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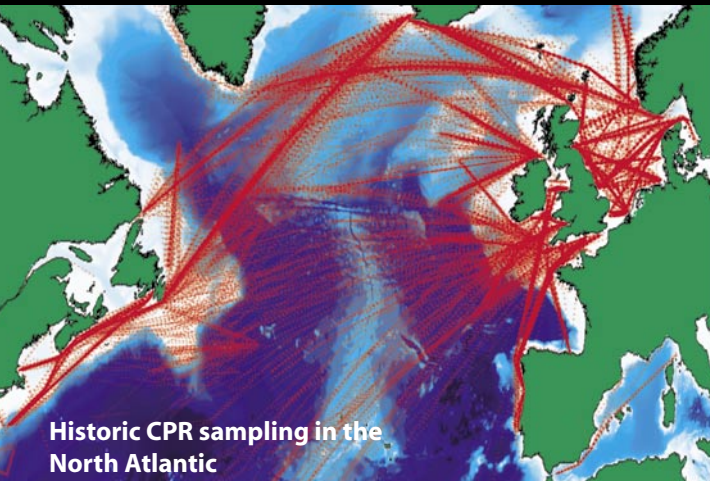
ecological status report  
2003/2004





Results from the Continuous Plankton Recorder survey for the period 2003 to 2004 summarising changes in the planktonic community in the North Atlantic. This report provides a macro-scale view of biological changes in many regions of the North Atlantic from oceanic waters like the Labrador Sea to shelf areas like the European Continental Shelf.

# Ecological Status Report 2003/2004



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## Ecological indicators

Using a number of ecological indices, this report summarises unusual species found, large phytoplankton blooms, changes in community structure and trends in hydrobiological indicators from regions in the North Atlantic (with an emphasis on the North Sea). In the majority of cases, the term 'unusual' or 'large' in referring to phytoplankton blooms refers to population increases greater than four standard deviations above the species recorded baseline mean (baseline mean: 1980-2003). Notable blooms that are geographically large refer to patch sizes greater than 100 km in diameter. The primary assessment area used to monitor changes in community structure, biomass and phenological changes is the central North Sea, an area that has been consistently sampled on a monthly basis over the last six decades. Most data analysis has been performed to highlight the year 2003 in relation to the long-term dataset. 2004 sample data is presented here as preliminary and has not yet undergone quality checks.

Annual abundance estimates were calculated for each CPR box for years when eight or more months were sampled (Colebrook, 1975) (Fig. 2). For years when fewer than eight months were sampled, no annual estimate of abundance was calculated. Sea surface temperature (SST) was used as an indicator of ocean climate and climate change, as organisms respond physiologically to temperature. Monthly sea surface temperature (SST) data on a 1° by 1° grid for the period 1946-2003 were obtained from the Hadley Centre, UK Met Office. This dataset is a gridded product combining in situ sea surface observations and satellite derived estimates. For each of the 41 regions, SST values were averaged per year to provide unbroken 58-year time series of annual/spring SST in each CPR box.

## The spring bloom

The trend in winter blooms (January and February), that has occurred over the last six years, of *Ceratium arcticum* continued in 2003 in the north-west Atlantic, particularly off the Newfoundland shelf break. This is thought to have occurred due to the increase in freshwater input to these areas and hence intensified haline stratification. Pre-spring blooms in the North Sea included *Coscinodiscus concinnus*, *Odontella regia*, *Cylindrotheca closterium* and *Bacillaria*

