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Biological assessment of the Baltic Sea 2015

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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 Arkona Basin was continued in 2015.

The phytoplankton spring bloom occurred in the Belt Sea at least from 24.2. to 18.3.2015, but extended much longer as additional samples from Mecklenburg Bight revealed. In the Arkona Basin, the peak was met in the period from 7. to 18.3.2015 and in the Bornholm Basin in late April. A succession from diatoms and *Mesodinium rubrum* to dinoflagellates and dictyochophyceae and finally to prymnesiophyceae appeared in Kiel Bay and the central Bay of Mecklenburg whereas the spring bloom in the Arkona Basin was dominated by *Mesodinium rubrum* and *Skeletonema marinoi*. In summer, a diatom bloom failed, but Cyanobacteria developed in the area from the western Baltic to the northern Gotland Basin up to 7 weeks, with phases of different distributions and intensities. In the autumn bloom, the typical *Ceratium* spp. were missing in the Belt Sea, but diverse diatoms dominated. Invading phytoplankton species after the Major Baltic Inflow were negligible.

The chlorophyll *a* concentrations were highest (9.45 mg m^{-3}) during the spring bloom in the Bay of Mecklenburg in mid-March.

The seasonal pattern of vertical export of particulate organic matter in the Arkona Basin in 2015 showed only a minor peak in spring and an elongated period of high flux during summer with a clear succession of algal species within and between the sedimentation maxima. Cyanobacterial summer flux was high and resuspension events of already settled material could be observed in periods of intense winter mixing in January and December. The total annual flux for single elements in 2015 corrected for resuspension amounted to 426 mmol C (5.1 g C), 60 mmol N, 77 mmol Si and 2.1 mmol P m^{-2} a^{-1} at a mass flux of 49 g dry mass m^{-2} a^{-1}.

The seasonal zooplankton development started considerably earlier in 2015 compared to previous years, particularly in the Bay of Mecklenburg and the Arkona Basin. Caused by a high density of rotifers and increased stocks of copepods and appendicularians the maximum abundance was already observed in late March. The abundance of cladocerans was, in contrast, exceptionally low; typical mass occurrences of the genus *Bosmina* were not observed in 2015. In addition to the seasonal timing, an increase in the number of the zooplankton taxa was recorded. This increase was related to the inflow of saline water in spring and autumn, which brought halophilic zooplankton into the investigation area. The species included, among others, were *Acartia clausi*, *Calanus* spp., *Oithona atlantica* (Copepoda), *Penilia avirostris* (Cladocera) and *Parasagitta setosa* (Chaetognatha).

The 119 species found in the macrozoobenthos mark a moderate diversity. The oxygen supply in bottom waters in the current year was always higher than 2.5 mg/l; no negative effects on macrozoobenthos were detected. Depending on the region, the abundances ranged from 389 to 19.003 ind./m^2, and the biomass (ash free dry weight) from 2.0 g/m^2 to 82.6 g/m^2. The high number of species (22) and salinity (22.7 psu) in the central Arkona Basin indicate a saltwater inflow in the year before. Twenty species of the German Red List were observed at the 8 monitoring stations. With three, the number of invasive species was low in 2015.

1. Introduction

This report presents the results of the biological monitoring carried through at the Leibniz-Institute for Baltic Sea Research in Warnemünde (IOW). Within Germany's Exclusive Economic Zone (EEZ), monitoring is undertaken on behalf of the Federal Maritime and Hydrographic Agency (BSH); in the Baltic Proper (Bornholm Basin, Eastern Gotland Basin), long-term data collection is financed from the IOW's own budget. This assessment is a substantially unaltered translation of the report submitted to the BSH in August 2015; it was supplemented by data from the Bornholm Basin and Eastern Gotland Basin.

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 a focus on marine biology, the monitoring programme also includes an extensive programme of hydrographic and chemical investigations (NAUSCH et al. 2016). 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 north German coastal states. When the administrative agreement relating to the protection of the marine environment ('Verwaltungsabkommen Meeresschutz') entered into force on 30 March 2012, the 'Arbeitsgemeinschaft Bund/Länder-Messprogramm Nord- und Ostsee' (ARGE BLMP) was succeeded by the 'Bund/Länder-Ausschuss Nord- und Ostsee' (BLANO) with an extended remit to ensure implementation of the requirements of the EU's Marine Strategy Framework Directive (MSFD) (see http://www.blmp-online.de/Seiten/Infos.html). Through national databases, the collected data are notified annually to ICES (International Council for the Exploration of the Sea, see http://www.ices.dk/indexnofla.asp). International monitoring results were collected, discussed and published by HELCOM in Periodic Assessments (HELCOM 1987, 1990, 1996, 2002). Now specialist Thematic Assessments are published on the influence of climatic change (HELCOM 2013a), or eutrophication (HELCOM 2014a), for instance. In similar manner, short reports known as 'Baltic Sea Environment Fact Sheets' (formerly 'Indicator Fact Sheets') are published annually (JAANUS et al. 2007, HAJDU et al. 2008, OLENINA et al. 2009, OLENINA AND KOWNACKA 2010, ÖBERG 2014, WASMUND et al. 2016). 'Indicator Fact Sheets' were also produced within the scope of the BLMP such as that on chlorophyll within Germany's EEZ in the Baltic Sea (WASMUND et al. 2011 b).

Cooperation is increasingly being framed in a European context. The European Committee for Standardization (CEN, see http://www.cen.eu/cenorm/homepage.htm), for instance, has elaborated Standard Operating Procedures that apply throughout Europe, and are largely compatible with the HELCOM methods we have applied consistently for many years. The legal framework for intensified international cooperation is provided by the EU's Water Framework Directive (WFD, see EUROPEAN UNION 2000, and http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:DE:HTML) and the EU's Marine Strategy Framework Directive (MSFD, see EUROPEAN UNION 2008, and http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:DE:PDF).
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. As part of its implementation in the

German sectors of the North Sea and Baltic Sea, among other things the following had been undertaken by 2012:

- an initial assessment of the seas
- a description of the good environmental status and
- a definition of environmental objectives

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

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

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

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

The monitoring data collected by IOW provide a solid foundation on which to develop and test these indicators and to implement the Marine Strategy Framework Directive. Close cooperation between oceanographers, marine biologists and marine chemists within IOW permits the comprehensive scientific analysis of the collected biological data which are interpreted in the light of the 2014 hydrographic-hydrochemical assessment of the Baltic Sea that has already been published (NAUSCH et al. 2016).

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 the satellite imagery.

2. Material and Methods

2.1 Sampling Strategy

The functions undertaken by IOW are defined by the BSH (Bundesamt für Seeschifffahrt Und Hydrographie 2015), and they follow HELCOM guidelines. Biological monitoring by IOW includes determining the qualitative and quantitative composition of phytoplankton, mesozooplankton and macrozoobenthos, determining the chlorophyll *a* content of water samples, and analysis of sediment traps. Phytoplankton growth is also tracked by means of satellite images. The methods to be applied are set out in the HELCOM manual (HELCOM 2014b).

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

61 additional phytoplankton samples were taken during 9 cruises outside the regular monitoring program for use in the project "Developing the indicator Diatom/Dinoflagellate index" funded by the Bundesamt für Naturschutz (funding number: Z 1.2 – 53202/AWZ/2015/ 5). Stations of the additional samples are not shown in Table 1 and Fig. 1. They may be looked up from the project report of Wasmund &Powilleit (2016). Information on the additional stations (e.g. sampling dates) can also be extracted from the Figs. 5-7.

Table 1
Sampling statistics (number of sampling events) of different parameters specified for regular monitoring sampling stations in 2015. The additional samples (mentioned above) are not included.

Station number	IOW-station number	Chloro-phyll	Phyto-plankton	Zoo-plankton	Zoo-benthos
Belt Sea					
OMBMPN3	TF0360	5	5	5	1
OMBMPN1	TF0010	-	-	-	1
OMBMPM2	TF0012	8	8	8	1
OMO22	TF0022	3	3	-	-
OM18	TF0018	-	-	-	1
OMBMPM1	TF0046	9	9	9	-
Arkona Basin					
OMBMPK8	TF0030	9	9	9	1
OMBMPK5	TF0113	9	9	9	-
OMBMPK4	TF0109	5	5	5	1
Pomeranian Bay					
OMBMPK3	TF0152	-	-	-	1
OM160	TF0160	-	-	-	1
Bornholm Basin					
OMBMPK2	TF0213	8	8	8	-
Eastern Gotland Basin					
OMBMPK1	TF0259	4	4	4	-
OMBMPJ1	TF0271	5	5	5	-

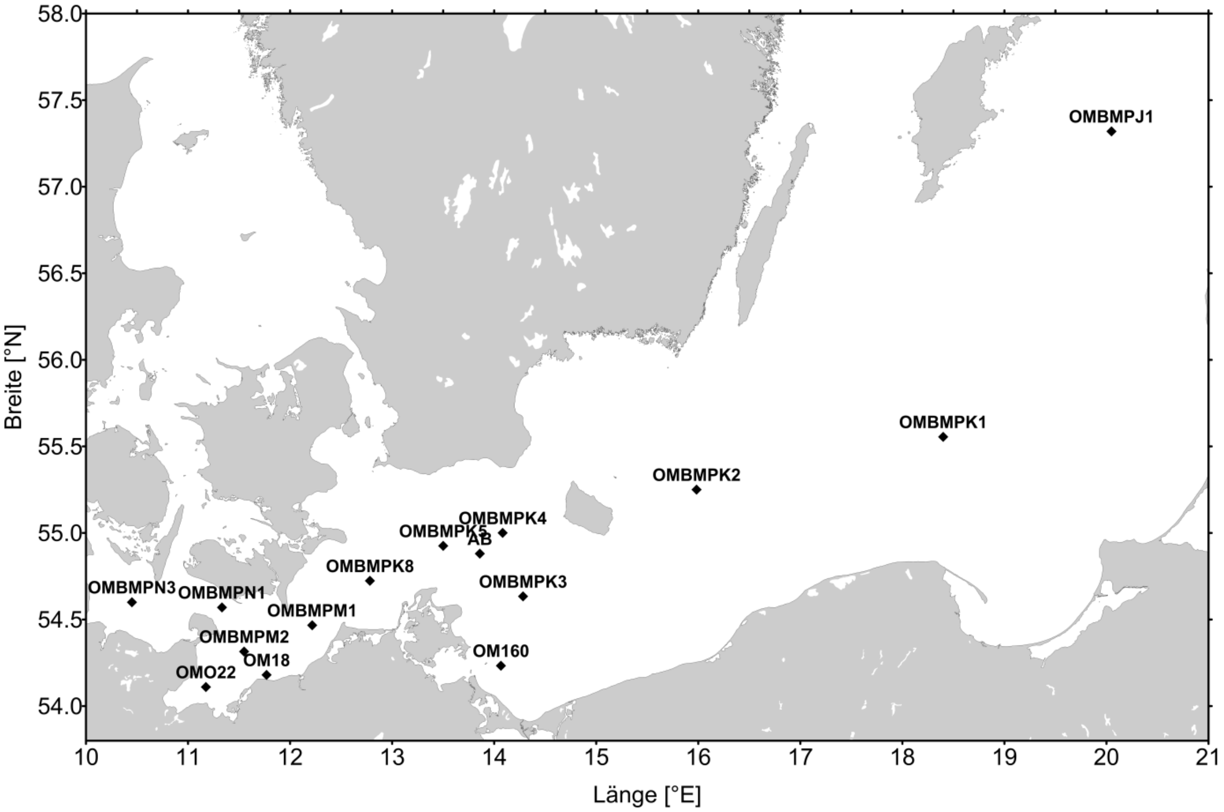


Fig. 1: The station grid for biological sampling in the Baltic Sea (except the additional cruises).

Also data from an in-house project of the IOW called “POSEC” were consulted. This project delivered phytoplankton and chlorophyll samples from the Eastern Gotland Basin from 12.4. to 16.5.2015 taken on the ship “Finnmaid” that traversed the Baltic two times a week. However, we cannot present the numerous phytoplankton and chlorophyll data (n=128) in the frame of this paper.

Within the regular monitoring program, plankton samples should be collected both on outbound and inbound cruises, if possible. Five cruises yield a maximum of 10 samples per station per year. Samples at stations OMBMPN3 (Kiel Bay), OMO22 (Lübeck Bay), OMBMPK4 (Arkona Basin) and OMBMPK1/OMBMPJ1 (Eastern Gotland Basin) are taken as standard on the outward leg only. On the February cruise, samples could not be taken on the return way, which is not problematic because the gap could be filled by samples from the additional cruises (cf. Figs. 5-6). The summer cruise was combined with a project cruise and therefore extended.

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

In line with HELCOM guidelines, sampling is adapted to suit hydrographic conditions. When the water column is well mixed, a zooplankton net sample is taken from the sea floor to the surface. Vertical hauls over specific depth ranges are taken when saline water at depth has produced a halocline, or when seasonal warming in spring and summer has produced a thermocline. On our scheduled cruises in 2015, we collected a total of 97 zooplankton samples. Table 2 gives details about the bodies of water that were sampled at the various stations.

Samples of macrozoobenthos are collected at 8 stations once a year in November (see Table 3, page 13).

2.2 Phytoplankton

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

The biomass of individual phytoplankton species is analysed microscopically using the standard method according to UTERMÖHL (1958). During counting, individuals are classified not just according to taxa, but also size classes in line with HELCOM guidelines (OLENINA et al. 2006). To obtain a statistically acceptable estimate, at least 50 individuals of the most abundant species need to be counted. Thus for the most common individual species, a statistical counting error of around 28 % may be assumed. Generally at least 500 individuals are counted per sample. The error in estimated total biomass is thus clearly reduced (< 10 %). Each species and size class has its own unique volume. This figure is multiplied by the number of counted individuals to obtain the biovolume of a particular species. Assuming a density of 1 g cm^{-3} the biovolume equates quantitatively 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, the species and biovolume list PEG_BVOL2015 was used;
see http://www.ices.dk/marine-data/Documents/ENV/PEG_BVOL.zip. The phytoplankton samples of the following cruises were analysed with the list PEG_BVOL2016, which is confirmed by PEG during the meeting in April 2016. Details about the species list are also available to view on the ICES website: http://www.ices.dk/marine-data/Pages/default.aspx (click on HELCOM PEG BIOVOLUME on the home page).

2.3 Chlorophyll

As chlorophyll *a* represents a percentage share of the biomass of all plant cells - and also therefore of phytoplankton - its concentration is indicative of the total biomass of phytoplankton. 1 mg chlorophyll *a* equates to some 30 mg of algal organic carbon in the spring and autumn, or up to 60 mg in the summer (after GARGAS et al. 1978). 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. Because of the variability of these factors, conversion is not usually done, and the concentration of chlorophyll *a* is taken directly as a phytoplankton parameter.

Samples for the determination of chlorophyll *a* concentrations are collected together with phytoplankton samples at standard depths of 1 m, 5 m, 10 m, 15 m and 20 m, and occasionally at other depths. 200-500 ml samples of water are filtered through glass-fibre filters (Whatman GF/F) that are flash-frozen in liquid nitrogen (-196°C) and stored in the Institute laboratory at -80°C for a maximum of three months. 96 % ethanol is used for extraction, as specified by HELCOM (2014b). It is thus possible to dispense with 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, however (cf. WASMUND 1984, STICH & BRINKER 2005). Unlike in shallow coastal waters, phaeopigments are not major players in the open sea, so there is no need for the 'acidification method'. This allows us to switch to a simpler and more readily reproducible method that does not involve acidification of the extracts.

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

2.4 Sedimentation

Within the IOW Arkona Basin sampling area, rates of vertical particle flux (sedimentation) were measured over the course of the year. To record the amount and quality of material sinking from the surface layer to the sea floor, we anchored 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 2015 went according to plan. Moorings could be retrieved at regular intervals without any technical or logistical problems. At the beginning and at the end of the year storm-induced resuspension events caused a massive collection of material of benthic origin. At this time of the year the material was with great certainty not formed in the water column but resuspended from the sediment. Therefore data from this period were omitted from mass flux calculations.

Due to the failure of a photoelectric barrier the samples in the second half of the year were not collected in successive glasses. By means of the electronic trap protocol the sequence of sampling could, however, be reconstructed. This was corroborated by a detailed analysis of the seasonal succession and temporal growth pattern of algae blooms in comparison with the previous years.

2.5 Mesozooplankton

In line with HELCOM guidelines, zooplankton sampling is adjusted to match the hydrographic conditions. Generally, vertical net tows are collected using a WP-2 net of 100 µm mesh size. In the case of a well-mixed water column like in shallow areas, zooplankton is sampled with a single net catch taken from a few meters above the sea floor to the surface. Stratified hauls in specific layers are 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° are avoided during sampling. Samples were fixed in 4 % aqueous formalin solution until processing. On the scheduled cruises in 2015, a total of 97 zooplankton samples were collected. 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; the remainder was examined for less common or invasive species. With the exception of nauplii, rotifers and Bosminidae, at least 100 individuals from three taxa were counted. The abundance (ind. m^{-3}) is then calculated from counts and the filtered volume of the net. The taxonomic classification of the zooplankton followed an internal species list of the long-term record of the species inventory as well as the zooplankton atlas of the Baltic Sea (TELESH et al. 2008) and was based on the Integrated Taxonomic Information System (ITIS, 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 statistic of zooplankton hauls on monitoring cruises in 2015.

Station-label	Period				
	03.02. - 13.02.	17.03. - 30.03.	05.05. - 15.05.	22.07. - 13.08.	06.11. - 17.11.
	Depth from - to (m)	Depth from - to (m)	Depth from - to (m)	Depth from - to (m)	Depth from - to (m)
OMBMPN3	15 - 7 - 0	14- 0	14- 0	15- 0	14- 0
OMBMPM2	20 - 8 -0	20 - 0 20 - 0	20 - 8 - 0 20 - 10 - 0	25 - 0	20 - 0 22 - 0
OMBMPM1	23 - 0	21 - 15 - 0 22 - 0	21 - 0 22 - 0	22 - 0 22 -0	20 - 0 22 - 0
OMBMPK8	19 - 0	20 - 0 18 - 0	19 - 0 20 - 11 - 0	17 - 0 17 - 0	20 - 0 19 - 0
OMBMPK5	44 - 0	43 - 0 44 - 0	43 - 0 43 - 24 - 0	41 - 0 40 - 18 - 0	45 - 25 - 0 44 - 17 - 0
OMBMPK4	44 - 36 - 0	44 - 0	44 - 23 - 0	43 - 0	42 - 0
OMBMPK2	86 - 50 - 0	85 - 47 - 0 85 - 47 - 0	84 - 45 - 0 86 - 54 - 0	87 - 55 - 25 - 0 81 - 40 - 20 - 0	81 - 40 - 20 - 0 85 - 65 - 48 - 0
OMBMPK1	72 - 0	85 - 67 - 0	86 - 0	77 - 28 - 0	-
OMBMPJ1	110 - 65 - 0	120 - 65 - 0	200 - 70 - 30 - 0	110 - 65 - 25 - 0	200 - 40 - 0

2.6 Macrozoobenthos

In November 2015, benthos investigations were undertaken at 8 stations from Kiel Bay to the Pomeranian Bay; Table 3 shows their locations. Depending on sediment type, two different Van Veen grab samplers were deployed (980 cm² and 1060 cm², weighing 38 kg - 70 kg, and 23 kg respectively). Three hauls were made at each station. Each haul was rinsed in seawater through a 1 mm mesh sieve. The sieve residue was then transferred to beakers, and fixed in 4 % formalin (HELCOM 2014 b). At all stations, a “Kieler Kinderwagen” botanical dredge with a 1 m rectangular mouth and a mesh size of 5 mm was deployed. Especially in relation to vagile and rarer species, the dredge yielded finds that would have been missed using only the grab sampler.

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

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

Table 3
Station list of macrozoobenthic investigations in November 2015.

Station	Date	Depth	° North	° East	Sea area
OMBMPN3	07.11.2015	16.8	54° 36.00	10° 27.00	Kiel Bay
OMBMPN1	06.11.2015	25.8	54° 33.20	11° 20.00	Fehmarnbelt
OMBMPM2	06.11.2015	23.5	54° 18.90	11° 33.00	Bay of Mecklenburg
OM18	06.11.2015	19.5	54° 11.00	11° 46.00	Bay of Mecklenburg, south
OMBMPK8	07.11.2015	21.0	54° 44.00	12° 47.40	Darss Sill
OMBMPK4	09.11.2015	45.8	55° 00.00	14° 05.00	Arkona Basin
OMBMPK3	09.11.2015	29.3	54° 38.00	14° 17.00	Pomeranian Bay, north
OM160	09.11.2015	13.4	54° 14.50	14° 04.00	Pomeranian Bay, central

2.7 Quality Assurance

The application documents for the accreditation of the phytoplankton, zooplankton, zoobenthos and chlorophyll review groups were submitted at the beginning of 2011. Since then we have operated in the manner of accredited laboratories, and have maintained the necessary documentation. After a three-year preparatory phase in line with DIN EN ISO/IEC 17025:2005, assessment by Deutsche Akkreditierungsstelle GmbH (DAkkS) finally took place on 14 and 15 May 2014. It was completed successfully.

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; for details see http://www.io-warnemuende.de/analytik.html.

QA activities for individual parameters are described here in brief:

Phytoplankton

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

Expert identification of phytoplankton species depends on a laboratory technician's level of knowledge. The Phytoplankton Expert Group (PEG, see http://helcom.fi/helcom-at-work/projects/phytoplankton/) therefore runs annual training courses, and undertakes a ring test approximately every three years. The PEG meeting of 2015 took place in Pärnu (Estonia) from 13-17 April 2015 and was attended by three representatives of the IOW.

The last HELCOM ring test for phytoplankton was conducted in 2012 (GRINIENE et al. 2013). Plans for a ring test to be coordinated by the German company AquaEcology in Oldenburg were agreed at a workshop in Berlin on 27 and 28 November 2013 ('Methodische Abstimmung und Harmonisierung der Phytoplankton-Biovolumenbestimmung für das marine Monitoring') and will be conducted in 2016.

As happens every year, the biovolume list of species and size classes was updated for the previous year. Samples taken up until March 2015 are based on the official ICES and HELCOM biovolume file PEG_BIOVOL2015, and from May 2015 on biovolume file PEG_BIOVOL2016.

Chlorophyll

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

As an internal quality assurance measure, IOW regularly participates in chlorophyll comparisons within the QUASIMEME AQ-11 regime (chlorophyll in seawater). Additionally, the Umweltbundesamt organized a comprehensive Ring Test with two natural water samples and a stock solution received on 9 September and 16 September 2015. The evaluation is not finalized yet.

Zooplankton

The duplicate analysis of every 10th zooplankton sample was performed as an intra-laboratory routine to check the reliability of the zooplankton analysis. In 2015, this was done by either an independent analysis of samples by separate analysts or by the repeated analysis of the sample at times when the analysis was conducted by a single analyst. Deviations were well below the threshold value for critical errors of 10%.

The quality of the taxonomical analysis of zooplankton depends on the individual skills of the responsible technicians. In 2015, one analyst of the working-group, therefore, participated in a taxonomic training workshop organised by the ‚Plymouth Marine Laboratory (PML)‘ and the ‚Marine Biological Association of the UK (MBA)‘ from 22.06. to 26.06.2015 in Plymouth (UK). The workshop focused on the identification of key marine crustacean zooplankton found in North Atlantic and European waters and helped to resolve uncertainties in the identification of the genus *Paracalanus*.

The quality assurance of the analysis and identification of Baltic zooplankton is hampered by the lack of a common zooplankton sample analysis (ring test) scheduled within the framework of HELCOM. IOW has, therefore, agreed on a regular exchange of samples with the ‘Finnish Environmental Institute (Syke)’ in Helsinki, Finland. The analysis of the first results is pending.

Due to strongly varying biomass conversion factors used by different laboratories in the HELCOM area, the HELCOM working group ZEN-ZIIM decided to establish area-specific factors for each of the zooplankton time series. The required analysis of samples is in progress.

Macrozoobenthos

The IOW macrozoobenthos working group has participated in all QA measures to date. The fifth macrozoobenthos ring test was initiated in autumn 2013 by Germany’s Federal Environment Agency, the body that oversees QA of the BLMP. Analysis of sediment particle-size, determination of biomass, and the sorting, identification and counting of benthic species were tested. The assessments and results of the ring test were published in March 2015. IOW’s benthos laboratory achieved excellent results in all three tests.

3. Abiotic Conditions in 2015

The development of sea surface temperature (SST) was derived for the year 2015 on the basis of satellite data from the US NOAA and the European MetOp- weather satellites provided daily by the BSH Hamburg (NAUSCH et al. 2016).

The year 2015 was after 2014 the second warmest year since 1990, 0.9 K above the long-term average (1990-2015) and 0.3 K colder than 2014. Except the summer month, June to August, all other months contributed with their positive anomalies to this high annual mean value. SST anomalies of up to +2 K characterized nearly the entire Baltic from January – May, due to one of the mildest winters in air-temperature since 1948. January – March and October belonged to the warmest months since 1990. In the Eastern Gotland Basin, March was the coldest month of the year, and February in Arkona Basin and Bothnian Sea. The coldest week of the year was 18-24 February. The SST increase in late spring was not as pronounced as usual, particularly in June leading to negative anomalies for the monthly mean SST. A warming phase and following windy deep pressure influence, made 5 July to the warmest day in the western Baltic and in the Eastern Gotland Basin and caused negative anomalies for July. In August, SST increased particularly in the northern Baltic and 19 August became the warmest day of the year there. August anomalies were therefore positive in the northern Baltic and slightly negative in the southern and western parts. As in long-term average, August was the warmest month 2015. From September to December, positive anomalies slightly increased. November and December became the warmest ones since 1990.

The Major Baltic Inflow of December 2014 (MOHRHOLZ et al. 2015) and some following minor inflows of water from the North Sea led to a strong increase in the salinity (Fig. 28) and relatively high oxygen concentrations (Table 7, page 54) in the bottom water. They should have influenced our samples in 2015 and will be discussed in section 4.1.4 for phytoplankton and in section 4.3.5 for zoobenthos.

4. Results and Discussion

4.1 Phytoplankton

4.1.1 Development of Cyanobacteria Identified by Satellite Imagery

The development of cyanobacteria in the summer of 2015 was observed as in the previous year on the basis of high spatial resolution MODIS True colour scenes (RGB, 250 m) of the satellites Aqua and Terra. The Lance Rapid Response System of NASA provided the data.

In recent years, the first cyanobacteria were mostly observed around 25 June. In 2015, the first signs were recognized on 22 June in a cloud gap of the southeastern Baltic Sea. A warming phase with low winds at the end of June led to a fast development in the central Baltic from the Gulf of Finland to the Gdansk Bay. The first image of the Szczecin Lagoon on June 30 showed signs of cyanobacteria there. On 1 July, filaments were also visible in the western Bornholm Basin and in the eastern Arkona Basin and particularly east of Rügen Island. The filaments intensified slightly until 3 July as presented in a MODIS-Terra quasi-true colour image in Fig. 2. Cyanobacteria filaments extended from the Gulf of Finland along the southeastern Baltic coast to the Pomeranian Bay.

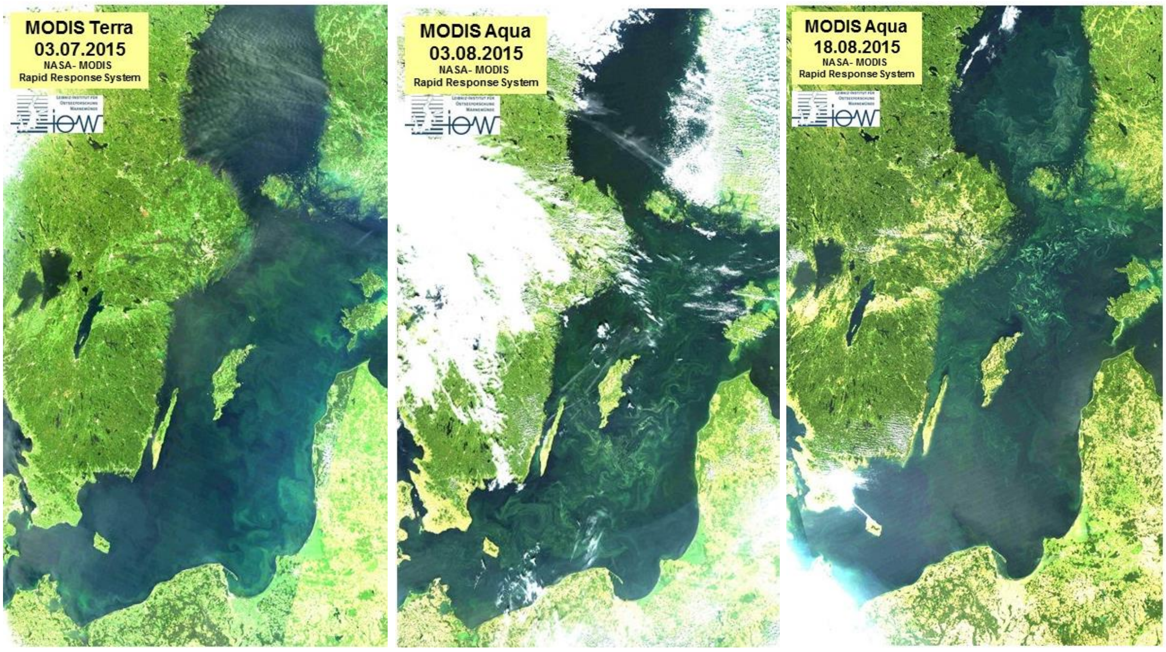


Fig. 2: Development of cyanobacteria in the central Baltic Sea on 3 July of MODIS Terra, on 3 August of MODIS Aqua and on 18 August 2015 of MODIS Aqua showing the different distributions.

During the following days, the weather changed completely and a cloudy period dominated the Baltic Sea region. This period lasted until end of July. The July 2015 is an example, where an automatic identification of cyanobacteria dominated areas based on satellite data and calculation of frequencies is rather critically. During this period, smaller cloudless areas not automatically identified, gave an idea about the activity below the clouds (http://www.smhi.se/en/weather/sweden-weather/1.11631). On 7 July, the central and southern Baltic was strongly mixed and high concentrations still existed in the Pomeranian Bay. The next information from 14 July included filaments in the cloudless northern Gotland Basin and in the Arkona Basin. On 23 July, filaments were visible in the entire cloudfree area from the Arkona Basin to the northern Gotland Basin. In the period until the end of the month, the distribution was rather the same with varying intensities. At the beginning of August the weather became better. The next cloudless scene from 3 August (Fig. 2) showed the coverage of the entire Baltic by cyanobacteria from the western Baltic to the entrance of the Gulf of Finland. In both images in Fig. 2 from 3 July and 3 August, filaments of cyanobacteria cover a rather similar area, but with different distribution patterns and intensities. On 3 August, surface accumulations formed detailed structures in the filaments generated by the current patterns during weak local wind. The dark areas north-west of Rügen Island, south of Swedish mainland, Öland and Gotland Islands reflect clearer water caused by upwelling of deep water (see also Fig. 3).

After a few cloudy days, the bloom intensified and reached its maximum intensity in the western Baltic on 9 and 13 August days illustrated by the high quality scenes in Fig. 3. On 7 August, the filaments developed particularly in the northern Gotland Basin and continued until 18 August (Fig. 2).

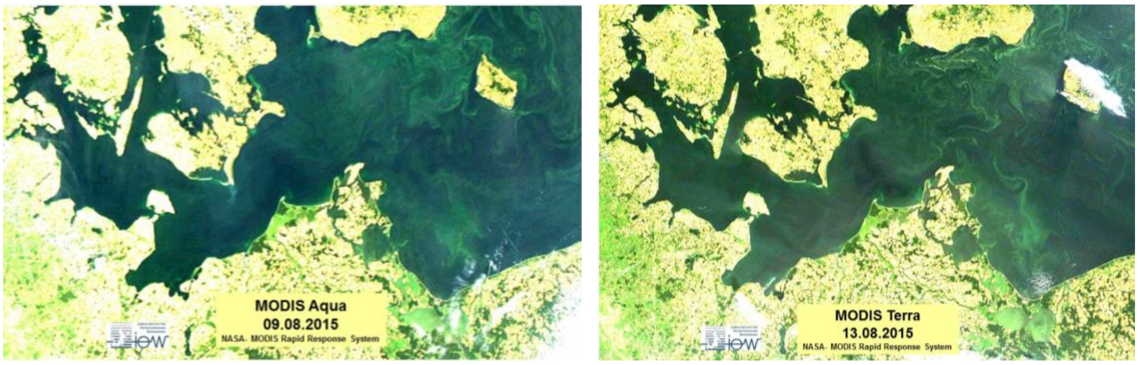


Fig. 3: Development of cyanobacteria in the western Baltic Sea with clearest filaments on 9 August 2015 of MODIS Aqua and on 13 August 2015 of MODIS Terra.

This phase contributed most to the distribution pattern derived from satellite data automatically as described in the HELCOM Environment Fact Sheet (http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/cyanobacterial-blooms-in-the-baltic-sea).

During the strong warming phase, cyanobacteria filaments propagated from 14 August into the Bothnian Sea and spread the following days more north as seen in the image from 18 August in Fig. 2. Until 20 August, the intensity reduces in the entire Baltic but particularly from the Arkona Basin to the southern Gotland Basin. In the northern Gotland Basin, Bothnian Sea and Gulf of Finland clear filaments still existed. Those decreased also in the following cloudy period. A scene from 29 August did not show any filaments. This could be the termination of the bloom since the windy and cloudy conditions continued.

In summary, the year 2015 was characterized by a cloudy and windy summer leading to SSTs below the long-term averages and to normally less surface accumulations of cyanobacteria. A low wind period at the end of June and beginning of July led to the warmest day in the central and southern Baltic Sea and cyanobacteria filaments from the western Baltic to the northern Baltic Proper (3 July). During the cloudy period until end of July, a few cloud gaps document the continuation of cyanobacteria activity with varying intensities. A MODIS scene from 3 August showed nearly the same extent of cyanobacteria as on 3 July. The intensity had the maximum between 9 and 13 August in the western Baltic, between 7 and 18 August particularly in the northern Baltic Proper. Up to 7 weeks, Cyanobacteria covered the area from western Baltic to the northern Baltic Proper with phases of rather different distributions and intensities.

4.1.2 Seasonal Variations in Species Composition and Biomass

The limited numbers of monitoring cruises, stations, and sampled depths rule out comprehensive analyses of the succession or horizontal and vertical distribution of phytoplankton. In contrast to zooplankton, however, the vertical distribution of phytoplankton is less of a priority as phytoplankton mainly occurs in the mixed surface layer. This allows us to focus on mixed samples from 0-10 m depth. The inclusion of additional samples from 9 cruises conducted outside the regular monitoring program consolidates the data series significantly. Especially in Mecklenburg Bay, 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-2015.html. Another tool that delivers information on phytoplankton dynamics and distribution are satellites (chapter 4.1.1). Sediment traps yield samples integrated over several days (chapter 4.1.5).

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

Table A2 shows the full list of phytoplankton taxa at all depths for each monitoring cruise in 2015. Species are arranged alphabetically. Individuals exhibiting a high degree of similarity to a species but which were not assignable to it with certainty are also considered, and are marked 'cf.'. Organisms that were classifiable only to genus level are also given, and are marked 'sp.' or 'spp.'. When classification to the level of species or genus was not possible, a higher taxonomic rank is given. We also include the unidentified categories Gymnodiniales, Peridiniales, Choanoflagellatea, Chrysophyceae, Centrales, Pennales, but exclude the 'Unidentified' and 'Unidentified flagellata', which have no taxonomic value. The biomass rank averaged over all stations (including the Baltic Proper) and all monitoring cruises in 2015 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. 5-7.

Heterotrophic species and groups such as *Ebria tripartita, Protoperidinium* spp., Choanoflagellatea and 'incertae sedis' are also considered. Choanoflagellatea were named "Craspedophyceae" in the 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. 5-7).

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. As it differs phenotypically from the original description of the species *A. flos-aquae* it is provisionally counted as *Aphanizomenon* sp. until a valid species description is published. Until final clarification of the issue, the HELCOM Phytoplankton Expert Group (PEG) will continue to list it as *Aphanizomenon* sp.

