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Variations in abundance and distribution of demersal fish species in the coastal zone of the Southeastern North Sea between 1980 and 1993

by

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Abstract

This paper presents a first comprehensive analysis of the fish catches of the beam trawl surveys carried out in the Scheldt estuary, the Dutch part of the Wadden Sea, the shallow zone of the continental coast between Belgium and the Horns Reef and offshore areas in the southern and southeastern North Sea. The species composition is analysed and compared among areas. Species richness varies between 32 - 49 species, and is highest in the coastal waters compared to the estuaries or offshore waters. Species richness further increased from the inner German Bight towards the southern North Sea and towards the central North Sea. The Shannon-Weaver index of diversity is generaly low due to the dominance of flatfish species in both inshore and offshore areas (e.g. dab, plaice) and shows a similar geographical pattern as species richness. Indices of diversity and eveness appeared to be rather stable over the years, except for a low in 1988 and 1991. These lows could be related to the exceptional high catch of dab and gobies, respectively. The annual variation and trends in species abundance is analysed for a selection of species. The species selected comprised of the resident estuarine and coastal species, dominant flatfish species using the coastal zone as nursery areas and some of the common open sea species which enter the coastal waters. Out of nine resident estuarine species studied, 4 species tend to decrease in recent years (eelpout, sea snail, flounder and eel) and 5 show a variable pattern. The trends in abundance are not always consistent among areas. The three flatfish species dab, plaice and sole that use the coastal waters as nursery ground show a decrease in catch rates since the late 1980s in all areas. Out of 8 open sea species, the solenette, scaldfish, lesser weever, grey gurnard show a substantial increase in abundance since the late 1980s.

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1. Introduction

Over the last decades there has been an increasing concern about men's impact on the ecosystem (Salomons et al. 1988; Anon, 1993). The marine environment may potentially be affected by a variety of human activities, both direct and indirect, such as coastal engineering works, pollution, eutrophication, fisheries and global warming. In order to analyse the possible influences of human activities, knowledge on the dynamics of the marine ecosystem is necessary. Such knowledge is mainly restricted to commercial fish species due to their economic importance. Time series data show major shifts in the abundance of some commercial fish species over periods of several decades or even hundreds of years (Hempel et al., 1978). These studies highlighted the natural dynamics of the system that is likely related to variability in ocean climate (Cushing, 1982). Large scale variability has also been shown in the trends in zooplankton abundance from the Continuous Plankton Recorder Programme (Franz et al. 1991).

The assessment of antropogenic changes in the ecosystem is difficult because of the complex nature of the system in which various natural processes and antropogenic activities interact, and because of the paucity of time-series data which are needed to test hypotheses. In this paper, time series information on the variability in abundance and composition of the demersal fish fauna is presented for the estuaries and the coastal zone of the south-eastern North Sea based on beam trawl surveys (DFS, Demersal Fish Surveys) carried out annually in autumn. Data are presented for the time period 1980-1993. At later stage we hope to extend the time period back to 1970 when these surveys were first started.

The paper comprises two parts. In the first part we analyse the differences in fish fauna between the estuarine and coastal habitats, but also between these and the open North Sea habitat. To this end we have analysed available BTS (Beam Trawl Survey) data from the open North Sea in addition to the DFS survey data. For a selection of the typical members of the estuarine and coastal waters, we then analyse the trends and variability in abundance in DFS data. The objective of this paper is restricted to the presentation of the data and a first exploration of possible hypotheses to explain the observed patterns.

2. Material and Methods

The Netherlands Institute for Fisheries Research (RIVO-DLO) has carried out two beam trawl surveys since 1970. The DFS surveys were originally carried out in autumn (September - October) and spring (April-May), but the latter have been stopped in 1987. The data of the spring survey have not been included in this analysis. In addition BTS surveys covering the open North Sea were carried out each summer (August - September) since 1985. A summary of the survey gear is given in Table 1. Details of the rigging of the DFS and BTS gears can be found in Boddeke et al. (1971) and ICES (1990), respectively.

The DFS sampling stations were stratified by geographical area, but the stations were not evenly distributed over the depth zones. The minimum depth sampled was determined by the depth of the research vessel and was generally more than 2 m. In the estuaries only the tidal channels and the sub-tidal flats were sampled. In the course of the years, some changes have been applied to allocate the stations more evenly over the depth zones, in particular in the coastal zone. The sampling stations in the BTS survey are stratified by ICES rectangle. Two to four stations by rectangle were selected pseudo-randomly.

For the analysis, the geographical sub-areas distinguished were grouped into larger units to facilitate the comparison and presentation of the results (Fig.1). The sub-areas comprise the Western and Easter Scheldt, three sub-areas in the Dutch Wadden Sea (western, central and eastern part), three coastal areas (coast of Holland, Dutch-German coast along the west Frisian Islands, German-Danish coast along the east Frisian islands) and four areas in open sea (Southern Bight, Dogger, German Bight and central North Sea).

For each sub-area we calculated the average catch per haul by species. Comparison of this measure of abundance among surveys is not straightforward because the measure of abundance does not take into account the differences in catchability for the various species and size-classes due to differences in gear type, mesh-size, towing speed and haul duration. Within survey comparison is possible, but some of the observed variation in abundance may be artificial due to variations in haul duration. Sometimes haul duration had to be reduced to 50% of the standard time in order to avoid gear damage or clogging of the net. Since this applies to only a few hauls during each survey it will not have affected our results seriously.

In the DFS surveys, the catch was sorted in a shrimp rotary sieve yielding three size fractions. All fish species were sorted from these size fractions, and their length distribution were recorded. Species that were caught in large numbers were subsampled. In the BTS survey the catch was sorted from a conveyer belt.

In some instances only species groups have been recorded. These include the gobies (*Pomatoschistus* sps, except *Gobius niger*) and the pipefish (*Syngnathus* sps, except *Entelures aequreus*). Rare species resembling more common ones may sometimes have been overlooked. For instance*Callionymus reticulatus* is generally included in *C. lyra*.

We employed the following community parameters to compare the demersal fish fauna among areas and years: species richness, Shannon-Weaver diversity index and eveness. A review of these measures is given in Pielou (1969). The diversity index of Shannon-Weaver, can be interpreted as the natural logarhitm of the number of species after taking account of the numerical abundance of each species to the community.

The Shannon-Weaver index of diversity, where p_j is the proportion of the catch number of species j in the total number of fish caught, is given by

$$H = S\ p_j \log p_j$$

Eveness, where s = number of species, can be calculated as

$$J = H / \log s$$

3. Results

3.1. Numerical composition of the fish fauna

Species richness varies between 32 species to 49 species (Table 2). In the coastal zone, the species richness is higher than in the estuaries as well as the areas further offshore in the open North Sea. Superimposed on this pattern, species richness is lowest in the German Bight and increases going towards the Southern Bight and to the central North Sea. A similar pattern is indicated by the Shannon-Weaver index of diversity. Diversity tends to be low in the German Bight and increases towards the central and southern North Sea.

Witin the estuaries, the fish fauna of the Wester Scheldt, although composed of a larger number of species, is less diverse than that of the Easter Scheldt. This implies that the Western Scheldt fauna is dominated by a single or a few species. Within the Wadden Sea, the central part shows a higher diversity than both the western (Marsdiep - Vliestroom) and eastern part (Eems-Dollart). The three estuarine areas with a lower diversity are all characterised by a relatively large runoff of fresh water as compared to the Easter Scheldt and the central part of the Wadden Sea.

