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1st annual report on groundfish assemblage species composition and diversity

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Work Package ***5***	Deliverable ***6***	MAFCONS Report 2004:001
Managing **F**isheries to **Cons**erve Groundfish and Benthic Invertebrate Species Diversity (**MAFCONS** Project: EC project number Q5RS-2002-00856)		

CONTENTS

1. Introduction

Species diversity is affected by fishing, but the relationship is unclear (Greenstreet & Hall 1996, Greenstreet et al 1999, Rogers et al 1999). The Rio Convention on Biological Diversity (CBD) requires that ecosystems be exploited in such a way that biological diversity is conserved. Indeed, article 8 of the CBD goes further than this in requiring that degraded systems should actually be restored. Similar sentiments are included in article 2 of Annex V (Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area) of the OSPAR (Protection of the Marine Environment of the North-East Atlantic) Convention. The Statement of Conclusions from the 1997 Intermediate Ministerial Meeting on the Integration of Fisheries and Environmental Issues in Bergen, and the subsequent Ministerial Declaration following the Bergen 2002 North Sea Ministerial Conference, makes it clear that fisheries managers will be required to balance fisheries and environmental objectives. These include the effects of fishing on the species diversity of fish and benthic invertebrate communities. To do this, the relationship between fishing and species diversity needs to be clearly defined to allow managers to predict the consequences of fisheries management policy on species diversity in much the same way as they currently predict the effects of particular levels of fishing mortality on future stock size.

In this first report we focus on the groundfish assemblage species composition and diversity. MAFCONS sampling took place on the Quarter 3 ICES International Bottom Trawl Survey (IBTS) so the full Q3 IBTS database is used to estimate the abundance and distribution of demersal fish species. Nine demersal fish species are considered; haddock *Melanogrammus aeglefinus*, whiting *Merlangius merlangus*, cod *Gadus morhua*, Norway pout *Trisopterus esmarki*, grey gurnard *Eutrigla gurnardus*, plaice *Pleuronectes platessa*, lemon sole *Microstomus kitt*, common dab *Limanda limanda* and long rough dab *Hippoglossoides platessoides*. These nine species account for over 90% of the biomass of demersal fish assemblage in the North Sea.

2. Methods

The EC funded project, MAFCONS (Managing Fisheries to Conserve Groundfish and Benthic Invertebrate Species Density) began in January 2003. The IBTS 3rd Quarter data will be used to assess changes in groundfish density during the duration of the project. The methods described will be used to analyse the groundfish data provided by the German, English, Norwegian, and Scottish partners. The Dutch do not take part in the IBTS 3rd Quarter bottom trawl survey and instead participate in the Beam Trawl Survey (BTS) using an 8m-beam trawl. The 8m-beam trawl dataset for 2003 can be analysed using the methods described and will be compared with the results obtained using the GOV.

Norwegian data

The Norwegian fishing data was not included in the 2003 analysis of the fishing data as all of the 14 tows were less than 25 minutes long. The 2003 Norwegian data has been analysed as described in the methods above but is presented separately in the results section.

Dutch data

The Dutch 8m-beam trawl data for 2003 has been analysed as described in the methods above but is presented separately in the results section.

ICES International Bottom Trawl Survey (IBTS) data for quarter 3 (Q3) for the period 1998 to 2003 were collated into two databases, Haul Summary Information and Species Abundance at length data. Only hauls of exactly 30 minutes duration were analysed to keep the effects of effort variation to a minimum.

To calculate fish density, estimates of the area sampled were required. Gear geometry data i.e. door-spread, wing-spread, headline height (Figure 2.1), were obtained using SCANMAR© recording units. Two measures of the area swept by the trawl gear were determined. Firstly the area swept by the whole gear i.e. between the otter boards, is given by:

Gear Swept Area (GSA) m^2 = Mean Door Spread (m) x Distance Towed (m)

Secondly the area swept by the net, i.e. between the wing ends of the trawl, is given by:

Net Swept Area (NSA) m^2 = Mean Wing Spread (m) x Distance Towed (m)

Data on door and wing-spread were not available for a substantial number of the hauls included in the analysis. Scottish SCANMAR© data for the years 1998, 2001, 2002 and 2003 were therefore analysed to determine the relationships between the two parameters and depth. The relationships in all four years were similar so the regression analysis was performed on the combined data (Figure 2.2). For samples where net geometry information was missing, mean door- and wing-spread could then be estimated from the depth information using the following equations:

Mean Door Spread = 33.251 x log Depth + 15.744

Mean Wing Spread = 6.8515 x log Depth + 5.8931

Where no depth data were available for a trawl sample, the average depth recorded on other occasions that the station was fished was applied. The distance towed for each haul is not a mandatory value in the ICES database. Where this information was missing the average distance towed for all trawls in that particular year was used.

Data in the ICES database are stored as the number of fish caught in each length class raised to one hour's fishing effort. In order to estimate densities in the original 30min tows all numbers at length were divided by 2. Fish density was calculated using the following formula:

Fish Density (nos. m^{-2}) = Total Number of Fish per ½ hour tow / Swept Area Measure (m^2)

In most years some statistical rectangles were fished more than once. In these cases the total number of fish caught in all samples in the rectangle was divided by the total area swept by all trawls in the rectangle combined to give the fish density estimate for that particular statistical rectangle.

To estimate biomass density, weight-at-length data are necessary. Since such data are not available in the ICES database, weight-at-length relationships maintained by FRS Marine Laboratory, Scotland, were used (e.g. Coull et al 1989). These relationships were used to convert numbers at length in the database to weight at length. Biomass density was then determined as:

Fish Biomass Density ($Kg.m^{-2}$) = Total Weight of Fish per ½ hour tow / Swept Area Measure (m^2)

In order to determine the IBTS derived biomass estimate of fish present in each entire statistical rectangle, these density estimates need to be multiplied by the "sea area" of the rectangle. As you move further north, the width of each statistical rectangle decreases due to the curvature of the earth. Taking this into account, the area of each rectangle was determined and then multiplied by the proportion that was sea to give the "sea area" in each ICES rectangle. The IBTS derived biomass estimate of each species present in each ICES statistical rectangle could then be estimated by multiplying species density by the sea area of each rectangle. Total species IBTS derived biomass estimates for each year were determined by summing the rectangle biomass estimates over all rectangles.

In each of the six years there were at least two statistical rectangles where no fishing took place. For these missing rectangles an IBTS derived biomass estimate value was interpolated based on the mean of the IBTS derived biomass estimates in the surrounding statistical rectangles.

Figure 2.3 shows the full extent of ICES area IV. The rectangles shaded light blue were included in the IBTS in at least one of the six years and were therefore included in the analysis. Areas shown in white were not included in the analysis so the total biomass stock estimates determined from the IBTS for the whole North Sea are for an area slightly smaller than the full ICES area IV. In order to compare these IBTS derived biomass estimates with biomass estimates derived for the full ICES area IV by the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) (ICES 2003), the IBTS derived biomass estimates were adjusted by a raising factor determined by the ratio:

Raising Factor = ICES Area IV area (m^2) / Area covered by the IBTS survey (m^2)

To take account of the fact that fish were not evenly distributed across the North Sea, raising factors were determined for the five separate sub-areas indicated in Figure 2.3 (Table 2.1).

Figure 2.4 shows the total number of hauls in each statistical rectangle within the study area in each year and Figure 2.5 shows the total number of times each statistical rectangle was fished over the six-year period 1998 to 2003. Figure 2.6 shows position of the stations that were fished as part of the MAFCONS project in 2003.

3. Results

The analyses presented here use density estimates derived using the area swept by the net. Densities of species that may have been herded into the path of the net to a significant extent by the action of the otter boards and sweeps may be over-estimated relative to species not susceptible to such herding effects. Data are presented for nine species: haddock, whiting, cod, Norway pout, grey gurnard, plaice, lemon sole, common dab, and long rough dab. These nine species account for between 91% and 98% of the individual fish sampled from the demersal component of the fish assemblage in each year by the IBTS (Table 3.1).

Distribution

Figures 3.1 to 3.9 illustrate variation in the biomass of each of the nine species in each year in each ICES rectangle covered by the IBTS. Haddock were mainly confined to the north-western North Sea in all six years (Figure 3.1). Whiting were more ubiquitous, but the largest biomasses tended to occur off the east coast of Britain and in the southern North Sea (Figure 3.2). Cod were also found over most of the North Sea, albeit in low numbers, but the largest biomass occurred in the north-eastern North Sea (Figure 3.3). Norway pout were mainly limited to the northern half of the North Sea in most years, although there was some indication of a southerly expansion of the distribution in 2000 (Figure 3.4). Figure 3.5 shows the distribution of Grey gurnard biomass over the whole North Sea. Grey gurnards were found over much the IBTS area, but were most abundant across the centre of the North Sea. Rectangle biomass estimates were low both north of 57.5°N and south of 53.5°N (Figure 3.5). Plaice were found over much of the area, but were relatively scarce in the north-eastern North Sea (Figure 3.6). The largest biomasses of lemon sole were located in the northern North Sea, just to the south of the Shetland Isles. Lemon sole biomass in the south-eastern North Sea was low (Figure 3.7). Common dab were mainly confined to the southern half of the IBTS area, with biomass highest in the south-east and central North Sea, particularly off the coasts of Denmark and Holland (Figure 3.8). Long rough dab were most abundant in the central North Sea. Whilst their distribution extended into the northern North Sea, almost no long rough dab were sampled south of 53.5°N (Figure 3.9). The actual rectangle biomass data for each species are given in figures 4.10 to 4.18.

Total North Sea IBTS and Stock Assessment Derived Biomass Estimates

Summing the individual rectangle IBTS derived biomass estimates across all ICES rectangles in the IBTS survey area (including interpolated values) provided IBTS derived estimates of the total biomass of each species in the area covered by the IBTS for each year. Table 3.2 gives the results of this summing procedure for each of the five sub-areas of the North Sea (see Figure 2.3) and also provides the raising factors for each sub-area to raise these totals to the whole of ICES area IV. Table 3.2 then gives the results following the application of these raising factors for each sub-area, and gives the area totals (IBTS area and ICES area IV) after summing across the five sub-areas. Annual variation in total IBTS derived biomass estimate for the whole of ICES area IV for each of the nine species is illustrated in Figure 3.19. The raised IBTS derived biomass estimate for haddock increased to a peak of 1,065,416t in 2000, then subsequently declined. Whiting biomass increased to a peak of 745,376t in 2001 and then decreased in the following two years. The biomass of cod decreased from 82,615t in 1998 to 42,660t in 2000, biomass rose slightly again in 2001 then decreased sharply to 23,187t in 2003. Norway pout biomass rose to a peak of 532,258t in 2000 and has decreased sharply since. Grey gurnard biomass has remained relatively constant over the six-year period, fluctuating around a biomass of approximately 80,000t. Plaice biomass increased to a peak of 30,571t in 1999, then decreased to a low of under 16,000t in 2000, and has then increased in each subsequent year. Lemon sole biomass has remained relatively constant at around 25,000t. Common dab biomass was relatively stable at 150,000t from 1998 to 2000, then increased rapidly to just under 240,000t in 2001, and its biomass has remained relatively stable since then. Long rough dab biomass has remained relatively constant over the six-year period at about 25,000t.

With some exceptions, the trends in the total North Sea biomass of each of the nine species indicated by the IBTS follow closely the ICES stock assessment estimates. The difference in the ICES area IV biomass estimates for cod, haddock, whiting, Norway pout and plaice in each year derived from the IBTS and the equivalent annual stock assessments made by the WGNSSK (Working Group on the North Sea and Skagerrak) are shown in Figure 3.20. The peak haddock biomass indicated by the stock assessment is picked up in the IBTS signal, but the amplitudes differ. This difference may be caused by over estimation of the large 1999 recruit cohort strength by the assessment process, and the difference may decline with future iterations of the VPA analysis in subsequent annual stock assessment exercises. Otherwise the haddock biomass estimates derived from the VPA are in close agreement with the IBTS derived estimates. The two whiting abundance trends follow similar trajectories, but the IBTS estimates are a factor of two to three times higher, suggesting a catchability in the GOV trawl of >1. For all other species, the IBTS derived biomass estimates are lower than the equivalent stock assessment estimates suggesting catchabilities of less than one in the IBTS. In the case of plaice, the assessment biomass estimates exceed the IBTS derived estimates by at least one order of magnitude. This is a clear indication of how badly the GOV trawl samples flatfish. Norway pout stock assessment estimates are approximately 6 times higher than the equivalent IBTS biomass estimates.

Fish Assemblages

In each year, the total number of individual fish of each species present in each statistical rectangle was estimated. Cluster analysis was performed on these data to group together rectangles with similar species composition, and distinguish between groups of rectangles with different species relative abundance composition. An example of the dendrogram produced by this analysis is provided in Figure 3.21, in this case for the year 1998. Similar dendrograms where obtained in all other years. For each year the main clusters, potentially different “fish communities”, were defined at a Bray-Curtis similarity of about 35%. This level of similarity left a single large single “fish community” cluster located geographically across most of the central and northern North Sea (Figure 3.22). This cluster broke down into two consistent sub-clusters at a similarity of around 40% (Figures 3.21 and 3.22). The spatial clustering of the species abundance data was reasonably consistent from year to year, suggesting the presence of distinct fish communities. These communities tended to exist as bands straddling the North Sea more or less with a south-west to north-east orientation. The locations of the boundaries between communities were reasonably stable in time. The data from all years were combined to produce a composite indication of the spatial extent of each “fish community” cluster across all six years (Figure 3.23). The same analysis was repeated but with the species considered to be pelagic, and thus not consistently sampled by the GOV trawl, excluded from the analysis. The pattern of clustering based on just the demersal species (Figure 3.24) was similar to that observed when all fish were included (Figure 3.22). Combining the data for all years for the demersal species only (Figure 3.25) again produced very similar clustering to the clustering observed when all fish were included (Figure 3.23).

In each year the average weight of all individual fish in the demersal fish community occupying each rectangle was estimated (Figure 3.26), this being one of the metrics considered to indicate best the impact of fishing on fish communities (ICES 2001), and accepted as an element of Ecological Quality for Fish Communities at the Bergen Ministerial North Sea Conference in 2002. Demersal fish communities consisting of the largest fish were found around the 200m depth contour towards the north of the IBTS region and the along the western edge of the Norwegian deeps. Mean individual weight in the demersal fish community also appeared to be higher in a region extending out in to the central North Sea from the east-coast of the UK. For each of the four fish community clusters identified in Figure 3.25, trends in the mean weight of demersal fish over the six-year period for which data were analysed are shown in Figure 3.27. Both positive and negative slopes were detected but none were statistically significant. This is not surprising given the small sample size. These data could provide baseline information from which to monitor the effects of remedial action taken to mitigate long term declines in this community indicator.

<u>Diversity Measures</u>

Figures 4.28 to 4.31 show spatial variation in four different measures of diversity, Species richness (S), Shannon-Wiener (*H'*), Simpson index (λ) and Hills N_2. These diversity indices were calculated on the combined species abundance for all hauls made in each statistical rectangle over the six years 1998 to 2003 for statistical rectangles that were fished more than five times within the time period. Species richness ranged from 14 to 41 species (Figure 3.28) and was highest in the north and in the south, with the lowest number of species being found in the central North Sea. The highest number of species (41) was found in 32F1 and the lowest number of species (14) was found in 42F2. The Shannon-Wiener index (Figure 3.29) ranged from 0.30 to 1.93. The largest value of 1.93 was found in 41E8 and the smallest value was in 33F3. Simpson's index (Figure 3.30) is an index of dominance, in the sense that the largest values correspond to assemblages whose total abundance is dominated

by one, or a very few, of the species present. The largest value of 0.88 was in 33F3 where the fish assemblage was dominated by Horse mackerel (*Trachurus trachurus*). Hill's (1973) N_2 index is the reciprocal of Simpson's index. This transformation converts the index into a more traditional diversity index, with increasing numerical value indicating greater community species diversity. This index effectively indicates the number of species that in effect dominate the community. The more species that effectively dominate the community, the more diverse the community is. Values of Hill's N_2 ranged from 1.12 – 5.69 with the largest value, the most diverse community, in 43F5 and the smallest value, the least diverse community, in 33F3 (corresponding to the largest value of the Simpson index). Generally, diversity tended to be higher in the western North Sea, and in a band stretching across the central North Sea to the Danish coast.

Norwegian data

The Norwegian data for 2003 is presented separately as all of the tows were less than 25 minutes long and were therefore not included in the analysis of the whole IBTS dataset. The purpose of analysing the Norwegian data alone was to compare the biomass estimates made using tows of less than 25 minutes with those calculated using tows of exactly 30 minutes duration. Figure 3.32 shows the location of the stations fished by the Norwegian partners in 2003. An estimate of the biomass of the nine major demersal species for each of the statistical rectangles sampled by the Norwegians was made using only the Norwegian data. These estimates were then compared with those made using the 2003 IBTS dataset for the same statistical rectangles and the results can be seen in Figure 3.33. Figure 3.33 shows that consistently the biomass estimates made using the whole IBTS dataset for 2003 were higher than those using just the Norwegian data, except possibly for the plaice and lemon sole. Figure 3.34 shows the cumulative species curves for both the Norwegian data and the IBTS data for the same statistical rectangles. The figure shows that the IBTS data contains more species than the Norwegian data in the same statistical rectangles. This is not entirely unexpected as the IBTS data contains the trawl data from all participating countries in 2003 (except the Norwegian data), so each statistical rectangle may have been fished multiple times. This was not the case for the Norwegian data, each statistical rectangle was only fished once (but only for 20 minutes whereas all the IBTS stations included in the analysis were fished for 30 minutes).

Dutch 8m-beam trawl data

Figure 3.35 shows the location of the Dutch 8m-beam trawling during the 3rd Quarter Beam trawl survey (BTS) in 2003. The analysis of the IBTS dataset has focused on nine main demersal species (haddock, whiting, cod, Norway pout, grey gurnard, plaice, lemon sole, common dab and long rough dab) which in all years since 1998 have made up over 92% of the demersal fish assemblage. The percentage contribution of these same nine species to the total demersal fish assemblage estimated using the 2003 Dutch 8m-beam trawl survey is only 72% in comparison. Figure 3.36 shows that when four more species (Starry ray, *Raja radiata*, Lesser weever, *Echiichthys vipera*, Scaldfish, *Arnoglossus laterna* and Dover sole, *Solea solea*) are added to the 8m-beam trawl data, the percentage contribution of these 13 fish increases by 18% to 90%. If these same four extra species are added to the GOV data, then the percentage contribution increases by only 1.97% to 94.5%.

Biomass estimates of the main demersal species were derived for each statistical rectangle fished by the Dutch in 2003 using the methods described above. These biomass estimates were then compared with those calculated using the IBTS, 2003 dataset. In order to be able to see the difference in biomass calculated using the two different survey methods, the biomass estimates made using the 8m-beam trawl were subtracted from those made using the IBTS, 2003 dataset. The differences in biomass for each species can be seen in Figures 3.37 to 3.45. In these figures, if the symbol is red then the 8m-beam trawl estimates were higher than those made using the GOV, if the symbol is black then the biomass estimate made using the GOV was greater than the biomass calculated using the 8m-beam trawl. The results show that as expected, biomass estimates made using the GOV were consistently higher than those made using the 8m-beam trawl for haddock (Figure 3.37), whiting (Figure 3.38), Norway pout (Figure 3.40) and grey gurnard (Figure 3.41). The biomass estimates made using the 8m-beam trawl were consistently higher for plaice (Figure 3.42) and lemon sole (Figure 3.43). There was no consistent pattern for the biomass estimates of cod (Figure 3.39), common dab (Figure 3.44) and long rough dab (Figure 3.45).

The total number of each fish species caught using each survey method in every statistical rectangle where both gears had been used was calculated and the results for a selection of species are shown in Figure 3.46. The fish have been divided in to two types, 'roundfish' and 'flatfish'. Figure 3.46 shows that the GOV caught more roundfish than the beam trawl and the 8m-beam trawl caught more flatfish than the GOV.

The cumulative species curves for the 8m-beam trawl and GOV over the same statistical rectangles are shown in Figure 3.47. The Figure shows that the GOV caught more species in each statistical rectangle than the 8m-beam trawl. It must be remembered that in the GOV dataset there were multiple hauls in each statistical rectangle, whereas in the 8m-beam trawl dataset there was only one haul per statistical rectangle. Also the swept area of the GOV is much higher than that of the beam trawl.

Figures 4.48 to 4.51 show spatial variation in four different measures of diversity, Species richness (S), Shannon-Wiener (*H'*), Simpson index (λ) and Hills N_2. These diversity indices were calculated on the combined species abundance for all hauls carried out in each statistical rectangle sampled during the Dutch beam trawl survey in 2003 and the results for both the GOV and 8m-beam trawl are shown for each year. Species richness calculated using the 8m-beam trawl data (Figure 3.48) was highest in the south and around the Scottish coast. Species richness ranged from 6 to 24 species with the highest number of species being found in statistical rectangles 42E8 and 34F2 and the lowest in 42F4. Species richness calculated using the IBTS data was highest in the north and lowest in the east. Species richness ranged from 2 to 28 with the highest number of species in 49E9 and the lowest in 35F0. The Shannon-Weiner index (Figure 3.49) ranged from 0.58-2.56 when calculated using the 8m-beam trawl data. The highest value was 2.56 in 50E9 and the lowest value of 0.58 in 41F4. The Shannon-Weiner index ranged from 0.27-1.89 when using the GOV data with the highest value in 42E8 and the lowest in 42F0. The Simpson index (Figure 3.50) is an index of dominance, in the sense that the largest values correspond to assemblages whose total abundance is dominated by one, or very few of the species present. Using the 8m-beam trawl data set, the largest value of 0.73 was in statistical rectangle 41F4 where the fish assemblage was dominated by the starry ray (*Raja radiata*), the smallest value of 0.11 was in statistical rectangle 50E9. Using the GOV data the largest value of 0.90 was in statistical rectangle 42F0 where the fish assemblage was dominated by herring (*Clupea harengus*) and the smallest in 39F0. Using the 8m-beam trawl dataset, Hill's N_2 (Figure 3.51) ranged from 1.36 to 8.43 with the largest value, the most diverse community in 50E9 and the smallest value, the least diverse community, in 41F4 (corresponding to the largest value of the Simpson index). Using the GOV data Hill's N_2 ranged from 1.11 to 4.85 with the most diverse community in 39F0 and the least diverse community in 42F0.

4. Discussion

The purpose of this report was to present the data collected by the MAFCONS partners in 2003 and to investigate the types of analyses which can be considered when assessing ground fish species composition and diversity and the types of problems which arise when using this kind of data. The main bulk of the data presented here is that of the IBTS 3rd Quarter surveys from 1998 to 2003. The distribution maps of the nine demersal species show very distinct patterns. Analysis here has shown that by using alternative data sources, such as the Dutch 8m-beam trawl survey data, collected in the same area at the same time, quite different results can be obtained.

The comparison between the abundance and biomass of species such as haddock and plaice in the GOV and 8m-beam trawl shows very clearly the difference in catchability of these two species in different gears. Recent work comparing the catchability of plaice, compared with other roundfish species in GOV trawls and beam trawls would appear to confirm the relatively low catchability of plaice in the GOV (ICES 2004a, 2004b). Obviously the issues regarding the catchability of different species in different gears need to be taken in to consideration when looking at measures of species diversity. The comparison between diversity measures such as species richness and Simpson's index calculated using the Dutch 8m-beam trawl data and the 2003 GOV show that the results can very different for the two different gears.

The stock biomass estimates produced by ICES stock assessment working groups are based on virtual population analysis of commercial landings data. The biomass estimates derived here using the IBTS 3rd Quarter survey are, with the exception of whiting, lower than those produced by the ICES WGNSSK. Fundamentally, this deviation can mainly be explained by the fact that trawl gear catchability is generally less than 1.0; trawls do not catch all the fish in the path of the net. Because of this, there will always be more fish in the sea than the catch densities of trawl surveys would suggest, but how much more? The differences each year between the IBTS derived total North Sea biomass estimates and the stock assessment biomass estimates for plaice were larger than for the four roundfish species, suggesting that this species had the lowest catchability in the GOV. Apparent catchabilities of the four roundfish species varied from approximately 0.25 for cod and Norway pout, 1.0 for haddock, to

1.76 for whiting. The apparent catchability in excess of 1.0 for whiting may be due to the herding effect of the otter boards on whiting in the path of the gear. In effect a much larger area is being sampled for whiting than is allowed for by the Net Swept Area. The distance between the otter boards is approximately 3.5 times greater than the distance between the trawl wing ends. If Gear Swept Area were to be used instead to estimate whiting densities, then the IBTS biomass estimates become approximately half the value of the assessment stock biomass estimates. The larger mesh size used in GOV research trawls compared with trawls used in the commercial industrial fishery for Norway pout could help to explain the apparent low catchability of this species in the GOV.

It is evident from the data presented here that is would be very useful to have the full 3rd Quarter 8m-beam trawl survey (BTS) dataset made available to the MAFCONS project. It is the intention to acquire the whole of the BTS dataset for the same time period as the IBTS data (1998 to 2003). The biomass estimates for plaice and Dover sole derived using the BTS data could then be compared with those produced by the WGNSSK. Also, if the whole BTS dataset were available then differences in the catchability of the two gears could be more accurately obtained.

In the past survey catches of assessed species have been compared with stock assessment data in effect to estimate apparent catchabilities in a similar way. The whole suite of species caught in the survey has been divided into groups of species considered to have similar catchabilities. The number of different groups was limited by the fact that each group had to include at least one assessed species for which there was a biomass estimate determined by VPA. Thus species such as grey gurnards and lesser spotted dogfish (*Scyliorhinus caniculus*) were grouped with cod, haddock and whiting, species such as poor cod (*Trisopterus minutus*) were grouped with Norway pout, and flatfish, skates and rays were grouped with plaice and sole. By comparing the catch rates of non-assessed and assessed species in each group, and relating these to the VPA estimate of the biomass of the assessed species, estimates of the biomass of the non-assessed species were determined. In this way estimates of the total biomass of the entire fish community were made (Yang 1982; Sparholt 1990; Daan et al 1990). A similar approach can be adopted here, and the distribution maps used to distribute the biomass of each species across the entire North Sea. Thus the total biomass of each species in each rectangle can be estimated.

The Norwegian fish data collected in 2003 has been analysed separately in this report. This data was kept separate as it was agreed in the MAFCONS methods manual that a valid fishing tow should be 30 minutes long as this is the standard duration of an ICES GOV tow. In 2003 all of the Norwegian tows were either 20 minutes or less in duration. In this report initial analysis investigating what effect tow duration has on the number of species caught in the GOV has begun. Once this analysis has been finished then a decision can be made as to whether to include the Norwegian data in to the full analysis of the 2003, IBTS data.

5. References

Coull, K.A, Jermyn, A.S, Newton, A.W & Hall, W.B (1989) Length/Weight Relationships for 88 species of fish encountered in the North East Atlantic. Scottish Fisheries Research Report, 43, 100pp.

Daan, N, Bromley, P. J, Hislop, J.R.G & Nielsen, N.A (1990) Ecology of North Sea Fish. Netherlands Journal of Sea Research, 26 (2-4), 343-386.

Greenstreet, S.P.R & Hall, S.J. (1996) Fishing and the ground-fish assemblage structure in the north-western North Sea: an analysis of long-term and spatial trends. Journal of Animal Ecology, 65, 577-598.

Greenstreet, S.P.R, Spence, F.E & McMillan, J.A (1999) Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. V. Changes in structure of the North Sea groundfish assemblage between 1925 and 1996. Fisheries Research, 40, 153-183.

Huston, A.H (1994) Biological Diversity: The Coexistence of Species on Changing Landscapes. Cambridge University Press, 681pp.

ICES (2001) Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES C.M.,

ICES (2004a) Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak. ICES C.M.,ACFM:07

ICES (2004b) Report of the Working Group on Fish Ecology. ICES C.M.,G:09

Rogers, S.I., Maxwell, D, Rijnsdorp, A.D, Damm, U & Vanhee, W (1999) Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. V. Can comparisons of species diversity be used to assess human impacts on coastal demersal fish faunas in the Northeast Atlantic? Fisheries Research, 40, 135-152.

Sparholt, H (1990) An estimate of the total biomass of fish in the North Sea. J. Cons. int. Explor. Mer. 46, 200-210.

Yang, J (1982) An estimate of the fish biomass in the North Sea. J. Cons. int. Explor. Mer, 40, 172-191.

Table 2.1. Total area of each of the five sub-areas that make up the whole North Sea (whole ICES area IV) and the area included within the IBTS coverage over the period 1998 to 2003. Raising factors to "raise" the area covered by the IBTS to the entire ICES area IV are given for each sub-area.

Area	ICES area Km^2	IBTS area Km^2	Raising Factor
IVa1	133,049	100,900	1.3174468
IVa2	131,294	85,069	1.543383
IVb1	125,519	121,142	1.0361325
IVb2	151,764	143,427	1.0581291
IVc	66,572	46,655	1.4269104

Table 3.1. Numbers of all demersal fish and numbers of the nine selected species sampled by the IBTS in each year. The contribution made by the nine species in each year is indicated.

Year	All demersal fish	Nine species	Percentage contribution
1998	15,376,053	14,952,958	97.2
1999	47,984,891	47,094,074	98.1
2000	28,254,466	27,484,404	97.3
2001	18,062,565	17,519,262	97.0
2002	16,208,788	14,747,917	91.0
2003	12,140,167	11,234,959	92.5

Table 3.2. Raised area weighted catch (tonnes) for each of the nine demersal fish species in each of the five sub-areas over the period 1998 to 2003. (HAD is haddock, WHI is whiting, COD is Cod, NPO is Norway pout, GGU is grey gurnard, PLA is plaice, LSO is lemon sole, CDA is common dab, LRD is long rough dab).