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

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

The species *Dictyocha speculum* occurs largely 'naked', i.e. without the typical silica skeleton (cf. JOCHEM & BABENERD 1989, HENRIKSEN 1993). It is difficult to identify in such a case, and is easily mistaken for *Pseudochattonella farcimen* (also Dictyochophyceae) and *Chattonella* spp. (Raphidophyceae). *Pseudochattonella verruculosa* is a new synonym for *Verrucophora farcimen* (see HOPPENRATH et al. 2009 and Table 4). It has already been pointed out before that its taxonomic classification is uncertain. As we have occasionally found both naked and skeleton-bearing stages, as well as transitional stages (WASMUND et al. 2015), we feel fairly certain that the round, naked cells are *Dictyocha speculum*. Within the HELCOM Phytoplankton Expert Group (PEG), we have agreed that elongated forms should count as *Pseudochattonella farcimen*. This uncertainty is not a problem when working at class level because both *Pseudochattonella farcimen* and *Dictyocha speculum* belong to the class of Dictyochophyceae. In the past it was assigned to the Chrysophyceae. In contrast to the previous years, we present the Dictyochophyceae separately in Figs. 8-10 and put the few representatives of the class of Chrysophyceae (*Dinobryon, Apedinella, Pseudopedinella*) to the group of "Others".

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

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

Table 4
Taxonomic revisions of phytoplankton names.

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

4.1.2.1 Spring Bloom

Belt Sea

Kiel Bay and Bay of Mecklenburg (including Lübeck Bay) have rather similar conditions and are combined to the area of the German Belt Sea. Figure 5 shows the seasonal variations in phytoplankton biomass in Kiel Bay, Lübeck Bay and Bay of Mecklenburg. In early February, the biomass still exhibited low winter values. The relatively high *Ceratium* biomass found at station OMBMPN3 in 2013 and 2014 could not be confirmed in 2015 (The dinoflagellates found on 25.2.2015 at stat. OMBMPN3 were mostly Gymnodiniales). Instead, diatoms were already dominating that early. The developments in the Arkona Basin were markedly different; they will be described below.

The spring bloom developed already by the end of February in Kiel Bay and the central Bay of Mecklenburg. The dates of the blooms could be stated fairly precisely thanks to an additional sample from end of February. The growth coincides with the consumption of inorganic nutrients from the water as shown in Table 5. The biomass peak is confirmed by peak chl.a concentrations on 17./18.3.2015 (Table 6). From the early peak in Kiel Bay, no corresponding chl.a data was available. The bloom decreased already by the mid of March in Kiel Bay but was still increasing in Bay of Mecklenburg. The bloom in Lübeck Bay was similar to that of the central Bay of Mecklenburg in qualitative and quantitative respects.

Just as in 2014, the spring bloom was composed of diatoms, dinoflagellates, dictyochophyceae and a small share of *Mesodinium rubrum*. The dominating species were, however, different. The diatom of 2014 in Kiel Bay was *Coscinodiscus concinnus* whereas that in 2015 was *Skeletonema marinoi* (817 µg/L on 25.2.2015; Fig. 4a). Overwintering *Ceratium tripos* was the main dinoflagellate in February 2013 and 2014 whereas those of 2015 were *Peridiniella danica*, unidentified Gymnodiniales and *Gyrodinium spirale*. The dictyochophyceae of 2013 and 2014 was *Dictyocha speculum* whereas that of 2015 was *Pseudochattonella farcimen* (Fig. 4b). The diatoms decreased strongly by the mid of March whereas dinoflagellates (*Peridiniella danica*, Fig. 4c) and prymnesiales (Fig. 4d) increased particularly in the central Bay of Mecklenburg and Lübeck Bay. Besides *Pseudochattonella farcimen*, also *Dictyocha speculum* (Fig. 4e) was an important dictyochophyceae in the samples. In Kiel Bay and Lübeck Bay, the spring bloom had clearly come to an end by the 5.5.2015. Only very small prymnesiales (2-4 µm) remained as significant representatives of the phytoplankton.

For the central Bay of Mecklenburg, data from additional cruises and from the coastal station Heiligendamm could fill gaps in the regular monitoring schedule. The data from Heiligendamm did fully support the data of the open sea concerning both the species composition and the timing of the diatom bloom, whose peak was found on 24.2.2015. The strong decline in biomass and the disappearance of prymnesiophyceae and dictyochophyceae by the 29.3.2015 may be caused by a flow of a different water body to the station. Also at Heiligendamm, we found a strong decrease in biomass and sudden dominance in dinoflagellates (*Peridiniella danica*, unidentified Gymnodiniales) by week 13 (31.3.2015). On 9.-11.4.2015, another water body was noticed in the central Bay of Mecklenburg, characterized by Prymnesiales and *Peridiniella danica*, as found already on 18.3.2015, but with strongly reduced dictyochophyceae. This bloom disappeared by the beginning of May. The phytoplankton became more diverse in May, with *Chaetoceros similis* (2.-6.5.2015), Prymnesiales (14.5.2015) and Gymnodiniales (26.5.2015) as dominating taxa.

The eastern Bay of Mecklenburg, represented by station OMBMPM1, was completely different from the central Bay of Mecklenburg, but very similar to the western Arkona Basin. Obviously, the Darss sill is not a strict border for the phytoplankton. We discuss the eastern Bay of Mecklenburg together with the Arkona Sea in the next section.

Arkona Basin

Phytoplankton biomass was generally low at the beginning of February also in the Arkona Basin, but already slightly higher in comparison with the previous years, particularly at station OMBMPK5. In contrast to the western Baltic, this early phase was dominated by *Mesodinium rubrum*. Diatoms (*Skeletonema marinoi*) developed at the end of February in the eastern Bay of Mecklenburg (Fig. 5d) but only in March in the Arkona Sea after a *Mesodinium*-peak (Fig. 6b). The additional sample from 7.3.2015 from the central Arkona Basin revealed a peak that early and a change in dominance from *Mesodinium rubrum* to *Skeletonema marinoi*. The diatom bloom reached its peak on 18./19.3.2015 both in the central Bay of Mecklenburg and the Arkona Basin. It was clearly dominated by *Skeletonema marinoi* (e.g. 1783 µg/L at station OMBMPK4; Fig. 4f). The diatom bloom had already declined on 29.3.2015 whereas dinoflagellates (Gymnodiniales) increased. Phytoplankton biomass decreased further until May which marks the end of the spring season. In the course of May, the diatoms and *Mesodinium rubrum* had widely disappeared whereas dinoflagellates (e.g. Gymnodiniales, *Dinophysis norvegica*) remained. Moreover, cyanobacteria (*Anathece, Aphanocapsa*) came up slowly, which indicates the start of the summer season.

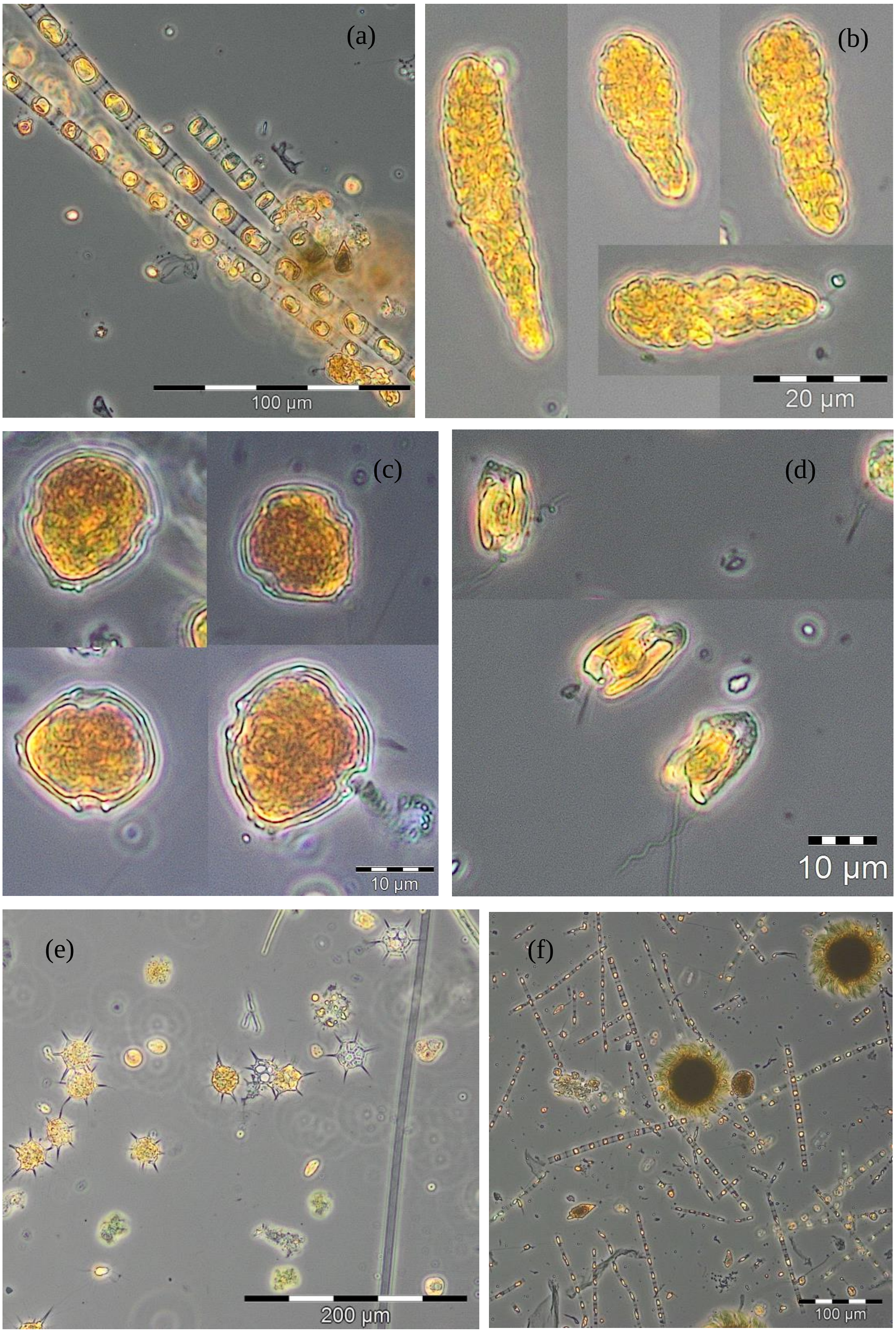


Fig. 4: Light microscopical images of the spring bloom in 2015. (a) *Skeletonema marinoi*, additional sample from 25.2.2015, station 22123 in Kiel Bay; (b) *Pseudochattonella farcimen*, additional sample from 25.2.2015, station 22123 in Kiel Bay; (c) *Peridiniella danica*, 31.3.2015, station Heiligendamm; (d) *Prymnesiales,* 18.3.2015, Station OMBMPM2; (e) *Dictyocha speculum*, 17.3.2015, station Heiligendamm; (f) *Skeletonema marinoi, Mesodinium rubrum* and *Amphidinium sphenoides*, station OMBMPK4, 19.3.2015. Photos: Susanne Busch.

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

Station	Date	Nitrate+nitrite	Phosphate	Silicate
OMBMPN3	02.02.2015	7.77	0.64	13.70
OMBMPN3	17.03.2015	0.14	0.07	4.70
OMBMPN3	05.05.2015	0.15	0.07	6.80
OMO22	03.02.2015	9.41	0.60	14.30
OMO22	17.03.2015	0.18	0.07	5.60
OMO22	05.05.2015	0.03	0.04	5.80
OMBMPM2	03.02.2015	5.93	0.60	13.10
OMBMPM2	18.03.2015	0.15	0.16	6.40
OMBMPM2	29.03.2015	0.11	0.09	3.30
OMBMPM2	06.05.2015	0.04	0.10	5.30
OMBMPM2	14.05.2015	0.30	0.12	6.20
OMBMPM1	03.02.2015	5.49	0.60	13.40
OMBMPM1	18.03.2015	0.05	0.21	4.80
OMBMPM1	29.03.2015	0.06	0.10	3.90
OMBMPM1	06.05.2015	0.04	0.21	7.20
OMBMPM1	14.05.2015	0.48	0.17	8.90
OMBMPK8	03.02.2015	4.53	0.58	13.00
OMBMPK8	18.03.2015	0.19	0.25	5.70
OMBMPK8	29.03.2015	0.07	0.15	3.10
OMBMPK8	06.05.2015	0.18	0.35	10.60
OMBMPK8	13.05.2015	0.31	0.28	9.10
OMBMPK5	04.02.2015	3.96	0.56	12.30
OMBMPK5	18.03.2015	0.01	0.08	3.00
OMBMPK5	29.03.2015	0.07	0.00	2.80
OMBMPK5	06.05.2015	0.09	0.35	11.10
OMBMPK5	13.05.2015	0.37	0.32	9.60
OMBMPK4	04.02.2015	3.65	0.60	11.90
OMBMPK4	19.03.2015	0.06	0.23	6.50
OMBMPK4	07.05.2015	0.18	0.27	8.70
OMBMPK2	05.02.2015	3.29	0.60	12.80
OMBMPK2	13.02.2015	3.34	0.66	12.60
OMBMPK2	19.03.2015	2.19	0.65	13.60
OMBMPK2	28.03.2015	1.72	0.58	13.70
OMBMPK2	07.05.2015	0.09	0.35	10.80
OMBMPK2	13.05.2015	0.16	0.43	15.80
OMBMPK1	12.02.2015	3.49	0.86	17.70
OMBMPK1	20.03.2015	2.65	0.70	15.50
OMBMPK1	08.05.2015	0.18	0.50	16.40
OMBMPJ1	10.02.2015	3.18	0.58	15.80
OMBMPJ1	22.03.2015	2.52	0.49	15.20
OMBMPJ1	09.05.2015	0.17	0.32	12.80

Bornholm Basin

As expected, the spring bloom development was retarded in the Bornholm Basin in comparison with the Arkona Basin. In the Arkona Basin, it started in early March with *Mesodinium rubrum*, which was followed by diatoms in mid-March. In the Bornholm Basin (Fig. 7a), the growth of *Mesodinium rubrum* extended until end of April, followed by a short diatom (*Chaetoceros similis* = 347 µg/L) growth at the beginning of May and subsequently by dinoflagellates (*Dinophysis norvegica* = 140 µg/L).

Eastern Gotland Basin

The Eastern Gotland Basin is represented by the central station OMBMPJ1 (Fig. 7c) and a more southern station OMBMPK1 (Fig. 7b), which is called “Southern Gotland Basin” in our case. Both stations were rather similar in their phytoplankton characteristics. The peak of the spring bloom is found in the period from18.4.-22.4.2015. It was dominated by *Mesodinium rubrum* and secondly by dinoflagellates (*Peridiniella catenata, Scrippsiella* complex). It has to be noted that this peak was only identified on the basis of additional cruises and would be missed in the regular monitoring schedule.

Summary on the spring bloom 2015:

1.) The spring bloom in Kiel Bay and, according to the coastal data from Heiligendamm, also in the central Bay of Mecklenburg, had its first peak on 24./25.2.2015. However, it stayed at least until 17./18.3.2015 in Lübeck Bay and the central Bay of Mecklenburg or until 7.4.2014 at the coastal station Heiligendamm. An additional cruise revealed that the biomass was even high on 9.-11.4.2015 in Bay of Mecklenburg. Consequently, the bloom lasted longer than expected.

2.) The spring bloom in Kiel Bay and the central Bay of Mecklenburg is rather diverse. It seems to undergo a succession from diatoms and *Mesodinium rubrum* to dinoflagellates and dictyochophyceae and finally to prymnesiophyceae. This succession may, however, be pretended if different water bodies pass the sampling station in this highly dynamic area.

3.) The phytoplankton of the western Baltic (Kiel Bay and Bay of Mecklenburg) is different from that of the Baltic proper. However, the Darss Sill is not always the line that separates the phytoplankton. In 2015, this border was situated in the eastern Bay of Mecklenburg.

4.) The unfortunately rather sparse nutrient data (Table 5) confirm that the spring bloom has grown at least until 17.-19.3.2015 in the western region up to the Arkona Basin. The inorganic nitrogen was consumed more intensively than phosphate, which is a symptom of nitrogen deficiency. Silicate was not used up and seems not to limit diatom growth.

5.) The spring bloom disappeared by mid of April. Inorganic nutrient concentrations increase in May in comparison with March, indicating a decomposition and remineralization of the biomass. Surprisingly, silicate concentrations increased much stronger than concentrations of phosphate and nitrate+nitrite. This was already discussed by WASMUND et al. (2015).

6.) The spring bloom development was retarded in the Bornholm Basin and Eastern Gotland Basin in comparison with the Arkona Basin. In the Arkona Basin, it started in early March with *Mesodinium rubrum*, which was followed by diatoms in mid-March. In the Bornholm Basin, the growth of *Mesodinium rubrum* extended until end of April, followed by a short diatom growth at the beginning of May and subsequently by dinoflagellates. In the Eastern Gotland Basin, diatoms were insignificant in comparison with dinoflagellates.

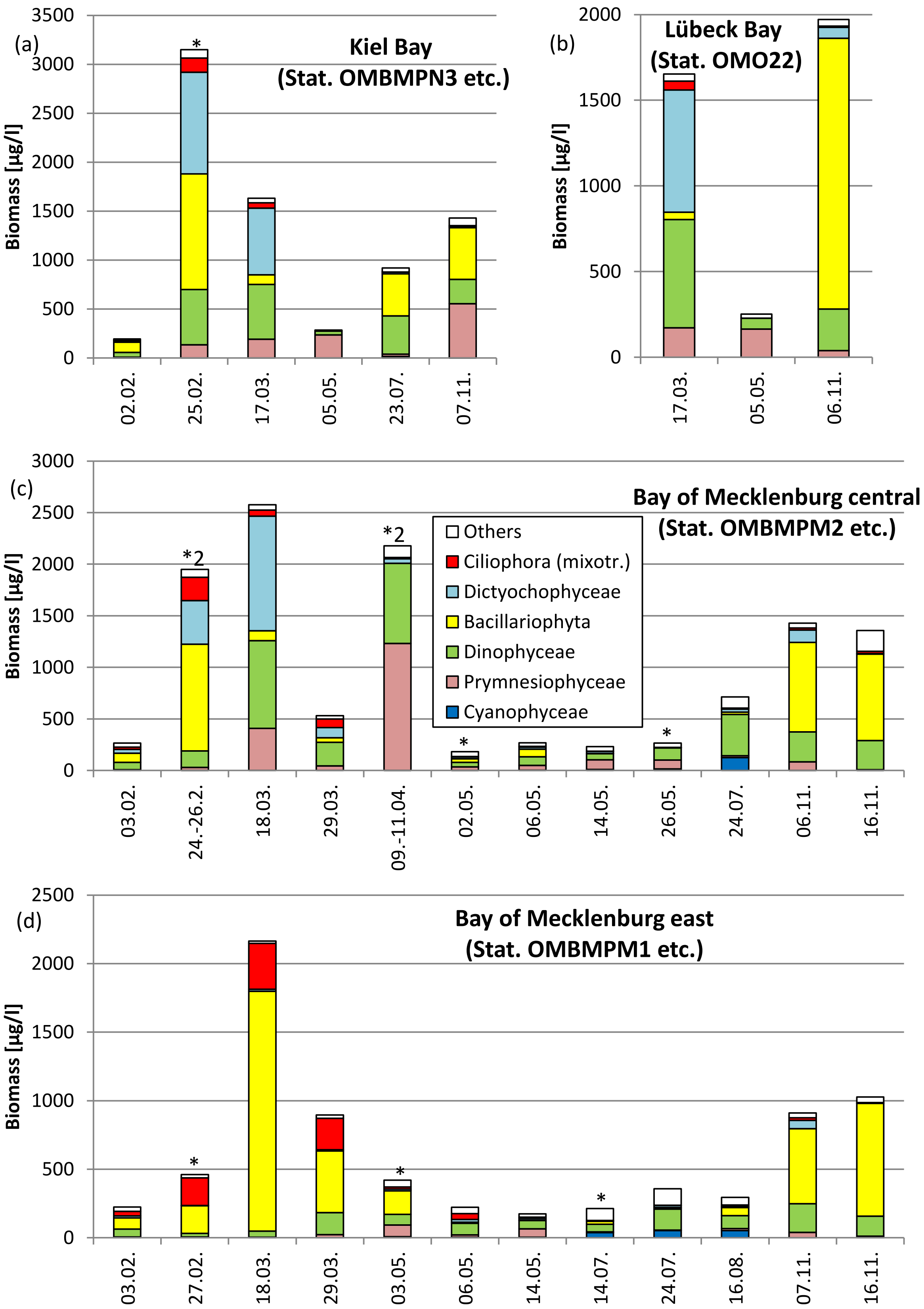


Fig. 5: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in Kiel Bay (a), Lübeck Bay (b) and Bay of Mecklenburg (c, d) in 2015. Additional samples are marked with an asterisk above the column. If two or more samples were combined, the number (n) is given after the asterisk.

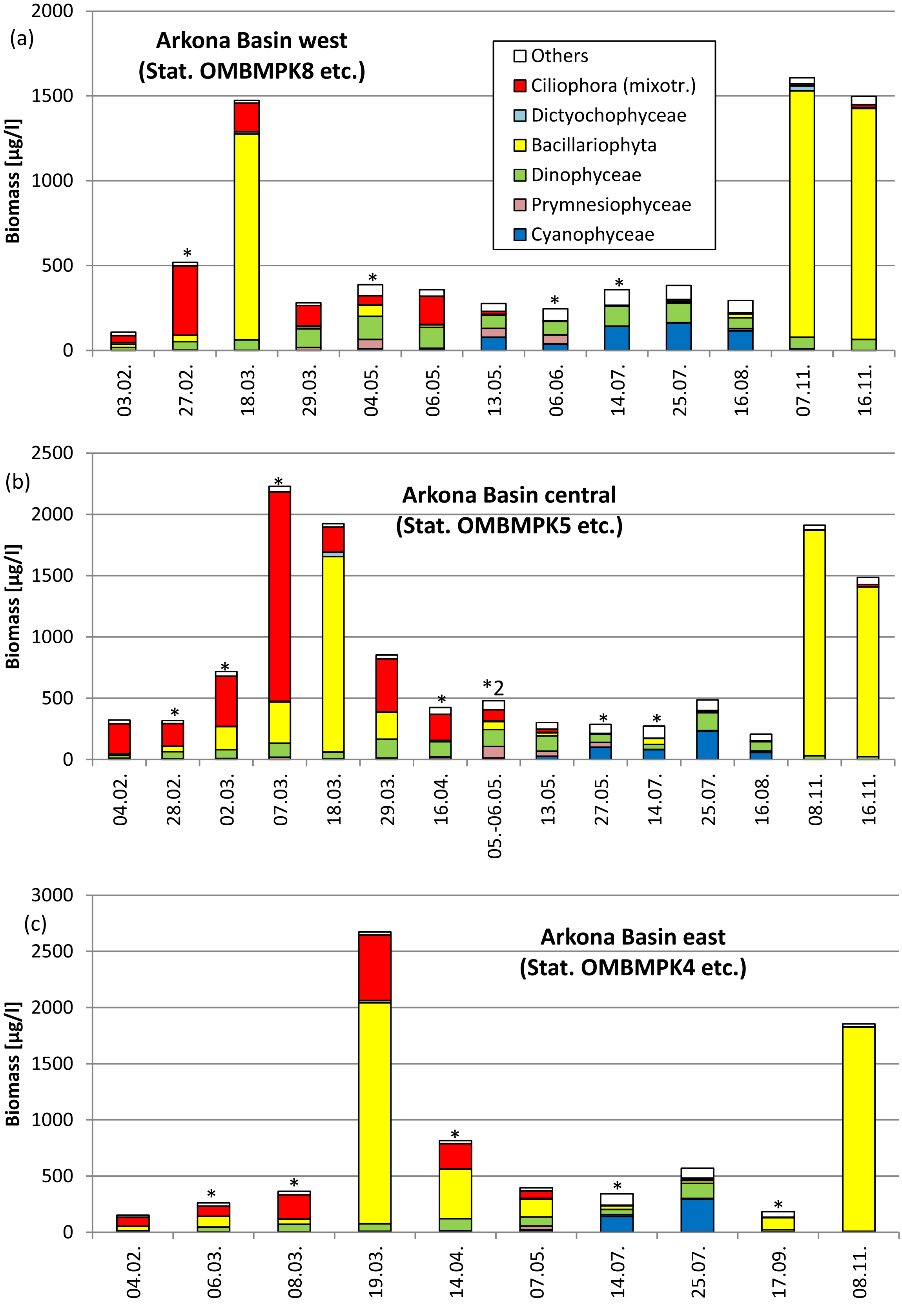


Fig. 6: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in the Arkona Basin (a-c) in 2015. Additional samples are marked with an asterisk above the column. If two or more samples were combined, the number (n) is given after the asterisk.

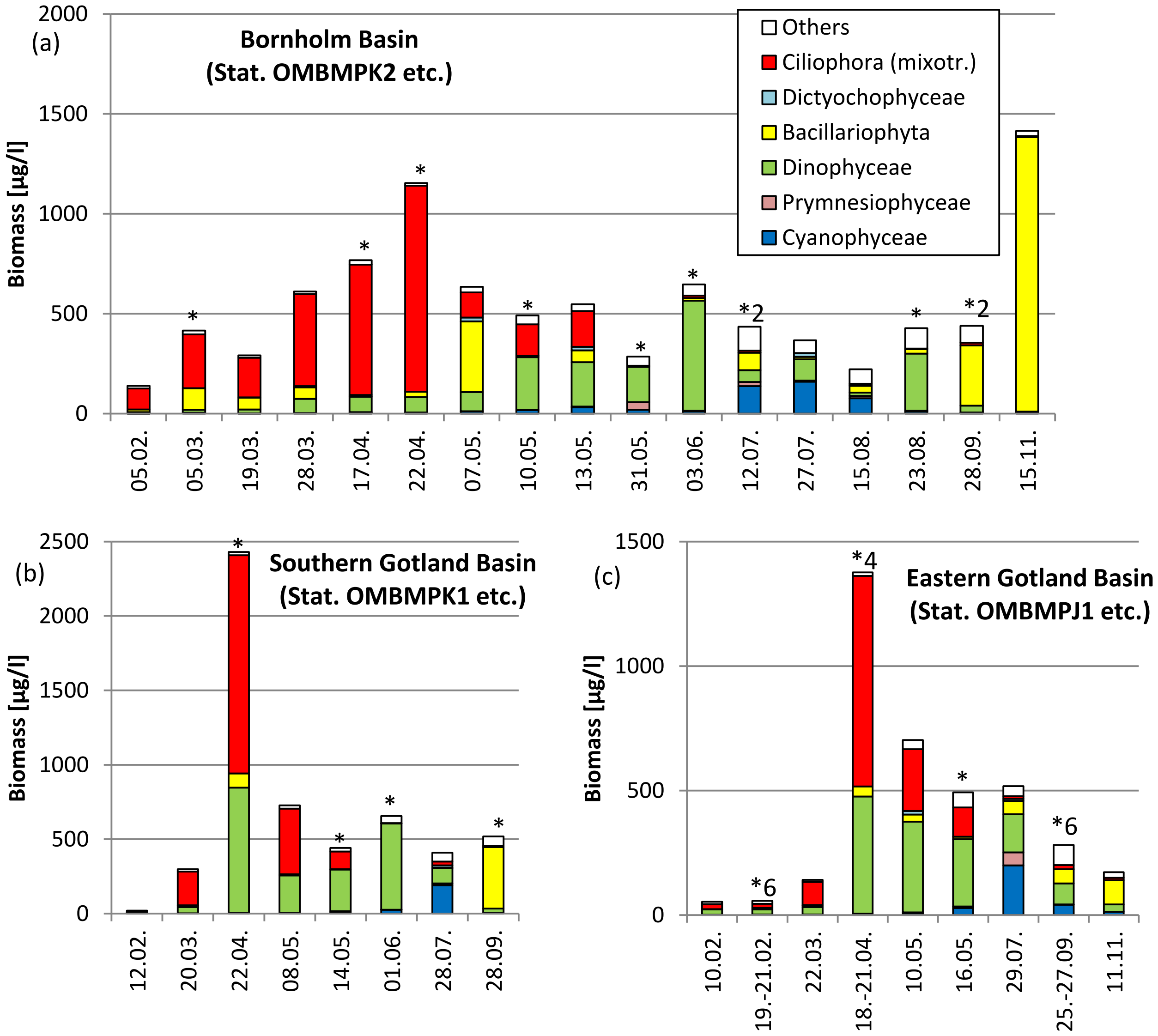


Fig. 7: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in the Bornholm Basin (a) and Eastern Gotland Basin (b, c) in 2015. Additional samples are marked with an asterisk above the column. If two or more samples were combined, the number (n) is given after the asterisk.

4.1.2.2 Summer Bloom

Belt Sea

No additional samples were available from Kiel Bay and Bay of Mecklenburg from summer 2015. Therefore, a summer diatom bloom as found in some previous years (e.g. in 2014) might have occurred but was not detected. The sample from 23.7.2015 from Kiel Bay contained 347 µg/L *Dactyliosolen fragilissimus*, which is the typical summer diatom. This may be a hint that a bloom occurred. Also dinoflagellates were present in this sample in rather high biomass: *Ceratium tripos* (174 µg/L) and *Alexandrium pseudogonyaulax* (132 µg/L). The sample from 17 m depth was even more diverse and contained a higher biomass (1482 µg/L) than the surface sample. Species with more than 100 µg/L in this 17m-sample were: *Dactyliosolen fragilissimus Chaetoceros affinis, Ditylum brightwellii, Cerataulina pelagica, Rhizosolenia setigera* f. *pungens, Ceratium tripos, Proboscia alata.*

In the Bay of Mecklenburg, however, the weekly samplings at the coastal station Heiligendamm did not reveal a diatom summer bloom. At station OMBMPM2, *Ceratium tripos* appeared (246 µg/L), which was supposed to grow further to form the autumn bloom.

The cyanobacteria that typically form summer blooms in the Baltic Proper were not present in Kiel Bay, as usual. At station OMBMPM2, *Aphanizomenon* sp. occurred with 95 µg/L whereas the typical *Nodularia spumigena* was negligible. This relatively low biomass cannot be considered as a bloom. Also satellite images (Section 4.1.1) did not identify cyanobacteria blooms in the western Baltic.

Arkona Basin

From the eastern Bay of Mecklenburg and the Arkona Sea, some additional samples allowed a better coverage of the summer season. These additional samples revealed that the phytoplankton composition and biomass are rather stable in summer. The biomass did not exceed 570 µg/L in this area. That means no bloom occurred. The same situation was found in previous years. Typically, a lot of unidentifiable single cells < 5µm occur, which are hardly to be separated from the small prymnesiales; therefore all these small cells were assigned to the "others". Dinoflagellates were still an important group, represented by *Ceratium tripos*, and *Alexandrium pseudogonyaulax* (station OMBMPM1) as well as *Dinophysis norvegica* (particularly at 20 m depth, e.g. at station OMBMPK4). Cyanobacteria were dominating especially at the end of July in the Arkona Basin. They just reached bloom concentrations, which were set at 200 µg/L according to WASMUND (1997). Satellite images revealed that the maximum of the cyanobacteria blooms in the Arkona Basin occurred in the first half of August (Fig. 3).

Bornholm Basin

Also in the Bornholm Basin, phytoplankton biomass was low throughout the summer. Dinoflagellates (*Dinophysis norvegica*), cyanobacteria (*Aphanizomenon* sp., *Nodularia spumigena*) and some diatoms (*Actinocyclus* sp.) were the most important components. According to satellite images, the cyanobacteria bloom reached its maximum in the first half of August (Fig 2b).

Eastern Gotland Basin

The summer is hardly represented in our data from the Eastern Gotland Basin. At the end of July 2016, cyanobacteria (*Nodularia spumigena, Aphanizomenon* sp.) and Dinoflagellates (*Dinophysis norvegica*) dominated, similar to the Bornholm Basin. The *Nodularia* trichomes were covered by the diatom *Nitzschia paleacea* at station OMBMPJ1.

Summary on the summer bloom 2015:

1.) A summer bloom typically made by diatoms in Kiel Bay and the central Bay of Mecklenburg (like in 2014) was definitely not developed in 2015.

2.) The development of cyanobacteria was typical in 2015, with no bloom in Kiel Bay and Bay of Mecklenburg, but a moderate bloom in the Baltic Proper. According to the Environment Fact Sheet (WASMUND et al. 2016), the cyanobacteria bloom was near the long-term average in the Arkona and Bornholm Basins and below the long-term average in the Eastern Gotland Basin.

4.1.2.3 Autumn Bloom

Belt Sea

The typical autumn bloom in the Belt Sea is 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. For example, from 2011 to 2014 the regular monitoring data showed a clear dinoflagellate bloom at least from Kiel Bay to the central Bay of Mecklenburg. The weekly samplings from the coastal station Heiligendamm enabled a more complete image. They showed in 2011 a strong diatom bloom which was completely missed in the monitoring data and only the subsequent smaller dinoflagellate bloom was noticed. Also in 2012 and 2013, such a succession from diatoms to dinoflagellates was recorded by weekly samplings but missed by the open-sea monitoring. In 2014 and 2015, mixtures of diatoms and dinoflagellates occurred at the coastal station. Such mixtures were also found in the monitoring data of station OMBMPM2, but the ratios are depending on the time of sampling. Our monitoring data from 16.11.2015 show a rather good agreement with the coastal data from 17.11.2015 concerning the biomass of the phytoplankton groups, but less on species level.

The sample from 6.11.2015 from station OMBMPM2 (Fig. 5c) did hardly contain the typical *Ceratium* spp. (only 18 µg/L) but mainly Gymnodiniales (136 µg/L) including *Gyrodinium spirale.* Other dinoflagellates were *Polykrikos schwartzii, Prorocentrum micans* and *Peridiniella danica*. The diatoms were represented mainly by *Pseudosolenia calcar-avis* (213 µg/L), *Rhizosolenia setigera* (194 µg/L), *Thalassiosira eccentrica* (90 µg/L), *Cerataulina pelagica* (70 µg/L), *Skeletonema marinoi* (52 µg/L) and *Chaetoceros convolutus* (43 µg/L). Also Prymnesiales and *Dictyocha speculum* were relevant. The sample from 16.11.2015 contained more *Ceratium* spp. (124 µg/L) but no *Polykrikos schwartzii* and *Peridiniella danica*. The diatoms were dominated by *Rhizosolenia setigera* (248 µg/L), *Proboscia alata* (144 µg/L), *Thalassiosira eccentrica* (104 µg/L), *Pseudosolenia calcar-avis* (56 µg/L) and *Skeletonema marinoi* (31 µg/L). The raphidophyceae *Heterosigma akashiwo* (168 µg/L), shown as “others” in Fig. 5c, is noteworthy.

The composition of the samples from station OMO22 and OMBMPM1 are similar to that from station OMBMPM2 of the same period (Fig. 8a). Also the sample from 16.11.2015 of station OMBMPM1 was similar to that of station OMBMPM2, but contained almost no *Ceratium* spp. and *Heterosigma akashiwo.* In contrast to the spring situation, station OMBMPM1 could be included in the Bay of Mecklenburg data. The sample from Kiel Bay shows a deviating composition with dominating prymnesiales (554 µg/L) and relatively little share of diatoms, which were still represented by *Pseudosolenia calcar-avis* (205 µg/L), *Rhizosolenia setigera* (99 µg/L) and *Thalassiosira eccentrica* (81 µg/L).

The status of the phytoplankton encountered at a fixed monitoring station depends also on the hydrographic conditions, particularly in the dynamic Belt Sea. Already BÜSE (1915) mentioned the changing condition at fixed stations (in his case the Fehmarn Belt). He noted that the salinity is an indicator for the water bodies. High salinity was related to high *Chaetoceros* and *Ceratium* biomass in autumn during his research.

