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Biological assessment of the Baltic Sea 2014

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und Michael L. Zettler

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Abstract

Dating to 1979, the HELCOM time series on species composition, biomass and abundance of phyto- and zooplankton as well as macrozoobenthos from Kiel Bay to the Eastern Gotland Basin was continued in 2014.

The phytoplankton spring bloom occurred in the Bay of Mecklenburg from 20.2. to 19.3.2014 and was met in the Arkona Basin in mid-March, dominated by *Skeletonema marinoi*. The appearance of *Ceratium tripos* in spring was surprising. The dominating species in May were *Dictyocha speculum* in the western Baltic and *Mesodinium rubrum* in the Arkona Basin. In summer, a diatom bloom occurred in the western Baltic, whereas no cyanobacteria bloom was observed there. The autumn bloom was not dominated by *Ceratium tripos* as is ususal, but by *C. fusus* instead. The presence of the marine species *Noctiluca scintillans* and *Spatulodinium pseudonoctiluca* indicates an inflow of North Sea water even before the Major Baltic Inflow of December 2014.

The chlorophyll *a* concentrations were highest (10.35 mg m^{-3}) during the spring bloom in the Arkona Basin in mid-March.

The sedimentation of particulate organic matter in the Arkona Basin was low in spring 2014, but increased in the second half of the year due to the colonisation of the trap by barnacles. This unusually high colonisation can be explained by the inflows of North Sea water, rich in oxygen and larvae, in February and March 2014. The extremely high sedimentation rates of 3.0 mol C, 429 mmol N, 1.2 mol Si and 9.3 mmol P m^{-2} a^{-1} at a mass flux of 293 g dry mass m^{-2} a^{-1} do not reflect the true vertical transport of detrital material and can quantitatively not be compared with previous periods. The diversity in the diatoms and dinoflagellates remained in the same range as in the previous year.

Zooplankton maxima were observed in summer 2014 in the Arkona and Bornholm Basins, caused mainly by *Bosmina* spp. and an unusual abundance of the copepods *Temora longicornis* and *Centropages hamatus*. Copepods and bivalve larvae dominated the zooplankton in the Bays of Kiel and Mecklenburg; *Paracalanus parvus* replaced *Pseudocalanus* spp. as the most abundant copepod species there. Polychaete larvae and *Evadne nordmanni* occurred earlier than usual; unlike previous years, rotifers were largely limited in their occurrence to the spring. The invasive species *Evadne anonyx* was previously known only in eastern areas of the Baltic Sea and was detected in Kiel Bay for the first time.

The 117 species found in the macrozoobenthos mark a moderate diversity. Long-lasting oxygen deficiency caused the loss of biodiversity and abundance at two stations in the Bay of Mecklenburg. Depending on the region, the abundances ranged from 183 to 10.899 ind./m², and the biomass (ash free dry weight) from 1.7 g/m² to 75.2 g/m². The high number of species (24) and salinity (22.1 psu) in the central Arkona Arkona Basin indicate a saltwater inflow even before the Major Baltic Inflow of December 2014. At the 8 monitoring stations altogether 17 species of the Red List could be found. 4 non-indigenous species were observed during 2014.

1. Introduction

This report presents the results of the biological monitoring undertaken 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 (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. 2015). 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. With the entry into force of an administrative agreement relating to the protection of the marine environment ('Verwaltungsabkommen Meeresschutz') 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 assessments of monitoring results were previously undertaken 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 like 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. 2015). '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 to be 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 was necessary to elaborate indicators, and this was achieved within the scope of HELCOM 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
- Cyanobacterial surface accumulations

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. 2015).

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 2014), 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 report. The equivalents to the formerly used internal IOW station numbers are given in Table 1.

Table 1
Sampling statistics (number of sampling events) of different parameters specified for sampling stations in 2014.

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	10	10	10	1
OMO22	TF0022	5	5	-	-
OM18	TF0018	-	-	-	1
OMBMPM1	TF0046	10	10	10	-
Arkona Basin					
OMBMPK8	TF0030	10	10	10	1
OMBMPK5	TF0113	10	10	9	-
OMBMPK4	TF0109	5	5	5	1
Pomeranian Bay					
OMBMPK3	TF0152	-	-	-	1
OM160	TF0160	-	-	-	1
Bornholm Basin					
OMBMPK2	TF0213	9	9	8	-
Eastern Gotland Basin					
OMBMPK1	TF0259	5	5	5	-
OMBMPJ1	TF0271	5	5	5	-

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), OMBMPK4 (Arkona Basin) and OMBMPK1/OMBMPJ1 (Eastern Gotland Basin) are taken as standard on the outward leg only, however.

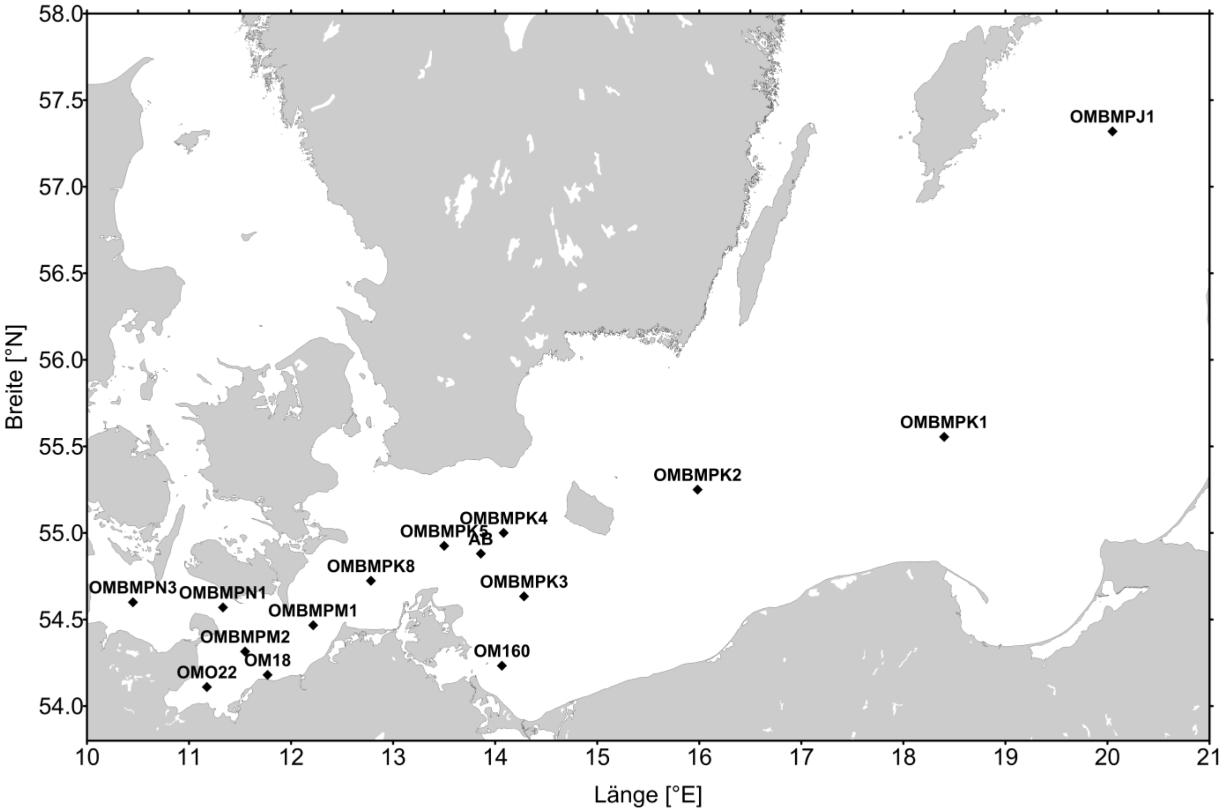


Fig. 1: The station grid for biological sampling in the Baltic Sea.

Sediment traps were installed in the Arkona Basin sampling area after 2008 (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 2014, we collected a total of 108 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 established 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 (fresh mass).

The counting, calculation and data output were facilitated by the software "OrgaCount", delivered by AquaEcology Oldenburg. The mandatory species and biovolume list PEG_BVOL2015 was used;
see http://www.ices.dk/marine-data/Documents/ENV/PEG_BVOL.zip. 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). 1 mg organic carbon equates to some 9 mg of algal wet weight (EDLER 1979). 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 sampling area, rates of vertical particle flux (sedimentation) were measured in the central Arkona Basin. 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 m^2, 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 2014 went according to plan. Moorings could be retrieved at regular intervals without any technical or logistical problems. However, during sample preparation, a defective measuring device caused the loss of a carbon measurement over a period of 7 days.

In 2014, it was found that the trap’s lattice grid baffle was being increasingly colonised by barnacles. As filter feeders they actively collect particles that are partly deposited as fecal matter into the trap.

The rates of passive transport of sinking material were so distorted by this process that a comparison with previous years was possible only on a qualitative level. It is not possible to distinguish between the two processes as both involve identical source material. In previous years, barnacle growth had been observed only occasionally on the trap’s exterior surface, and appears to have been inhibited by low near-bottom oxygen concentrations below the pycnocline. Even before the Major Baltic Inflow of December 2014, saline and oxygen-rich water had flowed into the Arkona Basin, and thus provided favourable growing conditions for barnacle larvae. Fig. 2 shows the increasing amount of fecal material filling up the trap’s sampling bottles, and shows traces of barnacles on them during the second half of the year.

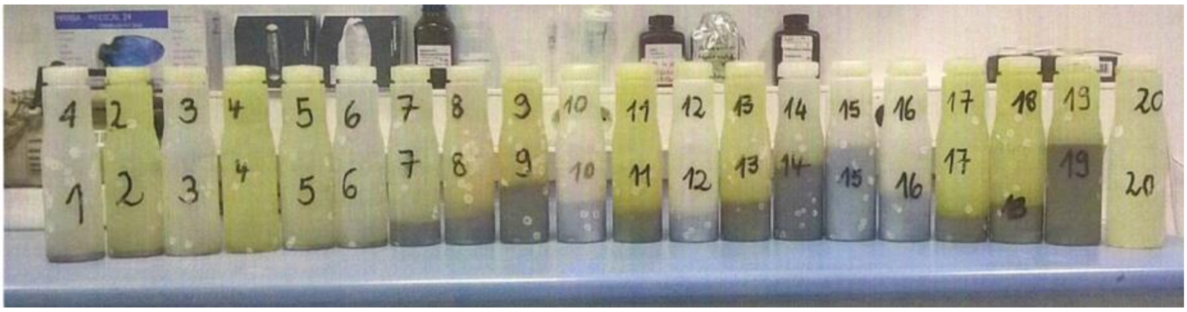


Fig.2: Sampling cups between June and November 2014 with traces of barnacle growth

2.5 Mesozooplankton

The 2014 assessment is based on zooplankton samples collected from 67 stations within Germany's Exclusive Economic Zone (EEZ) as well as from the Bornholm and Gotland Basin (Fig. 1). In line with standard HELCOM procedures, samples were collected by vertical net hauls using a WP-2 net (100 µm mesh size) at up to three depth levels per station, and if possible both on the outward and homeward leg. Net catches were taken as vertical hauls over specific depth ranges; nets were fitted with a flow metre to determine the volume of water filtered. Net angles greater than 40° are avoided during sampling. Samples were fixed in 4 % aqueous formalin solution until processing.

Taxonomic determination was undertaken in the laboratory. In each sample, a minimum number of individuals was identified, counted and their abundance calculated (ind./m^3). For the analysis, several subsamples from the total sample were counted microscopically in a Bogorov counting chamber. The remaining sample was then examined for less common animals and invasive species. All samples were processed in line with standard HELCOM procedures. With the exception of nauplii, rotifers and Bosminidae, at least 100 individuals from three taxa were counted. The total sample was then analysed; only those taxa that had not been present in the subsamples, or had been present only in very small numbers, were assessed quantitatively. Exuviae and phytoplankton were excluded from the count. In the case of animals that were broken and incomplete, only the head section was counted if it was possible to assign it to a taxon.

Zooplankton was analysed according to an internal species list based on the long-term record of the species inventory as well as the zooplankton atlas of the Baltic Sea (TELESH et al. 2008). The Integrated Taxonomic Information System (ITIS; http://www.itis.gov) was the reference database for taxonomic purposes. The reference databases used in relation to invasive species were the information system on Aquatic Non-Indigenous Species (AquaNIS, www.corpi.ku.lt/databases/index.php/aquanis) and the European Network on Invasive Species (NOBANIS, http://www.nobanis.org/Search.asp).
Taxonomic classifications are currently based on the Integrated Taxonomic Information System (ITIS, http://www.itis.gov/).
In the case of *Bosmina* spp., identifcation down to the species level is unresolved; its abundance was therefore recorded only down to genus level. In line with the standards of the Integrated Taxonomic Information System, Bryozoa were listed as Gymnolaemata and Mysidacea as Lophogastrida.

Table 2
Sample statistic of zooplankton hauls on cruises between February and November 2014.

Station number	Period				
	05.02. - 13.02.	17.03. - 25.03.	30.04. - 08.05.	19.07. - 29.07.	08.11. - 17.11.
	depth from - to (m)	depth from - to (m)	depth from - to (m)	depth from - to (m)	depth from - to (m)
OMBMPN3	15 - 0	14- 0	15- 0	16- 0	15- 0
OMBMPM2	20 - 0 20 - 0	20 - 0 21 - 0	20 - 0 20 - 9 - 0	21 - 0 22 - 0	21 - 13 - 0 20 - 0
OMBMPM1	21 - 13 - 0 21 - 0	21 - 0 22 - 6 - 0	22 - 10 - 0 21 - 6 - 0	22 - 0 22 - 11 -0	23 - 0 21 - 14 - 0
OMBMPK8	19 - 0 18 - 0	18 - 7 - 0 19 - 14 - 0	19 -14 - 0 18 - 13 - 0	19 - 0 20 - 13 - 0	20 - 13 - 0 19 - 0
OMBMPK5	41 - 0 50 - 0	42 - 12 - 0 53 - 0	41 - 25 - 0 41 - 28 - 0	44 - 15 - 0 43 - 0	44 - 24 - 0
OMBMPK4	42 - 0	42 - 0	41 - 22 - 0	45 - 22 - 0	45 - 28 - 0
OMBMPK2	80 - 50 - 0 80 - 50 - 0	82 - 50 - 0 83 - 50 - 0	85 - 45 - 0 85 - 35 - 0	85 - 42 - 12 - 0 85 - 42 - 0	
OMBMPK1	72 - 0	80 -61 - 0	85 - 70 - 0	80 - 10 - 0	86 - 38 - 0
OMBMPJ1	120 - 75 - 0	140 - 70 - 0	90 - 60 - 0	125 - 60 - 10 - 0	125 - 40 - 0

2.6 Macrozoobenthos

In November 2014, 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 repectively). 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 samler.

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

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 2014.

	Date	Depth (m)	Latitude (degree N)	Longitude (degree E)	Sea area
OMBMPN3	09.11.2014	16,8	54° 36,00	10° 27,00	Kiel Bay
OMBMPN1	08.11.2014	25,8	54° 33,20	11° 20,00	Fehmarnbelt
OMBMPM2	08.11.2014	23,5	54° 18,90	11° 33,00	Mecklenburg Bay
OM18	08.11.2014	19,5	54° 11,00	11° 46,00	Mecklenburg Bay South
OMBMPK8	17.11.2014	21,0	54° 44,00	12° 47,40	Darss Sill
OMBMPK4	10.11.2014	45,8	55° 00,00	14° 05,00	Arkona Basin Central
OMBMPK3	10.11.2014	29,3	54° 38,00	14° 17,00	Pommeranian Bight North
OM160	10.11.2014	13,4	54° 14,50	14° 04,00	Pommeranian Bight 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. Staff are inducted, monitored, and attend continuing professional development and QA (e.g. comparative laboratory tests) activities as a matter of course; 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 every three years or so. No one from IOW was able to attend the 2014 PEG meeting because of the interfering assessment process at 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'). As part of CEN/TC 230 Mandate M/424, IOW technicians responsible for phytoplankton analysis participated in a European biovolume comparative laboratory test in March 2014. Its initial results were presented at an international workshop on the development of a standard for a European phytoplankton biovolume held in Berlin at the offices of the German Institute for Standardization (DIN) from 7 to 11 October 2014.

As happens every year, the biovolume list of species and size classes was updated for the previous year. Samples taken up until March 2014 are based on the official ICES and HELCOM biovolume file PEG_BIOVOL2014, and from May 2014 on biovolume file PEG_BIOVOL2015.

Chlorophyll

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.

IOW regularly participates in chlorophyll comparisons within the QUASIMEME AQ-11 regime (chlorophyll in seawater). In accordance with BLMP-UAG Quality Assurance Plankton of 11.9.2008, only "uncorrected" total chlorophyll *a* ('chl.a-tot') was reported (see chapter 2.3). For this reason, our values tend to be slightly higher than the average of those of other participants. The results of round 73 of the QUASIMEME ring test for chlorophyll *a* (AQ-11) were nevertheless very good, producing z-scores of -0.1, 1.0, -0.4 and -0.9. In view of a general deterioration in the results achieved by participants, QUASIMEME convened a workshop for 4-6.2.2014 in Oostende (Belgium) to investigate the causes. IOW's Christian Burmeister, who is responsible for chlorophyll analysis, attended the workshop. In future, the HPLC results reported by at least some participants will be excluded from the total score.

Zooplankton

Quality Assurance of zooplankton testing was assured through a number of procedures. Each technician was trained in the analytical methods and followed standard operating procedures in line with the HELCOM COMBINE Manual (HELCOM 2014b).

Every tenth zooplankton sample was duplicated as standard. A regular intra-laboratory comparison was performed when species determination, abundance and biomass estimates was carried out by different staff. In 2014, measured deviations were well below the threshold value for critical errors. The in-house collection of reference species was expanded with a special focus on the species of *Evadne* that occurred in the study area. In working group meetings, a particular focus of discussion was the taxonomic identification of *Pseudo* and *Paracalanus* species, and the differentiation between genera and species of cladocerans. Uncertainties surrounding the possible occurrence of two different *Paracalanus* species were resolved with the help of international specialists at a taxonomy workshop held at SAHFOS, Plymouth (UK). Although clearly different in size, they proved to be morphotypes of *Paracalanus parvus*.

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 the Baltic Sea in 2014

The development of sea surface temperatures (SST) in 2014 was followed by American NOAA and European MetOp weather satellite images which were daily supplied by BSH in Hamburg (NAUSCH et al. 2015).

2014 was the warmest year since 1990 and thus was about 1.2 K above average for the period 1990-2014; it was 0.4 K higher than 2008, formerly the warmest year. Except for February and June, all other months contributed, especially July and August in the north of the Baltic Sea. The western Baltic Sea exceeded long-term mean values by +1 to +3 K in every month except February. After a mild start to the year, a cold spell starting around 20 January produced strong cooling until the beginning of February. Nevertheless, the monthly average for January exceeded the long-term means for 1990-2014 by +2 K; January was the second-warmest January in the western Baltic since 2007. February lay in the range of long-term means, and in the Arkona Basin and Gulf of Bothnia was the coldest month of the year. February 4 was the coldest day in the entire Baltic Sea, and 6 February was the day of maximum ice cover. As usual, March developed to the coldest month of the year in the Gotland Basin. From March to May throughout the Baltic Sea, and even from March to December in its western part, anomalies of +1 to +3 K were recorded. June was the only month with negative anomalies of -1 to -2 K throughout the basins of the central and northern Baltic Sea. July was the warmest month only in the Mecklenburg Bay; otherwise it was August. The warmest day was 28 July with temperatures of 21-25 °C. The atypically similar temperature distribution throughout the Baltic Sea in July and August led to large anomalies of up to +5 K in its northern part in July. July 2014 was the warmest month since 1990. With anomalies of up to +3 K, October and November were the warmest in the western Baltic Sea.

Even before the Major Baltic Inflow of December 2014 (MOHRHOLZ et al. 2015), some minor inflows of water from the North Sea occurred, especially in the months of February, March and August, as shown by increased salinity (Fig. 3; NAUSCH et al. 2015). They filled the western basins and prepared the way for the advance of more saline water as far as the Gotland Basin where - even during our July cruise, for instance - tongues of oxic water signalling the inflows were observed at various depths (WASMUND 2014). These modest inflows clearly influenced biological samples, but have received much too little attention because of December's Major Baltic Inflow whose effects will influence our samples in 2015 and will be considered in detail in our next report.

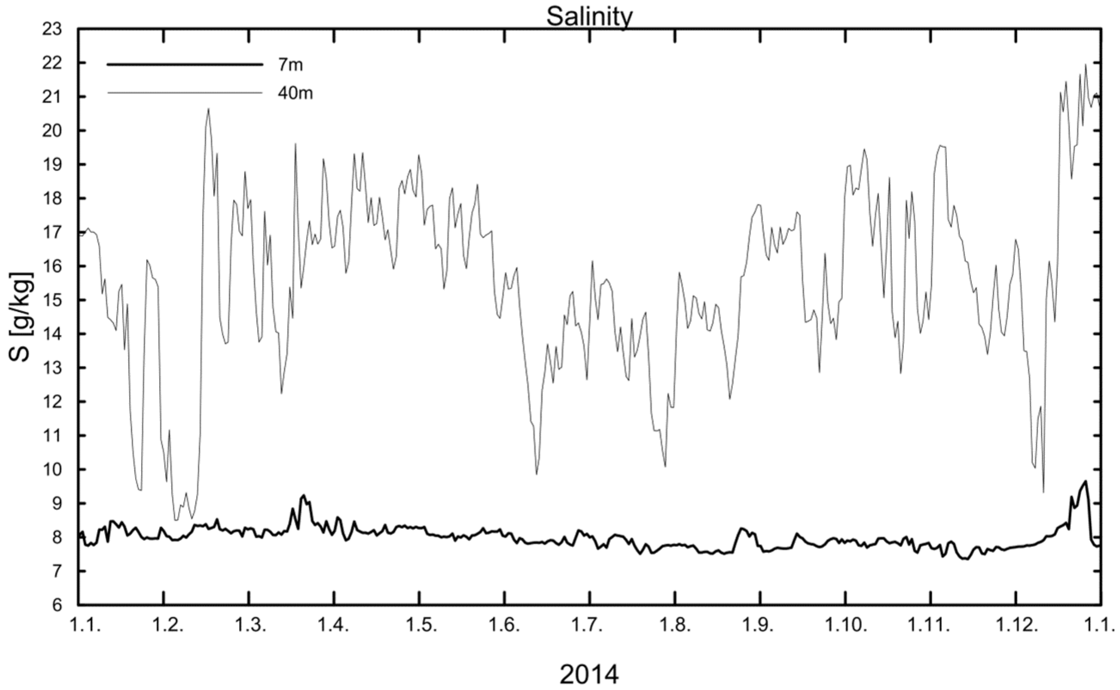


Fig. 3: Seasonal variations in salinity in the surface and bottom layer of the Arkona Basin (Station AB) in 2014 (NAUSCH et al. 2015).

4. Results and Discussion

4.1 Phytoplankton

4.1.1 Satellite Images of the Spatial and Temporal Development of Cyanobacteria

Chlorophyll charts have been used in recent years to track the development of phytoplankton. Since the failure of ESA's MERIS sensor, US MODIS data with a resolution of 1 km have been used. Data from a number of service providers varied in quality. As the number of providers has decreased, the procedures used are similar and the number of high-grade, cloud-free scenes has greatly reduced, it makes no sense, in our view, to continue to use the chlorophyll maps for the description of the plankton development.

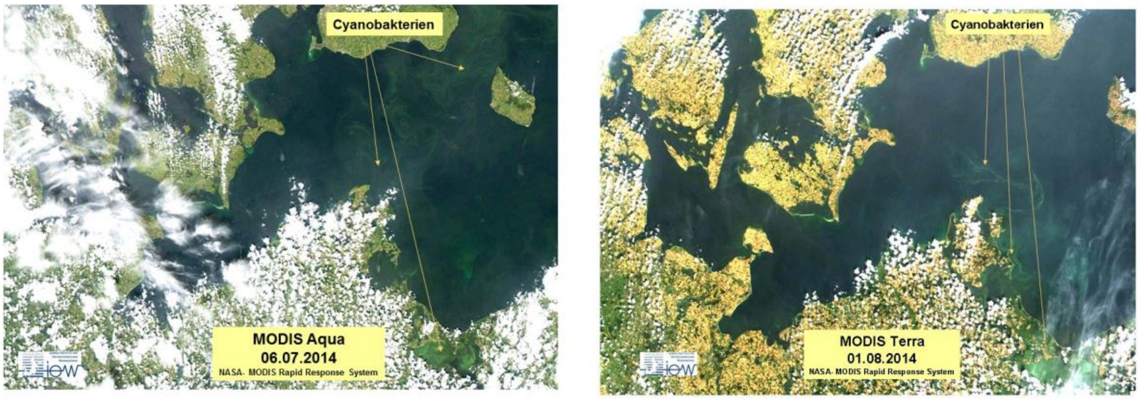


Fig. 4: Development of cyanobacteria on 6 July 2014 (a) and on 1 August 2014 (b) in the western Baltic Sea.

The high spatial resolution MODIS true color scenes (RGB, 250 m) of the satellites Aqua and Terra provided by the Lance Rapid Response System of NASA, were applied to trace the spatio-temporal development of Cyanobactera in summer.