## HABs in European waters 2003

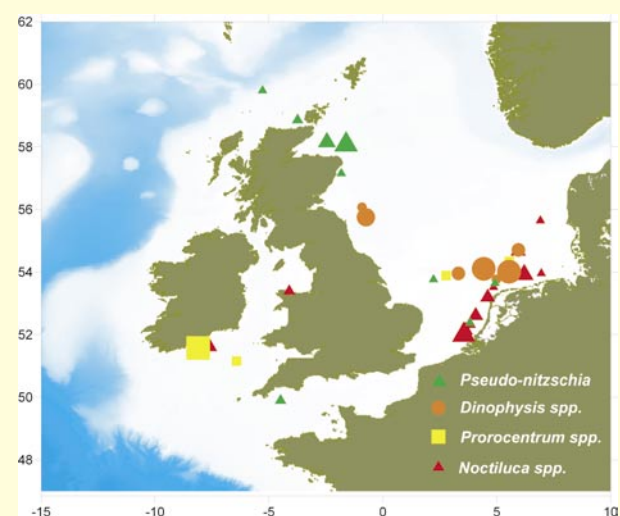


Fig. 1. Spatial distribution of 4 HAB taxa in Northern European waters during 2003 (proportional scaling). Only occurrences of the taxa above 4 standard deviations above its baseline mean (1960-2002) are shown, i.e. exceptional blooms.

