Analyse of Baltic fish community since 1980´s with regard to environmental changes

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Semesterarbeit

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Abstract

The fishery catches of the Baltic autumn acoustic surveys, conduced since 1978 and covering the Western Baltic Sea, were analysed concerning changes in diversity and community structure in the context of the climate change. The highest annual values for the number of species and the diversity after Shannon were found in the Kattegat and Belt Sea, lowest in the Baltic Proper. In general, the diversity indices show no strong trend over time, especially not in SD 22 and SD 24. This subdivisions provided the most comprehensive dataset. The community analyse of these areas evidenced only little change in the pelagic fish assemblage since 1991. Whereas the mean October temperature of medium water layer increased annually with an average of 0.19°C in the Belt Sea and 0.11°C in Arkona Sea during this time, the bottom salinity was variable but without trend. Neither temperature nor salinity had a clear correlation to associated diversity indices. Furthermore there was no explicit linkage between these abiotic properties and the pelagic fish community. Altogether a climate change driven shift in the Baltic fish community could not be found.

Introduction

The environmental conditions have a strong influence on the distribution of fish species. Main factors are temperature, salinity and oxygen, which affect all stages in fish life history. Concerning these properties the Baltic Sea offers a wide range, reaching from nearly marine salinity and moderate temperature range in the transition area to the North Sea and the Atlantic Ocean in the southwest, to low saline conditions with long periods of ice coverage in the north and northeast (Lehmann & Hinrichsen 2000; Winsor *et al.* 2001). The biggest part of the Baltic has a brackish attitude, which represents a great stress for many species and only specialised ones can live and reproduce there (Oikari 1978). Furthermore there is a great variability in the conditions over time, e.g. the irregularity of inflow events and the formation of different water bodies on top of each other. Consequently, there are marine as well as fresh water species forming a particular fish assemblage in distinct subdivisions in order to prevailing circumstances (Aro 1989).

In terms of the climate change a spatial shift of species towards higher latitudes in order to the prefered temperature range is proved by different studies (Perry *et al.* 2005). According to this a change in the fish community structure of the Baltic may be possible. It is already shown for inshore marine (the English Channel) and estuarine (the Bristol Channel) habitats (Genner *et al.* 2004).

A warming especially since 1970s was recorded for the North and Baltic Sea`s SST using long term monitoring data since 1860 (MacKenzie & Schiedek 2007). Higher temperature may support the introduction of marine species but other factors such as low salinity could prevent a successful colonisation (MacKenzie *et al.* 2007).

The aims of this study are to give an overview about the fish community and its development over the last 30 years in different areas of the Baltic Sea, with a special focus on the structure of the pelagic fish community. Furthermore the results are linked to environmental conditions to investigate the possible influence of the climate change.

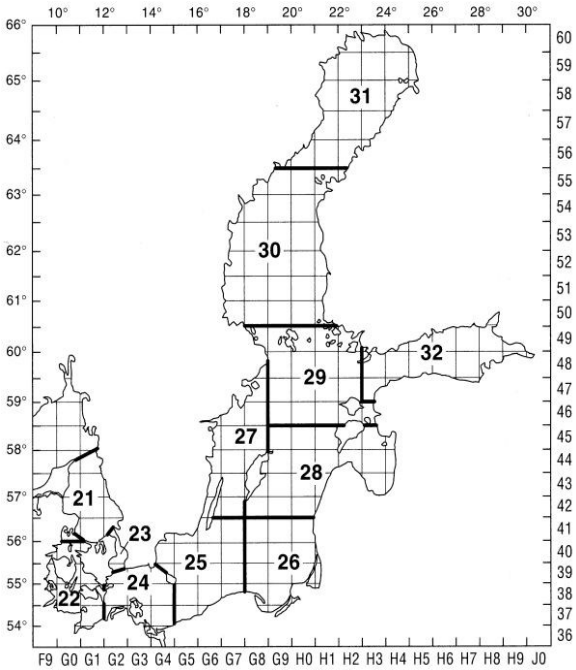

Fig. 1: Baltic Sea subdivisions of the Internatinal Council for the Exploration of the Sea (ICES)

Material and Methods

The present study is based on German fisheries data from the Baltic autumn acoustic surveys carried out annually from 1978 until 2008, except 1982 and 1985, between September and November.

The catch data were sampled on board of three research vessels, which used different pelagic and bottom trawls (Tab. 1). Until 1989 the surveys were conducted by the fishery research institutes of the GDR, focusing on subdivisions (SD) 24-26 and more northern areas (Tab. 2).During this time the pelagic gear “Jagernetz” was mainly used to perform the hauls. In general there is little information available about the circumstances of the survey, gears and treating of catch data, e.g. if non target species were recorded constantly. Therefore, obtained data for 1978 to 1989 have to be used with caution.

Additionally the FRG conducted surveys in 1987 and 1989 too. In 1991 the joint German-Danish autumn survey became part of the Baltic International Acoustic Survey (BIAS) coordinated by the ICES (WGBISF). The main focus of this survey series is to collect data used for the assessment of Baltic herring and sprat. Within this international framework, Germany covers the western Baltic Sea (SD 21-24 and in some years SD 25 (Tab. 2)). The samples were taken during night time. The sampling procedure applied for this survey series is internationally coordinated (since 2000) and described in ICES 2000.

Since 1996, the pelagic gear “PSN 388” with a codend mesh size of 10 mm and vertical net opening of about 8-10 meter was used during most cruises. In general the depth of the trawl was chosen in accordance to the echo signals and controlled by a netsonde. The haul duration was typically about 30 minutes, but was sometimes extended or shortened in order to the density predicted by echoes. All catches were standardised to catch per hour, because of differences in trawl duration. A further standardisation for gear effects could not be performed.

Tab. 1: ***Baltic acoustic autumn survey: detailed information about the surveys from 1978 to 2008.***

year	country	start-date	end-date	vessel	used gear(s)	
1978	GDR	10-03	10-19	Eisbär	PEL. JAGERNETZ	pelagic
1979	GDR	09-27	10-21	Eisbär	PEL. JAGERNETZ	pelagic
1980	GDR	09-26	10-21	Eisbär	PEL. JAGERNETZ	pelagic
1981	GDR	10-06	10-28	Eisbär	PEL. JAGERNETZ	pelagic
1982		no survey				
1983	GDR	09-29	10-24	Eisbär	PEL. JAGERNETZ	pelagic
1984	GDR	09-29	10-23	Eisbär	PEL. JAGERNETZ	pelagic
1985		no survey				
1986	GDR	10-04	10-29	Eisbär	PEL. JAGERNETZ	pelagic
1987	GDR/FRD	10-01	10-29	Eisbär/Solea	AALSTEERT	bottom
					GOV	bottom
					SCHERBOMBER	bottom
1988	GDR	10-01	10-28	Eisbär	PEL. JAGERNETZ	pelagic
1989	GDR/FRG	10-11	11-19	Eisbär/Solea	AALSACK	bottom
					ANTJE	pelagic
					SCHERBOMBER	bottom
1990	FRG	11-03	11-11	Solea	AALSACK	bottom
					SCHERBOMBER	bottom
1991	GDR	10-16	10-27	Solea	AAL 752	bottom
					KAB 664	bottom
1992	GDR	10-18	11-11	Solea	GOV	bottom
1993	GDR	09-30	10-18	Solea	BLACKSPRUTTE	pelagic
1994	GDR	10-01	10-17	Solea	AALHOPSER	bottom
					BLACKSPRUTTE	pelagic
1995	GDR	10-05	10-18	Solea	OCTOPUS	pelagic
1996	GDR	10-02	10-17	Solea	AALHOPSER PELAGISCH	bottom/ pelagic
					PSN 388	pelagic
1997	GDR	09-16	09-30	Solea	AALHOPSER	bottom
					HG 20/25	bottom
					PSN 388	pelagic
1998	GDR	10-03	10-18	Solea	AALHOPSER	bottom
					PSN 388	pelagic
1999	GDR	09-27	10-14	Solea	PSN 388	pelagic
2000	GDR	10-01	10-18	Solea	PSN 388	pelagic
2001	GDR	09-28	10-15	Solea	PSN 388	pelagic
2002	GDR	10-14	10-24	Solea	PSN 388	pelagic
2003	GDR	09-30	10-17	Solea	PSN 388	pelagic
2004	GDR	10-01	10-16	Solea(new)	PSN 388	pelagic
2005	GDR	10-06	10-20	Solea(new)	KRAKE	pelagic
2006	GDR	10-08	10-22	Solea(new)	PSN 388	pelagic
2007	GDR	10-06	10-22	Solea(new)	PSN 388	pelagic
2008	GDR	10-05	10-20	Solea(new)	PSN 388	pelagic

For every haul, the catch was determined to the lowest possible taxon, whereas catch composition, length distribution and weight of single species were recorded. The level of species-separation and used nomenclature differed between years. Therefore, the species names and species groups were standardized for further analysis ("species/species group" Tab. 4, Appendix). This nomenclature is used in the following as species, whereas species were grouped based on taxonomical affiliation. Furthermore, for all fish species the habitat (benthic or pelagic), status in the baltic (stationary (st), guest species (g) or vagrant (irr)), frequency (common, regular or rare) and environment (marine (M), diadromous (D) and fresh water (F) species) was determined based on the work of Winkler and Schröder concerning the fish species in the German area of the Baltic Sea (Winkler & Schröder 2003).

Tab. 2: ***Baltic acoustic autumn survey: Number of hauls per subdivision and year***

SD	1978	1979	1980	1981	1983	1984	1986	1987	1988	1989	1990	1991	1992	1993	1994
21	-	-	-	-	-	-	-	-	-	-	1	-	-	11	12
22	-	-	-	-	-	-	-	10	-	21	19	14	21	16	24
23	-	-	-	-	-	-	-	-	-	-	-	2	-	3	3
24	3	8	6	7	5	8	-	7	5	9	1	9	39	18	17
25	4	14	13	8	11	9	11	-	5	6	-	11	2	-	4
26	10	21	8	12	12	16	13	16	16	14	-	-	-	-	-
27	7	5	7	9	3	-	-	-	-	-	-	-	-	-	-
28	9	11	11	15	17	10	13	15	10	16	-	-	-	-	-
29	10	10	10	11	2	-	-	-	-	-	-	-	-	-	-
total	43	69	55	62	50	43	37	48	36	66	21	36	62	48	60

SD	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	total
21	4	8	9	6	10	10	11	-	9	17	14	14	12	11	159
22	18	17	17	18	21	15	19	16	21	13	17	17	17	18	369
23	6	3	5	3	2	4	-	3	3	4	4	5	7	4	61
24	20	19	17	14	12	21	17	18	17	17	16	18	17	20	385
25	-	5	-	7	-	-	-	-	-	-	-	-	-	-	110
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	138
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	127
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43
total	48	52	48	48	45	50	47	37	50	51	51	54	53	53	1423

data treatment and analysis

To get a general overview the whole catch or at least all fish data were analysed. For a more detailed examination only years since 1991 were taken into account because of mentioned uncertainty regarding catch analysis in earlier years. Especially SD 22 and 24 are selected because the sample size is comparable and the stations are distributed quite regular within each area. Furthermore, these

subdivisions present the main transition area separating the North Sea/Kattegat from the Baltic proper.

For community analysis of each subdivision, different indices were calculated based on standardized catch data of all fish species.

a) Number of species (s): The number of species is defined as total number of found species.

b) Margalef-Index (D): Whereas the number of species does not consider the size of the sample, the Margalef-Index (equat. 1) is more sensitive and considers the total number of caught individuals (N) (Margalef 1958). It is used as species richness in the following.

$$D = (s - 1) / \ln N \qquad \text{(equat. 1)}$$

c) Shannon-Wiener-Index (H_s): The Shannon-Wiener-Index (equat. 2), used as diversity, characterises variety in reference to number of species (s) and patterns of dominance. The values of this index increase with an increasing number of species as well as with a more equal distribution of the species abundances (Shannon 1948).

$$H_s = -\sum_{i=1}^{s} p_i \ln p_i \qquad \text{whereby} \qquad p_i = n_i / N \qquad \text{(equat. 2)}$$

Where n_i is the abundance and p_i the relative fraction of species i.

d) Evenness (E): More detailed evidence of dominance structure offers the evenness (equat. 3).

$$E = H_s / H_{max} \qquad \text{whereby} \qquad H_{max} = \ln s \qquad \text{(equat. 3)}$$

For $E \approx 1$ there is no dominance of one or more species, i.e. the relative abundance of species is similar, is $E \approx 0$ at least one species is dominant (Pielou 1966).