In recent years, the first signs of cyanobacteria were usually observed around June 25. Also in 2014, they appeared nearly at the same time in the southeastern Baltic Sea. As happened during spring, clouds dominated the satellite scenes from late June until early August. Less cloud cover in early July revealed the first signs of filaments in the northern Arkona and Bornholm Basin. On July 4, filaments were observed there and in Szczecin Lagoon, and were also well developed throughout the Baltic Sea from the Arkona Basin to the Gulf of Finland. Two days later they were present throughout the entire Arkona Basin as far as Darss Sill and the Pomeranian Bay (Fig. 4a). High wind speeds over the following days caused surface mixing: on July 9 and 10 filaments in the southern and western Baltic were no longer recognisable after being dispersed throughout the water column, and as far as Warnemünde. A maximum concentration developed between the island of Gotland and the entrance to the Gulf of Finland. Satellite scenes from July 17, 19, 23 and 31 revealed a similar picture caused by wind events and variable cloud in the western Baltic, with filament less strongly pronounced. Surface accumulations of filaments occurred only in Szczecin Lagoon. Thereafter, a maximum concentration largely persisted in the northern Gotland Basin, as the satellite scene from July 22 in Fig. 5 shows. Growth in the Gulf of Finland was negligible, but filaments carried via the Aland Sea into the Bothnian Sea were visible. From July 27 to the end of the month, cloud cover also influenced the central Baltic Sea. On August 1, after clear and calm conditions, filaments formed north and east of the Island of Rügen and moved towards its east coast (Fig. 4b). The distribution of filaments in other areas of the Baltic Sea was similar to what had already been seen: there was a high concentration in the northern Gotland Basin, and another extended southwards to the southern tip of the island of Gotland. On August 3, large parts of the Arkona Basin were again affected, and on August 8, cyanobacteria were present off Warnemünde. In the northern Gotland Basin, wind had reduced their concentration. The next few days were characterised by more wind and thick cloud coverage throughout the Baltic Sea area. In the next usable satellite scenes from August 12 and 13, no more accumulations of cyanobacteria were visible in the northern, eastern and western Baltic Sea. The remainder of August was characterised by wind and thick clouds. The next usable MODIS scene from August 28 showed that no more cyanobacteria were present anywhere in the Baltic Sea.

Fig. 5: Development of cyanobacteria in the central Baltic Sea on 22 July 2014.

Overall in 2014, the western Baltic Sea was not characterised by strong cyanobacteria growth, probably as a result of the passage of many low pressure systems and the meteorological conditions associated with them. There was intense cyanobacteria growth in the northern Gotland Basin, particularly caused by the July contribution.

4.1.2 Seasonal Variations in Species Composition and Biomass

The limited number 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 infrequent sampling frequency means our understanding of the seasonal development of phytoplankton is patchy. Any gaps in relation to Mecklenburg Bay can be filled by making use of additional data collected off Heiligendamm as part of the coastal monitoring undertaken by IOW. Information about monitoring in this coastal water is available here: http://www.io-warnemuende.de/algenblueten-vor-heiligendamm-2014.html. Satellite data permit observations at high temporal resolutions (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. Unidentified categories (‘Unidentified’, ‘Gymnodiniales’, ‘Peridiniales’, ‘Craspedophyceae’) have been omitted from the table if their 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.

Table A2 shows the full list of phytoplankton taxa at all depths for each monitoring cruise in 2014. 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 now also include the unidentified categories that were omitted from our reports before 2012 (Gymnodiniales, Peridiniales, Craspedophyceae, Chrysophyceae, Centrales, Pennales, ‘Unidentified’ and ‘Unidentified flagellata’). The biomass rank averaged over all stations (including the Baltic Proper) and all monitoring cruises in 2014 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: *Protoperidinium divergens*, *Spatulodinium pseudo-noctiluca*, *Dissodinium pseudolunula*, *Nitzschia seriata*, *Leptocylindrus danicus*, *Leptocylindrus minimus*, *Chaetoceros circinalis*, *Merismopedia punctata*, *Diatoma tenuis*, *Koliella* spp., *Calliacantha* spp. Note that no importance attaches to the rank order of rare species whose biomass can be determined only very inaccurately 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. 8-10.

Heterotrophic species and groups such as *Ebria tripartita, Protoperidinium* spp., Craspedophyceae and 'incertae sedis' are also counted. Craspedophyceae is the botanical name for the choanoflagellates. 'Incertae sedis' is a term used to refer to a taxonomic group that is still unassigned, such as *Katablepharis, Leucocryptos* and *Telonema*. We have included them in the species lists (Tables A1 and A2) and phytoplankton biomass data (Figs. 8-10).

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. While scientists were working on a new description of it, however, it was established that genotypically it does not differ from the freshwater species *A. flos-aquae* (Laamanen 2002). We could again therefore describe the Baltic Sea species as *A. flos-aquae*. 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 should now be named as '*Dolichospermum*' (see also Komárek & Zapomělová 2007, 2008). The HELCOM Phytoplankton Expert Group has now re-named this genus in its species list. 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 *Verrucophora farcimen* (also Dictyochophyceae) and *Chattonella* spp. (Raphidophyceae). The synonym *Pseudochattonella verruculosa* is under discussion (see Hoppenrath et al. 2009). 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 (Fig. 6 e-g), we feel fairly certain when it comes to these round, naked cells. Nevertheless within the HELCOM Phytoplankton Expert Group (PEG), we have discussed whether elongated forms might also be naked *Dictyocha speculum*, but then agreed that they should count as *Verrucophora farcimen*. This uncertainty is not a problem when working at class level because *Verrucophora farcimen* and *Dictyocha speculum* belong to the class of Dictyochophyceae. In the past it was assigned to the Chrysophyceae. In the interests of comparability with previous years, in Figs. 8-10 we have left these genera within the class of Chrysophyceae; in this category *Dictyocha* generally accounts for the greatest share of biomass by far.

The HELCOM Phytoplankton Expert Group (PEG) delt 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 will become be set in force 2015. Table 4 shows those synonyms which concern the taxa occurring in our own samples.

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.

Table 4
Taxonomic revisions of phytoplankton names.

Old Synonym	New Synonym
Aphanothece	*Anathece*
Chaetoceros impressus	*Chaetoceros castracanei*
Cladopyxis claytonii	*Micracanthodinium claytonii*
Craspedophyceae	Choanoflagellatea
Cylindrotheca closterium	*Ceratoneis closterium*
Dinophysis rotundata	*Phalacroma rotundatum*
Prorocentrum minimum	*Prorocentrum cordatum*
Scenedesmus acuminatus	*Acutodesmus acuminatus*
Scenedesmus acuminatus	*Acutodesmus acuminatus*
Scenedesmus obliquus	*Acutodesmus obliquus*
Earlier revisions (new names already used in this report):	
Anabaena	*Dolichospermum*
Skeletonema costatum	*Skeletonema marinoi*

4.1.2.1 Spring Bloom

Figures 8-10 show the seasonal variations in phytoplankton at the various sampling locations. In early February, the biomass still exhibited low winter values. As in 2013, biomass values were elevated only at station OMBMPN3 as a result of long-lived *Ceratium* species (*Ceratium tripos*: 296 µg/l) that had overwintered, but in contrast to previous year it did not disappear in spring, but increase until April (see below). The high concentration of *Coscinodiscus concinnus* (Fig. 6a) above the sea floor at a depth of 16.5 m (973 µg/l) was very surprising, while no trace of it was found at all in the upper 10 m. Depth samples (20 m) at stations OMO22, OMBMPM2 and OMBMPM1 were heavily contaminated with resuspended sediment and were not quantifyable, but large *Coscinodisus* and *Ceratium* cells were not found there (Fig. 6b). At stations OMO22 and OMBMPM2, however, concentrations of Chl.a at 15 m were high (1.6-1.8 µg/l).

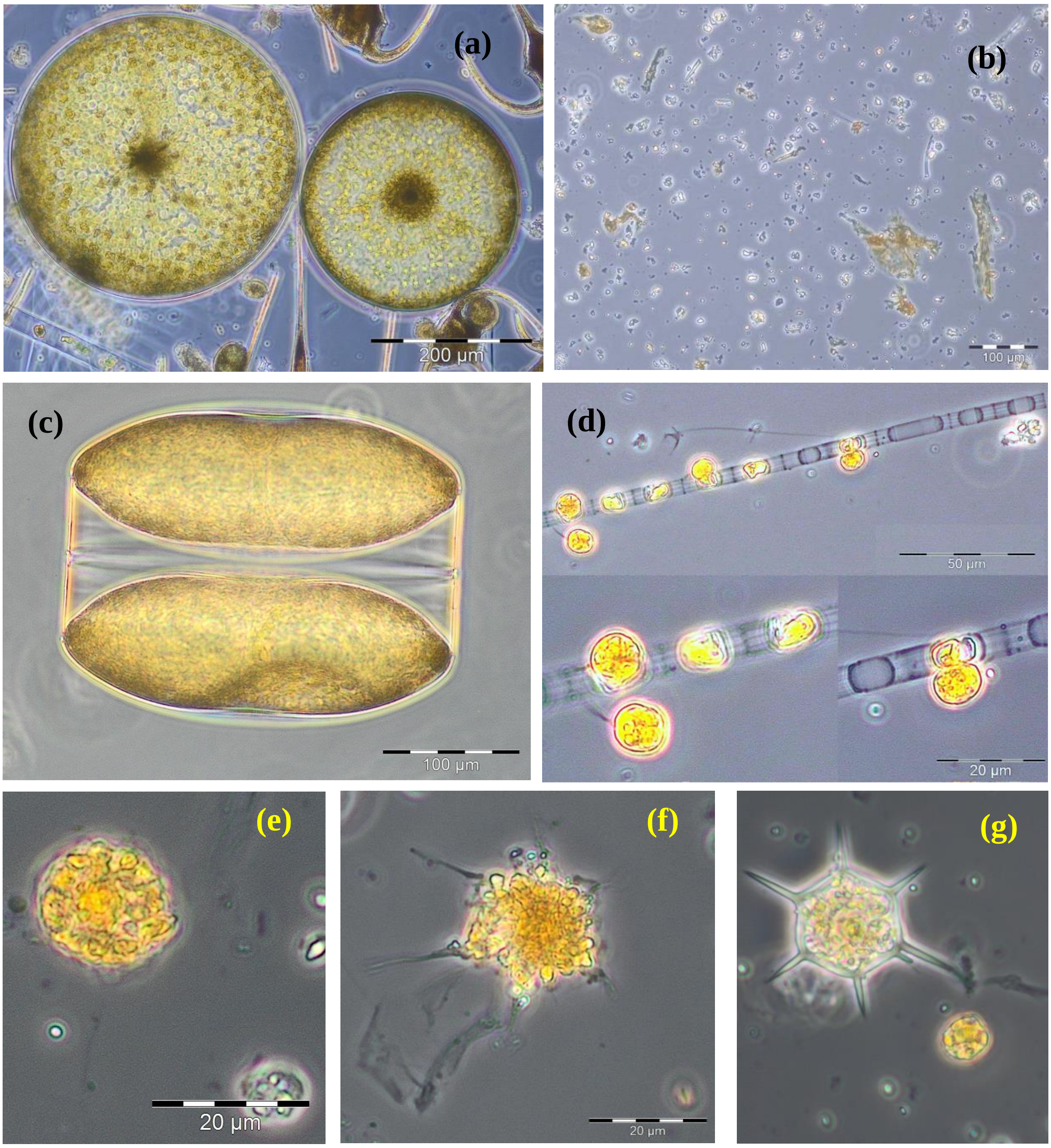


Fig. 6: Light microscopical images of the spring bloom in 2014.
(a) *Coscinodiscus concinnus* beside *Ceratium tripos* in a net sample from the upper 16 m on 4.2.2014, station OMBMPN3; (b) example of a silted sample, at 20 m depth on 4.2.2014, station OMO22; (c) *Coscinodiscus concinnus*, girdle view, live net sample from top 20 m on 13.2.2014, station OMBMPM2; (d) *Skeletonema marinoi* in surface sample on 4.3.2014, Heiligendamm coastal station. (e) to (g) various forms of *Dictyocha speculum*: naked (e: 25.3.2014, station OMBMPM2); intermediate (f: 25.3.2014, station OMBMPM2); skeleton-bearing (g: 1.5.2014, station OMBMPK8). Photos: Susanne Busch.

What was of interest on 13.2.2014 was the strong increase in *Coscinodiscus concinnus* biomass in the upper 10 m of the water column at station OMBMPM2 (411 µg/l; see Fig. 6c), but not at a depth of 20 m. Obviously, transport processes were taking place. This appearance of *Coscinodiscus concinnus* was not observed in the surface water at Heiligendamm, where *Ceratium* disappeared with an outflow from the Baltic. The western Baltic is evidently very dynamic, and the distribution of algae very patchy. In more easterly sea areas, algal growth was not yet obvious in February.

By the time of the monitoring cruise of mid-March, an increase in phytoplankton biomass had occurred at all the investigated stations, as also reflected in Chl.*a* values (Table 6). Strong phytoplankton growth can be inferred from the sharp decline in nutrient concentrations from mid-February to mid-March (Table 5). The inorganic nutrients of nitrogen and phosphorus had almost been depleted by mid-March in Kiel and Lübeck Bays and in central areas of Mecklenburg Bay, suggesting that a phytoplankton bloom had already occurred in early March. In 2013, in contrast, nutrients had been depleted only slightly by mid-March indicating the occurrence of the spring bloom in the western Baltic much later in that year, but whose timing could not be fixed because a cruise did not take place at just that time.

The growth of the spring bloom is associated with high rates of photosynthesis that in turn depletes the CO_2 concentration in the water. Since 2004, the partial pressure of carbon dioxide (pCO_2) has been measured by ferries sailing between Travemünde and Helsinki (currently the M/S *Finnmaid*). The reduction in pCO_2 in springtime can be used to determine the strength of primary production and its spatial and temporal distribution. Thus the 2013 spring bloom in Mecklenburg Bay did not occur until 21 March to 3 April, while in 2014 it occurred as early as 20 February to 19 March (SCHNEIDER et al. 2015), which agrees with our findings.

Thanks to weekly measurements at Heiligendamm sampling station (http://www.io-warnemuende.de/algenblueten-vor-heiligendamm-2014.html) we are able to confirm data from SCHNEIDER et al. (2015). On 25.2.2014, a marked increase in temperature to 2.9 °C and in salinity to 15.3 PSU produced a sudden bloom of diatoms composed of *Skeletonema marinoi* (918 µg/l), *Thalassiosira* spp. (403 µg/l), *Chaetoceros* cf. *wighamii* (357 µg/l), and *Detonula confervacea* (211 µg/l). This bloom persisted at least until 12.3.2014.

By the time of the monitoring cruise in mid-March, the spring bloom in the Kiel, Lübeck, and central Mecklenburg Bay had clearly come to an end. From silicate depletion rates (Table 5) we can infer that a diatom bloom had occurred, even if by 17./18.3.2014 diatoms (*Rhizosolenia setigera, Skeletonema marinoi*) had already largely been displaced by naked *Dictyocha speculum* (Figs. 6 e-f). The collapse of the bloom is probably due to a lack of nutrients, but parasites also played a part, as infested *Skeletonema marinoi* showed (Fig. 6d). Relatively large biomass accumulations of healthy-looking *Coscinodiscus concinnus* (e.g. 350 µg/l at station OMBMPM1 on 18.3.2014) were observed at 15-20 m depth. Such deep maximum of this species was never noticed before. Compared with February, *Ceratium tripos* had developed appreciably in the Bays of Lübeck and Mecklenburg – which was very unusual as this species normally vanishes in winter and spring. This tangible growth was indicated by the further increase in the biomass of *Ceratium tripos* to 357 µg/l at station OMBMPM2 on 25.3.2015; it finally disappeared by 30.4/1.5.2014. It was replaced by an almost pure bloom of *Dictyocha speculum* that occurred in the upper 10 m (but not at 20 m) of the water column (e.g. 885 µg/l at station OMO22; Figs. 6 e-f, 8a-d); listed in Figs. 8-10 under Chrysophyceae. This flagellate occurred mainly in its ‘naked’ form (Fig. 6e), less so with the typical siliceous skeleton (Fig. 6g). At Heiligendamm station on 22.4.2014, it even reached a maximum of 2230 µg/l. Faced with such a dense bloom of this late spring species, other classic types were barely able to flourish in late April/early May 2014 (Fig. 8).

Developments in the Arkona Basin in 2014 were markedly different. The phenomenon described by WASMUND et al. (1998) of a time delay in the spring bloom from west to east was clearly recognisable. With the spring bloom in Kiel, Lübeck and Mecklenburg Bays essentially over, in mid-March it was still fully developed in the Arkona Basin.

The obvious symptoms of nitrogen deficiency (Table 5) indicated that the bloom was nearing its end. Interestingly, unlike in the Arkona Basin, in Kiel Bay phosphorus was depleted first, indicating phosphorus limitation there. Silicate was consumed in all these sea areas (although not depleted), which is a clear sign of a diatom bloom.

We did indeed observe high levels of diatom biomass on 18./19.3.2014 at the three sampling locations in the Arkona Basin (Fig. 9 a-c), although they fell markedly by 24./25.3. Essentially they were composed of *Skeletonema costatum* (1590 µg/l at station OMBMPK5), *Thalassiosira* spp. (316 µg/l at station OMBMPK5), and *Chaetoceros* cf. *wighamii* (223 µg/l at station OMBMPK5). These blooms were also found to extend to a depth of 20 m. *Dictyocha speculum* did not occur in the Arkona Basin. *Mesodinium rubrum* developed after mid-March, and was observed within the diatom bloom. When the diatom bloom collapsed in early May 2014, *Mesodinium rubrum* became the dominant species.

Dictyocha and *Mesodinium* were apparently still able to grow despite low nutrient concentrations following the diatom bloom (Table 5), or they rapidly take up remineralised nutrients (see below). What is remarkable is that *Ceratium tripos* was even found in the Arkona Basin and at that unusual time (May) - as net samples showed (Fig. 11 a). The cyanobacterium *Aphanizomenon* sp. also occurred early.

In the Bornholm Basin, phytoplankton biomass had already grown by 20.3.2014 (*Mesodinium rubrum, Skeletonema marinoi*), while almost minimum winter levels were still present in the eastern Gotland Basin (Fig. 10). By the time of the sampling campaign in May, strong blooms clearly dominated by *Mesodinium rubrum* had developed in the Bornholm Basin and the southern part of the eastern Gotland Basin where admixtures of the dinoflagellates *Dinophysis acuta, Amylax triacantha, Peridiniella catenata* and *Gyrodinium spirale* were also observed.

Using the method of WASMUND et al. (2013) for diatom growth estimations, silicate depletion rates from February to March 2014 also suggest that pronounced diatom blooms occurred from the western Baltic to the Arkona Basin, whereas in more easterly areas diatom blooms failed to appear even until May. It is known that a more or less strong spring diatom bloom occurs every year in the Bays of Kiel and Mecklenburg, while the intensity of the diatom bloom in the Arkona Basin can already be greatly reduced, as happened in 2012 and 2013, for instance. Surprisingly, silicate concentrations increased again markedly from March to May, while concentrations of phosphorus and nitrate did not.

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 2014. Data extracted from the IOW database.

Station number	Date	Nitrate+Nitrite	Phosphate	Silikate
OMBMPN3	04.02.2014	5,98	0,57	16,50
OMBMPN3	17.03.2014	1,05	0,07	3,60
OMBMPN3	30.04.2014	0,84	0,01	3,90
OMO22	04.02.2014	7,98	0,75	19,10
OMO22	18.03.2014	0,11	0,07	1,10
OMO22	30.04.2014	0,02	0,08	3,60
OMBMPM2	05.02.2014	5,21	0,56	14,80
OMBMPM2	13.02.2014	5,81	0,60	16,60
OMBMPM2	18.03.2014	0,75	0,06	2,40
OMBMPM2	25.03.2014	0,12	0,07	2,50
OMBMPM2	01.05.2014	0,02	0,50	11,10
OMBMPM1	05.02.2014	4,45	0,61	14,60
OMBMPM1	13.02.2014	6,58	0,59	13,90
OMBMPM1	18.03.2014	2,34	0,27	3,80
OMBMPM1	25.03.2014	0,60	0,12	4,20
OMBMPM1	01.05.2014	0,06	0,52	11,00
OMBMPK8	05.02.2014	4,58	0,58	14,30
OMBMPK8	12.02.2014	5,70	0,59	14,70
OMBMPK8	18.03.2014	0,04	0,12	1,60
OMBMPK8	25.03.2014	0,01	0,18	2,70
OMBMPK8	01.05.2014	0,08	0,51	11,40
OMBMPK5	05.02.2014	5,83	0,53	14,90
OMBMPK5	12.02.2014	4,32	0,60	12,10
OMBMPK5	18.03.2014	0,03	0,14	1,50
OMBMPK5	24.03.2014	0,12	0,09	1,10
OMBMPK5	01.05.2014	0,08	0,69	14,20
OMBMPK5	08.05.2014	0,02	0,57	13,30
OMBMPK4	05.02.2014	3,77	0,48	9,10
OMBMPK4	12.02.2014	3,45	0,70	12,60
OMBMPK4	19.03.2014	0,06	0,22	3,60
OMBMPK4	02.05.2014	0,02	0,39	9,70
OMBMPK2	07.02.2014	4,10	0,71	13,20
OMBMPK2	20.03.2014	2,45	0,56	12,30
OMBMPK2	24.03.2014	3,05	0,54	11,30
OMBMPK2	03.05.2014	0,00	0,47	14,20
OMBMPK2	07.05.2014	0,03	0,32	12,10
OMBMPK1	11.02.2014	3,62	0,57	12,60
OMBMPK1	21.03.2014	3,20	0,62	12,90
OMBMPK1	04.05.2014	0,06	0,37	12,30
OMBMPJ1	09.02.2014	4,13	0,52	11,30
OMBMPJ1	21.03.2014	3,39	0,42	11,40
OMBMPJ1	04.05.2014	0,06	0,28	12,90

The selective mineralization of silica alone cannot be assumed; it is more likely that all algal components are decomposed, but phosphorus and nitrogen are taken up by flagellates as they grow, whereas they do not need silica. In any event, the rapid recycling of nutrients, including the seemingly stable silica of diatom shells, is very surprising.

4.1.2.2 Summer Bloom

With summer sampling based on only one cruise, it cannot adequately reflect the great diversity of the phytoplankton community. A summer diatom bloom often develops but goes undetected because of a lack of samples. In 2014, however, our sampling cruise between Kiel Bay and the central Mecklenburg Bay coincided with the summer diatom bloom. This bloom was composed almost exclusively of *Dactyliosolen fragilissimus* (e.g. 4377 µg/l at station OMO22). It was accompanied by the remarkable dinoflagellate *Alexandrium pseudogonyaulax* (e.g. 163 µg/l at station OMO22), which was first detected by us in 2010 (Fig. 11 b). *Ceratium tripos* was developing again. In terms of these species, 2014 was similar to 2013 – but not 2012. At Heiligendamm coastal station, *Dactyliosolen fragilissimus* yielded similar levels of biomass (3111 µg/l on 15.7.2014).

Dactyliosolen fragilissimus did not occur at all in the Arkona Basin incl. station OMBMPK8, but surprisingly *Ceratium tripos* did occur so far east, e.g. 101 µg/l at station OMBMPK5 on 29.7.2014. This might be indicative of an inflow that we detected during our sampling cruise in July, and whose effects were felt as far as the Eastern Gotland basin. As a general rule, summer samples contain numerous picoplankton cells ‹ 2µm, which we do not count as the method we apply is not suitable for their quantitative analysis.

The cyanobacteria that typically occur during the summer do not usually form blooms in the western Baltic, but their biomass increased noticeably in July: on 29.7.2014 at station OMBMPM2, for instance, it reached 50 µg/l for both *Aphanizomenon* sp. and*Nodularia spumigena*. During the monitoring cruise, we observed aggregates of cyanobacteria suspended in the surface water of some areas of Mecklenburg Bay and the Arkona Basin.

With low total biomass in the Bornholm Basin (station OMBMPK2) in July 2014, unclassified single cells (2-5 µm) were the dominant constituent besides unidentified Gymnodiniales and Prymnesiales. Biomass was also low in the southern Gotland Sea (station OMBMPK1) where cyanobacteria were dominant, less the nitrogen-fixing type (32 µg/l) than the colony-forming species *Cyanonephron styloides* (50 µg/l).

In the surface water of the eastern Gotland Basin (station OMBMPJ1), however, we detected a bloom of *Nodularia spumigena* (549 µg/l) and *Aphanizomenon* sp. (128 µg/l), besides significant numbers of Prymnesiales (182 µg/l). The bloom was especially strong in the north of the eastern section of the Gotland Basin, south of station 286 (Fårö Deep); see Fig. 7.


Foto: Wasmund

Fig. 7: Cyanobacteria bloom in the Eastern Gotland Basin (south of Station TF0286) on 25.7.2014.

