# The Sizewell C Project

## 6.3 Volume 2 Main Development Site C

### Chapter 22 Marine Ecology and Fisheries

### Appendix 22B - Sizewell Zooplankton Characterisation: 2008-2012

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# Sizewell Zooplankton Characterisation: 2008 -2012

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*Please note that the red line boundary was amended after this document was finalised, therefore figures in this document do not reflect the boundaries in respect of which development consent has been sought in this application. However, amendments to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.*

# Executive summary

Zooplankton include the early life stages of fish (ichthyoplankton) but also of many benthic organisms. They also include invertebrates that are planktonic throughout their life (i.e. holoplankton). Zooplankton feed on phytoplankton and other smaller zooplankton and form an important food source for higher trophic levels. Zooplankton are thus a core component of marine ecosystems; they are sensitive to changes in their environment and are therefore potentially affected by the proposed Sizewell C development.

This report characterises the zooplankton communities in the marine waters adjacent to the proposed Sizewell development by providing a synthesis of the knowledge acquired from the BEEMS zooplankton surveys between 2008 and 2012. Sampling primarily took place from February to July, surveys were also completed in September and October in 2008. For sampling and analytical purposes, the available data is broadly split into two size-based groups. Ichthyoplankton are further separated from the invertebrate zooplankton resulting in three groups of zooplankton, including:

- Ichthyoplankton (fish eggs and larvae, >4mm);
- The larger size fraction zooplankton (formally termed 'macrozooplankton', >4mm);
- The smaller size fraction zooplankton (formerly 'microzooplankton', ≤ 4 mm).

Spatio-temporal variations in the identified key taxa, and the wider community structure is investigated. To contextualise the data collected at Sizewell within the wider ecological context of the southern North Sea, the Sizewell dataset is also compared with that of the Continuous Plankton Recorder (CPR), which offers long term and large-scale information.

A total of 51 taxa of fish eggs and larvae were identified. Higher abundances of fish eggs and larvae were generally found in June-July. Anchovy, Dover sole, and sprat were the most dominant species accounting for over 95% of the total egg abundance across the full sampling period. Rockling and seabass eggs also accounted for over 1% of the total abundance. Solenette, unidentified specimens, lesser weever, pilchard, and mackerel all contributed to the top ten most abundant species (99.84% of total egg abundance). Rockling and sprat eggs started to appear in March, followed by Dover sole eggs in April and seabass eggs in May. The highest number of fish eggs was found in June-July and mostly comprised of anchovy.

Fish larvae were dominated to a lesser extent by a few highly abundant taxa. Seven taxa accounted for over 90% of abundance and included gobies, unidentified clupeids, herring, sprat, Dover sole, anchovy, and sandeels. Unidentified specimens, seabass and pilchards completed the top ten most abundant species (98.66% of total larvae). Larvae of clupeids and sandeel started to appear in April followed by Dover sole in May, goby in June and anchovy in July. Anchovy have recently become re-established in the North Sea and appeared to be increasing year on year in the Sizewell area, to the stage where they now form a major component of the ichthyoplankton and have the most abundant eggs (72.67%).

The larger size fraction zooplankton mostly included larvae of benthic species; 31 taxonomic groups were identified, these were mainly during the summer months. Characteristic taxa included mysids, ctenophores, gammarid amphipods, polychaetes, hooded shrimps (cumacea), jellyfish, *Crangon* spp., decapods, nematodes, isopods and krill. By far the most common and abundant group were mysids. Ctenophores were the second most common and abundant group. The first taxa to appear within the larger size fraction were the gammarids which were present from as early as February. Cumacea and polychaetes appeared in April, followed by cnidaria and decapods larvae in May. The highest number of individuals of the larger size fraction zooplankton were found in May and remained high up to at least July; of which mysids were the dominant taxa. Ctenophores and polychaetes were also high contributors to the total abundance in June.

The smaller size fraction zooplankton represented the most numerically abundant zooplankton group. They were present throughout the sampling period (February to July), the peak abundance for most taxa occurred in May. A total of 48 taxonomic groups were identified. The smaller size fraction zooplankton was characterised by invertebrate eggs, foraminifers, copepod juveniles and adult stages, bivalves, polychaetes, bryozoans, appendicularians, rotifers, gastropods, echinoderms, gelatinous zooplankton, cirripedia (barnacle) larvae, nematodes, arachnids and protozoans. By far the most common and abundant taxa were invertebrate eggs, foraminifers and copepod nauplii, which were found in over 90% of samples. Invertebrate eggs are a generic grouping encompassing a diverse range of taxa including benthic species with planktonic egg stages and zooplankton eggs. Adult copepods, mainly calanoids, also contributed substantially to the total abundance. The abundance of copepod juveniles and adults increased from April and remained high through to July, in line with the appearance of fish larvae in the water. Copepods accounted for over 28% of the total abundance of the smaller size fraction zooplankton.

**Comparison with other surveys**

The profiles for each of the characteristic ichthyoplankton and zooplankton groups broadly agree with those obtained from the long-term CPR survey. The advantage of the CPR is its extensive spatio-temporal coverage, thus allowing exploration of the long-term changes of each taxa within the wider environment. The zooplankton species recorded were typical of the southern North Sea with no unexpected species observed. Differences in the sampling methodologies employed by each survey has resulted in some differences in the data for benthic or bentho-pelagic taxa.

Between 2008 and 2012, zooplankton surveys in the Sizewell area evolved to address different purposes and, thus consisting of different designs. Samples were taken from a wide geographic area within the Greater Sizewell Bay (GSB) and characteristic zooplankton are described in detail. The spatio-termporal coverage of the data meant that zooplankton community analysis within the GSB focused on specific periods. Inferred zooplankton community differences can be driven by variable abundances of the most abundant groups (i.e. invertebrate eggs, foraminifers, and copepod early stages). These groups comprise of a wide range of species which are, in many cases, also part of the species-specific groups. Consequently, the broad taxonomic groups (“invertebrate eggs”, “unidentified copepods” and “copepod juveniles”), tend to be numerically large and display more variability than the species-specific groups. As such, changes in their abundance can skew analyses of community structure. Inclusion of abundant and variable broad taxonomic groups in statistical analyses, mask the variability of the less numerous species-specific groups. For the above reasons, the zooplankton characterisation excluded the numerically abundant broad taxonomic groups from multivariate analysis. The analysis revealed the existence of three to five zooplankton assemblages specific to each survey but no notable difference in community composition between stations located inshore and offshore of the Sizewell-Dunwich Bank was observed. This result highlights the importance of seasonality, inter-annual variability and patchiness of the plankton. For four out of the seven surveys between 2010-2011, there appeared to be a north-south and/or east-west gradient in assemblage composition. This variation in species distribution might be driven by temperature or salinity but could also be the result of sampling bias from the natural patchiness of the plankton, combined with the strong tidal currents in the area. Subsequent BEEMS surveys have focused on specific sites (Sizewell B intake, Sizewell B outfall, and Sizewell C intake/outfall) to determine spatial and temporal changes in the zooplankton communities and abundance from monthly samples between March 2014 and January 2017 (BEEMS Technical Reports TR326, TR379 and TR454).

Zooplankton data reported here identify and describe the characteristic zooplankton species collected between 2008 and 2012 with sampling from February to July. The surveys sampled from a wide geographic area and capturing the period of peak zooplankton abundance. Three years of monthly zooplankton surveys commenced in 2014 and provide supplementary information on seasonal patterns and the winter dynamics of the zooplankton. Broadly, samples collected between 2014-2017 conform to the observations made here, although differences in the seasonal composition of the community were observed. Site-specific differences in the most abundant taxa were also observed. Anchovy continued to dominate the ichthyoplankton abundance and mysids were the most important of the larger size fraction zooplankton. The monthly sampling identified a peak in chaetognaths abundance from September to November each year. Chaetognaths contributed to 14.7% of the total annual abundance of the larger size fraction zooplankton in 2016-17 and should therefore be considered within the characteristic component of the larger size fraction zooplankton community described here (BEEMS Technical Report TR454).

**Key zooplankton taxa to consider during the Environmental Impact Assessment**

As part of the Development Consent Order (DCO) for nationally-significant infrastructure projects, an Environmental Impact Assessment (EIA) is required for the proposed development of Sizewell C power station. The potential impacts of the proposed development on the marine ecology of the area must be assessed relative to baseline conditions. This report characterises the zooplankton communities within the vicinity of the proposed development and identified 40 taxa that characterise the invertebrate zooplankton community. The characteristic taxa are consistent with the species found in the wider southern North Sea.

Key zooplankton taxa for the EIA are selected based on the ecological importance, in terms of the most abundant and commonly occurring species, and potential socio-economic importance of taxa. None of the zooplankton reported here have direct commercial value[1].

The key zooplankton taxa for assessment purposed include mysids, amphipods, gelatinous zooplankton and copepods. These species are common and abundant in the coastal waters off Sizewell and are ecologically important components of the food-web. Gelatinous zooplankton, are both abundant and important for the EIA due to their potential socio-economic importance. Gelatinous zooplankton are an important consideration for the operational efficiency of power plants due to their gelatinous nature and propensity for populations to from “blooms”, resulting in the potential to cause blockage. These groupings provide an initial starting point for the assessment of impacts of activities associated with the proposed development.

Invertebrate eggs are widely distributed, and a ubiquitous component of the plankton. Invertebrate eggs form a life history stage for a wide variety of taxonomic groups of zooplankton and benthic species. Foraminifera were also a common and abundant component of the plankton at Sizewell. Foraminifera are taxonomically diverse and CPR data reveals they are abundant and highly variable group in the southern North Sea. The taxonomic breadth and ubiquitous nature of invertebrate eggs and formanifera precludes the application of standard sensitivity assessments and these taxa, whilst recognised are not proposed as key taxa for the ES assessments.

Ichthyoplankton and benthic larvae will be assessed as part of the life-stage vulnerably assessments in the fish and benthic community assessments. This report considers the ichthyoplankton results from the 2008-2012 surveys in relation to the wider fish assemblage detailed in the Fish Characterisation (BEEMS Technical Report TR345), entrainment studies from Sizewell B (BEEMS Technical Report TR235) and entrainment predictions for Sizewell C (BEEMS Technical Report TR318).

[1] Due to the suitability of sampling equipment, hyper-benthic *Crangon* spp. are considered within the Benthic Characterisation (BEEMS Technical Report TR348).

| Taxonomic grouping | Key taxa for EIA | Comments |
|---|---|---|
| Mysids | Mysids species include *Schistomysis spiritus, Siriella sp., Mysidopsis sp. and Schistomysis sp. Schistomysis spiritus* is the most abundant species off Sizewell (BEEMS Technical Report TR454). | Bentho-pelagic mysids were present in over 97 % of the larger size fraction samples and were the most abundant taxa accounting for over 76% of total abundance.<br><br>Mysids have high ecological value as the most abundant and common of the larger size fraction taxa. |
| Gelatinous zooplankton | - Ctenophores or sea gooseberries (not identified to species level).<br><br>- Cnidarians or jellyfish (not identified to species level). | Pelagic ctenophores and jellyfish were caught in over 59% and 27% of the larger size fraction samples, respectively and can dominate the plankton.<br><br>Gelatinous zooplankton have socio-economic importance due to their potential to reduce the efficiency of power station cooling water cooling systems. |
| Amphipods | - Gammarids<br><br>- Hyperiids<br><br>- Caprellids<br><br>- Corophiids | Amphipods are present in half of the larger size fraction samples.<br><br>Gammarids are the most common and abundant amphipod taxa and are typically benthic or epibenthic making periodic excursions to the water column. Shallow water depths and tidal currents account for the commonality of gammarids in plankton surveys.<br><br>Amphipods are selected based on their ecological value. |
| Copepods | - Copepod nauplii<br><br>- Harpacticoids (all species)<br><br>- Cyclopoids (all species)<br><br>- Calanoids (all species) | Copepods represent a diverse group zooplankton and include benthic (harpacticoid) and pelagic species.<br><br>Copepods were always present in samples of the smaller size fraction and accounted for approximately 28% of the total abundance of all taxa.<br><br>Copepods have high ecological value (abundant and common) and are important food source for fish, other zooplankton and benthic invertebrate larvae. |

# Purpose of the report

In 2007, British Energy (Now EDF Energy) commissioned Cefas to undertake a programme of scientific studies (BEEMS) in support of its intention to assess the potential for a NNB to the north of the current Sizewell B (SZB) power station at Sizewell, Suffolk.

Coastal power stations have the potential to impact on zooplankton communities. They use large volumes of water in their cooling systems, to condense the turbine steam. The current SZB power station abstracts approximately 51.5 $m^{-3}$ of seawater per second for its cooling system. Cooling water for SZB is pumped from an intake structure placed some 600 m off the coast. The proposed new nuclear build (NNB) at Sizewell C power station (SZC) will include a cooling system that abstracts approximately 132 cumecs. The proposed Sizewell C intakes will be ~3 km offshore. The locations of the two structures is provided in

Figure 1.

The cooling water intakes are protected by coarse screens to prevent the intake of larger fish and debris, but smaller organisms (i.e. zooplankton) enter the cooling water system. Though small fish and large invertebrates are removed before the water enters the power generation system through impingement on fine-mesh drum screens (mesh size yet to be determined for SZC but we have assumed 5mm for assessment purposes), smaller organisms including invertebrates and fish eggs and larvae pass through the power station cooling system before being discharged back into the environment. High temperatures, pressures and the addition of anti-fouling chemicals can all potentially impact on the zooplankton passing through the system. Cooling water discharges can also impact on plankton communities in the receiving waters around the station and the construction of station infrastructure (such as cooling water intake and discharge heads and any associated jetties or solid structures) may have a temporary effect if they suspend large amounts of sediment into the water column.

The application process for SZC requires evaluation of the impacts of the station development on the marine ecosystem of the Greater Sizewell Bay. As the zooplankton assemblages are a core component of the marine ecosystem and are potentially exposed to impacts, they are included in the Environmental Statement as part of the EIA process. In order to assess the potential for significant effects on zooplankton, a baseline understanding of the local spatio-temporal dynamics of the community in the vicinity of Sizewell power plant must be established. For sampling and analytical purposes, the available data is broadly split into two size-based groups[2]. Ichthyoplankton are considered separately from the invertebrate zooplankton, therefore three groups of zooplankton are detailed, these include:

- Ichthyoplankton (fish eggs and larvae, >4mm);
- The larger size fraction zooplankton (formally termed ‘macrozooplankton’, >4mm);
- The smaller size fraction zooplankton (formerly ‘microzooplankton’, ≤ 4 mm).

The aim of this report is to characterise the zooplankton communities off Sizewell by providing a synthesis on the knowledge acquired during survey campaigns between 2008 and 2012 as part of the BEEMS programme. Specifically, the following points are addressed:

1. Identify and describe the characteristic zooplankton species or taxonomic groups present at Sizewell;

[2] The invertebrate plankton is divided into two components because it is difficult to appropriately sample the full-size range of organisms with one specific sampler. Gears with large mesh can be towed for sufficient time to obtain a representative sample of the larger species, but miss most of the smaller ones; smaller meshes, in contrast, collect the smaller species but clog too quickly to effectively sample the larger species.

2. Identify the occurrence of spatio-temporal patterns in community structure, within the limitations of the available data;

3. Contextualise the species present at Sizewell against the wider southern North Sea;

4. From the characteristic zooplankton, identify ‘key taxa’ that are representative of the zooplankton community for the purpose of the Environmental Impact Assessment (EIA).

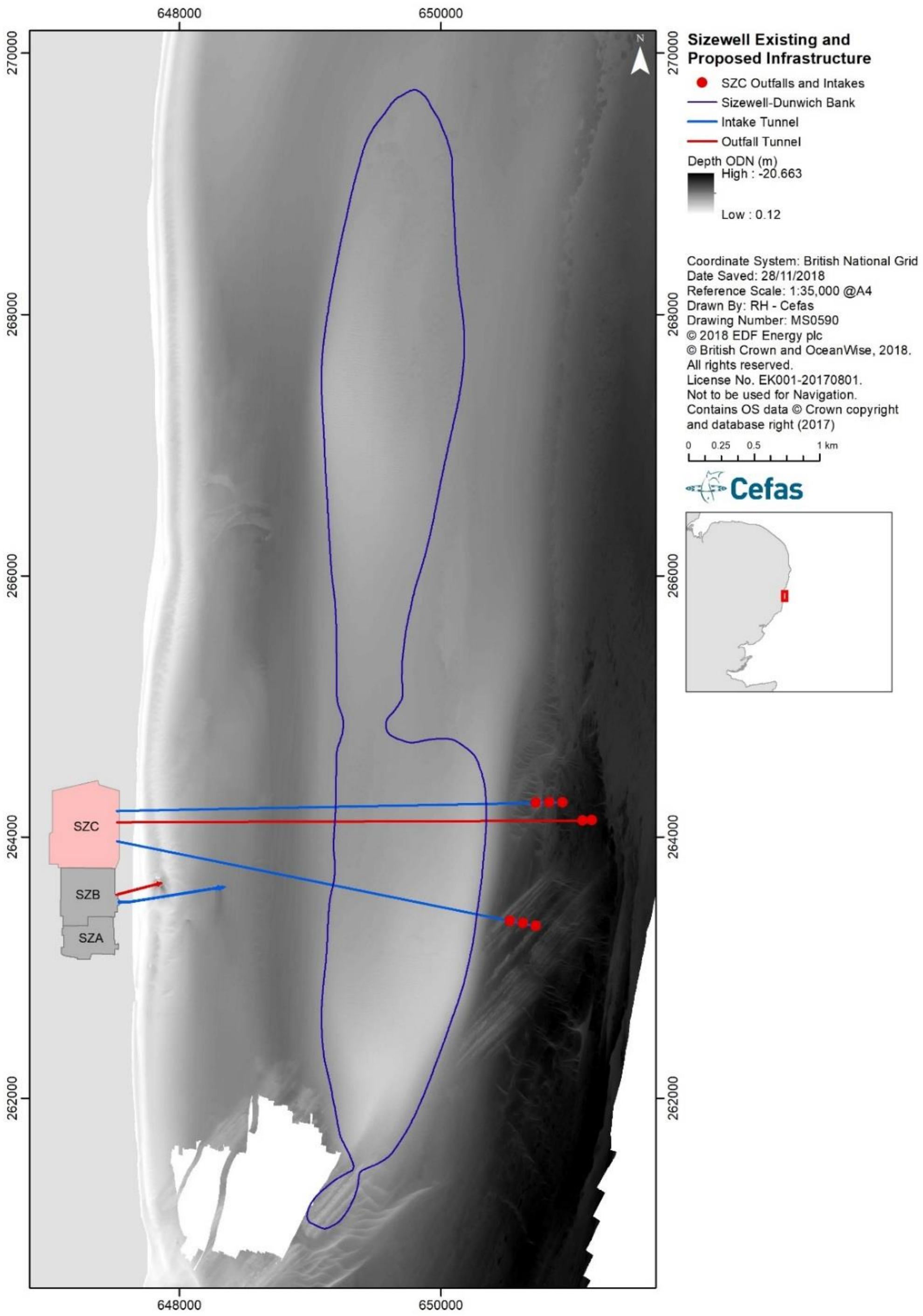



Figure 1: Map of the survey area showing the location of the Sizewell B station, the Sizewell-Dunwich Bank, and the location of the current SZB and proposed SZC intakes

# 1 Methods

## 1.1 Spatio-temporal coverage

The first tranche of BEEMS zooplankton surveys occurred between 2008 and 2012 (Table 1). The geographic extent of the surveys included in the characterisation is shown in Appendix A: Figures 85-89.

Table 1: Zooplankton surveys from 2008 to 2012. The number of stations sampled is shown in brackets.

| | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|
| January | | | | | |
| February | | | 17th-19th (24) | 11th-13th (39) | |
| March | 8th (20) | | 4th-6th (25) | 12th-15th (39) | |
| April | | | 2nd-4th (25) | 9th-12th (39) | 17th (6) |
| May | 1st (22) | | 1st-3rd (25) | 10th-13th (39) | 3rd, 15th, 31st (20) |
| June | | 21st (25) | 19th-20th (25) | 25th-27th (39) | 13th (22), 28th (20) |
| July | | | | | 13th (20), 29th (20) |
| August | | | | | |
| September | 13th (26) | | | | |
| October | 27th (25) | | | | |
| November | | | | | |
| December | | | | | |

Survey requirements (spatio-temporal coverage and types of data gathered) evolved over the survey years to fit EDF Energy evidence needs and as understanding of the potential stressors developed. Initial investigations took place before the locations of the proposed infrastructure and extent of the thermo-chemical plume were known; they utilised a large-scale grid and focussed on the commercially important groups (i.e. ichthyoplankton). Subsequent surveys incorporated other zooplankton groups of importance in the ecosystem and provided more detailed information over the main reproductive periods. More recently surveys have focussed on obtaining data in the vicinity of the existing and proposed station infrastructure and on better understanding any risks to station operation posed by specific species-groups. The rationale for each survey design can be summarised as follows:

- **2008**: A grid like design comprising 20 to 26 stations. The area was chosen because it was considered to be the region most likely to be exposed to the thermal plume from the proposed Sizewell C NNB. Data were available for ichthyoplankton but not for invertebrate zooplankton, as the programme was specifically focussed on fish during the early stages.
- **2009**: The surveys covered the same area as in 2008. Data were available for ichthyoplankton and the larger zooplankton fraction, as the programme widened to include other members of the food web.
- **2010**: A 25 station grid, designed to cover the spawning periods of most fish species known off the East Anglian coast, covering the same spatial extent as previously. These surveys consequently captured both a wider range and greater numbers of ichthyoplankton. The programme was also extended to the smaller size fraction zooplankton in May 2010, in addition to the larger size fraction zooplankton (BEEMS Technical Report 069A).
- **2011**: As in 2010, sampling was conducted with the aim of collecting samples representative of the full plankton community. In 2011, the area was extended further south to better encompass the extent of the predicted warm water discharge from Sizewell C, resulting in an increase from 25 to 39 stations (BEEMS Technical Report TR202).

- **2012**: Fortnightly surveys were conducted between April and July, at the locations of the SZB cooling water intake and the proposed SZC intake. The aims were to (1) explore potential differences between the plankton communities at the two sites, (2) explore community changes through the sampling season (i.e. April to July), and (3) investigate the potential effects of towing direction and sampling profile on the plankton communities (BEEMS Technical Report TR276).

This evolution of survey needs has resulted in datasets covering sometimes different months and locations over the years. While these inter-annual differences complicate statistical analyses, the data coverage gained from the survey series provides a wealth of information with which to characterise the zooplankton present. The analytical methods are described in Section 1.5 below.

Since the release of Version 1 of this report a three-year survey was completed between March 2014 and January 2017, with the aim of providing more detailed understanding of seasonal dynamics, particularly the overwinter dynamics of the zooplankton, and site-specific difference. Monthly surveys targeted specific locations around the SZB intakes and outfalls and proposed SZC infrastructure. These data are reported separately in BEEMS Technical Reports TR326, TR379 and TR454. A comparison of the 2014-2017 data with the 2008-2012 data is provided in Section 6.3.3.

## 1.2 Field sampling and sample processing

Full details of the sampling protocol are given in the BEEMS survey procedures SOP (BEEMS SOP0004v1).

Fish eggs and larvae were sampled with a Gulf VII high-speed plankton sampler fitted with a 270 µm mesh net and towed at about 3-4.5 knots (Nash *et al*., 1998). This is termed the MAIN sample. In addition, from 2010, an auxiliary fine mesh sampler (PUP) fitted with 80-µm mesh was used to collect smaller zooplankton. Between 2008 and 2011, the Gulf VII sampler was deployed as close to neap tides as possible and at either high water or with the ebb tide at shallow stations in order to minimise gear damage and avoid clogging. The 2012 survey showed that altering the tow profile and direction did not result in significant differences in the zooplankton sampled, so this practice was discontinued.

Individual organisms were identified to species level whenever possible, using microscopes. When this was not possible, identification was done to the lowest taxonomic description possible. The zooplankton components from the MAIN and PUP samples were kept separate as the larger size fraction zooplankton component comprising individuals ≥ 4mm, and the smaller size fraction zooplankton component comprising individuals ≤ 4mm, respectively.

## 1.3 Selection of species or taxonomic groups for further investigation

Socio-economic value and conservation status was considered for most fish larvae as these were often identified to genus or species level. Invertebrate zooplankton include many larval stages of benthic organisms, which only spend part of their life cycle within the plankton (i.e. meroplankton), some of which may have a high socio-economic value (e.g. lobster). However, in the vast majority of cases, these organisms cannot be identified further than group or even order level, each group/order comprising many species. Other zooplankton spend their entire lifecycle within the water column (i.e. holoplankton), these organisms are not exploited commercially and do not undergo any conservation status assessment (e.g. copepods). Thus, most taxa belonging to the invertebrate zooplankton groups were only assessed for their ecological importance.

A species or taxonomic group was considered for further investigation if it met at least one of the following criteria:

- Ecological importance within Greater Sizewell Bay: Abundance and commonality contribute towards potential ecological importance of a taxa, with more weight applied towards abundance. If a taxon contributes to at least 1% of the total abundance it is considered abundant enough to potentially play an important trophic role within the Sizewell Bay and is selected for further consideration. The plankton community includes life history stages (larvae and eggs) of species, which may be highly abundant but sporadic. Commonality may thus not truly reflect ecological importance, particularly if samples are not distributed evenly over time. To account for species that are commonly observed, a taxa that are present in at least 5% of samples are considered further.

- Socio-economic value: Sizewell is within ICES statistical rectangle 33F1 and commercial landings data is reported to the MMO. Ichthyoplankton and zooplankton that form part of the life history stages of the commercially targeted species (90% by value of weight of landings) or are directly targeted are considered to have potential socio-economic value. Seven species contribute to over 90% of the total commercial landings by weight in ICES rectangle 33F1.  These included: whelk (*Buccinum undatum*), thornback ray (*Raja clavate)*, sole (*Solea solea*), cod *(Gadus morhua*), brown shrimp (*Crangon crangon*), lesser spotted dogfish (*Scyliorhinus canicula*), and seabass (*Dicentarchus labrax*). Due to market value, the species that contribute over 90% to landings by value differ slightly and included: sole, whelk, seabass, thornback ray, cod, lobster, and brown shrimp (BEEMS Technical Report TR123). Furthermore, species that may have a beneficial or detrimental impact on socio-economic interests are considered. For example, gelatinous zooplankton, which have the potential to compromise power station efficiency.

- Conservation importance: Species “of principle importance for the purpose of conserving biodiversity” listed in Section 41 (England) of the Natural Environment and Rural Communities (NERC) Act 2006. It is worth noting however that measures in place to provide protection for the named species apply to the adult stock rather than the eggs or larvae, and focus on halting the decline of the spawning stock biomass mainly via restriction on exploiting recruited species.

Important taxa are listed in the individual icthyoplankton, invertebrate zooplankton sections (Sections Ichthyoplankton in Section 2.1, larger size fraction zooplankton in Section 3 and smaller size fraction zooplankton in Section 4). An overview of the zooplankton at Sizewell is provided in Section 6 and contextualised for the purposes of the EIA.

## 1.4 The Continuous Plankton Recorder (CPR)

The CPR has been running for more than 80 years, and is one of the longest and most extensive ecological time-series in the world, providing a unique source of long-term, large-scale information covering more than 300 species of zooplankton in the North Atlantic (Beare *et al*., 2003; Reid, *et al*., 2003). The CPR is towed by ‘‘ships of opportunity’’ at speeds of 15-20 knots and at an approximate depth of 10 m. Water enters the recorder through a square aperture of 1.62 $cm^2$, and is filtered through a continuously moving band of silk with an average mesh size of 270 mm. The plankton organisms are covered by a second band of silk, and this double band is wound into a storage tank containing formalin. When returned to the laboratory for processing, the roll of silk is unwound and divided in sections representing 10 nautical miles (18.52 km) of tow, equivalent to about 3 $m^3$ of filtered seawater. Methods of counting and data processing are described by Colebrook (1975) and Batten *et al*., (2003).

A total of 26 taxonomic groups of zooplankton (excluding ichthyoplankton) were extracted from the CPR dataset, these were selected for the purpose of comparison with the BEEMS surveys, and every endeavour was made to extract information on the abundance of the same taxonomic groups as those collected during the BEEMS surveys. The period 1989-2012 was selected to explore changes in community structure, covering 24 years within the southern North Sea area (2). Information on fish larvae is also available from the CPR but the data available do not go further than 2005 (Figure 3), thus making direct comparison between the two datasets impossible. The atlas produced by Edwards *et al*., (2011) was used as background information on long-term changes in the abundance of the fish larvae encountered in the Sizewell area.

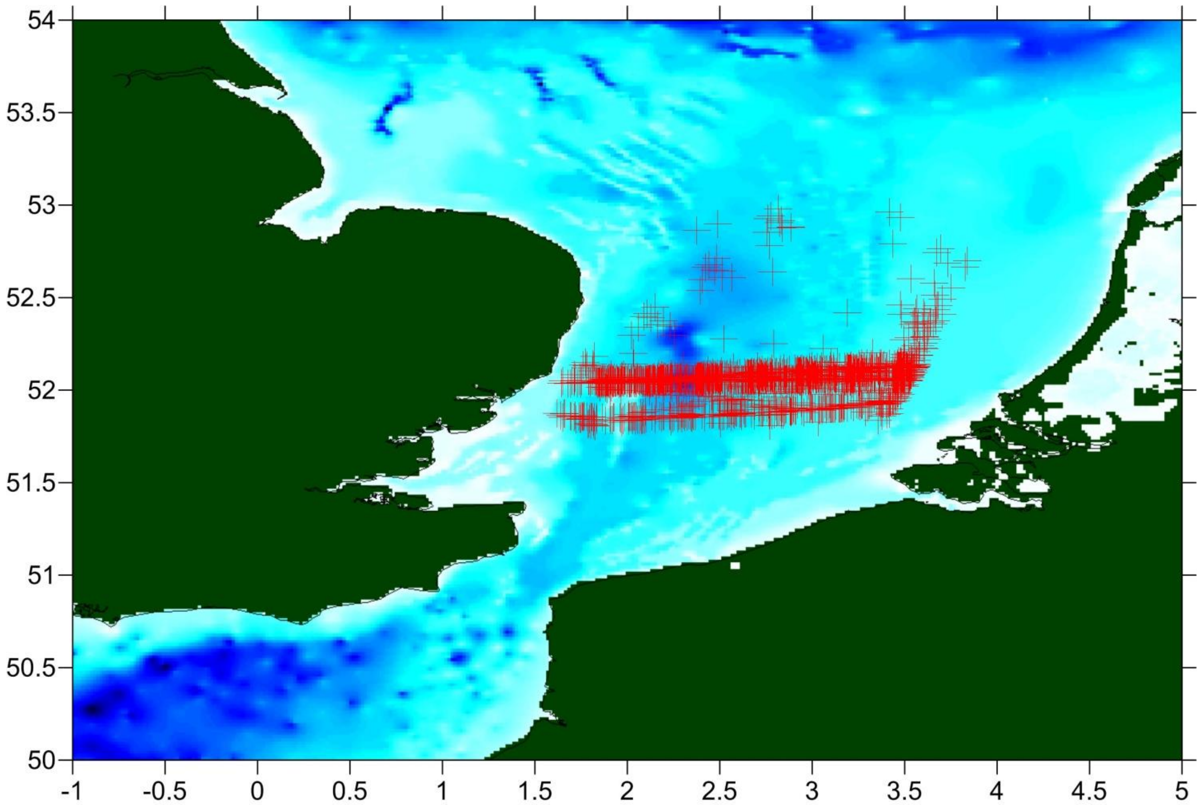



Figure 2: Location of the 1863 data points (1989-2012) from the Continuous Plankton Recorder (CPR) dataset in the vicinity of the BEEMS survey area. Information was extracted for the following taxonomic groups: *Para-pseudocalanus* spp., *Temora* spp., *Acartia* spp., *Centropages* spp. cyclopoid Copepoda, calanoid Copepoda, harpacticoid Copepoda, Bryozoa larvae, Echinodermata larvae, Gammaridae, Decapoda, Euphasiidae, Cirripedia larvae, Foraminifera, Cumacea, Ispoda, Mysidacea, Nematoda, Appendicularia, Lamellibranchia, Gastropoda/Thecosomata larvae, Amphipoda, Polychaeta, Cnidaria.

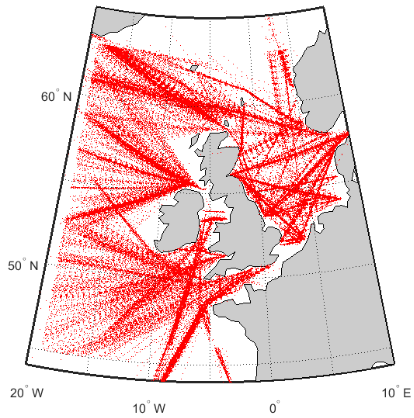



Figure 3: Distribution of the CPR samples. A total of 134,260 data points (1948-2005) was used to create the subsequent figures.

## 1.5 Data analysis

- Seasonal and year-to-year variabilities

Our approach was to first describe the selected key species and taxonomic groups of zooplankton present in Sizewell area, how these varied throughout the seasons and from year to year. It is however important to note that the spatio-temporal coverage of the Sizewell survey conducted between 2008 and 2012 does not allow for concise seasonality studies as samples were collected for different time periods within the window of February and September (Table 1).

As a reference for zooplankton in the wider environment, information available from the CPR was used. The CPR has the advantage of providing information on a much longer temporal scale, and consistently throughout the year.

- Community structure: Principal Component with cluster analysis

To investigate the structure of zooplankton communities in space and their potential variations in time, a multivariate technique (i.e. Principal Component Analysis, PCA) was used followed by a Hierarchical Cluster Analysis (HCA, with Euclidian distance and agglomerative ward criteria) applied to the table of scores obtained from PCA analysis. The aim of the PCA with HCA was to identify major patterns of zooplankton community structure over the study area and for each selected survey. The PCA reduces the number of dimensions (i.e. the number of variables) and hence the original data complexity, while preserving much of the original relationship between the variables (i.e. information on the explained variance). The HCA then grouping of stations that have similarities in term of zooplankton taxa present and their relative abundance (i.e. assemblages). These groups/assemblages of zooplankton taxa were characterised using indicator values IndVal which is described below.

PCA-HCA analysis was done for each survey of 2010 and 2011: these were the two years for which surveys were carried on a grid and both MAIN and PUP net samplers were used, and the resulting data were consistent across surveys (See Appendix A for details on survey design). Each dataset for each survey consisted of a data matrix station (x) taxa abundance. This resulted in 2 data matrices for 2010 for the month of May and June and 5 data matrices for 2011 for each month March to July. The analysis for each survey was completed separately rather than each year to ensure that no variation resulting from seasonal variability would interfere with our analysis.

The community structure analysis comprises the following steps which are also summarized in the flowchart in Figure 4:

(1) Invertebrate eggs and copepod nauplii are by far the most common and abundant taxonomic groups in the Sizewell area, they also comprise a wide range of taxa, which can only be further identified in the juvenile/adult stages. As a result, their variations would blur potential changes in the abundances of the associated taxa and overshadow any potential differences in the abundance of other less abundant groups. These very large groups were removed in order to focus on taxa identified to more discrete taxonomic levels.

(2) Taxa that were present in at least 5% of samples or contributed to at least 1% of the total abundance were selected, within either the larger of smaller zooplankton size fractions (i.e. ecological importance criteria described above). When a taxon fulfilled at least one condition in both MAIN (270µm mesh net) and PUP (80µm mesh net) fractions, the fraction in which it contributed the most to total abundance was selected.

(3) Each data series was rescaled to have a mean of zero (i.e. by removing the average); so that the stations can be classified according to the more representative groups of zooplankton (rather than the more abundant).

(4) Due to the highly skewed statistical distance of abundance values that characterize plankton data, these were log-transformed using a log(x+1) function, in order to reduce the asymmetry within the data and increase the normality.

(5) The PCA was performed using the MATLAB programming language, on each of the 7 matrices (station x taxon abundance) on centred and non-normalised data. This allows focus to be placed on the relative abundances of the taxa present at each station, as well as those taxa with high variability across stations. The output of the PCA is a table of scores, which is a matrix of stations (x) coordinates of selected taxa on the principal components.

(6) The components from the resulting table of scores that explained about 70-80% of the total variance were selected. This is a data smoothing exercise.

(7) The HCA was performed using the MATLAB programming language, with Euclidian distance and agglomerative ward's criteria, on each of the 7 table of scores using selected components only. Euclidian distance was used because it is the distance that was also used for the PCA. Agglomerative clustering is a "bottom up" approach: each station starts in its own cluster, and pairs of clusters are merged according to the ward's criteria (minimum variance) as one moves up the hierarchy, until all the stations are grouped in one class only. A dendrogram or tree diagram is produced to illustrate the arrangement of the clusters.

(8) The cophenetic distance and correlation (a value of how similar two objects have to be in order to be grouped into the same cluster) were then calculated, to determine the number of significant groups of stations resulting from the dendrogram; and define clusters of similar stations.

(9) Groups/assemblages of taxa were characterised, using indicator values IndVal for each taxa *i* in each group j according to the method described by Dufrene & Legendre (1997):

$$\text{IndVal} = A_{ij} \times B_{ij}$$

$A_{ij}$ (measure of specificity) = mean abundance of taxon *i* in the sites of group *j* compared to all groups in the study. $A_{ij}$ maximum when taxon *i* only present in group j.

$B_{ij}$ (measure of fidelity) = relative frequency of occurrence of taxon *i* in the sites of group *j*. $B_{ij}$ max when *i* is present in all sites of *j.*

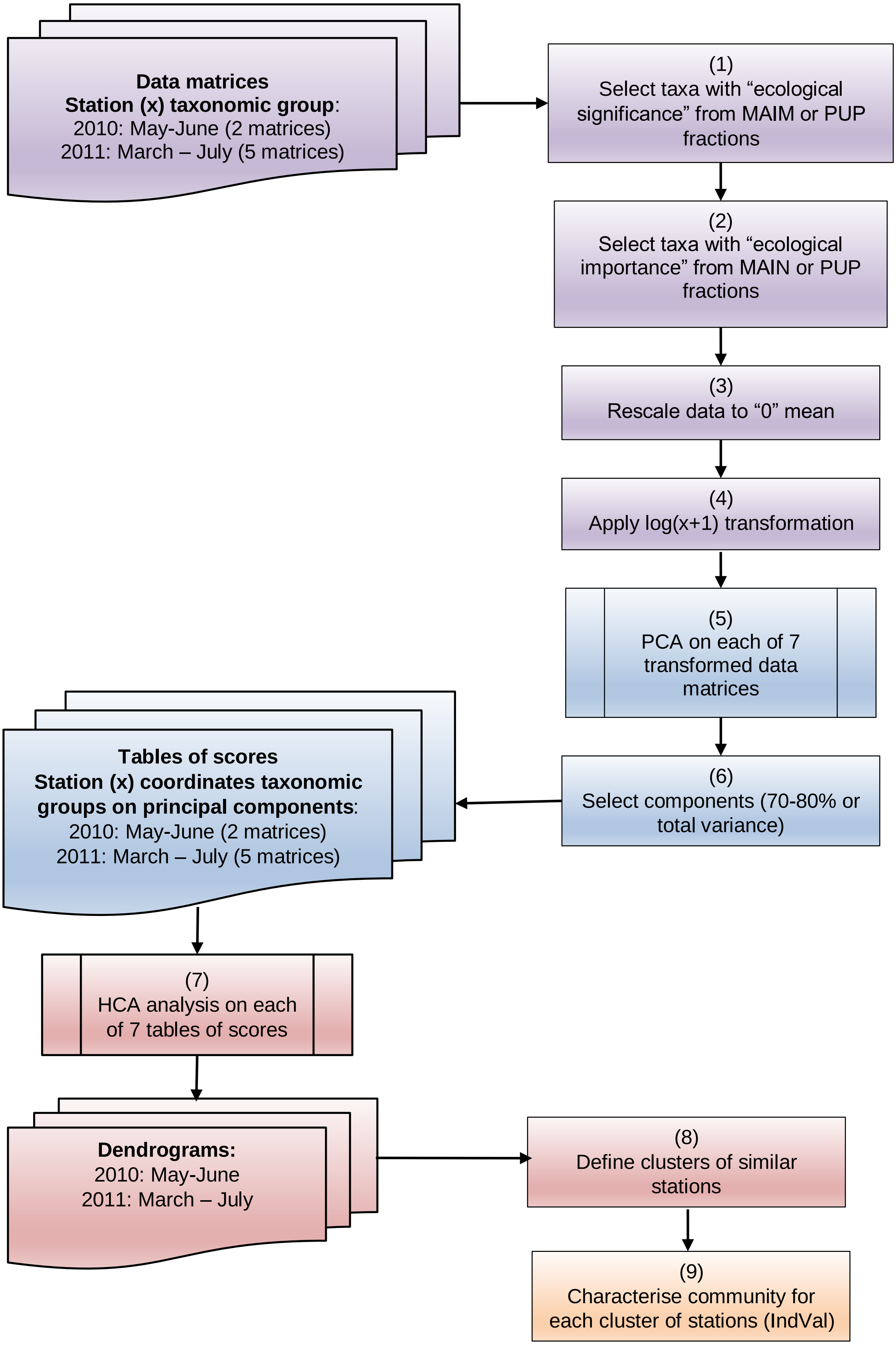



Figure 4: Flowchart summarizing the various steps to perform the community structure analysis.

