pressures is required. Indicators showing an empirical relationship to external manageable pressures are presented as potential *impact indicators* (Figure 2). However, these results should be evaluated further as more pressure data become available.

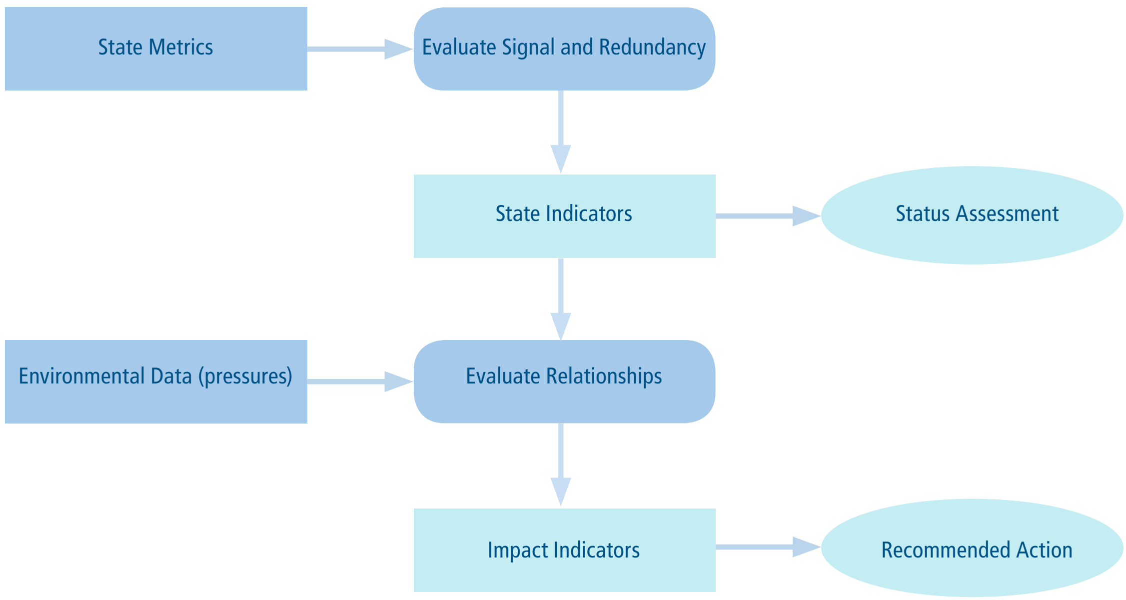


Figure 2. Schematic illustration of the steps involved in evaluating and selecting state indicators for coastal fish communities in the Baltic Sea.

Report overview

The present report consists of three parts. Part I develops the method for identifying state indicators, and explores the relationship between the indicators and external pressures. Temporal and spatial patterns revealed by the indicator-based approach are compared with results based on direct analyses of species data from the same dataset. The analyses were based on data from monitoring using Nordic coastal multi-mesh nets, focusing on spatial patterns and characteristics of the different monitoring areas. Part I concludes with an evaluation of the level of correspondence for the indicator results obtained by the different sampling methods. This was achieved by comparing monitoring data from Nordic coastal multi-mesh nets with monitoring data from Coastal survey nets (Gulf of Bothnia) or Net series (Baltic Proper), for areas where two sampling methods have been used in parallel.

Part II reports on the current status of the coastal fish communities. This was achieved by comparing the data obtained during the assessment period (2005–2009) with data from earlier years (1995–2004), where these were available. Coastal fish communities were compared in all areas sampled using the same gear type. Temporal trends were assessed within each monitoring area using the entire time series available at each site.

Part III provides an overview of current restoration and restocking programmes for threatened and declining coastal species in each country. The report concludes with a discussion and recommendations.

Part I. Identification and evaluation of state indicators

Summary

The performance of a range of metrics potentially indicating coastal fish community status was evaluated from the perspective of what they represent, how well they complement each other, and how they relate to external pressures. The analyses were performed on data from all areas monitored with Nordic coastal multi-mesh nets (Figure 3).

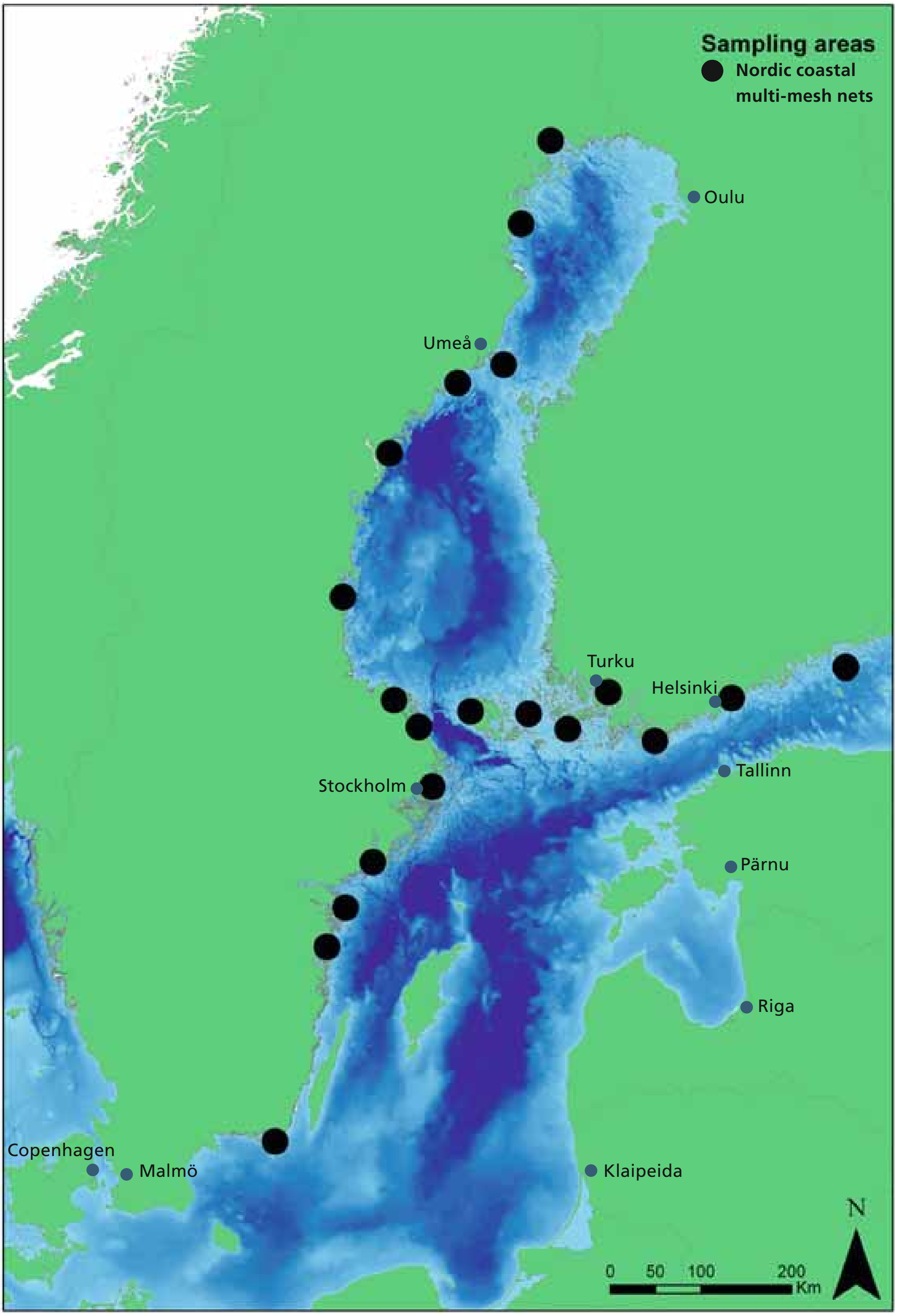


Figure 3. **Baltic Sea areas monitored using Nordic coastal multi-mesh nets.**

Test fishing in Mönsterås, southern Swedish Baltic coast, August

Based on these analyses, ten state indicators were identified. Spatial and temporal patterns described by the state indicators were compared to corresponding patterns based on analyses of species composition in the same datasets. Characteristics of both approaches were discussed and compared.

The relationship between the state indicators and some potential pressures was also studied. Effects of natural and manageable pressure variables were compared. A high level of redundancy was observed in the indicators' responses to pressures. However, the relationship between the state indicators and manageable pressures was consistently stronger than that between the state indicators and natural pressures. Among the manageable pressures, the strongest relationships were observed with commercial catches and population density.

Owing to the short time series available, it was not possible to identify temporal trends in the data from Nordic coastal multi-mesh nets.

The level of correspondence for the results obtained by the different monitoring methods was evaluated by comparing spatial patterns and temporal trends in the state indicators based on different methods. The same state indicators were calculated based on data from monitoring using Nordic coastal multi-mesh nets, Coastal survey nets and Net series. A comparison was possible within areas where both methods were used in parallel. Results show that indicators calculated from different monitoring methods cannot be directly compared, probably due to inherent differences in the monitoring methods. The results indicate that the assessment routine, starting with the initial evaluation of metrics of fish community state, should be repeated separately for each monitoring method.

Methods

Monitoring data used

The study was based on data from 18 areas within the Baltic Sea monitored using Nordic coastal multi-mesh nets (Figure 3). The 18 areas are all classified as national reference areas, which means they are not directly affected by anthropogenic disturbance (such as pollution, densely populated areas, and agriculture). The gillnet specifications and sampling strategy are described in detail by Söderberg et al. (2004).

Data from four years (2005-2008) were included in the analyses, as this was the largest subset of years during which all areas were monitored. In order to include only those species and size-groups suited to quantitative sampling by Nordic coastal multi-mesh nets, individuals smaller than 12 cm, small-bodied species (gobies, sticklebacks, butterfish), and species with eel-like body forms (taeniform, anguilliform or filiform shapes) were excluded.

To ensure the indicator estimates were representative for each monitoring area, the analyses were based on weighted means of data from all depth strata. This was because station density varied for the different monitoring areas owing to the depth-stratified sampling design (reflecting differences in the topography of each area). Preliminary analyses indicated significant differences among depth strata in terms of species caught, and that indicator estimates were different when computed separately for each stratum. The weighted means were based on the area covered by each depth stratum in each monitoring area, as estimated from sea charts. The total size of each monitoring area was defined as the area covering all monitoring stations, with an additional 200 m buffer zone.

Initial metrics

Twenty metrics were computed as a first step in the selection of a set of state indicators These covered a range of aspects of ecological status at fish community level. Three metrics at species level were also included for perch, which is a dominant species in these areas. The initial selection of 20 metrics was primarily based on Rice and Rochet (2005), previous use within the Baltic Sea (HELCOM, 2006), and suggestions by members of the HELCOM FISH project (Table 3).

Table 3. Initial metrics used in the analyses and their grouping in terms of the four categories.

Metric	Species Comp.	Size Structure	Trophic Structure	Species Diversity
Total Abundance	x			
Fresh-water Species	x			
Marine Species	x			
Warm-water Species	x			
Cold-water Species	x			
Perch	x			
Cyprinids	x			
Warm-water Species Proportion	x			
Slope of Size Spectrum		x		
Mean Maximum Length		x		
Mean Length		x		
Mean Length Perch		x		
Large Individuals 30		x		
Large Individuals 40		x		
Large Individuals Proportion		x		
Large Perch		x		
Mean Trophic Level			x	
Piscivores			x	
Non-piscivores			x	
Piscivore Proportion			x	
Number of Species				x
Diversity (Shannon Index)				x
Diversity Simpson (Simpsons Index)				x

The metrics were categorised as representing aspects of: species composition, size structure, trophic structure, and species diversity.

Species Composition. Metrics representing species composition were measures of abundance of different species groups, given as catch in numbers per unit of effort (CPUE). The metrics included were *Total Abundance*, *Freshwater Species*, *Marine Species*, *Warm-water Species*, *Cold-water Species*, *Perch* and *Cyprinids*. The metric *Warm-water Species Proportion* was also included. Each species was assigned to the different groups as shown in Table 4.

Metrics within this group potentially reflect the relative recruitment success and mortality rate for each species, which may in turn be influenced by species-specific responses to changes in the environment. For example, increases in *Cyprinids* may reflect a released predation pressure from piscivores, increasing eutrophication, or rising water temperature. The metric *Marine Species* is of special interest as it may be influenced by salinity changes in the Baltic Sea, which affect local recruitment success and/or range expansion of marine species from adjacent areas. However, the dominant species within this group is Baltic herring, which reproduces throughout the whole Baltic Sea.

Size Structure. Size structure was represented by the length-based metrics *Slope of Size Spectrum*[1], and *Mean Maximum Length*[2], as well as by *Mean Length* and *Mean Length Perch*, given as the mean length of all fish in the catch, and the mean length of all perch, respectively. The abundance-based metrics *Large Individuals 30* (abundance of fish larger than 30 cm), *Large Individuals 40* (abundance of fish larger than 40 cm), *Large Individuals Proportion* (proportion of fish larger than 30 cm), and *Large Perch* (number of perch larger than 25 cm) were also included.

Within the ecosystem, large fish often have a key structuring role through their predation on smaller fish. Thus, metrics reflecting size structure may be indicative of ecological function. Since fishing often targets large fish, changes in size structure may also reflect changes in fishing pressure. However, when reflecting changes in large non-piscivore species such as bream, increasing values of size-related metrics may also be indicative of eutrophication or rising water temperature. When the metrics are based on proportions, decreasing values in metrics reflecting size structure may also

Table 4. Fish species recorded in 2005–2008 in Baltic Sea coastal areas using Nordic coastal multi-mesh nets. Columns to the right show species categorizations applied in the calculation of the initial metrics.

Scientific name	English name	Short name	Marine / Freshwater	Warm / Cold-water	Piscivorous /Other
Abramis bjoerkna	Silver bream	Silver bream	F	W	O
Abramis brama	Bream	Bream	F	W	O
Abramis vimba	Vimba	Vimba	F	W	O
Alburnus alburnus	Bleak	Bleak	F	W	O
Carassius carassius	Crucian carp	Carp	F	W	O
Coregonus albula	Vendace	Vendace	F	C	O
Coregonus maraena	Baltic whitefish	Whitefish	F	C	O
Cottus gobio	Bullhead	Bullhead	F	C	O
Cottus poecilopus	Alpine bullhead	Alpine bullhead	F	C	O
Esox lucius	Northern pike	Pike	F	W	P
Gobio gobio	Gudgeon	Gudgeon	F	W	O
Gymnocephalus cernuus	Ruffe	Ruffe	F	W	O
Leuciscus idus	Ide	Ide	F	W	O
Leuciscus leuciscus	Dace	Dace	F	W	O
Lota lota	Burbot	Burbot	F	C	P
Onchorhynchus mykiss	Rainbow/steelhead trout	Rainbow trout	F	W	O
Osmerus eperlanus	Smelt	Smelt	F	C	O
Pelecus cultratus	Ziege	Ziege	F	W	O
Perca fluviatilis	Eurasian perch	Perch	F	W	P
Rutilus rutilus	Roach	Roach	F	W	O
Salmo salar	Salmon	Salmon	F	C	P
Salmo trutta	Trout	Trout	F	C	O
Sander lucioperca	European pike-perch (Sander)	Pike-perch	F	W	P
Scardinius erythrophthalmus	Rudd	Rudd	F	W	O
Thymallus thymallus	Grayling	Grayling	F	C	O
Tinca tinca	Tench	Tench	F	W	O
Ammodytes tobianus	Small sandeel	Small sandeel	M	-	O
Clupea harengus	Baltic herring	Herring	M	C	O
Gadus morhua	Cod	Cod	M	C	P
Gasterosteus aculeatus	Three-spined stickleback	Stickleback	M	W	O
Gobius niger	Black goby	Black goby	M	W	O
Hyperoplus lanceolatus	Greater sandeel	Sandeel	M	-	P
Myoxocephalus scorpius	Shorthorn sculpin	S. sculpin	M	C	O
Platichthys flesus	Flounder	Flounder	M	-	O
Psetta maxima	Turbot	Turbot	M	-	P
Sprattus sprattus	Sprat	Sprat	M	C	O
Taurulus bubalis	Longspined bullhead	L. bullhead	M	C	O
Triglopsis quadricornis	Fourhorned sculpin	Fourhorned sculpin	M	C	O
Zoarces viviparus	Eelpout, Viviparous blenny	Eelpout	M	C	O

1 The *Slope of Size Spectrum* quantifies the relative abundances of small and large fish and is defined by the regression slope of the size spectrum (Gislason and Rice, 1998; Shin and Cury, 2004).

2 *Mean Maximum Length* quantifies the relative abundances of large and small species (Jennings et al., 1999), and was calculated as a weighted mean of species-specific fixed maximum length, weighted by the relative abundance of that species. The fixed maximum length of each species was taken as the maximum observed length in the dataset, across all areas and across the years 2005–2008.

reflect an increased abundance of small-bodied species or individuals.

Trophic Structure. Trophic structure was represented by *Mean Trophic Level*, which is based on catch composition in combination with species-specific estimates of trophic level[3], and by *Piscivore Proportion,* which gives the relative abundance of piscivores in the catch. A decline in these metrics shows a shift towards the lower end of the food chain, and may reflect decreases in the abundance of piscivores and/or increases in the abundance of non-piscivores. The abundance of piscivores and non-piscivores, respectively, were included with the metrics *Piscivores* and *Non-piscivores*. For the latter three metrics, species with an estimated trophic level above 4 were assigned as piscivores, while the others were assigned as non-piscivores (based on Fishbase, www.fishbase.org).

Species Diversity. Species diversity was represented by three metrics, *Number of Species*, given as the total number of species observed in an area in a given year, *Diversity*, given as the Shannon index[4] and *Diversity Simpson*, given as the Simpson index of diversity[5]. Environmental conditions leading to dominance of a few species or to a small number of species are expected to result in low values for the metrics within this group.

Environmental data for analysis of pressures

The environmental data were categorised into natural and manageable pressures. The analyses were performed with a focus on manageable pressures, which are defined here as those that can in a relatively short time frame (1 to 10 years) be directly regulated by management, and for which management advice can be given. Manageable pressures can in this way be distinguished from natural pressures, which are highly likely to have an influence on coastal fish communities, but cannot be directly regulated by management in the short term. The scope of the analyses was restricted by the availability of data on potential pressures.

Manageable pressures

Four types of manageable pressures were included; *Commercial Catches, Population Density, Seal Consumption* and *Water Transparency*.

Commercial Catches. Data on commercial catches of demersal fish were compiled from Swedish and Finnish national catch statistics. The data were reported on the level of ICES statistical rectangles, which are 55 by 55–60 km. Numbers represent average catches per square kilometre water area during 2004–2008. All species landed, except the pelagic species herring, sprat and vendace, were included to get at measure of fishing impact on the demersal and benthopelagic fish community.

Population Density. An index of human population density was calculated to indicate the relative use of coastal areas for human activities, mainly recreational fishing, which is estimated to make up a significant part of the total catches at least in Swedish coastal areas (Swedish Board of Fisheries, 2011; Thörnqvist, 2009). *Population Density* was estimated as the number of inhabitants within a 30 km radius from the monitoring site.

Seal Consumption. An index of fish consumption by seals was estimated based on information on seal population density and seal diet. Data on population densities were obtained from the Swedish and Finnish national censuses of grey seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida*) carried out in 2009 and 2010, respectively (Swedish Museum of Natural History, www.nrm.se). The census data were available per sub-basin and country, which make a dataset with a fairly coarse spatial resolution (six different levels of consumption). The average consumption of a grey seal in the Baltic Sea was estimated at 1640 kg per year, and for ringed seal at 730 kg per year (K. Lundström, Swedish Board of Fisheries, pers. comm.). *Seal Consumption* was estimated as the biomass of fish consumed per square kilometre sea area, assuming that seal feeding was evenly distributed from the shoreline to 12 nautical miles from the baseline.

3 *Mean Trophic Level* was calculated as a weighted average of species-specific trophic levels, weighted by the relative abundance of each species. Estimates of the trophic level for each species were taken from the Fishbase database (www.fishbase.org, Froese and Pauly, 2004).

4 The Shannon index combines measures of species richness and equitability, and is calculated as $H=-\sum P_i(\ln P_i)$ where Pi is the proportion of each species in the sample.

5 Simpson's index of diversity measures the probability that two individuals randomly selected from a sample will belong to the same species $D=-(\sum(N_i(N_i-1) / N(N-1)$ where N_i is the total number of individuals of each species in the sample and N is the total number of individuals.


Underwater vegetation with marine Eelgrass and Fennel-leaved Pondweed in the Blekinge Archipelago in Southern Baltic Proper, Sweden.

Water Transparency. Water transparency was used to indicate differences in eutrophication level among areas. Data were obtained from direct measurements of water transparency in connection with the monitoring of fish communities in August. For each area, the mean secchi depth for all included years was used in the analyses.

Natural pressures

The natural pressure variables included in the analyses were *Depth, Wave Exposure, Salinity* and *Water Temperature*. These variables are likely to influence the composition of coastal fish communities, and thereby differences among areas studied, but are not directly related to human activities. Although, salinity and water temperature can be influenced by human induced global warming, potential effects of this type were not considered significant within the time frame of the assessment (2005–2009).

Depth. The mean depth within each fishing area was estimated from digital elevation modelswith 25m grid cell size, based on nautical chart data. Two other bathymetric characteristics, mean slope and mean curvature, were also tested. However, as these variables were found to be highly correlated with mean depth, they were not used in the analyses.

Wave Exposure. Estimates of wave exposure were obtained from Swedish and Finnish maps produced using a simplified wave model (Isaeus, 2004). The model is based on fetch and wind speed plus direction, and incorporates refraction and diffraction effects. The size of the grid cell was 25 m.

Salinity. Estimates of salinity were obtained from Bendtsen et al. (2007), giving a Baltic Sea-wide grid layer of bottom salinity based on output from a three-dimensional hydrodynamic model. The size of the grid cell was 5000 m.

Water Temperature. Field measurements of water temperature in each area were obtained from the fish-monitoring programme. Temperature was measured at each station on the day of fishing at 1 m above the bottom. Mean values for each area and for all years (2005–2008) were used in the analyses.

Selecting state indicators

As a first step all metrics were evaluated for signal strength and redundancy. Pairs of metrics showing a high level of correlation[6] were examined according to a series of selection criteria (see Rice and Rochet, 2005):

1) Conceptually clear and easy to compute
2) Representing a feature category not represented by any other retained indicator (species composition, size structure, trophic structure, species diversity)
3) Recognised as being of high interest to stakeholders.

When selecting among a pair of correlated metrics, the metric that best responded to criterion 1 was retained. All metrics responding to criteria 2 or 3 were retained in the further analyses.

Principal component analysis (PCA) was then performed on all metrics retained[7]. The number of principal components to be examined was decided based on a Scree Test (Tabachnick and Fidell, 1983). The contribution of each metric was evaluated from their loadings on the first three principal components, and from its vector length in PCA eigenvector plots (Clarke and Gorley, 2006). Metrics contributing strongly to the observed pattern on any of the first three principal components, or on a combination of these, were retained. When two candidate indicators were observed to signal a similar pattern, they were examined according to the selection criteria above, in order to decide whether they should be removed or retained.

The analyses were based on data from all 18 monitoring areas, using the mean values of each metric from all years (2005–2008). The metrics selected from these analyses were termed 'state indicators' and analysed further for their relationship with pressure variables.

Assessing the relationship to pressures

The relationship between the selected state indicators and potential pressures was analysed using distance-based linear models (DISTLM)[8] across all monitoring areas, using manageable and natural pressure data for each area, as outlined above. The analyses were performed separately for each indicator of state, based on their mean values for the period 2005–2008 across all 18 areas.

It was not possible to include all pressure variables (explanatory variables) simultaneously in the model to explain the spatial change in each indicator of state (independent variable), as this would exceed the recommended number of variables (Burnham and Anderson, 2002). Therefore, the analyses were performed in two steps:

In the first step, the analyses were performed separately for the natural and manageable pressure variables, respectively, and the variable importance weights for each pressure were computed[9]. The variable importance weights represent the likelihood of a variable to be a good predictor of the indicator based on the available information. The aim of this analysis was to assess the relative contribution of different pressure variables within the separate sets of natural and manageable pressures.

In the second step, the two outputs were compared to investigate if changes in the indicator

6 Pearson correlation coefficient >0.95. Indicators based on abundances were square-root transformed prior to analyses, and indicators based on proportion were arc-sine transformed, in order to improve linearity.

7 The PCA was performed on a correlation matrix based on Euclidian distances, as implemented in PRIMER-E and PERMANOVA plus (version 6, Clarke and Gorley, 2006; Anderson et al., 2008; www-primer-e.com. Data were transformed in the same way as in the pair-wise comparisons.

8 As implemented in PERMANOVA+ for PRIMER v6 (Clarke and Gorley, 2006; Anderson et al., 2008). Since the analyses were performed for one indicator at a time, the output of the analysis is comparable to that of a univariate linear multiple regression model, however, the p-values are obtained by permutation. The environmental variables were transformed and normalised prior to analyses. The variables were checked for multi-collinearity by analysing the variance inflation factors (VIF, Zuur et al., 2007).

9 The importance weights for each pressure variable were computed based on model differences in the Akaike criterion and from these differences subsequently estimated Akaike weight (w) for each model. Akaike weights provide a relative likelihood of each model (Akaike, 1983; Burnham and Anderson, 2002). Subsequently, the obtained w was summed for each variable, across all models for which the variable was selected, in order to give a relative variable importance weight (Burnham and Anderson, 2002).

were more strongly related to manageable or natural pressures. For this, a new set of variable importance weights were computed and compared based on the combined set of environmental and manageable models[10]. The model including only the most important variables, as indicated by the variable importance weights, was referred to as the 'final model'. Finally, estimates of how much of the spatial variation in the investigated indicator of state was explained by the final model were computed[11]. Thus, the aim of this analysis was to assess the relative importance of environmental and manageable variables in explaining the spatial variation in each indicator of state.

Potential impact indicators were defined among the state indicators, as those showing (i) a stronger modelled relationship to the manageable pressures than to the natural pressures, (ii) a conceptually logical direction of the observed relationship to the pressure variable, and (iii) a high level of spatial change explained by the final model[12]

Comparing the indicator dataset and species dataset

The advantage of basing the assessment on indicators, rather than on species composition, is that the indicators may encompass additional aspects, such as size structure and trophic structure, in addition to species identity. However, a potential disadvantage of using indicators is clearly that they require extra time and expertise for computation prior to analysis. In practise, the indicators may also in some cases simply reflect the population dynamics of dominant species, particularly in a species-poor area such as the Baltic Sea. The performance of the indicators in describing spatial and short-term temporal patterns was evaluated by comparing the patterns shown by the indicators with spatial and short-term temporal patterns in species composition.

The analyses were based on data from all 18 monitoring areas, including data from the different years as separate data points (2005–2008).

The indicator dataset was analysed by PCA in the same way as described above. Species composition data were analysed by principal coordinate analysis (PCO) using a species similarity matrix based on the Bray-Curtis similarity index[13].

Comparing indicators across monitoring programmes

Patterns shown by the state indicators based on monitoring using Nordic coastal multi-mesh nets were compared to the patterns shown by corresponding indicators and years computed based on monitoring using Coastal survey nets (Gulf of Bothnia) and Net series (Baltic Proper). This comparison was possible for areas where monitoring had been undertaken by more than one method. Monitoring using Nordic coastal multi-mesh nets has been undertaken in parallel with monitoring using Coastal survey nets at Finbo, Forsmark, Holmön, Råneå and Brunskär in the Gulf of Bothnia, and in parallel with Net series at Kvädöfjärden in the Baltic Sea (Figure 3). The aim of the evaluation was to see if the results from two different monitoring methods showed similar patterns in the temporal development of the indicators.

The indicators were first analysed together by PCA[14], including data from all areas and years monitored by both Nordic coastal multi-mesh nets and Coastal survey nets. The effect of monitoring method on the pattern obtained was tested by an Analysis of Similarities (ANOSIM)[15], testing the effects of 'area' and 'monitoring method' in a two-way crossed design, where coherence among the two monitoring methods would be indicated by a relatively low contribution of the factor 'monitoring method' to the pattern observed.

The correlation at the level of individual indicators was then compared, by pair-wise comparison. For this analysis, it was also possible to include data from Kvädöfjärden in the Baltic Sea.

10 These were calculated by the same procedure as described for the first step.

11 R^2 values for the models including variables with high importance weights were calculated to indicate how well the model could predict spatial changes in the state indicators.

12 R^2 values > 0.4 were considered as a moderate degree of explanation and R^2 values > 0.8 were considered as a high degree of explanation.

13 Analyses were based on data on the abundance of each species, given as the weighted average catch per unit effort for each area and year. Data were log(x+1)-transformed prior to analysis.

14 Based on Euclidian distances. Indicators based on abundances were square-root transformed prior to analyses, and indicators based on proportion were arc-sine transformed.

15 As implemented in PRIMER v6.

Results and discussion

Selected state indicators

Ten state indicators were identified, based on the analyses of monitoring data from Nordic coastal multi-mesh nets. Selected indicators reflecting species composition were *Total Abundance*, *Cyprinids* and *Marine Species*. Indicators reflecting aspects of size structure were *Large Individuals 40*, *Large Perch*, and *Mean Maximum Length*. For trophic structure, the indicators *Mean Trophic Level*, *Piscivores* and *Non-piscivores* were selected. *Diversity,* as defined by the Shannon index, was the only selected indicator of state reflecting species diversity.

The outcome of the analyses is illustrated in Figure 4. The main part of the variation observed was attributed to changes in size structure, trophic level and diversity, as indicated by high loadings of the indicators *Mean Maximum Length, Large Perch, Piscivores, Mean Trophic Level* and *Diversity* on the first principal component (Table 5). Areas characterised by high values in these indicators were Forsmark, Kumlinge, Brunskär and Holmön, as indicated by their low scores on the first principal component (Figure 5). These areas were also characterised by relatively low valus in the indicator *Diversity.* On the other hand, areas with high scores on the first principal component were characterised by the opposite characteristics, mainly Norrbyn, Helsinki and Gaviksfjärden.

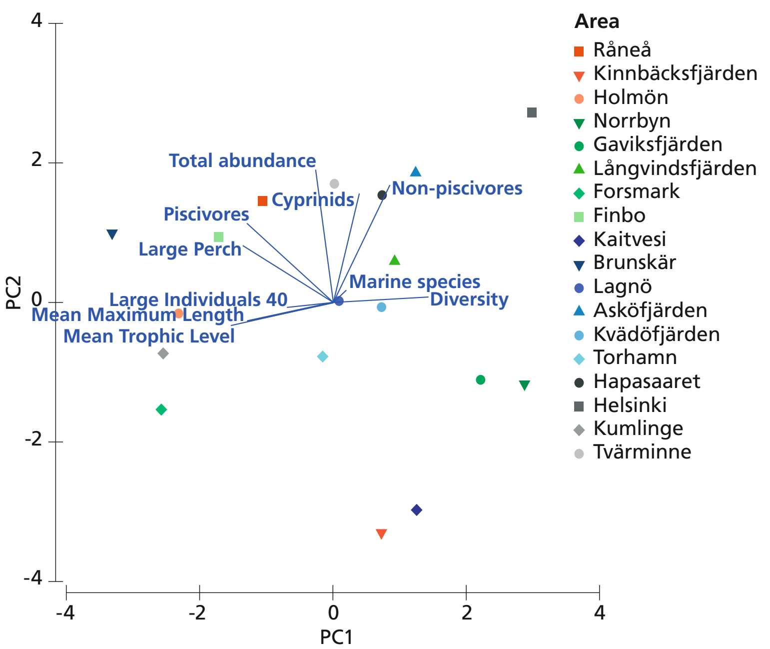


Figure 4. Principal component analysis showing the relative similarity among areas monitored within the Baltic Sea using Nordic coastal multi-mesh nets based on the ten state indicators. Data points in close proximity have similar indicator value. The vector of each indicator shows its contribution to the observed pattern on the first two principal components. For example, areas to the right were characterized by high values in *Diversity* and low values in *Large Individuals 40, Mean Maximum Length* and *Mean Trophic Level*, while the opposite was the case for areas to the left. Areas at the upper end were characterized by high values in *Total Abundance, Cyprinids and Non-piscivores*. The first component (PC-1) explained 36.0% of the variance while the second (PC-2) explained 27.3%. The analysis was based on average values for the years 2005–2008 in all areas monitored (see Figure 3).

Table 5. The loadings of the selected state indicators on the three first principal components (PC). Values above 0.3 are highlighted in order to show the main patterns in the output.

