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Biological assessment of the Baltic Sea 2016

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and Michael L. Zettler

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Abstract

Dating to 1979, the HELCOM time series on species composition, biomass and abundance of phyto- and zooplankton as well as macrozoobenthos from Kiel Bay to the Eastern Gotland Basin was continued in 2016.

The phytoplankton spring bloom occurred almost simultaneously in the Belt Sea, Arkona Basin and Bornholm Basin, presumably in the first half of March. It was clearly dominated by diatoms, without significant contribution of *Dictyocha* in the Belt Sea. The western Arkona Basin was influenced by the Bay of Mecklenburg by elevated biomass at the end of February already. Darss Sill is not a strict border. A succession from diatoms and *Mesodinium rubrum* to dinoflagellates and finally to prymnesiophyceae appeared in some areas. In summer, a diatom bloom appeared in the Belt Sea and the western Arkona Basin. Satellite observations have shown that the cyanobacteria developed from mid May until mid September 2016 with lower intensity but longer duration than in other years. A strong autumn bloom was characterized by diatoms (*Cerataulina pelagica*), but not the typical *Ceratium*, in the Belt Sea.

The chlorophyll *a* concentrations were highest (10.5 mg m^{-3}) during the autumn bloom in the Bay of Mecklenburg at the beginning of November 2016.

The seasonal pattern of vertical export of particulate organic matter in the Arkona Basin in 2016 showed a distinct peak in spring, a period of high flux during summer and high rates during late autumn with a clear succession of algal species within and between the sedimentation maxima. Summer flux was high and derived from a mixture of diatoms and cyanobacteria. The total annual flux for single elements in 2016 amounted to 718 mmol C (8.6 g C), 93 mmol N, 85 mmol Si and 3 mmol P m^{-2} a^{-1} at a mass flux of 70 g dry mass m^{-2} a^{-1}. The mass weighted $\delta^{15}N$ signature documents a lower nitrogen fixation than in the previous year.

A considerable increase in the diversity of zooplankton was recorded in 2016. A total of 73 taxa were observed, which was related to the occurrence of pelagic larvae of benthic crustaceans, polychaetes and echinoderms. Among the cladocera the neozoon *Cercopagis pengoi* was found in the Arkona Basin. The seasonal development and the zooplankton composition were remarkably similar in the Kiel Bight, the Bay of Mecklenburg and the Arkona Sea. The spring increase in abundance occurred already in March and was caused by the early occurrence of high densities of rotifers. In contrast, the typical summer blooms of cladocera in the Arkona Sea were lacking. Copepods generally dominated the zooplankton.

The 141 species found in the macrozoobenthos mark a high diversity, mainly driven by the high species number in the Kiel Bay. The oxygen supply in bottom waters in the current year was always higher than 2 ml/l; nevertheless we observed a significant decline in diversity and abundance at the stations in the Fehmarnbelt and Bay of Mecklenburg. Depending on the region, the abundances ranged from 78 to 8 830 ind./m^2, and the biomass (ash free dry weight) from 3.4 g/m^2 to 51.1 g/m^2. With 18 species and a salinity of 21.3 psu in the central Arkona Basin the indication of the saltwater inflow two years before is still visible. Nineteen species of the German Red List (Categories 1, 2, 3 and G) were observed at the 8 monitoring stations. With four, the number of invasive species in 2016 was low.

1. Introduction

This report presents the results of the biological monitoring carried through at the Leibniz-Institute for Baltic Sea Research in Warnemünde (IOW). Within Germany's Exclusive Economic Zone (EEZ), monitoring is undertaken on behalf of the Federal Maritime and Hydrographic Agency (BSH); in the Baltic Proper (Bornholm Basin, Eastern Gotland Basin), long-term data collection is financed from the IOW's own budget. This assessment is the public version of the report submitted to the BSH in August 2017.

The biological monitoring is one element of the international environmental monitoring programme of the Helsinki Commission (HELCOM) in which the IOW's predecessor institute had participated since its launch in 1979. Besides marine biology, the monitoring programme also includes an extensive programme of hydrographic and chemical investigations (NAUMANN et al. 2017). The establishment of the IOW in 1992 assured the continuance of re-unified Germany's contribution to the HELCOM Monitoring Programme.

The collected data form part of the co-ordinated programme of measurements undertaken by the northern German coastal states. When the administrative agreement relating to the protection of the marine environment ('Verwaltungsabkommen Meeresschutz') was established in March 2012, the 'Arbeitsgemeinschaft Bund/Länder-Messprogramm Nord- und Ostsee' (ARGE BLMP) was succeeded by the 'Bund/Länder-Ausschuss Nord- und Ostsee' (BLANO) with an extended remit to ensure implementation of the requirements of the EU's Marine Strategy Framework Directive (MSFD) (see http://www.blmp-online.de/Seiten/Infos.html). Through national databases, the collected data are notified annually to ICES (International Council for the Exploration of the Sea, see http://www.ices.dk/indexnofla.asp). International monitoring results were collected, discussed and published by HELCOM in Periodic Assessments (HELCOM 1987, 1990, 1996, 2002). Now specialized Thematic Assessments are published on the influence of climatic change (HELCOM 2013a) and eutrophication (HELCOM 2014a). In a similar manner, short reports known as the 'Baltic Sea Environment Fact Sheets' (formerly 'Indicator Fact Sheets') are published annually (JAANUS et al. 2007, HAJDU et al. 2008, OLENINA et al. 2009, OLENINA AND KOWNACKA 2010, ÖBERG 2016, WASMUND et al. 2016 b).

Cooperation is increasingly being framed in a European context. The European Committee for Standardization (CEN, see http://www.cen.eu/cenorm/homepage.htm), for instance, has elaborated Standard Operating Procedures that apply throughout Europe, and are largely compatible with the HELCOM methods we have applied consistently for many years. The legal framework for intensified international cooperation is provided by the EU's Water Framework Directive (WFD, see EUROPEAN UNION 2000) and the EU's Marine Strategy Framework Directive (MSFD, see EUROPEAN UNION 2008). The Marine Strategy Framework Directive (Directive 2008/56/EG) creates the regulatory framework for the necessary measures in all EU member states to achieve or maintain 'good environmental status' in all European waters by 2020.

Appropriate monitoring programmes need to be maintained or developed. A programme of measures and a network of marine reserves complement the Marine Strategy's objective of maintaining the good status of the marine environment or, where required, restoring it.

In order to determine 'good environmental status', it is necessary to elaborate indicators. Suggestions and first works for some biological indicators were made within the scope of the HELCOM project CORESET (HELCOM 2013b). The process of developing and testing indicators has yet to be completed both at national and international level. IOW members of staff within the Biological Oceanography section are involved in the development of the following HELCOM 'Core' and 'Pre-core' indicators in connection with descriptors for biodiversity (D1), non-native species (D2), food web (D4) or eutrophication (D5):

- Zooplankton mean size and total stock
- State of the soft-bottom macrofauna communities
- Population structure of long-lived macrozoobenthic species
- Cumulative impact on benthic habitats
- Extent, distribution and condition of benthic biotopes
- Trends in arrival of new non-indigenous species
- Lower depth distribution limit of macrophyte species
- Chlorophyll *a* concentrations
- Diatom/Dinoflagellate Index
- Seasonal succession of dominating phytoplankton groups
- Phytoplankton community composition indicator
- Cyanobacterial surface accumulations

Especially for the elaboration of the Diatom/Dinoflagellate Index on the national basis, a project was funded by the Bundesamt für Naturschutz (16.09.2015 – 15.05.2016; see WASMUND&POWILLEIT 2016). Within this project, additional phytoplankton samples were taken, which may be used also for this paper in order to consolidate the data basis.

The monitoring data collected by IOW provide a solid foundation on which to develop and test these indicators and to implement the Marine Strategy Framework Directive. Close cooperation between oceanographers, marine biologists and marine chemists within IOW permits the comprehensive scientific analysis of the collected biological data which are interpreted in the light of the 2014 hydrographic-hydrochemical assessment of the Baltic Sea that has already been published (NAUMANN et al. 2017).

Dr. NORBERT WASMUND wrote the chapters on phytoplankton and chlorophyll; Dr. JÖRG DUTZ wrote the chapter on zooplankton; and Dr. MICHAEL L. ZETTLER wrote the chapter on macrozoobenthos. Dr. FALK POLLEHNE was in charge of the sediment traps, Dr. HERBERT SIEGEL of the satellite imagery.

2. Material and Methods

2.1 Sampling Strategy

The functions undertaken by IOW in the monitoring programme are defined by the BSH (BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE 2016), and they follow HELCOM guidelines. Biological monitoring by IOW includes determining the qualitative and quantitative composition of phytoplankton, mesozooplankton and macrozoobenthos, determining the chlorophyll *a* content of water samples, and analysis of sediment traps. Phytoplankton growth is also tracked by means of satellite images. The methods to be applied are set out in the HELCOM manual (HELCOM 2014b).

Fig. 1 shows the locations of biological monitoring stations. They are named in accordance with the official nomenclature of the ICES Station Dictionary. If space is limited in figures and tables the 'OMBMP' prefix is omitted in this paper. The equivalents to the internal IOW station numbers are also given in Table 1.

Within the regular monitoring program, plankton samples should be collected both on outbound and inbound cruises, if possible. Five cruises yield a maximum of 10 samples per station per year. Samples at stations OMBMPN3 (Kiel Bay), OMO22 (Lübeck Bay), OMBMPK4 (Arkona Basin) and OMBMPK1/OMBMPJ1 (Eastern Gotland Basin) are taken as standard on the outward leg only. Due to technical problems at the beginning of the March cruise, samples of stations OMBMPN3 to OMBMPK4could only be taken on the return way.

Fortunately, the reduced samplings of the March cruise could partly compensated by 7 additional phytoplankton samples that were taken during two cruises outside the regular monitoring program in order to support the project "Developing the indicator Diatom/Dinoflagellate index" funded by the Bundesamt für Naturschutz (funding number: Z 1.2 – 53202/AWZ/2015/5; see project report of WASMUND &POWILLEIT, 2016). They were (1) cruise Solea716 by the Thünen-Institute of Baltic Sea Fisheries from 18 February to 10 March 2016 and (2) cruise EMB126 from 14 April to 21 April 2016. Stations of the additional samples are not shown in Table 1 and Fig. 1, but they are marked by an asterisk in Figs. 12-14.

Table 1
Sampling statistics (number of sampling events) of different parameters specified for regular monitoring sampling stations in 2016. Additional samples are not included here.

Station number	IOW-station number	Chloro-phyll	Phyto-plankton	Zoo-plankton	Zoo-benthos
Belt Sea					
OMBMPN3	TF0360	5	5	5	1
OMBMPN1	TF0010	-	-	-	1
OMBMPM2	TF0012	8	8	8	1
OMO22	TF0022	5	5	-	-
OM18	TF0018	-	-	-	1
OMBMPM1	TF0046	9	9	9	-
Arkona Basin					
OMBMPK8	TF0030	9	9	8	1
OMBMPK5	TF0113	9	9	8	-
OMBMPK4	TF0109	5	5	5	1
Pomeranian Bay					
OMBMPK3	TF0152	-	-	-	1
OM160	TF0160	-	-	-	1
Bornholm Basin					
OMBMPK2	TF0213	10	10	-	-
Eastern Gotland Basin					
OMBMPK1	TF0259	5	5	-	-
OMBMPJ1	TF0271	5	5	-	-

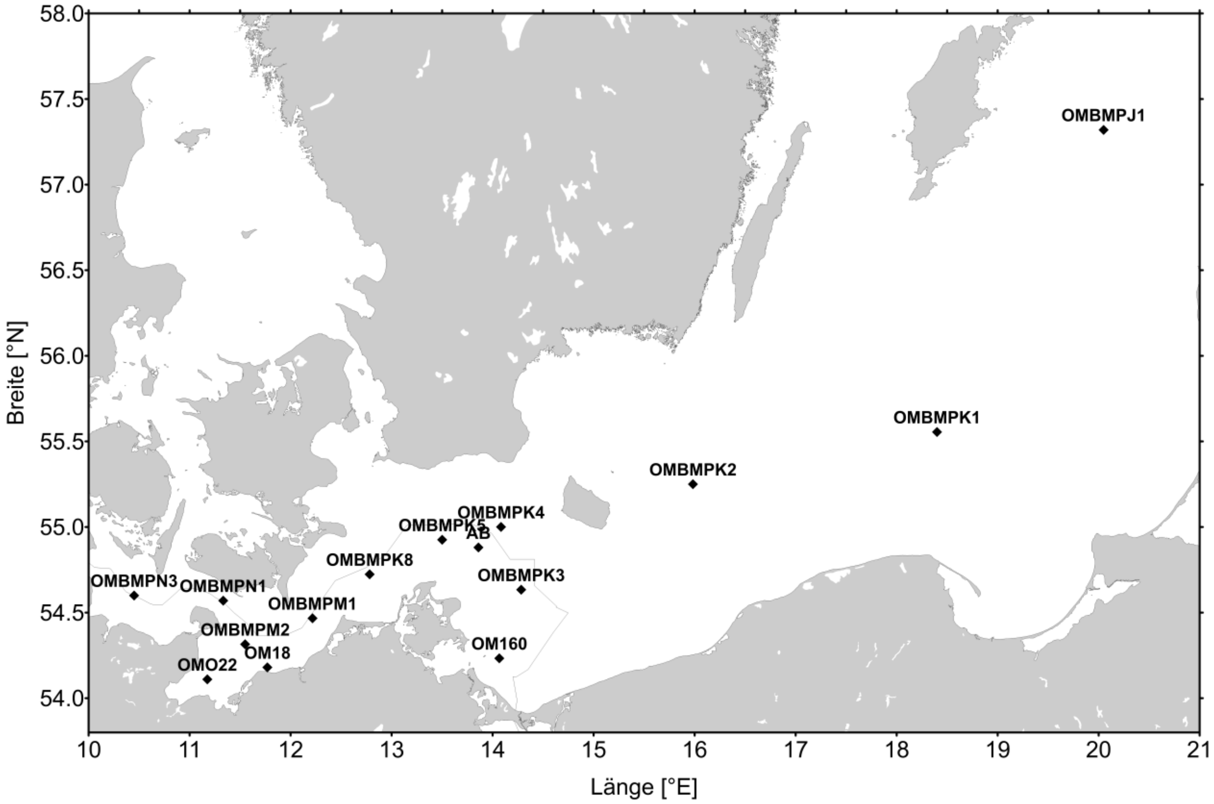

Fig. 1: The station grid for biological sampling in the Baltic Sea (except the additional cruises as mentioned above) with depiction of the border of the exclusive economic zone of Germany.

Sediment traps were installed in the Arkona Basin sampling area (see station AB in Fig. 1).

Zooplankton samples were regularly taken on 6 stations (Table 2). Due to technical problems in March 2016, samples could only be taken on the return journey on stations OMBMPN3 to OMBMPK4; sampling on station OMBMPK5 had to be cancelled. One sample from station OMBMPK4 from August 2016 was lost.

Samples of macrozoobenthos are collected at 8 stations once a year in November (see Table 3, page 12).

2.2 Phytoplankton

As a rule, two phytoplankton samples are taken at each station: a composite sample is mixed from equal parts of surface water from depths of 1 m, 2.5 m, 5 m, 7.5 m and 10 m; in addition, a sample is taken from below the upper pycnocline (usually from a depth of 20 m). If something of interest is present (for instance distinctive fluorescence maxima in deeper layers), additional samples are taken from that depth. Samples (200 ml) are fixed with 1 ml of acid Lugol's solution and are stored until analysis (6 months at most).

The biomass of individual phytoplankton species is analysed microscopically using the standard method according to UTERMÖHL (1958). During counting, individuals are classified not just according to taxa, but also size classes in line with HELCOM guidelines (OLENINA et al.

2006). To obtain a statistically acceptable estimate, at least 50 individuals of the most abundant species need to be counted. Thus for the most common individual species, a statistical counting error of around 28 % may be assumed. Generally at least 500 individuals are counted per sample. The error in estimated total biomass is thus clearly reduced (< 10 %). Each species and size class has its own unique volume. This figure is multiplied by the number of counted individuals to obtain the biovolume of a particular species. Assuming a density of 1 g cm^{-3} the figure of biovolume equates to the biomass (wet weight).

The counting, calculation and data output were facilitated by the software "OrgaCount", delivered by AquaEcology Oldenburg. For the cruises of January/February, March and May 2016, the species and biovolume list PEG_BVOL2015 was used;
see http://www.ices.dk/marine-data/Documents/ENV/PEG_BVOL.zip. The phytoplankton samples of the following cruises were analysed with the list PEG_BVOL2016, which was confirmed by PEG during the meeting in April 2016. Details about the species list are also available on the ICES website: http://www.ices.dk/marine-data/Pages/default.aspx (click on HELCOM PEG BIOVOLUME on the home page).

2.3 Chlorophyll

As chlorophyll *a* represents a share of the biomass of all plant cells, and also therefore of phytoplankton, its concentration is indicative of the total biomass of phytoplankton. For rough estimates, 1 mg chlorophyll *a* equates to 50 mg of algal organic carbon as assumed by EILOLA et al. (2009) in the Baltic Sea. In reality, the factors are highly variable. SMETACEK & HENDRIKSON (1979) found in Kiel Bay factors of 10-16 in winter, 22 and 69-77 during a growing and starving spring bloom, respectively, 80-110 during summer and 36-56 during the autumn bloom. LIPS et al. (2013) reported on C/chl.a ratios of 12-47 in March to May in the Gulf of Finland. More detailed information on these conversion factors can be found in the papers of SPILLING et al. (2014) and PACZKOWSKA et al. (2017). Because of the variability of these factors, conversion is not usually done, and the concentration of chlorophyll *a* is taken directly as a phytoplankton parameter.

Samples for the determination of chlorophyll *a* concentrations are collected together with phytoplankton samples at standard depths of 1 m, 5 m, 10 m, 15 m and 20 m, and occasionally at other depths. 200-500 ml samples of water are filtered through glass-fibre filters (Whatman GF/F) that are flash-frozen in liquid nitrogen (-196°C) and stored in the institute at -80°C for a maximum of three months. 96 % ethanol is used for extraction, as specified by HELCOM (2014b). It is thus possible to omit homogenisation and centrifugation (WASMUND et al. 2006 b).

Several methods are available for determining concentrations of chlorophyll *a*. They are reviewed by WASMUND et al. (2011 a). In addition to chlorophyll *a*, it is possible using the 'acidification method' (LORENZEN 1967) to determine phaeopigment *a*, which contains various constituents (phaeophytin, phaeophorbide) that are essentially regarded as degradation products of chlorophyll *a*. The 'acidification method' is susceptible to significant inaccuracies (cf. WASMUND 1984, STICH & BRINKER 2005). Unlike in shallow coastal waters, phaeopigments are not major players in the open sea, so there is no need for the 'acidification method'. This allows us to switch to a simpler and more readily reproducible method that does not involve acidification of the extracts.

In doing so, we no longer obtain a value for chlorophyll *a* that is 'corrected' for phaeopigment ('chl.a-cor'); instead we obtain an 'uncorrected' value that we name as 'chlorophyll *a* total' ('chl.*a*-tot'). This is the method recommended by HELCOM (2014 b). Between 2008-2010, we used concurrent methods with and without acidification; in 2010 we even used a 'new' and 'old' method in parallel when determining 'chl.*a*-tot' (see WASMUND et al. 2011 a). The 'chl.*a*-cor' and 'chl.*a*-tot-OLD' values we determined were markedly different. Our previous reports have already advised against use of the 'chl.*a*-tot-OLD' values from 2008-2010. The 'new method' used after 2010 is based on a specially configured fluorometer (TURNER-Fluorometer 10-AU-005-CE) that eliminates interference from chlorophyll *b* (procedure by WELSCHMEYER 1994). The 'chl.*a*-tot-NEW' values that we determined were surprisingly almost identical to the 'chl.*a*-cor' values. WASMUND et al. (2011 a) therefore recommended use of the 'chl.*a*-cor' values up until 2009; after 2010, they recommended use of 'chl.*a*-tot-NEW' values. Continuity in the long-term data series is thus assured. As 'chl.*a*-tot-OLD' values are not measured anymore the nowadays measured 'chl.*a*-tot-NEW' values are simply called 'chl.*a*-tot' (since 2013).

2.4 Sedimentation

Within the IOW Arkona Basin sampling area, rates of vertical particle flux (sedimentation) were measured over the course of the year. To record the amount and quality of material sinking from the surface layer to the sea floor, we moored a programmable sediment trap (type SM 234) with a collection area of 0.5 m², that was equipped with 21 sampling bottles. The mooring was deployed at a depth of 45 m with a surface float and a recovery line, and was retrieved after 3 to 4 months. Sampling intervals ranged between 7 and 10 days. In the mooring, the trap was located below the pycnocline at a depth of 35 m. The collected material was used to perform elemental analyses, determination of the natural isotopic composition of nitrogen and carbon and microscopic taxonomic analyses. The sampling programme in 2016 went according to plan. Moorings could be retrieved at regular intervals without any technical or logistical problems and the collection cups turned at the preprogrammed intervals. During 2016 storm-induced resuspension events were infrequent and did not influence the pattern of primary sedimentation.

2.5 Mesozooplankton

Zooplankton sampling was adjusted to match the hydrographic conditions according to the HELCOM guidelines. Vertical net tows were collected using a WP-2 net of 100 µm mesh size. In the case of a well-mixed water column, zooplankton was sampled with a single net catch taken from a few meters above the sea floor to the surface. Stratified hauls in specific layers were taken when a halocline or a thermocline was established through saline inflows or the seasonal warming of the surface in spring and summer, respectively. Nets were fitted with a flow metre to determine the volume of filtered water. Net angles greater than 40° were avoided during sampling. Samples were fixed in 4 % aqueous formalin solution until processing in the laboratory. In total 60 zooplankton samples were collected on 45 stations. Table 2 provides the details about the specific depth layers sampled over the season at the monitoring stations.

The taxonomic analysis was conducted in the laboratory according to HELCOM guidelines. In short, a minimum number of individuals was identified and counted microscopically in a Bogorov chamber. Several subsamples from the total sample were counted. With the exception of nauplii, rotifers and Bosminidae, at least 100 individuals from three taxa were counted. The abundance (ind. m^{-3}) is then calculated from counts and the filtered volume. The taxonomic classification of the zooplankton followed an internal species list of the long-term record of the species inventory as well as the zooplankton atlas of the Baltic Sea (Telesh et al. 2008) and was based on the Integrated Taxonomic Information System (ITIS[1]). In the case of *Bosmina* spp., identification to the species level is unresolved; its abundance was therefore only recorded as genus. In line with the standards of the Integrated Taxonomic Information System, Bryozoa were listed as Gymnolaemata and Mysidacea as Lophogastrida. The databases of the information system on Aquatic Non-Indigenous Species (AquaNIS[2]) and of the European Network on Invasive Species (NOBANIS[3]) served as references for the classification of invasive species.

Table 2
Sample statistics of zooplankton hauls on monitoring cruises in 2016.

Station	**Period**				
	26.01.- 08.02.	18.03.- 28.03.	10.05.- 19.05.	02.08.- 12.08.	02.11.- 13.11.
	Depth from –to (m)	Depth from –to (m)	Depth from –to (m)	Depth from –to (m)	Depth from –to (m)
OMBMPN3	15 - 9 - 0	17- 0	16- 0	15 - 8 - 0	16 - 0
OMBMPM2	21 - 0	21 - 0	19 - 6 -0 21 - 0	21 - 8 -0 21 - 0	23 - 0 21 - 0
OMBMPM1	21 - 0 20 - 0	21 - 0	20 - 10 - 0 23 - 0	22 - 14 - 0 22 - 0	23 - 0 22 - 0
OMBMPK8	18 - 0 20 - 0	19 - 0	20 - 0	20 - 7 - 0 19 - 12 - 0	20 - 0 19 - 0
OMBMPK5	44 - 28 - 0 45 - 0		42- 20 - 0 44 - 23 - 0	44 - 26 - 18 - 0 43 - 20 - 15 - 0	44 - 22 - 0 44 - 0
OMBMPK4	43 - 0	44 - 0	42 - 15 - 0	42 - 26 - 0	45 - 0

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[1] http://www.itis.gov/

[2] http://www.corpi.ku.lt/databases/index.php/aquanis

[3] http://www.nobanis.org

2.6 Macrozoobenthos

In November 2016, benthos investigations were undertaken at 8 stations from Kiel Bay to the Pomeranian Bay; Table 3 shows their locations. Depending on sediment type, two different Van Veen grab samplers were deployed (980 cm² and 1060 cm², weighing 38 kg - 70 kg, and 23 kg respectively). Three hauls were made at each station. Each haul was rinsed in seawater through a 1 mm mesh sieve. The sieve residue was then transferred to beakers, and fixed in 4 % formalin (HELCOM 2014 b). At all stations, a “Kieler Kinderwagen” botanical dredge with a 1 m rectangular mouth and a mesh size of 5 mm was deployed. Especially in relation to vagile and rarer species, the dredge yielded finds that would have been missed using only the grab sampler.

Further processing of samples was undertaken in the laboratory. After rinsing each haul, taxa were sorted under a binocular microscope at 10-20 x magnification and, except for a few groups (e.g., Nemertea, Halacaridae), were determined to species level. As much as possible, nomenclature complied with the ‘World Register of Marine Species (WoRMS[4]). Abundance and biomass were also recorded (ashfree dry weight, afdw).

To ensure comparability of weight determinations, HELCOM guidelines were followed (HELCOM 2014 b), and samples were stored for three months before processing. Wet, dry, and ash-free dry weights were measured on a microbalance.

Table 3
Station list of macrozoobenthic investigations in November 2016.

Station	Date	Depth	° North	° East	Sea area
OMBMPN3	03.11.2016	19.0	54° 36.00	10° 27.00	Kiel Bay
OMBMPN1	03.11.2016	28.6	54° 33.20	11° 20.00	Fehmarnbelt
OMBMPM2	02.11.2016	25.3	54° 18.90	11° 33.00	Bay of Mecklenburg
OM18	02.11.2016	19.0	54° 11.00	11° 46.00	Bay of Mecklenburg, south
OMBMPK8	03.11.2016	23.0	54° 44.00	12° 47.40	Darss Sill
OMBMPK4	04.11.2016	48.3	55° 00.00	14° 05.00	Arkona Basin
OMBMPK3	05.11.2016	31.3	54° 38.00	14° 17.00	Pomeranian Bay, north
OM160	05.11.2016	14.8	54° 14.50	14° 04.00	Pomeranian Bay, central

2.7 Quality Assurance

The main measure for quality assurance was the accreditation in line with DIN EN ISO/IEC 17025:2005 by Deutsche Akkreditierungsstelle GmbH (DAkkS) which took place on 14 and 15 May 2014. It covers the analyses of the phytoplankton, zooplankton, zoobenthos and chlorophyll and the respective documentation and reporting.

Phytoplankton (including chlorophyll), zooplankton, and zoobenthos data are collected in line with standard operating procedures (SOP), and the required documentation is maintained. All

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[4] http://www.marinespecies.org/index.php

results, quality assurance measures, and operating procedures are filed in the quality management system at IOW. QA activities for individual parameters are described here in brief:

Phytoplankton

From every tenth sample, two important species are counted a second time, and the replicate results are entered into the range control chart. This complies with the strategy agreed internationally by the HELCOM Phytoplankton Expert Group (PEG).

Expert identification of phytoplankton species depends on a laboratory technician's level of knowledge. The Phytoplankton Expert Group (PEG[5]) therefore runs annual training courses, and undertakes a ring test approximately every three years. The IOW was the host of the PEG meeting of 2016 which took place in Warnemünde from 25-29 April 2016 and was attended by 25 representatives of the riparian states of the Baltic Sea, except Russia.

A ring test for phytoplankton, prepared by the Federal Environment Agency (Umweltbundesamt, UBA) was conducted in 2016. Two phytoplankton experts of the IOW participated, but the evaluation of the ring test is not finalized yet.

As happens every year, the biovolume list of species and size classes was updated for the previous year. Samples taken until May 2016 are based on the official ICES and HELCOM biovolume file PEG_BIOVOL2015, and from August 2016 on biovolume file PEG_BIOVOL2016.

Chlorophyll

As an internal quality assurance measure, every tenth chlorophyll sample is taken twice and analysed separately to test parallel deviations (the result is entered into the range control chart). The fluorometer is calibrated every six months.

As an internal quality assurance measure, IOW regularly participates in chlorophyll comparisons within the QUASIMEME AQ-11 regime (chlorophyll in seawater). The results were very good (absolute values of z-scores $<$ 0.7). Additionally, the Umweltbundesamt organized a comprehensive Ring Test with two natural water samples and a stock solution received on 9 September and 16 September 2015. The evaluation is still pending.

Mesozooplankton

The duplicate analysis of every 10th zooplankton sample was done as an intra laboratory routine to check the reliability of the zooplankton analysis. In 2016, this was done by either an independent analysis of samples by separate analysts or by the repeated analysis of the sample at times when the analysis was conducted by a single analyst. Deviations were well below the threshold value for critical errors of 10%.

The external quality control of the taxonomic analyses was conducted by a duplicate analysis of samples taken by the monitoring group of the Marine Research Centre of the Finnish Environmental Institute in Helsinki (Finland). No significant deviations were recorded between the laboratories.

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[5] http://helcom.fi/helcom-at-work/projects/phytoplankton

Macrozoobenthos

The IOW macrozoobenthos working group has participated in all QA measures to date. It participated in the recent ring test from summer 2015, prepared by the Federal Environment Agency (Umweltbundesamt, UBA). The evaluation of this test is still pending.

3. Abiotic Conditions in 2016

The development of sea surface temperature (SST) of 2016 was studied using satellite data from the US NOAA and the European MetOp- weather satellites provided daily by the BSH Hamburg (NAUMANN et al. 2017).

The year 2016 was the third warmest year in the Baltic since 1990. February to July and September showed positive temperature anomalies, especially with up to +5 K in May, which was the warmest May since 1990. August and November were characterised by negative anomalies of up to -3 K along the west and east coast of the central Baltic induced by upwelling due to abnormal westerly and easterly winds in those months. June and September belonged to the warmest months in the southern Baltic and October to the warmest in the Gulf of Bothnia.

A strong cooling at the beginning of 2016 led to ice in the inner German coastal water already on 6 January and continued until 23 January inducing the maximum ice coverage in the entire Baltic Sea. The week from 09 to 15 March 2016 was the coldest in the open parts of the entire Baltic Sea. The SST increase in late spring was more pronounced as usual, leading to positive anomalies in May and June and to an early development of cyanobacteria. A warming phase in the second half of July made 26 July to the warmest day of the year. After the decrease in SST at the beginning of August, which occurred particularly in the northern Baltic, a stable situation lasted until mid-September with SST's of 18-20°C in the southern and western Baltic. This led to the high temperature anomalies in September and presumably also to a long cyanobacteria season.

After the Major Baltic Inflow from December 2014 (MOHRHOLZ et al. 2015), some moderate Major Baltic Inflow events occurred in November 2015 and January-February 2016, which affected the situation in the basins of the Baltic Proper in 2016 and may influence especially the macrozoobenthos (cf. Fig. 40). Since mid of January 2016, the deep layers of the Eastern Gotland Basin were ventilated again. Also three smaller inflow events appeared from October to December 2016. Details of the hydrographic and hydrochemical situation in 2016 are given by NAUMANN et al. (2017).

4. Results and Discussion

4.1 Phytoplankton

4.1.1 Development of Cyanobacteria Identified by Satellite Imagery

The development of cyanobacteria in the summer of 2016 was observed as in the previous year on the basis of high spatial resolution MODIS True color scenes (RGB, 250 m) of the satellites Aqua and Terra. The Lance Rapid Response System (RRS) of NASA provided the data.

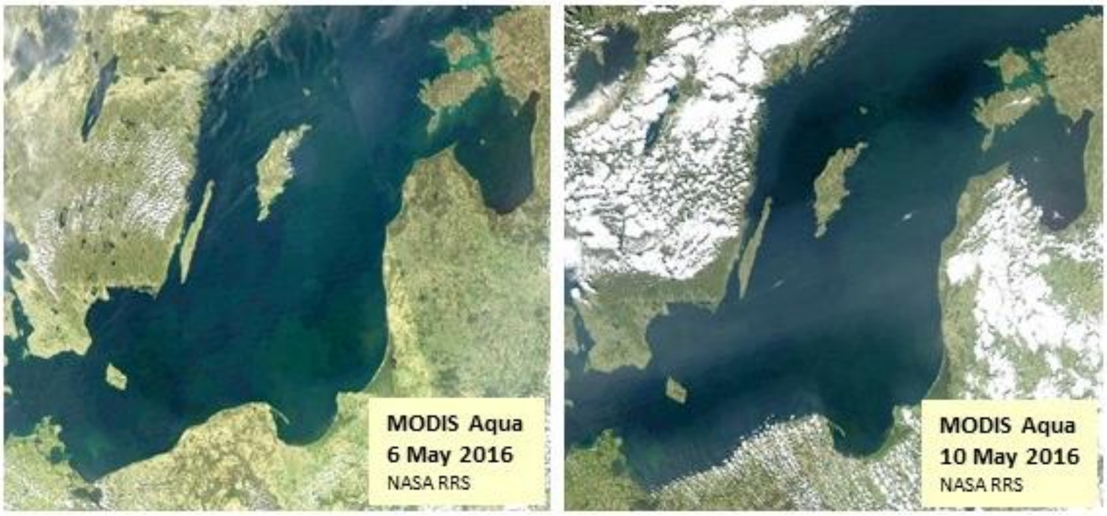


Fig. 2: MODIS Aqua images from 6 and 10 May 2016 showing higher concentration of cyanobacteria in the entire Baltic Proper and particularly in Eastern Gotland Basin.

The warming during a low wind period in the first decade of May started around 6 May and had a maximum on 10 May (Fig. 2), followed by a colder phase. In this warm phase, a rather early cyanobacteria development started. The images from 6 May demonstrate the higher concentrations of particles (cyanobacteria) in the Baltic Proper and on 10 May particularty in the Eastern Gotland Basin. Measurements during the monitor cruise from May 2016 have confirmed the satellite observations (Figs. 13, 14). The May was characterized by strong cloud coverage, but in the cloud gaps, higher concentration and first filaments could be identified in the southern Baltic from the Arkona Basin to the southern Gotland Basin. After 10 and 13 May, scenes are available from 21, 25, and 31 May with clear signs of cyanobacteria during the next warming phase. The cloudy situation continued nearly the entire summer, also at the beginning of June when cyanobacteria developed in the southern part of the Eastern Gotland Basin. Mid-June, southerly winds transported the cyanobacteria northwards and from June 20, surface blooms were established in wide areas of the Baltic Proper as observed in the image of 23 June (Fig. 3a).

During strongly changing meteorological conditions in the first half of July, wind mixing reduced the surface accumulations of cyanobacteria. During a low wind period in the second half of July, a strong warming occurred, which made the 26 July to the warmest day of the year. The MODIS image from 20 July shows the cyanobacteria in the entire Baltic Sea from the Mecklenburg Bight in the western Baltic Sea to the Gulf of Finland and in the Bothnian Sea (Fig. 3b). In the first decade of August, wind mixing initiated the first drop of temperature especially in the northern Baltic Sea. After this period, stable conditions prevailed at least until mid-September. Low wind periods in the second half of August and first half of September and temperatures of 18-20 °C in the southern and western Baltic Sea provided excellent conditions for cyanobacteria, which extended their development until mid- September (Figs. 3 c, d).

