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Sizewell Characterisation Report – Phytoplankton: Edition 2

Sizewell Characterisation Report – Phytoplankton: Edition 2

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Version and Quality Control

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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

EDF Energy is planning to construct a new nuclear power station, Sizewell C, at Sizewell on the Suffolk coast. As part of the planning/consent process, EDF Energy is required to undertake an environmental impact assessment (EIA) to identify and assess the potential impacts of the station construction and operation on the local marine ecology and a Water Framework Directive (WFD) assessment. Coastal ecosystems are supported by the internal primary production of phytoplankton, making them of importance in the coastal food web and, thus, for the EIA and WFD assessment.

This report characterises for the Greater Sizewell Bay area:

- 1) the spatial-temporal variability of the environmental drivers for phytoplankton,
- 2) the spatio-temporal patterns in phytoplankton communities off the East Anglian coast and
- 3) the key taxa on the basis of their ecological, socio-economic or conservation importance.

We use data from surveys undertaken by Cefas on behalf of EDF Energy in 2012 and 2014, the Environment Agency (EA) Water Framework Directive (WFD) data from the Sizewell area, from the Cefas West Gabbard site and information from remote sensing of the wider region.

The primary environmental controls on phytoplankton are light, for photosynthesis and growth, nutrients, for cell production, and temperature, which determines overall metabolic status. These are more variable in coastal waters than in the open sea, and thus coastal primary production cycles can be more irregular. Top-down control of phytoplankton by filter-feeders and grazing zooplankton can also be important in limiting the standing stock of algae. The spatio-temporal variability of the environmental drivers for phytoplankton at Sizewell are:

- 1) winter – sediment dominated and high quantities of nutrients;
- 2) spring – decrease in sediment loading, increase in temperature, decrease in nutrients due to uptake by phytoplankton; and
- 3) summer and autumn – increase in nutrients and sediment loading.

There were no detectable differences in phytoplankton taxon distribution within Greater Sizewell Bay, and the community is representative of the wider region (represented by the Suffolk EA and Cefas West Gabbard data), a system composed primarily of diatoms. The temporal patterns in the phytoplankton of Greater Sizewell Bay also mirror those of the wider region; all three *in situ* datasets described a similar trend of peak cell numbers in May (the “spring bloom”), corresponding to the highest concentrations of chlorophyll *a*, with some evidence of a smaller peak in August and September. The community was dominated by diatoms year-round, with their contribution relative to total abundance varying from 54 % in September to 99.5 % in May and June. The Sizewell mid-summer to autumn community was dominated by microflagellates but their proportions remained relatively low for the remainder of the year.

There are seven key taxa, defined on the basis of their ecological importance (= dominance) and socio-economic importance. These hail from the diatom and microflagellate taxonomic groups that dominate the Sizewell phytoplankton community and will be included or scoped into the Sizewell C EIA and WFD assessment. Their importance and seasonality can be summarised as follows:

	Winter			Spring			Summer			Autumn			Importance	
	D	J	F	M	A	M	J	J	A	S	O	N	Ecological	Socio-economic
Diatoms														
<i>Chaetoceros</i> (Hyalochaetae)													√	
Chain diatom													√	
<i>Paralia sulcata</i>													√	
<i>Pseudo-nitzschia</i>														√ Potentially toxic species
Raphiated pennate													√	
<i>Skeletonema</i>													√	
<i>Thalassiosira</i>													√	
Microflagellates														
Microflagellates													√	
<i>Phaeocystis</i>														√ Nuisance. Present at times

Coloured cells represent months when the taxon contributed at least 10 % of total abundance in any of the three datasets used (BEEMS, EA and Cefas West Gabbard).

Edition 2 of this report:

Since the first edition of the Phytoplankton Characterisation, ongoing plankton monitoring has been underway at Sizewell. Between March 2014 and January 2017, monthly monitoring studies were undertaken at Sizewell with the specific objective of determining the temporal and spatial variability in phytoplankton communities at a number of sites within the Greater Sizewell Bay. The sites included the location of the current Sizewell B intakes, the Sizewell B outfalls and the proposed location of the Sizewell C cooling water infrastructure approximately 3 km offshore. A reference site (SZ3) 5.8km to the north of Sizewell was also sampled. Section 4.1 provides an overview of the latest phytoplankton surveys drawing comparisons to the results presented in this report.

The results from the 2014-2017 data corroborates the information provided in this report. Diatoms continued to dominate phytoplankton communities accounting for >99% of the total abundance during the spring bloom. Microflagellates became more abundance in the autumn, peaking in relative abundance in September. Dinoflagellates were present but never accounted for more than 10% of the total abundance. A large degree of interannual variation in chlorophyll a biomass and abundance were observed for all sites. Community analysis revealed no significant differences between sites.

Data from the reference site and the Sizewell B intakes were used to determine the status of the phytoplankton community by applying the WFD phytoplankton assessment tool. The phytoplankton tool combines metrics for chlorophyll a ($\mu\text{g l}^{-1}$, 90th percentile) during the growing season (March to October, inclusive), elevated counts, and seasonal succession. The reference site scored and overall classification of 'good' status, whilst the Sizewell intake site was classified as 'high' status (lower threshold of good/high). The results were broadly consistent with the wider phytoplankton classification of 'good' within the Suffolk Coastal waterbody.

1 Context

1.1 Purpose of the report

EDF Energy proposes to construct and operate a new nuclear power station (new nuclear build, or NNB) immediately to the north of the existing operational and decommissioned stations (Sizewell B and Sizewell A, respectively) at Sizewell on the Suffolk coast. Under the Planning Act 2008, this development, as with other nationally-significant infrastructure projects, requires a Development Consent Order (including, in the case of conservation areas, a Habitats Regulations Assessment) to be granted by the UK Government's Planning Inspectorate. The new station, Sizewell C, will be of a once-through design, using water abstracted from, and returned to the local marine environment to cool the condensers. As part of the planning/consent process, EDF is required to undertake an EIA that will identify and assess all potential impacts of the build and station operation on the local marine ecology and a WFD assessment. Activities that have the potential to impact on marine communities include impingement and entrainment effects as a result of water abstraction and thermal and chemical effects from the discharged water.

Coastal ecosystems are supported by the internal primary production of plants and algae (autochthonous sources) and to a lesser extent by inputs of energy from the land (allochthonous sources), making phytoplankton of importance in the coastal food web and, thus, for the EIA and WFD assessment. This report presents the outcomes of the phytoplankton characterisation, which aims to describe the ecological breadth and natural variability of the phytoplankton taxa in the Greater Sizewell Bay marine ecosystem. This will be used to identify the key taxa that should be considered in the EIA and as the baseline data for the impact assessments. To this end, the phytoplankton components of the Sizewell marine system are described. On the basis of this and the specific characteristics of the biological components, the key phytoplankton taxa of the site are identified.

This report forms one of a series characterising the components of the Sizewell marine ecosystem; the other components are characterised elsewhere in the series (see BEEMS Technical Reports TR315 on zooplankton, TR348 on benthic invertebrates, TR345 on fish and TR324 on marine mammals).

1.2 Thematic coverage

The characterisation focuses on specific questions:

1. What is the spatial-temporal variability of the environmental drivers for phytoplankton?
2. What are the spatio-temporal patterns in phytoplankton communities off the East Anglian Coast (within the limitations of the available data)?
3. Which are the key species or taxa present around Sizewell over the characterisation period (2012 to 2014), according to their socio-economic value, conservation interest or ecological role within the ecosystem? What are their spatio-temporal patterns?

1.3 Data sources

To characterise the phytoplankton community and environmental drivers at Sizewell, we took into consideration the data collected by Cefas during the BEEMS surveys, those gathered by the EA for their Water Framework Directive (WFD) monitoring, data gathered by Cefas from the West Gabbard mooring site and information available from remote sensing of the wider region. Figure 1 shows the locations of the sampling sites of each of these datasets.

1.3.1 The Environment Agency WFD monitoring data

The EA operates a Water Framework Directive sampling programme which obtains up to 12 samples per year for phytoplankton taxonomic analysis, taken at five different sites – two are located to the north of Greater Sizewell Bay (near Lowestoft) and three are situated to the south of Thorpeness Point (Figure 1). Phytoplankton count data along with the associated nutrients are available to the BEEMS programme for the

time period from June 2010 to October 2013. However, for temperature, EA data from 1967 to 2013 have been used.

1.3.2 The BEEMS Sizewell characterisation surveys

BEEMS sampled for phytoplankton at sites in the vicinity of Sizewell (Greater Sizewell Bay) during 2012 and from 2014 onwards (Figure 1). Greater Sizewell Bay is a shallow embayment between headlands at Southwold in the north and Orford in the south (Figure 1). The 2012 Sizewell plankton study looked at the communities at the existing cooling water intake structure for SZB and the proposed intake site at SZC (BEEMS Technical Report TR276). These two sites represented the water mass inshore of the Sizewell-Dunwich Bank and offshore of the bank. The primary aims of the 2014 study were to further investigate the differences in plankton community structure around the existing intake at SZB and the proposed intake at SZC. Additional aims were to extend the investigation to differences between the existing and proposed cooling water outfall locations and to obtain the data required to support the WFD assessment for the Sizewell C (SZ3 reference site) permitting submissions. Environmental variables such as temperature and nutrients were also collected. The 2014 surveys are reported in BEEMS Technical Report TR326. Data collection continued in 2015, and phytoplankton count data from January and February 2015 have been used in order to compare with the same months in other datasets. The subsequent 2015 data are not yet available for analysis.

1.3.3 The Cefas West Gabbard mooring data

The Cefas West Gabbard mooring (Figure 1) is an autonomous, multi-parameter recording platform used to collect marine environmental data. It collects high-frequency time series of surface (at 1 metre) salinity, temperature, turbidity, oxygen saturation, chlorophyll fluorescence and nitrate concentration. Water samples are collected and preserved in the mooring and analysed later for nutrients and phytoplankton species. Water sample data for phytoplankton counts have been used from 2008 – 2014. Nitrate and silicate concentration data have been used from 2008 - 2013, Formazin Turbidity Unit (FTU) data from 2009 – 2013 and temperature data from 2010 – 2013. Phosphate data were not collected due to logistical constraints.

1.3.4 Regional-level remote sensing data

As part of the MarCoast project funded by the European Space Agency, ocean colour images of Europe from the MODIS-AQUA satellite were processed by Ifremer using the OC5 algorithm (Gohin *et al.* 2005) to retrieve synoptic maps of the mineral suspended matter (in mg l⁻¹) in surface waters. Individual daily images of suspended particulate matter (SPM) for the North Sea were processed at Cefas by Tiago Silva during the MEPF project (<http://cefas.defra.gov.uk/media/462931/mepf%2009%20p114%20final%20report.pdf>) to obtain a climatological average SPM for each month of the year (Eggleton *et al.* 2011). The algorithm jointly estimates chlorophyll *a* concentrations and non-algal SPM - this is the fraction of SPM not related to dead or alive endogenous phytoplankton. The coloured dissolved organic matter (CDOM) component is not estimated. The procedure was described in Gohin *et al.* (2005) for SeaWiFS and modified in Gohin (2011) for MODIS 4 channels and MERIS 5 channels.

A climatological time series for each of the twelve monthly SPM scenes was extracted for the inshore and offshore stations using a Spatial Analyst query in ArcGIS 10.3. The individual values of SPM for each month were plotted in MS Excel using an X-Y chart.