Indicator of state	PC1 (36.0 %)	PC2 (27.3 %)	PC3 (21.1 %)
Marine Species	0.06	-0.05	**0.62**
Cyprinids	0.12	**-0.47**	**-0.36**
Total Abundance	-0.08	**-0.57**	0.13
Non-piscivores	0.26	**-0.51**	0.02
Large individuals 40	-0.21	0.02	**-0.49**
Piscivores	**-0.39**	**-0.34**	0.12
Mean Maximum Length	**-0.39**	0.08	**-0.35**
Mean Trophic Level	**-0.46**	0.10	0.20
Diversity	**0.43**	-0.02	-0.23
Large Perch	**-0.41**	-0.25	-0.02

Variation along the second principal component was mainly attributed to changes in fish abundance, mainly in the indicators *Total Abundance*, *Cyprinids*, *Non-piscivores*, but to some extent also in *Piscivores*. Areas with relatively high values for these indicators were Haapasaaret, Helsinki, Asköfjärden, Tvärminne and Råneå.

Variation along the third principal component was mainly attributed to changes in the indicators *Marine Species, Cyrpinids,Large Individuals 40* and *Mean Maximum Lenght* (Table 5, not shown in Figure 4).

Relationship with pressures

General patterns in indicator relationships with pressures

The relationship between the state indicators and the natural pressure variables was weak to moderate (Table 6). The natural pressure variables most frequently included in the final models were *Depth* and *Water Temperature*. However, there were strong differences among models in terms of which final combination of pressure variables was included.

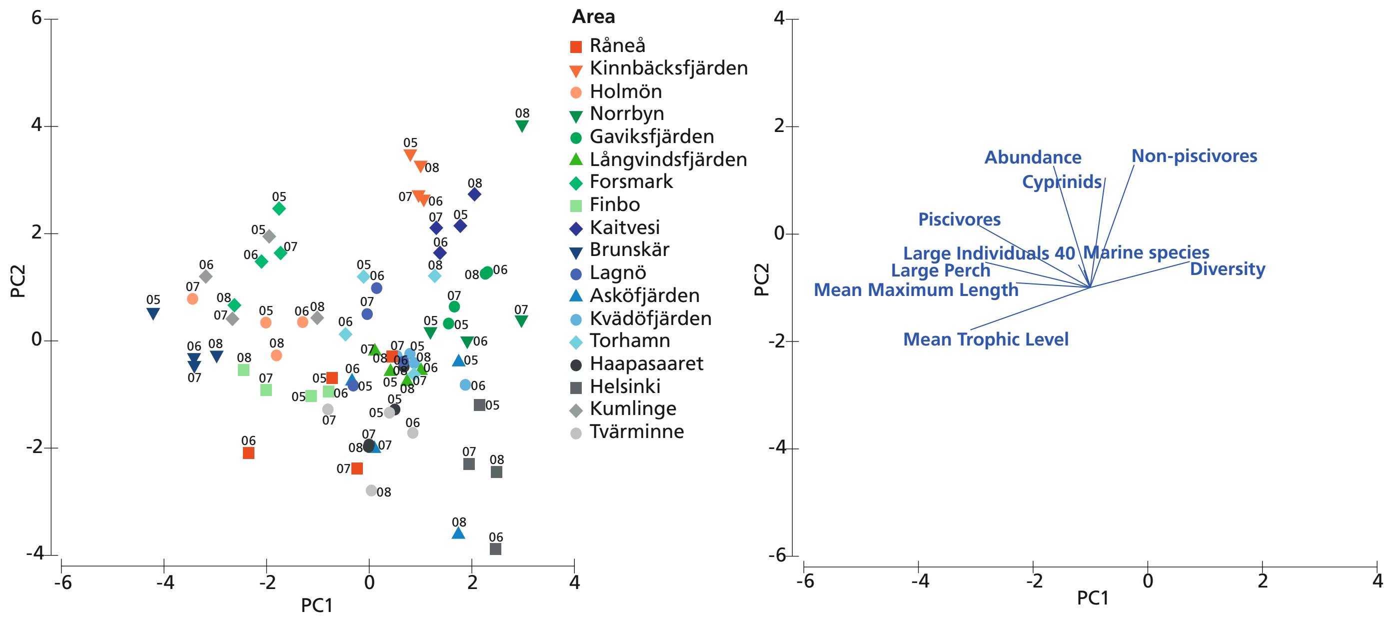


Figure 5. Principal component analysis showing the relative similarity of the ten state indicators within the Baltic Sea based on monitoring data from Nordic coastal multi-mesh nets. The graphic shows the similarities between indicator values based on Euclidian distances. The first component (PC-1) explained 36% of the total variance and the second (PC-2) explained 27.3%. The left plot shows scores for areas and years (18 areas, years 2004–2008). Data points in close proximity have similar indicator values. The right plot shows the vectors for all ten indicators. (The multivariate pattern shown here is similar to that in **FIGURE 4**, but gives more detail because individual years are included as data points.)

Table 6. Relationship between potential pressure variables and selected state indicators, based on DISTLM analyses. The analyses were run including (i) only natural pressures, (ii) only manageable pressures, and (iii) natural and anthropogenic pressures. The observed direction of the relationship between each pressure and the state indicator is given as (+) for positive and (-) for negative, for variables with importance weights above 0.4 according to the analyses. Variables with highest importance weight (>0.7) are indicated by shaded colour. The level of spatial variation explained by the final model for each indicator is indicated by Pearson correlation coefficient (R2, including pressure variables with importance weights above 0.4).

	Total Abundance	Large Individuals 40	Large Perch	Cyprinids	Non-piscivores	Marine Species	Mean Trophic Level	Mean Maximum Length	Diversity	Piscivores
Natural Pressures										
Depth		–	–			+	–	–		–
Salinity		+								
Wave Exposure										
Water Temperature	+			+	+		–			
R^2	11.0	47.2	15.3	53.4	11.6	48.2	11.4	37.4	2.0	7.1
Anthropogenic Pressures										
Commercial Catch	–	+			–	–	+	+	–	
Population Density			–	+	+		–		+	–
Seal Consumption							+	+		
Water Transparency				–		+			–	
R^2	4.6	10.4	24.5	35.1	43.0	62.2	77.5	42.5	77.0	32.0
Natural and Anthropogenic Pressures										
Depth		–						–		
Salinity		+								
Wave Exposure										
Water Temperature				+						
Commercial Catch					–	–	+		–	
Population Density			–		+		–		+	–
Seal Consumption							+			
Water Transparency						+			–	
R^2	-	47.2	24.5	53.4	43,0	62.2	77.5	37.4	77.0	32.0

Among the manageable pressure variables, *Commercial Catches* and *Population Density* were the most important for the final models. However, typically different combinations of pressure variables were included. The analyses should be developed further, since the direction of the observed relationships was not always clear.

In general, the manageable pressure variables explained more of the observed spatial variation in the state indicators than the natural pressure variables.

Pressures in relation to individual indicators

Total Abundance. The spatial variation in this indicator was not strongly related to any of the natural or manageable pressure variables studied.

Cyprinids. The most important natural pressure variables in explaining spatial variation in this indicator was *Water Temperature*, with higher values in areas with higher temperature. Among the manageable pressures, the indicator was also moderately related to *Population Density* and *Water Transparency*. The variation explained by the natural pressure variables was stronger than that explained by the manageable pressure variables, according both to variable importance weights and explanatory power of the final models.

Marine Species. The manageable pressure variables most important for explaining variation in this indicator were *Commercial Catches* and *Water Transparency*, which together explained 62% of the observed spatial variation. Higher values for the indicator were generally observed in areas with low levels of commercial catch and high water transparency. The most important natural pressure variable observed was *Depth*, indicating a higher rate of marine species in areas with higher mean depth. However, the level of variation explained by the natural pressure variables was much lower than for the manageable pressures.

Large Individuals 40. The most important variable in describing spatial variation in this indicator was the natural pressure variable *Depth* and to some extent also *Salinity*. Values for the indicator were higher in areas with lower mean depth, and in areas with higher salinity. The indicator was only weakly related to the manageable pressures, as indicated by the low variable weights and low explanatory power of the final model.

Large Perch. This indicator showed only weak relationships with both the natural and the manageable pressure variables studied. The most important variables in explaining spatial variation in the indicator however, was the manageable pressure variable *Population Density*, showing

Test fishing for whitefish larvae using beach seine in Öregrund, southern Swedish Bothnian Sea coast in May

lower values for the indicator in areas with high population density.

Mean Maximum Length. Among the natural pressure variables, the strongest relationship with this indicator was observed for *Depth,* indicating higher values in the indicator in areas with lower mean depth. However, the strength of the relationship was moderate. The indicator showed only weak relationships with manageable pressure variables.

Mean Trophic Level. The most important variables in describing variation in this indicator were *Population Density*, *Commercial Catch* and *Seal Consumption.* The level of explanation of the final model was fairly high. However, the relationship between the indicator and the pressure variables should be evaluated further, and the indicator should be interpreted together with other indicators. In the present model, the value of the indicator was highest in areas with high commercial catch, high seal predation, and low population density. Only a weak relationship was observed between the indicator and the natural pressure variables.

Non-piscivores. The manageable pressure variables *Commercial Catch* and *Population Density* were most important in explaining spatial variation in this indicator. The level of explanation of the model including these pressure variables was moderate, with higher values for the indicator in areas with lower commercial catch but high population density. Generally, the relationship with natural pressure variables was weak.

Piscivores. The indicator was most strongly related to the manageable pressure variable *Population Density.* Values for the indicator decreased with increasing population density. The explanatory power of the model was moderate.

***Diversity* (Shannon index).** The indicator showed a relatively stronger relationship with the manageable pressure variables than with the natural pressure variables. *Commercial Catch*, *Water Transparency*, and *Population Density* were the variables explaining most of the observed spatial variation. Values of this indicator were lower in areas with relatively high levels of commercial catches and high water transparency, and higher in areas with high population density.

Comparison of the indicator dataset and the species dataset

The spatial and temporal patterns observed in datasets based on the indicator dataset and on datasets of species composition were not identical, but there was some general agreement. As the two approaches reflect different aspects of the fish community, it may be useful to include information on the main trends in dominant species as a complement to the indicator-based assessment of communities.

The main pattern in the analysis based on species composition was relatively strongly influenced by a few species (roach, perch, silver bream, herring). This pattern was not captured by the indicator dataset. However, variation in functional aspects of the fish community, such as size structure, trophic structure and diversity, which were not captured by the species dataset, had a strong influence on the patterns in the analysis based on the indicator dataset.

Characteristics of the indicator dataset

Indicators with a high degree of influence on the variation observed were *Mean Trophic Level* and *Piscivores*, which reflect trophic structure and the three indicators reflecting aspects of size structure (*Mean Maximum Length, Large Perch* and *Large Individuals 40*). These, and also *Diversity,* had a high loading on the first principal component. Thus, areas and years with low values of indicators reflecting size structure and trophic structure, but relatively high values of species diversity, had high scores on the first principal component (Kinnbäcksfjärden, Norrbyn, Gaviksfjärden, Kaitvesi, Helsinki), and areas showing the opposite pattern had low scores (Holmön, Forsmark, Finbo, Brunskär, Kumlinge).

Differences along the second principal component were mainly due to variation in the indicators *Total Abundance, Cyprinids* and *Non-piscivores*. Areas and years with high abundances, especially of cyprinids and other non-piscivore species, had high scores on the second principal component (Kinnbäcksfjärden, Kaitvesi), whereas relatively low values for these indicators were observed for areas with low scores (Helsinki, Tvärminne).

Characteristics of the species dataset

The multivariate pattern of the species dataset showed a higher level of dispersal among areas, compared to the indicator dataset (see Figures 5 and 6). The two outputs were also different with respect to how different areas were grouped together.

One area, Kaitvesi, was particularly distinguished by high catches of silver bream, and also by pikeperch, in relation to the other areas. The Kaitvesi area showed a relatively high similarity to Kinnbäcksfjärden based on the indicator dataset, with high values for *Diversity*, *Non-piscivores* and *Cyprinids*, but low values for *Mean Trophic Level*. However, this similarity was not preserved in the species dataset, where Kinnbäcksfjärden was characterised mainly by ruffe, fourhorned sculpin and whitefish.

The main pattern based on the species dataset, separated areas with relatively high catches of roach and perch (low scores on both the first and second PCO, typified by Torhamn and Råneå) from areas with relatively high catches of ruffe, fourhorned sculpin, whitefish and smelt (Kinnbäcksfjärden, Norrbyn).

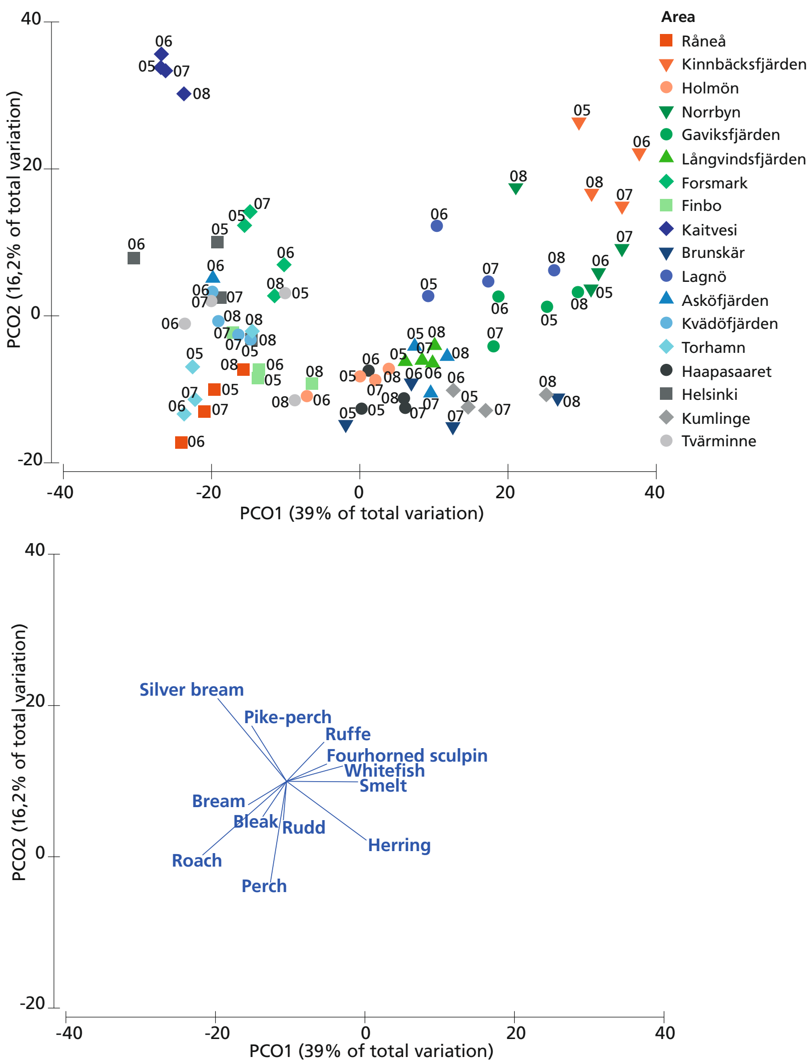


Figure 6. Principal coordinate analysis (PCO) of species composition within the Baltic Sea based on monitoring data from Nordic coastal multi-mesh nets. The analyses show similarity in species composition according to the Bray-Curtis similarity index. PCO-1 explained 68.3% of the total variance and PCO-2 explained 15%. The left plot shows scores for areas and years (18 areas, years 2004–2008). Data points in close proximity are similar in species composition. The right plot shows the vectors of species having the strongest influence on the observed pattern (defined as species with a multiple correlation of <0.2).

Comparison of indicators across monitoring programmes

Patterns in the selected state indicators shown by different monitoring methods were compared for areas where data from two different monitoring methods were available. Results based on data from monitoring using Nordic coastal multi-mesh nets were compared with corresponding data from monitoring using Coastal survey nets (Gulf of Bothnia) and Net series (Baltic Proper).

The level of correspondence was evaluated by multivariate analysis, including all ten state indicators simultaneously, and by univariate analyses of each indicator separately. In all, the same indicators estimated based on different monitoring programmes often showed different trends and varied in signal strength. Thus, the identification of state indicators should preferably be made separately for each monitoring method.

General differences among methods

The multivariate analysis was performed on data from the Gulf of Bothnia, where five areas were monitored with both Nordic coastal multi-mesh nets and Coastal survey nets between 2002–2004 (Brunskär, Råneå) or 2002–2008 (Finbo, Forsmark, Holmön; Figure 1). Data representing the ten state indicators based on both monitoring methods were included in a PCA for all areas.

The results showed that there were differences between the two monitoring methods. Results based on monitoring using Nordic coastal multi-mesh nets were characterised by higher values in the indicators *Large Individuals 40*, *Mean Maximum Length* and *Diversity*, whereas results based on monitoring using Coastal survey nets were characterised by higher values in the indicators *Total Abundance, Cyprinids*, *Non-piscivores*, *Marine Species*, *Large Perch* and *Piscivores*. Also, the variation among areas and years was higher in the Coastal survey net datasets than in the Nordic coastal multi-mesh net datasets (Figure 7). The observed pattern was attributable both to differences among areas and differences between monitoring methods, but the effect of monitoring method was slightly stronger[16]. Thus, the analysis indicated that the two different monitoring methods sampled somewhat different aspects of the fish community.

Differences among methods at indicator level

Separate analyses of each indicator were also performed for all available datasets. Data from Kvädöfjärden in the Baltic Sea sampled with Net series were also included in these analyses. Pair-wise analyses of correlation were applied separately for each area. Although some agreement between monitoring methods was observed, the relationship was often weak and was statistically significant in only a few cases (Table 7).

Selected indicators Nordic coastal multi-mesh nets (64) and Coastal survey nets (09)

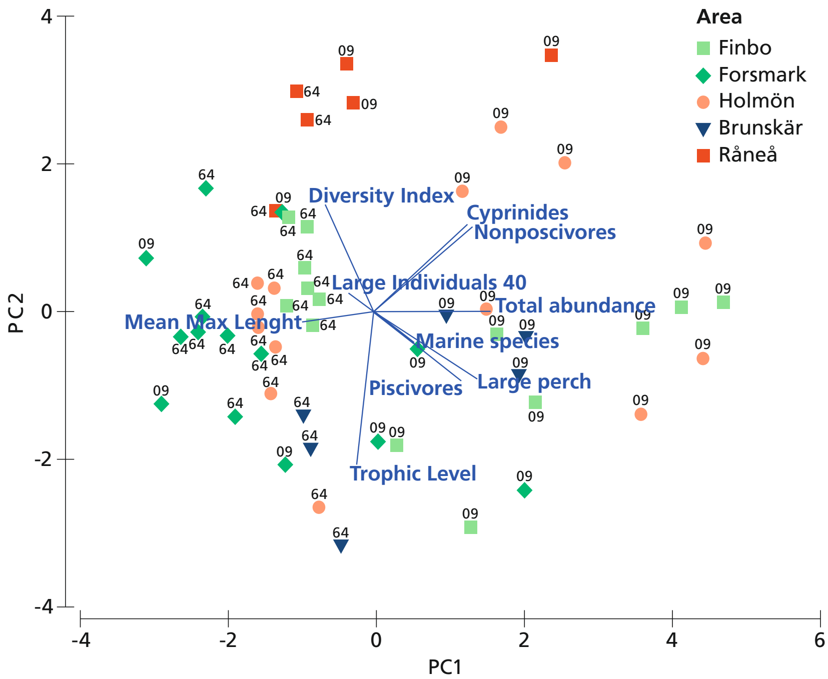


Figure 7. **Principal component analysis comparing the performance of the ten state indicators for two separate monitoring programmes: monitoring using Nordic coastal multi-mesh nets and monitoring using Coastal survey nets. Data points in close proximity have similar indicator values. The differences in indicator values are higher between monitoring methods within the same area than between areas. The first component (PC-1) explained 47.2% of the total variance and the second (PC-2) explained 24.5%.**

Table 7. **Correspondence between state indicator values computed based on data collected by different monitoring methods. Data based on monitoring using Nordic coastal multi-mesh nets were compared with data based on monitoring using Net series in Kvädöfjärden, and Coastal survey nets in all other areas. The years assessed are given beneath each area name. For each area, the slope of the relationship and the correlation coefficient (R^2) is shown. Bold indicates a significant linear relationship at $p < 0.05$.**

Indicator	Brunskär 2002–2004		Finbo 2002–2008		Forsmark 2002–2008		Holmön 2002–2008		Råneå 2002–2004		Kvädöfjärden 2001–2008	
	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
Marine Species	0.25	0.98	-0.03	0.00	0.06	0.06	0.50	**0.56**	3.05	0.67	0.20	0.21
Cyprinids	0.00	0.00	0.06	0.18	0.00	0.00	0.01	0.00	0.16	0.57	-0.39	0.01
Total Abundance	0.19	0.13	-0.01	0.03	0.04	0.08	-0.06	0.18	0.04	0.11	-0.15	0.00
Non-piscivores	0.38	0.75	0.04	0.25	0.07	0.06	-0.03	0.03	0.08	0.10	-0.88	0.06
Large individuals 40	0.025	0.24	0.29	0.09	0.15	0.08	0.24	0.10	-0.34	0.73	0.23	0.04
Piscivores	0.68	0.40	0.00	0.00	-0.02	0.02	-0.08	0.16	-0.06	0.38	0.87	0.28
Mean Maximum Length	0.44	0.96	0.21	0.43	0.08	0.20	0.33	**0.58**	0.31	0.23	-1.03	0.11
Mean Trophic Level	2.61	0.87	0.39	0.43	-0.48	0.39	-0.14	0.08	-2.49	**0.99**	0.31	0.07
Diversity	1.67	0.97	0.34	0.39	-0.35	0.26	-0.79	0.09	-0.63	0.15	-0.02	0.00
Large Perch	0.31	0.43	0.03	0.06	0.06	0.53	0.10	0.35	0.31	0.89	-0.36	0.02

16 Two-way crossed ANOSIM, Effect of 'Area': Rho = 0.55, $p = 0.001$, Effect of 'Monitoring Method': Rho = 0.65, $p = 0.001$)

Part II. Indicator-based assessment of Baltic coastal fish communities

Introduction

Fish community status in the Baltic Sea was assessed for the period 2005 to 2009. The assessment was made by relating the values of ten state indicators within this period to corresponding values during a reference period. The reference period was defined as 1995–2004, which was the longest period (excluding the assessment period) for which data were available from all areas. Long-term datasets from 11 areas were available for assessment (Figure 8). These included time series ranging from 9 to 23 years within the period 1987–2009.

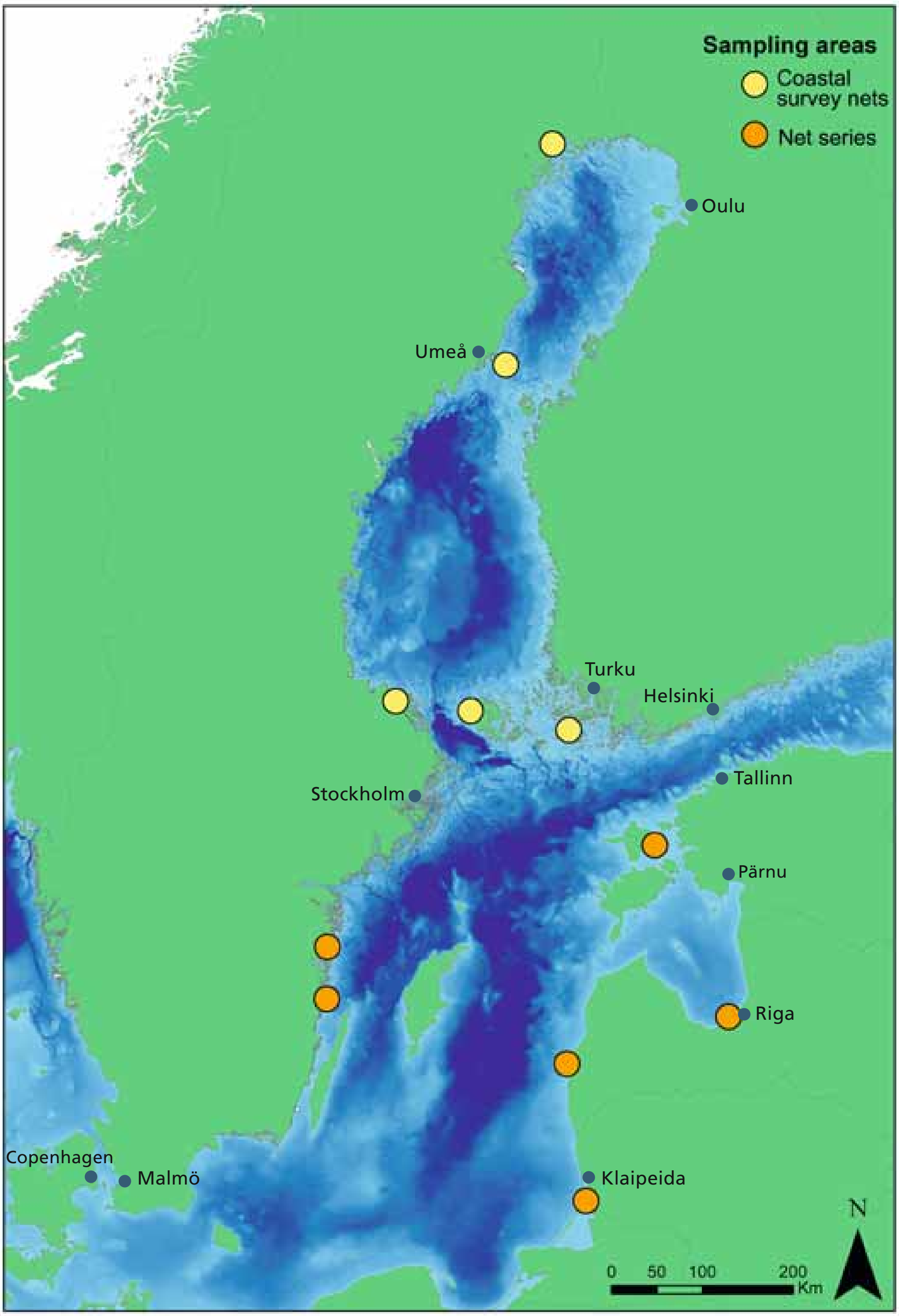


Figure 8. Baltic Sea areas monitored using Coastal survey nets and Net series.

Methods

First, an overall analysis of all areas was performed. The purpose of this analysis was to compare the level of differences among areas with the level of variation among years within the assessment period. The analyses were based on a set of ten state indicators, and also based on species composition. The state indicators were selected using the same procedure as described for monitoring using Nordic coastal multi-mesh nets in Part I.

Thereafter, separate area-wise assessments were performed. The status of the fish community in each area was assessed based on the set of ten state indicators, analysed together and separately. Trends in potential pressures were described, when available.

The analyses were performed separately for areas monitored using Coastal survey nets in the Gulf of Bothnia, and for areas monitored using Net series in the Baltic Proper. One limitation to the analysis was that there have been some methodological differences among areas in monitoring using Net series, with regards to net length, depth and mesh-size applied. As no corrections were made for these differences, quantitative comparisons among areas in the Baltic Proper can only be evaluated on a general level. However, the differences do not affect the assessment of trends within each area.

In all datasets, individuals less than 14 cm in length were excluded, as these were not considered to have been sampled representatively to their true abundance, as determined from plots of catches per length group.

State indicators

For each monitoring method, ten state indicators were identified based on the evaluation of 23 initial metrics for signal strength and redundancy, following the same procedure as described in Part I (Table 8). These state indicators were subsequently used for further assessment analyses.

Table 8. State indicators used for the assessment of coastal fish communities in the Gulf of Bothnia (Coastal survey nets) and Baltic Proper (Net series).

Gulf of Bothnia	Baltic Proper
Species Composition	
Total Abundance	*Total Abundance*
Cyprinids	*Cyprinids*
Marine Species	*Marine Species*
Fresh-water Species	
Size Structure	
Large Individuals 40	*Large Individuals 30*
Mean Maximum Length	*Mean Maximum Length*
Mean Length Perch	*Mean Length Perch*
Trophic Structure	
Mean Trophic Level	*Mean Trophic Level*
Piscivores	*Piscivores*
	Piscivore Proportion
Species Diversity	
Diversity	*Diversity*

Analyses of differences among areas

Analyses of differences among areas were performed for areas with data covering the assessment period (2005–2009). Thus, data from Råneå and Brunskär were not included. Differences were assessed with respect to the ten state indicators, as analysed using PCA, and also based on species composition, as analysed using PCO[17].

In addition, the importance of variation among areas in relation to variation over time within the same area was evaluated by a two-factor permutation-based MANOVA (PERMANOVA), testing for the effects of the factors 'area' and 'year'. If any of these factors were significant, pair-wise tests were undertaken between levels within these factors. However, the interaction effect between the two factors could not be assessed due to insufficient numbers of replicates.

Assessment of temporal trends

The assessment of the status of fish communities was based on the values of the ten state indicators in the assessment period (2005–2009), relative to the values in the reference period (1995–2004). The time frame of the reference period was chosen

17 Similarity was quantified based on Euclidian distances for the PCA and based on the Bray-Curtis similarity index for the PCO. Abundance-based indicators were square root-transformed prior to analyses, and values based on proportions were arc-sine transformed. The analyses of datasets on species composition, were performed on log (x+1) transformed values.

because it was the longest time series available for all areas included.

Overall changes in the fish community were assessed by a simultaneous analysis of all ten state indicators using PCA. This method also made it possible to identify the indicators which contributed most to temporal changes. The state of the fish community in each area was then assessed based on each indicator separately.

A divergence from the reference period was identified if a majority of values observed for the years 2005–2009 occurred outside the 95% confidence interval of the mean during the reference period (1995–2004). In addition, long-term trends in each indicator were assessed by linear regression.

Results

Differences among areas in indicator values and species composition

The spatial and temporal patterns observed based on the analysis of state indicators and based on species composition were roughly similar in the Baltic Proper, and somewhat less similar in the Gulf of Bothnia. In general, the variation among areas was smaller based on the indicator dataset than based on the species dataset. Another difference was that aspects of size structure, and to some extent trophic structure and species diversity, which were not encompassed by the species dataset, were important for characterising some areas within the indicator dataset.

For both the indicator and species datasets, variation among monitoring areas was higher than variation among years. The results indicate that local conditions must be taken into account when assessing basin-wide trends and when setting targets for the state of fish communities.

Gulf of Bothnia

Spatial and temporal patterns in state indicators and species composition were compared for the areas Holmön, Finbo and Forsmark over the period 2004–2009 (Figure 9).

For the state indicators, a difference was observed among areas but not among years[18]. Pair-wise tests of differences among areas suggested that

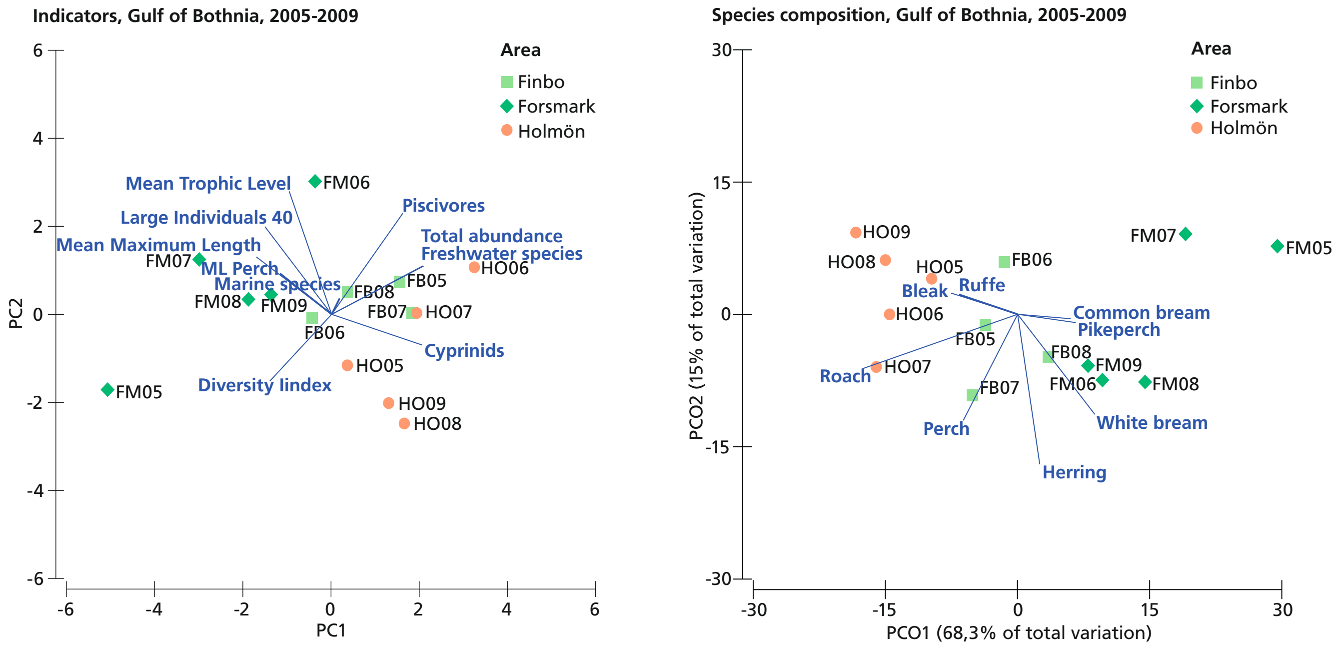


Figure 9. Differences among monitoring areas in the Gulf of Bothnia based on the ten state indicators (upper; PCA: PC-1 explained 49.9% of the total variance and PC-2 explained 21.2 %) and species composition (lower; PCO: PCO-1 explained 68.3% of the variance and PCO-2 explained 15%). Points in close proximity have a high degree of similarity. The main direction of the variables analysed is shown as vectors, including variables with a multiple correlation of > 0.2.