The analysis of community similarity in different areas over time was undertaken using multivariate methods. Presence and absence transformation was done to compare the occurrence of the species. Cluster analysis and multidimensional scaling (MDS) were performed using Bray-Curtis Distance δ_{jk} (equat. 4) derived from Bray-Curtis Index as dissimilarity index, which is typically used for ecological data sets with numerous zero values.

$$\delta_{jk} = 100 * [\sum_{i=1}^{s} | x_{ij} - x_{ik} | / \sum_{i=1}^{s} (x_{ij} + x_{ik})] \qquad \text{(equat. 4)}$$

Where x_{ij} is the abundance of species i in sample j and x_{ik} is the abundance of species i in sample k.

In the MDS ranks were allocate to samples in order to dissimilarity. Based on this ranks samples were arranged in the plot so that distance reflects the dissimilarity. An indicator for the quality of the plot is the stress value. A stress less than 0.1 shows a good ordination, a value up to 0.2 a potentially useful plot (Digby & Kempton 1987).

The cluster analysis, performed by using group average linkage as a conservative fusing method between groups, results in a dendrogram in which similar samples are allocated in the same group.

abiotic data

Temperature and salinity data for the period until 2005 were extracted from the BALTIC (Baltic Atlas of Long-Term Inventory and Climatology)-project database, established by Leibnitz Institute for Baltic Sea Research Warnemünde (IOW) (Wiley 2008). Within this project, hydrographic data from many sources were compiled. These data are used to provide monthly mean values of temperature and salinity for each 1° Latitude x 1° Longitude x 10 m grid cell in the Baltic Sea. Additionally, information about major Baltic inflow (MBI) events is also provided.

For analyses only October values are used because surveys took place mainly is in this time and there are some missing values in almost all other month, which make aggregation over a longer period not practicable.

Grid cell 13_55 (13°-14°E and 55°-56°N) was used to represent SD 24 and 11_54 (11°-12°E and 54°-55°N) represents SD 22 as the areas of main interest. For 2006 to 2008, hydrographical data were directly taken from survey CTD measurements in the corresponding area.

For salinity the deepest possible strata were applied to have an idea of inflow of heavier, high saline North Sea water. For temperature the medium layer of water column is used, to avoid effects of a eventually still existed warm surface layer or the bottom layer. To have an indicator of temperature and salinity for further investigation the derivation from the mean was calculated. Thereafter years are called warm, medium or cold as well as high, medium or low saline.

All statistical analyses were performed using the open source program R (R Development Core Team 2008).

Results

abiotic data

The analysis of the hydrografic data showed that mean october temperature increased obviously within the last two decades. This is detected for all depth strata in subdivision 22 and 24.

The annual temperature increase in the medium water layer was 0.19 °C in SD 22 and 0.11 °C in SD 24 (Fig. 2, top panel). Consequently warm years became more frequent over time (Fig. 2, lower panel).

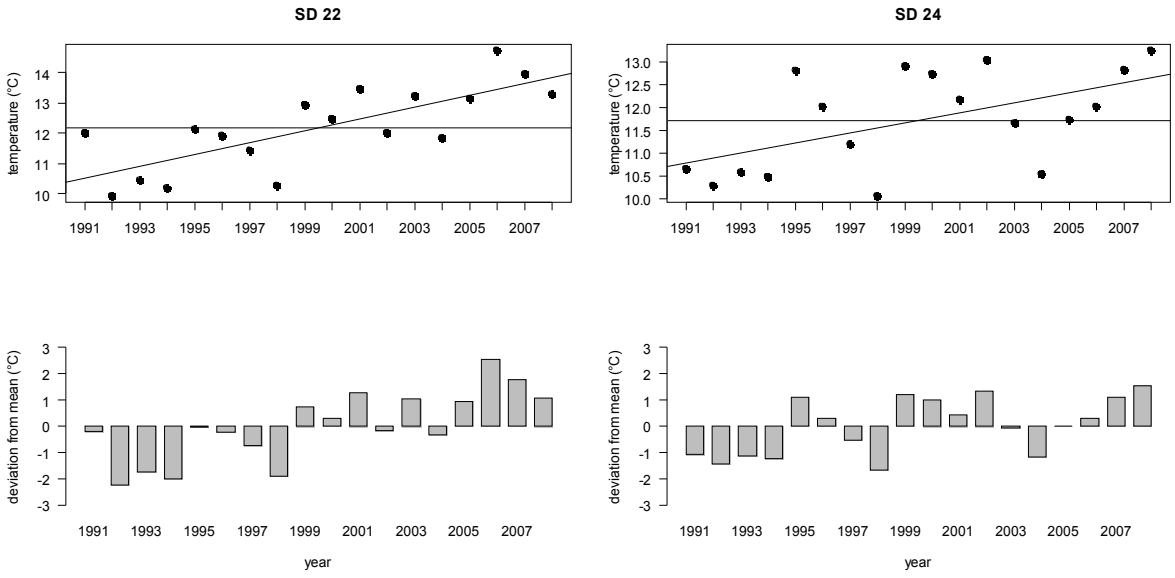

Fig. 2: ***Temporal development of the temperature in the Western Baltic Sea. Above: Mean October temperature of the medium water layer (10-20 m for SD 22 and 20-30 m for SD 24); dotted lines mark the arithmetic mean, solid lines show the linear regression (y = 0.194x - 376.568 with r^2 = 0.579 for SD22 and y = 0.111x – 209.764 with r^2 = 0.302 for SD24). Note the different scales on y-axis.***
Below: The deviation from the arithmetic mean temperature per subdivision.

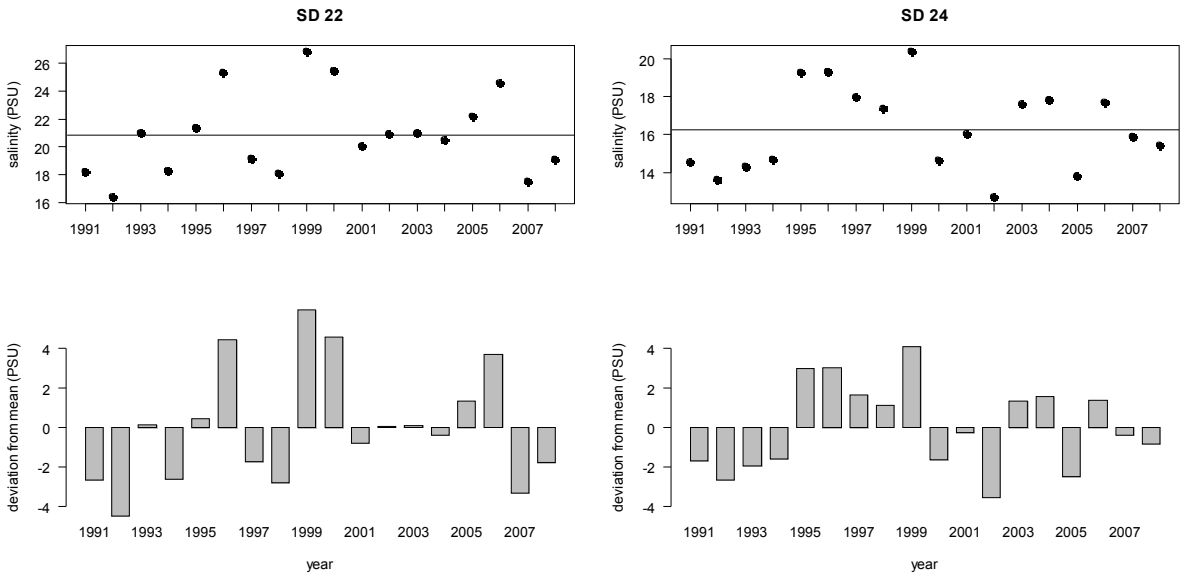

Fig. 3: ***Temporal development of the salinity in the Western Baltic Sea. Above: Mean October salinity in the deepest layer (20-30 m for SD 22 and 40-50 m for SD 24); dotted line marks the arithmetic mean. Note the different scales on y-axis. Below: The deviation from the arithmetic mean salinity per subdivision.***

The values for salinity are not following a trend. In the Belt Sea salinity highly fluctuated and alternated between every one to two years. Periods with values above or below average lasted longer in SD 24 especially in the 1990ies (Fig. 3).

catch data

During the surveys, 86 species, thereof 69 fish species, were found in 1423 hauls since 1978 (Tab. 3). The most frequent with an appearance in over 97 % and 87% of the hauls were the clupeids herring (*Clupea harengus L.*) and sprat (*Sprattus sprattus L.*), respectively. Other prevalent species were cod (*Gadus morhua L.*), whiting (*Merlangius merlangus L.*), horse mackerel (*Trachurus trachurus L.*) and gobies (*Pomatoschistus spec.)*. Whereas cod had the highest prevalence in SD 23-29 (more than 70%), the other were common in SD 21-24 and not found in SD 26-29. A similar pattern is observed for other marine species like anchovy *Engraulis encrasicolus L.*), mackerel (*Scomber scombrus L.*) and greater weever (*Trachinus draco L.*), too. They show highest prevalence in SD 21, which decreases rapidly with an increasing freshwater influence of the following subdivisions.

Tab. 3*: Baltic autumn survey: species list and frequency of occurrence in hauls per subdivision. Total refers to the apperence in all hauls.*