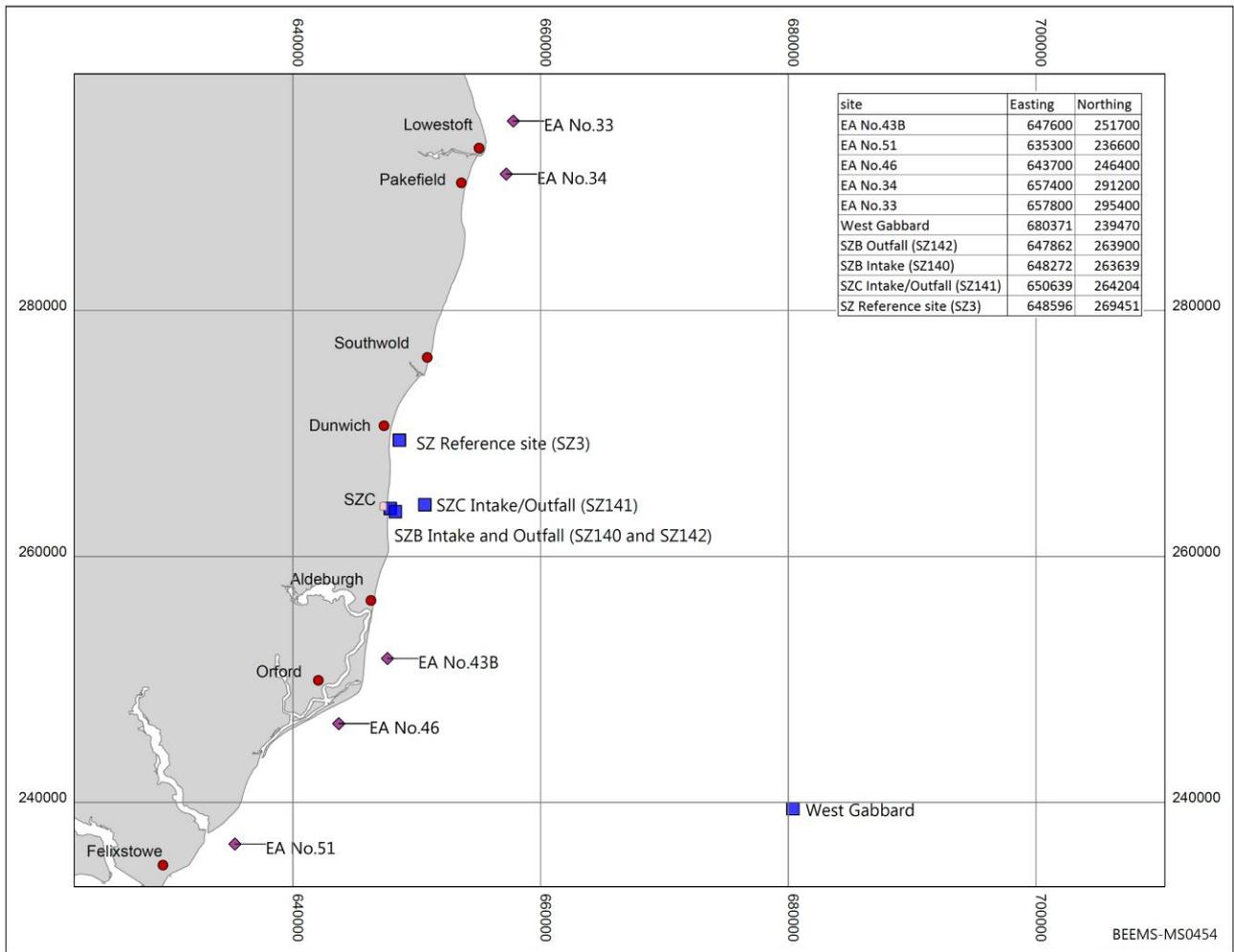


Figure 1 - Location of sampling sites for nutrient, turbidity, and phytoplankton biomass and diversity data used in this report. Sizewell sampling stations in 2012 and 2014 (SZ), EA WFD monitoring sites (EA), and the West Gabbard mooring site.

2 Spatio-temporal variability of the environmental drivers for phytoplankton

2.1 Background

Coastal ecosystems are supported by the internal primary production of plants and algae (autochthonous sources) and to a lesser extent by inputs of energy from the land (allochthonous sources). Primary production by attached vegetation such as seagrasses and macroalgae is possible only if sufficient light impinges upon the seafloor. In turbid coastal waters such as that of the Greater Sizewell Bay, benthic primary production is very limited, and it is the production of carbon by phytoplankton in the water column which is most important in supporting populations of invertebrate grazers and higher trophic level organisms. Phytoplankton are not evenly distributed in time and space, and an understanding of the factors which control their growth and mortality is needed in order to study their ecology with relation to the new nuclear build.

The primary environmental controls on phytoplankton are 1) light - necessary for photosynthesis and growth, 2) nutrients - needed for production of new cells; and 3) temperature - determines overall metabolic status (Underwood & Kromkamp, 1999). All of these controls are more variable in coastal waters than in the open sea, and as a result, coastal primary production cycles can be more irregular than those offshore (Cloern & Jassby, 2008). Phytoplankton limitation can occur via top down regulation which depends upon activities at higher trophic levels such as filter-feeders and zooplankton.

2.2 Environmental drivers

Phytoplankton are said to bloom when concentrations of biomass (measured by the main photosynthetic pigment, chlorophyll *a*) or abundance (cell counts) increase significantly above background levels, in response to a favourable combination of environmental conditions. The factors controlling primary production of phytoplankton alternate throughout the year but the factors which control the spring bloom are primarily the light and the nutrients. The general situation for the southern North Sea is that during the winter months a combination of low surface irradiance and rapid attenuation of photons within the water column causes a very strong light-limitation of phytoplankton growth. Supported also by a large amount of nutrients available (nitrogen, phosphorus, and silicates), the growth of the phytoplankton is stimulated when the light and the temperature increase during spring time. During late spring and summer, the lack of the nutrients in the water as well as the grazing pressure, decrease the microalgae biomass. In the autumn, another increase of the phytoplankton biomass can be observed due to the decrease of the grazing pressure and if enough nutrients are available. This section will discuss bottom up regulation factors: light, nutrients and temperature.

2.2.1 Availability of light and suspended particulate matter (SPM)

For the southern North Sea, it is the presence of a high suspended sediment load which primarily controls the underwater light climate (Devlin *et al.* 2008), and hence productivity of phytoplankton. Sand, mud and clay particles do not absorb light directly, but act as strong scattering agents. Scattering increases the path length of photons through the water column and this reduces the overall penetration of sunlight. The concentration of suspended sediment in the water column is given in units of mass per volume (g dry sediment matter per m³) and can be mapped accurately, as it scales linearly with the degree of back-scattering in the water. Scattering by sediments can be measured either *in situ* with optical back-scatter instruments, or from airborne and satellite remote sensing of the reflected sunlight. Cross-comparisons have shown excellent agreement between methods (e.g. Neukermans *et al.* 2012; Vanhellemont *et al.* 2014). The East Anglian coast is influenced by advection of material from south to north by the Thames plume. It is also influenced by wave action, resuspension of seabed sediments, estuarine run-off and erosion of the shoreline, which acts to increase the suspended sediment load in winter (Weston *et al.* 2008).

The remote sensing images further elucidate this general pattern. Concentrations of SPM are highest in inshore waters between eastern Kent, through the Thames Estuary, and Essex and Suffolk coasts as far as

Great Yarmouth (Figure 2). At this point the sediment-rich water is deflected north-eastwards into the Southern Bight to form an oceanographic feature known as the East Anglian Plume, which in some years may reach as far as the territorial waters of The Netherlands. The months of November through to March are similar off the coast of Sizewell, with a zone of high SPM extending offshore (Figure 2). In addition to these general features, sediment loads in the southern North Sea respond on shorter time scales to the prevailing wind direction, and to tidal current speeds (Fettweis *et al.* 2012). In mid-April, the concentration of SPM begins to decrease as calmer conditions became more prevalent, and by May the inshore waters off Sizewell have a reduced sediment load, and are noticeably clearer. SPM is relatively low throughout June and July, before concentrations begin to increase again in August and September (Figure 2). Throughout the year, the inshore sediment load to the south of Sizewell, off the Essex estuaries is higher than that to the north of the NNB site. The SPM concentration at all times of year is higher for the inshore Sizewell area than the offshore North Sea (e.g. West Gabbard, see Figure 3), which means that there was less penetration of sunlight in the inshore areas compared to the offshore areas.

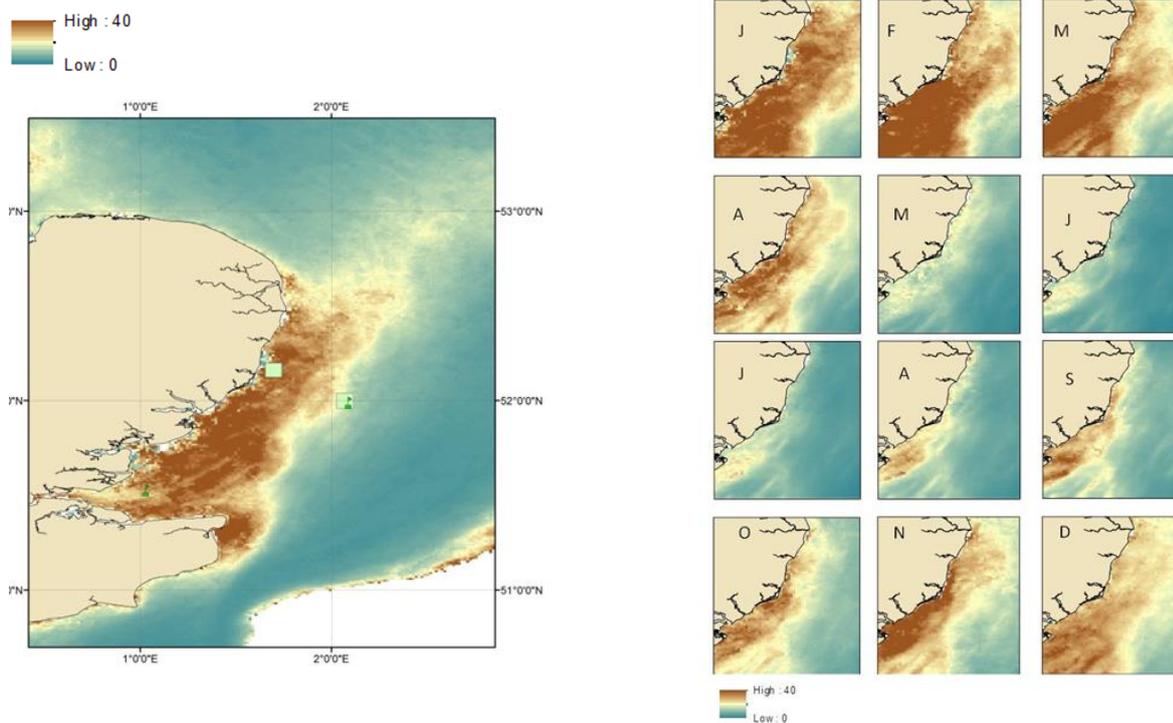


Figure 2 - Left: Distribution of suspended sediment concentrations in winter for East Anglian waters. Average SPM concentration for the month of February was estimated from satellite images of ocean colour between 2002 and 2012. Units are g m^{-3} . Green squares show positions of an inshore station, off Sizewell, and an offshore station at the Cefas West Gabbard mooring site. Right: Monthly climatological (2002-2012) average SPM maps for the East Anglian region derived from calibrated satellite ocean colour (Eggleton *et al.* 2011).

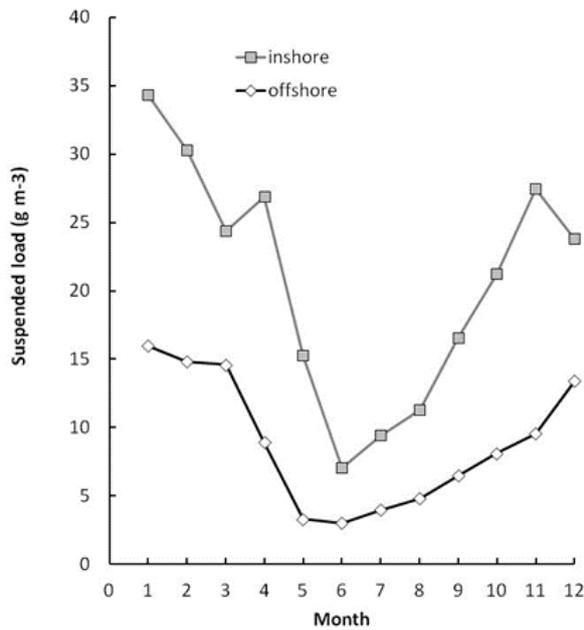


Figure 3 - Climatological time series of SPM concentration for inshore (Sizewell) and offshore (West Gabbard mooring site) areas calculated from remote sensing images (Eggleton *et al.* 2011).

