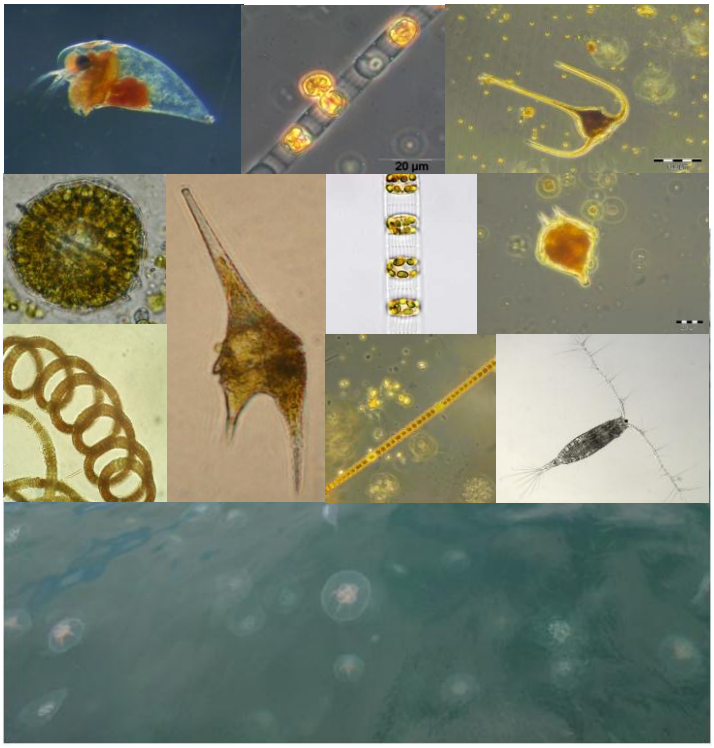
Final Report

FEHMARNBELT FIXED LINK
MARINE BIOLOGY SERVICES (FEMA)
HYDROGRAPHIC SERVICES (FEHY)

Marine Water & Fauna and Flora - Baseline

Water Quality and Plankton of the Fehmarnbelt Area

E2TR0020 - Volume IV



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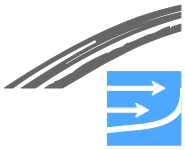

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Lists of figures and tables are included as the final pages

APPENDICES

Note to the reader:

In this report the time for start of construction is artificially set to 1 October 2014 for the tunnel and 1 January 2015 for the bridge alternative. In the Danish EIA (VVM) and the German EIA (UVS/LBP) absolute year references are not used. Instead the time references are relative to start of construction works. In the VVM the same time reference is used for tunnel and bridge, i.e. year 0 corresponds to 2014/start of tunnel construction; year 1 corresponds to 2015/start of bridge construction etc. In the UVS/LBP individual time references are used for tunnel and bridge, i.e. for tunnel construction year 1 is equivalent to 2014 (construction starts 1 October in year 1) and for bridge construction year 1 is equivalent to 2015 (construction starts 1st January).

0 SUMMARY

Purpose of the baseline investigation

The present report provides the technical documentation of the baseline investigation on water quality, plankton and jellyfish of the Greater Fehmarnbelt. The core of the baseline investigation is an almost two year's baseline study with monthly sampling at a number of stations in the Fehmarnbelt area.

The results of this study are related to available historical information on the plankton of the investigation area and discussed in relation to the Water Framework Directive (WFD). Furthermore, the importance of the environmental components water quality, phytoplankton, zooplankton and jellyfish is assessed.

The purpose of the water quality, plankton and jellyfish baseline investigations was to document baseline conditions in Fehmarnbelt and adjacent areas based on data collected during a two year investigation study 2009-2010, relevant historical data, modelling of pelagic biology and supporting information on hydrographic and chemical conditions from modelling and survey cruises of other consultants.

The field programme 2009 and 2010

The baseline investigations encompassed monthly monitoring cruises covering an area from the southern Great Belt in the west to east of the Darss Sill and also including the Mecklenburg Bight, see Figure 0-1. Within this area 12 off-shore stations (14 for the chlorophyll a (chl-a) parameter) and 10 near-shore stations distributed in the investigation area were visited on a monthly basis. The monitoring started in February 2009 and ended in December 2010. The spatial distribution of chl-a, the taxonomical composition and biomass of phytoplankton, mesozooplankton and macrozooplankton (jellyfish) communities as well as the phytoplankton production were some of the biological parameters determined. Feeding rates of jellyfish and the predation impact on mesozooplankton were investigated in summer 2009 and 2010. Furthermore, nutrients, oxygen, and turbidity were measured. The methods applied for sampling of water, filtration, conservation of samples, analysing samples and data followed accepted international guidelines, especially the HELCOM Combine Manual (HELCOM 2007) where applicable.

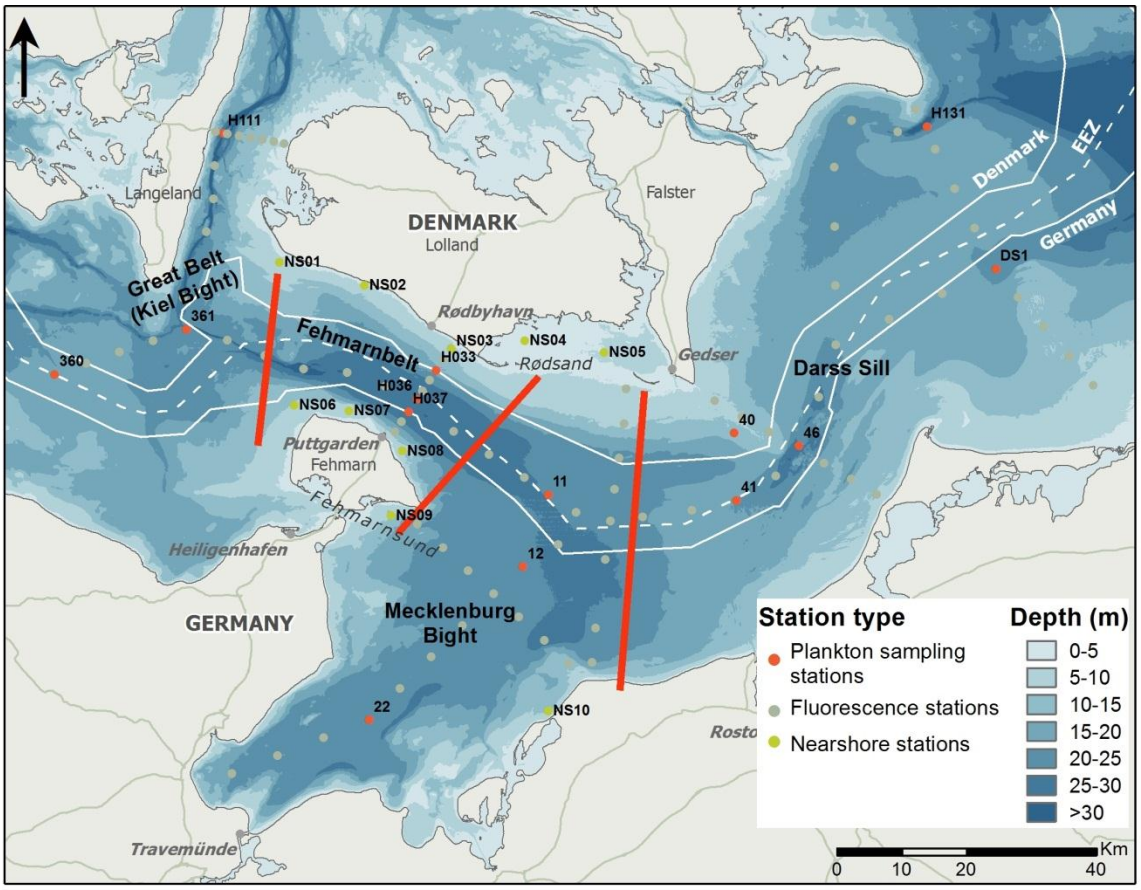


Figure 0-1 *Stations sampled in the Fehmarnbelt water quality, plankton, and jellyfish baseline investigation. Stations include 10 near-shore stations (NS01-NS10, dark red), 12 'water quality and plankton' stations (orange dots with associated numbers) and 110 fluorescence and oxygen stations (bright yellow). Red lines separate the investigation area into four subareas: Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill used when analysing the data.*

Important findings

Nutrients

Spatial and seasonal variation

The concentration of inorganic nutrients was rather uniform in the study area while the concentrations showed strong seasonal variation.

The seasonal variation in dissolved inorganic nitrogen, phosphate and dissolved silicate in the four subareas (Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill area, (see Figure 0-1 for station locations) is shown in Figure 0-2. Averaged over 2009 and 2010 the concentration of all inorganic nutrients peaked in January and February as a result of accumulated mineralisation during late autumn-winter and land run-off, combined with a low insolation preventing phototrophic production and uptake of nutrients in algae. Nutrients and in particular dissolved inorganic nitrogen (DIN) decreased in March due to the spring bloom and DIN remained exhausted until November. In contrast, phosphate was still available at the end of April and the concentration was varying between 2 and 5 mg PO_4-P m^{-3} from May through August. From September through December the concentration of phosphate increased gradually reaching peak winter values in January.

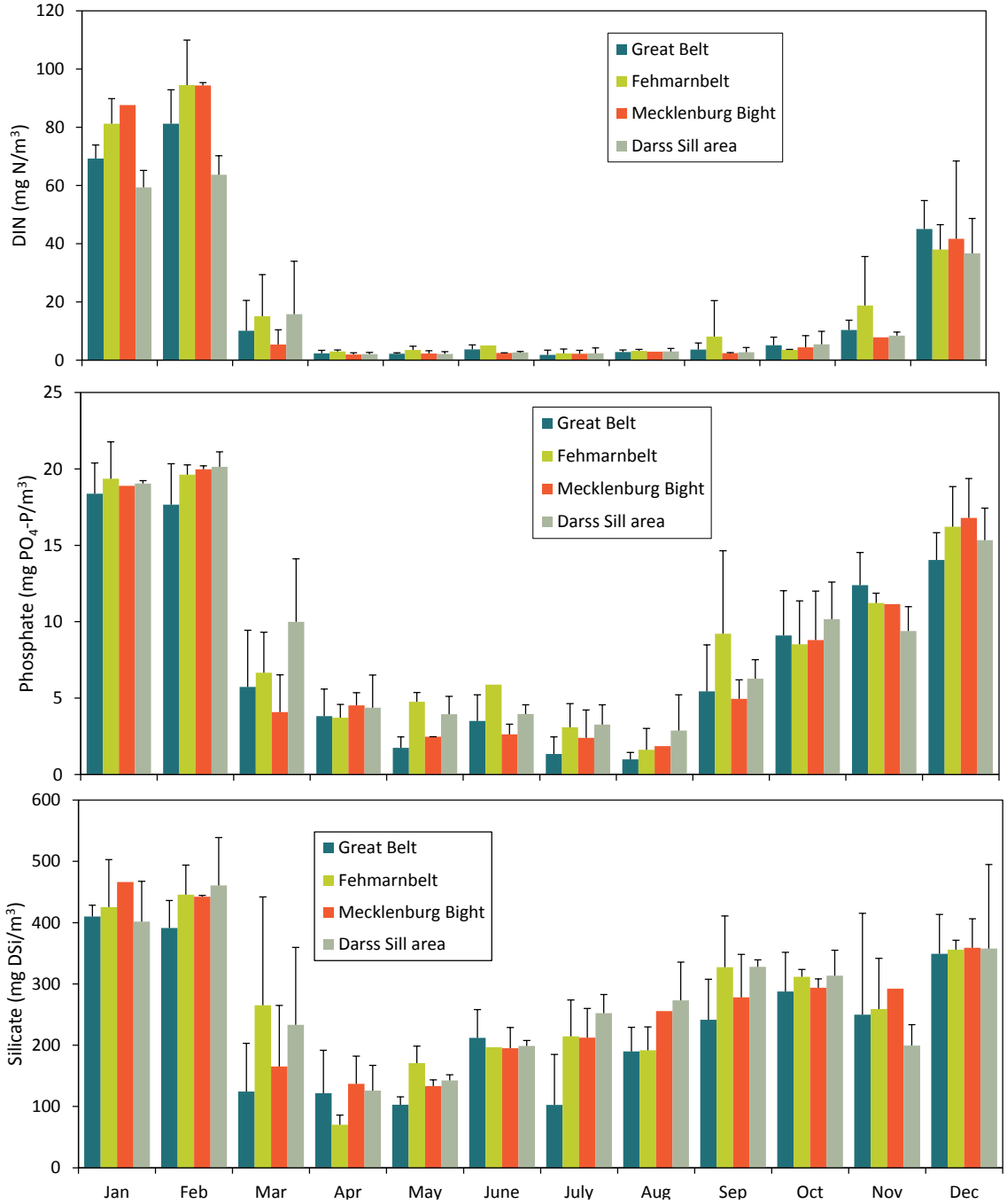


Figure 0-2 *Spatial and temporal variation in inorganic nutrients in surface waters (0-10m) of the Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill areas. Bars (+SD) show monthly averaged nutrient concentrations for the period March 2009-December 2010.*

Nutrient limitation

Based on nutrient concentrations and the ratio between inorganic nitrogen and phosphorus (Redfield ratio) phytoplankton were evaluated to be strongly limited by availability of nitrogen. The monthly N:P ratio from March to November (when nutrients were potentially limiting the production) varied between 0.5 (August-September) to 2.5 in July, and thus much below the Redfield ratio of 7. Therefore, as the concentrations were much below the half-saturation constant for uptake and

with N:P-ratios much below the Redfield ratio, nitrogen is the most limiting nutrient in the greater Fehmarnbelt. Using the same approach for silicate, it was found that this nutrient is never limiting the diatom production.

Long term trends

After a peak in nutrient concentrations reached in the early 1980's nutrient concentrations have been slowly (1% per year) decreasing in the open parts of the Fehmarnbelt while trends at more near-shore stations (station 22, see Figure 0-3) have been stronger, most probably reflecting the effect of nutrient reduction measures.

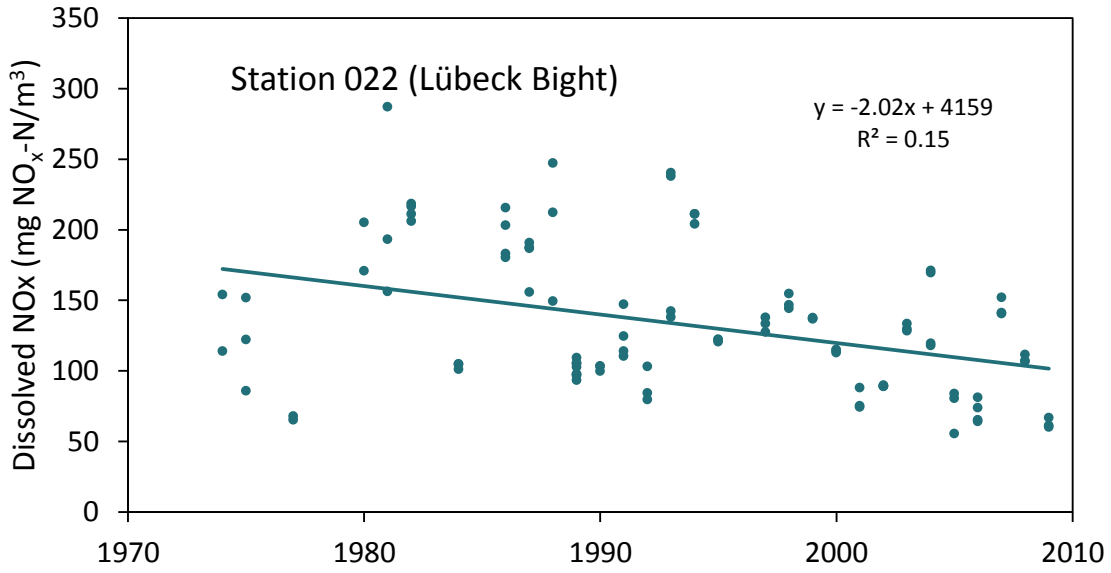


Figure 0-3 *Trends of NOx (nitrate + nitrite) in the winter surface layer at station 22 (Lübeck Bight). Data based on extracts from the IOW Odin database.*

Is the baseline period representative for recent years?

To evaluate if nutrients measured in the baseline period are representative for the immediate past, winter concentrations from 2010 (January-February) were compared with concentrations from the past 5 years (Table 0-1). For all nutrients winter concentrations showed large year-to-year variation in the Great Belt (stations 360 and 361) and in Mecklenburg Bight (station 12) probably reflecting that these stations are influenced by year-to-year variation in run-off, while concentrations were much more stable in the Darss Sill area (stations 30 and DS1) underlining the 'Baltic Sea' nature of this subarea. The winter nutrient concentrations fell within the range observed in the past 5 years. One exception was NOx (nitrite + nitrate) in the Darss Sill area. However, the deviation in 2010 was minor (57.8 mg NOx-N m^{-3} vs. 55.4 NOx-N m^{-3} in 2007). Therefore the nutrient situation under the baseline study was in line with the past years and no exceptional observations were done.

Table 0-1 Mean nutrient concentrations (mg m^{-3}) in the winter surface layer (0-10 m) during the past 6 years in the Great Belt area (360/361), in the Mecklenburg Bight area (12) and in the Darss Sill area (30/DS1).

	2005	2006	2007	2008	2009	2005/ 2009	2010
NO_x							
station							
360/361	55.2	43.7	120.8	90.3	55.6	73.1	**72.5**
12	40.2	49.6	90.7	108.8	51.8	68.2	**82.0**
30/DS1	34.6	40.3	55.4	40.0	38.5	41.7	**57.8**
DIN							
station							
360/361	64.5	54.7	144.9	105.4	66.4	111.0	**83.7**
12	44.5	62.2	103.9	125.3	64.4	80.1	**95.2**
30/DS1							**62.9**
PO_4							
station							
360/361	0.5	0.76	0.7	0.78	0.68	0.68	**0.58**
12	0.69	0.82	0.58	0.81	0.66	0.7	**0.65**
30/DS1	0.64	0.78	0.76	0.61	0.6	0.68	**0.64**
SiO_4							
station							
360/361	311	437	493	605	392	448	**400**
12	414	501	400	571	221	423	**451**
30/DS1	398	470	364	375	241	370	**400**

Secchi depth

Secchi depth was calculated from light attenuation measured using light sensors mounted on the profiling CTD. Secchi depth depends on concentration of dissolved (organic) matter and suspended organic and inorganic matter. Phytoplankton plays an important role for Secchi depth, because of the content of chlorophyll-a and other light-harvesting pigments.

Spatial and seasonal variation

Secchi depth varied between 4.5 and 9 m where the seasonal variation was much more pronounced than the spatial variation (Figure 0-4). Secchi depths were lowest during the declining spring bloom in February 2009 and during the spring bloom in March 2010 and, highest 1-2 months after the spring bloom peak in March/April 2009 and in May 2010. During autumn the Secchi depths were intermediate reflecting the autumn phytoplankton bloom that did not reach the high levels of the spring bloom. Very low Secchi depths were measured during the cruise in January 2010

that followed immediately after a storm and during high concentrations of suspended inorganic solids in the water column.

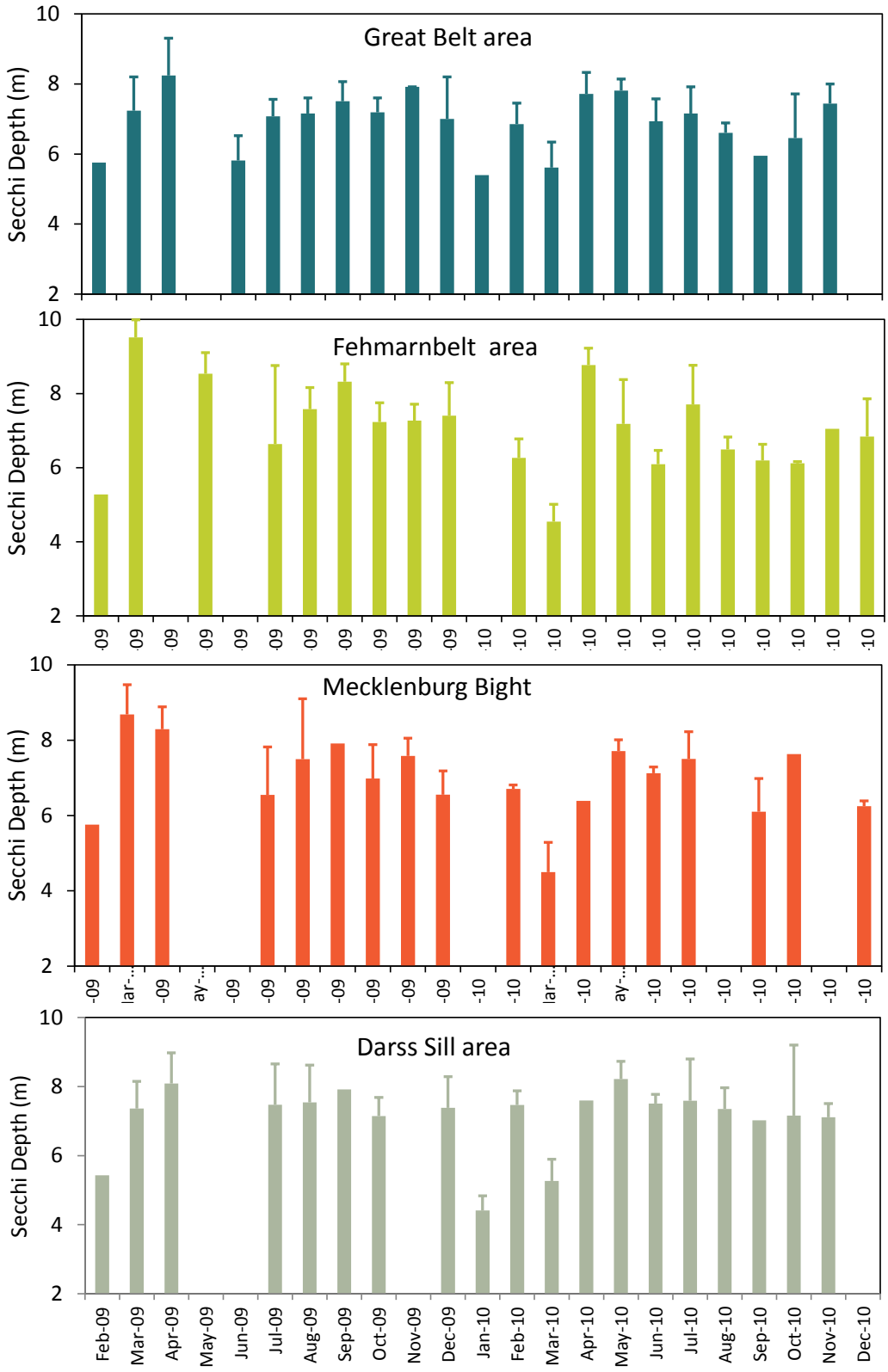


Figure 0-4 Monthly means of Secchi depth (+SD) at the 4 subareas. Note: the y-axis start at 2m.

Averaged over the baseline period Secchi depths in the four subareas were almost identical (Great Belt: 6.90 m; Fehmarnbelt: 7.05 m; Mecklenburg Bight: 7.00 m; Darss Sill: 7.10 m). In contrast, Secchi depths differed somewhat but not significantly (p = 0.09, t-test) between years (2009: 7.3 m; 2010: 6.8 m), see Table 0-2. When the different timing of spring bloom and other seasonal effects were accounted for by excluding February and March data and only including data where monthly data were available for both years (balanced data) the Secchi depth was significantly higher in 2009 than in 2010 (Table 0-2).

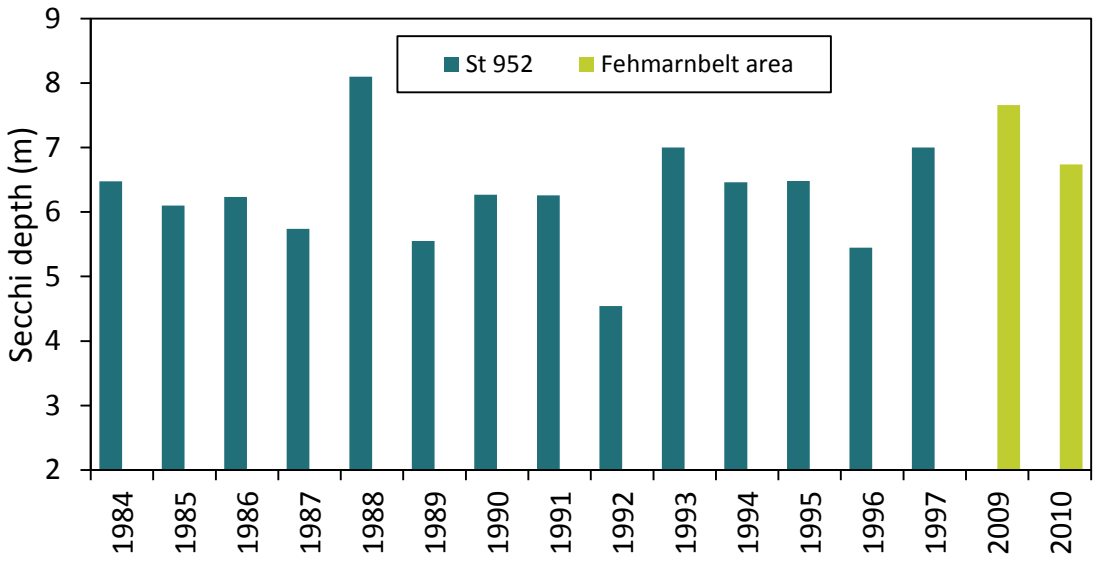
Table 0-2 Average Secchi depth (m) in 2009 and 2010 and p-level of Students t-test. H_0 hypothesis (i.e. Secchi depths were identical in 2009 and 2010) was rejected using balanced data.

Data selection	2009	2010	p-level
All data	7.30m	6.80m	0.09
Balanced data	7.45m	6.95m	0.02

Historical Secchi depths

Secchi depth in the Belt Sea including the Fehmarnbelt has been reduced from ca. 9.3 m prior to 1940 to ca. 6.5 m in the 1980- and 1990-ies as a result of increased phytoplankton production and biomass indicating that light availability may limit the benthic autotrophs at bottom.

Recent historical data from the central Fehmarnbelt (St. 952 equivalent to H037, see) and from the Darss Sill area (St. 954 equivalent to 46, see Figure 0-1) show yearly (averaged over May-October) Secchi depths between 4.5 m and 8.1 m (Figure 0-5). On average Secchi depths were about 1 m lower 20 years ago, but the baseline Secchi depths fall within the range of recent measurements.



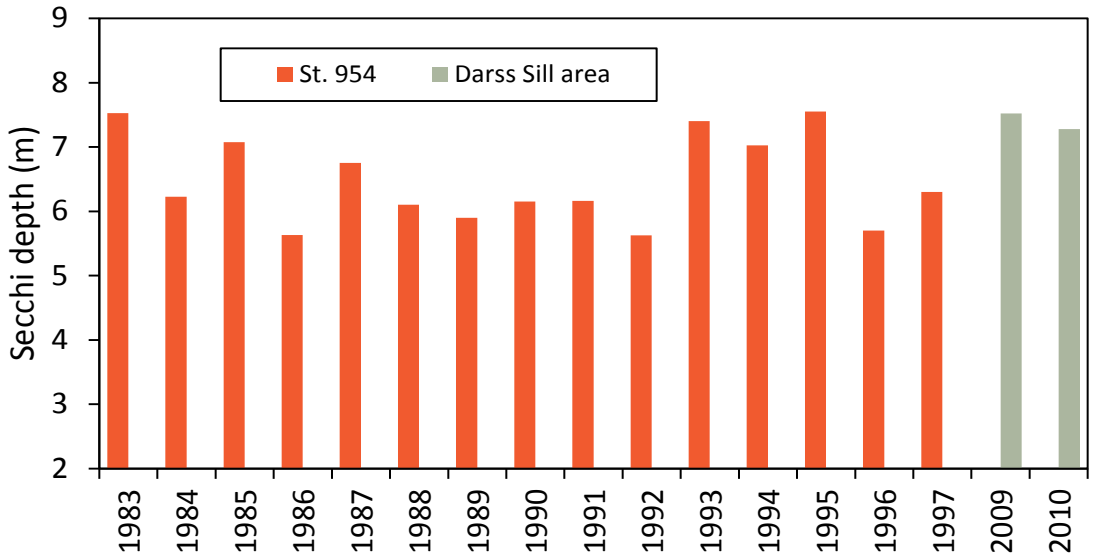


Figure 0-5 Historical Secchi depths measured in Fehmarnbelt (St. 952 and off Gedser Reef (St. 954). Data from the Danish monitoring programme NOVANA.

Oxygen in near bed water

Oxygen concentration in the near bed layer at the mooring stations in the central Fehmarnbelt and in the Mecklenburg Bight varied from 12 mg O_2 l^{-1} (i.e. fully saturated) during winter to minima reached in late summer-early August (Figure 0-6). The oxygen situation differed in 2009 and 2010. In 2009 the oxygen minima at MS02 (Southern Fehmarnbelt) was reached in late September but the concentration never fell below 1 mg O_2 l^{-1}. In 2010 the bottom water experienced extended periods of serious oxygen deficiency. At MS02 the oxygen concentration fell below 1 mg O_2 l^{-1} in beginning of September 2010 and reached anoxic conditions in late September persisting to 3rd October. The better oxygen conditions in 2009 compared to 2010 was due to stormy winds which prevailed at the end of August/beginning of September from varying directions. This caused a better vertical mixing.

The oxygen situation during 2010 was worse at MS03 (Mecklenburg Bight) with average concentrations in July at 1.1 mg O_2 l^{-1}, in August at 0.75 mg O_2 l^{-1} and in September at 1.3 mg O_2 l^{-1}. In July oxygen was lower than 1 mg O_2 l^{-1} in 47% of the time, in August 71% of the time and in September lower than 1 mg O_2 l^{-1} in 82% of the time. The difference between Fehmarnbelt (MS02) and Mecklenburg Bight (MS03) relates to better ventilation (i.e. higher current speeds at bottom) at MS02 and probably a higher oxygen demand in the organic rich sediments in Mecklenburg Bight.

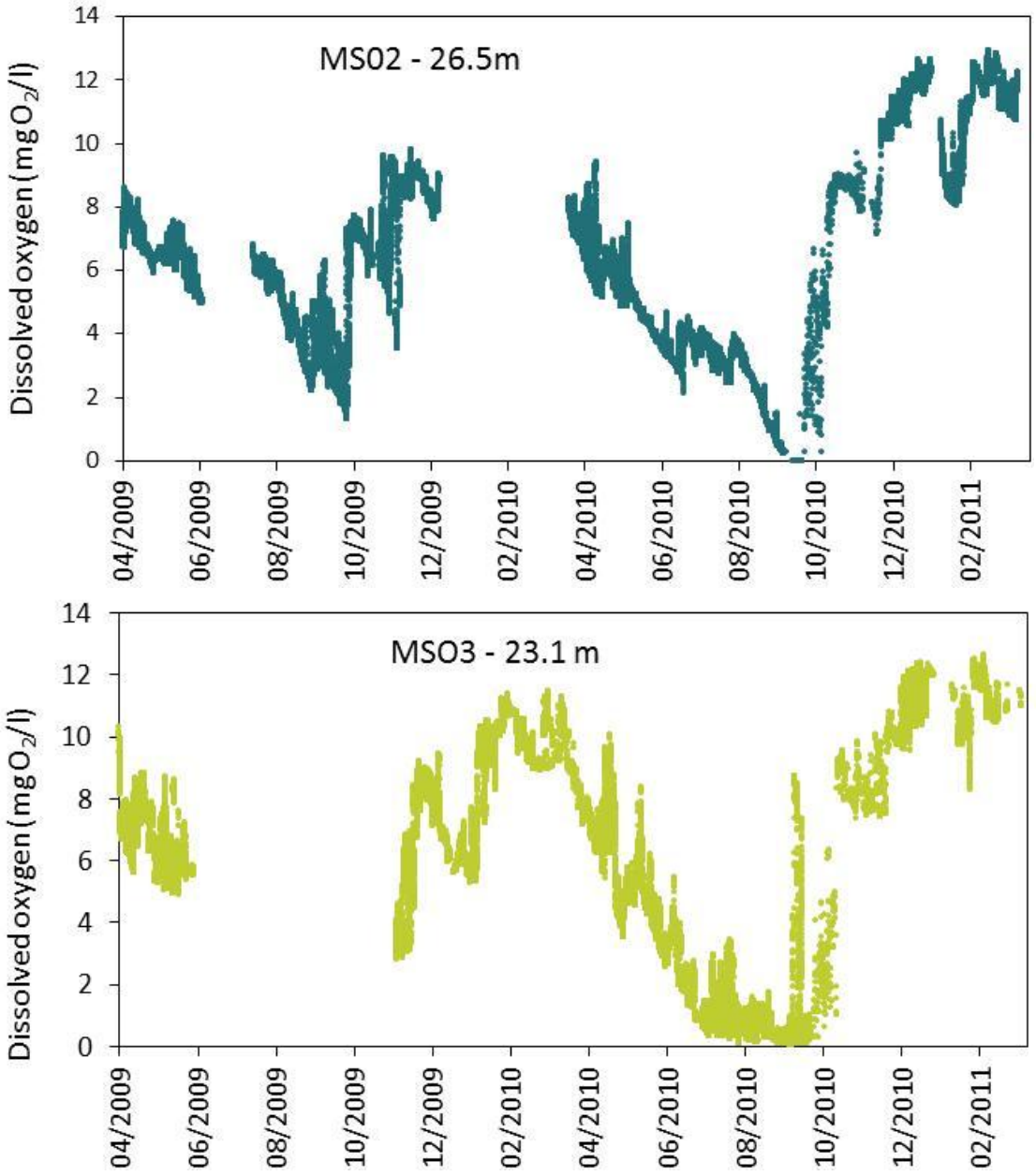


Figure 0-6 Near-bottom oxygen concentration at MS02 (Southern Fehmarnbelt) and MS03 (Mecklenburg Bight) main stations (moorings). Oxygen measurements were taken every 10 min.

Low oxygen concentration occurred all over the Fehmarnbelt area in the deep areas during autumn 2010, but with the worst conditions in the central Fehmarnbelt and in the Mecklenburg Bight (Figure 0-7).

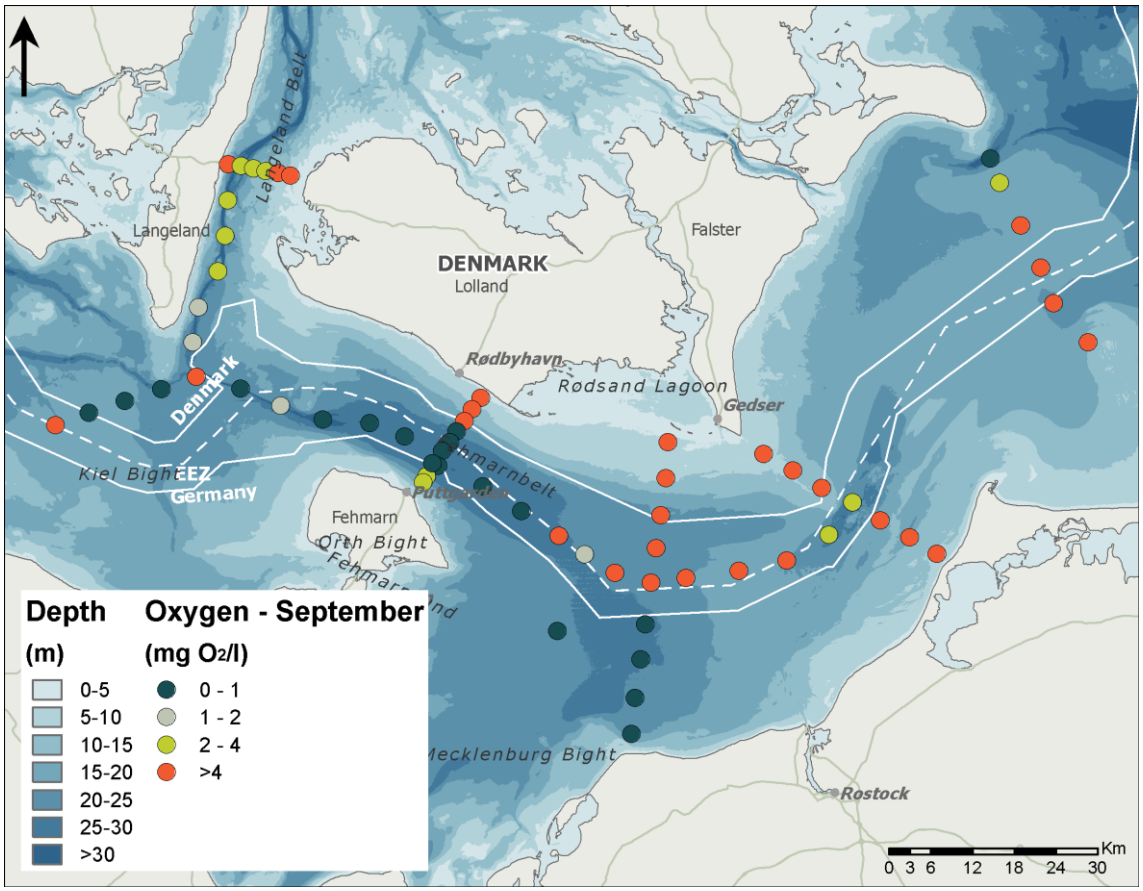


Figure 0-7 Concentration of oxygen in near bed layer in September (data from CTD mapping).

Bathing water quality

Sixteen official bathing water sites (beaches that are monitored regularly) are located in the vicinity of the planned link or located in an area that potentially may be influenced by the fixed link. The status of bathing water quality and the vulnerabilities are described by the socalled "bathing water profiles" that are prepared by municipalities every year. Evaluation of the quality of bathing water are based on two bacteriological parameters, i.e. the concentrations of *Escherichia coli* (*E. coli*) and Intestinal Enterococci (IE). Among the 16 beaches 13 had an excellent status in 2010, while 3 on Lolland coast (Kramnitze, Bredfjed and Holeby Østersøbad) had a lower (but sufficient) bathing water quality (Figure 0-8).

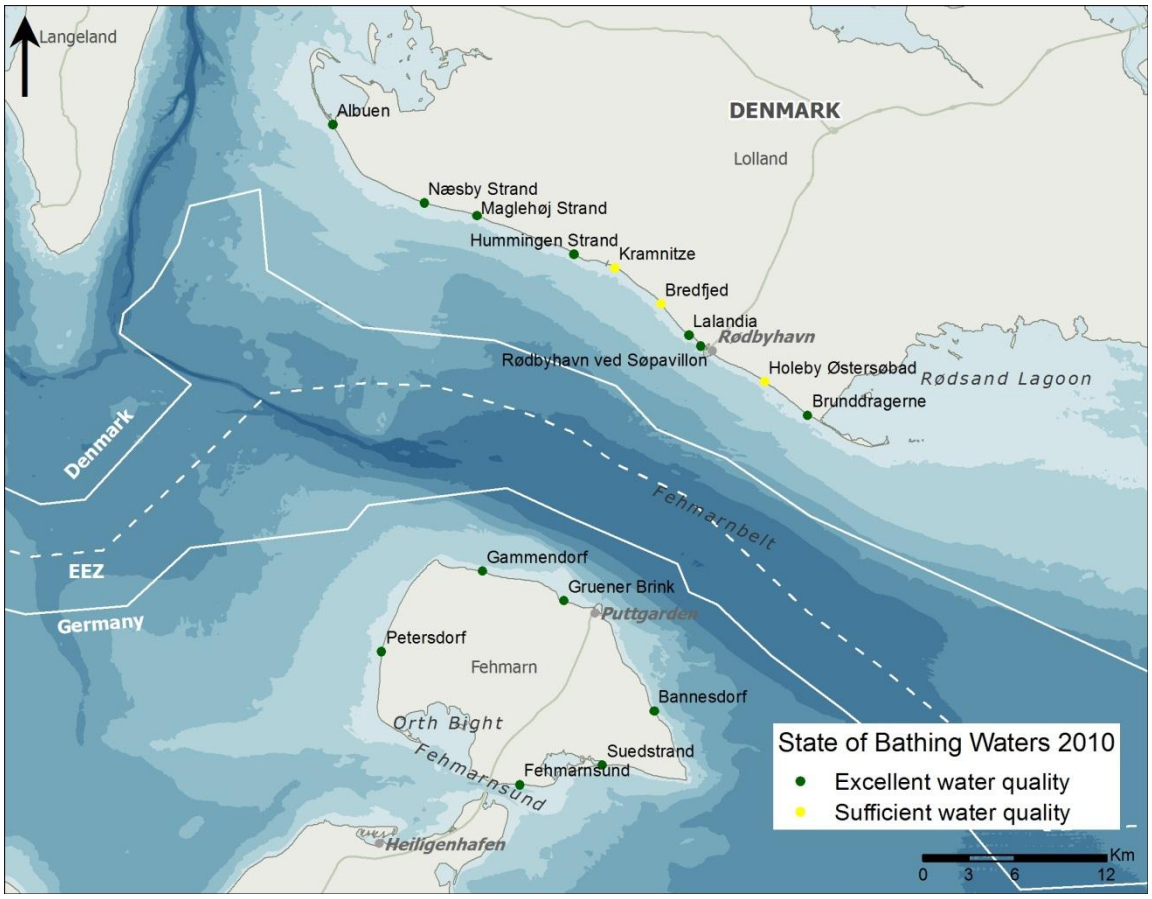


Figure 0-8 Status of bathing water quality at 16 official bathing water sites around Fehmarm and along southern Lolland coast.

Phytoplankton (chl-a, composition, and primary production)

Horizontal variation

Overall, the spatial variation in chl-a and primary production at the offshore stations were modest compared to the seasonal variation (Figure 0-9). However, notable patterns were a lower concentration in the Darss Sill area than in the other three areas, and a higher biomass in Mecklenburg Bight during autumn 2009 and spring bloom 2010 compared to the other three areas. The Darss Sill area had the lowest salinity and lowest concentration of inorganic nutrients and these conditions were probably leading to a lower productivity. Among the four areas the Fehmarnbelt area showed the least variation with respect to chl-a.

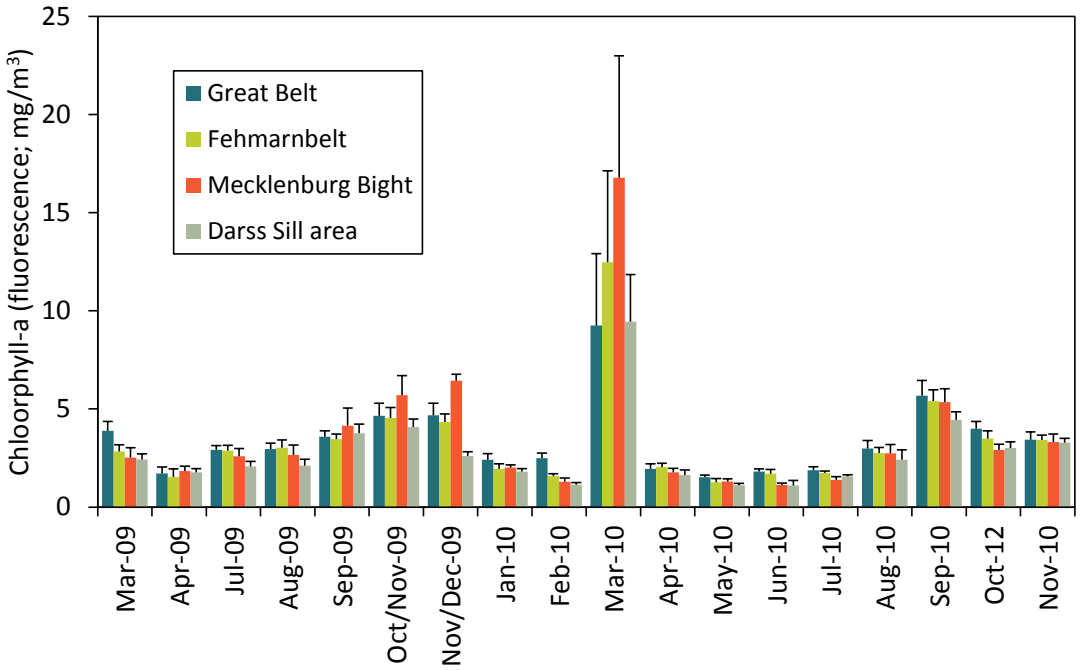


Figure 0-9 *Spatial variation in chl-a calculated from fluorescence in Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill areas. Bars represent averaged concentrations (with +SD error bars) over depth (5-15m) and subsequently over stations sampled within each of the four areas.*

The seasonal variation of the primary production in the four baseline subareas of Fehmarnbelt for March 2009 – December 2010 is shown in Figure 0-10. The monthly averaged values varied between 50-1125 mg C m^{-2} d^{-1}, showing the highest values in late summer when primary production occasionally exceeded 1200 mg C m^{-2} d^{-1}.

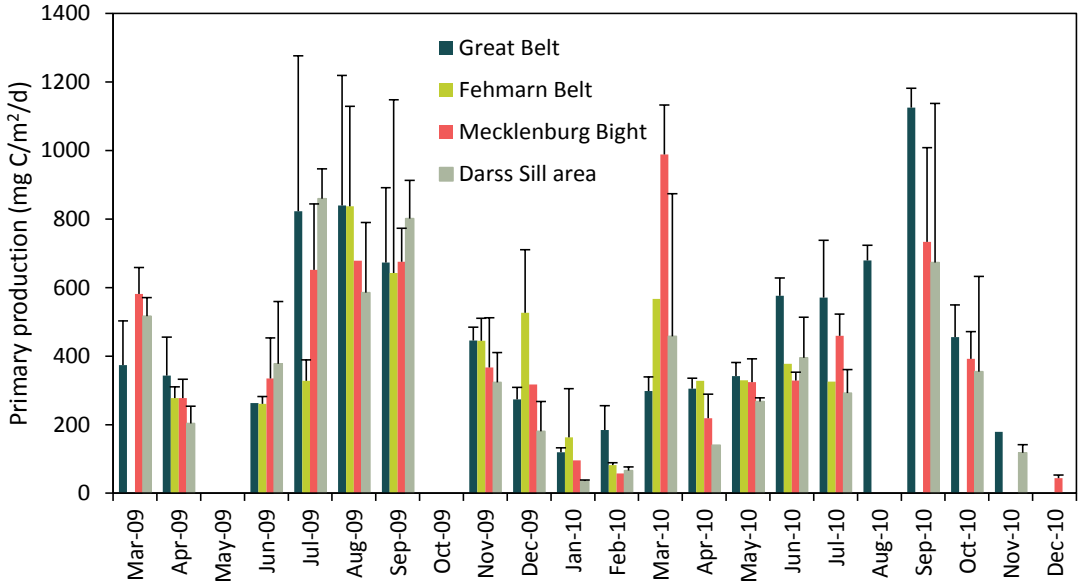


Figure 0-10 *Temporal variation (March 2009-December 2010) in depth-integrated primary production in the four parts of the Fehmarnbelt investigation area. Bars represent average values for 2-3 stations and error bars represent standard deviation. In case that error bars are not shown only one station in an area was sampled within a cruise.*

Near-shore stations

Chl-a at the near-shore stations grossly followed the variation in the near-by off-shore stations located along the proposed Fehmarnbelt link (H33, H37) except for samplings in November and December where chl-a along Lolland was about 50-75% lower compared to off-shore values (Figure 0-11). It is also notable that the chlorophyll concentration along the German coast was markedly higher than along the Danish coast. This trend was also observed in the *in situ* fluorescence data.

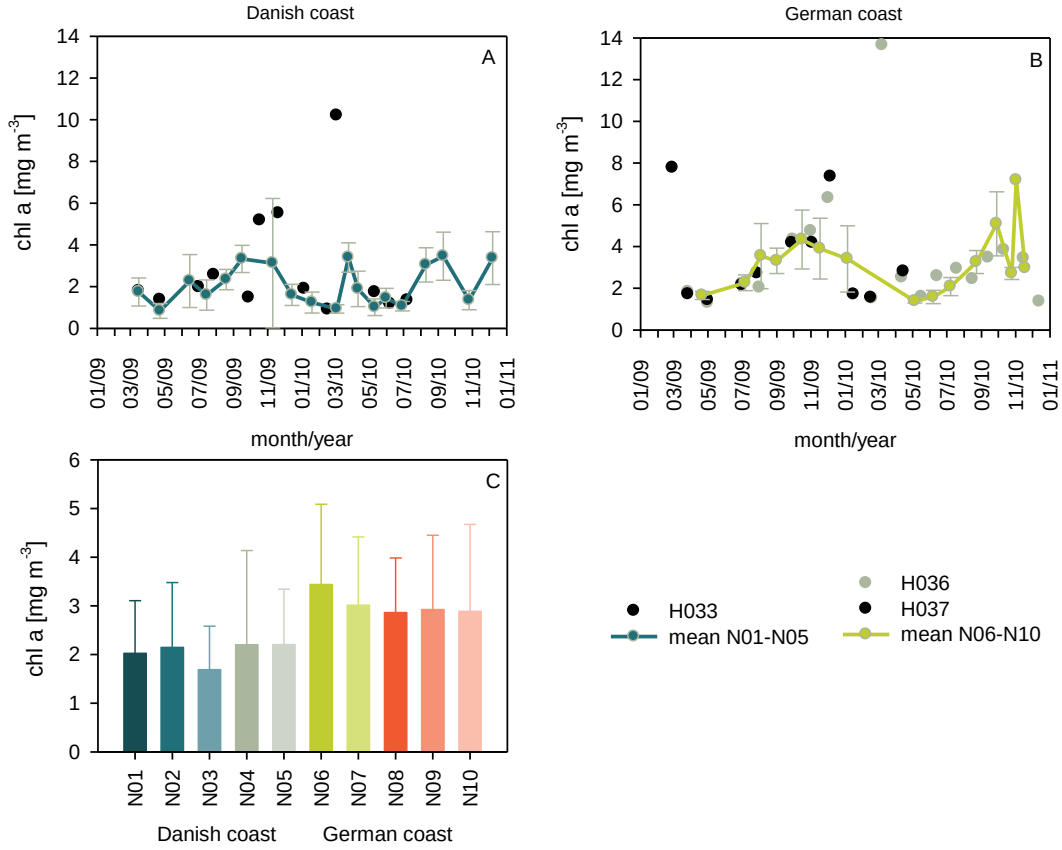


Figure 0-11 Chl-a concentration at the near-shore stations. A and B: Seasonal differences of Danish (N01-N05) and German (N06-N10) near-shore stations in comparison to the seasonal cycle of the off-shore Fehmarnbelt Link stations (black circles). Dots represent mean values (±SD) of the 5 stations along the national coasts (see Figure 0-1). C: Annual mean (+SD) of the chl-a concentration of the ten near-shore stations.

Species composition

The horizontal variation in phytoplankton composition measured at three stations where historical data are available (Great Belt area: 360, Mecklenburg Bight area: 12, Darss Sill area: 46) showed that the highest similarity in phytoplankton compositions was observed in autumn (Figure 0-12), with a co-dominance of dinoflagellates and large diatoms. Despite of generally low biomass in summer, a west-east gradient of chain forming buoyant cyanobacteria occurred with higher percentages in the eastern parts at the three stations (Figure 0-12).

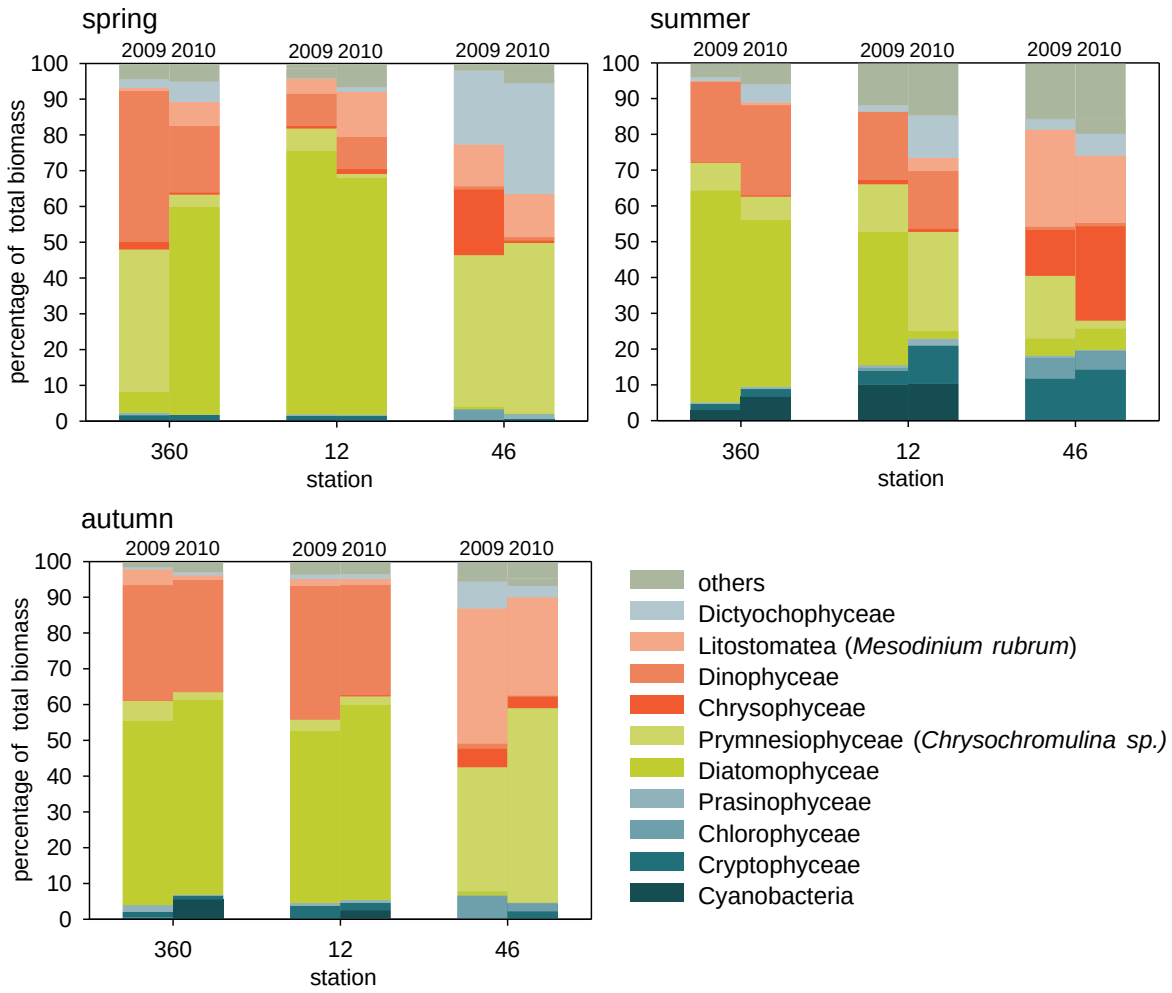


Figure 0-12 Taxonomical composition as percentage of main taxa groups from total biomass. The calculation based is on mean values of biomass (mg C m^{-3}) for the season given. The grouping follows the HELCOM-classification. Based on depth-integrated samples (1-10m).

Pigment analysis based on a larger pool of data generally confirmed a high similarity of phytoplankton composition within the baseline area, and also confirmed the east-west gradients in cyanobacteria during summer (Figure 0-13).

Vertical variation

In contrast to the high similarity of plankton biomass and composition horizontally in the investigation area a depth gradient was often evident for chl-a (Figure 0-14), primary production (Figure 0-15) and phytoplankton composition measured by pigments (Figure 0-13). Gradients in chl-a occurred mainly during blooms when high biomasses of phytoplankton were concentrated near the surface. High subsurface chl-a concentrations occurred on several occasions (Figure 0-14), but as primary production in general was low at 15 m and below (Figure 0-15) high subsurface chl-a concentrations probably originate from local sedimentation of surface primary production or advected chl-a from the Kattegat area rather than a local subsurface production (a subsurface peak in dissolved oxygen should be expected if the subsurface peak chl-a peak was a result of local production – such peaks could not be found). In periods of mixing of the water column the phytoplankton biomass was homogeneously distributed in the water column.

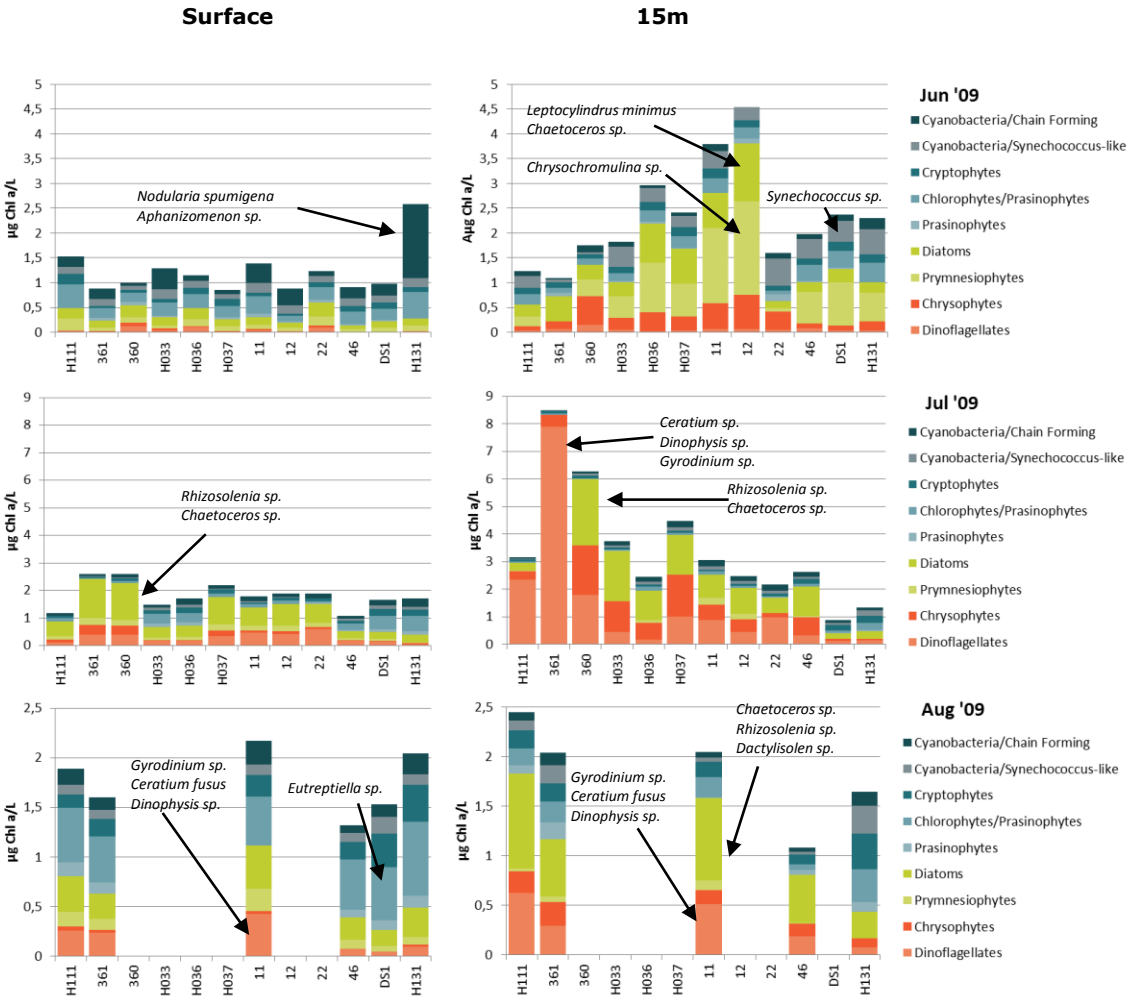


Figure 0-13 Phytoplankton group composition and biomass determined by pigment analyses during summer 2009 at two depths at the stations sampled shown from west to east (left to right). Dominant species identified by microscopy in the samples are indicated by arrows.

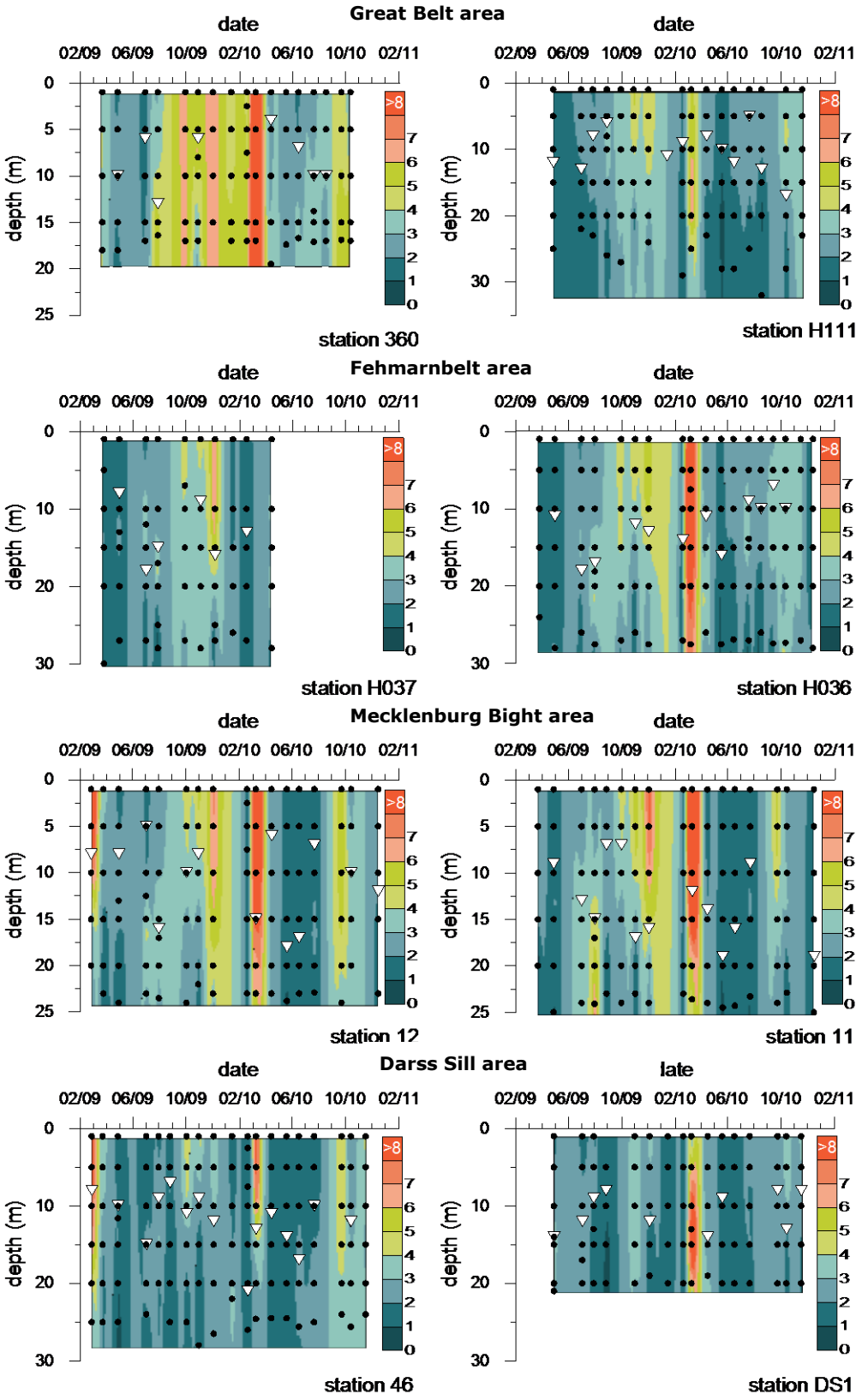


Figure 0-14 Depth profiles of chl-a from February 2009 through December 2010. Black dots indicate where chl-a samples were taken. The colour scales give chl-a concentration in mg m^{-3}. The white triangles indicate the depth of an observed halocline. For samplings without this marker a fully mixed water body was observed.

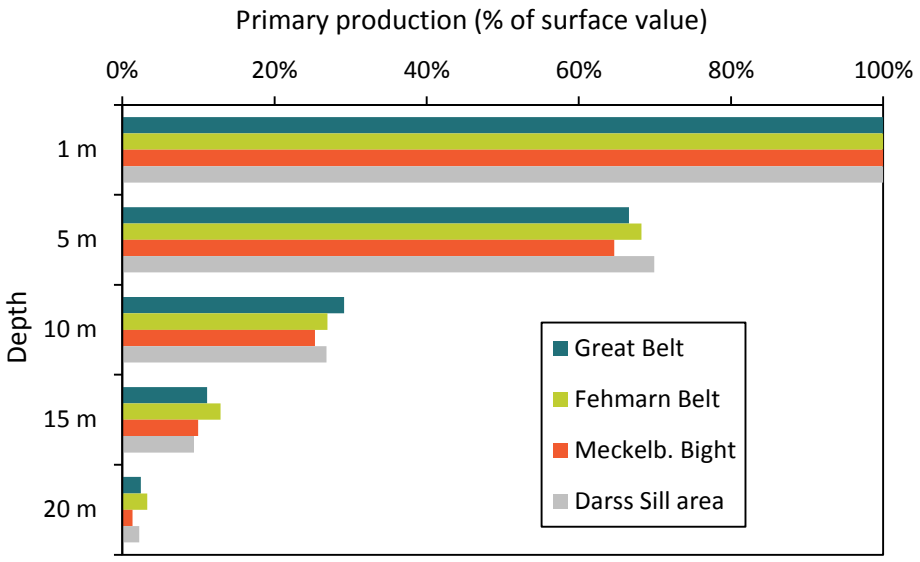


Figure 0-15 Depth distribution of the primary production as a percentage of the primary production in surface layer (1 m). Data are normalised per station and cruise and averaged for each subarea. The 4 areas are each represented by 3 stations and between 6 and 8 sampling events through the period March 2009 to November 2010.

Seasonal variation

The main and significant variation in phytoplankton composition originates from the seasonal succession and followed the annual cycle in environmental conditions, i.e. temperature, water column stratification, light, and nutrients. A typical seasonal cycle characterised by pronounced spring and autumn blooms was found in both investigation years.

The spring bloom started in February 2009 and in March in 2010 with a dominance of diatoms (particularly *Skeletonema costatum)*. The total pigment based chl-a biomass varied between stations reflecting the different timing of the spring bloom event. A post-spring bloom dominated by dinoflagellates and *Chrysochromulina* species as well as a subsurface bloom of chrysophytes (*Dictyocha speculum*) was detected.

In summer the stratification of the water column was building up and caused the heterogeneous distribution of phytoplankton (Figure 0-13, Figure 0-14) in the water column and generally low biomasses with high diversity. In late summer slightly enhanced cyanobacterial biomasses were detected in surface samples in both years.

In autumn diatoms became increasingly important and especially in 2009 also dinoflagellates became common at all stations. In 2010 the autumn bloom started 1-2 months earlier than 2009 with maximum biomass in September for all stations.

When averaging over all 12 stations it was found that diatoms dominated in the investigation area especially in winter 2009, and in spring and autumn of both years, and constituted between 35-80% of the total phytoplankton biomass. In summer, where the total biomass was low, diatoms constituted only a minor part of the phytoplankton community and the group composition was more homogeneous.

Annual primary production

The yearly primary production (March 2009 – November-December 2010) varied between 118 to 142 g C m^{-2} y^{-1} in the investigation area, with the Great Belt and Mecklenburg Bight having the highest production and the Darss Sill area the lowest production (Table 0-3).

Table 0-3 Yearly planktonic primary production (g C m^{-2} y^{-1}) in the Great Belt area, Fehmarnbelt, Mecklenburg Bight and the Darss Sill area. Yearly values at stations were calculated from individual sample (station) values trapez-integrated over depth and time and subsequently averaging over area

Great Belt	Fehmarnbelt	Mecklenburg Bight	Darss Sill area
142	128	138	118

The level of primary production measured during baseline in 2009-2010 are in the same size range to the rates measured in 1980-1990'ies, but rates are about 10-20% lower.

Mesozooplankton

The mesozooplankton community consisted of 30 taxa in the most western part of the investigation area (Great Belt) and 20 taxa in the most eastern area (Darss Sill) during the baseline investigations 2009-2010. The number of taxa was slightly lower in winter and early spring (16-18) compared to summer and autumn (23-25). The zooplankton community was dominated by holoplanktonic taxa with calanoid Copepoda as the most common group, and *Acartia bifilosa*, *Pseudocalanus* spp., *Temora longicornis*, *Acartia longiremis* and *Centropages hamatus* as the five most dominant zooplankton taxa.

Seasonal variation of mesozooplankton

The seasonal cycle of hydrographic parameters and thus of primary production and phytoplankton succession was found to be the main structuring force for the mesozooplankton community. The zooplankton community composition showed a pronounced seasonality from April to September whereas the winter/early spring community was more constant (Figure 0-16). The seasonal community succession was mainly structured by the phenology of subsequent generations of the dominating calanoid Copepoda throughout the year as well as by the strict seasonal occurrence of certain abundant taxa such as Rotifera (wheel animals) and planktonic larvae of Polychaeta (bristle worms) in spring and Cladocera (water fleas) and planktonic larvae of Mollusca in summer, respectively.

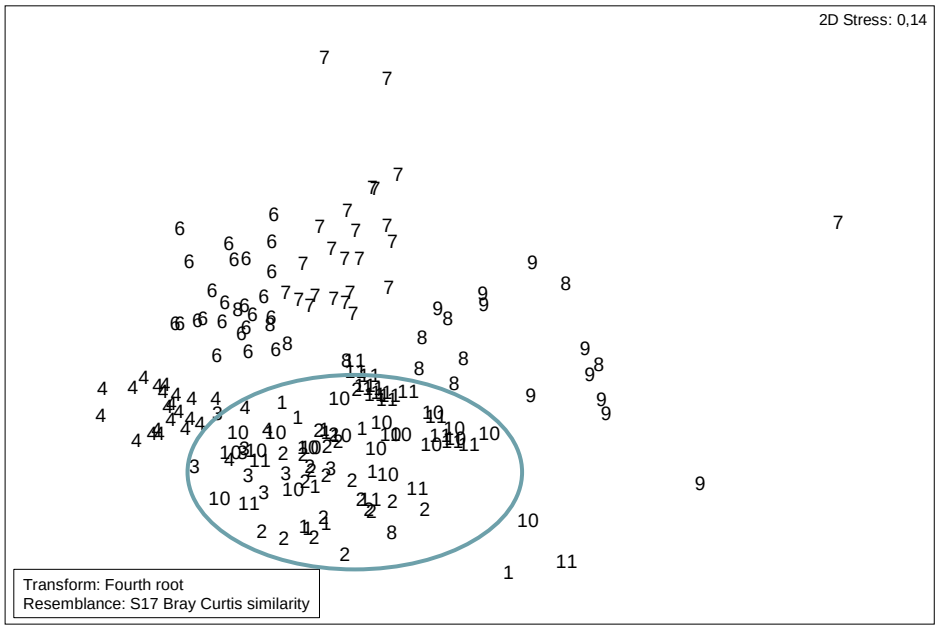


Figure 0-16 MDS-plot of zooplankton community structure at 12 stations within the investigation area of 2009. Numbers indicate months. The blue ellipse indicates late autumn to early spring season.

The mean zooplankton biomass was very similar in the 4 subareas and ranged between 180 mg m^{-3} (Great Belt) and 220 mg m^{-3} (Darss Sill) for whole investigation period and showed a very similar seasonality in all subareas (Figure 0-17).

In both 2009 and 2010 the mean biomass was low at the beginning of the season in February (20-100 mg m^{-3}) and started increasing approximately two months after the phytoplankton spring bloom in late April/beginning May to 200-500 mg m^{-3} (Figure 0-17). Biomass dominant taxa were the calanoid Copepoda Acartia, *Centropages, Temora* and *Pseudocalanus* spp. in spring. Rotifera were the second characteristic zooplankton taxon during spring 2009. A "bloom" of the genus *Synchaeta* spp. was measured in 2009 across the whole study area with mean biomasses up to 45 mg m^{-3}. Meroplanktonic larvae reached their annual biomass peak in spring of both study years (50 mg m^{-3}) with Polychaeta and Balanidae as the most abundant taxa.

The annual biomass maxima were observed in summer 2009 and 2010 (Figure 0-17). The values ranged between 480 mg m^{-3} (Great Belt area), 620 mg m^{-3} (Fehmarnbelt area), 610 mg m^{-3} (Mecklenburg Bight area), and 650 mg m^{-3} (Darss Sill area). The adult calanoid Copepoda *Acartia bifilosa*, *Pseudocalanus* spp., *Temora longicornis*, *Acartia longiremis* and *Centropages hamatus* reached their annual biomass maxima. Adults of the most abundant species *A. bifilosa* accounted for 40-60% of the total zooplankton biomass in summer of both years. The Tunicata (typically *Oikopleura dioica*) accounted for 50-100 mg m^{-3} in the western part of the study area while only 20-40 mg m^{-3} was measured in Darss Sill area. In July/August of both years, the rapidly reproducing Cladocera reached their annual biomass maximum in all subareas. Meroplanktonic taxa made up less than 5% of the total biomass in summer with Mollusca as the dominant group.

In autumn both years the zooplankton biomass was generally low across the study area and dominated by Calanoid Copepoda, particularly *Acartia* spp. and Tunicata (*Oikopleura dioica*). In winter 2009/2010 the zooplankton biomass (almost exclu-

sively copepodit stages and adults of *Acartia*, *Centropages* and *Temora*) stayed low across the study area (30-80 mg m^{-3}, Figure 0-16).

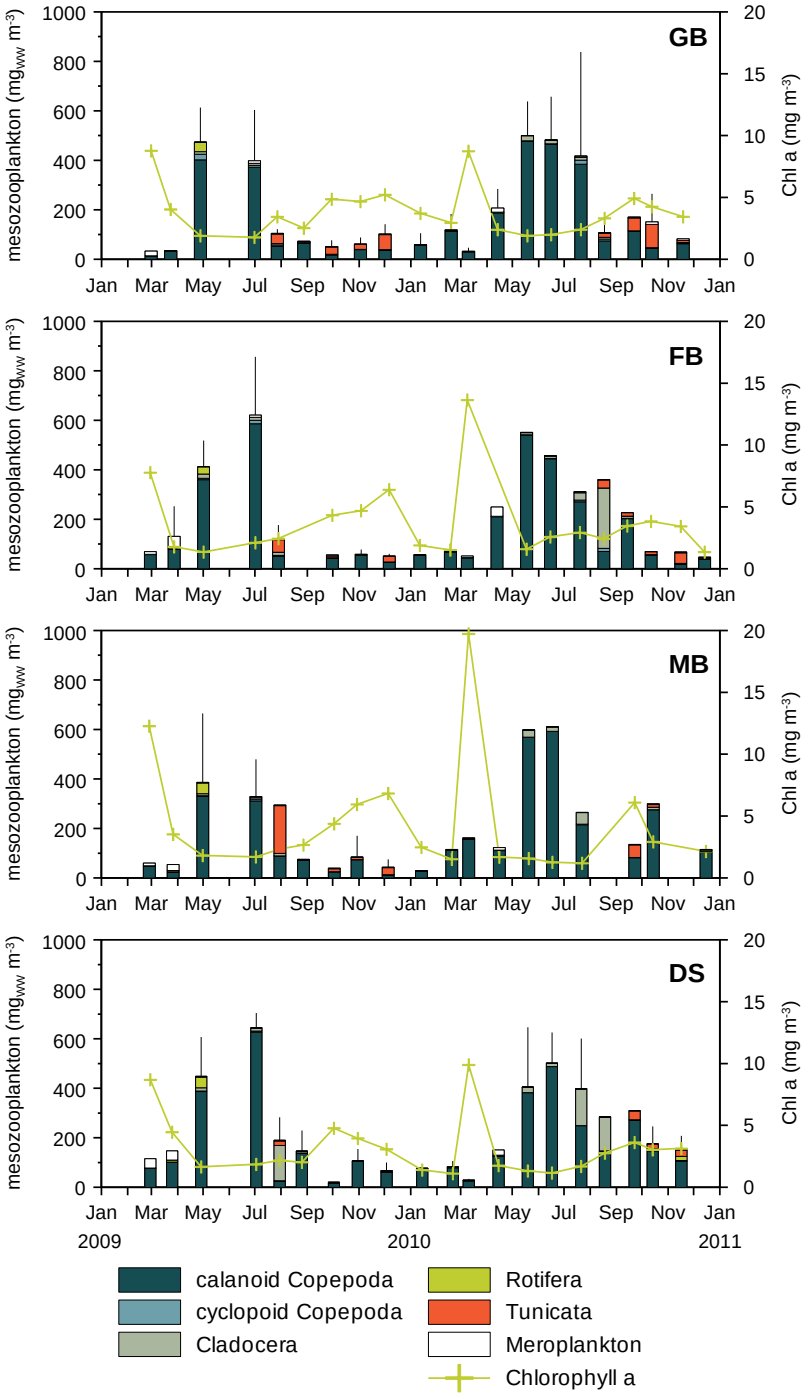


Figure 0-17 Zooplankton biomass for the main holoplanktonic and meroplanktonic taxa and chl-a concentration in 4 subareas of the south-western Baltic Sea between February 2009 and December 2010. GB- Great Belt, FB – Fehmarnbelt, MB - Mecklenburg Bight, DS - Darss Sill. Zooplankton data are calculated for the whole water column, chl-a concentrations correspond to the upper 10 m of the water column.

Spatial variation

The mesozooplankton community composition was similar across the whole baseline study area especially during spring 2009 and during autumn/winter 2009/10.

In summer, the zooplankton community composition above the halocline changed gradually from the most western part of the study area (Great Belt) to the most eastern part (Darss Sill area) (Figure 0-18). Below the halocline, spatial trends were less prominent.