18 Two-factor PERMANOVA, Effect of 'Area': Pseudo-F = 3.68, *p* = 0.01, 'Year': Pseudo-F = 0.74, *p* = 0.74.

the Forsmark area was characterised by higher values in the indicators *Mean Trophic Level*, and in indicators reflecting size structure (*Mean Length Perch*, *Mean Maximum Length*, and *Large Individuals 30*) than the two other areas, whereas the Holmön area was characterised by high values in *Cyprinids*[19].

A similar pattern was observed in the analyses based on species composition[20], but the difference among areas was stronger[21]. Species contributing most to the observed pattern were bream, white bream and pikeperch, which were more common at Forsmark, as well as roach, bleak and ruffe, which were more common at Holmön.

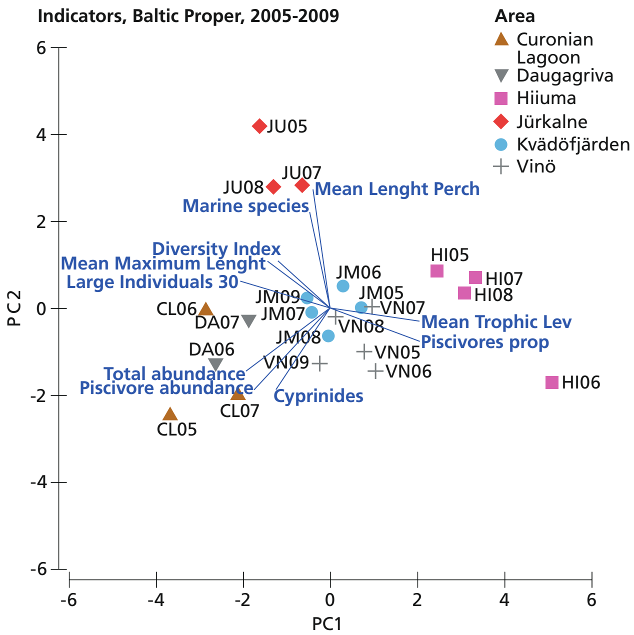
The Finbo area was intermediate to the other two areas in both analyses. But was almost statistically distinct from Holmön in the analysis based on species composition, but not based on indicators.

Baltic proper

Spatial and temporal patterns in state indicators and species composition were compared for the areas Curonian Lagoon, Daugavgriva, Hiiumaa, Jūrkalne, Kvädöfjärden, and Vinö over the period 2004–2009 (Figure_10).

In general, the results based on indicators and on species composition showed a similar pattern. The main difference between them was that the dataset based on indicators showed less variation among observations. In both datasets, however, differences were observed among areas, but not among years[22].

The areas Hiiumaa and Jūrkalne were clearly separated from all other areas. In the analyses based on state indicators, Hiiumaa was mainly characterised by high values in *Mean Trophic Level* and *Piscivore Proportion,* and Jūrkalne by high values in *Marine Species* and *Mean Length*



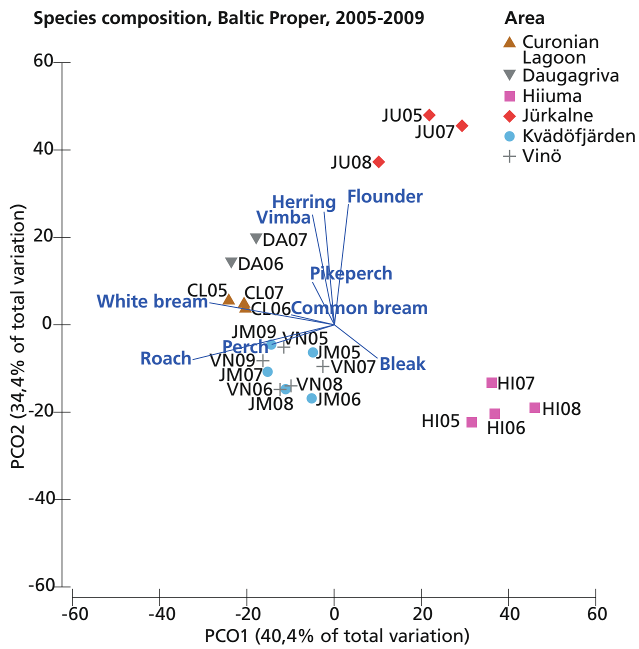


Figure 10. Differences among monitoring areas in the Baltic Proper based on the ten state indicators (upper; PCA: PC-1 explained 45.6% of the variance and PC-2 26.2%) and species composition (lower; PCO: PCO-1 explained 40.4% of the variance and PCO-2 explained 34.4%). Points in close proximity have a high degree of similarity. The main direction of the variables analysed is shown as vectors, including variables with a multiple correlation of > 0.2.

19 PERMANOVA pair-wise tests of 'Area': Finbo *vs* Forsmark: t = 1.54, *p* = 0.15, Finbo *vs* Holmön: t = 0.88, *p* = 0.58, Forsmark *vs* Holmön: t = 3.06, *p* = 0.0081.
20 Two-factor PERMANOVA, Effect of 'Area': Pseudo-F = 8.63, *p* = 0.0009, 'Year': Pseudo-F = 0.69, *p* = 0.76.
21 PERMANOVA pair-wise tests 'Area': Finbo *vs* Forsmark: t = 1.97, *p* = 0.075, Finbo *vs* Holmön: t = 2.10, *p* = 0.053, Forsmark *vs* Holmön: t = 4.16, *p* = 0.0081.
22 Indicator dataset, Two-factor PERMANOVA, Effect of 'Area': Pseudo-F = 7.82, *p* = 0.0001, 'Year': Pseudo-F = 0.72, *p* = 0.73. Species dataset, Two-factor PERMANOVA, Effect of 'Area': Pseudo-F = 21.7, *p* = 0.0001, 'Year': Pseudo-F = 1.64, *p* = 0.076.

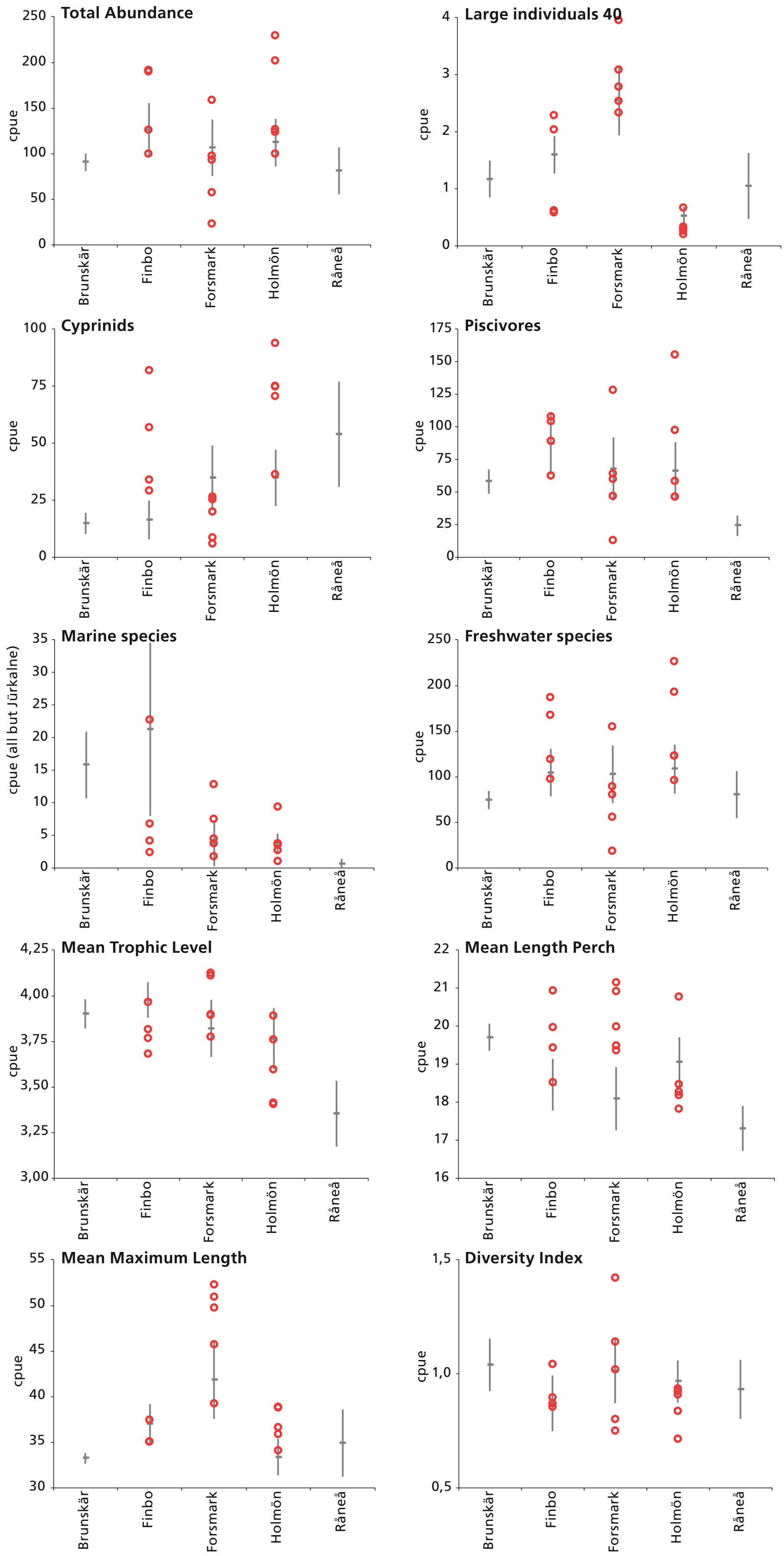


Figure 11. State indicators for the fish community in the Gulf of Bothnia. Values during the assessment period (2005–2009; red circles) are shown in relation to the 95% confidence interval of the mean within the reference period (1995–2004; grey bars). No monitoring with Coastal survey nets was performed in Brunskär and Råneå within the assessment period.

Perch. In comparison to Hiiumaa, the Curonian Lagoon area was characterised by relatively high values in the indicators *Large Individuals 30*, *Piscivores, Cyprinids*, *Mean Maximum Length,* and *Diversity*. The areas Kvädöfjärden and Vinö clustered together and were characterised by average values for all indicators.

In the analyses based on species composition, the main differences between areas were due to relatively high abundances of bleak at Hiiumaa and flounder at Jūrkalne. Again, Kvädöfjärden and Vinö were clustered together, and were mainly characterised by perch and roach.

Area-wise assessment of the Gulf of Bothnia

Summary

The state of the fish community in the Gulf of Bothnia was assessed within the period 2005–2008 for the Finbo area, and 2005–2009 for the Forsmark and Holmön areas. In the other two areas, Brunskär and Råneå, monitoring using Coastal survey nets ended in 2004, and was replaced by monitoring using Nordic coastal multi-mesh gillnets. See Figure 11 for a summary of the outcome. The presence of long-term trends over the whole dataset available in each area is shown in Table 9.

Table 9. Summary of trends in individual state indicators in the Gulf of Bothnia. Note that the analyses are performed over different time periods in different areas, as indicated in the column headings, in order to include the whole time series available for each area.

Gulf of Bothnia	Brunskär 1991–2004	Finbo 1991–2008	Forsmark 1987–2009	Holmön 1989–2009	Råneå 1994–2004
Species Composition					
Total Abundance	ns	ns	ns	ns	ns
Cyprinids	+	+	ns	+	ns
Marine Species	-	ns	ns	ns	ns
Freshwater Species	+	+	ns	ns	ns
Size Structure					
Large Individuals 40	ns	ns	+	-	ns
Mean Maximum Length	ns	ns	+	+	+
Mean Length Perch	ns	+	+	ns	ns
Trophic Structure					
Mean Trophic Level	ns	ns	ns	-	ns
Piscivores	ns	ns	ns	ns	ns
Species Diversity					
Diversity	ns	ns	ns	ns	ns

+ denotes an increasing trend; – denotes a decreasing trend; ns denotes a non-significant trend at $\alpha = 0.05$.

During the assessment period, values in the indicators reflecting species composition were average in relation to those for the reference period (1994–2004) in all areas, with the exception of *Cyprinids*, which showed a long-term trend of increasing abundance in three of the areas studied (Brunskär, Finbo, Holmön). This trend continued during the assessment period, when above average values where observed in the Finbo and Holmön areas (the Brunskär area was not included in this part of the analysis). Also, an increasing trend in *Freshwater Species* was observed in two of the areas (Brunskär, Finbo). The indicator *Marine Species* showed a decreasing trend in one area (Brunskär). However, this time series ended in 2004 and did not cover the most recent years. No changes were seen in *Total Abundance*.

The strongest overall changes were seen in indicators reflecting size structure. In fact in the Forsmark area, an increasing trend was seen in all indicators reflecting size structure. Within the assessment period in the Forsmark area, above average values were observed in all indicators reflecting size structure, with the exception of *Large Individuals 40*, which showed average values. As for the other areas, *Mean Length Perch* also showed above average values in the Finbo and Holmön areas during the assessment period, and a long-term increasing trend in the Finbo area. The indicator *Mean Maximum Length* showed an increasing trend also in the Holmön and Råneå areas. Only one incidence of a decreasing trend was seen in the indicators reflecting size structure. In the Holmön area, the indicator *Large Individuals 40* showed a decreasing trend. The contrasting trends among indicators of size structure observed for the Holmön area are not contradictory, as *Mean Maximum Length* reflects an aspect of species composition, indicating the abundance of potentially large-sized species, whereas *Large Individuals 40* reflects the actual number of large-sized fish in the dataset.

The indicators reflecting aspects of trophic state showed average values in relation to the reference period in all areas, and no general trends over time were observed. However, a decreasing trend in *Mean Trophic Level* was seen in the Holmön area, mainly reflecting an increase in non-piscivore species.

The indicator *Diversity* showed average values in relation to the reference period in all monitoring areas, and did not show any consistent trends over time in any area.

Brunskär

Monitoring data for the Brunskär area covered the period 1991–2004. Thus, the sampling programme does not cover the assessment period (2005–2009). The fish community in later years of monitoring differed from the first three years, but was relatively stable between 1994 and 2004. Over the years monitored, the abundance of freshwater species, particularly of Cyprinids, increased and the mean length of perch decreased. Also, the abundance of marine species decreased.

The analyses of all indicators together (Figure 12) showed that during years with high abundance of fish, the abundance of freshwater species, piscivores and estimated values of mean trophic level were also high. Such years occurred irregularly during the period studied. These years probably reflect periods with strong recruitment of perch, as they were also characterised by low values in the indicator *Mean Length Perch.* Simultaneously, relatively low values in the indicator *Diversity* were seen, which together with high values in *Total Abundance*, indicates that a few species were dominating the fish community. During years with high Cyprinid abundance, relatively high values in the indicators *Mean Maximum Length, Large Individuals 40* and *Diversity* were also often noted. However, the indicator *Mean Maximum Length* had a large influence on the overall picture mainly due to high values in one year (1991).

The abundance of freshwater species, and especially of Cyprinids, showed an increase over the years studied. The first years of the monitoring period were characterised by relatively high values in the indicator *Marine Species*. Thereafter, the abundance of marine species has decreased (Figure 13). In relation to the other areas studied, the trends observed for the Brunskär area were most similar to those observed in the Finbo area, with an increasing trend in *Cyprinids* and *Freshwater Species*. However, the areas differed in that the decrease observed in *Marine Species* in the Brunskär area was not observed in Finbo, where on the other hand an increase in *Mean Length Perch* was observed.

The observed changes did not coincide with changes in nutrient loading or water transpar-

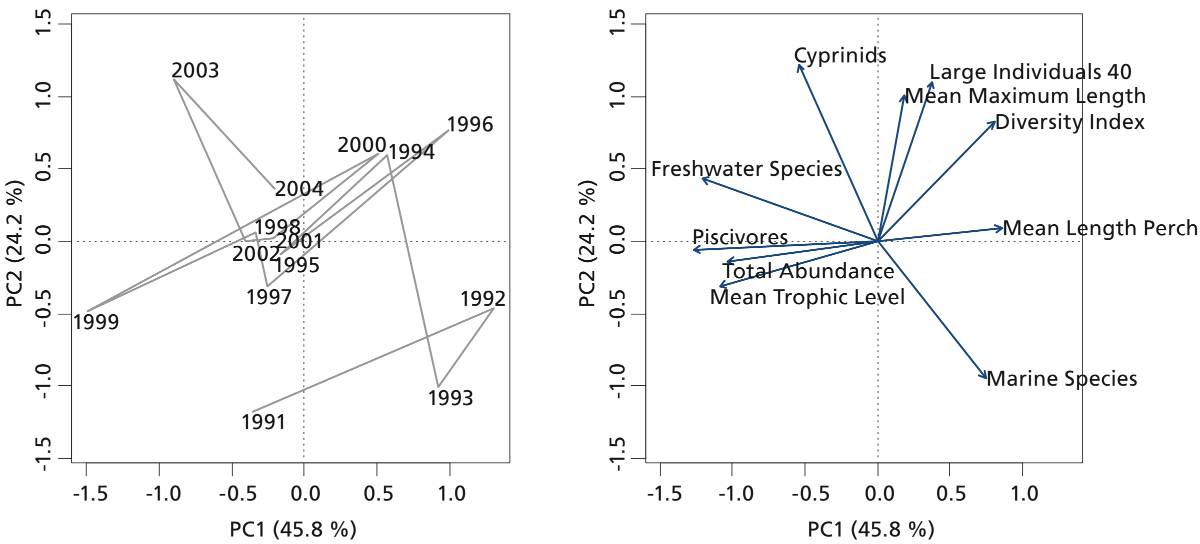


Figure 12. **Analysis of all state indicators for the Brunskär area (PCA, 1991–2004). In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 45.8% of the total variance and the second (PC-2) explained 24.2%.**

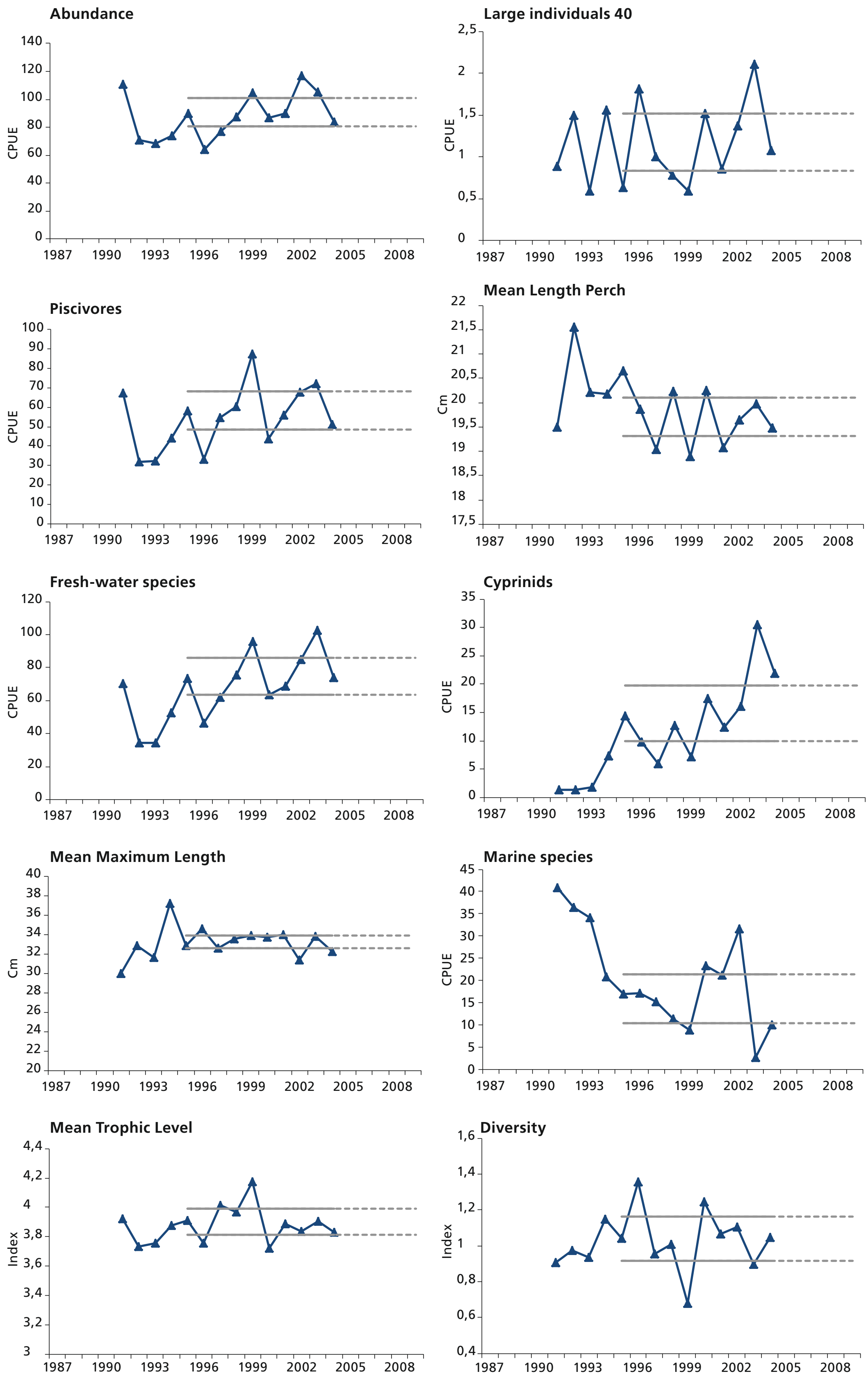


Figure 13. Temporal changes in the state indicators in the Brunskär area. The area was monitored using Coastal survey nets in 1991–2004. Since 2002, monitoring has continued using Nordic coastal multi-mesh nets (data not shown). Grey lines show the 95% confidence interval of the mean for each indicator value for the reference period (1995–2004).

ency, which have been stable in the area over the period studied (Figure 14). However, an increase in water temperature was observed, which may have had a positive effect on population increases in Cyprinid fish (mainly ide, roach and white bream). An increasing water temperature may also partly explain the observed increase in abundance of freshwater species and the decrease in abundance of marine species. Among the available pressure variables, an increased abundance of grey seals and cormorants was also observed in the area.

Since 2002, the area has been monitored using another gear; Nordic coastal multi-mesh nets. According to data from this monitoring method, the abundance of Cyprinids in the area remained high until 2009, when catches were relatively low.

The development of potential pressure over the same time period is shown in Figure 14. During 1991–2004, increases were observed in grey seals and cormorants. An increase was also seen in temperature until 2003, but not after including data

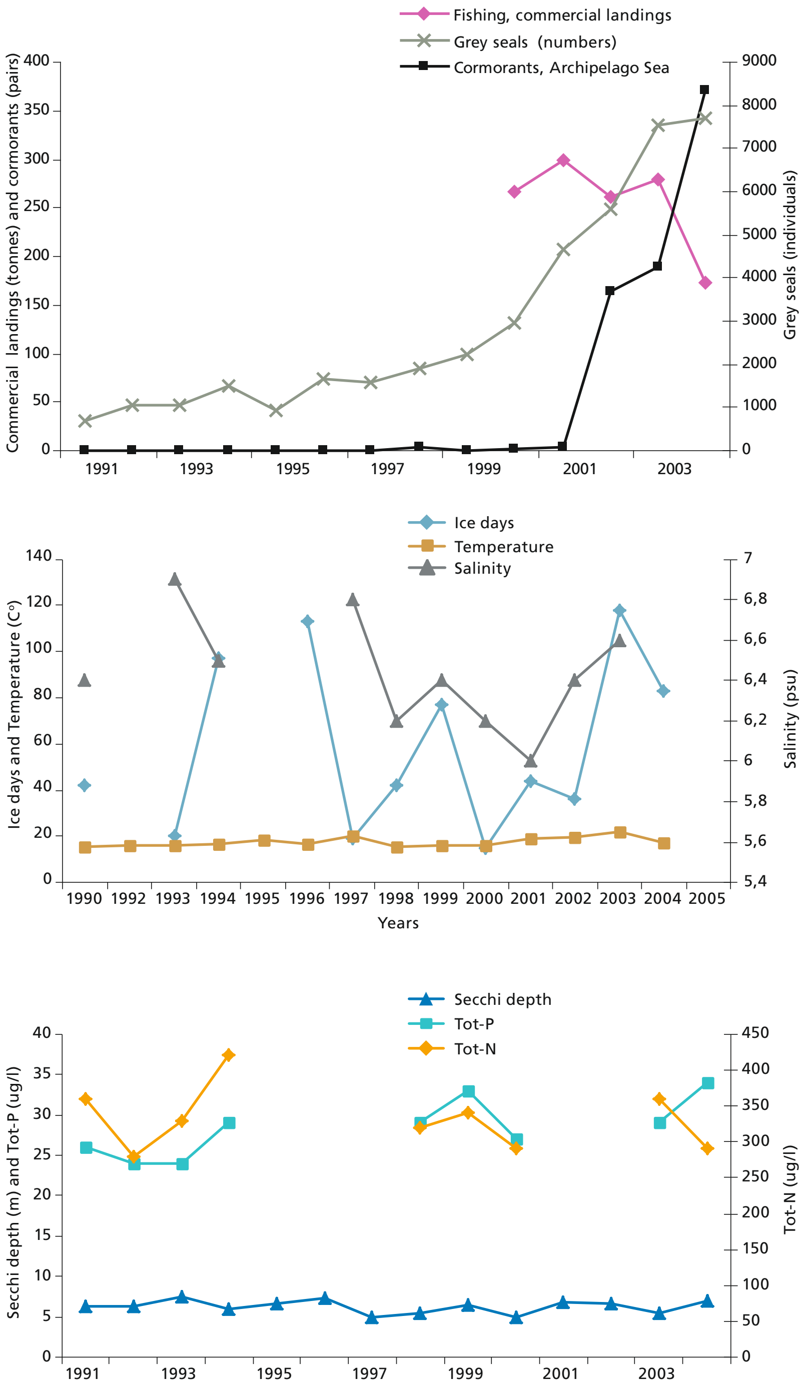


Figure 14. Temporal changes in variables potentially affecting fish communities in the Brunskär area.

from 2004. Notably, no long-term trend was seen in water transparency.

Finbo

The state of the fish community in the Finbo area in the four recent years of monitoring (2005–2008) was characterised by high abundance of freshwater fish, especially Cyprinids, as well as by relatively large values in indicators reflecting size structure. The changes were probably mainly related to environmental factors such as increasing temperature and decreasing water transparency. The abundance of marine species and the mean trophic level were lower than during the reference period.

Monitoring data covered the period 1991–2008. During the first years of monitoring, the overall pattern of the fish community was characterised by relatively high diversity and abundance of marine species, and in the early 2000s by relatively high values in the indicators *Mean Maximum Length* and *Mean Trophic Level*. During the four most recent years of monitoring (2005–2008), many of the indicators showed relatively high values. Some of the years within this period were specifically characterised by high abundances of freshwater species, including *Cyprinids* and *Piscivores* (Figure 15). The indicators *Cyprinids* and *Freshwater Species* also showed a linear increase over the whole period studied (Figure 16).

Looking at each indicator separately, several of the state indicators showed values above average during at least two of the four years of the assessment period, including *Cyprinids*, *Total Abundance*, *Large Individuals 40*, *Mean Length Perch*, and *Freshwater Species*. Values below average during at least two of the four years of the assessment period were seen in *Marine Species* and *Mean Trophic Level*.

The development of potential variables affecting fish communities are shown in Figure 17. In the Finbo area, increasing water temperatures in summer, as well as decreasing salinity and water transparency have been observed. These changes have probably had a positive effect on population development in Cyprinids and other freshwater species. These changes, in turn, may have resulted in relatively low values for the indicator *Mean Trophic Level* during the years of Cyprinid dominance. The same changes in the environment could also, at least partly, explain the relatively low abundance of marine species in recent years. The high values for the indica-

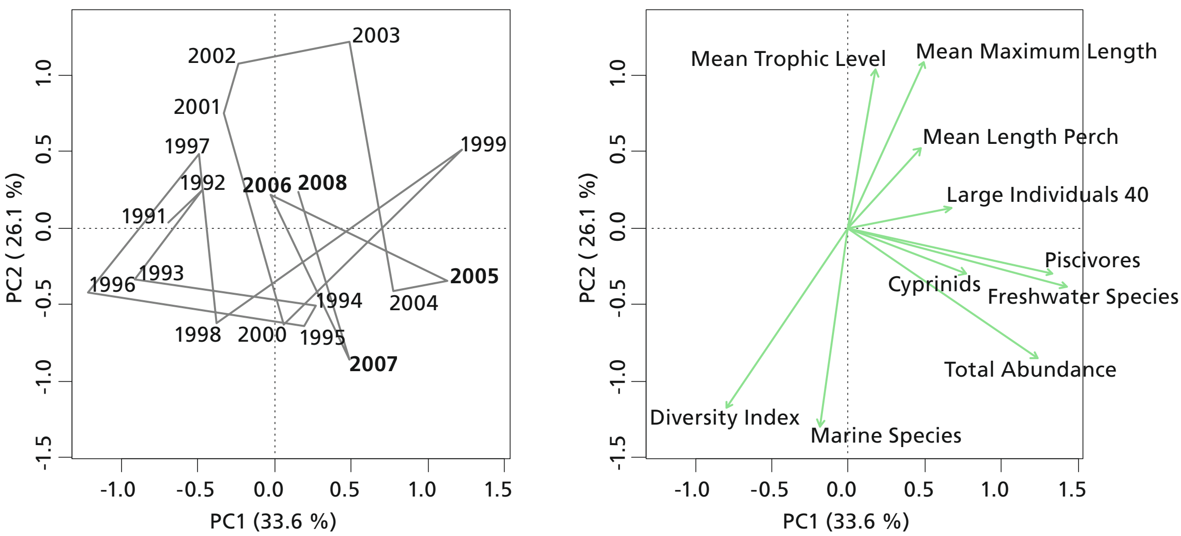


Figure 15. Analysis of all state indicators for the Finbo area (PCA, 1991–2008). In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years, by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 33.6% of the total variance and the second (PC-2) explained 26.1%.

tor *Mean Length Perch* in more recent years probably resulted from a strong recruitment of perch in the period 1997–2002. The other pressures showed a more variable signal. During the monitoring period, landings of coastal demersal fish decreased, as did cormorant abundance. Thus, the increasing abundance of fish may also be related to decreasing mortality. However, an increase was seen the abundance of grey seals in this period.

Figure 16. Temporal changes in the state indicators in the Finbo area. The area was monitored using Coastal survey nets in 1991–2008. In 2009, monitoring was only conducted using Nordic coastal multi-mesh nets (data not shown). Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2005–2009).