Examination of *in situ* turbidity measurements [expressed in monthly mean Formazin Turbidity Units (FTU)], confirmed the trend observed with the remote sensing images, with higher FTU in the winter/spring months (October to April) and a decrease during the summer (Figure 4). The *in situ* measurements also confirmed the difference between the inshore and offshore sites, with 4 to 13 times less suspended matter measured in West Gabbard compared to Sizewell.

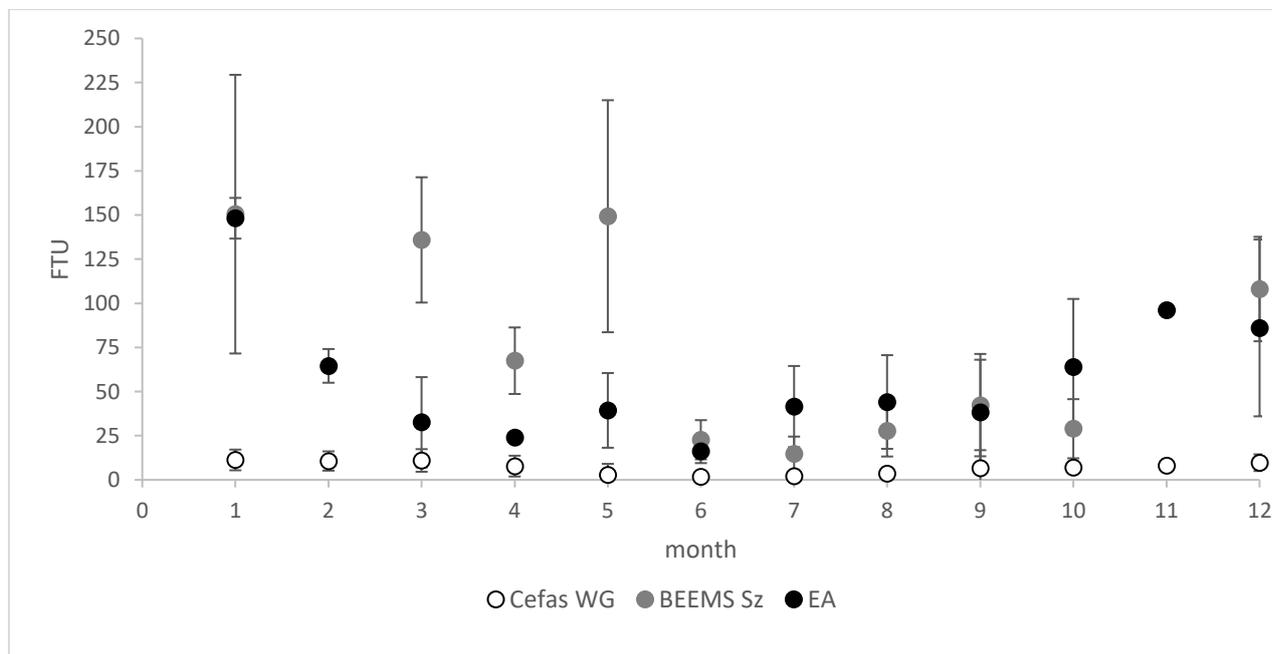


Figure 4 – Monthly mean (\pm SDVE) of turbidity (FTU) at the West Gabbard mooring site between 2009 and 2013 (Cefas WG), Sizewell plankton survey in 2014 (BEEMS Sz) and EA monitoring sites between 1992 and 2013 (EA). X-axis represents the month of the year from January to December (1 to 12).

2.2.2 Nutrient concentrations

The availability of inorganic nutrients – mainly nitrate and phosphate, but also silicate for diatoms – influences the size of phytoplankton populations when light is not limiting. Spatial and temporal information on nutrients for the Greater Sizewell Bay have been collected in this region over the time period between 2000 and 2012.

A climatology of all available late winter nutrient data from the Cefas archives showed that several of the inshore areas of eastern England have elevated levels of nutrients compared to the offshore North Sea (Figure 5). The Wash and the inner Thames Estuary have winter values in excess of 20 $\mu\text{mol nitrate l}^{-1}$. Similar values could be found for the WFD assessment unit ‘Suffolk’, an inshore zone containing Sizewell, located between the Deben estuary to the south and Corton to the north of Lowestoft. The southern sector of the ‘Suffolk’ zone, south of the Greater Sizewell Bay, appears to contain the highest concentrations of nutrients.

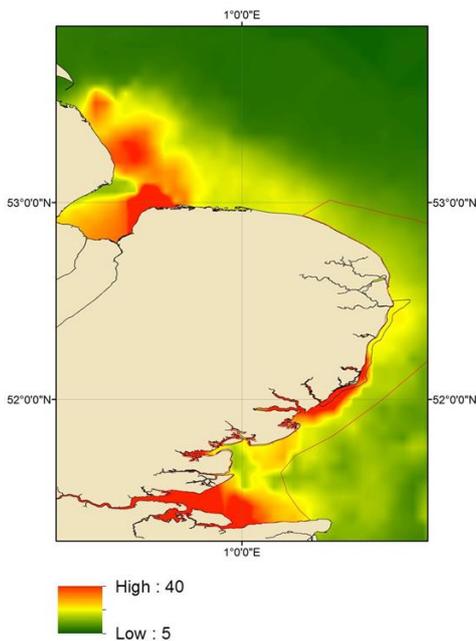


Figure 5 - Winter inorganic nitrate concentrations in the southern North Sea. All available data from the Cefas nutrients database (Sapphire) was queried within an area bounded by the region N 51° W 0.5° and N 54° E 3 °. The time period used for selection was 2000-2012 and values were restricted to between November and March. Kriging was then used to produce a continuous raster layer from discrete spatial values. Red and black polygons delimit areas used for OSPAR and WFD assessments.

The nutrient measurements (

Figure 6) confirmed that the Sizewell area has higher nutrient concentrations than the the areas further offshore. The highest nitrate and silicate concentrations were between January and March, with the EA data showing the highest maxima at approximately 35 $\mu\text{mol nitrate l}^{-1}$ and 25 $\mu\text{mol silicate l}^{-1}$, compared to BEEMS Sizewell at approximately 30 $\mu\text{mol nitrate l}^{-1}$ and 15 $\mu\text{mol silicate l}^{-1}$ and the offshore Cefas West Gabbard data at approximately 10 $\mu\text{mol nitrate l}^{-1}$ and 5 $\mu\text{mol silicate l}^{-1}$.

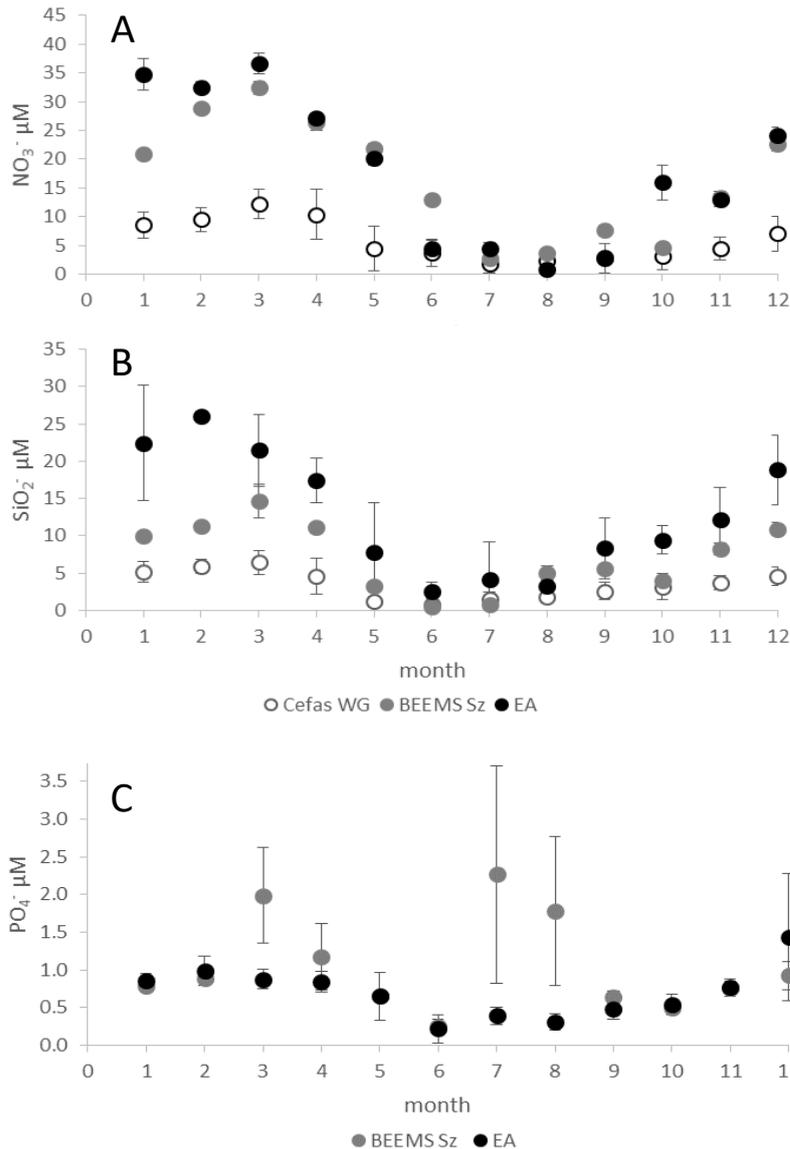


Figure 6 - Monthly mean (\pm SD) of nitrate (A) and silicate (B) concentrations in $\mu\text{mole l}^{-1}$ from the West Gabbard mooring site between 2008 and 2013 (Cefas WG), Sizewell monitoring sites between 2009 and 2013 and during the BEEMS plankton surveys of 2014 (BEEMS Sz) and EA monitoring sites between 1992 and 2013 (EA). Monthly mean phosphate (C) concentrations in $\mu\text{mole l}^{-1}$ from the Sizewell plankton surveys of 2014 (BEEMS Sz) and EA monitoring sites between 1992 and 2013 (EA). X-axis represents the month of the year from January to December (1 to 12).

In July and August, the concentrations of nitrates were the lowest whatever the sites ($< 5 \mu\text{mol nitrate l}^{-1}$). This summer reduction was also generally true for silicates, with low values seen from May through to August. All nutrients (nitrate, silicate and phosphate) in all three datasets showed similar trends with a decrease in concentration in the summer and autumn months and peak concentrations in the winter and spring months. The variations of phosphates were associated with the variations of suspended matter. The high concentrations of phosphates in the BEEMS samples in July and August could be an anomaly, resulting perhaps from localised stirring up of nutrients from the survey vessel.

2.2.3 Temperature

Temperature can also be a limiting parameter for phytoplankton growth, along with light and nutrient availability. Figure 7 shows the mean monthly sea surface temperatures for waters in and around Sizewell. All datasets showed the same trend of gradual increasing and decreasing sea surface temperatures between the range of approximately 4°C in winter and 20°C in summer (Figure 7). The highest mean sea surface temperature, of approximately 20°C, was recorded in August 2014 in the BEEMS Sizewell plankton data (no BEEMS temperature data for 2012). The August temperatures for the other data were lower, with the EA data lowest at approximately 18°C.