The high similarity of the zooplankton community within the baseline monitoring study area was mainly caused by similar abundances of the dominating calanoid Copepoda genera *Acartia*, *Centropages*, *Temora* and *Pseudocalanus* across the whole investigation area. The spatial differences in summer were based mainly on differences in the occurrence of 'marine' taxa such as Tunicata (*Oikopleura*), larvae of the common starfish *Asterias*, Bryozoa (moss animals) in the western part of the study area and the occurrence of brackish water preferring taxa such as Bosminidae (water fleas) in the eastern part of the study area.

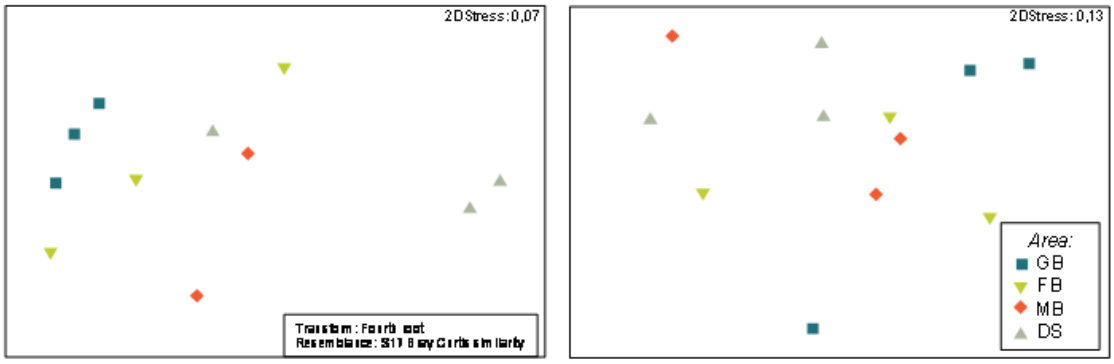


Figure 0-18 MDS-plot of mesozooplankton community of four geographical subareas in July 2009. All taxa contributing less than 1% to the total abundance were excluded from analyses. Left: above halocline, Right: below halocline. GB- Great Belt, FB - Fehmarnbelt, MB - Mecklenburg Bight, DS - Darss Sill.

Long-term trends

Historical data showed that the mean biomass of total zooplankton from 1998 to 2009 did not differ significantly between four HELCOM long-term stations within the baseline study area (Kiel Bight, Mecklenburg Bight, Kadet Channel and Darss Sill). However, the composition of the zooplankton community varied with regard to the salinity tolerance of zooplankton species, both spatially and temporally.

From the most western station (Kiel Bight) to the most eastern station (Darss Sill), a decline of truly marine taxa such as *Pseudocalanus* spp., Tunicata (typically *Oikopleura dioica*) and cyclopoid Copepoda (typically *Oithona similis*) was found. In contrast, the brackish water calanoid Copepoda *Acartia bifilosa* and *Acartia longiremis* as well as the Cladocera Bosminidae increased from the west to the east.

The time series of zooplankton data of the last decade indicate a decrease of truly marine taxa such as *Pseudocalanus* spp. Tunicata (typically *Oikopleura dioica*) and cyclopoid Copepoda (typically *Oithona similis*) since 2006. The spatial and seasonal zooplankton distribution of the baseline investigation years 2009 and 2010 were in a typical range compared to the last decade.

Jellyfish

The scyphozoan species *Cyanea capillata* (lion's mane jellyfish) and *Aurelia aurita* (moon jellyfish) dominated the gelatinous plankton community in the baseline investigation area besides the invasive ctenophore *Mnemiopsis leidyi*. The invasive species *M. leidyi* was the most abundant taxon, with a proportion of more than 90% on total annual jellyfish abundance in this region.

The three species showed a seasonal succession, with a different annual phenology in their appearance and their maximal abundance (Figure 0-19). *C. capillata* reached the highest abundance in early summer. In the same period a continuous increasing of the *A. aurita* abundance was observed. Whereas the abundance of *A. aurita* peaked in summer, the maximum abundance of *M. leidyi* occurred in early autumn, after the scyphozoan medusae had disappeared (Figure 0-19). In late winter and early spring, an increasing abundance of *A. aurita* ephyrae was observed across the whole investigation area, indicating an indigenous reproduction in the south-western Baltic Sea.

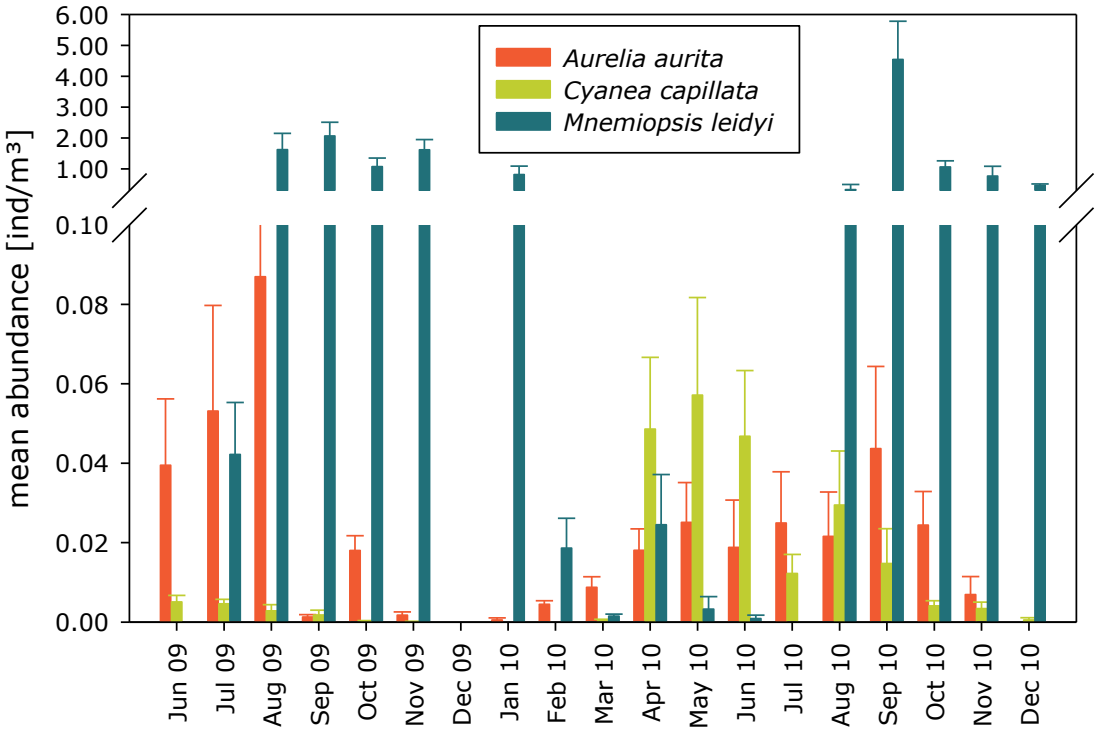


Figure 0-19 Abundance of Aurelia aurita, Cyanea capillata and Mnemiopsis leidyi between June 2009 and December 2010 as mean value (+SD) of the whole baseline investigation area (12 sampling stations, see Figure 1).

In 2009 the averaged abundance (mean value for the whole investigated area, Figure 0-19) of *C. capillata* reached 0.005 individuals m^{-3}, whereas in 2010 a 10-fold higher averaged abundance was observed. In contrast, the averaged abundance of *A. aurita* was halved from 0.08 individuals m^{-3} in summer 2009 to 0.04 individuals m^{-3} in summer 2010 (Figure 0-19). In both investigated years the very high averaged abundance of *M. leidyi* was more or less unchanged for 6 months, which covered the period from August up to January. For this period their average abundance reached values between 1.0 and 4.5 individuals m^{-3}. Thus, during bloom events of both species (e.g. Sep 2010) a 10-fold higher averaged abundance was observed

for the invasive species *M. leidyi* compared to the indigenous species *A. aurita* (Figure 0-19).

The horizontal variation of the abundance was low for the scyphozoan jellyfish *A. aurita* and *C. capillata* and might depend on hydrographical conditions as well as on food supply. In contrast to the similar distribution of the two scyphozoan species, *M. leidyi* showed an irregular distribution in the investigated area. During the main growth period in late autumn this species appeared in highest abundances in Mecklenburg Bight, whereas the lowest abundances occurred in the Darss Sill region. Intermediate abundances were observed for the Great Belt area and the Fehmarnbelt.

Comparing the vertical distribution of species, *A. aurita* preferred the zone above the halocline in all seasons and subareas, whereas the majority of *C. capillata* was found below the halocline, which might be explained by a species specific preference of higher salinity. No clear preference in vertical distribution could be observed for *M. leidyi.*

The analyses of the size structure of *C. capillata* population showed, that there was only one size group present in summer 2009, which ranged between 1 cm and 6 cm. The size of *A. aurita* ranged from few millimetres up to 30 cm. During summer 2009 three different cohorts could be determined. Comparing the size distribution of *A. aurita* from all stations between summer and autumn 2009, there was no increase of medusae size within the population observed. This indicated a seasonally determined loss of the mature generation after sexual reproduction (> 15 cm) and a stagnation of somatic growth. The youngest and smallest medusae were found mainly in spring, due to the strobilation of polyps during the winter season.

Feeding impact of Aurelia aurita

The highest annual feedings rates amounted by 825 prey items consumed per day and medusa (November 2010). During the main growth season (summer) averaged feedings rates between 200 and 600 prey items day^{-1} medusa^{-1} were measured. In autumn the average feeding rates decreased below 60 prey items consumed day^{-1} medusa^{-1}.

The composition of the food ingested by *A. aurita* reflected the succession and seasonal abundance of the zooplankton community indicating a very low specialisation within a given size spectrum. Depending on the seasonal occurrence, the gut content of *A. aurita* mainly consisted of Copepoda, Cladocera and larvae of Mollusca throughout summer and autumn. The percentage of fish larvae and eggs, which were found in the digestive organs of *A. aurita* in summer 2009, was very low. In Darss Sill area *A. aurita* showed with 10% of the total ingested prey the highest proportion of consumed fish larvae and fish eggs.

The predatory impact of *A. aurita* on the standing stock of Copepoda was quite low in all subareas in both years (<0.6%). The predation impact on Cladocera was generally low as well, except for the Darss Sill area where the annual mean value reached 35% in 2009. In Great Belt and Darss Sill areas up to 10% of the standing stocks of bivalve larvae and gastropod larvae were fed by *A. aurita* per day.

Importance

The importance of the plankton organisms has been defined by the functional value of the environmental components, phytoplankton, mesozooplankton, and jellyfish in the Fehmarnbelt area. Since these biological components, as well as the environ-

mental component water quality, are not protected by any international legislation or conventions and none of the plankton species are adopted on any "Red Lists", a two-level scale of importance, special and general, is appropriate for these components.

Special importance

Of special importance are phytoplankton communities which are characteristic for natural undisturbed conditions in the Fehmarnbelt area and phytoplankton with high diversity and low biomass. For mesozooplankton, species of special value for planktivorous fish (e.g., *Pseudocalanus* spp.), for the balance in food chains and the ecosystem, and for eutrophication control (grazing on phytoplankton) are also considered having special importance. For jellyfish, medusae which as predators have significance for the biomass of mesozooplankton and as competitors for zooplanktivorous fish are considered of special importance. For water quality all marine Natura 2000 areas and beaches (bathing water quality) are considered of special importance.

General importance

Considered of general importance are blooming of potential harmful phytoplankton species due to eutrophication, zooplankton species without special value for fish diet, and jellyfish medusae of minor importance for the food chains. For water quality all other areas than marine Natura 2000 areas and beaches (bathing water quality) are considered of general importance.

1 INTRODUCTION

Introduction

Plankton populations are generally not considered sensitive to disturbances from construction activities in coastal areas because of their short generation times, fast population changes in relation to environmental changes and the large exchange of water with adjacent areas. However, theoretically potential impacts on plankton have been identified in connection to the planned construction of the fixed link across the Fehmarnbelt (Fehmarn EIA Scoping Report 2010) and the present baseline report characterises the large scale environmental situation of the water quality and plankton before the construction work of establishing the fixed link commence.

Water Quality

Water quality in terms of nutrient richness, water transparency and oxygen levels constitutes an integral term reflecting the environmental quality in a broad sense and can be seen as the 'boundary conditions' for aquatic organisms and population living in the water. Plankton organisms are directly affected by the water quality, but on the other hand plankton also influences the water quality by reducing transparency during blooms and affects bottom water oxygen when settled phytoplankton is degraded on the seabed. The water quality variables of importance are nutrients, oxygen, and the phytoplankton biomass parameter chlorophyll a and the thereof derived transparency and light conditions. The baseline investigation has been designed to monitor these variables to be able to evaluate the main driving forces for plankton and other aquatic organisms in the Fehmarnbelt area.

Bathing water quality is a special issue of water quality focussing on human health risks. Evaluation of the quality of bathing water are based on two bacteriological parameters, i.e. concentrations of *Escherichia coli* (*E. coli*) and Intestinal Enterococci (IE). Baseline conditions in the Fehmarnbelt are evaluated based on "bathing water profiles" carried out by local municipalities.

Plankton

The present baseline investigation focus on plankton flora: phytoplankton and plankton fauna: zooplankton. For zooplankton the main emphasis is on the important plankton component: mesozooplankton, for example water fleas (copepods), which are the main food item particularly for fish larvae. However, another macro zooplankton: jellyfish has got special attention in this baseline investigation. Jellyfish plays an important role in coastal marine systems and may be able to restructure pelagic food webs by acting as competitors and predators for native mesozooplankton and commercially important planktivorous fish species. Recent concerns that jellyfish populations are increasing globally have stimulated speculation about possible causes including climate warming, eutrophication, overfishing, maritime construction, aquaculture and invasion.

Phytoplankton and mesozooplankton

Phytoplankton and mesozooplankton serve as the base of the food web supporting fish, bottom living (benthic) animals and other marine organisms. All fish and most invertebrates depend on plankton for food during their larval phases, and some species such as mussels continue to consume plankton their entire lives. Furthermore, plankton organisms can be important as indicators for environmental status

and changes and are considered as biological water quality indicators when determining the ecological status under the European Water Framework Directive.

The species composition and biomass of phytoplankton and zooplankton undergo seasonal variations reflecting the patterns of the entire investigation area. The highest activity and biomasses generally occur during summer time. Blooms of (toxic) blue-green algae are common during warm summers following winters with high concentrations of phosphorus.

Phytoplankton and mesozooplankton have been monitored regularly as part of the HELCOM monitoring programme in the Fehmarnbelt area since mid-1980. However, only three monitoring stations are located in the Fehmarnbelt area, which have been monitored only 5 times per year.

The phytoplankton and mesozooplankton baseline investigations have consequently been continued but intensified in the present baseline investigation. The plankton variables include: fluorescence, primary production (a parameter that has not been measured in the area since 1997), chlorophyll a, phytoplankton abundance, diversity and biomass, and mesozooplankton diversity and abundance.

Jellyfish

Jellyfish has not been monitored regularly in the Fehmarnbelt area, but has, as mentioned above, got special attention in the baseline investigation since recruitment seems to have increased in recent years. Predaceous gelatinous macrozooplankton such as jellyfish of the taxonomic group Scyphozoa are known to have major consequences for pelagic ecosystems and fisheries, when occurring in large numbers (Mills 1995). By feeding on zooplankton and ichthyoplankton, jellyfish acts as predator for native zooplankton and competitor for commercially important planktivorous fish species (Möller 1980, Schneider and Behrends 1998). Moreover, problems with jellyfish capture public attention in connection with interfering with fishing and aquaculture, clogging power plant systems and stinging swimmers (Purcell et al. 2007). Most of the problematic jellyfish blooms reported in the last 20 years have several possible contributing anthropogenic causes such as climate warming, eutrophication, overfishing, maritime construction, aquaculture and invasion of non-native species by marine traffic (Purcell et al. 2007).

In the Baltic Sea, mainly two scyphozoan medusae occur: The moon jelly *Aurelia aurita* and lion's mane jellyfish *Cyanea capillata*. The moon jelly *A. aurita* is the most abundant scyphozoan species in the Baltic Sea (Figure 1-1). The medusae generation of *A. aurita* is widely distributed from the western and central Baltic Sea up to the Bothnian Gulf and the Gulf of Finland. Large *A. aurita* polyp populations are reported from Kiel Bight (Schneider and Behrends 1998), Kerteminde Fjord (Olesen et al. 1994) and Gullmar Fjord (Hernroth and Gröndahl 1983). Strobilation of polyps and releasing of ephyrae are usually induced by decreasing water temperature and take mainly place between January and March in the western Baltic Sea. Barz et al. (2006) demonstrated the spatial distribution of *A. aurita* ephyrae and medusae from the strobilation areas in Kiel Bight and Kerteminde Fjord into the central Baltic Sea by advection.

Based on results from advection models, which consider ephyra larvae as passive items, it is suggested that polyp colonies in the Fehmarnbelt and adjacent seas might be responsible for medusae blooms even in the central Baltic Sea by drifting with deep water currents (Barz et al. 2006).

The abundance of second scyphozoan species in the Baltic Sea *C. capiliata* (Figure 1-1*)* is generally low compared to *A. aurita*. Their medusae generation occurs in the south western Baltic Sea up to the Bornholm Basin (Barz and Hirche 2005). Barz et al. (2006) report the absence of ephyrae in the central Baltic Sea. The nearest known polyp colonies of *C. capillata*, where strobilation takes place, is the Gullmar Fjord (Gröndahl 1988) at the west coast of Sweden. However, drift modelling did not support the hypothesis that the origin of *C. capillata* medusae in the Baltic Sea is Gullmar Fjord (Barz et al. 2006).

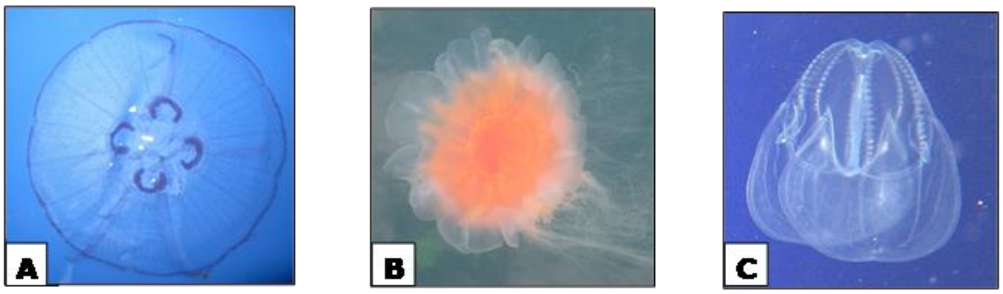


Figure 1-1 Dominant jellyfish species in the Baltic Sea A: Aurelia aurita *B:* Cyanea capillata *C:* Mnemiopsis leidyi *(Photos C. Augustin).*

Within the macroplanktonic and besides the scyphozoan, several ctenophore species occur regularly in the Baltic Sea. Since autumn 2006 the most common ctenophore is the West Atlantic comb jelly *Mnemiopsis leidyi* (Figure 1-1). *M. leidyi* is known as an invasive species originating from the Atlantic coast of North America. It invaded the Black Sea in the late 1980s and showed a massive population growth within 10 years (Vinogradov et al. 1989). This mass occurrence coincided with a drastic decrease in zooplankton biomass, changes in zooplankton species composition and a breakdown of the commercially important anchovy fishery (Shiganova 1998, Volovik et al. 1993). In general, *M. leidyi* has been observed impacting the plankton food web by massive feeding on zooplankton, fish eggs and fish larvae (e.g. Kremer 1982, Reeve et al. 1978). Although the abundance of *M. leidyi* in the central Baltic Sea is still low, reports of *M. leidyi* abundances in coastal Danish waters in summer of 2007 show its great invasive potential (Tendal et al. 2007).

1.1 Objectives of the baseline study

The baseline investigation has been designed to provide the necessary information on water quality, plankton communities and jellyfish of Fehmarnbelt and adjacent areas for a subsequent impact assessment and planning of monitoring during and after the construction phase. The position of water quality, plankton and jellyfish in the EIA framework is shown in Table 1-1.

Table 1-1 The position of water quality, plankton and jellyfish in the EIA environmental framework

Environmental factor	Environmental sub-factor	Environmental component
Water	Marine Water	Marine Water Quality Bathing Water Quality
Flora, fauna and biodiversity	Marine flora and fauna	Phytoplankton Zooplankton Jellyfish

The baseline investigation is providing baseline conditions of water quality, plankton, and jellyfish in Fehmarnbelt and adjacent areas based on data collected during a two year study 2009-2010, historical data, as well as modelling of water quality and pelagic biology.

The objectives in detail are:

- To obtain a thorough description of water quality including nutrient concentrations, chlorophyll-a (chl-a), water column transparency, bottom water oxygen concentration and bathing water quality
- To obtain a fine-scale description of phytoplankton biomass over large areas using mapping of *in situ* fluorescence and chl-a measurements.
- To assess the present spatial and temporal variation taxonomical composition and biomass of phytoplankton at three off-shore stations.
- To assess the present spatial and temporal variation of phytoplankton using algal pigments at 12 off-shore stations and at 10 near-shore stations in the Fehmarnbelt area combined by screening the samples in microscope to determine the dominating species present.
- To assess the present spatial and temporal variation of phytoplankton primary production.
- To assess the present spatial and temporal variation taxonomical composition and biomass of mesozooplankton.
- To assess the distribution and population dynamics of the jellyfish *Aurelia aurita* and *Cyanea capillata* and of the invasive jellyfish *Mnemiopsis leidyi* in the Fehmarnbelt and Mecklenburg Bight.
- To assess the importance of *A. aurita* medusae in the pelagic food web (zooplankton and fish larvae) in the Fehmarnbelt and Mecklenburg Bight.

1.2 The Report

The present baseline report is divided in the following sections:

- Summary - an extended summary of the main findings.
- Introduction (Chapter 1) – introducing the subjects assessed in the baseline report, lists the objectives, outlines the structure of the report, and presents the investigation area.
- Materials and Methods (Chapter 2) - give a brief account on the methods employed for data collection and data analysis.
- Water quality including nutrients, chl-a, water transparency, oxygen and bathing water quality (Chapter 3) - provide the results and discussion of the water quality parameters.
- Phytoplankton (Chapter 4) - provide the results and discussion of phytoplankton species composition, phytoplankton groups as well as primary production.
- Zooplankton (Chapter 5) - results and discussion of the zooplankton species composition and biomass; including historical data.
- Jellyfish (Chapter 6) - results and discussion of the jellyfish investigations and a presentation of the present scientific knowledge.
- WFD assessment (Chapter 7) - environmental status of plankton according to the water framework directive.
- Importance (Chapter 8) – definition and assessment of importance.
- Existing pressures (Chapter 9) – describes the existing pressures on water quality, plankton and jellyfish of Fehmarnbelt and neighbouring areas.

1.3 The investigation area

Fehmarnbelt is part of the transitional area, the Belt Sea, between the Baltic Sea and the Kattegat. Besides the Fehmarnbelt, this transitional sea also includes the Danish straits Lillebælt and the Great Belt and the Kiel and Mecklenburg Bights. East of Mecklenburg Bight, the Belt Sea is bordered by the Darss Sill with a water depth of 18 m.

The Belt Sea, and the Fehmarnbelt in particular, is characterised by horizontal variations and vertical gradients in salinity, driven by a long-time outflow from the Baltic due to freshwater surplus in the Baltic region but overridden by barotrophic forcing either causing influx of more saline water into the western Baltic or reinforcing the outflow from the Baltic. Mean surface salinities during spring, summer and autumn in 2009 are shown in Figure 1-2 (data from the investigations described in FEHY, 2012). Within the investigation area mean surface salinity varied between 8 and 20 PSU in spring and autumn and between 8 and 17 PSU during summer.

As in the Baltic Sea in general, the water column in the Fehmarnbelt is stratified with low saline surface water overlaying a bottom layer with higher salinity. Intermediary between these two layers is a halocline, a water layer featuring the salinity gradient between surface and bottom layers. However, there was no permanent salinity stratification of the water column throughout the year. From spring to early autumn a halocline located at 13-15 m separate surface water from higher saline bottom water. During late autumn and winter the water column was completely mixed on several occasions (Table 1-2).

Large input of nutrients, nitrogen and phosphorus is one of the main pressures in the Baltic Sea affecting the water quality. However, local nutrient run-off plays only a minor role in the Belt Sea and its sub-basins, because the local discharge is small compared to the outflow from the Baltic Sea. In the Baltic Sea catchment a net freshwater surplus of around 450 km^3 $year^{-1}$ leads to an outflow of 900 km^3 $year^{-1}$ with salinities of 8-10 PSU and an inflow of 450 km^3 $year^{-1}$ with salinities of 16-20 PSU. In relation to that the freshwater discharge into Belt Sea of about 7 km^3 is insignificant amounting to less than 1% of the 'background' flux through the Belt Sea.

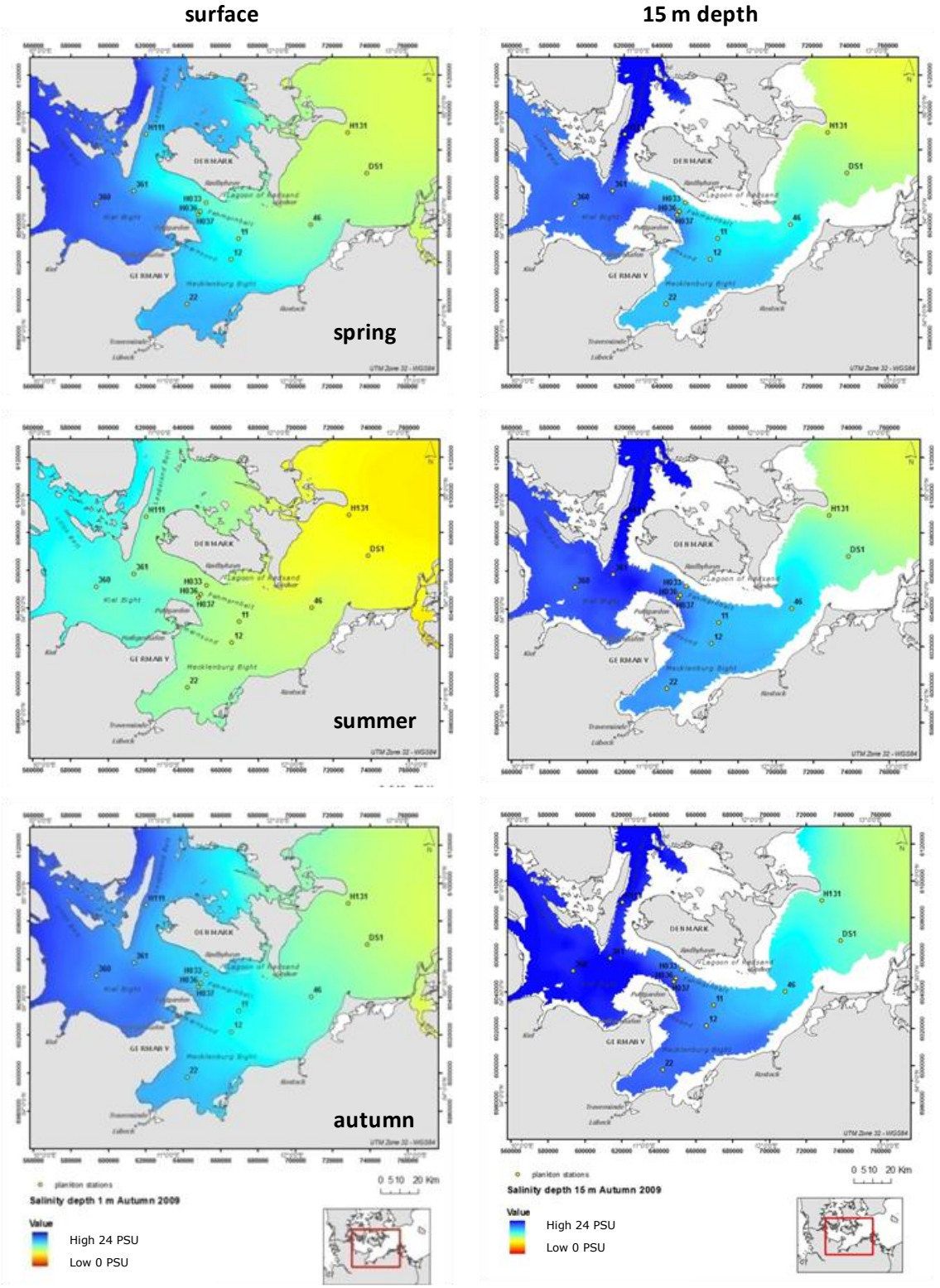


Figure 1-2 Horizontal variation of salinity at surface and in 15 m depth, respectively. Spring (February-April), summer (May-August), autumn (September-November) 2009. The maps are based on modelled data provided by the Hydrographical Services consortium (FEHY) (see FEHY, 2011). The position of 12 off-shore plankton stations is inserted.

Table 1-2 *Depth of halocline (m) according to CTD-measurements at monthly baseline cruises between February 2009 and December 2010. Seasons were defined according to the HELCOM-strategy for the Belt See region. w: winter season, m: mixed water column. For location of stations in the first column, see Figure 2-1.*

	2009										2010										
season	**spring**			**summer**			**autumn**			**w**	**spring**			**summer**				**autumn**			**w**
month	**F**	**M**	**A**	**J**	**J**	**A**	**S**	**O**	**N**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
360		m	10	6	13		m	6	m	m	m	m	4	m	7	10	10	m	m		
361	m		10	9	11	11	m	m	m	10	15	9	12	12	14	6	9		12		
H111			12	13	8	6	m	m	m	11	9	m	8	10	12	5	13		17	m	
H033		m	7	9	9			11	m	9											
H036		m	11	18	17		m	12	13		14	m	11	16	m	9	10	7	10	m	m
H037	m	m	8	18	15			9	16		13										
11			9	13	15	7	7	17	16			12	14	19	16	9			m		19
12	8	m	8	5	16		10	8	m		m	15	6	18	17	7		m	10		12
22		m	13	15	11			6	13	11											
46	8		10	15	9	7	11	9	12	m	21	13	11	14	17	10		m	12	m	
H131		m	20	23	14	16		14	15		19	18		18	19	19	21		18	18	
DS1			14	12	9	8		m	12	m	m	m	14	9	m	m		8	13	8	

The annual total nitrogen loads to the Belt Sea is dominated by loads to the Great Belt followed by loads to the Sound and Mecklenburg Bight (Figure 1-3). Over the period 2000-2009 the total nitrogen load varies around 40.000 tons N per year.

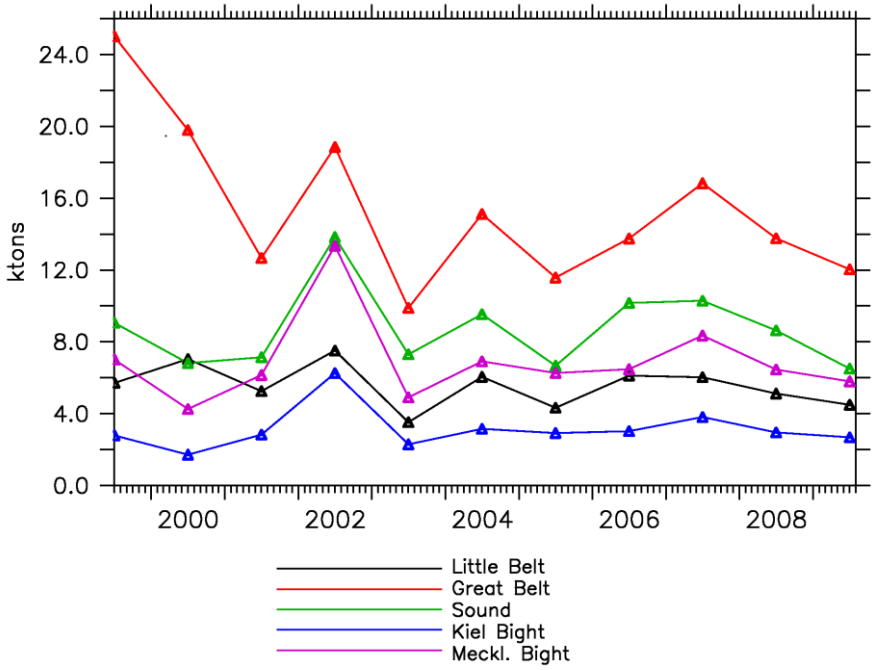


Figure 1-3 *Annual input of total nitrogen (kt) into the sub-basins of Belt Sea (FEHY 2011).*

2 MATERIALS AND METHODS

Chapter 2 presents the material and methods used for collecting the data during the baseline investigations and the historical data sources and methods used for analysing the data.

2.1 The investigation area

The investigation area appears from Figure 2-1. The area is defined so that it is possible to determine the basic characteristics of water quality and plankton of the Fehmarnbelt and the neighbouring areas, and to determine impacts of the EIA scenario. Four subareas have been defined within the investigation area: Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill (Figure 2-1).

2.2 Baseline investigation strategy

The baseline investigation operates at different scales and levels of details in order to obtain a comprehensive description of the water quality and plankton including jellyfish in the Fehmarnbelt and adjacent areas. The field program (monthly investigation cruises) includes:

- a wide area resolution of phytoplankton biomass distribution using *in situ* fluorescence
- an intermediate area resolution for quantifying group composition of phytoplankton (determined from pigment composition), chl-a, primary production, zooplankton composition and jellyfish at different depths
- at fewer stations a detailed description of phytoplankton community composition including abundance and biomass of potentially toxic algae.

Assessment of bathing water quality at designated beaches is obligatory and regulated through the EU Bathing Water Directive (EU 2006). The status of bathing water quality and the vulnerabilities are described by the socalled "bathing water profiles" that are prepared by municipalities every year. Evaluation of the quality of bathing water are based on two bacteriological parameters, i.e. the concentrations of *Escherichia coli* (*E coli*) and Intestinal Enterococci (IE). We have extracted bathing water profiles for 16 designated beaches located along the Lolland SE coast and around Fehmarn from the EU WISE database (http://www.eea.europa.eu/themes/water/interactive//bathing) covering the period 2007-2010.

2.3 The monthly investigation cruises

The baseline investigation was conducted in 2009 and 2010 in order to collect recent data on the water quality (nutrients, oxygen, water transparency/secchi depth, chl-a) and plankton (phytoplankton, mesozooplankton, jellyfish) in the investigation area.

Samples have been collected on monthly cruises covering off-shore and near-shore stations (110 and 10 stations, respectively). Deeper stations were visited with the ship M/S JHC Miljø, while smaller vessels such as M/S Maritina and M/S DHIVA covered shallow near-shore stations (primarily located along the Danish coast). Loca-

tions of stations in the investigation area as well as their distribution between four designated areas are shown in Figure 2-1. Positions of stations and their distribution between the four designated areas are given in Appendix A.

At the off-shore stations *in situ* fluorescence, light and oxygen profiles were measured on each cruise together with profiles of salinity and temperature (part of the hydrographic baseline field program; see FEHY (2011)). Between 40 and 115 profiles were sampled.

In addition, a more comprehensive water quality and plankton program was conducted at 12-14 of the off-shore stations and at the 10 near-shore stations. The off-shore stations comprised measurements of nutrients, total chl-a (in vitro analyses), proportion of algal group (based on pigment analyses), species composition, abundance and biomass of phytoplankton, mesozooplankton, and jellyfish. Station information and parameters sampled within the off-shore baseline program is shown in Table 2-1, number of samplings per cruise is shown in Table 2-2, and sampling methods and depths are shown in Table 2-3. Sample statistics for the near-shore programme is shown in Table 2-4.

Sampling for jellyfish has been carried out at 12 of the biological stations (Figure 2-2). Station information is given in Table 2-1, while number of samplings per cruise and sampling depths are shown in Table 2-2.

All sampling (water samples for chl-a, pigments, phytoplankton composition, primary production, and net samples for phytoplankton, zooplankton,) was carried out using standardized methods following the HELCOM Combine Manual (HELCOM 2007). A minor deviation from the HELCOM methods was use of a stronger light source in the incubator for primary production and in-house software to calculate P (production)-E (irradiance) relations and depth integrated primary production. Jellyfish samples have been carried out with international standardized methods.

The HELCOM Combine Manual does not deal with *in situ* fluorescence, but several guidelines exist. We used a Dr. Hardt fluorometer prior to June 2009 and a fluorometer fitted on the Seabird CTD (dual SBE911) during the remain of the study.

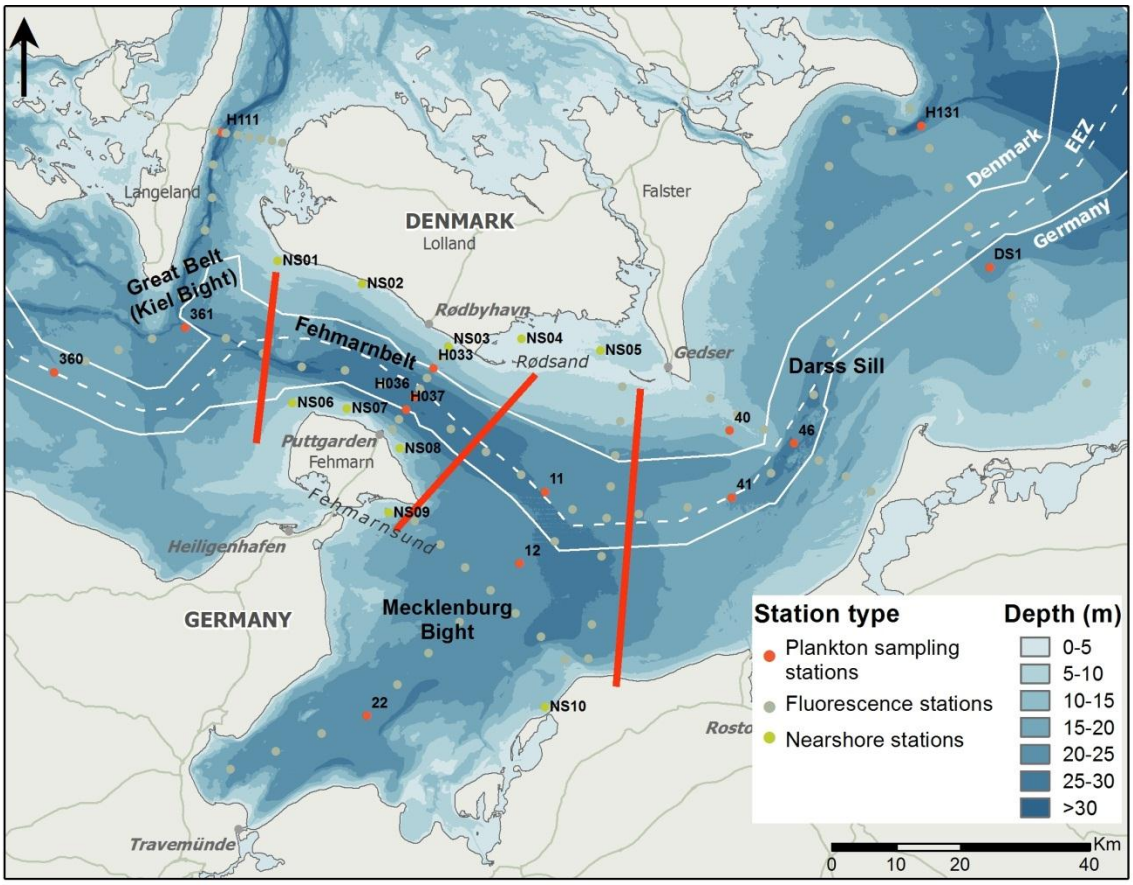


Figure 2-1 *Stations sampled in the Fehmarnbelt water quality, plankton, and jellyfish baseline investigation. Stations include 10 near-shore stations (NS01-NS10, dark red), 12 'water quality and plankton' stations (orange dots with associated numbers) and 110 fluorescence and oxygen stations (bright yellow). Red lines separate the investigation area into four subareas: Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill used when analysing the data.*

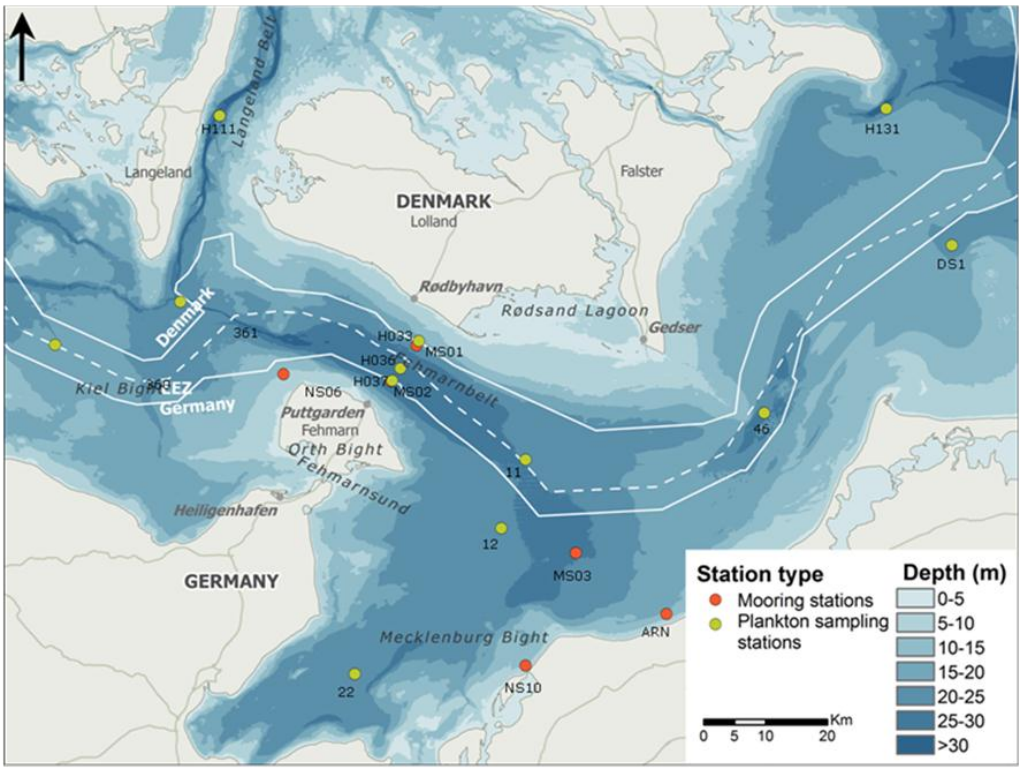


Figure 2-2 *Map of gelatinous plankton sampling stations (green dots) and mooring stations (red dots).*

Table 2-1 *Information on stations included in the off-shore water quality and plankton baseline investigation programme*

Station	Geographical area	Latitude	Longitude	Depth mean [m]	Phyto-plankton cell counts (HELCOM)	Primary production Phyto-plankton pigments Zooplankton	Water quality
H111	Great Belt	54..9275 2	10.87757	27.3		monthly	monthly
360		54.60000	10.45000	18.7	monthly	monthly	monthly
361		54.65833	10.76667	21.5		monthly	monthly
H033	Fehmarnbelt	54.59110	11.36100	17.2		monthly	monthly
H036		54.55230	11.31260	27.8		monthly	monthly
H037		54.53490	11.29110	28.4		monthly	monthly
11	Mecklenburg Bight	54.41333	11.61667	25.0		monthly	monthly
12		54.31500	11.55000	24.7	monthly	monthly	monthly
22		54.11000	11.17500	22.9		monthly	monthly
40	Darss Sill area	54.48833	12.06500	12.7			monthly
41		54.39520	12.06330	19.7			monthly
46		54.46667	12.21667	24.6	monthly	monthly	monthly
DS1		54.70000	12.70000	20.5		monthly	monthly
H131		54.90020	12.55900	28.0		monthly	monthly

Table 2-2 *Number of samples for phytoplankton species biomass and abundance, nutrient and chl-a concentration, algal pigments, primary production, mesozooplankton, and jellyfish during the baseline investigation. For phytoplankton biomass and abundance 1 denotes an integrated sample covering the upper 10m of the water column. For mesozooplankton, 1 denotes one haul for mixed water column, 2 hauls for stratified water column. Seasons were defined according to the HELCOM-strategy for the Belt See region. w: winter.*

year	2009										2010											
cruise	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	10	11	12	
season	spring			summer			autumn			w	spring			summer				autumn			w	
month	F	M	A	J	J	A	S	O	N	J	F	M	A	M	J	J	A	S	O	N	D	sum
Station																						
Phytoplankton species composition, abundance and biomass																						
360		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1			17
12	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1		1	1		1	18
46	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1		19
Nutrients & chl-a																						
360		5	5	6	5		6	7	5	5	8	6	6		6	7	6	6	6			95
361	6	5	6	6	5	7	5	6	5	5	6	7	7	7	7	7	6	4	6			113
H111			6	6	6	7	6	6	6		6	6	6	6	7	9	7		6	6		102
H033		5	5	4	5		4	5	4	4	4	4		4	4	5						57
H036		6	6	6	7		6	6	6		6	7	6	6	6	7	6	6	6	6	6	111
H037	6	6	7	7	8		7	6	7	6	6		6									72
11		5	6	6	7	6	6	6	6		6	6	6	6	7	6		6	6		6	103
12	5	6	7	9	7		7	7	7		9	7	7	7	7	7		7	6		6	118
22		6	7	7	6			6	5	6												43
40		4	4	4	4	4	3	4	3	4					4							38
41		5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5		96
46	6	6	7	7	5	6	7	7	7	6	9	7	7	7	7	7			7	7		122
H131		6	6	8	8	5		7	7		6	6		6	6	6	6	6	6	6		101
DS1			7	6	6	4		5	5	5	5	6	5	5	5	5		5	5	5		84
Pigments																						
360		2	2	2	2		2	3	2	2	2	2	2	2	2	3	2	2	2			36
361	2	2	2	3	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2			41
H111			2	2	3	3	2	3	2		2	2	2	2	2	3	2		2	2		36
H033		2	2	2	3		2	3	2	2		2		2	2	2						26
H036		2	2	2	3		2	2	2		2	3	2	2	2	3	2	2	2	2	2	39
H037	2	2	3	3	3		3	2	2	2	2		2									24
11		2	2	2	2	3	3	2	2			3	2	2	2	2		2	2		2	35
12	2	2	3	2	3		2	3	2		2	3	2	2	2	2		2	2		2	40
22		2	2	3	3			3	2	2												17
46	2	2	3	2	2	3	2	2	2	2	2	3	2	2	2	2		2	2	2		41
H131		2	2	3	3	2		3	2		2	3		2	2	2	2	2	2	2		36
DS1		2	2	3	3	2		2	2	2	2	3	2	2	2	2		2	2	2		37
Primary production																						
360		1	2	2	2	2	2	2	2			2	2	2	2	2	2	2	2			31
361	2	2	2	2	2	2	2	2	2				2	2	2	2	2	2	2			32
H111			2	2	2	2	2	2			2	2	2	2	2	2	2		2	2		28
H033		2	2	2	2		2	2	2	2		2		2	2	2						24
H036		2	2	2	2		2	2	2		2											16

year	2009										2010											
cruise	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	10	11	12	
season	spring			summer			autumn			w	spring			summer				autumn			w	
month	F	M	A	J	J	A	S	O	N	J	F	M	A	M	J	J	A	S	O	N	D	sum
Station																						
H037	2	2	2	2	2			2	2	2	2		2									20
11		2	2	2	2	2	2	2	2			2	2	2	2	2		2	2		2	32
12	2	2	2	2	2		2	2				2	2	2	2	2		2	2		2	30
22		2	2	2	2			2	2	2												14
46	2	2	2	2	2	2	2	2	2			2	2	2	2	2		2	2	2		34
H131		2	2	2	2	2	2	2	2		1			2	2	2	2		2			27
DS1		2	2	2	2	2		2	2	2	2	2		2	2	2		2	2	2		32
Mesozooplankton species composition, abundance and biomass																						
360		1	2	2	2		1	2	1	1	1	2	2	2	2	2	2	2	2			29
361	1		2	2	2	2	1	1	1	2	2	2	2	2	2	2	2		2			30
H111			2	2	2	2	1	1	1	2	2	2	2	2	2	2	2		2	1		30
H033		1	2	2	2			2	1	2												12
H036		1	2	2	2		1	2	2		2	2	2	2	2	2	2	2	2	2	2	34
H037	1	1	2	2	2			2	2		2											14
11			2	2	2	2	2	2	2			2	2	2	2	2			1		2	27
12	2	1	2	2	2		2	2	1		1	2	2	2	2	2		2	2		2	31
22		1	2	2	2			2	2	2												13
46	2		2	2	2	2	2	2	2	1	2	2	2	2	2	2		2	2	2		35
H131		1	2	2	2	2		2	2		2			2	2	2	2		2	2		27
DS1			2	2	2	2		1	2	1	1		2	2	2	2		2	2	2		27
Jellyfish medusa composition and abundance																						
360				2	1		1	2	1	1	1	2	2	2	2	2	2	4	4			29
361				2	2	2	1	1	1	2	2		2	2	2	2	2		2			25
H111				2	2	2	1	1	1	2	2	2	2	2	2	2	2		2			27
H033				2	2			2		2												8
H036				2	2		1	2	2		2	2		2	2	2	2	2	2	4	2	31
H037				2	2			2	2		2											10
11				2	2	2	2		2			2	2	2	2	2			1			21
12				2	2		2	2	1		1	2	2	2	2	2		4	2		2	28
22				2	2			2	2	2												10
46				2	2	2	2	2	2	1	2	2	2	2	2	2		4	2	3		34
H131				2	2	2		2	2		2			2	2	2	2		2	2		24
DS1				2	2	2		1	2	1	1		2	2	1	2		2	2	2		24

Table 2-3 Sampling methods and depths for species composition, chl-a, primary production, pigments and mesozooplankton and jellyfish at off-shore stations during the baseline investigation.

Component	Method	Sampling depth	Reference
Phytoplankton species composition	Niskin flasks	0-10 m (pooled sample)	HELCOM (2007)
Nutrients, Chl-a and primary production	Niskin flasks	1, 5, 10, 15, 20 m, 1 m above seabed and fluorescence max. (if present)	
In situ fluorescense	Hardt/Seabird sensor	Surface to bottom	
Pigments	Niskin flasks	1 m, 15 m and fluorescence max. (if present)	
Oxygen	O_2-Probe on CTD	Continuous through water column	
Mesozooplankton	WP-2, 100 µm net	1 vertical haul for mixed water column from bottom to surface, 2 vertical hauls for stratified water columns (bottom to halocline, halocline to surface)	HELCOM (2007)
Jellyfish	Multi Plankton Sampler (MPS)	1 oblique horizontal haul for mixed water column from bottom to surface, 2 oblique horizontal hauls for stratified water columns (bottom to halocline, halocline to surface)	

Table 2-4 Sampling statistics for chl-a, pigments and nutrients at the near-shore stations during baseline investigation. For location of stations, see Figure 2-1

year		09	09	09	09	09	09	09	09	09	10	10	10	10	10	10	10	10	10	10	
month		M	A	J	J	A	S	O	N	D	J	M	A	M	J	J	A	S	O	N	D	sum
N01	Danish coast	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1			1	17
N02	Danish coast	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1			1	17
N03	Danish coast	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1			1	17
N04	Danish coast	1	1	1	1	1	1		1	1		1	1	1	1		1	1	1			16
N05	Danish coast	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1	1		1	18
N06	German coast		1		1	1	1	1	1		1			1	1	1	1	1				12
N07	German coast		1		1	1	1	1	1		1			1	1	1	1	1				12
N08	German coast		1		1	1	1	1	1		1			1	1	1	1	1	1			13
N09	German coast		1		1	1	1	1	1		1				1	1	1	1	1			12
N10	German coast		1		1	2	1	1	1		1			1	1	1	1		1	1		14

As mentioned above the baseline investigation area has been divided into four different subareas: Great Belt, Mecklenburg Bight, Fehmarnbelt, and Darss Sill area (Figure 2-1). The Great Belt represents the most 'marine' area and the Darss Sill area the most 'Baltic' type area. Fehmarnbelt is located in-between and are expected to partly reflect Great Belt conditions and partly western Baltic conditions.

2.4 Sample processing and calculation

Overall, all sample processing was carried out following HELCOM (HELCOM 2007) or other internationally applied guidelines. Below is a brief summary of procedures for the individual pelagic components.

Nutrients: Nitrite, Nitrate, Phosphate and Silicate

The determination of the four inorganic nutrients nitrite, nitrate, phosphate and silicate is done simultaneously with a four-channel autoanalyzer (Evolution II, Alliance Instruments). The methods described below in short, are standard colorimetric methods used in seawater analysis. Details can be found in Grasshoff et al. (1983) as well as in the standard operation procedures of IOW's nutrient laboratory.

The determination of nitrite is based on the reaction of nitrite with an aromatic amine leading to the formation of a diazonium compound which reacts with a second aromatic amine to form an azo dye (Shinn 1941, Robinson 1952).

The most sensitive and generally applied method for the determination of nitrate in seawater is based on the reduction of nitrate to nitrite on copper-coated cadmium granules in the pH range 7.5 to 8.4 as it is likely in natural seawater. Under these conditions, the reaction is quantitative and no further reduction takes place. The nitrite is then determined as described above.

Phosphate ions react in an acid solution with molybdate under formation of a heteropoly-molybdate-phosphoric acid-complex which is reduced with ascorbic acid to molybdenium blue. The intensity of molybdenium blue is proportional to the phosphate content and is measured colourimetrically (Murphy and Riley 1962).

In the pH range between 1.4 and 1.6 "reactive silicate" forms together with molybdate a yellow coloured heteropoly-molybdate-silicic acid-complex, which is afterwards reduced to molybdenium blue. The blue colour is proportional to the silicate content and is determined colorimetrically (Carlberg 1972). For the reduction different reagents can be used, for example ascorbic acid or metol (Koroleff 1976).

The determination of ammonia is done photometrically as indophenol blue using the manual method. The blue colour of indophenol formed by phenol and hypochlorite in the presence of NH_3 was first reported by Berthelot (1959).

Total nitrogen and total phosphorus

By oxidation with potassiumperoxodisulfate in alkaline milieu, organic nitrogen and phosphorous compounds are quantitative transferred to nitrate and phosphate (Koroleff 1969). The digestion of the water samples is performed in a microwave oven. The determination of nitrate and phosphate is described above. The analysis is performed with the autoanalyzer "Evolution II", Alliance Instruments.

Secchi depth – water transparency

Because data on water transparency historically has been obtained using a Secchi disk, Secchi depths have in the present study been estimated based on light attenuation (Kd values) calculated from underwater measurements of light depth profiles conducted with a LiCor PAR sensor fitted on the Seabird CTD.

Attenuation of light is affected by the colour of the water such content of humic substances ('gelbstoff'), algae, and suspended sediments (i.e. particles). Inorganic suspended sediments primarily contribute to attenuation by light scattering that depends on the nature of particles (i.e. their shape, colour, and reflectivity).

There are several ways of quantifying transparency of water. The most direct being a measure of attenuation of light as it passes through a column of water. Ideally, attenuation measurements can be carried out using submerged light meters or more simple using a Secchi Disc. However, Secchi depth measurement is an approximate evaluation of the transparency of water, and it is used primarily for its simplicity. In the present study the secchi depth has therefore been calculated from light meter measurements. Light attenuation coefficients Kd were calculated for every 2m.

Secchi depth (SD) is related to the attenuation coefficient (Kd) by:

$$kd = \frac{k}{SD}$$

where k varies between 1 and 2, with the lowest values in turbid coastal waters. Secchi depth (SD) was calculated as SD = 1.90/Kd.

Oxygen

Oxygen was routinely measured using the integrated probe of the Seabird CTD. The probe was regularly (several times on every cruise) calibrated against the Winkler method.

Chl-a (water bottle analyses)

Water was filtered on board immediately after sampling using 25mm Whatman GF/F filters. Immediately after filtration the filter samples were frozen in liquid ni-

trogen up to the end of the cruise and were stored at -80°C in the laboratory until the extraction. Filters were extracted in 10 ml of 96% ethanol at room temperature in 4-6 h. The extract was decanted into a clean measuring cuvette of a TURNER 10-AU-005 fluorometer. Measurements were always done against a blank (reference) cuvette containing 96% ethanol. The fluorometer used a wide excitation band-pass at about 450 nm and measured at 670 nm.

The fluorometer was calibrated on the basis of spectrophotometric measurements of a dilution series of pure chl-a from *Anacystis nidulans* (Sigma Chemical Company) as described by UNESCO (1994). The calibration procedure was carried out in May and November 2009.

The total chl-a content was calculated without correction for phaeopigment according to equations described in UNESCO (1994), and recommended by HELCOM (1988):

$$chl\ a\ (mg\ m^{-3}) = F_0 * K_x * e * V^{-1}$$

where

F_0 = relative fluorescence
K_x = linear calibration factor [µg chl-a * l^{-1} per fluorescence unit]
e = volume of ethanol (ml)
V = volume of filtered water (ml)

These uncorrected data is the basis of all analyses in the present report except when comparing with historical data. Because long–term data generally are based on chl-a values corrected for phaeopigments, an additional determination of phaeophytin-a corrected chl-a concentration was applied for the baseline investigation to assure the comparability of data. For this correction, the extract was acidified after the measurement with approximately 10 µl 1 M HCl per cm^3 extract, and calculation carried out according to Lorenzen (1967):

$$chl\ a\ corr\ (mg\ m^{-3}) = F_m * (F_m - 1)^{-1} * (F_0 - F_a) * K_x * e * V^{-1}$$

where

F_m = acidification coefficient,
F_0 = relative fluorescence before acidification,
F_a = relative fluorescence after acidification

Plotting the pairs of chl-a concentration recommended by HELCOM (1988) and values calculated according to Lorenzen (1967), a strong linearity was obtained (Figure 2-3). Because of higher amounts of phaeopigments and degradation products of chl-a in near bottom samples and samplings during strong turbidity caused by resuspension of detritus, only samples from 0-10m depth were used for regression analyses.

Nevertheless, in this report, the comparison of historical and actual values was performed on the basis of the data set calculated according to Lorenzen (1967).

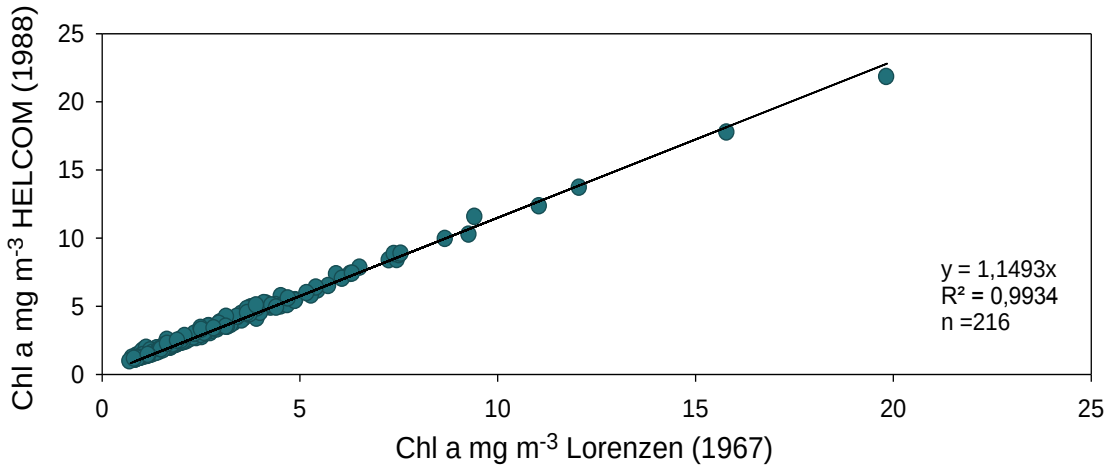


Figure 2-3 Comparison of uncorrected chl-a data (according to HELCOM, 1988) with the respective chl-a data corrected for phaeophytin (Lorenzen 1967). Chl-a data sets originate from the baseline investigation. Each dot represents the mean value for the sampling at 1, 5 and 10 m water depth.

Algal pigments and phytoplankton groups

The bottles with water samples were gently mixed prior to sub-sampling and exact volumes were filtered onto Whatman GF/F filters at a vacuum of approx. 25 kPa, immediately frozen and stored in liquid nitrogen and, at the end of a cruise brought to DHI laboratories for analysis.

Pigment analysis was carried out using DHI Standard Operating Procedure no.: 30/852:01 according to DHI's DANAK (the Danish Accreditation and Metrology Fund) accreditation for carrying out accredited measurements of pigment concentration in the aquatic environment. Briefly, the filters were extracted 95% acetone containing vitamin E as internal standard, sonicated and allowed to extract at 4 °C for 20 h. The filters and cell debris were filtered from the extracts and the samples were analysed by a Shimadzu LC-10ADVP High Performance Liquid Chromatography (HPLC) composed of one pump (LC-10ADVP), photodiode array detector (SPD-M10A VP), SCL-10ADVP System controller with Lab Solution software, temperature controlled auto sampler (set at 4 °C), a column oven (CTO-10ASVP) and a degasser. The samples were mixed with buffer using the auto injector by programming it to make a mix in the loop of buffer and sample in the ratio 5:2.

Pigments were analysed by HPLC according to Van Heukelem and Thomas (2001), with an Eclipse XDB C8, 4.6 mm*150 mm column (Agilent Technologies). Solvent A: (70:30) methanol: 28 mM aqueous TBA (hydroxide titrant, JT Baker HPLC reagent V365-07), pH 6.4, solvent B: 100% methanol. The time program was 0 min.: 95% A, 5% B, 22 min.: 5% A, 95% B, 30 min.: 95% A, 5% B, 31 min.: 100% A, 0% B, 34 min.: 100% A, 0% B, 35 min. 5% A, 95% B, 41 min: Stop. The flow rate was 1.1 ml min^{-1} and the temperature of the column oven was set to 60 °C. The HPLC was calibrated with pigment standards from DHI Lab Products, Denmark. The internal standard was detected at 222 nm, while the rest of the pigments were detected at 450 nm. Peak identities were routinely confirmed by on-line photodiode array analysis.

The biomass in units of chl-a of the phytoplankton groups detected by the pigments was calculated by CHEMTAX (Mackey et al. 1996) using the relevant pigment ratios from Schlüter et al. (2000).

Total chl-a is estimated by the HPLC method too. This allows checking correspondence between the HPLC method and the *in vitro* fluorescence method (Figure 2-4). Overall, concentrations of chl-a measured by the two methods in this baseline study was in good agreement (Figure 2-4). The outliers above the regression line indicate that other fluorescing pigments were interfering with the fluorescence measurements.

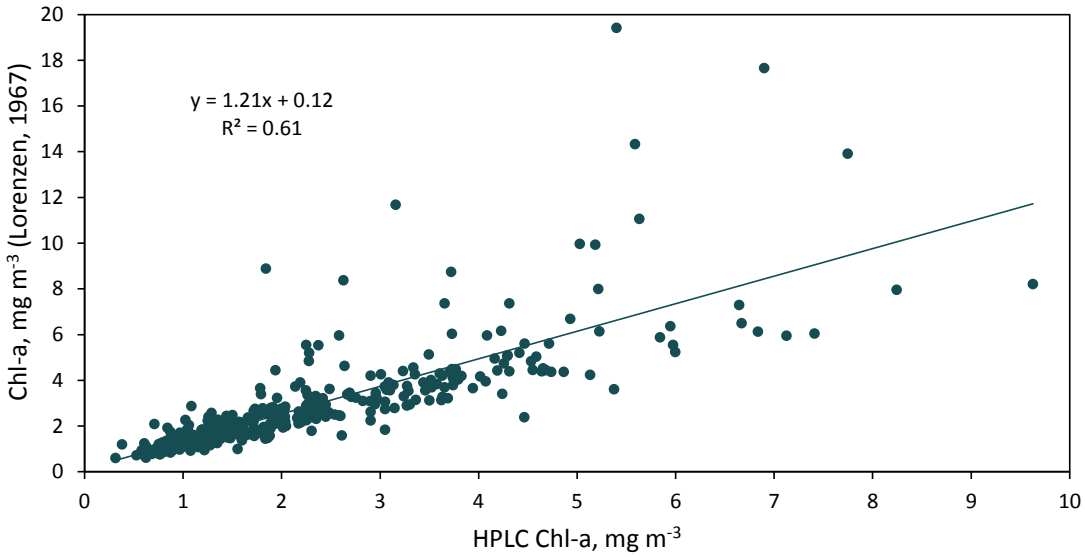


Figure 2-4 Relationship between chl-a measured by in vitro fluorescence and pigment analysis by HPLC.

In situ fluorescence chl-a

In situ fluorometers applied in the aquatic environment make fast measurements detecting chl-a in living algal populations. Such instruments are particularly useful at providing temporal and spatial estimates of chl-a distributions and in the Fehmarnbelt baseline study such measurements supplement the chl-a measurements of water samples taken at the 12 plankton stations by providing data from approx. 10 times more stations.

Briefly, an *in situ* fluorometer illuminates a water parcel with an excitation beam of light of specific wavelength and detecting at a 90° angle the longer-wavelength fluorescent light emitted by the substance or molecules in questions such as chlorophyll-a. Unfortunately, even for the same instrument the relation between true chl-a concentration (based on water samples) and *in situ* fluorescence is not fixed because of quenching effects in natural waters, dark-adaption of plankton in deep waters (resulting in higher fluorescence) and a varying composition of plankton groups etc. Therefore, the fluorometer readings were calibrated against true chl-a values using the water samples measurements mentioned above. For each baseline cruise, corresponding chl-a data (from water samples) and fluorescence data was extracted from the database and calibration equation calculated by linear regression.

Fluorescence intensity at 1 m depth consistently was lower (during summer especially) and also at 5 m depth during calm periods than the corresponding 1 m and 5-m chl-a values, probably due to photochemical quenching suppressing fluorescence. Hence, all 1 m values were excluded in calibrations, as was about 50% of 5 m values, all sub-surface samples showing peaks in fluorescence (usually between

10 and 15 m) and a few bottom samples showing very high values probably due to sediment resuspension. Despite sample elimination reliable calibration of *in situ* fluorometer could not be obtained for the June 2009 cruise, when the new CTD was in operation for the first time and fluorometer not being properly calibrated. Data from this cruise was therefore excluded from the analysis.

An example of calibration curves is shown in Figure 2-5 and regression equations for individual baseline cruises are shown in Table 2-5.

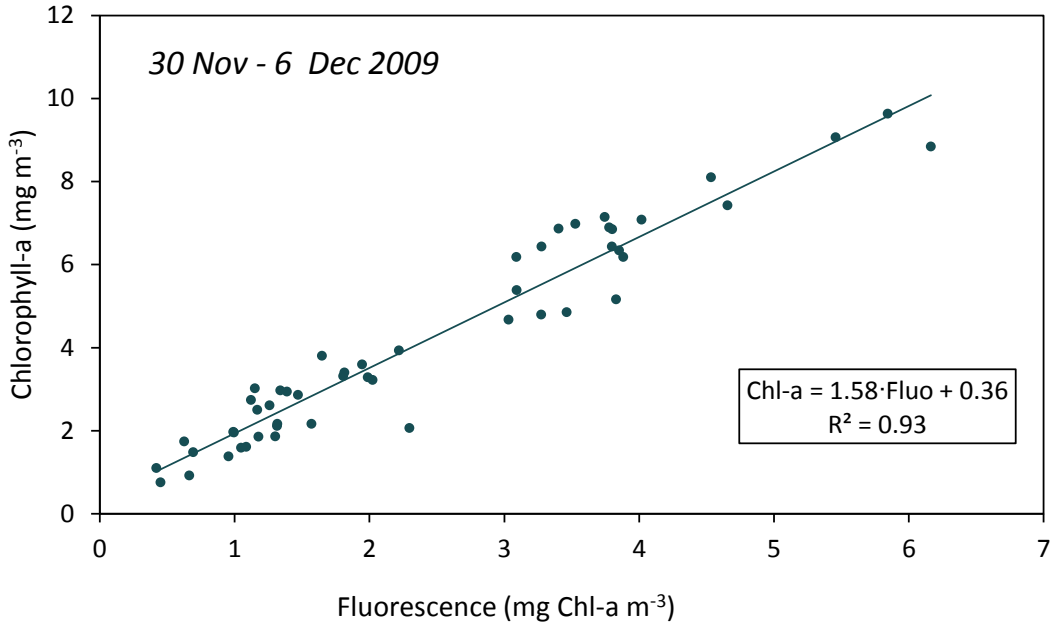


Figure 2-5 Example of calibration curves for calculating chl-a from in situ fluorescence.

Table 2-5 Calibration equations for calculating chl-a from in situ fluorescence.

Cruise dates	Calibration equation	R^2
26-28 Feb 09	Chl-a = 1.25·Fluo + 0.67	0.88
23-27 Mar 09	Chl-a = 0.75·Fluo + 0.99	0.73
27 Apr-1 May 09	Chl-a = 0.66·Fluo + 0.61	0.68
27 Jul-1 Aug 09	Chl-a = 0.90·Fluo + 0.74	0.70
25-28 Aug 09	Chl-a = 1.28·Fluo + 0.13	0.77
28 Sep-2 Oct 09	Chl-a = 1.62·Fluo + 0.05	0.82
27 Oct-3 Nov 09	Chl-a = 1.57·Fluo + 0.31	0.78
30 Nov-6 Dec 09	Chl-a = 1.58·Fluo + 0.36	0.93
11-16 Jan 10	Chl-a = 1.27·Fluo + 0.70	0.83
16-20 Feb 10	Chl-a = 1.13·Fluo + 0.24	0.93
8-11 Mar 10	Chl-a = 1.51·Fluo + 0.96	0.89
12-15 Apr 10	Chl-a = 0.86·Fluo + 0.71	0.70
17-20 May 10	Chl-a = 0.76·Fluo + 0.21	0.75
14-17 Jun 10	Chl-a = 0.66·Fluo + 0.31	0.72
19-22 Jul10	Chl-a = 0.93·Fluo + 0.74	0.68
16-23 Aug 10	Chl-a = 1.20·Fluo + 0.36	0.91
22-28 Sep 10	Chl-a = 1.34·Fluo + 0.52	0.77
11-14 Oct 10	Chl-a = 1.19·Fluo + 0.24	0.78
15-18 Nov 10	Chl-a = 1.34·Fluo + 1.05	0.34

Phytoplankton composition, abundance and species carbon biomass

Phytoplankton taxa and their size classes were determined microscopically (Nikon Eclipse TE2000-S) using the sedimentation method described by (Utermöhl 1958). To achieve an appropriate number of counts for each taxon, the quantitative determination was performed at 3 magnifications (100-fold, 200-fold, 400-fold) counting several transects per magnification and the whole chamber bottom at 100fold magnification, respectively. The lower size limit for quantitative analyses of plankton organisms was 2 µm (picoplankton).

At least 50 units of each dominating taxon were counted. This value corresponds to a statistical error of 28% per counting unit (HELCOM 1988). The total counts per sample normally exceed 1000 units, which reduced the statistical error per sample to 6% (HELCOM 1988). Counting, calculation and reporting was performed with the software package OrgaCount (AquaEcology, Oldenburg).

The phytoplankton carbon biomass is derived from abundance by species specific and size specific factors (Olenina et al. 2006). The wet weight was converted to carbon according to (Menden-Deuer and Lessard 2000). Taxonomical specification was based strictly on the taxa list of (Hällfors 2004). The autotrophic ciliate *Mesodinium rubrum* was included as phytoplankton.

Because chl-a is a widely used proxy for phytoplankton biomass, the relationship between chl-a and carbon biomass was tested based on baseline data (Figure 2-6). Knowing that relation between chl-a and biomass depends on abiotic conditions and composition of the phytoplankton community we may expect a strong variation

through the year. In accordance, only in spring a significant relationship of chl-a and biomass was observed in the investigated area (Figure 2-6).

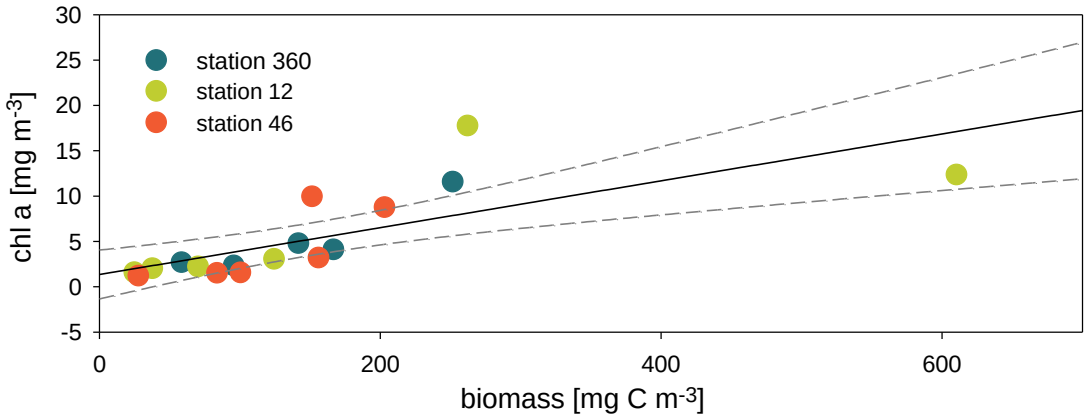


Figure 2-6 *Relationship of phytoplankton carbon biomass and chl-a concentration during the spring seasons of the baseline investigation. Chl-a values represent mean values of the upper ten meters.*

Primary production

The primary production of phytoplankton was determined by incubating samples with ^{14}C on-board JHC Miljø on the monthly monitoring cruises according to DHI Standard Operating Procedure No.: 30/853:01, DHI's DANAK accreditation for carrying out accredited measurements of primary production measurements using a laboratory incubator. Briefly, water was collected from 1, 5, 10, 15, 20 m, bottom. Water from two depths, 1 m and 15 m (three depths if a subsurface chl-a max was present), were used to quantify the relation between productivity and light intensity, so-called P-E curves (production-irradiance).

The water samples were gently mixed prior to sub-sampling. The numbered incubation bottles were rinsed in sample water and filled (max. 3% head space in bottles), and 2 µCi ^{14}C was added to each bottle. Dark bottles were wrapped in aluminium foil and all bottles were immediately mounted in the temperature regulated incubator. After 120 min. incubation, the samples were filtered onto Whatman GF/F filters in a fume hood, bottles and filters were rinsed two times with filtered seawater, and the filters containing the ^{14}C-labelled algae were transferred to glass vials. 200 µl 0.1 N HCl was added directly to the filters and after minimum 12 hours the vials were closed, and taken to DHI for liquid scintillation counting according to DHI Standard Operating Procedure no.: 30/851:02, DHI's DANAK accreditation for measuring radioactivity of filters.

Primary production (µg C l^{-1} h^{-1}) was calculated as:

$$P = [CO_2] * \left(DPM_{light} - DPM_{dark}\right) * 1.05 * \frac{60}{(DPM_{added} * t)}$$

where $[CO_2]$ is the concentration of dissolved CO_2, DPM_{light} and DPM_{dark} the activity on filters from samples incubated in light and dark, respectively, DPM_{added} the total activity added to the bottles and t the incubation time (min), see (Gargas and Hare

1976). We did not correct for respiration that as suggested by (Gargas and Hare 1976). The concentration of dissolved CO_2 was estimated from salinity, pH and temperature using "Buch Tables" (Buch 1945).

Photoinhibition at high light intensities (> 500 µE m^{-2} s^{-1}) was regularly observed during incubations in late autumn and winter, and also regularly observed in water from 15 m, hence parameters of photosynthesis versus irradiance (P-E) were calculated using the photo-inhibition equation of the PRIMPROD 2.0 program (Figure 2-7). For deep-waters (15 m) that never will experience irradiances above 600 µE m^{-2} s^{-1} (max incubator level = 850 µE m^{-2} s^{-1}) data from high-irradiance flasks was deleted prior to P-E equation fitting (see Figure 2-7 right).

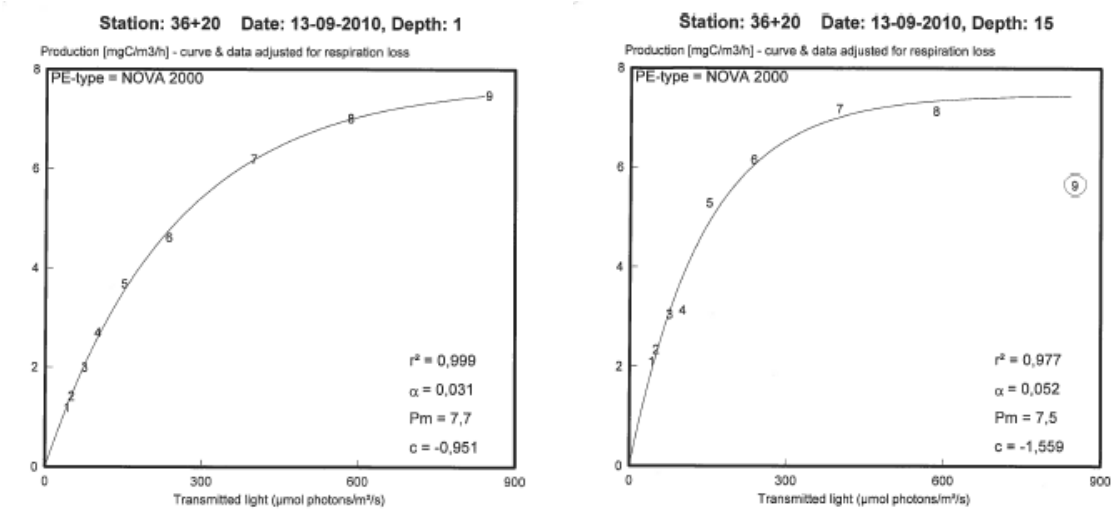


Figure 2-7 Examples of P-E relations based on onboard incubator measurement of primary production on 13 September 2010. Production value at 850 µE m^{-2} s^{-1} (point 9) was excluded in sample from 15m due to photoinhibition prior to curve-fitting.