# 2 Ichthyoplankton

51 taxonomic groups, including both fish eggs and larvae, were identified among the 585 samples collected between 2008 and 2012 at Sizewell. These include unidentified specimens of both eggs and larvae which were found in 13.16 % and 8.89 % of samples, respectively and contributed to 0.46 % and 0.36 % of the total ichthyoplankton abundance across all samples (Table 2 and Table 3).

Higher abundances of both fish eggs are larvae were found during the months of June and July, in general (Figure 5). However, year to year discrepancies in terms of spatio-temporal coverage of the surveys call for caution.

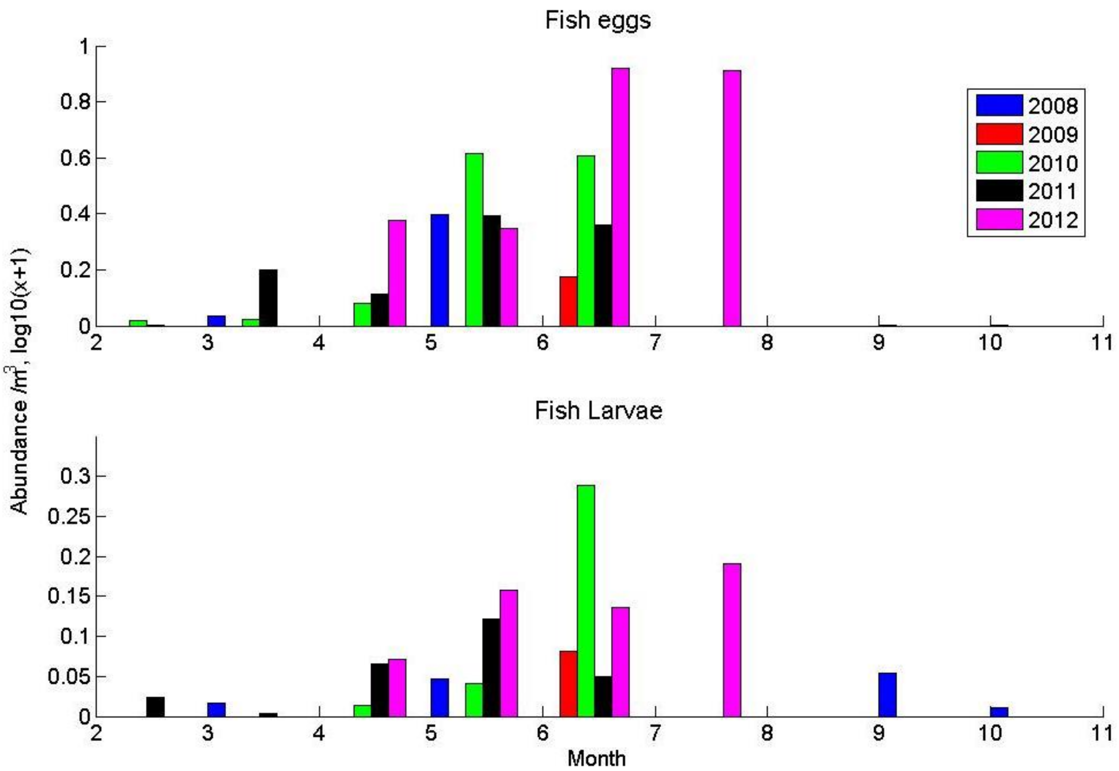



Figure 5: Mean numbers of fish eggs and larvae collected each month at Sizewell, between 2008 and 2012.

Table 2: Abundance of ichthyoplankton eggs from all surveys between 2008-2012. Taxa contributing to over 1% of the total egg abundance are shown in bold. Species underlined appeared in more than 5% of samples.

| **Fish egg abundance by taxa** | **Positive samples (*n* = 585 samples)** | **Contribution to total abundance (eggs and larvae) (%)** | **Contribution to total egg abundance (%)** | **Cumulative abundance (%)** |
|---|---|---|---|---|
| **Anchovy (*Engraulis encrasicolus*)** | **183 (31.28%)** | **64.39%** | **72.67** | **72.67** |
| **Dover sole (*Solea solea*)** | **215 (36.75%)** | **15.70%** | **17.72** | **90.38** |
| **Sprat (*Sprattus sprattus*)** | **196 (33.50%)** | **4.57%** | **5.16** | **95.54** |
| **Rockling (Lotidae)** | **175 (29.92%)** | **1.36%** | **1.53** | **97.08** |
| **Seabass (*Dicentrarchus labrax*)** | **34 (5.81%)** | **1.10%** | **1.24** | **98.32** |
| | | | | |
| Unidentified specimen | 77 (13.16%) | 0.46% | 0.52 | 98.84 |
| Solenette (*Buglossidium luteum*) | 37 (6.33%) | 0.27% | 0.30 | 99.14 |
| Lesser weever (*Echiichthys vipera*) | 38 (6.50%) | 0.24% | 0.27 | 99.41 |
| Pilchard (*Sardina pilchardus*) | 21 (3.59%) | 0.23% | 0.26 | 99.67 |
| Mackerel (*Scomber scombrus*) | 15 (2.56%) | 0.15% | 0.17 | 99.84 |
| Sandeels (Ammodytidae) | 9 (1.54%) | 0.05% | 0.06 | 99.90 |
| Gurnard (Triglidae) | 11 (1.88%) | 0.05% | 0.06 | 99.95 |
| Unidentified triglids (Triglidae) | 2 (0.34%) | 0.01% | 0.01 | 99.97 |
| Unidentified dragonet (Callionymidae) | 2 (0.34%) | 0.01% | 0.01 | 99.98 |
| Scadfish (*Arnoglossus laterna*) | 1 (0.17%) | 0.01% | 0.01 | 99.99 |
| Turbot (*Scophthalmus maximus*) | 1 (0.17%) | 0.01% | 0.01 | |
| Brill (*Scophthalmus rhombus*) | 1 (0.17%) | | | |
| Topknot (*Zeugopterus punctatus*) | 2 (0.17%) | | | |

Table 3: Abundance of ichthyoplankton larvae from all surveys between 2008-2012. Taxa contributing to over 1% of the total larvae abundance are shown in bold.

| **Fish larvae abundance by taxa** | **Positive samples (*n* = 585 samples)** | **Contribution to total abundance (eggs and larvae) (%)** | **Contribution to total larvae abundance (%)** | **Cumulative abundance (%)** |
|---|---|---|---|---|
| **Gobies (Gobidae)** | **181 (30.94%)** | **4.14%** | **36.87** | **36.87** |
| **Unidentified cupleids (Cupleidae)** | **154 (26.32%)** | **1.80%** | **16.03** | **52.89** |
| **Herring (*Clupea harengus*)** | **70 (11.97%)** | **1.26%** | **11.22** | **64.11** |
| **Sprat (*Sprattus sprattus*)** | **76 (12.99%)** | **0.90%** | **8.01** | **72.13** |
| **Dover sole (*Solea solea*)** | **58 (9.92%)** | **0.83%** | **7.39** | **79.52** |
| **Anchovy (*Engraulis encrasicolus*)** | **30 (5.13%)** | **0.79%** | **7.03** | **86.55** |
| **Sandeels (Ammodytidae)** | **86 (14.70%)** | **0.66%** | **5.88** | **92.43** |
| **Unidentified specimen** | **52 (8.89%)** | **0.36%** | **3.21** | **95.64** |
| **Seabass (*Dicentrarchus labrax*)** | **31 (5.30%)** | **0.22%** | **1.96** | **97.60** |
| **Pilchard (*Sardina pilchardus*)** | **12 (2.05%)** | **0.12%** | **1.07** | **98.66** |
| | | | | |
| Dab (*Limanda limanda*) | 7 (1.20%) | 0.04% | 0.36 | 99.02 |
| Solenette (*Buglossidium luteum*) | 3 (0.51%) | 0.01% | 0.09 | 99.11 |
| Sand sole (*Pegusa lascaris*) | 1 (0.17%) | 0.01% | 0.09 | 99.20 |
| Unidentified soleids (Soleidae) | 3 (0.51%) | 0.01% | 0.09 | 99.29 |
| Gurnard (Triglidae) | 2 (0.34%) | 0.01% | 0.09 | 99.38 |
| Bib (*Trisopterus luscus*) | 1 (0.17%) | 0.01% | 0.09 | 99.47 |
| Unidentified gadoids (Gadidae) | 2 (0.34%) | 0.01% | 0.09 | 99.55 |
| Unidentified dragonet (Callionymidae) | 2 (0.34%) | 0.01% | 0.09 | 99.64 |
| Sea scorpion (*Taurulus bubalis*) | 3 (0.51%) | 0.01% | 0.09 | 99.73 |
| Scadfish (*Arnoglossus laterna*) | 2 (0.34%) | 0.01% | 0.09 | 99.82 |
| Nilsson's pipefish (*Syngnathus rostellatus*) | 2 (0.34%) | 0.01% | 0.09 | 99.91 |
| Montague's seasnail (*Liparis montagui*) | 2 (0.34%) | 0.01% | 0.09 | 100 |
| Flounder (*Platichthys flesus*) | 1 (0.17%) | 0.00% | | |
| Plaice (*Pleuronectes platessa*) | 1 (0.17%) | 0.00% | | |
| Unidentified pleuronectids (Pleuronectidae) | 1 (0.17%) | 0.00% | | |
| Rockling (Lotidae) | 2 (0.34%) | 0.00% | | |
| Lesser weever (*Echiichthys vipera*) | 1 (0.17%) | 0.00% | | |
| Whiting (*Merlangius merlangus*) | 1 (0.17%) | 0.00% | | |
| Reticulate dragonet (*Callionymus reticulatus*) | 1 (0.17%) | 0.00% | | |
| Two-spotted clingfish (*Diplecogaster bimaculata*) | 1 (0.17%) | 0.00% | | |

## 2.1 Selected ichthyoplankton taxa

The ichthyoplankton selected for further investigation are based on their ecological, potentials socio-economic, and/or conservation importance (Table 4). Abundance was the overriding factor determining the ecological importance of fish eggs and larvae. Socio-economic importance was the top 90% of commercial landings weight and value for the ICES rectangle 33F1, it should be noted however that eggs and larvae do not have direct commercial value. Ichthyoplankton that was present, and are listed in section 41 of the NERC Act (2006) were included for conservation importance. Again it should be noted that it is the adult stages that are designated.

Table 2 identified solenette and lesser weever eggs as relatively common, occurring in approximately 6% of samples. Eggs of solenette (0.30%) and lesser weever (0.27%) had a minor contribution to total egg abundance and both species had a negligible contribution to the larval stages. These species are not designated and do not have meet the criteria for socio-economic importance and are therefore not considered further.

Table 4: Key ichthyoplankton taxa collected at Sizewell between 2008 and 2012. Ichthyoplankton are selected based on their socio-economic importance (adults contribute to 90% of the landings or value of the commercial fishery in ICES rectangle 33F1), conservation designations (NERC list), or ecological importance (contribute to at least 1 % of the total egg or larvae abundance).

| **Taxa** | **Selection Criteria** | | |
|---|---|---|---|
| | **[1]Socio-economic** | **Conservation** | **Ecological** |
| Anchovy (*Engraulis encrasicolus*) | | | Abundant Eggs<br>Abundant Larvae |
| Dover sole (*Solea solea*) | Important local fishery | NERC list | Abundant Eggs<br>Abundant Larvae |
| Sprat (*Sprattus sprattus*) | | | Abundant Eggs<br>Abundant Larvae |
| Seabass (*Dicentrarchus labrax*) | Important local fishery | | Abundant Eggs<br>Abundant Larvae |
| Gobies (Gobidae) | | | Abundant Larvae |
| Herring (*Clupea harengus*) | | NERC list | Abundant Larvae |
| Sandeels (Ammodytidae) | | [2]Raitt's or Lesser sandeel (*Ammodytes marinus)* on NERC list | Abundant Larvae |
| Pilchard (*Sardina pilchardus*) | | | Abundant Larvae |
| Rockling (Lotidae) | | | Abundant Eggs |
| Mackerel (*Scomber scombrus*) | | NERC list | Eggs Present |
| Plaice (*Pleuronectes platessa*) | | NERC list | [3] Larvae Present |
| Whiting larvae (*Merlangius merlangus*) | | NERC list | [3] Larvae Present |

[1]The adult stages contribute to 90% of landings by value or weight in ICES rectangle 33F1.
[2]Only *Ammodytes marinus* appears on the NERC list, the species collected in ichthyoplankton surveys is unknown but impingement sampling at Sizewell only found 2 species - the sand lance (*Ammodytes tobianus)* and Greater sandeel (*Hyperoplus lanceolatus*) (BEEMS Technical Report TR431).
[3]A single sample containing larvae was observed (Table 3).

### 2.1.1 Herring (*Clupea harengus*)

In the North Sea, the herring stock consists of several sub-stocks that spawn at different times of the year. Generally, spawning starts in August in the northern North Sea and ends in January in the southern North Sea and eastern English Channel (Nash & Dickey-Collas, 2005). There is a spring-spawning population of herring in the Blackwater and outer Thames Estuaries (Fox *et al*, 1999) with associated peak hatching at the end of March to early April. Herring, as a demersal spawner, deposit their eggs on the seabed; consequently, they are rarely caught during ichthyoplankton surveys. Larvae of clupeids are difficult to distinguish from each other, and as such larvae of herring, sprat and pilchard are often grouped together under the general taxonomic group "clupeid larvae". Overall, there has been a decrease in number of clupeids caught by the CPR over the last few decades and the spawning grounds have become more concentrated in the south-western North Sea and eastern English Channel, perhaps reflecting an increase in sprat, sardine and anchovy abundance compared to herring. Herring larvae were identified in 11.97 % of samples collected at Sizewell during the 2008-2012 period and they contributed to 11.22 % of the total larvae abundance, while unidentified clupeid larvae were present in 26.32 % of samples and contributed to 16.030 % of the total larvae abundance. The highest number of herring larvae was collected during May 2012 (Figure 6).

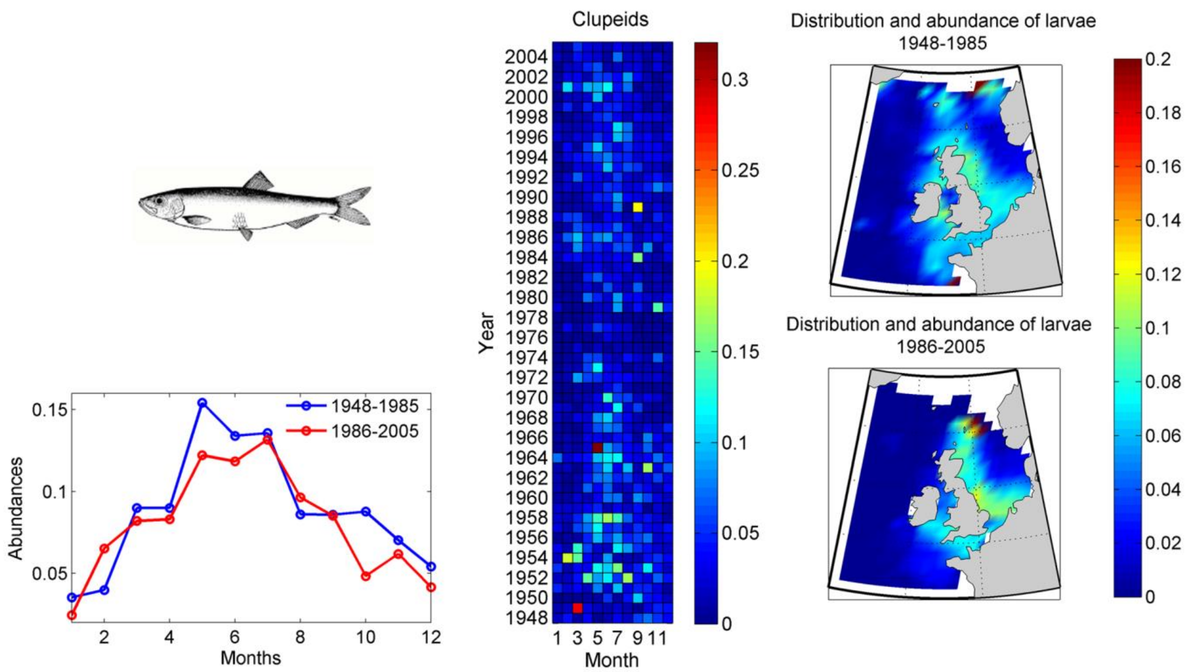



Figure 6: Clupeid larvae from the Continuous Plankton Recorder (CPR) over the period 1948-1985 (top right distribution map), 1986-2005 (bottom right distribution map), with seasonality (bottom left plot and middle graph).

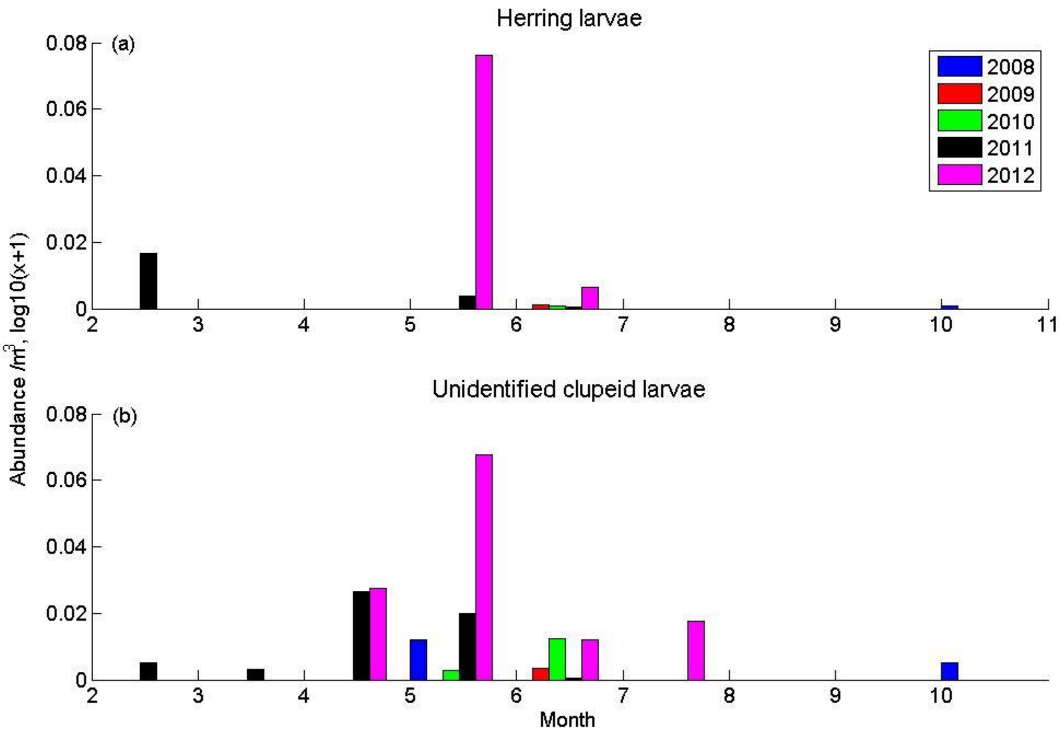



Figure 7: Mean monthly abundances of herring larvae and unidentified clupeid larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.2 Sprat (*Sprattus sprattus*)

This is a small and very abundant and common pelagic species of the Clupeidae group. As such, the larvae are sometimes difficult to identify to species level and often grouped together under the general taxonomic group “clupeid larvae” along with herring and pilchard. Spawning takes place in the North Sea from January to July, and eggs are pelagic, drifting inshore, where they hatch and develop. According to Russell (1976), sprats have an extended spawning season with eggs recorded from January to July. Sprat eggs were recorded in 33.50 % of all samples collected and contributed to 5.16% of the total egg abundance, while larvae were recorded in 12.99 % of all samples and contributed to 8.01% of the larvae abundance. The highest number of sprat eggs was collected in March 2011, while the highest number of sprat larvae was collected in June 2010 (Figure 8).

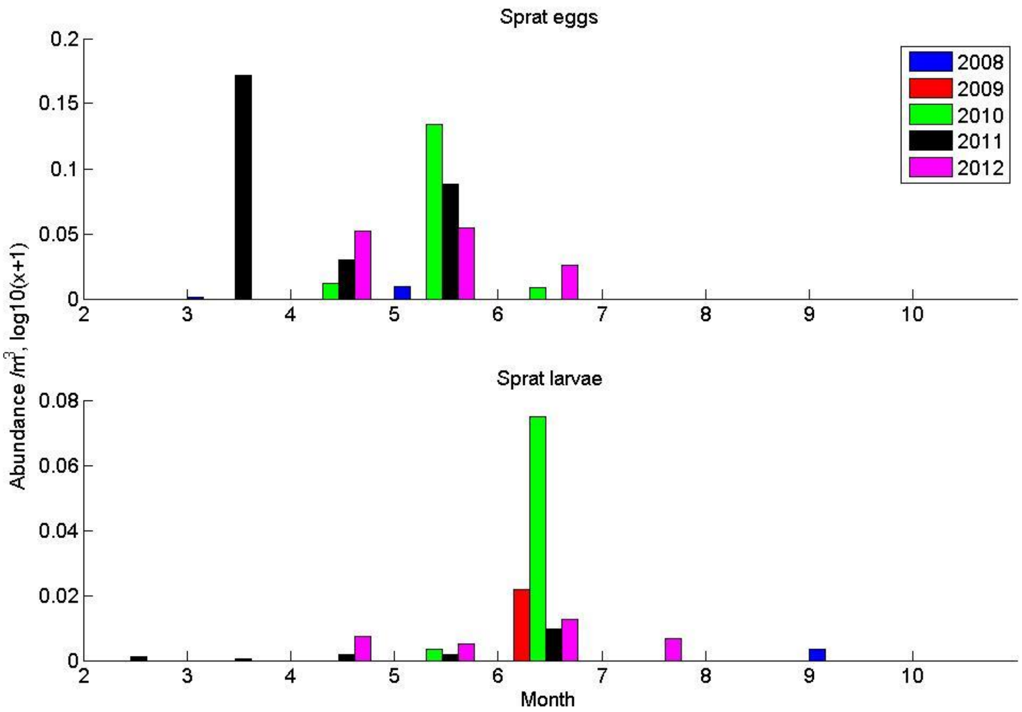



Figure 8: Mean monthly abundances of sprat eggs and sprat larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.3 Anchovy (*Engraulis encrasicolus*) and Pilchard (*Sardina pilchardus*)

Around the UK, anchovy are found mainly in south western-waters, in the English Channel and in the southern North Sea. Spawning takes place from April to August (Munk and Nielsen, 2005), peaking from May to July. Spawning populations of pilchard or European sardines (*Sardina pilchardus*) and anchovies (*Engraulis encrasicolus*) have become re-established in the southern North Sea after a ~30-year absence and now co-occur with sprat (*Sprattus sprattus*). Little is known concerning potential interactions among pilchard, anchovy and sprat larvae in this region (Kanstinger & Peck, 2009).

At Sizewell, anchovy eggs were caught in 31.28 % of all samples and contributed to 72.67 % of the total egg abundance, making this taxonomic group the most abundant. Larvae were caught in much lower numbers (i.e. 5.13 % of samples and contributing to 7.03 % of total larvae abundance). Larvae were recorded for the first time in 2011 at Sizewell (Figure 9). The highest number of anchovy eggs and larvae were collected in June and July 2012. Both eggs and larvae seem to be on an increasing trend in the Sizewell area.

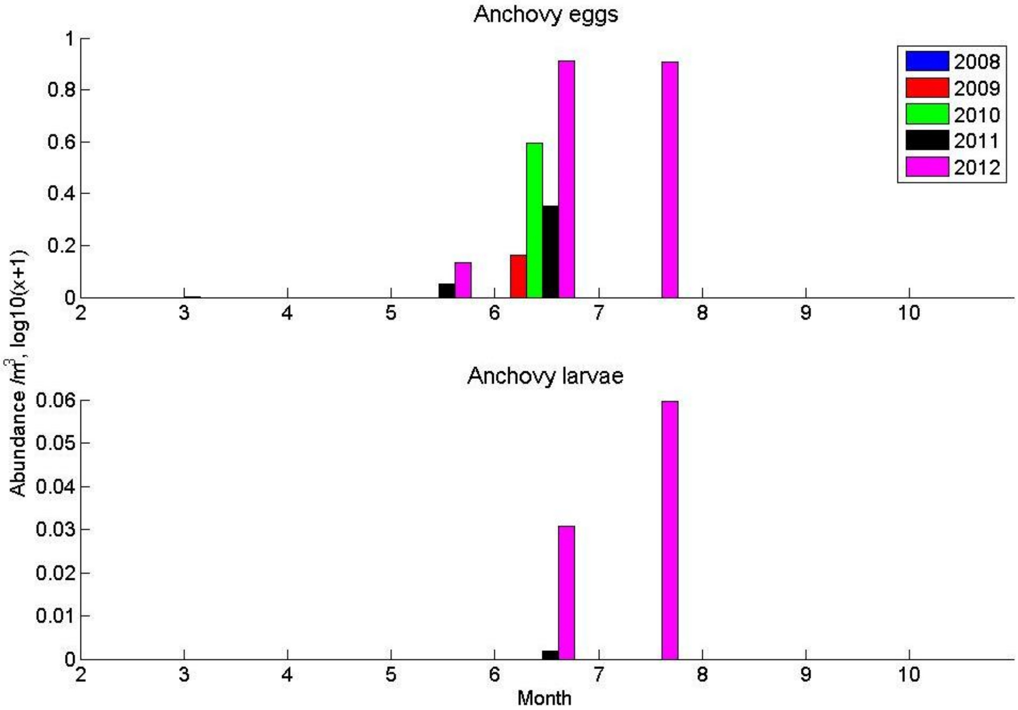
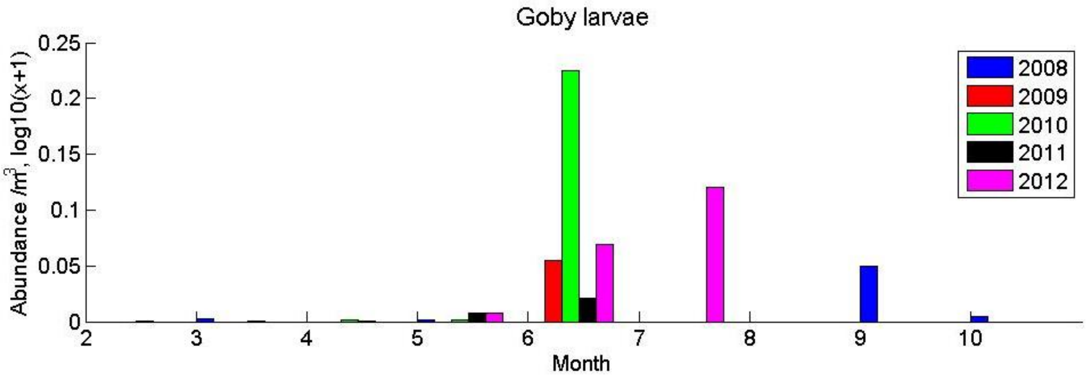



Figure 9: Mean monthly abundance of anchovy eggs and larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.4 Gobies (Gobidae)

Gobies are made up of a few species around the UK coast, the most common are: common goby (*Pomatoschistus microps*), which spawns in the spring and sand goby (*Pomatoschistus minutus*), which spawns in the summer. There are about 10-15 species recorded in the North Sea but the larvae of individual species are not well described and thus not routinely identified to that level. Spawning occurs in spring and summer; the eggs are deposited on the seafloor and are not taken by standard plankton samplers such as the one used in this study. CPR data show that generally, the abundance of goby larvae has decreased from the period 1948-1985 to 1986-2005, in particular in the North Sea and the south of Ireland (Figure 10). Larvae are present all year long and the shift in peak spawning season from the first period of time to the next may simply reflect a change in the relative abundance of the several species of gobies caught by the CPR.

Larvae were caught in 30.94 % of samples collected at Sizewell and contributed to 36.87 % of the total larval abundance; this makes this taxonomic group the most common and abundant type of fish larvae caught at Sizewell. The highest number of goby larvae was collected in June 2010 (Figure 11

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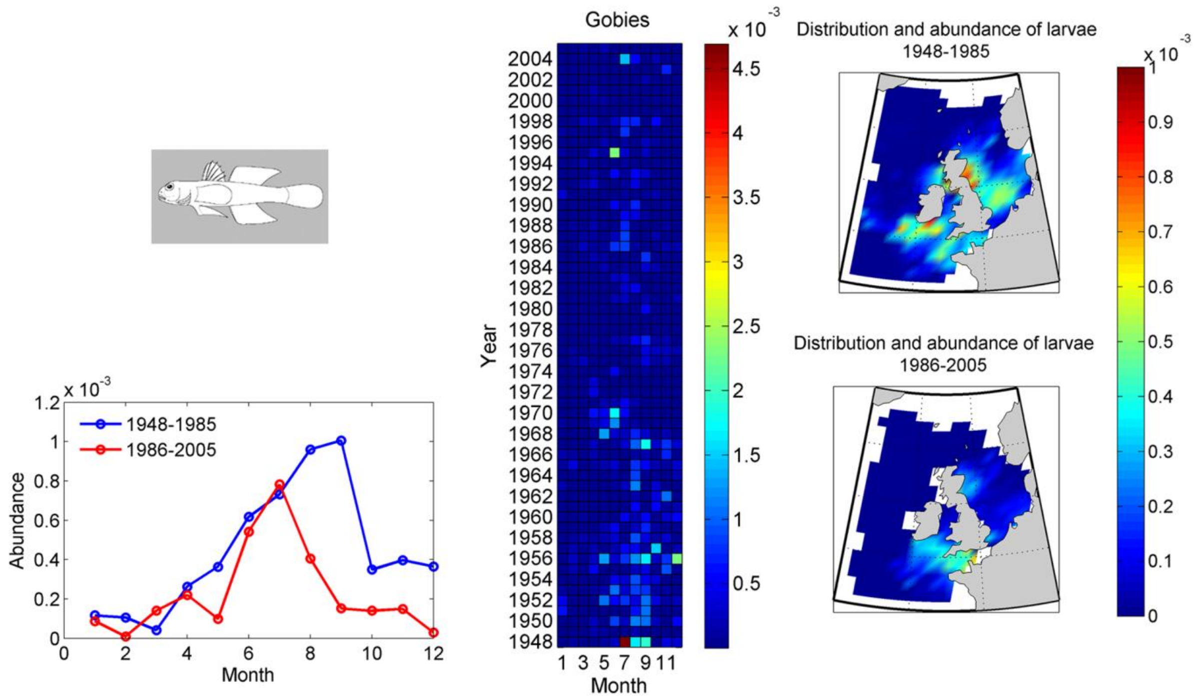


Figure 10: Goby larvae from the Continuous Plankton Recorder (CPR) over the period 1948-1985 (top right distribution map), 1986-2005 (bottom right distribution map), with seasonality (bottom left plot and middle graph).

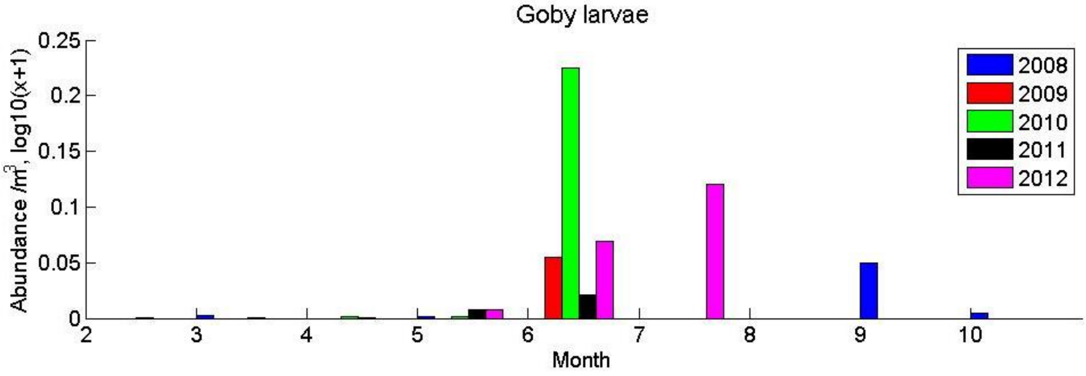


Figure 11: Mean monthly abundance of goby larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.5 Sandeels (Ammodytidae)

Five species of sandeel are found in the North Sea, and Raitt's or the lesser sandeel (*Ammodytes marinus*) has been identified as a priority species listed under the NERC Act. Sandeel eggs and larvae were not identified to species level in the zooplankton surveys. However, impingement sampling only found 2 species at Sizewell - the sand lance (*Ammodytes tobianus)* and Greater sandeel (*Hyperoplus lanceolatus*) (BEEMS Technical Report TR431).

Young sandeels are very numerous in CPR samples and are mostly sampled in shallow waters around the British Isles corresponding to the distribution of adults (Figure 12). Sandeel spawn in spring and late summer/autumn.

The eggs of species from the group Ammodytidae are benthic However, a few eggs can become detached from the substratum and resuspended in the water column but such eggs are not viable. Low numbers of sandeel eggs (0.06% of total egg abundance) were caught in the Gulf VII sampler at Sizewell.. Larvae were caught in 14.7 % of samples collected at Sizewell and contributed to 5.88 % of the total larvae abundance. The highest number of sandeel larvae were collected in April 2011 (Figure 13).

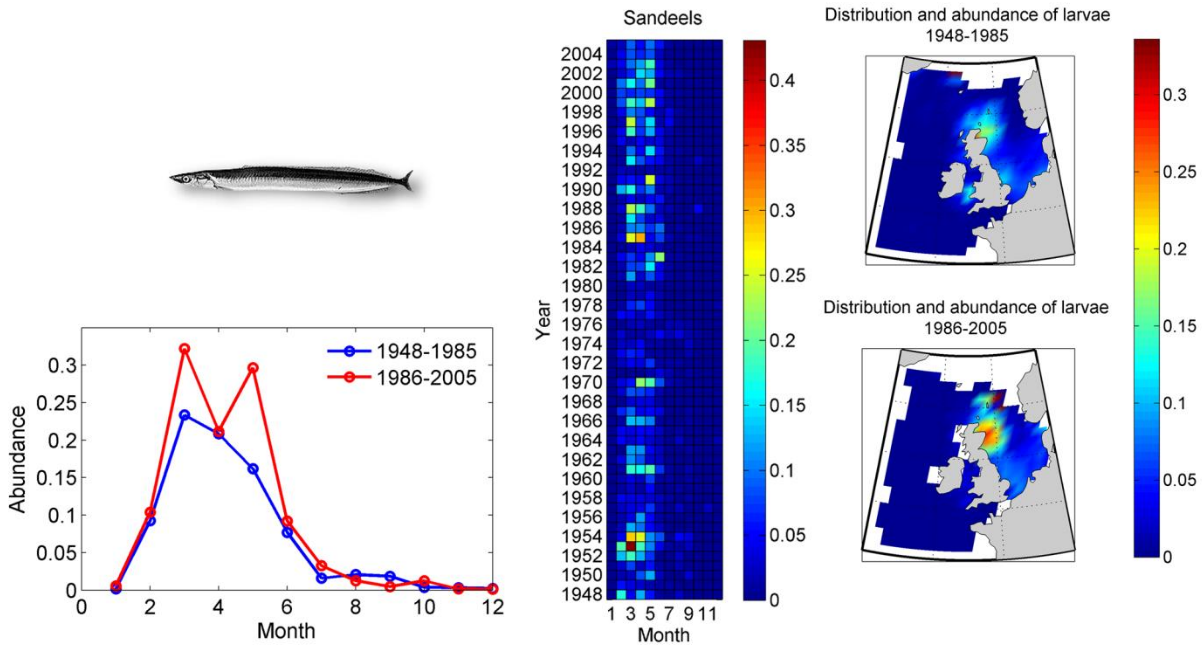


Figure 12: Sandeel larvae from the Continuous Plankton Recorder (CPR) over the period 1948-1985 (top right distribution map), 1986-2005 (bottom right distribution map), with seasonality (bottom left plot and middle graph).

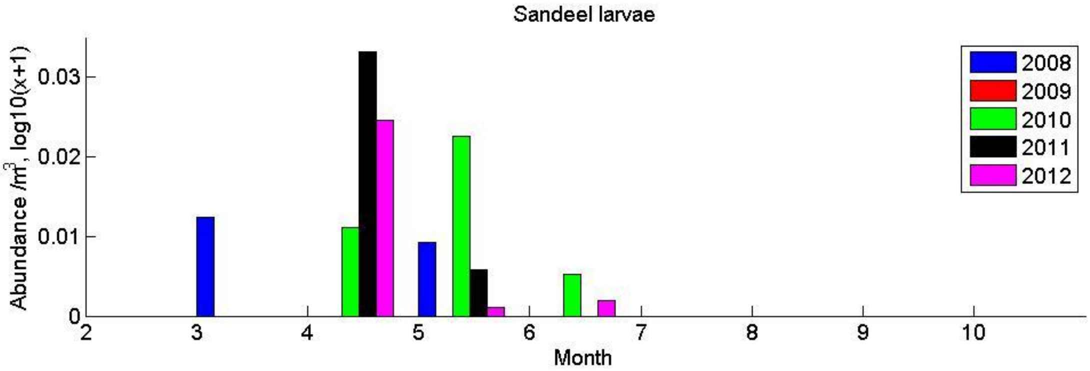


Figure 13: Mean monthly abundance of sandeel larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.6 Dover sole (*Solea solea*)

Sole are a common inshore and offshore species found around the UK. Spawning in the North Sea takes place mainly in the south, including the Suffolk coast, from spring to early summer. Sole is one of the most important commercial fisheries, in terms of weight and value, along the southern eastern coast of England. Sole has also been identified as a priority species for biodiversity and is as a priority species listed under the NERC Act (2006).

Eggs were found in 36.75 % of samples and contributed to 17.72 % of the total egg abundance, and were the second most abundant taxon at the site, reflecting the relative proximity of the site to spawning grounds. Larvae were present in 9.92 % of samples and contributed to 7.39 % of the total larvae abundance. Sole larvae only have a short pelagic stage before settling to the seabed, hence the low number of larvae compared to eggs. The highest number of sole eggs was collected in May 2010 while the higher number of larvae was collected in May 2011 (Figure 14), in agreement with the seasonal spawning times of April-August given by (Russell, 1976).