## CPR standard areas in the North Atlantic

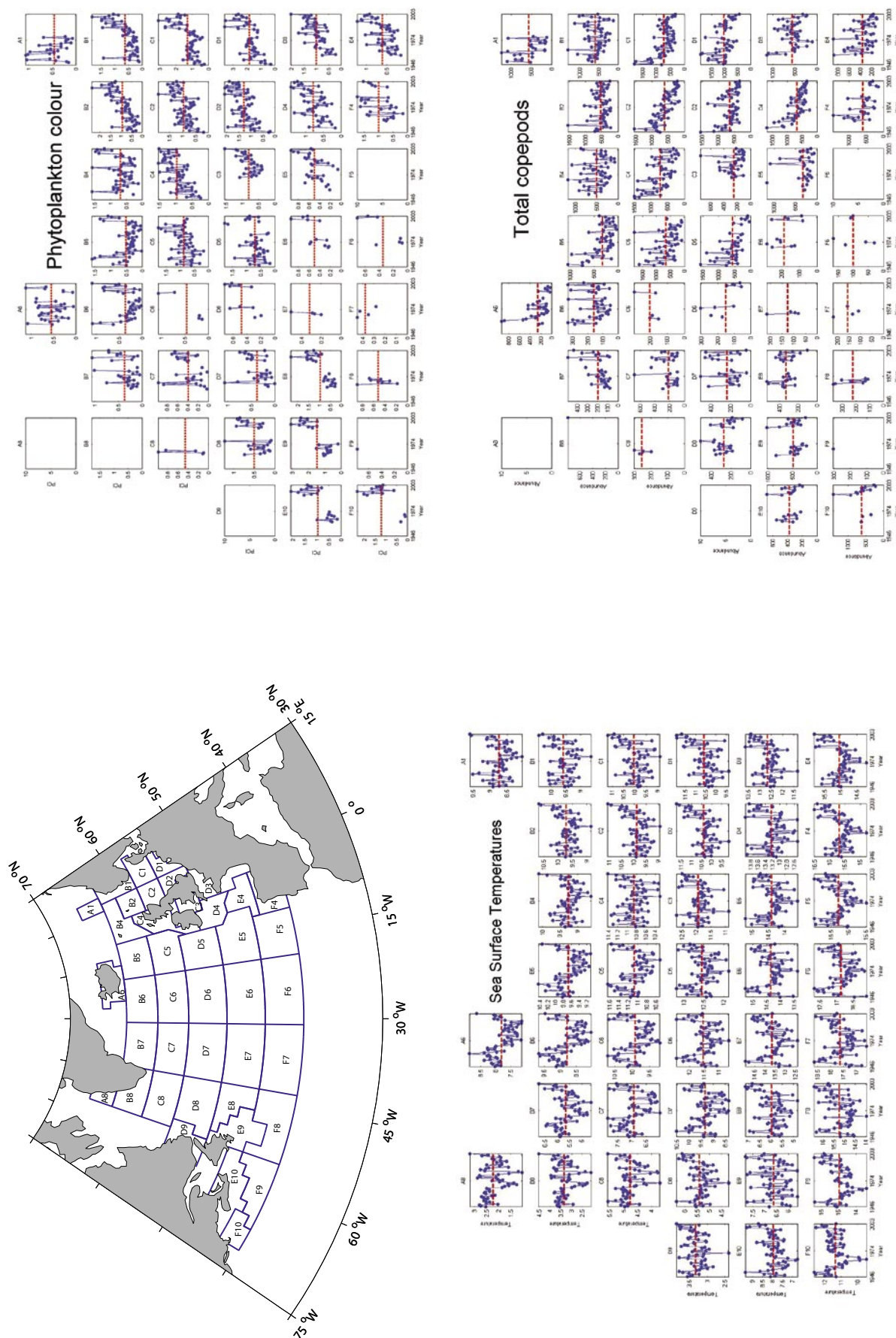


Fig. 2. Standard CPR boxes used to examine spatial variability in the North Atlantic and annual Sea Surface Temperatures, phytoplankton colour and total copepods for each CPR box from 1946–2003. Annual values were only calculated for each CPR box when eight or more months were sampled in any given year.



*paxillifer*. Traditional spring-bloom species were first evident in the first week of February off the coast of Portugal, unusually there was also a bloom of *Ceratium candelabrum* present during this time. During the second week of February the spring bloom was evident in the Bay of Biscay, mainly comprising of *Thalassionema nitzschioides*, *Thalassiosira* spp. and *Skeletonema costatum*. In the north-west Atlantic a large bloom of *Phaeoceros* spp. was also present in the Laurentian Channel during February. In the North Sea, the first sign of the spring bloom was evident off the Dogger Bank during early March, dominated by early spring-bloomers such as *Asterionella glacialis* and *Fragilaria* spp. The spring bloom was well under way on Georges Bank and the Scotian Shelf by mid-March, dominated by *Thalassionema nitzschioides* and *Thalassiosira* spp. and in the Labrador Sea by *Thalassiothrix longissima*. Peak spring bloom biomass in most of the North Atlantic occurred in April.

## Exceptional and Harmful Algal Blooms (HABs)

As well as providing an index of phytoplankton biomass (phytoplankton colour), the CPR survey identifies approximately 170 phytoplankton taxa. Apart from diatom species, by far the most common bloom-forming taxon recorded by the CPR survey in 2003 was Coccolithaceae and the genus *Ceratium*, in particular the ubiquitous species *C. fusus* and *C. furca* and *C. arcticum* in more arctic-boreal waters. The first coccolithophore blooms were recorded in late March and early April off the north coast of Spain and off the coast of Portugal and progressively spread northward as the season advanced, hitting a peak in June and July in the waters to the south of Iceland. The non-indigenous diatom *Coscinodiscus wailesii* reached bloom proportions in the southern North Sea during April. The warmer water *Ceratium* species *C. bucephalum* and *C. hexacanthum* were unusually found in high numbers in the northern North Sea (Moray Firth) during August and September. Apart from geographically extensive blooms, of particular note are the occurrences of Harmful Algal Blooms (HABs) in European waters. Figure 1 shows the geographical distribution of four common HAB taxa in European waters. It is evident from the figure that these HAB taxa are most numerous along the Dutch coast. In particular, the red-tide forming species *Noctiluca scintillans* forms extensive blooms during the summer period in this area. Both *Dinophysis* spp. and *Prorocentrum* spp. blooms were also most commonly recorded in this area, particularly during July, August and September. Unusually, a bloom of *N. scintillans* was found as late as November off the Danish coast. The largest *Prorocentrum* bloom was recorded off the south-east coast of Ireland during July. Blooms of *Pseudo-nitzschia* spp. were most prevalent in the waters between Aberdeen and the Orkney Islands. This taxa is sometimes associated with Amnesic Shellfish Poisoning (ASP). In comparison with previous years, HAB blooms were less common in 2003. In particular, large blooms of *Dinophysis* spp.

were absent off Norwegian coastal waters and in the English Channel.

