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Long-term trends in ten non-target North Sea fish species

Henk J. L. Heessen and Niels Daan

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Catch data on 10 non-target fish species from the International Bottom Trawl Survey during the years 1970–1993 are analysed for changes in distribution and abundance by size class. Trends in catch rates of spurdog, starry ray, bib, poor cod, four-bearded rockling, grey gurnard, bullrout, long rough dab, dab, and lemon sole have been compared using correlation and cluster analysis with indices describing different aspects of the North Sea ecosystem, including biomass of pelagic, demersal and industrial species, temperature, eutrophication, and beam trawl effort. Most species appear to have increased over the period. However, the statistical analysis does not provide a plausible explanation of the factors responsible for the observed changes.

Key words: abundance, distribution, long-term changes, non-target species, North Sea.

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Introduction

Demersal fisheries in the North Sea are associated with large by-catches of non-target fish species and invertebrates, most of which are discarded at sea. Fisheries obviously affect abundance of these species. However, possible changes in abundance might also have been induced by other anthropogenic factors (eutrophication, pollution, greenhouse effects), or by natural changes in the biotic or abiotic environment. Data on long-term changes in distribution and abundance present a basis for evaluating the interaction between fisheries, other human activities, and natural processes. For non-target species the source of time-series information is generally limited to research vessel surveys (e.g. Richards *et al.*, 1978; Knijn *et al.*, 1993; van Leeuwen *et al.*, 1994), but as yet the available data have not been fully utilized.

One of the longest North Sea time series for demersal species is provided by the ICES-coordinated International Bottom Trawl Survey (IBTS), which has been carried out annually in February since 1965. Of the most abundant non-target species caught (cf. Knijn *et al.*, 1993) 10 species have been selected for analysing changes in population parameters in relation to available information on trends in possible causal factors. The selected species consist of spurdog (*Squalus acanthias*), starry ray (*Raja radiata*), bib (*Trisopterus luscus*), poor cod (*Trisopterus minutus*) four-bearded rockling (*Rhinonemus cimbrius*), grey gurnard (*Eutrigla gurnardus*), bullrout (*Myoxocephalus scorpius*), long rough dab (*Hippoglossoides platessoides*), dab (*Limanda limanda*), and lemon sole (*Microstomus kitt*). Relatively little is known about the biology of many of these species, but a summary can be found in Knijn *et al.* (1993).

Changes over time might be expected in the size composition, the distribution, and abundance of individual species and therefore these aspects are considered. Because factors affecting abundance often operate at a regional scale (e.g. fisheries, eutrophication), variations in abundance are studied by area.

Material and methods

The IBTS started off as a young herring survey in 1965, when sampling was restricted to the southern and central North Sea. The survey area was gradually extended northwards and eastwards and from 1974 onwards included the entire North Sea, Skagerrak, and Kattegat. Over the years, the survey evolved to a highly standardized, internationally co-ordinated general trawl survey, in which nine countries have been participating. Full technical details are given in ICES (1992). Although commercially important fish species have been the principal target, length data of all by-catch species have routinely been collected by most participants. Stratification of hauls is based on the grid of ICES statistical rectangles. The ICES Roundfish Areas (Fig. 1) have been used here to investigate spatial differences in trends of abundance.

Data are stored in the ICES IBTS Database in Copenhagen, but to date only data collected since 1983 are completely computerized. For the period 1970–1982,

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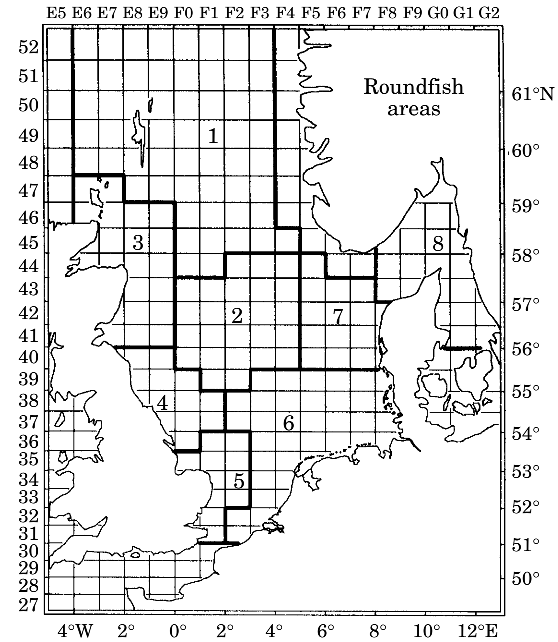

Figure 1. Subdivision of the North Sea in ICES "Roundfish Areas".

large gaps exist in the available data, because several countries have not yet submitted the computerized information. This causes problems when analysing trends in abundance, because some areas are inadequately covered by the reported catches during the early years. The number of rectangles for which data are available by area (Fig. 2) indicates that only areas 2 and 6 are well covered by data in most years.

Length-frequency distributions (LFD) were plotted by species to reveal indications of the constituting age classes. However, even the average LFDs (Fig. 3) for the period 1983–1993 are often variable or show merely one mode. Nevertheless, this information was used for splitting catches into juvenile and older components, which were treated separately in the analysis of distribution and abundance.

Both spurdog and starry ray exhibit unusual LFDs skewed to the left. Based on maturity data (Knijn *et al.*, 1993), the dividing line between immature and mature dogfish was set at 65 cm. For distinguishing between small and large starry ray, a line has been drawn arbitrarily at 20 cm. LFDs for bib and poor cod show peaks at 15–20 cm and at 11 cm, respectively. According to information from otolith samples taken in February

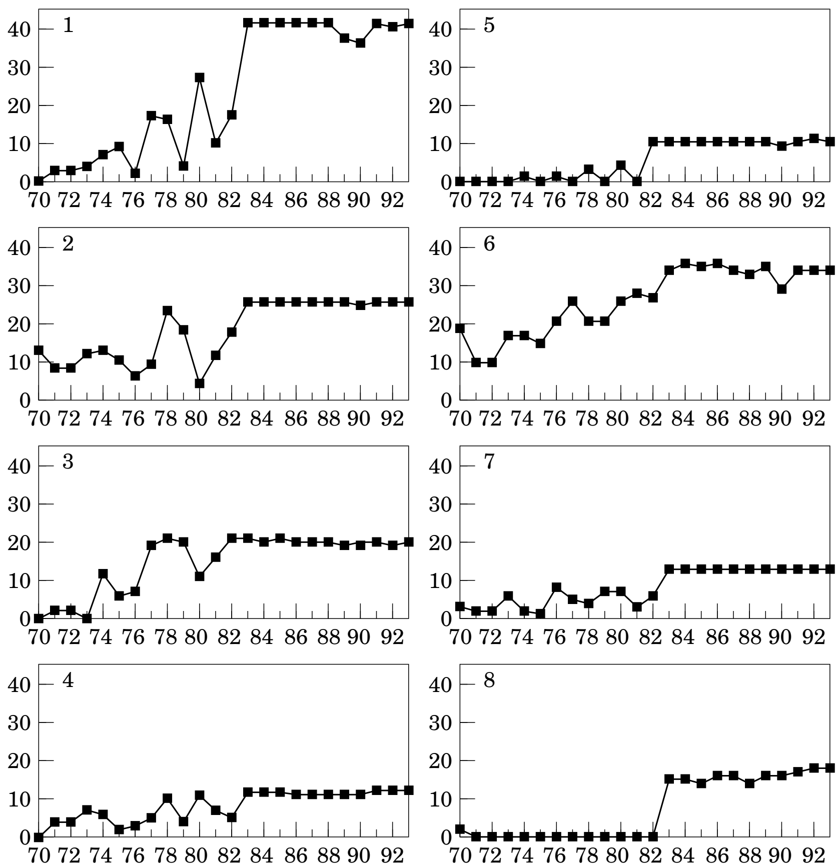

Figure 2. Number of rectangles for which data are available 1970–1993. 1–8 refer to areas shown in Fig. 1.