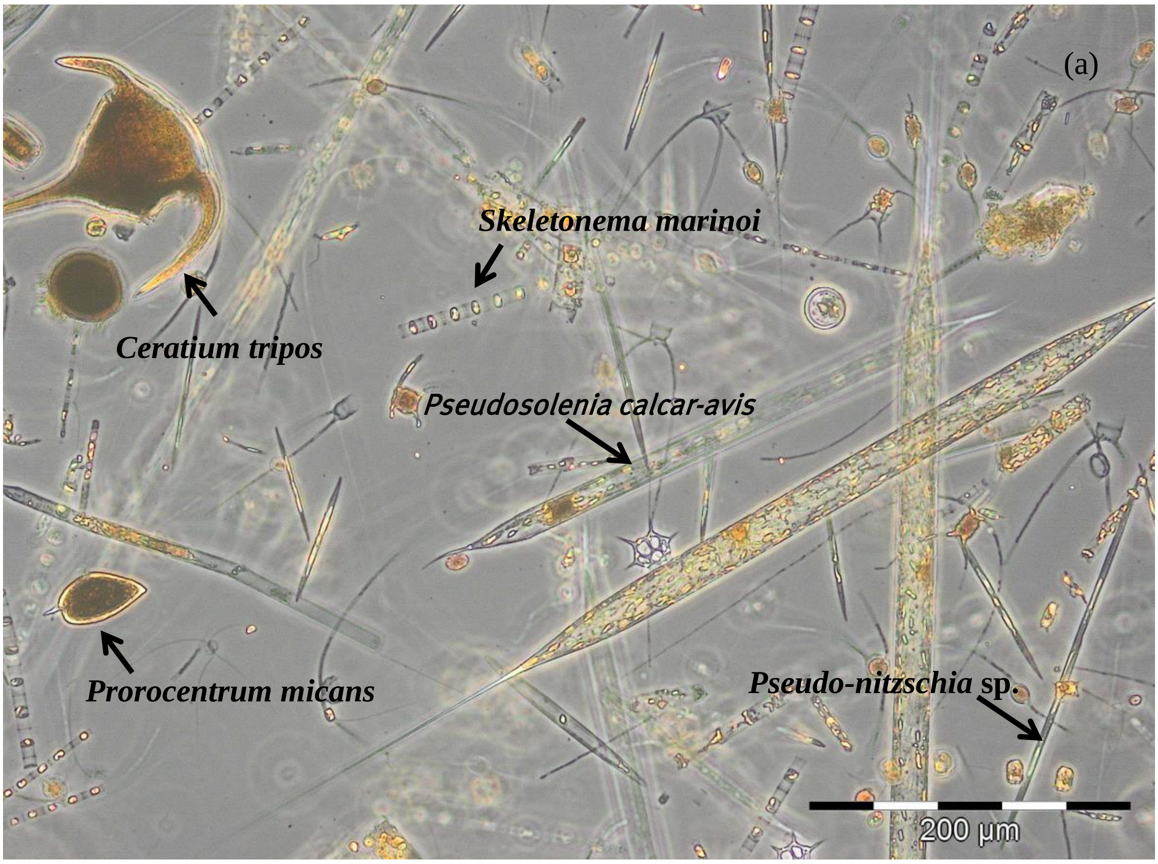


Fig. 8: (a) net sample from station OMO22, 6.11.2015 with diverse phytoplankton; (b) net sample from station OMBMPK5, 8.11.2015 with *Coscinodiscus granii*. Photos: Susanne Busch.

Arkona Basin

As usual, the share of dinoflagellates decreased from west to east in autumn. Station OMBMPK8 is very different from station OMBMPM1 in the Bay of Mecklenburg because it was characterized by the typical bloom of *Coscinodiscus granii* (1118 and 1256 µg/L on 7.11. and 16.11.2015, respectively) whereas this species was not found at station OMBMPM1. Also at the other stations of the Arkona basin, the same strong bloom of *Coscinodiscus granii* was found (Fig. 8 b) with only few accompanying species which may be looked up in Table A1.

Bornholm Basin

The autumn bloom in the Bornholm Basin (Fig. 7a) was very similar to that of the Arkona Basin (Fig. 6). The early phase of the diatom bloom (28.9.2015) was dominated by *Actinocyclus* sp. whereas the peak of the bloom (15.11.2015) was made by *Coscinodiscus granii*.

Eastern Gotland Basin

The southern part of the Eastern Gotland Basin (including station TF0256 and TF0253 around the station OMBMPK1, Fig. 7b) was very similar to the Bornholm Basin at the end of September 2015, dominated by *Actinocyclus* sp., whereas the stations in the central deep of the Eastern Gotland Basin did not show this diatom development, but a rather diverse phytoplankton (*Dinophysis norvegica, Aphanothece paralleliformis, Teleaulax* spp., *Mesodinium rubrum*). On 11.11.2015, *Coscinodiscus granii* dominated, but it did not reach bloom concentrations at that time.

Summary on the autumn bloom 2015:

1.) Autumn blooms were well-developed in Kiel Bay, Bay of Mecklenburg and the Arkona Basin.

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

3.) The typical bloom of *Coscinodiscus granii* was well-developed in the Arkona Basin and Bornholm Basin in mid-November 2015, but in the Eastern Gotland Basin not such bloom occurred at that time.

4.1.3 Regional Differences in Species Composition

Sampling locations are chosen so that basically they form a transect through the Baltic from Kiel Bay into the Arkona 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. 9-11 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. For species that do not occur in the central Baltic Proper, only the western Baltic is shown.

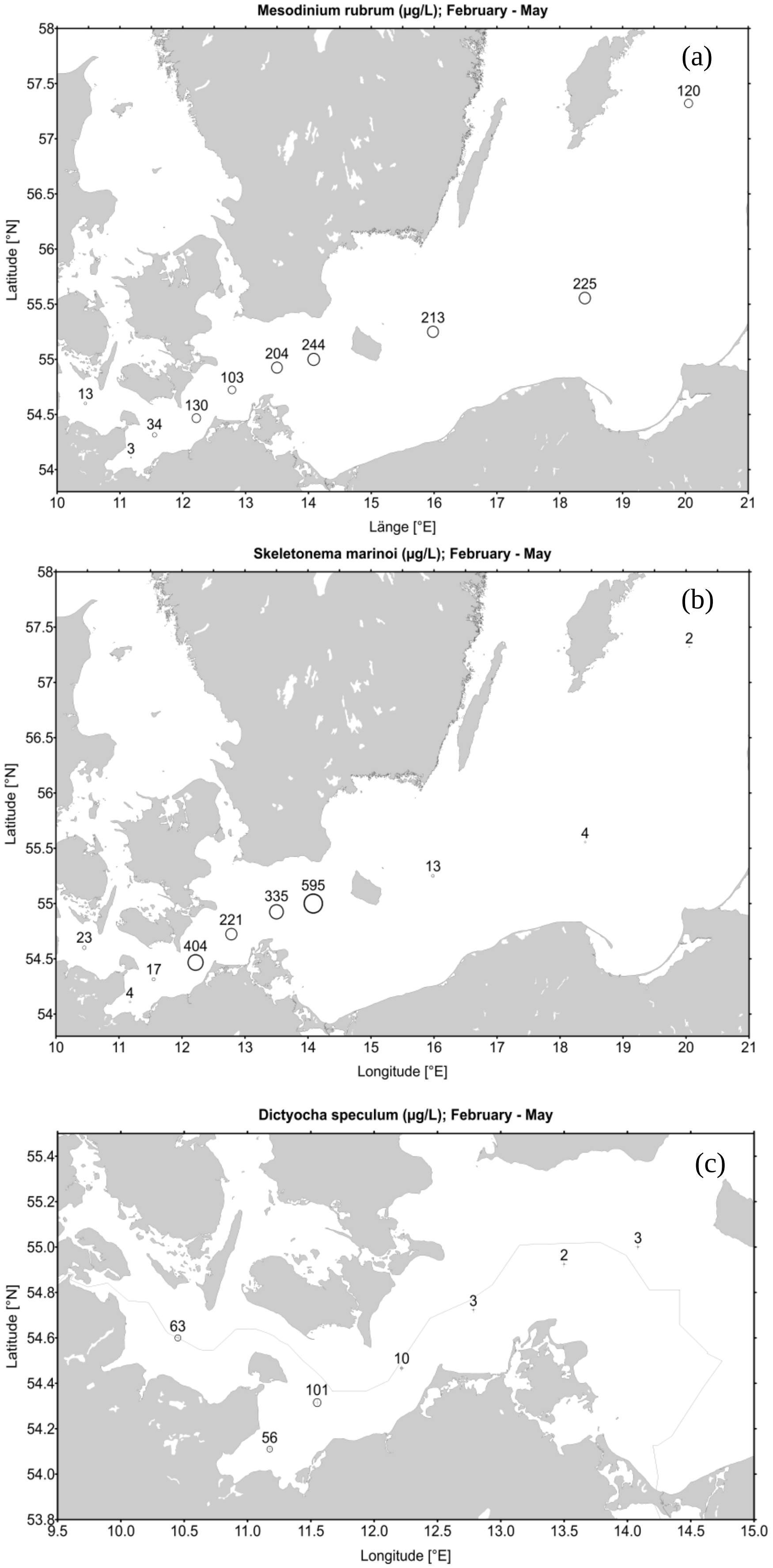


Fig. 9: Distribution of *Mesodinium rubrum* (a), *Skeletonema marinoi* (b) and *Dictyocha speculum* (c) in spring 2015.

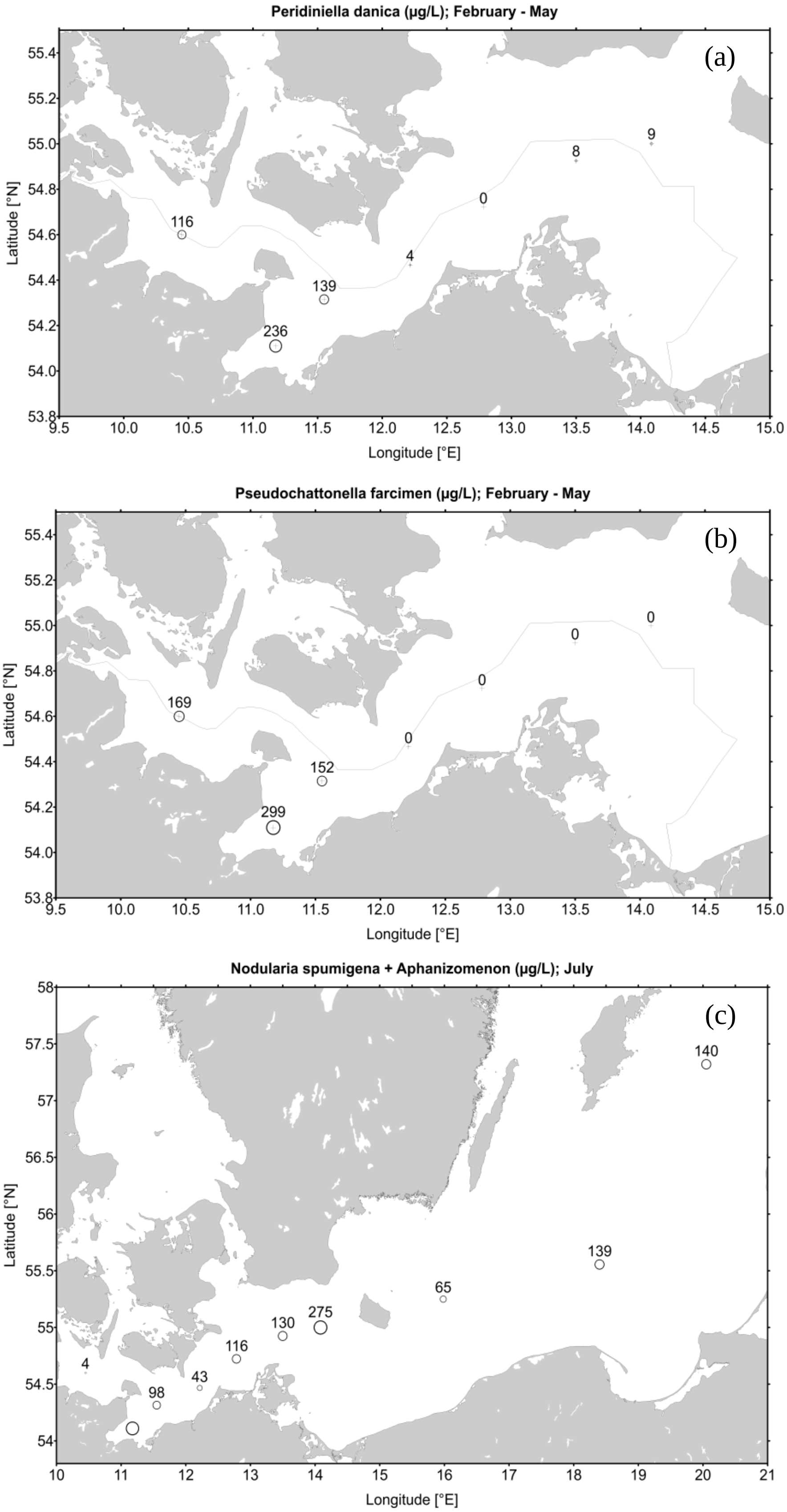


Fig. 10: Distribution of *Peridiniella danica* (a), *Pseudochattonella farcimen* (b) and the combined biomass of *Nodularia spumigena* and *Aphanizomenon* sp. (c) in the seasons of their main occurrence in 2015.

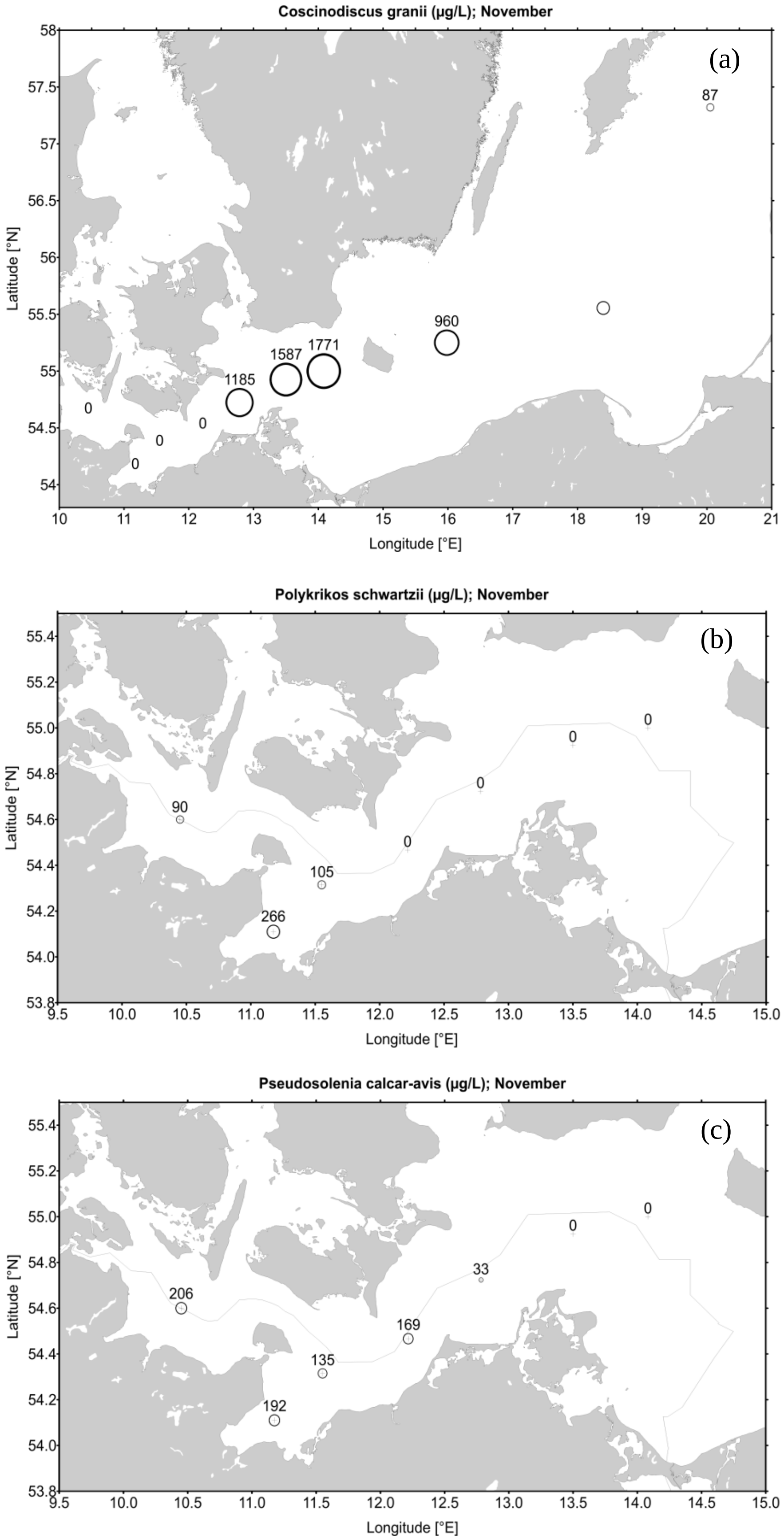


Fig. 11: Distribution of *Coscinodiscus granii* (a), *Polykrikos schwartzii* (b) and *Pseudosolenia calcar-avis* (c) in autumn 2015.

Mesodinium rubrum (Fig. 9 a) is the typical representative of the spring bloom in the Baltic Proper with decreasing tendency to the west. *Skeletonema marinoi* (Fig. 9 b) forms blooms in the western Baltic and seems to have its core area in the Arkona Basin (as already in 2014) but seems to be rare in the Bornholm Sea and further east. The higher salinities in the Belt Sea are preferred by species like *Dictyocha speculum* (Fig. 9 c), *Peridiniella danica* (Fig. 10 a) and *Pseudochattonella farcimen* (Fig. 10 b). The summer blooms of cyanobacteria, mainly composed of *Nodularia spumigena* and *Aphanizomenon* sp., are typical for the Baltic Proper but not for the Belt Sea (Fig. 10 c; missing sample in Lübeck Bay). Also in autumn, Belt Sea and Arkona Sea are clearly different. In autumn, Belt Sea and Arkona Sea are normally characterized by *Ceratium* species and *Coscinodiscus granii*, respectively. Depending on the direction of the currents, *Ceratium* species may invade the Arkona Basin or *Coscinodiscus granii* may be transported to the west. In 2015, the *Ceratium* bloom failed, but the *Coscinodiscus* bloom was well developed and stopped at Darss Sill (Fig. 11 a). Note that the station point of OMBMPK1 without number means that the samples is missing. The lacking *Ceratium* species were replaced by diverse dinoflagellates and diatoms, such as *Polykrikos schwartzii* (Fig. 11 b) and *Pseudosolenia calcar-avis* (Fig. 11 c).

4.1.4 Changes in Species Composition

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

This is why efforts are made to prevent the introduction of new species. In the case of phytoplankton, this is difficult as it has a great variety of entry routes that cannot be blocked. *Prorocentrum cordatum* (old synonym:*Prorocentrum minimum*, cf. Table 4) serves as an example of an invasive phytoplankton species that has probably entered the Baltic naturally via the Kattegat. HAJDU et al. (2000) and OLENINA et al. (2010) 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). In this special case, it is improbable that one species has displaced the other, however, as *P. balticum* is a spring species, and *P. cordatum* is a late summer species.

It is known that marine species such as *Cerataulina pelagica, Chaetoceros brevis,* and *Dactyliosolen fragilissimus* are sometimes carried into the Baltic Sea as far as the Lithuanian coast (HAJDU et al. 2006).

In this sense these species are indicators of inflows not only of deep water but also of surface water from the North Sea. Some of the intruded marine species had become established, while others had disappeared (OLENINA & KOWNACKA, 2010).

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

Spatulodinium pseudonoctiluca was new to us in 2014, and it was also found in 2015. 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 (Fig. 11 b). 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 since 2013. However, it reappeared in 2015 with high biomass (rank 7, Figs. 8 a, 11 c, 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 increased now to rank 10 (Table A2, Figs. 4 c, 10 a).

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*, cf. Table 4, Fig. 4 b) from the naked form of *Dictyocha speculum*, and have since included it in our lists. The spring species *Dictyocha speculum* (Fig. 4 e) occurred vigorously in 2007 and 2008, especially in the Belt Sea, but was relatively insignificant in 2010, nor were elevated levels of *Pseudochattonella* observed then. In 2011, Dictyochophyceae occurred in strength, ranking 6th, with *Pseudochattonella farcimen* identified to an increasing extent. *Pseudochattonella farcimen* did not reappear in samples in 2012 and 2014, however. Of these two species, we found almost only *Dictyocha speculum* in 2014, although in 2012 and 2013 its level of biomass was low, and in 2013 its presence was stronger in autumn than in spring, surprisingly. A strong spring bloom of *Dictyocha speculum* recurred in 2014. In 2015 the two species occurred together (Figs. 9 c, 10 b)

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 c). 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.

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. *Coscinodiscus centralis*, which was added to the species list of HELCOM-PEG in 2011, was found in our sample from 8.11.2015 (station OMBMPK4) and one cell looking like this species was found at station OMBMPK2 in the Bornholm Basin (15.11.2015). Also *Roperia tesselata* is new for us, but the identification is not sure (Fig. 12 a). It was added to the HELCOM-PEG list in 2006. We found it in our surface sample from 7.11.2015, station OMBMPK8.

Nematopsides vigilans (old synonym *Proterythropsis vigilans*, cf. Table 4, Fig. 12 b) occurred in our samples from 16.8.2015 (station OMBMPM1), 7.11.2015 (station OMBMPK8, 20 m) and 8.11.2015 (station OMBMPK5, 20 m). It was also found in a coastal sample from Heiligendamm on 6.10.2015. This species is not contained in the species list of HELCOM-PEG yet and the identification is not sure.

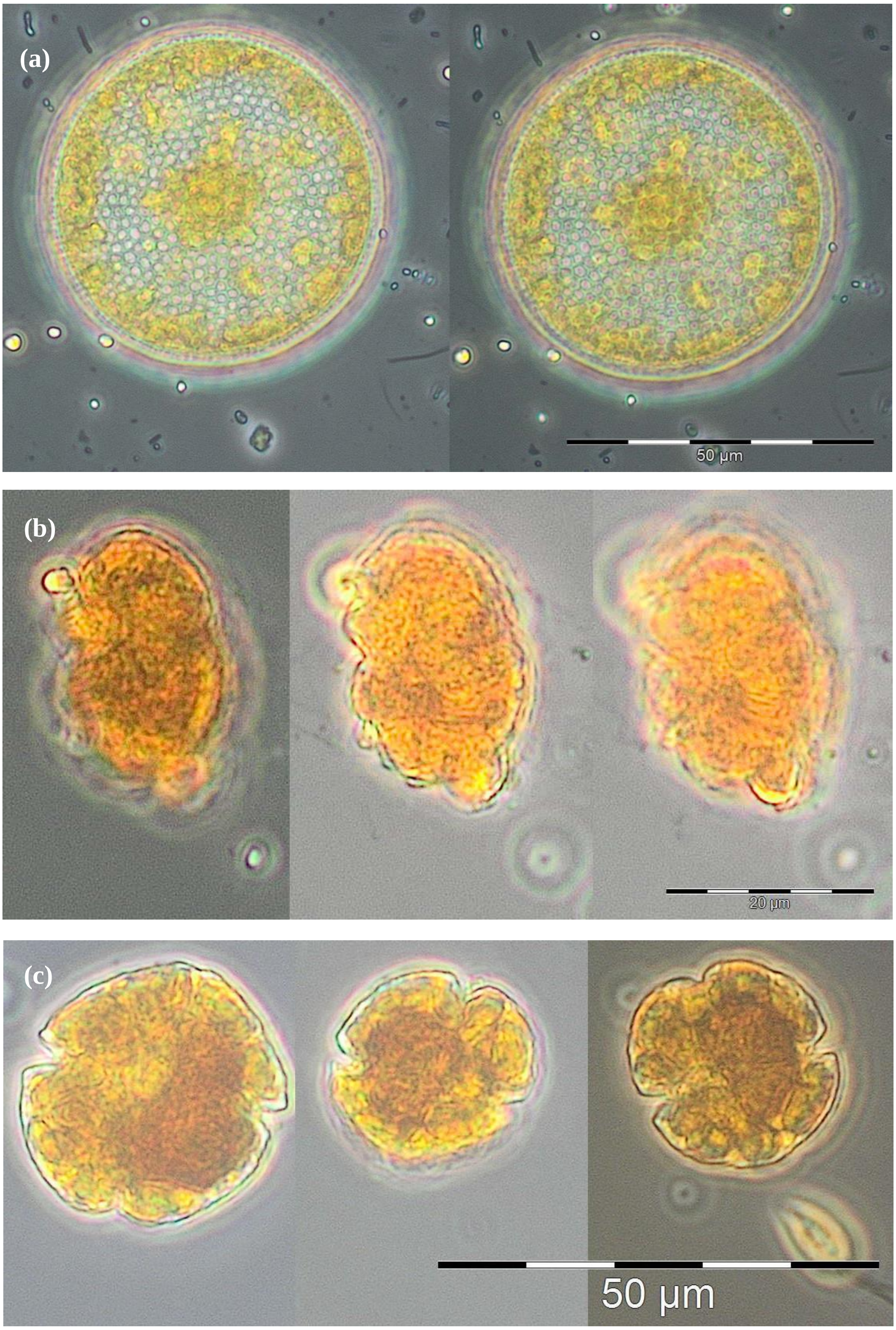


Fig. 12: Light microscopy images of "new" species in samples from 2015 (preliminary identification). (a) *Roperia tesselata* from station OMBMPK8, 7.11.2015; (b) *Nematopsides vigilans* from station OMBMPK5, 8.11.2015; (c) *Karenia mikimotoi* from station OMBMPM2, 20m, 16.11.2015. Photos: Susanne Busch.

Another doubtful species that was new for us is *Fragilidium subglobosum*, which was only found in a net sample from the coastal station Heiligendamm on 25.8.2015. Cells looking like *Karenia mikimotoi* were contained in samples from 16.11.2015, stations OMBMPM1 and OMBMPM2 (Fig. 12 c). All these “new” species occurred in only one or very few specimen and allowed no detailed observations; therefore identification is preliminary and could not be proved.

4.1.5 Chlorophyll *a*

Table 6

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

Station	Datum	Chl.a-tot (mg m^{-3})
OMBMPN3	02.02.2015	2.86
OMBMPN3	17.03.2015	4.46
OMBMPN3	05.05.2015	3.17
OMBMPN3	23.07.2015	1.65
OMBMPN3	07.11.2015	3.94
OMO22	17.03.2015	8.69
OMO22	05.05.2015	5.27
OMO22	06.11.2015	3.49
OMBMPM2	03.02.2015	2.64
OMBMPM2	18.03.2015	9.45
OMBMPM2	29.03.2015	2.42
OMBMPM2	06.05.2015	1.43
OMBMPM2	14.05.2015	1.75
OMBMPM2	24.07.2015	2.02
OMBMPM2	06.11.2015	4.18
OMBMPM2	16.11.2015	4.49
OMBMPM1	03.02.2015	2.75
OMBMPM1	18.03.2015	6.49
OMBMPM1	29.03.2015	2.50
OMBMPM1	06.05.2015	1.57
OMBMPM1	14.05.2015	1.73
OMBMPM1	24.07.2015	1.70
OMBMPM1	16.08.2015	2.53
OMBMPM1	07.11.2015	3.84
OMBMPM1	16.11.2015	3.38
OMBMPK8	03.02.2015	1.85
OMBMPK8	18.03.2015	5.79
OMBMPK8	29.03.2015	0.78
OMBMPK8	06.05.2015	1.48
OMBMPK8	13.05.2015	1.99
OMBMPK8	25.07.2015	1.67
OMBMPK8	16.08.2015	2.53
OMBMPK8	07.11.2015	4.08
OMBMPK8	16.11.2015	4.55
OMBMPK5	04.02.2015	2.06
OMBMPK5	18.03.2015	5.70
OMBMPK5	29.03.2015	3.19
OMBMPK5	06.05.2015	2.85
OMBMPK5	13.05.2015	2.31
OMBMPK5	25.07.2015	2.71
OMBMPK5	16.08.2015	2.16
OMBMPK5	08.11.2015	4.26
OMBMPK5	16.11.2015	4.88
OMBMPK4	04.02.2015	1.48
OMBMPK4	19.03.2015	7.18
OMBMPK4	07.05.2015	1.99
OMBMPK4	25.07.2015	2.45
OMBMPK4	08.11.2015	4.52
OMBMPK2	05.02.2015	1.05
OMBMPK2	19.03.2015	1.69
OMBMPK2	28.03.2015	2.33
OMBMPK2	07.05.2015	2.65
OMBMPK2	13.05.2015	2.83
OMBMPK2	27.07.2015	2.05
OMBMPK2	15.08.2015	1.92
OMBMPK2	15.11.2015	3.68
OMBMPK1	12.02.2015	0.36
OMBMPK1	20.03.2015	1.99
OMBMPK1	08.05.2015	1.90
OMBMPK1	28.07.2015	2.60
OMBMPJ1	10.02.2015	0.49
OMBMPJ1	22.03.2015	0.98
OMBMPJ1	09.05.2015	2.23
OMBMPJ1	29.07.2015	2.89
OMBMPJ1	11.11.2015	2.34

Table 6 shows the annual variations in chlorophyll *a* concentrations based on the monitoring cruises. Chlorophyll samples were not taken during the additional cruises. The annual variations in chlorophyll *a* correspond roughly to those given for biomass in Figs. 5-7. 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') only.

Typically, the annual maximum concentration of chlorophyll *a* coincided with the spring bloom that we encountered in mid-March if only the regular monitoring samples were considered.

Figs. 13-15 present the horizontal distribution of chlorophyll *a* values determined during the 5 monitoring cruises in 2015. The maximum appears in Fig. 12 a at station OMO22. The real maximum (9.45 mg*m^{-3}) which was found at station OMBMPM2 on 18.3.2015 is blurred in Fig. 12 a because mean values from the outward and return leg of each cruise are given in contrast to single values in Table 6. The mean value of March 2015 at station OMBMPM2 was only 5.94.

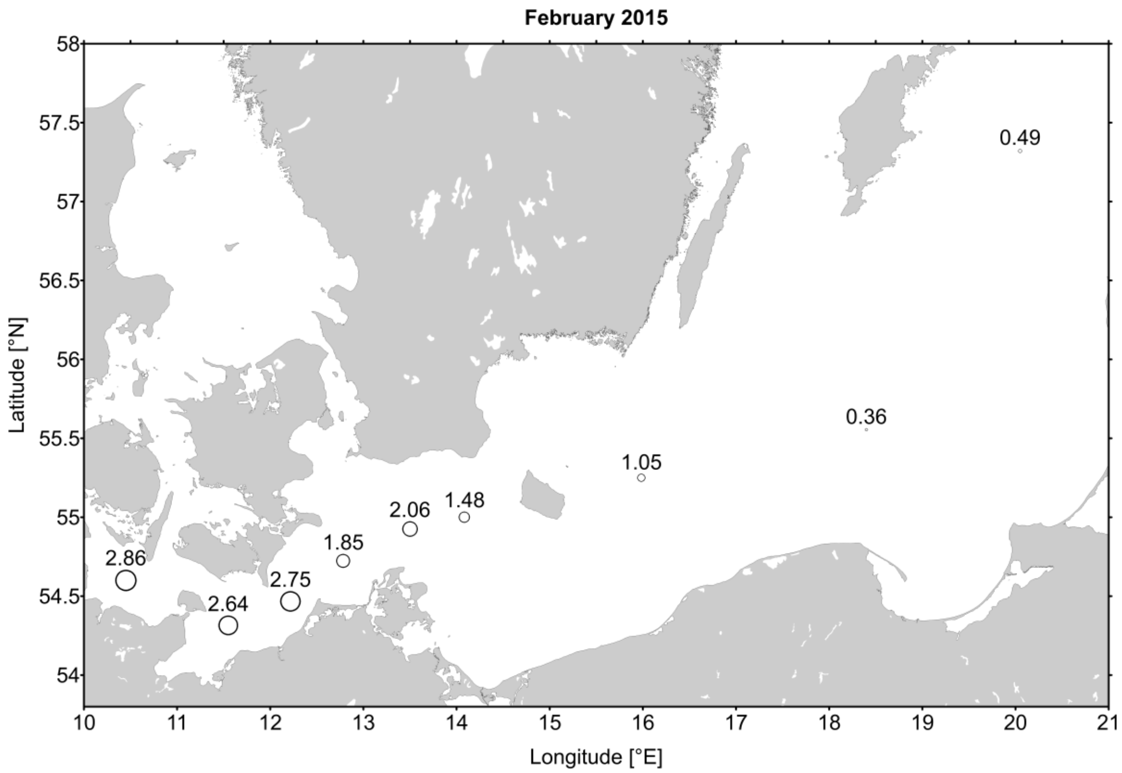


Fig. 13: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during the monitoring cruise of February 2015.

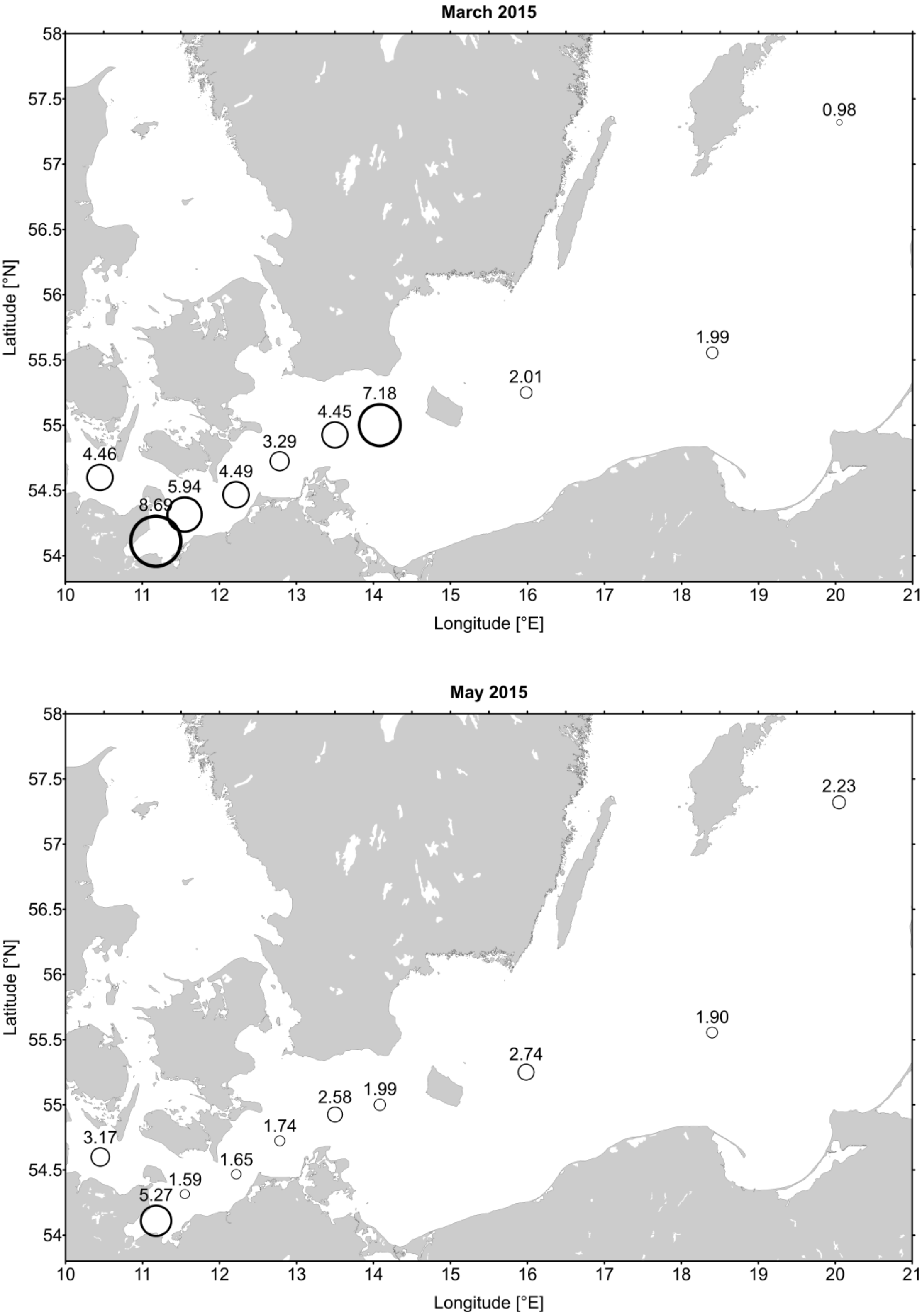


Fig. 12: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during monitoring cruises in March and May 2015.