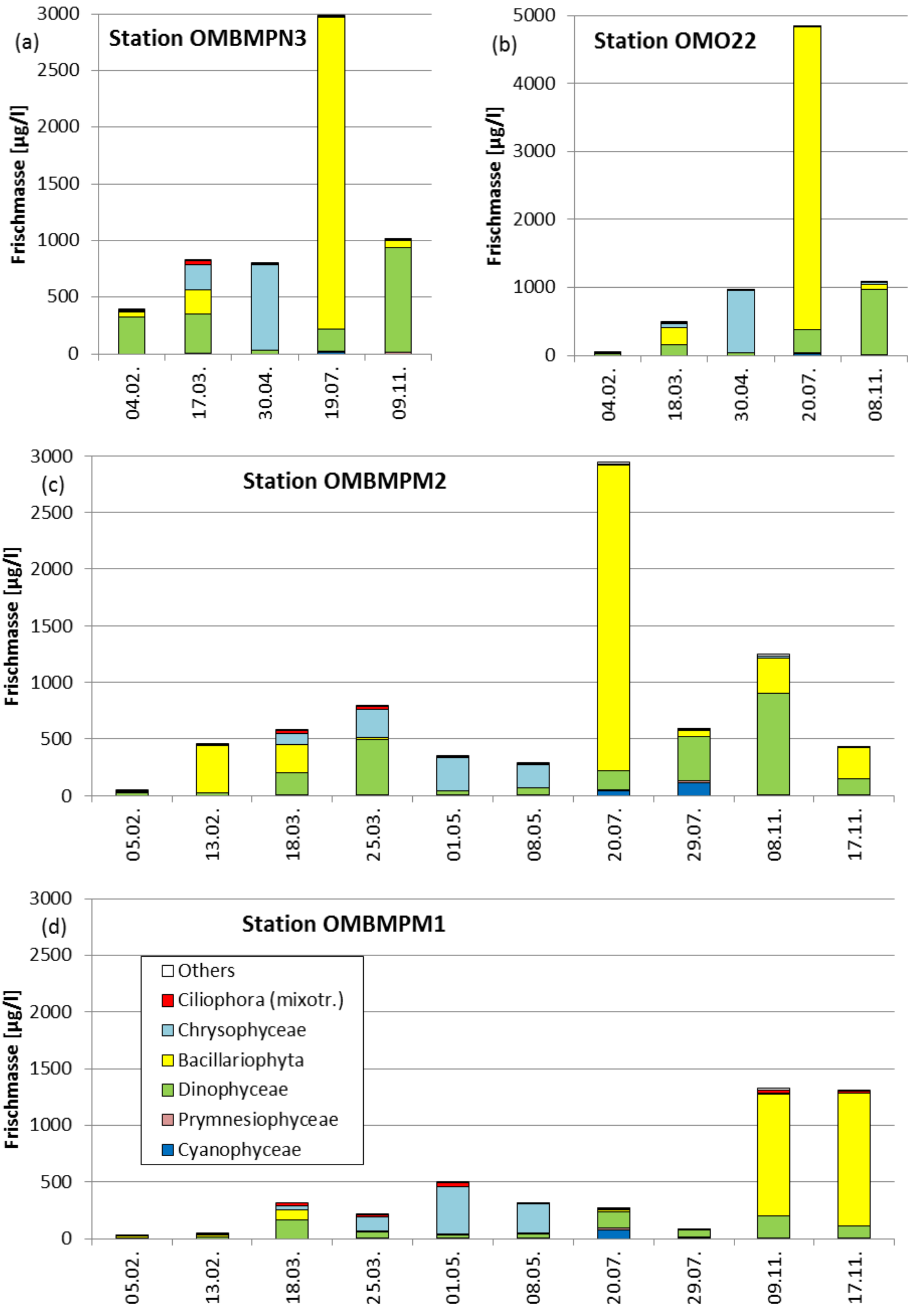


Fig. 8: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in Kiel Bay (a), Lübeck Bay (b) and Mecklenburg Bay (c, d) in 2014.

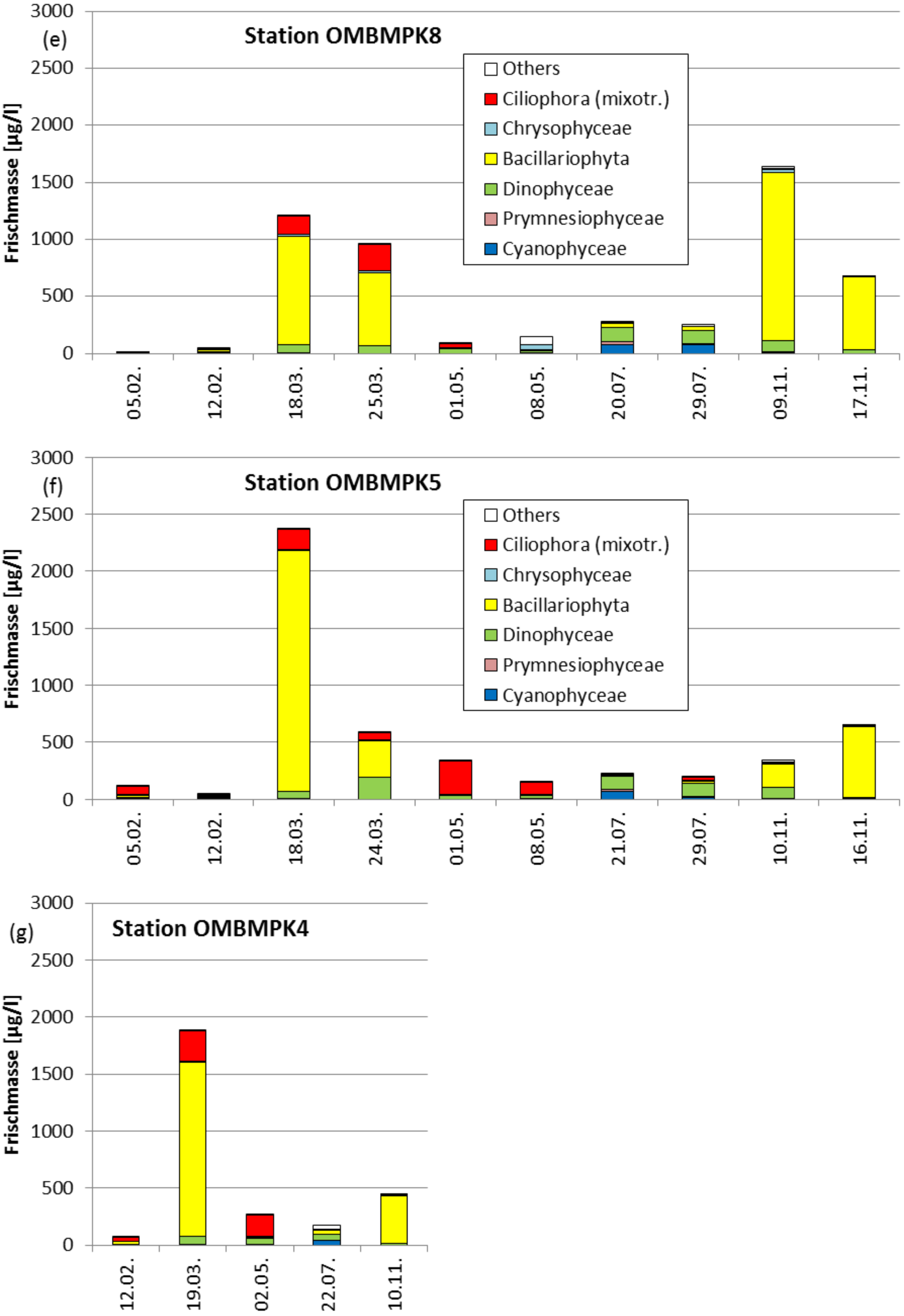


Fig. 9: Seasonal variation of phytoplankton wet weight, divided into main taxonomic groups, in the Arkona Basin (a-c) in 2014.

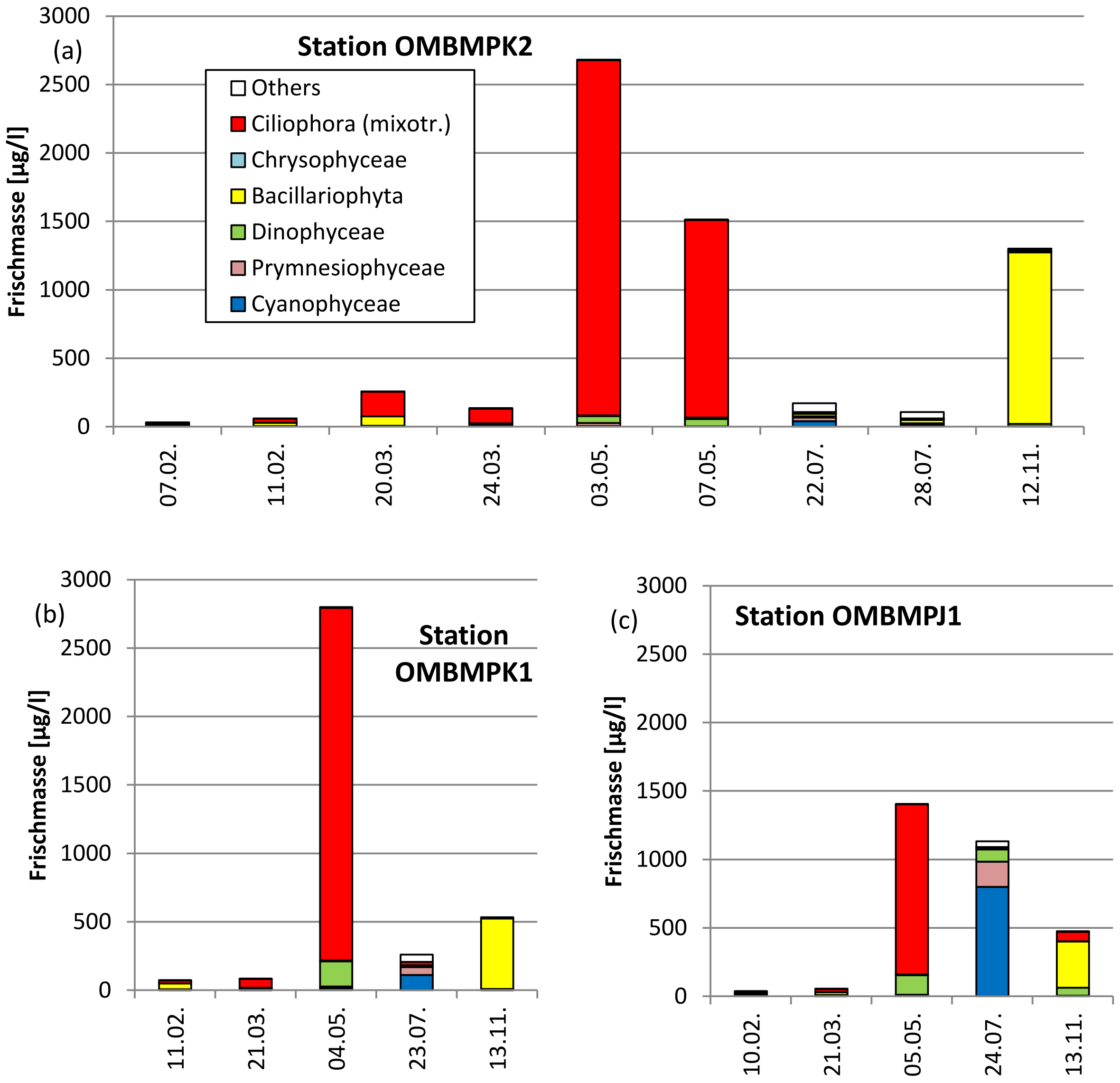


Fig. 10: Seasonal variation of phytoplankton wet weight, devided into main taxonomical groups, in the Bornholm Basin (a) and Eastern Gotland Basin (b-c) in 2014.

4.1.2.3 Autumn Bloom

We encountered the autumn bloom as expected, probably past its peak but at least still exhibiting the typically dominant phytoplankton groups. In the Bays of Kiel, Lübeck and Mecklenburg, *Ceratium* species were dominant (Fig. 12 a), although surprisingly not the usual *Ceratium tripos* (182 µg/l at station OMBMPM2), but rather *C. fusus* (430 µg/l at station OMBMPM2). At station OMBMPN3 (8.11.2014), we also found *Polykrikos schwartzii* (90 µg/l) and *Dinophysis norvegica* (81 µg/l); at station OMO22 *Polykrikos schwartzii* (266 µg/l); and at station OMBMPM2 *Cerataulina pelagica* (221 µg/l, Fig. 12 a) and *Polykrikos schwartzii* (195 µg/l). Numbers of *Ceratium tripos* fell markedly at station OMBMPM2 by 17.11.2014.

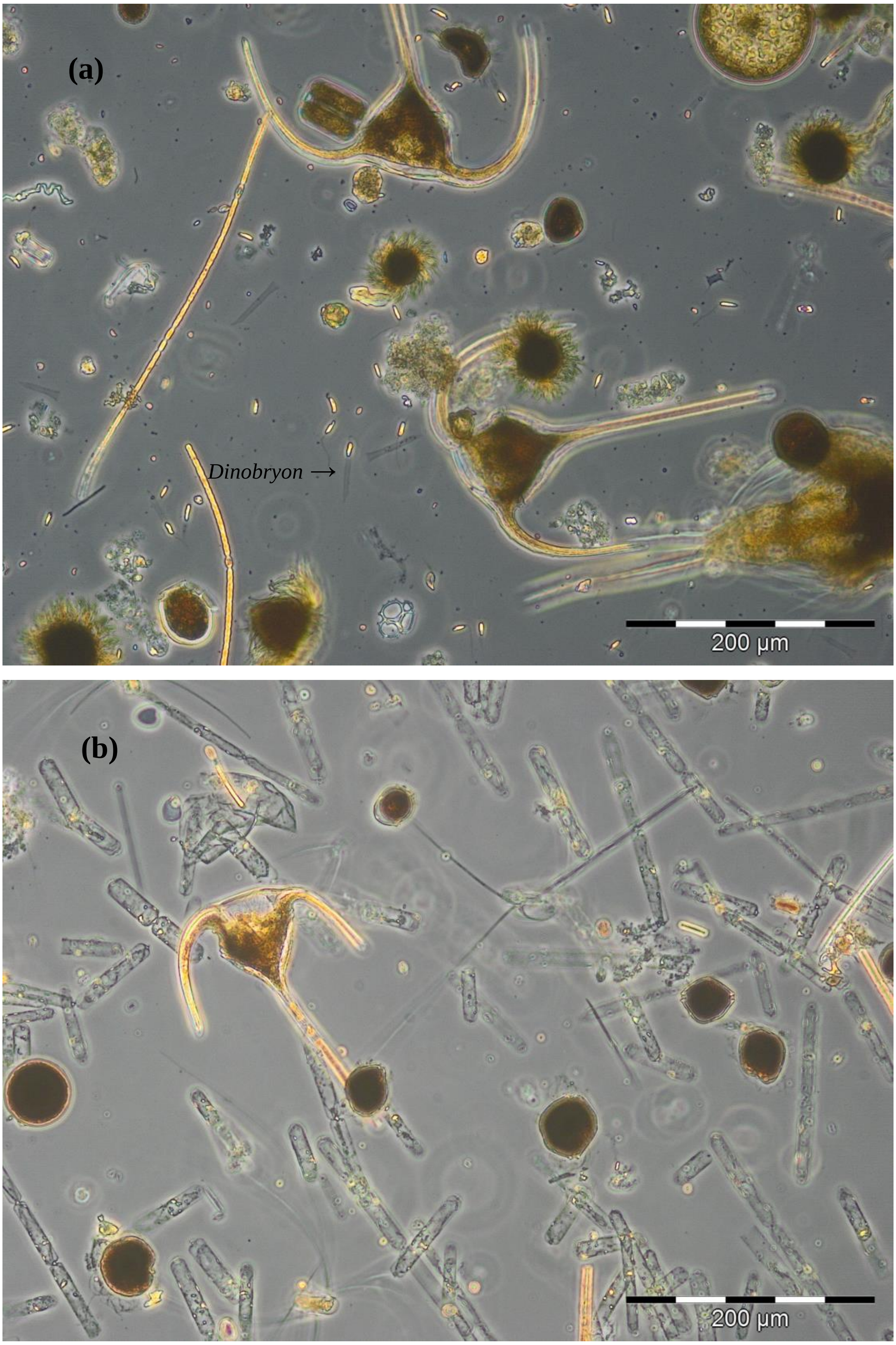


Fig. 11: Light microscopy images of net samples, (a) from station OMBMPK5, 1.5.2014: *Ceratium tripos, Mesodinium rubrum, Aphanizomenon* sp. and *Dinobryon balticum*; and (b) from station OMBMPN3, 19.7.2014: *Dactyliosolen fragilissimus, Alexandrium pseudogonyaulax* and *Ceratium tripos*. Photos: Susanne Busch.

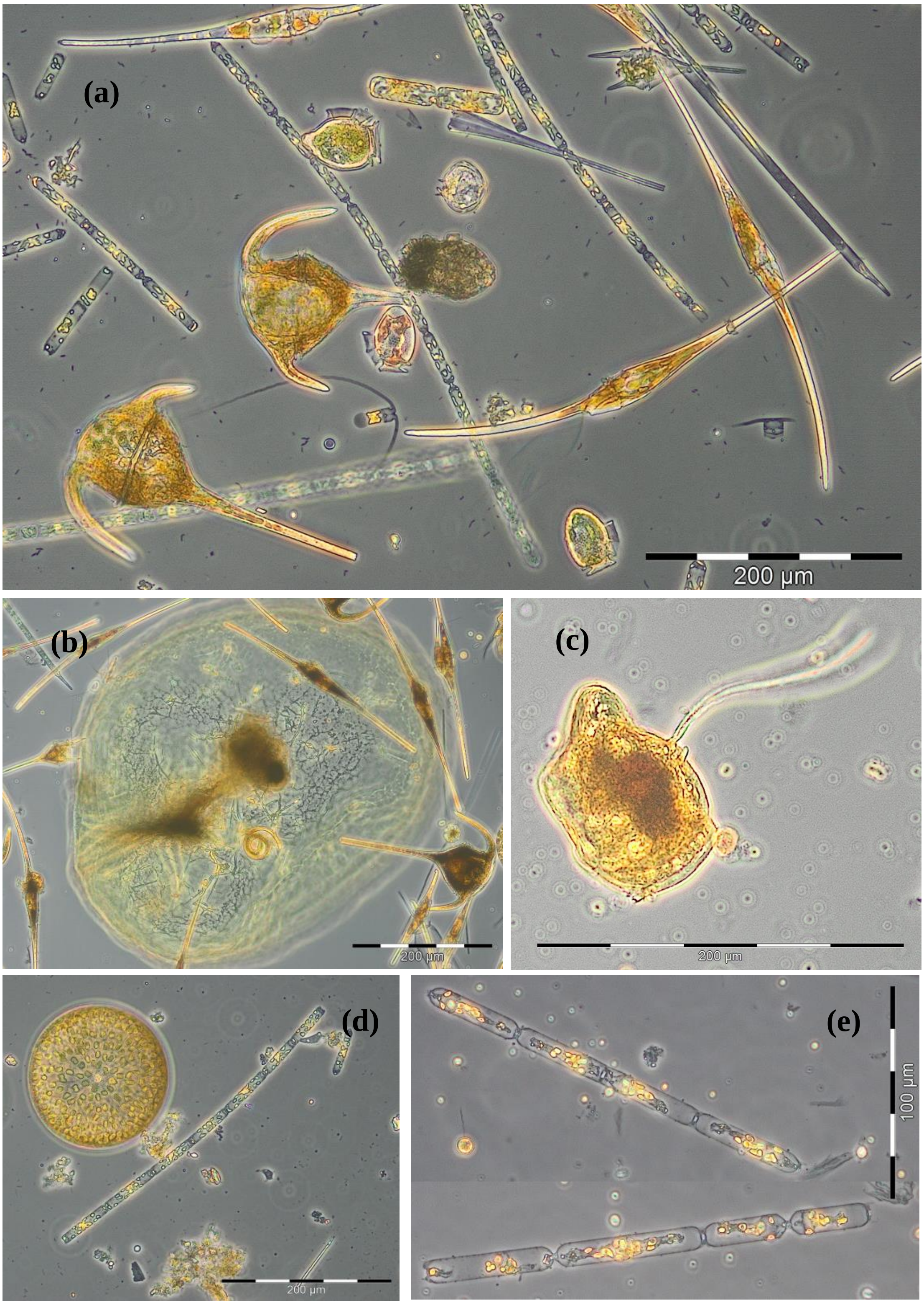


Fig. 12: (a) net sample from station OMBMPM2, 17.11.2014: *Ceratium tripos, C. fusus, C. lineatum, Cerataulina pelagica, Dactyliosolen fragilissimus, Dinophysis norvegica, Proboscia alata*; (b) net sample from station OMO22, 8.11.2015: *Noctiluca scintillans, C. tripos, C. fusus, C. lineatum*. (c) *Spatulodinium pseudonoctiluca* (8.11.2014, station OMBMPM2, 20 m); (d) *Coscinodiscus granii, Cerataulina pelagica* (17.11.2014, station OMBMPM1); (e) *Cerataulina pelagica* (9.11.2014, station OMBMPK8, 20 m). Photos: Susanne Busch.

Typically from west to east, *Ceratium* spp. decreased and diatoms increased. Accordingly at Darss Sill (station OMBMPM1) and in the Arkona Basin, we no longer found blooms of dinoflagellates, but diatoms instead. The principal species were *Coscinodiscus granii* and *Cerataulina pelagica* (Fig. 12 d), with the share of *Coscinodiscus granii* increasing from west to east, and that of *Cerataulina pelagica* decreasing from west to east. In the upper 10 m of the water column at station OMBMPM1, the biomass of *Cerataulina pelagica* was still 499 µg/l, while at station OMBMPK8 it was only 69 µg/l – yet there at 20 m depth 803 µg/l was recorded (Fig. 12 e). As in 2012, some specimens of *Coscinodiscus radiatus* occurred in samples at depth. In autumn 2013, the spring species *Dictyocha speculum* had been observed surprisingly often; during sampling in autumn 2014, only a negligible biomass < 6 µg/l was detected. Perhaps its vigorous growth in autumn 2013 (e.g. 63 µg/l on 1.11.2013 at station OMBMPM2) provided the basis for its particularly high level of biomass in spring 2014.

Especially noteworthy are the marine species of *Noctiluca scintillans* (Fig. 12 b) and *Spatulodinium pseudonoctiluca* (Fig. 12 c) that were found in the Bays of Lübeck and Mecklenburg. They signify an inflow of saline water from the North Sea, which is all the more significant as they function as indicators of several lesser inflows that occurred even before the Major Baltic Inflow of December 2014 (MOHRHOLZ et al. 2015).

In the Bornholm Basin we observed an almost pure bloom of *Coscinodiscus granii* (Fig. 10 a) that also occurred in the eastern Gotland Basin, although there it was weaker (Fig. 10 b, c); at station OMBMPJ1 specimens of *Mesodinium rubrum* and *Dinophysis* were also found.

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 Gotland Deep. For those species that do not occur in the Baltic Proper, only a section of the western Baltic is shown (also with the borders of the German Exclusive Economic Zone depicted). 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. 13-15 using the most important species as examples. Diagrams illustrate the seasons of main occurrence of species in 2014.

Ceratium tripos typically develops an autumn bloom in the western Baltic, but in early 2014 it still had a strong presence well into March, and it was no longer the dominant species that autumn when, in the Bays of Kiel, Lübeck and Mecklenburg (central area), *Ceratium fusus* instead took the first place. For that reason, spring rates of *Ceratium tripos* (mean values for February-May) are presented here for the first time (Fig. 13 a), while *Ceratium fusus* is shown for the autumn bloom (Fig. 15 a). This illustrates that these species do not spread into the Baltic Proper.

We did not encounter the usual spring diatom bloom in the western Baltic as it occurred between the February and March monitoring cruise. Thanks to the time lag that is known in west-to-east bloom times, we still encountered the diatom bloom in the Arkona Basin in March 2014. Its main agent, *Skeletonema marinoi*, is shown in Fig. 13 b. After the diatom bloom, in April/May *Dictyocha speculum* (Fig. 13 c) becomes dominant in the western Baltic, and *Mesodinium rubrum* becomes dominant in the Baltic Proper (Fig.14 a).

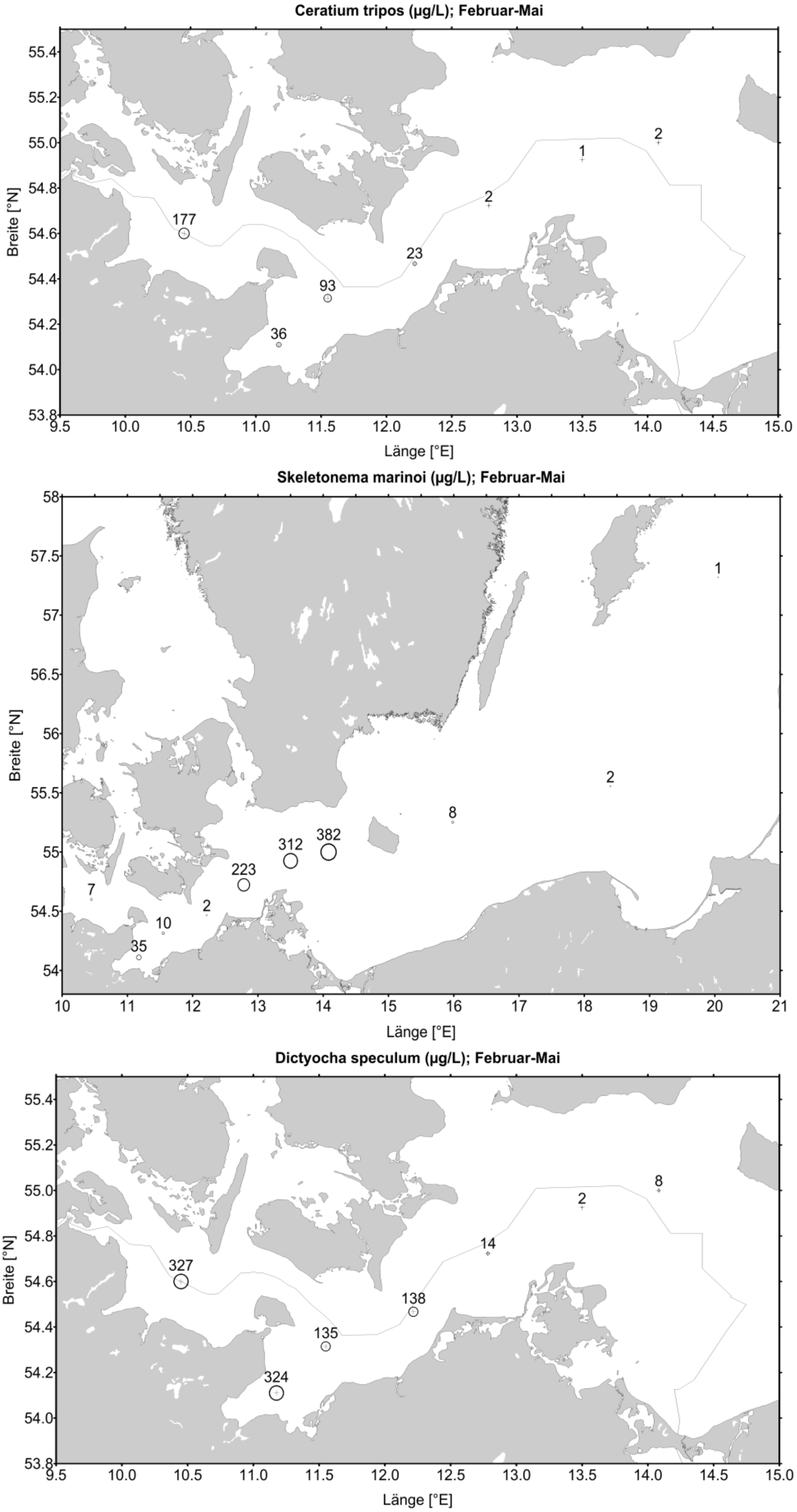


Fig. 13: Distribution of *Ceratium tripos, Skeletonema marinoi* and *Dictyocha speculum* in the areas and seasons of their main occurrence in 2014.