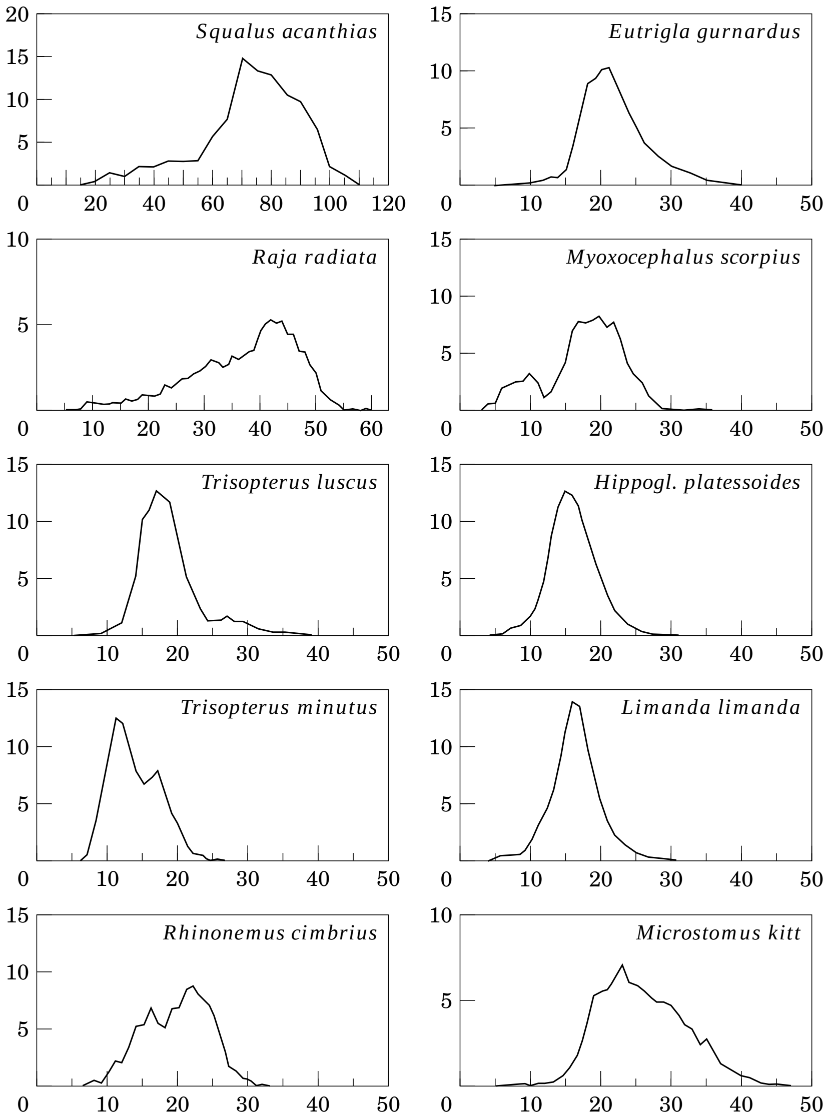

Figure 3. Average length-frequency distributions (in percentage) by species 1983–1993. Length in cm.

(Korf, 1971), bib <23 cm and poor cod <16 cm represent largely 1-year-old fish and size classes were defined accordingly. Four-bearded rockling and bullrout show rather irregular patterns, but the dips at 19 cm and 13 cm, respectively, have been used to separate juveniles from older fish. Grey gurnard, long rough dab, and dab are characterized by almost symmetrical, Gaussian distributions, which do not reveal information on the constituting age classes. According to Rijnsdorp *et al.* (1992), dab <9 cm represents 1-group. Limited otolith information for the other species indicated that grey gurnard <15 cm and long rough dab <10 cm were 1-group fish. The smaller size class represents only a very small part of the LFD, suggesting that catchability of recruits is very much lower than of older fish. For lemon sole the dividing line has been arbitrarily set at 19 cm.

Distribution maps are based on years from 1984 onwards. For each year and rectangle the average catch per 10 h fishing was calculated and these values were then averaged over 5-year periods (1984–1988; 1989–1993). Separate maps by 5-year period are only shown if they indicated marked differences, otherwise a 10-year average distribution is shown.

Average catch rates by size class were calculated by area and the total North Sea (cf. Fig. 1) for the period 1970–1993. For each species also an index of population size for each area has been calculated by multiplying the

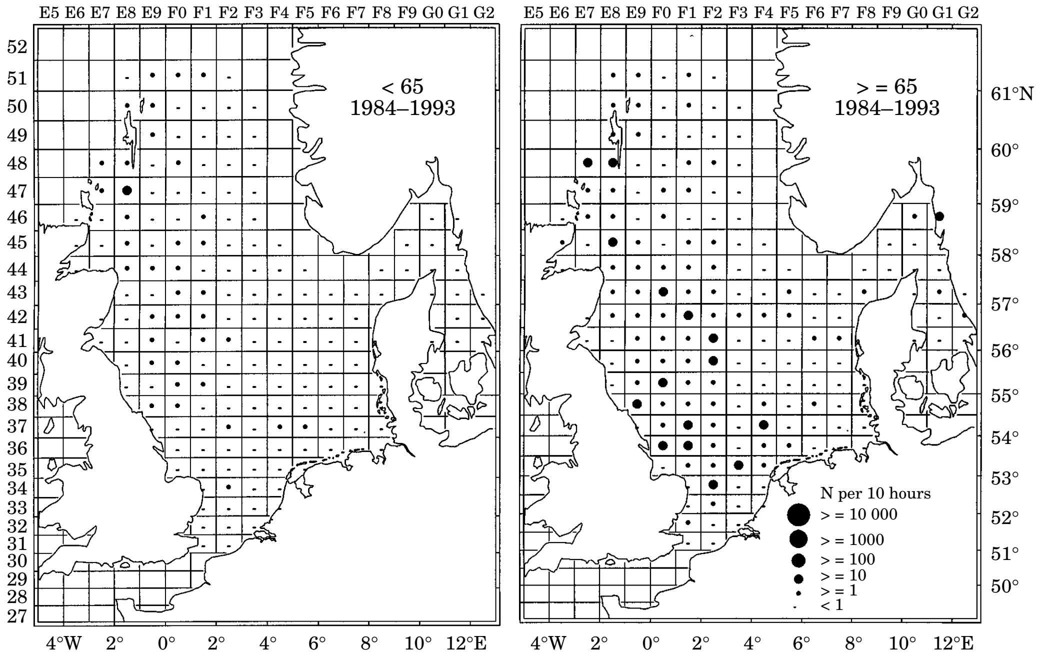

Figure 4. Spurdog. Average distribution (N 10 h^{-1} fishing) by size class 1984–1993.

average catch rate by the total number of rectangles (≈surface) within each area. The index for the North Sea was obtained by summing over areas 1–7 as shown in Fig. 14. Plots of trends of abundance by size class and area can be obtained on request from the authors.

To summarize trends in biomass of commercial species based on recent ICES working group reports, we distinguished four groups: gadoids (cod, haddock, whiting, and saithe), flatfish (plaice and sole), industrial species (sandeel, Norway pout), and herring. Mackerel and sprat are not included in an estimate of pelagic biomass because analytical assessments are lacking. Discharge of phosphate (PO_4-P) in kg s^{-1} by the river Rhine measured at the border between Germany and The Netherlands (data from RIZA, Lelystad) has been used as an index of eutrophication of the southern North Sea. Averaged bottom temperature measurements from 10 fixed locations during the IBTS (ICES, 1994a) serve as an index of climatic conditions during winter. Since integrated international measures of fishing effort are not available, we selected an index for the Dutch beam trawl fleet (number of fishing days corrected for Hp). These vessels intensively exploit the southern North Sea and are responsible for more than 50% of all flatfish landings in the North Sea.

The available time-series data (10 non-target species and 7 "environmental" variables) were subjected to linear regression analysis and the correlation coefficients were subjected to cluster analysis.

Results

Species summaries

1. Spurdog (Squalus acanthias)

North Sea spurdog probably represents a relatively small component of a much larger north-east Atlantic population (Vince, 1991). Dogfish are mainly landed as a by-catch in demersal fisheries, but directed fisheries with gillnets and long-lines do exist locally. There were no clear differences in distribution between two 5-year periods. Immature fish are found widely scattered over the western part of the North Sea, whereas mature fish occur scattered over the central and western and sometimes also in the south-eastern North Sea (Fig. 4). They are virtually absent from the Skagerrak/Kattegat.

Catch rates in different areas appear to fluctuate fairly independently. Population indices over the entire North Sea increased from 1970 to 1978. Only areas 1, 2, and 3 have contributed significantly to the total North Sea index and the apparent increase during this period may have been caused by an increase in survey coverage. Nevertheless, population indices have been very low everywhere since 1980 (Fig. 14).