species	engl. name	Subdivision									
		21	22	23	24	25	26	27	28	29	total
Agonus cataphractus	*hooknose*	0,8	4,6	-	0,3	-	-	-	-	-	1,5
Alosa fallax	*twaite shad*	0,6	-	-	0,3	-	-	-	-	-	0,1
Ammodytes	*sand eels*	1,3	3,3	1,6	2,6	0,9	-	-	-	-	1,8
Anarhichas lupus	*atlantik wolffish*	0,6	-	-	-	-	-	-	-	-	0,1
Anguilla anguilla	*european eel*	3,1	5,7	18,0	16,1	0,9	-	-	-	-	7,0
Aphia minuta	*transparent goby*	35,2	16,3	13,1	5,2	-	-	-	-	-	10,1
Aphrodite	*sea mouse*	0,6	-	-	-	-	-	-	-	-	0,1
Argentina sphyraena	*argentine*	1,3	-	-	-	-	-	-	-	-	0,1
Arnoglossus laterna	*mediterranean scaldfish*	0,6	-	-	-	-	-	-	-	-	0,1
Belone belone	*garfish*	3,1	3,3	-	3,6	1,8	-	-	-	-	2,3
Callionymus lyra	*dragonet*	1,3	-	-	-	-	-	-	-	-	0,1
Callionymus maculatus	*spotted dragonet*	1,3	-	-	-	-	-	-	-	-	0,1
Carcinus		3,8	-	1,6	-	-	-	-	-	-	0,5
Chelon labrosus	*thicklip grey mullet*	0,6	1,4	-	-	-	-	-	-	-	0,4
Clupea harengus	*atlantic herring*	99,4	93,5	98,4	100	98,2	95,7	100	99,2	100	97,5
Cangon crangon	*common shrimp*	5,0	7,0	1,6	4,7	-	-	-	-	-	3,7
Crenilabrus melops	*corkwing wrasse*	-	1,0	1,6	-	-	-	-	-	-	0,3
Crystallogobius linearis	*crystal goby*	5,7	5,1	3,3	0,5	-	-	-	-	-	2,2
Ctenolabrus rupestris	*goldsinny-wrasse*	1,9	5,4	3,3	-	-	-	-	-	-	1,8
Cyclopterus lumpus	*lumpfish*	13,8	7,3	3,3	5,5	3,6	-	-	-	-	5,3
Eledone		15,7	0,3	1,6	-	-	-	-	-	-	1,9
Engraulis encrasicolus	*european anchovy*	66,0	34,4	18,0	15,3	-	-	-	-	-	21,2
Entelurus aequoreus	*snake pipefish*	0,6	-	-	-	-	-	-	-	-	0,1
Euphausia		0,6	-	-	-	-	-	-	-	-	0,1
Eutrigla gurnardus	*grey gurnard*	23,9	2,2	6,6	0,8	-	-	-	-	-	3,7
Gadus morhua	*atlantic cod*	18,2	55,0	78,7	74,0	78,2	81,9	100	82,7	95,3	66,1
Gasterosteus aculeatus	*three-spined stickleback*	11,9	66,7	16,4	35,8	8,2	1,4	-	0,8	2,3	29,9
Glyptocephalus cynoglossus	*witch flounder*	1,3	-	-	-	-	-	-	-	-	0,1
Gobius		-	14,9	1,6	1,6						4,4
Gobiusculus flavescens	*two-spotted goby*	-	1,6	-	-	-	-	-	-	-	0,4
Hippoglossoides platessoides	*american plaice*	3,1	0,5	-	-	-	-	-	-	-	0,5
Idotea		-	-	-	-	3,6	-	-	-	-	0,3
Lampetra fluviatilis	*river lamprey*	-	-	-	0,3	0,9	-	-	-	-	0,1
Leander		-	1,6	-	-	-	-	-	-	-	0,4
Lepidorhombus whiffiagonis	*megrim*	0,6	-	-	-	-	-	-	-	-	0,1
Leptoclinus maculatus	*daubed shanny*	-	0,3	-	-	-	-	-	-	-	0,1
Limanda limanda	*common dab*	30,8	54,2	18,0	8,8	0,9	-	-	-	-	20,7
Liparis liparis	*striped seasnail*	-	0,5	-	-	-	-	-	-	-	0,1
Liparis montagui	*montagus seasnail*	-	-	-	0,3	-	-	-	-	-	0,1
Loliginidae		66,7	17,9	19,7	-	-	-	-	-	-	12,9
Lota lota	*burbot*	-	-	-	1,3	-	0,7	-	-	-	0,4
Lumpenus lampretaeformis	*snakeblenny*	1,3	0,5	-	-	-	-	-	-	-	0,3
Lumpenus maculatus	*spotted snake blenny*	-	0,3	-	-	-	-	-	-	-	0,1

Tab. 3: *cont.*

species	engl. name	Subdivision									
		21	22	23	24	25	26	27	28	29	total
Macropipus holsatus		2,5	-	1,6	-	-	-	-	-	-	0,4
Maurolicus muelleri	*silvery lightfish*	1,9	-	-	-	-	-	-	-	-	0,2
Melanogrammus aeglefinus	*haddock*	2,5	-	8,2	-	-	-	-	-	-	0,6
Merlangius merlangus	*whiting*	91,2	75,3	88,5	57,9	3,6	-	-	-	-	49,5
Merluccius merluccius	*european hake*	10,1	0,3	8,2	-	-	-	-	-	-	1,5
Microstomus kitt	*lemon sole*	0,6	-	-	-	-	-	-	-	-	0,1
Mullus surmuletus	*surmullet*	9,4	6,5	3,3	0,3	-	-	-	-	-	3,0
Myoxocephalus scorpius	*shorthorn sculpin*	0,6	1,6	-	1,3	-	-	-	-	-	0,8
Mysidacea		6,3	-	-	-	-	-	-	-	-	0,7
Nephrops norvegicus		1,3	-	-	-	-	-	-	-	-	0,1
Octopodidae		3,8	-	1,6	-	-	-	-	-	-	0,5
Osmerus eperlanus	*european smelt*	0,6	0,5	-	4,9	1,8	0,7	-	-	-	1,8
Pandalus		0,6	1,1	-	-	-	-	-	-	-	0,4
Petromyzon marinus	*sea lamprey*	-	0,3	-	-	0,9	0,7	-	-	-	0,2
Pholis gunellus	*rock gunnel*	-	1,9	-	-	-	-	-	-	-	0,5
Platichthys flesus	*european flounder*	-	5,7	3,3	10,4	0,9	-	-	-	-	4,5
Pleuronectes platessa	*european pleice*	4,4	3,0	-	6,0	1,8	-	-	-	-	3,0
Pollachius virens	*saithe*	-	0,5	-	0,3	0,9	-	-	-	-	0,3
Pomatoschistus		37,7	42,3	14,8	41,8	2,7	-	-	-	-	27,3
Psetta maxima	*turbot*	-	5,2	-	2,3	-	-	-	-	-	2,0
Pungitius pungitius	*ninespine stickleback*	-	0,3	-	-	-	-	-	-	-	0,1
Rhinonemus cimbrius	*fourbeard rockling*	0,6	1,6	-	4,4	0,9	0,7	-	0,8	-	1,9
Rutilus rutilus	*roach*	-	-	-	0,5	-	-	-	-	-	0,1
Salmo salar	*atlantic salmon*	-	0,3	-	2,6	1,8	3,6	3,2	5,5	11,6	2,2
Salmo trutta	*sea trout*	-	0,3	-	0,3	0,9	-	-	-	-	0,2
Sander lucioperca	*pike-perch*	-	-	-	2,3	-	0,7	-	-	-	0,7
Sardina pilchardus	*european pilchard*	14,5	1,1	-	0,3	-	-	-	-	-	2,0
Scomber scombrus	*atlantic mackerel*	27,7	4,3	8,2	5,2	-	-	-	-	-	6,0
Scophthalmus rhombus	*brill*	0,6	0,3	1,6	-	-	-	-	-	-	0,2
Sepia		1,3	-	-	-	-	-	-	-	-	0,1
Solea vulgaris	*common sole*	1,3	1,9	-	0,5	-	-	-	-	-	0,8
Spinachia spinachia	*sea stickleback*	-	2,2	-	0,3	-	-	-	-	-	0,6
Sprattus sprattus	*european sprat*	77,4	88,3	91,8	98,7	80,9	85,5	48,4	81,1	93,0	87,8
Squalus acanthias	*picked dogfish*	2,5	-	-	-	-	-	-	-	-	0,3
Syngnathus	*pipe fish*	2,5	19,2	-	1,6	-	-	-	-	-	5,7
Trachinus draco	*greater weever*	67,3	8,4	26,2	0,5	-	-	-	-	-	11,0
Trachurus trachurus	*atlantic horse mackerel*	88,1	65,6	47,5	32,5	0,9	-	-	-	-	37,7
Trigla lucerna	*tub gunard*	1,3	-	1,6	-	-	-	-	-	-	0,2
Trisopterus esmarki	*norway pout*	5,7	3,3	-	-	-	-	-	-	-	1,5
Trisopterus luscus	*pouting*	-	0,8	-	-	-	-	-	-	-	0,2
Trisopterus minutus	*poor cod*	3,1	0,8	-	-	-	-	-	-	-	0,6
Zoarces viviparus	*eelpout*	-	3,8	-	1,0	-	-	-	-	-	1,3
number of species		61	57	32	42	22	10	4	6	5	85

As a result, highest number of species was also found in SD 21 with 61 species (48 fish species). SD 22 had almost equal number of species but in SD 24 only 42 species (41 fish species) and in SD 25 only 22 species (21 fish species) were found.

In the northern areas, the number of species drops to 10 or less, due to strong fresh water influence. Whereas these areas where only sampled until 1983 (SD 29) and 1989 (SD 28) with mentioned uncertainty. Solely SD 23 diverged in species number. Due to geographical position this subdivision should be similar to SD 22, but species number is below that of SD 24.

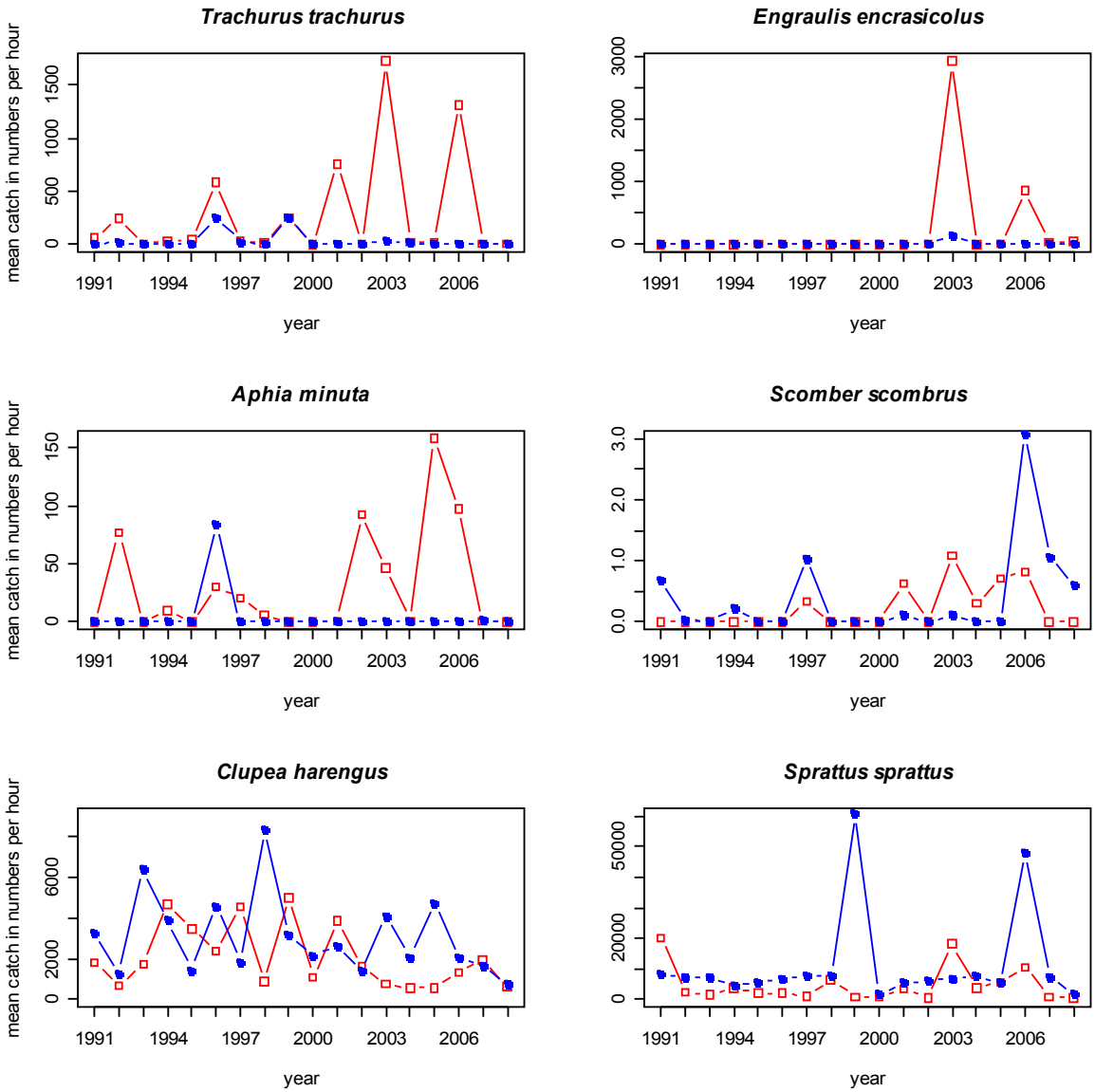

Fig. 4: *Mean catch of selected pelagic fish species; red squares and lines illustrate SD 22, blue points and lines SD 24 (note difference in scales on the y-axis).*

The catch data of selected so-called guest species show an irregular pattern (Fig. 4, top four plots) with years of a high abundance alternating with periods of a low number or absence. In general the number of the marine guest species is lower in SD 24, because they have to pass the Belt Sea or the Sound on their way from North Sea. This happens only under special conditions. An exception is when big shoals pass SD 22 and rest in SD 24 or migrate through the Sound.

