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## **ZOOPLANKTON MONITORING RESULTS IN THE ICES AREA, SUMMARY STATUS REPORT 2004/2005**

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## 1 Background

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In its strategic plan, ICES recognized its role in making scientific information accessible to the public as well as to fisheries and environmental assessment groups. During the 1999 Annual Science Conference, ICES requested that the Oceanography Committee Working Groups develop data products and summaries that could be routinely provided to the ICES community via the ICES website. The Working Group on Zooplankton Ecology (WGZE) has made it a priority to produce a summary report on zooplankton activities in the ICES area based on the time-series obtained from national monitoring programmes. WGZE has provided such an annual report since 2000.

This is the sixth summary of zooplankton monitoring in the ICES area. Phytoplankton and temperature data for some locations corresponding to the zooplankton sampling sites are also included in this report. Our goal is to produce a Plankton Status Report with environmental variables in the near future.

We have followed the scheme of last year's report, including the regional description and study of the annual means of zooplankton abundance anomalies. A general overview of SST and copepod abundance for the entire North Atlantic, provided by SAHFOS, discusses the regional description of the time-series results from the monitoring programmes and places the data in a basin scale context. In addition, we have improved this year's report with tables summarizing the ten top species and taxa dominating the mesozooplankton by their abundance at several sampling sites, as well as comparing the current year with the historical series. Finally, we have incorporated a comparison of the phytoplankton colour index provided by SAHFOS with the values of fluorescence obtained by remote sensing using SeaWiFS.

This report benefits from contributions from members of WGZE and from colleagues in ICES Member Countries, who lead zooplankton time-series programmes. In addition to the editors, the following have contributed material or provided comments to this report:

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## **2 Regional coverage**

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The information collated by WGZE is derived from zooplankton sampling programmes in the ICES area, which include six fixed stations and 35 standard sections (approximately 350 sampling stations) distributed on the continental margins of both North America and Europe and covering an area from the temperate latitudes south of Portugal to the colder regions north of Norway, Iceland, and Canada. In addition, there are several fixed CPR routes that cover coastal and oceanic waters in the Atlantic Ocean. The sampling networks and collections used in this report are shown in Figure 1.

As shown in the time-series presented here, zooplankton abundance varies substantially between years. Temperature can greatly influence the community structure and production of zooplankton and can cause large seasonal, annual, and decadal changes in zooplankton population size and species distribution. Other factors that explain biogeographical differences in species distribution, plankton abundance, and biological processes are the extent of exposure to sunlight (latitude), the timing of the spring bloom, the length of the season of water column stratification, etc. It is for these reasons that data sets in this report are presented by affinities in temperature and biogeographical areas, which correspond to regional seas or basins and are discussed under this biogeographical scheme.

The main characteristic of the zooplankton monitoring programmes is the temporal resolution of observations. Zooplankton is also sampled with a variety of nets and over a variety of temporal and spatial scales, so a comprehensive interpretation of the data sets requires information on metadata to describe the content, quality, and other data characteristics (sampling gear, mesh size, depth, sampling site, dates, ancillary data, personnel responsible for the data, etc.). These metadata can be found in Section 6.

Data are presented on biomass (Icelandic–Norwegian basin and Barents Sea) or abundance (Canada, Baltic Sea, North Sea, English Channel, Bay of Biscay, and Iberian coast), with only one data set expressed as abundance in number of organisms per sample (CPR), and another expressed in plankton volume (Georges Bank). Abundance and biomass are structural variables that are easily compared.

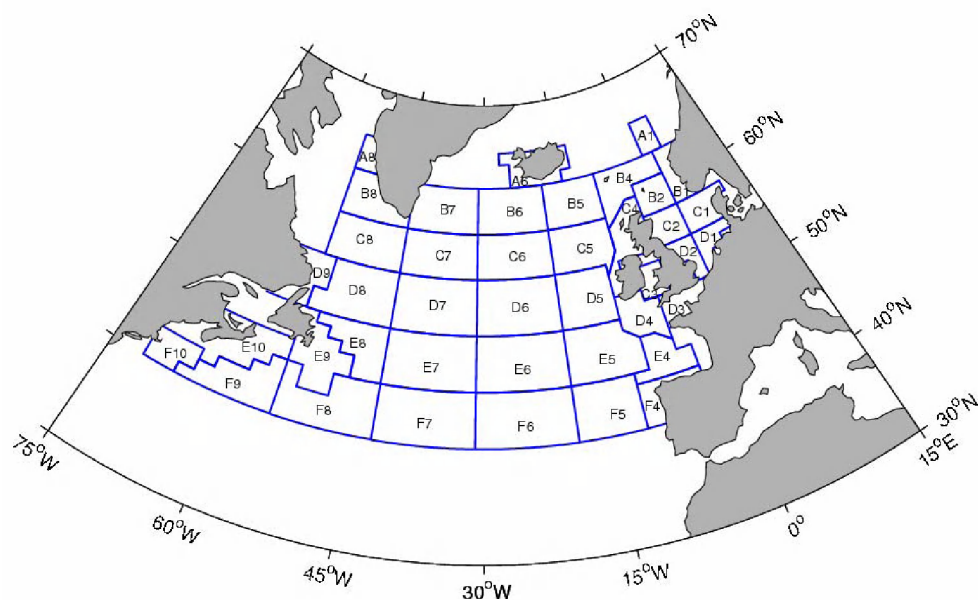
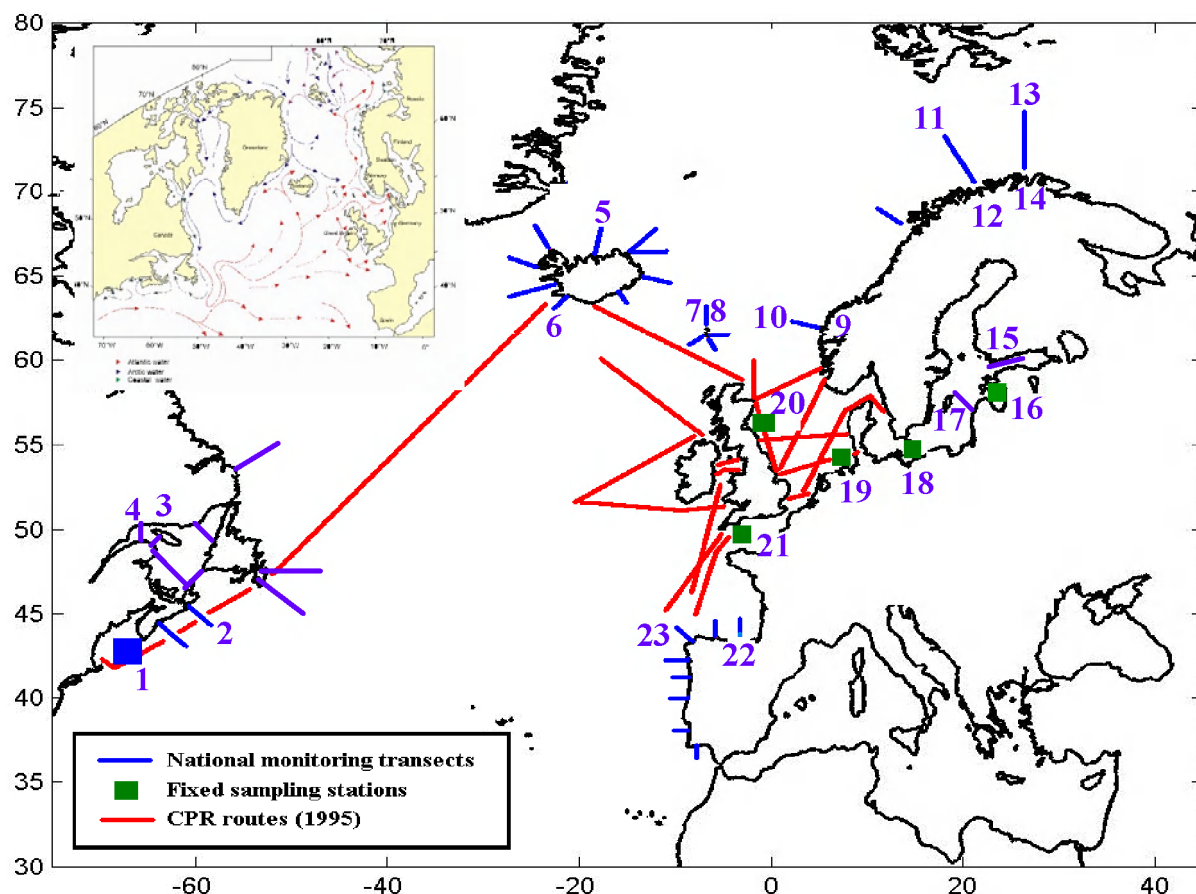


Figure 1. Top panel: zooplankton sampling network in the ICES area (only sampling programmes reported in WGZE); numbers refer to the collections used in this report. The map in the upper left corner represents the schematic general circulation of the North Atlantic. Bottom panel: map of CPR standard areas in the North Atlantic.

### 3 Regional descriptions

#### 3.1 Western Atlantic

##### 1 Georges Bank

The Northeast Fisheries Science Center conducts two types of zooplankton monitoring programmes, operated from the laboratory in Narragansett, Massachusetts. The first is CPR transects across the Gulf of Maine and across the shelf from New York towards Bermuda. The second type is by bongo net (333- $\mu\text{m}$  mesh) samples collected six times per year over the shelf region. Presented below is the median plankton displacement volume on Georges Bank in early spring and early autumn (Figure 2). The spring 2004 value was nearly three times larger than any other value in the 34-year series. This high volume resulted from a phytoplankton bloom that occurred over a wide area of the Bank at the time of the survey. The annual mean values combining the spring and fall data sets are quite stable around 40  $\text{ml m}^{-3}$  of displacement volume. Differences in the annual mean anomalies are shown in the same figure.

##### 2 Halifax Line Station 2 (west Atlantic, Scotian Shelf)

Zooplankton are sampled every 2–4 weeks (if possible), using research ships, trawlers, and a small SAR vessel with a net of 0.75 m diameter ring mounted with a 200- $\mu\text{m}$  mesh. Sampling is carried out on a number of stations on a series of transects that run perpendicular to the coast of Nova Scotia across the Scotian Shelf. The most frequently sampled station is in HL2 on the inshore edge of Emerald Basin, a 150-m depth station approximately 20 miles offshore from Halifax. CTD profiles are recorded, and samples for phytoplankton, nutrients, and extracted chlorophyll are collected using Niskin bottles at fixed depths. Subsamples are combined to give an integrated sample.

Zooplankton samples are split and one half is used for wet-dry weight determination. The other half is subsampled to give at least 200 organisms, which are identified to genus or species and enumerated. Another subsample is taken that contains at least 100 *Calanus* spp., which are identified and enumerated to species and stage. Biomasses of the dominant groups are calculated using dry weights of various groupings (*Calanus*, *Oithona*, *Pseudocalanus*, and *Metridia*) and abundance data. The data are entered in the “BioChem” database at the DFO.

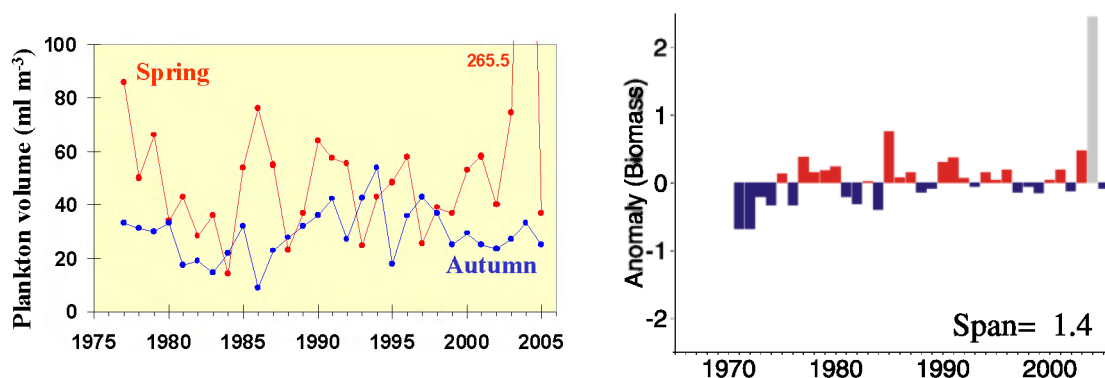


Figure 2. Left: plankton displacement volume on Georges Bank in early spring and early autumn. Right: interannual variability in terms of normalized anomalies combining the spring and autumn data sets.



An ecosystem status report on the state of the phytoplankton and zooplankton in Canadian Atlantic Waters is prepared every year and is published on the Internet at <http://www.dfo-mpo.gc.ca/csas/Csas/English/Status/general.htm>. During 1998 and 1999, the population was at high levels, decreasing to a low in 2002. This is also noted when the total population of copepods is plotted (Figure 3). In spring 2003, *Calanus finmarchicus* values were close to or a bit above the mean of the time-series. Copepods also increased in 2003 and 2004, but they are still below the mean (Figure 3, right).

### 3-4 Gaspé Current and Anticosti Gyre (northwest Gulf of St Lawrence)

The Atlantic Zone Monitoring Programme (AZMP) was implemented in 1998 with the aim of collecting and analysing the biological, chemical, and physical field data that are necessary to (1) characterize and understand the causes of oceanic variability at the seasonal, interannual, and decadal scales; (2) provide multidisciplinary data sets that can be used to establish relationships among the biological, chemical, and physical variables; (3) provide adequate data to support the sound development of ocean activities. The key element of AZMP sampling strategy is the oceanographic sampling at fixed stations and along sections. The fixed stations are occupied about every two weeks, conditions permitting, and the sections are sampled from one to three times during the year. The locations of the regular sections are shown in Figure 1. The zooplankton samples are analysed following the same protocol as the one described above for the Halifax Line Station 2. An ecosystem status report on the state of the phytoplankton and zooplankton is prepared every year and is published on the Internet at <http://www.dfo-mpo.gc.ca/csas/Csas/English/Status/general.htm>.

Data presented in the present report (Figure 4) are from two sampling stations: the Gaspé Current and the Anticosti Gyre, both in the northwest Gulf of St Lawrence (GSL). The GSL is a coastal marine environment with a particularly high zooplankton biomass relative to other coastal areas, dominated by *Calanus* species (de Lafontaine *et al.*, 1991). In 2004, the overall abundance and biomass of zooplankton observed in the Gaspé Current and the Anticosti Gyre were comparable with those observed from 1999 to 2003. Likewise, the mean annual zooplankton abundance and biomass observed in late spring and fall 2004 along all sections were comparable with observations made in 2000, 2001, 2002, and 2003 (Harvey *et al.*, 2005). Zooplankton abundance and biomass do not follow the same pattern as the concentration of chlorophyll *a*, e.g. the zooplankton peak observed in the Gaspé Current in 2003 corresponded to a chlorophyll *a* minimum, and the chlorophyll *a* peak in the Anticosti Gyre in 2001 corresponded to a zooplankton minimum. This absence of coupling between zooplankton and algal biomass has been observed in the GSL (de Lafontaine *et al.*, 1991; Roy *et al.*, 2000) and was attributed to the complex estuarine circulation pattern observed in both the Gaspé Current and the Anticosti Gyre. Annual cycles of surface temperature in both cases are similar, with values below 0°C in winter and peaks above 14°C during summer.

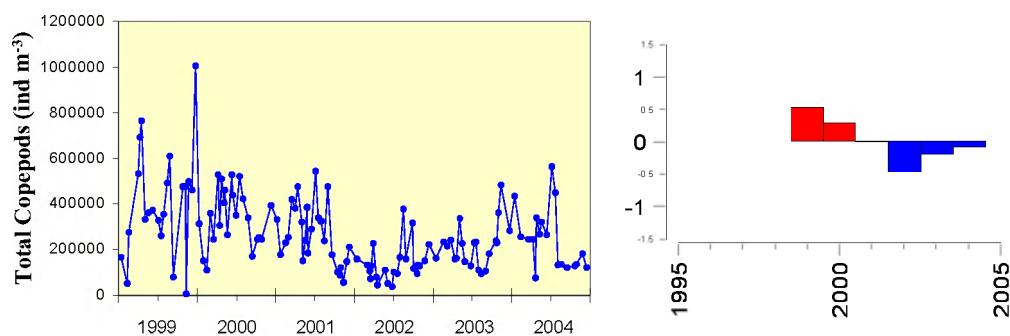


Figure 3. Left: Abundance of copepods at HL2 (1999–2004). Right: interannual variability in terms of normalized anomalies of annual means.

Abundances of the ten top taxa in the Anticosti Gyre and Gaspé Current and their percentages are shown in Table 1. Although *Oithona* spp. are the most abundant species at both locations, the copepods *Calanus finmarchicus*, *Pseudocalanus* spp., and *Calanus hyperboreus* are more important in terms of biomass. The presence of invertebrate eggs is quite variable, and they account for 12.59% of the mesozooplankton assemblage in 2005 in Gaspé Current, although they do not reach a position among the ten top taxa in the Anticosti Gyre.