2. Starry ray (Raja radiata)

Starry ray is the most abundant species of the group of rays and skates inhabiting the North Sea. It is a by-catch in demersal fisheries, usually discarded because of its

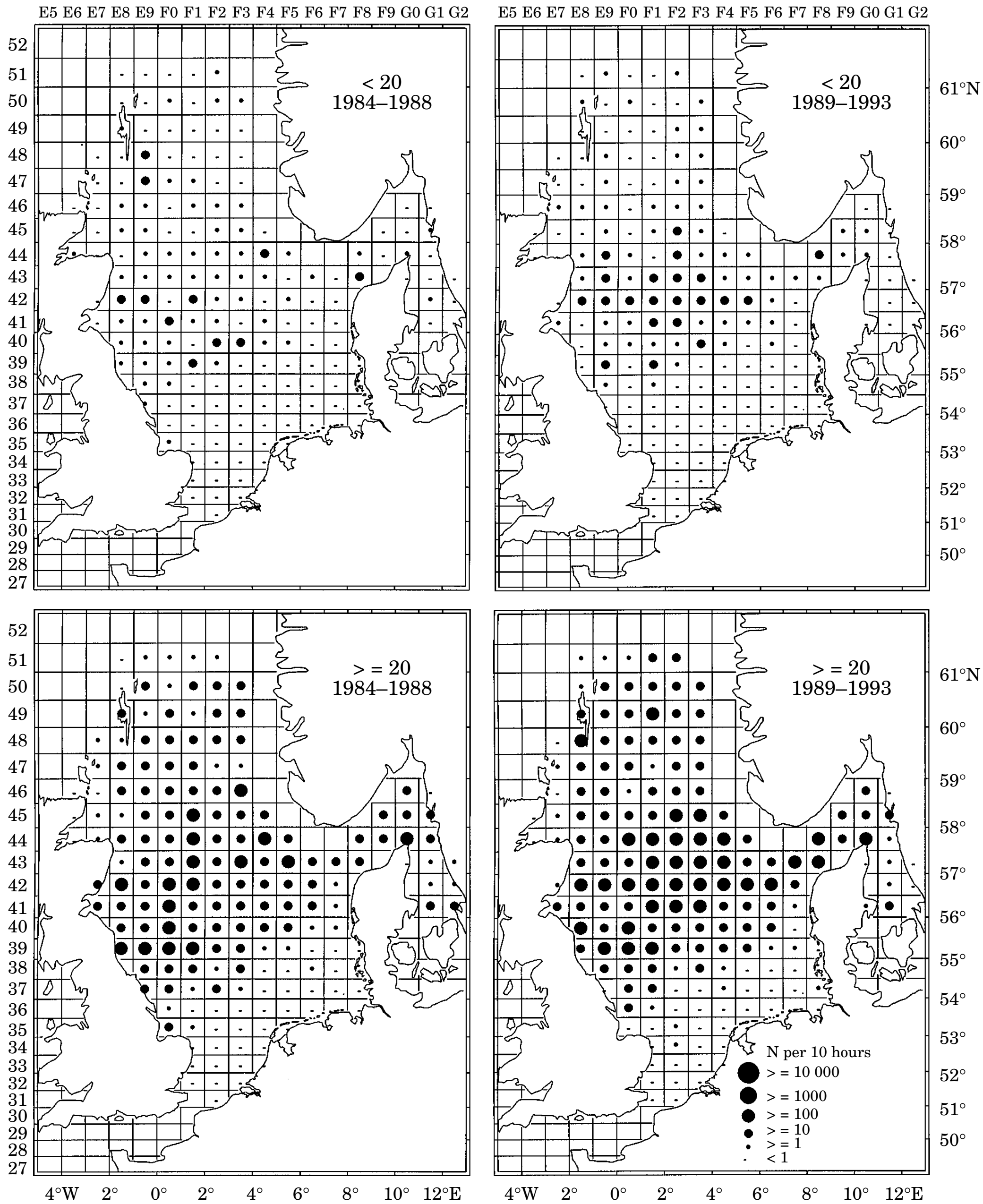

Figure 5. Starry ray. Average distribution (N 10 h^{-1} fishing) by size class 1984–1988 and 1989–1993.

small size. The distribution charts suggest that there is one population in the area surveyed (Fig. 5). Abundance is highest in the central North Sea, extends into the northern part and into the Skagerrak, and is largely absent from the Southern Bight and the German Bight. Both size classes are found scattered over the same area and they do not show marked differences. However, the centre of distribution appears to have shifted from the west during the earlier period to a more easterly position in the later period.

Since 1970, catch rates have gradually increased in both size groups as shown clearly by area 2, which has been well covered throughout the entire time period. Areas 1 and 2 contribute most to the total population index (Fig. 14). Other ray species do not show similar increases since 1970 (Walker and Heessen, 1996).

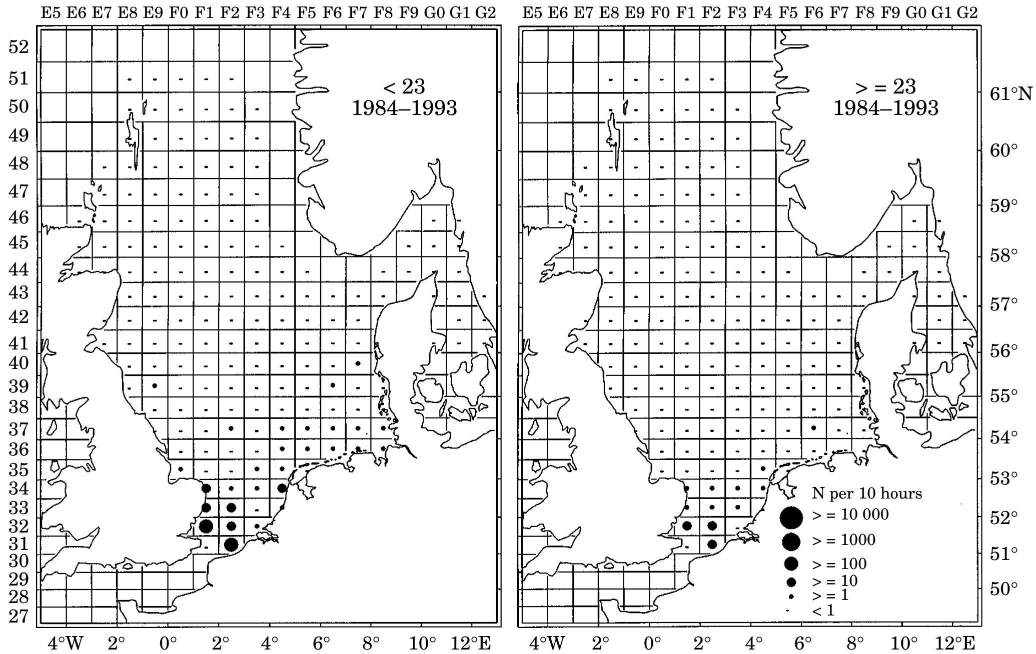

Figure 6. Bib. Average distribution (N 10 h^{-1} fishing) by size class 1984–1993.

3. Bib (Trisopterus luscus)

Bib is of marginal economic interest and is landed for human consumption in small quantities only. Distribution has not changed significantly and catches are virtually limited to the southern North Sea (Fig. 6). These fish probably represent part of a larger population that extends into the Channel, as shown by surveys that extend further south-west (ICES, 1994b). Juveniles are abundant near the entrance of the Channel. Low numbers are also caught in the German Bight, and along the English and Scottish east coast. Larger fish are even more restricted in their distribution.

Only areas 5 and 6 contribute significantly to the total North Sea population index (Fig. 14). Catch rates fluctuate strongly in both areas without obvious trend, except for area 4 which appears to have increased over recent years.

4. Poor cod (Trisopterus minutus)

Poor cod is too small for human consumption and abundance is too low for it to serve as a target species in industrial fisheries. It is mainly distributed over the western North Sea from the Southern Bight up to Shetland (Fig. 7), but the North Sea population may be linked to populations in the Channel and to the west of Scotland. Concentrations also occur in the Skagerrak and Kattegat, which are likely to represent a separate population. Both size groups were more abundant further north during the most recent 5-year period.

There has recently been a sudden increase in catch rates in the northerly areas, whereas abundance has remained fairly constant in southerly areas. Owing to poor coverage of areas with high abundance in years before 1983, trends for the earlier period are unreliable. Since then, a slight increase can be seen (Fig. 14).