		IBTS survey							Raised North Sea					
SP	AREA	1998	1999	2000	2001	2002	2003	RF	1998	1999	2000	2001	2002	2003
HAD	IVa1	107,498	171,662	279,287	219,713	202,633	215,541	1.3174	141,623	226,155	367,946	289,460	266,958	283,964
	IVa2	48,942	181,174	150,882	177,537	172,204	77,156	1.5434	75,536	279,621	232,868	274,008	265,777	119,081
	IVb1	128,128	129,227	344,137	274,368	231,290	145,562	1.0361	132,758	133,896	356,571	284,282	239,647	150,822
	IVb2	18,659	19,270	101,722	26,749	20,813	77,656	1.0581	19,744	20,390	107,635	28,304	22,023	82,170
	IVc	17	18	277	1,098	0	0	1.4269	24	26	395	1,566	0	0
	TOTAL	303,245	501,351	876,304	699,465	626,940	515,915		369,685	660,089	1,065,416	877,620	794,405	636,037
WHI	IVa1	78,500	160,544	120,935	70,190	86,931	80,988	1.3174	103,420	211,508	159,325	92,471	114,528	106,697
	IVa2	13,190	30,711	23,688	27,469	20,632	16,892	1.5434	20,358	47,399	36,560	42,396	31,843	26,071
	IVb1	146,378	218,397	292,977	236,953	231,912	195,413	1.0361	151,667	226,288	303,563	245,514	240,292	202,474
	IVb2	52,874	168,185	137,724	221,954	106,985	75,376	1.0581	55,947	177,961	145,730	234,856	113,203	79,757
	IVc	38,872	18,177	61,795	91,203	19,647	8,754	1.4269	55,468	25,937	88,176	130,138	28,035	12,491
	TOTAL	329,815	596,014	637,118	647,769	466,107	377,423		386,860	689,094	733,353	745,376	527,900	427,491
COD	IVa1	8,596	4,335	4,549	3,934	6,111	4,726	1.3174	11,324	5,711	5,993	5,183	8,050	6,226
	IVa2	16,114	12,520	11,701	15,041	8,109	6,450	1.5434	24,871	19,323	18,058	23,214	12,515	9,955
	IVb1	14,446	6,052	5,046	2,544	3,698	4,753	1.0361	14,968	6,271	5,228	2,635	3,832	4,925
	IVb2	20,908	11,133	7,287	24,165	7,240	1,391	1.0581	22,123	11,780	7,710	25,570	7,661	1,472
	IVc	6,537	3,073	3,973	4,645	9,374	427	1.4269	9,328	4,385	5,669	6,628	13,375	610
	TOTAL	66,601	37,113	32,556	50,329	34,531	17,747		82,615	47,470	42,660	63,230	45,433	23,187
NPO	IVa1	60,956	75,336	207,808	79,433	70,834	46,258	1.3174	80,307	99,251	273,776	104,648	93,320	60,943
	IVa2	36,603	94,246	101,272	57,793	20,951	16,382	1.5434	56,492	145,458	156,302	89,197	32,335	25,283
	IVb1	1,231	20,326	97,266	16,129	4,301	2,076	1.0361	1,275	21,060	100,780	16,711	4,456	2,151
	IVb2	4,096	674	1,323	1,735	1	81	1.0581	4,334	714	1,400	1,835	1	85
	IVc	0	0	0	35	0	0	1.4269	0	0	0	50	0	0
	TOTAL	102,886	190,583	407,669	155,124	96,086	64,796		142,408	266,483	532,258	212,443	130,112	88,462
GGU	IVa1	2,959	3,875	2,357	2,440	2,685	4,002	1.3174	3,898	5,105	3,105	3,215	3,537	5,273
	IVa2	972	2,295	2,240	4,057	3,531	4,136	1.5434	1,501	3,542	3,457	6,261	5,450	6,383
	IVb1	30,259	35,787	29,518	19,896	32,111	28,503	1.0361	31,352	37,080	30,585	20,615	33,272	29,533
	IVb2	48,465	52,836	39,765	56,254	33,727	36,024	1.0581	51,283	55,907	42,077	59,524	35,687	38,118
	IVc	1,402	1,041	459	2,397	496	23	1.4269	2,001	1,485	655	3,420	708	33
	TOTAL	84,057	95,834	74,339	85,043	72,551	72,688		90,034	103,120	79,878	93,034	78,654	79,339
PLA	IVa1	662	1,437	829	2,077	1,558	1,841	1.3174	872	1,893	1,092	2,736	2,053	2,425
	IVa2	115	299	293	493	543	520	1.5434	177	462	453	760	838	802
	IVb1	2,709	2,170	3,335	3,717	5,585	4,904	1.0361	2,807	2,248	3,455	3,851	5,786	5,082
	IVb2	17,997	20,306	8,412	11,467	10,872	14,400	1.0581	19,043	21,487	8,901	12,134	11,504	15,237
	IVc	939	3,140	1,050	2,257	2,099	1,160	1.4269	1,341	4,481	1,498	3,220	2,996	1,655
	TOTAL	22,422	27,353	13,919	20,010	20,658	22,824		24,240	30,571	15,399	22,702	23,178	25,201
LSO	IVa1	7,017	7,145	10,527	10,032	6,495	8,610	1.3174	9,245	9,413	13,868	13,217	8,557	11,344
	IVa2	1,092	1,817	1,991	1,915	2,083	1,713	1.5434	1,686	2,805	3,073	2,955	3,215	2,644
	IVb1	7,426	8,226	7,099	5,095	7,329	7,496	1.0361	7,695	8,523	7,355	5,279	7,594	7,766
	IVb2	3,800	2,132	1,850	1,374	1,925	2,539	1.0581	4,021	2,256	1,957	1,454	2,037	2,686
	IVc	230	116	55	195	155	0	1.4269	328	166	79	279	221	0
	TOTAL	19,566	19,437	21,522	18,611	17,988	20,358		22,974	23,163	26,333	23,183	21,624	24,441
CDA	IVa1	3,583	7,369	5,509	4,718	4,896	2,494	1.3174	4,720	9,709	7,257	6,215	6,450	3,286
	IVa2	2,663	8,034	4,247	6,922	5,048	5,181	1.5434	4,110	12,400	6,554	10,684	7,792	7,996
	IVb1	30,108	44,235	32,649	43,828	67,708	40,642	1.0361	31,196	45,833	33,829	45,412	70,155	42,110
	IVb2	98,250	82,311	72,240	118,451	143,598	153,965	1.0581	103,961	87,096	76,440	125,337	151,945	162,915
	IVc	7,930	7,260	4,484	35,032	10,249	5,119	1.4269	11,315	10,359	6,398	49,988	14,625	7,305
	TOTAL	142,534	149,209	119,129	208,952	231,500	207,401		155,303	165,396	130,478	237,636	250,966	223,611
LRD	IVa1	1,505	3,950	3,017	2,073	2,169	3,525	1.3174	1,983	5,204	3,974	2,731	2,857	4,644
	IVa2	2,789	5,133	4,412	4,430	2,495	3,684	1.5434	4,304	7,922	6,809	6,838	3,851	5,686
	IVb1	4,344	9,513	8,697	4,499	10,190	7,127	1.0361	4,500	9,857	9,011	4,661	10,558	7,384
	IVb2	13,248	6,811	5,330	9,332	6,893	7,816	1.0581	14,018	7,206	5,640	9,874	7,294	8,271
	IVc	14	31	0	10	0	0	1.4269	20	44	0	14	0	0
	TOTAL	21,899	25,437	21,455	20,344	21,747	22,152		24,826	30,233	25,434	24,118	24,560	25,985

Figure 2.1. Schematic drawing of a fishing net illustrating the terms "wing-spread" and "door-spread". Arrows indicate the possible herding effect of the otterboards and sweeps.

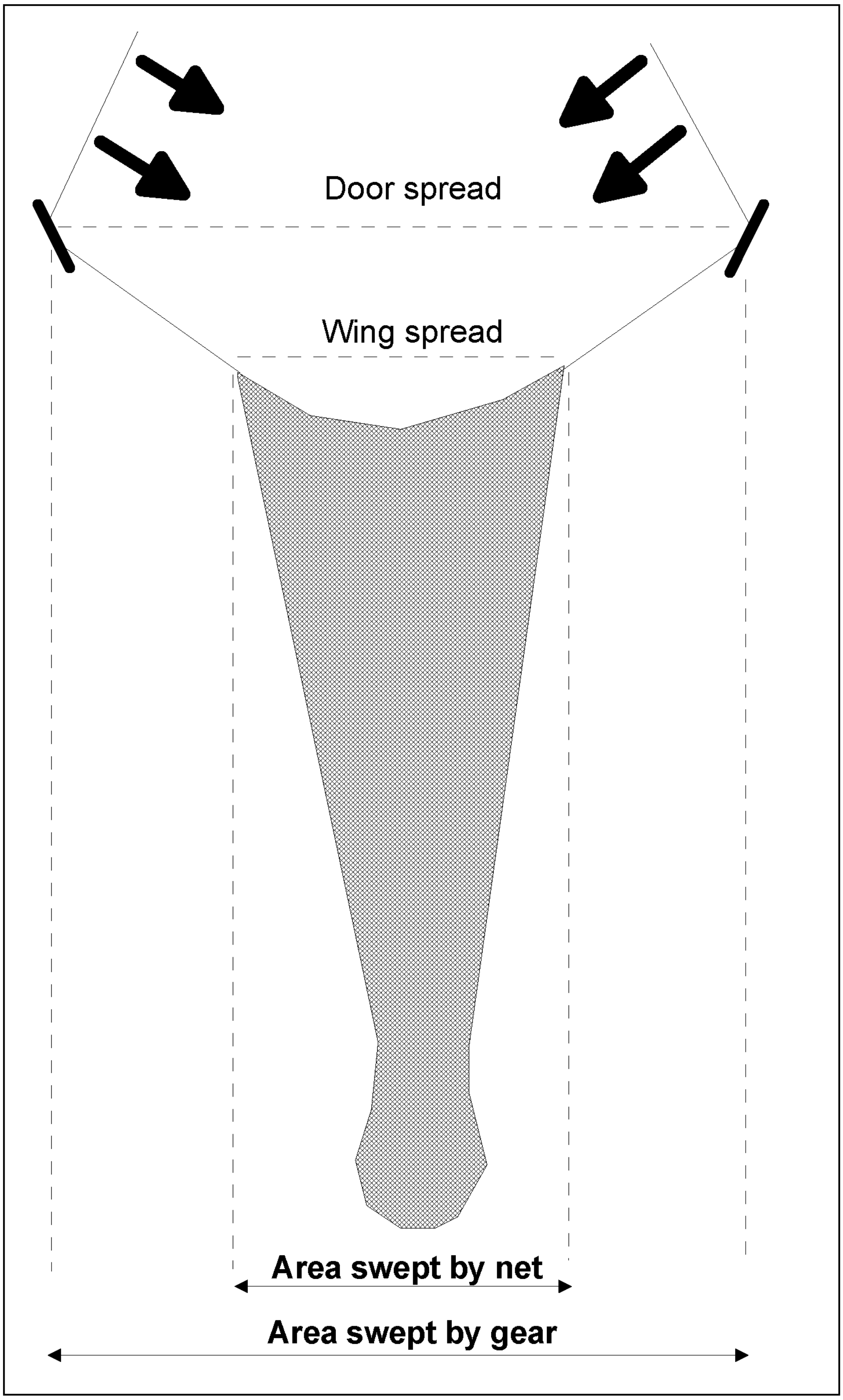
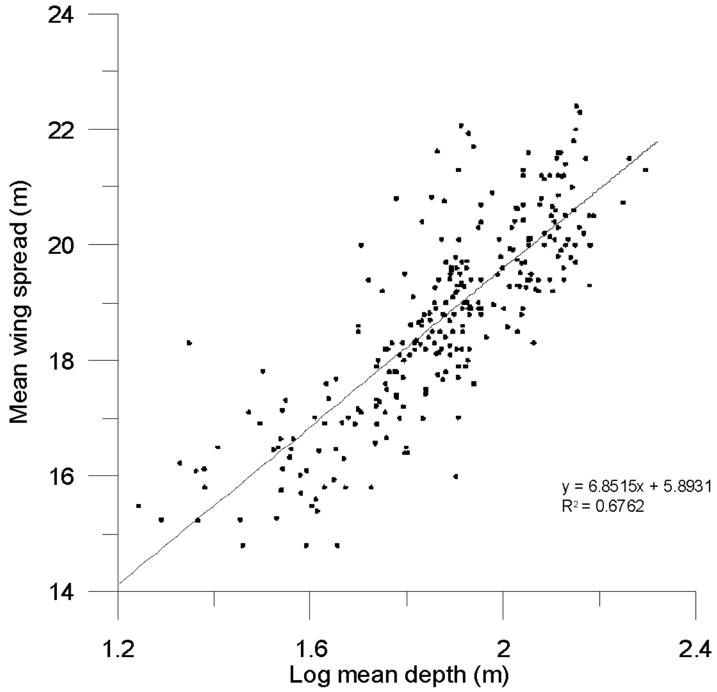


Figure 2.2. Relationship between mean wing and door spread and log depth using SCANMAR© data collected on the Scottish 3rd Quarter IBTS.



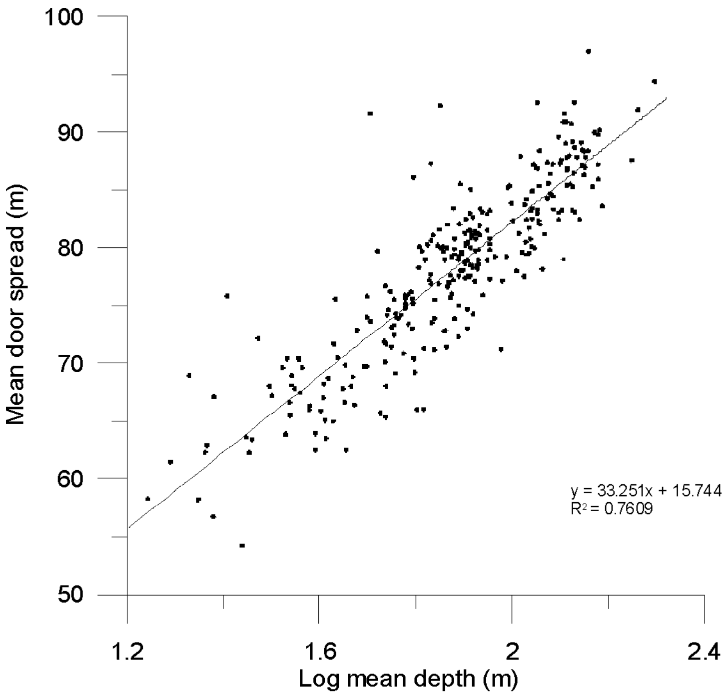


Figure 2.3. Areas shaded light blue are parts of ICES area IV which are included in the IBTS study area. White areas are part of ICES area IV which are not included in the IBTS study areas. The IBTS area has been divided in to five parts, area IVa1, IVa2, IVb1, IVb2, and IVc.

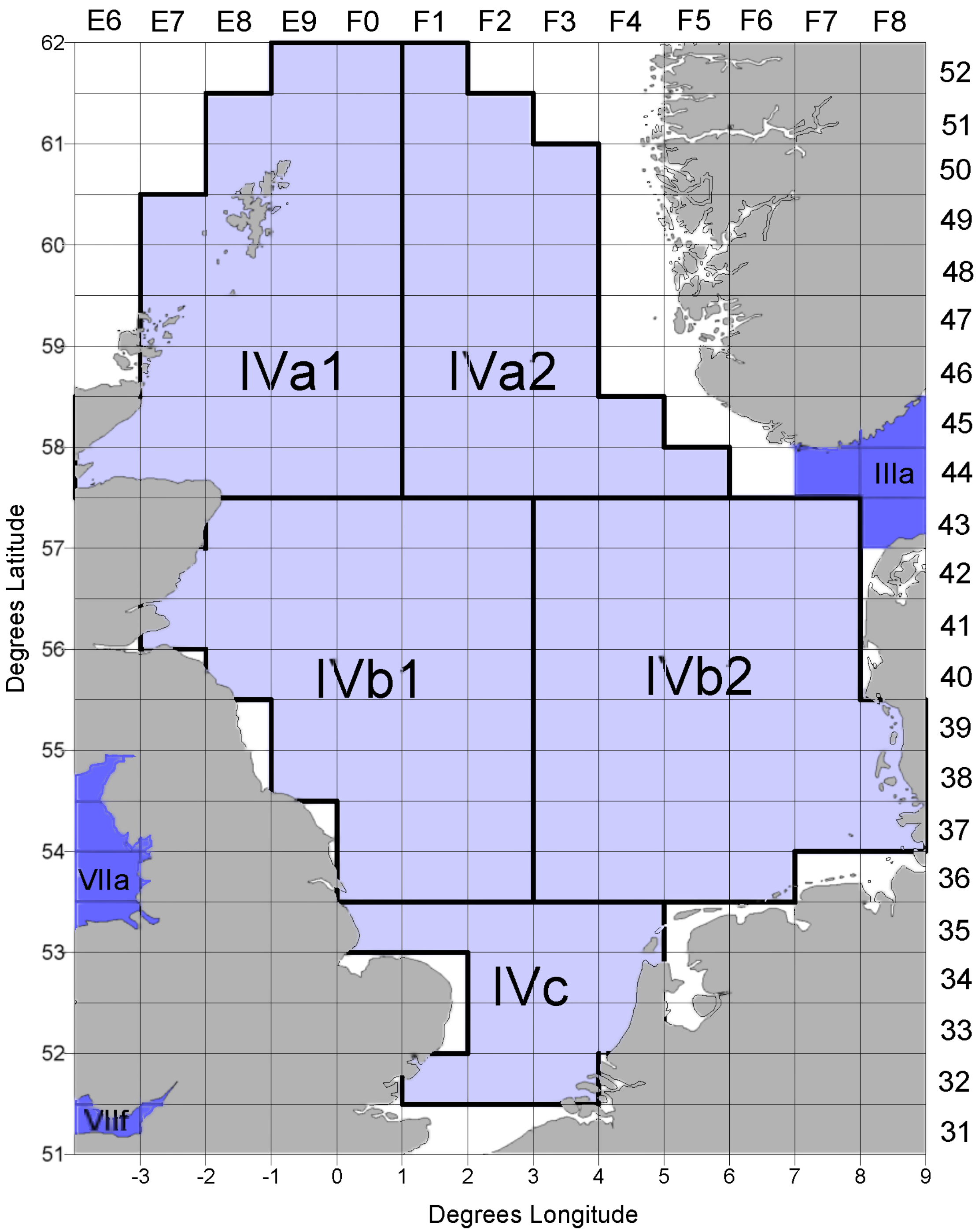


Figure 2.4. Number of hauls in each statistical rectangle in each of the years 1998 to 2003.

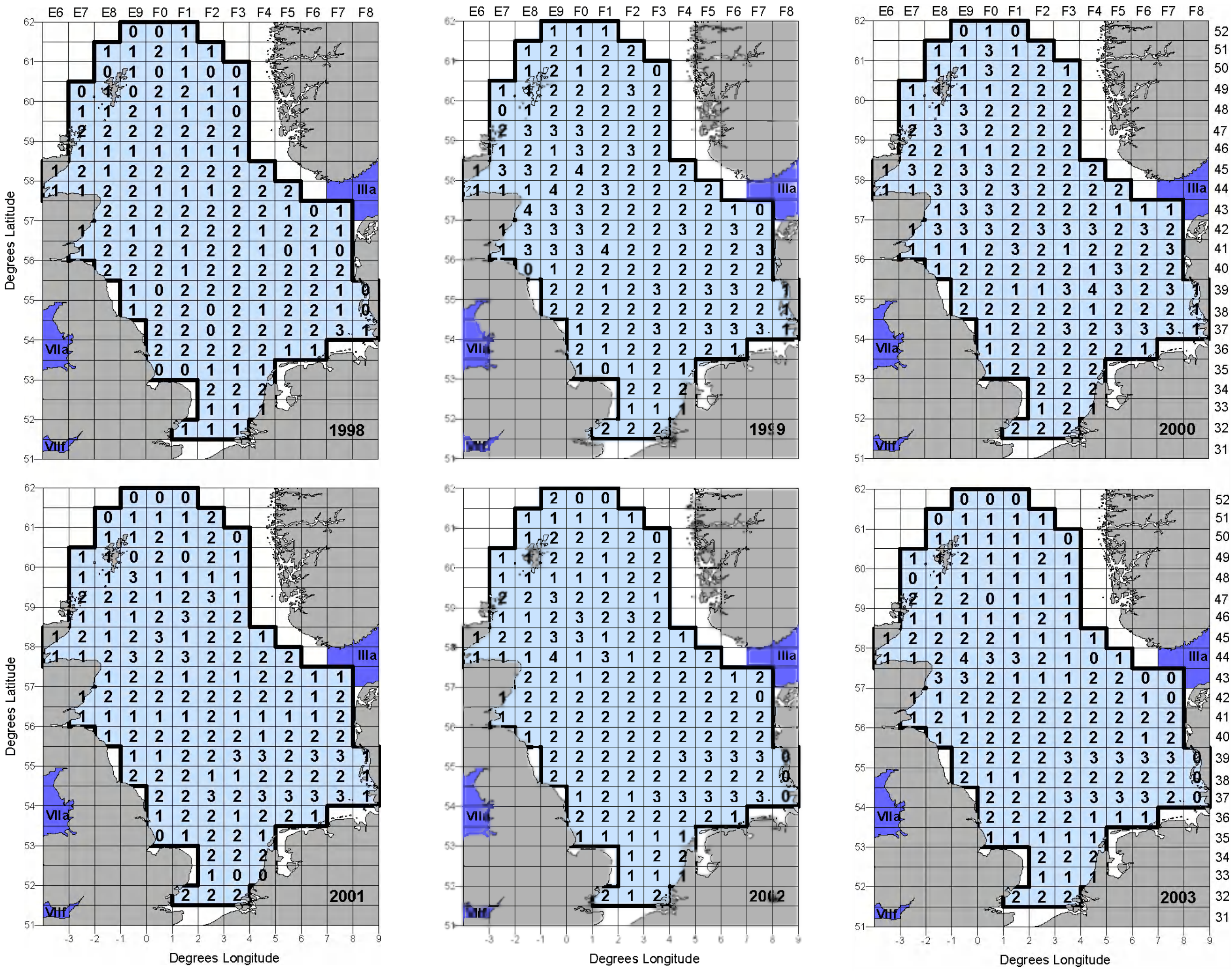


Figure 2.5. Total number of times each statistical rectangle has been fished over the six year period 1998 to 2003.

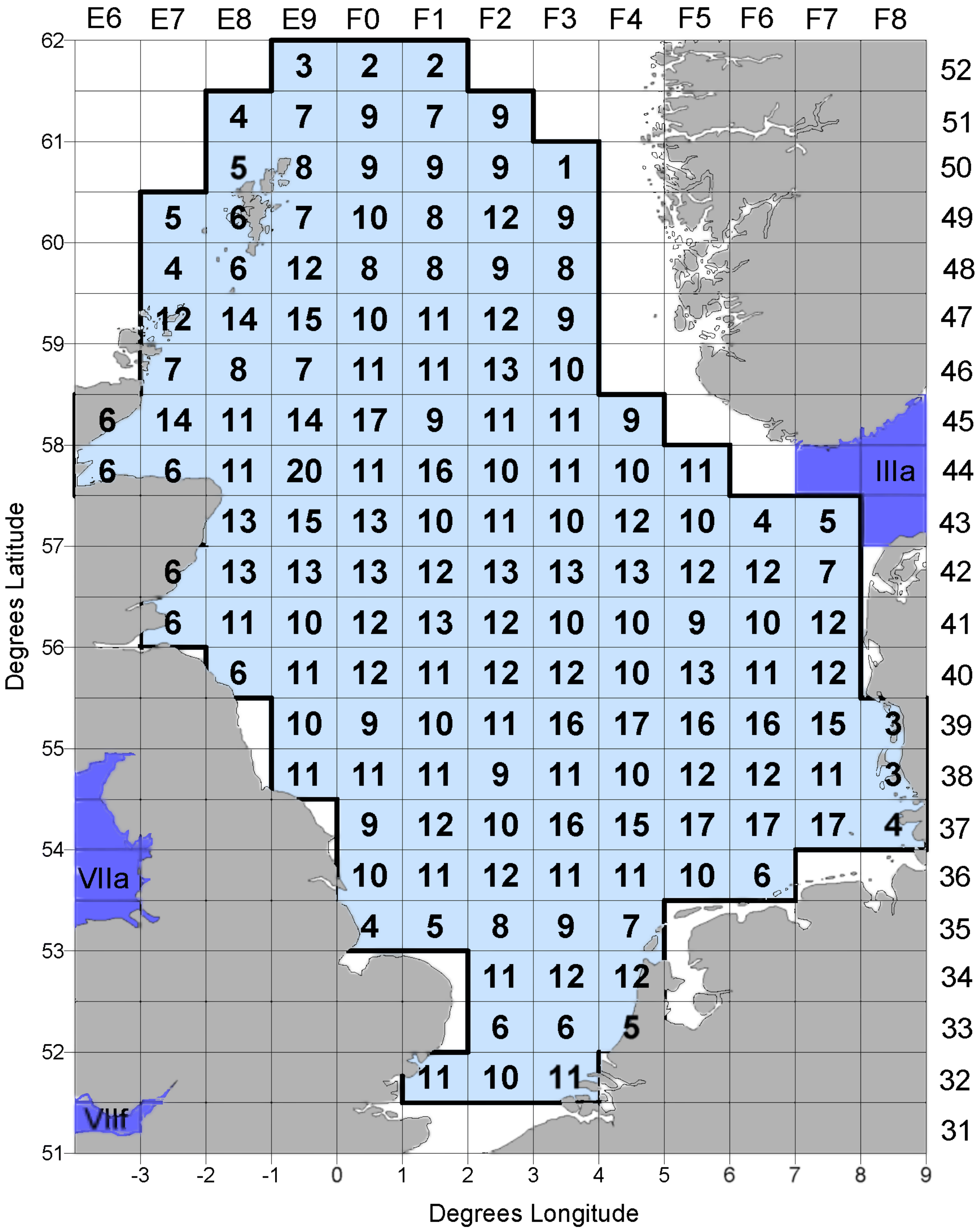


Figure 2.6. Location of all MAFCONS sampling in 2003.

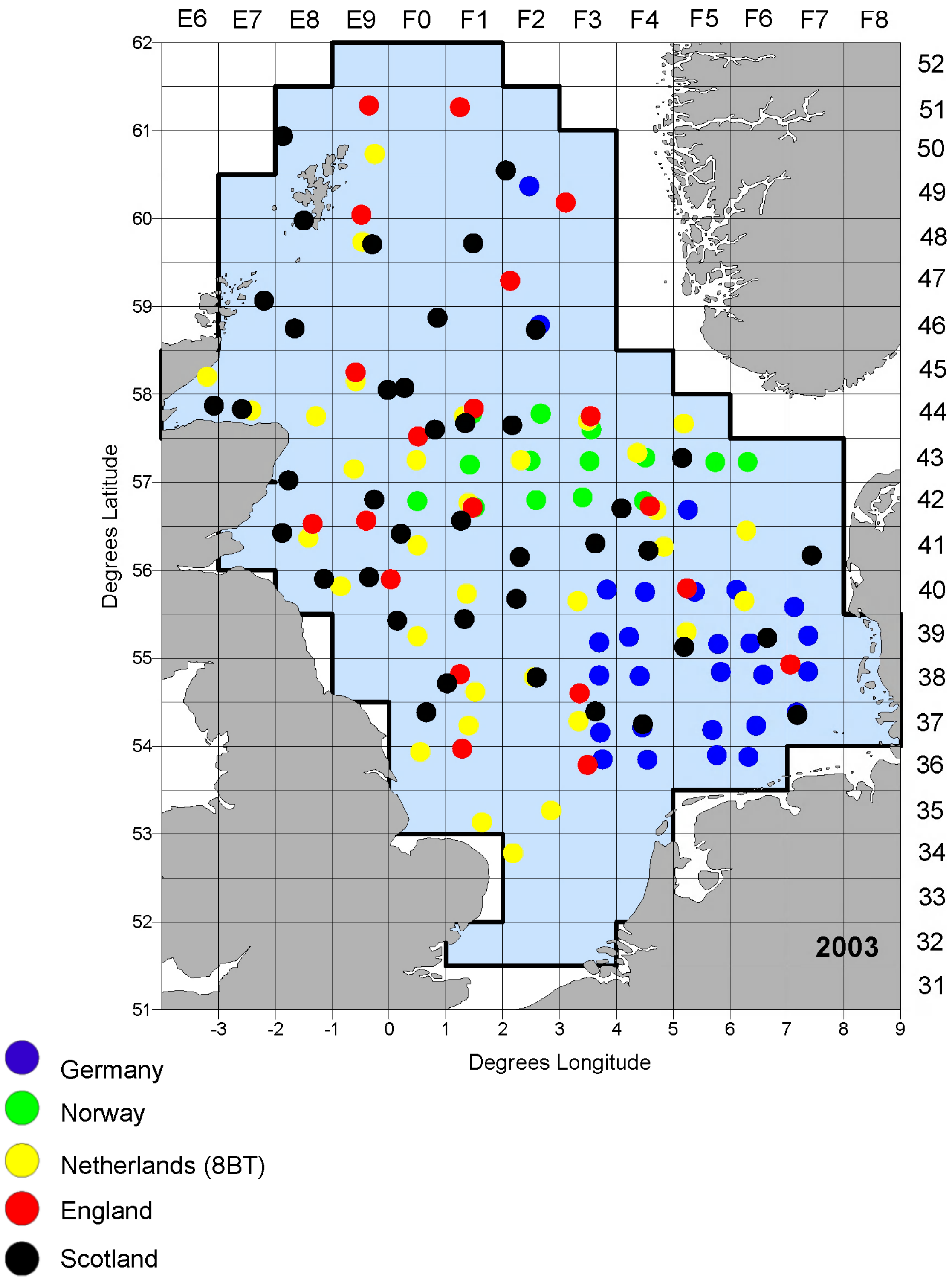


Figure 3.1. The distribution of haddock biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicate interpolated data). Symbol size varies from 0 to 76,000 tonnes and is the same for all years.