The number of horse mackerels has several peaks, which are higher after the year 2000 in SD 22. The transparent goby (*Aphia minuta L.*) has comparable peaks, but with abundances of only one tenth of that of horse mackerel and during other years. There are two years with high numbers of anchovy. Like for horse mackerel, the highest abundance for anchovy was found in 2003. At this year there was a medium inflow in January. The other MBI events during this period, the strong one in 1993 and the weak one in 1997, were not reflected thereof. The catches of mackerel were very low over the whole period.

The stationary pelagic species herring and sprat represent the major proportion of the total catch Fig. 4, bottom). Mean catches per hour (± standard deviation) for herring are 2084 (± 1538) in SD 22 and 3085 (± 1968) in SD 24. Sprat has arithmetic means of 4715 (± 5866) and 11412 (± 15879), respectively. The very high standard deviation in SD 22 is caused of extreme high abundance in particular years.

diversity

The spatial illustration of diversity indices (Fig. 5) showed a similar, low number of species for SD 25 to SD 29 in the early period. The same was true for species richness. In contrast SD 24 had higher medians and a wider range in both values. During the second period the number of species and the values for species richness increased almost threefold. SD 21 and 22 offer even higher values of 18 and 19 as well as 1.66 and 1.74. SD 23 had the lowest values for this period but still exceed that of SD 25-29. Overall there is a decrease with areas situated more in inner Baltic Sea.

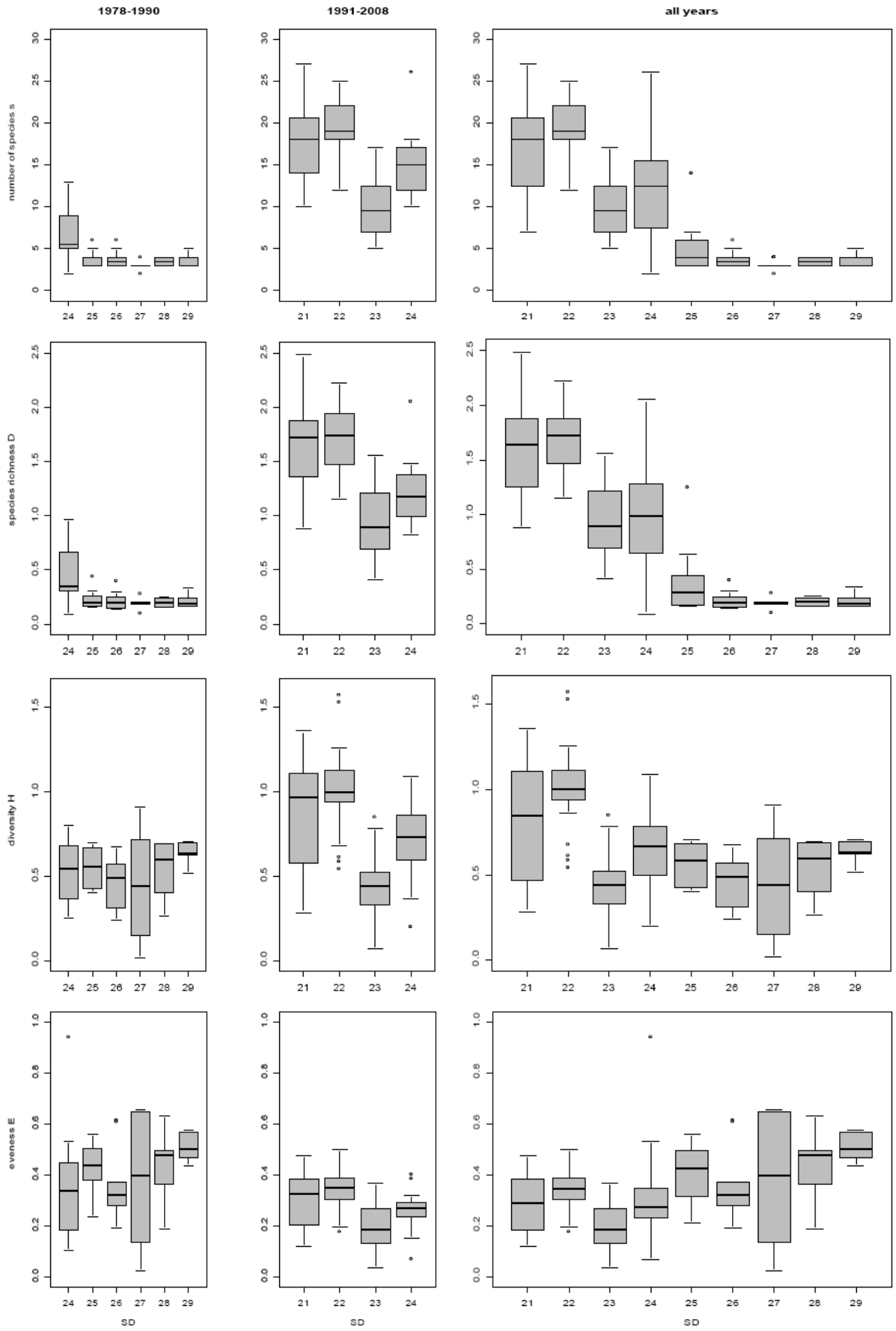

Fig. 5: ***Box-and-Whisker-Plot of annual diversity indices in the different subdivisions for the early, late and whole survey period.***

The evenness had a contrary pattern, with minor medians in the western areas compared to the northeast ones before 1990.

As a combination of quantity and dominance of species the Shannon-Wiener-Index did not differ significant between areas during the first period with median values of 0.45 to 0.64. Overall highest values occur in SD 22 and 21 whereas in 22 the range is much smaller.

The temporal developing of these indices is given in Fig. 6 and Fig. 7. In SD 21 all data alternated over a wide range with a weak increase of all indices. No clear trend was found in SD 22. A clear upward trend concerning number of species and species richness is recognised for SD 23, for diversity and evenness this trend is not that strong (Fig. 6).

Whereas species richness and number of species increased in SD 24 until 1990, all indices remained constant since 1991. The other areas showed no clear trends, except an increase in the evenness in SD 26 and a decrease of it in SD 28 (Fig. 7).

Relating diversity indices to the abiotic parameters, there is no clear correlation between temperature or salinity and diversity indices. In SD 22 it seems that extreme temperature and bottom salinity support higher species richness and diversity (Fig. 13, Annex 2). A weak decrease of indices with increasing temperature is indicated by linear regression in SD 24, but there is a great variation in values which gives the predication a significant uncertainness (Fig. 14, Annex 2). Especially a high bottom salinity appears to cause a lower number of species, diversity and evenness (Fig. 15, Annex 2).

For the horse mackerel the pattern of the spatial distribution over time illustrates the difference between years (Fig. 9 and Fig. 10). It is an example for the variability of occurrence of guest species. In SD 21 and 22 they are always found but with varying densities. In SD 24 no horse mackerel was found in some years like 1993 and 2000. On the other hand in e. g. 1996 or 1999 large numbers were caught in SD 24.

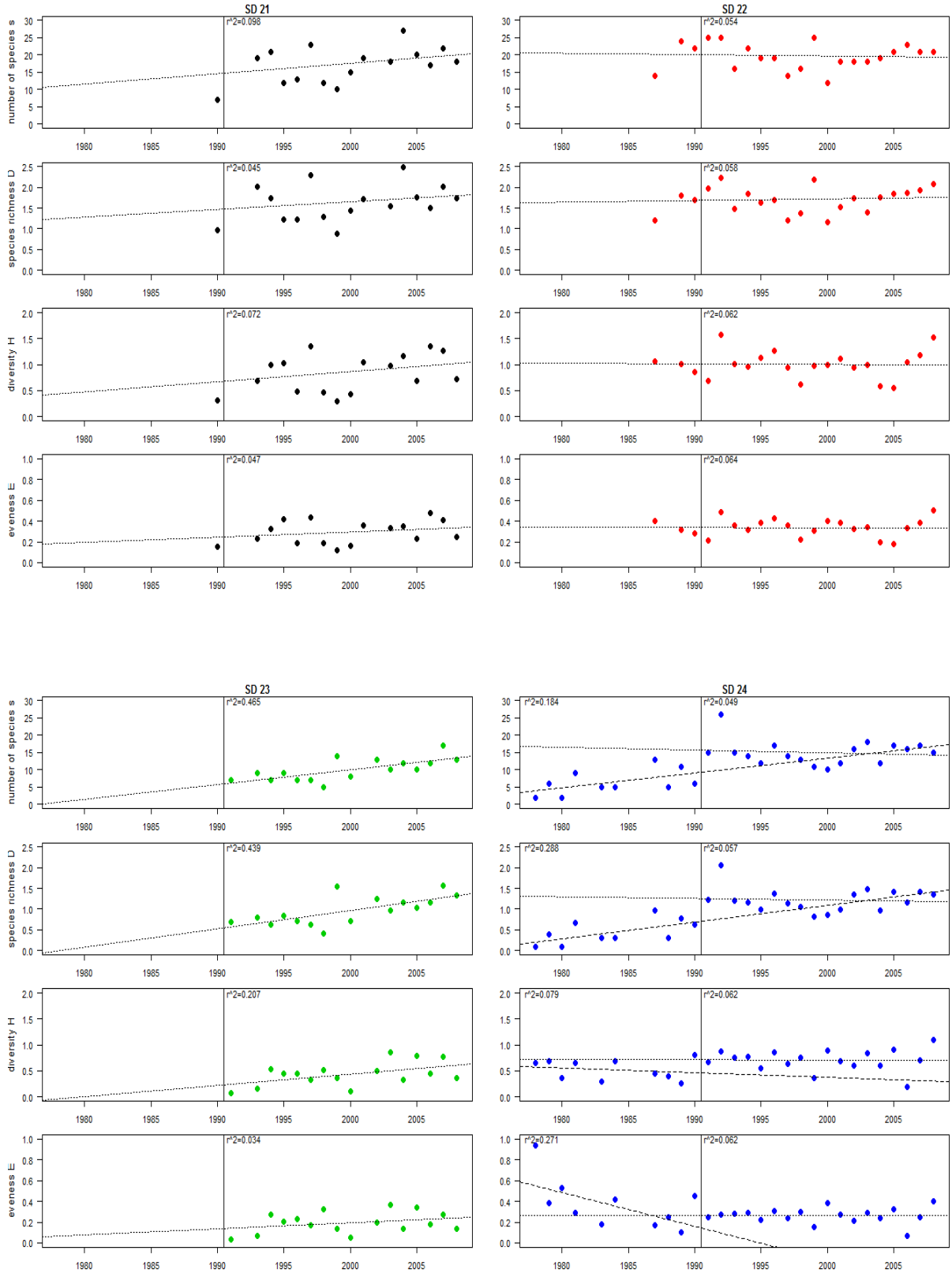

Fig. 6: ***Plots of diversity indices over time for selected areas: linear regression is given for detection of trends, dashed lines mean that only values until 1990, dotted lines that values since 1991 were used for regression***