5. Four-bearded rockling (Rhinonemus cimbrius)

Among the four species of rocklings found in the North Sea, the four-bearded rockling is the most common one. It is of no economic importance. Both size groups are found scattered over the south-eastern and north-western areas, and a major concentration occurs in the Skagerrak and Kattegat (Fig. 8). Intervening areas of very low abundance suggest that these concentrations represent different sub-populations. There are no clear differences between size categories or between periods.

Highest catch rates have been made in the Skagerrak/Kattegat area, whereas area 6 contributes most to the total North Sea population. Although population indices fluctuate widely and 1976 has been the highest year on record, on average the population appears to have gradually increased (Fig. 14).

6. Grey gurnard (Eutrigla gurnardus)

Of the four gurnard species found in the North Sea, grey gurnard is by far the most abundant. It is taken as a by-catch in demersal fisheries, part of which may be landed for human consumption. In recent years, grey

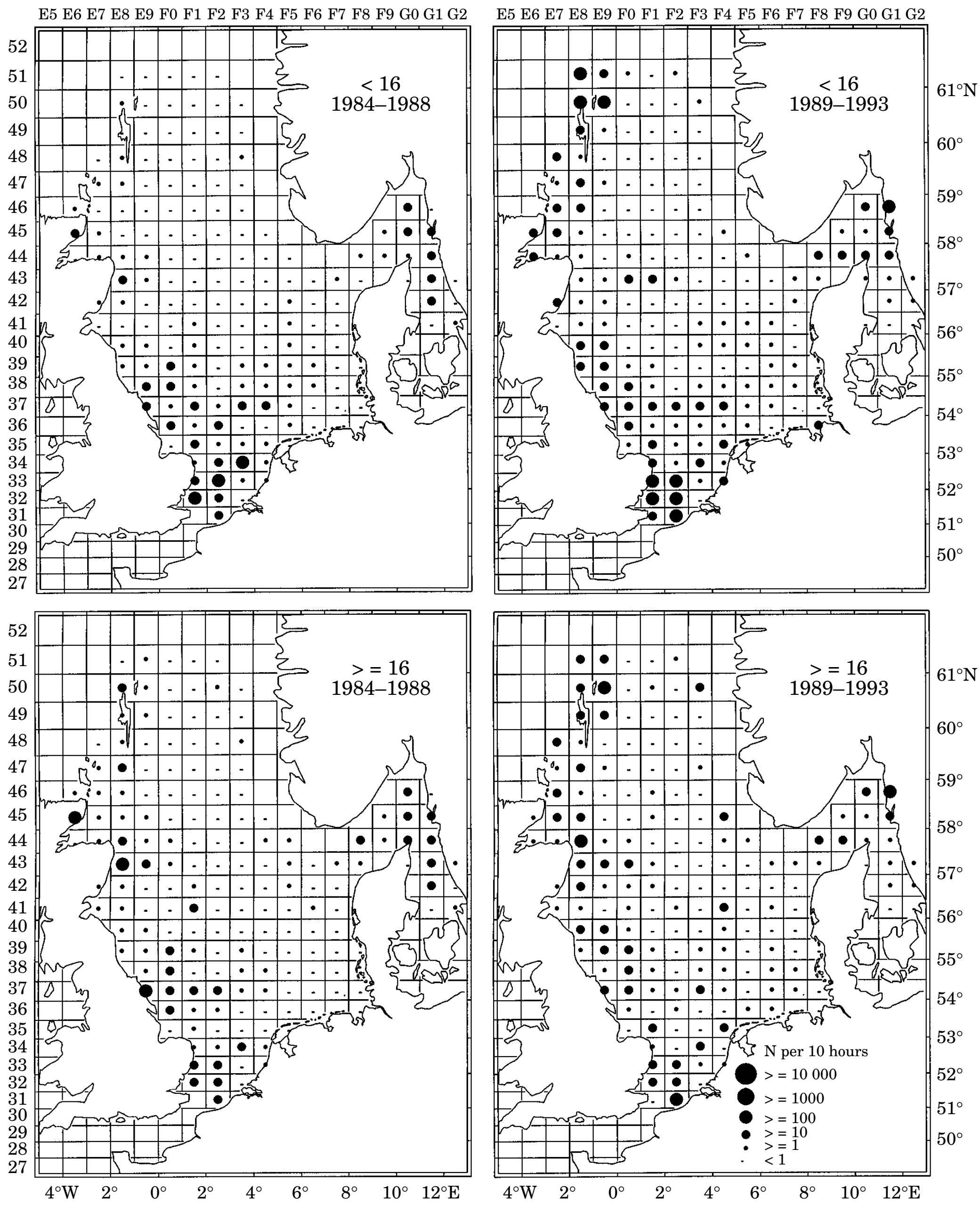

Figure 7. Poor cod. Average distribution (N 10 h^{-1} fishing) by size class 1984–1988 and 1989–1993.

gurnard has also been landed in significant quantities by industrial fleets. The survey catches present a problem because this species occasionally forms very dense shoals. Over the years, four extremely large catches have been reported from the same square (41F0) in the centre of the winter distribution area. These outliers have been omitted in the present analysis, because they represented more than 90% of the total catch in the years concerned and would have dominated the complete picture. However, this choice obviously has a large effect on estimated abundance.

The bulk of the total catch consists of the larger size category (Fig. 9), which has one major concentration north-west of the Dogger Bank and a secondary one around Shetland. Another more-or-less isolated concentration occurs in the Skagerrak/Kattegat, suggesting that the stock represents three sub-populations. Areas of higher concentrations have considerably extended in the

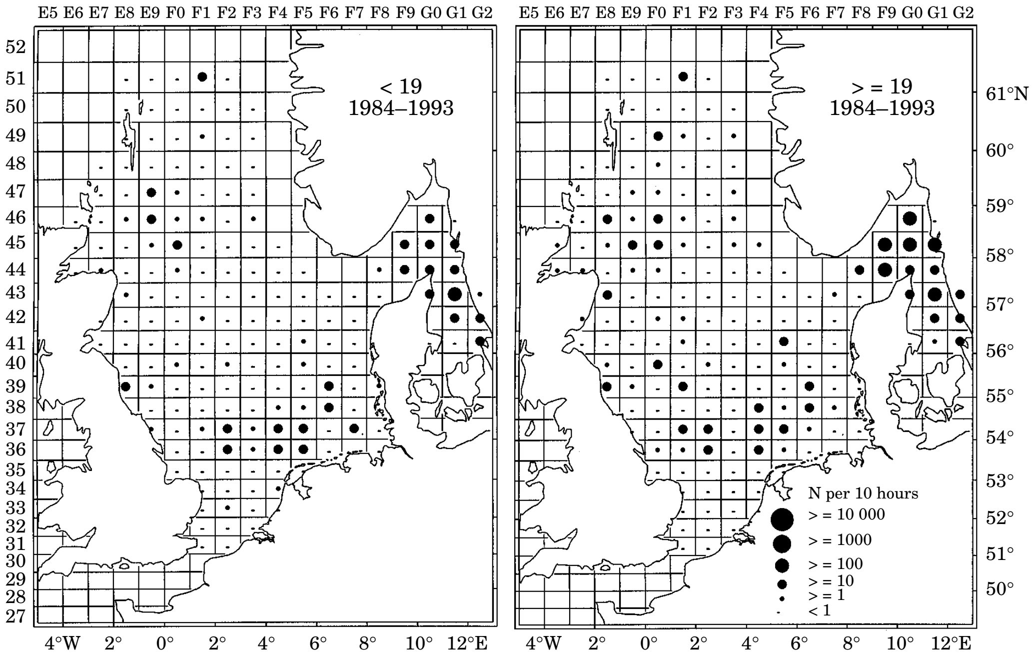

Figure 8. Four-bearded rockling. Average distribution (N 10 h^{-1} fishing) by size class 1984–1993.

recent 5-year period. Juveniles are almost absent from the northern areas and also from the Southern Bight, whereas they have a much more eastward distribution in the central part than larger fish. Also, abundance in the Skagerrak/Kattegat is relatively high. Juveniles have become more widespread and abundant in the central North Sea and Skagerrak/Kattegat area during the recent period, whereas the situation in the northern North Sea has hardly changed.