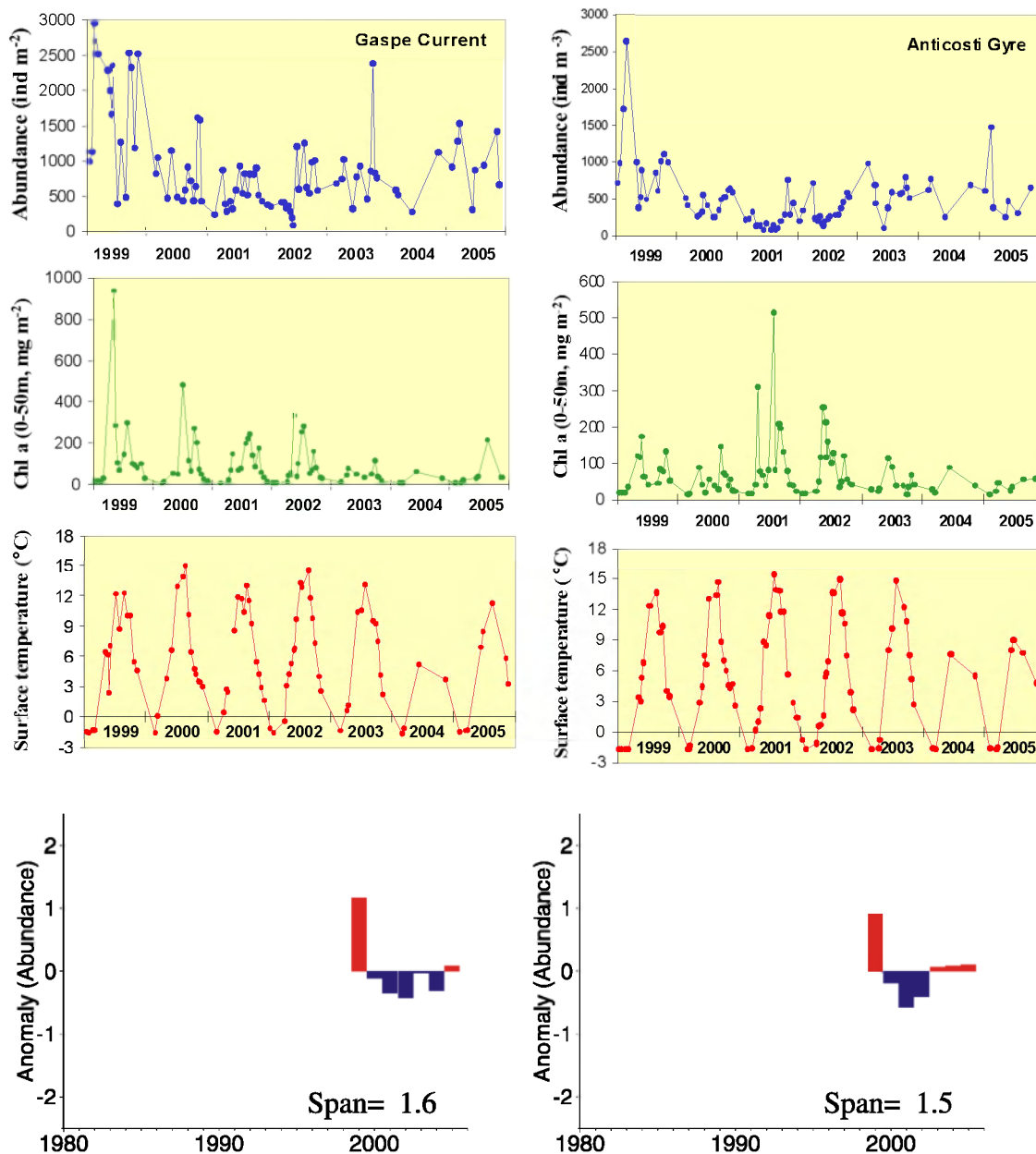


Figure 4. Time-series of zooplankton abundance and biomass, chlorophyll, and temperature in the northwest Gulf of St. Lawrence. Lower panels show interannual variability in terms of normalized anomalies of annual means.

**Table 1. Percentages and averages of the ten top taxa in the Gaspé Current and the Anticosti Gyre during the sampling period 2000–2004 and 2005.**

Average species dominance at Anticosti Gyre for the period 2000–2004 compared with 2005

Rank	Taxa	% total zooplankton 2000–2004	% total zooplankton 2005	Yearly average 2000–2004 (N/m <sup>3</sup> )	2005 average (N/m <sup>3</sup> )
1	<i>Oithona</i>	24.06	25.40	113	158
2	<i>Calanus finmarchicus</i>	15.01	9.94	71	62
3	Copepod nauplii	12.44	16.73	58	104
4	<i>Calanus hyperboreus</i>	12.00	12.25	56	76
5	Copepod egg	5.51	12.09	26	75
6	Microcalanus	4.42	3.81	21	24
7	Metridia	4.11	3.45	19	22
8	Ostracoda	3.87	5.44	18	34
9	<i>Pseudocalanus</i>	2.90	2.17	14	13
10	Invertebrate egg	2.21	0.64	10	4
Total		86.54	91.92	407	572.00
Total zooplankton (N/m <sup>3</sup> )				469.86	622.88

Species dominance at Anticosti Gyre during 2005

Rank	Taxa	% total zooplankton 2005	2005 average (N/m <sup>3</sup> )
1	<i>Oithona</i>	25.40	158
2	Copepod nauplii	16.73	104
3	<i>Calanus hyperboreus</i>	12.25	76
4	Copepod egg	12.09	75
5	<i>Calanus finmarchicus</i>	9.94	62
6	Ostracoda	5.44	34
7	Microcalanus	3.81	24
8	Metridia	3.45	22
9	<i>Pseudocalanus</i>	2.17	13
10	<i>Temora longicornis</i>	1.14	7
Total		92.41	575.61
Total zooplankton (N/m <sup>3</sup> )			622.88

Average species dominance at Gaspé Current for the period 2000–2004 compared with 2005

Rank	Taxa	% total zooplankton 2000–2004	% total zooplankton 2005	Yearly average 2000–2004 (N/m <sup>3</sup> )	2005 average (N/m <sup>3</sup> )
1	<i>Oithona</i>	35.87	48.10	296	626
2	<i>Calanus finmarchicus</i>	16.24	4.61	134	60
3	Copepod nauplii	9.77	6.69	80	87
4	Copepod egg	5.00	3.24	41	42
5	<i>Pseudocalanus</i>	4.11	2.70	34	35
6	Invertebrate nauplii	4.47	2.44	37	32
7	Invertebrate egg	2.98	12.59	25	164
8	<i>Calanus hyperboreus</i>	2.69	1.53	22	20
9	<i>Temora longicornis</i>	2.88	0.52	24	7
10	Invertebrate larvae	2.21	0.57	18	7
Total		86.23	82.99	710	1080.31
Total zooplankton (N/m <sup>3</sup> )				24	1301.77

Species dominance at Gaspé Current during 2005

Rank	Taxa	% total zooplankton 2005	2005 average (N/m <sup>3</sup> )
1	<i>Oithona</i>	48.10	626
2	Invertebrate egg	12.59	164
3	Copepod nauplii	6.69	87
4	<i>Calanus finmarchicus</i>	4.61	60
5	Copepod egg	3.24	42
6	<i>Pseudocalanus</i>	2.70	35
7	Invertebrate nauplii	2.44	32
8	<i>Calanus hyperboreus</i>	1.53	20
9	Metridia	1.10	14
10	Microcalanus	0.80	10
Total		83.80	1090.87
Total zooplankton (N/m <sup>3</sup> )			1301.77

### 3.2 Icelandic–Norwegian basin

#### 5–6 Siglunes (north Iceland) and Selvogsbanki (south Iceland)

The Icelandic monitoring programme for zooplankton consists of a series of transects perpendicular to the coastline. Sampling of the transects to the north and east of Iceland began in the 1960s. Additional section lines to the south and west were added in the 1970s. Currently, there are approximately 90 stations. Zooplankton investigations are carried out at these stations every year in May and June. Long-term changes in zooplankton biomass at Siglunes transect from the north of Iceland and at Selvogsbanki from the south are shown in Figure 5. At Siglunes, the values are averages from eight stations, while on Selvogsbanki the values represent averages from five stations.

At the Selvogsbanki transect, the zooplankton biomass showed a peak during the mid-1980s, while a low was observed during the late 1980s. Peaks were also observed around 1990, 1995, and 2000–2001. The period between the zooplankton peaks on the Selvogsbanki transect has been between five and ten years.

North of Iceland (Siglunes transect), the high values of zooplankton at the beginning of the series dropped drastically with the onset of the Great Salinity Anomaly of the 1960s. Since then, zooplankton biomass has varied with highs at approximately seven- to ten-year intervals. Maxima were observed around 1971, 1977, 1985, 1987, 1993–94, and 2000. In 2005, the value at the Siglunes transect was among the highest of the time-series.

The zooplankton biomass north of Iceland is influenced by the inflow of warm Atlantic Water (AW) to the area. Thus, in warm years (Figure 5), when the flow of AW onto the northern shelf is high, the zooplankton biomass is almost two times higher than in cold years, when this inflow is not as evident (Astthorsson and Gislason, 1998; Astthorsson and Vilhjalmsón, 2002). The reasons for this may include the better feeding conditions of the zooplankton, resulting from increased primary production in warm years, advection of zooplankton with the AW from the south, and faster temperature-dependent growth of the zooplankton in warm years. During both 2000 and 2001, when the biomass of zooplankton north of Iceland was particularly high, the inflow of warm AW onto the northern shelf was also high. South of Iceland, the links between climate and zooplankton biomass are not as evident as north of Iceland. Most likely, the variability off the south and west coasts is related to the timing and magnitude of the primary productivity on the banks, which in turn are influenced by the freshwater runoff from rivers and by the wind force and direction.

Comparison with other data from the northern North Atlantic shows that observed zooplankton biomass in spring is descriptive of the mean copepod biomass in that year. Recent research also shows that the variation of zooplankton biomass in the Icelandic area is in tune with long-term variability of zooplankton abundance over a much larger area, i.e. in the northern North Atlantic in general (Astthorsson and Gislason, 1995), as shown in Section 4 of this report.

At the Siglunes transect, *C. finmarchicus* is on average the most important species (~25% of the total zooplankton), followed by *Oithona* spp. (~15%) and the larvae of various classes of *Echinodermata* (14%; Table 2). These three taxonomic groups were also the most abundant in 2005, with the dominance of *C. finmarchicus* being unusually high (Table 2).

At the Selvogsbanki transect, *C. finmarchicus* is generally the most abundant species, (~33% of the total zooplankton), followed by *Oithona* spp. (*O. similis* and *O. spinirostris*, ~18%) and *Temora longicornis* (~9%) (Table 2). In 2005, the abundance of *Oithona* spp. was unusually high (~41%), with *C. finmarchicus* and euphausiids (mainly larval stages) ranking second and third (~14% and ~10%, respectively; Table 2).

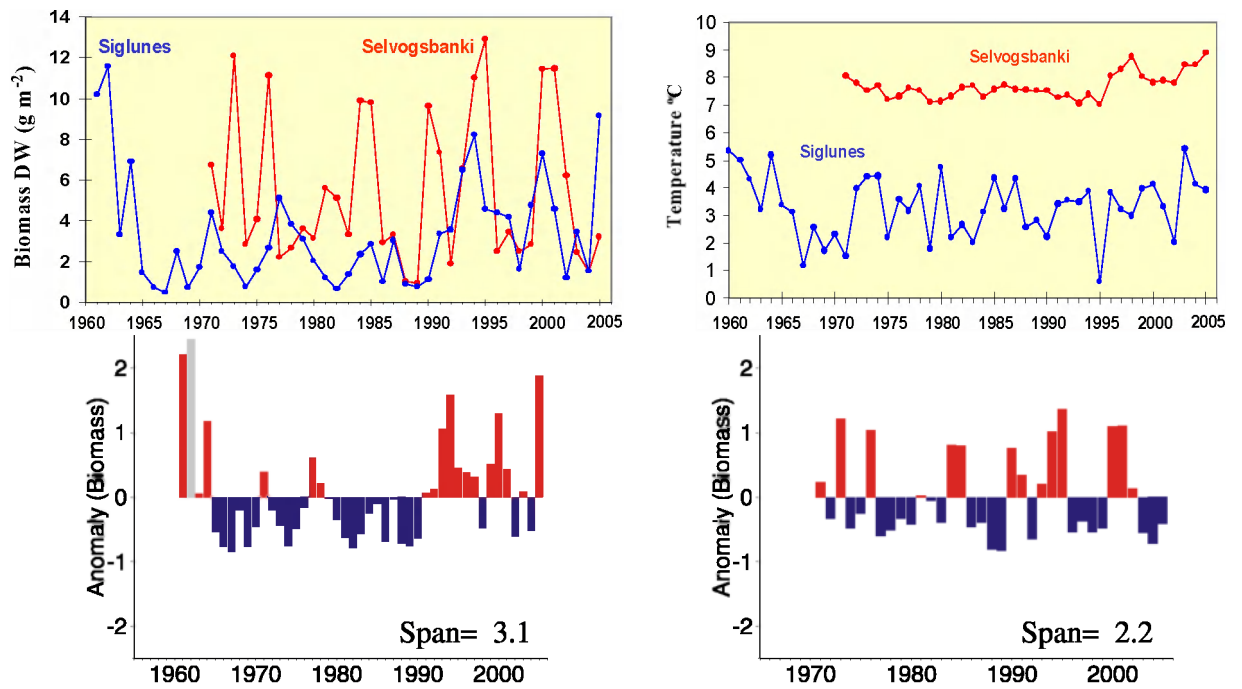


Figure 5. Upper left panel: year-to-year variability of zooplankton biomass. Upper right panel: temperature at Siglunes and Selvogsbanki. Lower left panel: interannual variability of plankton biomass in terms of normalized anomalies of annual means of Siglunes. Lower right panel: Selvogsbanki.

**Table 2. Percentages and averages of the ten top taxa at Siglunes and Selvogsbanki during the sampling period 1990–2004 and 2005.**

Average species dominance at Siglunes-transect for the period 1990-2004 compared with 2005

Rank	Taxa	% total zooplankton 1990-2004	% total zooplankton 2005	Yearly average 1990-2004 (N/m <sup>3</sup> )	2005 average (N/m <sup>3</sup> )
1	Calanus finmarchicus	25.43	53.21	567	3299
2	Oithona spp.	15.40	10.82	344	670
3	Echinodermata larvae	14.13	9.57	315	588
4	Euphausiacea (eggs+juv.)	12.06	1.00	269	62
5	Pseudocalanus spp	2.50	3.89	56	239
6	Larvacea indet	1.97	3.39	44	208
7	Calanus hyperboreus	1.35	1.21	30	75
8	Oncaea spp.	1.08	0.35	24	21
9	Acartia spp.	0.49	0.11	11	7
10	Microcalanus spp.	0.47	0.09	11	5
Total		74.90	83.64	1670	5174
Total zooplankton (N/m <sup>3</sup> )				2230	6199

Species dominance at Siglunes-transect during 2005

Rank	Taxa	% total zooplankton 2005	2005 average (N/m <sup>3</sup> )
1	Calanus finmarchicus	53.21	3299
2	Oithona spp.	10.82	670
3	Echinodermata larvae	9.48	588
4	Pseudocalanus spp	3.85	239
5	Larvacea indet	3.36	208
6	Calanus hyperboreus	1.20	75
7	Euphausiacea (eggs+juv.)	1.00	62
8	Calanus glacialis	0.44	27
9	Oncaea spp	0.35	21
10	Foraminifera indet	0.34	21
Total		84.05	5210
Total zooplankton (N/m <sup>3</sup> )			6199

Average species dominance at Selvogsbanki-transect for the period 1990-2004 compared with 2005

Rank	Taxa	% total zooplankton 1990-2004	% total zooplankton 2005	Yearly average 1990-2004 (N/m <sup>3</sup> )	2005 average (N/m <sup>3</sup> )
1	Calanus finmarchicus	33.81	15.35	1056	822
2	Oithona spp	17.70	45.15	552	2416
3	Temora longicornis	9.35	2.73	292	146
4	Evadne nordmanni	8.83	6.81	276	364
5	Euphausiacea (eggs+juv.)	7.04	9.61	220	569
6	Cirripedia nauplia/cyprii	3.58	0.46	112	25
7	Larvacea indet	2.78	0.13	87	7
8	Podon Leuckarti	1.73	3.02	54	161
9	Pseudocalanus spp	1.36	0.67	42	36
10	Foraminifera indet	1.23	0.50	39	27
Total		53.60	84.43	2729	4573
Total zooplankton (N/m <sup>3</sup> )				3122	5920

Species dominance at Selvogsbanki-transect during 2005

Rank	Taxa	% total zooplankton 2005	2005 average (N/m <sup>3</sup> )
1	Oithona spp	40.82	2416
2	Calanus finmarchicus	13.88	822
3	Euphausiacea (eggs+juv.)	9.61	569
4	Evadne nordmanni	6.15	364
5	Echinodermata larvae	5.24	310
6	Podon leuckarti	2.73	161
7	Temora longicornis	2.47	146
8	Pseudocalanus spp	0.60	36
9	Acartia spp	0.59	31
10	Polychaeta indet	0.50	27
Total		82.58	4882
Total zooplankton (N/m <sup>3</sup> )			5920

## 7–8 Faroe Islands

The Faroese Fisheries Laboratory operates four standard sections radiating northward, eastward, southward, and southwestward from the Faroes. These sections are sampled four times per year: in February, May, June/July, and November.

The northward section penetrating into the Norwegian basin (which is presented here) contains 14 stations with ten nautical miles between each station. The southern-most end of the section is on the Faroe shelf and is covered by warm AW, which in most years contains essentially neritic zooplankton, mixed with variable abundance of oceanic zooplankton. The abundance of oceanic zooplankton (mainly *C. finmarchicus*) on the shelf is highly variable between years. From the slope and northward, the northern-most part of the section is covered by cold East Icelandic Current Water (EICW).

Figure 6 shows the average zooplankton biomass in the upper 50 m of these two water masses in the oceanic part of the section in May 1990–2004. Usually, this is close to phytoplankton spring bloom. *C. finmarchicus* is the dominant species in both water masses. Except in 1993 and 2005, the biomass was clearly higher in the cold water mass in the northern part of the section than in the warmer southern part. The reason is that the abundance of over-wintered *C. finmarchicus* (CV and adults) is usually higher in the northern part, combined with the presence of *Calanus hyperboreus* in that water mass. In the AW, much fewer large individuals are present, but higher numbers of small stages are present in May. Because reproduction in most years starts earlier in the southern part of the section, the total numbers of *C. finmarchicus* usually are higher on average in the AW than in the EICW, despite the lower biomass (Gaard, 1996, 1999; Gaard and Nattestad, 2002).

However, in the past three years (May 2003–2005), the abundance of young *C. finmarchicus* copepodite stages in the northern part of the section has increased significantly, and no clear difference remained in the *C. finmarchicus* stage composition in these two water masses. This indicates an earlier reproduction in the EICW in the past three years than in previous years. In May 1990–2002, the fraction of *C. finmarchicus* recruits in this water mass was only ~10%, but in 2003 it increased to ~45% and in 2004–2005 to ~75–80%. Another change in recent years is that no *C. hyperboreus* were found in the northern part of the section. These were quite plentiful in most previous years and had a significant effect on the biomass.

Possibly, lower temperatures in the northern part of the section (Figure 6, lower left panel) could explain the generally later *C. finmarchicus* reproduction between the two water masses in previous years. The difference does not seem to be explained by phytoplankton abundance, since chlorophyll *a* concentrations in most years were higher in the cold EICW than in the warmer AW (Figure 6, lower right panel).

For the time being, it is difficult to explain the apparently early reproduction of *C. finmarchicus* and the disappearance of *C. hyperboreus* in the EICW in 2003–2005 compared with the previous years in the time-series. Potential weakening of the EIC or temperature changes of the EICW (or a combination of both) could explain this. The average temperature in the upper 50 m of this water mass in May 2003 and 2004 was 5.5°C, which is 1.6°C higher than in 2002. This was also the highest temperature recorded in the time-series in the EICW part of the section. However, in May 2005, the temperature had decreased again to 4.0°C, although similar changes in copepod composition could not be observed (Figure 6, lower left panel).

### 9–10 East and west off Svinøy (Norwegian Sea)

The IMR Monitoring Programme samples two fixed transects in the Norwegian Sea: the Svinøy transect (15 stations) and the Gimsøy transect (ten stations). These Norwegian Sea transects are sampled four to ten times each year. Additionally, the Norwegian Sea is surveyed in May and July/August, both surveys covering ca. 50–100 stations. Data are stored at the TINDOR database at IMR. Annual reports are made to the Ministry of Fisheries and in the IMR's Annual Report on Marine Ecosystems.

