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Biological assessment of the Baltic Sea 2017

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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 2017.

The phytoplankton spring bloom started its development already in February in Kiel Bay and even in the central Arkona Basin, but it occurred in the Eastern Gotland Basin only in May 2017. It was dominated by *Dictyocha speculum* in the Belt Sea, by *Skeletonema marinoi* in the Arkona Basin and by *Mesodinium rubrum* in the Bornholm and Eastern Gotland Basins. The development of cyanobacteria, observed by satellite imagery, started in the northern Baltic Proper at beginning of July and lasted exceptionally long in the western Baltic by end of August. The autumn bloom was well developed in the Belt Sea with *Ceratium* spp. dominating in Kiel Bay and *Pseudo-nitzschia* spp. dominating in the Bay of Mecklenburg

The chlorophyll a concentrations were highest (12.9 mg m⁻³) during the autumn bloom in Lübeck Bay.

The seasonal pattern of vertical export of particulate organic matter in the Arkona Basin in 2017 showed a clear succession of algal blooms and increased diversity in diatoms and dinoflagellates. The total annual flux for single elements in 2017 amounted to 580 mmol C, 76 mmol N, 91 mmol Si and 2.8 mmol P m⁻² a⁻¹ at a mass flux of 56 g dry mass m⁻² a⁻¹. However, these relatively high fluxes are also attributed to resuspension events. The mass weighted δ¹⁵N signature of 6.1 ‰ documents a lower nitrogen fixation than in the former years.

The zooplankton development was characterised by a recovery of the historically low stock size recorded in 2015-2016. This is particularly based on increasing abundances of cladocera in the Arkona Basin, and of cyclopoid and calanoid copepods in all areas. Due to a late occurrence of rotifers only in May, the seasonal development occurred late in 2017. Meroplankton was generally scarce. The high diversity of the zooplankton observed in preceding years was continuously present. A total of 63 species were recorded including the anthomedusae *Lizzia blondina* and *Staurosarsia gemmifera*, which are recorded the first time in the Kiel Bay and the Bay of Mecklenburg.

The 142 species found in the macrozoobenthos mark a high diversity, mainly driven by the high species number in the Kiel Bay and the Fehmarnbelt. The oxygen supply in bottom waters in the current year was not always higher than 2 ml/l at all stations, but basically no oxygen depletion was observed. Due to the good hydrographic conditions and the larval supply from the Kattegat area a fast recovery of the impoverished area around the island of Fehmarn was caused. Depending on the region, the abundances ranged from 242 to 8.790 ind./m², and the biomass (ash free dry weight) from 1.4 g/m² to 59.3 g/m². Some marine species were observed again since a long time or for the first time at all. Sixteen species of the German Red List (Categories 1, 2, 3 and G) were observed at the 8 monitoring stations. With five, the number of invasive species in 2017 was low. Two neozoan amphipod species, *Grandidierella japonica* and *Melita nitida*, were observed at the monitoring stations for the first time.

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.

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. 2018). 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 and updated in June 2018, the 'Arbeitsgemeinschaft Bund/Länder-Messprogramm Nord- und Ostsee' (ARGE BLMP) was succeeded by the 'Bund/Länder-Arbeitsgemeinschaft 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 transferred 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), endangered species (HELCOM 2013b) and eutrophication (HELCOM 2014). In a similar manner, short reports known as the 'Baltic Sea Environment Fact Sheets' (formerly 'Indicator Fact Sheets') are published annually (e.g. OLENINA AND KOWNACKA 2010, ÖBERG 2017, WASMUND et al. 2017 b).

Cooperation is increasingly 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. Members of the Biological Oceanography section of the IOW are involved in the development or at least contributing to 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); see for example HELCOM (2013c):

- Zooplankton mean size and biomass
- 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
- Chlorophyll *a* concentrations
- Diatom/Dinoflagellate Index
- Seasonal succession of dominating phytoplankton groups
- Cyanobacterial surface accumulations

These indicators are applied on the international (HELCOM) and/or national level for the evaluation of the status of the marine environment. One product is the Second Holistic Assessment of HELCOM (HELCOM 2017a). 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. 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) and the indicator was made applicable for the Belt Sea and the Baltic Proper (WASMUND 2017; WASMUND et al. 2017c).

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 2017 hydrographic-hydrochemical assessment of the Baltic Sea that has already been published (NAUMANN et al. 2018).

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 2017), 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 2017b).

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 on the outward leg only.

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

Zooplankton samples were regularly taken on the 6 stations in the German exclusive economic zone (Tab. 2). Samples were taken during outward and return journeys on all cruises as scheduled. The sampling was adjusted to match the hydrographic conditions according to the HELCOM guidelines.

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

Table 1

Sampling statistics (number of sampling events) of different parameters specified for regular monitoring sampling stations in 2017.

Station number	IOW-station number	Sea area	Chlorophyll	Phytoplankton	Zooplankton	Zoo-benthos
Belt Sea						
OMBMPN ₃	TFo360	Kiel Bay	5	5	5	1
OMBMPN ₁	TFo010	Fehmarnbelt	-	-	-	1
OMBMPM ₂	TFo012	Bay of Mecklenburg	10	10	10	1
OMO ₂₂	TFo022	Lübeck Bay	5	5	-	-
OM ₁₈	TFo018	Bay of Mecklenburg, south	-	-	-	1
OMBMPM ₁	TFo046	Bay of Mecklenburg, east	10	9	10	-
Arkona Basin						
OMBMPK ₈	TFo030	Arkona Basin, west	10	10	10	1
OMBMPK ₅	TFo113	Arkona Basin, central	10	10	10	-
OMBMPK ₄	TFo109	Arkona Basin, east	5	5	5	1
Pomeranian Bay						
OMBMPK ₃	TFo152	Pomeranian Bay, north	-	-	-	1
OM ₁₆₀	TFo160	Pomeranian Bay, central	-	-	-	1
Bornholm Basin						
OMBMPK ₂	TFo213	Bornholm Basin	10	10	-	-
Gotland Basin						
OMBMPK ₁	TFo259	Eastern Gotland Basin, south	5	5	-	-
OMBMPJ ₁	TFo271	Eastern Gotland Basin, central	5	5	-	-

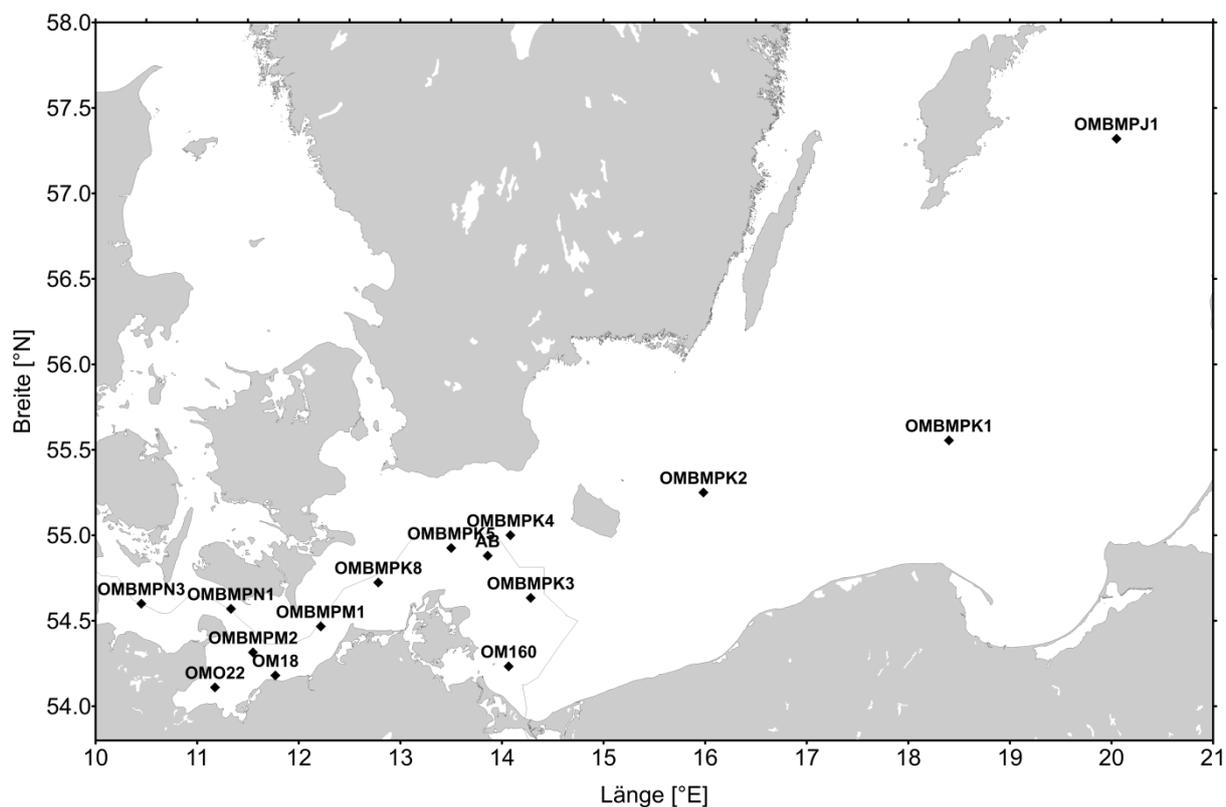


Fig. 1: The station grid for biological sampling in the Baltic Sea with depiction of the border of the exclusive economic zone of Germany.

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; HELCOM 2017c). To obtain a statistically acceptable estimate, at least 50 individuals of the most abundant species need to be counted. Thus for the most common 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 February and March 2017, the species

and biovolume list PEG_BVOL2016 was used. The phytoplankton samples of the May, August and November cruises were analysed with the list PEG_BVOL2017, which was confirmed by PEG during the meeting in April 2017. The latest biovolume file can be downloaded from http://www.ices.dk/marine-data/Documents/ENV/PEG_BVOL.zip.

2.3 Chlorophyll

As chlorophyll *a* represents a share of the biomass of all plant cells, including 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) and HOPPE et al. (2013) 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. (2014) 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 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 (2017d). 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 (2017d). 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 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 were 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 2017 worked 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. In January/February some storm-induced resuspension events were recorded, whereas during the pelagic growth periods the pattern of primary sedimentation of organic particles was not affected by such processes.

2.5 Mesozooplankton

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 is formed 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. The samples were fixed in 4 % aqueous formalin solution until processing in the laboratory. In total, 63 zooplankton samples were collected on 50 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 *Bosmina* spp., at least 100 individuals from three taxa were counted. The abundance (ind. m⁻³) is then calculated from the 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. 2009) and was based on the Integrated Taxonomic Information System (ITIS, <http://www.itis.gov/>). 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, www.corpi.ku.lt/databases/index.php/aquanis) and of the European Network on Invasive Species (NOBANIS, <http://www.nobanis.org>) served as references for the classification of invasive species.

Table 2

Sample statistics of zooplankton hauls on monitoring cruises between February and November 2017.

Station-label International/ IOW	Period				
	07.02. - 17.02.	14.03. - 26.03.	09.05. - 18.05.	10.08. - 22.08.	14.11. - 23.11.
	Depth from -to (m)	Depth from -to (m)	Depth from -to (m)	Depth from -to (m)	Depth from -to (m)
OMBMPN ₃	15 - 0	16 - 0	14 - 0	15 - 0	14 - 0
OMBMPM ₂	21 - 0 21 - 0	21 - 0 21 - 0	21 - 10 - 0 21 - 0	21 - 0 21 - 0	21 - 0 22 - 0
OMBMPM ₁	21 - 0 24 - 0	24 - 0 22 - 0	22 - 9 - 0 21 - 14 - 0	21 - 0 23 - 0	22 - 0 22 - 0
OMBMPK ₈	18 - 0 19 - 0	19 - 0 19 - 0	19 - 0 18 - 0	20 - 0 21 - 0	20 - 0 22 - 0
OMBMPK ₅	44 - 31 - 0 44 - 0	43 - 25 - 0 44 - 0	43 - 0 43 - 31 - 0	44 - 19 - 0 43 - 26 - 0	43 - 24 - 0 43 - 0
OMBMPK ₄	44 - 29 - 0	43 - 24 - 0	44 - 29 - 0	45 - 20 - 0	45 - 0

2.6 Macrozoobenthos

In November 2017, 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 2017 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)’ (<http://www.marinespecies.org/index.php>). Abundance and biomass were also recorded (ash free dry weight, afdw).

To ensure comparability of weight determinations, HELCOM guidelines were followed (HELCOM 2017 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 2017.

	date	depth	north	east	sea area
OMBMPN3	15.11.2017	19.3	54° 36.00	10° 27.00	Kiel Bay
OMBMPN1	15.11.2017	28.8	54° 33.20	11° 20.00	Fehmarnbelt
OMBMPM2	14.11.2017	24.9	54° 18.90	11° 33.00	Bay of Mecklenburg
OM18	14.11.2017	20.6	54° 11.00	11° 46.00	Bay of Mecklenburg, south
OMBMPK8	15.11.2017	23.1	54° 44.00	12° 47.40	Darss Sill
OMBMPK4	16.11.2017	48.3	55° 00.00	14° 05.00	Arkona Basin
OMBMPK3	17.11.2017	28.3	54° 38.00	14° 17.00	Pomeranian Bay, north
OM160	17.11.2017	14.5	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 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: <http://helcom.fi/helcom-at-work/projects/phytoplankton>).

Expert identification of phytoplankton species depends on a laboratory technician's level of knowledge. PEG therefore runs annual training courses and undertakes a ring test. The PEG meeting of 2017 took place in St. Petersburg (Russia) from 3-7 April 2017 and was attended by 27 representatives of all riparian states of the Baltic Sea.

Two phytoplankton experts of the IOW participated in all ring tests offered to the Baltic phytoplanktologists. A ring test prepared by the Federal Environment Agency (Umweltbundesamt, UBA) was conducted in 2016, but a first evaluation was shown as late as April 2018 during the latest PEG meeting. Also the evaluation of the Phytoplankton Proficiency Test (ProfTest SYKE 2017) was presented during that PEG meeting in Gothenburg (see

https://helda.helsinki.fi/bitstream/handle/10138/233179/SYKEre_6_2018.pdf?sequence=4).
The IOW participants passed with very good results.

As happens every year, the biovolume list of species and size classes was updated for the previous year. Samples taken until March 2017 are based on the official ICES and HELCOM biovolume file PEG_BIOVOL2016 and from May 2017 on biovolume file PEG_BIOVOL2017.

Chlorophyll

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

As an external quality assurance measure, IOW regularly participates in chlorophyll comparisons within the QUASIMEME AQ-11 regime (chlorophyll in seawater). The Rounds 2017.1 and 2017.2 were passed with very good results (mean z-scores of 0.25 and -0.45, respectively). Additionally, the UBA organized a comprehensive Ring Test with two natural water samples and a stock solution received on 9 September and 16 September 2015. The report is meanwhile available (SCHILLING et al. 2016).

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 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.

Macrozoobenthos

The IOW macrozoobenthos working group has participated in all QA measures to date. The results the recent ring test from summer 2015, presented by the UBA in November 2017, confirmed the high quality of the macrozoobenthos analyses.

3. Abiotic Conditions in 2017

The sea surface temperature (SST) development was derived for the year 2017 from satellite data of the US NOAA- and European MetOp-weather satellites daily provided by the BSH Hamburg (NAUMANN et al. 2018; SIEGEL & GERTH 2018).

Based on SST, 2017 was the eleventh-warmest year since 1990 for the Baltic Sea. The annual mean was with 0.24 K slightly above the long-term average. March/April and October-December were characterized by positive, July and August by negative anomalies. The anomalies reached maximum values of about ± 2 K. The winter 2016/2017 was comparatively

warm, as shown in air temperature and SST. The coldest month was February; the coldest day was 14 February with 0-3 °C. The warming in spring followed the long-term average. The warmest day of the year was in the period 31 July – 2 August, but not clearly pronounced. Daily mean SSTs of more than 20 °C were rarely achieved. A rather stable summer- situation started 28 July and lasted until beginning of September with 18-20 °C in the southern and western Baltic before the annual cooling started and continued steadily until the end of the year.

The intensified inflow activity, starting in 2014, led to the ventilation of the Farö Deep in the Northern Central Basin at the beginning of the year 2017. However, stagnation started in the deep basins of the Baltic Sea. Two weak inflows showing total volumes of 210 km³ (February) and 188 km³ (October) were registered in 2017. In conclusion, the impact of the observed phase of intensified water exchange processes with consequences for the biogeochemical cycles is weakening. Details of the hydrographic and hydrochemical situation in 2017 are given by NAUMANN et al. (2018).

4. Results and Discussion

4.1 Phytoplankton

4.1.1 Development of Cyanobacteria Identified by Satellite Imagery

The development of cyanobacteria in summer 2017 was observed 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 of NASA provided the data.

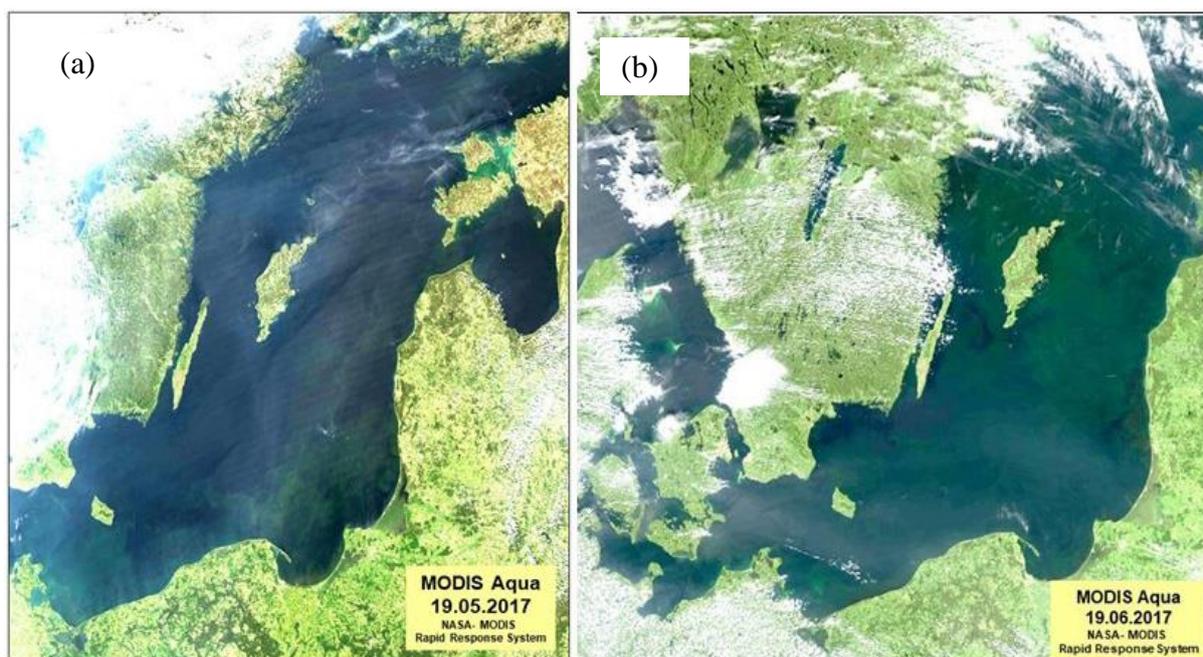
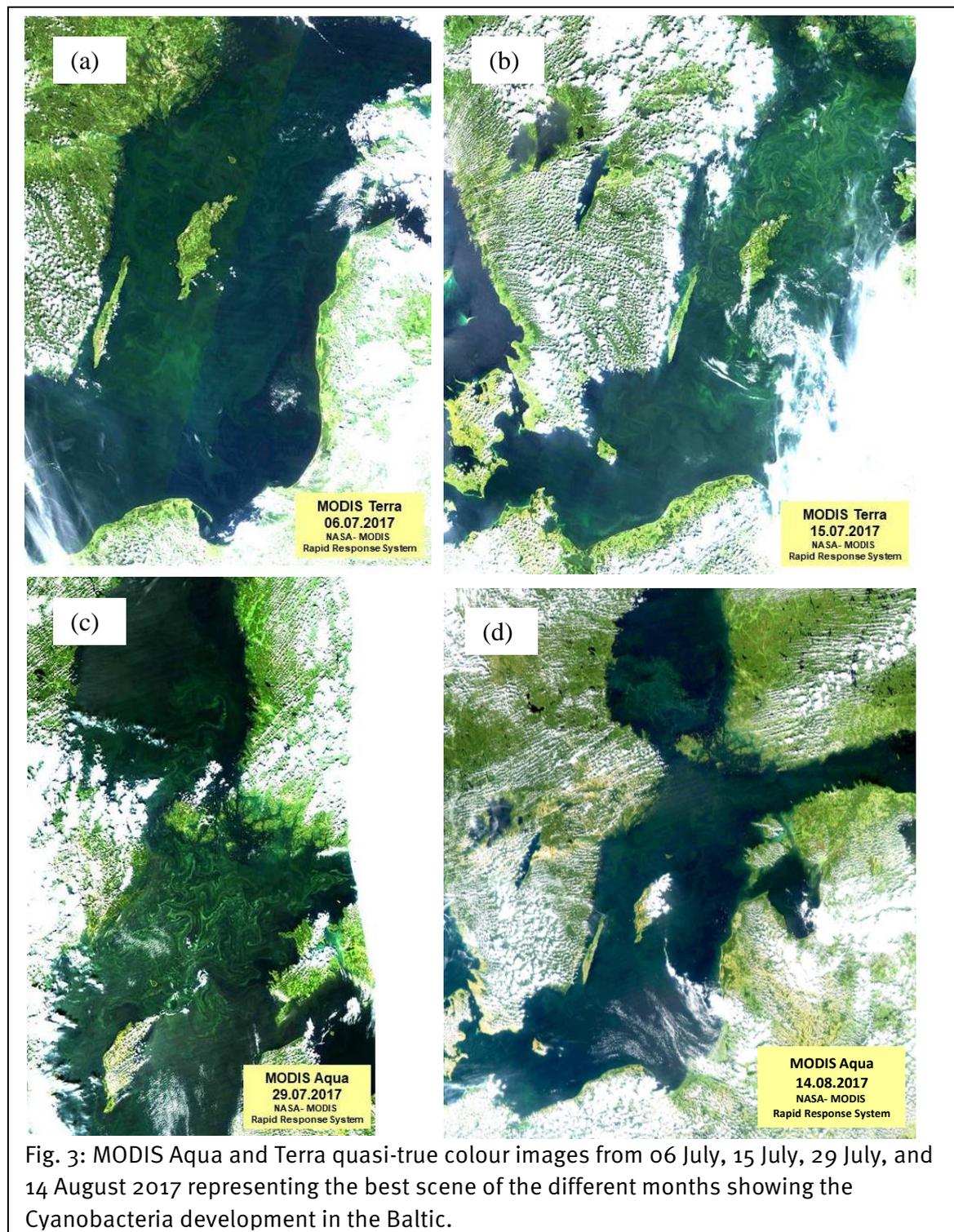


Fig. 2: MODIS Aqua images from 19 May and 19 June 2017 showing filaments of higher concentration from the western Baltic to the eastern Gotland Sea and in the entire Baltic.

Low wind periods after 10 May and warm air masses from the Atlantic supported the SST increase, a stable surface layer with partly 12-15°C and the first development of cyanobacteria from the western Baltic to the eastern Gotland Sea. The MODIS Aqua scene from 19 May in Fig. 2a shows impressively filaments of subsurface clouds in these regions. Water samples taken during the monitoring cruise in May confirm the presence of *Aphanizomenon*, the dominant filamentous cyanobacterium at that time.



During the following low wind period with strongly changing cloud coverage, the filaments remained recognizable in the cloud gaps until the end of the month. This situation continued in June where westerly winds dominated the meteorological conditions with a few wind events of 5-6 Beaufort. Despite these wind conditions, strongly changing clouds and the mixing of surface water the filaments remained intact and were traceable in the cloud gaps the entire June and beginning of July. During a low wind period 15 – 19 June, a warming took place and the filaments were more pronounced. A MODIS Aqua scene from 19 June is presented in Fig. 2b. Filaments are visible in the entire Baltic Proper and in the western parts.

The period from end of June to beginning of July was a stagnation period. Deep pressure systems with changing cloud coverage dominated the Baltic region leading to rather stable SSTs. Below the cloud coverage the development of cyanobacteria continued with pronounced filaments visible in cloud gaps. The next image with rather cloud-free Baltic Proper on 6 July shows the distribution of filaments in Fig. 3a with higher concentrations in the western and southwestern Gotland Sea with single surface accumulations. After that, a continuous warming during cloudy conditions produced an intermediate SST maximum on 15 July. The weak wind situation supported the development of cyanobacteria, the formation of surface accumulations as well as pronounced filaments in the northern Gotland Sea (Fig. 3b, upper right panel). The strong development of cyanobacteria in the entire northern Gotland Sea was already observed in cloud gaps on 10 July. In the image from 15 July filaments with lower concentrations also occurred from the western Baltic to the Gulf of Finland and already in the southern Bothnian Sea. The following period consists of a stagnation period with changing meteorological conditions and slight wind mixing. Between 31 July and 2 August was the warmest phase in the SST of the Baltic and the warmest day of the year. Nevertheless, the sky was dominated by clouds. The scene from 29 July in Fig. 3c shows the high concentrations particularly in the northern Gotland Sea and lower concentrations from the western Baltic to the Gulf of Finland. Filament developed also in the southern part of the Bothnian Sea. After this period cloudy condition dominated the meteorological situation in the entire August which also led to stagnation in SST. The best image of the month with large cloud-free areas was acquired on 14 August (Fig. 3d). Cyanobacteria filaments covered the entire Baltic Sea from the western Baltic Sea over the western Gotland Sea to the Bothnian Sea and Gulf of Finland with high concentrations in the northern Arkona Sea, western Gotland Sea, and particularly in the Bothnian Sea. The following days until beginning of September are rather cloudy. Only on 24 August information about cyanobacteria distribution are available showing filaments south of the islands Öland and Gotland, in the entrance of the Gulf of Finland and in the central Bothnian Sea. The western Baltic was covered by clouds. This distribution continued until 28 August and on 29 August whereas slight filaments were also visible in the area of the Darss Sill and in the Pomeranian Bight. The further limited cloud free areas did not allow an interpretation concerning the cyanobacteria filaments.

An image from 29 July 2017 of the European earth observation satellite Sentinel-3 with a spatial resolution of 300 m is shown in Fig. 4. The scene demonstrates the applicability for future investigations. The image presents the Gotland Sea with the filigree cyanobacteria distribution north of the island of Gotland.

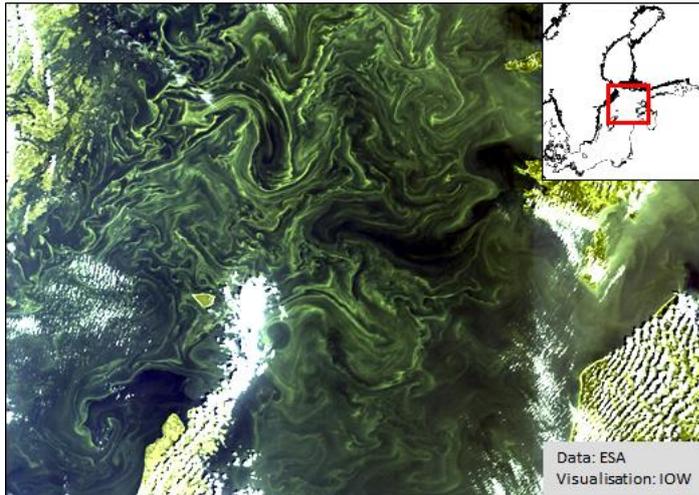


Fig. 4: The Sentinel 3 scene from 29 July 2017 shows Cyanobacteria- filaments north of Gotland with surface accumulations.

Scene: Copernicus Sentinel data (300 m res.)

Special attention was paid by the remote sensing group of the IOW on the western Baltic Sea and the influence of cyanobacteria on the German coast. In summer, the IOW daily informs the German local authorities about the spreading of cyanobacteria in the western Baltic and about potentially affected German coastal area since many years. 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.

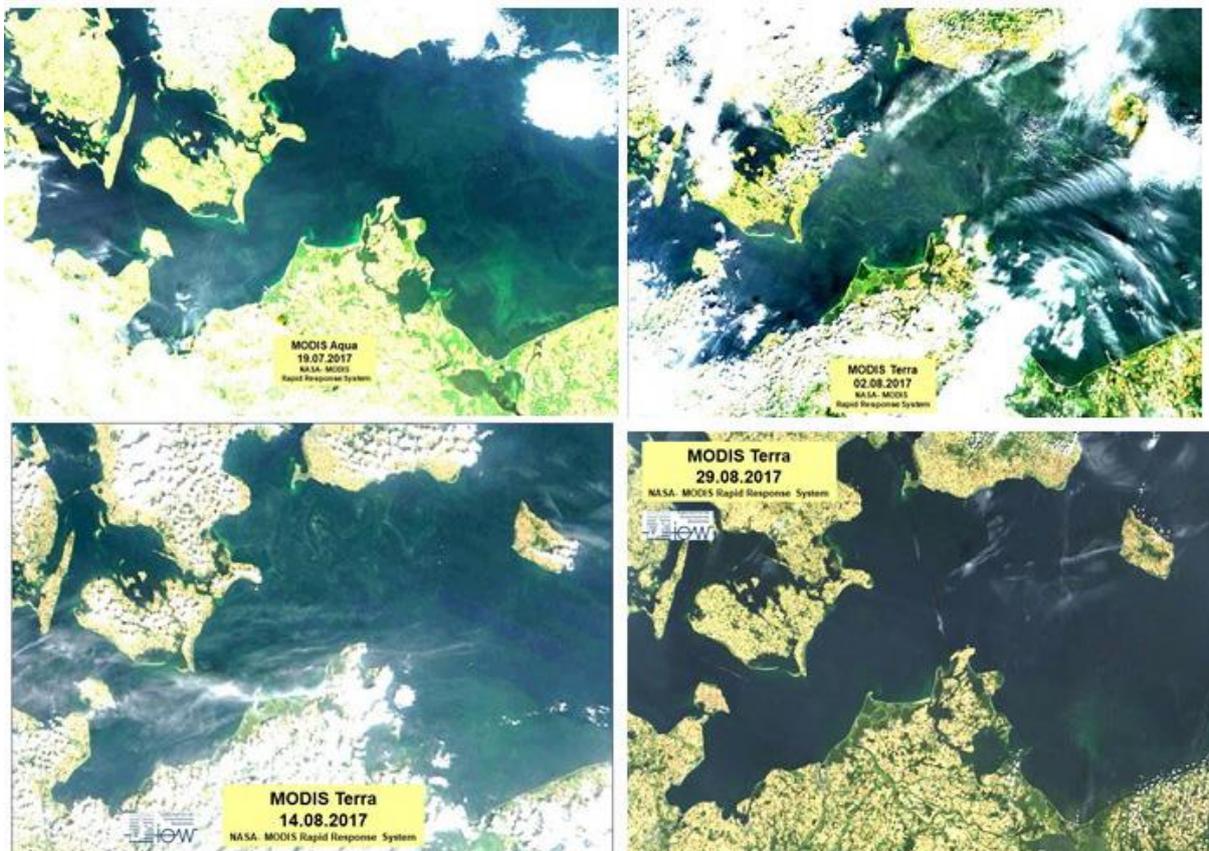


Fig. 5: Quasi-true colour images of MODIS Aqua on 19 July and MODIS Terra on 2 August, 14 August and 29 August 2017 showing cyanobacteria filaments in the western Baltic Sea.

Data: NASA MODIS Rapid Response System

In Figure 5, the four images of the western Baltic are presented showing the distribution of cyanobacteria filaments on 19 July as well as on 2, 14, and 29 August. Only around 19 July, the German coast was endangered. End of August the cyanobacteria were already mixed within the water column.

In summer 2017, the development of cyanobacteria was rather long despite the cloudy weather and SSTs below the long-term averages. Warm low wind period in May led to early filaments confirmed by in situ samples as cyanobacteria. A warm low-wind period in the northern Baltic Proper in July induced intense cyanobacteria filaments in the northern Gotland Sea, which lasted until beginning of August. Changing meteorological conditions combined with wind reduced surface accumulations and the development of cyanobacteria in late summer. In September, filaments could not be observed.

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 of less priority as phytoplankton mainly occurs in the mixed surface layer. This allows us to focus on mixed samples from 0-10 m depth. 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-2017.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 (annex), 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. If “unidentified” don’t block a place in the table, a succeeding taxon could move up. Similarly structured tables have been used in previous reports; this allows readers to make long-term comparisons. However, up to the report on the year 2015, more unidentified categories (‘Unidentified’, ‘Gymnodiniales’, ‘Peridinales’) have been omitted.

Table A2 shows the full list of phytoplankton taxa at all depths for each monitoring cruise in 2017. 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, Peridinales, Choanoflagellata, 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 2017 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 *Peridiniella danica*, *Katodinium glaucum*, *Polykrikos schwartzii*, *Gyrodinium spirale*, *Amphidinium sphenoides*, *Phalacroma rotundatum*, *Ebria tripartita*, *Protoperidinium* spp., Choanoflagellata and ‘incertae sedis’ are also considered. Choanoflagellata 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 flosaquae*. 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 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. 2006a). We began to apply the new name to samples after 2012.

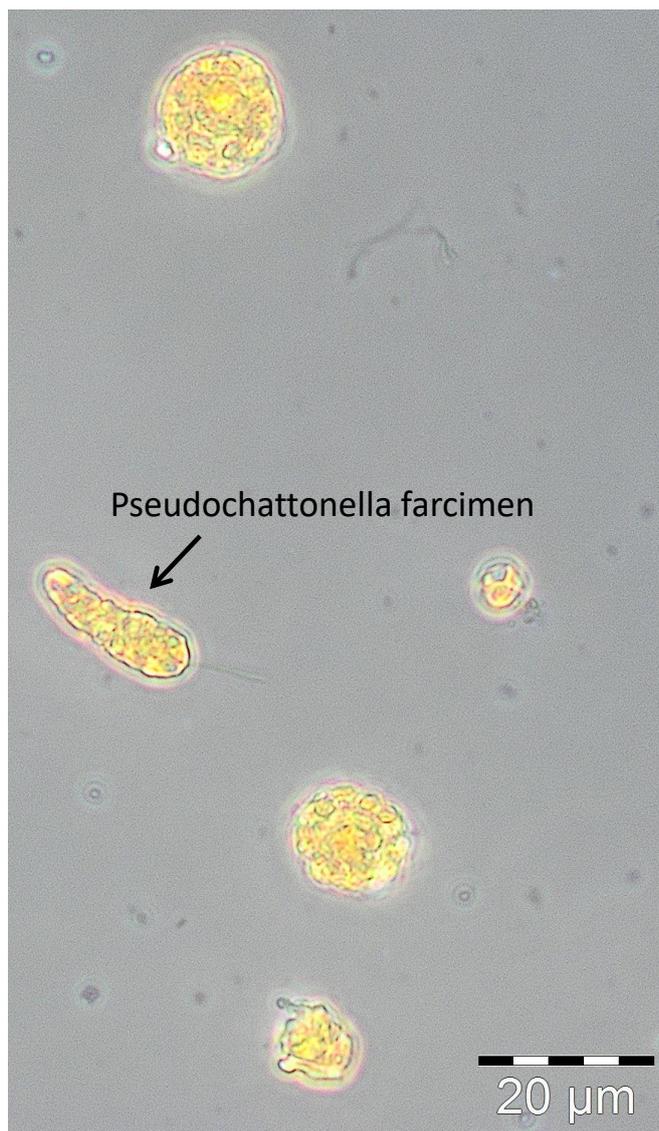


Fig. 6: *Pseudochattonella farcimen* and naked forms of *Dictyocha speculum* in a sample from station OMBMPM2, 10 m depth, from 26 March 2017. Foto: S. Busch (IOW).

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* (Fig. 6). 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. 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 conservatively 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	
<i>Aphanothece</i>	<i>Anathece</i> (but only partly)
<i>Chaetoceros impressus</i>	<i>Chaetoceros castracanei</i>
<i>Cladopyxis claytonii</i>	<i>Micracanthodinium claytonii</i>
Craspedophyceae	Choanoflagellata
<i>Cylindrotheca closterium</i>	<i>Ceratoneis closterium</i>
<i>Dinophysis rotundata</i>	<i>Phalacroma rotundatum</i>
<i>Gymnodinium galatheanum</i>	<i>Karlodinium veneficum</i>
<i>Karlodinium micrum</i>	<i>Karlodinium veneficum</i>
<i>Proterothropsis vigilans</i>	<i>Nematopsides vigilans</i>
<i>Prorocentrum minimum</i>	<i>Prorocentrum cordatum</i>
Since PEG-2016	
<i>Planctonema lauterbornii</i>	<i>Binuclearia lauterbornii</i>
<i>Chaetoceros socialis f. radians</i>	<i>Chaetoceros socialis</i>
<i>Chaetoceros socialis f. socialis</i>	<i>Chaetoceros socialis</i>
<i>Verrucophora farcimen</i>	<i>Pseudochattonella farcimen</i>
<i>Rhizosolenia pungens</i>	<i>Rhizosolenia setigera f. pungens</i>
<i>Thalassiosira rotula</i>	<i>Thalassiosira gravida</i>
Since PEG-2017	
<i>Woloszynskia halophila</i>	<i>Biecheleria baltica</i>
<i>Ceratoneis closterium</i>	<i>Cylindrotheca closterium</i>

4.1.2.1 Spring Bloom

Belt Sea

Kiel Bay and Bay of Mecklenburg (including Lübeck Bay) belong to the German Belt Sea but have kept separate as conditions may be different. Figure 12 shows the seasonal variations in phytoplankton biomass in Kiel Bay, Lübeck Bay and Bay of Mecklenburg. In early February, the biomass was enhanced in Kiel Bay, but still low in the Bay of Mecklenburg. A relatively high *Ceratium* biomass as found at station OMBMPN₃ in 2013 and 2014 (but not in 2015 and 2016), was also present in 2017 (e.g. 39 µg/l at station OMO₂₂; Fig. 7) and may represent remnants of an autumn/winter bloom, which was, however, poorly developed at the end of 2016. Diatoms (*Proboscia alata*, *Rhizosolenia setigera*, *Thalassionema nitzschioides*, *Guinardia delicatula*, *Dactyliosolen fragilissimus*) were clearly dominating at station OMBMPN₃ on 7 February 2017. These species are not typical spring species and probably also remnants of the preceding autumn bloom. *Coscinodiscus concinnus*, which was the dominating diatom in Kiel Bay in 2016, did not occur in spring 2017. The presence of this typical North Sea species would indicate an inflow event.

At the other stations of the Bay of Mecklenburg (OMBMPM₂ and OMBMP M₁), phytoplankton biomass was very low in February 2017. The samples from 8.2.2017, Station OMBMPM₁, could not be analysed because of high portion of sediment that made reliable cell counting impossible.

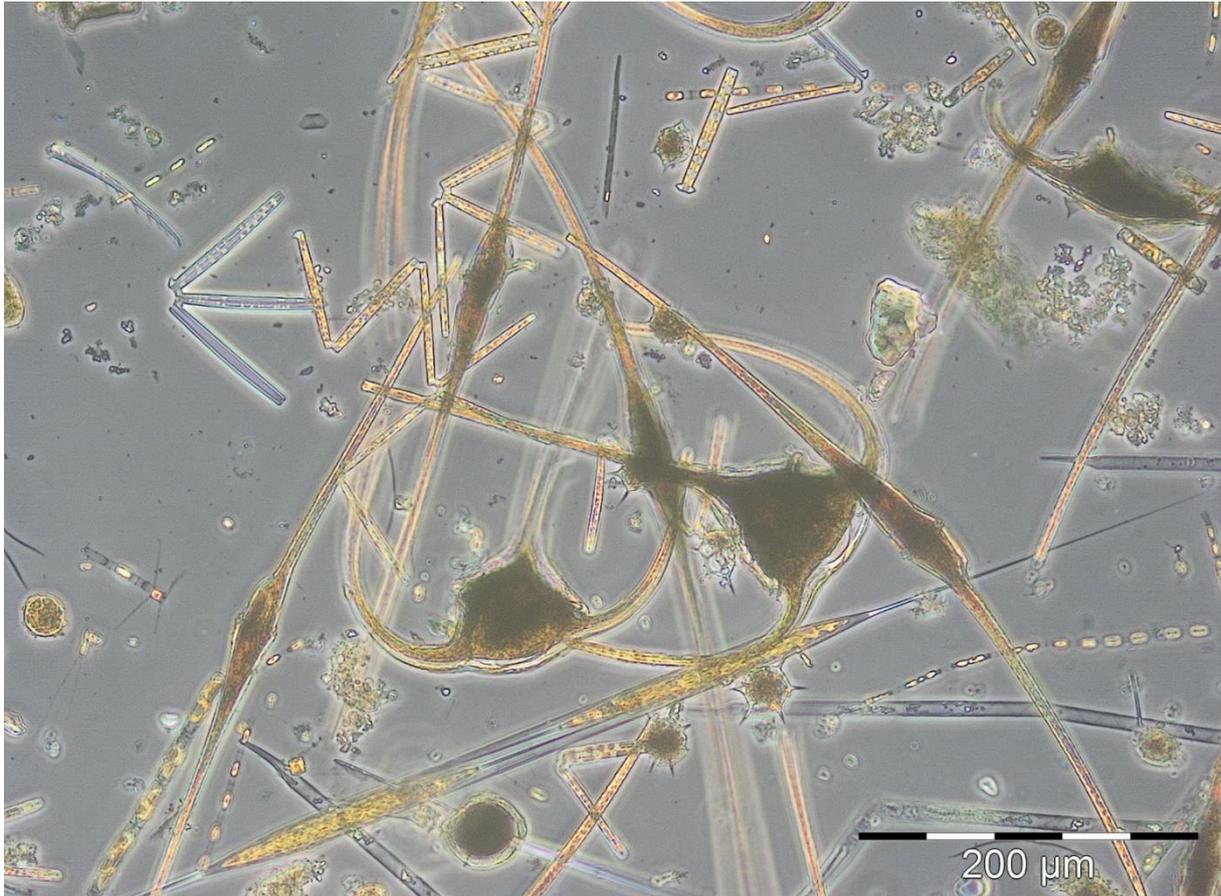


Fig. 7: *Ceratium fusus*, *Ceratium tripos*, *Proboscia alata*, *Rhizosolenia setigera*, *Thalassionema nitzschioides*, *Skeletonema marinoi*, *Dictyocha speculum* in a net sample from station OMO22 from 8 February 2017. Photo: S. Busch (IOW).