Daily primary production was calculated using P-E relations from the appropriate station, the light attenuation coefficient (calculated from CTD-mounted LiCor PAR sensor) and daily solar insolation.

The yearly production for Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill areas was calculated by trapezoid integration after cruise-wise averaging station values within areas.

Mesozooplankton

Zooplankton sampling was carried out according to HELCOM guidelines (HELCOM 2007) taking vertical hauls with a speed of about 0.5 m s^{-1} by using a WP2 net (opening area 0.25m²) of 100µm mesh size (Table 2-2and Table 2-3). To keep the wire vertical the WP2 net was equipped with a 28 kg weight. In case of divergence from 90° the actual wire angle was measured. One or two vertical hauls were taken according to the salinity stratification of the water column. Water layers (above and below halocline) were defined according to the respective CTD profile. A closing mechanism triggered by a wire messenger was used to close the net at a distinct depth. Sampling depths as well as hauling speed were controlled by a digital cable counter. Collected samples were preserved in 4% buffered formaldehyde solution.

The volume filtered (V_f) by the WP-2 net was calculated from the net opening area (A), the sampled depth difference (d_{max}-d_{min}) and the wire lengths, corrected for the wire angle (α) by the following equation:

$$V_f(m^3) = \frac{A * (d_{max} - d_{min})}{(cos(a * \pi)/180)}$$

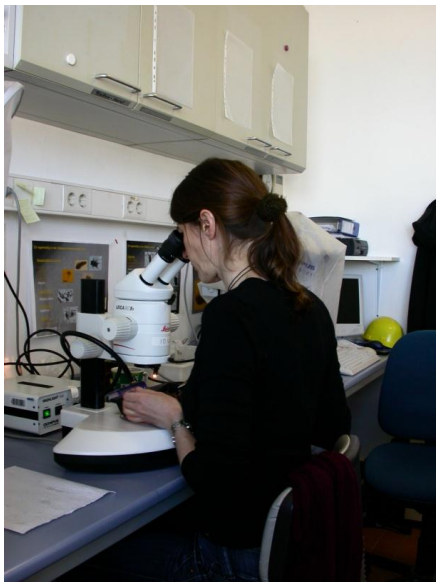


Figure 2-8 *Zooplankton microscopical analyses (Photo C. Augustin).*

Zooplankton sample processing was carried out in the laboratory according to HELCOM Combine Manual (2007).

To remove formaldehyde from preserved sample, the samples were rinsed in a sieve (55µm) with distilled water under the extractor hood in the laboratory. Samples were filled up with distilled water to a volume of 0.2 to 1 L, depending on the abundance of zooplankton. Several subsamples were taken with a 1 ml pipette in order to minimize the homogenisation error. Homogenisation was done by stirring the sample in different directions.

Samples were analysed in a 10 ml Bogorov chamber under microscopes with magnifications of at least 125 times. All individuals were identified to a specific taxonomic level (see below) and counted until a total number of at least 600 (most times about 1000) individuals. The three most abundant taxonomic units were counted until at least 100 specimens. To identify and count larger organisms as well as rare species the total sample was screened by using a 20 ml Bogorov counting chamber (Figure 2-8).

The abundance (individuals m^{-3}) of taxonomic units was calculated by the following equation:

$$ind\ m^{-3} = V_{lab} * \frac{n}{V_f} * V_c,$$

where V_{lab} is the sample volume filled up in the lab after formaldehyde rinsing, V_c is the sub-volume counted in the lab, n is the number of individuals counted and V_f is the volume filtered by the plankton net.

Biomass (in fresh mass/wet weight in this report) was calculated according to HELCOM recommendations by using individual biomass factors (Hernroth 1985).

Mesozooplankton taxa were determined to different taxonomic levels. Calanoid and cyclopoid Copepoda were generally determined to species level as adults (except *Pseudocalanus*, which was determined only at genus level), developmental stages of Copepoda (nauplii, copepodites I-III, copepodites IV-V) were determined to genus level.

All other holoplanktonic taxa were determined as given in Table 5-2. Meroplanktonic taxa were determined as given in Table 5-3.

Jellyfish

Jellyfish samples were taken by using a MultiPlanktonSampler (MPS) produced by HYDROBIOS which allows collecting 5 samples during one deployment (HYDROBIOS OPERATION MANUAL). The MPS "Type Midi" consisted of a controlling deck unit and an underwater sampling device with 5 net bags (opening area 0.25 m², mesh size 500 µm). An integrated pressure sensor allows sampling at defined depths, 2 electronic flow-meters measured the filtrated water volume. This MPS was towed horizontally with a maximum inflow speed of about 1 m s^{-1}.

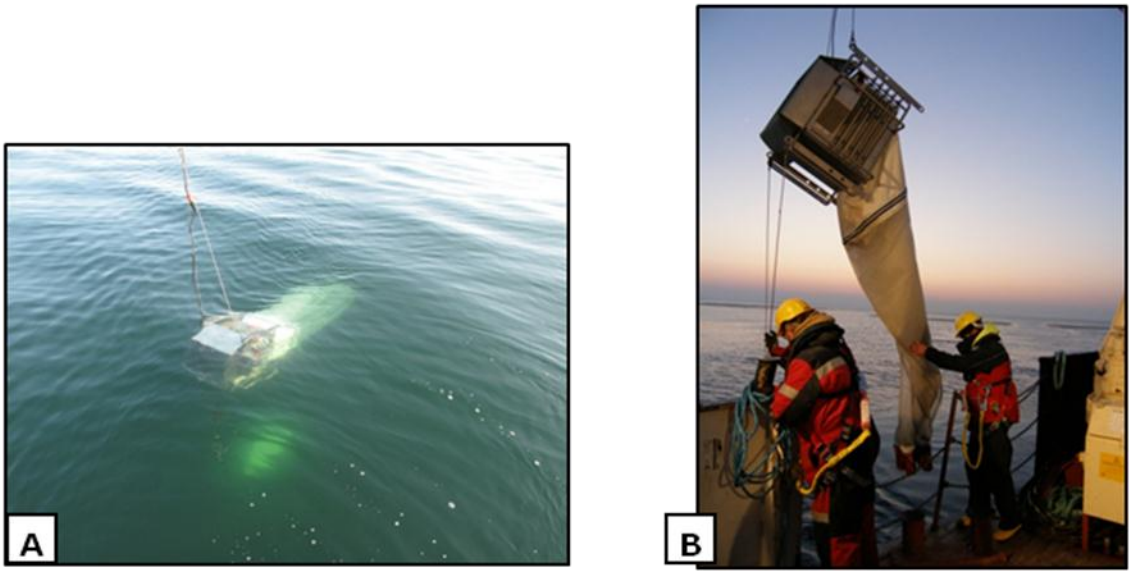


Figure 2-9 A. MPS while collecting samples B. MPS operation on deck of JHC Miljø

The MPS was deployed for jellyfish sampling during cruises from June 2009 to December 2010 (Figure 2-9, Table 2-2).

Scyphozoan medusae and ctenophores were counted and measured to the nearest 1 cm. The bell size (diameter) of each scyphozoan medusae (*Aurelia aurita, Cyanea capillata*) was determined. Specimens <0.5 cm were considered as ephyrae. The size of the ctenophore *Mnemiopsis leidyi* was determined by measuring the distance of the oral to the aboral end of the body. The samples were preserved in a 4% bo-

rax-buffered formalin-seawater solution for determining small medusae stages under the stereomicroscope.

Abundance (individuals m^{-3}) of jellyfish was obtained by calculating the counted number of each species in relation to the volume of water, which was sampled. Size groups with a bell shaped size distribution were considered as cohorts.

Prey selectivity and predation impact of Aurelia aurita

During 9 of the monthly baseline cruises, 83 individuals of *Aurelia aurita* were sampled for analysis of the food content on the biological stations in the Fehmarnbelt and Mecklenburg Bight (Table 2-6).

Medusae for analyses of the food content were only used when they were in well and complete condition after towing the net. Immediately after the net was received on board medusae of *A. aurita* were collected individually. The size of living medusae was measured by estimating the bell diameter before they were preserved separately in a 4% borax-buffered formalin-seawater solution. The medusae were analysed by dissecting the digestive canals, stomach and gastric pouches. The prey organisms were counted and identified to the lowest possible taxonomic level.

Analysis of the food content of *A. aurita* was only possible for the most abundant size class. The size of the collected medusae ranged from 8 to 26 cm. In July/August 2009 the average size was 22 cm, while the abundant size class from August to the end of October 2009 was 10 to 11 cm (Table 2-6). In 2010 the size of the analysed medusae ranged from 10 to 14 cm (Table 2-6).

Table 2-6 Overview of the stations with A. aurita samples for analysis of the stomach content.

cruise	cruise period	sampled stations	number of sampled medusae	mean size ±SD (cm)
26JL0905	28.07. - 02.08.2009	H033, H037, 360	8	22±2.5
26JL0906	25.08. - 28.08.2009	DS1, H111, H131	7	11±2.7
26JL0907	29.09. - 02.10.2009	11, 12, 361	4	10±1.9
26JL0908	27.10. - 03.11.2009	DS1, 11, 12, 46, H131	7	11±2.4
26JL1006	14.06. - 18.06.2010	H036, 46, H131, 360	6	10±3.4
26JL1007	19.07. - 23.07.2010	H037, H111, 360, 361	7	11±1.9
26JL1008	16.08. - 20.08.2010	H131, 360	7	14±4.1
26JL1010	11.10. - 14.10.2010	DS1, 12,H036, 46	28	12±1.7
26JL1011	15.11. - 19.11.2010	DS1, H131	9	13±1.4

Feeding rates of *A. aurita* were calculated in relation to zooplankton standing stock data obtained from the zooplankton baseline investigation.

Individual feeding rates were estimated as numbers of prey consumed per medusa per day:

$$F = \frac{C_m}{D} * 24h,$$

where F is the number of prey consumed per medusa per day, C_m is the number of prey in the medusa and D is digestion time (h). F is calculated for 24 h. The diges-

tion time of *A. aurita* is depending on temperature, prey size and numbers of prey in the gut. According to comparable analysis of *A. aurita* from the central Baltic Sea (Barz and Hirche 2005) 3 h was used for digestion time in this calculation.

The predatory impact (P) of *A. aurita* on populations of the abundant taxonomic groups, Copepoda and Cladocera, was calculated based on the equation:

$$P = F * \frac{M}{C} * 100,$$

where P is the percentage of the prey standing stock consumed per day. F is the number of prey consumed per medusa per day, M represents the abundance of medusae per m³ and C is the abundance of prey per m³. The feeding impact of *A. aurita* was calculated for the standing stock of abundant zooplankton groups: Copepoda, Cladocera, Bivalvia and Gastropoda. Field abundances of zooplankton prey species were obtained from the zooplankton baseline investigation. All different species found in the gut content of *A. aurita* were pooled according to their taxonomic group.

Data analysis and statistical testing

The horizontal distribution patterns of chl-a, phytoplankton groups, primary production, zooplankton and jellyfish were analysed by comparing the four *a-priori* defined geographical subareas: Great Belt area, including sampling stations 360, 361, H111 (GB), Fehmarnbelt area, including sampling stations H033, H036, H037 (FB), Mecklenburg Bight including sampling stations 22, 12, 11 (MB) and Darss Sill area including sampling stations 46, DS1, H131 (DS) (Figure 2-1). For chl-a calculated from in situ fluorescence, comparisons were based on between 12 and 30 sample stations per area.

Depending on nature and amount of data various statistical tests and analysis were employed.

Standard parametric and nonparametric tests were carried out using STATISTICA 6 software (fluorescence chl-a, primary production, zooplankton). Temporal and spatial variation between areas and seasons for phytoplankton groups (pigments), phytoplankton and zooplankton communities were examined by nonparametric multivariate techniques using the PRIMER 6 software package (Clarke and Warwick 2001). Nonmetric multidimensional scaling ordinations (MDS, Kruskal and Wish 1978) were based on Bray-Curtis similarity matrices (Bray and Curtis 1957). Particular transformation of data is mentioned in the sections presenting the results. Significance of spatial and temporal differences between phytoplankton communities and between zooplankton communities was tested by using ANOSIM permutation test (Clarke and Green 1988; Clarke 1993). This test computes a global measure R of community differences between areas and seasons. R will usually fall between 0 and 1, indicating some degree of discrimination between treatments: R=1 only if all data sets within treatments are more similar to each other than any data sets from different treatments, R=0 if similarities between and within treatments are the same on average. The global test for indications of differences between treatments is followed by tests between specific pairs of treatments.

2.5 Quality Assurance

2.5.1 *Nutrients and oxygen*

Methods for hydrochemical analysis are quality assured and comply to the quality assurance under the BLMP (Bund/Länder-Messprogramm für die Meeresumwelt) organized by BSH and described in DIN EN ISO/IEC 17025 quality management systems. IOW, being responsible for nutrient analysis apply validated sampling and analysis methods, use certified reference materials and participate in QUASIMEME intercalibration exercises for nutrients in seawater twice a year.

2.5.2 *Chl-a (water bottle analyses)*

The method applied for determination of chl-a is quality assured and carried out according to the HELCOM COMBINE Manual (2007). The laboratory has participated in the QUASIMEME tests on chl-a in seawater (AQ-11) since 1999, mostly two times per year and never reached unsatisfactory results (z-score >3). Own research on the chl-a method contributed to a high standard (Wasmund et al. 2006).

2.5.3 *Pigments*

The laboratories of DHI perform tests and analyses in accordance with ISO 17025, accredited by DANAK (the Danish Accreditation and Metrology Fund). DHI holds a DANAK accreditation for carrying out accredited measurements of pigment concentration in the aquatic environment. The results are validated according to DHI's Standard Operating Procedure no.: 30/852:01; accredited measurements of pigment concentrations in the aquatic environment, by injecting a chl-a standard four times to control of calibration and reproducibility of the HPLC, use of internal standard for correcting evaporation errors, and injection of a mixture of pigments to control the performance and correct elution of the HPLC. Furthermore, DHI has since 2003 participated in four round robins on pigment analyses of marine pigments arranged by NASA (National Aeronautics and Space Administration) and were in all four round robins part of the QA subset of laboratories, which satisfied the quantitative analysis performance metrics established as part of the exercises (e.g., Hooker et al. 2005, 2009).

Several QA steps are conducted when carrying out pigment analyses by HPLC and the subsequent calculation of the chl-a biomass and composition of phytoplankton groups: Furthermore, samples are analyzed by HPLC, according to DHI's quality control schedule, approved and controlled by the Danish Accreditation Scheme (DANAK) which includes control of calibrations and reproducibility of the HPLC.

2.5.4 *Phytoplankton composition, abundance and species biomass*

The methods applied for phytoplankton analyses (microscopical identification, taxa-specific analysis) are quality assured.

All methods are carried out according to the HELCOM COMBINE Manual (2007). In-house expertise in phytoplankton taxonomy is assured by participation in regular training courses, as a minimum the training course on Baltic phytoplankton conducted by the HELCOM Phytoplankton Expert Group (PEG) once a year (HELCOM PEG). Moreover, the phytoplankton experts at IOW take part in national training courses. In-house exchange of expert knowledge in the IOW is provided. The species are documented at http://www.io-warnemuende.de/mikroalgen-fotogalerie.html. The correctness of microscopical biomass identification was successfully tested in international ring-tests: Nov.1999-March 2000 in the BEQUALM

ring test; evaluation at a workshop in Büsum (30.3.-2.4.2000). 2003: HELCOM phytoplankton intercalibration and in 2007/2008 (preliminary evaluation in 2009) participation in the international comparison organised by the Quality Assurance Panel of the German marine monitoring programme and the HELCOM Phytoplankton Expert Group.

2.5.5 *Primary production*

DHI holds a DANAK accreditation for carrying out accredited measurements of primary production measurements using a laboratory incubator. The laboratories of DHI perform tests and analyses in accordance with ISO 17025, accredited by DANAK, "the Danish Accreditation and Metrology Fund". The results are validated according to DHI Standard Operating Procedure no.: 30/853:01; "Accredited measurements of primary production measurements using a laboratory incubator" by controlling that for more than 95% of the samples the ^{14}C uptake in the dark bottles is less than 5% of P_{max} and that the PE curve shows a clear decrease as function of the light intensity.

Furthermore, DHI is authorised by DANAK to carry out accredited measurements of ^{14}C radioactivity in phytoplankton samples by liquid scintillation counting. These measurements are validated according to DHI Standard Operating Procedure no.: 30/850:01; "Accredited measurements of radioactivity on filters" by liquid scintillation counting of certified standards. Results within predefined intervals, defined by the uncertainty budget established for the DHI liquid scintillation counter (April 2003), are accepted.

2.5.6 *Mesozooplankton and jellyfish*

Quality assurance of zooplankton data provided for the Fehmarnbelt Marine Biology Service is mainly based on guidelines for zooplankton assessments of HELCOM (2007). The IOW zooplankton laboratory is member of the HELCOM MONAS Zooplankton expert network (ZEN), which is the platform for QA issues. ZEN organized a laboratory workshop in 2005 at IOW and a sea-going workshop on r/v "Aranda" in 2006 in order to evaluate the compliance of HELCOM COMBINE standard operation procedure. In 2007, a ring test was organized. The IOW zooplankton laboratory successfully participated. The evaluation was performed by the independent QA Panel of the German Marine Monitoring Program (Federal Environmental Agency), Berlin, and Quo data GmbH, Dresden. The staff working within the Fehmarnbelt project was trained by professionals of the IOW zooplankton laboratory. Repeated zooplankton laboratory analysis checks (taxonomy and counting procedure) are performed quarterly. Jellyfish analyses were done with the same demand on quality as for zooplankton. Since there is no standardized HELCOM procedure internationally accepted methods were used by the professionals of the IOW zooplankton laboratory.

2.6 Storage of data

All quality assured data obtained have been send to Fehmarnbelt Data Handling Center.

2.7 Historical data

2.7.1 *Water quality, phytoplankton composition and chl-a*

Five stations that currently are or have been sampled regularly within the German (and Danish) HELCOM monitoring program or other programs are of relevance for

the Fehmarnbelt baseline study (Figure 2-10). The data sets are based on harmonized methods of recent HELCOM-monitoring program (HELCOM 2007) and thus directly comparable to samples from the Fehmarnbelt baseline study.

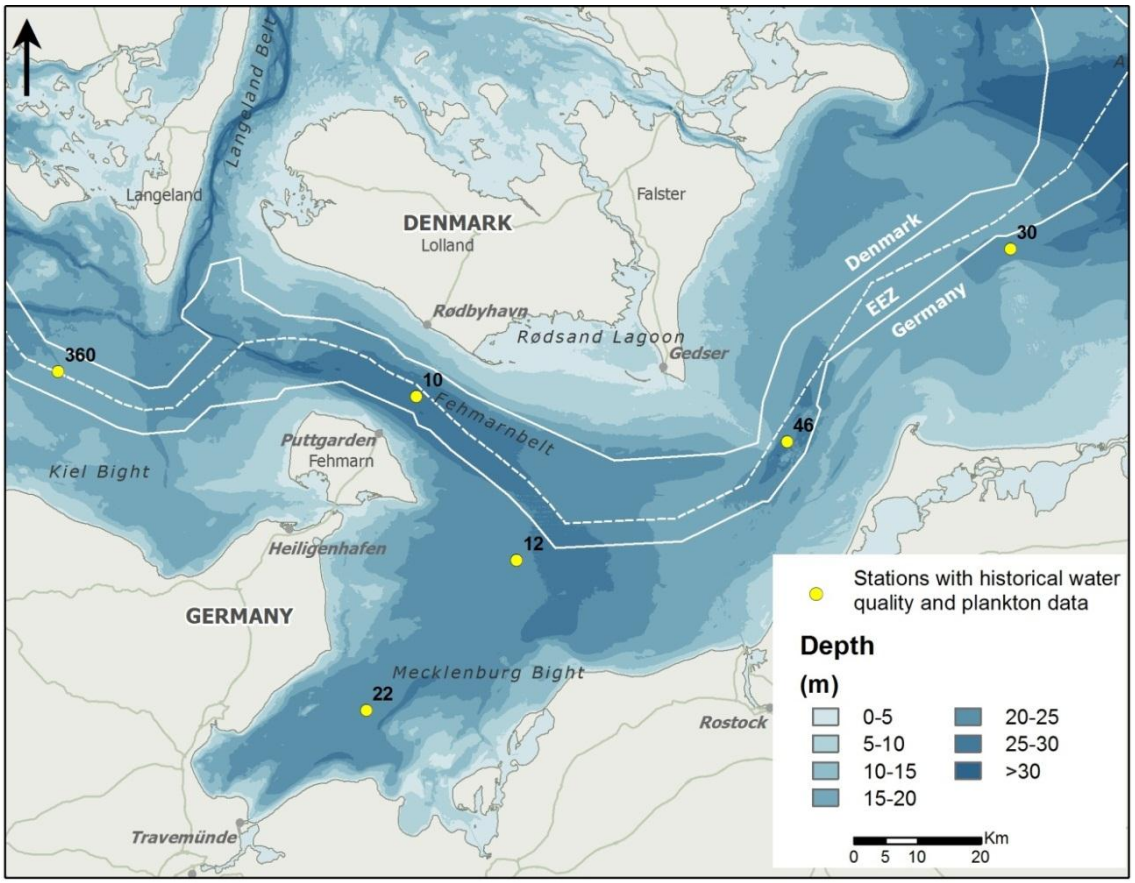


Figure 2-10 Geographical position of long-term nutrient, oxygen, phytoplankton and zooplankton stations.

Historical concentrations of chl-a were obtained from the updated long-term data set of Wasmund et al. (2006 b), because these authors have already compiled data from several national and international institutions to obtain a quality assured homogeneous data set for long-term trend analyses (Wasmund et al. 2006; Wasmund and Siegel 2008).

For the baseline report, the analysis focussed on stations within the Belt Sea and Darss Sill area. This data set was amended by IOW monitoring data sets for stations 10, 30 and 360 as well as actual data in the period from 2006 to 2009. Due to changes in the national monitoring program, the data series of station 10 end in 1995, while the series of station 360 started in 1993. Abundance of data is significantly weaker for stations 10, 30 and 360, as well as for data sets after 2006.

Because pigment analysis by HPLC is a relatively new method historical data for this area is not available.

Assessment of bathing water quality at the present level of temporal and spatial resolution is regulated by the EU Bathing Water Directive adopted in 2007 (EU 2006). Hence, systematic and comparable assessment data are only available from 2007 onwards.

2.7.2 *Primary production*

Denmark has carried out monitoring of primary production in the Danish marine environment including one station in Fehmarnbelt since 1980. Unfortunately, due to revision of the Danish monitoring program, primary production measurements have not been carried out on a regular basis in Fehmarnbelt since November 1997, while regular measurements have been continued in the Great Belt. Fifty to sixty year time series from Great Belt, the Sound and Kattegat were recently analyzed by Rydberg et al. (2006).

2.7.3 *Mesozooplankton*

The zooplankton time series analysed in this report were obtained from the German HELCOM monitoring program covering period 1998-2008 with different annual sampling frequencies at four stations within the baseline study area. Data were available from the IOW database ODIN.

Zooplankton laboratory analyses and data treatment in the German HELCOM zooplankton monitoring programme was carried out according to the HELCOM guidelines (HELCOM 2007); data are therefore comparable with the FEMA baseline zooplankton data.

2.7.4 *Jellyfish*

Jellyfish has not been monitored on a regular basis in the Fehmarnbelt region and no historical data exist.

3 WATER QUALITY

This chapter includes the results from the baseline investigation of a wide area-coverage of water quality that encompasses chlorophyll-a (chl-a) quantified in high resolution using *in situ* fluorescence, and chl-a by water chemistry at fewer stations, quantifying the concentration of nutrients, water transparency by Secchi depth and bottom water oxygen.

3.1 Nutrients

Following the definition, eutrophication is caused by enrichment of the water by inorganic nutrients. Hence, loads of nutrients, their concentration and especially their influence in the biological system are of fundamental importance for understanding the environment and evaluating the status of Fehmarnbelt.

3.1.1 *Seasonal variation*

The seasonal variation in dissolved inorganic nitrogen (DIN), phosphate and dissolved silicate in the four areas Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill area is shown in Figure 3-1 (see Figure 2-1 for station locations and Table 2-2 for sampling frequency). Averaged over 2009 and 2010 the concentration of all inorganic nutrients peaks in January and February as a result of accumulated mineralisation during late autumn-winter and land run-off, combined with a low insolation preventing phototrophic production and uptake of nutrients by algae. Nutrients and in particular DIN decreased in March due to the spring bloom and DIN remained exhausted until November. In contrast, phosphate was still available at the end of April and the concentration was varying between 2 and 5 mg PO_4-P m^{-3} from May through August. From September through December the concentration of phosphate increased gradually reaching peak winter values in January.

Concentration of silicate decreased from February to April in a 1:1 molar ratio with nitrogen (2:1 in weight) strongly supporting that the spring bloom was dominated by diatoms (Conley and Malone 1992, and see chapter 4). From April onwards to January the concentration of silicate increased to reach peak winter values.

3.1.2 *Spatial variation*

Compared to the seasonal variation, the spatial variation in nutrient concentrations is very small. Notable patterns are lower winter concentrations of DIN in the Darss Sill area reflecting a larger influence from the Baltic Sea being lower in inorganic nitrogen, and higher nutrient concentrations in April in the Darss Sill and Fehmarnbelt areas caused by a delayed spring bloom compared to Great Belt and Mecklenburg Bight.

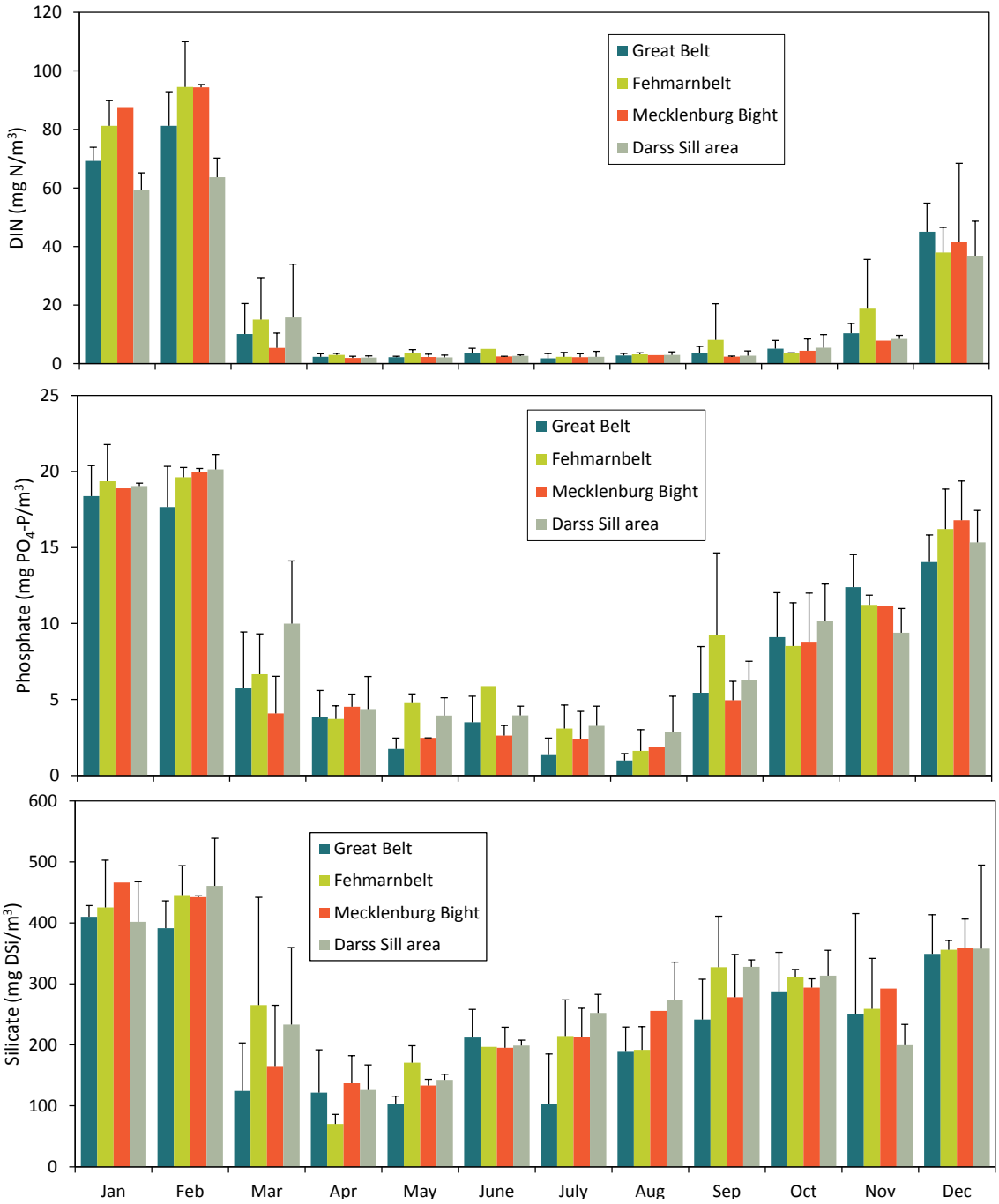


Figure 3-1 *Spatial and temporal variation in inorganic nutrients in surface waters (0-10 m) in the Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill areas. Bars (+SD) show monthly averaged nutrient concentrations for the period March 2009-December 2010.*

3.1.3 *Nutrient limitation*

A simple approach to assess potential nutrient limitation is to examine for periods when nutrient concentrations are below the theoretical half-saturation constant (Ks) for nutrient uptake, and to compare the nutrient stoichiometry to expected Redfield ratios (Fisher et al. 1992). Despite being crude, this approach is considered to be a rather robust method to indicate which nutrient is the most limiting. The Ks values used are 2 µM for dissolved inorganic nitrogen, DIN (≈28 mg DIN-N m^{-3}), 0.2 µM for dissolved inorganic phosphorus, DIP (≈6mg PO_4-P m^{-3}) and 2 µM for dissolved

silicate, DSi (≈56 mg SiO_3-Si m^{-3}) and Redfield ratio is 16 for DIN:DIP (=7 on weight basis).

Using the Ks-values as yard-stick inorganic nitrogen is potentially limiting the primary production from March through November, phosphate is potentially limiting production from April through August, and silicate is never limiting diatom production (Figure 3-1).

The monthly N:P ratio from March to November (when nutrients were potentially limiting production) varied between 0.5 (August-September) to 2.5 in July, and is thus much below the Redfield ratio of 7. Therefore, based on concentrations much below the half-saturation constant for uptake and with N:P-ratios much below the Redfield ratio, nitrogen is the most limiting nutrient in the greater Fehmarnbelt.

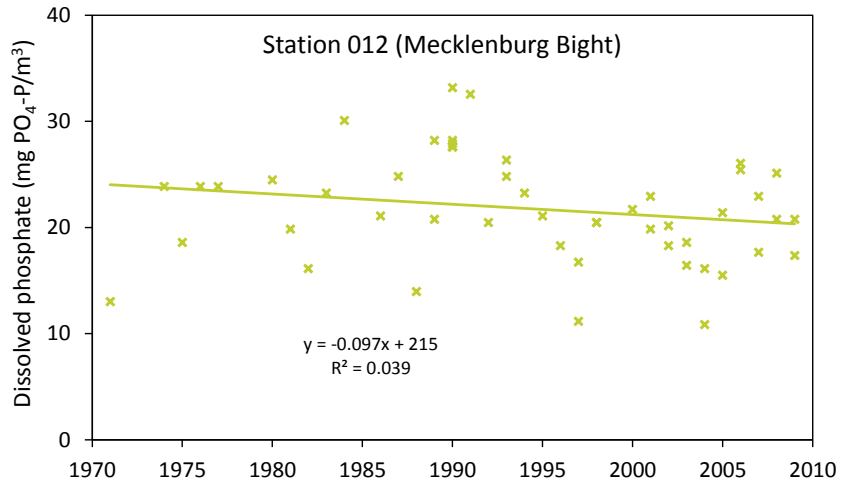
3.1.4 *Historical nutrient data*

Winter concentrations in the mixed surface layer are normally used when analysing for temporal trends, because it is only during winter that quasi-steady state is established between microbial mineralization, low productivity and high vertical exchange and mixing (Nehring 1981, Nehring and Matthäus 1991). After a peak in nutrient concentrations reached in the early 1980's nutrient concentrations have decreased slowly (0.5% - 1% per year) in the Fehmarnbelt (station 12, Mecklenburg Bight), see Figure 3-2. Thus, measures undertaken to reduce nutrient inputs are only poorly reflected in the open sea areas. For stations in the Mecklenburg Bight area (e.g., station 22) significant downward trends can be observed for nitrate (Figure 3-3) and phosphate (Nausch et al. 2010) especially if data prior to 1980 is not considered.

To evaluate if nutrient data collected during the baseline investigation is representative for the immediate past we compared winter concentrations from 2010 (January-February) with concentrations from the past 5 years (Table 3-1). For all nutrients (NOx: NO_3+NO_2, DIN: NO_3+NO_2+NH_4, PO_4, SiO_4) winter concentrations showed large variation in the southern Great Belt (stations 360/361) and in Mecklenburg Bight (station 12) probably reflecting that these stations are influenced by year-to-year variation in local run-off, while concentrations was much more stable in the Darss Sill area (stations 30 and DS1) underlining the 'Baltic Sea' nature of this subarea including large pools and long residence time. With one exception (NOx in the Darss Sill area), the winter nutrient concentrations fell within the range observed in the past 5 years. The deviation in 2010 at the Darss Sill area was minor (57.8 mg NOx-N m^{-3} vs. 55.4 NOx-N m^{-3} in 2007). Therefore we conclude that the nutrient situation under the baseline investigation was in line with the expected and no exceptional observations were done.

Table 3-1 *Mean nutrient concentrations (mg m^{-3}) in the winter surface layer during the past 6 years in the Great Belt area (360/361), in the Mecklenburg Bight area (station 12) and in the Darss Sill area (30/DS1). DIN represents the sum of NO_3, NO_2 and NH_4.*

	2005	2006	2007	2008	2009	2005/ 2009	2010
NO_x							
station							
360/361	55.2	43.7	120.8	90.3	55.6	73.1	**72.5**
12	40.2	49.6	90.7	108.8	51.8	68.2	**82.0**
30/DS1	34.6	40.3	55.4	40.0	38.5	41.7	**57.8**
DIN							
station							
360/361	64.5	54.7	144.9	105.4	66.4	111.0	**83.7**
12	44.5	62.2	103.9	125.3	64.4	80.1	**95.2**
30/DS1							**62.9**
PO_4							
station							
360/361	0.5	0.76	0.7	0.78	0.68	0.68	**0.58**
12	0.69	0.82	0.58	0.81	0.66	0.7	**0.65**
30/DS1	0.64	0.78	0.76	0.61	0.6	0.68	**0.64**
SiO_4							
station							
360/361	311	437	493	605	392	448	**400**
12	414	501	400	571	221	423	**451**
30/DS1	398	470	364	375	241	370	**400**



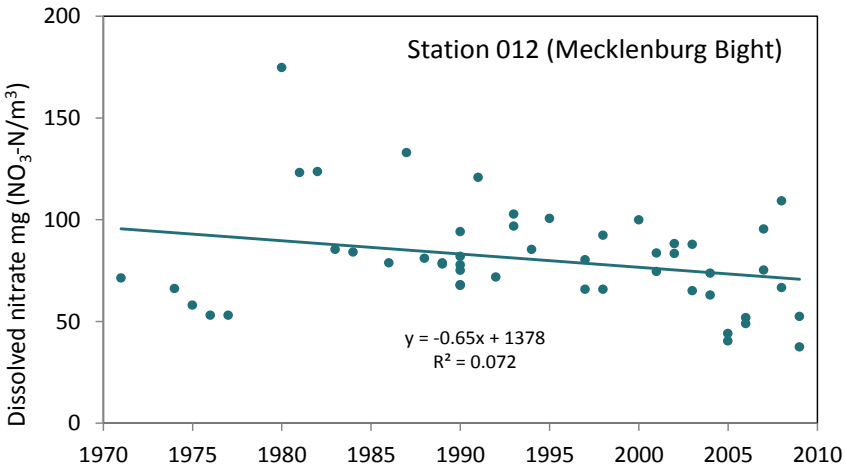


Figure 3-2 Trends of phosphate and nitrate in the winter surface layer at station 12 (Mecklenburg Bight). Data based on extracts for the IOW Odin database.

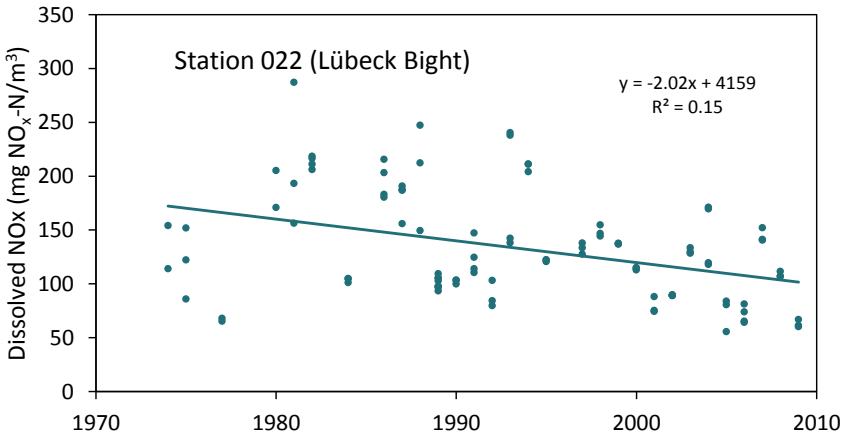


Figure 3-3 Trends of NOx (nitrate + nitrite) in the winter surface layer at station 22 (Lübeck Bight, southern Mecklenburg Bight). Data based on extracts for the IOW Odin database.

3.2 Toxic substances

Dredging and disposal of marine sediments may provide a source of various chemical contaminants. The impact pathway comprises dredging-induced disturbance, which changes the physical and chemical conditions of the seabed. As a result, toxic elements and compounds may be released into the water column potentially affecting pelagic and benthic organisms.

Concentration of dissolved and suspended contaminants (metals) was not measured as part of the baseline study because of very low concentrations (Pohl and Hennings 2009), while contaminants in sediments to be dredged were thoroughly assessed. These contaminants included metals cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn)), organo-tin compounds (tributyl-tin (TBT), dibutyl-tin(DBT), monobutyl-tin (MBT)), polyaromatic hydrocarbons (PAHs)), polychlorinated biphenyls (PCBs) and organo-chlorine pesticides (DDTs). Beside sediment contaminants, concentration and release of nutrients were assessed along with oxygen uptake of suspended sediments. These studies are reported separately (FEMA 2013).

3.3 Bathing water quality

The Bathing Water Directive sets the microbial standards for water quality at popular beaches that have been designated as bathing waters because they attract large numbers of bathers. Sixteen designated bathing water sites are located in the vicinity of the planned link or located in an area that potentially may be influenced by the fixed link. The status of bathing water quality and risk for fecal pollution are described by the socalled "bathing water profiles" that are prepared by municipalities every year. Evaluation of the quality of bathing water are based on two bacteriological parameters, i.e. the concentrations of *Escherichia coli* (*E. coli*) and Intestinal Enterococci (IE).

Potential sources for coliform bacteria at beaches are:

- waste water discharges, especially during extreme precipitation and overflow
- streams can carry a risk of fecal pollutions from wild animals and household
- rainwater outlet can introduce fecal bacteria in connection to precipitation where the rain washes fecal bacteria from roads and roofs.

Location of beaches and status of bathing water in 2010 is shown in Figure 3-4 and an overview of bathing water status for the past 4 years and potential sources of fecal contamination is listed in Table 3-2.

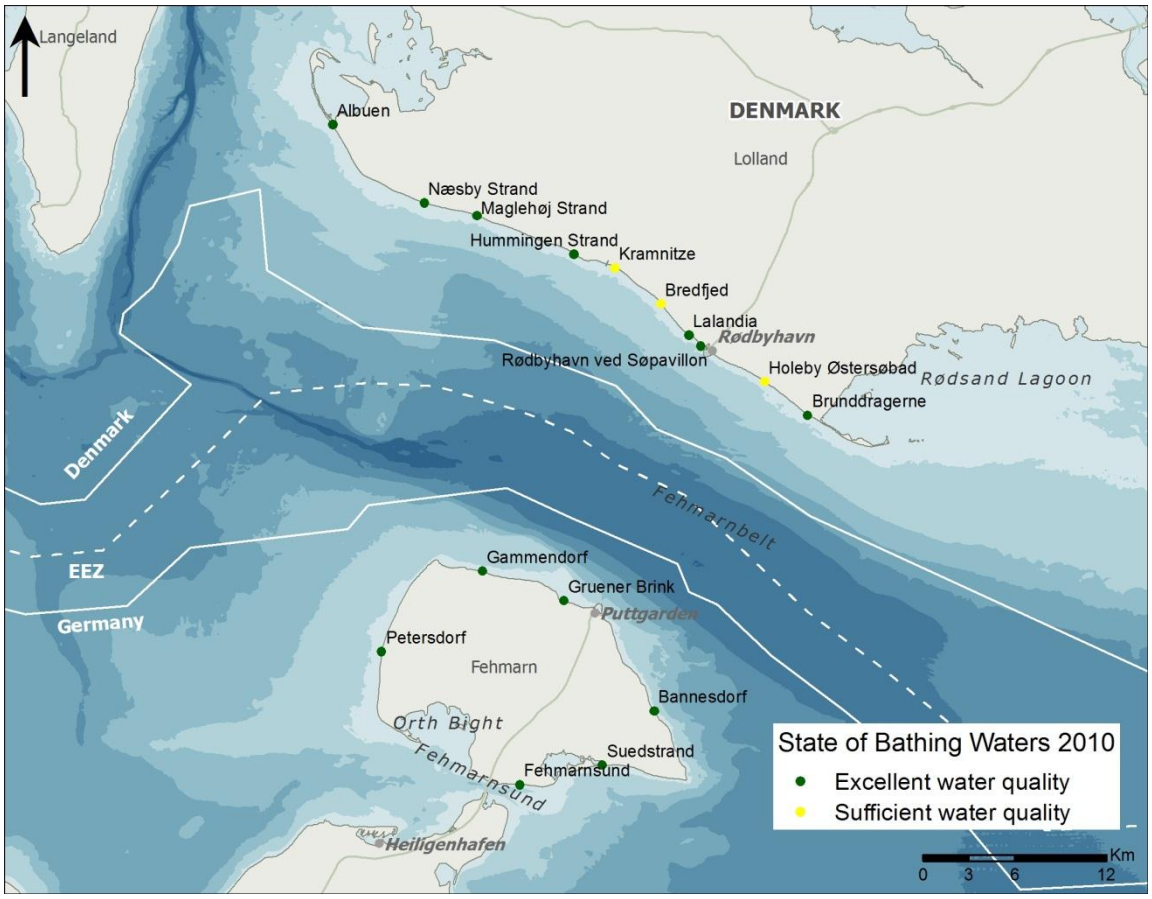


Figure 3-4 *Bathing water compliance. Green indicates that the water quality is compliant with the guide values of the Directive or excellent water quality for 2010. Yellow indicates that the water quality is compliant with the mandatory values of the Directive or sufficient water quality for 2010 (WISE database http:// www.eea.europa.eu/themes/water/interactive/bathing).*

Table 3-2 *Overview of bathing water status and potential sources to fecal contamination; ++: compliant with guide values of the Directive (excellent water quality); +: compliant with mandatory values of the Directive (sufficient water quality); -: not compliant with the mandatory values of the Directive (poor water quality)*

Beach	Potential threat	Bathing water status	
Albuen	Treated waste water from Nakskov treatment plant is discharged into the Langeland Belt ca. 1000 m from coastline. Few minor streams discharge in area.	2007: ++	2009: ++
		2008: ++	2010: ++
Næsby	Rainwater outlet 800 m south of the monitoring station.	2007: ++	2009: ++
		2008: ++	2010: ++
Maglehøj	Rainwater outlet 300 m east of the monitoring station. Small stream discharges approximately 1250 m west of the monitoring station.	2007: ++	2009: ++
		2008: ++	2010: ++
Hummingen	Freshwater outlet approximately 2000 m west of monitoring station. This stream might occasionally influence the bathing water quality.	2007: ++	2009: ++
		2008: +	2010: ++
Kramnitze	No firm knowledge of sources carrying fecal pollution to this beach. A small stream discharges in a small marina near to the beach.	2007: -	2009: ++
		2008: ++	2010: +
Bredfjed	The stream Sandholm Løbet discharges 500 m south-east from the monitoring station.	2007: ++	2009: ++
		2008: ++	2010: +

Lalandia	Treated waste water from Rødby treatment plant is discharged east of Rødby Harbour 3000 m from the monitoring station. Sandholm Løbet discharges 1900 m north-west from the monitoring station.	2007: ++ 2008: +	2009: ++ 2010: ++
Rødbyhavn	Treated waste water from Rødby treatment plant discharged east of Rødby Harbour 1500 m from the monitoring station.	2007: ++ 2008: +	2009: ++ 2010: ++
Holeby Østersøbad	No knowledge of sources carrying fecal pollution to this beach.	2007: ++ 2008: ++	2009: + 2010: +
Brunddragerne	No knowledge of sources carrying fecal pollution to the beach.	2007: ++ 2008: ++	2009: ++ 2010: ++
Petersdorf	South of Petersdorf near Orth treated waste water is discharged into Orther Reede, but this is unlikely to affect the bathing water quality at Petersdorf.	2007: ++ 2008: ++	2009: ++ 2010: ++
Gammendorf	No known sources. However, 2009 was compliant to the mandatory values, indicating that fecal pollution might exist. Minor freshwater outlets from rain water drainage or smaller streams might influence water quality.	2007: ++ 2008: ++	2009: + 2010: ++
Gruener Brink	A pumping station for run-off of surface water is located near the nature protection area of Grüner Brink.	2010: ++	
Bannesdorf	A pumping station for run-off of surface water is located north of Bannesdorf. However, this station is located approximately 4 km from Banesdorf and is not likely to influence the bathing water quality at the beach.	2007: ++ 2008: ++	2009: ++ 2010: ++
Suedstrand	Treated waste water from Burgstaaken is discharged into Burger Binnensee. This plant is however not expected to influence the water quality at Suedstrand.	2007: ++ 2008: ++	2009: ++ 2010: ++
Fehmarnsund	Near Orth treated waste water is discharge into Orther Reede, but this is unlikely to affect the bathing water quality at Fehmarnsund.	2007: ++ 2008: ++	2009: + 2010: ++

Among the 16 beaches 13 had an excellent status in 2010, while 3 on Lolland coast (Kramnitze, Bredfjed and Holeby Østersøbad) had a lower (but sufficient) bathing water quality (Figure 3-3). During the past 4 years there is only one record of poor bathing water quality (Kramnitze in 2007, Table 3-2) and across beaches and years, beaches with excellent status dominated with 89% of all records.

3.4 Secchi depth

The Secchi depth was calculated from light attenuation measured using light sensors mounted on the profiling CTD. Hence, Secchi depths could only be estimated from CTD profiles sampled during daylight. During the two year baseline study 344 Secchi depth values could be estimated.

Secchi depth varied between 4.5 and 9 m where the seasonal variation was much more pronounced than the spatial variation (Figure 3-5). Secchi depths were lowest during the declining spring bloom in February 2009 and during the spring bloom in March 2010 and, highest 1-2 months after the spring bloom peak in April-May. During autumn the Secchi depths were intermediate reflecting the autumn phytoplankton bloom that did not reach the high levels of the spring bloom. Very low Secchi depths were measured during the cruise in January 2010 that followed immediately after a storm and with high concentrations of suspended inorganic solids in the water column.

Averaged over the baseline period Secchi depths in the four subareas were almost identical (Great Belt: 6.90 m; Fehmarnbelt: 7.05 m; Mecklenburg Bight: 7.00 m; Darss Sill: 7.10 m). In contrast, Secchi depths differed somewhat but not significantly ($p = 0.09$, Student's t-test) between years (2009: 7.3 m; 2010: 6.8 m), see

Table 3-3. If the different timing of spring bloom and other seasonal effects were accounted for by excluding February and March data and, only including data where monthly data were available for both years (balanced data), the Secchi depth was significantly higher in 2009 than in 2010 using a p-level at 0.05 to reject H_0 hypothesis (Table 3-3).

Table 3-3 Average Secchi depth (m) in 2009 and 2010 and p-level of Student's t-test. H_0 hypothesis (i.e. Secchi depths were identical in 2009 and 2010) was rejected using balanced data.

Data selection	2009	2010	p-level
All data	7.30m	6.80m	0.09
Balanced data	7.45m	6.95m	0.02

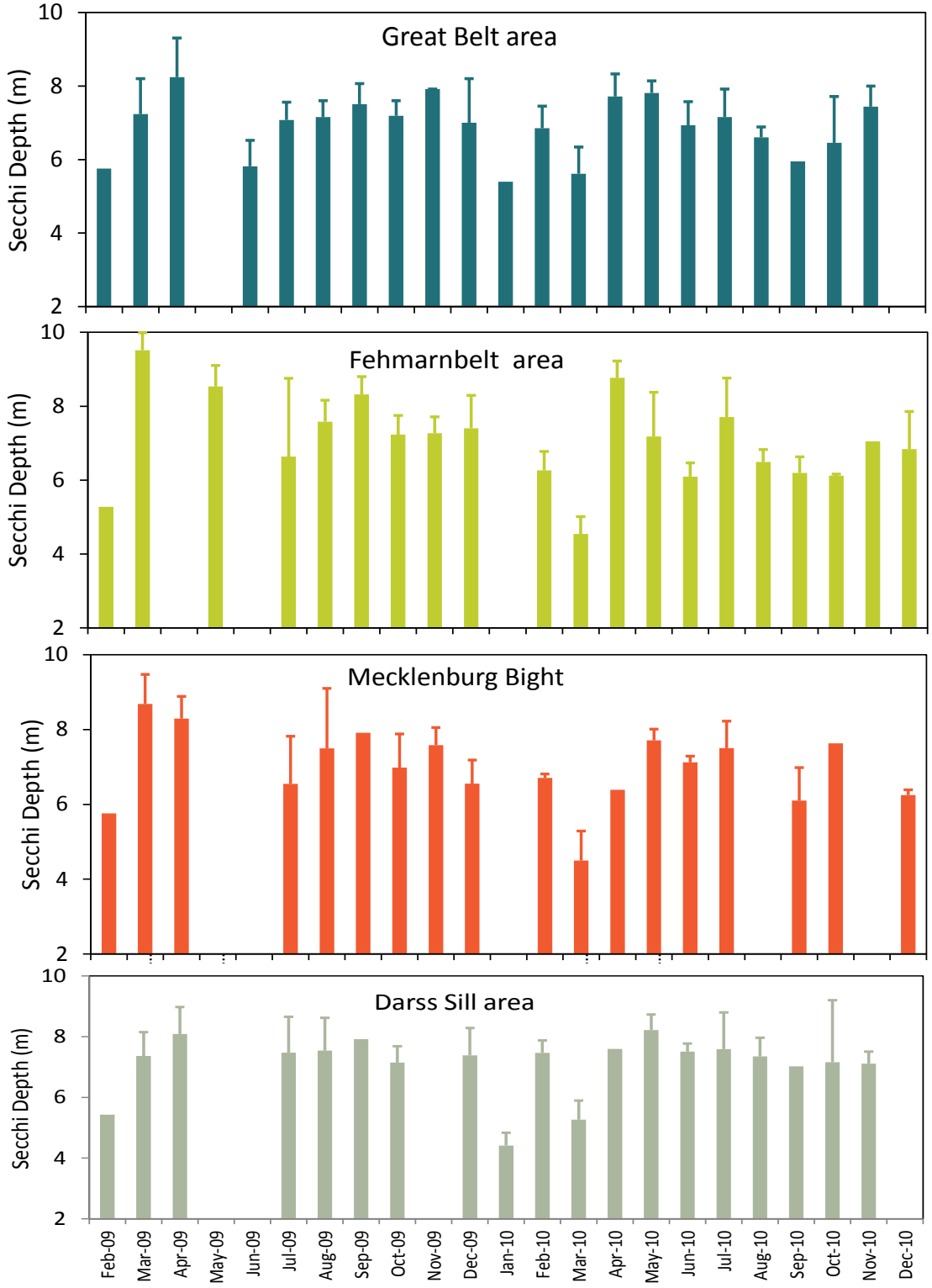


Figure 3-5 Monthly means of Secchi depth (+SD) at the 4 subareas. Note: the y-axis starts at 2m.

3.4.1 *Historical Secchi depths*

The first measurements of Secchi depth were carried out in the beginning of 1900 (Aarup 2002). Secchi depth in the Belt Sea including the Fehmarnbelt has decreased from ca. 9.3 m prior to 1940 to ca. 6.5 m in the 1980- and 1990'ies (Savchuk et al. 2006) as a result of increased phytoplankton production and bio-

mass, indicating that light availability may limit depth penetration of benthic autotrophs at bottom. Large Secchi depths (> 9 m) 100 years ago are indirectly confirmed by historic data from 1887 to 1891 that document the presence of extended macro-algal beds in the western Baltic including the Fehmarnbelt and the Darss Sill at depths larger than 20 m and scattered macroalgal populations down to 30 m depth (Reinke 1893).

Recent historical data from the Fehmarnbelt area (St. 952 equivalent to H037 in the alignment area, see Figure 2-1 and St. 954 equivalent to 46 in the eastern Darss Sill area, see Figure 2-1) collected under the Danish monitoring program show yearly (averaged over May-October) Secchi depths between 4.5 m and 8.1 m (Figure 3-6). In a direct comparison the average values Secchi depths were 0.8-1.1 higher during the baseline studies, but considering the variation in Secchi depth in the historical data and the use of different methods (Secchi disk in historical data, light extinction during the baseline study) differences in Secchi depth are probably not significant.

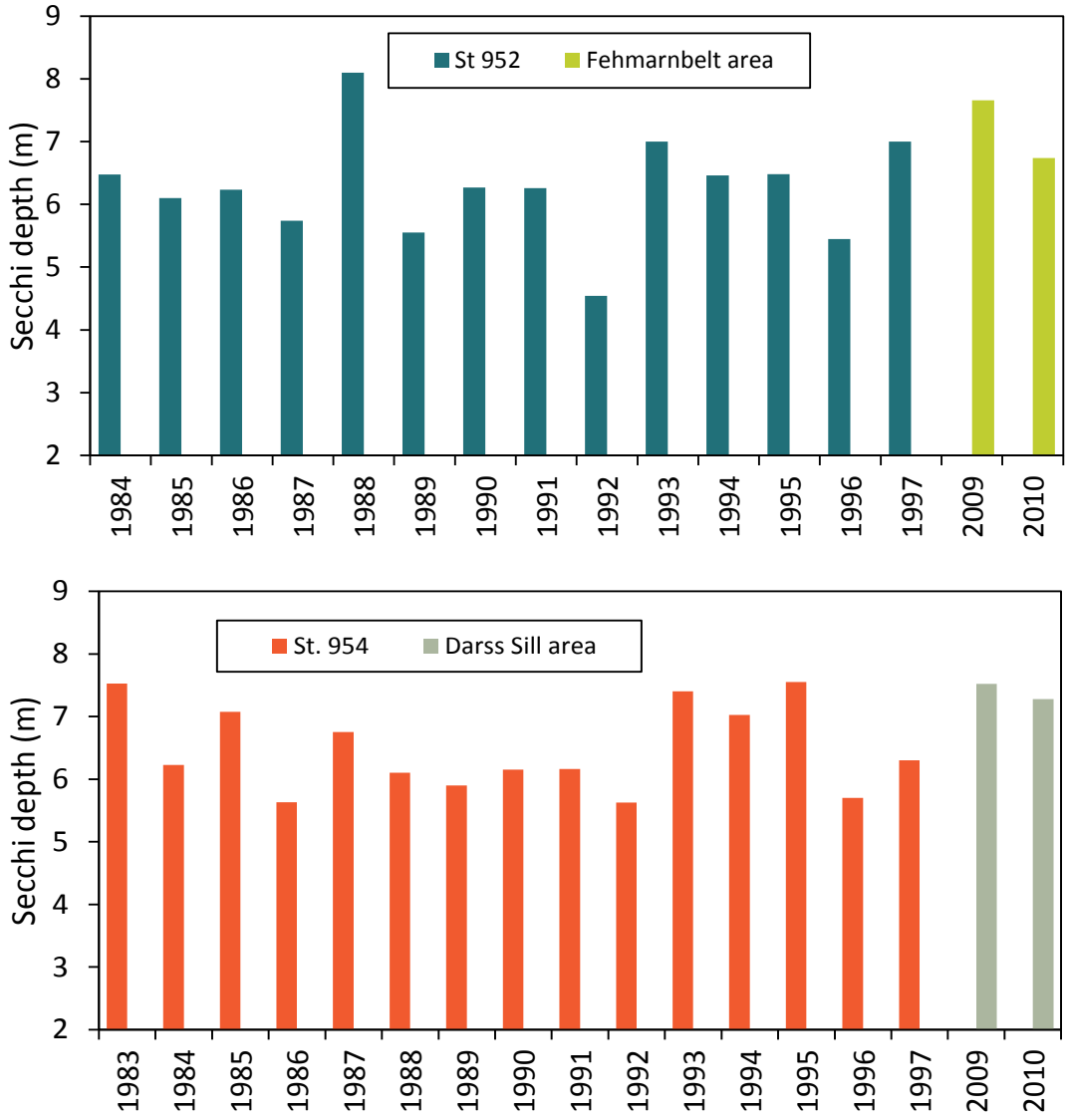


Figure 3-6 Historical Secchi depths measured in Fehmarnbelt (St. 952 and off Gedser Reef, St. 954). Data from the Danish national Monitoring Program extracted from the Marine database MADS (2011).

3.5 Oxygen

High concentrations of oxygen are required to support a healthy and diverse benthic system. If and when oxygen become becomes reduced to below 4-5 mg O_2 l^{-1} (i.e., oxygen deficiency) conditions gradually becomes detrimental to aquatic organisms living in and on the seabed.

The Belt Sea has a natural propensity for oxygen problems because of low tidal currents and an estuarine circulation giving rise to seasonal stratification separating the dense bottom water from the surface water and thus also from the atmospheric oxygen. As a consequence of regular stratification during summer, oxygen concentrations in bottom water in the Belt Sea show both seasonal and inter-annual variation. Main drivers for the oxygen concentrations include atmospheric forcing, temperature of bottom water, mixing/stratification and, inter-annual variation in sedimentation of organic matter. The latter show some correlation to N-load from land (Rasmussen et al. 2003).

Summer and autumn oxygen concentration in bottom water has decreased significantly between 1960-ies and 1990 in the Fehmarnbelt (Rasmussen et al. 2003); in accordance with long term increase in nutrient loads to the Belt Sea, but overall the physical forcing and especially the advection of oxygen rich waters and the intensity of vertical mixing during summer and autumn are the most important influences for bottom water oxygen (Bendtsen et al. 2008).

3.5.1 *Seasonal variation*

During the baseline investigation, dissolved oxygen was measured continuously from late March 2009 through March 2011 at the 3 mooring stations located in the Fehmarnbelt area at the proposed alignment between Rødbyhavn and Puttgarden (northern station MS01 and southern station MS02) and in Mecklenburg Bight (MS03) (see Figure 2-2). Oxygen concentration at the shallow Northern Fehmarnbelt (MS01) was generally good, while the Southern Fehmarnbelt (MS02) and Mecklenburg Bight (MS03) experienced oxygen deficiency during late summer, especially in 2010.

The oxygen situation differed in 2009 and 2010 (Figure 3-7). In 2009 the oxygen minima at MS02 (Southern Fehmarnbelt) was reached in late September, but the concentration never fell below 1 mg O_2 l^{-1}. In 2010 the bottom water experienced extended periods of serious oxygen deficiency. At MS02 the oxygen concentration fell below 1 mg O_2 l^{-1} in beginning of September 2010 and reached anoxic conditions in late September persisting to 3rd October when a low pressure front passed. The better oxygen conditions in 2009 compared to 2010 were due to stormy winds which prevailed at the end of August/beginning of September from varying directions.

The oxygen situation during 2010 was worse at MS03 (Mecklenburg Bight) with an average concentration in July at 1.1 mg O_2 l^{-1}, in August at 0.75 mg O_2 l^{-1} and in September at 1.3 mg O_2 l^{-1}. In July oxygen was below 1 mg O_2 l^{-1} in 47% of the time, in August 71% of the time and in September lower than 1 mg O_2 l^{-1} in 82% of the time. The difference between Fehmarnbelt (MS02) and Mecklenburg Bight (MS03) relates to better ventilation (i.e. higher current speeds at bottom) at MS02 and probably a higher oxygen demand in the organic rich sediments in Mecklenburg Bight.

Besides the seasonal variation bottom water, oxygen showed a high variability on a daily scale probably caused by frequently shifting current situations (Figure 3-8).

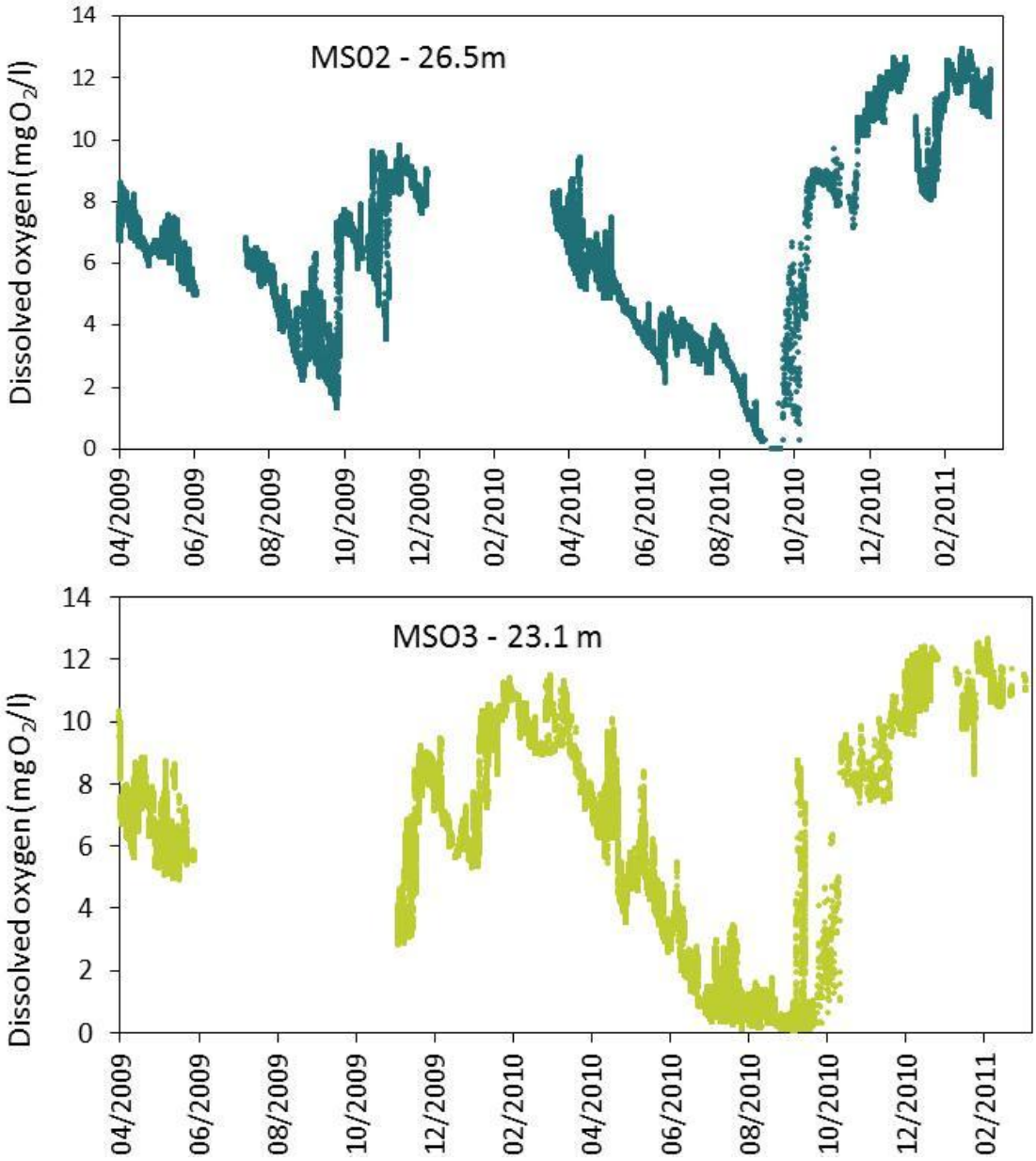


Figure 3-7 *Near-bottom oxygen concentration at MS02 (Southern Fehmarnbelt) and MS03 (Mecklenburg Bight) main stations (moorings). Oxygen measurements were taken every 10 min. Gabs in data was due to sensor failure.*

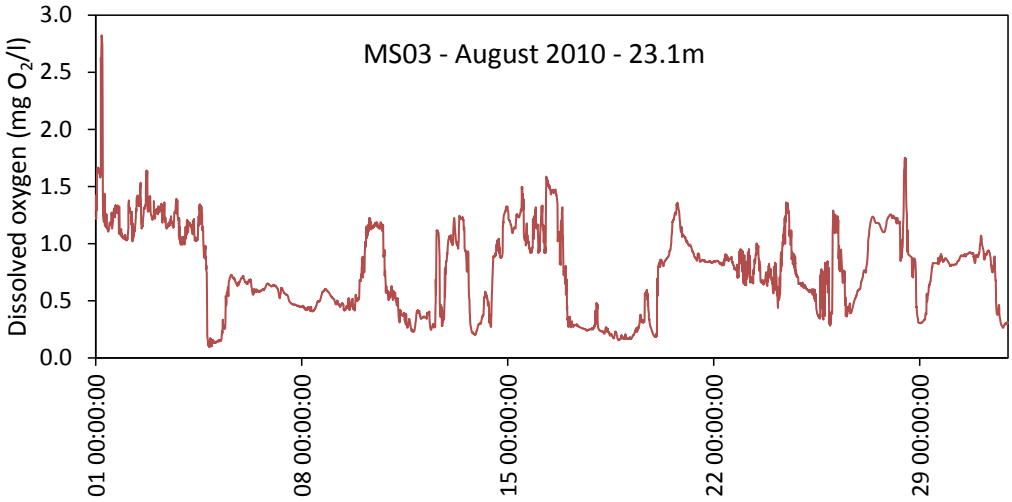


Figure 3-8 *Near-bottom oxygen content at MS03 during August 2010. Line drawn based on 10 min interval measurements.*

3.5.2 ***Spatial variation***

The very low oxygen concentration reached at the moored stations in August-October 2010 (Figure 3-7) was representative for all the deep parts of the Fehmarnbelt. This was confirmed by the monthly cruise data (Figure 3-9 and Figure 3-10). In June 2010 oxygen conditions generally were good in the Great Belt area, slightly depressed (2-4 mg O_2 l^{-1}) in Fehmarnbelt and further depressed in the Mecklenburg Bight area (Figure 3-8). In August the oxygen concentration was further decreased approaching anoxia in the Mecklenburg Bight area (Figure 3-9 lower).

In September 2010, the oxygen concentration was very low (0-1 mg O_2 l^{-1}) in the deep parts of Kiel Bight (southern part of Great Belt subarea), in the central deep parts of Fehmarnbelt subarea and in the Mecklenburg Bight (Figure 3-10). In October very low oxygen concentrations were found in the eastern deep part of the Fehmarnbelt and in the Mecklenburg Bight. The change in distribution patterns of oxygen in September and October indicates an eastward advection of oxygen poor water in the bottom layer.

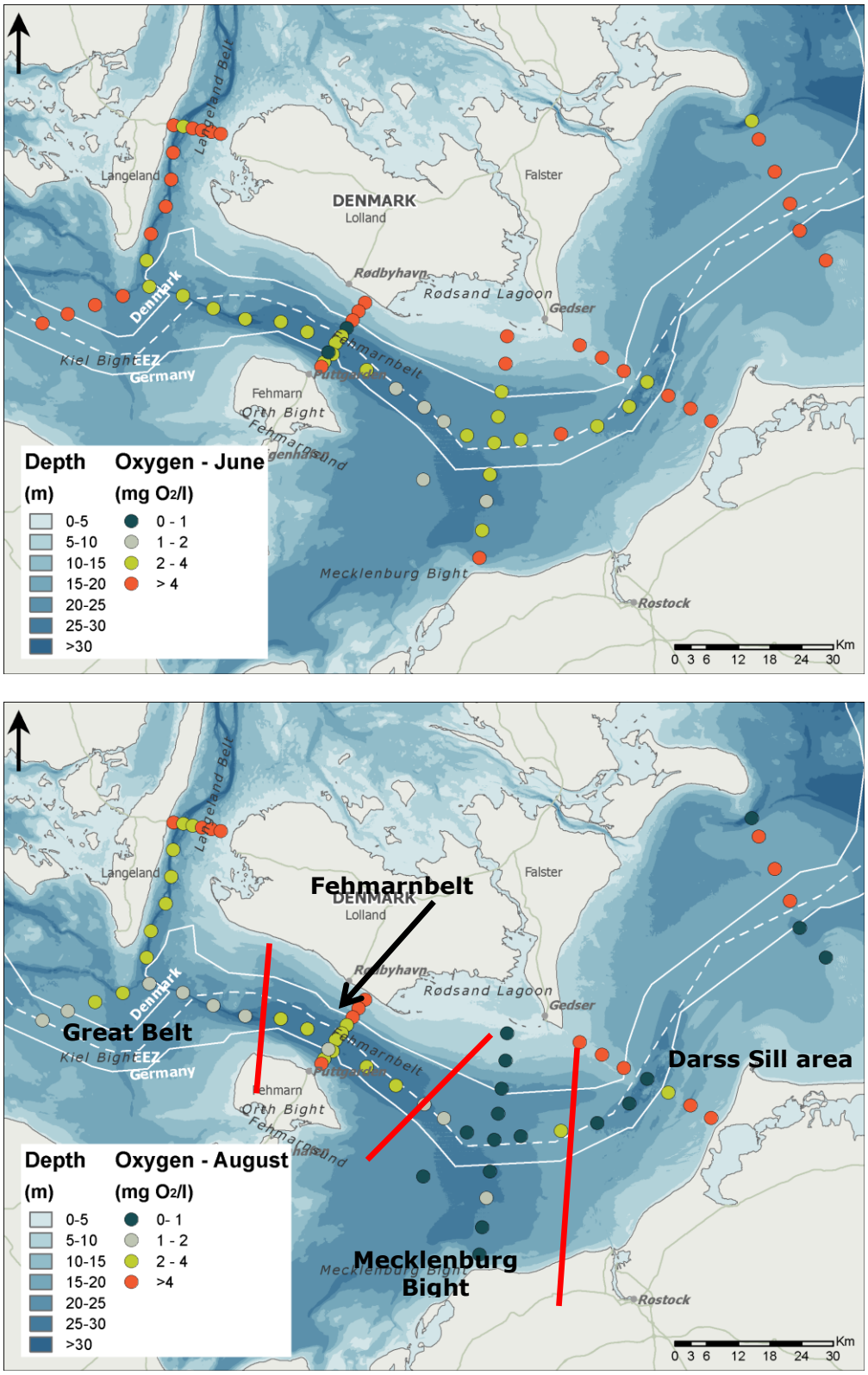


Figure 3-9 *Concentration of oxygen in near bed layer in June (14-17 June) and August (13-23 August) in 2010 (data from oxygen sensor mounted on CTD). Delineation of subareas indicated by red boundaries.*

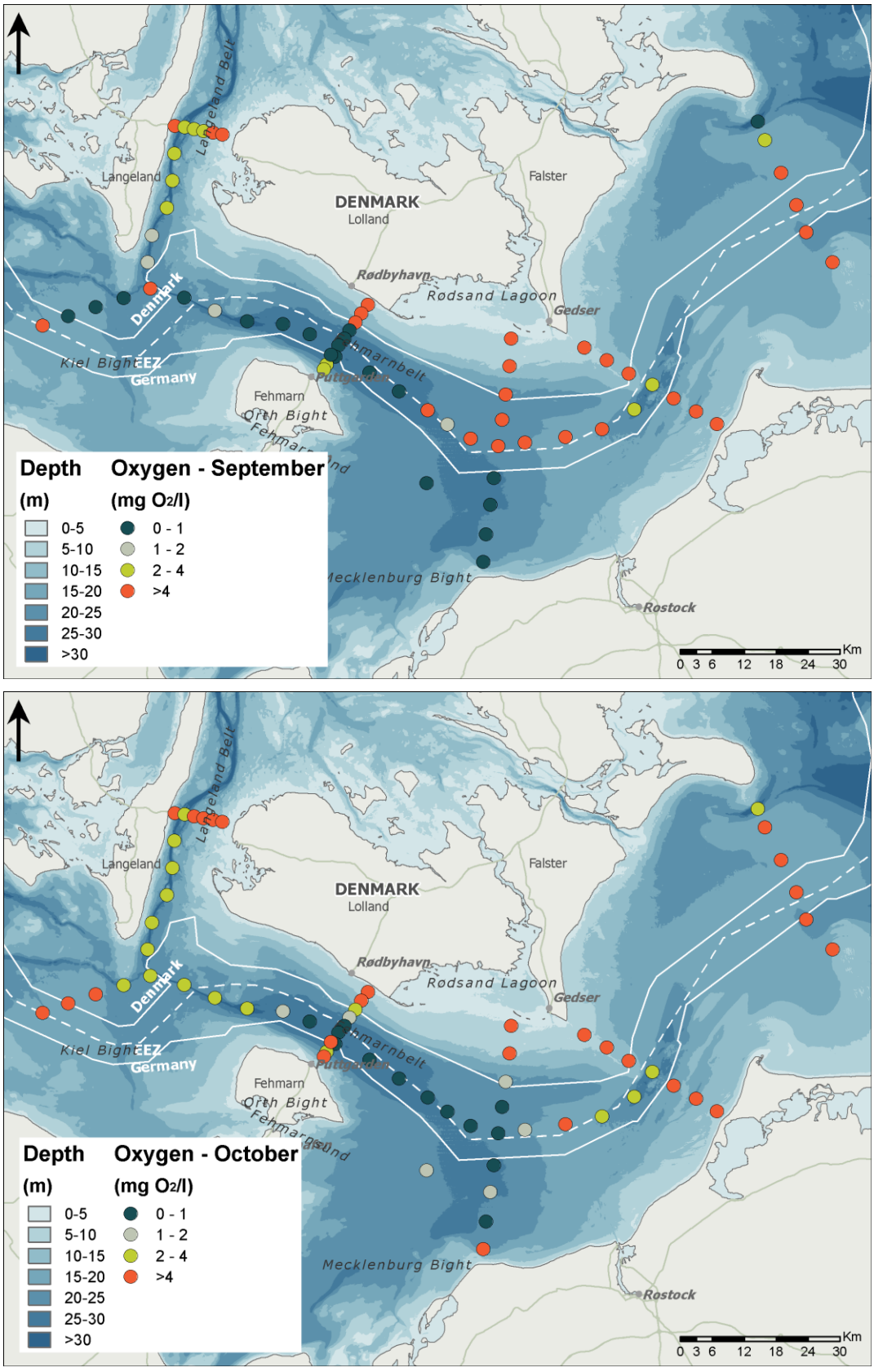


Figure 3-10 Concentration of oxygen in near bed layer in September (22-28 September) and October (11-14 October) 2010 (data from oxygen sensor mounted on CTD).

4 HLOROPHYL-A, PHYTOPLANKTON COMPOSITION AND PRIMARY PRODUCTION

4.1 Chlorophyll-a

Chl-a concentration is a proxy estimate of phytoplankton biomass and it is the most common parameter used to characterize the potential for plankton productivity. The chl-a concentration was investigated according to the HELCOM protocol (HELCOM 2007) which allows the direct comparison of actual and historical data for the base-line investigation. In addition *in situ* fluorescence depth profiles were sampled monthly at between 40 and 115 stations to obtain a wider coverage of samples, which allows a mapping of the chl-a concentrations for the whole investigation area.

4.1.1 *Spatial variation*

Phytoplankton and thus also chl-a often is irregularly distributed in the water body due to varying strength of physical forcing, nutrient loads and biological processes. In the greater Fehmarnbelt area the horizontal gradient most probably is determined by hydrographical processes (e.g., currents and mixing), nutrient richness and the large scale salinity gradient.

Horizontal distribution of surface chl-a varied in the investigation area depending on season; as evident from *in situ* fluorescence (see examples in Figure 4-1, Figure 4-2, Appendix B).