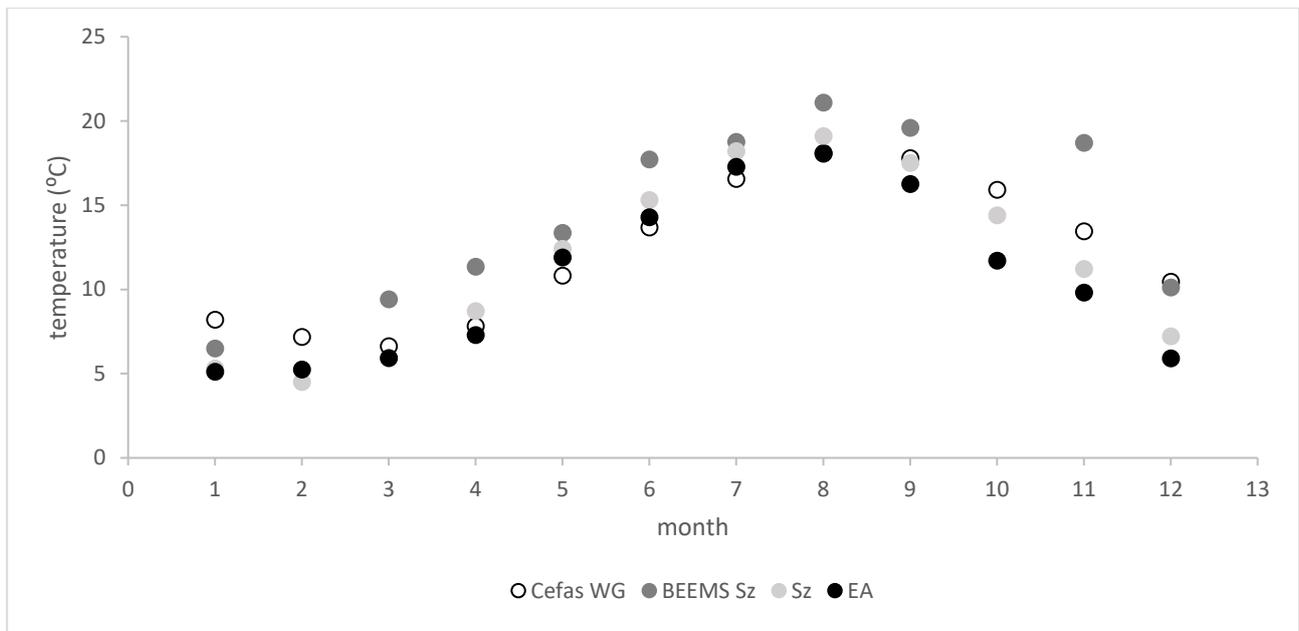


Figure 7 – Monthly mean sea surface temperatures at the West Gabbard mooring site between 2010 and 2013 (Cefas WG), Sizewell (52 13N, 1 38 E) between 1967 and 2013 from the Cefas database, BEEMS Sizewell plankton survey in 2014 (BEEMS Sz) and at EA monitoring sites between 1992 and 2013 (EA). X-axis represents the month of the year from January to December (1 to 12). Standard deviation omitted for clarity.

3 Spatio-temporal variability in phytoplankton in the Sizewell area

3.1 Spatio-temporal trends in chlorophyll a

The seasonality of North Sea phytoplankton has been particularly well described along the Dutch and German coastlines (Peperzak *et al.*, 1998; Wiltshire *et al.*, 2008; Brandt & Wirtz, 2010; Arndt *et al.*, 2011), and for eastern English locations such as The Wash (Owen, 2014) and outer Thames Estuary (Weston *et al.*, 2008). The presence of phytoplankton blooms can be mapped with reasonable accuracy at the regional scale using satellite ocean colour, except in the presence of very dense sediment plumes which can obscure the optical signal of algal cells and cause chlorophyll *a*-detecting algorithms to fail. A comparison of monthly maps for the years 2002 – 2012 showed that chlorophyll *a* is highest in April, May and June (Figure 8). The satellite maps also showed that the inshore estuaries have higher chlorophyll *a* values compared to waters further offshore.

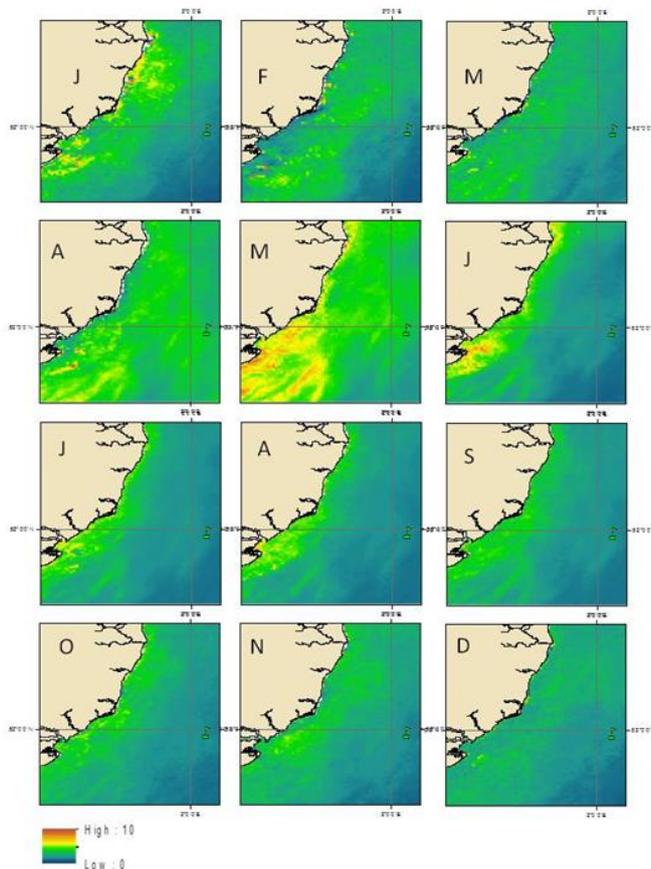


Figure 8 - Monthly mean of chlorophyll *a* maps for the East Anglian region (2002-2012) derived from calibrated satellite ocean colour. The green buoy symbol shows the position of the offshore reference station West Gabbard. Units: mg chlorophyll *a* m⁻³ (Eggleton *et al.* 2011).

Figure 9 shows the seasonal cycle for the West Gabbard instrumented mooring, at which chlorophyll *a* has been measured at 30 minute intervals since 2008, the BEEMS Sizewell survey sites (2012 and 2014) and the EA WFD monitoring sites. Periodicity in the region can be described thus (Underwood & Kromkamp, 1999):

- ▶ Period 1 – winter: Phytoplankton are not completely absent during the sediment-dominated winter period, but persist and are measureable as low quantities of chlorophyll *a*;

- ▶ Period 2 – the spring bloom: Following the springtime decrease in sediment loading, the most prominent bloom period for the southern North Sea is between April and mid-June, when rising water temperatures, combined with increased day length and a higher solar elevation, produce optimal conditions for phytoplankton growth. Phytoplankton are then able to effectively utilise the nutrients which have accumulated during the winter. Biomass increases quickly until a peak is reached in late May, at which point essential nutrients are exhausted, even in the nutrient-rich coastal waters. Chlorophyll *a* in May can reach 10 mg m⁻³ around Sizewell (derived values shown in Figure 8 and confirmed by the *in situ* data shown in Figure 9). Grazing rates may increase in response to the bloom, resulting in an eventual decrease in phytoplankton cell numbers and rapid disappearance of the bloom.
- ▶ Period 3 – summer and autumn: Phytoplankton populations remain actively growing over summer with continuous production, grazing and recycling of nutrients. Increased turbulence due to storms in late summer can lead to replenishment of surface water nutrients and, if sufficient light intensity remains, a smaller, secondary bloom may occur before populations decline to the winter level.

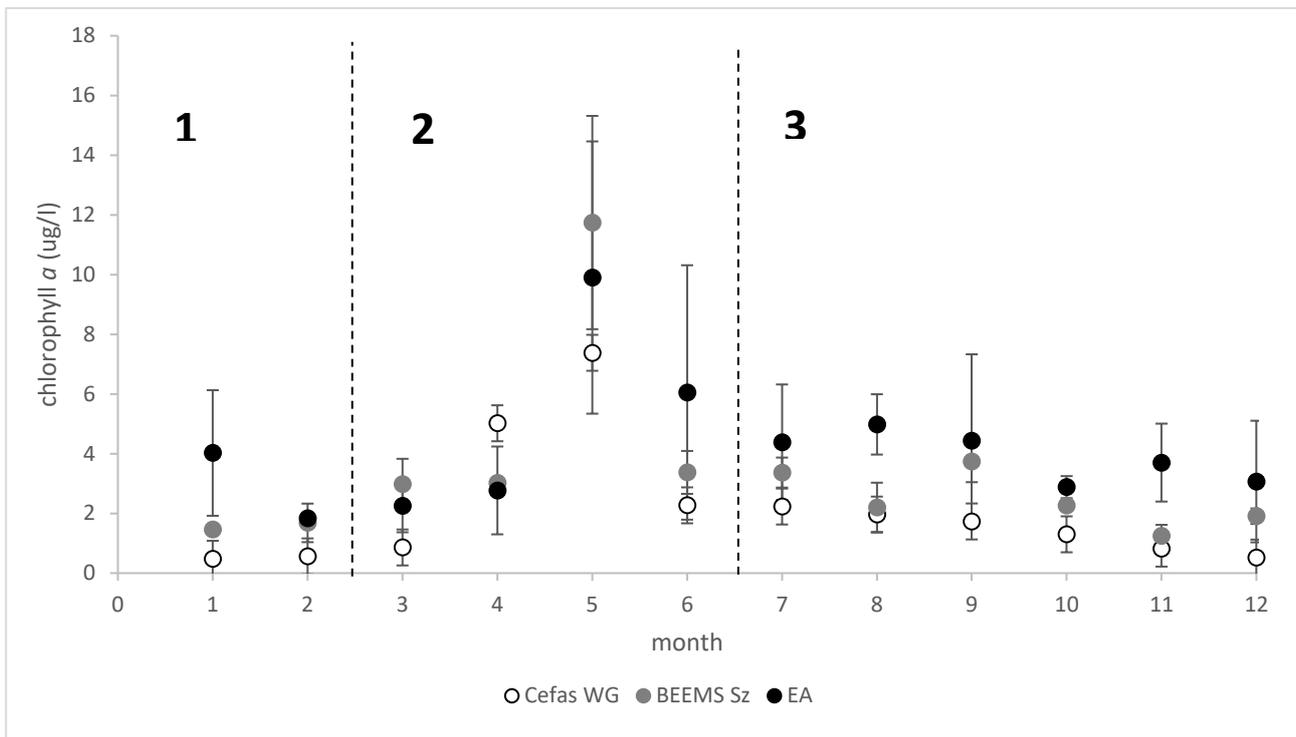


Figure 9 - Monthly mean (\pm SD) of chlorophyll *a* at the West Gabbard mooring site between 2008 and 2014 (Cefas WG), BEEMS Sizewell surveys 2012 and 2014 (BEEMS Sz) and EA monitoring sites between 1992 and 2013 (EA). The periodicity typical of the region is shown: (1) winter, with low values of chlorophyll *a*, (2) the spring bloom in May and (3) summer-autumn with moderate values of chlorophyll *a* and occasional blooms. X-axis represents the month of the year from January to December (1 to 12).

Figure 9 shows that there was higher interannual variability in the inshore sites (EA and Sizewell monitoring sites) compared to the offshore site (West Gabbard), which may be due to the higher SPM affecting the species composition and chlorophyll *a* levels. The differences between inshore and offshore areas noted in the satellite images were also seen in the *in situ* data, with discernably lower chlorophyll *a* levels at the West Gabbard site in most months of the year. The seasonal pattern over the characterisation period appeared to be consistent with that described from the wider region.

3.2 Spatio-temporal trends in the overall community

Figure 10 shows the monthly mean of total phytoplankton cells per litre from the West Gabbard mooring site, the Sizewell BEEMS plankton surveys and the EA Suffolk monitoring sites. All three datasets showed a similar trend of peak numbers of cells per litre in May, which corresponded to the highest concentrations of chlorophyll *a* (Figure 9), and there was some evidence of a smaller peak in August and September. Within

Greater Sizewell Bay itself, the phytoplankton community composition varied seasonally (2 way ANOSIM - Global R = 0.513, p<0.001), with the earliest surveys from around April to July showing more distinct changes than the later months of the year (Figure 11); this corresponds to periods 2 and 3 in Figure 9 and Figure 10. These changes in community composition were driven by the key phytoplankton taxa, which will be described in Section 3.3.