## Phytoplankton biomass

Figure 2 shows the long-term inter-annual values of phytoplankton colour (an index of total phytoplankton biomass) for standard CPR areas in the North Atlantic from 1946 to 2003. It is obvious from this figure that there has been a large increase in phytoplankton biomass since the late 1980s in most regional areas (particularly the north-east Atlantic and the Newfoundland shelf). From the late 1940s to the late 1980s, the majority of biomass was restricted to the spring and autumn bloom periods, i.e. diatoms dominated the phytoplankton assemblage. Since the late 1980s, biomass has increased throughout the seasonal cycle. 2003 showed a drop in phytoplankton colour, but generally the index was still higher than the base-line mean (1946-2003). In other parts of the North Atlantic, high increases in phytoplankton biomass were seen off the Newfoundland Shelf (with an increase in winter blooms), the Scotian Shelf and the Labrador

### Community structure and shifts

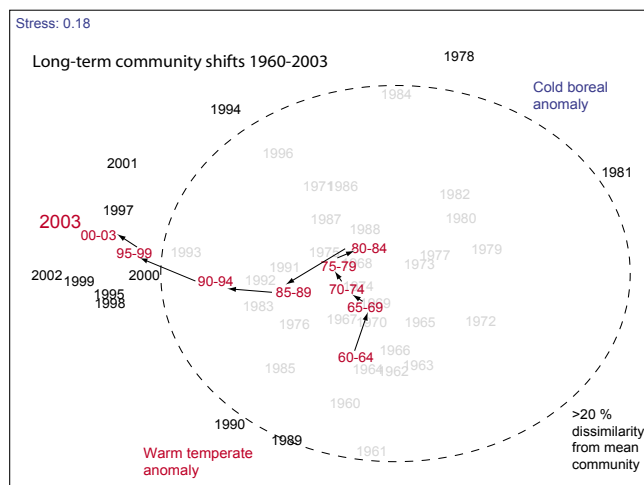
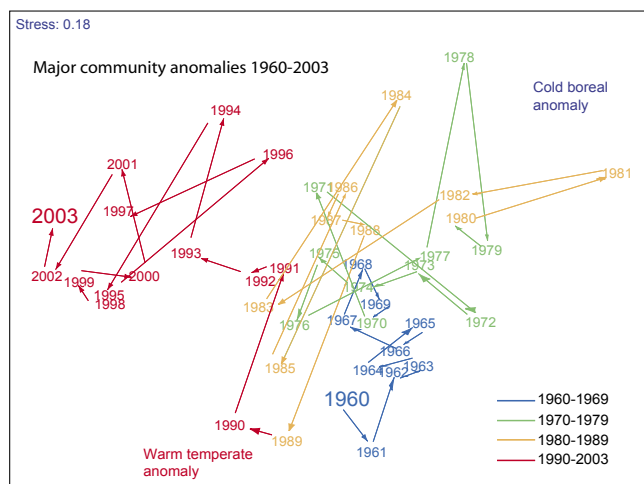


Fig. 3. Multi-dimensional scaling plot of the annual zooplankton community structure in the central North Sea from 1960-2003 showing major structural shifts (top figure) and five-year community averages (bottom figure). Similarity matrix based on Bray-Curtis and log (x+1) transformations.

Sea. In the northern North Atlantic and in the sub-polar gyre, phytoplankton biomass has been generally declining over the last two decades, but has shown an increase post 1998.