Inspection of the actual numerical composition of the fish fauna in Table 3 shows that in all inshore and offshore areas the fauna is dominated by flatfish species: dab *Limanda limanda*, plaice *Pleuronectes platessa* and to a lesser extend sole *Solea solea* . Although dominant in all areas, the size classes of flatfish differ between the areas. In the estuaries and shallow coastal zone these flatfishes comprise of 0- and 1-group fish, whereas in the open North Sea they comprise of larger specimens and older age groups. Pelagic species, although represented in the beam trawl catches, generally make up a minor fraction of the total catch.

In the estuarine and coastal areas the typical estuarine species such as *Pholis gunellus, Liparis liparis, Myoxocephalus scorpius, Zoarces viviparis, Platichthys flesus* are caught in relatively low numbers as compared to flatfish species employing the shallow waters as nursery grounds. Among the resident estuarine species, only the gobies (*Pomatoschistus* spc) are caught in large numbers.

In the open North Sea, the fish fauna is dominated by flatfish and roundfish (whiting *Merlangius merlangus* , cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*). In addition, grey gurnard *Eutrigla gurnardus* and*Callionymus lyra* , and in the Southern Bight, the lesser weever *Trachinus vipera* is, are important.

Inter-annual variations of the community parameters, shown in Fig.2, do not indicate a trend in time. Around 1988 there is a temporary reduction in the diversity in the coastal zone and the Wadden Sea, which appears to be related to an increase in the abundance of dab. In the Wadden Sea and Scheldt estuary a second year with a low diversity occurs in 1991 when the catches of gobies were exceptional high.

3.2. Trends in the abundance of individual species between 1980 and 1993

The interannual variations in abundance is shown for a selection of species for the DFS survey. Species are grouped according the function of coastal waters and estuaries in their life cycle. Hence, we distinguish 1 - resident species of the estuaries; 2 - species which use the coastal areas and estuaries as nursery grounds, 3 - species of the open North Sea which may enter the coastal waters and estuaries.

Time trends in log abundance are shown in Fig.3 for the coastal waters (left panel), the Wadden Sea (central panel) and the Scheldt estuary (right panel) separately. The abundance index is expressed as a ratio of the annual abundance over the arithmetic mean abundance between 1980-1993. The mean abundance is indicated by the dashed horizontal line. The heavy line shows the variations in abundance for the total area, whereas the thin lines represent the variations in abundance of the sub-areas. Zero catches have been shown as a value of 0.01.

3.2.1. Estuarine and coastal residents

Bull rout *Myoxocephalus scorpius*. In the coast al waters, the abundance of bull rout varied without a trend. In the estuaries of the Wadden Sea and Scheldt, however, a consistent decline is apparent since 1988.

Butterfish*Pholis gunnellus*. This species is caught in the Wadden Sea and Eastern Scheldt. Catches in the coastal areas and the Wester Scheldt are few. In the Wadden Sea the abundance was slightly below average in the second half of the 1980s. This pattern is also apparent from the Easter Scheldt except the peak in 1987.

Sea snail *Liparis liparis*. Highest numbers are caught in the Western Scheldt and the central and eastern Wadden Sea. In all areas the abundance of sea snails was low in the late 1980s. The abundance increased again in the early 1990s in both the coastal zone and Wadden Sea, but not in the Scheldt estuary.

Gobies *Pomatoschistus spc*. This species group comprises several species among which *P. minutes* and *P. microps* will be the main ones. Abundance varies without a consistent pattern among areas.

Flounder *Platichthys flesus*. This flatfish species inhabits freshwater, estuarine and coastal waters, which it only leaves for spawning in the open North Sea. The abundance of flounder decreased in both the coastal zone and the Wadden Sea, but in the Scheldt estuary no consistent pattern could be detected.

Eel *Anguilla anguilla*. Although eel is an katadromous species, which has its stronghold in freshwater habitats, small number of juveniles inhabit shallow marine habitats. The abundance of eel has declined substantially in coastal waters as well as in estuarine waters.

Five-bearded rockling *Ciliata mustela*. The trend in abundance of the five-bearded rockling shows a consistent pattern among the three areas with a period of a lower abundance around 1985.

Eelpout *Zoarces viviparis*. The time trend in abundance differs among the three areas. In the Wadden Sea the abundance gradually decreased since 1983. This decrease in consistent for all sub-areas in the Wadden Sea. In the Scheldt estuary the abundance increased in the early 1980s, although the numbers caught are small. In the coastal zone the abundance increased in the early 1980s, but decreased sharply since 1987.

Pipefishes *Syngnathus spc*. Catches of this species group mainly comprised *S. acus* and *S. rostellatus*. Abundance index is highly variable between years in all areas without a common pattern.

Tub gurnard *Trigla lucerna*. This coastal species immigrates the coastal waters of the North Sea during the summer. No consistent trend is apparent between 1980 and 1993, although the peak in abundance in 1989 is apparent in the coastal waters as well as the Wadden Sea, but not in the Scheldt estuary.

3.2.2. Species using coastal areas and estuaries as nursery grounds

Dab *Limanda limanda*. Catches of dab are rather stable in the coastal zone, but in the estuaries, the abundance is more variable. In all three areas, dab appears to decline since the late 1980s. A peak in dab abundance was recorded in 1988 in all areas.

Plaice *Pleuronectes platessa*. Plaice catches are dominated by the 0- and 1-group fish and are equally variable in the three areas. In recent years, the plaice abundance decreases from a high level reached in the mid 1980s. This high level in the mid 1980s coincides with the overall strong recruitment observed in these years with exceptional strong year classes born in 1981 and 1985.

Sole *Solea solea*. Sole catches are dominated by pre-recruits (0- and 1-group). Between 1980 and 1993 the abundance of sole shows a gradual decrease with two peaks in 1987 and 1991. These peaks coincide with above average recruitment of the 1987 and 1991 year class.

3.2.3. Trends in abundance of species from the open North Sea

Scaldfish *Arnoglossus laterna* and solenette *Buglossidium luteum*. Scaldfish and solenette catches represent the several age groups of juvenile and adult fish. The abundance of scaldfish increased sharply since 1989. The abundance of solenette increased since 1980.

Whiting *Merlanguius merlangus*. The catches of whiting which are dominated by 0-groups fish tend to decrease in the coastal waters, but this tendency is not apparent in the estuaries. There appears to be a reasonably consistency in the years with peak abundance among the three areas. Peak abundance is recorded in 1983, 1986-1987 and 1990.

Bib *Trisopterus luscus*. No trend in abundance is apparent, although in the coastal waters the highest abundances were recorded in 1980-1983. Low abundance is recorded in the mid 1980s, especially in the estuaries.

Grey gurnard *Eutrigla gurnardus*. This species is a typical representative of the open North Sea and is only caught in reasonable numbers in the coastal waters but not in the estuaries. After peak abundance in 1980 and 1981, grey gurnards virtually disappeared from the coastal waters in 1982 and 1983 and increased since then. The 1993 abundance, however, is still well below the values recorded in the early 1980s.