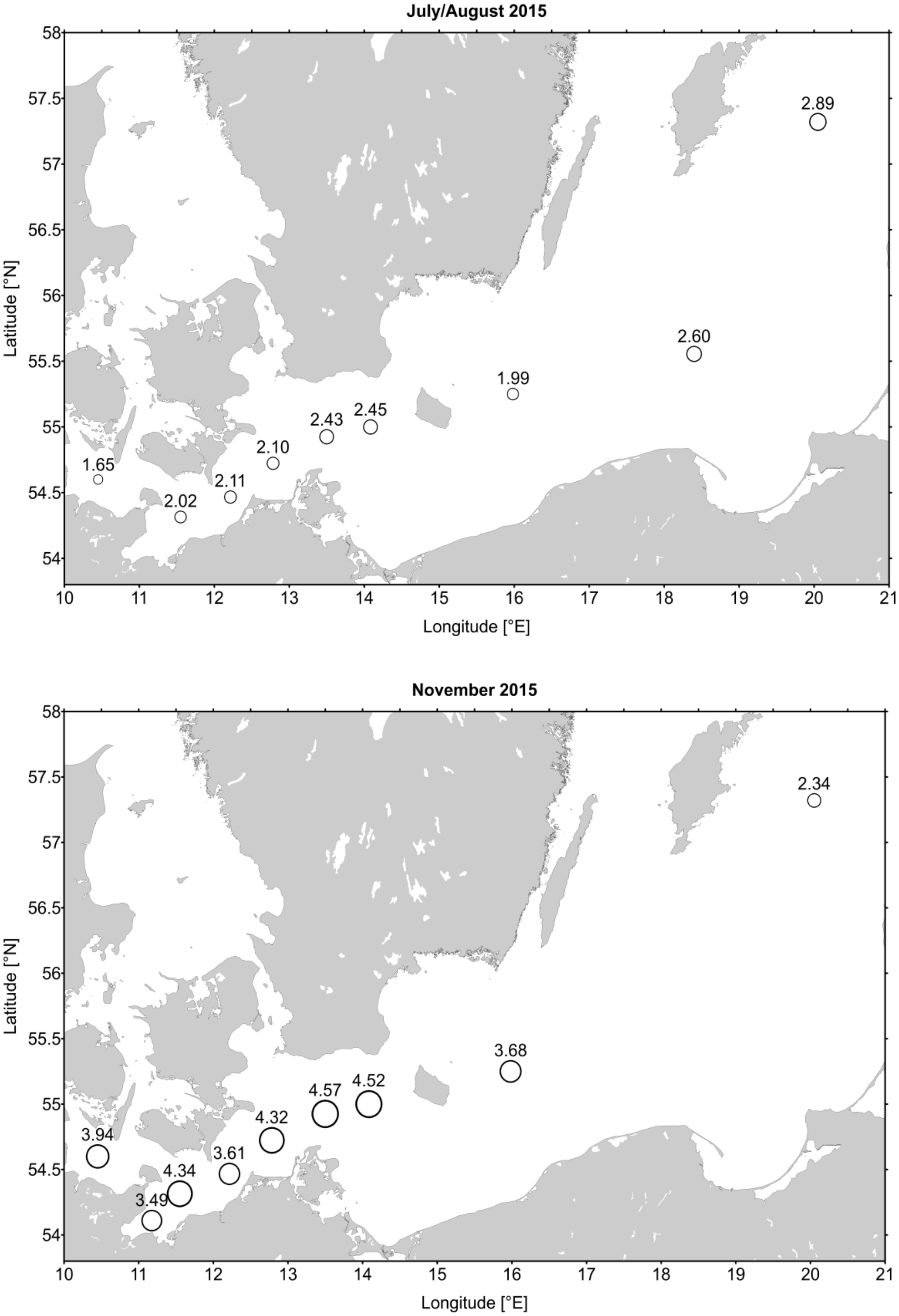


Fig. 12: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during monitoring cruises in July/August and November 2015.

4.1.6 Sedimentation

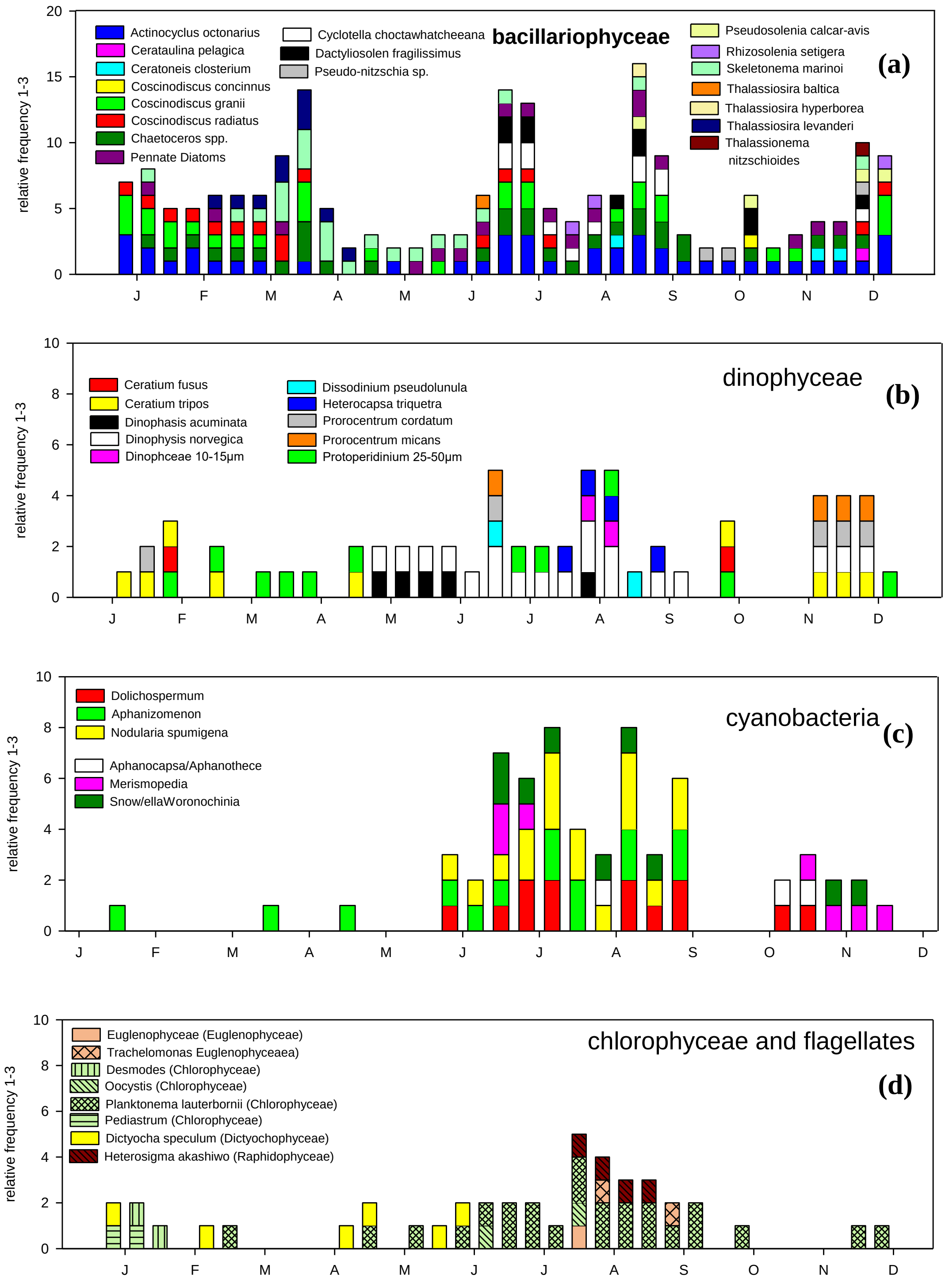
After the year 2014, that was heavily influenced by the inflow-related growth of barnacles on the samplers and the resulting corruption of the data due to their excrements, the microscopic examination of the material collected in the Arkona Basin in 2015 showed the typical pattern of pelagic growth in the Western Baltic. A low particle flux in spring was compensated by higher rates in summer and autumn. With 18 species of diatoms found in the trapped material in 2015 the number increased by 3 respectively 4 compared to the previous years.

During the pelagic growth phase (March to December; Fig. 16 a-d), the typical seasonal succession of communities was observed. Similar to the springs of the previous years *Thalassiosira levanderi, Skeletonema marinoi, Coscinodiscus granii* and *Chaetoceros* spp. dominated the diatoms whereas *Actinocyclus octonarius*, *Coscinodiscus radiatus* and pennate diatoms were less abundant. *Achnanthes taeniata, Ceratoneis closterium, Melosira arctica* and *Diatoma tenue* did not occur in this spring and were missing over the whole year and *Thalassiosira hyperborea* was shifted towards the second half of the year.

After the spring phase the number of diatom species decreased sharply: *Skeletonema marinoi, Coscinodiscus granii, Actinocyclus octonarius* and *Chaetoceros* spp. appeared temporarily in early summer, and later on were joined by pennate diatoms until June. In late June a more diverse summer population constituted consisting of *Thalassiosira baltica, Coscinodiscus radiatus, Skeletonema marinoi, Chaetoceros* spp., *Actinocyclus octonarius* and pennate diatoms that were until September supplemented by *Dactyliosolen fragilissimus, Coscinodiscus granii, Cyclotella choctawhatcheeana* and to a smaller extent *Rhizosolenia setigera* and *Ceratoneis closterium.* In September small amounts of *Pseudosolenia calcar-avis* and *Thalassiosira hyperborea* joined and increased diatom diversity. After a period in late September, where diatoms species decreased to a number of 2-3 the diversity increased again during the autumn bloom, however at a generally lower abundance level. In contrast to the previous years, summer and late autumn were the periods with the richest diatom flora in 2015.

The number of dinoflagellate species observed in 2015 increased to 10 (Fig. 16 b). In contrast to the diatoms, the dinoflagellates displayed a comparatively strict seasonal succession with only up to 4 species occurring at the same time. In spring we mainly found *Protoperidinium* spp. and *Ceratium tripos* followed in May/June by *Dinophysis acuminata* and *Dinophysis norvegica*, which over the period from late June to August were joined by *Prorocentrum micans, Prorocentrum cordatum, Dissodinium pseudolunula* and later until September by *Heterocapsa triquetra*. The autumn population consisted of *Prorocentrum* species (*P.micans, P.cordatum*), *Dinophysis norvegica* and *Ceratium tripos*. In terms of abundance and diversity, dinoflagellates showed a similar pattern as in the previous years.

The number of cyanobacterial species observed in 2015 increased in comparison with the previous year (Fig. 16 c). Diazotrophic species (*Aphanizomenon* and *Nodularia*) co-appeared during summer with genera like *Merismopedia* and *Snowella*, whereas there was a stricter seasonal succession in the previous years. The spring was characterized by the intermittent occurrence of *Aphanizomenon* whereas during autumn (October/November) species like *Snowella/Woronochinia*, *Dolichospermum*, *Merismopedia* and *Aphanocapsa/Aphanotheca* dominated the cyanobacteria.



1= present 2= abundant 3= highly abundant

Fig. 16 a-d: Relative frequency of selected species of diatoms, dinoflagellates, cyanobacteria, green algae and other flagellates in sedimented organic material in 2015.

The occurrence of the nitrogen-fixing species between June and September is well reflected by the shift in the isotopic signature of the particulate nitrogen from 6‰ to between 2 and 4‰ during this period (Fig. 23). This indicates that during summer a substantial part of sinking organic matter was produced by nitrogen-fixing organisms.

The temporal distribution of Chlorophyceae and Dictyochophyceae (Fig. 16 d) shows a clear seasonality. Whereas in winter and spring *Dictyocha speculum*, *Planktonema lauterbornii* , *Desmodesmus* and *Pediastrum* were abundant, the summer period between June and September was characterized by the dominating *Planktonema lauterbornii* and the co-occurrence of raphidophytes (*Heterosigma akashiwo*) and euglenophytes (*Trachelomonas* and further unidentified species). During autumn/winter the green algae were exclusively represented by *Planktonema lauterbornii.*

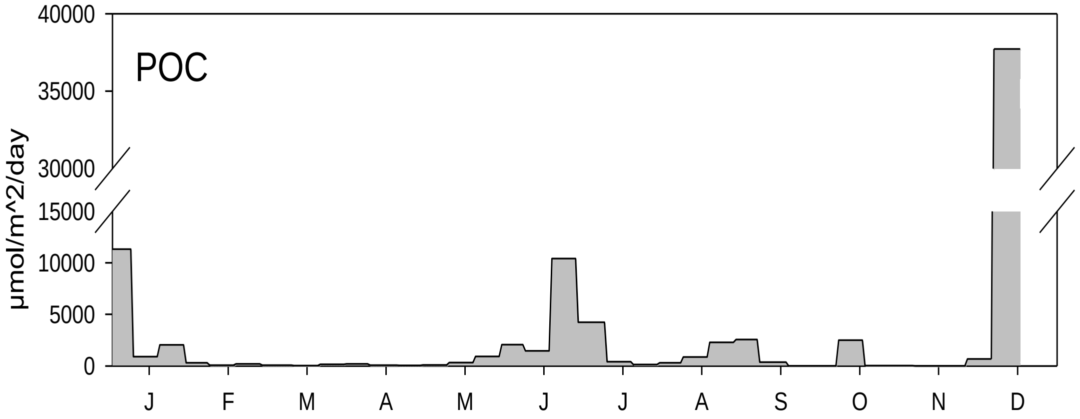


Fig. 17: Daily sedimentation rates of particulate organic carbon (POC) at 35 m depth in the central Arkona Sea in 2015.

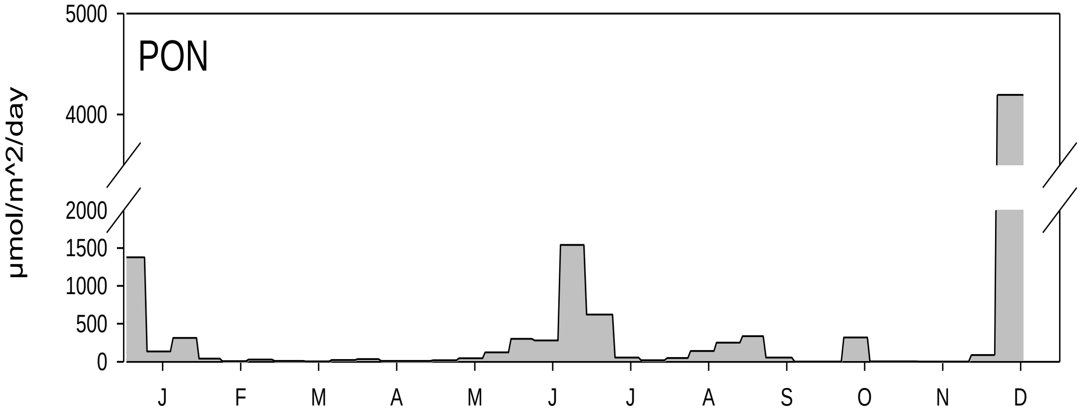


Fig. 18: Daily sedimentation rates of particulate organic nitrogen (PON) at 35 m depth in the central Arkona Sea in 2015.

The seasonal patterns of the vertical transport of particulate carbon (Fig. 17), nitrogen (Fig. 18), silica (Fig. 19) and phosphorus (Fig. 20) displayed distinct seasonal differences in 2015. In the beginning and at the end of the year resuspension events of benthic particles interfered with the measurement. These periods can be identified by the high mass flux and extremely high silica content of the samples that derives from the high proportion of clay and other siliceous minerals.

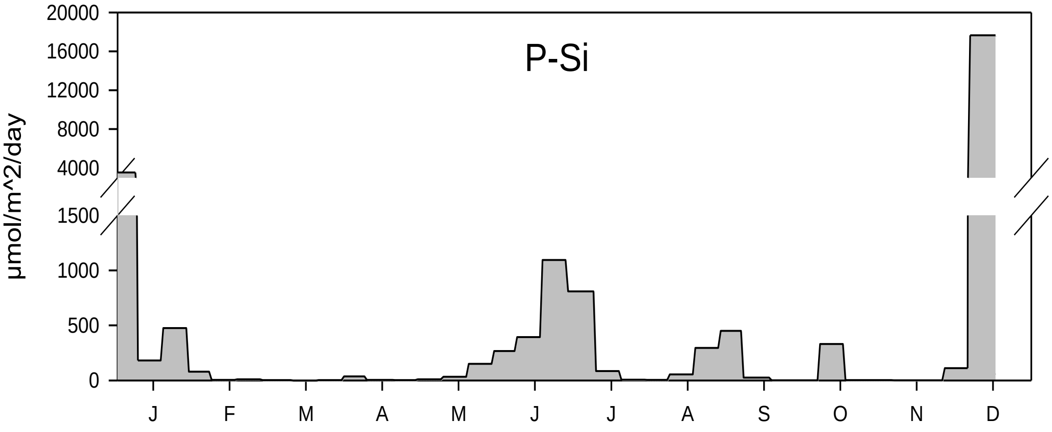


Fig. 19: Daily sedimentation rates of particulate biogenic silicate (P-Si) at 35 m depth in the central Arkona Sea in 2015.

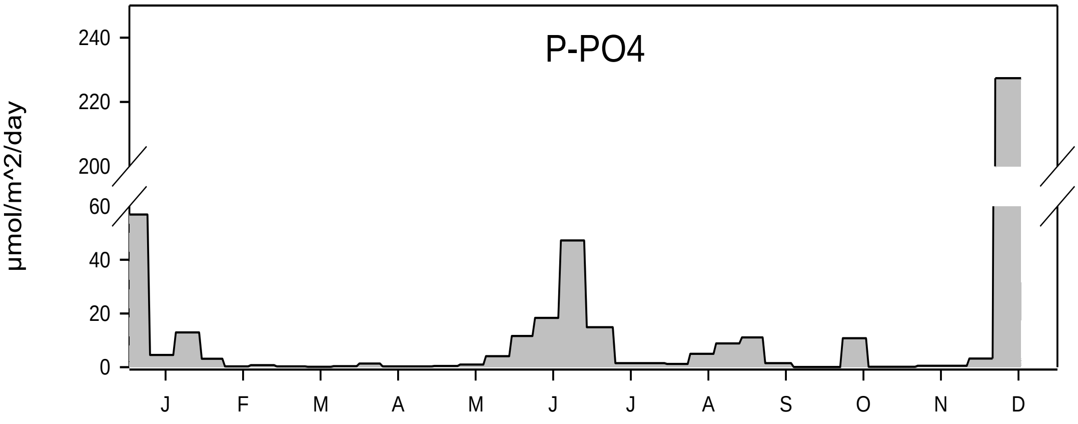


Fig. 20: Daily sedimentation rates of particulate phosphorus (P-PO4) at 35 m depth in the central Arkona Sea in 2015.

Contrary to the typical seasonal Baltic pattern of particle flux, the spring bloom sedimentation was extremely weak in 2015. Although between March and April diatom species, which typically occur in spring, were detected in the trap, their quantitative contribution to the mass and elemental flux at that time was only rather low. Mass flux based on diatoms did, however, not completely vanish but shifted to the summer season, where they co-occured with the cyanobacteria. This is rather uncommon, as diazotrophic cyanobacteria make use of their ability to fix atmospheric nitrogen when this nutrient is limiting for other primary producers like diatoms, which are typically growing in nutrient-rich water masses. Both groups of organisms were, however, observed in the samples from that period together with independent indicators like high biogenic silica levels and a low δ15N-signature. This indicates a phase of quickly changing hydrographical settings in a summer with extreme variations in temperature and wind conditions. The Arkona Basin, as a small water body between the central Baltic Sea in the east and the shallow Western Baltic, could have been influenced successively by both of these larger water masses over short periods in the summer. While at easterly winds filaments of cyanobacteria could have been blown into the surface waters of the area, westerly winds could have pushed them back and introduced a different microalgal flora in the surface layer of the basin. This could have provided favourable conditions for diatoms, if upwelling processes were involved that transported nutrients from deeper layers to the surface. As the glasses of the sediment trap were collecting over a period from one week to 10 days, successive changes in boundary conditions could have left their qualitative and quantitative traces in one sample. This confirms the fact, that visible properties of the small Arkona Basin are generally not always a product of the basins own dynamic processes but could be due to import from both sides. This becomes very evident in the inorganic particles of the sediment, which are known to derive from many different and even outer-Baltic sources.

The quantitative effect of this alternating bloom pattern is, however, dominant for the annual budget. Most of the organic material, that reaches the sediment, is produced in this period between June and July. A second smaller peak in August/September is still based on a similar mixture of very different sources and only in October material is sinking, which is primarily of diatom origin.

Both the C/N-ratio (Fig. 21) and the C/P ratio (Fig. 22) display a large scatter between successive samples in summer and late summer which as well points to a heterogeneous input. In the mean both ratios remain in a similar range over the whole growth period.

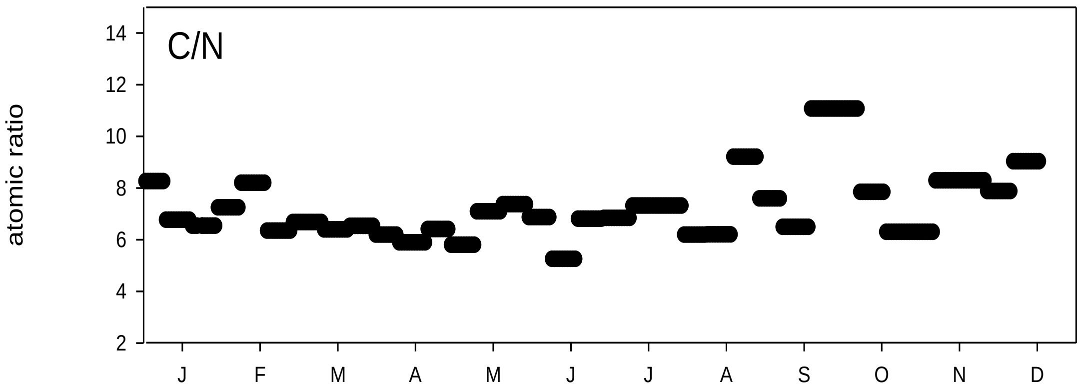


Fig. 21: Atomic ratio between carbon and nitrogen (C/N) in sedimenting particles at at 35 m depth in the central Arkona Sea in 2015.

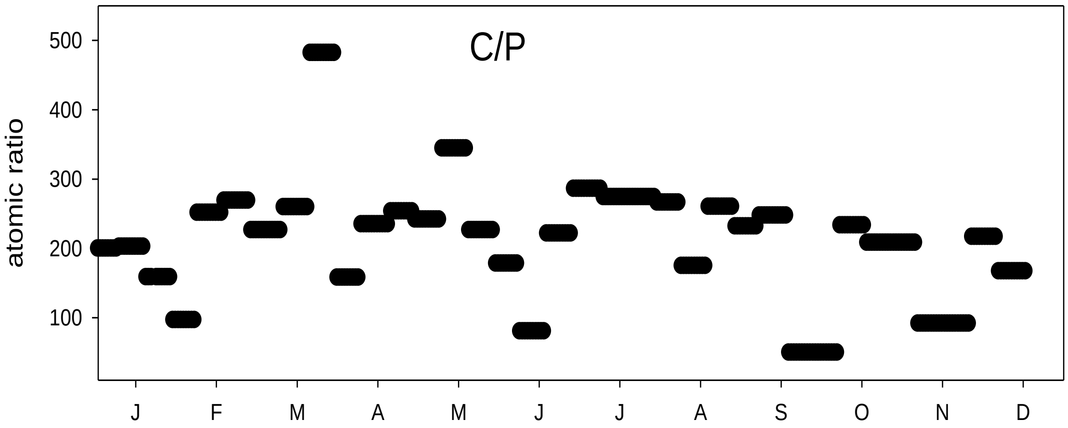


Fig. 22: Atomic ratio between carbon and phosphorus (C/P) in sedimenting particles at at 35 m depth in the central Arkona Sea in 2015.

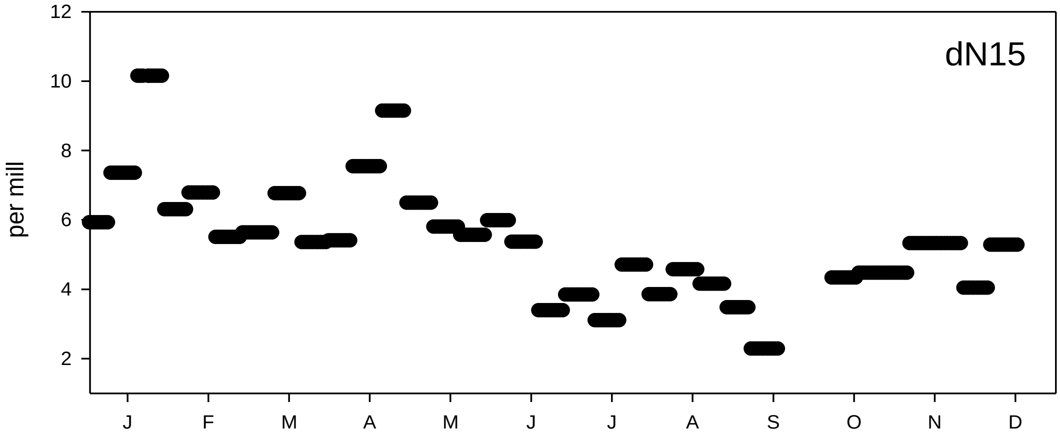


Fig. 23: Isotopic signature of nitrogen (‰ δ15N) in sediment trap material from the central Arkona Sea in 2015.

The δ15N-signature (Fig. 23) reflects the period in summer, when nitrogen fixation by diazotrophic cyanobacteria sets in and increases the amount of light nitrogen isotopes in the sinking material. The scatter between 5 and 3 ‰ δ15N in this phase indicates as well, that the material is not completely homogeneous. The variation in δ15N of spring and summer data suggests an equal share between diatoms and cyanobacteria in the sinking material, assuming a δ15N of 2 ‰ for the latter group.

The total annual flux for single elements in 2015 corrected for resuspension amounted to 426 mmol C (5.1 g C), 60 mmol N, 77 mmol Si and 2.1 mmol P m^{-2} a^{-1} at a mass flux of 49 g dry mass m^{-2} a^{-1}. Uncorrected values were 841 mmol C, 106 mmol N, 271 mmol Si and 4.6 mmol P m^{-2} a^{-1} at a mass flux of 102 g dry mass m^{-2} a^{-1}. Extremely high mass flux and silica values in the uncorrected data clearly indicate the sediment as source for the winter material. The level of the corrected values is well within the range of long term annual flux rates. Still the year is special due to the shift of export production from spring to summer and obviously quite heterogeneous production patterns during that time.

4.2 Mesozooplankton

4.2.1 Species Composition and Invasive Species

The composition of the zooplankton in 2015 was characterized by a notable increase in the number of species found in the investigation area. A total of 61 Taxa was recorded (Table A3). The diversity is generally higher compared to preceding years (2013: 52 taxa, 2014: 45 taxa). The increase was mainly caused by inflow events in spring and autumn, which brought halophilic zooplankton into the investigation area. Thus, the number of species recorded was higher in February and November, while in May-August the average number of taxa was slightly lower than usual (Fig. 24). The additionally recorded species were *Acartia clausi* (in Nov.), *Calanus* spp. (Feb.-Nov), *Centropages typicus* (Feb., Nov.), *Corycaeus* spp. (April), *Longipedia* spp. (Feb.), *Oithona atlantica* (Feb.) and *Oncaea* spp. (Nov.) among the abundant group of copepods. Other groups were represented by *Penilia avirostris* (Nov., Cladocera), *Parasagitta setosa* (Nov., Chaetognatha) or *Phoronis mülleri* (Nov., Phoronida). These species were primarily recorded in the western area (Kiel Bight – Arkona Basin). They are not novel to the area and have been observed earlier with inflow events. Their record is often based on single specimens found in the net catches.

Apart from the additional species recorded due to inflows, some marked differences in the composition within the dominating groups of zooplankton occurred in 2015. Most striking is the lack of mass occurrences of the cladocerans. In the past, cladocerans were one of the most prominent members of the zooplankton achieving concentrations up to 7-11 x 10^4 ind. m^{-3} in the Bay of Mecklenburg, the Arkona Basin and the Bornholm Basin. In 2015, the abundance was one order of magnitude lower with concentrations below 5.5 x 10^3 ind. m^{-3} except at one station (OMBMP-K5, 2.7 x 10^4 ind. m^{-3}). However, cladocerans are known for their ephemeral blooms and peaks might have been missed due to the long sampling interval during the summer. This might be particularly important in years with an early zooplankton development as in 2015. *Evadne nordmanni* was the single most important species occurring at 0.7- 4.0 x 10^3 ind. m^{-3} at all stations. The genus *Bosmina* spp., which is regularly responsible for the large peaks in the abundance of cladocerans, ranked on average only second with maximal 3.5 10^3 ind. m^{-3} except at OMBMP-K5 (2.6 x 10^4 ind. m^{-3}). *Podon leuckartii* and *P. intermedius* occurred regularly in the Bay of Mecklenburg and the Arkona Basin, but were a minor component (max 335-400 ind. m^{-3}). *Pleopsis polyphemoides* was generally rare. In addition to cladocerans, the abundance of adult cyclopoid copepods, mainly represented by the species *Oithona similis*, was lower than usual. In the past the species was responsible for large winter and autumn concentrations of up to 5.0 x 10^4 ind. m^{-3} in Kiel Bay and the Bay of Mecklenburg. In 2015 these high winter abundances were lacking and the species achieved only moderate densities in the western Baltic.

Due to the low abundance of cladocera, rotifers were the most abundant group followed by copepods, meroplankton and appendicularians. Meroplankton showed particularly high densities in the Kiel Bay and the Bay of Mecklenburg, while their abundance in the Arkona Basin was lower than expected. In the deeper basins of the eastern Baltic Sea they traditionally contribute only little to total zooplankton. Polychaete- and bivalve larvae were most abundant with up to 2.0 and 1.4 x 10^4 ind. m^{-3}, respectively. The rotifers were mainly represented by *Synchaeta*, while several species of *Keratella* were rather rare. As in preceding years, *Synchaeta* was particularly abundant in the Arkona Basin (>4.3 x 10^4 ind. m^{-3}) and in the deeper areas of the Bornholm and Gotland Basins (2.6 – 4.1 10^4 ind. m^{-3}). Among the appendicularians, *Fritellaria borealis* was abundant in spring with up to 7 x 10^3 ind. m^{-3} in the Arkona Basin. While its occurrence in the south-western part of the Baltic Sea was confined to this area in the preceding years, it was very abundant in the Bay of Mecklenburg in 2015 as well. In the Bornholm – Gotland Basins, *Fritellaria borealis* was the density was generally lower than in previous years. *Oikopleura dioica* occurred in low concentrations at all stations, particularly during late summer.

The composition of the adult calanoid copepods was generally dominated by the genus *Acartia* in nearly all areas except the Gotland Basin. While the brackish species *Acartia bifilosa* was the most abundant species in Kiel Bay, *Acartia longiremis* dominated in the Bay of Mecklenburg, the Arkona Basin and the Bornholm Basin, in which *A. bifilosa* ranked second. *A. longiremis* is an artic – sub-arctic copepod occurring in the Atlantic and Pacific (HOPCROFT et al. 2010). In the Baltic Sea it is a regular and abundant species. Nevertheless, it is rather exceptional that this species dominates among the copepods. The abundance of another brackish species, *A. tonsa*, was low in 2015. In contrast to *Acartia*, the abundance of *Pseudocalanus* spp. and *Paracalanus parvus* was exceptionally low in 2015. These species often dominate the calanoids in Kiel Bay and have been abundant in the Bay of Mecklenburg and the Arkona Basin with concentrations larger than 4 x 10^3 ind. m^{-3}. Maximum concentrations in 2015 were, in contrast, 239 and 35 ind.m^{-3}, respectively. In the eastern part of the Baltic Sea, however, their abundance was similar to preceding years. Apart from *Acartia*, *Temora longicornis* and *Centropages hamatus* contributed considerably to the copepod community, particularly in the Arkona Basin (both species) and the Bornholm and Gotland Basins (*Temora* only).

With the exception of the brackish water copepod species *Acartia tonsa*, no other invasive species were recorded in 2015 in the study area. First records of *A. tonsa* in Baltic Sea originate from the Gulf of Riga in 1924 and the Gulf of Finland in 1934 (SEGERSTRÅLE, 1957). In German coastal water it was found in 1981 (GOLLASCH & NEHRING, 2006).

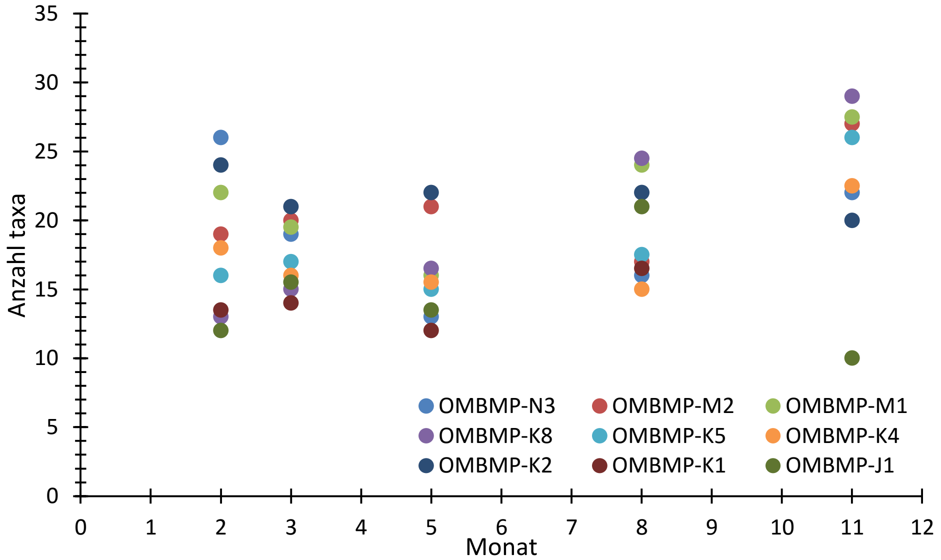


Fig. 24: Seasonal variation of the number of taxa recorded at different stations in the investigation area in 2015.

4.2.2 Seasonal Zooplankton Variation in Sub-Areas

Although samples are taken at monitoring sites usually on the outward and return journeys, the low number of samples allows only limited conclusions about seasonal variations in the dynamics of stocks and succession of species. Particularly, short-lived blooms of rotifers and cladocerans can only be recorded to a limited extent with only five scheduled cruises per year.

Kiel Bay

The seasonal variation of the zooplankton in Kiel Bay (OMBMP-N3) showed a pronounced maximum with 5.5 x 10^4 ind. m^{-3} during July (Fig. 25). High densities in winter based on the typical early occurrence of the copepod genera *Oithona* spp. or *Pseudocalanus* spp as in previous years were not observed in 2015. Nevertheless, the zooplankton abundance during spring and summer was similar to the preceding years. Meroplankton contributed only little to the zooplankton stocks (Fig. 25). Only few polychaete larvae occurred in spring (459 ind. m^{-3}), bivalve and gastropod larvae were present mainly in July with 4.0 and 1.1 x 10^3 ind. m^{-3}, respectively. On an annual basis, the observed dominance of copepods is typical for Kiel Bay (Fig. 26). Other groups were generally of minor importance, except in summer, when a bloom of tintinnid ciliates with up to 3.6 x 10^4 ind. m^{-3} was recorded. Rotifers occurred in low density in March (855 ind. m^{-3}), cladocerans mainly in August (1.3 x 10^3 ind. m^{-3}), and appendicularians in November (2.3 x 10^3 ind. m^{-3}). Similar to the preceding years, *Synchaeta* spp., *Evadne nordmanni* and *Oikopleura* spp. were the dominant species among the rotifers, the cladocerans and the appendicularians, respectively. In the abundant group of copepods differences in the composition and seasonal development occurred in comparison to preceding years (Fig. 27). Following the low winter abundance of *Oithona* and *Pseudocalanus*, copepodites and adults of the group of *Pseudo-* and *Paracalanus* remained unusually low during spring and summer (< 104 ind. m^{-3}). The abundance of the genera *Temora* and *Centropages* were also lower than usual (max. 254 and 770 ind. m^{-3}). The copepod community was, therefore, dominated by the genera *Oithona* and *Acartia* (max. 6.8 and 5.9 x 10^3 ind. m^{-3}), among the adult copepods *Acartia bifilosa* (max. 2.2 x 10^3 ind. m^{-3}) was the single most important species (Fig. 27).

