Analysing patterns in epibenthic biodiversity and productivity in the North Sea and to the west of Scotland

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1. Introduction

The epibenthos are the component of the benthic invertebrate community that spend the majority of their lifecycle extending from, or living in close association with the surface of the seafloor. They form a major component of the North Sea fauna and previous studies of these animals have described the distribution of a number of characteristics of the community, such as species diversity and species relative abundance, with interpretations of the physical and biological factors affecting their distribution (for examples see Basford *et al.*, 1989; Frauenheim *et al.*, 1989; Rees *et al.*, 1999). Based on the findings of these studies, the major factors affecting the distribution of epifaunal invertebrate communities within the North Sea are depth, sediment composition, water temperature and hydrography. This leads, at the coarsest level, to a division of northern and southern epifaunal communities split at the 70m-depth contour. However, the interpretation of these studies at a North Sea scale is restricted, as the sampling methods and analyses employed were not consistent amongst surveys and conclusions were often based on a limited number of samples.

The EC project FAIR (project CT 95-0817) (Jennings *et al.*, 1999) developed a standardised epibenthic sampling methodology that could be used onboard routine fish stock surveys as part of the national groundfish surveys (IBTS, GFS). This would enable minimisation of funding required to undertake regular North Sea scale epibenthic surveys. Using the standardised methodology developed from this, a subsequent EC project, Biodiversity (project 98/021), undertook the first North Sea wide survey during the 3rd quarter IBTS survey in 1999 and repeated this with five participating nations in 2000. The results of these surveys have now been published (Zühlke, 2001; Zühlke *et al.*, 2001; Callaway *et al.* 2002) and information is given on distribution patterns, diversity and community structure at the scale of the ICES rectangle. Initial interpretations of the environmental factors affecting these patterns confirm the findings of the earlier studies, emphasising the importance of hydrography, sediment type and temperature. Three major boundaries between community types were noted, following the 50m, 100m and 200m depth contours (Zühlke, 2001).

The purpose of this report is to present the findings of the epibenthic surveys that have been undertaken since the Biodiversity project as part of the Scottish Executive (SE) funded ROAME MF0753 and the EC 5th framework project MAFCONS. These projects have extended the sampling protocol to include infaunal benthic communities and to link characteristics of the benthic invertebrate communities to demersal fish diversity and to levels of ecological disturbance associated with the North Sea demersal fishing industry (www.mafcons.org/). As part of this development, methods for estimating secondary production from the epibenthic community have been explored, as this is an important link to the overlying demersal fish community.

In this report the epibenthic invertebrate sampling data are presented for the full international North Sea sampling trip of 2003. Interannual variation in epibenthic community dynamics is also explored using a study undertaken by the Scottish partner over the years 2001, 2002 and 2003 for an area extending from the North Sea to the west coast of Scotland.

The objectives of this report are to:

Extensive North Sea study, 2003

- Describe the distribution of total epibenthic abundance, biomass, species diversity and community composition for approximately 100 stations across the North Sea in 2003.
- Describe the distributions of the key epibenthic species for 2003.
- Describe the distribution of secondary production from the epibenthos in 2003.

FRS surveys, 2001-2003

- Describe variation in the distribution of total epibenthic abundance, biomass, species diversity and community composition for approximately 60 stations per year between 2001-2003 from the northern North Sea extending to the west coast of Scotland.
- Describe the variation in distribution of the key epibenthic species for 2001, 2002 and 2003.

2. Methods

One beam trawl tow was taken at each station sampled, close to the track of the main demersal fish-sampling trawl. In 2003 a total of 134 Stations were sampled across the North Sea (Figure 2.1).

The following countries contributed to the 2003 MAFCONS survey:

- Scotland (FRS Marine Laboratory)
- England (University of Wales Swansea with CEFAS, Lowestoft;)
- The Netherlands (RIVO, Ijmuiden)
- Belgium (Gent University)
- Germany (Senckenburg Institute and Institute for Sea Fisheries)
- Norway (Institute for Marine Research).

In the years 2001 and 2002 the Scottish partner (FRS) also sampled on average 40 stations in the North Sea and 20 stations on the west coast of Scotland per year (Figure 2.2). North Sea samples were taken in August of each year, whilst Scottish west coast samples were taken in November of each year. Implications of seasonality on the interpretation of these data are considered in Section 3.2.6.

2.1 Sampling Gear.

All surveys – MAFCONS and MF0753

All samples were taken with a 2-m beam trawl constructed from galvanised steel, fitted with a 20mm mesh (10mm knot to knot) and a liner of 4mm knotless mesh (2mm 'knot to knot') (a detailed description of the specifications can be found in Jennings *et al.*, 1999). The beam trawl was shot with a warp length of approximately three times water depth and towed at between 1-1.5 knots for 5 minutes. Where possible, a Scanmar depth unit (which shows when the trawl reaches and leaves the seabed) was attached to allow accurate timing of the duration of beam trawl fishing.

2.2 Sample Treatment.

2003 North Sea survey – MAFCONS

Samples were washed through a 5mm and 2mm sieve (internal mesh size) and epibenthic invertebrates and fish separated from the remains. For those animals retained in the 5mm sieve the majority of species were identified, measured and weighed (blotted wet weight) onboard. Sessile animals were recorded as present or absent with a total weight given where possible. Weights were taken using a seagoing marine scale (Pols) with an accuracy of 0.01g. For those species that were either too small to be accurately weighed onboard, or too difficult to identify without a microscope, specimens were preserved in 4% buffered formaldehyde and returned to the laboratory. Species identification was based on Haywood & Ryland (1990), a number of specialised identification keys (see Appendix 3 in Deliverable 1: Methods Manual at www.mafcons.org/), and a digital identification key (SID) developed under EC FAIR project CT 95-0817. Specimens that individual partners had found difficult to identify were examined at a workshop held six months after the surveys at the Senckenburg Institute, Germany. All names were standardised to the nomenclature of Picton & Howson (1999) and where more recent changes in nomenclature have occurred, or new species found, a record was made. All specimens in the 5mm-sieve fraction were identified to the lowest taxonomic level.

Those animals retained in the 2mm sieve were preserved and returned to the laboratory for productivity analysis. They were not identified to species or individually weighed and measured. Demersal fish caught in the 2m-beam trawl samples are not considered further in this report.

MF0753 2001, 2002

The only difference in the methodology used by FRS in 2001 and 2002 was that all fauna retained in the beam trawl, rather than just those remaining in the 2 & 5mm sieves, were identified and enumerated. The effect of this on the interpretation of results for these years is considered in Section 3.2.6.

2.3 Data Analysis.

Individual partners collected their own data in standardised Excel data entry sheets (see Appendix 5 in Deliverable 1: Methods Manual at www.mafcons.org/). The scientific co-ordinators were responsible for cross-checking the individual datafiles and then assembling a master ACCESS database.

Univariate analyses

For each station, total abundance (N) and total biomass (B) were standardised to numbers per $1000m^2$ by dividing the individual totals by the station specific swept area (m^2) and multiplying by 1000. Swept area was itself calculated by multiplying the total track fished by the width of the beam trawl (two metres). Univariate indices of total abundance, total biomass, and species diversity were calculated for each station as point estimates.

The following diversity indices were calculated:

Hill's N0	total number of species (species richness)
Hill's N1	an index of abundant species (exp. (H′), where H′ is the Shannon-Wiener diversity index)
Hill's N2	an index of dominant species (1/SI, where SI is Simpson's dominance index).

Species richness (Hill's N0) was broken down to all species (presence/absence data) and motile species, whilst Hill's N1 and N2 were calculated using only the motile species data as they require the individual species abundance values. All analyses were carried out in the statistical package PRIMER V.5 (Clarke & Warwick, 1994).

Multivariate analyses

Multivariate community analyses were also completed in PRIMER V.5. Mean species abundance (per $1000m^2$) for each station was used as the basic input data. In order to enable full analysis where only presence/absence data were available, the fauna were subdivided into two groups – all epifauna (includes sessile species) and motile fauna only. The Bray-Curtis similarity in species composition between stations for the entire survey in 2003, and individually for the FRS data of 2001, 2002 and 2003, was calculated and hierarchical cluster analysis used to separate groups of stations with similar species compositions. Species characteristic of these individual community clusters were extracted using the SIMPER routine in PRIMER. This examines the percentage contribution of each species to the similarity within the characteristic community group and between different groups. The term ‘characteristic community’ is used here to depict a group of stations with similar epibenthic species composition and does not imply any particular ecological interactions.

Distribution of key species

The distributions of the 10 dominant species based on total abundance across the survey area (motile species only), and the 10 dominant species based on total biomass across the survey area (including sessile species) were plotted for each year.

Secondary production

Total production per day (per $1000m^2$) was estimated using an empirical model based on the relationship between production, mean individual body mass and water temperature following the method of Edgar (1990a).

$$\text{Log } P = -1.99 + 0.78 * \log B + 0.68 * \log T \qquad \text{(Epifauna)}$$

Where:

P = daily production ($\mu g.day^{-1}$)

B = mean individual weight (AFDM/μg)

T = bottom water temperature (°C)

For each sample the total weight per species was converted to ash free dry mass (AFDM) using published conversion factors (Brey, 2002) and the mean individual weight per species calculated using the total number of individuals and total weight (AFDM). Water temperatures were taken from the environmental data recorded at each station. All species were classified as Mollusca, Crustacea, other Epifauna or other Infauna, as Edgar gives different coefficients for these groups (Epifauna shown above). Daily production per species was then calculated and all species in a sample summed to give total daily production of the sampled epifaunal community. A detailed description of the methods used to calculate secondary production according to Edgar (1990a) is given in MAFCONS Deliverable 10 (www.mafcons.org/).

3. Results

In the first instance, analyses of the individual FRS surveys (2001-2003 inclusive) are considered separately to the results from the international collaborative survey of 2003. Following this interpretation, the implications of combining the surveys to increase sample size are considered in the final discussion.

3.1 International survey MAFCONS, 2003

Including all surveys a total of 134 stations were sampled. However, due to a number of logistical problems, the Dutch epifauna data were not included in the analyses of abundance, biomass, diversity and community structure. The dataset and 2003 distributions will be updated with these data in time for the next report. Based on the results of the other four surveys, a total of 100 stations were surveyed, covering 78 different ICES statistical rectangles (Figure 2.1). From these surveys alone, a total of 452 epibenthic species were recorded.

3.1.1. Total abundance

There was high variation in the total number of individuals (based on motile species) between stations (Figure 3.1.1.a). At the least abundant station there were only 40 individuals per $1000m^2$, whilst at the highest there were over 12 000. High abundance stations were mainly found along the continental coast in the southern North Sea and in the northern North Sea (Table 3.1.1. for high abundance species in these areas). Sessile species were analysed based on presence/absence and thus it was only possible to deduce that sessile species were at least present at all stations apart from six, all of which were located in the southern North Sea.

3.1.2. Total biomass

Variation in total biomass per station was also considerable (Figure 3.1.2.), with only 59 grams (blotted wet weight) of epifauna per $1000m^2$ at the lowest biomass station, whilst the highest had 13,328 grams. In some cases, stations with high biomass also had relatively high numbers of individuals, but in others abundance was low, whilst biomass was high (Figures 3.1.1.a & 3.1.2.). High biomass stations were found along the continental coast in the southern North Sea, along the northeastern coast of Scotland, in the northern North Sea and across the 50-70m depth contours in the central North Sea (Table 3.1.1. for high biomass species in these areas). Along the continental coast of the southern North Sea, high biomass species corresponded with those also contributing in high abundance. It was, however, noticeable that for many of the stations with high biomass in the central North Sea and along the northeastern coast of Scotland, there was not a correspondingly high value for total abundance (see Figures 3.1.1a & 3.1.2. and Table 3.1.1.). This was due to the dominance of sessile colonial species at the high biomass stations, which did not contribute to the total abundance values. Large predatory gastropods were also found to contribute substantially to biomass in the central North Sea, and to a lesser extent in the northern North Sea, due to their high individual body masses. Again high biomass values for these species would not be reflected in overall total abundance values.

3.1.3. Species diversity

Based on the motile species alone, species richness (the total number of species) was greater in the central-west and northern North Sea than in the eastern and southern North Sea (Figure 3.1.3. (a)). As expected, the same index calculated from the presence/absence data for all species, showed higher overall species richness (Figure 3.1.3. (b)). However, there were also some stations that had disproportionally higher species richness when all species were included, suggesting that sessile species had a high contribution to the overall species number in those areas (for example see stations northeast of Scotland in Figure 3.1.3 (b)). The inclusion of sessile species changed the pattern of species richness distribution, with areas of high richness being found in the central North Sea, in addition to the northern and central-west area. For motile fauna, Hill's diversity indices N1 and N2 were also calculated, taking into account the effect of individual abundance in addition to the number of species (Figure 3.1.3 (c) & (d)). The general trend of higher diversity in the northern North Sea is confirmed, but both indices also indicate some relatively diverse areas in the central North Sea.

3.1.4. Community structure

Following hierarchical cluster analysis of the stations based on the Bray Curtis similarity in species composition, two main clusters were identified in the epifaunal community data. These clusters were identified independent of whether the analysis included just the abundance-weighted motile species data or the presence/absence data of all species including sessiles (Figure 3.1.4. & Figure 3.1.5.). The within-cluster similarity in the relative composition of species of the sampled community at each station was at least 29% in both cases.

The first major cluster was found in the central-eastern and southern North Sea, south of the 50m-depth contour, whilst the second was found in the deeper central-west and northern North Sea. The top four characteristic species for the more southerly cluster were the same regardless of whether data were abundance-weighted or based only on presence. This suggests that either sessile species were not consistently important contributors to the similarity in these communities and/or that it was the compliment of species found that characterised the community, not their individual relative abundances. In the more northerly cluster, similarity of communities was largely attributed to the presence of the hermit crabs *Anapagurus laevis* and *Pagurus bernhardus* and the sympatric sessile species that they host (*Hormathia digitata* and *Epizoanthus incrustatus*). The asteroid *Asterias rubens* contributed to the overall similarity in both clustered areas (see discussion of key species below). It must therefore be either the compliment of other species that characterises the two community types differently or the difference in relative abundance of this species in the two geographic areas.

A number of smaller clusters also emerged. These included one that showed over 35% similarity based on either treatment of the data, with four stations along a line northeast of the Moray Firth. These stations differed to the other stations in the northern North Sea as they were not characterised by hermit crabs, but by a mixture of the asteroid *Astropecten irregularis*, the crustaceans *Crangon allmanni* and *Nephrops norvegicus*, the gastropod *Turritella communis* and the echinoid *Brissopsis lyrifera*. Based on presence/absence data, the seapen *Pennatula phosphorea* was also an important contributor to the within-cluster similarity of this smaller group of stations. A further cluster was found in the central North Sea when based only on the presence/absence transformed dataset (Figure 3.1.5.). The remaining stations were outliers, sharing less than 25% similarity in species composition with any of the other stations. The central North Sea area, between 56.5° N and 58° N and 0.5° E and 7° E stood out as the area of greatest heterogeneity in community structure. In this area the inclusion of sessile species caused the greatest difference in the similarity in communities found (but see notes in summary – section 3.1.6.).

3.1.5. Distribution of key species

10 most abundant species (motile species only)

The distributions of the 10 species contributing the highest abundance when summed across the whole survey are shown in Figure 3.1.6. ((a) to (j)). A number of species were present in high abundance across a wide area (e.g. *Asterias rubens* and *Ophiura albida*), whilst in other cases, species were particularly abundant at one point in space (e.g. the juveniles of the echinoid *Echinus* sp. and the bivalve mollusc *Corbula gibba*). A number of the abundant species were restricted in their distribution to a particular area of the North Sea (e.g. *Echinus acutus* and *Hyalinoecia tubicola*). In these cases, their contribution to total abundance in particularly high abundance areas has already been noted (see Table 3.1.1. and Figure 3.1.1.). *Astropecten irregularis* was particularly abundant in the eastern and southern North Sea and this species made the greatest contribution to within-cluster similarity of stations in that area (Figures 3.1.4. and 3.1.5.).

10 species of greatest biomass

A number of the species found to have the highest biomass when summed across the survey area were consistent with those also found to be high in abundance (e.g. *Asterias rubens* and *Astropecten irregularis*). In these cases, overall distribution of biomass was similar to that of abundance, but at some stations there was a disproportionally higher level of biomass in comparison with abundance and *vice versa* (Figures 3.1.5. and 3.1.6.). This may be explained by the distribution of different age classes and thus size structures but could simply be an artefact of the scaling of the bubble plots in the figures and the data would need to be examined more closely to verify this. Most of the other species were not however present in the top 10 most abundant species. This can be explained either because of their high individual body masses (e.g. *Neptunea antiqua* and *Buccinum undatum*), or because they are sessile species that would not be represented in the individual abundance data (e.g. *Flustra foliacea* and *Alcyonium digitatum*). Other than *Asterias rubens* and *Astropecten irregularis*, the distributions of species of high biomass tended to be confined to particular areas (Figure

3.1.7.). This is particularly true of the bryozoan *Alcyonium digitatum* and the actinarian *Bolocera tuediae* (see Table 3.1.1 for individual contributions to high biomass areas).

3.1.6. Distribution of secondary production

Edgar's (1990a) method for estimating secondary production from the benthos is based on the relationship between somatic production and mean individual body mass and water temperature. The distribution of epifaunal production across the North Sea in 2003, based on this method, is shown in Figure 3.1.8. Total community production ranged between 0.5 and 450 grams per day (per 1000m^2). Edgar (1990b) calculated total community production using the same approach as that used here, for macrofaunal communities of seagrass beds in Western Australia. Total production ranged between 4.9 and 47.2 grams per year (per m^2), which translates to 13.42 to 129.32 grams per day (per 1000m^2), based on the assumption that productivity is constant across the year. This fits within the range observed in this study. Stations with over 80 grams production per day (per 1000m^2) were found along the continental coast in the southern North Sea, in the central west North Sea, east of Scotland and in the northwest North Sea due northeast of Orkney. The overall pattern is similar to that of the distribution of high biomass and high abundance stations (Figures 3.1.1a and 3.1.2.), although it is important to note that more stations were included in the estimation of productivity.

Individual P/B ratios per species ranged between 0.02 and 0.74. Total production per species ranged between 0.904*10^{-5} to 25.45 grams per day (per 1000m^2). This large difference in total production per species represents the range in number of individuals and mean individual weights recorded across the survey. At the highest productivity station (ICES rectangle 34F2 in Figure 3.1.8.) the sample was dominated by a very large population of Ophiuroids (~115,000 individuals per 1000m^2). Whilst at the second highest production station (ICES rectangle 41E8 in Figure 3.1.8.) numbers of individuals were not as high but several of the key species had high mean individual weights. High productivity per species was found either where the mean individual weight was high and/or there was a high total number of individuals. Brey (1990) presented production values for a number of macrofaunal species using an alternative empirical relationship based on the relationship between production and mean individual weight and total biomass. Brey's values for total production per species ranged between 0.04 to 13.56 grams per year (per m^2). This would translate to 0.11 to 37.40 grams per day (per 1000m^2), if it is assumed that productivity is constant across the year.

These values are comparable with the upper end of the species production values found for this report.

The empirical relationship developed by Edgar (1990a) was designed to be applied to samples that have been size structured by sieving prior to analysis. The epifaunal samples analysed here contained all animals retained on a 5mm sieve with no further size classes. It is likely that the mean individual weights calculated here will have been skewed by the presence of large individuals. Jennings *et al.* (2001) estimated community production of epifauna for a number of sites in the North Sea using a size-based method. Their estimates of total community production ranged between approximately 50 and 700 grams per sample per year. If it is assumed that productivity is constant over that year and that the area sampled was on average 400m^2, this translates to a range of 0.34 to 4.79 grams per day (per 1000m^2). This range is all within the lowest productivity range of the estimated values for the MAFCONS 2003 survey as calculated here using the Edgar (1990) method without size structuring. Efforts will be made to find published records of both species level and community level production for other studies undertaken in the North Sea to compare with the results found here. The 2003 data will also be reanalysed with the 2004 epifauna data using log body mass size classes to group the data before calculating production per species (see MAFCONS Deliverable 10 for more detail on the development of the productivity analyses – www.mafcons.org/).

3.1.7. Summary

All analyses indicate differences between the epifaunal communities found in the southern North Sea with those found in the deeper area, north of the 50m-depth contour. Composition of the community is different in the two areas and species diversity higher in the deeper northern area. In the central North Sea, around the area where depth changes from 50-70m, the differences in species composition indicate a transitional area with heterogeneous community types where sessile species are important contributors. However, it is important to note that some of the heterogeneity in community composition seen in the central North Sea area may be due to deviations in the processing of samples by the Norwegian partner that occurred due to a number of logistical problems. Further exploration of the data will be undertaken to establish whether the differences in composition found for the Norwegian stations can be attributed to deviations in the sample processing methodology. The differences between the distributions of biomass and abundance across the surveyed area also confirm that sessile species are important contributors in the central North Sea. In contrast, the southern North Sea is dominated by a number of highly abundant motile echinoderms and sessile species are not important members of these communities. High biomass is not always associated with areas of high abundance and in some cases the presence of species with high individual body masses is enough to increase total community biomass to a high level. Stations of high total productivity were found across the North Sea but in particular aggregated around the continental coast in the southern North Sea and in the northwestern and central western North Sea. Further work will be undertaken to validate the method used to estimate secondary production from the epifauna before updating with the 2004 data.

3.2 FRS surveys, 2001-2003

A total of 528 epibenthic species were recorded over the period August 2001-August 2003 for the area surveyed from the west coast of Scotland into the northern and central North Sea. Counting all 5 surveys (2 November west coast and 3 August North Sea), 157 stations were sampled (Figure 2.2). In 2001, coverage of the offshore stations to the west of Scotland was not as good as that achieved in 2002, whilst in 2002, coverage of the central and southern North Sea areas was not as good as that achieved in either the 2001 or 2003 North Sea surveys. The implications of lower coverage at these times will be considered in interpreting the distribution patterns.

3.2.1. Total abundance

As was found for the international survey undertaken in 2003, total abundance was highly variable at the scale of the North Sea and was perhaps even more so when taking into account the stations surveyed to the west of Scotland (Figure 3.2.1.). In each individual year, the least abundant stations had less than 40 individuals per $1000m^2$, but the highest abundance stations ranged between 1962 individuals per $1000m^2$ in 2003 to 16,465 individuals per $1000m^2$ in 2001 (>16000 of which were individuals of one sea urchin species, *Strongylocentrotus droebachiensis*).

As was found in the more extensive 2003 survey (see Section 3.1), high abundance stations were mainly found in the northern North Sea, with a number aggregated around the northeast coast of Scotland. In 2002 a particularly high total abundance value was recorded in the southern North Sea, near to the European continental coast (Table 3.2.1. for high abundance species in these areas). To the west of Scotland, high abundance stations were mainly aggregated around the northwest coast in 2001, but in 2002, a number of stations of higher abundance were found further offshore. Sessile species were analysed based only on presence/absence and thus it was only possible to deduce that sessile species were at least present at all stations in 2002 and all stations except a few in the southern North Sea in 2001 and 2003 (Figure 3.2.2).

Based on the total abundance data for motile species, overall patterns of taxonomic groups contributing most to high abundance stations within individual areas (e.g. continental coast, southern North Sea or west of Scotland), were fairly consistent across years. For example, in the southern North Sea, starfish, brittle stars and a number of shrimps and crabs were important contributors. In the northern North Sea, however, sea urchins were the more dominant echinoderms and a number of molluscs and polychaetes were also present in high numbers. However, the identity of the actual species making up each group varied between years as did the relative contribution between taxonomic groups (see Table 3.2.1). For example, on the continental coast of the southern North Sea, echinoderms dominated high abundance stations in 2001, but in 2002 and 2003 crustaceans were also important. The starfish *Asterias rubens* was the only species found to dominate high abundance stations in each year for that area. In the northern North Sea, none of the species were consistently dominant across all three years. For example, the sea urchin *Strongylocentrotus droebachiensis*, was found in high abundance in 2001 and 2002, but was replaced in dominance by the sea urchin *Echinus acutus* in 2003. However, it must be noted that the observed interannual variation in the dominance of individual species is more likely to be due to the spatial heterogeneity of species distributions within years. It is really only valid to draw conclusions on the interannual variability of the higher taxonomic groups.

3.2.2. Total biomass

Variation in total biomass per station was also considerable within individual year's surveyed (Figure 3.2.3). The lowest total biomass recorded was in the Irish Sea in 2001, with only 22 grams per $1000m^2$, whilst the highest was also recorded in 2001, in the central North Sea, with over 54,273 grams per $1000m^2$. Within the North Sea area, total biomass was higher across the majority of stations surveyed in 2001 than it was in either of the years 2002 and 2003. It is more difficult to interpret interannual variability in biomass for the stations west of Scotland because of the spatial differences in samples taken in 2001 and 2002.

The patterns of total biomass distribution within the North Sea area were not as easy to distinguish based on the individual surveys of FRS as they were based on the more extensive international data for 2003 (see Figures 3.1.1c and 3.2.3). In 2001, stations to the west of Scotland did not appear to be as high in biomass as those in the greater North Sea area, whilst in 2002 distribution of biomass was more consistent across the northern North Sea and to the west coast. In 2003, only one station was found to be in the highest biomass group and this was on the eastern coast of Scotland. On comparing the distribution of total biomass with that of the total abundance of motile species within each year (Figures 3.2.1 & 3.2.3), it was evident that there was not always a linear relationship between the two variables. For example in 2001, the station surveyed in ICES rectangle 41F3 had a very high total biomass, but not a correspondingly high number of motile individuals. The distribution of dominant species found at high total biomass stations (Table 3.2.2) illustrates why some stations with high overall biomass do not also have a high corresponding total abundance. Many of the species contributing to high biomass were either sessile (eg. bryozoans or hydroids) and so not included in the abundance measures, or of high individual body mass (eg. large predatory gastropod like *Buccinum undatum*).

3.2.3. Species diversity

In 2001 and 2003, overall patterns of species diversity in the North Sea area reflected those observed using the international dataset for 2003 (Section 3.1). All indices indicated lowest diversity in the southern North Sea and, based on motile species alone the central west and northern North Sea had higher species diversity, whether determined by the number of species present or when also including weighting to abundant and dominant species. Also in agreement with the international survey, species richness was higher across the central North Sea when sessile species were included in the analysis (Figures 3.2.4. and 3.2.6.). In the North Sea in 2002, patterns were less clear, but it was difficult to determine whether this is just an artefact of the lower coverage of stations in the central and southern North Sea that occurred during the 2002 survey (Figure 3.2.5.). As sample size does effect the calculation of diversity indices this is quite possible and this also precluded the interpretation of interannual variability in species diversity for the west coast surveys.

3.2.4. Community structure

Species compositions were identified for each of the years surveyed following hierarchical cluster analysis of the stations based on the Bray Curtis similarity in species composition. Initially community patterns within each year are discussed before interpreting interannual variation in the distribution of particular community types.

2001 surveys

In 2001 to the west of Scotland, two communities were present independent of whether the analysis included abundance-weighted motile species or a presence/absence transformation of the entire epifaunal dataset. These separated into an inshore group, close to the western coast of Scotland, and a group further offshore. The characteristic species did not overlap (Figures 3.2.7 (a) and (b)). The fact that these communities did not cluster differently based on either data treatment suggests that either sessile species were not important in their characterisation and/or that the compliment of species was more important than the relative abundances of those species present. This was also true for a number of smaller communities that were identified in the North Sea to the northeast of Scotland.

The formation of communities for most of the North Sea stations in 2001, did however, differ depending on the treatment of data used. Based on abundance-weighted motile species data, most of the central and southern North Sea was identified as one community type, characterised by a number of scavenging echinoderms and crustaceans. However, in the most northerly area of the survey, a number of different communities were found all tightly clustered across relatively small areas. On inclusion of the whole presence/absence transformed dataset, however, the stations in the more northerly area become part of a larger central and western North Sea cluster, which was characterised again by scavenging echinoderms and crustaceans. This was then separated from a cluster south of the 50m-depth contour, which only overlapped in characterising species, by the inclusion of two key scavenging starfish *Asterias rubens* and *Astropecten irregularis*. Outlier stations had less than 25% similarity in species composition to any of the other stations in the survey. These were mainly recorded in the area to the north of Scotland and combined with the higher heterogeneity in community types across the stretch from northwest Scotland to the northern-central North Sea, results suggest an area of transition particularly when based on abundance-weighted motile species data.

2002 surveys

The greater coverage to the west of Scotland in 2002 illustrated that, as in 2001, there was a separation of communities into offshore and more coastal types (Figures 3.2.8. (a) & (b)). The offshore community was characterised by shrimps, scavenging hermit crabs and the tubeworm *Hyalinoecia tubicola,* and was consistently found except for a number of outlier stations to the south of the Outer Hebrides. The shallower inshore stations separated into two different community types. These differed by the fact that the similarity in species composition of one type was almost entirely due to the presence of the prawn *Nephrops norvegicus* and the bivalve *Nucula sulcata*, whilst the other cluster was more diverse in its' characterising species. In the North Sea area only two community types were identified with the 2002 data, one south of the 50m-depth contour and one to the north and west of this. A number of the characterising species overlapped (see Figures 3.2.8. (a) & (b)) but the overall species complexes were different.

It was noticeable that there were only very minor differences in distribution of community types in 2002 between the two different data treatments. For some communities the characterising species did differ in their composition dependent on how the data was analysed, but only a few sessile species joined the characterising species when the presence/absence transformed whole dataset was analysed. The lack of difference in clustering between the two analyses suggests that sessile species did not contribute much to the formation of community types in this year and/or that the relative abundance of the species present was not important.