Lesser weever *Trachinus vipera*. This open sea species of sandy bottoms shows a remarkable pattern with a peak in abundance between 1981 and 1985, low numbers in 1986 and 1987 and gradually increasing to a record level in 1992.

Dragonet *Callionymus lyra*. This species is mainly distributed in offshore waters but enters the shallow coastal waters and estuaries in relatively low numbers. Qualitatively the pattern in abundance seems similar between the coastal zone and the Wadden Sea with lower numbers recorded around 1985 and peak abundace in 1989-1990. In recent years, the abundance is somewhat reduced compared to previous years.

Hooknose *Agonus cataphractus*. This species is widely distributed in shallow waters, but also occurs in small numbers in offshore waters. The trends in abundance in the Wadden Sea and Scheldt estuary tend to indicate a decline in abundance. This trend is less evident in the coastal zone.

4. Discussion

Throughout the paper we have interpreted the beam trawl catches as a reflection of the demersal fish fauna. This is obviously a gross simplification. Fishing gears are highly selective and will catch certain species better than others. The beam trawl is particularly suitable for catching demersal fish (especially flatfish) and will not sample the pelagic fish representatively (Breckling & Neudecker, 1994). In addition, the monitoring of fish populations in estuarine and coastal areas pose specific problems due to the heterogenic character of the area due to the tidal dynamics and morphology of the area (tidal flats, subtidal flats, tidal channels, sand banks, mussel beds, areas of sea grass ect: see reviews in Hinz,1989 and Ruth & Berghahn, 1989).

The comparison of the fish fauna of the estuaries, coastal zone and open North Sea clearly illustrated that these habitats are characterised by a different demersal fish fauna. The typical estuarine and coastal species follows the classification made by Zijlstra (1978). Comparison of demersal fauna of the open North Sea with similar data obtained by other sampling gear such as an otter trawl (GOV-trawl: Knijn et al. 1993) highlights the bias in anyone survey. The GOV-surveys showed a numerical dominance of roundfish over flatfish, whereas the beamtrawl gives an opposite result. In future work more attention should be given to comparative fishing in order to make a quantitative comparison of the fish fauna possible.

The DFS surveys were restricted to the tidal channels and subtidal flats and therefore have grossly underestimated the abundance of those species which occur on the tidal flats (plaice, flounder) and mussel beds (sea snails, eelpout). Because, the surface areas of the unsampled habitat in the tidal channels (mussel beds) is relatively small as compared to the sandy areas sampled in our surveys, and the fish fauna on the temporarily submerged tidal flats are dominated by flatfish, we believe that the dominance of flatfish in the estuaries and coastal zone indicated by our results is real. This poses the question, why flatfish populations of which the adults inhabit the open North Sea dominate the coastal habitats, as compared to the species which employ the coastal and estuarine habitats permanently as spawning area, nursery area and adult distribution area? This question can be related to the geographical pattern in diversity and species number which showed a lowest value in the inner German Bight.

The geographical pattern in diversity and species richness corresponds to the general pattern of an increase from north to south. The low diversity and species richness in the German Bight might be related to the fact that this area shows the highest variation in temperature condition, both in the amplitude of the annual cycle and the frequency of occurence of extreme cold winters or warm summers.

Inspection of the trends in the variabiltiy in abundance of individual species does not provide strong evidence for any association with extreme environmental conditions. In the period 1980-1993, severe winters occurred in 1985, 1986 and 1987, whereas the winters of 1988, 1989 and 1990 were relatively warm. The interpretation of interannual variations in abundance is hampered by the lack of information on the age structure of the populations. A peak in abundance occurring in a single year will lead to a different interpretation if the population is composed of several year classes, or if the population comprises of only one year class. In the first case, there may have been an invasion of fish from elsewhere. In the latter case, the peak relates to a particularly strong year class. The age structure of the populations is known for the commercial flatfish species plaice and sole, but not for the other species. Future work should aim to fill this gap in order to facilitate the interpretation of the patterns in abundance.

A search for similar patterns in abundance point at two groups of species. The first group comprises plaice, sole, dab and flounder which show a consistent decline in abundance since the late 1980s. The second group consists of scaldfish, solenette and lesser weever showing a consitent increase. The trends observed in the DFS surveys in these species corresponds to the trends observed in a sole net survey (van Leeuwen, 1993) and the BTS survey (ICES, 1993). These opposite trends of both groups coincided with years of exceptionally warm winters. Whether these are related is an open question.

The similarity in the pattern of abundance will be affected by the interaction between the population structure of a species and the main environmental variables affecting its recruitment and survival. Environmental conditions in coastal habitats will show broadly similar patterns between years with regard to for instance temperature conditions or effects of eutrophication. However, there are also factors that have a local effect. For instance, coastal engineering works and pollution may locally affect fish spopulations. In the Easter Scheldt a storm surge barrier has been constructed in the 1980s that has reduced considerably the volume of water flowing in and out with the tides. Other examples of local effects are pollution and aquaculture (mussel culture).

The fact that the group of scaldfish, solenette and lesser weever, showing a substantial increase in abundance in recent years, are open sea species of sandy and muddy sediments, which spawn their pelagic eggs in late spring and have populations composed of several year classes, tentatively suggests that the increase may be related to the factors affecting recruitment.

The present study is a first step in exploring the kind of data available from the beam trawl survey monitoring programmes. In the near future the time series will be extended back to 1970, the first year of the surveys, and the patterns in abundance have to be analysed in much greater detail in relation to changes in the environmental and ecological conditions in the coastal areas. Such a study will form a baseline to evaluate the possible effects of human activities on the coastal habitats.

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Table 1. Details of survey for DFS (Wadden Sea; Scheldt estuary; Coastal zone) and BTS (Open North Sea).

Survey	DFS			BTS
	Scheldt estuary	Wadden Sea	Coastal zone	Open North Sea
Beam trawl size (m)	3-m	3-m	6-m	8-m
Ship	Schollevaar	Stern	ISIS	ISIS / charter
Ground rope	bobbins	bobbins	bobbins	chain + rubber discs
Number of tickler	1	1	1	8
Mesh size (streched, mm)	20	20	20	40
Haul duration (min)	15	15	15	30
Towing speed (knots)	3	3	3	4
Number of hauls	±70	±100	±100	±100

Table 2. Summary of species richness, Shannon Weaver index of diversity and index of eveness diversity indices by sub-area as obtained from the summer-autumn beam trawl surveys carried out between 1980-1993

Area	#	Number hauls	Number species	Diversity Shanon Weaver	Eveness
Wester scheldt	1	276	45	1.46	0.38
Easter scheldt	2	282	39	1.76	0.48
Wadden Sea west	3	525	39	1.75	0.48
Wadden Sea middle	4	317	36	2.21	0.62
Wadden Sea east	5	214	32	1.88	0.54
Cont. coast south	6	390	49	1.73	0.44
Cont. coast middle	7	376	48	2.02	0.52
Cont. coast north	8	256	40	1.90	0.51
Southern Bight	9	94	38	1.93	0.53
Dogger	10	222	35	1.33	0.37
German Bight	11	250	37	1.05	0.29
Central North Sea	12	312	44	1.76	0.47
Total	1-12		75		

Table 3. Species composition by sub-area as obtained from the summer-autumn beam trawl surveys carried out between 1980-1993 (Number $haul^{-1}$).