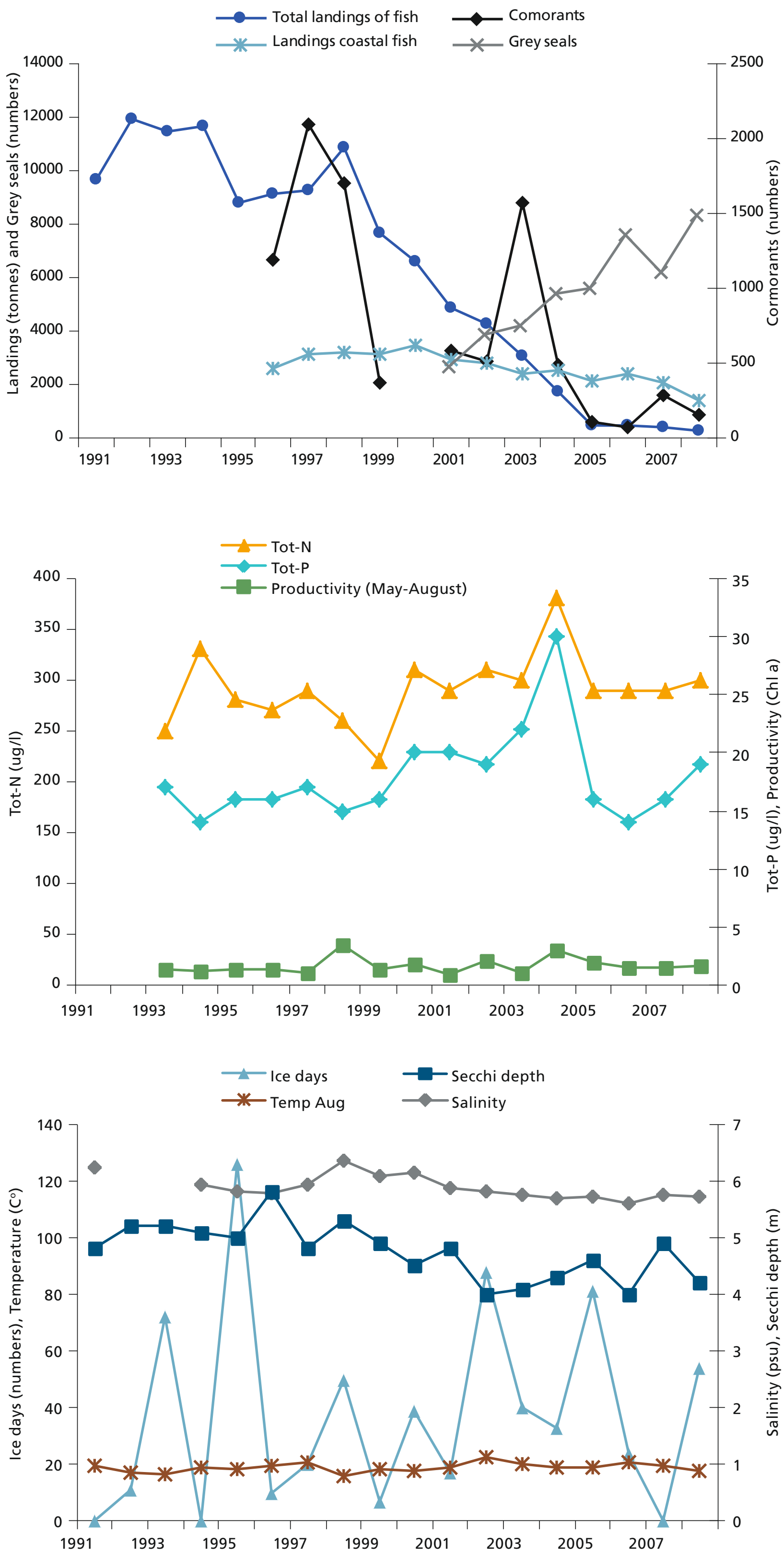


Figure 17. Temporal changes in variables potentially affecting fish communities in the Finbo area. The first panel shows trends in indicators primarily related to fish mortality.

Forsmark

The state of the fish community in the Forsmark area during the assessment period (2005–2009) was characterised by relatively high values in indicators reflecting size structure, and by average values in the other indicators. The abundance of freshwater species showed a small decreasing trend, mainly due to relatively high catches in earlier years (mid-1990s).

Monitoring data covered the period 1987–2009. The most recent years of monitoring were characterised by average values in most indicators, with a tendency towards high values in indicators reflecting size structure and also by relatively low values in *Cyprinids* (Figure 18). *Total Abundance* was strongly correlated to *Freshwater Species,* and also to *Piscivores*, mainly reflecting a dominance of perch in all years of monitoring. The highest values in these indicators occurred in the mid-1990s. The indicators *Diversity* and *Mean Trophic Level* showed opposite patterns, with low values in diversity during years with quantitative dominance of piscivores (mainly perch). *Diversity* was positively correlated with *Marine Species*, which showed high values at irregular time intervals throughout the monitoring period.

Looking at trends in each indicator separately, linear increases were observed over the whole monitoring period in two of the indicators reflecting size structure: *Large Individuals 40* and *Mean Maximum Length*. The indicators *Mean Maximum Length* and *Mean Length Perch* showed higher than average values within the assessment period. In addition, a small decreasing trend was seen in the indicator *Freshwater Species* (Figure 19).

The development of potential variables affecting the state of coastal fish communities is shown in Figure 20. A decrease was seen in the level of total phosphorus loading from land, which may be related to changes in *Cyprinid*s. No trend over time was seen in the other indicators.

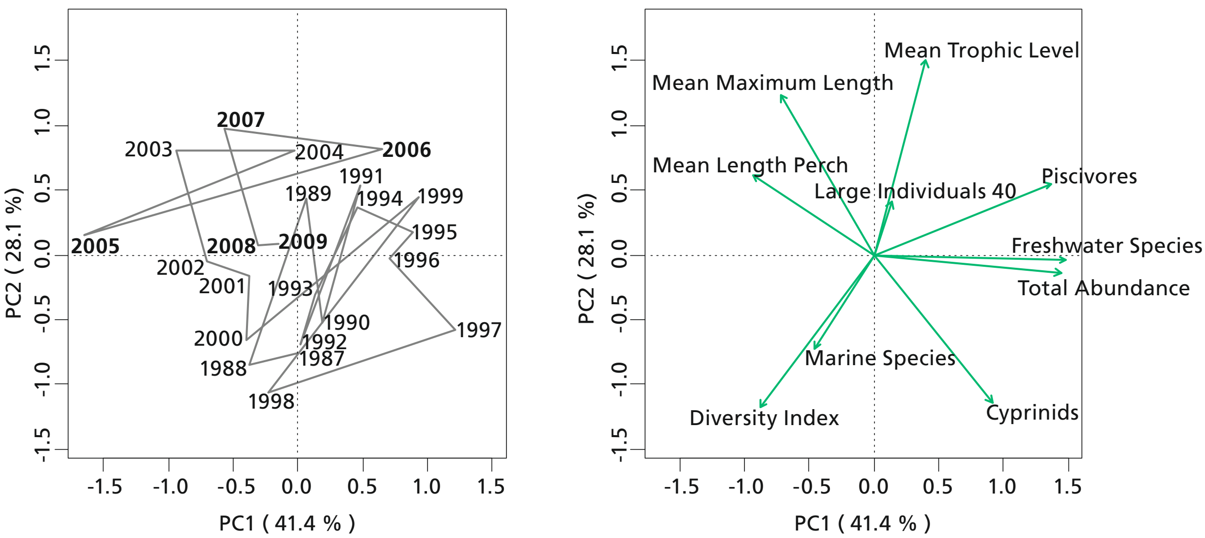


Figure 18. Analysis of all state indicators for the Forsmark area (PCA, 1987–2009). In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 41.4% of the total variance and the second (PC-2) explained 28.1%.

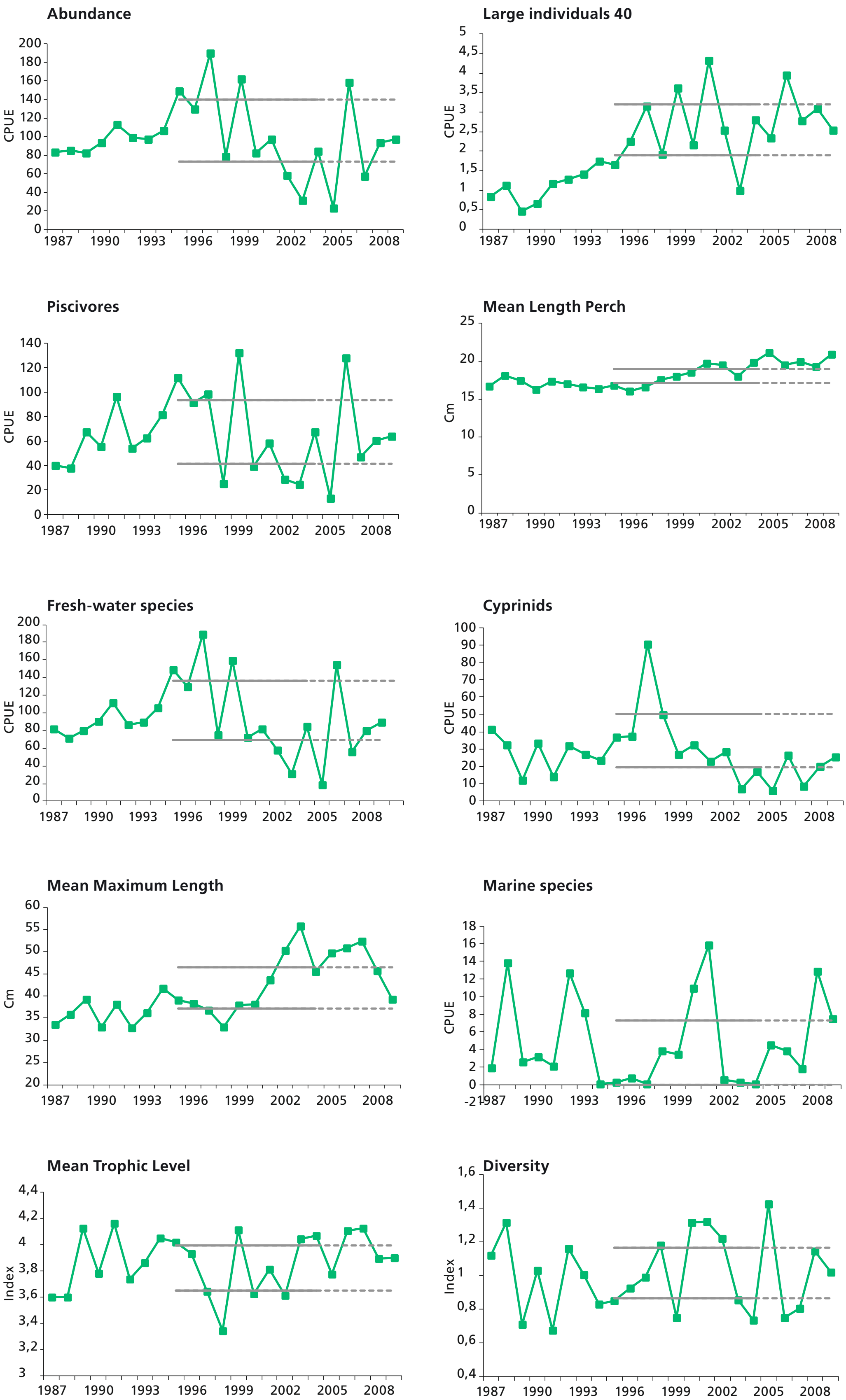


Figure 19. Temporal changes in the state indicators in the Forsmark area. The area was monitored using Coastal survey nets in 1987–2009. Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2005–2009).

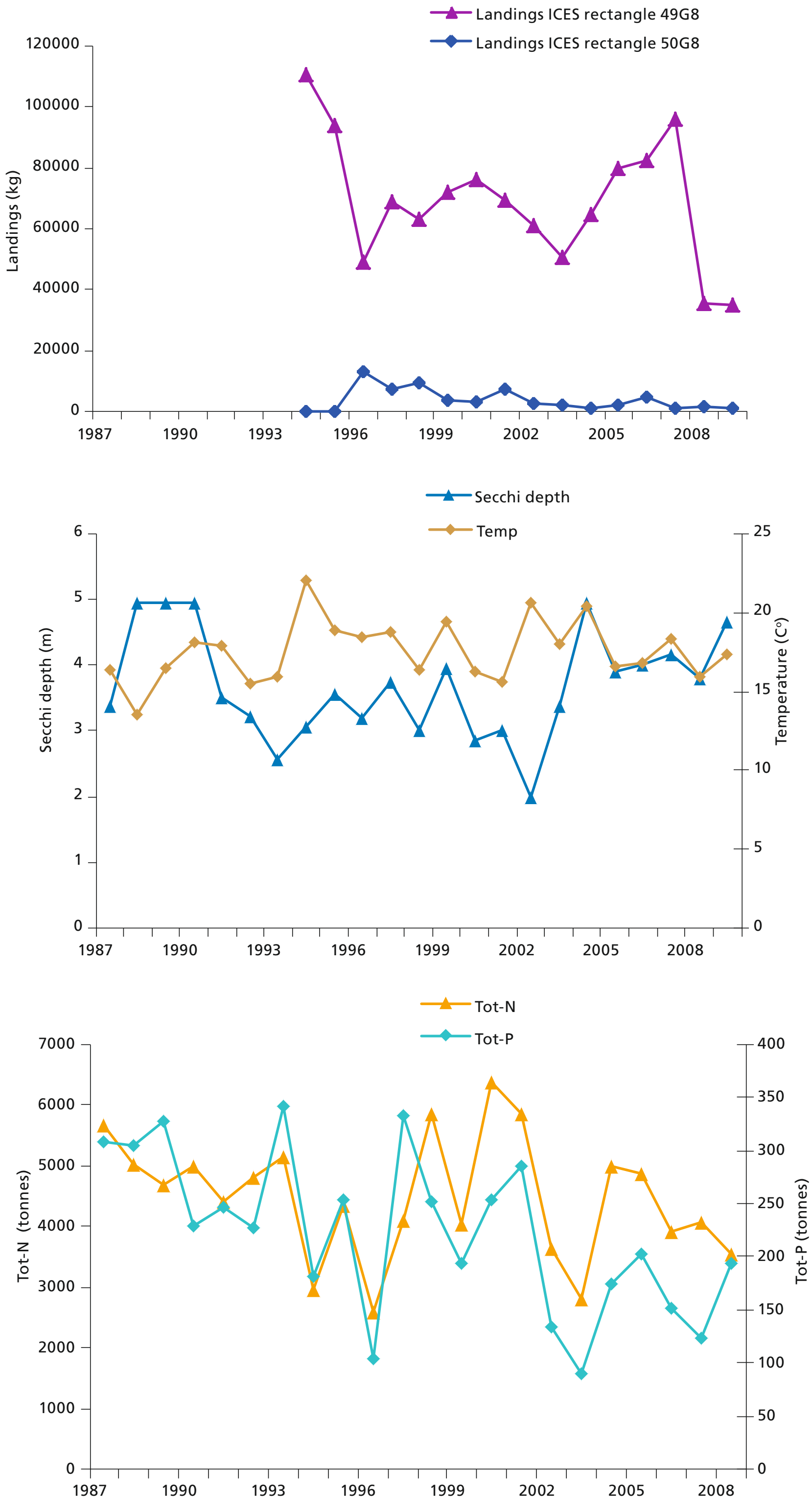


Figure 20. Temporal changes in variables potentially affecting fish communities in the Forsmark area.

Holmön

The state of the fish community in the Holmön area during the assessment period (2005–2009) showed some divergence from previous years of monitoring, mainly characterised by increased abundance of potentially large-bodied fish species and Cyprinids, but by low abundance of large individuals, a decreasing mean length of perch and a low mean trophic level.

Monitoring data covered the period 1989–2009. A relatively high similarity among years was seen within the assessment period, when looking at all indicators simultaneously. The period 2005–2009 differed from previous years mainly by high values in the indicators *Mean Maximum Length* and *Cyprinids*, and by low values in *Large Individuals 40* and *Mean Trophic Level* (Figure 21).

The main trends observed in the multivariate analyses were seen as above average values in *Mean Maximum Length,* and an increasing trend in *Cyprinids* (Figure 22). The indicator *Mean Trophic Level* showed a decreasing trend over the monitoring period as a whole, mainly reflecting an increased abundance of roach and bleak. The indicator *Large Individuals 40* showed lower than average values during the main part of the assessed years. A decreasing trend was also seen in *Mean Length Perch.*

There was, however, no strong relationship between the changes in state indicators and the potential pressures variables studied, as these did not show any significant trends during the years for which data were available (Figure 23). However, there appeared to be a slight decrease in phosphorus loading from land.

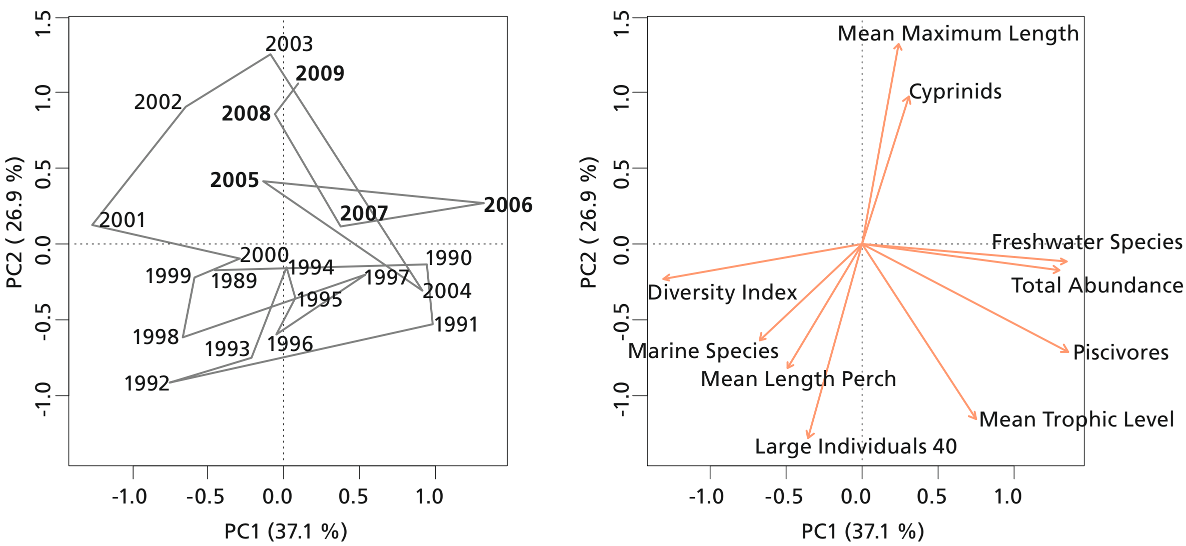


Figure 21. Analysis of all state indicators for the Holmön area (PCA, 1989–2009). In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 37.1% of the total variance and the second (PC-2) explained 26.9%.

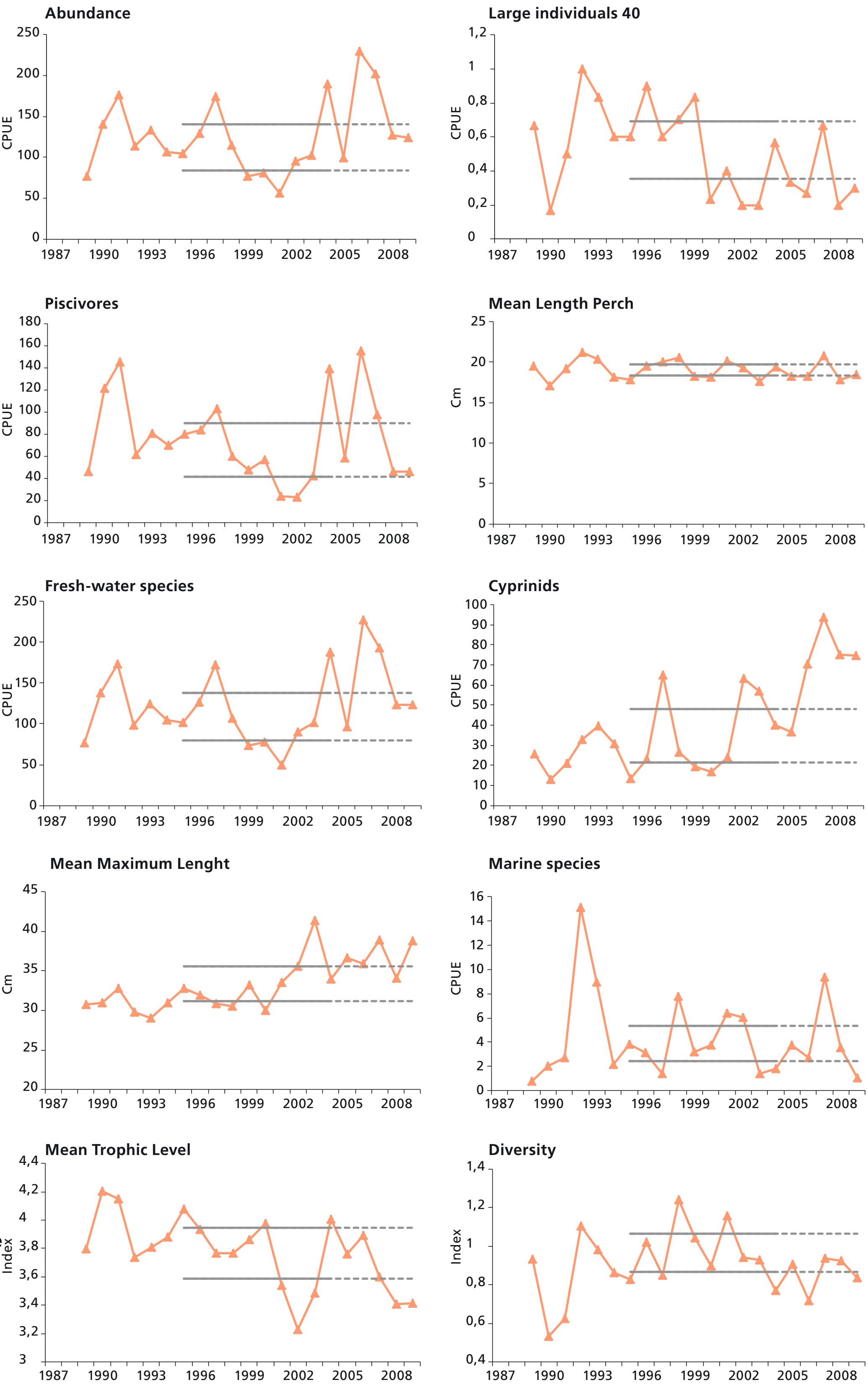


Figure 22. Temporal changes in the state indicators in the Holmön area. The area was monitored using Coastal survey nets in 1989–2009. Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2004–2009).

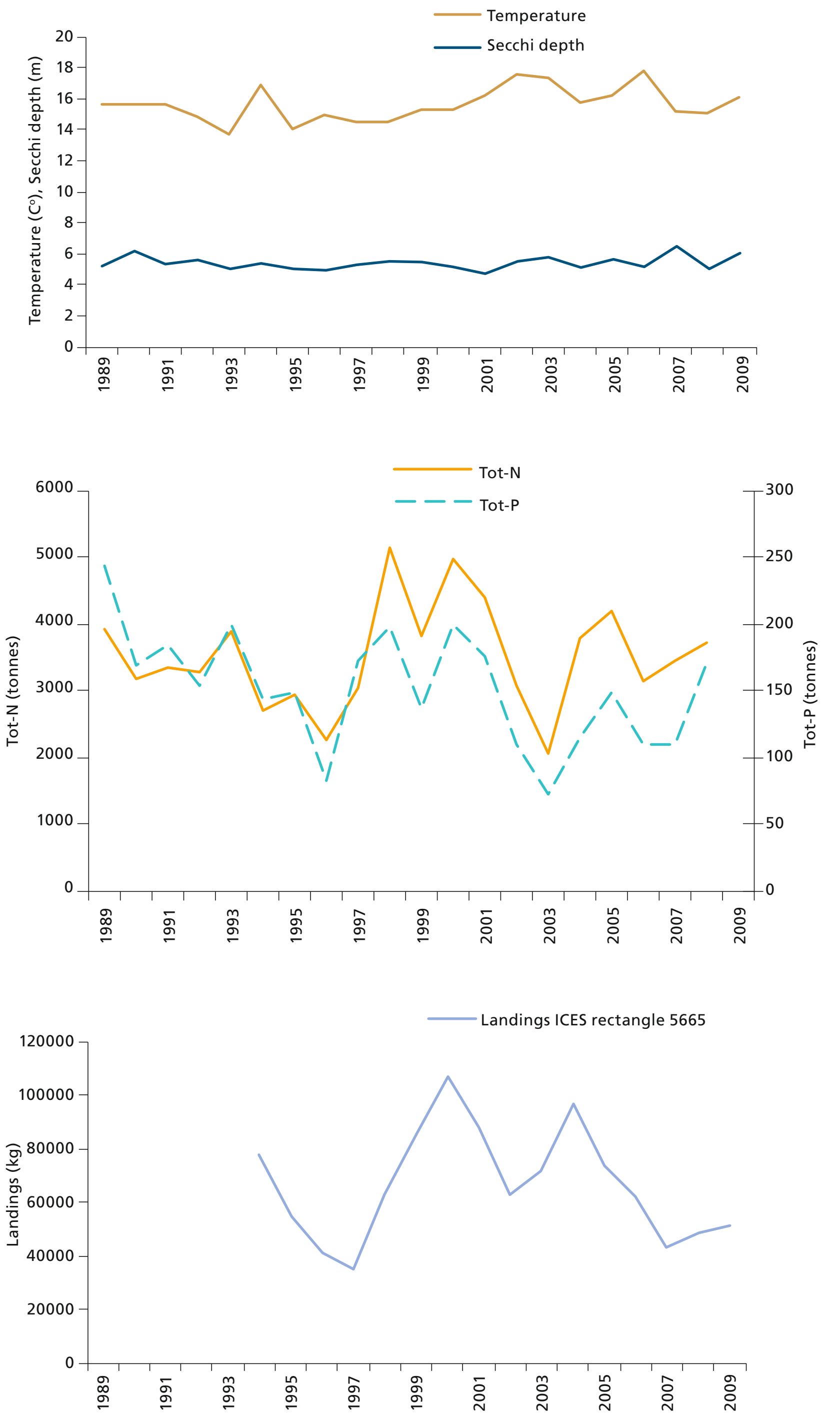


Figure 23. Temporal changes in variables potentially affecting fish communities in the Holmön area.

Råneå

Monitoring data covered the period 1994–2004. Thus, the sampling programme does not cover the assessment period (2005–2009). During the years of monitoring, no strong changes in the fish community were observed, and most indicators showed similar values in different years. However, an increase in the abundance of potentially large-bodied fish species was observed.

According to the multivariate analysis, many indicators contributed equally to the observed temporal development (Figure 24). The most influential indicators were *Mean Length Perch*, *Mean Trophic Level*, *Piscivores*, *Cyprinids*, *Total Abundance* and *Freshwater Species*. However, no clear overall temporal trend was seen. Assessing linear trends for each indicator separately, an increase over time was seen in *Mean Maximum Length*, whereas no trend was seen in the other indicators (Figure 25). No trends over time were seen in the data on potential variables driving changes in the fish community (Figure 26).

From 2002 onward, the Råneå area has been monitored using Nordic coastal multi-mesh nets. This monitoring method is not directly comparable to the time series presented here. However, data from monitoring using Nordic coastal multi-mesh nets indicate an increasing trend in size structure of the fish community up to 2009.

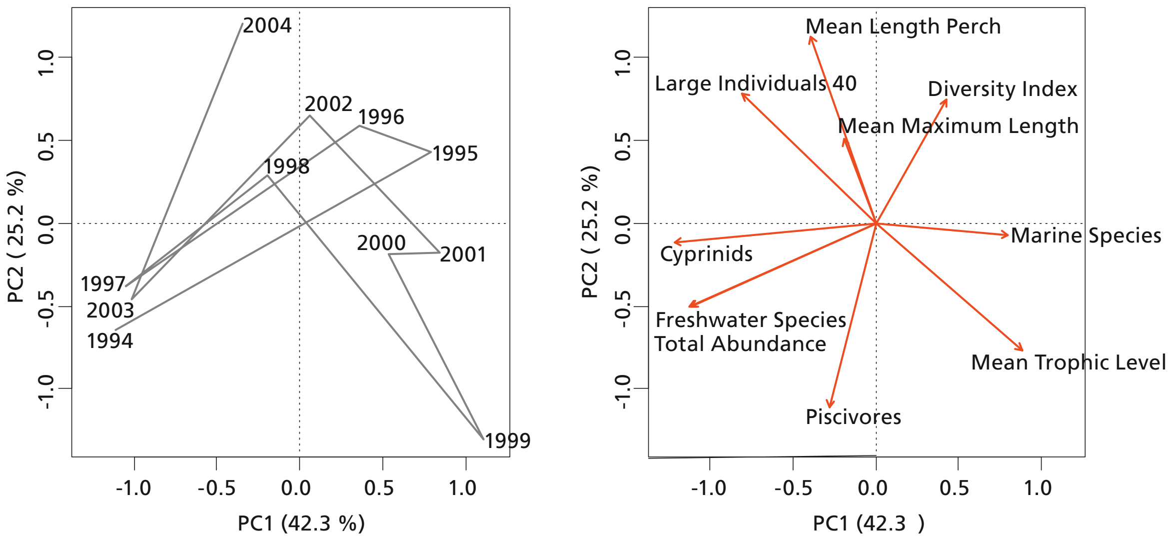


Figure 24. Analysis of all state indicators for the Råneå area (PCA, 1991–2004). In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 42.3% of the total variance and the second (PC-2) explained 25.2%.

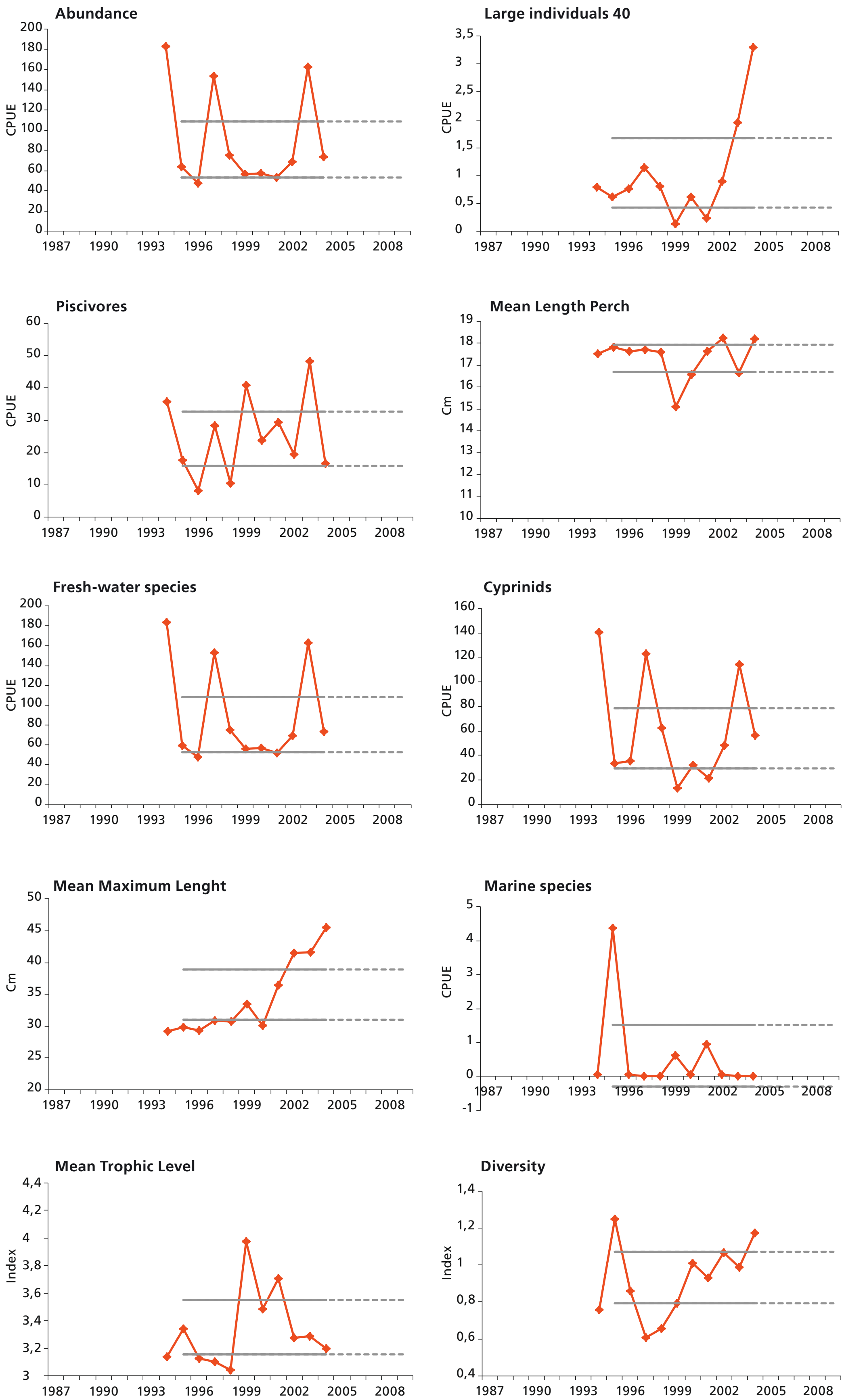


Figure 25. Temporal changes in the state indicators in the Råneå area. The area was monitored using Coastal survey nets in 1991–2004. Since 2002, monitoring has continued using Nordic coastal multi-mesh nets (data not shown). Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004).