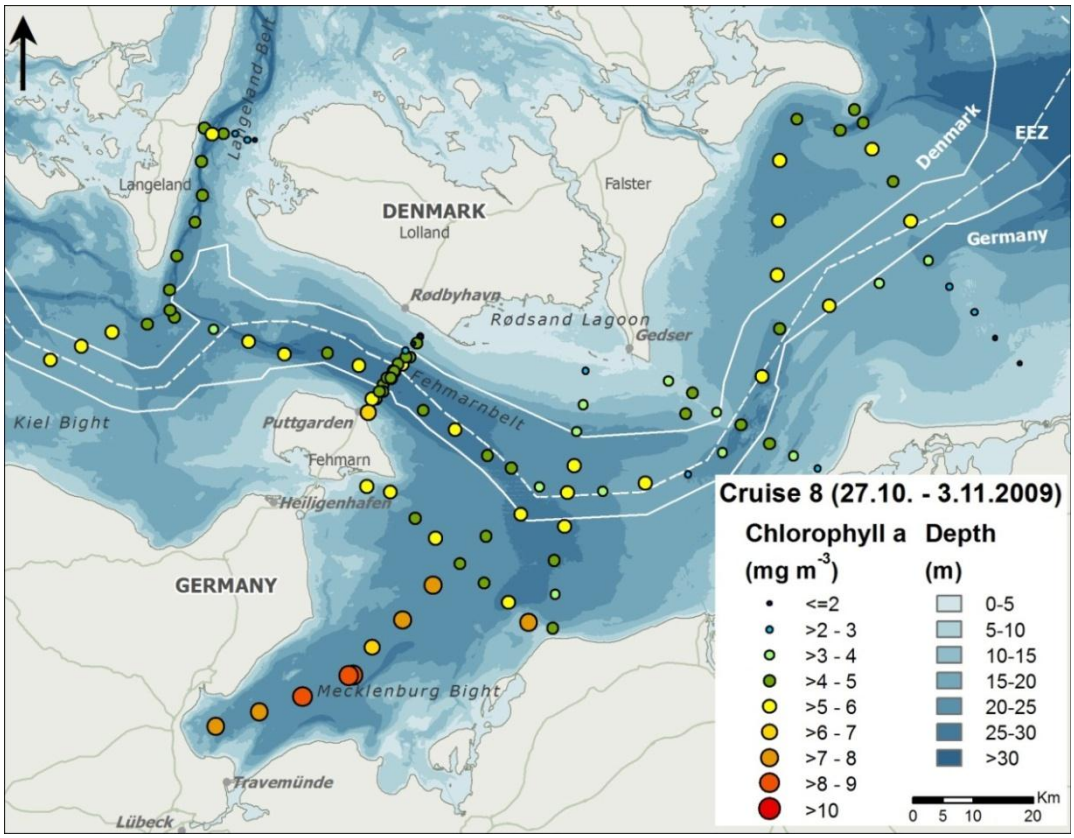


Figure 4-1 Spatial distribution of chl-a in greater Fehmarnbelt during a cruise in late autumn 2009 (based on in situ fluorescence profiles calibrated with in vitro measurements).

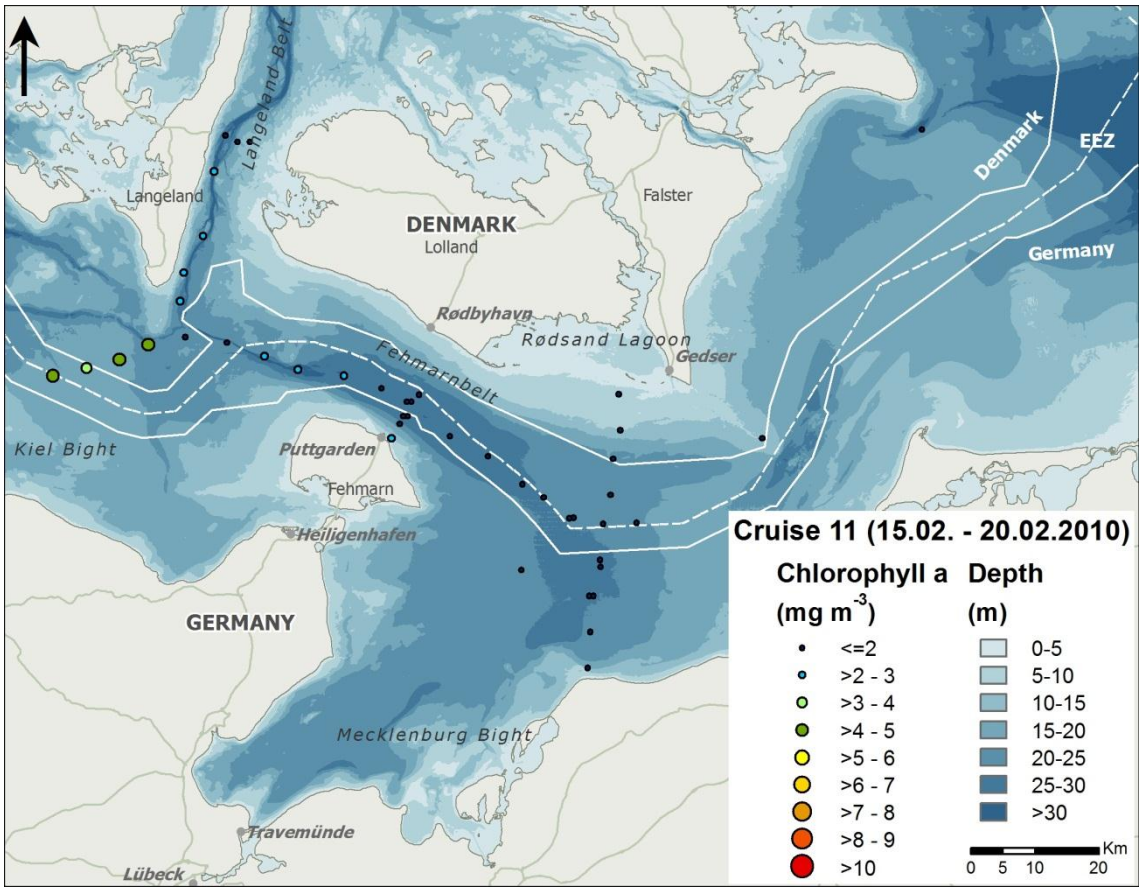


Figure 4-2 Spatial distribution of chl-a in greater Fehmarnbelt during cruise early spring 2010 (based on in situ fluorescence profiles calibrated with in vitro measurements).

Overall, the spatial variation in chl-a was modest compared to the seasonal variation. However, notable patterns were a lower concentration in the Darss Sill area than in the other three areas, and a higher biomass in Mecklenburg Bight during autumn 2009 and spring bloom 2010 compared to the other three areas (Figure 4-3).

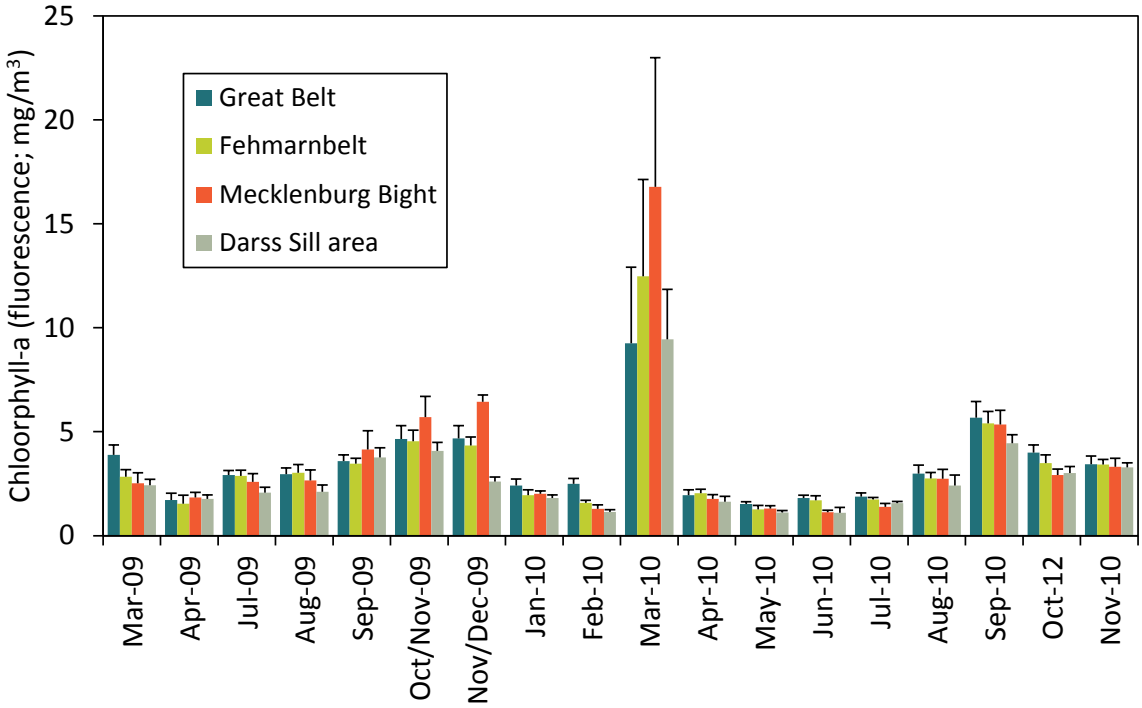


Figure 4-3 *Spatial variation in chl-a calculated from in situ fluorescence in Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill areas. Bars represent averaged concentrations (with +SD error bars) over stations sampled within each of the four areas (stations included in different areas and their positions are shown in Appendix A).*

Are water quality and plankton stations representative for pre-defined areas?
Data in Table 4-1 show that with respect to chl-a the 12 plankton stations provided a good representation of the general conditions in the predefined areas. With the exception of the Great Belt area the average chl-a concentration did not differ between the off-shore biological stations and the wider distributed and more numerous off-shore stations. For the Great Belt area the average concentration of chl-a was 0.19 mg chl-a m^{-3} higher (p=0.04) at the 'plankton stations´ compared to all off-shore stations sampled in this area. This difference was caused by an almost consistently higher concentration at station 360 which is the most western located station in the baseline study.

Table 4-1 *Comparison of average concentration of chl-a (mg m^{-3}) at the off-shore biological stations ("Plankt.") and all off-shore stations ("Fluoro") within the respective area at the 18 cruises conducted. Based on* in situ *fluorescence profiles. Differences in average concentration were tested by pair-wise 2-tailed t-test (lower row).*

	Great Belt		Fehmarnbelt		Mecklenburg Bight		Darss Sill area	
Cruise	**Plankt.**	**Fluoro**	**Plankt.**	**Flouro**	**Plankt.**	**Flouro**	**Plankt.**	**Flouro**
Mar-09	4.22	3.89	1.76	2.83	2.60	2.52	2.50	2.43
Apr-09	1.65	1.72	1.46	1.54	1.92	1.84	1.66	1.77
Jul-09	3.32	2.92	2.77	2.88	2.31	2.59	2.04	2.07
Aug-09	2.77	2.95	2.77	3.03	2.57	2.65	2.18	2.11
Sep-09	4.20	3.59	3.36	3.46	4.36	4.15	3.88	3.76
Oct-09	4.89	4.66	4.43	4.54	5.90	5.70	4.00	4.08
Nov-09	4.80	4.68	5.83	4.33	6.20	6.45	2.74	2.60

	Great Belt		Fehmarnbelt		Mecklenburg Bight		Darss Sill area	
Cruise	**Plankt.**	**Fluoro**	**Plankt.**	**Flouro**	**Plankt.**	**Flouro**	**Plankt.**	**Flouro**
Jan-10	3.07	2.41	1.87	1.94	1.97	2.01	1.80	1.81
Feb-10	2.69	2.50	1.38	1.58	1.31	1.30	1.18	1.14
Mar-10	10.27	9.25	14.80	12.48	20.78	16.78	8.44	9.44
Apr-10	2.04	1.95	1.48	2.04	1.59	1.77	1.52	1.64
May-10	1.56	1.52	1.11	1.26	1.26	1.31	1.22	1.11
Jun-10	1.63	1.81	1.15	1.70	1.15	1.13	1.27	1.11
Jul-10	1.96	1.88	1.70	1.74	1.44	1.39	1.62	1.56
Aug-10	3.29	2.98	2.75	2.75	2.74	2.75	2.23	2.41
Sep-10	5.08	5.67	6.30	5.40	5.27	5.34	5.10	4.45
Oct-10	4.38	3.99	3.21	3.48	3.74	2.91	3.57	3.01
Nov-10	3.45	3.44	3.73	3.42		3.32	3.88	3.29
Average	3.62	3.43	3.44	3.36	3.95	3.68	2.82	2.77
p-level	*0.04*		*0.67*		*0.29*		*0.51*	

A direct comparison based on water samplings at biological stations (i.e. independent of the seasonal cycle) shows that the variation in chl-a is dominated by seasonal variation rather than spatial variation. According to the MDS-ordination analyses (Figure 4-4) the variability within the stations is much greater than between the areas (Figure 4-4 left). When plotting seasons instead (Figure 4-4 right) an aggregation of summer and autumn samples could be observed by MDS-ordination, although the differences were not statistically significant, primarily due to a limited sample number.

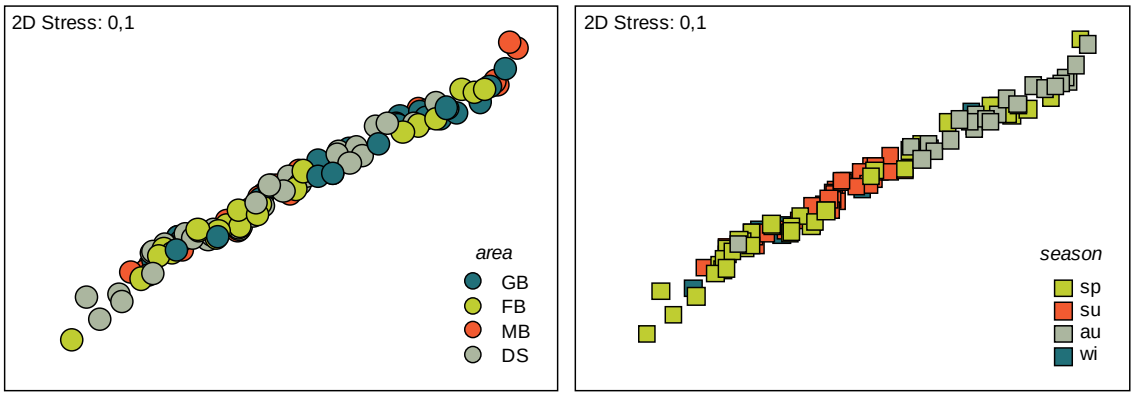


Figure 4-4 *MDS plots of spatial chl-a data sets (water bottle measurements). The analyses included all samplings at all biological stations (February 2009-February 2010) and are based on mean values of 0-10 m sampling. For area aggregation see Figure 2-1. MB: Mecklenburg Bight; DS: Darss Sill; FB: Fehmarn Belt; GB: Great Belt; sp: spring, su: summer; au: autumn; wi: winter.*

Near-shore stations

Chl-a at the near-shore stations grossly followed the variation in the off-shore stations located along the proposed Fehmarnbelt link (H033, H037), except for samplings in November and December where chl-a along Lolland was about 50-75% lower compared to off-shore values (Figure 4-5). It is also notable that the chl-a concentration along the German coast was markedly higher than along the

Danish coast. This trend is also observed in the *in situ* fluorescence data (Figure 4-1, Figure 4-2, Appendix B).

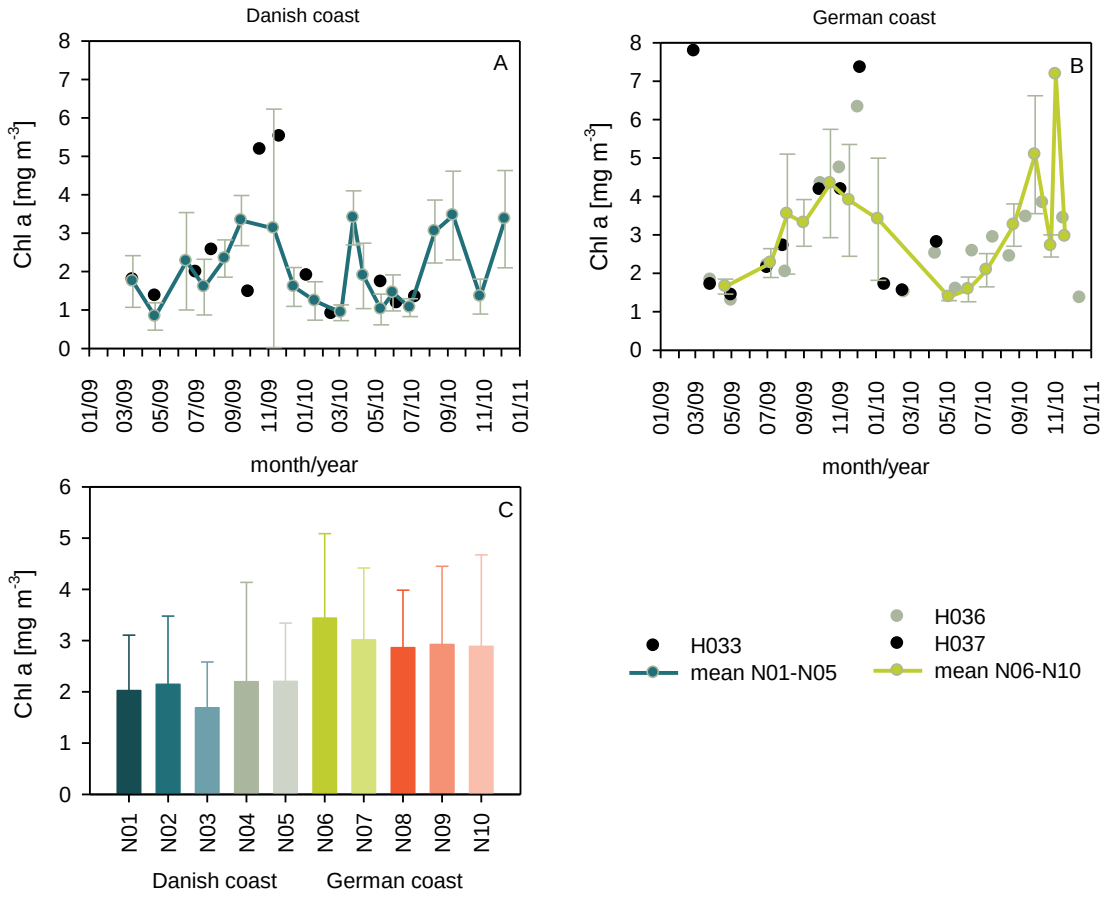


Figure 4-5 *Chl-a concentration at the near-shore stations (water bottle measurements). A and B: Seasonal variation at Danish (N01-N05) and German (N06-N10) near-shore stations in comparison to the seasonal cycle of the off-shore stations at the proposed alignment (black circles). Dots represent mean values (±SD) of the 5 stations along the national coasts (compare with Figure 2-1). C: Annual mean (+SD) of the chl-a concentration of the ten near-shore stations. For number of data sets see Table 2-4.*

4.1.2 ***Seasonal variation***

The seasonal cycle of the chl-a concentration (Figure 4-6) follows the development of the phytoplankton biomass (see Figure 4-4). For the Fehmarnbelt area distinct spring and less distinct but longer lasting autumn blooms were observed in 2009 and 2010. Although the chl-a concentrations are comparable in 2009 and 2010 (Figure 4-3), the growth season was shorter in 2010, due to 1-2 month later start of the spring bloom and a 1 month earlier decline of the autumn bloom. For all stations, the summer chl-a concentrations were similar in 2009 and 2010.

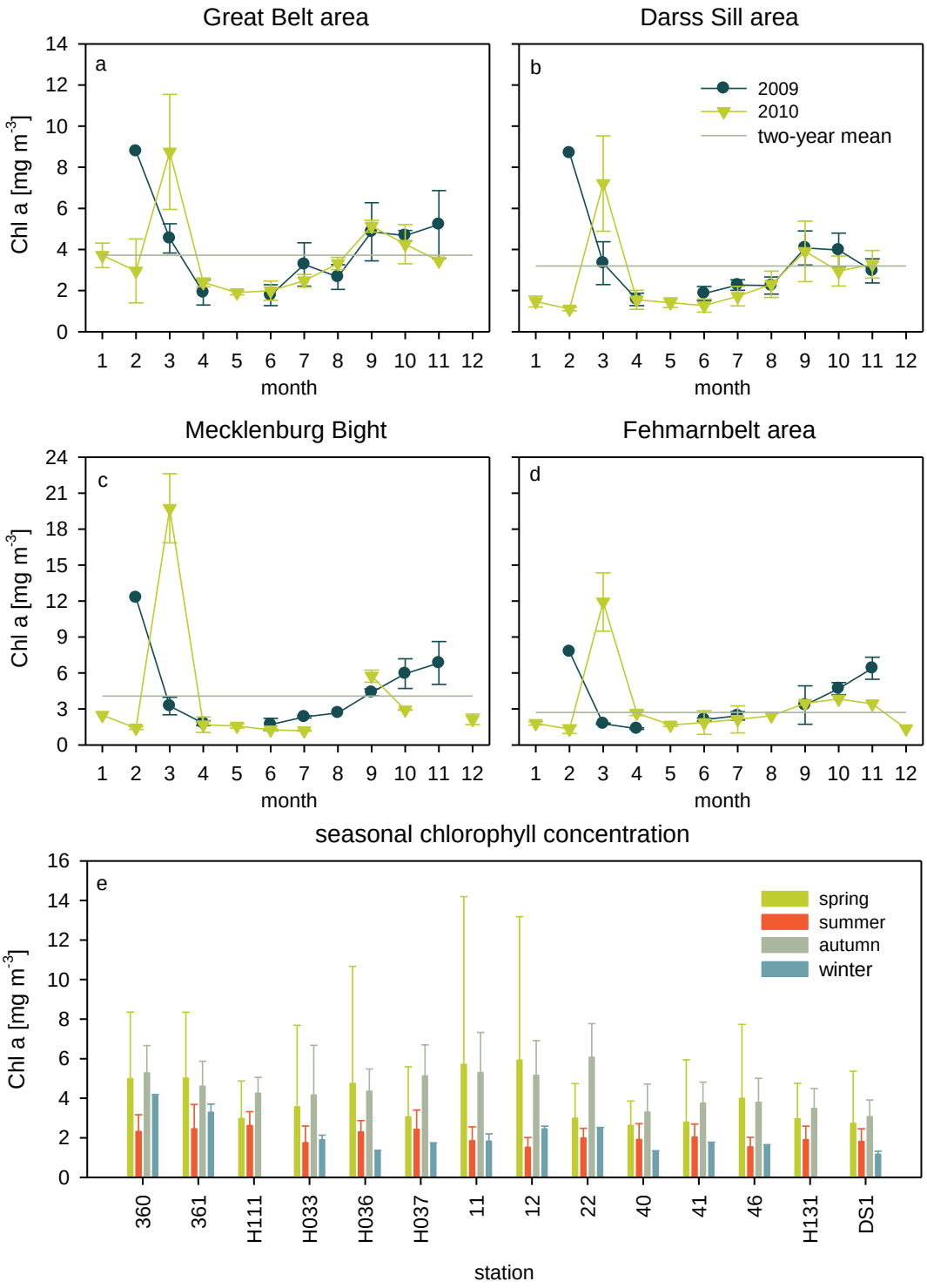


Figure 4-6 *Seasonality of chl-a concentration for the baseline off-shore study area (water bottle measurements). The symbol and bars denote mean values (2009-2010) with standard deviations for the four geographical areas (a-d) and for seasons per station (e). Note the different scales in Figure 3-9a/b and Figure 3-9c/d and e.*

4.1.3 *Vertical distribution*

The vertical gradients of chl-a depend on stratification of the water column and on light penetration. Photosynthetic active phytoplankton is restricted to the upper 8-10 meters (the euphotic zone; see section 4.3). This zone is normally fairly homogeneous due to wind induced mixing (Wasmund and Siegel 2008).

During the baseline study, the depth profile of chl-a was sampled at 4-5 depths (0-1 m, 5 m, 10 m, 20 m). Additional samples were taken, when a strong fluorescence maximum was observed in the CTD depth profile. Figure 4-7 shows depth profiles of selected stations along the west-east gradient.

For most samplings the biomass was homogeneously distributed within the mixing zone of the water column. Gradients in chl-a occurred mainly in times of blooming, when high biomasses of phytoplankton was highest near the surface. Pronounced subsurface maxima were rarely observed (e.g. H111 and DS1 in spring 2010).

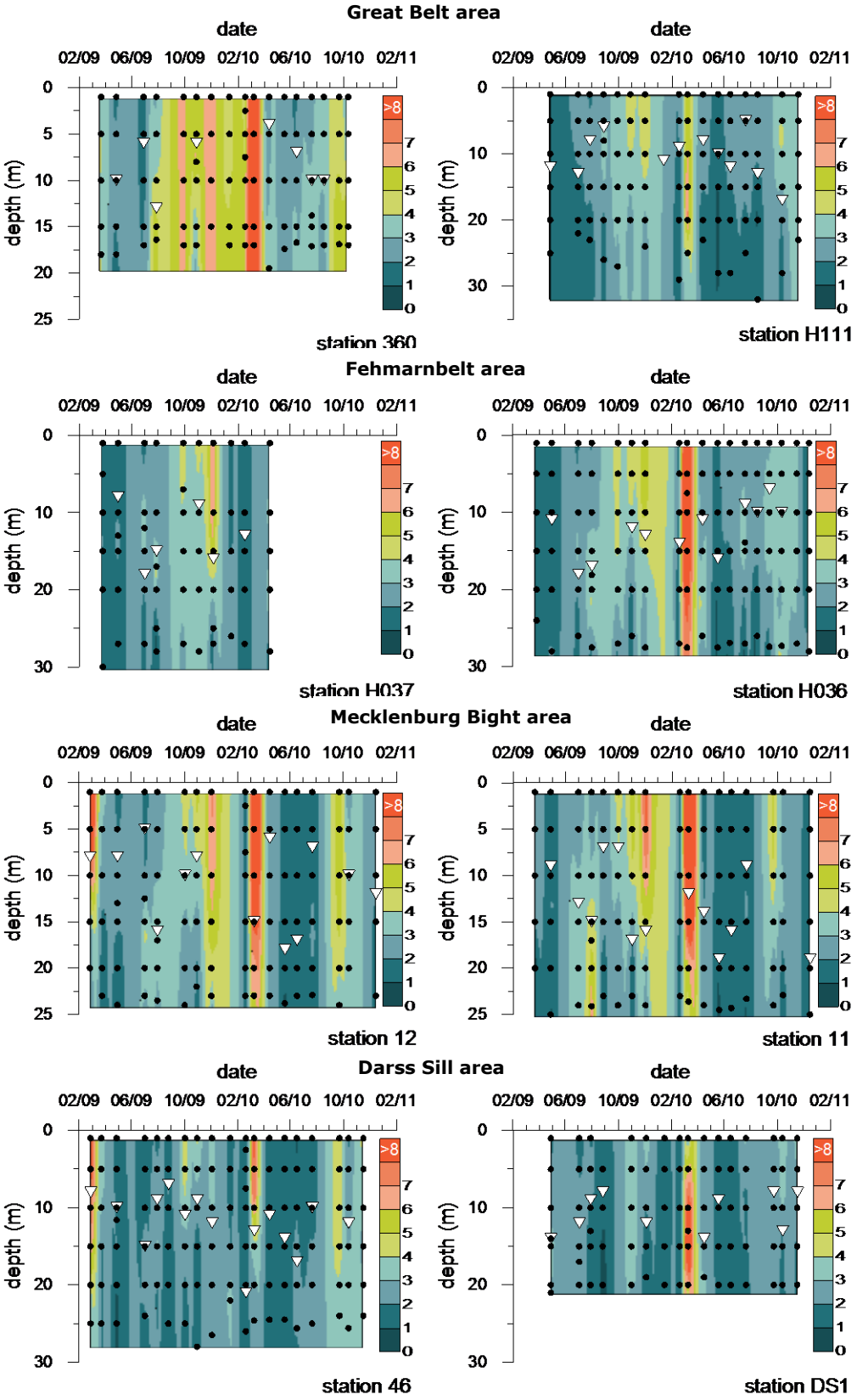


Figure 4-7 *Depth profiles of chl-a from February 2009 through December 2010. Black dots indicate where chl-a samples were taken. The colour scales give chl-a concentration in mg m^{-3}. The white triangles indicate the depth of an observed halocline. For samplings without this marker a fully mixed water body was observed.*

4.1.4 *Historical Chl-a data*

The purpose of analysing historical data and comparing these with data from the baseline study is two-fold. Firstly, we need to quantify if data from the baseline study is in agreement with other datasets (present and historical) for the same area and, secondly we need information on data showing long-term temporal trends.

The concentration of chl-a in 2009 and 2010 follows the succession described by the long term data sets. Figure 4-8 shows a comparison of the historical data sets with measurements from 2009/2010 at the plankton stations. Notable deviations were a very high spring bloom in 2009 at stations 12 and 46. In addition, the 2-3 fold higher concentration during spring bloom in 2009 was observed one month earlier than in previous years. Similar patterns are reported from Kattegat and Arkona Sea for the recent years (HELCOM 1996). In 2010, the spring bloom occurred in March. The summer values as well as the autumn blooms in both years correspond well to the long-term mean values at the stations.

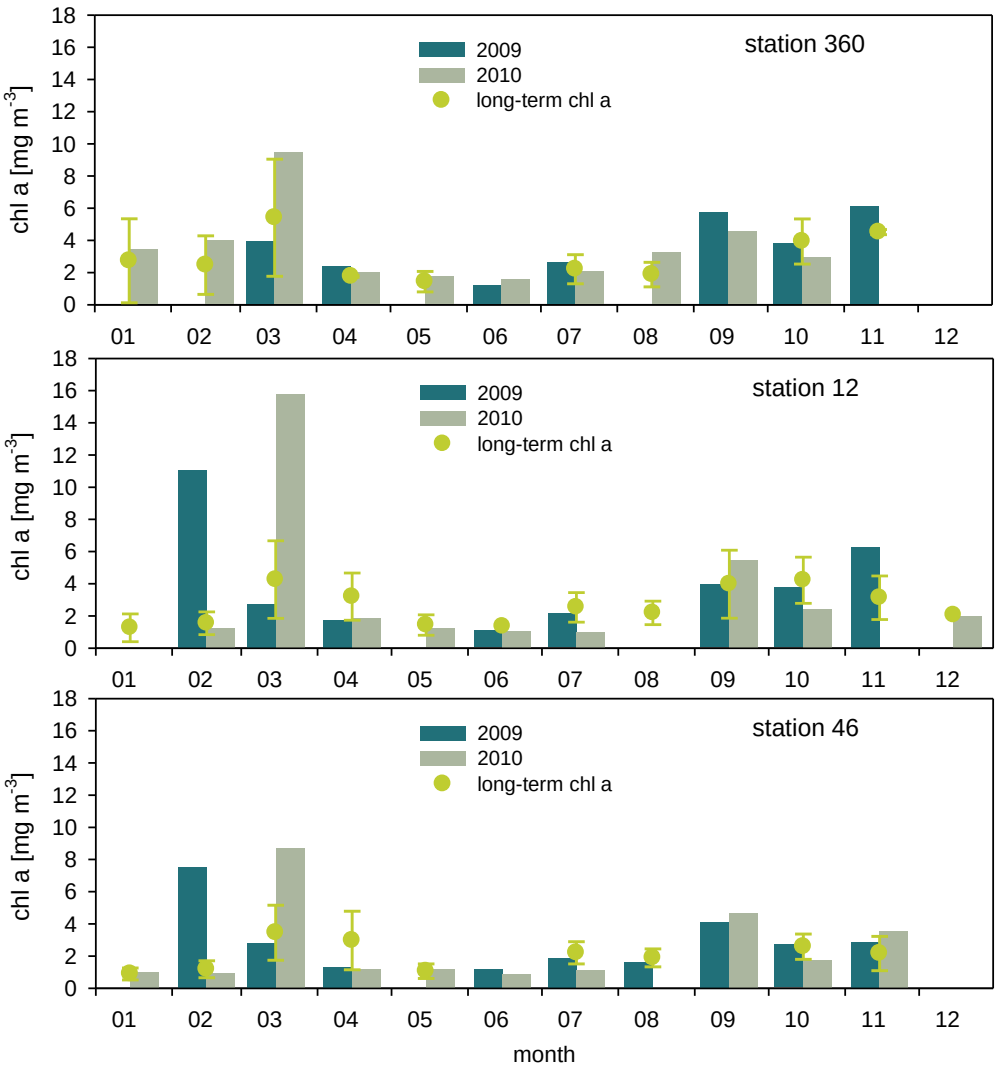


Figure 4-8 *Comparison of monthly means of chl-a in 2009-2010 (bars) with the historical chlorophyll concentrations (dots ± SD 1993-2009). Historical data originate from HELCOM monitoring program and ICES-database. To assure the comparability of data, the chlorophyll concentrations measured according to Lorenzen (1967) were used.*

Seasonal chl-a data (0-10m) from HELCOM monitoring, supplemented by other national and international data sets (Wasmund and Siegel 2008), are presented in Figure 4-9 for the Fehmarnbelt region. Decreasing trends could be observed for chl-a during spring only for station 12 and 46 ($p<0.05$). The summer values are more or less stable for the investigated time-series (Figure 4-9). It is not yet clear, if the trend with a decreasing spring bloom is coupled to a time shifts in spring bloom events, which would mean that the blooms are not sampled during the regular HELCOM monitoring as this normally starts by the end of February. This would lead to an underestimation of the spring biomass measured as chl-a. However, high variability in phytoplankton in both time and space makes trend analyses difficult, especially if the sampling frequency is low.

HELCOM conclude that due to increasing nutrient inputs in the 1970-1990s, the chl-a concentration increased in most parts of the Baltic Sea, especially in the coastal waters (HELCOM 2009). According to Wasmund et al. (2007) the phytoplankton biomass of Kiel Bight increased in the last century from 48-55 mg C m^{-3} (annual means for the time period 1905-1950) to 83-216 mg C m^{-3} (annual means, 2001-2003). The largest increase was observed up to the 1960s, followed by more or less stable biomass values since the 1970'ies (Wasmund et al. 2008). Since the 1990'ies data indicates a downward trend (not significantly) for spring, whereas the summer values are stable or slightly enhanced in the last decade (station 360, Figure 4-9).

For the Fehmarnbelt area (station 10), the time-series end in the 1990'ies, but indicate a non-significantly downward trend starting in the mid 1980'ies. Wasmund and Uhlig (2003) and HELCOM (2002) reported further decreasing of spring values in the Fehmarnbelt area in comparison to the late 1980'ies.

In contrast to the decreasing trends for station 12 and 46 (Wasmund and Siegel 2008), the station 30 (Darss Sill in the transition zone to the Arkona Basin) did not show any clear trends since end of the 1980'ies. According to (Wasmund and Siegel 2008) a slight, but significant increase was observed for the Arkona Basin and the Bornholm Sea. The increase in chl-a in the open waters of the Baltic Sea, with exception of the Bothnian Sea and the Northern Baltic proper, has also been confirmed by (Jaanus et al. 2007) for summer values in the period 1992-2006.

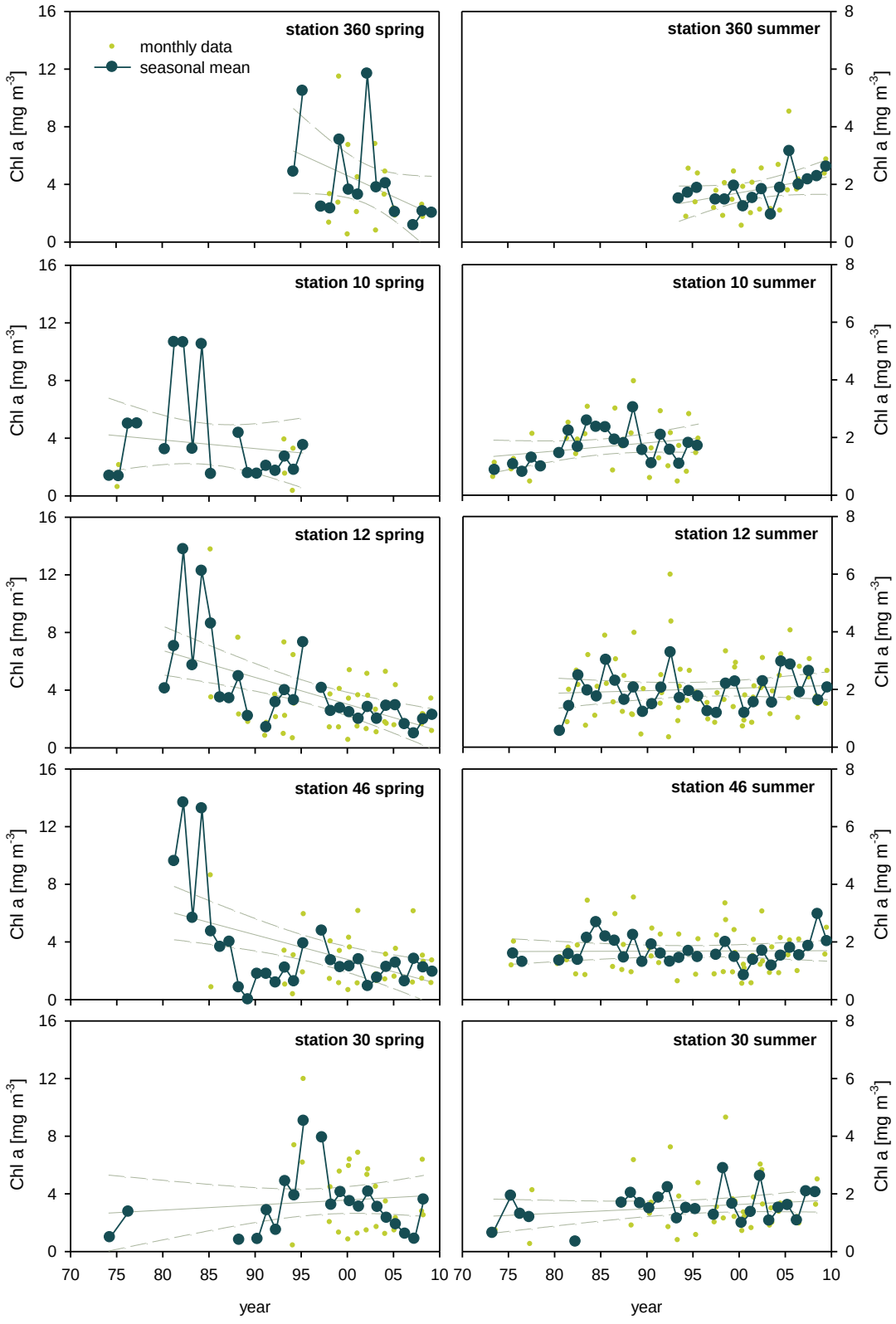


Figure 4-9 *Long-term investigations of chl-a concentrations, both for seasonal means (blue circles and lines) and monthly data (green circles) for spring and summer data (water sample measurements). Data series of Wasmund and Uhlig (2003) and Wasmund et al. (2009). The grey lines denote regression lines and 95% confidence intervals.*

4.2 Phytoplankton composition and distribution

4.2.1 Taxonomic composition

The total number of taxonomic categories recorded during the two years baseline investigation on the three HELCOM stations was 175. Table C.1 (Appendix C) provides the complete species list with indications of nutritional type, rank and seasonal occurrence. The ranking is only a rough indication for species dominance as uncertainties in ranking persist especially for small and rare species.

Within the 175 counting categories, 47 taxa were counted on the genus and 8 on the class or order level. The group "unicell" comprises nano phytoplankton in the size class 2-5 µm which could not be determined in the inverse microscope at 400-fold magnification (mainly Prymnesiophyceae (*Chrysochromulina* sp.) and unicellular and colony forming Cyanophyta). The category "flagellates" includes all unidentified flagellates in various taxonomical classes, but mainly in size classes from 2-10 µm.

The highest number of taxa was observed during summer (119 taxa). Slightly lower numbers were observed in spring and autumn (118 and 110, respectively). The winter sampling was restricted to January and December 2010, due to problems with fixation, the January samples were not analyzed quantitatively and are therefore excluded from all following analyses.

The three stations showed little difference in species richness (Table 4-2). The highest taxa number was observed for station 46 (143 taxa), closely followed by station 12 and 360 (141 taxa). Similar results were obtained for averaged species richness in different seasons (comparing average number of counted species per season).

Table 4-2 Total taxon richness of phytoplankton and average richness during 2009-2010.

station	total	spring	summer	autumn	winter
360	141	85	92	92	64
12	141	83	94	91	70
46	143	93	93	87	52

The ten most abundant taxa and their percentage contribution to total carbon biomass are listed for each station and sampling in Appendix C.

Invasive and potential harmful species

According to Olenina et al. (2009) nine of the identified phytoplankton species are non-native to the Baltic Sea region. These are 5 diatoms: *Coscinodiscus wailesii, Odontella sinensis, Pleurosigma simonsenii, Pleurosira leavis f. polymorpha* and *Thalassiosira punctigera*; and 4 dinophytes: *Alexandrium tamarense, Gymnodinium catenatum, Karenia (Gyrodinium) mikimotoi* and *Prorocentrum minimum)*.

Only the dinoflagellate *Prorocentrum minimum* (Pavillard) Schiller can be categorized as an invasive species, which is spreading and causing significant impacts on plankton community, habitat and ecosystem functioning (Olenina et al. 2009). In the last decade *Prorocentrum minimum* has established a stable occurrence in the Baltic Sea, but no reports of toxic effects exist for this region (Hajdu et al. 2005),

although the species is known to produce toxins (Heil et al. 2005). The impact of this species for the Belt Sea and Arkona Sea is estimated as "level 3" on a five-level-scale in the period 1980-2008 (Olenina et al. 2009). This level 3 denotes a strong biopollution impact, where the invasive species dominated over native species in terms of biomass and lead to alteration of key habitat, as well as shifts in ecosystem functioning and in food web structures. Blooms of *Prorocentrum minimum* was not observed in the investigation area during the baseline investigations. The species occurred on 3 cruises at 2 stations only; attaining a maximum percentage of 3.3% on total biomass in July 2009 (Table 4-3).

Table 4-3 *Occurrence of the invasive species* Prorocentrum minimum *during the baseline field program. Biomass is given in mg C* m^{-3}.

	station 360		**station 12**		**station 46**	
	species biomass	% of total biomass	species biomass	% of total biomass	species biomass	% of total biomass
Jul 2009					1.94	3.29
Aug 2009					0.18	0.30
Oct 2009	0.08	0.08			0.10	0.33
Jul 2010	1.29	0.64	0.16	0.41		
Aug 2010	1.29	0.58				
Sep 2010			0.15	0.09		
Oct 2010	0.09	0.07	0.01	0.01	0.28	0.39

In comparison with data sets from 2000-2008 (Figure 4-10), the percentage and biomass of *P. minimum* was very low in 2009 and 2010. Nevertheless, in the last decade notable values (>10 % of the total biomass) were recorded only in 2002 and 2003. In summer 2002 *P. minimum* reached up to 60% of the total biomass (Figure 4-10).

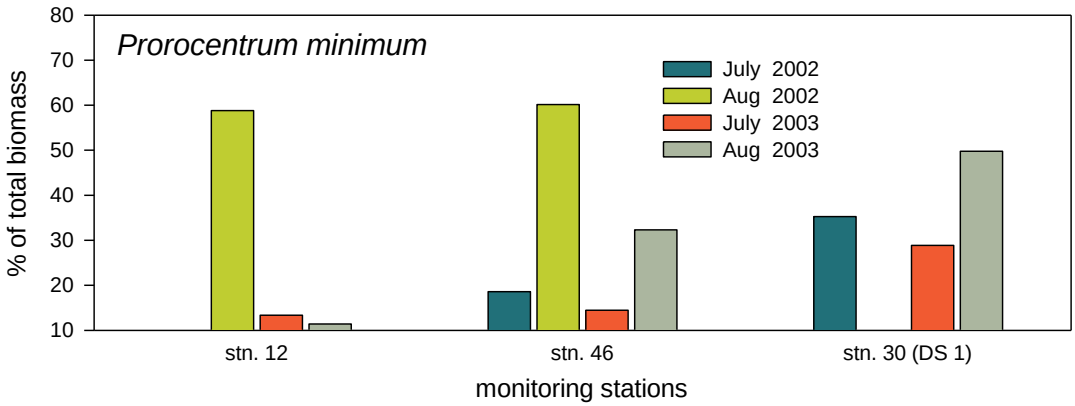


Figure 4-10 *Occurrence of Prorocentrum minimum in the period 2000-2008 in Belt Sea and Arkona Sea. Only observations where P. minimum accounted more than 10% of total biomass are included. For station locations see Figure 2-1.*

The list of potential harmful species found during the baseline field study is shown in Appendix D. The list comprises 32 taxa; 23 of which are known to be able to produce toxin, and 9 which are known to cause mechanical nuisance or other or-

ganism impacts. For comparison, Edler et al. (1996) stated that about 30 potential harmful species of phytoplankton have been found in the Baltic Sea. The list of ICES (2007) comprises 57 species. According to Uronen (2007) ”harmful species” cannot be determined by taxonomy only. A species can be harmful in some situations and harmless in other, depending on its genotype, growth phase and/or nutrient status. The harmful effects vary in intensity and way of acting; in worst cases ecosystems are disturbed or human health is at risk by consuming seafood.

Filamentous cyanobacteria represent a well-known harmful algal group in the Baltic Sea. They have gained attention because they form dense surface-accumulating blooms during late summer. The cyanobacterial biomass observed in 2009 and 2010 were higher than the mean of the HELCOM time series from 1994-2008 but lie within the range detected in these years (Figure 4-11). The biomass did however with few exceptions make up less than 10% of the total biomass (Figure 4-12).

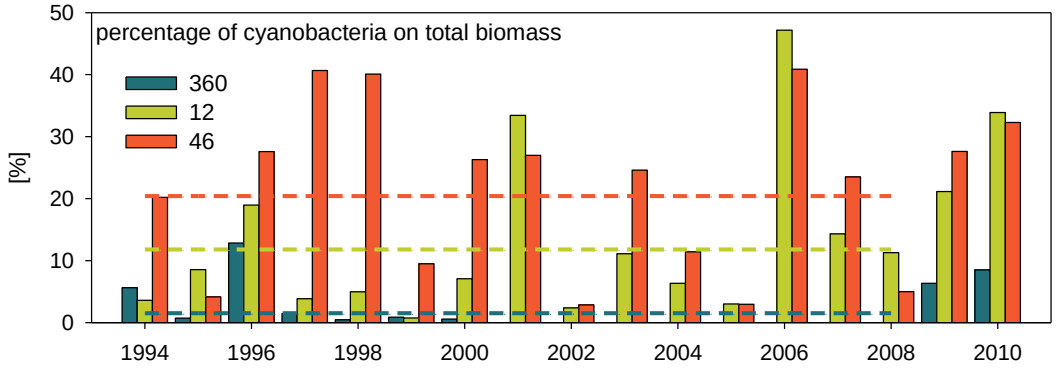


Figure 4-11 *Maximal percentage of cyanobacteria biomass out of total biomass. Estimated per summer season (June, July and August). No HELCOM investigations were conducted at station 360 after 2000. The data of 2009 and 2010 represent the baseline investigation. Lines denote the mean values of the time series.*

In contrast to harmful cyanobacteria, the toxicity of other potentially harmful algal species is less studied in the Baltic Sea (Uronen 2007). Species such as the prymnesiophytes *Prymnesium parvum* and *Chrysochromulin*a spp.; and dinoflagellates (*Dinophysis* spp.) occur regularly in the Baltic Sea plankton (Hällfors 2004), and they are well-known as potentially harmful species worldwide. The largest effects have been reported in the late 1980s, when the prymnesiophytes *Chrysochromulina* spp. caused massive blooms in Skagerrak-Kattegat (Lindahl and Dahl 1990), affecting both plankton and fish (Nielsen et al. 1990). As for the dinoflagellate *Prorocentrum minimum*, the naked form of the silicoflagellate *Dictyocha speculum* which first bloomed in the Kiel Bight area in 1983 is now regularly recorded in this area (Jochem and Babenerd 1989). A bloom of *Dictyocha speculum* was probably responsible for fish mortality in the Danish Alssund in 1988 (Jochem and Babenerd 1989).

The dominating genus of potentially toxic algae observed at the three HELCOM stations during baseline investigation was *Chrysochromulina* spp. (Prymesiophyceae) (Figure 4-12). This taxon was abundant at all HELCOM stations in spring 2009 and 2010. In 2009 the genus reached a maximum of 57% of total carbon biomass in April at station 46 and of 42% at station 360 in March. The pigment analyses showed that this species was also abundant at the other biological stations, particularly in surface samples in April (between 21-46% of the total biomass, Figure

4-13) and subsurface samples in early summer (between 5-42% of the total biomass, Figure 4-14).

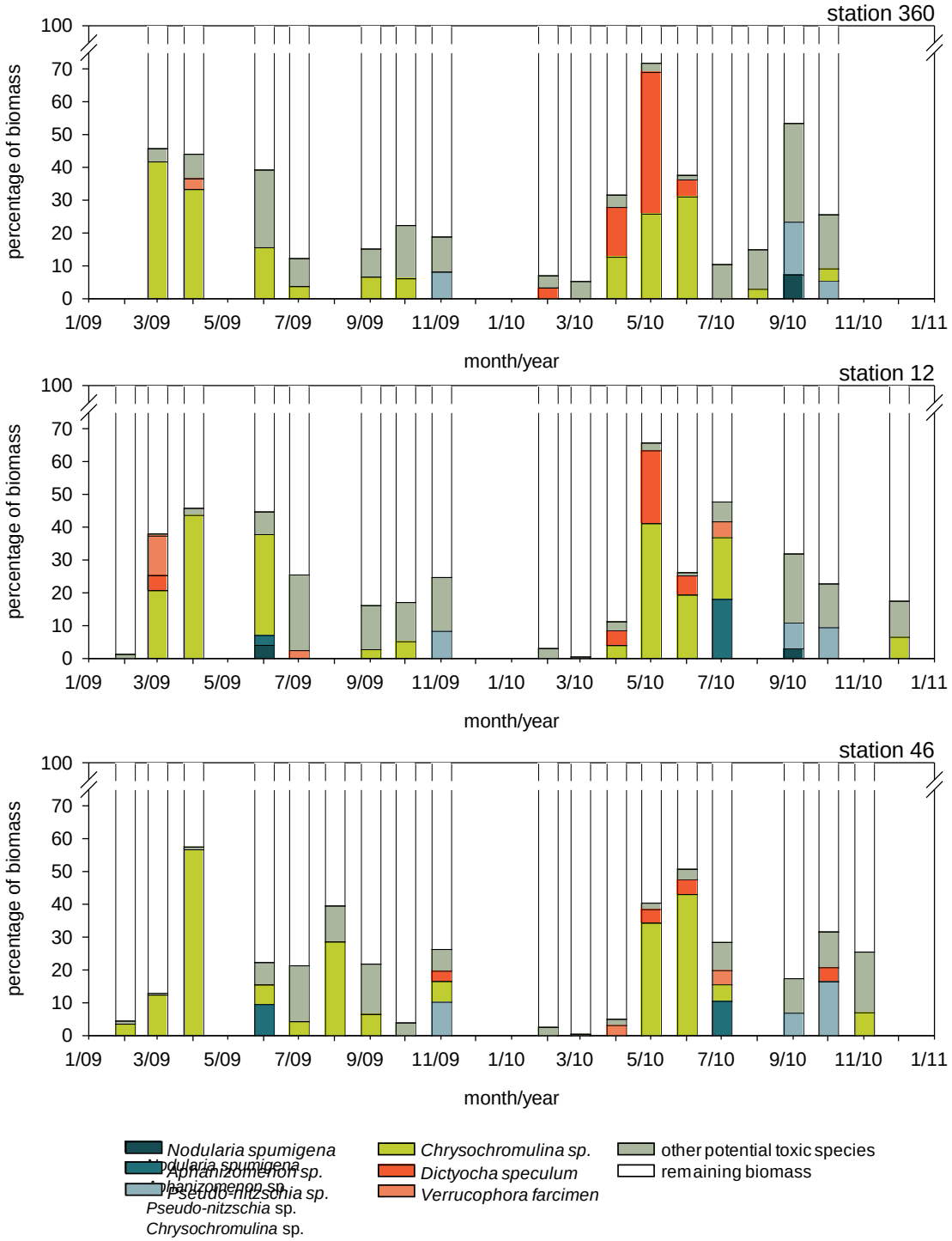


Figure 4-12 Seasonality of the most abundant potentially harmful species as percentage of total biomass [mg C m^{-3}] for baseline investigation. For a total list of potential harmful species see Appendix D.

A second, but lower, occurrence of *Chrysochromulina* sp. followed in late summer and autumn. According to Dahl et al. (1989) this genus is in general dominant at all

stations during spring, because it benefits from the higher N:P ratios in spring as well as from stratified conditions (Lagus et al. 2004, Dahl et al. 2005). In 2010 the percentage of *Chrysochromulina* species was lower, and in contrast to 2009, the maximum values were observed in late spring and early summer.

In late spring and early summer 2010 a comparably high percentage of *Dictyocha speculum* (primarily the form without a silica skeleton – "naked" occurred in Kiel Bight (station 360) and Mecklenburg Bight (station 12). Pigment analysis indicated that this species was dominant in March 2009 at station 360 and 361 in the Great Belt area occurring also in high biomass at 15 m (Figure 4-13).

4.2.2 *Spatial variation*

Phytoplankton is often irregularly distributed in the water body due to varying strength of physical forcing, nutrient loads and biological processes. In the Fehmarnbelt area the horizontal gradients are determined by hydrological processes (especially currents), nutrient richness and the large scale salinity gradient (see Figure 1-2).

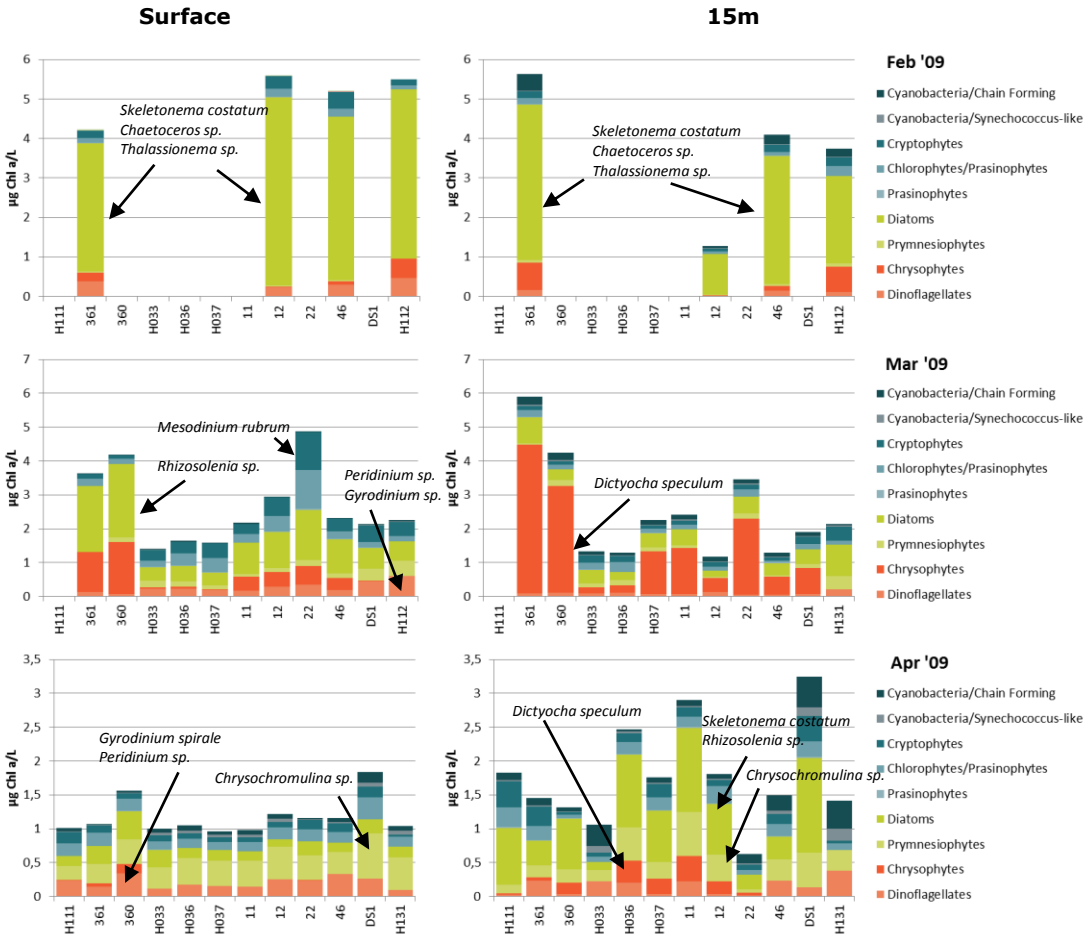


Figure 4-13 Phytoplankton group composition and chl-a biomass determined by pigment analyses during spring 2009 at two depths. Dominant species identified by microscopy of the samples are indicated by arrows.

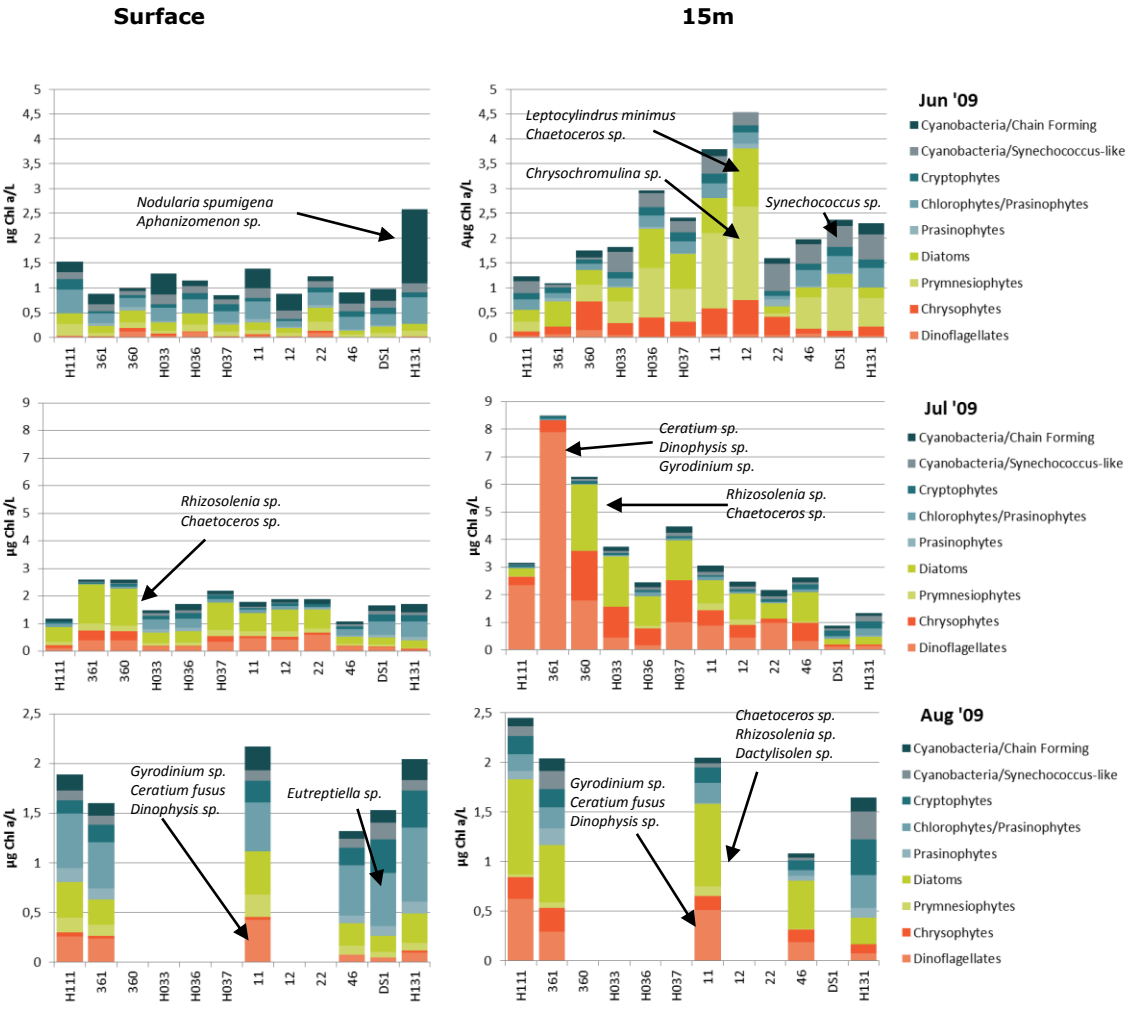


Figure 4-14 Phytoplankton group composition and biomass determined by pigment analyses during summer 2009 at two depths. Dominant species identified by microscopy in the samples are indicated by arrows

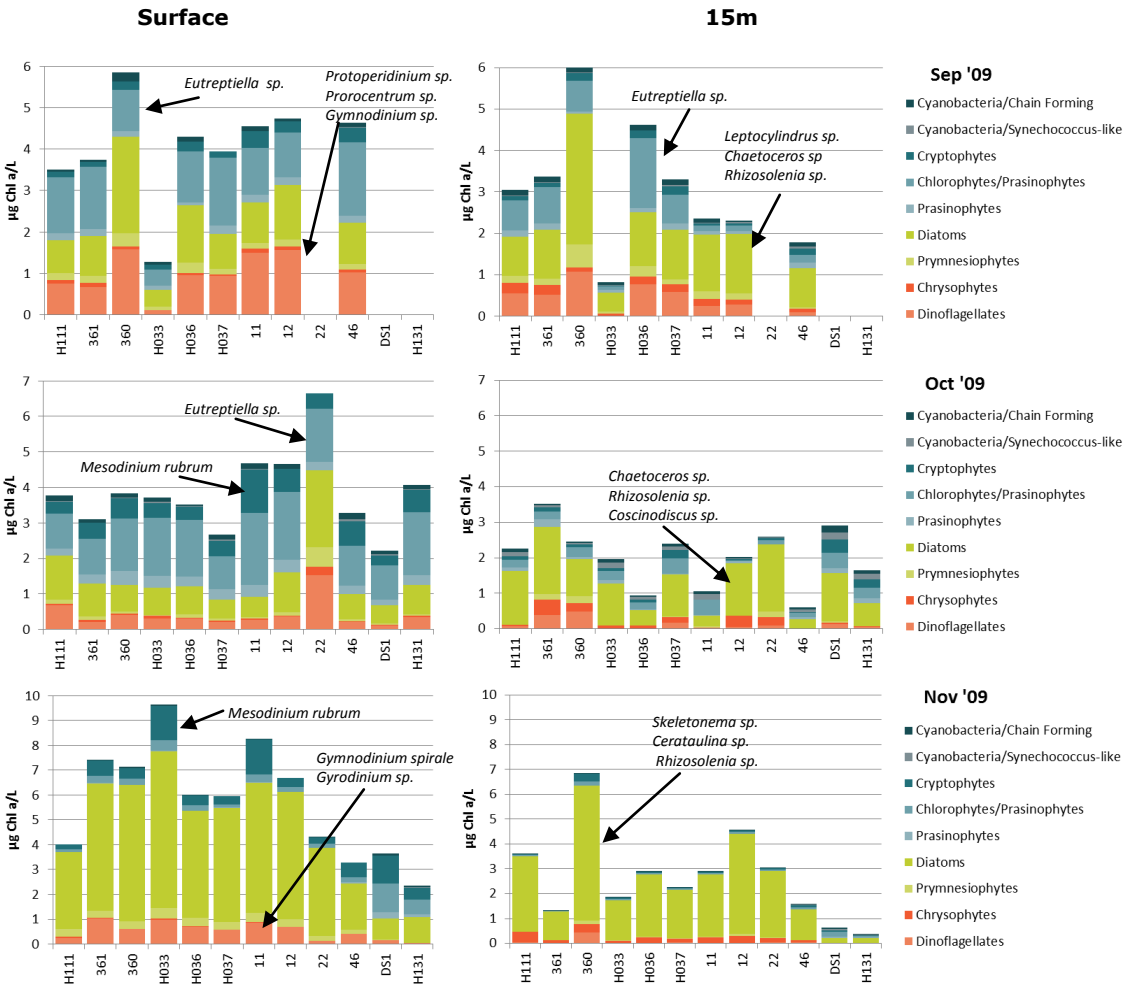


Figure 4-15 Phytoplankton group composition and biomass determined by pigment analysis during autumn 2009 at two depths. Dominant species identified in the samples are indicated.

The spatial distribution is based on the pigment analyses as these cover a larger area and a higher spatial resolution (12 stations). Furthermore, the pigment data provides analyses of the vertical distribution of the phytoplankton. The results on pigment based phytoplankton groups are shown in Figure 4-13, Figure 4-14, Figure 4-15, and Appendix E1-E4 for 2010.

When comparing the spatial variation of phytoplankton populations measured by pigments, the group composition is remarkable equal horizontally in the investigation area in spite of a large difference in total biomass on some stations. However, large differences in biomasses and group composition are found vertically in the water column particularly in summer (comparing surface to 15 m samples in Figure 4-13, Figure 4-14, Figure 4-15, and Appendix E1-E4).

Spatial variation, both horizontally and vertically, occurred particularly when *species* or taxonomic groups bloomed at individual stations, e.g., at the massive occurrence mentioned above of *Dictyocha speculum* at 15 m depth at westerly stations 360 and 361 (Figure 4-14) and the dinoflagellates also at 15 m at the most westerly stations in July 2009 (Figure 4-15). Differences in total biomasses were also seen in the autumn bloom in September and October 2009 (Figure 4-15).

A high community similarity of the off-shore stations is confirmed when the phytoplankton populations determined by pigments are averaged over areas of same depth (ANOVA, P=0.38, and 0.15 for surface and P=0.07 and 0.40 for 15 m, for 2009 and 2010, respectively) (Figure 4-16). The distribution of phytoplankton groups show some (non-significantly) differences from the western part to the eastern part of the investigation area. Particularly dinoflagellates, diatoms, and chrysophytes seemed to be more abundant in the Great Belt area, while chlorophytes, cryptophytes and chain-forming cyanobacteria became increasingly important toward the eastern part of the baseline area.

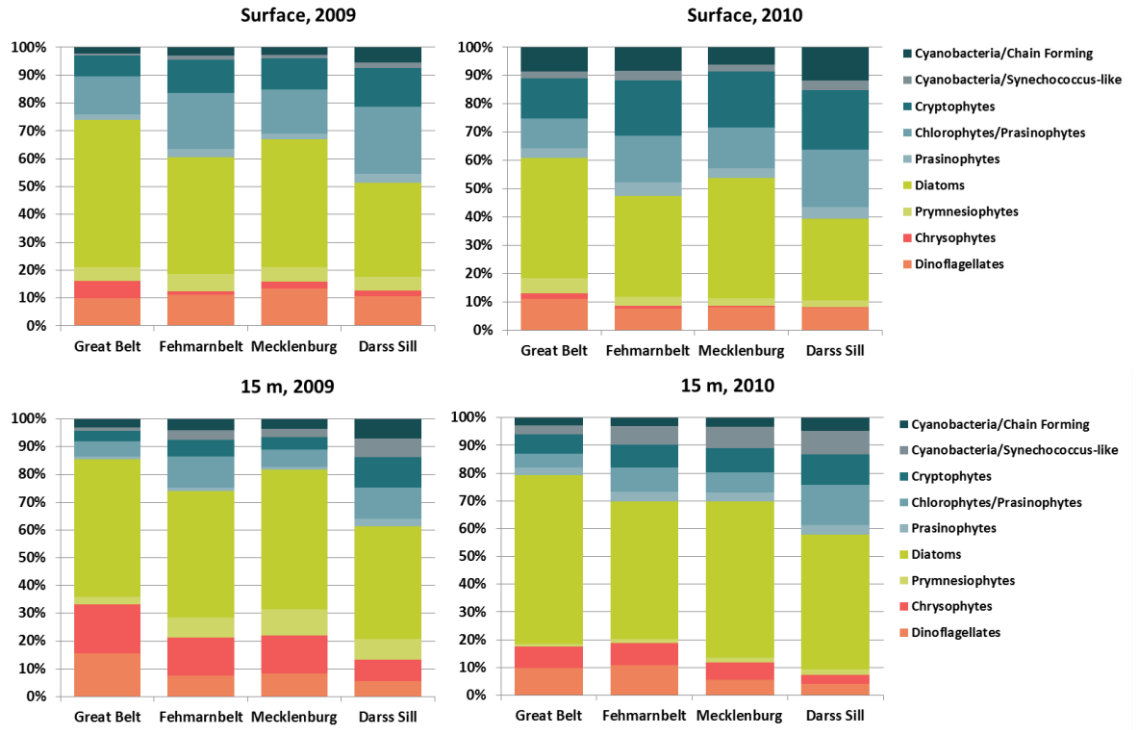


Figure 4-16 The distribution of phytoplankton groups in the four parts of the baseline investigation area measured by pigments; averaged over each year of investigation. Group composition between areas did not differ (ANOVA, P=0.38, and 0.15 for surface and P=0.07 and 0.40 for 15 m, for 2009 and 2010, respectively).

This pattern was also evident in the microscopic analyses of the species compositions at the 3 HELCOM stations (Figure 4-17) The greatest (but still not large) differences between the 3 stations were obtained during spring season 2009 when e.g. higher percentage of naked forms of *Dictyocha speculum* and *Verrucophora farcimen*[1] (Dictyochophyceae) were observed in the western part (station 360). Despite of generally low biomass in summer, a west-east gradient of cyanobacteria (mainly *Aphanizomenon* spp.) with higher percentages in the eastern parts occurred. This gradient of cyanobacteria was also evident in the summer group compositions (Figure 4-14) and in the yearly averaged compositions (Figure 4-17). The

[1] *Verrucophora farcimen (Dictyochophyceae) was renamed in 2009 to* Pseudochattonella farcimen (Eikrem et al. 2009).

highest similarity was observed in autumn (Figure 4-17), with a co-dominance of dinoflagellates and large diatoms.

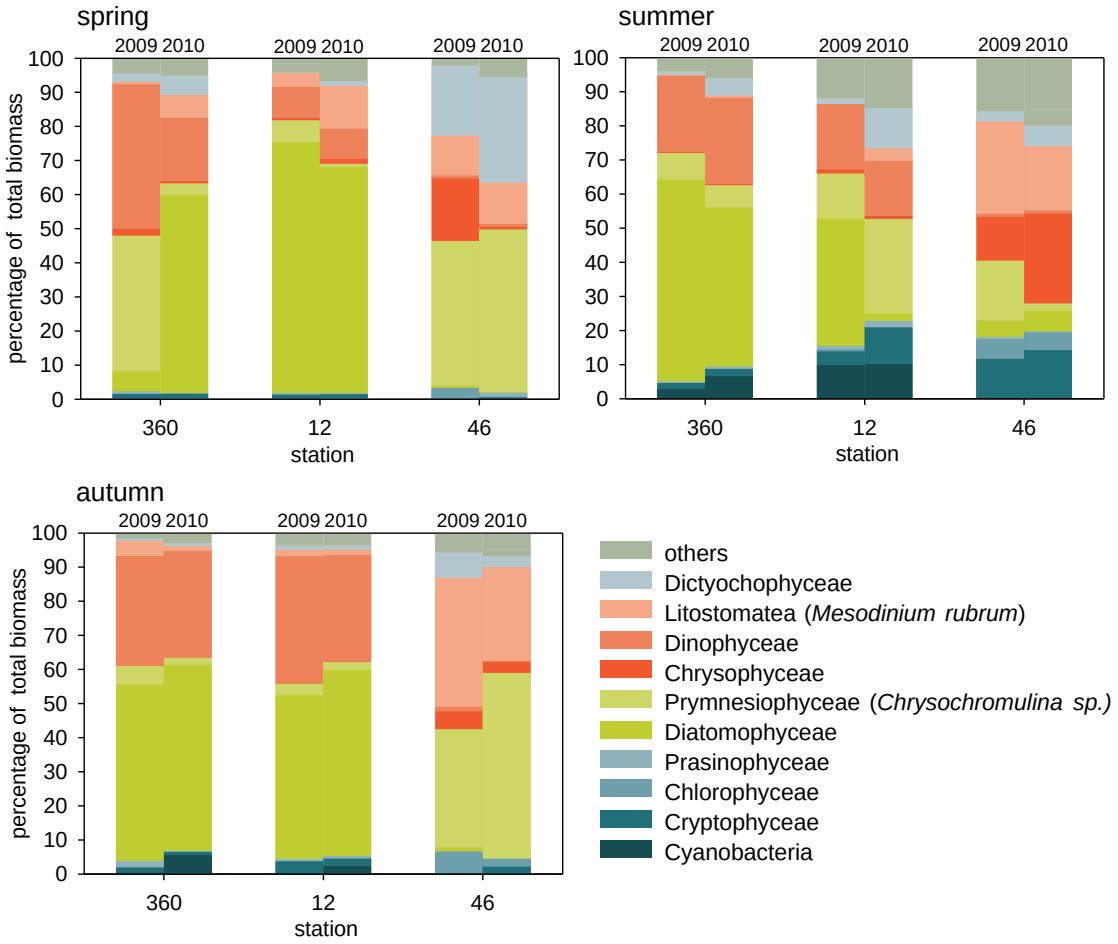


Figure 4-17 Taxonomical composition as percentage of main taxa groups of total biomass in 2009 and 2010, respectively. The calculation based on mean values of biomass (mg C m^{-3}) for the season given. The taxonomical groupings follow the HELCOM-classification. Stations and subareas: 360-Great Belt, 12-Mecklenburg Bight, 46-Darss Sill.

MDS and cluster analyses of the community structure based on the percentage of main taxa groups in relation to total carbon biomass confirm a high community similarity between the 3 HELCOM stations in autumn 2009, intermediate similarity during summer whereas greater differences between stations were obtained for the spring season (Figure 4-18). The horizontal similarity was confirmed by the pigment analyses from the 12 biological stations (see Figure 4-19).

In coastal waters (near-shore stations), the phytoplankton community 'separated' into four groups according to total, pigment based chl-a biomass (Figure 4-20). The separation was especially determined by the chl-a biomass of diatoms and dinoflagellates. Overall, both the total chl-a biomass, and the chl-a biomass of diatoms and dinoflagellates were higher (40-80%) along the German coast (Stations NS6-NS10) compared to the Lolland coast. Along the Lolland coast pigment concentrations were highest in the Rødsand Lagoon (NS4, NS5) due to higher concentrations of diatoms and chain-forming cyanobacteria. The differences along the German coast were mainly due a lower biomass of diatoms at NS8 and NS9 compared to the other 3 stations.

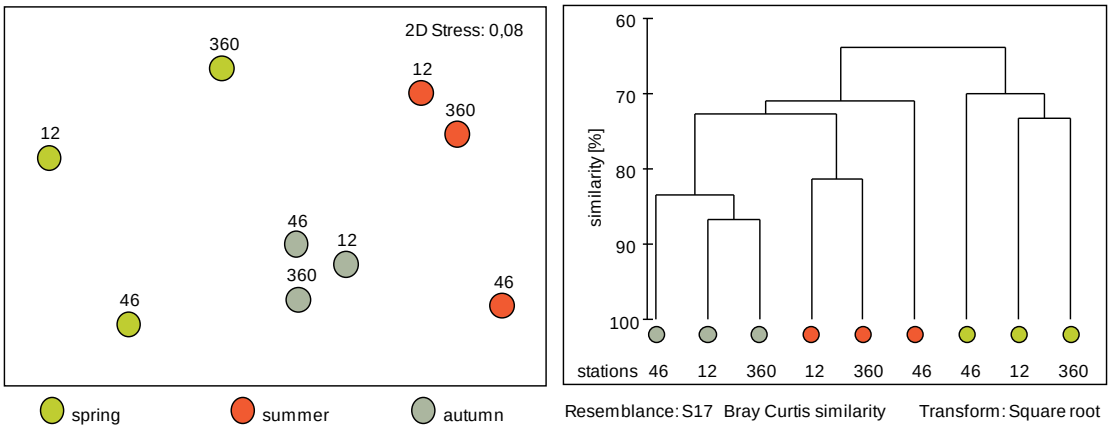


Figure 4-18 MDS and cluster analysis of seasonal and spatial data for 2009. Data from microscopic analyses of the 3 HELCOM phytoplankton station. The analysis was performed with square root transformed data using the Bray-Curtis index of similarity and single linkage clustering. Anosim test: Global R=0.689. Pair-wise test: au/sp r=0.70; au/su r=0.67; sp/su r=0.92

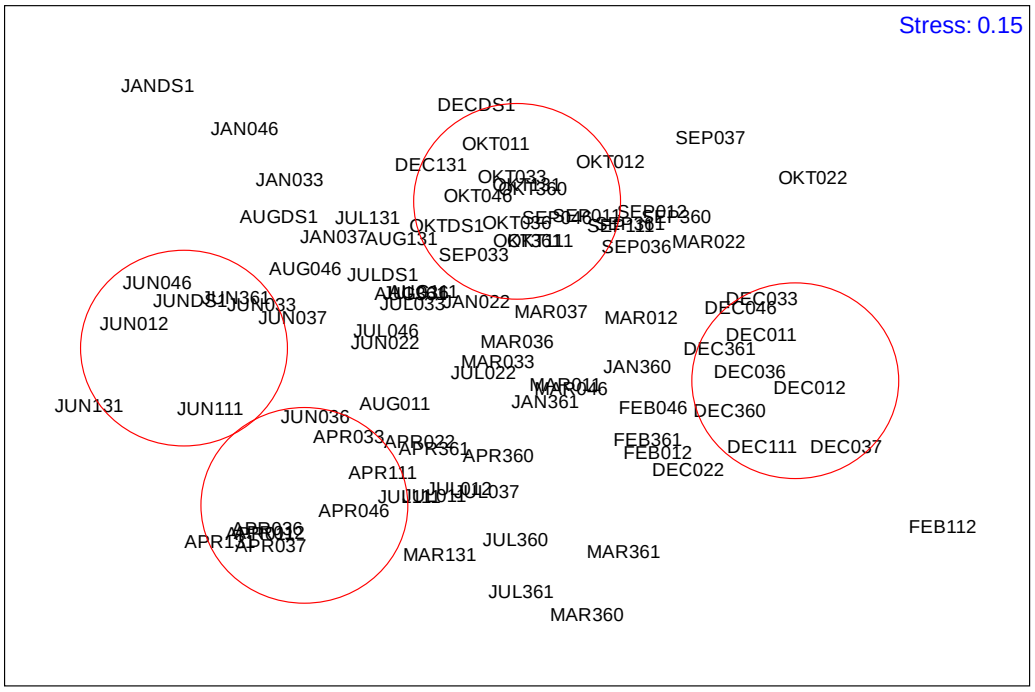


Figure 4-19 MDS analysis of the phytoplankton group chl-a biomass (based on pigment analyses) in the surface at the 12 biological stations in the Fehmarnbelt subarea. The 3 letter abbreviation indicated the sampling month; it is followed by the station number.