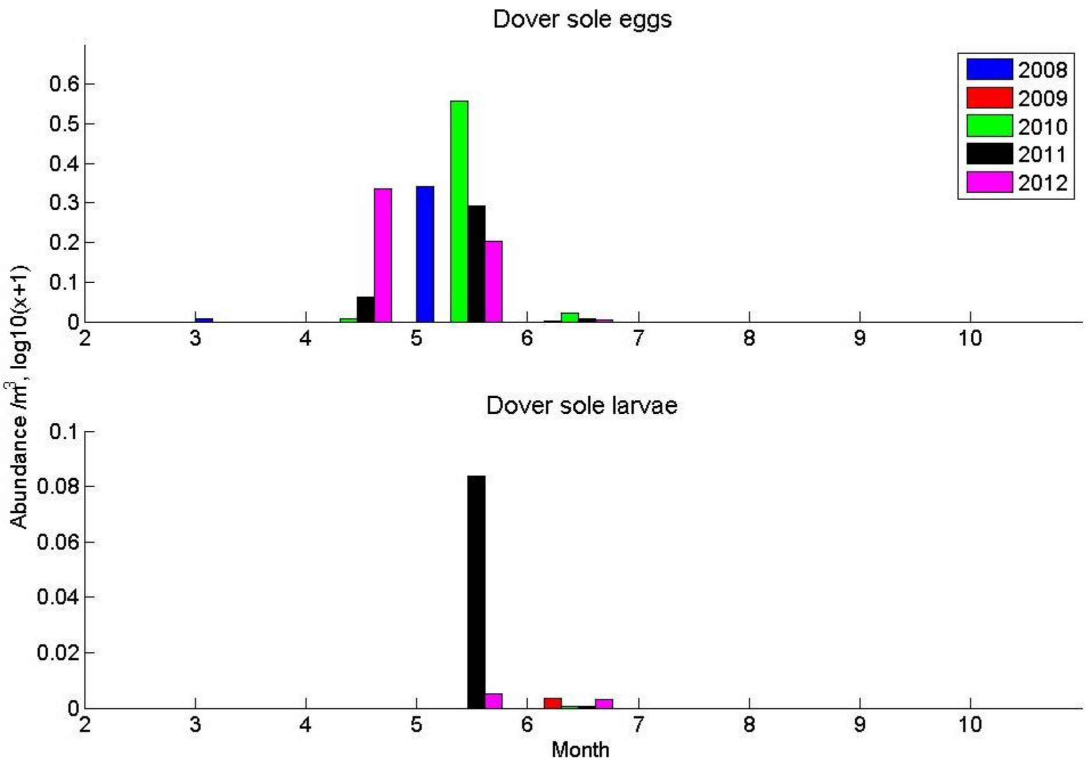


Figure 14: Mean monthly abundance of sole eggs and larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.7 Solenette (*Buglossidium luteum*)

Solenette is the smallest of the European family of true soles. Solenettes spawn chiefly between April and August. Both eggs and larvae are first pelagic before settling on the seabed once they reach a length of 12 mm.

Solenette eggs were caught in 6.33 % of all samples collected in the Sizewell area and contributed to 0.30 % of the total egg abundance, while the larvae were caught in only three samples and their contribution to abundance was negligible. The highest number of solenette eggs were caught in March 2011 and April 2012 (Figure 15).

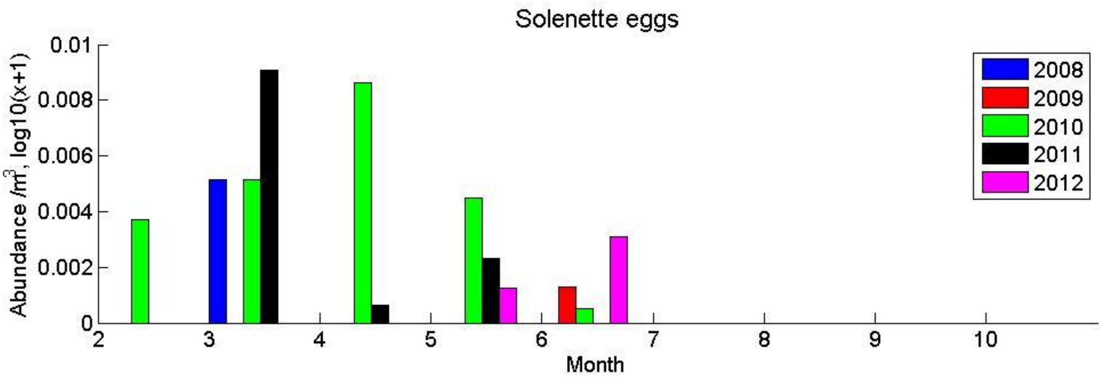


Figure 15: Mean monthly abundance of solenette eggs, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.8 Plaice (*Pleuronectes platessa*)

Plaice is an important species in European waters that has been exploited for centuries, although it does not contribute to the top 90% of landings weight or value in ICES rectangle 33F1, however, a small commercial fishery for plaice operates in the Sizewell area. It has been identified as a priority species for biodiversity under the NERC Act (2006). Plaice spawns offshore from where the eggs and larvae are transported effectively to the coastal nurseries. The main location for larval distribution is in the German Bight (Figure 16), the population seems to have spread along the Netherlands and to the southern North Sea from the first to the second period of time. Eggs of plaice did not appear in the samples collected at Sizewell, and the larvae occurred in only 1 sample collected in April 2010.

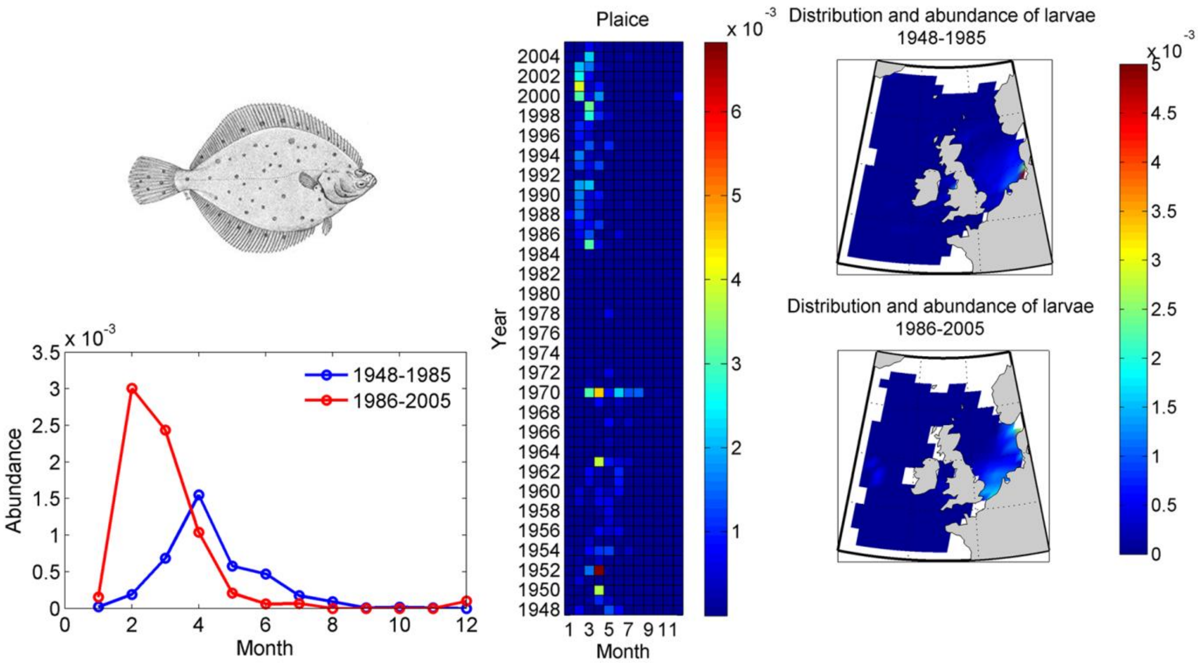


Figure 16: Plaice larvae from the Continuous Plankton Recorder (CPR) over the period 1948-1985 (top right distribution map), 1986-2005 (bottom right distribution map), with seasonality (bottom left plot and middle graph).

### 2.1.9 Seabass (*Dicentrarchus labrax*)

Seabass spawns in the waters around England between February and July. Seabass is one of the most important commercial fisheries in the Sizewell area, in term of weight and value.

Seabass eggs were found in 5.81 % of all samples collected at Sizewell and contributed to 1.24 % of the total egg abundance. Larvae were found in 5.30 % of samples and contributed to 1.92 % of the total larval abundance. The highest number of seabass eggs was caught in May 2011 while the highest number of larvae was caught in June 2011 (Figure 17).

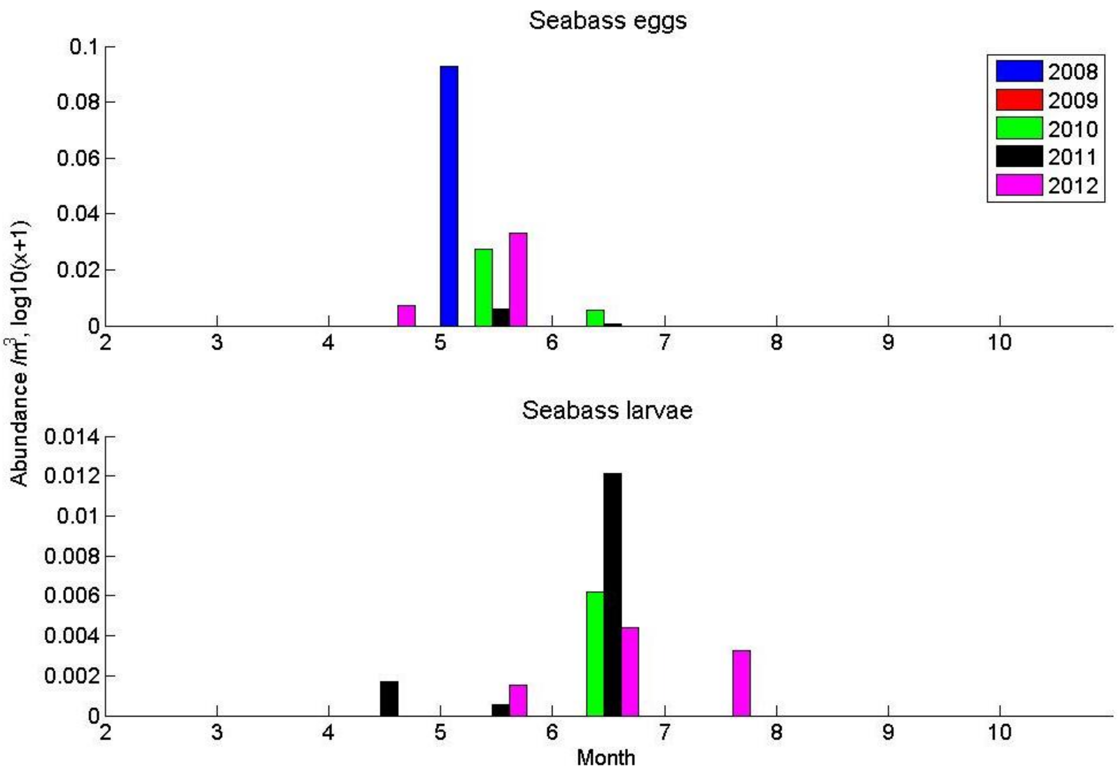


Figure 17: Mean monthly abundance of seabass eggs and larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.10 Rockling (Lotidae)

The larvae of rockling are distributed all over the European shelf, and their seasonality extends from March to September, reflecting their multispecies composition (Figure 18). Fours species are found in the North Sea: five-bearded rockling (*Ciliata mustela*), four-bearded rockling (*Enchelyopus cimbrius*), three-bearded rockling (*Gaidropsarus vulgaris*) and northern rockling (*Ciliata septentrionalis).* Eggs and larvae are almost impossible to distinguish at species level. Eggs were found in 29.91 % of samples and contributed to 1.53 % of the total egg abundance. Although eggs were very commonly caught, rockling larvae were only found in 2 samples out of a total of 585, in June 2010 and July 2012. The highest number of rockling eggs was caught in April 2010 (Figure 19).

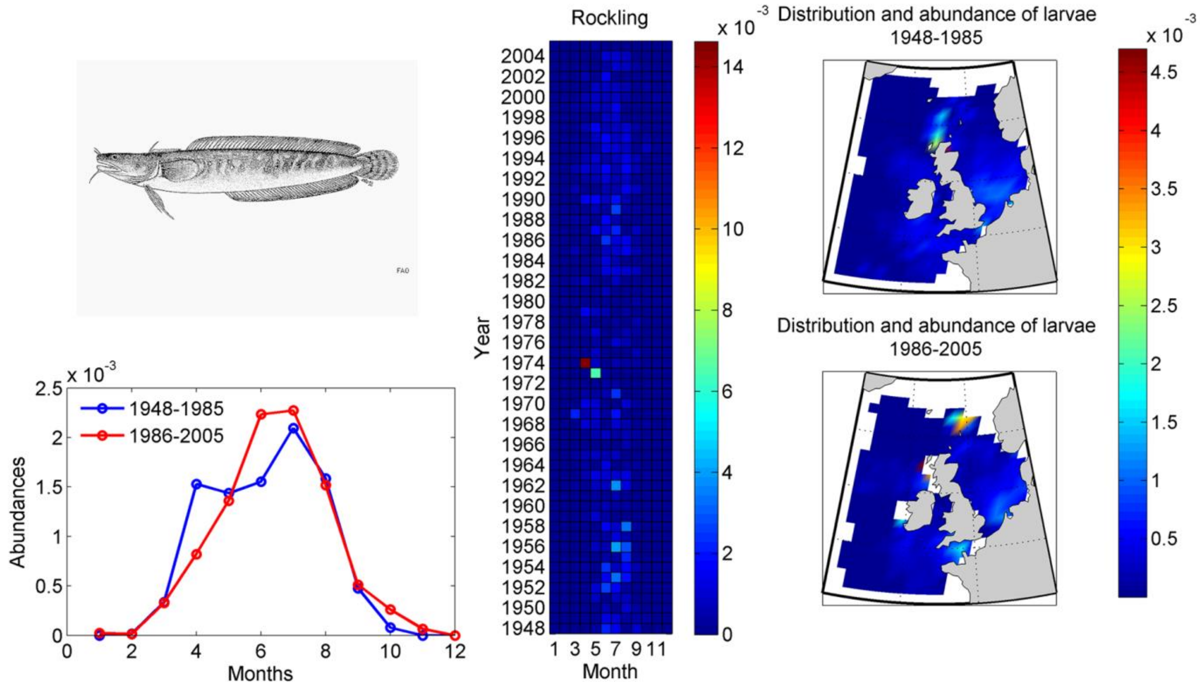


Figure 18: Top: Rockling larvae from the Continuous Plankton Recorder (CPR) over the period 1948-1985 (top right distribution map), 1986-2005 (bottom right distribution map), with seasonality (bottom left plot and middle graph).

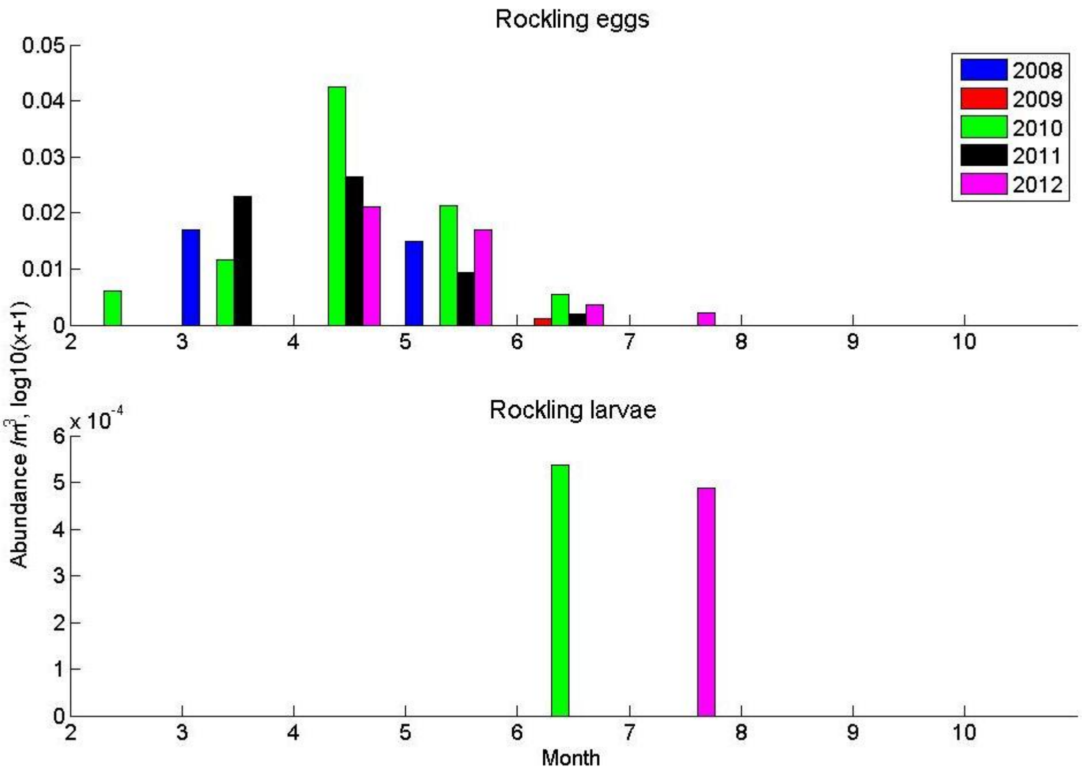


Figure 19: Mean monthly abundance of rockling eggs and larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

### 2.1.11 Whiting (*Merlangius merlangus*)

Whiting is one of the most numerous and widespread gadoid species found in the North Sea. It has been identified as a priority species listed under the NERC Act (2006). CPR results show a fairly widespread distribution around the British Isles with highest concentrations in the south-eastern North Sea (Figure 20). The spawning season is quite extended, mostly from March to July, with a prominent peak in April in the North Sea in the early 1990s. Until fairly recently whiting was a low valued catch but has become more commercially important with the general decline in other fish stocks, and there is a small commercial fishery in the Sizewell area. Eggs of whiting did not appear in the samples collected at Sizewell, and the larvae occurred in only 1 sample in April 2011.

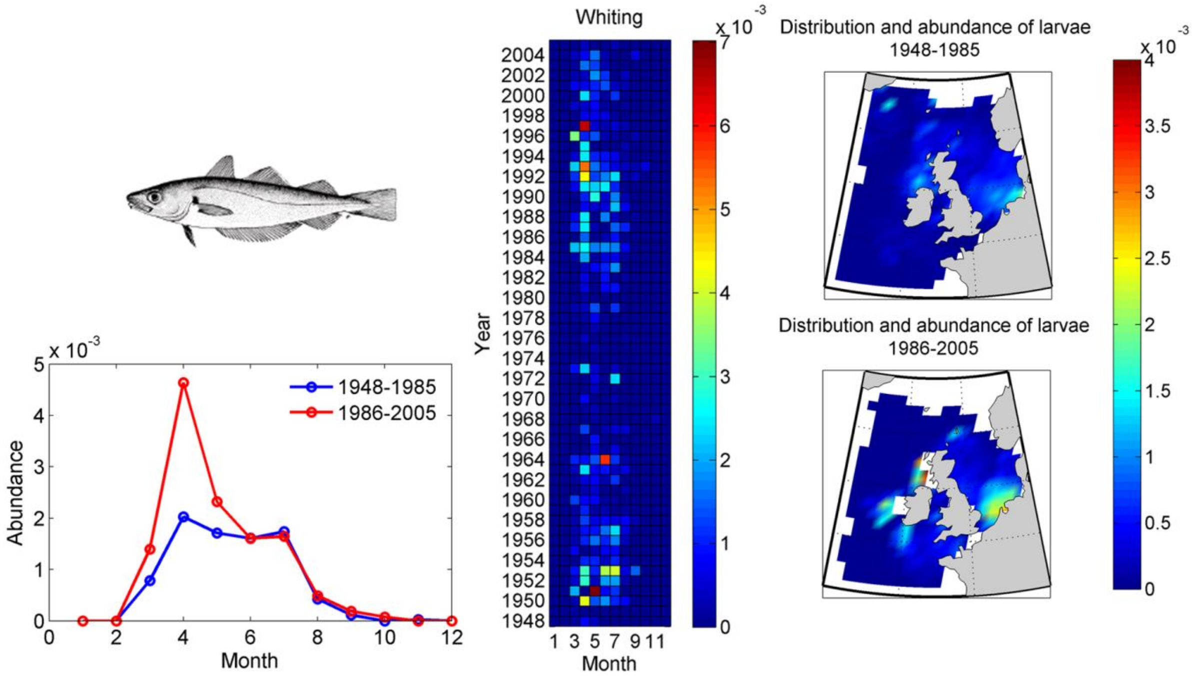


Figure 20: Whiting larvae from the Continuous Plankton Recorder (CPR) over the period 1948-1985 (top right distribution map), 1986-2005 (bottom right distribution map), with seasonality (bottom left plot and middle graph). Reproduced from Edwards *et al*. (2011).

### 2.1.12 Mackerel (*Scomber scombrus*)

Mackerel has been identified as a priority species for biodiversity in England and is listed under the NERC Act (2006). Results from the CPR survey show the two separate spawning stocks of mackerel, these being in the central North Sea and to the west and south-west of the British Isles (Figure 21). In the North Sea mackerel larvae are caught predominately between June and August with highest numbers occurring in July (for the first period1948-1985) and in June for the second period (1986-2005). Observing the overall trend, mackerel larvae declined substantially over the last few decades to 2005, reflecting the decline of first the North Sea stock and subsequently the western population. Mackerel eggs were caught in 15 samples out of the 585 collected at Sizewell and contributed to 0.17 % of the total egg abundance. The highest number of mackerel eggs was caught in May 2011 (Figure 22). No larvae were caught.

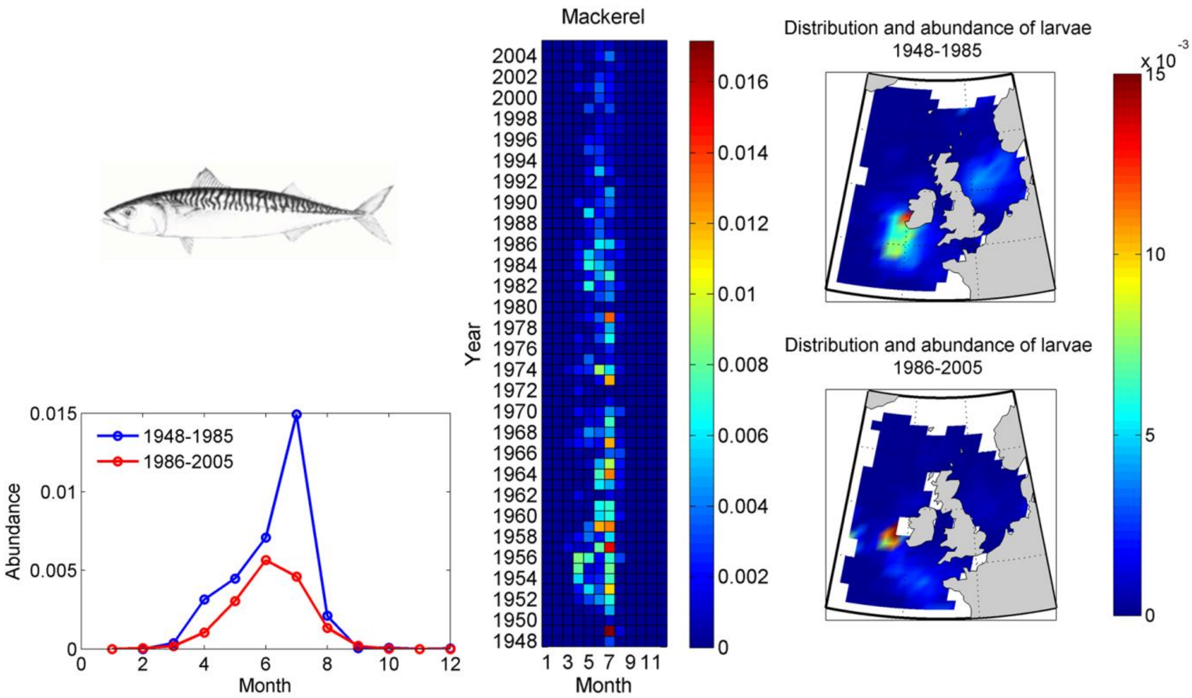


Figure 21: Mackerel larvae from the Continuous Plankton Recorder (CPR) over the period 1948-1985 (top right distribution map), 1986-2005 (Bottom right distribution map), with seasonality (bottom left plot and middle graph). Reproduced from Edwards et al. (2011).

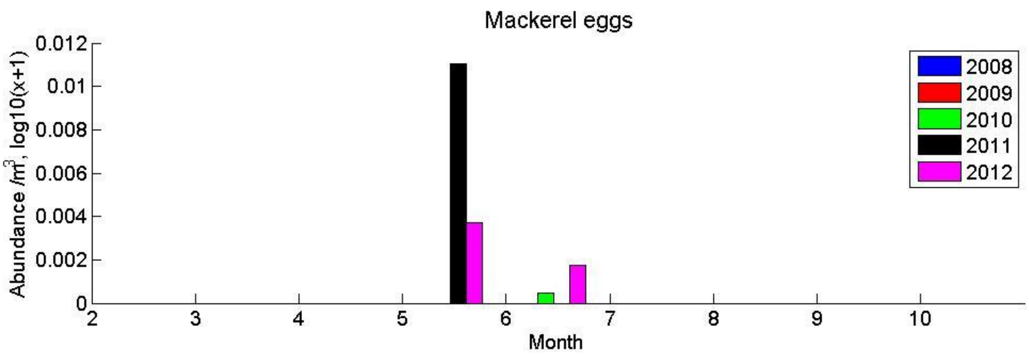


Figure 22: Mean monthly abundance of mackerel eggs and larvae, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2008 and 2012.

# 3 Large size fraction zooplankton (>4 mm)

The larger size fraction zooplankton were defined in this instance as those specimens caught in the MAIN 270µm net and larger than 4mm; they mainly comprise holoplankton, meroplankton or bentho-pelagic species. The 4mm cut-off point was chosen based on the efficiency of the nets selected. That is the MAIN 270µm is more efficient at retaining individual > 4mm while the PUP 80µm net is more efficient at retaining individuals < 4mm. Although the MAIN net was used from 2008, sample analysis for the larger size fraction zooplankton was not done prior to 2010.

A total of 31 taxonomic groups were identified among the 468 samples collected between 2010 and 2012 at Sizewell (Table 5). Higher abundances of the larger size fraction zooplankton occurred during the months of May to July (Figure 23). However, as with the ichthyoplankton, year to year differences in term of spatio-temporal coverage of the surveys call for caution.

The larger size fraction zooplankton included the larval stages of benthic species and identification further than group or order could only be done in a very few cases: a parasitic copepod (*Caligus* spp.), the brown shrimp (*Crangon* spp.), squat lobsters (*Galathea* spp.), and the great spider crab (*Hyas araneus)*. None of these species have been given a conservation status, and only the shrimp is commercially exploited in the Sizewell area. Only the jellyfish (i.e. Cnidaria) and comb-jellies (i.e. Ctenophora; commonly known as sea gooseberries) can be regarded of socio-economic importance as broad taxonomic groups. The high abundance of gelatinous zooplankton, sometimes encountered around coasts, is unsightly and may comprise stinging species, resulting in a negative impact on tourism (Schaafsma *et al.,* 2013; Vandendriessche *et al*., 2013). Furthermore, they can affect the operation of power plants (Gunasingh Masilamoni *et al*., 2000) due to their gelatinous nature and propensity for populations to expand exponentially (i.e. to from “blooms”), they have the potential to cause blockage of the cooling water intake filters of power stations, which in severe cases can lead to station shutdown.

For further species- or group- specific exploration, we selected the taxa that were either common or abundant enough so any change in their abundance and/or distribution may have an impact on other organisms present through trophic cascade effects. These taxa are potentially of ecological value and are indicated in Table 5. It should be noted that the larger fraction zooplankton community includes life history stages (larvae) of species, which may be abundant but highly sporadic. Commonality may thus not truly reflect ecological importance of these taxa, particularly if samples are not distributed evenly over time. Greater weight is applied to abundance, particularly for the meroplankton.

Table 5: Summary of the larger size fraction zooplankton data. Taxa, in aqua, are those that are of socio-economic, conservation or ecological importance. Ecological importance is defined as contributing to at least 1 % of the total abundance or occurring in at least 5 % of all samples (out of the 468 collected between 2008 and 2012; positive samples are those in which at least one specimen was found). These taxa are further described individually below.

| Taxa | Ecological | | Socio-economic | Conservation |
|---|---|---|---|---|
| | No. of positive samples | % of total abundance | | |
| Mysids | 454 (97.01%) | 76.87% | - | - |
| Comb jellies (Ctenophora) | 277 (59.19%) | 10.33% | Nuisance | - |
| Unidentified Amphipoda | 23 (4.92%) | 0.09% | - | - |
| Gammaridae (Amphipoda) | 200 (42.74%) | 0.86% | - | - |
| Hyperiidae (Amphipoda) | 3 (0.64%) | 0.01% | - | - |
| Caprellidae (Amphipoda) | 2 (0.43%) | 0.00% | - | - |
| Corophiidae (Amphipoda) | 1 (0.21%) | 0.00% | - | - |
| Polychaete larvae (Polychaeta) | 182 (38.89%) | 5.81% | - | - |
| Hooded shrimps (Cumacea) | 136 (29.06%) | 0.74% | - | - |
| Jellyfish (Cnidaria) | 129 (27.56%) | 1.59% | Nuisance | - |
| Unidentified Decapoda | 98 (20.94%) | 2.19% | - | - |
| **Crangon* spp. (Decapoda, Pleocyemata, Caridea) | 72 (15.39%) | 0.35% | Fishery | - |
| Unidentified schrimps and prawns (Decapoda, Pleocyemata, Caridea) | 83 (17.74%) | 0.32% | - | - |
| Unidentified Pleocyemata (decapoda, pleocyeamata) | 45 (9.62%) | 0.36% | - | - |
| Squat lobsters (decapoda, galatheidae) | 3 (0.64%) | 0.00% | - | - |
| Hermit crabs (decapoda, paguridae) | 3 (0.64%) | 0.00% | - | - |
| Unidentified crabs (decapoda, Brachyura) | 11 (2.35%) | 0.04% | - | - |
| *Galathea* spp. (decapoda, Brachyura) | 1 (0.21%) | 0.00% | - | - |
| Nematodes | 54 (11.54%) | 0.14% | - | - |
| Unidentified isopoda | 33 (7.05%) | 0.08% | - | - |
| Krills (Euphausiidae) | 24 (5.28%) | 0.04% | - | - |
| *Caligus* spp. (parasitic copepod) | 20 (4.27%) | 0.03% | - | - |
| Sea spiders (Pycnogonida) | 16 (3.42%) | 0.02% | - | - |
| unidentified bivalve larvae (Bivalvia) | 6 (1.28%) | 0.05% | - | - |
| Cuttlefishes (cephalopoda, sepiolidae) | 6 (1.28%) | 0.00% | - | - |
| Squids and octopuses (Cephalopoda) | 6 (1.28%) | 0.01% | - | - |
| Razor shells larvae (bivalva, solenidae) | 5 (1.07%) | 0.04% | - | - |
| Sea butterflies (Pteropoda) | 2 (0.43%) | 0.00% | - | - |
| Appendicularia (tunicata) | 1 (0.21%) | 0.00% | - | - |
| Brittle star larvae (ophiuroidea) | 1 (0.21%) | 0.00% | - | - |
| Arachnida | 1 (0.21%) | 0.00% | - | - |

* Due to their hyper-benthic association, *Crangon* spp. was most effectively sampled during surveys to characterise the benthic ecology characterisation and is considered elsewhere (see BEEMS Technical Report TR348).

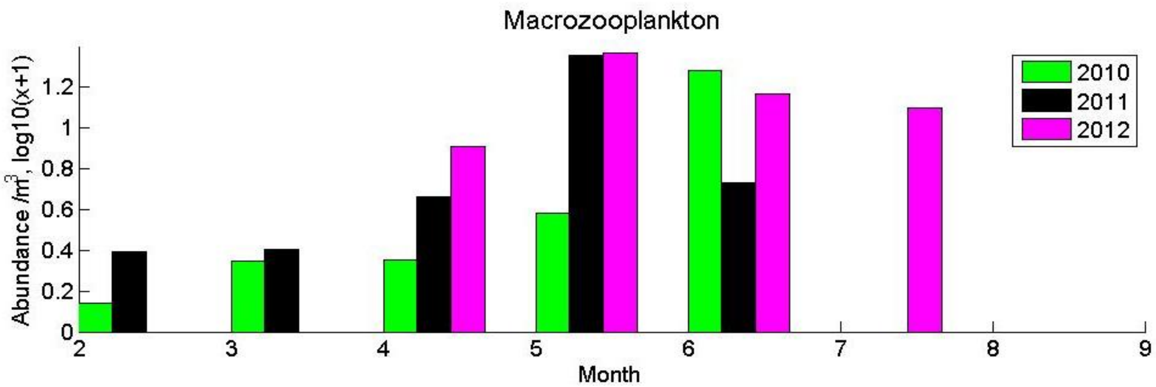


Figure 23: Mean number of larger size fraction zooplankton, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2010 and 2012.

### 3.1.1 Mysids (Mysida)

Mysids are shrimp-like crustaceans of the Peracarida superorder, commonly known as opossum shrimps. They can be benthic or pelagic. CPR data suggest that mysids have been increasing in abundance in the southern North Sea between 2010 and 2012, in agreement with the Sizewell data (Figure 24). Mysids were caught in 97.01 % of samples collected at Sizewell, and contributed to 76.87 % of the total larger size zooplankton fraction abundance. The highest number of mysids were caught in May of 2011 and 2012 (Figure 25). Samples collected for as part on the BEEMS plankton surveys between 2014-2017 identified four species including *Schistomysis spiritus, Siriella sp., Mesopodopsis sp. and Schistomysis sp.,* of which *Schistomysis spiritus* was the most abundant (BEEMS Technical Report TR454). Seasonality from the CPR and Sizewell data seem at odds with each other: The CPR data show the highest abundances of mysids recorded during the winter months, and very low levels during the period May to August, while the Sizewell data suggest a peak of abundance during the May-June period. This is unexplained and is likely a consequence of the very difference sampling methods used in this comparison (CPR and GULF-VII) combined with the ecological characteristics of mysids (i.e. seasonal distribution).

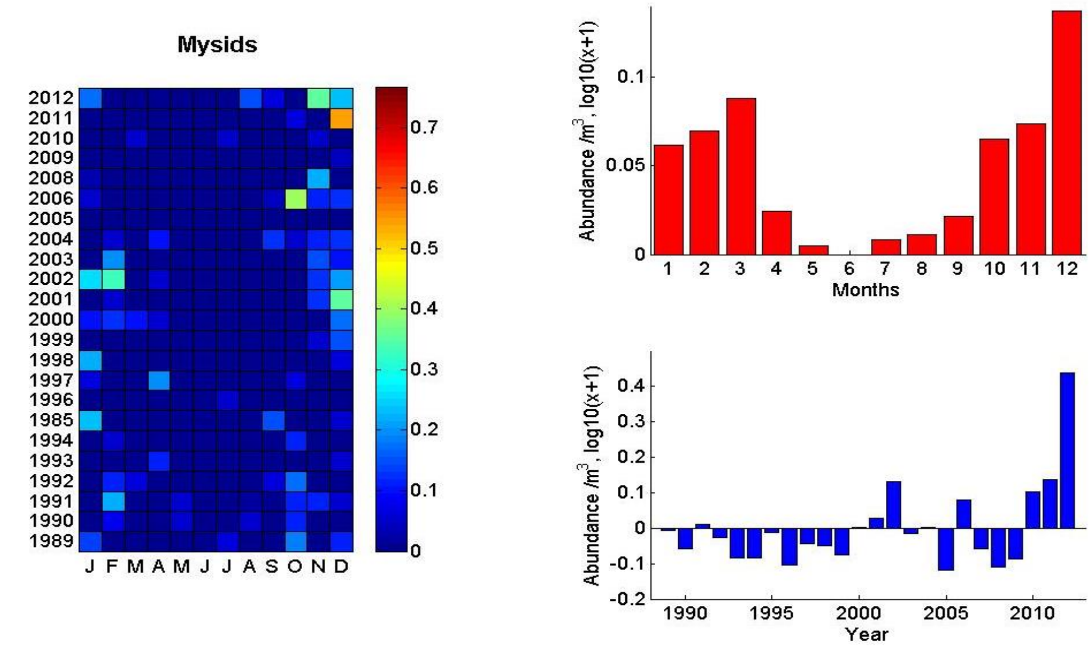


Figure 24: Mean monthly abundance of mysids collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

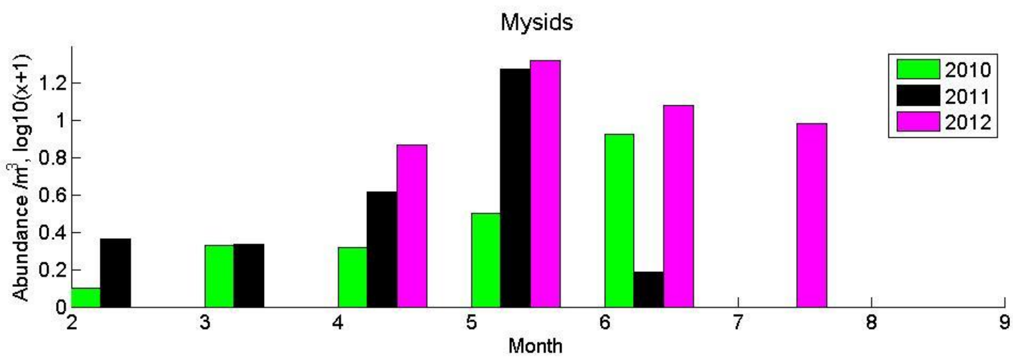


Figure 25: Mean number of mysids, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2010 and 2012.

### 3.1.2 Comb jellies or sea gooseberries (Ctenophora)

Comb jellies (or sea gooseberries) are often confused with jellyfish. Jellyfish and comb jellies are however different enough to be classified in separate phyla. Most species of ctenophores are hermaphrodites, and juveniles are capable of reproduction before reaching adulthood. The combination of hermaphroditism and early reproduction enables small populations to grow at an explosive rate, to form blooms. Ctenophores may balance marine ecosystems by preventing an over-abundance of copepods from eating all the phytoplankton. However, high numbers of ctenophores may have an adverse effect as they can also feed on fish larvae; For example, in the late 1980s the Western Atlantic ctenophore *Mnemiopsis leidyi* was accidentally introduced into the Black Sea and, and has been blamed for causing sharp drops in fish catches by eating both fish larvae and small crustaceans that would otherwise feed the adult fish (Finenko *et al*., 2006).

Although not recorded to species level here, *Pleurobracchia pileus* is by far the most common comb-jelly found in the southern North-Sea.

Ctenophores were caught in 59.19 % of samples collected at Sizewell, and contributed to 10.33 % of the total larger size fraction zooplankton abundance, thus making them the second most abundant taxonomic group. The presence of ctenophores around Sizewell is very seasonal as they seem to appear suddenly in May/June; the highest numbers of ctenophores were recorded in June of 2010 and 2011 (Figure 26).

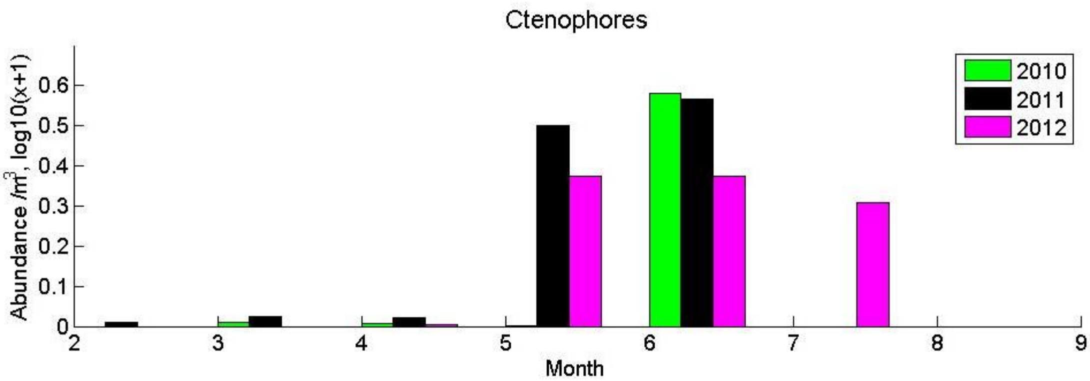


Figure 26: Mean number of ctenophores, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2010 and 2012.