Bay of Mecklenburg

The zooplankton development in the Bay of Mecklenburg in 2015 (OMBMP-M2-M1) was characterised by an unusually early increase in stock size (Fig. 25). Whereas a maximum abundance in this region is generally observed in summer/autumn, the maximum concentration of up to 3.5 x 10^4 ind. m^{-3} was already recorded in late March, which was based on abundant rotifers, polychaete larvae and copepods. While the zooplankton density in early summer (May) was similar to preceding years, it was considerably lower during the summer and autumn (max 0.7 - 2.8 x 10^4 ind. m^{-3}; 2013-2014: max 5.3 - 7.8 x 10^4 ind. m^{-3}).

Meroplankton was, in contrast to Kiel Bay, generally abundant (Fig. 25, 26). Apart from the high concentrations of polychaete larvae in March at station OMBMP-M2 (2.0 x 10^4 ind. m^{-3}), bivalve larvae caused another maximum in autumn (0.9 - 1.4 x 10^4 ind. m^{-3}). Copepods dominated the zooplankton composition on an annual basis (Fig. 26). The rotifer peak in March caused by *Synchaeta* spp. (0.3 - 1.4 x 10^4 ind. m^{-3}) is rather unusual. In preceding years a mass development was observed in this area during May. In addition to rotifers, the appendicularian *Fritellaria borealis* also showed an early occurrence in March (1.2 - 1.6 x 10^3 ind. m^{-3}). The autumn maximum caused by *Oikopleura dioica* (2.3 – 5.4 x 10^3 ind. m^{-3}) in November, in contrast, is a typical observation for the area. Most striking in the seasonal development in the Bay of Mecklenburg is the lack of pronounced summer peaks in the abundance of zooplankton caused by the mass occurrence of the cladoceran *Bosmina* spp. (Fig. 26). In 2015, this species was only of minor importance (range 12 – 816 ind. m^{-3}); instead, *Evadne nordmanni* dominated among the cladocerans and was abundant from May to August without pronounced peak concentrations (1.0 - 1.2 x 10^3 ind. m^{-3}).

Among the copepods, the genus *Oithona* dominated in February (1.0 - 1.2 x 10^3 ind. m^{-3}), while the abundance of *Acartia*, *Temora* and *Pseudocalanus* was low (Fig. 27). Single finds of *Calanus* spp., *Centropages typicus* and *Oithona atlantica* during this time reflect the inflow of saline water into the Baltic during winter. The seasonal development of the copepods started considerably early in 2015. Stocks generally increased at the end of March (0.8 - 1.2 x 10^4 ind. m^{-3}) and achieved maximal concentrations already in May (1.8 – 2.4 x 10^4 ind. m^{-3}). An increase in the stocks of *Oithona* (2.1 – 2.6 x 10^3 ind. m^{-3}), *Acartia* (1.5 – 4.3 x 10^3 ind. m^{-3}) and *Pseudo-/Paracalanus* (2.6 – 6.0 x 10^3 ind. m^{-3}) contributed to the early zooplankton development in March. The community shifted to a dominance of *Acartia* (range 0.8 - 1.4 x 10^4 ind. m^{-3}) followed by *Oithona*, *Temora* and *Centropages* (range 1.3 – 4.6 x 10^3 ind. m^{-3}), but declined already in August. The large stock size of *Acartia* is common in the area, but *Oithona* and particularly *Pseudo-/Paracalanus* (range 49 – 968 ind. m^{-3}) were considerably less abundant during May-August than usual. Also autumn densities were exceptionally low, primarily caused by low *Oithona* stocks.

Among the adult stages *Acartia longiremis* dominated (Fig. 27). The species was the most abundant during March-May (range 1.4 – 9.0 x 10^3 ind. m^{-3}) and was replaced by *A. bifilosa* in August (range 1.0 – 3.1 x 10^3 ind. m^{-3}). *Oithona similis* achieved higher concentrations in the western part of the Bay only during March (OMBMP-M2, range 1.0 – 1.9 x 10^3 ind. m^{-3}). The stocks of *Temora longicornis* and *Centropages hamatus* remained generally low (< 1.0 x 10^3 ind. m^{-3}). While a high abundance of *Acartia* is not unusual for the Bay of Mecklenburg, the dominance of *Acartia longiremis* until May together with only very low concentrations of *Pseudocalanus* spp. and *Paracalanus parvus* is remarkable. Associated with inflows of saline water more rare species like *Acartia clausi*, *Calanus* spp., *Centropages typicus*, *Oithona atlantica* or *Oncaea* spp. were found in February and November.

Arkona Basin

The characteristic changes in the zooplankton development recorded in the Bay of Mecklenburg were also observed in the Arkona Basin (OMBMP-K8 –K4, Figs. 25, 26, 27). Again, the zooplankton season started early and the conspicuous peaks in summer caused by peaks of the cladoceran *Bosmina* spp. were lacking. High concentrations of 2.8 – 5.8 x 10^4 ind. m^{-3} were already recorded in March. However, annual maxima of 4.0 – 5.8 x 10^4 ind. m^{-3} remained below those observed in the preceding years, primarily because of unusually low summer concentrations (2013-2014: 9.4 – 14.9 x 10^4 ind. m^{-3}). Also the seasonal development of the community resembled that of the Bay of Mecklenburg. The contribution of meroplankton in spring by polychaete larvae was less pronounced than in the Bay of Mecklenburg (0.7 – 1.1 x 10^3 ind. m^{-3}), bivalve larvae contributed primarily in July/August to the community (0.6 – 8.2 x 10^3 ind. m^{-3}). Copepods dominated on an annual basis (Fig. 26), but both the rotifer *Synchaeta* spp. and the appendicularian *Fritellaria borealis* displayed peak densities of 1.4 – 4.3 x 10^4 ind. m^{-3} and 2.3 – 7.2 x 10^3 ind. m^{-3}, respectively, at the end of March. The appendicularian *Oikopleura dioica* showed peak concentrations in November (0.3 – 1.4 x 10^3 ind. m^{-3}).

The genus *Acartia* was also the dominant copepod genus in the Arkona Basin (Fig. 27). It was already numerous during February (1.1 – 1.8 x 10^3 ind. m^{-3}) and primarily responsible for the spring increase in March (2.3 – 7.2 x 10^3 ind. m^{-3}). It remained dominating until August (3.8 – 8.4 x 10^3 ind. m^{-3}). In May, *Temora* and *Centropages* became abundant (1.2 – 2.6 x 10^3 ind. m^{-3} and 0.8 – 2.3 x 10^3 ind. m^{-3}, respectively). The genus *Pseudocalanus*, however, remained unusually low during the year (max. 2.6 x 10^3 ind. m^{-3}). As in the Bay of Mecklenburg, *Acartia longiremis* was the most abundant single species (March-August: 1.4 – 5.2 x 10^3 ind. m^{-3}, Fig. 27). It remained dominating during summer and was not replaced by A*. bifilosa*. *A. bifilosa*, *Temora longicornis* and *Centropages hamatus* which occurred mainly during May-August with concentrations of 0.4 – 2.0, 1.0 – 1.7 and 0.4 – 1.0 x 10^3 ind. m^{-3}, respectively. In autumn *A. tonsa* was abundant (356-720 ind. m^{-3}).

Bornholm and Gotland Basin

In contrast to the south-western Baltic, less pronounced seasonal and compositional changes compared to receding years were observed in the deeper, eastern Bornholm and Gotland Basins. Typical for these areas, meroplankton was only a minor component of the zooplankton (Fig. 25). Following low winter stocks dominated by copepods and appendicularians, the zooplankton numbers rose due to increasing stocks during March-May, which is not unusual (Fig. 26). However, exceptionally large peak concentrations of the rotifer *Synchaeta* spp. ranging from 2.6 to 4.1 x 10^4 ind. m^{-3} were observed in the Bornholm but also in the southern and central Gotland Basin, for which high concentrations during this time of the year are less common. During summer, the composition of the zooplankton shifted from a rotifer/copepod/appendicularian dominated community to the dominance of copepods (9.3 – 12 x 10^3 ind. m^{-3}) followed by cladocera (2.9 – 5.3 x 10^3 ind. m^{-3}) in the Bornholm Basin. Only in the southern and central Gotland Basin rotifers remained abundant (max 2.0 x 10^3 ind. m^{-3}). Similar to the shallower western stations, the concentrations of cladocerans were generally low and did not exceed 5.5 x 10^3 ind. m^{-3} compared to › 4.1 x 10^4 ind. m^{-3} observed in previous years. Nevertheless, *Bosmina* spp. was still the dominating genus.

Among the copepods, the single dominance of *Acartia* in the Mecklenburg Bight and Arkona Basin did not continue to the deeper areas of the Baltic. On an annual basis, the copepodites *Acartia*, *Temora* and *Centropages* were equally abundant in the Bornholm Basin, while the contribution of *Acartia* to the total stock further decreased towards the eastern study area (Fig. 27). The abundance of *Acartia*, *Temora* and *Centropages* was similar to preceding years (max. 3.1, 7.3 and 2.6 x 10^3 ind. m^{-3}, respectively). In contrast, the reduction of the stock of *Pseudo/Paracalanus* copepodites seen in the western areas was also apparent in the Bornholm and southern Gotland Basins, but not in the central Gotland Basin. While maximal concentrations of › 7.7 x 10^3 ind. m^{-3} were observed in 2013-2014, the abundance of *Pseudo/ Paracalanus* did not exceed 1.8 x 10^3 ind. m^{-3} in 2015. *Acartia longiremis* was the single most abundant species among the adult copepods in the Bornholm Basin (0.9 – 2.3 x 10^3 ind. m^{-3}) followed by *Temora longicornis* (0.3 – 1.9 x 10^3 ind. m^{-3}), which occurred in summer mainly. In the Gotland Basin, however, *Temora longicornis* (1.2 – 2.4 x 10^3 ind. m^{-3}) was dominating.

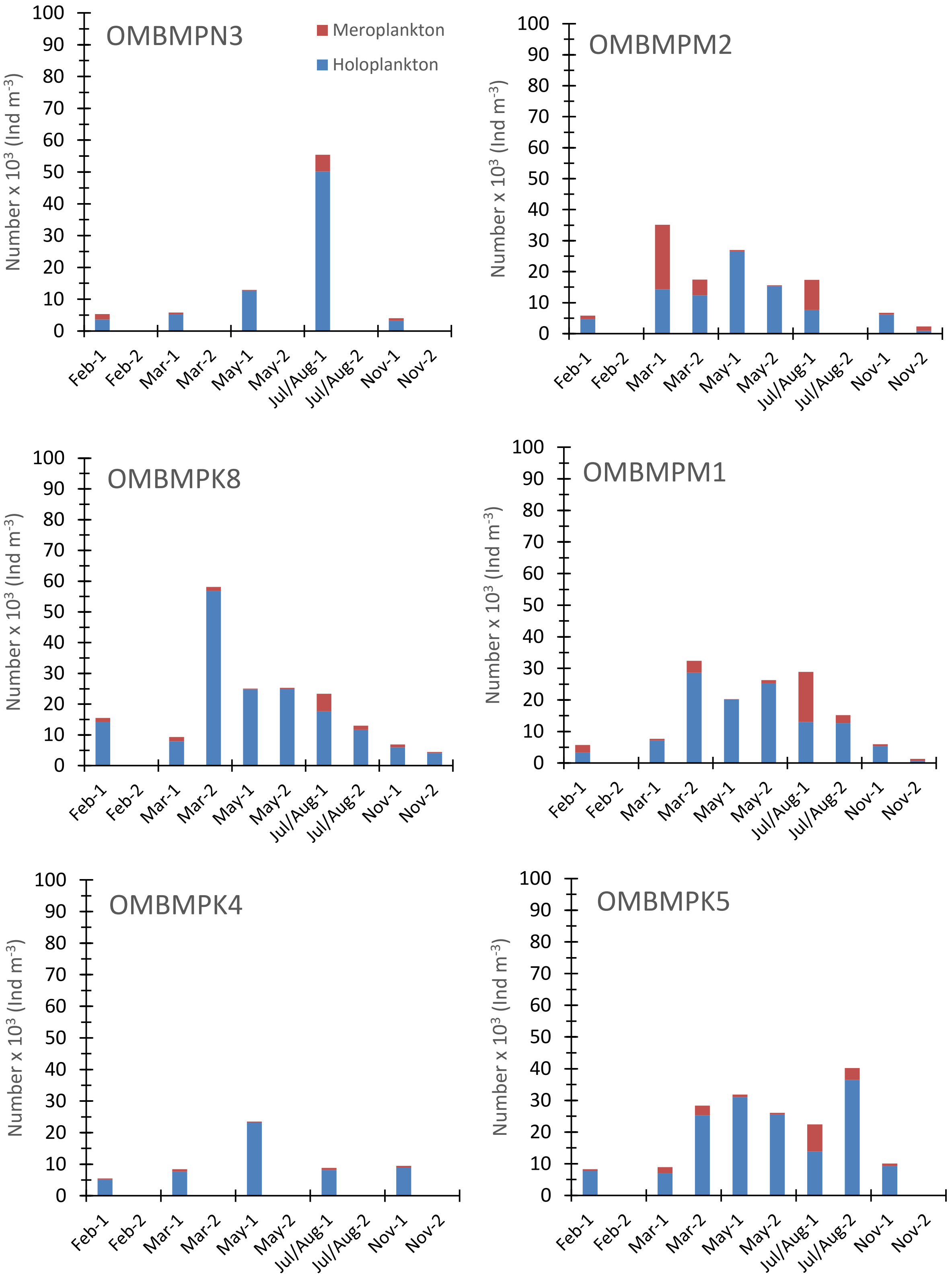
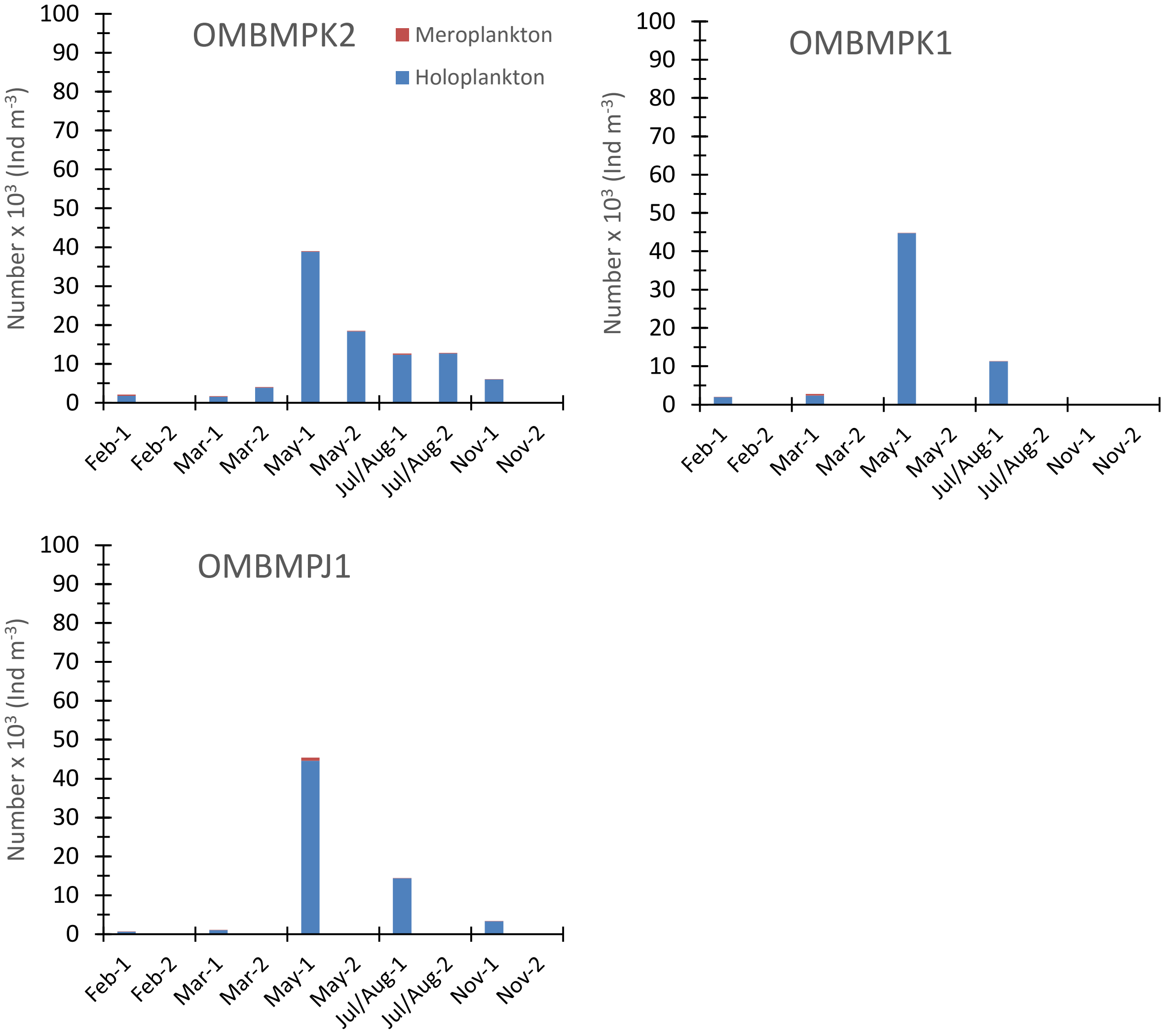


Fig. 25: Seasonal variation of the abundance of mesozooplankton and the the contribution of mero- and holoplankton to the total stock of zooplankton at different stations in the investigation area in 2015.



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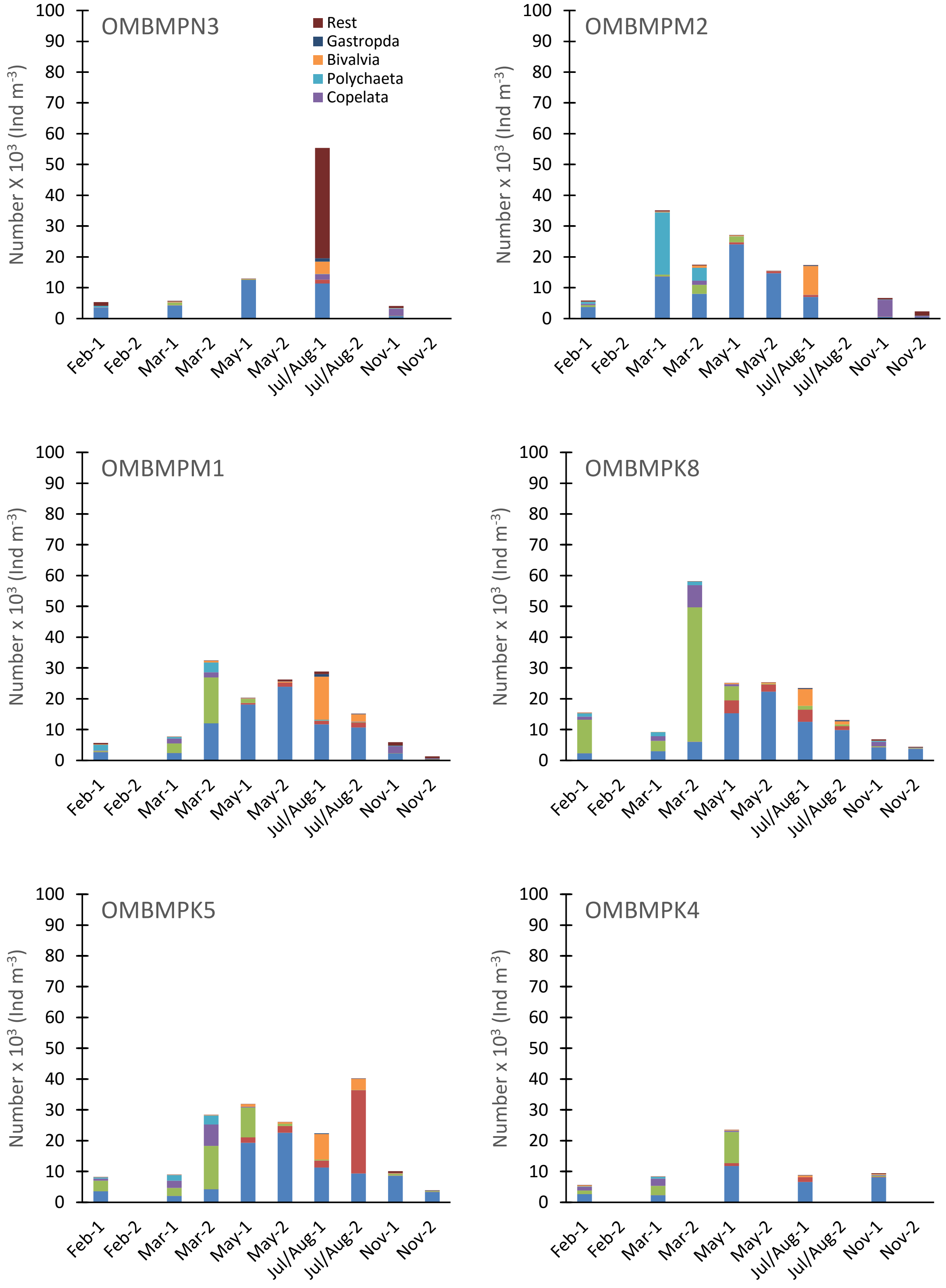


Fig. 26: Seasonal variation of the main taxonomic groups of the mesozooplankton at different stations in the investigation area in 2015.

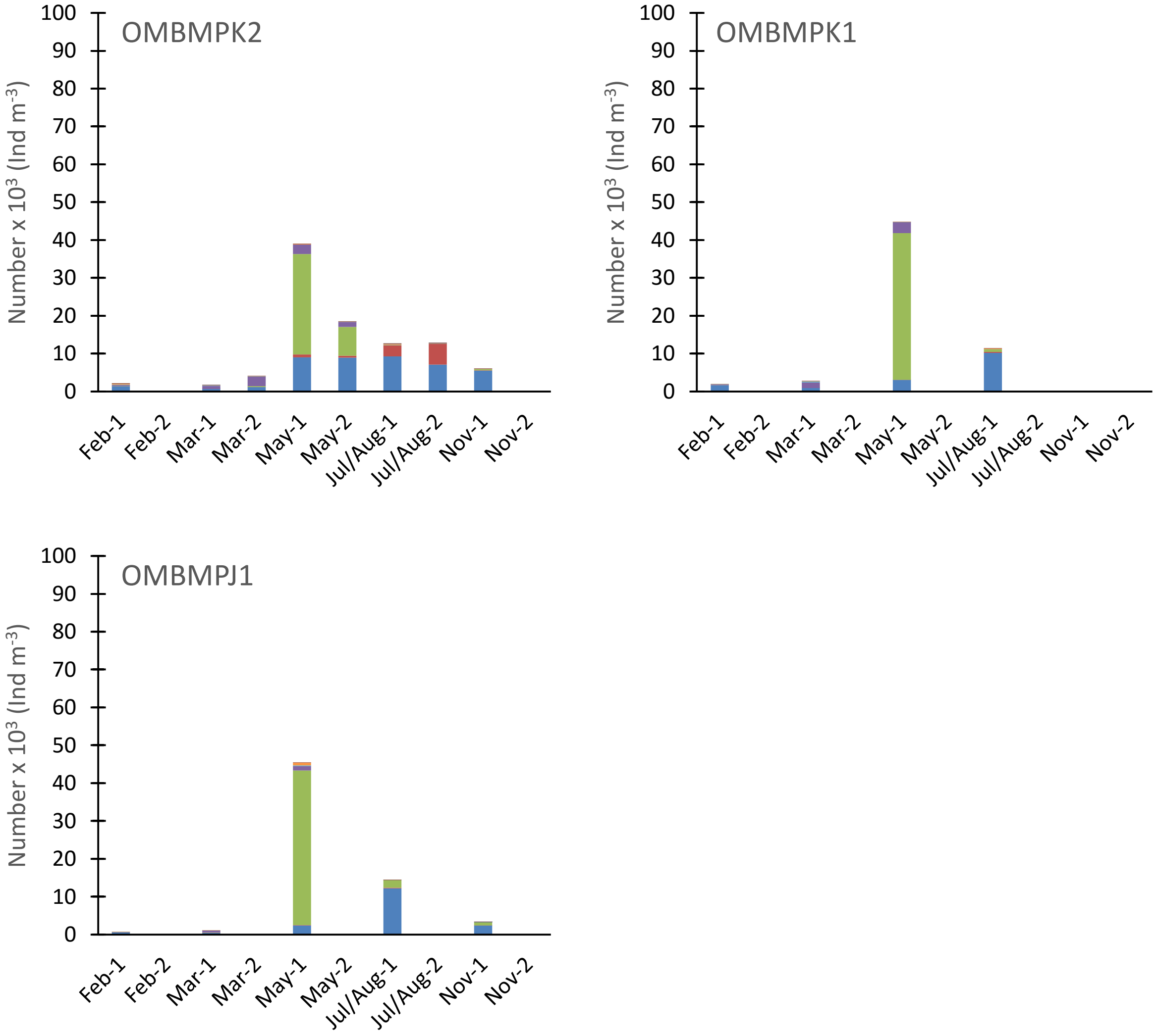


Fig. 26: continued.

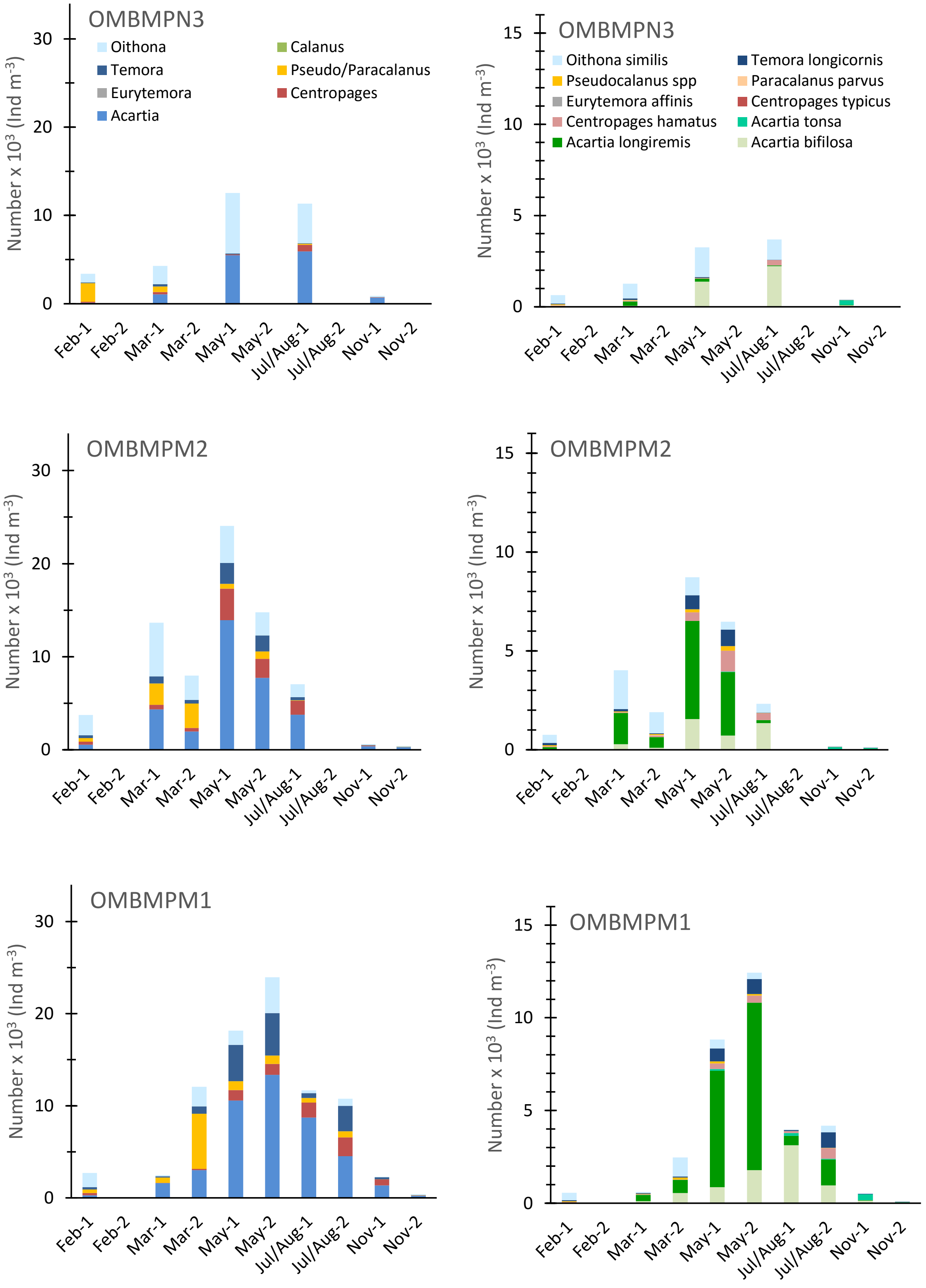
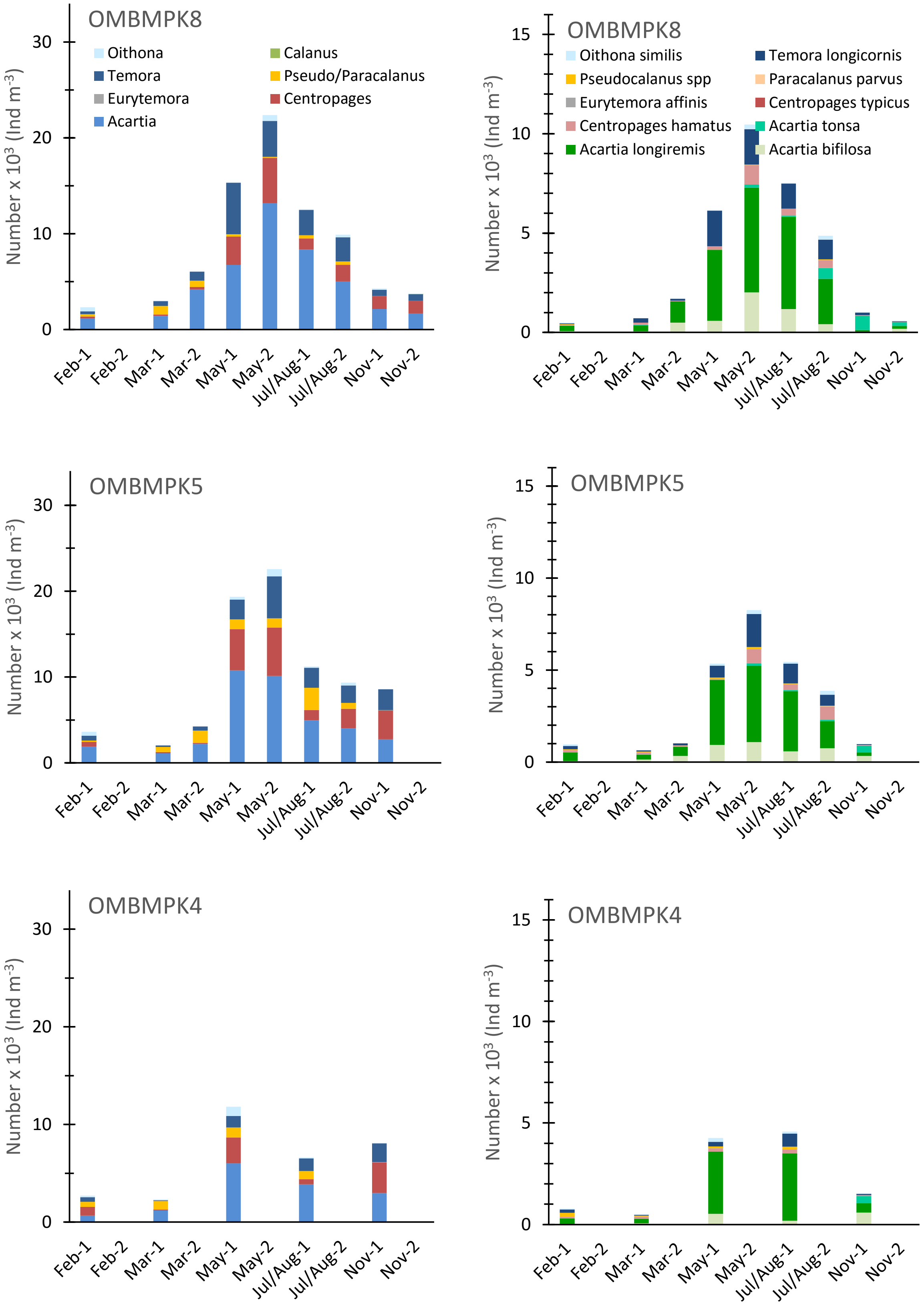


Fig. 27: Seasonal variation of the abundance and composition of juvenile (left) and adult stages of copepods (right) of different genera at various stations in the investigation area. Note the different scale in the abundance of juveniles.



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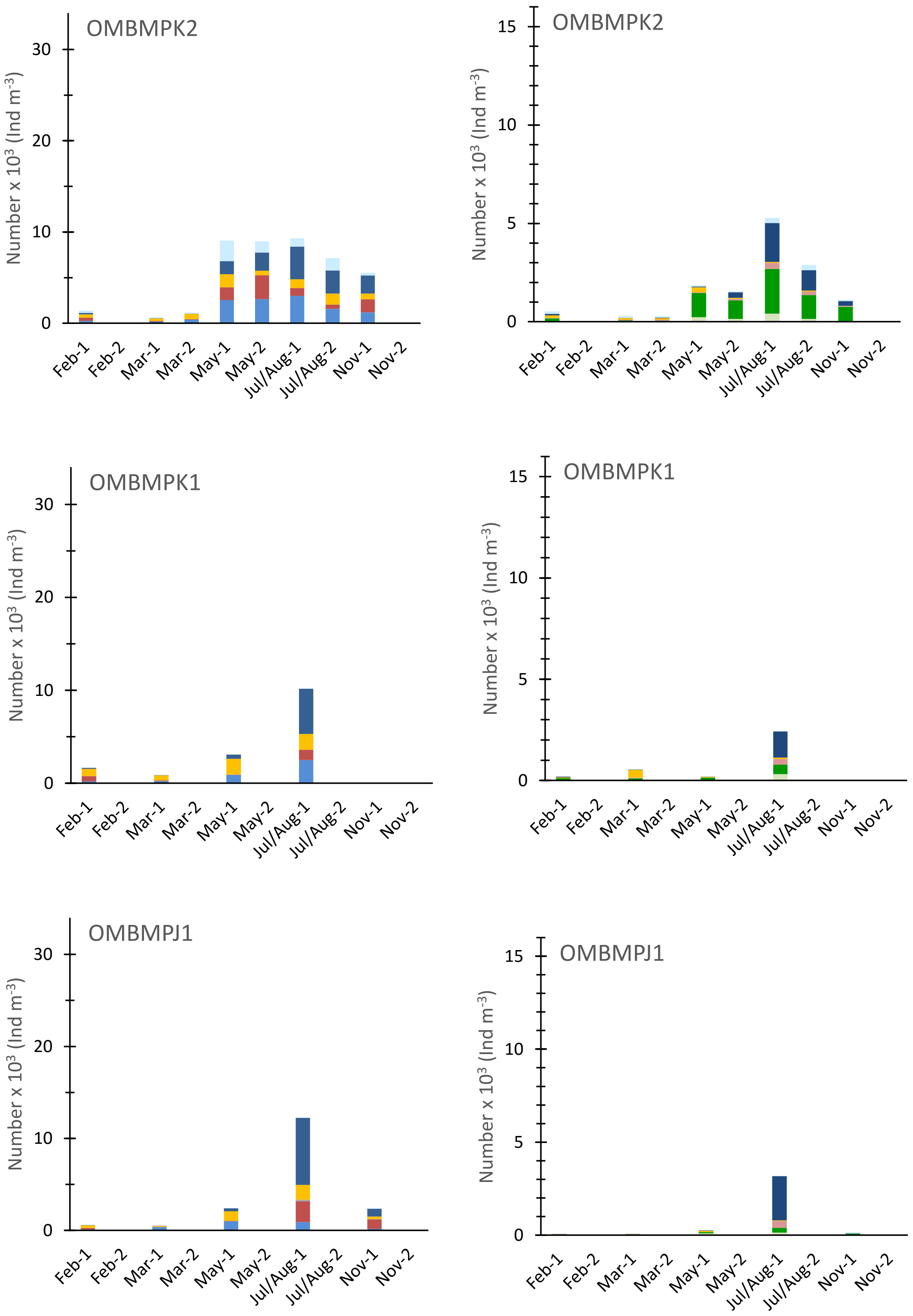

Fig. 27: continued.