2003 survey

In 2003, there was a difference in the clustering of communities between the two different data treatments (Figures 3.2.8. (a) & (b)). Based on abundance-weighted motile species data, two main communities were identified with a smaller cluster of four stations in a line east of the Moray Firth. The two main clusters differed little in the identity of their characteristic species and their separation was not clearly related to any particular hydrographical features. The area to the northeast of Scotland was more heterogeneous in community types than the rest of the North Sea area with a number of outlier stations also present. On inclusion of the presence/absence transformed entire epifaunal dataset, however, clustering of community types appeared more related to changes in depth and hydrography. Stations in the southeastern North Sea, south of the 50-m depth contour, were characterised by a small number of scavenging crustaceans and the starfish *Asterias rubens*. Stations to the north and west of the 50m-depth contour then separated into two main clusters with the same additional smaller cluster out of the Moray Firth as was identified based on motile species data. The two larger clusters overlapped in their characterisation by a number of key hermit crabs and the starfish *Asterias rubens*, but the overall complexes were different. The more westerly and northern stations had a number of characteristic filter feeding sessile species, whilst the more easterly and southern community was characterised almost entirely by scavenging starfish and crustaceans and the only sessile species was a symbiont of one of the scavenging hermit crabs.

Interannual variation in community types

For both years surveyed to the west of Scotland, a stable inshore community at stations close to the western coastline was identified, characterised by the burrowing prawn *Nephrops norvegicus* and the bivalve *Nucula sulcata*. With the greater coverage of stations attained in 2002, another community cluster was identified slightly further offshore and the characterising species of this community overlapped with a number of those that were found in the only inshore cluster of 2001. It is possible that this second cluster only separated out in 2002 because the broader coverage included more similar stations (Figures 3.2.7. and 3.2.8.). Further offshore to the west of Scotland, only one community type was identified in each of the years 2001 and 2002. The characterising species in both years were dominated by scavenging crustaceans, the tubeworm *Hyalinoecia tubicola* and a number of shallow burrowing shrimps. However, the identity of the actual species varied between years, but again, as discussed in section 3.2.1., interannual variability of individual species abundances may be simply attributable to spatial heterogeneity that is not picked up in the sampling design used. Whilst the area from the northwest of Scotland to the east of Shetland was noticeably heterogeneous in community composition in 2001, there were only two clusters across the same area in 2002 and there were less outliers.

When considering the interannual variation across the North Sea area, three years of data were available (Figures 3.2.7., 3.2.8. and 3.2.9.). However, there are a number of issues to consider in interpreting the differences between clusters found in 2003 and those found in the other two years. First, the communities analysed in the first two years included all invertebrates caught in the beamtrawl, whilst in 2003, only those retained in a 5mm sieve were analysed. Second, because the west coast survey data is not yet included in the 2003 analysis, the clustering of stations will be more sensitive to the dissimilarity of communities within the North Sea area. Based on the 2001 and 2002 data it is clear that west coast stations separate out from North Sea stations. Because the dissimilarity between west coast and North Sea stations is greater than that between stations in the North Sea itself, it is likely that more clusters would be identified in 2003 just because there is no west coast data included.

On comparison of the clustering in the North Sea area across the three years surveyed, there was obvious interannual variation in the distribution of clusters. In both the 2001 and 2003 surveys, an area of heterogeneity in community types was identified in the northern North Sea, east of the Moray Firth. The 2002 survey only separated into two clusters in the North

Sea area. This may be a reflection of the lower coverage of stations in certain areas in 2002. For example, lower coverage of the area to the east of the Moray Firth during 2002 might explain why the heterogeneity recorded in this area in the other two years was not recorded here. It is also possible that the greater coverage of the much more different west coast communities in 2002 would make the relative dissimilarity between stations in the North Sea itself less obvious.

In all three years a small cluster was identified south of the 50m-depth contour based on the whole presence/absence transformed dataset (and also on the motile species data in 2002). However, the only characterising species that was consistent across the three years in this community was *Asterias rubens*. There was greater overlap in characterising species of this community in 2001 and 2002 than there was with 2003. It is unlikely, however, that this was due to the change in methodology in 2003, as all of the characteristic species recorded in 2001 and 2002 would be retained on a 5mm sieve. Again interannual variation in individual species contributions to species composition can not be accurately interpreted from this sampling design as it is likely to reflect spatial heterogeneity within years. The interpretation of interannual variation in community types will benefit from the addition of the 2003 west coast survey data and from the 2004 data for the whole area (see Section 4. Discussion).

3.2.5. Distribution of key species

2001 surveys

10 most abundant species (motile species only)

As was found in the more intensive international survey of 2003, a number of species were present in high abundance across a wide area (e.g. *Astropecten irregularis* and *Ophiura albida*), whilst in other cases, species were particularly abundant at one point in space (e.g. *Abra nitida*) (Figure 3.2.10. (a) to (j)). A number of the abundant species were restricted in their distribution to a particular area (e.g. *Abra nitida* to the western coast of Scotland and *Calocaris macandreae* to the inshore areas around Scotland). In these cases, their contribution to total abundance in particularly high abundance areas has already been noted (see Table 3.2.1. and Figure 3.2.1. (a)). There were also a number of species that were more widespread in overall distribution, but that were particularly abundant in a given area. In these cases there was often a strong contribution of that species to the similarity in a particular cluster based on community type in that area (e.g. *Pagurus prideaux*, the blue circle cluster in Figure 3.2.7. (a), also see Figure 3.2.10. (j)).

10 species of greatest biomass

Half the species found to have the highest biomass when summed across the survey area were consistent with those also found to be high in abundance (e.g. *Strongylocentrotus droebachiensis*, *Asterias rubens* and *Astropecten irregularis*) (Figures 3.2.10. and 3.2.11.). In these cases, overall distribution of biomass was similar to that of abundance, but at some stations there was a disproportionally higher level of biomass in comparison with abundance and *vice versa.* As discussed in section 3.1, this may be explained by the distribution of different age classes, but could also simply be an artefact of the scaling of the bubble plots in the figures. The data would need to be examined more closely to verify this.

The other five species were not present in the top 10 most abundant species. This can be explained either because of their high individual body masses (e.g. *Neptunea antiqua* and *Spatangus purpureus*), or because they are sessile species that would not be represented in the individual abundance data (e.g. *Flustra foliacea* and *Alcyonium digitatum*). Most of the species of high biomass were widely distributed, but in some case they were of particularly high biomass in a smaller area and in such cases, they tended to be a major contributor to high overall biomass stations (e.g. see *Alcyonium digitatum* in Table 3.2.1. and Figure 3.2.11.).

2002 surveys

10 most abundant species (motile species only)

It was noticeable that in 2002, the majority of the most abundant species had a northern North Sea and west coast distribution (Figure 3.2.12.). This result may have been biased by the method of determining the dominant species (i.e. that abundance was summed across all stations), as in 2002, the coverage of the west coast was more intensive than the coverage of the central and southern North Sea. A number of the species were, however, distributed across the whole survey area (e.g. *Crangon allmanni* and *Astropecten irregularis*). In particular, *Crangon allmanni* was fairly ubiquitous in its distribution. A couple of the species were fairly rare over the survey area but very common at one or a few stations (e.g. *Ditrupa arietina* and *Processa nouveli holthuisi*). Others were abundant across a whole area (e.g. *Anapagurus laevis* and *Processa canaliculata*). As would be expected, the symbionts *Pagarus prideaux* and *Adamsia carciniopados* had very similar distributions. Interestingly, although *Asterias rubens* was a serious contributor to the stations of highest biomass in the southern North Sea (Table 3.2.1.), it did not make it into the top 10 species for the total surveyed area based on summed totals, potentially because of the survey coverage issues as discussed above.

10 species of greatest biomass

Only one of the species found to be in the top 10 high biomass species when summed across the survey area, was consistent with those also found to be high in abundance – *Pagurus prideaux* (Figures 3.2.12. and 3.2.13.). In this case, overall distribution of biomass was similar to that of abundance. For the other species, a number have high individual body mass and would not therefore need a high abundance to achieve high biomass (e.g. *Cancer pagurus* and *Colus gracilis*). Others were sessile species that would not be represented in the individual abundance data (e.g. *Flustra foliacea* and *Halecium halecinum*), but some can not be explained by these reasons and it is difficult to explain why they did not feature in the top 10 most abundant species. Most of the species of high biomass had a central to northern North Sea distribution and/or a west coast distribution (Figure 3.2.12.). There were no species that were clearly of a southern North Sea distribution but this could be an artefact of the survey coverage issues as discussed above. One species was included based on its particularly high biomass at a single station (*Philocheras trispinosus*), but most were distributed over a wider area.

2003 survey

10 most abundant species (motile species only)

A number of species were present in high abundance across a wide area (e.g. *Astropecten irregularis, Asterias rubens* and *Crangon allmanni*), whilst in other cases, species were particularly abundant at one point in space (e.g. *Amphiura chiajei*) (Figure 3.2.14. (a) to (j)). A number of the abundant species were restricted in their distribution to a particular area (e.g. *Pandalus montagui* and *Hyalinoecia tubicola* to the NE coast of Scotland and the northern North Sea). In these cases, their contribution to total abundance in particularly high abundance areas has already been noted (see Table 3.2.1). There were also a number of species that were more widespread in their overall distribution, but particularly abundant in a given area (e.g. *Crangon allmanni* and *Asterias rubens*). In these cases there was often a strong contribution of that species to the similarity in a particular cluster based on community type in that area (e.g. *Asterias rubens*, the red cluster in Figure 3.2.9. (a), also see Figure 3.2.14. (e)). *Turitella communis* was unusual in that it was rare across the whole survey area, but had a few stations of high abundance in two different areas of the survey (the southern North Sea and off the NE coast of Scotland) (Figure 3.2.14 (i)).

10 species of greatest biomass

Three of the 10 species found to have the highest biomass when summed across the survey area were consistent with those also found to be high in abundance (*Asterias rubens, Astropecten irregularis* and *Echinocardium flavescens*). In these cases, overall distribution of biomass was similar to that of abundance, but at some stations there was a disproportionally higher level of biomass in comparison with abundance and *vice versa* (Figures 3.2.14. and 3.2.15.). As noted before, this may be explained by the distribution of different age classes and thus size structures but could simply be an artefact of the scaling of the bubble plots in the figures and the data would need to be examined more closely to verify this. Most of the other species were not, however, present in the top 10 most abundant species. This could be explained for some of the species, either because of their high individual body masses (e.g. *Neptunea antiqua* and *Bolocera tuediae*), or because they were sessile species that would not be represented in the individual abundance data (e.g. *Flustra foliacea* and *Alcyonium digitatum*). Other than *Asterias rubens* and *Astropecten irregularis*, the distributions of species of high biomass tended to be confined to particular areas (Figure 3.2.15.). This is particularly true of the actinarian *Bolocera tuediae* and the bryozoan *Flustra foliacea* (see Table 3.2.1 for individual contributions to high biomass areas).

Interannual variation in key species distributions

10 most abundant species (motile species only)

Three species remained in the top 10 most abundant species across all three years surveyed. These were the starfish *Astropecten irregularis,* the shrimp *Crangon allmanni* and the hermit crab *Pagurus prideaux*. *Astropecten irregularis* had an overall distribution that varied little between years, with highest abundance in the southern North Sea in all three years and the lowest maximum numbers in 2002. 2002 was also the only year when the other dominant scavenging starfish, *Asterias rubens* was not in the top 10 species based on abundance. *Crangon allmanni's* distribution was also similar throughout the three-year period, particularly in 2001 and 2003. Maximum abundance was observed at a station in the southern North Sea in 2002. *Pagurus prideaux* showed little variation in distribution of abundance across the three-year period.

A further four species were present in the top 10 most abundant species in two of the three years and the remaining species were only present in one out of the three. Species included brittle stars, echinoids, shrimps, tubeworms, a hermit crab, a bivalve, and a gastropod. Of the species that were not present in all three years, some were not widely distributed but were particularly abundant at one station (e.g. *Echinocardium flavescens* in 2003, *Ditrupa arietina* in 2002 and *Abra nitida* in 2001). Others were more evenly distributed in their abundance in the year(s) that they were found in the top 10 and in these cases, the species were actually found within the top 20 abundant species when the data was further examined (e.g. *Asterias rubens*, *Echinocardium cordatum*, *Ophiura albida*).

10 species of greatest biomass

Only one species was present in the top 10 species based on biomass in all three years, the bryozoan *Flustra foliacea*. The distribution of *Flustra* was very similar in 2001 and 2003, but in 2002 coverage extended further to the northeast of the North Sea. Overall, dominant species based on biomass showed much greater congruence in 2001 and 2003 than they did in 2002. In total seven out of the ten species in 2001 were also found in the 2003 top 10, whilst only one species other than *Flustra* was found in both 2002 and another year (*Pagurus prideaux* in 2001 and 2002). Of the species that were found in both 2001 and 2003, the majority were present in greater biomass in 2001. However, the starfish *Asterias rubens* and *Astropecten irregularis* varied little in distribution of biomass between 2001 and 2003.

3.2.6. Summary

Although abundance was very variable amongst individual stations, overall distribution of total abundance varied little between the years. Total biomass was, however, noticeably higher in 2001 and overall patterns in distribution of biomass were more difficult to distinguish than those based on the more extensive international survey of 2003 (Section 3.1.2.). Taxonomic groups contributing to high abundance and biomass areas did, however, remain constant between years. For example, within the echinoderms, scavenging highly motile groups (e.g. starfish and brittle stars) were prevalent in the southern North Sea, whilst less mobile groups (e.g. regular and irregular echinoids) dominated the northern areas. Due to the sampling design it is not possible to draw conclusions on the interannual variation in abundance and biomass of individual species because this may simply be a representation of spatial heterogeneity within years.

As sessile species were only recorded based on presence/absence, it was difficult to establish variability in these over the three-year period. However, in considering the species contributing to high biomass areas and the spatial distributions of individual high biomass sessile species, it was obvious that the area south of the 50m-depth contour in the southern North Sea was not an area characterised by sessile species. This was true in all three years surveyed and in two out of the three years there were stations with no sessile species present at all in that area. The southern North Sea was also characterised by low diversity in comparison with the rest of the area surveyed. This was particularly noticeable in 2001 and 2003 but less so in 2002. The lack of clarity in 2002 could however be an artefact of the lower sampling coverage in this area of the North Sea in 2002.

Overall, however, the results suggested the greatest interannual variation between 2002 and the other two years. Epifaunal communities of 2001 and 2003 had similar characteristics. This may be a reflection of bi-annual population cycles, with peaks of particular dominating species occurring every other year, or alternatively could be a result of a change in extrinsic drivers in 2002. The environmental and hydrographical data will need to be examined to establish why these differences were observed.

Interpretation of interannual variation in the epibenthic community west of Scotland would benefit from the addition of recent survey data from 2003 and 2004, as the differences in coverage of 2001 and 2002 made it difficult to analyse variability. However, it was evident from the available data, that communities west of Scotland were quite different to those found in the North Sea when based on distributions of dominant species and clustering of similar communities. Overall patterns in total abundance, biomass and species diversity were, however, less distinguishable from levels seen in the North Sea. It is important to note that the sampling surveys in the North Sea and to the west of Scotland took place at different times of year. The samples on the west coast were taken in winter whilst those in the North Sea were taken in summer.

Hinz *et al*. (2004) and Reiss & Kroncke (2004) have studied the seasonal variability in epifauna at a number of sites within a small area of the southern North Sea. Both studies found that both biomass and abundance varied considerably between seasons. Biomass in winter was almost always less than that in summer and clustering of species composition varied due to changes in the relative abundances of the species present. Community composition was evidently different for the west of Scotland stations to that of the North Sea stations for both of the years 2001 and 2002. However, in both years, one of the key communities on the west coast (sampled in winter) extended into the northern North Sea around Shetland (sampled in summer) when based on the relative abundances of motile species. This suggests that seasonality was not a key contributor to the differences in community composition for the two areas. There was also further evidence that the differences in community composition between the two surveyed areas were not due to seasonality because the characteristic species did not show a high level of congruence. Hinz *et al*. (2004) found that species composition of communities did not alter between seasons, rather it was their relative abundances. It was more difficult to elucidate whether differences in abundance and biomass of dominant species between the North Sea and the west coast were due to seasonal effects or just a reflection of actual distribution.

Between 2002 and 2003 a change in the sampling methodology occurred and rather than including all animals caught in the beam trawl, only those retained in a 5mm sieve were analysed. This was to bring sampling inline with the wider international methodology developed in the earlier Biodiversity project. Overall, results did not suggest any noticeable effect of this change in methodology.

4. Discussion

In this report the preliminary findings of the epibenthic surveys that have been undertaken as part of the Scottish Executive (SE) funded ROAME MF0753 and the EC 5th framework project MAFCONS have been presented. The epibenthic invertebrate sampling data were presented for the full international North Sea sampling trip of 2003 and interannual variation in epibenthic community dynamics explored using a study undertaken by the Scottish partner over the years 2001, 2002 and 2003. In 2001 and 2002 the surveyed area extended from the North Sea to the west coast of Scotland and transitional changes in species compositions and overall community dynamics from the northeast Atlantic into the northern North Sea are discussed below. A first attempt at estimating secondary production from the epifauna using the empirical relationship of Edgar (1990a) was undertaken for the full international dataset for 2003. Ultimately characteristics of the benthic invertebrate communities will be linked to demersal fish diversity and to levels of ecological disturbance associated with the North Sea demersal fishing industry (www.mafcons.org/).

Within the greater North Sea area, overall patterns in distribution of epifaunal species diversity, community composition and total abundance were consistent for both the international 2003 survey and the less intensive surveys of the Scottish partner (FRS) in 2001 and 2003. This suggests that for interpretation of gross changes in these community parameters, 40 stations surveyed can provide as much information as 100 at the scale of the North Sea. In 2002, however, coverage of the North Sea area was lower (31 rather than 40 stations) and it was noticeable that where areas were less well sampled, patterns were not distinguishable. Clearly the greater the sampling intensity, the easier it is to resolve boundaries between different community types, but the findings of this report suggest that a coverage of at least 40 stations will be sufficient. At this resolution it is possible to elucidate the following major points:

1. Species diversity is lowest south of the 50m-depth contour in the southeastern North Sea.
2. Sessile species are important contributors to the community in the central and northern North Sea, whilst communities south of the 50m-depth contour are dominated by a number of highly abundant motile species.

3. Total abundance based on motile species is highest in the southeastern North Sea along the continental coast, on the northeast coast of Scotland and in the northern North Sea.
4. Areas of high total biomass are more variable in their distribution than total abundance, with stations also being high in some areas of the central North Sea.
5. Areas of high total biomass and high total abundance do not always correspond, reflecting both the contribution of high individual body mass species and sessile species (not counted in the abundance figures) to community-level biomass in certain areas.

These overall distributions also agree with the findings of Callaway *et al.* (2002), who undertook an even more extensive study of the North Sea in 2000, covering 270 stations.

All surveys indicated that there were two key dominant species in the North Sea that remained in the top 10 most abundant from year to year. These were *Astropecten irregularis* and *Crangon allmanni*. A number of other species including starfish, brittlestars and scavenging crustaceans were found in the top 20 most abundant species across all surveys. Others were rarer in their distribution but had peaks in abundance or biomass in one particular area within one year, dominating the community of that station at the time that the survey was undertaken. The bryozoan *Flustra foliacea,* dominated biomass in the North Sea in all surveyed years and the starfish *Astropecten irregularis* and *Asterias rubens* were also key species based on biomass. There was evidence from all surveys that particular taxonomic groups, fulfilling identifiable niches in the community, were consistently present in specific areas of the North Sea. For example, within the echinoderm phyla, highly motile scavenging starfish and brittle stars were common in the southern North Sea, whilst deep burrowing irregular sea urchins were more common in the central to northern North Sea and regular surface dwelling sea urchins in the northern North Sea.

Clustering of community types based on the similarity in species composition of the stations sampled did vary between surveys. The method used to calculate similarity values between pairs of stations (Bray-Curtis similarity index in PRIMER) is, however, influenced by the coverage of stations because the similarity value of an individual pair is relative to the dissimilarity to all other surveyed stations. This makes it difficult to compare clustering of communities between surveys that have been subject to different levels of sampling and that have variable geographic limits in the area covered. Based on the presence/absence data, which included sessile species, all surveys had an identifiable separation in community types between those stations surveyed south of the 50m-depth contour and those in the deeper northern areas. Where west coast data were also included (2001 and 2002 FRS data), it was clear that community types do differ between the North Sea and the west coast.

Both the distributions of key species and of clusters of similar community compositions indicated transitions in epifaunal communities from the northeast Atlantic on the west coast of Scotland into the northern North Sea. Results indicated that based just on the available data, identities of characterising species and even wider taxonomic groups were quite different on the western coast. Initial interpretation of the data did not suggest that seasonal differences in the two areas had affected the differences in community types found, but it is not possible to tell whether actual levels of abundance, biomass and species diversity would be different had the west coast been sampled in summer rather than winter. With the addition of the 2003 and 2004 west coast data it may be important to re-analyse the two surveys (i.e. summer North Sea and winter west coast) separately for each of the years and to then consider any links and influences across the transitional area.

Further work will be undertaken to validate the method used to estimate secondary production from the benthos. In this report the preliminary results were presented for the data using Edgar's (1990) method. Patterns of overall distribution are similar to those of total abundance and biomass but it is likely that some of the results will be biased by the dependence of the model on mean individual weights. Future work will include a new estimation of production based on the epifaunal community data broken down into body mass size classes as developed by Jennings *et al.* (2001). A detailed description of the models used to estimate secondary production for both the infauna and the epifauna is given in MAFCONS Deliverable 10 (www.mafcons.org).

Work will also be undertaken to assess the effect that catchability of the 2metre beamtrawl is having on the biodiversity and productivity results. The 2metre beamtrawl is not a fully quantitative sampler and initial results from a study of catch efficiency in the southern North Sea, found that between 67-75% of the total available species were caught, whilst only 34-39% of the total available productivity was sampled. When considering individual species, the lowest catch efficiency based on abundance and biomass was for the swimming crab *Liocarcinus holsatus* (only 9% of available population sampled), whilst the highest catch efficiency based on abundance and biomass was for shrimps of the genus *Processa* (72% of available abundance and 83% of available biomass) (Reiss, *pers comm.* 2005). The study by *Reiss et al.* (pers comm., 2005) did not suggest big differences in catchability between the two different habitats that were tested, suggesting that the results presented here should at least be consistent in the underestimation of numbers and biomass.

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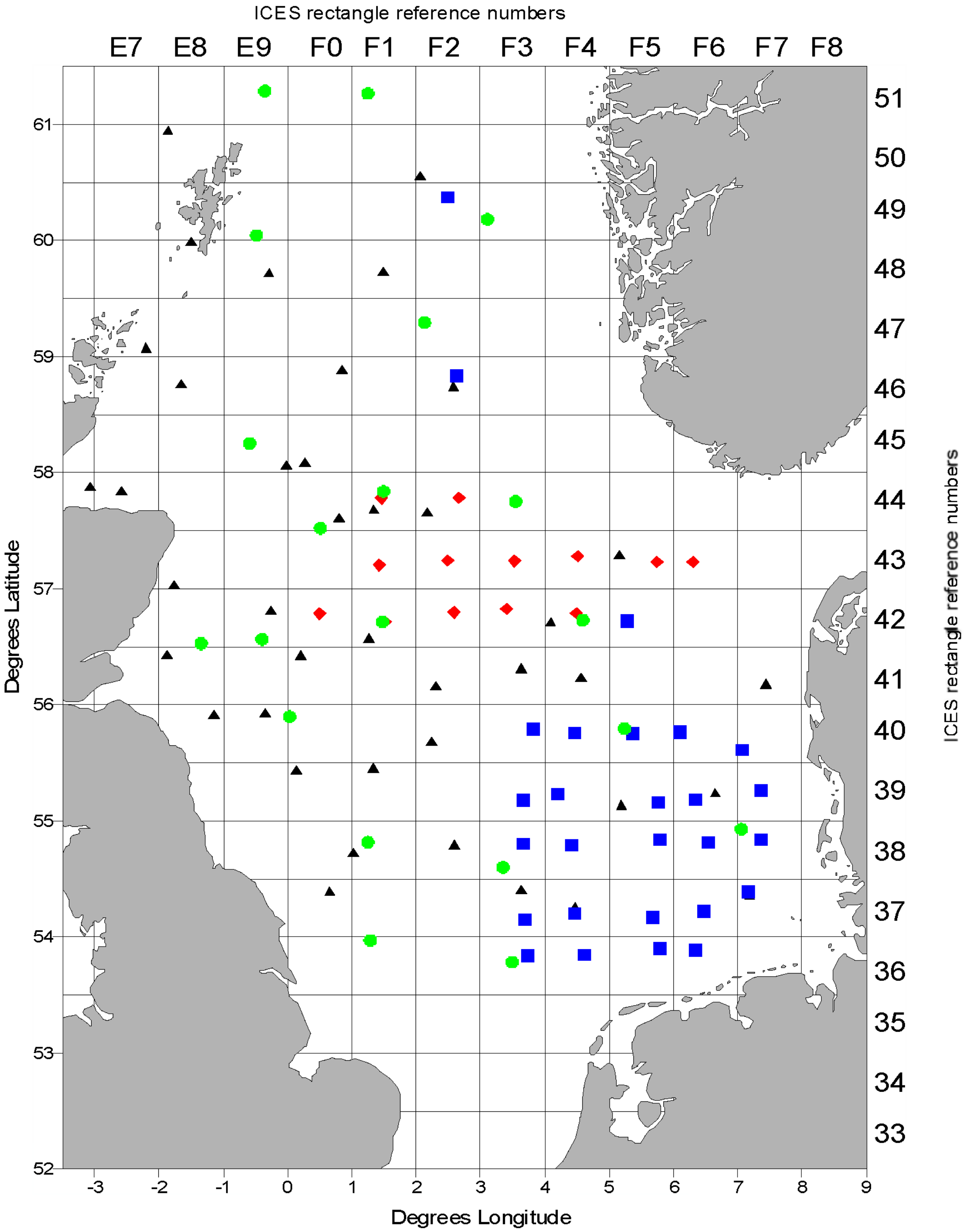
Appendix – All Figures and Tables

Figure 2.1 Stations sampled for epifauna by the participants of the EC project MAFCONS in 2003. Dutch sampled stations are not included at this point (see note in Section 3.1).



Institutes participating in the 2003 MAFCONS surveys:

Germany	■ (blue square)	The Senckenburg Institute & Sea Fisheries Institute
England	■ (green square)	University of Wales Swansea & CEFAS
Norway	◆	Institute for Marine Research, Tromso
Scotland	▲	FRS Marine Laboratory, Aberdeen

Figure 2.2 Stations sampled by FRS Marine Laboratory in 2001, 2002 and 2003. Stations west of –3° longitude were sampled during the November west coast groundfish surveys, whilst those east of –3° longitude were sampled during the August groundfish survey.