### 3.1.3 Gammarids (Amphipoda)

Most of the amphipods captured by the MAIN 270 µm net were gammarids. Gammarids are usually benthic or epibenthic. Some make periodic excursions to the water column and some appear to be swept into the plankton by strong tides or currents. Data from the CPR show a strong year to year variability in the southern North Sea between 1989 and 2012, with maximum abundances recorded between October and December (Figure 27).

Gammarids were caught in 42.74 % of all of the larger size fraction zooplankton samples collected at Sizewell, and contributed to 0.86 % of the total abundance. They are therefore common but not very abundant. They seem to be found from February to July with a peak in April (Figure 28). Similarly to mysids, their seasonality from the Sizewell data does not match that recorded from the CPR: while the CPR data show a decreasing trend from February to April, the Sizewell data suggests the opposite.

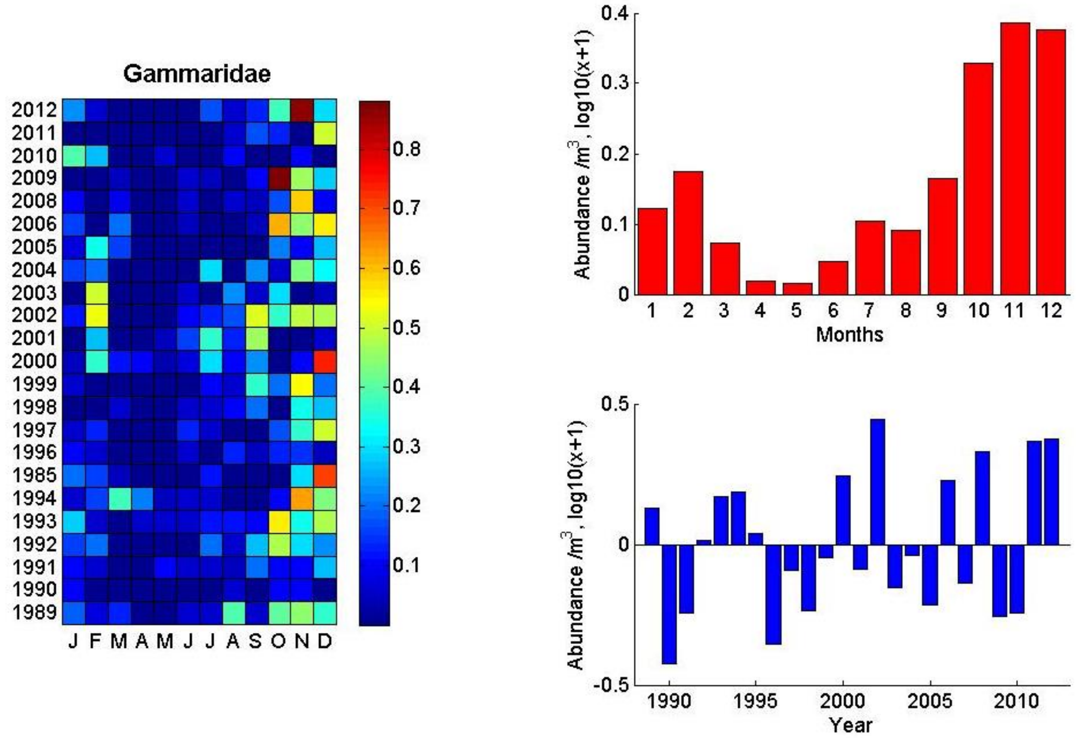


Figure 27: Mean monthly abundance of gammarids collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

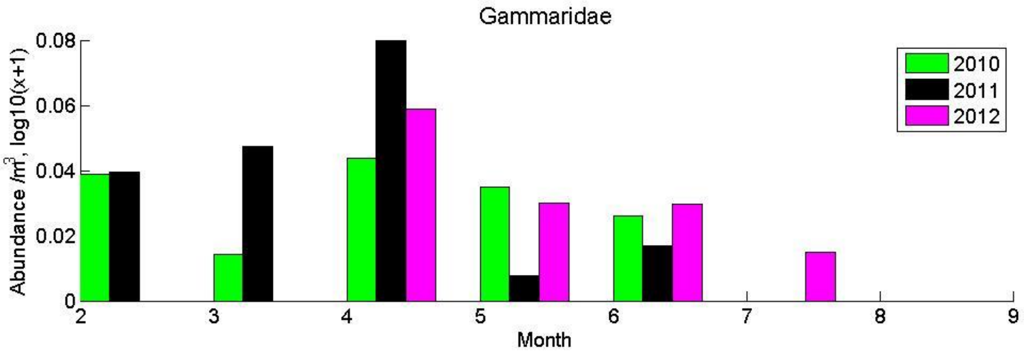


Figure 28: Bottom: Mean number of gammarids, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2010 and 2012.

### 3.1.4 Polychaete (Polychaeta) larvae

Polychaete larvae are notoriously difficult to identify. It is however possible that some of these larvae found belonged to the reef-forming *Sabellaria* genus; but this is not possible to know without further taxonomic identification. These are species of potential conservation interest because the reef structures that *Sabellaria* create can qualify as reef habitat under the Habitat Directive, and are listed as priority species under the UK BAP. Data from the CPR suggest that polychaete abundance peaks in June-July and has remained below average levels between 2008 and 2012 within the southern North Sea (Figure 29).

Polychaetes were caught in 38.89 % of all the larger size fraction zooplankton samples collected at Sizewell and contributed to 5.81 % of the total abundance. The highest number of polychaete larvae was recorded in June 2010 (Figure 30). They were more regularly caught in the PUP 80 µm sampler (Figure 58).

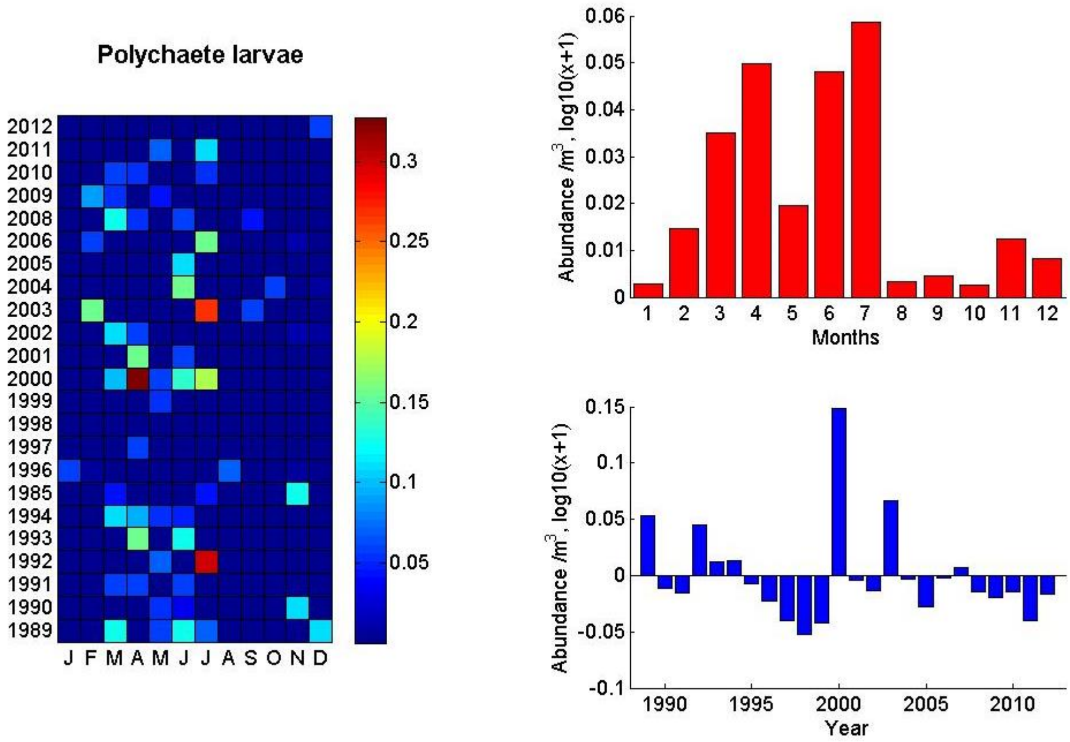


Figure 29: Mean monthly abundance of polychaete larvae collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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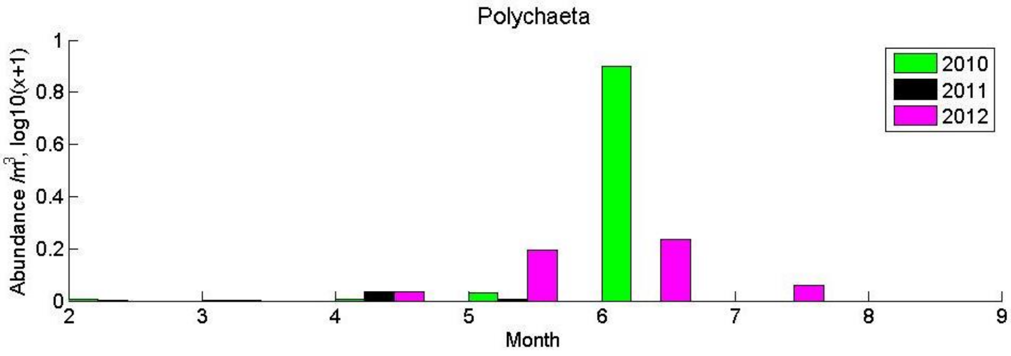


Figure 30: Mean number of polychaetes, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2010 and 2012, with MAIN 270 µm mesh net.

### 3.1.5 Hooded shrimps (Cumacea)

Cumacea is an order of small marine crustaceans of the superorder Peracarida (those that brood their young in a marsupium under the body), commonly called “hooded shrimps”. They are bottom dwellers but are occasionally stirred up in the plankton and as a result are probably underestimated from this plankton survey. Some species also display some diurnal cycle, emerging from the sediments at night and swimming to the surface. Data from the CPR suggest that the abundance of cumacea reach their highest levels in November-December, and have been increasing between 2008 and 2012 (Figure 31).

Cumaceans were caught in 29.06 % of all the larger size fraction zooplankton samples collected at Sizewell and contributed to 0.74 % of the total abundance. The highest numbers of cumacea were recorded in May 2010 and April 2011 (Figure 23). There seems to be some opposite patterns of seasonality resulting for the CPR and Sizewell datasets.

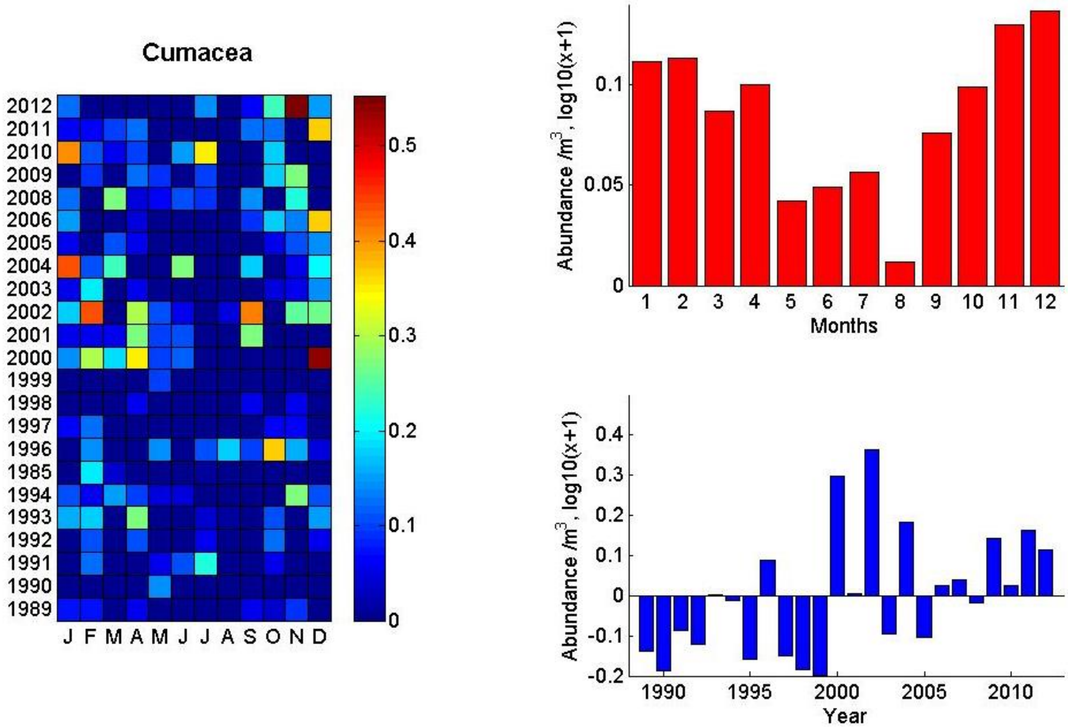


Figure 31: Mean monthly abundance of cumacea collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

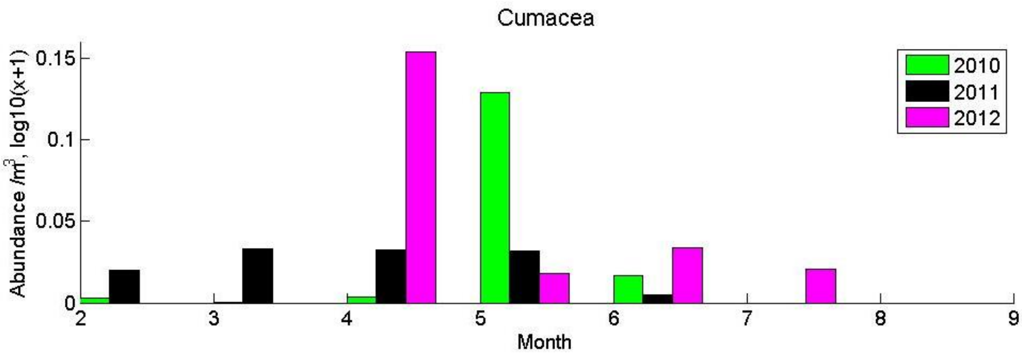


Figure 32: Mean number of cumacea, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2010 and 2012.

### 3.1.6 Hydrozoans and jellyfish (cnidaria)

Cnidaria include the true jellyfish as well as the hydrozoans and hydromedusa. Data from the CPR suggest that cnidaria are present at fairly high levels all year long, with peaks in May to June, as well as record abundances in 2011 and 2012 (Figure 33). Plankton sampling gear is inappropriate for gathering information on the larger medusa and alternative methods would need to be developed for these. The cnidarians caught in the MAIN 270 µm net could be either hydrozoans > 4mm or early life stages of jellyfish. Cnidaria were caught in 29.65 % of all samples and contributed to 0.69 % of the total abundance of the larger size fraction zooplankton. The highest abundances were recorded in July of 2012 (Figure 34). A large increase in numbers was observed in 2012, in line with results obtained from the CPR in the wider southern North Sea.

In recent years there has been increased attention on jellyfish and jellyfish blooms, following high numbers of gelatinous species reported in many estuarine and coastal ecosystems during the past few decades. Some marine ecologists (e.g., Richardson *et al.* (2009)) have suggested that anthropogenic effects drive jellyfish blooms to the detriment of other marine organisms. Coupled with media-driven public perception, the resulting paradigm is that global ocean ecosystems are heading toward being dominated by “nuisance” jellyfish. However, the data supporting this paradigm has been found inconsistent, and the above paradigm challenged with the hypothesis that jellyfish population changes reflect the human-mediated alteration of global ecosystems (Condon *et al.*, 2012).

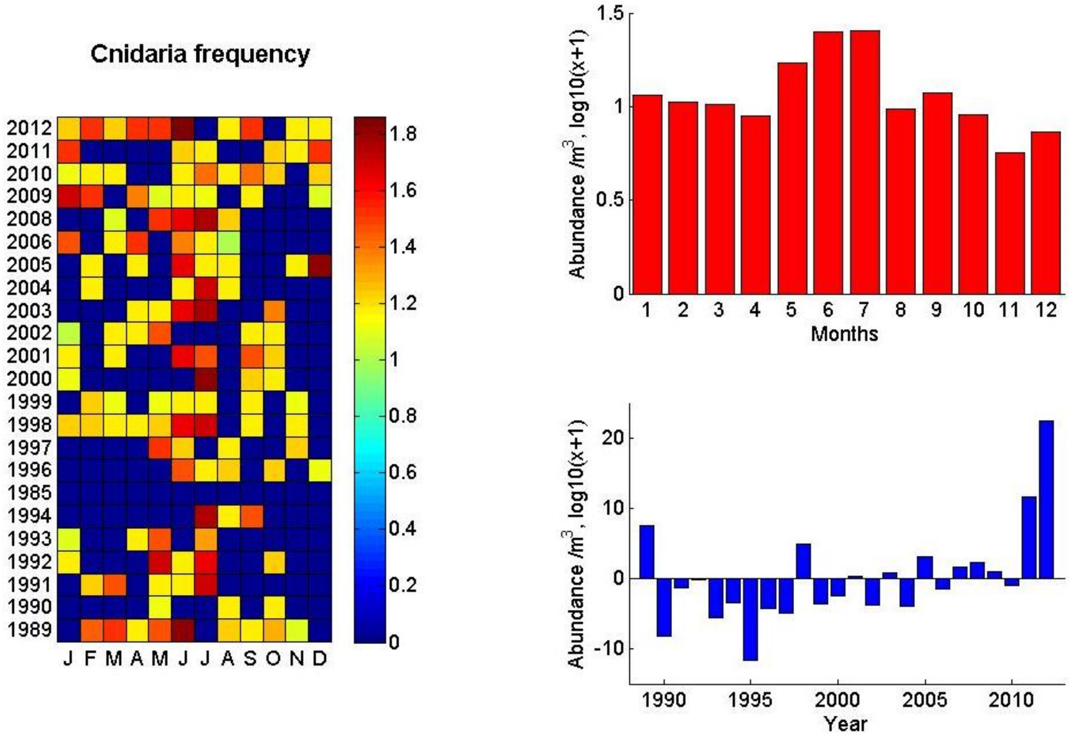


Figure 33: Mean monthly abundance of cnidaria (namatocytes) collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

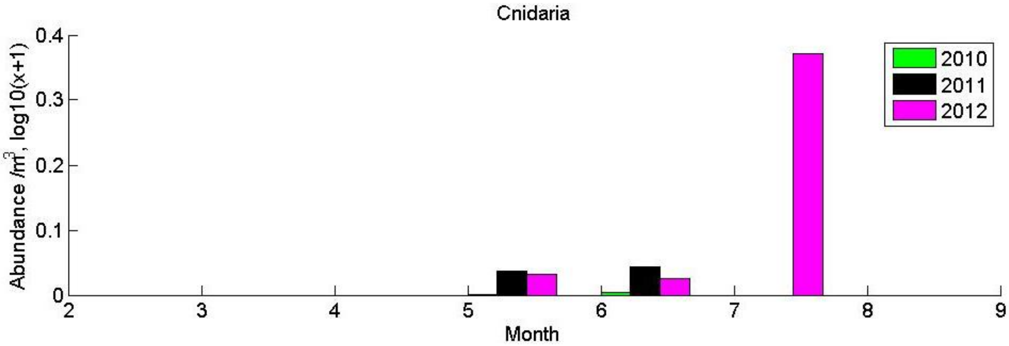


Figure 34: Mean number of cnidaria, collected from the MAIN 270 µm mesh net, each month at Sizewell, between 2010 and 2012.

### 3.1.7 Decapod larvae

The decapods (literally "ten-footed") are an order of crustaceans that comprises many familiar groups, such as crabs, lobsters, prawns and shrimp. Data from the CPR show high year to year variability in the abundance of decapods larvae in the southern North Sea. The lowest levels are recorded in December and then increase to peak in July and decrease again (Figure 35).

In total decapod larvae were caught in 61.41 % of all the larger size fraction zooplankton samples collected at Sizewell and contributed to 3.28 % of the total abundance. The highest numbers of decapods were caught in May and June of 2011 (Figure 36). In 2011, a high proportion of these were not further identified. Overall, decapods seem to mostly comprise individuals of the Pleocyemata suborder, itself including individuals from the Caridea infraorder. *Crangon* spp. was the only species that could be identified. Pleocyemata include all the crabs, lobsters, and others, and Caridea contains the true shrimp. There seems to be a lack of consistency of taxonomic analysis level across surveys: on one hand there were a high number of unidentified decapods combined with low number of caridea in 2011, and the trend is reversed in 2012 with a high number of caridea and very low number of unidentified decapods (Figure 36). For further analysis we will use an index of “total decapods” only.

*Crangon crangon* (the brown shrimp) is a commercially important species of shrimp fished mainly in the southern North Sea and there is a small commercial exploitation in the vicinity of Sizewell. *Crangon* spp. is found on sandy and muddy bottoms around all British and Irish coasts. Adults live epibenthically (on or near the sea-floor) especially in the shallow waters of estuaries or near the coast (Campos *et al*., 2009). It is generally highly abundant, and as such has a significant effect on the ecosystems it lives in. The highest numbers of *Crangon* spp. were caught in June 2010 (Figure 36). *Crangon* spp. are primarily hyper-benthic and were most effectively sampled as part of the surveys designed to characterise the benthic ecology of Sizewell Bay. *Crangon* spp. is considered in greater detail in BEEMS Technical Report TR348.

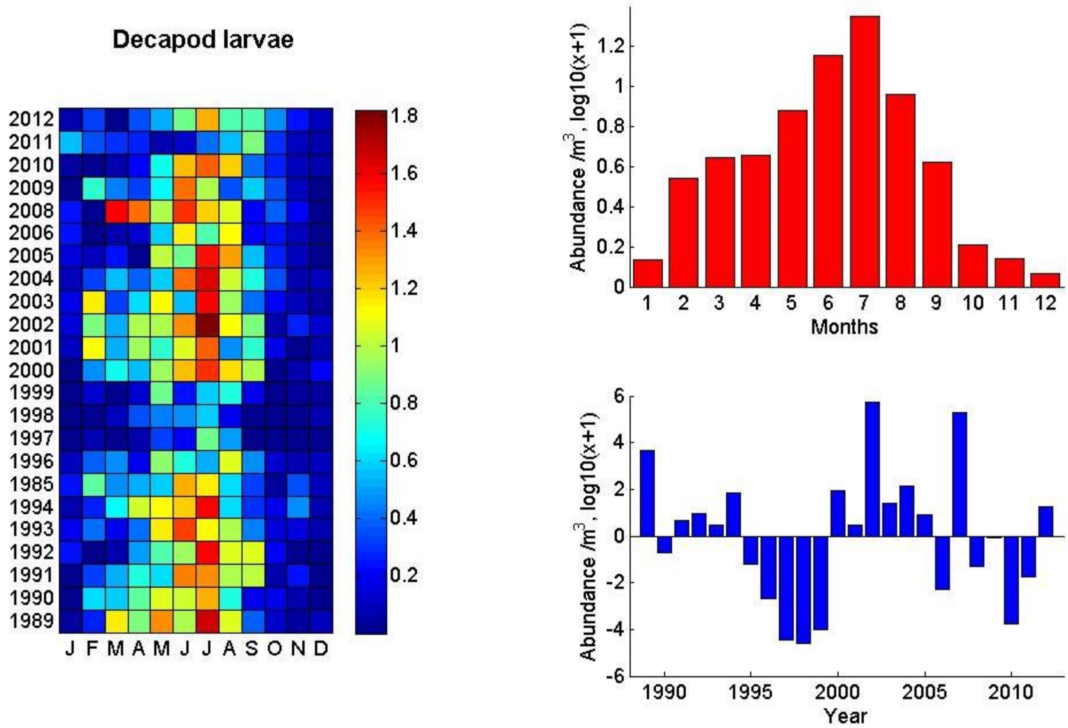


Figure 35: Mean monthly abundance of decapods larvae collected by the CPR in the southern North Sea from 1989 to 2012 (top left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

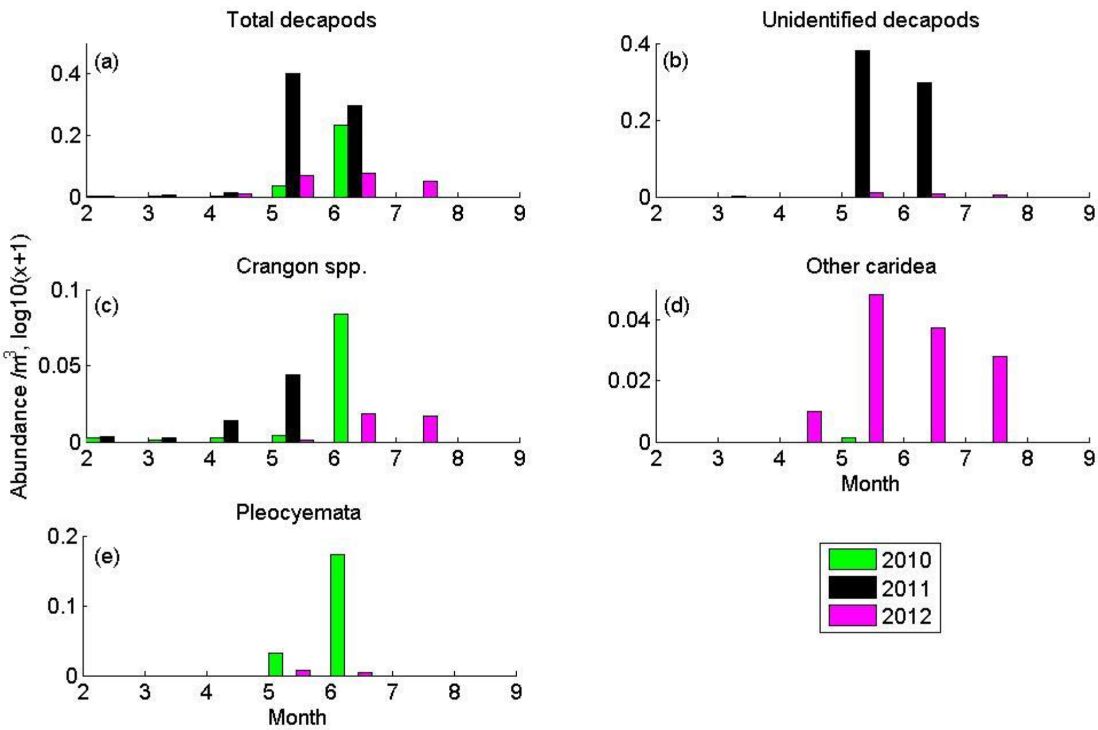


Figure 36: Mean month abundance of main decapod taxonomic groups collected at Sizewell site between 2010 and 2012, with MAIN 270 µm mesh net. (a) sum of all decapods, (b) unidentified decapods, (c) Crangon spp. is a member of the Caridea, (d) other unidentified caridea, (e) Pleocyemata.

### 3.1.8 Nematodes

Free-living nematodes, such as those found in marine environments are small and inconspicuous and relatively little is known about them. They are however numerous and ecologically important (Heip *et al.*, 1985). Nematodes are poorly captured by the CPR, probably due to their small size, but nevertheless they appear all year long (Figure 37). Nematodes were caught in 11.54 % of all of the larger size fraction zooplankton samples and contributed to 0.14 % of the total abundance. The highest numbers were caught in June 2010 (Figure 38). Nematodes were not recorded in the MAIN net in 2011.

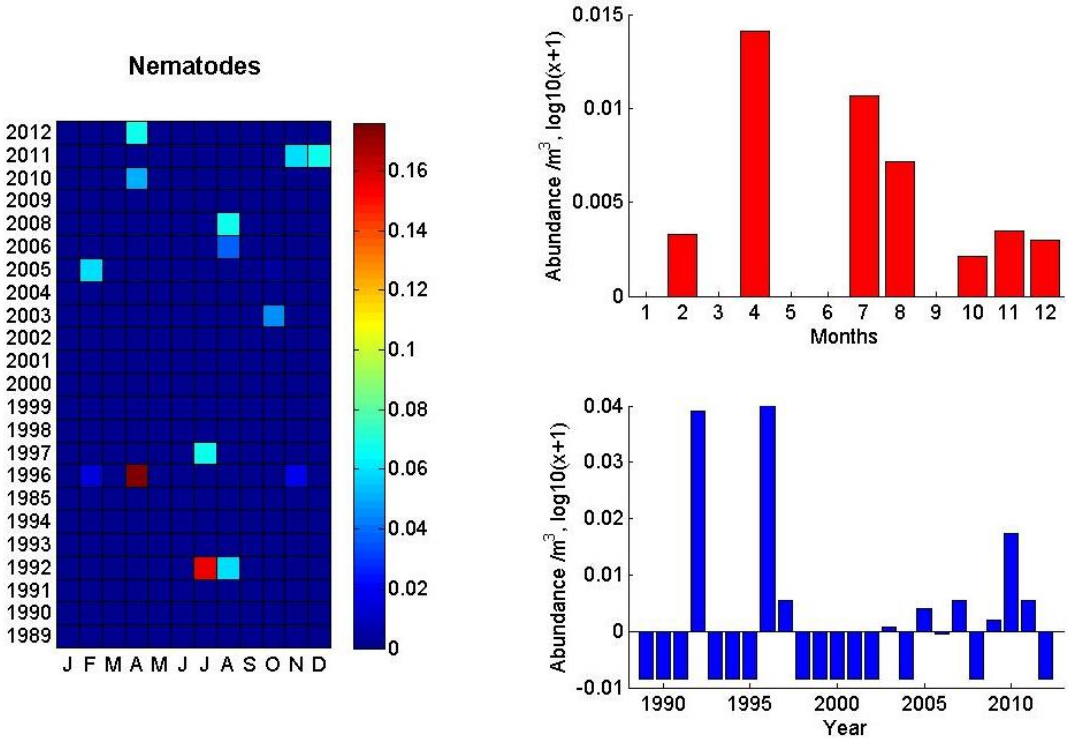


Figure 37: Mean monthly abundance of nematodes collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

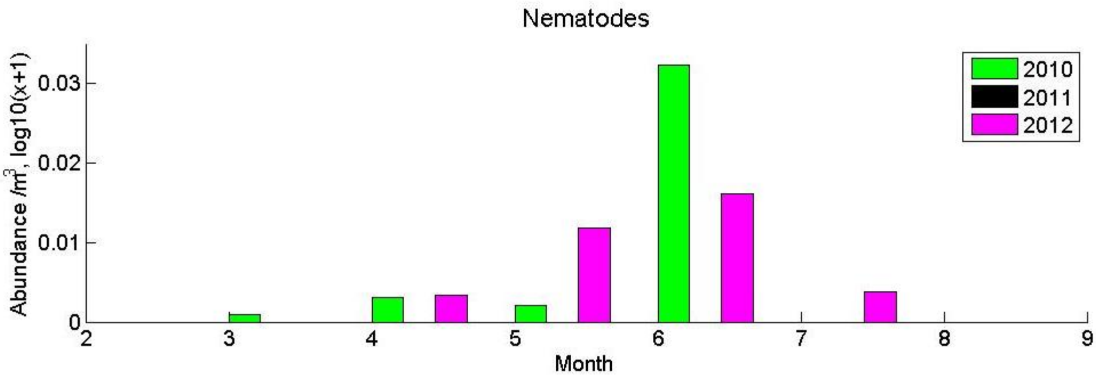


Figure 38: Mean month abundance of nematodes (≥4mm), collected from the MAIN 270 µm mesh net, each month at Sizewell site between 2010 and 2012.

### 3.1.9 Isopods

The Isopoda is one of the orders of peracarid crustaceans and comprises over 6000 marine species. Isopods range in size from less than 1 mm to the deep-water species *Bathynomus giganteus* at over 30 cm long (Poore *et al*., 2012). Most species are limited to shallow-water habitats on rocky shores, muddy environments and sandy beaches. Isopods are not well captured by the CPR, reflecting their benthic lifestyle, but nevertheless, they abundance seems to have increased between 2008 and 2012 (Figure 39).

Isopods were also poorly captured by the MAIN net: they were caught in 7.05% of all of the larger size fraction zooplankton samples collected at Sizewell and contributed to 0.08% of the total abundance. The highest numbers of isopods were caught in June-July 2012 (Figure 40). The very low abundance of this taxa means it is not considered further as an important component of the plankton at Sizewell.

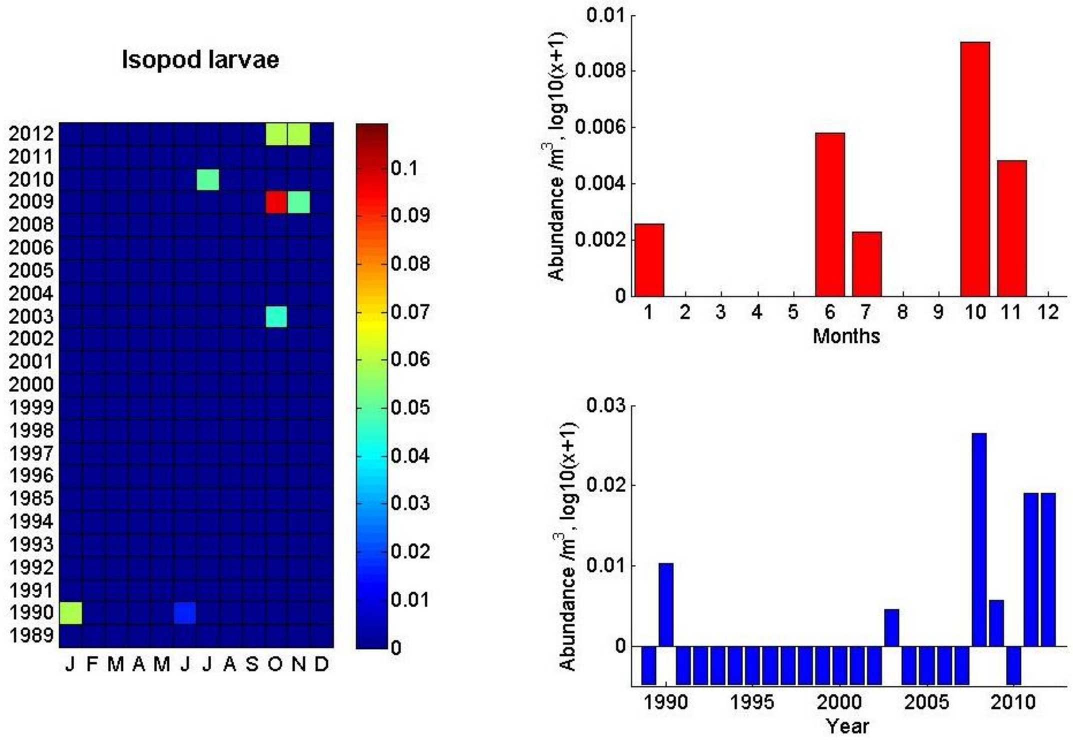


Figure 39: Mean monthly abundance of isopod larvae collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

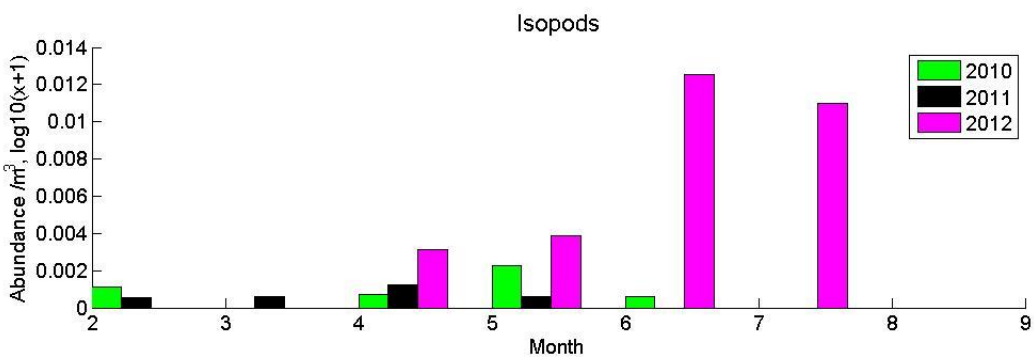


Figure 40: Mean month abundance of isopod larvae (≥4 mm), collected from the MAIN 270 µm mesh net, each month at Sizewell site between 2010 and 2012.

### 3.1.10 Krill (Euphasidea)

Data from the CPR show very high abundances in 1997 and 2007. Krill are present all year long with peak abundances in March and July-August (Figure 41). Krill were caught in 5.28 % of the larger size fraction zooplankton samples collected at Sizewell, but in very low quantities, thus only contributing to 0.04 % of the total abundance.

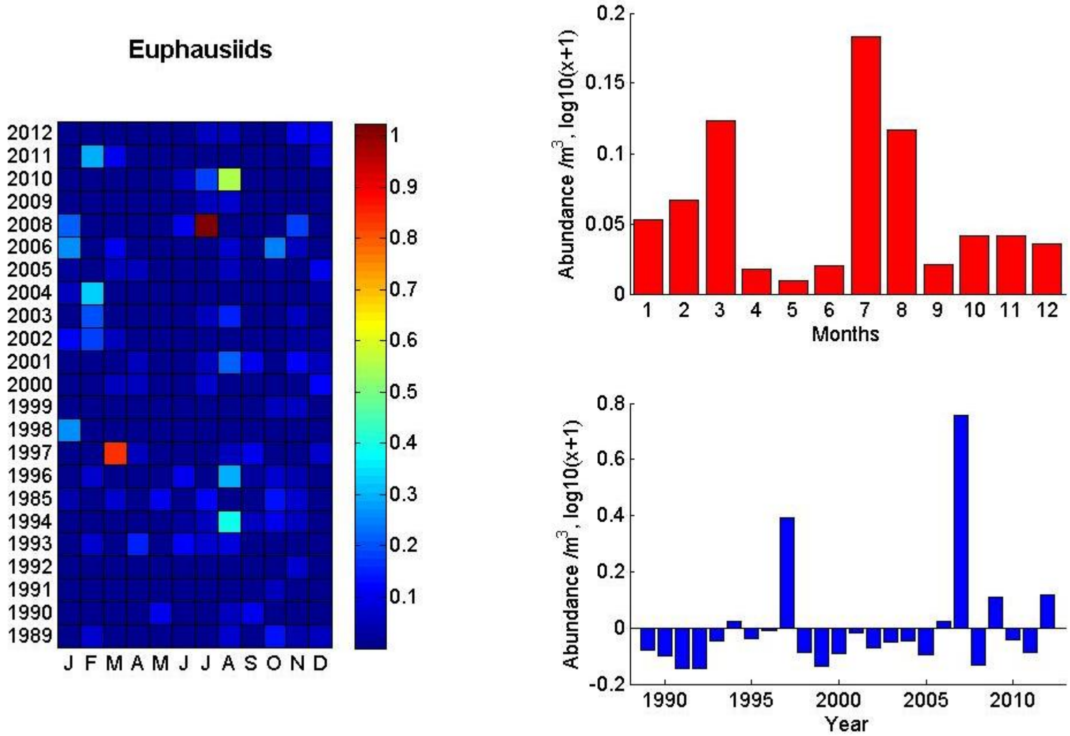


Figure 41: Mean monthly abundance of krill collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

# 4 Small size fraction zooplankton (< 4 mm)

The smaller size fraction zooplankton was defined in this instance as those specimens < 4mm in length; they mainly comprise holoplankton (organisms that are planktonic for their entire life cycle) and some meroplankton organisms that are planktonic for only a part of their life cycles, usually the larval stage). In all, 48 taxonomic groups were identified from the 398 samples collected and analysed between 2009 and 2012 (Table 6). In 2009 the smaller size fraction zooplankton started to be analysed. However, the PUP 80µm net, which is most effective in sampling organisms within this size spectrum, was only used from 2010. Although we have included the 2009 data here, it is important to note that those two nets display very different sampling efficiencies; in particular for those specimens whose size is the furthest away from the 4mm cut-off point. Consequently, some of the smallest taxa such as invertebrate eggs, foraminifera and copepod nauplii, would pass through the MAIN 270µm net and appear in very small number in 2009 compared to 2010 onward, when the PUP 80µm net was being used for the first time. It is, therefore, not possible to compare the data from the PUP samples collected from 2010 onwards with those from the MAIN samples collected in 2009.