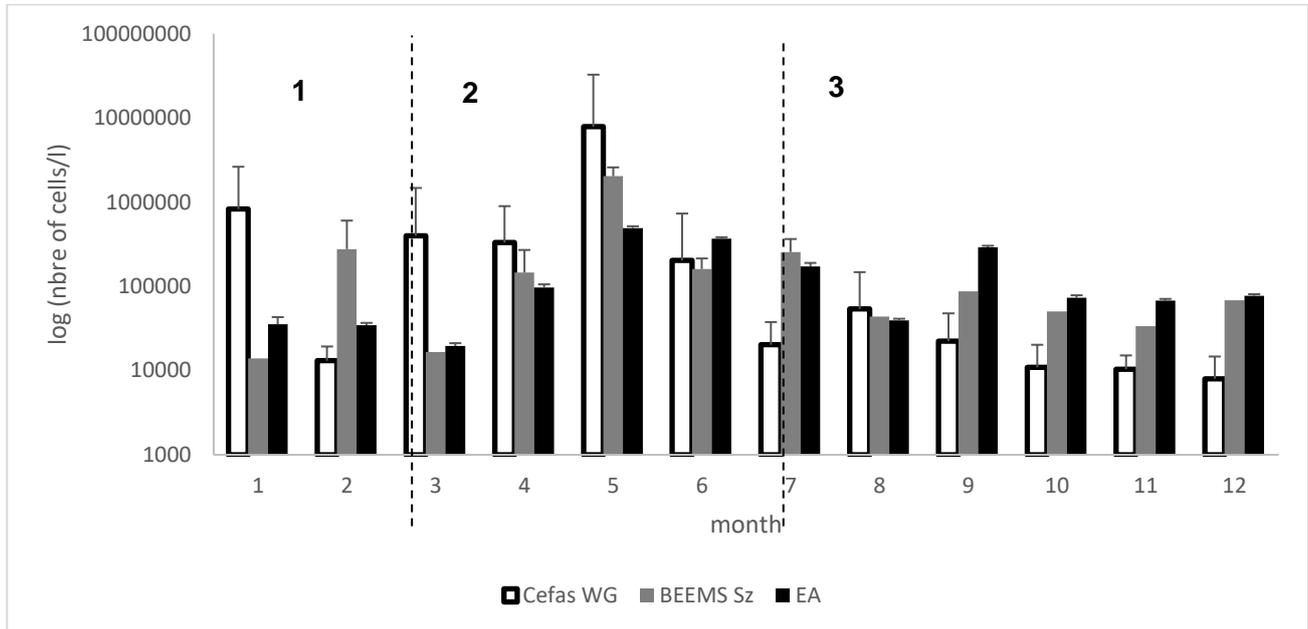


Figure 10 – Monthly mean (± SD) of total number of phytoplankton cells l⁻¹ from data collected at the Cefas West Gabbard mooring site between 2008 and 2014 (Cefas WG), the Sizewell monitoring sites between 2012 and 2014 (BEEMS Sz) and EA monitoring sites between 2010 and 2013 (EA). The periodicity typical of the region is shown: (1) winter, with low values of chlorophyll a, (2) the spring bloom in May and (3) summer-autumn with moderate values of chlorophyll a and occasional blooms. X-axis represents the month of the year from January to December (1 to 12).

Figure 10 shows that the Cefas West Gabbard data had the highest variability in cell number between years, this was due to blooms of microflagellate cells and *Phaeocystis* cells (further described in Section 3.3). In May, phytoplankton abundance varied from 4.9E⁵ cells per litre for the EA monitoring sites to 7.9E⁶ cells per litre for the Cefas West Gabbard mooring site (Figure 10), with Sizewell (BEEMS Sz) somewhere between the two at 2E⁶ cells per litre. The statistical analysis of the samples collected during the BEEMS plankton surveys in 2014 showed no significant differences in community structure between the four sites in Sizewell (BEEMS Technical Report TR326), suggesting that any spatial patterns are limited to larger-scale differences between inshore coastal waters and the open surface waters found offshore. Thus, at the scale of interest for the SZC EIA and WFD assessment, there's little in the way of spatial differentiation in the phytoplankton communities.

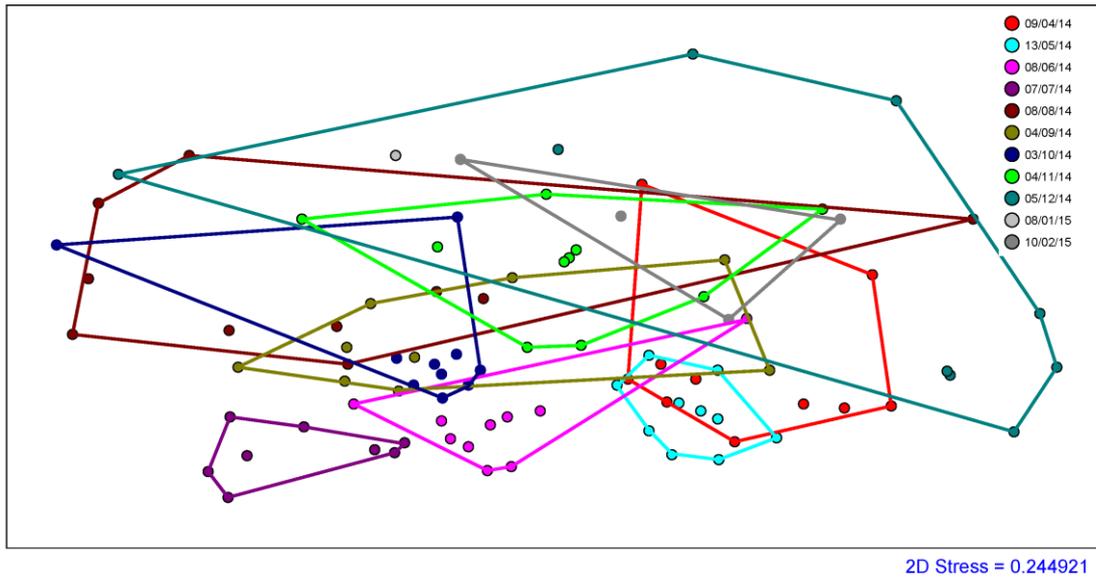


Figure 11 - nMDS analysis of phytoplankton abundances per taxon for all survey dates in the 2014/2015 Sizewell survey series (BEEMS TR326)

3.3 Key taxa

For the purposes of the Sizewell marine ecology impact assessment and WFD assessment, taxa are considered to be key in the ecosystem if they meet at least one of the following criteria: socioeconomic value, conservation importance or ecological importance.

A taxon is regarded as key if it meets at least one of the following criteria:

- ▶ Contribution to abundance within Greater Sizewell Bay: If a taxon contributes to at least 10 % of the total abundance and appears in all three datasets (Sizewell, EA and West Gabbard) we consider it to be common and/or abundant enough to potentially play a key trophic role within the Greater Sizewell Bay.
- ▶ Socio-economic value: Species that could influence humans or commercially harvested organisms e.g. harmful algae, or those that could be a 'nuisance' to the operation of the power station or produce unsightly blooms in the local area (e.g. *Phaeocystis* sp.).
- ▶ Conservation importance: Species that are listed as protected or have conservation status e.g. Biodiversity Action Plan Priority Lists (BAP lists for taxa identified as priorities for conservation action), species listed on European Directives, species listed on the Schedules of the Wildlife & Countryside Act, together with lists of rare and scarce species.

There were no phytoplankton taxa of formal conservation importance. Combining data from the BEEMS plankton surveys (2012 and 2014), Cefas West Gabbard mooring site (2008 – 2014), and EA monitoring sites (2010 – 2013), Table 1 shows the phytoplankton taxa which represented at least 10 % of the community for each month of the year. On the basis of ecological value (abundance), there were seven key taxa in the Greater Sizewell Bay:

- ▶ Microflagellates
- ▶ Chain diatom
- ▶ *Paralia sulcata*
- ▶ *Skeletonema*
- ▶ Raphiated pennate
- ▶ *Thalassiosira*
- ▶ *Chaetoceros* (Hyalochaetae)

There were also two species that occur in the Greater Sizewell Bay that have potential socio-economic value:

- ▶ *Pseudo-nitzschia* – potential to cause harmful blooms, see section 3.3.1
- ▶ *Phaeocystis* sp. – potential to cause foam and unsightly/disruptive blooms, see 3.3.2

The key taxa hail from two main phytoplankton groups; diatoms and microflagellates. Dinoflagellates never represented a high proportion of the phytoplankton community at Sizewell and did not appear in all three datasets. The highest values had been recorded in August and September (12.8 % of the total community).

Table 1 - Phytoplankton taxa representing at least 10 % of the community from the **BEEMS Sizewell surveys** (2012 and 2014), **Cefas West Gabbard surveys** (2008 - 2014) or the **EA surveys** (2010 - 2013). Key taxa are highlighted.

	J	F	M	A	M	J	J	A	S	O	N	D
Microflagellates												
Chain diatom												
<i>Paralia sulcata</i>												
<i>Fragilaria</i>												
<i>Skeletonema</i>												
Raphiated pennate												
<i>Thalassiosira</i>												
<i>Chaetoceros</i> (Hyalochaetae)												
<i>Asterionellopsis glacialis</i>												
<i>Phaeocystis</i> cells												
<i>Guinardia delicatula</i>												
<i>Leptocylindrus danicus</i>												
<i>Cylindrotheca closterium</i> / <i>Nitzschia longissima</i>												
<i>Cymatosira beligica</i>												
<i>Cymatosira lorenziana</i>												
<i>Rhizosolenia</i>												
Centric Diatom												
<i>Guinardia flaccida</i>												
<i>Heterocapsa</i> / <i>Azadinium sp. minima</i>												
<i>Leptocylindrus minimus</i>												
<i>Dactyliosolen fragilissimus</i>												
<i>Pseudo-nitzschia</i>												

3.3.1 Diatoms

Diatoms are unicellular microalgae but they can form colonies in the shape of filaments or ribbons. Their cell wall (frustule) is made of silica, which is a unique characteristic in microalgae. They are divided into two groups, centric diatoms in the pelagic environment and the pennate diatoms found in the benthic environment. They range in size from 2 µm to 500 µm and belong to two phytoplankton functional types - nanophytoplankton and microphytoplankton. Diatoms are primarily photosynthetic autotrophs.

The phytoplankton community around Sizewell was dominated by diatoms year round (Figure 12B), with their contribution relative to the total community varying from 54 % in September to 99.5 % in May and June. This trend was observed for the wider area, represented by the Suffolk EA data and West Gabbard, which confirmed that southern North Sea phytoplankton assemblages are composed primarily of diatoms (Figure 12A and C). In the North Sea, this peak abundance of diatoms is characteristic of the “spring bloom” (Hoppenrath *et al.*, 2009).

The May peak was due to 1) higher quantities of nutrients such as inorganic nitrogen and silicate in the coastal water from precipitation during winter, 2) an increase in sea temperatures and 3) an increase in light intensity which penetrates the surface water (Underwood & Kromkamp, 1999). The diatoms rapidly depleted the silicate levels, as is apparent across all sites (

Figure 6). However, the concentration of nitrogen and particularly nitrates can support the growth of other taxa such as microflagellates and dinoflagellates (see below) later in the year.

Within the diatom group, the **chain diatoms** (Figure 13B) was one of the most abundant taxa in the Greater Sizewell Bay, particularly during winter and spring (i.e. approximately 50 – 70 % of the population during December, February and March).

The trend of increasing numbers of chain diatoms during the winter and spring months at Sizewell was also reflected in the EA and West Gabbard data, with chain diatoms representing approximately 25% of the population in December, March and April. *Fragilaria* sp. (Figure 13D) represented approximately 30 – 75% of the population in the EA data from October to April, however in the other datasets *Fragilaria* sp. may have been identified as a chain diatom and therefore it is difficult to separate these two classifications.

The other key diatom taxa were *Thalassiosira* sp. (Figure 14A), *Paralia sulcata* (Figure 14B), *Chaetoceros* sp. (Hyalochaetae) (Figure 14C), *Skeletonema* sp. (Figure 14D) and raphiated pennates (Figure 14E). ***Thalassiosira* sp.** and ***Skeletonema* sp.** were abundant from late spring into summer and autumn (several months between April and September) and **raphiated pennates** and ***Paralia sulcata*** from autumn into winter and spring (months between November and March and months between December and March, respectively). Centric diatoms and ***Chaetoceros* sp.** (Hyalochaetae) were abundant in both summer and winter (July and November and August and January, respectively).