On 14 March 2017, a strong bloom of *Dictyocha speculum* (2198 $\mu\text{g/l}$, almost exclusively as naked form), *Rhizosolenia setigera* (692 $\mu\text{g/l}$) and *Rhizosolenia hebetata* f. *semispina* (414 $\mu\text{g/l}$) occurred at station OMBMPN3. However, at a depth of 15 m, besides of *Rhizosolenia setigera* (2666 $\mu\text{g/l}$) and *Rhizosolenia hebetata* f. *semispina* (3904 $\mu\text{g/l}$), also *Guinardia delicatula* was present in high biomass (1129 $\mu\text{g/l}$) whereas *Dictyocha speculum* was unimportant (60 $\mu\text{g/l}$).

The species composition was different on that date at station OMO22: *Dictyocha speculum* (347 $\mu\text{g/l}$), *Pseudochattonella farcimen* (128 $\mu\text{g/l}$, see Fig. 6), and *Peridiniella danica* (127 $\mu\text{g/l}$) occurred. The two stations of the Bay of Mecklenburg (OMBMPM1, OMBMPM2) were similar to each other but still different from the western stations. They were characterized by *Skeletonema marinoi*, *Dictyocha speculum* and *Mesodinium rubrum*, and in contrast to the previous year the spring bloom was found at the two stations at the same time. *Coscinodiscus* spp. that formed a spring bloom in 2016 was found as dominating species at 20 m depth on 15 March 2017 at station OMBMPM2. *Dictyocha speculum* increased further by the 26 March 2017 and showed a specific accumulation at 10 m depth at station OMBMPM2 (2469 $\mu\text{g/l}$).

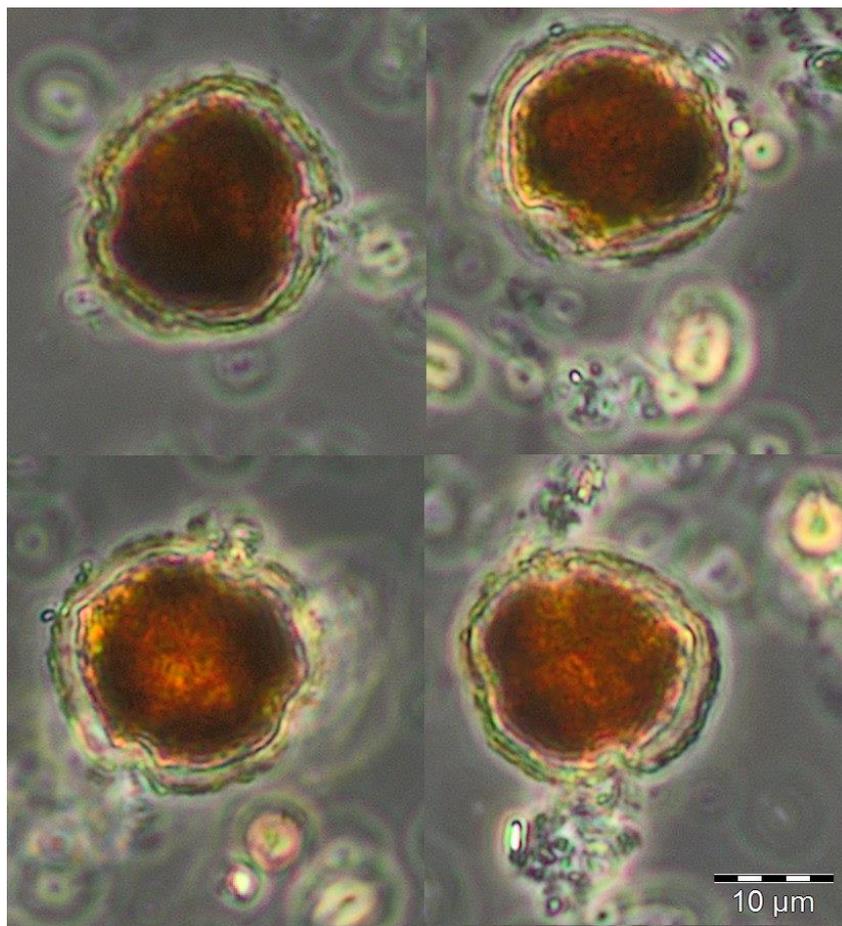


Fig. 8: *Scrippsiella* cf. *hangoei* from station OMO22 from 9 May 2017. Photo: S. Busch (IOW).

The timing of the spring bloom cannot be determined on the basis of the sketchy routine monitoring alone. In contrast to previous years, we had no additional samples at our disposal. Data from the coastal station Heiligendamm may fill the gaps in the case of Bay of Mecklenburg. The weekly chlorophyll data of the coastal station suggest the maximum of the spring bloom on 7 March 2017, but a post-spring bloom based on *Dictyocha speculum* appeared in late April 2017 (WASMUND et al. 2018). The occurrence of a spring bloom may also be verified by nutrient consumption data (Table 5). Significant phosphate consumption was found between the February and the March cruise at the stations of the Belt Sea. Surprisingly, the consumption of nitrate is retarded and occurs at some stations only between March and May. More surprising is the lack of significant silicate consumption despite the high share of diatoms in the spring bloom. Significantly reduced silicate concentrations are only found at stations OMBMPN₃ and OMO22. Also the data of the sediment traps may provide information on the timing of the bloom (chapter 4.1.6). The temporal discrepancy in uptake and remineralization of the different nutrients is still a matter to be investigated. This was already discussed by WASMUND et al. (2015).

The spring bloom has disappeared by 9/10 May 2017 in the Belt Sea. At station OMO22, a post-bloom of dinoflagellates developed, which was mainly composed of a species resembling *Scrippsiella hangoei* (Fig. 8). This species was also important in the samples from stations OMBMPM₁ and OMBMPM₂, besides of *Mesodinium rubrum* and *Peridiniella danica* (the latter mainly at station OMBMPM₂).

Table 5

Concentrations of nitrate+nitrite, phosphate, and silicate ($\mu\text{mol/L}$) from 1-3 m water depth at the biological stations in 2017. Data extracted from the IOW database.

Station	Date	Nitrate+Nitrite	Phosphate	Silicate
OMBMPN3	07.02.2017	3.46	0.54	8.2
OMBMPN3	14.03.2017	3.77	0.01	7.0
OMBMPN3	09.05.2017	0.10	0.09	11.2
OMBMPN3	10.08.2017	0.10	0.09	6.1
OMBMPN3	14.11.2017	0.04	0.50	17.2
OMO22	08.02.2017	4.54	0.46	10.2
OMO22	14.03.2017	0.41	0.01	4.3
OMO22	09.05.2017	0.12	0.12	9.9
OMO22	10.08.2017	0.06	0.09	11.1
OMO22	14.11.2017	0.19	0.38	14.7
OMBMPM2	08.02.2017	4.75	0.56	11.3
OMBMPM2	15.03.2017	0.31	0.18	10.8
OMBMPM2	10.05.2017	0.02	0.19	11.5
OMBMPM2	10.08.2017	0.26	0.12	13.4
OMBMPM2	14.11.2017	0.06	0.26	11.2
OMBMPM1	08.02.2017	3.91	0.49	12.5
OMBMPM1	15.03.2017	3.56	0.29	15.2
OMBMPM1	10.05.2017	0	0.20	12.5
OMBMPM1	11.08.2017	0.05	0.21	15.8
OMBMPM1	15.11.2017	0.31	0.41	14.2
OMBMPK8	08.02.2017	3.78	0.48	12.5
OMBMPK8	16.03.2017	3.80	0.35	16.3
OMBMPK8	10.05.2017	0	0.24	12.2
OMBMPK8	13.08.2017	0.10	0.15	15.1
OMBMPK8	15.11.2017	0.45	0.41	14.9
OMBMPK5	08.02.2017	5.87	0.53	15.8
OMBMPK5	15.03.2017	2.34	0.48	15.9
OMBMPK5	10.05.2017	0	0.29	13.1
OMBMPK5	13.08.2017	0.04	0.14	13.7
OMBMPK5	15.11.2017	0.84	0.42	15.6
OMBMPK4	09.02.2017	4.10	0.56	14.2
OMBMPK4	17.02.2017	5.28	0.47	16.0
OMBMPK4	16.03.2017	3.49	0.42	14.7
OMBMPK4	10.05.2017	0	0.22	12.7
OMBMPK4	14.08.2017	0.03	0.08	14.2
OMBMPK4	16.11.2017	0.77	0.40	15.3
OMBMPK2	09.02.2017	4.04	0.59	14.2
OMBMPK2	15.02.2017	3.87	0.52	15.3
OMBMPK2	17.03.2017	3.00	0.62	16.4
OMBMPK2	25.03.2017	1.90	0.60	16.2
OMBMPK2	12.05.2017	0.02	0.40	19.8
OMBMPK2	15.08.2017	0.04	0.08	14.7
OMBMPK2	22.11.2017	0.89	0.40	14.7
OMBMPK1	10.02.2017	3.85	0.68	17.1
OMBMPK1	17.03.2017	4.00	0.65	16.5
OMBMPK1	12.05.2017	0.02	0.29	17.2
OMBMPK1	15.08.2017	0.07	0.06	14.2
OMBMPK1	22.11.2017	1.77	0.41	14.7
OMBMPJ1	11.02.2017	4.27	0.64	15.3
OMBMPJ1	18.03.2017	3.93	0.69	16.3
OMBMPJ1	14.05.2017	0	0.28	15.2
OMBMPJ1	16.08.2017	0.32	0.01	17.8
OMBMPJ1	19.11.2017	2.04	0.37	12.5

Arkona Basin

The timing of the spring bloom in the Arkona Basin was similar to that of the Belt Sea, but the species composition was clearly different. The development started with *Mesodinium rubrum*, which was exceptionally early at station OMBMPK5 with an autotrophic phytoplankton biomass of 376 µg/l (Fig. 9). A few filaments of *Aphanizomenon* sp. appeared already that early.

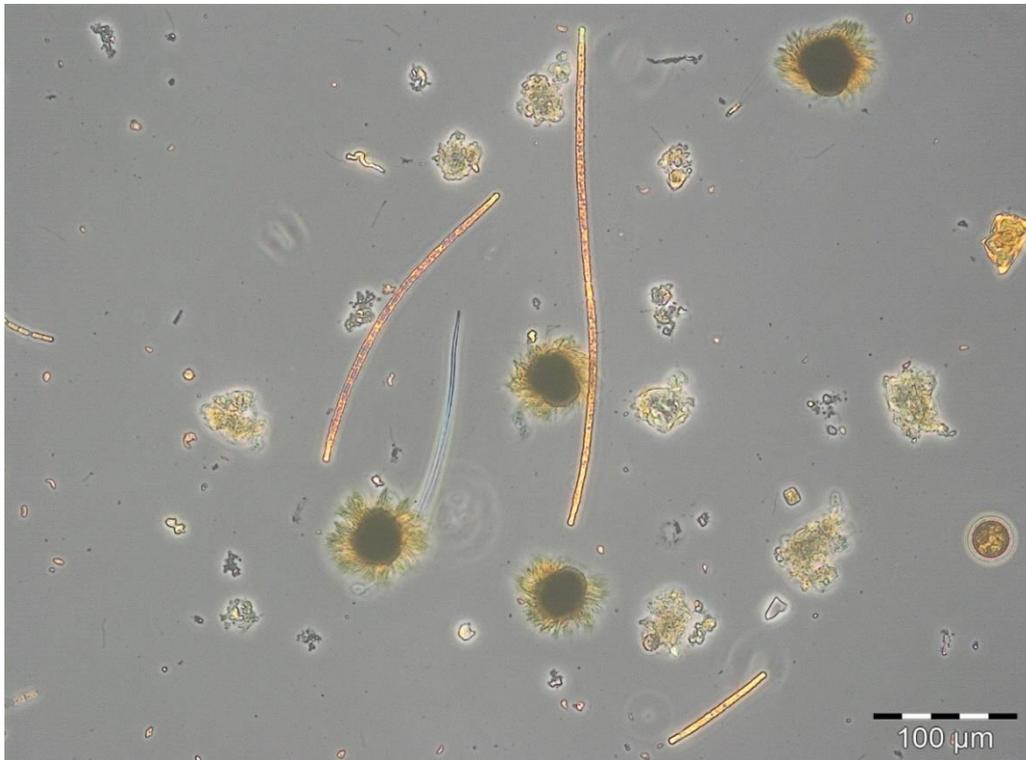


Fig. 9: *Mesodinium rubrum* and *Aphanizomenon* sp. in a net sample from station OMBMPK5 from 17 February 2017. Photo: S. Busch (IOW).

The spring bloom established in the second half of March by further growth of *Mesodinium rubrum* as well as the diatoms *Skeletonema marinoi* and *Thalassiosira* spp. at all stations of the Arkona Basin (Fig. 13). An overlap in the species composition happened at the border between the sea areas. The typical spring species of the Baltic Proper, *Mesodinium rubrum*, occurred in high biomass also in the eastern part of the Bay of Mecklenburg (station OMBMPM1) whereas the typical spring species of the Bay of Mecklenburg, *Dictyocha speculum*, occurred also in the western part of the Arkona Basin (station OMBMPK8). After the spring bloom, in May 2018, unidentified Prymnesiales appeared not only in the Arkona Basin, but also in the eastern part of the Bay of Mecklenburg.

As mentioned already in the previous report (WASMUND et al. 2017 a), the common strategy of assuming the spring bloom in the Baltic Proper in the period from March to May has to be revised if the start of the bloom occurs already in February. The early start of the spring growth especially at station OMBMPK5 can be proved by the consumption of inorganic nitrogen from 8 February to 15 March 2017, but it continued further (Table 5). Nitrogen is the limiting nutrient and is exhausted by the 10 May 2017. Phosphate is still present after the spring bloom. Compared with the high diatom biomass, the silicate consumption is low. The diatom growth was much stronger than in 2016 whereas dinoflagellates grew less.

Bornholm Basin

The Bornholm Basin was represented by only one station (OMBMPK₂), and no additional samples were available. The spring bloom appeared as a long-lasting phenomenon of moderate biomass. The peak of the bloom could not be identified, but the strongest decrease in the dissolved inorganic nitrogen concentrations occurred between 25 March and 12 May, suggesting the peak in April 2017. On 17 May, when the highest biomass value was measured, a strong nitrogen limitation should already occur and restrict further growth except for nitrogen-fixing cyanobacteria. In contrast to the previous year, the typical retard of the spring bloom in the Bornholm Basin in comparison with the central Arkona Basin was found, as described by WASMUND et al. (1998).

Mesodinium rubrum is absolutely dominating. It starts already in February and reaches its maximum in May (Fig. 14 a). Diatoms started with *Actinocyclus* sp. in February (Fig. 10). *Thalassiosira* spp. and *Skeletonema marinoi* gained some importance in March, but disappeared by 12 May completely whereas dinophyceae (*Peridiniella danica*, *Heterocapsa rotundata*) developed. The cyanobacterium *Aphanizomenon* sp., which was present in the net samples already since February, accelerated growth when inorganic nitrogen was exhausted, but phosphate was still present in the water.

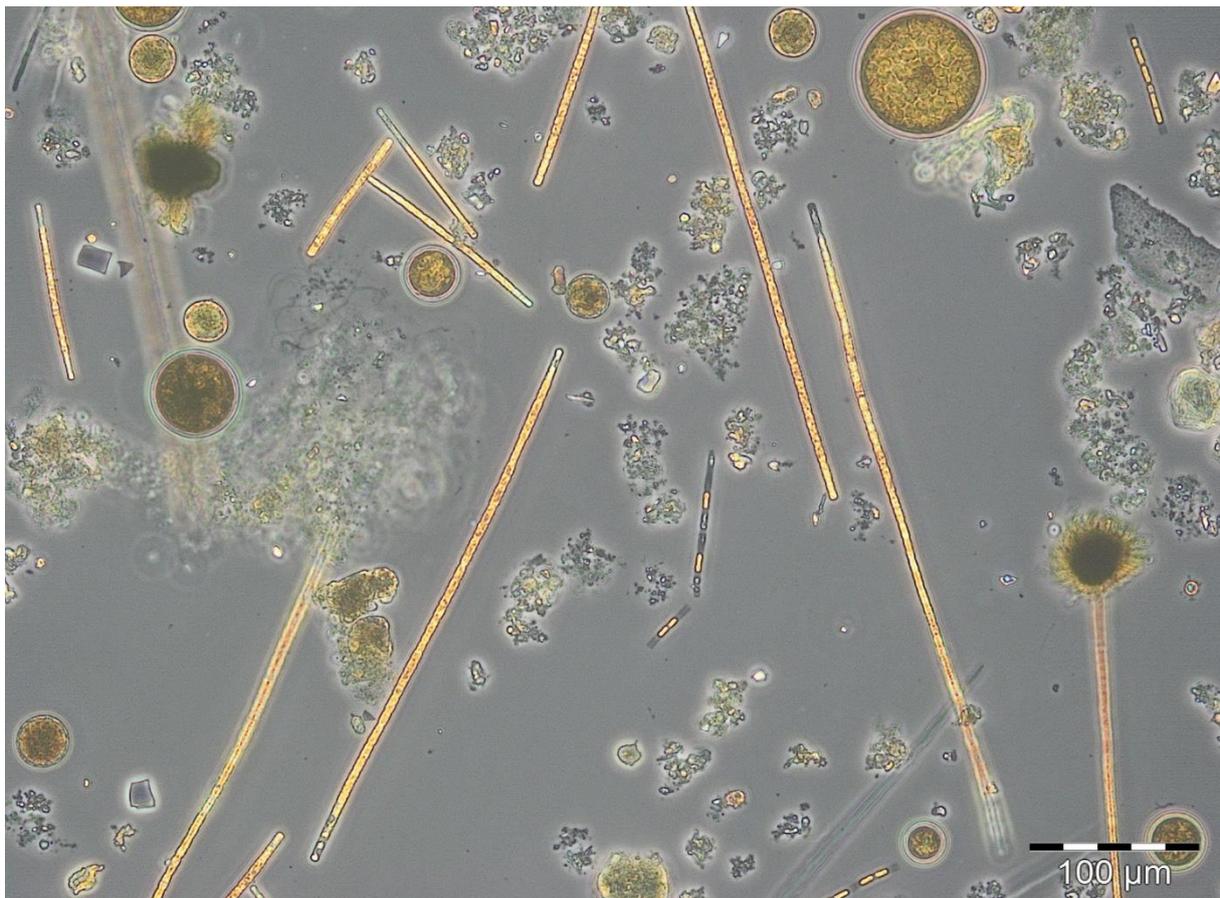


Fig. 10: *Aphanizomenon* sp., *Actinocyclus* sp., *Mesodinium rubrum*, *Skeletonema marinoi*, *Binuclearia lauterbornii* and inorganic particles in a net sample from 9 February 2017, Station OMBMPK₂. Photo: S. Busch (IOW).

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, in February 2017, they were rather different. *Mesodinium rubrum* dominated in the surface water of station OMBMPK1, but the diatom *Actinocyclus* sp. at station OMBMPJ1. *Actinocyclus* sp. is a typical autumn species and may have survived the winter. An extremely early *Actinocyclus* bloom, as found in February 2016, could not be confirmed.

Actinocyclus sp. was still present on 19 March 2017 at station OMBMPJ1, but diatoms could not form a bloom. *Mesodinium rubrum* became the dominating species at stations OMBMPK1 and OMBMPJ1, accompanied primarily by *Aphanizomenon* sp. and *Teleaulax* sp. (Fig. 11). *Peridiniella catenata* and *P. danica* were of little importance in March. The spring bloom was found in fairly similar composition and biomass in mid of May 2017 at stations OMBMPK1 and OMBMPJ1 alike. It was composed mainly of *Mesodinium rubrum*, *Peridiniella catenata*, *P. danica*, *Aphanizomenon* sp., *Amylax tricantha*, *Heterocapsa rotundata*, *Dinobryon balticum* and *Dinophysis* spp. As dissolved inorganic nitrogen was exhausted on that date, no significant further growth was expected.

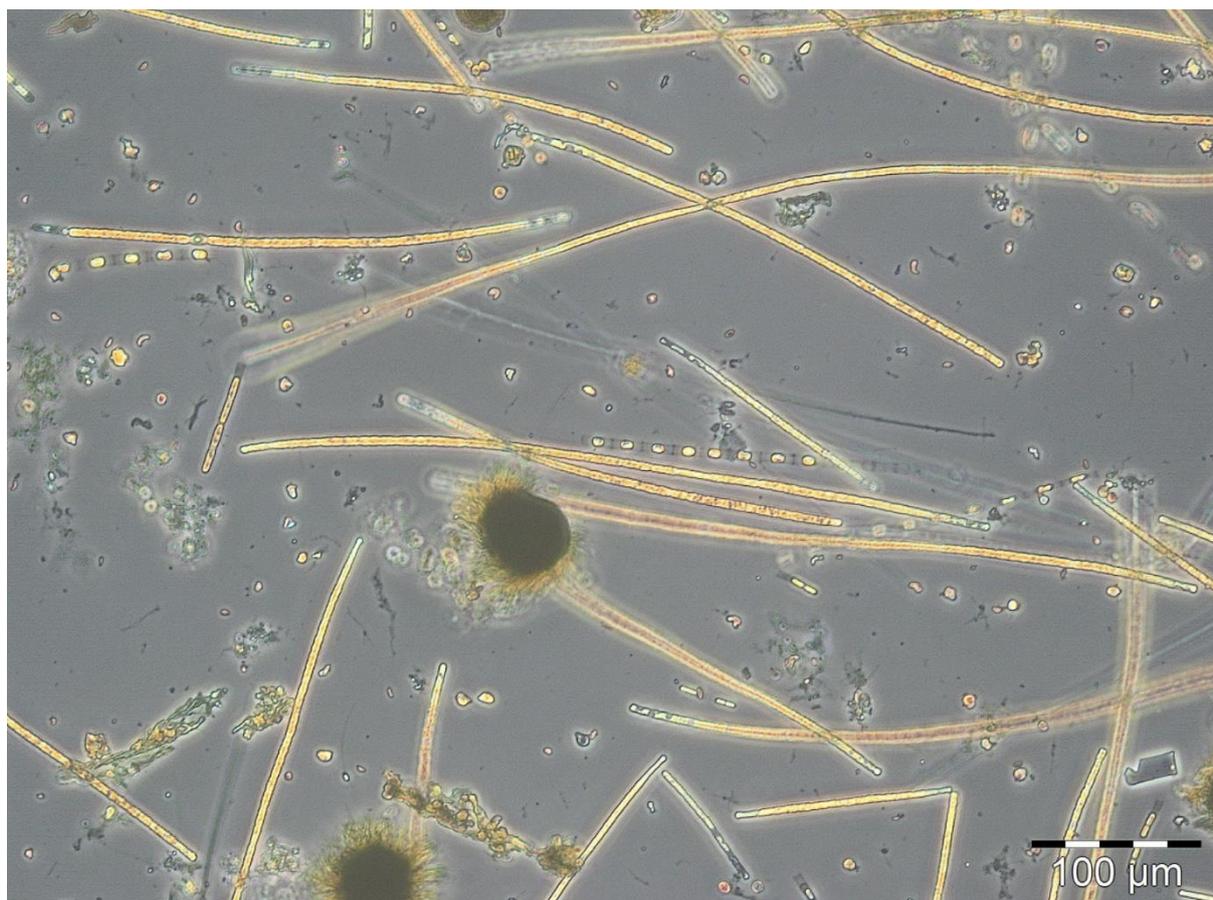


Fig. 11: *Aphanizomenon* sp., *Mesodinium rubrum*, and *Skeletonema marinoi* in a net sample from 19 March 2017, Station OMBMPJ1. Photo: S. Busch (IOW).

Summary on the spring bloom 2017:

1.) Some diatoms and dinoflagellates from the autumn bloom seem to stay over winter and contribute to the regular spring bloom at least in the western Baltic. The cyanobacterium *Aphanizomenon* sp. was found already in winter, at least in net samples. Some diatoms stay in deeper water layers of Kiel Bay and Bay of Mecklenburg, which was probably transported with inflowing water from the North Sea (this was *Coscinodiscus concinnus* in 2016 and *Guinardia delicatula* in 2017).

2.) In contrast to the previous year, *Dictyocha speculum* was the main component, besides of diatoms, in the spring bloom in Kiel Bay and Bay of Mecklenburg. Towards the east, in the Bay of Mecklenburg and Arkona Basin, the common *Skeletonema marinoi* was the dominating diatom, but it was negligible in the Bornholm and Eastern Gotland Basins. *Mesodinium rubrum* was the dominating spring bloom species in the Baltic Proper except the western Arkona Basin which was influenced by the Bay of Mecklenburg. No diatoms, but dinoflagellates occurred in the spring bloom of the Eastern Gotland Basin.

3.) As found already in the previous year, the inorganic nitrogen was consumed more intensively than phosphate, which is a symptom of nitrogen deficiency. Only in Kiel Bay and Lübeck Bay, phosphate is almost exhausted already in March when dissolved inorganic nitrogen is still available. Silicate was only slightly reduced even in diatom blooms and seems not to limit diatom growth.

4.) The spring bloom occurred in March 2017 in most areas. However, it started its development already in February in Kiel Bay and the central Arkona Basin, but it occurred in the Eastern Gotland Basin only in May 2017. The typical retard of the spring bloom into eastern direction was obviously also found in 2017.

4.1.2.2 Summer Bloom

Belt Sea

Samples from only one cruise are available from the summer situation. Therefore, the information is fragmentary. A summer diatom bloom as supposed but not always identified in previous years was only found at station OMBMPN₃ on 10 August 2017 in rather weak appearance. It was mainly formed by *Pseudosolenia calcar-avis* (194 µg/l), *Proboscia alata* (145 µg/l), *Cerataulina pelagica* (17 µg/l), and *Rhizosolenia setigera* f. *pungens* (16 µg/l). The accompanying dinoflagellates were *Ceratium tripos* (87 µg/l), *C. fusus* (14 µg/l), *Alexandrium pseudogonyaulax* (61 µg/l), and *Prorocentrum micans* (58 µg/l). The species composition in Lübeck Bight and the Bay of Mecklenburg was similar to that of Kiel Bay, but the share of diatoms was strongly reduced whereas that of the cyanobacteria (*Aphanizomenon*, *Dolichospermum*) increased towards the east. In contrast to the year 2016, the samples from the deeper water layers (20 m) did not contain higher biomass than the surface samples.

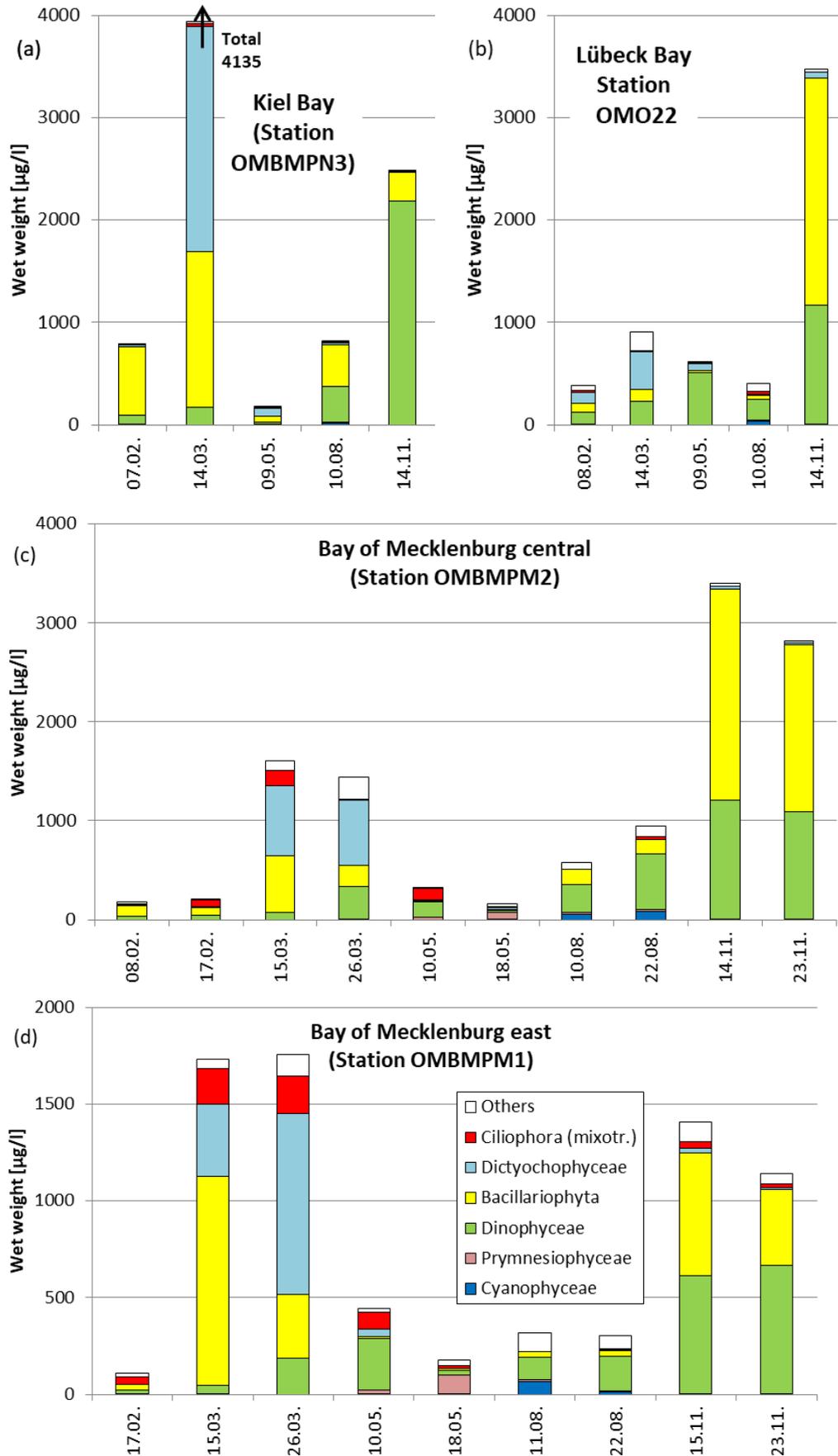


Fig. 12: Seasonal variation of phytoplankton wet weight of the main taxonomic groups in Kiel Bay (a), Lübeck Bay (b), and Bay of Mecklenburg (c, d) in 2017.

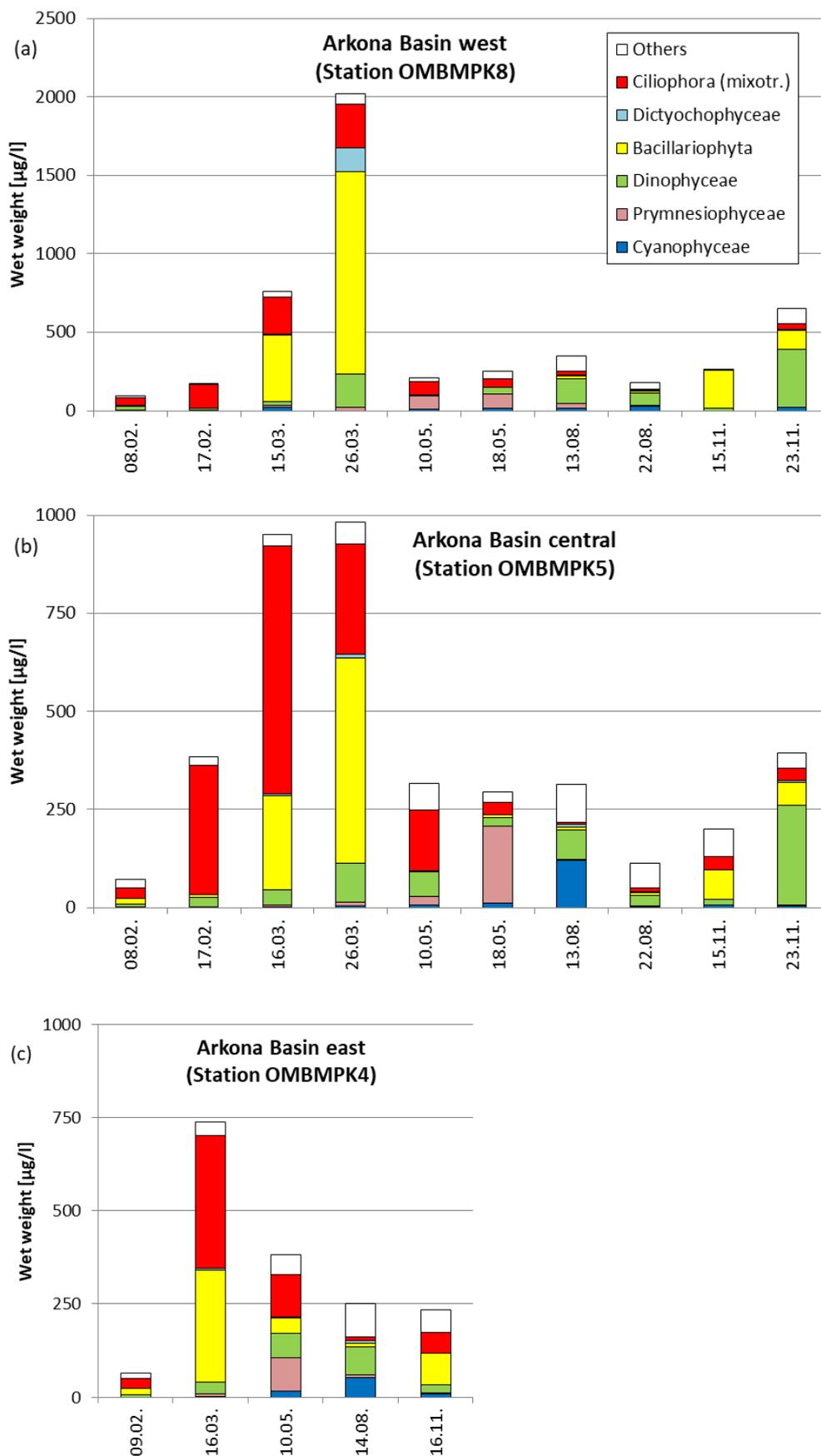


Fig. 13: Seasonal variation of phytoplankton wet weight of the main taxonomic groups in the Arkona Basin (a-c) in 2017.

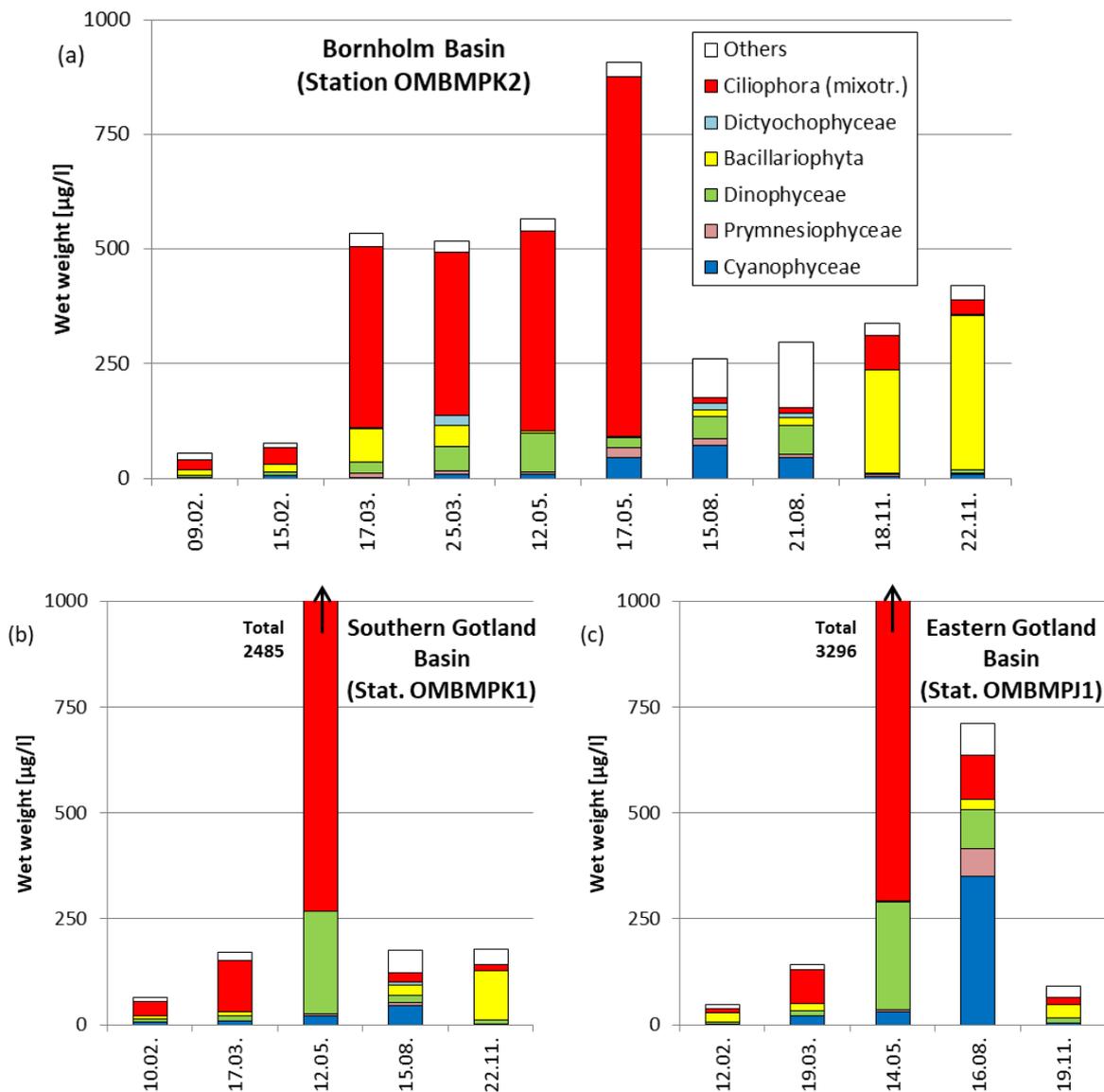


Fig. 14: Seasonal variation of phytoplankton wet weight of the main taxonomic groups in the Bornholm Basin (a) and Eastern Gotland Basin, southern part (b) and central part (c), in 2017.

If the coastal data of Heiligendamm are consulted, an earlier diatom bloom of *Dactyliosolen fragilissimus* was found in July 2017, which could not be identified in our open-sea data series because no monitoring cruise was conducted at that time. For this reason, also the relatively high biomass of the nitrogen-fixing cyanobacteria *Aphanizomenon* sp. (221 µg/l) and *Nodularia spumigena* (228 µg/l) from 1 August 2017 do not show up in our open-sea data.

Cyanobacteria blooms are not usual in Kiel Bay and Bay of Mecklenburg. In August 2017, cyanobacteria formed moderate biomass, e.g. *Aphanizomenon* sp. and *Nodularia spumigena* 16 µg/l and 24 µg/l at station OMBMPM₁ (11.8.2017), respectively; *Aphanizomenon* sp. and *Dolichospermum* spp. 16 µg/l and 28 µg/l at station OMBMPM₂ (22.8.2017), respectively.