Only the juvenile copepodite and adult copepods could be identified to genus/species level. Early life stages such as nauplii are too similar across species to be separated. There appear to be small differences in abundance of the smaller size fraction zooplankton from month to month and year to year (Figure 42).

Smaller size fraction zooplankton are not commercially exploited, nor are they designated under conservation legislation. However, they have an important role within the ecosystem as they are prey items for many early life stages of fish and benthic species, as well as other holoplankton. As for the other zooplankton, these taxa are considered to be potentially ecologically important if they are present in at least 5 % of the BEEMS samples and/or contribute to at least 1 % of the total abundance.

Table 6: Summary of smaller size fraction zooplankton data. Key taxa, highlighted in aqua, are those of socio-economic, conservation or ecological importance. Ecological importance is defined as contributing to at least 1 % of the total abundance or occurring in at least 5 % of all samples (out of the 398 collected between 2009 and 2012). These taxa are further described individually below.

| Taxa | Ecological | | Socio-economic | Conservation |
|---|---|---|---|---|
| | No. of positive samples | % of total abundance | | |
| Invertebrate eggs | 390 (97.99%) | 39.30% | - | - |
| Foraminifera | 381 (95.73%) | 19.18% | - | - |
| Copepod nauplii (copepoda) | 367 (91.46%) | 15.96% | - | - |
| Unidentified copepods (copepoda) | 85 (21.36%) | 0.15% | - | - |
| Unidentified Harpacticoids (copepoda, | 232 (58.29%) | 5.24% | - | - |
| Harpacticoid nauplii (copepoda, harpacticoida) | 60 (15.08%) | 2.08% | - | - |
| Unidentified cyclopoids (copepoda, cyclopoida) | 203 (51.01) | 0.72% | - | - |
| Unidentified calanoids (copepoda, calanoida) | 190 (47.74%) | 1.25% | - | - |
| *Temora* spp. (copepoda, calanoida) | 221 (55.53%) | 1.22% | - | - |
| *Centropages* spp. (copepoda, calanoida) | 184 (46.23%) | 0.64% | - | - |
| *Acartia* spp. (copepoda, calanoida) | 150 (37.69%) | 0.58% | - | - |
| *Paracalanus* spp. (copepoda, calanoida) | 41 (10.30%) | 0.06% | - | - |
| *Pseudocalanus* spp. (copepoda, calanoida) | 36 (9.05%) | 0.04% | - | - |
| *Calanus* spp. (copepoda, calanoida) | 11 (2.76%) | 0.01% | - | - |
| *Parapontella brevicornis* (copepoda, calanoida) | 3 (0.75%) | <0.01% | - | - |
| *Isias* spp. (copepoda, calanoida) | 2 (0.50%) | <0.01% | - | - |
| *Eurytemora* spp. (copepoda, calanoida) | 1 (0.25%) | <0.01% | - | - |
| *Oncaea* spp. (copepoda, poecilostomatoida) | 15 (3.77%) | 0.04% | - | - |
| Unidientified Siphonostomatoids (copepoda, | 4 (1.01%) | <0.01% | - | - |
| Bivalve larvae (Bivalva) | 303 (76.13%) | 4.31% | - | - |
| Bivalve eggs (Bivalva) | 9 (2.26%) | 0.01% | - | - |
| Polychaete larvae (Polychaeta) | 303 (76.13%) | 2.32% | - | - |
| Bryozoa | 280 (70.35%) | 1.29% | - | - |
| Appendicularia (tunicata) | 207 (52.01%) | 2.04% | - | - |
| Rotifers (Rotifera) | 96 (24.12%) | 1.13% | - | - |
| Gastropod larvae (gastropoda) | 95 (23.87%) | 0.12% | - | - |
| Isopoda | 16 (4.02%) | <0.01% | - | - |
| Amphipod larvae (amphipoda) | 14 (3.52%) | <0.01% | - | - |
| Ascidiacea (tunicata) | 2 (0.5%) | <0.01% | - | - |
| Unidentified Urochordata (tunicata) | 1 (0.25%) | <0.01% | - | - |
| Echinoderm larvae (echinodermata) | 151 (37.94%) | 0.88% | - | - |
| Jellyfish and hydrozoa (cnidaria) | 118 (29.65%) | 0.69% | Nuisance | - |
| Barnacle larvae (cirripedia) | 68 (17.09%) | 0.08% | - | - |
| Nematoda | 29 (7.29%) | 0.03% | - | - |
| Arachnida | 27 (6.78%) | 0.04% | - | - |
| Protozoa | 24 (6.03%) | 0.15% | - | - |
| Phoronida | 18 (4.52%) | 0.04% | - | - |
| Unidentified ctenophores (ctenophora) | 14 (3.52%) | 0.01% | - | - |
| Unidentified arrow worms (chaetognatha) | 11 (2.76%) | <0.01% | - | - |
| Unidentified cumacea | 10 (2.51%) | <0.01% | - | - |
| Unidentified mysids (mysidacea) | 9 (2.26%) | 0.01% | - | - |
| Unidentified decapoda | 7 (1.76%) | 0.01% | - | - |
| Unidentified euphausiids (euphausiidae) | 5 (1.26%) | <0.01% | - | - |
| *Evadne* spp. (cladocera) | 2 (0.50%) | <0.01% | - | - |
| *Podon* spp. (cladocera) | 1 (0.25%) | <0.01% | - | - |
| Flat worms (Platyhelminthes) | 1 (0.25%) | <0.01% | - | - |
| Sea spiders (Pycnogonida) | 1 (0.25%) | <0.01% | - | - |
| Unidentified specimens (multiple taxa) | 77 (19.35%) | 0.34% | - | - |

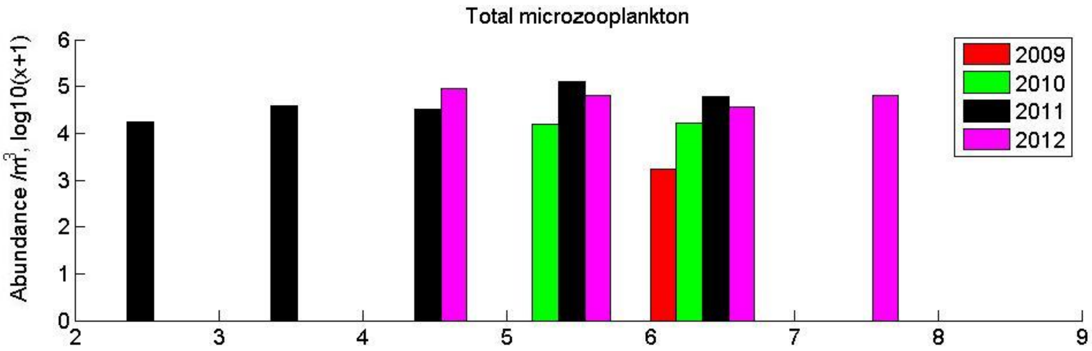


Figure 42: Mean number of zooplankton from the smaller size fraction collected each month at Sizewell, between 2009 and 2012. Note that the low numbers collected in 2009 can be explained by the use of the MAIN 270 µm mesh size prior to 2010, after which time the finer mesh PUP sampler was installed.

### 4.1.1 Invertebrate eggs and foraminifera

Invertebrate eggs are widely distributed, and a ubiquitous component of the plankton. Invertebrate eggs from a life history stage for a wide variety of taxonomic groups of zooplankton and benthic species. Invertebrates eggs were the most common and abundant group, being found in 97.99 % of samples and contributing to 39.3 % of the total abundance of the smaller size fraction zooplankton. No real seasonality and year to variability can be seen from monthly abundances values (Figure 43).

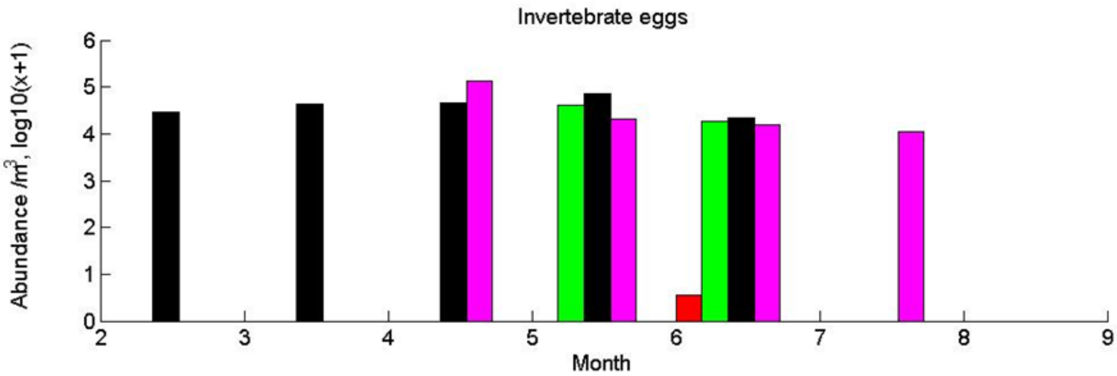


Figure 43: Mean number of invertebrate eggs from the smaller size fraction collected each month at Sizewell, between 2009 and 2012. Note that the low numbers collected in 2009 can be explained by the use of the MAIN 270 µm mesh size prior to 2010, after which time the finer mesh PUP sampler was installed.

Foraminifera are testate (possess a shell) protozoa (single celled organisms), found in all marine environments; they may be planktonic, but most are benthic. Foraminifera are a hugely diverse group of protozoa, which typically range in size from tens of microns to millimetres but can achieve sizes of up to 20cm in the case of the largest deep-water species. Data from the CPR show that foraminifera are found all year long in the southern North Sea, with higher abundances found during the period May to October. Their abundance was very low until 2000 and has since been highly variable from year to year (Figure 44).

Foraminifera were caught in 95.73 % of the smaller size fraction zooplankton samples at Sizewell, and contributed to 19.18 % of the total abundance. No year to year variability and no seasonal pattern can be seen (Figure 45).

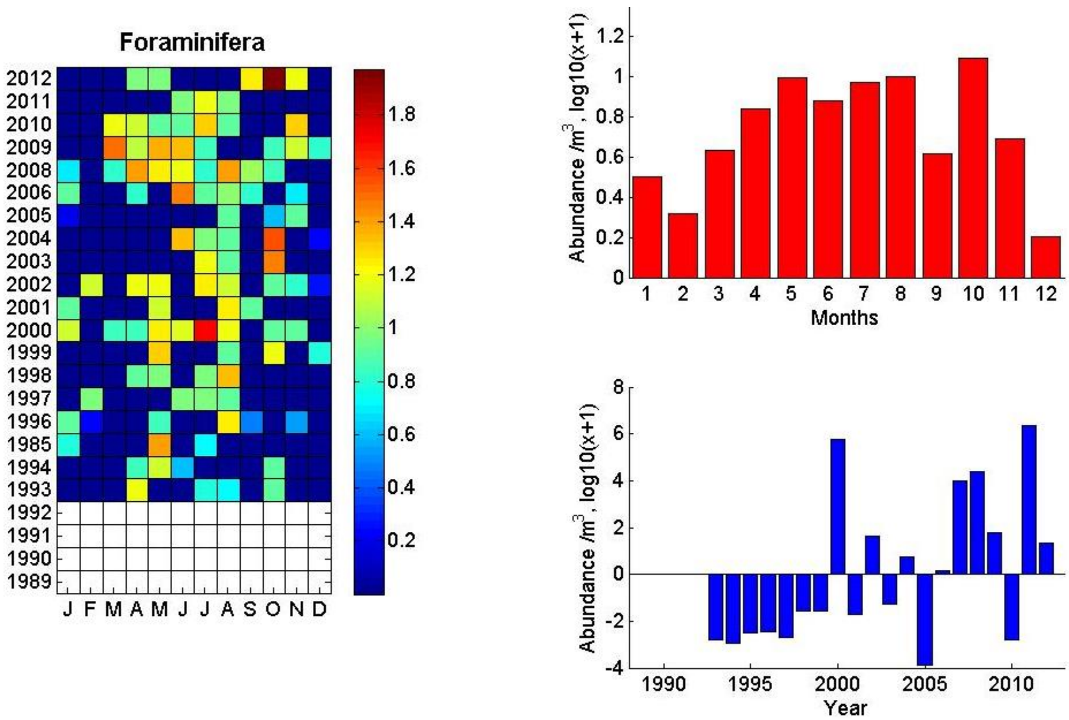


Figure 44: Mean monthly abundance of foraminifera collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

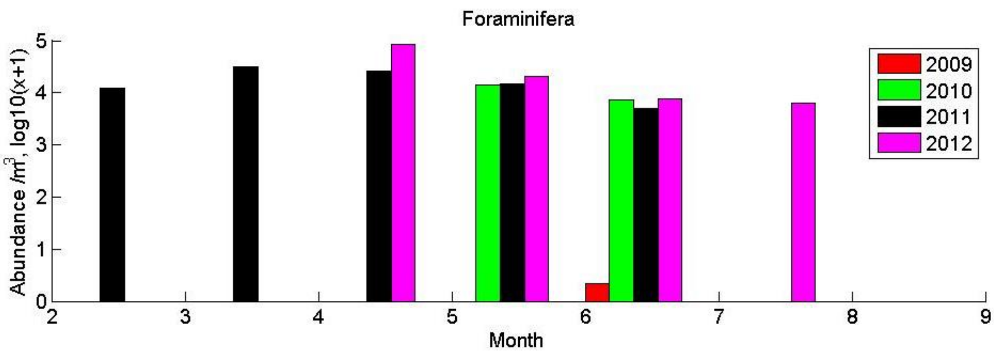


Figure 45: Mean month abundance of foraminifera in the smaller size zooplankton fraction collected at Sizewell, between 2009 and 2012 (note: In 2009, the MAIN 270 µm net was used instead of 80 µm, thus explaining the very low abundances of the foraminifera due to poor retention by the coarser mesh employed).

### 4.1.2 Copepods (Copepoda)

Copepods are important food for many larvae of fish and benthic species, they include the orders Harpacticoida, Calanoida, Cyclopoida, Poecilostomatoida and Siphonostomatoida, all present within samples collected at Sizewell. Copepod nauplii (first free-swimming planktonic stages) are the earliest stages of crustacean copepods and could not be identified to lower taxonomic level. Copepod nauplii were present in 91.46 % of samples and contributed to 15.96 % of the total smaller size fraction zooplankton abundance (Table 6). Figure 46 shows mean monthly abundances of all copepods, adults and copepodites stages summed up together as well as copepod nauplii; while Figure 47 shows mean abundances of the main copepod orders (i.e. Calanoida, Harpacticoida, Cyclopoida) encountered. For all 3 orders, mean abundances were higher in 2011-12 than 2010.

Calanoids were the most common taxonomic groups among copepods at Sizewell, with individuals present in 68.09 % of the smaller size fraction zooplankton samples; their highest level was recorded in May 2011 and July 2012. Calanoids were also the most abundant taxon in CPR samples from the southern North Sea, peaking in June-July; the CPR data also suggest that their abundance has been undergoing a decreasing trend since 1989 (Figure 48).

Harpacticoids are usually more benthic in origin than the calanoid copepods and are mostly herbivorous or detritivore. They include many species which are not easily distinguishable from each other. Adult and copepodite stages were caught in 58.29 % of the smaller size fraction zooplankton samples collected at Sizewell, and contributed to 2.04 % of the total abundance. Nauplii stages were found in 15.08% of sampling and contributing to 2.08 % of the total abundance. Their highest level was recorded in May 2011. Harpacticoid copepods collected from the CPR show a high degree of year to year variability and highest abundances recorded in October (Figure 49).

Cyclopoids were present in 51.01 % of the smaller size fraction zooplankton samples collected at Sizewell but only contributed to 0.72 % of the total abundance. They did not seem to display any seasonal pattern. However, data from the CPR suggest higher level of cyclopoids in the southern North Sea during the period July to November (Figure 50).

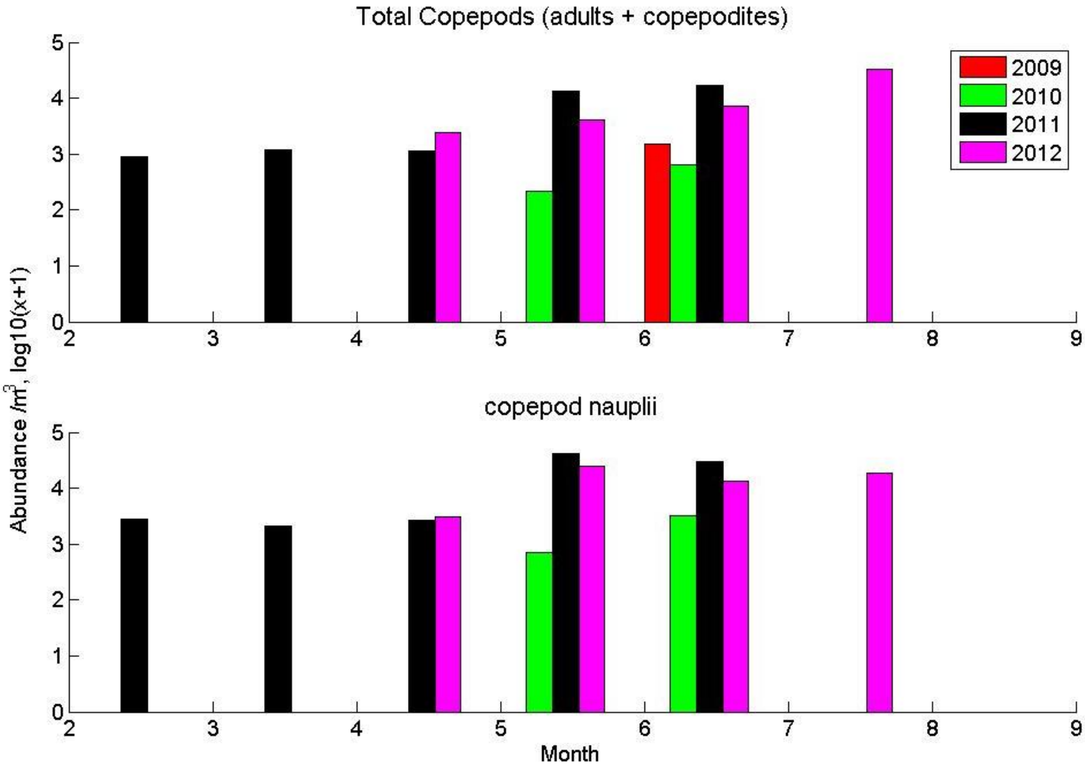


Figure 46: mean month abundance of copepods (adults + copepodites stages) and nauplii summed together in the smaller size fraction zooplankton collected at Sizewell, between 2009 and 2012. Note: In 2009, the MAIN 270 µm net was used instead of 80µm, hence no nauplii found in 2009 samples as they are too small to be retained by wider mesh net.

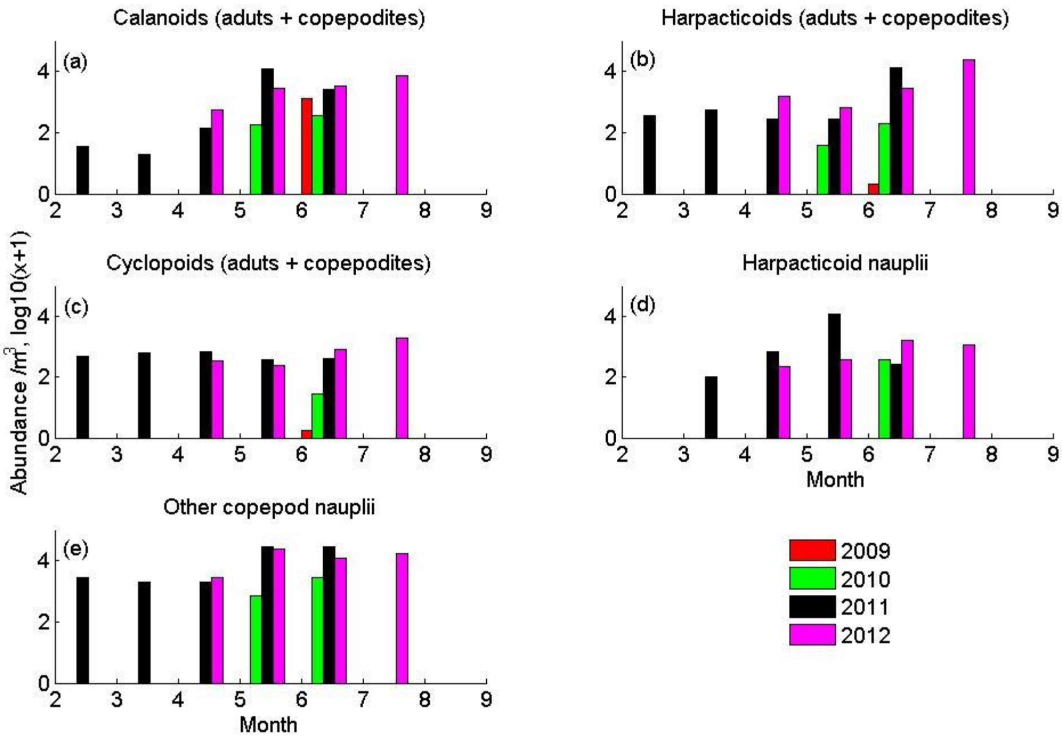


Figure 47: Mean month abundance of main copepod orders (adults + copepodites stages) collected at Sizewell, between 2009 and 2012. Note: In 2009, the MAIN 270 µm net was used instead of 80µm, hence the low abundances of the smallest organisms in 2009 samples, as these are too small to be retained by wider mesh net.

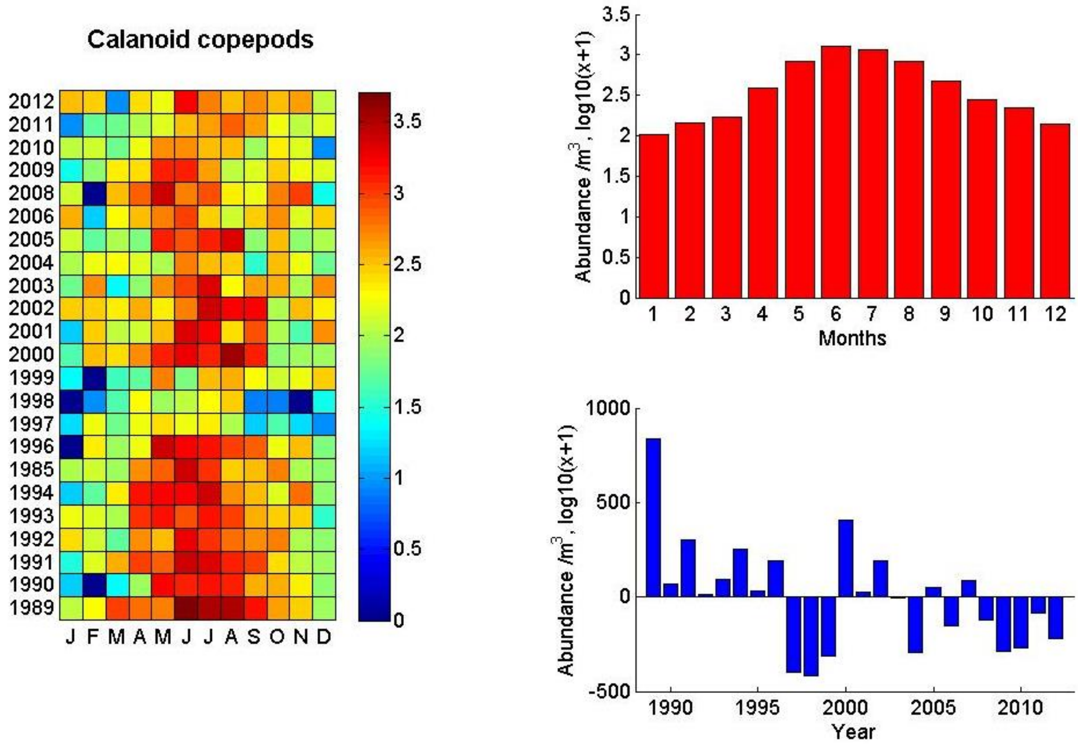


Figure 48: Mean monthly abundance of calanoid copepods collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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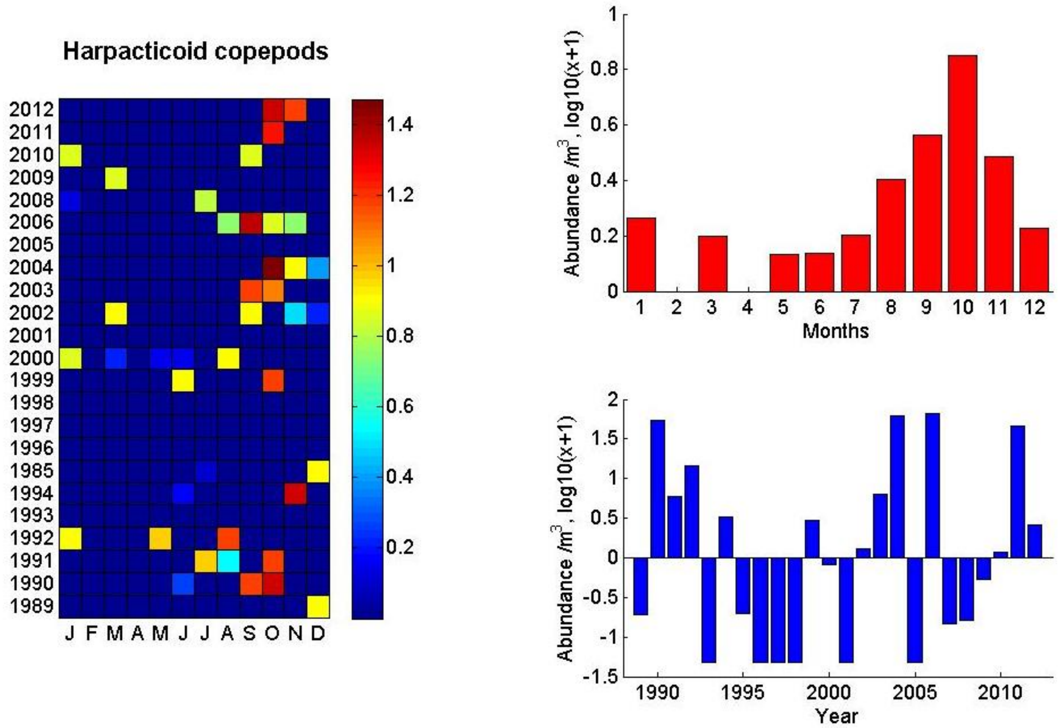


Figure 49: Top: Mean monthly abundance of harpacticoid copepods collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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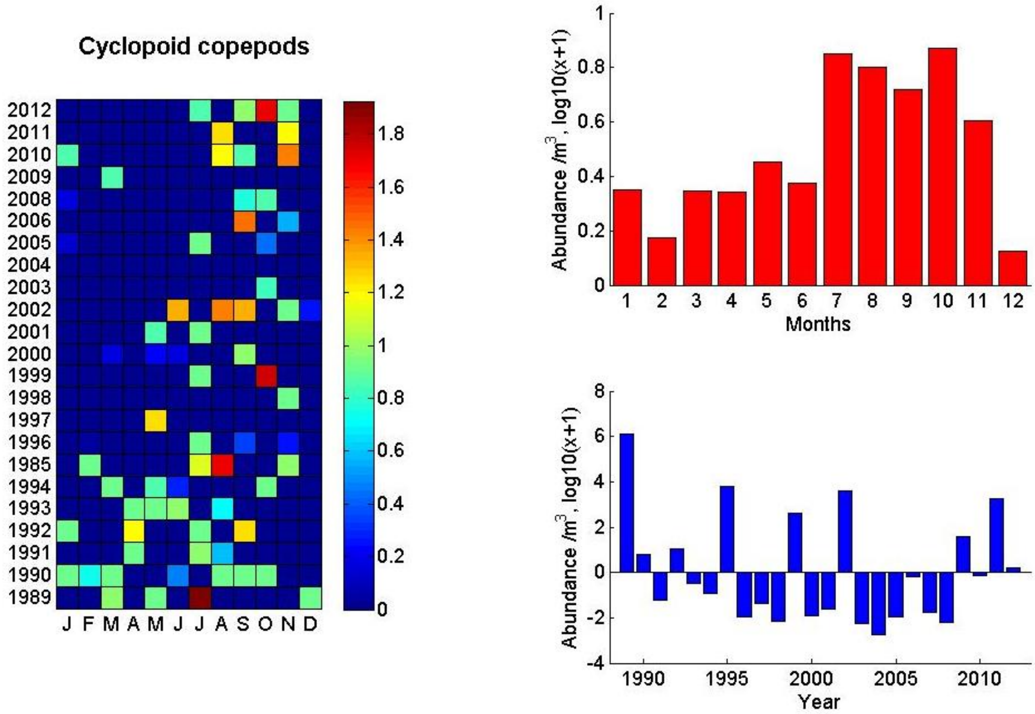


Figure 50: Mean monthly abundance of cyclopoid copepods collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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The species composition of the copepods was typical of inshore waters of the southern North Sea with calanoid copepods such as *Acartia* spp., *Centropages* spp., *Temora* spp. and to a lesser extent *Para-* and *Pseudo-calanus* spp. *Paracalanus* and *Pseudocalanus* are very similar genus and are notoriously difficult to separate taxonomically, they have therefore been grouped together and are referred to as "*Para-pseudocalanus*", forming a large proportion of the calanoid species found (Figure 51 to Figure 54). These 5 taxonomic groups were also well captured by the CPR and all show similar seasonality in both CPR and Sizewell datasets (Figure 51 - Figure 54). Of these, *Acartia* spp. and *Para-pseudocalanus* show decreasing trends in the southern North Sea between 1989 and 2012; while *Centropages* spp. and *Temora* spp. display a high degree of year to year variability. This is an important observation because copepods are a critical part of the diet of fish larvae, and their decreasing availability to fish larvae could have negative consequences on recruitment of some commercial species (Beaugrand *et al*., 2003).

*Temora* spp. were present in 55.53 % of the samples collected at Sizewell and contributed to 1.22% of the total abundance; *Acartia* spp. were present in 37.69 % of samples and contributed to 0.58 % of the total abundance; *Centropages* spp. were present in 46.23 % of samples and contributed to 0.64 % of total abundance; *Paracalanus* spp. were present in 10.30 % of samples and contributed to 0.06 % of the total abundance; and finally. *Pseudocalanus* spp. were present in 9.05 % of samples and contributed to 0.04 % of the total abundance (Figure 55).

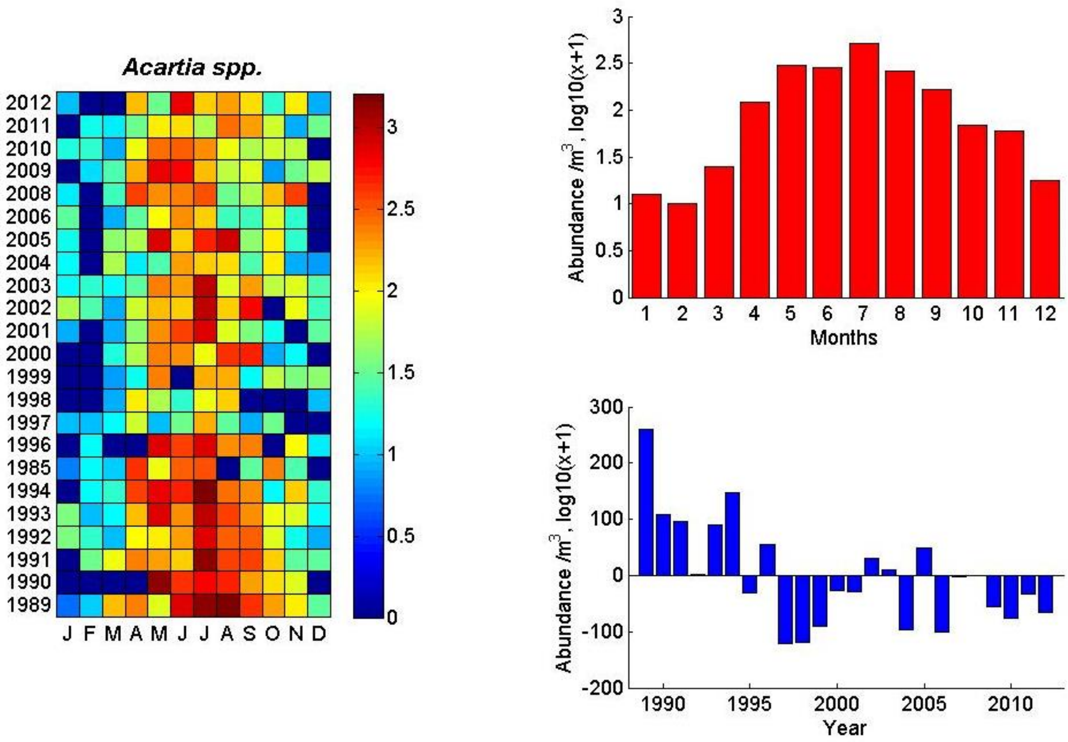


Figure 51: Mean monthly abundance of Acartia spp. collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

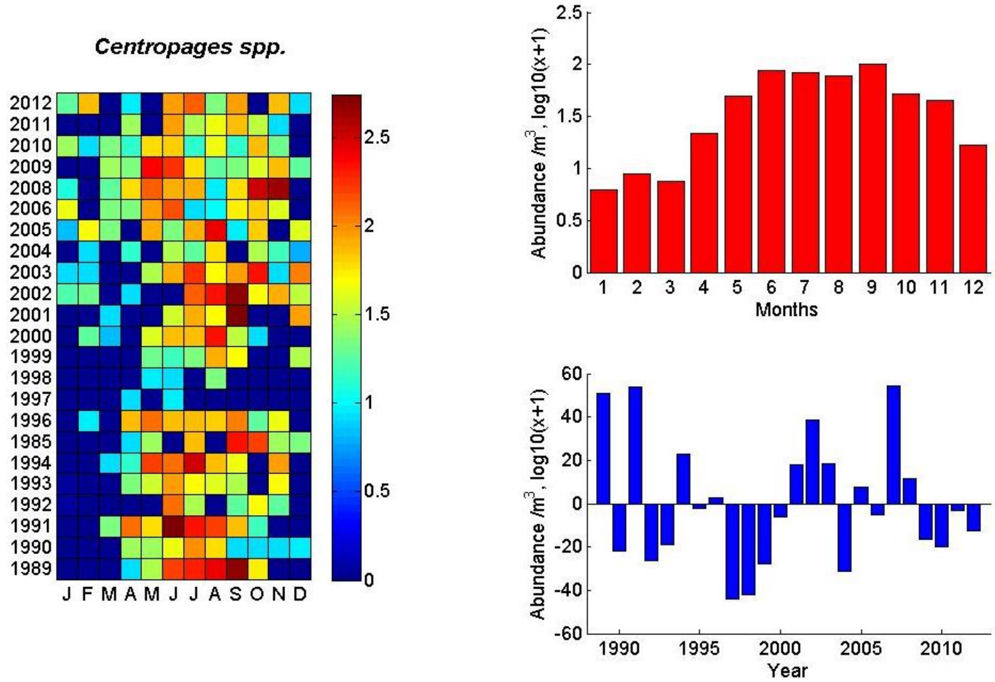


Figure 52: Mean monthly abundance of Centropages spp. collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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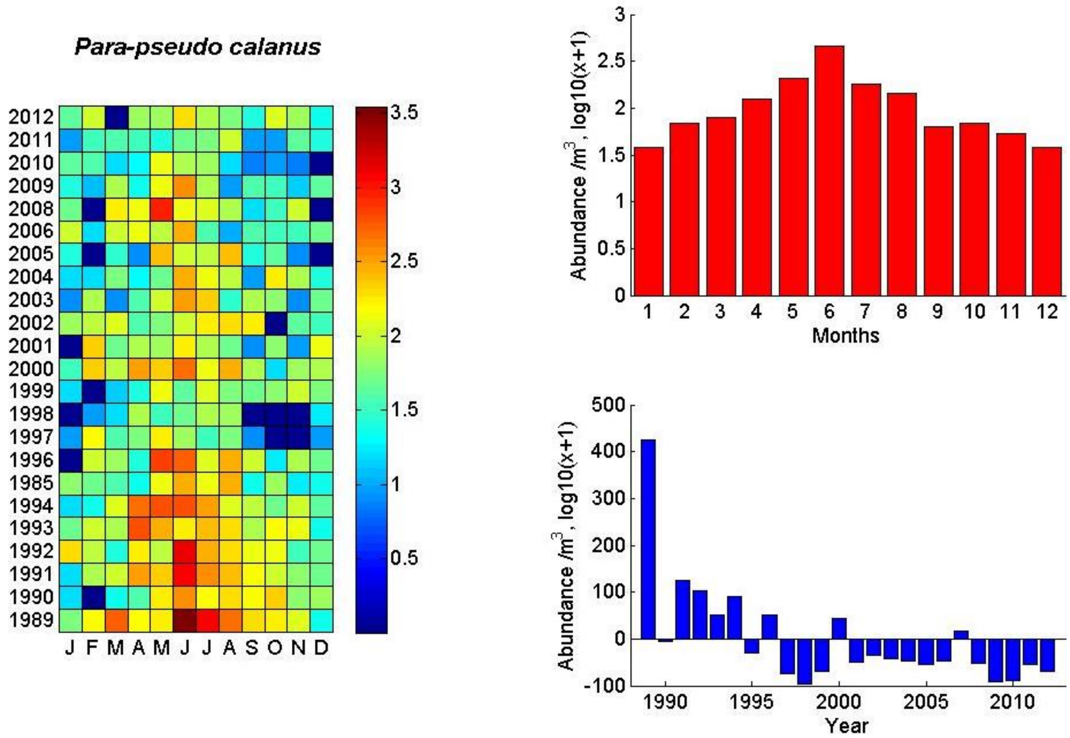


Figure 53: Mean monthly abundance of Para-pseudocalanus spp. collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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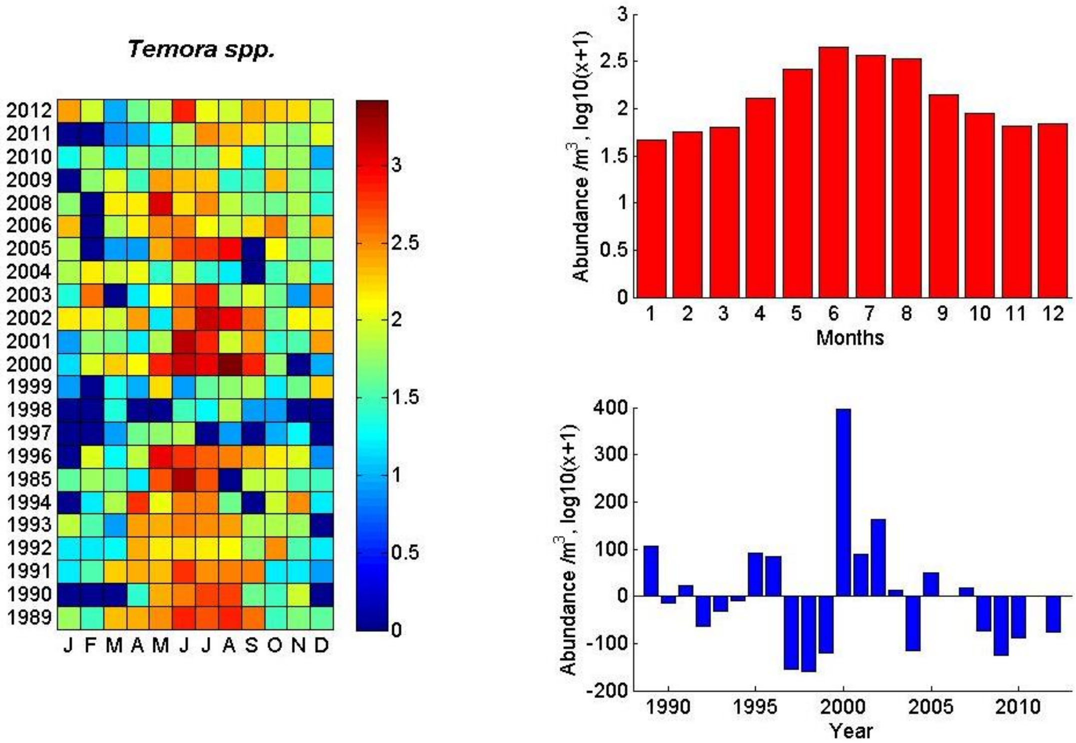


Figure 54: Mean monthly abundance of Temora spp. collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

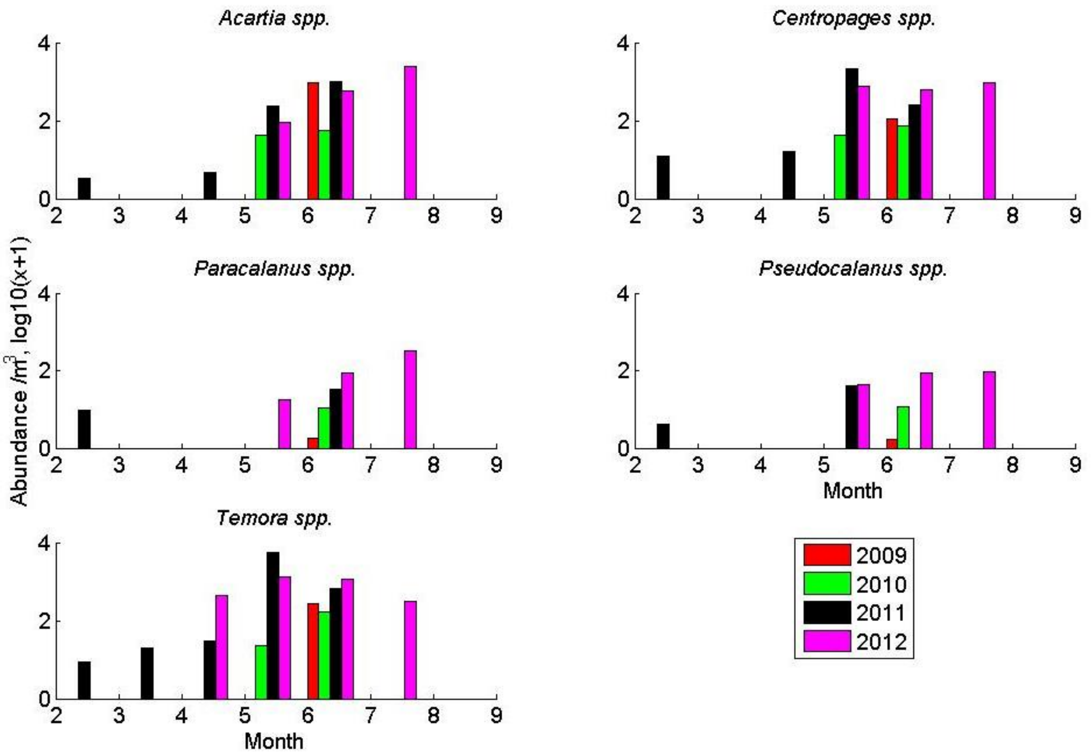


Figure 55: Mean month abundance of main copepod genus (adults + copepodites stages) collected at Sizewell in the smaller size zooplankton fraction, between 2009 and 2012. Note: In 2009, the MAIN 270 µm net was used instead of 80µm, hence the bias towards larger species in 2009.