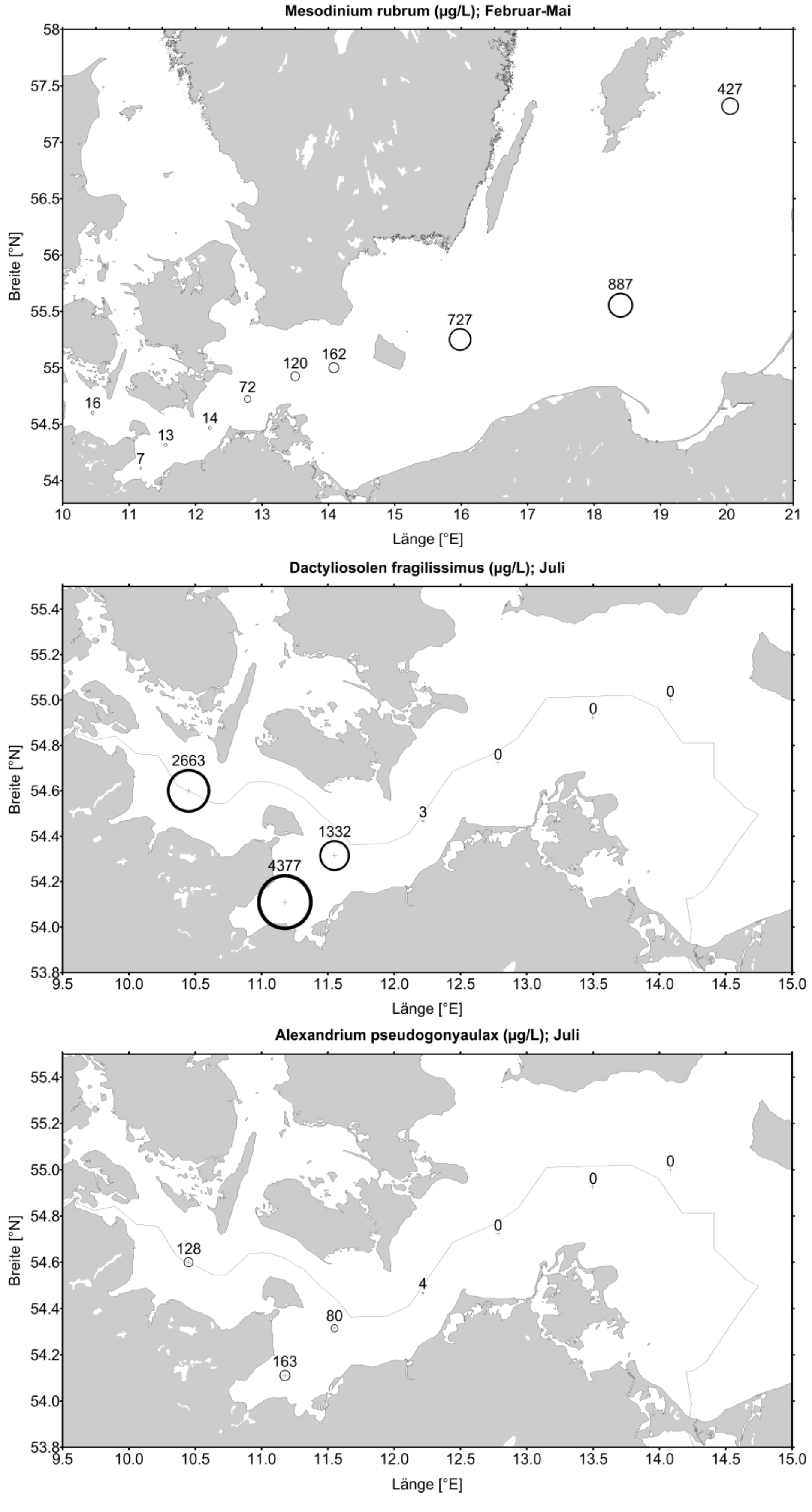


Fig. 14: Distribution of *Mesodinium rubrum, Dactyliosolen fragilissimus* and *Alexandrium pseudogonyaulax* in the areas and seasons of their main occurrence in 2014.

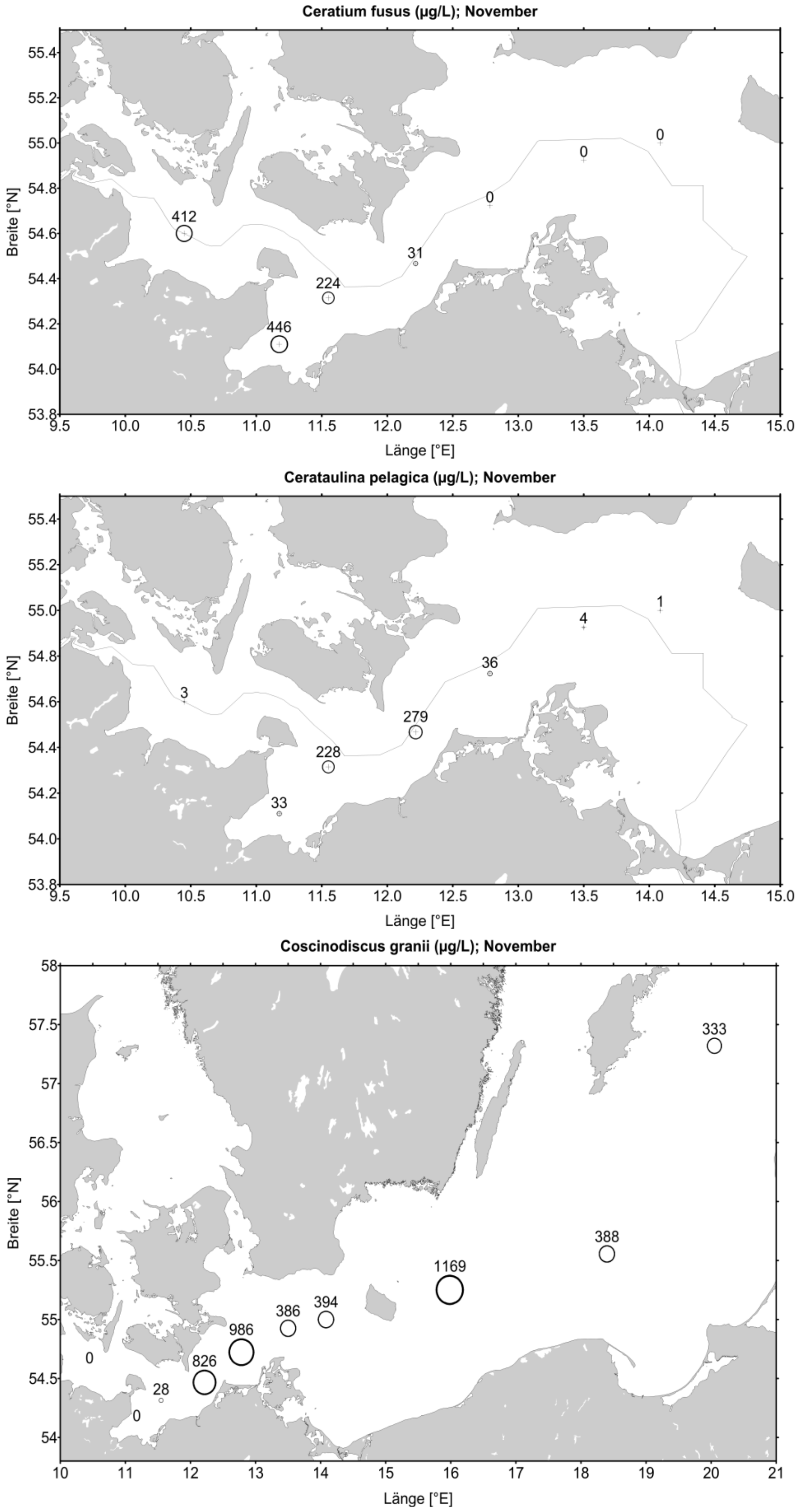


Fig. 15: Distribution of *Ceratium fusus, Cerataulina pelagica* and *Coscinodiscus granii* in the areas and seasons of their main occurrence in 2014.

Dactyliosolen fragilissimus and *Alexandrium pseudogonyaulax*, our selected summer species, favour the saltier conditions of the western Baltic (Figs. 14 b and c). In the Baltic Proper, on the other hand, it is mainly blooms of cyanobacteria that occur. In 2014, however, cyanobacteria blooms there were weak, and for that reason they are not presented separately.

Regional variations are often most obvious during the autumn. Dinoflagellates (*Ceratium* spp.) are generally dominant in the western Baltic, while diatoms (*Coscinodiscus granii*) are dominant in the Baltic Proper. As mentioned above, *Ceratium fusus* was the dominant dinoflagellate species in 2014 (Fig. 15 a). With fewer numbers in Kiel Bay, the marine diatom *Cerataulina pelagica* exhibited an atypical distribution (Fig. 15 b). Similarly, *Coscinodiscus granii* did not exhibit its classic pattern of a steady increase towards the Baltic Proper as observed in previous years (Fig. 15 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 minimum* 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. minimum* 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 - and not just by deep, salt-water inflows, but also by warm surface currents - and that simple salinity measurements do not detect them (HAJDU et al. 2006). In this sense these species are indicators of inflows of surface water from the North Sea.

OLENINA & KOWNACKA (2010) re-examined species composition five years after HAJDU et al. (2006) described the wide-ranging intrusion of marine species. They found that some had become established, while others had disappeared. After 2008, *Cerataulina pelagica* was observed in Gdańsk Bay with increasing levels of biomass. Since 2007, *Dactyliosolen fragilissimus* has regularly been a constituent of the autumn phytoplankton bloom in Polish and Lithuanian waters. A mass occurrence of *Chaetoceros brevis* was observed in 2005, but it has vanished again from southern areas of the Baltic Proper (still absent in 2014).

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 appeared again in 2014, however, probably in connection with inflow events in the western Baltic. In addition, we found *Spatulodinium pseudonoctiluca*, a species that was new to us (Fig. 12 c). Normally the marine dinoflagellate *Polykrikos schwartzii* is rarely found in our samples, but in autumn 2014 it had relatively high levels of biomass in the western Baltic, and thus ranks 17th in Table A2. *Chaetoceros circinalis* and *Chaetoceros pseudobrevis* were first observed in our samples from Kiel and Mecklenburg Bays in March 2010, and are still present there.

We first detected the dinoflagellate *Alexandrium pseudogonyaulax* in the western Baltic in summer 2010; it has now become established and is ranked 23rd in our list for 2014 (Table A2). In contrast, the diatom *Pseudosolenia calcar-avis*, which occurred in large numbers in autumn 2010, has not been observed since 2013 (however, it appeared again in 2015, as will be reported in our next Biological Assessment and in a paper by KAISER et al., submitted). High biomass levels of *Peridiniella danica* first occurred in 2011 (5th place); this dinoflagellate has since declined significantly and is now ranked 50th.

The difficulties involved in identifying naked Dictyochophyceae have already been discussed in chapter 4.1.2. Since 2009 we have attempted to distinguish *Verrucophora farcimen* from the naked form of *Dictyocha speculum*, and have since included it in our lists. The spring species *Dictyocha speculum* occurred vigorously in 2007 and 2008, especially in the Belt Sea, but was relatively insignificant in 2010; nor were elevated levels of *Verrucophora* observed then. In 2011, Dictyochophyceae occurred in strength, ranking 6th, with *Verrucophora farcimen* identified to an increasing extent. *Verrucophora farcimen* did not re-appear in samples in 2012 and 2014, however. Of these two species, we now find almost only *Dictyocha speculum*, 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.

Mesodinium rubrum is a very common mixotrophic ciliate that is habitually counted in phytoplankton samples. It always has a strong presence in the Baltic Proper during the spring (Fig. 10, 14 a), but lower levels of biomass also occur in autumn. Compared with previous years, *Mesodinium rubrum* had a much weaker presence in the western Baltic in 2014.

Exceptionally, the unusual diatom *Achnanthes taeniata* was dominant in 2011. From 2012 to 2014 it was hardly represented at all, and in 2014 it occurred only in March in the Arkona Basin. In the 1980s, this cold-water species formed blooms in the Baltic Proper, but has since been in sharp decline (HELCOM 1996; WASMUND et al. 2011 c). The mild winters of the 1990s appear to have harmed it.

4.1.5 Chlorophyll *a*

Table 6 shows approximate annual variations in chlorophyll *a* concentrations. Annual variations in chlorophyll *a* correspond roughly to those given for biomass in Figs. 8-10. Mean values for the uppermost 10 m are shown for each sample. As explained in chapter 2.3, we now determine 'total chlorophyll *a*' values ('chl.a-tot') only.

Typically, the annual maximum concentration of chlorophyll *a* (10.35 mg m^{-3}) coincided with the spring bloom that we encountered in mid-March in the Arkona Basin. We missed the spring bloom in the western Baltic, which is why we observed its maximum chlorophyll *a* value in autumn.

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

Station	Date	Chl.a-tot (mg m^{-3})
OMBMPN3	04.02.2014	1.86
OMBMPN3	17.03.2014	2.96
OMBMPN3	30.04.2014	2.62
OMBMPN3	19.07.2014	1.18
OMBMPN3	09.11.2014	5.20
OMO22	04.02.2014	1.16
OMO22	18.03.2014	1.70
OMO22	30.04.2014	2.95
OMO22	20.07.2014	1.66
OMO22	08.11.2014	5.17
OMBMPM2	05.02.2014	0.90
OMBMPM2	13.02.2014	1.32
OMBMPM2	18.03.2014	1.82
OMBMPM2	25.03.2014	2.84
OMBMPM2	01.05.2014	1.43
OMBMPM2	08.05.2014	1.09
OMBMPM2	20.07.2014	1.49
OMBMPM2	29.07.2014	2.11
OMBMPM2	08.11.2014	5.68
OMBMPM2	17.11.2014	2.72
OMBMPM1	05.02.2014	0.88
OMBMPM1	13.02.2014	0.96
OMBMPM1	18.03.2014	1.20
OMBMPM1	25.03.2014	1.50
OMBMPM1	01.05.2014	2.36
OMBMPM1	08.05.2014	1.83
OMBMPM1	20.07.2014	1.67
OMBMPM1	29.07.2014	1.37
OMBMPM1	09.11.2014	4.05
OMBMPM1	17.11.2014	4.44
OMBMPK8	05.02.2014	0.92
OMBMPK8	12.02.2014	1.23
OMBMPK8	18.03.2014	5.44
OMBMPK8	25.03.2014	3.06
OMBMPK8	01.05.2014	0.99
OMBMPK8	08.05.2014	0.79
OMBMPK8	20.07.2014	2.22
OMBMPK8	29.07.2014	2.23
OMBMPK8	09.11.2014	4.42
OMBMPK8	17.11.2014	2.71
OMBMPK5	05.02.2014	1.53
OMBMPK5	12.02.2014	0.87
OMBMPK5	18.03.2014	9.46
OMBMPK5	24.03.2014	2.32
OMBMPK5	01.05.2014	1.59
OMBMPK5	08.05.2014	2.21
OMBMPK5	21.07.2014	1.94
OMBMPK5	29.07.2014	3.03
OMBMPK5	10.11.2014	3.71
OMBMPK5	16.11.2014	2.41
OMBMPK4	12.02.2014	1.06
OMBMPK4	19.03.2014	10.35
OMBMPK4	02.05.2014	2.26
OMBMPK4	22.07.2014	2.14
OMBMPK4	10.11.2014	2.46
OMBMPK2	07.02.2014	0.65
OMBMPK2	11.02.2014	0.69
OMBMPK2	20.03.2014	1.25
OMBMPK2	24.03.2014	1.50
OMBMPK2	03.05.2014	5.63
OMBMPK2	07.05.2014	4.83
OMBMPK2	22.07.2014	1.76
OMBMPK2	28.07.2014	1.39
OMBMPK2	12.11.2014	2.36
OMBMPK1	11.02.2014	0.66
OMBMPK1	21.03.2014	0.99
OMBMPK1	04.05.2014	4.39
OMBMPK1	23.07.2014	2.11
OMBMPK1	13.11.2014	2.47
OMBMPJ1	09.02.2014	0.57
OMBMPJ1	21.03.2014	0.63
OMBMPJ1	04.05.2014	3.47
OMBMPJ1	24.07.2014	4.40
OMBMPJ1	13.11.2014	3.07

Typical annual cycles of chlorophyll *a* in 3 areas of the Baltic are shown by KAITALA et al. (2011) in an Environment Fact Sheet (now discontinued).

Figs. 16-18 present the horizontal distribution of chlorophyll *a* values determined during 5 monitoring cruises in 2014. Fig. 16 a clearly shows that in February no significant phytoplankton growth had yet occurred.

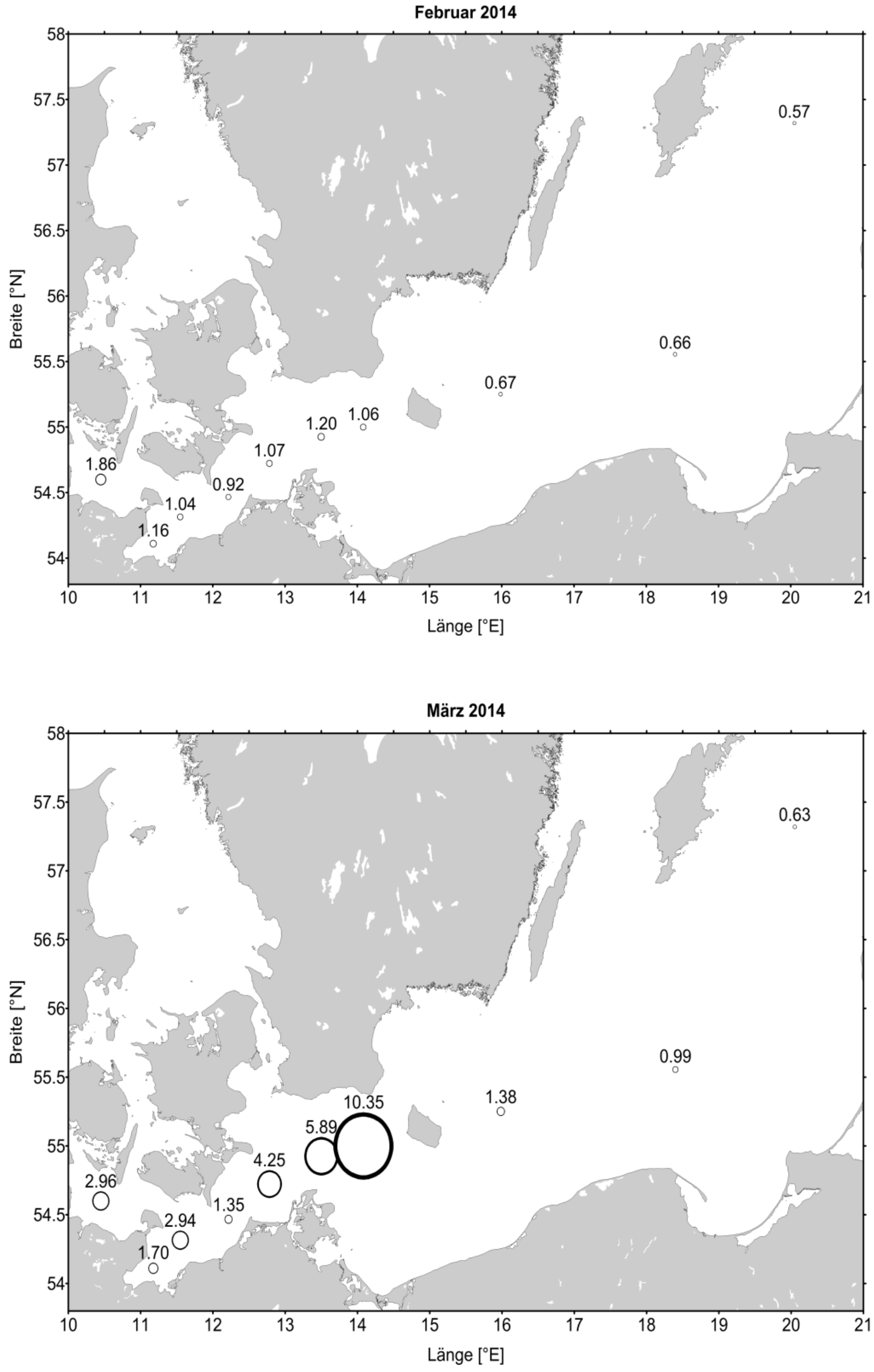


Fig. 16: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during cruises in February and March 2014.

Around mid-March 2014, the spring bloom in Mecklenburg Bay had already ended, but was still active in the Arkona Basin (Fig. 16 b). Growth of *Dictyocha speculum* in the western Baltic and of *Mesodinium rubrum* in the Arkona Basin in late April/early May was not very strong: chlorophyll *a* concentrations did not exceed 3 mg m^{-3} (Fig. 17 a). July's bloom of *Dactyliosolen fragilissimus* in the western Baltic was not observable from chlorophyll *a* values (Fig. 17 b) because large-celled diatoms are deficient in chlorophyll.

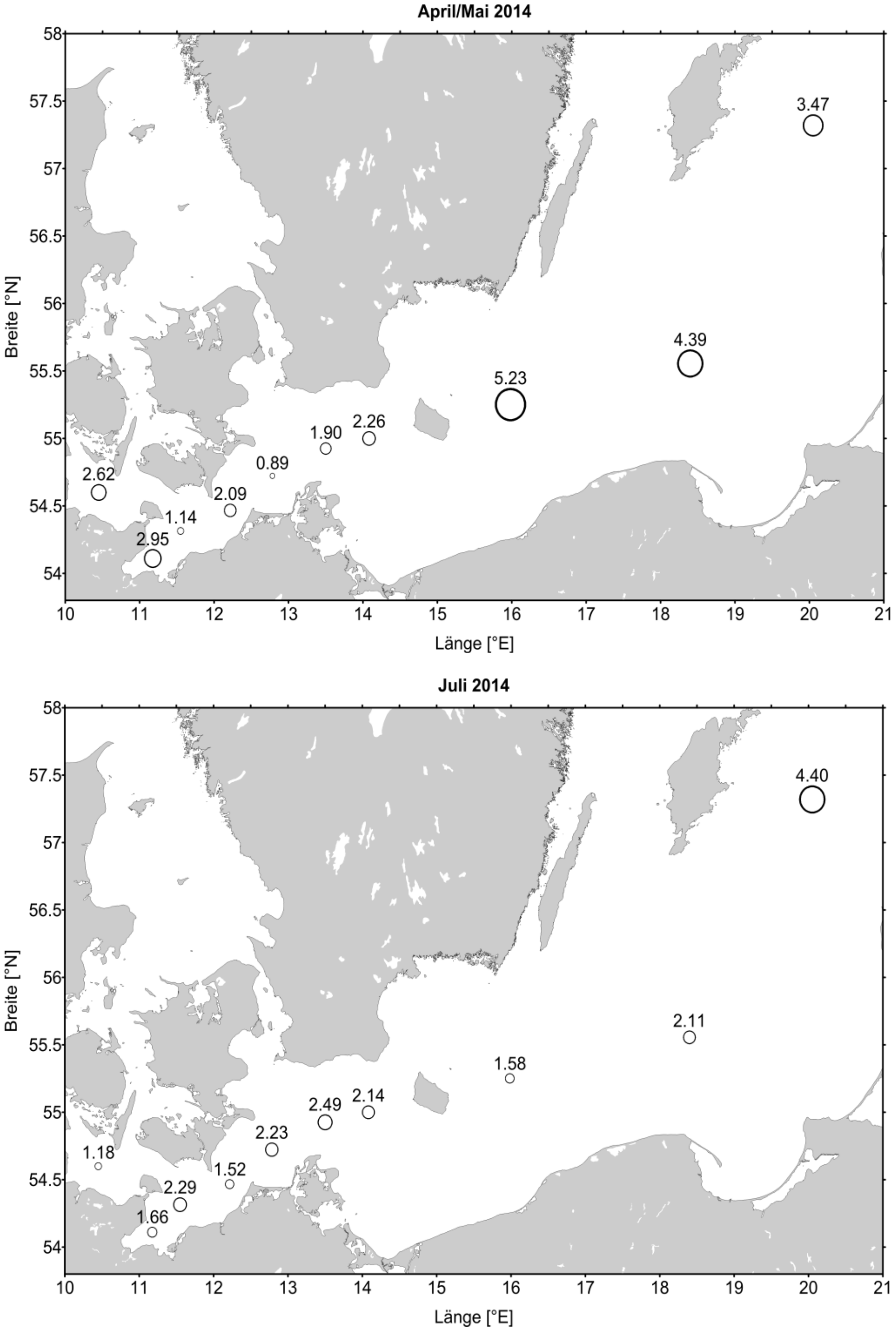


Fig. 17: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during cruises in April/May and July 2014.