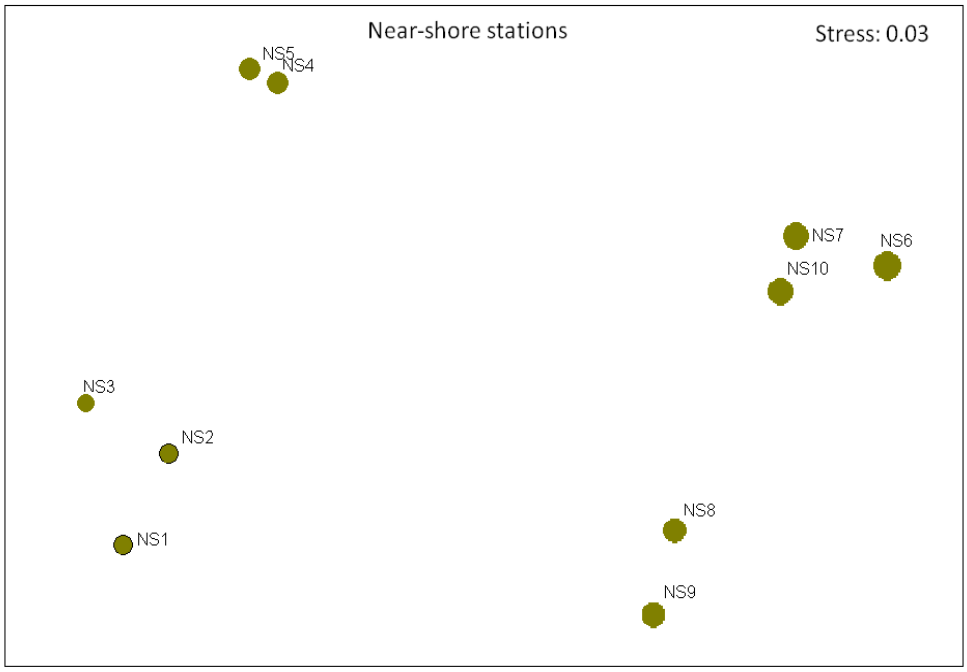


Figure 4-20 MDS analysis of the phytoplankton group chl-a biomass (based on pigment analyses) at near-shore water stations along the Lolland coast (NS1-NS5) and along German coast (NS6-NS10). Based on yearly averaged biomass of 8 different phytoplankton groups. Area of dots indicates relative chl-a level at stations. See Figure 2-1for station locations.

4.2.3 *Seasonal variation*

Overall and averaged over all cruises, both microscopic analyses of the 3 HELCOM stations and pigment analyses of the 12 biological stations (including the HELCOM stations) confirm that the community structure was rather similar at the investigated stations, and the main variation in phytoplankton composition originates from the seasonal succession (Figure 4-18 and Figure 4-19). For the HELCOM stations, the seasonal variation in carbon biomass was significant (Anosim test: r=0.68). For the 12 biological station (chl-a biomass), at least four clusters of monthly cruises are identified (Figure 4-19). The seasonal separation of the phytoplankton community at 15 m depth was less distinct (Appendix F).

Figure 4-12 shows the seasonal succession observed at the 3 HELCOM stations during the baseline investigation. Independently from the total biomass, the timing and general characteristics of the succession stages are comparable for these stations.

Phytoplankton succession follows the annual cycle in environmental conditions, i.e. temperature, water column stratification, light and nutrients. For the Western Baltic (Kiel Bight) four seasonal stages were described by Wasmund et al. (2008): spring bloom, late spring or post-spring bloom, summer, and autumn, besides the minimum in winter.

In the present investigation a typical seasonal cycle characterised by pronounced spring and autumn blooms was demonstrated in both investigation years (Figure 4-21).

In 2010 the spring bloom starts one month earlier than 2009 (Figure 4-21). Whereas the spring bloom in 2009 occurred in January-February, in 2010 the maximum

spring biomass was observed in the mid of February-March, due to the longer colder winter period. In addition a slightly shorter and lower autumn bloom was observed in 2010 with respect to chl-a concentration (Figure 4-7). The shorter time period could attribute to early autumn storm events in October and November 2010.

Despite the comparable group composition during autumn and spring (Figure 4-17), the HELCOM stations differed from each other with respect to species specific composition (compare with Table C.2, Appendix C).

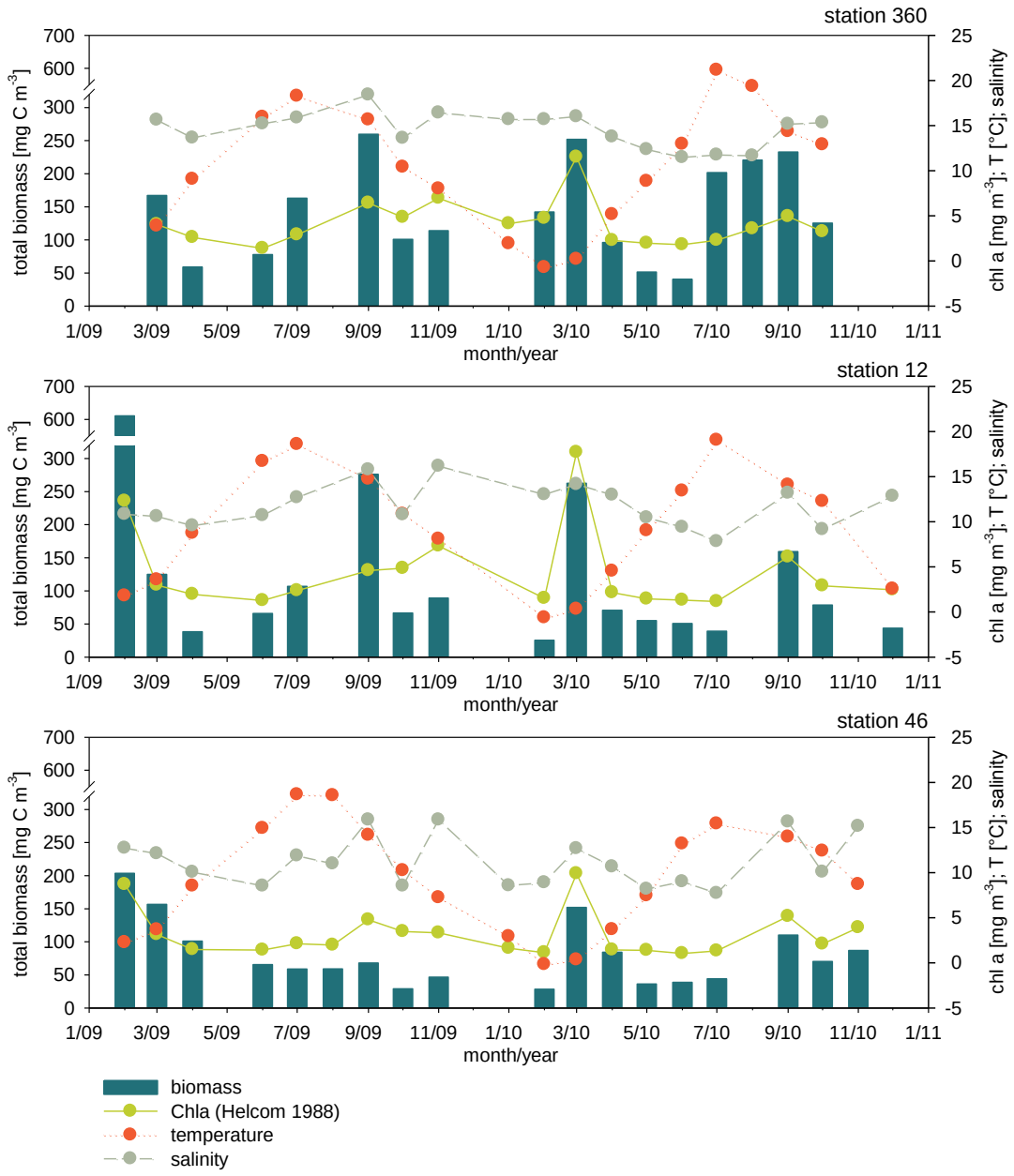


Figure 4-21 Seasonal differences in carbon biomass at stations 360, 12 and 46 during baseline investigation. The lines marked the salinity, temperature and average chl-a concentration values (0-10 m).

The seasonal cycle of major taxonomic groups is shown for the three HELCOM stations in Figure 4-21 (based on microscopic counting). For detailed results from pigment analyses see Appendix E, Figure E1-E4.

Spring (February to May):
The 2009 spring bloom started in February with a dominance of diatoms. From the total pigment based chl-a biomass some variation was observed between stations, reflecting the different timing of the spring bloom event and date of sampling (Figure 4-13). In 2010 the spring bloom started one month later (in March). In 2009 the main spring species was *Skeletonema costatum* which dominated the biomass at all stations investigated (Figure 4-21), whereas in spring 2010 various *Thallassiosira* species were most abundant in Mecklenburg Bight and Darss Sill. This diatom bloom was followed by a post-spring bloom dominated by dinoflagellates and *Chrysochromulina* species in both years, which is typical for the western Baltic (station 360 and 12). At station 46 *Mesodinium rubrum* dominated (42% (2009) and 50% (2010) of total carbon biomass) the late spring bloom, later replaced by increasing *Chrysochromulina* spp. biomass (reaching 56% in 2009 and 35% in 2010). This pattern was common for the whole baseline area. As mentioned earlier a subsurface bloom of chrysophytes (*Dictyocha speculum*) was detected by pigments in March 2009 at 15 m depth in the western part of the investigation area (Figure 4-13).

However, the general composition regarding the spring bloom succession as well as the taxonomic group composition was comparable between the two years of investigation.

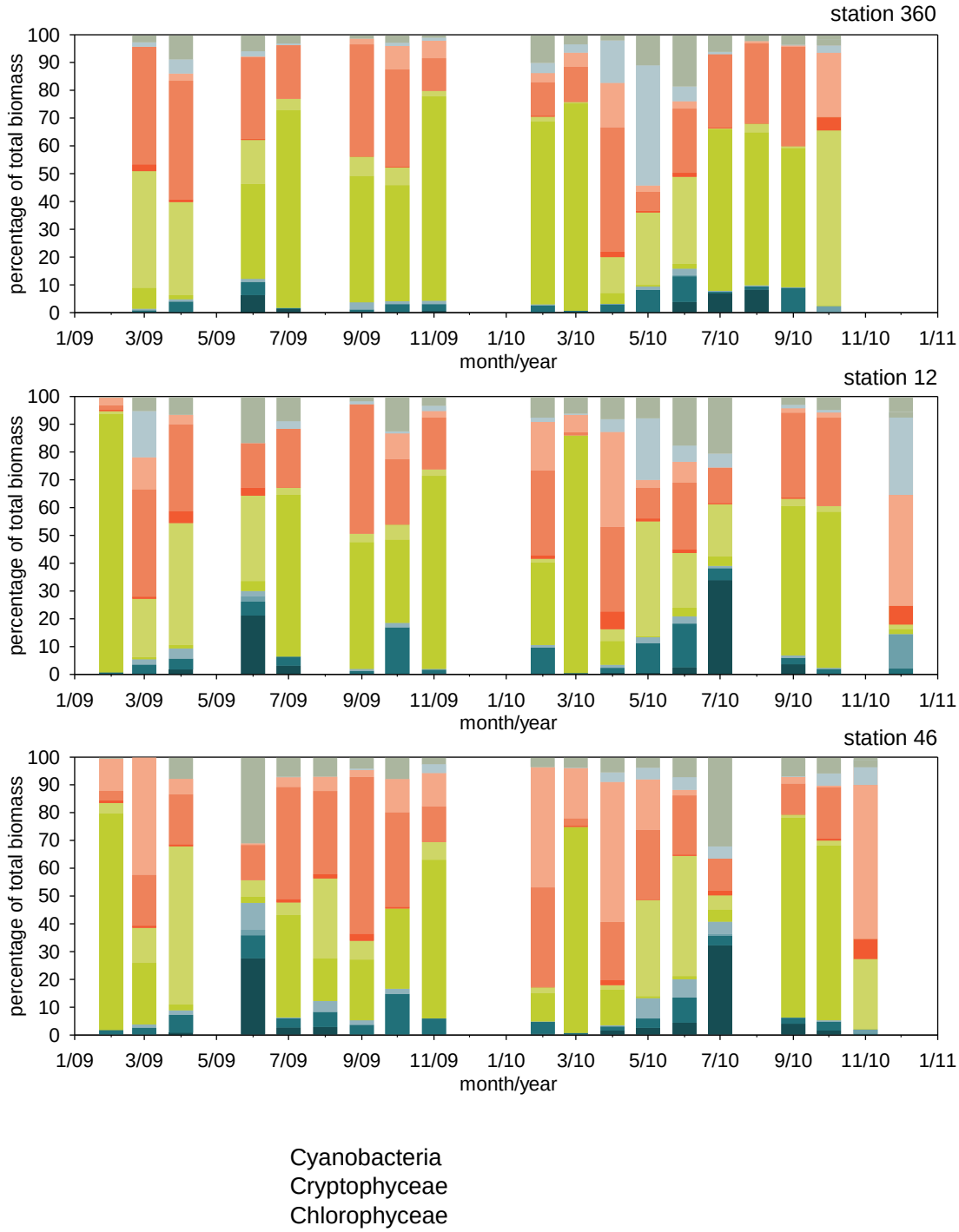


Figure 4-22 Seasonality of taxonomical composition as percentage of main taxa groups with respect to total biomass. Calculation based on mean values of biomass (mg C m^{-3}) for baseline investigation 2009-2010. Taxonomic analysis is based on microscopically counting.

Summer (June to August):
Summer 2009 was characterized by generally low biomasses and in particularly in June a high diversity. At station 360 the dinophyte *Ceratium tripos* was common, and small unidentified nanoplankton as well as Chlorophytes like *Pyramimonas* sp. (summarized in "others") became abundant at station 46. In July and August the

three HELCOM stations were characterized by increasing diatom biomass and co-dominant Dinophytes. *Proboscia alata* was the most abundant species at this time. Diatoms were less abundant in 2010 and in the early summer of 2010 *Chrysochromulina* species became abundant. In July the cyanobacteria biomass increased in the surface at all stations (Figure E3, Appendix E).

The pigment analyses show that particularly in summer the surface populations were quite different from the populations at 15 m (Figure 4-14), where prymnesiophytes and dinoflagellates constituted important subsurface populations in June and July in both years. Other important groups especially in the surface waters in late summer were Prasinophytes/Chlorophytes (e.g., *Eutreptiella sp.*, Figure 4-14), constituting approx. 1-2 µg chl-a l^{-1}.

Despite of a low biomass in summer, a west-east gradient of cyanobacteria, *Aphanizomenon* sp. and *Nodularia spumigena,* with higher percentages in the eastern parts, occurred on the three HELCOM stations (Figure 4-21). In June 2009 and July-September 2010, cyanobacteria were forming visible aggregates at the surface. However, they did not turn into extensive blooms as often seen in the western Baltic Sea (Kononen 1992, Schlüter et al. 2004). But as seen in Figure 4-14 and Figure E3 in Appendix E, these chain-forming cyanobacteria constituted more than 50% of the chl-a biomass in June 2009 and more than 70% in July 2010 in the Darss Sill area, at station H131 and DS1, respectively.

For the Baltic proper Hansson and Öberg (2009) considered the cyanobacterial bloom in 2009 as relatively small and unspectacular in comparison to previous years. After the first observations end of June, no surface accumulation of cyanobacteria was detected in the off-shore parts of the Baltic Sea after 25th August (Hansson and Öberg 2009). In 2010 the cyanobacterial bloom in the Baltic Sea was restricted to the first three weeks of July and mostly affected the south-eastern parts of the Baltic Proper (Hansson and Öberg 2010).

In contrast to the conditions in the Baltic Proper, slightly elevated cyanobacterial biomass was observed in the investigation area in 2009 and 2010 (Figure 4-11). This indicates an autochthonal development of cyanobacteria rather than a wind- and current-induced drift of eastern populations.

Autumn (September to November)
In 2009 and 2010 Gymnodiniales (dinoflagellates) became common at all station in September (shown both by the microscopic analyses). Higher percentages of Dinophytes were recorded in the western part of the investigation area. At stations 360 and 12 the diatoms *Leptocylindrus minimus* and *Cerataulina pelagica* prevailed. The maximum percentage of diatoms in 2009 was reached in November, while in 2010 the biomass of diatoms was high in September and October as well (Figure 4-21, Figure E.4, Appendix E).

According to the pigment analyses, cryptophytes constituted a minor but relative constant part in autumn due to occurrence of the autotrophic ciliate *Mesodinium rubrum*, which contains cryptophyte endosymbionts. According to the analyses, the autotroph ciliate was more abundant in the eastern parts of the investigation are, which is confirmed by the higher amount of Cryptophytes in the pigment analyses.

Winter 2010 (December and January)
Winter phytoplankton growth is generally limited by light availability. The biomass was rather low, and the group composition was more variable, with a dominance of cryptophytes in the surface (Figure E.1, Appendix E). Pigment analyses showed that

the spring bloom of diatoms occurred in January 2010 in the Great Belt (stations 360, 361, Figure E.1, Appendix E) but had not started yet in the other sampling areas.

4.2.4 *Historical data*

Comparison with the present investigation
Available long-term data are compared with the measurements from the baseline investigation in Figure 4-22. Both total carbon biomass and species composition fit well into the time series. Because of the lack of data for station 360 the lower values in 2009 compared to former investigations could not be verified. During the last 4 years the measured spring bloom at stations 12 and 46 showed high biomasses. However, because of the short period of bloom occurrence, the spring biomass values are closely coupled to the sampling time and there is a large risk for missing a spring bloom. The temperature lines suggest for 2009 an above-average summer period and a below-averaged winter period, due to the very low spring temperatures in 2010.

Long-term trends in species composition
Long-term trends in species composition, especially for the western Baltic and along the saline gradient of the Baltic Sea, are described in detailed by Wasmund and Siegel (2008) and Wasmund and Uhlig (2003). These investigations aimed to describe eutrophication and climate effects on the succession and composition of plankton community. The main results for the Belt Sea can be summarised as follows:

- the phytoplankton biomass has roughly doubled in the last century
- timing of the spring bloom has shifted in the last decades from April to February/March
- earlier spring blooms are more intense than late spring blooms and with a larger contribution by diatoms than later spring blooms
- the seasonal diatom species composition has changed, including increased occurrence of potentially harmful species in the ecosystem
- for South Arkona Sea and Belt Sea diatom biomass in spring has decreased significantly, coinciding with an increase in dinoflagellate biomass

Long-term trends in bloom-forming cyanobacteria
Bloom-forming cyanobacteria play an important role in the Baltic ecosystem because of their nitrogen fixation capabilities and their toxicity. Spatially extended surface blooms of *Aphanizomenon* sp. and *Nodularia spumigena* occur regularly during summer in the Baltic proper, but blooms are rare in the Kattegat and the northern Gulf of Bothnia (Kahru et al. 1994, Wasmund 1997). Nodularia bloomed in coastal waters in the southeastern Kattegat in 1971, 1975, 1986 and 1977 (Miljøstyrelsen 1979), but mass occurrence has not been registered since then.

According to (Finni et al. 2001) the intensity and frequency of cyanobacterial blooms increased in the last century. During the last decade intensive blooms were detected by satellite imaging in 1999, 2003, 2005 and 2006 (Hansson and Öberg 2009). Apparently, cyanobacterial blooms are more variable than those of diatoms and dinoflagellates, and it is difficult to deduce steady trends. Nevertheless, Wasmund and Uhlig (2003) described downward trends in summer data for the Kattegat region, where the general level of cyanobacterial biomass is, however, relatively low.

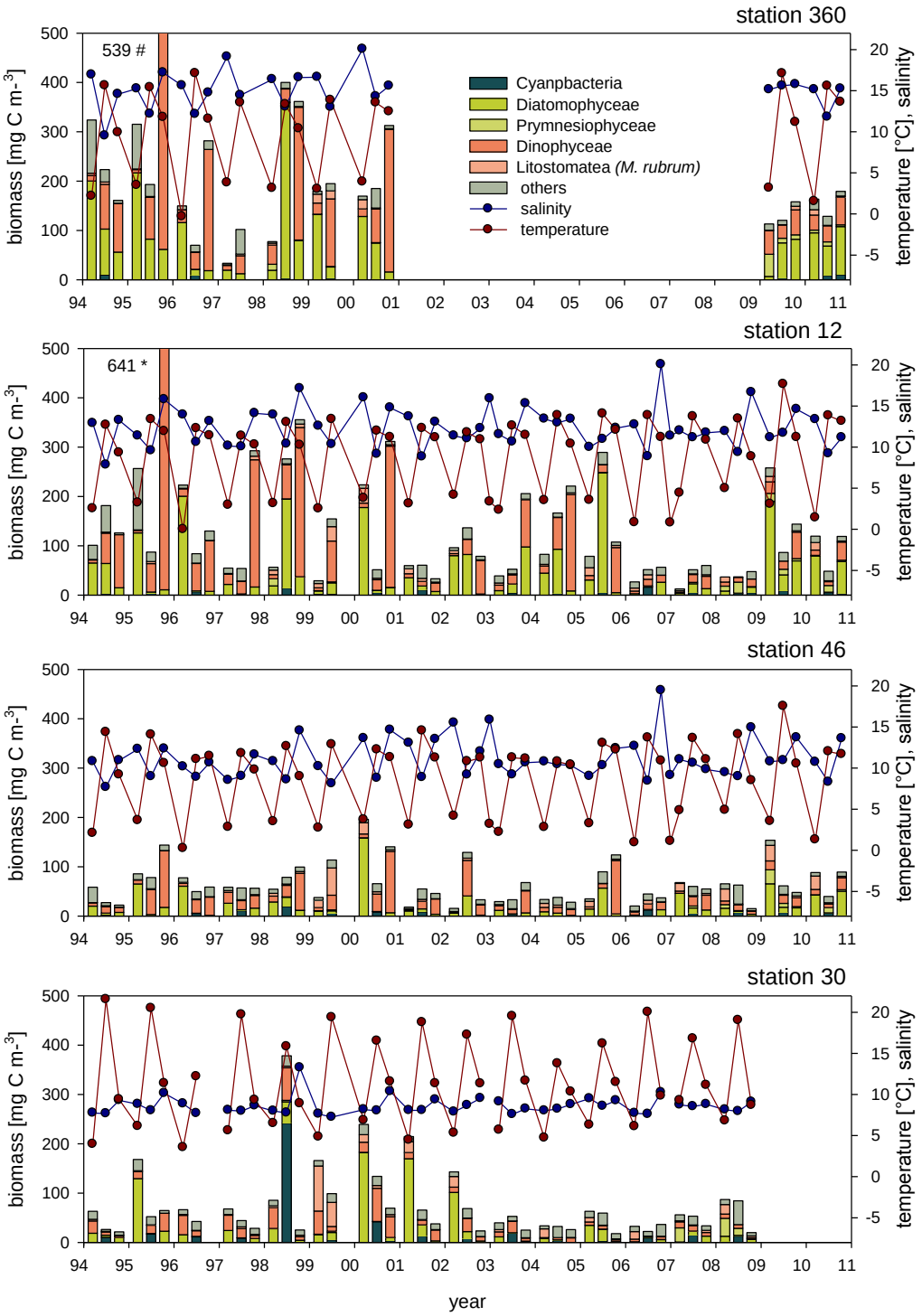


*Figure 4-23 Phytoplankton seasonality described based on long-term HELCOM monitoring data and the baseline investigation 2009 and 2010. Bars denote total carbon biomass and percentage of main taxa groups. Dots denote salinity and temperature (0-10m). All bars represent seasonal means (first bar of year: spring, second: summer; third: autumn, gaps: no data available). Values for winter periods are not shown. They are: sum: 539, Cyanophyta: 0.04, others: 2.4; *: sum: 641, Cyanophyta: 0.02, others: 5.7 mg C m^{-3}.*

The HELCOM monitoring data for selected stations show higher cyanobacterial biomass during 1998, 2005 and 2006 (Figure 4-23). The notable differences between satellite observation and HELCOM-sampling data from the fixed stations reveal an

outstanding problem in monitoring. Cyanobacterial blooms are inhomogeneously distributed in time (both seasonal and short-term) and space (both horizontal and vertical) and therefore, it is problematic to conduct representative sampling during monitoring; the monitoring data sets will reflect snap shots of the seasonal and annual changes in mean surface concentrations (usually 0-10m).

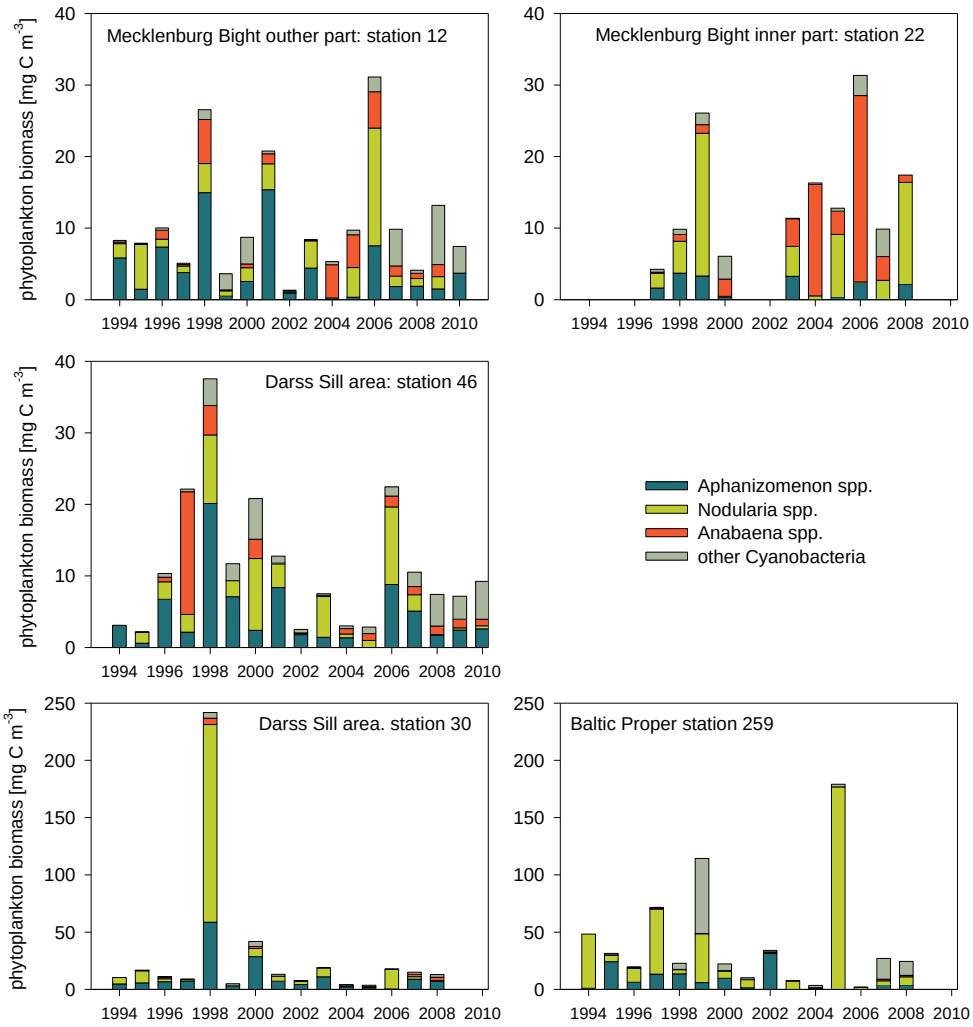


Figure 4-24 Long-term data of Cyanophyta in summer. To assure comparable data, summer values were defined as mean values for June, July and August. Note the difference in y-axis. The data of 2009 and 2010 (station 12 and 46) represent the data of the present baseline study.

4.3 Primary Production

Pelagic primary production constitutes an important input of organic carbon and nutrients 'feeding' the aquatic food web in deeper off-shore waters. Benthic vegetation constitutes another source but based on depth and benthic substrate the contribution of benthic vegetation probably do not exceed 10% of the total primary production in the area. Hence, neglecting advection from land and adjacent marine areas, phytoplankton production is the prime source of organic material in the area.

Phototrophic primary production is the process where autotrophs (algae or higher plants) incorporate inorganic carbon (CO_2) into organic molecules using light as energy source. Besides light and carbon, autotrophs also require macro- (nitrogen, phosphorus, silica) and micronutrients for their growth.

Primary production (PP) is determined by the phytoplankton biomass (B) and the growth rate (μ) of that biomass:

$$PP = \mu * B$$

Growth rate cannot be determined *in situ*, but the ratio PP/chl-a will roughly provide a relative estimate of growth rate. Growth rate is under control by light and nutrient availability in addition to temperature, while biomass is controlled by growth rate and losses due to sedimentation, grazing and death. If growth rate is larger than the sum of loss rates there will be an increase in biomass.

4.3.1 *Seasonal and spatial variation in primary production*

The seasonal variation of the primary production in the four baseline areas of the Fehmarnbelt region for March 2009 – December 2010 is shown in Figure 4-25. The monthly averaged values varied between 50-1125 mg C m^{-2} d^{-1}, showing the highest values in late summer when primary production occasionally exceeded 1200 mg C m^{-2} d^{-1}.

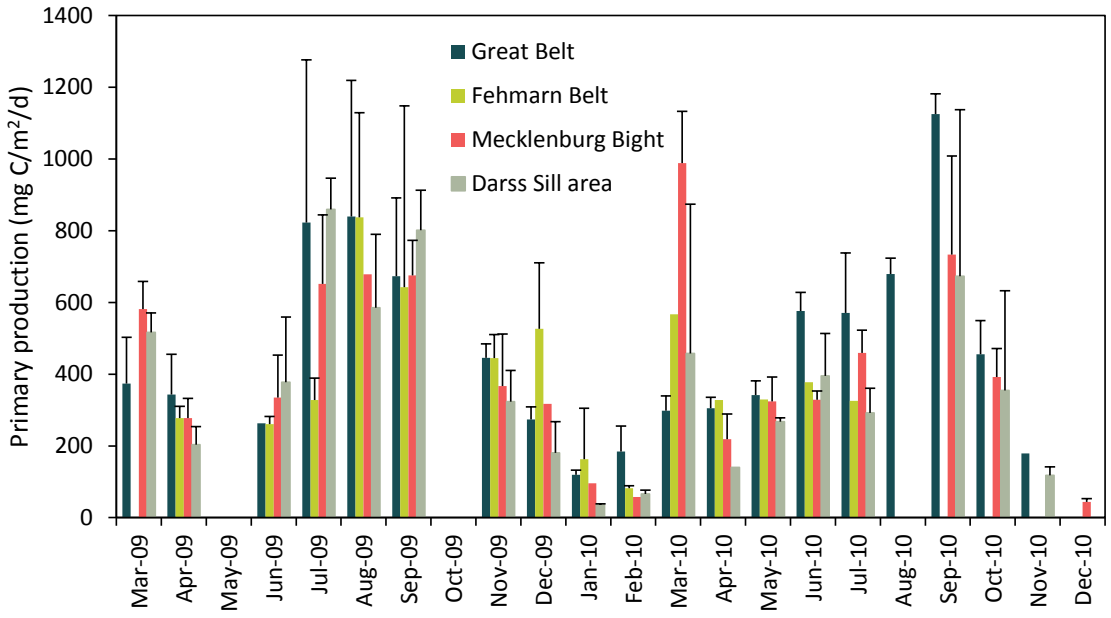


Figure 4-25 Seasonal variation (March 2009-December 2010) in depth-integrated primary production in the four parts of the Fehmarnbelt investigation area. Bars represent average values for 2-3 stations and error bars represent +SD. In case that error bars are not shown only one station in an area was sampled within a cruise.

The depth distribution of the primary production was rather similar for the four different sampling areas with an exponential decreasing production over depth reflecting the light attenuation in the water column (Figure 4-26).

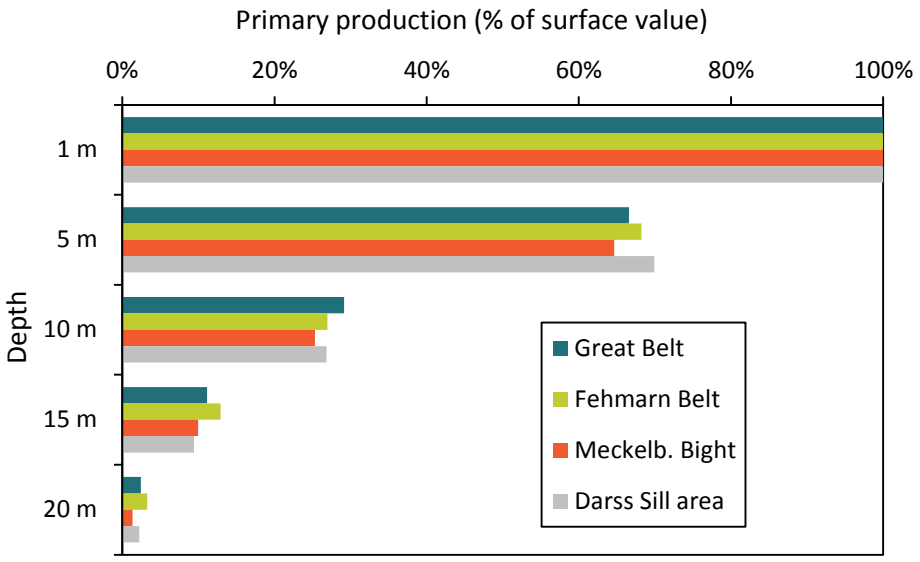


Figure 4-26 Depth distribution of the primary production as a percentage of the primary production in surface layer (1 m). Data are normalised per station and cruise. The 4 areas are each represented by 3 stations and between 6 and 8 sampling events through the period March 2009 to November 2010.

As were the case for phytoplankton biomass and community composition, the seasonal variation of the primary production was much larger than the spatial variation within cruises. This indicates that the main forcing factors in the Fehmarnbelt region are the seasonal variation in insolation and temperature, although other parameters, such as nutrient availability and grazing, are known to have significant impact on the production and biomass of phytoplankton communities too.

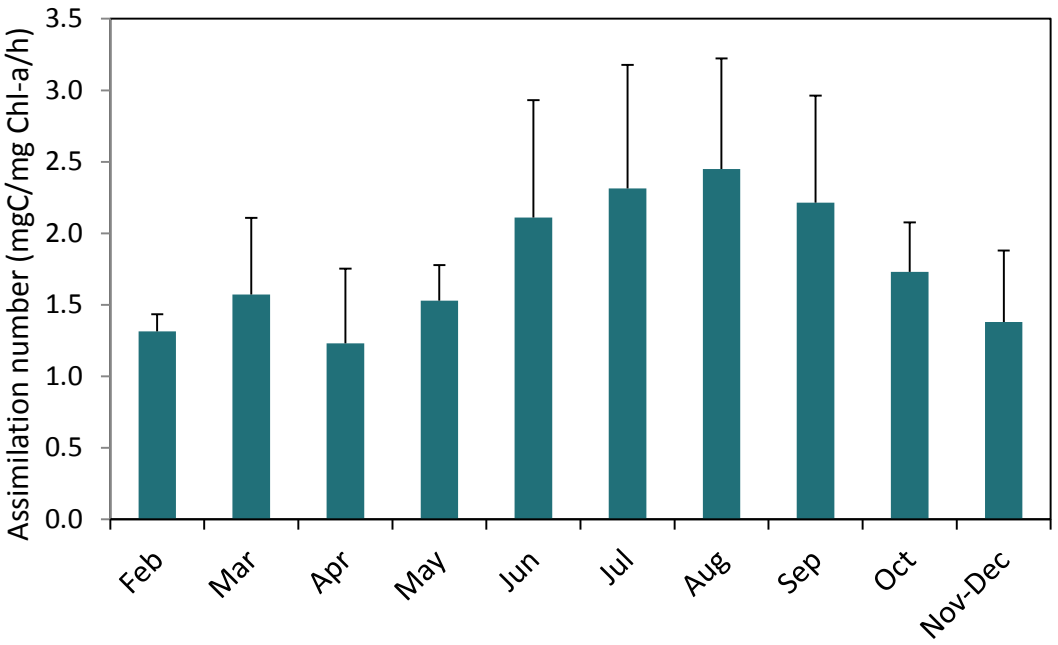


Figure 4-27 Monthly variation in assimilation number (i.e. light-saturated primary production per unit Chl-a) in the Fehmarnbelt and adjacent areas. Bars show depth- (1-10m), station- and monthly-averaged values + SD.

The variation in light-saturated primary production per unit chl-a, i.e. the so-called 'assimilation number' (P^B_m) was considerable (10-fold variation between samples, 2-fold variation between sampling months) but overall P^B_m followed the temperature variation with highest values in July-September (Figure 4-27) underlining that temperature is important for the max growth rate. Assimilation number was relative high in February and March reflecting that a high nutrient availability (around spring bloom) is also affecting the growth rate.

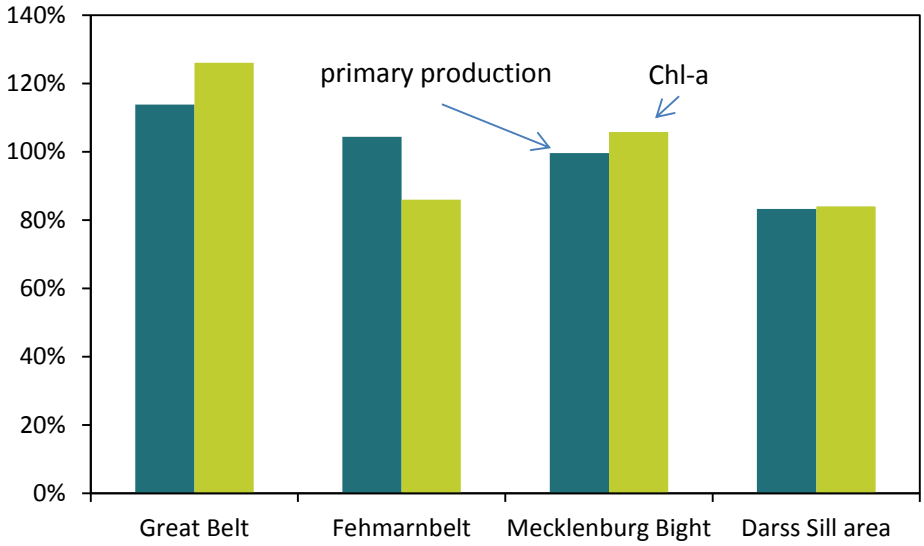


Figure 4-28 Spatial variation in primary production and chl-a in the baseline investigation area from March 2009 through November 2010. Bars represent normalised rates and concentrations (over stations and sampling cruises).

Overall, the spatial variation in primary production mimicked the variation in chl-a: underlining that variation in biomass is very important for primary productivity (Figure 4-28). The Great Belt area had a primary production that was 14% higher than the average, with a concentration of chl-a that 26% higher than the average. In contrast, primary production and chl-a were 17 and 16% respectively below the average in the Darss sill area.

In the Fehmarnbelt area (stations H033, H036, H037) the concentration of chl-a was 14% below the average while primary production was 4% above the average (Figure 4-28) indicating a higher primary productivity per algal biomass in this area compared to the other areas. A likely explanation for a higher primary productivity is that upwelling of nutrient rich water across the pycnocline could be more intense and occurs more frequently here than in the other areas (see example in Figure 4-29). The mechanisms are not fully described, but upwelling and downwelling events seem to shift between the German and Danish coasts associated with in- and outflow periods.

Assuming a mean NO_3 concentration of 1 µM below the pycnocline at the investigation stations in the Fehmarnbelt area during 28-30 September, upwelling (at an average rate of 0.00009 m s^{-1}) will theoretically supply 120 mg NO_3-N m^{-2} to surface layer per day, which theoretically can fuel a new (primary) production of 650 mg C m^{-2} d^{-1}.

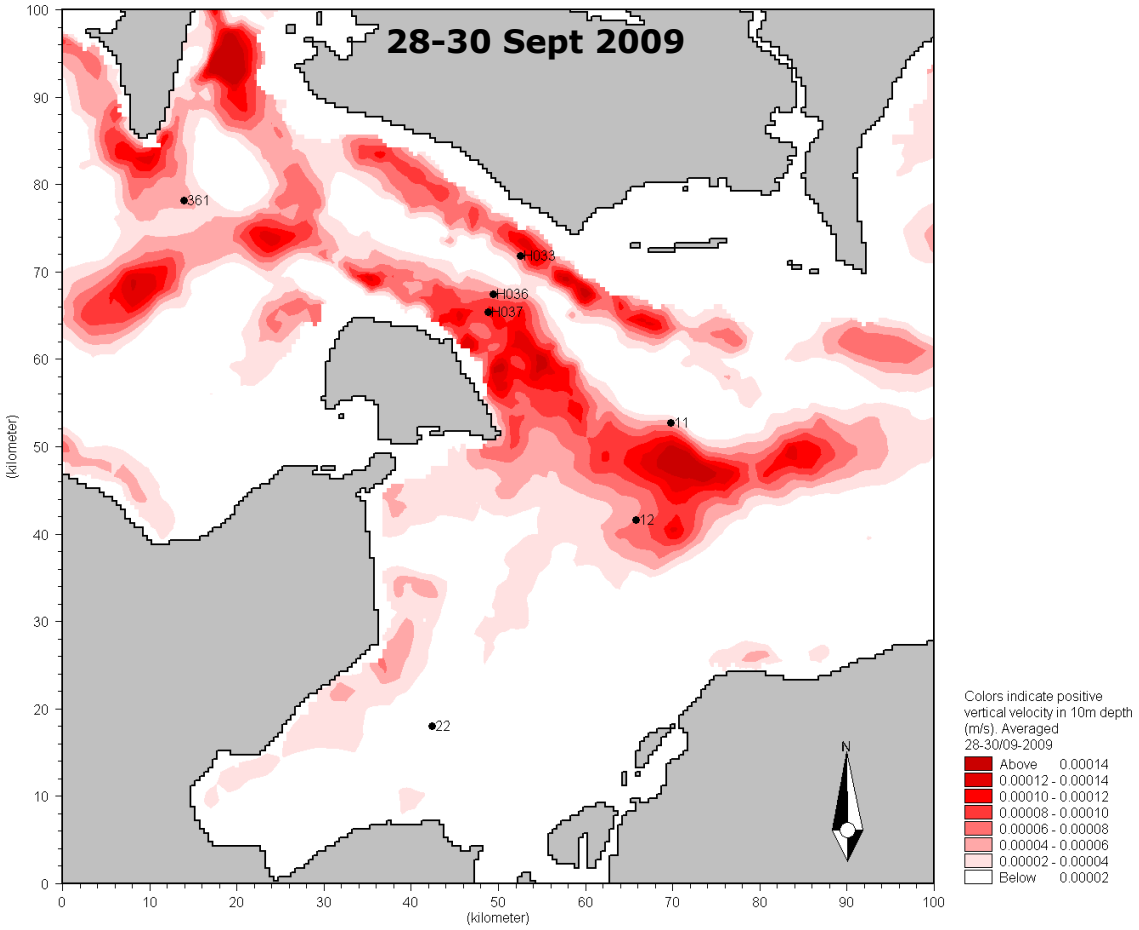


Figure 4-29 "Upwelling" across pycnocline (10 m depth). 2-D plot of modelled vertical (upward) currents in baseline area. Values represent average of positive (upward) current speeds over 3 days coinciding with the investigation cruises. Rate values were extracted from a calibrated hydrodynamic model (MIKE 3 FM) run for January 2009 to 1 June 2010.

The yearly production (March 2009 – November-December 2010) varied between 118 to 142 gC m^{-2} y^{-1} in the investigation area, with the Great Belt having the highest production and the Darss Sill area the lowest production (Table 4-4).

Table 4-4 Yearly planktonic primary production (gC m^{-2} y^{-1}) in the Great Belt area, Fehmarnbelt, Mecklenburg Bight and the Darss Sill area. Yearly values at stations were calculated from individual sample (station) values trapez-integrated over depth and time and subsequently averaging over area

Great Belt	Fehmarnbelt	Mecklenburg Bight	Darss Sill area
142	128	138	118

4.3.2 *Historical data*

The HELCOM monitoring (Danish measurements) of the primary production in the Fehmarnbelt was discontinued in 1997 after 16 years of monitoring. Figure 4-30shows the average monthly variation of the primary production measured at station 952 (equivalent to H037) in Fehmarnbelt averaged over 1982-1997. A seasonal variation is apparent with an increase in primary production rates in spring

caused by yearly recurring diatom blooms, and another increase in production rates in summer where temperatures and insolation are high reaching average production rates in August of more than 800 mg C m^{-2} d^{-1}. In between these two periods the algal production was lower with values of approx. 300 mg C m^{-2} d^{-1} in early summer, primarily due to limitation by nutrients and zooplankton grazing, and low values of around 100 mg C m^{-2} d^{-1} in winter, where mainly the light limits the algal production.

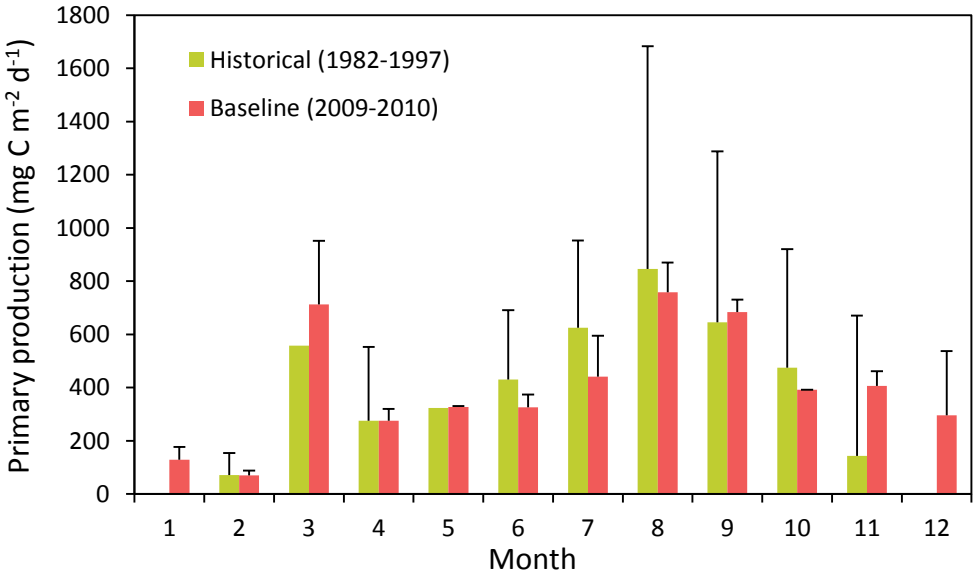


Figure 4-30 Seasonal variation in primary production (monthly average + SD) in Fehmarnbelt. Historical data is based on 16 years of monitoring. Baseline data based on two years measurements at 5 stations (H033, H036, H037, 11, 12). Historical data from the Danish national monitoring program extracted from the Marine database MADS (2011).

The occasionally very high standard deviations in Figure 4-30indicate the natural variation of the 'historical' algal populations (in particular cyanobacteria blooms during summer). The correspondence between the historical data and primary production measured during the baseline investigation is remarkably good, with almost identical yearly productions (Historical: 137 g C m^{-2} y^{-1}; baseline (Fehmarn-Mecklenburg): 132 g C m^{-2} y^{-1}).

Long-term monitoring on a station in the Great Belt, Denmark (55° 22' 36" N, 11° 00' E) in close vicinity to the Fehmarnbelt baseline investigation area has shown considerable changes in the levels of the primary production (Figure 4-31). The production rates have almost doubled since 1950's and show a decreasing tendency in the last part of the century.

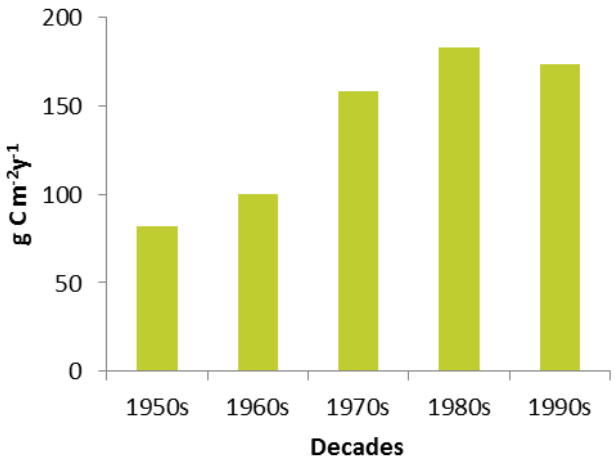


Figure 4-31 Long-term changes in the primary production measured during 5 decades in the Great Belt, Denmark, depicted as averages of the annual production of each decade (figure re-drawn from Andersen et al. 2006, data from G. Ærtebjerg, NERI, Denmark).

In a later study yearly primary production in the 2000s was estimated to 240 gC m^{-2} y^{-1} (Rydberg et al. 2006). The authors explain the unexpected increase by method changes that occurred in the late 1990s.

5 MESOZOOPLANKTON

5.1 Taxonomic composition of mesozooplankton

The mesosaline conditions, characterized by horizontal and vertical salinity gradients, form a rather species-poor mesozooplankton community compared to fully marine habitats. Between the Great Belt/Kiel Bight region in the west and Darss Sill as the most eastern part of the study area, 31 mesozooplankton taxa were distinguished during the two years of baseline plankton assessment (Appendix G.1). There are no red list mesozooplankton species. Jellyfish species are members of the meso- and macrozooplankton community (Scyphozoa, Ctenophora) but are treated in a separate chapter.

The number of mesozooplankton taxa was very similar across the whole study area and ranged at most stations between 21 and 25. At the most eastern sampling station (Darss Sill, DS1) only 20 taxa were found, while 30 taxa were found at the most western station (Kiel Bight, 361) (Table 5-1). The number of taxa differed slightly between seasons, with a tendency of lower numbers in winter and early spring (16-18 taken all stations together) and highest numbers in late summer/autumn (23-25).

Table 5-1 Number of zooplankton taxa at 12 sampling stations between February 2009 and December2010. The last column gives the total number of taxa per station; the last row gives the total number of taxa per season. w: winter

	2009												**2010**											
	spring			summer				autumn			w		spring			summer				autumn			w	
mo.	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	**Σ**
stn.																								
360		8	14		14	18		15	15	12		13	12	8	13	9	11	14	19	14	16			**23**
361	16		13		18	17	16	16	14	20		16	12	13	17	15	13	20	22		19			**30**
111			16		17	18	16	17	13	19		13	13	13	17	15	18	18	17		21	15		**25**
033		14	11		13	18			14	14		12												**21**
036		14	12		15	18		17	16	18			10	10		13	14	18	17	18	18	14	17	**25**
037	12	15	15		16	17			16	17			12											**23**
11			16		14		15	17	14	17				12	15	12	12	15			16		15	**24**
12	16	13	13		16	16		15	16	14			11	14	18	12	14	18		11	16		15	**23**
22		11	15		15	17			15	15		15												**23**
46	13		14		14	15	16	17	17	17		12	11	15	15	14	15	15		18	20	15		**24**
131		14	13		14	17	16		14	15			11			17	14	16	18		19	19		**24**
DS1			14		12	16	15		13	15		8	7		12	14	15	11		14	17	17		**20**
Σ	**18**	**16**	**21**		**21**	**22**	**23**	**25**	**19**	**23**		**18**	**17**	**20**	**19**	**20**	**20**	**22**	**23**	**22**	**24**	**20**	**18**	**31**

The mesozooplankton community consisted of holoplanktonic taxa (organisms that spend their entire life cycle in the pelagic environment) and meroplanktonic taxa (epibenthic taxa or larvae of benthic species). The holoplanktonic taxa dominated the biomass throughout the year (Appendix G.2) with crustaceans dominated by calanoid Copepoda as the most common group (Table 5-2).

The calanoid copepod community consisted mainly of five species. These are the brackish water species *Acartia bifilosa* and *Acartia longiremis*, the euryhaline coastal species *Temora longicornis* as well as *Pseudocalanus* spp. and *Centropages hamatus*, which also inhabit fully marine habitats. The genera *Acartia*, *Centropages*,

Temora and *Pseudocalanus* were present in more than 95% of the samples from all stations and seasons. *Oithona similis* was the most common cyclopoid copepod at all stations and seasons. The marine water fleas (Cladocera) of the family Podonidae include the genera *Evadne* as well as *Podon* and *Pleopsis.* No distinction were made between the two latter, they are summed as Podonidae. The Bosminidae included the genera *Bosmina* and *Eubosmina*. *Penilia avirostris* is a cosmopolitan species, invading the Baltic Sea most probably from the North Sea and has been occasionally observed in the western Baltic Sea since 2001.

Table 5-2 Presence (% of samplings) of holoplanktonic taxa between February 2009 and December 2010 at 12 stations in the baseline investigation area.

Area	**Great Belt**			**Fehmarnbelt**			**Mecklenb Bight**			**Darss Sill**			**all**
	111	**361**	**360**	**033**	**036**	**037**	**11**	**12**	**22**	**46**	**DS1**	**131**	**stn**
Crustacea/Copepoda/Calanoida													
Acartia	100	100	100	100	100	100	100	100	100	100	100	100	100
Centropages	100	100	100	100	100	100	100	100	100	100	100	100	100
Temora	100	95	94	100	100	100	100	94	100	100	100	100	98
Pseudocalanus	88	89	65	71	88	100	85	71	86	85	87	100	84
Eurytemora	12	16	0	0	19	0	8	12	0	25	27	36	15
Calanus	35	16	0	0	25	38	23	6	14	10	0	0	14
Paracalanus	12	26	0	29	19	13	8	6	0	15	7	21	13
Crustacea/Copepoda/Cyclopoida													
Oithona	100	100	100	86	100	100	92	100	100	100	80	93	96
Cyclopoida	0	5	0	0	0	0	0	6	14	5	0	0	2
Crustacea/Branchiopoda/Cladocera													
Evadne	88	89	76	86	88	100	92	88	100	95	87	93	89
Podonidae	94	100	65	100	88	88	92	888	71	85	87	100	88
Bosminidae	29	37	35	43	38	25	62	53	29	60	67	71	47
Penilia	18	21	18	14	19	13	15	12	14	20	0	0	14
Nemathelminthes/Rotifera													
Synchaeta	41	37	29	57	44	50	62	76	57	70	73	71	55
Tunicata													
Oikopleura	65	68	47	43	63	38	31	47	43	45	33	43	49
Fritillaria	41	53	47	29	38	38	31	47	43	30	33	29	39
Chaetognatha													
Sagitta	6	11	0	0	0	0	0	0	0	0	0	21	4

Eleven meroplanktonic taxa (at very different taxonomic levels – from clade to genus) were distinguished in this baseline study (Table 5-3). Meroplanktonic taxa usually contributed with less than 5% of the total mesozooplankton biomass during most time of the year. However, in March/April the meroplankton comprised 20-40% of the zooplankton community at all stations. Especially larvae of Polychaeta (in the whole investigation area) and *Balanus* spp. (mainly in the Great Belt area) accounted for the relatively high biomass of meroplanktonic taxa in spring. The Polychaeta larvae were not determined at lower taxonomic levels, but include mainly Terebellidae and Spionidae. Larvae of Bivalvia and Gastropoda occurred regularly at all stations in summer. Bivalvia larvae were most likely dominated by *Mytilus* spp., and Gastropoda larvae were probably mainly *Hydrobia* spp. Gymnolaemata (Bryozoa) larvae were present at all stations, mainly in late autumn and winter. Larvae

of the common starfish *Asterias rubens* were only found in June 2009. In the Great Belt area and Fehmarnbelt area they occurred in the whole water column, but further east these larvae were only observed in the deeper water layer.

Table 5-3 Presence (% of samplings) of meroplanktonic taxa between February 2009 and December 2010 at 12 stations in the baseline investigation area.

Area	Great Belt			Fehmarnbelt			Mecklenb Bight			Darss Sill			all
	111	361	360	033	036	037	11	12	22	46	DS1	131	stn
Annelida													
Polychaeta	94	89	82	86	88	100	77	88	100	80	73	79	85
Crustacea/Cirripedia													
Balanus	100	100	94	86	100	88	85	88	100	90	60	64	88
Crustacea/Copepoda													
Harpacticoida	88	89	24	29	63	50	46	41	14	65	13	57	52
Crustacea													
Decapoda	47	32	12	0	31	13	15	24	29	25	13	50	26
Mysidacea	0	5	0	0	0	0	8	0	0	0	0	0	1
Mollusca													
Bivalvia	82	74	88	57	88	88	92	88	86	90	80	79	84
Gastropodaa	94	74	65	57	75	63	85	65	57	75	80	79	74
Tentaculata													
Gymnolaemata	76	74	71	71	69	75	54	65	71	60	40	50	64
Phoronidae	6	11	6	0	0	0	0	0	0	5	0	0	3
Echinodermata													
Asterias	12	21	24	14	25	25	8	12	29	10	13	14	16
Ophiura	6	11	0	0	0	0	0	0	0	0	0	0	2

5.2 Spatial variation

5.2.1 *Vertical distribution patterns*

The vertical distribution patterns of the zooplankton community in the investigation area partly reflected the hydrographical condition with vertical salinity gradients (halocline) caused by deep layer inflows of saline water from the Kattegat into the Baltic proper and surface brackish water outflows. The mesozooplankton community showed significant differences between the water layers above and below the halocline in April, June, July, October and November 2009 (ANOSIM, Global R 0.17-0.24). Hierarchical clustering of the zooplankton data set for the same months showed a segregation of the community above and below the halocline at similarity levels between 70% and 80%. The monthly MDS plots of the "halocline" grouping confirm distinctive communities in the different water layers (for example in November: Figure 5-1). In contrast, the mesozooplankton community was highly similar in the upper and lower water layer in January/February 2010, even when a halocline was detected (ANOSIM, Global R<0.1).

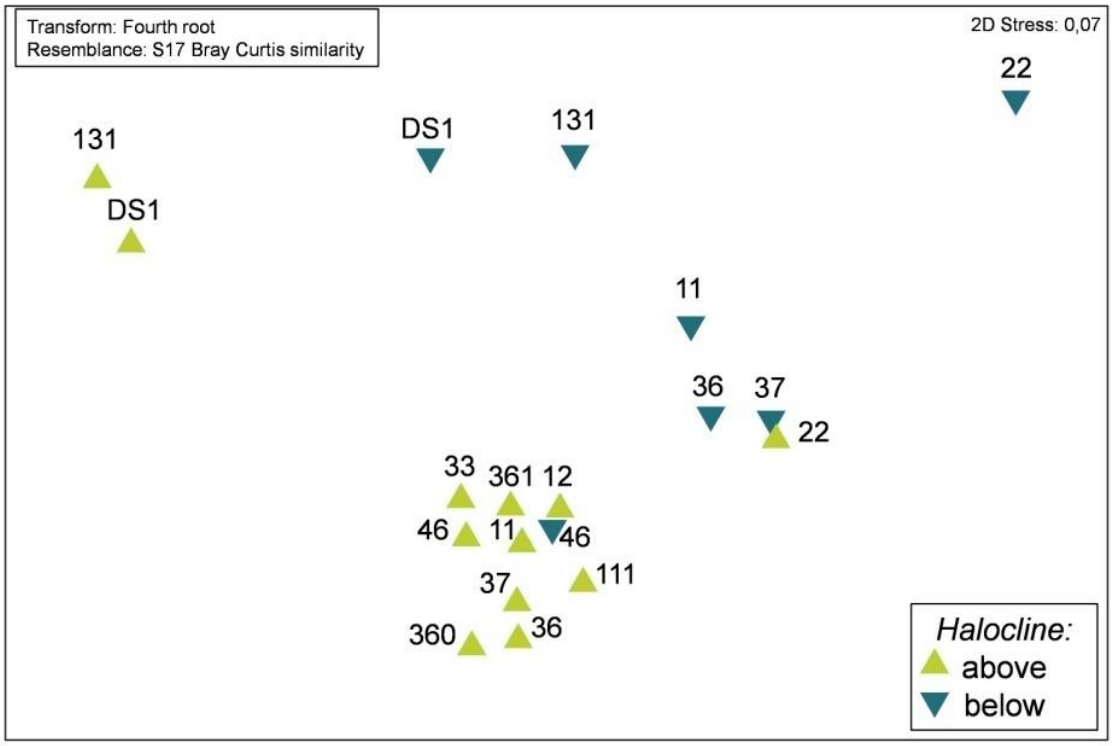


Figure 5-1 *MDS-plot of the mesozooplankton community abundance for November 2009. All taxa contributing less than 1% to the total abundance were excluded from analyses. Communities above halocline: green, below halocline: blue. There was no halocline at stations 361, 360, 111, 33 in November therefore samples were labelled as "above halocline".*

However, many species of crustacean zooplankton, especially the adult forms, conduct diurnal vertical migrations through the water column. This involves rising to the surface at dusk and grazing on phytoplankton during the night, before descending to deeper water layers before dawn to avoid visually feeding predators. Our data set does not allow an assessment of diurnal migration patterns of Copepoda since all data were obtained at daytime with a low vertical resolution. However, the very similar abundances of all developmental stages of *Acartia* spp., *Temora longicornis* and *Centropages hamatus* above and below the halocline at daytime indicate a homogeneous vertical distribution pattern of these species. In contrast, at daytime the abundances of copepodites and adults of the calanoid copepod *Pseudocalanus* spp. and the cyclopoid copepod *Oithona similis* were generally higher below the halocline compared to the surface water layer, indicating either diurnal migration or a general preference of the deeper higher saline water (Figure 5-2 and Figure 5-3).

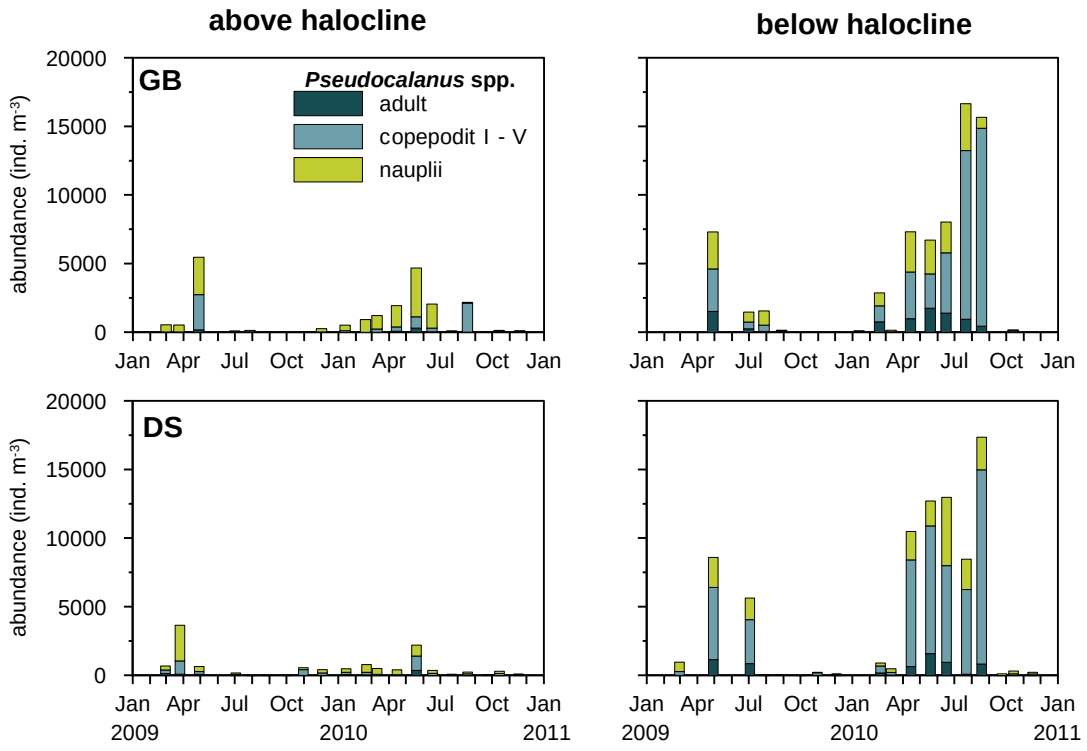


Figure 5-2 *Abundance of Pseudocalanus spp. developmental stages and adults between February 2009 and December 2010 above and below the halocline in Great Belt area (above, GB) and Darss Sill area (below, DS)*

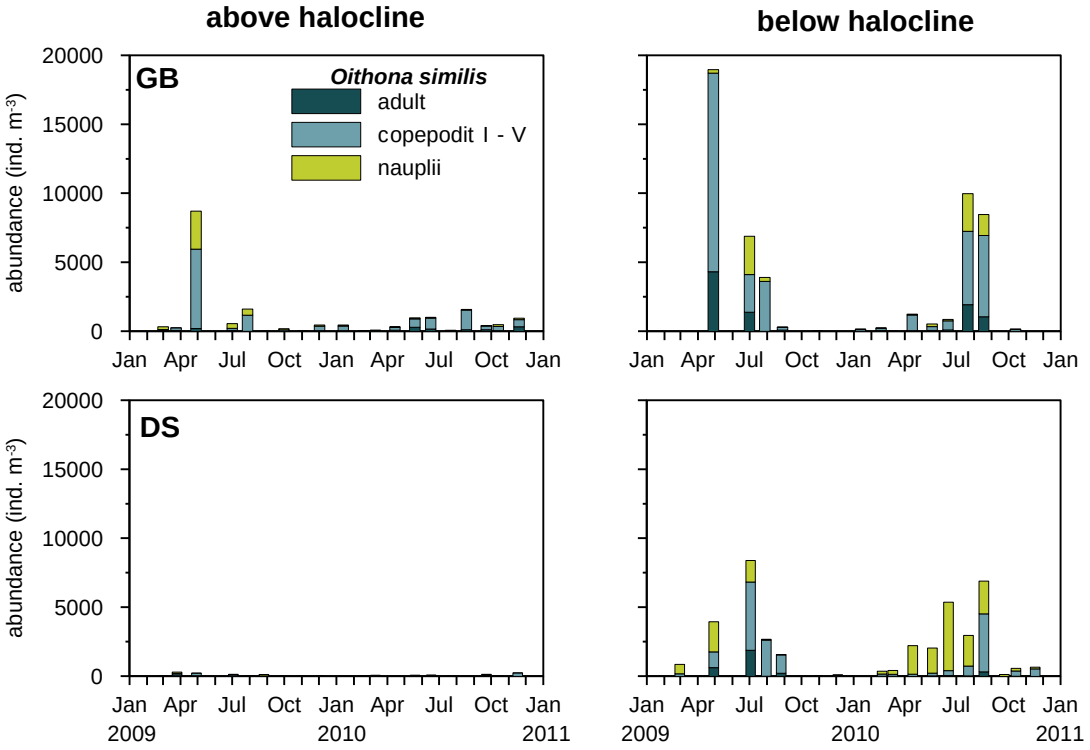


Figure 5-3 *Abundance of Oithona similis developmental stages and adults between February 2009 and December 2010 above and below the halocline in Great Belt area (above, GB) and Darss Sill area (below, DS).*

5.2.2 *Horizontal distribution patterns*

The main environmental parameter expected to structure the horizontal distribution of the mesozooplankton community is the salinity gradient from west to east, which is more pronounced in the upper water layer compared to the deeper layer (Figure 1-2).

The structure of the zooplankton community partly supported the *a priori* separation of the study area into the four geographical subareas: Great Belt (GB), Fehmarnbelt (FB), Mecklenburg Bight (MB), and Darss Sill (DS) (Figure 2-1). Above the halocline, ANOSIM analysis indicated that the similarity of the zooplankton community of stations within one geographical subarea was higher than between the four subareas in summer 2009 (Table 5-4). High R-values for the comparison of the most distant subareas (Great Belt and Darss Sill) indicate significant differences between these subareas whereas the differences between the zooplankton communities from adjoined geographical subareas were smaller and for Fehmarnbelt and Mecklenburg Bight subareas even insignificant (Table 5-4). The MDS plots of the "subarea" grouping support the ANOSIM results and show that the zooplankton communities above the halocline changed gradually from the most western subarea (Great Belt) to the most eastern subarea (Darss Sill area) (for example in July, Figure 5-4). In spring 2009 and in autumn/winter 2009/10 the zooplankton communities were not significantly different in surface waters of the four subareas.

Below the halocline, the zooplankton community was very similar between the four subareas (ANOSIM, Global R<0.1; Figure 5-4).

Table 5-4 Summary of ANOSIM of zooplankton community for geographical subareas above the halocline (R values of Monte Carlo test). Grey cells: variability within subareas < between subareas; White cells: variability within subareas > between subareas. GB: Great Belt, FB: Fehmarnbelt, MB: Mecklenburg Bight, DS: Darss Sill (see Figure 2-1).

	June	July	Oct
Global R	0.426	0.391	0.485
Groups R			
DS, FB	0.444	0.333	0.704
DS, GB	0.926	0.741	1
DS, MB	0.259	0.417	0.148
FB, GB	0.259	0.185	0.852
FB, MB	0.037	0.167	0
GB, MB	0.333	0.917	0.37

The high similarity of the zooplankton community within the whole study area was mainly due to similar abundances of the community dominating calanoid copepod genera *Acartia*, *Centropages*, *Temora* and *Pseudocalanus* as well as the seasonally occurring *Synchaeta* and Podonidae. The minor spatial differences during summer were caused by the occurrence of 'marine' taxa in the western part of the study area (*Oikopleura*, *Fritillaria*, *Asterias* larvae, Tentaculata, *Penilia*) and of taxa tolerating low salinities in the eastern part of the study area (Bosminidae, Figure 5-5).

Figure 5-4 *MDS-plot of zooplankton community of the four geographical subareas in July 2009. All taxa contributing less than 1% to the total abundance were excluded from analyses. Left: above halocline, Right: below halocline. GB: Great Belt, FB: Fehmarnbelt, MB: Mecklenburg Bight, DS: Darss Sill (see Figure 2-1).*

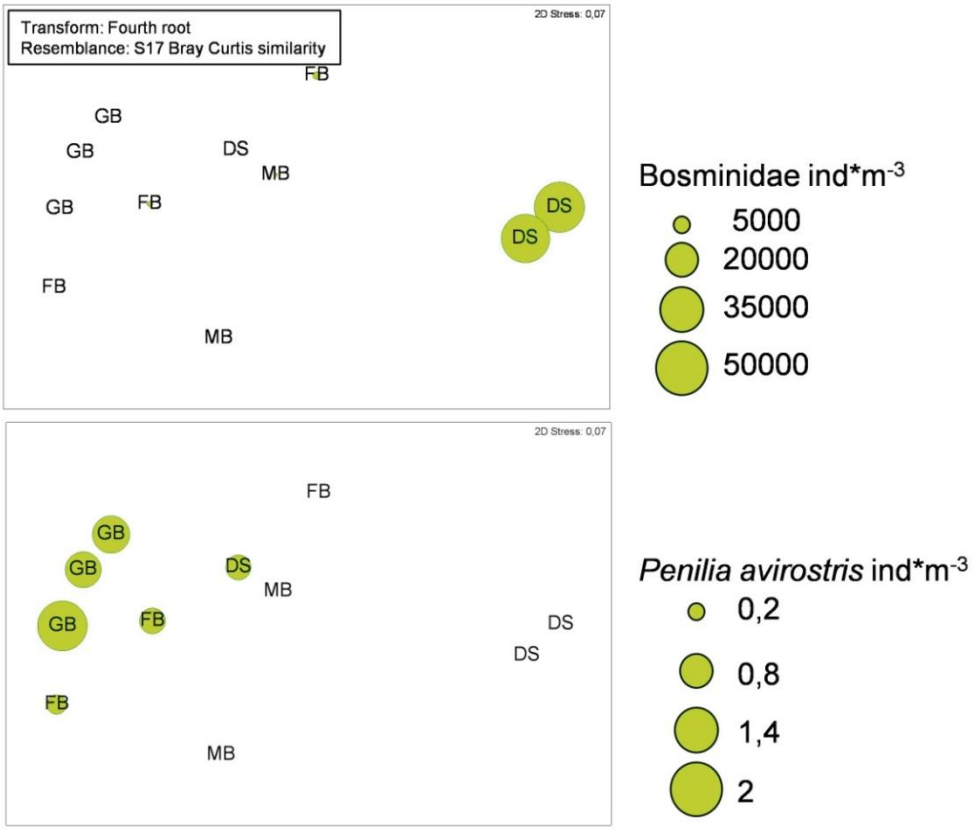


Figure 5-5 *MDS-plot of mesozooplankton community of the four geographical subareas in July 2009 above the halocline (GB: Great Belt, FB: Fehmarnbelt, MB: Mecklenburg Bight, DS: Darss Sill). All taxa contributing less than 1% to the total abundance were excluded from analyses. Green bubbles show spatial distribution of two Cladocera taxa. Above: abundance of Bosminidae, below: abundance of Penilia avirostris.*

5.3 Seasonal variation

5.3.1 Seasonal variation of the mesozooplankton community

The Baltic Sea pelagic ecosystem is strongly influenced by the seasonality of temperature and light conditions, which regulate primary production and the length of

the growing period of the next trophic levels. As a consequence, the seasonal variability of the zooplankton community was more pronounced than the spatial variation within the study area.

The MDS ordination shows a significant clustering of the different months and a continuous change in the zooplankton community composition throughout the year. A pronounced seasonality of the community structure was found from April to September as a consequence of seasonal recruitment and community succession of the dominating taxa (Figure 5-6). The winter/early spring community (October to March) appeared to be more stable.

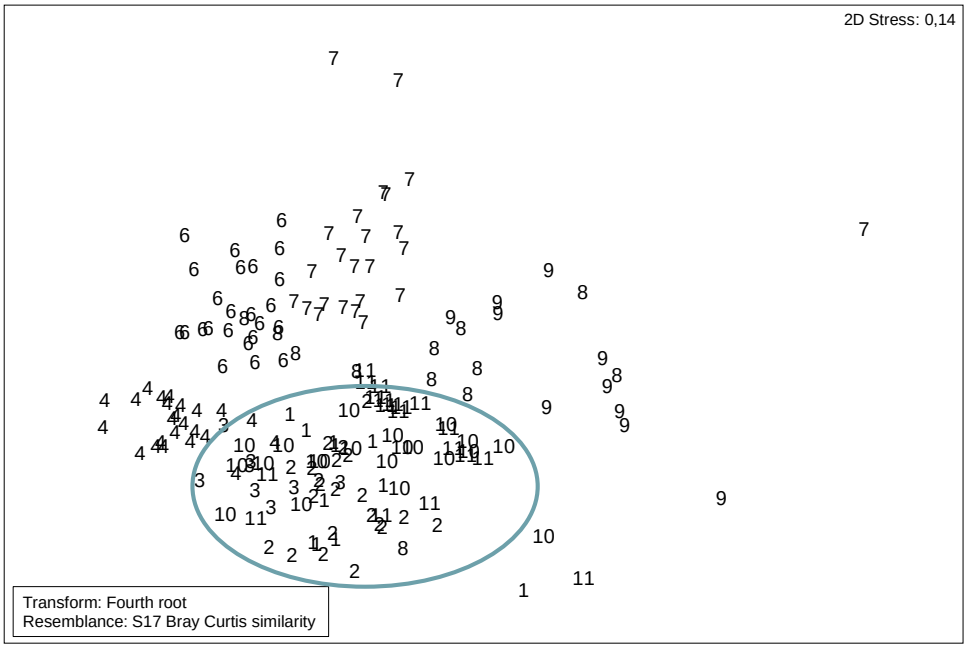


Figure 5-6 MDS-plot of zooplankton community in 2009 at 12 stations (Figure 2-1) Numbers indicate months. The blue ellipse indicates late autumn to early spring season.

The seasonal cycle of the zooplankton community was mainly structured by the phenology of subsequent developmental stages of the dominant calanoid copepods *Acartia*, *Centropages*, *Temora* and *Pseudocalanus*. The data do not give a complete picture of the intra annual succession of copepod generations as the sampling frequency (4-8 weeks) is too low to resolve the very short generation cycles (1-2 weeks for nauplii, 1-2 weeks for copepodits). However, the seasonal occurrence of copepod nauplii and copepodite stages (all genera in spring, *Centropages*, *Temora* also in winter) and adults (all genera in summer, *Temora* also in winter) mainly structured the zooplankton community in the whole study area.

The strict seasonal occurrence of a range of less biomass-dominant taxa also contributed to the intra annual zooplankton community succession. A "bloom" of the Rotifera genus *Synchaeta* spp. across the whole study area and in the entire water column was found in April 2009 following the spring bloom in March (Figure 5-7). The Cladocera reproduce very rapidly at high temperatures and accordingly showed high densities in July/August 2009. The Tunicata genus *Oikopleura* showed an abundance peak in late July 2009. Meroplanktonic larvae also showed a strong seasonality with abundance peaks of Polychaeta larvae in March/April, larvae of the

common starfish *Asterias* in June, Bivalvia and Gastropoda larvae in June/July (Figure 5-7) and Gymnolaemata (Bryozoa) larvae in December-February.