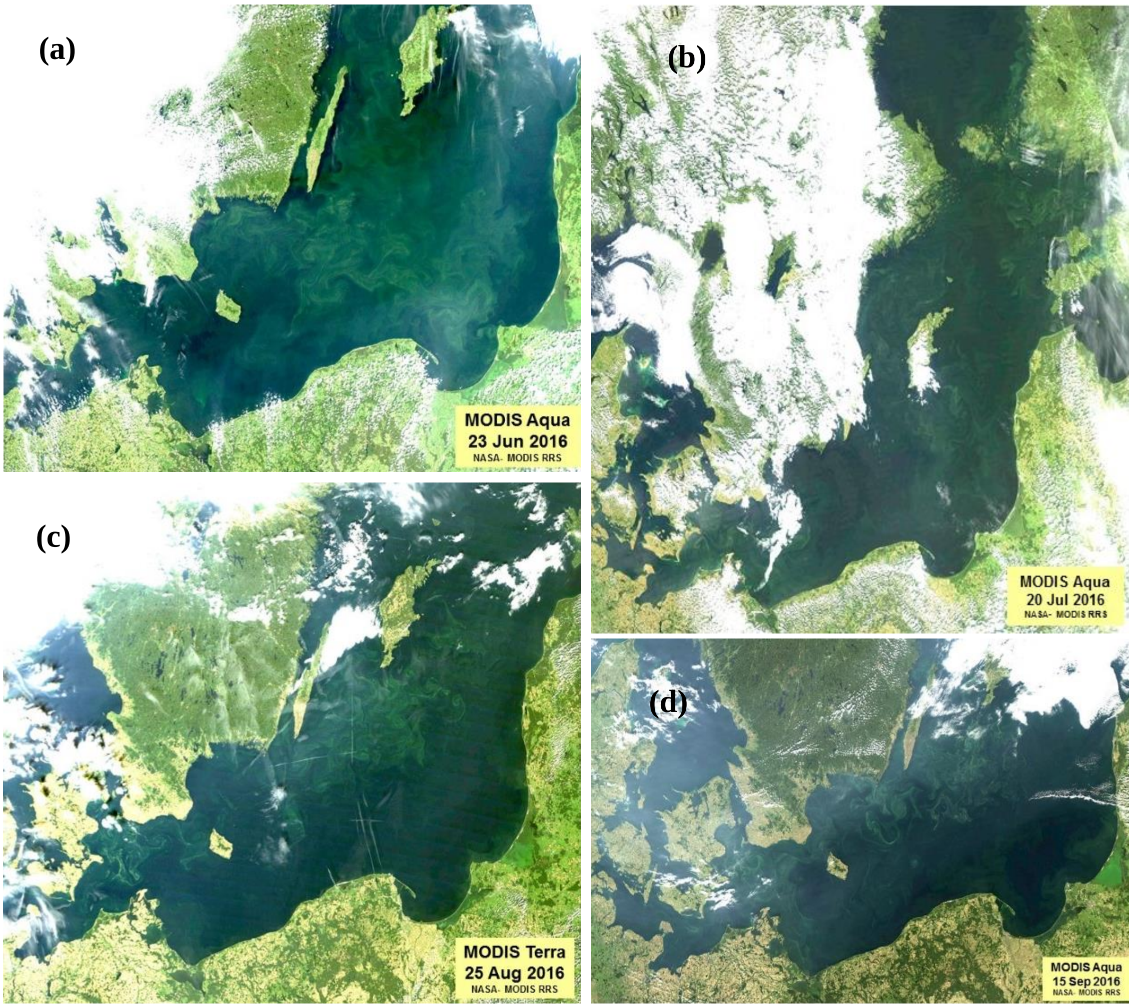


Fig. 3: MODIS Aqua and Terra quasi-true colour images from 23 Jun, 20 Jul, 25 Aug, and 15 Sep 2016 representing the best scene of the different months showing the Cyanobacteria development in the Baltic.
Data: NASA MODIS Rapid Response System

Fig. 4: The Sentinel 2 scene from 24 August 2016 shows filigree Cyanobacteria- filaments south-west of Gotland with a spatial resolution of 10 m.
Szene: Copernicus Sentinel data

In Fig. 4, a scene of the Sentinel 2 land observation satellite from 24 August 2016 with a spatial resolution of 10 m shows the possibilities for detailed investigation of structures, as in this case of the filigree filaments south-west of the island of Gotland. Wind mixing at beginning of September reduced the intensity of visible filaments, but the following stabilization improved the situation from 10 September again. The image from 15 September in Fig. 3d shows the maximum development in this phase before wind mixing and strong cloud coverage dominated in the following weeks. Further appearance of cyanobacteria could not be identified.

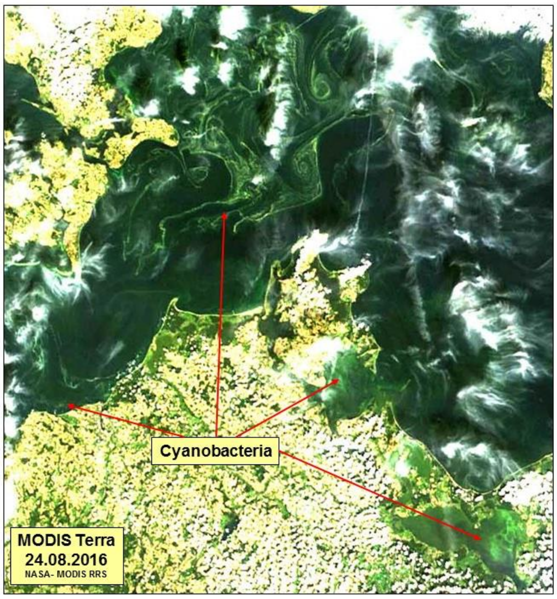


Fig. 5: MODIS Terra quasi-true colour images from 24 Aug 2016: cyanobacteria filaments reached the German coast.
Data: NASA MODIS Rapid Response System

For many years, the IOW has informed the German local authorities on nearly a daily basis about the spreading of cyanobacteria in the western Baltic and about potentially affected German coastal area. These authorities are the State Office for the Environment, Nature Conservation and Geology (LUNG); State Office of Health and Social Affairs (LAGUS); State Office for Agriculture, Environment and Rural Areas Schleswig-Holstein (LLUR) and the Tourist office of MV. In the period between 20 and 25 August 2016, beaches west of Rügen Island were partly affected by cyanobacteria. Fig. 5 represents an example from 24 August. Red arrows point to cyanobacteria filaments in the Bay of Mecklenburg, Arkona Basin, Greifswalder Bodden and in the Szczecin Lagoon.

In summary, the summer 2016 was characterized by rather different meteorological conditions, from low wind warming phases to cloudy and windy periods and without clear satellite days for the entire Baltic. Strong warming in the late spring during low wind periods led not only to the positive temperature anomalies in May and June, but also to an early cyanobacteria development confirmed by measurements during the monitoring cruise from May 2016. A warming in the second half of July and a temperature drop beginning of August made 26 July to the warmest day and July to the warmest month of the year. After this drop beginning of August, stable low wind conditions prevailed and lasted until mid-September with temperatures of 18-20 °C in the southern and western Baltic Sea leading to an extended cyanobacteria development until mid-September. Up to 4 months, cyanobacteria covered the area from western Baltic to northern Gotland Sea. The intensity of surface accumulation was lower than in other years, but the length of the development was rather extreme without special interruptions.

4.1.2 Seasonal Variations in Species Composition and Biomass

The limited numbers of monitoring cruises, stations, and sampled depths rule out comprehensive analyses of the succession or horizontal and vertical distribution of phytoplankton. In contrast to zooplankton, however, the vertical distribution of phytoplankton is less of a priority as phytoplankton mainly occurs in the mixed surface layer. This allows us to focus on mixed samples from 0-10 m depth. The inclusion of additional samples from 2 cruises conducted outside the regular monitoring program consolidates the data series. Especially in Bay of Mecklenburg, gaps can be filled by making use of weekly data collected off Heiligendamm as part of the coastal monitoring undertaken by IOW. Information about monitoring in this coastal water is available at http://www.io-warnemuende.de/algenblueten-vor-heiligendamm-2016.html. Another tool that delivers information on phytoplankton dynamics and distribution are satellites (chapter 4.1.1). Sediment traps yield samples integrated over several days (chapter 4.1.5).

The 10 most important phytoplankton taxa in terms of biomass from surface samples (0-10 m) collected on the five monitoring cruises are summarised in Table A1 (appendix), arranged by their percentage share in total biomass for each station and season. The three cruises over the winter and spring have been averaged. The completely “unidentified” category has been omitted from the table if its share of total phytoplankton biomass was <10 % as their information content is negligible. Succeeding taxa could move up. Similarly structured tables have been used in previous reports; this allows readers to make long-term comparisons. However, in the previous years, more unidentified categories (‘Unidentified’, ‘Gymnodiniales’, ‘Peridiniales’, ‘Craspedophyceae’) have been omitted.

Table A2 shows the full list of phytoplankton taxa at all depths for each monitoring cruise in 2016. Species are arranged alphabetically. Individuals exhibiting a high degree of similarity to a species but which were not assignable to it with certainty are also considered, and are marked ‘cf.’. Organisms that were classifiable only to genus level are also given, and are marked ‘sp.’ or ‘spp.’. When classification to the level of species or genus was not possible, a higher taxonomic rank is given. We also include the unidentified categories Gymnodiniales, Peridiniales, Choanoflagellatea, Chrysophyceae, Centrales, Pennales, but exclude the ‘Unidentified’ and ‘Unidentified flagellata’, which have no taxonomic value. The biomass rank averaged over all stations and all monitoring cruises in 2016 is also given. Also taxa that did not occur in surface samples, but only in samples at 20 m depth, are recorded in Table A2 and are ranked. Note that no importance attaches to the rank order of rare species whose biomass can be determined only very imprecisely and does not permit greater differentiation. Table A2 contains also information on the taxonomic affiliation of the species. All large multi-page tables are placed in the Annex.

Related species often have similar ecological requirements and can simply be grouped together. Although class is a high taxonomic rank, one that includes ecologically disparate species, abstraction at class level is generally established and is also applied here. Seasonal variations in biomass for the most important classes of phytoplankton such as diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae) are shown for the sampled stations in Figs. 12-14.

Heterotrophic species and groups such as *Ebria tripartita, Protoperidinium* spp., Choanoflagellatea and ‘incertae sedis’ are also considered. Choanoflagellatea were named “Craspedophyceae” in previous reports. ‘Incertae sedis’ is a term used to refer to a taxon whose taxonomic position is unclear, such as *Katablepharis, Leucocryptos* and *Telonema*. We have included them in the species lists (Tables A1 and A2) and phytoplankton biomass data (Figs. 12-14).

Mixotrophic ciliates were also recorded. Until 2011 *Mesodinium rubrum* was the sole representative of this group in our samples. Since 2011 also the oligotrich ciliate *Laboea strobila* is considered, as it is believed to be mixotrophic (STOECKER et al. 1988; SANDERS 1995).

The *Aphanizomenon* species from the Baltic Proper was identified as *Aphanizomenon flos-aquae* until the mid-1990s. JANSON et al. (1994) noticed morphological inconsistencies of the Baltic *Aphanizomenon* species with the taxonomic description of the fresh-water *Aphanizomenon flos-aquae*. Therefore we counted the species provisionally as *Aphanizomenon* sp. According to LAAMANEN et al. (2002), the Baltic *Aphanizomenon* consists of only one genotype, with is not different from the freshwater type, despite morphological differences. Also PALIŃSKA & SUROSZ (2008) verified high overall sequence identity (97.5 – 99%) of the *Aphanizomenon* population from the Gulf of Gdańsk to freshwater isolates, but they found also significant differences in ultrastructure and morphology. Until a final solution of this problem, the HELCOM Phytoplankton Expert Group (PEG) continues to count it as *Aphanizomenon* sp.

Following the taxonomic revision of the genus *Anabaena* by WACKLIN et al. (2009), the planktonic *Anabaena* species are now named as '*Dolichospermum*' (see also KOMÁREK & ZAPOMĚLOVÁ 2007, 2008). We have made use of the new name since 2014.

The taxonomic revision of the genus *Skeletonema* (SARNO et al. 2005, ZINGONE et al. 2005) necessitated a redefinition of *Skeletonema costatum*, a typical spring diatom. We immediately undertook electron microscopic investigations, and designated the species found in our samples as *S. marinoi* (WASMUND et al. 2006 a). With the finding later confirmed by other institutes, we began to apply the new name to samples after 2012.

The species *Dictyocha speculum* occurs largely 'naked', i.e. without the typical silica skeleton (cf. JOCHEM & BABENERD 1989, HENRIKSEN et al. 1993). It is difficult to identify in such a case, and is easily mistaken for *Pseudochattonella farcimen* (also Dictyochophyceae) and *Chattonella* spp. (Raphidophyceae). As we have occasionally found both naked and skeleton-bearing stages, as well as transitional stages (WASMUND et al. 2015), we feel fairly certain that the round, naked cells are *Dictyocha speculum*. Within the HELCOM Phytoplankton Expert Group (PEG), we have agreed that elongated forms should count as *Pseudochattonella farcimen*. This uncertainty is not a problem when working at class level because both *Pseudochattonella farcimen* and *Dictyocha speculum* belong to the class of Dictyochophyceae. Up to the report of WASMUND et al. (2015), these genera were assigned to the Chrysophyceae in Figs. 12-14. Now we present the Dictyochophyceae separately in Figs. 12-14 and put the few representatives of the class of Chrysophyceae (*Dinobryon, Apedinella, Pseudopedinella*) to the group of "Others".

In the past, the HELCOM Phytoplankton Expert Group (PEG) dealt with synonyms cautious and conservative and has not immediately adopted taxonomic revisions in its species list. However, in 2014 PEG started to include new synonyms which were set in force 2015. Table 4 shows those synonyms which concern the taxa occurring in our own samples. This knowledge is important for comparisons with earlier reports.

We know from our long-term data series that three pronounced blooms occur in the study area in spring, summer, and autumn every year; they can often be further split into phases of varying species succession. We structure the following section for the seasons and within the seasons for the regions.

Table 4
Taxonomic revisions of phytoplankton names.

Old Synonym	New Synonym
Since PEG-2015	
Aphanothece	*Anathece*
Chaetoceros impressus	*Chaetoceros castracanei*
Cladopyxis claytonii	*Micracanthodinium claytonii*
Craspedophyceae	Choanoflagellatea
Cylindrotheca closterium	*Ceratoneis closterium*
Dinophysis rotundata	*Phalacroma rotundatum*
Gymnodinium galatheanum	*Karlodinium veneficum*
Karlodinium micrum	*Karlodinium veneficum*
Proterythropsis vigilans	*Nematopsides vigilans*
Prorocentrum minimum	*Prorocentrum cordatum*
Since PEG-2016	
Planctonema lauterbornii	*Binuclearia lauterbornii*
Chaetoceros socialis f. radians	*Chaetoceros socialis*
Chaetoceros socialis f. socialis	*Chaetoceros socialis*
Verrucophora farcimen	*Pseudochattonella farcimen*
Rhizosolenia pungens	*Rhizosolenia setigera* f. *pungens*
Thalassiosira rotula	*Thalassiosira gravida*
Since PEG-2017	
Woloszynskia halophila	*Biecheleria baltica*
Ceratoneis closterium	*Cylindrotheca closterium*

4.1.2.1 Spring Bloom

Belt Sea

Kiel Bay and Bay of Mecklenburg (including Lübeck Bay) have rather similar conditions and are combined to the area of the German Belt Sea. Figure 6 shows the seasonal variations in phytoplankton biomass in Kiel Bay, Lübeck Bay and Bay of Mecklenburg. In late January, the biomass was still low. The relatively high *Ceratium* biomass found at station OMBMPN3 in 2013 and 2014 could neither be confirmed in 2015 nor in 2016, presumably because *Ceratium tripos* biomass was low in the preceding autumns. Instead, besides of *Teleaulax* sp., the diatom *Proboscia alata* was dominant in the surface water of stations OMBMPN3, OMO22 and OMBMPM2 as a remnant of the preceding autumn bloom. Most interesting is the unusually high biomass of *Coscinodiscus* spp. (mostly *C. concinnus*; see Fig. 6) at 17 m or 20 m depth, i.e. below the pycnocline, on these stations. For example, *C. concinnus* amounted to 617 µg/L at 17 m depth on station OMBMPN3 on 26 January 2016. This genus was not a component of the autumn bloom in the Belt Sea, but in the Arkona Basin (in that case *C. granii*). *Coscinodiscus concinnus* is typical for the North Sea and presumably transported with the inflow events that occurred in November 2015 and January-February 2016. Extremely high biomass of *C. concinnus* above the bottom of Kiel Bay was already reported from early February 2014 (WASMUND et al. 2015), which might be related to an inflow event from November/December 2013 (NAUSCH et al. 2014). The effect of the Major Baltic Inflow from December 2014 could not be observed in winter/spring 2015 as samples from the deep layer were not completely available.

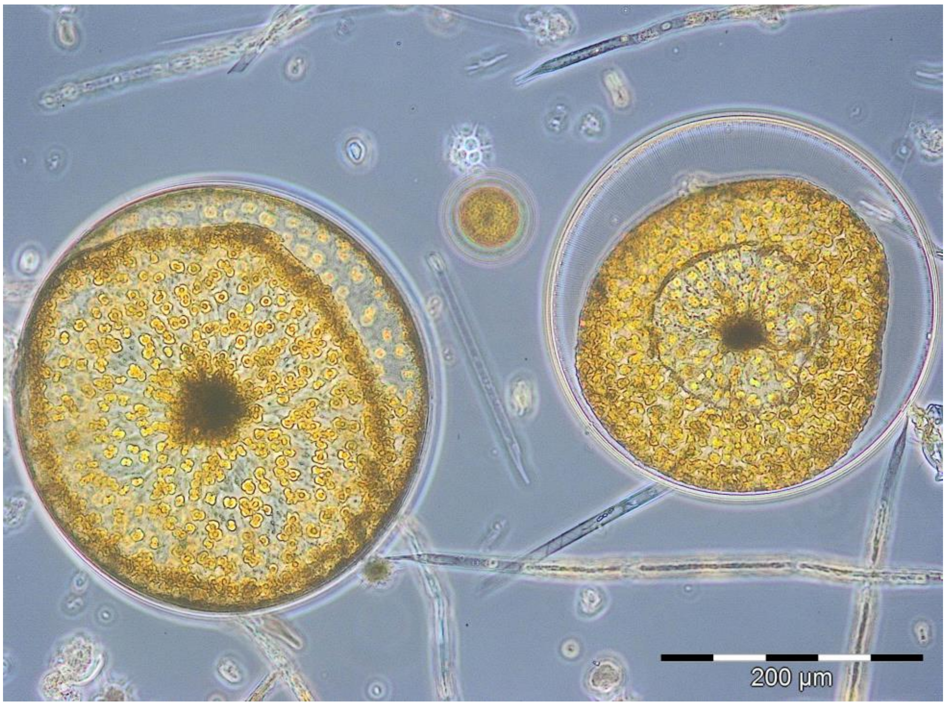


Fig. 6: *Coscinodiscus concinnus* in a net sample from 26 January 2016, Station OMBMPN3. Photo: S. Busch (IOW).

Surprisingly, *C. concinnus* appeared even in surface samples of station OMBMPM1 on 7 February 2016, but with a biomass of only 88 µg/L, which is based on only 1 counted cell. Due to its large cell-size, total biomass of *C. concinnus* becomes rather large even at relatively low abundance. Later, on 1 March 2016, this species formed a bloom (2361 µg/L) at the coastal station Heiligendamm. WASMUND et al. (2017) believed that this bloom developed in an inflowing marine water body, characterized be high salinity (17.3 psu). Already one week later, by the 8 March 2016, this water body together with its phytoplankton content was replaced by a water body of lower salinity (12.9 psu), containing a bloom of *Skeletonema marinoi* (3022 µg/L) at the coastal station. Fortunately, we have got an additional sample from28 February from a place north of station OMBMPM1, which confirmed a developing autochthonous bloom of *Skeletonema marinoi* (209 µg/L). Further west, on station OMBMPM2, the diatom spring bloom was a mixture of *S. marinoi* (776 µg/L) and *C. concinnus* (1052 µg/L) on 7 March 2016. In Kiel Bay, *S. marinoi* was almost absent (1 µg/L) whereas *C. concinnus* formed a strong bloom (4858 µg/L). It was accompanied by *Chaetoceros decipiens, Rhizosolenia setigera*, *Mesodinium rubrum*, and members of the *Pseudo-nitzschia seriata* group. It is worth mentioning that the spring bloom of the Belt Sea contained, in contrast to previous years, almost exclusively diatoms, but relatively low biomass of *Mesodinium rubrum* and dinoflagellates and almost no other flagellates like Dictyochophyceae, Prymnesiophyceae, Euglenophyceae and Cryptophyceae.

The diatom bloom declined by the 27/28 March 2016 whereas the share of *Mesodinium rubrum* and dinoflagellates increased. In Kiel Bay, there was still a significant diatom biomass of *C. concinnus* (688 µg/L) and *Pseudo-nitzschia seriata* (168 µg/L) in the surface water, but also at 15 m depth (251 µg/L and 604 µg/L, respectively). Also at station OMBMPM2, the biomass of *P. seriata* was higher in the deep water layer (650 µg/L) than in surface water (66 µg/L); for image from station OMO22 see Fig. 7. The identification of *Pseudo-nitzschia seriata* was facilitated by electron microscopy. This species is included in the genus *Pseudo-nitzschia* spp. in Table A1. The occurrence of high biomass of *Pseudo-nitzschia* spp. is not usual in spring.

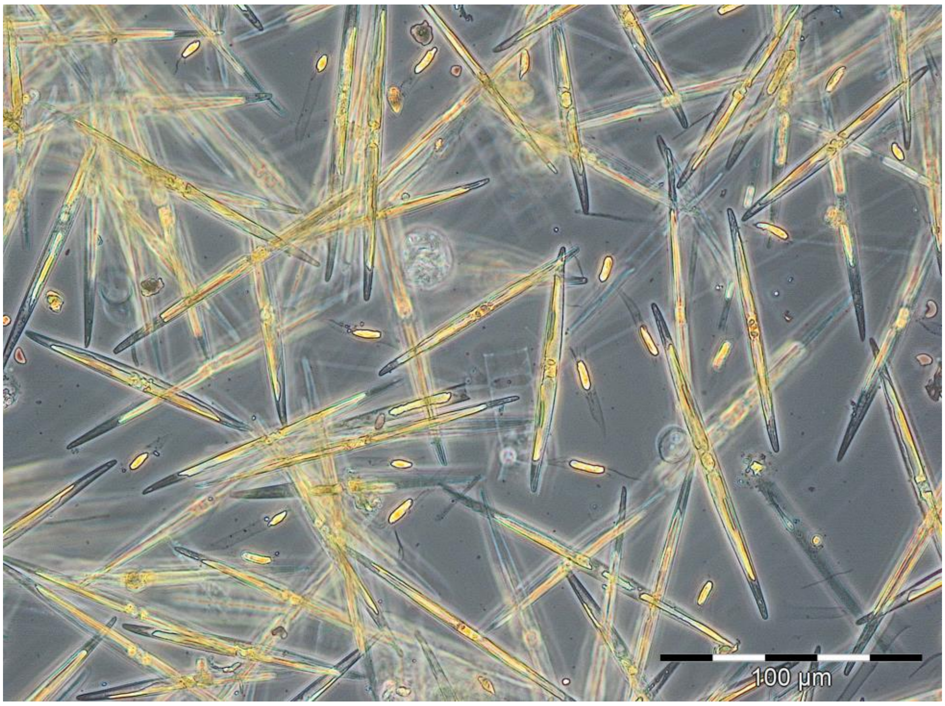


Fig. 7: *Pseudo-nitzschia pungens,* together with single cells of *Dinobryon balticum* in a net sample from 28 March 2016, Station OMO22. Photo: S. Busch (IOW).

The data from the eastern part of the Bay of Mecklenburg near Darss Sill, represented by station OMBMPM1, are hardly comparable with those of the central Bay of Mecklenburg because the spring bloom was not represented in the samples. Nevertheless, some differences concerning species composition become obvious: *Coscinodiscus* and *Pseudo-nitzschia*, dominating in the central Bay of Mecklenburg, did not occur in the surface water of station OMBMPM1 on 28 February, but *Skeletonema marinoi* and *Mesodinium rubrum* dominated, which are typical in the Arkona Basin. On the other hand, *Coscinodiscus concinnus* was still present in high biomass at 20 m depth on 27 March at station OMBMPM1, but not in the Arkona Basin. Obviously, the Darss sill is not a strict border for the phytoplankton of the surface water, but for that of the deeper water layers.

After the spring bloom (May 2016), phytoplankton biomass was very low, but highly diverse, mainly represented by prymnesiales, naked *Dictyocha speculum* and Gymnodiniales*;* in Kiel Bay additionally *Peridiniella danica, Ceratium tripos, Proboscia alata,* and the heterotrophic flagellate *Leucocryptos marina*. *Coscinodiscus* did not occur anymore neither in surface nor in deep water.

These results on the timing of the spring bloom underline the insufficiency of the routine monitoring because the spring bloom could be identified only by the additional samples. As we have no accompanying chlorophyll data from the additional samples, the spring bloom remains still undetected if only the chlorophyll data are consulted (Table 6). Data from the coastal station Heiligendamm may fill the gaps in the case of Bay of Mecklenburg. The occurrence of a spring bloom may also be verified by nutrient consumption data. The consumption of silicate confirms that the spring bloom contained a high share of diatoms. The nutrient data from the stations of the Belt Sea reveal blooms between end of January and end of March (Table 5). The few additional samples from the open sea and the data from the coastal station could narrow the time of the bloom peak down to the beginning of March in Kiel Bay and to the first half of March in the Bay of Mecklenburg. After the spring bloom, remineralization of the nutrients seems to occur. Surprisingly, silicate concentrations increased much stronger than concentrations of phosphate and nitrate+nitrite. This was already discussed by WASMUND et al. (2015).

Arkona Basin

As mentioned above, the development of phytoplankton biomass and species composition in the western Arkona Basin (an additional station north of OMBMPK8) was rather similar to that in the eastern part of the Bay of Mecklenburg. Even the unusual occurrence of *Coscinodiscus* spp. in the deep water layers (20 m depth: 154 µg/L) was found there on 27 January. Another similarity was the elevated biomass and the dominance of *Skeletonema marinoi* and *Mesodinium rubrum* on 28 February 2016. Such early bloom is unusual in the Arkona Basin and may be based on inflowing water. Therefore, the common strategy to assume the spring bloom in the Baltic Proper in the period from March to May has to be revised. The central Arkona Basin seems not to be influenced by the Bay of Mecklenburg as the biomass was still low at that time. Whether a diatom bloom occurred there cannot be proved; the silicate consumption data (Table 5) do not indicate a diatom bloom on station OMBMPK5. Nutrient (N and P) consumption data reveal phytoplankton growth until the 27 March 2016. As dissolved inorganic nitrogen is nearly exhausted on 27 March, no significant further growth is assumed. The succession from diatoms to dinoflagellates (Gymnodiniales) within the bloom is clearly seen in Fig. 13 a. *Actinocyclus* spp. (741 µg/L; see Fig. 8) and *Pseudo-nitzschia seriata* (270 µg/L), but no *Coscinodiscus*, accumulated at 20 m depth at that situation (stat. OMBMPK8). In comparison, biomass was still rather high in the central and eastern Arkona Basin at that time.

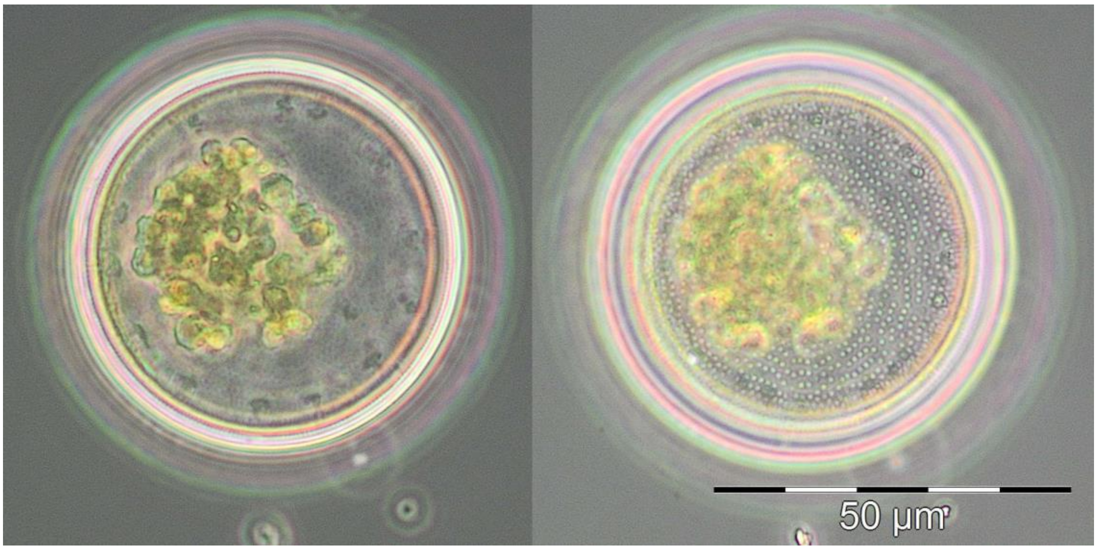


Fig. 8: *Actinocyclus octonarius* (probably synonymous to *Actinoptychus octonarius*) from 27 January 2016, Station OMBMPM5. Photo: S. Busch (IOW).

Table 5
Concentrations of nitrate+nitrite, phosphate, and silicate (µmol/L) from 5 m water depth at the biological stations in 2015. Data extracted from the IOW database.

Station	Date	Nitrate+Nitrite	Phosphate	Silicate
OMBMPN3	26.01.2016	4.75	0.63	11.4
OMBMPN3	28.03.2016	0.08	0.1	1.4
OMBMPN3	10.05.2016	0.14	0.01	3.5
OMBMPN3	02.08.2016	0.02	0.07	1
OMBMPN3	03.11.2016	0.16	0.3	5.4
OMO22	27.01.2016	7.12	0.71	14.1
OMO22	28.03.2016	0.21	0.21	2.2
OMO22	10.05.2016	0.14	0	4.2
OMO22	03.08.2016	0.09	0.04	2.6
OMO22	02.11.2016	0.02	0.17	4.6
OMBMPM2	27.01.2016	5.51	0.67	12
OMBMPM2	28.03.2016	0.19	0.17	2.6
OMBMPM2	10.05.2016	0.05	0.07	7.2
OMBMPM2	03.08.2016	0.08	0.03	3.7
OMBMPM2	02.11.2016	0.62	0.52	9.5
OMBMPM1	27.01.2016	4.79	0.64	11.2
OMBMPM1	27.03.2016	0.02	0.3	3.1
OMBMPM1	11.05.2016	0.18	0.17	8.9
OMBMPM1	03.08.2016	0.09	0.04	6.4
OMBMPM1	03.11.2016	0.58	0.52	11.9
OMBMPK8	27.01.2016	3.58	0.64	10.3
OMBMPK8	27.03.2016	0.11	0.36	5.7
OMBMPK8	11.05.2016	0.16	0.15	12
OMBMPK8	03.08.2016	0.11	0.01	8.4
OMBMPK8	03.11.2016	1.38	0.37	12
OMBMPK5	27.01.2016	3.23	0.64	8.1
OMBMPK5	07.02.2016	3.67	0.64	9.5
OMBMPK5	27.03.2016	0.35	0.41	8.1
OMBMPK5	11.05.2016	0.16	0.26	15.8
OMBMPK5	03.08.2016	0.04	0.02	7.5
OMBMPK5	04.11.2016	1.18	0.35	11.5
OMBMPK4	28.01.2016	3.13	0.63	10.7
OMBMPK4	27.03.2016	0.05	0.2	4.1
OMBMPK4	12.05.2016	0.16	0.15	13.2
OMBMPK4	03.08.2016	0.05	0.04	6.6
OMBMPK4	04.11.2016	1.16	0.31	11.4
OMBMPK2	30.01.2016	3.1	0.63	8.9
OMBMPK2	06.02.2016	3.14	0.63	9
OMBMPK2	18.03.2016	0.05	0.61	12
OMBMPK2	26.03.2016	0.02	0.49	12.2
OMBMPK2	12.05.2016	0.31	0.35	12.1
OMBMPK2	05.08.2016	0.01	0.03	9
OMBMPK2	06.11.2016	2.38	0.41	11.6
OMBMPK1	06.02.2016	3.55	0.7	12.2
OMBMPK1	19.03.2016	1.41	0.7	13.8
OMBMPK1	13.05.2016	0.36	0.04	15
OMBMPK1	05.08.2016	0.07	0	10.8
OMBMPK1	06.11.2016	2.19	0.32	12
OMBMPJ1	04.02.2016	3.69	0.61	14.7
OMBMPJ1	20.03.2016	2.86	0.6	15.8
OMBMPJ1	14.05.2016	0	0.08	16.3
OMBMPJ1	06.08.2016	0.11	0.01	13.6
OMBMPJ1	11.11.2016	2.15	0.32	12.5

This late phase of the spring bloom was characterized by *Mesodinium rubrum* and dinoflagellates (Gymnodiniales). After the spring bloom, in May 2016, Prymnesiales (Fig. 9) and Dinoflagellates (Gymnodiniales, *Peridiniella danica*) were the dominating groups. *Mesodinium rubrum* has strongly declined but Cyanobacteria (*Aphanocapsa, Anathece*) developed slowly.

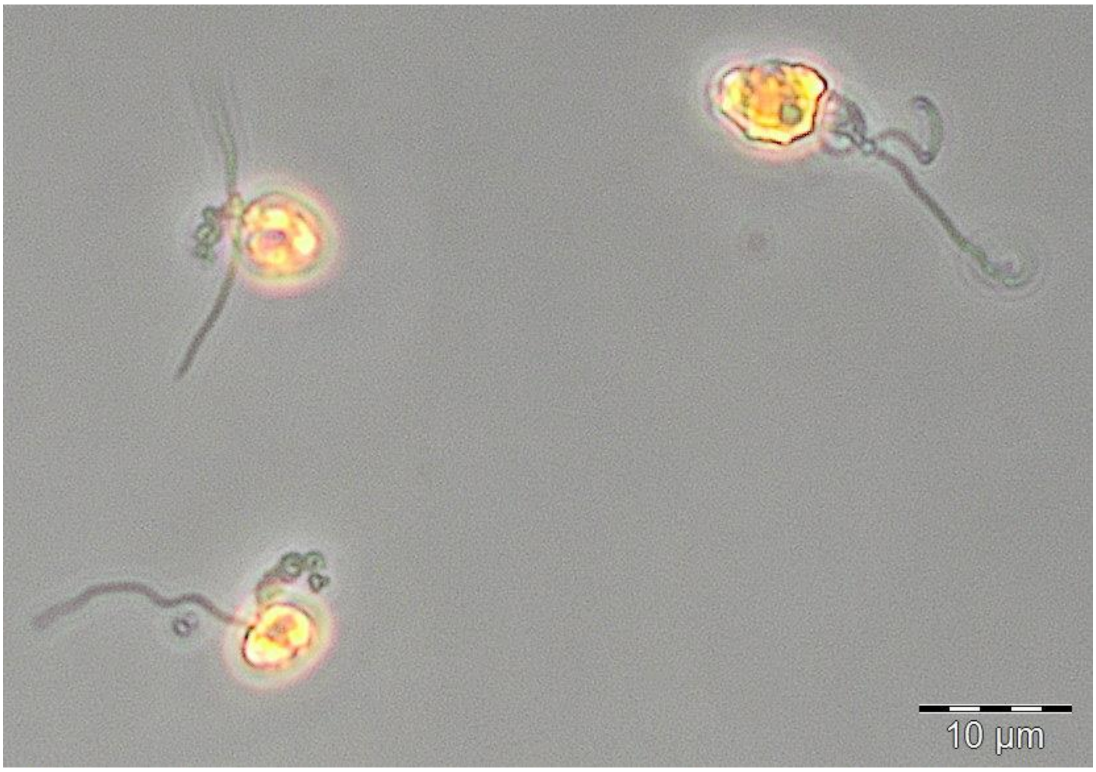


Fig. 9: Prymnesiales in a net sample from 19 May 2016, Station OMBMPM5. Photo: S. Busch (IOW).

Bornholm Basin

The Bornholm Basin was represented by only one station (OMBMPK2), and no additional samples were available. Nevertheless, the timing of the spring bloom could be determined with some certainty. Rather high biomass was found already on 18 March 2016 with a decreasing tendency to the 26 March 2016 (Fig. 14 a). Nitrate and nitrite concentrations have nearly been exhausted by the 18 March (Table 5), which suggests that the growth of the bloom has finished already. Surprisingly, phosphate concentrations as well as silicate concentrations did not decrease in correspondence with the concentrations in dissolved inorganic nitrogen despite the growth of diatoms. It has, however, to be kept in mind that presentation of biomass data of diatoms exaggerates their growth in comparison with the carbon accumulation because they contain a big vacuole that contains only littly organic carbon. On the other hand, the biovolume respectively the biomass reflects the extent of the silicate-requiring valves quite well. Phosphate reduction occurred only after the bloom, perhaps because of “Luxury uptake” by the developing cyanobacteria.

In contrast to earlier knowledge, the spring bloom development was not retarded in the Bornholm Basin in comparison with the central Arkona Basin in 2016. According to WASMUND et al. (1998), this may occur after mild winters.

The low biomass in January and February was dominated by *Actinocyclus*, probably in the state of spores, which may have been remains of the previous autumn bloom. In contrast, the new spring bloom was formed by *Skeletonema marinoi* (901 µg/L) on 18 March 2016. It was accompanied by *Mesodinium rubrum, Chaetoceros* spp., *Thalassiosira* spp., Gymnodiniales, *Peridiniella catenata* and, surprisingly, a few *Nodularia spumigena*. The diatoms declined strongly by the 26 March 2016, whereas *Mesodinium rubrum*, Gymnodiniales, Prymnesiales, and *Teleaulax* spp. increased. High biomass extended into the month of May, primarily caused by growth of Prymnesiales, Gymnodiniales and Cyanobacteria (*Aphanocapsa, Anathece*). It was surprising that *Aphanizomenon* sp. occurred in high density in the net samples, but rarely in the water samples (Fig. 10).

Fig. 10: *Aphanizomenon* sp. and *Dinophysis norvegica* in a net sample from 12 May 2016, Station OMBMPK2. Photo: S. Busch (IOW).

Eastern Gotland Basin

The Eastern Gotland Basin is represented by the central station OMBMPJ1 (Fig. 14 c) and a more southern station OMBMPK1 (Fig. 14 b), which is called “Southern Gotland Basin” in our case. In many years, both stations were rather similar in their phytoplankton characteristics. However, at the beginning of February 2016, they were very different. On 6 February, a very high biomass (2533 µg/L) of the diatom *Actinocyclus* spp. occurred in the surface water of station OMBMPK1 (Fig. 11), whereas it was low (9 µg/L) at station OMBMPJ1. Perhaps it was a remain of the autumn bloom, that was dominated by *Coscinodiscus granii* and *Actinocyclus* sp. in the Bornholm Basin on 15 November 2015. Unfortunately we have not got a sample from station OMBMPK1 in November 2015. If *Actinocyclus* sp. survives the winter, it may have a kick-start in early February if conditions are favourable. Unfortunately, the nutrient data (Table 5) do not support the finding of an early diatom growth. Probably these diatoms are an accumulation of older cells (spores ?) that have not just grown and are poor in chlorophyll (cf. Table 6). A spring bloom has never occurred that early in the region of the Eastern Gotland Basin. If this bloom was real, the strategy by HELCOM, to expect the spring bloom from March to May in the Baltic Proper, has to be revised. However, we are reserved with this finding. It is based on only one sample and needs confirmation by data from other countries, if available.