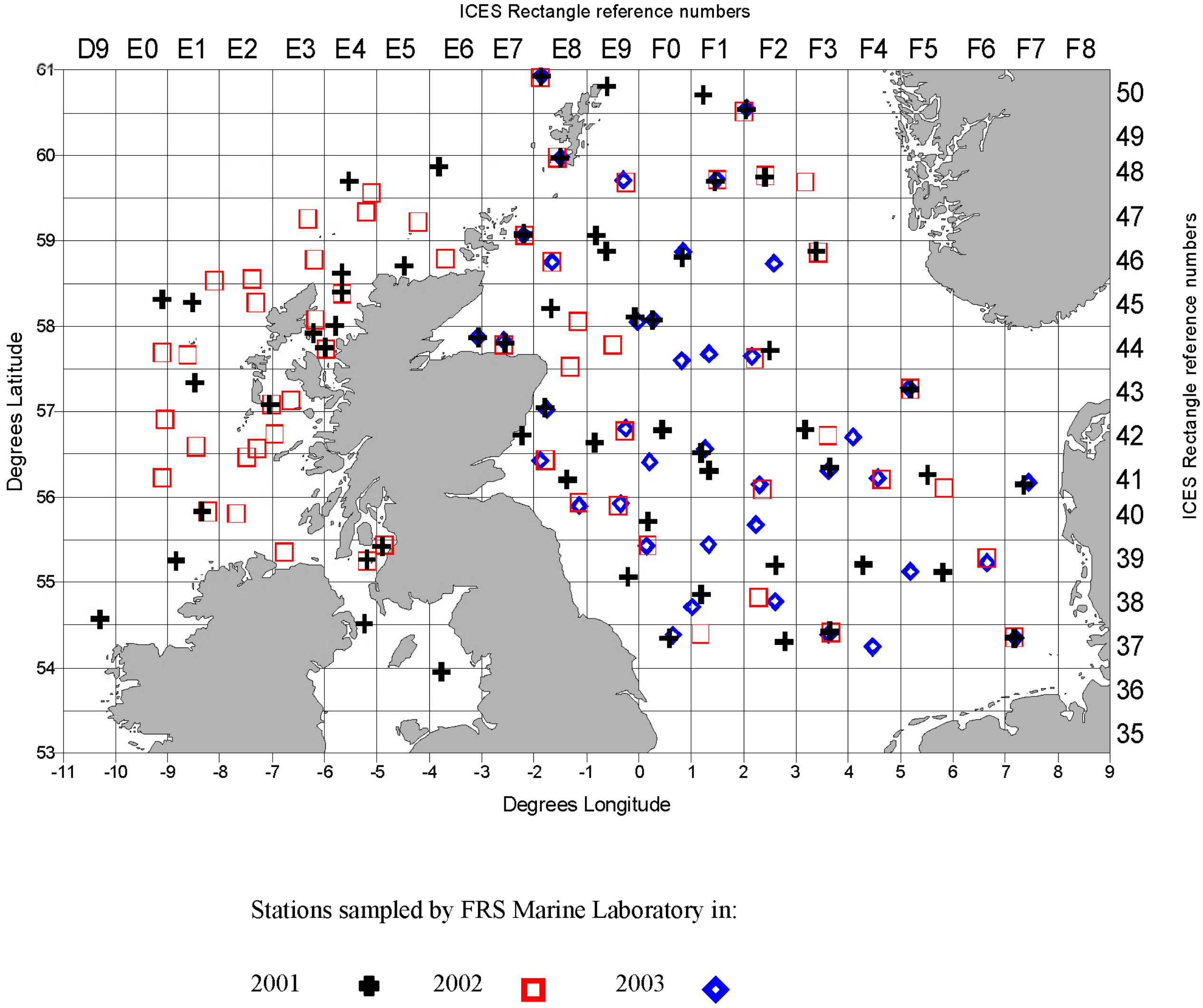
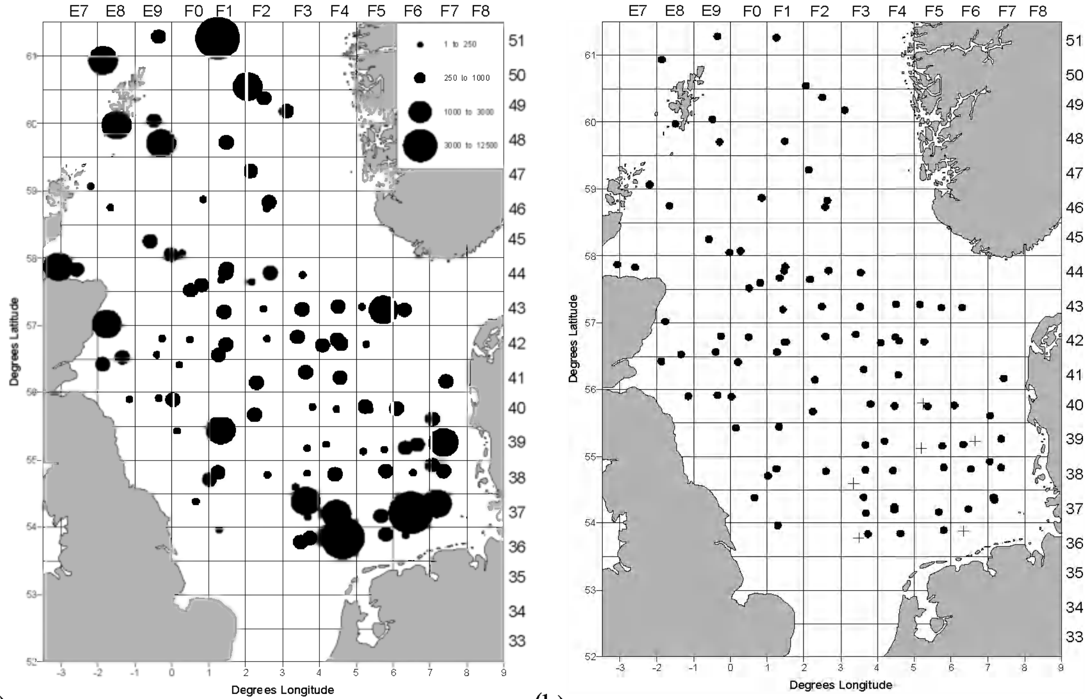


Figure 3.1.1. (a) Total abundance (no.1000m^{-2}) of motile species and, (b) Presence /absence distribution of sessile species (stations where there are no sessile species represented by +).



(a) (b)

Figure 3.1.2. Total biomass (grams.1000m^{-2}) of all species sampled in the August 2003 MAFCONS 2-m beam trawl survey.

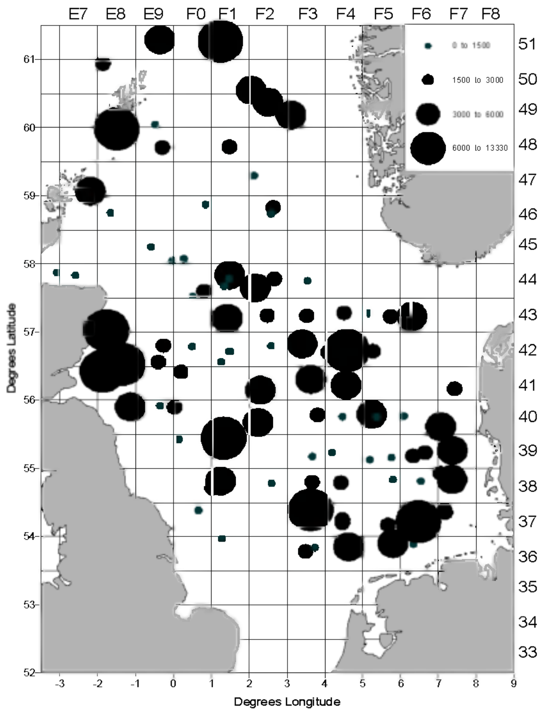
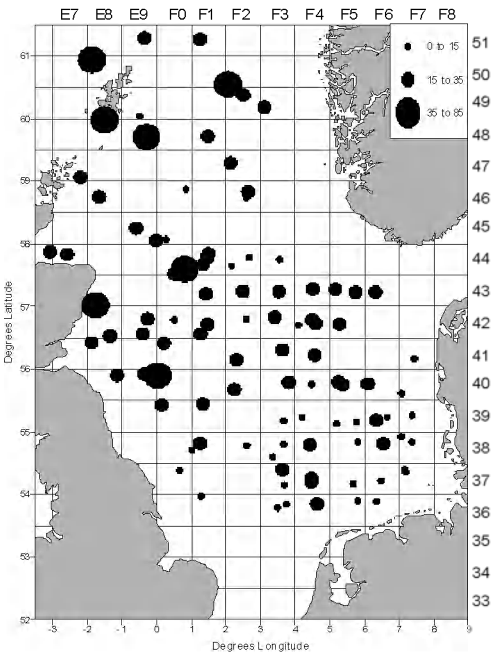
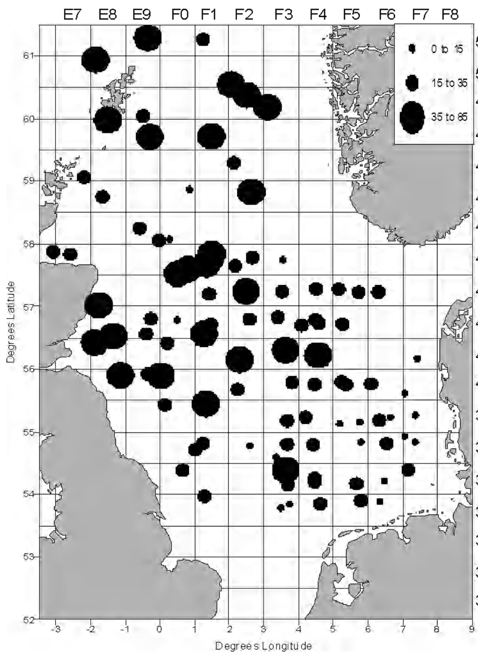


Figure 3.1.3. Total number of species (Hill's N0) (a) motile species only, (b) all species – presence/absence data; (c) Hill's N1 diversity – motile species (d) Hill's N2 diversity -motile species.

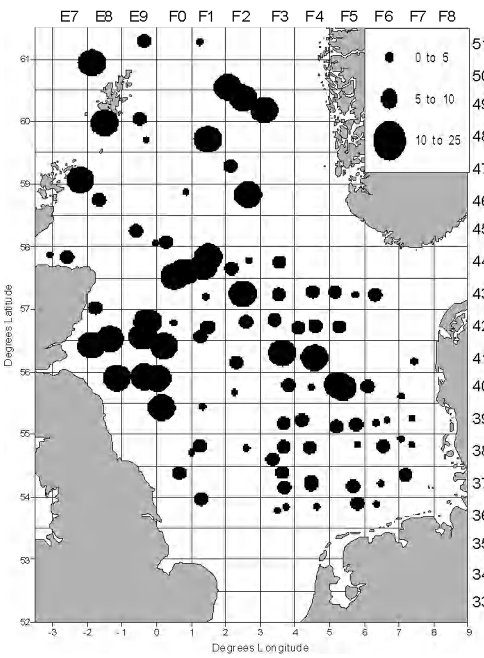
(a)



(b)



(c)



(d)

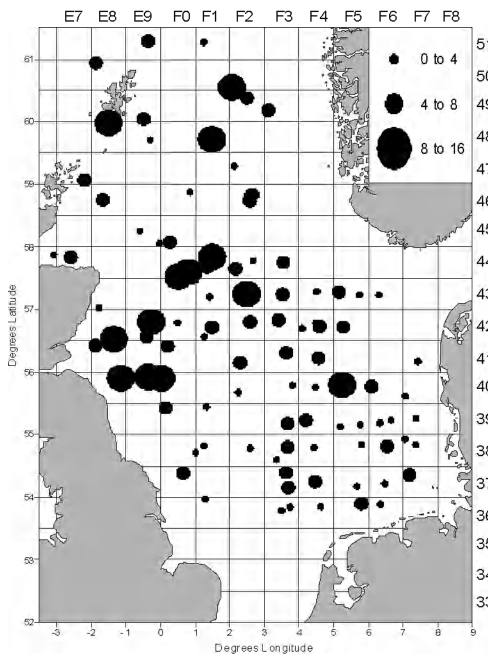
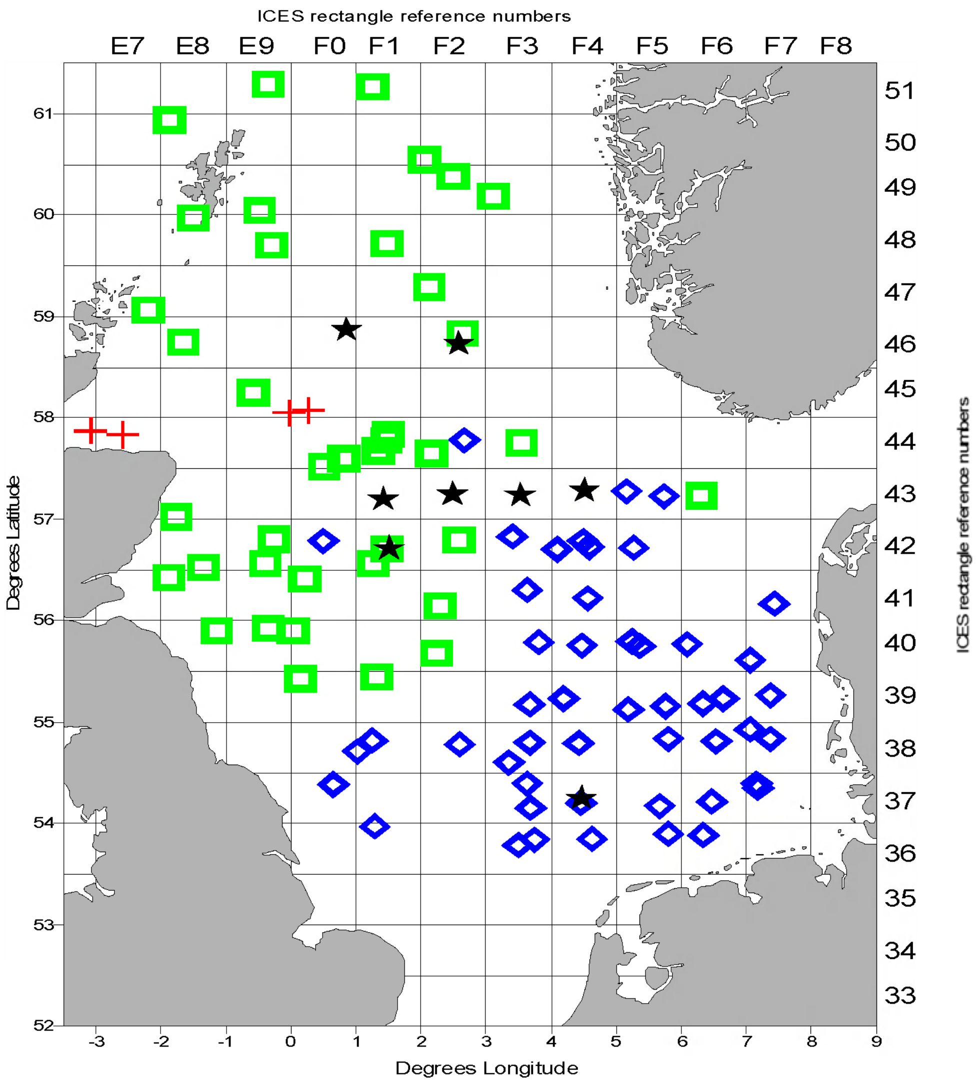


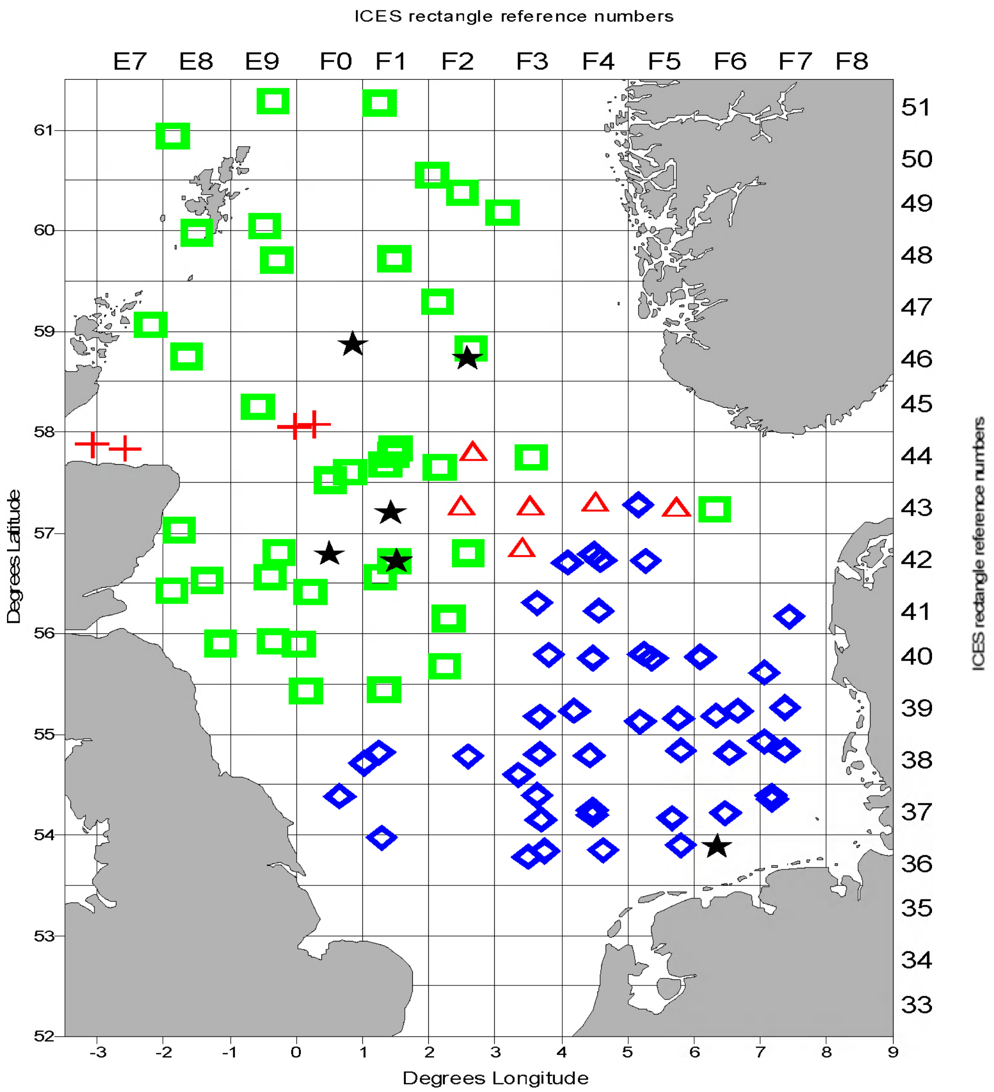
Figure 3.1.4. Location of clusters of similar species based on hierarchical cluster analysis of fourth root transformed motile species abundance data. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.



Cluster ◇	Cluster □	Cluster +
Average similarity – 38.43	Average similarity – 29.83	Average similarity – 35.76
Astropecten irregularis	*Anapagurus laevis*	*Turritella communis*
Asterias rubens	*Pagurus bernhardus*	*Brissopsis lyrifera*
Pagurus bernhardus	*Asterias rubens*	*Astropecten irregularis*
Liocarcinus holsatus	*Crangon allmanni*	*Nephrops norvegicus*
	Astropecten irregularis	*Crangon allmanni*
	Hyalinoecia tubicola	

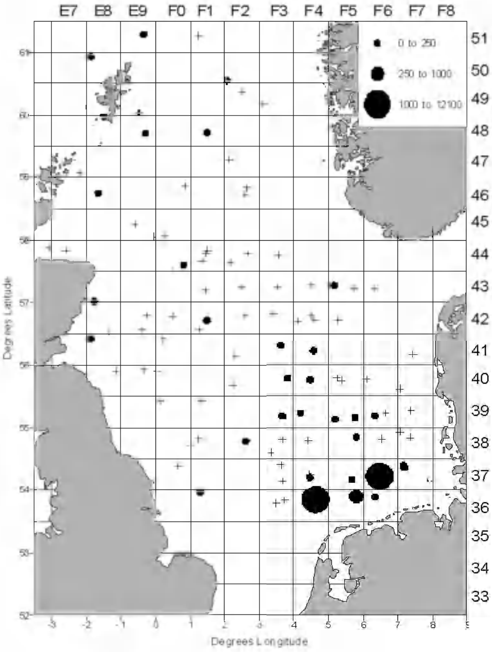
Outliers = ★

Figure 3.1.5. Location of clusters of similar species based on hierarchical cluster analysis of presence/absence transformed data for all epifauna. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.

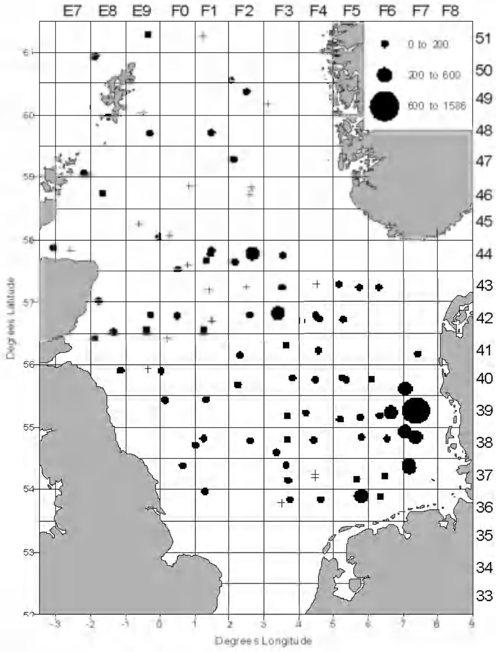


Cluster ◇	Cluster □	Cluster +
Average similarity – 35.88	Average similarity – 31.06	Average similarity – 37.51
Astropecten irregularis	*Anapagurus laevis*	*Turritella communis*
Asterias rubens	*Pagurus bernhardus*	*Pennatula phosphorea*
Pagurus bernhardus	*Asterias rubens*	*Nephrops norvegicus*
Liocarcinus holsatus	*Hormathia digitata*	*Crangon allmanni*
Corystes cassivelaunus	*Crangon allmanni*	*Brissopsis lyrifera*
	Epizoanthus incrustatus	*Astropecten irregularis*
Cluster △	Cluster △ continued….	Outliers = ★
Average similarity – 29.56		
Pagurus bernhardus	Mysidae	
Luidia sarsi	*Hyas coarctatus*	
Flustra foliacea	*Neptunea antiqua*	

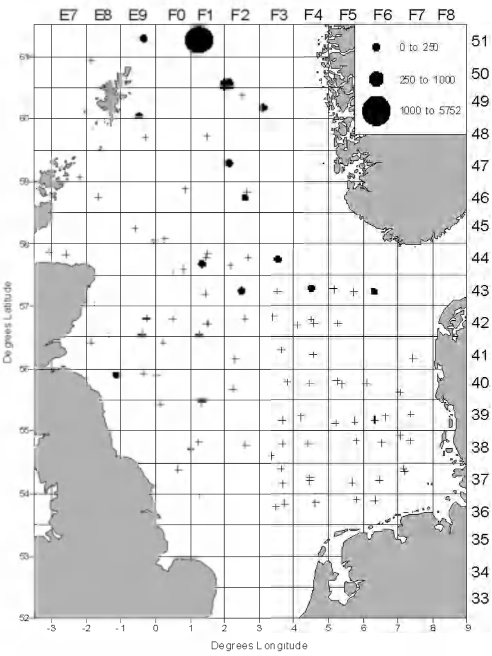
Figure 3.1.6. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species when summed over the whole survey. A '+' represents a station where the species was not present. N.B. Scales vary between species.



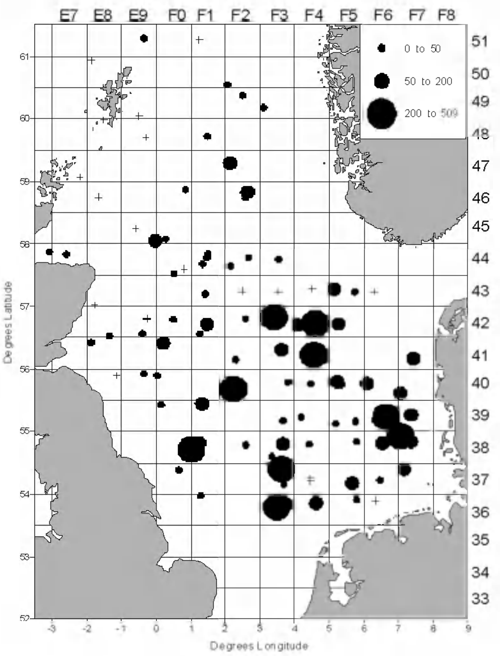
(a) Ophiura albida



(b) Asterias rubens

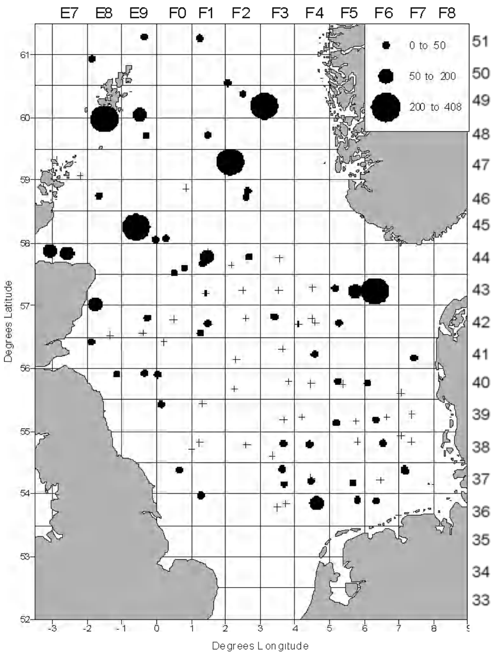


(c) Echinus acutus

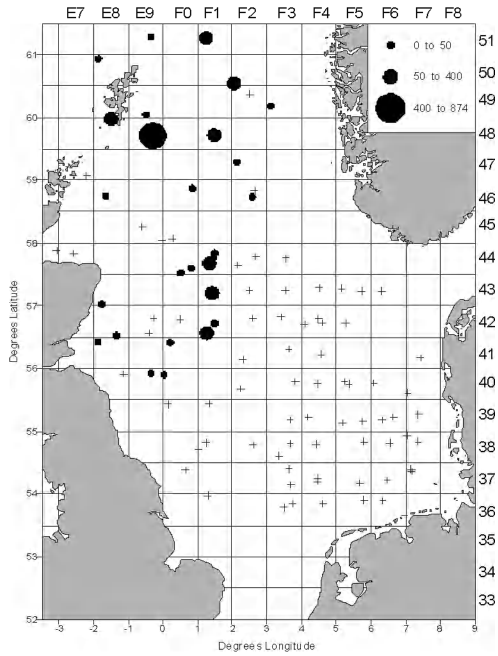


(d) Astropecten irregularis

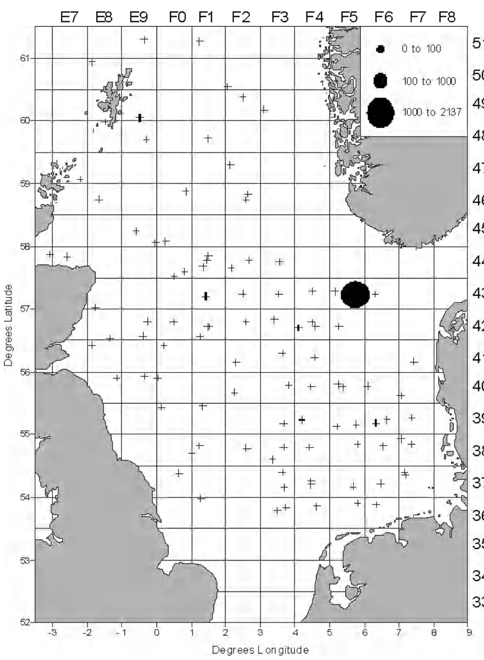
Figure 3.1.6. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species when summed over the whole survey. A '+' represents a station where the species was not present. N.B. Scales vary between species.



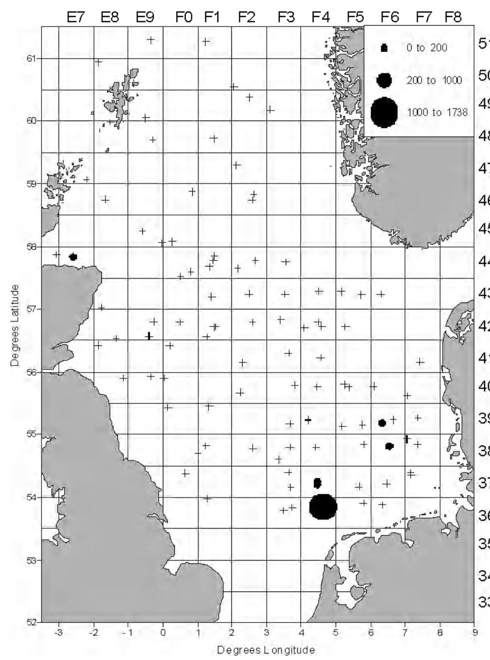
(e) Crangon allmanni



(f) Hyalinoecia tubicola

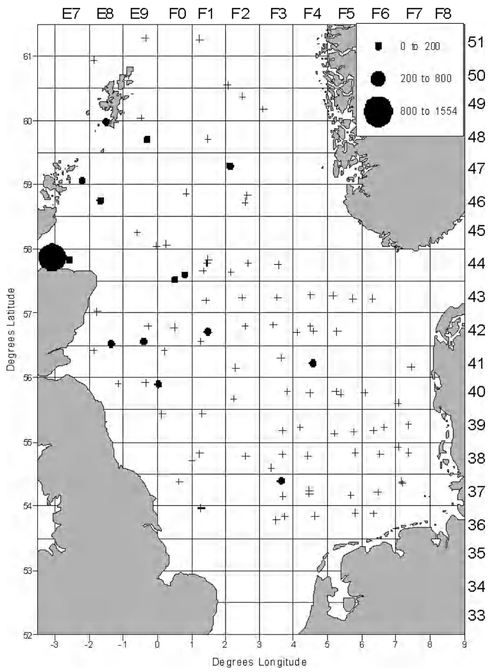


(g) Echinus (juveniles)

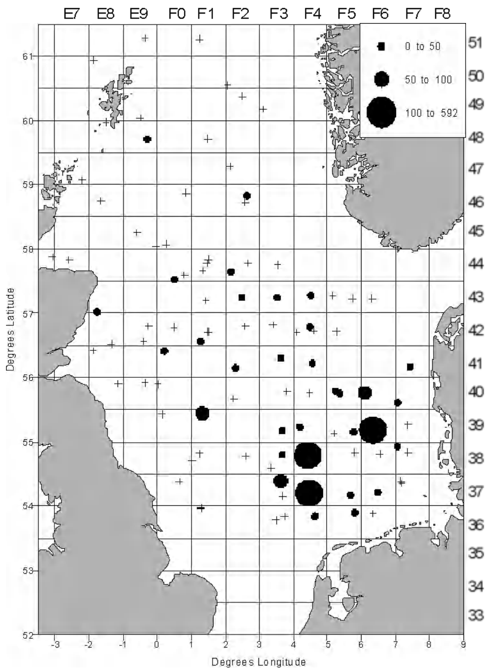


(h) Corbula gibba

Figure 3.1.6. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species when summed over the whole survey. A '+' represents a station where the species was not present. N.B. Scales vary between species.