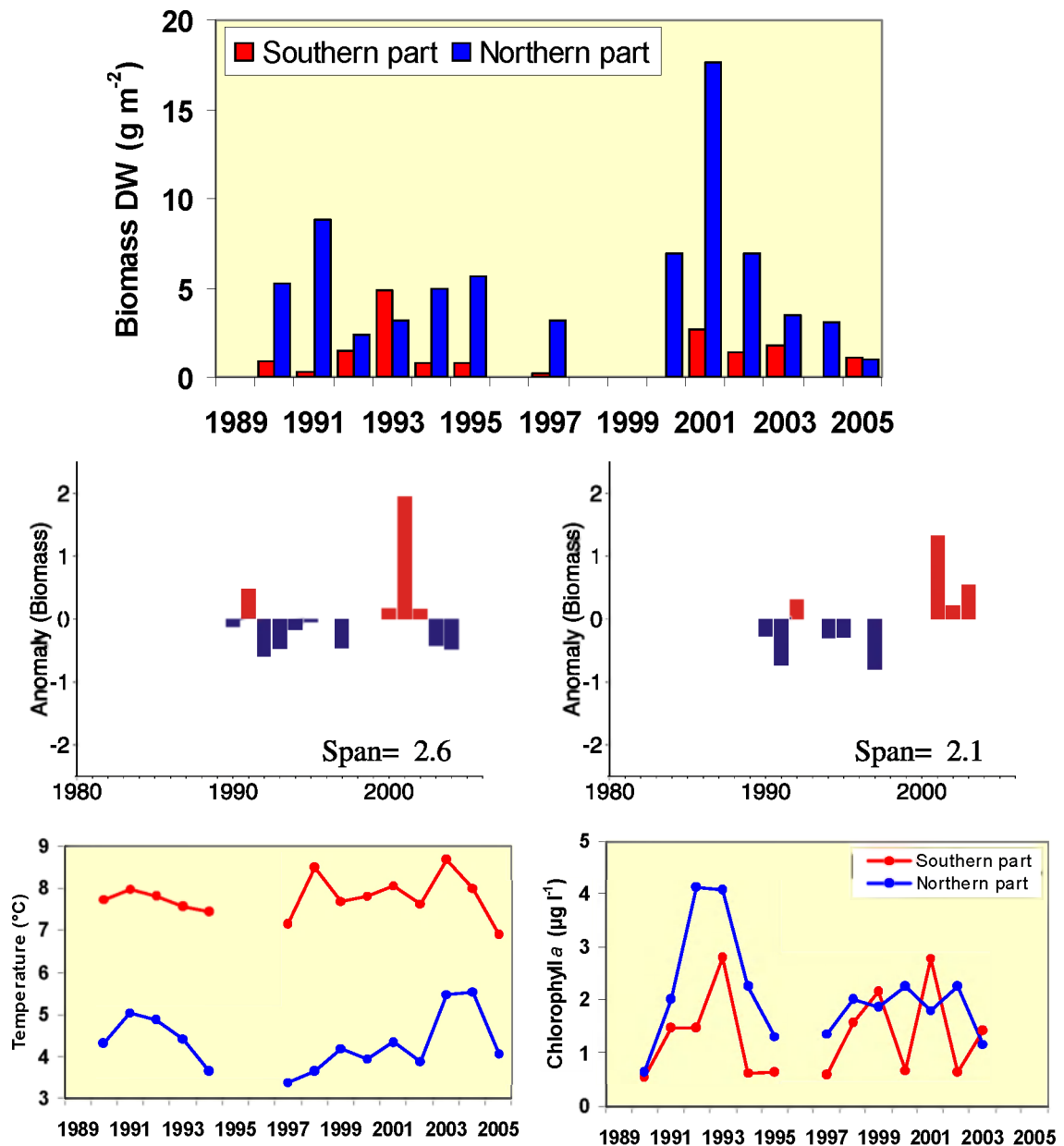


Figure 6. Upper panel: zooplankton biomass at 0- to 50-m depth in Atlantic Water (southern part) and the East Icelandic Current Water (northern part) in Faroes section North in May 1990–2004. No data are available from 1996, 1998, 1999, 2000, and 2004 south because phytoplankton abundance was too high in the net samples. Middle panel: interannual variability in terms of normalized anomalies of annual means, north and south (left and right, respectively). Lower panels: temperature (left) and chlorophyll *a* (right) concentrations at 0- to 50-m depth in section North.



The development of zooplankton biomass in spring at the Svinøy transect showed very small variations among years in the period 1997–2004 (Figure 7), and the maximum biomass in early summer varied from 8 to 9.3 g DW m<sup>-2</sup>. In 2002, the biomass average for all stations was 11.32 g DW m<sup>-2</sup> (28–30 April), higher than previous years. The maximum biomasses were 11.8 and 11.1 g DW m<sup>-2</sup> as an average for the eastern and western part, respectively. In 2003, the highest biomasses were observed in the second half of April, 12.6 g DW m<sup>-2</sup> in the eastern part and 11.3 g DW m<sup>-2</sup> in the western part, similar to the previous year.

Chlorophyll at 10-m depth shows that the bloom at the Svinøy transect occurs in late April and early May. A protracted post-bloom period persists through summer and early autumn, which is typical for the southern Norwegian Sea.

### 3.3 Barents Sea

The IMR Monitoring Programme samples two standard sections in the Barents Sea: the Fugløya–Bjørnøya transect (seven stations) and the Vardø North transect (eight stations). These Norwegian transects are usually sampled 3–6 and 2–3 times each year, respectively. The zooplankton are sampled with two WP2-net hauls from 100 m to the surface and from the bottom to the surface. Data are stored at the TINDOR database at IMR.

#### 11–12 North and south off Fugløya–Bjørnøya

The data presented in Figure 8 is based on bottom-to-surface hauls. During the mid-1990s, zooplankton biomass was high. Since then, biomass has decreased, and the biomass in 2004 was the lowest observed in the sampling period. Fluctuations in biomass from year to year have also decreased over the years. Maximum biomass in the Barents Sea occurs somewhat later than in the Norwegian Sea.

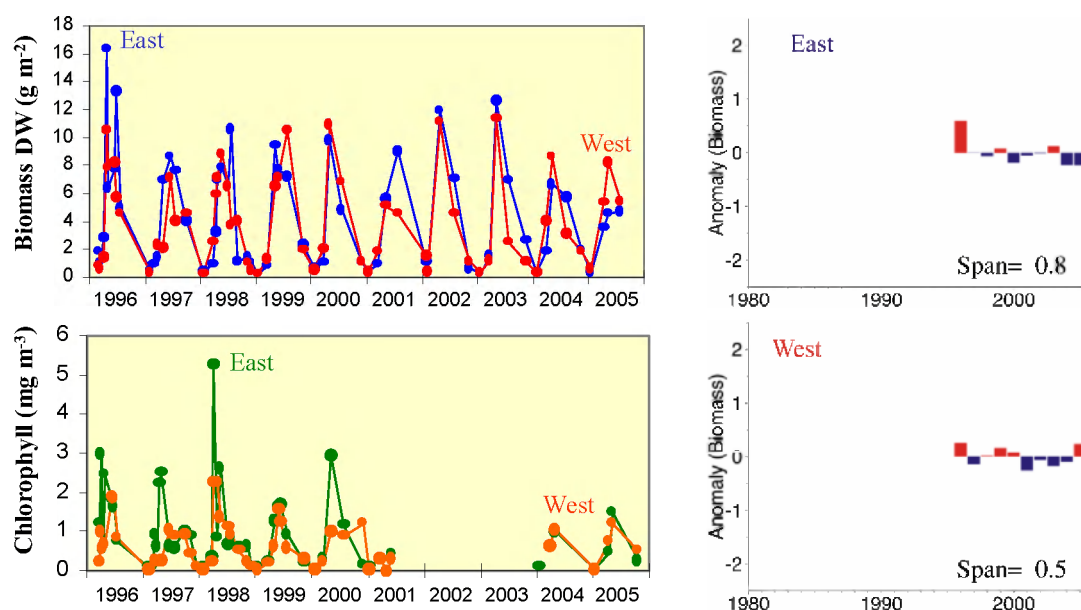


Figure 7. Left: zooplankton biomass and chlorophyll at Svinøy transect. Right: interannual variability in terms of normalized anomalies of annual means.

### 13–14 North and south off Vardø

Zooplankton biomass of the Vardø North standard section was high during the first three years and low during subsequent years, except for 2003 (Figure 9). Low sampling frequency makes comparison with the other time-series difficult. The timing of seasonal cycles is likewise difficult with a sampling frequency of 2–3 per year.

### 3.4 Baltic Sea

The Baltic Sea Monitoring Programme (BMP) consists of 24 international stations. The stations cover the different subareas of the Baltic Sea from the southwesterly Mecklenburg Bay to the northeasterly Gulf of Finland. Each station is sampled at least four times a year, but laboratories of all Baltic states contribute to the BMP, increasing the amount and frequency of data. Data are stored at HELCOM (Helsinki Commission). Periodic Assessment Reports are prepared every five years with contributions from all HELCOM member states and are published on the Internet at <http://www.helcom.fi> (HELCOM, 1996).

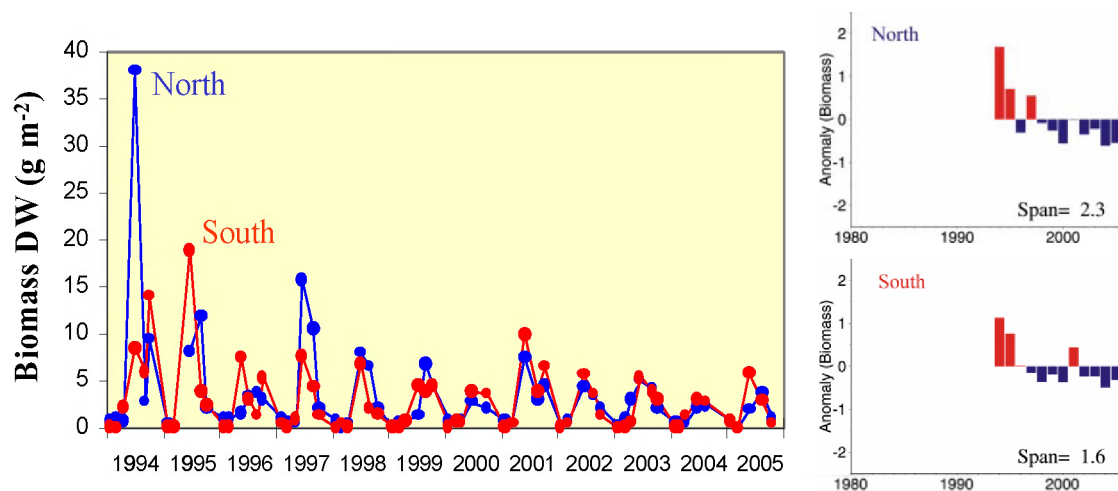


Figure 8. Left: zooplankton biomass at Fugløya-Bjørnøya transect, divided in northern and southern sections. Right: interannual variability in terms of normalized anomalies of annual means.

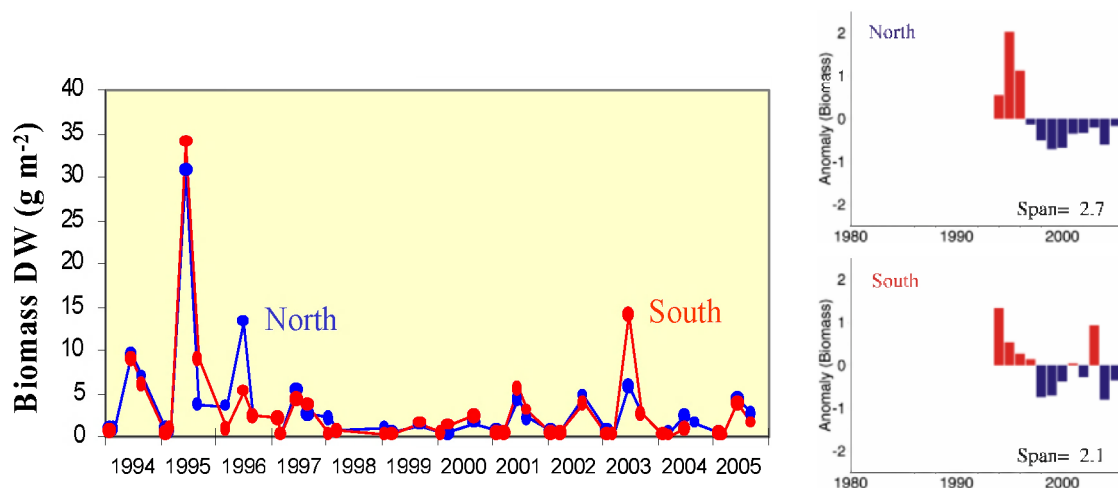


Figure 9. Left: zooplankton biomass at the Vardø transect, divided in northern and southern sections. Right: interannual variability in terms of normalized anomalies of annual means.

### 15 Gulf of Finland (Estonia)

One sampling location was selected from the Estonian national monitoring programme to represent the Gulf of Finland. Zooplankton was collected using vertical hauls of Juday plankton net (mouth opening 38 cm and mesh size 90  $\mu\text{m}$ ). As shown in last year's report, data are also available since 1963, but for another station. Sampling at that location was interrupted in 1992. Because good temporal coverage is required to plot a time-series, we have decided to use only data here for the station that has been visited more regularly since 1993 to illustrate the abundance of copepods (Figure 10).

Zooplankton in the Baltic Sea are typically rather small in size. The dominating copepod species in Estonian waters are *Eurytemora affinis* and *Acartia bifilosa*, the most abundant cladoceran is *Bosmina coregoni*, and rotifers also constitute a large share of the total zooplankton abundance. The maximum zooplankton biomass is usually observed in late summer, although in some years the abundance may already be observed in spring. Using the data from the time-series that extends back to the 1960s, a decrease in zooplankton numbers was reported in the early 1980s.

This decrease has been explained primarily by the beginning of stagnant conditions and lowered salinity (Lumberg and Ojaveer, 1991). During the last decade, high interannual variability in copepod abundance has been recorded, with extremely low values during the beginning of the century.

Chlorophyll *a* in May as well as in August shows a slight increase, and water transparency has decreased.

### 16 Gulf of Riga (Latvia)

The Gulf of Riga is the third largest gulf of the Baltic Sea, and its monitoring is shared by Latvia and Estonia. The Latvian monitoring programme has ten monitoring stations for zooplankton sampled with frequencies of 3 to 15 times a year. The present data are from a station in the central Gulf, and months with the best data coverage through the years (May, August, and November) are used for illustration. The average abundance and biomass in May has always been low, as in 1996 and 2003 when the Gulf was covered with ice during winter (Figure 11). The level of summer biomass is determined by the abundance of the cladoceran species *Bosmina longispina* and rotifers of the *Keratella* genus.

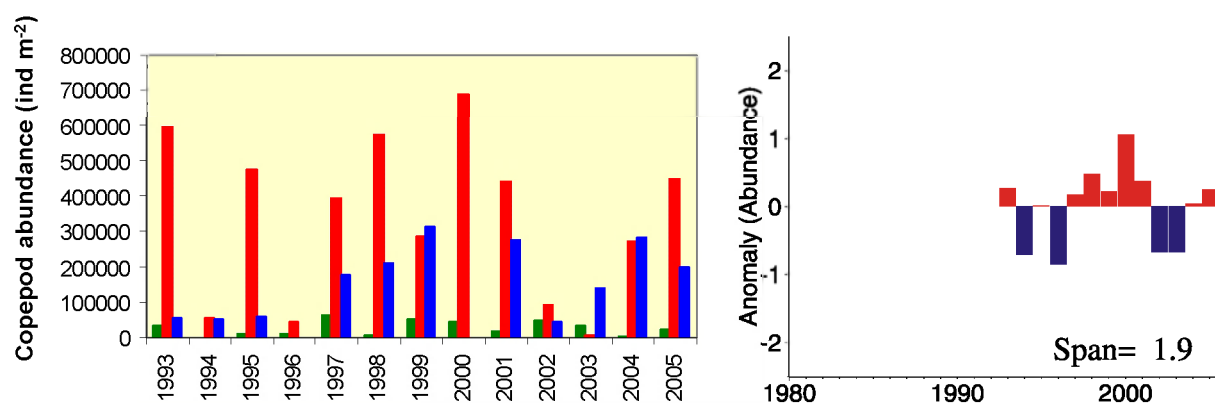


Figure 10. Left: spring (green bars), summer (red bars), and autumn (blue bars) copepod abundance in the Gulf of Finland for the period 1993–2005. Right: interannual variability in terms of normalized anomalies of annual means since 1993.

### 17 Central Baltic Sea (Latvia)

The mesozooplankton monitoring performed by the Latvian Fisheries Research Agency (LatFRA) has been conducted with varying intensity since 1959, with the goal of understanding the effect of zooplankton on local commercial fish populations. Figure 12 shows the combined biomass development of the dominating calanoid copepods (*Pseudocalanus* sp., *Acartia* spp., *Temora longicornis*, *Centropages hamatus*) in the different seasons. Biomass was low at the beginning of the time-series and increased during the late 1970s and early 1980s. After decreasing in the late 1980s and early 1990s, the calanoid biomass has peaked in recent years.

A change in the dominance from *Pseudocalanus* sp. to *T. longicornis*/*Acartia* spp. during the past two decades has been documented. A decrease in *Pseudocalanus* sp. standing stocks has been caused by decreasing salinities resulting from the reduced inflow frequency of North Sea Waters, while *Acartia* spp. and *T. longicornis* increased because of warmer temperatures (Möllmann *et al.*, 2000, 2003a). Both hydrographic effects were ultimately driven by climate changes (Matthäus and Nausch, 2003). The trends in these copepod species have been shown to affect cod recruitment (Hinrichsen *et al.*, 2002) as well as pelagic fish growth (Rönkkönen *et al.*, 2004; Möllmann *et al.*, 2003b, 2005).