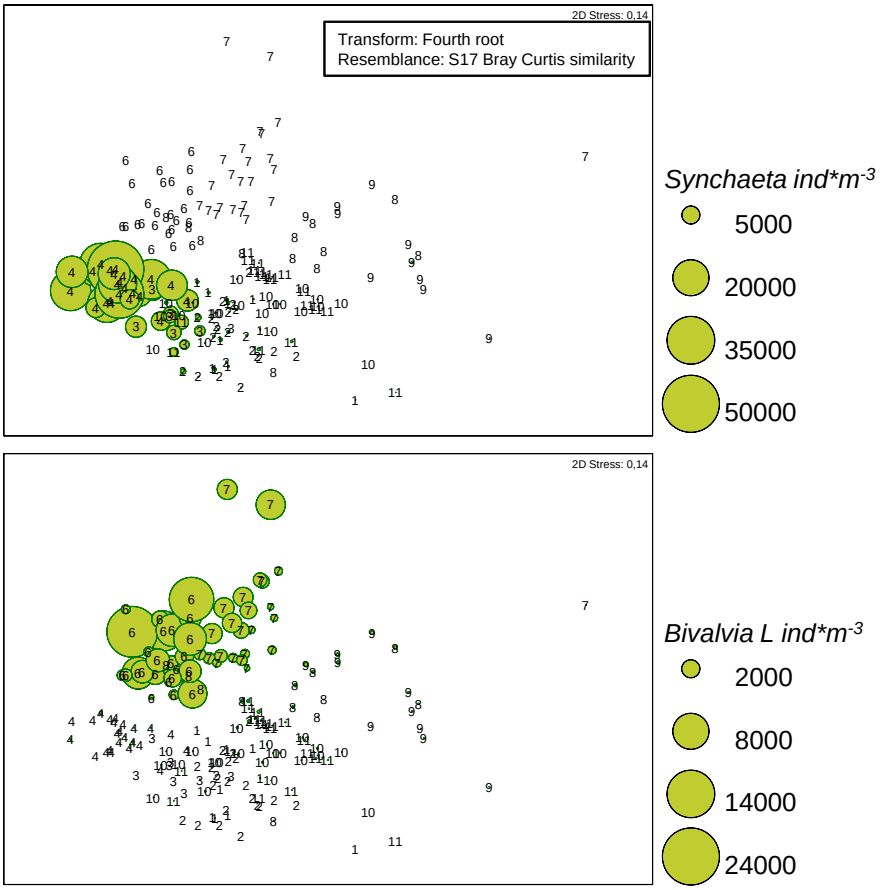


Figure 5-7 *MDS-plot of mesozooplankton community 2009 at 12 stations. Numbers indicate months. The green bubbles show the spatial distribution of Synchaeta (above) and larvae of Bivalvia (below).*

5.3.2 ***Seasonal variation of biomass***

The total biomass of mesozooplankton showed a clear seasonality in all subareas. Biomass maxima were observed between late April and late June in 2009 and between May and July in 2010, respectively (Figure 5-8). Integrated over the whole water column, the annual biomass maxima were remarkably similar in all subareas during the investigation period (February 2009 to December 2010). The values ranged between 480 mg m^{-3} (Great Belt area), 620 mg m^{-3} (Fehmarnbelt area), 610 mg m^{-3} (Mecklenburg Bight area), and 650 mg m^{-3} (Darss Sill area) (Figure 5-8). The mean biomasses of the subareas for the period between February 2009 and December 2010 were very similar and ranged between 180 mg m^{-3} (Great Belt area) and 220 mg m^{-3} (Darss Sill area).

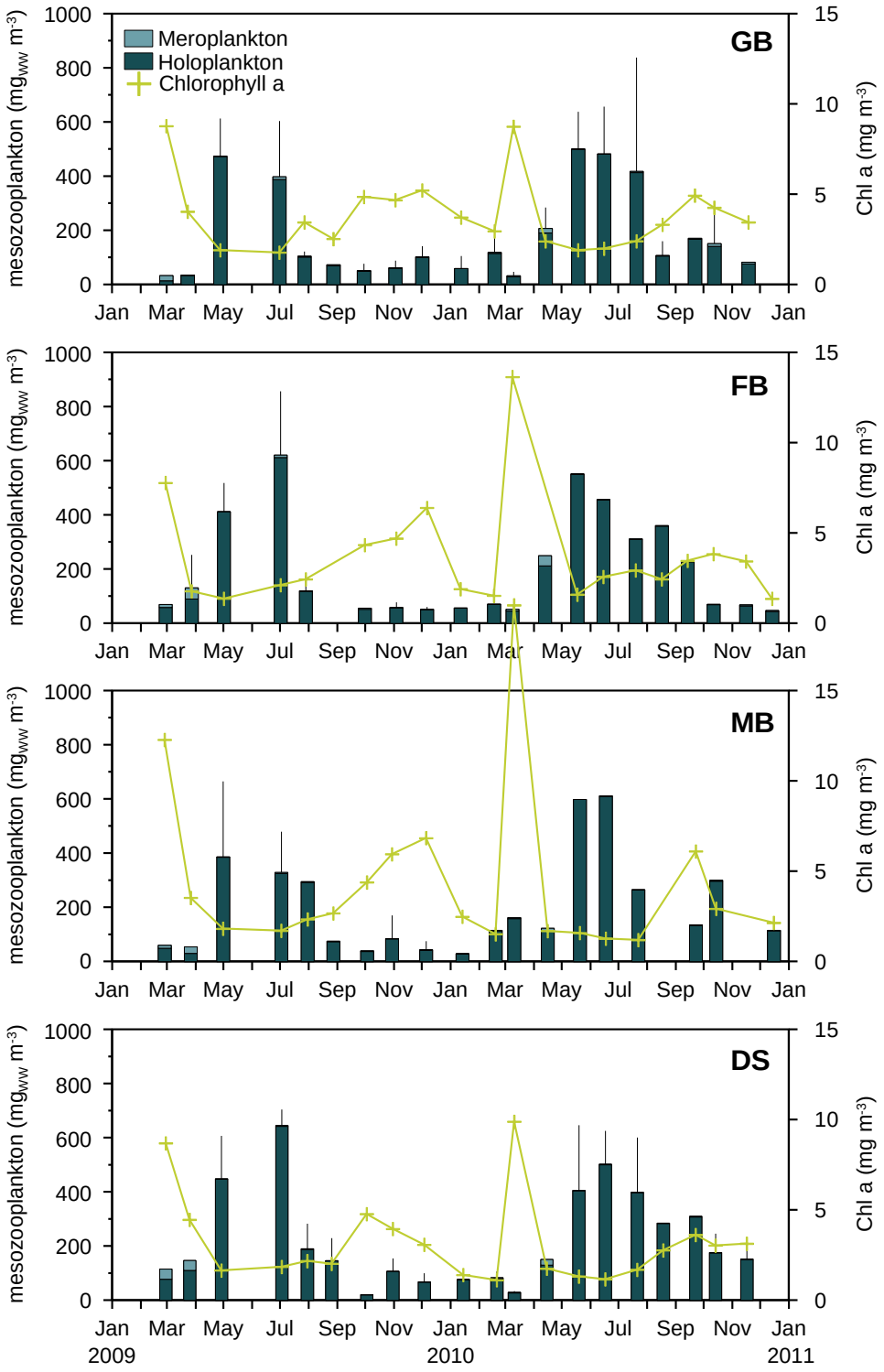


Figure 5-8 *Mesozooplankton biomass of holoplanktonic and meroplanktonic taxa and chl-a concentration in 4 subareas of the baseline investigation area between February 2009 and December 2010. GB: Great Belt, FB: Fehmarnbelt, MB: Mecklenburg Bight, DS: Darss Sill area (see Figure 2-1). Mesozooplankton biomasses are calculated for the whole water column, while chl-a concentrations represent the upper 10 m of the water column.*

Spring (February to May)

The seasonal mean biomass of zooplankton in spring 2009 and 2010 was low and ranged between 20-500 mg m^{-3} (Great Belt area), 50-400 mg m^{-3} (Fehmarnbelt area), 50-400 mg m^{-3} (Mecklenburg Bight area), and 50-450 mg m^{-3} (Darss Sill area) (Figure 5-8).

The spring bloom of phytoplankton peaked in February 2009 and in March/April 2010, respectively and formed the basis for the development of the next trophic levels. Subsequently, reproduction and growth of zooplankton increased rapidly up to maximal biomasses of 500-600 mg m^{-3} (Figure 5-8). Probably due to lower water temperatures and a spring bloom occurring 4 week later than in 2009, zooplankton biomass was still 50% lower in April 2010 compared to April 2009 (Figure 5-8).

The dominant taxa were the calanoid copepods (Figure 5-9). For nauplii and copepodits the abundance was quite similar in the 4 subareas (Figure 5-10). A precise assessment of abundances of juvenile stages of copepods is difficult due to the very short developmental cycle of nauplii and copepodit stages. However, nauplii and copepodites of *Acartia*, *Centropages*, *Temora* and *Pseudocalanus* peaked in late April 2009 in the entire water column in the whole investigation area. In 2010, the spring abundances of juvenile copepods were only half as high as in 2009 (Figure 5-10). The proportion of species differed between the two years. *Centropages* and *Temora* were much more abundant in all subareas during spring 2009 compared to 2010.

Abundances of adult calanoid Copepoda were generally low in early spring across the study area in the entire water column. Merely the wintering stock of adult *Centropagus hamatus* was higher with about 600 individuals m^{-3} in Darss Sill area in 2009. In early spring 2010 *Temora longicornis* dominated the adult copepod community with about 500 individuals m^{-3} in all subareas (Figure 5-11). Abundances of all adult copepod taxa increased rapidly in late April 2009 in all subareas. In 2010, the increase of adult *Acartia* spp. was delayed one month compared to 2009 (Figure 5-11).

Rotifera was the second most characteristic zooplankton taxon during spring. As mentioned earlier a "bloom" of the genus *Synchaeta* spp. across the whole study area and in the entire water column occurred in April 2009 with mean abundances of 16000 individuals m^{-3} (Great Belt area) to 19000 individuals m^{-3} (Darss Sill area). In contrast, rotifer bloom was not observed in spring 2010 (Figure 5-9).

In late April 2009 the first peak of the cladoceran Podonidae was measured, with similar abundances in the western part (*Podon* max. 450 individuals m^{-3}, *Evadne* max. 750 individuals m^{-3}) as in the eastern part (*Podon* max. 440 individuals m^{-3}, *Evadne* max. 1030 individuals m^{-3}). In 2010 the spring Podonidae peak were observed one month later in May (Figure 5-12).

Meroplanktonic larvae reached their annual peak in spring of both study years and comprised up to 20% of the total mesozooplankton biomass (Figure 5-8). In both years, the major group were Polychaeta larvae with increasing abundances from the western part (Great Belt: mean 2000 individuals m^{-3}) to the eastern part of the investigation area (Darss Sill: mean 4000 individuals m^{-3}). The second taxon of meroplanktonic larvae in spring of both years were *Balanus* larvae, showing higher abundances in the western part of the investigation area (Great Belt/Fehmarnbelt: mean 100 individuals m^{-3} in 2009, 300 individuals m^{-3} in 2010) compared to the

eastern part, were the distribution was restricted to the bottom water layer (Darss Sill: <100 individuals m^{-3} in both years) (Figure 5-13).

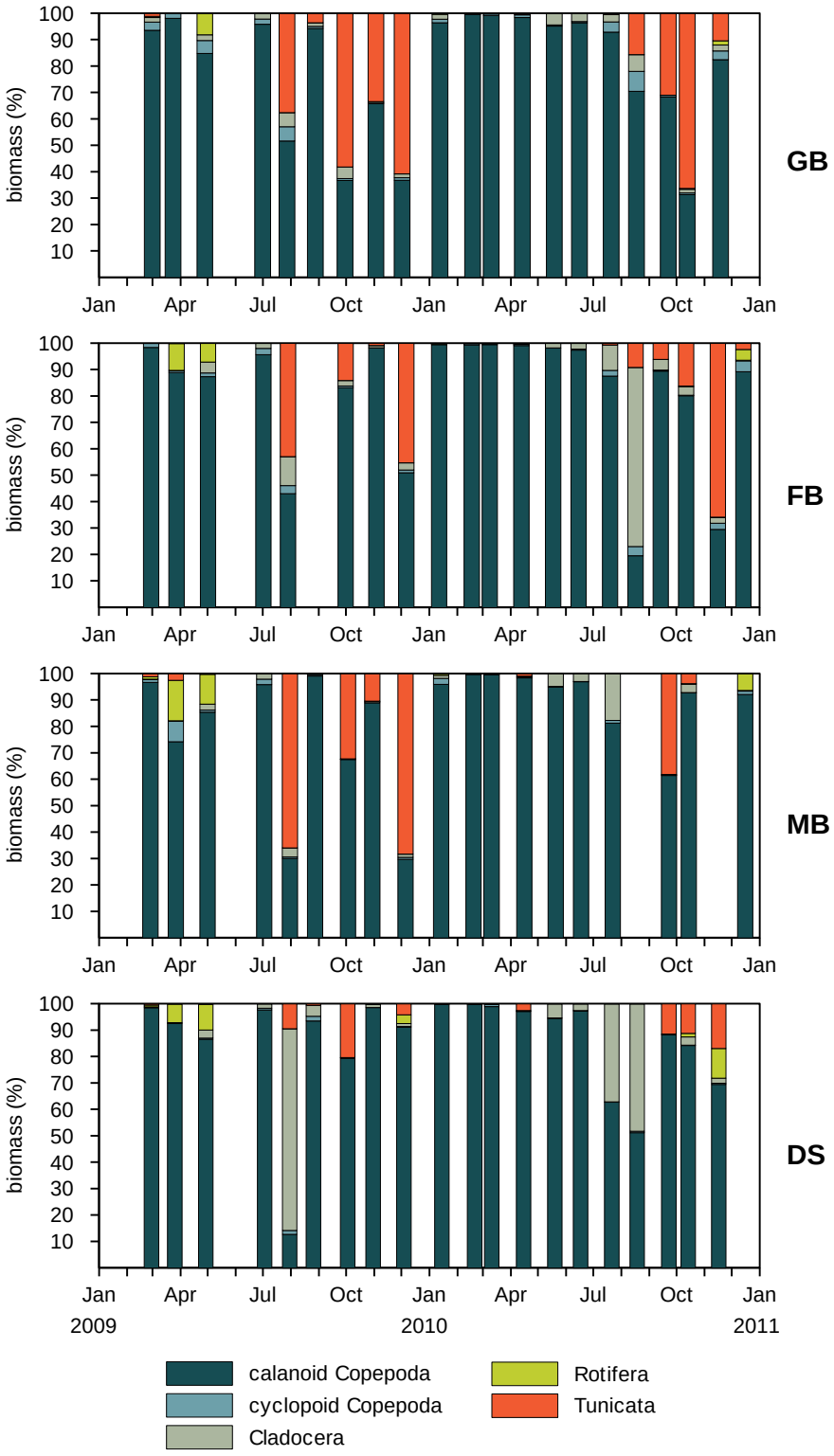


Figure 5-9 *Proportion of biomass (%) for holoplanktonic taxa in the 4 subareas of the baseline investigation area. GB: Great Belt area, FB: Fehmarnbelt area, MB: Mecklenburg Bight area, DS: Darss Sill area.*

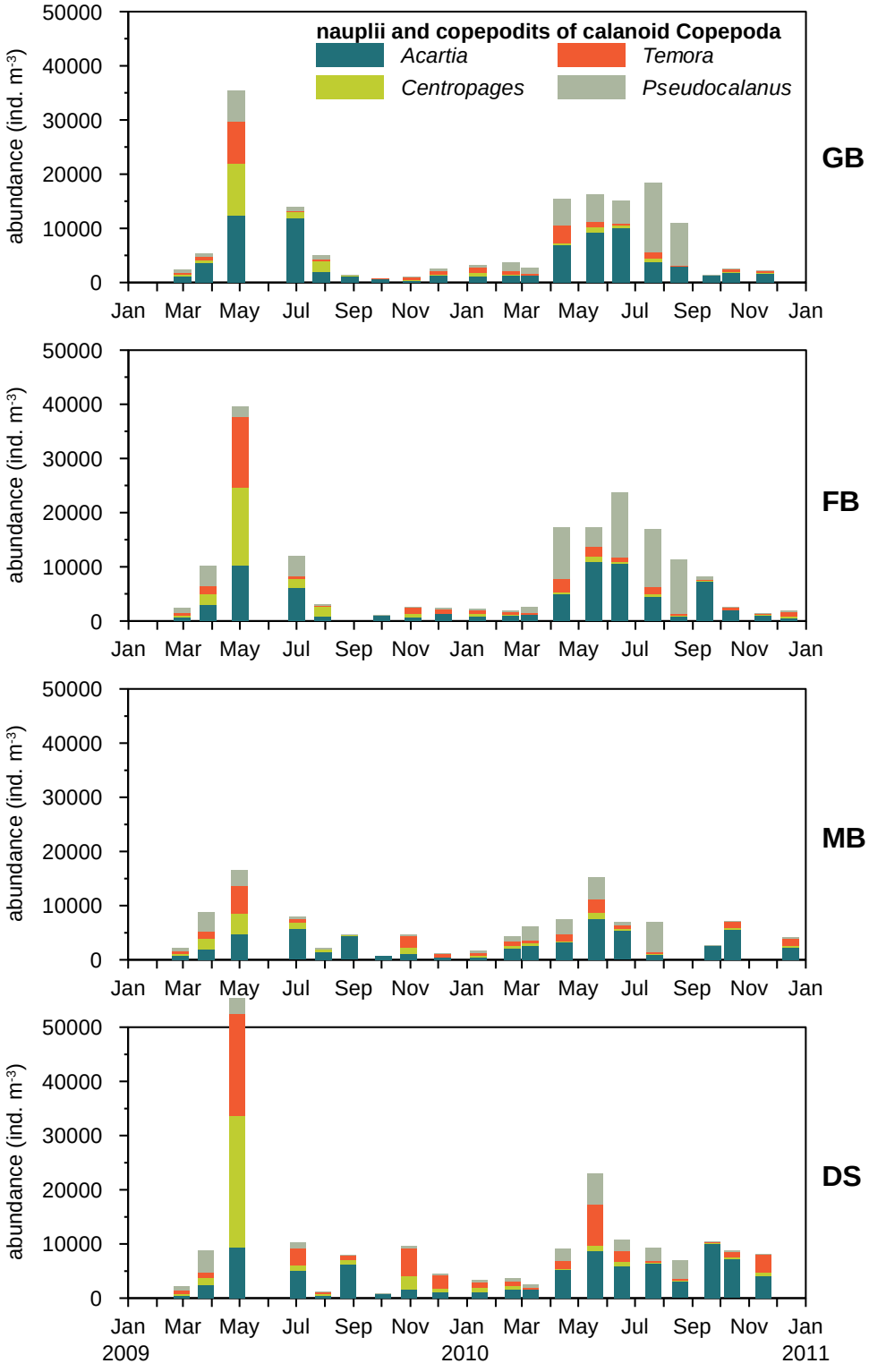


Figure 5-10 Abundance of juvenile developmental stages of 4 calanoid Copepoda genera between February 2009 and December 2010 in the 4 subareas of the baseline investigation area. GB: Great Belt area, FB: Fehmarnbelt area, MB: Mecklenburg Bight area, DS: Darss Sill area.

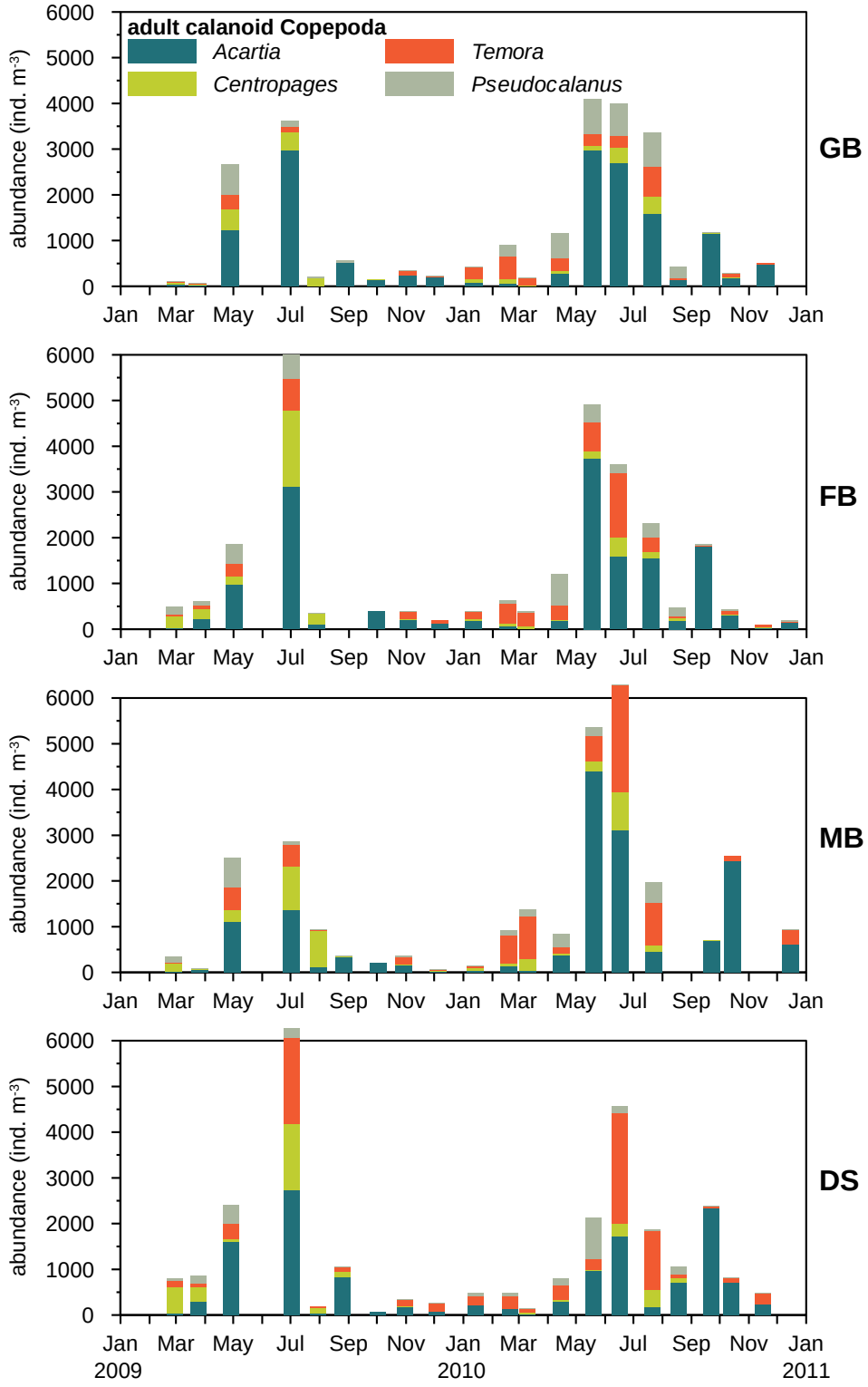


Figure 5-11 Abundance of 4 genera of adult calanoid Copepoda between February 2009 and December 2010 in the 4 subareas of the baseline investigation subarea. GB: Great Belt area, FB: Fehmarnbelt area, MB: Mecklenburg Bight area, DS: Darss Sill area.

Summer (June to August)

The zooplankton biomass increased to the annual maxima in summer 2009 and 2010 (600 and 820 mg m^{-3} in Great Belt area, 830 and 550 mg m^{-3} in Fehmarnbelt area, 500 and 600 mg m^{-3} in Mecklenburg Bight area and 700 and 650 mg m^{-3} in Darss Sill area). In late summer 2009 the zooplankton biomass declined abruptly with a temporal shift of about one month towards the eastern part of the baseline study area (to 90-120 mg m^{-3}, Figure 5-8). The late summer biomass decline was less pronounced in 2010 (120-400 mg m^{-3} in August, Figure 5-8). During summer the zooplankton community was more diverse than in spring, consisting of 23 taxa (Table 5-1).

In early summer, the dominant taxa in terms of biomass were the calanoid copepods (Figure 5-9). Nauplii and copepodits of *Acartia* spp. dominated the juvenile copepod community in summer 2009, high abundances of juvenile *Acartia* spp. and *Pseudocalanus* spp. were observed in summer 2010 in all subareas (Figure 5-10). In the eastern part of the study area, all juvenile stages of *Pseudocalanus* spp. preferred the water layer below the halocline (Figure 5-2).

The adult calanoid Copepoda *Acartia bifilosa*, *Acartia longiremis*, *Centropages hamatus*, *Temora longicornis* and *Pseudocalanus* spp. reached their annual maxima in summer. Adults of the most abundant species *Acartia bifilosa* accounted for 40-60% of the total biomass in summer of both years. In late July/August, the populations of all stages of *Acartia bifilosa*, *Centropages hamatus*, *Temora longicornis* and *Acartia longiremis* disappeared in both years almost completely in all subareas (Figure 5-11).

The Tunicata species *Oikopleura dioica* appeared in late July 2009 in the whole study area and accounted for about 50% of the total biomass in entire water column from Great Belt area to Mecklenburg Bight area. In Darss Sill area *Oikoplaeura dioica* was less dominant and accounted for 10 % of the total biomass (Figure 5-9). In 2010, *Oikopleura dioica* occurred later in the season compared to 2009 and was less biomass dominant (Figure 5-9).

In July/August of both years, the rapidly reproducing Cladocera reached their annual biomass maxima in all subareas. Abundances of *Podon* decreased during summer to less than 100 individuals m^{-3}. Evadne showed stable densities throughout the summer season in the whole investigation area (about 1000 individuals m^{-3}) (Figure 5-12). Podonidae occurred in similar abundances above and below the halocline. A *Bosmina* "bloom" was recorded in late July in both study years in the Darss Sill area above the halocline with maximal abundances of 20000 individuals m^{-3} (Figure 5-12) which accounted up to 85% of the total zooplankton biomass (Figure 5-9).

Meroplanktonic taxa made up less than 5% of the total biomass in summer, consisting up to a level of 95% of Mollusca larvae and, in 2009, 5% of Echinodermata larvae *Asterias* in the entire water column of the western part of the study area (Great Belt and Fehmarnbelt subareas). Further east (Mecklenburg Bight and Darss Sill areas), *Asterias* larvae only occurred in the bottom water layer. Mollusca larvae were the only meroplanktonic larvae in the surface layer (Figure 5-13).

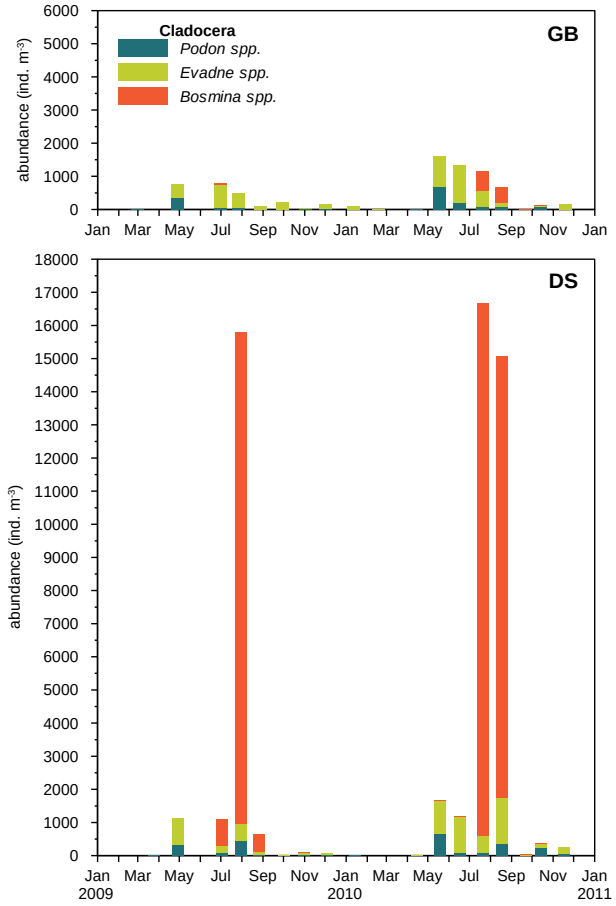


Figure 5-12 Abundance of Cladocera between February 2009 and December 2010 in Great Belt (GB) area and Darss Sill (DS) area.

Autumn (September to November)

The autumn phytoplankton bloom was not followed by an autumn zooplankton peak in 2009. From September to November 2009, the zooplankton biomass stayed at the low late summer level (50-60 mg m^{-3} in all subareas) (Figure 5-8). The autumn zooplankton biomass was higher in 2010 (100–300 mg m^{-3}). The zooplankton community was as diverse as in summer, consisting of 25 taxa across the whole study area (Table 5-1).

Calanoid Copepoda and Tunicata dominated the zooplankton community as during summer (Figure 5-9). Juvenile copepod stages were less abundant in the western part (2000 individuals m^{-3}) than in the eastern part of the study area (10000 individuals m^{-3}). *Acartia* spp. were the most abundant taxa (Figure 5-10).

The adult copepod community was dominated by *Acartia* spp. as well. The abundances of adult *Acartia* spp. were approximately 4 times higher in 2010 (1000 individuals m^{-3}) compared to 2009 (250 individuals m^{-3}) in the Great Belt and Fehmarnbelt subareas and 10 times higher in 2010 (2000 individuals m^{-3}) compared to 2009 (200 individuals m^{-3}) in Mecklenburg Bight and Darss Sill areas (Figure 5-11).

During autumn 2009 and 2010 the biomass of Tunicata showed an West-East gradient (from about 100 mg m^{-3} in the Great Belt area to about 50 mg m^{-3} in the

Darss Sill area). The biomass of *Oikopleura dioica* was about ten times higher as the biomass of *Fritillaria borealis*.

All Cladoceara were found in very low abundances in autumn 2009 and 2010 across the study area, except Bosminidae which occurred only occasionally in the Darss Sill area (Figure 5-12). The invasive species *Penilia avirostris* was observed in the study area with decreasing abundances from west (400 individuals m^{-3}) to east (10 individuals m^{-3}) in early October 2009. In autumn 2010 *Penilia* was found occasionally in very low abundances (<10 individuals m^{-3}).

The Rotifera *Synchaeta* spp. was occasionally detected in low abundances in autumn 2009 from Fehmarnbelt area to Darss Sill area. A remarkable peak of 1000 individuals m^{-3} was detected in the beginning of December 2009 in Darss Sill area. In 2010, an autumn bloom of *Synchaeta* spp. was observed in Darss Sill area (7000 individuals m^{-3}).

The group of meroplanktonic taxa showed the highest annual diversity in autumn and strong differences in the taxonomic composition from the western part of the study area to the east (Figure 5-13). In the Great Belt and Fehmarnbelt areas, the meroplanctonic community consisted of Polychaeta larvae, *Balanus* larvae, Bivalvia larvae, Gastropoda larvae as well as *Asterias* larvae in early autumn. During the season, the share of these taxa decreased to less than 10% (2009) and 50% (2010), respectively and larvae of Tentaculata (Bryozoa) increased and accounted in late November for 90% (2009) and 50% (2010) of the meroplanktonic community.

Winter (December to January)

With decreasing temperature and light intensity, primary production decreased to its annual lowest level. In winter 2009/10, the zooplankton biomass stayed at the low late autumn level (30 mg m^{-3} to 80 mg m^{-3}, Figure 5-8). The winter zooplankton community was dominated by a relatively small number of taxa (Table 5-1). The composition was stable from November 2009 to March 2010 (Figure 5-6) and similar across the whole study area (Figure 5-7).

Calanoid Copepoda overwinter as resting eggs or as specific developmental stages. The community consisted primarily of adult *Acartia longiremis* (max 180 individuals m^{-3}), *Acartia bifilosa* (max 40 individuals m^{-3}), *Centropages* (max 60 individuals m^{-3}), *Temora* (max 250 individuals m^{-3}) as well as copepodite stages of all Copepoda genera (about 1000 individuals m^{-3}) (Figure 5-10, Figure 5-11). Cladocera and Rotifera overwinter mostly as resting eggs. Adult Podonidae occurred in very low numbers in January 2010 across the study area (<10 individuals m^{-3}), the most abundant taxon was *Evadne* spp. with up to 200 individuals m^{-3} in Great Belt area. Bosminidae was not found in January (Figure 5-12). Abundances of *Synchaeta* spp. were very low (60-70 individuals m^{-3}) in the study area in winter 2009/10 and showed higher values in December 2010 (up to 2000 individuals m^{-3} in Mecklenburg Bight).

The meroplanktonic taxa were dominated by Polychaeta larvae, Tentaculata (Bryozoa) and *Balanus* larvae in winter (Figure 5-13).

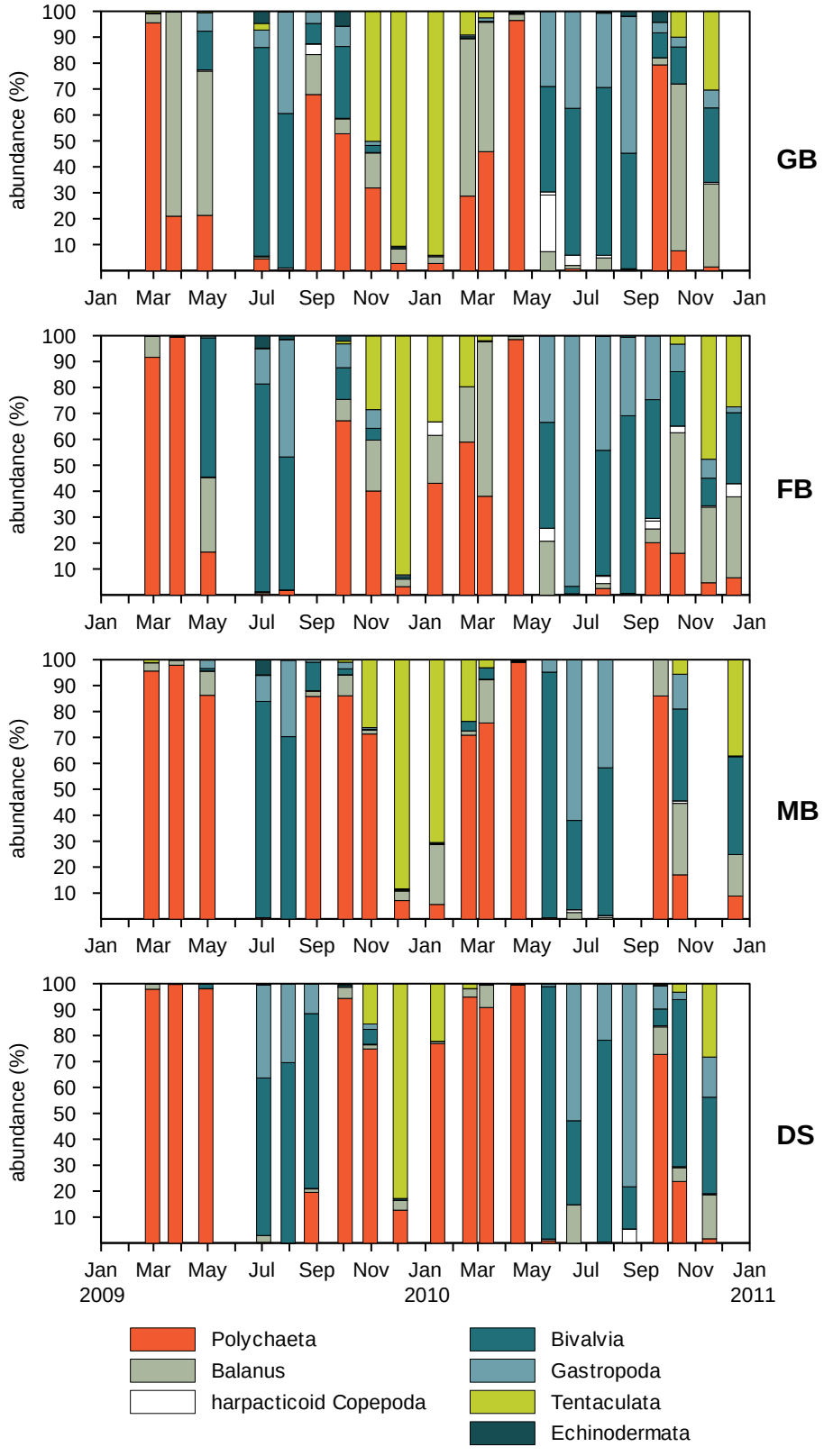


Figure 5-13 Proportion of abundance (%) for meroplanktonic taxa in the 4 subareas of the baseline investigation area. GB: Great Belt area, FB: Fehmarnbelt area, MB: Mecklenburg Bight area, DS: Darss Sill area.

5.4 Historical data

A 10-year HELCOM monitoring dataset from 4 sampling stations within the baseline study area (Kiel Bight station 360, Mecklenburg Bight station 12, Kadet Channel station 46, Darss Sill station 30) was analysed to describe long-term temporal and spatial trends of mesozooplankton community structure and variability.

5.4.1 *Spatial patterns*

The mean biomass of total mesozooplankton from 1998 to 2009 did not differ significantly between the four long-term trend stations but showed a slight increasing gradient from west to east (Figure 5-14).

The taxonomic composition varied between the stations according to the salinity tolerance of the taxa. Marine species such as Tunicata (mainly *Oikopleura dioica*) and cyclopoid Copepoda (*Oithona similis*) declined from the most western station (stn 360) to the most eastern station (stn 30). Both taxa accounted frequently for up to 40% of the total biomass at stations 360 and 12 in summer/autumn. In contrast, these marine species rarely occurred at the most eastern station (Figure 5-15). In contrast, the brackish water Cladocera Bosminidae increased from the west to the east and accounted for up to 40% of the total zooplankton biomass in summer at station 30 (Figure 5-15).

All stations were dominated by calanoid Copepoda of the genera *Acartia*, *Centropages*, *Temora* and *Pseudocalanus*, although with different community compositions. Generally, the abundances of the brackish water species *Acartia bifilosa* and *Acartia longiremis* were higher in the eastern part of the investigation area than in the western part during the past decade. The mean abundance of the marine *Pseudocalanus* spp. was slightly lower at station 30 compared to the western part of the study area. The abundance of this genus shows a further decreasing trend beyond the baseline study area towards the Northern Baltic Sea (Flinkmann et al. 2007).

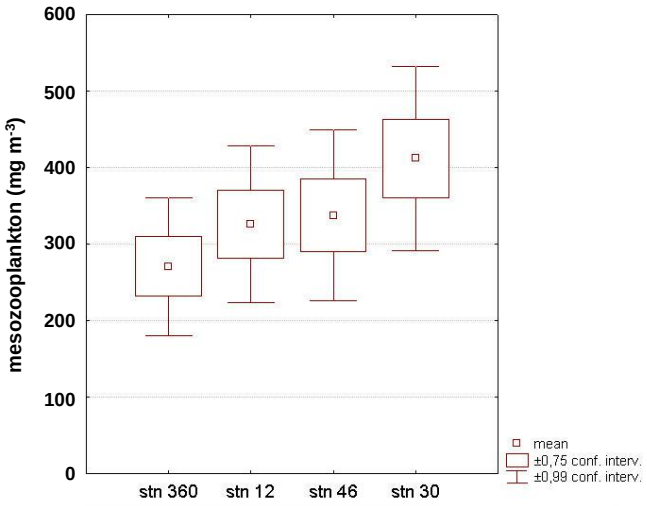


Figure 5-14 Total mesozooplankton biomass (mg m^{-3}) at HELCOM long-term trend stations from 1998-2009. Dots: mean of all data from 1998-2009, boxes: 75% confidence interval, whisker: 99% confidence interval.

5.4.2 *Long-term patterns*

The total biomass of mesozooplankton varied irregularly during the last 10 years without any signs of longterm temporal trends. The biomasses in 2009 and 2010 were rather low (Figure 5-15). However, this was apparently a general pattern as

the HELCOM data from Baltic Proper show similar low zooplankton biomass in 2009 (Wasmund et al. 2010).

The composition of the community varied with regard to the share of truly marine species. Particularly the abundance of pelagic Tunicata (typically *Oikopleura*) has declined considerably since 2006 (Figure 5-15).

The marine Copepoda *Pseudocalanus* spp., *Temora longicornis* and *Acartia* spp. are important as food source for zooplanktivorous fish like the Baltic herring and sprat (Flinkman et al. 1998) and are thus proposed as indicators for monitoring the status of the Baltic Sea pelagic food web. Changes in long-term copepod abundances in the central Baltic Sea are expected to reflect temperature changes (Möllmann et al. 2000), salinity changes (Möllmann et al. 2003) and changes in the phytoplankton composition. Ecological shifts which involved increasing phytoplankton biomasses, changes in phytoplankton composition and zooplankton communities were described for the central Baltic Sea for the late 1980s (Alheit et al. 2005).

Pseudocalanus spp. depends strongly on salinity conditions and prefers the deeper, higher saline water layers in the Baltic Sea. A significant decline of *Pseudocalanus* spp. has been observed in the Bornholm Basin, the Gotland Sea, the northern Baltic proper and the Gulf of Finland in the last 30-years (Alheit et al. 2005, HELCOM 2009). The 10-year time-series of the abundance of adult *Pseudocalanus* spp. in the baseline investigation area showed a stable (stations 360 and 30) or slightly decreasing trend (stations 12 $p<0.01$ and 46 $p<0.01$) (Figure 5-16).

In contrast to *Pseudocalanus* spp. temperature rather than salinity is important for *Acartia spp.*. Alheit et al. (2005) showed increasing biomasses of *Acartia* spp. in the Gotland Sea since the late 1980s. However, considering the species level, *Acartia bifilosa* and *Acartia longiremis* showed opposite trends in abundance during the last 10 years in the south-western Belt Sea. The abundance of *A. bifilosa* has decreased, with steeper slopes in the eastern part of the study area (station 46 $p<0.05$, station 30 $p<0.01$) compared to the western part (stations 12 and 360, not significant). *A. longiremis* showed an increasing, but not significant, trend at all stations during the past decade (stations 12 and 46 $p=0.08$, stations 360 and 30 $p=0.1$) (Figure 5-16). Thus, there was a shift in dominance from *A. bifilosa* to *A. longiremis* in the early 2000 years in the entire study area. The reason for this shift is unknown. Both *Acartia* species are of rather low importance as food item for planktivorous fish due to their low energy content.

T. longicornis, which is also a favoured food item by herring and sprat, as well as *Centropages hamatus,* show no trends in abundance during the last 10 years within the baseline study area. However, long term data sets from the Bornholm Basin, the Gotland Sea, the northern Baltic proper and the Gulf of Finland showed an increase in *T. longicornis* abundances during the last 30 years (Alheit et al. 2005; HELCOM 2009).

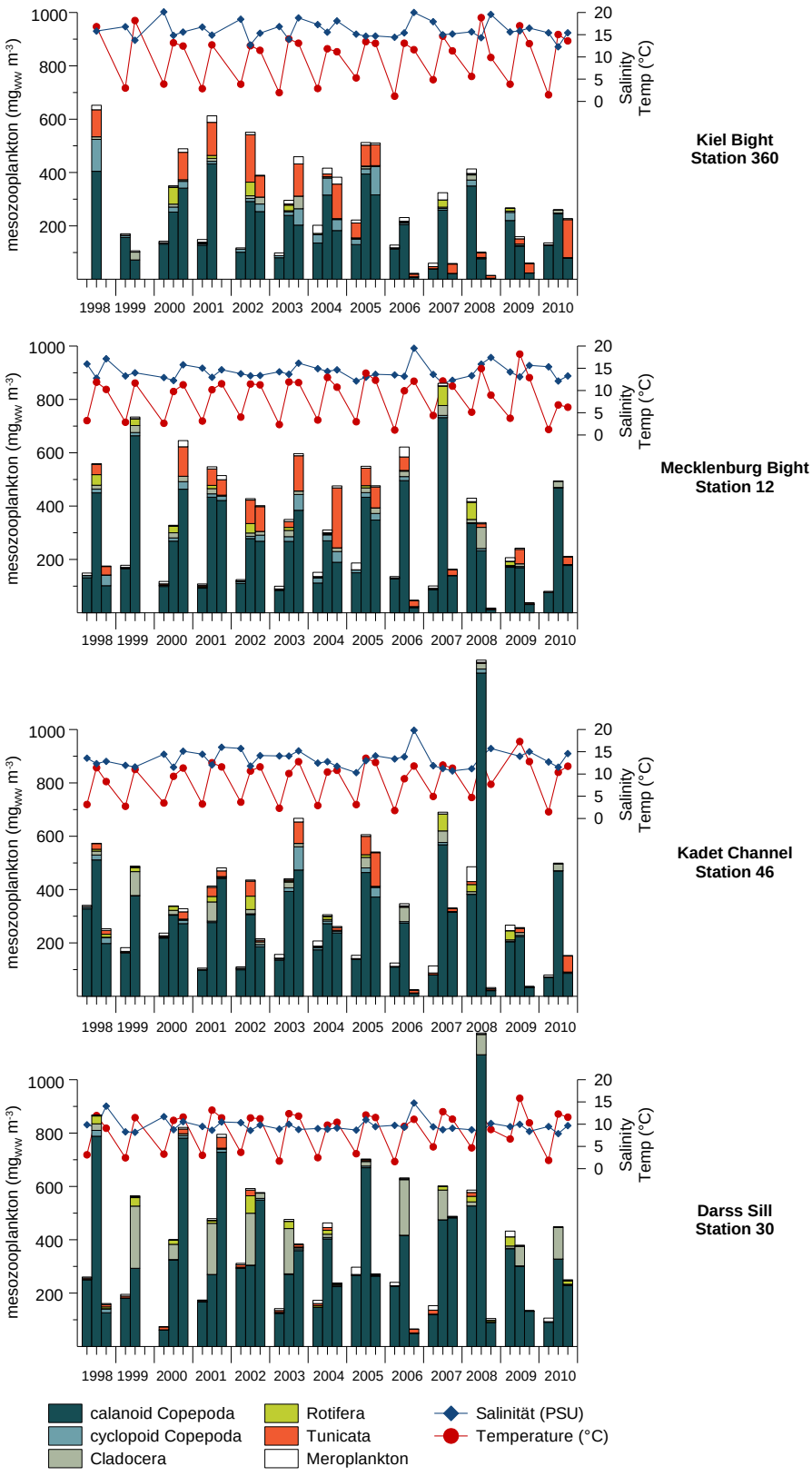


Figure 5-15 Biomass of main mesozooplankton groups at four sampling stations from Kiel Bight to Darss Sill. Bars give the means of spring, summer and autumn samplings from 1998 - 2008 (HELCOM zooplankton monitoring) and baseline investigation (2009-2010). All zooplankton and abiotic data are calculated for the whole water column.

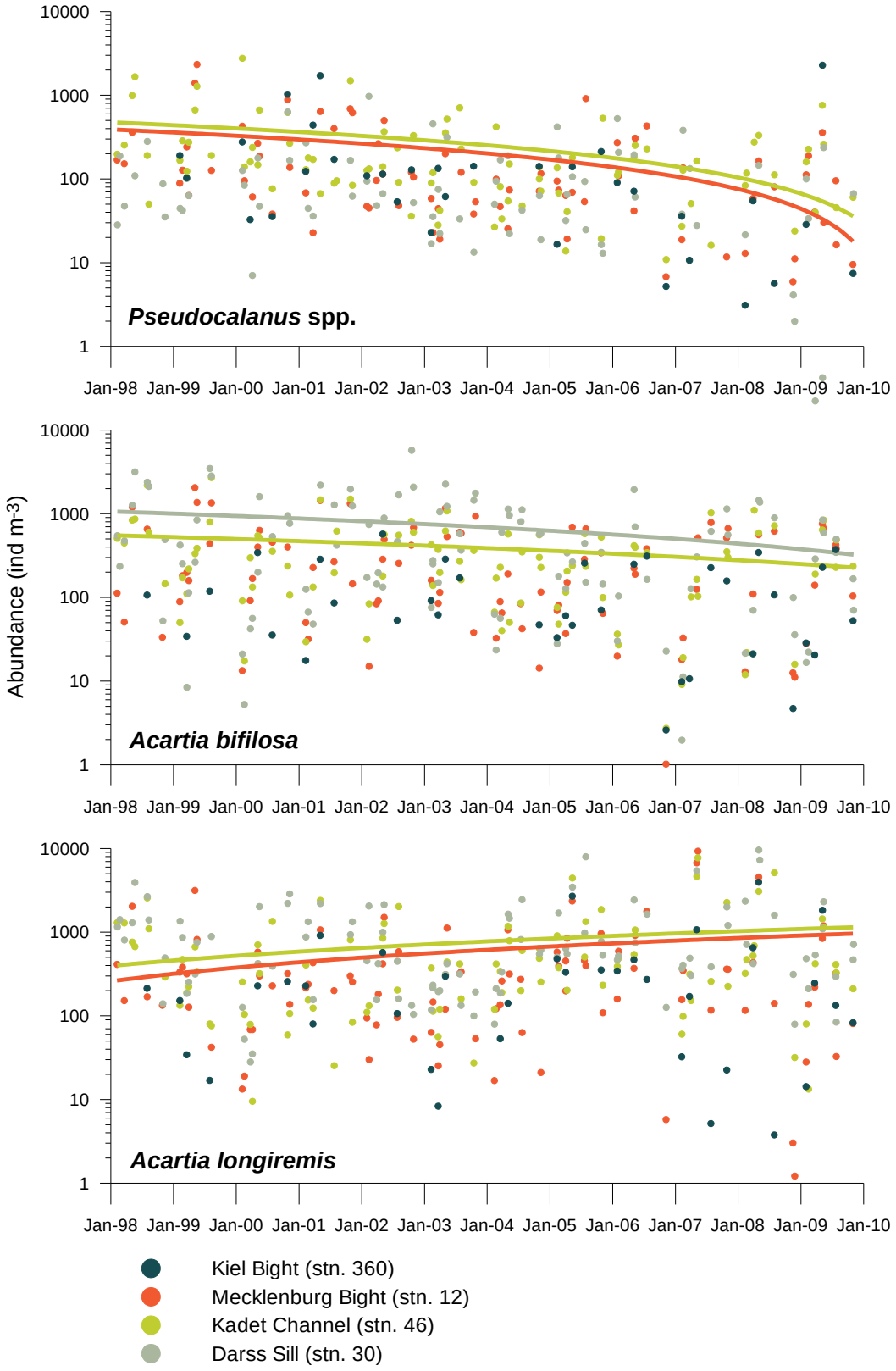


Figure 5-16 Abundance of the adult calanoid Copepoda Pseudocalanus spp., Acartia bifilosa and Acartia longiremis at four sampling stations from 1998 - 2009 (HELCOM zooplankton monitoring). Lines indicate significant trends, colours of lines refer to colours of stations. Non significant trends are not shown. Regarding significant trends see text.

6 JELLYFISH

6.1 Spatial and temporal fluctuations of Scyphozoa medusae and Ctenophora

The three jellyfish species *Aurelia aurita, Cyanea capillata* and *Mnemiopsis leidyi* were present in all geographical subareas during the baseline investigation. Considering the three jellyfish species, the ctenophore *M. leidyi* was the most dominant species with 85-95% of the mean abundance during the investigation time and in all geographical subareas followed by the moon jellyfish *A. aurita*, which had its highest proportion with 11% in Darss Sill area. The scyphozoan species *C. capillata* showed a similar range with highest proportion of 5% in the Great Belt (Figure 6-1).

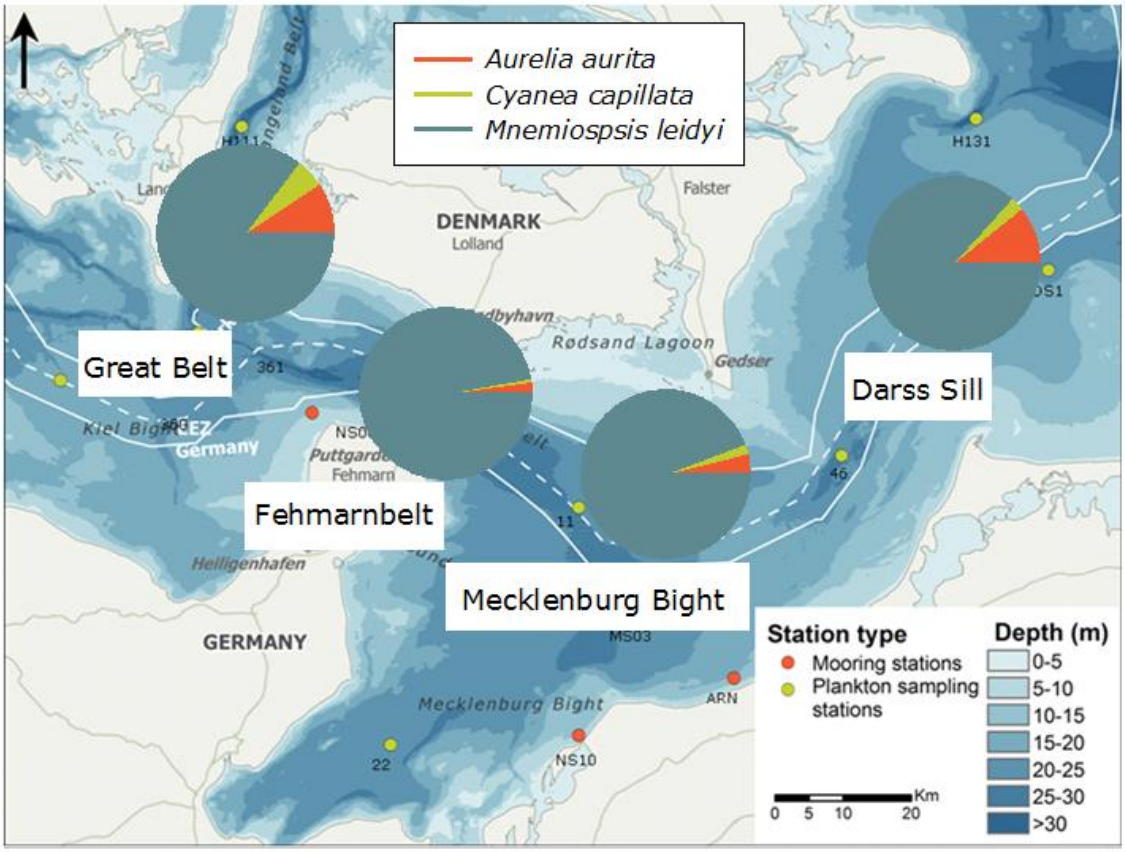


Figure 6-1 *Share of* Aurelia aurita, Cyanea capillata *and* Mnemiopsis leidyi *in the four geographical subareas based on mean abundances of all sampling occasions from June 2009 to December 2010.*

Comparing the mean abundances in the whole investigation area based on monthly sampling the scyphozoan species *A. aurita* and *C. capillata* were observed during the whole investigation period from June 2009 to December 2010 (Figure 6-2). At the beginning of the sampling campaign in July 2009 *C. capillata* was found with its annual highest abundances of up to 0.005 individuals m^{-3} averaged for the whole area. At the same time the abundance of *A. aurita* was still increasing and peaked in late summer (August/September) with a maximum abundance of 0.14 individuals m^{-3}. In 2010 *C. capillata* reached high abundances with a maximum of 0.06 individuals m^{-3} in spring.

The newly invaded comb jellyfish *M. leidyi* (Javidpour et al. 2006) appeared in July 2009 within the whole baseline investigation area. A rapid increase of abundance was measured in August (mean of all subareas 2 individuals m^{-3}, maximum peak abundance 7 individuals m^{-3} in Mecklenburg Bight). Consistently high abundances of *M. leidyi* were observed until January 2010. Afterwards the mean abundance decreased until March 2010. In spring and summer 2010 *M. leidyi* was almost absent. Significantly increased abundances of about 1 individuals m^{-3} were observed in August 2010. The annual abrupt rise of abundance was one month later compared to 2009. The highest abundance was found in September 2010 (11 individuals m^{-3} at stn 12). Similar to the previous year, a 6 months lasting period of high abundances of *M. leidyi* was observed in 2010. The seasonally high abundances of the ctenophore *M. leidyi* occurred simultaneously with low abundances of the scyphozoan species (Figure 6-2).

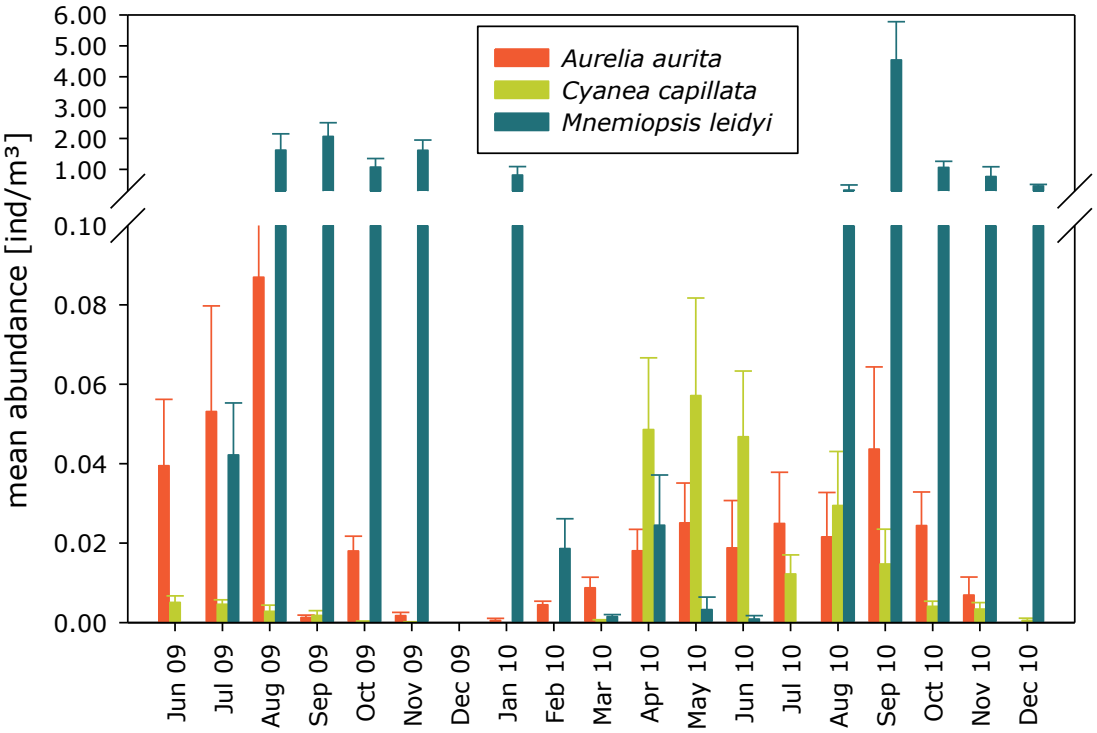


Figure 6-2 *Abundance of* Aurelia aurita, Cyanea capillata *and* Mnemiopsis leidyi *between June 2009 and December 2010 (mean of 12 sampling stations +SD).*

6.1.1 ***Seasonal and spatial distribution of Aurelia aurita***

Highest abundances *of A. aurita* were found in summer 2009 (0.33 individuals m^{-3}). The abundance was clearly lower in autumn. In winter 2009 *A. aurita* was almost absent. In spring 2010 abundances up to 0.03 individuals m^{-3} were observed. In summer 2010 the abundance increased compared to spring 2010, but was much lower compared to summer 2009. In 2010 the abundance peaked in autumn 2010 with 0.11 individuals m^{-3} in Mecklenburg Bight (Figure 6-3).

The seasonal patterns of *A. aurita* were similar in all subareas except for summer 2009 when highest abundances were observed in Darss Sill area. A similar range in abundance has been observed in the Kiel Bight (Schneider 1989).

Comparing the abundance below and above the halocline, higher abundances of *A. aurita* were found above the halocline in all seasons and subareas. Only in Mecklen-

burg Bight higher abundances were observed below the halocline in autumn 2010 (Figure 6-3).

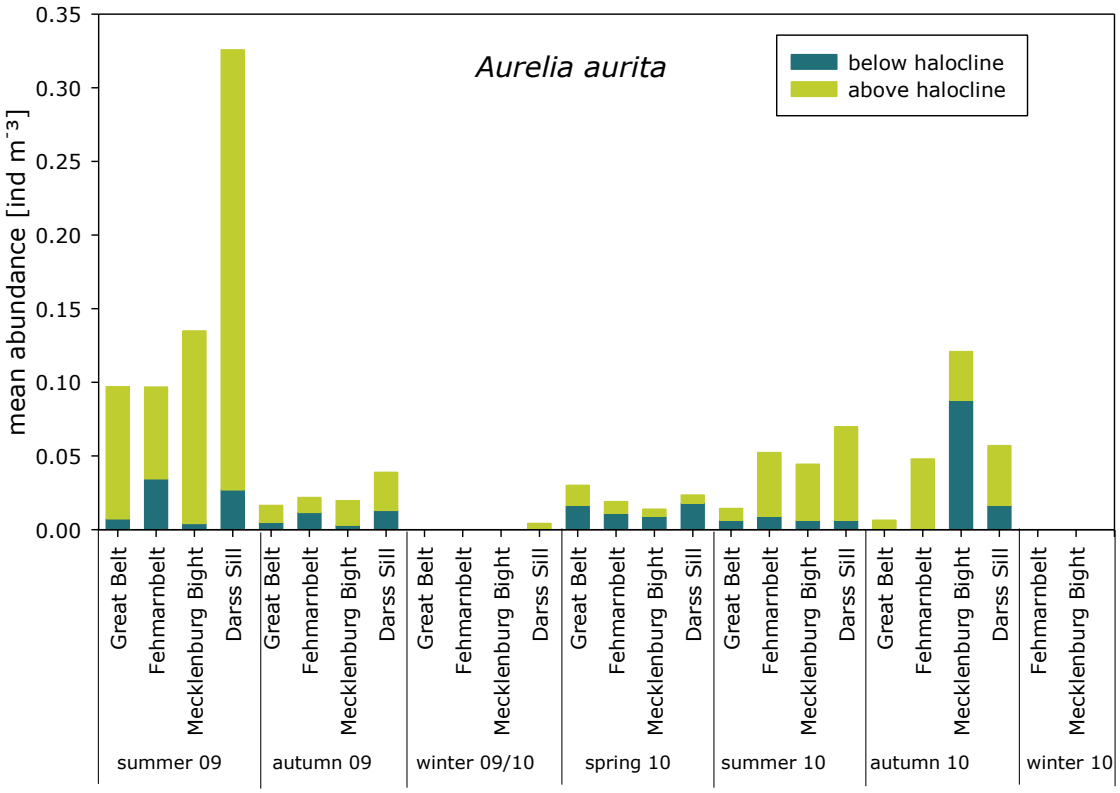


Figure 6-3 *Abundance of* Aurelia aurita *above (green) and below the halocline (blue) between June 2009 and December 2010 (means of seasons and subareas).*

6.1.2 ***Seasonal and spatial distribution of Cyanea capillata***

In 2009 *C. capillata* was mainly present during summer, when abundances ranged from 0.01 to 0.02 individuals m^{-3}. In autumn and winter 2009 *C. capillata* was mostly absent. In 2010 high abundances of *C. capillata* were detected in spring and summer with a maximum of 0.11 individuals m^{-3}. Low abundances of less than 0.02 individuals m^{-3} were found in autumn. In winter 2010 almost no specimens were present in the water column (Figure 6-4).

The horizontal variation of the seasonal abundance of *C. capillata* was low. In spring 2010 *C. capillata* abundance was low in the Great Belt area compared to the more eastern subareas. However, in summer 2010 highest abundances were found in the Great Belt area (0.11 individuals m^{-3}), while from Fehmarnbelt to Darss Sill only 0.06 individuals m^{-3} were observed. Similar patterns have been reported from the Bornholm Sea (Barz and Hirche 2005), although the reported abundances were much lower compared to the data from this baseline study. Considering data of this circumpolar species from different places of the world the abundance found in the baseline investigation area, are within the same range (Fancett 1986).

Contrary to *A. aurita*, the majority of *C. capillata* was found below the halocline (Figure 6-4), which might be explained by the species specific preference of higher salinities. Similar vertical distribution patterns have been reported from the Bornholm Sea (Barz and Hirche 2005).

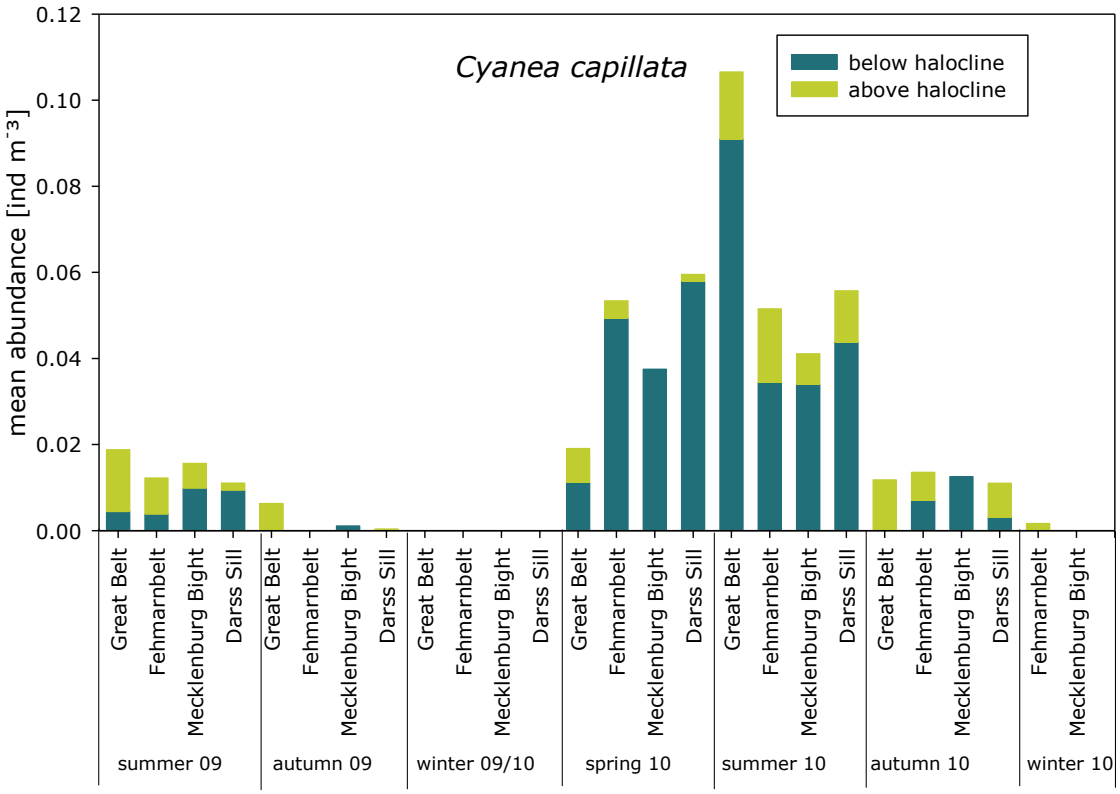


Figure 6-4 *Abundance of* Cyanea capillata *above (green) and below the halocline (blue) between June 2009 and December 2010 (means of seasons and subareas).*

6.1.3 ***Seasonal and spatial distribution of Mnemiopsis leidyi***

The overall seasonality of *M. leidyi* was similar for the four subareas. In summer 2009 *M. leidyi* occurred in all subareas with abundances between 0.05 individuals m^{-3} and 3 individuals m^{-3}. The seasonal abundance reached a maximum in autumn 2009 with 6.9 individuals m^{-3}. Contrary to the scyphozoan medusa *M. leidyi* was mainly observed during winter 2009/10 until summer 2010 in low abundances. In autumn 2010 *M. leidyi* showed high abundances ranging from 2 individuals m^{-3} to 6 individuals m^{-3}, while in winter 2010 the abundance was below 1 individuals m^{-3} (Figure 6-5).

Comparing the subareas the abundances showed no clear pattern. The highest abundances of *M. leidyi* within the whole baseline investigation area were found in Mecklenburg Bight, while the lowest values were observed in Darss Sill area.

M. leidyi seemed to occur mainly in the deeper water layers in summer 2009. However, in autumn 2009 and 2010 they also became abundant above the halocline. There is no clear distribution pattern in the water column, which might indicate that salinity is not the primary factor affecting the vertical distribution (Figure 6-5).

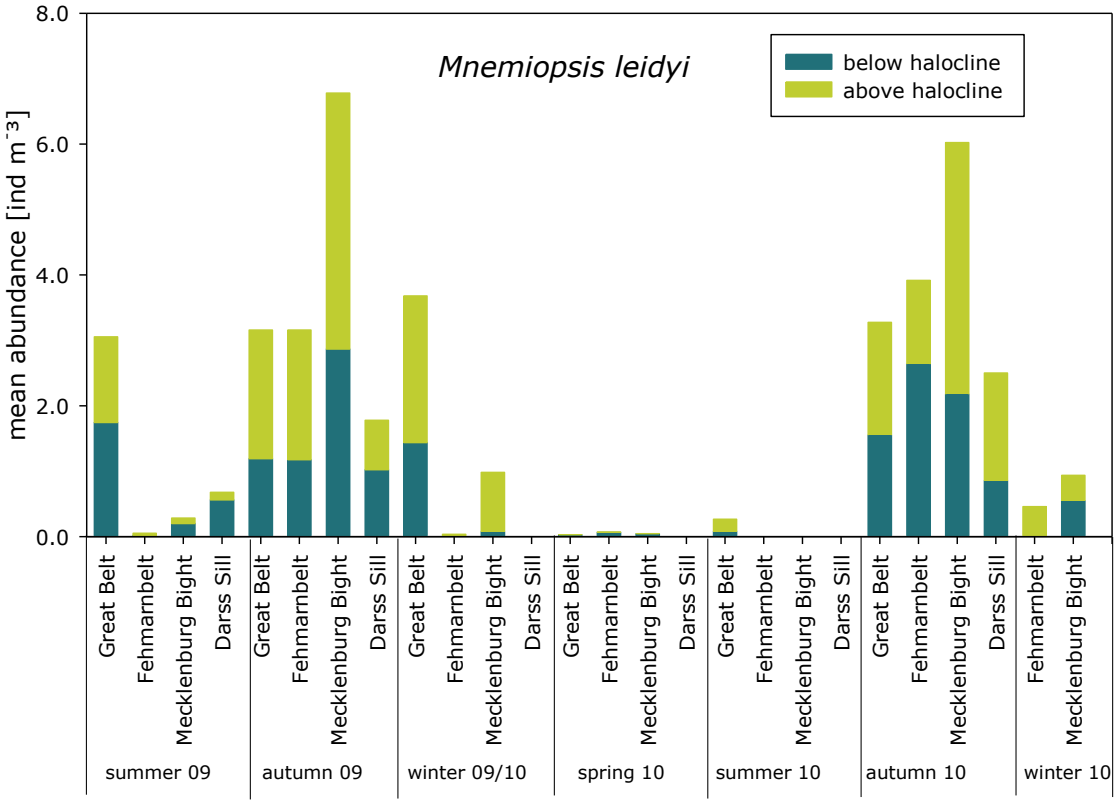


Figure 6-5 Abundance of Mnemiopsis leidyi above (green) and below the halocline (blue) between June 2009 and December 2010 (means of seasons and subareas).

6.1.4 ***Size variability of A. aurita***

In the Baltic Sea *A. aurita* has shown a size range from a few millimeters up to 30 cm.

In summer 2009 three different *A. aurita* cohorts were observed within the baseline investigation area (Figure 6-6). In the Great Belt area ephyrae (< 1cm), young medusae (4 cm to 15 cm) and older mature medusae (15 cm to 30 cm) co-occurred, whereas in the other subareas mostly ephyrae and young medusae (1 cm – 15 cm) were found. Contrary to Mecklenburg Bight in the Darss Sill area, the young medusae cohort (1 cm – 15 cm) appeared with two abundance peaks at 5 and 10 cm. These two peaks were recorded at two different timepoints (July and August 2009) indicating a bell growth within the same cohort at an interval of one month.

In autumn 2009 mainly one cohort was sampled in all subareas (5 – 15 cm) while adult *A. aurita* disappeared from the water column. In Great Belt area ephyrae occurred in very low abundances. Comparing the size distribution of *A. aurita* from all subareas between summer and autumn, there was no further increase of medusae size within the *A. aurita* population observed. This indicates that the somatic growth stagnated.

In winter only a few specimen were found at Darss Sill with the same size range (5-8 cm) as the specimen had in autumn. The low abundance of *A. aurita* can be explained by their annual lifecycle in the Baltic Sea.

The number of ephyrae increased in spring 2010. This was expected due to the known life cycle of *A. aurita*. In winter and spring scyphozoan polyps strobilate and produce the ephyrae (Hernroth and Gröndahl 1983).

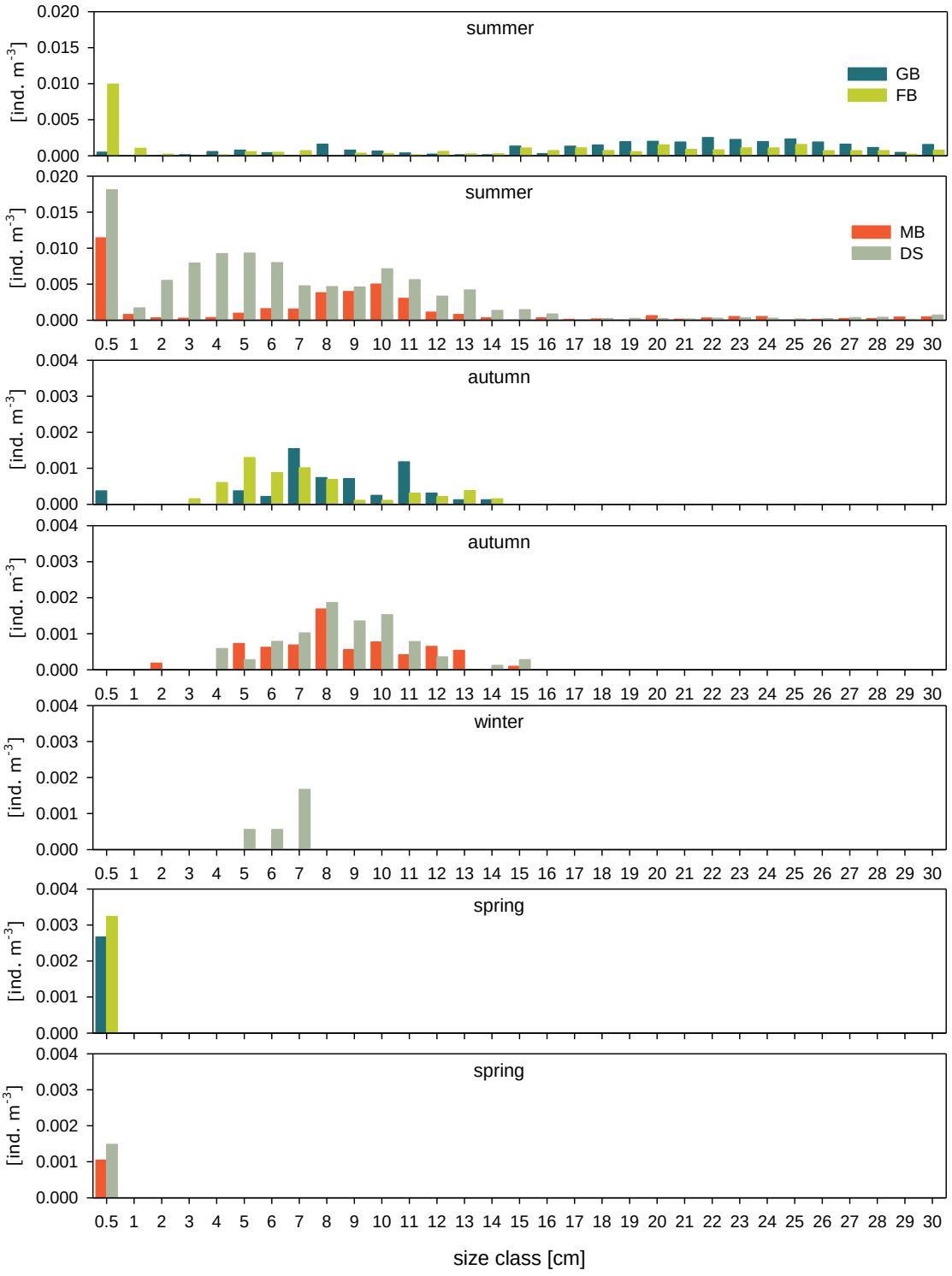


Figure 6-6 *Size distribution of* Aurelia aurita *(abundance of individuals per m³) from summer2009 to spring 2010 for 4 geographical subareas. GB: Great Belt area, FB: Fehmarnbelt area, MB: Mecklenburg Bight area, DS: Darss Sill area.*

The analysis of the size structure of the *C. capillata* population showed that there was only a single size group present in summer 2009 from Great Belt area to Darss Sill area, which ranged from 1 cm up to 6 cm (Figure 6-7). Only very few larger (>10 cm) individuals were found indicating very low abundances of older cohorts. Autumn, winter and spring data of *C. capillata* did not allow size structure analyses due to very low abundances.

6.1.5 *Size variability of C. capillata*

The analysis of the size structure of the *C. capillata* population showed that there was only a single size group present in summer 2009 from Great Belt area to Darss Sill area, which ranged from 1 cm up to 6 cm (Figure 6-7). Only very few larger (>10 cm) individuals were found indicating very low abundances of older cohorts. Autumn, winter and spring data did not allow size structure analyses due to very low abundances.