Area 2 represents the most important area. Over the 25-year period there have been considerable fluctuations, but abundance has been consistently high since 1989 (Fig. 14). Catch rates have also increased in the Skagerrak/Kattegat.

7. Bullrout (Myoxocephalus scorpius)
Bullrout is not landed for human consumption. Juveniles are predominantly found in coastal waters both along the continent and close to the Wash (Fig. 10). Larger fish are more widespread and extend further off the coast. Highest abundances are found near the Wash and off Schleswig-Holstein and lower ones scattered along the Dutch and Scottish coasts and in the Kattegat. The distribution suggests four sub-populations. Differences between the two periods are small, but particularly along the Dutch coast abundance appears to have decreased. Areas 6 and 5 contribute most to the total population index (Fig. 14). There is no obvious trend in catch rates in most areas except an increasing one in area 6, which also determines the total North Sea population index.

8. Long rough dab (Hippoglossoides platessoides)
Long rough dab is commercially unimportant in the eastern Atlantic, but a different subspecies known as "American plaice" and growing to a larger size is a valuable target species in the Western Atlantic. Juveniles are widely distributed over the northern and central area (Fig. 11), but they have been particularly abundant in the Skagerrak and Kattegat during recent years. Larger fish follow the same pattern, but extend more to the south. The charts suggest that the Skagerrak/Kattegat population is isolated from the North Sea population.

Catch rates show an increasing trend since around 1980 (Fig. 14), especially in areas 1–4, which contribute most to the total population index, and in the Skagerrak/Kattegat. However, catch rates in areas 6 and 7 have decreased in recent years.

9. Dab (Limanda limanda)
Dab is the most abundant species of the 10 investigated here. Large quantities are caught as a by-catch in demersal fisheries. However, a very large proportion of the catches is considered too small for human consumption and is discarded at sea (van Beek, 1990). Dab is widely distributed over the entire area without major changes over the last 10 years (Fig. 12), but the centres of concentration are to a large extent complementary to

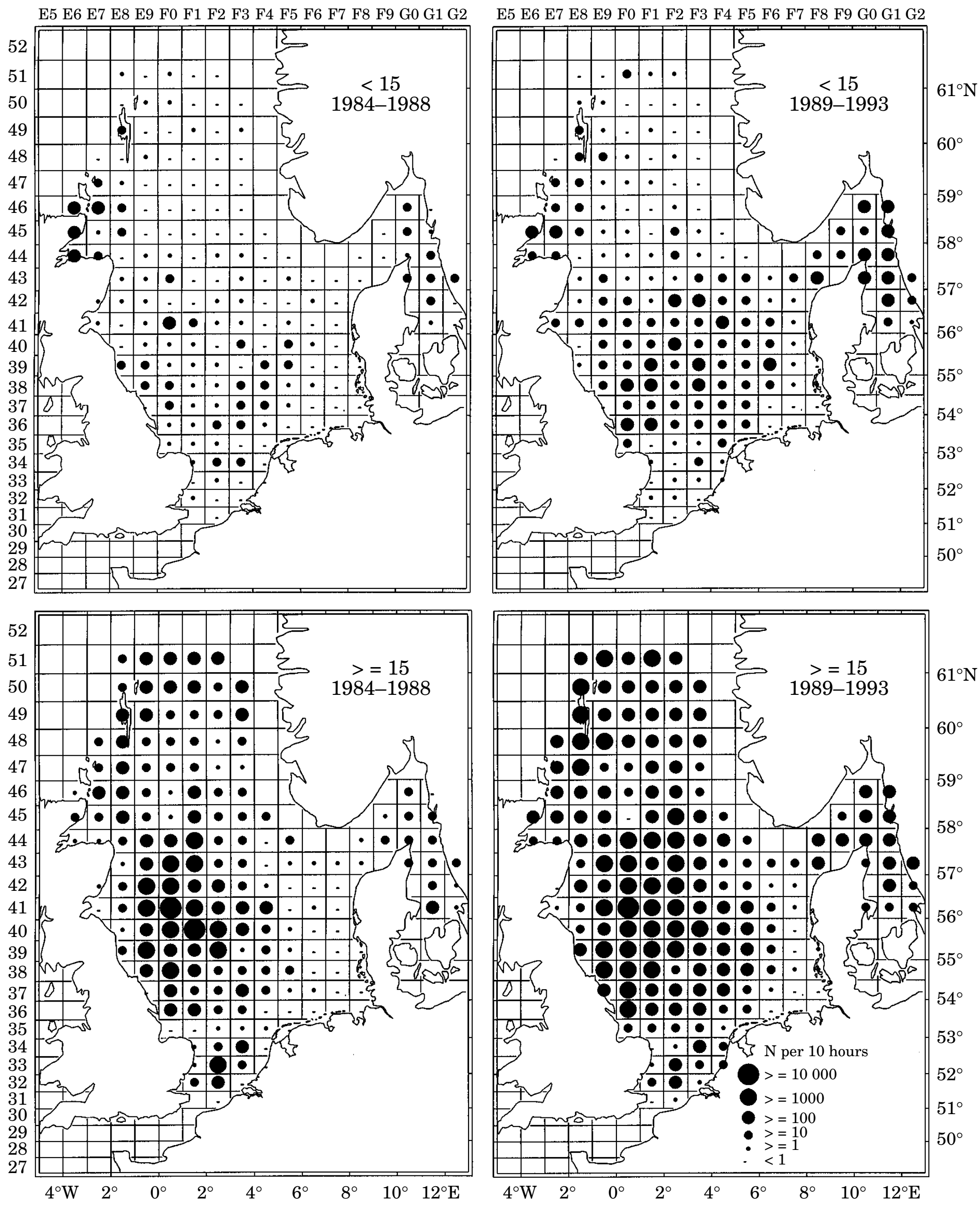

Figure 9. Grey gurnard. Average distribution (N 10 h^{-1} fishing) by size class 1984–1988 and 1989–1993.

those of long rough dab. Juveniles are mainly found along the continental coast with a north-westerly tongue stretching into the central North Sea. Larger dab have a much wider distribution in the southern, central, and north-western North Sea. They are also abundant in the Kattegat and less so in the Skagerrak.

Catch rates vary substantially between areas and years, and 1972 and 1982 have been particularly poor years. Population indices have been increasing since the early 1980s, especially in the central areas (Fig. 14).

10. Lemon sole (Microstomus kitt)

Lemon sole is the most valuable non-target species in this study, usually caught as a by-catch in demersal fisheries. Juveniles are mainly caught along the UK east coast, particularly in the north-western area (Fig.