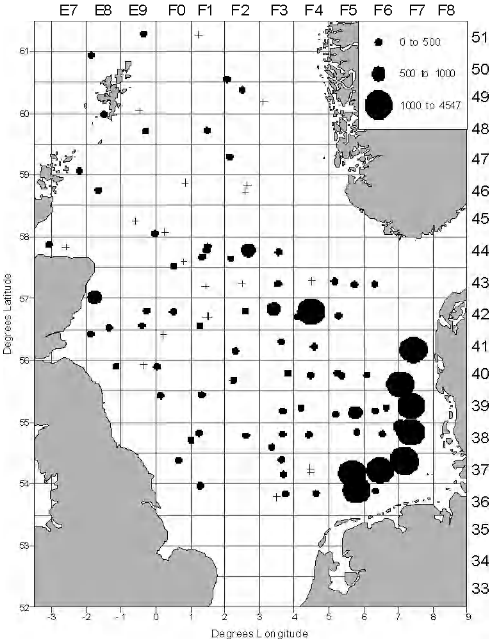


(i) Amphiura chiajei

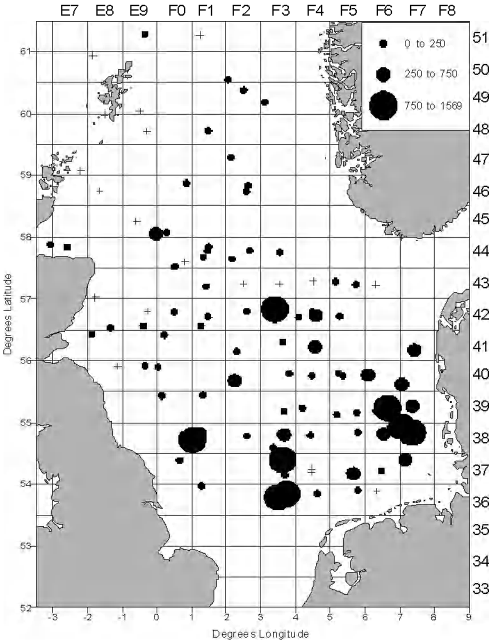


(j) Echinocardium cordatum

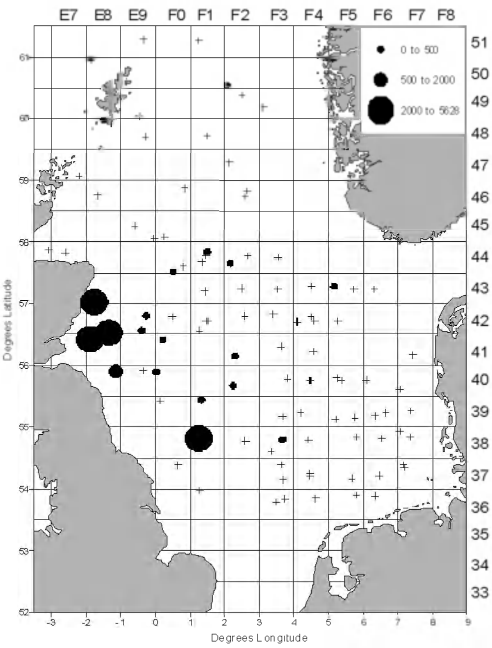
Figure 3.1.7. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass when summed over the whole survey. A '+' represents a station where the species was not present. N.B. Scales vary between species.



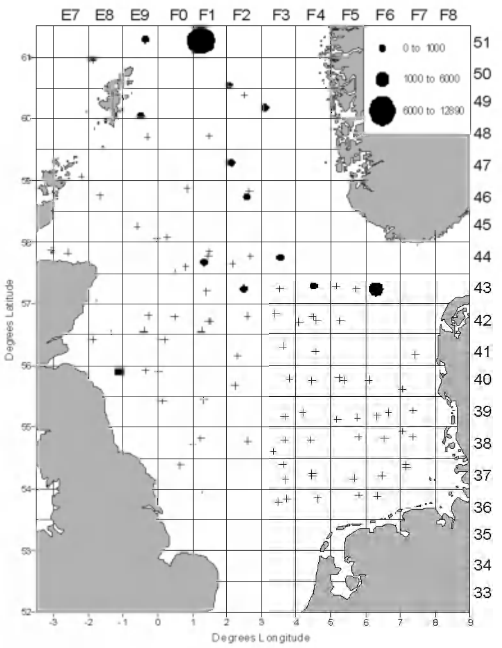
(a) Asterias rubens



(b) Astropecten irregularis

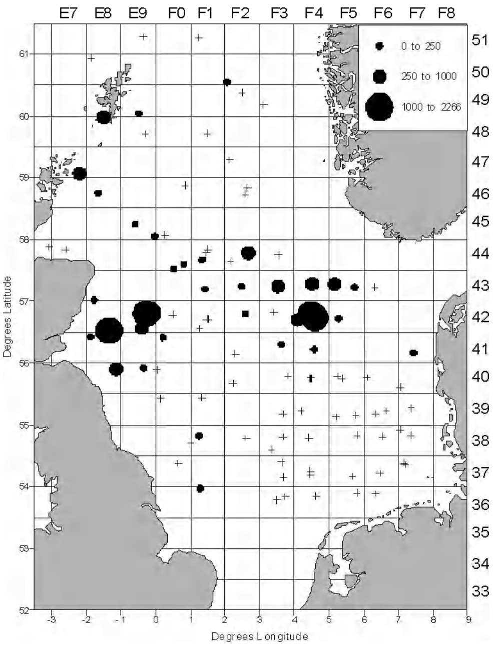


(c) Alcyonium digitatum

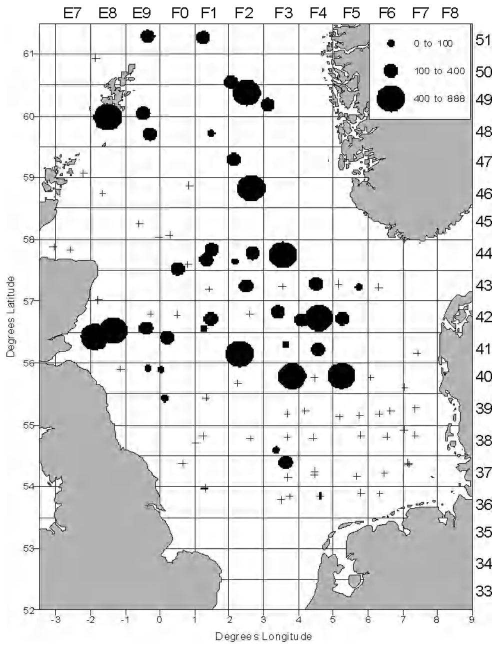


(d) Echinus acutus

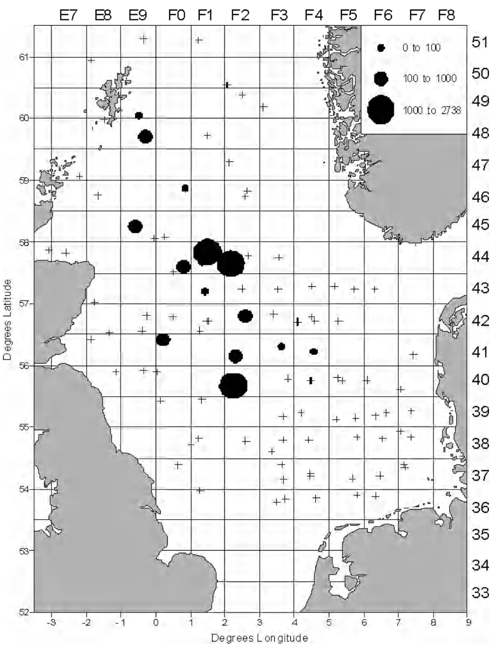
Figure 3.1.7. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass when summed over the whole survey. A '+' represents a station where the species was not present. N.B. Scales vary between species.



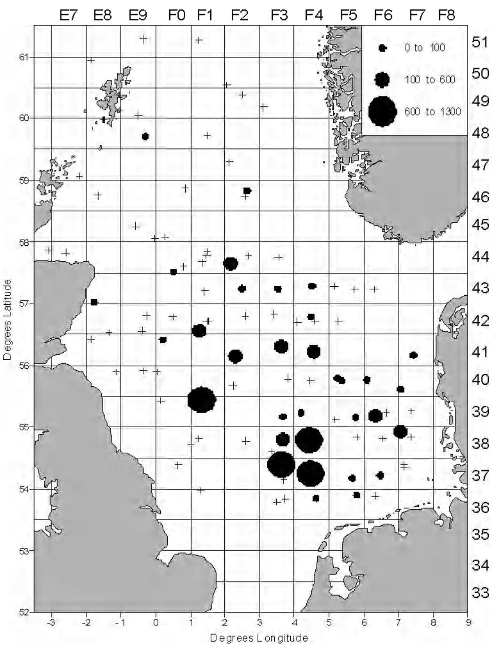
(e) Flustra foliacea



(f) Neptunea antiqua

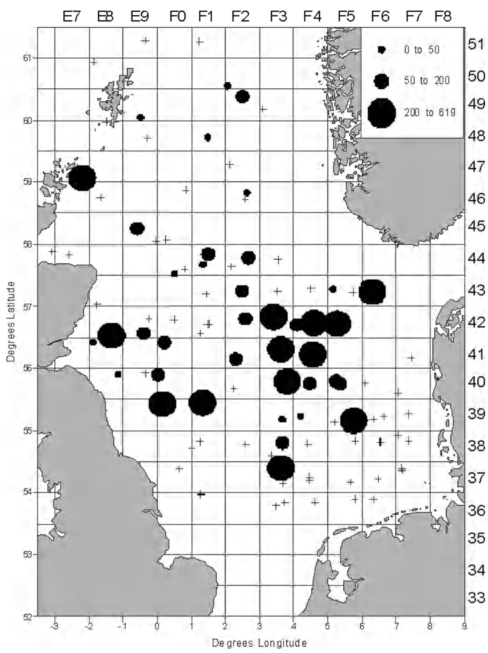


(g) Bolocera tuediae

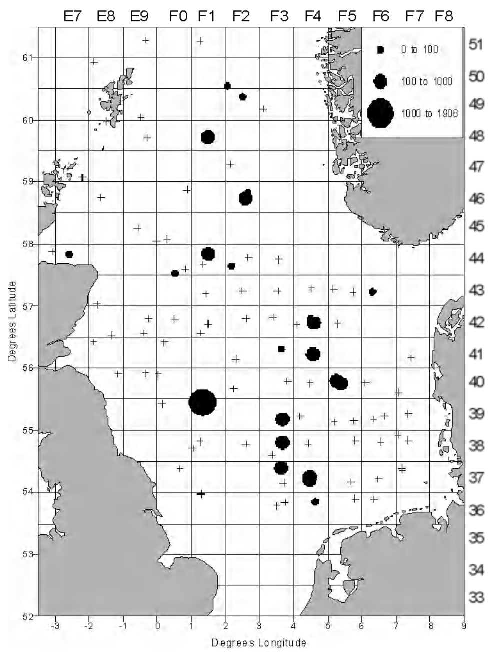


(h) Echinocardium cordatum

Figure 3.1.7. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass when summed over the whole survey. A '+' represents a station where the species was not present. N.B. Scales vary between species.



(i) Buccinum undatum



(j) Echinocardium flavescens

Figure 3.1.8. Distribution of secondary production from the epifauna (grams.day.1000m^{-2}) N.B. This analysis also included the Dutch data with a total of 133 stations.

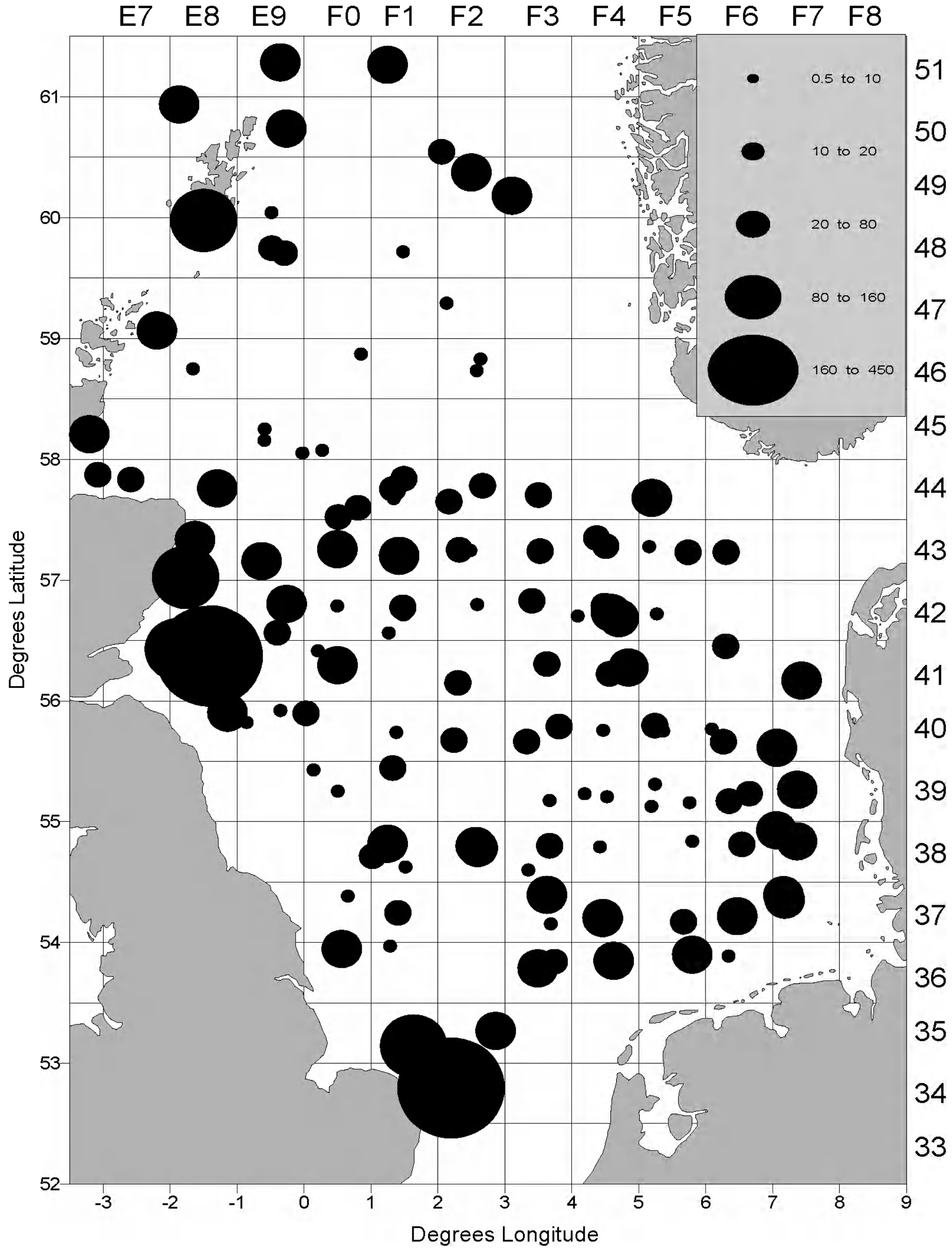
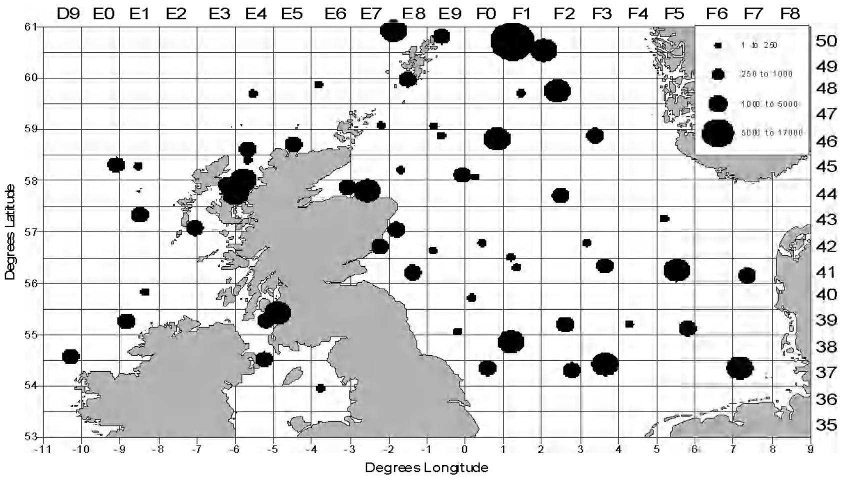
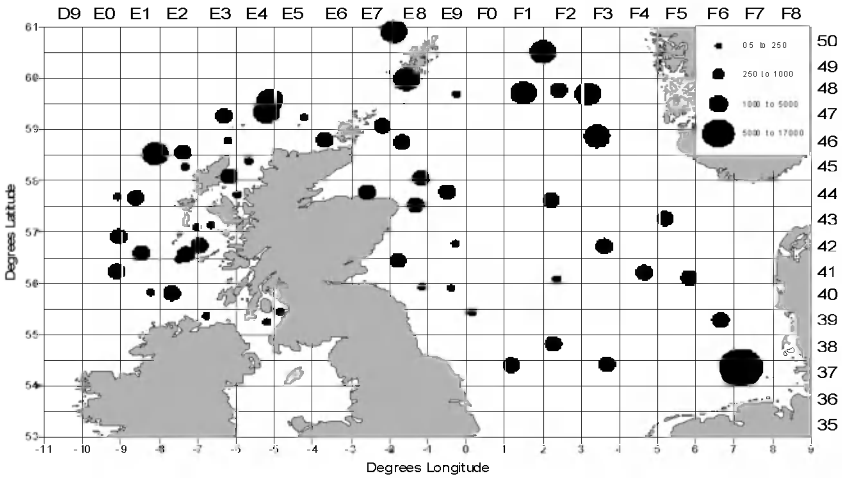


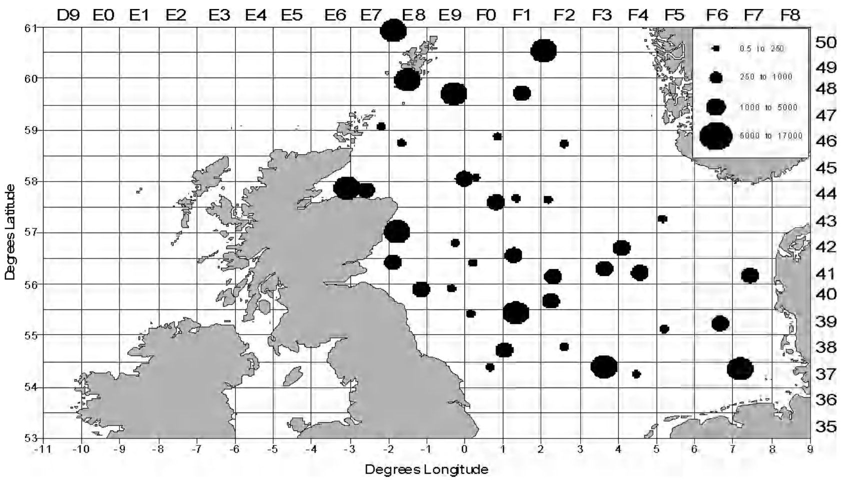
Figure 3.2.1. Distribution of the total abundance (no.1000m^{-2}) of motile species in each of the three years surveyed by FRS



(a) 2001 – west coast and North Sea

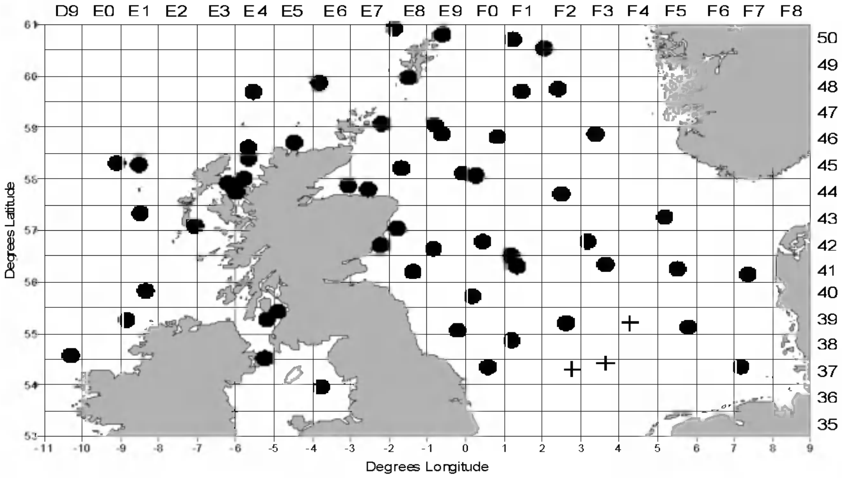


(b) 2002 – west coast and North Sea

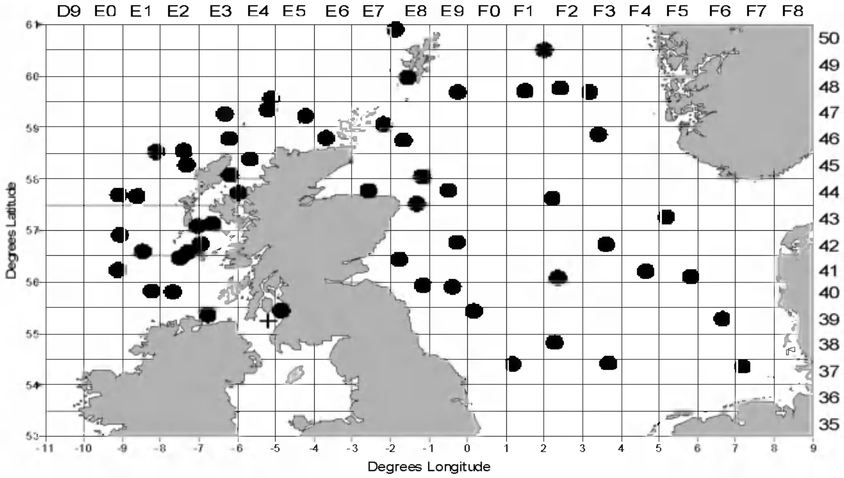


(c) 2003 – North Sea only

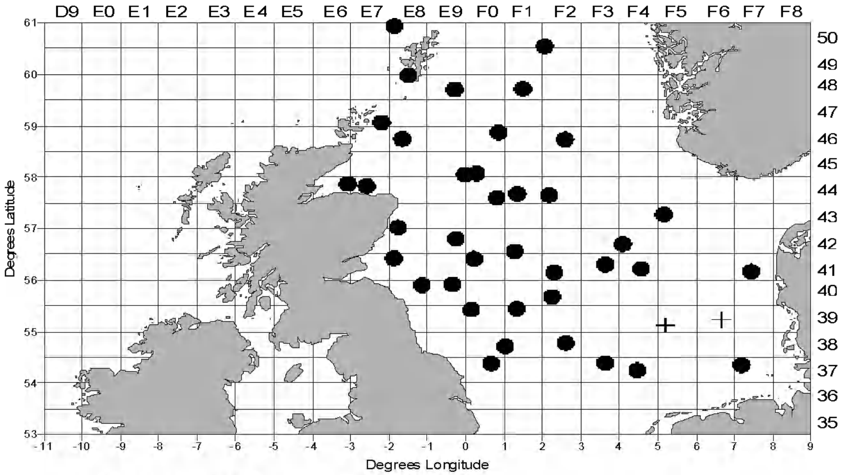
Figure 3.2.2. Distribution of the presence/absence of sessile species in each of the three years surveyed by FRS. A '+' marks the stations where no sessile species were recorded.



(a) 2001 – west coast and North Sea

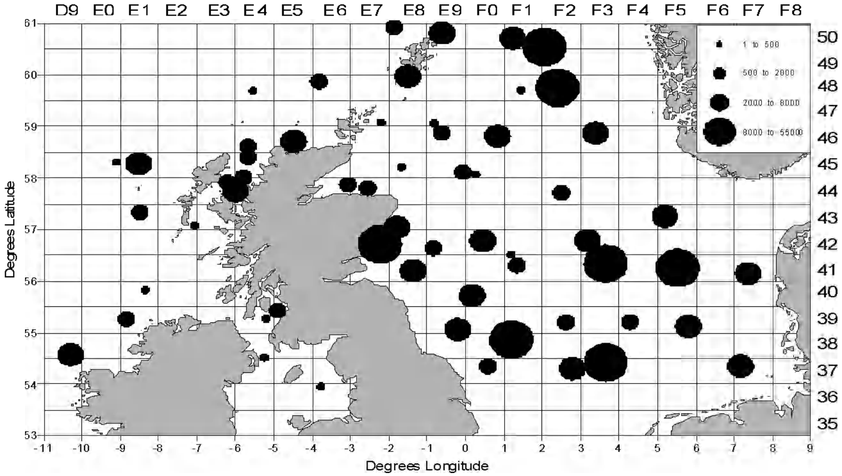


(b) 2002 – west coast and North Sea

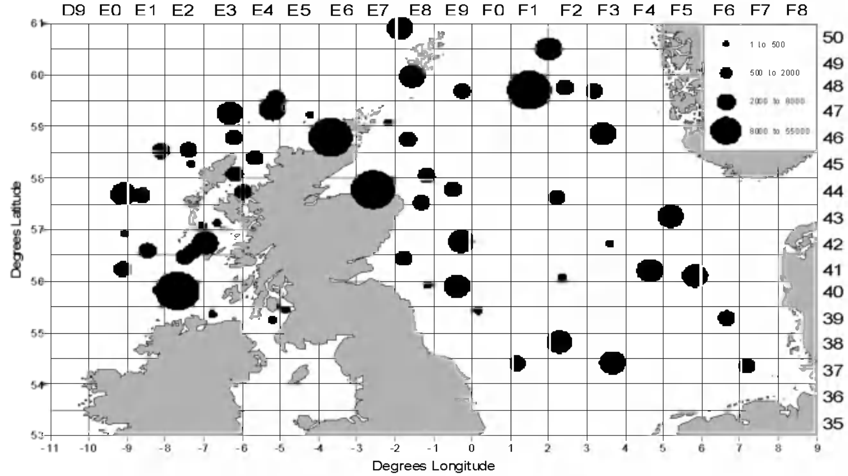


(c) 2003 – North Sea only

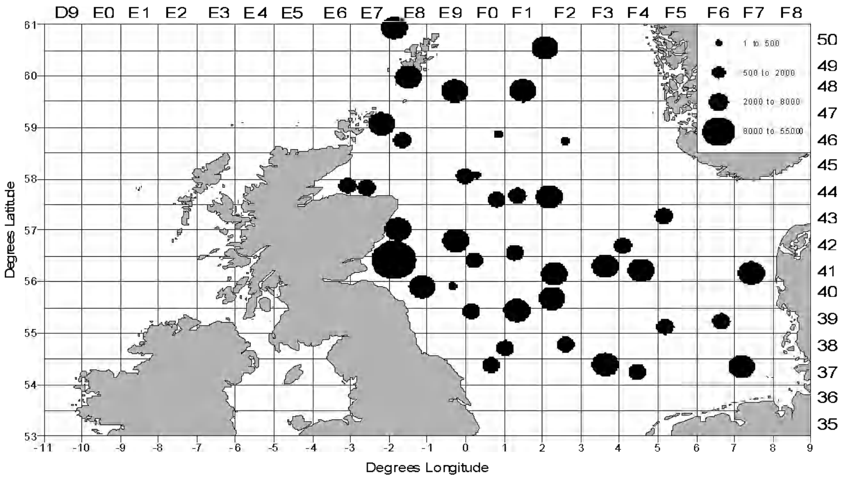
Figure 3.2.3. Distribution of total biomass (grams.1000m^{-2}) in each of the three years surveyed by FRS.



(a) 2001 – west coast and North Sea

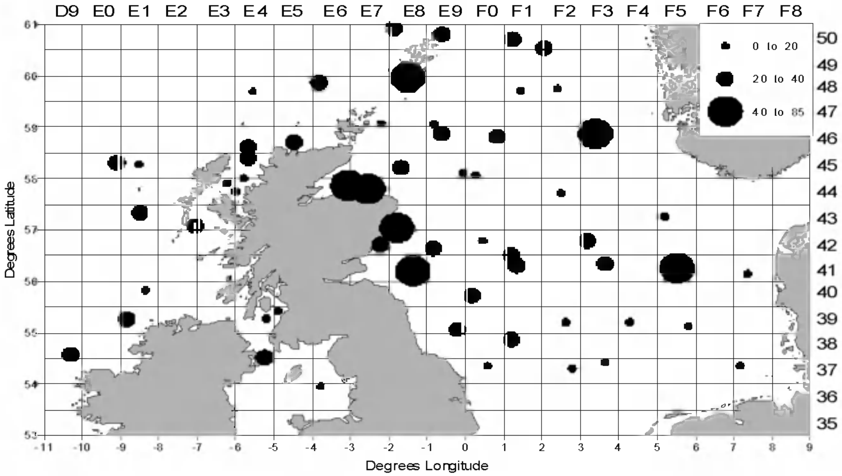


(b) 2002 – west coast and North Sea

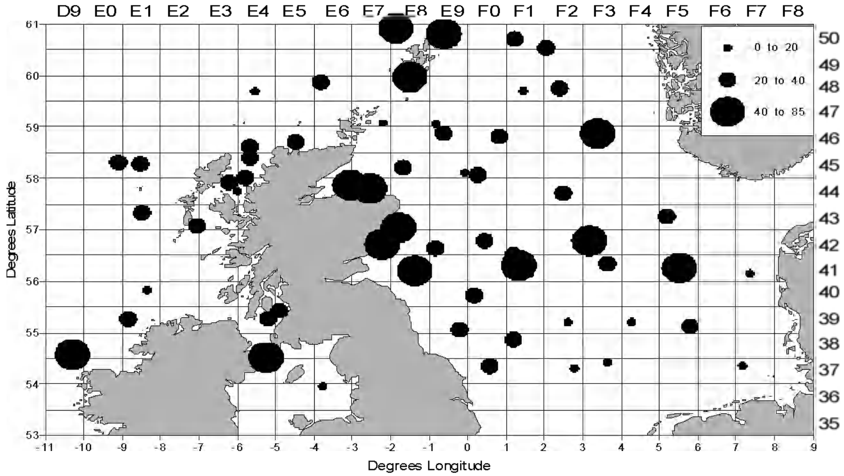


(c) 2003 – North Sea only

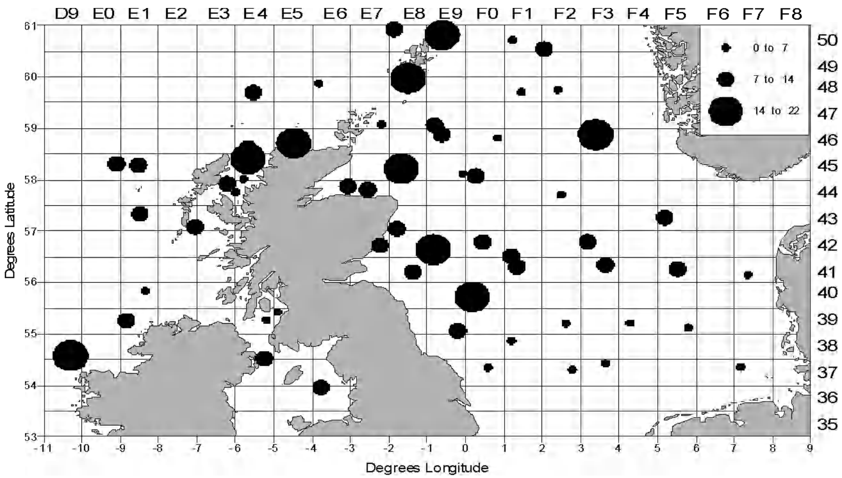
Figure 3.2.4 Indices of species diversity for the FRS 2001 surveys: (a) Total number of species (Hill's N0) - motile species only; (b) all species – presence/absence data; (c) Hill's N1 diversity – motile species (d) Hill's N2 diversity -motile species.