Fig. 11: *Actinocyclus* sp., *Aphanizomenon* sp. and *Chaetoceros impressus* in a net sample from 6 February 2016, Station OMBMPJ1. Photo: S. Busch (IOW).

By the 19/20 March 2016, the phytoplankton composition has changed completely on stations OMBMPK1 and OMBMPJ1. It was dominated by *Mesodinium rubrum* and secondly by dinoflagellates (Gymnodiniales), but *Actinocyclus* sp. did still occur and *Aphanizomenon* sp. was already present especially in the net samples. In addition, *Gyrodinium spirale* was worth mentioning on station BMPK1 and *Peridiniella catenata* on station BMPJ1. This composition is more usual for a spring bloom than the *Actinocyclus* bloom. In contrast to the Bornholm Basin, nutrients (nitrate and nitrite, Table 5) were not used up in March, which indicates that the bloom will still grow and might reach its peak only in April. Finally, by 13/14 May 2016, phosphate (on station OMBMPK1) or nitrate+nitrite (on station OMBMPJ1) were nearly exhausted. At that time, still high biomass of about 1200 µg/L was found, dominated by *Mesodinium rubrum,* dinoflagellates (*Peridiniella* spp., Gymnodiniales) and Prymnesiales.

The samples from the range of the thermocline (15-20 m) contained high biomass of Prymnesiales (e.g. 2782 µg/L at station BMPK1 from 13 May 2016, 15 m) and *Dinophysis* spp. (e.g. 110 µg/L at station BMPJ1 from 14 May 2016, 20 m).

Summary on the spring bloom 2016:

1.) Rather high biomass of *Coscinodiscus concinnus* occurred in January and February especially in the deeper water layers of Kiel Bay and Bay of Mecklenburg, which was probably transported with inflowing water from the North Sea. This species formed the spring bloom in Kiel Bay at the beginning of March 2016 and was later accompanied by *Pseudo-nitzschia seriata*, but towards the east, in the Bay of Mecklenburg, it was more and more replaced by the autochthonous *Skeletonema* bloom, which occurred in the first half of March.

2.) In contrast to previous years, the spring bloom in Kiel Bay and Bay of Mecklenburg was almost exclusively represented by diatoms, with only a little share of *Mesodinium rubrum* and dinoflagellates and almost no dictyochophyceae. Only after the spring bloom, in May 2016, prymnesiophyceae and some dictyochophyceae and cyanobacteria developed.

3.) Darss Sill is not a strict border that separates the phytoplankton of the Belt Sea from that of the Baltic Proper. However, in the deeper water layers, in was separating *C. concinnus* and *Pseudo-nitzschia seriata* in the Bay of Mecklenburg from *Actinocyclus* in the central Arkona Sea and the more eastern regions of the Baltic Proper.

4.) As found already in the previous year, the inorganic nitrogen was consumed more intensively than phosphate, which is a symptom of nitrogen deficiency. Silicate was not used up and seems not to limit diatom growth. Moreover, silicate concentrations did not decrease in the Bornholm Basin and southern part of the Eastern Gotland Basin despite a strong diatom growth. In these Basins, “luxury uptake” of the “excess” phosphorus occurred after the bloom, perhaps by the developing cyanobacteria. Surprisingly, silicate concentrations increased much stronger after the diatom spring bloom than concentrations of phosphate and nitrate+nitrite.

5.) In contrast to earlier knowledge, the spring bloom development was not clearly retarded into eastern directions. It might have occurred in Kiel Bay at the beginning of March 2016, and in the Bay of Mecklenburg, Arkona Basin and Bornholm Basin in the first half of March. In the southern part of the Eastern Gotland Basin, an exceptionally early occurrence of high diatom biomass (*Actinocyclus,* probably as spores) was noticed already at the beginning of February. This data is based on only one sample and needs confirmation. A spring bloom of usual composition (*Mesodinium rubrum*, Dinoflagellates) developed in mid of March in the Eastern Gotland Basin and continued by mid of May with increasing share of Prymnesiales and cyanobacteria.

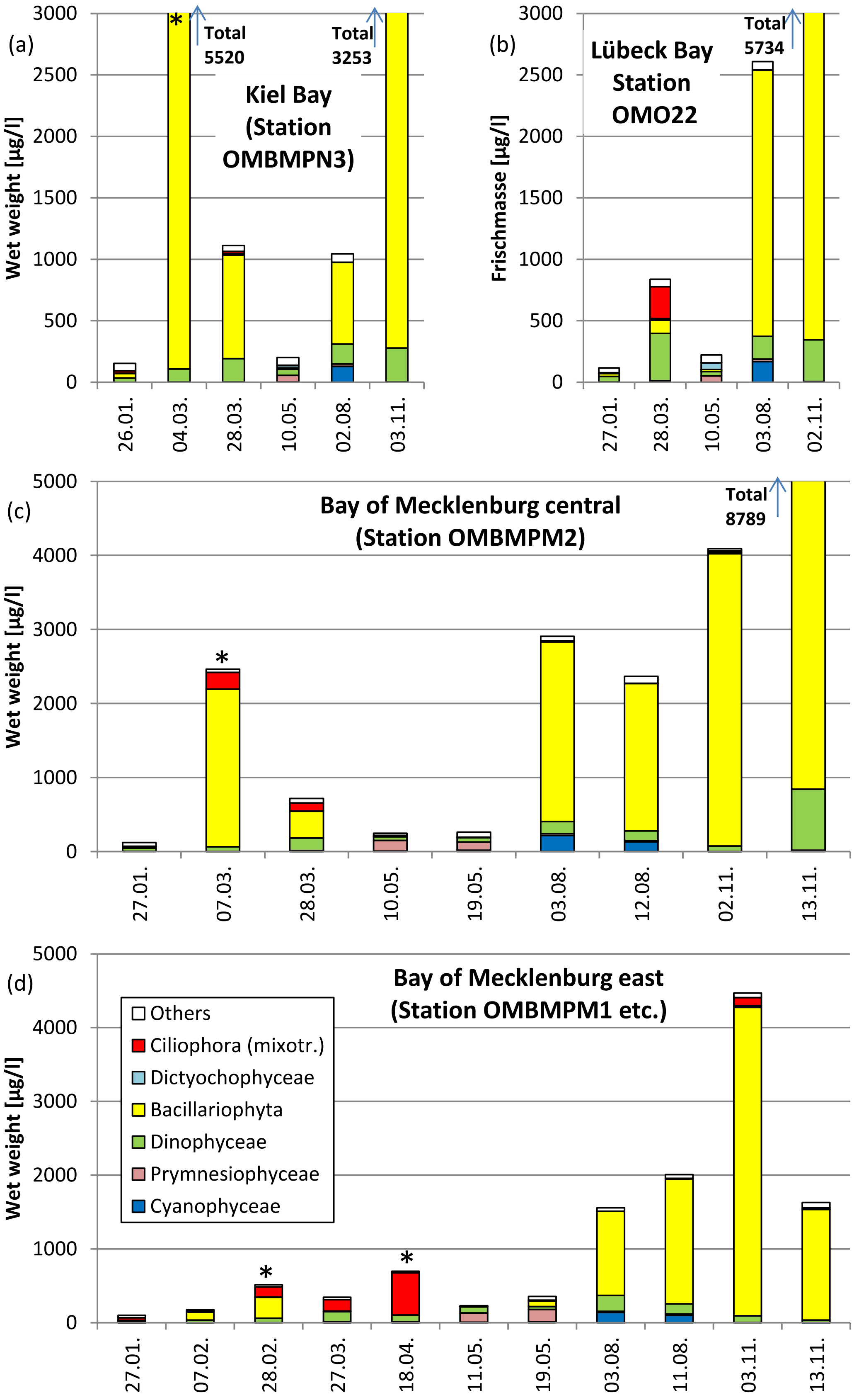


Fig. 12: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in Kiel Bay (a), Lübeck Bay (b) and Bay of Mecklenburg (c, d) in 2016. Additional samples are marked with an asterisk above the column.

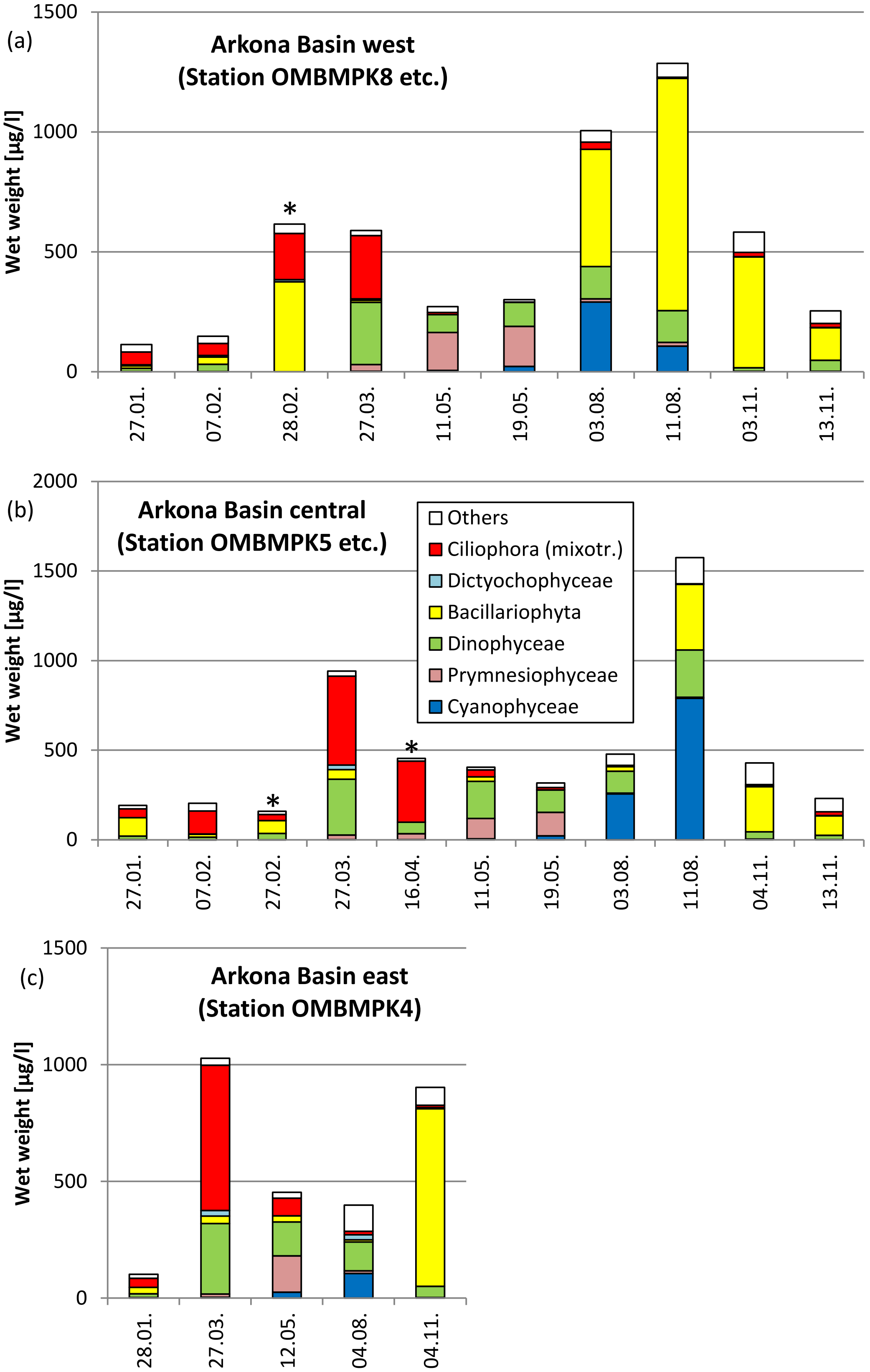


Fig. 13: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in the Arkona Basin (a-c) in 2016. Additional samples are marked with an asterisk above the column.

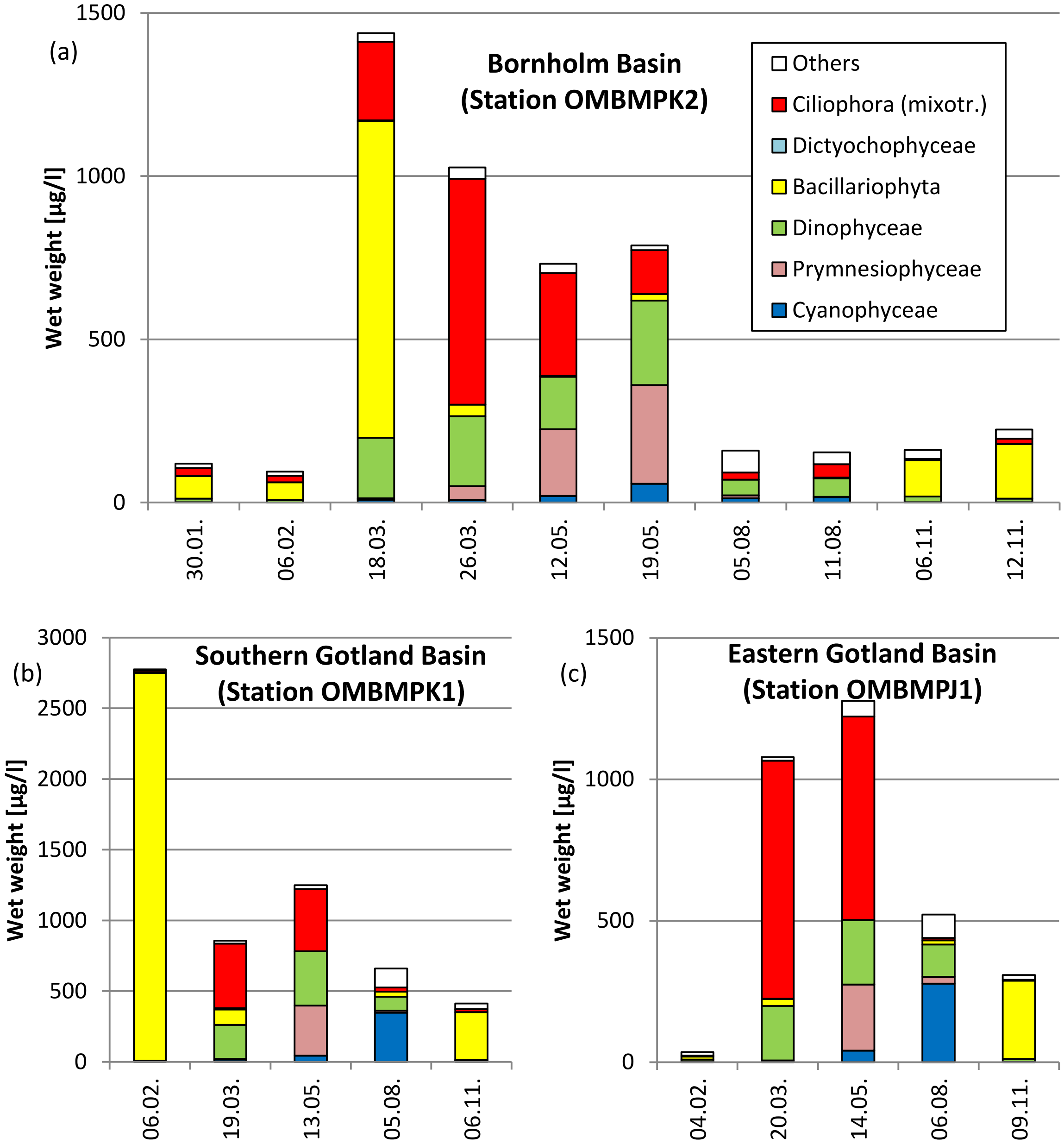


Fig. 14: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in the Bornholm Basin (a) and Eastern Gotland Basin (b, c) in 2016.

4.1.2.2 Summer Bloom

Belt Sea

Samples from only one cruise are available from the summer situation. Therefore, the information is fragmentary. Kiel Bay and Bay of Mecklenburg revealed a similar phytoplankton composition in summer 2016. Interestingly, a summer diatom bloom as supposed but not identified in some previous years was clearly proved in 2016. The summer diatom bloom was formed by *Proboscia alata*, *Dactyliosolen fragilissimus* and with a smaller contribution *Guinardia flaccida*, which are typical summer diatoms. The sample from 17 m depth was even more diverse and contained a higher biomass (11734 µg/L on station OMBMPN3, 17 m) than the surface sample. Species with more than 100 µg/L in this 17-m-sample were: *Guinardia flaccida* (10036 µg/L !), *Ceratium tripos* (408 µg/L), *Cerataulina pelagica, Prorocentrum micans, Thalassiosira eccentrica*, and *Proboscia alata*. A similar situation was found in the deep sample

(20 m) of station OMBMPM2: *Guinardia flaccida* (9825 µg/L !) and *Proboscia alata* (193 µg/L). In eastern direction, *Ceratium tripos* became insignificant.

Cyanobacteria blooms are not usual in Kiel Bay and Bay of Mecklenburg. However, in early August 2016, they formed rather high biomass (e.g. *Nodularia spumigena* 114 µg/L on station OMBMPN3, and 188 µg/L on station OMBMPN3, whereas *Aphanizomenon* was insignificant). Data from the coastal station Heiligendamm provide a more complete image. On 5 June 2016, the nitrogen-fixing cyanobacterium *Dolichospermum* sp. appeared suddenly with 261 µg/L, accompanied by *Aphanizomenon* sp. (19 µg/L) and *Nodularia spumigena* (only 7 µg/L). The short but extremely high cyanobacterium peak on 23 August 2016 (1934 µg/L in surface water) is of special importance as it provoked strong public interest (e.g. article by Maria Pistor in the newspaper „Norddeutsche Neueste Nachrichten“ from 23 August 2016). It was formed by *Nodularia spumigena*, which seems to be aged already as it is covered by *Nitzschia paleacea*. As it disappeared rather quickly, it was not necessary to close beaches. Also satellite images (Section 4.1.1) identified these cyanobacteria blooms in the western Baltic, which stayed at least until 24 August 2016 (Fig. 5), but may have extented even to the mid of September.

Arkona Basin

In the western Arkona Basin (stat. OMBMPK8), the diatoms known from the Bay of Mecklenburg (*Dactyliosolen fragilissimus* and with lower biomass also *Proboscia alata* and *Guinardia flaccida*) were dominating (Fig. 15). The biomass of *Dactyliosolen fragilissimus* (762 µg/L) may be considered as a bloom whereas in some previous years, a diatom bloom could not be proved. The contribution of diatoms decreased towards the east. Dinoflagellates were mainly represented by *Ceratium tripos*, *Alexandrium pseudogonyaulax* and *Prorocentrum* spp. A previously recorded accumulation of *Dinophysis* spp. at 20 m depth was not found here. Cyanobacteria were strongly developed in August 2016 (Fig. 15). They reached bloom concentrations, because they exceeded 200 µg/L (threshold according to WASMUND, 1997) and reached a peak of 790 µg/L (thereof 657 µg/L by *Nodularia spumigena*) on 11 August 2016 at station OMBMPK5. Satellite images revealed that the maximum of the cyanobacteria blooms in the Arkona Basin may have occurred around 24./25. August 2016 (Figs. 3c, 5).

Bornholm Basin

In the Bornholm Basin, phytoplankton biomass was low. In contrast to the Arkona Basin, neither a diatom bloom nor a cyanobacteria bloom could be found. However, satellite images revealed that cyanobacteria developed also in the Bornholm Basin (Fig. 3). Unidentified Gymnodiniales, *Plagioselmis prolonga, Mesodinium rubrum* and *Ebria tripartita* were the main taxa in surface water whereas also *Actinocyclus* sp. was found in the deeper water layer (20 m).

Eastern Gotland Basin

The summer was represented by only one sampling event, which cannot be representative for the whole season. Both in the southern part and the central part of the Eastern Gotland Basin, cyanobacteria were dominating. On station OMBMPJ1, they were composed of *Nodularia spumigena* (122 µg/L), *Aphanothece paralleliformis* (55 µg/L), *Aphanizomenon* sp. (33 µg/L) and *Pseudanabaena limnetica* (32 µg/L). The *Nodularia* trichomes were covered by the diatom *Nitzschia paleacea*. Dinoflagellates were mainly represented by unidentified Gymnodiniales (75 µg/L) and *Peridiniella danica* (14 µg/L). Other taxa were Prymnesiales, *Cymbomonas tetramitiformis, Pyramimonas* spp., *Anathece* and the *Scrippsiella*-complex.

Fig. 15: *Dactyliosolen fragilissimus, Guinardia flaccida, Proboscia alata, Ceratium tripos, Nodularia spumigena, Aphanizomenon* sp.*, Prorocentrum micans* in a net sample from 11 August 2016, Station OMBMPK8. Photo: S. Busch (IOW).

Summary on the summer bloom 2016:

1.) A summer diatom bloom was formed by *Proboscia alata*, *Dactyliosolen fragilissimus* and *Guinardia flaccida* in the Belt Sea and the western part of the Arkona Basin in the first half of August.

2.) Moderate to strong cyanobacteria blooms were found in all regions observed. They were not found in the samples from the Bornholm Basin, but satellite images proved that cyanobacteria blooms did also occur in that region.

4.1.2.3 Autumn Bloom

Belt Sea

The typical autumn bloom in the Belt Sea should be composed of dinoflagellates (*Ceratium*) and diatoms, sometimes as a mixture, but frequently as a succession of these two groups. As our autumn data are generally based on only one monitoring cruise, they may miss the blooms or some phases of the blooms. Therefore we have no complete and sometimes even misleading information. The weekly samplings from the coastal station Heiligendamm enabled a more complete image and are consulted in addition.

After the diatom summer bloom (*Proboscia alata*, *Dactyliosolen fragilissimus, Guinardia flaccida*), a diatom autumn bloom succeeded, dominated by *Cerataulina pelagica* (Fig. 16), in the entire Belt Sea area. This autumn bloom was proved for the period from 2 November to 13 November 2016 (Fig. 12), but according to the weekly coastal data from Heiligendamm, it stayed until the end of the year with changing intensity and composition (WASMUND et al. 2017). The accompanying species may be looked up in the Table A1.

It is striking that *Ceratium tripos*, that formed strong autumn blooms in some previous years, cannot grow to blooms anymore despite the presence of start populations in summer. The dinoflagellates were mainly represented by *Peridiniella danica, Polykrikos schwartzii, Ceratium fusus* and unidentified Gymnodiniales. Other taxa that were noteworthy in autumn 2015, like Prymnesiales, *Dictyocha speculum* or *Heterosigma akashiwo*, were insignificant in autumn 2016.

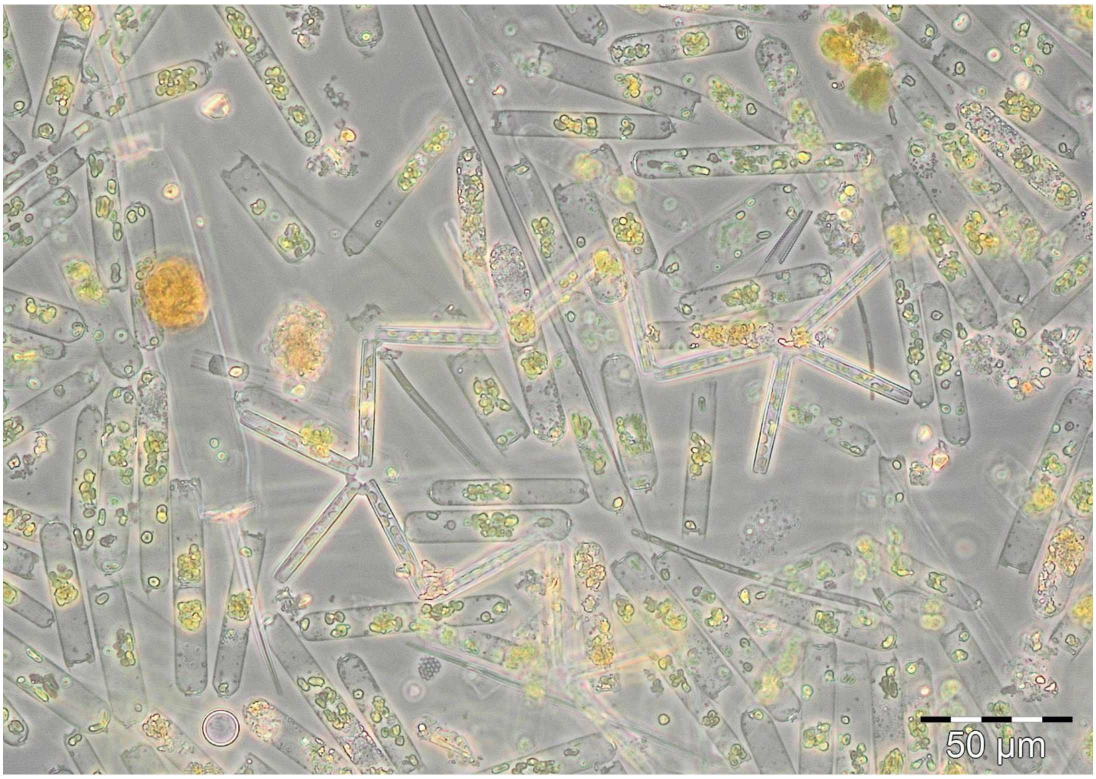


Fig. 16: *Cerataulina pelagica, Thalassionema nitzschioides, Ditylum brightwellii, Rhizosolenia pungens* and *Skeletonema marinoi* in a net sample from station OMBMPM1 from 13 November 2016. Photo: S. Busch (IOW).

Arkona Basin

As in the Bay of Mecklenburg, *Cerataulina pelagica* was the dominating species in autumn in the Arkona Basin. However, it less accompanied by *Ditylum brightwellii* but more by *Coscinodiscus granii* and *Actinocyclus* sp. as usual. The “bloom” was much smaller than in the Bay of Mecklenburg und the share of Dinoflagellates was smaller, too. A typical bloom of *Coscinodiscus granii* did not show up.Other flagellates of importance were *Pyramimonas* spp., *Teleaulax* spp. and *Plagioselmis prolonga*.

Bornholm Basin

The autumn phytoplankton of the Bornholm Basin (Fig. 8a) was clearly dominated by the typical *Coscinodiscus granii,* accompanied by *Actinocyclus* spp., but it did not reach bloom concentrations in the first half of November 2016. As *Cerataulina pelagica* was completely lacking, Bornholm Basin was different from the Arkona Basin.

Eastern Gotland Basin

Both the southern part and the central part of the Eastern Gotland Basin (stations OMBMPK1 and OMBMPJ1) were very similar to the Bornholm Basin concerning phytoplankton species composition and biomass.

Summary on the autumn bloom 2016:

1.) Autumn blooms were well-developed in Kiel Bay, Bay of Mecklenburg and the Arkona Basin, dominated by *Cerataulina pelagica*.

2.) In the Belt Sea, the development of *Ceratium* spp. started in the summer as usual, but for unknown reasons, they did not form the typical autumn bloom in 2016. Already in 2014 and 2015, we noticed the reduced presence of the typical *Ceratium tripos*.

3.) The typical *Coscinodiscus granii* developed in the Bornholm Basin and the Eastern Gotland Basin, but biomass stayed rather low in the first half of November 2016.

4.1.3 Regional Differences in Species Composition

Sampling locations are chosen so that they form a transect through the Baltic from Kiel Bay to the Eastern Gotland Basin. The composition of phytoplankton species along this transect changes markedly corresponding to the salinity gradient. While this has already been explained in the previous chapter, it is reiterated here in Figs. 17-20 using the most important species as examples. Sampling points with size corresponding to the mean seasonal biomass of the selected species are inserted into the maps.

Coscinodiscus concinnus, as a marine species, formed a spring bloom only in the surface water of Kiel Bay (station OMBMPN3) and in the central Bay of Mecklenburg (station OMBMPM2), but was also highly present in deep water up to Darss Sill. *Skeletonema marinoi* may form blooms in the Arkona Basin and the Bornholm Basin. *Mesodinium rubrum* (Fig. 17 a) is the typical representative of the spring bloom in the Baltic Proper with decreasing tendency to the west whereas Prymnesiales seem to be rather indifferent (Fig. 17 b). The large summer blooms of diatoms occur primarily in the western Baltic: *Guinardia flaccida* (Fig. 17 c), *Dactyliosolen fragilissimus* (Fig. 18 a), and *Proboscia alata* (Fig. 18 b). Cyanobacteria blooms, mainly represented by *Nodularia spumigena*, are typical for the Baltic Proper but were exceptionally occurring also in the western Baltic (Fig. 18 c). The autumn bloom in the Belt Sea was mainly represented by *Cerataulina pelagica* (Fig. 19 a), *Ditylum brightwellii* (Fig. 19 b), *Skeletonema marinoi* (Fig. 19 c), *Pseudosolenia calcar-avis* (Fig. 20 a), and *Pseudo-nitzschia* spp. (Fig. 20 b). On the other hand, *Coscinodiscus granii* was the bloom-forming diatom of the autumn in the Baltic Proper (Fig. 20 c).

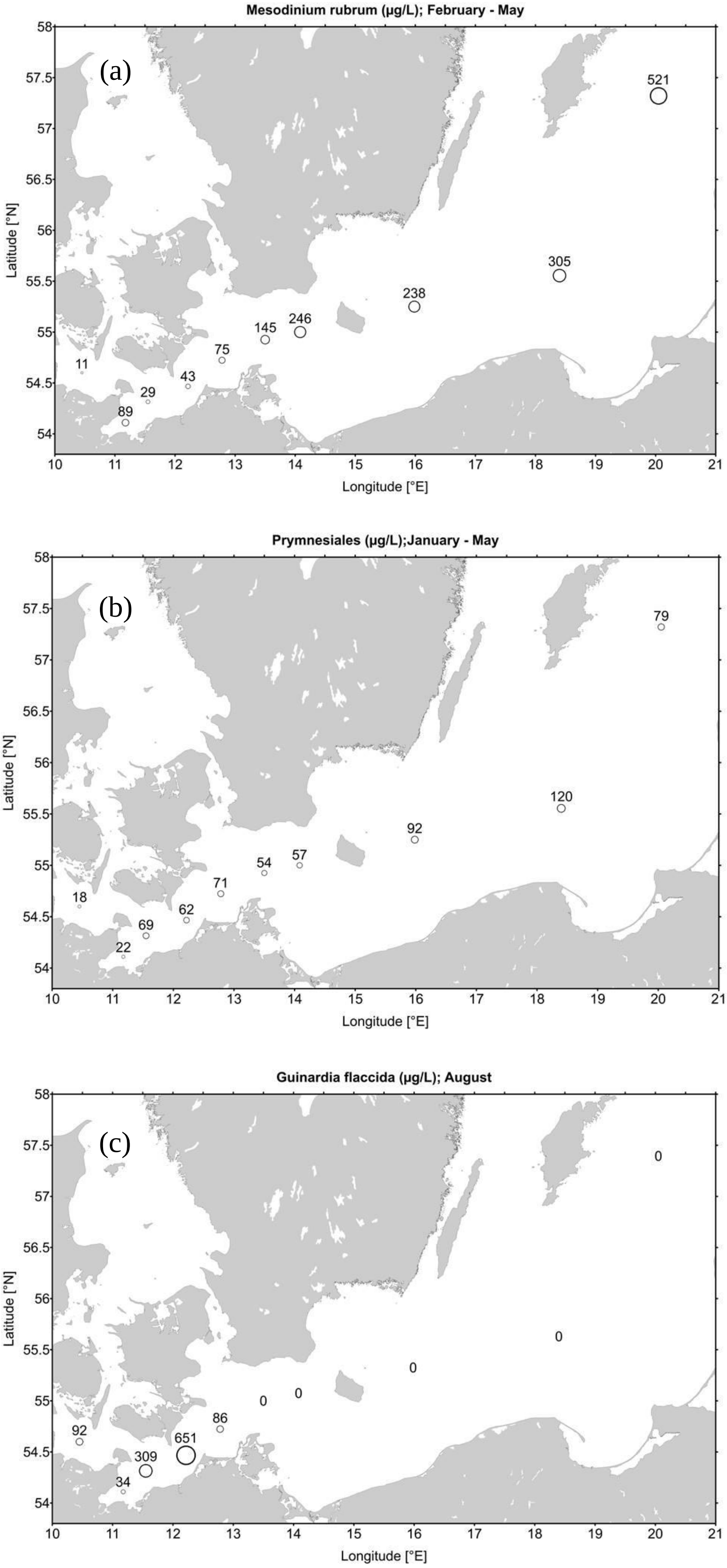


Fig. 17: Distribution of *Mesodinium rubrum* (a) and *Prymnesiales* (b) in spring 2016 and *Guinardia flaccida* (c) in summer 2016.

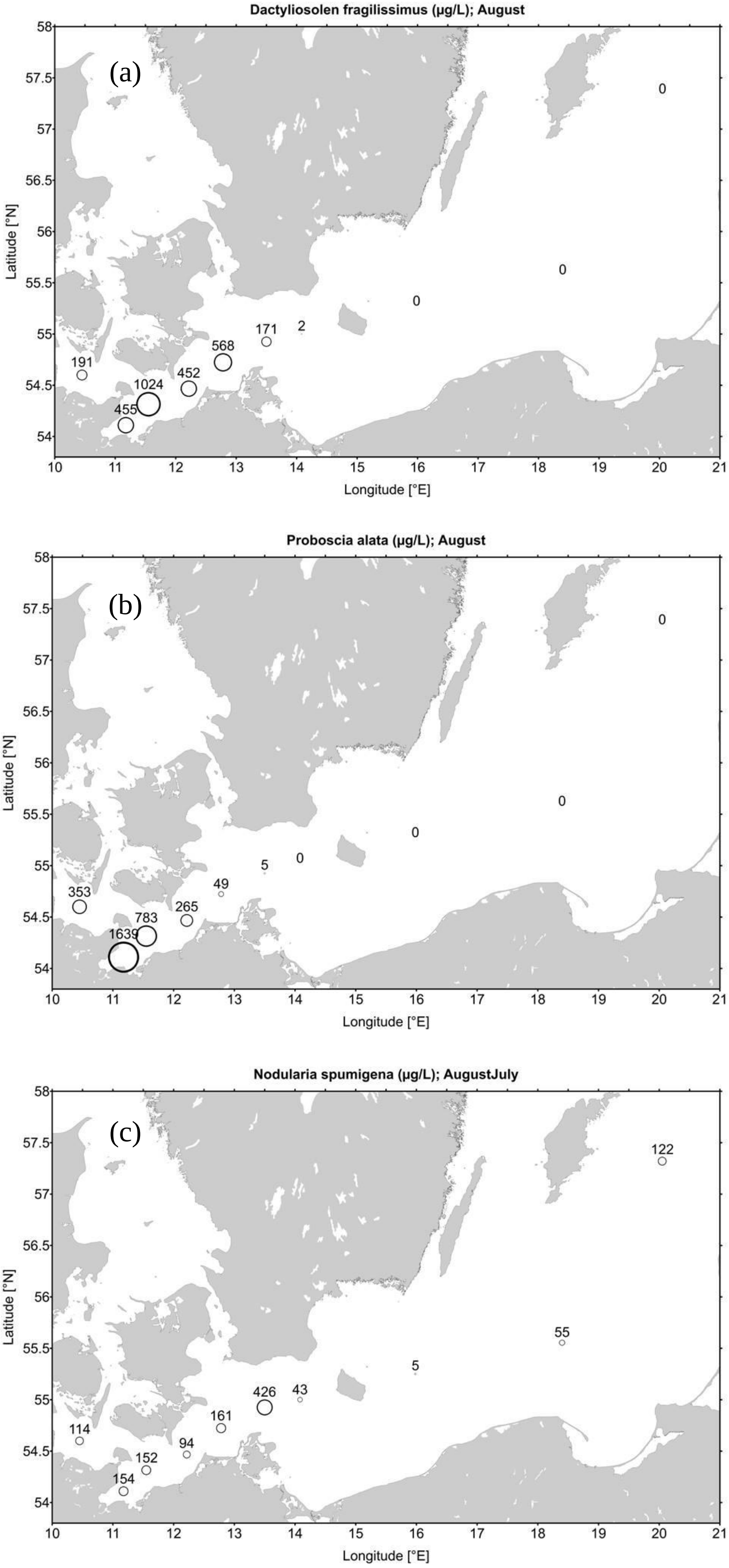


Fig. 18: Distribution of *Dactyliosolen fragilissimus* (a), *Proboscia alata* (b) and *Nodularia spumigena* (c) in summer 2016.