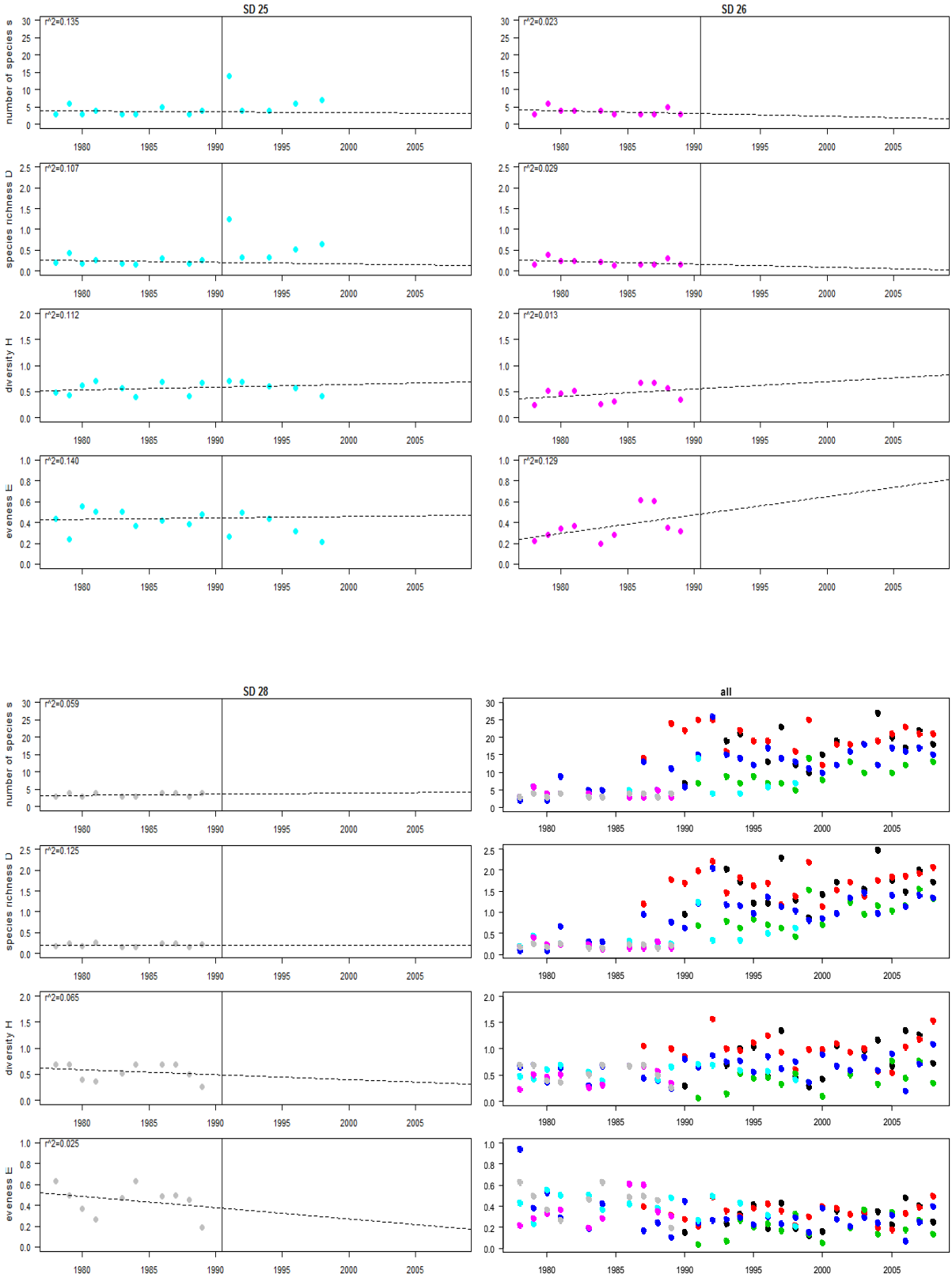

Fig. 7: ***Plots of diversity indices over time for selected areas: linear regression is given for detection of trends, dashed lines mean that values until 1990 were used for regression.***

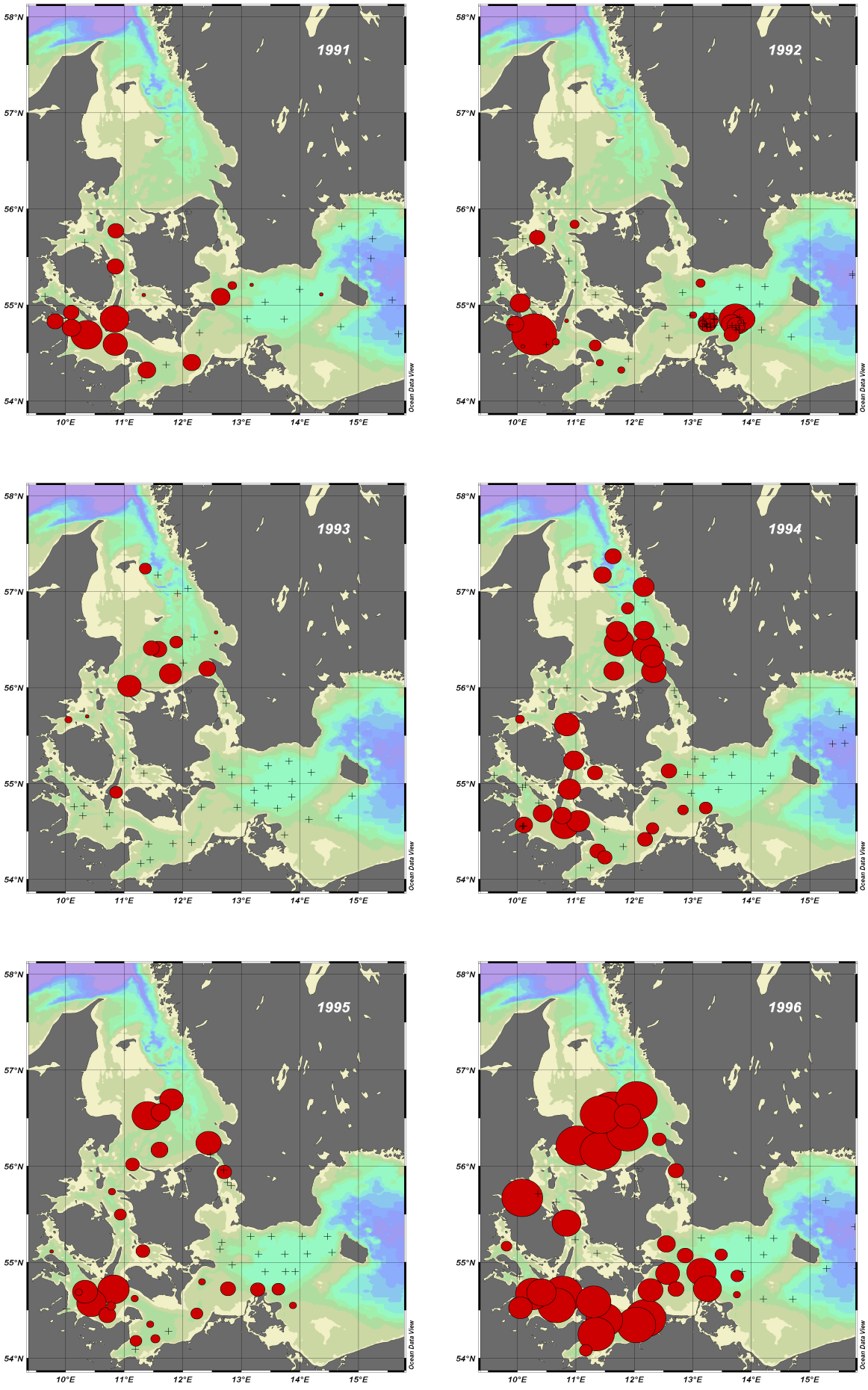

Fig. 8: *catch per hour of horse mackerel from 1991 to 1996, crosses denote hauls without horse mackerels.*

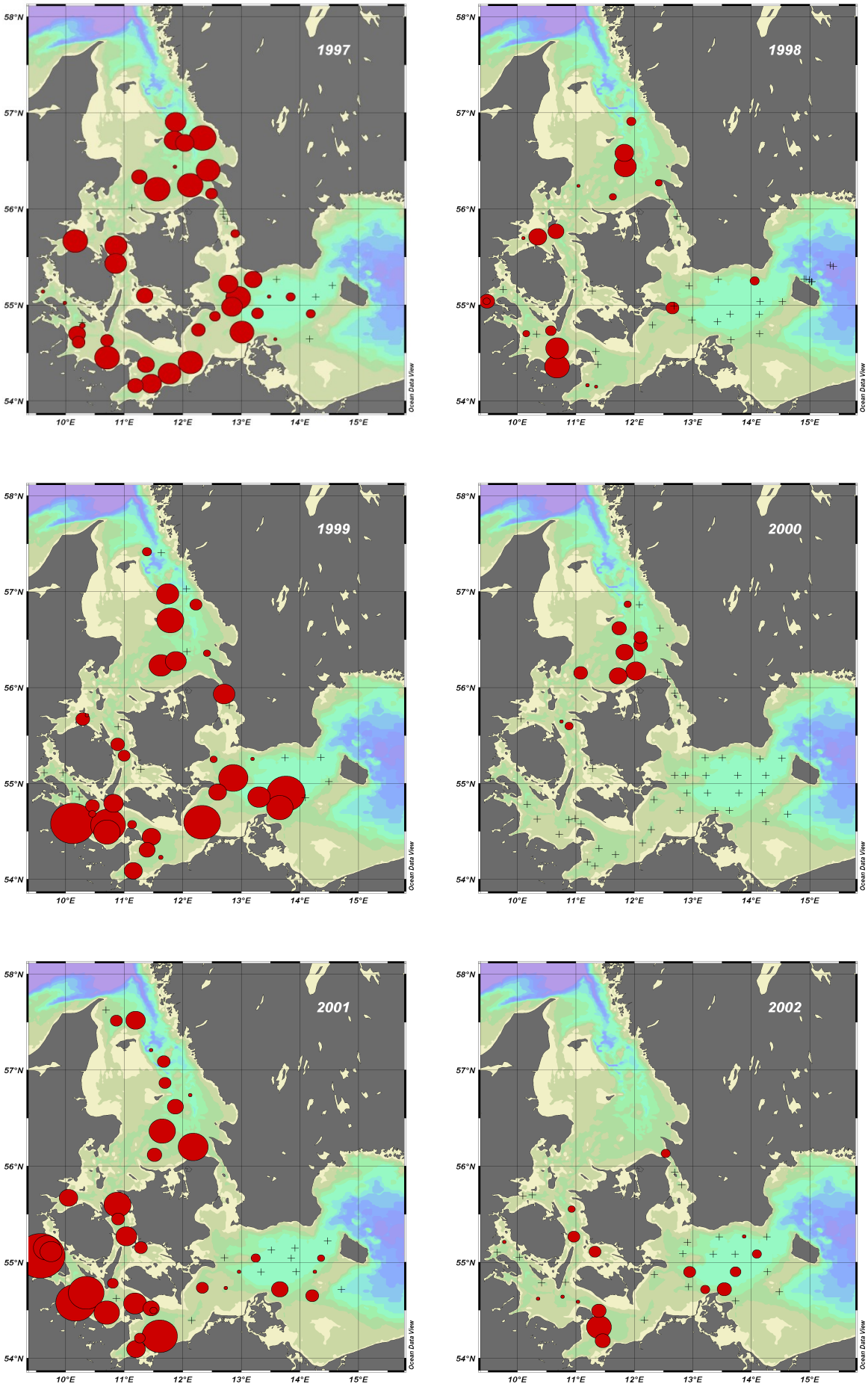

Fig. 9: *catch per hour of horse mackerel from 1997 to 2002, crosses denote hauls without horse mackerels.*