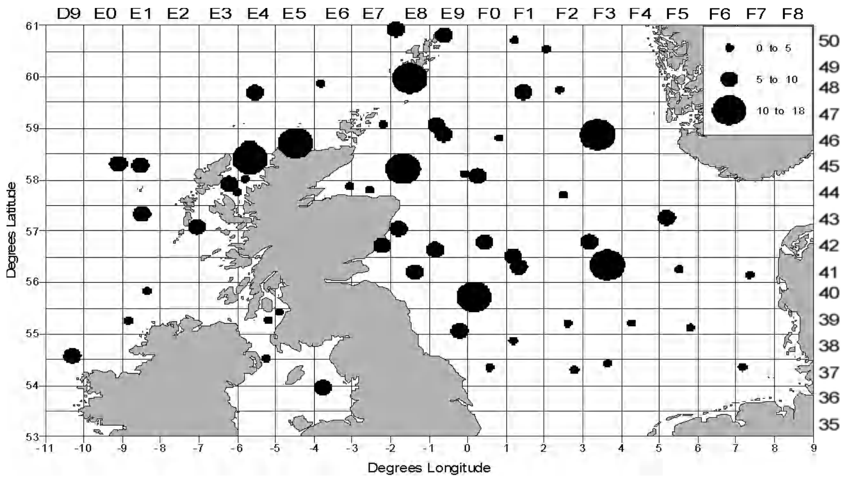
(a) Hill's N0 –motile species only



(b) Hill's N0 – all species

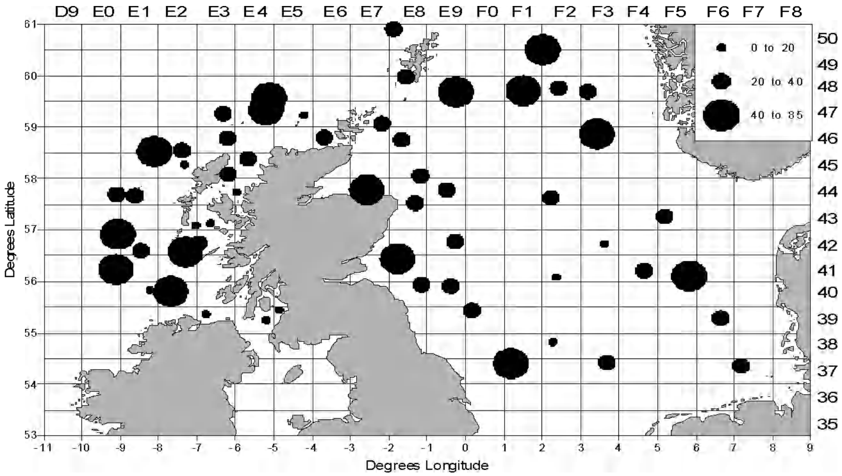


(c) Hill's N1 – motile species only

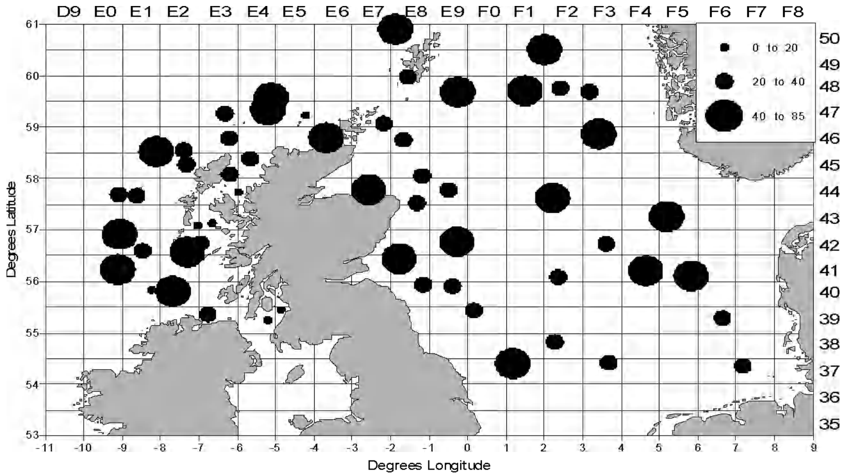


(d) Hill's N2 – motile species only

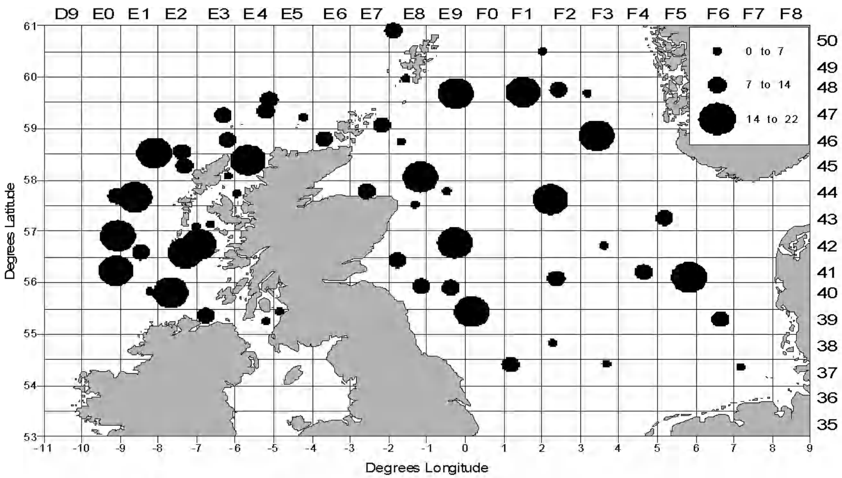
Figure 3.2.5. Indices of species diversity for the FRS 2002 surveys: (a) Total number of species (Hill's N0) - motile species only; (b) all species – presence/absence data; (c) Hill's N1 diversity – motile species (d) Hill's N2 diversity -motile species.



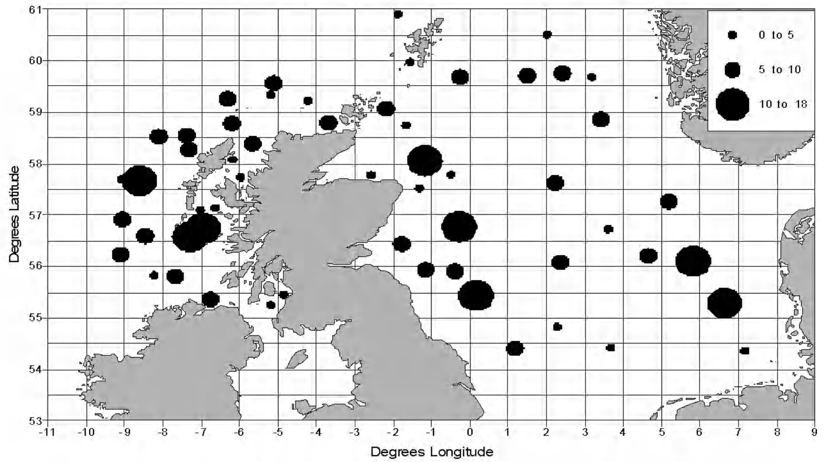
(a) Hill's N0 –motile species only



(b) Hill's N0 – all species

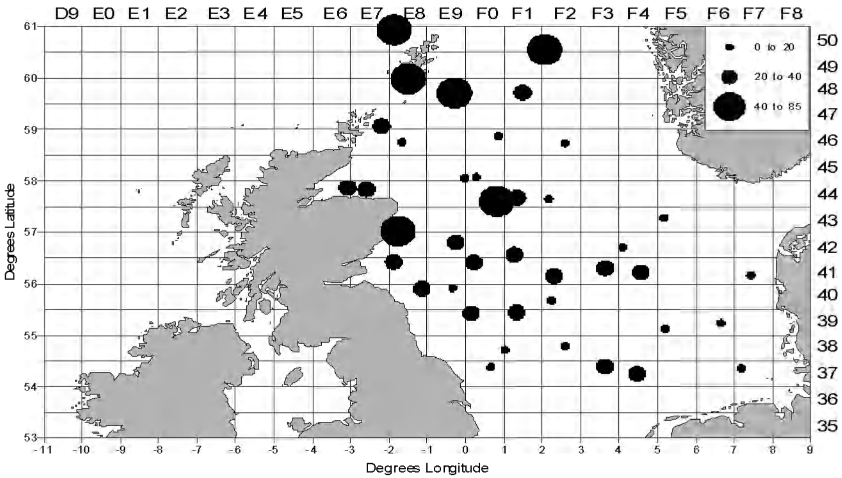


(c) Hill's N1 – motile species only

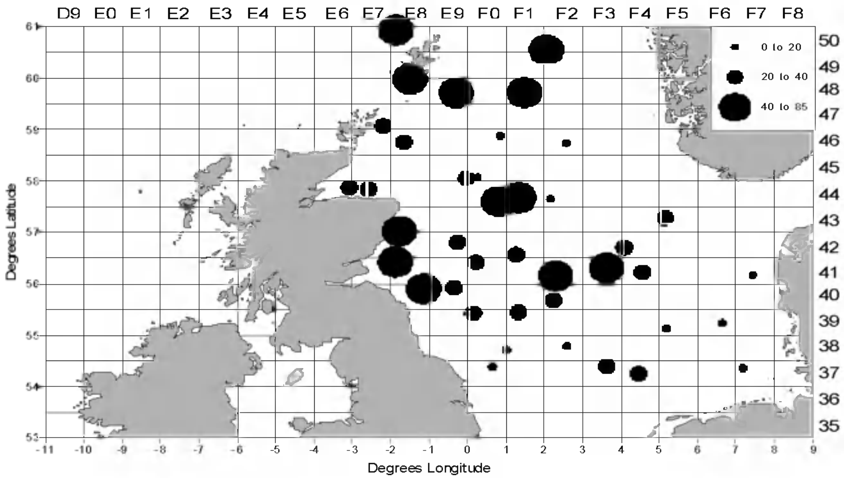


(d) Hill's N2 – motile species only

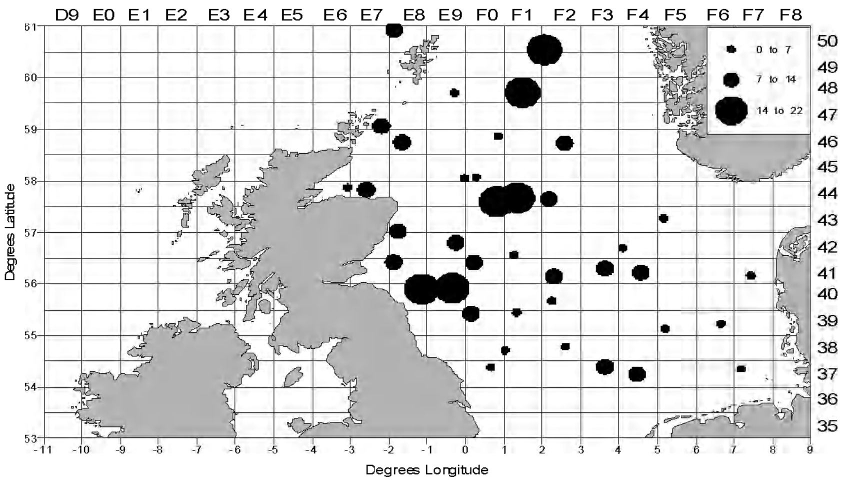
Figure 3.2.6. Indices of species diversity for the FRS 2003 survey: (a) Total number of species (Hill's N0) - motile species only; (b) all species – presence/absence data; (c) Hill's N1 diversity – motile species (d) Hill's N2 diversity -motile species.



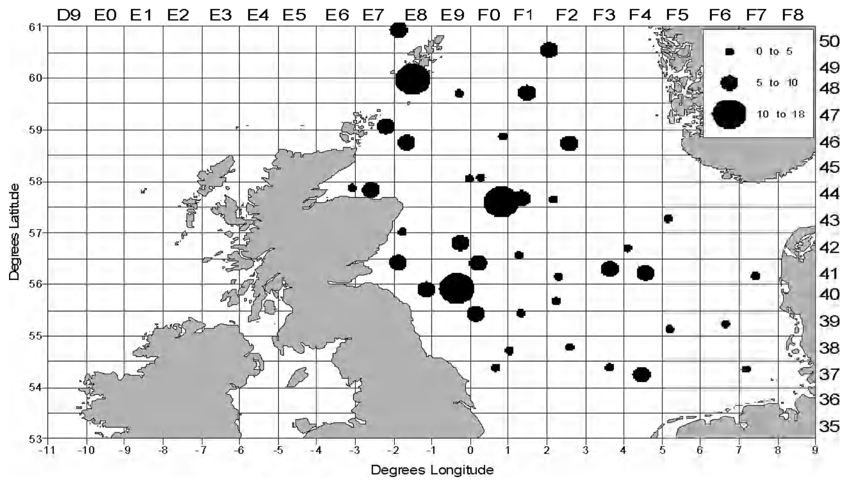
(a) Hill's N0 –motile species only



(b) Hill's N0 – all species

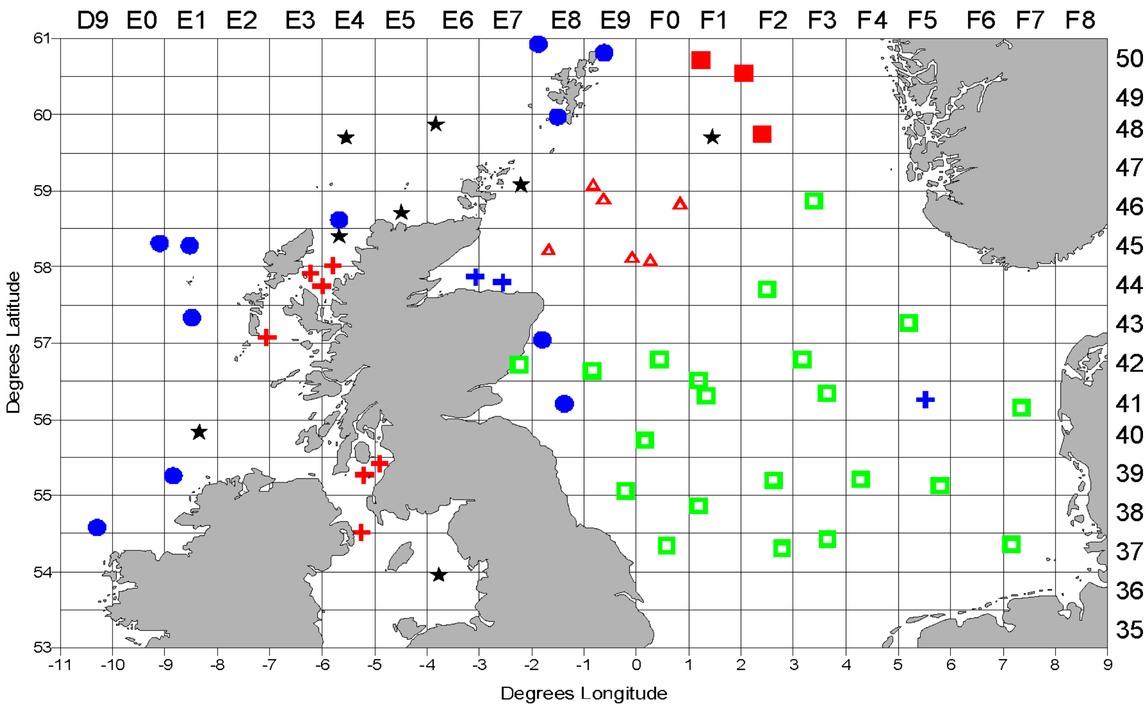


(c) Hill's N1 – motile species only



(d) Hill's N2 – motile species only

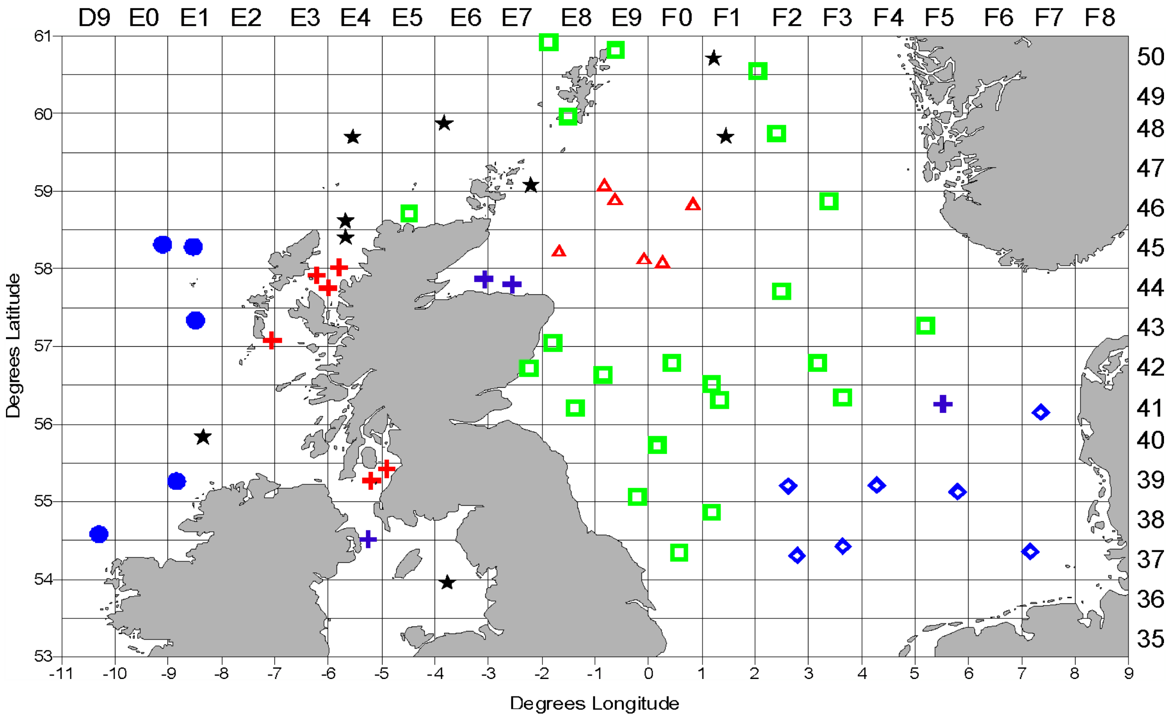
Figure 3.2.7. (a). Location of clusters of similar species based on hierarchical cluster analysis of fourth root transformed motile species abundance data from the FRS 2001 surveys. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.



Cluster □	Cluster ■	Cluster +
Average similarity – 33.87	Average similarity – 37.28	Average similarity – 39.60
Astropecten irregularis *Asterias rubens* *Pagurus bernhardus* *Aphrodita aculeata* *Liocarcinus holsatus* *Ophiura albida*	*Strongylocentrotus droebachiensis* *Pagurus bernhardus* *Crangon allmanni* *Pagurus prideaux*	*Nucula sulcata* *Nephrops norvegicus* *Calocaris macandreae* *Abra prismatica* *Abra nitida*
Cluster △	Cluster +	Cluster ●
Average similarity – 32.87	Average similarity – 32.93	Average similarity – 30.81
Astropecten irregularis *Turitella communis* *Antalis entalis* *Aporrhais serresianus* *Pagurus bernhardus*	*Turitella communis* *Echinocardium flavescens* *Crangon allmanni* *Ampelisca tenuicornis* *Liocarcinus holsatus* *Phaxas pellucidus*	*Pagurus prideaux* *Adamsia carciniopados* *Pagurus bernhardus* *Hyalinoecia tubicola* *Ophiura albida* *Macropodia tenuirostris*

Outliers = ★

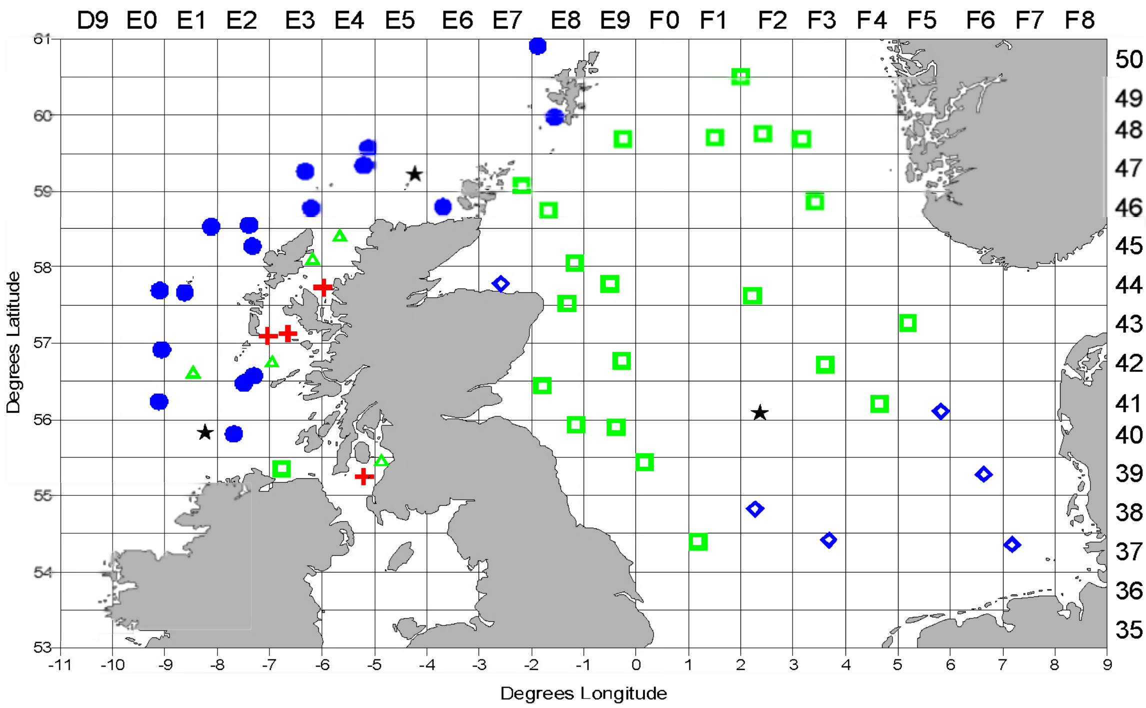
Figure 3.2.7. (b). Location of clusters of similar species based on hierarchical cluster analysis of presence/absence transformed data for all epifauna from the FRS 2001 surveys. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.



Cluster ◇	Cluster □	Cluster ✚
Average similarity – 44.55	Average similarity – 34.05	Average similarity – 41.92
Ophiura albida	*Pagurus bernhardus*	*Nucula sulcata*
Asterias rubens	*Asterias rubens*	*Nephrops norvegicus*
Aphrodita aculeata	*Pagurus prideaux*	*Calocaris macandreae*
Corystes cassivelaunus	*Astropecten irregularis*	*Virgularia mirabilis*
Astropecten irregularis	*Crangon allmanni*	*Glycera rouxii*
	Hyas coarctatus	*Abra nitida*
Cluster △	**Cluster ✚**	**Cluster ●**
Average similarity – 35.19	Average similarity – 30.89	Average similarity – 34.11
Turitella communis	*Phaxas pellucidus*	*Pagurus bernhardus*
Astropecten irregularis	*Nephrops norvegicus*	*Pagurus prideaux*
Antalis entalis	*Liocarcinus holsatus*	*Galathea squamifera*
Pennatula phosphorea	*Crangon allmanni*	*Porania pulvillus*
Aporrhais serresianus	*Aphrodita aculeata*	*Munida rugosa*
Pagurus bernhardus	*Abra prismatica*	*Pandalina brevirostris*

Outliers = ★

Figure 3.2.8. (a). Location of clusters of similar species based on hierarchical cluster analysis of fourth root transformed motile species abundance data from the FRS 2002 surveys. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.

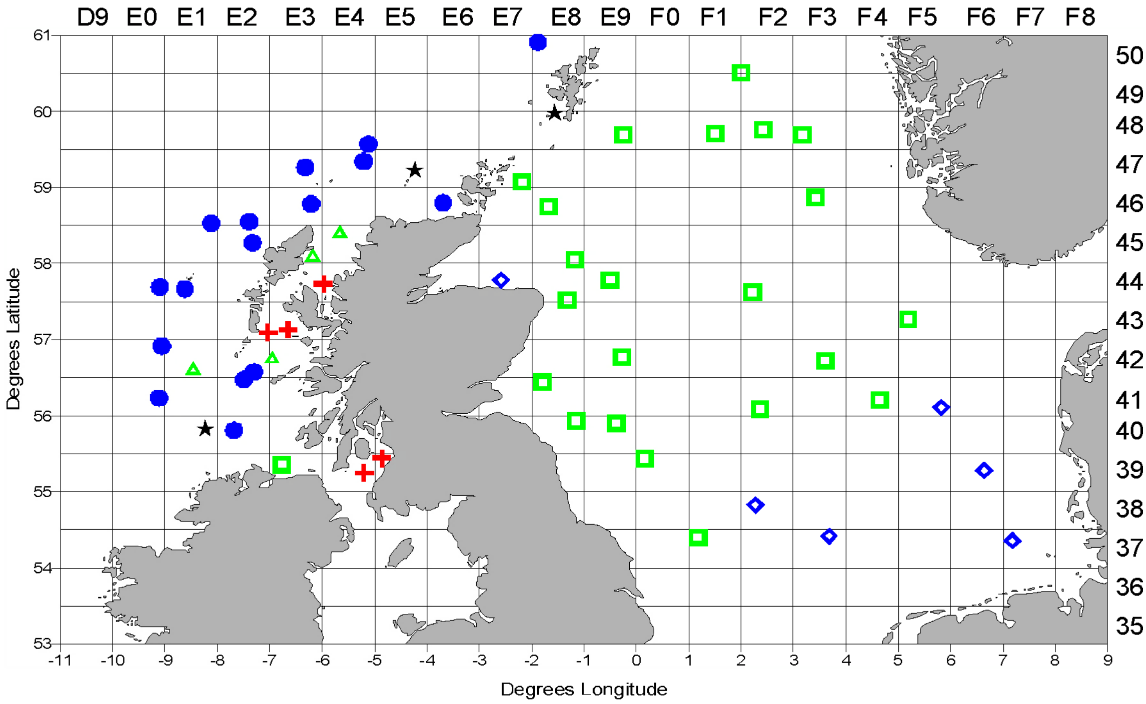


Cluster ◇	Cluster □	Cluster +
Average similarity – 35.27	Average similarity – 33.61	Average similarity – 72.57
Astropecten irregularis	*Pagurus bernhardus*	*Nephrops norvegicus*
Asterias rubens	*Crangon allmanni*	*Nucula sulcata*
Processa nouveli holthuisi	*Asterias rubens*	*Brissopsis lyrifera*
Liocarcinus holsatus	*Pagurus prideaux*	
Turitella communis	*Ophiura albida*	
Pagurus bernhardus	*Astropecten irregularis*	

Cluster △	Cluster ●
Average similarity – 41.50	Average similarity – 41.06
Calocaris macandreae	*Hyalinoecia tubicola*
Nephrops norvegicus	*Crangon allmanni*
Amphiura chiajei	*Adamsia carciniopados*
Glycera rouxii	*Anapagurus laevis*
Goneplax rhomboides	*Pagurus prideaux*
Brissopsis lyrifera	*Processa canaliculata*

Outliers = ★

Figure 3.2.8. (b). Location of clusters of similar species based on hierarchical cluster analysis of presence/absence transformed data for all epifauna from the FRS 2002 surveys. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.