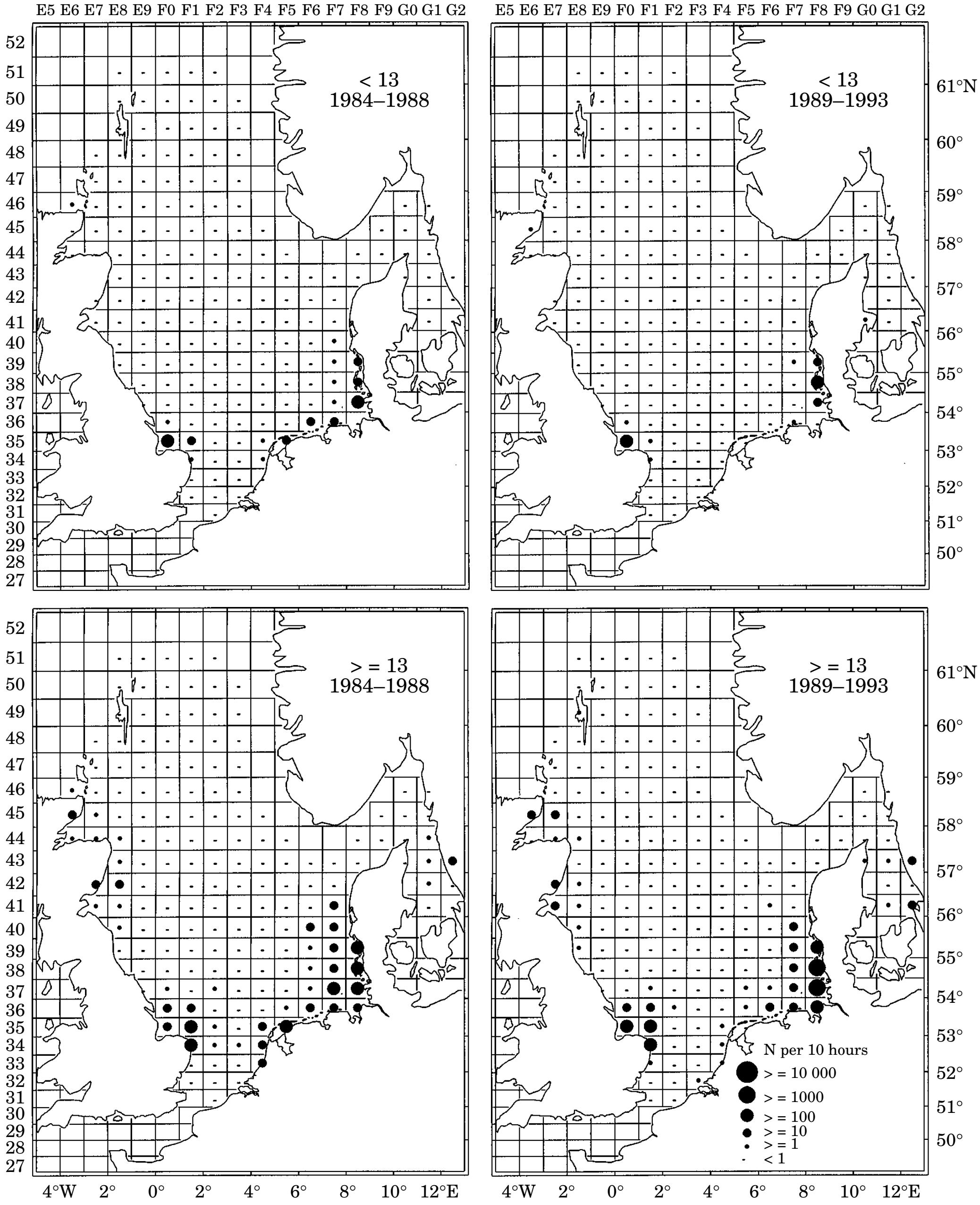

Figure 10. Bullrout. Average distribution (N 10 h^{-1} fishing) by size class 1984–1988 and 1989–1993.

13), but small numbers are scattered throughout most of the North Sea. Larger lemon sole are much more widespread, but also reach highest abundance in western parts. The distribution extends into the eastern part off Jutland and into the Skagerrak/Kattegat. There were no marked differences between the 5-year periods.

The total North Sea population index (Fig. 14) has been fairly stable from 1974 until the early 1980s and then increased to a higher but again stable level since 1983. Since the most important area 3 was poorly covered in the early years, the total North Sea picture for years before 1974 is probably distorted.

Statistical analyses

Figure 14 summarizes the observed trends in abundance of the 10 species and in the "environmental" factors

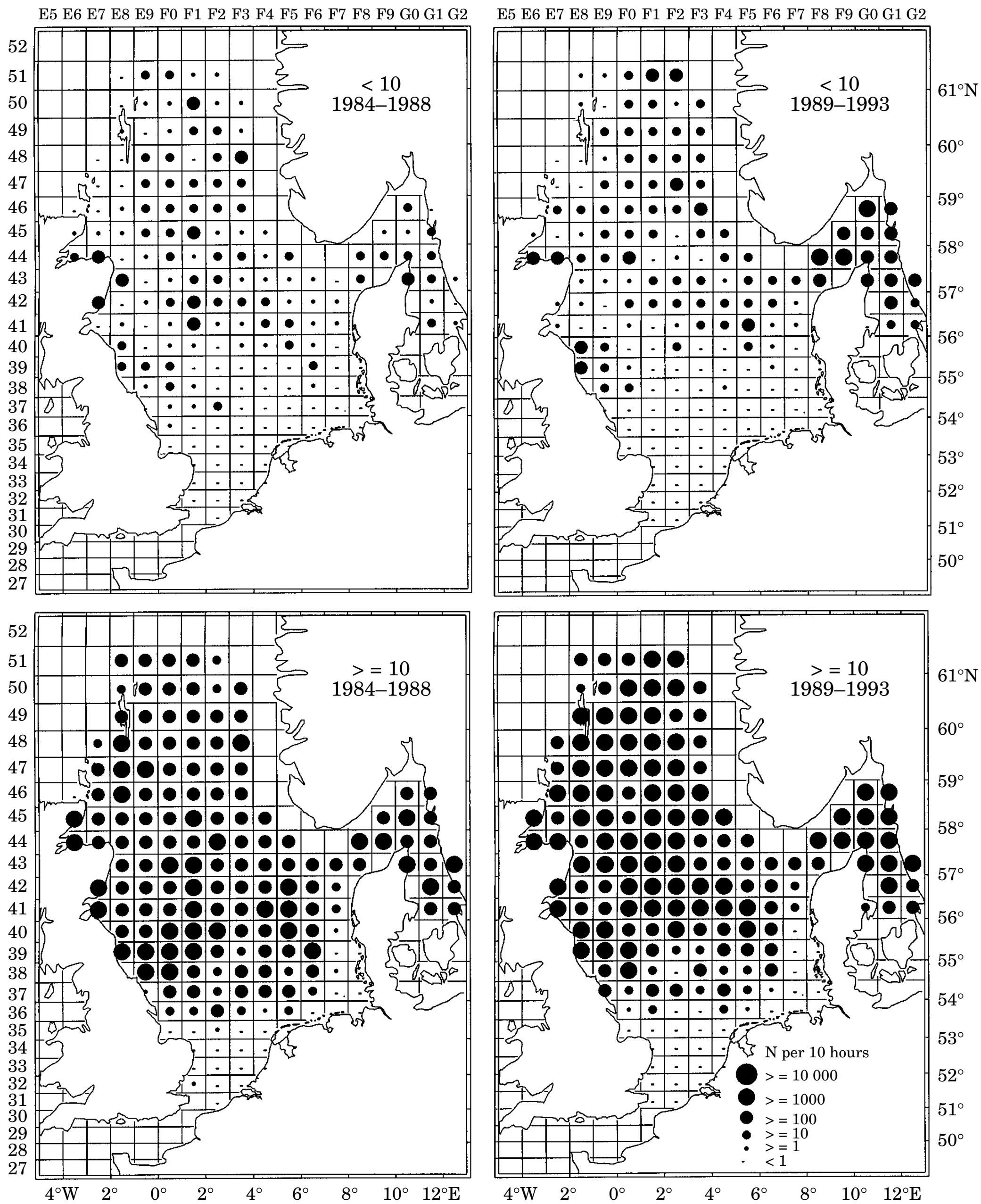

Figure 11. Long rough dab. Average distribution (N h^{-1} fishing) by size class 1984–1988 and 1989–1993.

considered. Spurdog peaked in the late 1970s, but ever since has remained at a low level. Bib has fluctuated without a clear trend. All other species appear to have increased over the time period, although patterns differ in detail.

The gadoid biomass, which strongly increased from the early 1960s to a peak in 1970 ("gadoid outburst", Cushing, 1980), has gradually been declining since 1970, as has the industrial species biomass. Biomass of North Sea herring declined sharply from 1970 onwards to extremely low levels in the late 1970s, when the fishery was closed. Subsequently, the stock recovered and since 1985 herring biomass has been relatively stable. Flatfish biomass does not reveal a clear temporal signal.