## Zooplankton abundance

Figure 2 shows the time series of total zooplankton abundance (numbers.sample<sup>-1</sup>) from 1946–2003 in CPR standard areas in the North Atlantic. This method excludes years in which data from fewer than eight months were available. The dashed line represents the long-term mean in each standard area. The most striking feature of the time series is a general long-term decline in total copepod abundance east of Iceland, although some areas show no trend (e.g. northern North Sea areas B1 and B2). It is clear that the year 2003 is broadly consistent with this trend, with lower than usual copepod abundance throughout most of the standard areas, particularly in the southeast.

## Zooplankton community structure and shifts

Figure 3 shows a multi-dimensional scaling plot of the annual zooplankton community in the central North Sea. The decadal changes in the community are characterised by the colder-water community in the 1960s and the warmer-water community in the 1990s. The two most distinguishable shifts are those that occurred in the late 1970s and late 1980s. Both these community shifts are associated with ocean climate anomalies (Edwards et al. 2002). Since the 1990s, when a notable regime shift occurred, the planktonic community has remained in a warm-water state. One of the main reasons why the 1990s community is so distinctive compared to the 'normal' community is that the zooplankton community has more warmer/sub-tropical species present in the 1990s assemblage (e.g. *Penilia avirostris*). The planktonic community in 2003 has remained in a position of post regime shift characteristic of a warm-temperate zooplankton community. The bottom figure (using five-year community averages) emphasises the temporal evolution of the zooplankton community since the 1960s. The similarity matrix was based on 60 of the most abundant zooplankton taxa using Bray-Curtis similarity with log (x+1) transformations.

## Cold/warm indicator species

Over the last decade there has been a progressive increase in the presence of warm-water/sub-tropical species into the more temperate areas of the north-east Atlantic, with 2003 continuing with this trend. Sea Surface Temperature (SST) was very high in the North Sea during 2003, particularly in August and September.

The plankton community in 2003 had unusually high numbers of warm-water/sub-tropical species as well as oceanic species including Doliolids. The sub-tropical cladoceran *Penilia avirostris* has increased considerably in abundance in the North Sea in recent years. In 2003 and 2004 high numbers were present in the eastern North Sea west of Denmark in September, and in the south-eastern North Sea and off the Dutch coast in October. A nauplius of the stalked barnacle *Lepas* was found just south of Iceland (at 62°36'N 14°34'W) in

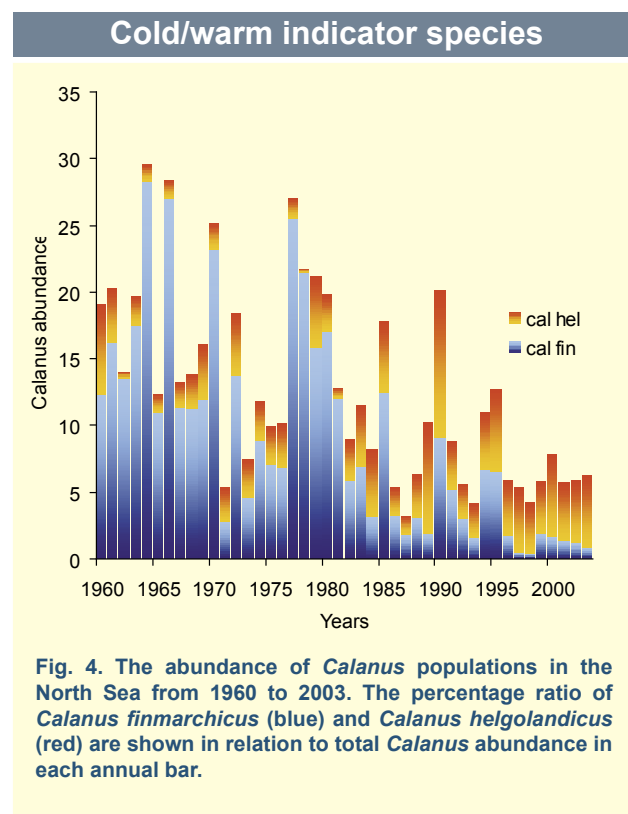


Fig. 4. The abundance of *Calanus* populations in the North Sea from 1960 to 2003. The percentage ratio of *Calanus finmarchicus* (blue) and *Calanus helgolandicus* (red) are shown in relation to total *Calanus* abundance in each annual bar.