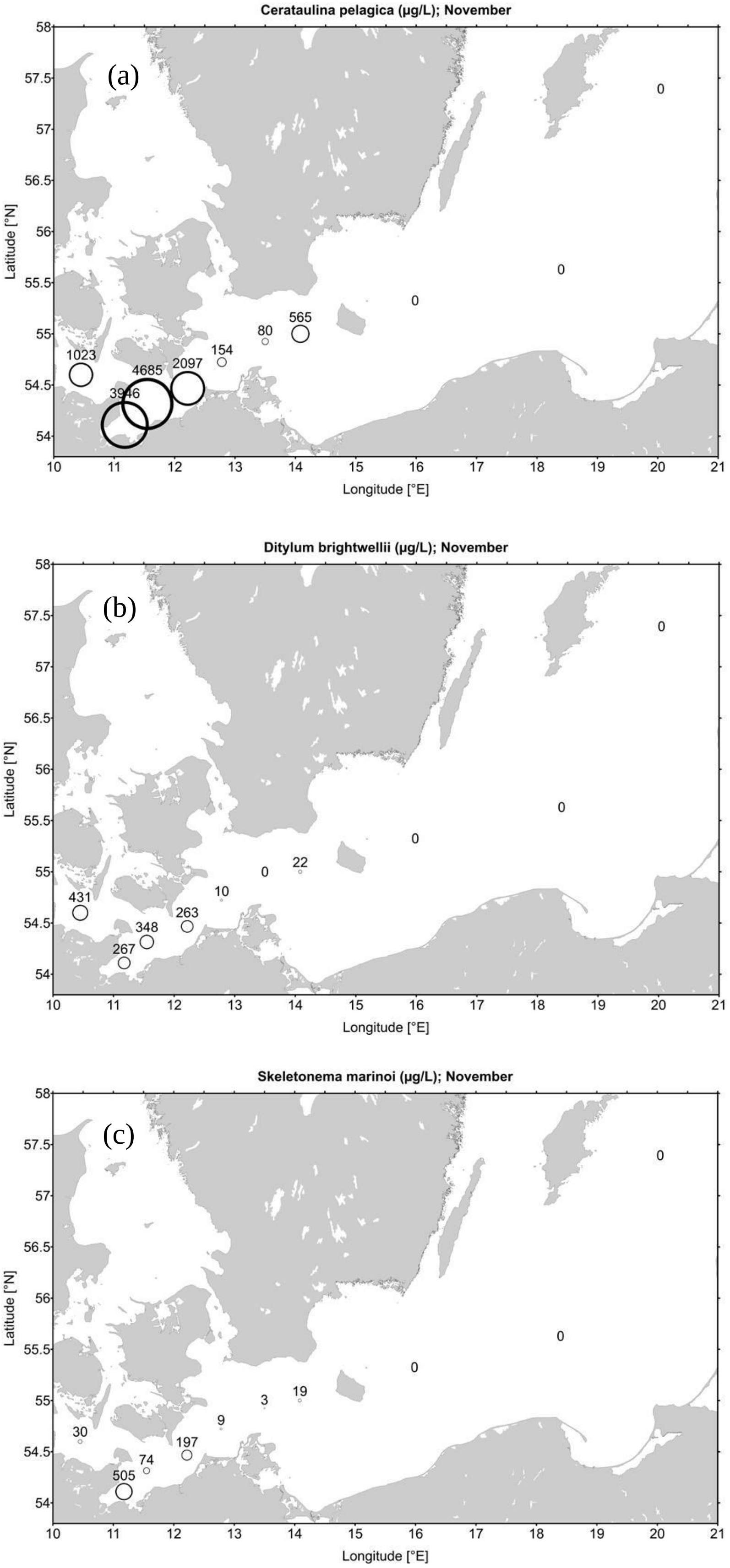


Fig. 19: Distribution of *Cerataulina pelagica* (a), *Ditylum brightwellii* (b) and *Skeletonema marinoi* (c) in autumn 2016.

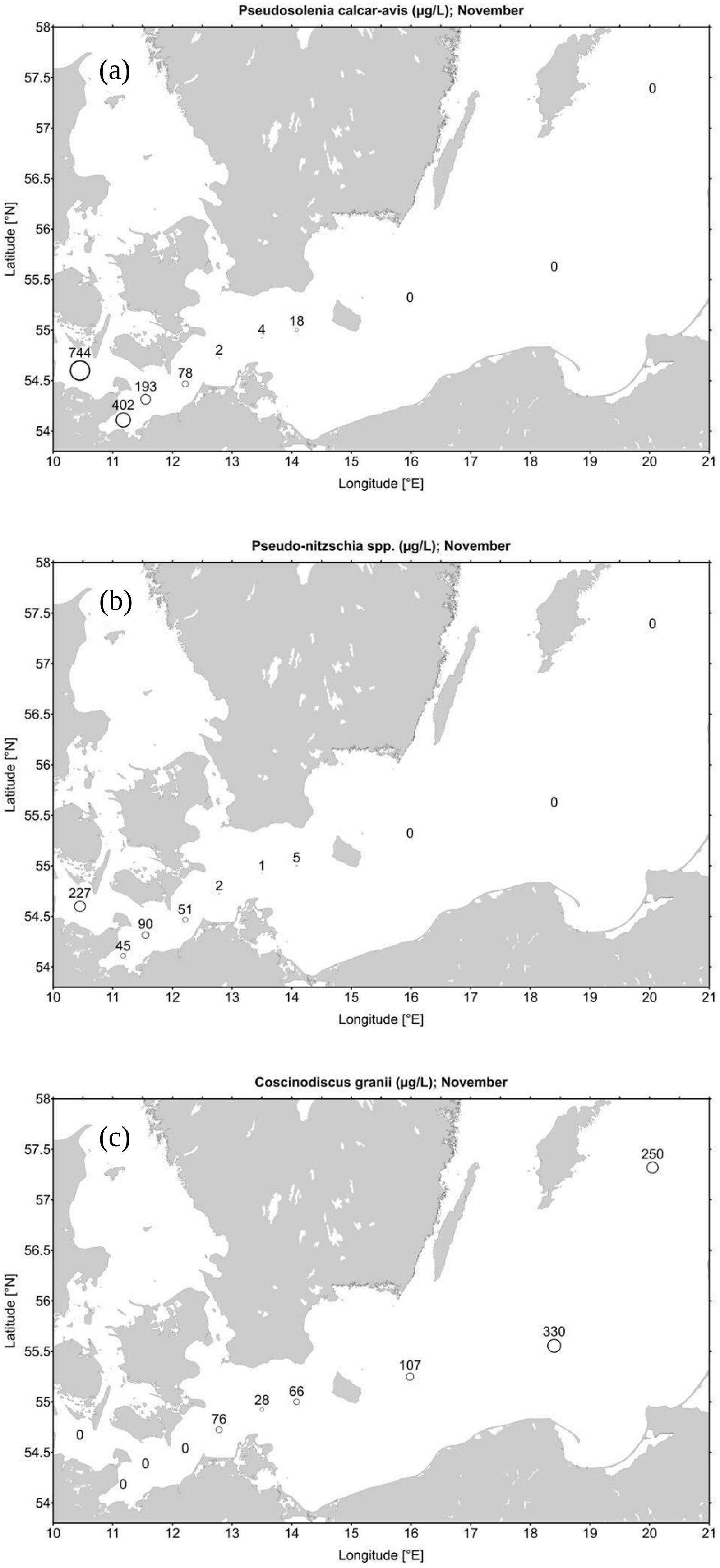


Fig. 20: Distribution of *Pseudosolenia calcar-avis* (a), *Pseudo-nitzschia* spp. (b) and *Coscinodiscus granii* (c) in autumn 2016.

4.1.4 Changes in Species Composition

The protection of the marine environment not only means achieving and maintaining good water quality and the natural productivity of a waterbody, but also means preserving its natural diversity. The immigration and establishment of new species is associated with the displacement of native species. While this might temporarily increase biodiversity locally (α-diversity), it causes typical biocoenotic structures to disappear, and leads to a reduction in global biodiversity (β-diversity).

This is why efforts are made to prevent the introduction of new species. In the case of phytoplankton, this is difficult as it has a great variety of entry routes that cannot be blocked. *Prorocentrum cordatum* (old synonym: *Prorocentrum minimum*, cf. Table 4) serves as an example of an invasive phytoplankton species that has probably entered the Baltic naturally via the Kattegat. HAJDU et al. (2000), OLENINA et al. (2010), and TELESH et al. (2016) have impressively traced the advance of this species which in places has occasionally become dominant. In contrast, *Prorocentrum balticum* has vanished (WASMUND et al. 2008).

It is known that marine species such as *Cerataulina pelagica, Chaetoceros brevis,* and *Dactyliosolen fragilissimus* are sometimes carried into the Baltic Sea as far as the Lithuanian coast (HAJDU et al. 2006). In this sense these species are indicators of inflows not only of deep water but also of surface water from the North Sea. Some of the intruded marine species had become established, while others had disappeared (OLENINA & KOWNACKA, 2010).

In 2009, *Noctiluca scintillans, Lennoxia faveolata, Chaetoceros lorenzianus* and *Phaeodactylum tricornutum* were new marine species in our samples, but they should be regarded as isolated finds in only a few specimen: they disappeared again by 2012 at the latest. The first three reappeared in 2014, and *Lennoxia faveolata* and *Phaeodactylum* cf. *tricornutum* established in 2015 and 2016 (Table A2).

Spatulodinium pseudonoctiluca was new to us in 2014, and it was still present in 2015 and 2016. Normally the marine dinoflagellate *Polykrikos schwartzii* was rarely found in our samples before, but in autumn 2014 it had relatively high levels of biomass in the western Baltic, and it is still important there. We first detected the dinoflagellate *Alexandrium pseudogonyaulax* in the western Baltic in summer 2010; it has now become established. The diatom *Pseudosolenia calcar-avis*, which occurred in large numbers in autumn 2010, has not been observed in 2013 and 2014. However, it reappeared in 2015 and holds the high biomass rank of 10 (Table A2, Fig. 20 a, see also KAISER et al. 2016). High biomass levels of *Peridiniella danica* first occurred in 2011 (rank 5). This dinoflagellate has declined in the following years but has re-established.

The difficulties involved in identifying naked Dictyochophyceae have already been discussed in chapter 4.1.2. Since 2009 we have attempted to distinguish *Pseudochattonella farcimen* (old synonym: *Verrucophora farcimen*) from the naked form of *Dictyocha speculum*, and have since included it in our lists. The spring species *Dictyocha speculum* occurred vigorously in 2007 and 2008, especially in the Belt Sea, but was relatively insignificant in 2010, nor were elevated levels of *Pseudochattonella* observed then. In 2011, Dictyochophyceae occurred in strength, ranking 6th, with *Pseudochattonella farcimen* identified to a high extent. However, *Pseudochattonella farcimen* did not appear in samples in 2012, 2014 and 2016. In 2012 and 2013, biomass of *Dictyocha speculum* was low, but a strong spring bloom of *Dictyocha speculum* recurred in 2014. In 2015 the two species occured together and formed a spring bloom in Kiel Bay and the Bay of Mecklenburg. In 2016, the appearance of *Dictyocha speculum* was weak. Already in 2013 its presence was stronger in autumn than in spring, surprisingly. Also in 2016, this species occurred both in spring and in autumn mainly in Kiel Bay and Lübeck Bay.

The cold-water diatom *Achnanthes taeniata* formed blooms in the Baltic Proper in the 1980s, but has sharply declined (HELCOM 1996; WASMUND et al. 2011 b). The mild winters of the 1990s seem to have harmed it. Exceptionally it was dominant in 2011 after a strong winter. From 2012 to 2015 it was hardly represented at all, and it was completely absent in 2016.

The recent series of inflow events, e.g. the Major Baltic Inflow of December 2014 (MOHRHOLZ et al. 2015), should have transported marine species into the Baltic Sea which should appear in our samples from 2015. Only *Coscinodiscus centralis, Roperia tesselata, Karenia mikimotoi* and *Nematopsides vigilans* were new for us in 2015, but their identification was not proved. They were not found in 2016 anymore.

The only species that were new for us in 2016 was *Karlodinium veneficum* (Fig. 21; old synonyms: *Karlodinium micrum, Gymnodinium galatheanum*). Also this identification was not easy and is not verified. Moreover, this species may have occurred earlier and was simply put into the group of unidentified Gymnodiniales before.

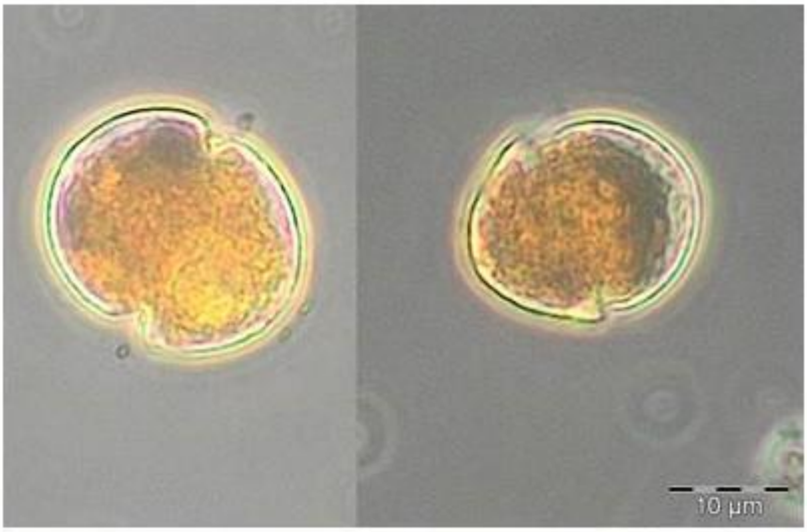


Fig. 21: *Karlodinium veneficum* from station OMBMPJ1, 20 m depth, on 14 May 2016. Photo: S. Busch (IOW).

4.1.5 Chlorophyll *a*

Table 6 shows the annual variations in chlorophyll *a* concentrations based on the monitoring cruises. The annual variations in chlorophyll *a* correspond roughly to those given for biomass in Figs. 12-14. Mean values for the uppermost 10 m, averaged from samples of 1 m, 5 m and 10 m depth, are shown for each date and station. As explained in chapter 2.3, we determine 'total chlorophyll *a*' values ('chl.a-tot'), which are uncorrected for phaeopigments.

Table 6
Mean concentrations of total chlorophyll *a* from 0 – 10 depth.

Station	Datum	Chl.a-tot (mg m^{-3})
OMBMPN3	26.01.2016	1.76
OMBMPN3	28.03.2016	1.66
OMBMPN3	10.05.2016	1.42
OMBMPN3	02.08.2016	1.46
OMBMPN3	03.11.2016	7.05
OMO22	27.01.2016	1.16
OMO22	28.03.2016	2.12
OMO22	10.05.2016	1.08
OMO22	03.08.2016	2.20
OMO22	02.11.2016	8.76
OMBMPM2	27.01.2016	1.31
OMBMPM2	28.03.2016	1.37
OMBMPM2	10.05.2016	1.68
OMBMPM2	19.05.2016	1.59
OMBMPM2	03.08.2016	2.95
OMBMPM2	12.08.2016	2.21
OMBMPM2	02.11.2016	10.45
OMBMPM2	13.11.2016	8.06
OMBMPM1	27.01.2016	1.38
OMBMPM1	07.02.2016	1.01
OMBMPM1	27.03.2016	0.92
OMBMPM1	11.05.2016	1.84
OMBMPM1	19.05.2016	2.06
OMBMPM1	03.08.2016	2.40
OMBMPM1	11.08.2016	2.00
OMBMPM1	03.11.2016	10.46
OMBMPM1	13.11.2016	4.14
OMBMPK8	27.01.2016	1.71
OMBMPK8	07.02.2016	1.24
OMBMPK8	27.03.2016	1.15
OMBMPK8	11.05.2016	1.43
OMBMPK8	19.05.2016	2.22
OMBMPK8	03.08.2016	2.79
OMBMPK8	11.08.2016	2.27
OMBMPK8	03.11.2016	3.70
OMBMPK8	13.11.2016	2.44
OMBMPK5	27.01.2016	1.12
OMBMPK5	07.02.2016	1.70
OMBMPK5	27.03.2016	2.10
OMBMPK5	11.05.2016	1.32
OMBMPK5	19.05.2016	1.85
OMBMPK5	03.08.2016	3.23
OMBMPK5	11.08.2016	6.69
OMBMPK5	04.11.2016	3.72
OMBMPK5	13.11.2016	2.76
OMBMPK4	28.01.2016	1.21
OMBMPK4	27.03.2016	2.24
OMBMPK4	12.05.2016	1.47
OMBMPK4	03.08.2016	3.24
OMBMPK4	04.11.2016	4.09
OMBMPK2	30.01.2016	0.89
OMBMPK2	06.02.2016	0.85
OMBMPK2	18.03.2016	4.81
OMBMPK2	26.03.2016	3.29
OMBMPK2	12.05.2016	2.54
OMBMPK2	19.05.2016	3.41
OMBMPK2	05.08.2016	2.11
OMBMPK2	11.08.2016	2.11
OMBMPK2	06.11.2016	1.48
OMBMPK2	12.11.2016	1.35
OMBMPK1	06.02.2016	0.70
OMBMPK1	19.03.2016	2.13
OMBMPK1	13.05.2016	4.11
OMBMPK1	05.08.2016	3.62
OMBMPK1	06.11.2016	2.04
OMBMPJ1	04.02.2016	0.45
OMBMPJ1	20.03.2016	3.05
OMBMPJ1	14.05.2016	3.71
OMBMPJ1	06.08.2016	3.18
OMBMPJ1	09.11.2016	1.44

Typically, the annual maximum concentration of chlorophyll *a* coincided with the spring bloom. In 2016, the spring bloom was best met by the additional cruises (cf. Figs. 12 a, c), but chlorophyll samples were not taken during these cruises. Thus, the spring bloom is not visible in the chlorophyll data. Moreover, large diatoms are poor in chlorophyll. Therefore, the summer bloom is best reflected in chlorophyll values if the bloom was rich in dinoflagellates and cyanobacteria (11 August 2016, station OMBMPK5). The maxima of the chlorophyll concentrations appear during the autumn bloom (2/3 November 2016 in Bay of Mecklenburg).

Figs. 22-24 present the horizontal distribution of chlorophyll *a* values determined during the 5 monitoring cruises in 2016. They visualise the maxima in autumn in the Bay of Mecklenburg. The values are lower than those given in Table 6 because mean values from the outward and return leg of each cruise are depicted in contrast to single values in Table 6.

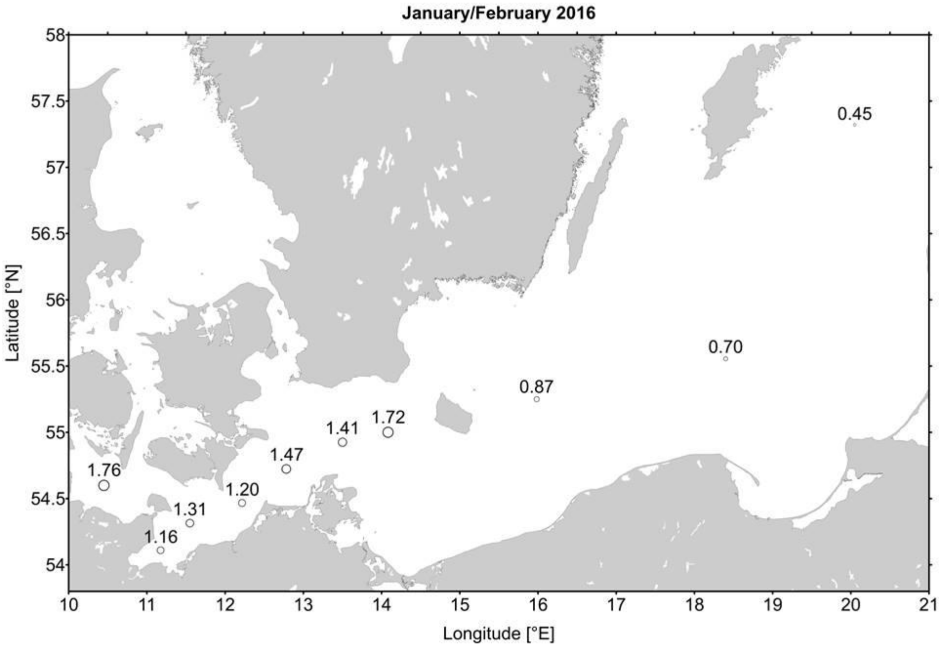


Fig. 22: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during the monitoring cruise of January/February 2016.

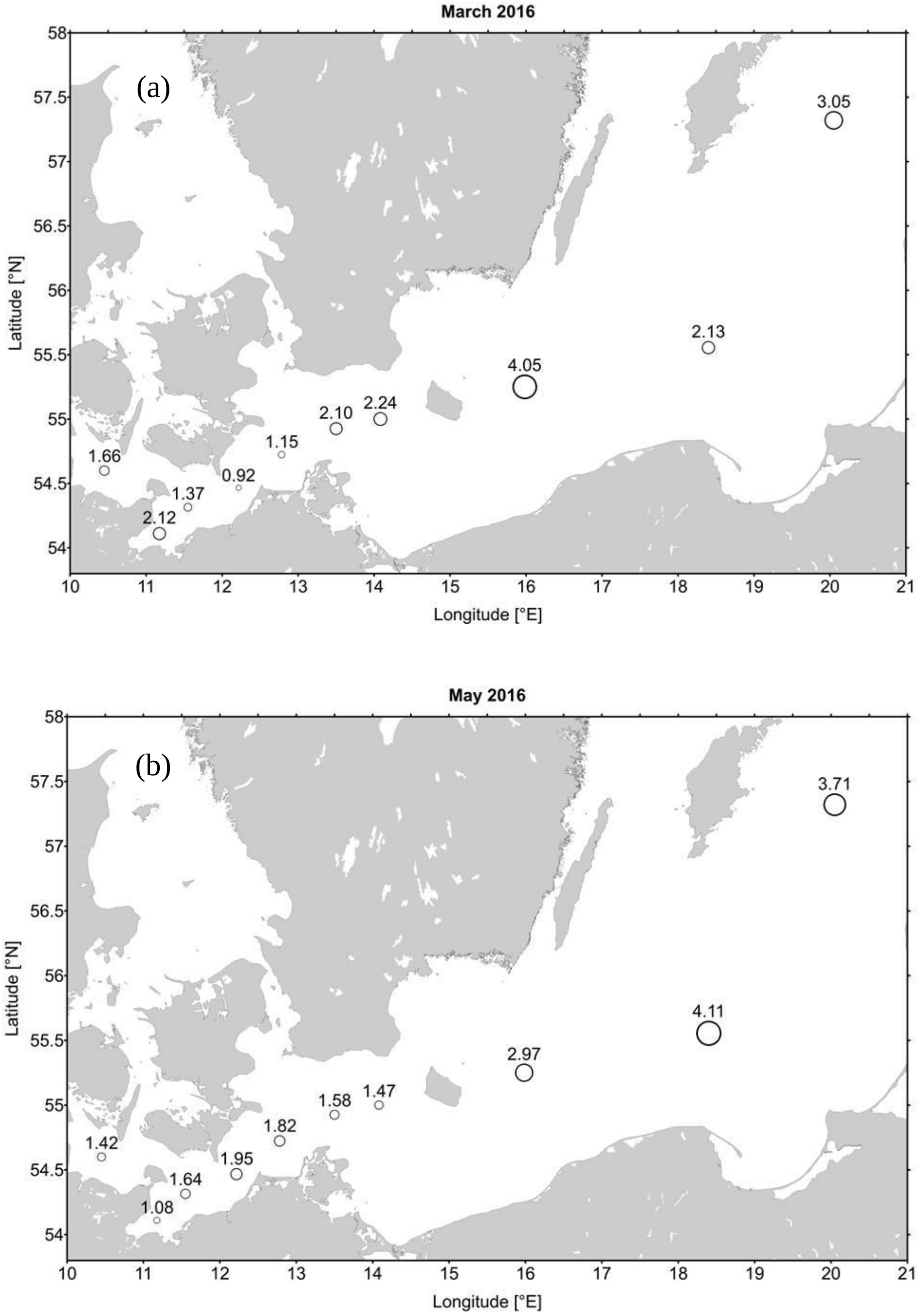


Fig. 23: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during monitoring cruises in March and May 2016.

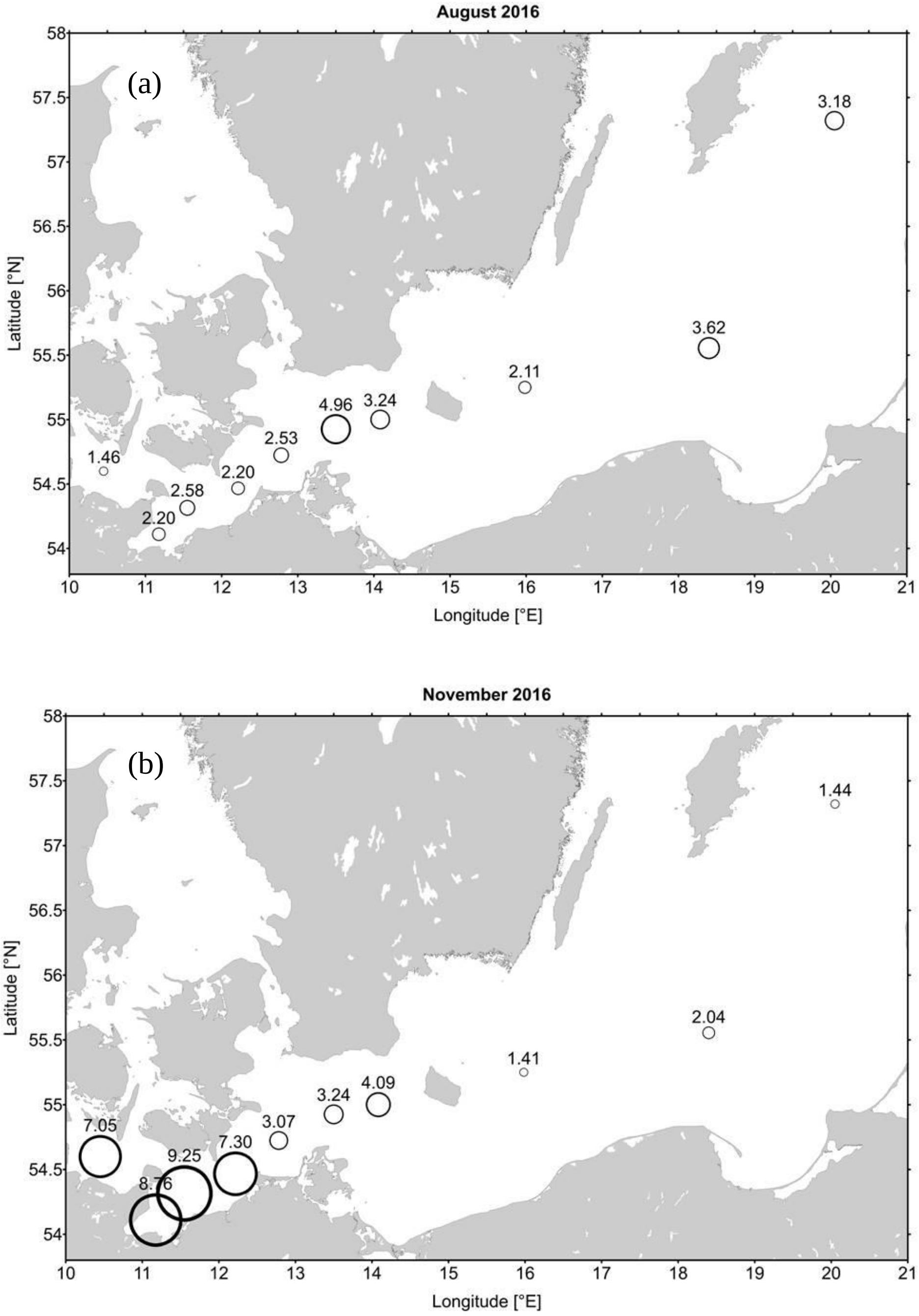


Fig. 24: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during monitoring cruises in August and November 2016.

4.1.6 Sedimentation

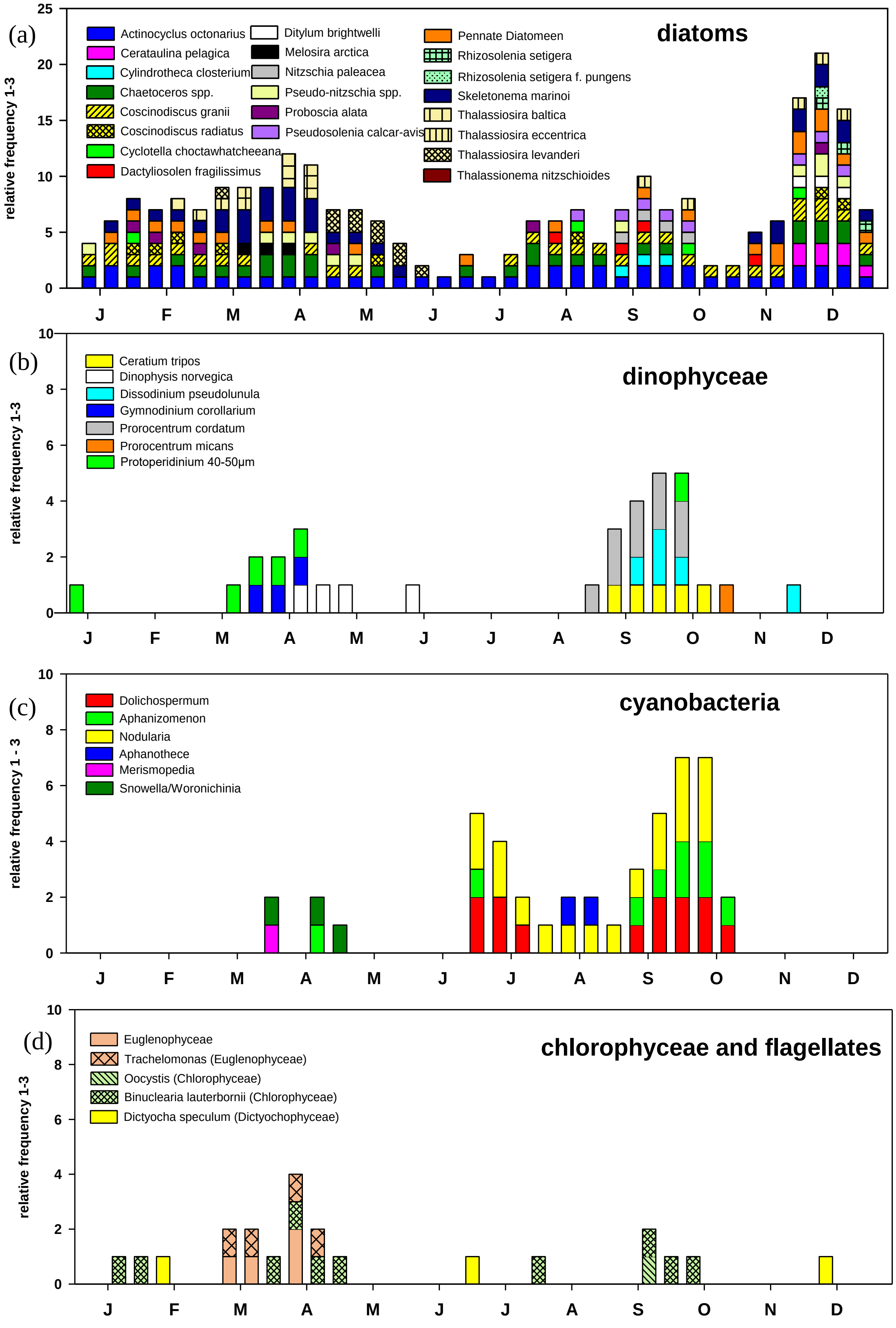
The microscopic examination of the material collected in the Arkona Basin in 2016 showed again the typical growth pattern of pelagic algae in the western Baltic. High particle flux in spring and late autumn was met by equivalent rates in summer. With 22 species/groups of diatoms found in the trapped material in 2016 the number increased again by 4 compared to the previous years and caused domination by diatoms in terms of species richness and quantity.

Over the pelagic growth phase (March to December; Fig. 25), again the known seasonal succession of communities was observed. However, in this year the regular spring bloom in late March was already preceded by a diverse (6-8 species) community of diatoms from February onwards, which consisted of typical spring species: *Actinocyclus octonarius, Chaetoceros* spp., *Coscinodiscus granii, Coscinodiscus radiatus, Skeletonema marinoi*, *Thalassiosira baltica, Thalassiosira levanderi* and some pennate diatoms (Fig. 25 a). In the quantitatively important stage of the bloom in March and April, *Skeletonema marinoi, Thalassiosira baltica,* and *Chaetoceros* spp. increased their abundance and formed the bulk of pelagic algae like in the previous year. In April, *Thalassiosira levanderi* and *Coscinodiscus radiates* joined the declining biomass of the spring community and diatoms then decreased in numbers and biomass over the summer period. In this phase, only *Actinocyclus octonarius* was present, which was the only diatom that could be continuously found in samples over the entire year. From July until October, diatom diversity increased again with a mixture of *Chaetoceros* spp., *Coscinodiscus granii, Proboscia alata, Dactyliosolen fragilissimus, Pseudosolenia calcar-avis, Cyclotella choctawhatcheeana, Thalassiosira eccentrica, Nitzschia paleacea,* and other small pennate diatoms. After a second minimum with just *Coscinodiscus grani* and *Actinocyclus octonarius* in October a late development of diatoms followed towards the end of the year with the high diversity of 14 species occurring simultaneously, among them *Ditylum brightwellii*, *Cerataulina pelagica* and *Rhizosolenia setigera*, which had not been observed before in this year.

In contrast to diatoms, the number of dinoflagellate taxa decreased from 10 in 2015 to 7 in 2016 (Fig. 25 b). The dinoflagellates displayed a comparatively strict seasonal succession with only up to 4 species occurring at the same time and distinct distribution peaks in spring and late summer with assemblages of different species. In the spring period (March to May) we mainly found *Protoperidinium* spp., *Dinophysis norvegica* and *Gymnodinium corollarium* whereas summer/autumn *Prorocentrum cordatum, Prorocentrum micans, Dissodinium pseudolunula, Ceratium tripos* and *Protoperidinium* spp. made up the dinoflagellate community with a low diversity but high abundance. The general seasonal pattern of dinoflagellate succession was similar to previous years.

The number of cyanobacterial species observed in 2016 remained on the same level in comparison with the previous year (Fig. 25 c). During summer, a mixture of diazotrophic genera (*Aphanizomenon, Dolichospermum* and *Nodularia*) co-appeared with *Aphanothece (Anathece)* which has no capability of nitrogen-fixation. The spring population of *Aphanizomenon, Snowella/Woronochinia* and *Merismopedia* was quantitatively not important and in late autumn/winter no cyanobacteria were detected in the sediment traps, which was quite different in the previous year. The occurrence of the nitrogen-fixing species between June and September is again reflected by the shift in the isotopic signature of the particulate nitrogen from 6 ‰ to 2-4 ‰ over the summer. The high abundance of diazotrophs and the isotopic signature of the particulate nitrogen suggest that during summer 2016 a substantial part of sinking organic matter was produced by nitrogen-fixing organisms.

The temporal distribution of Chlorophyceae (green algae; Fig. 25 d) shows a picture different from that in 2015. A low abundance in winter and during the summer growth period contrasts with higher numbers in spring from March to May. These maxima are based on high abundances of euglenophytes (*Trachelomonas* and unidentified species) and *Binuclearia lauterbornii* (old synonym: *Planctonema lauterbornii). Dictyocha speculum* occurred sporadically over the year in lower numbers.



1= present 2= abundant 3= highly abundant

Fig. 25 a-d: Relative frequency of selected species of diatoms, dinoflagellates, cyanobacteria and green algae in sedimented organic material in 2016.

The vertical flux of carbon (Fig. 26), nitrogen (Fig. 27), suspended particulate matter (SPM) (Fig. 28) and phosphorus (Fig. 29) showed a coherent seasonal pattern in 2016. This year, currents and turbulence levels at the benthic boundary seem to have been lower than in previous periods, so that resuspension events were of minor importance. This is reflected in the weight percentage of carbon in the collected matter (Fig. 30). Whereas the sediment contains 3-5 % carbon, the trapped material always was above 8 % with 12.4 % for the bulk and more than 25 % in the maximum. Extremes in the sedimentation of silica (Fig. 31) compared to the other biogenic variables were missing and the peaks in organic compounds and microscopically observed diatoms always corresponded to those of silica, which indicates a low contribution of sediment derived clay and other inorganic siliceous minerals.

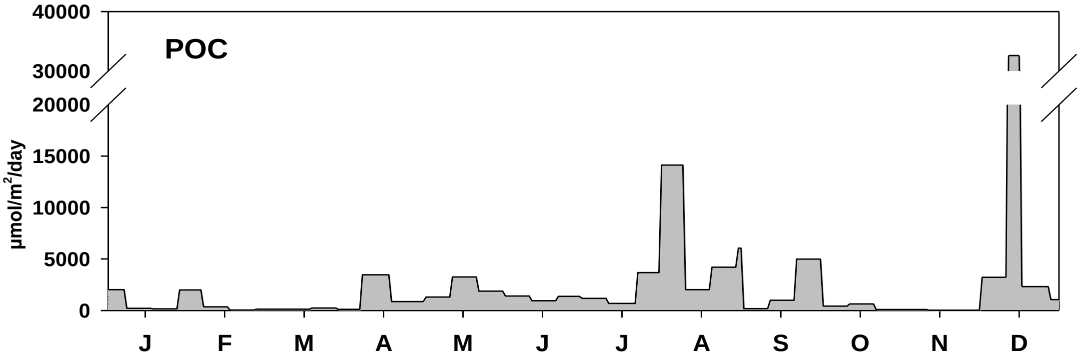


Fig. 26: Daily sedimentation rates of particulate organic carbon (POC) at 35 m depth in the central Arkona Basin in 2016.