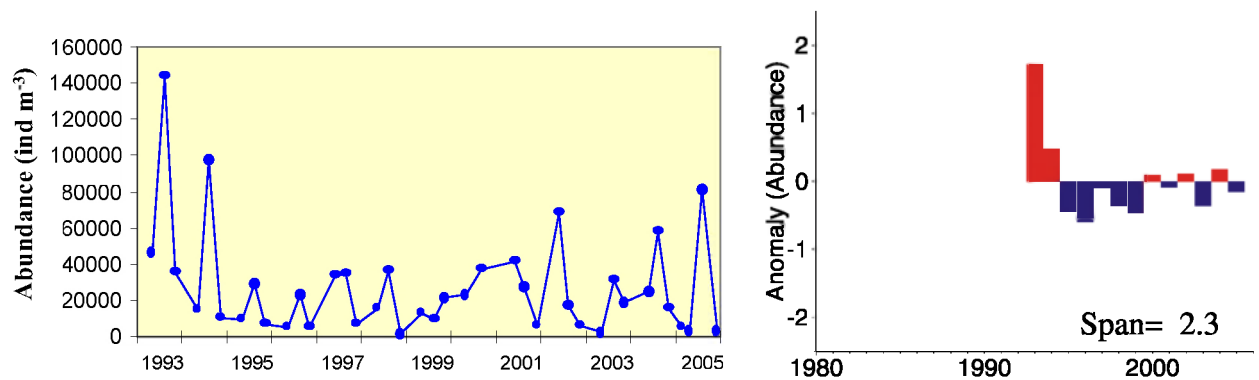


Figure 11. Left: zooplankton abundance in the Gulf of Riga for the period 1993–2005. Right: interannual variability in terms of normalized anomalies of annual means.

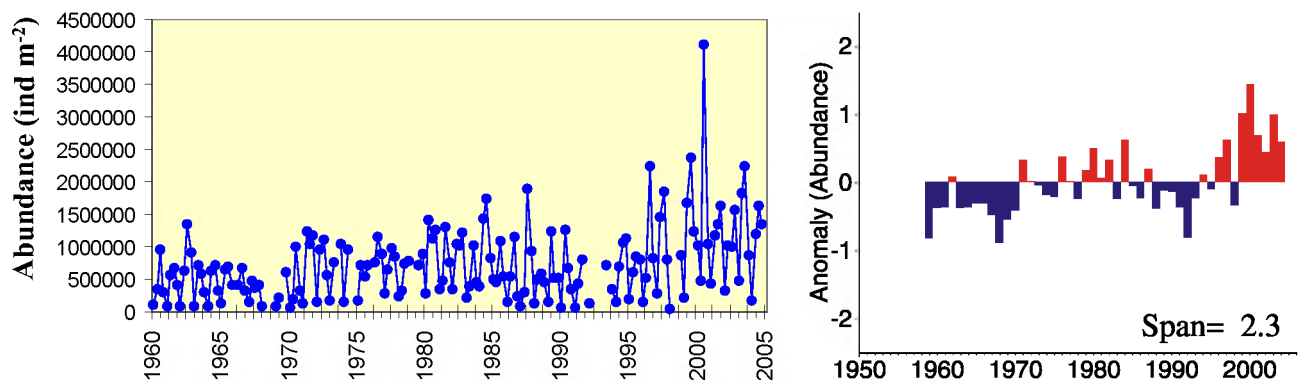


Figure 12. Left: abundance of the main calanoid copepods in the Central Baltic Sea since 1960. Right: interannual variability in terms of normalized anomalies of annual means.

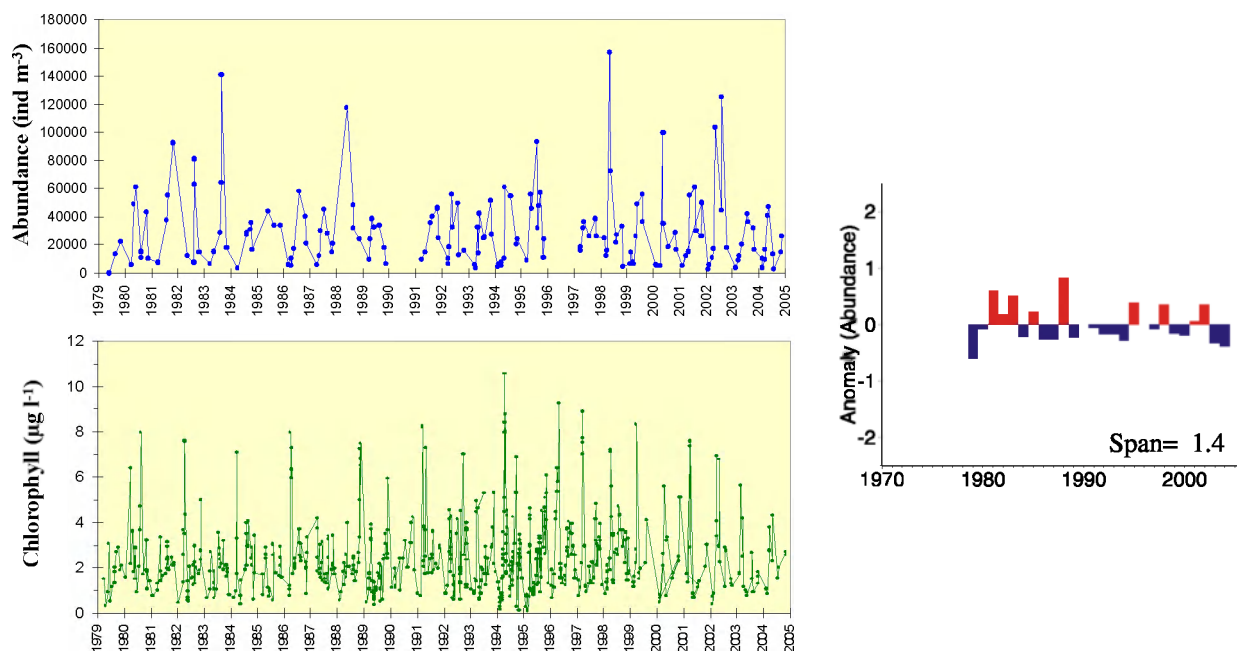
### 18 Arkona Basin (Germany)

This station in the Arkona Basin (54°55'N, 13°30'E, Germany) is sampled from the surface down to 15 to 36 m (25 m average). The total series covers the period from 1973 to the present. In some years, the sampling coverage is quite poor (e.g. 1995 and 1996). Variations in the range of 10 000–50 000 ind m<sup>-3</sup> are typically observed during the seasonal cycle in the western Baltic Sea (Figure 13).

Maximum abundances reflect the typical seasonal course: dominance of *Acartia* spp. and *Pseudocalanus* spp. nauplii in early spring, followed by meroplanktonic larvae (polychaetes) in March. *T. longicornis* nauplii and rotifers dominate in early May. In summer, we observed maximum quantities of bivalve larvae.

Peaks of plankton observed in spring in 1983, 1988, 1995, 1998, 2000, and 2002 were caused by mass developments of rotifers, which often happens after mild winters. Despite these peaks, the cladoceran *B. coregonii* is the dominant species during summer, when the water temperature reaches 16°C (HELCOM, 1996). Although no statistical trend is observed, four of the six spring peaks mentioned above have occurred in the past ten years. Chlorophyll concentration at the Arkona Basin shows high values year-round, with seasonal spring blooms over 6 µg l<sup>-1</sup> and over 2 µg l<sup>-1</sup> most of the year (Figure 13). However, a decreasing trend has been noted since 1994, where maximum values reach 11 µg l<sup>-1</sup> (Wasmund and Uhlig, 2003). Normalized anomalies of annual means in Figure 13 (right) show that, except for the low values in 1979 and 2003 and the high values of abundance in 1989, the time-series is quite stable, and no trends are apparent.

The sampling date was quite early in 2004, i.e. the mass occurrence of cladocerans were not properly met in the Arkona Sea. The maximum was formed by the nauplia of the second generation of *T. longicornis* at the end of October. In November, rotifers were most abundant again, probably as a late reaction to the phytoplankton autumn bloom.



**Figure 13.** Left: zooplankton and phytoplankton abundance in the Arkona Basin (Baltic Sea) in 1979–2003. Right: interannual variability of zooplankton in terms of normalized anomalies of annual means.

### 3.5 North Sea and English Channel

#### 19 Helgoland (southeast North Sea)

Since 1975, every Monday, Wednesday, and Friday two oblique plankton net samples (150  $\mu\text{m}$ , 500  $\mu\text{m}$ ) have been collected at the station Helgoland Roads (54°11'18"N, 7°54'E), Helgoland being the only offshore island of the North Sea. Almost 400 taxonomic entities of holoplankton and meroplankton (benthic and fish larvae) are counted. The time-series were started at the Biologische Anstalt Helgoland and have continued after the institutional re-organization in cooperation with the German Centre for Marine Biodiversity and the Federal Maritime and Hydrographic Agency.

The purpose of the programme is to document plankton population dynamics for the recognition of variances and regularities in abundance distribution. This will allow plankton prognosis in season, dimension, and finally abundance, and for the detection of biodiversity changes possibly caused by external forcing. Examples of results using several analytical techniques, types of information extracted from the data, and models on prognosis for zooplankton dynamics on several time scales can be found in Greve (1994), Greve *et al.* (2001, 2004), Heyen *et al.* (1998), and Johannsen *et al.* (1999).

Small copepods represent a significant fraction of the total zooplankton in Helgoland. Seasonal cycles and year-to-year variability of small copepods can be observed in Figure 14. The ~30-year time-series 1975–2005 shows two periods (Figure 14, right): a first period 1975–1990 when the copepods showed an increasing trend; during the second period (1991–2005), the population oscillated quite regularly with the average values of abundances approximately halfway through the first period (4293 vs. 2441 ind  $\text{m}^{-3}$  in the first and second periods, respectively).

In 2004, the composition of the mesozooplankton abundance was influenced by the mass recruitment of the warm-water cladoceran *Penilia avirostris* that first appeared in the North Sea in 1990 in negligible numbers, reappeared at the end of the 1990s at a higher abundance level and reached an abundance level exceeding 10 000 ind  $\text{m}^{-3}$  in the last year. In addition to the higher abundance, the population increase also occurred earlier than in the preceding years.

Also in 2004, the calanoid copepods were less abundant (e.g. *Acartia* spp. reached 13% and *T. longicornis* 67% less than their long-term mean abundance). The *Oithona* spp. ranked higher with almost twice the long-term mean. The abundance dynamics display a higher winter dynamics and a retarded spring increase of calanoid copepods. The summer abundance exceeds the long-term mean.

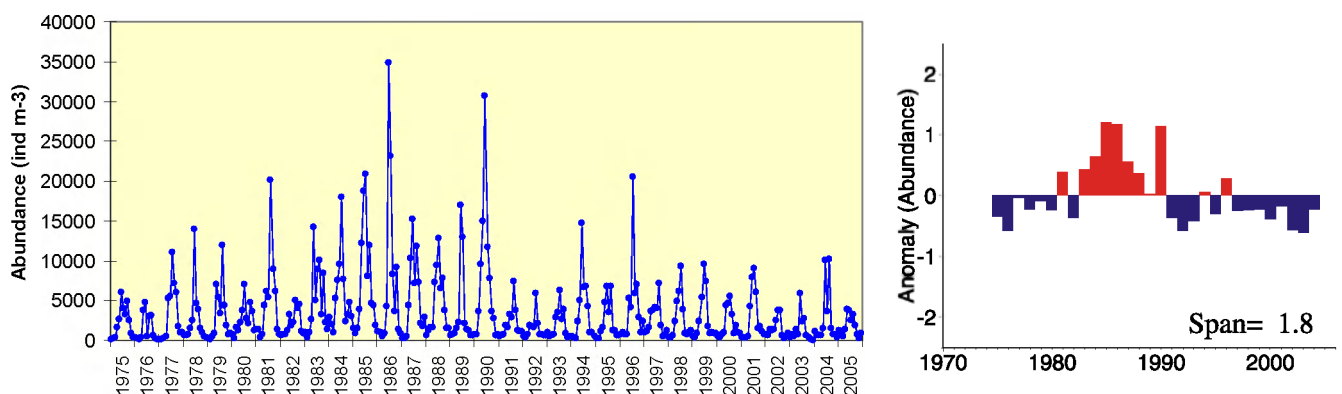


Figure 14. Left: abundance of small copepods at Helgoland. Right: interannual variability in terms of normalized anomalies of annual means.



The response in seasonality of plankton to changing temperatures, which is common to all populations, is not the same in all species. Some copepod species (e.g. *Centropages* spp. and *T. longicornis*) were observed much earlier in 2004; others like the *Acartia* spp., *Paracalanus* spp., and *Pseudocalanus elongatus* had their start of season six to eight weeks later than in mean years.

A paradigmatic example is that of the appendicularian *Oikopleura dioica*. This abundant filter-feeder depends on winter temperatures in its phenological start of season (SOS). A trend can be observed in the shift of the SOS from week 27 to week 24 in recent years. This trend is hardly seen in the middle of season (MOS) and in the end of season (EOS). The distance from the SOS to the EOS is a measure of the length of the season. Although *Oikopleura dioica* was present in the plankton in the 1970s for eight to nine weeks, the length of the season has now reached a mean length of 12 weeks. An extended discussion on phenological stages is included in Section 4.

## 20 Stonehaven (Scotland, northwest North Sea)

The Stonehaven sampling site is located at 56°57.80'N, 02°06.20'W, approximately 5 km offshore from Stonehaven, a fishing harbour 28 km south of Aberdeen. The water depth at the site is 50 m. Sampling for hydrographic parameters, concentrations of inorganic chemical nutrients, and the abundance of phytoplankton and zooplankton species has been carried out weekly off Stonehaven since January 1997. The objective of the programme is to establish a monitoring base for assessing the status of the Scottish coastal waters ecosystem and responses to climate change. Comparison of the results with archive regional data on temperature, salinity, and nutrients and phytoplankton biomass indicates that the site off Stonehaven provides a reasonable index of the state of the coastal waters. The biological data illustrate the consistencies and variability in seasonal succession of plankton species and their abundance. It is evident that there are significant differences among seasons and years.

The water column at the sampling site remains well mixed throughout much of the year, except in late summer and autumn when surface heating and settled weather often cause temporary thermoclines to appear. The seasonal minimum temperature generally occurs in the last week of February/first week of March. Water movement is generally southerly with quite strong tidal currents. In late summer and through autumn of most years, water with a high Atlantic Ocean content passes down the Scottish east coast. These events are particularly observable in the salinity signal. For example, 1997 showed a strong salinity increase in late summer, whereas 1998 showed very little. These influxes often bring oceanic species, for example, the chaetognath *Sagitta serratodentata* and the siphonophore *Muggiea atlantica* are indicators of this oceanic influence.

The seasonal pattern of plankton production is clearly evident in these data, as is the variability among years in its extent. Nutrient data also show strong seasonal cycles, but again there is interesting interannual variability. This is also seen in the variations observed in the phytoplankton and chlorophyll data (Figure 15). Large differences can be seen between years in the observed biomass of many common species of zooplankton, with a general increase from 1997 to 2000 (Figure 15) but a lower observed abundance overall in 2001 and 2002. In 2003, zooplankton peaked again with the second highest values of the time-series. This was followed by a low in 2004. A peak was seen in 2005, although the annual mean is below the series average.

Although short, the time-series is at a fairly high observational frequency, allowing insight into the seasonal dynamics and succession of species throughout the annual cycle. This provides an excellent background against which to carry out process studies, modelling, and comparisons with other sites. Data also provide assessment of the extent of local variability and allow consideration of the local effects of broader patterns of ocean climate change.

Several zooplankton species are of particular interest in that they show wide variations in their abundance (Table 3). For example, the important common copepod genus *Calanus* is represented by two species off Stonehaven. First and most abundant in spring and summer is *C. finmarchicus*, an important species in that the large spring influx and production provides food for fish larvae in spring.

However, its congener *C. helgolandicus*, a more southern species and generally most abundant in summer and autumn, has shown evidence of increased productivity and extended winter survival. Most likely, this reflects changes in the physical environment during the final few months of the year, with faster or slower cooling of the sea affecting the strongly temperature-dependent physiology of these small plankton.

Interannual variability in over-winter survival is likely to affect the population dynamics for a number of species and may kick-start the production cycle when it begins in spring each year. For example, such dynamics may have considerable implications for larval survival and recruitment to fish populations as well as consequences for assessments of the effects of local eutrophication pressures on the coastal marine ecosystems of eastern Scotland.

Data are regularly processed in the FRS MLA database, and some of these data are displayed on the MLA website (<http://www.marlab.ac.uk/Monitoring/Stonehaven/Stoneframe.html>) and published in periodic reports (e.g. Heath *et al.*, 1999).

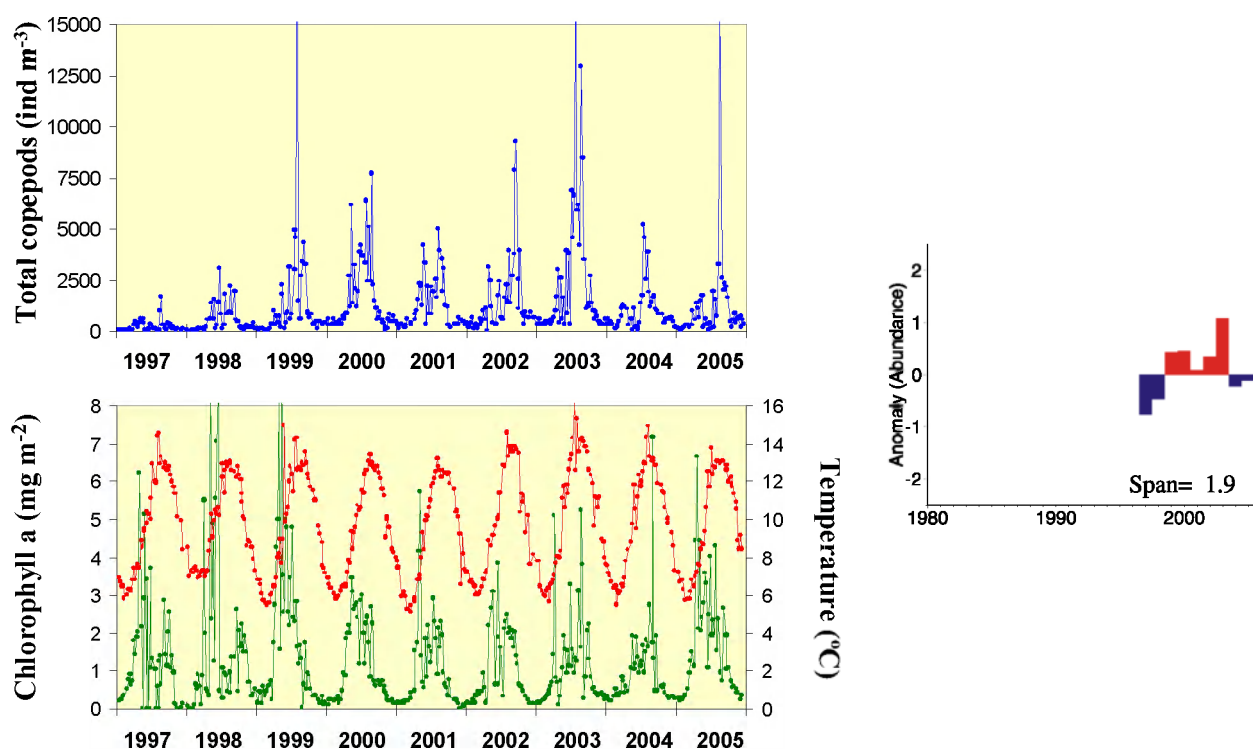


Figure 15. Left: weekly abundance of copepods and chlorophyll at Stonehaven and values of sea surface temperature. Right: interannual variability in terms of normalized anomalies of annual means.