Figure 26. **Temporal changes in variables potentially affecting fish communities in the Råneå area.**

Area-wise assessment of the Baltic Proper

Summary

The state of the fish community in the Baltic Proper was assessed for the period 2005–2009 for six areas (Curonian Lagoon, Daugavgriva, Jūrkalne, Hiiumaa, Kvädöfjärden, Vinö). Small changes in the state of the fish community were seen in three of the areas, whereas more pronounced changes over time were seen in the Hiiumaa, Vinö and Kvädöfjärden areas. See Figure 27 for a summary of the outcome. The presence of long-term trends in the whole dataset available in each area is shown in Table 10.

Table 10. Summary of trends in individual state indicators in the Baltic Proper. Note that the analyses are performed over different time periods in different areas, as indicated in the column headings, in order to include the whole time series available for each area.

Baltic Proper	Curonian Lagoon 1994–2007	Jūrkalne 1999–2008	Daugavgriva 1995–2007	Hiiumaa 1991–2008	Vinö 1995–2009	Kvädöfjärden 1987–2009
Species Composition						
Total Abundance	ns	ns	ns	–	–	–
Cyprinids	ns	ns	ns	–	ns	–
Marine Species	ns	ns	ns	ns	ns	+
Size Structure						
Large Individuals 30	–	ns	ns	–	–	+
Mean Maximum Length	ns	ns	ns	–	–	ns
Mean Length Perch	ns	ns	ns	ns	–	+
Trophic Structure						
Mean Trophic Level	ns	ns	ns	ns	ns	+
Piscivores	ns	ns	ns	ns	–	ns
Piscivore Proportion	ns	ns	ns	ns	ns	+
Species Diversity						
Diversity	ns	ns	ns	+	ns	+

\+ denotes an increasing trend; – denotes a decreasing trend; ns denotes a non-significant trend at $\alpha = 0.05$.

During the assessment period (2005–2009), indicators reflecting species composition showed average values in relation to the reference period (1994–2004) in three areas (Curonian Lagoon, Jūrkalne, Daugavgriva). In the three other areas, there was a decreasing trend in *Total Abundance*, reflecting a decrease in *Cyprinids* in all areas, and a decrease in *Piscivores* in the Vinö and Kvädöfjärden areas. In addition, in the Kvädöfjärden area, an increase in the indicator *Marine Species* was observed.

The indicators reflecting size structure showed a decreasing trend in all areas, with the exception of the Kvädöfjärden area, where an increasing trend was seen. The strongest decrease was seen in the Vinö area, where all indicators of size structure showed a long-term decreasing trend, and in Hiiumaa, where a decreasing trend was seen in *Large Individuals 30* and *Mean Maximum Length*. However, although the long-term trends were often clearly identified, the mean values of the indicators during the assessment period were often at the same level as the values for the reference period, indicating that the highest values in the indicators reflecting size structure generally occurred in years before the reference period. In the Kvädöfjärden area, an increasing trend and values higher than average for the reference period were observed in two indicators, *Large Individuals 30* and *Mean Length Perch*, indicating an increased abundance of large perch and potentially also an increased growth rate.

The indicators reflecting aspects of trophic state showed no trend and average values were observed in relation to the reference period in all areas, with no general trends over time. In the Kvädöfjärden area, an increasing long-term trend was seen in *Mean Trophic Level* and *Piscivore Proportion.* However, this was not seen within the assessment period, when lower than average values where observed.

The indicator *Diversity* showed average values in relation to the reference period in all monitoring areas, except Vinö, where values higher than average were observed. A long-term increasing trend was seen in Hiiumaa and Kvädöfjärden.

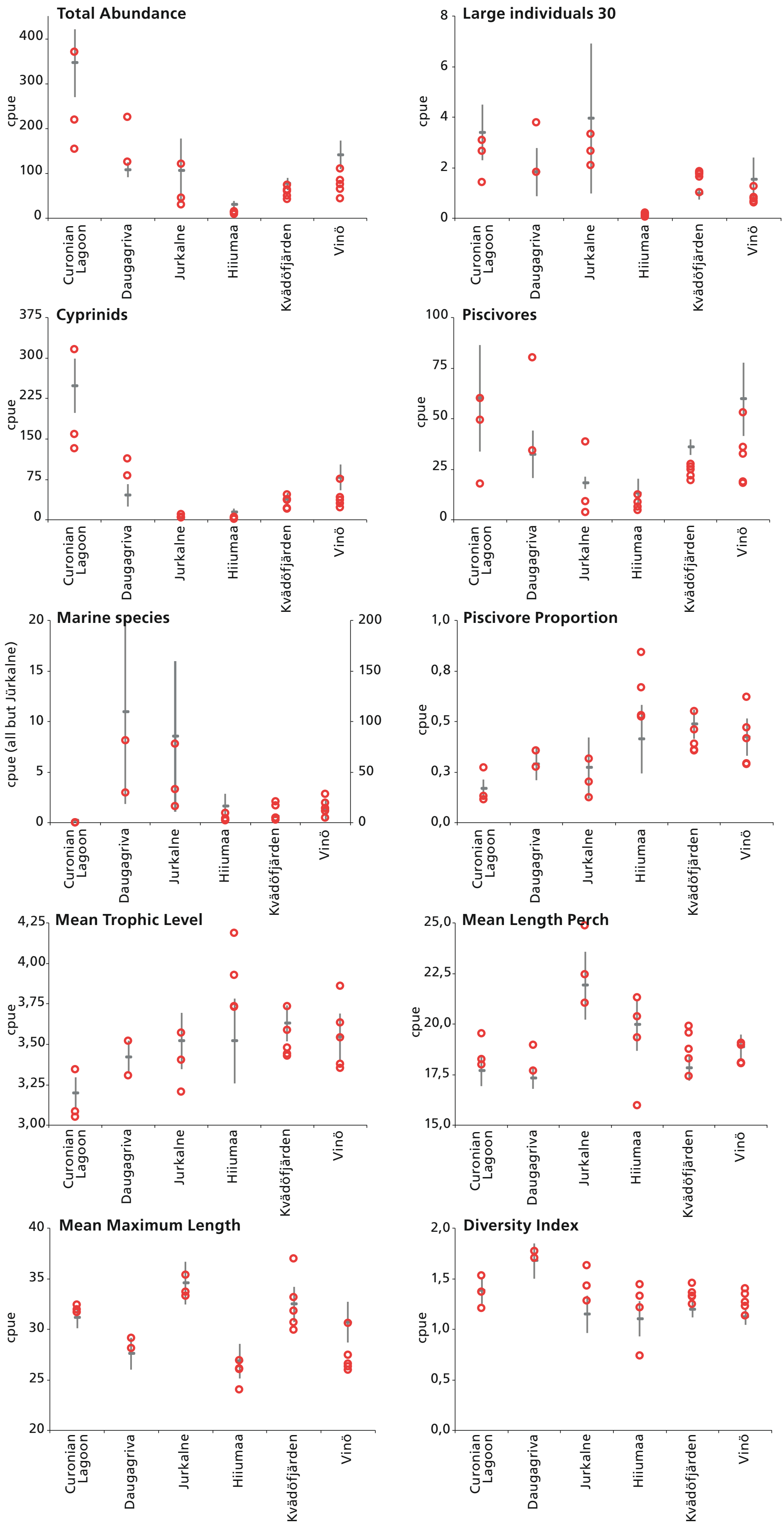


Figure 27. State indicators for the fish community in the Baltic Proper. Values during the assessment period (2005–2009; red circles) are shown in relation to the 95% confidence interval of the mean within the reference period (1995–2004; grey bars).

Curonian Lagoon

The state of the fish community in Curonian Lagoon in the three most recent years of monitoring (2005–2007) showed average values for most indicators in comparison to the reference period. However, a tendency to a divergence of the indicator dataset was seen in 2006 and 2007, which mainly reflected a decreasing abundance of fish. This trend was seen in all species groups but mainly in Cyprinids. Most individual indicators showed average levels during the three years assessed (2005–2007), but the values for Total Abundance and Cyprinids were below average.

Although monitoring started in 1993, the data covered the period 1994–2007. Thus, only three years of the assessment period (2005–2009) were included. Seen over the monitoring period as a whole, all indicators except *Large Individuals 30* and *Marine Species* were influential for the temporal development of the fish community in the Curonian Lagoon (Figure 28). At the end of the 1990s, *Piscivores, Piscivore Proportion* and *Mean Trophic Level* showed above average levels (Figure 29). During these years, abundances of perch and pikeperch were relatively high. In more recent years, below average values were observed for *Total Abundance*, which was mainly explained by decreasing abundances of perch and pikeperch. The observed pattern could at least be partly attributed to increasing commercial and recreational fishing pressure, in combination with increasing predation from cormorants. In addition, surface water temperature in the Curonian Lagoon increased by 0.6 °C during the period 1961–2005. Water temperature appears to be the key factor determining the seasonal and long-term variability of primary production and the abundance of phytoplankton and therefore also the level of biological production and trophic status in the area. The rise in temperatures has also fostered the ongoing eutrophication and 'hyperblooms' of cyanobacteria in the Curonian Lagoon despite the reduction in external nutrient loading from land in the form of fertilisers and industrial products. Increased incidence of more westerly winds in combination with sea level rise and reduced river discharge has also resulted in a long-term increase in annual mean salinity in the area (Dailidienė et al. in press).

Looking at the individual indicators separately, no significant changes over time were seen. Noticeably, the indicator *Cyprinids* showed strong variation between years within the assessment period, with above average values in 2005 and below average values in 2006–2007. This variable is probably influenced by predation from cormorants and pikeperch, as well as pressure by the fisheries. Cormorants are seen to have increased in the area in more recent years, whereas the level of predation

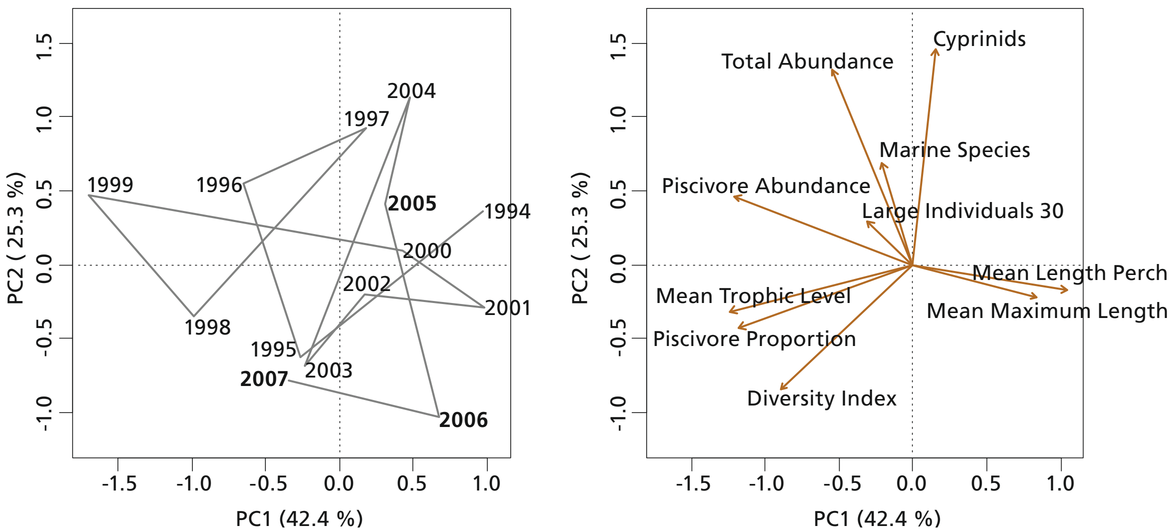


Figure 28. Analysis of all state indicators for the Curonian Lagoon area. In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 42.4% of the total variance and the second (PC-2) explained 25.3%.

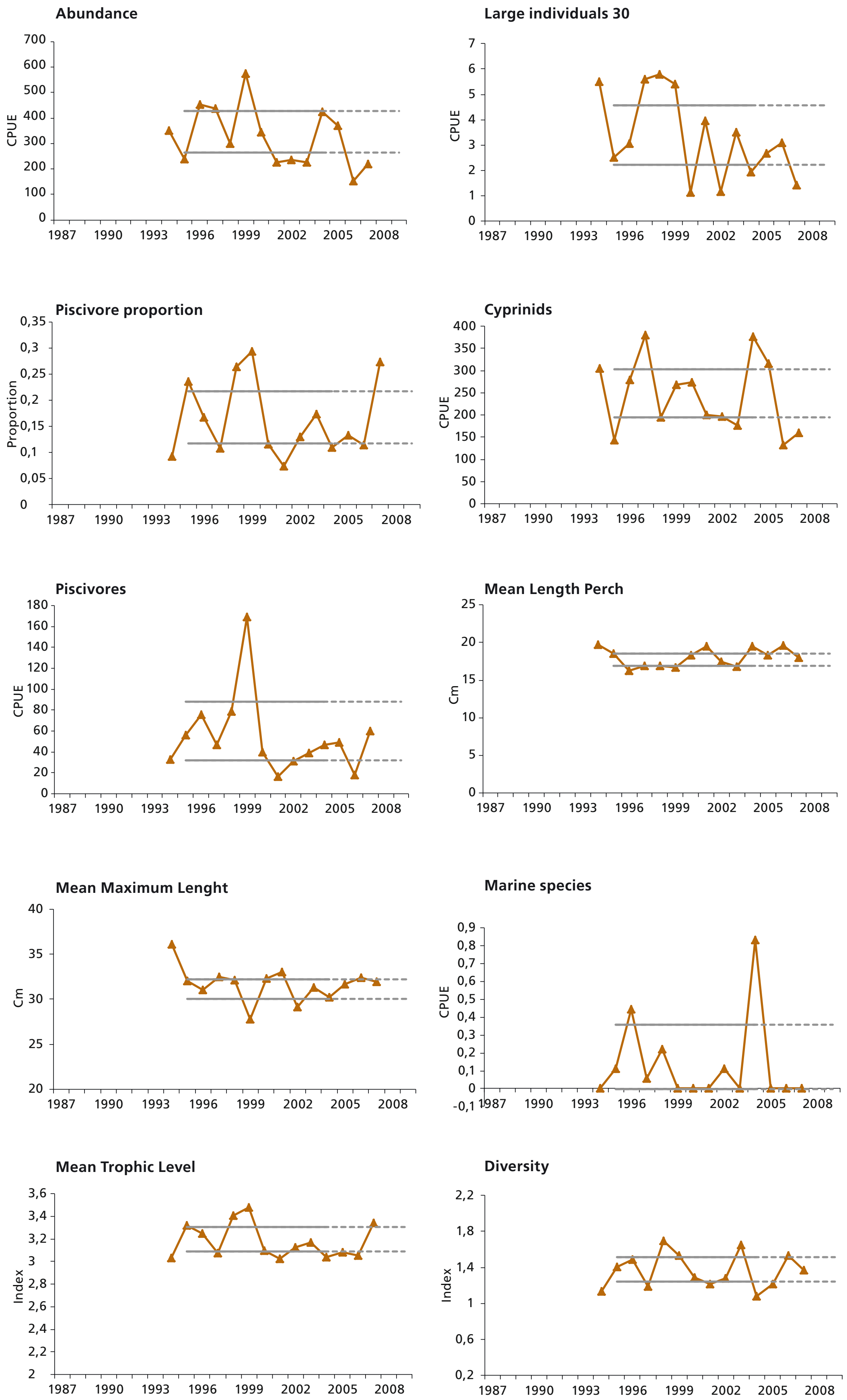


Figure 29. Temporal changes in the state indicators in the Curonian Lagoon area.

pressure from pikeperch has varied over the years, depending on year-class strength of the species.

Daugavgriva

Coastal fish monitoring at Daugavgriva covered two years of the assessment period. The state of the fish community was characterised by intermediate to high abundances of fish, mainly Cyprinids. During part of the period, an increased abundance of piscivores and large individuals was also observed, as well as a high mean length of perch. However, the level of variation between adjacent years was high. The observations may be related to a reduced fishing pressure on pikeperch since the mid-2000s.

Monitoring data covered the period 1995–2007, with gaps in 1998, 2003 and 2005. Thus, two years of the assessment period (2005–2009) were included. When analysing all indicators simultaneously, many indicators had a similar amount of influence on temporal development. This could be related to a high variation among years in many of the indicators. Particularly high values in the indicator *Marine Species* were observed in 1997 and 2002 and had a strong influence on the overall pattern (Figure 30). The high abundance of marine species in these years was attributed to incidences of strong upwelling.

Looking at the indicators separately, above average values were observed in *Total Abundance* and *Cyprinids* within the assessment period (Figure 31). In addition, relatively high values in *Piscivores*, *Large Individuals 30* and *Mean Length Perch* were observed during part of the assessment period. No analysis of linear trends was attempted due to missing data points.

The natural level of variation in many of the indicators can be expected to be high for many of the indicators in the Daugavgriva area, due to frequent upwelling events. In addition, a strong decline in fishing pressure at least on pikeperch during the mid-2000s might partly contribute to the high values observed in *Total Abundance* and *Piscivores* in 2006. The temporal development of potential pressures driving changes in the fish communities in Daugavgriva is shown in Figure 32. The only significant trend observed was a decrease in total nitrogen loading. However, catches of pikeperch in the five most recent years were all below average for the preceding eight years.

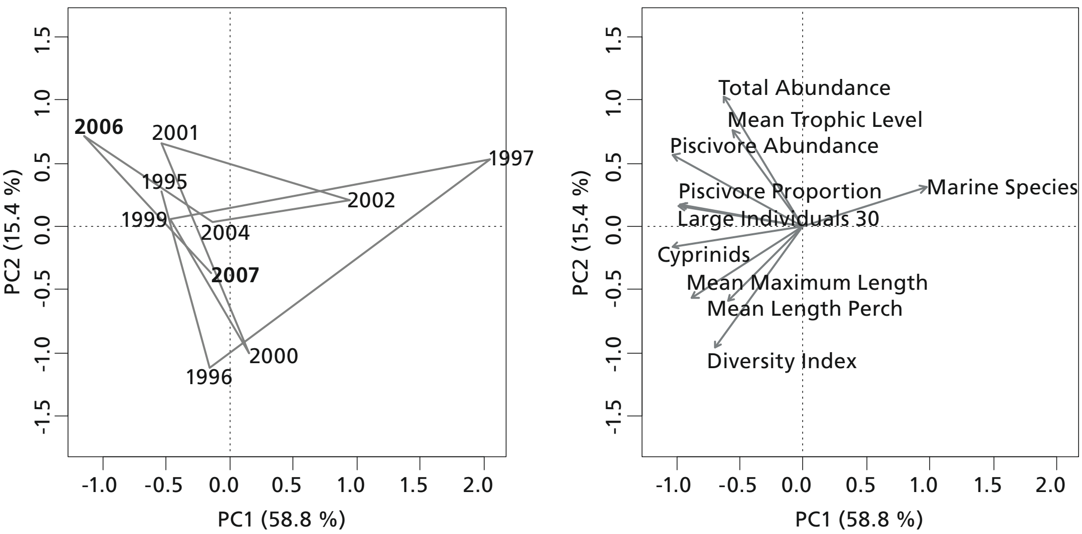


Figure 30. Analysis of all state indicators for the Daugavgriva area In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 58.8% of the total variance and the second (PC-2) explained 15.4%.

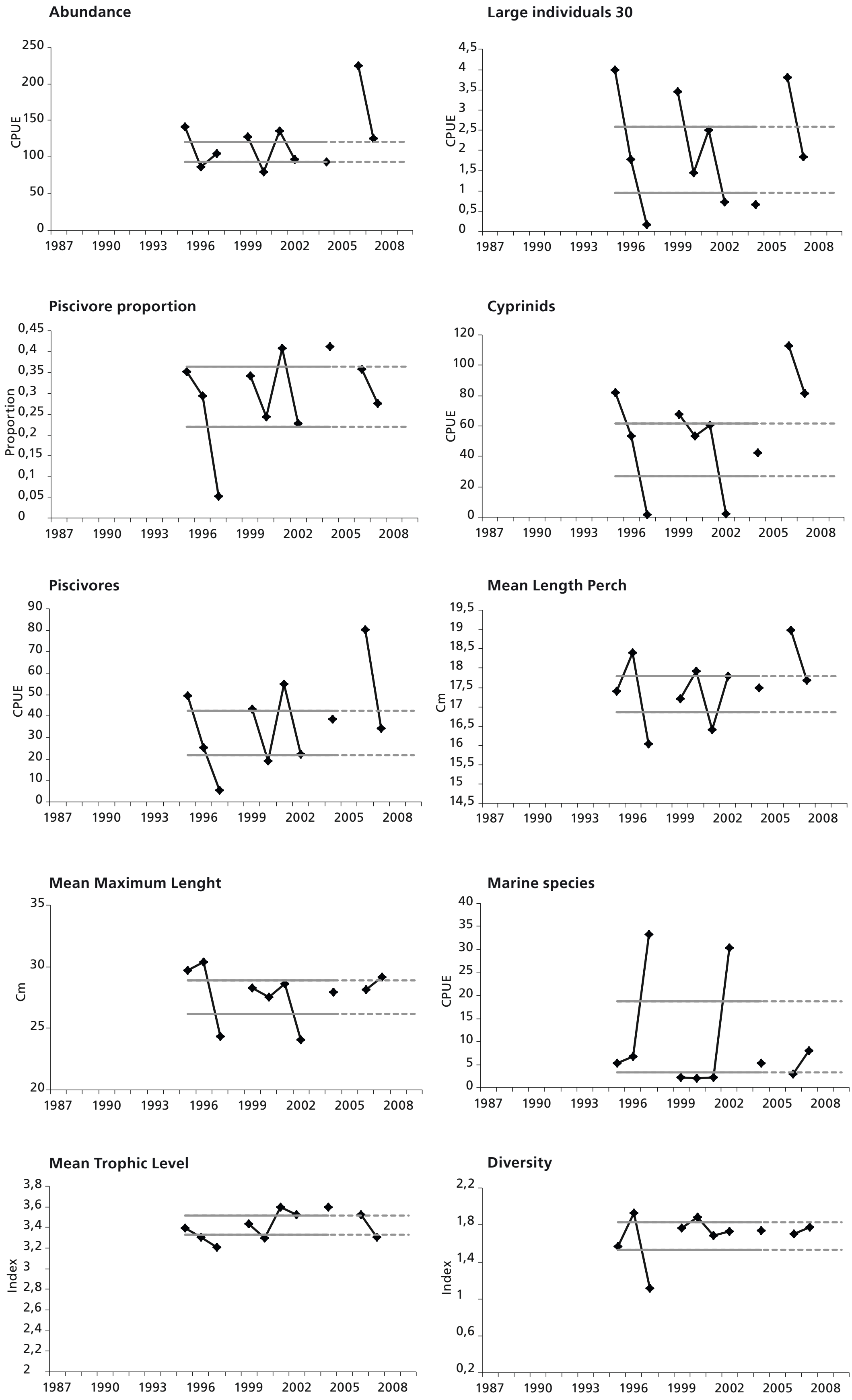


Figure 31. **Temporal changes in the state indicators in the Daugavgriva area. Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2005–2009).**

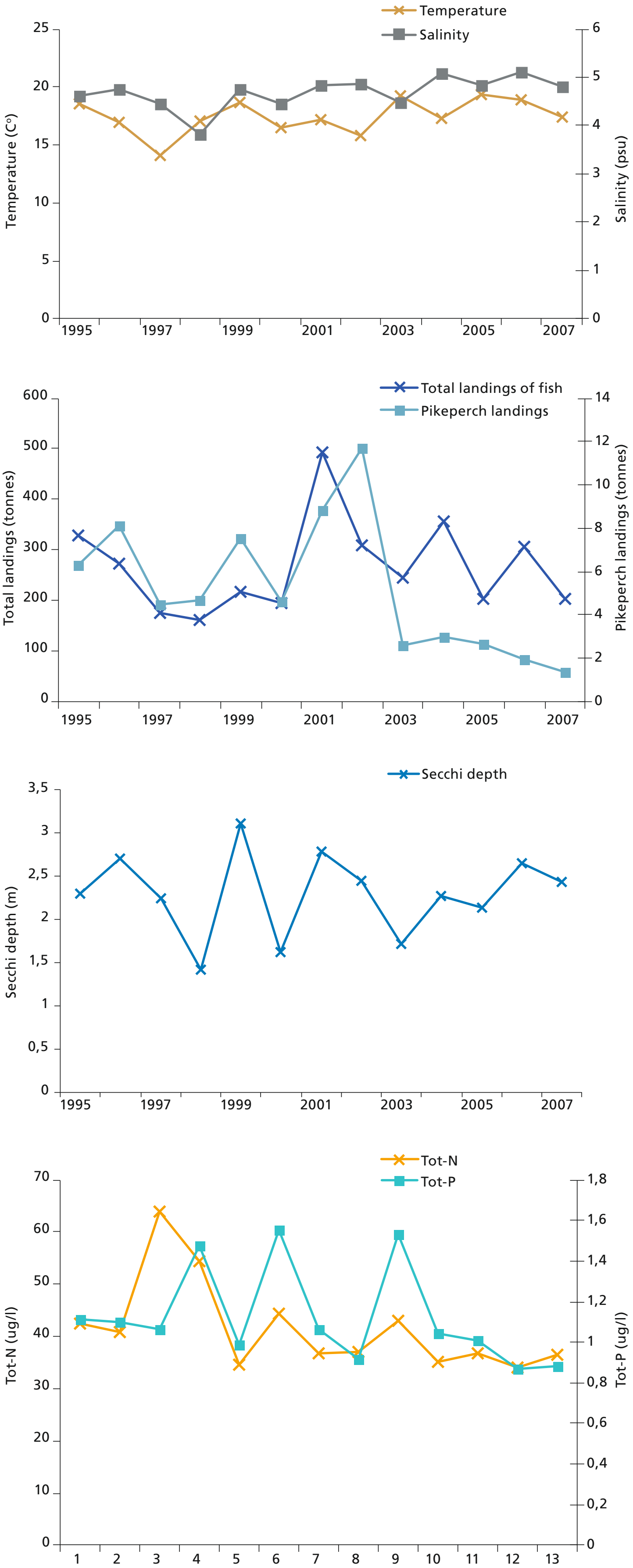


Figure 32. Temporal changes in variables potentially affecting fish communities in the Daugavgriva area.

Jūrkalne

The state of the fish community in Jūrkalne was characterised by average values in most indicators. However, the abundance of Cyprinids, as well as the observed diversity, was higher than average during part of the assessment period. Many indicators showed high variability over time, which was mainly attributed to strong interannual variation in hydrological conditions.

Monitoring data covered the period 1999–2008, with a gap in 2006. Thus, three years of the assessment period (2005–2008) were included. These years were characterised by relatively high values in *Cyprinids* and *Diversity*, and by relatively low values in *Piscivores*, especially in 2005. Average values were observed in *Total Abundance* and in the indicators reflecting size structure (Figure 33). Over the whole period monitored, the years 1999 and 2001 differed from the others by having relatively high values in *Piscivore Proportion* and *Mean Trophic Level.* This coincided with relatively low values in *Cyprinid*s. The main pattern was also strongly driven by indicator values in 2003, when high values in *Mean Maximum Length, Total Abundance, Marine Species* and *Large Individuals 30* occurred. In this year, very high abundances of flounder, which was characterised as a non-piscivore and marine species, occurred in connection with unusually strong winds and cold water.

Looking at each indicator separately, values in *Cyprinids* and *Diversity* were higher than average in two of the assessed years (2005 and 2007). The indicator *Piscivores* varied within the assessment period, being higher than average in 2008 but lower than average in 2005 and 2007 (Figure 34). A high level of variation between adjacent years was also observed in other indicators. For some indicators, the average values estimated for the reference period may have been influenced by the exceptional catches of flounder in 2003. This is reflected, for example, as a peak in *Total Abundance, Large Individuals 30,* and *Marine Species* in 2003, and as a dip in *Diversity.* None of the indicators showed a trend over the monitoring period as whole.

No data on the development of potential pressures were available for the monitoring area. The level of anthropogenic impact on this area is generally thought to be low. The area is subject to natural influence from frequent upwelling, which is likely to affect fish community structure by migration of species and differences in year-class strength.

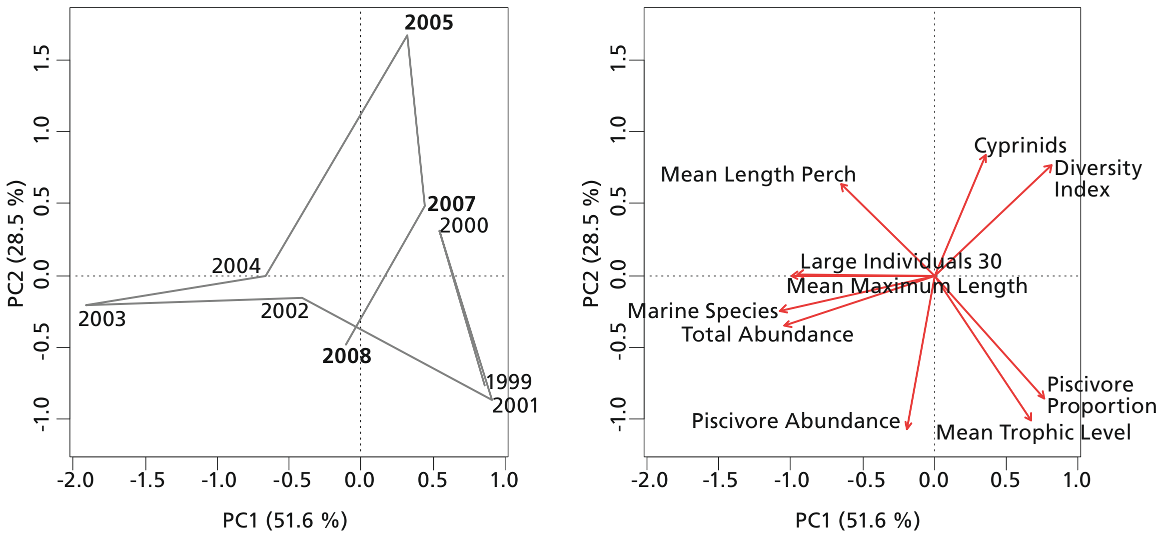


Figure 33. Analysis of all state indicators for the Jūrkalne area. In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 51.6% of the total variance and the second (PC-2) explained 28.5%.

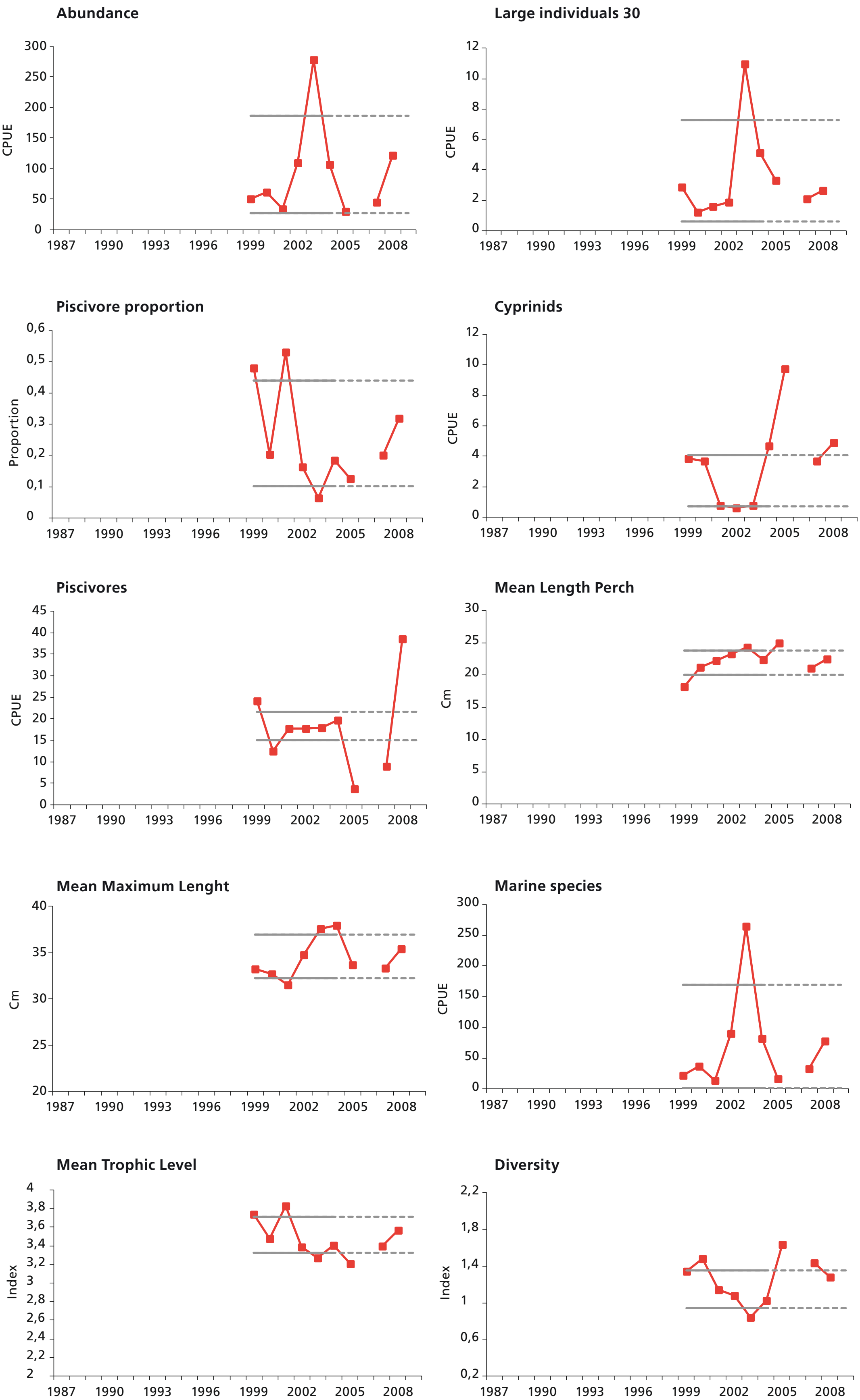


Figure 34. Temporal changes in the state indicators in the Jūrkalne area. Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2005–2009).