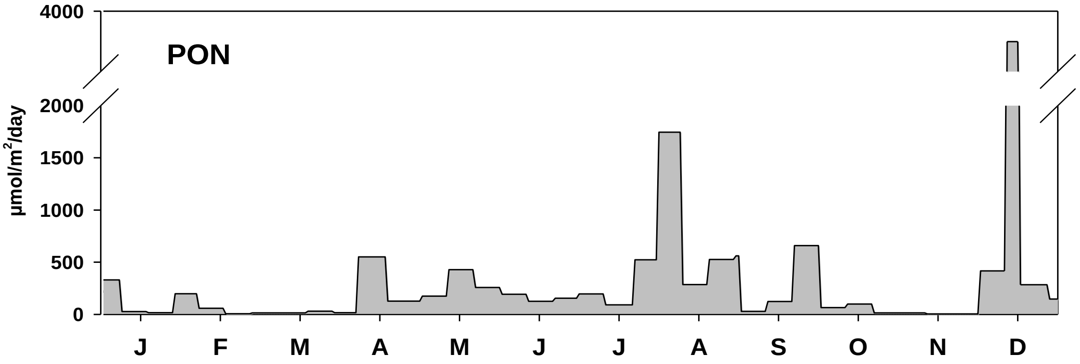


Fig. 27: Daily sedimentation rates of particulate organic nitrogen (PON) at 35 m depth in the central Arkona Basin in 2016.

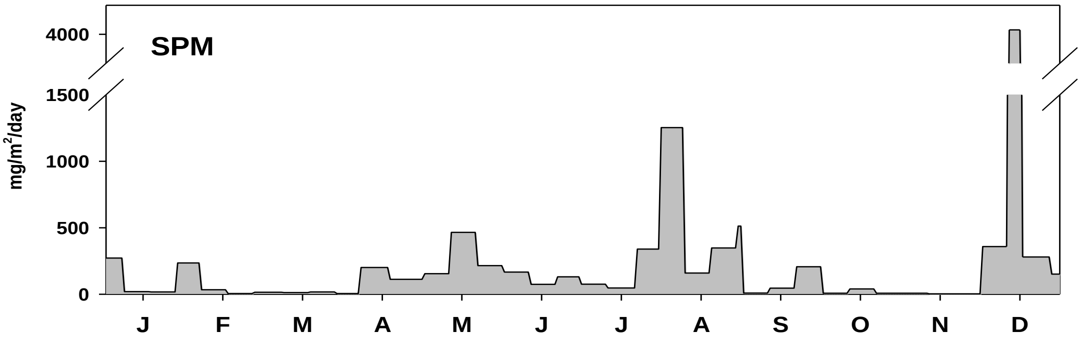


Fig. 28: Daily sedimentation rates of suspended particulate matter (SPM) at 35 m depth in the central Arkona Basin in 2016.

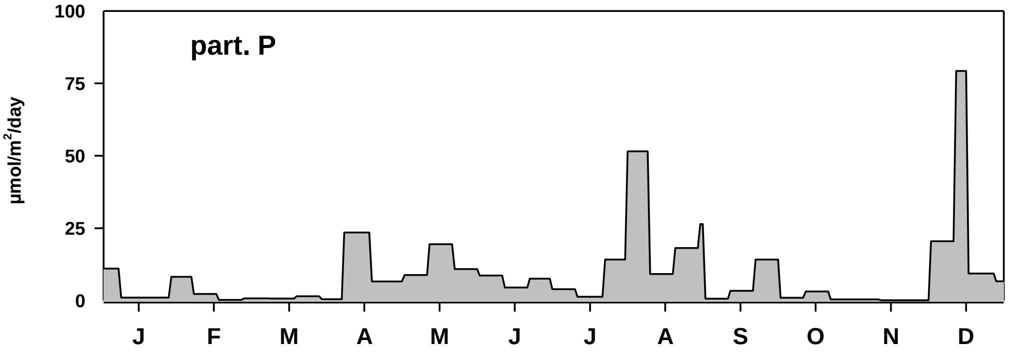


Fig. 29: Daily sedimentation rates of particulate phosphorus (part. P) at 35 m depth in the central Arkona Basin in 2016.

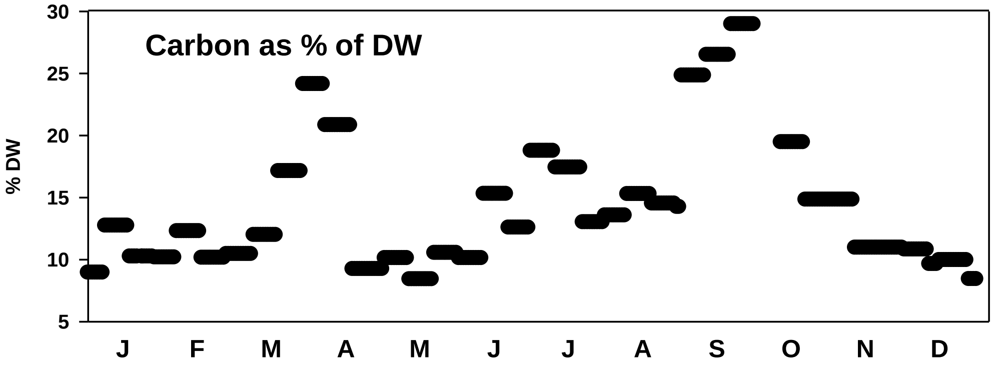


Fig. 30: Percentage of organic carbon in sedimented matter (% dry weight) at 35 m depth in the central Arkona Basin in 2016.

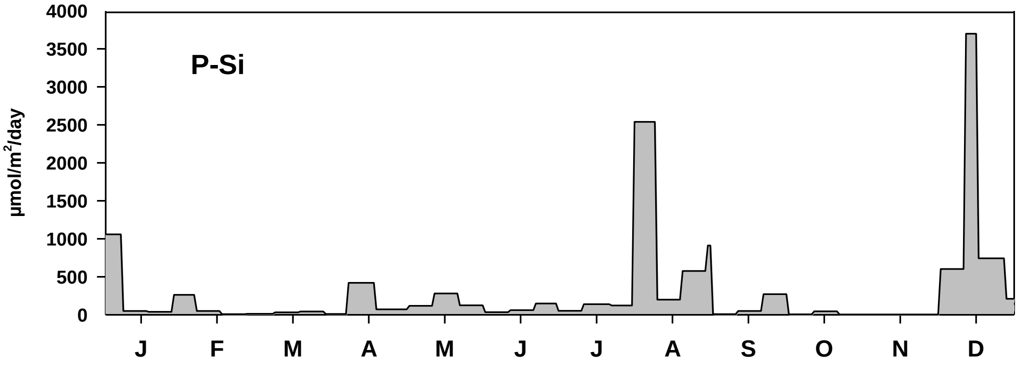


Fig. 31: Daily sedimentation rates of particulate biogenic silica (P-Si) at 35 m depth in the central Arkona Basin in 2016.

Similar to 2015 the spring diatom bloom, although highly divers in species, was not the main contributor of organic material to the sea floor. Highest peaks in particle flux occurred in summer derived from a sequence of diatoms and cyanobacteria with only few but highly abundant species. This resembles both the qualitative and quantitative pattern of 2015 and poses the same questions. Diazotrophic cyanobacteria are indicators for nitrogen limitation, whereas diatoms usually indicate new production modes based on free nitrate or ammonia. Like in 2015 both groups of organisms were again observed in consecutive samples over that period together with independent indicators for both sources like high biogenic silica levels (Fig. 31) and a low δ¹⁵N-signature (Fig. 32). This succession of diverging communities provided a high export of biogenic material from the photic zone (Figs. 26-29, 31). The species spectrum within the diatoms was different from the spring community, so that the combination of a late spring bloom and a consequential summer bloom can be excluded. Therefore only a fast sequential transition between diatom-rich water masses from the Western Baltic and nitrogen depleted surface water with diazotrophic cyanobacteria from the Bornholm Basin could have provided such a pattern. Wind direction measured on the IOW-Marnet station Arkona during this period showed several short term changes from easterly to westerly winds and therefore support the idea of a periodic exchange of the surface mixed layer.

Another quantitatively important portion of sinking biomass in 2016 was contributed by a late autumn bloom in November/December that consisted of a large variety of diatom species (up to 14 in one sample) and produced the largest single peak in C, N, P, Si and SPM of the year. Whereas the elemental ratios like C/N and C/P (Figs. 33, 34) in this material did not differ from the general level during that period, the δ¹⁵N-signature (Fig. 32) shows a sudden increase from around 4‰ up to 8‰, which indicates the source of the nitrogen in the late algal biomass to be external. As the central Baltic up to the western Bornholm Sea is characterized by a large input of light nitrogen isotopes due to nitrogen fixation over the summer and cannot supply heavy nitrogen isotopes, an intrusion of a surface water mass loaded with nitrogeneous nutrients from livestock farming can be assumed as an explanation. As northerly winds and high salinity occurred during that time, the origin of the water may be assumed rather in Danish waters of the Öresund than in the riverine input (Rivers Peene or Oder) of the southern Arkona basin.

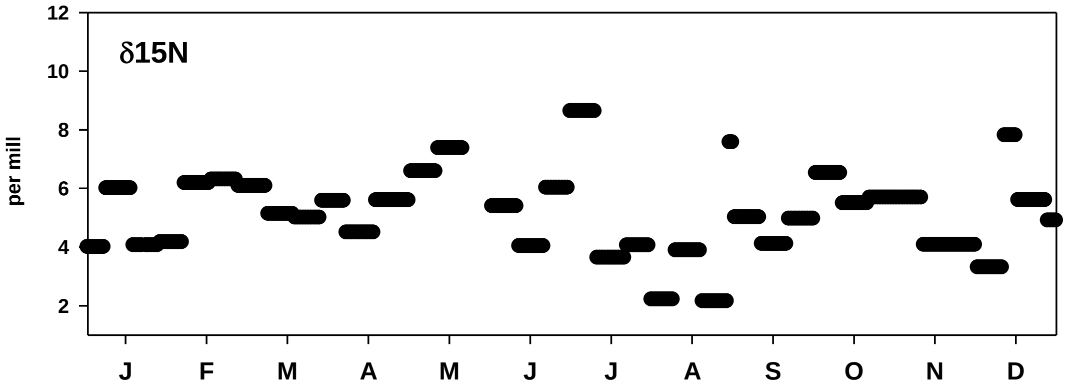


Fig. 32: Isotopic signature of nitrogen (‰ δ¹⁵N) in sediment trap material from the central Arkona Basin in 2016.

The systematic increase of the δ¹⁵N values in the trapped material between the spring sedimentation maximum at the beginning of April and the situation in the middle of May may reflect fractionation effects within the decreasing nitrate reservoir over that period.

Whereas the C/N-ratio (Fig. 33) displays a large scatter between successive samples in summer which point to a heterogeneous input during that time, the C/P ratio (Fig. 34) shows a gradual increase from spring until October which seems to reflect the decreasing stock of inorganic phosphate in the water over the growth period.

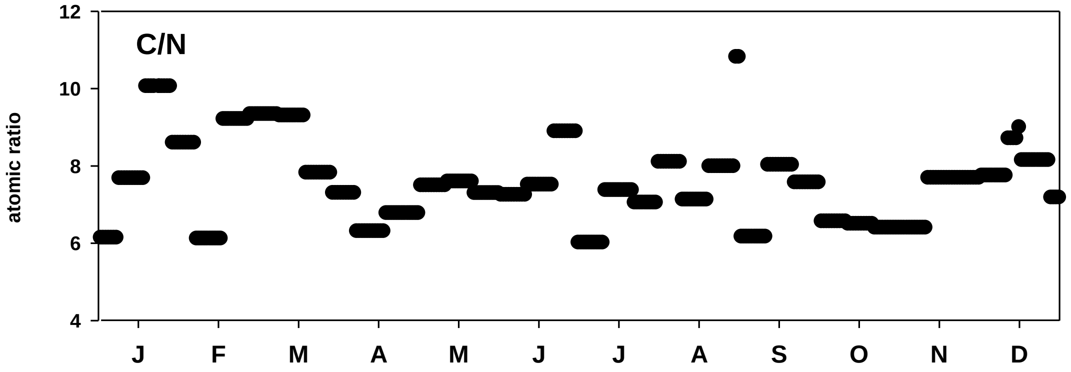


Fig. 33: Atomic ratio between carbon and nitrogen (C/N) in sedimenting particles at 35 m depth in the central Arkona Basin in 2016.

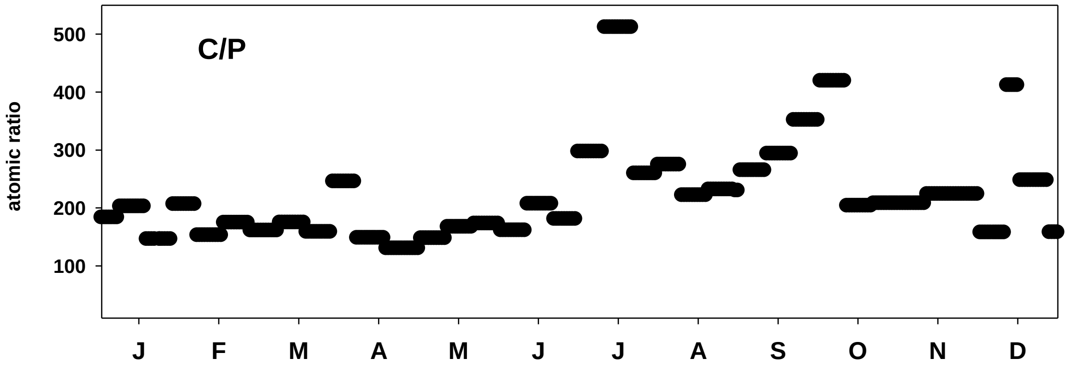


Fig. 34: Atomic ratio between carbon and phosphorus (C/P) in sedimenting particles at 35 m depth in the central Arkona Basin in 2016.

The total annual flux for single elements in 2016 amounted to 718 mmol C (8.6 g C), 93 mmol N, 95 mmol Si and 3 mmol P m^{-2} a^{-1} at a mass flux of 70 g dry mass m^{-2} a^{-1}. A correction for resuspension events was not necessary in this year, as no such events could be detected. Considering this fact, the flux of primary sedimenting organic material in 2016 was higher than in the previous years by about 30 %, which is the range of the contribution of the material during the unusual peak at the end of the year. This and a late onset of spring sedimentation are the characteristic features of vertical particle flux in 2016 in the Arkona Basin.

4.2 Mesozooplankton

4.2.1 Species Composition and Invasive Species

The composition of the zooplankton in 2016 showed a continuation of an increasing trend in biodiversity during the recent years. While the diversity was rather low in 2013 (52 Taxa) and 2014 (45 Taxa), it considerably increased to 58 taxa in 2015 and 73 Taxa in 2016 (Table A3). In contrast to the preceding year, the increase was not related to the transport of halophilic plankton during marine inflows into the Baltic but to the frequent occurrence of pelagic larvae of benthic organisms during summer (Fig. 35). Among these, larvae of the crustaceans were especially diverse and included species like *Liocarcinus* spp., *Pagurus bernhardus, Palaemon serratus, Peltogaster paguri* or *Upogebia stellata.* In addition, *Pectinaria* spp., Spionidae (Polychaeta), *Echinus* spp. and Spatangoida (Echindermata) have not been observed during the preceding years. The diversity of the holoplankton was also high. Halophilic species such as *Acartia clausi*, *Calanus* spp. or *Centropages typicus,* which have already been observed in 2015, were regularly found. Other rare species such as *Longipedia* spp., *Oncaea* spp. or *Oithona atlantica*, however, have disappeared.

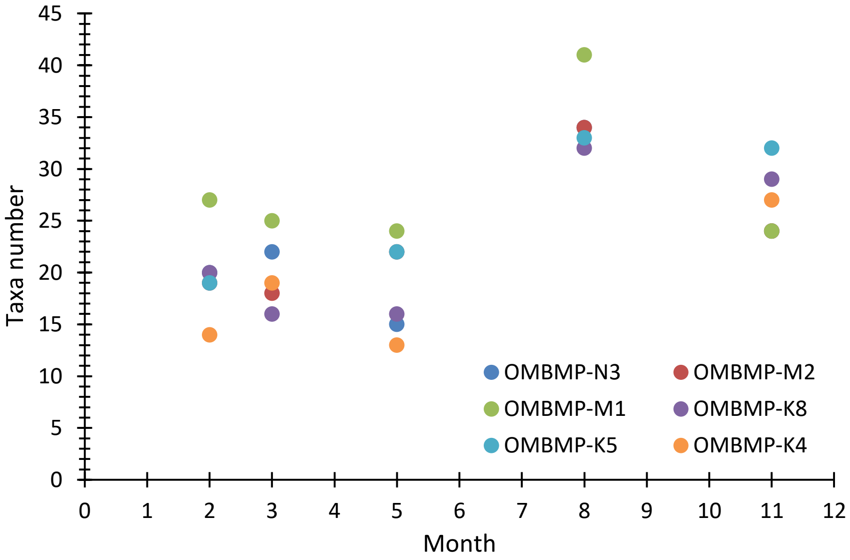


Fig. 35: Seasonal variation of the number of taxa recorded at different stations in the investigation area in 2016.

The zooplankton abundance was low in 2016 compared to preceding years and marked differences from the long-term composition of the zooplankton, similar to the year 2015, occurred. The relatively low total abundance in zooplankton was primarily caused by the very low numbers and lacking mass development of cladocerans. Until 2014, they have been the single most abundant group with concentrations regularly exceeding 10 x 10^4 ind. m^{-3} particularly in the Bay of Mecklenburg and the Arkona Basin. In the year 2016, their maximal abundance of 6 x 10^3 ind. m^{-3} was again considerably lower than the 27 x 10^3 ind. m^{-3} observed in 2015. Cladocerans are known for their ephemeral blooms and peaks might have been missed due to the long sampling interval. However, the repeated lack of high concentrations is striking.

Bosmina spp. was the single most important species among the cladocerans occurring with 0.2-5.3 x 10^3 ind. m^{-3} particularly in the Arkona Basin. The concentrations were similar to 2015, but rather low for this species, which is regularly responsible for the mass development of cladocera in summer. *Evadne nordmanni* ranked second with maximal concentrations of 0.9-1.6 x 10^3 ind. m^{-3}. Other cladocerans had a considerably lower abundance, but were found at the expected densities. *Podon intermedius* and *P. leuckartii* occurred regularly with maximal concentrations of 783 and 494 ind. m^{-3}. *Pleopsis polyphemoides* was rare in 2015, but was frequently observed in 2016, especially in the Kiel Bight and the Bay of Mecklenburg (25-191 ind. m^{-3}). This applies also to *Penilia avirostris*, which was regularly found at low concentrations in the plankton (‹ 73 ind. m^{-3}).

The copepods were the most abundant zooplankton group in 2016 followed by the rotifers and meroplankton. This is rather unusual, because rotifers can, similar to the cladocera, form dense blooms of mass occurrences. Thus, copepods were the dominant group in 2016, when the cladocera were less abundant. The rotifers were abundant in March only, but occurred in relatively high concentrations in the whole study area (10.2-18.5 x 10^4 ind. m^{-3}). As in preceding years, this was related to the occurrence of high concentrations of the genus *Synchaeta* with 1.0-18.5 x 10^4 ind. m^{-3}. *Keratella* was represented in low numbers (‹ 222 ind. m^{-3}) by *K. quadrata* and *K. cochlearis*. *K. cruciformis* was not found in 2016. Meroplankton was abundant in early spring when the polychaete larvae occurred at densities of 1.5-4.2 x 10^3 ind. m^{-3} and during summer when bivalve larvae had large stock sizes (6.2-12.1 x 10^3 ind. m^{-3}). Other larval groups were only of minor importance. Despite the high diversity of the meroplankton in 2016, the total concentrations of the larvae were similar to the preceding years. However, polychaetes were observed at considerably lower density than usual. Typical for the appendicularians, *Fritellaria borealis* was abundant in spring with 0.4-2.9 x 10^3 ind. m^{-3} in the Mecklenburg Bight and the Arkona Basin. *Oikopleura dioica*, in contrast, is a summer-autumn species. It was regularly found in an abundance of 1.1-8.0 x 10^3 ind. m^{-3} in the Kiel Bight and the Bay of Mecklenburg. The seasonal timing and densities of both species were similar to preceding years.

Another similarity to 2015 was the dominance of the genus *Acartia* within the most abundant group of the calanoid copepods and the rather low stocks of *Pseudocalanus*/*Paracalanus*. Brackish water species of *Acartia* (*A. bifilosa*, *A. tonsa*) were considerably more abundant in 2016 than in 2015. *A. bifilosa* was found at high densities of 1.6-4.7 x 10^3 ind. m^{-3} particularly in spring in the western areas (Kiel Bight, Bay of Mecklenburg). *A tonsa*, in contrast, was more confined to the Bay of Mecklenburg and the Arkona Sea and was most abundant in summer (0.6-3.3 x 10^3 ind. m^{-3}). *A. longiremis*, which is a marine euryhaline species, occurred regularly in high abundance at all stations except Kiel Bight (1.2-3.1 x 10^3 ind. m^{-3}). The density of *A. tonsa* was considerably higher than in preceding years; the species shows a trend of recovery in recent years after some years of low abundance or absence. *A. bifilosa* and *A. longiremis* occurred at usual density. *Temora longicornis* and *Centropages hamatus* were less abundant and occurred in concentrations of 0.3-2.3 x 10^3 ind. m^{-3} and 0.3-1.1 x 10^3 ind. m^{-3}, respectively. Similar to 2015, the abundance of *Pseudocalanus* spp. and *Paracalanus parvus* was again exceptionally low (‹ 0.4 x 10^3 ind. m^{-3}). The cyclopoid copepod *Oithona similis* was together with *A. tonsa* the most important copepod during summer (1.7-2.7 x 10^3 ind. m^{-3}).

The calanoid copepod *Acartia tonsa* and the cladoceran *Cercopagis pengoi* belong to the species listed as invasive in the Baltic Sea. *A. tonsa* is well-established and was already introduced during the 1920s. It is recorded in German coastal waters the first time in 1981 (GOLLASCH & NEHRING 2006). *Cercopagis pengoi* was observed as a single individual in the Arkona Basin in February. The species was not found in 2014-2015, but has been recorded from the Arkona Basin in July 2013. In the Baltic Sea, it was first found in the Muuga-Bight (Finnish Bight, Estonia) and in the Pärnu Bight (Gulf of Riga, Estonia) in 1992. The species appears to spread in the Baltic Sea and was recorded the first time in German waters from the Pomeranian Bight in 2004 (ICES 2005).

4.2.2 Seasonal Zooplankton Variation in Sub-Areas

Kiel Bay

The zooplankton in Kiel Bay (OMBMPN3) showed only a moderate seasonal variation in the abundance which contrasts with the pronounced seasonality observed in previous years (Fig. 36). The winter stocks were unusually low (1.4×10^3 ind. m^{-3}). This was related to a low abundance of copepods, in particular the cyclopoid *Oithona similis*, and polychaete larvae. The major seasonal increase in total abundance was observed in March (1.8×10^4 ind. m^{-3}) and was early owing to an unusually high density of rotifers exclusively consisting of the genus *Synchaeta* (1.1×10^4 ind. m^{-3}), which is rather exceptional for this area (Fig. 37). The total zooplankton stock remained high from May to November (1.7 - 2.1×10^4 ind. m^{-3}) and displayed a succession of zooplankton typical for the Kiel Bight (Fig. 37). The copepods increased considerably during May when they dominated nearly exclusively the zooplankton (2.1×10^4 ind. m^{-3}). In summer, the contribution of larvae of bivalves (6.3×10^3 ind. m^{-3}) increased. They dominated the zooplankton together with the copepods (9.1×10^3 ind. m^{-3}) and the copelate *Oikopleura dioica* (4.3×10^3 ind. m^{-3}), which remained abundant until November. The bivalve larvae were replaced by the cladocera *Evadne nordmanni*, *Podon intermedius* and *Pleopis polyphemoides* in autumn which occurred at concentrations of $0.2 – 0.9 \times 10^3$ ind. m^{-3}.

Among the copepods, the genus *Acartia*, in particular *Acartia bifilosa* was the dominant copepod during winter-spring (1.1-4.7×10^3 ind. m^{-3}, Fig. 38). This contrasts with the prevalence of *Pseudocalanus* and the cyclopoid copepod *Oithona similis* during this time in preceding years. However, *Oithona similis* (1.7-2.4×10^3 ind. m^{-3}) replaced *Acartia* spp. ($<$ 298 ind. m^{-3}) as the dominant copepod in summer/autumn. The species was accompanied by *Centropages hamatus* (1.2×10^3 ind. m^{-3}) and *Temora longicornis* (216 ind. m^{-3}). In contrast, the abundance of *Pseudocalanus* spp ($<$ 9.6 ind. m^{-3}) and *Paracalanus parvus* (135 ind. m^{-3}) remained unusually low.

Bay of Mecklenburg

The zooplankton development in the Bay of Mecklenburg (OMBMPM2 and OMBMPM1) largely resembled that in the Kiel Bight with low winter stocks (3.3-7.2×10^3 ind. m^{-3}) and an early development in March (1.9-2.1×10^4 ind. m^{-3}) followed by rather constant stocks during summer and autumn (1.4-2.8×10^4 ind. m^{-3}, Fig. 36). Copepods, the copelate *Fritellaria borealis* and diverse larvae of polychaetes primarily contributed to the zooplankton in winter and increased moderately towards March. The high abundance of rotifers (1.0-1.2×10^4 ind. m^{-3}), again solely represented by *Synchaeta*, caused the early increase in the total stock in March (Fig. 37). While a mass occurrence of rotifers is, in contrast to the Kiel Bight, not unusual for the area, the peak in March is rather early.

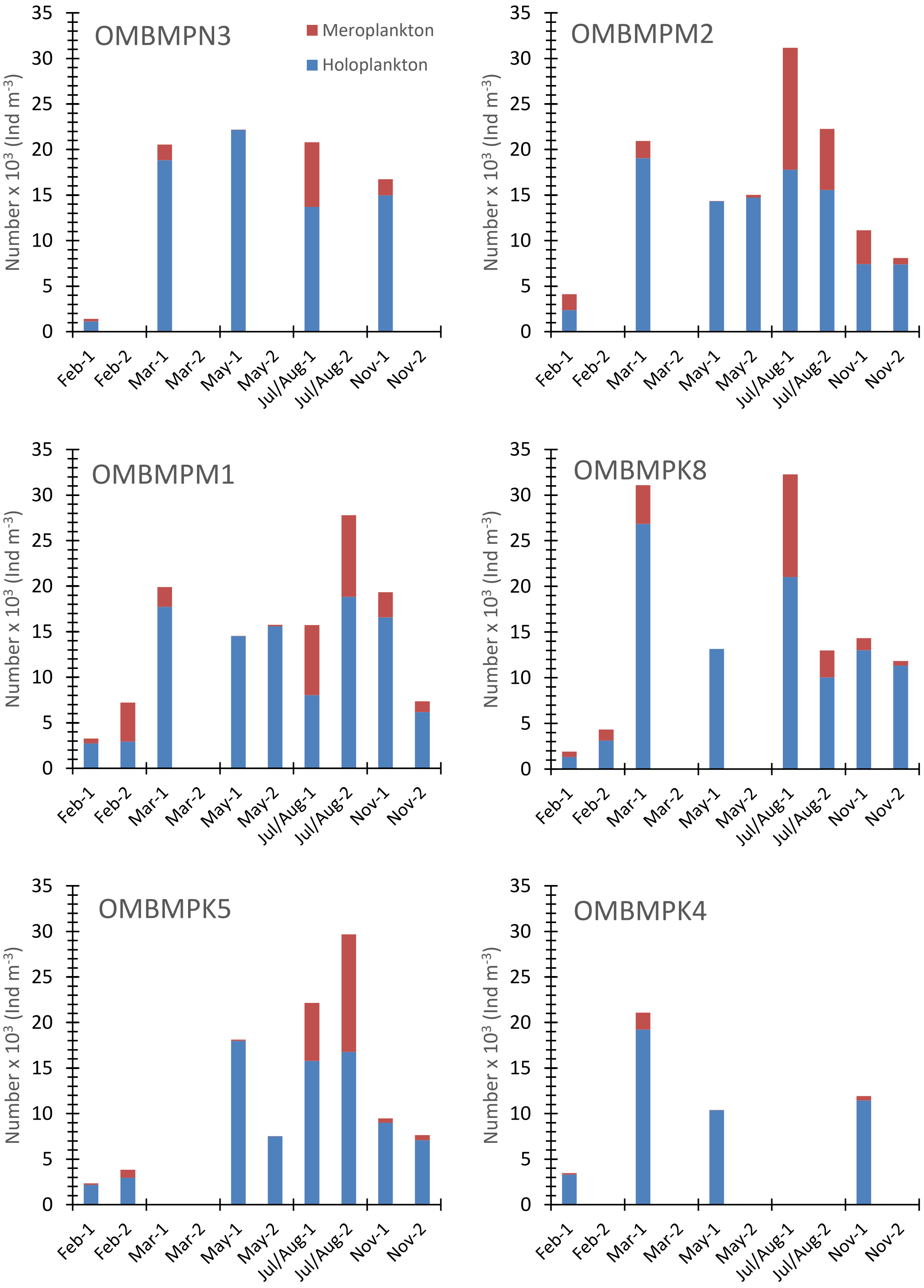


Fig. 36: Seasonal variation of the abundance of mesozooplankton and the contribution of mero- and holoplankton to the total stock of zooplankton at different stations in the investigation area in 2016.

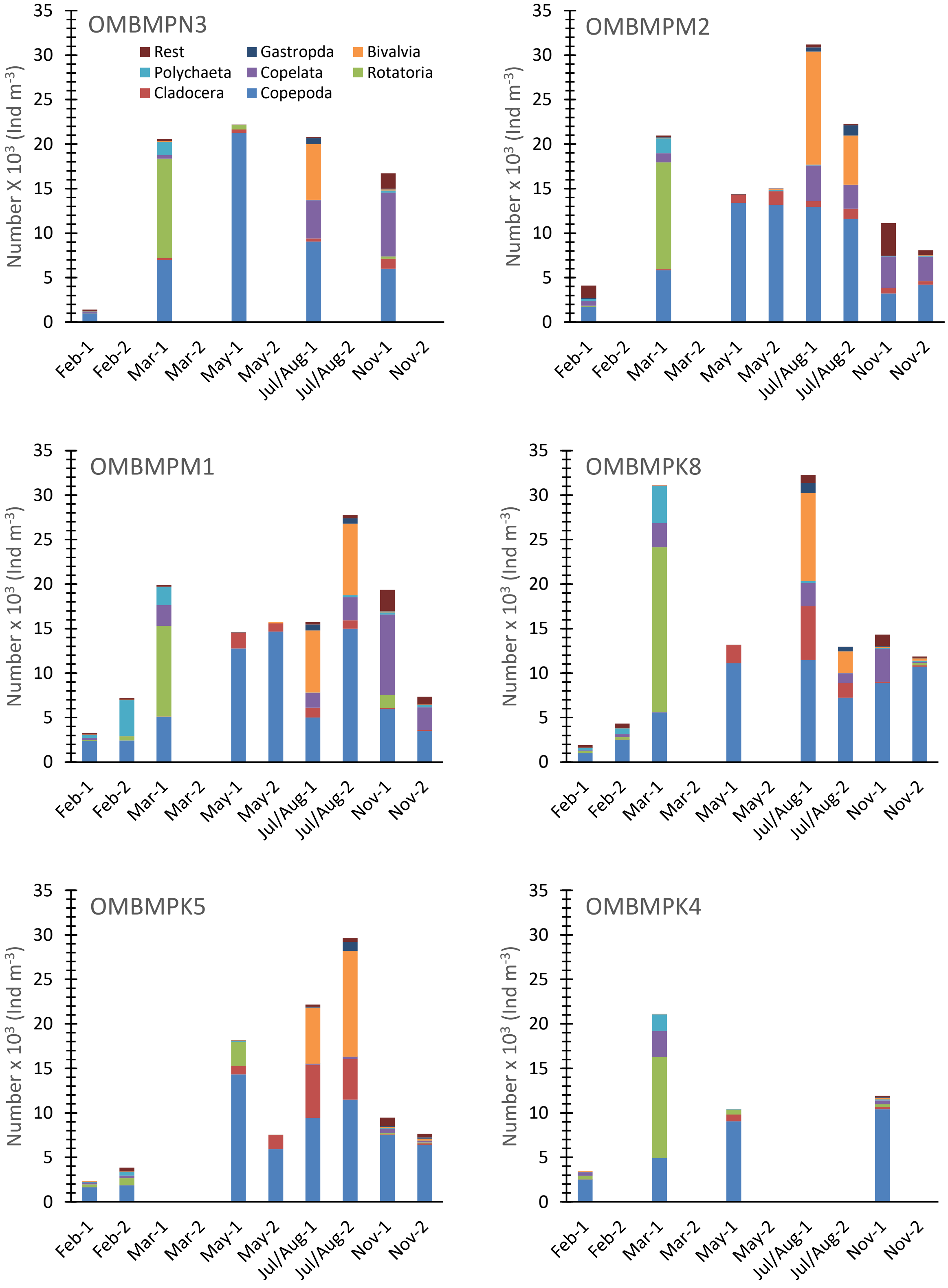


Fig. 37: Seasonal variation of the main taxonomic groups of the mesozooplankton at different stations in the investigation area in 2016.

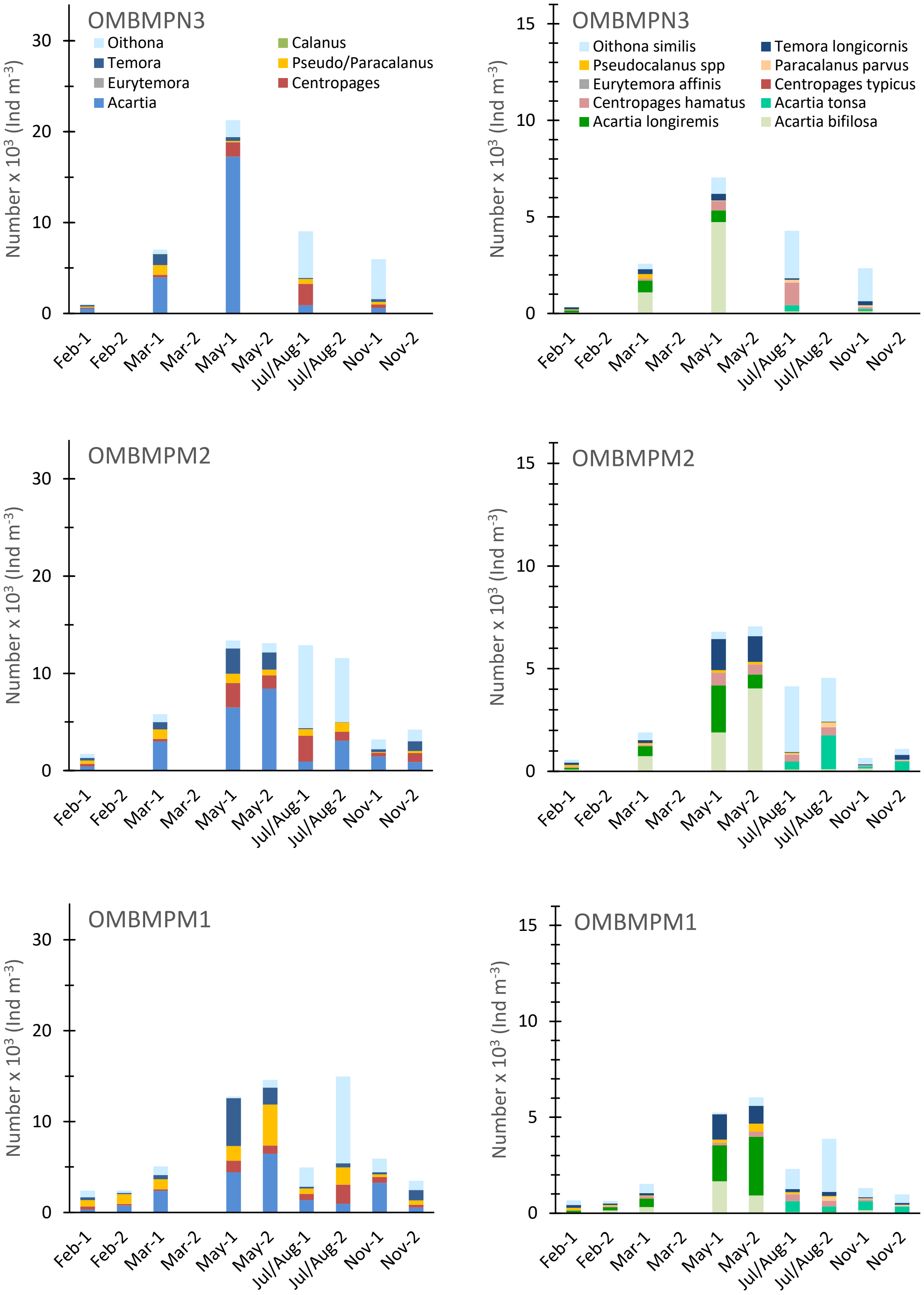


Fig. 38: Seasonal variation of the abundance and composition of juvenile (left) and adult stages of copepods (right) of different genera at various stations in the investigation area in 2016. Note the different scale in the abundance of juveniles.