September 2003. This species is rarely recorded this far north. As mentioned earlier, was the presence of the warmer water *Ceratium* species *C. bucephalum* and *C. hexacanthum* which were unusually found in high numbers in the northern North Sea (Moray Firth) during August and September of 2003.

A useful indicator of the warming trend in the North Sea is the percentage ratio of the cold-temperate copepod *Calanus finmarchicus* and the warm-temperate copepod *Calanus helgolandicus*. Figure 4 shows the overall abundance of *Calanus* and the percentage ratio of *C. finmarchicus* and *C. helgolandicus*. 2003 was dominated by *C. helgolandicus*, a trend that has been evidently accelerating over the last decade. The late 1970s and late 1980s anomalies are also clearly visible. What is also worth noting is that, while *C. helgolandicus* is becoming more abundant in the North Sea, the overall *Calanus* abundance has considerably declined. This has important implications for other trophic levels.

## Phenology indicator

Phenology is the study of the timing of recurring natural phenomena (e.g. seasonal events). Interannual changes in seasonal/successional timing is considered to be a good indicator of climate change. For example, interannual changes in the timing of species associated with the spring bloom, or the earlier appearance of dinoflagellates, associated with summer stratified conditions, may indicate hydroclimatic changes. Due to the sensitivity of the physiological development of meroplankton to temperature, we have chosen echinoderm larvae as a representative of phenological changes in shelf sea environments. Figure 5 shows the annual peak seasonal abundance 'centre of gravity index' of echinoderm larvae from 1960–2003 in the central North Sea. It is clear that there is a major trend towards an earlier seasonal peak. In particular, since 1988, with the exception of 1996 (a negative NAO year), the seasonal development of echinoderm larvae has occurred

## Phenology indicator

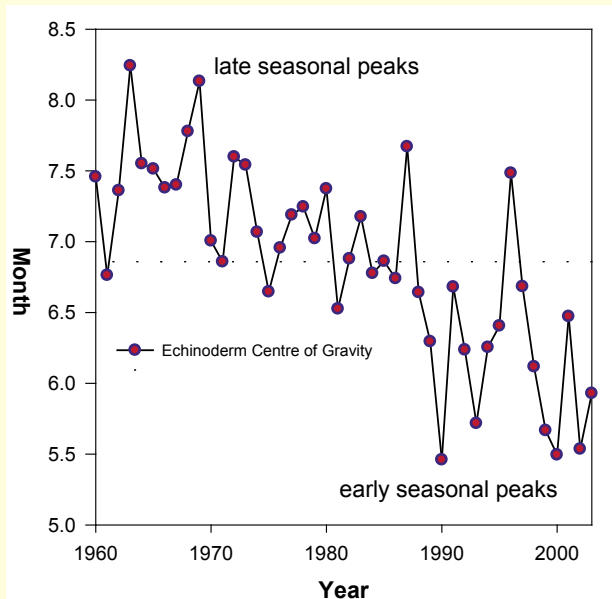


Fig. 5. Inter-annual variability in the peak development of echinoderm larvae (an indicator of plankton phenology) in CPR averaged areas C2 and C1 from 1960–2003.

much earlier than the long-term average (baseline mean: 1960–2003). For example, the seasonal cycle has been up to 4–5 weeks earlier in the 1990s than the long-term mean. This trend towards an earlier seasonal appearance of meroplanktonic larvae during the last decade is highly correlated to spring Sea Surface Temperature (see Edwards & Richardson, 2004). 2003 continued with this trend with the early seasonal appearances of meroplankton larvae.