	Wester scheldt	Easter scheldt	Wadden Sea west	Wadden Sea middle	Wadden Sea east	Cont. coast south	Cont. coast middle	Cont. coast north	Southern Bight	Dogger	German Bight	Central North Sea
	1	2	3	4	5	6	7	8	9	10	11	12
NUMBER OF HAULS	276	282	525	317	214	390	376	256	94	222	250	312
LAMPETRA FLUVIATILIS	0.004	0	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
PETROMYZON MARINUS	0.004	0	0.000	0.000	0.000	0.015	0.005	0.000	0.000	0.000	0.000	0.000
MYXINE GLUTINOSA	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.567
SCYLIORHINUS CANICULUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.096	0.000	0.000	0.045
SQUALUS ACANTHIAS	0.004	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.221	0.000	3.242
GALEORHINUS GALEUS	0	0	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
DASYATIS PASTINACA	0	0	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RAJA	0.007	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.096	1.572	0.016	76.164
ANGUILLA ANGUILLA	0.406	1.787	1.446	0.751	0.617	3.036	0.610	0.117	0.022	0.000	0.064	0.000
ALOSA FALLAX	0.007	0	0.560	1.101	0.757	4.805	10.378	0.543	0.000	0.000	0.000	0.000
CLUPEA HARENGUS	13.953	3.759	30.987	39.713	8.598	97.113	82.361	7.781	1.362	0.128	0.184	0.470
SPRATTUS SPRATTUS	3.522	0.667	7.284	10.801	2.846	56.474	31.593	3.246	0.022	0.572	0.328	0.023
SARDINA PILCHARDUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENGRAULIS ENCRASICOLUS	0.123	0.035	0.000	0.000	0.000	0.018	0.574	0.004	0.000	0.000	0.000	0.000
ARGENTINA SPHYRAENA	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.034
OSMERUS EPERLANUS	0.018	0.004	38.735	5.296	14.486	0.987	0.907	6.145	0.000	0.000	0.000	0.000
LOPHIUS PISCATORIUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.113	0.012	3.601
GADUS MORHUA	0.638	0.418	0.764	4.012	6.266	1.667	8.625	38.336	0.873	6.396	6.684	32.234
POLLACHIUS VIRENS	0.004	0	0.000	0.000	0.000	0.010	0.003	0.000	0.000	0.000	0.000	0.298
POLLACHIUS POLLACHIUS	0.004	0	0.000	0.000	0.000	0.005	0.000	0.004	0.000	0.000	0.000	0.023
MELANOGRAMMUS AEGLEFINUS	0	0	0.000	0.000	0.000	0.000	0.016	0.000	0.000	4.611	0.416	77.229
RHINONEMUS CIMBRIUS	0.004	0	0.000	0.025	0.005	0.003	0.000	0.019	0.022	3.903	0.792	0.974
TRISOPTERUS MINUTUS	0.123	0.007	1.899	0.041	0.079	4.523	1.790	0.075	10.117	2.899	0.580	0.777
TRISOPTERUS LUSCUS	4.315	17.131	4.669	1.697	0.486	26.020	11.321	0.680	19.809	0.162	0.336	0.034
TRISOPTERUS ESMARKI	0	0	0.000	0.000	0.000	0.031	0.000	0.000	0.000	0.016	0.000	0.893
MERLANGIUS MERLANGUS	3.145	3.695	9.113	22.908	11.079	47.241	54.601	101.266	11.192	78.081	47.578	237.051
MOLVA MOLVA	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.016	0.078
MERLUCCIUS MERLUCCIUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.068	0.108	0.316
GAIDROPSURUS VULGARIS	0.014	0.028	0.000	0.028	0.000	0.000	0.000	0.027	0.000	0.027	0.000	0.000
CILIATA MUSTELA	0.663	0.11	0.754	8.565	2.449	1.362	0.970	0.746	0.000	0.000	0.000	0.000
ZOARCES VIVIPARIS	0.043	2.791	23.607	13.918	7.388	0.459	0.665	9.461	0.000	0.000	2.520	0.006
BELONE BELONE	0	0	0.002	0.003	0.000	0.018	0.013	0.000	0.000	0.025	0.008	0.000
SEBASTES VIVIPARUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.056
ATHERINA PRESBYTER	0.127	0.078	0.015	0.003	0.000	0.359	0.021	0.000	0.000	0.000	0.000	0.000
ZEUS FABER	0	0.004	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
GASTEROSTEUS ACULEATUS	0.051	0.007	0.006	0.038	0.005	0.041	0.107	0.000	0.107	0.000	0.000	0.000
SPINACHIA SPINACHIA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000
SYNGNATHUS	1.634	0.851	4.663	93.151	9.715	7.038	10.224	6.555	0.022	0.000	0.000	0.000
ENTELURUS AEQUOREUS	0.058	0.007	0.004	0.000	0.000	0.003	0.005	0.000	0.043	0.000	0.000	0.000
TRIGLA LUCERNA	0.04	0.028	0.139	0.262	0.145	0.693	1.846	0.906	4.160	0.095	1.036	0.051
EUTRIGLA GURNARDUS	0.091	0.053	0.016	0.035	0.126	0.084	0.455	0.328	7.436	42.451	25.361	29.509
ASPITRIGLA CUCULUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.064	0.000	0.000	0.000
MYOXOCEPHALUS SCORPIUS	0.804	4.496	18.747	10.417	6.612	0.730	0.697	5.250	0.000	0.000	0.952	0.272
AGONUS CATAPHRACTUS	1.812	3.518	4.099	3.328	4.486	15.672	15.827	16.969	16.873	11.052	38.162	6.985
LIPARIS LIPARIS	2.051	0.596	1.581	9.123	10.322	3.208	0.402	0.039	0.000	0.000	0.000	0.000
CYCLOPTERUS LUMPUS	0.007	0	0.012	0.057	0.028	0.059	0.000	0.027	0.000	0.016	0.016	0.000
TRACHURUS TRACHURUS	0.062	0.312	0.111	0.092	0.033	1.897	11.708	12.090	1.032	0.982	0.370	0.462
MULLUS SURMULETUS	0	0	0.000	0.000	0.000	0.023	0.348	0.000	0.468	0.000	0.000	0.000
DICENTRARCHUS LABRAX	0.025	0.014	0.000	0.000	0.000	0.044	0.003	0.000	0.000	0.000	0.000	0.000
MUGILIDAE	0.004	0	0.002	0.000	0.000	0.026	0.027	0.000	0.000	0.000	0.000	0.000
CRENIMUGIL LABROSUS	0	0	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000
TRACHINUS VIPERA	0.004	0	0.025	0.012	0.000	2.157	1.628	0.000	126.745	11.403	0.000	0.000
ANARHICHAS LUPUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.044	0.488
LUMPENUS LAMPRETAEFORMIS	0	0	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
PHOLIS GUNNELLUS	0.018	0.184	0.524	0.366	0.547	0.064	0.040	0.664	0.000	0.000	0.000	0.000
AMMODYTIDAE	0.293	1.106	0.638	0.543	0.220	1.915	13.929	5.343	1.468	0.016	0.048	2.005
HYPEROPLUS LANCEOLATUS	0.152	0.089	0.122	0.110	0.047	0.164	0.856	0.731	2.639	0.387	0.024	0.074
CALLIONYMUS LYRA	2.21	2.163	0.408	0.072	0.075	130.728	28.729	8.340	65.798	35.336	34.136	5.748
POMATOSCHISTUS	219.32	81.755	39.593	98.710	102.710	1080.297	362.564	279.094	11.319	0.000	0.000	0.000
GOBIUS NIGER	0	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
APHIA MINUTA	0	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SCOMBER SCOMBER	0	0	0.000	0.000	0.000	0.021	0.083	0.004	0.128	0.090	0.032	0.023
SCOPHTHALMUS MAXIMUS	0.007	0.004	0.175	0.269	0.000	2.433	1.242	0.746	0.256	0.311	0.952	0.562
SCOPHTHALMUS RHOMBUS	0.043	0.089	0.086	0.038	0.070	0.536	0.583	0.262	0.160	0.081	0.122	0.042
ARNOGLOSSUS LATERNA	0	0	0.000	0.000	0.084	0.062	0.979	0.000	8.883	15.890	8.442	0.000
PHRYNORHOMBUS NORVEGICUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.000	0.128	0.006
LEPIDORH. WHIFFIAGONIS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.056
GLYPTOCEPH. CYNOGLOSSUS	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.000	4.650
HIPPOGLOSS. PLATESSOIDES	0	0	0.000	0.000	0.000	0.000	0.000	0.004	0.000	7.704	4.239	111.071
LIMANDA LIMANDA	92.928	92.78	201.928	120.063	197.243	667.741	341.143	377.008	292.309	797.096	1341.049	665.892
MICROSTOMUS KITT	0	0.067	0.010	0.000	0.000	0.000	0.120	0.160	1.394	2.112	2.159	11.142
PLATICHTHYS FLESUS	2.841	1.025	4.682	5.236	3.570	2.513	2.585	8.504	0.415	0.000	0.288	0.019
PLEURONECTES PLATESSA	37.08	137.35	368.920	159.943	184.949	165.718	457.776	308.156	61.277	96.061	464.594	161.569
HIPPOGLOSSUS HIPPOGLOSSUS	0	0	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.011
SOLEA SOLEA	14.254	37.883	40.257	38.858	66.771	208.372	149.351	74.551	15.064	3.791	14.534	0.503
BUGLOSSIDIUM LUTEUM	0	0	0.004	0.000	0.000	1.416	13.122	0.035	16.085	45.289	5.368	0.736