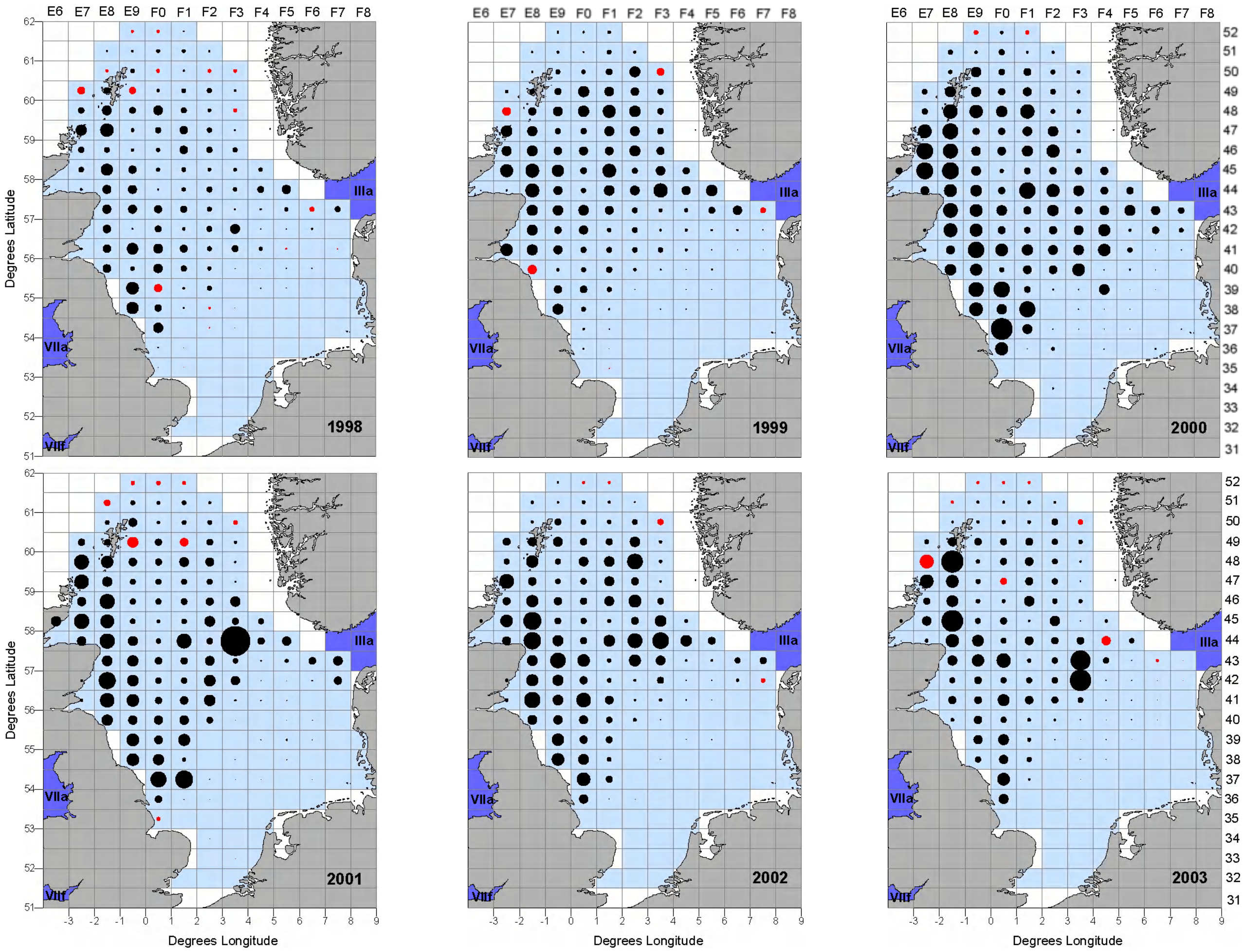


Figure 3.2. The distribution of whiting biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 79,000 tonnes and is the same for all years.

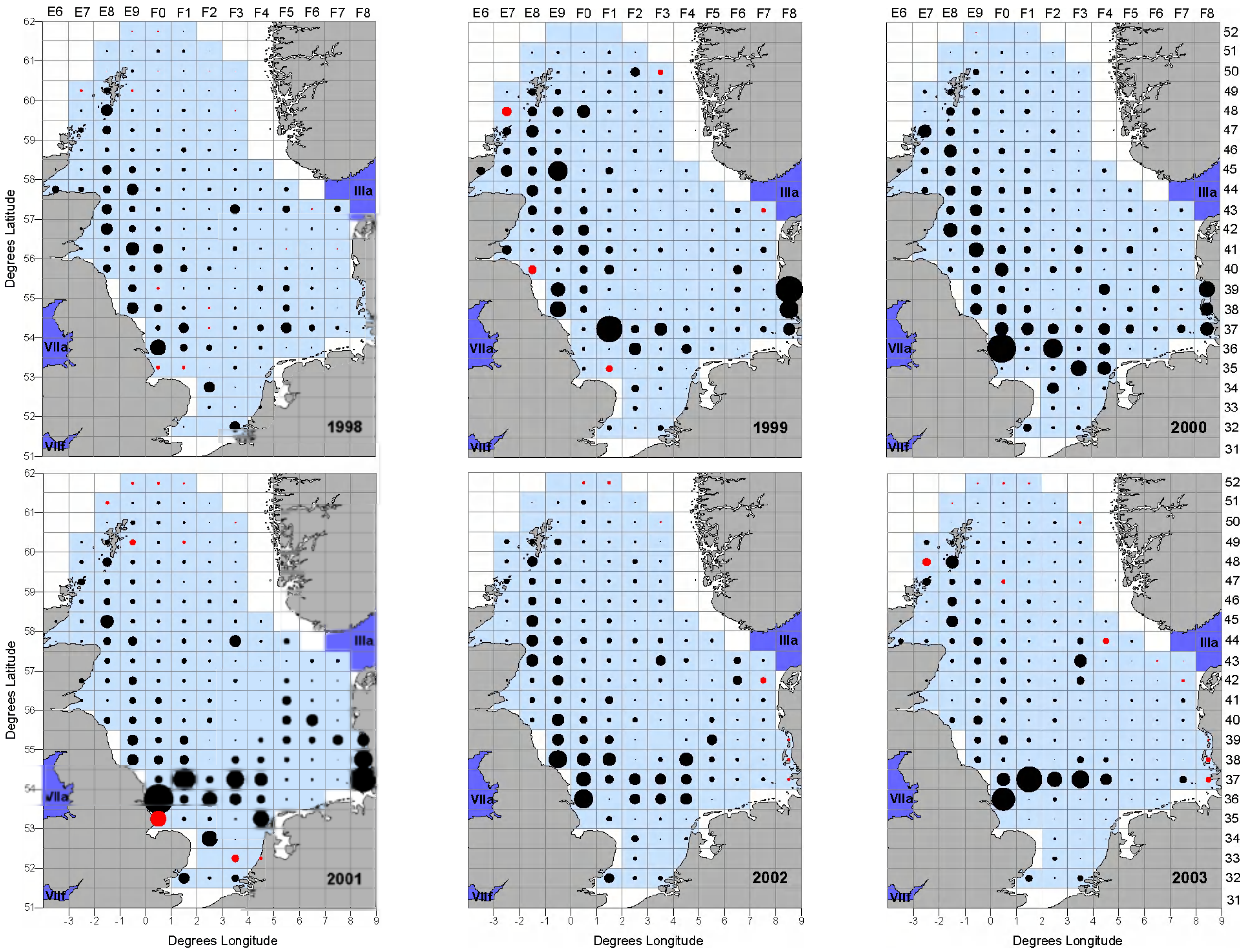


Figure 3.3. The distribution of cod biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 20,000 tonnes and is the same for all years.

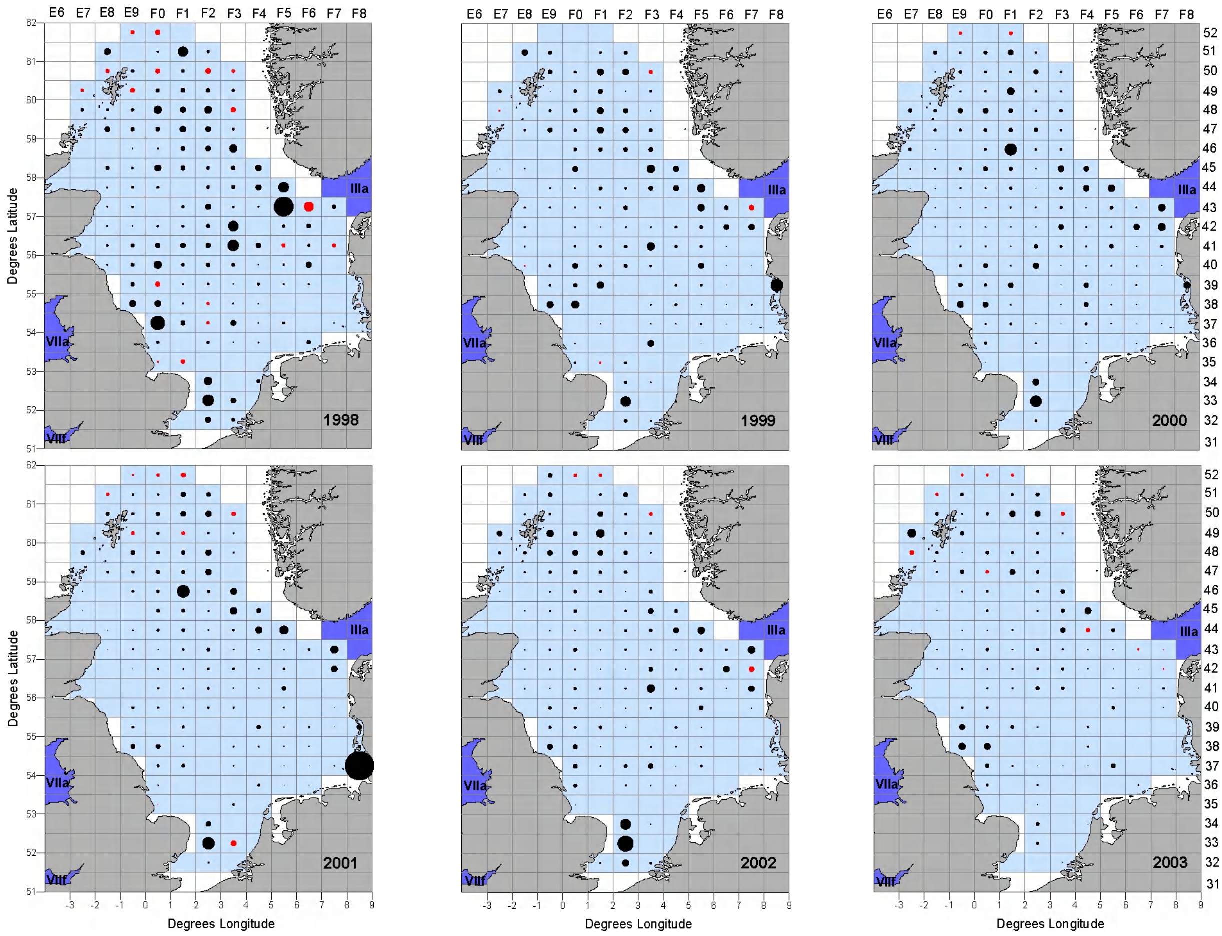


Figure 3.4. The distribution of Norway pout biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 45,000 tonnes and is the same for all years.

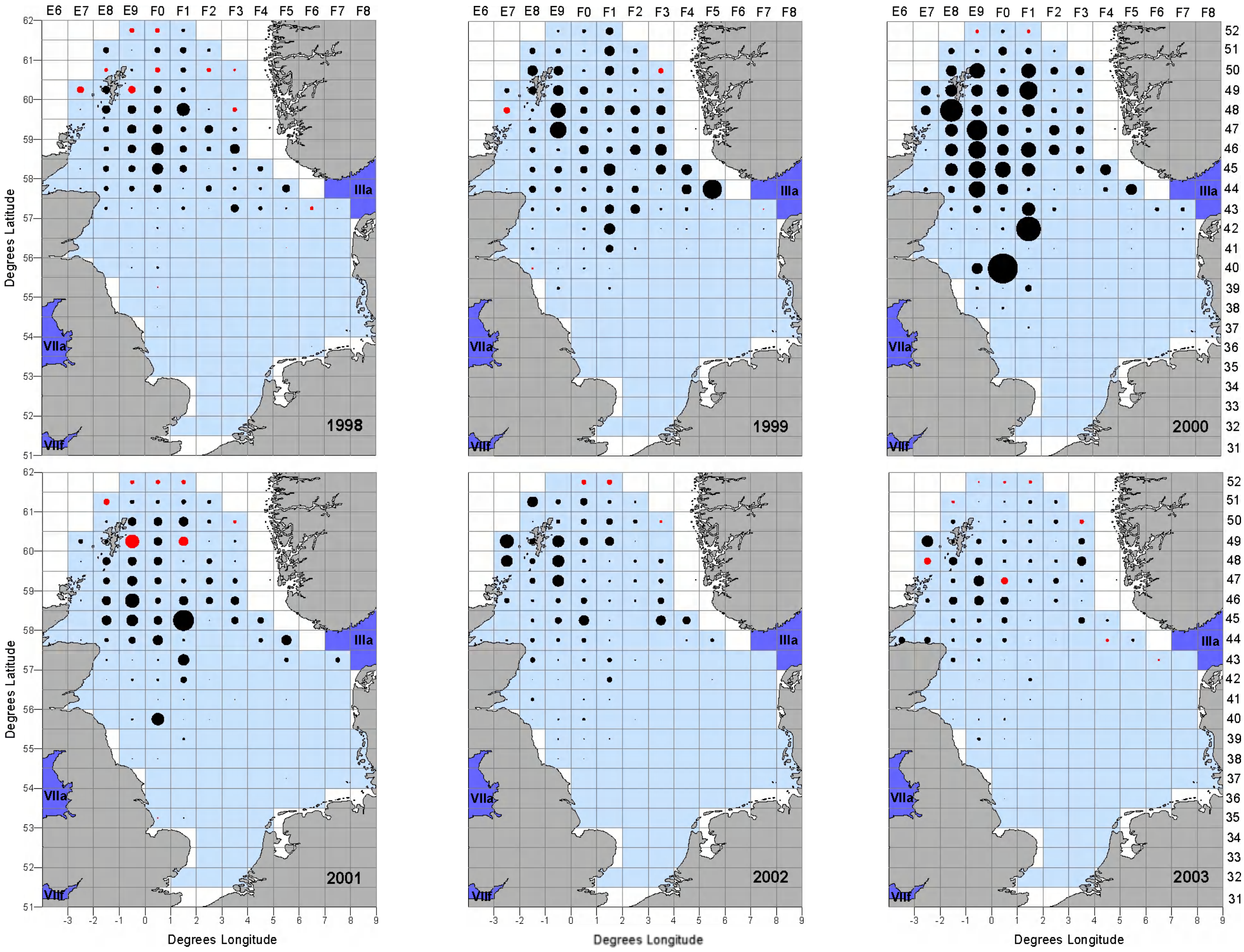


Figure 3.5. The distribution of grey gurnard biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 27,000 tonnes and is the same for all years.

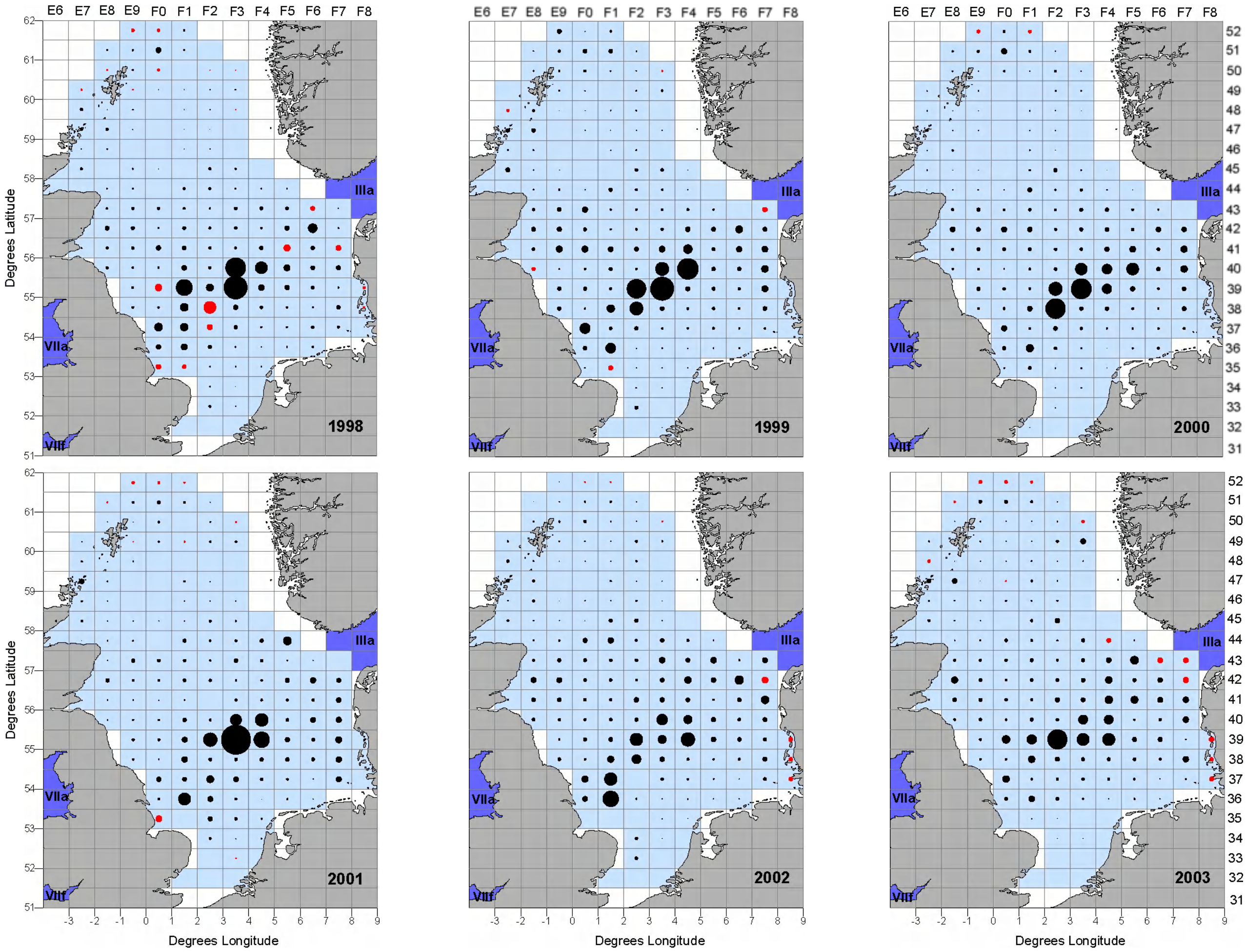


Figure 3.6. The distribution of plaice biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 3,500 tonnes and is the same for all years.

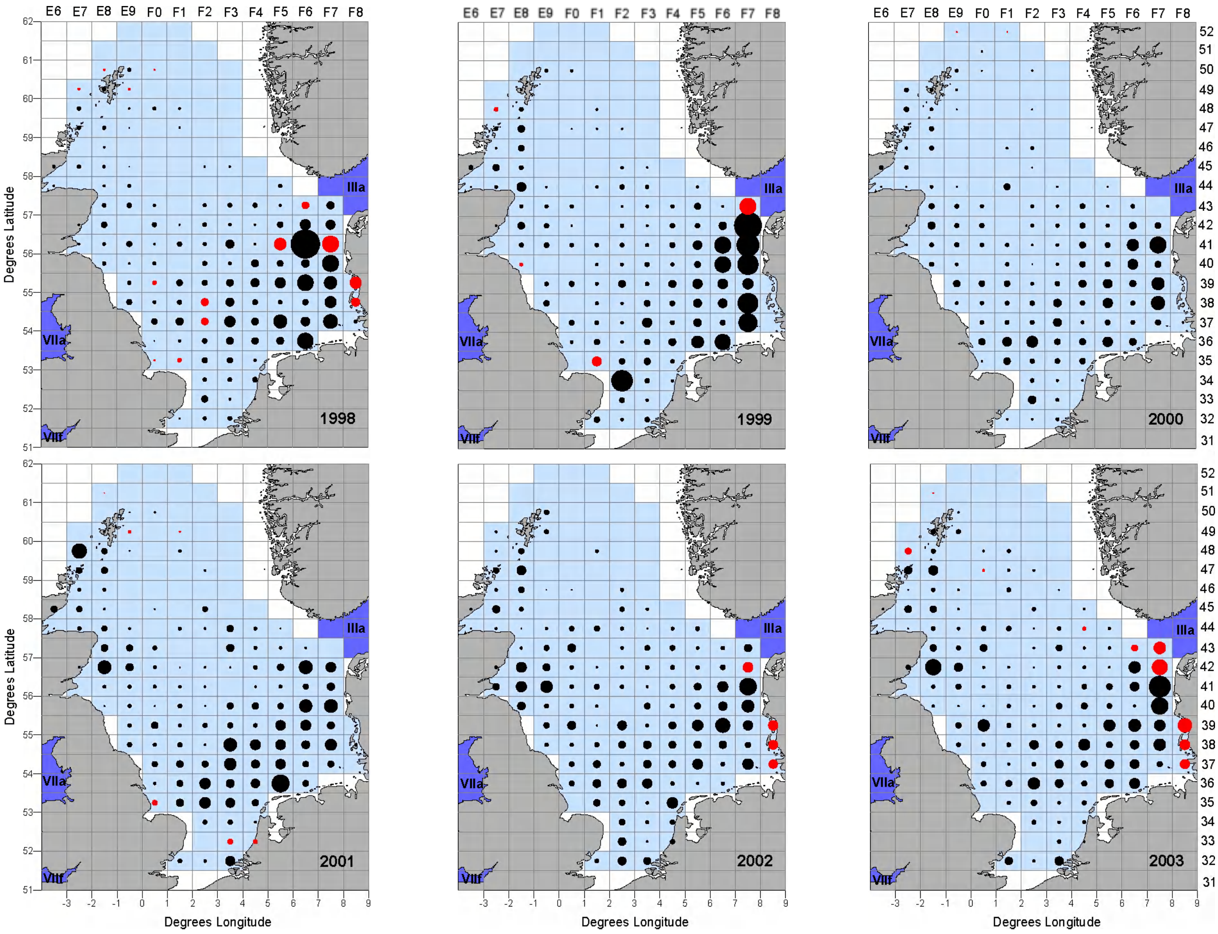


Figure 3.7. The distribution of lemon sole biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 5,000 tonnes and is the same for all years.

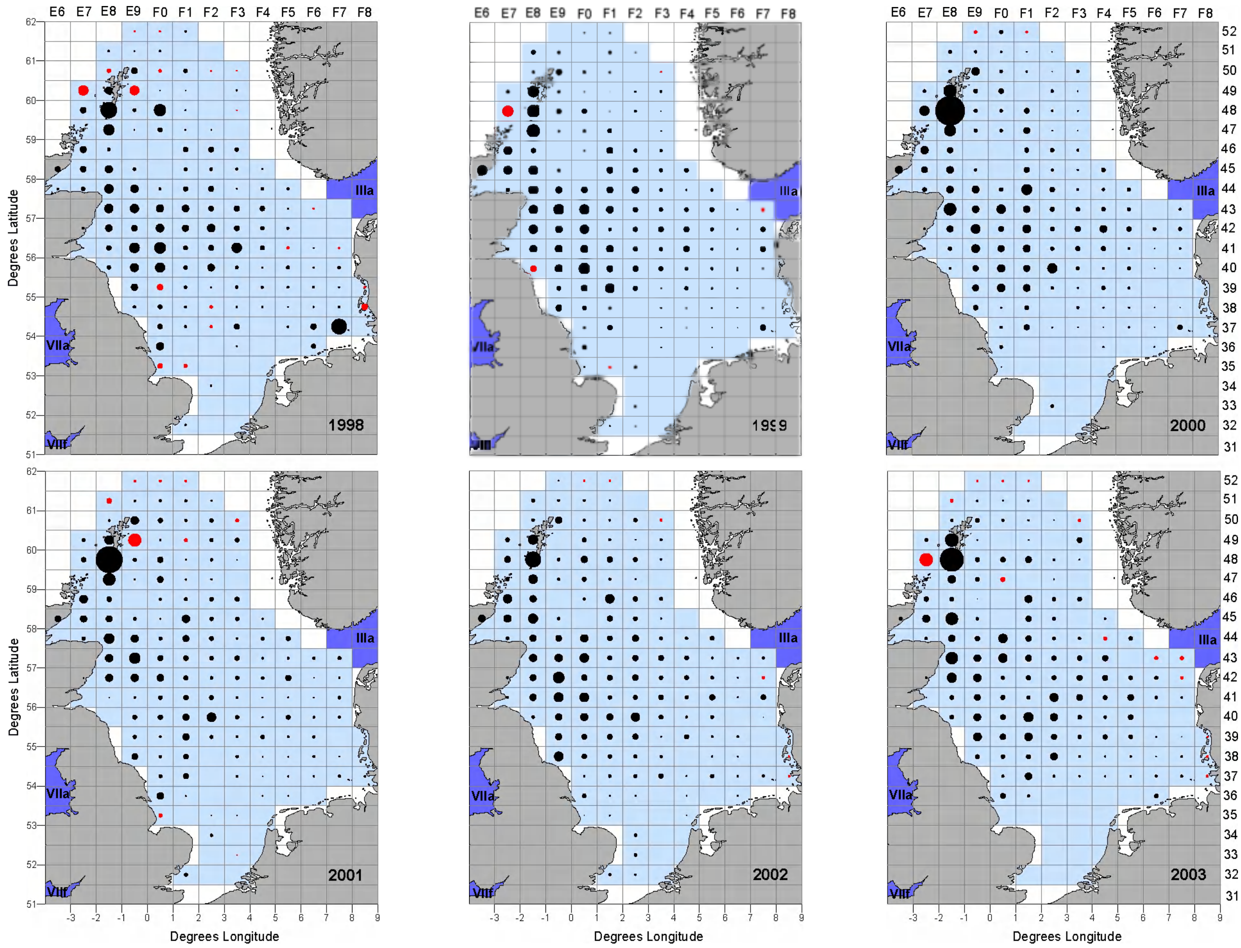


Figure 3.8. The distribution of common dab biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 17,500 tonnes and is the same for all years.

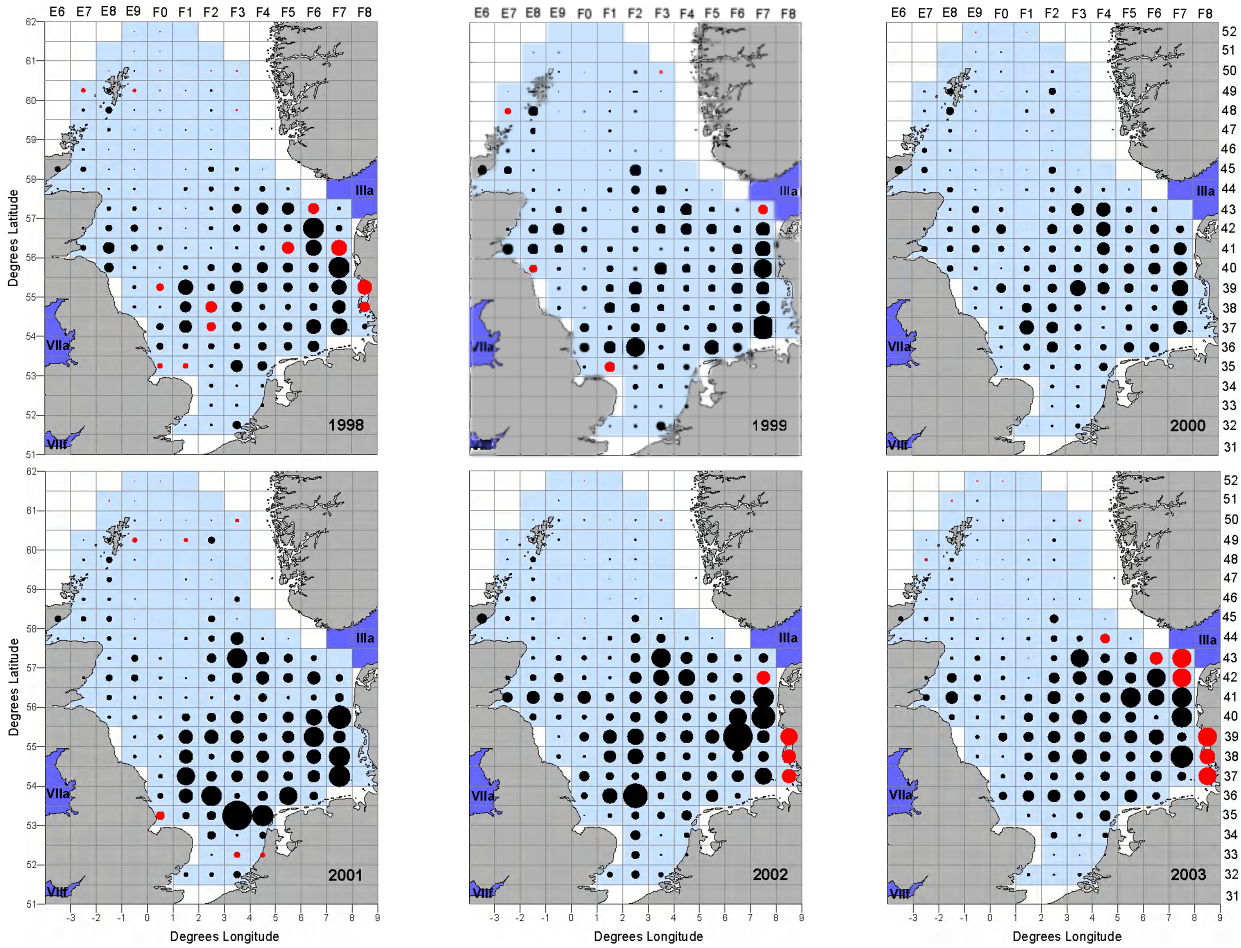


Figure 3.9. The distribution of long rough dab biomass in each statistical rectangle, 1998 to 2003 (Red symbols indicates interpolated data). Symbol size varies from 0 to 3,000 tonnes and is the same for all years.