Arkona Basin

A diatom summer bloom, which was sometimes found, could not be identified in the Arkona Basin in 2017. The summer biomass was low ($< 350 \mu\text{g/l}$) at all Arkona Basin stations. Station OMBMPK8 was characterized by *Prorocentrum cordatum* ($79 \mu\text{g/l}$), *Heterocapsa rotundata* ($47 \mu\text{g/l}$), *Pyramimonas* sp. ($25 \mu\text{g/l}$), Prymnesiales ($25 \mu\text{g/l}$), *Plagioselmis prolunga* ($17 \mu\text{g/l}$) and *Teleaulax* sp. ($11 \mu\text{g/l}$) on 13 August 2017, but *Alexandrium pseudogonyaulax* ($36 \mu\text{g/l}$) and *Aphanizomenon* sp. ($21 \mu\text{g/l}$) dominated on 22 August. In the central and eastern Arkona Basin (stat. OMBMPK5, OMBMPK4), the same species as at station OMBMPK8 occurred on 13/14 August 2017, but cyanobacteria became much more prominent. In contrast to 2016, the cyanobacteria did not exceed the threshold for bloom concentrations of $200 \mu\text{g/L}$ (according to WASMUND 1997). They reached a peak of $120 \mu\text{g/L}$ (thereof $93 \mu\text{g/L}$ by *Nodularia spumigena*) on 13 August 2017 at station OMBMPK5. A satellite image from 14 August 2017 confirms the presence of cyanobacteria blooms (Fig. 3d).

Bornholm Basin

In the Bornholm Basin, phytoplankton biomass was low. The species composition was similar on the two sampling days, characterized by *Pyramimonas* sp. (shown in the category of “Others” in Fig. 14 a), *Plagioselmis prolunga*, *Teleaulax* sp., *Pseudanabaena limnetica*, *Actinocyclus* sp., *Heterocapsa rotundata*, *Aphanizomenon* sp., *Nodularia spumigena*, *Ebria tripartita* and unidentified Gymnodiniales. The nitrogen-fixing cyanobacteria *Aphanizomenon* sp., *Nodularia spumigena* and *Dolichospermum* spp. contribute $< 42 \mu\text{g/l}$ and are therefore far from bloom concentrations. However, satellite images revealed that cyanobacteria developed also in the Bornholm Basin (Fig. 3 b.d).

Eastern Gotland Basin

The summer was represented by only one sampling event, which cannot be representative for the whole season. The biomass was very low in the southern part of the Eastern Gotland Basin (station OMBMPK1), mainly composed of *Aphanizomenon* sp., *Nodularia spumigena*, *Mesodinium rubrum*, *Actinocyclus* sp., *Ebria tripartita*, *Plagioselmis prolunga* and *Teleaulax* sp. In the central part of the Eastern Gotland Basin (station OMBMPJ1), cyanobacteria were clearly dominating, composed of *Nodularia spumigena* ($75 \mu\text{g/L}$), *Cyanodictyon planctonicum* ($65 \mu\text{g/l}$), *Aphanothece paralleliformis* ($51 \mu\text{g/L}$), *Aphanocapsa* spp. ($46 \mu\text{g/l}$), *Aphanizomenon* sp. ($30 \mu\text{g/L}$), *Pseudanabaena limnetica* ($16 \mu\text{g/L}$), *Lemmermanniella pallida* ($15 \mu\text{g/l}$) and *Coelosphaerium minutissimum* ($14 \mu\text{g/l}$). Consequently, the nitrogen-fixing cyanobacteria contributed only $105 \mu\text{g/l}$ to the phytoplankton biomass and did not reach bloom concentrations. Dinoflagellates were mainly represented by unidentified Gymnodiniales ($77 \mu\text{g/L}$) and the *Scrippsiella*-complex ($7 \mu\text{g/l}$).

Summary on the summer bloom 2017:

1.) Clear summer blooms could not be identified in 2017 in the open Baltic Sea. Elevated biomass, but still below $1000 \mu\text{g/l}$, could be found in Kiel Bay (diatom dominance), central Bay of Mecklenburg (dinoflagellate dominance) and central Eastern Gotland Basin (cyanobacteria dominance). A bloom of nitrogen-fixing cyanobacteria as identified at our coastal station Heiligendamm was not identified in our low-frequency open-sea data.

2.) The “excess” phosphorus remaining after the spring bloom is widely consumed between May and August in the Baltic Proper with strongest consumption in the Eastern Gotland Basin where cyanobacteria developed most.

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.

The autumn bloom was well developed in the Belt Sea during the time of our autumn cruise. Typically, *Ceratium* spp. start development already in summer und reach bloom concentrations in autumn. This was realized in Kiel Bay where *Ceratium tripos* accounted for 1560 µg/l. Moreover, the biomasses of *Ceratium fusus* (278 µg/l), *Dinophysis norvegica* (185 µg/l), *Thalassiosira punctigera* (94 µg/l), *Th. eccentrica* (54 µg/l), *Prorocentrum micans* (51 µg/l) and *Pseudosolenia calcar-avis* (36 µg/l) were important. *Cerataulina pelagica*, which was forming the bloom in 2016, was lacking in our Kiel Bay samples from 2017.

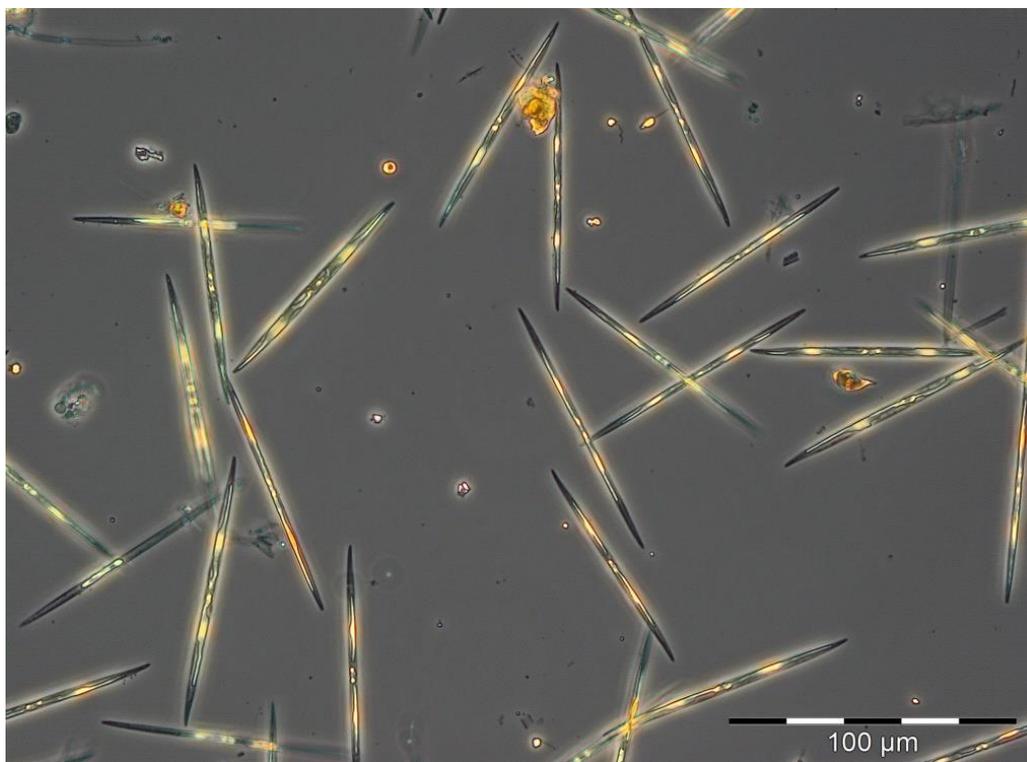


Fig. 15: *Pseudo-nitzschia* spp. in the surface sample (0-10 m) from 14 November 2017, Station OMO22. Photo: S. Busch (IOW).

The bloom in Lübeck Bay contained less dinoflagellates (*Ceratium tripos* 816 µg/l, *C. fusus* 120 µg/l, *Prorocentrum micans* 69 µg/l), but more diatoms: *Pseudo-nitzschia* spp. 1534 µg/l (Fig. 15), *Rhizosolenia setigera* incl. f. *pungens* 278 µg/l, *Cerataulina pelagica* 238 µg/l, *Thalassiosira eccentrica* 42 µg/l). At the two stations of the Bay of Mecklenburg, species compositions and even the proportions were similar to those of the Lübeck Bay, e.g. at station OMBMPM2: *Ceratium tripos* 906 µg/l, *C. fusus* 126 µg/l, *Prorocentrum micans* 43 µg/l, *Pseudo-nitzschia* spp. 1508 µg/l, *Rhizosolenia setigera* incl. f. *pungens* 139 µg/l, *Cerataulina pelagica* 243 µg/l, *Thalassiosira eccentrica* 34 µg/l (Fig. 16).

However, according to the weekly coastal data from Heiligendamm, a diatom bloom composed of *Dactyliosolen fragilissimus*, *Cerataulina pelagica* and *Coscinodiscus granii* occurred in September 2017. A peak of *Ceratium tripos* was found on 24 October 2017 and another diatom peak (*Pseudo-nitzschia* spp.) was found on 21 November 2017 at our coastal station (WASMUND et al. 2018). Electronmicroscopic analyses revealed that *Pseudo-nitzschia pseudodelicatissima* was the main species whereas *Pseudo-nitzschia pungens* was sub-dominant.

In the last reports (WASMUND et al. 2017 a, WASMUND et al. 2018), we hypothesized on a long-term decrease of *Ceratium*. However, in 2017, *Ceratium tripos* regained its usually strong presence.

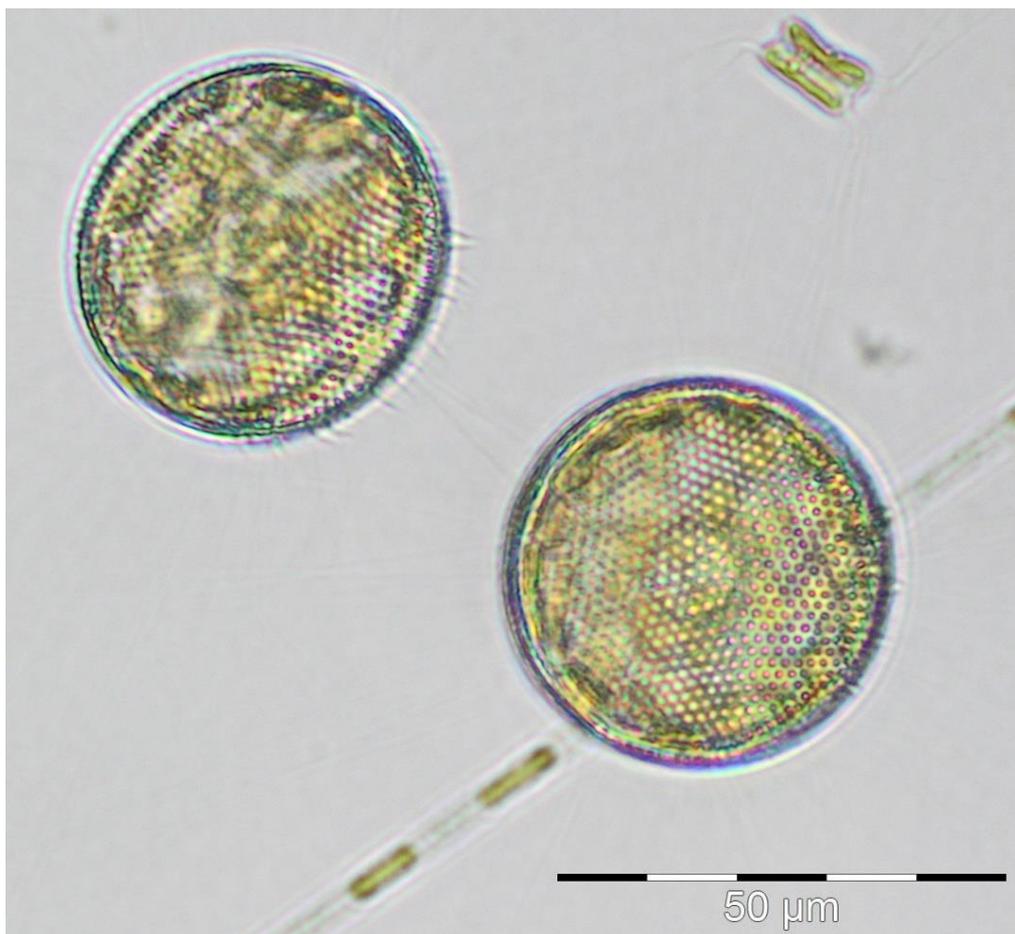


Fig. 16: *Thalassiosira eccentrica* in the surface sample (0-10 m) from 23 November 2017, Station OMBMPM2. Photo: S. Busch (IOW).

Arkona Basin

No autumn bloom was found in the Arkona Basin during the time of the cruise. This basin was heterogeneous in time and space in autumn 2017. The western station OMBMPK8 was completely dominated by diatoms (*Pseudo-nitzschia* spp. 137 µg/l, *Cerataulina pelagica* 53 µg/l) on 15 November 2017, but these diatoms were strongly reduced on 23 November, when *Ceratium tripos* accounted for 331 µg/l. This shift may be caused by transport of water masses in this highly dynamic region (Darss Sill). The central and eastern station of the Arkona Basin was more influenced by the Baltic Proper on 15/16 November, which is indicated by the typical diatoms *Coscinodiscus granii* and *Actinocyclus* sp. as well as *Mesodinium rubrum*. However, on 23 November, station OMBMPK5 is characterized by *Ceratium tripos* (223 µg/l), which is a typical species of the Bay of Mecklenburg.

Bornholm Basin

The phytoplankton biomass was too low for a bloom in November 2017 in the Bornholm Basin (Fig. 8a), but the species composition was typical for the autumn bloom, dominated by *Coscinodiscus granii* and accompanied by *Actinocyclus* spp. The species of the western Baltic, *Ceratium* spp., *Pseudo-nitzschia* spp. and *Cerataulina pelagica* were completely lacking.

Eastern Gotland Basin

The species composition in the southern part of the Eastern Gotland Basin (station OMBMPK1) was similar to that of the Bornholm Basin, but *Actinocyclus* spp. was dominating in this case (79 µg/l). In the central part of the Eastern Gotland Basin (station OMBMPJ1), *Coscinodiscus* spp. are completely lacking and *Actinocyclus* sp. is representing the diatoms almost completely (28 µg/l).

Summary on the autumn bloom 2017:

- 1.) The autumn bloom was well developed in the Belt Sea during the time of our autumn cruise with *Ceratium* spp. dominating in Kiel Bay and *Pseudo-nitzschia* spp., besides of *Ceratium* spp., dominating in Lübeck Bay and the Bay of Mecklenburg. The supposed reduction of *Ceratium* spp. was stopped in 2017.
- 2.) Bloom concentrations were not reached in November 2017 in the Bornholm Basin and the Eastern Gotland Basin but the species composition was typical for the autumn bloom (*Coscinodiscus granii*, *Actinocyclus* spp.).

4.1.3 Regional Differences in Species Composition

Sampling locations are chosen so that they form a transect through the Baltic Sea 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.

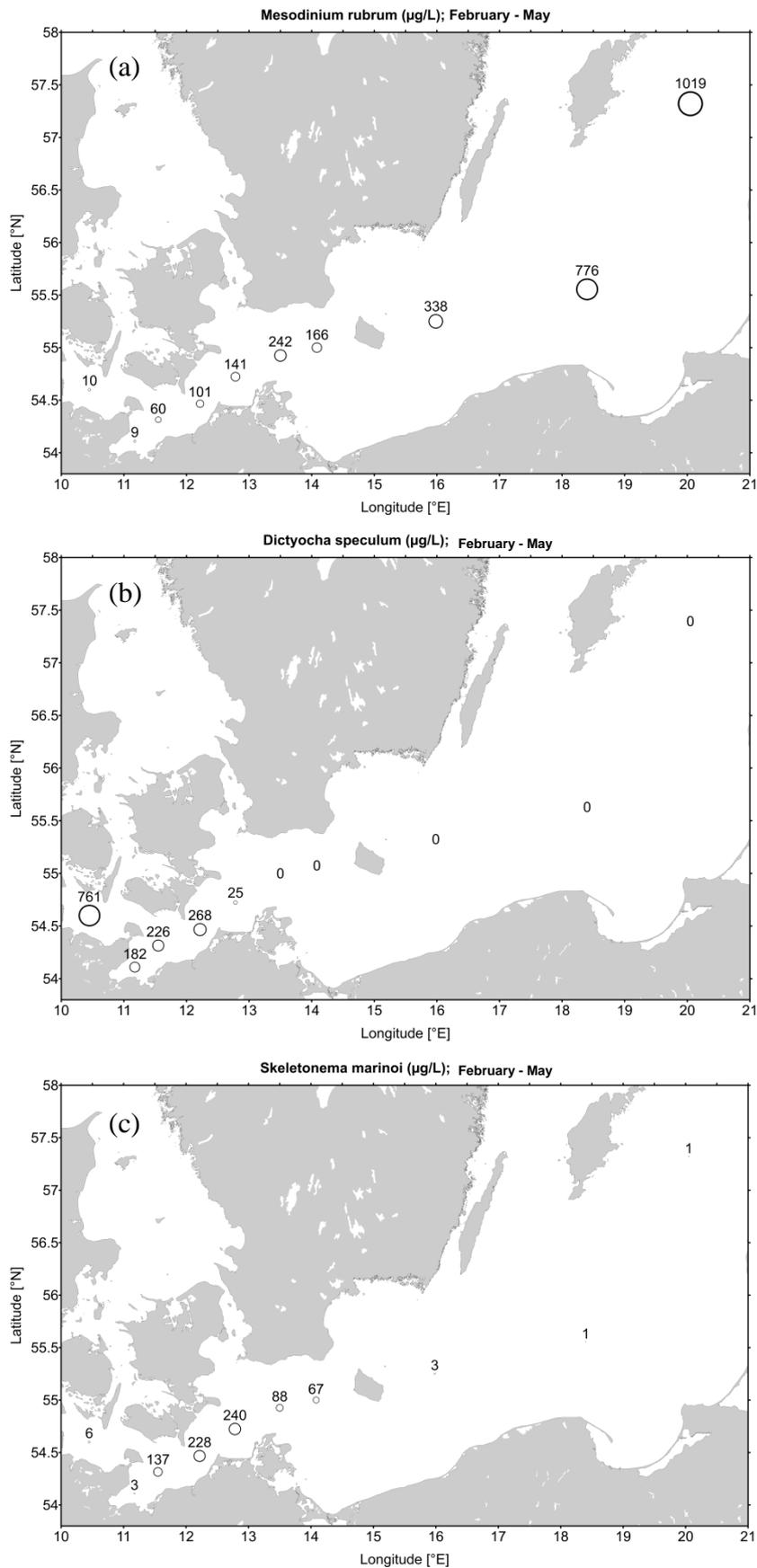


Fig. 17: Distribution of the main spring species, *Mesodinium rubrum* (a), *Dictyocha speculum* (b) and *Skeletonema marinoi* (c) in spring 2017 (mean values of three cruises).

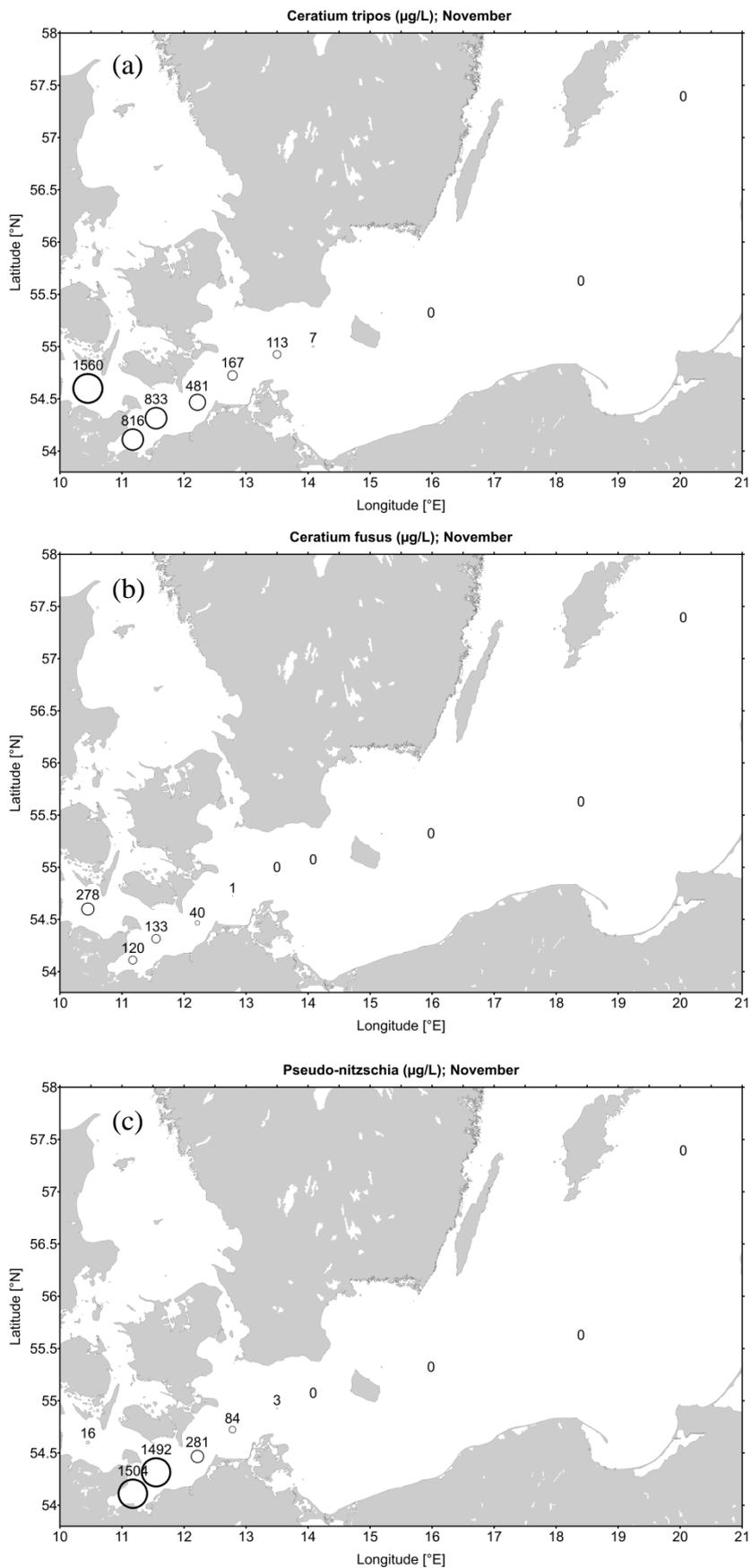


Fig. 18: Distribution of the main autumn species, *Ceratium tripos* (a), *Ceratium fusus* (b) and *Pseudo-nitzschia* spp. (c) in November 2017.

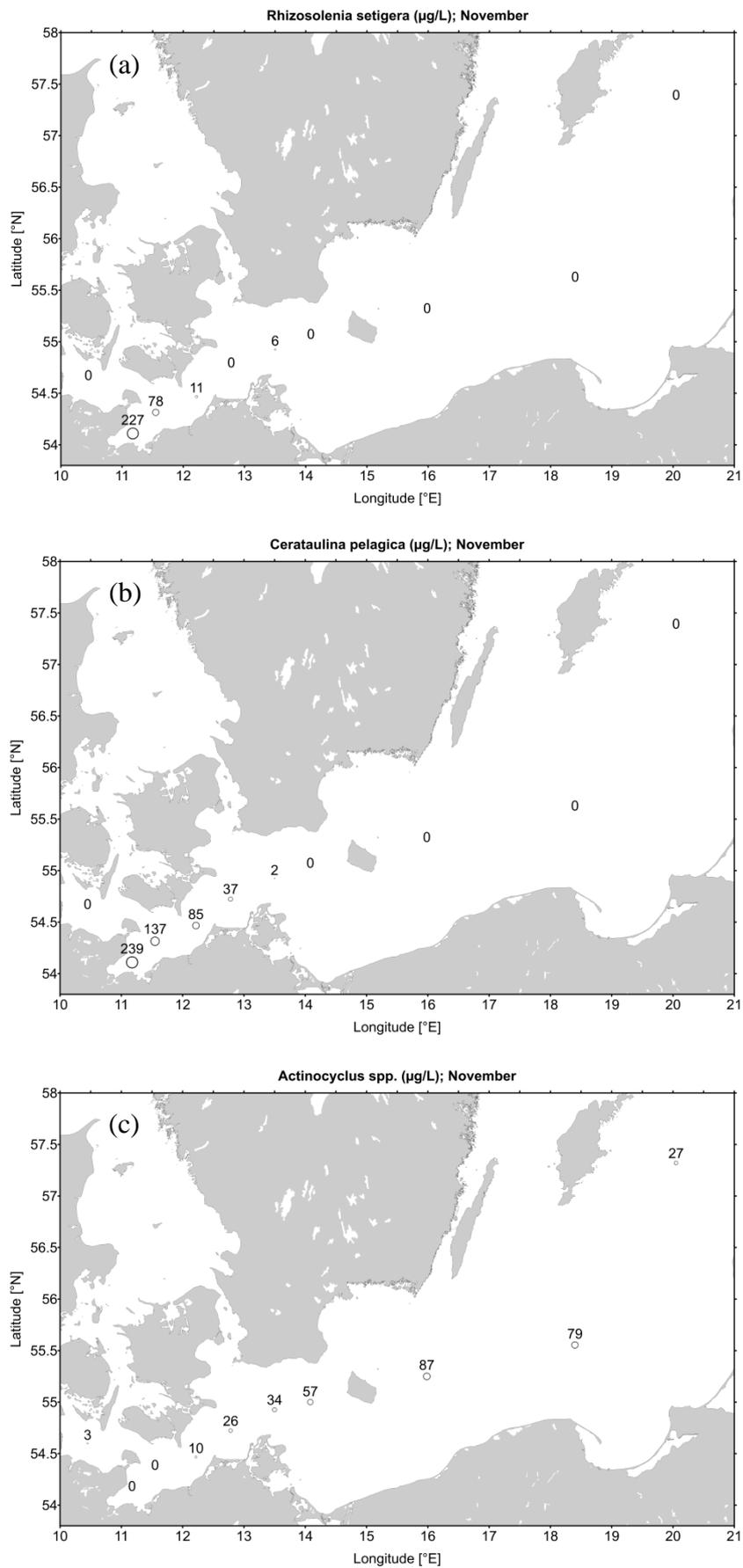


Fig. 19: Distribution of the autumn species *Rhizosolenia setigera* (a), *Cerataulina pelagica* (b) and *Actinocyclus* spp. (c) in November 2017.

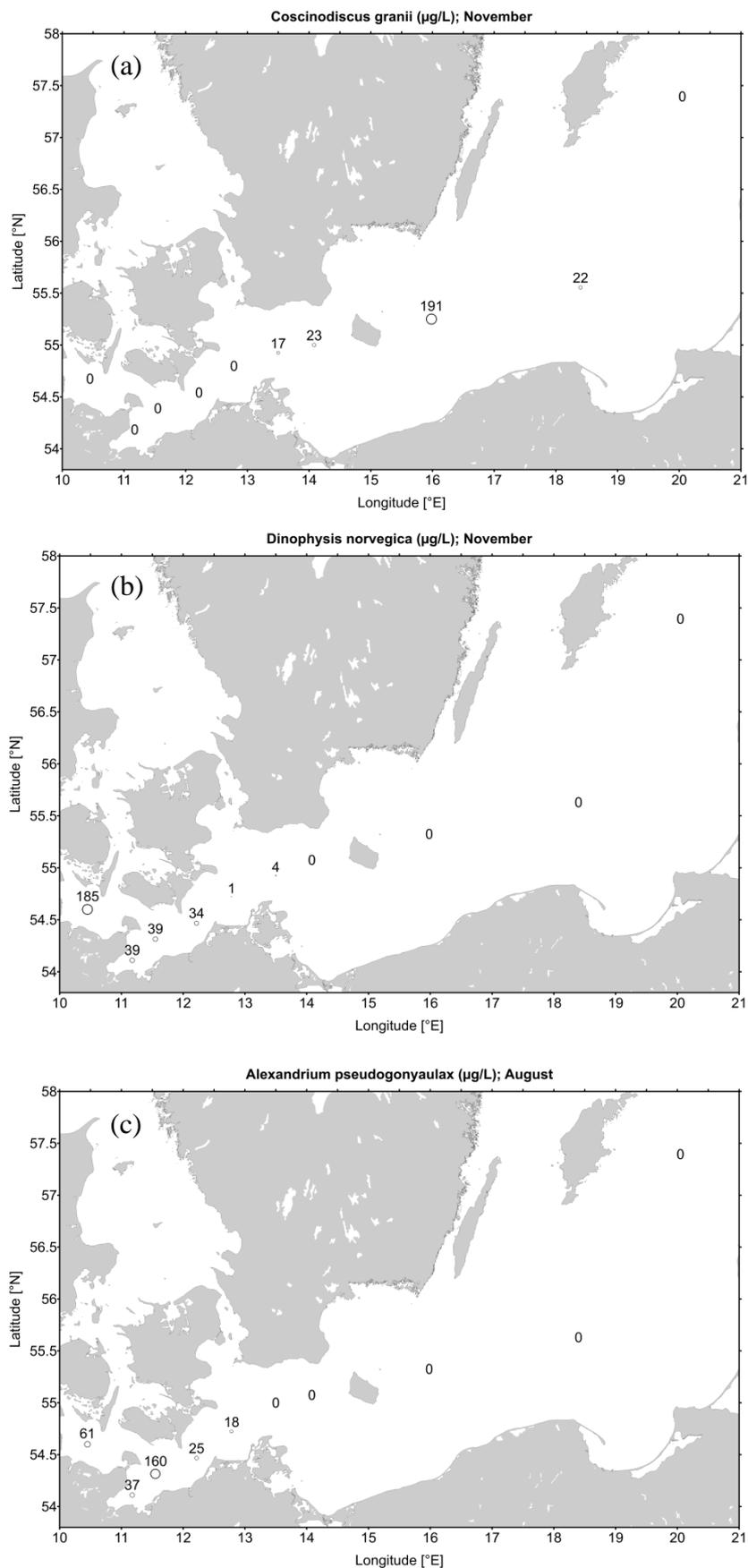


Fig. 20: Distribution of the *Coscinodiscus granii* (a), *Dinophysis norvegica* (b) and *Alexandrium pseudogonyaulax* (c) in November or August 2017.

Mesodinium rubrum (Fig. 17 a) is the typical representative of the spring bloom in the Baltic Proper with decreasing tendency to the west whereas *Dictyocha speculum* is the dominating spring species in the western Baltic (Fig. 17 b). However, *Dictyocha speculum* is highly variable from year to year, as discussed in chapter 4.1.4. *Skeletonema marinoi* formed the usual spring blooms in the Bay and Mecklenburg and the Arkona Basin (Fig. 17 c), but may occur in some years even in autumn.

The summer blooms of large diatoms that usually occur in the western Baltic were not noticed in 2017. As an example of a rather “new” dinoflagellate (cf. chapter 4.1.4) that became abundant in the Bay of Mecklenburg, *Alexandrium pseudogonyaulax* is represented in Fig. 20 c. The bloom-forming cyanobacteria are not worth presenting in this respect as they did not reach bloom-concentrations.

The autumn blooms were well developed in the western Baltic, represented by the dinoflagellates *Ceratium tripos* (Fig. 18 a) and *C. fusus* (Fig. 18 b) and the diatom genus *Pseudonitzschia* (Fig. 18 c) that usually does not form such strong blooms. Other important autumn diatoms of the western Baltic are *Rhizosolenia setigera* (Fig. 19 a) and *Cerataulina pelagica* (Fig. 19 b). The autumn diatoms the Baltic Proper are represented by *Actinocyclus* spp. (Fig. 19 c) and *Coscinodiscus granii* (Fig. 20 a). A dinoflagellate that usually occurs also in the Baltic Proper in summer, *Dinophysis norvegica*, was surprisingly abundant in autumn 2017 in Kiel Bay and the Bay of Mecklenburg (Fig. 20 b).

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 may be 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 TELESCH 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 even to 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 disappeared by 2012 at the latest. Again, *Noctiluca scintillans*, *Lennoxia faveolata* and *Phaeodactylum* cf. *tricornutum* established in 2015 and 2016, and the latter two were also present in 2017 in low biomass (Table A2).

Spatulodinium pseudonociluca was new to us in 2014, and it was still present in 2015 and 2016, but not in 2017. 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 18 in 2017 (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 and held the rank 12 in 2017, if objects are included which were similar but not reliably identified as this species.

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*, Fig.6) from the naked form of *Dictyocha speculum*, and have included it in our lists. The spring species *Dictyocha speculum* occurred vigorously in 2007 and 2008, but was relatively insignificant in 2010. In 2011, Dictyochophyceae were highly abundant, dominated by *Pseudochattonella farcimen* (named *Verrucophora* cf. *farcimen* at that time). 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 occurred together and formed a spring bloom in the Belt Sea. The appearance of *Dictyocha speculum* was weak in 2016. Already in 2013 its presence was stronger in autumn than in spring. Also in 2016 and 2017, 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 and 2017. *Coscinodiscus concinnus* formed a spring bloom in Kiel Bay and in the Bay of Mecklenburg in 2016, but not at all in 2017.

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 tessellata*, *Karenia mikimotoi* and *Nematopsides vigilans* were new for us in 2015, but their identification was not proved. They were not found in 2016 and 2017 anymore.

Thalassionema frauenfeldii was new for us. It was identified in samples from Kiel Bay and Bay of Mecklenburg from November 2017. However, this species was already known from the Kattegat/Belt Sea area according to the checklist of HÄLLFORS (2004).

4.1.5 Chlorophyll *a*

Table 6 shows the chlorophyll *a* data of the monitoring cruises. 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	Date	Chl.a-tot (mg m ⁻³)	Station	Date	Chl.a-tot (mg m ⁻³)
OMBMPN3	07.02.2017	3.04	OMBMPK8	15.11.2017	3.35
OMBMPN3	14.03.2017	9.92	OMBMPK8	23.11.2017	3.71
OMBMPN3	09.05.2017	2.50	OMBMPK5	08.02.2017	1.44
OMBMPN3	10.08.2017	2.55	OMBMPK5	17.02.2017	1.52
OMBMPN3	14.11.2017	8.35	OMBMPK5	16.03.2017	3.43
OMO22	08.02.2017	2.83	OMBMPK5	26.03.2017	4.95
OMO22	14.03.2017	3.53	OMBMPK5	10.05.2017	1.81
OMO22	09.05.2017	3.16	OMBMPK5	18.05.2017	2.59
OMO22	10.08.2017	1.92	OMBMPK5	13.08.2017	3.05
OMO22	14.11.2017	12.94	OMBMPK5	22.08.2017	1.89
OMBMPM2	08.02.2017	1.43	OMBMPK5	15.11.2017	2.94
OMBMPM2	17.02.2017	1.71	OMBMPK5	23.11.2017	2.85
OMBMPM2	15.03.2017	7.89	OMBMPK4	09.02.2017	0.66
OMBMPM2	26.03.2017	4.97	OMBMPK4	16.03.2017	4.16
OMBMPM2	10.05.2017	1.50	OMBMPK4	10.05.2017	2.23
OMBMPM2	18.05.2017	1.60	OMBMPK4	14.08.2017	2.60
OMBMPM2	10.08.2017	2.32	OMBMPK4	16.11.2017	3.18
OMBMPM2	22.08.2017	3.00	OMBMPK2	09.02.2017	0.88
OMBMPM2	14.11.2017	8.71	OMBMPK2	15.02.2017	0.63
OMBMPM2	23.11.2017	7.40	OMBMPK2	17.03.2017	2.48
OMBMPM1	08.02.2017	1.71	OMBMPK2	25.03.2017	2.32
OMBMPM1	17.02.2017	1.49	OMBMPK2	12.05.2017	1.91
OMBMPM1	15.03.2017	6.63	OMBMPK2	17.05.2017	2.19
OMBMPM1	26.03.2017	7.32	OMBMPK2	15.08.2017	2.39
OMBMPM1	10.05.2017	1.88	OMBMPK2	21.08.2017	2.98
OMBMPM1	18.05.2017	1.41	OMBMPK2	18.11.2017	3.11
OMBMPM1	11.08.2017	1.80	OMBMPK2	22.11.2017	2.82
OMBMPM1	22.08.2017	2.26	OMBMPK1	10.02.2017	0.50
OMBMPM1	15.11.2017	7.02	OMBMPK1	17.03.2017	1.13
OMBMPM1	23.11.2017	5.04	OMBMPK1	12.05.2017	4.92
OMBMPK8	08.02.2017	1.65	OMBMPK1	15.08.2017	2.45
OMBMPK8	17.02.2017	1.94	OMBMPK1	22.11.2017	2.08
OMBMPK8	15.03.2017	4.33	OMBMPJ1	11.02.2017	0.50
OMBMPK8	26.03.2017	4.58	OMBMPJ1	19.03.2017	0.93
OMBMPK8	10.05.2017	1.58	OMBMPJ1	14.05.2017	5.43
OMBMPK8	18.05.2017	1.56	OMBMPJ1	16.08.2017	3.67
OMBMPK8	13.08.2017	3.19	OMBMPJ1	19.11.2017	1.51
OMBMPK8	22.08.2017	1.66			

The seasonal variations of the chlorophyll data corresponds to those given for biomass in Figs. 12-14. The highest concentrations of chlorophyll *a* coincided with the spring and autumn blooms. A summer bloom was neither found in biomass data nor in chlorophyll values. The maxima of the chlorophyll concentrations appear during the autumn bloom (14 November 2017 in Lübeck Bay).

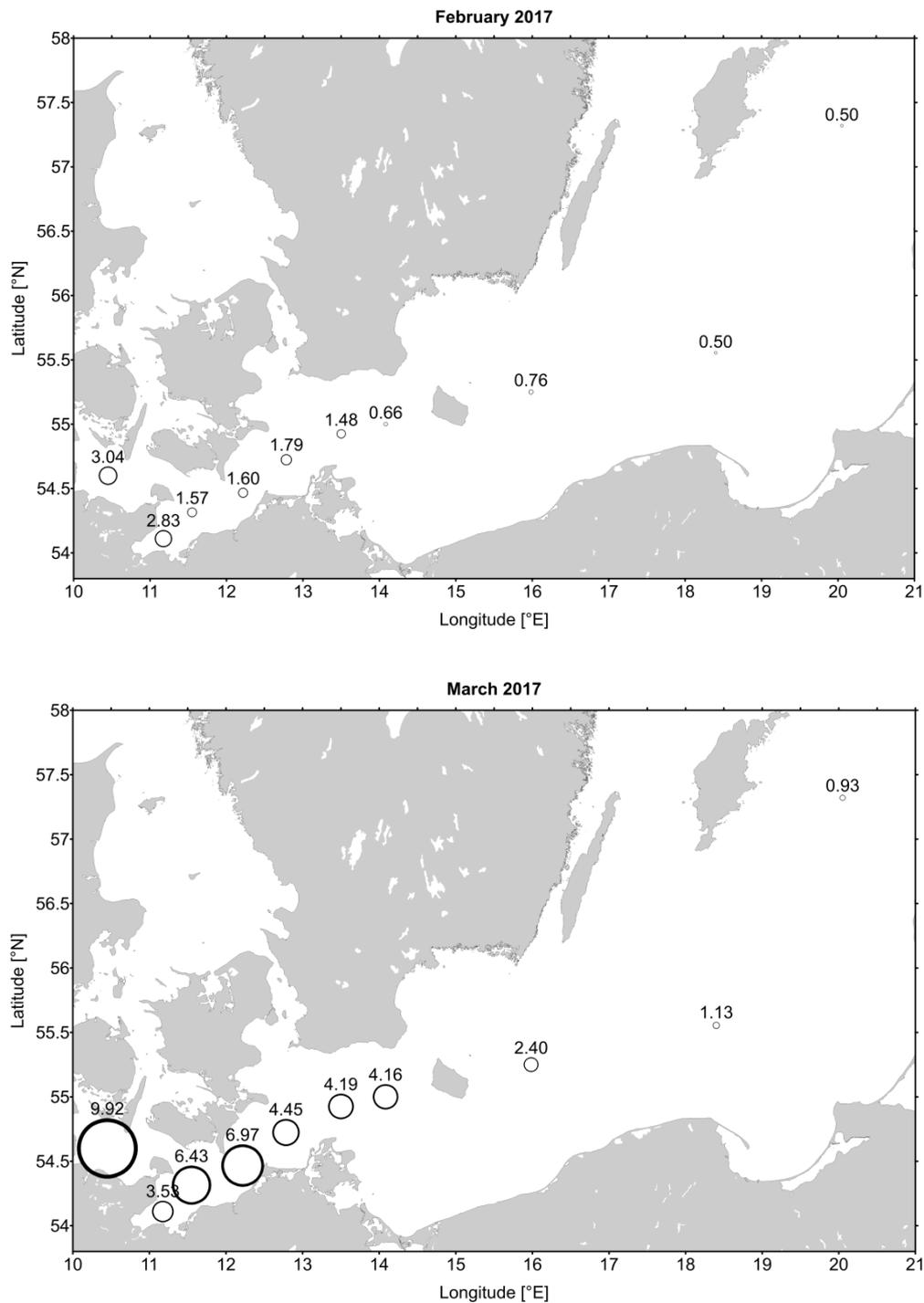


Fig. 21: Horizontal distribution of chlorophyll *a* concentrations ($\mu\text{g/L}$) at sampling locations during the monitoring cruises of February and March 2017.