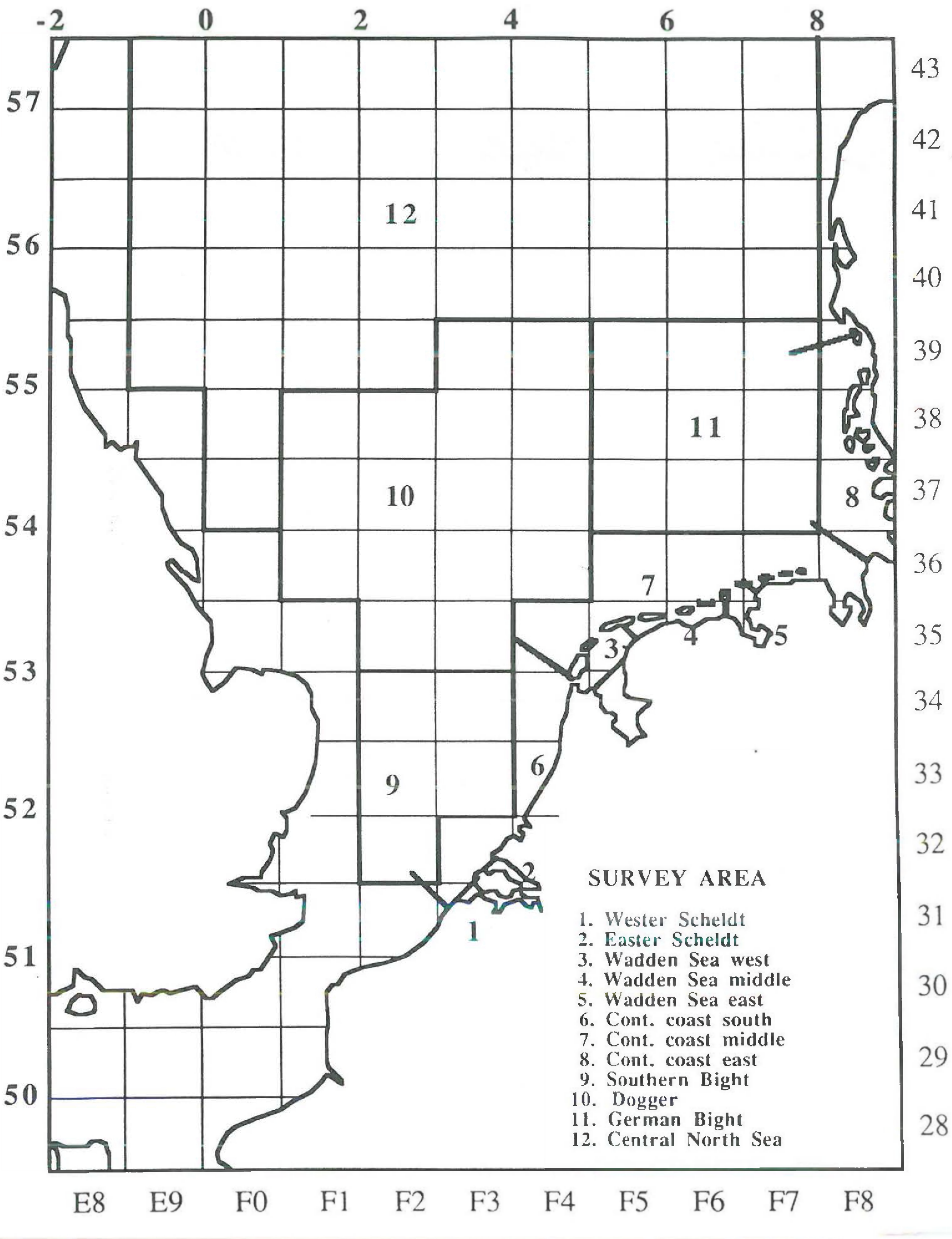


Figure 1. Map of survey area with the areacodes.