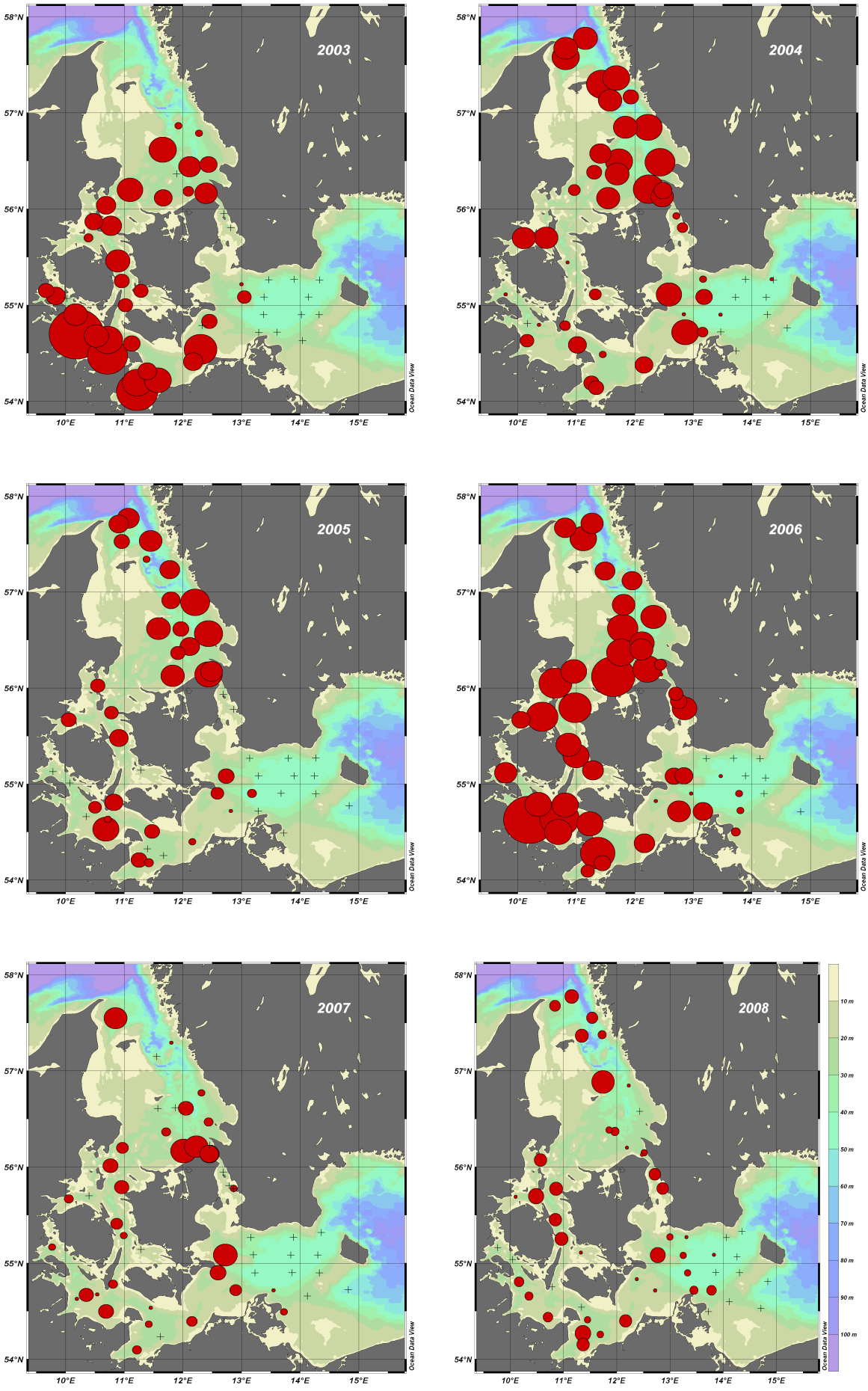

Fig. 10: *catch per hour of horse mackerel from 2003 to 2008, crosses denote hauls without horse mackerels.*

community analysis

The cluster analysis of SD 24 separated two main groups (Fig. 11). One group contains all surveys since 1991 plus two earlier cruises conducted by the FRG, that means every journey with RV “Solea” except 1990. The other cluster comprehends all surveys conducted by the GDR with the vessel “Eisbär” plus 1990. But in 1990 only one haul was performed in SD 24.

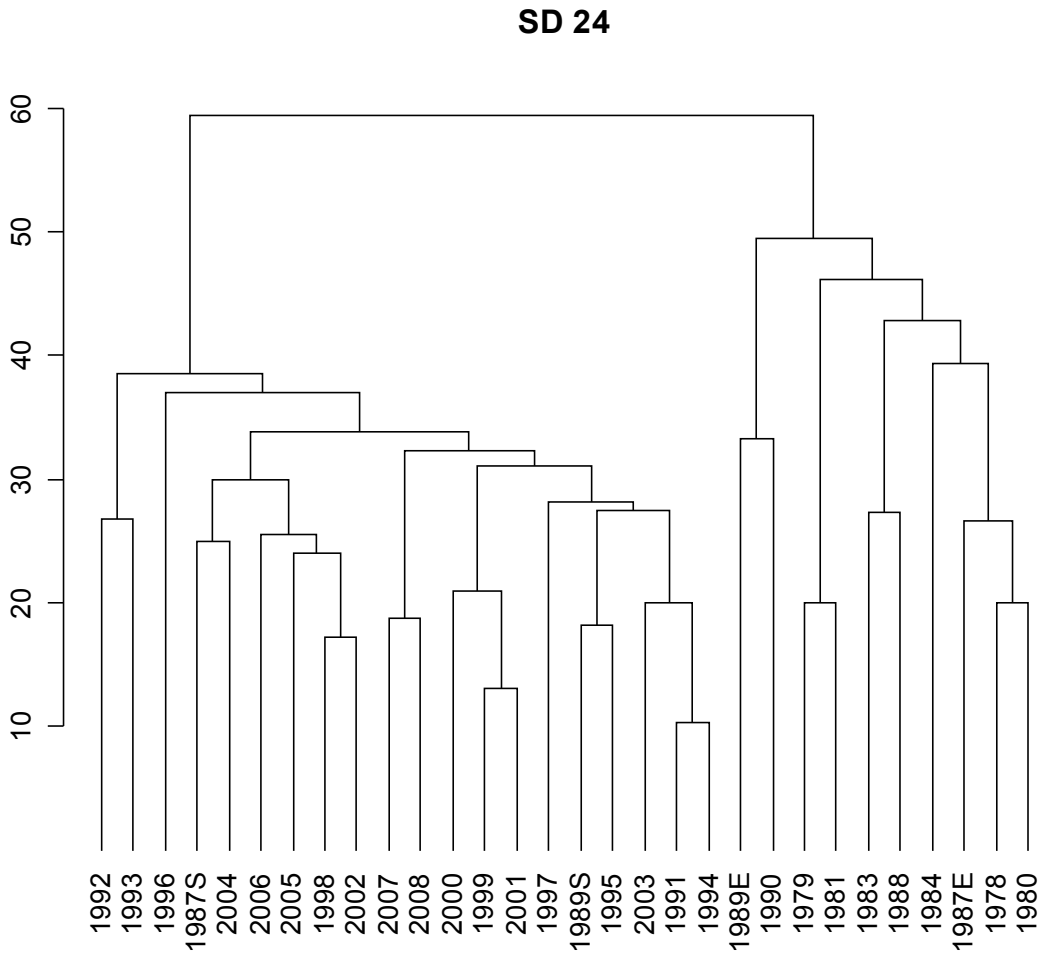

Fig. 11: ***Dendrogram as the result of the cluster analysis performed with presence and absence data of all fish species. The Bray-Curtis-Dissimilarity matrix was used and cluster were linked by group average method. To distinguish the two surveys in 1987 and 1989 the vessel, Solea (S) or Eisbär (E), is given with the year.***

The analyses of the pelagic fish assemblage did not show a temporal trend in the development of the community. in both subdivisions early years are not separated from the more recent years, so no

general shift is obvious (Fig. 12). The analysis of MDS plots with respect to temperature do not show clear pattern that e.g. years with cold October temperature do not significantly distinguish from the other. Only a weak tendency could be observed. Namely the warm years are situated in an opposite direction compared with colder years. But there are outliners, overlapping areas and groups with comparable species composition containing warm and cold years.

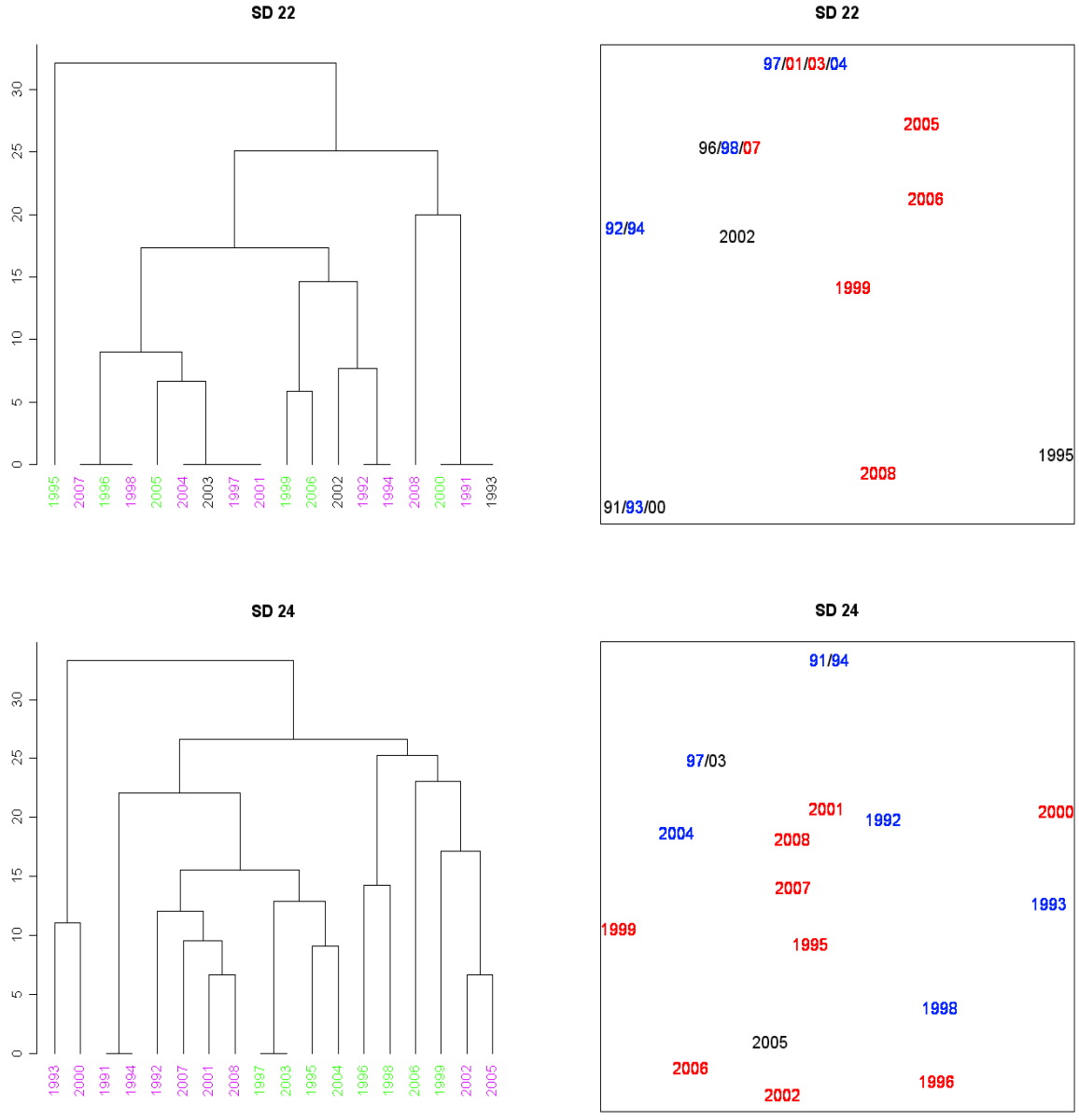

Fig. 12: : ***Results of cluster analysis and MDS based on presence and absence data of the pelagic fish as defined in table 4 in annex 1. The colours attached to the years illustrate temperature and salinity conditions. Green stands for above average salinity, purple for below average salinity, whereas red and blue denote warm and cold years. Black labels indicate near average values (following Fig. 2 and Fig. 3). Stress values for MDS are 0.15 and 0.2.***

The analysis of clusters with respect to salinity do not show strong trends, too. However in SD 24 there is at least the tendency that low saline years form distinct groups. But these groups are in part more similar to high saline years than to other groups with a low salinity.

Consequently, october temperature and salinity poorly explain species occurrence.