Figs. 21-23 present the horizontal distribution of chlorophyll *a* values determined during the 5 monitoring cruises in 2017. They visualise the maxima in March and November in the western Baltic Sea. Most values indicated in the figures are lower than the peak values given in Table 6 because mean values from the outward and return leg of each cruise are depicted in Figs. 21-23 in contrast to single values in Table 6.

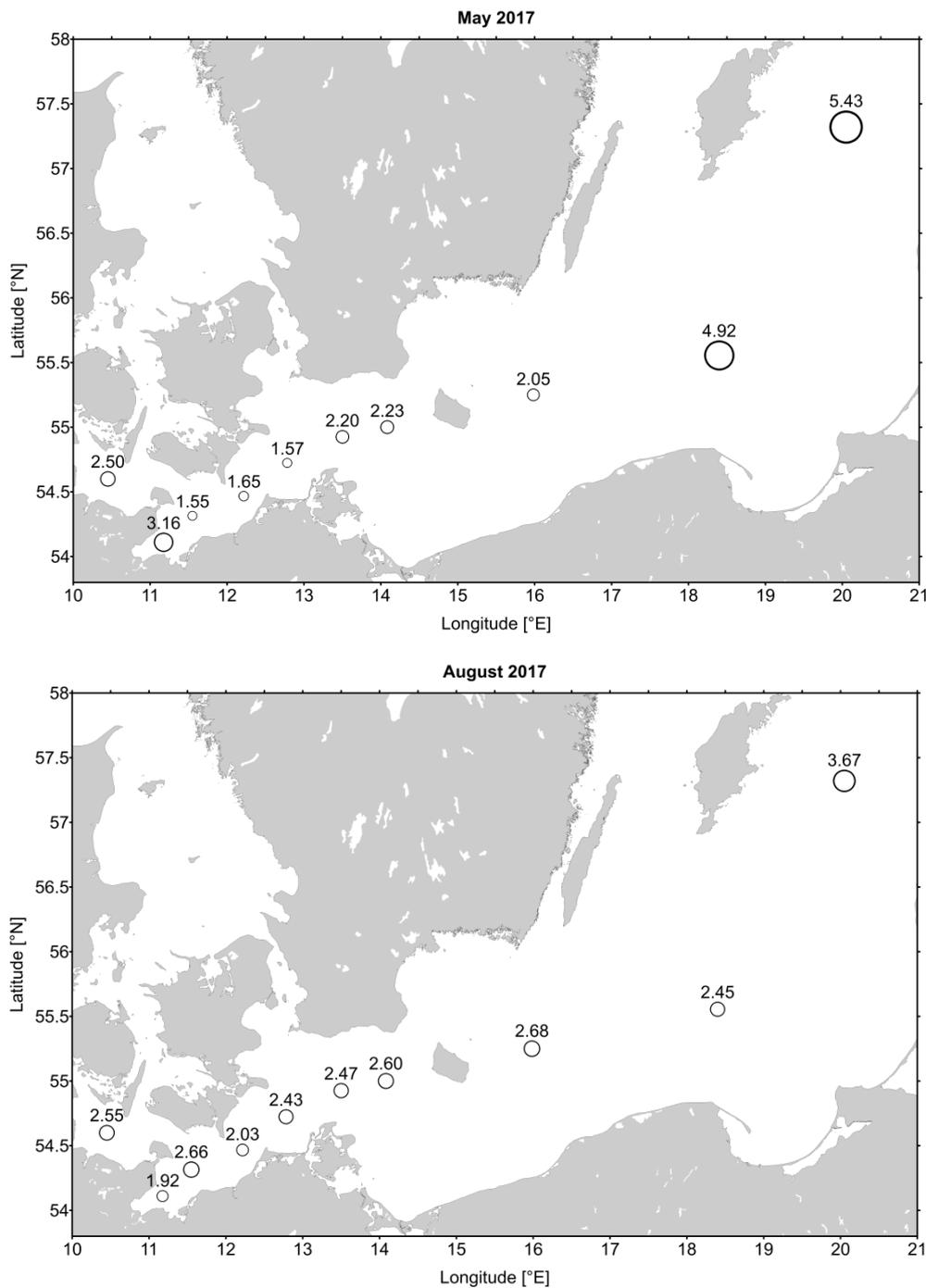


Fig. 22: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during monitoring cruises in May and August 2017.

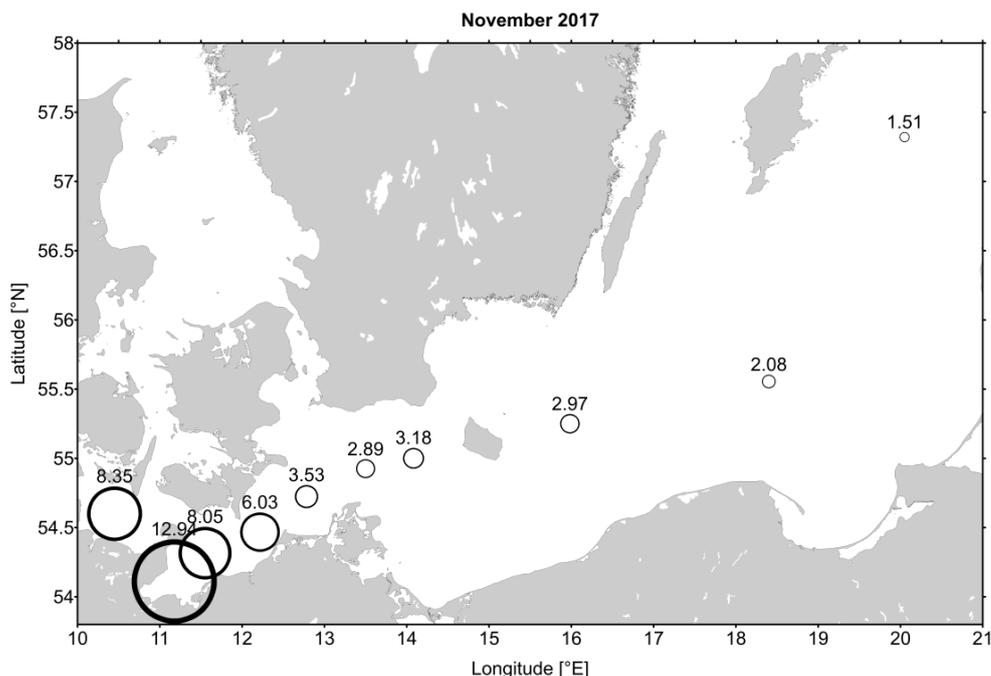


Fig. 23: Horizontal distribution of chlorophyll *a* concentrations ($\mu\text{g/L}$) at sampling locations during the monitoring cruise in November 2017.

4.1.6 Sedimentation

The microscopic examination of the material collected in the Arkona Basin in 2017 showed an increased richness of diatom species throughout the year. With 26 species/groups of diatoms found in the trapped material the number increased again by 4 compared to the previous year and made 2017 the year with the highest diversity within this group since the beginning of the study. Diatoms dominated the mass flux in spring, contributed moderately in a mixture with cyanobacteria in summer and again to a higher degree together with dinoflagellates in autumn. This altogether led to a very similar quantitative pattern of mass and element flux over all three growth periods during 2017.

In general, again the familiar seasonal succession of microalgal/cyanobacterial communities was observed over the pelagic growth phase between March and December 2017 (Fig. 24 a-d).

The diatoms (Fig. 24 a) showed a distinct succession of spring-, summer- and autumn-communities. In this year the regular spring bloom was preceded by a community of 3-5 diatoms species from February onwards, which consisted of typical spring species: *Actinocyclus octonarius*, *Chaetoceros* spp., *Coscinodiscus granii*, *Skeletonema marinoi*, *Thalassiosira eccentrica* and some pennate diatoms. Except for *Thalassiosira eccentrica* this species assemblage of early diatoms was the same as in 2016 and likewise some of them (*Chaetoceros* spp., *Thalassiosira eccentrica*) returned in late autumn with colder water temperature, whereas *Actinocyclus octonarius* remained present in variable abundance over the whole year. A similar temporal distribution could be observed for *Coscinodiscus granii*, who was just absent in brief periods during February and June. In a single January sample *Proboscia alata* appeared.

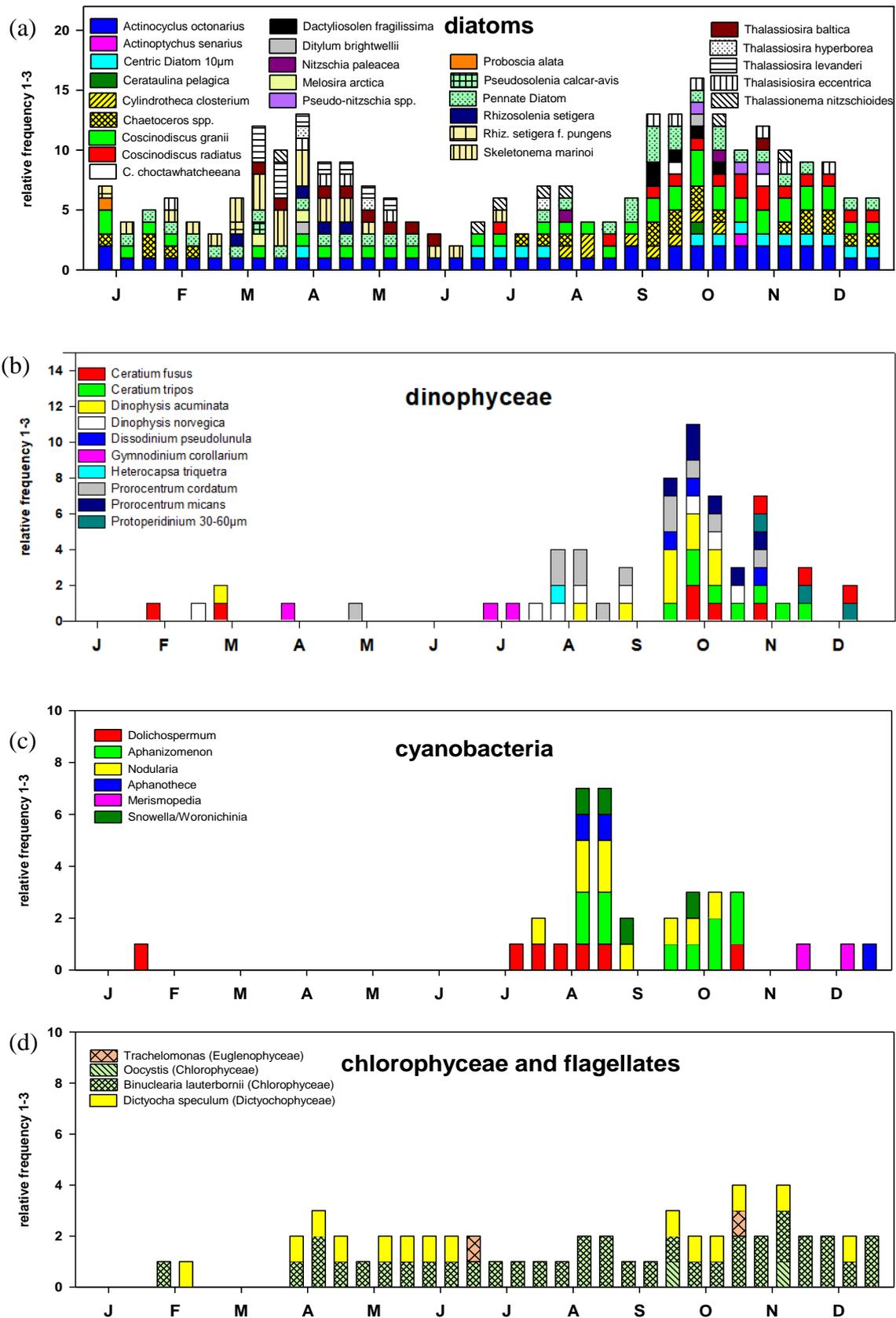


Fig. 24 a-d: Relative frequency of selected species of diatoms, dinoflagellates, cyanobacteria and green algae/ flagellates in sinking organic material in 2017.

The spring bloom between the middle of March and middle of April with 7-11 species consisted of *Actinocyclus octonarius*, *Coscinodiscus granii*, *Skeletonema marinoi*, *Thalassiosira eccentrica*, *Thalassiosira hyperborea*, *Thalassiosira levanderi*, *Ditylum brightwellii*, *Melosira arctica*, *Rhizosolenia setigera*, pennate diatoms and a non-identified centric diatom of 10 μ diameter with *Skeletonema marinoi* and in the early phase *Thalassiosira levanderi* as dominant species. Unlike in the previous year, in this spring period *Chaetoceros* spp. and *Coscinodiscus radiatus* were not present.

In the summer phase between June and August diatom diversity slowly increased starting with *Actinocyclus octonarius*, *Skeletonema marinoi*, *Thalassiosira baltica* and *Thalassionema nitzschioides* and a later appearance of *Thalassiosira hyperborea*, *Cylindrotheca closterium*, *Nitzschia paleacea* and other pennate diatoms.

From September on with a peak in October until November diatom diversity increased further in a mixture of *Cyclotella choctawhatcheeana*, *Actinocyclus octonarius*, *Cerataulina pelagica*, *Cylindrotheca closterium*, *Chaetoceros* spp., *Coscinodiscus granii*, *Coscinodiscus radiatus*, *Dactyliosolen fragilissimus*, *Ditylum brightwellii*, *Pseudo-nitzschia* spp., *Thalassiosira eccentrica*, a non-identified centric diatom of 10 μ diameter and a small pennate diatom. In this autumn bloom, *Actinocyclus octonarius*, *Cerataulina pelagia* and, to a minor extent, *Coscinodiscus radiatus* were the most abundant species.

The diversity of dinoflagellates observed in 2017 (Fig. 24 b) returned to a standard of 10 species after a decrease to 7 in 2016. Over the whole winter and spring, species like *Ceratium fusus*, *Dinophysis acuminata*, *Dinophysis norvegica*, *Gymnodinium corollarium* and *Prorocentrum cordatum* appeared just occasionally and in small numbers. Between July and September, *Prorocentrum cordatum* increased in numbers and co-occurred with *Heterocapsa triquetra*, *Dinophysis acuminata* and *Dinophysis norvegica*. The main growth period of dinophytes, however, was in the autumn between October and the beginning of November. Here, a mixture of *Ceratium fusus*, *Ceratium tripos*, *Dinophysis acuminata*, *Dinophysis norvegica*, *Dissodinium pseudolunula*, *Prorocentrum cordatum* and *Prorocentrum micans* with a simultaneous occurrence of 7 species became important both in terms of diversity and biomass. In late November both abundance and species number decreased again and a *Protoperidinium* species of 30-60 μ m appeared in the samples. In general the occurrence of dinoflagellates in 2017 followed the classical pattern for microalgae communities in late summer/autumn blooms.

The number of cyanobacterial species observed in 2017 remained on the same level as in the previous year (Fig. 24 c). The succession and seasonal distribution of the major species, however, differed. In this year the cyanobacterial species relevant for biomass- and nitrogen-fixation (*Aphanizomenon* and *Nodularia*) occurred simultaneously in late summer instead of the usual succession of *Aphanizomenon* in June/July and *Nodularia* in August/September. There is always an overlap, but this year a small proportion of *Nodularia* appeared already in advance of *Aphanizomenon* in July together with *Dolichospermum*. In August the three nitrogen-fixers appeared in high numbers, which is directly reflected in a drastic drop of the $\delta^{15}\text{N}$ -signature in the trap material (Fig. 30), decreasing C/N (Fig. 31), and increasing C/P (Fig. 32), ratios which are all distinct indicators for this mode of primary production. They were accompanied by the non-diazotrophic *Aphanothece* and *Snowella/Woronichinia* and remained present until October. Towards late autumn and winter the cyanobacterial abundance decreased with occasional occurrence of *Aphanothece* and *Merismopedia*.

The temporal distribution of chlorophyceae and flagellates (Fig. 24 d) differs from that in 2016. A low abundance or absence in winter and spring is succeeded by a moderate to high abundance of the chlorophyte *Binuclearia lauterbornii* and the dictyochophyceae *Dictyocha speculum* over the whole growth period. In autumn the euglenophyte *Trachelomonas* and the chlorophyte *Oocystis* spp. appeared in low numbers. Contrary to diatoms and dinoflagellates, the annual growth pattern of chlorophyceae and flagellates does not follow a regular pattern and shows large interannual differences. This may be based either on an opportunistic life strategy of these small organisms with a fast reaction to specific environmental situations and/or may partly be related to the difficulties in conservation and taxonomical identification of these small organisms under the light microscope.

The vertical fluxes of carbon (Fig. 25), nitrogen (Fig. 26), suspended particulate matter (SPM) (Fig. 27) and phosphorus (Fig. 28) in 2017 reflect the microscopical finding of high rates during pelagic bloom periods. An exception is the winter phase in January and February 2017, where resuspended material from the sediment entered the traps due to intense vertical mixing in the comparatively shallow area of the Arkona Basin in periods with missing vertical density gradients in the upper water column. The low percentage of carbon and nitrogen, the high C/N ratio and nearly no discernable algal remains at still high silica values (Fig. 29) in this material support this view. If this material would be subtracted from the annual total, then the rates were lower by about 25 % and thereby in the long-term mean again.

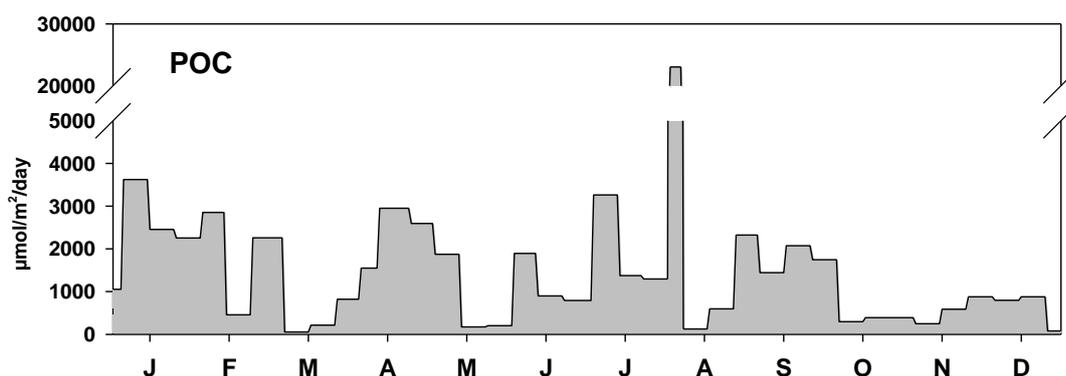


Fig. 25: Daily sedimentation rates of particulate organic carbon (POC) at 35 m depth in the central Arkona Sea in 2017.

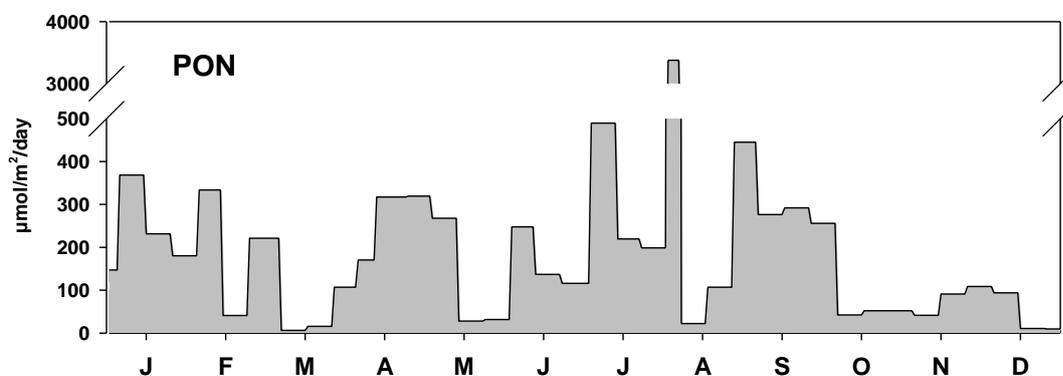


Fig. 26: Daily sedimentation rates of particulate organic nitrogen (PON) at 35 m depth in the central Arkona Sea in 2017.

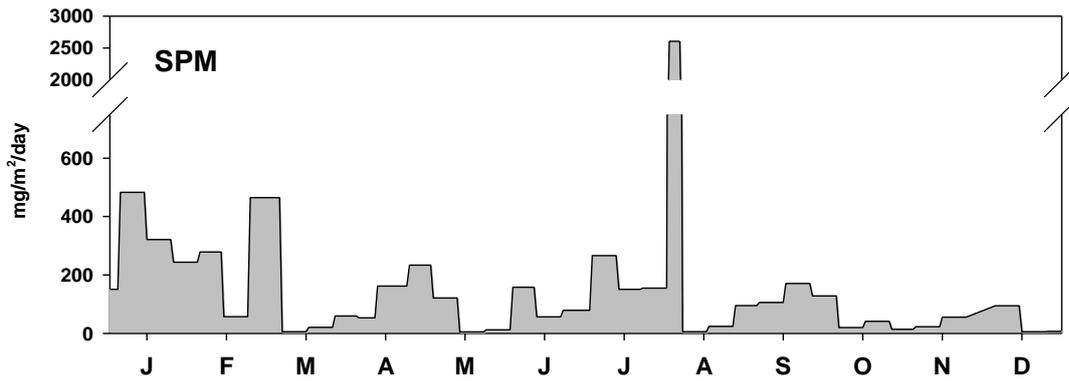


Fig. 27: Daily sedimentation rates of particulate suspended matter (SPM) at 35 m depth in the central Arkona Sea in 2017.

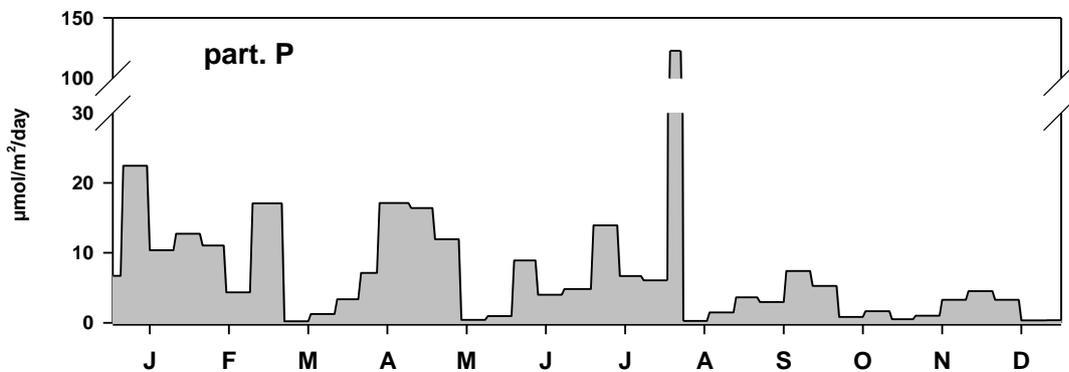


Fig. 28: Daily sedimentation rates of particulate phosphorus (part. P) at 35 m depth in the central Arkona Sea in 2017.

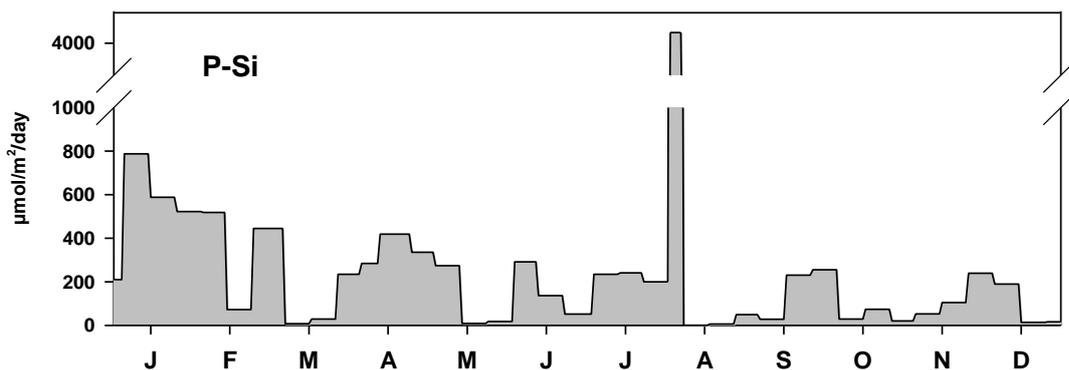


Fig. 29: Daily sedimentation rates of particulate biogenic silica (P-Si) at 35 m depth in the central Arkona Sea in 2017.

Contrary to 2016, a clear sequence of bloom periods could be observed with clearly separated peaks in mass transfer that can be related to a diatom spring bloom, a summer bloom of diazotrophic cyanobacteria and a mixed autumn bloom of diatoms and dinoflagellates. Each of these periods is characterized by a specific biogeochemical marker like the low C/Si ratio in spring, the light isotopic signature of nitrogen (Fig. 30) in summer along with a low C/N-ratio

(Fig. 31) and a high C/P-ratio (Fig. 32) typical for summer cyanobacterial communities and a higher C/Si ratio during the growth of a mixed diatom/dinoflagellate population in early autumn.

In contrast to 2016, the spring diatom bloom was a major contributor of organic material and biogenic silica to the sea floor. It provided about one third of the sinking material during the pelagic growth season. A further significant proportion of material was sinking in the early phase of the autumn bloom in a mixed population of diatoms and dinoflagellates, so that in this year diatoms provided the bulk of the vertical particle flux.

With 2000-3000 $\mu\text{mol m}^{-2} \text{d}^{-1}$, the sedimentation of organic carbon (Fig. 25) was in the same range during peak periods of the three different growth phases. An exception occurred in the beginning of August, where over a period of just 5 days a tenfold (23000 $\mu\text{mol m}^{-2} \text{d}^{-1}$) flux was recorded which was associated with a mixture of diatoms and dinoflagellates. This singular peak comprised all measured elements (C, N, P, Si) and bulk mass but showed no anomalies in qualitative terms (C/N, C/P, C/Si, $\delta^{13}\text{C}$ -signature) except for the $\delta^{15}\text{N}$ - values (Fig. 30), which were extremely high (11,85 ‰). As this value is much higher than the $\sim 8\text{‰}$ which can be found in nitrate-rich deep or winter water and later in spring bloom material, it is very probable that at that time a lateral intrusion of water with land-derived dissolved nitrogen from livestock farming occurred. In July 2017, the rainfall in the North-East of Germany was extremely high (223% of the long-term mean in the Rostock region) and it is therefore very likely that runoff from manure loaded rivers draining into the Arkona Sea (e.g. river Peene), from the Danish Sound or from diffuse coastal sources increased the nutrient levels correspondingly at the end of July.

It followed a decrease in the $\delta^{15}\text{N}$ - values by about 10 ‰ within few days with a concomitant change of the species composition into a community dominated by cyanobacteria with a typical shift from nitrogen- to phosphorus limitation (reversal of high C/N (Fig. 31) and low C/P (Fig. 32) to low C/N and high C/P ratios). This drastic change in biological and biogeochemical conditions indicates rather an intrusion of a surface water mass with westerly currents from the Bornholm Basin than a shift in generic growth patterns. Similar patterns of fast sequential transition between diatom-rich water masses from the Western Baltic and nitrogen depleted surface water with diazotrophic cyanobacteria from the Bornholm Basin have been observed in the previous years and seem to be characteristic for the summer season with its rapid changes between easterly and westerly wind directions.

After the end of this cyanobacterial period a mixed population of diatoms and dinoflagellates provided another maximum in particle flux from the end of August until October. This autumn bloom peaked comparatively early and displayed lower C/N and higher C/P ratios, than the pure diatom bloom in spring. Whether this is only based on the intermixture of dinoflagellates or the general shift in the availability of inorganic N or P for algal growth over the growth period, is not clear.

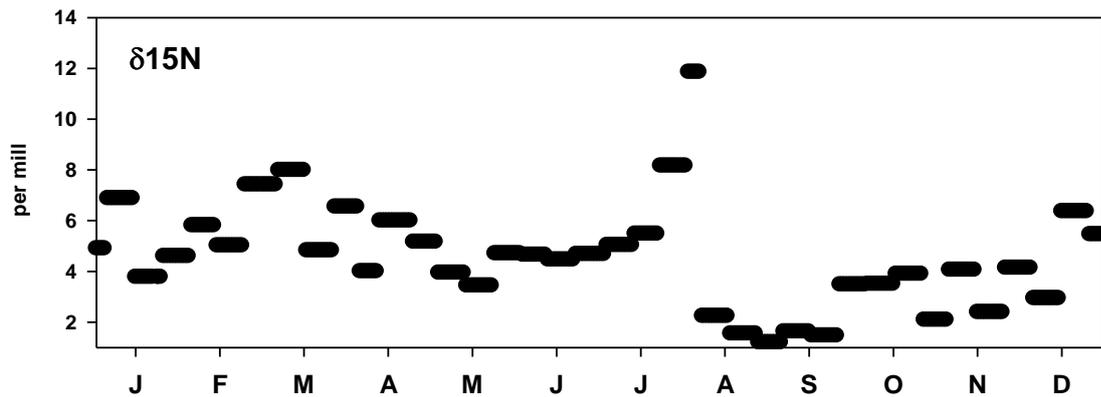


Fig. 30: Isotopic signature of nitrogen (‰ $\delta^{15}\text{N}$) in sediment trap material from the central Arkona Sea in 2017.

However, both the C/N-ratio (Fig. 31) and the C/P ratio (Fig. 32) display harmonic developments with decreasing C/N and increasing C/P over the annual growth period which may indicate such a general shift from nitrogen to phosphorus limitation over the summer. The last minor diatom-derived events in sedimentation occurred in November/December and restored both ratios back to spring values. This indicates a higher contribution of nutrients in the normal marine composition from deeper water layers by increased autumn convection of the water masses. An increase of the $\delta^{15}\text{N}$ values to the range of 4-6 ‰ that can be found in spring supports this.

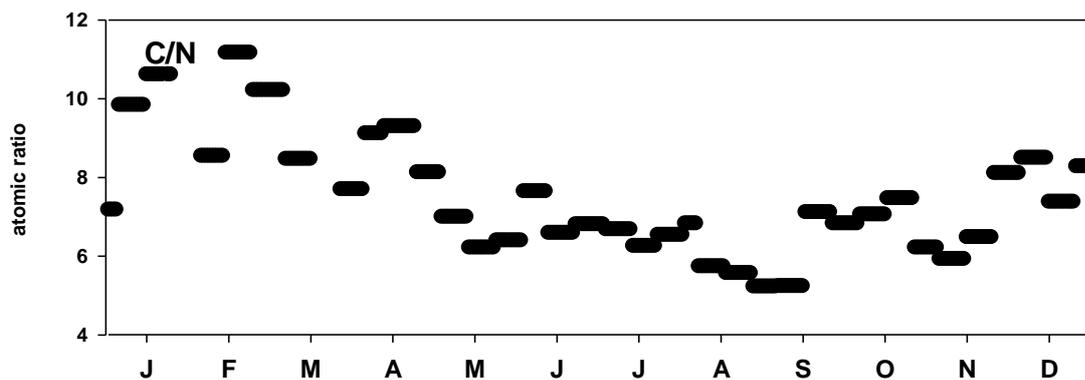


Fig. 31: Atomic ratio between carbon and nitrogen (C/N) in sedimenting particles at 35 m depth in the central Arkona Sea in 2017.

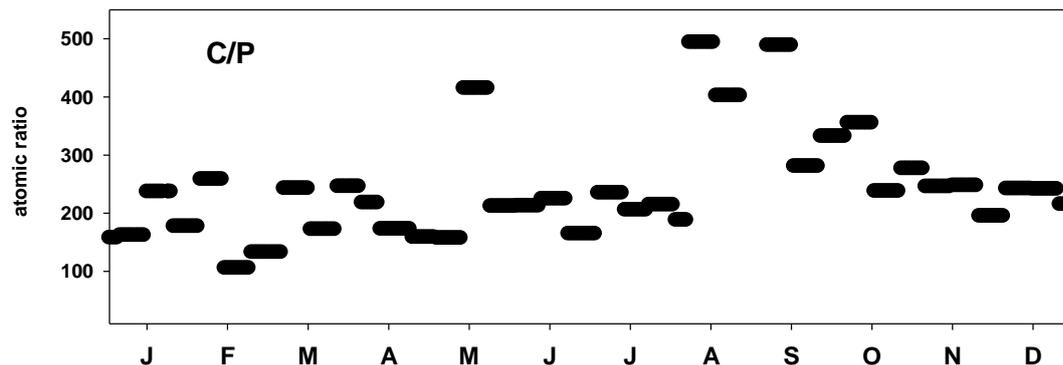


Fig. 32: Atomic ratio between carbon and phosphorus (C/P) in sedimenting particles at 35 m depth in the central Arkona Sea in 2017.

The total annual flux for single elements in 2017 amounted to 580 mmol C (7 g C), 76 mmol N, 91 mmol Si and 2.8 mmol P $\text{m}^{-2} \text{a}^{-1}$ at a mass flux of 56 g dry mass $\text{m}^{-2} \text{a}^{-1}$. The level of these values is still in a high range of long-term annual flux rates, which is certainly related to the series of strong resuspension events during winter. The high input from sediment sources during this time is reflected in indicators like the C/Si ratio and in C as % of dry weight, both of which are lower than in the previous year that had no comparable resuspension events. An exclusion of the input during this period would reduce the annual flux by about 25% and place the values back into the range of long term means.

4.2 Mesozooplankton

4.2.1 Species Composition and Invasive Species

In 2017, 63 taxa were recorded in the study area (Tab. A3). The number of taxa was lower than in the preceding year (2016: 73 taxa, WASMUND et al. 2017a), in which the diversity of the zooplankton has peaked in the recent decade. Nevertheless, compared to earlier years the diversity remained high. The lower number of taxa relates to a lower frequency in the occurrence of pelagic larvae of benthic organisms during summer that were responsible for the peak in species number. Especially larvae of benthic crustacean species such as *Liocarcinus* spp., *Pagurus bernhardus* or *Upogebia stellata* occurring during summer were lacking in 2017. In addition, some marine, holoplanktonic species such as *Acartia clausi* or *Centropages typicus* were not found. The reduction in species number was partly offset by the occurrence of the halophilic anthomedusae *Lizzia blondina* or *Staurosarsia gemmifera*. With a total of 40-48 taxa, the species number was highest in the western areas of the German exclusive economic zone (Kiel Bay – OMBMPN₃, Bay of Mecklenburg – OMBMPM₁, OMBMPM₂) and decreased to 28-37 taxa in the Arkona Basin (Fig. 33). This is owed to the restriction in the distribution of several species of Cnidaria (*Euphysa aurata*, *Obelia geniculata*, *Rathkea octopunctata*), Crustacea (*Calanus helgolandicus*, *Diastylis* spp., Isopoda, Lophogastrida, Ostracoda) or meroplanktonic larvae (*Ophiura* spp., *Echinus* spp., *Pectinaria* spp., *Peltogaster* spp.) to areas of higher salinity. Following two years of very low zooplankton abundance (2015-2016), the zooplankton stocks show some recovery, but remained generally low (compare Fig. 37 a).

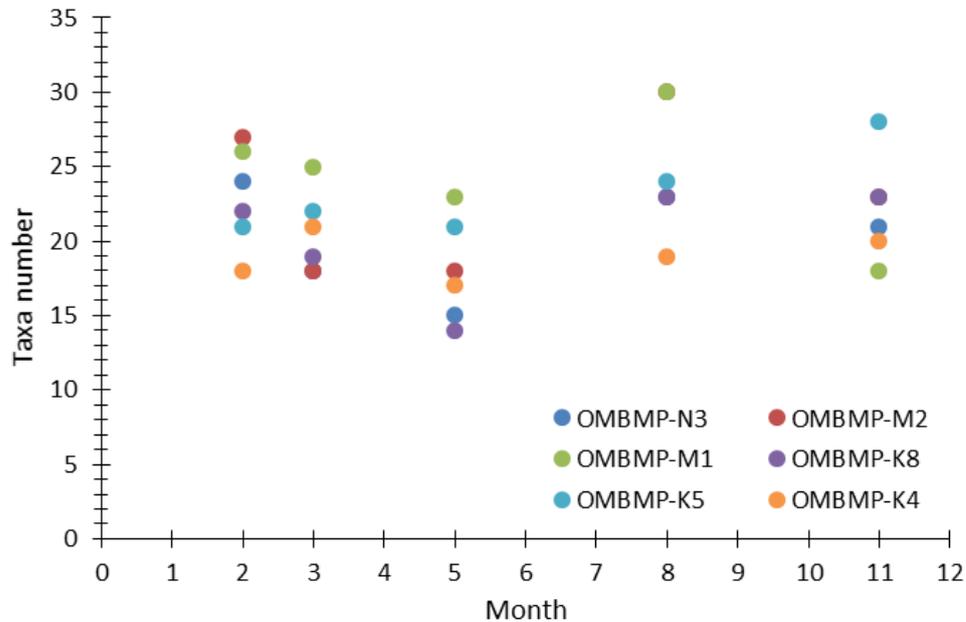


Fig. 33: Seasonal variation of the number of taxa recorded at different stations in the investigation area in 2017.

The recovery relates to the increase in the abundance of cladocera and copepoda, particularly in the Bay of Mecklenburg and Arkona Basin. In the Arkona Basin, the stocks of cladocera increased 10-fold in comparison to 2016, providing evidence for mass development during summer, which was lacking in the previous years. Cladocera were, therefore, the most important single zooplankton group in the area with maximum concentrations of 5.1×10^4 ind. m^{-3} , but were of less importance in the Kiel Bay and Bay of Mecklenburg. The copepoda showed increased stocks in the entire area, largely because of higher abundances of the early development stages. The abundance of both calanoid and cyclopoid copepods was on average about 2-4-fold higher than in 2016, with maximal abundances of 4.9 and 2.9×10^4 ind. m^{-3} , respectively. The stock size of the remaining major zooplankton groups – rotifers, appendicularians and meroplankton (polychaete-, bivalve- and gastropod larvae) displayed only small differences compared to preceding years. These groups have, thus, a lower relative contribution to the total zooplankton in 2017.

Bosmina spp. was the single most important genus among the cladocerans occurring with $2.8 - 4.8 \times 10^4$ ind. m^{-3} during summer in the Arkona Basin. The species contributed primarily to the increased stock size of cladocera in 2017. In the Bay of Mecklenburg and the Kiel Bay, *Bosmina* spp. was of less importance and was outnumbered by *Evadne nordmanni*, *Podon intermedius* and *P. leuckartii*. *E. nordmanni* ranked second among the cladocera with concentrations ranging from $1.3 - 3.4 \times 10^3$ ind. m^{-3} , which is in the range of the abundance at which the species is regularly observed in the area. *P. intermedius* and *P. leuckartii* were rare in 2015-2016 and the abundance barely exceeded 500 ind. m^{-3} . In 2017, their stocks size achieved 1.1×10^3 and 2.1×10^3 ind. m^{-3} , respectively. Other cladoceran species were rare. The only other cladoceran observed was *Pleopsis polyphemoides* occurring at maximal concentrations of 37 ind. m^{-3} .

The stocks of the ecological important group of the copepoda showed a general recovery. However, not all taxa were equally affected. A considerable increase in abundance in the calanoid genus *Temora* and the cyclopoid genus *Oithona* was particularly recorded in the Bay

of Mecklenburg where the concentrations exceeded 2.8×10^4 ind. m^{-3} , but also in the Kiel Bay and Arkona Basin. A high abundance was also observed for the genus *Acartia* spp. in all areas, which achieved maximum concentrations of $0.9 - 1.5 \times 10^4$ ind. m^{-3} . Only moderate changes were observed in the stocks of *Centropages* and *Pseudo/Paracalanus*. An increase in the abundance in the Kiel Bay and Bay of Mecklenburg (max. 1.1×10^4 ind. m^{-3}) contrasts with a continuously low abundance of especially *Pseudo/Paracalanus* in the Arkona Basin (max 1.3×10^3 ind. m^{-3}).

Oithona similis was the single most abundant species among the adult copepods. The cyclopid species exceeded concentrations of more than 1.0×10^4 ind. m^{-3} in the Kiel Bay and Bay of Mecklenburg, but declined in its importance in the Arkona Basin. Here, they were outnumbered by *Acartia longiremis* and *Temora longicornis*, which occurred at concentrations of $1.8 - 7.7 \times 10^4$ ind. m^{-3} and $2.2 - 5.1 \times 10^4$ ind. m^{-3} in the study area, respectively. Another species of the genus *Acartia*, *A. bifilosa*, achieved $1.8 - 4.1 \times 10^4$ ind. m^{-3} and was the main species together with *Oithona similis* in the Kiel Bay. *Centropages hamatus*, *Paracalanus parvus* and *Pseudocalanus* spp. were of less importance (max. $1.4 - 2.1 \times 10^4$ ind. m^{-3}) and their stocks remained low without a sign of recovery particularly in the Arkona Basin.