Some diatom species are harmful, such as *Pseudo-nitzschia australis* and *Pseudo-nitzschia multiseries*, which are responsible for amnesic shellfish poisoning (ASP). Thus, ***Pseudo-nitzschia* sp.** could be classed as a key taxa due to its potential detrimental socio-economic value. *Pseudo-nitzschia* sp. represented at least 10 % of abundance in only the EA dataset and there only in June. Not all species of *Pseudo-nitzschia* produce the neurotoxin domoic acid (DA) that can cause amnesic shellfish poisoning. However, as the EA data do not classify to species level then it cannot be determined whether the *Pseudo-nitzschia* found at Sizewell is the harmful DA producing species or not.

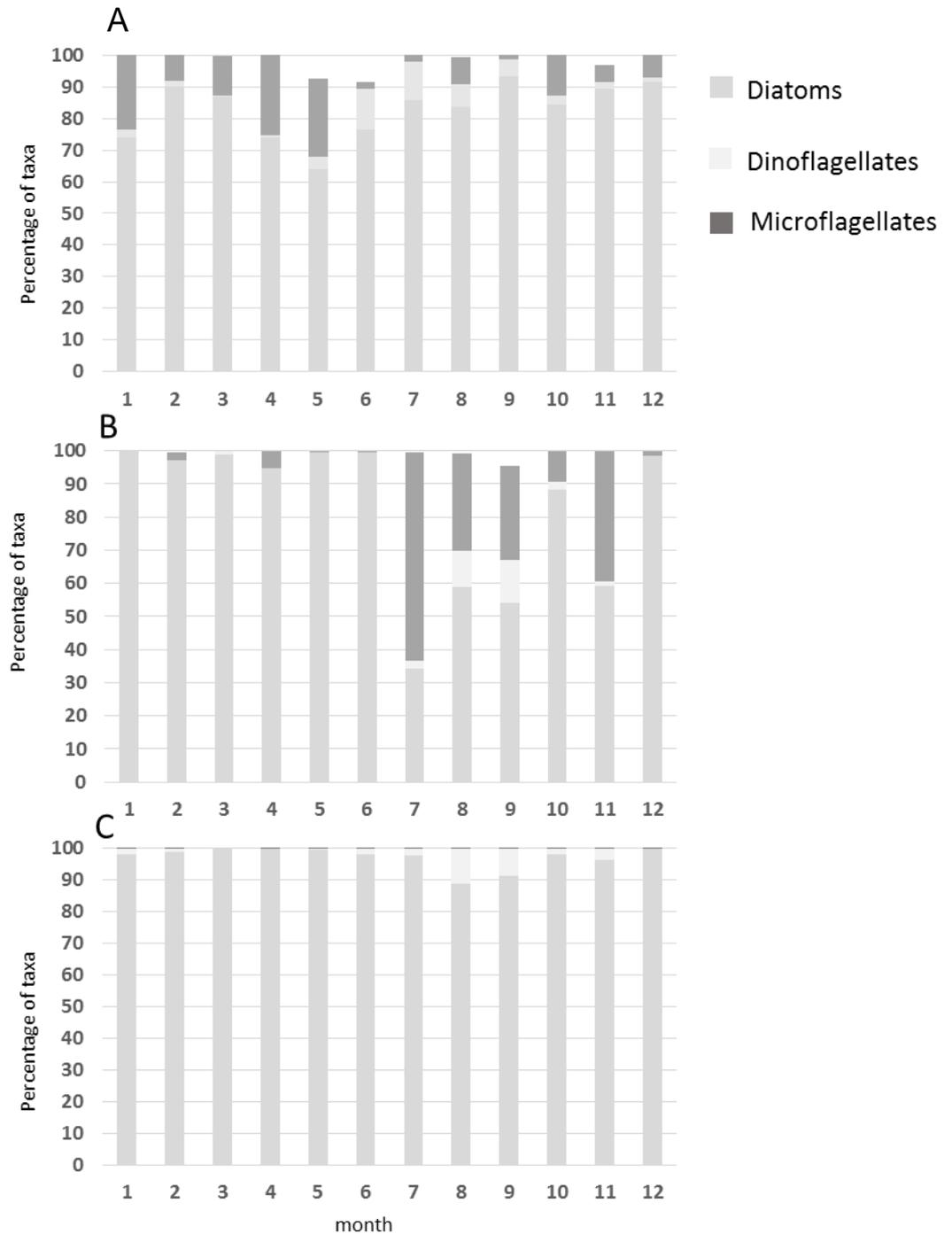


Figure 12 – Monthly mean of percentages of diatoms, dinoflagellates and microflagellates collected at the Cefas West Gabbard mooring site between 2008 and 2014 (Cefas WG, A), the Sizewell monitoring sites between 2012 and 2015 (BEEMS Sz, B) and EA monitoring sites between 2010 and 2013 (EA, 3). X-axis represents the month of the year from January to December (1 to 12).

3.3.2 Microflagellates

Microflagellates were the second most ecologically important (here = abundant) phytoplankton group after the diatoms. Some microflagellates (*Phaeocystis* sp.) may also have a socioeconomic impact as they can potentially clog power station cooling water intake systems if they form a large gelatinous bloom; unsightly blooms may also have an impact on local tourism and recreation.

The microflagellates ranged in size between 2 and 20 µm. As some species are photosynthetic organisms (e.g. *Micromonas* sp.) and some grazers, they can dominate the community after a phytoplanktonic bloom.

They dominated the community in mid-summer at Sizewell - they were the most abundant of the three phytoplankton groups during the summer and autumn months, with a contribution of more than 63 % in July and around 30 to 40 % in August, September and November - but their abundance remained low for the rest of the survey period (Figure 12).

Microflagellates (Figure 13A) are a difficult group to identify taxonomically, especially cells which are $<5 \mu\text{m}$, due to their small size and because their flagella can be hidden depending on their position on the microscope slide. Therefore, some small species may be misidentified as microflagellates i.e. *Phaeocystis* cells. This may explain why there is anecdotal evidence of *Phaeocystis* colonies in the water at Sizewell (they have been seen by the field teams during the BEEMS plankton surveys) but they have not been identified in the BEEMS samples – they may have been present but classed as microflagellates. *Phaeocystis* cells were identified at the West Gabbard site, representing approximately 90 % of the population in August and November.

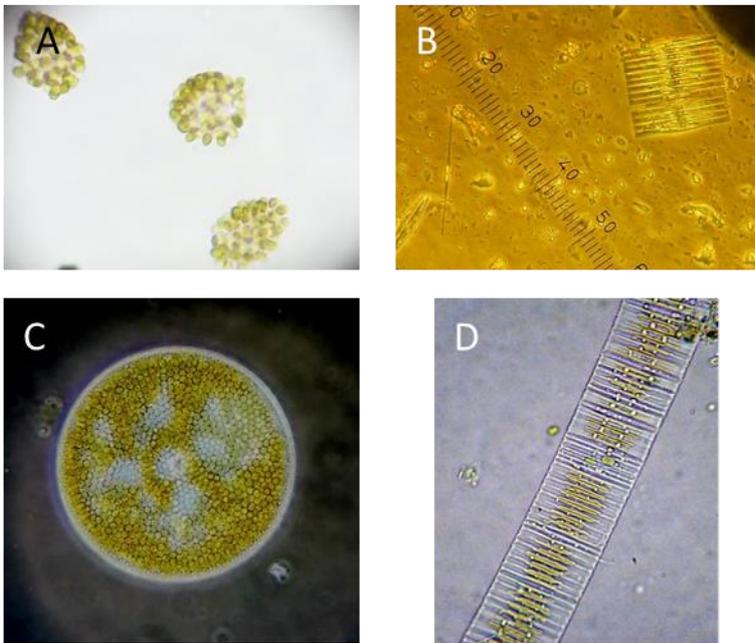


Figure 13 – Abundant phytoplankton species at Sizewell. A - microflagellates ($< 20 \mu\text{m}$); B - diatoms forming chains ($2\text{-}200 \mu\text{m}$); C - centric diatoms ($2\text{-}500 \mu\text{m}$); and D – *Fragilaria* ($>40 \mu\text{m}$). All Crown copyright (Cefas, plankton lab).

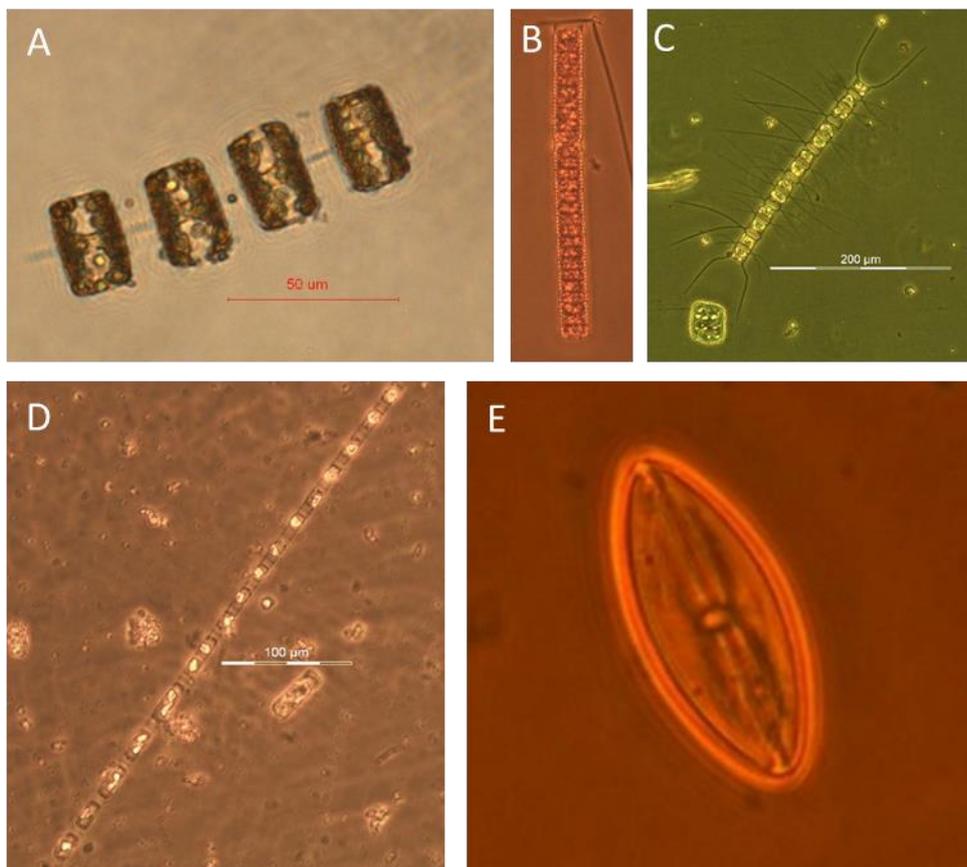


Figure 14 - Other abundant phytoplankton species from the Sizewell, EA and West Gabbard data. A – *Thalassiosira* sp. (11-186 µm); B – *Paralia sulcata* (8-130 µm); C- *Chaetoceros* sp. (7-80 µm); D - *Skeletonema costatum* (5-16 µm); E – Raphiated pennate diatom (2-500 µm). All Crown copyright (Cefas, plankton lab).

4 Discussion

Hydrographical, chemical and biological factors affect the seasonal and geographical fluctuations in the abundance and in the diversity of the phytoplankton. Phytoplankton activity is mainly driven by light and nutrient availability (Underwood and Komkramp, 1999), and both depend on local physical conditions: stratification can limit nutrient access and turbulent mixing can cause increased levels of suspended particulate matter, affecting light attenuation. The bloom starts when nutrient/light conditions are sufficient for positive growth in the bloom-forming species and terminates through the onset of nutrient limitation (Smetacek, 1999). However, stratification, vertical mixing, salinity and temperature are also important factors for primary production (Underwood and Komkramp, 1999). The stability of the water column as well as vertical mixing influence directly the availability of the light and nutrients. Salinity and temperature have a direct effect on physiology such as metabolic and reproductive processes. All these parameters vary not only locally but at a larger scale across the North Sea. Six different areas have been defined by the ICES Study Group on the flushing times of the North Sea (ICES, 1983). Recently, hydrodynamic parameters and phytoplankton functional types have been combined in a coupled hydrobiogeochemical model (GETM-ERSEM-BFM) to determine five geographical zones of the North Sea according to the hydrodynamic regime (Van Leeuwen *et al.* (2015): 1) permanently stratified (PS), 2) seasonally stratified (SS), 3) intermittently stratified (IS), 4) permanently mixed (PM), and 5) region of freshwater influence (ROFI). According to the model, the region of interest for the Sizewell C phytoplankton characterisation belongs to the PM zone, which represents 13 % of the total surface area of the North Sea. The region has relatively shallow waters (40 m at most) and is characterised as continuously mixed by tide and wave action.