Hiiumaa

Strong changes in the fish community over time were observed in the Hiiumaa monitoring area. The assessment period (2005–2008) was characterised by a decreased abundance of fish, mainly Cyprinids, and a decreased abundance of large individuals. In parallel, these changes caused an increase in indicators reflecting species diversity and trophic structure. However, no increase in the abundance of piscivores was observed. The changes were mainly related to fishing pressure in earlier years, but in more recent years mainly to predation pressure from cormorants.

Monitoring data covered the period 1991–2008. Thus, four years of the assessment period (2005–2009) were included. The assessment period was characterised by relatively low values in *Cyprinids* and *Total Abundance*, as well as in *Mean Maximum Length* and *Large Individuals 30* (Figure 35).

Looking at each indicator separately, seven showed a significant trend over the monitoring period as a whole (Figure 36). The indicators *Total Abundance*, *Large Individuals 30*, *Cyprinids, Mean Maximum Length* and *Mean Length Perch* showed a decreasing trend. At the same time, *Piscivore Proportion* and *Diversity* showed an increasing trend. The increase in these two indicators was attributed to a decrease in the abundance of dominant species groups, mainly Cyprinid species. In line with these trends, the indicators *Total Abundance*, *Large Individuals 30* and *Cyprinids* showed values below average in comparison with the reference period (1994–2004). *Piscivore Proportion* and *Mean Trophic Level* showed above average levels during two years within the assessment period.

Overfishing was the pressure factor most likely to be related to the decreasing abundances of fish and weakened size structure observed during the early 1990s. Fishing pressure has, however, decreased strongly in recent years. The continued decreasing trend in the indicators in more recent years is more likely to be attributed to predation pressure from cormorants (Vetemaa et al. 2010; Figure 37). The cormorant population close to the Hiiumaa area has increased steadily since the 1990s. The closest cormorant populations are centred on Käina Bay, approximately 10 km from the monitoring area, which is also one of the most important spawning areas for freshwater species.

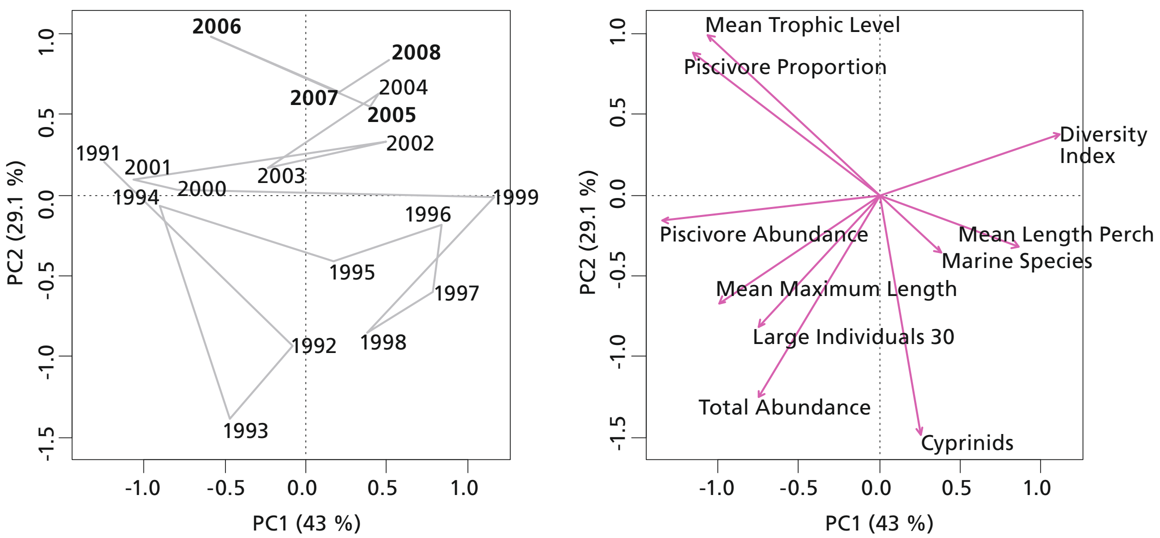


Figure 35. Analysis of all state indicators for the Hiiumaa area. In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 43.0% of the total variance and the second (PC-2) explained 29.1%.

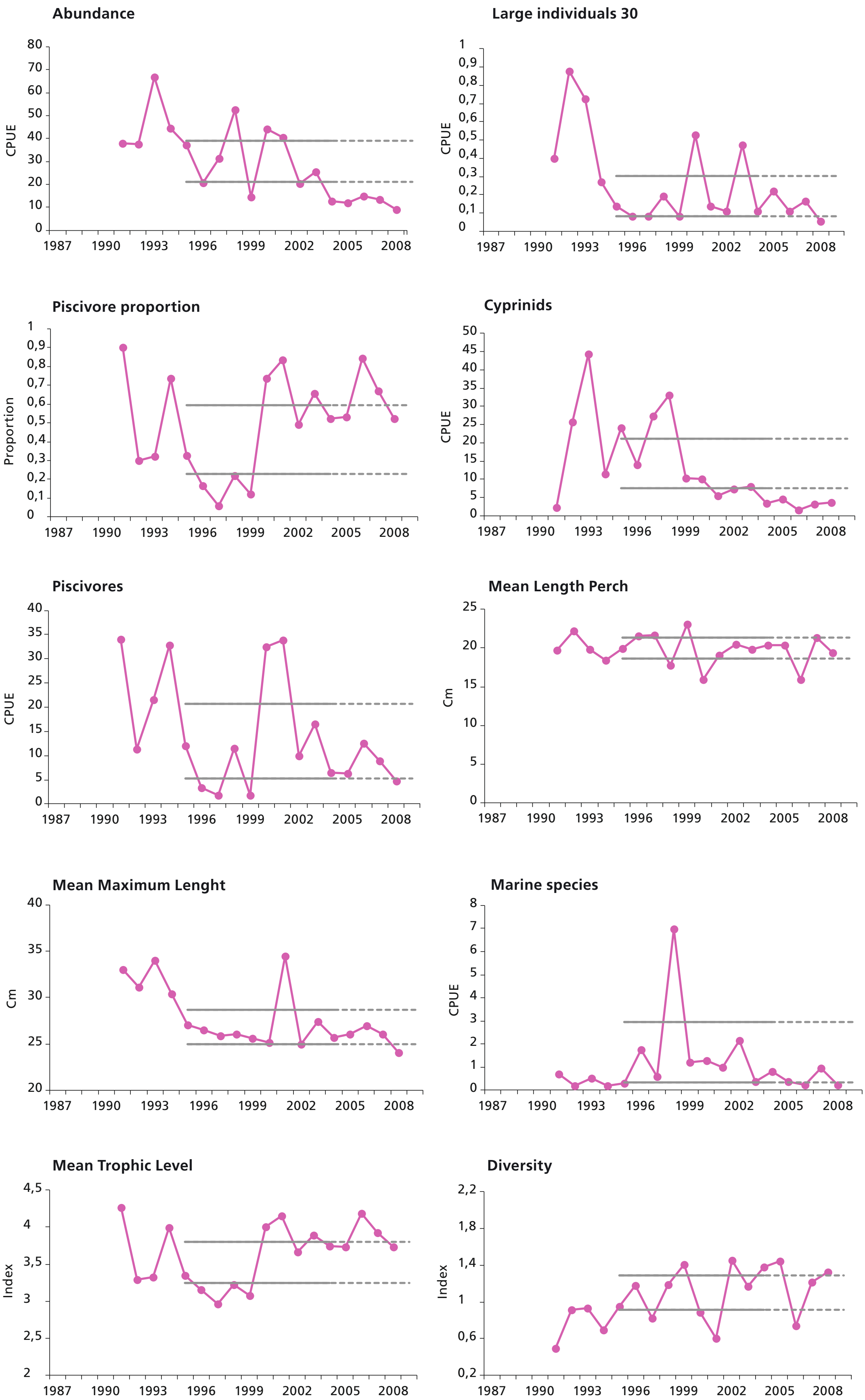


Figure 36. Temporal changes in the state indicators in the Hiiumaa area. Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2005–2009).

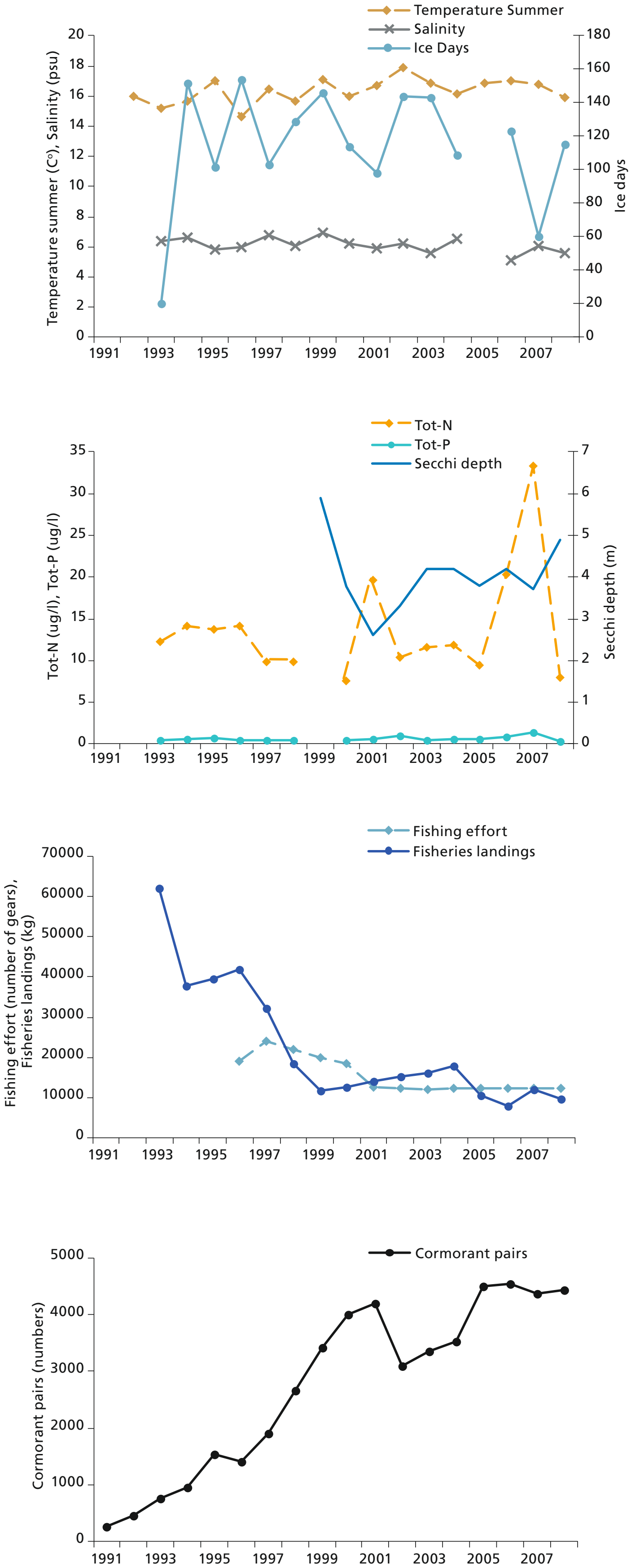


Figure 37. **Temporal changes in variables potentially affecting fish communities in the Hiiumaa area.**

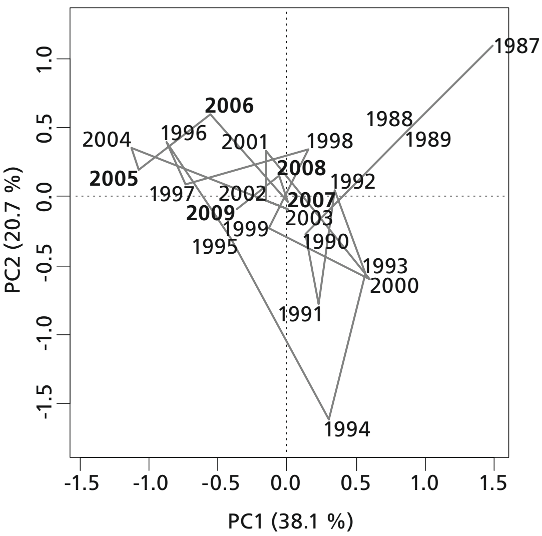
Kvädöfjärden

An increasing trophic structure, size structure and diversity were seen over the whole monitoring period in the Kvädöfjärden area. However, the assessment period was characterised by relatively low values in indicators related to trophic structure and by low abundances of fish, particularly piscivore species. A decreasing trend was also seen in the abundance of Cyprinids, whereas the abundance of marine species showed an increasing trend. The abundance of large fish increased. The changes may be attributed to reduced fishing pressure and climate-related variables, and potentially also to increased predation pressure and low recruitment success in recent years.

Monitoring data covered the period 1987–2009. The most recent years were characterised by average to low values in indicators reflecting species composition, such as *Total Abundance*, *Piscivores,* and *Cyprinids.* The indicators reflecting size structure and trophic structure showed highly similar patterns in the area, with average to high values during the assessment period. A gradual increase in indicators reflecting size structure and trophic structure was also seen over the monitoring period as a whole. The highest abundance of fish, including both Cyprinids and piscivores, were seen in 1994 (Figure 38).

Looking at each indicator separately, eight showed a linear trend over the monitoring period as a whole. The indicators *Large Individuals 30*, *Piscivore Proportion*, *Mean Length Perch*, *Marine Species*, *Mean Trophic Level* and *Diversity* showed an increase, while *Total Abundance* and *Cyprinids* showed a decrease. In comparison to the reference period (1994–2004), the five most recent years of monitoring were characterised by lower than average values in *Total Abundance*, *Piscivores*, *Piscivore Proportion* and *Mean Trophic Level*, all indicating a low occurrence of piscivores in relation to previous years. This was also reflected in relatively high values in *Diversity* during the assessment period. Two of the indicators reflecting size structure, *Mean Length Perch* and *Large Individuals 30*, showed higher values than average, indicating an increased growth rate or a decreased mortality of fish in the area, as the relative abundances of potentially large-bodied species, as indicated by *Mean Maximum Length*, were at average level (Figure 39).

The development of potential pressures affecting the fish community over the same period is shown in Figure 40. Over time, commercial catches in nearby areas showed a decrease, and water transparency also decreased. The reduced levels of commercial catches may be



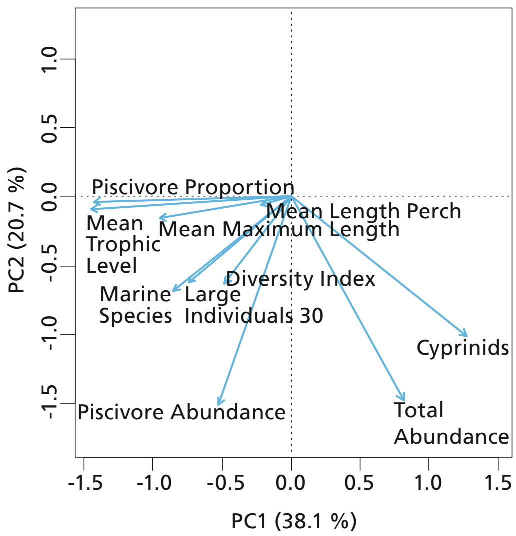


Figure 38. Analysis of all state indicators for the Kvädöfjärden area. In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 38.1% of the total variance and the second (PC-2) explained 20.7%.

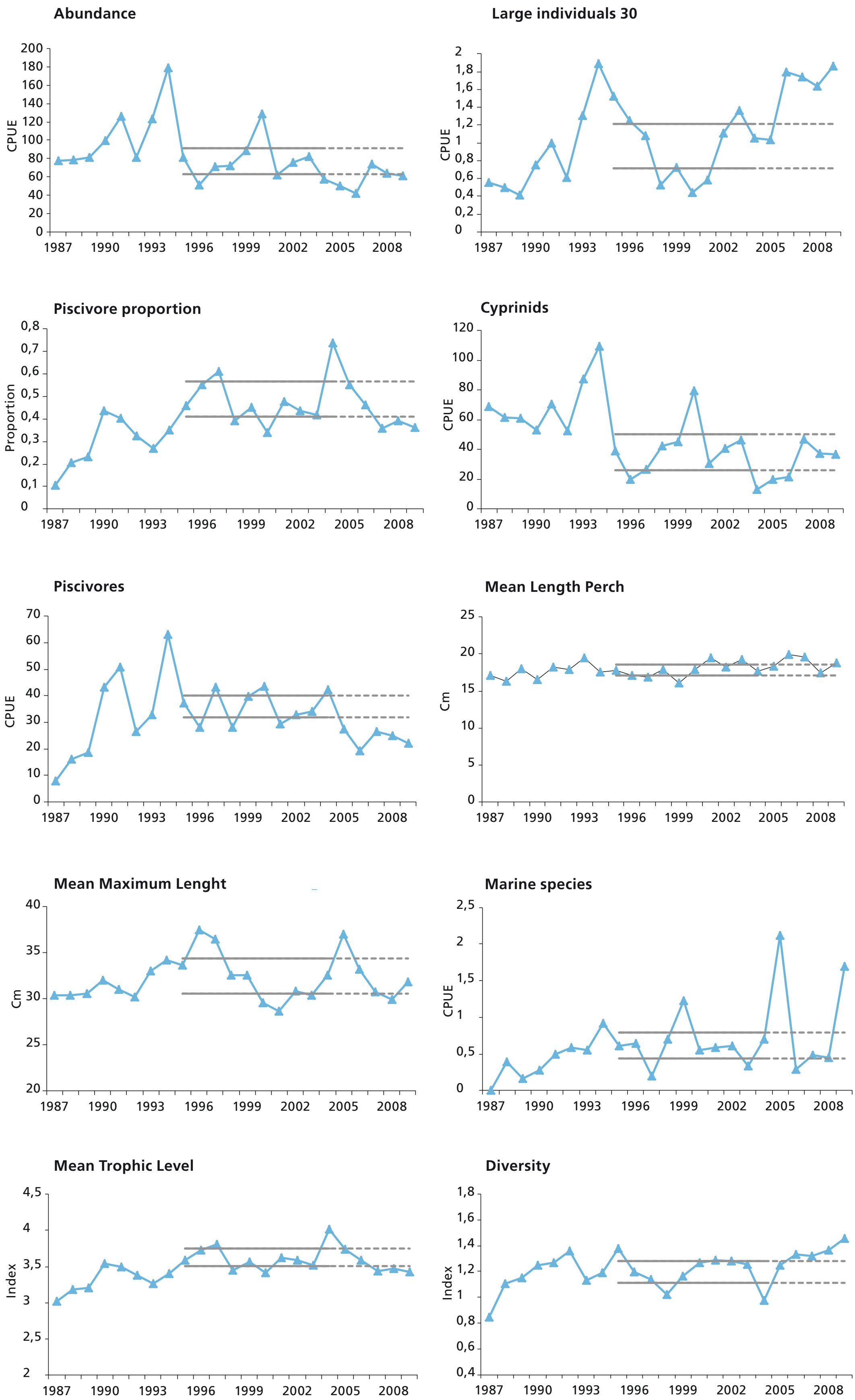


Figure 39. **Temporal changes in the state indicators in the Kvädöfjärden area. Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2005–2009).**

attributed to the increased abundance of large individuals observed. They may also be related to the increased abundance of marine species and increased mean length of perch observed, although changes in these indicators may also be linked to climate related variables not covered here. The decreased abundance observed in piscivores as well as in Cyprinids could not be explained by trends in the environmental variables studied. Changes in these indicators may be related to predation from seals, birds or fish, or to decreased recruitment success.

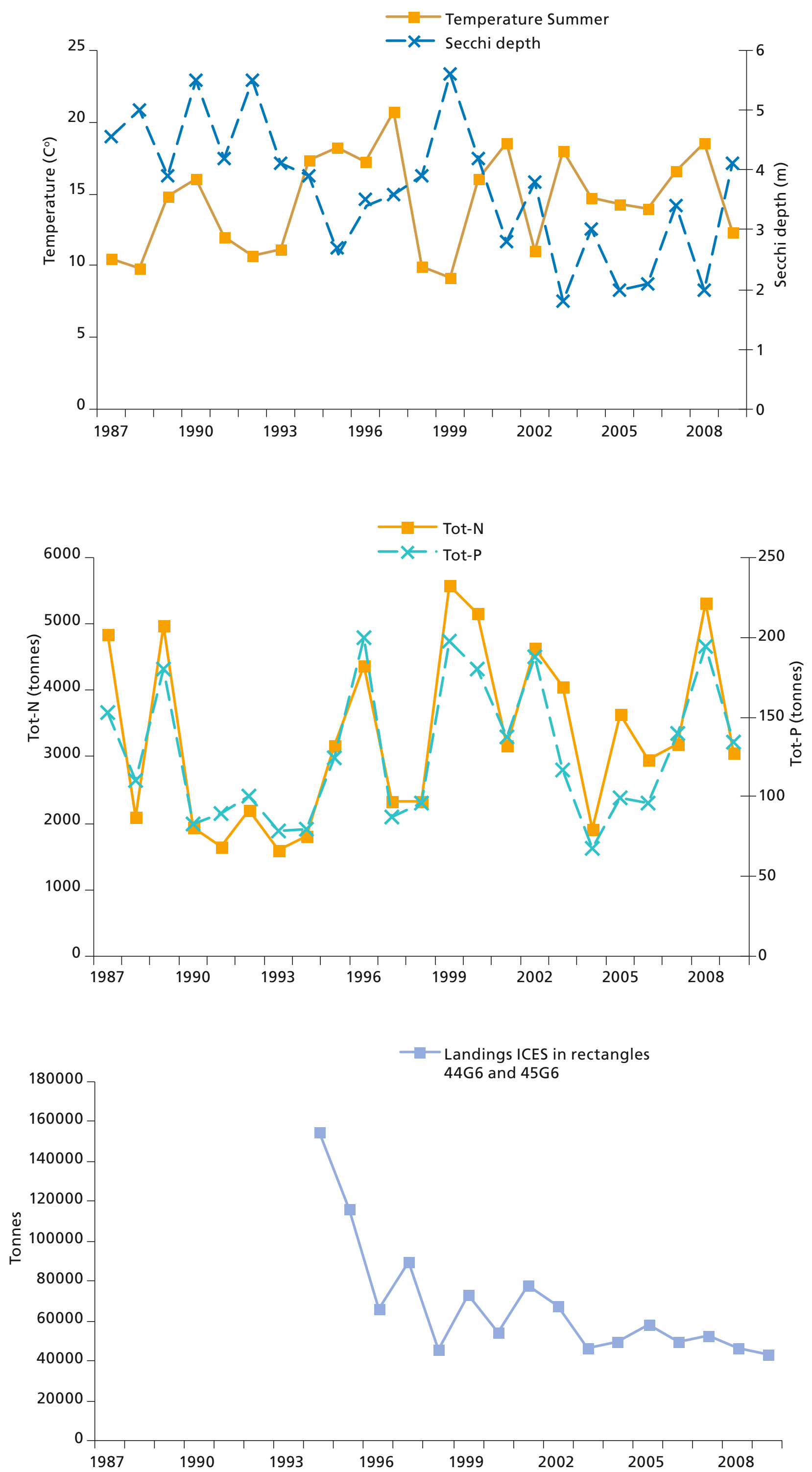


Figure 40. **Temporal changes in variables potentially affecting fish communities in the Kvädöfjärden area.**

Vinö

The state of the fish community in the Vinö area was characterised by low fish abundance and a decreased size structure in relation to earlier years of monitoring. The decrease was seen both in piscivores and Cyprinids. Diversity was slightly higher than average, which may be attributed to a small increase in marine species in recent years. No changes may be related to increased fishing pressure or to variables not covered by the available data on potential pressure factors.

Monitoring data covered the period 1995–2009. The fish community during the assessment period (2005–2009) was characterised by low values in most indicators, but high values in *Diversity* and *Marine Species* in comparison to the reference period (1995–2004). Over the monitoring period as a whole, the first year of monitoring was characterised by large catches of perch, as indicated by relatively high values in *Total Abundance*, *Piscivores*, and *Large Individuals 30*. After this, a decrease was seen in indicators reflecting trophic structure and size structure. The years 1997 and 2000 were characterised by relatively high abundances of Cyprinids. *Piscivore Proportion* and *Mean Trophic Level* were highly similar, with highest values in 2003 and 2006 (Figure 41).

Looking at each indicator separately, five showed a decreasing trend over the monitoring period as a whole. A decreasing trend was seen in all indicators reflecting size structure (*Large Individuals 30*, *Mean Length Perch* and *Mean Maximum Length*), as well as in *Total Abundance* and *Piscivores*. In comparison to the reference period, the assessment period was characterised by values lower than average in *Total Abundance*, *Piscivores, Cyprinids* and *Mean Maximum Length*, indicating a reduced occurrence of fish within all species categories. Values for *Diversity* were higher than average (Figure 42).

The development of potential pressures affecting the fish community over the same period is shown in Figure 43. No linear trends over time were seen in any of the variables. However, commercial catches in nearby areas increased in the latter half of the 1990s in comparison to the first years of study. This pattern might be attributed to the observed temporal development in indicators reflecting size structure.

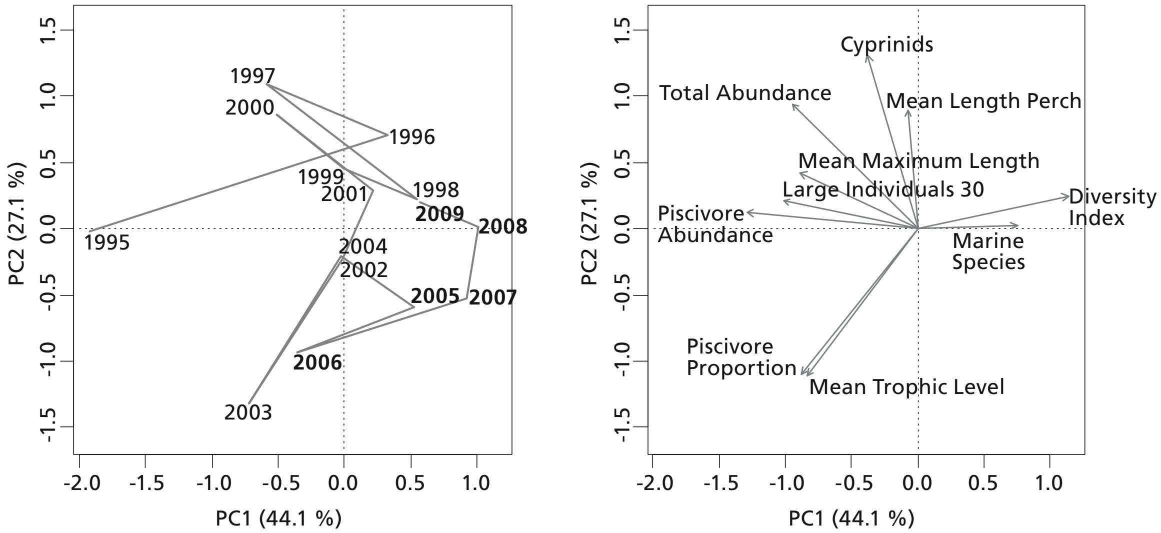


Figure 41. Analysis of all state indicators for the Vinö area. In the left plot, years in close proximity have similar values for the indicators studied. Years within the assessment period are highlighted. The right plot shows which indicators characterise particular years by pointing in the direction of the year. Long vectors indicate a strong relationship between the indicator and the years studied. The first component (PC-1) explained 44.1% of the total variance observed and the second (PC-2) explained 27.1%.

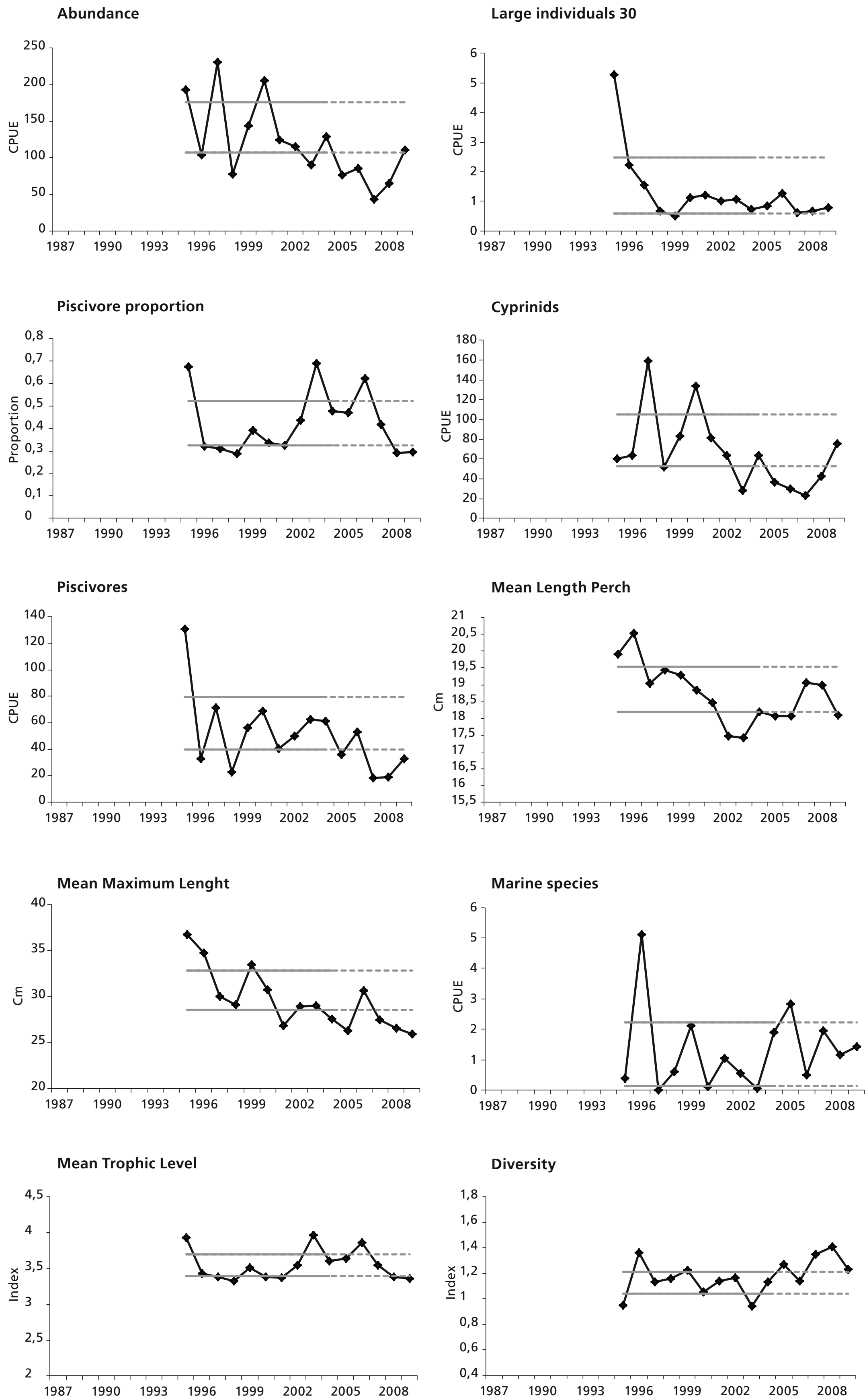


Figure 42. **Temporal changes in the state indicators in the Vinö area. Grey lines show the 95% confidence interval of the mean for each indicator within the reference period (1995–2004). Hatched grey lines extrapolate the confidence interval into the assessment period (2005–2009).**

Figure 43. Temporal changes in variables potentially affecting fish communities in the Vinö area.