Phosphate discharge indicates a marked increase until 1980, followed by a sharp decline. The index of winter temperature shows no long-term trend but relatively

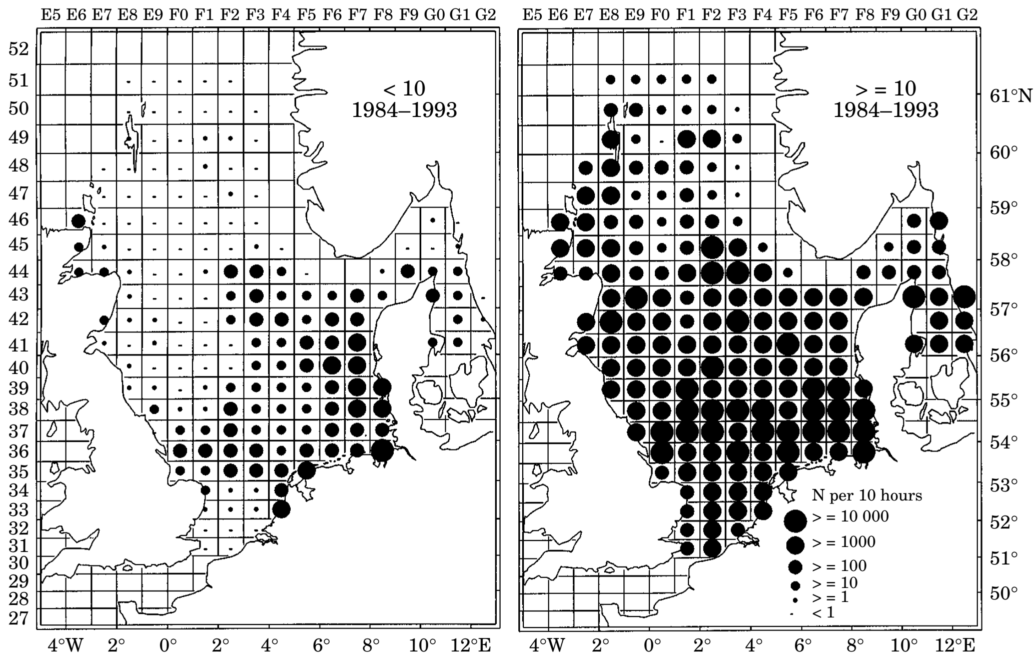

Figure 12. Dab. Average distribution (N h^{-1} fishing) by size class 1984–1993.

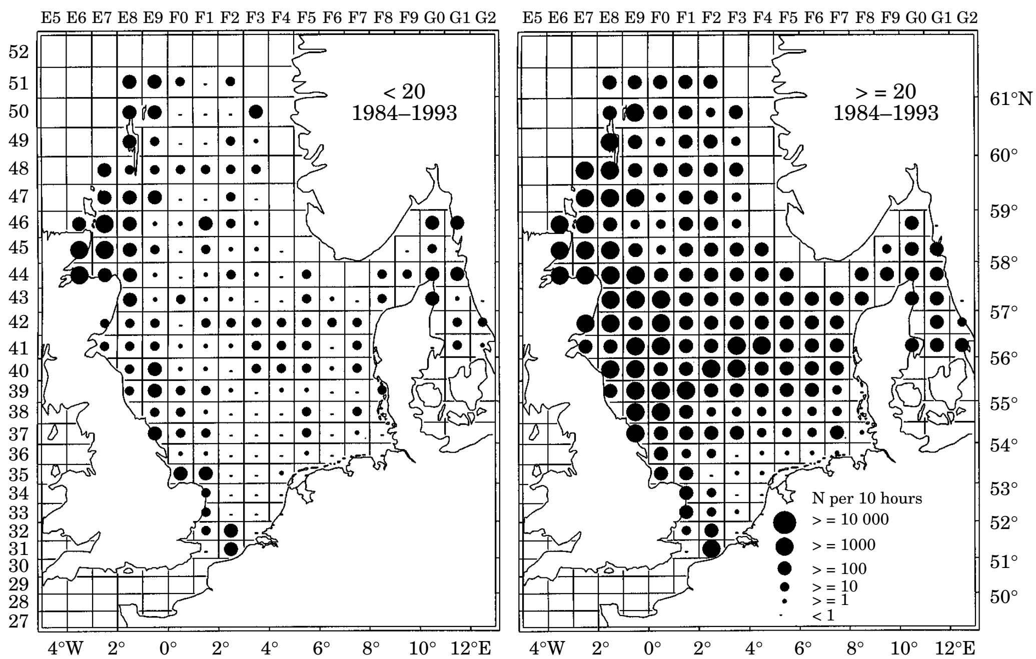

Figure 13. Lemon sole. Average distribution (N h^{-1} fishing) by size class 1984–1993.

warm periods occurred in the beginning and at the end of the time series. The development of beam trawl effort shows a cyclic pattern superimposed on a marked increase over the entire period.

Significant positive and negative correlations between the 17 time series are indicated in Table 1. The order in which the variables are given is based on a cluster analysis on the correlation coefficients (Fig. 15). Three

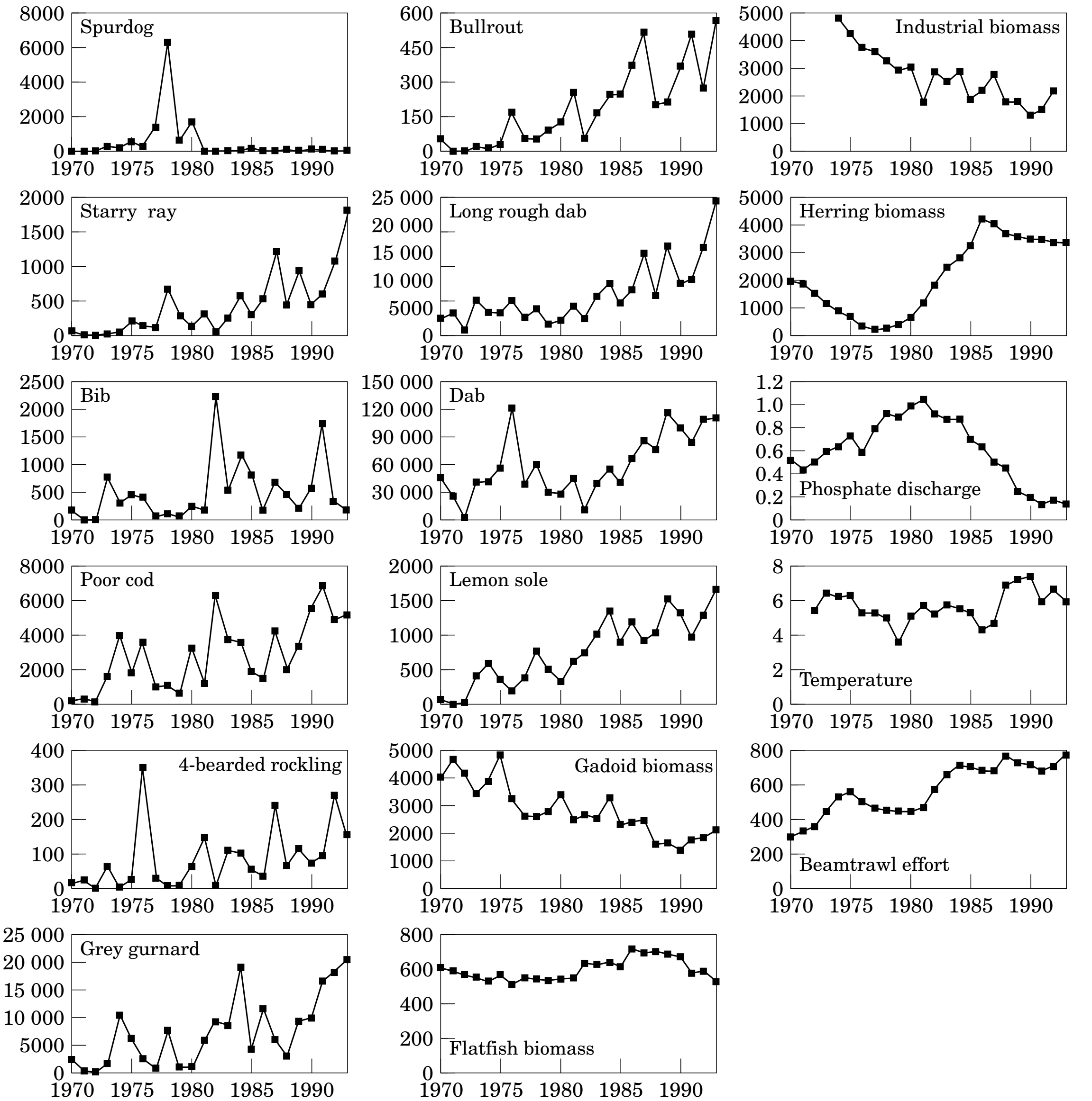

Figure 14. Trends in abundance of 10 non-target species and 7 "environmental" time series.

main clusters can be distinguished: Cluster A comprises seven non-target species plus beam trawl effort, which are all (28 ×) significantly positively correlated. Cluster B consists of two non-target species, herring, and flatfish biomass, as well as temperature. The coherence of this group in terms of significant positive correlations is much less (5 out of 10) than in cluster A. Significant correlations between elements of B and A are always positive. Cluster C consists of spurdog, phosphate, and biomass of industrial species and gadoids, five out of six correlations being significant. Significant correlations between elements of this cluster and A (14 out of 32) and B (13 out of 20) are always negative.