The rotifera occurred at densities similar to the preceding year ($0.2 - 2.4 \times 10^4$ ind. m^{-3}), but concentrations were low compared to historical values. In the Kiel Bay, they showed only a minor contribution to the total zooplankton (max. 76 ind. m^{-3}), which is in agreement with the long-term record. Only in 2016, exceptional high concentrations were observed. The maximum concentrations occurred in May, which indicates a late seasonal timing in the occurrence compared to 2015-2016. As usual, the rotifers were exclusively dominated by the genus *Synchaeta* spp. Individuals of the diverse genus *Keratella* (*K. quadrata*, *K. cochlearis*, and *K. cruciformis*) were not observed in 2017. They were a regular component of the zooplankton in preceding years, although encountered only at low abundance.

Apart from cladocera, copepods and rotifers, diverse meroplankton and the appendicularians were important contributors to the zooplankton. Their abundance is traditionally higher in the shallower western areas, and 2017 was no exception. While polychaete and gastropod larvae occurred at concentrations similar to preceding years ($1.7 - 4.5$ and $0.2 - 2.4 \times 10^3$ ind. m^{-3} , respectively), the abundance of bivalve larvae was lower, particularly in the Arkona Basin, than in preceding years (max. 7.9×10^3 ind. m^{-3} vs. $1.2 - 1.4 \times 10^4$ ind. m^{-3} in 2015-2016). The appendicularians were as usual represented by *Fritellaria borealis*, a spring species, and *Oikopleura dioica*, an autumn species. The seasonal timing and densities of both species were similar to preceding years. *F. borealis* occurred at densities of $0.5 - 5.9 \times 10^3$ ind. m^{-3} in all areas. *Oikopleura dioica* was regularly found in an abundance of $0.2 - 4.7 \times 10^3$ ind. m^{-3} in the Kiel Bay and the Bay of Mecklenburg, mainly.

Only few exceptional species were observed in the zooplankton in 2017. The calanoid copepod *Acartia tonsa*, which was already introduced during the 1920s, is a well-established calanoid copepod in Baltic Sea. The concentrations of 11-457 ind. m^{-3} were rather low in 2017. Not unusual, *Calanus helgolandicus* was observed with a few specimen in the Kiel Bay and Bay of Mecklenburg in February. In contrast, the records of the anthomedusae *Lizzia blondina* and *Staurosarsia gemmifera* are new for the Kiel Bay and the Bay of Mecklenburg. Both species occur regularly around the coasts of the British Isles and the southern North Sea. They have also

been recorded from the Skagerrak and the Kattegat (RUSSEL 1970, GREVE et al. 2004). The occurrence in the lower saline water of the Baltic Sea is, therefore, not unexpected.

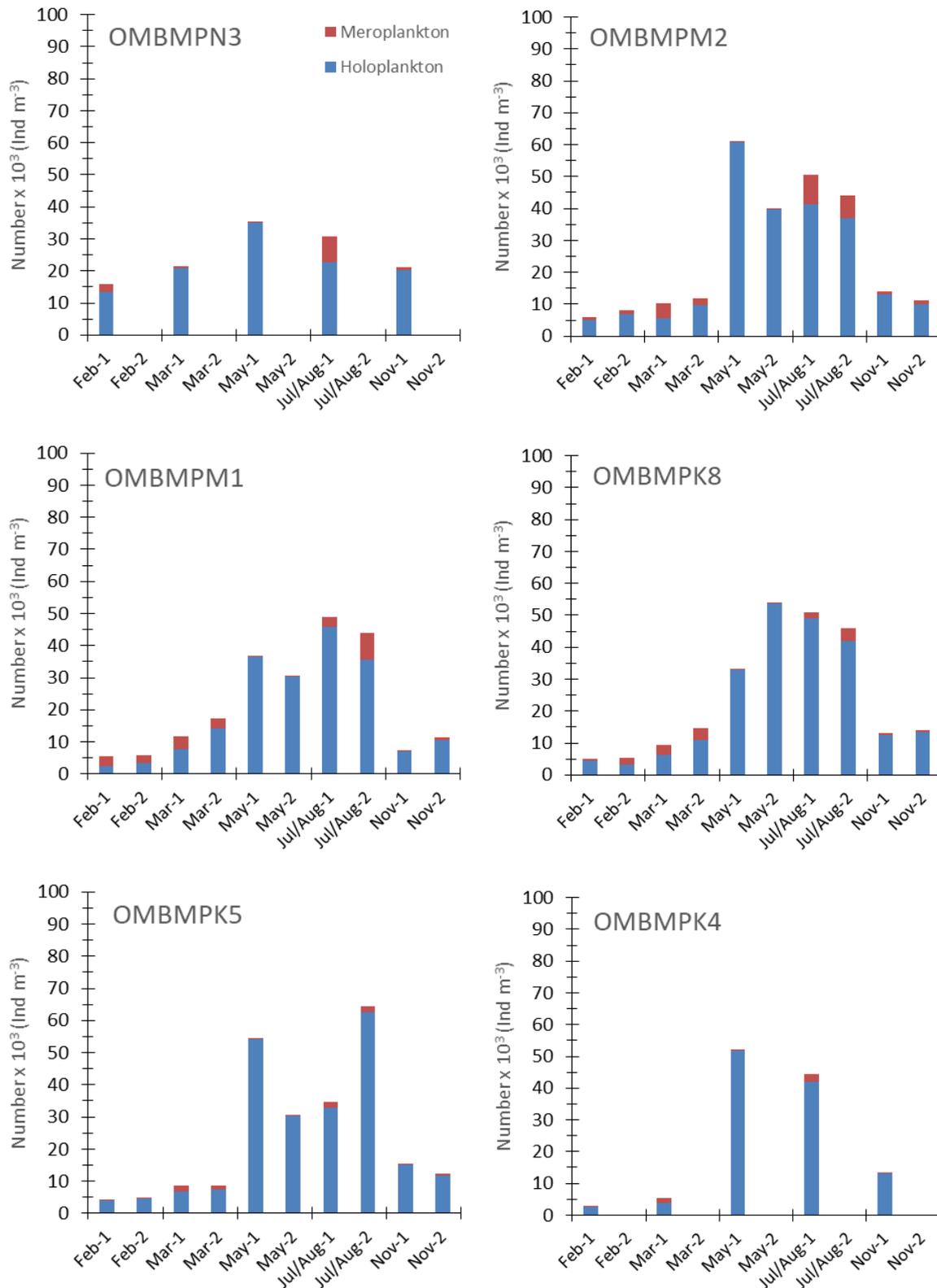


Fig. 34: Seasonal variation of the abundance of mesozooplankton and the contribution of mero- and holoplankton to the total stock of zooplankton at different stations in the investigation area in 2017.

4.2.2 Seasonal zooplankton variation in sub-areas

Kiel Bay

The zooplankton in Kiel Bay (OMBMP-N₃) is usually characterized by a lower seasonality compared to the strong numerical variation caused by ephemeral zooplankton groups such as cladocera and rotifers in the Bay of Mecklenburg or the Arkona Basin. Copepods are, therefore, the major zooplankton group in this area. The moderate variation in total abundance together with an overall dominance of copepods in 2017 fit again well in this general scheme (Figs. 34, 35). The winter stocks of zooplankton of 1.6×10^4 ind. m^{-3} were considerably higher than in the two preceding years ($\sim 1.4 \times 10^4$ ind. m^{-3}). This is related to the very high frequency of the cyclopoid copepod *Oithona similis* in February which contributed to more than 1.0×10^4 ind. m^{-3} to the overwintering stock (Fig. 36). The abundance of this copepod species remained unusually high for the rest of the year ($> 1.0 \times 10^4$ ind. m^{-3}). The species dominates usually during a restricted season, which can nevertheless be variable. Apart from *Oithona*, calanoid copepods (3.1×10^3 ind. m^{-3}), polychaete larvae (248 ind. m^{-3}) and few cladocera (< 20 ind. m^{-3}) contributed mainly to the overwintering stock (Fig. 35).

The zooplankton increased until May to maximum concentrations of 3.5×10^4 ind. m^{-3} , while copepods remained the dominating zooplankton group and contributed to more than 97% to the total stock (Figs. 34, 35). This contrasts with the exceptional year 2016, in which rotifers formed an early maximum in the zooplankton already in March. The increase in the stock size was largely caused by the development of the calanoid copepod community to an abundance of 3.5×10^4 ind. m^{-3} (Fig. 36). The concentration of *Oithona* remained high (1.3×10^4 ind. m^{-3}). Cladocera (*Evadne nordmanni*, *Podon intermedius*) as well as rotifers and appendicularians were generally rare. The copepods were the dominant zooplankton group also during summer and autumn (Fig. 35). The concentrations ranged from $1.6 - 1.9 \times 10^4$ ind. m^{-3} and were above the average. The contribution of other zooplankton was minor and the stocks of meroplankton (mainly bivalve larvae) and the appendicularian *Oikopleura dioica* were lower than usual (Figs. 34, 35).

Among the copepods, *Oithona* ($1.0 - 1.3 \times 10^4$ ind. m^{-3}) and *Acartia* ($1.0 - 8.7 \times 10^3$ ind. m^{-3}) were the dominating genera from February to May (Fig. 36). In May, the stocks of *Centropages*, *Temora* and *Pseudo/Paracalanus* contributed considerably to the copepods ($3.0 - 5.3 \times 10^3$ ind. m^{-3}). While the high concentrations of *Acartia* and *Oithona* are not unusual, the frequency of *Temora* was above normal levels. In addition, the low stocks of *Pseudo/Paracalanus* in recent years show signs of recovery. Among the adult calanoid copepods, *Acartia bifilosa* was the dominant copepod during winter-spring ($1.1 - 4.7 \times 10^3$ ind. m^{-3} , Fig. 36). The species was accompanied by *Temora longicornis* and *Pseudocalanus* spp. in May ($3.0 - 5.9 \times 10^3$ ind. m^{-3}). In summer and autumn, *Oithona* spp, and *Pseudo/Paracalanus* dominated, while the other groups and species became rare. *Pseudo/Paracalanus* consisted of both *Pseudocalanus* spp. and *Paracalanus parvus*.

Bay of Mecklenburg

The zooplankton in the Bay Mecklenburg (OMBMPM₂, OMBMPM₁) was characterized by a normally low overwintering stock ($5.7 - 8.1 \times 10^3$ ind. m^{-3}), but a high spring and summer abundance ($3.0 - 6.1 \times 10^4$ ind. m^{-3} , Fig. 35). Comparable to Kiel Bay, this is owed to the strong development of the copepod stock during spring, while other groups remained below the average. The spring increase appears generally retarded in comparison to the preceding years.

This is related to the late occurrence of rotifers. While this group was very abundant already in March in 2015-2016 ($1.0 - 1.4 \times 10^4$ ind. m^{-3}), numbers of $0.5-1.4 \times 10^4$ ind. m^{-3} were observed only in May 2017. In addition, the contribution of meroplankton – in particular that of bivalve larvae during summer – to the zooplankton was rather minor in 2017.

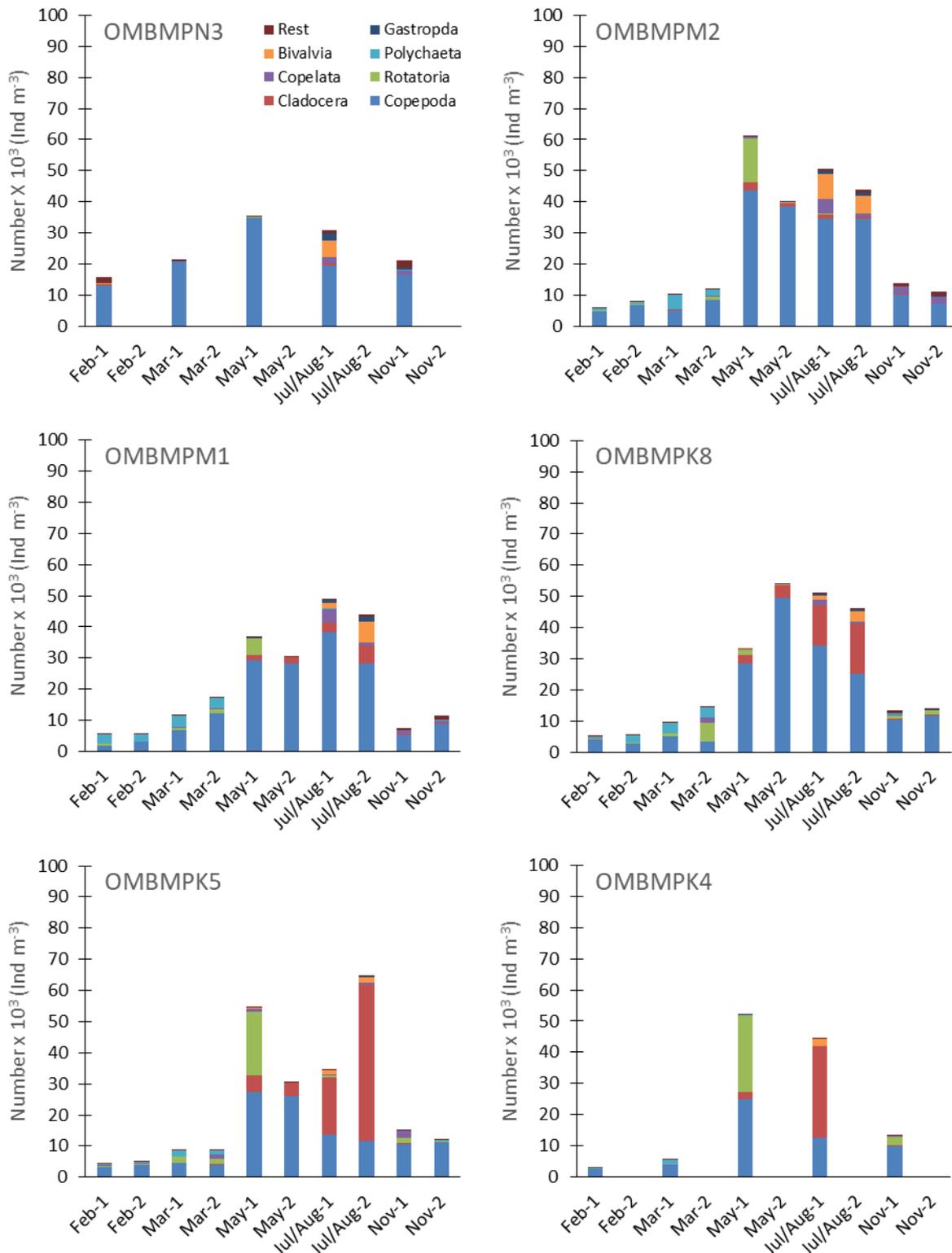


Fig. 35: Seasonal variation of the main taxonomic groups of the mesozooplankton at different stations in the investigation area in 2017.

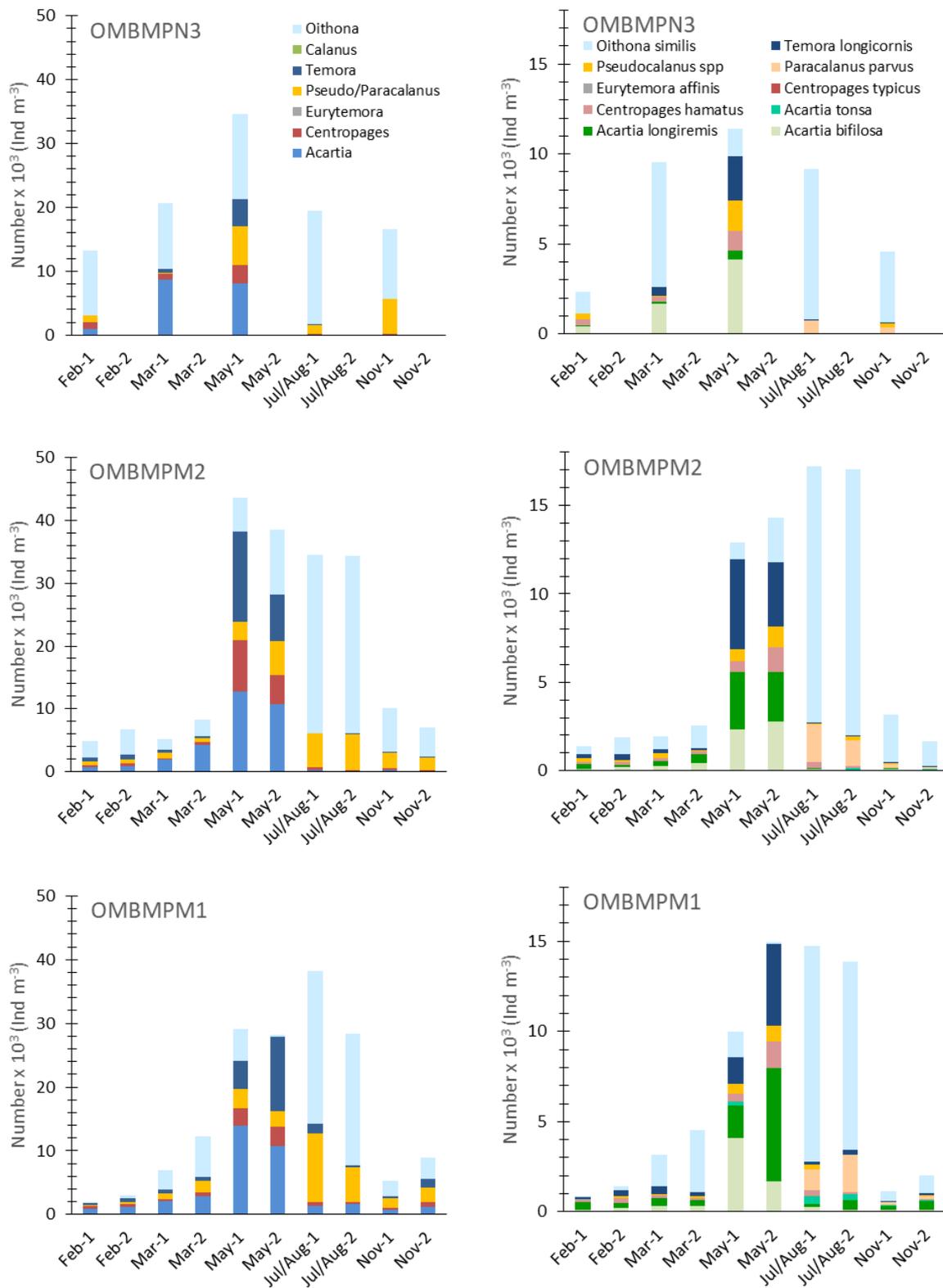


Fig. 36: Seasonal variation of the abundance and composition of juvenile (left) and adult stages of copepods (right) of different genera in 2017. Note the different scale in the abundance of juveniles and adults.

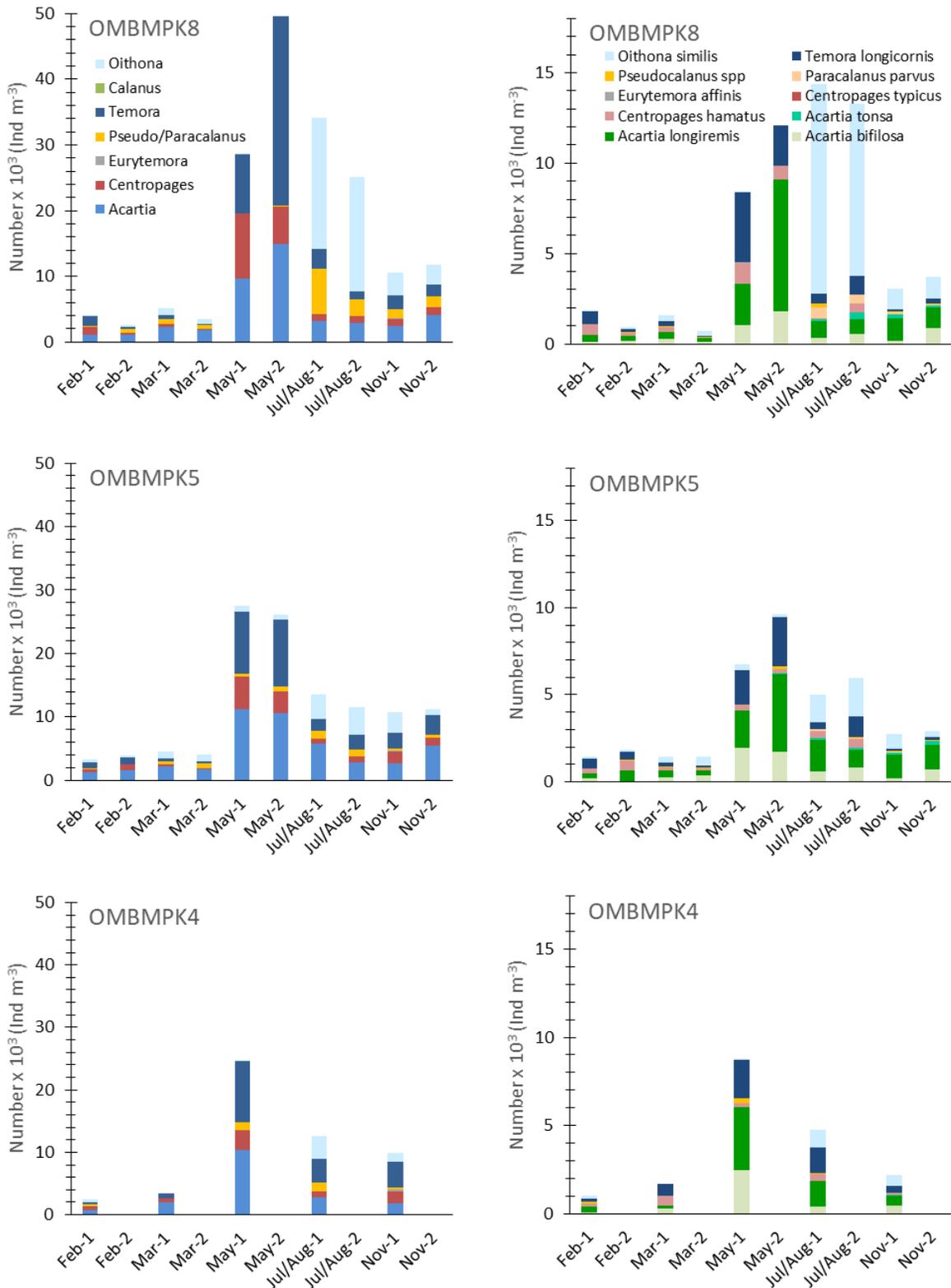


Fig. 36: continued

The overwintering stock consisted mainly of copepods together with meroplanktonic polychaetes, rotifers and cladocera, which show little change in February-March except rising numbers of the polychaete larvae to their maximum in March ($2.0 - 4.5 \times 10^3 \text{ ind. m}^{-3}$, Figs. 34, 35). The major increase of the zooplankton took place in May with a rise in the numbers of

copepods ($2.8 - 4.3 \times 10^4$ ind. m^{-3}) and rotifers ($0.5 - 1.4 \times 10^4$ ind. m^{-3}). *Synchaeta* spp. was the major species among the rotifers, while cladocera ($1.1 - 2.4 \times 10^3$ ind. m^{-3}) were dominated by *Evadne nordmanni* and *Podon leuckartii* which are typically for the area during spring. The zooplankton stock remained high during summer ($4.3 - 5.0 \times 10^4$ ind. m^{-3}) with copepods being still the most important group ($2.8 - 3.4 \times 10^4$ ind. m^{-3}). Meroplanktonic larvae of bivalves and gastropods ($1.0 - 7.8 \times 10^3$ ind. m^{-3}) and appendicularian *Oikopleura dioica* ($0.8 - 4.7 \times 10^3$ ind. m^{-3}) were frequently observed, while the rotifers and cladocerans became rare. The autumn stock consisted of copepods ($0.5 - 1.0 \times 10^4$ ind. m^{-3}) and the appendicularian *Oikopleura* ($1.1 - 2.4 \times 10^3$ ind. m^{-3}).

The stocks of the copepods were considerably larger than in previous years, particularly during the spring-summer period (March-August, Fig. 36). Typically all major genera contributed in varying proportions to the stocks during the year. In 2017, however, a stronger temporal separation was observed with a diverse composition during the spring and a dominance of *Pseudo/Paracalanus* and *Oithona* during the second half of the year. The low overwintering stocks were dominated by *Acartia* and *Oithona* ($8.8 - 4.1 \times 10^3$ ind. m^{-3}), while other groups were rare. The major increase in stock size was typically observed in May. Dominant genera were *Acartia* ($1.1 - 1.4 \times 10^4$ ind. m^{-3}) and *Temora* ($0.2 - 1.4 \times 10^4$ ind. m^{-3}) followed by *Centropages* ($0.3 - 0.8 \times 10^4$ ind. m^{-3}) and *Pseudo/Paracalanus* ($0.2 - 0.6 \times 10^4$ ind. m^{-3}). The high concentration of *Acartia* in spring is not unusual for the area. Both *A. bifilosa* and *A. longiremis* contributed equally to the stock of adults (Fig. 36). In contrast, the stocks of *Temora*, represented by the single species *T. longicornis*, were unusually high in 2017. Similarly, the concentrations of *Pseudo/Paracalanus* were higher in comparison to preceding years. This might indicate a recovery in the stock, with *Pseudocalanus* spp. as the major genus. In summer, *Temora*, *Acartia* and *Centropages* ($0.2 - 1.7 \times 10^3$ ind. m^{-3}) were outnumbered by *Oithona* ($2.1 - 2.8 \times 10^4$ ind. m^{-3}) and *Pseudo/Paracalanus* ($0.2 - 1.1 \times 10^4$ ind. m^{-3}). *Paracalanus parvus* was dominating the stocks of the latter group.

Arkona Basin

The recovery of the zooplankton stocks following the historical low values during 2015-2016 observed in the Kiel Bay and the Bay of Mecklenburg was also visible in the Arkona Basin (OMBMPK8, OMBMPK5, OMBMPK4, Figs. 34, 35, 36). Nevertheless, based on the long-term record, this increase was rather moderate due to the lack of a mass occurrence of cladocera. These were recorded for the last time in 2014 with more than 10^5 ind. m^{-3} . The stocks of the copepods, in contrast, were significantly enhanced (max. $2.5 - 4.9 \times 10^4$ ind. m^{-3}) compared to 2015-2016 (max. $0.2 - 2.2 \times 10^4$ ind. m^{-3}). As in the other areas, the abundance of meroplankton (Fig. 34) and in particular bivalve larvae during summer was low in 2017 (Fig. 35). The zooplankton composition at station OMBMPK8 reflected a transition featuring a high abundance of *Oithona*, the presence of *Oikopleura* and the lack of large concentrations of rotifers in the Bay of Mecklenburg as well as the high abundance of *Acartia*, *Temora* and *Fritellaria* characteristic for the more eastern stations of the Arkona Basin. The meroplankton abundance was rather low in 2017.

The low overwintering stock was dominated by copepods ($2.5 - 5.1 \times 10^3$ ind. m^{-3}), appendicularia ($0.1 - 1.6 \times 10^3$ ind. m^{-3}) and rotifers ($0.4 - 0.5 \times 10^3$ ind. m^{-3}). In March polychaete larvae ($1.1 - 3.1 \times 10^3$ ind. m^{-3}) and rotifers ($0.8 - 6.0 \times 10^3$ ind. m^{-3}) increased. Similar to the Bay of Mecklenburg, the spring increase in the zooplankton occurred rather late

in May (Figs. 34, 35). Again, this is largely caused by the late occurrence of rotifers (*Synchaeta* spp., $2.0 - 6.0 \times 10^4$ ind. m^{-3}). Copepods were abundant as well, particularly in the westernmost station OMBMPK8 ($2.4 - 4.9 \times 10^4$ ind. m^{-3}). The cladocerans *Evadne nordmanni* and *Podon leuckartii* as well as the appendicularian *Oikopleura dioica* had a low contribution. In summer, the stocks of the cladocerans dominated. *Bosmina* spp. was the major genus and achieved $1.2 - 4.8 \times 10^4$ ind. m^{-3} , which is a moderate concentration for the species. *E. nordmanni* and *Podon intermedius* occurred in lower numbers ($0.5 - 2.1 \times 10^3$ ind. m^{-3}). The copepod concentration remained high ($1.2 - 3.4 \times 10^4$ ind. m^{-3}) and the appendicularian *Fritellaria borealis* replaced *Oikopleura* ($0.4 - 1.4 \times 10^3$ ind. m^{-3}). Both groups remained abundant until November.

Acartia and *Temora* dominated the overwintering stock of copepods ($0.5 - 2.1 \times 10^3$ ind. m^{-3}), while *Centropages* and *Pseudo/Paracalanus* occurred in lower numbers (Fig. 36). The spring increase was mainly caused by very high abundance of the genus *Acartia*, *Centropages* and *Temora* ($0.5 - 1.5 \times 10^4$ ind. m^{-3}). *A. longiremis* was more abundant ($2.1 - 7.3 \times 10^3$ ind. m^{-3}) than *Acartia bifilosa* ($1.1 - 1.9 \times 10^4$ ind. m^{-3}) among the adult copepods. *T. longicornis* and *C. hamatus* were abundant as well ($0.7 - 2.8 \times 10^3$ ind. m^{-3}). In contrast to Kiel Bight and the Bay of Mecklenburg, *Pseudocalanus* spp. was rare (< 200 ind. m^{-3}) and did apparently not recover. *Acartia* (*A. longiremis*) and *Temora* (*T. longicornis*) together with *Pseudo/Paracalanus* were major contributors to the summer/autumn copepod community ($1.8 - 5.6 \times 10^3$ ind. m^{-3}). In the westernmost station, *Oithona*, however, outnumbered these groups ($0.4 - 2.0 \times 10^4$ ind. m^{-3}).

4.2.3 Long-term trend

Despite the reversal in the trend of a decreasing abundance in the long-term development of the zooplankton since the 2000's, the stock size of zooplankton is still low. Based on the maximal seasonal abundance, the concentration of 1.24×10^5 ind. m^{-3} in 2017 has doubled in comparison to 2016 (Fig. 37 a). However, this represents only one third of the mean abundance of 3.77×10^5 ind. m^{-3} recorded in the years 2000-2010. Particularly, the concentrations of rotifers and cladocera remain very low (2.4 and 5.1×10^4 ind. m^{-3}). The increase in 2017 compared to 2016 is largely based on the cladocera, cyclopoid copepod, calanoid copepods and gastropod larvae, which increased in abundance by a factor of 8.4, 4.7, 2.3 and 2.1, respectively. A decrease was recorded in the abundance of appendicularia and bivalve larvae. Caution needs to be taken in the interpretation of the changes, because changes in timing and in abundance cannot be fully assessed with the frequency in sampling. As indicated by the long-term variation in the species abundance and composition of adult calanoid copepods, there was a moderate, overall increase in the abundance of most species (Fig. 37 b) resulting in an increase in stock size by 25% in comparison to 2016. There was a disproportional increase particularly in the stock of *Acartia longiremis*, *Temora longicornis* and *Pseudocalanus* spp. In contrast, *A. tonsa* was rare.

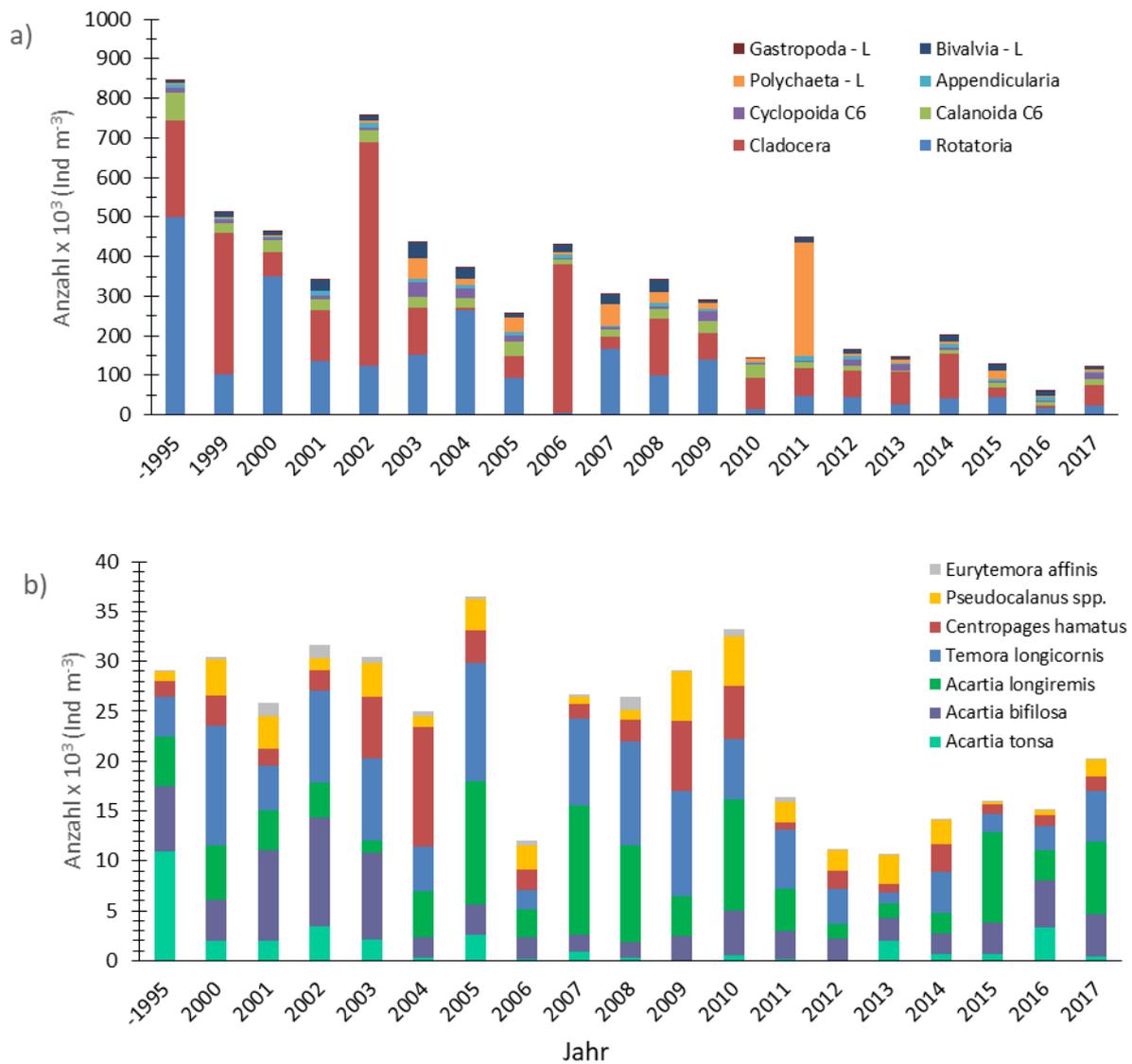


Fig. 37: Long-term trends in the maximal abundance of a) holoplanktonic taxa (Rotatoria, Cladocera, Cyclopoida, Calanoida, Copelata) and meroplanktonic taxa (Polychaeta, Bivalvia, Gastropoda) and b) of seven calanoid copepod species in the years 1995 to 2017.

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 station almost the whole year a good oxygen supply was observed. Only in the Arkona Basin the oxygen content was slightly lower than 2 ml/l during few summer weeks.

For almost all stations the salinity ranged in an average value. The autumn bottom water salinity ranged from west to east between 18.7 and 7.9 psu (Table 2). The long term development of the minimum and maximum salinity in near bottom waters at the station OMBMPK₄ in the Arkona Basin is shown in Figure 38. The maximum values are here higher as the median (see blue line).

Table 7

Abiotic parameters at 8 monitoring stations in autumn 2017 (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
OMBMPN ₃	1.65	229	6.8	18.7	fine to middle sand
OMBMPN ₁	2.72	30	6.7	18.1	muddy sand
OMBMPM ₂	9.16	19	6.9	16.6	mud
OM18	1.56	65	7.2	15.4	muddy sand
OMBMPK ₈	0.26	233	6.6	12.8	fine sand
OMBMPK ₄	11.50	15	4.6	17.9	mud
OMBMPK ₃	0.26	176	7.4	7.9	fine sand with marl
OM160	0.24	186	7.5	8.3	fine sand

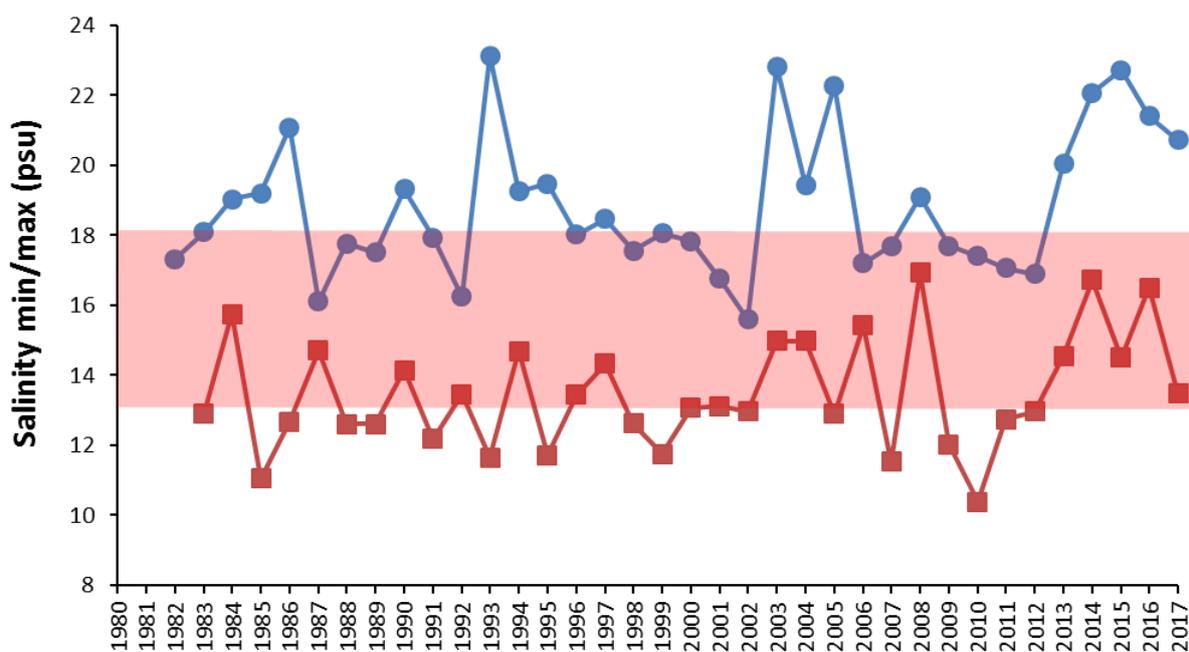


Fig. 38: Long-term development of the bottom water salinity in the Arkona Basin (OMBMPK₄) from 1980 to 2017 (5-10 measurements per year). The red line indicates the lowest and the blue line the highest value per year, respectively. The shaded range shows the long-term median of the lowest and highest values.

Regarding the oxygen content only in the Arkona Basin the values dropped down below 2 ml/l along the year (summer) (Fig. 39). With 1.47 ml/l the lowest value were observed in the summer.

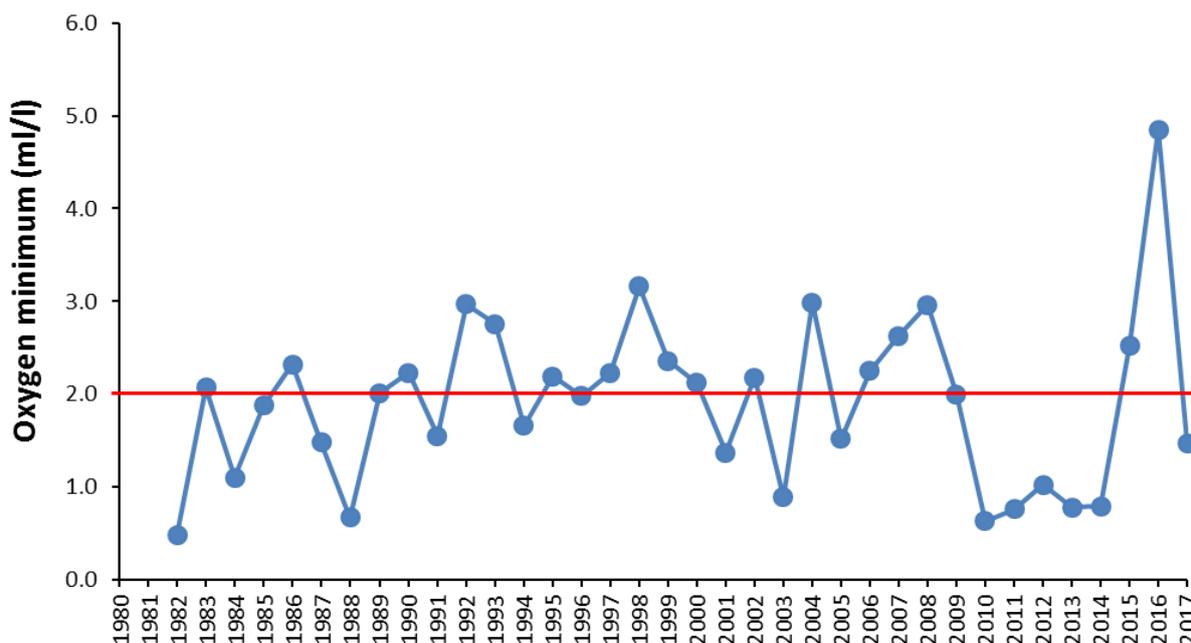


Fig. 39: Long-term development of the bottom water oxygen content in the Arkona Basin (OMBMPK₄) from 1980 to 2017 (5-10 measurements per year). The blue line indicates the lowest value per year and the red line the median value of the lowest oxygen content in all years, respectively.