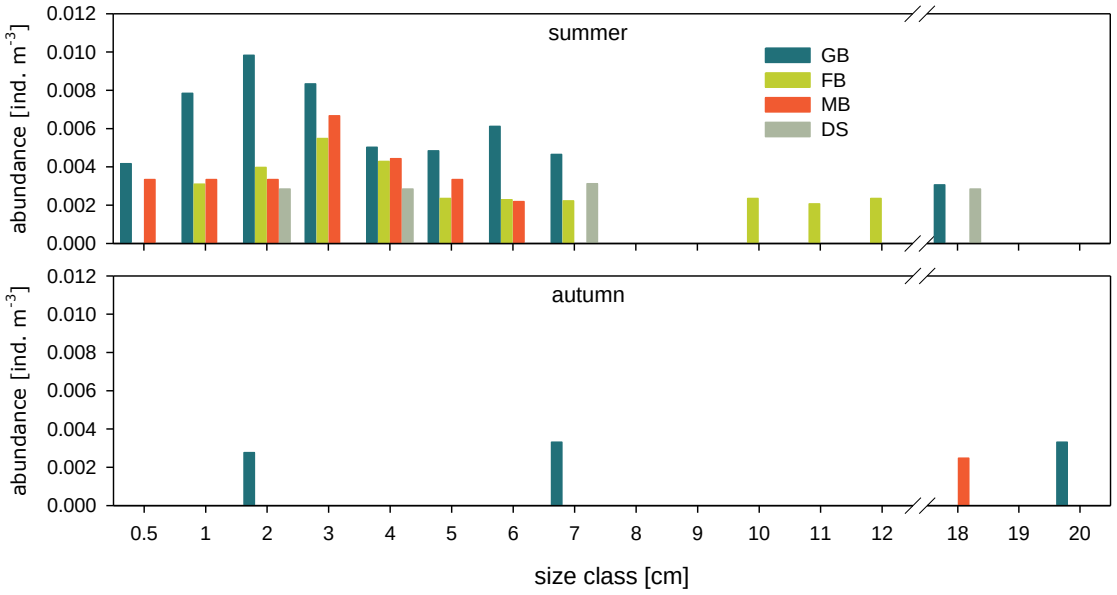


Figure 6-7 *Size distribution of* Cyanea capillata *(abundance of individuals per m³) from summer2009 and autumn 2009 for 4 geographical subareas. GB: Great Belt area, FB: Fehmarnbelt area, MB: Mecklenburg Bight area, DS: Darss Sill area.*

6.1.6 *Size variability of M. leidyi*

The maximal size of *M. leidyi* in the Baltic Sea was found to be 7 cm. The size range of *M. leidyi* in the Baltic Sea is similar to the native habitat of the species in Northern America (Purcell et al. 2001). In the Black Sea *M. leidyi* reached up to 18 cm (Vinogradov et al. 1989).

In summer 2009 the size of *M. leidyi* ranged from 0.5 cm to 6 cm (Figure 6-8). About 70% of the individuals were smaller than 2 cm. Only a few specimens were larger than 4 cm.

In autumn 2009 the size range of *M. leidyi* remained similar compared to summer. About 90% of the individuals were smaller than 2 cm, while the abundance increased at all stations. Comparing all stations from Great Belt to Darss Sill areas the size range was rather uniform, but with some variation in the dominant size. For example on station 11 (Mecklenburg Bight) and H111 (Great Belt) the highest abundance (>3 individuals m-³) occurred at the size range 0.5 – 1 cm, while on station 46 (Darss Sill) the highest number of individuals was found at a size of

2 cm. However, there was no intra-seasonal shift of the size range and therewith no indication for somatic growth of *M. leidyi* in autumn (Figure 6-8).

In winter 2009/10 the size range of *M. leidyi* did not change compared to autumn.

In spring 2010 small sized *M. leidyi* (0.5 – 1 cm) appeared in Great Belt, Fehmarnbelt and Mecklenburg Bight areas. The data did not allow analysing whether these specimens were a new generation or an overwintering cohort consisting of reduced sized individuals and in very low abundances (Figure 6-8).

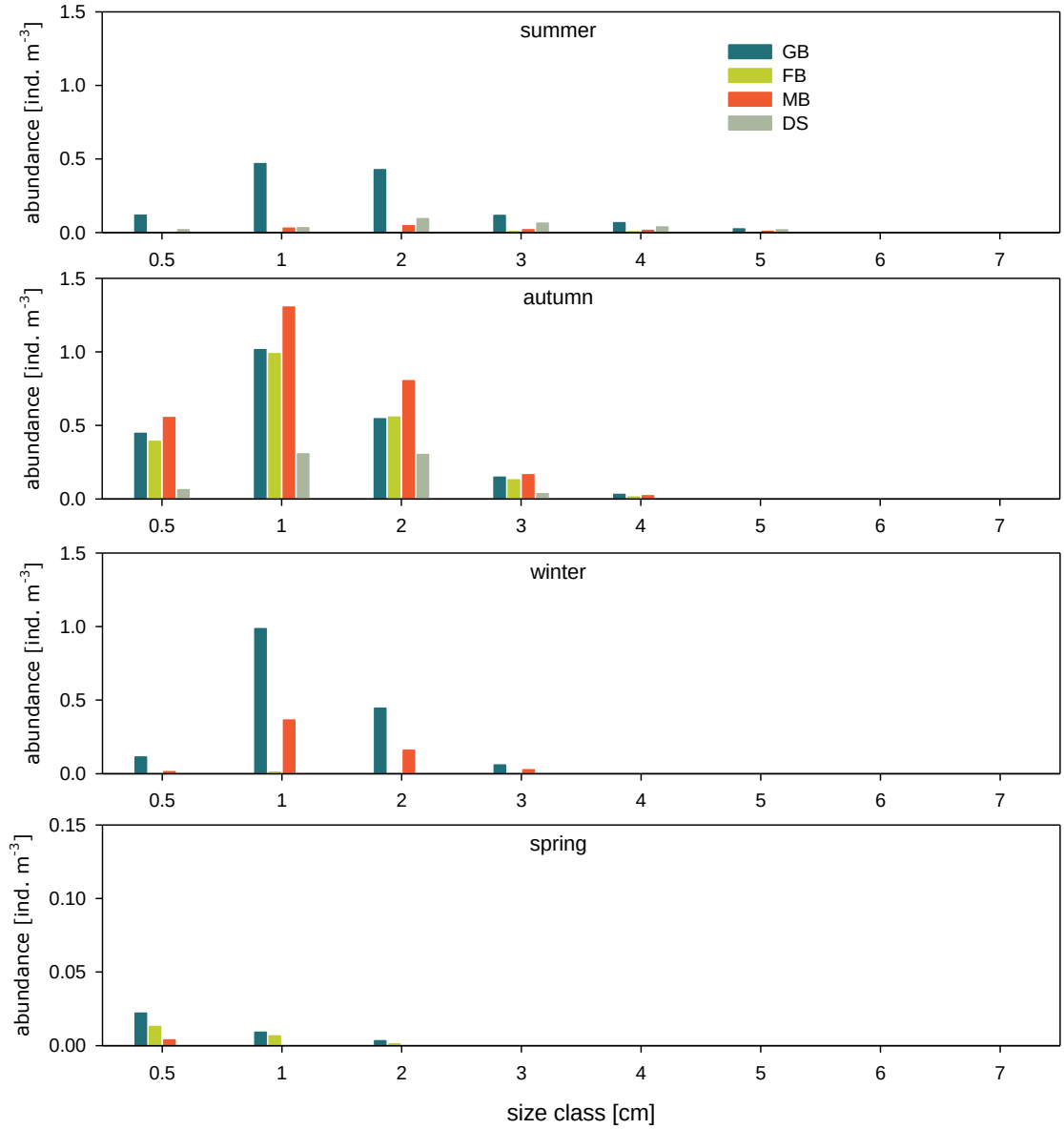


Figure 6-8 *Size distribution of* Mnemiopsis leidyi *(abundance of individuals per m³) from summer2009 to spring 2010 for 4 geographical subareas. GB: Great Belt area, FB: Fehmarnbelt area, MB: Mecklenburg Bight area, DS: Darss Sill area.*

6.2 Prey selectivity and predation impact of Aurelia aurita

6.2.1 Seasonal variation of food composition

Feeding rates of *A. aurita* were high in summer of both years (200-600 prey items consumed day^{-1} medusa^{-1}) and decreased in autumn (50-60 prey items consumed day^{-1} medusa^{-1}) except for November 2010 when feeding rates of 825 prey items consumed day^{-1} medusa^{-1} were measured (Figure 6-9). The composition of the food ingested by *A. aurita* consisted of the dominating zooplankton organisms present in the zooplankton community during the same time period and in the same geographical subareas (Chapter 5).

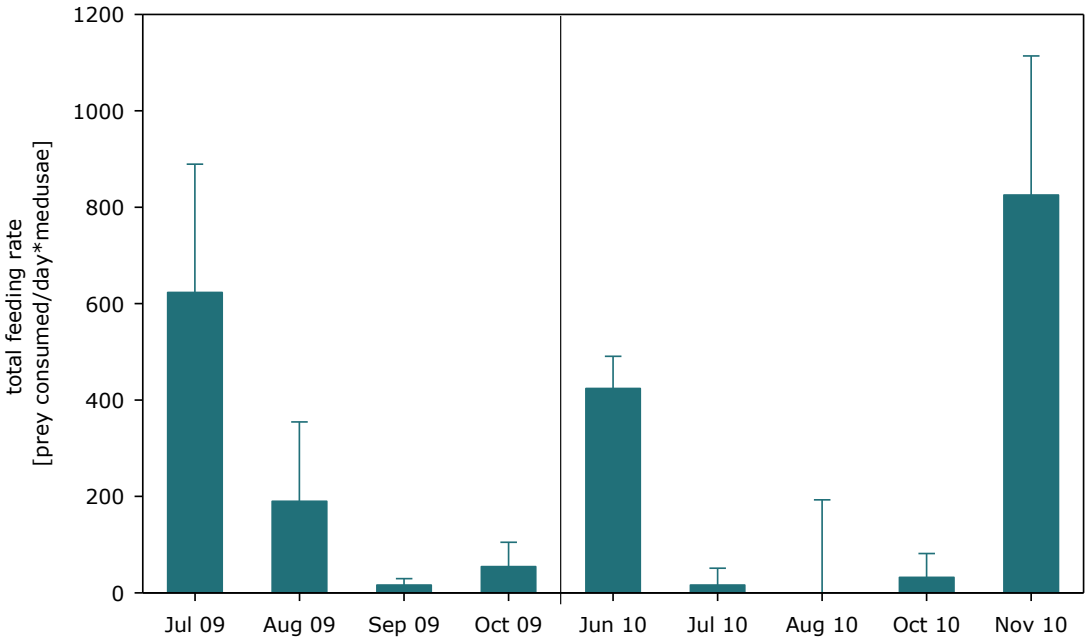


Figure 6-9 Aurelia aurita *total feeding rate (monthly mean of all areas +SD, N=4-28) for each sampling month from July to November 2009 and from June to November 2010.*

The composition of the food ingested by *A. aurita* consisted of dominant zooplankton organisms present in the zooplankton community during the same time period and in the same geographical subareas (Chapter 5).

In July 2009, mainly meroplanktonic larvae such as mussels (Bivalvia) and snails (Gastropoda) were consumed. In August 2009 the food consisted mainly of Cladocera (90%) (Figure 6-10) with *Bosmindae spp.* dominating. The remaining gut content consisted of Copepoda (5%) and other taxa. The percentage of fish larvae and eggs, which were found in the digestive organs of *A. aurita* in summer 2009, was very low.

In autumn 2009, 80-100% of the consumed prey consisted of calanoid Copepoda. Dominant species within this group were *Temora longicornis* and *Centropages hamatus* (Appendix G). While in September 2009 the ingested prey was mainly represented by Copepoda (90%), in November 2009 the gut content was composed by 76% Copepoda, 18% Cladocera and 6% Bivalvia larvae.

In June 2010 *A. aurita* fed on copepods, fish larvae, fish eggs and meroplanktonic larvae. Similarly as in August 2009, in July 2010 mainly copepods were ingested. In August 2010 the food of *A. aurita* contained 80% bivalve larvae and 16 % gastropod larvae. In autumn *A. aurita* had mostly consumed bivalve larvae, copepods and phytoplankton. The diatom *Coscinodiscus* sp. was the only phytoplankton species, which could be recognized in the gut.

In November 2010 the percentage of copepod ingested was with about 35% similar compared to October. The remaining gut content mainly consisted of rotifers.

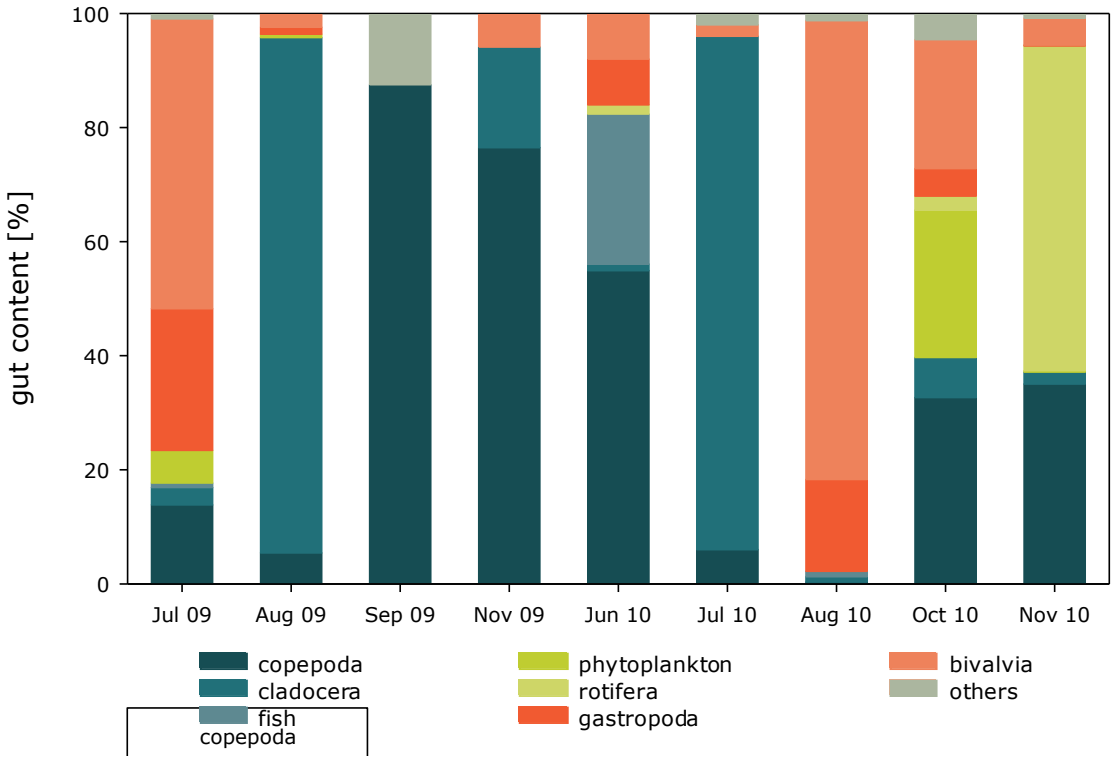


Figure 6-10 Composition of the gut content (%) of Aurelia aurita *(monthly mean of all subareas) for each cruise from July to November 2009 and from June to November 2010.*

6.2.2 ***Spatial variation of food composition***

The seasonal food composition of *A. aurita* differed between the geographical subareas. Comparing the ingested food in the three areas Great Belt, Fehmarnbelt, Darss Sill in summer of both years, the share of Bivalvia and Gastropoda larvae was higher in the western part than in the eastern part of the investigation area. On the other hand, the share of Cladocera in the food content of *A. aurita* was higher in the eastern part compared to the western part. In the Darss Sill area *A. aurita* showed with 10% the highest proportion of consumed fish larvae and fish eggs (Figure 6-11).

In Great Belt, Fehmarnbelt and Darss Sill areas, mainly copepods were ingested by *A. aurita* in autumn 2009. Within the latter two areas, the share of cladocerans accounted for 50 and 10%, respectively (Figure 6-11). In Fehmarnbelt *A. aurita* consumed mainly bivalve larvae and phytoplankton in autumn 2010. Comparing Fehmarnbelt with the more eastern region Mecklenburg Bight the share of bivalve larvae and phytoplankton was lower in Mecklenburg Bight, while the share of copepods was higher.

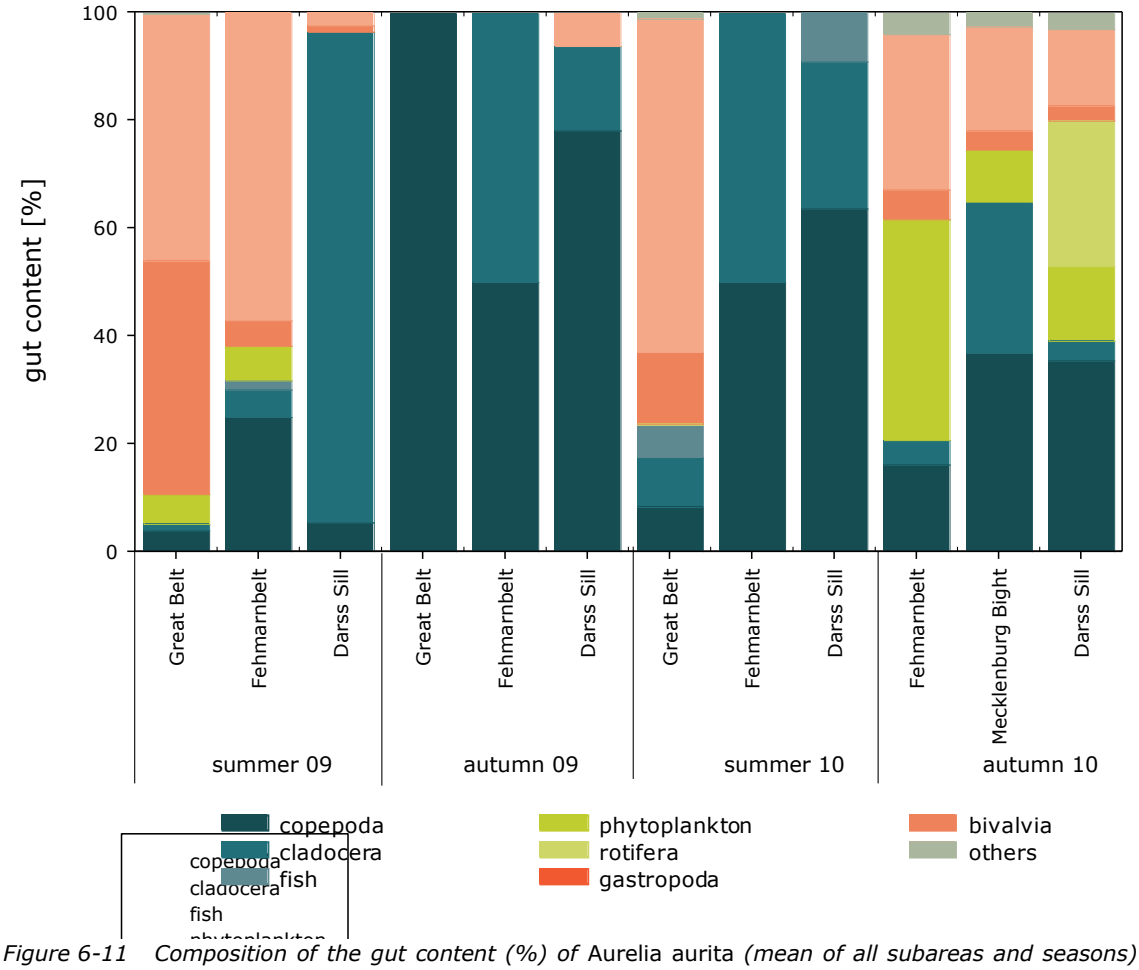


Figure 6-11 Composition of the gut content (%) of Aurelia aurita *(mean of all subareas and seasons) from July to November 2009 and from June to November 2010.*

6.2.3 *Seasonal variation of the predation impact*

Scyphozoan medusae can have a strong impact by top-down controlling the marine food web as predator on zooplankton including fish larvae and eggs and as competitor for food (Purcell 1997). They can change the zooplankton abundance and biomass through predation on organisms in various trophic levels.

The greatest impact of predation of *A. aurita* on cladocerans and bivalves was found in August and October 2009 where the predation was equivalent to 24% and 30% of the standing stock biomass, respectively. In contrast there was a low predation impact on the standing stock of copepods, cladocerans, bivalves and gastropods in September and November 2009 (Figure 6-12).

In 2010 overall predation impact was with less than 5% very low, which can be attributed to the generally lower abundance of *A. aurita* medusae in 2010 (Figure 6-2). While there was almost non predation impact detectable in June and July 2010, increasing predation impact was observed in August 2010. The predation impact peaked in autumn 2010 with highest predation on gastropod and bivalve larvae and decreased until November (Figure 6-12).

6.2.4 *Spatial variation of the predation impact*

The predatory impact of *A. aurita* on the standing stock of Copepoda was quite low in all subareas in both years (<0.6%). The predation impact on Cladocera was generally low as well, except for Darss Sill area were the annual mean value reached

35% in 2009 (Figure 6-13). In Great Belt and Darss Sill areas up to 10% of the standing stocks of bivalve larvae and gastropod larvae were fed by *A. aurita* day^{-1}.

The measured predation impacts on the standing stocks of Copepoda and Cladocera were comparable to former investigations in the Bornholm Sea (Barz and Hirche 2005). Specimens of the Cladocera can have a very rapid parthenogentic reproduction and thus they are able to outgrow its predators numerically (Viitasalo et al. 2001).

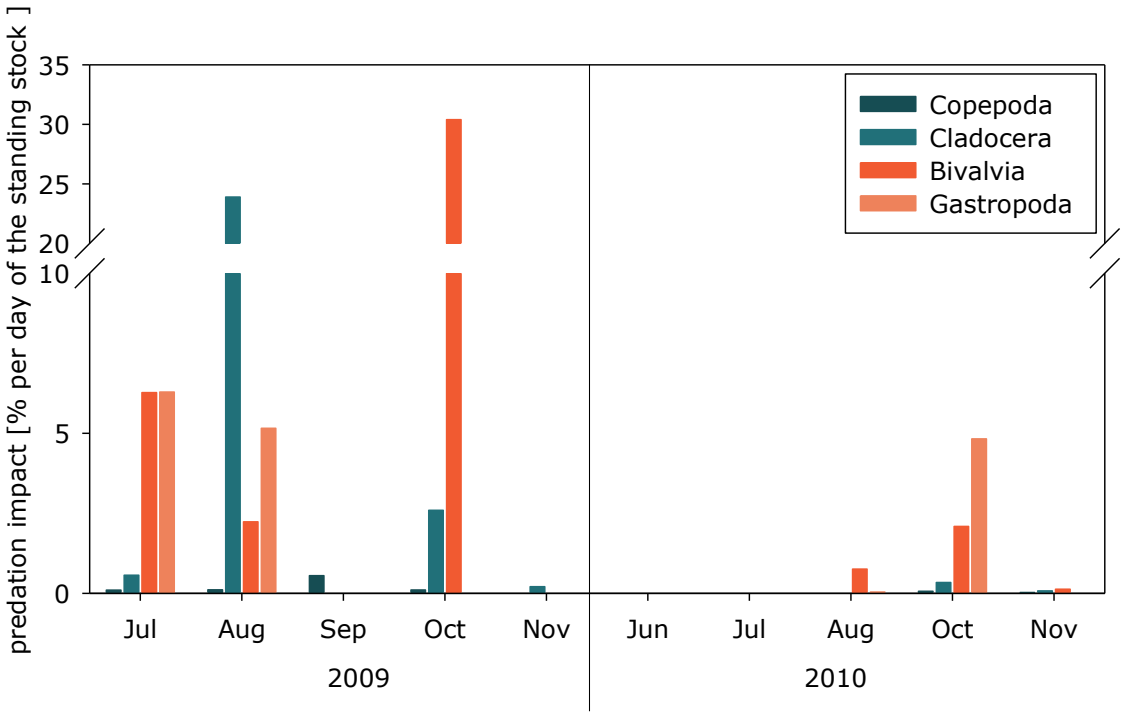


Figure 6-12 *Seasonal variation of the predation impact (%) of* Aurelia aurita *on the standing stocks of dominant zooplankton taxonomic groups (monthly mean of all subareas) from July to November 2009 and from June to November 2010.*

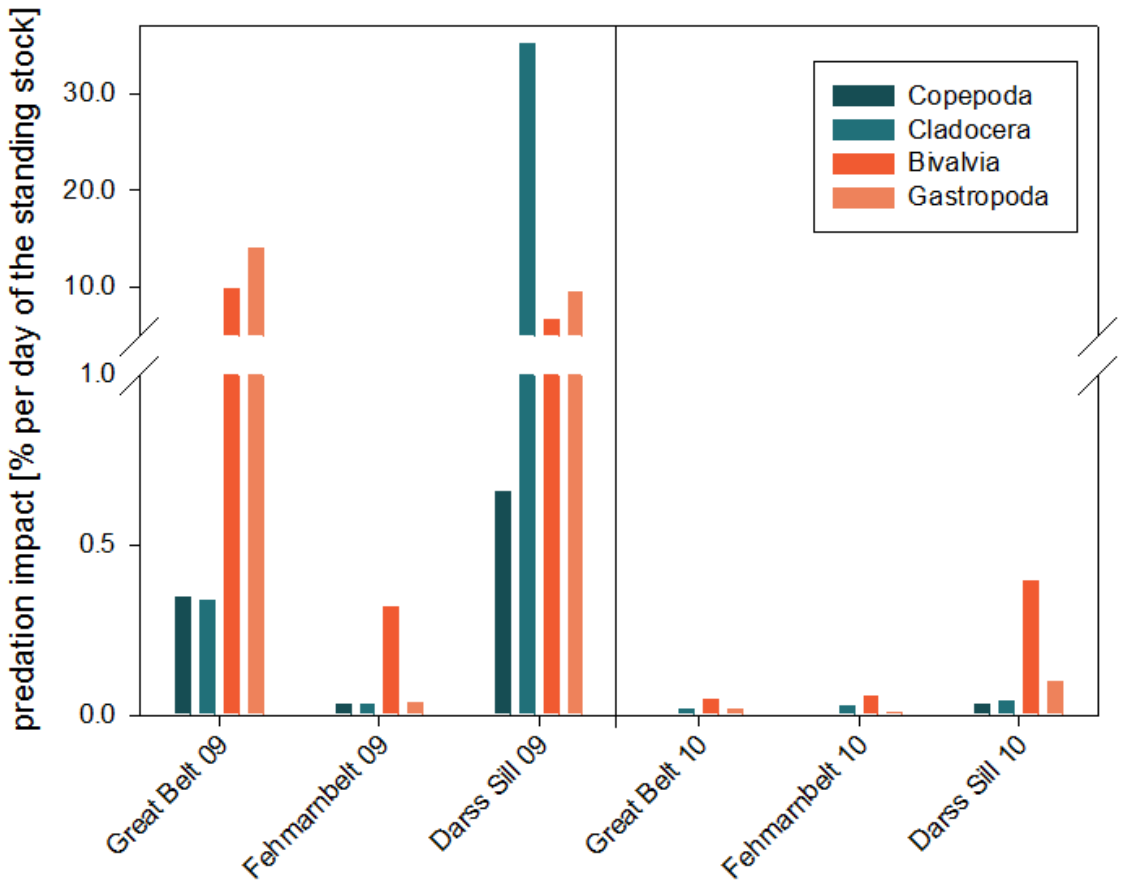


Figure 6-13 Spatial variation of the predation impact (%) of Aurelia aurita *on the standing stocks of dominant zooplankton taxonomic groups (annual mean) for all subareas.*

6.3 Potential predation impact of Mnemiopsis leidyi

The newly invaded comb jellyfish *M. leidyi* can become a threat the Baltic ecosystem and fisheries resources by increasing predation on cod eggs (Haslob et al. 2007) and zooplankton (Javidpour et al. 2009). Predation on zooplankton was not explicitly quantified during the baseline study, but the seasonal timing of zooplankton decrease in August since *M. leidyi* invation in 2006 (Figure 5-15) may be due to predation.

7 ENVIRONMENTAL STATUS OF PLANKTON ACCORDING TO THE WATER FRAMEWORK DIRECTIVE

The European Water Framework Directive (WFD) stipulates evaluating coastal system health using biological indicators for ecosystem functioning instead of abiotic driver variables (Anonymous 2000). This provides a new direction of ecological classification of coastal waters in Europe. According to WFD guidelines, phytoplankton is one of the key elements in the determination of the ecological status of all water types, including coastal waters. For each indicator the current status is evaluated against the so-called 'reference condition' that represents the status under no or very low human pressure. The 'reference condition' is the best status achievable in an area and constitutes the benchmark to scale the current status against. The status of an indicator is expressed by the Ecological Quality ratio (EQR) that is the quantitative ratio between the current and the reference condition.

Despite long time-series are available for various areas in the Baltic region no generally accepted indicative tools exist for phyto- and zooplankton species composition. Instead of direct measurement of production or species composition, chl-a concentration has been used as a worldwide accepted equivalent parameter for phytoplankton biomass (HELCOM 2009) also for the Baltic Sea region. In Germany beside the chl-a concentration the biovolume of Cyanophytes and Chlorophytes are considered relevant biological quality elements as well for the assessment (Baltic Sea, GIG 2011). The method is, however, still under development. In Denmark the assessment tool is under development too; summer (May-September) mean chl-a concentration or 90th percentile of the chl-a concentration from March through September are considered relevant parameters (Baltic Sea, GIG 2011).

HELCOM (HELCOM 2009) has published a first integrated thematic assessment of eutrophication in the open waters of the Baltic Sea in 2009, covering the period 2001–2006. The used assessment tool (HEAT) links the effects of eutrophication to the causative factors such as nutrient enrichment and anthropogenic activities which result in emissions, discharges, and the losses and deposition of nutrients to the marine environment (HELCOM 2009). HEAT is indicator-based assessment tool and uses different parameters in similarly to the EU-WFD.

Within to the HELCOM assessment (2001-2006, HELCOM 2009) the chl-*a* concentration was investigated as one of the key parameters for eutrophication assessment. In most open and coastal Baltic areas, the chl-a concentration indicated the prevalence of eutrophication and showed a clear deviation from reference conditions (Figure 7-1, HELCOM 2009). In the Belt Sea and the Mecklenburg Bight the chl-a EQR values indicated 'not acceptable' environmental conditions (poor/moderate). An 'Acceptable' status was determined for the Kiel Bight, Arkona Sea inner and outer coastal waters, Fehmarnbelt, Lübeck Bight, and Darss-Zingst outer coastal waters.

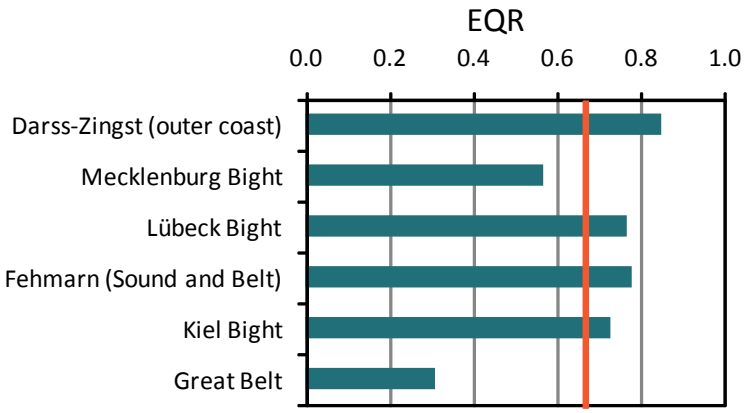


Figure 7-1 *Chl-a status in the Fehmarnbelt and adjacent areas expressed as Ecological Quality Ratio (EQR) values. The EQR values are based on the average summer (June-September) chl-a concentrations for the period 2001-2006 and reference conditions for the respective areas. The red line indicates the target EQR of 0.67 (modified from HELCOM 2009).*

8 ASSESSMENT OF IMPORTANCE

The baseline investigations of water quality, plankton and jellyfish have been carried out to support the impact assessment which has to identify, describe and assess the impacts of the fixed link project on the plankton components. During this process the importance categories of the plankton organisms have been defined by the functional value of the three environmental components, phytoplankton, zooplankton, and jellyfish in the Fehmarnbelt area. Since these biological components, as well as the environmental component water quality, are not protected by any international legislation or conventions and none of the plankton species are adopted on any "Red Lists", a two-level scale of importance is appropriate for these components.

Table 8-1 Importance criteria for plankton of the Fehmarnbelt area

Environmental factor	Criteria	Importance	Environmental component	Explanation
Sea water	International and national protection status and relevance	Special	Water quality	• All marine Natura 2000 areas • Beaches – bathing water quality
		General	Water quality	• All other areas
Marine flora and fauna Plankton	Diversity Biomass	Special	Phytoplankton Mesozooplankton Macrozooplankton (jellyfish)	• Phytoplankton communities which are characteristic for natural undisturbed conditions in the Fehmarnbelt area and phytoplankton with high diversity and low biomass. • Mesozooplankton species of special value for planktivorous fish, and for the balance in food chains and the ecosystem and for eutrophication control (grazing on phytoplankton) • Macrozooplankton (jellyfish): jellyfish medusae which as predators have importance for the biomass of mesozooplankton and as competitors for zooplanktivorous fish.
		General	Phytoplankton Mesozooplankton Macrozooplankton (jellyfish)	• Blooming of potential harmful phytoplankton species due to eutrophication • Mesozooplankton species without special value for fish diet • Macrozooplankton (jellyfish): early jellyfish medusae of minor importance for the food chains

The importance criteria of the environmental components in the Fehmarnbelt area are shown in Table 8-1. The criteria used for determining the importance levels, special or general, for the phytoplankton component are diversity and biomass. In the legal framework given by the Water Framework Directive (WFD) classification of water quality according to the WFD is based on the deviation of the present conditions from the reference conditions representing conditions prior to significant human influence (see chapter 7). For phytoplankton excessive blooms and high biomass are classical examples of unwanted responses most often resulting from increased nutrients inputs to the sea, but changes in the hydrographic regime could potentially also affect the nutrient availability.

The criteria used for determining the importance levels of zooplankton are diversity and biomass seen in relation to the central food web function of zooplankton in the pelagic ecosystem. Zooplankton serves as food resource for planktivorous fish (bottom up control) and subsequently also for higher trophic levels (predatory fish and birds). Top down, zooplankton has a grazing function on phytoplankton.

The ecological importance of jellyfish is defined by its functional value in the pelagic ecosystem of the Fehmarnbelt area. Jellyfish of the taxonomic groups Scyphozoa (commonly called the "true jellyfish") and Ctenophora (comb jellyfish) are of important value in coastal marine ecosystems by acting as predators of native zooplankton and food competitor for commercially important planktivorous fish species.

For the environmental component: water quality, areas of special importance are particularly the marine Natura 2000 areas and the beaches as indicated in Figure 8-1. All other areas are assigned as having general importance.

The most important ecosystem services related to plankton in the Fehmarnbelt are the level of primary production and composition of phyto- and mesozooplankton that together is of high importance for production of planktivorous fish such as fish larvae and herring, and for production of blue mussels that again constitute the prime food for eiders. Depth-integrated primary production and plankton biomass increase with water depth and areas of special importance have been delineated by a 6 m depth contour (Figure 8-2). At water depths larger than 6 m the water column production (above the pycnocline) is double as high as the production at water depths below 6 m. Areas with a depth below 6 m have consequently been assigned having general importance in Figure 8-2.

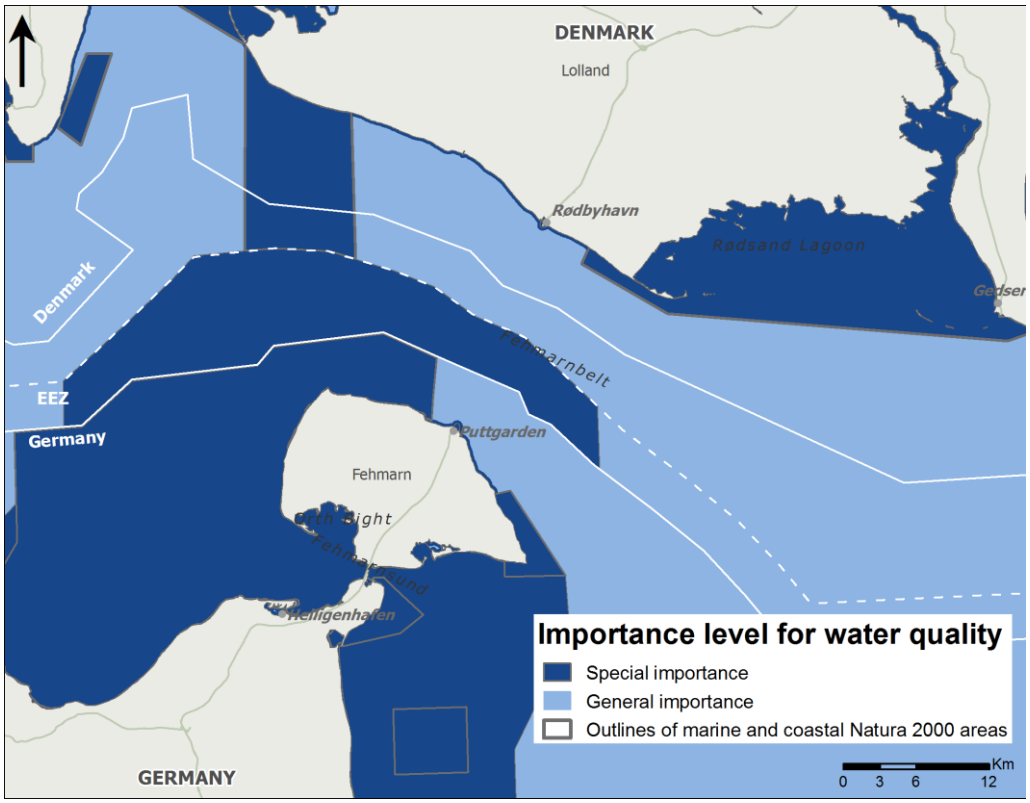


Figure 8-1 Importance level indicated for water quality in the Fehmarnbelt and adjacent areas.

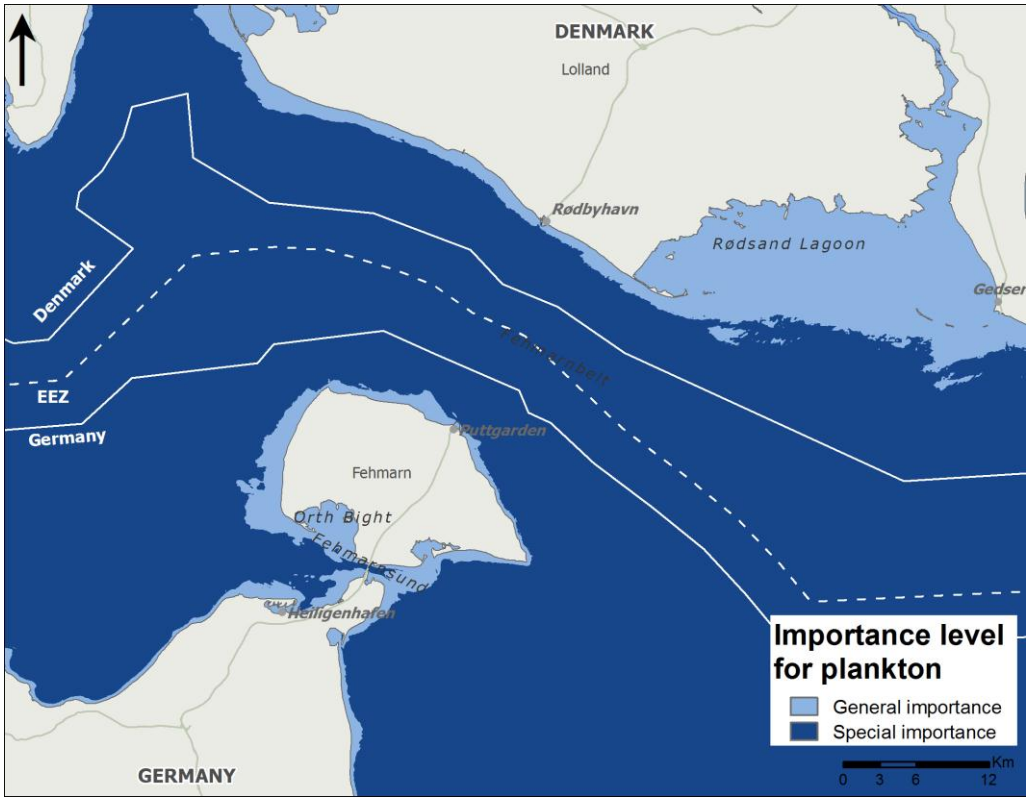


Figure 8-2 Importance level for plankton in the Fehmarnbelt and adjacent areas.

9 EXISTING PRESSURES

The baseline pressure analysis, based on expert judgement, attempts to assess the existing anthropogenic pressure drivers and the pressures deriving from them. It should be noted that some pressures are natural but may be amplified due to the anthropogenic influence on the pressure drivers.

The aim of this section is to outline major existing pressure drivers with potential impact on the Baltic Sea ecosystems, and to discuss some of the documented effects of the resulting pressures. This forms the basis for the assessment of existing anthropogenic pressure drivers with respect to their influence on the plankton and jellyfish communities in the area of interest, and how they may interact with pressures from the planned project.

9.1.1 *Overall Pressures in the Baltic Sea*

In a recent peer-reviewed publication (HELCOM 2010), the Helsinki Commission (HELCOM) has established no less than 52 anthropogenic pressure drivers and derived the so-called Baltic Sea Pressure Index (BSPI). The BSPI brings together all available data layers relevant to human uses and pressures acting on the Baltic Sea and evaluates the spatial distribution of the cumulative impact of these pressures.

The Baltic Sea Impact Index (BSII) is a tool to estimate the potential anthropogenic impacts on the marine ecosystem, taking into account areas of the Baltic Sea that are sensitive to human-induced pressures. The concentration of anthropogenic pressures (=BSPI) is combined with the spatial distribution of species, biotopes and biotope complexes to yield the potential anthropogenic impacts (=BSII).

The BSII has been established for the entire Baltic Sea on a grid of 5 km × 5 km (HELCOM 2010). It was found that only the open sea areas of the Gulf of Bothnia are considered to be relatively free of human impact, whereas almost all coastal areas of the Baltic Sea are impaired. Among the most notorious and widespread of anthropogenic stressors are: eutrophication, commercial fisheries, input of hazardous substances and land/seascape modification. The Belt Sea and Arkona Basin are under relatively high pressure and focussing on the basins of the Kiel Bight and the Mecklenburg Bight (of which the Fehmarnbelt is the connecting sea strait) a number of area-specific pressures could be identified. The area-specific anthropogenic pressures that ranked highest within these basins were:

- Extraction of species by bottom trawling, gillnet fishing, surface and mid-water trawling and fishing with coastal stationary gear (standing nets, fykes)
- Input of nutrients and heavy metals (lead and cadmium)
- Abrasion of the seabed by bottom trawling
- Underwater noise by shipping activities (coastal and offshore)

The BSPI, the sum of the anthropogenic pressures within the study area in the Fehmarnbelt has a range between 47 and 90 (Figure 9-1). The areas with the highest index values are notably both ferry harbour entrances at Puttgarden and Rødbyhavn, the coastal waters around Gedser and the Fehmarnsund between the island of Fehmarn and the German mainland. Also, southeast offshore Langeland and areas in the central Fehmarnbelt are under noticeable pressure. Areas with notably low BSPI values are the Lagoon of Rødsand, the central Lolland coast and the eastern part of the Kiel Bight, west offshore Heiligenhafen.

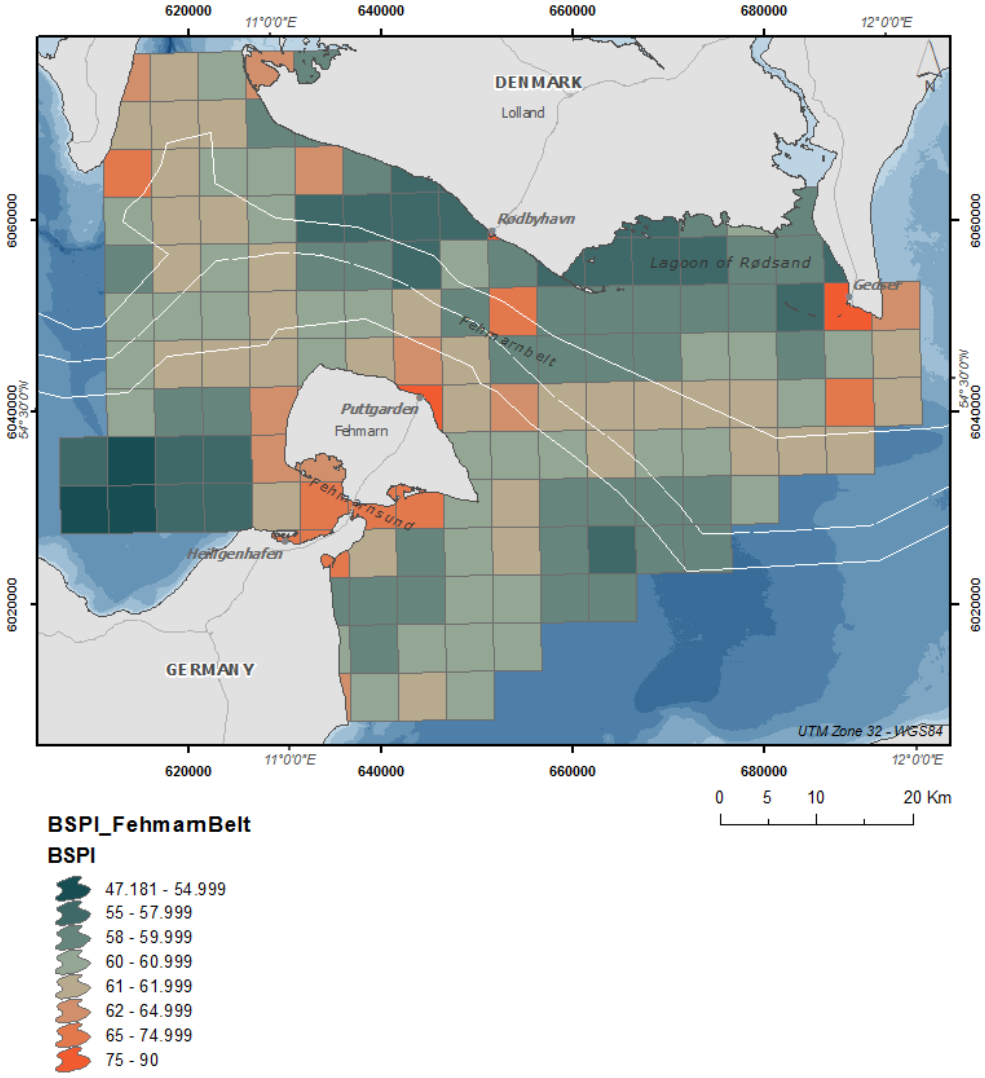


Figure 9-1 The Baltic Sea Pressure Index (BSPI), for the Fehmarnbelt area.

A break-down of the BSPI shows that the most important overall pressures identified in the HELCOM analysis are related to species extraction (fishing) and the (excess) input of anthropogenic substances (Figure 9-2). By far the most important pressure in the Fehmarnbelt area is the extraction of species and the physical disturbance of the sea bed by bottom trawling and the extraction of species by gillnet fisheries (Figure 9-2). The second cluster of pressures consist of excess input of lead (Pb), phosphorus, dioxines and organic matter. Besides fishing, bird hunting is among the ten most important pressures.

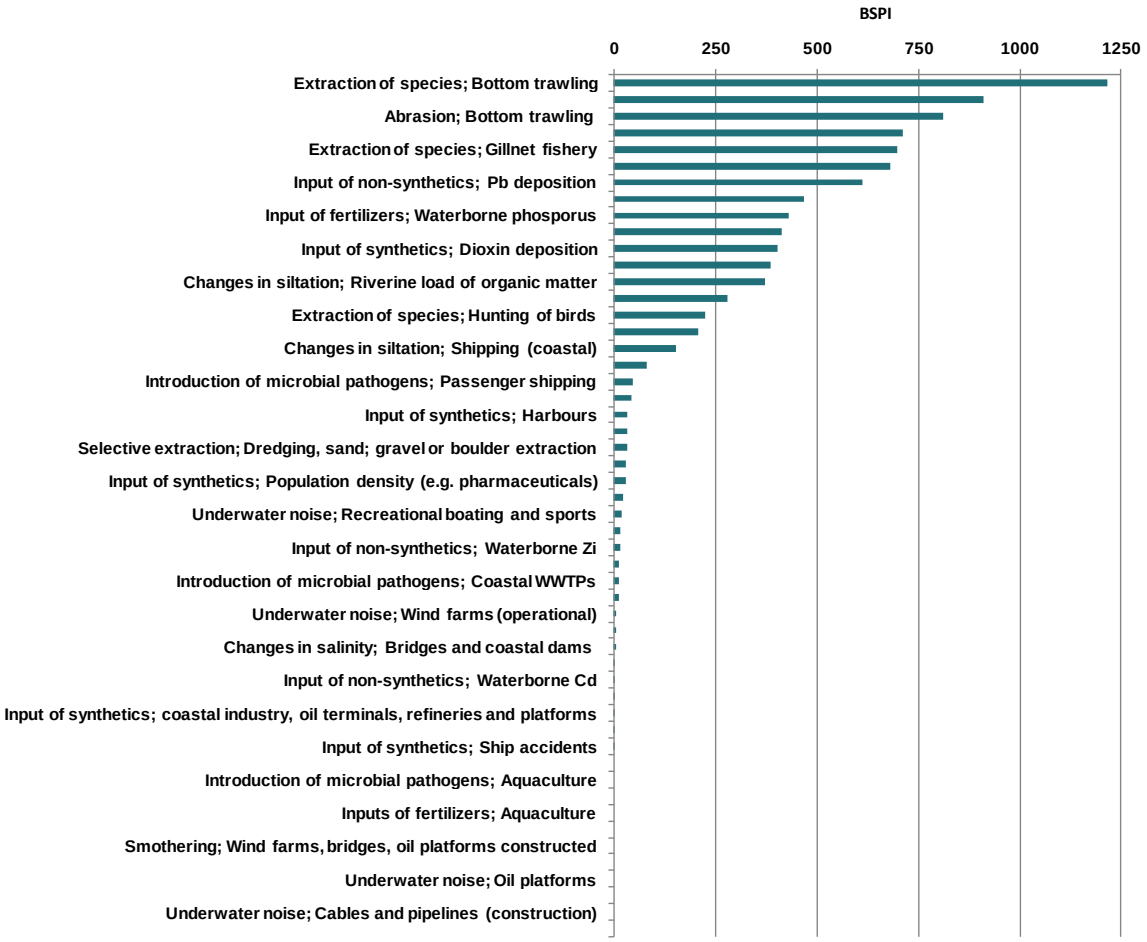


Figure 9-2 The most important pressures in the Fehmarnbelt area, with their respective Baltic Sea Pressure Index (BSPI) values, according to the HELCOM BSPI analysis.

9.1.2 ***Eutrophication***

Eutrophication is one of the most serious threats to species diversity and stability of marine ecosystems worldwide (Kotta and Witman 2009). The Baltic Sea has been exposed to very high amounts of nutrients throughout the last 50–80 years. According to the HELCOM Holistic Assessment (HELCOM 2010) the eutrophication status of the Fehmarnbelt region is poor to bad.

Increased availability of dissolved nutrients in the sea water primarily increases the growth of phytoplankton, and, thus, leads to an increase in the deposition of their remains as e.g. detritus in deeper waters. This can lead to a decrease in oxygen at the sea floor due to the bacterial decomposition of the organic material.

Another phenomenon of eutrophication is changes in the conditions in shallow waters, where fast-growing and opportunistic filamentous algae can build up dense coverage in spring utilizing the high amount of nutrients.

Jellyfish may benefit from eutrophication, which can increase micro- and mesozooplankton abundance, turbidity and hypoxia (Purcell 2007). Such changes are expected to give jellyfish a competitive advantage compared to fish (Eiane at al. 1999). This relation is not yet investigated in the eutrophicated Fehmarnbelt area (HELCOM 2009).

9.1.3 *Climate change*

Recently, climate change has been identified as a major threat for aquatic environments. In the Baltic Sea, a climate related regime shift in plankton community structure was assessed for the central Baltic Sea (Alheit et al. 2005), and in the Baltic Sea, where cyanobacteria form recurrent blooms in warm summers, rising temperatures favour particularly the cyanobacteria. Global warming also affects patterns of precipitation and drought. For example, more intense precipitation will increase surface and groundwater nutrient discharge into water bodies, and such changes in the hydrological cycle could further enhance cyanobacterial dominance (Dippner et al. 2008). Regarding zooplankton, a climate related regime shift in community structure was assessed in the Central Baltic Sea (Ahlheit et al. 2005). Key copepod species which are essential in fish diets decreased in the central Baltic Sea in the late 1980s, which is expected to cause severe consequences for commercial fish species and hence for Baltic Sea fisheries.

Literature shows evidences that jellyfish abundances fluctuate with climatic cycles (Attrill et al. 2007). North Sea species with preference to slightly higher temperatures for reproduction and growth (*Cyanea lamarckii, Chrysaora hysoscella, Rhizostoma octopus*) are likely to change distribution limits towards the Baltic Sea with climate warming (Holst 2008).

9.1.4 *Invasive species*

Invasive species is another issue of major concern for the Fehmarnbelt area. Several phytoplankton species have been identified as non-native to the Baltic Sea region (section 5). Invasive mesozooplankton species in the Central Baltic Sea are known to be responsible for significant changes in the pelagic food web structure (Gorokhova et al. 2005).

Invasive jellyfish species are another issue of major concern for the Fehmarnbelt area. The planktivorous comb jelly *M. leidyi* has been identified as non-native in the Baltic Sea in 2006 and was most likely introduced by ballast water from the western Atlantic. *M. leidyi* is currently developing stable populations in the Baltic Sea, which could cause significant changes in the Baltic pelagic ecosystem as already happened in other marine systems (GESAMP 1997).

9.1.5 *Artificial hard substrate*

Increasing artificial underwater hard substrate has been described to provide new habitat for the settlement and asexual reproduction of benthic stages of scyphozoan jellyfish and can subsequently cause jellyfish blooms (Purcell 2007). Considering the fact that several marinas, harbours, windfarms etc. are located in the western Baltic Sea, increased benthic polyp colonies and subsequently increased medusa blooms are likely for the Baltic Sea.

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A P P E N D I C E S

A P P E N D I X A

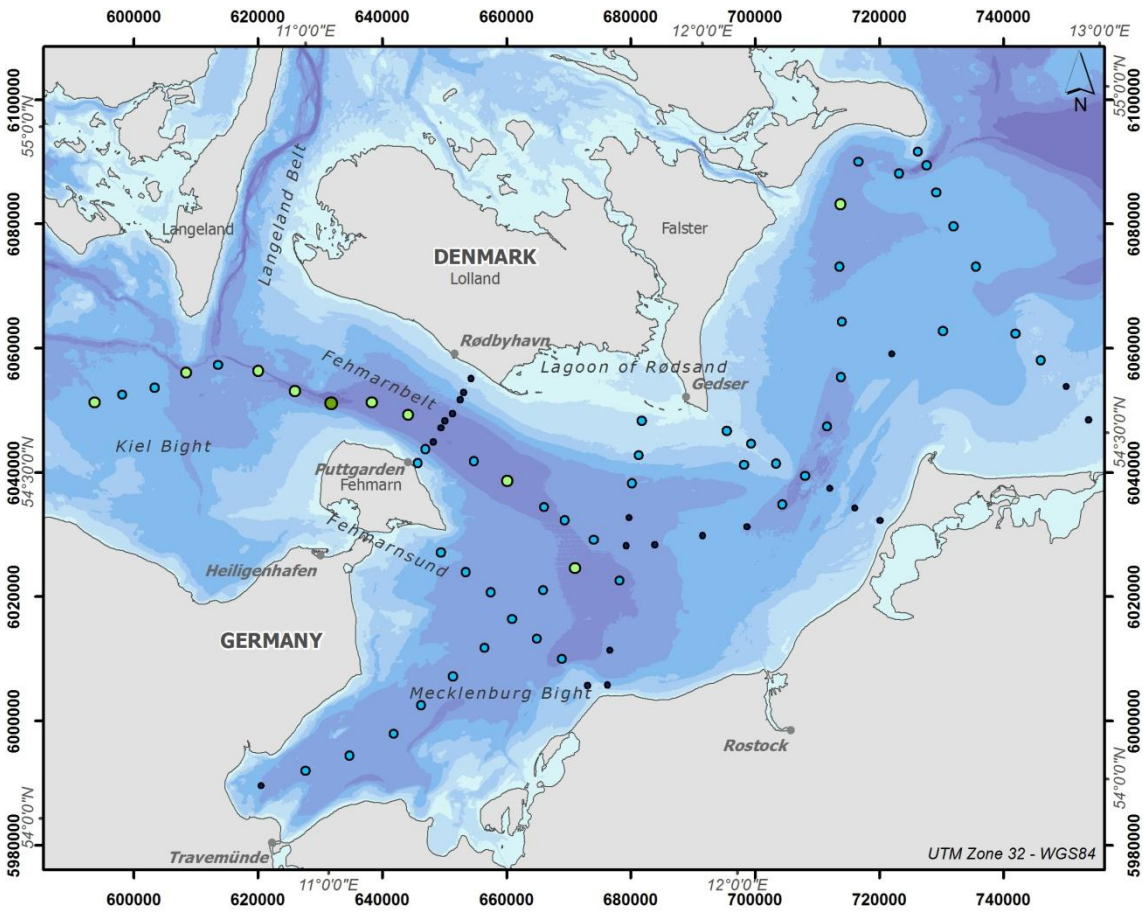
Position of fluorescence stations allocated to Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill areas

Station	Lat	Lon
Darss Sill area		
40	54.48	12.06
41	54.39	12.06
46	54.46	12.2
46	54.46	12.2
DS1	54.69	12.7
H090	54.37	11.84
H091	54.38	11.95
H093	54.42	12.15
H094	54.53	12.26
H095	54.6	12.31
H096	54.63	12.44
H097	54.66	12.57
H102	54.51	12.08
H103	54.48	12.14
H105	54.43	12.27
H106	54.41	12.33
H107	54.39	12.39
H122	54.89	12.49
H123	54.91	12.38
H124	54.85	12.33
H125	54.76	12.32
H126	54.68	12.31
H130	54.92	12.53
H131	54.9	12.55
H132	54.86	12.57
H133	54.81	12.62
H134	54.75	12.66
H136	54.65	12.75
H137	54.61	12.81
H138	54.57	12.86
H139	54.53	12.92
Fehmarnbelt area		
H031	54.61	11.39
H032	54.6	11.38
H033	54.58	11.36
H034	54.57	11.34
H035	54.56	11.32
H036	54.55	11.31
H037	54.53	11.29
H038	54.52	11.27
H039	54.5	11.25
H053	54.59	11.04
H054	54.59	11.15
H055	54.57	11.23
H057	54.5	11.39
H058	54.47	11.47

Station	Lat	Lon
Great Belt area		
360	54.59	10.44
361	54.65	10.76
H020	54.88	10.84
H021	54.83	10.84
H023	54.79	10.82
H024	54.74	10.77
H025	54.69	10.75
H027	54.64	10.69
H028	54.63	10.6
H029	54.61	10.52
H051	54.63	10.86
H052	54.61	10.95
H088	54.06	10.95
H089	54.04	10.84
H110	54.93	10.85
H111	54.92	10.87
H112	54.92	10.9
H113	54.92	10.93
H114	54.91	10.96
H115	54.91	10.98
Mecklenburg Bight area		
11	54.41	11.61
12	54.31	11.54
22	54.11	11.19
H059	54.43	11.55
H060	54.38	11.68
H065	54.37	11.75
H066	54.32	11.74
H067	54.22	11.71
H068	54.17	11.7
H069	54.18	11.64
H071	54.38	11.3
H072	54.34	11.36
H073	54.31	11.41
H074	54.27	11.47
H075	54.24	11.53
H076	54.21	11.59
H081	54.34	11.63
H083	54.24	11.4
H084	54.19	11.32
H085	54.15	11.24
H087	54.08	11.06

A P P E N D I X B

Horisontal distribution of chl-a

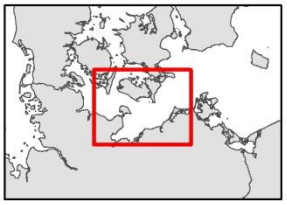


Cruise 2 (23.03. - 27.03.2009)

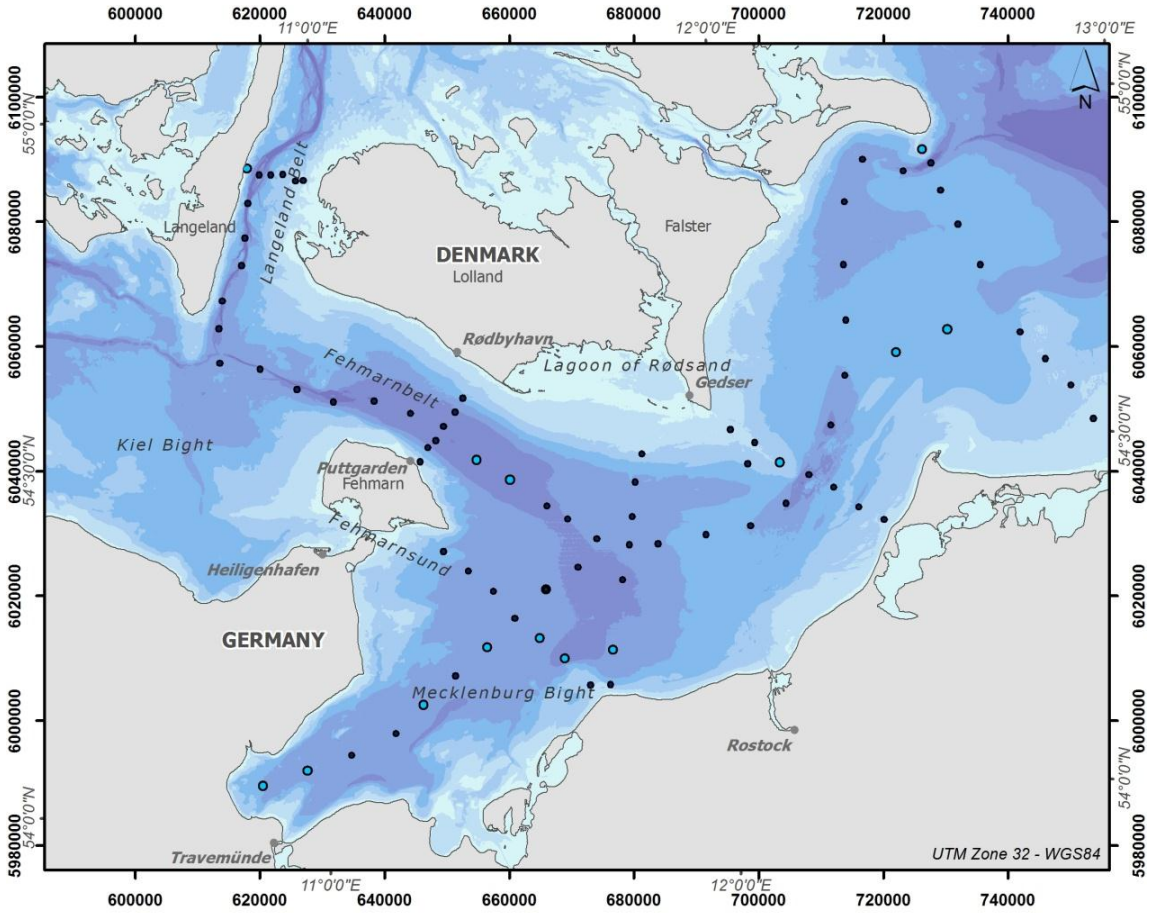
0 5 10 20 Km

Measured chlorophyll a (mg / m^3)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 -10
- 10 - 12
- 12 - 14
- 14 - 16
- > 16



Depth (m)

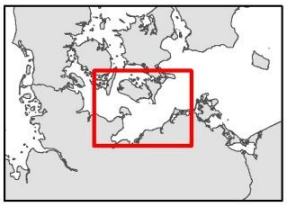


Cruise 3 (27.04. - 01.05.2009)

0 5 10 20 Km

Measured chlorophyll a (mg / m^3)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 -10
- 10 - 12
- 12 - 14
- 14 - 16
- > 16



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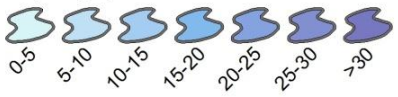
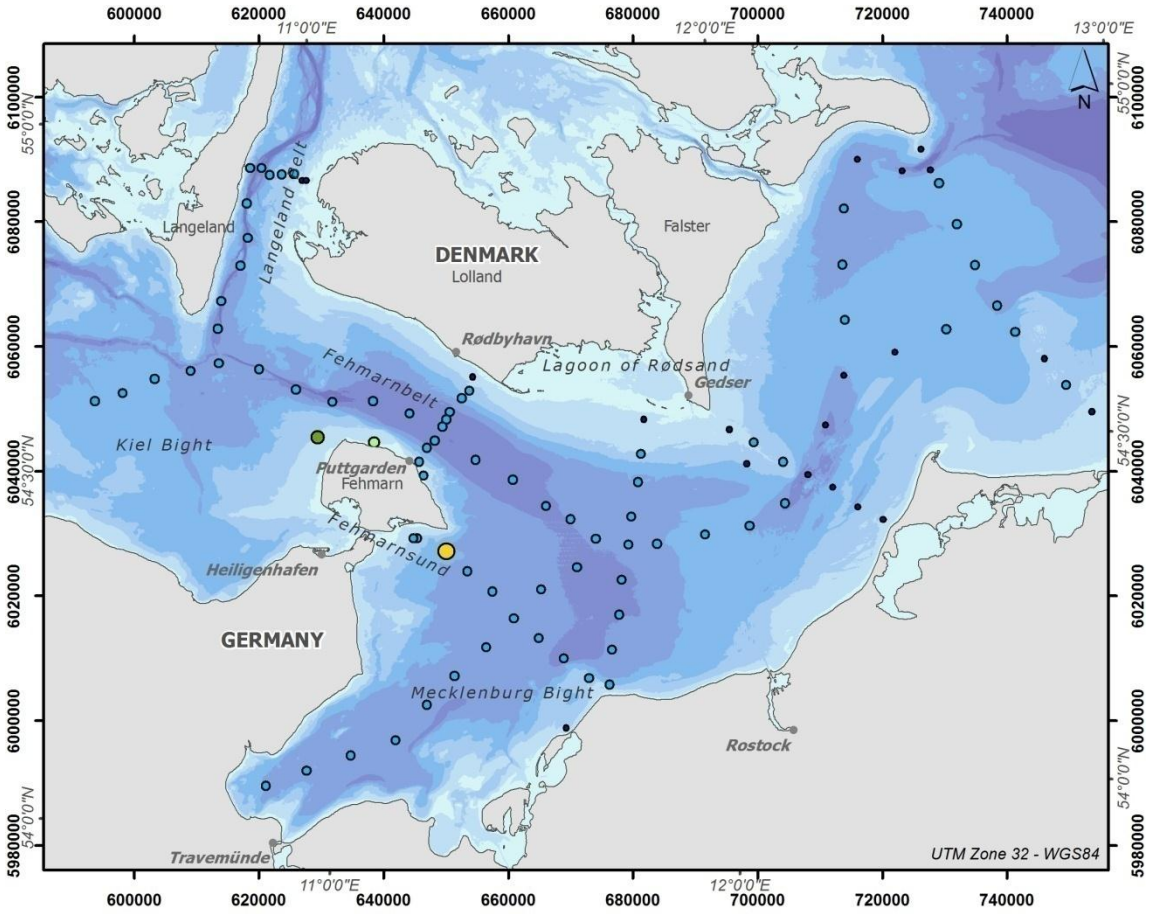


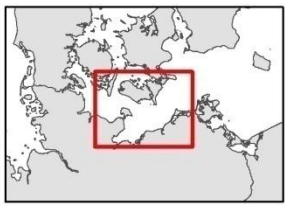


Cruise 5 (25.07. - 05.08.2009)

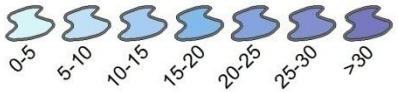
Measured chlorophyll a (mg / m^3)

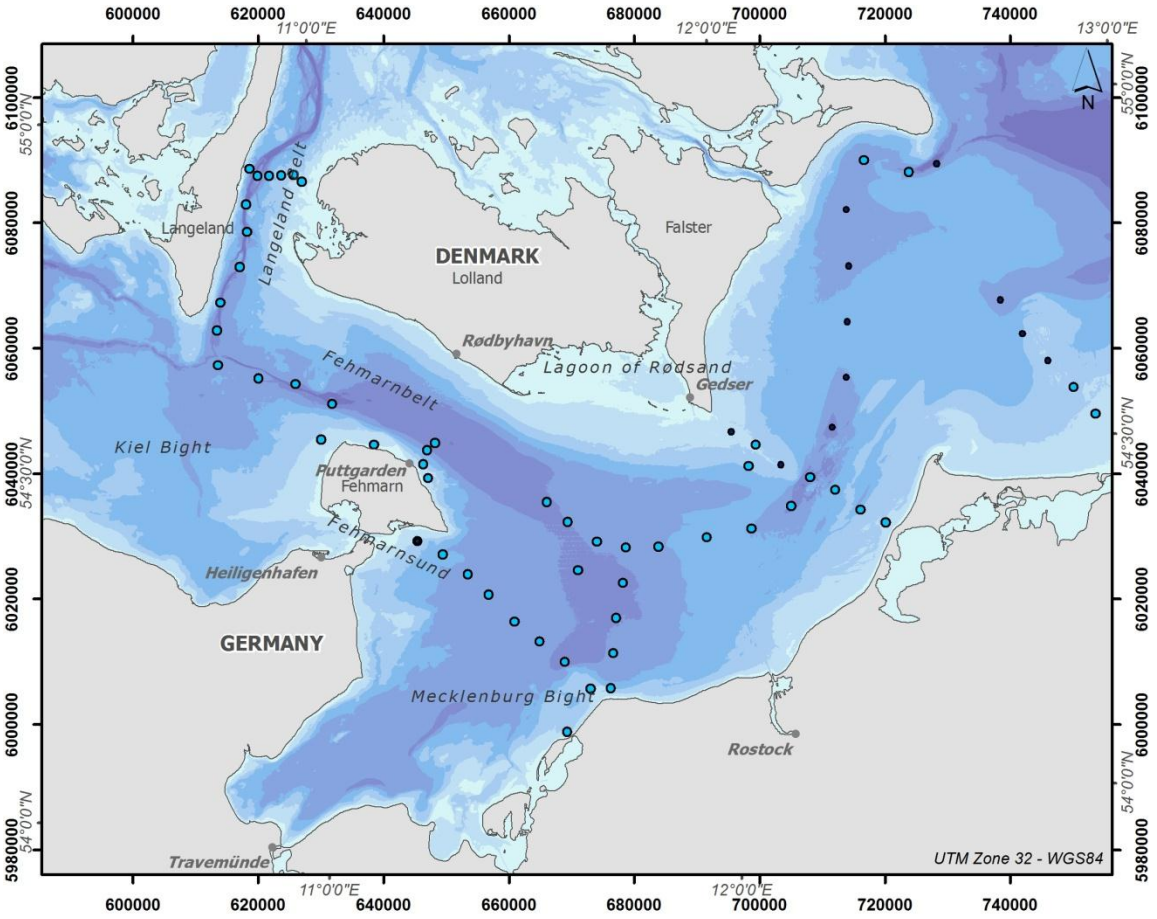
- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 -10
- 10 - 12
- 12 - 14
- 14 - 16
- > 16

0 5 10 20 Km



Depth (m)



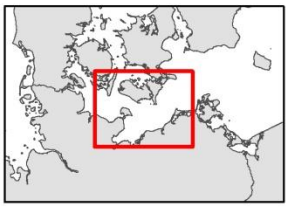


Cruise 6 (24.08. - 02.09.2009)

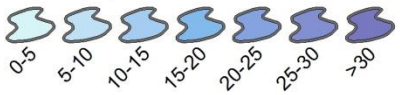
0 5 10 20 Km

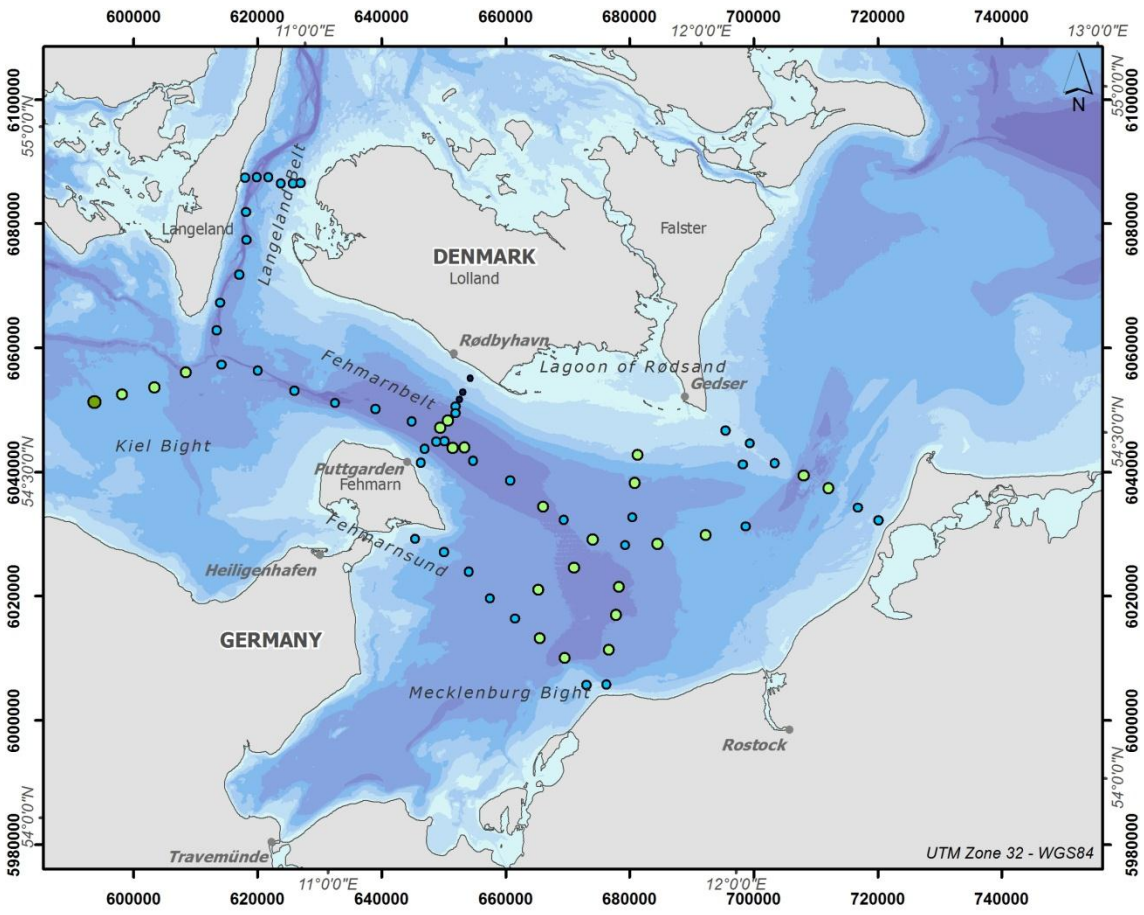
Measured chlorophyll a (mg / m^3)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 -10
- 10 - 12
- 12 - 14
- 14 - 16
- > 16



Depth (m)



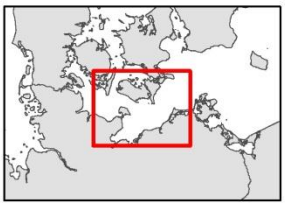


Cruise 7 (28.09. - 03.10.2009)