Discussion

abiotic data

The detected warming in both areas is coincident with the results of Mackenzie and Schiedek, who found a warming in nothern european seas, especially since the 1980ies (Mackenzie & Schiedek 2007). But of course it is variable and cold years like 2004 can occur.

The salinity did not show such a trend, because the frequence of major inflow events was quite low and did not change notably over this time. Consequently, the alternating salinity is caused of smaller scaled differences in current pattern between the years. This leads to the disparity between the areas in some years, too .

catch data and diversity

In general the number of found fish species (69) during the whole period reflects the species poor fish community of the Baltic Sea. As the main target of this survey series were pelagic fish species, demersal or shallow water species might not be sampled representativ and complete. Therefore, catch data of such species has to be taken with caution. But species numbers are in accordance to European Environment Agency, which specifies about 100 species for the whole Baltic area compared to , 230 fish species in the North Sea and approximately 170 in the Black Sea (Walday & Kroglund 2002).

The main reason for this is the brackish character of the Baltic. The declining salinity from western to eastern and northern parts causes a great physiological stress for marine species (Remane 1958). On the other hand especially in the Western Baltic Sea salinity is still too high for fresh water species. Therefore, only few euryhaline species are able to live and reproduce successfully in the Western and Central Baltic. This explains the decrease in total and annual number of species and species richness from Skagerrak and Belt Sea along Mecklenburg Bight and Arkona Sea to the areas northeast of Bornholm with decresing salinity. Solely SD 23 diverged in species number. Due to geographical position this subdivision should be similar to SD 22, but species number is below that of SD 24. This could be caused of the relative small area and low number of samples. The number of species affects the diversity and evenness. In all areas herring and sprat had the highest abundances. Consequently, there evenness was very low especially in subdivisions with numerous other species that had little abundance like in SD 21-24. Additionally, diversity is rather low and comparable in SD 23 to 29 and higher in SD 21 and 22, due to the influence of the species with high abundances.

In spite of the proven increase in mean October temperature since 1991 no trend in diversity or species richness is apparent, neither in the Belt Sea nor in the area west of Bornholm. Another study conducted in Lübeck Bight during nearly the same period even found a decrease in number of species and diversity (Zander 2008). The highest abundances of the guest species, such as horse mackerel, anchovy and transparent goby in the Belt Sea are independent of high salinity, but most peaks are detected in warm years e.g. 2001, 2003 and 2006. For these species salinity in SD 22 seems to be high enough even in years below average so that temperature is a more important parameter. In SD 24 all years with high abundances are characterized by above average salinity values like 1996, 1999 and 2003. Mean or low salinity could hamper the immigration of marine species in this area.

The spatial distribution of the horse mackerel catches shows a highly variable pattern and does not correspond with the catch distribution of anchovy (Gröhsler 2009, working document). An increasing abundance and an eastward shift of distribution was observed for anchovy since 2000.

community analysis

Whereas a shift in bottom fish assemblage was assumed in the beginning of 1990s for Arkona Sea (SD 24) and Lübeck Bight (SD 22) (Ehrich *et al.* 2006), the cluster analysis of all surveys in SD 24 indicates differences between the GDR and FRG surveys. According to this it seems that data variation discriminating the periods before and after 1990 is mainly caused by differences in vessel, gears and treatment of catch. Consequently, it is no evidence for a possible shift in community composition at this time.

The analyses of the pelagic fish assemblage do not show general trends, which means that there was no shift in the community during the period of investigation and catch data are hardly explained by the temperature and salinity conditions. This points out that there are other, important factors which influence the species composition witch were not covered during this investigation.

Altogether the rising temperature does not consequently lead to a higher species richness and diversity in most areas of the western Baltic. As warmer temperature provides the possibility for immigration of warm water species there are other parameters that have to be taken into account. Salinity is one of them, because potential marine immigrants often need salinity higher than offered by the Baltic Sea and salinity is predicted to abate with ongoing climate change because of e.g. higher precipitation und fresh water runoffs (MacKenzie *et al.* 2007). So in the next decades an increase in immigration of marine species seems to be improbable, more likely is a spreading of fresh water species.

Acknowledgements

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Annex 1

Tab. 4: ***List of all names for species that occurred in the catch data. For each the term of the species/species group as used in this work is given. Furthermore the species/species groups are characterized by taxonomical status, habitat (benthic or pelagic), status in the baltic (stationary (st), guest species (g) or vagrant (irr)), frequency (common, regular or rare) and environment (marine (M), diadromous (D) and fresh water (F) species)***

name	species/species group	group 2	dem./pel.	type	presence	frequency
Agonus cataphractus	*Agonus cataphractus*	fish	demersal	M	st	regular
Alosa fallax	*Alosa fallax*	fish	pelagic	D	st	rare
Ammodytes	*Ammodytes*	fish	demersal	M	st	common
Ammodytes marinus						
Ammodytes tobianus						
Anarhichas lupus	*Anarhichas lupus*	fish	demersal	M	g	rare
Anguilla anguilla	*Anguilla anguilla*	fish	demersal	D	st	common
Aphia minuta	*Aphia minuta*	fish	pelagic	M	g	regular
Aphrodite	*Aphrodite*	bristleworms				
Argentina sphyraena	*Argentina sphyraena*	fish	demersal	M	g	rare
Arnoglossus laterna	*Arnoglossus laterna*	fish	demersal	M	irr	rare
Belone belone	*Belone belone*	fish	pelagic	M	st	common
Callionymus lyra	*Callionymus lyra*	fish	demersal	M	g	rare
Callionymus maculatus	*Callionymus maculatus*	fish	demersal	M	irr	rare
Carcinus	*Carcinus*	crustacean				
Carcinus maenas						
Chelon labrosus	*Chelon labrosus*	fish	demersal	M	g	common
Clupea harengus	*Clupea harengus*	fish	pelagic	M	st	common
Crangon	*Crangon*	crustacean				
Crangon crangon						
Crenilabrus melops	*Crenilabrus melops*	fish	demersal	M	irr	rare
Crystallogobius linearis	*Crystallogobius linearis*	fish	demersal	M	irr	rare
Ctenolabrus rupestris	*Ctenolabrus rupestris*	fish	demersal	M	st	rare
Cyclopterus lumpus	*Cyclopterus lumpus*	fish	demersal	M	st	common
Eledone	*Eledone*	cephalopod				
Eledone cirrosa						
Engraulis encrasicolus	*Engraulis encrasicolus*	fish	pelagic	M	g	rare
Entelurus aequoreus	*Entelurus aequoreus*	fish	demersal	M	irr	rare
Euphausia	*Euphausia*	crustacean				
Eutrigla gurnardus	*Eutrigla gurnardus*	fish	demersal	M	st	regular
Gadus morhua	*Gadus morhua*	fish	demersal	M	st	common
Gasterosteus aculeatus	*Gasterosteus aculeatus*	fish	pelagic	M, F	st	common
Glyptocephalus cynoglossus	*Glyptocephalus cynoglossus*	fish	demersal	M	st	rare
Gobius	*Gobius*	fish	demersal	M	st	common
Gobius niger						
Gobiusculus flavescens						
Hippoglossoides platessoides	*Hippoglossoides platessoides*	fish	demersal	M	irr	rare
Hyperoplus lanceolatus	*Hyperoplus lanceolatus*	fish	demersal	M	st	common
Idotea	*Idotea*	crustacean				
Lampetra fluviatilis	*Lampetra fluviatilis*	fish	demersal	D	st	regular
Leander	*Leander*	crustacean				
Leander squilla						
Lepidorhombus whiffiagonis	*Lepidorhombus whiffiagonis*	fish	demersal	M	irr	rare
Leptoclinus maculatus	*Leptoclinus maculatus*	fish	demersal	M	irr	rare
Limanda limanda	*Limanda limanda*	fish	demersal	M	st	common
Liparis liparis	*Liparis liparis*	fish	demersal	M	st	regular
Liparis montagui	*Liparis montagui*	fish	demersal	M	g	rare
Loliginidae	*Loliginidae*	cephalopod				
Loligo						
Loligo forbesi						
Lota lota	*Lota lota*	fish	demersal	F	st	rare
Lumpenus lampretaeformis	*Lumpenus lampretaeformis*	fish	demersal	M	st	rare
Lumpenus maculatus	*Lumpenus maculatus*	fish	demersal	M	g	rare
Macropipus holsatus	*Macropipus holsatus*	crustacean				

Tab. 4: cont.

name	species/species group	group 2	dem./pel.	type	presence	frequency
Maurolicus muelleri	*Maurolicus muelleri*	fish	pelagic	M	irr	rare
Melanogrammus aeglefinus	*Melanogrammus aeglefinus*	fish	demersal	M	g	rare
Merlangius merlangus	*Merlangius merlangus*	fish	demersal	M	g	common
Merluccius merluccius	*Merluccius merluccius*	fish	pelagic	M	irr	rare
Microstomus kitt	*Microstomus kitt*	fish	demersal	M	g	rare
Mullus surmuletus	*Mullus surmuletus*	fish	demersal	M	g	rare
Myoxocephalus scorpius	*Myoxocephalus scorpius*	fish	demersal	M	st	common
Mysidacea	*Mysidacea*	crustacean				
Nephrops norvegicus	*Nephrops norvegicus*	crustacean				
Octopodidae	*Octopodidae*	cephalopod				
Octopus						
Osmerus eperlanus	*Osmerus eperlanus*	fish	pelagic	D	st	common
Pandalus	*Pandalus*	crustacean				
Pandalus borealis						
Petromyzon marinus	*Petromyzon marinus*	fish	demersal	D	st	rare
Pholis gunellus	*Pholis gunellus*	fish	demersal	M	st	regular
Pholis gunnellus						
Platichthys flesus	*Platichthys flesus*	fish	demersal	M	st	common
Pleuronectes platessa	*Pleuronectes platessa*	fish	demersal	M	st	common
Pollachius virens	*Pollachius virens*	fish	demersal	M	g	rare
Pomatoschistus	*Pomatoschistus*	fish	demersal			
Pomatoschistus minutus				M	st	common
Pomatoschistus pictus				M	st	regular
Psetta maxima	*Psetta maxima*	fish	demersal	M	st	common
Scophthalmus maximus						
Pungitius pungitius	*Pungitius pungitius*	fish	demersal	F	st	common
Rhinonemus cimbrius	*Rhinonemus cimbrius*	fish	demersal	M	st	regular
Rutilus rutilus	*Rutilus rutilus*	fish	demersal	F	st	common
Salmo salar	*Salmo salar*	fish	pelagic	D	st	common
Salmo trutta	*Salmo trutta*	fish	pelagic	D	st	common
Scomber scombrus	*Scomber scombrus*	fish	pelagic	M	g	regular
Scophthalmus rhombus	*Scophthalmus rhombus*	fish	demersal	M	st	regular
Sepia	*Sepia*	cephalopod				
Solea vulgaris	*Solea vulgaris*	fish	demersal	M	g	regular
Spinachia spinachia	*Spinachia spinachia*	fish	demersal	M	st	regular
Sprattus sprattus	*Sprattus sprattus*	fish	pelagic	M	st	common
Squalus acanthias	*Squalus acanthias*	fish	demersal	M	irr	rare
Stizostedion lucioperca	*Sander lucioperca*	fish	demersal	F	st	regular
Syngnathus	*Syngnathus*	fish	demersal	M		
Syngnathus acus					g	rare
Syngnathus rostellatus					st	common
Syngnathus typhle					st	common
Trachinus draco	*Trachinus draco*	fish	demersal	M	g	rare
Trachurus trachurus	*Trachurus trachurus*	fish	pelagic	M	g	regular
Trigla lucerna	*Trigla lucerna*	fish	demersal	M	st	regular
Trisopterus esmarki	*Trisopterus esmarki*	fish	pelagic	M	irr	rare
Trisopterus luscus	*Trisopterus luscus*	fish	demersal	M	irr	rare
Trisopterus minutus	*Trisopterus minutus*	fish	demersal	M	irr	rare
Zoarces viviparus	*Zoarces viviparus*	fish	demersal	M	st	common