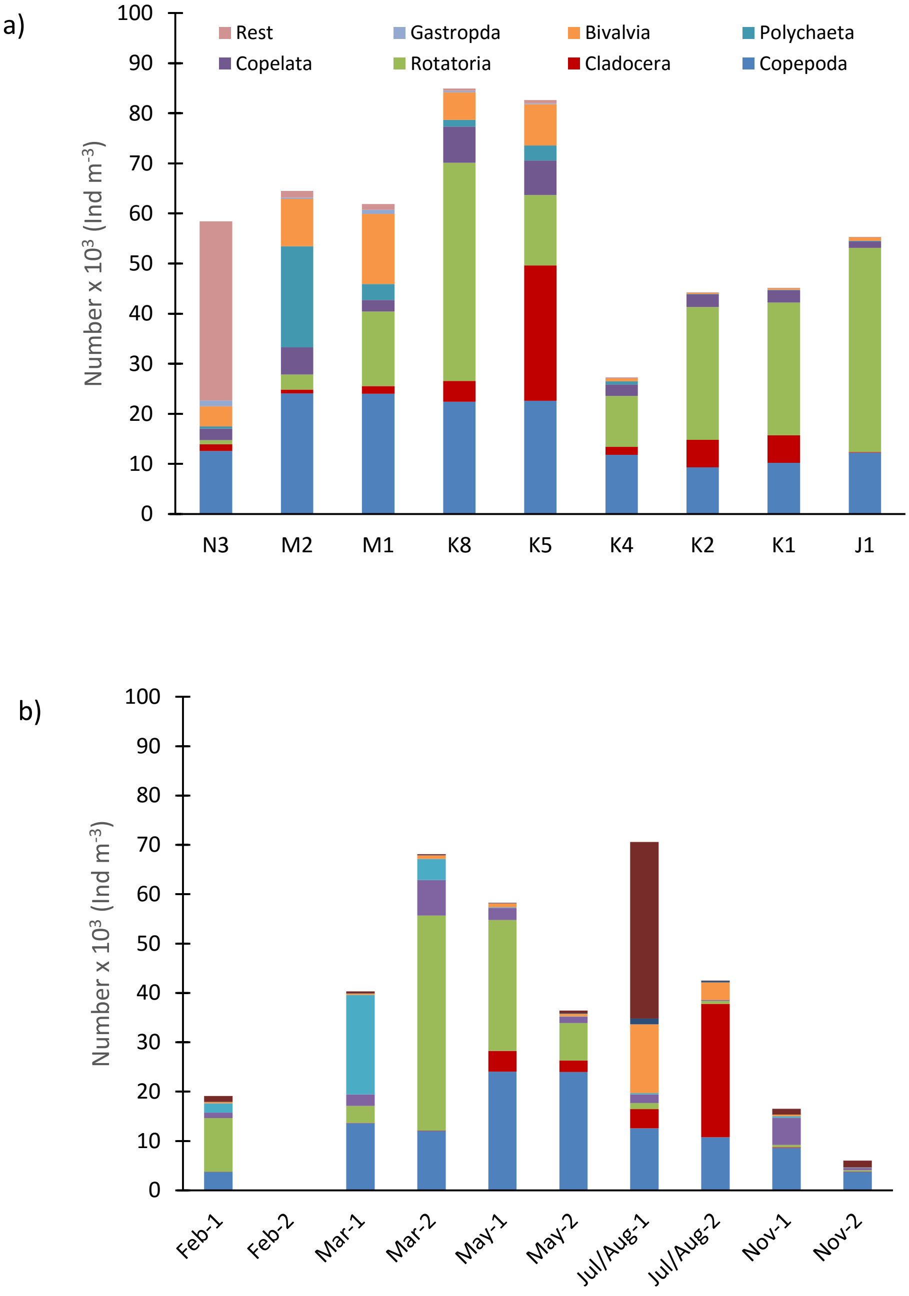

Fig. 28 a, b: Spatial and seasonal variation of the maximal abundance of the mesozooplankton groups.

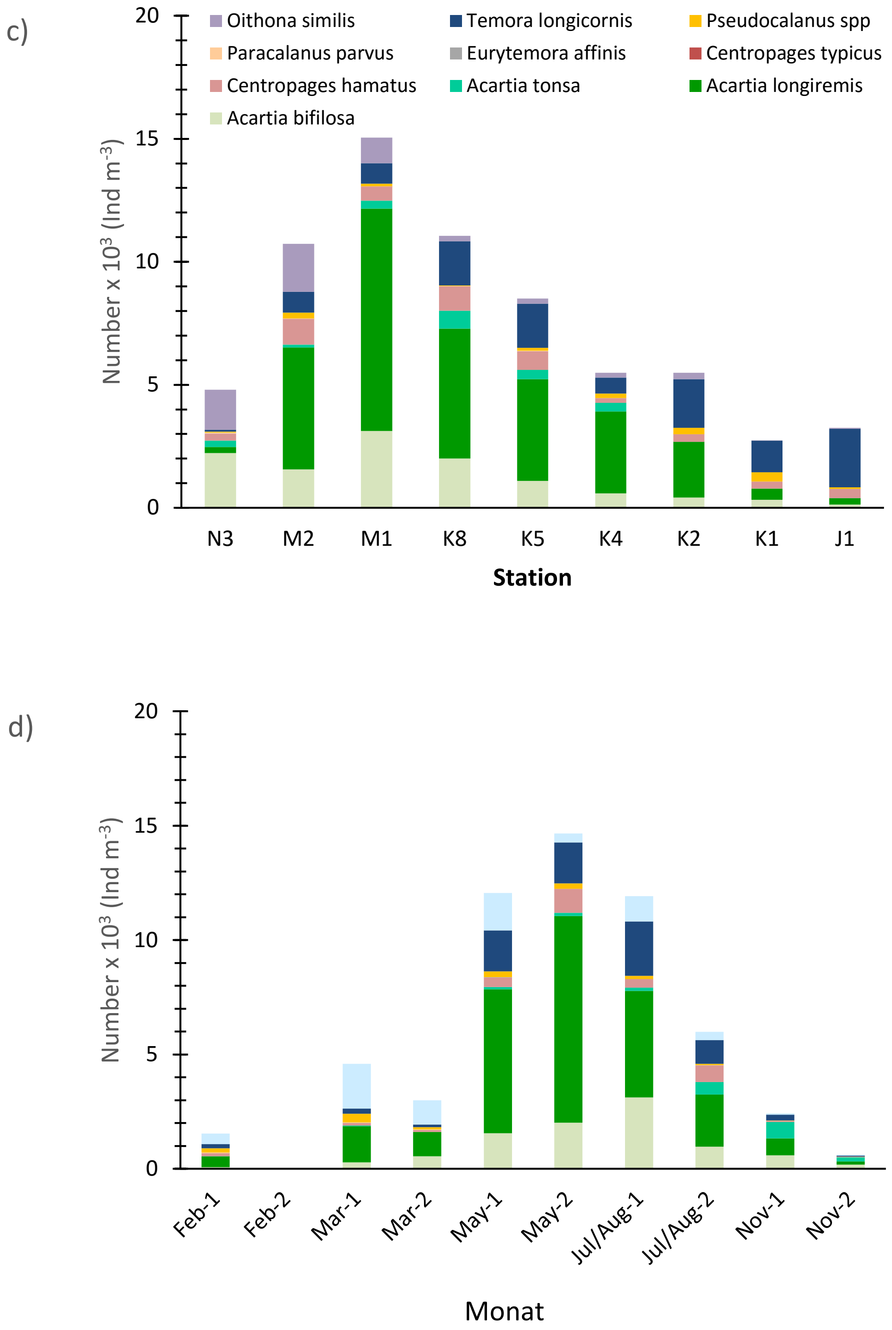

Fig. 28 c, d: Spatial and seasonal variation of adults of calanoid and cyclopoid copepods in the investigation area.

Synopsis

In terms of maximum abundance of the major groups, the composition of the zooplankton displayed the typical, pronounced spatial variation observed for the Baltic Sea (Fig. 28 a). While the zooplankton in Kiel Bay (OMBMP-N3) was dominated by copepods and – exceptionally - by tintinnid ciliates, meroplankton, rotifers, appendicularians and cladocera became more abundant in the Bay of Mecklenburg (OMBMP-M2-M1) and the Arkona Basin (OMBMP-K8 – K4). Rotifers remained the most abundant group in the eastern areas of the Bornholm and the Gotland Basins. However, most conspicuous is the lack of the high concentrations of the cladocera usually observed in the Bay of Mecklenburg to the Bornholm Basin. Therefore, the maximal zooplankton abundance in 2015 was on average lower than in previous years. With regard to the seasonal development, the zooplankton community exhibited a succession from rotifers, appendicularians, copepods and polychaete larvae in the winter/spring to a community dominated by copepods, cladocerans and bivalve larvae in the summer (Fig. 28 b). Most striking in comparison to preceding years is the early increase in abundance around late March. Particularly rotifers were observed much earlier than in preceding years (Fig. 28 b). Among the ecologically relevant group of copepods, the large scale dominance *Acartia bifilosa* in Kiel Bay (OMBMP-N3) or of *Acartia longiremis* in the Bay of Mecklenburg (OMBMP-M2-M1), the Arkona Basin (OMBMP-K8 – K4) and the Bornholm Basin (OMBMP K2) in 2015 is most striking (Fig. 28 c).In previous years, the copepod community was generally more diverse and the contribution of *Oithona similis* and *Pseudo-/Paracalanus* spp. and *Temora longicornis*/ *Centropages hamatus* was considerably higher. The seasonal variation of the copepods with an increase in the abundance of the adult copepods in May, however, is similar to preceding years (Fig. 28 d).

4.2.3 Long-term Trend

Similar to the preceeding years, the decrease in the abundance of zooplankton observed since 2000 continued also in 2015. (Fig. 29 a). The concentrations of the dominating rotifers and cladocera remained very low. Maximum concentrations of rotifers were below 4.4×10^4 ind. m^{-3} , in contrast to 2000-2009 when the density – with the exception of 2006 - regularly exceeded 10^5 ind. m^{-3} (range $1.0 – 3.5 \times 10^5$ ind. m^{-3}). Also among the cladocera, the high concentrations of the last decade of more than 5.0×10^5 ind. m^{-3} were not observed. The total zooplankton abundance of 1.3×10^5 ind. m^{-3} is, therefore, the lowest zooplankton density recorded since the year 2000. Also the calanoid copepods showed the trend to historically low stocks. Among these, a particularly low density were recorded for *Pseudo-/Paracalanus*, *Temora longicornis* and *Centropages hamatus*, while for *Acartia* spp. no trend is visible (Fig. 29 b). The cyclopoid copepods, appendicularians and the diverse groups of meroplankton remained on a similar level to the preceding years.

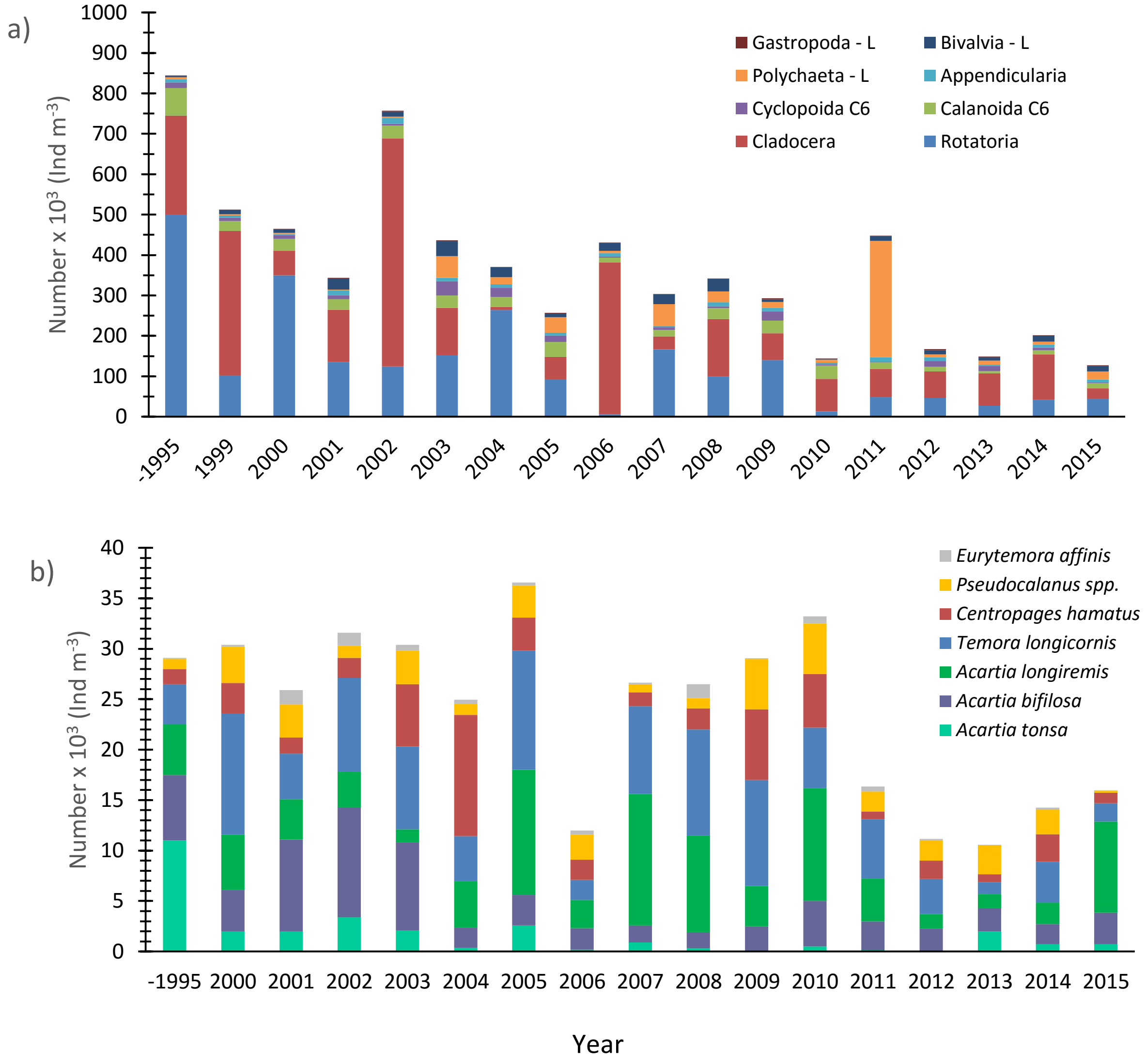

Fig. 29: Long-term trends in the maximal abundance of a) holoplanktonic taxa (Rotatoria, Cladocera, Cyclopoida, Calanoida, and Copelata) and meroplanktonic taxa (Polychaeta, Bivalvia, Gastropoda) and b) of seven calanoid copepod species in the years 1995 to 2015.

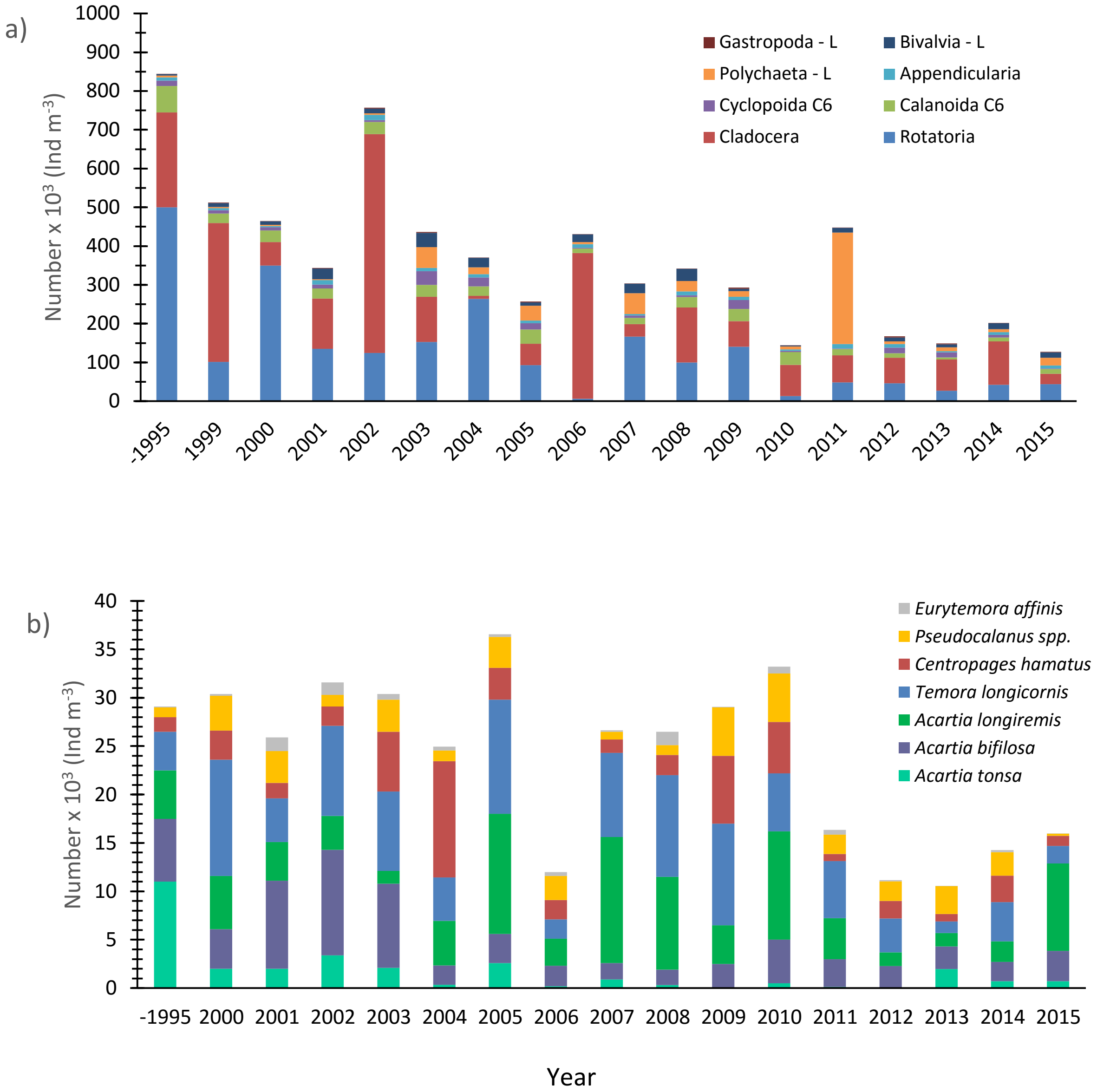

Fig. 29: Long-term trends in the maximal abundance of a) holoplanktonic taxa (Rotatoria, Cladocera, Cyclopoida, Calanoida, and Copelata) and meroplanktonic taxa (Polychaeta, Bivalvia, Gastropoda) and b) of seven calanoid copepod species in the years 1995 to 2015.

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 a good oxygen supply was observed. In contrast to the previous year the oxygen values were higher than 2.5 mg/l at all stations.

Table 7
Abiotic parameters at 8 monitoring stations in autumn 2015 (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 (mg/l)	S (psu)	Sediment characteristics
OMBMPN3	1.00	168	3.40	20.3	fine to middle sand
OMBMPN1	4.34	29	5.74	20.5	muddy sand
OMBMPM2	8.89	18	5.17	21.5	mud
OM18	1.42	73	2.48	19.6	muddy sand
OMBMPK8	0.28	215	6.02	15.6	fine sand
OMBMPK4	10.32	18	4.04	22.7	mud
OMBMPK3	0.39	194	3.74	12.7	fine sand with marl
OM160	0.24	182	7.42	7.9	fine sand

The salinity at the Arkona Basin station (OMBMOK4) was with 22.7 psu relatively high, a direct effect of the saltwater inflow of the previous year. The mean salinity at this station ranges normally from 13-18 psu (Fig. 30). Other stations seem to be not affected by this inflow event.

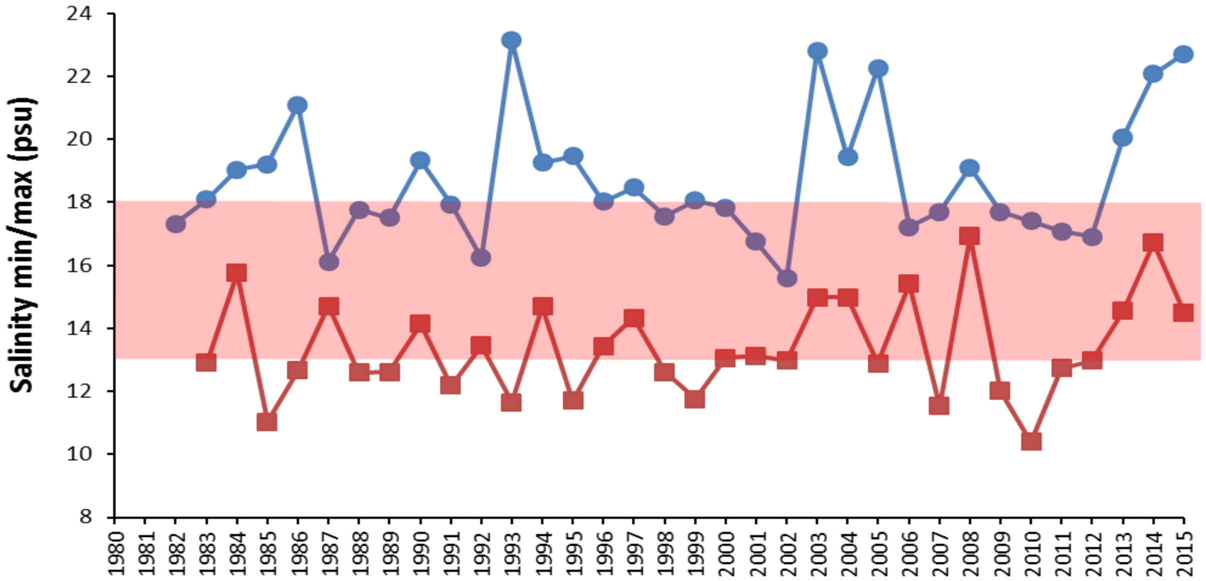

Fig. 30: Long-term development of the bottom water salinity in the Arkona Basin (OMBMPK4) from 1980 to 2015 (5-10 measurements per year). The red line indicates the lowest and the blue line the highest value per year, respectively. The shaded range shows the long-term median of the lowest and highest values.

4.3.2 Macrozoobenthos at the Stations

In November 2015, 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 2015, the number of species was average at 119 (Table A4, Fig. 31). In line with expectations, station OMBMPN3 in Kiel Bay proved to be the richest in species in the entire study area: 69 taxa were identified there. Compared with their long-term averages, all stations show similar or even higher species richness. At three stations (OMBMPM2, OMBMPK8 and OMBMPK4) the observed numbers of taxa were higher than the long-term median.

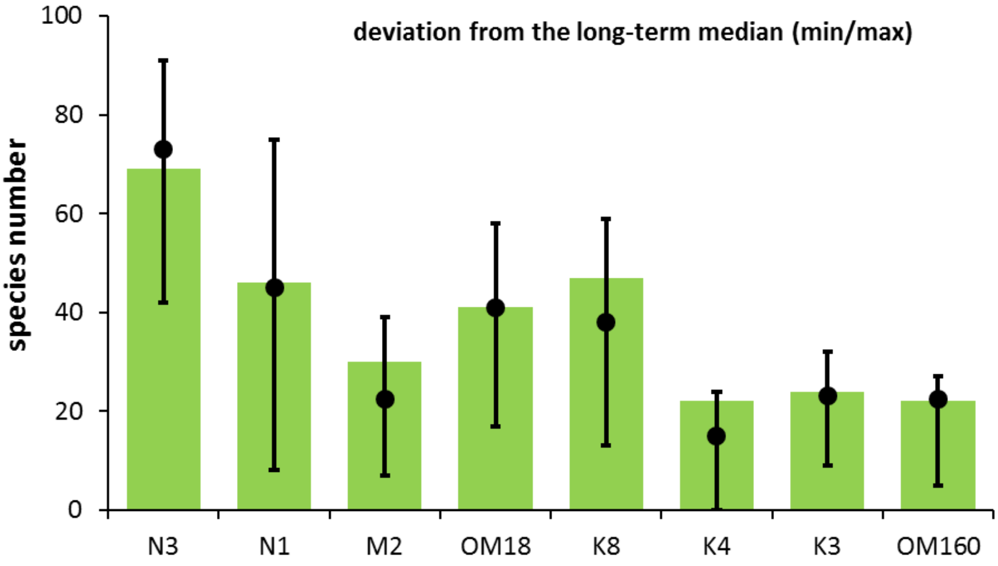

Fig. 31: Number of species (columns) of macrozoobenthos at 8 monitoring stations in November 2015. The median values of the years 1991 to 2015 are shown as dots; the minimum and maximum values are indicated as interval. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

At station OMBMPK4 in the central basin of the Arkona Basin (some 45 m deep) was an increase in the number of species obvious: 22 taxa were identified there. In over 30 years of monitoring (data have been available every year since 1981), a similarly high value was detected only in 2003 and last year. Still high salinity of 22.7 psu (Table 4) showed there had previously been a salt-water inflow (see above) that also imported marine species into the Baltic. Some euryhaline species were observed at this station for the first time or after a long absence again, including the white furrow shell *Abra alba*, the European clam *Corbula gibba*, the polychaete *Nephtys hombergii*, and the brittle star *Ophiura albida*. At the Darss Sill (OMBMPK8) with 47 species the diversity was high in comparison to the last 20 years. Only in in the years 2003, 2007 and 2010 similar high species numbers were observed. However, the observed species were unexceptional; no “unexpected” taxa were recorded. Due to the good oxygen supply in the current year the benthic fauna in the Mecklenburg Bight seems to profit. 30 species, for this high affected area a relatively high number, could be observed. Most of them are known from previous years. Nevertheless, *Phaxas pellucidus* and *Ophiura albida* can establish there only sporadically (Fig. 32).

Fig. 32: *Ophiura albida*, a sporadic “guest” at the deeper parts of the Mecklenburg Bight.

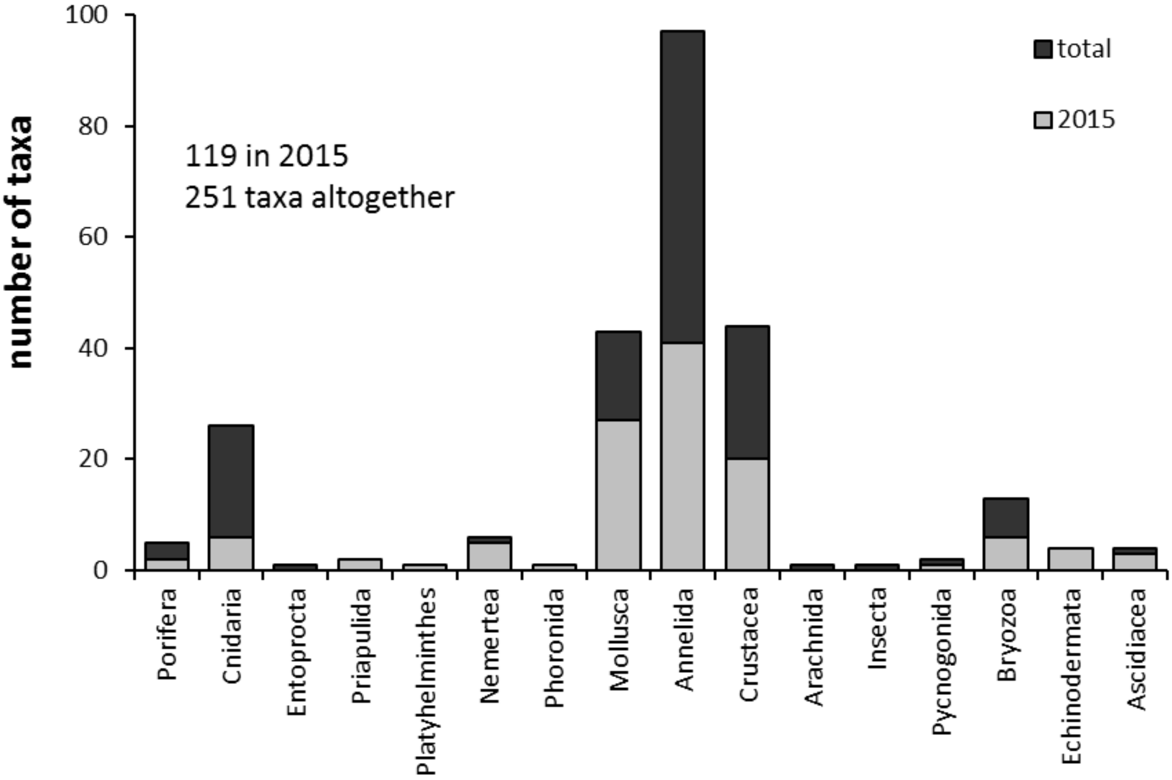

Fig. 33: Taxonomical classification of macrozoobenthos at 8 monitoring stations in November 2015. The species number of the entire monitoring from 1991 to 2015 is also indicated.

Fig. 33 gives the taxa found at our 8 monitoring stations in 2015 as well as the total number of species found in measurements since 1991. Not just in 2015, the Annelida (Polychaeta and Oligochaeta) emerged as the group that is richest in species, numbering 97; in 2015, 41 species were identified. Other species-rich groups in 2015 were Mollusca (27), Crustacea (20), Cnidaria (6) and Bryozoa (also 6).

Depending on the sea area, abundances varied between 389 (Arkona Basin) and 19.003 ind./m² (Pomeranian Bay) (Fig. 34, Table A4). In the central Pomeranian Bay (OM160), abundances were thus significantly higher than the long-term average (Fig. 34). Compared with previous years, average values were observed at the station at Mecklenburg Bight (OMBMPM2), at the Darss Sill (OMBMPK8), in the central Arkona Basin (OMBMPK4), and in the northern Pomeranian Bay (OMBMPK3). At the other stations, abundances were unmistakably lower. Particularly in the western part of the investigation area (Kiel Bay and Fehmarn Belt) the decrease was obvious.

Which species was dominant in a given sea area varied greatly; it depended essentially on salinity and substrate. While the molluscs *Abra alba*, *Arctica islandica*, *Corbula gibba* and *Kurtiella bidentata* accounted for over 30 to 40 % of density in Kiel Bay (OMBMPN3), Mecklenburg Bight (OMBMPM2) and in Fehmarn Belt (OMBMPN1) (the cumacean *Diastylis rathkei*, the polychaete *Nephtys ciliata* and the brittle star *Ophiura albida* were subdominant alternately), in the Pomeranian Bay (OM160) only the mud snail *Peringia ulvae* at 80 % accounted for high abundance. The blue mussel (*Mytilus edulis*) and the spionid *Pygospio elegans* reached more than 50% of the abundance of the station OMBMPK8 at the Darss Sill. In the northern Pomeranian Bay (OMBMPK3) also the spionid *Pygospio elegans* (71%) and additionally the tellinid *Macoma balthica* (18%) dominated the community (Fig. 35).

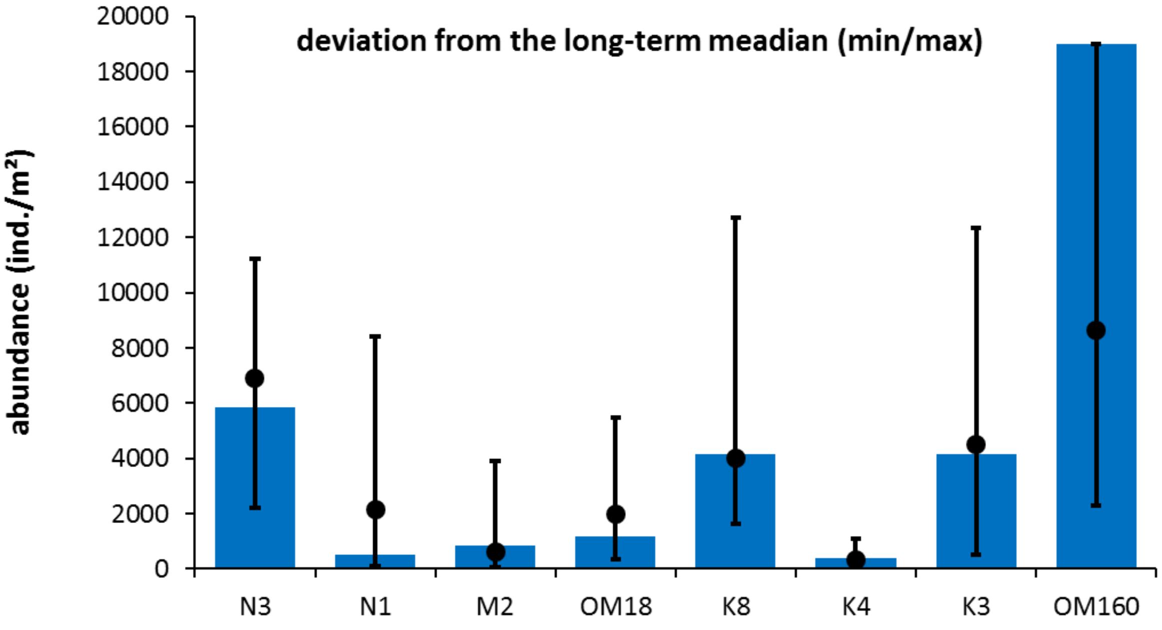

Fig. 34: Total abundances (columns) of macrozoobenthos at 8 monitoring stations in November 2015. The median values of the years 1991 to 2015 are shown as dots; the minimum and maximum values are indicated as interval.

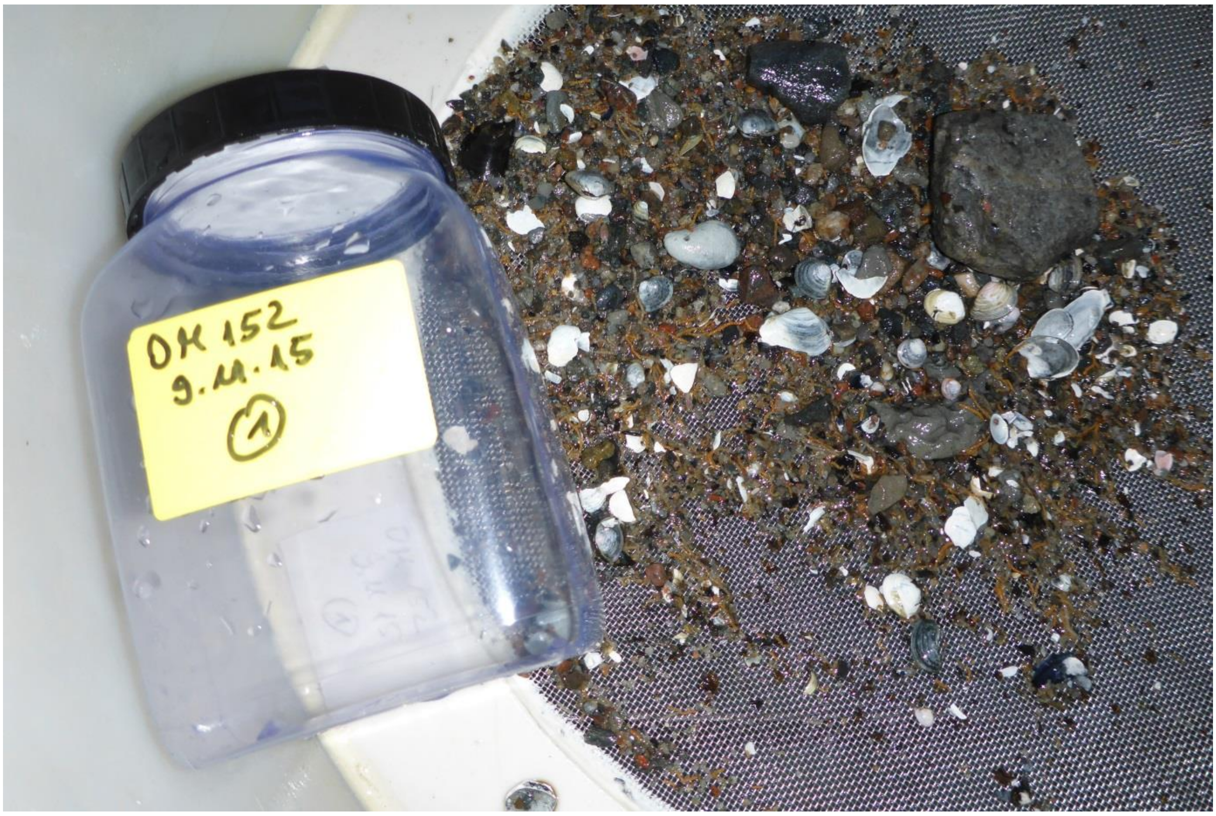

Fig. 35: In 2015 dominant species in the northern Pomeranian Bay (OMBMPK3) were *Pygospio elegans* and *Macoma balthica.*

The highest biomasses were observed at stations in Kiel Bay (OMBMPN3) (Fig. 36). 82.6 g afdw/m^2 was measured, consisting of 29 % *Astarte borealis* (24 g afdw/m^2) and 56 % *Arctica islandica* (46 g afdw/m^2). In addition, dredge catches yielded echinoderms (*Asterias rubens, Ophiura albida*), common whelk (*Buccinum undatum*) and red whelk (*Neptunea antiqua*) that were certainly under-represented in the quantitative grab samples. At Fehmarnbelt (OMBMPN1) and in the Bay of Mecklenburg (OMBMPM2 and OM18), *Arctica islandica* contributed as much as 90-95 % to biomass (Fig. 37); total values between 12 and 29 g AFDM/m^2 were obtained there. At Darss Sill (OMBMPK8), biomass (13.5 g AFDM/m^2) was dominated by the bivalves *Astarte borealis* (73 %) and *Macoma balthica* (10 %). In the Arkona Basin, (OMBMPK4), *Macoma balthica* accounted for 61 % of the total biomass (2 g afdw/^{2}), *Nephtys ciliata* and *Nephtys hombergii* for 15 and 11 %, respectively. In the north of the Pomeranian Bay (OMBMPK3), 4.2 g of total biomass was measured, made up of 86 % *Macoma balthica*. Further east in the central Pomeranian Bay (OM160; 9.8 g afdw/m^2), *Cerastoderma glaucum* (16 %), *Macoma balthica* (26 %), *Mya arenaria* (16 %) and *Peringia ulvae* (27 %) were prominent.