## Unusual taxonomic records and biodiversity

The Pacific diatom *Neodenticula seminae*, which has been present in the northwest Atlantic for several years, was recorded in the eastern Atlantic on 401 BA in July (49°21'N 9°33'W) and 403 BA in September. A large and extensive bloom of coccolithophores, which included *Syracosphaera pulchra* and *Coccolithus pelagicus*, extended for over 400 miles of the August V route from 59°30'N to 62°50'N (south of Iceland). Several sub-tropical dinoflagellates were recorded off the Portuguese coast in November (on 513 SB), including *Ceratium belone*, *C. inflatum* and *C. limulus* (only the 4<sup>th</sup> CPR record), together with the warm water diatom *Rhizosolenia* (now *Guinardia*) *cylindrus*.

The copepod *Gaetanus miles*, previously unrecorded in the CPR survey, was found ca 80 nm south of the Faeroe Islands in January (on 680 V). The harpacticoid copepod *Parathalestris croni* occurred in the outer Gulf of Maine in February (on 284 EB), off Aberdeen in May (484 LR) and east of Newfoundland in December (506 ZC). This species has been found in clumps of drifting algae well offshore around Iceland (Ingólfsson & Ólafsson 1997). *Labidocera acutifrons* was recorded south of Cape Cod in October (292 EB). A great variety of subtropical copepods was recorded in January ca 500 nm west of the Azores and south of 39°N (on 394 BD). These included *Candacia longimana*, *Euaetideus* sp. and *Scolecithrix bradyi*, all of which are rare in CPR samples. Over 100 cestode larvae were observed in a *Calanus helgolandicus* found in June on 212 IB

in the inner Celtic Sea (51°05'N 6°16'W). A siphonostomatoid copepod (possibly *Asterocheres* spp) was found ca 10 nm west of Texel on the LG route in January. In March the heteropod mollusc *Cavolinia* was recorded on six samples taken ca 150 nm north of the Azores from 41°08'N to 42°26'N (on 396 BC). A stomatopod was found in the central English Channel in July (on 401 BA). Larger than normal numbers of nauplii of the stalked barnacle *Lepas* sp. were present near the Azores from January to March (on the BD route). A stage VI nauplius larva of the Boreo-arctic barnacle *Chirona* (formerly *Balanus*) *hameri* (identified by A.J. Southward) was recorded in April on Georges Bank ca 100 nm east of Cape Cod (on 286 EB).

## Status summary

The trend in winter blooms (January and February), that has occurred over the last six years, of *Ceratium arcticum* continued in 2003 in the north-west Atlantic, particularly off the Newfoundland shelf break. This has thought to have occurred due to the increase in freshwater input to these areas and hence intensified haline stratification caused by regional climate change. In terms of the numerical occurrence of exceptional and Harmful Algal Blooms, 2003 can be considered fairly average. Annual means of phytoplankton biomass in 2003 were slightly lower than 2002, but continued to remain above the long-term mean. The zooplankton assemblage in the North Sea was again dominated by meroplankton, in particular echinoderm larvae. Conversely, copepod abundance, which dominated the zooplankton community from the 1950s to the late 1970s, has continued to decline. What is also worth noting is that while *Calanus helgolandicus* is becoming more abundant in the North Sea, the overall *Calanus* abundance has considerably declined. This has important implications for other trophic levels.

The phenology indicator, in this case echinoderm larvae, again occurred much earlier in the season, reflecting a trend that has been occurring since the late 1980s and a trend of many planktonic taxa also share (Edwards & Richardson, 2004). In the North Sea, the overall zooplankton community has shown a considerable shift since the 1990s, mainly due to the presence of sub-tropical species. The phytoplankton community in the North Sea was also found to have unusual warm *Ceratium* species present. The fingerprint of climate warming is strongly evident in the plankton recorded by the CPR survey, from both the biogeographical shifts in many populations and the changing seasonal cycles associated with the timing of life-cycle events. 2003 was again a warm year in the north-east Atlantic and this was reflected in our suite of indicators.

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