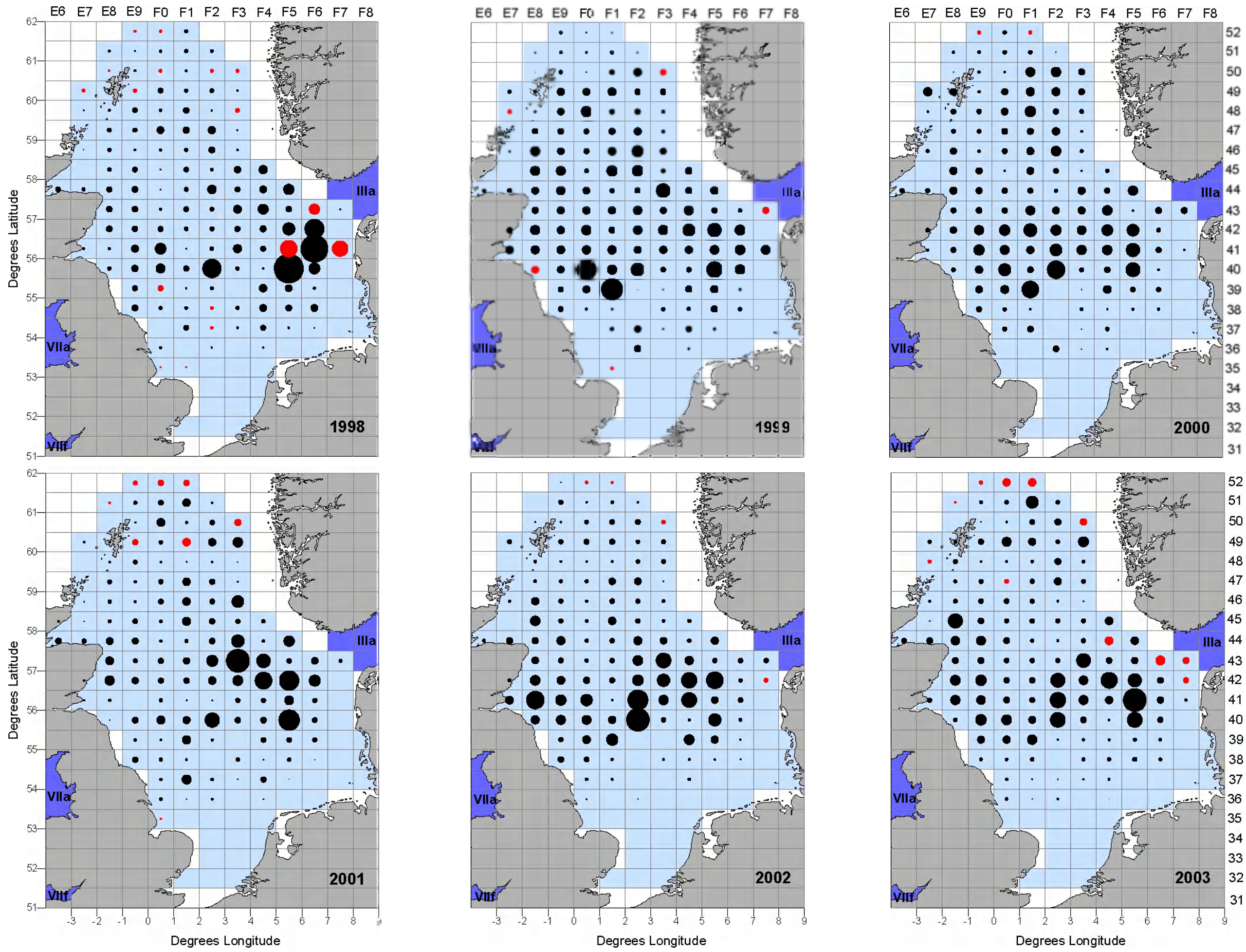


Figure 3.10. Biomass (tonnes) of haddock in each statistical rectangle, 1998 to 2003.

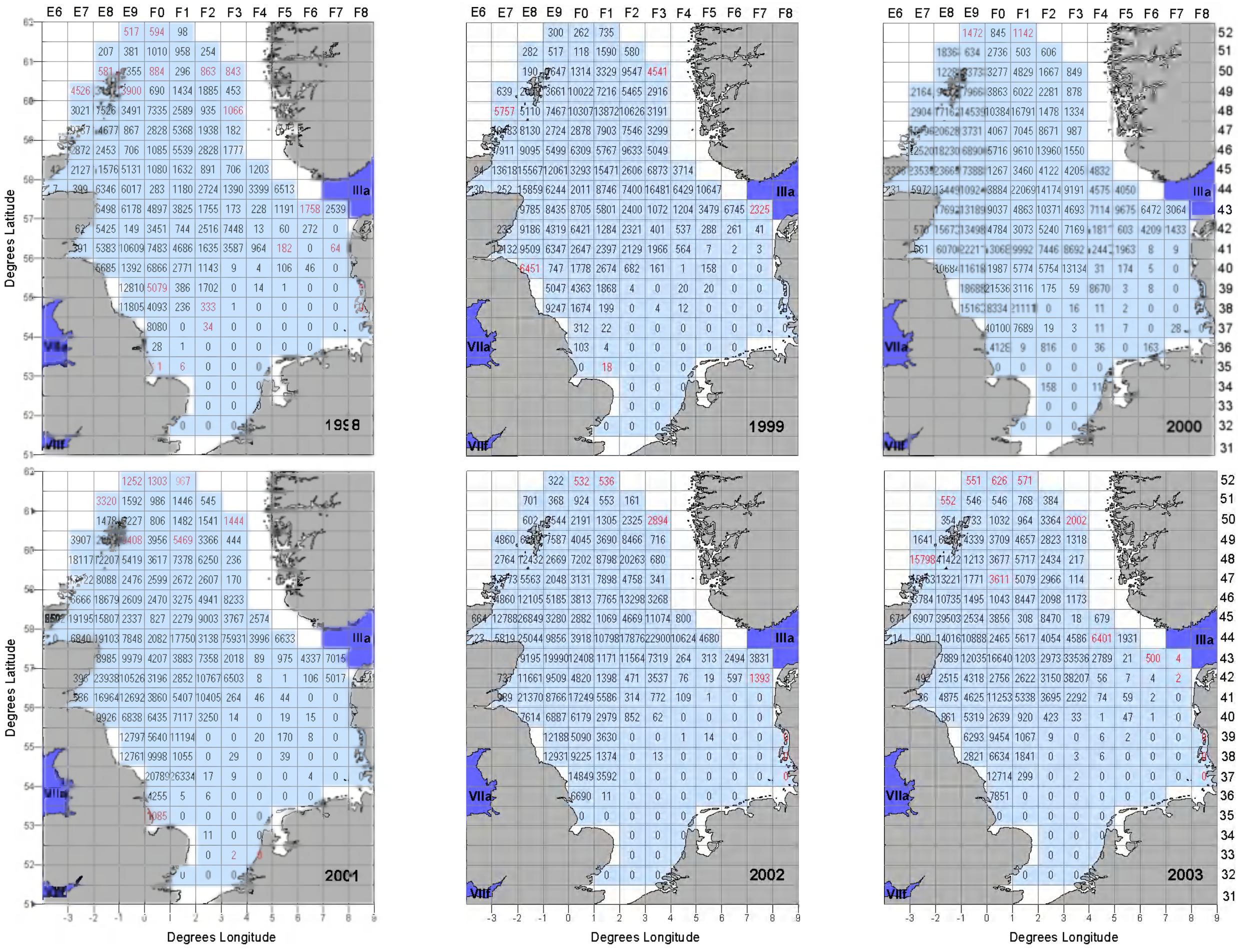


Figure 3.11. Biomass (tonnes) of whiting in each statistical rectangle, 1998 to 2003.

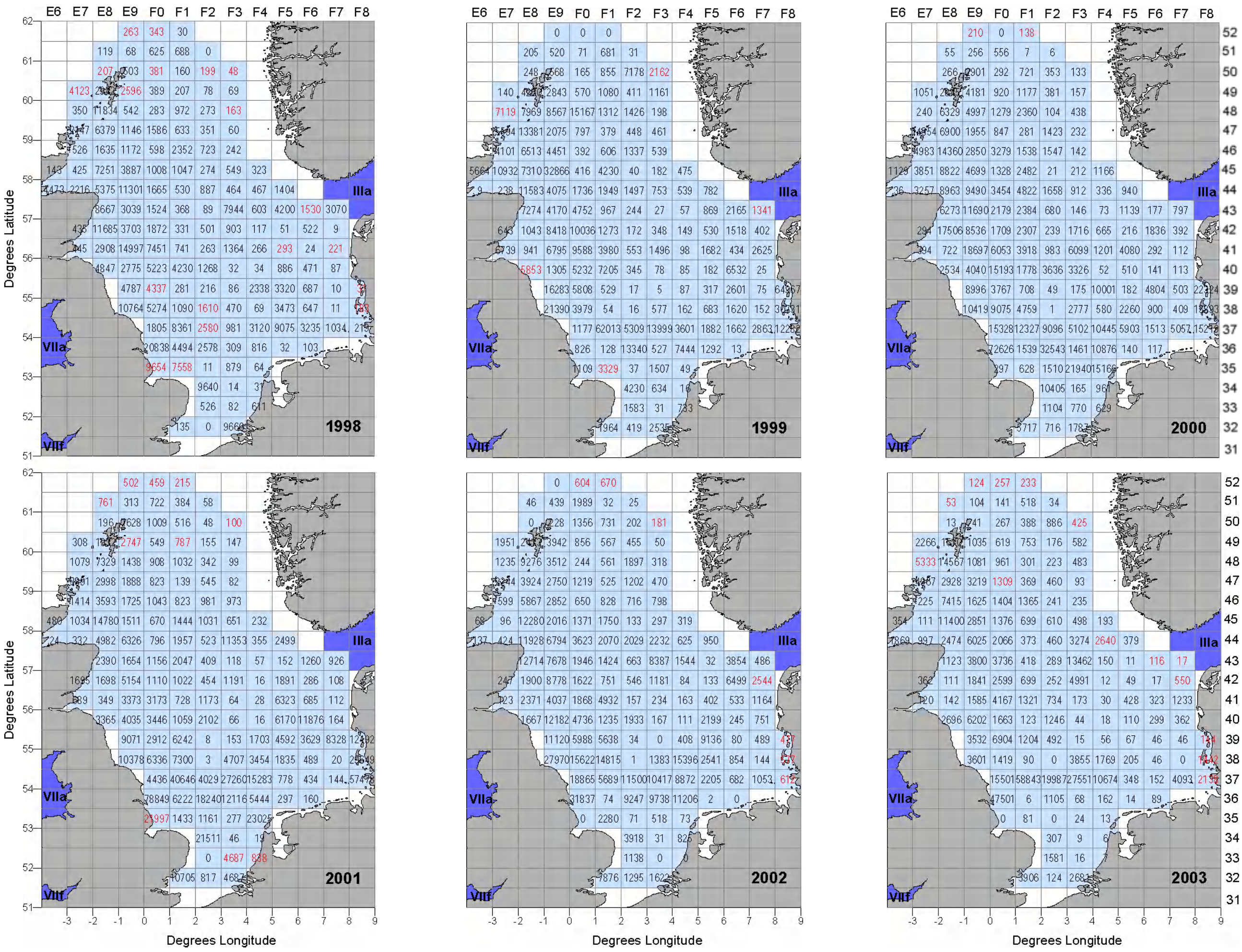


Figure 3.12. Biomass (tonnes) of cod in each statistical rectangle, 1998 to 2003.

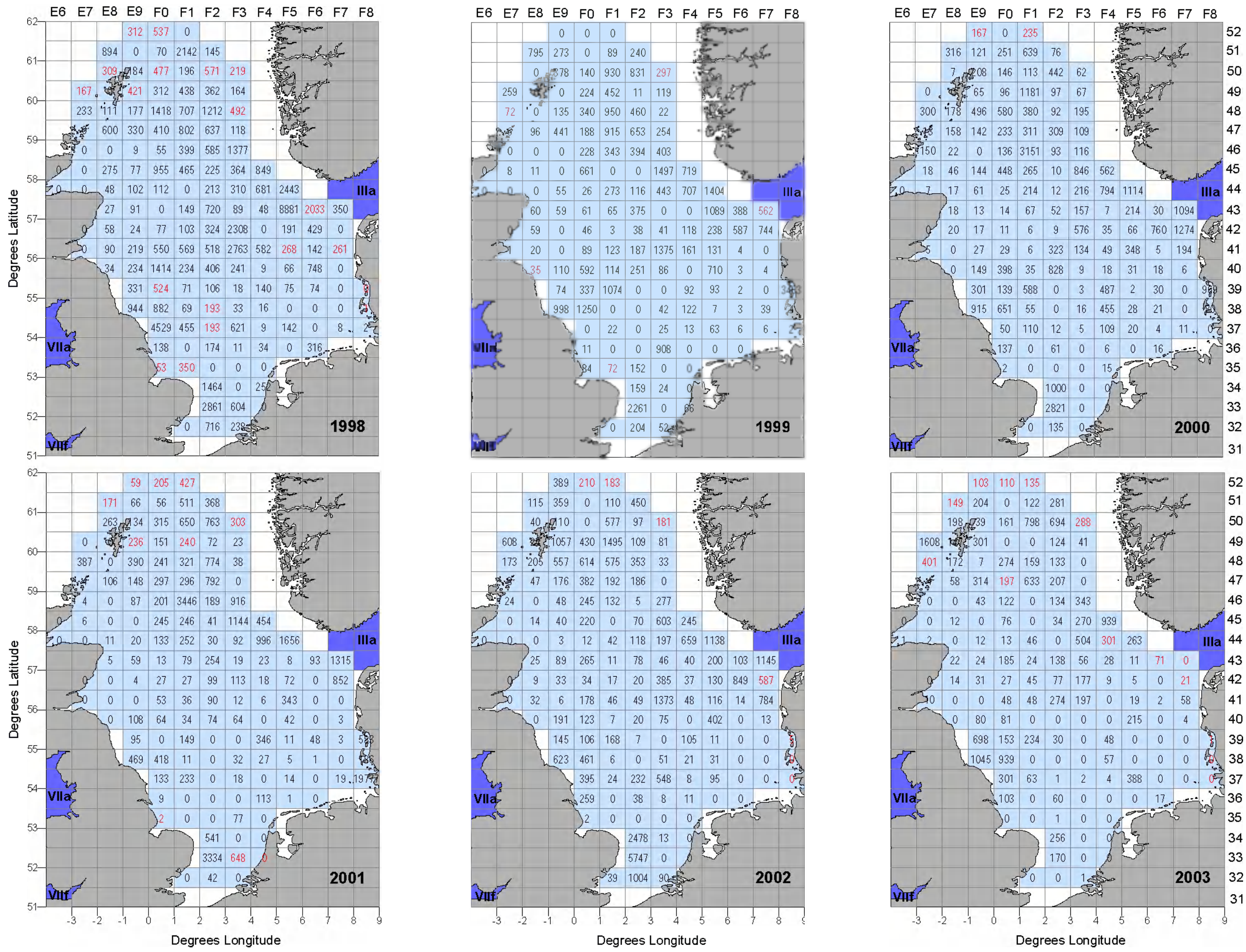


Figure 3.13. Biomass (tonnes) of Norway pout in each statistical rectangle, 1998 to 2003.

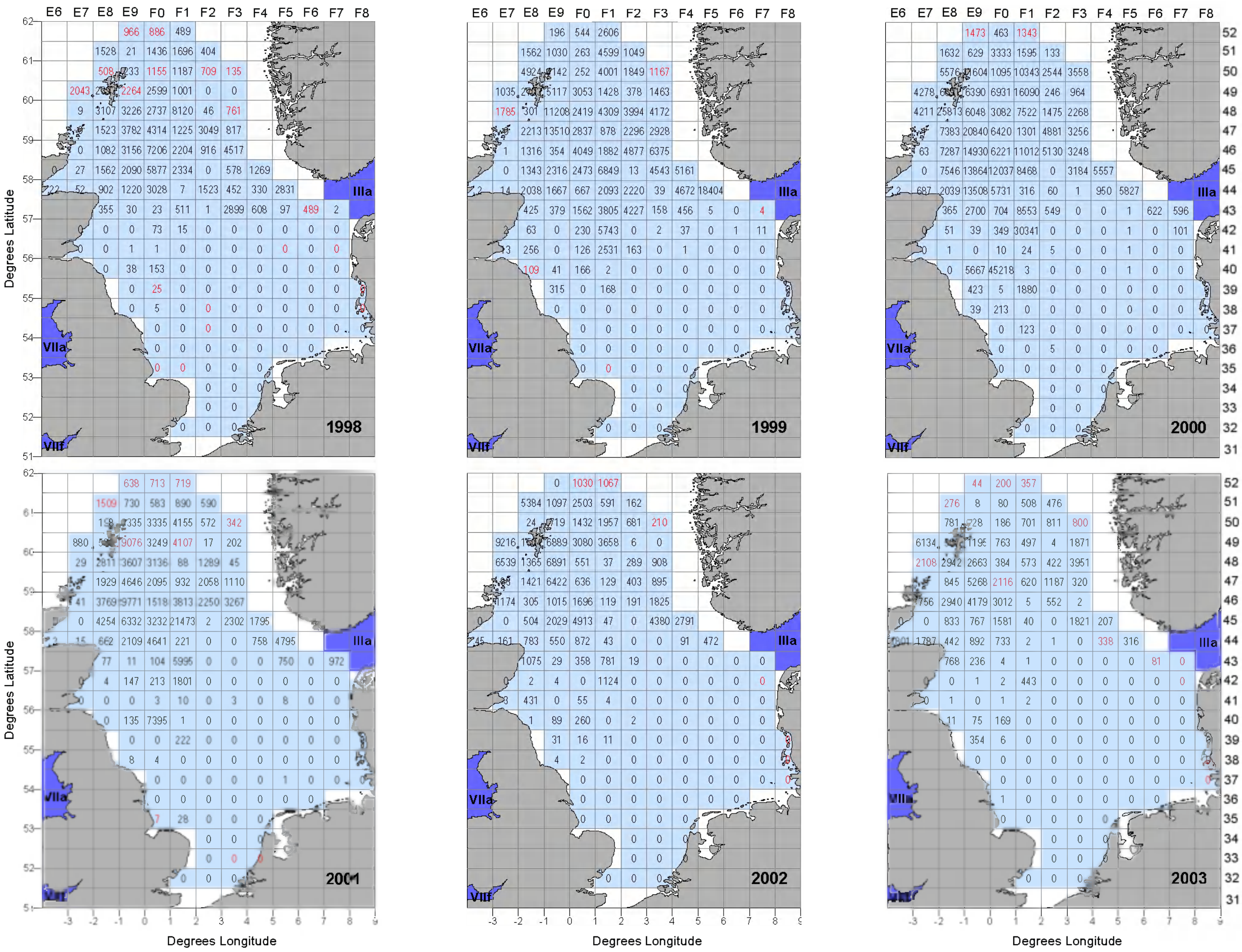


Figure 3.14. Biomass (tonnes) of grey gurnard in each statistical rectangle, 1998 to 2003.

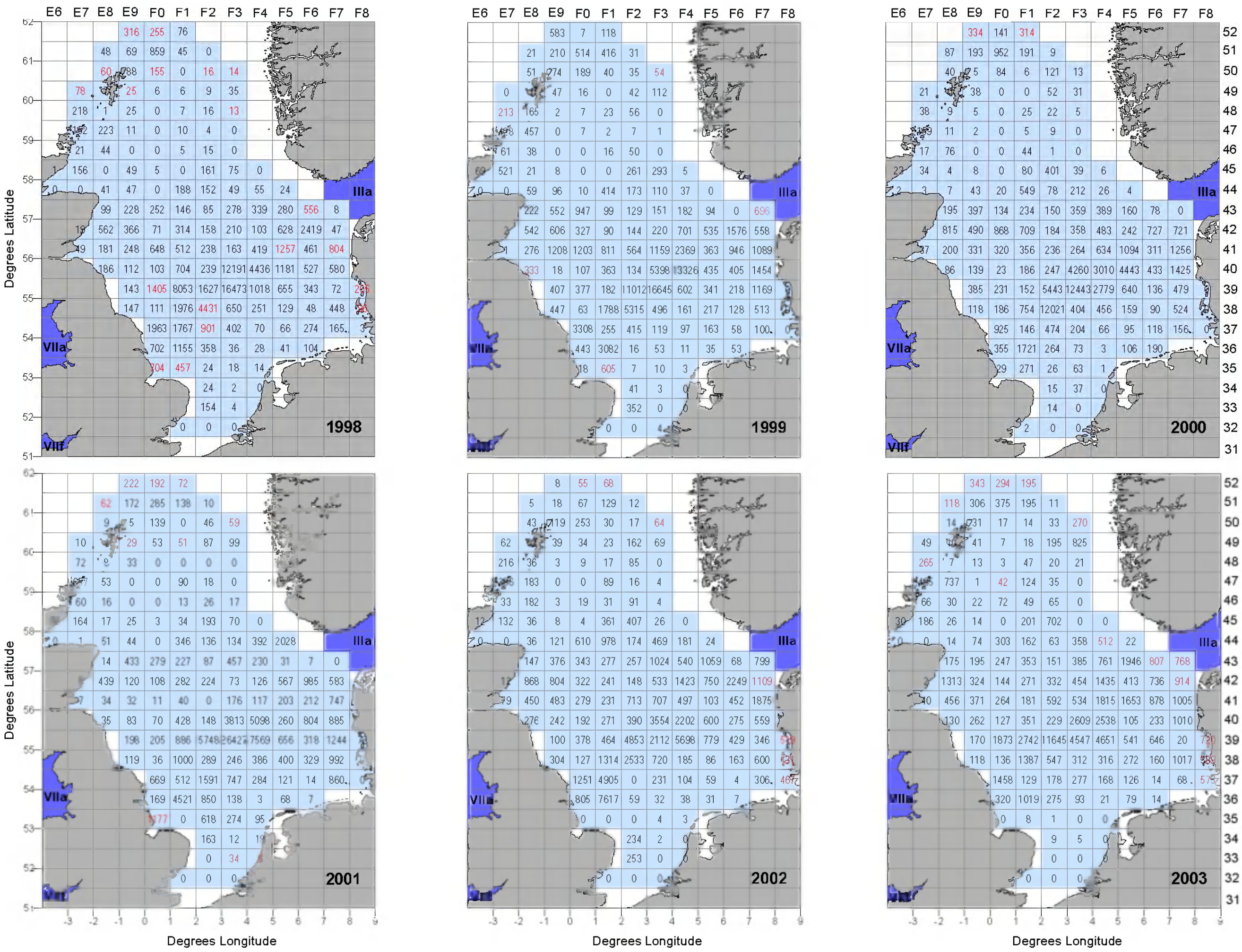


Figure 3.15. Biomass (tonnes) of plaice in each statistical rectangle, 1998 to 2003.

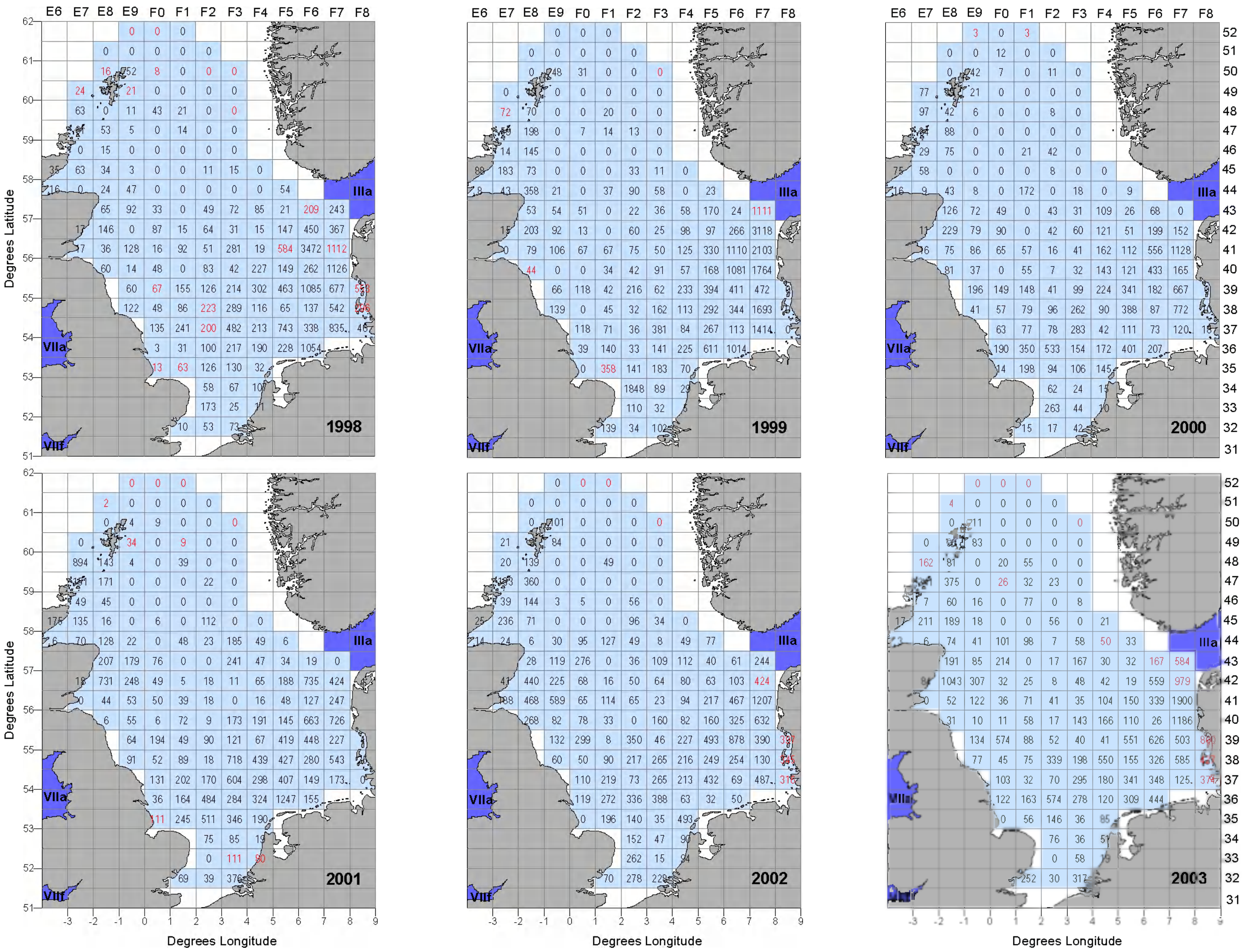


Figure 3.16. Biomass (tonnes) of lemon sole in each statistical rectangle, 1998 to 2003.

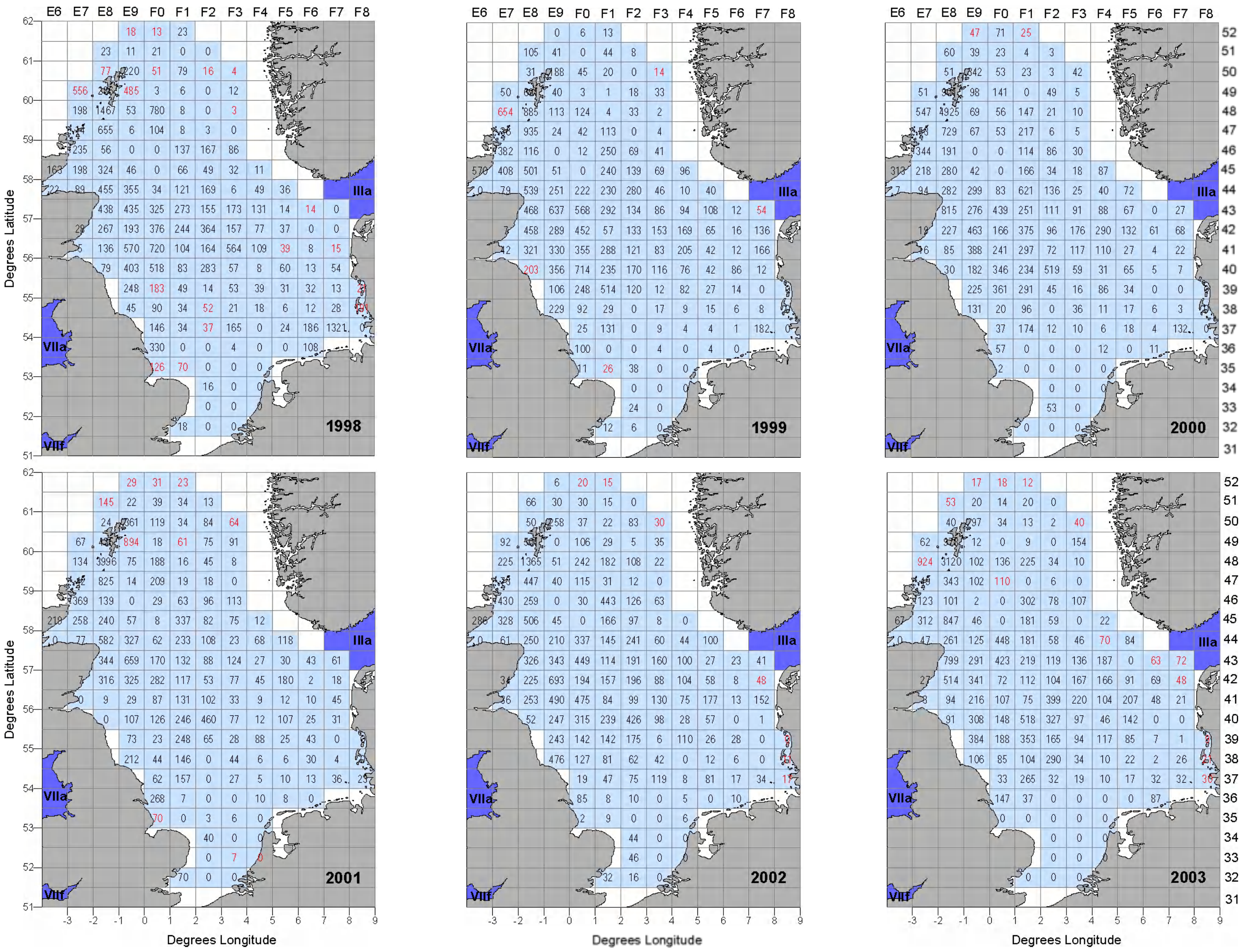


Figure 3.17. Biomass (tonnes) of common dab in each statistical rectangle, 1998 to 2003.