The Greater Sizewell Bay area and offshore areas are both within the PM zone but according to the satellite imagery and *in-situ* measurements from the three datasets used here (BEEMS Sizewell surveys, EA WFD monitoring and Cefas West Gabbard mooring site), the inshore Greater Sizewell Bay area has higher SPM (as a function of FTU) and elevated levels of nutrients compared to the offshore North Sea. The highest nitrate and silicate concentrations were between January and March, with the EA data the highest maxima at approximately 35 $\mu\text{mol nitrate l}^{-1}$ and 25 $\mu\text{mol silicate l}^{-1}$, compared to BEEMS Sizewell at approximately 30 $\mu\text{mol nitrate l}^{-1}$ and 15 $\mu\text{mol silicate l}^{-1}$ and the offshore Cefas West Gabbard data at approximately 10 $\mu\text{mol nitrate l}^{-1}$ and 5 $\mu\text{mol silicate l}^{-1}$.

All nutrients (nitrate, silicate and phosphate) in all three datasets showed similar trends, with a decrease in concentration in the summer and autumn months and peak concentrations in the winter and spring. A strong feedback loop exists between nutrients and phytoplankton seasonality. Together with increased seawater temperatures and light intensity, the peak nutrient concentrations in winter and spring fuel the phytoplankton spring bloom (Underwood & Kromkamp, 1999). The blooming phytoplankton then alter the nutrient balance such that from around March the nutrients are depleted, particularly silicate which diatoms need to build their frustule. The subsequent decrease in phytoplankton biomass in early summer is then accompanied by a small increase in nutrients, which supports a different phytoplankton community that is smaller in size and doesn't rely on silicate.

According to Louis *et al.* (1974), all areas of the North Sea exhibit strong diatom-based spring blooms, with diatoms being predominant in the south and the dinoflagellates in the north. The diatom bloom did not start until late April/May on the East Anglian coast. According to Van Leeuwen *et al.* (2015), this bloom is followed by a long period of abundance of *Phaeocystis* sp., with a late summer increase in dinoflagellate levels. At Sizewell, the phytoplankton community was dominated by diatoms year round (contributing 99.5 % of total abundance in May and June, see Figure 12B). The diatoms rapidly depleted the silicate levels, as is apparent across all sites (

Figure 6). However, nitrogen and particularly nitrates can support the growth of other taxa such as microflagellates and dinoflagellates and the Sizewell community in mid-summer was dominated by microflagellates, which could have been misidentified *Phaeocystis* sp. (see Section 3.3.2). Dinoflagellates were present in July and August but never in high abundance. Nevertheless, the Sizewell data still generally fit the Van Leeuwen *et al.* (2015) model of the diatom-*Phaeocystis* (here, microflagellates)-dinoflagellate community of the PM zone.

The key taxa for the Greater Sizewell Bay area - those that represent at least 10 % of the total number of cells in all three datasets (BEEMS Sz, EA and Cefas WG) or are of socio-economic importance - hail from two main phytoplankton groups; diatoms and microflagellates. Within the diatom group, the chain diatoms were some of the most abundant, particularly during winter and spring (i.e. up to approximately 50 – 70 % of the population). Of the other key diatoms, *Thalassiosira* sp. and *Skeletonema* sp. were abundant from late spring into summer and autumn, raphiated pennates and *Paralia sulcata* from autumn into winter and spring and *Chaetoceros* sp. (Hyalochaetae) in both summer and winter. *Pseudo-nitzschia* sp., of potential socio-economic importance due to its link to amnesic shellfish poisoning, was of sufficient abundance to be considered key in only one month in one dataset (EA). While we cannot be certain whether this *Pseudo-nitzschia* was one of the toxic species and it was not found in consistently high abundance, it will be included in the Sizewell C EIA and WFD assessment due to its potential to cause harm.

Microflagellates were the most abundant of the three phytoplankton groups during the summer months. While the distribution of *Phaeocystis*, the nuisance bloom-forming species, is uncertain due to issues associated with sample processing, there is circumstantial evidence of its presence in the bay so it will also be included in the EIA and WFD assessment.

The three datasets used in this study show that the phytoplankton community in the Greater Sizewell Bay is typical of the wider North Sea PM zone, with a spring bloom of diatoms followed by a late summer increase in microflagellates. The seasonal occurrence of each of the key taxa is summarised in Table 2.

Table 2 – Summary of the key phytoplankton taxa of the Greater Sizewell Bay (seasonality information taken from Table 1). Coloured cells represent months when the taxon contributed at least 10 % of total abundance in any of the three datasets used (BEEMS, EA and Cefas West Gabbard).

	Winter			Spring			Summer			Autumn			Importance	
	D	J	F	M	A	M	J	J	A	S	O	N	Ecological	Socio-economic
Diatoms														
<i>Chaetoceros</i> (Hyalochaetae)													√	
Chain diatom													√	
<i>Paralia sulcata</i>													√	
<i>Pseudo-nitzschia</i>														√
Raphiated pennate													√	
<i>Skeletonema</i>													√	
<i>Thalassiosira</i>													√	
Microflagellates														
Microflagellates													√	
<i>Phaeocystis</i>														√

4.1 Update: Plankton monitoring surveys 2014-2017

Since the first edition of the Phytoplankton Characterisation, ongoing plankton monitoring has been underway at Sizewell. This section provides an overview of the latest phytoplankton surveys drawing comparisons to the results presented in this report.

Between March 2014 and January 2017, monthly monitoring studies were undertaken at Sizewell with the specific objective of determining the temporal and spatial variability in phytoplankton communities at a number of sites within the Greater Sizewell Bay. Four sites were surveyed for nutrients, chlorophyll a, environmental parameters and phytoplankton (Table 3). The sites included the location of the Sizewell B intakes, the Sizewell B outfalls and the proposed location of the Sizewell C cooling water infrastructure approximately 3 km offshore. A reference site (SZ3) to the north of Sizewell was also sampled (Figure 15). The results of the annual surveys are detailed in the following reports and a summary is provided below:

- ▶ 2014-2015 results are presented in BEEMS Technical Report TR276;
- ▶ 2015-2016 results are presented in BEEMS Technical Report TR379;
- ▶ 2016-2017 results, and analysis of the three year monitoring period are presented in BEEMS Technical Report TR454.

Temperature profiles were consistent with those reported here peaking in August across all sites with a mean temperature of 22.49 °C (± 2.98) at the SZB outfall site and of 19.26 °C (± 0.20) for the three other sites. The temperature at the SZB outfall site was on average 3.12 °C higher than the other sites throughout the year. Temperatures between the Sizewell B outfall and other sites was most similar in February: 0.85 °C (± 1.34). Annual trends in turbidity, salinity and nutrients (TOxN, nitrite, ammonia, phosphate and silicate) are described in BEEMS Technical Report TR454.

Table 3 Summary of number and type of samples types taken over the three survey years.

Sampling Site	Degrees/Min/Sec		2014-15	2015-16	2016-17
	Latitude	Longitude			
SZ3 reference	52° 16' 00"N	01° 38' 30"E	Nutrients ESM2 logger Phytoplankton	Nutrients ESM2 logger Phytoplankton	Nutrients ESM2 logger Phytoplankton
SZC intake/ outfall	52° 13' 07"N	01° 40' 05"E	Nutrients ESM2 logger Phytoplankton	Nutrients ESM2 logger Phytoplankton	<i>Phytoplankton samples not collected</i>
SZB intake	52° 12' 53"N	01° 38' 00"E	Nutrients ESM2 logger Phytoplankton	Nutrients ESM2 logger Phytoplankton	Nutrients ESM2 logger Phytoplankton
SZB outfall	52° 12' 55"N (2014-15)	01° 37' 36"E (2014-15)	Nutrients ESM2 logger Phytoplankton	Nutrients ESM2 logger Phytoplankton	<i>Phytoplankton samples not collected</i>
	'A' - 52° 12' 44"N 'B' - 52° 12' 48"N (2015-16)	'A' 01° 37' 42"E 'B' 01° 37' 47"E (2015-16)			

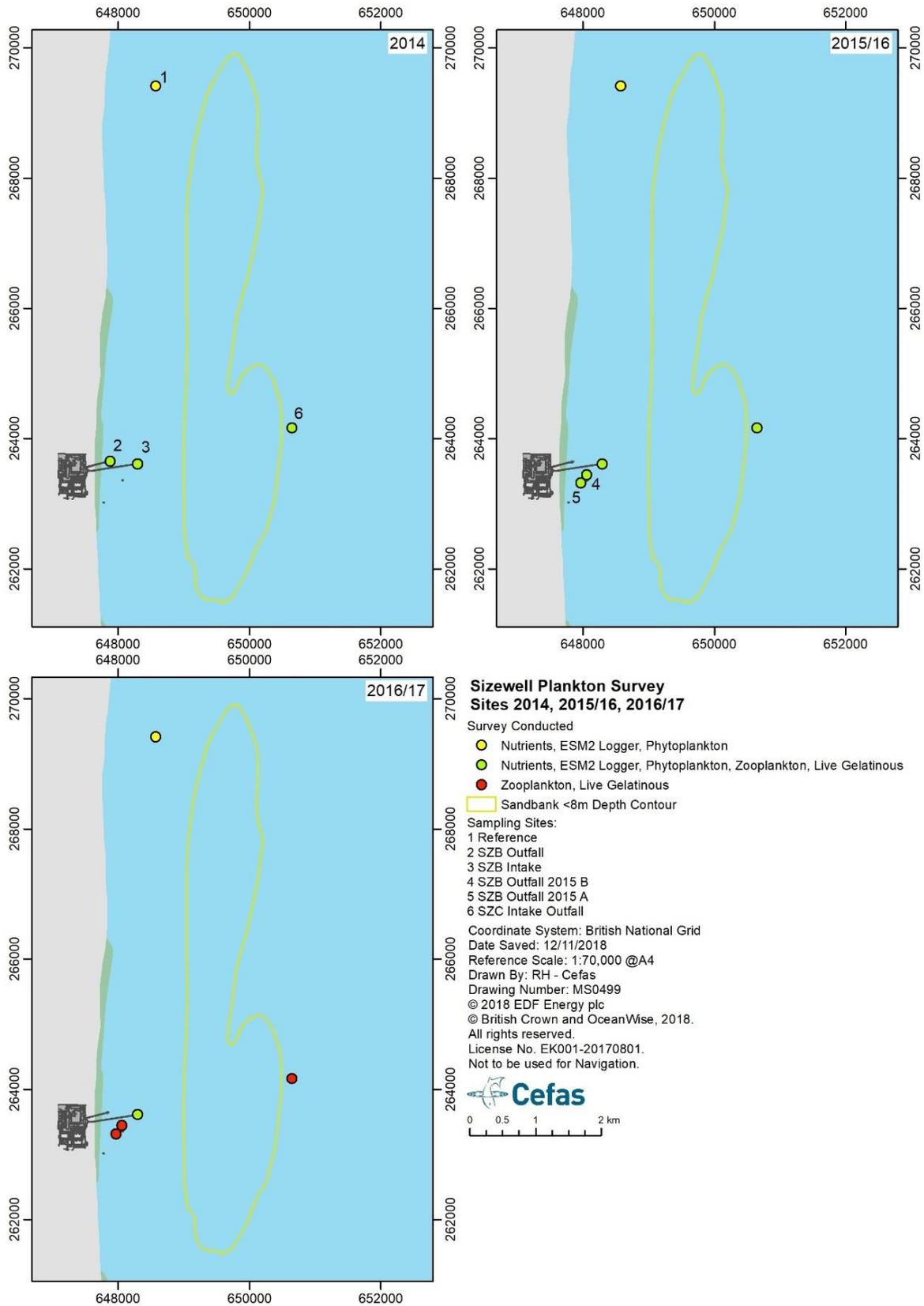


Figure 15 Location of sampling sites for phytoplankton and zooplankton and collection of nutrients and environmental data.