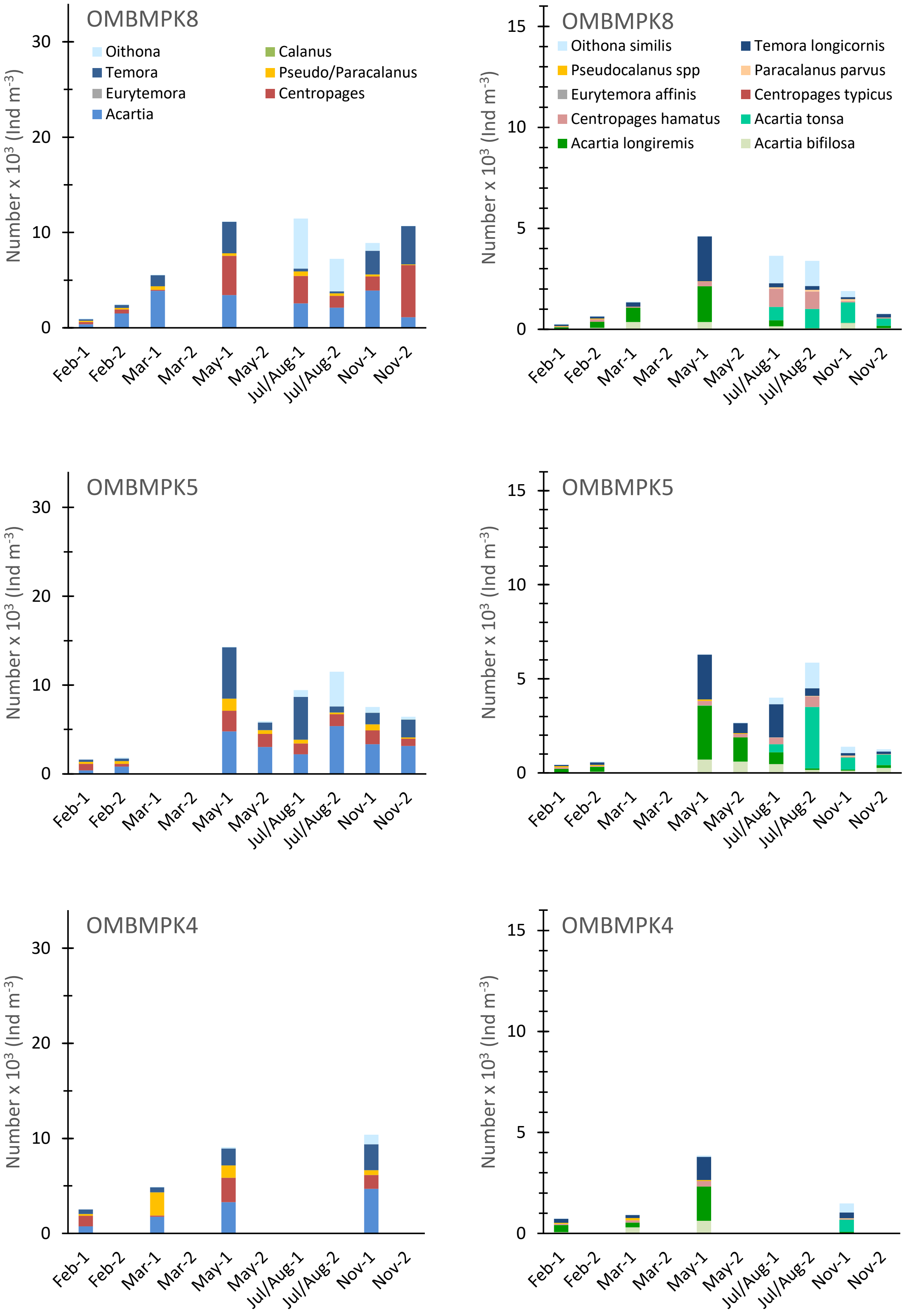


Figure 38: continued

Copepoda dominated nearly exclusively the zooplankton in May (1.3-1.5 x 10^4 ind. m^{-3}). Cladocera were regularly observed with *Evadne nordmanni* (1.2-1.3 x 10^3 ind. m^{-3}) and *Podon leuckartii* (190-430 ind. m^{-3}) as the major species. Other groups were rare. In summer copepods (1.2-1.5 x 10^4 ind. m^{-3}) and cladocera (0.7-1.2 x 10^3 ind. m^{-3}) were still abundant, but the copelate *Oikopleura dioica* (1.6-4.2 x 10^3 ind. m^{-3}) and larvae of bivalves (0.6-1.3 x 10^4 ind. m^{-3}) and gastropods (0.5-1.1 x 10^3 ind. m^{-3}) were very common as well. The diversity among cladocera increased with *Bosmina* spp., *Podon intermedius*, *Pleopsis polyphemoides* and *Penilia avirostris* occurring at low density (5-345 ind. m^{-3}) in addition to the abundant *E. nordmanni* (500-800 ind. m^{-3}). Copepods and copelata dominated together with diverse meroplankton (bivalves, gastropods, polychaetes and bryozoans) during autumn.

The overwintering stock of copepods consisted of diverse genera like *Acartia*, *Pseudo/Paracalanus*, *Oithona*, *Centropages* and *Temora* without a particular dominance (30 - 248 ind. m^{-3}, Fig. 38). The genus *Acartia* with *A. bifilosa* and *A. longiremis* was frequent in March (485-743 ind. m^{-3}), while the stocks of *Pseudo/Paracalanus*, *Oithona similis* and *Temora longicornis* were slowly increasing. All four genera dominated in May (0.9 -6.5 x 10^4 ind. m^{-3}). In summer, the community shifted to a dominance of *Oithona similis*, but *Acartia* spp., *Centropages hamatus* and *Temora longicornis* remained abundant as well. At this time, *Acartia tonsa* (0.3-1.7 x 10^3 ind. m^{-3}) was the major species within the diverse group of the genus *Acartia*. *Oithona similis* (295-487 ind. m^{-3}) and *Acartia tonsa* (104-474 ind. m^{-3}) dominated also during autumn. In comparison to preceding years, the abundance of *Pseudocalanus* and *Paracalanus* spp. was low during all seasons ($<$417 ind. m^{-3}).

Arkona Basin

Although the sampling during spring time was somewhat incomplete in the Arkona Basin (OMBMPK8 to OMBMPK4, Figs. 36-38), the seasonal development of zooplankton resembled largely that of the zooplankton in the western areas for which an early development in March and relative stable zooplankton concentrations over the productive season were characteristic. In the past, this was not regularly the case because of mass occurrences of cladocera in the Arkona Basin. However, this event was lacking in 2016. The winter stocks were again low (1.9-3.3 x 10^3 ind. m^{-3}). Copepods numerically dominated (0.9-2.5 x 10^3 ind. m^{-3}), followed by rotifers (275-800 ind. m^{-3}) and polychaete larvae (80-650 ind. m^{-3}). In March, these groups together with the appendicularian *Fritellaria borealis* caused an early maximum in total zooplankton abundance (2.1-3.1 x 10^4 ind. m^{-3}). In May, copepods dominated the community (0.6-1.4 x 10^4 ind. m^{-3}), while the cladocerans *Evadne nordmanni* and *Podon leuckartii* (0.3-1.6 x 10^3 ind. m^{-3}) and the rotifer *Synchaeta* spp. (0.6-2.6 x 10^3 ind. m^{-3}) occurred frequently. The copepods dominated also during summer (0.7-1.5 x 10^4 ind. m^{-3}), but larvae of the bivalves achieved high concentrations (0.2-1.2 x 10^4 ind. m^{-3}). In contrast, cladoceran densities, in particular those of *Bosmina* spp. which is responsible for mass occurrences remained low ($<$ 6.0 x 10^3 ind. m^{-3}). Again, *Evadne nordmanni* and *Podon intermedius*, which replaced *Podon leuckartii*, occurred frequently (0.8-1.1 x 10^3 ind. m^{-3}). *Oikopleura dioica* replaced *Fritellaria borealis* among the abundant appendicularians (1.1-2.6 x 10^3 ind. m^{-3}). Copepods (0.6-1.1 x 10^4 ind. m^{-3}) and appendicularians (0.1-3.7 x 10^3 ind. m^{-3}) remained frequent during autumn, whereas other groups were rare.

Acartia longiremis and *Temora longicornis* were the dominating copepod species during winter-spring, but their concentration was still low (190-290 and 106-191 ind. m^{-3}, respectively). Their stock size increased considerably until May (1.7-2.1 and 1.2-2.4 x 10^3 ind. m^{-3}). The abundance of *A. bifilosa* and *Centropages hamatus* remained low (< 600 ind. m^{-3}) while other copepod species were generally rare. A major shift in the copepod community composition was observed in summer. *A. longiremis* and *T. longicornis* considerably decreased in abundance (< 620 ind. m^{-3}), whereas *A. tonsa* (0.7-3.3 x 10^3 ind. m^{-3}) and the cyclopoid *Oithona similis* (0.4-1.4 x 10^3 ind. m^{-3}) dominated. Other species were generally less abundant. *Acartia* spp. dominated also during autumn, with *A. tonsa* was the single most important copepod (0.4-1.0 x 10^3 ind. m^{-3}). However, other species like *T. longicornis, Centropages hamatus* or *Oithona similis* also occurred frequently in lower numbers (31-440 ind. m^{-3}). Again, the abundance of *Pseudo-/Paracalanus* remained below 100 ind. m^{-3}.

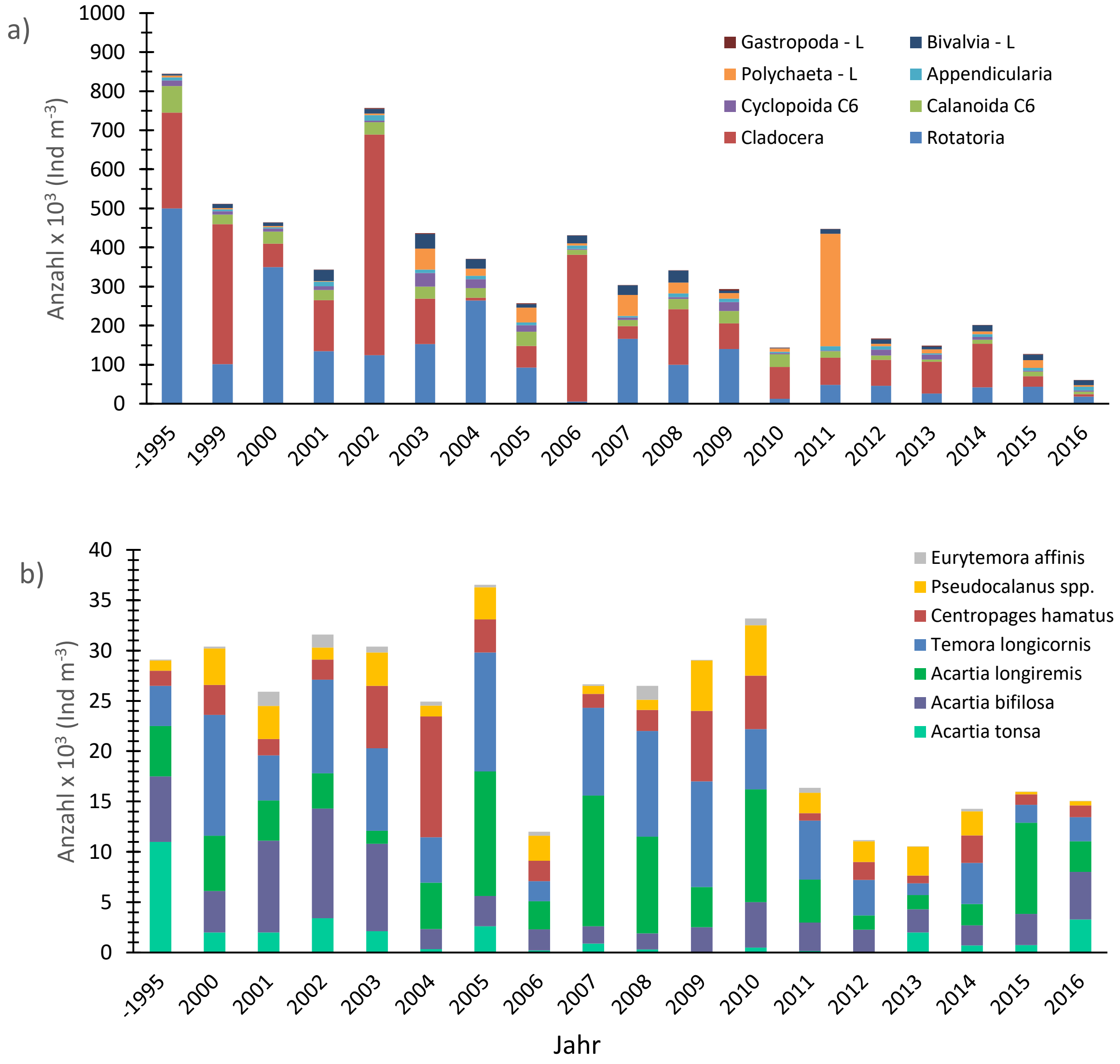


Fig. 39: Long-term trends in the maximal abundance of a) holoplanktonic taxa (Rotatoria, Cladocera, Cyclopoida, Calanoida, and Copelata) and meroplanktonic taxa (Polychaeta, Bivalvia, Gastropoda) and b) of seven calanoid copepod species in the years 1995 to 2016.

4.2.3 Long-term Trends

Based on the maximal seasonal abundance of the diverse zooplankton groups, the total abundance of mesozooplankton was low in 2016 and continued a trend observed since the beginning of the century (Fig. 39 a). While the concentration of zooplankton varied from 2.57-7.56 x 10^5 ind. m^{-3} the years 2000-2008, it was only 6.14 x 10^4 ind. m^{-3} in 2016. The abundance of rotifers and cladocerans appears particularly low. Mass occurrences of both zooplankton groups were frequently observed during 2000-2008, but disappeared in recent years. Whether this is caused by a decline in standing stocks or a shift in the seasonal timing of the peak abundance by which large concentrations would be missed through a low sampling frequency cannot be resolved at present. Also in other groups a decline in maximal abundances was apparent, except in the appendicularians. Stock sizes of the adult calanoid copepods remained low (Fig. 39 b), but were comparable to the preceding years (1.4 x 10^4 ind. m^{-3}). The composition largely resembled that of 2015, when *Acartia* species dominated the community composition. Striking are the low maximal concentrations of *Pseudo/Paracalanus* in both years.

4.3 Macrozoobenthos

4.3.1 Sediments and Oxygen

At each of the eight monitoring stations, samples were taken using separate Van Veen grabs for analysis of the particle size and organic content of sediment. In addition, CTD dips were made to determine associated parameters such as oxygen concentrations and near-bottom salinity (Table 7). At all stations a good oxygen supply was observed. In contrast to the year 2012 the oxygen values were higher than 2 ml/l at all stations.

The salinity at the Arkona Basin station (OMBMPK4) was with 21.3 psu relatively high, a direct effect of the saltwater inflow of the previous years. The mean salinity at this station ranges normally between 13 and 18 psu (Fig. 40). The other stations seem to be not much affected by this inflow event.

Table 7
Abiotic parameters at 8 monitoring stations in autumn 2016 (org=organic content of sediment in %, GS=mean grain size in µm, O2=oxygen content of near bottom water in ml/l, S=salinity at near bottom water in psu).

Station	Org %	GS (µm)	O_2 (ml/l)	S (psu)	Sediment characteristics
OMBMPN3	0.60	182	6.5	16.5	fine to middle sand
OMBMPN1	4.39	182	6.4	19.4	muddy sand
OMBMPM2	6.41	20	6.77	16.5	mud
OM18	1.08	100	6.48	19.9	muddy sand
OMBMPK8	0.23	226	6	16.1	fine sand
OMBMPK4	12.21	21	4.5	21.3	mud
OMBMPK3	0.36	223	6.74	8.4	fine sand with marl
OM160	0.12	184	7.3	7.7	fine sand

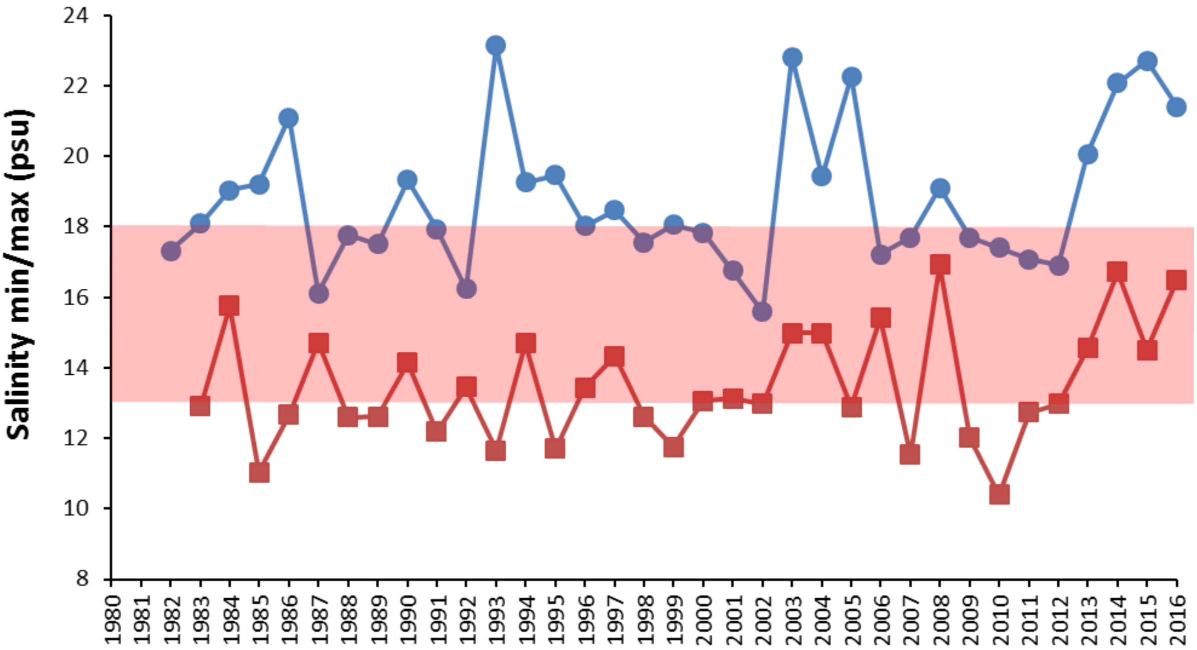


Fig. 40: Long-term development of the bottom water salinity in the Arkona Basin (OMBMPK4) from 1980 to 2016 (5-10 measurements per year). The red line indicates the lowest and the blue line the highest value per year, respectively. The shaded range shows the long-term median of the lowest and highest values.

4.3.2 Macrozoobenthos at the Stations

In November 2016, we deployed a Van Veen grab sampler to collect 3 samples from each of the 8 stations for macrozoobenthic analysis. In addition, a dredge was deployed at all stations to record rarer and vagile species. Our monitoring stations belong to four or five different macrozoobenthic communities along the salinity and depth gradient (see GOGINA et al. 2016).

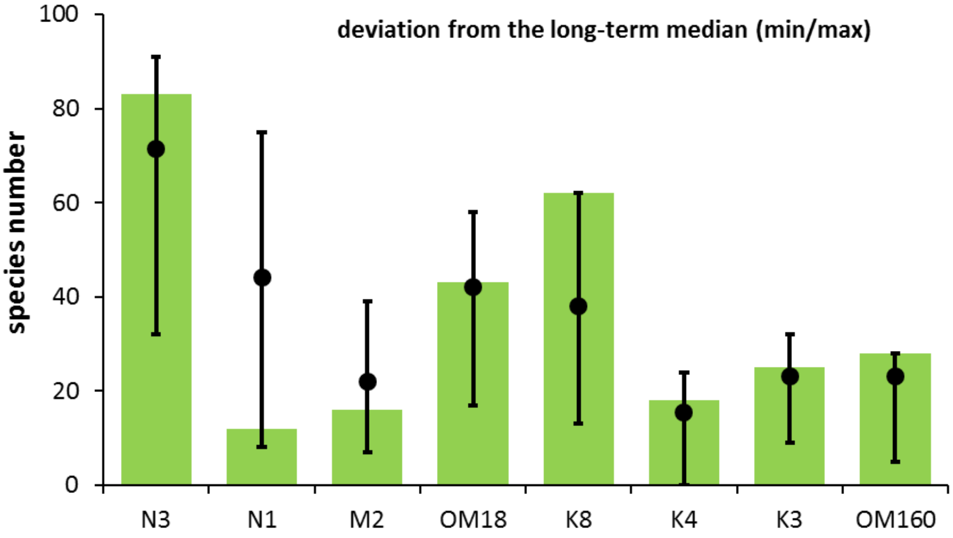


Fig. 41: Number of species (columns) of macrozoobenthos at 8 monitoring stations in November 2016. The median values of the years 1991 to 2016 are shown as dots; the minimum and maximum values are indicated as interval. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

Compared with the period 1991 to 2016, the number of species was high at 141 (Table A4, Figs. 41 and 44). In line with expectations, station OMBMPN3 in Kiel Bay proved to be the richest in species in the entire study area: 83 taxa were identified there. Compared with their long-term averages, six stations show similar or even higher species richness (Fig. 2). At two stations (OMBMPN1 and OMBMPM2) the observed numbers of taxa were significantly lower than the long-term median.

At station OMBMPN3 in the Kiel Bay an increase in the number of species was obvious: 83 taxa were identified there. In the last 10 years only in 2009 and 2012 a similar high diversity was observed. Some species were noticed for the first time within the last 11 years (and longer). For example the sea urchin *Echinocardium cordatum* was found for the first time in the Kiel Bay and is probably a relic of the last saltwater inflow two years before. Other "new" species were for instance the polychaetes *Rhodine loveni*, *Enipo kinbergi* and the gastropod *Hermania scabra*. Altogether 12 species were recorded for the first time at this station.

The diversity of the Fehmarn Belt area and the central Bay of Mecklenburg were completely different and has significantly decreased in comparison to the previous years (Fig. 41). Both the species number and the abundance (see below) are affected. Even the population of the robust ocean quahog (*Arctica islandica*) seems to be diminished; a lot of new dead shells were visible (Fig. 42).

Fig. 42: *Arctica islandica*, a lot of new dead shells in the Fehmarn Belt area.

At the Darss Sill (OMBMPK8) with 62 species the diversity was highest in comparison to the last 20 years. Eight species were recorded for the first time there. For instance the neozoan species *Rhithropanopeus harrisii*, normally occurring in nearshore areas and not expected for these deep offshore waters, was found. Additionally the polychaetes *Neoamphitrite figulus* and *Eumida sanguinea*, the bivalve *Musculus subpictus* and the sponges *Chalinula limbata* and *Halichondria panicea* could be observed. The epibenthic dredge sample was dominated by the blue mussel (*Mytilus edulis*) and the common starfish (*Asterias rubens*) (Fig. 43).

Fig. 43: The dredge sample of the Darss Sill (OMBMPK8) was dominated by the blue mussel (*Mytilus edulis*) and the common starfish (*Asterias rubens*).

Figure 44 presents the number of taxa found at our 8 monitoring stations in 2016 as well as the total number of species found in measurements since 1991. Not just in 2016 (see Zettler et al. 2014), the Annelida (Polychaeta and Oligochaeta) emerged as the group that is richest in species, numbering 101; in 2016, 52 species were identified. Other species-rich groups in 2016 were Mollusca (33), Crustacea (23), Cnidaria (6) and Bryozoa (9).

Depending on the sea area, abundances varied between 78 (Fehmarnbelt) and 8 830 ind./m^2 (Kiel Bay) (Fig. 45, Table A4). Only in the Kiel Bay (OMBMPN3) and slightly in the southern Bay of Mecklenburg (OM18) the abundance increased compared with previous years (Fig. 45). At all other stations the abundance was significantly lower than the median values of the last 11 years; most obvious in the Fehmarnbelt (OMBMPN1), at the central Bay of Mecklenburg (OMBMPM2), at the Darss Sill (OMBMPK8) and in the Pomeranian Bay (OM160).

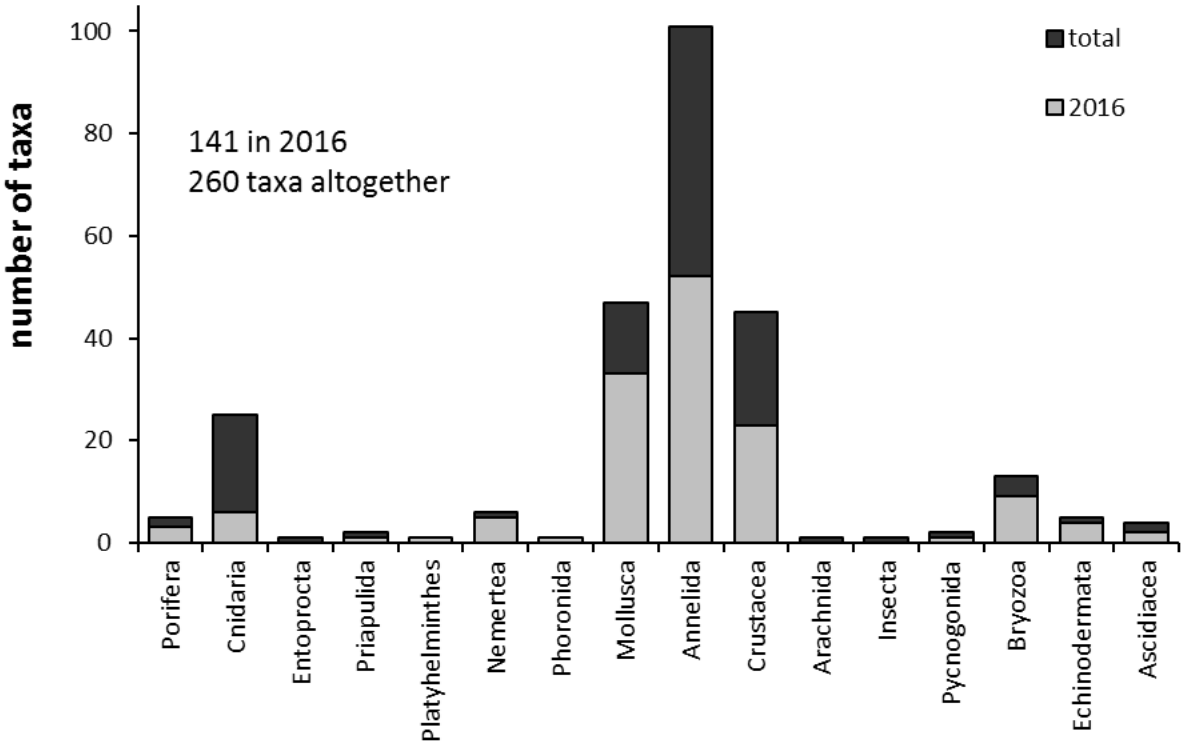


Fig. 44: Taxonomical classification of macrozoobenthos at 8 monitoring stations in November 2016. The species number of the entire monitoring from 1991 to 2016 is also indicated.

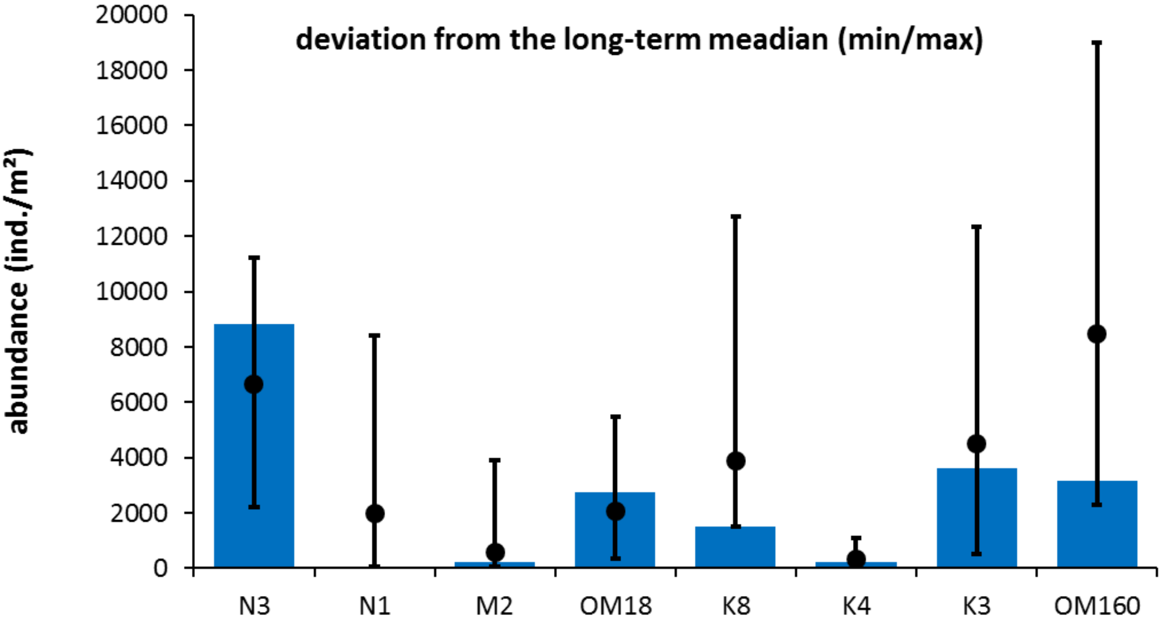


Fig. 45: Total abundances (columns) of macrozoobenthos at 8 monitoring stations in November 2016. The median values of the years 1991 to 2016 are shown as dots; the minimum and maximum values are indicated as interval.

Which species was dominant in a given sea area varied greatly; it depended essentially on salinity and substrate. While the molluscs *Abra alba*, *Arctica islandica*, *Corbula gibba* and *Kurtiella bidentata* accounted for over 30 to 40 % of density in Kiel Bay (OMBMPN3), Bay of Mecklenburg (OMBMPM2) and in Fehmarn Belt (OMBMPN1) (the cumacean *Diastylis rathkei*, the polychaetes *Heteromastus filiformis* and *Dipolydora quadrilobata* were subdominant alternately), in the Pomeranian Bay (OM160) only the mud snail *Peringia ulvae* at 60 % accounted for high abundance. However, epibenthic structures sampled by the dredge were mainly consisting of blue mussels (*Mytilus* sp.) and common shrimps (*Crangon crangon*) (Fig. 46). The orbinid polychaete *Scoloplos armiger* reached more than 20% of the abundance of the station OMBMPK8 at the Darss Sill. In the northern Pomeranian Bay (OMBMPK3) the spionid *Pygospio elegans* (70%) and additionally the tellinid *Limecola balthica* (15%) dominated the community.

Fig. 46: In 2016 dominant epibenthic species in the Pomeranian Bay (OM160) were *Mytilus edulis* and *Crangon crangon.*

The highest biomass was observed at the Kiel Bay station (OMBMPN3) (Fig. 47). 51.1 g afdw/m^2 was measured, consisting of 45 % *Astarte borealis* (22.3 g afdw/m^2) and 46 % *Arctica islandica* (23.6 g afdw/m^2). In addition, dredge catches yielded echinoderms (*Asterias rubens, Ophiura albida*), common whelk (*Buccinum undatum*) and red whelk (*Neptunea antiqua*) that were certainly under-represented in the quantitative grab samples. Although much affected in species richness and abundance the biomass was similar or even higher at stations in the Fehmarnbelt and Bay of Mecklenburg, which is almost explainable with the dominance and patchy distribution of heavy adults of the ocean quahog. In Fehmarnbelt (OMBMPN1) and in Bay of Mecklenburg (OMBMPM2), *Arctica islandica* contributed as much as 99 % to biomass (Fig. 48); total values between 21 and 39 g AFDM/m^2 were obtained there. At Darss Sill (OMBMPK8), biomass (10.9 g AFDM/m^2) was dominated by the bivalves *Astarte borealis* (63 %) and *Mytilus edulis* (21 %). In the Arkona Basin, (OMBMPK4), *Limecola balthica* accounted for 75 % of the total biomass (3.9 g afdw/^{2}), *Arctica islandica* for 17 %. In the north of the Pomeranian Bay (OMBMPK3), 3.4 g of total biomass was measured, made up of 83 % *Limecola balthica*. Further east in the central Pomeranian Bay (OM160; 5 g afdw/m^2), *Limecola balthica* (37 %), *Mya arenaria* (20 %) and *Mytilus edulis* (17 %) were prominent.

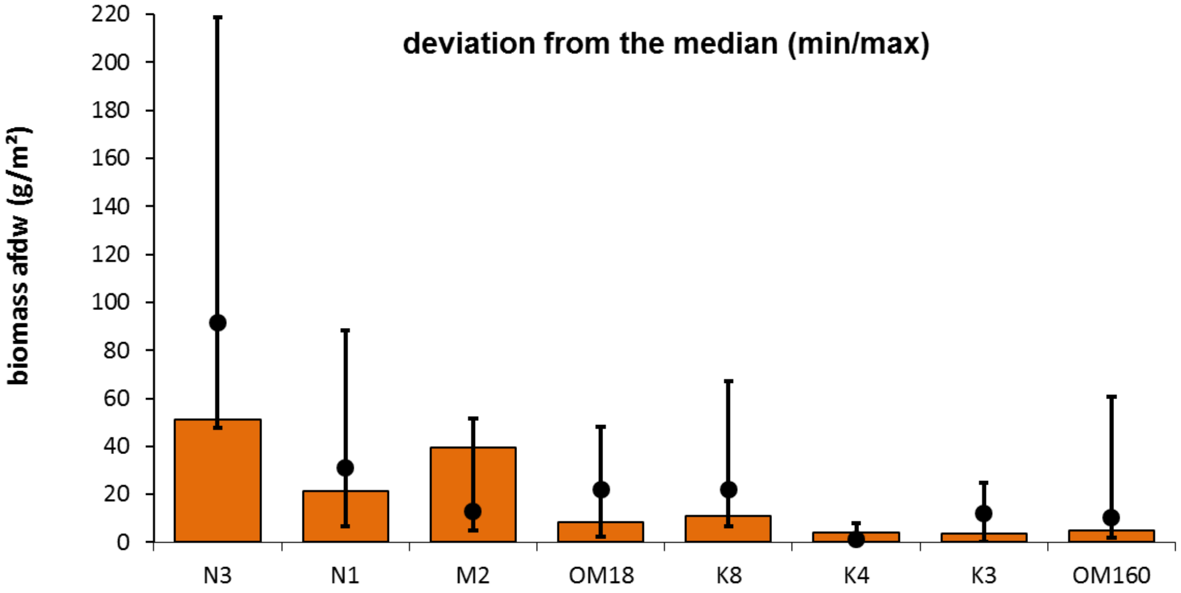


Fig. 47: Total biomasses (columns) of macrozoobenthos at 8 monitoring stations in November 2016. The median values of the years 1991 to 2016 are shown as dot and the minimum and maximum values are indicated as intervals.

Fig. 48: In the Bay of Mecklenburg (OMBMPM2), the ocean quahog (*Arctica islandica*) dominated the grab sample.

Both for abundance and biomass, analysis of long-term data in part revealed considerable fluctuations that are illustrated as error bars (min/max) in Figs. 45 and 47. Basically fluctuations relate to the population dynamics of long-living species (molluscs mostly). Another influence is population collapse following a phase of oxygen deficiency. Not least, however, the randomness of sampling and the clustered distribution of organisms are responsible for these fluctuations. Human induced direct effects (exclusive the eutrophication) were not evidently visible in the analysis of the data. Nevertheless, impacts or effects of for example bottom trawling on the benthic community are not to be excluded, but it was not an objective of the present study.

4.3.3 Long-term Trends

For an assessment of long-term trends since 1980 refer to our recently published study (Zettler et al. 2017). The development of major macrozoobenthic parameters (abundance, biomass, species number) has been successfully interpreted relying on the modelling of the long-term fluctuations of salinity and oxygen, incorporation of the North Atlantic Oscillation index (NAOI) for winter, and the alliance of modelled and measured data along the 35 years of observation. The effects of oxygen deficiency on ecosystem functions, as well as temporal and spatial variations at selected monitoring stations, were published also in Gogina et al. (2014).

To ensure maximum comparability in our analysis of long-term trends, we referred to the last 11 years only (2006 to 2016). Eight stations were sampled every autumn using three grab samples and one dredge. Stations are thus assessed on an identical basis. Figure 49 shows the relative number of species (see previous reports, e.g. Wasmund et al. 2016 a, and Table A4 for absolute numbers). As expected, species diversity falls from west to east (Kiel Bay OMBMPN3 to Pomeranian Bay OM160). During this period, the station OMBMPN1 (Fehmarnbelt) was characterised by a severe loss of species due to oxygen deficiency. In 2008 and 2010, up to 50 % fewer species were found there than in the previous or subsequent year. In 2016 again a dramatically loss in species number occurred and also in the Bay of Mecklenburg (OMBMPM2).

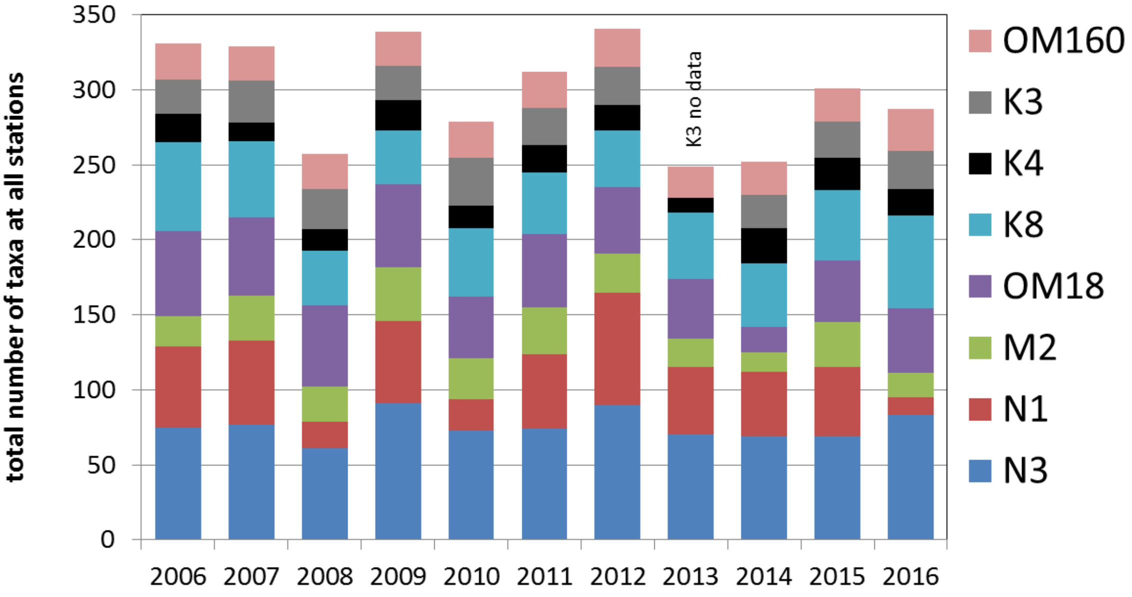


Fig. 49: Cumulative number of taxa of macrozoobenthos at 8 monitoring stations from 2006 to 2016. The stations are arranged within the columns from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

The reasons for this decline are not well recognized yet. The oxygen conditions around the year cannot be used as explanation, because no oxygen depletion was observed at all (at least during the sampling campaign). All other stations had diversity rates that were relatively stable; no further significant changes were observed.