### 4.1.3 Bivalve larvae (Bivalvia)

Bivalve larvae consist of the larval stages of a wide range of species including clams (razor clams constituting an important part of the benthic species caught in 2 m beam trawls at Sizewell (BEEMS Technical Report TR069, BEEMS Technical Report TR201), oysters, cockles, mussels, scallops, and numerous other families. Data from the CPR show a high degree of year to year variability and a seasonal pattern of no bivalve recorded in January to March and then the highest levels recorded between April and October (Figure 56).

Bivalve larvae were caught in 76.13 % of all the smaller size fraction zooplankton samples collected at Sizewell and contributed to 4.31 % of the total abundance. Their highest abundance was recorded in May 2011 and unlike the CPR data bivalve larvae were also seen in February and March, albeit only in 2011 (Figure 57).

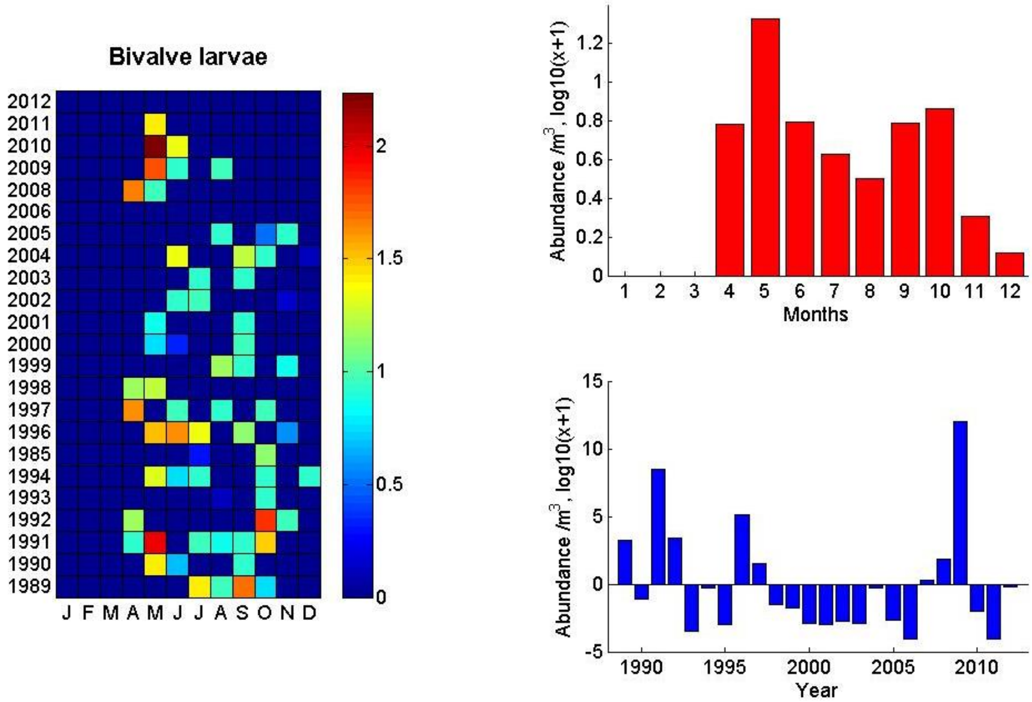


Figure 56: Mean monthly abundance of bivalve larvae collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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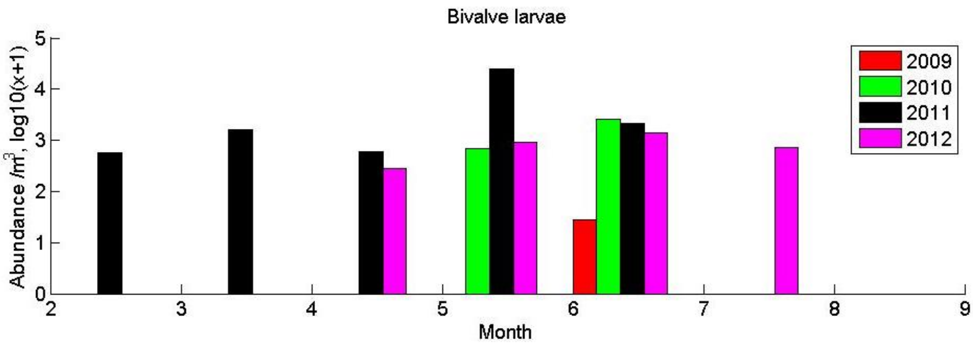


Figure 57: Mean month abundance of bivalve larvae collected at Sizewell in the smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80 µm, hence a lower number of bivalve larvae caught in 2009 samples as these are too small to be retained by wider mesh net.

### 4.1.4 Polychaete larvae (Polychaeta)

Polychaete larvae were caught in 76.13 % of samples and contributed to 4.31 % of the total abundance. Highest abundances were recorded in May to July (Figure 58) and are in line with results obtained from the CPR data in the southern North Sea (Figure 29).

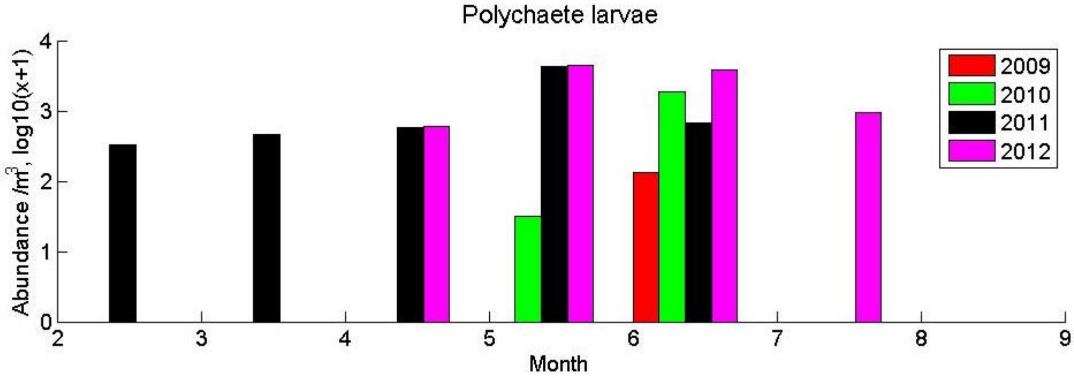


Figure 58: Mean month abundance of polychaete larvae collected at Sizewell in smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80µm, hence a bias towards larger individuals in 2009 results.

### 4.1.5 Appendicularia

Appendicularia are solitary, free-swimming tunicates found throughout the pelagic zone of the world's oceans. CPR data show appendicularia abundances to be at their lowest during December then quickly rising to reach their highest levels during the period April to August (Figure 59). Appendicularia were found in 52.01 % of samples collected at Sizewell and contributed to 2.04 % of the total smaller size fraction zooplankton abundance. The highest abundance was recorded in May of 2011 and 2012 (Figure 60).

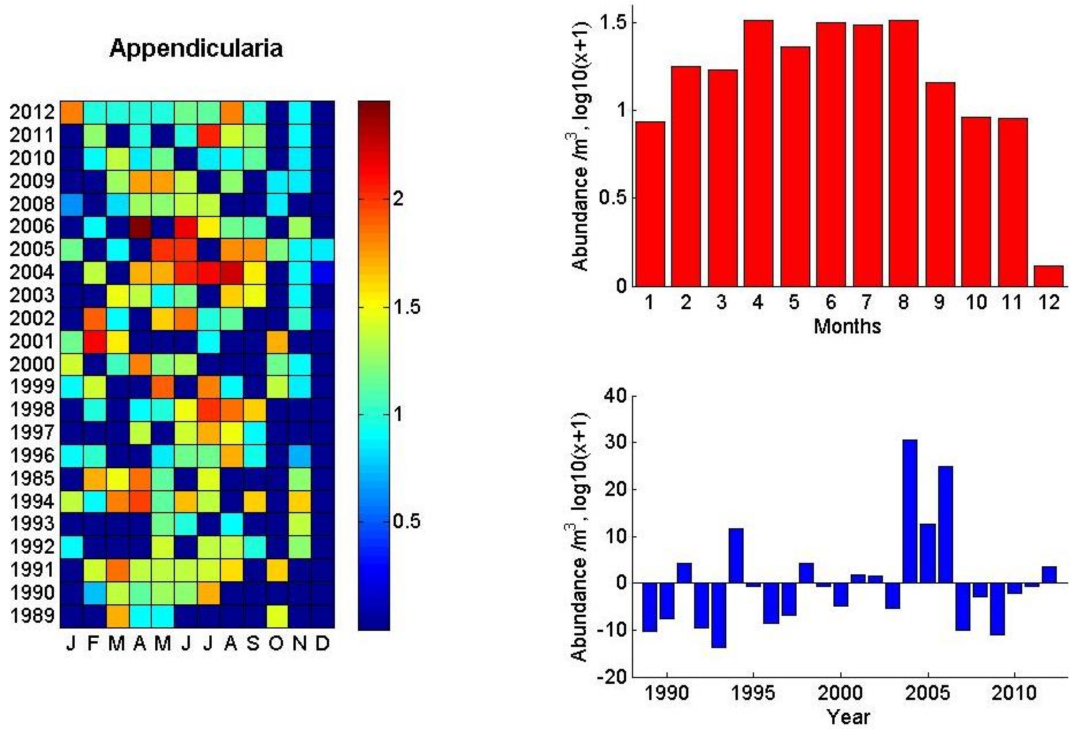


Figure 59: Mean monthly abundance of appendicularia collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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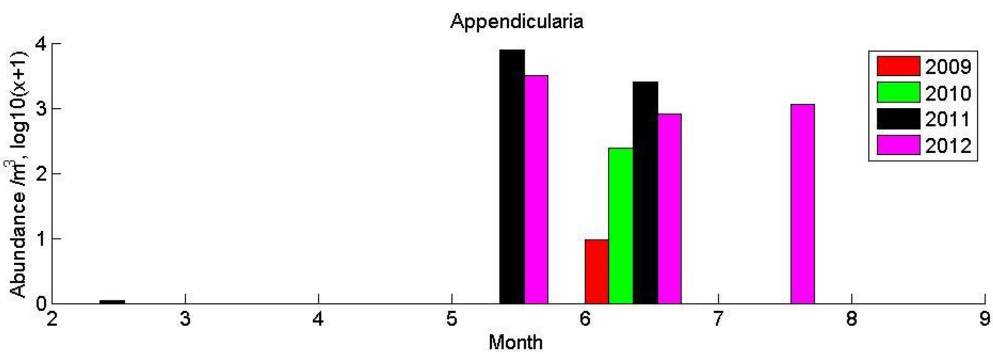


Figure 60: Mean month abundance of appendicularia collected at Sizewell in smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80µm, hence a bias towards larger individuals in 2009 results.

### 4.1.6 Rotifers (Rotifera)

Rotifers are bilaterally symmetrical, tiny, transparent, and little is known about them. They are highly efficient reproducers, able to reproduce asexually when environmental conditions are favourable, and sexually when environmental conditions are stressful. They were caught in 24.12 % of the smaller size fraction zooplankton samples collected at Sizewell and contributed to 1.13 % of the total abundance. The highest abundances were recorded in May of 2011 and 2012 (Figure 61).

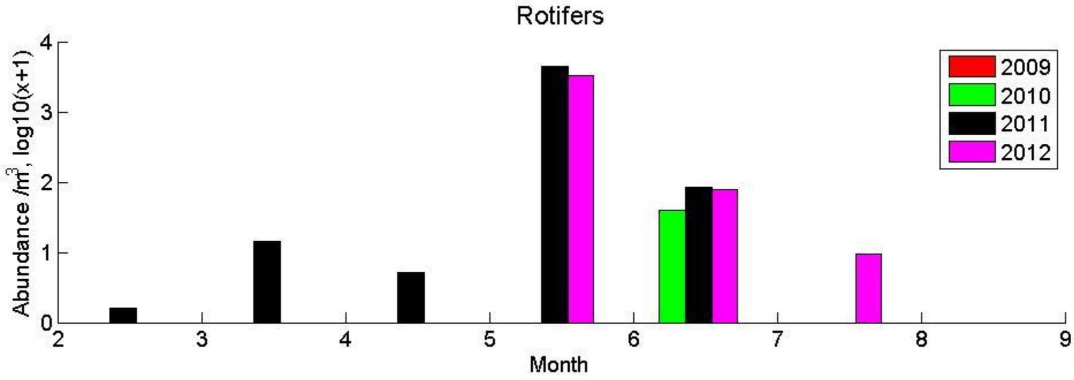


Figure 61: Mean month abundance of rotifers collected at Sizewell in the smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80 µm, hence no rotifers caught in 2009 samples as these are too small to be retained by wider mesh net.

### 4.1.7 Bryozoa larvae

The Bryozoa are commonly known as moss animals. They form colonies that take a variety of forms, including fans, bushes and sheets. They are one of the most common epifaunal groups in the vicinity of Sizewell, are biofouler of power plants cooling systems when left uncontrolled.

CPR data show that bryozoa larvae were present at their highest levels in 1991 (Figure 62). Their abundance then dropped dramatically and have remained consistently low since then. They are recorded all year, but peak in April and May. Larvae of bryozoa were caught in 70.35 % of the smaller size fraction zooplankton samples collected at Sizewell and contributed to 1.29 % of the total abundance. The highest abundances were recorded in May of 2011 and 2012 (Figure 63). Unlike data from the CPR, there is no obvious seasonality recorded in Sizewell data.

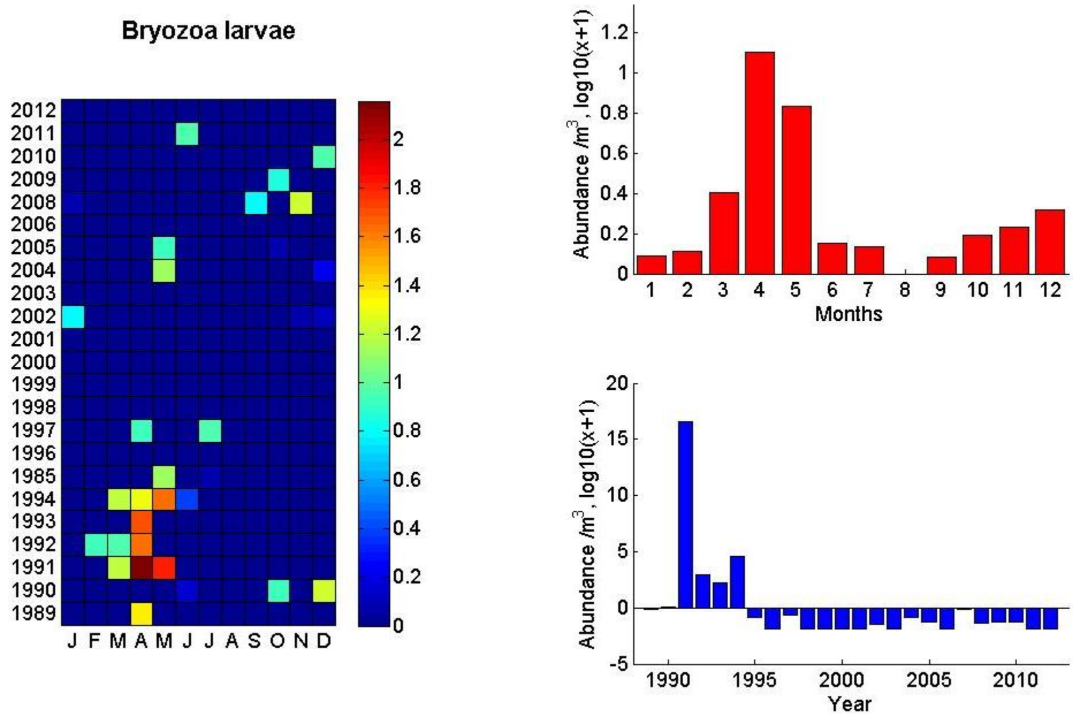


Figure 62: Mean monthly abundance of bryozoa larvae collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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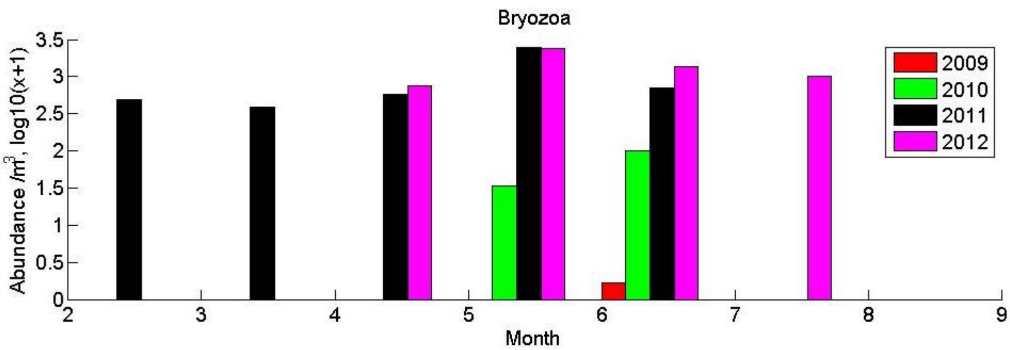


Figure 63: Mean month abundance of bryozoa larvae collected at Sizewell in the smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80µm, hence very few bryozoa larvae caught in 2009 samples as these are too small to be retained by wider mesh net.

### 4.1.8 Gastropod larvae (Gastropoda)

The marine shelled species of gastropod include edible species such as periwinkles, whelks, and numerous other sea snails that produce seashells that are coiled in the adult stage. Data from the CPR show a high degree of year to year variability in the North Sea and higher abundances recorded during the period April to September (Figure 64).

Gastropod larvae were caught in 23.87 % of all smaller size fraction zooplankton samples collected at Sizewell and contributed to 0.12 % of the total abundance. The highest abundances were recorded in June of 2011 and 2012 (Figure 65), but no clear seasonal signal can be seen. In 2011, they were recorded consistently between February and June.

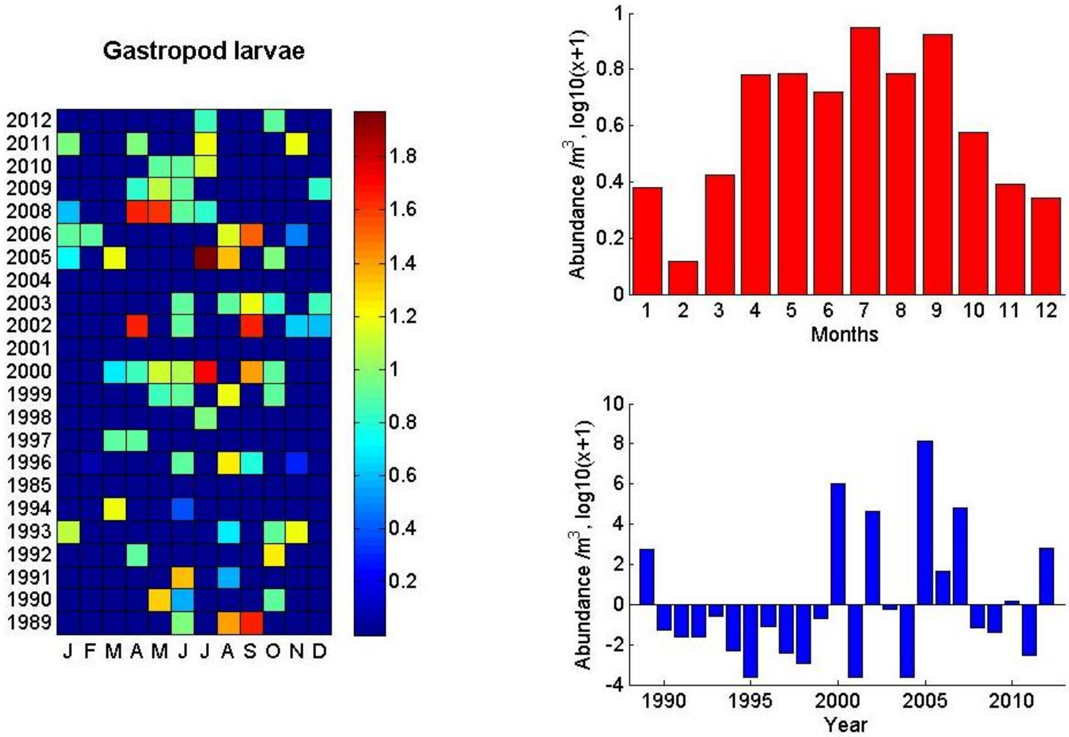


Figure 64: Mean monthly abundance of gastropod larvae collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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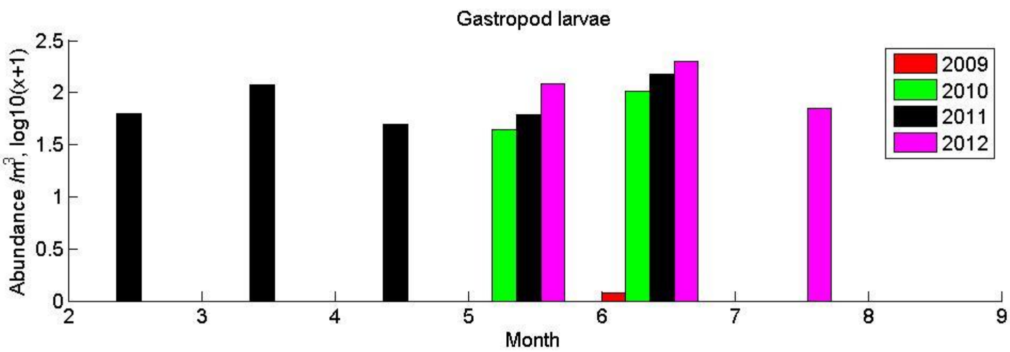


Figure 65: Mean month abundance of gastropod larvae collected at Sizewell in the smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80µm, hence very few gastropod larvae caught in 2009 samples as these are too small to be retained by wider mesh net.

### 4.1.9 Echinoderm larvae (Echinodermata)

The vast majority of echinoderms are benthic and have a pelagic larval stage. Species include starfish, brittle stars, sea urchins, and sea cucumbers. Data from the CPR show two peaks of abundance in May-June and then in October (Figure 66). Echinoderm larvae seem to have been generally increasing in abundance between 1989 and 2012 in the southern North Sea.

Echinoderm larvae were caught in 37.94 % of all the smaller size fraction zooplankton samples collected at Sizewell and contributed to 0.88 % of the total abundance. The highest abundances were recorded in May of 2011 and 2012 (Figure 67).

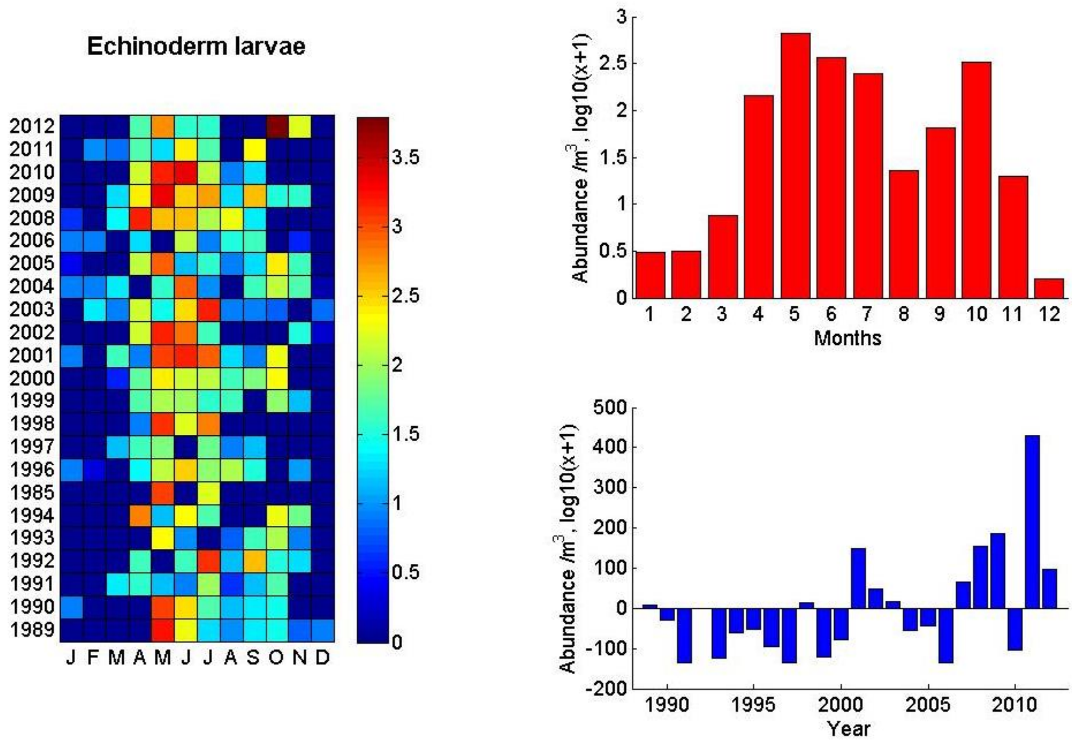


Figure 66: Mean monthly abundance of echinoderm larvae collected by the CPR in the southern North Sea from 1989 to 2012 (left plot), with seasonality (top right plot), and yearly anomalies in total abundance (bottom right plot).

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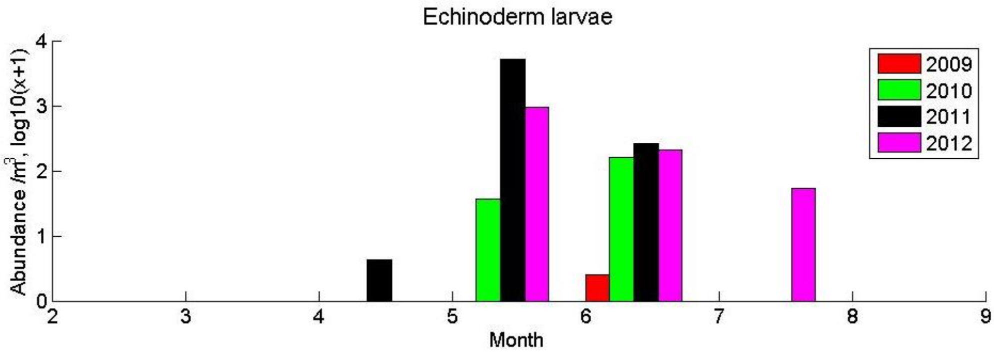


Figure 67: Mean month abundance of echinoderm larvae collected at Sizewell in the smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80µm, hence very few echinoderm larvae caught in 2009 samples as these are too small to be retained by wider mesh net.

### 4.1.10 Jellyfish and hydrozoa (Cnidaria)

Cnidaria include the true jellyfish as well as the hydrozoans and hydromedusa, and were mentioned in section 3.1.4 as they were caught in the larger zooplankton size fraction. It is unlikely that many jellyfish would be caught by the PUP 80 µm net as they would be too large for the small opening of the PUP sampler; the vast majority of cnidaria caught by the PUP sampler are therefore the small hydrozoans. Some are solitary and some colonial, the colonies of which can be large. Cnidaria were caught in 29.65 % of the smaller size fraction zooplankton samples and contributed to 0.69 % of the total abundance. The highest abundances were recorded in May and June of 2011 (Figure 68). Their numbers seem to have exploded from 2010 to 2011 and 2012, in line with results obtained from the CPR data (Figure 33).

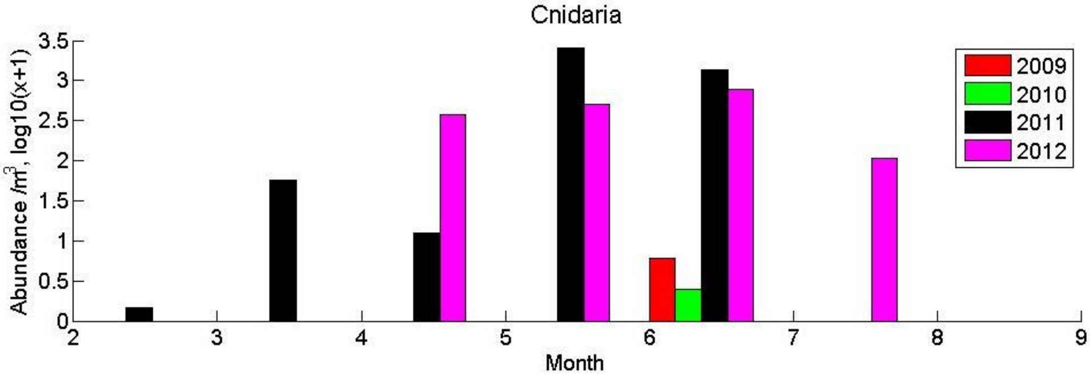


Figure 68: Mean month abundance of cnidaria collected at Sizewell in the smaller size zooplankton fraction, between 2009 and 2012. Note: In 2009, the MAIN 270 µm net was used instead of 80µm, there is therefore a bias towards larger species in 2009.

### 4.1.11 Barnacle larvae (Cirripedia)

These are early life stages of the familiar stalked and acorn barnacles found on hard surfaces in the marine environment. CPR data suggest a decreasing trend in the abundance of cirripede larvae between 1989 and 2012 (Figure 69), the seasonality chart show higher level recorded in March to April.

Cirripede larvae were recorded in 17.09 % of the smaller size fraction zooplankton samples collected at Sizewell and contributed to 0.08 % of the total abundance. The highest abundances was recorded in May 2012 (Figure 70).

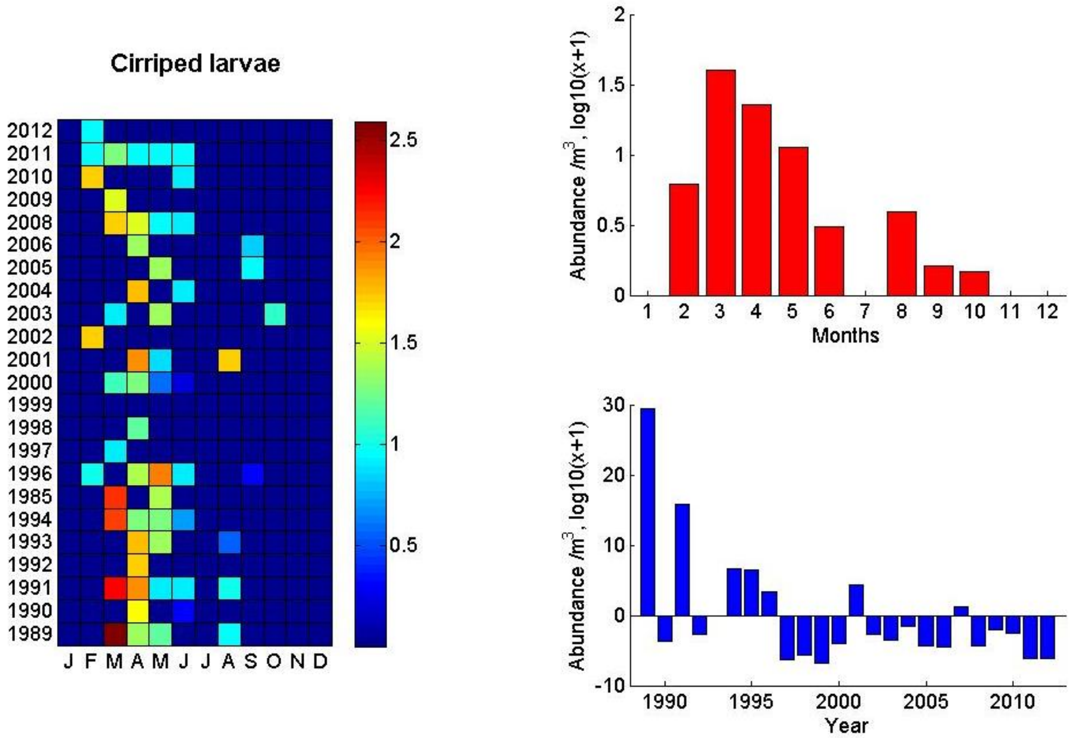


Figure 69: Mean monthly abundance of cirriped larvae collected by the CPR in the southern North Sea from 1989 to 2012 (top left plot), with seasonality (top right plot), and yearly anomalies in total abundance (middle right plot).

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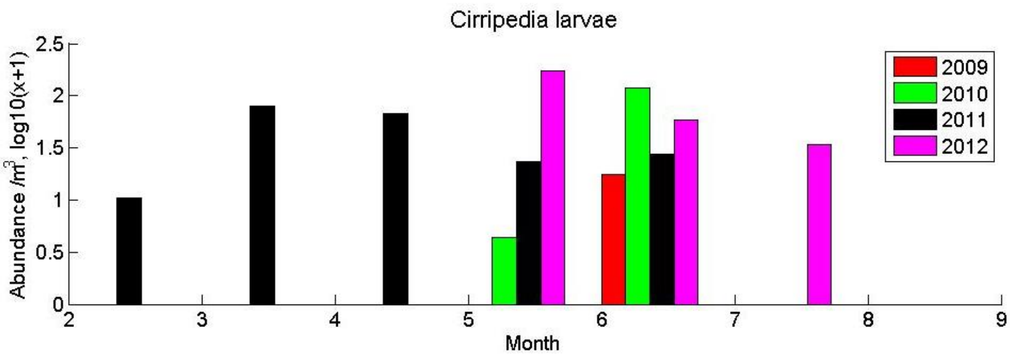



Figure 70: Mean month abundance of cirripede larvae collected at Sizewell the smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80µm, there is therefore a bias towards larger species in 2009.

### 4.1.12 Nematodes

Nematode were also captured by the MAIN net and were mentioned in section 3.1.8. In the PUP net, they appeared in 7.29 % of samples collected at Sizewell and contributed to only 0.03 % of the total abundance. Highest levels were recorded in April of 2011 and 2012 (Figure 71).

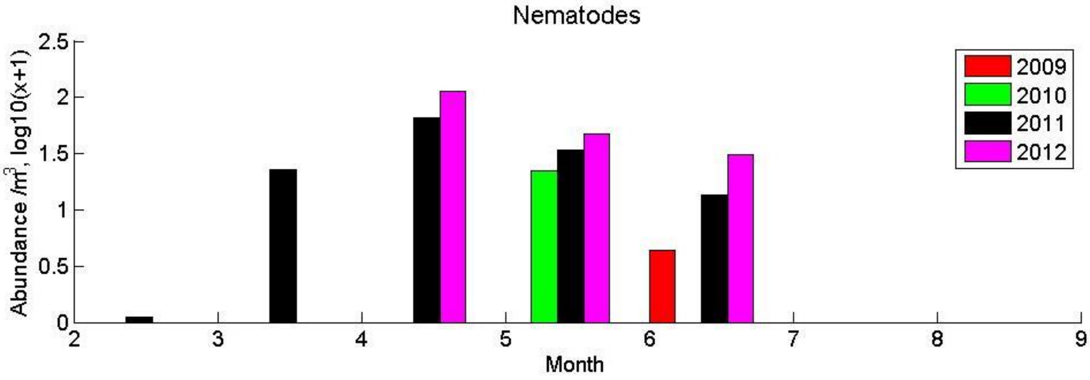



Figure 71: Mean month abundance of nematodes collected at Sizewell the smaller size zooplankton fraction, between 2009 and 2012. Note: In 2009, the MAIN 270 µm net was used instead of 80µm, there is therefore a bias towards larger species in 2009.

### 4.1.13 Protozoa

Protozoa are usually eukaryotic, single-celled heterotrophic organisms. They are motile with either flagella, cilia or pseudopodia (like amoebas). They commonly range in length between 10 to 52 µm but can grow as large as 1 mm. Accordingly, the vast majority of these single celled zooplankton will not be sampled and are not considered further in assessments. Protozoa were caught in 6.03 % of the smaller size fraction zooplankton samples collected at Sizewell and contributed to 0.14 % of the total abundance. They were caught in May and June only, their highest levels were recorded in May 2011 (Figure 72).

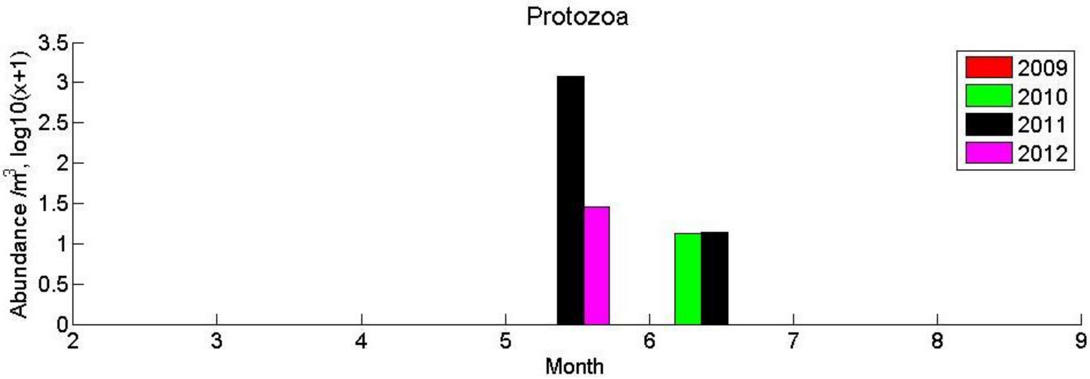



Figure 72: Mean month abundance of protozoa collected at Sizewell the smaller size zooplankton fraction, between 2009 and 2012. Note: in 2009, the MAIN 270 µm net was used instead of 80µm, there is therefore a bias towards larger species in 2009.