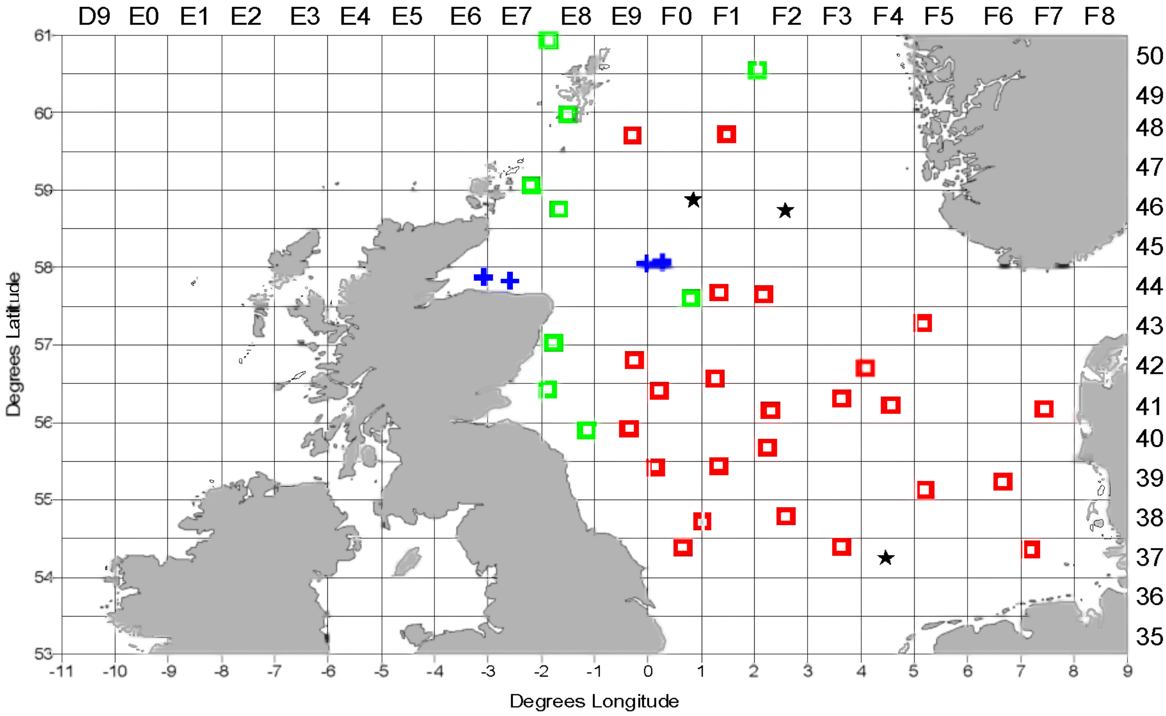


Cluster ◇	Cluster □	Cluster +
Average similarity – 37.26	Average similarity – 36.54	Average similarity – 56.80
Processa nouveli holthuisi	*Pagurus bernhardus*	*Nucula sulcata*
Asterias rubens	*Asterias rubens*	*Nephrops norvegicus*
Astropecten irregularis	*Crangon allmanni*	
Corystes cassivelaunus	*Flustra foliacea*	
Flustra foliacea	*Halecium halecinum*	
	Ophiura albida	

Cluster △	Cluster ●
Average similarity – 48.36	Average similarity – 41.24
Virgularia mirabilis	*Pagurus prideaux*
Processa canaliculata	*Hyalinoecia tubicola*
Nephrops norvegicus	*Crangon allmanni*
Goneplax rhomboides	*Anapagurus laevis*
Glycera rouxii	*Adamsia carciniopados*
Euspira catena	*Processa canaliculata*

Outliers =

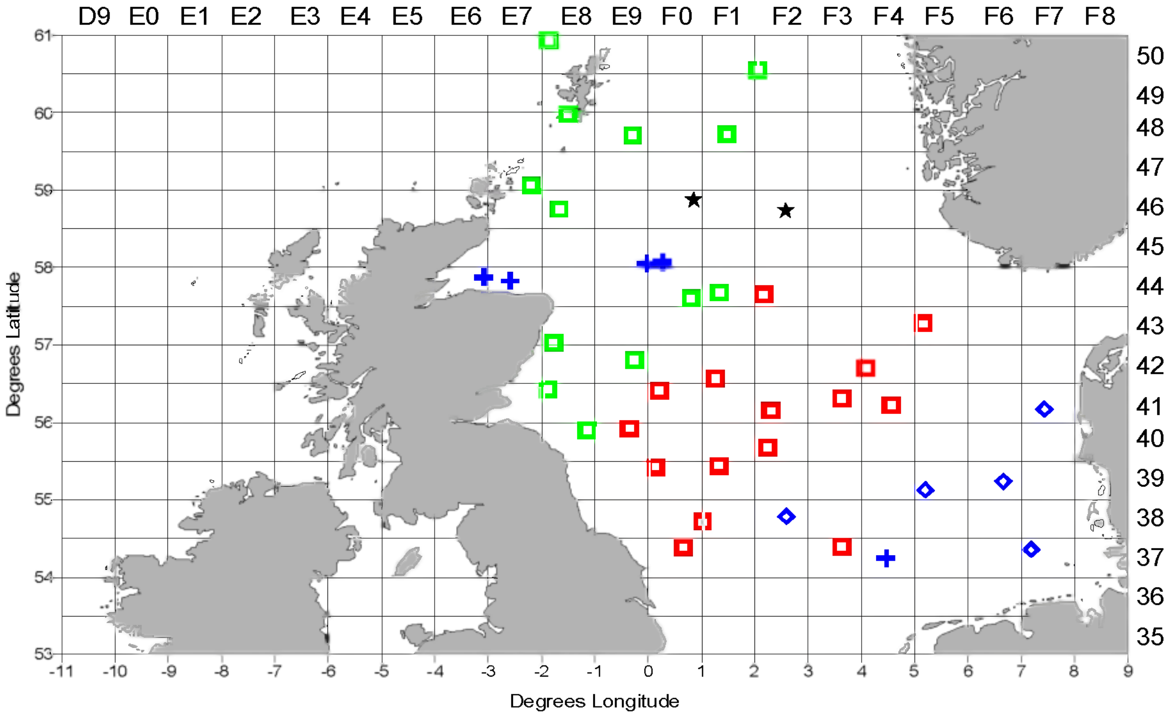
Figure 3.2.9. (a). Location of clusters of similar species based on hierarchical cluster analysis of fourth root transformed motile species abundance data from the FRS 2003 survey. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.



Cluster (red square)	Cluster (green square)	Cluster (blue cross)
Average similarity – 32.53	Average similarity – 34.74	Average similarity – 35.76
Astropecten irregularis	*Pagurus prideaux*	*Turritella communis*
Asterias rubens	*Anapagurus laevis*	*Brissopsis lyrifera*
Pagurus bernhardus	*Adamsia carciniopados*	*Astropecten irregularis*
Liocarcinus holsatus	*Pagurus bernhardus*	*Nephrops norvegicus*
Anapagurus laevis	*Asterias rubens*	*Crangon allmanni*
Crangon allmanni	*Crangon allmanni*	

Outliers = ★

Figure 3.2.9. (b). Location of clusters of similar species based on hierarchical cluster analysis of presence/absence transformed data for all epifauna from the FRS 2003 survey. Species mainly contributing to the similarity within the clusters are listed below. Species either make up at least 60% of the within-cluster similarity, or are the 6 species contributing most.

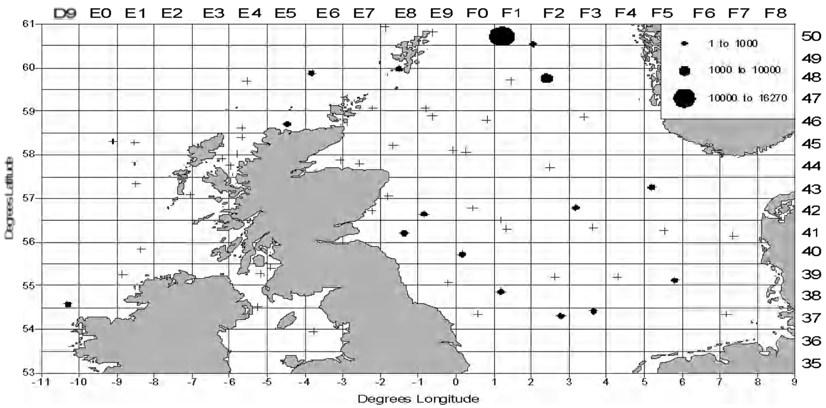


Cluster ◇	Cluster □ (green)	Cluster +
Average similarity – 54.29	Average similarity – 36.09	Average similarity – 31.44
Pagurus bernhardus	*Asterias rubens*	*Turritella communis*
Liocarcinus holsatus	*Anapagurus laevis*	*Nephrops norvegicus*
Liocarcinus depurator	*Crangon allmanni*	*Brissopsis lyrifera*
Asterias rubens	*Abietinaria abietina*	*Pennatula phosphorea*
	Pagurus bernhardus	*Crangon allmanni*
	Flustra foliacea	*Astropecten irregularis*

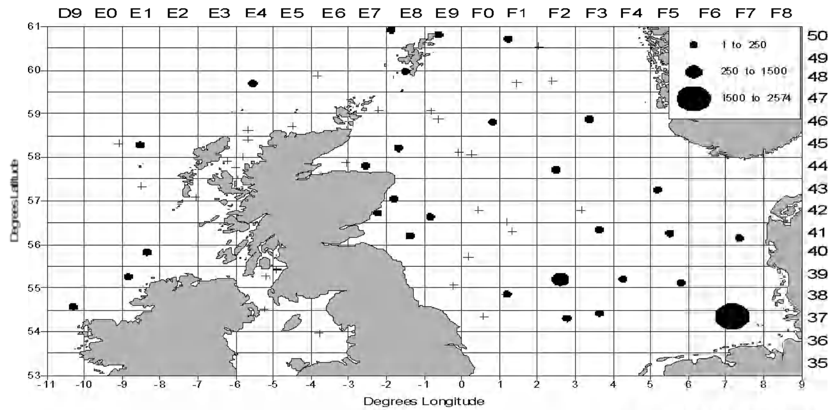
Cluster □ (red)
Average similarity – 36.04
Astropecten irregularis
Pagurus bernhardus
Asterias rubens
Hyas coarctatus
Anapagurus laevis
Epizoanthus incrustatus

Outliers = ★

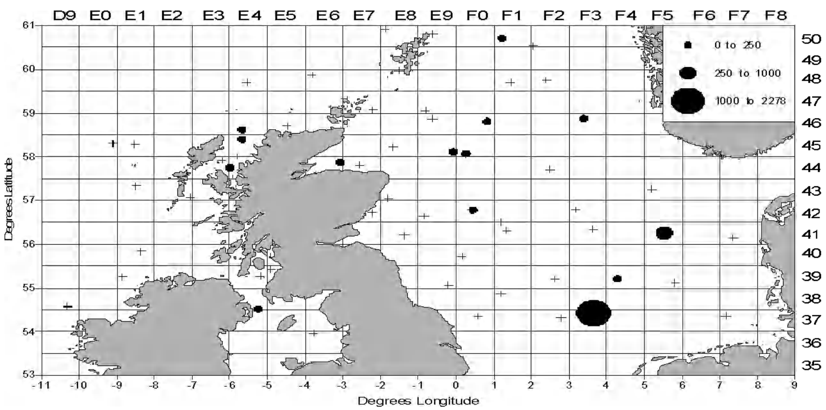
Figure 3.2.10. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2001 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.



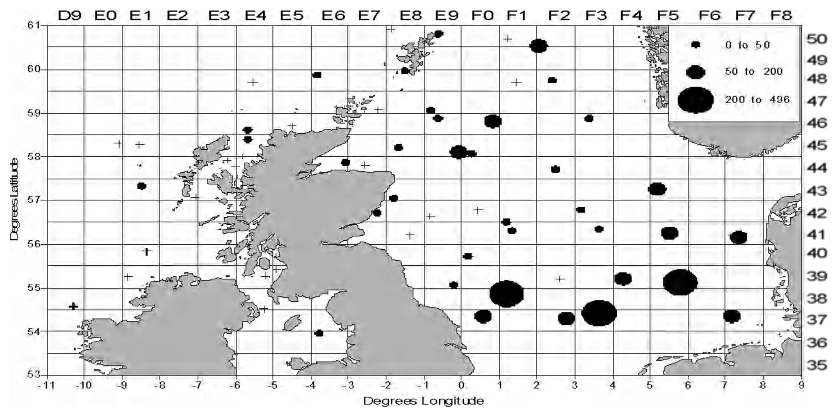
(a) *Stongylocentrotus droebachiensis*



(b) *Ophiura albida*

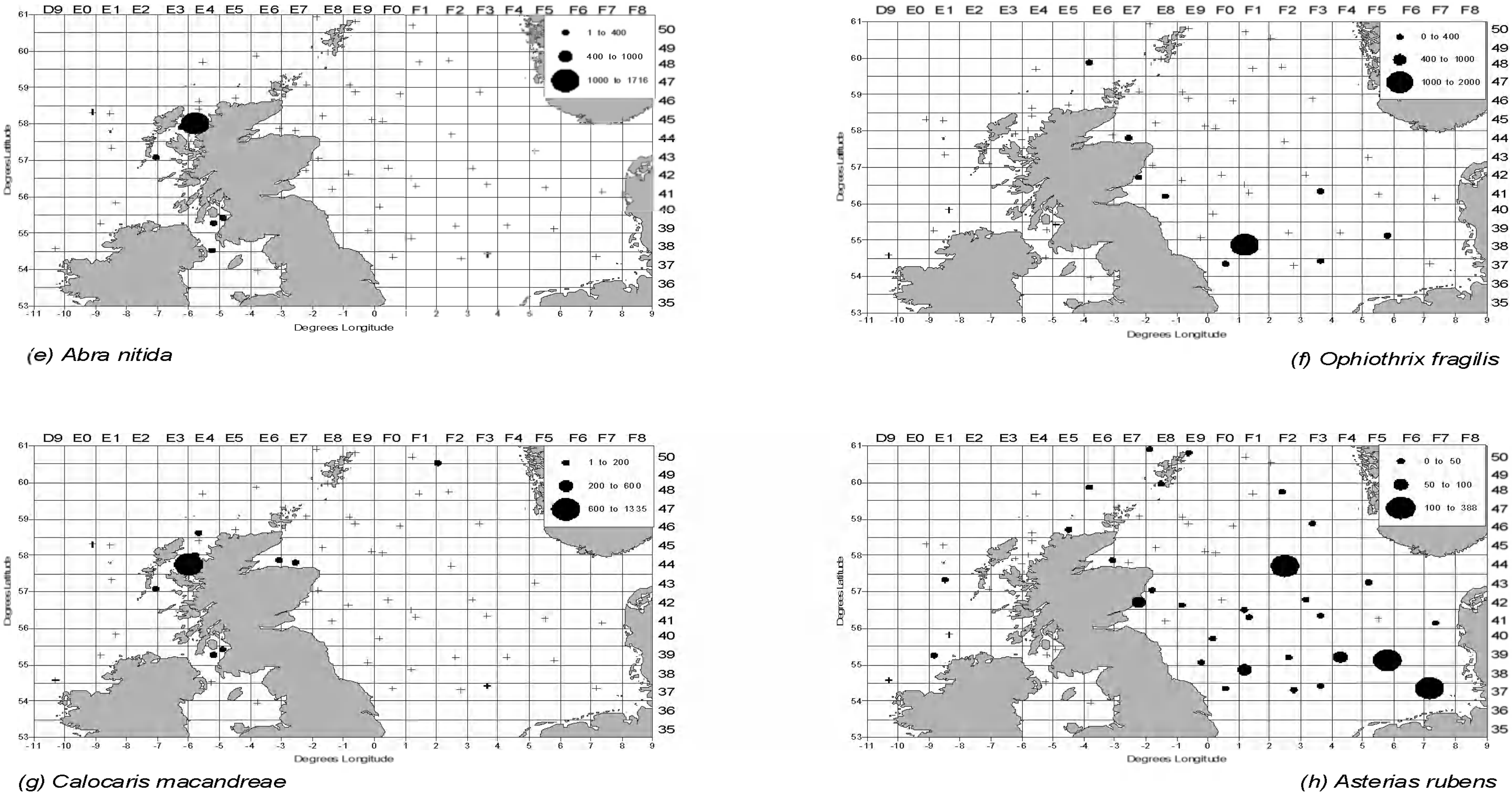


(c) *Brissopsis lyrifera*



(d) *Astropecten irregularis*

Figure 3.2.10. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2001 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.



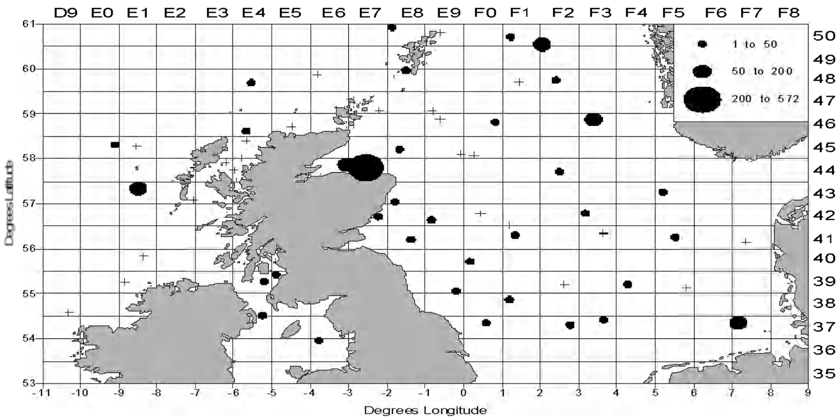
(e) *Abra nitida*

(f) *Ophiothrix fragilis*

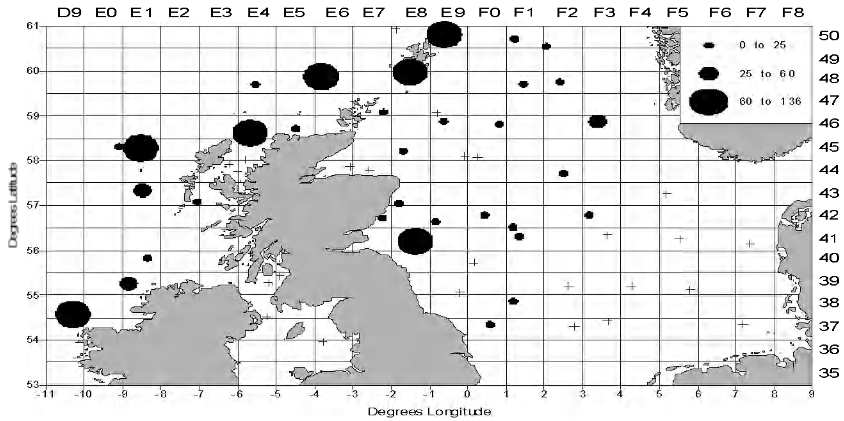
(g) *Calocaris macandreae*

(h) *Asterias rubens*

Figure 3.2.10. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2001 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.

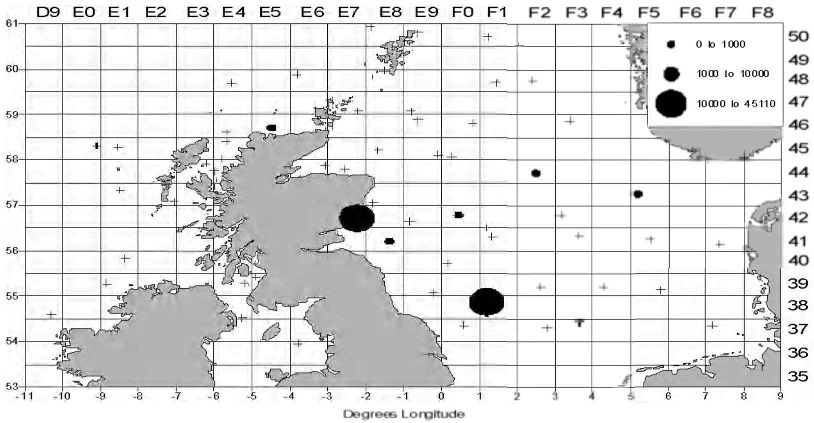


(i) Crangon allmani

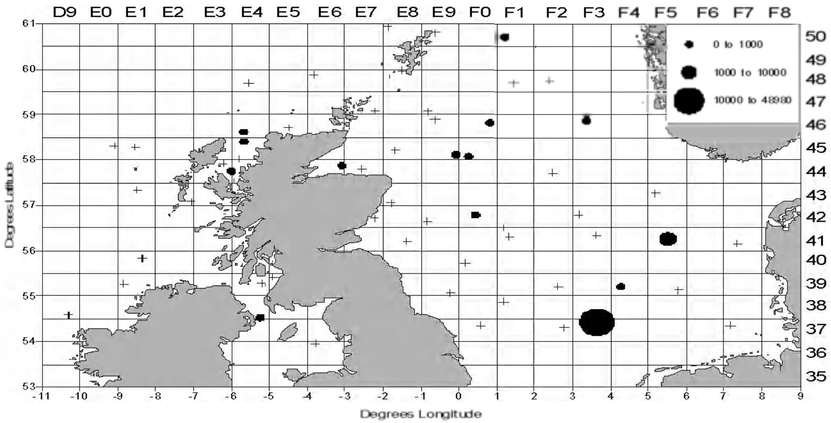


(j) Pagurus prideaux

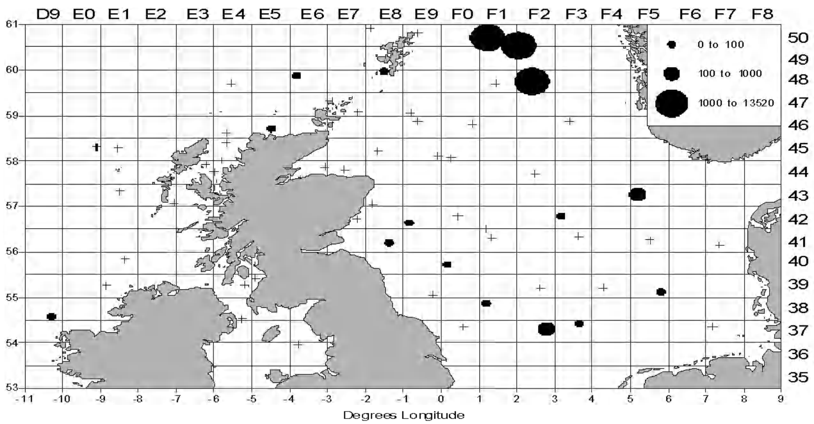
Figure 3.2.11. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2001 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.



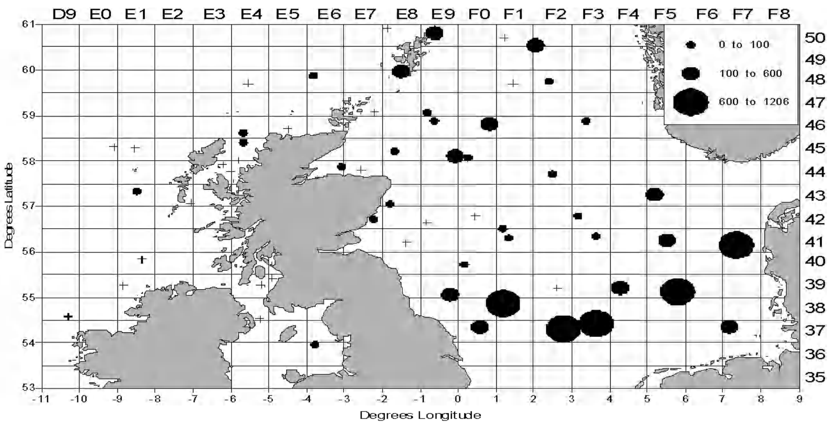
(a) Alcyonium digitatum



(b) Brissopsis lyrifera

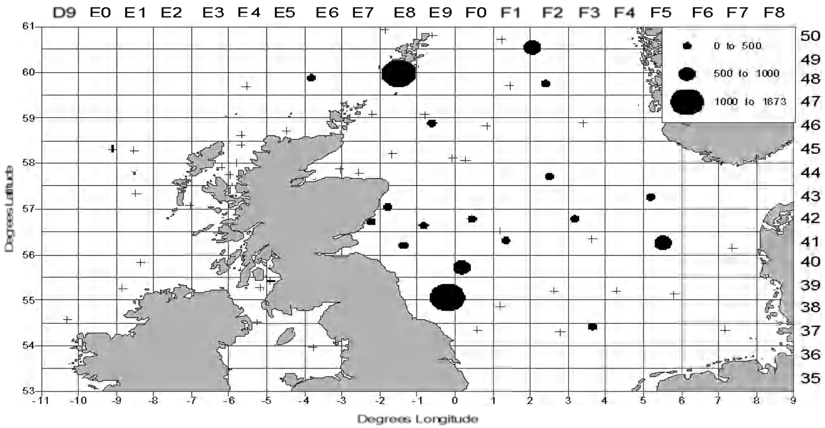


(c) Strongylocentrotus droebachiensis

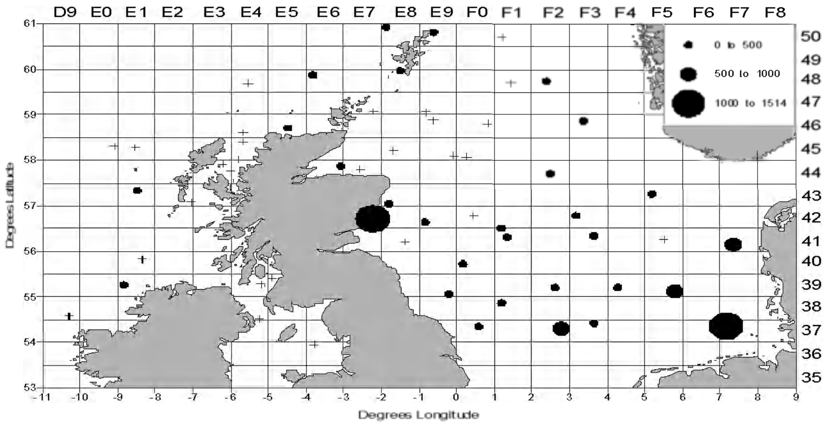


(d) Astropecten irregularis

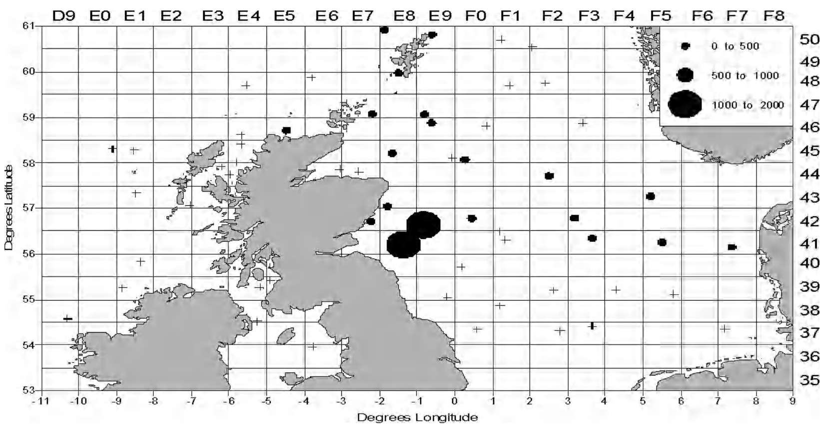
Figure 3.2.11. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2001 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.



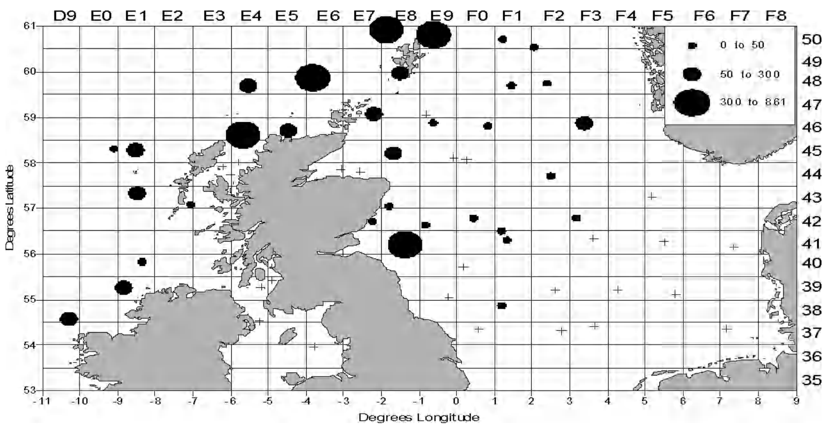
(e) Neptunea antiqua



(f) Asterias rubens

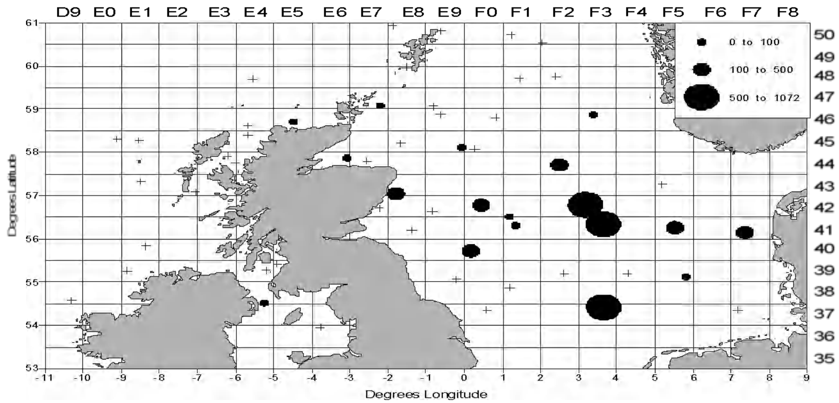


(g) Flustra foliacea

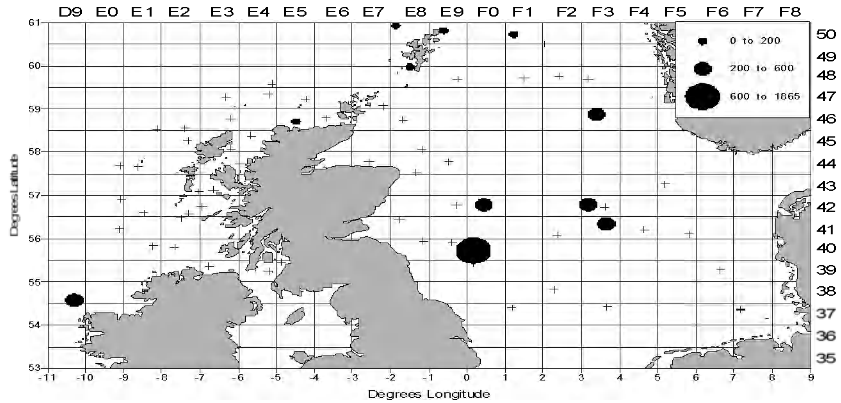


(h) Pagurus prideaux

Figure 3.2.11. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2001 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.