Annex 2

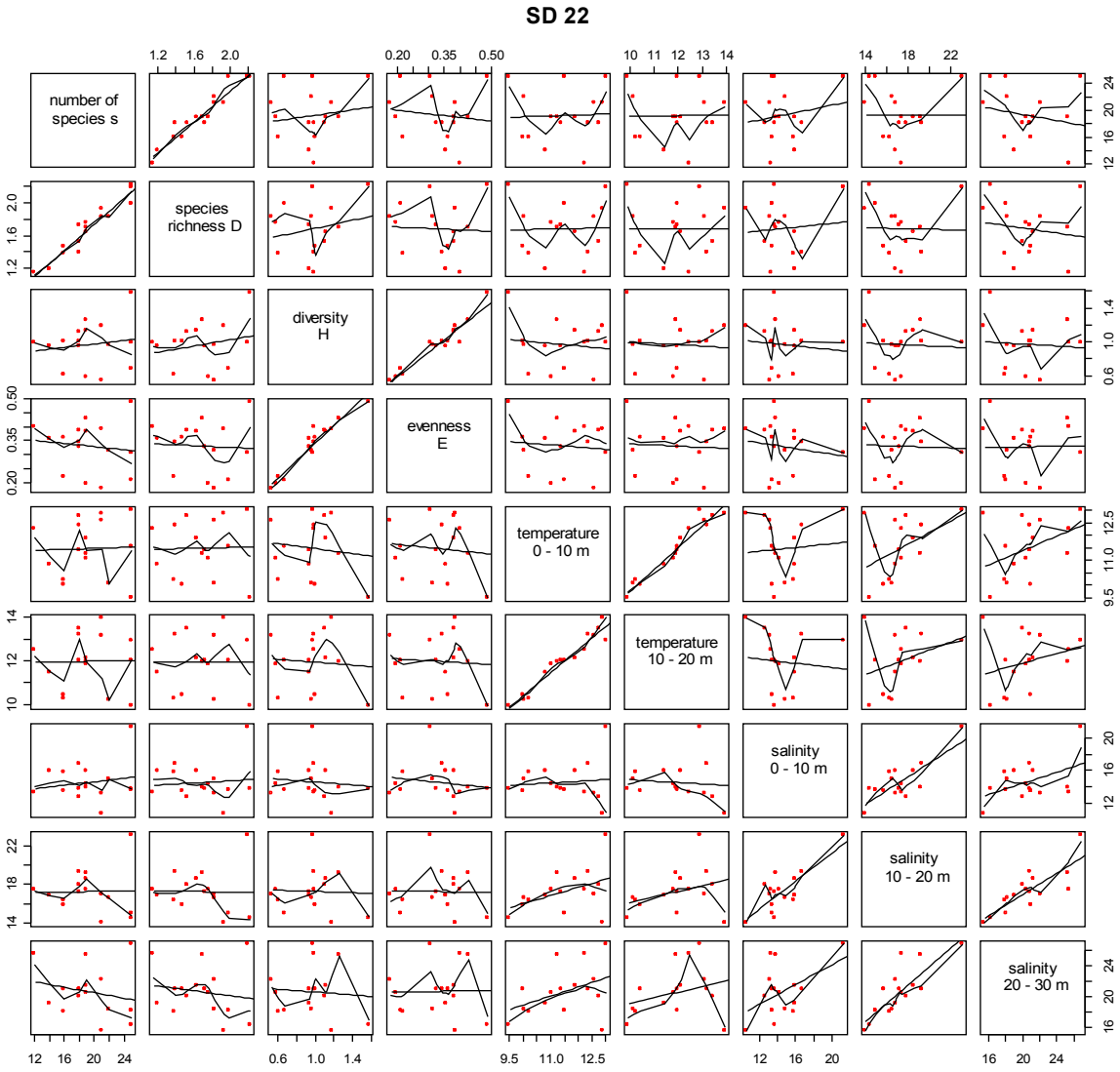

Fig. 13: ***Scatterplot of diversity indices and abiotic data of available depth strata; the dashed lines show the linear regression, the solid lines are smoothed curves.***

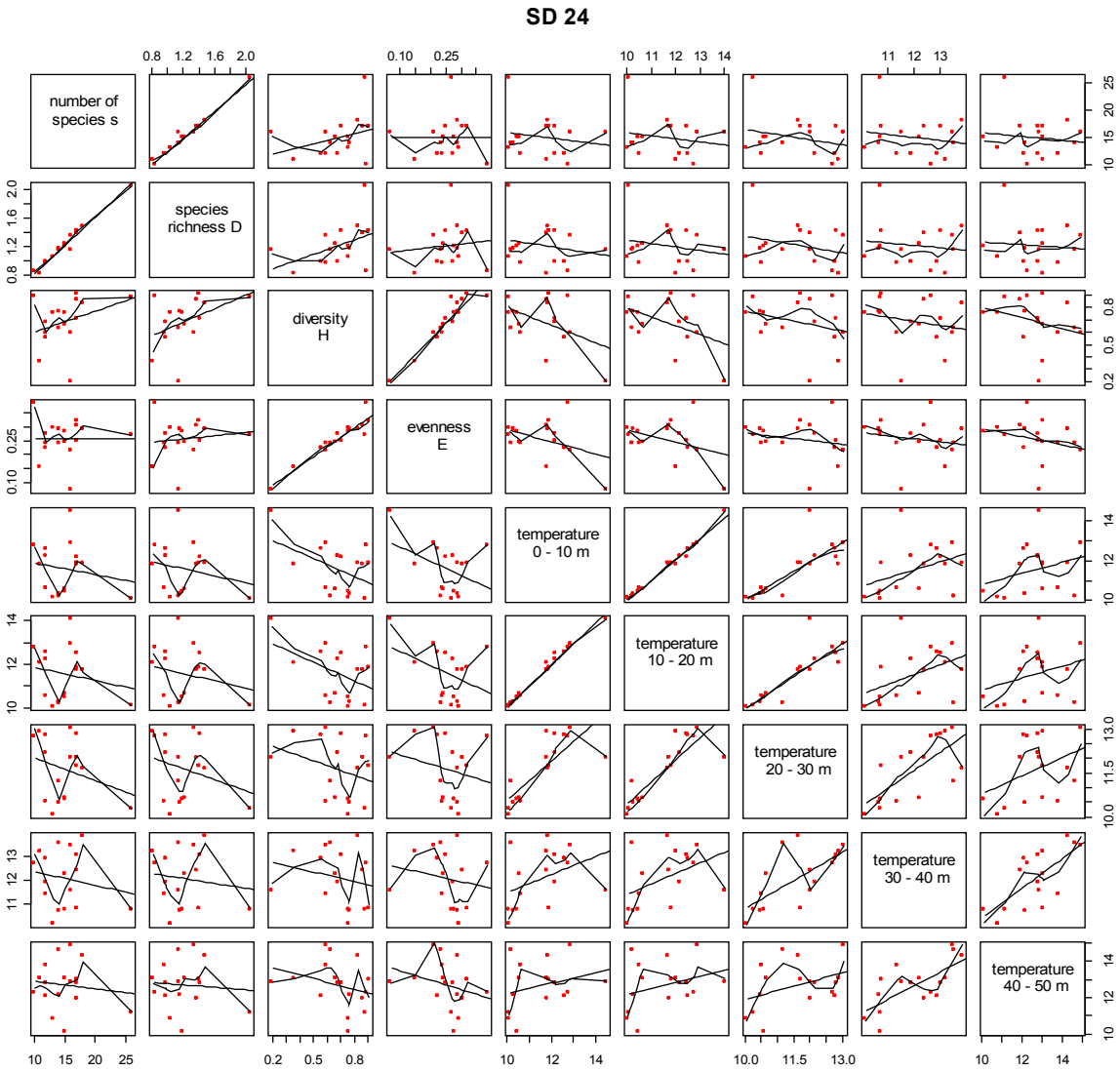

Fig. 14: ***Scatterplot of diversity indices and temperature data of available depth strata; the dashed lines show the linear regression, the solid lines are smoothed curves.***

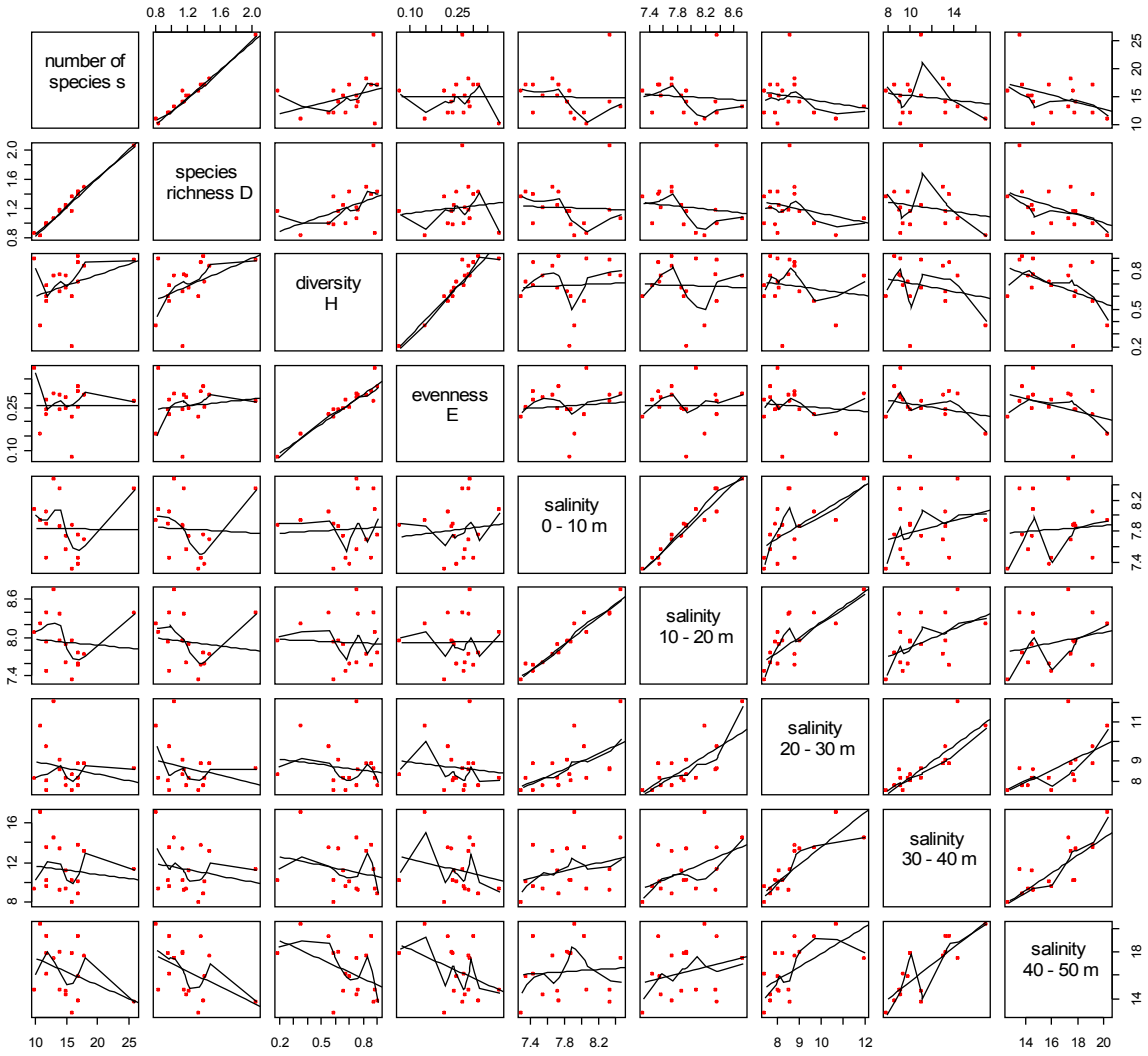

Fig. 15: ***Scatterplot of diversity indices and salinity data of available depth strata; the dashed lines show the linear regression, the solid lines are smoothed curves.***