# 5 Zooplankton community structure

The previous sections described the seasonal and year to year variability of the characteristic zooplankton off Sizewell. In this section, the structure of the zooplankton community is described. For this specific study, multivariate analysis (PCA combined with HCA) described in Section 1.5, was applied to the data covering May to June 2010 and February to June 2011.

Overall, the analysis revealed between 3 and 5 zooplankton groups per survey. In most cases, there is no strictly defined geographical boundary between the groups and they are specific to each survey, thus highlighting the importance of seasonality, year to year variability and patchiness of the plankton. In this respect, they are better referred to as assemblages rather than communities in the strict ecological sense.

The 2012 survey (see Annex A for sampling locations) showed some small differences in the communities present between the SZB intakes and SZC (BEEMS Technical Report TR276). These differences included some expected strong seasonal variations, but also some weaker differences between the two sites. The latter were determined by varied abundances of small invertebrates (copepod nauplii, foraminifera, invertebrate eggs and harpacticoid copepods). Because these taxonomic groups are by far the most common and abundant in the Sizewell area, their variations mask potential differences in the abundance of other less abundant groups. Furthermore, invertebrate eggs and copepod nauplii comprise a wide range of taxa, which can only be further identified in the juvenile/adult stages, thus blurring further potential changes in the abundances of the associated taxa. Here, these very large groups were removed in order to focus on more strictly defined taxonomic groupings. Using the present approach, no notable difference in community composition between stations located inshore and offshore of the Sizewell-Dunwich Bank was observed ( Figure 1), but more of a North-South and/or East-West gradient. This gradient is in coincidence with a temperature and salinity gradient (Figure 73 to Figure 79). More details for zooplankton assemblage determined at each survey are given below:

- May 2010 (Figure 73): Three assemblages were observed, the most distinctive one is characterised by mysids and cumacea (blue circles). The other 2 (red open and filled circles) result from a further split within the dendrogram, leading to one diverse assemblage characterised by bivalves, foraminifers, mysids, decapods, cumacea and gammarids, and a second assemblage comprising 2 stations only and characterised by the copepod *Temora spp.*, gastropod larvae and ctenophores.

- June 2010 (Figure 74): A first split of the dendrogram revealed 2 assemblages (red and blue), which were both further spit into another 2 assemblages (open and filled circles). Red assemblages are mostly located in the southern half of the study area and are largely characterised by copepods (red filled circles) but also mysids, foraminifers, decapods, cirripeds and bivalves (red open circles). Blue assemblages are mostly located in the Northern half of the study area, of which 2 groups can be distinguished: one group is more diverse and characterised by mainly bryozoa and appendicularia (blue filled circles), while the other is mostly characterised by copepod harpacticoids (blue open circles).

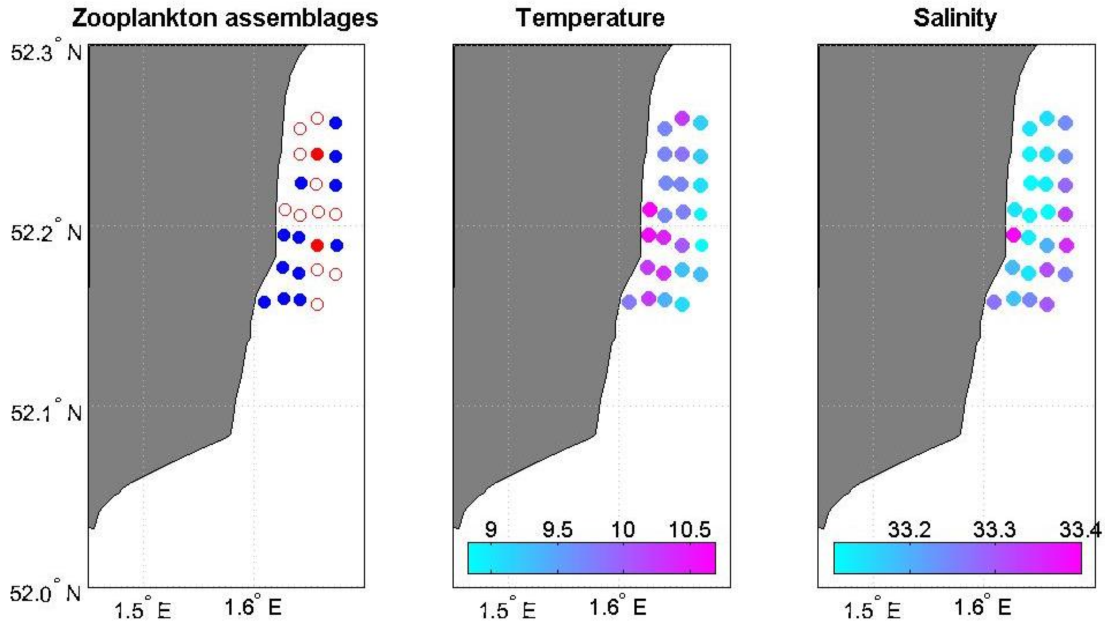
- February 2011 (Figure 75): A first split of the dendrogram revealed 2 assemblages (red and blue), which were both further spit into another 2 assemblages (open and filled circles). One assemblage (blue filled circles) is characterised mostly by calanoid copepods, chaetognaths and cnidaria and is located at 3 stations on the eastern and southern edges of the survey area. The second blue assemblage (blue open circles) is mostly characterised by copepod harpacticoids. The red assemblages are split into two groups: one group, located in the south-eastern area and characterised by mysids, bryozoa and copepod cyclopoids (red filled circles), and another group with stations spread across the area and characterised mostly by cyclopoid copepods, polychaetes and mysids.

- March 2011 (Figure 76): A first split of the dendrogram revealed 2 assemblages (red and blue), with the blue assemblage further split in two distinct assemblages (filled and open circles). There seems to be a gradient, from South to North, starting with a zooplankton community characterised by gastropods, bivalve and foraminifers; moving through a community characterised by polychaetes and copepod harpacticoids, in the middle section of the survey area; and to a more diverse community characterised mostly by copepod cyclopoids, mysids, polychaetes and bryozoa.

- April 2011 (Figure 77): A first split of the dendrogram revealed 2 assemblages with a North (blue) to South (red) gradient distribution. These 2 groups were further split into 2 assemblages each (open and filled circles). In the northern half of the survey area, we find sampling locations with a diverse assemblage characterised by mostly by bryozoa, polychaetes, harpacticoid copepods and mysids (open blue circles). An assemblage characterised mostly by polychaete larvae is located mainly on coastal stations (blue filled circles). Another assemblage characterised mostly by cyclopoid copepods and foraminifers, seems to cover more coastal stations, but in southern half of the survey area (red filled circles). The last assemblage is characterised by foraminifers and gammarids (red open circles).

- May 2011 (Figure 78): A first split of the dendrogram revealed 2 assemblages (red and blue), which were further spit into another 2 assemblages (open and filled circles). The five stations with the blue filled circle are located at the north end of the survey area, they comprise an assemblage characterised by mysids, the copepod *Acartia spp*. and decapods larvae. 4 stations in the middle of the survey area comprise an assemblage characterised by phoronids and cyclopoid copepods. Also in the middle of the survey area is an assemblage characterised by protozoa, ctenophores, rotifers and the copepod *Centropages spp*. (red open circles). Half the stations (blue open circles) actually comprise a very diverse assemblage where cnidaria dominate, these are spread over the entire area.

- June 2011 (Figure 79): A first split of the dendrogram revealed 2 assemblages (red and blue). The red stations comprise an assemblage characterised mostly by foraminifers. The blue section is further split in 2 more sections (circles and triangles), each even further split into open and filled symbols. The blue circles comprise are located in the southern half of the survey areas, they comprise few stations and are each characterised by a single taxonomic group (i.e. chaetognaths for blue filled circles and bryozoa for blue open circles). Most of the survey stations are represented by the blue open triangles, spread over the study area, these are characterised by a very diverse community.

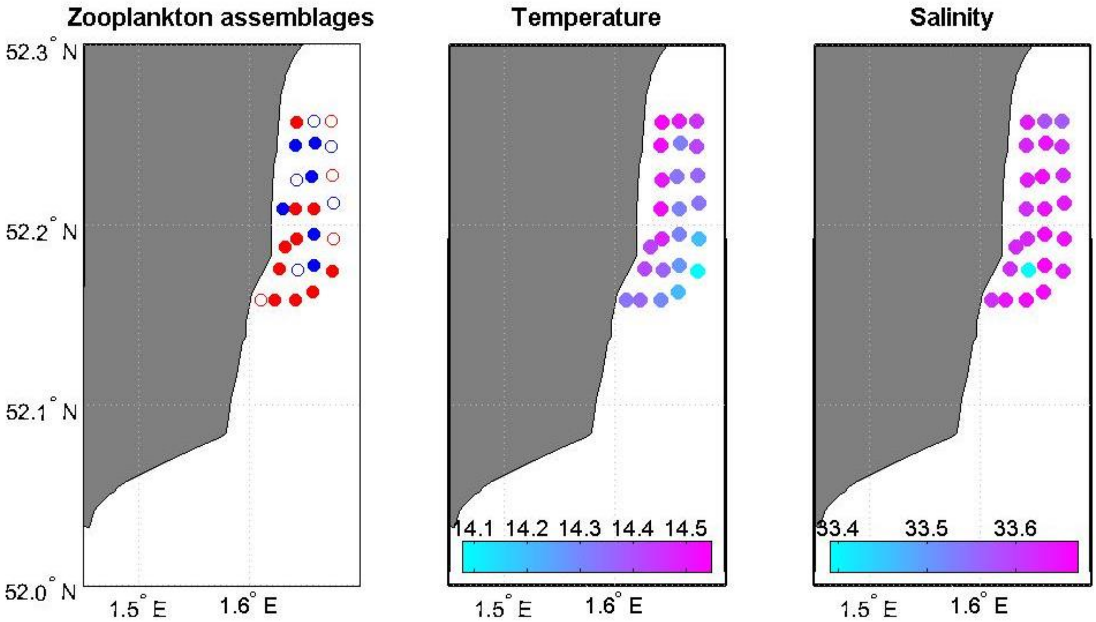



| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Mysida | Mysidae | 0.48 | 1 | 47.76 |
| Peracarida | Cumacea | 0.52 | 0.83 | 42.94 |
| Foraminifera | Foraminifera | 0.34 | 1 | 33.52 |
| Peracarida | Isopoda | 1 | 0.25 | 25 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Bivalvia | Bivalvia | 0.65 | 1 | 64.68 |
| Foraminifera | Foraminifera | 0.51 | 1 | 50.82 |
| Mysida | Mysidae | 0.49 | 1 | 48.63 |
| Eucarida | Decapoda | 0.63 | 0.73 | 46.16 |
| Peracarida | Cumacea | 0.43 | 1 | 43.27 |
| Amphipoda | Gammaridae | 0.6 | 0.64 | 38.07 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | *Temora spp.* | 1 | 1 | 100 |
| Gastropoda | Gastropoda | 0.68 | 1 | 67.62 |
| Ctenophora | Ctenophora | 1 | 0.5 | 50 |

Figure 73: Distribution of zooplankton assemblages for May 2010 surveys, along with temperature and salinity values obtained from CTD profiles at the time of sampling, and simplified dendrogram showing the taxa characteristic of each assemblage characterised using indicator values (indVal). Selected taxa are those for which IndVal >= 25 (see method in Section 1.5).



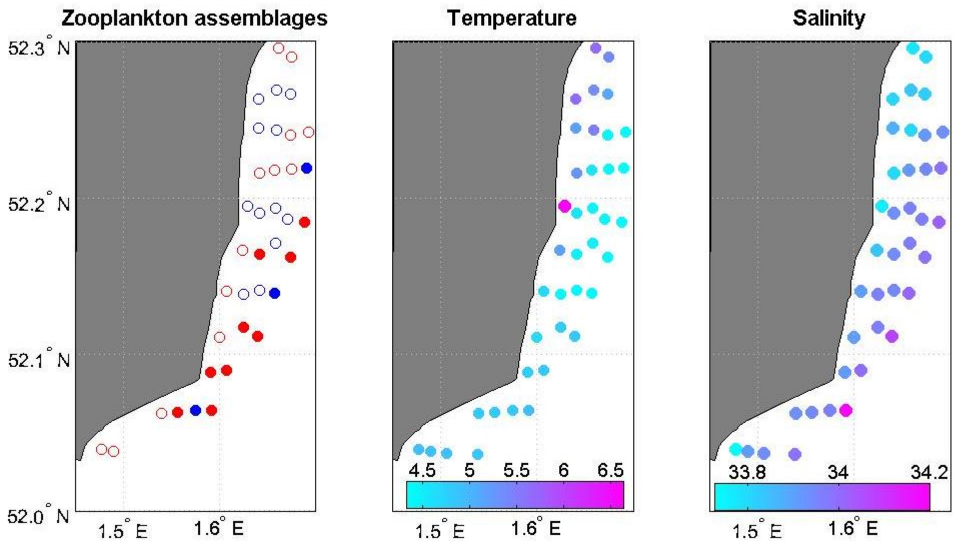

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Bryozoa | Bryozoa | 0.88 | 1 | 87.65 |
| Tunicata | Appendicularia | 0.83 | 1 | 83.02 |
| Echinodermata | Echinodermata | 0.62 | 0.83 | 51.47 |
| Annelida | Polychaeta | 0.41 | 1 | 40.64 |
| Copepoda | *Centropages spp.* | 0.58 | 0.67 | 38.77 |
| Copepoda | Harpacticoida | 0.43 | 0.83 | 36.2 |
| Rotifera | Rotifera | 1 | 0.33 | 33.33 |
| Copepoda | *Paracalanus spp.* | 1 | 0.33 | 33.33 |
| Bivalvia | Bivalvia | 0.32 | 1 | 32.42 |
| Foraminifera | Foraminifera | 0.32 | 1 | 32.4 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | Harpacticoida | 0.57 | 1 | 56.56 |
| Gastropoda | Gastropoda | 0.5 | 0.6 | 29.91 |
| Foraminifera | Foraminifera | 0.26 | 1 | 25.88 |
| Bivalvia | Bivalvia | 0.25 | 1 | 25.48 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Mysida | Mysidae | 0.38 | 1 | 38.23 |
| Foraminifera | Foraminifera | 0.34 | 1 | 33.84 |
| Eucarida | Decapoda | 0.37 | 0.9 | 32.92 |
| Cirripedia | Cirripedia | 0.82 | 0.4 | 32.92 |
| Bivalvia | Bivalvia | 0.32 | 1 | 31.93 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | *Acartia spp.* | 0.68 | 1 | 67.71 |
| Copepoda | Cyclopoida | 0.76 | 0.75 | 56.8 |
| Copepoda | *Temora spp.* | 0.48 | 1 | 47.78 |
| Eucarida | Decapoda | 0.35 | 1 | 35.43 |
| Peracarida | Isopoda | 1 | 0.25 | 25 |

Figure 74: Distribution of zooplankton assemblages for June 2010 surveys, along with temperature and salinity values obtained from CTD profiles at the time of sampling, and simplified dendrogram showing the taxa characteristic of each assemblage characterised using indicator values (indVal). Selected taxa are those for which IndVal >= 25 (see method in Section 1.5).



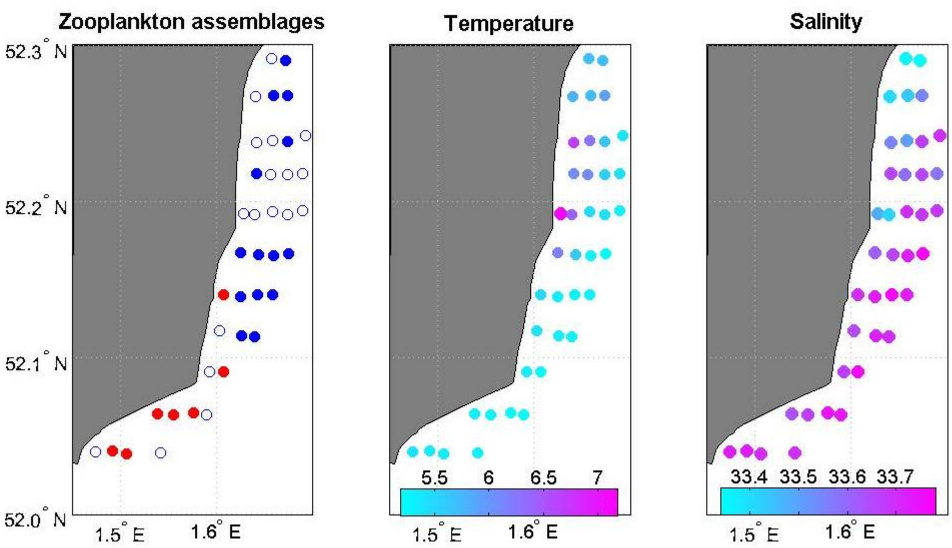

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | *Pseudocalanus spp.* | 1 | 1 | 100 |
| Copepoda | *Acartia spp*. | 0.74 | 1 | 73.55 |
| Chaetognatha | Chaetognatha | 1 | 0.67 | 66.67 |
| Cnidaria | Cnidaria | 1 | 0.67 | 66.67 |
| Copepoda | *Temora spp.* | 0.53 | 1 | 53.22 |
| Tunicata | Appendicularia | 1 | 0.33 | 33.33 |
| Nematoda | Nematoda | 1 | 0.33 | 33.33 |
| Copepoda | *Centropages spp.* | 0.33 | 1 | 33.18 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | Harpacticoida | 0.82 | 1 | 82.38 |
| Bivalvia | Bivalvia | 0.66 | 0.92 | 60.25 |
| Foraminifera | Foraminifera | 0.55 | 1 | 55.41 |
| Annelida | Polychaeta | 0.43 | 0.67 | 28.82 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Mysida | Mysidae | 0.32 | 1 | 32.11 |
| Bryozoa | Bryozoa | 0.33 | 0.89 | 29.35 |
| Copepoda | Cyclopoida | 0.34 | 1 | 28.82 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | Cyclopoida | 0.66 | 0.87 | 57.26 |
| Annelida | Polychaeta | 0.55 | 0.93 | 51.78 |
| Mysida | Mysidae | 0.49 | 1 | 48.81 |
| Amphipoda | Gammaridae | 0.53 | 0.73 | 39.21 |
| Foraminifera | Foraminifera | 0.33 | 1 | 32.93 |
| Peracarida | Cumacea | 0.62 | 0.47 | 29.07 |
| Bryozoa | Bryozoa | 0.38 | 0.73 | 27.59 |

Figure 75: Distribution of zooplankton assemblages for February 2011 surveys, along with temperature and salinity values obtained from CTD profiles at the time of sampling, and simplified dendrogram showing the taxa characteristic of each assemblage characterised using indicator values (indVal). Selected taxa are those for which IndVal >= 25 (see method in Section 1.5 ).

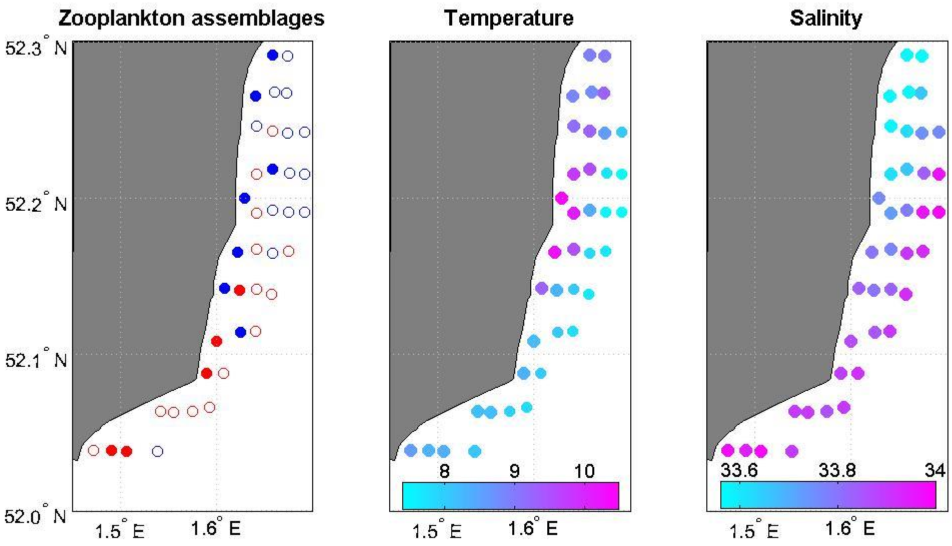



| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Annelida | Polychaeta | 0.36 | 0.71 | 25.44 |
| Copepoda | Harpacticoida | 0.45 | 0.57 | 25.43 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | Cyclopoida | 0.77 | 1 | 77.15 |
| Mysida | Mysidae | 0.68 | 1 | 68.37 |
| Annelida | Polychaeta | 0.64 | 0.89 | 57.23 |
| Bryozoa | Bryozoa | 0.61 | 0.83 | 50.55 |
| Bivalvia | Bivalvia | 0.43 | 0.89 | 38.01 |
| Foraminifera | Foraminifera | 0.38 | 1 | 37.75 |
| Cirripedia | Cirripedia | 0.64 | 32.12 | 32.12 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Gastropoda | Gastropoda | 1 | 0.71 | 71.43 |
| Bivalvia | Bivalvia | 0.51 | 1 | 51.11 |
| Foraminifera | Foraminifera | 0.43 | 1 | 43.83 |

Figure 76: Distribution of zooplankton assemblages for March 2011 surveys, along with temperature and salinity values obtained from CTD profiles at the time of sampling, and simplified dendrogram showing the taxa characteristic of each assemblage characterised using indicator values (indVal). Selected taxa are those for which IndVal >= 25 (see method in Section 1.5).



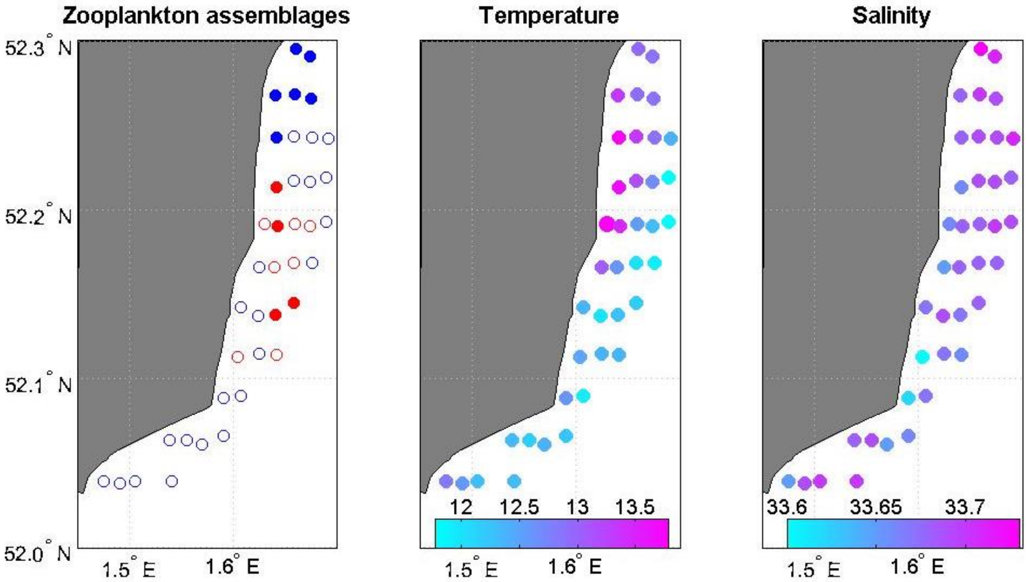

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Annelida | Polychaeta | 0.41 | 1 | 41.37 |
| Copepoda | *Temora spp.* | 1 | 0.29 | 28.57 |
| Mysida | Mysidae | 0.27 | 1 | 27.06 |

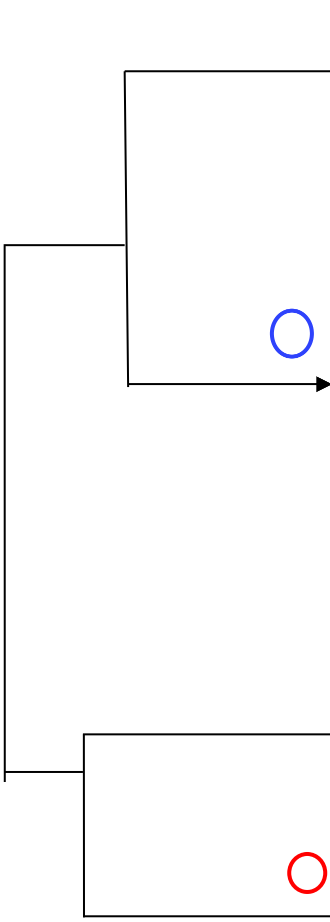
| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Bryozoa | Bryozoa | 0.89 | 1 | 88.83 |
| Annelida | Polychaeta | 0.59 | 1 | 58.63 |
| Copepoda | Harpacticoida | 0.56 | 1 | 56.03 |
| Mysida | Mysidae | 0.45 | 1 | 44.68 |
| Cirripedia | Cirripedia | 0.64 | 0.38 | 24.48 |
| Copepoda | Cyclopoida | 0.26 | 0.92 | 24.27 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | Cyclopoida | 0.39 | 1 | 38.77 |
| Foraminifera | Foraminifera | 0.32 | 1 | 31.83 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Foraminifera | Foraminifera | 0.46 | 1 | 45.96 |
| Amphipoda | Gammaridae | 0.4 | 0.71 | 28.77 |

Figure 77: Distribution of zooplankton assemblages for April 2011 surveys, along with temperature and salinity values obtained from CTD profiles at the time of sampling, and simplified dendrogram showing the taxa characteristic of each assemblage characterised using indicator values (indVal). Selected taxa are those for which IndVal >= 25 (see method in Section 1.5).



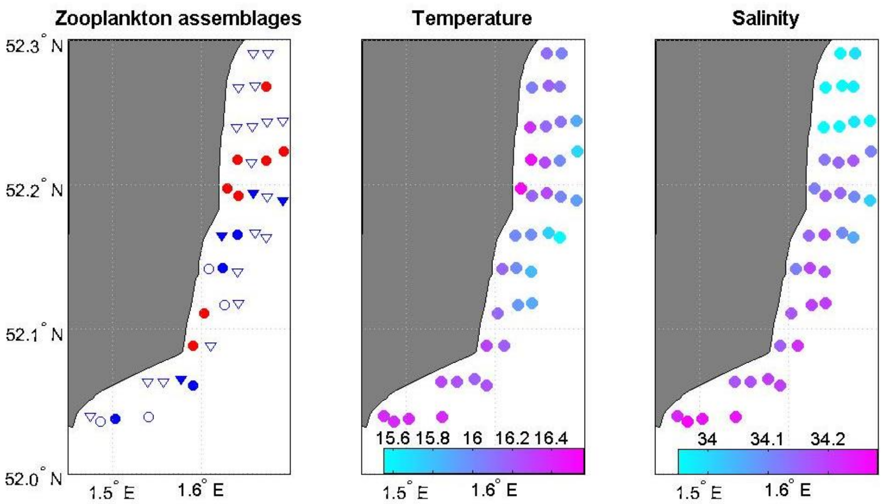
| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Mysida | Mysidae | 0.42 | 1 | 41.62 |
| Copepoda | *Acartia spp.* | 0.57 | 0.67 | 37.95 |
| Eucarida | Decapoda | 0.29 | 1 | 29.4 |

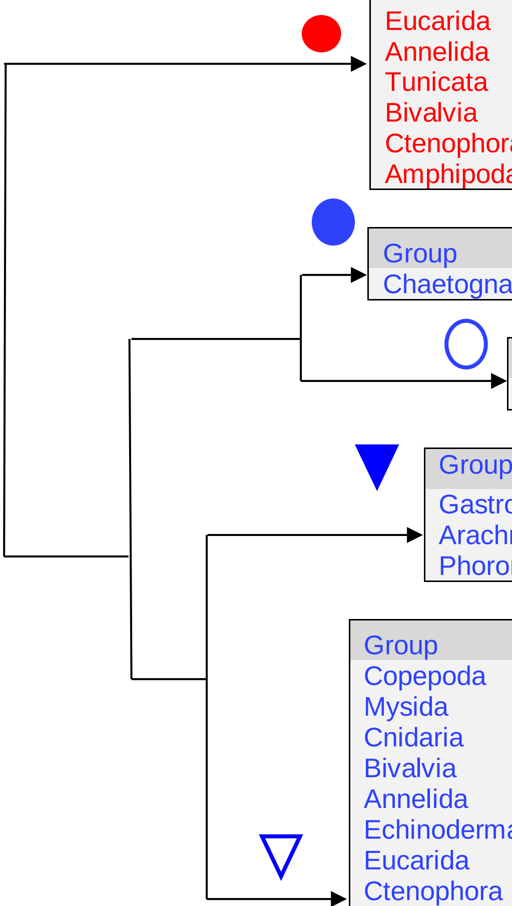
| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Cnidaria | Cnidaria | 0.95 | 0.91 | 86.79 |
| Bryozoa | Bryozoa | 0.81 | 0.91 | 73.4 |
| Bivalvia | Bivalvia | 0.67 | 1 | 67.33 |
| Echinodermata | Echinodermata | 0.69 | 1 | 68.75 |
| Rotifera | Rotifera | 0.69 | 1 | 68.5 |
| Annelida | Polychaeta | 0.67 | 0.95 | 63.53 |
| Tunicata | Appendicularia | 0.58 | 1 | 58.83 |
| Foraminifera | Foraminifera | 0.6 | 0.95 | 57.4 |
| Copepoda | *Temora spp.* | 0.52 | 0.95 | 49.67 |
| Eucarida | Decapoda | 0.49 | 1 | 49.29 |
| Ctenophora | Ctenophora | 0.49 | 1 | 48.75 |
| Mysida | Mysidae | 0.46 | 0.95 | 43.69 |
| Copepoda | Harpacticoida | 0.81 | 0.36 | 29.29 |
| Peracarida | Cumacea | 0.59 | 0.41 | 24.25 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Phoronida | Phoronida | 0.58 | 0.75 | 43.42 |
| Copepoda | Cyclopoida | 0.35 | 1 | 35.02 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Protozoa | Protozoa | 0.41 | 0.86 | 34.79 |
| Ctenophora | Ctenophora | 0.28 | 1 | 27.84 |
| Rotifera | Rotifera | 0.25 | 1 | 25.25 |
| Copepoda | *Centropages spp.* | 0.29 | 0.86 | 24.79 |

Figure 78: Distribution of zooplankton assemblages for May 2011 surveys, along with temperature and salinity values obtained from CTD profiles at the time of sampling, and simplified dendrogram showing the taxa characteristic of each assemblage characterised using indicator values (indVal). Selected taxa are those for which IndVal >= 25 (see method).



| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Foraminifera | Foraminifera | 0.48 | 0.88 | 42.14 |
| Eucarida | Decapoda | 0.29 | 1 | 29.33 |
| Annelida | Polychaeta | 0.33 | 0.88 | 28.72 |
| Tunicata | Appendicularia | 0.28 | 1 | 27.89 |
| Bivalvia | Bivalvia | 0.26 | 1 | 25.9 |
| Ctenophora | Ctenophora | 0.26 | 1 | 25.67 |
| Amphipoda | Gammaridae | 0.65 | 0.38 | 24.73 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Chaetognatha | Chaetognatha | 1 | 0.25 | 25 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Bryozoa | Bryozoa | 0.24 | 1 | 23.84 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Gastropoda | Gastropoda | 0.4 | 1 | 39.7 |
| Arachnida | Arachnida | 1 | 0.25 | 25 |
| Phoronida | Phoronida | 0.6 | 0.5 | 29.76 |

| Group | Taxon | Aij | Bij | IndVal (%) |
|---|---|---|---|---|
| Copepoda | Cyclopoida | 0.82 | 0.94 | 77.06 |
| Mysida | Mysidae | 0.64 | 0.89 | 56.79 |
| Cnidaria | Cnidaria | 0.52 | 1 | 52.29 |
| Bivalvia | Bivalvia | 0.52 | 1 | 51.54 |
| Annelida | Polychaeta | 0.51 | 1 | 50.82 |
| Echinodermata | Echinodermata | 0.67 | 0.72 | 48.11 |
| Eucarida | Decapoda | 0.47 | 1 | 46.93 |
| Ctenophora | Ctenophora | 0.46 | 1 | 45.81 |
| Tunicata | Appendicularia | 0.45 | 1 | 45.32 |
| Copepoda | Harpacticoida | 0.42 | 1 | 42.42 |
| Copepoda | *Temora spp.* | 0.43 | 0.94 | 40.5 |
| Copepoda | *Acartia spp.* | 0.44 | 0.89 | 39.46 |
| Foraminifera | Foraminifera | 0.37 | 0.94 | 35.19 |
| Bryozoa | Bryozoa | 0.34 | 0.83 | 28.68 |

Figure 79: Distribution of zooplankton assemblages for June 2011 surveys, along with temperature and salinity values obtained from CTD profiles at the time of sampling, and simplified dendrogram showing the taxa characteristic of each assemblage characterised using indicator values (indVal). Selected taxa are those for which IndVal >= 25 (see method).

# 6 Overview of the zooplankton off Sizewell

## 6.1 Characteristic ichthyoplankton taxa

A total of 51 taxa of fish eggs and larvae were identified, the most important ichthyoplankton taxa are identified in Table 3. Higher abundances of fish eggs and larvae were generally found in June-July. Anchovy, Dover sole, and sprat were the most dominant species accounting for over 95% of the total egg abundance across the full sampling period. Rockling and seabass eggs also accounted for over 1% of the total abundance. Solenette, unidentified specimens, lesser weever, pilchard, and mackerel all contributed to the top ten most abundant species (99.84% of total egg abundance). Rockling and sprat eggs started to appear in March, followed by Dover sole eggs in April and seabass eggs in May. The highest number of fish eggs was found in June-July and mostly comprised of anchovy (Figure 80).

Fish larvae were dominated to a lesser extent by a few highly abundant taxa. Seven taxa accounted for over 90% of abundance and included gobies, unidentified clupeids, herring, sprat, Dover sole, anchovy, and sandeels. Unidentified specimens, seabass and pilchards completed the top ten most abundant species (98.66% of total larvae). Larvae of clupeids and sandeel started to appear in April followed by Dover sole in May, goby in June and anchovy in July. Anchovy have recently become re-established in the North Sea and appeared to be increasing year on year in the Sizewell area, to the stage where they now major component of the ichthyoplankton population and have the most abundant eggs (72.67%; Figure 80).

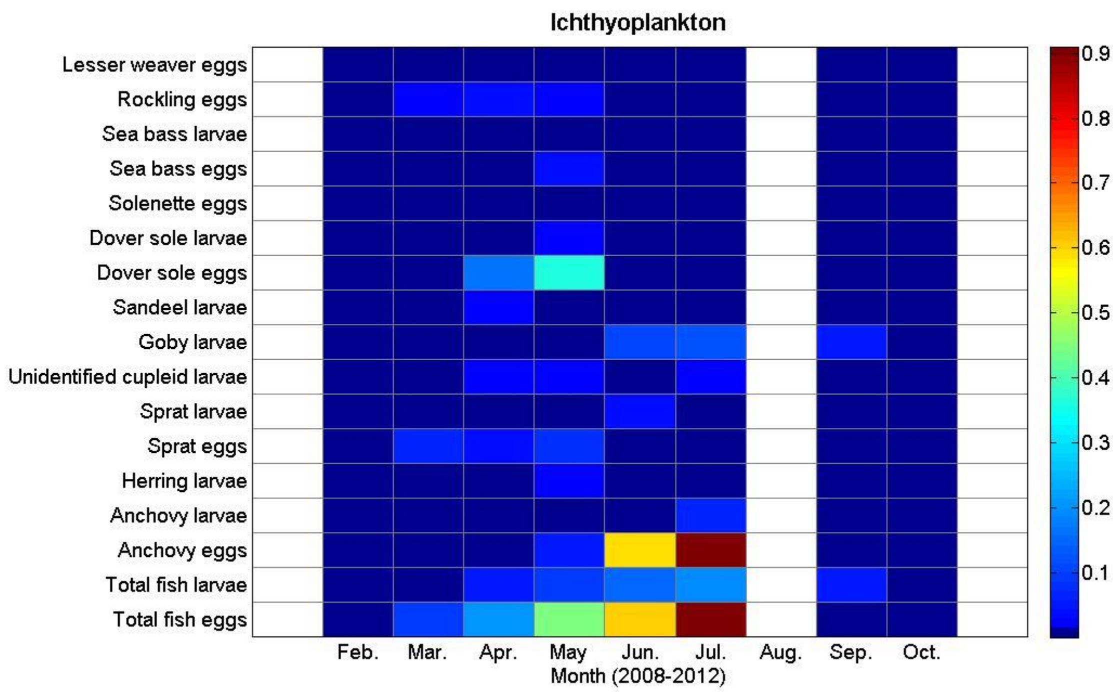



Figure 80: Seasonality for available months and across years of study using ichthyoplankton data from Sizewell area (scale bar is average abundance per month $Log_{10}(n+1)$ ind.m$^{-3}$).

### 6.1.1 Characteristic ichthyoplankton taxa compared to 2014 – 2017 surveys

The trend in ichthyoplankton observed here was consistent with subsequent sampling between 2014-2017 (BEEMS Technical Report TR454). Anchovy was the dominant ichthyoplankton group with eggs accounting for up to 81% of the total ichtyoplankton abundance in 2016-2017. In 2015-16 lower numbers of anchovy were found and Dover sole eggs dominated the ichthyoplankton. However, the lower anchovy numbers in 2015-2016 may be due to timing of the survey as the peak abundance may have been missed as the eggs are short lived in the plankton. Sprat and sole eggs also continued to be found regularly. Other fish eggs included seabass were observed from March to June, rocklings were recorded during March to July and sprat and solenette in April to June, all of which consisted of ≤ 1% of the total ichthyoplankton abundance for each year. After the anchovy spawning period finished in September, very few eggs were found until the following February.

Gobies continued to be the most abundant larvae in 2015-16 and 2016-17 surveys but few fish larvae were found throughout the three survey years. The most common larval group were Clupeidae (likely a mix of sprat and herring), which were most abundant in 2014-15 (BEEMS Technical Report TR454). Fewer taxonomic groups of ichthyoplankton were found from 2014-17 with 38 taxa including eggs and larvae compared to 51 in this report.

### 6.1.2 Ichthyoplankton proposed for ES assessments

The ES draws on a range of data sources to make predictions about the potential effects of development impacts on fish. Ichthyoplankton are part of the life history stages of the fish assemblage at Sizewell. The fish assemblage was characterised at Sizewell as part of BEEMS Technical Report TR345 and the key taxa were identified. This section contextualises the results from the 2008-2012 ichthyoplankton surveys (this study) in relation to entrainment sampling at Sizewell B, entrainment predictions for the proposed Sizewell C development, and the key taxa selected as part of the wider fish assemblage at Sizewell.

Between May 2010 and May 2011 plankton samples were collected from the cooling water system of Sizewell B power station and ichthyoplankton entrainment rates were established (BEEMS Technical Report TR235). Anchovy and sole dominated the egg entrainment rates at Sizewell B, whilst the larvae of gobies and clupeids were the most numerous in entrainment samples (BEEMS Technical Report TR235). Entrainment rates established in BEEMS Technical Report TR235 and *in-situ* ichthyoplankton abundance reported herein was used to inform entrainment predictions for Sizewell C (BEEMS Technical Report TR318).

Fish eggs identified in this report corresponded to the entrainment samples at Sizewell B (Table 7). Based on the relative abundance of eggs collected between 2008-2012, entrainment predictions for Sizewell C have provided estimates for taxa contributing to over 98% of the total *in-situ* abundance. Species that account for the top 95% of eggs (anchovy, Dover sole and sprat) also form part of the key fish assemblage at Sizewell (Table 7).