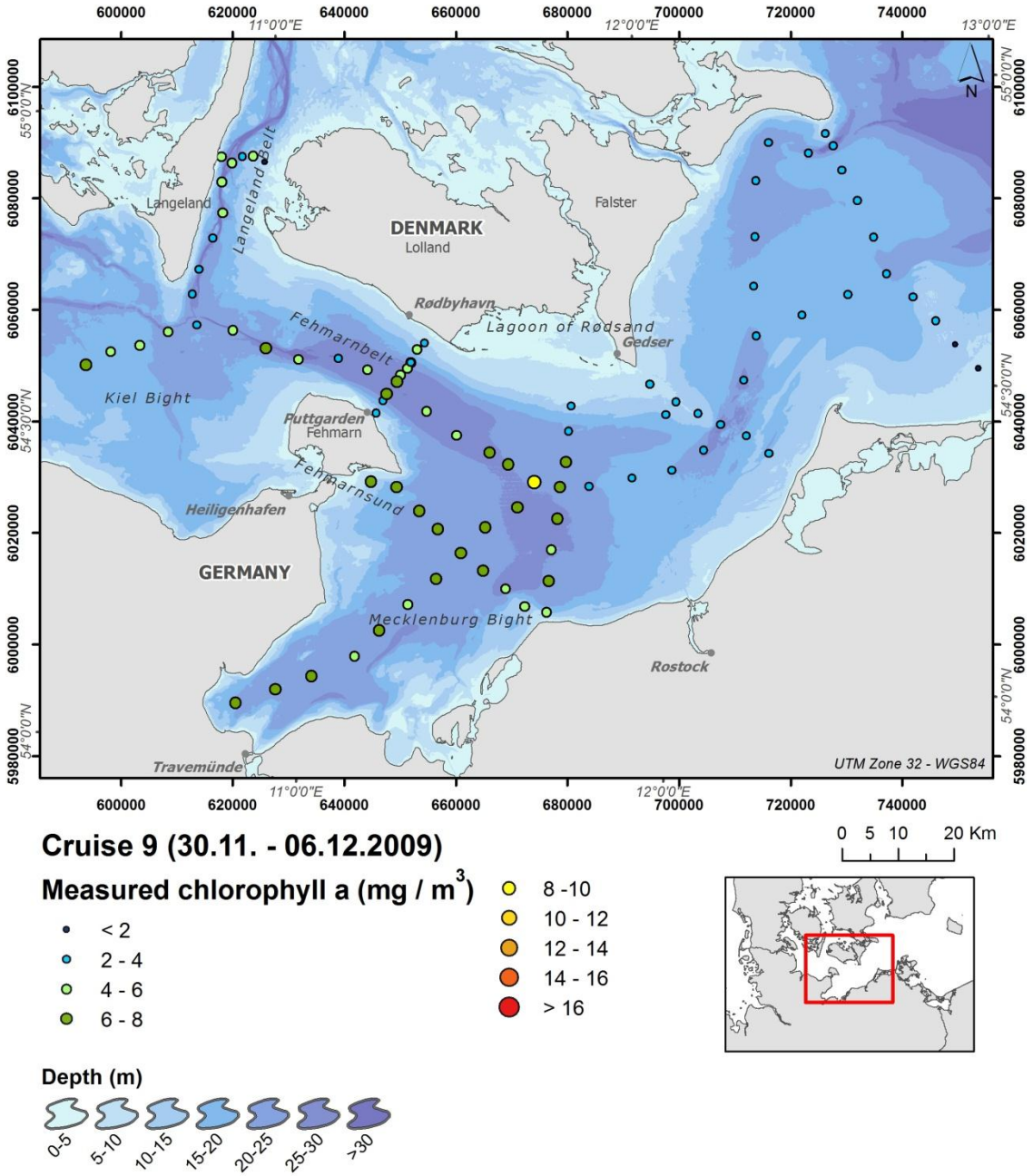
0 5 10 20 Km

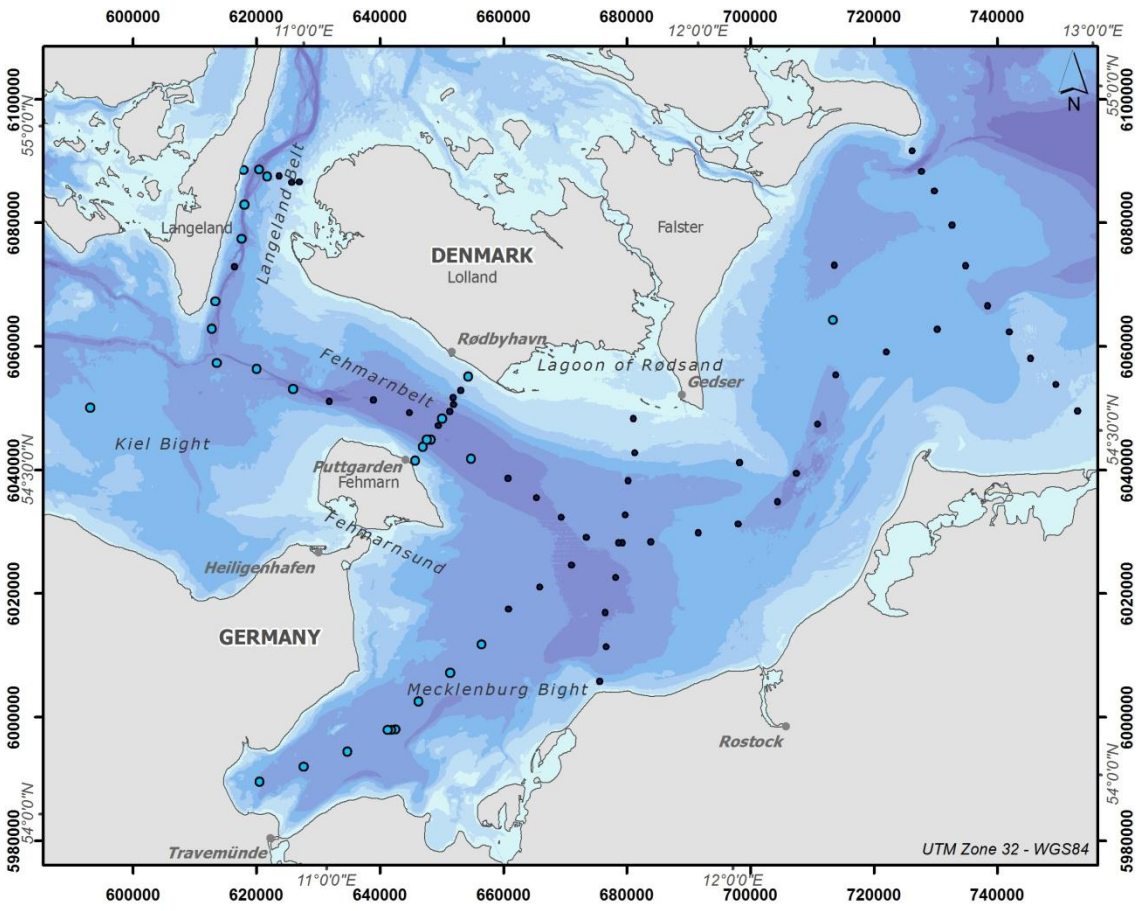
Measured chlorophyll a (mg / m^3)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 -10
- 10 - 12
- 12 - 14
- 14 - 16
- > 16



Depth (m)


600000
620000
640000
660000
680000
700000
720000
740000
11°0'0"E
12°0'0"E
13°0'0"E
55°0'0"N
54°30'0"N
54°0'0"N
6100000
6080000
6060000
6040000
6020000
6000000
5980000
N
Langeland
Langeland Belt
DENMARK
Lolland
Falster
Rødbyhavn
Lagoon of Rødsand
Gedser
Fehmarnbelt
Kiel Bight
Puttgarden
Fehmarn
Fehmarnsund
Heiligenhafen
GERMANY
Mecklenburg Bight
Rostock
Travemünde
UTM Zone 32 - WGS84
0 5 10 20 Km
Cruise 9 (30.11. - 06.12.2009)
Measured chlorophyll a (mg / m3)
< 2
2 - 4
4 - 6
6 - 8
8 -10
10 - 12
12 - 14
14 - 16
> 16
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
>30

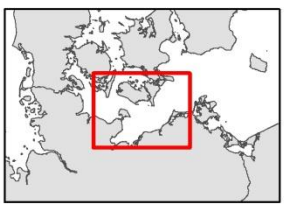


Cruise 10 (11.01. - 16.01.2010)

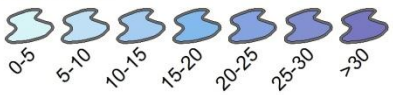
0 5 10 20 Km

Measured chlorophyll a (mg / m^3)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 -10
- 10 - 12
- 12 - 14
- 14 - 16
- > 16



Depth (m)



A P P E N D I X C

Phytoplankton species observed during baseline investigation 2009-2010

Table C.1 Phytoplankton species list of baseline monitoring (all stations all cruises). rank: ranking number according to total biomass of the species in all quantitative observations; sp: spring; su: summer; au: autumn; wi: winter (only qualitative data); AU:autotroph; HT: heterotroph; MX: mixotroph, tr.: nutritional groups

Division	Class	Species	tr.	rank	sp	su	au	wi
Chlorophyta	Chlorophyceae	Monoraphidium contortum	AU	174	X			
Chlorophyta	Chlorophyceae	Monoraphidium minutum	AU	171	X			
Chlorophyta	Chlorophyceae	Monoraphidium sp.	AU	165	X	X	X	
Chlorophyta	Chlorophyceae	Oocystis lacustris	AU	156		X		
Chlorophyta	Chlorophyceae	Oocystis sp.	AU	103	X	X	X	
Chlorophyta	Chlorophyceae	Planctonema lauterbornii	AU	80	X	X	X	X
Chlorophyta	Prasinophyceae	Cymbomonas tetramitiformis	AU	38	X	X	X	X
Chlorophyta	Prasinophyceae	Pachysphaera sp.	AU	85	X	X	X	
Chlorophyta	Prasinophyceae	Pterosperma sp.	AU	83	X		X	
Chlorophyta	Prasinophyceae	Pyramimonas longicauda	AU	120			X	
Chlorophyta	Prasinophyceae	Pyramimonas sp.	AU	23	X	X	X	X
Chrysophyta	Chrysophyceae	Apedinella radians	AU	122	X		X	
Chrysophyta	Chrysophyceae	Dinobryon balticum	MX	73	X	X		
Chrysophyta	Chrysophyceae	Dinobryon faculiferum	MX	90	X	X	X	
Chrysophyta	Chrysophyceae	Dinobryon sp.	MX	105	X	X	X	X
Chrysophyta	Chrysophyceae	Pseudopedinella	AU	32	X	X	X	X
Chrysophyta	Diatomophyceae	Achnanthes taeniata	AU	151	X			
Chrysophyta	Diatomophyceae	Actinocyclus octonarius v. octonarius	AU	115		X		
Chrysophyta	Diatomophyceae	Actinocyclus sp.	AU	53	X	X	X	
Chrysophyta	Diatomophyceae	Actinoptychus senarius	AU	100		X		
Chrysophyta	Diatomophyceae	Asterionellopsis glacialis	AU	168	X		X	
Chrysophyta	Diatomophyceae	Attheya septentrionalis	AU	86	X	X	X	X
Chrysophyta	Diatomophyceae	Centrales	AU	63	X	X	X	X
Chrysophyta	Diatomophyceae	Cerataulina pelagica	AU	4	X	X	X	X
Chrysophyta	Diatomophyceae	Chaetoceros affinis	AU	91			X	
Chrysophyta	Diatomophyceae	Chaetoceros brevis	AU	121		X	X	
Chrysophyta	Diatomophyceae	Chaetoceros ceratosporus v. ceratospo-rus	AU	154			X	
Chrysophyta	Diatomophyceae	Chaetoceros circinalis	AU	134			X	
Chrysophyta	Diatomophyceae	Chaetoceros constrictus	AU	99		X		
Chrysophyta	Diatomophyceae	Chaetoceros contortus	AU	116			X	
Chrysophyta	Diatomophyceae	Chaetoceros convolutus	AU	41		X	X	X
Chrysophyta	Diatomophyceae	Chaetoceros curvisetus	AU	30	X	X	X	X
Chrysophyta	Diatomophyceae	Chaetoceros danicus	AU	89	X	X	X	X
Chrysophyta	Diatomophyceae	Chaetoceros debilis	AU	56	X		X	X
Chrysophyta	Diatomophyceae	Chaetoceros decipiens	AU	133	X	X		
Chrysophyta	Diatomophyceae	Chaetoceros diadema	AU	60	X		X	
Chrysophyta	Diatomophyceae	Chaetoceros didymus v. didymus	AU	145			X	
Chrysophyta	Diatomophyceae	Chaetoceros impressus	AU	68	X	X	X	X
Chrysophyta	Diatomophyceae	Chaetoceros laciniosus	AU	169	X			
Chrysophyta	Diatomophyceae	Chaetoceros lorenzianus	AU	102			X	X
Chrysophyta	Diatomophyceae	Chaetoceros similis	AU	44	X	X	X	X
Chrysophyta	Diatomophyceae	Chaetoceros simplex	AU	144		X		
Chrysophyta	Diatomophyceae	Chaetoceros socialis f. radians	AU	113			X	X
Chrysophyta	Diatomophyceae	Chaetoceros socialis f. socialis	AU	26			X	X
Chrysophyta	Diatomophyceae	Chaetoceros sp.	AU	65	X	X	X	X
Chrysophyta	Diatomophyceae	Chaetoceros subtilis v. subtilis	AU	76	X	X	X	X

Division	Class	Species	tr.	rank	sp	su	au	wi
Chrysophyta	Diatomophyceae	Chaetoceros throndsenii v. throndsenii	AU	142	X	X		
Chrysophyta	Diatomophyceae	Chaetoceros wighamii	AU	78	X			
Chrysophyta	Diatomophyceae	Coscinodiscus granii	AU	28		X	X	
Chrysophyta	Diatomophyceae	Coscinodiscus radiatus	AU	125		X		
Chrysophyta	Diatomophyceae	Coscinodiscus sp.	AU	140			X	
Chrysophyta	Diatomophyceae	Cyclotella choctawhatcheeana	AU	51	X	X	X	X
Chrysophyta	Diatomophyceae	Cyclotella sp.	AU	112		X	X	
Chrysophyta	Diatomophyceae	Cylindrotheca closterium	AU	69	X	X	X	X
Chrysophyta	Diatomophyceae	Dactyliosolen fragilissimus	AU	14	X	X	X	X
Chrysophyta	Diatomophyceae	Diatoma tenuis	AU	98	X			
Chrysophyta	Diatomophyceae	Ditylum brightwellii	AU	47	X	X	X	X
Chrysophyta	Diatomophyceae	Guinardia delicatula	AU	74		X	X	X
Chrysophyta	Diatomophyceae	Guinardia flaccida	AU	36		X	X	X
Chrysophyta	Diatomophyceae	Lennoxia faveolata	AU	143	X	X	X	X
Chrysophyta	Diatomophyceae	Leptocylindrus danicus	AU	66	X	X	X	X
Chrysophyta	Diatomophyceae	Leptocylindrus minimus	AU	29		X	X	X
Chrysophyta	Diatomophyceae	Melosira arctica	AU	146	X			
Chrysophyta	Diatomophyceae	Navicula sp.	AU	126	X	X	X	X
Chrysophyta	Diatomophyceae	Nitzschia longissima	AU	170	X			
Chrysophyta	Diatomophyceae	Nitzschia sp.	AU	161		X		
Chrysophyta	Diatomophyceae	Pennales	AU	150	X	X		
Chrysophyta	Diatomophyceae	Porosira glacialis	AU	84	X		X	
Chrysophyta	Diatomophyceae	Proboscia alata	AU	9	X	X	X	X
Chrysophyta	Diatomophyceae	Pseudo-nitzschia delicatissima	AU	104	X	X	X	X
Chrysophyta	Diatomophyceae	Pseudo-nitzschia pseudodelicatissima	AU	55	X	X		X
Chrysophyta	Diatomophyceae	Pseudo-nitzschia pungens	AU	88	X		X	X
Chrysophyta	Diatomophyceae	Pseudo-nitzschia seriata	AU	163	X	X		
Chrysophyta	Diatomophyceae	Pseudo-nitzschia seriata f. seriata	AU	155	X			
Chrysophyta	Diatomophyceae	Pseudo-nitzschia sp.	AU	12	X	X	X	X
Chrysophyta	Diatomophyceae	Pseudosolenia calcar-avis	AU	18			X	X
Chrysophyta	Diatomophyceae	Rhizosolenia hebetata f. semispina	AU	124	X			
Chrysophyta	Diatomophyceae	Rhizosolenia pungens	AU	75	X	X	X	X
Chrysophyta	Diatomophyceae	Rhizosolenia setigera	AU	16	X	X	X	X
Chrysophyta	Diatomophyceae	Rhizosolenia sp.	AU	160	X			
Chrysophyta	Diatomophyceae	Rhizosolenia styliformis	AU	40	X		X	
Chrysophyta	Diatomophyceae	Skeletonema costatum	AU	5	X	X	X	X
Chrysophyta	Diatomophyceae	Thalassionema nitzschioides	AU	39	X	X	X	X
Chrysophyta	Diatomophyceae	Thalassiosira anguste-lineata	AU	109	X			X
Chrysophyta	Diatomophyceae	Thalassiosira nordenskioeldii	AU	59	X		X	
Chrysophyta	Diatomophyceae	Thalassiosira rotula	AU	52			X	X
Chrysophyta	Diatomophyceae	Thalassiosira sp.	AU	8	X	X	X	X
Chrysophyta	Dictyochophyceae	Dictyocha speculum	AU	11	X	X	X	X
Chrysophyta	Dictyochophyceae	Verrucophora farcimen [4]	AU	31	X	X	X	
Chrysophyta	Raphidophyceae	Chattonella verruculosa	AU	108	X			
Chrysophyta	Raphidophyceae	Heterosigma akashiwo	AU	101	X			
Cryptophyta	Cryptophyceae	Cryptomonadales	AU	92	X	X		X
Cryptophyta	Cryptophyceae	Hemiselmis sp.	AU	17	X	X	X	X
Cryptophyta	Cryptophyceae	Plagioselmis prolonga	AU	20	X	X	X	X
Cryptophyta	Cryptophyceae	Rhodomonas sp.	AU	135	X			
Cryptophyta	Cryptophyceae	Teleaulax acuta	AU	128		X		
Cryptophyta	Cryptophyceae	Teleaulax amphioxeia	AU	118		X		
Cryptophyta	Cryptophyceae	Teleaulax sp.	AU	13	X	X	X	X
Cyanophyta	Nostocophyceae	Anabaena flos-aquae	AU	58		X	X	X

Division	Class	Species	tr.	rank	sp	su	au	wi
Cyanophyta	Nostocophyceae	Anabaena sp.	AU	70		X		
Cyanophyta	Nostocophyceae	Anabaenopsis elenkinii	AU	96		X		
Cyanophyta	Nostocophyceae	Aphanizomenon sp.	AU	19	X	X	X	X
Cyanophyta	Nostocophyceae	Aphanocapsa sp.	AU	33	X	X		
Cyanophyta	Nostocophyceae	Aphanothece paralleliformis	AU	87	X	X		
Cyanophyta	Nostocophyceae	Aphanothece sp.	AU	42	X	X	X	X
Cyanophyta	Nostocophyceae	Chroococcales	AU	138		X		
Cyanophyta	Nostocophyceae	Coelosphaerium minutissimum	AU	129		X		
Cyanophyta	Nostocophyceae	Coelosphaerium sp.	AU	159	X			
Cyanophyta	Nostocophyceae	Cyanodictyon imperfectum	AU	167	X	X		
Cyanophyta	Nostocophyceae	Cyanodictyon planctonicum	AU	137	X	X		
Cyanophyta	Nostocophyceae	Cyanodictyon sp.	AU	162		X		
Cyanophyta	Nostocophyceae	Lemmermanniella pallida	AU	93	X	X		X
Cyanophyta	Nostocophyceae	Lemmermanniella sp.	AU	119		X		
Cyanophyta	Nostocophyceae	Merismopedia punctata	AU	153	X			X
Cyanophyta	Nostocophyceae	Merismopedia sp.	AU	175			X	
Cyanophyta	Nostocophyceae	Merismopedia tenuissima	AU	172	X			
Cyanophyta	Nostocophyceae	Merismopedia warmingiana	AU	164		X		
Cyanophyta	Nostocophyceae	Microcystis sp.	AU	173	X			
Cyanophyta	Nostocophyceae	Nodularia spumigena	AU	34	X	X	X	
Cyanophyta	Nostocophyceae	Oscillatoriales	AU	132		X		X
Cyanophyta	Nostocophyceae	Planktolyngbya contorta	AU	141	X			
Cyanophyta	Nostocophyceae	Pseudanabaena limnetica	AU	61	X	X		
Cyanophyta	Nostocophyceae	Pseudanabaena sp.	AU	106		X	X	X
Cyanophyta	Nostocophyceae	Romeria sp.	AU	166		X		
Cyanophyta	Nostocophyceae	Snowella litoralis	AU	152	X			
Cyanophyta	Nostocophyceae	Snowella septentrionalis	AU	64		X		
Cyanophyta	Nostocophyceae	Snowella sp.	AU	62	X	X	X	X
Cyanophyta	Nostocophyceae	Woronichinia compacta	AU	97	X	X		X
Dinophyta	Dinophyceae	Akashiwo sanguinea	AU	139			X	
Dinophyta	Dinophyceae	Alexandrium sp.	AU	46		X		
Dinophyta	Dinophyceae	Amphidinium crassum	HT	95	X	X	X	
Dinophyta	Dinophyceae	Amphidinium sp.	AU	157				X
Dinophyta	Dinophyceae	Ceratium fusus	AU	21	X	X	X	X
Dinophyta	Dinophyceae	Ceratium lineatum	AU	57	X	X	X	X
Dinophyta	Dinophyceae	Ceratium longipes	AU	117			X	X
Dinophyta	Dinophyceae	Ceratium tripos	AU	10	X	X	X	X
Dinophyta	Dinophyceae	Cladopyxis claytonii	AU	123	X		X	X
Dinophyta	Dinophyceae	Dinophyceae	AU	79		X	X	
Dinophyta	Dinophyceae	Dinophysis acuminata	MX	77	X	X	X	X
Dinophyta	Dinophyceae	Dinophysis acuta	MX	54	X	X		X
Dinophyta	Dinophyceae	Dinophysis norvegica	MX	49	X	X	X	X
Dinophyta	Dinophyceae	Dinophysis rotundata	HT	149	X	X		
Dinophyta	Dinophyceae	Diplopsalis sp.	HT	107				X
Dinophyta	Dinophyceae	Dissodinium pseudolunula	AU	136			X	
Dinophyta	Dinophyceae	Glenodinium sp.	AU	111				X
Dinophyta	Dinophyceae	Gymnodiniales	AU	2	X	X	X	X
Dinophyta	Dinophyceae	Gymnodinium sp.	AU	82	X	X	X	X
Dinophyta	Dinophyceae	Gyrodinium sp.	AU/HT	43	X	X	X	
Dinophyta	Dinophyceae	Gyrodinium spirale	HT	24	X	X	X	X
Dinophyta	Dinophyceae	Heterocapsa rotundata	AU	27	X	X	X	X

Division	Class	Species	tr.	rank	sp	su	au	wi
Dinophyta	Dinophyceae	Katodinium glaucum	HT	110	X		X	
Dinophyta	Dinophyceae	Katodinium sp.	AU	127	X	X		
Dinophyta	Dinophyceae	Peridiniales sp.	AU	6	X	X	X	X
Dinophyta	Dinophyceae	Peridiniella catenata	AU	147	X			
Dinophyta	Dinophyceae	Prorocentrum balticum	AU	131		X		
Dinophyta	Dinophyceae	Prorocentrum micans	AU	48		X	X	X
Dinophyta	Dinophyceae	Prorocentrum minimum	AU	72		X	X	
Dinophyta	Dinophyceae	Prorocentrum redfeldii	AU	148			X	
Dinophyta	Dinophyceae	Protoperidinium	HT	25	X	X	X	X
Dinophyta	Dinophyceae	Protoperidinium pallidum	HT	130	X			
Dinophyta	Dinophyceae	Scrippsiella sp.	AU	81	X	X	X	X
Euglenophyta	Euglenophyceae	Euglena sp.	AU	94		X		
Euglenophyta	Euglenophyceae	Eutreptia sp.	AU	158			X	
Euglenophyta	Euglenophyceae	Eutreptiella sp.	AU	37	X	X	X	X
Euglenophyta	Euglenophyceae	Trachelomonas sp.	AU	67		X	X	X
Haptophyta	Prymnesiophyceae	Chrysochromulina hirta	MX	114			X	
Haptophyta	Prymnesiophyceae	Chrysochromulina sp.	MX	1	X	X	X	X
Incertae sedis	Incertae sedis	Katablepharis remigera	HT	22	X	X	X	X
Incertae sedis	Incertae sedis	Leucocryptos marina	HT	45	X	X	X	X
Incertae sedis	Incertae sedis	Telonema sp.	HT	15	X	X	X	X
Ciliophora	Litostomateae	Mesodinium rubrum	AU	3	X	X	X	X
Sarcomastigophora	Choanoflagellidea	Craspedophyceae	HT	71	X	X	X	X
Zoomastigophora	Ebriidea	Ebria tripartita	HT	50	X	X	X	
others	others	Flagellates	AU	35	X	X	X	
others	others	Unicell	AU	7	X	X	X	X

[1] *By use of the common identification books, Skeletonema was traditionally identified as Skeletonema costatum. Sarno et al. (2005) showed that also other species have to be taken into consideration for the Baltic. The taxonomical differentiation is not possible by Utermöhl technique. Electron microscopic analyses of a sample from 7.3.2006 (IOW) revealed that the Skeletonema species in all investigated waters should be Skeletonema marinoi. However, independent from these findings Sceletonema marinoi is not yet confirmed in HELCOM PEG list and will continue to be counted as Skeletonema costatum.*

[2] *Mesodinium rubrum is a photoautotrophic marine ciliate, which for several years has been counted as phytoplankton. Mesodinium rubrum is responsible for so-called "red-tides" in different coastal waters (e.g. Montagnes and Lynn 1989). The species persists under a wide range of environmental conditions (Crawford et al. 1997), but increase in temperature and increased stability of the water column were postulated as triggering factors for blooming. Wasmund et al. (2001) described Mesodinium rubrum as one of the dominant species in the Baltic Proper in spring and summer beginning with the year 1999.*

[3] *Dictyocha speculum occurs in two growth forms: a naked, either mononucleated or multinucleated form and a form bearing a silica skeleton. Dictyocha speculum is very variable in shape, and therefore difficult to differentiate from Chatonella spp. (Raphidophyceae) and Verrucophora farcimen (Dictyochophyceae).*

[4] *Verrucophora farcimen (Dictyochophyceae) was renamed in 2009 in* Pseudochattonella farcimen *(Eikrem et al. 2009).*

Table C.2 The ten most abundant (referred to mg C m^{-3}) phytoplankton species and their percentage of total biomass for the three investigated stations during the baseline monitoring.

	station 360		station 12		station 46	
cruise	**species/taxon**	**%**	**species/taxon**	**%**	**species/taxon**	**%**
26JL0901			Skeletonema costatum	88	Skeletonema costatum	68
Feb 09			Thalassiosira	2.8	Mesodinium rubrum	12
			Mesodinium rubrum	2.8	Thalassiosira nordenskioeldii	4.3
			Thalassiosira nordenskioeldii	1.6	Chrysochromulina	3.8
			Chrysochromulina	0.9	Thalassiosira	3.7
			Gymnodiniales	0.8	Teleaulax	1.4
			Teleaulax	0.5	Peridiniales	1.4
			Pseudopedinella	0.5	Pseudopedinella	0.9
			Heterocapsa rotundata	0.4	Gymnodiniales	0.9
			Eutreptiella	0.4	Heterocapsa rotundata	0.8
26JL0902	Chrysochromulina	42	Gymnodiniales	24	Mesodinium rubrum	42
Mar 09	Peridiniales	24	Chrysochromulina	21	Skeletonema costatum	22
	Gymnodiniales	7.4	Verrucophora farcimen	12	Chrysochromulina	13
	Gyrodinium spirale	7.0	Mesodinium rubrum	11.5	Peridiniales	8.7
	Rhizosolenia styliformis	5.5	Peridiniales	10	Gymnodiniales	6.5
	Unicell	2.3	Unicell	4.7	Gyrodinium spirale	1.8
	Pseudopedinella	2.3	Dictyocha speculum	4.6	Teleaulax	1.4
	Dictyocha speculum	1.5	Gyrodinium spirale	3.6	Pyramimonas	1.0
	Protoperidinium	1.0	Teleaulax	2.4	Heterocapsa rotundata	0.8
	Gymnodinium	0.8	Pyramimonas	0.8	Pseudopedinella	0.7
26JL0903	Chrysochromulina	34	Chrysochromulina	44	Chrysochromulina	57
Apr 09	Peridiniales	27	Gymnodiniales	14	Gymnodiniales	8.3
	Gymnodiniales	7.7	Peridiniales	8.0	Unicell	7.1
	Unicell	4.9	Protoperidinium	7.2	Peridiniales	6.4
	Leucocryptos marina	4.0	Unicell	5.5	Mesodinium rubrum	5.6
	Verrucophora farcimen	3.2	Pyramimonas	3.6	Plagioselmis prolonga	5.4
	Mesodinium rubrum	2.6	Mesodinium rubrum	3.3	Heterocapsa rotundata	2.4
	Teleaulax	2.2	Dinobryon balticum	2.1	Diatoma tenuis	1.8
	Ceratium tripos	2.0	Pseudopedinella	2.0	Pyramimonas	1.7
	Dinophysis acuminata	2.0	Hemiselmis	1.9	Dinobryon balticum	0.6
26JL0904	Ceratium tripos	20	Chrysochromulina	31	Unicell	21
Jun 09	Chrysochromulina	16	Katablepharis	8.5	Pyramimonas	9.7
	Proboscia alata	16	Unicell	7.3	Aphanizomenon	9.7
	Cerataulina pelagica	15	Gymnodiniales	6.0	Katablepharis	9.4
	Gymnodiniales	4.9	Ceratium tripos	6.0	Gymnodiniales	6.4
	Peridiniales	3.6	Nodularia spumigena	4.3	Aphanocapsa	6.3
	Snowella septentrionalis	3.4	Aphanothece	3.6	Chrysochromulina	6.0
	Hemiselmis	2.2	Aphanizomenon	3.0	Peridiniales	5.7
	Unicell	2.1	Dinobryon balticum	2.9	Teleaulax	4.7
	Leucocryptos marina	2.0	Pseudanabaena limnetica	2.7	Aphanothece	4.3
26JL0905	Proboscia alata	57	Proboscia alata	40	Gymnodiniales	21
Jul 09	Gymnodiniales	5.6	Ceratium tripos	13	Proboscia alata	21
	Ceratium tripos	5.5	Guinardia flaccida	8.0	Ceratium tripos	8.3
	Guinardia flaccida	4.6	Gymnodiniales	5.8	Dactyliosolen fragilissimus	6.6
	Chrysochromulina	4.0	Katablepharis	4.7	Chrysochromulina	4.5
	Dactyliosolen fragilissimus	3.8	Unicell	3.9	Peridiniales	4.5
	Peridiniales	3.8	Verrucophora farcimen	2.7	Mesodinium rubrum	3.5
	Cyclotella choctawhatcheeana	1.6	Chrysochromulina	2.5	Unicell	3.4

	station 360		station 12		station 46	
cruise	species/taxon	%	species/taxon	%	species/taxon	%
	Thalassionema nitzschioides	1.2	Actinoptychus senarius	2.4	Prorocentrum minimum	3.3
	Unicell	1.2	Hemiselmis	2.2	Guinardia flaccida	2.7
26JL0906					Chrysochromulina	29
Aug 09					Gymnodiniales	19
					Dactyliosolen fragilissimus	7.8
					Mesodinium rubrum	5.1
					Unicell	4.4
					Ceratium tripos	3.4
					Hemiselmis	2.7
					Pyramimonas	2.5
					Chaetoceros constrictus	2.4
					Chaetoceros convolutus	2.2
26JL0907	Leptocylindrus minimus	33	Cerataulina pelagica	39	Gymnodiniales	34
Sep 09	Gymnodiniales	16	Gymnodiniales	24	Peridiniales	12
	Peridiniales	12	Peridiniales	12	Cerataulina pelagica	6.9
	Chrysochromulina	6.9	Ceratium fusus	5.7	Chrysochromulina	6.7
	Ceratium fusus	4.5	Chrysochromulina	3.0	Ceratium fusus	5.8
	Chaetoceros debilis	3.8	Chaetoceros convolutus	2.2	Chaetoceros convolutus	3.1
	Gyrodinium spirale	3.5	Gyrodinium spirale	1.5	Pseudo-nitzschia pungens	2.8
	Dactyliosolen fragilissimus	2.6	Ceratium tripos	1.3	Chaetoceros curvisetus	2.7
	Pterosperma	2.5	Pseudo-nitzschia pungens	1.0	Mesodinium rubrum	2.5
	Mesodinium rubrum	2.0	Dictyocha speculum	1.0	Unicell	2.3
26JL0908	Cerataulina pelagica	31	Peridiniales	13	Gymnodiniales	28
Oct 09	Gymnodiniales	11	Coscinodiscus granii	10	Coscinodiscus granii	22
	Mesodinium rubrum	8.4	Cerataulina pelagica	9.5	Mesodinium rubrum	12
	Ceratium fusus	6.4	Mesodinium rubrum	9.2	Teleaulax	12
	Chrysochromulina	6.4	Unicell	9.0	Katablepharis remigera	4.3
	Peridiniales	5.2	Hemiselmis	8.6	Heterocapsa rotundata	2.8
	Chaetoceros convolutus	3.4	Teleaulax	7.0	Plagioselmis prolonga	2.7
	Gyrodinium spirale	2.6	Chrysochromulina	5.4	Actinocyclus	2.7
	Gyrodinium	2.5	Gymnodiniales	3.7	Chaetoceros impressus	2.4
	Ceratium lineatum	2.3	Gyrodinium spirale	3.3	Peridiniales	2.1
26JL0909	Cerataulina pelagica	28	Thalassiosira	13	Cerataulina pelagica	15
Nov 09	Thalassiosira	8.5	Skeletonema costatum	13	Mesodinium rubrum	12
	Pseudo-nitzschia	8.4	Pseudo-nitzschia	8.6	Pseudo-nitzschia	10
	Rhizosolenia setigera	7.4	Cerataulina pelagica	7.3	Skeletonema costatum	7.2
	Mesodinium rubrum	6.4	Thalassiosira rotula	6.7	Thalassiosira	6.3
	Skeletonema costatum	5.6	Rhizosolenia setigera	4.9	Chrysochromulina	6.3
	Proboscia alata	5.2	Proboscia alata	4.3	Rhizosolenia setigera	5.1
	Chaetoceros curvisetus	3.4	Gymnodiniales	3.9	Proboscia alata	3.5
	Gymnodiniales	3.2	Ceratium tripos	3.4	Teleaulax	3.4
	Ceratium tripos	3.0	Dinophysis acuta	3.1	Dictyocha speculum	3.1
26JL1002	Skeletonema costatum	36	Gymnodiniales	25	Mesodinium rubrum	43
Feb 10	Gymnodiniales	7.9	Mesodinium rubrum	17	Gymnodiniales	29
	Rhizosolenia setigera	7.7	Thalassiosira	8.7	Thalassiosira	4.9
	Flagellates	7.3	Rhizosolenia setigera	7.7	Peridiniales	3.7
	Porosira glacialis	4.2	Teleaulax	7.4	Teleaulax	3.2
	Thalassionema nitzschioides	4.1	Skeletonema costatum	5.5	Heterocapsa rotundata	2.4
	Dictyocha speculum	3.6	Unicell	4.5	Chrysochromulina	2.1
	Rhizosolenia styliformis	3.4	Chaetoceros similis	4.4	Centrales	1.8
	Mesodinium rubrum	3.3	Heterocapsa rotundata	3.9	Rhizosolenia setigera	1.5
	Heterosigma akashiwo	2.4	Eutreptiella	2.3	Ebria tripartita	1.1

	station 360		station 12		station 46	
cruise	species/taxon	%	species/taxon	%	species/taxon	%
26JL1003	Skeletonema costatum	23	Thalassiosira	62	Thalassiosira	54
Mar 10	Rhizosolenia setigera	18	Skeletonema costatum	8.6	Mesodinium rubrum	18
	Rhizosolenia styliformis	13	Chaetoceros similis	6.6	Chaetoceros similis	6.8
	Thalassiosira	11	Mesodinium rubrum	6.3	Skeletonema costatum	6.3
	Gyrodinium spirale	5.3	Eutreptiella	5.5	Rhizosolenia setigera	4.7
	Mesodinium rubrum	5.1	Chaetoceros diadema	4.0	Unicell	1.5
	Gymnodiniales	4.7	Rhizosolenia setigera	2.0	Eutreptiella	1.4
	Chaetoceros curvisetus	4.6	Heterocapsa rotundata	0.9	Heterocapsa rotundata	1.4
	Eutreptiella	2.1	Chaetoceros subtilis v. subtilis	0.7	Gymnodiniales	0.8
	Chaetoceros diadema	1.9	Chaetoceros wighamii	0.5	Teleaulax	0.6
26JL1004	Gymnodiniales	19	Mesodinium rubrum	34	Mesodinium rubrum	50
Apr 10	Protoperidinium	17	Gymnodiniales	19	Gymnodiniales	16
	Mesodinium rubrum	16	Pseudopedinella	6.1	Skeletonema costatum	3.5
	Dictyocha speculum	15	Unicell	5.5	Verrucophora farcimen	3.4
	Chrysochromulina	13	Dictyocha speculum	4.5	Chaetoceros wighamii	3.1
	Dinophysis acuta	3.3	Chrysochromulina	4.3	Peridiniales	3.1
	Gyrodinium spirale	3.1	Peridiniales	3.6	Chaetoceros curvisetus	2.2
	Teleaulax	1.9	Skeletonema costatum	3.1	Thalassiosira	2.1
	Pseudopedinella	1.8	Gyrodinium spirale	2.5	Ebria tripartita	2.1
	Peridiniales	1.5	Heterocapsa rotundata	2.0	Flagellates	1.8
26JL1005	Dictyocha speculum	43.2	Chrysochromulina	41	Chrysochromulina	34.6
May 10	Chrysochromulina	26	Dictyocha speculum	22	Mesodinium rubrum	18
	Telonema	7.9	Hemiselmis	6.7	Gymnodiniales	15
	Gymnodiniales	3.5	Gymnodiniales	4.4	Heterocapsa rotundata	8.6
	Plagioselmis	3.4	Telonema	4.2	Pyramimonas	7.1
	Dinophysis norvegica	2.6	Unicell	3.6	Dictyocha speculum	4.1
	Unicell	2.5	Heterocapsa rotundata	3.4	Unicell	2.5
	Mesodinium rubrum	2.3	Mesodinium rubrum	2.8	Aphanizomenon	1.7
	Hemiselmis	1.8	Plagioselmis	2.1	Teleaulax	1.4
	Teleaulax	1.5	Pyramimonas	2.1	Hemiselmis	1.1
26JL1006	Chrysochromulina	31	Chrysochromulina	20	Chrysochromulina	43
Jun 10	Peridiniales	13	Peridiniales	14	Gymnodiniales	12
	Telonema	10	Gymnodiniales	9.6	Peridiniales	6.7
	Gymnodiniales	7.2	Plagioselmis	8.0	Hemiselmis	5.1
	Dictyocha speculum	5.2	Unicell	7.4	Dictyocha speculum	4.5
	Plagioselmis	4.9	Mesodinium rubrum	7.4	Pyramimonas	4.0
	Hemiselmis	3.0	Dictyocha speculum	5.8	Telonema	3.0
	Katablepharis	3.0	Teleaulax	4.6	Plagioselmis	2.4
	Aphanocapsa	2.8	Telonema	4.3	Unicell	2.3
	Mesodinium rubrum	2.7	Katablepharis	3.2	Cymbomonas tetramitiformis	2.1
26JL1007	Dactyliosolen fragilissimus	58	Chrysochromulina	19	Unicell	15
Jul 10	Peridiniales	14	Aphanizomenon	19	Aphanizomenon	11
	Ceratium tripos	4.3	Unicell	11	Flagellates	10
	Unicell	4.2	Aphanothece	9.9	Gymnodiniales	7.1
	Gymnodiniales	3.3	Gymnodiniales	6.6	Aphanocapsa	5.6
	Alexandrium	3.2	Verrucophora farcimen	4.9	Chrysochromulina	5.1
	Anabaena	2.1	Aphanocapsa	4.6	Verrucophora farcimen	4.3
	Aphanizomenon	1.8	Scrippsiella	3.2	Snowella	4.1
	Aphanocapsa	1.8	Euglena	3.1	Anabaena	4.0
	Flagellates	1.5	Plagioselmis	2.8	Cyclotella choctawhatcheeana	3.9

	station 360		station 12		station 46	
cruise	species/taxon	%	species/taxon	%	species/taxon	%
26JL1008	Cerataulina pelagica	51				
Aug 10	Alexandrium	13				
	Ceratium tripos	8.0				
	Nodularia	4.6				
	Proboscia alata	3.7				
	Peridiniales	3.6				
	Chrysochromulina	3.1				
	Gymnodiniales	2.1				
	Aphanizomenon	1.4				
	Unicell	1.2				
26JL1009	Ceratium tripos	24	Cerataulina pelagica	32	Chaetoceros socialis f. socialis	33
Sep 10	Pseudo-nitzschia	16	Gymnodiniales	13	Pseudo-nitzschia	7.1
	Nodularia spumigena	7.5	Ceratium tripos	12	Gymnodiniales	4.7
	Cerataulina pelagica	7.3	Pseudo-nitzschia	7.9	Skeletonema costatum	4.4
	Chaetoceros socialis f. socialis	6.4	Chaetoceros socialis f. socialis	3.5	Ceratium tripos	3.7
	Proboscia alata	5.4	Nodularia spumigena	3.3	Ditylum brightwellii	3.7
	Pseudosolenia calcar-avis	3.3	Chaetoceros curvisetus	2.8	Rhizosolenia pungens	3.2
	Gymnodiniales	2.8	Gyrodinium	2.7	Cerataulina pelagica	3.1
	Ceratium fusus	2.7	Chrysochromulina	2.6	Nodularia spumigena	2.9
	Peridiniales	2.4	Skeletonema costatum	2.2	Proboscia alata	2.5
26JL1010	Pseudosolenia calcar-avis	27	Cerataulina pelagica	35	Cerataulina pelagica	23.7
Oct 10	Cerataulina pelagica	17	Gymnodiniales	19	Pseudo-nitzschia	17
	Ceratium fusus	6.3	Pseudo-nitzschia	9.7	Pseudosolenia calcar-avis	12
	Pseudo-nitzschia	5.7	Pseudosolenia calcar-avis	5.0	Gymnodiniales	6.0
	Gymnodiniales	5.0	Ceratium fusus	3.5	Gyrodinium	4.3
	Chrysochromulina	3.7	Gyrodinium	2.9	Dictyocha speculum	4.2
	Guinardia flaccida	3.6	Ceratium tripos	2.4	Unicell	3.8
	Gyrodinium	2.9	Chrysochromulina	1.9	Protoperidinium	2.4
	Mesodinium rubrum	2.7	Mesodinium rubrum	1.9	Peridiniales	2.1
	Peridiniales	2.3	Trachelomonas	1.6	Teleaulax	2.1
26JL1011					Gymnodiniales	36
Nov 10					Pseudosolenia calcar-avis	21
					Ceratium tripos	9.3
					Chrysochromulina	7.3
					Mesodinium rubrum	6.4
					Ceratium fusus	3.4
					Dictyocha speculum	2.5
					Prorocentrum micans	2.1
					Protoperidinium	2.0
					Teleaulax	1.3
26JL1012			Mesodinium rubrum	28		
Dec 10			Gymnodiniales	23		
			Ceratium tripos	7.7		
			Chrysochromulina	6.7		
			Peridiniales	6.4		
			Hemiselmis	4.9		
			Teleaulax	4.5		
			Unicell	4.0		
			Dictyocha speculum	2.0		
			Pyramimonas	1.8		

A P P E N D I X D

Potential harmful species found during baseline investigation

Table D.1 Potential harmful phytoplankton species observed during the baseline investigation. The classification based on a modified lists of Wasmund (2002) and ICES (2007). For species counted on genus level, potential harmfulness was assumed. The area gives the reported findings of this species in the Baltic Sea. WB: whole Baltic, KB: Kattegat and Belt Sea, AS: Arkona Sea, SB: southern Baltic proper, CB: central Baltic, NB; Northern Baltic, GR: Gulf of Riga, BS Bothnian Sea, BB: Bothnian Bay. Ability to form bloom: XXX regular blooms, XX occasional blooms, X regularly but not in blooms, - occasional in plankton in low numbers. Toxins: Amnesic shellfish poisoning (ASP), Neurotoxin (NT), Ichthyotoxin (IT), Hepatotoxin (HT), Paralytic shellfish poisoning (PSP), Diarrhetic shellfish poisoning (DSP), Ciguatera fish poisoning (CFP)

species	toxin	distribution	blooms
Alexandrium spp.[3]	PSP, NT	KB, SB	-
Akashiwo sp.[3]	(harmful to fish)	WB	-
Amphidinium sp.	IT?, heamolytic substances	KB	-
Anabaena sp. (various species)	HT, NT, PSP	WB	X
Aphanizomenon sp.[1]	HT,NT, PSP	WB	XXX
Ceratium fusus	(anoxia), harmful to invertebrate larvae	KB to SB	XX
Ceratium tripos	(anoxia, hypoxia)	WB	X
Chaetoceros convolutus	(mechanical[2])	KB	X
Chaetoceros danicus	(mechanical[2])	WB	XX
Chaetoceros decipiens	(mechanical[2])	KB to GF	XX
Chaetoceros impressus	(mechanical[2])	KB to SB	XX
Chaetoceros sp.	mechanical[2]	WB	X
Chrysochromulina sp.	DSP?, IT	KB to GF, NB	XX
Coelosphaerium sp.[3]	HT, NT	WB without BB	-
Dictyocha speculum	IT	KB to AS	XX
Dinophysis acuminata	DSP	WB	XX
Dinophysis acuta	DSP	KB to GF	X
Dinophysis norvegica	DSP	WB	XX
Dinophysis rotundata	DSP	WB	X
Gymnodinium sp.	PSP	KB WB	-
Gyrodinium sp.	PSP	KB WB	-
Microcystis sp.[3]	HT	Estuarine waters	X
Nodularia spumigena	HT	WB	XXX
Prorocentrum micans	PSP	KB to SB	XX
Prorocentrum minimum	DSP?, CFP?, harmful to oyster larvae	WB without BS and BB	XX
Pseudo-nitzschia pungens	ASP	KB to AS	XX
Pseudo-nitzschia seriata	ASP	KB to AS	XX
Pseudo-nitzschia sp.	ASP	KB to SB	XX
Scrippsiella sp.	IT?	WB without GR and BB	-
Snowella sp.	HT	WB	-
Verrucophora farcimen (Pseudochattonella farcimen[3])	NT?, mucus excretion, heamolytic substances	KB	X
Woronichinia sp.	HT, NT	WB	-

[1] only coastal species (e.g. flos-aquae) are toxic
[2] Chaetoceros species do not contain toxins but damage fish by spines
[3] added to list from ICES WGHABD REPORT (2007)
[4] Verrucophora farcimen (Dictyochophyceae) was renamed in 2009 (Eikrem et al. 2009).

A P P E N D I X E

Spatial variation in phytoplankton group composition during 2009 and 2010

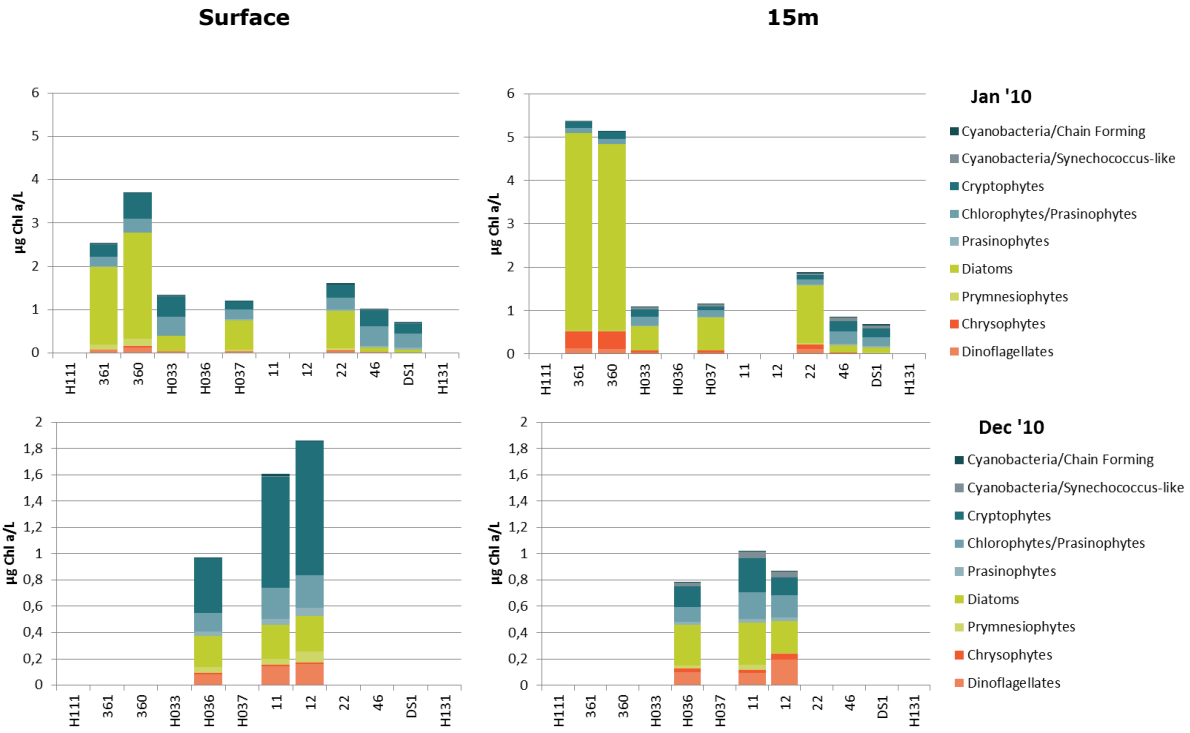


Figure E.1 Phytoplankton group composition and biomass determined by pigment analysis during winter 2010 at two depths.

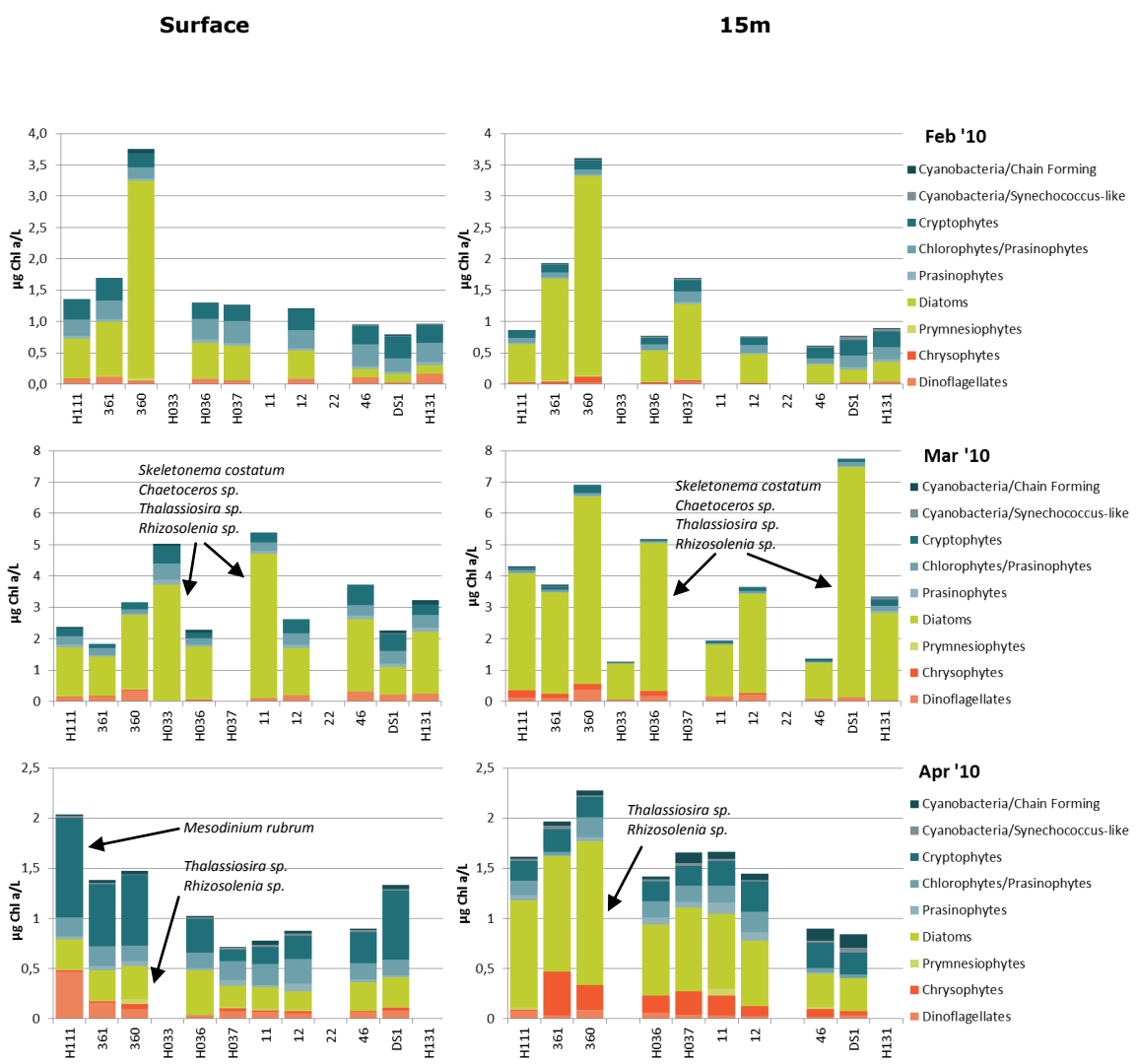


Figure E.2 *Phytoplankton group composition and biomass determined by pigment analysis during spring 2010 at two depths. Dominant species identified in the samples are indicated for March and April.*

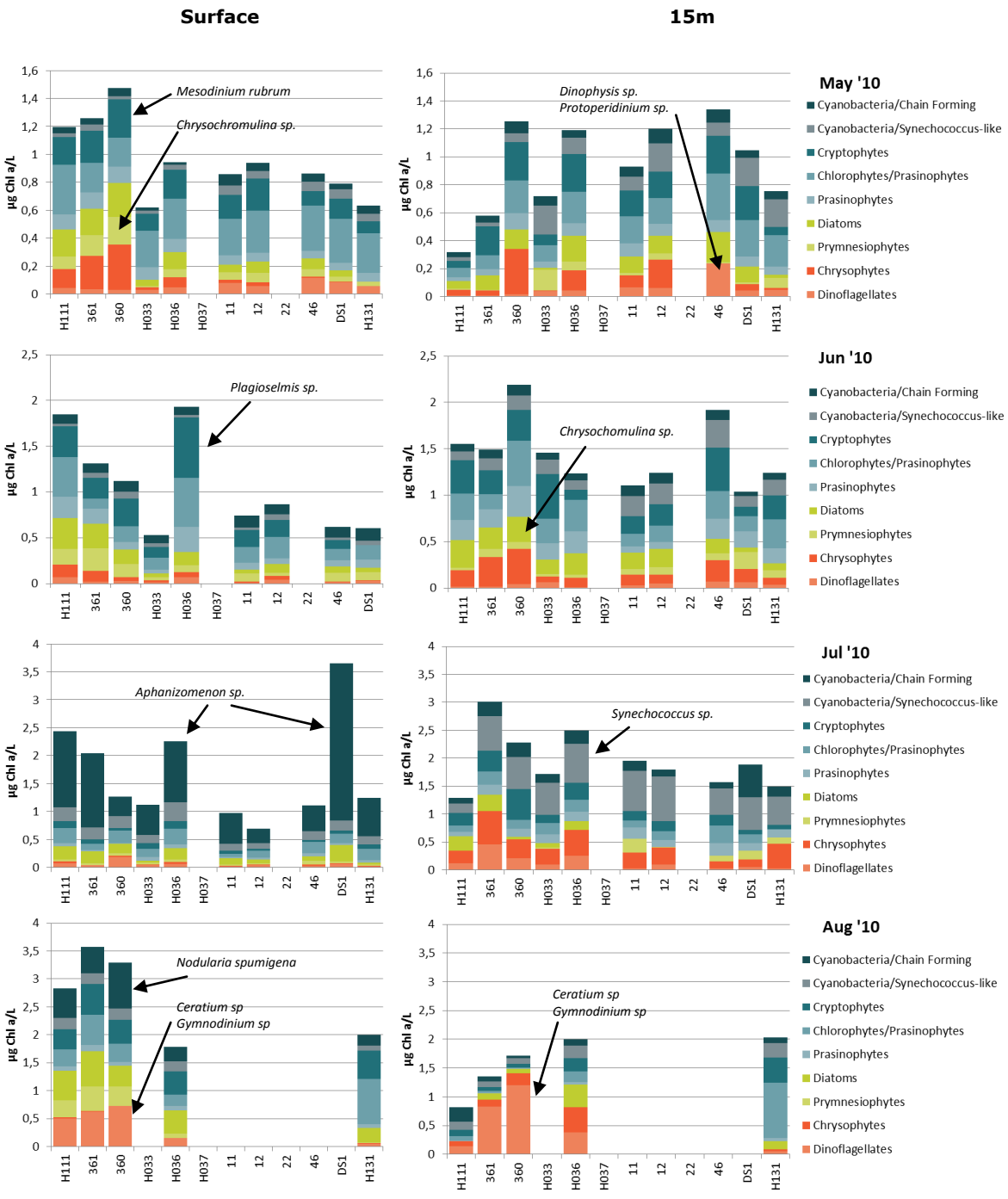


Figure E.3 Phytoplankton group composition and biomass determined by pigment analysis during summer 2010 at two depths. Dominant species identified in the samples are indicated.

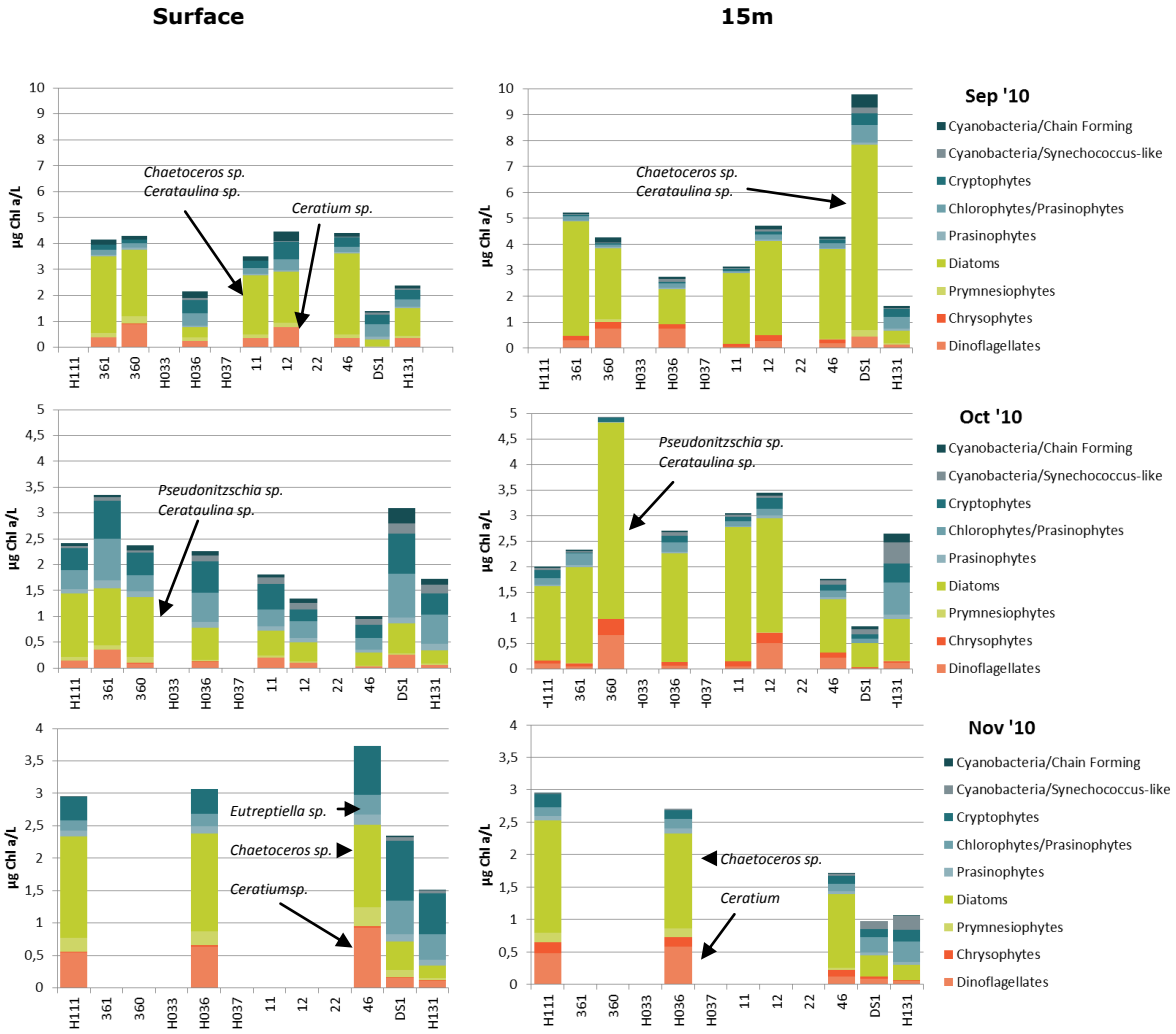


Figure E.4 Phytoplankton group composition and biomass determined by pigment analysis during autumn 2010 at two depths. Dominant species identified in the samples are indicated.

A P P E N D I X F

Multidimensional scaling (MDS) of off-shore phyto-plankton composition at 15 m depth using pigments

Compared to surface waters the similarity of phytoplankton community at 15m was much higher (see Figure 4.10 and Figure F.1). However, the outermost stations, stations H131, located in the eastern part of Darss Sill area and the stations 360 and 361 located in the western part of Great belt area were often located in the outer part of the clusters in Figure F.1 and were frequently showing a somewhat different distribution of the phytoplankton groups, e.g., chrysophytes were absent in the samples from station H131 in March, while quite abundant on all other stations, and no diatoms were detected at 15 m in April, while abundant on other stations.

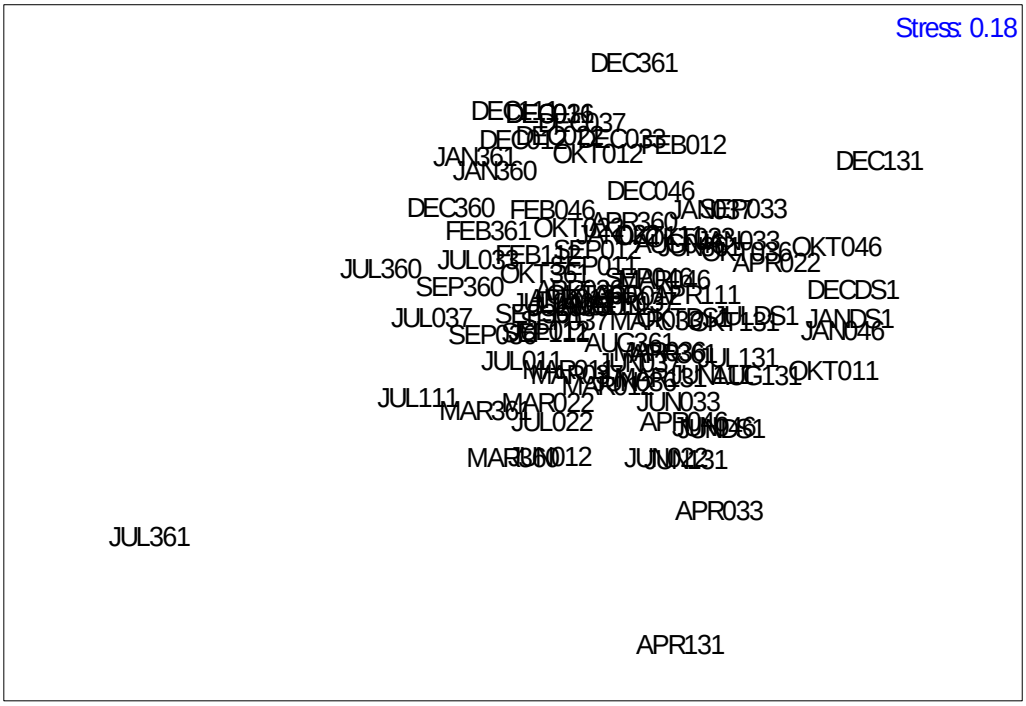


Figure F.1 *MDS analysis of the phytoplankton group biomass in 15 m depth on stations in the Fehmarnbelt area determined in the different samplings months indicated by three letters followed by the station number.*

A P P E N D I X G

Zooplankton species observed during baseline investigation

Table G.1 *Zooplankton species list of baseline monitoring (all stations all cruises February 2009 – December 2010). ad: adult; C: copepodit; N: nauplia; L: larvae; FG: functional group; HP: Holoplankton; MP: Meroplankton, rank: ranking number according to total abundance of the taxon in all quantitative observations; sp: spring; su: summer; au: autumn; wi: winter.*

Phylum	Class	Determined Taxon	FG	rank	sp	su	au	wi
Arthropoda	Copepoda	Acartia spp. C	HP	1	X	X	X	X
Arthropoda	Copepoda	Acartia spp. N	HP	2	X	X	X	X
Rotifera	Eurotatoria	Synchaeta spp.	HP	3	X	X	X	X
Arthropoda	Copepoda	Pseudocalanus spp./Paracalanus parvus C	HP	4	X	X	X	X
Arthropoda	Copepoda	Temora longicornis N	HP	5	X	X	X	X
Arthropoda	Copepoda	Centropages spp. N	HP	6	X	X	X	X
Arthropoda	Branchiopoda	Bosminidae spp.	HP	7	X	X	X	
Arthropoda	Copepoda	Pseudocalanus spp./Paracalanus parvus N	HP	8	X	X	X	X
Arthropoda	Copepoda	Oithona similis C	HP	9	X	X	X	X
Arthropoda	Copepoda	Temora longicornis C	HP	10	X	X	X	X
Arthropoda	Copepoda	Acartia bifilosa ad	HP	11	X	X	X	X
Mollusca	Bivalvia	Bivalvia spp. L	MP	12	X	X	X	X
Arthropoda	Copepoda	Centropages spp. C	HP	13	X	X	X	X
Annelida	Polychaeta	Polychaeta spp. L	MP	14	X	X	X	X
Arthropoda	Branchiopoda	Evadne nordmanni	HP	15	X	X	X	X
Arthropoda	Copepoda	Temora longicornis ad	HP	16	X	X	X	X
Arthropoda	Copepoda	Oithona similis N	HP	17	X	X	X	X
Chordata	Appendicularia	Oikopleura dioica	HP	18	X	X	X	X
Arthropoda	Copepoda	Acartia longiremis ad	HP	19	X	X	X	X
Arthropoda	Copepoda	Centropages hamatus ad	HP	20	X	X	X	X
Arthropoda	Copepoda	Oithona similis ad	HP	21	X	X	X	X
Arthropoda	Copepoda	Pseudocalanus spp. ad	HP	22	X	X	X	X
Mollusca	Gastropoda	Gastropoda spp. L	MP	23	X	X	X	X
Ectoprocta	Gymnolaemata	Gymnolaemata spp. L	MP	24	X	X	X	X
Arthropoda	Branchiopoda	Podonidae spp.	HP	25	X	X	X	X
Arthropoda	Cirripedia	Balanus N	MP	26	X	X	X	X
Chordata	Appendicularia	Fritillaria borealis	HP	27	X	X	X	X
Echinodermata	Asteriodea	Asterias rubens L	MP	28		X	X	
Arthropoda	Branchiopoda	Penilia avirostris	HP	29		X	X	
Arthropoda	Copepoda	Paracalanus parvus ad	HP	30	X	X	X	
Arthropoda	Copepoda	Harpacticoida spp.	MP	31	X	X	X	X
Arthropoda	Cirripedia	Balanus L	MP	32	X	X	X	X
Arthropoda	Copepoda	Centropages typicus ad	HP	33		X	X	
Arthropoda	Malacostraca	Decapoda spp. L	MP	34	X	X	X	
Arthropoda	Copepoda	Eurytemora affinis C	HP	35		X	X	X
Arthropoda	Copepoda	Calanus spp. C	HP	36	X	X	X	
Arthropoda	Copepoda	Eurytemora affinis N	HP	37		X	X	
Arthropoda	Copepoda	Eurytemora affinis ad	HP	38		X	X	X
Echinodermata	Ophiuroidea	Ophiura L	MP	39		X	X	
Arthropoda	Copepoda	Longipedia sp.	HP	40	X	X	X	
Chaetognatha	Sagittoidea	Sagitta spp.	HP	41		X	X	

Phylum	Class	Determined Taxon	FG	rank	sp	su	au	wi
Phoronidae		Phoronis muelleri L	MP	42			X	
Ciliphora	Ciliatea	Tintinnidae ind/m³	HP	43			X	
Arthropoda	Copepoda	Calanus finmarchicus ad	HP	44	X	X	X	
Arthropoda	Copepoda	Cyclopoida spp.	HP	45	X	X	X	X
Arthropoda	Malacostraca	Mysidacea spp. L	MP	46		X		
Arthropoda	Copepoda	Calanus helgolandicus ad	HP	47		X	X	

Table G.2 *10 biomass dominant zooplankton taxa of baseline monitoring (all stations all cruises February 2009 – December 2010). FG: functional group; HP: Holoplankton; MP: Meroplankton, rank: ranking number according to biomass of the taxon in all quantitative observations.*

Phylum	Class	Determined Taxon	FG	rank
Arthropoda	Copepoda	Acartia bifilosa	HP	1
Arthropoda	Copepoda	Pseudocalanus spp.	HP	2
Arthropoda	Copepoda	Temora longicornis	HP	3
Arthropoda	Copepoda	Acartia longiremis	HP	4
Arthropoda	Copepoda	Centropages hamatus	HP	5
Chordata	Appendicularia	Oikopleura dioica	HP	6
Arthropoda	Branchiopoda	Bosminidae spp.	HP	7
Rotifera	Eurotatoria	Synchaeta spp.	HP	8
Annelida	Polychaeta	Polychaeta spp. (larvae)	MP	9
Arthropoda	Branchiopoda	Evadne nordmanni	HP	10

A P P E N D I X H

Feeding rates of Aurelia aurita

Table H.1. Feeding rates of Aurelia aurita *(prey items consumed day^{-1} medusa^{-1}) presented per cruise and ingested taxonomic group.*

Cruise	JI9005									JL9006						26JI9007				26JI9008				
Date of sampling	1/8/09	1/8/09	28/7/09	28/7/09	28/7/09	28/7/09	28/7/09	28/7/09	26/8/09	26/8/09	26/8/09	26/8/09	26/8/09	28/8/09	28/8/09	29/9/09	30/9/09	30/9/09	2/10/09	29/10/09	30/10/09	31/10/09	1/11/09	3/11/09
Station	H033	H033	360	360	H037	H037	H037	H037	H131	H131	DS1	DS1	DS1	H111	H111	361	11	11	12	12	46	DS1	11	H037
Copepoda																								
Acartia spp.	0	8	0	0	0	0	0	0	0	0	8	0	0	0	0	8	0	0	0	0	0	16	0	8
Centropages hamatus	88	32	24	32	0	8	0	0	0	0	8	0	0	0	0	8	0	0	0	0	0	0	0	0
Eurytemora affinis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Para+Pseudocalanus	0	8	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0
Pseudocalanus spp.	0	16	8	0	0	8	24	0	8	0	0	0	0	0	0	40	0	0	0	0	0	16	0	0
Temora longicornis	176	72	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0
Copepoda Nauplius	0	0	0	8	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda calanoida	0	16	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oithona similis	8	16	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
Harpacticoida	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepod	88	0	8	8	0	8	0	0	8	0	8	0	0	0	0	0	0	0	0	0	0	128	0	0
Cladocera																								
Eubosmina sp.	48	24	0	0	0	0	0	0	1120	24	8	48	0	0	0	0	0	0	0	0	0	8	0	0
Evadne spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0
Podon spp.	16	8	0	32	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	8
Gastropoda																								
Gastropoda larvae	56	8	56	1080	48	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia																								
Bivalvia larvae	208	136	240	960	856	56	24	72	24	8	0	0	0	0	0	0	0	0	0	0	0	16	0	0
Rotifera																								
Synchaeta sp.																								

Fish																											
Fisch larvae	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Fish eggs	0	0	0	0	16	0	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Phytoplankton																											
Bacillariophycea	0	0	0	136	152	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	
Others																											
Crustacea unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	
Balanus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Decapoda Megalopa	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Cruise	26JI1006					26JI1007							26JI1008							26JI1011							
Date of sampling	14.6.10	16.6.10	15.6.10	15.6.10	19.7.10	20.7.10	20.7.10	20.7.10	20.7.10	20.7.10	20.7.10	17.8.10	17.8.10	17.8.10	17.8.10	17.8.10	18.8.10	18.8.10		16.11.10	16.11.10	16.11.10	16.11.10	16.11.10	16.11.10	16.11.10	16.11.10
Station	H036	46	360	360	H037	H111	H111	H111	360	361	361	360	360	360	360	360	H131	H131		DS1	DS1	DS1	DS1	DS1	H131	H131	H131
Copepoda																											
Acartia spp.	0	0	32	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0		88	0	32	464	0	320	152	80
Calanus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	16	0	8	0	0
Centropages hamatus	0	0	0	8	0	0	8	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	8	0	0
Eurytemora affinis	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	8	0
Para+Pseudocalanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		16	0	8	24	0	48	40	0
Paracalanus parvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Pseudocalanus	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	8	0	0
Temora longicornis	40	48	8	176	0	0	8	0	8	0	0	0	0	0	0	0	0	0		32	0	8	48	0	128	48	16
Copepoda Nauplius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		16	0	16	0	0	48	32	16
Copepoda Calanoida	0	8	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0		64	0	16	88	0	72	24	32
Oithona similis	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Copepoda undefined	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Cladocera																											

Eubosmina sp.	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	24	0		0	0	0	8	0	16	0	0
Evadne spp.	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0		8	0	0	0	0	64	0	8
Podon spp.	8	0	0	0	24	0	24	248	8	0	16	0	0	0	0	0	0	0		0	0	0	0	0	8	0	0
Cladocera undefined	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0		8	0	0	0	0	0	0	0
Balanus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		8	0	0	16	0	0	16	0
Gastropoda																											
Gastropoda larvae	0	0	8	32	0	0	0	0	0	0	0	160	32	136	40	40	0	0		0	0	0	0	0	0	8	0
Bivalvia																											
Bivalvia larvae	0	0	16	16	0	0	0	8	0	0	0	1280	216	336	128	80	0	0		0	8	0	16	0	0	152	96
Rotifera																											
Synchaeta sp.	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		736	0	0	600	0	1472	288	192
Fish																											
Fish eggs	0	8	0	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Fish larvae	0	0	0	32	0	0	0	0	0	0	0	8	8	8	0	0	0	0		0	0	0	0	0	0	0	0
Phytoplankton																											
Bacillariophycea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	16	0	0	0	0
Polychaeta	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Bryozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	8	0	0	0	0	0
Decapoda larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	8	16	0	0	0		0	0	0	0	0	0	0	0
Tunicata	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Cruise	26JI1010																										
Date of sampling	11.10.10	11.10.10	11.10.10	11.10.10	11.10.10	11.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	13.10.10	14.10.10	14.10.10	14.10.10	14.10.10	14.10.10
Station	H036	H036	H036	H036	H036	H036	DS1	DS1	DS1	DS1	DS1	DS1	DS1	DS1	DS1	DS1	DS1	DS1	DS1	46	46	46	46	46	12	12	12	12	12
Copepoda																													
Acartia spp.	24	24	16	64	0	0	8	8	32	48	24	64	32	24	64	24	72	56	72	192	144	72	24	0	136	56	24	0
Calanus spp.	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centropages sp.	0	0	0	0	0	0	8	0	0	0	8	0	8	0	0	0	0	0	16	0	0	24	0	0	8	0	0	0	0
Eurytemora sp.	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Para+Pseudocalanus	0	0	0	8	0	0	8	0	8	8	0	0	24	32	8	0	8	16	0	24	24	16	24	0	16	0	0	0
Paracalanus parvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
Pseudocalanus sp.	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	8	40	0	0	0	0	0
Temora longicornis	24	0	0	0	0	0	0	0	0	16	0	8	16	0	8	0	8	0	0	24	16	8	96	0	0	0	0	0
Copepoda Nauplius	16	0	0	0	0	0	0	0	0	0	0	16	0	8	8	0	24	0	16	72	8	8	56	0	16	24	8	0
Copepoda Calanoida	0	0	24	8	0	0	16	8	32	24	0	56	88	40	40	32	64	0	16	152	80	56	152	0	8	24	0	8
Oithona similis	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda undefined	8	16	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0
Cladocera																												
Eubosmina sp.	8	0	8	0	16	0	8	0	0	8	8	0	0	0	48	0	0	0	0	0	0	0	0	0	8	0	0	8
Evadne spp.	0	0	8	0	0	8	8	0	0	0	0	0	8	8	0	0	0	0	32	16	48	8	32	0	72	16	0	8
Podon spp.	0	8	16	0	0	0	0	0	0	24	8	0	8	24	0	0	0	0	8	40	0	8	8	0	88	32	24	0
Cladocera undefined	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus sp.	8	40	0	8	0	8	56	8	8	0	56	0	0	56	24	24	32	24	32	24	0	0	8	0	8	0	16	0
Gastropoda																												
Gastropoda larvae	8	0	0	8	72	0	40	8	0	8	0	56	0	16	0	8	32	24	0	32	88	16	24	0	8	16	8	0
Bivalvia																												
Bivalvia larvae	160	200	48	0	48	0	136	8	8	128	48	312	8	152	32	24	160	104	56	248	88	8	64	0	48	72	48	8
Rotifera																												
Synchaeta sp.	0	0	0	0	0	0	0	0	16	16	0	48	0	32	8	8	32	24	8	32	0	16	0	0	0	0	0	0
Fish																												
Fish eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fish larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phytoplankton																												
Bacillariophycea	320	264	40	0	24	0	232	8	8	32	24	136	728	64	16	0	88	408	16	8	24	0	0	0	80	8	0	0
Polychaeta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tunicata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0