In the autumn, elevated chlorophyll *a* concentrations were evidence of the autumn bloom, with the dinoflagellate bloom in the western Baltic producing higher rates than the diatom bloom in the Arkona Basin (Fig. 18). It should be noted that the amounts given in Figs. 16-18 represent mean values from the outward and return leg of each cruise.

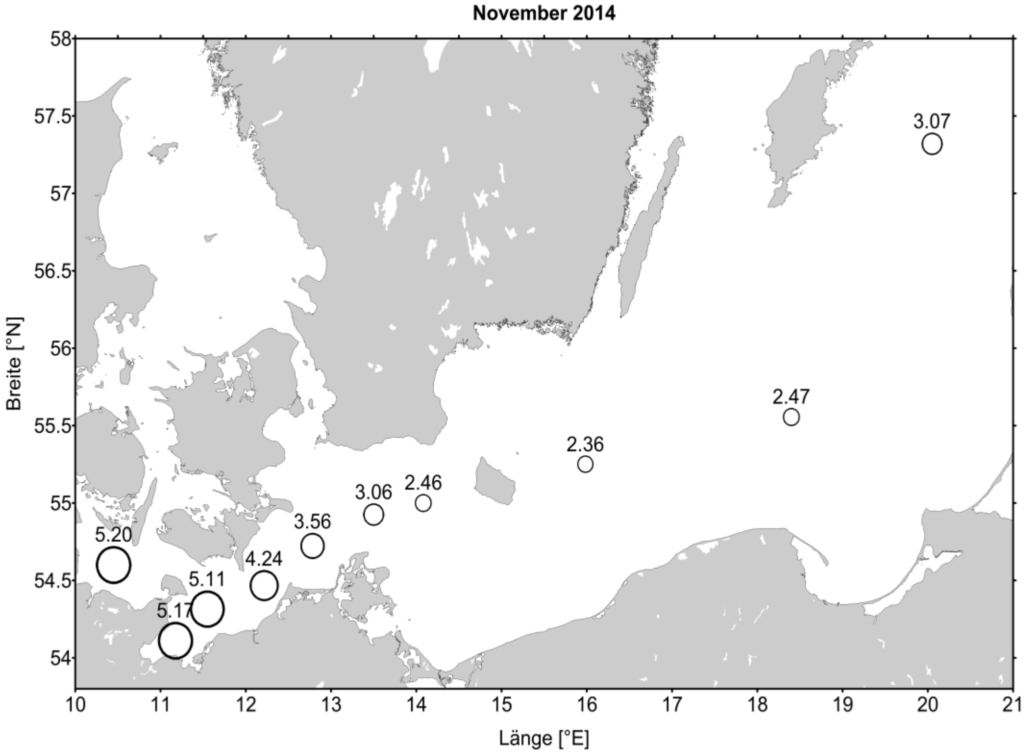


Fig. 18: Horizontal distribution of chlorophyll *a* concentrations (µg/L) at sampling locations during the cruise in November 2014.

4.1.6 Sedimentation

The microscopic examination of the material collected in the Arkona Basin in 2014 showed a steady increase over the year in the number of large, and partly broken, fecal pellets that were probably attributable to the growth of barnacles (Balanoids), and possibly other filter-feeders associated with them (Fig. 19 a). Apart from sunken microalgae, many fragments - mainly of diatom shells - were also found; they were very probably from the same source (Fig. 19 b).

While this process strongly masks the quantitative conditions (see below), interestingly the qualitative signals, i.e. the taxonomical composition examined by microscopy, are only affected to a minor extent. Microplankton evidently fits exactly into the food spectrum of the fauna colonising the sediment trap: filtration by these organisms thus mainly enriches the sinking material, but does not induce qualitative changes. With the sediment trap located far below the photic zone, only the fraction of the phytoplankton that has already been sinking from the surface layer towards the seabed can be enriched. In the process of predation, however, the non-shelled - and hence easily digestible - fraction of sinking organisms is removed from the spectrum. This also explains why the number of flagellate species fell from 7 to 4 - in contrast to the more resilient diatoms and dinoflagellates.

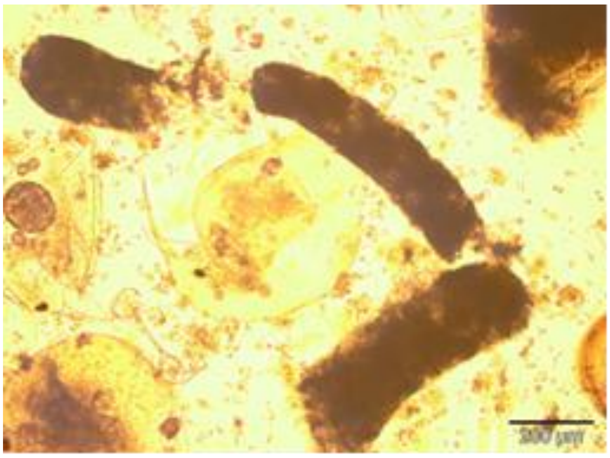


Fig. 19 a: Large fecal pellets in the trap sample

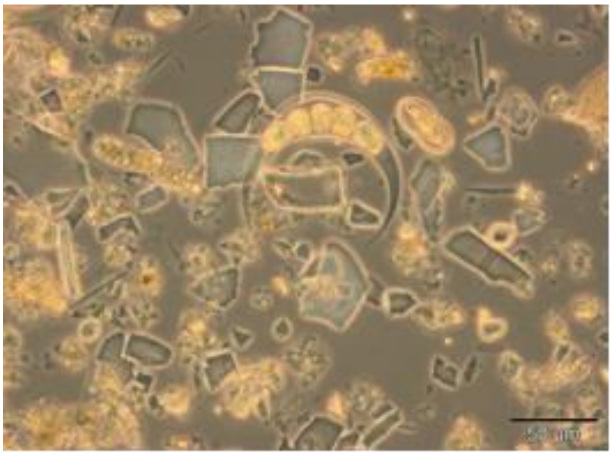


Fig. 19 b: Fragments of diatom frustules

15 species of diatoms were observed in 2014 compared with 14 in 2013. During the pelagic growth phase (March to December; Fig. 20 a-d), the typical seasonal succession of communities was again observed. The spring bloom was much more evident in terms of diatom abundance and diversity than in terms of mass flow.

As in spring 2013, *Achnanthes taeniata, Chaetoceros* spp., *Coscinodiscus granii, Actinocyclus octonarius, Skeletonema marinoi* and *Thalassiosira levanderi* were observed from the start. New species were *Melosira arctica, Ceratoneis closterium, Coscinodiscus radiatus* and *Thalassiosira hyperborea,* whereas *Diatoma tenue* did not occur in this spring.

After the spring phase the number of diatom species decreased: *Skeletonema marinoi, Coscinodiscus granii, Actinocyclus octonarius* and *Chaetoceros spp.* appeared in early summer, and later on were joined by *Coscinodiscus radiatus* and *Dactyliosolen fragilissimus*, while numbers of *Skeletonema marinoi* decreased. The diatom community lasted well into late autumn when its diversity began to decrease.

The number of dinoflagellate species observed in 2014 remained unchanged at 8 (Fig. 20 b) in comparison to the previous year. In 2013, however, greater diversity of species was observed over almost the entire growth phase (April – December). Nevertheless, a distinct seasonal succession of key species was still observed in 2014: in spring we found *Protoperidinium* spp., *Gymnodinium corollarium, Dinophysis acuminata* and *Dinophysis rotundata* (=*Phalacroma rotundatum*); over the summer we observed *Ceratium tripos* and *Ceratium fusus*, as well as *Dinophysis acuminate* both at the beginning and the end of the summer. We no longer encountered *Dinophysis norvegica*. Starting in August, *Dissodinium pseudolunula* appeared; in late autumn and through the winter it was the main constituent of the dinoflagellate population. As in 2013, *Prorocentrum minimum* and *Prorocentrum micans* were as well absent over the summer 2014. While species diversity in the first half of the year was dominated by diatoms, dinoflagellates did not become significant until August/September, although overall they ranked second to diatoms.

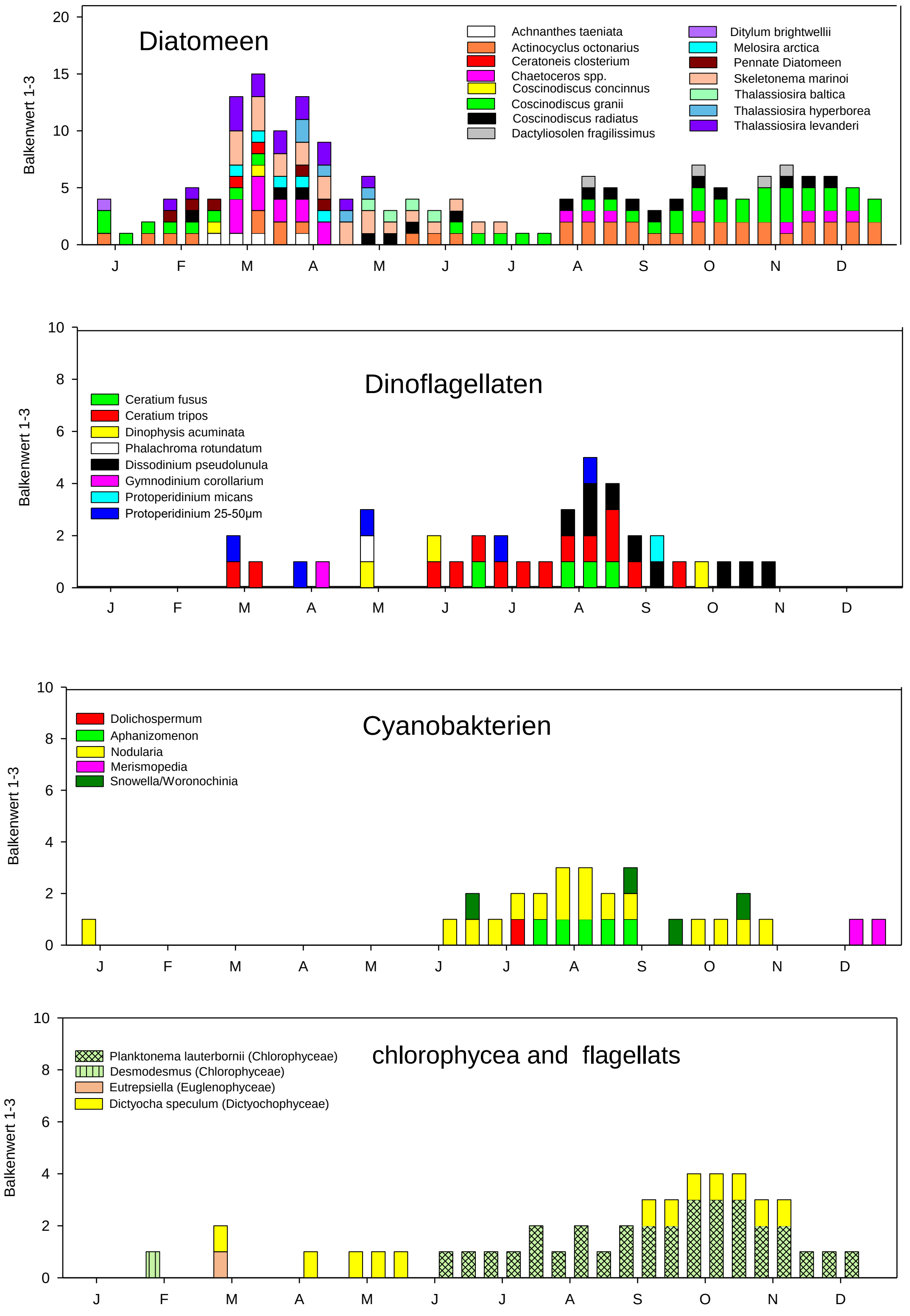


Fig. 20 a-d: Relative frequency of selected species of diatoms, dinoflagellates, cyanobacteria, chlorophyceae and flagellates in sedimented organic material in 2014.

The number of cyanobacterial species observed in 2014 was small (Fig. 20 c); diazotrophic species (*Aphanizomenon* and *Nodularia*) were nevertheless dominant in summer. The seasonal shift to the non-nitrogen-fixing *Snowella* and *Merismopedia* during autumn and winter was again pronounced (even if species of *Snowella* and *Woronochinia* also occurred to a lesser extent during summer). In 2014, as always, the main growing season for diazotrophic species was June-August, which for short periods correlated with the decrease in the $\delta^{15}N$ signature (Fig. 26). This process was, however, quantitatively insignificant in the Arkona Basin – unlike in the Baltic Proper. Given that the trophic effects of colonising organisms mask the isotopic signatures, these values by and large have limited validity.

The quantitative seasonal distribution of Chlorophyceae (green algae; Fig. 20 d) correlated well with the input of fecal material into the sediment traps. It can be assumed that the dominant species, *Planktonema lauterbornii*, found its way into the traps mainly via this route. Apart from the silicoflagellate *Dictyocha speculum* that occurs in spring, and occasionally also in the summer, *Planktonema lauterbornii* appears to be one of the few unarmoured species that in the process of predation does not become totally unrecognisable. This indicates the general importance of flagellates within the food web. Except for a few species, they appear to be readily ingestible and digestible.

The seasonal patterns of the vertical transport of carbon (Fig. 21), nitrogen (Fig. 22), phosphorus (Fig. 23) and silica (Fig. 24) were masked in 2014 by a process that had not previously occurred (or did so only to a minor extent): the colonisation of the sediment trap's lattice grid baffle by barnacles (*Balanus improvisus*) that actively filtered particles from the water and so enriched detritus material.

The fecal matter of these organisms was deposited as compact fecal pellets measurable in millimetres; the pellets had correspondingly fast sinking rates. As digestion was not always complete, these fecal pellets, which are coated with a thin membrane, often yielded identifiable food particles upon breaking open. Shelled organisms such as dinoflagellates and diatoms were are still recognisable, even if their silica shells were broken. Microscopic analyses of sediment trap samples (Fig. 19) over the course of 2014 revealed an increasing number of large, broken fecal pellets that were filled with microalgae and numerous fragments, mainly of diatoms. The special inflow events of 2014 may be cited as the reason for the rapid and vigorous colonisation by barnacles, something that had not previously been observed. Even before December's major inflow of North Sea water, lesser inflows of saline water into the Arkona and Bornholm basins had already occurred in February, March and August 2014.

Fig. 3 (p. 16) shows salinity at the sediment trap location at a depth of 40 m in the Arkona Basin. Except for the occasional sharp fall, salinity was high throughout the entire growth period. The saline inflows imported high concentrations of oxygen into the otherwise oxygen-deficient bottom layer of the Baltic's basins as well as the larvae of organisms in the surface water that reproduce in pelagic phases.

Such organisms include barnacles and mussels whose easily recognisable larvae were found in the sediment trap. With such favourable conditions, many organisms were able to attach to the trap. As they grew in size so did their filtering capacity; the amount of fecal matter they produced grew accordingly, and was deposited in the sediment trap (Fig. 2, p. 11). The amount of collected material was thus no longer determined by gravity-dependent vertical particle transport, but by the filtration capacity of the colonising organisms and local currents instead.

An interesting aspect here, certainly, is that the filter-feeders can only enrich material that has sunk from the surface layer, i.e. material that would have reached the sediment anyway. As explained above, this means that the spectrum of food filtered by the aufwuchs organisms on the trap corresponds to the material that reaches the trap by sedimentation. It thus still makes sense to analyse the species composition of the microalgae that largely make up the food. The quantitative relationship between material that sinks naturally and the amounts of material in the sediment trap cannot be reconstructed As it derives from the same source, it is not possible to separate it.

The extremely high annual values of 3.0 mol C, 429 mmol N, 1.2 mol Si, and 9.3 mmol P m^{-2} a^{-1} at a mass flux of 293 g dry mass m^{-2} a^{-1} (Figs. 21-25) exceeded those in previous years by as much as a factor of 5. The elemental composition of the material was interesting: at 12.3 % of the total weight, it had the highest carbon content ever measured. Based on this finding alone, it contains no - or only a small - load of resuspended sediment.

The carbon-to-nitrogen ratio of 6.9 in the material collected over 2014 was in the range of previous measurements (5.9-8.4). The carbon-to-phosphorous ratio of 320 (Fig. 26) is twice as high as previous values (120-160). The carbon transport increased by a factor of 3.8, while the P flux increased only by a factor of 1.5. This means that use of pelagic food by the epibenthic community supplies the sediment with material that in terms of carbon and nitrogen is of similar composition, but whose phosphorus content is reduced. While our investigation was not intentionally geared towards such findings, they might still prove pertinent if benthic processes replace pelagic processes as a result of the increased availability of solid substrate that can potentially support colonies within the western Baltic (e.g. wind farms). Of course, this would then raise questions about how biologically relevant factors between sediment and water would shift.

The nitrogen and carbon isotopic signatures of the material (Figs. 27 and 28) exhibited different reactions to the changed conditions in 2014. While the $\delta^{13}C$ pattern over the course of the year differed little from that in previous years, and mainly indicated temperature effects in the surface water, the isotopic signature of nitrogen differed from that observed in previous years.

Instead of an undulating development between the spring and autumn blooms caused by nitrate inputs with elevated $\delta^{15}N$, and the summer phase with the input of lighter isotopes due to nitrogen fixation, in 2014 a continuous, if negligible, diminution of the signal was observed.

With the share of detritus produced by benthic organisms increasing over the year, biological fractionation may be assumed, but its trend cannot be explained reasonably. While quantitative measurements of sedimentation in the Arkona Basin in 2014 cannot be meaningfully summarised, the qualitative picture of microalgae succession suggests that the year was not unusual.

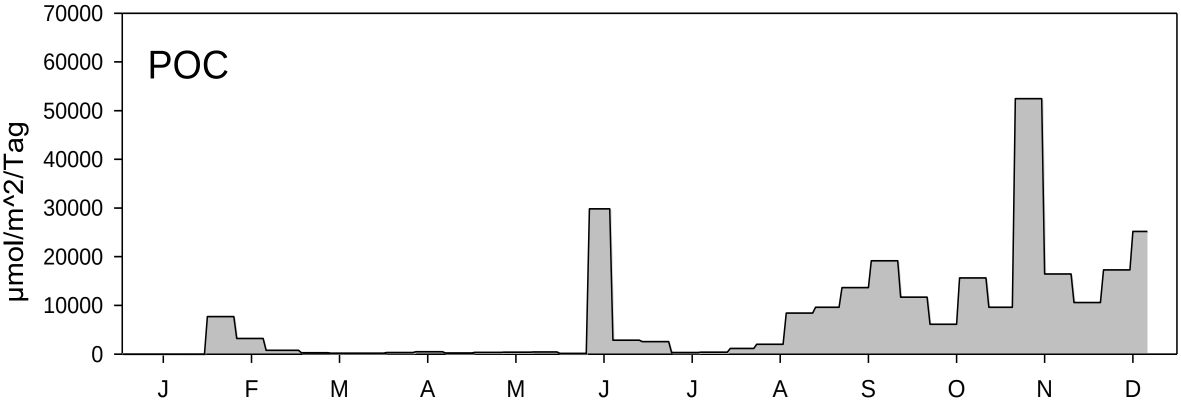


Fig. 21: Daily sedimentation rates of particulate organic carbon at 35 m depth in the central Arkona Basin in 2014.

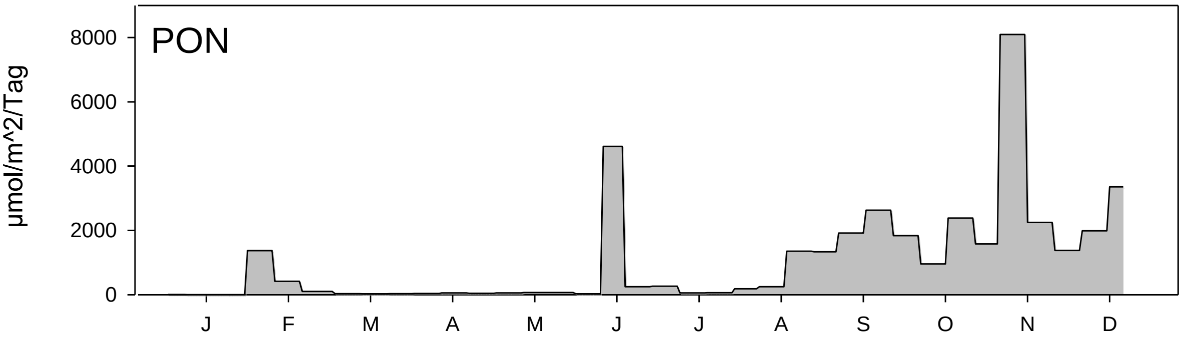


Fig. 22: Daily sedimentation rates of particulate organic nitrogen at 35 m depth in the central Arkona Basin in 2014.

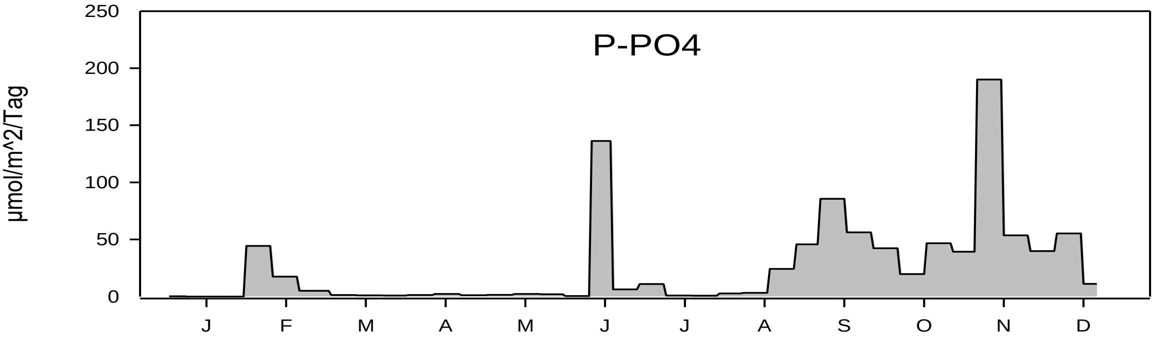


Fig. 23: Daily sedimentation rates of particulate phosphorus at 35 m depth in the central Arkona Basin in 2014.

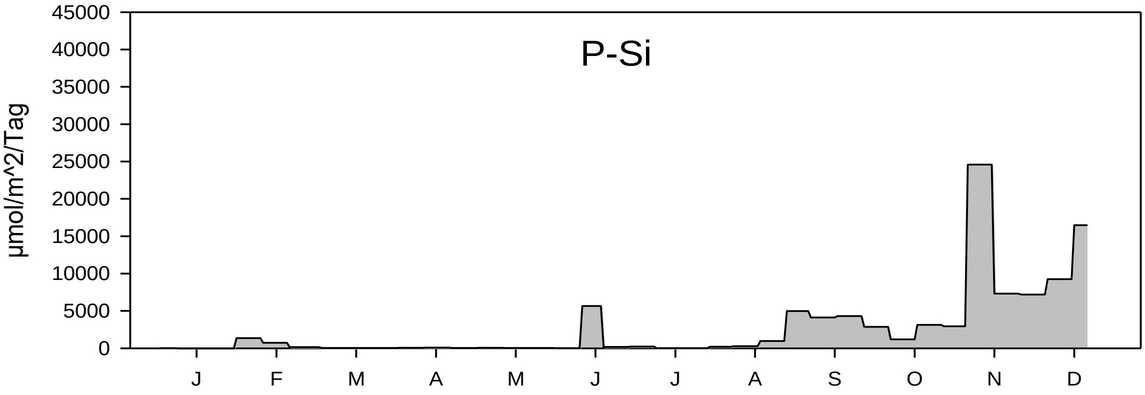


Fig. 24: Daily sedimentation rates of particulate biogenic silicate at 35 m depth in the central Arkona Basin in 2014.

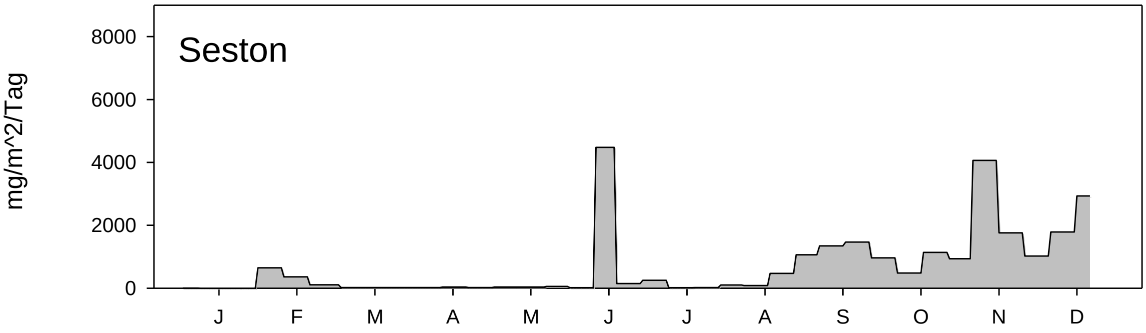


Fig. 25: Daily sedimentation rates of dry mass (seston) at 35 m depth in the central Arkona Basin in 2014.