**Table 3. Percentages and averages of the top taxa at Stonehaven station during the sampling period 1998–2004 time-series and in 2005.**

Average species dominance at Stonehaven for the period 1998-2004 compared with 2005					
Rank	Taxa	% total zooplankton 1988-2004	% total zooplankton 2005	Yearly average 1998-2004 (N/m <sup>3</sup> )	2005 average (N/m <sup>3</sup> )
1	Acartia clausi	30.50	31.63	642.01	485.31
2	Ps. elongatus	11.86	11.00	251.02	176.39
3	Oithona species	9.97	19.21	211.59	301.36
4	Appendicularia	7.49	4.83	173.76	79.34
5	Temora longicornis	6.45	3.69	139.77	59.22
6	Lamellib. larvae	4.68	1.65	108.28	29.09
7	Polychaete larvae	3.24	1.81	71.43	28.99
8	Paracalanus parvus	2.46	3.00	54.48	51.68
9	Bryozoa larvae	2.45	2.24	52.97	36.01
10	Echinoderm larvae	2.31	1.46	70.41	30.32
Total		81.41	80.53	1775.71	1277.70
Total zooplankton (N/m <sup>3</sup> )				2154.45	1534.34

Species dominance at Stonehaven during 2005			
Rank	Taxa	% total zooplankton 2005	2005 average (N/m <sup>3</sup> )
1	Acartia clausi	31.63	485.31
2	Oithona species	19.21	301.36
3	Ps. elongatus	11.00	176.39
4	Appendicularia	4.83	79.34
5	Temora longicornis	3.69	59.22
6	Cirripedia spp nauplii	3.07	77.51
7	Paracalanus parvus	3.00	51.68
8	Cirripedia spp cypris	2.83	66.65
9	Eggs of invertebrate	2.83	60.50
10	Bryozoa larvae	2.24	36.01
Total		84.35	1393.97
Total zooplankton (N/m <sup>3</sup> )			1534.34

## 21 Plymouth (English Channel)

Zooplankton is collected weekly at station L4 (04°13'W, 50°15'N) approximately ten miles southwest of Plymouth in the Western English Channel. The station is about 50 m deep and is influenced by seasonally stratified and transitional mixed-stratified waters (Pingree and Griffiths, 1978). Organisms are collected with a 200-µm WP2 net towed vertically from sea floor to surface. Samples are split and counted for major taxonomic groups, as well as identifying some groups (particularly copepods) to species level. For chlorophyll *a* measurement, three replicates of 100 ml surface water from L4 are filtered through 25-mm GF/F filters. These filters are then stored in the freezer until extraction in 10 ml acetone. The extract is then analysed using a 10 AU Turner fluorometer. The L4 data are maintained at the Plymouth Marine Laboratory and are published on the Internet at [www.pml.ac.uk/L4](http://www.pml.ac.uk/L4).

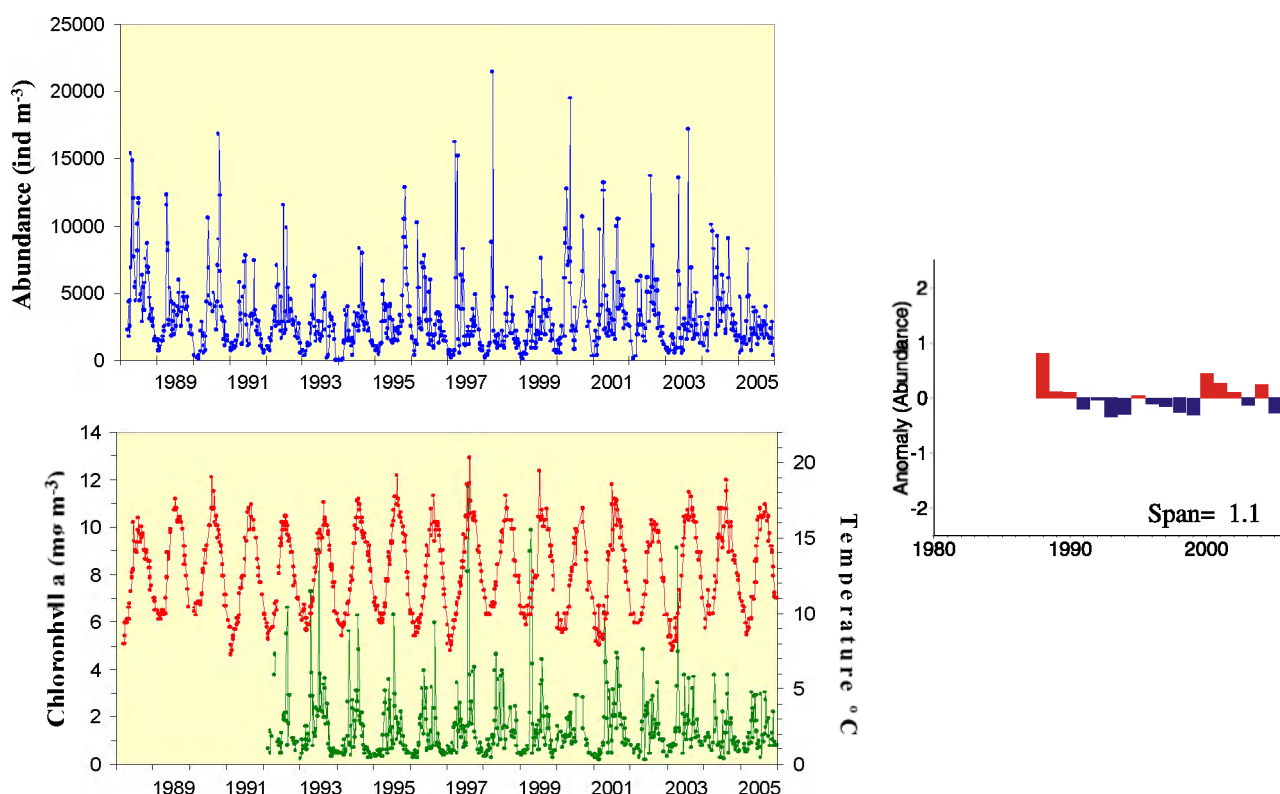


Figure 16. Left: weekly chlorophyll *a* concentration and surface temperature (lower panel) and zooplankton abundance (upper panel) at Station L4 (Plymouth). Right: interannual variability in zooplankton abundance in terms of normalized anomalies of annual means.

The ten most abundant taxa at L4 have been ranked according to their annual mean proportion of the total zooplankton (Table 4). In 2005, some major changes in the zooplankton composition can be observed within the top ten taxa over the time-series. Not only has the rank order of the top ten species changed, but new groups, Echinoderm larvae, *Noctiluca scintillans*, Siphonophores, and *C. helgolandicus* appear in the dominant species for the first time in 2005, contributing 4.6% to 3% of the total zooplankton abundance respectively.

In addition, *Ps. elongatus*, which was the most abundant species during the period 1988–2004 when it contributed nearly 12% of the total zooplankton abundance, represented only 2.3% of the zooplankton community in 2005. *Ps. elongatus* abundance in 2005 is the lowest abundance observed over the whole time-series (53 ind m<sup>-3</sup>).

Weekly zooplankton abundance as well as chlorophyll *a* concentration at L4 shows clear seasonal cycles (Figure 16). Peaks of high zooplankton abundance and chlorophyll *a* concentration are regularly observed in spring and late summer/beginning of autumn, the latter resulting from intense summer dinoflagellate blooms in some years. Zooplankton abundance (Figure 16) at L4 shows two decreasing trends from 1988 to 1995 and from 2001 to 2005. This is mainly the result of relatively low abundances of the spring species *Paracalanus*, *Pseudocalanus*, and *A. clausi*. Small copepods like *Oncaea*, *Oithona*, and *Corycaeus* contribute greatly to the total zooplankton population.

**Table 4. Percentages and averages of the top taxa at Plymouth L4 station during the sampling period 1988–2005 time-series and in 2005.**

Average species dominance at L4 for the period 1988-2004 compared with 2005					
Rank	Taxa	% total zooplankton 1988-2004	% total zooplankton 2005	Yearly average 1988-2004 (N/m <sup>3</sup> )	2005 average (N/m <sup>3</sup> )
1	Pseudocalanus	11.74	2.32	380	54
2	Oithona	11.30	6.23	366	144
3	Oncaea	11.11	7.69	360	178
4	Paracalanus	9.53	4.23	309	98
5	Temora longicornis	9.19	8.52	298	198
6	Cirripeda nauplii	8.69	7.93	281	184
7	Acartia clausi	6.18	2.74	200	64
8	Evadne	5.85	2.25	190	52
9	Appendicularia	2.59	1.22	84	28
10	Corycaeus	2.25	5.72	73	133
Total		78.43	48.90	2540.62	1133.30
Total zooplankton (N/m <sup>3</sup> )				3239.60	2320.40

Species dominance at L4 during 2005			
Rank	Taxa	% total zooplankton 2005	2005 average (N/m <sup>3</sup> )
1	Temora longicornis	8.52	198
2	Cirripeda nauplii	7.93	184
3	Oncaea	7.69	178
4	Oithona	6.23	144
5	Corycaeus	5.72	133
6	Echinoderm larvae	4.63	107
7	Paracalanus	4.23	98
8	Noctiluca scintillans	3.75	87
9	Siphonophore	3.03	70
10	Calanus helgolandicus	2.96	69
Total		54.69	1268
Total zooplankton (N/m <sup>3</sup> )			2320.4

### 3.6 Bay of Biscay and Iberian coast

#### 22 Santander (southern Bay of Biscay)

Five transects are monitored in the ICES area off the Spanish coast. This involves an extensive physical, chemical, and biological monthly sampling series at each site, with special attention to the sampling and analysis of hydrographical parameters, nutrients, chlorophyll *a*, and phytoplankton and zooplankton species (Valdés *et al.*, 2002). Data are regularly entered in the IEO databases, and hydrographic and nutrients data are also available in the ICES database. Depending on the transect, the time-series extend from 1988 (A Coruña and Vigo), 1991 (Santander), 1993 (Cudillero), and 2001 (Gijón) to the present.

Long-term changes in zooplankton abundance at Santander show a slightly decreasing trend (Figure 17). The result is in opposition to the upward trend shown by the water column stratification index (Lavín *et al.*, 1998). This relationship between zooplankton and environmental conditions highlights the importance that the longer duration of the water column stratification could have in limiting the interchange of nutrients from deeper to surface waters and consequently limiting the growth of phytoplankton and zooplankton (Valdés and Moral, 1998). A similar relationship between an increasing trend in the water column stratification and a decline of zooplankton biomass was reported by Roemmich and McGowan (1995) along the Californian coast (CalCOFI series).

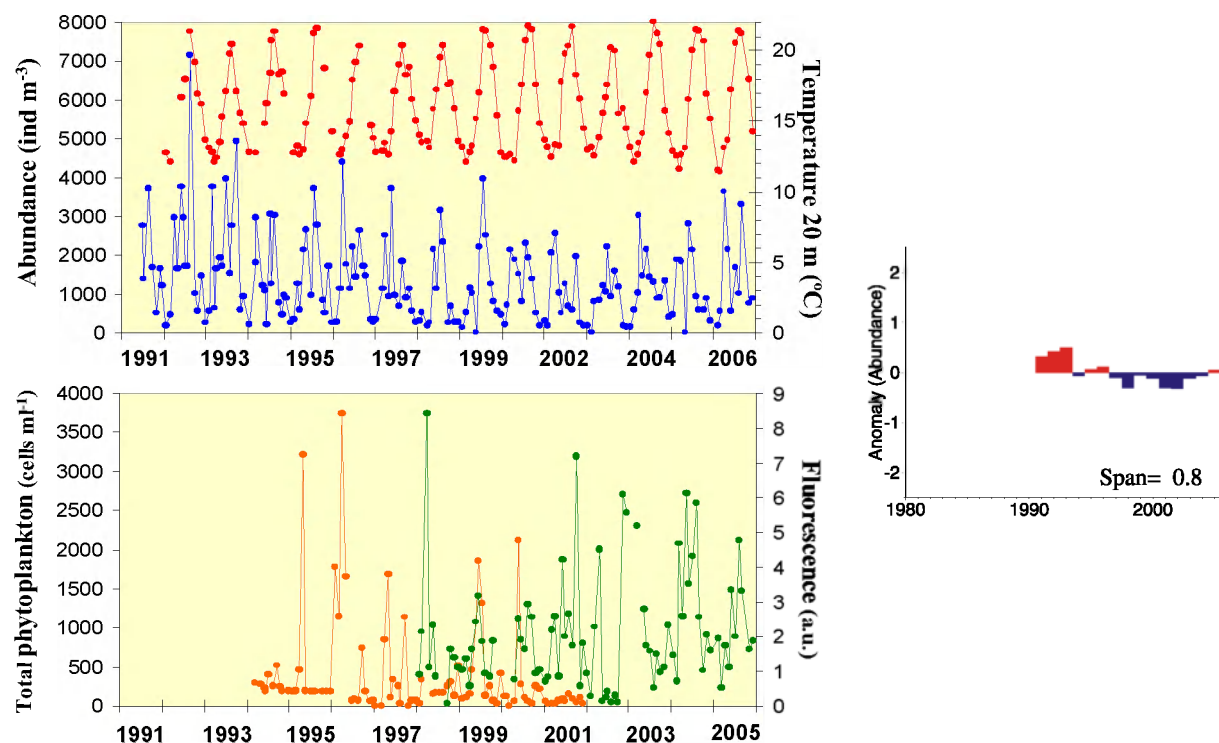


Figure 17. Left: (upper panel) monthly zooplankton abundance and (lower panel) phytoplankton cells (orange line, left scale) and fluorescence in arbitrary units (green line, right scale) in a neritic station off Santander. Right: interannual variability in terms of normalized anomalies of annual means.

### 23 A Coruña (northwest Iberian Peninsula)

In the coastal and neritic regions off Galicia (northwest Spain), the classical pattern of seasonal stratification of the water column in temperate regions is masked by upwelling events from May to September. These upwelling events provide zooplankton populations with favourable conditions for development in the summer, the opposite of what occurs in other temperate seas during this season. Nevertheless, upwelling is highly variable in intensity and frequency, revealing a substantial year-to-year variability.

Zooplankton values in A Coruña (Figure 18) differ from those in Santander: zooplankton abundance is higher in A Coruña, and the time-series shows an increasing trend since 1997. Both characteristics are partly caused by the influence of the seasonal upwelling, which prevents the water column from properly stratifying, reinforces the input of nutrients to the photic layer, enhances the growth of phytoplankton populations, and therefore enhances the growth of zooplankton populations. Note that the time-series shown in Figure 18 is composed of two curves, one for zooplankton  $>250\ \mu\text{m}$ , and the other for zooplankton  $>200\ \mu\text{m}$ .

Abundances of the ten top taxa in A Coruña and their percentages are shown in Table 5. The coastal location of this station and influence of the rías determined the dominance in abundance of the invertebrate larvae and small copepods.

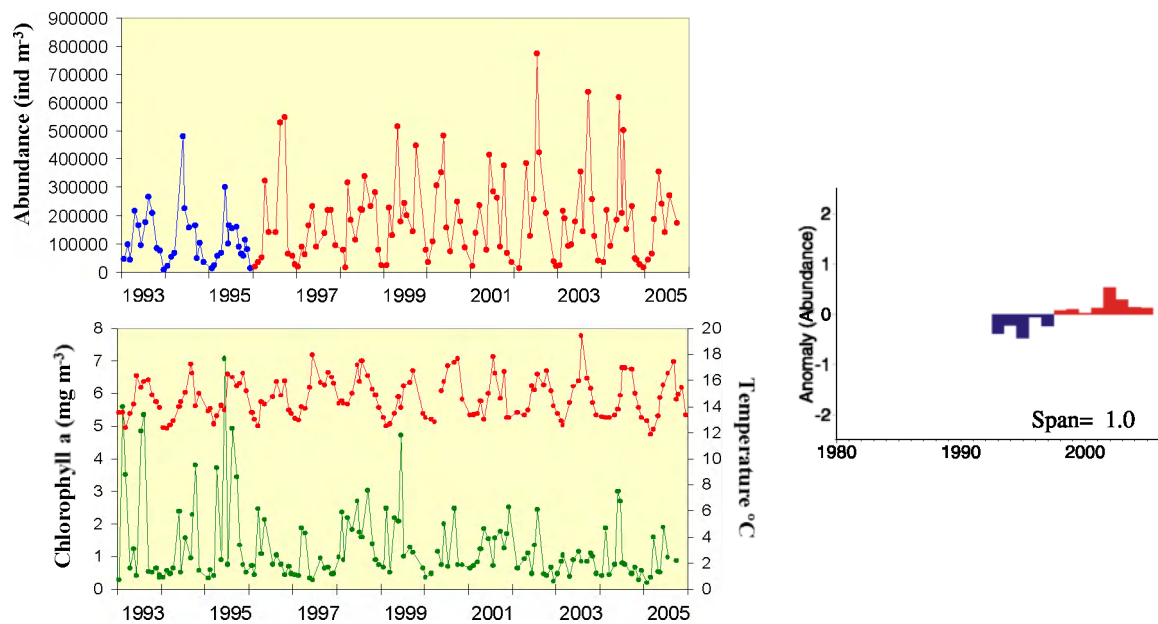


Figure 18. Left: monthly zooplankton abundance and chlorophyll *a* in a neritic station off A Coruña. Right: interannual variability in terms of normalized anomalies of annual means.

Table 5. Percentages and averages of the ten top taxa off A Coruña (Station 2), during the sampling period 1993–2003 and 2004.