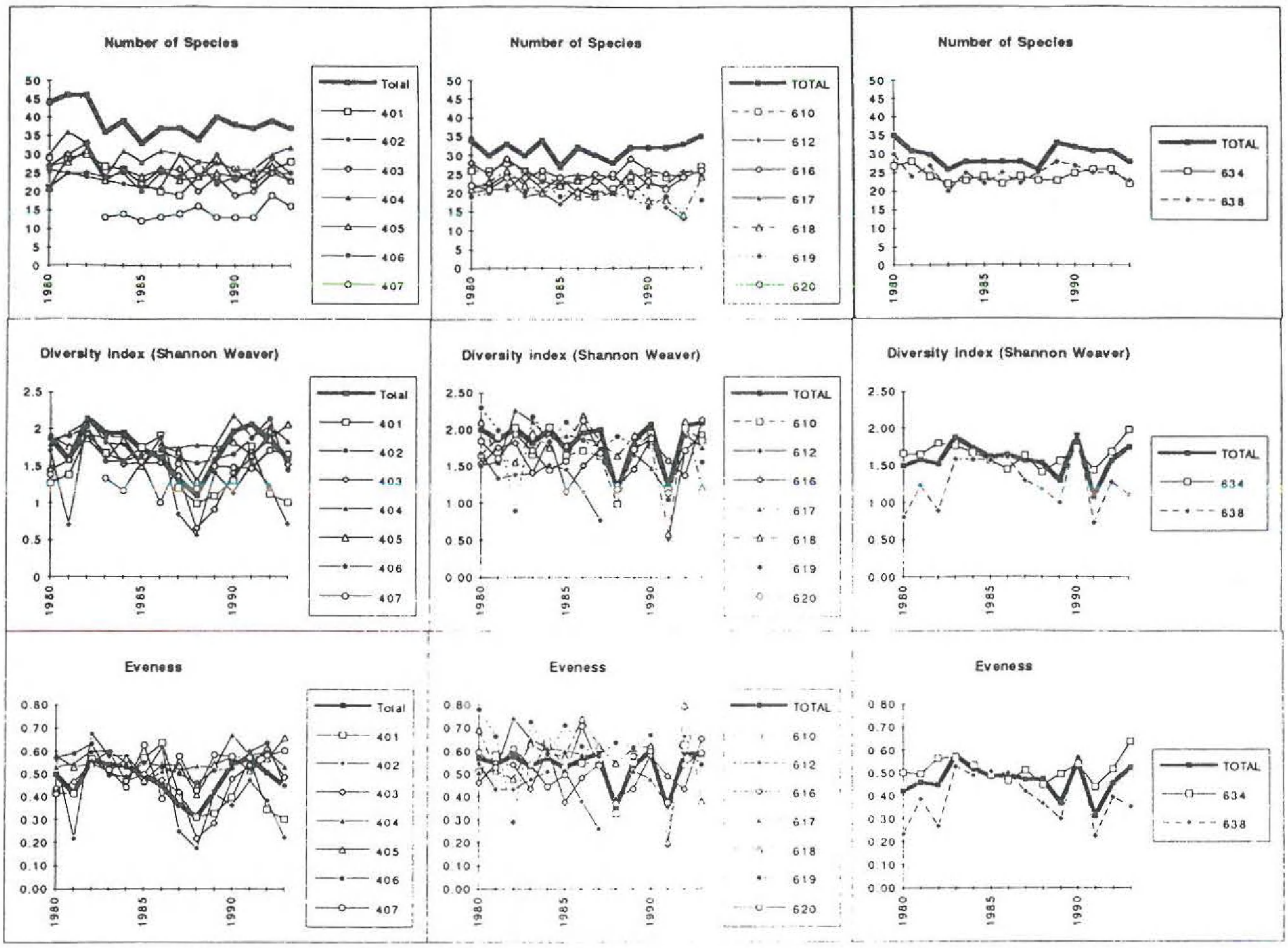
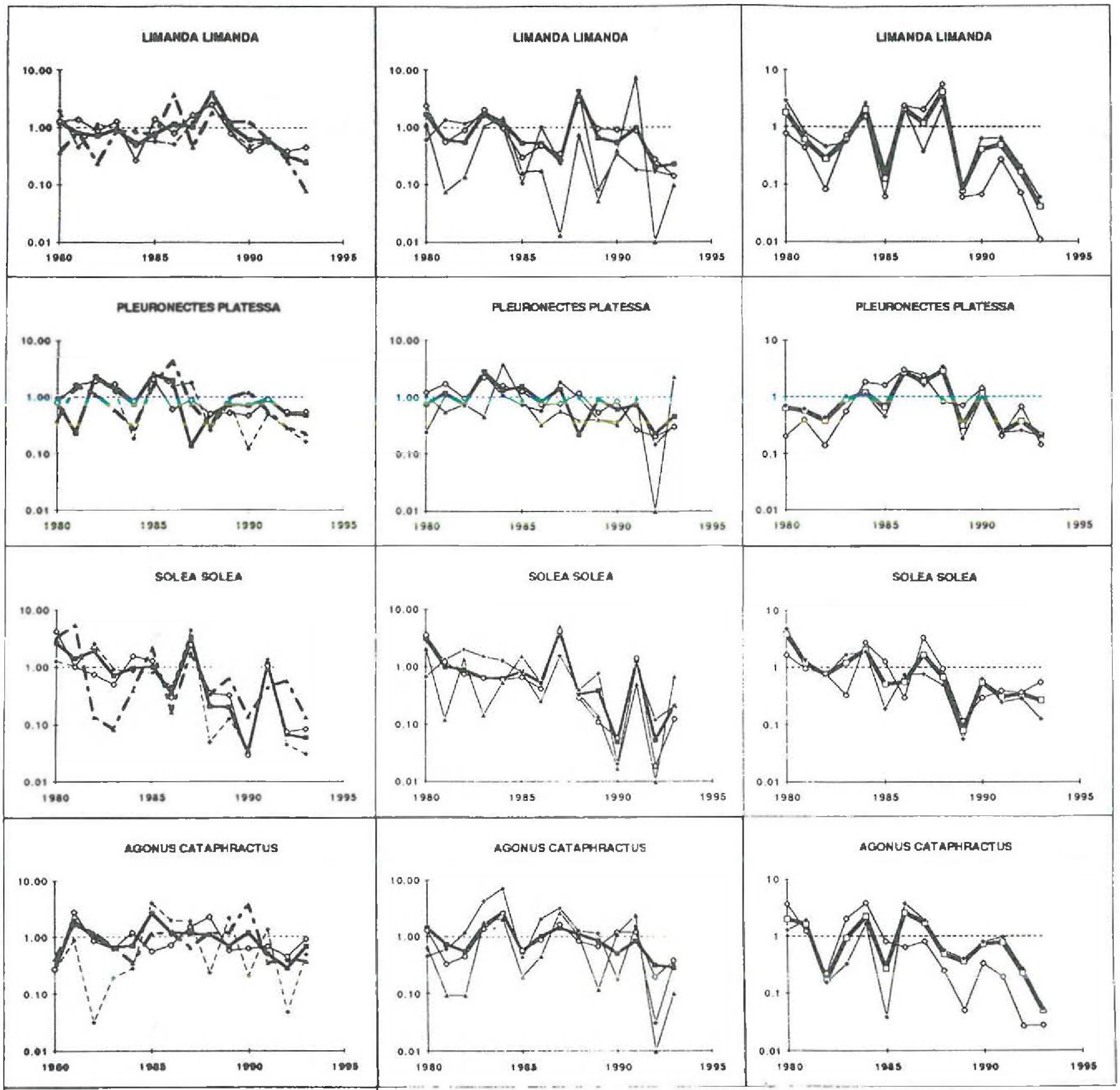


Figure 2. Trends in species richness, diversity and eveness indices for the coastal zone (lefthand panel), the Dutch Wadden Sea (central panel) and the Scheldt estuary (righthand panel). The heavy lines show the indices for the total area. The thin lines that for the sub-areas.

The Scheldt estuary is split in 2 areas: nr.1 (Wester Scheldt) subarea 638, nr.2 (Easter Scheldt) subarea 634.

The Dutch Wadden Sea in 3 areas: nr.3 (west) subarea 610+616, nr.4 (middle) subarea 617+618+619, nr.5 (east) subarea 620.