In terms of abundance, the situation is very different (Fig. 50). Only the westernmost station (Kiel Bay, OMBMPN3) was characterised by high abundances. In some years, values fell below those of other years by more than 50 % - 2007 and 2008 at station OMBMPN3, and 2010 and 2016 at station OM160, for instance. Some significant variations also occurred at other stations, but they were based on substantially lower absolute values. At Fehmarnbelt (OMBMPN1) and in the Bay of Mecklenburg (OMBMPM2), oxygen deficiency in e.g. 2008 and 2010 caused a serious decline in abundance rates. A similar loss of abundance was observed for 2016 as well. At least at some other stations no significant decline was observed.

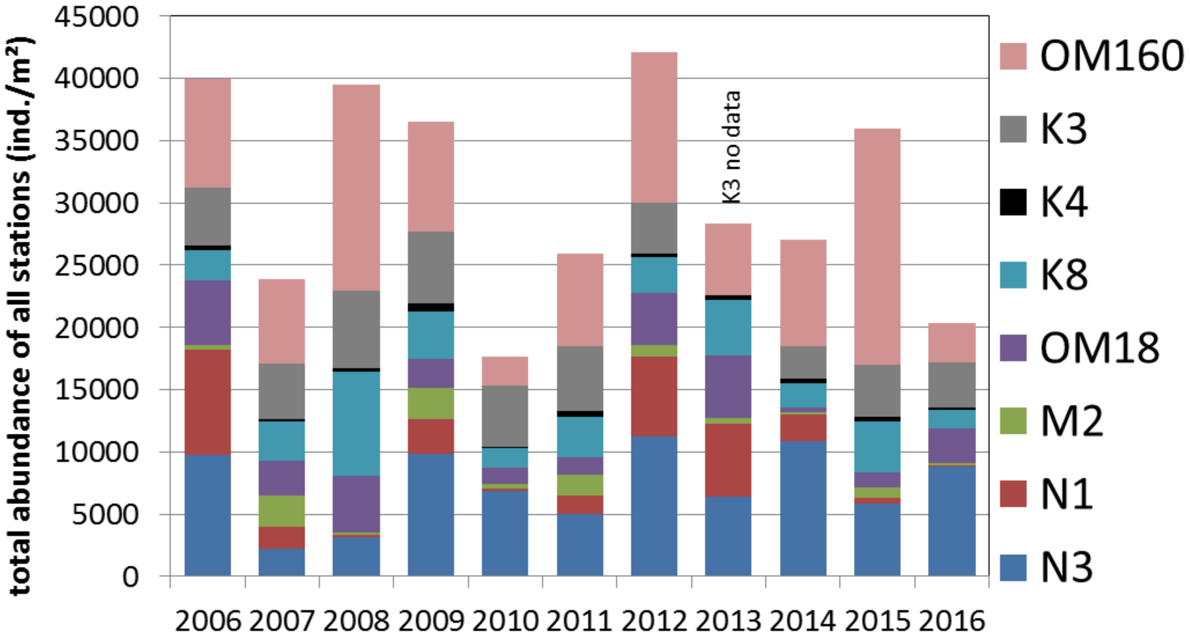


Fig. 50: Cumulative abundance of macrozoobenthos at 8 monitoring stations from 2006 to 2016. The stations are arranged within the columns from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

Figure 51 illustrates the long-term trend in biomass. Firstly, it is obvious the greatest values were observed in the west (Kiel Bay = OMBMPN3 and Fehmarnbelt OMBMPN1) followed by the Bay of Mecklenburg (OMBMPM2); and secondly it is obvious that biomass is not as strongly influenced as species numbers or abundance. Similarly, variations can be significant, although we did not observe the sharp decline in biomass that we saw in species numbers and abundance due to oxygen deficiency at Fehmarnbelt (OMBMPN1) and Bay of Mecklenburg (OMBMPM2) in 2008 and 2010, and in Bay of Mecklenburg (OMBMPM2, OM18) in 2014. The dominating species (bivalves of the genera *Arctica* and *Astarte*) with high individual weights buffer the loss of species and their weights for the total biomass. Overall, the total biomass observed in 2016 was relatively low; the lowest value for all monitoring stations together since 2006.

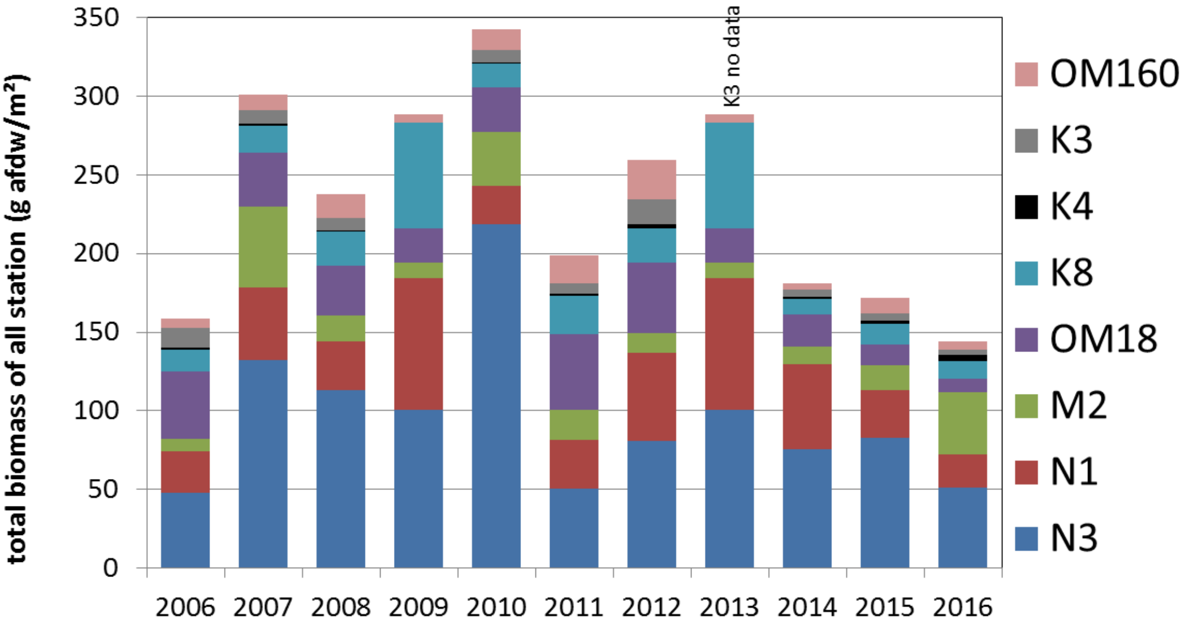


Fig. 51: Cumulative biomass of macrozoobenthos at 8 monitoring stations from 2006 to 2016. The stations are arranged within the columns from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

The decline of biomass in the Pomeranian Bay is mainly caused by the strong decline of larger bivalves as *Cerastoderma glaucum*, *Limecola balthica* and *Mya arenaria*. Whereas in 2012 the biomass of these three species reached values between 4 and 11 g/m² afdw each (together 20 g/m²) the values in 2016 ranged between 0 and 2 g/m² (together 2.9 g/m²). About the reasons we can only speculate, maybe the strong feeding pressure by diving ducks or varying food supply, as KUBE (1996) has stated already, could cause the significant changes.

As an example for the long-term variation of the macrozoobenthos the development of population parameters at station OMBMPN3 are presented in Fig. 52. Within the time span of the last 11 years three main collapses are obvious. In 2008, 2010 and 2016 the abundance, the species number and to a least degree also the biomass decreased rapidly.

4.3.4 Red List

This section refers to the recently published Red List of bottom-dwelling invertebrates by RACHOR et al. (2013). Of a total of 141 species, 19 are classed as threatened (1, 2, 3, G) (Fig. 53, Table 8). Five species are still classed as being near threatened. Four species are categorised as extremely rare. Currently, 79 species are classed as being of least concern. Data are deficient for 18 species, and 16 taxa on the Red List were not evaluated. *Macoma calcarea* (chalky macoma) and the anthozoan *Halcampa duodecimcirrata* are critically endangered. As in previous years, the first occurs in low densities (7 ind./m²) in Kiel Bay (OMBMPN3) and the second was detected in the southern Bay of Mecklenburg (OM18) in medium densities (54 ind./m²). Species that are classed as endangered (category 2) were also found at the westernmost station (OMBMPN3), including *Buccinum undatum* (common whelk). Additionally the sabellid *Euchone papillosa* was identified from the southern Bay of Mecklenburg.

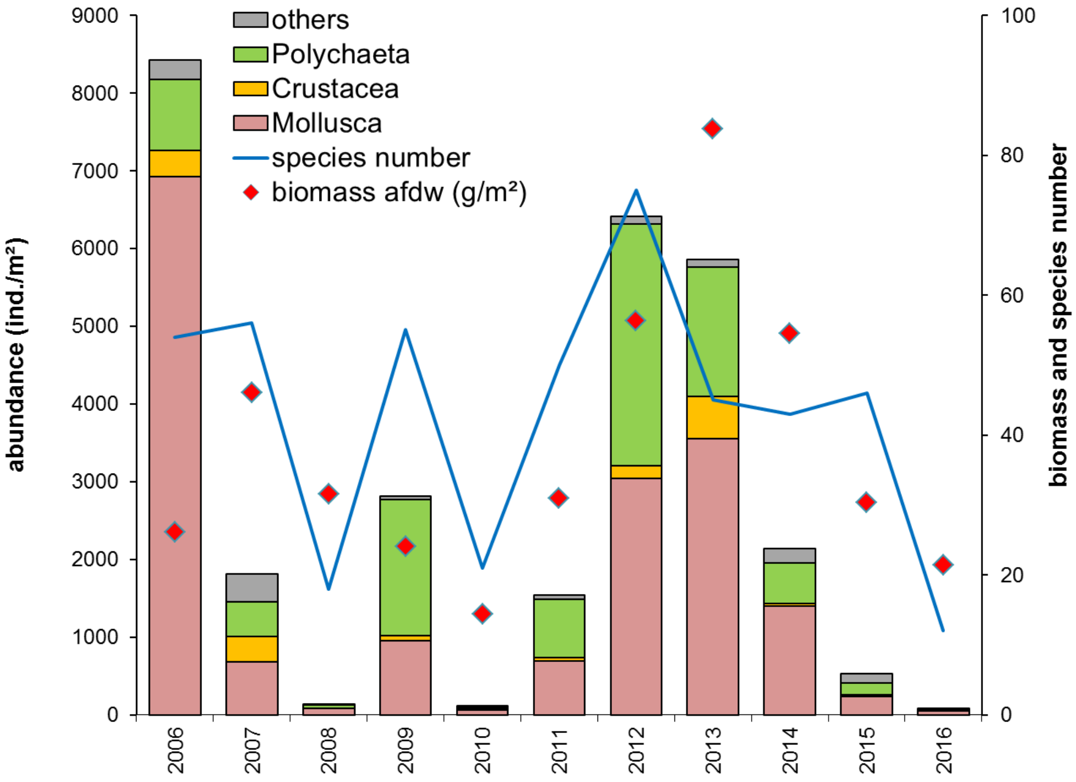


Fig. 52: The development of the abundance, biomass and species number at the monitoring station in Fehmarnbelt (OMBMPN3) from 2006 to 2016

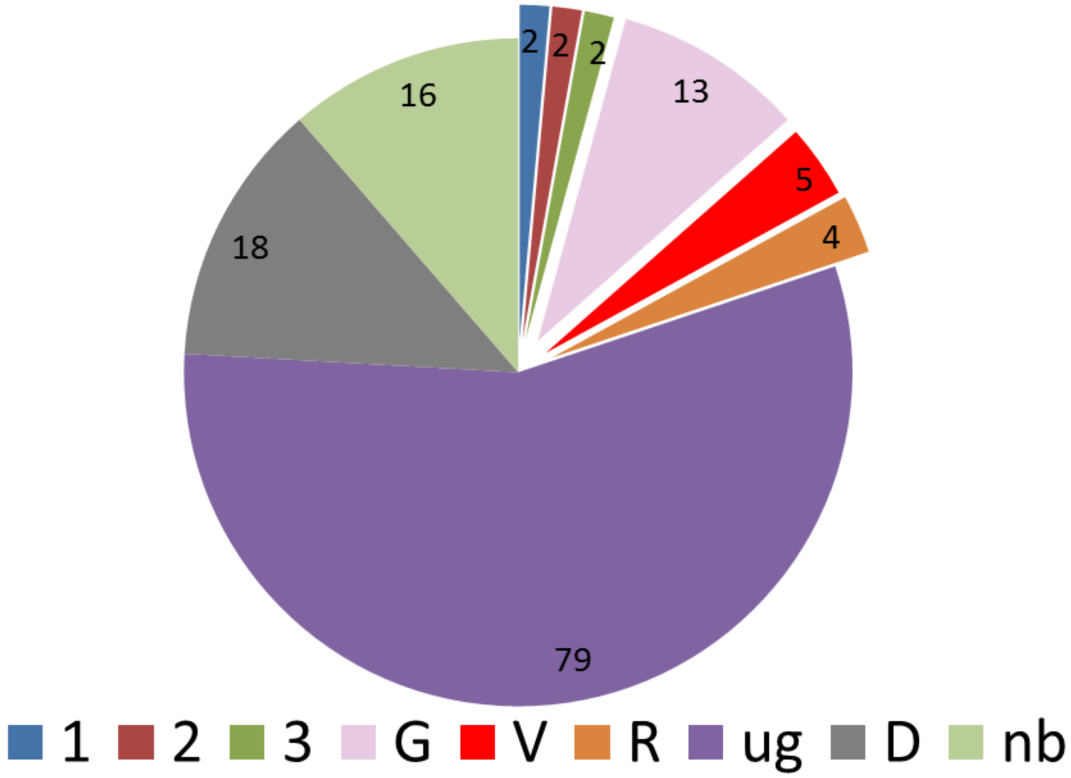


Fig. 53: Percentage of red list categories (Rachor et al. 2013) in relation to macrozoobenthos in autumn 2016 (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, R=extremely rare, UG=least concern, D=data deficient, nb=not evaluated).

Table 8
Consistency (%) of records of red list species (categories 1, 2, 3, G, V and R) at the 8 monitoring stations between 2006 and 2016. The observations of 2016 are indicated as grey boxes.

species	**N3**	**N1**	**M2**	**OM18**	**K8**	**K4**	**K3**	**OM160**	**RL**
Amphitrite cirrata	9								G
Apherusa bispinosa		9							G
Aporrhais pespelecani	45								G
Arctica islandica	100	100	100	100	45	91			3
Astarte borealis	100	45		64	100	9			G
Astarte elliptica	100	73	9	18		64			G
Astarte montagui	91			9	27				3
Buccinum undatum	64	18							2
Callipallene brevirostris	36				9				R
Caprella linearis	9	9							V
Dendrodoa grossularia	100	82	9	18	27				V
Dendronotus frondosus	9								V
Echinocyamus pusillus	55								G
Ecrobia ventrosa								9	G
Enipo kinbergi	9								R
Euchone papillosa	55	27	27	27	9				2
Eucratea loricata	73	64	73	91	18	9			V
Eulalia bilineata	36	9		18		18			G
Halcampa duodecimcirrata	9			27					1
Halichondria panicea	36	18		18	9				G
Halitholus yoldiaarcticae		9	9		9		18		3
Hermania scabra	9								R
Lysilla loveni	9	18							R
Macoma calcarea	91			18					1
Melita palmata					9			36	V
Metridium senile		18		9	9				G
Monoporeia affinis							36		3
Musculus discors	82								G
Musculus niger	91								G
Musculus subpictus	100	27	9	18	9				G
Mya truncata	82			9					2
Nassarius reticulatus	9								G
Neptunea antiqua	36								G
Nereimyra punctata	100	55		55					G
Ophelia rathkei					18				V
Palaemon adspersus	9								V
Pholoe inornata	18								R
Pontoporeia femorata		36	9	9		36	18		V
Protomedeia fasciata	9	18							R
Rhizocaulus verticillatus		9							G
Saduria entomon							36		G

species	**N3**	**N1**	**M2**	**OM18**	**K8**	**K4**	**K3**	**OM160**	**RL**
Scalibregma inflatum	82	55	9	27					G
Sertularia cupressina	18	64		27	9				G
Spirorbis spirorbis		9							G
Spisula subtruncata	9								G
Stenothoe monoculoides	9								R
Streblospio shrubsolii		9						36	V
Travisia forbesii					100		36		G
Urticina felina	9								G
total species number	**36**	**23**	**9**	**18**	**15**	**6**	**5**	**3**	**49**

Specimens of *Arctica islandica* (ocean quahog; category 3, vulnerable) were observed at all western stations (OMBMPN3, OMBMPN1, OMBMPM2, and OM18) and in the deeper Arkona Basin (OMBMPK4) at various levels of abundance. Montagu's Astarte (*Astarte montagui*) occurred in the Kiel Bay only. Category G (probably vulnerable) includes species that cannot be assigned to category 1, 2 or 3 above, but which - based on current knowledge - are assumed to be endangered. They are declared to be at risk (uncategorized). The 13 species observed in 2016 were distributed across almost all sea areas: 9 species in Kiel Bay (OMBMPN3), 2 at southern Bay of Mecklenburg (OM18), 5 at the Darss Sill (OMBMPK8), and one each in Arkona Basin (OMBMPK4) and Pomeranian Bay (OM160). Since 2013 there has also been a Red List for the entire Baltic Sea as compiled by a HELCOM group of experts (KONTULA et al. 2013). It lists one of the above-mentioned species found in our investigation: *Macoma calcarea* (chalky macoma) is classified as vulnerable (VU).

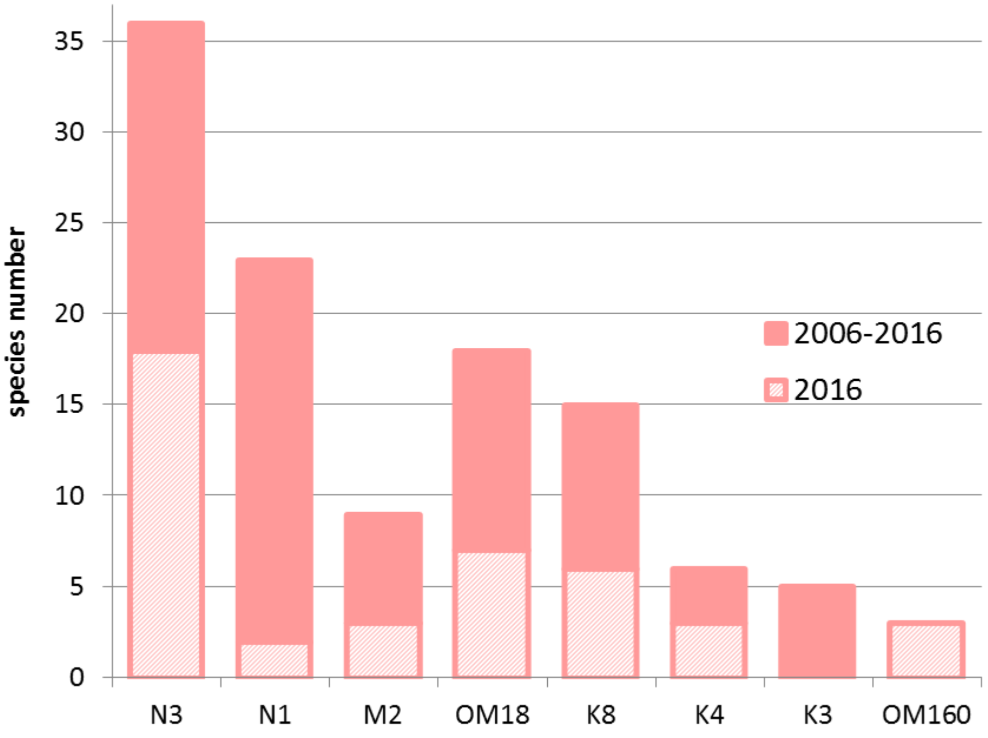


Fig. 54: Number of red listed species (categories 1, 2, 3, G, V and R) at the 8 monitoring stations in 2016 and in total (2006-2016).

In general the number of potentially occurring red listed species at the monitoring stations is decreasing systematically with the salinity gradient from the West to the East (Figs. 54, 55). The percentage of red listed species in 2016 in comparison to observations in the whole investigation time (2006 to 2016) ranges between 0 and 100 % (Fig. 53). Especially at the stations in the Fehmarnbelt and Mecklenburg area (OMBMPN1 and OMBMPM2) the number was significantly lower than in the previous years (Fig. 55). In the Arkona Basin (OMBMPK3) no red listed species were observed in 2016. Contrary, in some stations the number of red listed species increased clearly (e.g. Darss Sill and Pomeranian Bay).

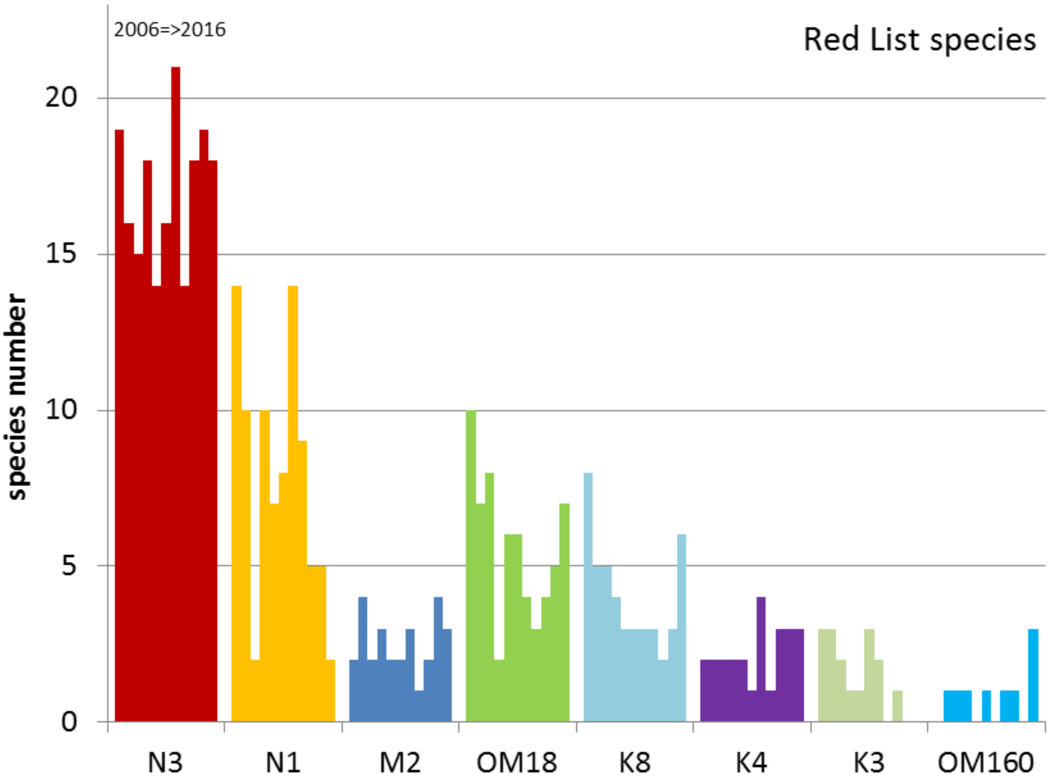


Fig. 55: Development of the number of red listed species (categories 1, 2, 3, G, V and R) at the 8 monitoring stations from 2006 to 2016.

4.3.5 Invasive Species

The role of invasive species in the open Baltic Sea is negligible (Zettler et al. 2014). Only four species were observed at our 8 monitoring stations in 2016. *Amphibalanus improvisus* (bay barnacle) and *Mya arenaria* (soft-shell clam) have been present in the Baltic region for so long now that they barely still qualify as invasive species. Two species of polychaete from North America have been present in the Baltic since the 1980s and 1990s: while *Marenzelleria neglecta* mainly occurs in inshore waters where it can achieve significant abundances, *Marenzelleria viridis* finds suitable habitat conditions in offshore waters. In 2016 we observed the following abundances of *M. viridis*: 3 ind./m² at Darss Sill (OMBMPK8); 14 ind./m² in the north of the Pomeranian Bay (OMBMPK3); and 132 ind./m² in the central Pomeranian Bay (OM160). In 2016 *M. neglecta* was not observed at the monitoring stations. However, in near coastal waters it is still abundant. In 2016 we found the estuarine mud crab *Rhithropanopeus harrisii* in offshore waters at the Darss Sill for the first time and again in the Pomeranian Bay. This species is commonly distributed in some German coastal waters like the Darss-Zingst-Lagoon, Greifswald Lagoon and around the island of Rugia. In the central Pomeranian Bay we find it occasionally since 2004.

Summary

As part of the German contribution to the HELCOM monitoring, data on species composition and biomass or abundance of phyto- and zooplankton as well as macrozoobenthos from Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin and Eastern Gotland Basin (Fig. 1) were gathered in 2016 in order to continue the time series which exists since 1979. A general sample statistics is shown in Table 1 and special statistics of the zooplankton and zoobenthos samplings are presented in Tables 2 and 3. Data from sediment traps deployed in the Arkona Basin give information on particle dynamics. Also satellite data are used to trace especially the development of cyanobacteria blooms.

Information from satellite images

Strong warming in the late spring during low wind periods led not only to the positive temperature anomalies in May and June, but also to an early cyanobacteria development as confirmed by measurements during the monitoring cruise from May 2016. After a generally warm summer, stable low wind conditions and surface water temperatures of 18-20 °C prevailed until mid-September in the southern and western Baltic Sea, leading to an extended cyanobacteria occurrence until mid-September. Consequently, cyanobacteria covered the area from western Baltic to northern Gotland Sea up to 4 month, which was unusually long.

Phytoplankton

Quantitative information on the species composition and succession of the phytoplankton was gathered from water samples, taken during the cruises and analysed microscopically in the lab. In this report, we concentrated mainly on mixed samples from 0-10 m depth. Gaps owing to the low sampling frequency in routine monitoring could be partly closed by additional samples taken on a cruise of the Thünen-Institute of Baltic Sea Fisheries and of the IOW. Moreover, information from the coastal monitoring of the IOW in front of Heiligendamm could be used, to be found on http://www.io-warnemuende.de/algenblueten-vor-heiligendamm-2016.html.

The 10 most important phytoplankton taxa of each season in each sea area are compiled in Table A1 (Annex), sorted by their percentage in total phytoplankton biomass. A complete species list of the year 2016, including a seasonal indicator, is shown in Table A2 (Annex). The ranking according to their biomass in 2016 is also given.

Spring bloom:

Rather high biomass of *Coscinodiscus concinnus* occurred in January and February especially in the deeper water layers of Kiel Bay and Bay of Mecklenburg, which was probably transported with inflowing water from the North Sea. This species formed the spring bloom in Kiel Bay at the beginning of March 2016 and was later accompanied by *Pseudo-nitzschia seriata*, but towards the east, in the Bay of Mecklenburg, it was more and more replaced by the autochthonous *Skeletonema* bloom, which occurred in the first half of March. In contrast to previous years, the spring bloom in Kiel Bay and Bay of Mecklenburg was almost exclusively represented by diatoms, with only a little share of *Mesodinium rubrum* and dinoflagellates and almost no dictyochophyceae. Only after the spring bloom, in May 2016, prymnesiophyceae and some dictyochophyceae and cyanobacteria developed.

Darss Sill is not a strict border that separates the phytoplankton of the Belt Sea from that of the Baltic Proper. However, in the deeper water layers, in was separating *C. concinnus* and *Pseudo-*

nitzschia seriata in the Bay of Mecklenburg from *Actinocyclus* in the central Arkona Sea and the more eastern regions of the Baltic Proper.

As found already in the previous year, the inorganic nitrogen was consumed more intensively than phosphate, which is a symptom of nitrogen deficiency. Silicate was not used up and seems not to limit diatom growth. Moreover, silicate concentrations did not decrease in the Bornholm Basin and southern part of the Eastern Gotland Basin despite a strong diatom growth. In these Basins, “luxury uptake” of the “excess” phosphorus occurred after the bloom, perhaps by the developing cyanobacteria. Surprisingly, silicate concentrations increased much stronger after the diatom spring bloom than concentrations of phosphate and nitrate+nitrite.

In contrast to earlier knowledge, the spring bloom development was not clearly retarded into eastern directions. It might have occurred in Kiel Bay at the beginning of March 2016, and in the Bay of Mecklenburg, Arkona Basin and Bornholm Basin in the first half of March. In the southern part of the Eastern Gotland Basin, an exceptionally early occurrence of high diatom (*Actinocyclus,* probably as spores) biomass was noticed already at the beginning of February. This extreme event is based on only one sample and needs confirmation. A spring bloom of usual composition (*Mesodinium rubrum*, Dinoflagellates) developed in mid of March in the Eastern Gotland Basin and continued by mid of May with increasing share of Prymnesiales and cyanobacteria.

Summer bloom:
A summer diatom bloom was formed by *Proboscia alata*, *Dactyliosolen fragilissimus* and *Guinardia flaccida* in the Belt Sea and the western part of the Arkona Basin in the first half of August. Moderate to strong cyanobacteria blooms were found in all regions observed. They were not found in the samples from the Bornholm Basin, but satellite images proved that cyanobacteria blooms did also occur in that region.

Autumn bloom:
Autumn blooms were well-developed in Kiel Bay, Bay of Mecklenburg and the Arkona Basin, dominated by *Cerataulina pelagica*. In the Belt Sea, the development of *Ceratium* spp. started in the summer as usual, but for unknown reasons, they did not form the typical autumn bloom in 2016. Already in 2014 and 2015, we noticed the reduced presence of the typical *Ceratium tripos*. The typical *Coscinodiscus granii* developed in the Bornholm Basin and the Eastern Gotland Basin, but biomass stayed rather low in the first half of November 2016.

Invading phytoplankton species:
Some species which were new for us in previous years (*Lennoxia faveolata, Phaeodactylum* cf. *tricornutum, Spatulodinium pseudonoctiluca, Alexandrium pseudogonyaulax*) have established. Other species which invaded in 2015 (*Coscinodiscus centralis*, *Roperia tesselata, Nematopsides vigilans, Fragilidium subglobosum*, and *Karenia mikimotoi*), were not found in 2016 anymore. Obviously, the Mayor Baltic Inflows had no effect on the phytoplankton composition.

Chlorophyll: The concentrations of chlorophyll *a* are compiled in Table 6. They were highest (10.5 mg m^{-3}) during the autumn bloom in the Bay of Mecklenburg at the beginning of November 2016. The spring bloom was not sufficiently represented in the chlorophyll data.

Sedimentation: Over the year 2016 the seasonal pattern of vertical export of particulate organic matter in the Arkona Basin showed a distinct spring peak, a period of high flux during summer and high rates during late autumn with a clear succession of algal species within and between the sedimentation maxima. Summer flux was high and derived from a mixture of diatoms and cyanobacteria. This year, resuspension events of already settled material were not relevant. In comparison to the previous years the diversity of diatoms increased whereas the number of dinoflagellate and flagellate species/groups decreased. The number of cyanobacterial species and green algae remained on the same level.

The total annual flux for single elements in 2016 amounted to 718 mmol C (8.6 g C), 93 mmol N, 85 mmol Si and 3 mmol P m^{-2} a^{-1} at a mass flux of 70 g dry mass m^{-2} a^{-1}. The level of these values is in the upper range of long term annual flux rates, except for silica, which is related to the lack of strong resuspension events.

The presence of diazotrophic cyanobacteria was documented by microscopy and was also reflected in the drop of the isotopic signature of nitrogen over the summer period between June and September. With 5.1 ‰, the mass weighted $\delta^{15}N$ signature for the whole year documents a lower influence of nitrogen fixation for the total annual balance than in the previous year. Over the whole year, the mass-weighted means of elemental ratios were 7.8 for C/N, 236 for C/P and 8.3 for C/Si. With -25.3‰, the mean $\delta^{13}C$ signature of the organic carbon was within the range of the previous years.

Zooplankton

The investigation of the long-term variation in abundance and community composition of the zooplankton in 2016 was based on 60 samples taken at 45 stations in the western Baltic Sea. In 2016, a notable increase in the number of recorded taxa from 45-52 during the preceding years to 73 was recorded. This increase was caused by the appearance of pelagic larvae of crustaceans, polychaetes and Echinodermata such as *Liocarcinus* spp., *Pagurus bernhardus, Palaemon serratus, Peltogaster paguri*, *Upogebia stellata, Pectinaria* spp. or *Echinus* spp. which have not been recorded in previous years, but are known from the area. Among the holoplankton, halophilic species such as *Acartia clausi*, *Calanus* spp. or *Centropages typicus* were also regularly found.

The composition of the zooplankton was generally dominated by the calanoid and cyclopoid copepods. This is rather unusual, because blooms of the parthenogenetic cladocera and rotifers usually outnumber the copepods. Similar to the year 2015, the genus *Acartia* was the most abundant group of the calanoid copepods and rather low stocks of *Pseudocalanus*/*Paracalanus* were observed. Among the genus *Acartia*, the brackish water species of *A. bifilosa* and *A. tonsa* were considerably more abundant in 2016 than in 2015, particularly in the Kiel Bight. The marine euryhaline species *A. longiremis*, in contrast, was largely confined to the Bay of Mecklenburg and the Arkona Sea. Other abundant and frequently observed species were *Oithona similis*, *Temora longicornis* and *Centropages hamatus*. Among the cladocera, *Bosmina* spp. was the single most important species, but it density was rather low in 2016. *Evadne nordmanni* ranked second, while the *Podon intermedius* and *P. leuckartii* species *Pleopsis polyphemoides* occurred frequently, but at low abundance. *Penilia avirostris*, which was rather rare in preceding years, occurred also frequently but at low concentration. Rotifers were generally dominated by the genus *Synchaeta*, while species of the genus

Keratella was represented in low numbers, only. Typical for the appendicularians, *Fritellaria borealis* was abundant in spring, while *Oikopleura dioica*, in contrast occurred mainly in summer-autumn.

The composition of the zooplankton and the seasonal development was rather homogenous in the different areas in 2016. The winter stocks were unusually low and dominated by copepods. In March, the early spring increase with a rise in the numbers of the rotifer *Synchaeta* was recorded. This is unusual for the Kiel Bight, for which rather low abundances of the genus were hitherto observed. Apart from rotifers, the larvae of polychaetes and appendicularians (*Fritellaria borealis*) contributed to the increase, while copepods still remained low. They showed a major increase in May, particularly in the species *Acartia bifilosa*, *A. longiremis* and *Temora longicornis*. While *Acartia bifilosa* was abundant in the Kiel Bight and Bay of Mecklenburg, and *A. longiremis* was more frequent in Bay of Mecklenburg the Arkona Sea. In summer, copepods dominated the zooplankton together with abundant larvae of bivalves, cladocera (*Bosmina* spp, *Evadne nordmanni*) and appendicularians (*Oikopleura dioica*). Among the copepods a shift from *A. bifilosa* and *A. longiremis* to the brackish *A. tonsa* and the cyclopoid *Oithona similis* occurred in summer. They remained abundant until autumn, during which also *T. longicornis, Centropages hamatus* frequently occurred. The seasonal abundance of *Pseudocalanus* spp. and *Paracalanus parvus* was low.

Macrozoobenthos

This study presents the results of macrozoobenthos monitoring in the southern Baltic Sea in November 2016. The following parameters were measured: species richness, and the abundance and biomass of organisms per station. Compared to previous years, the 141 species recorded at the 8 monitoring stations were considered to be a high number. No long-lasting oxygen deficiency was observed in 2016. The oxygen supply in bottom waters in the current year was always higher than 2 ml/l; however, at two stations (Fehmarnbelt and Bay of Mecklenburg) a significant decline of population parameters was observed. Depending on the region, abundances varied between 78 and 8 830 ind./m². In terms of biomass, similarly high variations were observed (3.4g in the northern Pomeranian Bay to 51.1 g afdw/m² in the Kiel Bay). With 18 species and a salinity of 21.3 psu in the central Arkona Basin the indication of the saltwater inflow two years before is still visible. Some marine species were observed again since a long or for the first time at all. For example, the urchin *Echinocardium cordatum* was never recorded before and is now occurring in the Kiel Bay in low numbers. Altogether, 10 “new” species were observed at the 8 monitoring stations in 2016.

Nineteen species of the German Red List (Categories 1, 2, 3 and G) were observed at the 8 monitoring stations. The bivalve *Macoma calcarea*, very rarely observed and critically endangered in German waters, was found in the Kiel Bay, for instance. One species of the HELCOM Red List (KONTULA et al. 2013) was detected: *Macoma calcarea* (VU).