Vistula and Szczecin (Odra) Lagoons

Data for the Vistula and Szczecin (Odra) Lagoons were obtained from commercial catches, mainly from the fyke net fishery targeting eel. This fishery is generally not highly selective and the data should thus represent major changes for a few target species important for the coastal fishery. Problems that can result from this type of dataset are the change in use of gear over time and the reliability of the catch statistics due to changes in effort, especially following the changes in political setting.

The species used for this assessment were chosen according to the following criteria; statistics of the species should be available for more than 60 years; the species should not have a TAC (International Total Allowable Catch limit); existing additional knowledge for the species and potential explanations for changes in abundance should be available; and the species should have been common in catches for at least some period during the 60 years (1930 to 2010) considered.

In the Vistula Lagoon the following species were chosen: eel (*Anguilla anguilla*), ruffe (*Gymnocephalus cernuus*), pike (*Esox lucius*), sea trout (*Salmo trutta*), burbot (*Lota lota*), twaite shad (*Alosa fallax*), vimba bream (*Vimba vimba*), tench (*Tinca tinca*) and ziege (*Pelecus cultratus*).

In the Szczecin (Odra) Lagoon the following species were chosen: eel, ruffe, pike, sea trout, burbot, twaite shad/alosa (*Alosa fallax/ Alosa alosa*), vimba bream, tench and whitefish (*Coregonus lavaretus*).

Based on expert judgement, the abundance of each species in each area in a given period was scaled according to five categories based on the catches of the species in relation to the whole period assessed. The relative abundance of each species was then assessed within ten-year periods (Tables 11 and 12).

Based on this approach it appears that pike abundance in the Vistula Lagoon has decreased substantially over the almost 80 years assessed. The most abundant species were eel, ruffe, ziege, twaite shad and tench. Abundance of ruffe, burbot, ziege and tench has been relatively stable. For the remaining species there have been periods of low abundance (sea trout 1950–1980, burbot 1960–1990, twaite shad 1950–1990, vimba bream 1970–2000), but these species have all increased again over the past 10 to 30 years.

Table 11. **Summary of results for Vistula Lagoon.**

Period	Species									
	Eel	Ruffe	Pike	Sea trout	Burbot	Ziege	Twaite shad	Vimba bream	Tench	**Total**
1930/39	15	15	10	5	5	10	10	5	10	**85**
1940/49										
1950/59	10	15	10	1	5	5	1	5	10	**62**
1960/69	10	15	10	1	1	5	1	5	5	**53**
1970/79	15	15	5	1	1	1	1	1	5	**45**
1980/89	15	15	5	5	1	5	1	1	1	**49**
1990/99	15	10	1	5	5	10	5	1	5	**57**
2000/10	10	10	1	5	5	10	5	5	10	**61**

'15' denotes a relatively common abundance; '10' denotes often present, '5' denotes sometimes present; '1' denotes rarely present; '0' denotes not present.

Table 12. **Summary of results for Szczecin (Odra) Lagoon.**

Periods	Species									
	Eel	Ruffe	Pike	Sea trout	Burbot	***Alosa sp.***	Vimba bream	Tench	Whitefish	**Total**
1930/39	15	5	10	5	5	10	10	10	5	**75**
1940/49										
1950/59	15	15	10	1	5	5	5	10	5	**71**
1960/69	10	15	10	1	1	5	1	5	1	**49**
1970/79	15	15	5	1	1	1	1	1	1	**41**
1980/89	15	15	5	5	1	5	1	1	1	**49**
1990/99	10	10	1	5	5	10	1	1	1	**44**
2000/10	5	10	1	5	5	10	5	5	5	**51**

'15' denotes a relatively common abundance; '10' denotes often present, '5' denotes sometimes present; '1' denotes rarely present; '0' denotes not present.

The pattern is similar in the Szczecin (Odra) Lagoon. The most abundant species are eel, ruffe, *Alosa* sp., vimba bream and tench. There has been a decrease in the abundance of pike and eel. For sea trout (1950–1980), burbot (1960–1990), *Alosa* sp. (1950–1990), vimba bream (1960–2000), tench (1970–2000) and whitefish (1960–1990) there has been a marked decrease in abundance over time, as well as an increase over the past 10 to 30 years.

Part III. Restoration and restocking programmes for threatened and declining species

Background

Knowledge of stocks of threatened and declining fish species is often poor. However, successful management of these species is possible only if sufficient knowledge is available on their distribution, habitat requirements and responses to environmental impacts. Information supporting the national monitoring programmes of coastal fish in this respect can be obtained by mapping and monitoring of fish stocks and communities. Results from scientific studies and experience from management action are also important.

Concerning measures for the most threatened and declining fish species, through the Baltic Sea Action Plan HELCOM members have agreed to:

Develop national programmes for the conservation of eel stocks as a contribution to a Baltic co-ordinated programme to ensure successful eel migrations from the Baltic Sea drainage basin to natural spawning grounds. For EU Member States this means the implementation of EC Regulation No. 1100/2007 by establishing measures for the recovery of the stock of European eel, by 2008[23].

- Classify rivers with historic and existing migratory fish species (e.g. salmon, eel, sea trout and sturgeon), no later than by 2012.
- Develop restoration plans (including restoration of spawning sites and migration routes) in suitable rivers to reinstate migratory fish species, by 2010[24].
- Actively conserve at least ten endangered/threatened wild salmon river populations in the Baltic Sea region as well as reintroduce the native Baltic Sea salmon in at least four potential salmon rivers, by 2009[25].
- Enhance restoration of lost biodiversity by joining and/or supporting Poland and Germany in reintroducing Baltic Sturgeon to its potential spawning rivers.

The proposals for restoration programmes and measures for the most threatened and/or declining coastal fish species (including anadromous species) has been a central request to the HELCOM coastal fish expert community (HELCOM, 2007). In order to evaluate how successfully the Contracting Parties have fulfilled these commitments, Part III of this report aims to provide an overview of national activities and recommendations for further action in restoration and restocking of coastal fish populations. Information about the success rate of different activities, when coupled with data on the status of coastal fish populations, can be used to identify areas where further restoration activities would be necessary for ensuring sustainable populations and coastal ecosystems.

Part III also presents information on activities concerning the mapping of fish habitat and recruitment habitat for coastal fish. These types of map are important as they can help to identify areas to be prioritised for conservation, restoration and management. They also provide information of high interest for the development of status assessments for coastal fish.

A particular interest here is to put more focus on fish recruitment areas. Several fish species use coastal habitat for reproduction and as nursery habitat and natural reproduction areas are vital for maintaining sustainable fish stocks. The reproduction areas in the coastal zone, including freshwater tributaries used for spawning, are currently under strong pressure from human activities. The growing interest in mapping coastal areas along the Baltic coast is therefore a positive development that will have a substantial input to spatial planning at the local, and possibly regional, level.

National restoration programmes for non-commercial coastal fish species

Further information about the programmes and projects described below are listed in Annex 1, Table A1.

Denmark

Denmark has provided information on three programmes contributing to restoration of coastal fish populations. The Sea trout project on the island of Fyn, carried out during 1998–2010 aimed to

23 Presently all EU countries have an accepted plan for conservation of the eel stock, several of them focussing on restocking. The rate of implementation varies among countries.

24 The development of restoration plans for reinstating migratory fish species varies among participating countries.

25 Actions have been initiated, however, the goal is to our understanding not achieved

Underwater vegetation with bladder wrack from the west coast of Sweden.

provide a better foundation for angling tourism, based on an attractive coastal fishery on a naturally occurring wild sea trout. The outcome of the project includes increased tourism of coastal anglers, more than 50 restoration projects in freshwater streams, and about 3.5 million trout smolt released between 1998 and 2008[26].

During 2002–2009, there was an initiative in the Vejle Fjord (on the Belt Sea side of Jylland) to investigate whether restoring seabed locally (with net bags containing mussel shells) could increase populations of coastal fish and other marine organisms. Initial results indicate positive effects on benthic organisms and coastal fish species.

The BlueReef project in the Kattegat (2006–2012) concerns the rebuilding of marine cavernous boulder reefs with 60 000 m^3 of boulders of various sizes, to provide a significant contribution to maintaining the populations of species dependent on the cave-forming boulder reef in Danish waters. Such reefs also function as a crucial steppingstone within a marine corridor linking sites within the EU Natura 2000 protected area network and serve as a sanctuary for donor populations. The first results from some extensive surveys in 2009 and 2010 show that the reef has begun to be colonised, and includes fish such as cod and wrasse species. Larger biomasses of key species are still missing, but are expected to be established in the coming years (Dahl and Lundsteen 2010).

Estonia

Since the early 1980s, artificial spawning substrata ('nests') for pikeperch have been created in Pärnu Bay in the north-eastern part of the Gulf of Riga with the primary aim to provide improved conditions for hatching. To assess the success of the restoration programme, two factors are routinely calculated based on visual inspections: the proportion of nests used by pikeperch, and the proportion of normally developed embryos. The results show

26 For more information, see www.nordfynskommune.dk/nordfynsftp/agenda/OxMpOc-7fXB_oY2PNIpgMQ.pdf (available only in Danish).

that up to 90% of nests are used each year as spawning habitat and the proportion of normally developed embryos usually exceeds 80%. For the next five years several projects will be undertaken to restore access to historic spawning grounds for anadromous coastal fish species in several western and north-Estonian rivers by dam removal. For example, a dam will be removed from the Kasari river in western Estonia for vimba bream[27].

Finland

There are numerous local and small fisheries restriction areas along the coast of Finland aimed at protecting important bird and predatory fish species. These protective measures vary from place to place and are often seasonal, associated with breeding periods. No specific register of these activities is maintained at the national level.

Commercial catches of pikeperch at the Åland Islands have recently decreased and were particularly low in 2008 and 2009. The reasons for the decline are high fishing pressure, weak year-class strengths in 2002–2005 and increased predation by seals and cormorants. Since 2004, the local government of the Åland Islands has implemented a recovery plan for the pikeperch population. This includes a ban on all forms of fishing targeting pikeperch during the reproduction period and a limit to the number of gears used. It is difficult to establish the impact of the regulations, but it is notable that commercial catches of pikeperch were 25% higher in 2010 than 2009.

Since the 1950s, the government has restocked trout, pike and Baltic whitefish populations. There is a government-owned hatchery and fry production plant, and this is where the larvae and fry for the target species are produced.

The Åland Islands have no native trout population due to the lack of suitable reproduction areas. The material for restocking originates from trout populations in Sweden and Finland, but is now collected from the trout population created in the Åland Islands. Long-term restocking of trout has been so successful that the Åland Islands are now recognised as an attractive sport fishing area for trout.

Pike is restocked as larvae and so it is difficult to assess the success of this programme. Water owners have an interest increasing pike stocks owing to its importance in sport fishing. The larvae used for increasing stocks are collected from the native population.

Nets used in coastal fish monitoring and test fishing.

27 For more information, see www.loodushoid.ee/HAPPYFISH_LIFE_project_Saving__19.htm

Baltic whitefish is the most important commercial species at Åland Island and water owners and fishermen have an interest in increasing stocks. Tagging of restocked whitefish has shown very good commercial recaptures in the vicinity of the release area. The restocking material is collected from the native population.

A new project which concerns the restocking of pikeperch and burbot is planned to start in 2011.

Poland

There are numerous restoration and reintroduction projects for fish on-going in Poland. Since 1994 there has been restocking and improvement of fish passages to restore salmon and sea trout in Polish waters. In addition, 300 000 to 500 000 salmon smolt and 1 to 1.5 million sea trout smolt are being released each year. The main aim of these activities is to increase recruitment, sustain mixed populations in rivers, restore spawning possibilities and compensate for landings. Annual electrofishing surveys have been carried out in potential salmonid rivers to determine the effectiveness of the restocking and creation of fish passages[28].

In 2010, Poland implemented a National Eel Management Plan based on EC Regulation No. 1100/2007. The plan covers the Odra and Vistula River Basin Districts as well as transboundary waters. Measures include restocking with glass eel or elvers, making migration routes passable, combating poaching and addressing the problem of cormorants. New catch regulations have also been established, for example, there are new closed seasons, a daily rod catch limit, unifying protected size, improved gear selectivity etc. The target is to reach 40% escapement of the potential escapement based on reference points in each river basin district.

Poland has also continued to restock whitefish and vimba bream populations. National funding has supported whitefish restocking programmes in Szczecin (Odra) Lagoon (1995–2002 and 2005–2009), Pucka Bay (1993–2002 and 2005–2009) and in some of coastal Pomeranian rivers. From the year 2000, some river district owners have restocked vimba bream populations, and from the year 2005 this has been supplemented by additional programmes from national funding[29]. The restocking programmes have taken place in Odra, Vistula basins and some coastal Pomeranian rivers.

Since 1994, Poland has re-introduced whitefish (*Coregonus lavaretus*) in Pucka Bay with the aim of restoring the population to the natural levels occurring up until the 1980s. Approximately 20 000 to 100 000 juveniles have been released each year and after several years the population has recovered and catches are now up to 1000 kg per year[30].

ZOSTERA is a project initiated in inner Puck Bay in 2010 in order to restore the ecosystem there. The project will continue until 2013 and has been implemented in cooperation with local authorities. The aim of the project is the restoration of three important elements of the ecosystem: increasing the amount of piscivorous fish species, increasing the surface area of underwater meadows, and increasing the surface area of common reed (*Phragmites australis*) in degraded areas. An integral part of the project is to carry out research on the actual composition of the fish assemblages during three seasons (spring, summer and autumn). The surveys are conducted using bottom trawl of different types adjusted to water depth. Trawl stations are stratified according to depth, bottom type and area. The catch of fish and mobile epifauna is counted, weighed and measured.

To estimate the impact of fishery on ichthyofauna, an observer survey on fishery boats has started. All the catch from different type of fishing gears and fishing grounds, including by-catch and discard, are counted and if possible - measured.

The diversity of the coastal fish fauna in Poland will be increased by stocking of piscivorous species. There will be annual restocking of 200 000 pikeperch fry (minimum length 3.5 cm) and 200 000 pike fry (minimum length 8.0 cm). In addition, 400 000 roach fry (> 2.0 cm) will be introduced in order to minimise the cannibalism associated with the high density of fry of piscivorous species. The spawners will be

28 The results of the surveys are documented in several ICES WGBAST reports. The findings are also summarised the following report: www.pzw.org.pl/pliki/prezentacje/1395/cms/szablony/3622/pliki/015_rbartel.pdf (available only in Polish)

29 The results of evaluations of the effectiveness of the programme are reported in www.pzw.org.pl/pliki/prezentacje/1395/cms/szablony/3622/pliki/015_rbartel.pdf (available only in Polish)

30 For more information about the effectiveness of the stocking activities, see www.ejpau.media.pl/volume9/issue1/art-36.html

selected for genetic compatibility with the indigenous (pikeperch) or historical (pike) population. Spawners will be obtained from areas such as lower Reda River, Orle Lake (upper Reda River), Motława River, Martwa Vistula and Vistula Delta channels escaping into the Vistula Lagoon. Roach fry production will be based on a population of native spawners reared in a pond. A professional fish farm will produce the fry of all fish species involved. Fish released into Puck Bay will be marked by immersion in a solution of fluorochrome, which will be visible in otoliths. Piscivorous species will be released in batches every two to three days for about six weeks, depending on meteorological conditions at sea. The release areas will be determined with control fish to avoid areas already inhabited by piscivorous species. In areas where piscivorous species are introduced, protected areas will be established for these species. Control fish will be used to monitor the effectiveness of the method after the restocking and for analysis of trophic relationships (piscivorous/non-piscivorous).

The long-term success of the pike restocking programme will be achieved by restoring local conditions so that natural spawning can take place. Before 1972, an important spawning ground for pike was destroyed in the Płutnica River. Currently the river mouth is regulated by a pump station without an operating fish passage. In addition, the mouth of the river is blocked for fish passage by assemblages of mud. The project is expected to allow pike to spawn again on flooded meadows. So far many challenges have been observed, including ownership of land, the law requiring the maintenance of ground water at the appropriate level (too low for pike spawning), and the NATURA 2000 site limitation for dredging in sensitive areas.

Poland and Germany

A Baltic variety of the Atlantic sturgeon (*Acipenser oxyrinchus*) was once abundant throughout the southern waters of the Baltic Sea, spawning in several major rivers. However, only occasional catches have been reported since 1915, and the Baltic sturgeon may already be extinct in the wild. According to the 2008 progress report of the Baltic sturgeon remediation project, by Jörn Gessner, in the tenth meeting of the HELCOM Nature Protection and Biodiversity Group in 2009 (HABITAT 10/2009), the reasons for its decline include dams preventing migration to spawning sites, water pollution and other changes in rivers affecting spawning sites, as well as overfishing.

HELCOM has supported a German-Polish project to re-establish the sturgeon in the Baltic region carried out during 2001–2009 (for more information see Arndt et al. 2006 and Fredrich et al. 2008). This bilateral project on remediation of Baltic sturgeon focused on the Odra and Vistula rivers and their tributaries. Initially, experimental releases were made to obtain information on the migration patterns and habitat utilization of the released fish. Later releases focused on assessing individual migration, daily rhythms, and habitat structures used.

A total of 60 000 fish were released between 2001 and 2009. Fish exceeding 20 cm in length were tagged, making it possible to monitor fish obtained as by-catch in commercial fisheries. Recapture data were collected from the reports provided by commercial fishermen and, when possible, the tagged sturgeons were released. Reporting was strongest in areas where there was intensive communication with stakeholders prior to the release and close contact upon initial catches.

Among the conclusions of the project are that cost-effective production of restocking material is a prerequisite for the release of the large numbers of sturgeon needed to establish a population. In addition, early release reduces the potential impact of controlled rearing conditions on the behaviour of the fish while allowing the imprinting that is the key to high homing fidelity.

Sweden

In an attempt to increase the recruitment success of coastal fish species there have been temporary closures of 25 recruitment areas (mainly for pike and perch) in small bays in the Stockholm Archipelago since 2003. Successful involvement of stakeholders in the process of temporarily closing areas has resulted in a general acceptance of the measure, and a call for closures of other particularly valued habitat. The selection of recruitment areas to be temporally closed to all types of fisheries was based on habitat-models of potentially


Scenery from Björkö, Vaasa Archipelago, Northern Quark, Finland.

important recruitment areas for these species. Evaluation of the closed areas has not shown any clear effect on local recruitment in areas where recruitment is regarded as poor, indicating that processes other than fisheries are also likely to affect recruitment dynamics. It also indicates the importance of a network of temporary closures of areas with good recruitment, as these may potentially act as source regions for areas with non-functioning coastal pike and perch recruitment.

On the western coast of the Baltic Proper, measures have been taken to restore migration paths and the recreation of wetlands connected to five creeks and streams in Kalmar county. The main aim of the activity has been to restore spawning habitat of coastal fish species, mainly pike and perch. The Swedish Board of Fisheries, the Linné University, the county administration of Kalmar county and Kalmar and Mönsterås municipalities initiated a research project in 2006 ('*Pilotprojekt kustfiskevård*') to describe and scientifically evaluate the restoration of three watercourses in Kalmar sound (Ljunggren et al. 2011). An additional purpose of the project was to generate information that could be used as guidance and to provide recommendations for future conservation and restoration measures.

The results of the project show that there is considerable migration of spring-spawning fish such as percids, pike and cyprinids into coastal rivers and streams. In total, about 4000 migrating pike in six different watercourses were marked during 2006–2009. Analyses based on otolith chemistry of coastal pike suggest that about 45% of individuals were recruited in freshwater (Engstedt et al. 2010). These results show that coastal watercourses could potentially contribute to the recruitment of coastal pike stocks despite the size of the available spawning areas in these environments being negligible compared to those of the coastal zone.

Tagging experiments on pike in Kalmar sound showed that the fish exhibited a significant amount of homing behaviour. Otolith chemistry also suggested that the spawning fish returned to their watercourse of birth (natal homing). Results from preliminary population genetic studies indicated


Catch from test fishing including common roach and European perch.

that pike from different watercourses in the Kalmar sound might to some extent represent genetically isolated populations, presumably adapted to the particular local environment. In all, these results suggest that a similar conservation strategy to that implemented for salmon for example, should be applied for pike. However, the effects of such a restoration measure would be local and to achieve a more wide-ranging effect on coastal pike stocks, conservation measures would need to be distributed all along the coast.

The restoration programme yielded an increase in the production of pike juveniles in only one (Kronobäck) of the three watercourses intensively studied. The incidence of spawning migration for adult pike was substantial in all watercourses, but the most important factor for the production of juveniles was likely to be the area of suitable spawning- and juvenile habitat. The only watercourse in which this area increased after the restoration programme was Kronobäck. In the other two watercourses, the area of suitable recruitment habitat decreased initially, due to a reduction in vegetation areas and exposure of sediments/soil surfaces, thus causing a loss of important microhabitats for larvae. However, it is reasonable to assume that the vegetation in these watercourses will recover within a few years.

More detailed studies suggested that the production of pike larvae was greatest in those parts of the watercourses with flooded vegetation. Vegetation is the preferred spawning substrate for pike, and together with the relatively high water temperatures in this habitat offers suitable food resources for newly hatched pike larvae. In all, these results show that watercourse restoration should proceed carefully, and that shallow and flooded areas are to be preferred. Such an alternative is also likely to be the most economic option and should be combined with other conservation measures such as grazing of cattle.

The generation time of pike and the length of this project meant it was not possible to assess the measures taken in relation to the adult pike stock. To make this kind of assessment, long-term evaluations and knowledge of the extent of pike dispersal is essential. Despite this, the results suggest a three-fold increase in young-of-the-year pike in a coastal bay outside Kronobäck.

Today, wetlands in coastal watercourses are primarily constructed to reduce the discharge of nutrients. An important conclusion from this research project is that the benefits of wetlands in coastal areas could be double. A true artificial wetland might thus serve as both a nutrient sink and a recruitment area for spring-spawning coastal fish species.

There is also another measure ongoing along the coast of the Baltic Proper to increase population size for coastal predatory fish. Since 2007, pikeperch juveniles have been released in Himmerfjärden Bay (Stockholm Archipelago) in order to increase the pikeperch stock and to monitor the effects of biomanipulation. The aim of the programme has been to restore the food web structure in a eutrophic bay. The basic idea is to increase the amount of predatory fish (pikeperch), in order to decrease the amount of zooplanktivores (herring and sprat). This in turn, is expected to increase zooplankton predation on phytoplankton, thereby increasing water transparency and shifting the regulation of the pelagic food web from a bottom-up to a predator-driven (top-down) food web. This requires the stocking of young pikeperch for a number of years. The effects are expected to include better water quality and better fishing for pikeperch, one of the most valuable coastal freshwater species. As the project had not been completed at the time this report was compiled, information is not yet available about the ecosystem effects of the programme.

A general problem in restoration programmes is the lack of a long-term evaluation of any actions. To ensure efficient use of available funding, it is important that action taken is followed-up and evaluated from an ecological as well as a socio-economic perspective. A related issue is the importance of designing self-sustaining / long-term action. Prioritising activities that are self-sustaining will be most cost-efficient over the long term. Generally, such action would also be of most value for the ecosystem.

Mapping of reproduction areas

Finland

In Finland, there are several ongoing projects producing maps of coastal fish reproduction areas. An important element of these projects has also been to develop cost-effective field sampling methods and new mapping methods. The latter includes spatial modelling methods, which can use a variety of environmental data to produce predictive maps for areas where fish have not been sampled. Field sampling for these projects has mostly focused on fish larvae. In the Bothnian Bay, much work is ongoing with sea-spawning whitefish in the INTERSIK–project. In the Gulf of Finland and the Archipelago Sea, the VELMU-project has produced predictive maps of reproduction areas for pike, pikeperch and roach (Figure 44) to cover the entire coast in these sea areas. These predictive maps will be further validated and developed over the coming years. In these areas, field data have also been collected for herring, perch and flounder, and the spatial modelling of their reproduction areas is underway. Similar work is also underway in Åland Island.

Mapping of fish reproduction areas provides crucial information for developing recommendations and proposals for possible restoration programmes. In addition, maps of fish reproduction areas facilitate the protection of important habitats and spatial information on reproduction areas is a prerequisite for viable local fishing restrictions during spawning.

Sweden

In Sweden, spatial modelling methods for mapping fish reproduction areas are being developed within several national and international projects. By combining statistical modelling of species-environment relationships based on field data with predictions made in GIS, comprehensive maps of fish habitat can be produced. These methods have proved

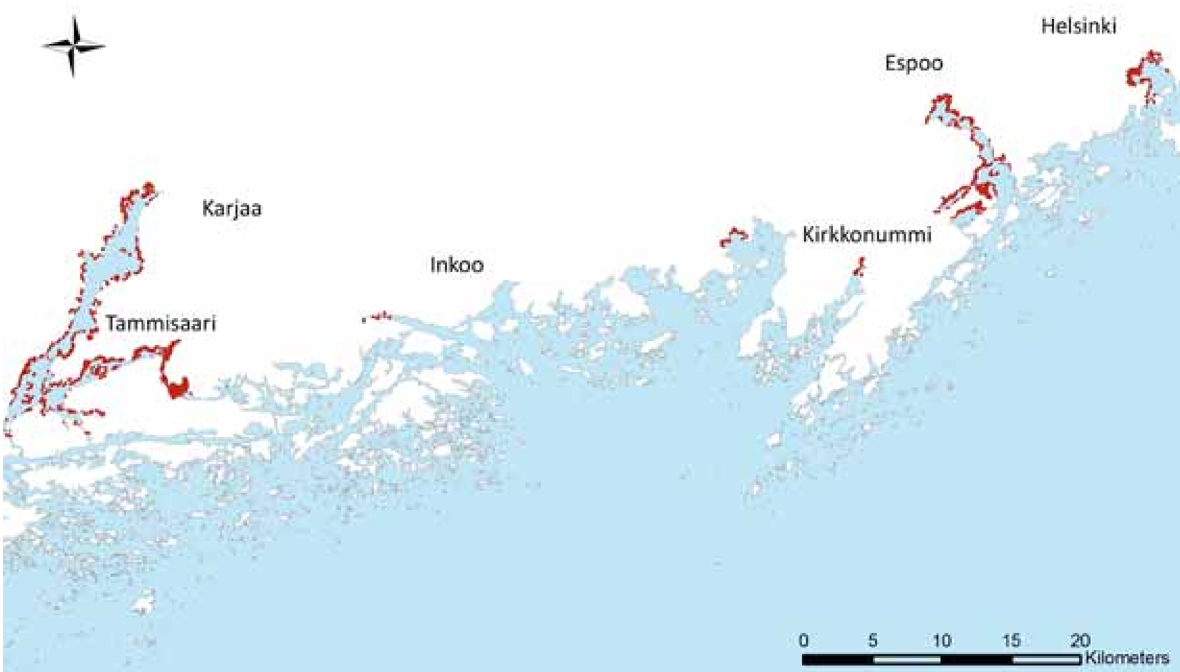


Figure 44. A predictive map of roach reproduction areas in the western Gulf of Finland. Source: Finnish Game and Fisheries Research Institute

useful even for mapping over large spatial scales (Sundblad et al. 2009, 2011) and are now applied in mapping projects at the national and local level. The resulting maps have been adopted by managers for use in conservation and spatial planning.

An important contribution has been made by the BALANCE project (Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning), an INTERREG III B co-funded project between July 2005 and December 2007 aimed at the development of informed marine management tools for the Baltic Sea based on spatial planning and cross-sectoral and transnational co-operation. As part of the project, habitat modelling was developed as a tool for mapping coastal fish habitat, using the archipelagos of the northern Baltic Proper and the southern Gulf of Bothnia as a pilot area. This led to the development of maps of essential fish habitat for this area (for example, see Figure 45). Since then, the method has been further developed in national projects, producing maps for other areas. The ecological coherence of the marine protected area network in the Baltic Sea was also evaluated as part of the BALANCE project and tools for spatial planning were developed (www.balance-eu.org). Several countries in the Baltic Sea area took part in the project, including Denmark, Sweden, Finland and Estonia.

Within the BONUS project PREHAB (Spatial PREdiction of Benthic HABitats in the Baltic Sea), modelling methods are further developed and used for forecasting effects of eutrophication mitigation measures on fish habitat. The project should also result in a website with advice for managers (www.prehab.gu.se). Methods for empirical modelling and mapping of benthic habitats are developed as part of the project. The project also aims at integrating ecological and economic predictions to evaluate consequences of future changes using different scenarios of human pressures. Among other results, the project has assessed what can be mod-

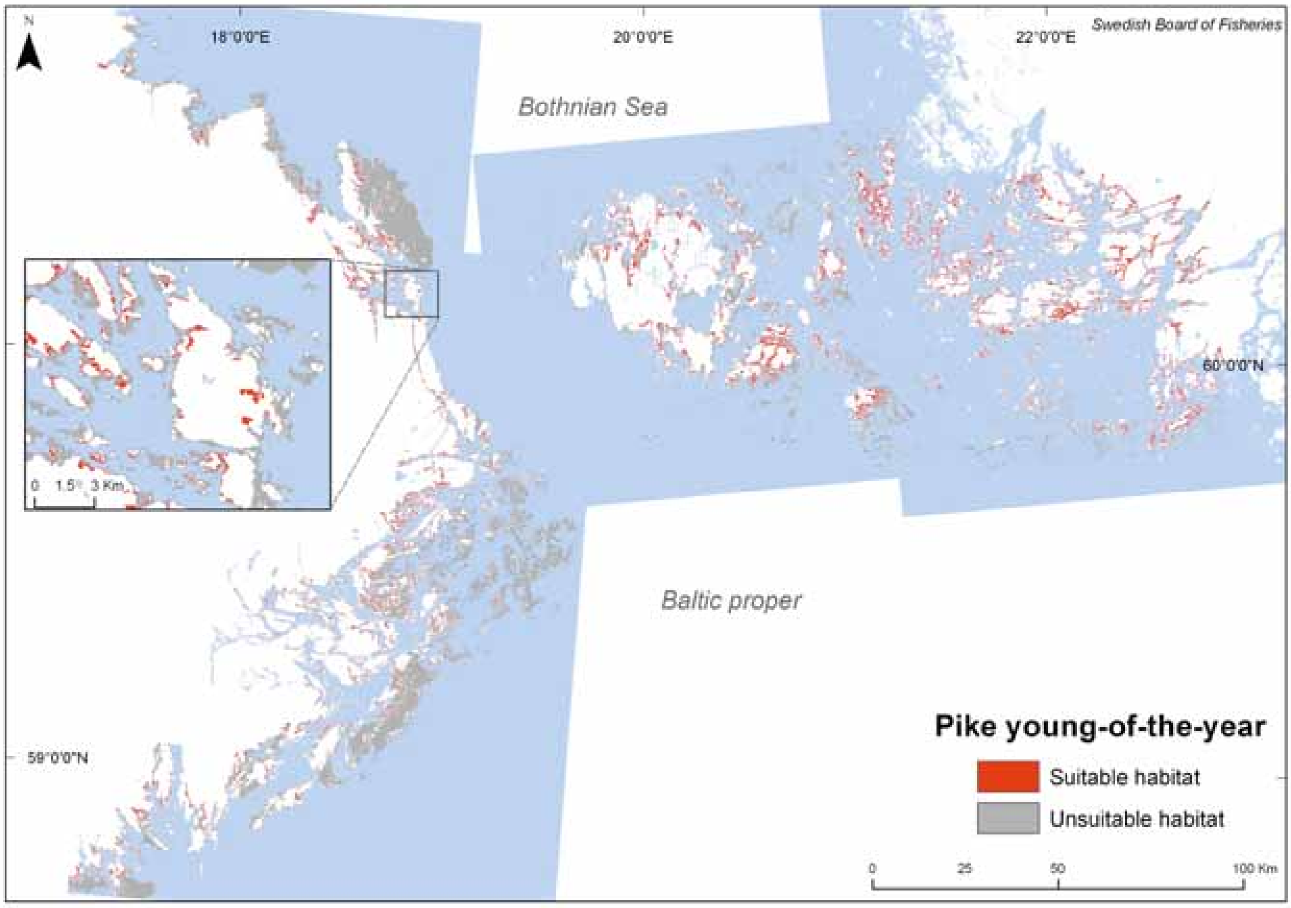


Figure 45. An example of an essential fish habitat map (potential pike nursery areas) for pilot area 3, produced as part of the BALANCE project. Source: Bergström et al. (2007).

elled, the type of information that can be used for modelling, and which statistical tools can be used for modelling. In terms of coastal fish, bathymetry, hydrography and wave exposure were found to be the most important predictors for coastal fish in the western Baltic Proper.