The coastal zone in 3 areas: nr.6 (south) subarea 401+402+403, nr.7 (middle) subarea 404+405, nr.8 (north) subarea 406+407



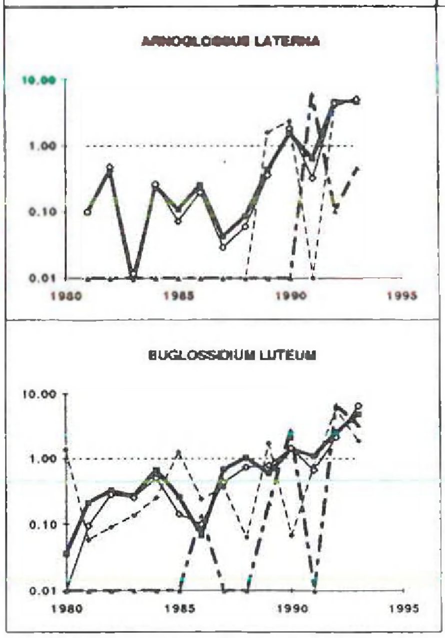


Figure 3 cntd. Trends in abundance (Number haul^{-1}) for a selected number of species in the coastal zone (lefthand panel), the Dutch Wadden Sea (central panel) and the Scheldt estuary (righthand panel). The heavy lines show the abundance for the total area. The thin lines that for the sub-areas. These are: lefthand panel - coastal zone south (◆), central (◇) and north (▲); middle panel - Wadden Sea west (◆), central (◇) and east (▲); righthand panel - Wester (◇) and Easter Scheldt (◆).

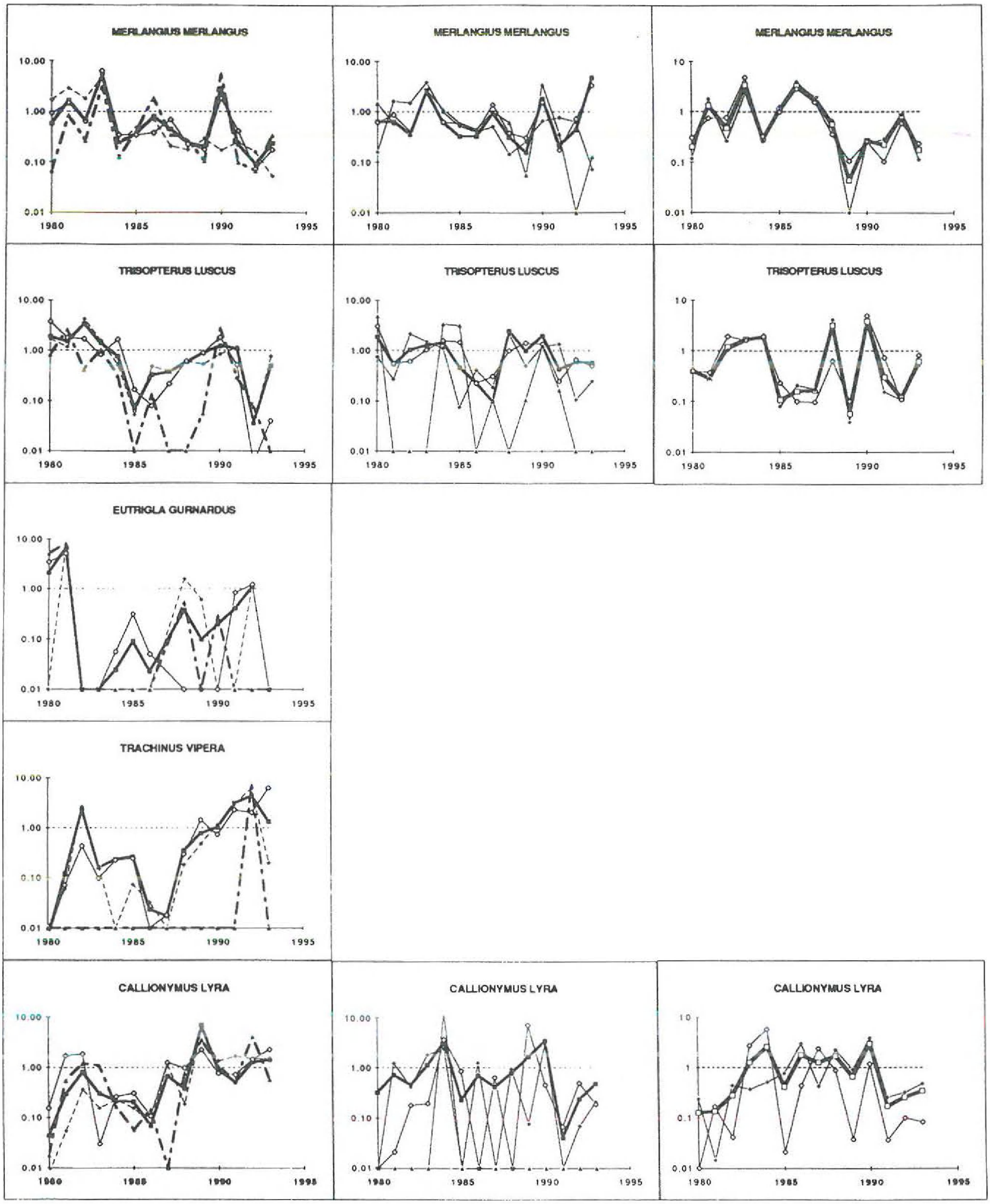


Figure 3 cntd. Trends in abundance (Number haul^{-1}) for a selected number of species in the coastal zone (lefthand panel), the Dutch Wadden Sea (central panel) and the Scheldt estuary (righthand panel). The heavy lines show the abundance for the total area. The thin lines that for the sub-areas. These are: lefthand panel - coastal zone south (◆), central (◇) and north (▲); middle panel - Wadden Sea west (◆), central (◇) and east (▲); righthand panel - Wester (◇) and Easter Scheldt (◆).