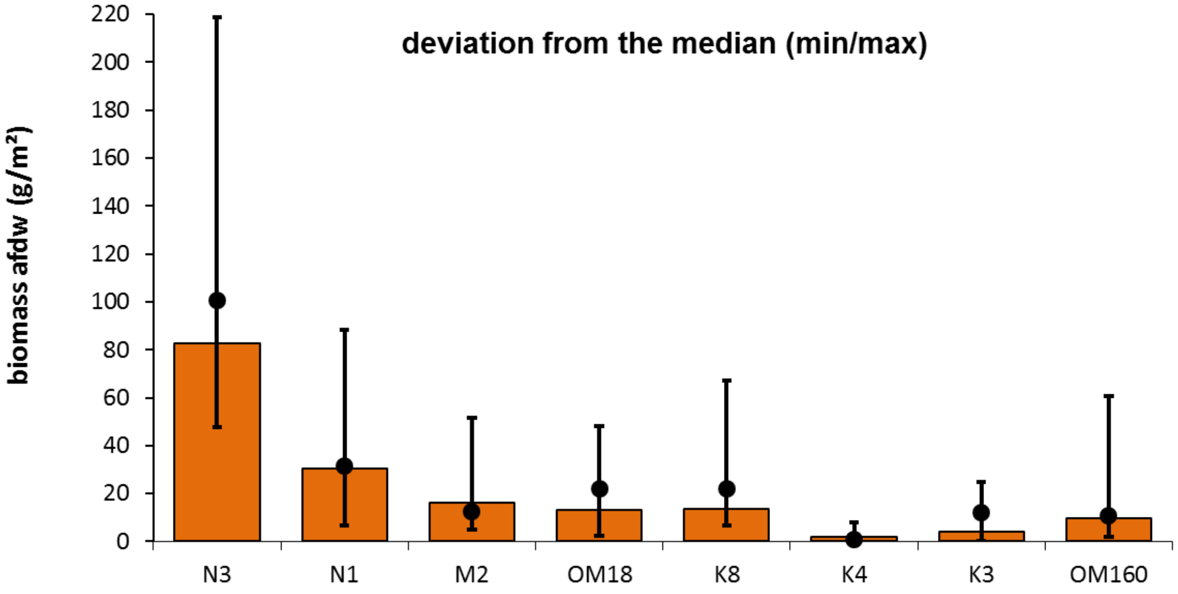

Fig. 36: Total biomasses (columns) of macrozoobenthos at 8 monitoring stations in November 2015. The median values of the years 1991 to 2015 are shown as dot and the minimum and maximum values are indicated as interval.

Fig. 37: In Fehmarn Belt (OMBMPN1), the ocean quahog (*Arctica islandica*) and brittle stars (*Ophiura albida*) dominated the dredge sample.

Both for abundance and biomass, analysis of long-term data in part revealed considerable fluctuations that are illustrated as error bars (min/max) in Figs. 34 and 36. 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.

4.3.3 Long-term Trend

For an assessment of long-term trends since 1991 refer to our recently published reports (WASMUND et al. 2015). The effects of oxygen deficiency on ecosystem functions, as well as temporal and spatial variations at selected monitoring stations, were published in GOGINA et al. (2014). To ensure maximum comparability in our analysis of long-term trends, we referred to the last 10 years only (2006 to 2015). Eight stations were sampled every autumn using three grab samples and one dredge. Stations are thus assessed on an identical basis. Fig. 38 shows the relative number of species (see previous reports and Table A4 Appendix for absolute numbers). As expected, species diversity falls from west to east (Kiel Bay OMBMPN3 to Pomeranian Bay OM160). During this period, only station OMBMPN1 (Fehmarnbelt) was characterised by 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 the previous year, a similar situation was observed at station OM18 for the first time: its species diversity had more than halved (WASMUND et al. 2015). All other stations had diversity rates that were relatively stable. In 2015 the situation is almost recovered; no further significant changes were observed.

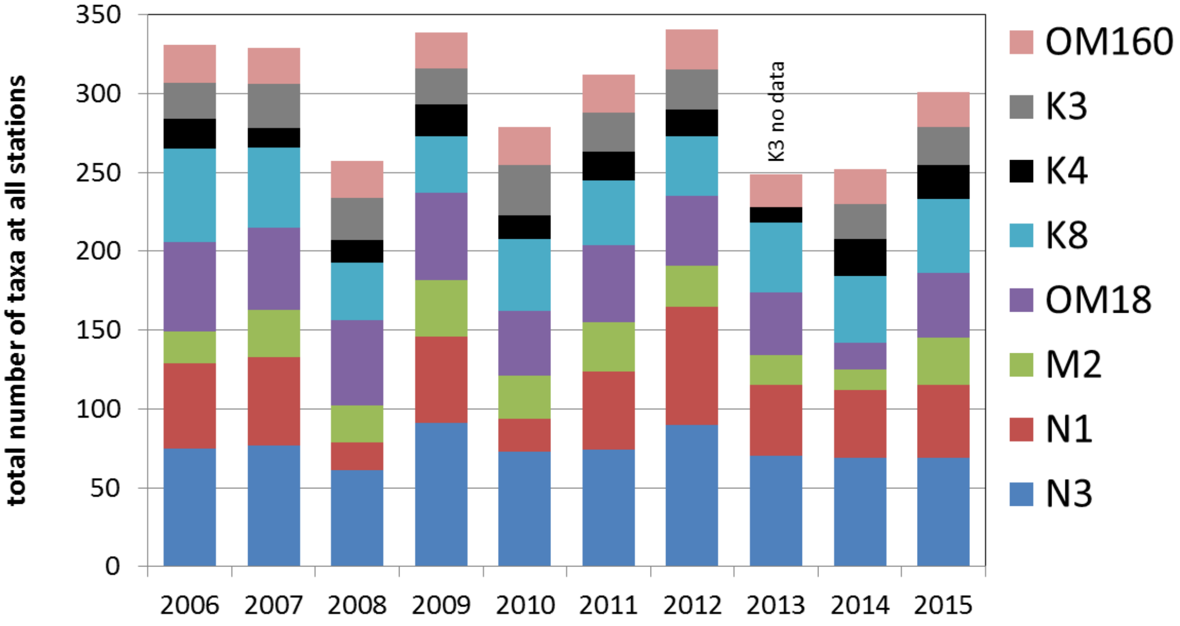

Fig. 38: Number of species of macrozoobenthos at 8 monitoring stations from 2006 to 2015. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

In terms of abundance, the situation is very different (Fig. 39). Both the westernmost (Kiel Bay OMBMPN3) and easternmost stations (Pomeranian Bay OM160) were characterised by high to very high abundances (as explained above), but in part the differences are significant. In some years, values fell below those of other years by more than 50 % - 2007 and 2008 at station

OMBMPN3, and 2010 and 2014 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), oxygen deficiency in 2008 and 2010 caused a serious decline in abundance rates. The Bay of Mecklenburg (OMBMPM2) was affected only in 2008 and 2014. A similar loss of abundance was observed for the first time in 2014 at statin OM18. In 2015 the density seems to be at least at some stations as high as the average; no significant decline was observed.

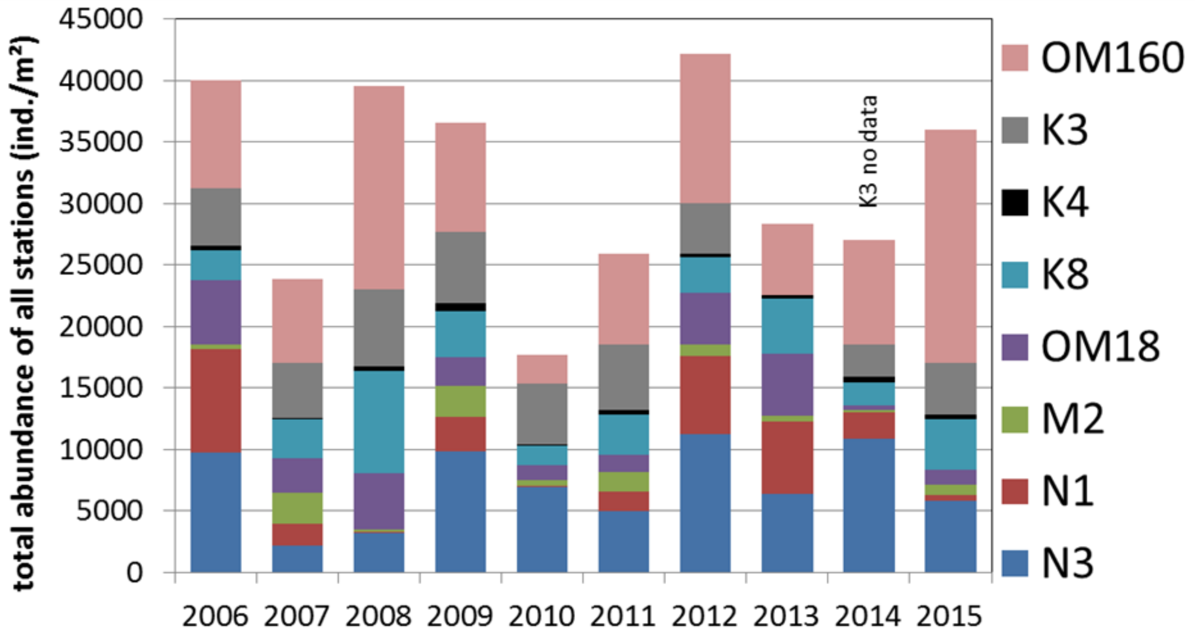

Fig. 39: Abundance of macrozoobenthos at 8 monitoring stations from 2006 to 2015. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

Figure 40 illustrates the long-term trend in biomass. Firstly, it is obvious the greatest values were observed in the west (Kiel Bay = OMBMPN3 and Fehmarnbelt OMBMPN1) followed by the southern Bay of Mecklenburg (OM18); and secondly it is obvious that biomass is not as strongly influenced as species numbers or abundance. 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 the Bay of Mecklenburg (OMBMPM2, OM18) in 2014. Overall, the total biomass observed in 2015 was relatively low.

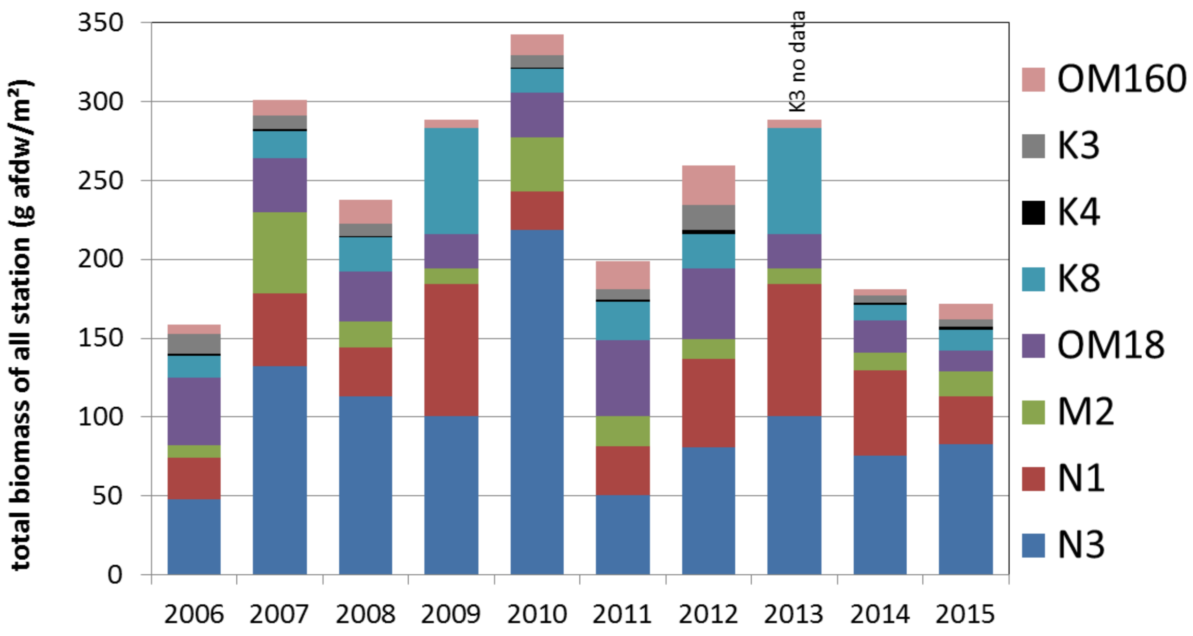

Fig. 40: Biomass of macrozoobenthos at 8 monitoring stations from 2006 to 2015. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

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 119 species, 20 are classed as threatened (1, 2, 3, G) (Fig. 41). Three species are still classed as being near threatened. Currently, 63 species are classed as being of least concern. Data are deficient for 16 species, and 17 taxa on the Red List were not evaluated. *Macoma calcarea* (chalky macoma) is critically endangered. As in previous years, low densities (30 ind./m²) were detected in Kiel Bay (OMBMPN3). The anthozoan *Halcampa duodecimcirrata* was observed in low numbers at the southern Bay of Mecklenburg (OM18) only. Species that are classed as endangered (category 2) were also found at the westernmost station (OMBMPN3), including *Buccinum undatum* (common whelk) (Fig. 42) and *Mya truncata* (blunt gaper). Additionally the sabellid *Euchone papillosa* was identified from the Kiel Bay and the central Bay of Mecklenburg. Specimens of *Arctica islandica* (ocean quahog; category 3, vulnerable) were observed at all western stations (OMBMPN3, OMBMPN1, OMBMPM2, OM18) and in the deeper Arkona Basin (OMBMPK4) at various levels of abundance. Category G (probably vulnerable) includes species that cannot be assigned to category 1, 2 or 3 above, but which - based on current knowledge - are assumed to be endangered. They are declared to be at risk (uncategorized). The 13 species observed in 2015 were distributed across almost all sea areas: 11 species in Kiel Bay (OMBMPN3), 3 in Fehmarnbelt (OMBMPN1), 2 at southern Bay of Mecklenburg (OM18) and Darss Sill (OMBMPK8), and one each in the Bay of Mecklenburg (OMBMPM2) and the Arkona Basin (OMBMPK4). 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 two of the above-mentioned species found in our investigation: *Macoma calcarea* (chalky macoma) is classified as vulnerable (VU), while *Mya truncata* (blunt gaper) is classified as near threatened (NT).

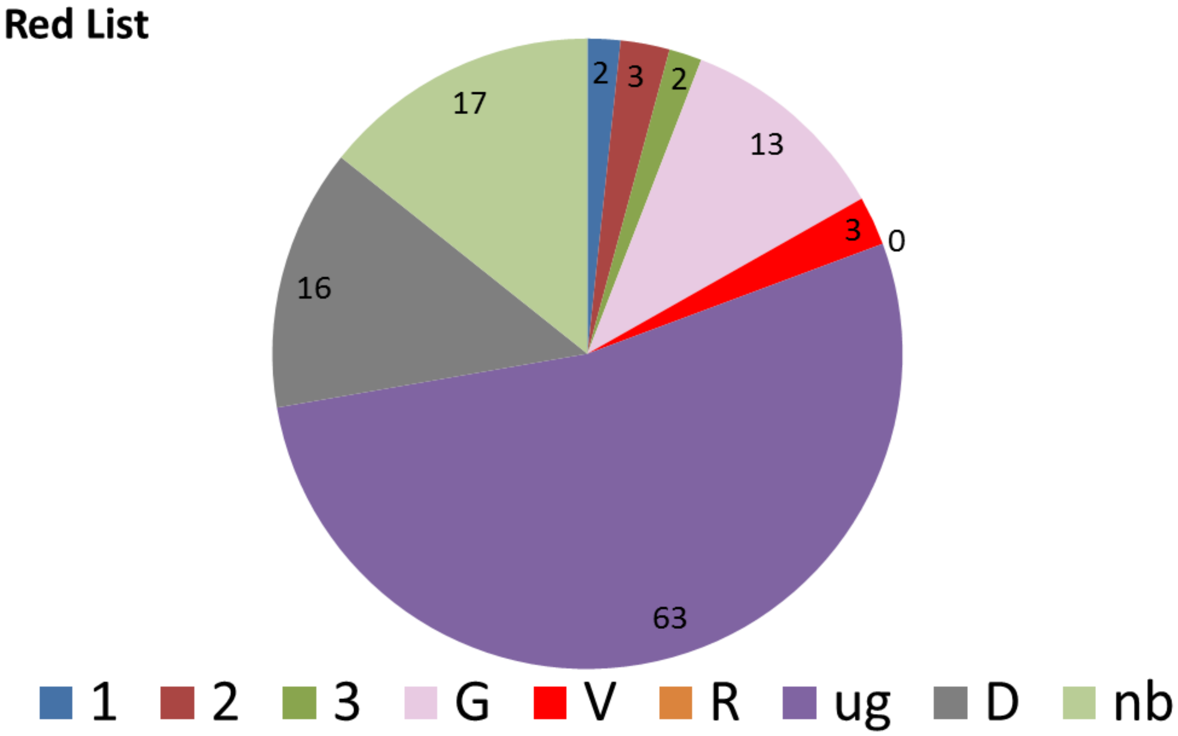

Fig. 41: Percentage of red list categories (RACHOR et al. 2013) in relation to macrozoobenthos in autumn 2015 (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, UG=least concern, D=data deficient, nb=not evaluated).

Fig. 42: The common whelk (*Buccinum undatum*) is rather common in the Fehmarnbelt area and the Kiel Bight. The pictured specimens come from the Fehmarnbelt area (Photo: J. Harder).

4.3.5 Invasive Species

The role of invasive species in the open Baltic Sea is negligible (ZETTLER et al. 2014). Only 3 species were observed at our 8 monitoring stations in 2015. *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 2015 we observed the following abundances of *M. viridis*: 10 ind./m² at Darss Sill (OMBMPK8); 20 ind./m² in the north of the Pomeranian Bay (OMBMPK3); and 287 ind./m² in the central Pomeranian Bay (OM160). In 2015 *M. neglecta* was not observed at the monitoring stations. However, in near coastal waters it is still abundant. In contrast to two years earlier, *Mytilopsis leucophaeata* was not observed again in 2015. As was supposed already, this species will very probably be unable to establish itself in our off-shore waters (WASMUND et al. 2014). However, in some coastal waters this species has established now (e.g. Warnow Estuary, Rugia Lagoons, Greifswald Lagoon).

Summary

As part of the German contribution to the HELCOM monitoring, financed by the German Maritime and Hydrographic Agency (BSH), data on species composition and biomass or abundance of phyto- and zooplankton as well as macrozoobenthos from Kiel Bay, Bay of Mecklenburg and the Arkona Basin (Fig. 1) were gathered in 2014 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

According to satellite images, the year 2015 was characterized by a cloudy and windy summer leading to Sea Surface Temperatures (SST) below the long-term averages and to normally less surface accumulations of cyanobacteria. A low wind period at end of June and beginning of July led to the warmest day in the central and southern Baltic Sea and appearance of cyanobacteria filaments from the western Baltic to the northern Gotland Basin (3 July 2015; Fig. 2a). During the cloudy period until end of July, a few cloud gaps document the continuation of cyanobacteria activity with varying intensities. A MODIS scene from 3 August showed nearly the same extent of cyanobacteria as on 3 July 2015. The intensity had the maximum between 9 and 13 August in the western Baltic (Fig. 3) and between 7 and 18 August particularly in the northern Gotland Basin. Cyanobacteria covered the area from the western Baltic to the northern Gotland Basin up to 7 weeks, with phases of rather different distributions and intensities.

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 closed by additional samples taken on

cruises of the Thünen-Institute of Baltic Sea Fisheries and the IOW. Moreover, information from the coastal monitoring of the IOW in front of Heiligendamm could be used, to be found on http://www.io-warnemuende.de/algenblueten-vor-heiligendamm-2014.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 2015, including a seasonal indicator, is shown in Table A2 (Annex). The ranking according to their biomass in 2015 is also given.

Spring bloom:
The spring bloom in Kiel Bay and, according to the coastal data from Heiligendamm, also in the central Bay of Mecklenburg, had its first peak on 24./25.2.2015. However, it stayed at least until 17./18.3.2015 in Lübeck Bay and the central Bay of Mecklenburg or until 7.4.2014 at the coastal station Heiligendamm. An additional cruise revealed that the biomass was even high on 9.-11.4.2015 in Bay of Mecklenburg. Consequently, the bloom lasted longer than expected.

The spring bloom in Kiel Bay and the central Bay of Mecklenburg is rather diverse. It seems to undergo a succession from diatoms and *Mesodinium rubrum* to dinoflagellates and dictyochophyceae and finally to prymnesiophyceae. This succession may, however, be pretended if different water bodies pass the sampling station in this highly dynamic area.

The phytoplankton of the western Baltic (Kiel Bay and Bay of Mecklenburg) is different from that of the Baltic proper. However, the Darss Sill is not always the line that separates the phytoplankton. In 2015, this border was situated in the eastern Bay of Mecklenburg.

The nutrient data (Table 5) confirm that the spring bloom has grown at least until 17.-19.3.2015 in the western region up to the Arkona Basin. The inorganic nitrogen was consumed more intensively than phosphate, which is a symptom of nitrogen deficiency. Silicate was not used up and seems not to limit diatom growth.

The spring bloom disappeared by mid of April. Inorganic nutrient concentrations increase in May in comparison with March, indicating a decomposition and remineralization of the biomass. Surprisingly, silicate concentrations increased much stronger than concentrations of phosphate and nitrate+nitrite. This was already discussed by WASMUND et al. (2015).

The spring bloom development was retarded in the Bornholm Basin and Eastern Gotland Basin in comparison with the Arkona Basin. In the Arkona Basin, it started in early March with *Mesodinium rubrum*, which was followed by diatoms in mid-March. In the Bornholm Basin, the growth of *Mesodinium rubrum* extended until end of April, followed by a short diatom growth at the beginning of May and subsequently by dinoflagellates. In the Eastern Gotland Basin, diatoms were insignificant in comparison with dinoflagellates.

Summer bloom:
A summer bloom typically made by diatoms in Kiel Bay and the central Bay of Mecklenburg (like in 2014) was definitely not developed in 2015. The development of cyanobacteria was typical in 2015, with no blooms in Kiel Bay and Bay of Mecklenburg, but a moderate bloom in the Baltic Proper.

Autumn bloom:

Autumn blooms were well-developed in Kiel Bay, the Bay of Mecklenburg and the Arkona Basin. In the Belt Sea, the development of *Ceratium* spp. started in the summer, but for unknown reasons, they did not form the typical autumn bloom in 2015. Already in 2014, we noticed the reduced presence of the typical *Ceratium tripos* but *C. fusus* developed at least in 2014. Instead, diverse diatoms dominated the autumn bloom in the Belt Sea. The typical bloom of *Coscinodiscus granii* was well-developed in the Arkona Basin and Bornholm Basin in mid November 2015, but in the Eastern Gotland Basin not such bloom occurred at that time.

Invading phytoplankton species:

With the recent inflow events into the Baltic Sea, some invading species were expected. The uncommon phytoplankton species *Lennoxia faveolata, Phaeodactylum* cf. *tricornutum*, *Spatulodinium pseudonoctiluca* and *Polykrikos schwartzii* were already present in 2014. New species in 2015 were *Coscinodiscus centralis*, *Roperia tesselata, Nematopsides vigilans, Fragilidium subglobosum*, and *Karenia mikimotoi.* They were, however, found only as one or a few cells, which made them less relevant and, moreover, the taxonomic identification difficult and uncertain.

Chlorophyll: The concentrations of chlorophyll *a* are compiled in Tab. 6. The annual maximum (9.45mg m^{-3}) was found during the time of the spring bloom which was registered in mid of March in the Bay of Mecklenburg.

Sedimentation: Over the year 2015 the seasonal pattern of vertical export of particulate organic matter in the Arkona Basin showed only a minor peak in spring and an elongated period of high flux during summer with a clear succession of algal species within and between the sedimentation maxima. Cyanobacterial summer flux was high and resuspension events of already settled material could be observed in periods of intense winter mixing in January and December. In comparison to the previous years the diversity of diatoms and dinoflagellates increased, whereas the number of cyanobacterial species and green algae remained on the same level.

The total annual flux for single elements in 2015 corrected for resuspension amounted to 426 mmol C (5.1 g C), 60 mmol N, 77 mmol Si and 2.1 mmol P m^{-2} a^{-1} at a mass flux of 49 g dry mass m^{-2} a^{-1}. Uncorrected values were 841 mmol C, 106 mmol N, 271 mmol Si and 4,6 mmol P m^{-2} a^{-1} at a mass flux of 102 g dry mass m^{-2} a^{-1}. Extremely high mass flux and silica values in the uncorrected data clearly indicate the sediment as source for the winter material. The level of the corrected values is well within the range of long term annual flux rates.

The presence of diazotrophic cyanobacteria was documented by microscopy and was alike reflected in the drop of the isotopic signature of nitrogen over the summer period between June and September. With 4.8 ‰ the mass weighted δ^{15}N signature for the whole year documents a moderate influence of nitrogen fixation for the total annual balance in 2015. Over the whole year the mass-weighted means of elemental ratios were C/N =7.15, C/P =201 and C/Si = 5.5. With -26.7‰ the mean δ^{13}C signature of the organic carbon did not differ much from the previous years.

Zooplankton

The investigation of the long-term variation in abundance and community composition of the zooplankton in 2015 was based on 97 samples taken at 9 stations in the western Baltic Sea. The composition of the zooplankton was characterized by a notable increase in the number of species found in Kiel Bay, the Bay of Mecklenburg, the Arkona and Bornholm Basin and to a lesser extent in the Gotland Basin. This increase was mainly caused by inflow events in spring and autumn, which brought halophilic zooplankton into the investigation area. The species include several copepod species like *Acartia clausi*, *Calanus* spp., *Centropages typicus* or *Oithona atlantica*, but representatives of other groups like *Penilia avirostris* (Cladocera), *Parasagitta setosa* (Chaetognatha) or *Phoronis mülleri* (Phoronida) were found as well. However, often only single specimens were found.

The year 2015 was marked with some pronounced differences in the composition of the zooplankton. Most striking is the low abundance of cladocera, particularly in the Arkona and Bornholm Basin, where high densities of the genus *Bosmina* spp. of more than 10^5 ind. m^{-3} can be common. In contrast, *Evadne nordmanni* was the single most important species in 2015, but its concentrations rarely exceeded 4×10^3 ind. m^{-3}. Due to the low abundance of cladocera, rotifers were the most abundant group followed by copepods, meroplankton and appendicularians. Meroplankton was particularly common in the Kiel Bay and the Bay of Mecklenburg, while their abundance in the Arkona Basin was lower than expected. Polychaete and bivalve larvae were most abundant. The appendicularian *Fritellaria borealis* was abundant in spring. Its occurrence was confined to the Arkona and Bornholm Basin in the preceding years, but the species was abundant in the Bay of Mecklenburg in 2015 as well. In contrast, *Oikopleura dioica* occurred regularly in autumn at all stations in Kiel Bay, the Bay of Mecklenburg and the Arkona Basin, but was observed in the eastern areas only in spring.

The composition of the adult calanoid copepods was dominated by the genus *Acartia*. While the brackish species *Acartia bifilosa* was the most abundant species in Kiel Bay, *Acartia longiremis* dominated in the Bay of Mecklenburg and the Arkona Basin. In the Bornholm and Gotland Basin, however, the dominance of *Acartia* vanished and other copepods, particularly *Temora longicornis* were more common. In contrast to *Acartia*, the abundance of *Pseudocalanus* spp. and *Paracalanus parvus* was exceptionally low in 2015. These species often dominate the calanoids in Kiel Bay and have been abundant in the Bay of Mecklenburg and the Arkona Basin.

Except the brackish water copepod species *Acartia tonsa*, no other invasive species were recorded in 2015 in the study area.

The seasonal development of the zooplankton also differed from previous years, particularly in the Bay of Mecklenburg and the Arkona Basin. In Kiel Bay, the typical dominance of copepods was observed in 2015, but the high winter stocks of *Oithona* spp. or *Pseudocalanus* spp in previous years were lacking. Other groups were generally of minor importance except in summer, when a bloom of tintinnid ciliates occurred and caused a pronounced zooplankton maximum in summer. The copepod community was dominated by the genera *Oithona* and *Acartia* with *Acartia bifilosa* as the single most abundant species. Copepodites and adults of *Pseudo-* and *Paracalanus* remained unusually low during spring and summer.

The zooplankton development in the Bay of Mecklenburg and the Arkona Basin was characterised by an unusual early increase in stock size in late March which was based on abundant rotifers, polychaete larvae and copepods. However, such earlier development was not recorded in the deeper, eastern areas (Bornholm and Gotland Basin). In contrast, the summer and autumn abundance of zooplankton was considerably lower than usual due to the lack of pronounced peak concentrations of the cladoceran *Bosmina* spp. The seasonal dynamics of the zooplankton were similar in most areas. Copepods dominated the zooplankton composition on an annual basis, meroplankton showed peak concentrations in spring (polychaete larvae) and summer (bivalve larvae), particularly in the shallower, western areas. A rotifer peak in March caused by *Synchaeta* spp. is rather unusual because a mass development of the species is generally observed during May. The copepoda were dominated by the genus Acartia, with *Acartia longiremis* as the single most abundant species that was replaced by *A. bifilosa* in autumn. Again, the low concentrations of *Pseudocalanus* spp. and *Paracalanus parvus* observed in the Bay of Mecklenburg, the Arkona Basin and Bornholm Basin are rather unusual.

The total zooplankton abundance of 1.3×10^5 ind. m^{-3} was historically the lowest zooplankton density observed since the year 2000; the decrease in the stocks of zooplankton, therefore, continued also in 2015. Rotifers and cladocera remained particularly low, the high concentrations of more than 3.5×10^5 ind. m^{-3} from the beginning of the century were not observed in the last decade.

Macrozoobenthos

This study presents the results of macrozoobenthos monitoring in the southern Baltic Sea in November 2015. The following parameters were measured: species richness, and the abundance and biomass of organisms per station. Compared to previous years, the 119 species recorded at the 8 monitoring stations were considered to be a moderate number. No long-lasting oxygen deficiency was observed in 2015. The oxygen supply in bottom waters in the current year was always higher than 2.5 mg/l; no negative effects on macrozoobenthos were detected. Depending on the region, abundances varied between 389 and 19.003 ind./m². In terms of biomass, similarly high variations were observed (2 g in the Arkona Basin to 82.6 g afdw/m² in Kiel Bay). The high species number (22) and salinity (22.7 psu) in the central Arkona Basin is an effect of the salt water inflow reaching the central Arkona Basin in 2014 (see also WASMUND et al. 2015), bringing some marine species with it. For example, since 2014 some euhaline species like the bivalves *Abra alba* and *Corbula gibba*, the polychaetes *Nephtys ciliata* and *N. hombergii*, and the brittle star *Ophiura albida* were observed there either for the first time or again after a long absence.

At the 8 monitoring stations, 20 species on the German Red List were observed (CR, EN, VU, G). The bivalve *Macoma calcarea*, very rarely observed and critically endangered in German waters, was found in the Bay of Kiel, for instance. Two species on the HELCOM Red List (KONTULA et al. 2013) were detected: *Macoma calcarea* (VU) and *Mya truncatula* (NT).

In line with expectations, the number of invasive species found during the 2015 sampling campaign was low: only 3 were observed, among them long-established species like *Amphibalanus improvisus* (Cirripedia) and *Mya arenaria* (Bivalvia). Recently introduced species (since the 1980s and 1990s) of the genus *Marenzelleria* (Polychaeta) are locally important, whereof *Marenzelleria viridis* colonised the Pomeranian Bay in densities of around 300 ind./m².

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References

Bundesamt für Seeschiffahrt und Hydrographie, 2015: Arbeitsplan 2016. Zur Wahrnehmung meereskundlicher Aufgaben in der Ostsee durch das Leibniz-Institut für Ostseeforschung Warnemünde für das Bundesamt für Seeschifffahrt und Hydrographie. Hamburg, November 2015.

Büse, T. (1915). Quantitative Untersuchungen von Planktonfängen des Feuerschiffes "Fehmarnbelt" vom April 1910 bis März 1911. Wissenschaftliche Meeresuntersuchungen, Neue Folge , Abt. Kiel 17, 229-280.

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.

Gargas, E., Nielsen, G.E., Mortensen, S., 1978: Phytoplankton production, chlorophyll-a and nutrients in the open Danish waters 1975-1977. – The Belt Project. The National Agency of Environmental Protection, Denmark, 103 pp.

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., Blomqvist, 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.

GRINIENE, E., DAUNYS, D., OLENINA, I., HÖGLANDER, H., WASMUND, N., 2013: Phytoplankton ring test 2013. Counting of *Rhodomonas* sp. and *Nodularia spumigena* using different counting strategies and sedimentation chamber volumes. Report to HELCOM, November 2013. Klaipėda: HELCOM Phytoplankton Expert Group (HELCOM PEG). 39 pp.

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.

HAJDU, S., HÄLLFORS, S., GROMISZ, S., SKJEVIK, A.-T., BUSCH, S., KOWNACKA, J., JURGENSONE, I., OLENINA, I., HUSEBY, S., WASMUND, N., JAANUS, A., HÄLLFORS, G., RINTALA, J.-M., MAJANEVA, M., BLOMSTER, M., 2008: Unusual phytoplankton event during winter-spring 2007-2008. – HELCOM Indicator Fact Sheets. http://www.helcom.fi/Documents/Baltic%20sea%20trends/Environment%20fact%20sheets/Unusual%20phytoplankton%20event%20during%20winter%202007-2008_BSEFS2008.pdf

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 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, 2014b: Manual for marine monitoring in the COMBINE programme of HELCOM. – Internet, updated January 2014: http://www.helcom.fi/Documents/Action%20areas/Monitoring%20and%20assessment/Manuals%20and%20Guidelines/Manual%20for%20Marine%20Monitoring%20in%20the%20COMBINE%20Programme%20of%20HELCOM.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.

HOPPENRATH, M., ELBRÄCHTER, M., DREBES, G., 2009: Marine Phytoplankton. Selected microphytoplankton from the North Sea around Helgoland and Sylt. – Kleine Senckenberg-Reihe, 49.