Average species dominance at St2 for the period 1993-2003 compared with 2004					
Rank	Taxa	% total zooplankton 1993-2003	% total zooplankton 2004	Yearly average 1993-2003 (N/m <sup>3</sup> )	2004 average (N/m <sup>3</sup> )
1	<i>Oncaea media</i>	18.36	24.50	594	1199
2	<i>Acartia clausi</i>	12.21	6.50	395	318
3	Juvenile copepods	11.51	10.53	373	515
4	<i>Paracalanus parvus</i>	8.05	7.01	261	343
5	Cirripeda nauplii	7.71	13.92	250	681
6	Bivalve larvae	4.72	4.4	153	217
7	<i>Pseudocalanus</i>	4.22	2.81	137	138
8	<i>Clausocalanus</i> spp	3.27	1.50	106	71
9	<i>Temora longicornis</i>	2.97	1.42	96	67
10	<i>Podon intermedius</i>	2.87	2.02	93	99
Total		73.04	74.58	2363.62	3647.10
Total zooplankton (N/m <sup>3</sup> )				3236.30	4887.69

Average species dominance at St2 for the period 2003-2004			
Rank	Taxa	% total zooplankton 2004	Yearly average 2004
1	<i>Oncaea media</i>	24.53	1199
2	Cirripeda nauplii	13.92	681
3	Juvenile copepods	10.53	515
4	<i>Paracalanus parvus</i>	7.01	343
5	<i>Acartia clausi</i>	6.50	318
6	<i>Oithona similis</i>	4.82	236
7	Bivalve larvae	4.41	217
8	<i>Centropages chierchiae</i>	3.32	162
9	<i>Pseudocalanus</i>	2.83	138
10	<i>Podon intermedius</i>	2.03	99
Total		79.90	3906.5
Total zooplankton (N/m <sup>3</sup> )			4887.7

## 4 Discussion

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### 4.1 A general overview of the North Atlantic

The time-series of total copepod abundance (numbers per sample ( $\sim 3 \text{ m}^{-3}$ )) from 1946 to 2002 in CPR standard areas throughout the North Atlantic (see Figure 1 for map) is shown in Figure 19 (Edwards *et al.*, 2006). Annual means were calculated according to Colebrook (1975). 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). In the western North Atlantic, total copepod abundance has remained relatively unchanged since 1946. Highest copepod abundance is in the eastern North Atlantic and particularly in the southeastern North Sea. It is clear that 2004 is broadly consistent with this trend, with lower than usual copepod abundance throughout most of the standard areas, particularly in the southeast. Some of the areas in the northeast Atlantic show a copepod abundance in 2004 that is slightly higher than usual. These results are coherent with the time-series shown in the regional description.

To understand long-term changes in zooplankton populations, it is essential to have a previous understanding of the changes occurring at the lower trophic levels. For this purpose, we have analysed the Continuous Plankton Recorder phytoplankton colour index (PCI) with the SeaWiFS chlorophyll data, the two data sets that provide the most comprehensive information on the changes occurring in the phytoplankton over the North Atlantic. The long-term interannual values from 1946 to 2004 of phytoplankton colour in CPR standard areas in the North Atlantic are shown in Figure 20 (Edwards *et al.*, 2006). Phytoplankton colour is the degree of greenness of the CPR silk. It includes the chloroplasts of unbroken and broken cells, as well as small unarmoured flagellates, which tend to disintegrate on contact with formalin. Phytoplankton colour is a good index of total chlorophyll content (Hays and Lindley, 1994) and is closely related to biomass estimates from satellite observations (Batten *et al.*, 2003; Raitos *et al.*, 2005). There has been a large increase in phytoplankton colour since the late 1980s in most regions (particularly the northeast Atlantic and the Newfoundland Shelf).

From the late 1940s to the late 1980s, high biomass was restricted to spring and autumn when diatoms dominate (data not shown). Since the late 1980s, however, the biomass has increased throughout the seasonal cycle. Biomass generally dropped in 2002, but was still generally higher than the long-term mean. In other parts of the North Atlantic, large increases in biomass were seen off the Newfoundland Shelf (with an increase in winter blooms), the Scotian Shelf, and the Labrador Sea. In the northern North Atlantic and in the sub-polar gyre, phytoplankton biomass has generally declined over the past two decades, but has shown an increase since 1998.

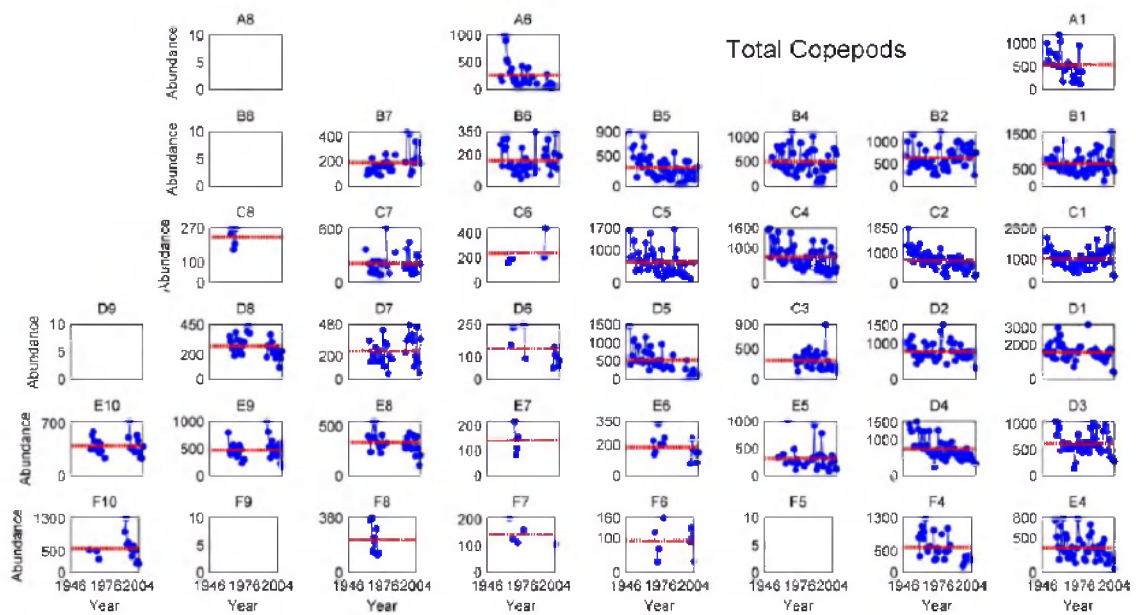


Figure 19. Time-series from 1946 to 2004 of the total copepod abundance in CPR standard areas in the North Atlantic (see Figure 1 for map) From Edwards *et al.* (2006).

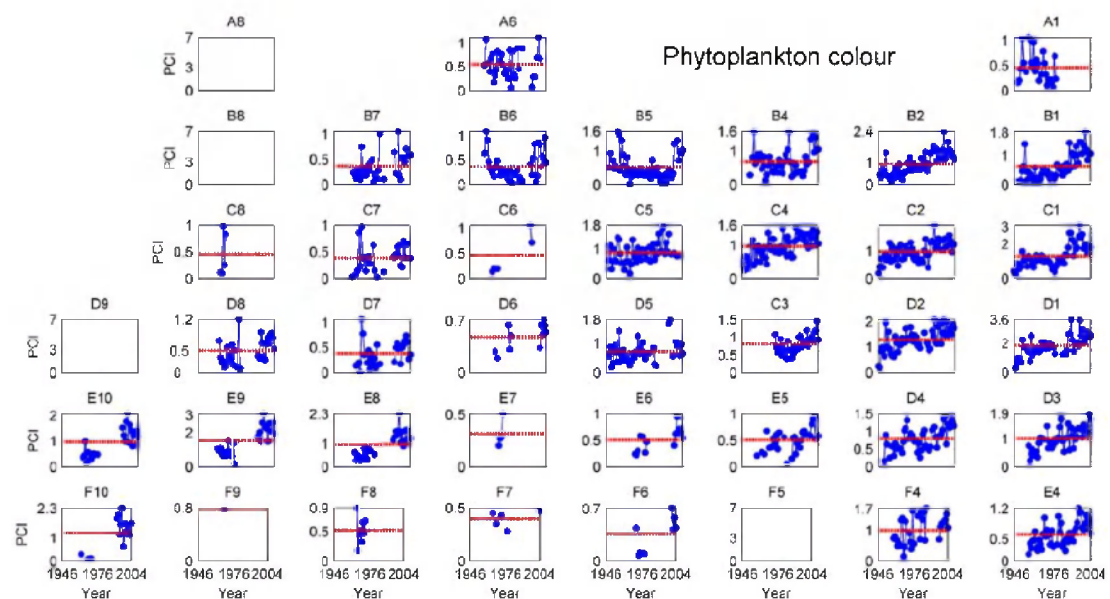
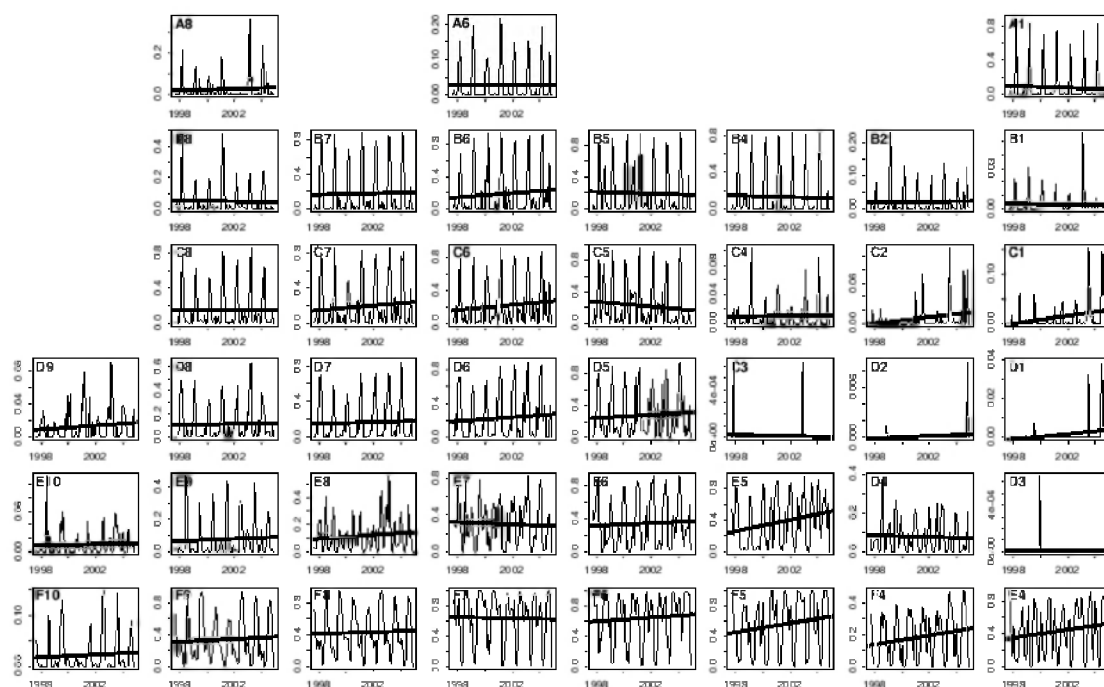


Figure 20. Time-series from 1946 to 2004 of the Phytoplankton Colour Index in CPR standard areas in the North Atlantic (see Figure 1 for map). Annual values were only calculated for each CPR box when eight or more months were sampled in any given year. From Edwards *et al.* (2006).





**Figure 21.** Time-series from 1997 to 2004 of the oligotrophy index from the SeaWiFS chlorophyll data for each CPR standard area in the North Atlantic (see Figure 1 for map) following McClain *et al.* (2004).

The drop in phytoplankton biomass recorded by the CPR PCI since 2002 is also apparent in the SeaWiFS chlorophyll data (Figure 21). Following McClain *et al.* (2004), we have analysed the percentage of the total SeaWiFS pixels with a chlorophyll value lower than 0.3 for each CPR standard area. Hence, high values represent prevailing oligotrophic conditions for a given area. For most of the North Atlantic, an increasing trend in this oligotrophy index has been recorded since 1997, except for areas C5 and B5 between Ireland and Iceland that have registered a decreasing trend. Especially for the southeastern-most areas, the increase in areas of low chlorophyll concentration has been remarkable, suggesting a recent recession of the high phytoplankton biomass period recorded by the CPR.

Figure 22 shows the long-term interannual values of Sea Surface Temperature (SST) from 1946 to 2004 in CPR standard areas in the North Atlantic. Temperature shows an overall increase since the early 1970s for the entire North Atlantic, as indicated by the pronounced positive anomalies. On the other hand, a decreasing trend in SST from the early 1950s until the early 1970s can be observed particularly in the southern part of the central North Atlantic. This decreasing signal in SST is less relevant in the North Sea, where temperatures during this period show no clear trend. This general pattern corresponds well to the division proposed by Beaugrand (2003), based on both SST and scalar wind. Beaugrand (2003) suggested that the northeast Atlantic can be divided into three hydroclimatic regions. The first division lies approximately north and south of a line of 53°N and in the region north of about 53°N, while the two other regions (the Subarctic gyre and the North Sea) are defined by their long-term monthly changes in SST. Both regions have been characterized by an increasing trend in wind intensity, which is highly positively correlated with monthly NAO indices, especially in spring and autumn. In the Subarctic gyre south of Iceland, phytoplankton biomass has decreased, while in the North Sea phytoplankton biomass has increased (Figure 21; Beaugrand, 2003). This tends to suggest that temperature is an important factor that limits phytoplankton biomass south of Iceland. However, it could also be argued that if we follow a top-down hypothesis instead of an hydrographically driven ecosystem, the decrease in zooplankton abundance in



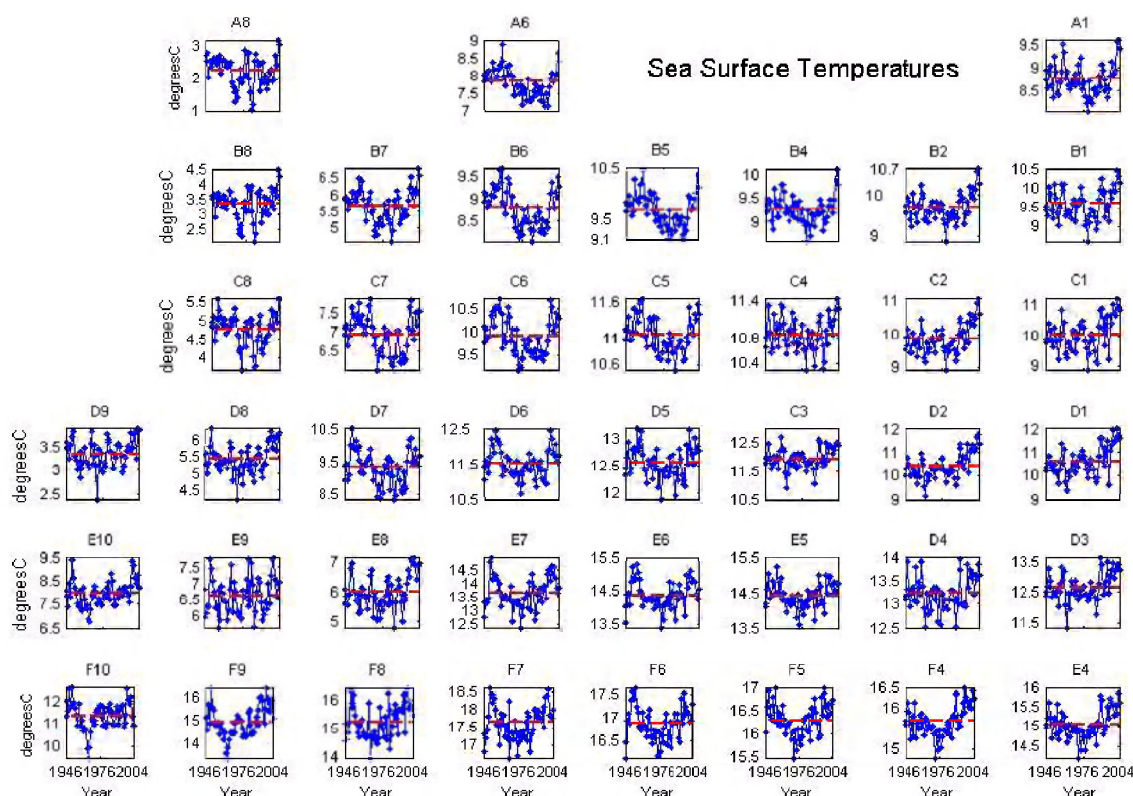


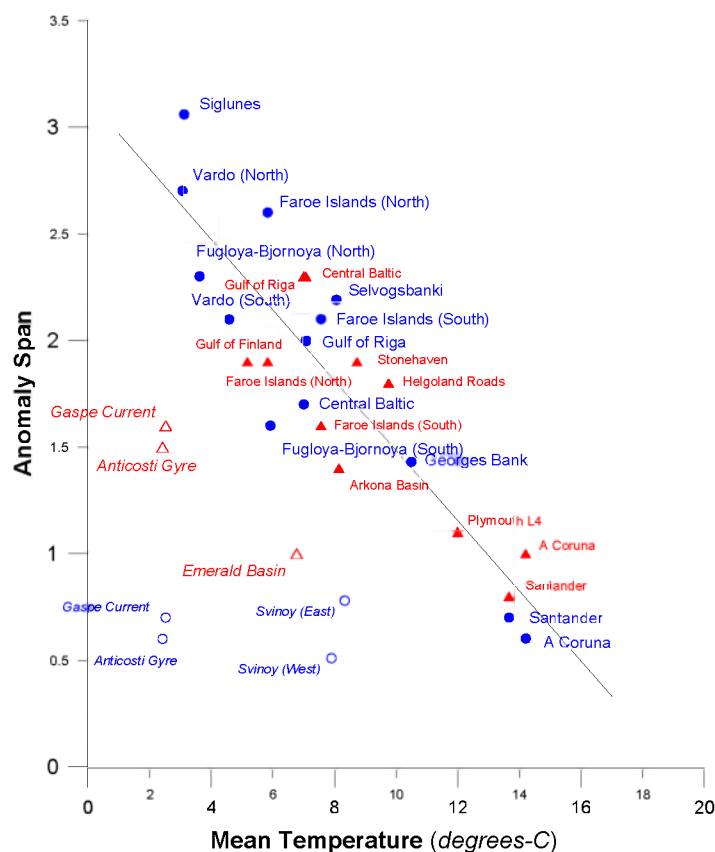
Figure 22. Time-series from 1946 to 2004 of the Sea Surface Temperature in CPR standard areas in the North Atlantic (see Figure 1 for map). From Edwards *et al.* (2006).

the North Atlantic could be realizing the predatory pressure over the phytoplankton and trigger an increase in their biomass, which could explain the increase in the CPR colour index.

## 4.2 Latitudinal patterns and relationship with temperature

In last year's report, the anomaly plots from time-series in higher latitudes tended to have a visually greater anomaly span (the difference between the minimum and maximum anomaly values) than those in lower latitudes. As water temperature generally decreases with increasing latitude and zooplankton production is dependent on water temperature, we examined the anomaly span as a function of mean water temperatures and found that cooler waters had a higher anomaly span. A relationship between temperature, latitude, and anomaly span was clearly evident.

To continue this work with the updated 2006 time-series, we again recalculated an anomaly span for each time-series by subtracting the minimum yearly anomaly value from the maximum; for example, if a time-series had a minimum anomaly value of  $-0.5$  and a maximum of  $1.0$ , it would have an anomaly span of  $1.5$ . This year, annual mean water temperatures were calculated using the higher resolution temperature fields of Boyer *et al.* (2005), which allowed for a better temperature estimation of near-shore sampling sites than was possible with the coarser fields of the World Ocean Atlas fields used last year. For each time-series location, a mean water temperature was calculated from all values sampled from 0 to 200-m depth (or the bottom). This average-over-depth value was used instead of surface temperatures because it better represents the vertical environment over which the zooplankton live and from which they were sampled.