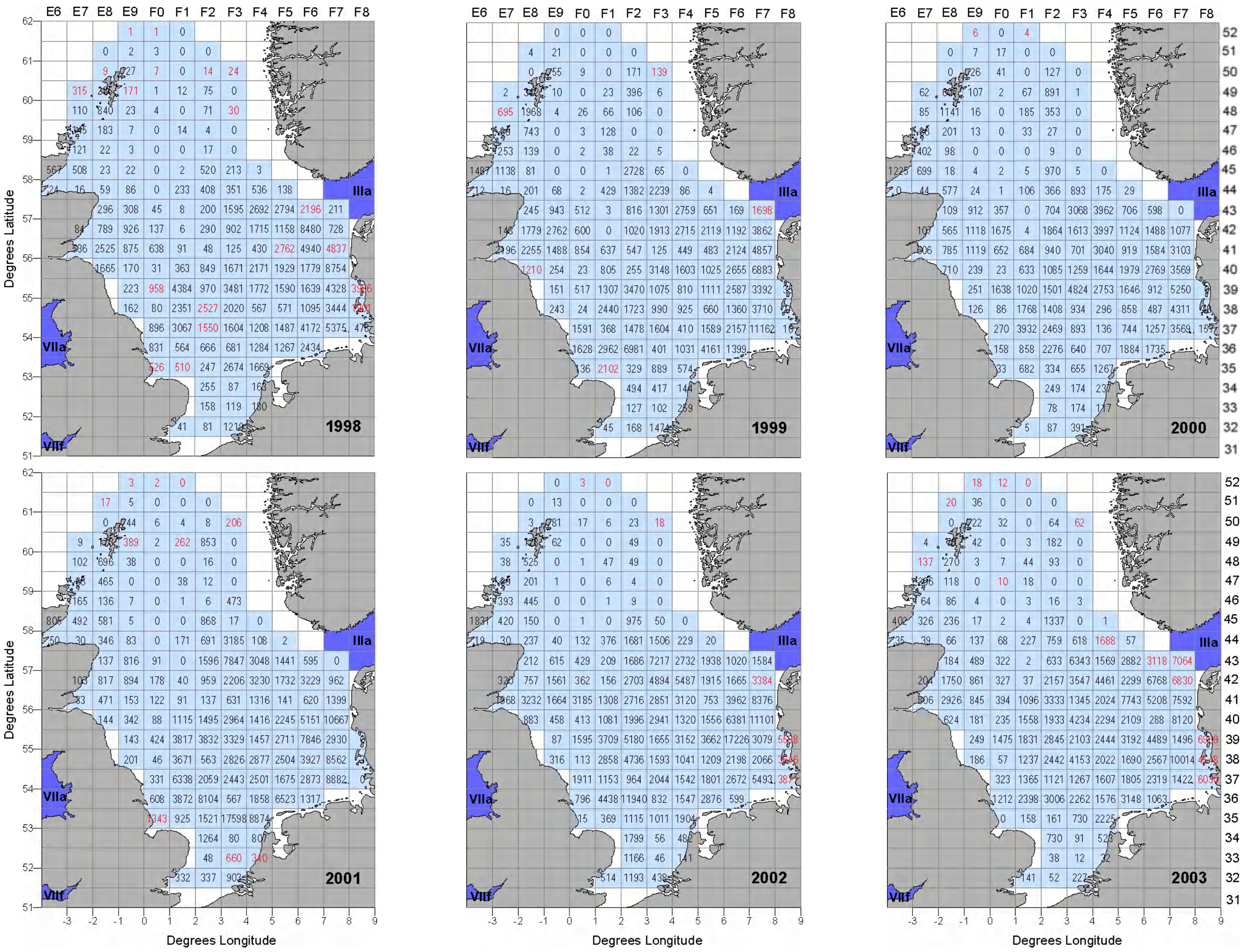


Figure 3.18. Biomass (tonnes) of long rough dab in each statistical rectangle, 1998 to 2003.

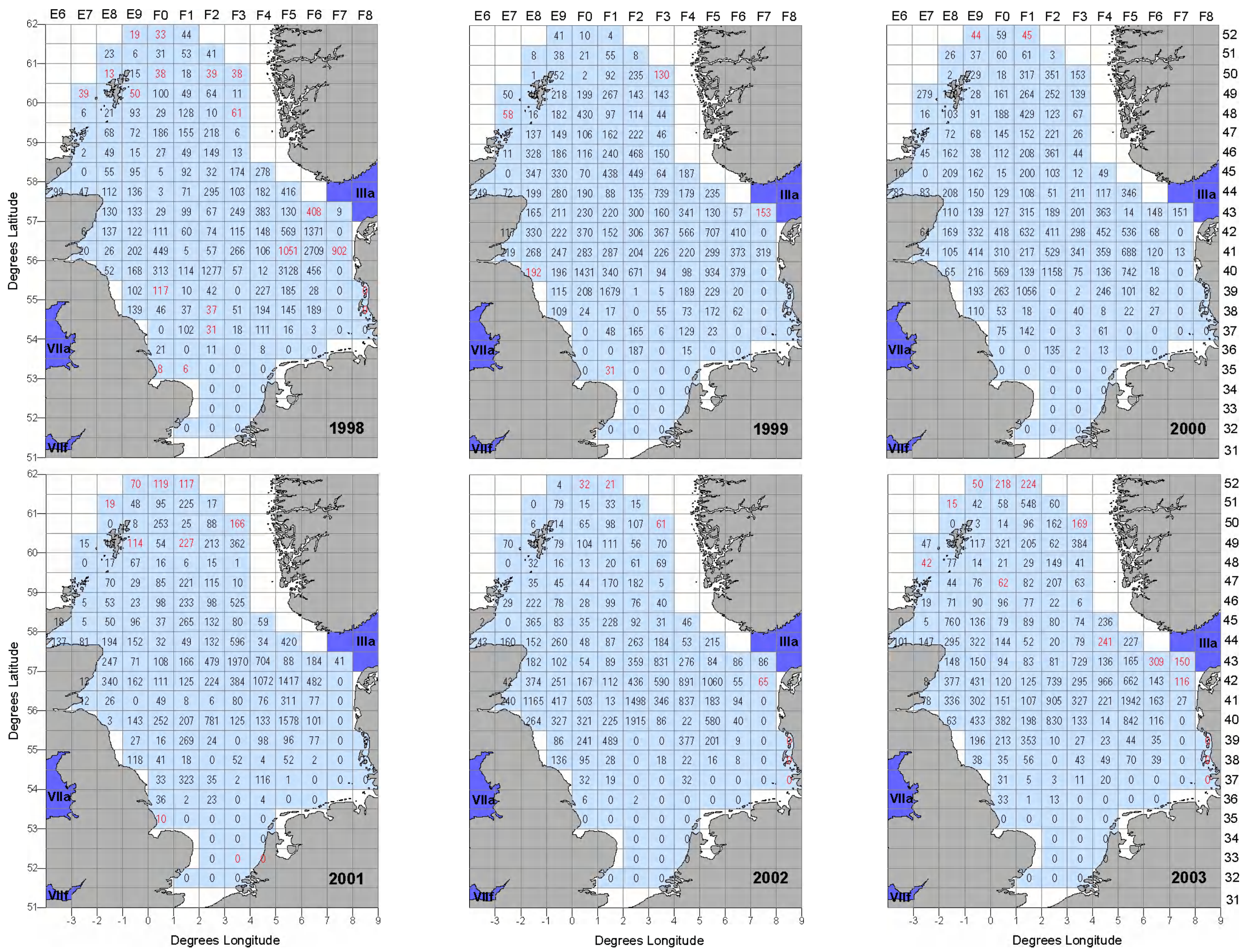


Figure 3.19. Biomass estimates for each of the nine species 1998 to 2003 using the IBTS 3rd Quarter data. (HAD is haddock, WHI is whiting, COD is Cod, NPO is Norway pout, GGU is grey gurnard, PLA is plaice, LSO is lemon sole, CDA is common dab, LRD is long rough dab).

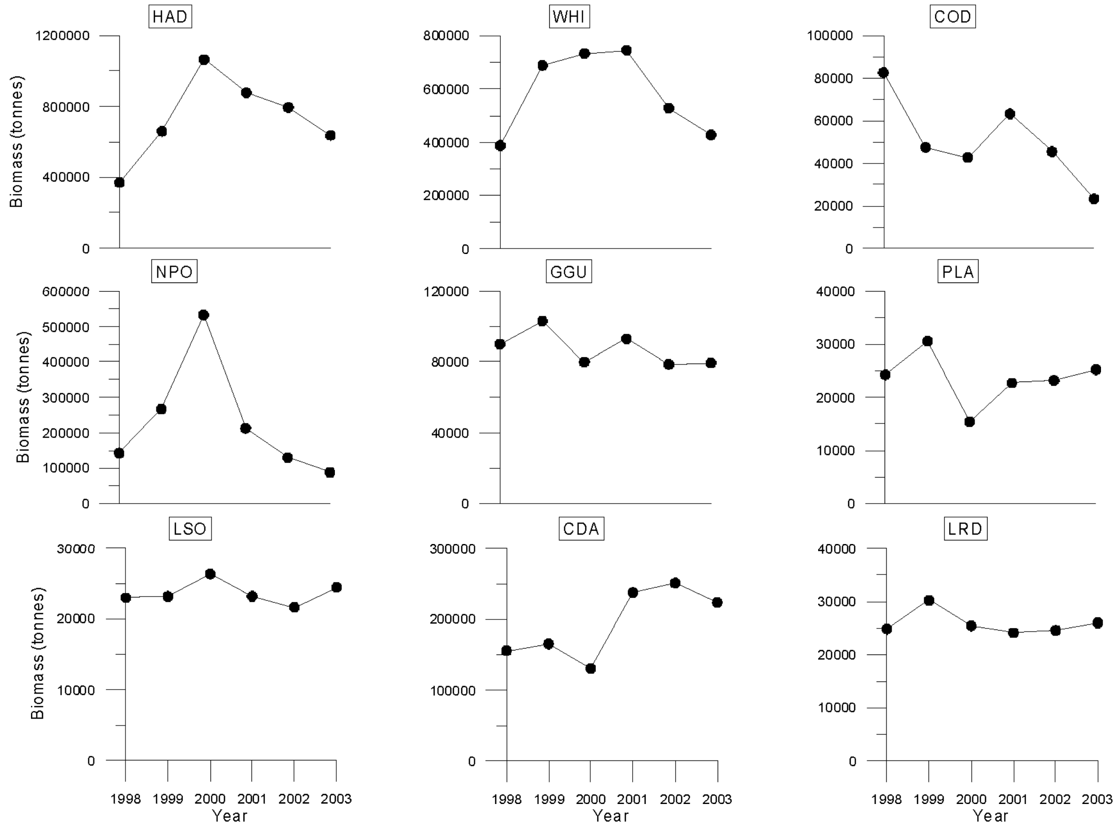


Figure 3.20. Comparison of the IBTS derived biomass estimates of the five "assessed" species, cod, haddock, whiting, Norway pout and plaice, with estimates of total stock biomass derived from VPA in the stock assessments made by the ICES WGNSSK (ICES 2003a).

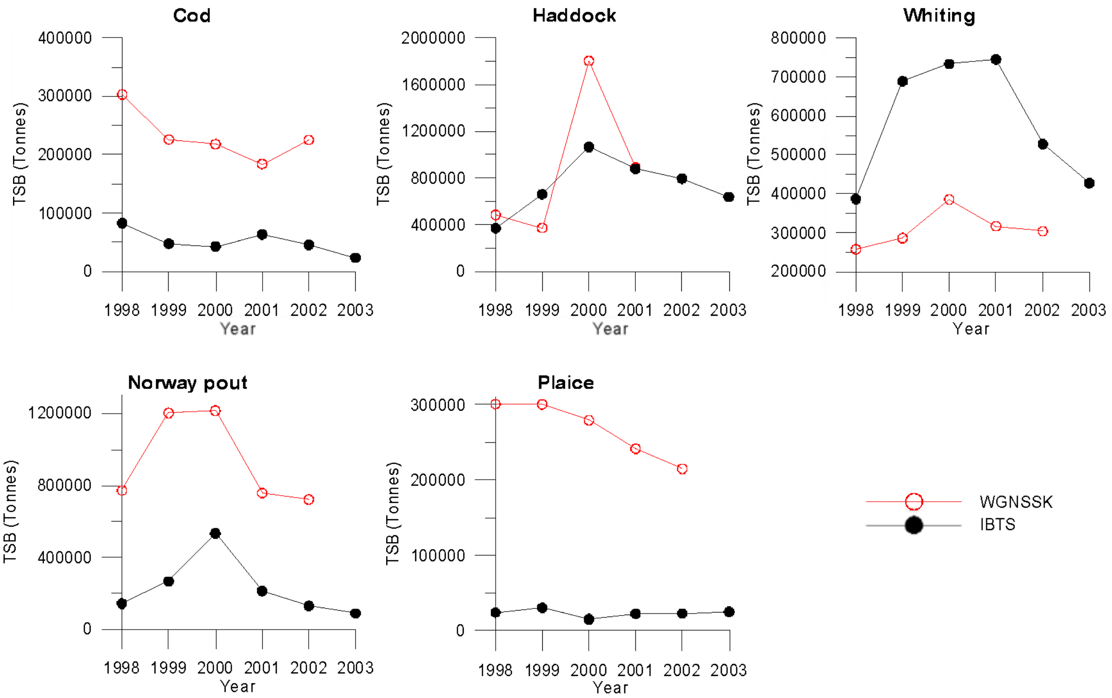


Figure 3.21. PRIMER dendrogram: clustering of statistical rectangles which have a similar species composition using the 1998 IBTS data. In this figure, four separate clusters are identified at a similarity of 35%. A sub cluster with a similarity of 45% is also indicated. The symbols correspond to those shown in figures 4.33 and 4.34.

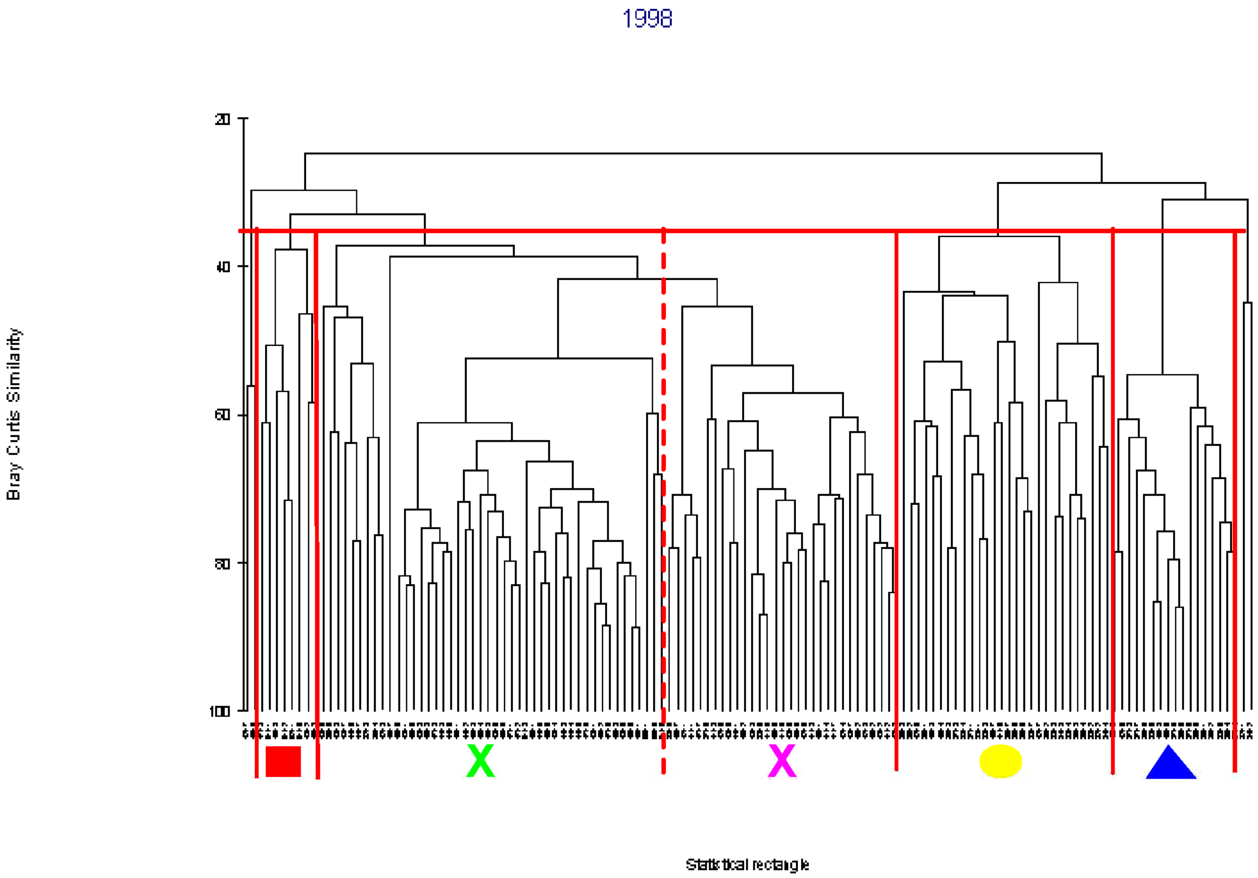


Figure 3.22. Results of the cluster analysis including all fish species for each year 1998 to 2003. Clusters ■, ●, ▲ (X, X) have a similarity of 35%, X and X are sub-clusters at a similarity of 40%.

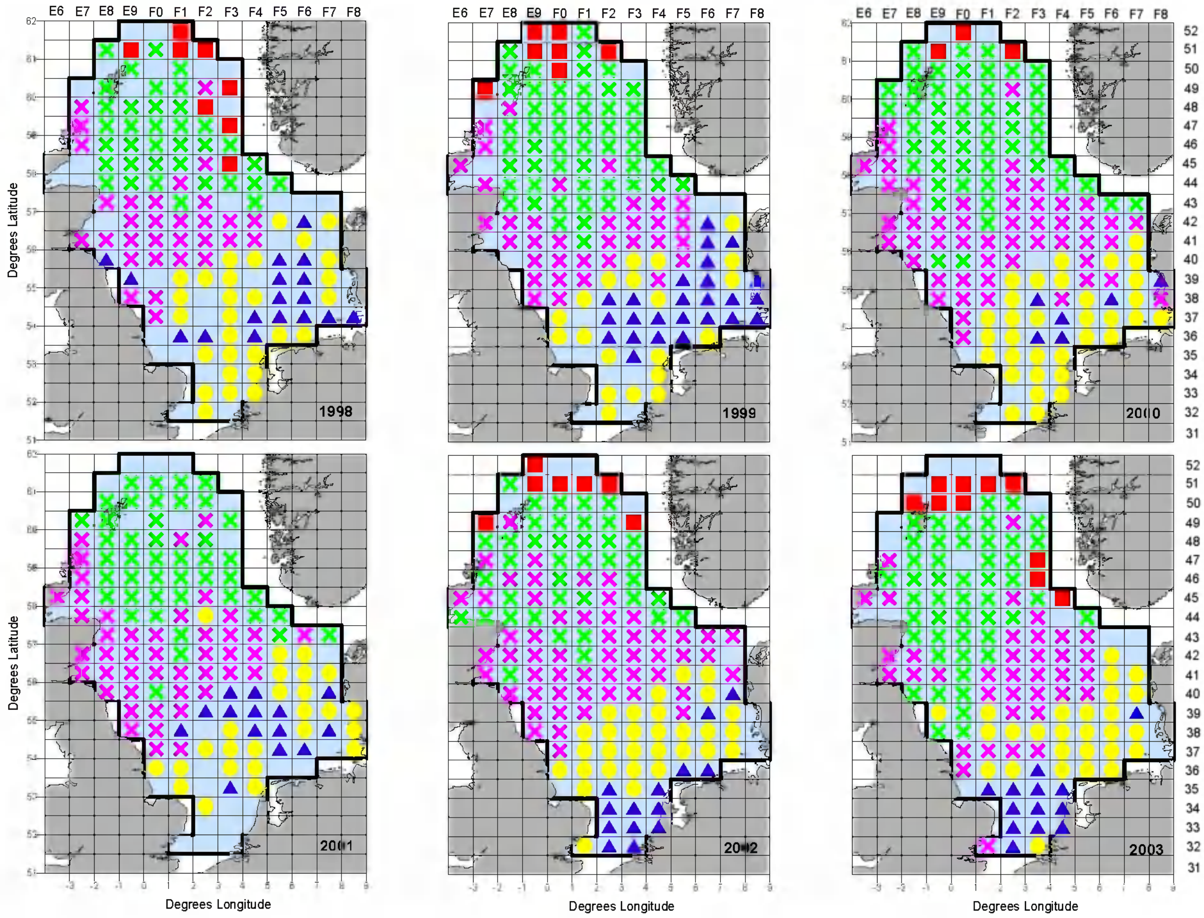


Figure 3.23. Results of the cluster analysis for all fish species for all six years combined. Clusters ■, ●, ▲ (X, X) have a similarity of 35%. X and X are sub-clusters at a similarity of 40%.

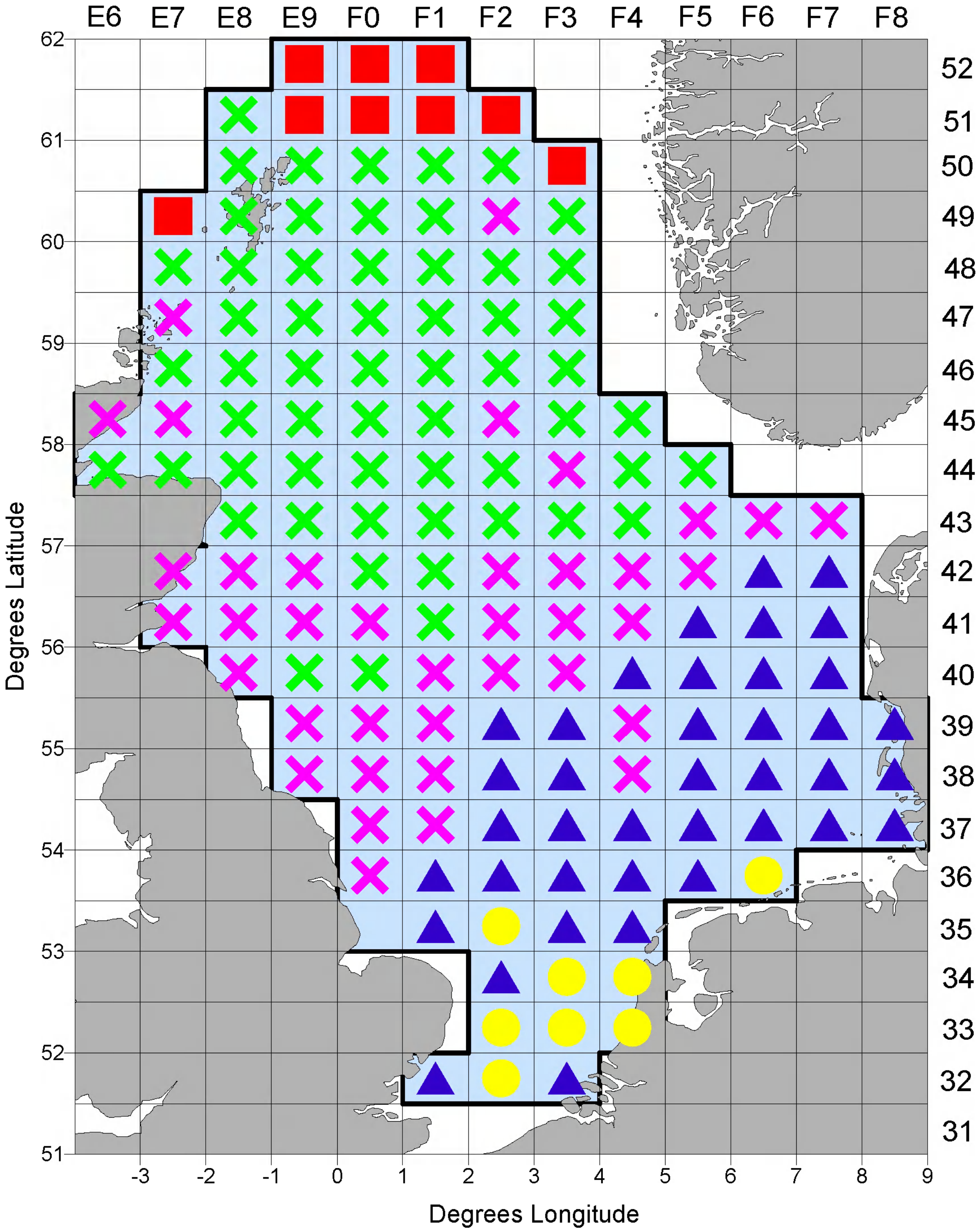


Figure 3.24. Results of the cluster analysis for demersal fish only for each year 1998 to 2003. Clusters ■, ●, ▲ and + have a similarity of 40%.

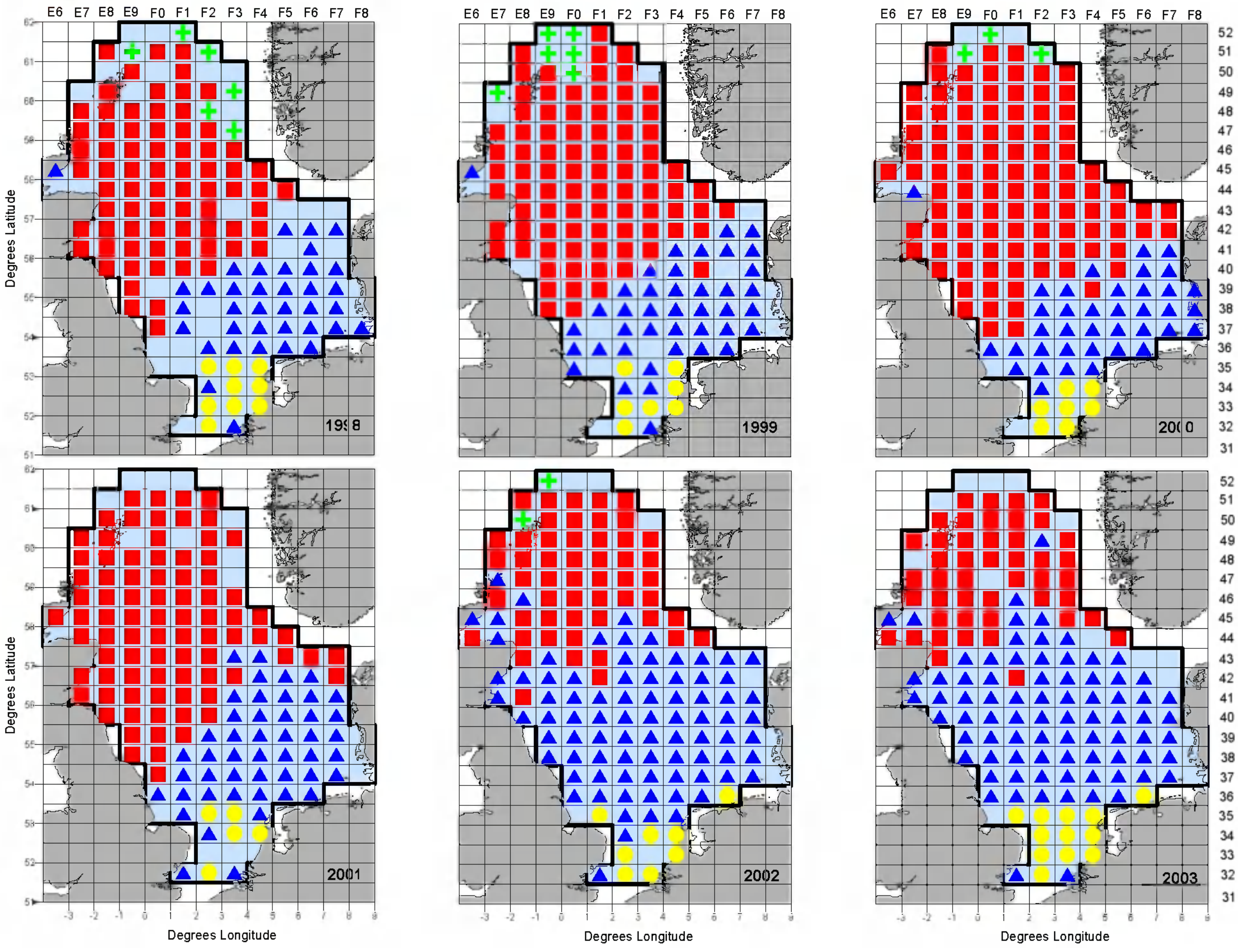


Figure 3.25. Results of the cluster analysis for demersal fish only for all six years combined. Clusters ■, ●, ▲ and + have a similarity of 40%.