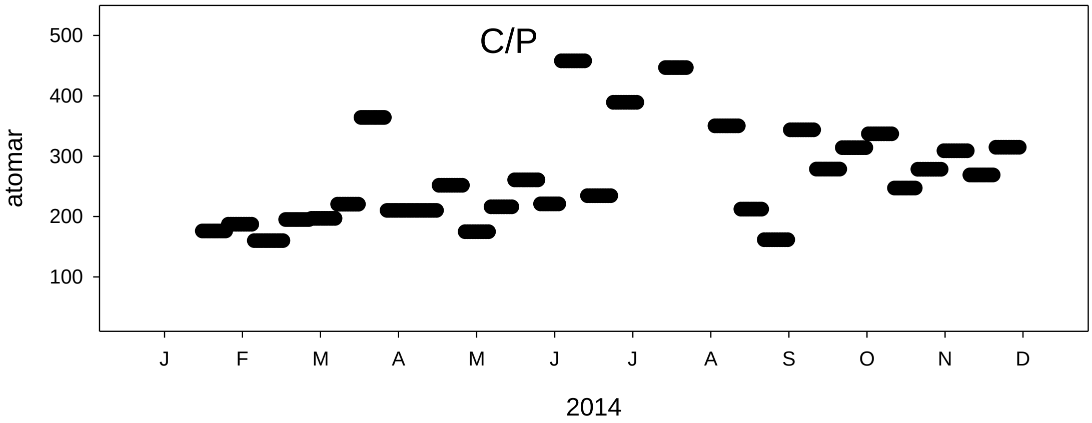


Fig. 26: Atomic ratio between carbon and phosphorus in sedimenting particles at at 35 m depth in the central Arkona Basin in 2014.

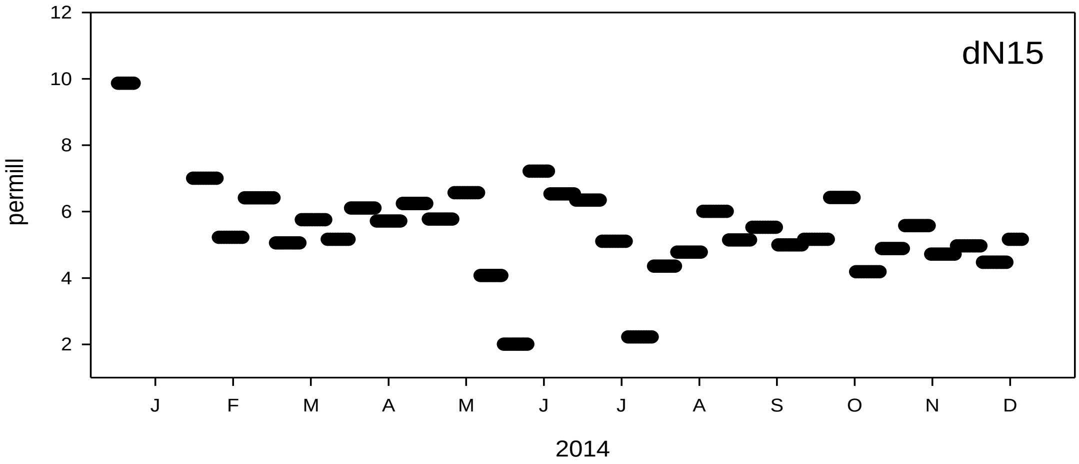


Fig. 27: Isotopic signature of nitrogen (‰ δ^{15}N) in sediment trap material in 2014.

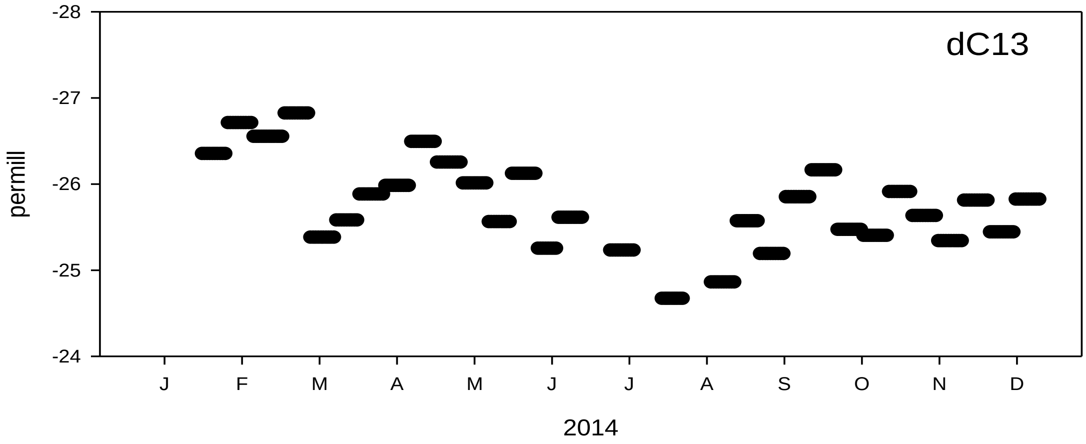


Fig. 28: Isotopic signature of particulate carbon (‰ δ^{13}C) in sediment trap material in 2014.

4.2 Mesozooplankton

4.2.1 Species Composition, Water Exchange, and Invasive Species

The faunistic composition of the zooplankton in the study area during 2014 showed great similarity to that observed in previous years. With a total of 49 taxa, diversity remained high when compared with an average of over 50 for 2011-2013 (Table A3). The characteristic seasonal increase in the number of taxa, which is usually attributable to the occurrence of thermophilic species, was less pronounced in 2014, however (Fig. 29). This was mainly due to isolated finds of *Limnocalanus macrurus*, *Eurytemora affinis* or *Acartia tonsa* in the western Baltic in March and May during the cold time of the year, reflecting the brief influence of inshore waters.

Compared with 2013, the the species composition in 2014 showed little change, although shifts in the frequency of various species were more conspicuous (see 4.2.2.). Among the copepods, mainly *Pseudocalanus* spp., *Temora longicornis*, *Centropages hamatus*, *Paracalanus parvus*, three *Acartia* species (*A. bifilosa*, *A. longiremis*, *A. tonsa*) as well as the cyclopoid copepod *Oithona similis* occurred regularly and frquently in the entire study area. Compared with the previous year, we observed a markedly greater abundance of *Temora longicornis* and *Centropages hamatus*; the differences for other species were only negligible. As in 2013, *A. tonsa* was regularly found in samples, but was only of secondary importance compared with *A. bifilosa* and *A. longiremis*. *A. tonsa* occurred mainly in shallower sea areas (OMBMPM2 to OMBMPK4). *Limnocalanus macrurus* was restricted to the Gotland Basin whereit occurred in greater numbers especially in the southern parts. In contrast, individuals of *Eurytemora affinis* were observed at almost every sampling location, albeit intermittently. Copepodites of *Calanus* spp. occurred regularly during the winter and spring (February-May), mainly in the Bornholm Basin (OMBMPK2); their occurrence was probably due to early inflows into the Arkona and Bornholm Basins in February and March. The occurence of *Calanus* spp. in the Gotland Basin in March are certainly due to an earlier inflow. Females of the species were identified as *Calanus helgolandicus*. *Centropages typicus* and the harpacticoid copepod *Longipedia* spp. were not observed in 2014.

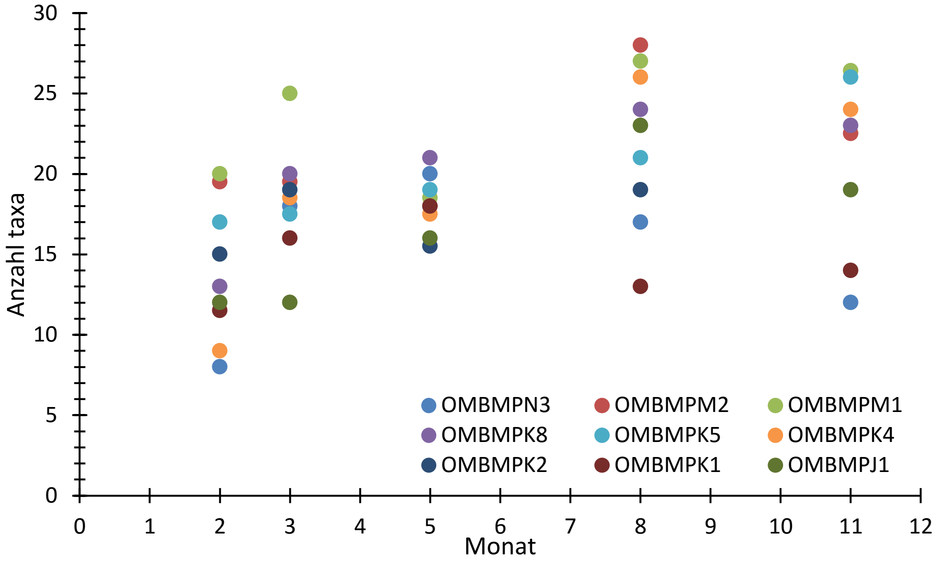


Fig. 29: Seasonal variation in the number of taxa observed at different stations in the investigation area.

The dominant species among the prolific group of cladocerans were *Bosmina* spp. and *Evadne nordmanni*, as in previous years. *Bosmina* spp. was the commonest group by far, and were found primarily in the Arkona and Bornholm Basins with up to 3.3-4.7 x 10^6 individuals m^{-2} (OMBMPK5 to OMBMPK2). *E. nordmanni* and *Podon leuckartii* were observed throughout the study area; the highest abundance of 2.0-4.1 x 10^5 individuals m^{-2} were recorded in the Arkona Basin. Large populations of *E. nordmanni* occured in the western Baltic already in May, and not during the late summer as observed in previous years. *P. leuckartii* displaced *Podon intermedius* (maximum density 4.9 x 10^4 m^{-2}) as the third commonest species. *P. intermedius* was of greater significance only in the east of the Baltic (OMBMPK2 to OMBMPJ1). *Pleopsis polyphemoides* was recorded for the first time in 2012. While it was found only occasionally in 2012/2013, it, it was found regularly and in markedly greater numbers in 2014, especially in the western Baltic and the Gotland Basin (0.9-1.4 x 10^4 m^{-2}). Apart from these species, *Evadne spinifera* (1387 individuals m^{-2}) and *E. anonyx* (87 individuals m^{-2}) were also observed in isolated samples from Kiel Bay in 2014. It is rather rare to find *Evadne spinifera* in the Baltic; it is a species common to the North Atlantic, but it does also occur in the northern North Sea and the Skagerrak (GIESKES 1971). In general, it is characterised as a thermophilic and stenothermal species. Its presence in Kiel Bay is probably due to an inflow of saline water from the Skagerrak. *Evadne anonyx* is an invasive species in the Baltic (see below).

Besides the cladoerans, the rotifers are also characterised by mass occurrences. The genus *Synchaeta* largely occurs year-round, but at up to 2.2 x 10^6 individuals m^{-2}, it was dominant in the Arkona, Bornholm and Gotland Basins, particularly in May. Various species of the genus *Keratella* were less important generally, even if a mass occurrence - at 1.8 x 10^6 individuals m^{-2} - was observed in the Gotland Basin in August. Apart from cladocerans, appendicularians (*Oikopleura*, *Fritellaria*), as well as bivalve and gastropod larvae, were frequent. In contrast, the concentration of larvae of benthic echinoderms was conspicuously low after occurring regularly the year before. Individual specimens of chaetognaths were found along with *Calanus* spp. in bodies of water with high levels of salinity.

Listed as an invasive species in the Baltic, the cladoceran *Evadne anonyx* was identified in Kiel Bay (AquaNIS, www.corpi.ku.lt/databases/index.php/aquanis; NOBANIS, http://www.nobanis.org/Search.asp). Its occurrence thus far is limited to one isolated find in May 2014, however. *Evadne anonyx* is a small cladoceran species that mainly occurs in the Caspian Sea and estuaries of the Black Sea. In the Baltic, *Evadne anonyx* was first discovered in the Gulf of Finland in 1999; a year later, it was found in the Gulf of Riga. Since then it has spread into the Arkona Basin, Landsort Deep and Bothnian Sea (PÕLLUPÜÜ et al. 2008, KALAUS & OJAVEER 2014). The species is described as stenothermal and euryhaline (ALADIN 1995). Among the other aquatic and non-native species listed in AquaNIS and NOBANIS, the copepod *Acartia tonsa* occurred frequently during the investigation period. The cladoceran species *Cercopagis pengoi*, observed occasionally in 2013, was not recorded in 2014; nor were *Mnemiopsis leidyi* or *Eurytemora carolleeae*.

4.2.2 Seasonal variations in species composition

Although samples are taken at monitoring sites usually on the outward and return journey, analysis of the sampled material does not allow us to draw elaborate conclusions about seasonal variations in zooplankton dynamics and succession. It is known that short-lived bloomsespecially of rotifers and cladocerans occur. However, with only five scheduled cruises a year, IOW can record them only in part. The assessment of long-term trends is, therefore, based on the maximum abundance observed.

The seasonal development of total zooplankton was typical, with a winter minimum and summer maxima - except in the Gotland Basin (Fig. 30). The population size in the Arkona and Bornholm Basins (OMBMPK5 to OMBMPK2) exceeded the 2013 level; in other sea areas, they were comparable, however.

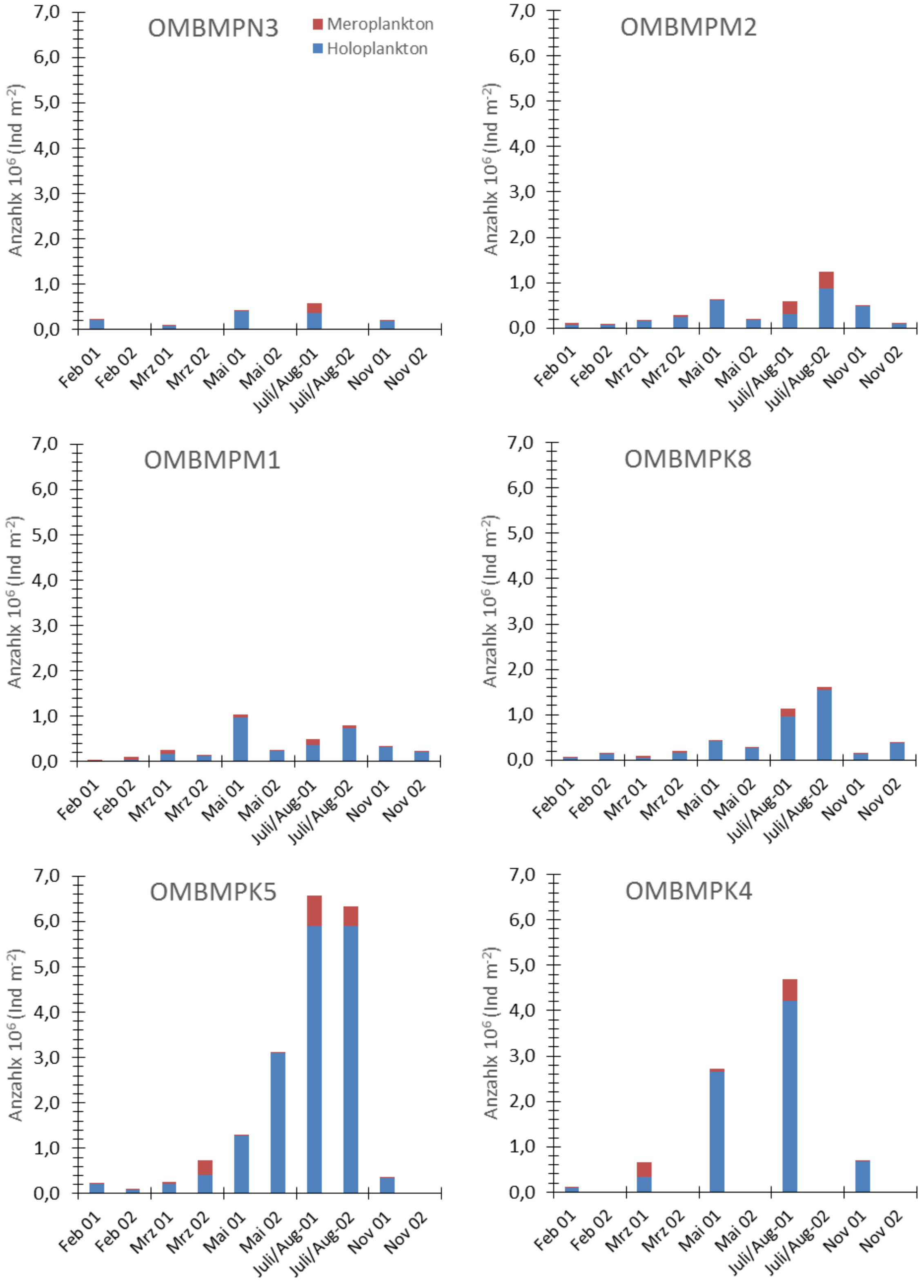


Fig. 30: Seasonal variation in the contribution of mero- and holoplankton to the total abundance of mesozooplankton at different stations in the investigation area in2014.

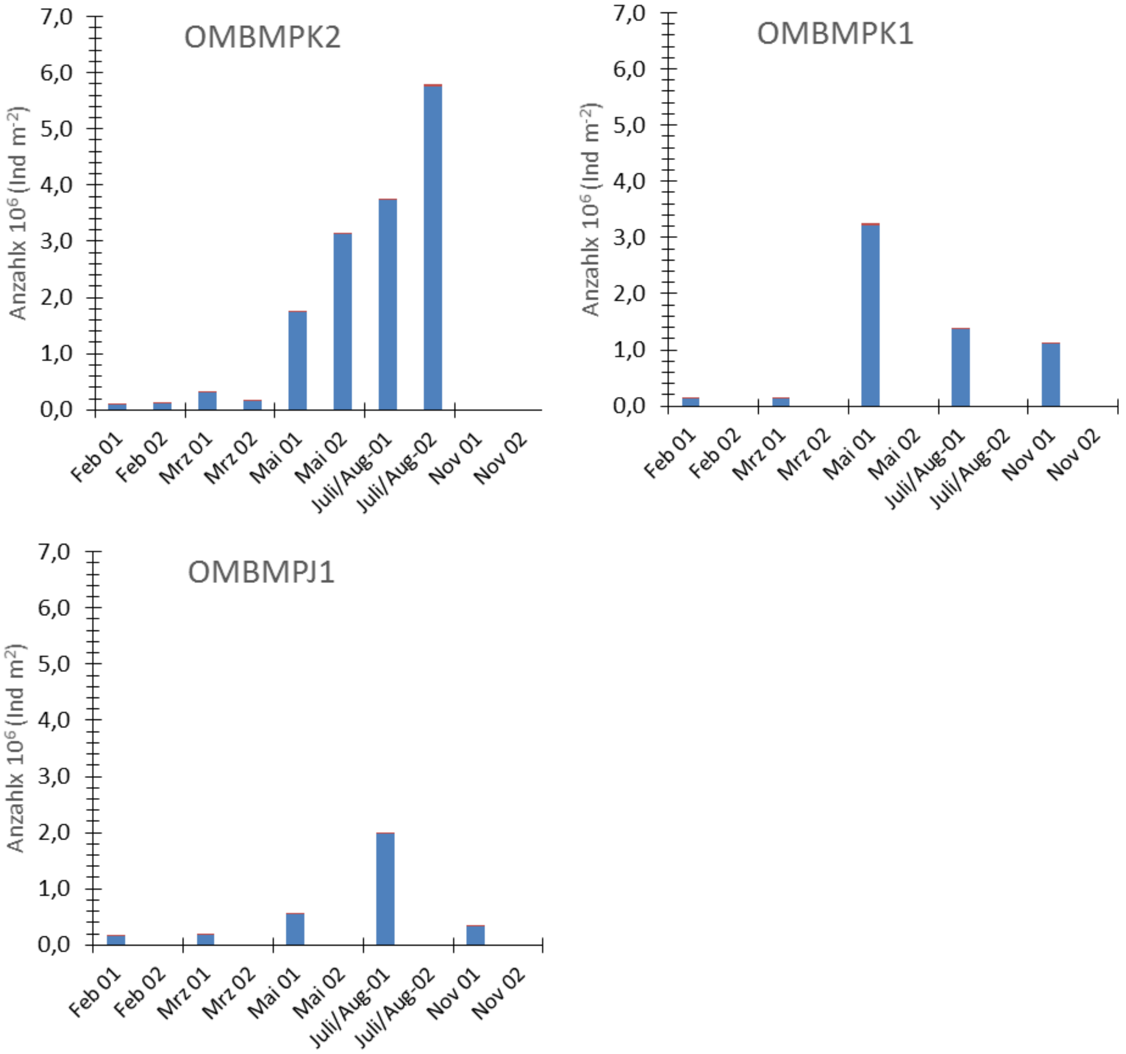


Fig. 30: continued.

Typically, maximum concentrations increased from west to east due to mass occurrences of cladoceransin the Arkona and Bornholm Basins. As a result of infrequent sampling in the spring and summer, it is possible that such mass occurrences in the western part of the study area are not fully recorded. The zooplankton was mostly dominated by holoplanktonic taxa. During spring and summer in the western Baltic (OMBMPN3 to OMBMPK4), meroplankton largely occurred in the form of polychaete, bivalve and gastropod larvae. Polychaete larvae appeared mostly in spring. In Kiel Bay, they were already observed in February and, therefore, earlier than in 2013. The abundance of polychaete larvae, however, remainded throughout 2014.

The seasonal development of zooplankton was less strongly pronounced in the western sections of the study area than elsewhere in the Baltic Sea (Fig. 31). Copepod and bivalve larvae were dominant among zooplankton in the Bays of Kiel and Mecklenburg (OMBMPN3 to OMBMPM2, Fig. 31).

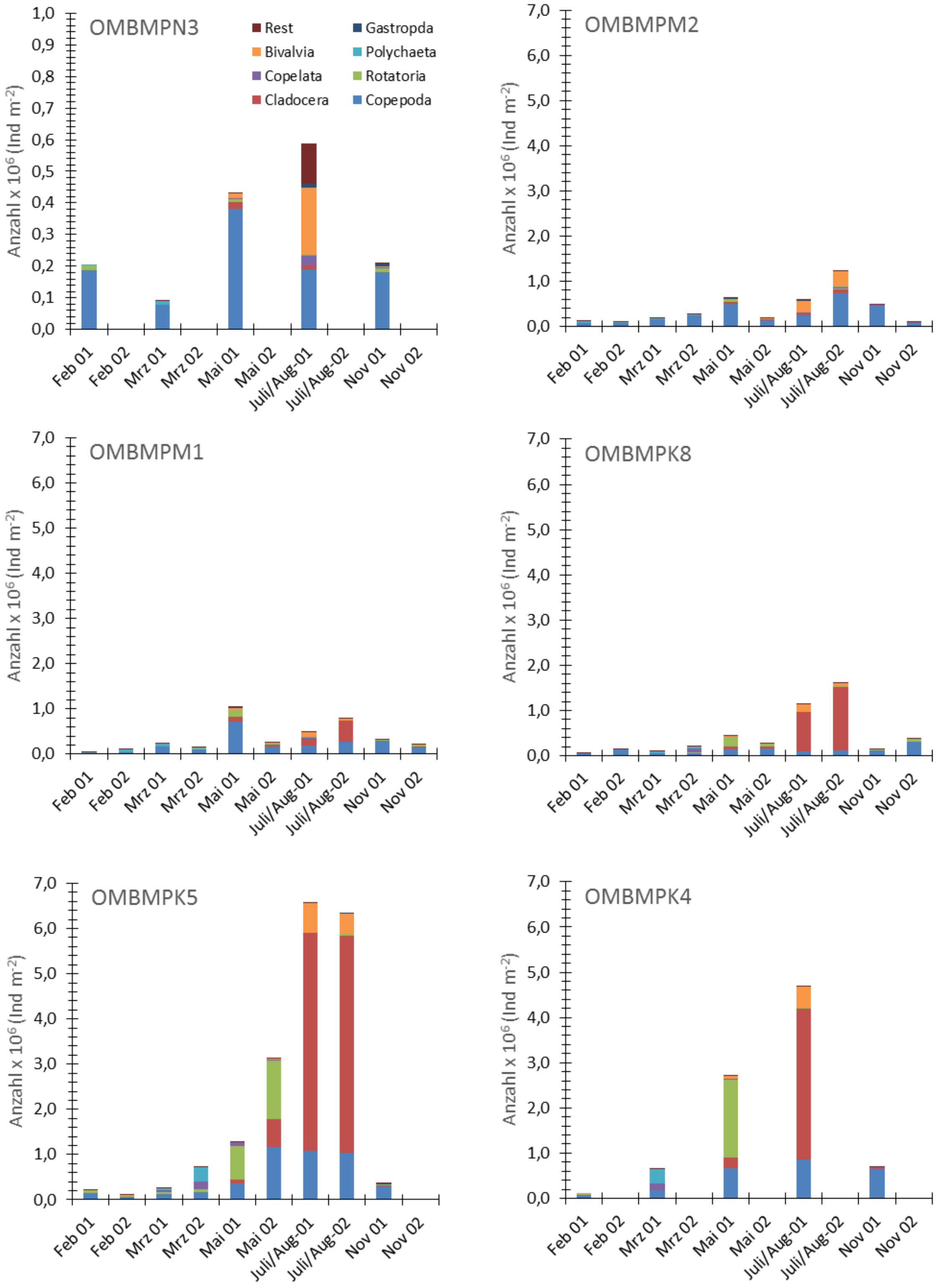


Fig. 31: Seasonal variation in the main taxonomic groups of the mesozooplankton at different stations in the investigation area.