4.3.2 Macrozoobenthos at the Stations

In November 2017, 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). Compared with the period 1991 to 2017, the number of species was high at 142 (Table A4, Fig. 40 and 43). Whereas the species number in the Kiel Bay (OMBMPN₃) decreased from 83 to 63 clearly within one year, the number at station Fehmarnbelt (OMBMPN₁) increased significantly from 12 to 71. Thereby the species diversity in the Fehmarnbelt area was much higher than the long-term median value. Compared with their long-term averages six stations show similar or even higher species richness than in the years before.

At station OMBMN₃ in the Kiel Bay the decrease in the number of species was obvious: 63 taxa were identified there, less than the long-term median. Nevertheless, some species were noticed for the first time within the last 12 years (and longer). For example the polychaete *Phyllodoce rosea* was found for the first time in the Kiel Bay and is probably a relict of the last saltwater inflow three years before. Another “new” species was for instance the shrimp *Pandalina brevisrostris*. Altogether 3 species were recorded for the first time at this station.

The diversity of the Fehmarn Belt area was completely different and has significantly increased in comparison to the previous years (Fig. 40). Both the species number and the abundance (see later) are affected. 8 “new” species were observed at this station for the first time, e.g. the polychaete *Poecilochaetus serpens* and the shrimp *Eualus pusiolus*. The high benthic diversity seems to be attracting also benthivorous fishes (Fig. 41).

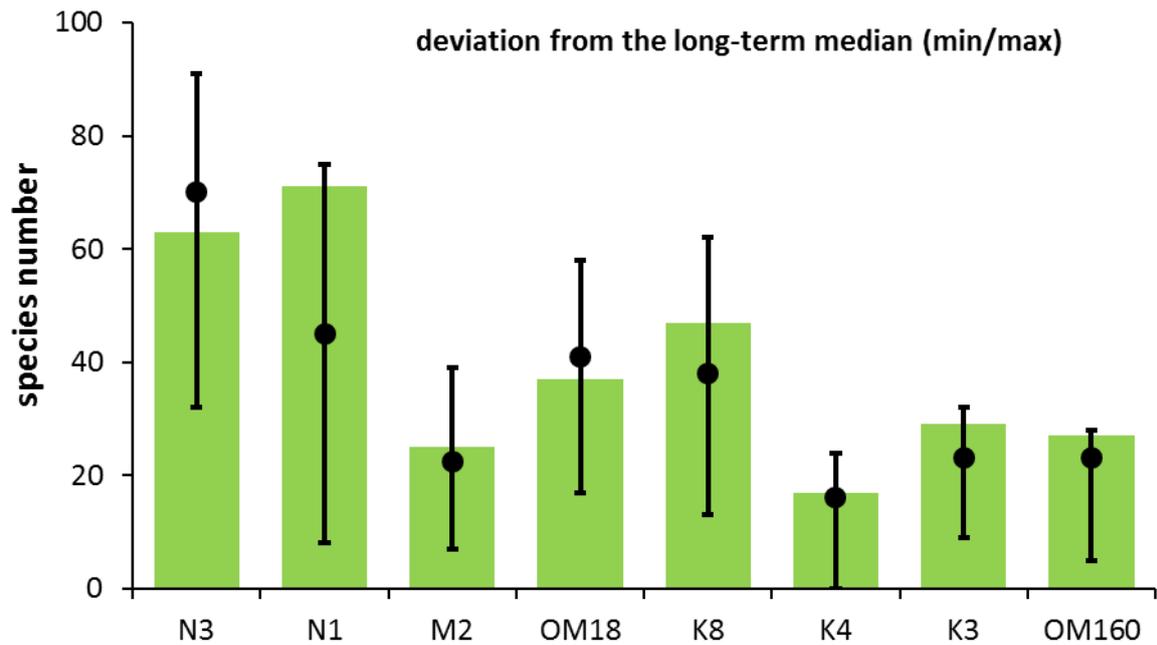


Fig. 40: Number of species (columns) of macrozoobenthos at 8 monitoring stations in November 2017. The median values of the years 1991 to 2017 are shown as dots; the minimum and maximum values are indicated as interval. The stations are plotted from west to east (Kiel Bay = OMBMPN₃ to Pomeranian Bay = OM160).



Fig. 41: *Arctica islandica* and some flatfishes (*Platichthys flesus*) were caught by the dredge in the Fehmarn Belt area.



Fig. 42: The dredge sample of the Darss Sill (OMBMPK8) was dominated by the blue mussel (*Mytilus edulis*) and red algae (*Delesseria sanguinea*), in the middle *Carcinus maenas*.

At the Darss Sill (OMBMPK8) with 47 species the diversity was in the mean in comparison to the last 20 years. Five species were recorded for the first time there. For instance the mysid species *Mesopodopsis slabberi*, normally occurring in nearshore areas and not expected for these deep offshore waters, was found. Additionally the gastropods *Pusillina inconspicua* and *Rissoa membranacea* could be detected. The epibenthic dredge sample was dominated by the blue mussel (*Mytilus edulis*). Between the red algae *Delesseria sanguinea* some green crabs *Carcinus maenas* were observed (Fig. 42).

Figure 43 gives the taxa found at our 8 monitoring stations in 2017 as well as the total number of species found in measurements since 1991. Not just in 2017 (see ZETTLER et al. 2014, 2018), the Annelida (Polychaeta and Oligochaeta) emerged as the group that is richest in species, numbering 103; in 2017, 48 species were identified. Other species-rich groups in 2017 were Mollusca (27), Crustacea (33), Cnidaria (5) and Bryozoa (10).

Depending on the sea area, abundances varied between 242 (Arkona Basin) and 8.790 ind./m² (Pomeranian Bay) (Fig. 44, Table A4). Only in the Fehmarnbelt area (OMBMPN₁) and slightly at the Darss Sill (OMBMPK₈) the abundance was increased compared with previous years (Fig. 44). At all other stations the abundance was lower than or similar to the median values of the last 12 years; the decrease was most obvious in the northern Pomeranian Bay (OMBMPK₃).

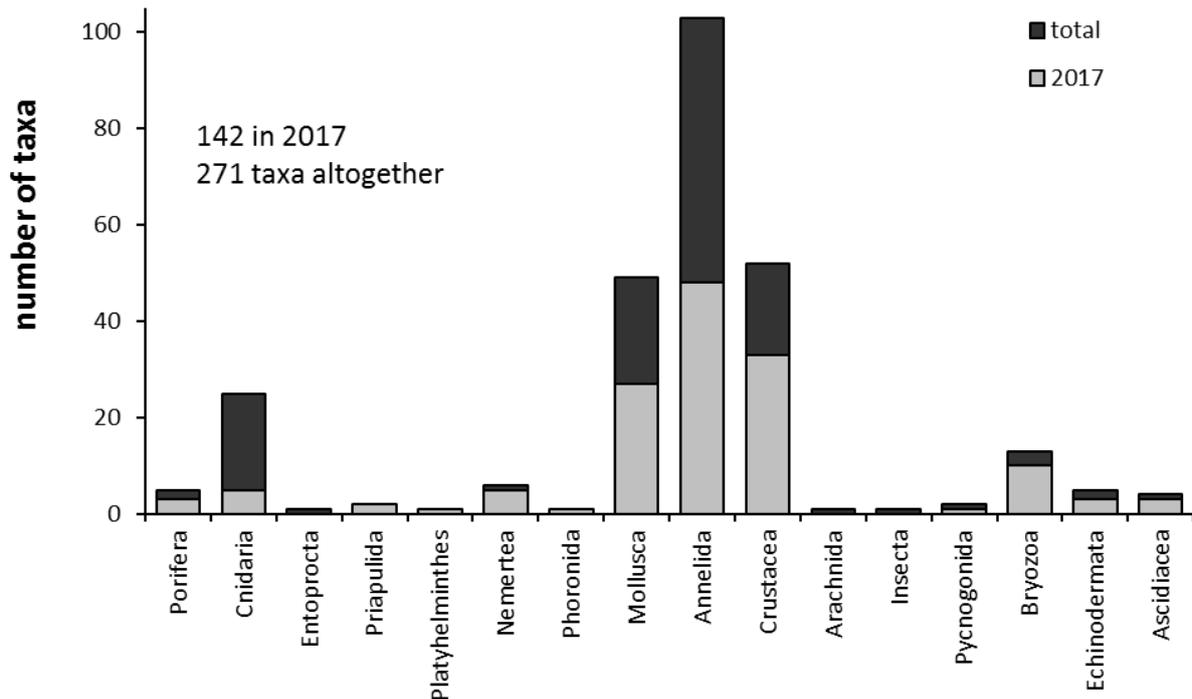


Fig. 43: Taxonomical classification of macrozoobenthos at 8 monitoring stations in November 2017. The species number of the entire monitoring from 1991 to 2017 is also indicated.

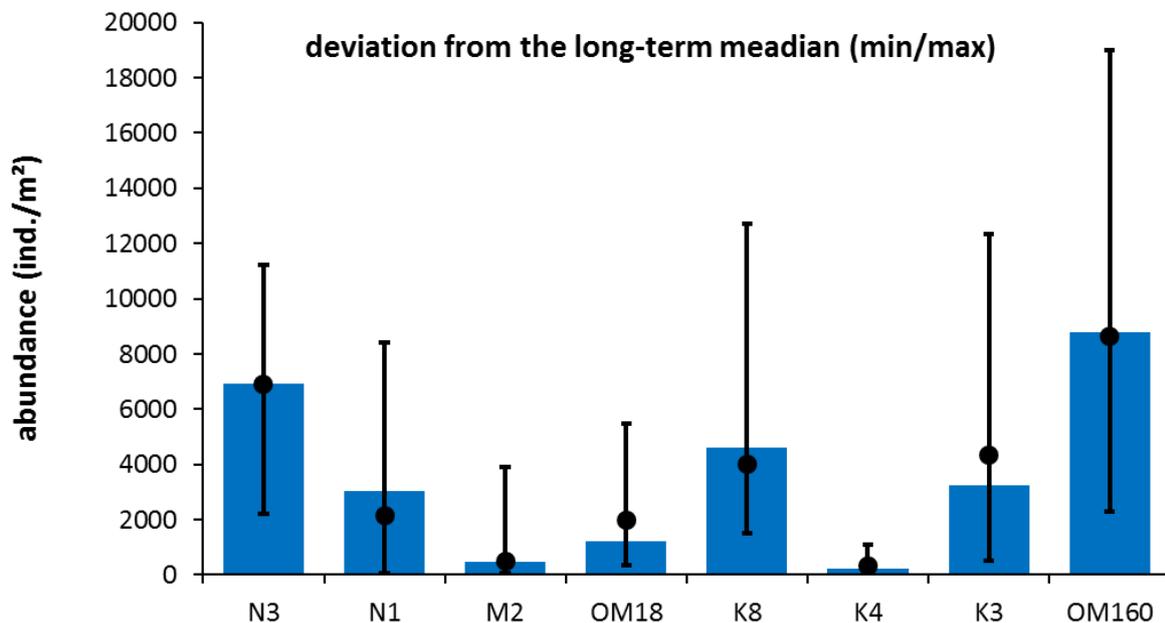


Fig. 44: Total abundances (columns) of macrozoobenthos at 8 monitoring stations in November 2017. The median values of the years 1991 to 2017 are shown as dots; the minimum and maximum values are indicated as interval.

Which species was dominant in a given sea area varied greatly; it depended essentially on salinity and substrate. While the molluscs *Corbula gibba* and *Kurtiella bidentata* accounted for over 50 % of density in Kiel Bay (OMBMPN₃) and *Mytilus edulis* dominated the abundance in the southern Mecklenburg Bight (OMo18), the Darss Sill (OMBMPK₈) and the Arkona Basin (OMBMPK₄), in the Pomeranian Bay (OM160) the mud snail *Peringia ulvae* and the bivalves

Cerastoderma glaucum and *Mya arenaria* accounted for high abundance. However, epibenthic structures sampled by the dredge were mainly consisting of blue mussels (*Mytilus* sp.) (Fig. 45). At the central Bay of Mecklenburg (OMBPM2) the spionid *Dipolydora quadrilobata* and the bivalves *Arctica islandica* and *Mytilus edulis* dominated the community. The orbinid *Scoloplos armiger* and the polychaete *Lagis koreni* reached more than 40% of the abundance of the station in the Fehmarnbelt area (OMBMPN1). In the northern Pomeranian Bay (OMBMPK3) the spionid *Pygospio elegans* (75%) dominated the community.

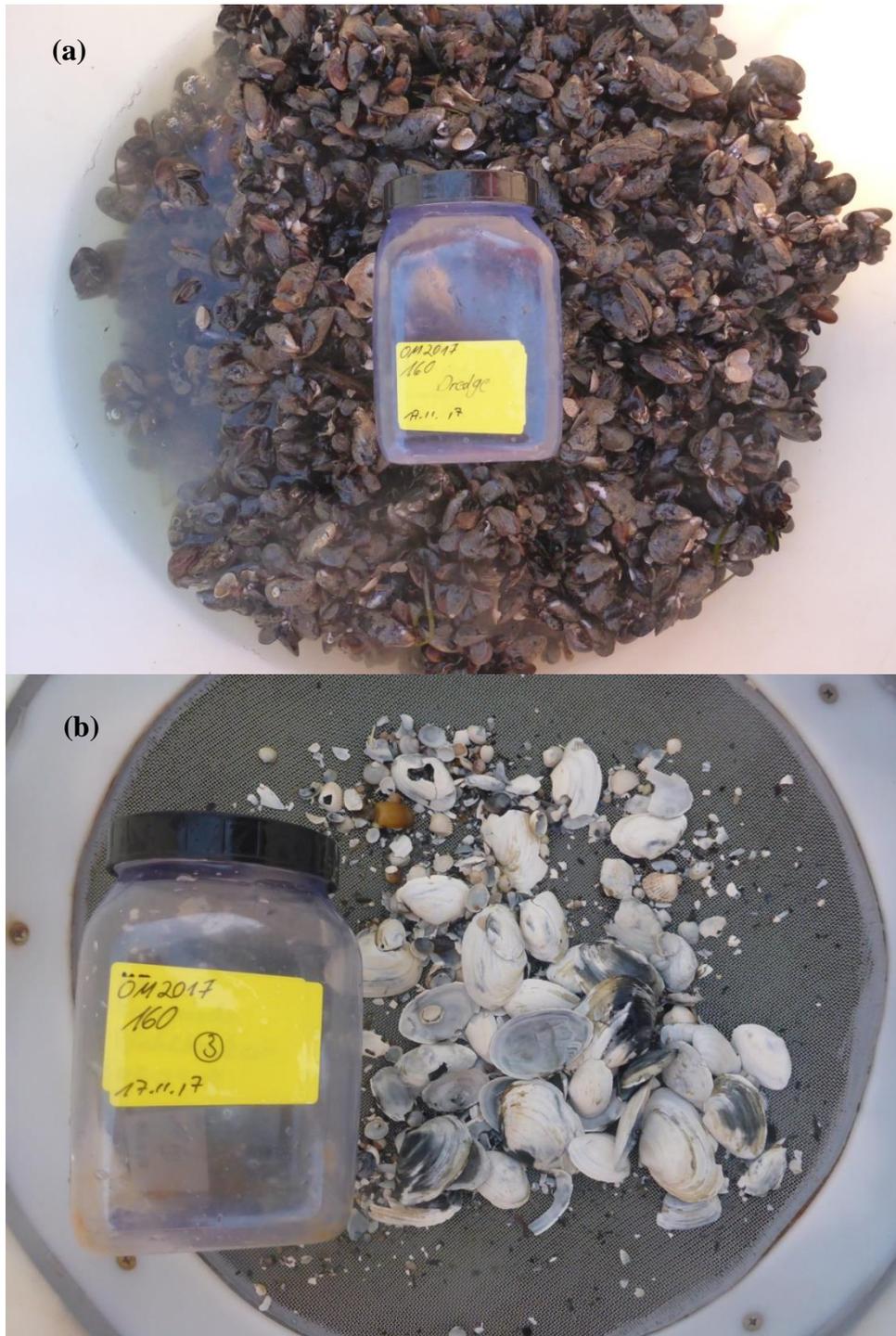


Fig. 45: In 2017 dominant epibenthic species in the Pomeranian Bay (OM160) were *Mytilus edulis* and *Crangon crangon* (a), whereas the endobenthic samples consisted mainly of *Mya arenaria*, *Cerastoderma glaucum* and *Peringia ulvae* (b).

The highest biomass was observed at the Kiel Bay station (OMBMPN₃) (Fig. 46). 59.2 g afdw/m² was measured, consisting of 49 % *Astarte borealis* (28.9 g afdw/m²) and 38 % *Arctica islandica* (22.3 g afdw/m²). In addition, dredge catches yielded echinoderms (*Asterias rubens*, *Ophiura albida*) and shrimps (*Crangon crangon*, *Pandalina brevirostris*) that were certainly under-represented in the quantitative grab samples. At stations in the Fehmarnbelt and Bay of Mecklenburg the biomass was rather high; this is almost explainable with the dominance and patchy distribution of heavy adults of the ocean quahog. At Fehmarnbelt (OMBMPN₁) and in Bay of Mecklenburg (OMBMPM₂), *Arctica islandica* contributed as much as 90 % to biomass (Fig. 47); total values between 15 and 18 g AFDM/m² were obtained there. At Darss Sill (OMBMPK₈), biomass (12.3 g AFDM/m²) was dominated by the bivalve *Astarte borealis* (70 %) and the polychaete *Travisia forbesi* (20 %). In the Arkona Basin, (OMBMPK₄), *Limecola balthica* accounted for 93 % of the total biomass (2.3 g afdw/m²). In the north of the Pomeranian Bay (OMBMPK₃), 1.4 g of total biomass was measured, made up of 39 % *Limecola balthica*, 21 % *Marenzelleria viridis* and 15 % *Pygospio elegans*. Further east in the central Pomeranian Bay (OM160; 17.2 g afdw/m²) *Mya arenaria* (64 %), *Cerastoderma glaucum* (14 %) and *Limecola balthica* (9 %) were prominent.

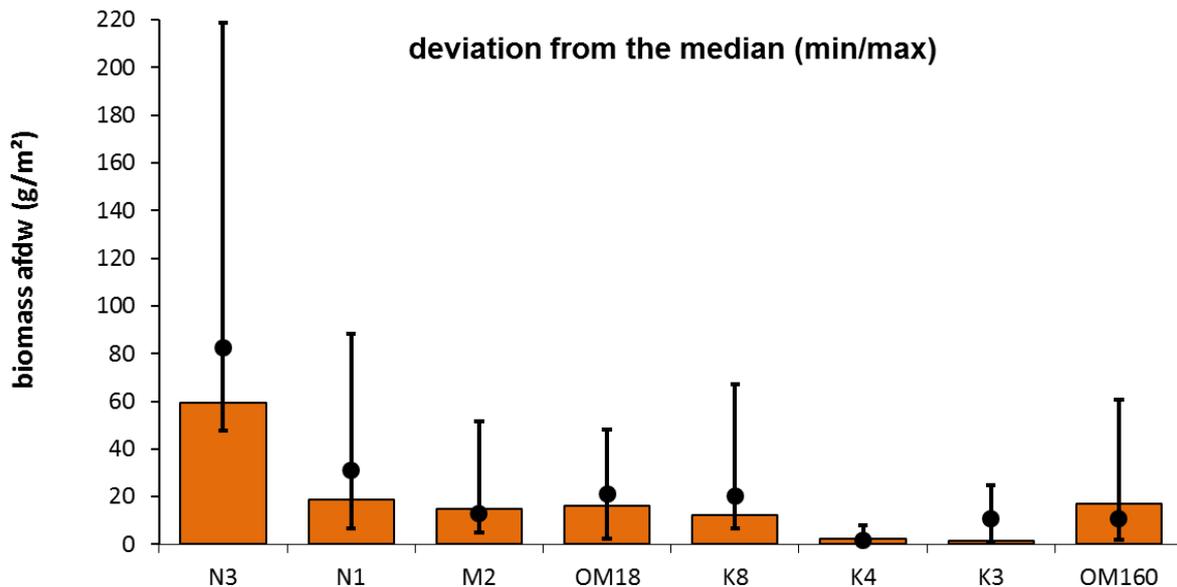


Fig. 46: Total biomasses (columns) of macrozoobenthos at 8 monitoring stations in November 2017. The median values of the years 1991 to 2017 are shown as dot and the minimum and maximum values are indicated as interval.

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. 44 and 46. 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, although and because it was not an objectivity of the present study.



Fig. 47: In the Bay of Mecklenburg (OMBM018), the ocean quahog (*Arctica islandica*) dominated the dredge sample.

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 12 years only (2006 to 2017). Eight stations were sampled every autumn using three grab samples and one dredge. Stations are thus assessed on an identical basis. Figure 48 shows the relative number of species (see previous reports, e.g. WASMUND et al. 2017a, and Table A4 in the Annex 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). The reasons for this decline are not well recognized yet. The oxygen conditions around the year 2016 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 2017 the diversity (species number) is even at the station in the Fehmarnbelt area in a range of the “normal

condition” and showed with 71 species the second highest diversity during the last 12 years. In the Kiel Bay (OMBMPN₃) the species number (63) was as low as in 2008 and indicated a clear decrease in comparison to the previous years.

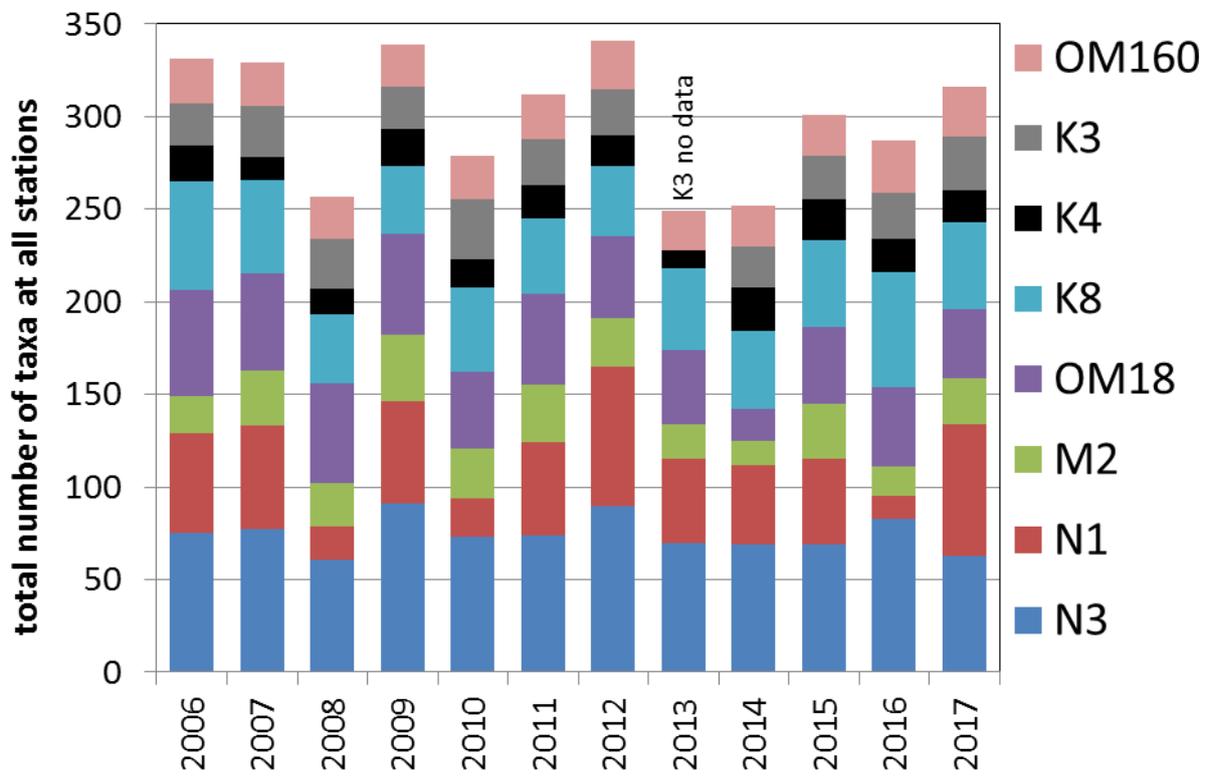


Fig. 48: Cumulative number of taxa of macrozoobenthos at 8 monitoring stations from 2006 to 2017. The stations are arranged within the columns from west to east (Kiel Bay = OMBMPN₃ to Pomeranian Bay = OM160).

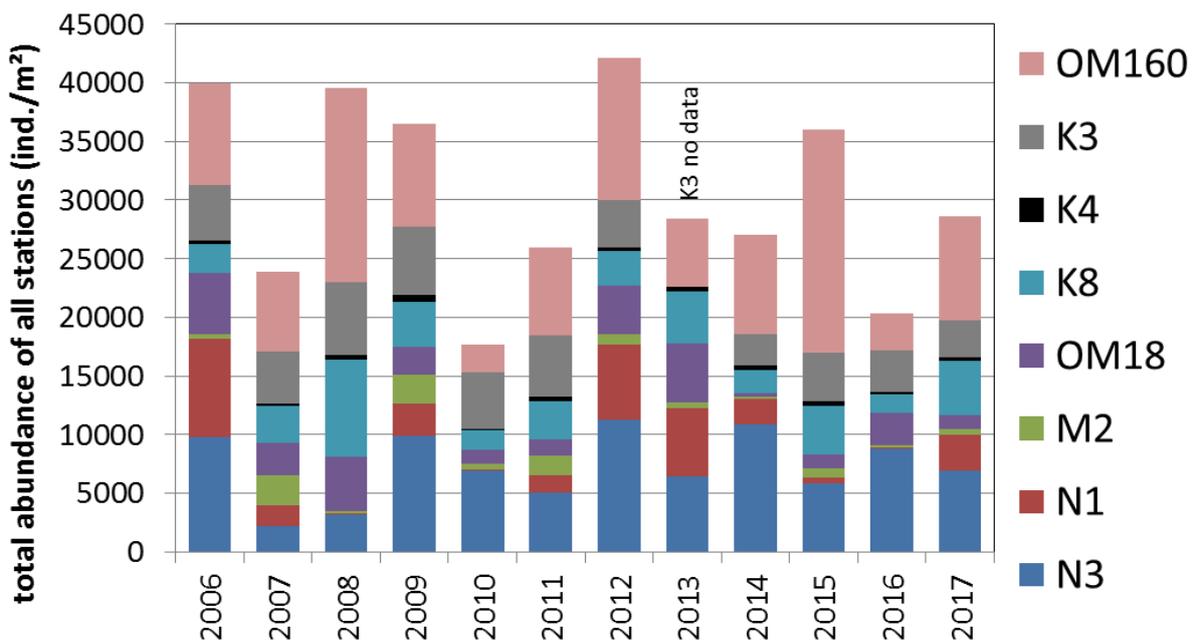


Fig. 49: Cumulative abundance of macrozoobenthos at 8 monitoring stations from 2006 to 2017. The stations are arranged within the columns from west to east (Kiel Bay = OMBMPN₃ to Pomeranian Bay = OM160).

In terms of abundance, the situation is very different (Fig. 49). Only the western and eastern most stations (Kiel Bay, OMBMPN₃ and Pomeranian Bay, OM160) were 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.

Figure 50 illustrates the long-term trend in biomass. Firstly, it is obvious the greatest values were observed in the west (Kiel Bay = OMBMPN₃) followed by the Bay of Mecklenburg (OMBMPM₂, OM18) and Fehmarnbelt (OMBMPN₁) and secondly it is obvious that biomass is not as strongly influenced as species numbers or abundance. Nevertheless, we can observe a clear decline during the last few years. If this trend is significant cannot be answered so far. Also the reasons for this decrease can only be speculated. For any reason the large bivalves seem to be reduced in abundances (and therefore biomass) since few years. Similarly, variations can be significant, although at no point did we observe the sharp decline in biomass that we saw in species numbers and abundance due to oxygen deficiency at Fehmarnbelt (OMBMPN₁) 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 2017 was relatively low; the lowest value for all monitoring stations together since 2006.

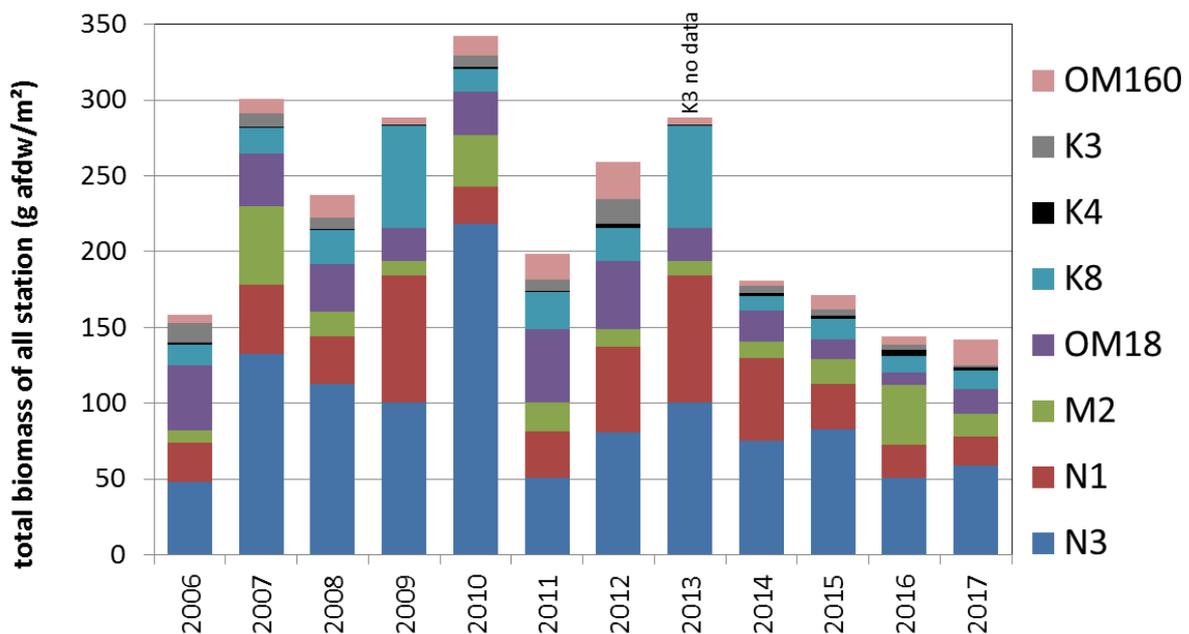


Fig. 50: Cumulative biomass of macrozoobenthos at 8 monitoring stations from 2006 to 2017. The stations are arranged within the columns from west to east (Kiel Bay = OMBMPN₃ to Pomeranian Bay = OM160).

The decline of biomass in the Fehmarnbelt is mainly caused by the strong decline of larger bivalves as *Arctica islandica*. Whereas between 2012 and 2014 the biomass of the ocean quahog reached values between 50 and 80 g/m² afdw, the values in 2016 and 2017 ranged between 16 and 20 g/m². About the reasons we can only speculate, maybe fishery pressure or an unknown shellfish disease are responsible.

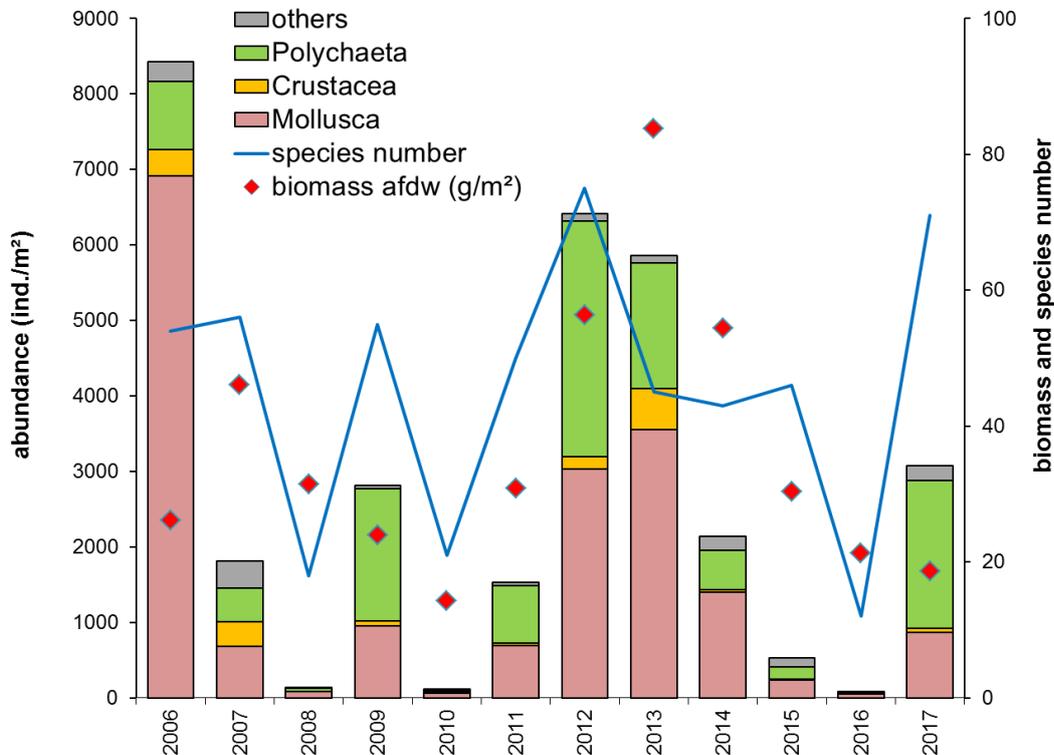


Fig. 51: The development of the abundance, biomass and species number at the monitoring station in Fehmarnbelt (OMBMPN3) from 2006 to 2017.

As example for the long-term variation of the macrozoobenthos the development of population parameters at station OMBMPN3 are presented in figure 51. Within the time span of the last 12 years three main collapses are obvious. In 2008, 2010 and 2016 the abundance, the species number and to a least degree also the biomass (see above) 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 142 species, 16 are classed as threatened (1, 2, 3, G) (Fig. 52, Tab. 8). Six species are still classed as being near threatened. Two species are categorised as extremely rare. Currently, 81 species are classed as being of least concern. Data are deficient for 14 species, and 23 taxa on the Red List were not evaluated. The anthozoan *Halcampta duodecimcirrata* is critically endangered. It was detected in the Fehmarnbelt (OMBMPN1) in very low densities (3 ind./m²). Species that are classed as endangered (category 2) were found at the westernmost stations (OMBMPN3), including *Mya truncata* (blunt gaper). Additionally the sabellid *Euchone papillosa* was identified from the Fehmarnbelt. 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).

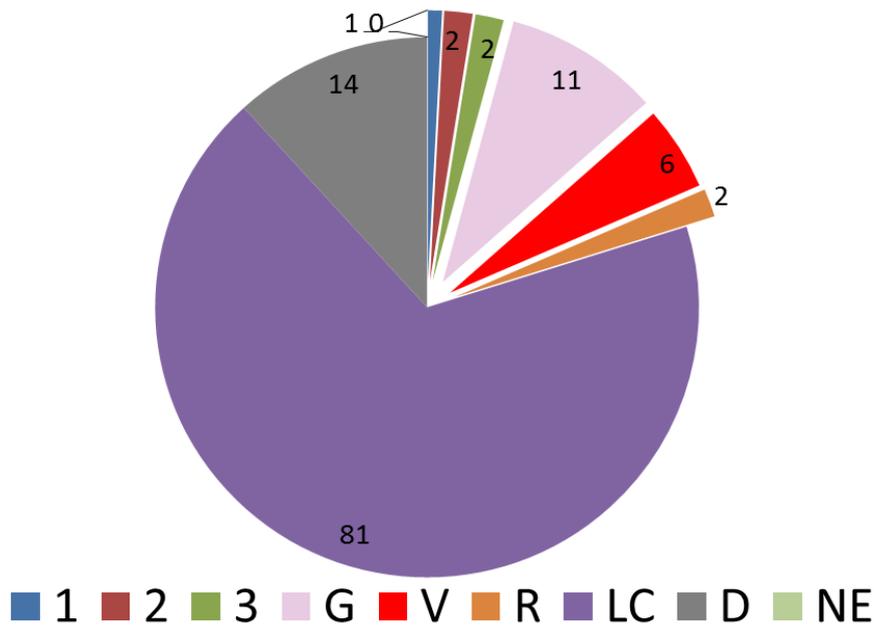


Fig. 52: Percentage of red list categories (RACHOR et al. 2013) in relation to macrozoobenthos in autumn 2016 (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, R=extremely rare, LC=least concern, D=data deficient, NE=not evaluated).

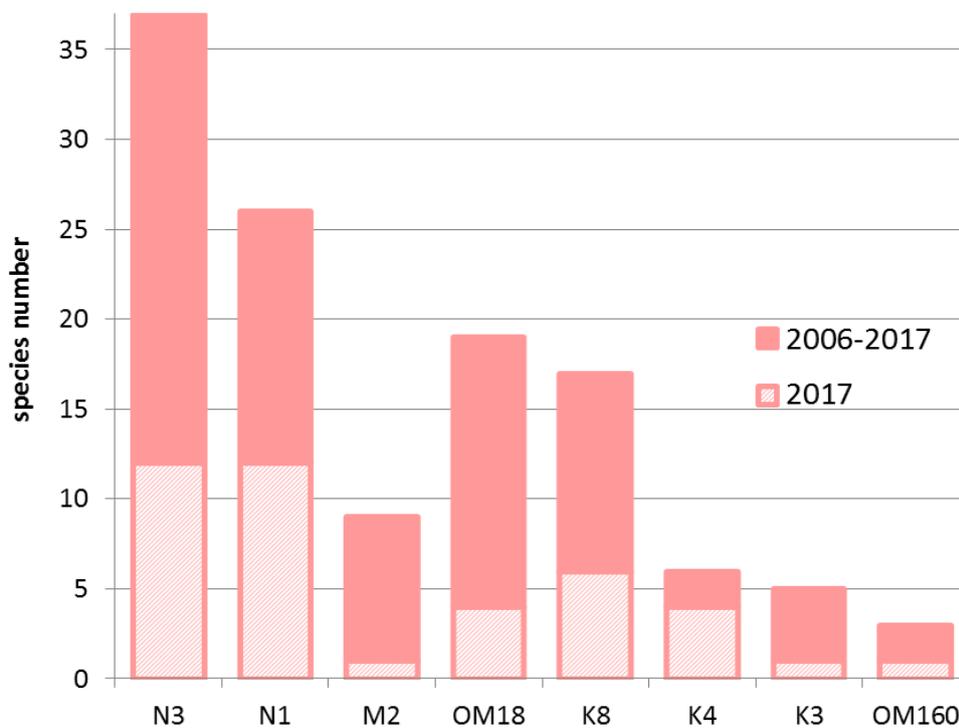


Fig. 53: Number of red listed species (categories 1, 2, 3, G, V and R) (RACHOR et al. 2013) at the 8 monitoring stations in 2017 and in total (2006-2017).

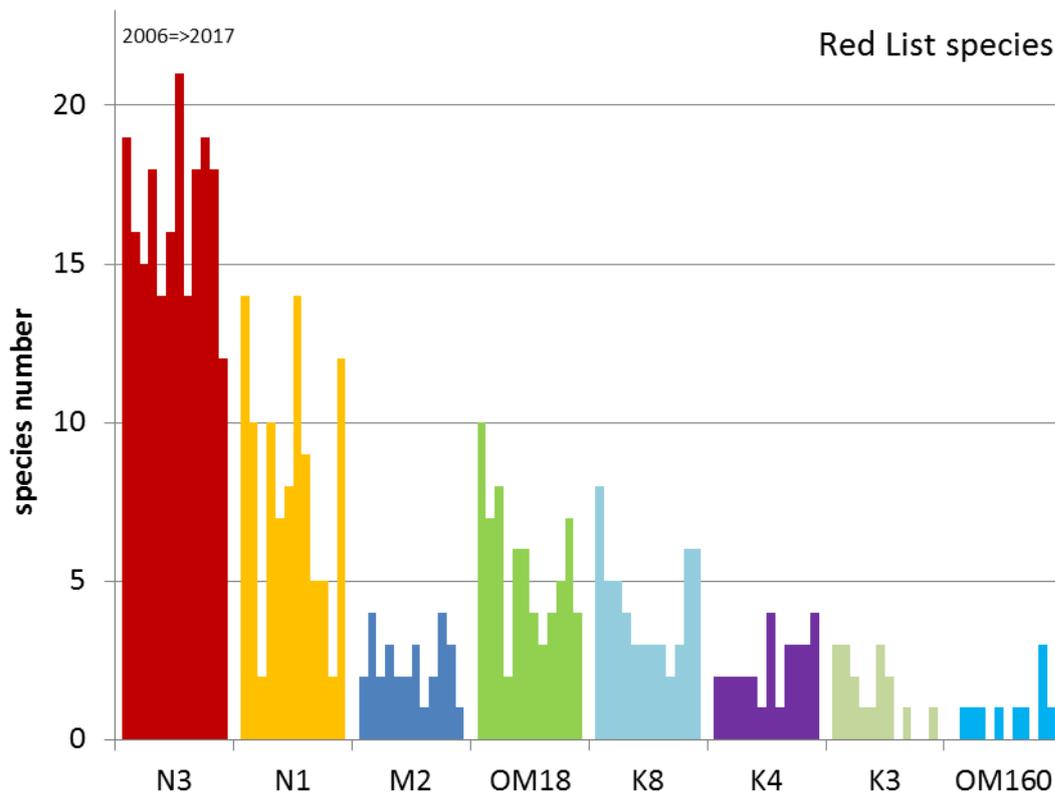


Fig. 54: Development of the number of red listed species (categories 1, 2, 3, G, V and R) (Rachor et al. 2013) at the 8 monitoring stations from 2006 to 2017

The 11 species observed in 2017 were distributed across almost all sea areas: 8 species in Kiel Bay (OMBMPN₃), 4 at the Fehmarnbelt (OMBMPN₁), 1 at southern Bay of Mecklenburg (OM18), 3 at the Darss Sill (OMBMPK₈), 2 in Arkona Basin (OMBMPK₄) and one in northern Pomeranian Bay (OMBMPK₃). 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: *Mya truncata* (blunt gaper) is classified as near threatened (NT).