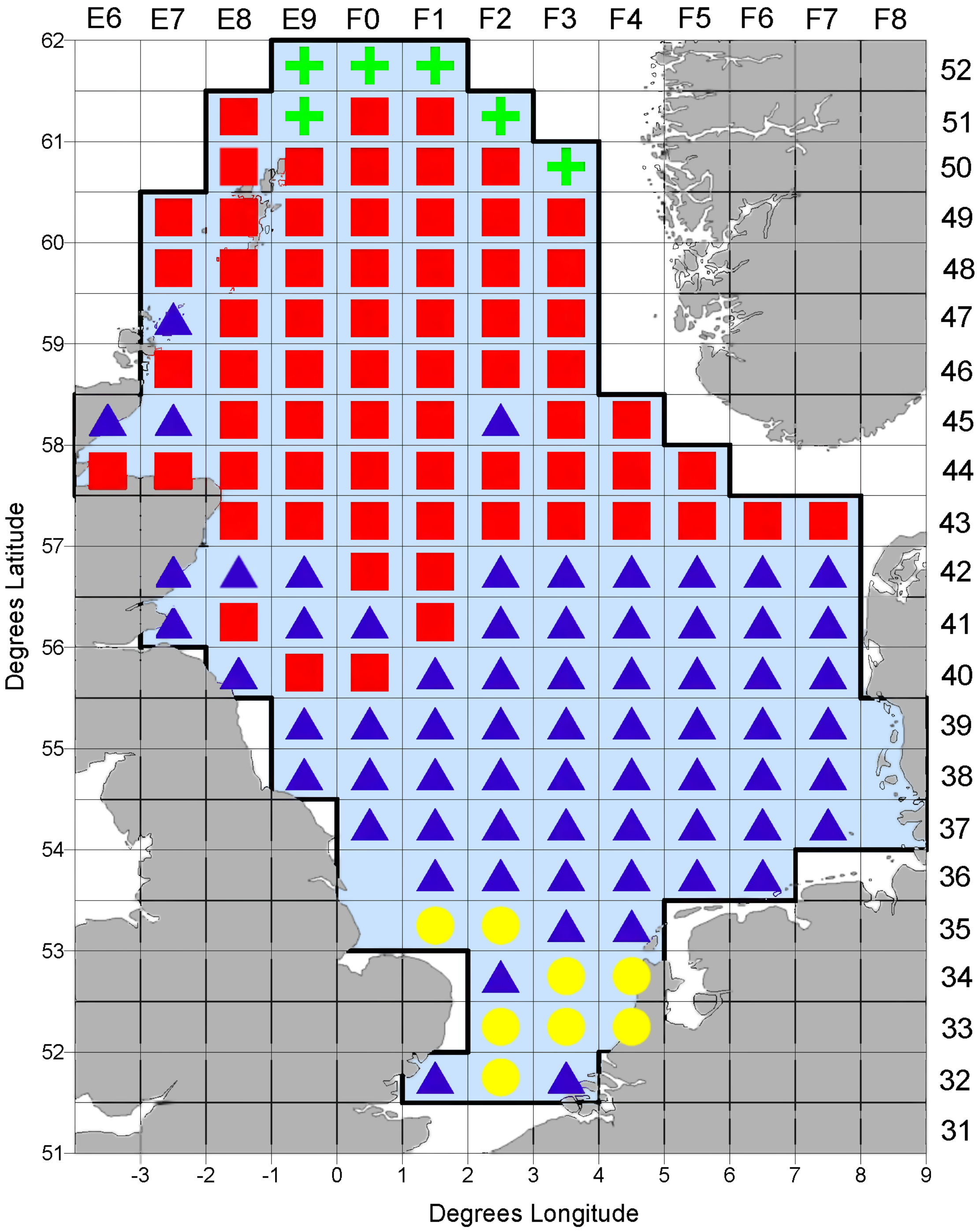


Figure 3.26. Changes in average weight (g) of demersal species in each statistical rectangle from 1998 to 2003. Symbol size ranges from 0 to 627g.

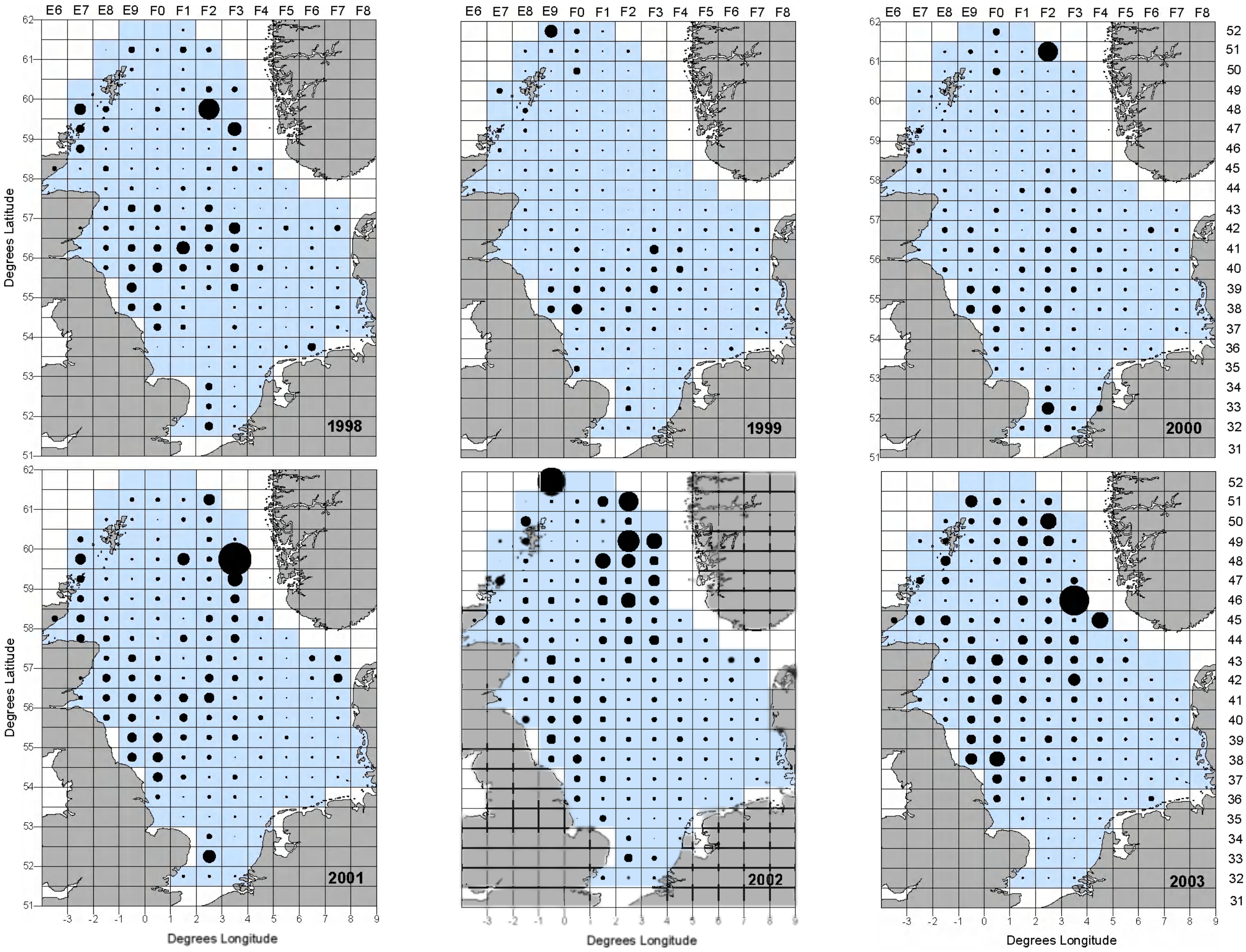


Figure 3.27. Changes in average weight (g) of demersal fish in each of the community composition clusters.

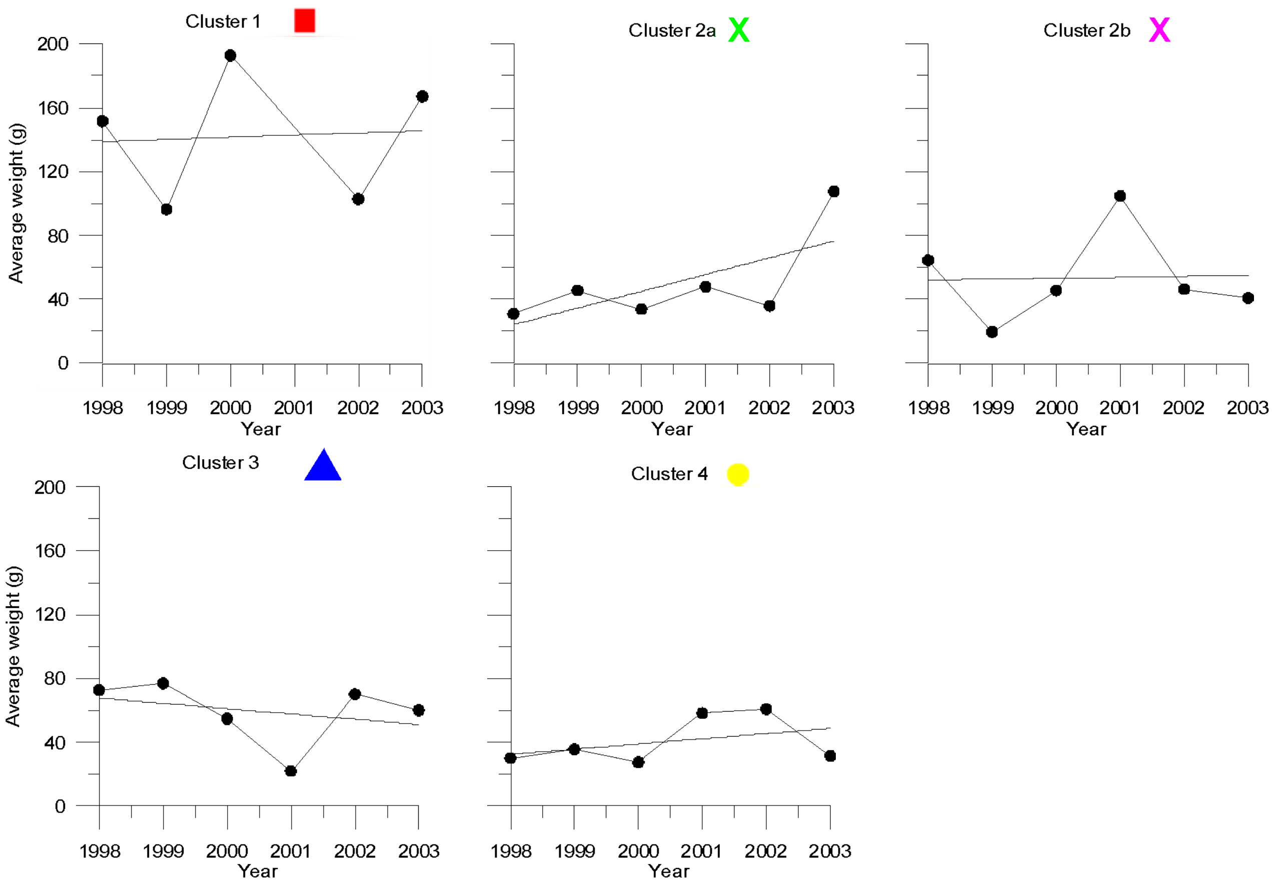


Figure 3.28. Species richness (S) in statistical rectangles fished more than five times during the period 1998 to 2003. Symbol size ranges from 16 to 41 species.

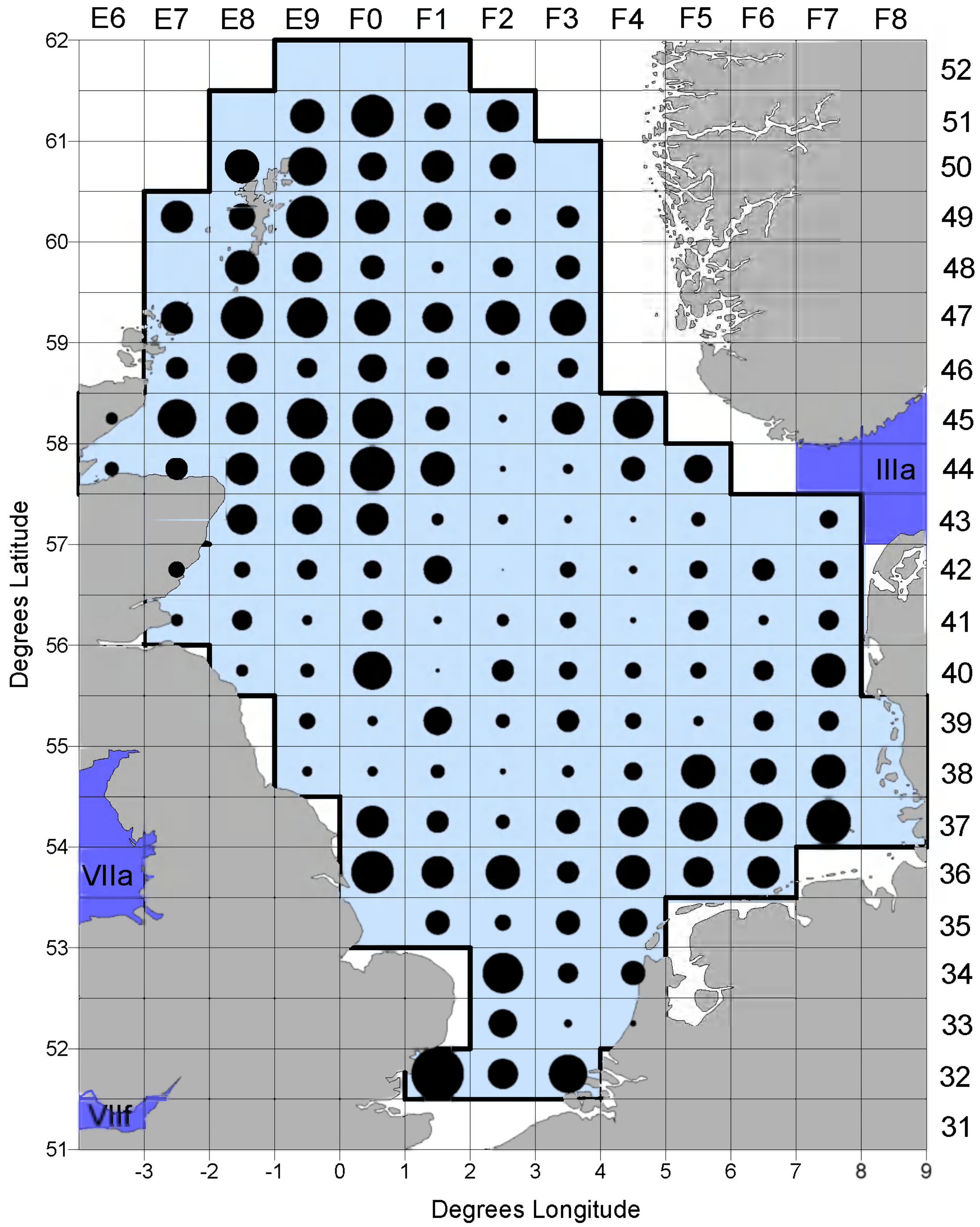


Figure 3.29. Shannon-Wiener diversity index (H') for statistical rectangles fished more than five times during the period 1998 to 2003. Symbol size ranges from 0.30 to 1.93.

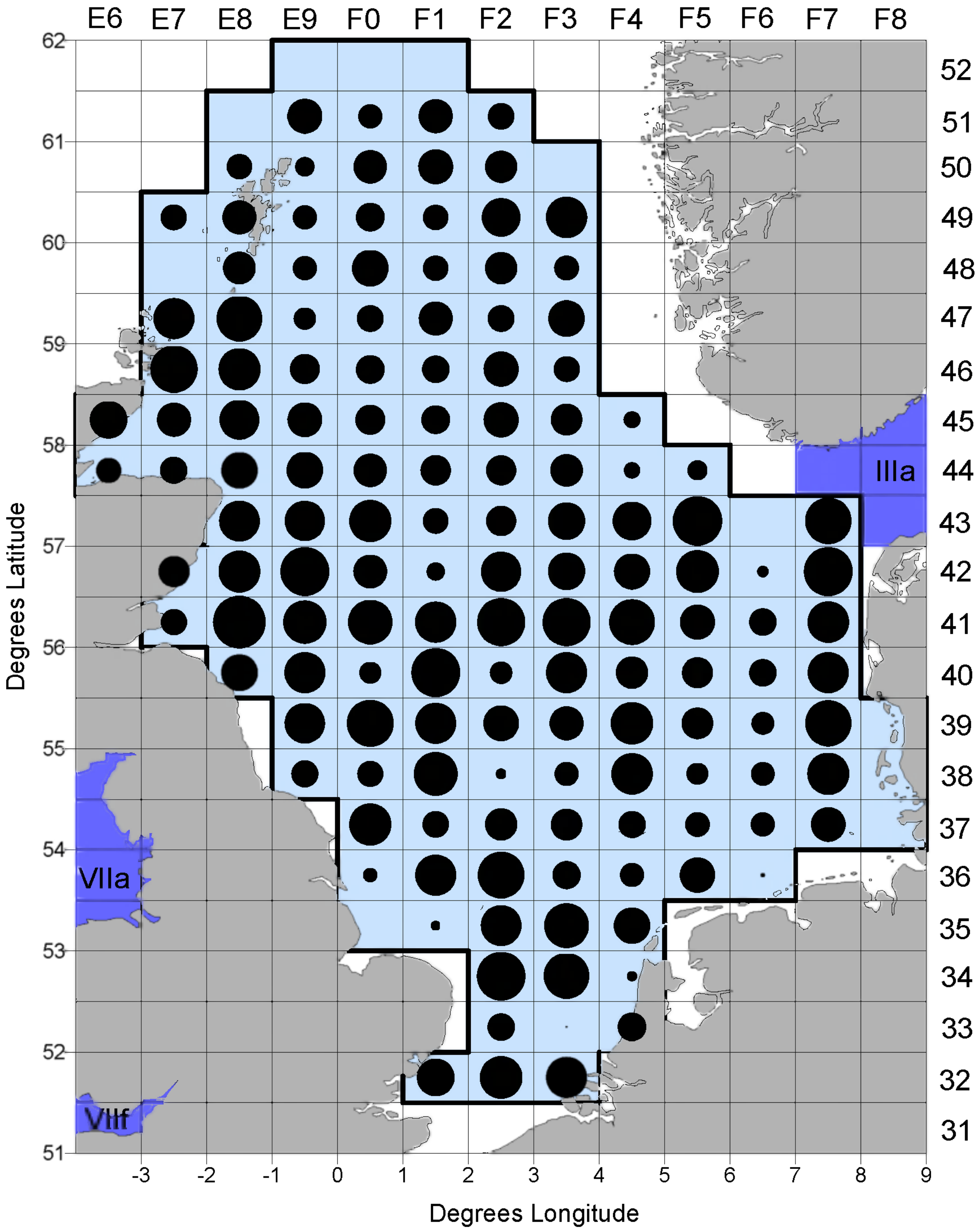


Figure 3.30. Simpson index (λ) for statistical rectangles fished more than five times during the period 1998 to 2003. Symbol size ranges from 0.17 to 0.88.

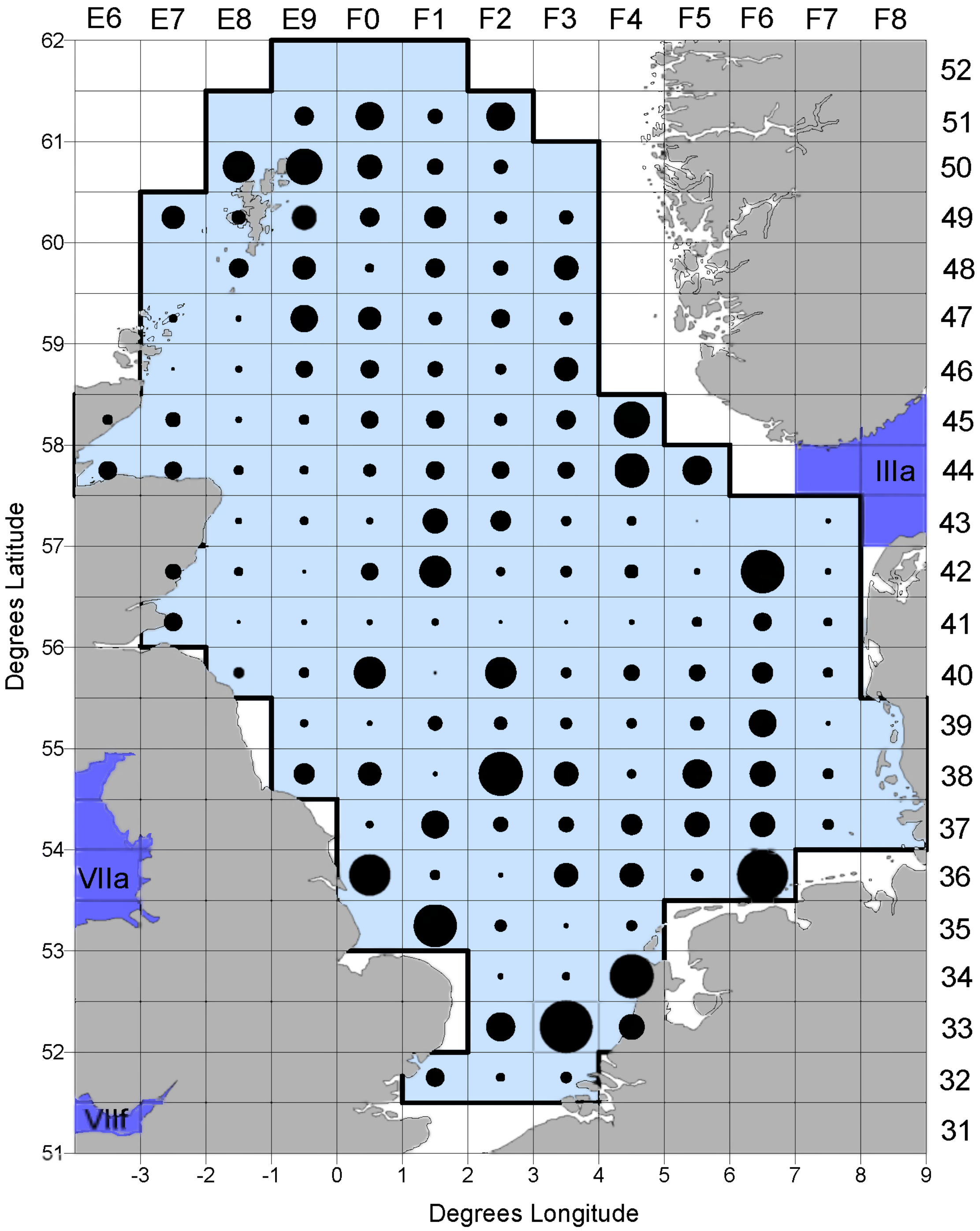


Figure 3.31. Hills N_2 for statistical rectangles fished more than five times during the period 1998 to 2003. Symbol size ranges from 1.12 to 5.69.

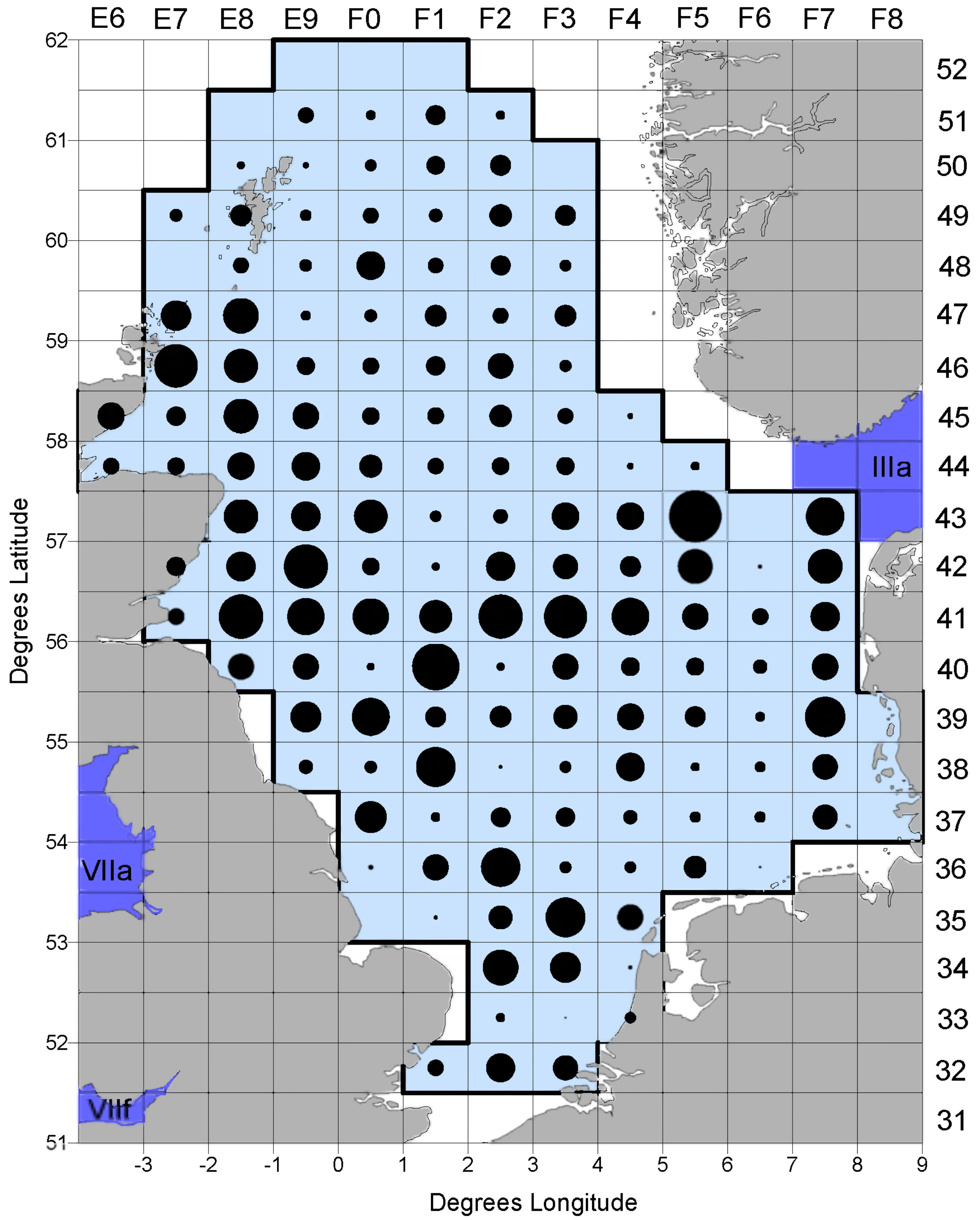


Figure 3.32. Location of the Norwegian fishing stations in 2003.

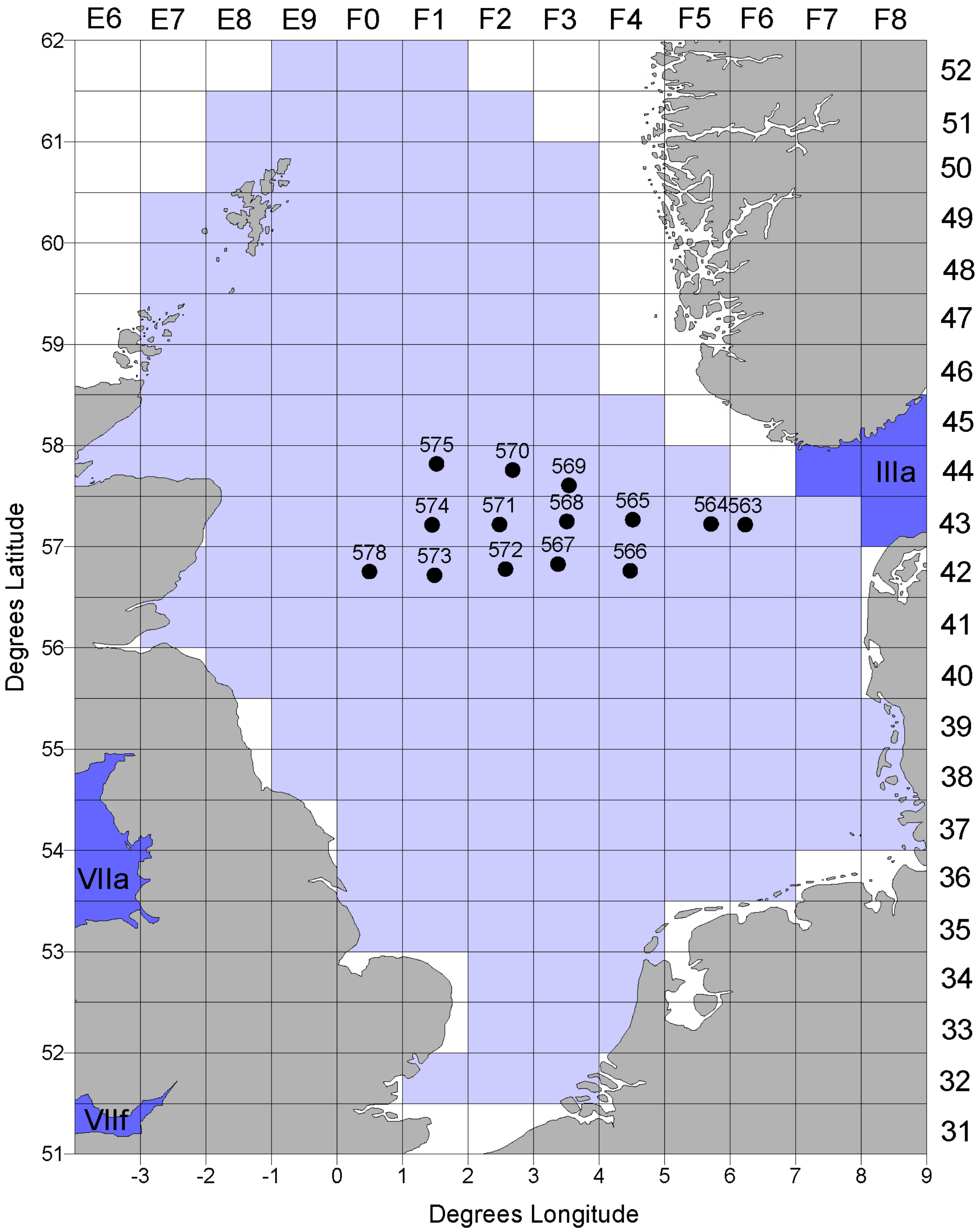


Figure 3.33. Comparison of the biomass estimates made using the Norwegian data alone and the whole of the IBTS dataset for 14 statistical rectangles in 2003.