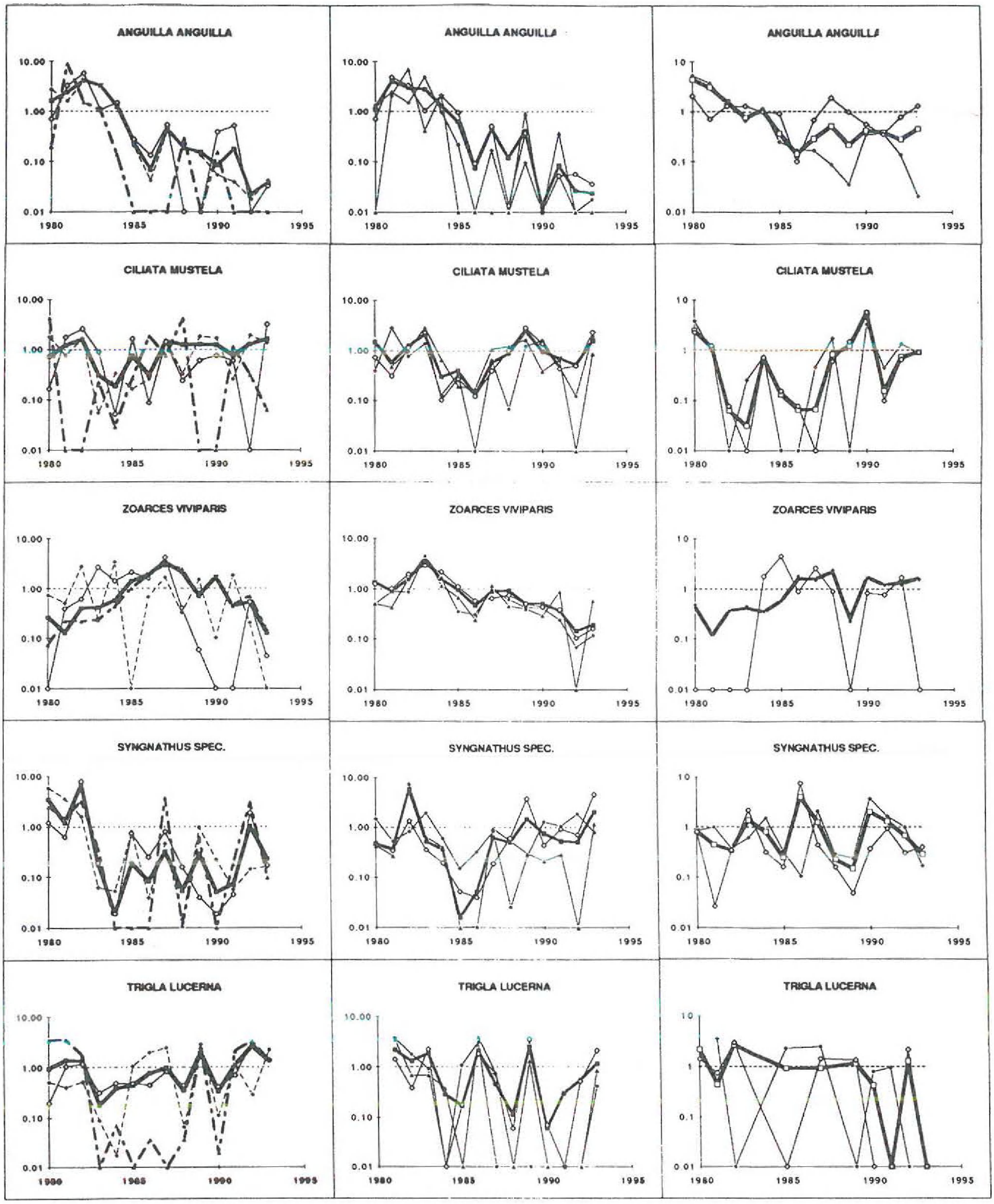


Figure 3. Trends in abundance (Number haul^{-1}) for a selected number of species in the coastal zone (lefthand panel), the Dutch Wadden Sea (central panel) and the Scheldt estuary (righthand panel). The heavy lines show the abundance for the total area. The thin lines that for the sub-areas. These are: lefthand panel - coastal zone south (◆), central (◇) and north (▲); middle panel - Wadden Sea west (◆), central (◇) and east ( ); righthand panel - Wester (◇) and Easter Scheldt (◆).

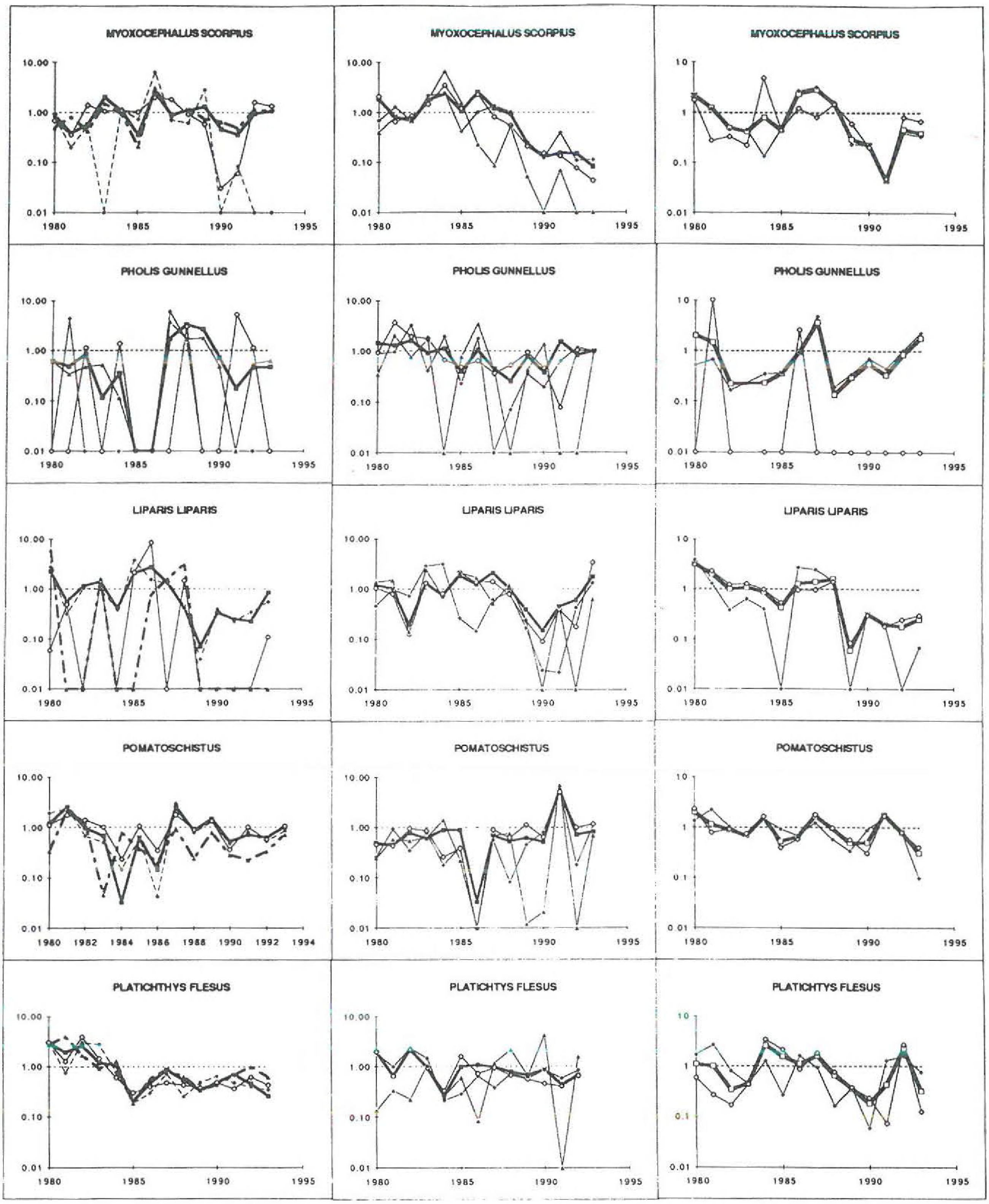


Figure 3 cntd. Trends in abundance (Number haul^{-1}) for a selected number of species in the coastal zone (lefthand panel), the Dutch Wadden Sea (central panel) and the Scheldt estuary (righthand panel). The heavy lines show the abundance for the total area. The thin lines that for the sub-areas. These are: lefthand panel - coastal zone south (◆), central (◇) and north (▲); middle panel - Wadden Sea west (◆), central (◇) and east (▲); righthand panel - Wester (◇) and Easter Scheldt (◆).