The phytoplankton community composition between March 2014 and January 2017, largely reflected that described in this report. Diatom cells dominated the community in 2016-2017, comprising 73% of the total mean annual abundance compared to 85% in 2014-2015, and 74% in 2015-2016. Peak abundances occurred consistently from April to June, during which time >99% of the total abundance were diatoms. The latest onset of the spring bloom happened in June of 2016 when chlorophyll *a* peaked at 8.5 (±1.0) µg l⁻¹ at the reference site and 7.6 (±1.0) µg l⁻¹ at the SZB intake. Cell densities of 1,451,433 (± 41,908) cells l⁻¹ were recorded and the diatom *Asterionellopsis glacialis* was the dominant species. *Asterionellopsis glacialis* species was far less abundant in previous years. A mixture of *Skeletonema* spp., raphiate pennate diatoms including *Ceratoneis closterium*, and chain diatoms occurred in 2015, and *A. glacialis* comprised just 4%. In 2014, peak abundance was dominated by chain diatoms including *Cymatosira* sp. and *Skeletonema* spp and *A. glacialis* was absent. The annual pattern in chlorophyll *a* between 2014 and 2017 corresponded with those reported above (Figure 8 and Figure 9), with maximum values typically occurring in May when concentrations of up to 10 µg l⁻¹ (10 mg m³) can occur (Figure 17). A high degree of interannual variability was observed in the chlorophyll *a* concentration at each site. For example, at the SZC site the coefficient of variation of the mean monthly chlorophyll *a* concentration was 44%, 91% and 48% for the months April, May and June, respectively. Over the same months the reference site had a coefficient of variation of 51%, 64% and 51% (Figure 17). The high variability in chlorophyll biomass and phytoplankton abundance at the coastal stations is consistent with this report (Figure 9 and Figure 10)

The lowest diatom abundance occurs in March (60,767 cells l⁻¹ in 2016) but diatoms still comprised the largest fraction of the community (80% of total abundance). Between 2014-2017, microflagellate abundance peaked in September. At the SZB intake a mean value of 288,622 cells l⁻¹ occurred in September (71% of overall abundance). Dinoflagellates remained in relatively low numbers all year round, never exceeding 10% of total abundance in any of the sampling years (Figure 16). Community analysis showed no significant differences between the four sampling sites (BEEMS Technical Report TR454; Section 3.2 above). Interannual variability was observed.

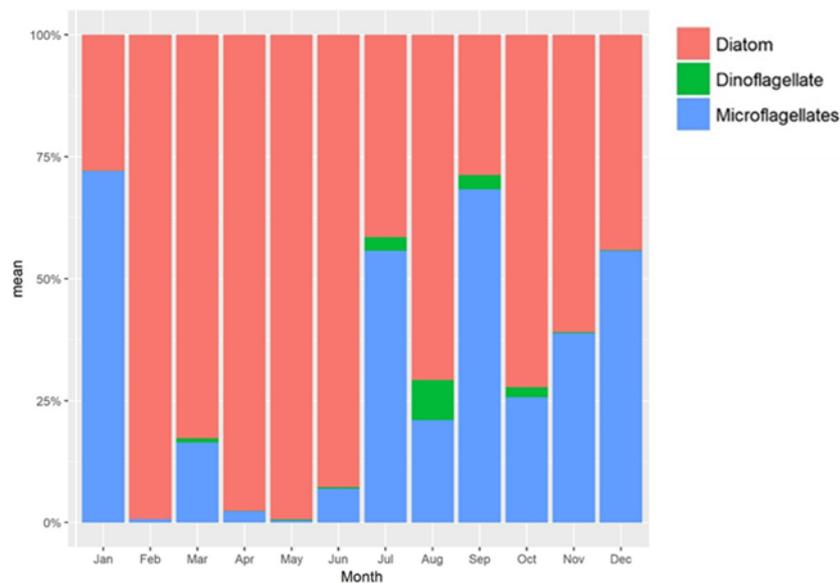


Figure 16 The mean percentage abundance of the main functional groups per month for the three-year survey period (March 2014- January 2107).

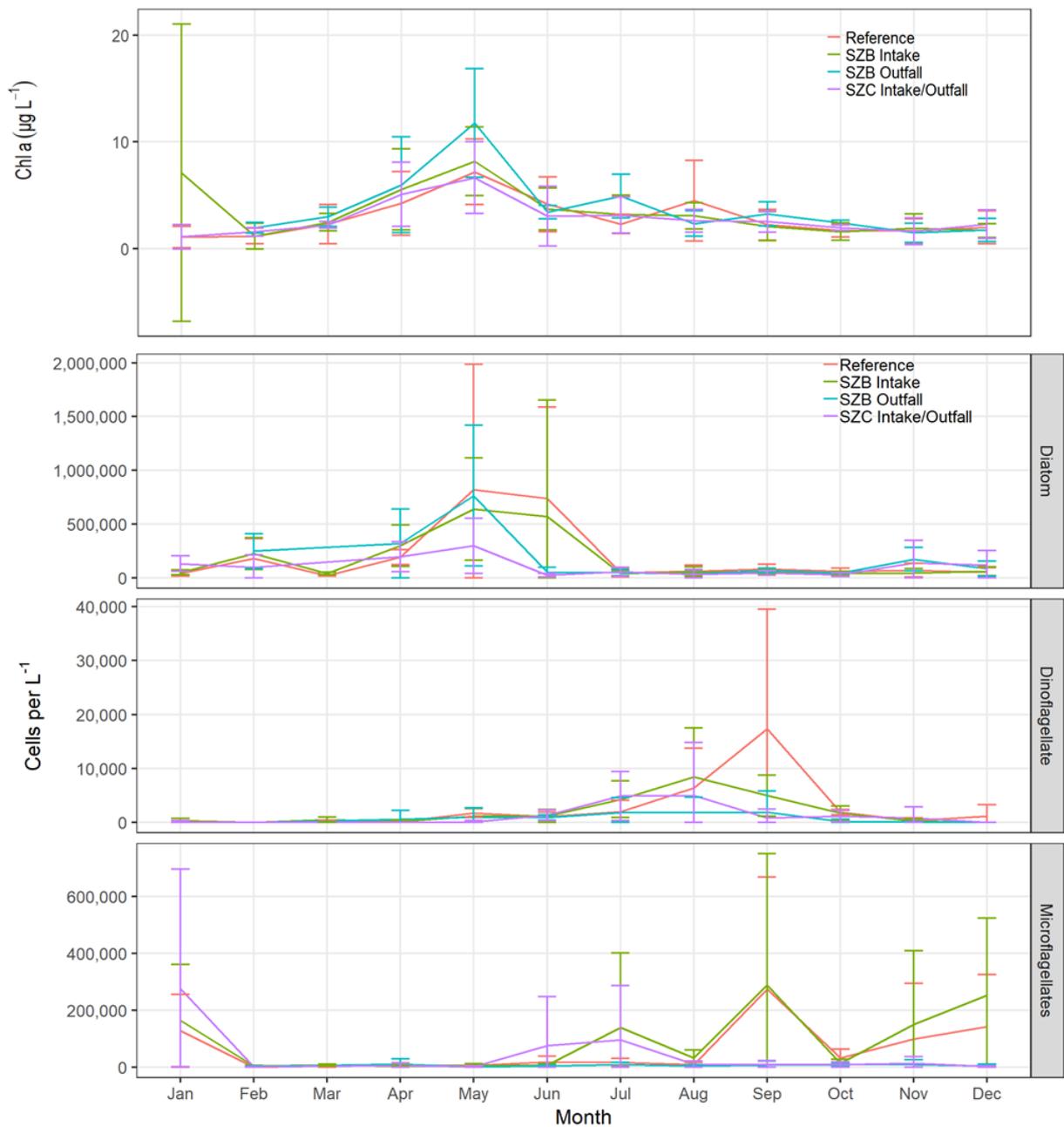


Figure 17 Mean (\pm SD) monthly values for chlorophyll a ($\mu\text{g l}^{-1}$), and cell abundance (cells l^{-1}) for the key taxonomic groups during surveys conducted between March 2014 and January 2017 (reference site and SZB intakes) and March 2014 and January 2016 (SZB outfalls and SZC proposed cooling water infrastructure).

4.2 WFD Phytoplankton Assessment Tool

The EU Water Framework Directive (WFD, 2000/60/EC, EU, 2000) requires EU member states to assess the ecological status of their water bodies. Assessments are based on a range of Biological Quality Elements (BQE, e.g. macroalgae, phytoplankton, fish and invertebrates) and Supporting Quality Elements (SQE, e.g. physico-chemical conditions, hydromorphology). Biological standards are values defined for measures of ecological quality, such as the abundance of different species or groups of species of phytoplankton, fish or

invertebrates. They describe the boundaries for ecological quality ratios (EQRs) between five ecological status classes (high, good, moderate, poor and bad) used to classify water bodies. The coastal waters (up to 1 nm offshore) at Sizewell are part of the Suffolk Coastal waterbody, a heavily modified waterbody with an overall ecological potential of ‘moderate’ based on the ‘one-out all out’ principle.

Phytoplankton are classified using a tool developed by UK TAG (Devlin *et al.*, 2014). The phytoplankton tool combines metrics for chlorophyll *a* (µg l⁻¹, 90th percentile) during the growing season (March to October, inclusive), elevated counts, and seasonal succession. The elevated count metric is based on the number of occasions that phytoplankton parameters exceed established thresholds over the reporting period. The seasonal succession metric works on the measurement of the two taxonomic groupings (diatoms and dinoflagellates) falling within a seasonal reference growth curve. The three metrics are averaged to provide an overall phytoplankton assessment. Between 2013 and 2016, the Environment Agency (EA) phytoplankton classification has been assessed as ‘good’ (Table 4)

Table 4: Suffolk Coastal waterbody classification (EA: <https://environment.data.gov.uk/catchment-planning/WaterBody/GB650503520002>, accessed on 22 January 2019).

Classification Item		2013	2014	2015	2016
▼	Overall Water Body	Moderate	Moderate	Moderate	Moderate
▼	Ecological	Moderate	Moderate	Moderate	Moderate
▶	Supporting elements (Surface Water)	Good	Good	Good	Good
▼	Biological quality elements	Good	Good	Good	Good
	Phytoplankton	Good	Good	Good	Good
▼	Physico-chemical quality elements	Moderate	Moderate	Moderate	Moderate
	Dissolved Inorganic Nitrogen	Moderate	Moderate	<u>Moderate</u>	Moderate
	Dissolved oxygen	High	High	High	High
▶	Specific pollutants	High	High	-	-
▶	Chemical	Good	Good	Good	Good

Phytoplankton data collected between March 2014 and December 2016 was used to determine if the waters off Sizewell correspond to the wider waterbody classification of ‘good’ by applying the phytoplankton tool for two sites. The two sites included a references site (SZ3), located north of Sizewell B and a site at Sizewell B intake (BEEMS Technical Report TR476).

At the reference site, chlorophyll *a* (0.83) and elevated counts (0.85) reflected ‘high’ status, whereas seasonal succession (0.40) had a ‘moderate’ score. This resulted in an overall equidistant index of ‘good’ (0.69). Confidence is class for the phytoplankton status assessment at the reference site was good (99.9 % within the ‘good’ category).

At the Sizewell B site, chlorophyll *a* (0.87) and elevated counts (0.89) reflected ‘high’ status, whereas seasonal succession (0.64) had a ‘good’ score. This resulted in an overall equidistant index of ‘high’ (0.80, the lower boundary of high status). Confidence is class for the phytoplankton status assessment at the Sizewell B intake site was high (51.3 % in the ‘high’ category, 100% ‘good or better’).

Over the three year period of data collection, the phytoplankton assessments at the reference site and the Sizewell B intake indicated that the phytoplankton status broadly conformed to that of the wider waterbody (BEEMS Technical Report TR476). The WFD phytoplankton assessment tool is primarily designed as a risk assessment for nutrient enrichment (Devlin *et al.*, 2007); the effects of which include increases in chlorophyll *a* biomass and elevated cells counts.

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