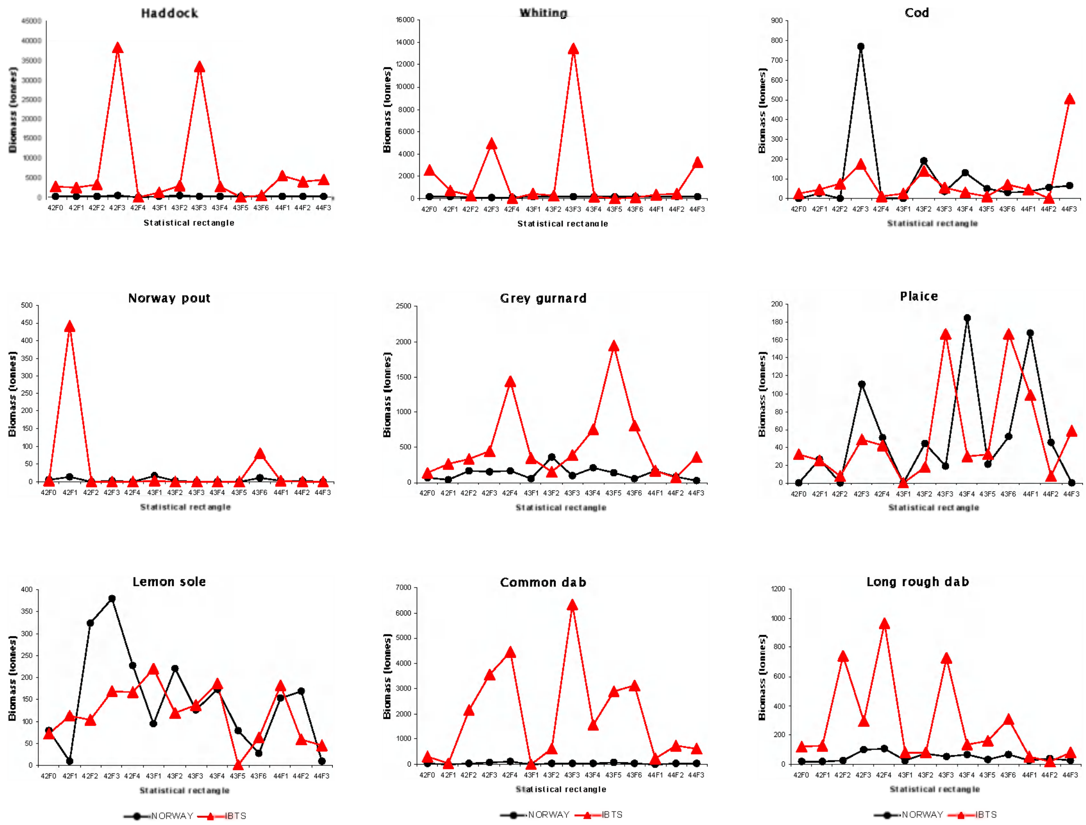


Figure 3.34. Cumulative species curves for both the Norwegian and IBTS data, 2003.

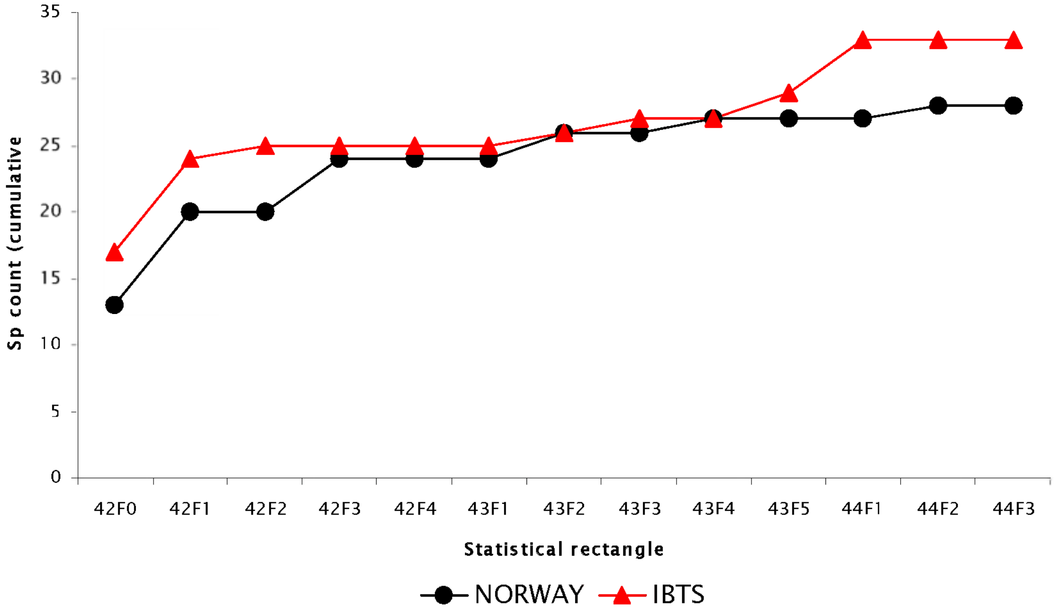


Figure 3.35. Location of the Dutch 8m-beam trawl station during the 3rd Quarter, 2003.

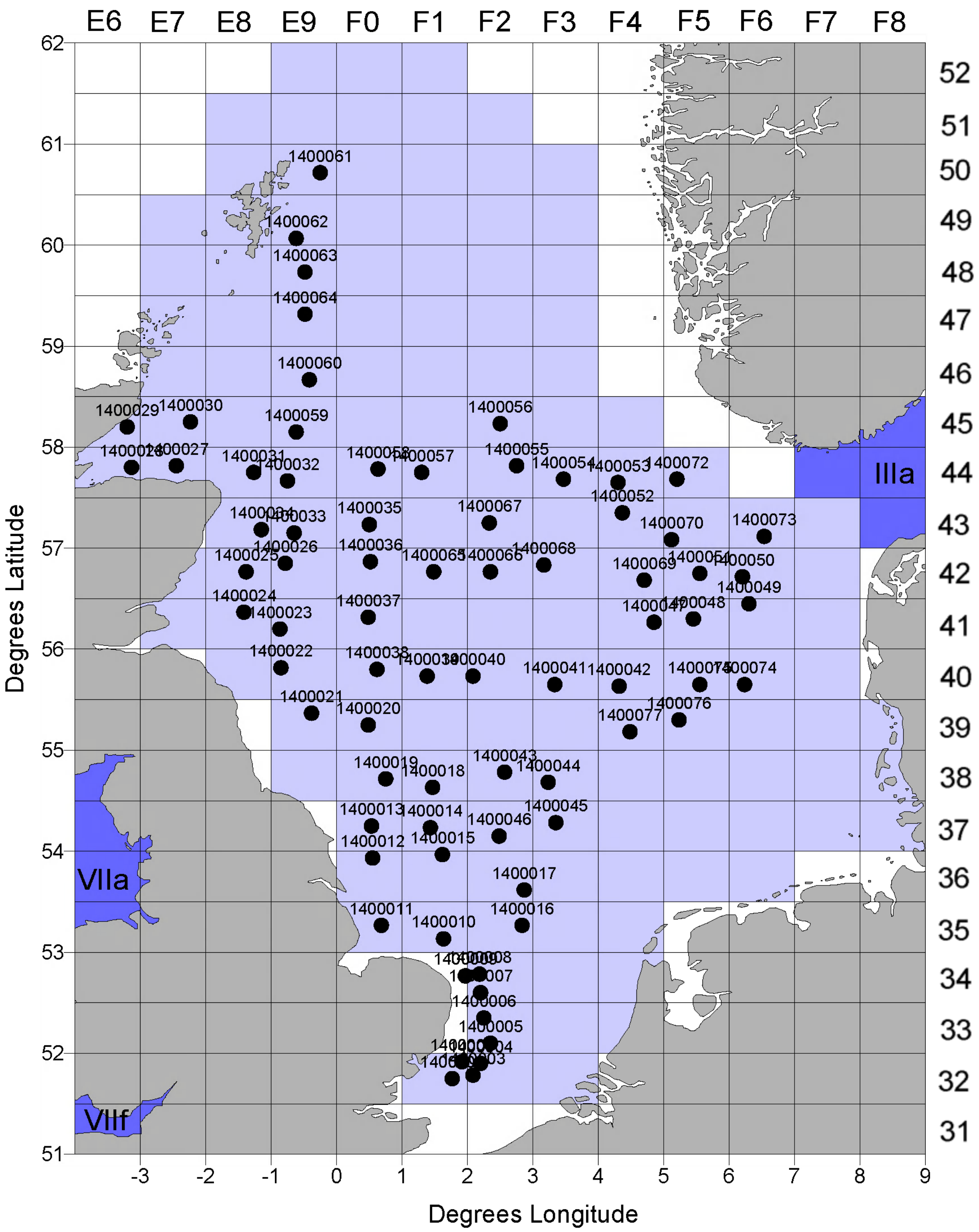
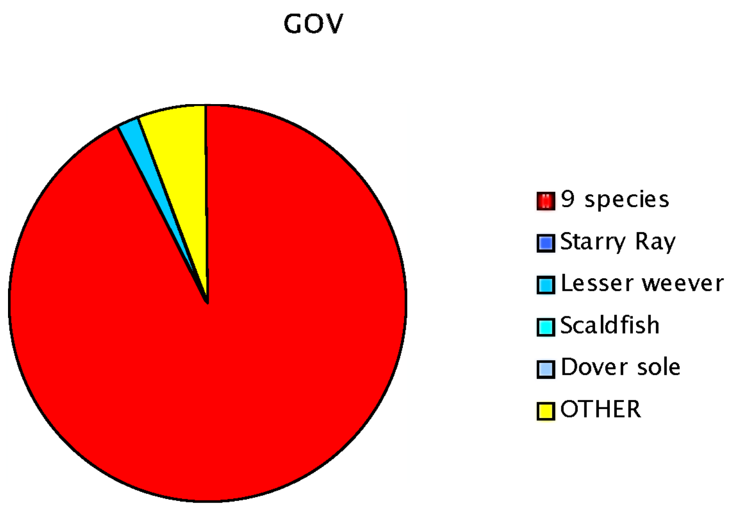


Figure 3.36. The percentage contribution to the total number of demersal fish made up by the nine selected species (haddock, whiting, cod, Norway pout, grey gurnard, plaice, lemon sole, common dab and long rough dab) in the GOV and the 8m-beam trawl datasets in 2003.



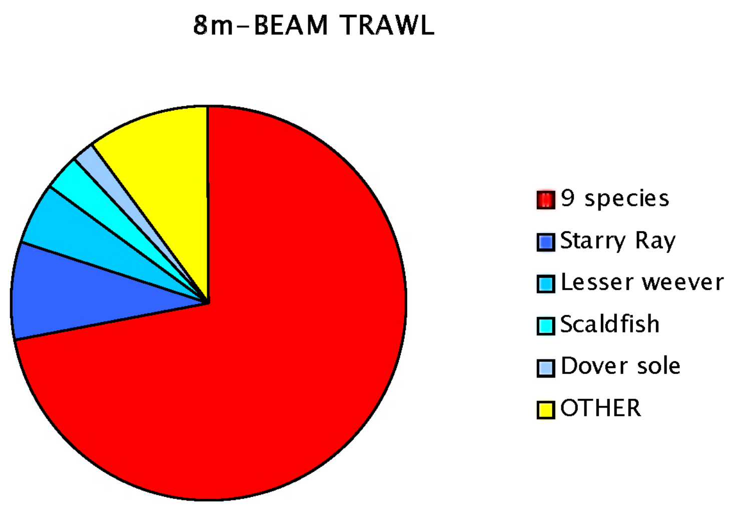


Figure 3.37. The biomass estimate of haddock made using the GOV data subtracted from the biomass estimates of haddock made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

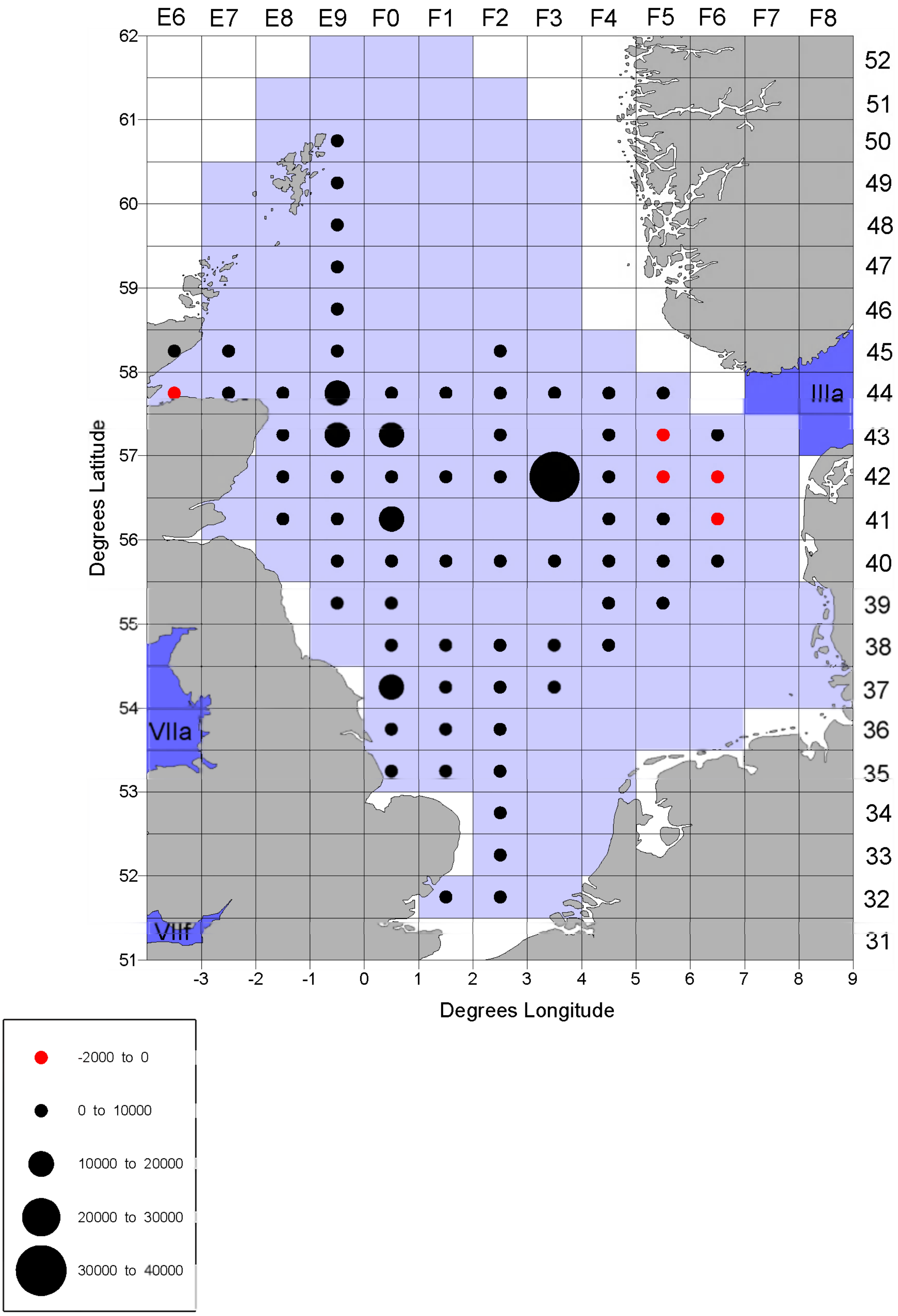


Figure 3.38. The biomass estimate of whiting made using the GOV data subtracted from the biomass estimates of whiting made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

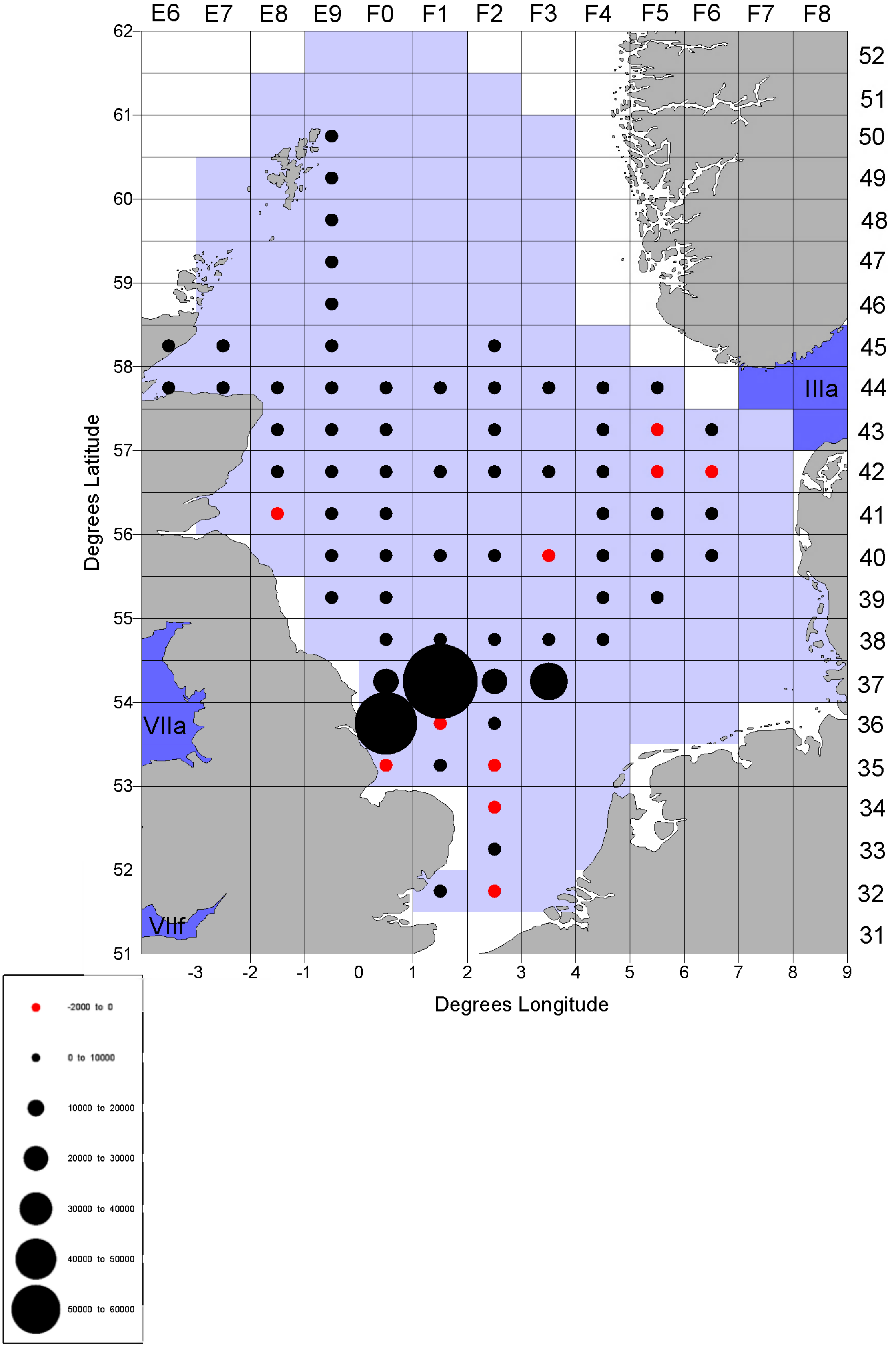


Figure 3.39. The biomass estimate of cod made using the GOV data subtracted from the biomass estimates of cod made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

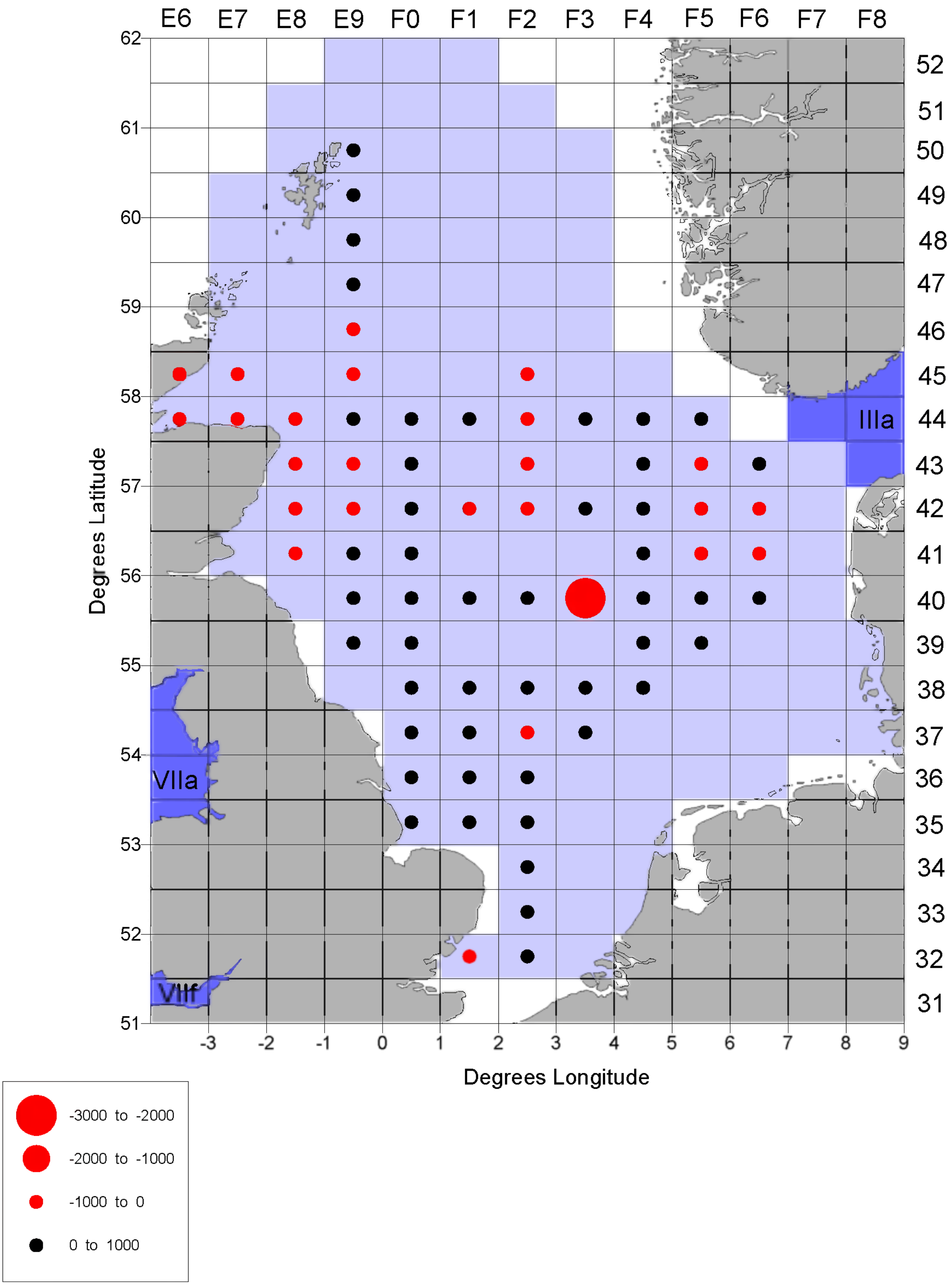


Figure 3.40. The biomass estimate of Norway pout made using the GOV data subtracted from the biomass estimates of Norway pout made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

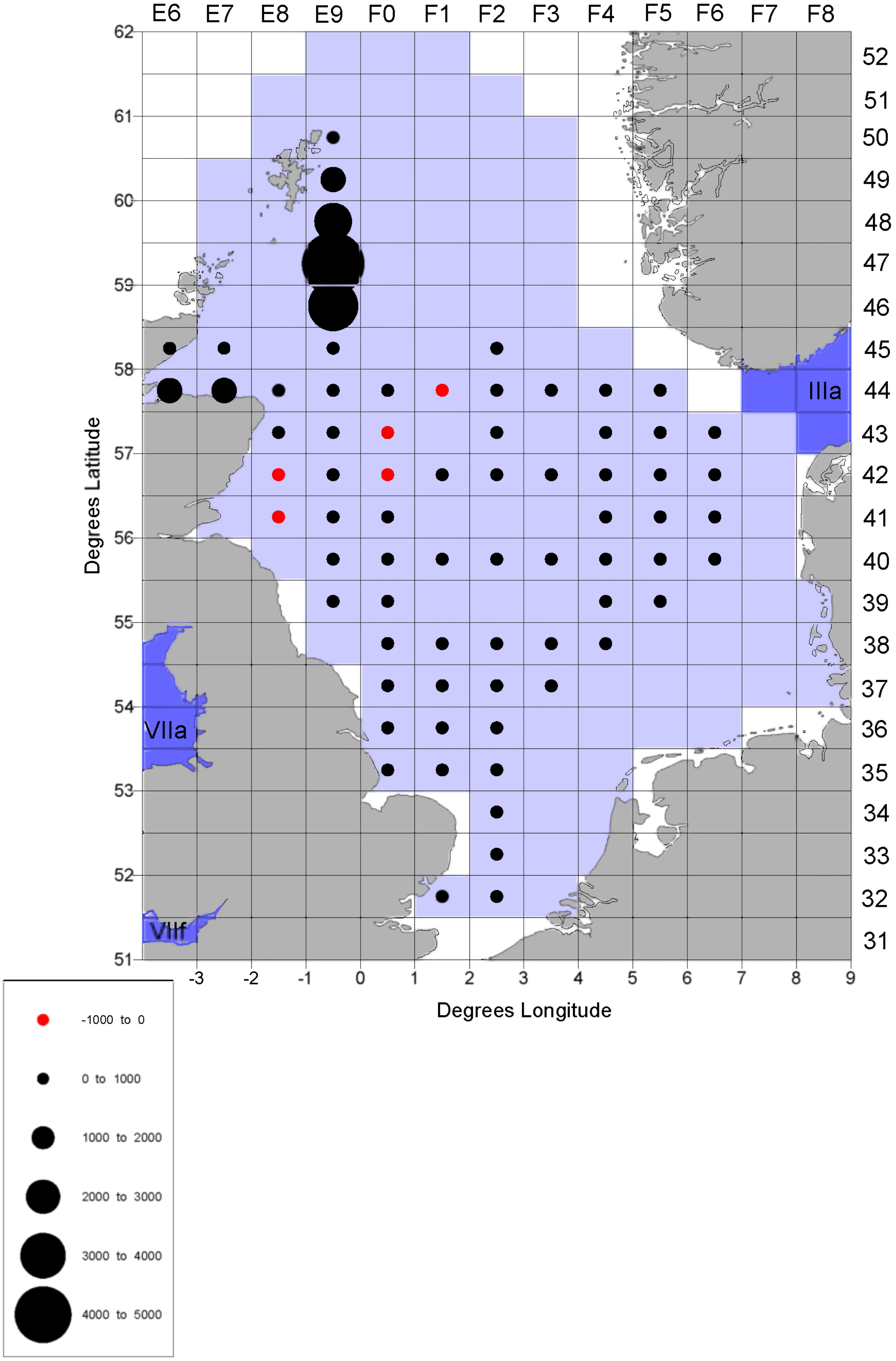


Figure 3.41. The biomass estimate of grey gurnard made using the GOV data subtracted from the biomass estimates of grey gurnard made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

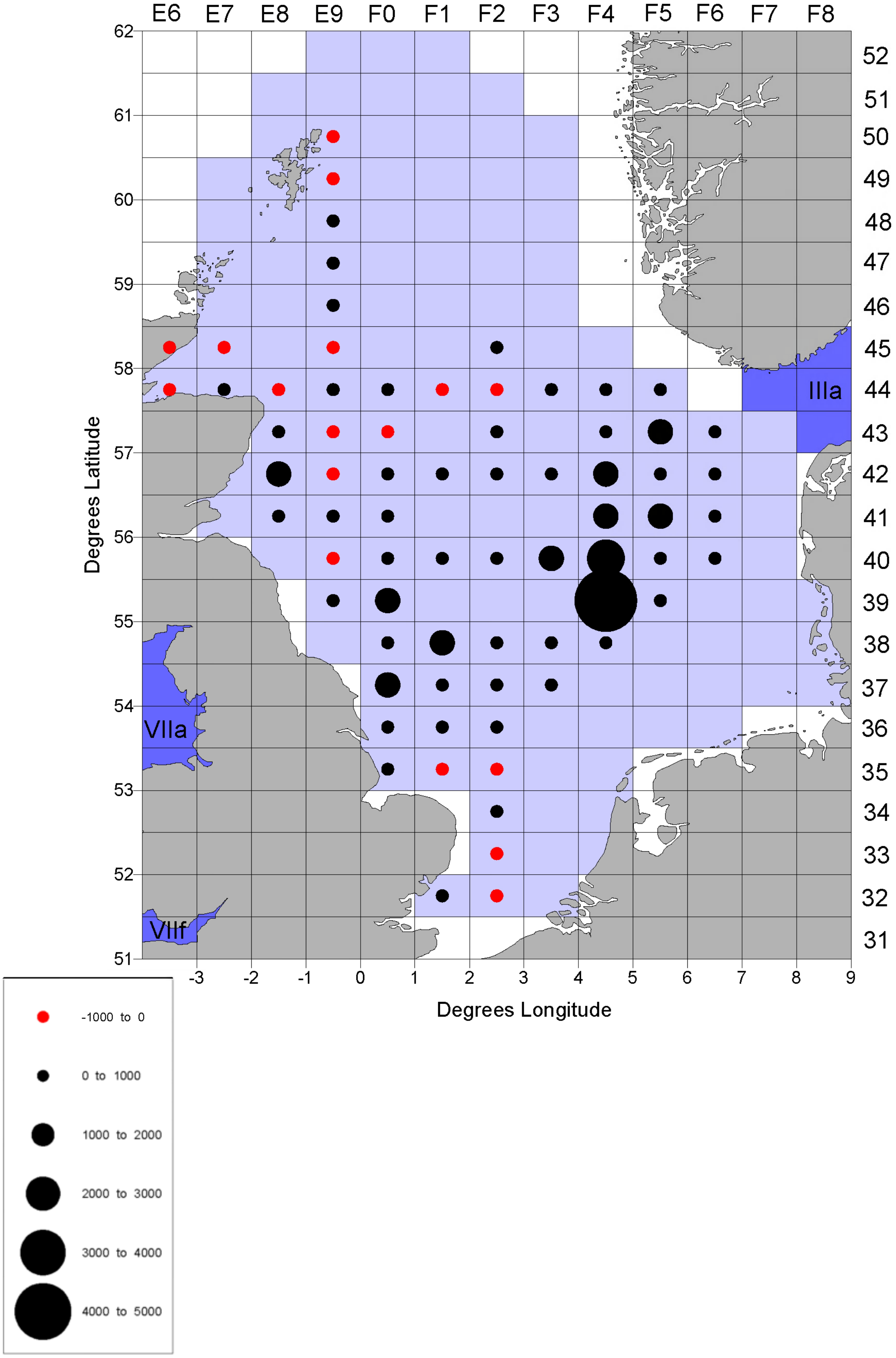


Figure 3.42. The biomass estimate of plaice made using the GOV data subtracted from the biomass estimates of plaice made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