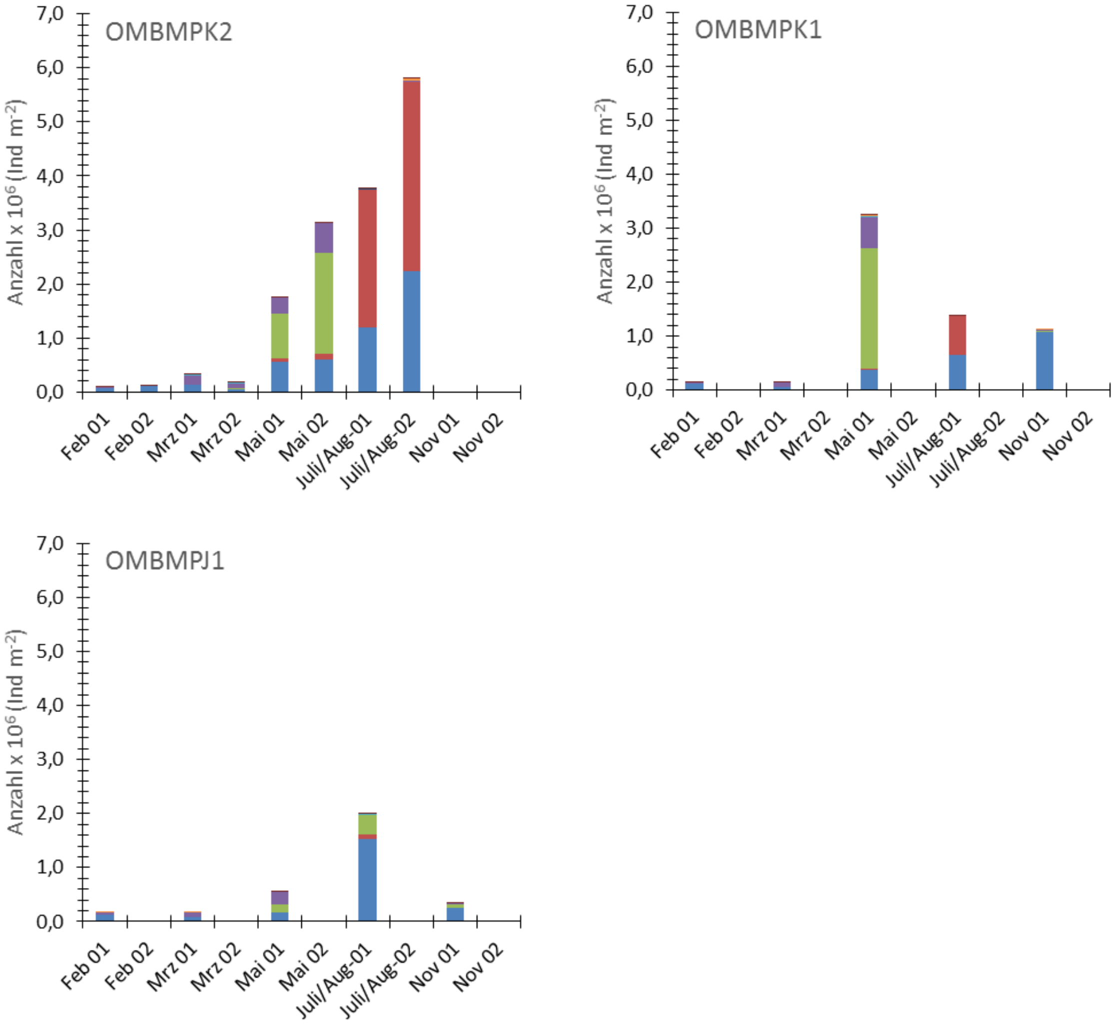


Fig. 31: continued

At up to 7.3 x 10^5 individuals m^{-2}, copepods occurred quite commonly during the entire productive phase, while bivalve larvae were mainly observed during the summer (max. 3.4 x 10^5 individuals m^{-2}). The high abundance of tintinnids in July was conspicuous (1.2 x 10^5 individuals m^{-2}). Cladocerans (mainly *Evadne nordmanni*), rotifers and appendicularians (mainly *Fritellaria borealis*) occurred more frequently in the eastern section of Mecklenburg Bay, although their numbers were generally low (‹ 1.0 x 10^5 individuals m^{-2}). There was a pronounced seasonal increase in zooplankton concentrations in the Arkona and Bornholm Basins. While small numbers of copepods and appendicularians were still dominant in March, the importance of rotifers and cladocerans grew rapidly in the spring and summer (OMBMPK5 to OMBMPK2, Fig. 31) as a result of mass occurrences of *Synchaeta* spp. (rotifers) and *Bosmina* spp. (cladocerans). In contrast to 2013, the occurrence of rotifers - at up to 1.7 x 10^6 individuals m^{-2} - was largely restricted to the spring. Represented by *Fritellaria borealis*, appendicularians were also common in May; their importance increased from west to east. *Bosmina* spp. reached maximum numbers of up to 3.5 – 4.7 x 10^6 individuals m^{-2} during the summer. Such an occurrence is typical of the Arkona and Bornholm Basins, and is observed regularly. Bivalve and gastropod larvae occurred frequently, mainly in the summer. The development of zooplankton in the eastern Baltic Sea essentially mirrored the trend in the Arkona and Bornholm Basins, although again ladocerans declined in importance.

In terms of maximum abundance of the major groups in the Arkona and Bornholm Basins, there were only insignificant differences compared to the previous year (Fig. 32 a). While cladocerans and rotifers were unimportant in Mecklenburg Bay, and were succeeded by copepods as the dominant group (OMBMPM2 to OMBMPM1), their maximum concentrations increased mainly in the Arkona and Bornholm Basins (OMBMPK5 to OMBMPK2). In its seasonal development, the zooplankton community in the study area exhibited a succession of copepod and polychaete larvae in the winter followed by a community dominated by rotifers, copepods and cladocerans in the spring and summer (Fig. 32 b).

As in 2013, the cyclopoid copepod *Oithona similis* and representatives of the calanoid copepod *Pseudo/ Paracalanus* dominated the ecologically important group of copepods in Kiel and Mecklenburg Bays (OMBMPN3, OMBMPM2, OMBMPM1; Fig. 33). An increased frequency of both these groups was observed already in the winter, a phenomenon that is regularly observed in Kiel Bay. Unlike in 2013, adult *Pseudo/ Paracalanus* were dominated in 2014 by the species *Paracalanus parvus*, not *Pseudocalanus* spp.

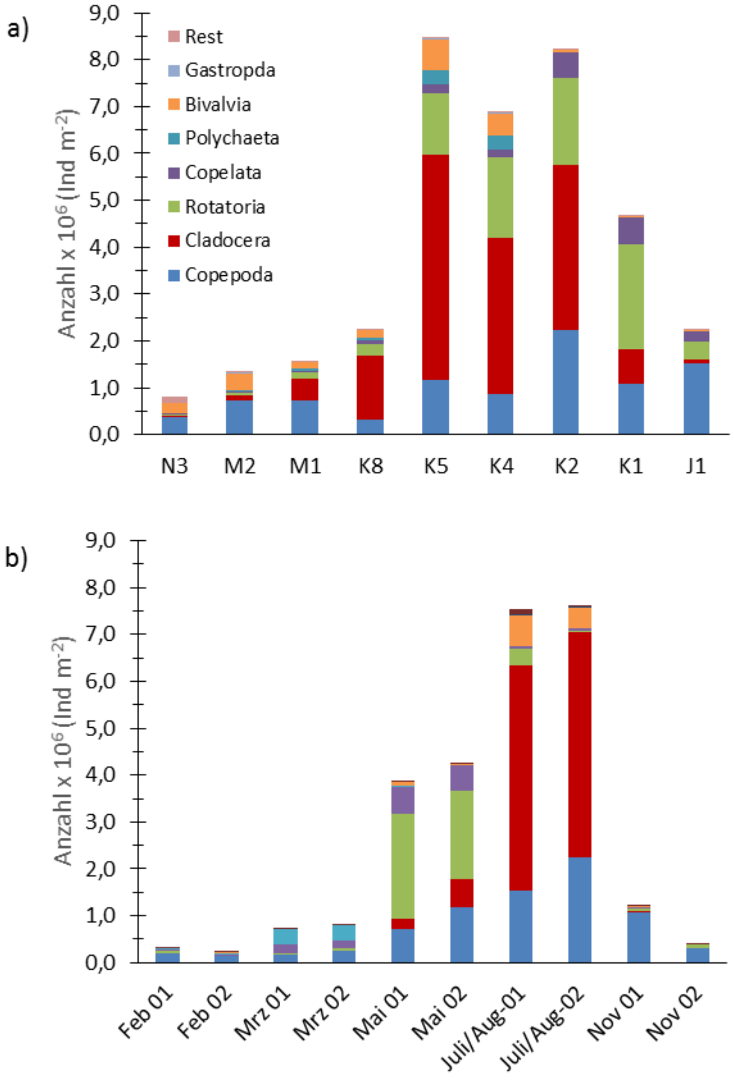


Fig. 32: Spatial variation of the maximal abundance of the main mesozooplankton groups at different stations (a) and seasonal variation in the maximal abundance of the main mesozooplankton groups in the investigation area (b).

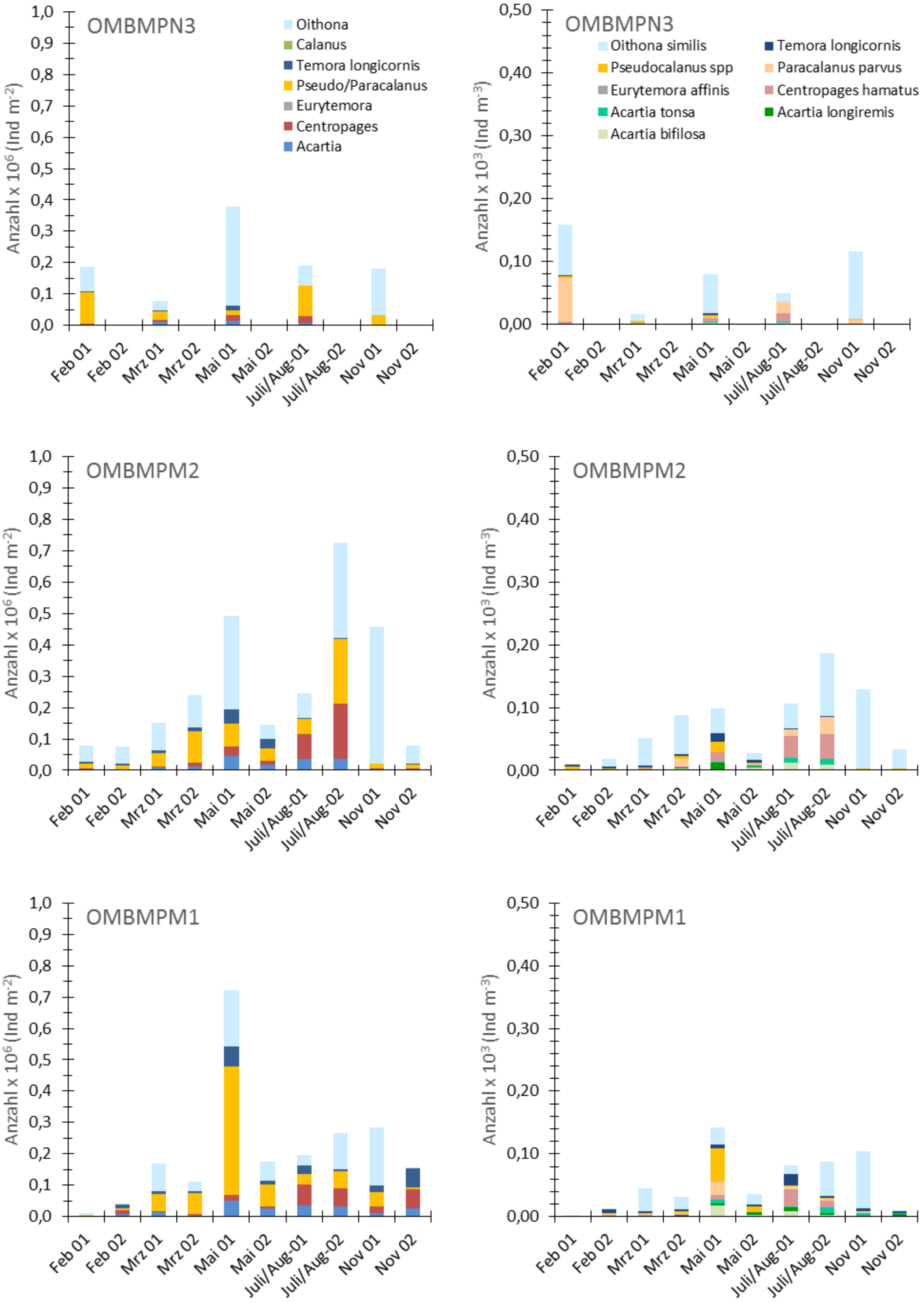
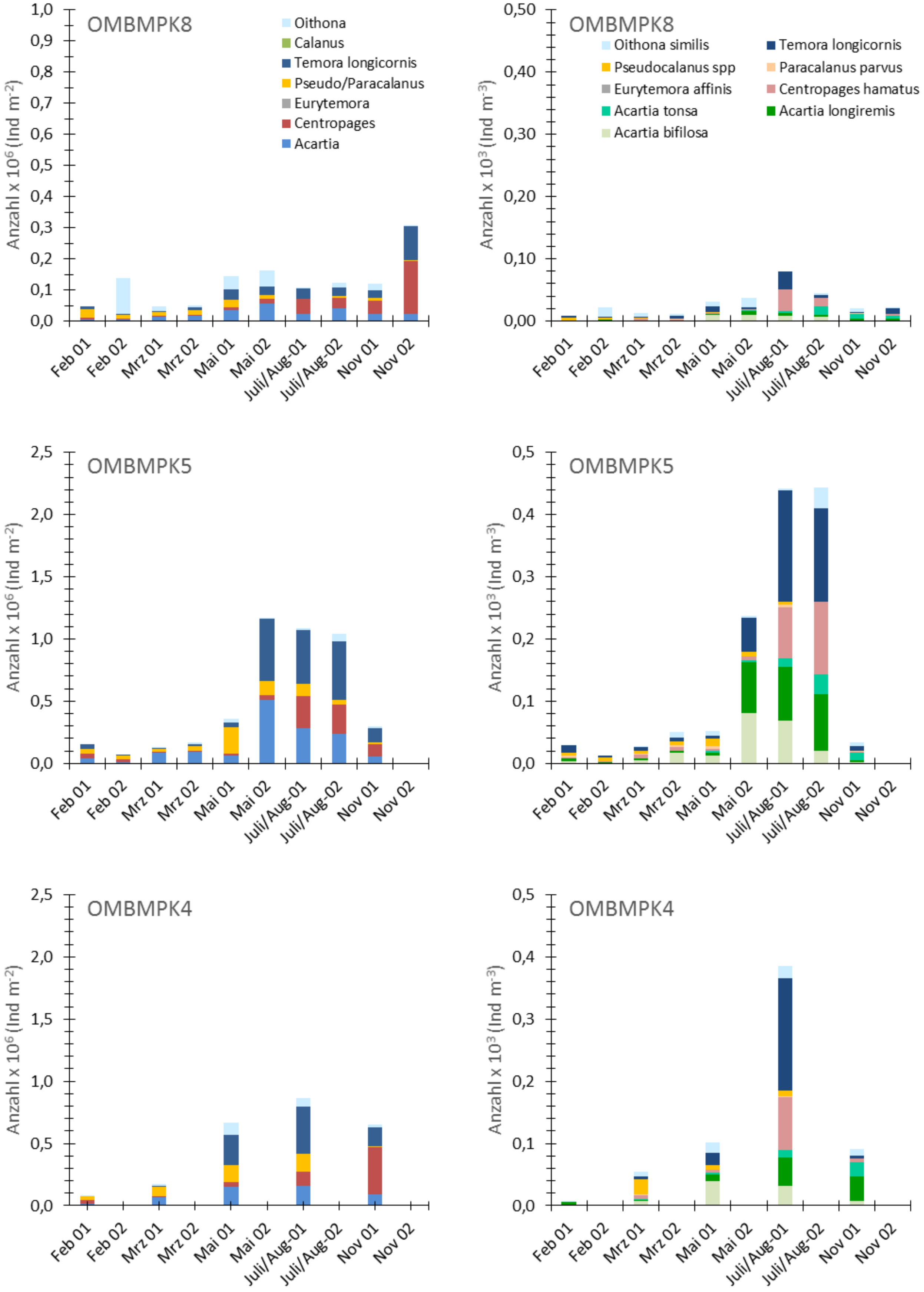


Fig. 33: Seasonal variation of the abundance and composition of juvenile (left) and adult stages of copepods (right) of different genera at various stations in the investigation area. Note the different scale in the left and right pannels.



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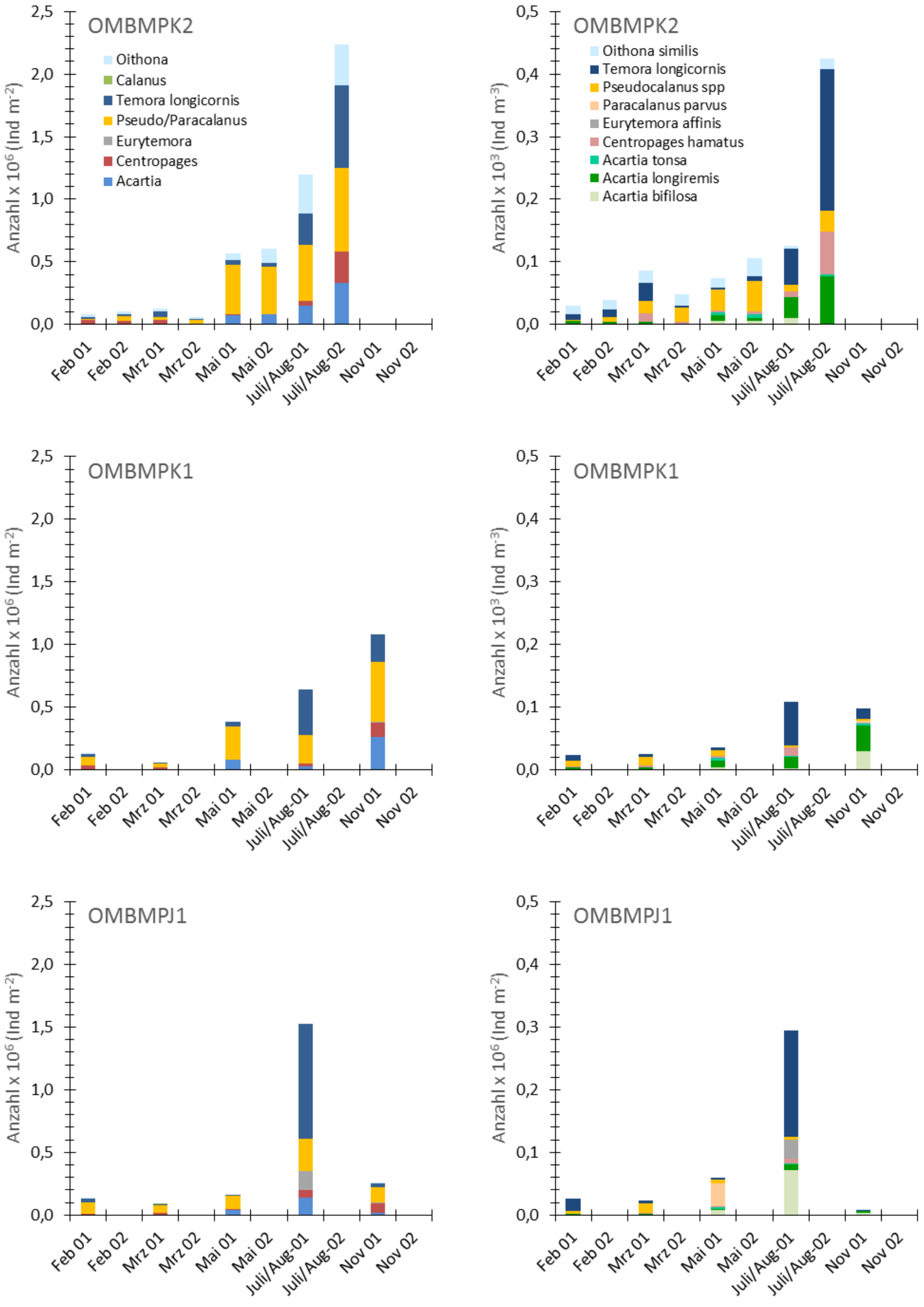

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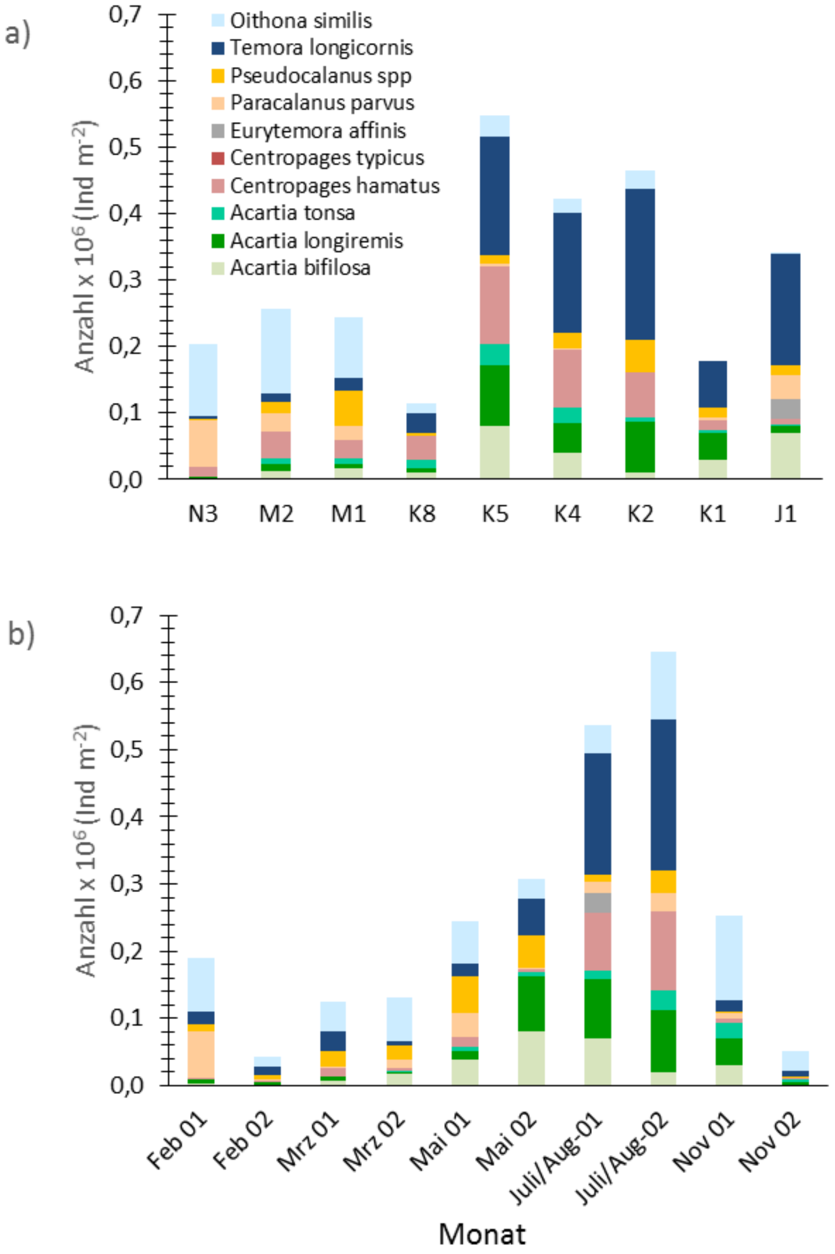

Fig. 34: Spatial variation (a) and mean seasonal (b) maximal abundance of adults of calanoid and cyclopoid copepods in the entire investigation area.

In Mecklenburg Bay, *Centropages hamatus* also occurred unusually frequent during the summer (OMBMPM2 and OMBMPM1). Other species and genera were of minor importance; their abundance was generally similar to the year before. In contrast, the concentration of copepods in the Arkona and Bornholm Basins on occasion clearly exceeded the findings of 2013 (OMBMPK5 to OMBMPK2; Fig. 33). This increase was largely due to greater numbers of *Temora longicornis* and *Centropages hamatus* during the summer when, on average, up to 3.8-6.6 x 10^5 individuals m^{-2} and 1.2-2.3 x 10^5 individuals m^{-2} were observed for copepodites and adults, respectively.