**Figure 23.** Time-series anomaly span as a function of sampling site mean temperature. Blue circles are anomaly spans based on biomass data. Red triangles represent abundance data. Empty symbols were excluded from the regression calculation.

Plotting the anomaly span against mean temperature, we found a strong correlation between variability span and mean water temperature (Figure 23). In general, the year-to-year relative variability in zooplankton biomass or abundance decreases with increasing mean water temperature. It is already known that the growth and production of zooplankton are dependent on food availability and water temperature. In regions with colder water, the gradient between winter and summer air and water temperatures may be larger than those in the warmer water regions. These larger differences would lead to stronger seasonal winds and mixing between the surface and deeper nutrient-rich waters, resulting in stronger phytoplankton blooms and ultimately stronger zooplankton responses.

As was done in last year's analysis, anomaly spans from the Gaspé Current, Anticosti Gyre, Emerald Basin, and Svinøy sampling sites were excluded from the regression (Figure 23, empty symbols). These sites are thought to be influenced by strong current systems that may mask any temperature effects in those regions.

In last year's report, we did not differentiate between anomaly spans calculated from biomass data vs. those calculated from abundance data. There was some question whether the trends we saw were an artefact caused by comparing these two measurement types. To address this, we have distinguished biomass data (blue circles) from the abundance data (red triangles) in Figures 23–25. In Figure 24, we also show that both measurement types feature the same pattern and approximate line fittings in the anomaly span vs. temperature plot.

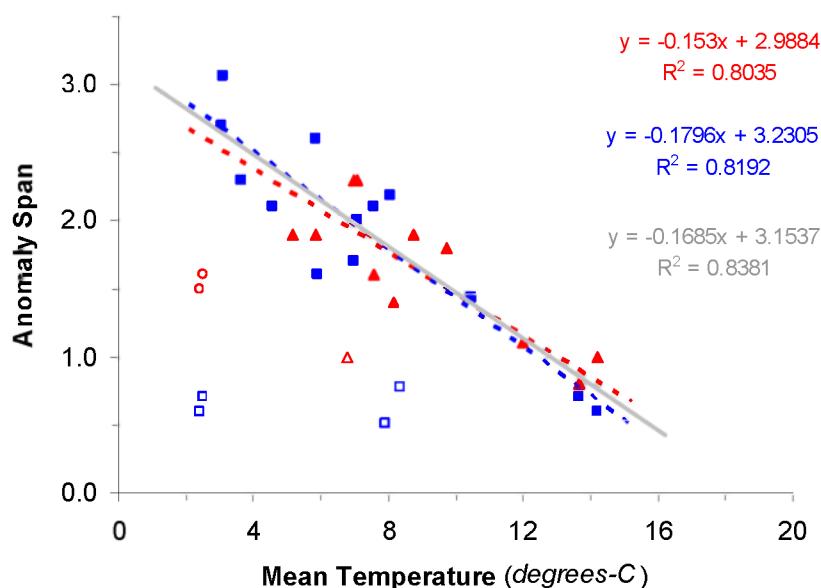


Figure 24. Anomaly span as a function of sampling site mean temperature. The blue squares and blue line fit are anomaly spans based on biomass data. Red triangles and the red line fit are based on abundance data. The gray line fit represents the combination of both biomass and abundance anomalies. Empty symbols were excluded from the regression calculation.

In last year's report, we did not calculate anomaly spans for the CPR data. This year we have added anomaly span values calculated from CPR abundance data for each standard CPR sampling area shown in Figure 1 (bottom). These values are plotted vs. temperature (Figure 25) with nearshore (solid black circle) and open-ocean (empty circle) sampling areas indicated. In general, the nearshore CPR regions fit the relationship much better than those from the open-ocean regions. These fits are not perfect but pretty decent, considering that the CPR data are from surface-only sampling over large spatial regions. Note that the highest CPR anomaly span value in the plot is from the Iceland region, which is also the highest non-CPR anomaly span value in our collection. Likewise, the anomalous Canada values are joined by a CPR point from the region immediately offshore from the Canada sites.

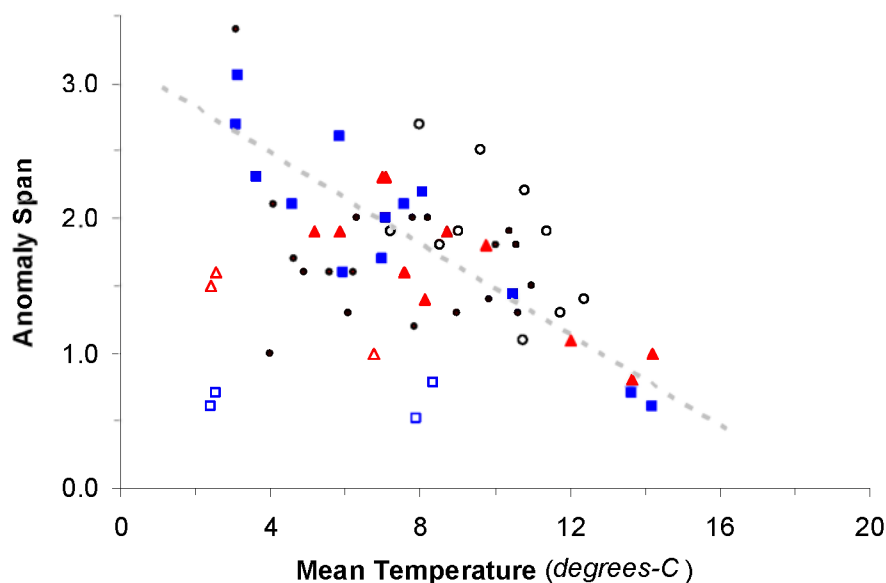


Figure 25. Anomaly span as a function of sampling site mean temperature, with the addition of CPR regional data. Near-shore CPR regions are indicated with solid black circles. Open-ocean CPR regions are represented with empty black circles. The gray dashed line represents the without-CPR fit seen in Figures 23 and 24.

#### 4.3 Phenological changes in relation to temperature

The EU Marine Strategy Initiative requires information on the typical zooplankton communities, including the typical species, seasonal and geographic variability, and estimates of secondary productivity. Global warming alters the timing of annual recursive events: the phenophases. Here we use the Helgoland Roads time-series data to show how existing time-series data can confront the demands of the EU Marine Strategy directive while providing valuable ecological information regarding the phenological properties of planktonic communities in relation to climate change. The Helgoland time-series of mesozooplankton, based on samples taken every other workday, records the taxonomy and abundance of 80 species and species groups, while 360 species and species groups of macrozooplankton are sampled once a week. This high temporal resolution permits a detailed study of the seasonal dynamics, in particular phenological observations. The time-series has been in continuous operation since April 1974.

The start of season (SOS), middle of season (MOS), and end of season (EOS) are defined as the passage of the threshold values representing 15%, 50%, and 85% of the cumulative sum of individuals for a given year. The length of season (LOS) is calculated from the difference of the EOS and the SOS. Values are given in weeks, calculated as means of the available weekly measurements. Generally, a negative correlation of the timing of phenophases with the slowly increasing seawater temperature is regarded as a consequence of accelerated physiological processes, but also as a function of the species-specific characteristics. The inclination of the corresponding regressions varies from species to species. The spectrum of variations includes positive correlations.

Because the SOS and EOS are basically independent of each other, the LOS also varies from a lengthening of the season to a shortening of the season in different populations (Figure 26 A–H). Although the population of the hydromedusa *Bougainvillia* spp. retards its season from 1975 to 2005 by 11 weeks (Figure 26B), the hydromedusa *Eutonina indicans* is shifted forward by 22 w (Figure 26C). Because of the opposite changes of SOS and EOS from 1975 to 2005, the LOS in the Eutimidae is reduced from 13 w to 1 w (Figure 26D) in contrast to

*Pleurobrachia pileus* that shows a LOS expanded from 2 w to 25 w (Figure 26E). These measurements in coelenterates exemplify the variance in population response patterns in zooplankton, which is also monitored in copepod populations as in *Acartia* spp. with a decadal SOS change of  $-1.4$  w (i.e. starts 1.4 w earlier), a MOS of  $-1$  w, and an EOS of  $-2.7$  w (Figure 26G). *Temora longiremis* displays a decadal SOS change =  $-23$  w, a MOS of  $-0.7$  w, and an EOS of 3 w (Figure 26H). From 1975 to 2005, the LOS of *Acartia* spp. was reduced from 16 to 13 w; during the same period, the LOS of *T. longicornis* increased from 13 to 21 w. The relationship between phenophase and temperature (Figure 26F) allows the calculation of the past and future phenology of zooplankton populations, based on preceding winter temperatures. The variability in seasonality is related to the warming of the sea by  $1.4^{\circ}\text{C}$  during the past 40 years. Besides primary effects such as the temperature dependence of physiological processes, other effects are responsible for the observed changes and represent intriguing challenges for functional food web analysis. In Table 6, the ranking of the annual variances is given for the abundance changes, the start of season changes, and the length of season changes. It is significant that neozoa like *Penilia avirostris* have 800% deviation from the mean annual abundance in the comparison. It is obvious that abundance and seasonality are independent zooplankton variables.

The lateral displacement of populations is observed at a fixed station by the invasion of neozoa, the abundance change of single components of the local community, or by the disappearance of species. At Helgoland Roads the continuing occurrence of *Penilia avirostris* and *Doliolum nationalis* represents the neozoa of the German Bight for the past 15 years. Losses of species have not been registered.

**Table 6. Ranking of the 2005 mesozooplankton abundance and phenology deviations according to the 30-year means.**

parameter	deviation from mean annual abundance %	parameter	deviation from mean start of season positive=weeks earlier negative=weeks later	parameter	deviation from mean length of season %
Penilia avirostris	800	Beroe spp. juv.	21	Penilia avirostris	66
Oithona spp.	128	Para- Pseudocalanus	13	Ophiuroidea pluteus	66
Noctiluca scintillans	124	Gastropod larvae	10	Para- Pseudocalanus	16
Fritillaria borealis	108	Copepoda nauplii	9	Obelia spp.	5
Spatangoid pluteus	35	Asterias rubens bip.	6	Lanice spp.	0
Corycaeus spp.	34	Penilia avirostris	5	Asterias rubens bip.	0
Pleurobrachia p. juv.	16	Ophiuroidea pluteus	5	Sagitta	0
Cirripedia nauplii	15	Obelia spp.	4	Fritillaria borealis	0
Cyphonautes	8	Centropages spp.	3	Copepoda nauplii	-4
Fish-eggs	-12	Lamellibranch larvae	3	Lamellibranch larvae	-4
Oikopleura dioica	-23	Podon spp.	2	Corycaeus spp.	-14
Gastropod larvae	-32	Fritillaria borealis	2	Centropages spp.	-15
Ophiuroidea pluteus	-41	Fish-eggs	2	Spatangoid pluteus	-16
Lamellibranch larvae	-42	Cyphonautes	0	Actinotrocha	-18
Centropages spp.	-44	Evadne spp.	0	Gastropod larvae	-21
Alaurina composita	-45	Oithona spp.	0	Oithona spp.	-22
Sagitta	-51	Actinotrocha	-1	Evadne spp.	-33
Copepoda nauplii	-54	Noctiluca scintillans	-2	Noctiluca scintillans	-41
Rathkea + Lizzia	-57	Pleurobrachia p. juv.	-2	Fish-eggs	-42
Acartia spp.	-58	Trochophora unident.	-2	Cirripedia nauplii	-46
Spionid larva	-66	Acartia spp.	-2	Oikopleura dioica	-49
Obelia spp.	-70	Corycaeus spp.	-2	Pleurobrachia p. juv.	-50
Calanus spp.	-70	Spatangoid pluteus	-2	Acartia spp.	-53
Asterias rubens bip.	-70	Fish-larvae	-2	Cyphonautes	-56
Para- Pseudocalanus	-72	Magelona spp.	-3	Fish-larvae	-60
Fish-larvae	-73	Temora longicornis	-3	Beroe spp. juv.	-61
Temora longicornis	-77	Alaurina composita	-4	Magelona spp.	-62
Lanice spp.	-78	Spionid larva	-4	Podon spp.	-62
Actinotrocha	-78	Cirripedia nauplii	-4	Calanus spp.	-64
Evadne spp.	-80	Sagitta	-4	Temora longicornis	-66
Podon spp.	-87	Oikopleura dioica	-4	Alaurina composita	-69
Magelona spp.	-93	Lanice spp.	-6	Trochophora unident.	-76
Beroe spp. juv.	-97	Calanus spp.	-10	Spionid larva	-85
Trochophora unident.	-97	Rathkea + Lizzia	-11	Rathkea + Lizzia	-86



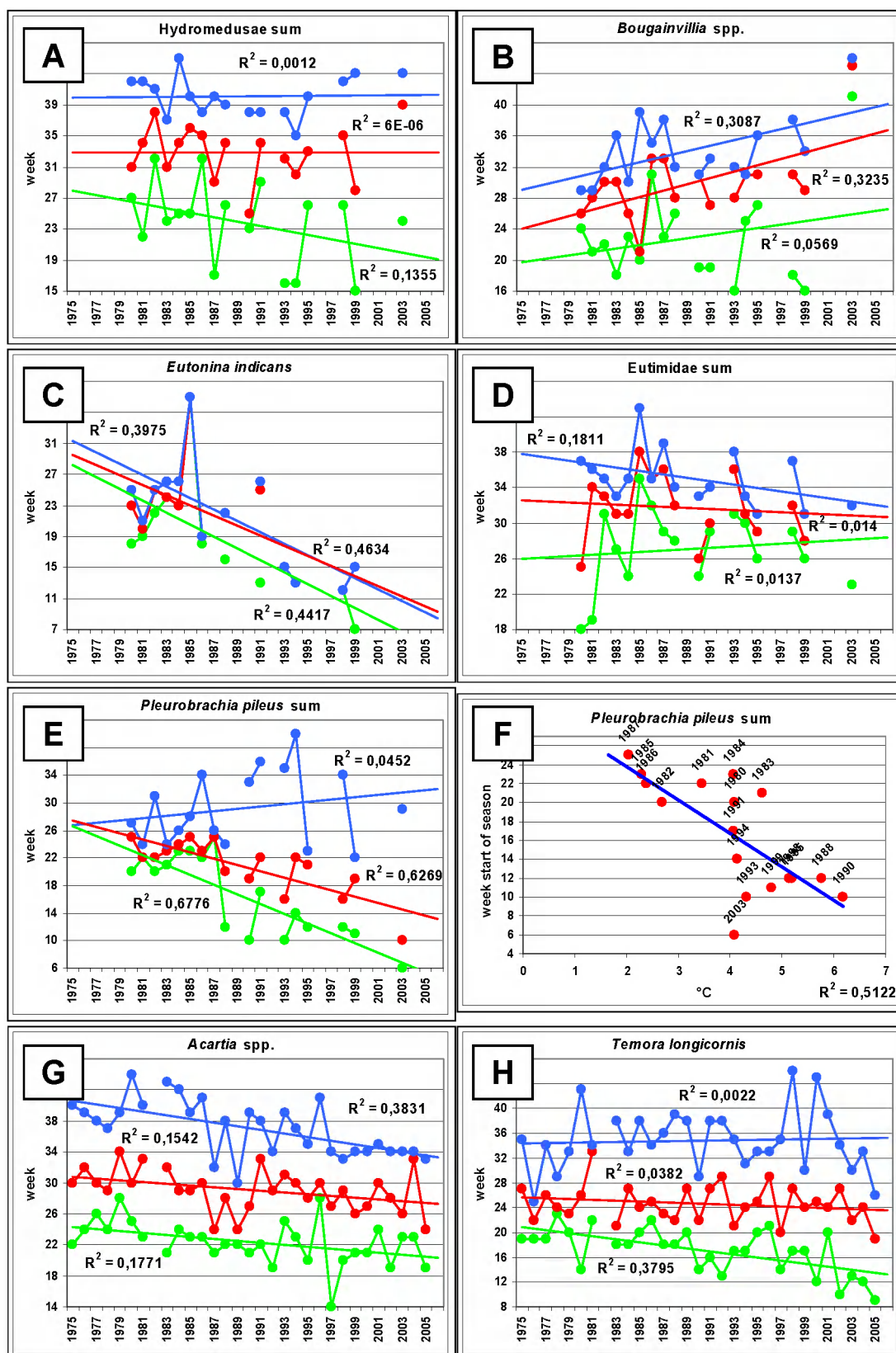


Figure 26. Variability in the phenophase dynamics in coelenterates and calanoid copepods. A: Hydromedusae; B: *Bougainvillia* spp.; C: *Eutonina indicans*; D: Eutimidae; E: *Pleurobrachia pileus*; F: *P. pileus* winter temperature relationship with phenophase start of season; G: *Acartia* spp.; H: *Temora longicornis* 1975–2005. Green: start of season; Red: middle of season; Blue: end of season.