JAANUS, A., ANDERSSON, A., HAJDU, S., HUSEBY, S., JURGENSONE, I., OLENINA, I., WASMUND, N., TOMING, K., 2007: Shifts in the Baltic Sea summer phytoplankton communities in1992-2006. HELCOM Indicator Fact Sheet. http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/shifts-in-the-baltic-sea-summer-phytoplankton-communities-in-1992-2006/

JOCHEM, F., BABENERD, B., 1989: Naked *Dictyocha speculum* - a new type of phytoplankton bloom in the western Baltic. – Mar. Biol. **103**, 373-379.

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.

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.

NAUSCH, G., NAUMANN, M., UMLAUF, L., MOHRHOLZ, V., SIEGEL, H., Schulz-Bull, D.E., 2016: Hydrographic-hydrochemical assessment of the Baltic Sea 2015. – Meereswiss. Ber., Warnemünde **101**, 1-96.

ÖBERG, J., 2014: Cyanobacterial blooms in the Baltic Sea in 2014. - HELCOM Baltic Sea Environment Fact Sheets 2014. 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., HAJDU, S., WASMUND, N., JAANUS, A., JURGENSONE, I., GROMISZ, S., KOWNACKA, J., TOMING, K., OLENIN, S., 2009: Impacts of invasive phytoplankton species on the Baltic Sea ecosystem in 1980-2008. HELCOM Indicator Fact Sheet. http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/impacts-of-invasive-phytoplankton-species-on-the-baltic-sea-ecosystem-in-1980-2008/

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., VAICIŪTĖ, D., OLENIN, S., 2010: Assessing impacts of invasive phytoplankton: the Baltic Sea case. – Marine Pollution Bulletin. doi:10.1016/j.marpolbul.2010.06.046.

RACHOR, E., BÖNSCH, R., BOOS, K., GOSSELCK, F., GROTJAHN, 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.

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.

SMETACEK, V., HENDRIKSON, P., 1979: Composition of particulate organic matter in Kiel Bight in relation to phytoplankton succession. – Oceanologica Acta **2**, 287-298.

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., 2008: Zooplankton of the open Baltic Sea: Atlas. - Meereswissenschaftliche Berichte **73**, 3-251.

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., BUSCH, S., GÖBEL, J., GROMISZ, S., HÖGLANDER, H., JAANUS, A., JOHANSEN, M., JURGENSONE, I., KARLSSON, C., KOWNACKA, J., KRASNIEWSKI, W., LEHTINEN, S., OLENINA, I., v.Weber, M., 2016: Cyanobacteria biomass. – HELCOM Baltic Sea Environment Fact Sheet 2016. Online. http://helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/cyanobacteria-biomass/

WASMUND, N., DUTZ, J., POLLEHNE, F., SIEGEL, H., ZETTLER, M.L., 2014: Biologische Zustandseinschätzung der Ostsee im Jahre 2013. – Meereswiss. Ber., Warnemünde **94**, 1-93.

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., 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., 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., SCHÖPPE, C., GÖBEL, J., VONWEBER, M., 2011 b: Chlorophyll-a in den deutschen Ostseegewässern. – Meeresumwelt Aktuell Nord- und Ostsee 2011/2. 1-8. http://www.blmp-online.de/PDF/Indikatorberichte/2011_02_d.pdf

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 c: 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.

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 July and November 2014. The mean phytoplankton biomass (in µg/l) is given on the top of each station block. „Unidentified“, „Gymnodiniales“, and „Peridiniales“ were deleted from the list. Continued on page 87-88 !

February-May	(%)	July/August	(%)	November	(%)
Kiel Bay (Stat. OMBMPN3)					
Phytopl. biomass in µg/L	704	Phytopl. biomass in µg/L	920	Phytopl. biomass in µg/L	1430
Pseudochattonella farcimen	24.05	Dactyliosolen fragilissimus	37.72	Prymnesiales	38.78
Prymnesiales	20.79	Ceratium tripos	18.94	Pseudosolenia calcar-avis	14.38
Peridiniella danica	16.53	Alexandrium pseudogonyaulax	14.31	Gymnodiniales	9.33
Dictyocha speculum	8.90	Chaetoceros affinis	3.15	Rhizosolenia setigera	6.89
Gymnodiniales	7.15	Gymnodiniales	3.03	Thalassiosira eccentrica	5.63
Gyrodinium spirale	3.29	Ceratium fusus	2.95	Pseudo-nitzschia	3.07
Skeletonema marinoi	3.24	Prymnesiales	2.37	Protoperidinium	3.03
Mesodinium rubrum	1.79	Dictyocha speculum	1.81	Heterosigma akashiwo	2.94
Proboscia alata	1.47	Protoperidinium claudicans	1.42	Proboscia alata	1.94
Ceratium tripos	1.41	Chaetoceros contortus	1.25	Ceratium tripos	1.47
Lübeck Bay (Stat. OMO22)					
Phytopl. biomass in µg/L	953			Phytopl. biomass in µg/L	1971
Pseudochattonella farcimen	31.37			Skeletonema marinoi	15.29
Peridiniella danica	24.78			Rhizosolenia setigera	14.88
Prymnesiales	17.68			Chaetoceros convolutus	12.42
Gymnodiniales	6.04			Cerataulina pelagica	11.01
Dictyocha speculum	5.84			Pseudosolenia calcar-avis	9.75
Gyrodinium spirale	2.71			Gymnodiniales	6.12
Laboea strobila	2.46			Thalassiosira eccentrica	3.50
Rhizosolenia setigera	1.18			Thalassiosira	3.14
Telonema	1.11			Dictyocha speculum	2.94
Katodinium glaucum	0.92			Gyrodinium spirale	2.79
Central Mecklenburg Bay (Stat. OMBMPM2)					
Phytopl. biomass in µg/L	775	Phytopl. biomass in µg/L	714	Phytopl. biomass in µg/L	1393
Pseudochattonella farcimen	19.65	Ceratium tripos	34.45	Rhizosolenia setigera	15.88
Peridiniella danica	17.93	Aphanizomenon	13.25	Pseudosolenia calcar-avis	9.70
Prymnesiales	15.52	Alexandrium pseudogonyaulax	10.64	Thalassiosira eccentrica	7.08
Dictyocha speculum	13.08	Gymnodiniales	6.62	Heterosigma akashiwo	6.05
Gymnodiniales	7.08	Dictyocha speculum	4.04	Gymnodiniales	6.00
Mesodinium rubrum	4.39	Cymbomonas tetramitiformis	3.12	Proboscia alata	5.97
Gyrodinium spirale	3.26	Peridiniales	3.05	Thalassiosira	5.25
Skeletonema marinoi	2.23	Katablepharis remigera	2.16	Dictyocha speculum	3.93
Chaetoceros similis	2.04	Prymnesiales	2.16	Pseudo-nitzschia	3.46
Rhizosolenia setigera	1.54	Actinocyclus	2.10	Ceratium tripos	3.33
Eastern Mecklenburg Bay (Stat. OMBMPM1)					
Phytopl. biomass in µg/L	737	Phytopl. biomass in µg/L	326	Phytopl. biomass in µg/L	969
Skeletonema marinoi	54.82	Gymnodiniales	13.95	Pseudosolenia calcar-avis	17.45
Mesodinium rubrum	17.60	Unidentified	12.44	Rhizosolenia setigera	17.17
Gymnodiniales	5.54	Ceratium tripos	11.50	Gymnodiniales	5.72
Prymnesiales	2.98	Aphanizomenon	9.94	Cerataulina pelagica	5.16
Chaetoceros wighamii	2.32	Actinocyclus	8.47	Skeletonema marinoi	4.66
Thalassiosira	1.98	Alexandrium pseudogonyaulax	5.23	Proboscia alata	4.37
Dictyocha speculum	1.38	Nodularia spumigena	3.32	Thalassiosira	4.23
Chaetoceros	1.26	Plagioselmis prolonga	2.86	Chaetoceros convolutus	3.94
Heterocapsa rotundata	1.20	Prymnesiales	2.61	Thalassiosira punctigera	3.49
Teleaulax	1.05	Katablepharis remigera	2.17	Gyrodinium spirale	3.45

Western Arkona Basin (Stat. OMBMPK8)					
Phytopl. biomass in µg/L	500	Phytopl. biomass in µg/L	340	Phytopl. biomass in µg/L	1552
Skeletonema marinoi	44.19	Aphanizomenon	20.60	Coscinodiscus granii	76.31
Mesodinium rubrum	20.54	Gymnodiniales	15.19	Dactyliosolen fragilissimus	4.63
Gymnodiniales	8.66	Nodularia spumigena	13.53	Cerataulina pelagica	2.68
Prymnesiales	3.12	Katablepharis remigera	6.54	Pseudosolenia calcar-avis	2.12
Thalassiosira	3.01	Heterocapsa triquetra	6.19	Gymnodiniales	1.40
Heterocapsa rotundata	1.74	Plagioselmis prolonga	3.43	Teleaulax	1.07
Dinophysis norvegica	1.50	Cyclotella	2.83	Dictyocha speculum	0.97
Anathece	1.35	Prymnesiales	2.46	Thalassiosira eccentrica	0.95
Aphanocapsa	1.29	Peridiniales	1.90	Protoperidinium	0.90
Pyramimonas	1.24	Pseudanabaena limnetica	1.89	Actinocyclus normanii f. subsalsus	0.71
Central Arkona Basin (Stat. OMBMPK5)					
Phytopl. biomass in µg/L	762	Phytopl. biomass in µg/L	347	Phytopl. biomass in µg/L	1697
Skeletonema marinoi	44.01	Aphanizomenon	19.82	Coscinodiscus granii	93.51
Mesodinium rubrum	26.78	Nodularia spumigena	17.73	Teleaulax	1.29
Gymnodiniales	6.64	Gymnodiniales	15.26	Actinocyclus normanii f. subsalsus	0.68
Prymnesiales	4.17	Heterocapsa triquetra	6.59	Mesodinium rubrum	0.63
Chaetoceros wighamii	2.65	Dinophysis norvegica	5.60	Ceratium tripos	0.56
Dinophysis norvegica	1.96	Plagioselmis prolonga	3.48	Actinocyclus	0.50
Pyramimonas	1.36	Katablepharis remigera	2.59	Gymnodiniales	0.46
Chaetoceros similis	1.19	Prymnesiales	2.38	Thalassiosira	0.24
Peridiniella danica	1.08	Peridiniella danica	1.97	Plagioselmis prolonga	0.22
Teleaulax	0.96	Mesodinium rubrum	1.40	Hemiselmis	0.19
Eastern Arkona Basin (Stat. OMBMPK4)					
Phytopl. biomass in µg/L	1074	Phytopl. biomass in µg/L	569	Phytopl. biomass in µg/L	1854
Skeletonema marinoi	55.41	Nodularia spumigena	24.83	Coscinodiscus granii	95.53
Mesodinium rubrum	22.67	Aphanizomenon	23.49	Coscinodiscus centralis	1.36
Chaetoceros similis	4.71	Dinophysis norvegica	9.91	Actinocyclus	0.79
Chaetoceros	2.59	Gymnodiniales	7.04	Teleaulax	0.50
Chaetoceros wighamii	1.90	Katablepharis remigera	5.09	Actinocyclus normanii f. subsalsus	0.33
Gymnodiniales	1.88	Heterocapsa triquetra	4.02	Micracanthodinium claytonii	0.17
Actinocyclus	1.55	Actinocyclus	3.75	Mesodinium rubrum	0.17
Prymnesiales	1.30	Ebria tripartita	1.90	Gymnodiniales	0.15
Thalassiosira	0.94	Heterocapsa rotundata	1.63	Plagioselmis prolonga	0.10
Peridiniella danica	0.85	Mesodinium rubrum	1.27	Eutreptiella	0.08
Bornholm Basin (Stat. OMBMPK2)					
Phytopl. biomass in µg/L	445	Phytopl. biomass in µg/L	295	Phytopl. biomass in µg/L	1414
Mesodinium rubrum	47.98	Gymnodiniales	13.62	Coscinodiscus granii	67.89
Chaetoceros similis	18.10	Nodularia spumigena	13.02	Actinocyclus	21.90
Dinophysis norvegica	8.76	Unidentified	11.04	Coscinodiscus centralis	7.14
Gymnodiniales	4.66	Aphanizomenon	9.13	Mesodinium rubrum	0.40
Skeletonema marinoi	2.89	Aphanocapsa	8.97	Teleaulax	0.35
Actinocyclus	1.85	Dinophysis norvegica	5.94	Gymnodiniales	0.31
Chaetoceros	1.42	Actinocyclus	5.60	Dinophysis norvegica	0.28
Teleaulax	0.99	Plagioselmis prolonga	4.56	Plagioselmis prolonga	0.14
Dinophysis acuminata	0.95	Aphanothece paralleliformis	3.08	Hemiselmis	0.13
Aphanocapsa	0.80	Prymnesiales	2.98	Thalassiosira	0.10
Southern Gotland Basin (Stat. OMBMPK1)					
Phytopl. biomass in µg/L	349	Phytopl. biomass in µg/L	410		
Mesodinium rubrum	64.40	Nodularia spumigena	24.85		
Dinophysis norvegica	6.44	Dinophysis norvegica	13.77		
Scrippsiella spp. CPX	5.56	Gymnodiniales	9.79		
Gymnodiniales	5.21	Aphanizomenon	9.19		
Dinophysis acuta	2.92	Mesodinium rubrum	6.33		
Peridiniella catenata	2.22	Plagioselmis prolonga	5.59		
Dinophysis acuminata	2.03	Pyramimonas	3.91		
Teleaulax	1.38	Prymnesiales	2.97		

Skeletonema marinoi	1.11	Aphanothece paralleliformis	2.95		
Heterocapsa rotundata	1.02	Chrysophyceae	2.57		
Eastern Gotland Basin (Stat. OMBMPJ1)					
Phytopl. biomass in µg/L	299	Phytopl. biomass in µg/L	517	Phytopl. biomass in µg/L	172
Mesodinium rubrum	40.33	Nodularia spumigena	25.05	Coscinodiscus granii	50.63
Dinophysis norvegica	22.77	Dinophysis norvegica	12.41	Dinophysis norvegica	10.18
Gymnodiniales	7.06	Nitzschia paleacea	10.25	Mesodinium rubrum	5.92
Dinophysis acuminata	4.49	Prymnesiales	10.25	Gymnodiniales	4.84
Thalassiosira	3.23	Protoperidinium	9.46	Teleaulax	3.46
Dinophysis acuta	2.74	Gymnodiniales	4.36	Actinocyclus	2.93
Peridiniella danica	2.29	Aphanocapsa	3.33	Cyclotella	2.10
Peridiniella catenata	1.76	Pseudanabaena limnetica	2.89	Planktolyngbya	2.00
Scrippsiella spp. CPX	1.62	Peridiniales	2.74	Aphanocapsa	1.93
Peridiniales	1.46	Pyramimonas	2.48	Eutreptiella	1.55

Table A2

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

Taxon	**Class**	**Rank**	**Feb.**	**March**	**May**	**July/ Aug.**	**Nov.**
Achnanthes taeniata	Bacillarioph.	130		X			
Actinocyclus sp.	Bacillarioph.	11	X	X	X	X	X
Actinocyclus normanii f. *subsalsus*	Bacillarioph.	54	X	X		X	X
Alexandrium pseudogonyaulax	Dinophyceae	39				X	X
Amphidinium crassum	Dinophyceae	108	X	X	X	X	X
Amphidinium sphenoides	Dinophyceae	65		X	X		X
Amylax triacantha	Dinophyceae	105		X	X		
Anathece sp.	Cyanobact.	56	X	X	X	X	X
Apedinella radians	Chrysophyc.	96	X	X	X	X	X
Aphanizomenon sp.	Cyanobact.	21	X	X	X	X	X
Aphanocapsa sp.	Cyanobact.	35	X	X	X	X	X
Aphanothece paralleliformis	Cyanobact.	63		X	X	X	X
Attheya septentrionalis	Bacillarioph.	109		X		X	X
Binuclearia lauterbornii	Ulvophyceae	91	X	X	X	X	X
Botryococcus sp.	Trebouxioph.	145	X	X			
Centrales	Bacillarioph.	72	X	X	X	X	X
Cerataulina pelagica	Bacillarioph.	16				X	X
Ceratium furca	Dinophyceae	118	X				X
Ceratium fusus	Dinophyceae	55				X	X
Ceratium lineatum	Dinophyceae	61	X	X	X	X	X
Ceratium longipes	Dinophyceae	86	X	X	X	X	X
Ceratium tripos	Dinophyceae	14	X	X	X	X	X
Ceratoneis closterium	Bacillarioph.	89	X	X	X	X	X
Chaetoceros spp.	Bacillarioph.	25	X	X	X	X	X
Chaetoceros affinis	Bacillarioph.	38				X	X
Chaetoceros brevis	Bacillarioph.	77	X	X		X	
Chaetoceros castracanei	Bacillarioph.	74	X	X		X	X
Chaetoceros ceratosporus var. *ceratosporus*	Bacillarioph.	94		X			
Chaetoceros circinalis	Bacillarioph.	102				X	
Chaetoceros contortus	Bacillarioph.	68				X	X
Chaetoceros convolutus	Bacillarioph.	26	X				X
Chaetoceros curvisetus	Bacillarioph.	121	X			X	
Chaetoceros danicus	Bacillarioph.	103	X	X	X	X	X
Chaetoceros decipiens	Bacillarioph.	104					X
Chaetoceros minimus	Bacillarioph.	149					X
Chaetoceros similis	Bacillarioph.	17	X	X	X	X	X
Chaetoceros socialis	Bacillarioph.	87				X	X
Chaetoceros subtilis	Bacillarioph.	115	X	X	X	X	X
Chaetoceros throndsenii	Bacillarioph.	144		X	X	X	
Chaetoceros wighamii	Bacillarioph.	30	X	X			
Choanoflagellatea	Choanoflag.	73	X	X	X	X	X
Chrysophyceae	Chrysophyc.	57		X	X	X	
Cocconeis spp.	Bacillarioph.	129					X
Coelosphaerium minutissimum	Cyanobact.	93			X	X	
Coscinodiscus centralis	Bacillarioph.	59					X

Coscinodiscus granii	Bacillarioph.	1					X
Cyanodictyon spp.	Cyanobact.	137				X	
Cyanodictyon planctonicum	Cyanobact.	71	X	X	X	X	X
Cyanonephron styloides	Cyanobact.	127		X	X	X	X
Cyclotella spp.	Bacillarioph.	84		X		X	X
Cymbomonas tetramitiformis	Prasinophyc.	69		X	X	X	X
Dactyliosolen fragilissimus	Bacillarioph.	24	X	X	X	X	X
Diatoma tenuis	Bacillarioph.	155	X				
Dictyocha speculum	Dictyochoph.	12	X	X	X	X	X
Dinobryon spp.	Chrysophyc.	141			X	X	
Dinobryon balticum	Chrysophyc.	82		X	X	X	
Dinobryon faculiferum	Chrysophyc.	123		X	X	X	X
Dinophysis acuminata	Dinophyceae	43	X	X	X	X	X
Dinophysis acuta	Dinophyceae	50	X	X	X		X
Dinophysis norvegica	Dinophyceae	9	X	X	X	X	X
Ditylum brightwellii	Bacillarioph.	31	X			X	X
Dolichospermum spp.	Cyanobact.	79				X	
Ebria tripartita	Ebriophyc.	46	X	X	X	X	X
Euglena spp.	Euglenoph.	151	X				
Euglenales	Euglenoph.	135				X	
Eutreptiella spp.	Euglenoph.	62	X	X	X	X	X
Eutreptiella braarudii	Euglenoph.	111	X	X			
Guinardia delicatula	Bacillarioph.	36	X	X		X	X
Guinardia flaccida	Bacillarioph.	60	X				X
Gymnodiniales	Dinophyceae	4	X	X	X	X	X
Gyrodinium spp.	Dinophyceae	110	X				
Gyrodinium spirale	Dinophyceae	22	X	X	X	X	X
Hemiselmis sp.	Dinophyceae	80	X	X	X	X	X
Heterocapsa rotundata	Dinophyceae	29	X	X	X	X	X
Heterocapsa triquetra	Dinophyceae	40	X	X	X	X	X
Heterosigma akashiwo	Dinophyceae	37					X
Karenia mikimotoi cf.	Dinophyceae	120					X
Katablepharis remigera	Incertae sed.	42	X	X	X	X	X
Katodinium glaucum	Dinophyceae	53	X	X	X	X	X
Laboea strobila	Oligotrichea	52	X	X		X	X
Lauderia annulata	Bacillarioph.	114					X
Lemmermanniella pallida	Cyanobact.	124	X	X	X	X	
Lemmermanniella parva	Cyanobact.	90		X	X	X	X
Lennoxia faveolata	Bacillarioph.	153					X
Leptocylindrus danicus	Bacillarioph.	99	X	X			X
Leptocylindrus minimus	Bacillarioph.	128	X			X	X
Leucocryptos marina	Incertae sed.	58	X	X	X	X	X
Licmophora sp.	Bacillarioph.	156			X		
Merismopedia spp.	Cyanobact.	140				X	X
Mesodinium rubrum	Litostomatea	3	X	X	X	X	X
Micracanthodinium claytonii	Dinophyceae	85		X	X	X	X
Monoraphidium contortum	Chlorophyc.	147		X	X	X	X
Nematopsides vigilans cf.	Dinophyceae	146				X	X
Nitzschia paleacea	Bacillarioph.	75				X	
Nitzschia seriata	Bacillarioph.	97	X	X			X
Noctiluca scintillans	Dinophyceae	41				X	
Nodularia spumigena	Cyanobact.	19				X	
Oocystis spp.	Chlorophyc.	98	X	X	X	X	X
Pachysphaera sp.	Prasinophyc.	138			X	X	
Pennales	Bacillarioph.	106	X	X	X	X	X

Peridiniales	Dinophyceae	34	X	X	X	X	X
Peridiniella catenata	Dinophyceae	67		X	X		
Peridiniella danica	Dinophyceae	10		X	X	X	X
Phaeodactylum tricornutum cf.	Bacillarioph.	136				X	
Phalacroma rotundatum	Dinophyceae	134	X	X		X	X
Plagioselmis prolonga	Cryptophyc.	27	X	X	X	X	X
Planktolyngbya spp.	Cyanobact.	122		X			X
Polykrikos schwartzii	Dinophyceae	70					X
Porosira glacialis	Bacillarioph.	125		X			X
Proboscia alata	Bacillarioph.	20	X	X		X	X
Pronoctiluca pelagica	Dinophyceae	157	X				
Prorocentrum cordatum	Dinophyceae	107	X			X	X
Prorocentrum micans	Dinophyceae	64				X	X
Protoperidinium spp.	Dinophyceae	33	X	X	X	X	X
Protoperidinium bipes	Dinophyceae	131	X	X	X	X	X
Protoperidinium claudicans	Dinophyceae	112				X	
Protoperidinium pallidum	Dinophyceae	101		X			X
Protoperidinium pellucidum	Dinophyceae	92	X	X	X		X
Protoperidinium steini	Dinophyceae	142				X	
Prymnesiales	Prymnesioph.	5	X	X	X	X	X
Pseudanabaena spp.	Cyanobact.	139			X	X	
Pseudanabaena limnetica	Cyanobact.	66	X	X	X	X	X
Pseudochattonella farcimen	Dictyochoph.	8		X			
Pseudo-nitzschia	Bacillarioph.	28	X			X	X
Pseudo-nitzschia delicatissima	Bacillarioph.	158	X				
Pseudo-nitzschia pungens	Bacillarioph.	143		X		X	
Pseudo-nitzschia seriata GROUP	Bacillarioph.	150		X			
Pseudopedinella spp.	Chrysophyc.	76	X	X	X	X	X
Pseudosolenia calcar-avis	Bacillarioph.	7					X
Pterosperma spp.	Prasinophyc.	116		X		X	X
Pyramimonas spp.	Prasinophyc.	32	X	X	X	X	X
Rhizosolenia hebetata f. *semispina*	Bacillarioph.	88				X	
Rhizosolenia setigera	Bacillarioph.	6	X	X		X	X
Rhizosolenia setigera f. *pungens*	Bacillarioph.	48				X	X
Rhodomonas spp.	Cryptophyc.	132					X
Romeria spp.	Cyanobact.	154				X	
Roperia tesselata cf.	Bacillarioph.	117					X
Scrippsiella COMPLEX	Dinophyceae	44	X	X	X	X	X
Skeletonema marinoi	Bacillarioph.	2	X	X	X	X	X
Snowella spp.	Cyanobact.	78	X	X	X	X	X
Spatulodinium pseudonoctiluca	Dinophyceae	81					X
Teleaulax spp.	Cryptophyc.	23	X	X	X	X	X
Telonema spp.	Incertae sed.	49	X	X	X	X	X
Thalassionema frauenfeldii	Bacillarioph.	152		X			
Thalassionema nitzschioides	Bacillarioph.	113	X	X		X	X
Thalassiosira spp.	Bacillarioph.	13	X	X	X	X	X
Thalassiosira angulata cf.	Bacillarioph.	51					X
Thalassiosira anguste-lineata	Bacillarioph.	119		X			X
Thalassiosira eccentrica	Bacillarioph.	15				X	X
Thalassiosira gravida	Bacillarioph.	83	X				X
Thalassiosira nordenskioeldii	Bacillarioph.	126	X	X			
Thalassiosira punctigera	Bacillarioph.	47	X				X
Trachelomonas sp.	Euglenoph.	100			X	X	X
Woronichinia spp.	Cyanobact.	133				X	X
Number of taxa: total 154			**82**	**94**	**72**	**108**	**114**

Table A3
Seasonal occurrence of taxa found in the investigation area in 2015 with information on original description, taxonomic rank and serial number according to the Integrated Taxonomic Information System (ITIS). Continued on page 93 !

	rank	TSN	Feb	March	May	Aug	Nov
Protozoa							
Tintinnidae	Family	46743	o	o	o	o	
Annelida							
Polychaeta - Trochophora	Subphylum	914166	o	o	o	o	o
Polychaeta - others	Subphylum	914166	o	o	o	o	
Harmothoe spp. Kinberg, 1855	Genus	64502	o	o	o	o	o
Arthropoda - Crustacea							
Copepoda							
Acartia bifilosa Giesbrecht, 1881	Species	86095	o	o	o	o	o
Acartia longiremis Lilljeborg, 1853	Species	86087	o	o	o	o	o
Acartia tonsa Dana, 1849	Species	86088	o	o	o	o	o
Acartia clausi Giesbrecht, 1889	Species	86088					o
Calanus spp. Leach, 1819	Species	85263	o	o			o
Centropages hamatus Lilljeborg, 1853	Species	85766	o	o	o	o	o
Centropages typicus Krøyer, 1849	Species	85767	o				o
Corycaeus anglicus Lubbock, 1857	Species	88573				o	
Eurytemora affinis Poppe, 1880	Species	85863		o	o	o	o
Euterpina acutifrons Dana, 1849	Species	86546			o		
Harpacticoida G. O. Sars, 1903	Ordnung	86110	o			o	o
Limnocalanus macrurus G.O. Sars, 1863	Species	85775				o	o
Longipedia Claus, 1863	Genus	86127	o				
Microsetella spp. Brady & Robertson, 1873	Genus	86208	o	o	o		o
Oncaea Philippi, 1843	Genus	88540					o
Oithona atlantica Farran, 1906	Species	88824	o				
Oithona similis Claus, 1866	Species	88805	o	o	o	o	o
Paracalanus parvus Claus, 1863	Species	85323	o	o	o	o	o
Pseudocalanus spp. Boeck, 1872	Genus	85369	o	o	o	o	o
Temora longicornis O.F.Müller, 1785	Species	85877	o	o	o	o	O
Phyllopoda							
Bosmina spp. Baird, 1845	Genus	83936	o		o	o	o
Evadne nordmanni Lovén, 1836	Species	86546	o	o	o	o	o
Penilia avirostris Dana, 1849	Species	83836					o
Podon intermedius Lilljeborg, 1853	Species	83965				o	o
Podon leuckartii G. O. Sars, 1862	Species	83966		o	o	o	
Pleopsis polyphaemoides (Leuckart,1859)	Species	684626		o		o	o
other Crustacea							
Balanus spp. Da Costa, 1778	Genus	89600	o	o	o	o	o
Crangon crangon Linnaeus, 1758	Species	107552				o	

Table A3 continued.

	Rang	TSN	Feb	März	Mai	Aug	Nov
other Crustacea (ctd.)							
Diastylis Say, 1818	Genus	90836			o	o	
Decapoda Latreille, 1802	Order	95599				o	
Gammaridea Latreille, 1802	Suborder	93295					o
Lophogastrida Sars, 1870	Order	89808					o
Bryozoa							
Gymnolaemata Allman, 1856	Class	155471	o	o	o	o	o
Chaetognatha							
Parasagitta setosa Mueller, 1847	Species	158795		o			o
Sagittidae Claus and Grobben, 1905	Family	158726	o				o
Chordata							
Fritellaria borealis Lohmann, 1896	Species	159675	o	o	o	o	o
Oikopleura dioica Fol 1872	Species	159669	o	o		o	o
Teleostei	Infraclass	161105	o	o	o	o	o
Echinodermata							
Asterias spp. Linnaeus, 1758	Genus	157215				o	
Cnidaria & Ctenophora							
Ctenophora Eschscholtz, 1829	Phylum	53856	o				o
Aurelia aurita Linnaeus, 1758	Species	51701			o	o	
Rathkea octopunctata M. Sars, 1835	Species	49387	o				
Euphysa aurata Forbes, 1848	Species	48976			o	o	
Leptothecatae	Ordnung	718926			o		
Sarsia tubulosa M. Sars, 1835	Species	49055		o			
Steenstrupia natans (M. Sars, 1835)	Species	48970				o	
Phoronida							
Phoronis muelleri Selys-Longchamps, 1903	Species	206663					o
Nematoda							
Nematoda	Phylum	59490					o
Platyhelminthes							
Alaurina spp. Metschnikoff, 1861	Genus	54024		o	o	o	o
Platyhelminthes	Phylum	53963	o	o			o
Xenapolymorpha							
Acoelomorpha	Subphylum	914172					o
Mollusca							
Bivalvia Linnaeus, 1758	Class	79118	o	o	o	o	o
Gastropoda Cuvier, 1797	Class	69459	o	o	o	o	o
Rotifera							
Synchaeta spp. Ehrenberg, 1832	Genus	59255	o	o	o	o	o
Keratella quadrata O. F. Muller, 1786	Species	58352				o	o
Keratella cochlearis Gosse, 1851	Species	58360				o	
Keratella cruciformis Thompson, 1892	Species	58349				o	o

Table A4:
Distribution of macrozoobenthos at 8 stations in November 2014. In the right column the red list (RACHOR et al. 2013) species are indicated (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, R=very rare, D=data deficient, *=least concern, nb=not evaluated). Continued on page 95-97 !

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Amphipoda									
Crassicorophium crassicorne					1				*
Gammarus oceanicus					1		1		*
Gammarus salinus					1	1	1	1	*
Gammarus zaddachi							1		*
Microdeutopus gryllotalpa				1	1			1	*
Monocorophium insidiosum				1					*
Pontoporeia femorata						1			V
Anthozoa									
Edwardsia danica	1	1		1					D
Halcampa duodecimcirrata				1					1
Sagartia sp.			1						nb
Ascidiacea									
Ciona intestinalis	1								*
Dendrodoa grossularia	1	1			1				V
Molgula manhattensis	1								D
Bivalvia									
Abra alba	1	1	1	1		1			*
Arctica islandica	1	1	1	1		1			3
Astarte borealis	1				1				G
Astarte elliptica	1	1				1			G
Astarte montagui	1								3
Cerastoderma glaucum					1		1	1	*
Corbula gibba	1	1	1	1		1			*
Hiatella arctica	1								*
Kurtiella bidentata	1	1	1	1	1				*
Macoma balthica	1			1	1	1	1	1	*
Macoma calcarea	1								1
Musculus discors	1								G
Musculus niger	1								G
Musculus subpictus	1	1	1	1					G
Mya arenaria	1			1	1		1	1	*
Mya truncata	1								2
Mytilus edulis	1	1		1	1	1	1	1	*
Parvicardium pinnulatum	1	1	1						D
Phaxas pellucidus	1		1						*
Bryozoa									
Alcyonidium polyoum					1				D
Callopora lineata		1			1				*
Einhornia crustulenta		1			1		1	1	*

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Eucratea loricata	1		1	1					V
Farrella repens	1								D
Flustra foliacea	1								*
Cirripedia									
Amphibalanus improvisus							1	1	nb
Balanus crenatus		1							*
Cumacea									
Diastylis rathkei	1	1	1	1	1	1	1		*
Eudorellopsis deformis		1							*
Decapoda									
Carcinus maenas					1				*
Crangon crangon	1	1			1	1	1	1	*
Pandalus montagui		1							*
Echinodermata									
Asterias rubens	1	1	1	1	1	1			*
Echinocyamus pusillus	1								G
Ophiura albida	1	1	1		1	1			*
Psammechinus miliaris	1								*
Gastropoda									
Aporrhais pespelecani	1								G
Buccinum undatum	1								2
Facelina bostoniensis	1								*
Nassarius reticulatus	1								G
Neptunea antiqua	1								G
Peringia ulvae		1		1	1		1	1	*
Retusa obtusa	1	1			1				*
Retusa truncatula	1								*
Hydrozoa									
Hartlaubella gelatinosa	1	1		1	1			1	D
Opercularella lacerata					1				D
Sertularia cupressina		1							G
Isopoda									
Cyathura carinata								1	D
Jaera albifrons					1		1		*
Mysida									
Gastrosaccus spinifer	1			1					nb
Mysis mixta						1	1		nb
Neomysis integer				1	1	1	1	1	nb
Praunus flexuosus							1	1	nb
Nemertea									
Cyanophthalma obscura					1				nb
Lineus ruber	1	1	1	1					nb
Malacobdella grossa			1	1					nb
Nemertea	1	1	1	1	1				nb
Tubulanus polymorphus	1								nb
Oligochaeta									
Baltidrilus costatus								1	*

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Tubificidae		1		1	1		1	1	nb
Tubificoides benedii				1	1		1	1	*
Phoronida									
Phoronis sp.	1	1							nb
Platyhelminthes									
Turbellaria								1	nb
Polychaeta									
Alitta succinea				1	1			1	D
Ampharete acutifrons	1					1			*
Ampharete baltica	1	1	1	1	1	1			*
Arenicola marina				1	1		1		*
Aricidea suecica	1	1			1				*
Bylgides sarsi	1	1	1	1	1	1			*
Capitella capitata		1		1	1				*
Dipolydora quadrilobata			1	1	1	1			*
Eteone barbata	1								*
Eteone longa					1				*
Euchone papillosa	1		1						2
Harmothoe imbricata	1	1		1	1				D
Harmothoe impar	1								*
Hediste diversicolor					1			1	*
Heteromastus filiformis	1	1	1						*
Lagis koreni	1		1	1					*
Laonome kroyeri	1								D
Lepidonotus squamatus	1	1							*
Marenzelleria viridis					1		1	1	nb
Neoamphitrite figulus				1					*
Nephtys caeca	1								*
Nephtys ciliata	1	1	1			1	1		*
Nephtys hombergii	1	1	1	1		1			*
Nereimyra punctata	1								G
Paradoneis eliasoni	1								*
Pherusa plumosa	1	1	1						D
Pholoe assimilis	1	1		1					D
Phyllodoce groenlandica			1						*
Phyllodoce mucosa	1	1	1	1		1			*
Polydora cornuta				1	1				*
Prionospio steenstrupi		1							*
Pygospio elegans	1				1		1	1	*
Scalibregma inflatum	1			1					G
Scoloplos armiger	1	1		1	1		1		*
Spio goniocephala					1				*
Terebellides stroemii	1	1	1	1					*
Travisia forbesii					1				G
Trochochaeta multisetosa		1	1	1		1			D
Porifera									
Chalinula limbata		1							D
Haliclona oculata	1	1			1				D

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL
Priapulida									
Halicryptus spinulosus			1		1		1		nb
Priapulus caudatus			1						nb
Pycnogonida									
Nymphon brevirostre		1							*
Species number 119	69	46	30	41	47	22	24	22	
Total abundance (ind./m^2)	5828	509	833	1157	4134	389	4151	19003	
Total biomass (afdw g/m^2)	82,6	30,4	16,1	13,0	13,5	2,0	4,2	9,8	

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CONTENT

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