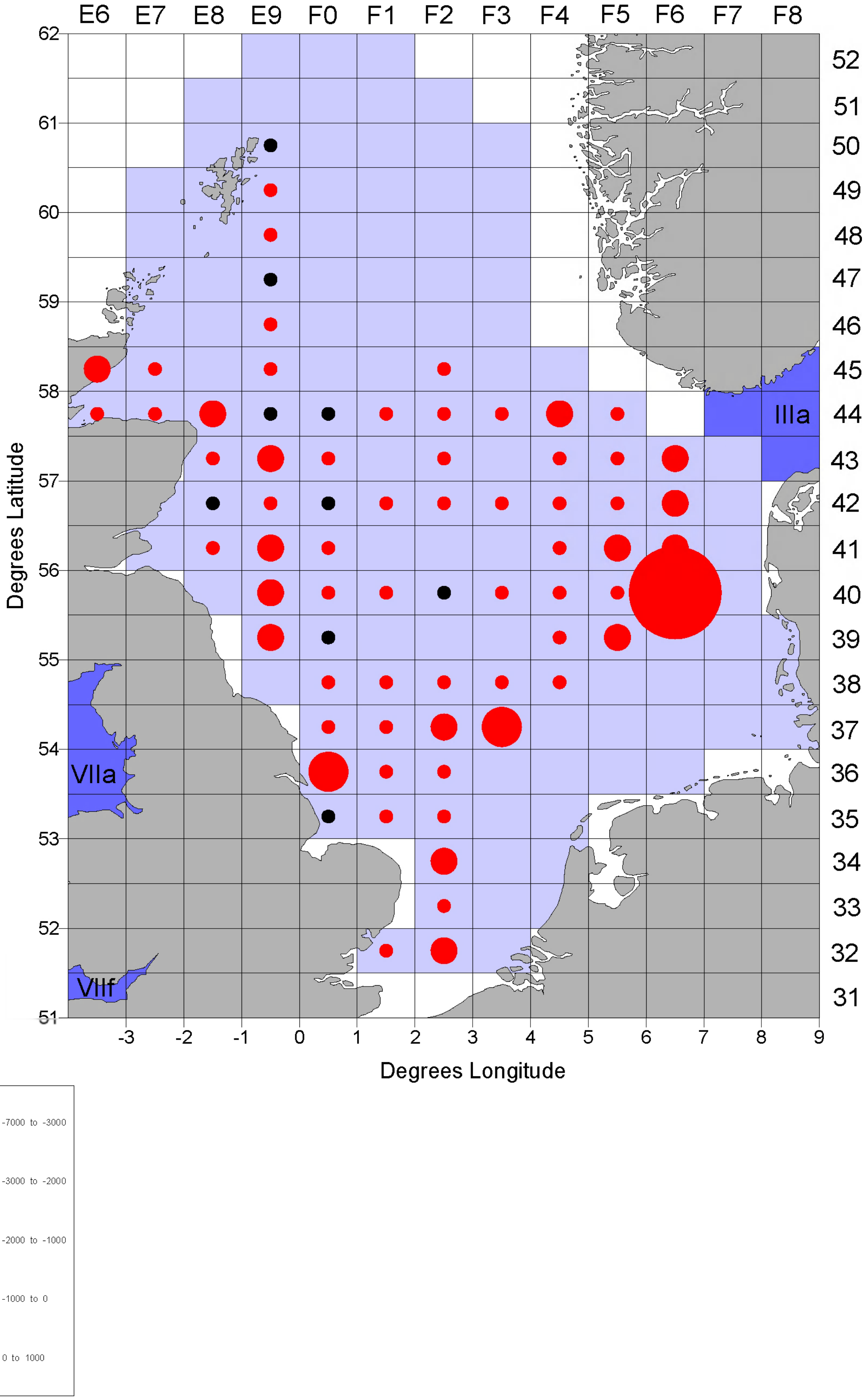


Figure 3.43. The biomass estimate of lemon sole made using the GOV data subtracted from the biomass estimates of lemon sole made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

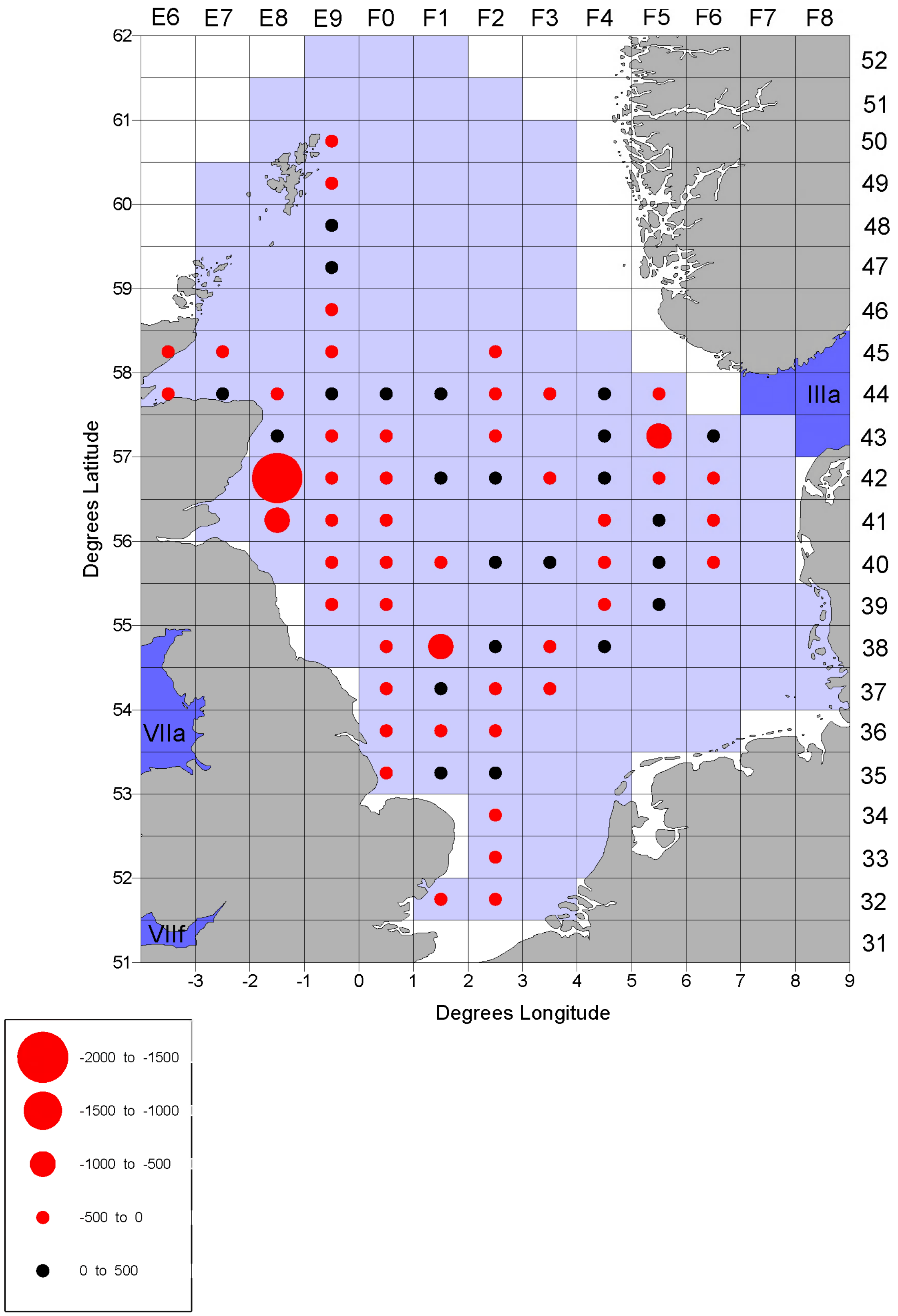


Figure 3.44. The biomass estimate of common dab made using the GOV data subtracted from the biomass estimates of common dab made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

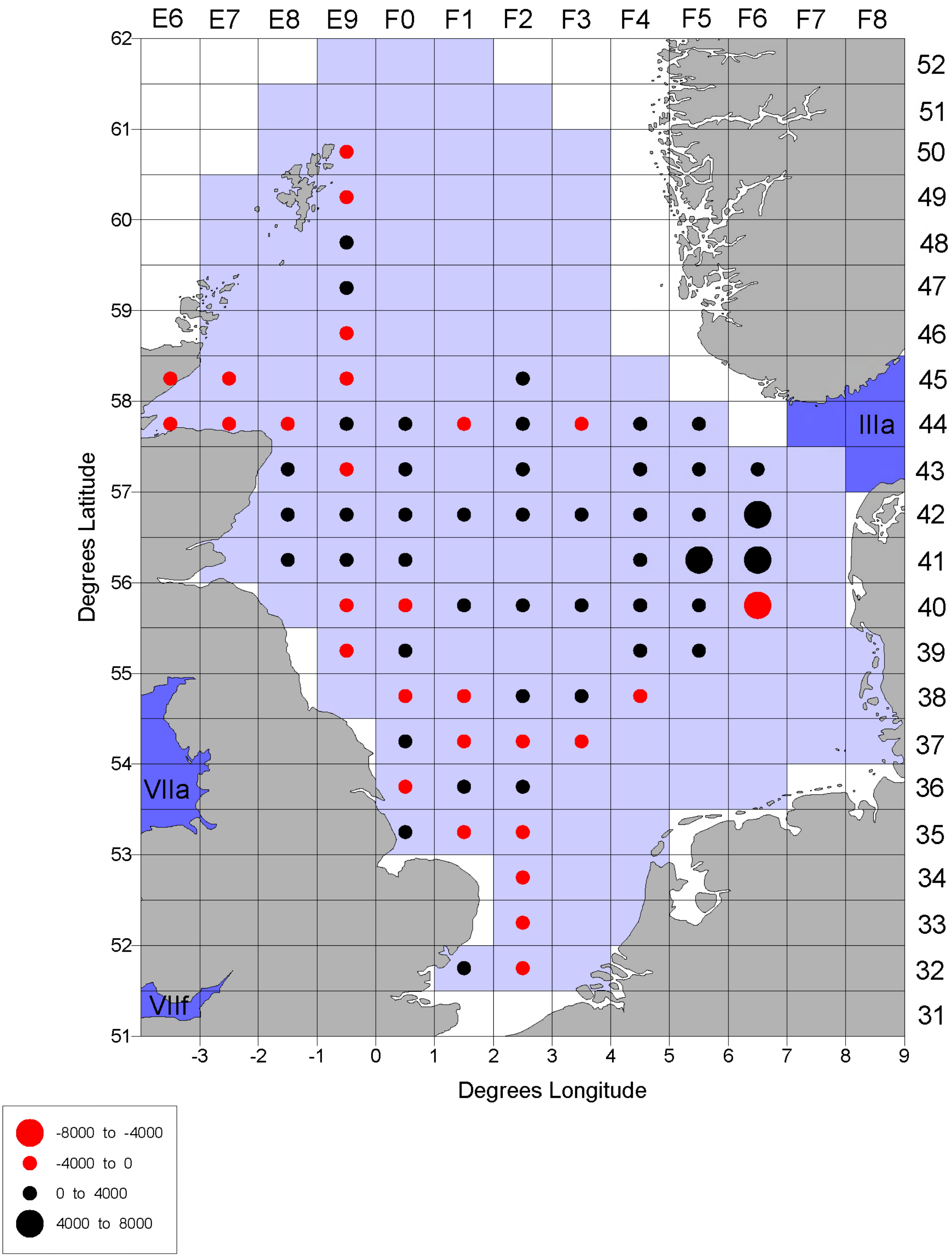


Figure 3.45. The biomass estimate of long rough dab made using the GOV data subtracted from the biomass estimates of long rough dab made using the 8m-beam trawl data set in each statistical rectangle. If symbols are black than the biomass estimates made using the GOV are higher, if symbols are red then the biomass estimates made using the 8m-beam trawl are higher.

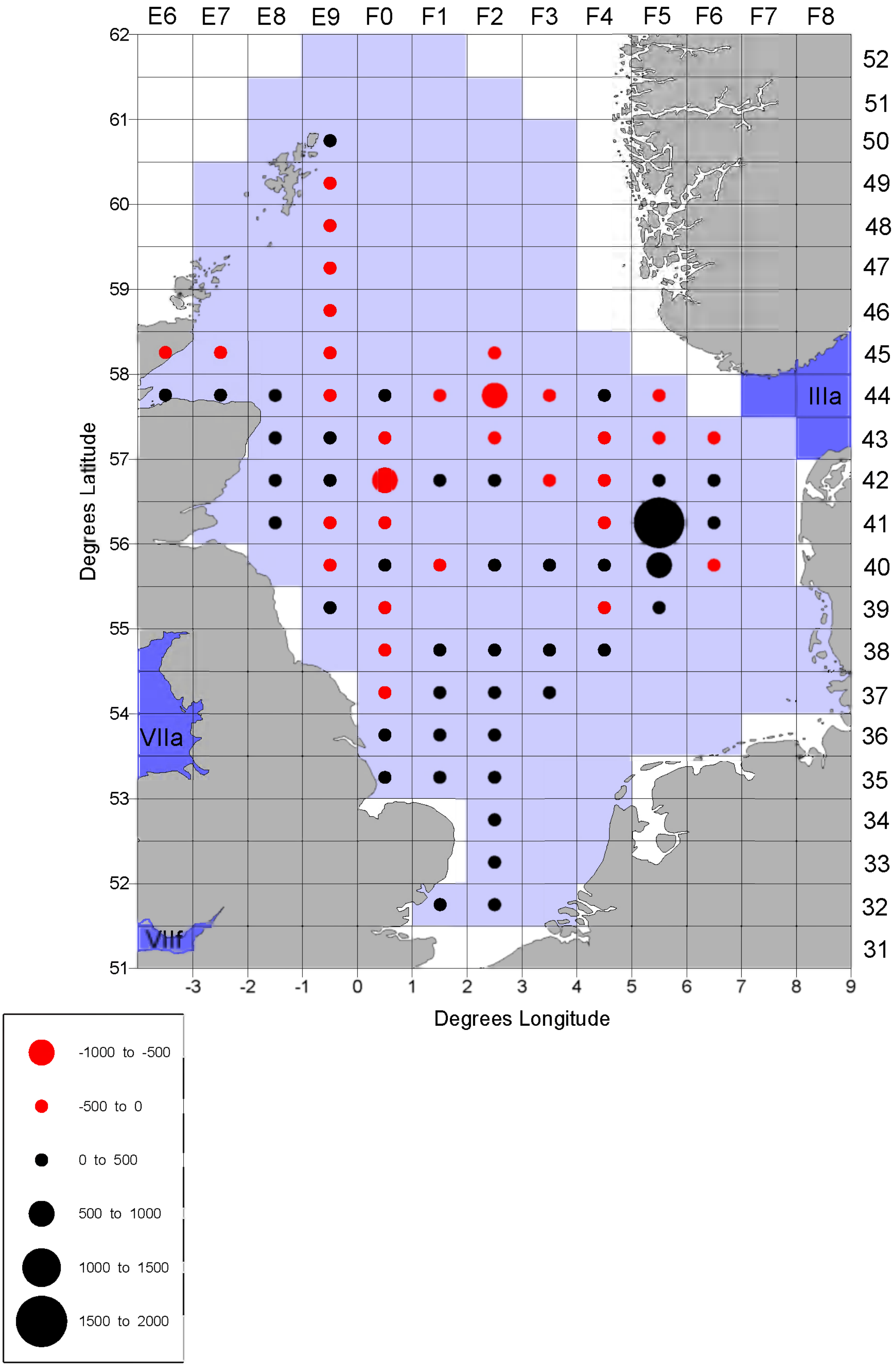
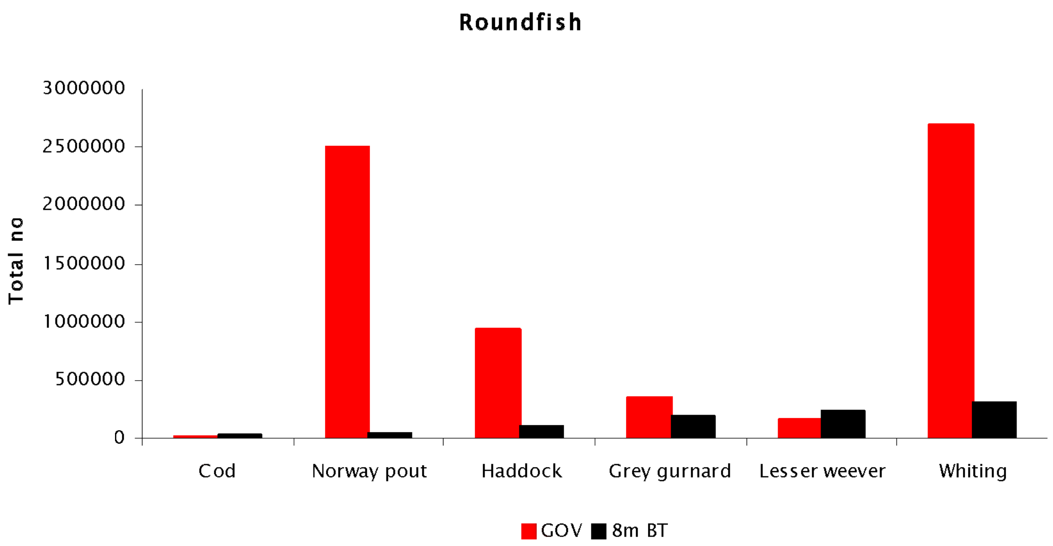


Figure 3.46. Differences in abundance estimates of fish species based on catches of the GOV and 8m-beam trawl.



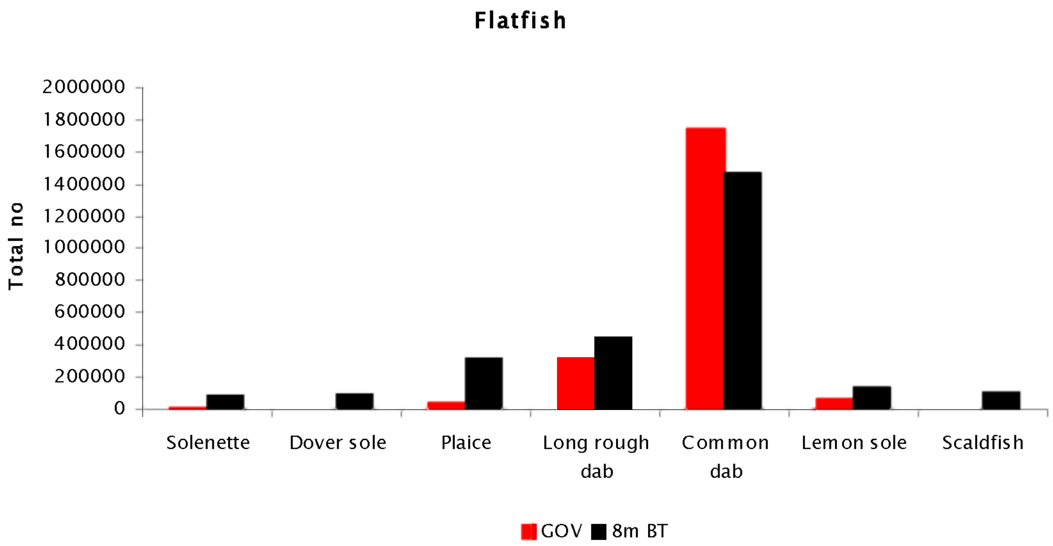


Figure 3.47. Cumulative species curves for both the Dutch 8m-beam trawl and the GOV in 2003.

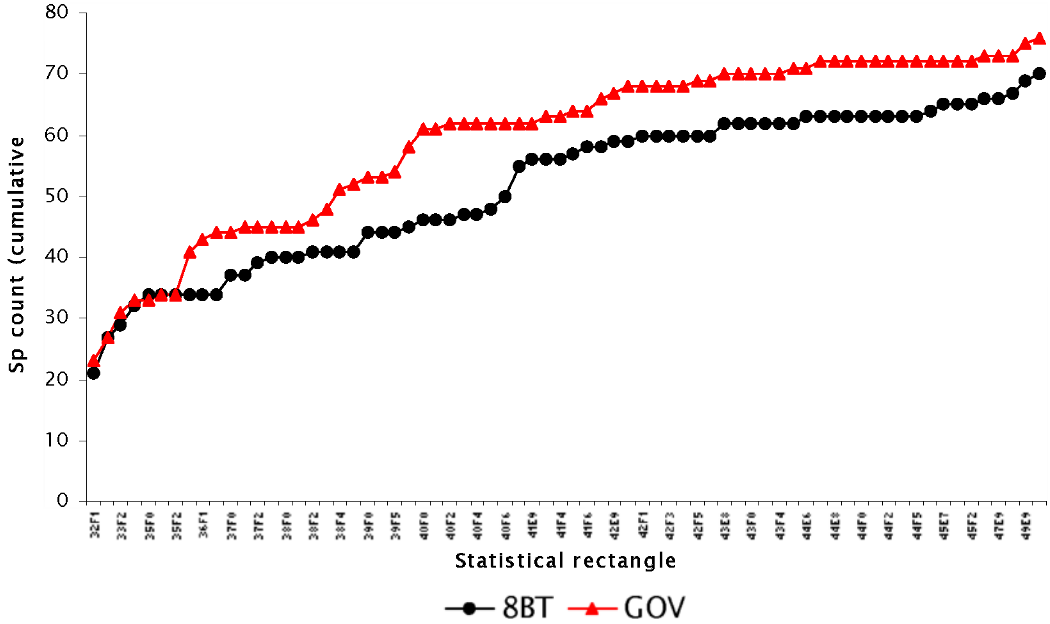


Figure 3.48. Species diversity (S) in statistical rectangles fished using both the 8m-beam trawl and the GOV in 2003.

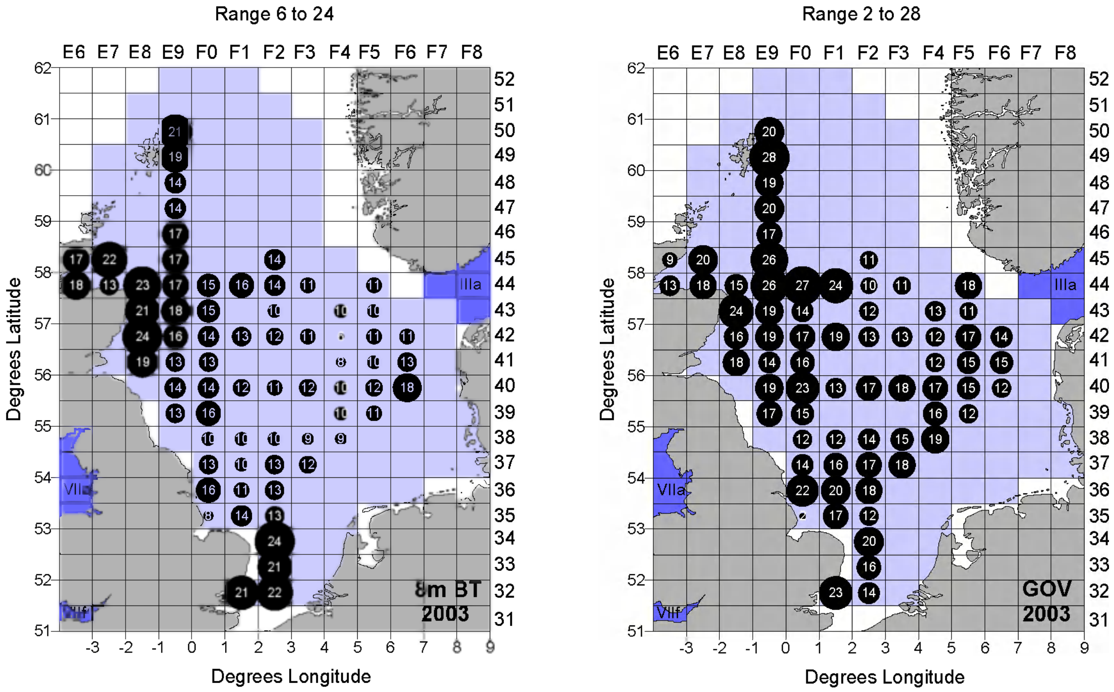


Figure 3.49. Shannon-Weiner (*H'*) in statistical rectangles fished using both the 8m-beam trawl and the GOV in 2003.

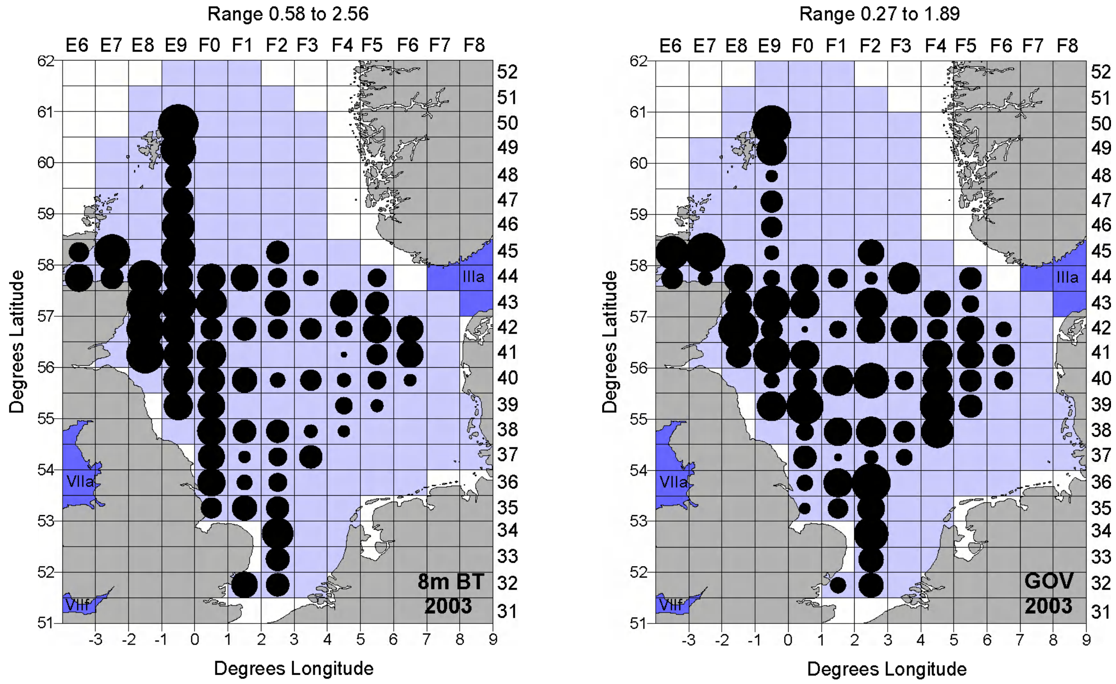


Figure 3.50. Simpson index (λ) in statistical rectangles fished using both the 8m-beam trawl and the GOV in 2003.

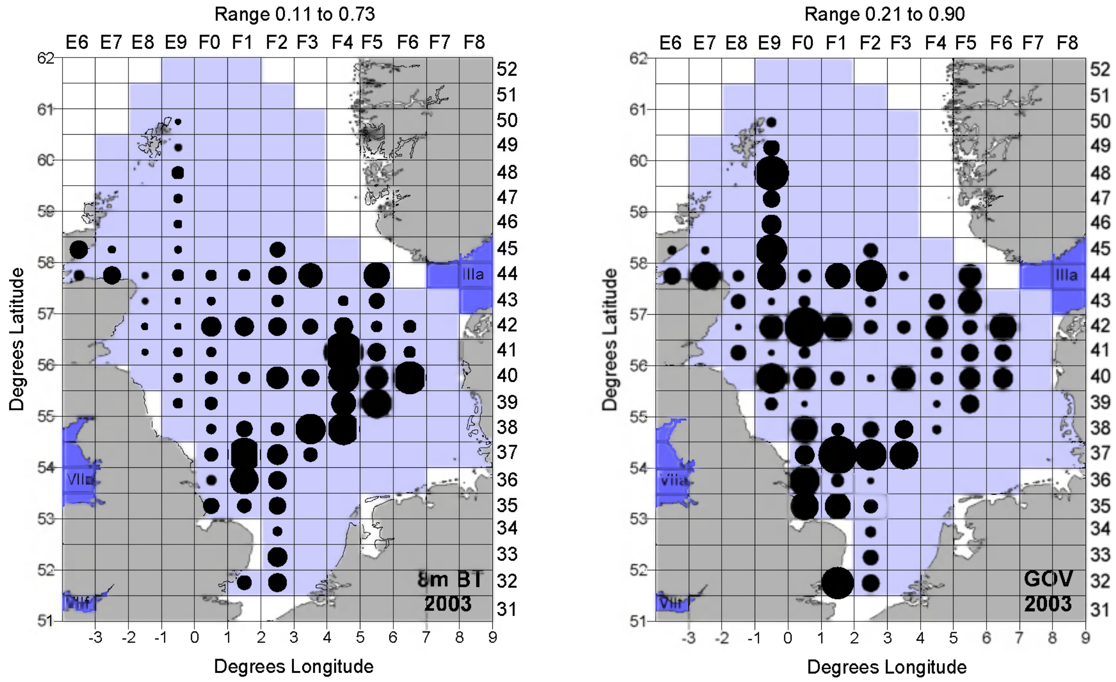


Figure 3.51. Hill's N_2 in statistical rectangles fished using both the 8m-beam trawl and the GOV in 2003.