Discussion

Interpretation of the data presented is strongly hampered by incomplete data for the years prior to 1983. This is unfortunate, because more data are available in different laboratories in paper format. Although results for earlier years (1970–1982) must therefore be interpreted with care, results for those species having their main area of distribution in areas 2 and 6 (starry ray, grey gurnard, bullrout, long rough dab, dab) may be considered fairly reliable.

There are other limitations in survey data (Knijn *et al.*, 1993). Small individuals may be poorly sampled if

Table 1. Correlation coefficient matrix. Bold figures indicate significant correlations. Species are indicated with the first letter of the Latin name of the genus and the first two letters of the species name. Names of environmental variables are self-explanatory.

	A.								B.					C.			
Cluster	Rra	Mki	Hpl	HP days	Lli	Tlu	Tmi	Egu	Temp	Bher	Bflat	Rci	Msc	Sac	PO4P	Bind	Bgad
Mki	**0.84**	X															
Hpl	**0.76**	**0.67**	X														
HP days	**0.76**	**0.86**	**0.77**	X													
Lli	**0.77**	**0.61**	**0.82**	**0.56**	X												
Tlu	**0.47**	**0.71**	**0.50**	**0.63**	**0.46**	X											
Tmi	**0.64**	**0.80**	**0.70**	**0.76**	**0.66**	**0.81**	X										
Egu	**0.72**	**0.79**	**0.78**	**0.74**	**0.66**	**0.71**	**0.78**	X									
Temp	0.08	0.22	**0.43**	0.38	0.32	0.32	0.32	0.34	X								
Bher	0.29	0.28	**0.58**	**0.56**	0.19	0.33	0.24	**0.45**	0.36	X							
Bflat	0.29	0.32	0.38	**0.49**	0.18	0.30	0.17	0.31	0.17	**0.73**	X						
Rci	**0.45**	0.27	**0.69**	**0.48**	**0.61**	0.31	0.44	0.26	0.33	**0.45**	0.20	X					
Msc	**0.76**	**0.48**	**0.62**	**0.57**	**0.49**	0.13	0.29	0.31	− 0.04	**0.56**	**0.42**	**0.71**	X				
Sac	0.15	0.23	− 0.24	− 0.03	0.06	0.03	0.11	− 0.14	− 0.32	**− 0.73**	**− 0.45**	− 0.29	− 0.36	X			
PO4P	− 0.33	− 0.17	**− 0.60**	**− 0.39**	**− 0.42**	− 0.07	− 0.25	− 0.33	**− 0.55**	**− 0.55**	− 0.17	**− 0.41**	**− 0.45**	**0.41**	X		
Bind	**− 0.54**	**− 0.65**	**− 0.52**	**− 0.58**	− 0.31	− 0.24	− 0.19	− 0.30	− 0.34	**− 0.68**	**− 0.56**	**− 0.43**	**− 0.76**	**0.55**	**0.57**	X	
Bgad	**− 0.70**	**− 0.72**	**− 0.63**	**− 0.74**	**− 0.52**	− 0.38	**− 0.53**	**− 0.50**	− 0.35	**− 0.45**	**− 0.49**	− 0.39	**− 0.66**	0.08	**0.52**	**0.87**	X

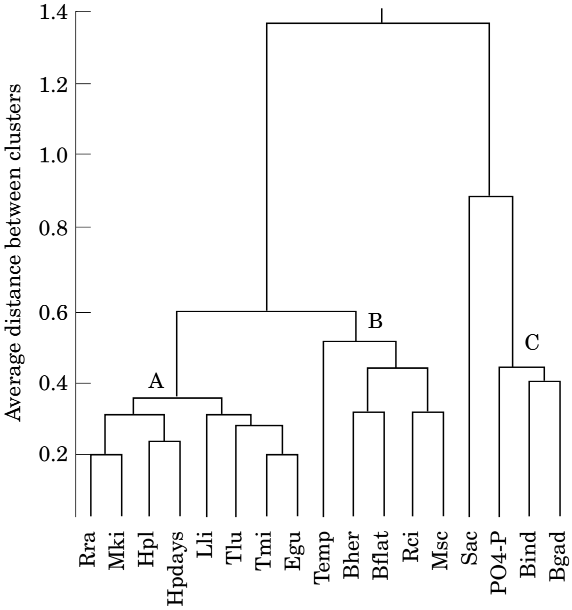

Figure 15. Results of cluster analysis. For abbreviated names, see legend of Table 1.

they can escape through the meshes of the trawl. However, in February the vast majority of the 1-group of the species selected exceed 7 cm, which is approximately the size at which they become fully recruited to the gear. Other problems may be caused by changes in behaviour. For instance, spurdog may sometimes exhibit a pelagic rather than a demersal lifestyle (Wheeler, 1978). Thus, bottom-trawl catches may not always be a good indicator of its relative distribution and abundance. Also, muddy and rough fishing grounds have been avoided in order to prevent gear damage and this may distort absolute abundance if particular species or size groups prefer these habitats. However, these factors will not necessarily distort year-to-year changes or general trends, unlike differences in spatial coverage and behaviour.

Geographical distribution areas of all species selected stretch beyond the boundaries of the North Sea, but little is known about unit stocks. Some species (e.g. spurdog, bib) migrate into the North Sea and the estimated abundance may not reflect actual population size of these species if migration rates vary between years. Other species are likely to represent true North Sea populations (e.g. dab, long rough dab, and lemon sole). Inferences about unit stocks may be made from distribution data, which suggest that different (sub-) populations do exist for some species (bullrout, four-bearded rockling) or that there are links with populations in areas surrounding the North Sea (poor cod).

Four out of the 10 species have been the subject of a study by Richards *et al.* (1978) based on Scottish research vessel data collected in the northern North Sea over the period 1922–1971. Grey gurnard decreased in Scottish coastal waters during the period 1922–1939, but no trend was found in the northern and central parts. The recent increase since the early 1980s therefore appears to be an isolated event. The other three species were long rough dab, dab, and lemon sole, which essentially exhibited the same pattern. They decreased or remained constant in certain parts of the northern North Sea before World War II, and increased thereafter. The recent data indicate that these species have increased further since the 1970s.

The majority of the species studied appears to have increased in abundance over the period. The original criterion for selecting species was based on their absolute abundance during recent years, according to Knijn *et al.* (1993). It is possible that, in applying this criterion, our selection has been biased to species with life history characteristics which allow them to thrive despite the increasing fishing pressure in the North Sea. Therefore, the emerging picture of mostly positive trends in the fish fauna may be a biased one.

Nevertheless, the increasing trend common to most species residing in cluster A may be indicative of a significant change in the North Sea ecosystem. Although the effort series resides in this cluster, a causal effect of beam trawling seems highly unlikely, at least for some species (starry ray, lemon sole, and long rough dab) whose centres of distribution lie outside Area 6, where beam trawl effort is concentrated. However, it is also possible that beam trawl effort is indicative of an overall increasing trend in demersal effort. One characteristic all species in this cluster appear to have in common is that they mature at a relatively small size compared to most commercial demersal species. Early maturation might put them in an advantageous position.

It is not directly obvious how the changes within cluster B could be causally linked. However, this group appears to be less coherent than cluster A. Temperature, for instance, is not correlated with any other variable in this group.

Changes in the North Sea fish fauna have in the past been attributed to eutrophication (Boddeke and Hagel, 1995). Effects of eutrophication reside in cluster C, but might be expected in the south-eastern North Sea (Area 6), which is particularly important for flatfish and much less so for gadoids and industrial species. Also, the only non-target species in this cluster is spurdog, which is rarely caught in the south-eastern North Sea. Typical species for this area are bib, poor cod, four-bearded rockling, bullrout, and dab, but these as well as flatfish biomass reside in another cluster. If eutrophication has an effect on these species, the correlation analysis indicates a negative rather than a positive one.

This analysis has been carried out as a first investigation of the coherence between different time series, rather than as hypothesis testing. The results certainly do not single out a particular factor as the causal explanation for any of the observed trends. It appears to be more likely that factors like beam trawl effort, phosphate load, and temperature result in spurious correlations rather than causal ones. At this stage, it is clearly impossible to provide a sound explanation of the observed changes. However, the analysis does reveal some of the complexity in dealing with changes in the fish fauna on a North Sea scale.

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