Recent studies have also focused on shallow offshore areas, motivated by the increasing interest in establishing wind farms in these areas, and the need to study their potential effects on the local fish fauna. The use of GIS-based models for producing maps of essential fish habitat at offshore grounds in the central Baltic and Kattegat have been evaluated (Bergström et al. 2011), and a map of fish habitat in shallow areas of the Kattegat has been produced (Fredriksson et al. 2010 based on data from coastal as well as offshore areas. The distribution maps can be used for identifying important spawning and nursery areas, and for identifying areas with exceptional conservation value.

The Kattegatt study (Fredriksson et al. 2010) was based on data collected in a nationally funded project on an inventory of offshore banks, as well as on monitoring data from coastal areas that was collected using the same gear (fyke nets). Habitat maps were produced for a number of species/groups in the Kattegat area: cod <18 cm, cod 18–37 cm, cod >37 cm (*Gadus morhua*), saithe (*Pollachius virens*), sole (*Solea solea*), dab (*Limanda limanda*), eel (*Anguilla anguilla*), poor cod (*Trisopterus minutus*), lobster (*Homarus gammarus*), rock cook (*Centrolabrus exoletus*), goldsinny wrasse (*Ctenolabrus rupestris*), and species richness (number of species). The general results from the offshore bank inventories, including a comparative status assessment, were reported by the Swedish national EPA (Naturvårdsverket 2010).

The ongoing PLAN FISH project[31] is a nationally funded project with the overall aim of understanding how cod and coastal piscivorous fish stocks can be restored by the management of cod and clupeid fisheries, and how the ecosystem would respond to such changes. As a part of the project, surveys and modelling of fish recruitment habitat have been performed in the Blekinge and Kalmar counties (south-western Baltic Proper).

31 www.slu.se/en/faculties/department-of-aquatic-resources/research/plan-fish/

Poland

Project to study potential recruitment areas in the coastal waters of Pomeranian Bay from Międzyzdroje to Swietousc using direct underwater monitoring (2007-2008).

The project aimed for identification of spawning areas of fish in the coastal waters of the Pomeranian Bay (Baltic Sea), was initiated by the scientists from the Department of Marine Ecology and Environmental Protection (Agricultural University, presently West Pomeranian University of Technology in Szczecin, Poland). The study area covered a one nautical mile broad and about 14 km long area along the Wolin Island belonging to the Woliński National Park.

Inventory of the bottom and its cover was carried out by scuba divers operating video cameras as well as gears designed for sampling of bottom epifauna and makroplankton including fish larvae. Eight video and photo transects were directed perpendicularly to the shore line to show the variety of habitats sampled along transect lines, and to document bathymetric changes in environmental characteristics (physical-chemical properties of water and bottom morphology) and epibenthic as well makroplanktonic assemblages. After a preliminary survey carried out on the transects from 100 to 900 m off the shore (depth range from 1-2 m to about 10 m) in late Autumn 2007, transects comprising most diverse bottom habitats (mixed sediments consisting of clay, sand, gravel, stones, and, in some areas boulders) were chosen to be visited again in early spring 2008.

The 2008 survey of the chosen transects indicated the presence of herring roe layer covering blue mussel (*Mytilus edulis*) dominated bottom community present on stones and boulders. Roe biomass of nearly 0.5 kg per square metre, which corresponds to more than 400 thousand eggs, was recorded. Research carried out from the r/v Nawigator XXI later in spring 2008, showed that more diverse bottom supporting epifaunal assemblages in deeper waters (stretching from 0.5 to 1 nautical mile off the shore) are present only in the eastern part of the studied area.

Herring larvae dominated ichthyoplankton sampled in the spring. Eggs of garfish could be found attached to green and brown algae in the western part of the studied area in late spring. The project results showed that the most diverse bottom habitats supporting spawning of commercially exploited fish, such as spring spawning herring and garfish, can be found on the inshore bottom in the western part of the Woliński National Park waters. The main results of the project were presented to the representatives of the fisheries sector as well as scientists and managers of the Polish coastal national parks.

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IGUM - Inventory of ichthyofauna of the Vistula Lagoon - a project carried out within the framework of the NATURA 2000 areas and the designation of new areas.

The aim of the IGUM project (2010–2012) is to make an inventory of the ichthyofauna of the Vistula Lagoon with a particular emphasis on species protected by national and international law. This is carried out by an inventory of spawning grounds: 1) to confirm the location of bream and pikeperch spawning by analysing the presence of spawners, 2) to locate spawning grounds of species protected by national and international law; and 3) to examine the effectiveness of individual spawning grounds of bream and pikeperch.

Pikeperch and bream in the Vistula Lagoon are important due to the joint management of these species with Russia, Kaliningrad region. Protecting the natural resources is achieved through the TAC, minimum dimensions of protection and minimum mesh size of fishing gear and the establishment of protective areas on the spawning grounds. In the Polish part of the Vistula Lagoon, there are currently protected areas and spawning areas. However, owing to ongoing changes in the aquatic environment caused by anthropogenic pressure and increasing eutrophication of Vistula Lagoon, some of these may no longer be functioning.

Research carried out under the IGUM Project will help to verify the location of spawning grounds and to identify new protected areas. In order to identify the location and extent of different habitats, sampling of adult fish, fry and larvae during spawning time will be combined with hydroacustic studies, allowing description of bottom structure. Especially the distribution of early larvae should be useful in identifying and describing the main

Baltic Sea scenery

spawning areas for the investigated species. Field data obtained during the three-year-long IGUM project will be compared with historical information on spawning grounds distribution in the Polish part of the Vistula Lagoon.

National experience of stakeholder involvement in applying ecosystem-based management to coastal fisheries

As for fisheries management in general, the management of coastal fish communities has been moving toward the application of an ecosystem-based approach. This indicates that there is a recognition that benefits can be achieved by considering the coastal ecosystems as a whole entity, rather than addressing coastal fish stocks in isolation.

If ecosystem-based coastal fish management is to be reliable, it must be based on reliable ecosystem assessments, covering both coastal fish communities and their relationship with the surrounding environment. Targets, limits and reference points are a central feature of such assessments and of the ecosystem-based approach used by HELCOM.

Reference points are needed for setting the goals to be achieved through management action. Due to the large variation in coastal habitat around the Baltic Sea, reference points for coastal fish must be local and area-specific. Ecosystem-based management programmes are therefore challenging to draft and implement.

Ecosystem-based management plans should ensure long-term sustainability of commercial and recreational fisheries and should also take into consideration the other uses of the coastal zone. To be effective, the development of such plans calls for stakeholder involvement. Participation of stakeholders is also crucial for enforcing management plans and thus implementing the ecosystem-based approach to the management of coastal fish communities.

The following sections describe some national efforts to implement ecosystem-based management of coastal fisheries, with a particular emphasis on the role of stakeholder involvement in these processes.

Case studies

Coastal fisheries management in Estonia

In Estonia, drafts of new legislative acts on coastal fisheries management, including the specification of catch limits, are sent to fishers for consultation and comment before their final approval. Scientific advice forms the basis for the proposed management measures. If the advice provided implies substantial restrictions to fishing possibilities, it will be discussed prior to implementation with fishers in a specially arranged stakeholder consultation meeting.

Fisheries management in Finland

In Finland, fisheries are managed regionally by so-called 'fisheries regions'. These are legal co-operating organisations, represented by local water owners, commercial fishermen and recreational fishermen. The fisheries regions aim to promote fisheries at the local scale and agreed principles of local fisheries management and fish stocking programmes are written into local 'master plans'. The fisheries regions also have a legal right to regulate the minimum mesh sizes of gill-net fisheries and to set temporary fishing restrictions in order to protect spawning of predatory fish (pike, pikeperch). As an example to illustrate the scale of these organisations, along the Gulf of Finland there are fourteen fisheries regions covering the Finnish coastal area. In some regions, the work of the fisheries regions has been successful and based on good knowledge, but in others the decision-making has been less successful. A reform of the Finnish fishery legislation started in 2008, and the future of the fisheries regions is unclear.

Åland Islands has its own legislation on fisheries management. The water owners are responsible for the management of fish resources, such as by regulating the number of gears and the protection of reproduction areas from fishing. In some cases several water owners unite to form a cooperative on fishery issues. There is a diverse range of ownership for the coastal waters of the Åland islands and so stakeholder involvement in fishery issues may be large for a cooperative, but low for some water owners.

Marine Protected Area (MPA), Gotska Sandön in the Baltic Proper, Sweden

Pike is subject to a tagging and monitoring project at Åland Islands. Stakeholders, in this case fishing guides, undertake the tagging and monitoring and local government provides equipment and data storage.

Input to fisheries legislation in Latvia

Fishermen's organisations have been increasingly involved in fisheries management in Latvian coastal waters over the past five years. An example, is proposals made by fishermen's organisations for changes to be made in national fisheries legislation, suggesting alternative measures in coastal fisheries regulation etc. With the support of fisheries biologists, some of these proposals have already been adopted in national legislation.

Co-management of coastal fisheries in Poland

Co-management of coastal fisheries management in Poland is realised jointly through the cooperation of Regional Inspectorates of Fishery and fishermen associations together with a ministerial Team for Restocking. The Polish Angling Association is also engaged in the process of salmonid restocking. All changes in legislation are proposed by the Ministry of Agriculture and Rural Development or Regional Inspectorates based on recommendations by scientists.

A new programme designed within the European Fisheries Fund (EFF) was launched in 2010. Special operational funds were assigned to create new local organisations, comprising local administration and fishery organisations. So-called Local Fishery Groups competed for the funds on the basis of a programme for sustainable development of fishery dependent areas. The successful organisations signed an agreement with the Polish fishery administration in early 2011, some represent the coastal area.

Stakeholder involvement in restoration activities in Swedish coastal areas

Stakeholder involvement has been crucial in most of the restoration actions of coastal fish recruitment habitats in Sweden (see above). Local sport fishery organisations, municipalities and landowners and fishing right owners have often conducted the actual restoration, while universities, county agencies and the Swedish Board of Fisheries have performed follow-up studies and assessment of the action taken. In the temporal closures of recruitment habitats in the Stockholm Archipelago, for example, representatives from the commercial and recreational fishery, local environmental agency, and local water owner association, and fishery scientists, agreed upon a temporary closure of the fishery in areas where recruitment of pike and perch is considered especially important for local stocks. The selection of recruitment areas for temporary closure to all types of fisheries was made on the basis of habitat-models of areas of potential importance for recruitment of these species. All stakeholders involved agreed on the decision, and follow-up studies have called for an increase in the number of protected areas.

Coastal streams are often of significant importance for the recruitment of fish to the coastal fish communities. Many of these streams were drained in the 1900s, to provide more land for agriculture. However, this ruined migration routes as well as recruitment areas for many of the freshwater species that make up the main coastal fish communities. The project on restoring recruitment areas mentioned above, enhanced collaboration between national fisheries authorities, the scientific community, the regional environmental agency, and the local authorities and fishing right owners that jointly selected a number of areas for restoration. The roles and involvement of the stakeholders differ, but the common goal is to evaluate methods to be used in similar restoration activities along the coast.

In recent years, so-called ‘regional fishing areas’ have been established in Sweden. These cover most of the Swedish coast and have the aim of developing new methods and enterprises in coastal areas with focus on fish. The work is funded by regional and local funds and by the European Fisheries Fund. Examples of such projects are the temporary and permanent closure of whitefish recruitment habitats.

Concluding comments

Lessons learned from these case studies highlight the importance of involving stakeholders in managing coastal fish communities. Involvement is necessary both at the planning (objective setting) stage as well as for successful implementation of agreed action (management plan). Decisions that are of relevance to coastal fisheries should take into account the experience of fishermen as well as scientific advice. Importantly, the application of an ecosystem-based approach to managing coastal fish communities requires strategies that allow for adaptive management approaches, which can respond to the changing status of the ecosystem and to new information as this becomes available.

Discussion and recommendations

This assessment had three objectives. First (Part I), to suggest a method for selecting indicators of coastal fish community status and to evaluate the relationship between selected indicators and environmental and manageable pressures. Second (Part II), to use the method selected to assess the current status of coastal fish communities for Contracting Parties to the HELCOM FISH PRO project. Third (Part III), to review existing restoration and restocking programmes for threatened and declining coastal fish species in the HELCOM Member States.

The outcome of this assessment served as the basis for selecting indicators of coastal fish community status in the Baltic Sea, as required by the EU Marine Strategy Framework Directive (MSFD) and developed within the HELCOM CORESET project in 2011. The set of selected indicators presented in this report were categorised within Descriptor 1 (biodiversity) of the MSFD in the following categories: Population abundance/biomass (1.2.1), Population demographic characteristics (1.3.1), Habitat condition - Condition of typical species and communities (1.6.1), Habitat condition - Relative abundance and /or abundance (1.6.2), and Ecosystem structure - Composition and relative proportions of ecosystem components (habitats and species) (1.7.1) for coastal fish communities in the Baltic Sea.

In Part I, a multivariate method (based on PCA-ordination) is suggested to select indicators for coastal fish community assessment. This method is generally applicable across monitoring methods. It will result in a unique combination of indicators for each monitoring method, accounting for differences among methods and areas in, for example, species composition and gear-specific properties. The selected indicators represent the following categories, *Species Composition*, *Size Structure*, *Trophic Structure* and *Species Diversity,* and the outcome of the resulting assessment should be generally comparable across monitoring programmes with respect to these categories.

Recording position of the station and water temperature in Mönsterås, southern Swedish Baltic coast, August

There was some redundancy in the final set of selected indicators and in their responses to pressures. The relationship of the state indicators to manageable pressures was, however, consistently stronger than to the natural pressure factors (water temperature, salinity, wave exposure and depth). *Non-piscivores*, *Marine Species* and *Diversity* were generally negatively related to commercial catches, whereas *Mean Trophic Level* exhibited a positive relationship with this pressure. *Piscivores* and *Mean Trophic Level* were negatively related to the population density in the area.

The observed relationships between indicators and pressures are not necessarily causative. A relationship between indicators and pressures shows that the indicator is able to reflect the variation in the pressure. This variation might potentially also be caused by some unknown, third, variable that is directly affected by environmental or anthropogenic disturbances. Hence, the analyses represent a first step to resolve pressures on coastal fish communities in the Baltic Sea. Moreover, the results are limited by the availability of data on potential pressure factors. Coastal ecosystems are influenced by several potentially important factors that are not well documented, such as the extent of recruitment areas and the abundance of apex predators (i.e. cormorants and seals). Essential for the study is also that it is based on data from reference areas, where the level of anthropogenic disturbance is expected to be lower than for many other areas in the Baltic Sea. Future analyses should benefit from including additional potential pressure factors, as well as data from areas with higher levels of anthropogenic disturbance. There are also differences in natural environmental conditions between areas. Levels in the indicator abundance of Cyprinids, for example, are sensitive to ambient conditions. If the monitoring area is situated in a bay with relatively high water temperatures, conditions are favourable for Cyprinids, whereas monitoring areas further away from sheltered bays, with cooler waters, offer a less suitable habitat for this group of species. In such areas, differences in natural conditions may potentially interact with the effects of anthropogenic stressors, and mask these.

A range of methods for coastal fish monitoring are in use in the Baltic Sea. The most important differences relate to the type of gill-net used, the number of stations sampled per year, and the depth interval covered. As a consequence of these differences, slightly different sections of the fish community are sampled by the different methods, making it difficult to harmonise the data obtained and to directly compare indicator trends among areas when sampled by different methods. Therefore, indicators are not directly transferable across gears and the final selection of indicators for assessment should be gear-specific. There is a need to further harmonise assessment routines for different monitoring methods, in order to diminish problems associated with differences in methodologies across the region.

In spite of these potential shortcomings, there was agreement between the spatial pattern of indicators and species composition for all three gear types considered. This suggests that the set of selected indicators largely represents the spatial differences in species composition for the communities assessed.

In Part II, the temporal development and current status of coastal fish communities in Sweden, Finland, Estonia, Latvia, Lithuania and Poland was assessed. As a reference period for the assessment, the longest period in common for all monitoring areas was used, 1995–2004. The assessment was performed for the last five years of the time period, 2005–2009. In the Gulf of Bothnia, coastal fish monitoring is conducted using Coastal survey nets, and in the Baltic Proper using Net series. Because of this, somewhat different sets of indicators were used for the two basins. The indicator datasets do, however, encompass indicators representing the four categories; *Species Composition*, *Size Structure*, *Trophic Structure* and *Species Diversity* in both basins. At this level, the assessment results should be comparable across basins.

In the Gulf of Bothnia, the five assessed communities have been stable with regard to total abundance, trophic state and species diversity. The only major change in indicators related to abundance was observed in the abundance of Cyprinids, which increased in three of the studied areas (Brunskär, Finbo, Holmön). This was also manifested as a decrease in the trophic level of the fish community in Holmön. In the two Finnish areas (Brunskär, Finbo) there has been an increase in freshwater species over time. The overall strongest change was seen in the indicators related to size structure, which generally increased over time. This pattern was particularly pronounced in the Forsmark area, and was driven by an increase in the mean length of the key species perch, which was also above average levels in the Finbo and Holmön areas during the assessment period. Multivariate analyses, considering all ten state indicators at the same time, showed that the overall state of the fish community was different to that during the reference period only in the Holmön area. This was mainly due to an increased abundance of Cyprinids and large-bodied fish species. Concurrent to the changes observed in the communities assessed, there has been a general increase in water temperature over time that supposedly favours the growth of perch and other freshwater species, including Cyprinids.

In the Baltic Sea, a somewhat different pattern in the development of the six fish communities assessed was discernable. For three of the areas, the assessed communities have been stable (Daugavgriva, Curonian Lagoon, Jūrkalne). In Hiiumaa, Vinö and Kvädöfjärden a decrease in total abundance was observed, mainly due to a decrease in Cyprinid abundance. In Vinö and Kvädöfjärden, a diminishing trend was also seen in the abundance of piscivores. In contrast to the Gulf of Bothnia areas, the indicators reflecting size structure showed a decreasing trend in all areas, with the exception of the Kvädöfjärden area, where an increasing trend was seen. The strongest decrease in the size-related indicators was seen in the Vinö and Hiumaa areas. Despite the long-term decreasing trends, the mean values of the indicators during the assessment period were often at the same level as the values during the reference period, indicating that the highest values in the indicators reflecting size structure generally occurred in years prior to the reference period. The indicators related to trophic state were generally similar to the reference period, with the exception of the decrease in the abundance of piscivores observed at Vinö. Also, an increase was observed in the proportion of piscivores and trophic level in Kvädöfjärden, probably related to the decrease in Cyprinids observed in the same area. For species diversity, significant and increasing trends were discernable for the Hiumaa and Kvädöfjärden areas. The multivariate ordination of all ten state indicators suggested that the state of the communities at Hiumaa and Vinö has departed from that of the reference period. In both areas, the most recent years were mainly characterised by low total abundances and low abundances of Cyprinids. In Vinö, the abundance of piscivores in the most recent years was also below average.

In some areas, Hiumaa and Curonian Lagoon, the changes observed in the assessed communities might be attributable to increased fishing pressure, predation from cormorants and increased eutrophication. In other areas, such as Vinö and Kvädöfjärden, the temporal development of potentially important pressures was not related to the development observed in the fish communities. The changes might be related to pressures that are not monitored in the area in sufficient detail to be included in the analyses, such as predation from seals, birds or fish, or to decreased recruitment success.

For the Polish areas, a similar analysis was not possible due to data limitation. Data at species level from the Vistula and Szczecin (Odra) Lagoons since the 1930s, however, suggest that there has been a substantial decrease in pike in both areas. In the Szczecin (Odra) Lagoon, this was also accompanied by a decrease in eel and an increase in *Alosa* sp.

To conclude, the assessment indicates that the communities in the Gulf of Bothnia and Baltic Proper have to some extent differed in their temporal trajectories over the past 15 years and are impacted by different influential stressors.

Summarising the results from the present assessment, the following recommendations are suggested:

- Owing to the inherent differences in natural conditions among regions and areas in the Baltic Sea, information on long-term changes in each area is a vital part of the status assessment. It is therefore important for all Contracting Parties to continue current monitoring programmes.
- To widen the geographical coverage of future assessments and to harmonise sampling programmes, additional Contracting Parties such as Russia, Germany and Denmark are invited to take part in the future work of HELCOM FISH PRO.
- The monitoring programmes described in this report do not cover all sub-regions of the Baltic Sea. Thus, they can support, but not fully meet the required spatial coverage of reporting in

relation to the EU Marine Strategy Framework Directive. Potential solutions might either be to establish additional monitoring programmes, as is currently happening in Poland, or to make use of alternative datasets. Other potential data sources include samples from commercial catches (collected within the EU Data Collection Framework), commercial catch statistics, trawl surveys or hydroacoustic surveys, provided that the data meet the requirements of representative sampling for biodiversity of the coastal fish community. The potential to include alternative datasets as part of the assessment should be evaluated further in the near future.

- Coastal fish communities in the Baltic Sea are to a large extent influenced by local natural conditions such as salinity, water temperature, habitat characteristics and depth. Ideally, future assessments should consider these factors or control for them as part of the analyses. Evidence of substantial changes in the composition of marine ecosystems is accumulating, and further highlights the need for an adaptive approach to coastal management, and the need to re-evaluate reference periods when needed.
- The effects and influence of non-indigenous species on coastal ecosystems are largely overlooked in this report, but insights from studies on these species should be considered in future assessments.
- The results reported here emphasise the usefulness of basing the status assessment on multiple indicators, in order to help interpret the causes of observed changes. Typically, a change will be detected in some of the state indicators but not in others. In other cases, the nature of the changes in one indicator can only be understood if interpreted together with changes in one or more other indicators. This is further emphasised by the fact that it is generally difficult to identify causal relationships between changes in fish communities and external pressures, although common patterns (correlations) can be detected. The final set of indicators used in the assessment should be area- and gear-specific and based on the intended use of the results.
- The availability of reliable data on potential pressure factors provided a limitation to the data analyses. Thus, there is a need for increased effort on collecting data on pressure factors. Another constraint was that information on potential recruitment habitats in the different areas was not included due to data limitation. Including the quantity and quality of recruitment areas may provide a significant improvement on future assessments of coastal fish communities.
- Regular meetings between Contracting Parties to share data and experience are essential for future joint assessments. There is an ongoing need to harmonise assessment methods among the different countries to reduce potential difficulties associated with region-wide assessments.
- Interactions within the coastal fish communities (such as related to changes in trophic level and effects of predatory fish), as well as interactions between the coastal and open sea habitats possibly influence the response of the indicators suggested in this report. These types of interaction must be further investigated and taken into account in future coastal fish assessments.

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Annex 1

Table A1. Summary of restoration programmes for coastal and migratory fish species in the Baltic Sea area.

Restoration activity name or ID	Species	Locality	Time period (years)	Measure	Primary aim	Evaluation of success	Contact
Seatrout Funen (Havørred Fyn), Denmark	Sea trout (*Salmo trutta trutta*)	Funen, Belt Sea, ICES rectangle 22	1998-2010	Tourism of coastal anglers; Artificial releases of smolt; Habitat restoration of freshwater streams	To provide a better foundation for angling tourism based on attractive coastal fishery on natural resources of wild sea trout	Increased tourism of coastal anglers, more than 50 restoration projects in freshwater streams, about 3.5 million trout smolt released in the period 1998- 2008, see also; www.nordfynskommune.dk/nordfynsftp/agenda/OxM-pOc-7fXB_oY2PNIpgMQ.pdf	Havørred Fyn Sekretariatet Odense Kommune Park & Natur Att. Birgit Bjerre Laursen E-mail: bbl@odense.dk Website: www.odense.dk/WEB3/Havoerred-Fyn.aspx and www.seatrout.dk/index.php?page=7_50
Restoration of sea floor in Vejle Fjord (Restaurering af havbund i Vejle Fjord), Denmark	Coastal fish communities	Vejle Fjord, Belt Sea, ICES rectangle 22	2002-2009	Sea floor coverage of netbags with mussel shells; Coastal fishery with gill nets and fykes; Fish larvae and sprat surveys	To evaluate if local seafloor restoration projects can increase populations of coastal fish and other marine organisms	Primary results show that the project positively affects both benthic organisms and coastal fish species.	Josianne Støttrup, Per Dolmer and Claus Stenberg DTU Aqua, Institut for Akvatiske Ressourcer, Denmark Email: jgs@aqua.dtu.dk or CSI@aqua.dtu.dk www.fiskepleje.dk/kyst/restaurering/vejle_fjord.aspx
DTU Aqua, Institut for Akvatiske Ressourcer, Denmark	Marine organisms living in boulder reef habitats	Læsø Trindel, Kattegat, ICES rectangle IIIa	2006-2012	Rebuilding reef with about 60 000 m3 boulders of various sizes; Biodiversity and abundance of benthic organisms, macroalgae and fish	To provide a significant contribution to maintaining the populations of species dependent on the cave-forming boulder reef in Danish waters and function as a crucial steppingstone within a marine corridor linking sites within the Natura 2000 network, as well as being a sanctuary for donor populations	Information not yet available	The project is managed by the Forest and Nature Agency in cooperation with The Agency for Spatial and Environmental Planning, The National Environmental Research Institute and The National Institute of Aquatic Resources. DTU aqua contacts: Josianne Støttrup and Claus Stenberg DTU Aqua, Institut for Akvatiske Ressourcer, Denmark Email: jgs@aqua.dtu.dk or CSI@aqua.dtu.dk Website: www.skovognatur.dk/Naturprojekter/Projekter/Vendsyssel/BlueReef/English/
Email: jgs@aqua.dtu.dk or CSI@aqua.dtu.dk	Pikeperch	Pärnu Bay (NE Gulf of Riga)	Since early 1980s	Placement of artificial spawning substrata ('nests')	Provide better conditions for hatching	Two categories of parameters are routinely calculated (based on evaluations by visual inspection): i) proportion of nests used by pikeperch, ii) proportion of normally developed embryos. These results show that up to 90% of nests are annually used as a spawning habitat and the proportion of normally developed embryos usually exceeds 80%.	heli.spilev@ut.ee
www.fiskepleje.dk/kyst/restaurering/vejle_fjord.aspx	Sea trout, salmon, whitefish	Coastal areas of Finland	Several ongoing projects	Building of fish ladders and ways, habitat restoration in rivers, supporting stockings	Increase the natural smolt production	????	aki.maki-petays@rktl.fi
Mapping of reproduction areas (VELMU and INTERSIK), Finland	Pike, perch, pikeperch, roach, flounder, herring, sea spawning whitefish	Coastal areas of Finland	2005-2012	GIS mapping	Conservation of reproduction areas. Basic information to support local fishery restrictions during the spawning period	????	antti.lappalainen@rktl.fi

Restoration activity name or ID	Species	Locality	Time period (years)	Measure	Primary aim	Evaluation of success	Contact
Stocking of burbot and sander	Sander, burbot	Coastal areas of Åland	2011	Pilot project	Stocking of commercially important species to compensate landings of fishery and recreational fishery	Starting in 2011 and ongoing if successful	kaj.adjers@regeringen.ax
Tagging and monitoring of pike	Pike	Coastal areas of Åland Islands	Start 2005 and ongoing	Tagging and registration of CPUE	Following the size of the pike population, migrations	Ongoing	kaj.adjers@regeringen.ax
Mapping of reproduction areas, Åland Islands	Pike, perch, sander, roach, burbot, flounder, turbot	Coastal areas of Åland	Start 2009 and ongoing	GIS mapping	Conservation of reproduction areas from different constructions and human measures	Ongoing	kaj.adjers@regeringen.ax
Restoration plan for sander stocks at Åland	Sander (*Sander lucioperca*)	Åland	2004-2015	Legislation, prohibit fishing of sander during reproduction period	To allow stock recovery of sander		kaj.adjers@regeringen.ax
Introduction of trout, Åland Islands	Trout	Small streams at Åland Islands	Start 2006 and ongoing	Stocking of trout of genetically suitable form (Gotland)	Stocking of trout into possible reproduction areas		kaj.adjers@regeringen.ax
Stocking of commercial important species, Åland Islands	Trout, pike, whitefish	Åland	Start in 1950s and ongoing	Stocking of commercial important species	Stocking of commercially important species to compensate landings of fishery and recreational fishery		kaj.adjers@regeringen.ax
Temporal closures of recruitment areas in the Stockholm Archipelago, Sweden	Mainly pike and perch	Bays in Stockholm Archipelago, Sweden	2003 - ongoing	Temporal closures of 25 recruitment areas	Increase recruitment success of coastal fish species	The successful involvement of stakeholders in the process of temporary closures has resulted in a general acceptance of the measure, and a call for a closure of other particularly valued areas. An early evaluation showed no clear effect on local recruitment in recruitment poor areas, pointing to the importance of larger scale processes to functioning recruitment dynamics. It also highlights the importance of a network of temporal closures for functioning recruitment areas as these areas potentially function as sources to areas with non-functioning coastal pike and perch recruitment	ulf.bergstrom@slu.se

Restoration activity name or ID	Species	Locality	Time period (years)	Measure	Primary aim	Evaluation of success	Contact
Restoration of spawning habitats in coastal freshwaters, Sweden	Mainly pike and perch	Creeks and streams in the Kalmar County, Sweden	2006-2010	Restoration of migration paths and recreation of wetlands connected to five creeks and streams in the Kalmar County	Restore spawning habitats of coastal fish	The involvement of stakeholders in the programme has been highly successful. Stakeholders and counties have themselves undertaken the actual restoration measures. The evaluation so far shows a several-fold increase in the amount of migrating larvae (from freshwater to coastal areas). It is not yet clear whether the number of sexually mature individuals swimming up the streams to spawn has increased compared to before restoration measures. That is, future evaluation will reveal how restoration measures have contributed to the number of individuals in coastal stocks	jens.olsson@slu.se
Pikeperch stocking for mediating effects of eutrophication, Sweden	Pikeperch	Himmerfjärden, Stockholm Archipelago, Sweden	2007-2011	Pikeperch stocking followed by monitoring the effects of biomanipulation	Restore the food web structure in an eutrophied bay through pikeperch stocking	Information not yet available	sture.hansson@ ecology.su.se
Restoration of salmon and sea trout in Polish waters	Salmon, sea trout	Polish rivers in ICES sub-div 24-26	Start in 1994-ongoing	Artificial releases; improving fish passages	Increase recruitment, sustain mixed populations in rivers, restore spawning possibilities, compensate landings	Yearly releases of 300-500 thousand salmon smolt and 1-1.5 million sea trout smolt. Yearly electrofishing surveys in potential rivers is documented in many ICES WGBAST Reports. Several publications on effectiveness of stockings and effectiveness of passages. www.pzw.org.pl/pliki/prezentacje/1395/cms/szablony/3622/pliki/015_rbartel.pdf	Prof. Ryszard Bartel, gdansk@infish.com.pl
Reintroduction of whitefish in Puck Bay, Poland	whitefish, *Coregonus lavaretus*	Puck Bay, ICES-sub-div 26	Start in 1994-ongoing	Artificial releases	Restoration of existing until 1980s natural population	Yearly releases of 20-100 thousand juveniles. After some years the population is rebuilt with its catches up to 1000 kg. Several publications on effectiveness of stockings, see also: www.ejpau.media.pl/volume9/issue1/art-36.html	wpelczar@mir.gdynia.pl
Polish-German reintroduction of sturgeon	*Acipenser oxyrhynchus oxyrhynchus*	River Odra with tributaries	2001-2009	Artificial releases	To establish self-sustaining population	In the 2001-2009 period a total of 60 000 fish were released. Several publications on effectiveness of stockings have been published. Several sturgeons with tags were caught within the past few years.	Prof. Ryszard Kolman, kolrys@infish.com.pl
Reintroduction of vimba, Poland	*Vimba Vimba vimba*	Odra and Vistula Rivers	2003-ongoing	Artificial releases	To improve and sustain populations	Up to 400 000 juvenile vimba were released over the past few years , see also: www.pzw.org.pl/pliki/prezentacje/1395/cms/szablony/3622/pliki/015_rbartel.pdf	Prof. Ryszard Bartel, gdansk@infish.com.pl
National Eel Management Plan based on Regulation (EC) No 1100/2007, Poland	*Anguilla anguilla*	Odra and Vistula River Basen Districts and transboundary waters	2010-ongoing	Stocking with glass eel or fingerlings, making migration routes passable, combating poaching, new catch rules (new closed seasons, daily rod catch limit, unifying protected size, improving gear selectivity)	40 % of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock	Will be carried out initially every third year, with the first report to be presented by 30 June 2012	nermer@mir.gdynia.pl

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