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 (Fig. 53 and 54). The percentage of red listed species in 2017 in comparison to observations in the whole investigation time (2006 to 2017) ranges between 11 and 67 % (Fig. 53). Especially at the stations in the Kiel Bay (OMBMPN₃) and Bay of Mecklenburg (OMBMPM₂) the number was significantly lower than in the previous years (Fig. 54). The strong salinity gradient and its effect on the distribution of red listed marine species are clearly visible in figure 55. Both the number of records and the species number decrease with decreasing salinities from west to east. The consistency of records of red listed species per station varies as well (see table 8).

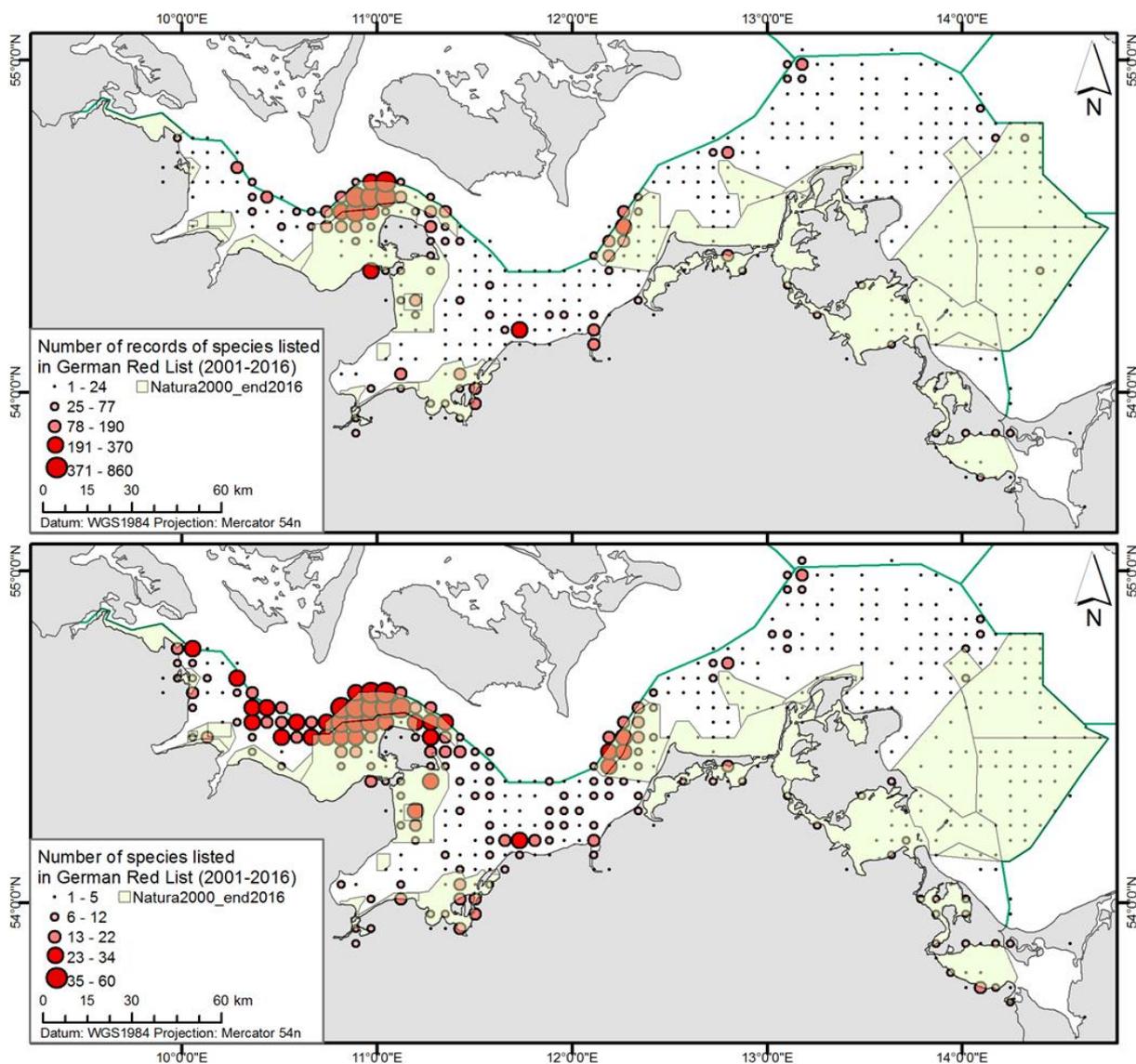


Fig. 55: Red listed species (categories 1, 2, 3, G, V and R by Rachor et al. 2013) in German Baltic Sea waters between 2001 and 2016: a) number of records (above) and b) number of species (below).

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 2017. The observations of 2017 are indicated as grey boxes.

species	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
<i>Amphitrite cirrata</i>	8								G
<i>Apherusa bispinosa</i>		8							G
<i>Aporrhais pespelecani</i>	50								G
<i>Arctica islandica</i>	100	100	100	100	42	92			3
<i>Astarte borealis</i>	100	42		67	100	17			G
<i>Astarte elliptica</i>	100	67	8	17		67			G
<i>Astarte montagui</i>	92			8	25				3
<i>Buccinum undatum</i>	58	17							2
<i>Callipallene brevirostris</i>	33				8				R

species	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Caprella linearis	8	8							V
Dendrodoa grossularia	100	83	8	17	25				V
Dendronotus frondosus	8								V
Echinocyamus pusillus	50								G
Ecrobia ventrosa								8	G
Enipo kinbergi	8								R
Euchone papillosa	50	33	25	25	8				2
Eucratea loricata	67	67	67	92	25	8			V
Eulalia bilineata	33	8		17		17			G
Gammarus locusta				8	8				V
Halcompa duodecimcirrata	8	8		25					1
Halichondria panicea	33	17		17	8				G
Halitholus yoldiaarcticae		8	8		8		18		3
Hermania scabra	8								R
Lysilla loveni	8	25							R
Macoma calcarea	83			17					1
Melita palmata					8			33	V
Metridium senile		17		8	8				G
Monoporeia affinis							36		3
Musculus discors	75								G
Musculus niger	92								G
Musculus subpictus	100	25	8	17	8				G
Mya truncata	83			8					2
Nassarius reticulatus	8								G
Neptunea antiqua	33								G
Nereimyra punctata	92	58		50					G
Ophelia rathkei					17				V
Palaemon adspersus	8								V
Pandalina brevisrostris	8								G
Pholoe inornata	17								R
Pontoporeia femorata		33	8	8		42	18		V
Protomedeia fasciata	8	25							R
Rhizocaulus verticillatus		8							G
Rissoa membranacea		8			8				V
Saduria entomon							36		G
Scalibregma inflatum	75	58	8	25					G
Sertularia cupressina	25	67		25	17				G
Spirorbis spirorbis		8							G
Spisula subtruncata	17	8							G
Stenothoe monoculoides	8								R
Streblospio shrubsolii		8						42	V
Travisia forbesii					100		45		G
Urticina felina	8								G
total species number	37	26	9	19	17	6	5	3	52

4.3.5 Invasive Species

The role of invasive species in the open Baltic Sea is negligible (ZETTLER et al. 2014, 2018). Only five species were observed at our 8 monitoring stations in 2017. *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 2017 we observed the following abundances of *M. neglecta*: 3 ind./m² at northern Pomeranian Bay (OMBMPK3) and 164 ind./m² in the central Pomeranian Bay (OM160). In 2017 *M. viridis* was observed at the same stations with 102 ind./m² and 181 ind./m², respectively. In 2017 we found two new non-indigenous amphipod species for the first time during our monitoring program. Whereas *Grandidierella japonica* occurred at the southern Bay of Mecklenburg (OM018), *Melita nitida* was observed at the central Pomeranian Bay (OM160). Both species invaded recently German coastal waters of the Baltic Sea; *G. japonica* in 2015 and *M. nitida* in 2011 (ZETTLER & ZETTLER 2017).

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 2017 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

In summer 2017, the development of cyanobacteria was rather long despite the cloudy weather and SST below the long-term averages. A warm low-wind period in May led to the formation of early filaments indicating cyanobacteria, confirmed by cyanobacteria found *in situ* samples. A warm low-wind period in the northern Baltic Proper in July induced intense cyanobacteria filaments in the northern Gotland Sea, which lasted until beginning of August. Changing meteorological conditions combined with wind reduced surface accumulations and terminated the development of cyanobacteria in late summer. In September, filaments could not be observed.

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 information from the coastal monitoring of the IOW in front of Heiligendamm, to be found on <https://www.io-warnemuende.de/algae-blooms-at-heiligendamm-2017.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 2017, including a seasonal indicator, is shown in Table A2 (Annex). The ranking according to their biomass in 2017 is also given.

Spring bloom:

Some diatoms and dinoflagellates from the autumn bloom seem to stay over winter and contribute to the regular spring bloom at least in the western Baltic. The cyanobacterium *Aphanizomenon* sp. was found already in winter, at least in net samples. Some diatoms stay in deeper water layers of Kiel Bay and Bay of Mecklenburg, which was probably transported with inflowing water from the North Sea (this was *Coscinodiscus concinnus* in 2016 and *Guinardia delicatula* in 2017).

In contrast to the previous year, *Dictyocha speculum* was the main component, besides of diatoms, in the spring bloom in Kiel Bay and Bay of Mecklenburg. Towards the east, in the Bay of Mecklenburg and Arkona Basin, the common *Skeletonema marinoi* was the dominating diatom, but it was negligible in the Bornholm and Eastern Gotland Basins. *Mesodinium rubrum* was the dominating spring bloom species in the Baltic Proper except the western Arkona Basin which was influenced by the Bay of Mecklenburg. No diatoms, but dinoflagellates occurred in the spring bloom of the Eastern Gotland Basin.

As found already in the previous year, the inorganic nitrogen was consumed more intensively than phosphate, which is a symptom of nitrogen deficiency. Only in Kiel Bay and Lübeck Bay, phosphate is almost exhausted already in March when dissolved inorganic nitrogen is still available. Silicate was only slightly reduced even in diatom blooms and seems not to limit diatom growth.

The spring bloom occurred in March 2017 in most areas. However, it started its development already in February in Kiel Bay and the central Arkona Basin, but it occurred in the Eastern Gotland Basin only in May 2017. The typical retard of the spring bloom into eastern direction was obviously also found in 2017

Summer bloom:

Clear summer blooms could not be identified in 2017 in the open Baltic Sea. Elevated biomass, but still below 1000 µg/l, could be found in Kiel Bay (diatom dominance), central Bay of Mecklenburg (dinoflagellate dominance) and central Eastern Gotland Basin (cyanobacteria dominance). A bloom of nitrogen-fixing cyanobacteria identified at our coastal station Heiligendamm was not identified in our low-frequency open-sea data.

The “excess” phosphorus remaining after the spring bloom is widely consumed between May and August in the Baltic Proper with strongest consumption in the Eastern Gotland Basin where cyanobacteria developed most.

Autumn bloom:

The autumn bloom was well developed in the Belt Sea during the time of our autumn cruise with *Ceratium* spp. dominating in Kiel Bay and *Pseudo-nitzschia* spp., besides of *Ceratium* spp., dominating in Lübeck Bay and the Bay of Mecklenburg. The supposed reduction of *Ceratium* spp. was stopped in 2017.

Bloom concentrations were not reached in November 2017 in the Bornholm Basin and the Eastern Gotland Basin but the species composition was typical for the autumn bloom (*Coscinodiscus granii*, *Actinocyclus* spp.).

Invading phytoplankton species:

Some species which were new for us in previous years (*Lennoxia faveolata*, *Phaeodactylum* cf. *tricornutum*, *Alexandrium pseudogonyaulax*) have established. Other species which invaded in 2015 (*Coscinodiscus centralis*, *Roperia tesselata*, *Nematopsides vigilans*, and *Karenia mikimoto*), were not found in 2017 anymore. Obviously, the last Mayor Baltic Inflows had no effect on the phytoplankton composition.

Chlorophyll: The concentrations of chlorophyll *a* are compiled in Table 6. They were highest (12.9 mg m⁻³) during the autumn bloom in Lübeck Bay at the beginning on 14 November 2017. Also the spring bloom was well represented in the chlorophyll data of March 2017 at least in the western Baltic whereas chlorophyll *a* concentrations were highest in May in the Eastern Gotland Basin.

Sedimentation: Over the year 2017, the seasonal pattern of vertical export of particulate organic matter in the Arkona Basin showed, except for a resuspension-related period in January/February, a textbook-like succession of spring-, summer- and autumn blooms of pelagic autotrophs (microalgae and cyanobacteria), each associated with a typical cluster of species. Sedimentation peaks over these production periods were in a similar range with no quantitative preference of one season. The diversity of both diatoms (26) and dinoflagellates (10) increased again in comparison with the previous year and made 2017 the year with the highest number of recognized species within those groups. The number of cyanobacterial species and green algae remained on the same level.

The total annual flux for single elements in 2017 amounted to 580 mmol C (7 g C), 76 mmol N, 91 mmol Si and 2.8 mmol P m⁻² a⁻¹ at a mass flux of 56 g dry mass m⁻² a⁻¹. The level of these values is still in a high range of long-term annual flux rates, which is partly a result of the strong resuspension events during winter. This is also reflected in indicators for inorganic input like the C/Si ratio and in C as % of DW, both of which were lower than in the previous year that had no comparable resuspension events. An exclusion of these processes would reduce the flux by about 25% and place the values back into the long term mean.

The presence of diazotrophic species was documented by microscopy and could as well be seen in a drastic drop of the isotopic signature of nitrogen with the appearance of *Nodularia* and *Aphanizomenon*, both of which were collected together in August in contrast to the usual successive appearance pattern. With 6.1 ‰, the mass weighted δ¹⁵N signature shows a lower contribution of nitrogen fixation to the total annual nitrogen flux than in former years, which reflects the high contribution of non-diazotrophic production to the total annual budget.

Over the whole year the mass-weighted means of elemental ratios were 7.6 for C/N, 205 for C/P and 8.4 for C/Si. With -26.1‰, the mean δ¹³C signature of the organic carbon was slightly above the range of the previous year.

Zooplankton

The evaluation of the long-term variation in abundance and community composition of Baltic Sea zooplankton in 2017 was based on 63 samples taken at 50 stations in the western Baltic Sea. Following the high diversity observed in 2016 (73 taxa), the number of taxa decreased in

2017 (63 taxa) but remained high compared to earlier years (45-52 taxa). The diminution was related to a lower frequency of benthic larvae which was associated with a low abundance of meroplankton. Apart from *A. tonsa*, which is present in the Baltic Sea for nearly a century, no other invasive species were recorded. With the anthomedusae *Lizzia blondina* and *Staurosarsia gemmifera*, however, two hydrozoans were observed that were not recorded in the Kiel Bay and Bay of Mecklenburg before.

The trend of a decreasing zooplankton abundance - apparent since the 2000's - reversed. However, the stocks remained generally low. The reversal is related to the increasing abundance of cladocera and copepoda. In the Arkona Basin, the stocks of cladocera increased 10-fold in comparison to 2017, providing evidence for mass development during summer, which was lacking in the previous years. The abundance of calanoid and cyclopoid copepods was on average about 2-4-fold higher than in 2017. The remaining major zooplankton groups, rotifers, appendicularia or polychaete larvae, displayed only small differences to preceding years. *Bosmina* spp. was the single most important species among the cladocera. Among the copepoda, the genus *Acartia* dominated in high numbers, which is not unusual. A considerable increase, however, was recorded in the genera *Temora* and *Oithona*. *Oithona similis* was the single most abundant species among the adult copepods. High concentrations were observed in the Kiel Bay and the Bay of Mecklenburg, but it was outnumbered by *Acartia longiremis* and *Temora longicornis* in the Arkona Basin. As usual, rotifers were represented by *Synchaeta* spp. and the appendicularia by *Fritellaria borealis* and *Oikopleura dioica*.

The seasonal zooplankton development was delayed in 2017, particularly in the Bay of Mecklenburg and the Arkona Basin. This is owed to the late occurrence of rotifers in May. In previous years, they were observed as early as in March. In the Kiel Bay, calanoid and cyclopoid copepods dominated the plankton whole year round. Cladocera and rotifers, which were abundant in 2017, were rare and the abundance of meroplankton and the appendicularia was lower than usual. *Oithona* was the dominating copepod genus during the whole year, while *Acartia*, *Centropages*, *Temora* and *Pseudo/Paracalanus* contributed considerably to the spring community. The dominance of *Oithona similis* is rather exceptional, the species normally shows a high frequency in restricted periods. The copepods were also the dominating zooplankton in the Bay of Mecklenburg. The contribution of rotifers and polychaete meroplankton increased in May compared to the Kiel Bay. The abundance of copepods during spring and summer was higher than in previous years. Dominant genera were *Acartia*, *Temora* and *Centropages* in spring. They were replaced by *Pseudo/Paracalanus* and *Oithona* during the second half of the year. Copepods were also the dominant taxon in the Arkona Basin, with considerably enhanced stock sizes in comparison to 2015-2016. Rotifers and the copepod genera *Acartia*, *Centropages* and *Temora* contributed to the spring increase in zooplankton abundance. In summer, the cladocera dominated. *Bosmina* spp. was the major species. *Acartia*, *Temora* and *Pseudo/Paracalanus* were major contributors to the summer/autumn copepod community. The zooplankton composition at station OMBMP-K8 reflected the transition from the Bay of Mecklenburg to the Arkona Basin with a high abundance of *Oithona* the lack of large concentrations of rotifers as well as the high abundance of *Acartia*, *Temora* and *Fritellaria*.

Macrozoobenthos

This study presents the results of macrozoobenthos monitoring in the southern Baltic Sea in November 2017. The following parameters were measured: species richness, and the abundance and biomass of organisms per station. Compared to previous years, the 142 species recorded at the 8 monitoring stations were considered to be a high number. No long-lasting oxygen deficiency was observed in 2017. The oxygen supply in bottom waters in the current year was always higher than 2 ml/l; only in the Arkona Basin the value dropped down to 1.47 ml/l for a short time in summer. Depending on the region, abundances varied between 242 and 8 790 ind./m². In terms of biomass, similarly high variations were observed (1.4g in the northern Pomeranian Bay to 59.3 g afdw/m² in the Kiel Bay). Some marine species were observed again since a long or for the first time at all. For example, the polychaete *Phyllodoce rosea* was never recorded before and now occurring in the Kiel Bay in low numbers. In the Fehmarnbelt the polychaete *Poecilochaetus serpens* occurred for the first time. Altogether, 25 “new” species were observed at the 8 monitoring stations in 2017 regarding their occurrence in the previous years at the same stations.

Sixteen species of the German Red List (Categories 1, 2, 3 and G) were observed at the 8 monitoring stations. The anthozoan *Halcapa duodecimcirrata*, very rarely observed and critically endangered in German waters, was found in the Fehmarnbelt, for instance. One species of the HELCOM Red List were detected: *Mya truncata* (NT).

In line with expectations, the number of invasive species found during the 2017 sampling campaign was low: five 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* and *M. neglecta* colonised the Pomeranian Bay in densities of around 100 to 200 ind./m². Additionally, two new recently invaded non-indigenous amphipods species, *Grandidierella japonica* and *Melita nitida*, were recorded for the first time during the monitoring program.

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References

- BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE, 2017: Arbeitsplan 2018. Zur Wahrnehmung meereskundlicher Aufgaben in der Ostsee durch das Leibniz-Institut für Ostseeforschung Warnemünde für das Bundesamt für Seeschifffahrt und Hydrographie. Hamburg, Dezember 2017.
- EILOLA, K., MEIER, M.H.E., ALMROTH, E., 2009: On the dynamics of oxygen, phosphorus and cyanobacteria in the Baltic Sea; a model study. – *Journal of Marine Systems* **75**, 163-184.
- EUROPEAN UNION, 2000: Wasserrahmenrichtlinie. – Richtlinie 2000/60/EG des Europäischen Parlaments und des Rates vom 23. Oktober 2000, L 327, 67pp. + Anhänge
- EUROPEAN UNION, 2008: Marine Strategy Framework Directive. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008: Establishing a Framework for Community Action in the field of Marine Environmental Policy. – *Official Journal of the European Union*, L **164**, 19-39.
- GOGINA, M., DARR, A., ZETTLER, M.L., 2014: Approach to assess consequences of hypoxia disturbance events for benthic ecosystem functioning. – *Journal of Marine Systems* **129**, 203-213.
- GOGINA, M., NYGÅRD, H., BLOMQUIST, M., DAUNYS, D., JOSEFSON, A.B., KOTTA, J., MAXIMOV, A., WARZOCHA, J., YERMAKOV, V., GRÄWE, U., ZETTLER, M.L., 2016: The Baltic Sea scale inventory of benthic faunal communities in the Baltic Sea. – *ICES Journal of Marine Science* **73**, 1196-1213.
- GREVE, W., REINERS, F., NAST, J., HOFFMANN S., 2004: Helgoland Roads meso- and macrozooplankton time-series 1974 to 2004: lessons from 30 years of single spot, high frequency sampling at the only off-shore island of the North Sea. – *Helgol. Mar. Res.* **58**, 275-288.
- HAJDU, S., EDLER, L., OLENINA, I. and WITEK, B., 2000: Spreading and establishment of the potentially toxic dinoflagellate *Prorocentrum minimum* in the Baltic Sea. – *Internat. Review of Hydrobiology* **85**, 561-575.
- HAJDU, S., OLENINA, I., WASMUND, N., EDLER, L., WITEK, B., 2006: Unusual phytoplankton events in 2005. – HELCOM/MONAS Indicator Fact Sheet.
- HÄLLFORS, G., 2004: Checklist of Baltic Sea Phytoplankton Species (including some heterotrophic protistan groups). – *Baltic Sea Environment Proceedings* 95: 1-208.
- HELCOM, 1987: First periodic assessment of the state of the marine environment of the Baltic Sea area, 1980-1985; background document. – *Baltic Sea Environment Proceedings* **17 B**, 1-351.

- HELCOM, 1990: Second periodic assessment of the state of the marine environment of the Baltic Sea, 1984-1988; background document. – Baltic Sea Environment Proceedings **35 B**, 1-432.
- HELCOM, 1996: Third periodic assessment of the state of the marine environment of the Baltic Sea, 1989-1993; background document. – Baltic Sea Environment Proceedings **64 B**, 1-252.
- HELCOM, 2002: Environment of the Baltic Sea area, 1994-1998. – Baltic Sea Environment Proceedings **82 B**, 1-215.
- HELCOM, 2013a: Climate change in the Baltic Sea area. HELCOM Thematic Assessment in 2013. – Baltic Sea Environment Proceedings **137**, 1-70.
<http://www.helcom.fi/Lists/Publications/BSEP137.pdf>
- HELCOM, 2013b: HELCOM Red List of Baltic Sea species in danger of becoming extinct. – Baltic Sea Environment Proceedings **140**, 1-106.
<http://www.helcom.fi/Lists/Publications/BSEP140.pdf>
- HELCOM, 2013c: HELCOM core indicators. Final report of the HELCOM CORESET project. – Baltic Sea Environment Proceedings **136**, 1-74.
<http://www.helcom.fi/Lists/Publications/BSEP136.pdf>
- HELCOM, 2014a: Eutrophication status of the Baltic Sea 2007-2011- A concise thematic assessment. – Baltic Sea Environment Proceedings **143**, 1-41.
<http://www.helcom.fi/Lists/Publications/BSEP143.pdf>
- HELCOM, 2017a: State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016.
<https://www.helcom.fi/Lists/Publications/BSEP155.pdf>
- HELCOM, 2017b: Manual for marine monitoring in the COMBINE programme of HELCOM. – Internet, Last updated July 2017:
<http://www.helcom.fi/Documents/Action%20areas/Monitoring%20and%20assessment/Manuals%20and%20Guidelines/Manual%20for%20Marine%20Monitoring%20in%20the%20COMBINE%20Programme%20of%20HELCOM.pdf>
- HELCOM, 2017c: Monitoring of phytoplankton species composition, abundance and biomass.
<http://www.helcom.fi/Documents/Action%20areas/Monitoring%20and%20assessment/Manuals%20and%20Guidelines/Guidelines%20for%20monitoring%20phytoplankton%20species%20composition,%20abundance%20and%20biomass.pdf>
- HELCOM, 2017d: Guidelines for monitoring of chlorophyll a.
<http://www.helcom.fi/Documents/Action%20areas/Monitoring%20and%20assessment/Manuals%20and%20Guidelines/Guidelines%20for%20measuring%20chlorophyll%20a.pdf>

- HENRIKSEN, P., KNIPSCHILDT, F., MOESTRUP, Ø., THOMSEN, H.A., 1993: Autecology, life history and toxicology of the silicoflagellate *Dictyocha speculum* (Silicoflagellata, Dictyochophyceae). – *Phycologia* **32**, 29-39.
- HOPPE, H.-G., GIESENHAGEN, H.C., KOPPE, R., HANSEN, H.-P., GOCKE, K., 2013: Impact of change in climate and policy from 1988 to 2007 on environmental and microbial variables at the time series station Boknis Eck, Baltic Sea. – *Biogeosciences* **10**, 4529-4546.
- JANSON, S., CARPENTER, E.J., BERGMAN, B., 1994: Finestructure and localisation of proteins in *Aphanizomenon* sp. from the Baltic Sea. – *Eur. J. Phycol.* **29**, 203-211.
- JOCHEM, F., BABENERD, B., 1989: Naked *Dictyocha speculum* - a new type of phytoplankton bloom in the western Baltic. – *Mar. Biol.* **103**, 373-379.
- KAISER, J., BELT, S.T., TOMCZAK, M., BROWN, T.A., WASMUND, N., ARZ, H.W., 2016: C₂₅ highly branched isoprenoid alkenes in the Baltic Sea produced by the marine planktonic diatom *Pseudosolenia calcar-avis*. – *Organic Geochemistry* **93**: 51-58.
- KOMÁREK, J., ZAPOMĚLOVÁ, E., 2007: Planktic morphospecies of the cyanobacterial genus *Anabaena* = subg. *Dolichospermum* – 1. part: coiled types. – *Fottea, Olomouc* 2007, **7** (1), 1-31.
- KOMÁREK, J., ZAPOMĚLOVÁ, E., 2008: Planktic morphospecies of the cyanobacterial genus *Anabaena* = subg. *Dolichospermum* – 2. part: straight types. – *Fottea, Olomouc* 2008, **8** (1), 1-14.
- KONTULA, T., HALDIN, J. (EDS.) KARLSSON, A., FLORIN, A.B., FÜRHAUPTER, K., HERRMANN, C., KARLSSON, O., SONNTAG, N., AUTIO, I., LAAMANEN, M., ARRENDAL, J., BIRZAKS, J., BRZESKA, P., BOEDEKER, D., BUČAS, M., CHERNOVA, N., FEDOROV, V., GALATIUS, A., GERB, M., GLAZKOVA, E., GRUSZKA, P., HARIO, M., HERKÜL, K., HÄRKÖNEN, T., JOHANSSON, G., KARVINEN, V., KAUTSKY, H., KIECKBUSCH, J., KOSTAMO, K., KOVALCHUK, N., LAINE, A., LOŽYS, L., MARTIN, G., MAXIMOV, A., MORITZ, T., PUSCH, C., PŪTYS, Z., SCHIELE, K., SKÓRA, K., STERNIK, L., STĪPNIECE, A., SVEDÄNG, H., SVENSSON, M., THORUP, O., TJERNBERG, M., TORN, K., TYLIK, K., URHO, L. VITALE, F., VOLODINA, A., ZETTLER, M.L., 2013: HELCOM Red List of Baltic Sea species in danger of becoming extinct. – *Baltic Sea Environment Proceedings* **140**, 1-106.
- LAAMANEN M.J., FORSSTRÖM L., SIVONEN K., 2002: Diversity of *Aphanizomenon* populations (cyanobacteria) on a Baltic Sea salinity gradient - Only one ITS₁-S genotype persists in the Baltic Sea. In: M. LAAMANEN: Genetic and species diversity of planktonic cyanobacteria in the northern Baltic Sea. Finnish Inst. Marine Research, Contributions, Helsinki 4: Part IV, 14 pp.
- LIPS, I., RÜNK, N., KIKAS, V., MEERITS, A., LIPS, U., 2014: High-resolution dynamics of the spring bloom in the Gulf of Finland of the Baltic Sea. – *Journal of Marine Systems* **129**, 135-149.
- LORENZEN, C.J., 1967: Determination of chlorophyll and phaeopigments: spectrophotometric equations. – *Limnol. Oceanogr.* **12**, 343-346.

- MOHRHOLZ, V., NAUMANN, M., NAUSCH, G., KRÜGER, S., GRÄWE, U., 2015: Fresh oxygen for the Baltic Sea – An exceptional saline inflow after a decade of stagnation. – *J. Mar. Syst.* **148**, 152-166.
- NAUMANN, M., UMLAUF, L., MOHRHOLZ, V., KUSS, J., SIEGEL, H., WANIEK, J., SCHULZ-BULL, D.E., 2018: Hydrographic-hydrochemical assessment of the Baltic Sea 2017. – *Meereswiss. Ber., Warnemünde* **107**, 1-86.
- ÖBERG, J., 2017: Cyanobacterial blooms in the Baltic Sea in 2017. – HELCOM Baltic Sea Environment Fact Sheets 2017. Online. <http://helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/cyanobacterial-blooms-in-the-baltic-sea/>
- OLENINA, I., HAJDU, S., ANDERSSON, A., EDLER, L., WASMUND, N., BUSCH, S., GÖBEL, J., GROMISZ, S., HUSEBY, S., HUTTUNEN, M., JAANUS, A., KOKKONEN, P., LEDAINE, I., NIEMKIEWICZ, E., 2006: Biovolumes and size-classes of phytoplankton in the Baltic Sea. – *Baltic Sea Environment Proceedings* **106**, 1-144.
<http://www.helcom.fi/Lists/Publications/BSEP106.pdf>
- OLENINA, I., KOWNACKA, J., 2010: An unusual phytoplankton event five years later: the fate of the atypical range expansion of marine species into the south-eastern Baltic. – HELCOM Indicator Fact Sheet. <http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/an-unusual-phytoplankton-event/>
- OLENINA, I., WASMUND, N., HAJDU, S., JURGENSONE, I., GROMISZ, S., KOWNACKA, J., TOMING, K., VAICIŪTĒ, D., OLENIN, S., 2010: Assessing impacts of invasive phytoplankton: the Baltic Sea case. – *Marine Pollution Bulletin* **60**, 1691-1700. doi:10.1016/j.marpolbul.2010.06.046.
- PACZKOWSKA, J., ROWE, O.F., SCHLÜTER, L., LEGRAND, C., KARLSON, B., ANDERSSON, A., 2017: Allochthonous matter - an important factor shaping phytoplankton community in the Baltic Sea. – *J. Plankton Res.* **39**, 23-34.
- PALIŃSKA, K.A., SUROSZ, W., 2008: Population of *Aphanizomenon* from the Gulf of Gdańsk (Southern Baltic Sea): differences in phenotypic and genotypic characteristics. – *Hydrobiologia* **607**: 163-173.
- RACHOR, E., BÖNSCH, R., BOOS, K., GOSSELCK, F., GROTHJAHN, M., GÜNTHER, C.-P., GUSKY, M., GUTOW, L., HEIBER, W., JANTSCHIK, P., KRIEG, H.-J., KRONE, R., NEHMER, P., REICHERT, K., REISS, H., SCHRÖDER, A., WITT, J., ZETTLER, M.L., 2013: Rote Liste der bodenlebenden wirbellosen Meerestiere. – *Naturschutz und Biologische Vielfalt* **70**(2), 81-176.
- RUSSEL, F.R., 1970: The medusa of the British Isles. Anthomedusae, Leptomedusae, Limnomedusae, Trachymedusae and Narcomedusae. Cambridge University Press, 533 pp.
- SANDERS, R.W., 1995: Seasonal distributions of the photosynthesizing ciliates *Laboea strobila* and *Myrionecta rubra* (= *Mesodinium rubrum*) in an estuary of the Gulf of Maine. – *Aquat. Microb. Ecol.* **9**, 237-242.

- SARNO, D., KOOISTRA, W.H.C.F., MEDLIN, L., PERCOPO, I., ZINGONE, A.J., 2005: Diversity in the genus *Skeletonema* (Bacillariophyceae). II. An assessment of the taxonomy of *S. costatum*-like species with the description of four new species. – J. Phycol. **41**, 151-176.
- SCHILLING P., DÜRSELEN C.-D., HEYDEN B., RAABE T. & KÖHLER J., 2016: 2.Chlorophyll-Ringversuch. Vergleichbarkeit von Chlorophyll-a-Bestimmungen. Abschlussbericht. Bund/Länder Messprogramm für die Meeresumwelt von Nord- und Ostsee. Berichte der Qualitätssicherungsstelle 2016/4. Dessau-Roßlau und Berlin, Umweltbundesamt, 103 S.
- SIEGEL, H., GERTH, M., 2018: Sea surface temperature in the Baltic Sea in 2017. – HELCOM Baltic Sea Environ. Fact Sheets Hydrography / Development of sea surface temperature in the Baltic Sea. HELCOM Baltic Marine Environment Protection Commission. <http://helcom.fi/baltic-sea-trends/environment-fact-sheets/hydrography/development-of-sea-surface-temperature-in-the-baltic-sea>
- SMETACEK, V., HENDRIKSON, P., 1979: Composition of particulate organic matter in Kiel Bight in relation to phytoplankton succession. – Oceanologica Acta **2**, 287-298.
- SPILLING, K., KREMP, A., KLAIS, R., OLLI, K., TAMMINEN, T., 2014: Spring bloom community change modifies carbon pathways and C:N:P:Chl a stoichiometry of coastal material fluxes. – Biogeosciences Discuss. **11**, 7275-7289.
- STICH, H.B., BRINKER, A., 2005: Less is better: Uncorrected versus pheopigment-corrected photometric chlorophyll-a estimation. – Arch. Hydrobiol. **162**, 111-120.
- STOECKER, D.K., SILVER, M.W., MICHAELS, A.E., DAVIS, L.H., 1988: Obligate mixotrophy in *Laboea strobila*, a ciliate which retains chloroplasts. – Marine Biology **99**, 415-423.
- TELESH, I., POSTEL, L., HEERKLOSS, R., MIRONOVA, E., SKARLATO, S., 2009: Zooplankton of the Open Baltic Sea: Extended Atlas. BMB Publication No.21. – Meereswiss. Ber., Warnemünde, **76**, 1–290.
- TELESH, I., SCHUBERT, H., SKARLATO, S.O., 2016: Ecological niche partitioning of the invasive dinoflagellate *Prorocentrum minimum* and its negative congeners in the Baltic Sea. – Harmful Algae **59**, 100-111.
- UTERMÖHL, H., 1958: Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. – Ass. intern. Limnol. théor. **9**, 1-38.
- WACKLIN, P., HOFFMANN, L., KOMÁREK, J., 2009: Nomenclatural validation of the genetically revised cyanobacterial genus *Dolichospermum* (Ralfs ex Bornet et Flahault) comb. nova. – Fottea **9**, 59-64.
- WASMUND, N., 1984: Probleme der spektrophotometrischen Chlorophyllbestimmung. – Acta hydrochim. hydrobiol. **12**, 253-270.

- WASMUND, N., 1997: Occurrence of cyanobacterial blooms in the Baltic Sea in relation to environmental conditions. – *Int. Revue ges. Hydrobiol.* **82**, 169-184.
- WASMUND, N. 2017: The diatom/dinoflagellate index as an indicator of ecosystem changes in the Baltic Sea. 2. Historical data for use in determination of good environmental status. – *Frontiers in Marine Science* **4**(153): 1-12.
- WASMUND, N., BUSCH, S., BURMEISTER, C., 2018: Phytoplankton development at the coastal station “Seebrücke Heiligendamm” in 2017. <https://www.io-warnemuende.de/algal-blooms-at-heiligendamm-2017.html>
- WASMUND, N., BUSCH, S., GÖBEL, J., GROMISZ, S., HÖGLANDER, H., HUSEBY, S., JAANUS, A., JAKOBSEN, H.H., JOHANSEN, M., JURGENSONE, I., KOWNACKA, J., KRASNIEWSKI, W., LEHTINEN, S., OLENINA, I., v.Weber, M., 2017b: Cyanobacteria biomass 1990-2016. – HELCOM Baltic Sea Environment Fact Sheet 2017. Online. <http://helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/cyanobacteria-biomass/>
- WASMUND, N., DUTZ, J., POLLEHNE, F., SIEGEL, H., ZETTLER, M.L., 2015: Biological assessment of the Baltic Sea 2014. – *Meereswiss. Ber., Warnemünde* **98**, 1-91.
- WASMUND, N., DUTZ, J., POLLEHNE, F., SIEGEL, H., ZETTLER, M.L., 2017a: Biological assessment of the Baltic Sea 2016. – *Meereswissenschaftliche Berichte* **105**: 1-98.
- WASMUND, N., GÖBEL, J., v.BODUNGEN, B., 2008: 100-years-changes in the phytoplankton community of Kiel Bight (Baltic Sea). – *J. Mar. Syst.* **73**, 300-322.
- WASMUND N., KOWNACKA J., GÖBEL J., JAANUS A., JOHANSEN M., JURGENSONE I., LEHTINEN S. & POWILLEIT M., 2017c: The diatom/dinoflagellate index as an indicator of ecosystem changes in the Baltic Sea. 1. Principle and handling instruction. – *Frontiers in Marine Science* **4**(22): 1-13.
- WASMUND, N., NAUSCH, G., MATTHÄUS, W., 1998: Phytoplankton spring blooms in the southern Baltic Sea – spatio-temporal development and long-term trends. – *J. Plankton Res.* **20**, 1099-1117.
- WASMUND, N., POLLEHNE, F., POSTEL, L., SIEGEL, H., ZETTLER, M.L., 2006 a: Biologische Zustandseinschätzung der Ostsee im Jahre 2005. – *Meereswiss. Ber., Warnemünde* **69**, 1-78.
- WASMUND, N., POLLEHNE, F., POSTEL, L., SIEGEL, H., ZETTLER, M.L., 2011 a: Biologische Zustandseinschätzung der Ostsee im Jahre 2010. – *Meereswiss. Ber., Warnemünde* **85**, 1-87.
- WASMUND, N., POWILLEIT, M., 2016: Entwicklung des Indikators Diatomeen/Dinoflagellaten-Index. – Project report to the BfN. 58 pp.

- WASMUND, N., TOPP, I., SCHORIES, D., 2006 b: Optimising the storage and extraction of chlorophyll samples. – *Oceanologia* **48**, 125-144.
- WASMUND, N., TUIMALA, J., SUIKKANEN, S., VANDEPITTE, L., KRABERG, A. 2011 b: Long-term trends in phytoplankton composition in the western and central Baltic Sea. – *Journal of Marine Systems* **87**, 145–159. <http://dx.doi.org/10.1016/j.jmarsys.2011.03.010>
- WELSCHMEYER, N.A., 1994: Fluorometric analysis of chlorophyll a in the presence of chlorophyll b and pheopigments. – *Limnol. Oceanogr.* **39**, 1985-1992.
- ZETTLER, M.L., KARLSSON, A., KONTULA, T., GRUSZKA, P., LAINE, A., HERKÜL, K., SCHIELE, K., MAXIMOV, A., HALDIN, J., 2014: Biodiversity gradient in the Baltic Sea: A comprehensive inventory of macrozoobenthos data. – *Helgoland Marine Research* **68**, 49-57.
- ZETTLER, M.L., FRIEDLAND, R., GOGINA, M., DARR, A., 2017: Variation in benthic long-term data of transitional waters: Is interpretation more than speculation? – *PLoS ONE* **12**(4): e0175746.
- ZETTLER, M.L., BEERMANN, J., DANNHEIM, J., EBBE, B., GROTHJAHN, M., GÜNTHER, C.P., GUSKY, M., KIND, B., KUHLENKAMP, R., ORENDT, C., RACHOR, E., SCHANZ, A., SCHRÖDER, A., SCHÜLER, L., WITT, J., 2018: An annotated checklist of macrozoobenthic species in German waters of the North and Baltic Seas. – *Helgoland Marine Research* **72**: 5 (10pp.)
- ZETTLER, M.L., ZETTLER, A. 2017: Marine and freshwater Amphipoda from the Baltic Sea and adjacent territories. – *Conchbooks*, Harxheim: 845pp.
- ZINGONE, A., PERCOPO, I., SIMS, P.A., SARNO, D., 2005: Diversity in the genus *Skeletonema* (Bacillariophyceae). I. A reexamination of the type material of *S. costatum* with the description of *S. grevillei* sp. nov. – *J. Phycol.* **41**, 140-150.