In line with expectations, the number of invasive species found during the 2016 sampling campaign was low: four species were identified, among them long-established species like *Amphibalanus improvisus* (Cirripedia) and *Mya arenaria* (Bivalvia). Recently introduced species (since the 1980s and 1990s) of the genus *Marenzelleria* (Polychaeta) are locally important, whereof *Marenzelleria viridis* colonised the Pomeranian Bay in densities of about 150 ind./m². Additionally, the estuarine mud crab *Rhithropanopeus harrisii* was observed in deeper offshore waters at the Darss Sill for the first time and again in the central Pomerania Bay.

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ANNEX (for multi-page tables)

Table A1

The 10 most abundant phytoplankton taxa (percentage of total phytoplankton biomass) in the different sea areas (upper 10 m): averages from the three cruises January-May as well as cruises from August and November 2016. The mean phytoplankton biomass (in µg/l) is given on the top of each station block. „Unidentified“ were deleted from the list. Continued on page 87-88 !

January-May	(%)	August	(%)	November	(%)
Kiel Bay (Stat. OMBMPN3)					
Phytopl. biomass in µg/L	488	Phytopl. biomass in µg/L	1046	Phytopl. biomass in µg/L	3281
Coscinodiscus concinnus	46.97	Proboscia alata	33.79	Cerataulina pelagica	31.17
Pseudo-nitzschia spp.	9.49	Dactyliosolen fragilissimus	18.25	Pseudosolenia calcar-avis	22.67
Gymnodiniales	5.84	Nodularia spumigena	10.90	Ditylum brightwellii	13.14
Protoperidinium depressum	4.48	Guinardia flaccida	8.83	Pseudo-nitzschia	6.92
Teleaulax spp.	4.34	Gymnodiniales	6.35	Polykrikos schwartzii	2.81
Prymnesiales	3.77	Ceratium tripos	4.61	Ceratium fusus	2.27
Proboscia alata	2.88	Prymnesiales	1.97	Proboscia alata	2.13
Dictyocha speculum	2.36	Actinocyclus normanii f. subsalsus	1.74	Chaetoceros danicus	1.82
Mesodinium rubrum	2.31	Telonema spp.	1.01	Chaetoceros decipiens	1.56
Leucocryptos marina	2.17	Prorocentrum micans	0.99	Thalassiosira eccentrica	1.55
Lübeck Bay (Stat. OMO22)					
Phytopl. biomass in µg/L	392	Phytopl. biomass in µg/L	2609	Phytopl. biomass in µg/L	5734
Gymnodiniales	26.81	Proboscia alata	62.81	Cerataulina pelagica	68.81
Mesodinium rubrum	22.55	Dactyliosolen fragilissimus	17.43	Skeletonema marinoi	8.81
Pseudo-nitzschia	8.81	Nodularia spumigena	5.88	Pseudosolenia calcar-avis	7.02
Prymnesiales	5.51	Gymnodiniales	3.66	Ditylum brightwellii	4.66
Dictyocha speculum	5.31	Ceratium tripos	1.74	Spatulodinium pseudonoctiluca	2.31
Teleaulax spp.	4.23	Guinardia flaccida	1.31	Ceratium fusus	0.88
Dinophysis norvegica	3.62	Katablepharis remigera	0.91	Pseudo-nitzschia spp.	0.78
Leucocryptos marina	3.19	Prymnesiales	0.74	Gymnodiniales	0.68
Protoperidinium pellucidum	3.09	Cerataulina pelagica	0.68	Polykrikos schwartzii	0.62
Heterocapsa rotundata	2.49	Alexandrium pseudogonyaulax	0.57	Rhizosolenia setigera f. pungens	0.61
Central Bay of Mecklenburg (Stat. OMBMPM2)					
Phytopl. biomass in µg/L	336	Phytopl. biomass in µg/L	2637	Phytopl. biomass in µg/L	6440
Actinocyclus normanii f. subsalsus	22.25	Dactyliosolen fragilissimus	38.81	Cerataulina pelagica	72.75
Prymnesiales	20.42	Proboscia alata	29.67	Ditylum brightwellii	5.41
Gymnodiniales	14.29	Guinardia flaccida	11.72	Gymnodiniales	2.99
Mesodinium rubrum	8.68	Nodularia spumigena	5.78	Pseudosolenia calcar-avis	2.99
Pseudo-nitzschia spp.	4.36	Gymnodiniales	2.60	Peridiniella danica	2.66
Teleaulax spp.	3.72	Cerataulina pelagica	1.85	Rhizosolenia setigera	1.81
Cymbomonas tetramitiformis	2.32	Ceratium tripos	1.59	Rhizosolenia setigera f. pungens	1.44
Peridiniella danica	2.04	Pseudosolenia calcar-avis	0.86	Pseudo-nitzschia spp.	1.39
Peridiniales	1.69	Prymnesiales	0.71	Skeletonema marinoi	1.16
Proboscia alata	1.57	Aphanizomenon sp.	0.69	Proboscia alata	0.81
Eastern Bay of Mecklenburg (Stat. OMBMPM1)					
Phytopl. biomass in µg/L	240	Phytopl. biomass in µg/L	1782	Phytopl. biomass in µg/L	3049
Prymnesiales	25.83	Guinardia flaccida	36.53	Cerataulina pelagica	68.78
Mesodinium rubrum	17.84	Dactyliosolen fragilissimus	25.35	Ditylum brightwellii	8.63
Gymnodiniales	11.87	Proboscia alata	14.89	Skeletonema marinoi	6.47
Coscinodiscus concinnus	7.29	Gymnodiniales	5.36	Pseudosolenia calcar-avis	2.55
Peridiniella danica	4.55	Nodularia spumigena	5.29	Mesodinium rubrum	1.82
Teleaulax spp.	4.15	Ceratium tripos	2.33	Pseudo-nitzschia	1.68
Guinardia delicatula	3.69	Cerataulina pelagica	1.60	Chaetoceros danicus	0.74
Actinocyclus spp.	2.09	Aphanizomenon sp.	1.07	Gymnodiniales	0.67
Gyrodinium spirale	1.88	Prymnesiales	1.00	Thalassiosira spp.	0.66
Proboscia alata	1.87	Pseudosolenia calcar-avis	0.62	Chaetoceros castracanei	0.55

Western Arkona Basin (Stat. OMBMPK8)

Phytopl. biomass in µg/L	284	Phytopl. biomass in µg/L	1146	Phytopl. biomass in µg/L	418
Mesodinium rubrum	26.35	Dactyliosolen fragilissimus	49.57	Cerataulina pelagica	36.82
Prymnesiales	24.93	Nodularia spumigena	14.05	Coscinodiscus granii	18.29
Gymnodiniales	23.44	Guinardia flaccida	7.47	Teleaulax spp.	6.12
Teleaulax spp.	2.79	Gymnodiniales	4.28	Actinocyclus spp.	6.07
Scrippsiella COMPLEX	2.40	Proboscia alata	4.23	Mesodinium rubrum	4.09
Peridiniales	2.15	Ceratium tripos	3.22	Pyramimonas spp.	3.40
Protoperidinium spp.	1.82	Aphanizomenon sp.	2.90	Gymnodiniales	2.97
Heterosigma akashiwo	1.11	Mesodinium rubrum	1.38	Ditylum brightwellii	2.37
Actinocyclus spp.	1.02	Alexandrium pseudogonyaulax	1.31	Ceratium tripos	2.31
Aphanocapsa spp.	0.93	Prymnesiales	1.24	Skeletonema marinoi	2.08

Central Arkona Basin (Stat. OMBMPK5)

Phytopl. biomass in µg/L	412	Phytopl. biomass in µg/L	1026	Phytopl. biomass in µg/L	330
Mesodinium rubrum	35.22	Nodularia spumigena	41.52	Cerataulina pelagica	24.40
Gymnodiniales	19.75	Dactyliosolen fragilissimus	16.70	Actinocyclus spp.	9.91
Prymnesiales	13.02	Aphanizomenon sp.	7.64	Coscinodiscus granii	8.38
Peridiniella danica	7.64	Gymnodiniales	7.03	Pyramimonas spp.	6.87
Actinocyclus spp.	6.64	Prorocentrum cordatum	4.39	Teleaulax spp.	5.80
Skeletonema marinoi	2.59	Ceratium tripos	3.76	Eutreptiella spp.	4.04
Teleaulax spp.	1.54	Plagioselmis prolonga	3.35	Mesodinium rubrum	4.00
Micracanthodinium claytonii	1.46	Alexandrium pseudogonyaulax	1.80	Dactyliosolen fragilissimus	3.70
Peridiniales	1.36	Pyramimonas spp.	1.68	Gymnodiniales	3.68
Ebria tripartita	1.27	Aphanocapsa spp.	1.28	Actinocyclus normanii f. subsalsus	3.03

Eastern Arkona Basin (Stat. OMBMPK4)

Phytopl. biomass in µg/L	527	Phytopl. biomass in µg/L	397	Phytopl. biomass in µg/L	902
Mesodinium rubrum	46.58	Gymnodiniales	15.54	Cerataulina pelagica	62.59
Gymnodiniales	18.33	Aphanizomenon sp.	11.91	Coscinodiscus granii	7.37
Prymnesiales	10.77	Nodularia spumigena	10.80	Actinocyclus spp.	3.38
Peridiniella danica	5.19	Alexandrium pseudogonyaulax	10.30	Teleaulax spp.	2.47
Actinocyclus spp.	3.33	Ebria tripartita	5.47	Ditylum brightwellii	2.46
Peridiniella catenata	1.82	Mesodinium rubrum	3.76	Pyramimonas spp.	2.34
Skeletonema marinoi	1.82	Plagioselmis prolonga	3.73	Skeletonema marinoi	2.12
Ebria tripartita	1.53	Prymnesiales	2.81	Pseudosolenia calcar-avis	2.04
Gyrodinium spirale	1.49	Katablepharis remigera	2.59	Gymnodiniales	1.74
Peridiniales	1.42	Prorocentrum cordatum	2.36	Dactyliosolen fragilissimus	1.59

Bornholm Basin (Stat. OMBMPK2)

Phytopl. biomass in µg/L	702	Phytopl. biomass in µg/L	165	Phytopl. biomass in µg/L	192
Mesodinium rubrum	33.84	Gymnodiniales	23.87	Coscinodiscus granii	55.77
Skeletonema marinoi	21.58	Mesodinium rubrum	19.21	Actinocyclus spp.	11.67
Prymnesiales	13.13	Plagioselmis prolonga	11.03	Gymnodiniales	5.99
Gymnodiniales	10.19	Ebria tripartita	5.66	Mesodinium rubrum	5.41
Actinocyclus spp.	4.24	Pyramimonas spp.	4.96	Teleaulax spp.	3.84
Peridiniella danica	2.76	Teleaulax spp.	4.17	Actinocyclus normanii f.subsalsus	2.45
Scrippsiella COMPLEX	1.67	Nodularia spumigena	3.17	Chaetoceros castracanei	2.06
Peridiniales	1.31	Akashiwo sanguinea	3.05	Plagioselmis prolonga	1.68
Heterocapsa rotundata	0.90	Pseudanabaena limnetica	3.05	Eutreptiella spp.	1.23
Teleaulax spp.	0.84	Prymnesiales	2.85	Telonema spp.	1.21

Southern Gotland Basin (Stat. OMBMPK1)

Phytopl. biomass in µg/L	1627	Phytopl. biomass in µg/L	659	Phytopl. biomass in µg/L	413
Actinocyclus spp.	52.78	Aphanothece paralleliformis	14.27	Coscinodiscus granii	79.81
Mesodinium rubrum	18.74	Gymnodiniales	10.07	Mesodinium rubrum	5.25
Prymnesiales	7.36	Cyanonephron styloides	8.40	Teleaulax spp.	3.04
Gymnodiniales	5.05	Nodularia spumigena	8.36	Gymnodiniales	1.71
Actinocyclus normanii f. subsalsus	3.38	Pseudanabaena limnetica	7.13	Actinocyclus spp.	1.32
Peridiniella danica	2.24	Aphanothece spp.	4.71	Plagioselmis prolonga	1.13
Micracanthodinium claytonii	1.59	Teleaulax spp.	4.60	Aphanizomenon sp.	0.72
Skeletonema marinoi	1.22	Mesodinium rubrum	4.46	Hemiselmis spp.	0.63
Gyrodinium spirale	1.07	Chaetoceros castracanei	3.64	Telonema spp.	0.51
Dinophysis norvegica	0.97	Cyanodictyon planctonicum	3.11	Pyramimonas spp.	0.30

Eastern Gotland Basin (Stat. OMBMPJ1)					
Phytopl. biomass in µg/L	796	Phytopl. biomass in µg/L	522	Phytopl. biomass in µg/L	308
Mesodinium rubrum	65.43	Nodularia spumigena	23.31	Coscinodiscus granii	81.22
Prymnesiales	9.86	Gymnodiniales	14.38	Actinocyclus sp.	7.66
Gymnodiniales	6.61	Aphanothece paralleliformis	10.56	Gymnodiniales	2.85
Peridiniella catenata	5.99	Aphanizomenon sp.	6.34	Teleaulax spp.	1.84
Peridiniales	1.81	Pseudanabaena limnetica	6.06	Mesodinium rubrum	1.29
Aphanizomenon sp.	1.72	Prymnesiales	4.69	Plagioselmis prolonga	0.93
Dinobryon balticum	1.51	Plagioselmis prolonga	3.25	Actinocyclus normanii f. subsalsus	0.75
Actinocyclus spp.	1.22	Peridiniella danica	2.62	Gyrodinium spirale	0.31
Dinophysis norvegica	0.98	Cymbomonas tetramitiformis	2.56	Eutreptiella spp.	0.21
Teleaulax spp.	0.58	Aphanothece spp.	2.42	Hemiselmis spp.	0.21

Table A2
Phytoplankton taxa list of 2015, with class affiliation, biomass rank (for all stations, all depths) and seasonal occurrence from the five monitoring cruises.
Continued on page 90-91.

Taxon	**Class**	**Rank**	**Jan./Feb.**	**March**	**May**	**Aug.**	**Nov.**
Actinocyclus sp.	Bacillarioph.	9	X	X	X	X	X
Actinocyclus normanii f. *subsalsus*	Bacillarioph.	25	X	X	X	X	X
Actinoptychus senarius	Bacillarioph.	102				X	
Akashiwo sanguinea	Dinophyceae	86				X	
Alexandrium pseudogonyaulax	Dinophyceae	55	X	X		X	
Amphidinium crassum	Dinophyceae	116	X			X	
Amphidinium sphenoides	Dinophyceae	76	X	X	X	X	X
Amylax triacantha	Dinophyceae	103		X		X	X
Anabaenopsis sp.	Cyanobact.	156				X	
Anathece sp.	Cyanobact.	57		X	X	X	X
Apedinella radians	Chrysophyc.	108	X	X	X	X	X
Aphanizomenon sp.	Cyanobact.	30	X	X	X	X	X
Aphanocapsa sp.	Cyanobact.	53	X	X	X	X	X
Aphanothece paralleliformis	Cyanobact.	45	X	X	X	X	
Attheya longicornis	Bacillarioph.	135	X	X	X		
Attheya septentrionalis	Bacillarioph.	87	X	X	X	X	X
Bacillaria paxillifer	Bacillarioph.	120				X	
Binuclearia lauterbornii	Ulvophyceae	118	X	X	X	X	X
Botryococcus sp.	Trebouxioph.	143					X
Centrales	Bacillarioph.	96	X			X	X
Cerataulina pelagica	Bacillarioph.	1	X	X	X	X	X
Ceratium furca	Dinophyceae	119	X				
Ceratium fusus	Dinophyceae	44	X			X	X
Ceratium lineatum	Dinophyceae	65	X			X	X
Ceratium longipes	Dinophyceae	69				X	
Ceratium tripos	Dinophyceae	18	X		X	X	X
Chaetoceros spp.	Bacillarioph.	81	X	X	X	X	X
Chaetoceros affinis	Bacillarioph.	85				X	X
Chaetoceros castracanei	Bacillarioph.	46	X	X	X	X	X
Chaetoceros ceratosporus	Bacillarioph.	154		X			
Chaetoceros contortus	Bacillarioph.	56				X	X
Chaetoceros convolutus	Bacillarioph.	40					X
Chaetoceros curvisetus	Bacillarioph.	106		X	X		X
Chaetoceros danicus	Bacillarioph.	28	X	X	X	X	X
Chaetoceros debilis	Bacillarioph.	100		X		X	
Chaetoceros decipiens	Bacillarioph.	74	X	X	X		X
Chaetoceros minimus	Bacillarioph.	153	X				
Chaetoceros similis	Bacillarioph.	104	X	X	X		X
Chaetoceros socialis	Bacillarioph.	71				X	X
Chaetoceros subtilis	Bacillarioph.	95	X	X	X	X	X
Chaetoceros throndsenii	Bacillarioph.	138	X	X	X	X	X
Chaetoceros wighamii	Bacillarioph.	136		X			
Choanoflagellatea	Choanoflag.	67	X	X	X	X	X
Chrysophyceae	Chrysophyc.	130	X		X		X
Coelosphaerium minutissimum	Cyanobact.	98	X	X	X	X	
Coscinodiscus spp.	Bacillarioph.	27	X	X		X	
Coscinodiscus concinnus	Bacillarioph.	11	X	X	X		
Coscinodiscus granii	Bacillarioph.	15	X			X	X
Cyanodictyon sp.	Cyanobact.	114	X	X	X		

Cyanodictyon planctonicum	Cyanobact.	80	X	X	X	X	
Cyanonephron sp.	Cyanobact.	155			X		
Cyanonephron styloides	Cyanobact.	78			X	X	
Cyclotella spp.	Bacillarioph.	112	X	X	X	X	X
Cylindrotheca closterium	Bacillarioph.	79	X	X	X	X	X
Cymbomonas tetramitiformis	Prasinophyc.	61			X	X	
Dactyliosolen fragilissimus	Bacillarioph.	5	X	X	X	X	X
Diatoma tenuis	Bacillarioph.	131					X
Dictyocha speculum	Dictyochoph.	42	X	X	X	X	X
Dinobryon sp.	Chrysophyc.	134		X	X	X	
Dinobryon balticum	Chrysophyc.	83		X	X		
Dinobryon faculiferum	Chrysophyc.	110		X	X	X	
Dinophysis spp.	Dinophyceae	149	X				
Dinophysis acuminata	Dinophyceae	51	X	X	X	X	X
Dinophysis acuta	Dinophyceae	88		X		X	
Dinophysis norvegica	Dinophyceae	29	X	X	X	X	X
Diplopsalis COMPLEX	Dinophyceae	129				X	
Ditylum brightwellii	Bacillarioph.	8				X	X
Dolichospermum spp.	Cyanobact.	90				X	
Ebria tripartita	Ebriophyc.	36	X	X	X	X	X
Eutreptiella sp.	Euglenoph.	49	X	X		X	X
Eutreptiella braarudii	Euglenoph.	109	X				
Gonyaulax sp.	Dinophyceae	151				X	
Guinardia delicatula	Dinophyceae	19	X	X	X	X	X
Guinardia flaccida	Dinophyceae	2	X	X	X	X	X
Gymnodiniales	Dinophyceae	6	X	X	X	X	X
Gymnodinium spp.	Dinophyceae	73		X	X		
Gyrodinium spirale	Dinophyceae	31	X	X		X	X
Hemiselmis sp.	Dinophyceae	63	X	X	X	X	X
Heterocapsa sp.	Dinophyceae	125			X	X	
Heterocapsa rotundata	Dinophyceae	39	X	X	X	X	X
Heterocapsa triquetra	Dinophyceae	89	X	X	X	X	X
Heterosigma akashiwo	Raphidophyc.	82	X	X			
Karlodinium cf. *veneficum*	Dinophyceae	124			X		
Katablepharis remigera	Incertae sedis	54	X	X	X	X	X
Katodinium glaucum	Dinophyceae	68	X	X	X	X	X
Koliella spp.	Trebouxioph.	150				X	
Laboea strobila	Oligotrichea	59	X	X		X	X
Lemmermanniella spp.	Cyanobact.	122	X		X		
Lemmermanniella pallida	Cyanobact.	101		X	X	X	
Lemmermanniella parva	Cyanobact.	127			X	X	
Lennoxia faveolata	Bacillarioph.	147	X		X	X	X
Leptocylindrus danicus	Bacillarioph.	107				X	X
Leptocylindrus minimus	Bacillarioph.	137	X	X			X
Leucocryptos marina	Incertae sedis	50	X	X	X	X	X
Merismopedia spp.	Cyanobact.	157	X				
Mesodinium rubrum	Litostomatea	3	X	X	X	X	X
Micracanthodinium claytonii	Dinophyceae	37	X	X	X	X	X
Monoraphidium contortum	Chlorophyc.	148			X	X	X
Nitzschia longissima	Bacillarioph.	146					X
Nitzschia paleacea	Bacillarioph.	94				X	
Nodularia spumigena	Cyanobact.	14		X	X	X	X
Oocystis spp.	Trebouxioph.	139	X	X		X	
Pachysphaera sp.	Prasinophyc.	132	X		X		
Pennales	Bacillarioph.	111	X	X	X	X	X

Peridiniales	Dinophyceae	23	X	X	X	X	X
Peridiniella catenata	Dinophyceae	43	X	X			
Peridiniella danica	Dinophyceae	17		X	X	X	X
Phaeodactylum cf. *tricornutum*	Bacillarioph.	140			X	X	
Phalacroma rotundatum	Dinophyceae	126				X	
Plagioselmis prolonga	Cryptophyc.	24	X	X	X	X	X
Planktolyngbya spp.	Cyanobact.	91	X	X	X	X	X
Planktolyngbya contorta	Cyanobact.	144			X		
Polykrikos schwartzii	Dinophyceae	41					X
Proboscia alata	Bacillarioph.	7	X	X	X	X	X
Pronoctiluca pelagica	Dinophyceae	152	X			X	
Prorocentrum cordatum	Dinophyceae	58	X			X	X
Prorocentrum micans	Dinophyceae	34	X			X	X
Protoperidinium spp.	Dinophyceae	47	X	X		X	X
Protoperidinium bipes	Dinophyceae	121	X	X		X	X
Protoperidinium cf. *claudicans*	Dinophyceae	97				X	
Protoperidinium depressum	Dinophyceae	35	X	X		X	
Protoperidinium divergens	Dinophyceae	93				X	X
Protoperidinium oblongum	Dinophyceae	128				X	
Protoperidinium pallidum	Dinophyceae	113		X			
Protoperidinium pellucidum	Dinophyceae	62	X	X		X	X
Protoperidinium thorianum	Dinophyceae	99		X			
Prymnesiales	Prymnesioph.	4	X	X	X	X	X
Pseudanabaena spp.	Cyanobact.	115			X	X	
Pseudanabaena limnetica	Cyanobact.	66	X		X	X	X
Pseudo-nitzschia spp.	Bacillarioph.	16	X	X	X	X	X
Pseudo-nitzschia delicatissima GROUP	Bacillarioph.	145	X			X	X
Pseudo-nitzschia seriata	Bacillarioph.	13		X			
Pseudopedinella sp.	Chrysophyc.	72	X	X	X	X	X
Pseudosolenia calcar-avis	Bacillarioph.	10	X			X	X
Pterosperma sp.	Prasinophyc.	92				X	X
Pyramimonas spp.	Prasinophyc.	38	X	X	X	X	X
Pyramimonas longicauda	Prasinophyc.	141					X
Rhizosolenia hebetata f. *semispina*	Bacillarioph.	75		X		X	X
Rhizosolenia setigera	Bacillarioph.	32		X	X	X	X
Rhizosolenia setigera f. *pungens*	Bacillarioph.	20				X	X
Rhodomonas spp.	Cryptophyc.	142		X			
Romeria spp.	Cyanobact.	123			X	X	
Scrippsiella COMPLEX	Dinophyceae	52	X	X	X	X	X
Skeletonema marinoi	Bacillarioph.	12	X	X	X	X	X
Snowella spp.	Cyanobact.	77	X	X	X	X	X
Spatulodinium pseudonoctiluca	Dinophyceae	60					X
Teleaulax spp.	Cryptophyc.	22	X	X	X	X	X
Telonema spp.	Incertae sedis	48	X	X	X	X	X
Thalassionema nitzschioides	Bacillarioph.	64		X	X	X	X
Thalassiosira spp.	Bacillarioph.	21	X	X	X	X	X
Thalassiosira anguste-lineata	Bacillarioph.	133		X			
Thalassiosira eccentrica	Bacillarioph.	26			X	X	X
Thalassiosira gravida	Bacillarioph.	70					X
Thalassiosira nordenskioeldii	Bacillarioph.	33		X			
Thalassiosira punctigera	Bacillarioph.	84					X
Trachelomonas spp.	Euglenoph.	117	X		X	X	
Woronichinia spp.	Cyanobact.	105	X	X	X	X	
Number of taxa: total 157			**92**	**93**	**87**	**118**	**96**

Table A3
Seasonal occurrence of taxa found in the investigation area in 2016 with information on original description, taxonomic rank and taxonomic serial number (TSN) according to the Integrated Taxonomic Information System (ITIS). Continued on page 93-94 !

	Rank	TSN	Feb	March	May	Aug	Nov
Protozoa							
Noctiluca scintillans Kofoid and Swezy, 1921	Species	10150				o	
Tintinnidae	Family	46743				o	o
Annelida							
Polychaeta - Trochophora	Subphylum	914166	o	o	o	o	o
Polychaeta - others	Subphylum	914166	o	o	o	o	o
Harmothoe spp. Kinberg, 1855	Genus	64502		o	o		
Pectinaria spp. Savigny in Lamarck, 1818	Genus	67706				o	o
Spionidae Grube, 1850	Family	66781			o	o	o
Arthropoda - Crustacea							
Copepoda							
Acartia bifilosa Giesbrecht, 1881	Species	86095	o	o	o	o	o
Acartia longiremis Lilljeborg, 1853	Species	86087	o	o	o	o	o
Acartia tonsa Dana, 1849	Species	86088			o	o	o
Acartia clausi Giesbrecht, 1889	Species	86088	o				
Calanus spp. Leach, 1819	Species	85263	o	o	o	o	o
Centropages hamatus Lilljeborg, 1853	Species	85766	o	o	o	o	o
Centropages typicus Krøyer, 1849	Species	85767					o
Corycaeus anglicus Lubbock, 1857	Species	88573					o
Eurytemora affinis Poppe, 1880	Species	85863	o		o		o
Euterpina acutifrons Dana, 1849	Species	86546		o	o	o	o
Harpacticoida G. O. Sars, 1903	Ordnung	86110	o		o	o	o
Microsetella spp. Brady & Robertson, 1873	Genus	86208	o	o	o	o	o
Oithona similis Claus, 1866	Species	88805	o	o	o	o	o
Paracalanus parvus Claus, 1863	Species	85323	o	o	o	o	o
Pseudocalanus spp. Boeck, 1872	Genus	85369	o	o	o	o	o
Temora longicornis O.F.Müller, 1785	Species	85877	o	o	o	o	o
Phyllopoda							
Bosmina spp. Baird, 1845	Genus	83936		o	o	o	o
Cercopages pengoi Ostroumov, 1891	Species	684625	o				
Evadne nordmanni Lovén, 1836	Species	86546	o	o	o	o	o
Penilia avirostris Dana, 1849	Species	83836				o	o
Podon intermedius Lilljeborg, 1853	Species	83965			o	o	o
Podon leuckartii G. O. Sars, 1862	Species	83966		o	o	o	o
Pleopsis polyphaemoides (Leuckart,1859)	Species	684626				o	o

Table A3 continued.

	Rank	TSN	Feb	March	May	Aug	Nov
other Crustacea							
Balanus spp. Da Costa, 1778	Genus	89600	o	o	o	o	o
Crangon crangon Linnaeus, 1758	Species	107552			o	o	
Carcinus maenas Linnaeus, 1758	Species	107381				o	
Diastylis spp Say, 1818	Genus	90836	o	o		o	o
Decapoda Latreille, 1802	Order	95599		o			
Gammaridea Latreille, 1802	Suborder	93295	o	o			
Isopoda Latreille, 1817	Order	92120				o	
Liocarcinus spp. Stimpson, 1871	Genus	660431				o	
Lophogastrida Sars, 1870	Order	89808					o
Pagurus bernhardus (Linnaeus, 1758)	Species	97805				o	
Palaemon serratus (Pennant, 1777)	Species	96451				o	
Peltogaster paguri Rathke, 1842	Species	89745		o	o		
Upogebia stellata (Montagu, 1808)	Species	98212				o	
Bryozoa							
Gymnolaemata Allman, 1856	Class	155471	o	o	o	o	o
Chaetognatha							
Parasagitta setosa Mueller, 1847	Species	158795	o				
Sagittidae Claus and Grobben, 1905	Family	158726	o	o	o	o	o
Chordata							
Fritellaria borealis Lohmann, 1896	Species	159675	o	o	o	o	
Oikopleura dioica Fol 1872	Species	159669	o			o	o
Teleostei	Infraclass	161105	o	o	o	o	
Echinodermata							
Asterias spp. Linnaeus, 1758	Genus	157215		o		o	
Ophiura spp. Lamarck, 1801	Genus	157411				o	
Echinus spp. Linnaeus, 1758	Genus	157944				o	
Spatangoida Claus, 1876	Order	158069				o	
Cnidaria & Ctenophora							
Ctenophora Eschscholtz, 1829	Phylum	53856		o	o		o
Actinulida Swedmark and Teissier, 1958	Order	50864				o	
Aurelia aurita Linnaeus, 1758	Species	51701				o	
Obelia geniculata (Linnaeus, 1758)	Species	49522		o	o	o	
Rathkea octopunctata M. Sars, 1835	Species	49387				o	
Euphysa aurata Forbes, 1848	Species	48976			o	o	o
Antothecatae	Order	718925			o	o	
Leptothecatae	Order	718926				o	
Sarsia tubulosa M. Sars, 1835	Species	49055				o	
Phoronida							
Phoronis muelleri Selys-Longchamps, 1903	Species	206663				o	o

Table A3 continued.

	Rank	TSN	Feb	March	May	Aug	Nov
Nemertea							
Nemertea	Phylum	57411		o			
Nematoda							
Nematoda	Phylum	59490	o			o	
Platyhelminthes							
Alaurina spp. Metschnikoff, 1861	Genus	54024	o	o		o	o
Leptoplanidae Stimpson, 1857	Family	54115				o	o
Platyhelminthes Minot, 1876	Phylum	53963	o	o			
Mollusca							
Bivalvia Linnaeus, 1758	Class	79118	o	o	o	o	o
Gastropoda Cuvier, 1797	Class	69459	o	o	o	o	o
Rotifera							
Synchaeta spp. Ehrenberg, 1832	Genus	59255	o	o	o	o	o
Keratella quadrata O. F. Muller, 1786	Species	58352				o	o
Keratella cochlearis Gosse, 1851	Species	58360		o		o	

Table A4:
Distribution of macrozoobenthos at 8 stations in November 2016. In the right column the red list (RACHOR et al. 2013) species are indicated (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, R=very rare, D=data deficient, *=least concern, nb=not evaluated). Continued on page 96-98 !

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Amphipoda									
Crassicorophium crassicorne	1				1				*
Gammarus oceanicus					1				*
Gammarus salinus					1		1	1	*
Gammarus zaddachi							1	1	*
Melita palmata								1	V
Microdeutopus gryllotalpa	1			1					*
Monocorophium insidiosum	1								*
Pariambus typicus	1								*
Pontoporeia femorata				1					V
Protomedeia fasciata	1								R
Anthozoa									
Edwardsia danica	1			1					D
Halcampa duodecimcirrata				1					1
Ascidiacea									
Ciona intestinalis	1								*
Dendrodoa grossularia	1		1		1				V
Bivalvia									
Abra alba	1			1		1			*
Arctica islandica	1	1	1	1		1			3
Astarte borealis	1				1				G
Astarte elliptica	1					1			G
Astarte montagui	1								3
Cerastoderma glaucum							1	1	*
Corbula gibba	1	1	1	1	1	1			*
Hiatella arctica	1								*
Kurtiella bidentata	1	1		1					*
Limecola balthica	1			1	1	1	1	1	*
Macoma calcarea	1								1
Musculus discors	1								G
Musculus niger	1								G
Musculus subpictus	1				1				G
Mya arenaria	1				1	1	1	1	*
Mytilus edulis	1			1	1	1	1	1	*
Parvicardium pinnulatum	1			1	1				D
Parvicardium scabrum	1								D
Phaxas pellucidus	1								*
Spisula subtruncata	1								G
Bryozoa									
Alcyonidium diaphanum				1					*
Alcyonidium polyoum					1		1		D

Taxa	**N3**	**N1**	**M2**	**OM18**	**K8**	**K4**	**K3**	**OM160**	**RL**
Callopora lineata				1	1				*
Einhornia crustulenta		1		1		1	1	1	*
Electra pilosa					1	1			*
Eucratea loricata		1	1	1		1			V
Farrella repens	1				1				D
Flustra foliacea	1								*
Walkeria uva				1					*
Cirripedia									
Amphibalanus improvisus							1	1	nb
Cumacea									
Diastylis rathkei	1	1	1	1	1	1	1	1	*
Decapoda									
Carcinus maenas					1				*
Crangon crangon	1			1	1	1	1	1	*
Palaemon elegans		1			1			1	*
Rhithropanopeus harrisii					1			1	nb
Echinodermata									
Asterias rubens	1			1	1	1	1		*
Echinocardium cordatum	1								*
Ophiura albida	1	1		1	1				*
Psammechinus miliaris	1								*
Gastropoda									
Acanthodoris pilosa					1				*
Ancula gibbosa	1								*
Brachystomia scalaris					1				*
Buccinum undatum	1								2
Diaphana minuta	1								*
Ecrobia ventrosa								1	G
Facelina bostoniensis	1								*
Hermania scabra	1								R
Neptunea antiqua	1								G
Onchidoris muricata					1				*
Peringia ulvae		1		1	1		1	1	*
Philine aperta	1								*
Retusa obtusa					1				*
Hydrozoa									
Clytia hemisphaerica	1				1				D
Hartlaubella gelatinosa					1		1	1	D
Opercularella lacerata				1					D
Sertularia cupressina				1	1				G
Isopoda									
Idotea balthica					1			1	*
Idotea chelipes								1	D
Jaera albifrons							1		*
Mysida									
Gastrosaccus spinifer					1				nb
Mysis mixta							1		nb
Neomysis integer							1	1	nb

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Praunus flexuosus								1	nb
Nemertea									
Cyanophthalma obscura				1	1				nb
Lineus ruber	1			1	1		1		nb
Malacobdella grossa		1	1						nb
Nemertea	1				1				nb
Tubulanus polymorphus	1								nb
Oligochaeta									
Tubificidae		1	1		1		1	1	nb
Tubificoides benedii					1		1	1	*
Phoronida									
Phoronis sp.	1		1						nb
Plathelminthes									
Turbellaria				1				1	nb
Polychaeta									
Alitta succinea								1	D
Ampharete baltica	1			1	1	1			*
Arenicola marina				1	1				*
Aricidea minuta	1								*
Aricidea suecica	1				1				*
Bylgides sarsi	1			1	1				*
Capitella capitata			1		1				*
Dipolydora quadrilobata	1		1	1	1				*
Enipo kinbergi	1								R
Eteone barbata	1			1					*
Eteone longa					1				*
Euchone papillosa				1					2
Eumida sanguinea					1				*
Exogone naidina	1								D
Galathowenia oculata	1								*
Gattyana cirrhosa	1								*
Harmothoe imbricata	1			1	1				D
Harmothoe impar	1								*
Hediste diversicolor					1		1	1	*
Heteromastus filiformis	1		1		1				*
Lagis koreni	1		1	1	1				*
Laonome kroyeri	1								D
Lepidonotus squamatus	1								*
Levinsenia gracilis			1						*
Lysilla loveni	1								R
Marenzelleria viridis					1		1	1	nb
Neoamphitrite figulus	1				1				*
Nephtys caeca	1								*
Nephtys ciliata	1			1		1			*
Nephtys hombergii			1	1		1			*
Nereimyra punctata	1								G
Nicolea zostericola	1								*
Paradoneis eliasoni	1								*

Taxa	**N3**	**N1**	**M2**	**OM18**	**K8**	**K4**	**K3**	**OM160**	**RL**
Pherusa plumosa	1			1					D
Pholoe assimilis	1								D
Phyllodoce mucosa	1			1	1				*
Poecilochaetus serpens	1								*
Polydora ciliata			1	1	1				*
Polydora cornuta					1				*
Prionospio steenstrupi	1								*
Pseudopolydora pulchra	1								*
Pygospio elegans	1				1		1	1	*
Rhodine loveni	1								D
Scalibregma inflatum	1			1					G
Scolelepis foliosa	1								*
Scoloplos armiger	1			1	1		1		*
Spio goniocephala					1				*
Streblospio shrubsolii								1	V
Terebellides stroemii	1			1		1			*
Travisia forbesii					1				G
Porifera									
Chalinula limbata		1			1				D
Halichondria panicea					1				G
Halisarca dujardinii					1				D
Priapulida									
Halicryptus spinulosus			1				1		nb
Pycnogonida									
Nymphon brevirostre	1			1	1	1			*
species number 141	**83**	**12**	**16**	**43**	**62**	**18**	**25**	**28**	
abundance (ind m^{-2})	**8830**	**78**	**227**	**2762**	**1491**	**216**	**3600**	**3168**	
biomass (afdw g m^{-2})	**51.1**	**21.3**	**39.5**	**8.6**	**10.9**	**3.9**	**3.4**	**5.0**	

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CONTENT

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