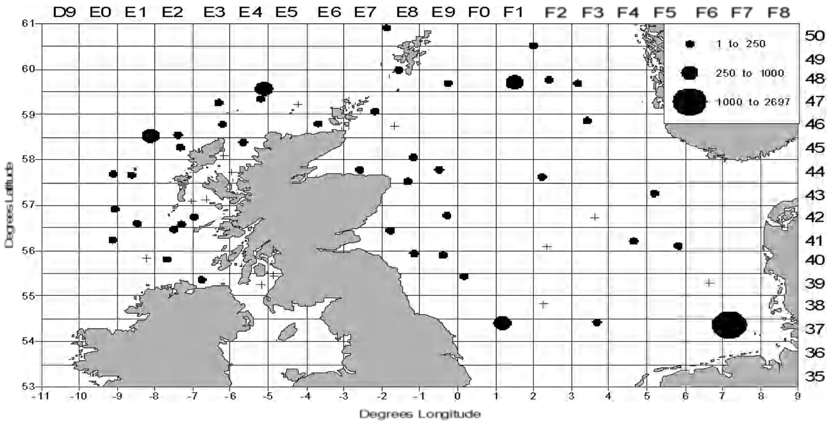


(i) Echinocardium cordatum

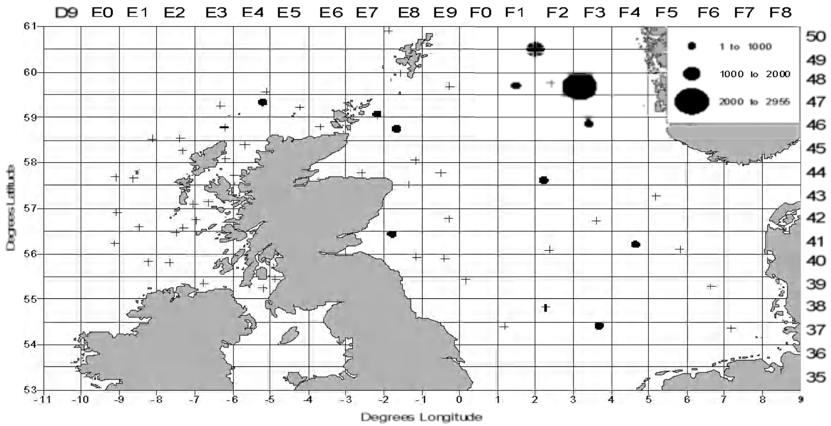


(j) Spatangus purpureus

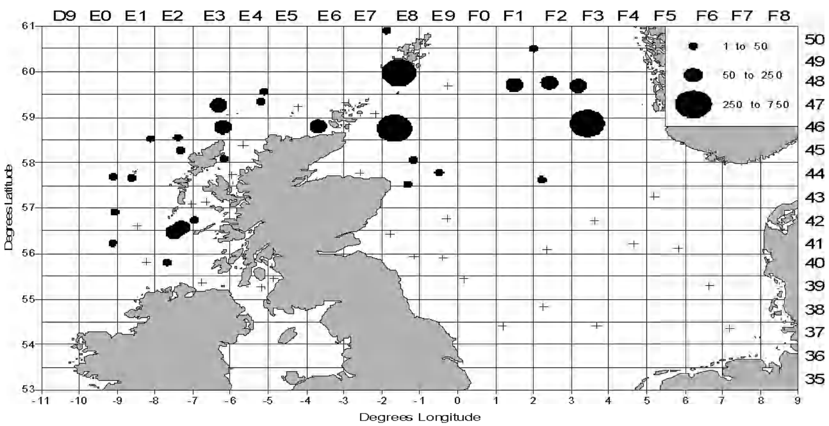
Figure 3.2.12. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2002 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.



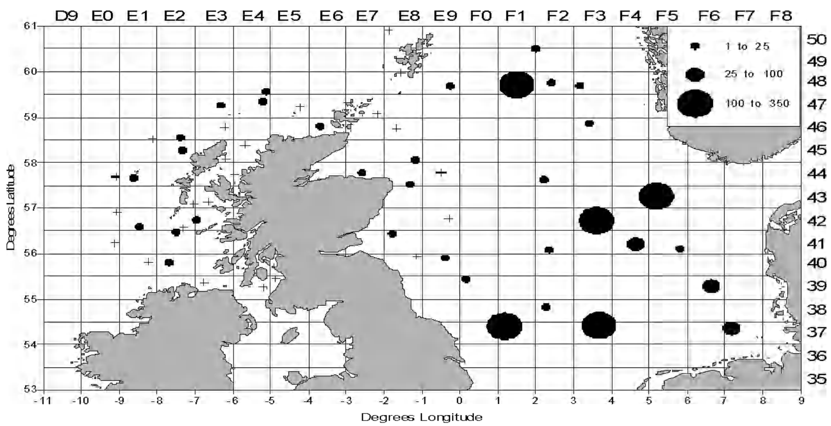
(a) Crangon allmani



(b) Strongylocentrotus droebachiensis

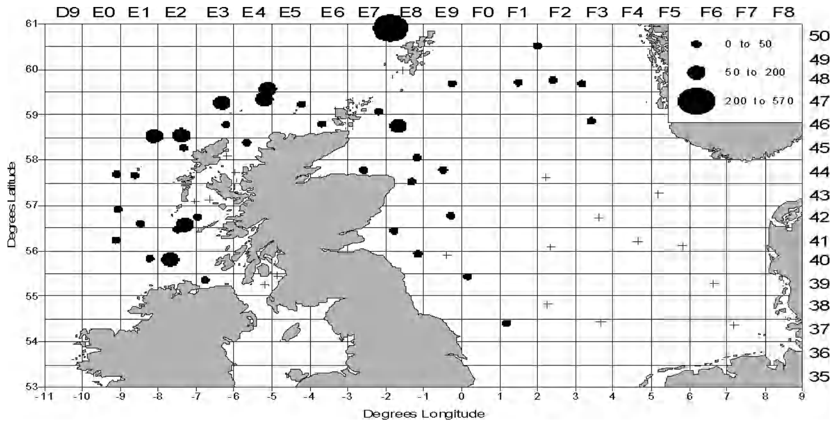


(c) Hyalinoecia tubicola

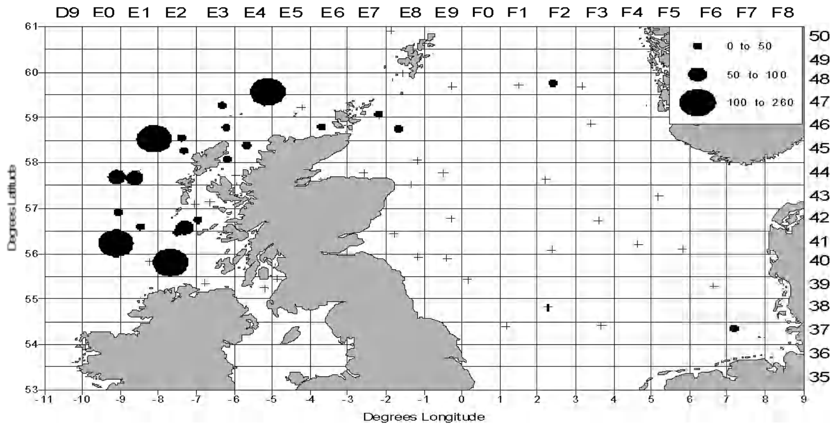


(d) Astropecten irregularis

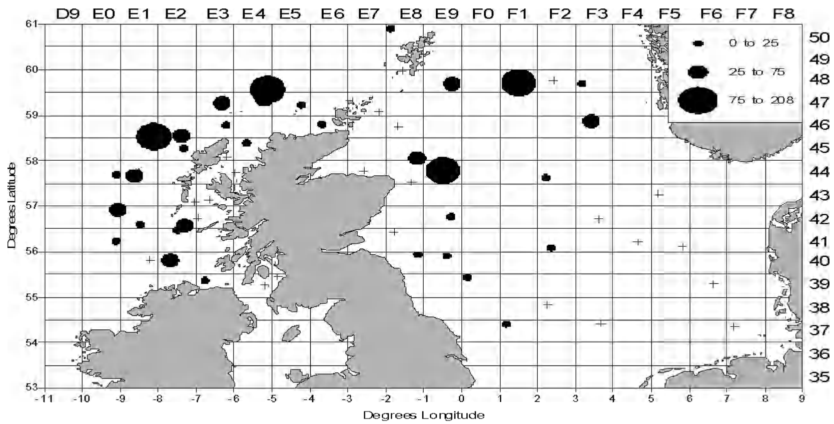
Figure 3.2.12. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2002 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.



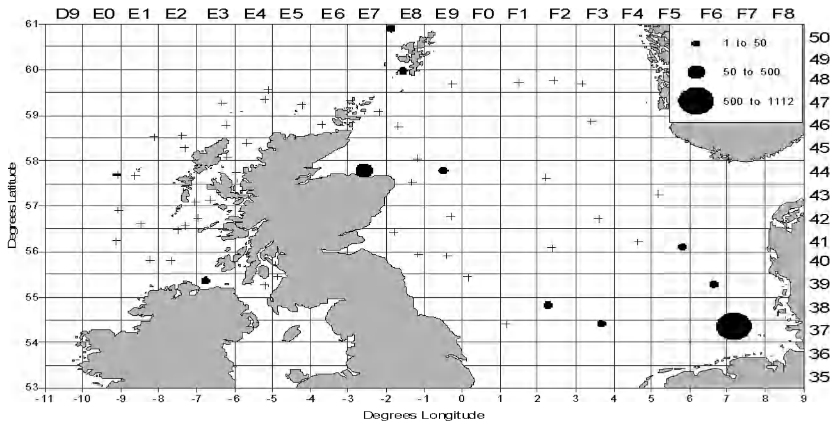
(e) Pagurus prideaux



(f) Processa canaliculata

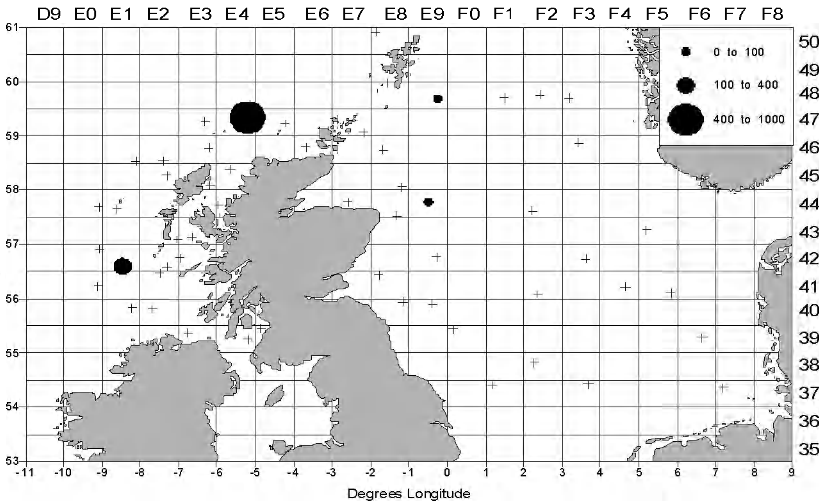


(g) Anapagurus laevis

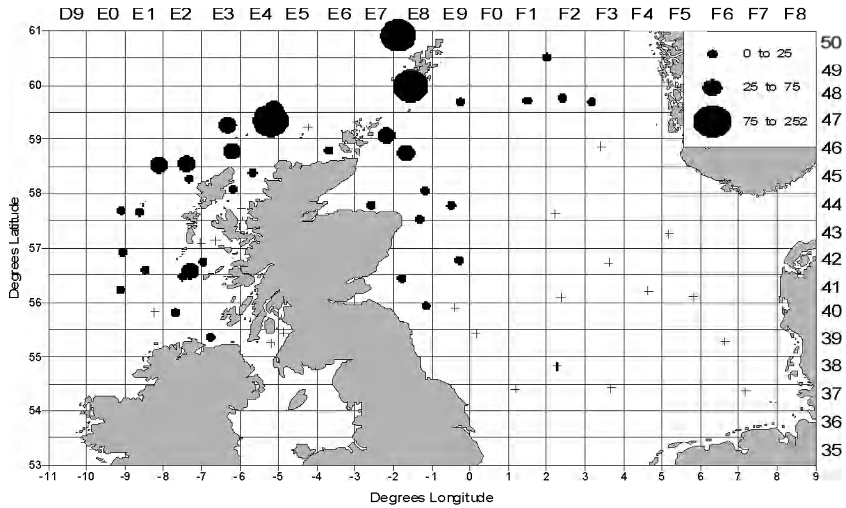


(h) Processa nouveli hothuisi

Figure 3.2.12. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2002 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.

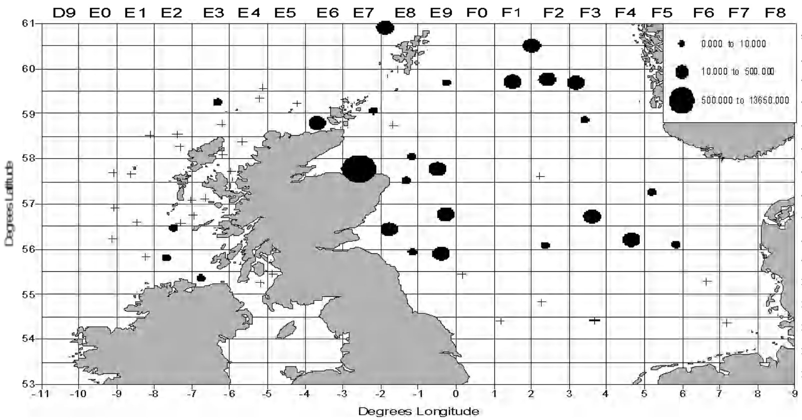


(i) Ditrupa arietina

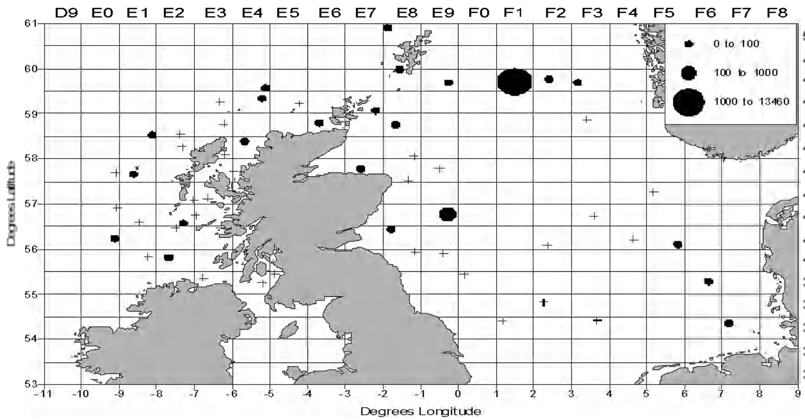


(j) Adamsia carciniopados

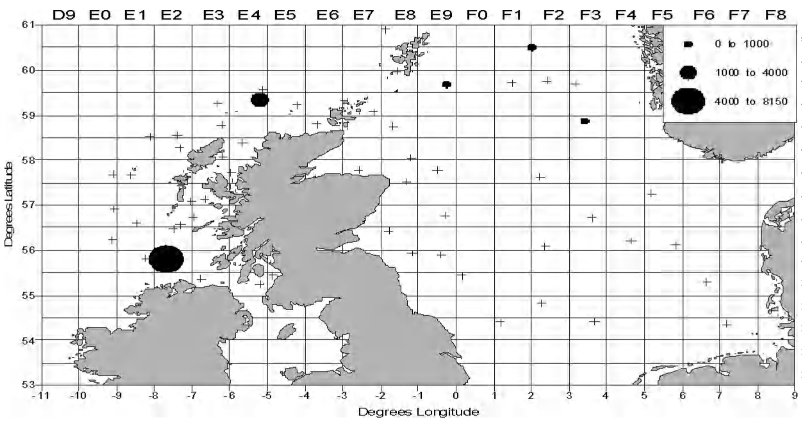
Figure 3.2.13. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2002 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.



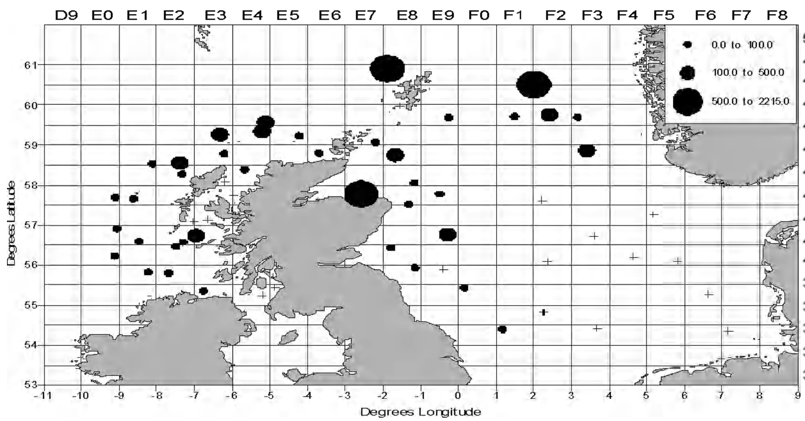
(a) Halecium halecinum



(b) Liocarcinus depurator

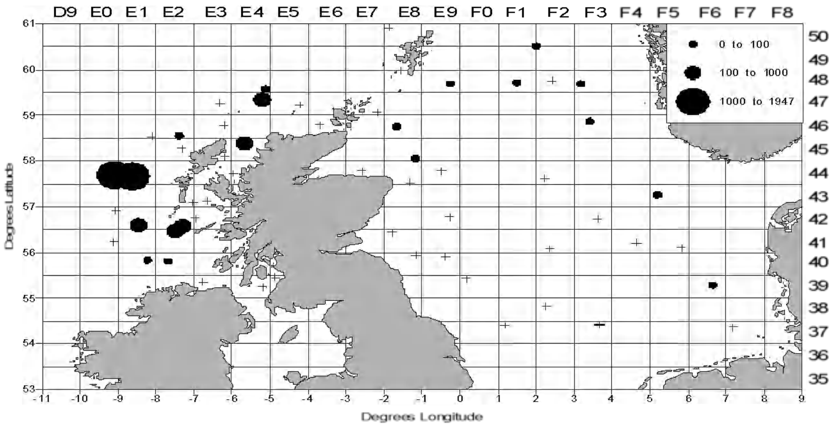


(c) Caryophyllia smithii

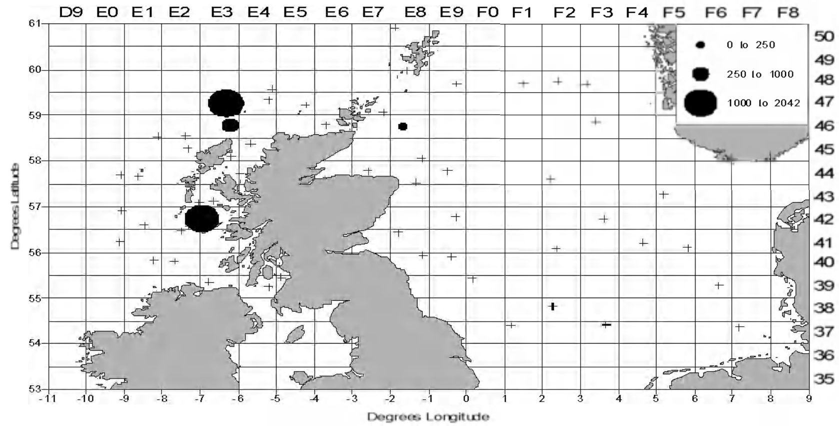


(d) Pagurus prideaux

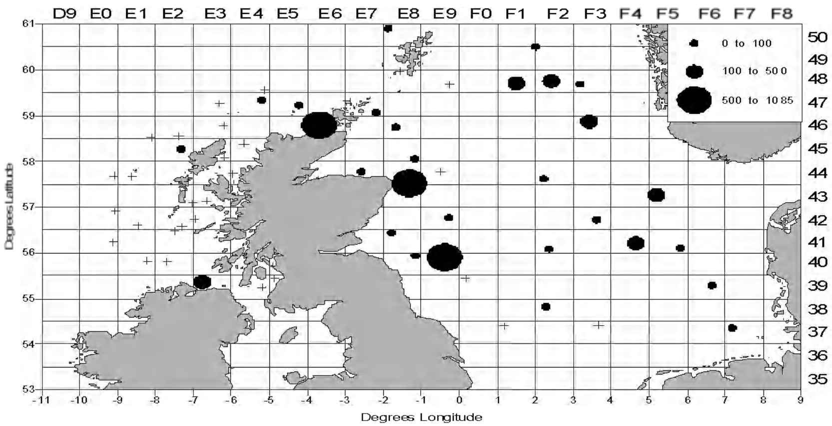
Figure 3.2.13. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2002 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.



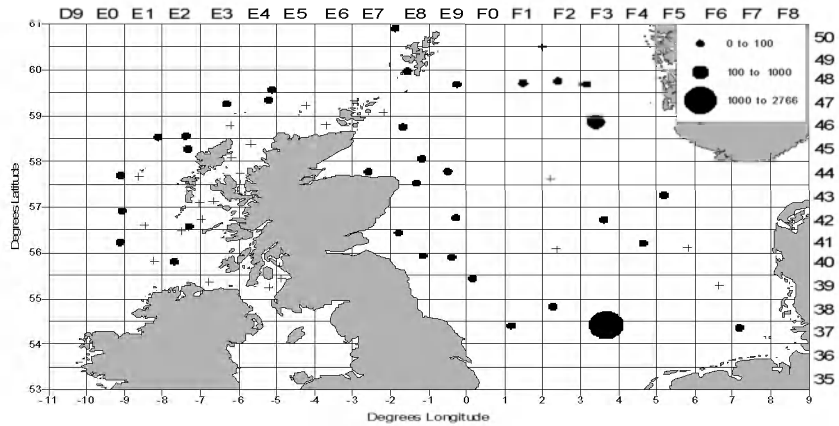
(e) Actinauge richardi



(f) Cancer pagurus

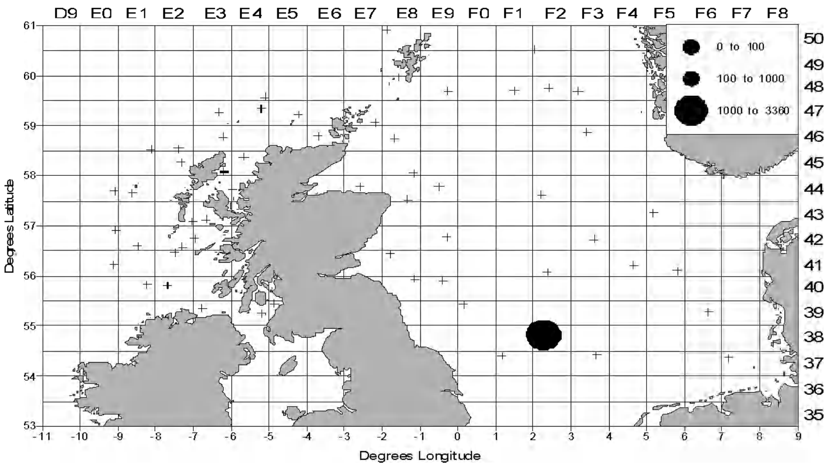


(g) Flustra foliacea

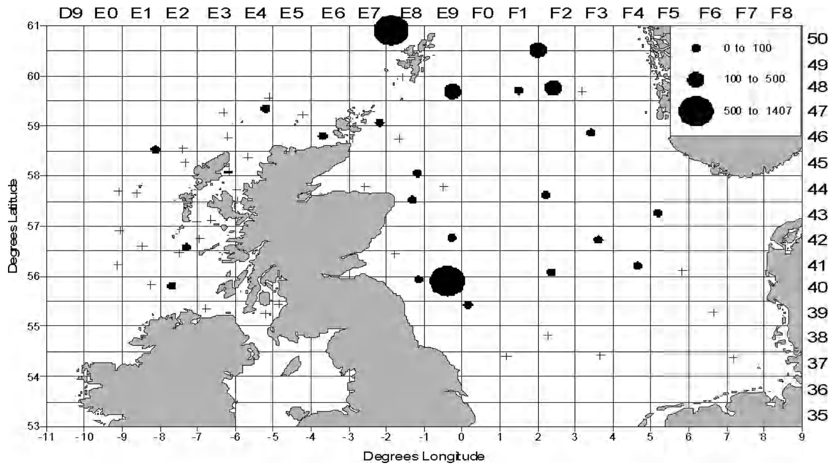


(h) Ophiura albida

Figure 3.2.13. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2002 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.

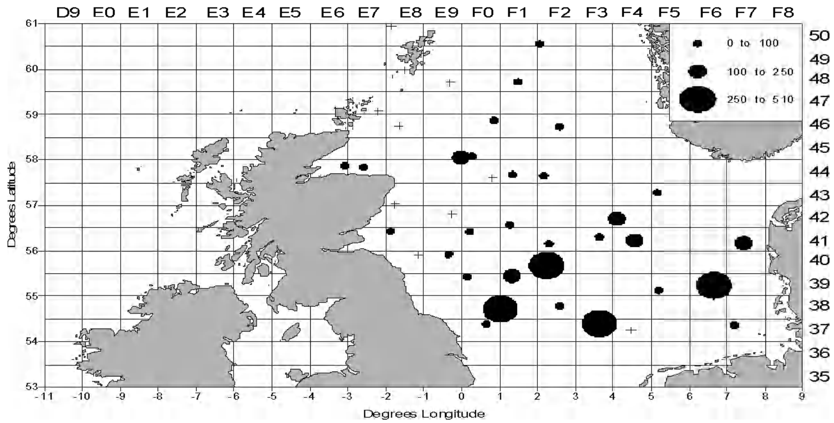


(i) Philocheras trispinosus

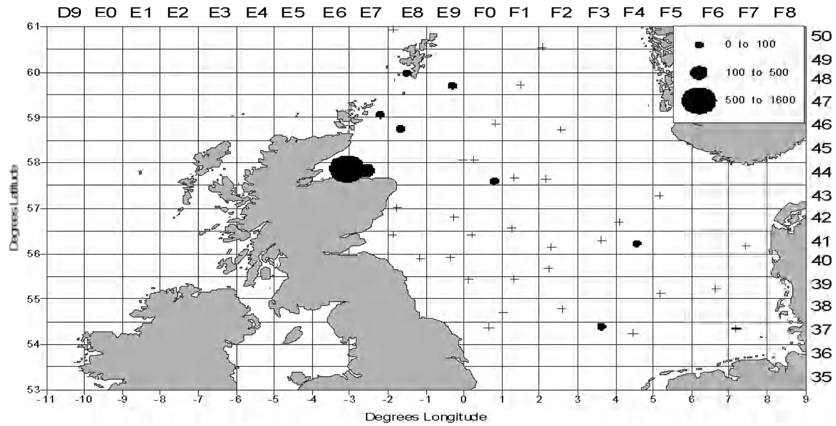


(j) Colus gracilis

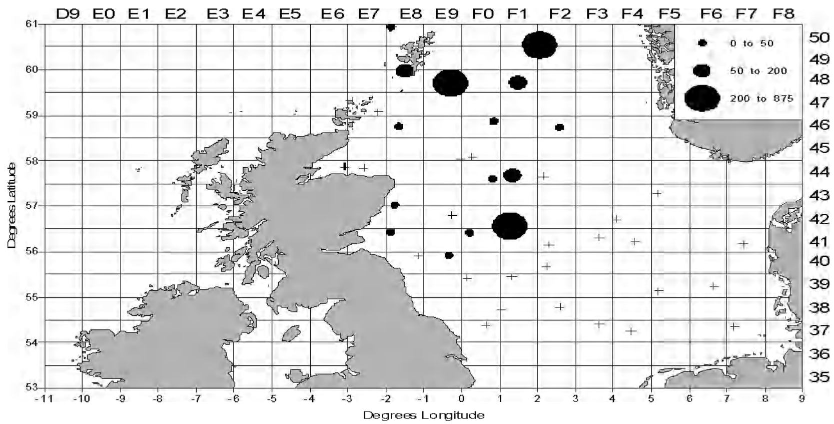
Figure 3.2.14. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2003 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.