Larvae from ichthyoplankton samples collected in the field corresponded well with the entrainment sampling at Sizewell B and most larvae identified in the top 10 most abundant species in this report have been assessed in terms of entrainment predictions for Sizewell C (Table 8). The exceptions are anchovy and seabass, which were not observed in larvae entrainment studies at Sizewell B. All of the larvae identified to species level from the ichthyoplankton surveys form part of the key fish taxa at Sizewell, with the exception of pilchard and sandeels (Table 8).

Table 7 Comparison between the data for the most abundant 10 fish egg collected during *in-situ* surveys (this report) and entrainment sampling at Sizewell B (BEEMS Technical Report TR235). Taxa that have been subject to entrainment predictions (BEEMS Technical Report TR318) are indicated. Eggs of fish species that have been identified as key taxa for the wider fish assemblage at Sizewell are identified (BEEMS Technical Report TR345). Species that contribute to over 1% of the total egg abundance are shown in bold.

| Fish eggs - TR315 | | | | | Entrainment sampling (2010-2011) rank of annual entrainment (TR235) | Entrainment predictions estimated for SZC (TR318) | Component of the Sizewell Key Fish Taxa TR345) | | |
|---|---|---|---|---|---|---|---|---|---|
| Taxa | Positive samples (*n* = 585 samples) | Contribution to total ichthyoplankton abundance (eggs and larvae) (%) | Contribution to total egg abundance (%) | Cumulative abundance (%) | | | Ecological importance | Socio-Economic Importance | Conservation importance |
| **Anchovy (*Engraulis encrasicolus*)** | 183 (31.28%) | 64.39 | 72.67 | 72.67 | 1 | ✓ | ✓ | · | · |
| **Dover sole (*Solea solea*)** | 215 (36.75%) | 15.70 | 17.72 | 90.38 | 2 | ✓ | ✓ | ✓ | ✓ |
| **Sprat (*Sprattus sprattus*)** | 196 (33.50%) | 4.57 | 5.16 | 95.54 | 6 | ✓ | ✓ | · | · |
| **Rockling (Lotidae)** | 175 (29.92%) | 1.36 | 1.53 | 97.08 | 7 | ✓ | · | · | · |
| **Seabass (*Dicentrarchus labrax*)** | 34 (5.81%) | 1.10 | 1.24 | 98.32 | 5 | ✓ | ✓ | ✓ | ✓ |
| Unidentified specimen | 77 (13.16%) | 0.46 | 0.52 | 98.84 | NA | x | · | · | · |
| Solenette (*Buglossidium luteum*) | 37 (6.33%) | 0.27 | 0.30 | 99.14 | - | x | · | · | · |
| Lesser weever (*Echiichthys vipera*) | 38 (6.50%) | 0.24 | 0.27 | 99.41 | 11 | ✓ | · | · | · |
| Pilchard (*Sardina pilchardus*) | 21 (3.59%) | 0.23 | 0.26 | 99.67 | 4 | ✓ | · | · | · |
| Mackerel (*Scomber scombrus*) | 15 (2.56%) | 0.15 | 0.17 | 99.84 | - | x | · | · | ✓ |

Table 8 Comparison between the data for the most abundant 10 fish larvae collected during *in-situ* surveys (this report) and entrainment sampling at Sizewell B (BEEMS Technical Report TR235). Taxa that have been subject to entrainment predictions (BEEMS Technical Report TR318) are indicated. Larvae of fish species that have been identified as key taxa for the wider fish assemblage at Sizewell are identified (BEEMS Technical Report TR345). Species that contribute to over 1% of the total larvae abundance are shown in bold.

| Fish eggs - TR315 | | | | | Entrainment sampling (2010-2011) rank of annual entrainment (TR235) | Entrainment predictions estimated for SZC (TR318) | Component of the Sizewell Key Fish Taxa TR345) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | **Positive samples (*n* = 585 samples)** | **Contribution to total ichthyoplankton abundance (eggs and larvae) (%)** | **Contribution to total larvae abundance (%)** | **Cumulative abundance (%)** | | | **Ecological importance** | **Socio-Economic Importance** | **Conservation importance** |
| **Gobies (Gobidae)** | 181 (30.94%) | 4.14 | 36.87 | 36.87 | 1 | ✓ | ✓ | | |
| **Unidentified clupeids (Cupleidae)** | 154 (26.32%) | 1.80 | 16.03 | 52.89 | NA | NA | | | |
| **Herring (*Clupea harengus*)** | 70 (11.97%) | 1.26 | 11.22 | 64.11 | 2 | ✓ | ✓ | ✓ | ✓ |
| **Sprat (*Sprattus sprattus*)** | 76 (12.99%) | 0.90 | 8.01 | 72.13 | 4 | ✓ | ✓ | | |
| **Dover sole (*Solea solea*)** | 58 (9.92%) | 0.83 | 7.39 | 79.52 | 9 | ✓ | ✓ | ✓ | ✓ |
| **Anchovy (*Engraulis encrasicolus*)** | 30 (5.13%) | 0.79 | 7.03 | 86.55 | - | x | ✓ | | |
| **Sandeels (Ammodytidae)** | 86 (14.70%) | 0.66 | 5.88 | 92.43 | 10 | ✓ | | | |
| **Unidentified specimen** | 52 (8.89%) | 0.36 | 3.21 | 95.64 | NA | x | | | |
| **Seabass (*Dicentrarchus labrax*)** | 31 (5.30%) | 0.22 | 1.96 | 97.60 | - | x | ✓ | ✓ | ✓ |
| **Pilchard (*Sardina pilchardus*)** | 12 (2.05%) | 0.12 | 1.07 | 98.66 | 7 | ✓ | | | |

## 6.2 Invertebrate zooplankton communities / assemblages

Multivariate analysis indicates that the structure of the zooplankton community changes from survey to survey and year to year, as a consequence of seasonal and interannual variability; hence the reference to assemblages rather than communities. Previous analysis on the 2010 and 2011 datasets suggested differences in abundance of taxa between the two years which were perhaps a reflection of differences in environmental conditions (BEEMS Technical Report TR202); it is however impossible to validate this hypothesis statistically with only 2 years of comparable data. A study on Sizewell plankton communities using data from samples collected in 2012 (see figures in Appendix A for sampling locations) showed some small differences in the communities present on both sides of the Sizewell-Dunwich Bank (

Figure 1), which were driven mostly by varied abundances of mainly copepod nauplii and invertebrate eggs but also foraminifera and harpacticoid copepods (BEEMS Technical Report TR276).

In the present study, invertebrate eggs and copepod nauplii were removed from the analyses to prevent changes in abundance of the most abundant and poorly taxonomically resolved groups influencing the results. No notable difference in community composition between stations located inshore and offshore of the Sizewell-Dunwich Bank was observed. There appears to be a north-south and/or east-west gradient, in coincidence with a temperature and/or a salinity gradient (Figure 73 - Figure 79). The variation in species distribution might be driven by temperature or salinity but could also be the result of sampling bias from the natural patchiness of the plankton distribution combined with the strong tidal currents in the area.

Further studies completed monthly between March 2014 and January 2017 specifically investigated spatial and intra-annual (seasonal) differences in zooplankton communities at a restricted number of sites at the SZB intakes, SZB outfalls and the proposed location of the SZC cooling water infrastructure. Data collected from these surveys investigated differences in the relative abundance of the major species temporally and between sites (BEEMS Technical Reports TR326; TR379; TR454).

## 6.3 Characteristic invertebrate zooplankton taxa of Sizewell Bay

A total of 38 invertebrate taxa were identified from the small and larger zooplankton size fractions as being potentially ecologically important during the 2008-2012 surveys and are provided in section 4. Monthly sampling as part of the 2014-2017 BEEMS surveys identified that chaetognaths (arrow worms) and *Calanus* spp. copepods are also important components of the invertebrate zooplankton communities and should be considered as characteristic species (section 6.3.3).

### 6.3.1 Characteristic taxa of the larger zooplankton size fraction (> 4 mm)

Mysids (76.87 %) and ctenophores (10.33%) are the dominant components of the larger zooplankton size fraction. Seasonally, the first taxa to appear within the larger zooplankton size fraction are the gammarids which are present from as early as February and are common in zooplankton samples. Cumacea and polychaete larvae appear in April, followed by cnidaria and decapods larvae in May. The highest number of individuals occurs in May and remains high up to at least July; these are largely dominated by mysids. Polychaete larvae are also high contributors to the total abundance in June (Figure 81). Ctenophores are of interest, because they tend to appear in very high numbers and have to potential to interfere with power station cooling water systems and reducing operational efficiency.

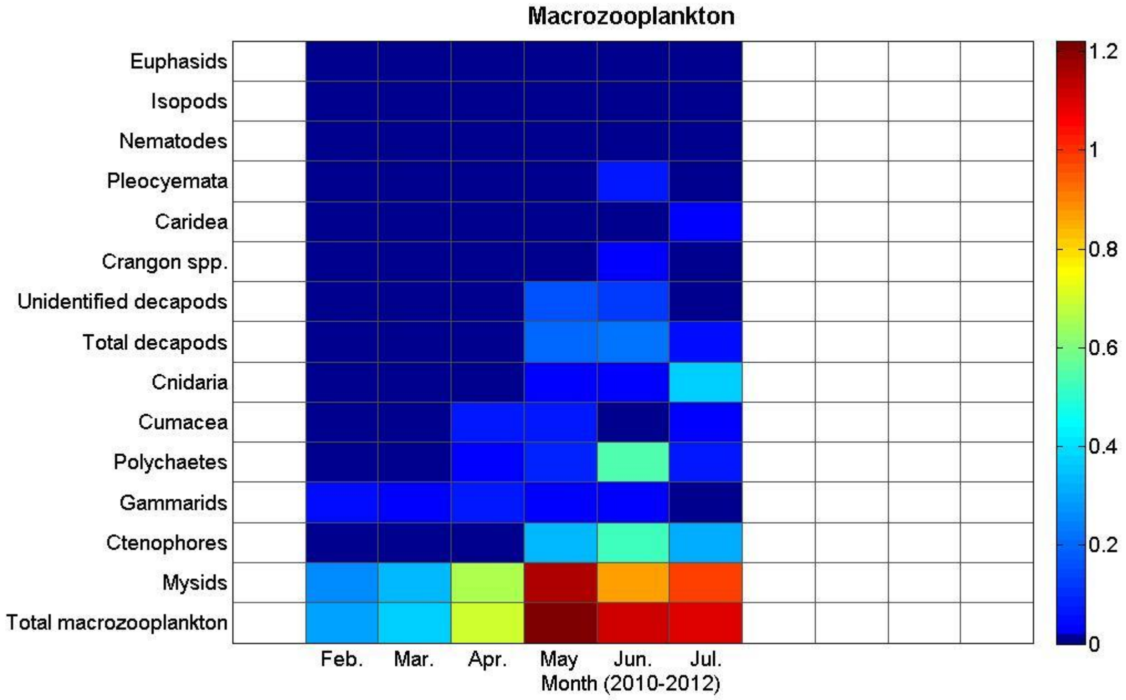



Figure 81: Seasonal abundance of the large size fraction zooplankton for available months and across years of study from the Sizewell area (scale bar is average abundance per month Log10(n+1) ind.m$^{-3}$).

### 6.3.2 Characteristic taxa of the smaller zooplankton size fraction (≤ 4 mm)

The smaller size fraction zooplankton represent the most abundant zooplankton group. Copepods form an abundant and common component of the smaller zooplankton community. They are present throughout the sampling period (February to July). Most taxa see their abundance peak in May. The abundance of juvenile and adult copepods increases from April and remains high through to July, in line with the appearance of fish larvae in the water (Figure 82).

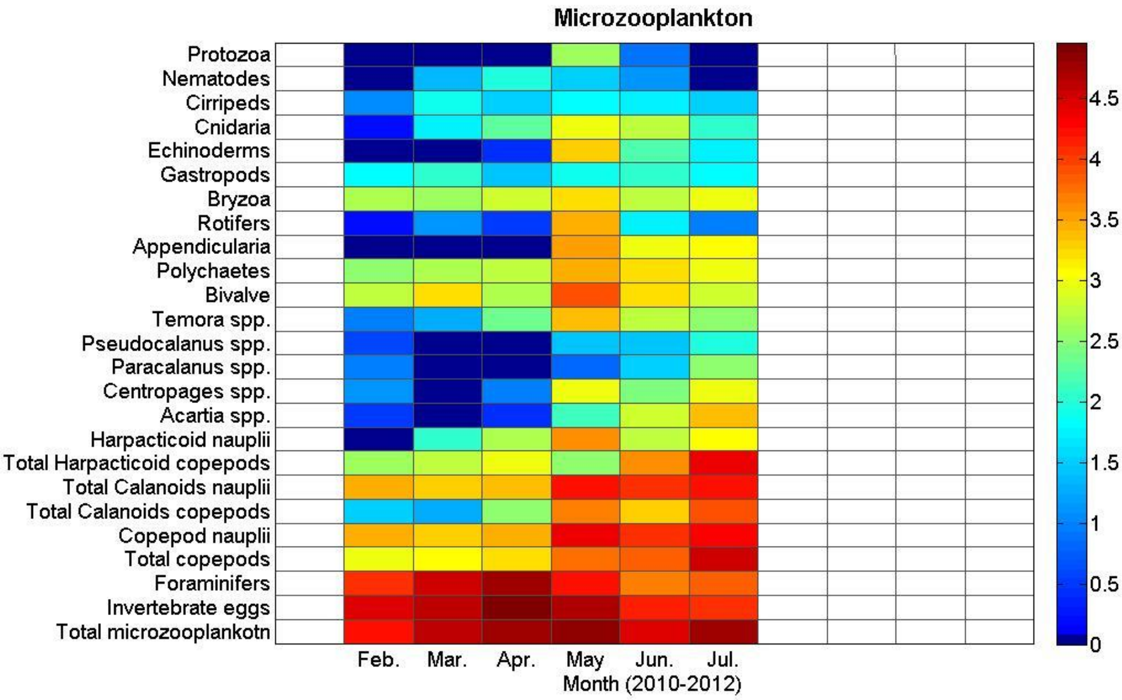



Figure 82: Seasonal abundance of the small size fraction zooplankton for available months and across years of study from the Sizewell area (scale bar is average abundance per month). $Log_{10}(x+1)$ $ind.m^{-3}$

Table 9. Characteristic zooplankton of Greater Sizewell Bay. Positive samples = % of BEEMS samples in which the taxon was present, out of the 468 analysed for the larger size fraction zooplankton and 398 analysed for the smaller size fraction zooplankton.

| | Taxon | Positive samples | Contribution to total abundance |
|---|---|---|---|
| Larger size fraction zooplankton (> 4 mm) | Mysids | 97.01 % | 76.87 % |
| | Comb jellies (Ctenophora) | 59.19 % | 10.33 % |
| | Polychaete larvae (Polychaeta) | 38.89 % | 5.81 % |
| | Unidentified Decapoda larvae | 20.94 % | 2.19 % |
| | Jellyfish (Cnidaria) | 27.56 % | 1.59 % |
| | Gammaridae (Amphipoda) | 42.74 % | 0.86 % |
| | Hooded shrimps (Cumacea) | 29.06 % | 0.74 % |
| | Unidentified Pleocyemata (Pleocyeamate decapods) | 9.62 % | 0.36 % |
| | *Crangon* spp. (Decapoda, Pleocyemata, Caridea) | 15.39 % | 0.35 % |
| | Unidentified shrimps and prawns (Caridean decapods) | 17.74 % | 0.32 % |
| | Nematodes | 11.54 % | 0.14 % |
| | Unidentified isopoda | 7.05 % | 0.08 % |
| | Krills (Euphausiidae) | 5.28 % | 0.04 % |
| Smaller size fraction zooplankton (≤ 4 mm) | Invertebrate eggs | 97.99 % | 39.30 % |
| | Foraminifera | 95.73 % | 19.18 % |
| | Copepod nauplii (copepoda) | 91.46 % | 15.96 % |
| | Unidentified Harpacticoids (copepoda, harpacticoida) | 58.29 % | 5.24 % |
| | Bivalve larvae (Bivalva) | 76.13 % | 4.31 % |
| | Polychaete larvae (Polychaeta) | 76.13 % | 2.32 % |
| | Harpacticoid nauplii (copepoda, harpacticoida) | 15.08 % | 2.08 % |
| | Appendicularia (tunicata) | 52.01 % | 2.04 % |
| | Bryozoa | 70.35 % | 1.29 % |
| | Unidentified calanoids (copepoda, calanoida) | 47.74 % | 1.25 % |
| | *Temora* spp. (copepoda, calanoida) | 55.53 % | 1.22 % |
| | Rotifers (Rotifera) | 24.12 % | 1.13 % |
| | Echinoderm larvae (echinodermata) | 37.94 % | 0.88 % |
| | Unidentified cyclopoids (copepoda, cyclopoida) | 51.01 % | 0.72 % |
| | Jellyfish and hydrozoa (cnidaria) | 29.65 % | 0.69 % |
| | *Centropages* spp. (copepoda, calanoida) | 46.23 % | 0.64 % |
| | *Acartia* spp. (copepoda, calanoida) | 37.69 % | 0.58 % |
| | Unidientified copepods (copepoda) | 21.36 % | 0.15 % |
| | Protozoa | 6.03 % | 0.15 % |
| | Gastropod larvae (gastropoda) | 23.87 % | 0.12 % |
| | Barnacle larvae (cirripedia) | 17.09 % | 0.08 % |
| | *Paracalanus* spp. (copepoda, calanoida) | 10.30 % | 0.06 % |
| | *Pseudocalanus* spp. (copepoda, calanoida) | 9.05 % | 0.04 % |
| | Arachnida | 6.78 % | 0.04 % |
| | Nematoda | 7.29 % | 0.03 % |

### 6.3.3 Characteristic taxa compared to 2014 – 2017 zooplankton surveys

Additional sampling was undertaken between 2014 and 2017 with the aim to understand the temporal and spatial variability at the SZB intake, SZB outfall and the proposed SZC intake/outfall over a three-year period. Sampling occurred monthly, beginning in March 2014 and ended in January 2017. The monthly sampling allowed a greater understanding of the full seasonal cycle of the zooplankton. The results from the 2014-2017 surveys (BEEM Technical Reports TR454) in comparison to the characterisation surveys between 2008-2012 are provided below.

The characteristic zooplankton taxa identified within this report are consistent with the subsequent surveys (2014-2017; BEEMS Technical Report TR454). In total, 62 taxonomic groups were identified as part of the larger size fraction zooplankton from 2014-2017 compared to 31 identified in this report. This was due to a greater level of taxonomic identification and infrequently found taxa contributing to the difference. Despite more taxonomic groups, the same taxa dominated. Mysids continued to be the most dominant taxa. Mysids reversed the trend observed from 2010-12 by increasing in numbers and had the greatest abundance inshore at the SZB outfall and intake sites from May to September. Gelatinous zooplankton also continued to be numerous in 2014-15 and 2015-16 but were considerably less numerous in 2016-17 with no single large peak in abundance.

The monthly sampling identified a peak in chaetognaths abundance from September to November each year when no sampling had previously been conducted. Chaetognaths contributed to 14.7% of the total annual abundance of the larger size fraction zooplankton in the 2016-17 sampling year and therefore should be considered a characteristic component of the zooplankton community (outlined in Table 9). In addition, the large *Calanus* spp. copepods were infrequently found in the pup (80 µm mesh) samples. However, they were present in larger numbers in the main samples (270 µm mesh) samples. As a result, from the 2015-16 and 2016-17 surveys they were picked out from main samples (despite being < 4mm). *Calanus* spp. copepods were found to be abundant at the SZC intake/outfall site contributing to 2.9% of the total larger size fraction zooplankton abundance in 2016-17 compared to the inshore sites where they consisted of 0.1% of the total abundance combined. Small differences were observed in the zooplankton community between the Sizewell B intake, Sizewell B outfall, and proposed Sizewell C cooling water infrastructure sampling sites. These differences were driven by variable abundances of the most abundance species. However, there was evidence for higher mysid abundance at the SZB outfall in comparison to the SZB intakes and SZC sites (BEEMS Technical Report TR454).

The smaller size fraction zooplankton consisted of 60 taxonomic groups in 2014-2017, compared to 48 reported here. Invertebrate eggs, copepod nauplii and foraminifera continued to be the three most numerous taxa. Seasonal and interannual differences were observed in the smaller zooplankton community. *Acartia* spp was the most dominant calanoid copepod compared to *Temora longicornis* reported here. Differences between the SZB outfall, SZB intakes and SZC sites were observed with the relative abundance of invertebrate eggs, copepod nauplii and foraminifera the main cause for the dissimilarity between sites. In general, the total abundance of the smaller zooplankton at SZB outfall was lower than the other two sites. However, considerable temporal, and taxa-specific variation occurred (BEEMS Technical Report TR454).

### 6.3.4 Characteristic taxa in comparison to the CPR

The profiles for each of the selected invertebrate zooplankton taxonomic groups broadly agree with those obtained from the long-term CPR survey, thus showing that the zooplankton found off Sizewell are typical of the area. But because of differences in the sampling methodologies employed by each survey some discrepancies arise. The CPR operates at a fixed depth (i.e. approximately 10 m) at more offshore locations (therefore generally deeper) while the BEEMS Sizewell survey samples the entire water column at more onshore, shallower locations. BEMMS surveys are more likely to catch some of the benthic associated and bentho-pelagic species than the CPR. Taxonomic groups with profiles from the CPR and Sizewell datasets that are at odds with each other are gammarids (Figure 27-31) and cumacea (Figure 31-35), both groups have a benthic association, but also mysids (Figure 24-28) which are bentho-pelagic. The advantage of the CPR is its extensive spatio-temporal coverage, thus allowing us to explore the long-term changes of each taxa within the wider environment.

## 6.4 Key zooplankton taxa for consideration in the EIA

As part of the Development Consent Order (DCO) for nationally significant infrastructure projects, an Environmental Impact Assessment (EIA) is required for the proposed development of Sizewell C power station. The potential impacts of the proposed development on the marine ecology of the area effected must be assessed relative to baseline conditions. This report characterises the zooplankton communities within the vicinity of the proposed development and identified 38 taxa that characterise the invertebrate zooplankton communities (Table 9). Two further taxa identified in subsequent monthly sampling campaigns between 2014-2017 (section 6.3.3). The characteristic taxa are consistent with CPR data of the species found in the wider southern North Sea.

Identification of key taxa allows a starting point for evidence-based assessments of impacts from the proposed development on representative species or species groups. It should be noted that key zooplankton taxa are identified for impact assessment and monitoring approaches, designed to determine impacts of the proposed development, would consider the zooplankton community, and not necessarily be restricted to the key taxa.

Key zooplankton taxa for the ES are selected based on the ecological importance and potential socio-economic importance. None of the zooplankton reported here have direct commercial value[3].

The key zooplankton taxa for assessment purposed include mysids, amphipods, gelatinous zooplankton and copepods (Table 10). These species are common and abundant in the coastal waters off Sizewell and are considered to be ecologically important components of the food-web. Gelatinous zooplankton, are both abundant and important for the EIA due to their potential socio-economic importance. Gelatinous zooplankton are an important consideration for power plants (Gunasingh Masilamoni *et al.,* 2000), due to their gelatinous nature and propensity for populations to expand exponentially (i.e. to from "blooms"), resulting in the potential to cause blockage of the cooling water intake filters of power stations, which in severe cases can lead to station shutdown (Schrope, 2012).

The selected taxonomic groupings provide an initial starting point for the assessment of impacts of activities associated with the proposed development. These taxa may be applied as proxies for the wider zooplankton community as they are relatively well studied allowing a pragmatic approach to evidence-based sensitivity assessments for a range of development impacts.

Invertebrate eggs and single-celled foraminifera are not selected as key taxa for EIA purposes despite being present in 98% and 96% of samples, respectively. Invertebrate eggs is a generic grouping encompassing a diverse range of taxa including benthic species with planktonic egg stages and zooplankton eggs. Foraminifera represent a diverse group of single celled protozoa, which whilst abundant are unlikely to be effectively sampled.

Ichthyoplankton are assessed as part of the life-stage vulnerably assessments in the fish assessments (Section 6.1.2). Benthic larvae are assessed as part of the life-stage vulnerably assessments in the benthic community assessments.

[3] Due to the suitability of sampling equipment, hyper-benthic *Crangon* spp. are considered within the Benthic Characterisation.

Table 10 Key representative zooplankton taxa for consideration during Environmental Impact Assessments

| Taxonomic grouping | Key taxa | Comments |
|---|---|---|
| Mysids | Mysids were not identified to species level.<br><br>Based on subsequent surveys species are likely to include *Schistomysis spiritus, Siriella sp., Mysidopsis sp. and Schistomysis sp.*<br><br>*Schistomysis spiritus* is the most abundant species. | Bentho-pelagic mysids were present in over 97 % of the larger size fraction zooplankton samples and were the most abundant taxa accounting for over 76% of total abundance.<br><br>Mysids have high ecological value as the most abundant and common zooplankton taxa from the larger size fraction. |
| Gelatinous zooplankton | - Ctenophores or sea gooseberries (not identified to species level)<br><br>- Cnidarians or jellyfish (not identified to species level) | Pelagic ctenophores and jellyfish were caught in over 59% and 27% of larger size fraction zooplankton samples, respectively and can dominate the plankton.<br><br>Gelatinous zooplankton have socio-economic importance due to their potential to reduce the efficiency of power station cooling water cooling systems. They many also be unsightly and have the potential to sting causing potential effects to coastal tourism. |
| Amphipods | - Gammarids<br><br>- Hyperiids<br><br>- Caprellids<br><br>- Corophiids | Amphipods are present in half the larger size fraction zooplankton samples.<br><br>Gammarids are the most common and abundant amphipod taxa and are typically benthic or epibenthic making periodic excursions to the water column. Shallow water depths and tidal currents account for the commonality of gammarids in plankton surveys.<br><br>Amphipods are selected based on their ecological value. |
| Copepods | - Copepod nauplii<br><br>- Harpacticoids (all species)<br><br>- Cyclopoids (all species)<br><br>- Calanoids (all species) | Copepods represent a diverse group of zooplankton for assessment purposes and include benthic (harpacticoid) and pelagic species.<br><br>Copepods were always present in samples of the smaller size fraction and accounted for approximately 28% of the total abundance of all taxa.<br><br>Copepods have high ecological value (abundant and common) and are important food source for fish, other zooplankton and benthic invertebrate larvae. |

# 7 References

Batten, S. D., Clark, R., Flinkman, J., Hays, G., John, E., John, A. W. G., . . . Walne, A. (2003). CPR sampling: the technical background, materials and methods, consistency and comparability. *Progress in Oceanography, 58*, 193-215. doi:10.1016/j.pocean.2003.08.004

Beare, D. J., Batten, S. D., Edwards, M., McKenzie, E., Reid, P. C., & Reid, D. G. (2003). Summarizing spatial and temporal information in CPR data. *Progress in Oceanography, 58*, 217-233. doi:10.1016/j.pocean.2003.08.005

Beaugrand, G., Brander, K. M., Lindley, J. A., Souissi, S., & Reid, P. C. (2003). Plankton effect on cod recruitment in the North Sea. *Nature, 426*, 661-664.

BEEMS Technical Report TR069. *Sizewell nearshore communities: results of the 2 m beam trawl and plankton surveys 2008-2010.* Cefas, Lowestoft.

BEEMS Technical Report TR069a. *Sizewell nearshore communities: plankton surveys 2010*. Cefas, Lowestoft.

BEEMS Technical Report TR202. *Sizewell nearshore communities; plankton surveys 2011*. Cefas, Lowestoft.

BEEMS Technical Report TR201. *Sizewell nearlshore communities: results of the 2 m beam trawl and day grab surveys 2011-12.* Cefas, Lowestoft.

BEEMS Technical Report TR235. Comprehensive Entrainment Monitoring Programme (CEMP) 2010/11; Final Report. Pisces Conservation Limited.

BEEMS Technical Report TR276. *Sizewell plankton communities: 2012*. Cefas, Lowestoft.

BEEMS Technical Report TR318. *Predictions of entrainment by Sizewell C in relation to adjacent fish and invertebrate populations*. Cefas,Lowestoft.

BEEMS Technical Report TR326. *Sizewell plankton communities: 2014 – 2015.* Cefas, Lowestoft.

BEEMS Technical Report TR345.*Sizewell Characterisation Report Fish.* Cefas, Lowestoft

BEEMS Technical Report TR348.*Sizewell Benthic Ecology Characterisation*. Cefas, Lowestoft.

BEEMS Technical Report TR379. *Sizewell plankton communities: 2015-2016.* Cefas, Lowestoft.

BEEMS Technical Report TR431. Sizewell SPA/SAC features and associated marine prey species. Cefas,Lowestoft.

BEEMS Technical Report TR454. *Sizewell plankton communities: 2016-2017.* Cefas, Lowestoft.

BEEMS SOP0004v1. *Manual and procedures for the execution of subtidal Cefas BEEMS surveys. Standard Operating Porcedure (SOP).* Cefas

Campos, J., Pedrosa, C., Rodrigues, J., Santos, S., Witte, J. I., Santos, P., & van der Veer, H. W. (2009). Population zoogeography of brown shrimp *Crangon crangon* along its distributional range based on morphometric characters. *Journal of the Marine Biological Association of the U.K., 89*(3), 499-507. doi:10.1017/S0025315408002312

Colebrook, J. M. (1975). The continuous plankton recorder survey: automatic data processing methods. *Bulletin of Marine Ecology, 8*, 123-142.

Condon, R. H., Graham, W. M., Duarte, C. M., Pitt, K. A., Lucas, K. H., Haddock, S. H. D., . . . Madin, L. P. (2012). Questioning the Rise of Gelatinous Zooplankton in the World's Oceans. *BioScience, 62*(2), 160-169. doi: doi:10.1525/bio.2012.62.2.

Dufrene, M., & Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs, 67*(3), 345-366.

Edwards, M., Helaouet, P., N., H., Beaugrand, G., Fox, C., Johns, D. G., Licandro P., Lynam, C., Pitois, S., Stevens D., Combes, S., Fonseca, L. (2011). Fish Larvae Atlas of the NE Atlantic. Results from the Continuous Plankton Recorder survey 1948-2005 (pp. 22). Plymouth: Sir Alister Hardy Foundation for Ocean Science.

Finenko, G. A., Kideys, A. E., Anninsky, B. E., Shiganova, T. A., Roohi, A., Tabari, M., . . . Bagheri, S. (2006). Invasive ctenophore *Mnemiopsis leidyi* in the Caspian Sea: feeding, respiration, reproduction and predatory impact on the zooplankton community. *Marine Ecology Progress Series, 314*, 171-185.

Fox, C. J., Harrop, R., & Wimpenny, A. (1999). Feeding ecology of herring (Clupea harengus) larvae in the turbid Blackwater Estuary. *Marine Biology, 134*, 353-365.

Gunasingh Masilamoni, J., Jesudoss, K. S., Nankakumar, K., Satpathy, K. K., Nair, K. V. K., & Azariah, J. (2000). Jellyfish ingress: A threat to the smooth operation of coastal power plants. Current Science, 79(5): 567-569.

Heip, C., Vincx, M., & Vranken, g. (1985). *The ecology of marine nematodes* (Vol. 23): CRC Press.

Kanstinger, P., & Peck, M. A. (2009). Co-occurrence of European sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and sprat (*Sprattus sprattus*) larvae in southern North Sea habitats: Abundance, distribution and biochemical-based condition. *Scientia Marina, 73S1*, 141-152. doi:10.3989/scimar.2009.73s1141

Munk, P. & Nielsen, J.G. (2005) Eggs and larvae of North Sea Fishes. Biofolia Frederiksberg, Denmark, 215 pp.

Nash, R. D. M., & Dickey-Collas, M. (2005). The influence of life history dynamics and environment on the determination of year class strength in North Sea herring (*Clupea harengus L*.). *Fisheries Oceanography, 14*(4), 279-291. doi:10.1111/j.1365-2419.2005.00336.x

Nash, R. D. M., Dickey-Collas, M., & Milligan, S. P. (1998). Descriptions of the Gulf VII/PRO-NET and MAFF/Guideline unencased high-speed plankton samplers. *Journal of Plankton Research, 20*, 1915-1926.

Palmieri, M.G., Schaafsma, M., Luisetti, T., Barausse, A., Harwood, A., Sen, A. & Turner, R.K. (2015). Jellyfish Blooms and Their Impacts on Welfare Benefits: Recreation in the UK and Fisheries in Italy. In *Coastal Zones Ecosystem Services* (pp. 219-240). Springer International Publishing.

Poore, G. C. B., & Bruce, N. L. (2012). Global Diversity of Marine Isopods (Except Asellota and Crustacean Symbionts). *PLoS one, 7*(8), e43529. doi:10.1371/journal.pone.0043529

Reid, P. C., Colebrook, J. M., Matthews, J. B. L., & Aiken, J. (2003). The continuous plankton recorder: concepts and history, from plankton indicator to undulating recorders. *Progress in Oceanography, 58*, 117-173. doi: doi:10.1016/j.pocean.2003.08.002

Richardson, A. J., Bakun, A., Hays, G. C., & Gibbons, M. J. (2009). The jellyfish joyride: causes, consequences and management responses to a more gelatinous future. *Trends in Ecolog and Evolution, 24*, 312-322.

Russell, F. S. (1976). *The eggs and planktonic stages of British Marine Fishes*. London - New York - San Francisco: Academic Press.

Schaafsma M., Luisetti T., Turner K. (2013) Potential economic impacts of jellyfish invasions along the English Coast, with a special focus on the *Mnemiopsis leidyi*. MEMO project Activity 3 report.

Schrope, M. (2012). Marine ecology: attack of the blobs. *Nature*, *482*(7383), pp.20-21.

Vandendriessche, S. Vansteenbrugge, L., Hostens K. & Maelfait H. (2013) Jellyfish, jellypress and jellyperception. ILVO mededeling nr 142, ISSN 1784-3197, 21pp.

# Appendix A Zooplankton survey design

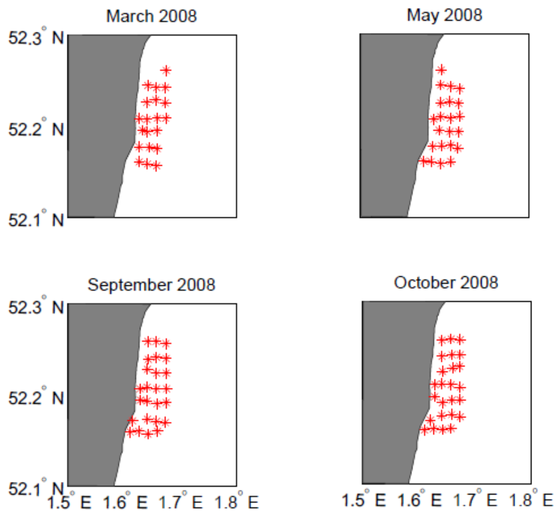



Figure 83: Coverage of 2008 plankton surveys, per month, using Gulf VII sampler.

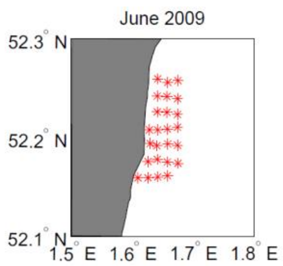



Figure 84: Coverage of 2009 plankton survey, per month, using the Gulf VII sampler.

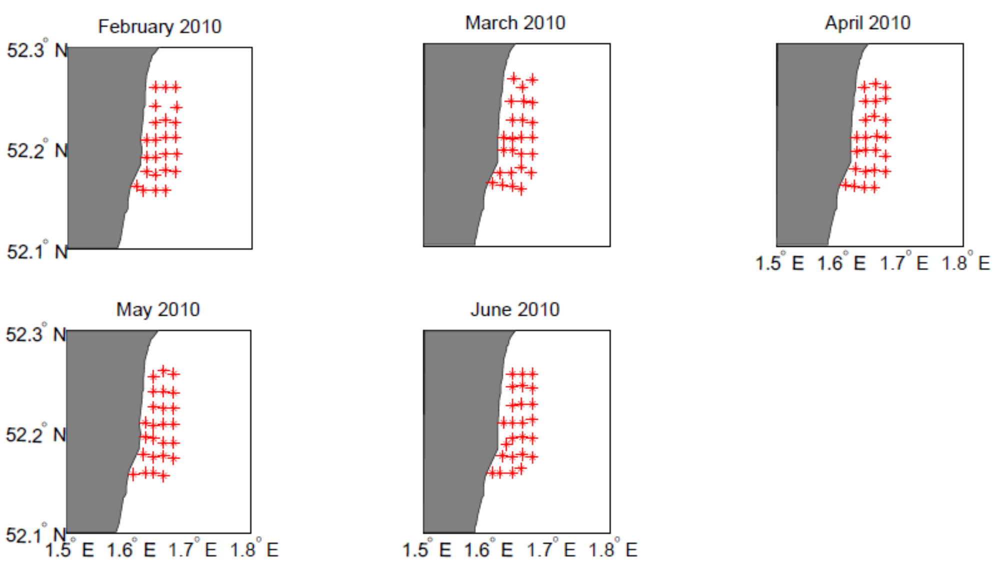



Figure 85: Coverage of 2010 plankton survey, per month, using the Gulf VII sampler with attached PUP sampler.

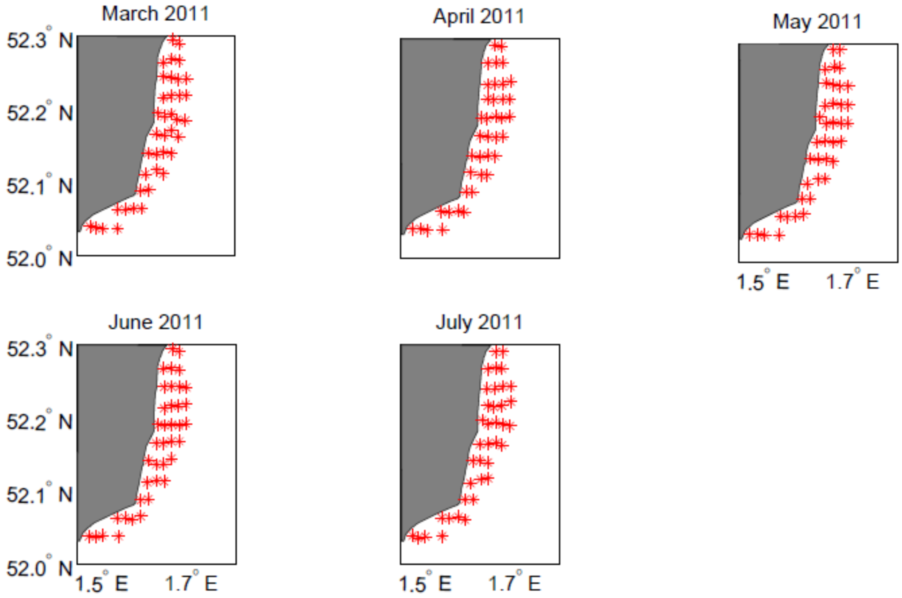



Figure 86: Coverage of 2011 plankton survey, per month, using the Gulf VII sampler with attached PUP sampler.

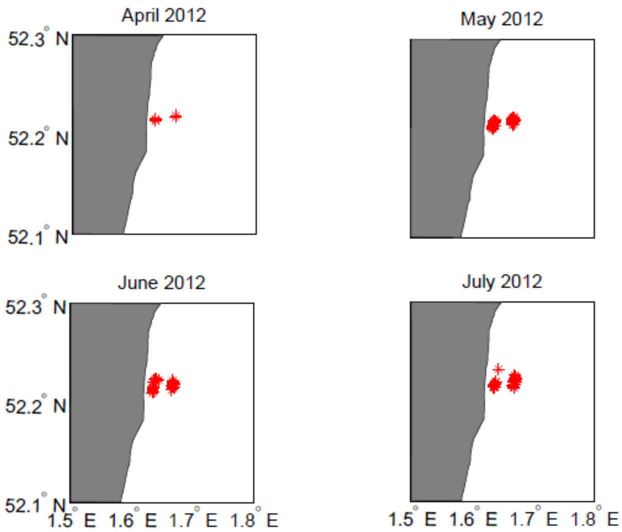



Figure 87: Coverage of 2012 plankton survey, per month, using the Gulf VII sampler with attached PUP sampler.