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 February-May as well as cruises from August and November 2017. The mean phytoplankton biomass (in µg/l) is given on the top of each station block. „Unidentified“ were deleted from the list if biomass share was <10%. Continued on page 91-92 !

February-May	(%)	August	(%)	November	(%)
Kiel Bay (Stat. OMBMPN3)					
Phytopl. biomass in µg/L	1708	Phytopl. biomass in µg/L	883	Phytopl. biomass in µg/L	2493
Dictyocha speculum	44.58	Pseudosolenia calcar-avis	21.88	Ceratium tripos	62.56
Rhizosolenia setigera	16.51	Proboscia alata	16.41	Ceratium fusus	11.16
Rhizosolenia hebetata f. semispina	8.29	Ceratium tripos	9.86	Dinophysis norvegica	7.41
Proboscia alata	6.38	Gymnodiniales	9.44	Thalassiosira punctigera	3.76
Guinardia delicatula	5.90	Alexandrium pseudogonyaulax	6.94	Thalassiosira eccentrica	2.18
Peridiniella danica	3.14	Prorocentrum micans	6.51	Prorocentrum micans	2.04
Dactyliosolen fragilissimus	2.47	Peridinales	2.02	Pseudosolenia calcar-avis	1.45
Pseudopedinella	1.93	Dictyocha speculum	1.96	Thalassiosira	1.27
Pseudochattonella farcimen	1.78	Prymnesiales	1.92	Protoperidinium divergens	1.04
Thalassiosira	1.27	Cerataulina pelagica	1.88	Gymnodiniales	0.96
Lübeck Bay (Stat. OMO22)					
Phytopl. biomass in µg/L	631	Phytopl. biomass in µg/L	406	Phytopl. biomass in µg/L	3474
Dictyocha speculum	28.76	Ceratium fusus	14.64	Pseudo-nitzschia	43.29
Scrippsiella hangoei cf.	20.49	Gymnodiniales	13.97	Ceratium tripos	23.48
Gymnodiniales	11.08	Unicell spp.	10.43	Cerataulina pelagica	6.89
Peridiniella danica	8.13	Alexandrium pseudogonyaulax	9.05	Rhizosolenia setigera	6.52
Pseudochattonella farcimen	6.76	Ceratium tripos	8.58	Ceratium fusus	3.45
Actinocyclus	3.65	Mesodinium rubrum	8.22	Prorocentrum micans	1.99
Thalassiosira	2.18	Dolichospermum spp.	6.65	Rhizosolenia setigera f. pungens	1.52
Ceratium tripos	1.84	Proboscia alata	5.44	Dictyocha speculum	1.48
Apedinella radians	1.82	Plagioselmis prolonga	3.09	Thalassiosira eccentrica	1.21
Teleaulax	1.77	Telonema	2.86	Dinophysis norvegica	1.13
Central Bay of Mecklenburg (Stat. OMBMPM2)					
Phytopl. biomass in µg/L	654	Phytopl. biomass in µg/L	760	Phytopl. biomass in µg/L	3107
Dictyocha speculum	34.63	Alexandrium pseudogonyaulax	21.04	Pseudo-nitzschia	48.04
Skeletonema marinoi	20.93	Ceratium tripos	16.97	Ceratium tripos	26.81
Mesodinium rubrum	9.18	Pseudosolenia calcar-avis	10.28	Cerataulina pelagica	4.41
Peridiniella danica	8.46	Prorocentrum micans	4.77	Ceratium fusus	4.29
Gymnodiniales	3.25	Ceratium fusus	3.97	Rhizosolenia setigera	2.50
Prymnesiales	2.37	Gymnodiniales	3.95	Dinophysis norvegica	1.27
Pseudochattonella farcimen	1.87	Proboscia alata	3.36	Thalassiosira eccentrica	0.94
Scrippsiella hangoei cf.	1.86	Plagioselmis prolonga	2.84	Prorocentrum micans	0.88
Thalassiosira	1.24	Prymnesiales	2.73	Gymnodiniales	0.85
Apedinella radians	1.13	Dolichospermum spp.	2.32	Thalassiosira	0.83
Eastern Bay of Mecklenburg (Stat. OMBMPM1)					
Phytopl. biomass in µg/L	843	Phytopl. biomass in µg/L	312	Phytopl. biomass in µg/L	1273
Dictyocha speculum	31.73	Ceratium tripos	15.65	Ceratium tripos	37.78
Skeletonema marinoi	26.99	Gymnodiniales	12.90	Pseudo-nitzschia	22.10
Mesodinium rubrum	12.00	Alexandrium pseudogonyaulax	8.06	Cerataulina pelagica	6.70
Scrippsiella hangoei cf.	5.18	Plagioselmis prolonga	4.99	Ceratium fusus	3.16
Actinocyclus	4.72	Prorocentrum micans	4.93	Dinophysis norvegica	2.65
Peridiniella danica	3.13	Nodularia spumigena	3.90	Thalassiosira eccentrica	2.57
Gymnodiniales	2.83	Aphanizomenon	3.35	Prorocentrum micans	2.50
Prymnesiales	2.80	Katablepharis remigera	2.99	Teleaulax	2.07
Pseudochattonella farcimen	2.04	Prorocentrum cordatum	2.33	Mesodinium rubrum	1.98
Thalassiosira	1.41	Pseudosolenia calcar-avis	2.23	Gymnodiniales	1.67

Western Arkona Basin (Stat. OMBMPK8)					
Phytopl. biomass in µg/L	586	Phytopl. biomass in µg/L	264	Phytopl. biomass in µg/L	456
Skeletonema marinoi	40.89	Prorocentrum cordatum	15.98	Ceratium tripos	36.66
Mesodinium rubrum	24.06	Heterocapsa rotundata	9.30	Pseudo-nitzschia	18.38
Thalassiosira	6.48	Gymnodiniales	8.95	Cerataulina pelagica	8.03
Prymnesiales	5.95	Alexandrium pseudogonyaulax	6.90	Actinocyclus	5.71
Dictyocha speculum	4.19	Prymnesiales	6.83	Mesodinium rubrum	4.17
Gymnodiniales	3.81	Mesodinium rubrum	6.47	Lobocystis planctonica	3.07
Peridiniella danica	2.43	Pyramimonas	6.19	Actinoptychus senarius	2.12
Teleaulax	1.42	Aphanizomenon	5.84	Thalassiosira eccentrica	1.98
Peridinales	0.90	Plagioselmis prolonga	4.76	Teleaulax	1.81
Protoperidinium	0.83	Katablepharis remigera	2.93	Gymnodiniales	1.75
Central Arkona Basin (Stat. OMBMPK5)					
Phytopl. biomass in µg/L	500	Phytopl. biomass in µg/L	214	Phytopl. biomass in µg/L	297
Mesodinium rubrum	48.50	Nodularia spumigena	21.68	Ceratium tripos	38.12
Skeletonema marinoi	17.62	Gymnodiniales	14.33	Actinocyclus	11.58
Prymnesiales	7.86	Unicell spp.	13.86	Mesodinium rubrum	10.53
Thalassiosira	7.36	Plagioselmis prolonga	6.36	Coscinodiscus granii	5.68
Gymnodiniales	4.24	Prorocentrum cordatum	6.20	Teleaulax	4.52
Teleaulax	1.91	Pyramimonas	5.85	Gymnodiniales	2.20
Heterocapsa rotundata	1.35	Teleaulax	5.77	Pyramimonas	2.08
Peridiniella danica	1.14	Aphanizomenon	4.03	Rhizosolenia setigera	1.90
Plagioselmis prolonga	1.08	Mesodinium rubrum	3.99	Plagioselmis prolonga	1.88
Actinocyclus	0.93	Eutreptiella	3.04	Dinophysis norvegica	1.38
Eastern Arkona Basin (Stat. OMBMPK4)					
Phytopl. biomass in µg/L	395	Phytopl. biomass in µg/L	251	Phytopl. biomass in µg/L	233
Mesodinium rubrum	42.13	Gymnodiniales	20.27	Actinocyclus	24.47
Skeletonema marinoi	16.91	Nodularia spumigena	15.00	Mesodinium rubrum	23.67
Prymnesiales	8.06	Unicell spp.	11.27	Coscinodiscus granii	9.67
Thalassiosira	8.06	Plagioselmis prolonga	7.79	Teleaulax	7.21
Actinocyclus	4.76	Pyramimonas	4.59	Gymnodiniales	6.06
Peridiniella danica	3.46	Heterocapsa rotundata	4.19	Plagioselmis prolonga	3.87
Gymnodiniales	3.29	Teleaulax	4.04	Ceratium tripos	3.00
Teleaulax	2.26	Aphanizomenon	3.63	Pyramimonas	2.69
Plagioselmis prolonga	1.68	Mesodinium rubrum	3.37	Chaetoceros castracanei	2.19
Aphanizomenon	1.31	Ebria tripartita	3.33	Hemiselms	1.25
Bornholm Basin (Stat. OMBMPK2)					
Phytopl. biomass in µg/L	442	Phytopl. biomass in µg/L	279	Phytopl. biomass in µg/L	379
Mesodinium rubrum	76.45	Gymnodiniales	16.43	Coscinodiscus granii	50.48
Gymnodiniales	4.45	Unicell spp.	10.95	Actinocyclus	22.84
Thalassiosira	2.34	Pyramimonas	10.19	Mesodinium rubrum	13.98
Aphanizomenon	2.30	Pseudanabaena limnetica	8.81	Teleaulax	1.91
Prymnesiales	1.80	Plagioselmis prolonga	8.44	Gymnodiniales	1.27
Teleaulax	1.69	Aphanizomenon	7.11	Eutreptiella	0.78
Actinocyclus	1.51	Mesodinium rubrum	4.57	Plagioselmis prolonga	0.68
Heterocapsa rotundata	1.11	Actinocyclus	4.30	Prymnesiales	0.66
Ebria tripartita	0.94	Teleaulax	4.22	Aphanizomenon	0.54
Skeletonema marinoi	0.78	Prymnesiales	4.13	Centrales	0.30
Southern Gotland Basin (Stat. OMBMPK1)					
Phytopl. biomass in µg/L	907	Phytopl. biomass in µg/L	176	Phytopl. biomass in µg/L	178
Mesodinium rubrum	85.58	Aphanizomenon	13.42	Actinocyclus	44.30
Peridiniella catenata	3.64	Mesodinium rubrum	11.90	Coscinodiscus granii	12.33
Peridiniella danica	1.94	Actinocyclus	11.34	Unicell spp.	11.55
Gymnodiniales	1.39	Nodularia spumigena	7.97	Mesodinium rubrum	7.61
Aphanizomenon	1.24	Plagioselmis prolonga	7.73	Actinocyclus normanii f. subsalsus	5.29
Heterocapsa rotundata	0.85	Gymnodiniales	5.26	Gymnodiniales	5.12
Teleaulax	0.74	Ebria tripartita	4.41	Teleaulax	4.04
Amylax triacantha	0.43	Teleaulax	4.38	Chaetoceros castracanei	1.24
Dinophysis	0.37	Prymnesiales	4.30	Eutreptiella	1.16
Dinobryon balticum	0.32	Pyramimonas	3.86	Chaetoceros danicus	1.06

Eastern Gotland Basin (Stat. OMBMPJ1)					
Phytopl. biomass in µg/L	1161	Phytopl. biomass in µg/L	712	Phytopl. biomass in µg/L	90
Mesodinium rubrum	87.74	Mesodinium rubrum	14.66	Actinocyclus	30.29
Peridiniella danica	2.37	Gymnodiniales	10.82	Mesodinium rubrum	20.71
Aphanizomenon	1.47	Nodularia spumigena	10.57	Gymnodiniales	12.64
Amylax triacantha	1.31	Prymnesiales	9.08	Unicell spp.	12.57
Actinocyclus	0.95	Cyanodictyon planctonicum	8.89	Teleaulax	9.47
Gymnodiniales	0.95	Aphanothece paralleliformis	7.21	Chaetoceros danicus	1.92
Peridiniella catenata	0.74	Aphanocapsa	6.49	Chaetoceros castracanei	1.61
Dinophysis acuta	0.43	Aphanizomenon	4.23	Aphanothece	1.40
Dinophysis acuminata	0.43	Aphanothece	3.25	Plagioselmis prolonga	1.37
Peridiniales	0.39	Actinocyclus	2.55	Hemiselmis	1.28

Table A2

Phytoplankton taxa list of 2017, with class affiliation, biomass rank (for all stations, all depths) and seasonal occurrence from the five monitoring cruises.

Continued on page 94-95.

Taxon	Class	Rank	Feb.	March	May	Aug.	Nov.
<i>Actinocyclus</i> sp.	Bacillarioph.	10	X	X	X	X	X
<i>Actinocyclus normanii</i> f. <i>subsalsus</i>	Bacillarioph.	39	X	X		X	X
<i>Actinoptychus senarius</i>	Bacillarioph.	79				X	X
<i>Alexandrium pseudogonyaulax</i>	Dinophyceae	25				X	X
<i>Amphidinium crassum</i>	Dinophyceae	120		X		X	X
<i>Amphidinium sphenoides</i>	Dinophyceae	92	X	X	X	X	X
<i>Amylax triacantha</i>	Dinophyceae	66		X			
<i>Apedinella radians</i>	Chrysophyc.	51	X	X	X	X	X
<i>Aphanizomenon</i> sp.	Cyanobact.	26	X	X	X	X	X
<i>Aphanocapsa</i> spp.	Cyanobact.	48	X	X	X	X	X
<i>Aphanothece</i> spp.+ <i>Anathece</i> spp.	Cyanobact.	71			X	X	X
<i>Aphanothece paralleliformis</i>	Cyanobact.	68	X		X	X	X
<i>Attheya longicornis</i>	Bacillarioph.	135	X	X		X	X
<i>Attheya septentrionalis</i>	Bacillarioph.	96	X	X		X	X
<i>Binuclearia lauterbornii</i>	Ulvophyceae	72	X	X	X	X	X
<i>Centrales</i>	Bacillarioph.	56	X	X	X	X	X
<i>Cerataulina pelagica</i>	Bacillarioph.	16	X	X		X	X
<i>Ceratium furca</i>	Dinophyceae	108					X
<i>Ceratium fusus</i>	Dinophyceae	14	X	X		X	X
<i>Ceratium lineatum</i>	Dinophyceae	57					X
<i>Ceratium longipes</i>	Dinophyceae	83				X	X
<i>Ceratium tripos</i>	Dinophyceae	2	X			X	X
<i>Chaetoceros</i> spp.	Bacillarioph.	67	X	X	X	X	X
<i>Chaetoceros affinis</i>	Bacillarioph.	119				X	X
<i>Chaetoceros brevis</i>	Bacillarioph.	106					X
<i>Chaetoceros castracanei</i>	Bacillarioph.	65	X	X		X	X
<i>Chaetoceros contortus</i>	Bacillarioph.	112				X	X
<i>Chaetoceros convolutus</i>	Bacillarioph.	73					X
<i>Chaetoceros curvisetus</i>	Bacillarioph.	125					X
<i>Chaetoceros danicus</i>	Bacillarioph.	75		X	X	X	X
<i>Chaetoceros decipiens</i>	Bacillarioph.	133	X		X		
<i>Chaetoceros minimus</i>	Bacillarioph.	136				X	
<i>Chaetoceros similis</i>	Bacillarioph.	82	X	X	X	X	X
<i>Chaetoceros socialis</i>	Bacillarioph.	128		X		X	X
<i>Chaetoceros subtilis</i>	Bacillarioph.	70	X	X	X	X	X
<i>Chaetoceros thronsenii</i>	Bacillarioph.	98		X		X	
<i>Chaetoceros wighamii</i>	Bacillarioph.	99	X	X			
<i>Choanoflagellate</i> spp.	Choanoflag.	63	X	X	X	X	X
<i>Chroococcales</i>	Cyanobact.	147				X	
<i>Cocconeis</i> spp.	Bacillarioph.	152					X
<i>Coelosphaerium minutissimum</i>	Cyanobact.	91			X	X	X
<i>Coscinodiscus</i> spp.	Bacillarioph.	32		X			
<i>Coscinodiscus concinnus</i>	Bacillarioph.	47				X	
<i>Coscinodiscus granii</i>	Bacillarioph.	19				X	X
<i>Cyanodictyon planctonicum</i>	Cyanobact.	59	X	X	X	X	X
<i>Cyanonephron styloides</i>	Cyanobact.	90			X	X	X
<i>Cyclotella</i> spp.	Bacillarioph.	74	X	X		X	X
<i>Cylindrotheca closterium</i>	Bacillarioph.	114	X	X	X	X	X
<i>Cymbomonas tetramitiformis</i>	Prasinophyc.	100				X	

<i>Dactyliosolen fragilissimus</i>	Bacillarioph.	31	X	X	X	X	X
<i>Dictyocha speculum</i>	Dictyochoph.	3	X	X	X	X	X
<i>Dinobryon</i> spp.	Chrysophyc.	131		X	X	X	
<i>Dinobryon balticum</i>	Chrysophyc.	94		X	X		
<i>Dinobryon faculiferum</i>	Chrysophyc.	117		X	X	X	
<i>Dinophysis</i> spp.	Dinophyceae	77					X
<i>Dinophysis acuminata</i>	Dinophyceae	49	X		X	X	X
<i>Dinophysis acuta</i>	Dinophyceae	81				X	
<i>Dinophysis norvegica</i>	Dinophyceae	23	X	X	X	X	X
<i>Dissodinium pseudolunula</i>	Dinophyceae	121				X	
<i>Ditylum brightwellii</i>	Bacillarioph.	34	X	X		X	X
<i>Dolichospermum</i> spp.	Cyanobact.	58			X	X	
<i>Ebria tripartita</i>	Ebriophyc.	37	X	X	X	X	X
<i>Eucampia zodiacus</i>	Bacillarioph.	104					X
<i>Euglenales</i>	Euglenoph.	129				X	
<i>Eutreptiella</i> spp.	Euglenoph.	44	X	X		X	X
<i>Eutreptiella braarudii</i>	Euglenoph.	113		X			
<i>Gonyaulax</i> spp.	Dinophyceae	134	X	X			
<i>Guinardia delicatula</i>	Bacillarioph.	11	X	X	X	X	X
<i>Guinardia flaccida</i>	Bacillarioph.	53					X
<i>Gymnodiniales</i>	Dinophyceae	8	X	X	X	X	X
<i>Gymnodinium corollarium</i>	Dinophyceae	88			X		
<i>Gyrodinium spirale</i>	Dinophyceae	64	X	X	X	X	X
<i>Hemiselmis</i> spp.	Dinophyceae	62	X	X	X	X	X
<i>Heterocapsa rotundata</i>	Dinophyceae	29	X	X	X	X	X
<i>Heterocapsa triquetra</i>	Dinophyceae	86				X	X
<i>Katablepharis</i> spp.	Incertae sedis	89			X	X	X
<i>Katablepharis ovalis</i>	Incertae sedis	141			X		
<i>Katablepharis remigera</i>	Incertae sedis	45	X	X	X	X	X
<i>Katodinium glaucum</i>	Dinophyceae	76	X	X	X	X	X
<i>Koliella longiseta</i>	Trebouxioph.	146				X	
<i>Koliella</i> spp.	Trebouxioph.	143	X			X	
<i>Laboea strobila</i> (incl. cf.)	Oligotrichea	95	X	X			X
<i>Lemmermanniella</i> spp.	Cyanobact.	156		X			
<i>Lemmermanniella pallida</i>	Cyanobact.	97				X	
<i>Lemmermanniella parva</i>	Cyanobact.	126			X	X	X
<i>Lennoxia faveolata</i>	Bacillarioph.	140	X				
<i>Leptocylindrus danicus</i>	Bacillarioph.	101	X			X	X
<i>Leptocylindrus minimus</i>	Bacillarioph.	105	X	X	X	X	X
<i>Leucocryptos marina</i>	Incertae sedis	60	X	X	X	X	X
<i>Lobocystis planctonica</i>	Chlorophyc.	85					X
<i>Melosira arctica</i>	Bacillarioph.	142		X			
<i>Merismopedia</i> spp.	Cyanobact.	155				X	
<i>Mesodinium rubrum</i>	Litostomatea	1	X	X	X	X	X
<i>Micracanthodinium claytonii</i>	Dinophyceae	78	X	X	X	X	X
<i>Monoraphidium contortum</i>	Chlorophyc.	150	X	X	X		X
<i>Monoraphidium minutum</i>	Chlorophyc.	157	X	X			
<i>Nitzschia longissima</i>	Bacillarioph.	154	X				
<i>Nitzschia paleacea</i>	Bacillarioph.	145				X	
<i>Nodularia spumigena</i>	Cyanobact.	35		X	X	X	X
<i>Oocystis</i> spp.	Trebouxioph.	107	X	X	X	X	X
<i>Pachysphaera</i> spp.	Prasinophyc.	139				X	
<i>Pennales</i>	Bacillarioph.	87	X	X		X	X
<i>Peridinales</i>	Dinophyceae	33		X	X	X	X
<i>Peridiniella catenata</i>	Dinophyceae	41	X	X	X		

<i>Peridiniella danica</i> (incl. cf.)	Dinophyceae	12	X	X	X		
<i>Phaeodactylum</i> cf. <i>tricornutum</i>	Bacillarioph.	130			X	X	
<i>Phalacroma rotundatum</i>	Dinophyceae	148					X
<i>Plagioselmis prolunga</i>	Cryptophyc.	20	X	X	X	X	X
<i>Planktolyngbya</i> spp.	Cyanobact.	144	X	X		X	
<i>Polykrikos schwartzii</i>	Dinophyceae	61				X	X
<i>Porosira glacialis</i>	Bacillarioph.	111		X			
<i>Proboscia alata</i>	Bacillarioph.	13	X	X	X	X	X
<i>Pronoctiluca pelagica</i>	Dinophyceae	153		X			X
<i>Prorocentrum cordatum</i>	Dinophyceae	50		X		X	X
<i>Prorocentrum micans</i>	Dinophyceae	24	X			X	X
<i>Protooperidinium</i> spp. (incl. cf.)	Dinophyceae	38	X	X	X	X	X
<i>Protooperidinium bipes</i>	Dinophyceae	127	X	X		X	X
<i>Protooperidinium depressum</i>	Dinophyceae	36	X	X			
<i>Protooperidinium divergens</i>	Dinophyceae	55					X
<i>Protooperidinium oblongum</i>	Dinophyceae	110				X	
<i>Protooperidinium pellucidum</i>	Dinophyceae	54	X	X		X	X
<i>Protooperidinium pentagonum</i>	Dinophyceae	124					X
<i>Prymnesiales</i>	Prymnesioph.	15	X	X	X	X	X
<i>Pseudanabaena</i> spp.	Cyanobact.	109				X	X
<i>Pseudanabaena limnetica</i>	Cyanobact.	46	X	X	X	X	X
<i>Pseudochattonella farcimen</i>	Dictyochoph.	27		X			
<i>Pseudo-nitzschia</i> spp.	Bacillarioph.	4	X	X		X	X
<i>Pseudo-nitzschia delicatissima</i> group	Bacillarioph.	151			X	X	
<i>Pseudo-nitzschia pungens</i>	Bacillarioph.	132			X		
<i>Pseudo-nitzschia seriata</i>	Bacillarioph.	69					X
<i>Pseudopedinella</i> spp.	Chrysophyc.	42	X	X	X	X	X
<i>Pseudosolenia calcar-avis</i>	Bacillarioph.	18	X		X	X	X
<i>Pterosperma</i> spp.	Prasinophyc.	116			X	X	
<i>Pyramimonas</i> spp.	Prasinophyc.	30	X	X	X	X	X
<i>Rhizosolenia hebetata</i> f. <i>semispina</i>	Bacillarioph.	7	X	X			
<i>Rhizosolenia setigera</i>	Bacillarioph.	6	X	X		X	X
<i>Rhizosolenia setigera</i> f. <i>pungens</i>	Bacillarioph.	40	X			X	X
<i>Rhodomonas</i> spp.	Cryptophyc.	137		X			
<i>Rhodomonas</i> cf. <i>marina</i>	Cryptophyc.	123		X			
<i>Romeria</i> spp.	Cyanobact.	138				X	X
<i>Scenedesmus</i> spp.	Chlorophyc.	149	X				
<i>Scrippsiella</i> cf. <i>hangoei</i>	Dinophyceae	21			X		
<i>Scrippsiella</i> spp. complex	Dinophyceae	84		X			
<i>Skeletonema marinoi</i>	Bacillarioph.	5	X	X	X	X	X
<i>Snowella</i> spp.	Cyanobact.	80	X	X	X	X	X
<i>Teleaulax</i> spp.	Cryptophyc.	17	X	X	X	X	X
<i>Telonema</i> spp.	Incertae sedis	52	X	X	X	X	X
<i>Thalassionema frauenfeldii</i>	Bacillarioph.	122					X
<i>Thalassionema nitzschioides</i>	Bacillarioph.	43	X	X	X	X	X
<i>Thalassiosira</i> spp.	Bacillarioph.	9	X	X	X	X	X
<i>Thalassiosira anguste-lineata</i>	Bacillarioph.	102	X	X			X
<i>Thalassiosira baltica</i>	Bacillarioph.	103		X			X
<i>Thalassiosira eccentrica</i>	Bacillarioph.	22	X		X	X	X
<i>Thalassiosira gravida</i>	Bacillarioph.	115					X
<i>Thalassiosira punctigera</i>	Bacillarioph.	28					X
<i>Trachelomonas</i> spp.	Euglenoph.	118		X	X	X	X
<i>Woronichinia</i> spp.	Cyanobact.	93	X			X	X
Number of taxa: total 157			81	90	70	109	109

Table A3: Seasonal occurrence of taxa found in the investigation area in 2017 with information on original description, taxonomic rank and taxonomic serial number (TSN) according to the Integrated Taxonomic Information System (ITIS).

	rank	TSN	Feb	March	May	Aug	Nov
Protozoa							
Tintinnidae Claparède & Lachmann, 1858	Family	46743		0			0
Annelida							
Polychaeta - Trochophora	Subphylum	914166	0	0		0	
Polychaeta - others	Subphylum	914166	0	0	0	0	0
<i>Harmothoe</i> spp. Kinberg, 1856	Genus	64502	0	0	0		0
<i>Pectinaria</i> spp. Savigny in Lamarck, 1818	Genus	67706		0		0	0
<i>Spionidae</i> Grube, 1850	Family	66781		0	0	0	0
Arthropoda - Crustacea							
Copepoda							
<i>Acartia bifilosa</i> Giesbrecht, 1881	Species	86095	0	0	0	0	0
<i>Acartia longiremis</i> Lilljeborg, 1853	Species	86087	0	0	0	0	0
<i>Acartia tonsa</i> Dana, 1849	Species	86088			0	0	0
<i>Calanus</i> spp. Leach, 1819	Genus	85263	0				0
<i>Calanus helgolandicus</i> Claus, 1863	Species	85276	0				
<i>Centropages hamatus</i> Lilljeborg, 1853	Species	85766	0	0	0	0	0
<i>Eurytemora affinis</i> Poppe, 1880	Species	85863	0	0	0	0	0
<i>Euterpina acutifrons</i> Dana, 1847	Species	86546	0	0	0	0	0
Harpacticoida G. O. Sars, 1903	Ordnung	86110			0		
<i>Microsetella</i> spp. Brady & Robertson, 1873	Genus	86208	0	0	0	0	0
<i>Oithona similis</i> Claus, 1866	Species	88805	0	0	0	0	0
<i>Paracalanus parvus</i> Claus, 1863	Species	85323	0		0	0	0
<i>Pseudocalanus</i> spp. Boeck, 1872	Genus	85369	0	0	0	0	0
<i>Temora longicornis</i> O.F.Müller, 1785	Species	85877	0	0	0	0	0
Phyllopoda							
<i>Bosmina</i> spp. Baird, 1845	Genus	83936			0	0	0
<i>Evadne nordmanni</i> Lovén, 1836	Species	86546	0	0	0	0	0
<i>Podon intermedius</i> Lilljeborg, 1853	Species	83965		0	0	0	0
<i>Podon leuckartii</i> G. O. Sars, 1862	Species	83966	0	0	0		
<i>Pleopsis polyphaemoides</i> (Leuckart, 1859)	Species	684626		0		0	0
other Crustacea							
<i>Balanus</i> spp. Costa, 1778	Genus	89600	0	0	0	0	0
<i>Crangon crangon</i> Linnaeus, 1758	Species	107552				0	
<i>Carcinus maenas</i> Linnaeus, 1758	Species	107381					
<i>Diastylis</i> spp. Say, 1818	Genus	90836	0				
Gammaridea Latreille, 1802	Suborder	93295				0	
Isopoda Latreille, 1817	Order	92120					0
<i>Liocarcinus</i> spp. Stimpson, 1871	Genus	660431				0	
Lophogastrida G. O. Sars, 1870	Order	89808				0	
Ostracoda Latreille, 1802	Class	84195	0				

Table A3 continued.

	Rang	TSN	Feb	March	May	Aug	Nov
other Crustacea							
<i>Palaemon serratus</i> (Pennant, 1777)	Species	96451				0	
<i>Peltoaster paguri</i> Rathke, 1842	Species	89745		0			
Bryozoa							
Gymnolaemata Allman, 1856	Class	155471	0	0	0	0	0
Chaetognatha							
Sagittidae Claus and Grobben, 1905	Family	158726	0	0		0	0
Chordata							
<i>Fritellaria borealis</i> Lohmann, 1896	Species	159675	0	0	0		0
<i>Oikopleura dioica</i> Fol 1872	Species	159669	0			0	0
Teleostei	Infraclass	161105	0	0	0	0	0
Echinodermata							
<i>Asterias</i> spp. Linnaeus, 1758	Genus	157215				0	
<i>Ophiura</i> spp. Lamarck, 1801	Genus	157411				0	
<i>Echinus</i> spp. Linnaeus, 1758	Genus	157944				0	
Cnidaria & Ctenophora							
Actinulida Swedmark and Teissier, 1958	Order	50864				0	
Anthothecatae Cornelius, 1992	Order	718925	0	0		0	
<i>Aurelia aurita</i> Linnaeus, 1758	Species	51701	0	0			
Ctenophora Eschscholtz, 1829	Phylum	53856	0	0	0	0	0
<i>Euphysa aurata</i> Forbes, 1848	Species	48976				0	
<i>Lizzia blondina</i> Forbes, 1848	Species	48874				0	0
<i>Obelia geniculata</i> (Linnaeus, 1758)	Species	49522			0	0	
Leptothecatae Cornelius, 1992	Order	718926				0	
<i>Rathkea octopunctata</i> M. Sars, 1835	Species	49387	0				
<i>Stauridosarsia gemmifera</i> Forbes, 1848	Species	49055				0	
Phoronida							
<i>Phoronis muelleri</i> Selys-Longchamps, 1903	Species	206663				0	
Nemertea							
Nemertea	Phylum	57411					0
Nematoda							
Nematoda	Phylum	59490	0	0			
Platyhelminthes							
<i>Alaurina</i> spp. Metschnikoff, 1861	Genus	54024	0		0	0	0
Leptoplanidae Stimpson, 1857	Family	54115	0	0			
Mollusca							
Bivalvia Linnaeus, 1758	Class	79118	0	0	0	0	0
Gastropoda Cuvier, 1797	Class	69459	0	0	0	0	0
Rotifera							
<i>Synchaeta</i> spp. Ehrenberg, 1832	Genus	59255	0	0	0	0	0
<i>Keratella quadrata</i> O. F. Muller, 1786	Species	58352					0

Table A4: Distribution of macrozoobenthos at 8 stations in November 2017. 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=extremely rare, D=data deficient, *=least concern, ne=not evaluated).

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Amphipoda									
<i>Ampithoe rubricata</i>				1					*
<i>Corophium volutator</i>								1	*
<i>Crassikorophium crassicorne</i>					1				*
<i>Dexamine spinosa</i>		1		1					*
<i>Gammarellus homari</i>		1							*
<i>Gammarus locusta</i>				1	1				V
<i>Gammarus oceanicus</i>				1	1	1		1	*
<i>Gammarus salinus</i>				1	1	1	1	1	*
<i>Gammarus zaddachi</i>					1		1	1	*
<i>Grandidierella japonica</i>				1					ne
<i>Melita nitida</i>								1	ne
<i>Microdeutopus gryllotalpa</i>	1	1	1	1	1		1	1	*
<i>Monocorophium insidiosum</i>				1					*
<i>Phtisica marina</i>	1	1							*
<i>Pontoporeia femorata</i>						1			V
<i>Protomedeia fasciata</i>		1							R
Anthozoa									
<i>Edwardsia danica</i>				1					D
<i>Halcompa duodecimcirrata</i>		1							1
<i>Sagartia</i> sp.		1		1					ne
Asciacea									
<i>Ciona intestinalis</i>		1							*
<i>Dendrodoa grossularia</i>	1	1							V
<i>Molgula manhattensis</i>	1								D
Bivalvia									
<i>Abra alba</i>		1			1				*
<i>Arctica islandica</i>	1	1	1	1		1			3
<i>Astarte borealis</i>	1			1	1	1			G
<i>Astarte elliptica</i>	1					1			G
<i>Astarte montagui</i>	1								3
<i>Cerastoderma glaucum</i>								1	*
<i>Corbula gibba</i>	1	1	1	1	1	1			*
<i>Kurtiella bidentata</i>	1	1	1	1					*
<i>Limecola balthica</i>					1	1	1	1	*
<i>Musculus niger</i>	1								G
<i>Musculus subpictus</i>	1								G
<i>Mya arenaria</i>					1		1	1	*
<i>Mya truncata</i>	1								2
<i>Mytilus edulis</i>	1	1	1	1	1	1	1	1	*
<i>Nucula nitidosa</i>		1							*
<i>Parvicardium pinnulatum</i>	1	1							D
<i>Parvicardium scabrum</i>	1								D
<i>Phaxas pellucidus</i>	1	1							*

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
<i>Spisula subtruncata</i>	1	1							G
Bryozoa									
<i>Alcyonidium diaphanum</i>	1								*
<i>Alcyonidium polyoum</i>							1		D
<i>Callopora lineata</i>		1			1				*
<i>Cribrilina punctata</i>	1	1							*
<i>Einhornia crustulenta</i>		1					1	1	*
<i>Electra pilosa</i>	1	1			1				*
<i>Escharella immersa</i>		1							*
<i>Eucratea loricata</i>		1		1	1				V
<i>Farrella repens</i>	1								D
<i>Flustra foliacea</i>	1	1							*
Cirripedia									
<i>Balanus crenatus</i>			1		1				*
Cumacea									
<i>Diastylis rathkei</i>	1	1	1	1	1	1	1		*
<i>Eudorella truncatula</i>		1							*
Decapoda									
<i>Carcinus maenas</i>					1				*
<i>Crangon crangon</i>	1	1	1	1	1		1	1	*
<i>Eualus pusiolus</i>		1							D
<i>Palaemon elegans</i>				1					*
<i>Pandalina brevirostris</i>	1								G
Echinodermata									
<i>Asterias rubens</i>	1	1		1	1				*
<i>Ophiura albida</i>	1	1							*
<i>Psammechinus miliaris</i>	1								*
Gastropoda									
<i>Aporrhais pespelecani</i>	1								G
<i>Facelina bostoniensis</i>	1	1		1					*
<i>Peringia ulvae</i>		1	1	1	1	1	1	1	*
<i>Philine aperta</i>	1	1							*
<i>Pusillina inconspicua</i>	1			1	1				*
<i>Retusa obtusa</i>			1		1				*
<i>Retusa truncatula</i>	1	1			1				*
<i>Rissoa membranacea</i>		1			1				V
Hirudinea									
<i>Piscicola</i> sp.							1		ne
Hydrozoa									
<i>Hartlaubella gelatinosa</i>							1		D
<i>Sertularia cupressina</i>	1	1			1				G
Isopoda									
<i>Idotea balthica</i>				1	1				*
<i>Idotea chelipes</i>								1	D
<i>Jaera albifrons</i>					1		1	1	*
Mysida									
<i>Gastrosaccus spinifer</i>	1	1		1					ne
<i>Mesopodopsis slabberi</i>					1				ne

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
<i>Mysis mixta</i>							1		ne
<i>Neomysis integer</i>						1	1	1	ne
<i>Praunus flexuosus</i>								1	ne
<i>Praunus inermis</i>		1							ne
Nemertea									
<i>Cyanophthalma obscura</i>					1				ne
<i>Lineus ruber</i>		1	1		1		1		ne
<i>Malacobdella grossa</i>	1		1						ne
<i>Nemertea</i>	1	1			1		1		ne
<i>Tubulanus polymorphus</i>	1				1				ne
Oligochaeta									
<i>Baltidrilus costatus</i>								1	*
<i>Nais elinguis</i>							1		*
Tubificidae		1	1	1	1	1	1	1	ne
<i>Tubificoides benedii</i>	1			1	1		1	1	*
Phoronida									
<i>Phoronis</i> sp.	1	1							ne
Plathelminthes									
<i>Turbellaria</i>	1						1	1	ne
Polychaeta									
<i>Alitta succinea</i>	1							1	D
<i>Ampharete baltica</i>	1	1			1	1			*
<i>Arenicola marina</i>		1			1				*
<i>Aricidea suecica</i>	1	1			1				*
<i>Bylgides sarsi</i>		1							*
<i>Capitella capitata</i>	1			1	1				*
<i>Dipolydora coeca</i>	1								*
<i>Dipolydora quadrilobata</i>	1	1	1	1	1				*
<i>Eteone longa</i>					1				*
<i>Euchone papillosa</i>		1							2
<i>Harmothoe imbricata</i>		1							D
<i>Harmothoe impar</i>	1	1		1	1				*
<i>Hediste diversicolor</i>				1			1	1	*
<i>Heteromastus filiformis</i>	1		1			1			*
<i>Lagis koreni</i>	1	1	1	1					*
<i>Levinsenia gracilis</i>	1								*
<i>Lysilla loveni</i>		1							R
<i>Marenzelleria neglecta</i>							1	1	ne
<i>Marenzelleria viridis</i>							1	1	ne
<i>Neoamphitrite figulus</i>		1							*
<i>Nephtys ciliata</i>		1							*
<i>Nephtys hombergii</i>	1	1	1	1		1			*
<i>Nereimyra punctata</i>		1							G
<i>Paradoneis eliasoni</i>	1								*
<i>Paraonis fulgens</i>			1						*
<i>Pherusa plumosa</i>		1							D
<i>Pholoe baltica</i>	1								*
<i>Phyllodoce groenlandica</i>		1							*

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
<i>Phyllodoce mucosa</i>	1	1	1	1					*
<i>Phyllodoce rosea</i>	1								*
<i>Poecilochaetus serpens</i>		1							*
<i>Polydora ciliata</i>	1			1	1				*
<i>Polydora cornuta</i>	1		1	1					*
<i>Prionospio steenstrupi</i>	1	1							*
<i>Pseudopolydora pulchra</i>	1		1	1					*
<i>Pygospio elegans</i>					1		1	1	*
<i>Scalibregma inflatum</i>		1							G
<i>Scoloplos armiger</i>		1			1		1		*
<i>Spio arndti</i>		1							*
<i>Spio gonioccephala</i>	1	1			1				*
<i>Streblospio shrubsolii</i>								1	V
<i>Terebellides stroemii</i>		1	1			1			*
<i>Travisia forbesii</i>					1		1		G
Porifera									
<i>Chalinula limbata</i>	1	1							D
<i>Haliclona oculata</i>		1							D
<i>Leucosolenia</i> sp.		1							ne
Priapulida									
<i>Halicryptus spinulosus</i>		1	1				1		ne
<i>Priapulus caudatus</i>			1						ne
Pycnogonida									
<i>Nymphon brevirostre</i>			1						*
species number 142	63	71	25	37	47	17	29	27	
abundance (ind m⁻²)	6930	3038	488	1239	4605	242	3246	8790	
biomass (afdw g m⁻²)	59.3	18.7	15.0	16.2	12.3	2.3	1.4	17.2	

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Summary

Acknowledgements

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Annex