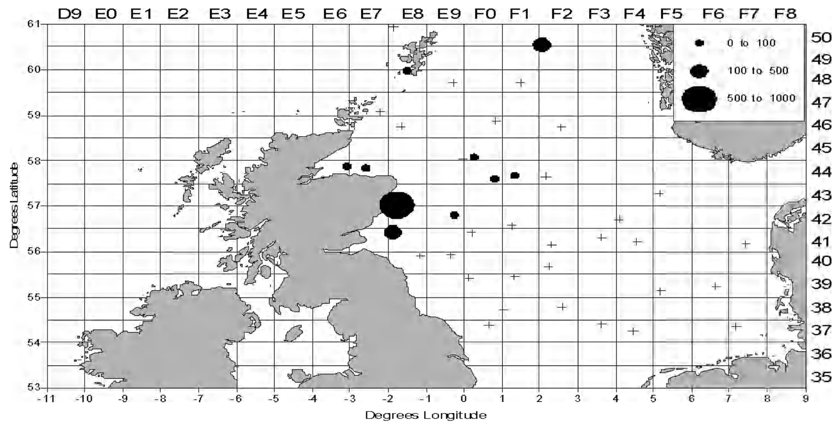
(a) Astropecten irregularis



(b) Amphiura chiajei

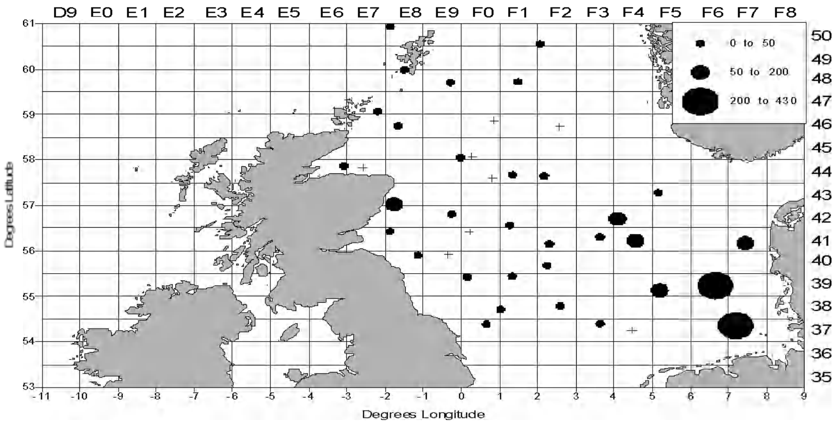


(c) Hyalinoecia tubicola

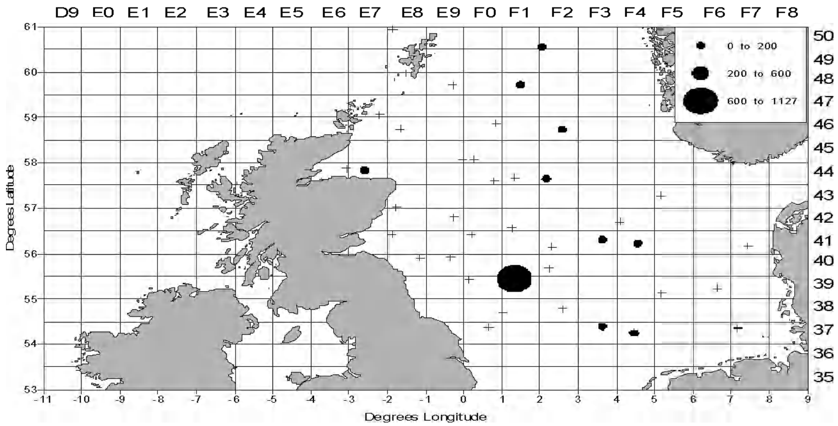


(d) Pandalus montagui

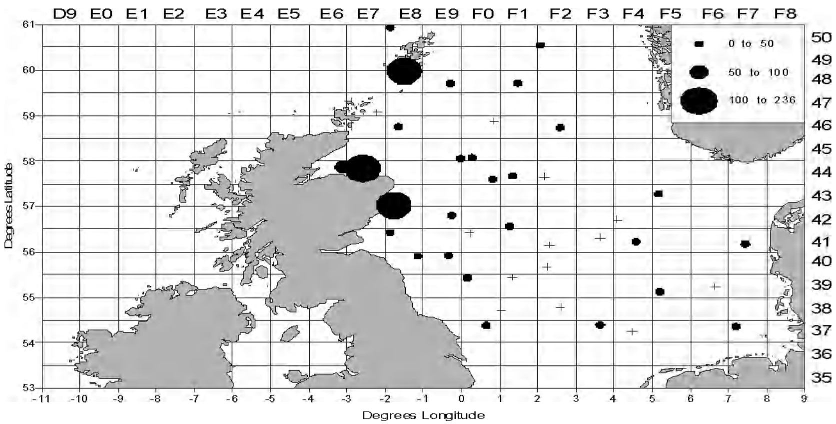
Figure 3.2.14. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2003 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.



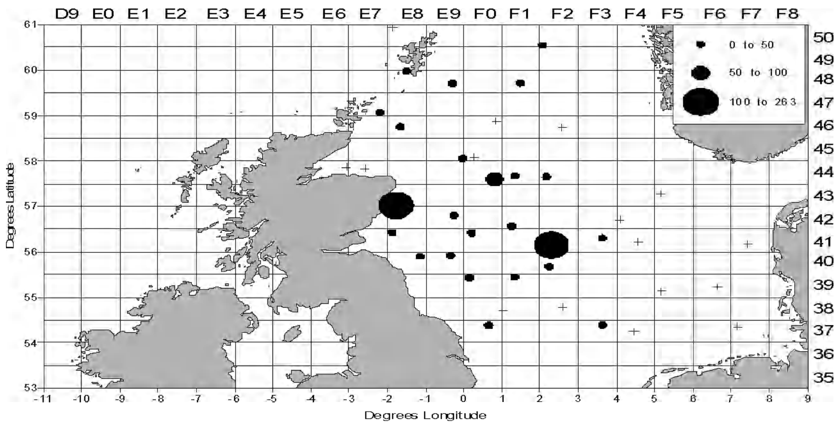
(e) Asterias rubens



(f) Echinocardium flavescens

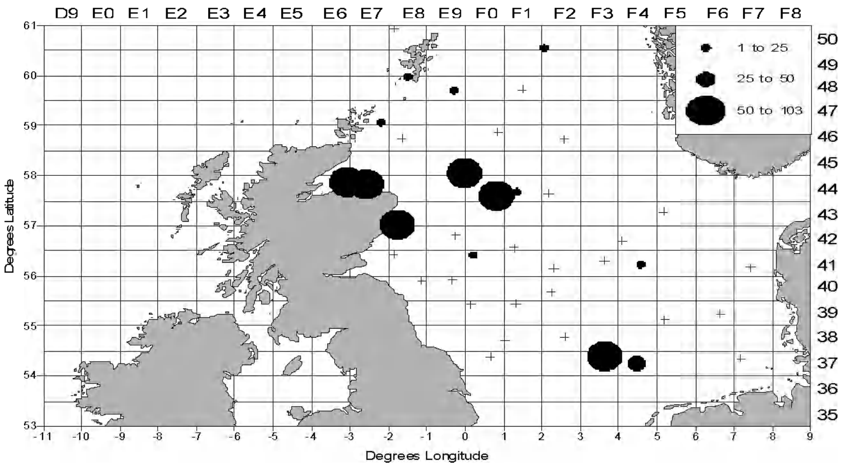


(g) Crangon allmanni

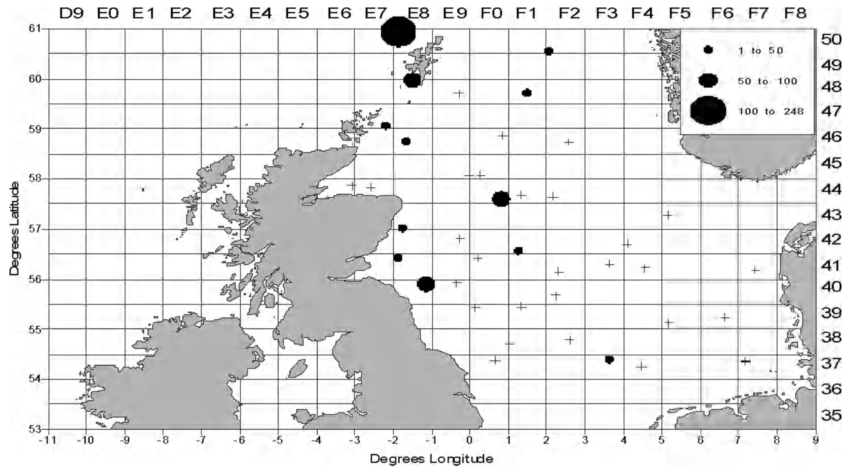


(h) Anapagurus laevis

Figure 3.2.14. Distribution of the abundance of motile epifaunal species (no.1000m^{-2}) that were found to be in the top 10 most abundant species in the 2003 surveys. A '+' represents a station where the species was not present. N.B. Scales of abundance vary between species – see keys.

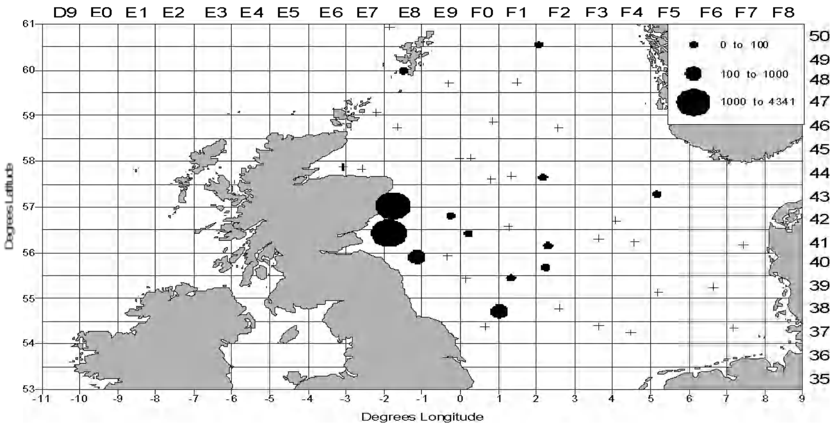


(i) Turritella communis

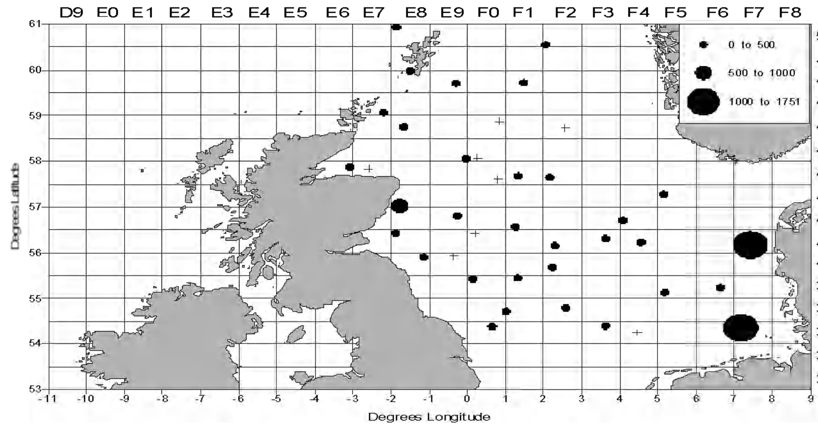


(j) Pagurus prideaux

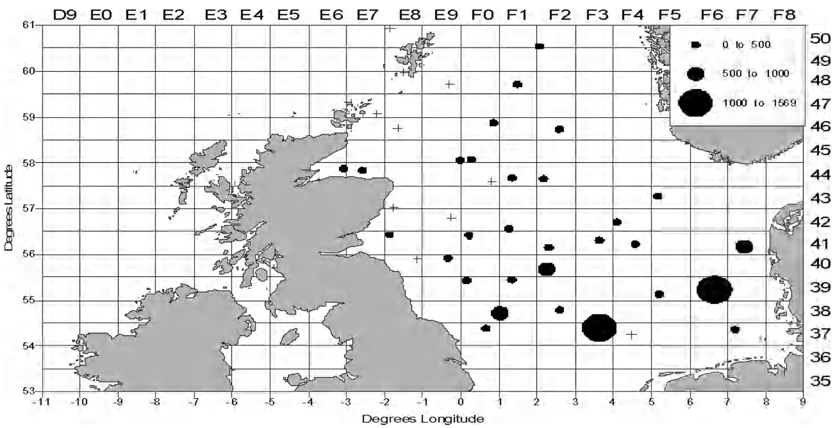
Figure 3.2.15. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2003 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.



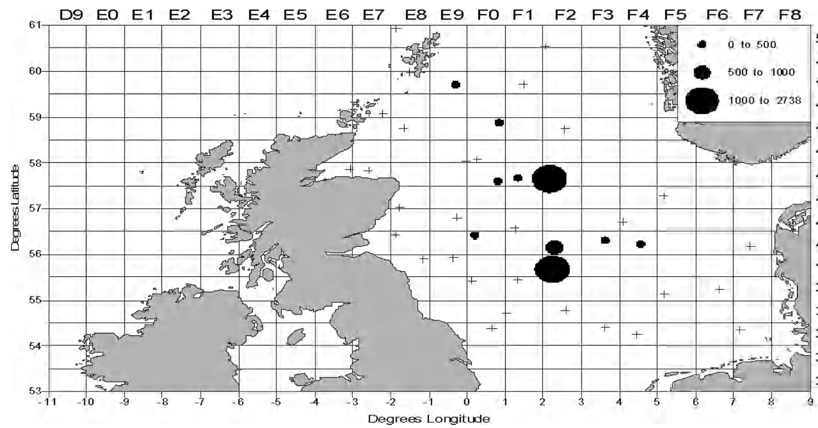
(a) Alcyonium digitatum



(b) Asterias rubens

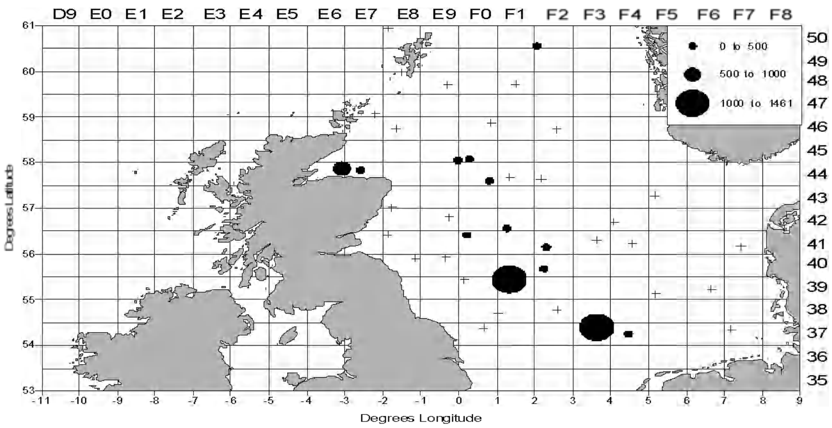


(c) Astropecten irregularis

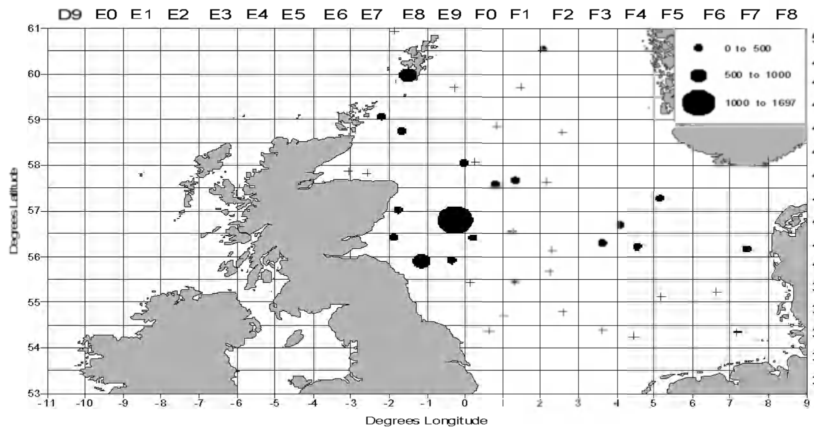


(d) Bolocera tuediae

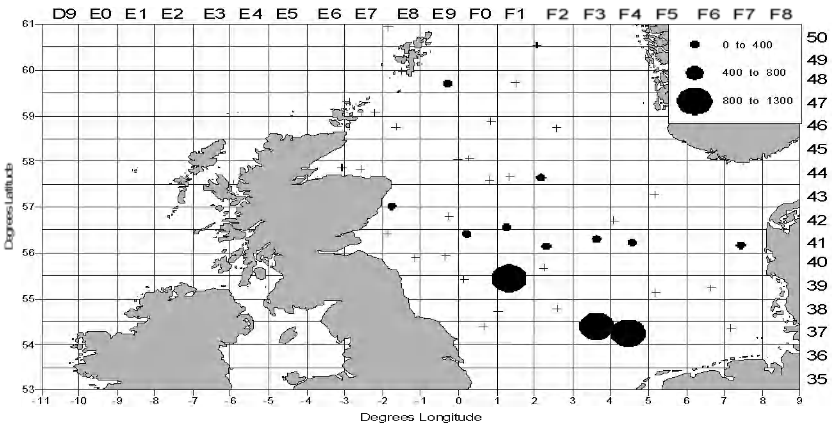
Figure 3.2.15. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2003 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.



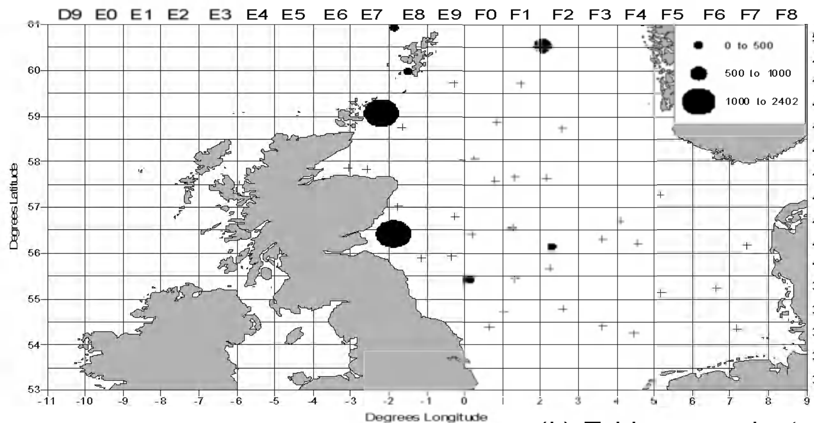
(e) Brissopsis lyrifera



(f) Flustra foliacea

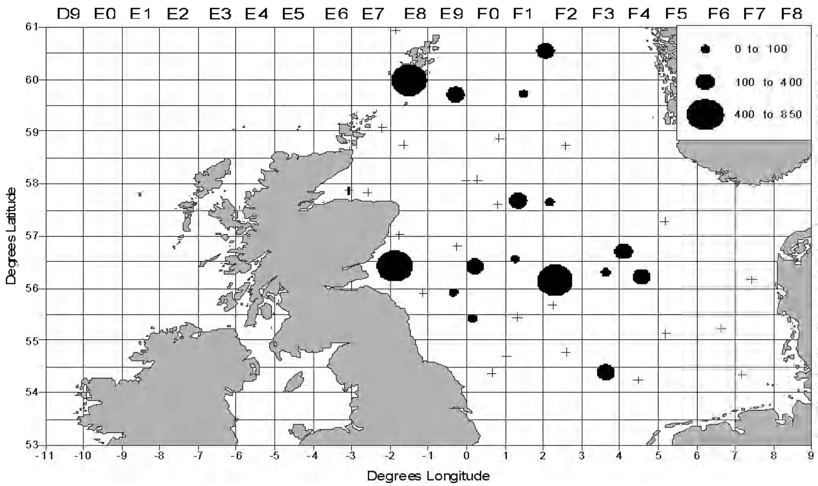


(g) Echinocardium cordatum

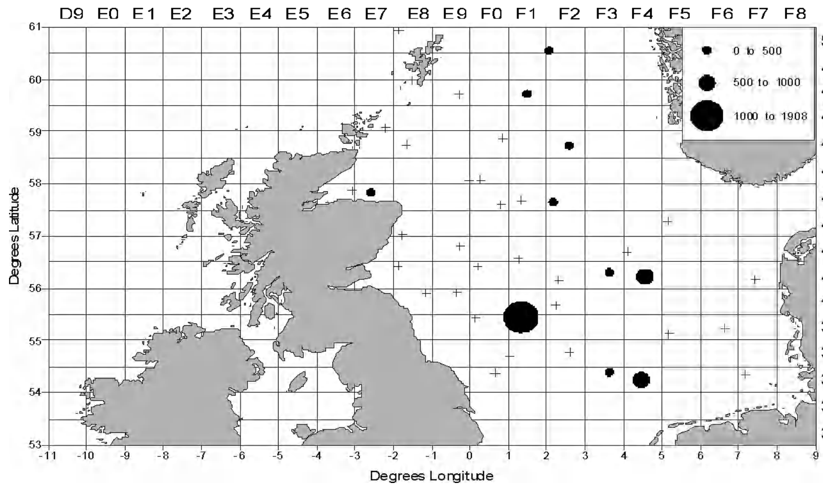


(h) Echinus esculentus

Figure 3.2.15. Distribution of the biomass of epifaunal species (grams.1000m^{-2}) that were found to be in the top 10 species based on total biomass over the whole 2003 survey. A '+' represents a station where the species was not present. N.B. Scales of biomass vary between species – see keys.



(i) *Neptunea antiqua*



(j) *Echinocardium flavescens*

Table 3.1.1. Dominant epifaunal species at high abundance and/or high biomass stations in four areas of the North Sea in 2003 based on the MAFCONS surveys. The spatial distributions of the most abundant or high biomass species are given in Figures 3.1.6 and 3.1.7.

Area of the North Sea	High total abundance species	High total biomass species
Continental coast, Southern North Sea	Echinoderms - *Ophiura albida, Asterias rubens, Astropecten irregularis, Echinocardium cordatum* Molluscs - *Turitella communis, Corbula gibba* Crustaceans - *Liocarcinus holsatus*	Echinoderms – *Ophiura albida, Asterias rubens, Astropecten irregularis, Echinocardium cordatum, Echinocardium flavescens, Brissopsis lyrifera* Molluscs - *Turitella communis, Corbula gibba, Arctica islandica* Crustaceans – *Liocarcinus holsatus*
Central North Sea (50-70m depth contours)	Echinoderms – *Echinus* juveniles, *Echinocardium flavescens*	Echinoderms – *Asterias rubens, Astropecten irregularis, Echinocardium flavescens, Brissopsis lyrifera, Spatangus purpureus* Molluscs - *Neptunea antiqua, Buccinum undatum, Colus gracilis* Cnidarians - *Bolocera tuediae, Alcyonium digitatum* Bryozoans - *Flustra foliacea* Porifera - *Suberites ficus*
Northeast coast, Scotland	Echinoderms – *Amphiura chiajei* Crustaceans - *Pandalus montagui*	Echinoderms -*Echinus esculentus, Crossaster papossus* Crustaceans - *Cancer pagurus, Pagurus prideaux* Molluscs - *Modiolus modiolus, Neptunea antiqua* Cnidarians – *Alcyonium digitatum, Alcyonidium diaphanum* Bryozoans - *Flustra foliacea*
Northern North Sea	Echinoderms – *Echinus acutus* Crustaceans – *Crangon allmanni, Palliolum tigerinum, Pagurus prideaux* Annelids - *Hyalinoecia tubicola*	Echinoderms – *Echinus* esculentus, *Echinus acutus, Echinocardium flavescens, Spatangus purpureus* Crustaceans – *Liocarcinus depurator, Caryophyllia smithii, Flabellum macandrewi* Molluscs – *Neptunea antiqua* Hydroids – *Alcyonidium diaphanum* Cnidarians - *Bolocera tuediae*

Table 3.2.1. Dominant epifaunal species at high abundance stations in four areas of the North Sea and to the west coast of Scotland. The distributions of the most abundant species are given in Figures 3.2.10., 3.2.12. and 3.2.14.

	High total abundance species		
Area of the North Sea	2001	2002	2003
Continental coast, Southern North Sea	Echinoderms - *Ophiura albida, Brissopsis lyrifera, Asterias rubens, Astropecten irregularis, Ophiothrix fragilis*	Echinoderms – *Asterias rubens* Crustaceans – *Processa nouveli holthuisi, Philocheras bispinosus, Crangon allmanni*	Echinoderms – *Asterias rubens, Astropecten irregularis* Crustaceans – *Liocarcinus holsatus*
Central North Sea (50-70m depth contours)	Echinoderms – *Brissopsis lyrifera, Amphiura filiformis*		Echinoderms – *Echinocardium flavescens*
Northeast coast, Scotland	Crustaceans – *Crangon allmanni*		Echinoderms – *Amphiura chiajei* Crustaceans – *Pandalus montagui*
Northern North Sea	Echinoderms – *Strongylocentrotus droebachiensis* Molluscs – *Tridonta elliptica, Antalis entalis, Apporhais serresianus* Polychaetes – *Ditrupa arietina*	Echinoderms – *Strongylocentrotus droebachiensis* Molluscs – *Antalis entalis, Cirolana borealis* Polychaetes – *Hyalinoecia tubicola* Crustaceans - *Pandalus montagui*	Echinoderms – *Echinus acutus* Polychaetes – *Hyalinoecia tubicola* Crustaceans – *Crangon allmanni, Palliolum tigerinum, Pagurus prideaux*
West Coast of Scotland	Crustaceans – *Calocaris macandreae* Molluscs – *Abra alba, A. nitida, Nucula nitidosa, N. sulcata*	Crustaceans – *Crangon allmanni, Processa canaliculata* Polychaetes – *Ditrupa arietina*	

Table 3.2.2. Dominant epifaunal species at high biomass stations in the southern and central North Sea (other areas given on next page**).** The distributions of the highest biomass species are given in Figures 3.2.11., 3.2.13. and 3.2.15.

	High total biomass species		
Area of the North Sea	2001	2002	2003
Continental coast, Southern North Sea	Echinoderms – *Echinocardium cordatum, Brissopsis lyrifera, Astropecten irregularis, Ophiothrix fragilis*	Echinoderms - *Ophiura albida*	Echinoderms – *Echinocardium cordatum, E. flavescens, Brissopsis lyrifera, Astropecten irregularis*
	Crustaceans – *Cancer pagurus*	Crustaceans –*Philocheras trispinosus, Pagurus* sp.	
	Molluscs – *Buccinum undatum*	Molluscs – *Phaxas pellucidus, Nucula sulcata*	
Central North Sea (50-70m depth contours)	Echinoderms – *Echinocardium cordatum, E. flavescens, Spatangus purpureus, Brissopsis lyrifera, Ophiura ophiura,*		Echinoderms – *Echinocardium flavescens, Crossaster papposus, Spatangus purpureus, Astropecten irregularis*
	Molluscs – *Buccinum undatum, Neptunea antiqua*	Molluscs – *Colus gracilis, Roxania utriculus, Turitella communis, Thracia pubescens*	Molluscs – *Buccinum undatum, Neptunea antiqua, Modiolus modiolus, Acanthocardia echinata, Arctica islandica*
	Cnidarians - *Bolocera tuediae*	Cnidarians – *Metridium senile*	Cnidarians - *Bolocera tuediae, Alcyonium digitatum*
		Crustaceans – *Crangon allmanni, Ampelisca brevicornis, Scopelocheirus hopei*	
		Polychaetes – *Amphictene auricoma, Terebellides stroemi*	
	Bryozoans - *Securiflustra securifrons*	Bryozoans - *Flustra foliacea*	Bryozoans - *Flustra foliacea*
	Porifera – *Suberites ficus*		Porifera - *Suberites ficus*

Table 3.2.2. cont. **Dominant epifaunal species at high biomass stations in the northern North Sea and to the west coast of Scotland.** The distributions of the highest biomass species are given in Figures 3.2.11., 3.2.13. and 3.2.15.

	High total biomass species		
Area of the North Sea	2001	2002	2003
Northeast coast, Scotland	Echinoderms – *Asterias rubens*		Echinoderms – *Asterias rubens, Echinus esculentus*
	Crustaceans – *Pagurus prideaux*	Crustaceans – *Pagurus prideaux*	Crustaceans – *Cancer pagurus*
	Cnidarians – *Metridium senile, Halecium halecinum, Alcyonium digitatum, Alcyonidium diaphanum*	Cnidarians – *Halecium halecinum*	Cnidarians – *Halecium sessile, Alcyonium digitatum, Alcyonidium diaphanum*
	Bryozoans - *Flustra foliacea*		
		Polychaetes – *Nephtys caeca*	
			Molluscs – *Pecten maximus, Modiolus modiolus, Neptunea antiqua*
Northern North Sea	Echinoderms – *Strongylocentrotus droebachiensis, Hiippasteria phrygiana, Echinus elegans*	Echinoderms – *Psammechinus miliaris*	Echinoderms – *Hiippasteria phrygiana, Porania pulvillus, Echinus esculentus, Spatangus purpureus*
	Molluscs – *Neptunea antiqua*	Molluscs – *Colus gracilis, Ensis arcuatus*	Molluscs – *Pecten maximus*
	Cnidarians - *Bolocera tuediae*	Cnidarians – *Epizoanthus incrustatus, Tubularia indivisa*	Cnidarians - *Bolocera tuediae, Alcyonium digitatum, Alcyonidium diaphanum Tubularia* sp
		Crustaceans – *Pagurus prideaux, Galathea strigosa, Liocarcinus depurator*	
			Bryozoans – Flustra foliacea
West Coast of Scotland	Echinoderms – *Luidia ciliaris, Echinus esculentus*		
		Bryozoans – *Flustra foliacea, Securiflustra securifrons*, Bryozoan sp.	
	Cnidarians – *Alcyonium digitatum*	Cnidarians – Hydrozoan sp., *Abietinaria abietina, Caryophillia smithii*	