## 5 References

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- Astthorsson, O. S., and Gislason, A. 1995. Long-term changes in zooplankton biomass in Icelandic waters in spring. *ICES Journal of Marine Science*, 52: 657–668.
- Astthorsson, O. S., and Gislason, A. 1998. Environmental conditions, zooplankton, and capelin in the waters north of Iceland. *ICES Journal of Marine Science*, 55: 808–810.
- Astthorsson, O. S., and Vilhjalmsen, H. 2002. Iceland shelf LME: decadal assessment and resource, pp. 219–243. *In* Large marine ecosystems of the North Atlantic. Changing states and sustainability. Ed. by K. Sherman and H. R. Skjoldal. Elsevier, Amsterdam. 449 pp.
- Batten, S. D., Walne, A. W., Edwards, M., and Groom, S. B. 2003. Phytoplankton biomass from continuous plankton recorder data: an assessment of the phytoplankton colour index. *Journal of Plankton Research*, 25: 697–702.
- Beaugrand, G. 2003. Long-term changes in copepod abundance and diversity in the northeast Atlantic in relation to fluctuations in the hydroclimatic environment. *Fisheries Oceanography*, 12(4–5): 270–283.
- Boyer, T., Garcia, H., Locarnini, R., Stephens, C., and Antonov, J. 2005. Objective analyses of annual, seasonal, and monthly temperature and salinity for the World Ocean on a 0.25° grid. *International Journal of Climatology*, 25(7): 931–945.
- Colebrook, J. M. 1975. The Continuous Plankton Recorder survey: automatic data processing methods. *Bulletin of Marine Ecology*, 8: 123–142.
- de Lafontaine, Y., Demers, S., and Runge, J. 1991. Pelagic food web interactions and productivity in the Gulf of St Lawrence: a perspective, pp. 99–123. *In* The Gulf of St Lawrence: small ocean or big estuary? Ed. by J-C. Therriault. Canadian Special Publication of Fisheries and Aquatic Sciences, 113.
- Edwards, M., Licandro, P., John, A. W. G., and Johns, D. G. 2006. Ecological Status Report: results from the CPR survey 2004/2005. SAHFOS Technical Report, No. 3. ISSN 1744–0750.
- Gaard, E. 1996. Life cycle, abundance and transport of *Calanus finmarchicus* in Faroese waters. *Ophelia*, 44: 59–70.
- Gaard, E. 1999. Zooplankton community structure in relation to its biological and physical environment on the Faroe Shelf, 1989–1997. *Journal of Plankton Research*, 21(6): 1133–1152.
- Gaard, E., and Nattestad, K. 2002. Feeding, reproduction and seasonal development of *Calanus finmarchicus* in relation to water masses and phytoplankton in the southern Norwegian Sea. *ICES CM 2002/N:08*.
- Greve, W. 1994. The potential of and limitations to marine population prognosis. *Helgoländer Meeresuntersuchungen*, 49: 811–820.
- Greve, W., Lange, U., Reiners, F., and Nast, J. 2001. Predicting the Seasonality of North Sea Zooplankton, pp. 263–268. *In* Burning issues of North Sea ecology, The 14th International Senckenberg Conference “North Sea 2000”, Wilhelmshaven, Germany, 8–12 May 2000. Ed. by I. Kröncke, M. Türkay, and J. Sündermann. *Senckenbergiana Maritima*, 31(2). 273 pp.
- Greve, W., Reiners, F., Nast, J., and Hoffmann, S. 2004. Helgoland Roads time-series Meso- and Macrozooplankton 1975 to 2004: lessons from 30 years of single spot high frequency sampling at the only offshore island of the North Sea. *Helgoland Marine Research*, 58: 274–288.
- Harvey, M., St-Pierre, J-F., Devine, L., Gagné, A., Gagnon, Y., and Beaulieu, M. F. 2005. Oceanographic conditions in the Estuary and the Gulf of St Lawrence during 2004: zooplankton. Canadian Science Advisory Secretariat Research Document, 2005/043.



- Hays, G. C., and Lindley, J. A. 1994. Estimating chlorophyll *a* abundance from the “PCI” recorded by the Continuous Plankton Recorder survey: validation with simultaneous fluorometry. *Journal of Plankton Research*, 16: 23–34.
- Heath, M. R., Adams, R. D., Brown, F., Fraser, S., Hay, S. J., Kelly, M. C., Macdonald, E. M., Robertson, M. R., Robinson, S., and Wilson, C. 1999. Plankton monitoring off the east coast of Scotland in 1997 and 1998. Fisheries Research Services Report, No. 13/99, 32 pp.
- HELCOM. 1996. Third Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1989–1993. *Baltic Sea Environment Proceedings*, 64B: 252 pp.
- Heyen, H., Fock, H., and Greve, W. 1998. Detecting relationships between the interannual variability in ecological time-series and climate using a multivariate statistical approach; a case study on Helgoland Roads zooplankton. *Climate Research*, 10(3): 179–191.
- Hinrichsen, H.-H., Möllmann, C., Voss, R., Köster, F. W., and Kornilovs, G. 2002. Bio-physical modelling of larval Baltic cod (*Gadus morhua*) survival and growth. *Canadian Journal of Fisheries and Aquatic Sciences*, 59: 1958–1873.
- Johannsen, S., Lange, U., Reick, C., Backhaus, J.-O., Greve, W., and Page, B. 1999. Abschlußbericht des Verbundprojekts: Zooplankton-Analyse und –Prognose gefördert durch das BMBF unter BEO 03 F223. 291 pp.
- Lavín, A., Valdés, L., Gil, J., and Moral, M. 1998. Seasonal and interannual variability in properties of surface water off Santander (Bay of Biscay) (1991–1995). *Oceanologica Acta*, 21(2): 179–190.
- Lumberg, A., and Ojaveer, E. 1991. On the environment and zooplankton dynamics in the Gulf of Finland in 1961–1990. *Proceedings of the Estonian Academy of Sciences, Ecology*, 1(3): 131–140.
- Matthäus, W., and Nausch, G. 2003. Hydrographic-hydrochemical variability in the Baltic Sea during the 1990s in relation to changes during the 20th century. *ICES Marine Science Symposia*, 219: 132–143.
- McClain, C. R., Signorini, S. R., and Christian, J. R. 2004. Subtropical gyre variability observed by ocean-color satellites. *Deep Sea Research Part II*, 22: 281–301.
- Möllmann, C., Kornilovs, G., and Sidrevics, L. 2000. Long-term dynamics of main mesozooplankton species in the central Baltic Sea. *Journal of Plankton Research*, 22: 2015–2038.
- Möllmann, C., Köster, F. W., Kornilovs, G., and Sidrevics, L. 2003a. Interannual variability in population dynamics of calanoid copepods in the Central Baltic Sea. *ICES Marine Science Symposia*, 219: 220–230.
- Möllmann, C., Kornilovs, G., Fetter, M., Köster, F. W., and Hinrichsen, H.-H. 2003b. The marine copepod, *Pseudocalanus elongatus*, as a mediator between climate variability and fisheries in the Central Baltic Sea. *Fisheries Oceanography*, 12: 360–368.
- Möllmann, C., Kornilovs, G., Fetter, M., and Köster, F. W. 2005. Climate, zooplankton, and pelagic fish growth in the Central Baltic Sea. *ICES Journal of Marine Science*, 62: 1270–1280.
- Pingree, R. D., and Griffiths, D. K. 1978. Tidal fronts on the shelf seas around the British Isles. *Journal of Geophysical Research*, 83 (C9): 4615–4622.
- Raitsos, D., Reid, P., Lavender, S., Edwards, M., and Richardson, A. 2005. Extending the SeaWiFS chlorophyll data set back 50 years in the Northeast Atlantic. *Geophysical Research Letters* 32(6): doi: 10.1029/2005GL022484.
- Roemmich, D., and McGowan, J. 1995. Climatic warming and the decline of zooplankton in the California current. *Science*, 267: 1324–1326.

- Rönkkönen, S., Ojaveer, E., Raid, T., and Viitasalo, M. 2004. Long-term changes in Baltic herring (*Clupea harengus membras*) growth in the Gulf of Finland. *Canadian Journal of Fisheries and Aquatic Sciences*, 61: 219–229.
- Roy, S., Silverberg, N., Romero, N., Deibel, D., Klein, B., Savenkoff, C., Vézina, A. F., Tremblay, J. E., Legendre, L., and Rivkin, R. B. 2000. Importance of mesozooplankton feeding for the downward flux of biogenic carbon in the Gulf of St Lawrence (Canada). *Deep-Sea Research II*, 47: 519–544.
- Valdés, L., and Moral, M. 1998. Time-series analysis of copepod diversity and species richness in the southern Bay of Biscay off Santander, Spain, in relation to environmental conditions. *ICES Journal of Marine Science*, 55: 783–792.
- Valdés, L., Lavín, A., Fernández de Puellas, M. L., Varela, M., Anadón, R., Miranda, A., Camiñas, J., and Mas, J. 2002. Spanish Ocean Observation System. IEO Core Project: Studies on time-series of oceanographic data. *In: Operational Oceanography: Implementation at the European and Regional Scales*. N. C. Fleming *et al.* (ed.), pp. 99–105. Elsevier Science BV, Amsterdam.
- Wasmund, N., and Uhlig, S. 2003. Phytoplankton trends in the Baltic Sea. *ICES Journal of Marine Science*, 60: 177–186.

## 6 Characteristics of the collections used (table of metadata)

COUNTRY	USA (1)	CANADA (2)	CANADA (3)	CANADA (4)
<b>Monitoring programme</b>	NFSC, Narragansett, RI	AZMP	AZMP	AZMP
<b>Sampling location</b>	Georges Bank	Halifax Line Stn 2 (HL2) West Atlantic, Scotian Shelf	Gaspé Current	Anticosti Gyre
<b>Latitude (N)</b>	40°15 to 42°15 N	44°16'N	49.24°N	49.72 N
<b>Longitude (E-W)</b>	69°15 to 65°30 W	64°19'W	66.20°W	66.25 W
<b>Station depth (m)</b>		150	265	265
<b>Period of data available</b>	1971–in progress	1998–in progress	1999–in progress	1999–in progress
<b>Frequency (number of cruises/yr)</b>	4–6	Monthly/Biweekly (~20)	Every two weeks with some gaps	Every two weeks with some gaps
<b>Gear/diam (cm)</b>	Bongo net	Ring/75	Ring/75	Ring/75
<b>Mesh (µm)</b>	333	200	202*	202*
<b>Depth of sampling (m)</b>		150	Bottom–surface	Bottom–surface
<b>Ancillary data</b>		hydrography, nutrients, phytoplankton, chlorophyll		
<b>Contact person</b>	David G. Mountain	Erica Head/Glen Harrison	Michel Harvey	Michel Harvey
<b>Email address</b>	dmountain@whsun1.wh.who.edu	HeadE@mar.dfo-mpo.gc.ca	HarveyM@dfo-mpo.gc.ca	HarveyM@dfo-mpo.gc.ca
<b>Location of data</b>		BIOCHEM database*, DFO, BIO	MEDS (Ottawa)	MEDS (Ottawa)
<b>* Observations</b>		Data will reside at MEDS in Ottawa, when database development is complete.	The mesh size of the net used in 1999 was 158 µm.	The mesh size of the net used in 1999 was 158 µm.

COUNTRY	ICELAND (5)	ICELAND (6)	FAROE (7)	FAROE (8)	NORWAY (9)
<b>Monitoring programme</b>	MRI-Iceland	MRI-Iceland	FFI-Faroe Islands	FFI-Faroe Islands	IMR-Bergen
<b>Sampling location</b>	Siglunes-transect	Selvogsbanki-transect	Faroe Shelf	Faroe Shelf	Svinøy transect East Norwegian Sea
<b>Latitude (N)</b>	*	*	62.20° to 63°N	63° to 64.30°N	*
<b>Longitude (E-W)</b>	*	*	6.05°W	6.05°W	*
<b>Station depth (m)</b>	*	*	*	*	*
<b>Period of data available</b>	1961–in progress	1971–in progress	1989–in progress	1989–in progress	1993–in progress
<b>Frequency (number of cruises/yr)</b>	Annually (1 May–June)	Annually (1 May–June)	Annually (late May)	Annually (late May)	6–10
<b>Gear/diam (cm)</b>	1971–91: Hensen; 1992–present: WP-2	1971–91: Hensen; 1992–present: WP-2	1990–1991: Hensen; 1992–present: WP-2	1990–1991 Hensen; 1992–present: WP-2	WP-2 (56)
<b>Mesh (µm)</b>	200	200	200	200	180
<b>Depth of sampling (m)</b>	0–50	0–50	0–50	0–50	0–200
<b>Ancillary data</b>	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll
<b>Contact person</b>	Astthor Gislason	Astthor Gislason	Eilif Gaard	Eilif Gaard	Webjørn Melle
<b>Email address</b>	astthor@hafro.is	astthor@hafro.is	eilifg@frs.fo	eilifg@frs.fo	webjom@imr.no
<b>Location of data</b>	database MRI	database MRI	FFL	FFL	TINDOR database, IMR
<b>* Observations</b>	Transect of eight stations from 66°16'N, 18°50'W (bottom depth: 80 m) to 68°00'N, 18°50'W (bottom depth: 1045 m).	Transect of five stations from 63°41'N, 20°41'W (bottom depth: 46 m) to 63°00'N, 21°28'W (bottom depth: 1004 m).	Transect with bottom depth from 50 to 100 m.	Transect with bottom depth from 50 to 100 m.	Four stations in the eastern part of a transect of 15 stations 62°22'N, 5°12'E (bottom depth: 160 m) to 63°12'N, 3°24'E (bottom depth: 1000 m).

COUNTRY	NORWAY (10)	NORWAY (11)	NORWAY (12)	NORWAY (13)	NORWAY (14)
<b>Monitoring programme</b>	IMR-Bergen	IMR-Bergen	IMR-Bergen	IMR-Bergen	IMR-Bergen
<b>Sampling location</b>	Svinøy transect West Norwegian Sea	Western Barents Sea (Fugloya-Bjornøya; North)	Western Barents Sea (Fugloya-Bjornøya; South)	Eastern Barents Sea (Vardo-North)	Eastern Barents Sea (Vardo-South)
<b>Latitude (N)</b>	*	*	*	*	*
<b>Longitude (E-W)</b>	*	*	*	*	*
<b>Station depth (m)</b>	*	*	*	*	*
<b>Period of data available</b>	1993–in progress	1994–in progress	1994–in progress	1994–in progress	1994–in progress
<b>Frequency (number of cruises/yr)</b>	6–10	4–10	4–10	4–10	4–10
<b>Gear/diam (cm)</b>	WP-2 (56)	WP-2 (56)	WP-2 (56)	WP-2 (56)	WP-2 (56)
<b>Mesh (µm)</b>	180	180	180	180	180
<b>Depth of sampling (m)</b>	0–200	0–100	0–100	0–100	0–100
<b>Ancillary data</b>	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll	hydrography, nutrients, chlorophyll
<b>Contact person</b>	Webjørn Melle	Webjørn Melle	Webjørn Melle	Webjørn Melle	Webjørn Melle
<b>Email address</b>	webjom@imr.no	webjom@imr.no	webjom@imr.no	webjom@imr.no	webjom@imr.no
<b>Location of data</b>	TINDOR database, IMR	TINDOR database, IMR	TINDOR database, IMR	TINDOR database, IMR	TINDOR database, IMR
<b>* Observations</b>	Four stations in the western part of a transect of 15 stations from 62°22'N, 3°08'E (bottom depth: 1100 m) to 64°40'N, 0°00'E (bottom depth: 2700 m).	Three stations in the northern part of a transect from 72°30'N, 19°34'E (depth 380 m) to 74°40'N, 19°13'E (depth 140 m).	Four stations in the southern part of a transect from 72°30'N, 20°E (depth 130 m) to 74°40'N, 19°41'E (depth 311 m).	Seven stations in the northern part of a transect from 73°15'N, 31°13'E (depth 280 m) to 75°30'N, 31°13'E (depth 352 m).	Five stations in the southern part of a transect from 70°30'N, 31°13'E (depth 192 m) to 72°30'N, 31°13'E (depth 298 m).

COUNTRY	ESTONIA (15)	LATVIA (16)	LATVIA (17)	GERMANY (18)	GERMANY (19)
<b>Monitoring programme</b>	HELCOM Monitoring	National monitoring programme of Latvia	LatFRA-monitoring	IOW	BSH and DZMB
<b>Sampling location</b>	Gulf of Finland Baltic Sea	Gulf of Riga Baltic Sea	Baltic Sea	Arkona Basin, Baltic Sea	Helgoland
<b>Latitude (N)</b>	59°32.2'N	57°37'N	south of 58°N	54°55'N	54°11.18'N
<b>Longitude (E-W)</b>	24°41.3'E	23°37'E	east of 15°E	13°30'E	7°54'E
<b>Station depth (m)</b>	44	54	variable, maximum 200	48	
<b>Period of data available</b>	1993–in progress	1993–present	1959–2004 (with gaps)	1973–in progress	1975–in progress
<b>Frequency (number of cruises/yr)</b>	3–12	3–4	seasonally (in general February, May, August, November)	Seasonally (4)	Monday, Wednesday, and Friday
<b>Gear/diam (cm)</b>	Juday net 38 cm	WP-2	Juday/36 cm	WP-2	Hydrobios and Calcofi
<b>Mesh (µm)</b>	90	100	160	100	150 and 500
<b>Depth of sampling (m)</b>	0–bottom	50	variable, maximum 100 m		
<b>Ancillary data</b>	hydrography, nutrients, chlorophyll <i>a</i> (0–10 m), phytoplankton cells (0–10 m)	hydrography, nutrients, chlorophyll <i>a</i> , phytoplankton species composition	temperature, salinity		hydrography, nutrients, chlorophyll, pigments (recently)
<b>Contact person</b>	Arno Põllumäe	Anda Ikauniece	Georgs Kornilovs, Christian Möllmann	Lutz Postel	Wulf Greve
<b>Email address</b>	arno@sea.ee	anda@monit.lv.lv	georgs.kornilovs@latzra.lv, cmo@dfu.min.dk	lutz.postel@io-wamemuende.de	wgreve@meeresforschung.de
<b>Location of data</b>	Estonian Marine Institute, University of Tartu	Institute of Aquatic Ecology, University of Latvia	LatFRA, Riga, Latvia	German Ocean Data Centre, IOW	
<b>* Observations</b>			Variable number and location of stations.		

COUNTRY	UK (20)	UK (21)	UK	SPAIN (22)	SPAIN (23)
<b>Monitoring programme</b>	FRS-MLA	L4-PML/UK	Continuous Plankton Recorder	IEO-SPAIN	IEO-SPAIN
<b>Sampling location</b>	Stonehaven, Aberdeen	Plymouth	North Atlantic	Santander	A Coruña
<b>Latitude (N)</b>	56°57.80'N	50°15'N		43°34.4'N	43°25.3'N
<b>Longitude (E-W)</b>	2°06.80'W	4°13'W		3°47.0'W	8°26.2'W
<b>Station depth (m)</b>	50	50	*	110	77
<b>Period of data available</b>	1997–in progress	1988–1997*	1946–in progress	1991–in progress	1990–in progress
<b>Frequency (number of cruises/yr)</b>	Weekly (52)	Weekly (~40)	approx. 12, some missing mon/yrs	Monthly (12)	Monthly (12)
<b>Gear/diam (cm)</b>	Bongo/40	WP2	CPR, aperture 1.24 cm x 1.24 cm	Juday 50	Juday 50
<b>Mesh (µm)</b>	200	200	280	250	1971–96: 250; 1996–present: 200
<b>Depth of sampling (m)</b>	47	50	7–10	50	50
<b>Ancillary data</b>	hydrography, nutrients, chlorophyll	hydrography, CNH, chlorophyll, <i>Calanus</i> egg production	Temperature, colour index	hydrography, nutrients, chlorophyll, phyto. cells	hydrography, nutrients, chlorophyll, phyto. cells
<b>Contact person</b>	Steve Hay	Roger Harris/X. Irigoien	Chris Reid	Luis Valdés	Maite Alvarez-Ossorio
<b>Email address</b>	haysj@marlab.ac.uk	rph@ccms.ac.uk	pcrc@wpo.nerc.ac.uk	luis.valdes@gi.ieo.es	maite.alvarez@co.ieo.es
<b>Location of data</b>	SERAD, FRS MLA	PML/CCMS	SAHFOS database	Database SIRENO IEO	Database SIRENO IEO
<b>* Observations</b>		Later samples in process.	Data correspond to several CPR routes and are presented here as the CPR standard areas of the North Atlantic.		





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