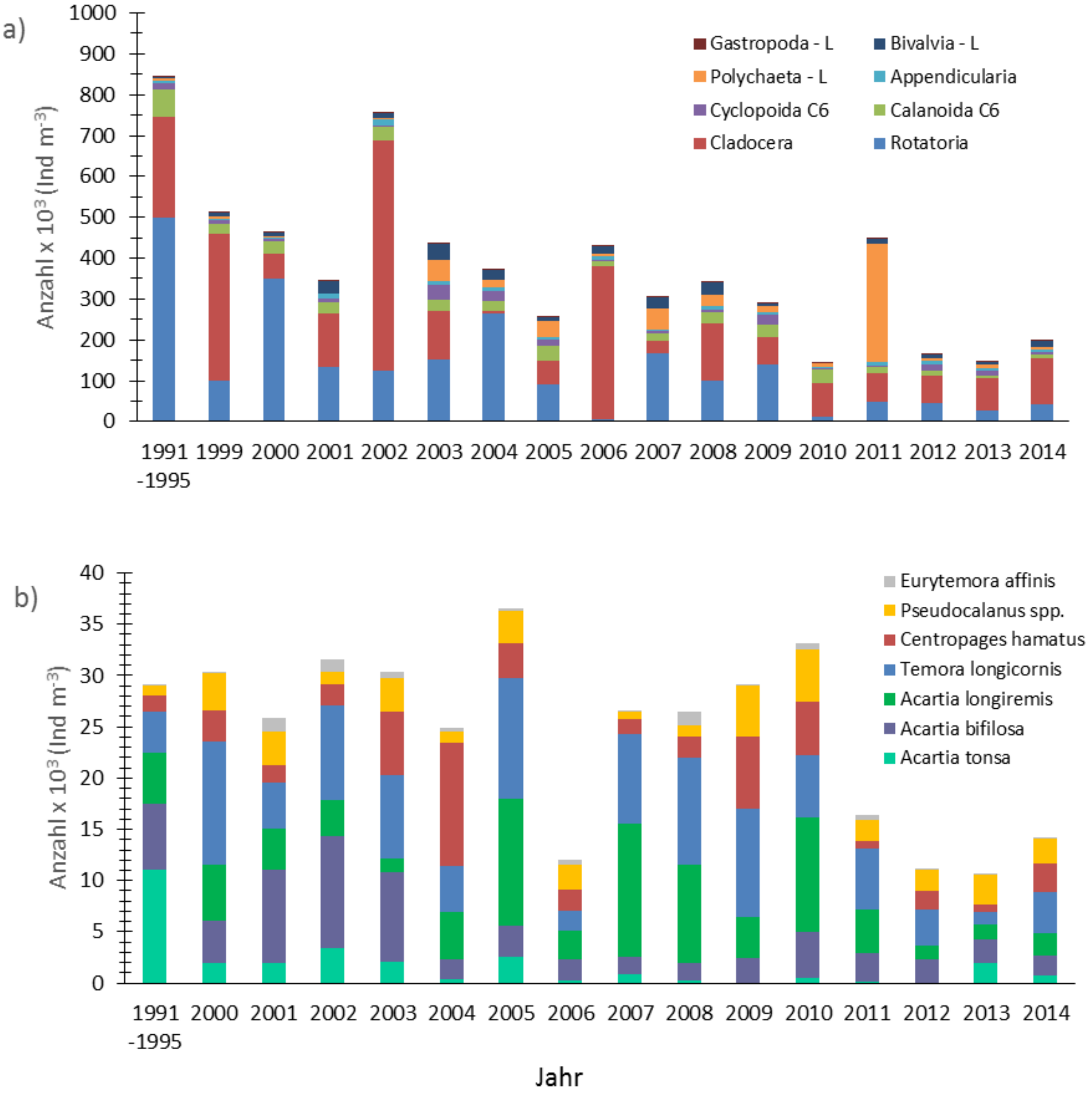

Fig. 35: Long-term trends in the maximal abundance of (a) five holoplanktonic taxa (Rotatoria, Cladocera, Cyclopoida, Calanoida, Copelata) and three meroplanktonic taxa (Polychaeta, Bivalvia, Gastropoda) and (b) seven calanoid copepod species in the years 1991 to 2014.

Pseudo/ Paracalanus again became more common in the Bornholm Basin. Towards the Gotland Basin, numbers of copepodswere on the level observed in 2013. In summary, 2014 saw a marked increase in copepod numbers in the Arkona and Bornholm Basins that coincided with a shift in the composition of the dominant species from *Acartia bifilosa*, *Acartia longiremis* and *Oithona similis* to *Temora longicornis*, *Centropages hamatus* and *Acartia longiremis* (Fig. 34 a). A clear seasonal succession was apparent in the maximum abundances of adults (Fig. 34 b). *Oithona similis* and *Paracalanus parvus* were dominant mainly during the winter and spring, whereas *Temora longicornis*, *Centropages hamatus*, *Acartia longiremis* and *Acartia bifilosa* occurred during the summer in increasing numbers together with *Oithona similis* (Fig. 34 b).

Despite the elevated zooplankton concentrations observed in the Arkona and Bornholm Basin, the long-term development of total zooplankton remained as low as in previous years (Fig. 35a). Particularly in terms of the very common rotifers and cladocerans, maximum concentrations fell well short of the values observed from 1991-2006; at 1.9 x 10^5 individuals m^{-3}, the total abundance of zooplankton in 2014 again fell well short of the long-term mean of 3.9 x 10^5 individuals m^{-3}. Only a slight improvement was noted even in the calanoid copepods: numbers of the ecologically most significant species such as *Temora longicornis*, *Acartia bifilosa / A. longiremis* or *Pseudocalanus* spp. - at a maximum of 1.4 x 10^4 individuals m^{-3} - in 2014 remained below their long-term average of 2.49 x 10^4 individuals m^{-3} (Fig. 35 b).

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). Very low near-bottom oxygen concentrations were measured at station OM18. At 0.1 mg/l, they fell well short of the accepted oxygen threshold of 2 mg/l for macrozoobenthic species. This was the lowest oxygen concentration ever recorded by us at this station in autumn.

Table 7

Abiotic parameters at 8 monitoring stations in autumn 2014 (org=organic content of sediment in %, GS=mean grain size in µm, O_2=oxygen content of near bottom water in ml/l, S=salinity at near bottom water in psu).

Station	**Org (%)**	**GS (µm)**	**O2 (mg/l)**	**S (psu)**	**Sedimentansprache an Bord**
OMBMPN3	1,18	174	4,45	24,2	Sand mit Schlickanteil
OMBMPN1	2,56	128	4,1	25,1	Schlick mit Feinsand
OMBMPM2	9,96	19	4,32	23,5	Schlick
OM18	1,67	86	0,1	22,7	Schlick mit Feinsand
OMBMPK8	0,30	226	6,88	8,3	Feinsand
OMBMPK4	10,83	18	4,77	22,1	Schlick
OMBMPK3	0,63	215	4,91	14,4	Mergel mit Feinsandauflage
OM160	0,49	160	1,92	12,5	Feinsand

At 1.92 mg/l, even the values at Oder Bank, which is normally a well-ventilated body of water, were deficient. While no depressed oxygen concentrations were observed at the other stations, the low level of colonisation indicated that anoxic conditions must also have prevailed beforehand in Mecklenburg Bay (OMBMPM2). The inflow of well-ventilated deep water (see chapter 3) appears to have had no effect on the shallow-water stations.

4.3.2 Macrozoobenthos at the Stations

In November 2014, 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. Compared with the period 1991 to 2014, the number of species was average at 117 (Table A4, Fig. 36). 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, the stations in Mecklenburg Bay (OMBMPM2 and OM18) exhibit a clear loss of species, due to previous (and ongoing) oxygen deficiency (see above).

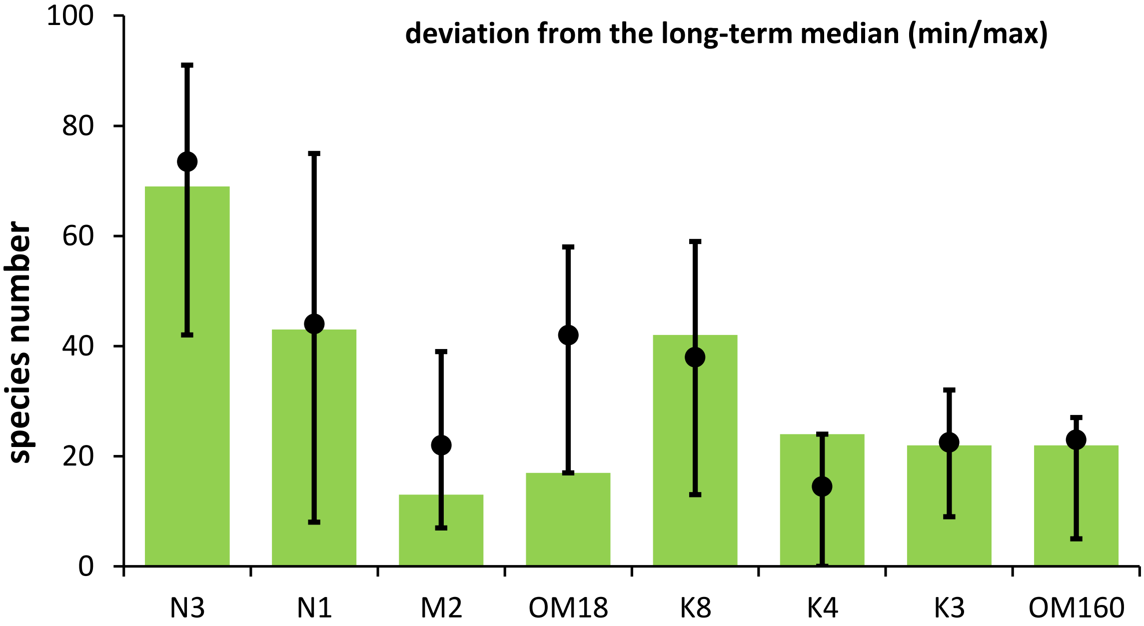

Fig. 36: Number of species (columns) of macrozoobenthos at 8 monitoring stations in November 2014. The median values of the years 1991 to 2014 are shown as dots; the minimum and maximum values are indicated as interval. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

If their long-term median values are compared to the observed number of species at other stations, it is seen that current values lie within the long-term average (Fig. 36). Only at station OMBMPK4 in the central basin of the Arkona Basin (some 45 m deep) was an increase in the number of species observed: 24 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. High salinity of 22.1 psu (Table 4) showed there had previously been a salt-water infow (see chapter 3) 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 caeca*, and the brittle star *Ophiura albida*.

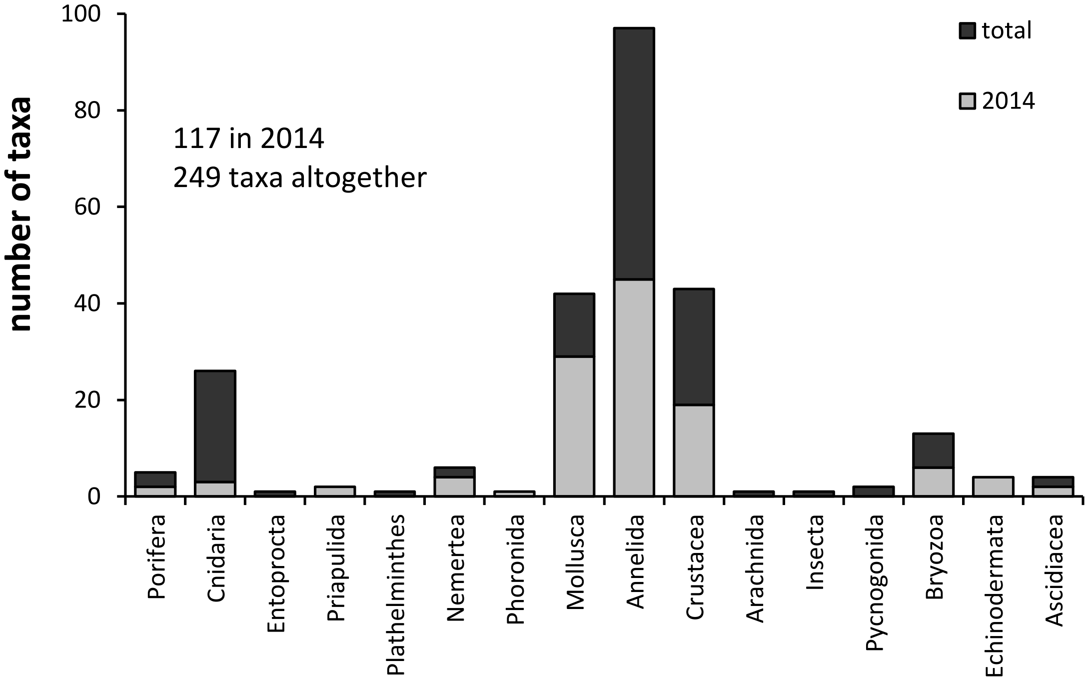

Fig. 37: Taxonomical classification of macrozoobenthos at 8 monitoring stations in November 2014. The species number of the entire monitoring from 1991 to 2014 is also indicated.

Figure 37 gives the taxa found at our 8 monitoring stations in 2014 as well as the total number of species found in measurements since 1991. Not just in 2014, the Annelida (Polychaeta and Oligochaeta) emerged as the group that is richest in species, numbering 97; in 2014, 45 species were identified. Other species-rich groups in 2014 were Mollusca (29), Crustacea (19) and Bryozoa (6).

Depending on the sea area, abundances varied between 183 (Mecklenburg Bay) and 10,899 ind./m² (Kiel Bay) (Fig. 38, Table A4). In Kiel Bay, abundances were thus significantly higher than the long-term average (Fig. 38). Compared with previous years, average values were observed at the station at Fehmarnbelt (OMBMPN1), in the central Pomeranian Bay (OM160), and in the central Arkona Basin (OMBMPK4). At the other stations, abundances were unmistakably lower.

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 40 % of density in Kiel Bay (OMBMPN3) and in Fehmarn Belt (OMBMPN1) (at up to 10 % *Lagis koreni* and *Ophiura albida* were subdominant), in the Pomeranian Bay (OM160) only the mud snail *Peringia ulvae* at 70 % accounted for high abundance.

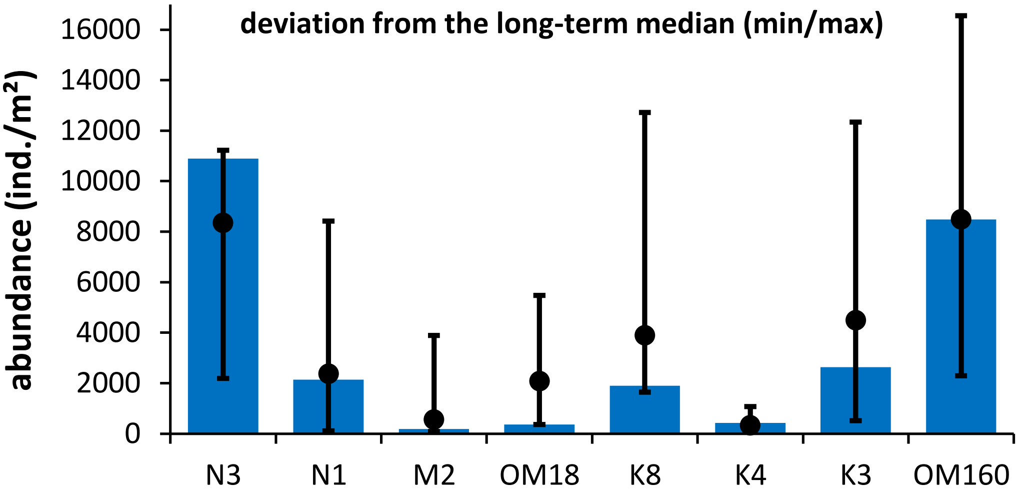

Fig. 38: Total abundances (columns) of macrozoobenthos at 8 monitoring stations in November 2014. The median values of the years 1991 to 2014 are shown as dots; the minimum and maximum values are indicated as interval.

Mecklenburg Bay (OMBMPM2) was dominated by the cumacean *Diastylis rathkei* (64 %), and the ocean quahog *Arctica islandica* (19 %). Dominant species in the south of Mecklenburg Bay (OM18) were *Diastylis rathkei* (25 %), *Arctica islandica* (20 %), and *Corbula gibba* (12 %). Dominant species at Darss Sill (OMBMPK8) were the polychaetes *Pygospio elegans* (23 %) and *Scoloplos armiger* (21 %), as well as the mud snail *Peringia ulvae* (19 %). Dominant in the central Arkona Basin (OMBMPK4) were the polychaete *Scoloplos armiger* (66 %) and the amphipod *Pontoporeia femorata* (24 %). The north of the Pomeranian Bay (OMBMPK3) was dominated by the mollusc *Macoma balthica* (51 %), and the polychaete *Pygospio elegans* (37 %).

The highest biomasses were observed at stations in Kiel Bay (OMBMPN3) (Fig. 39). 75 g AFDM/m² was measured, consisting of 41 % *Astarte borealis* and 44 % *Arctica islandica*. In addition, dredge catches yielded echinoderms (*Asterias rubens*, *Ophiura albida*) and red whelk (*Neptunea antiqua*) (Fig. 40) that were certainly under-represented in the quantitative grab samples. At Fehmarnbelt (OMBMPN1) and in Mecklenburg Bay (OMBMPM2 and OM18), *Arctica islandica* contributed as much as 93-99 % to biomass; total values between 11 and 54 g AFDM/m² were obtained there. At Darss Sill (OMBMPK8), biomass (9.5 g AFDM/m²) was dominated by the bivalves *Astarte borealis* (55 %) and *Macoma balthica* (12 %). In the Arkona Basin, (OMBMPK4), *Macoma balthica* accounted for 74 % of biomass, *Nephtys hombergii* for 13 % (1.7 g AFDM/m²). In the north of the Pomeranian Bay (OMBMPK3), 4.7 g of total biomass was measured, made up of 90 % *Macoma balthica*. Further east in the central Pomeranian Bay (OM160; 3.8 g AFDM/m²), *Mya arenaria* (22 %), *Peringia ulvae* (27 %) and the two polychaetes *Hediste diversicolor* (19 %) and *Marenzelleria viridis* (14 %) were prominent.

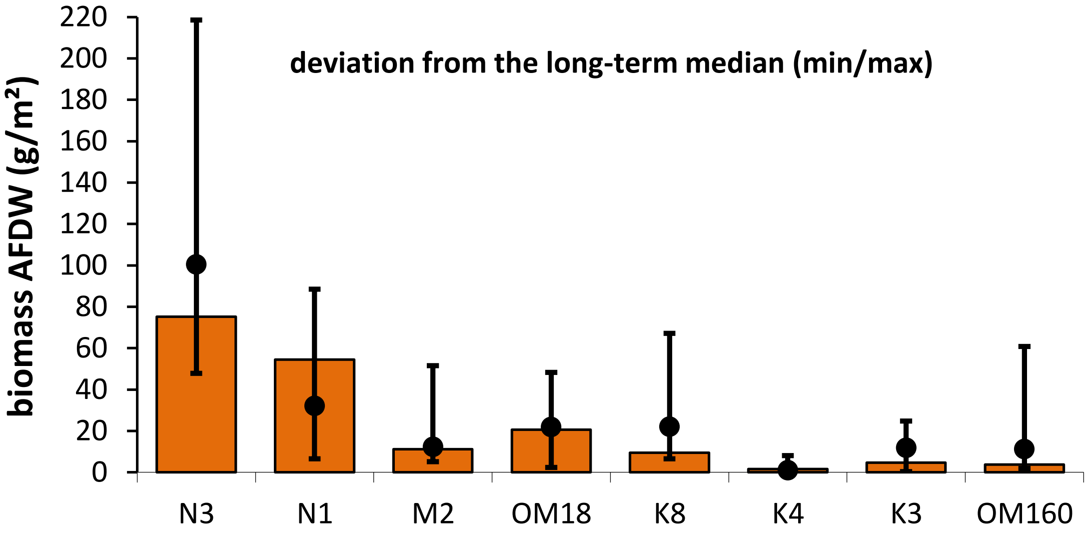

Fig. 39: Total biomasses (columns) of macrozoobenthos at 8 monitoring stations in November 2014. The median values of the years 1991 to 2014 are shown as dot and the minimum and maximum values are indicated as interval.

Fig. 40: In Kiel Bay (OMBMPN3), the ocean quahog (*Arctica islandica*) and brittle stars (*Ophiura albida*) dominated the dredge sample. Individual red whelks (*Neptunea antiqua*) were also found.

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. 35 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.

4.3.3 Long-term Trends

For an assessment of long-term trends since 1991 refer to our recently published reports (Wasmund et al. 2014). 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 9 years only (2006 to 2014). Eight stations were sampled every autumn using three grab samples and one dredge. Stations are thus assessed on an identical basis. Fig. 41 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 2014, a similar situation was observed at station OM18 for the first time: its species diversity had more than halved. All other stations had diversity rates that were relatively stable.

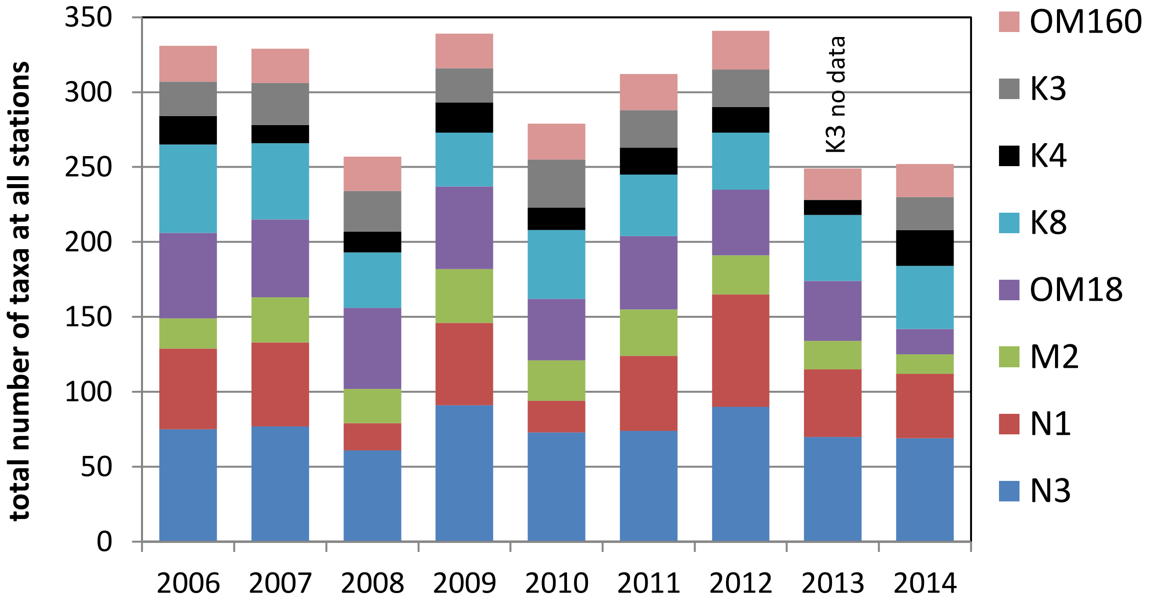

Fig. 41: Number of species of macrozoobenthos at 8 monitoring stations from 2006 to 2014. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

In terms of abundance, the situation is very different (Fig. 42). 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 (see remarks on species numbers above). Mecklenburg Bay (OMBMPM2) was affected only in 2008 and 2014. A similar loss of abundance was observed for the first time in 2014 at station OM18.

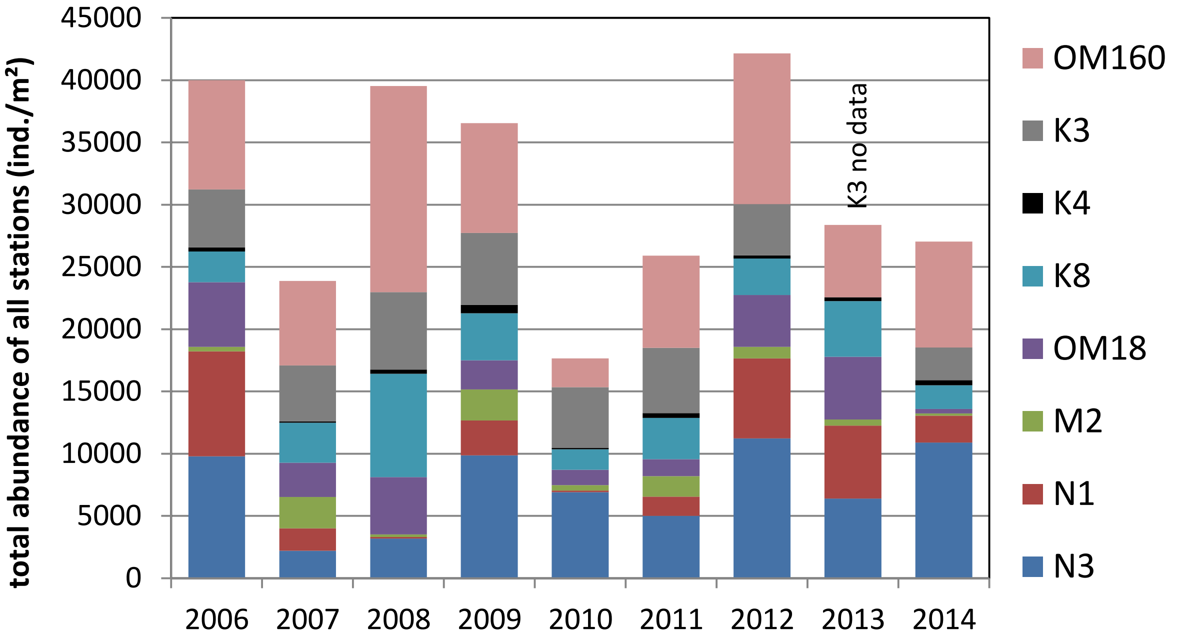

Fig. 42: Abundance of macrozoobenthos at 8 monitoring stations from 2006 to 2014. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

Figure 43 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 south of Mecklenburg Bay (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 Mecklenburg Bay (OMBMPM2, OM18) in 2014. Overall, the total biomass observed in 2014 was relatively low.

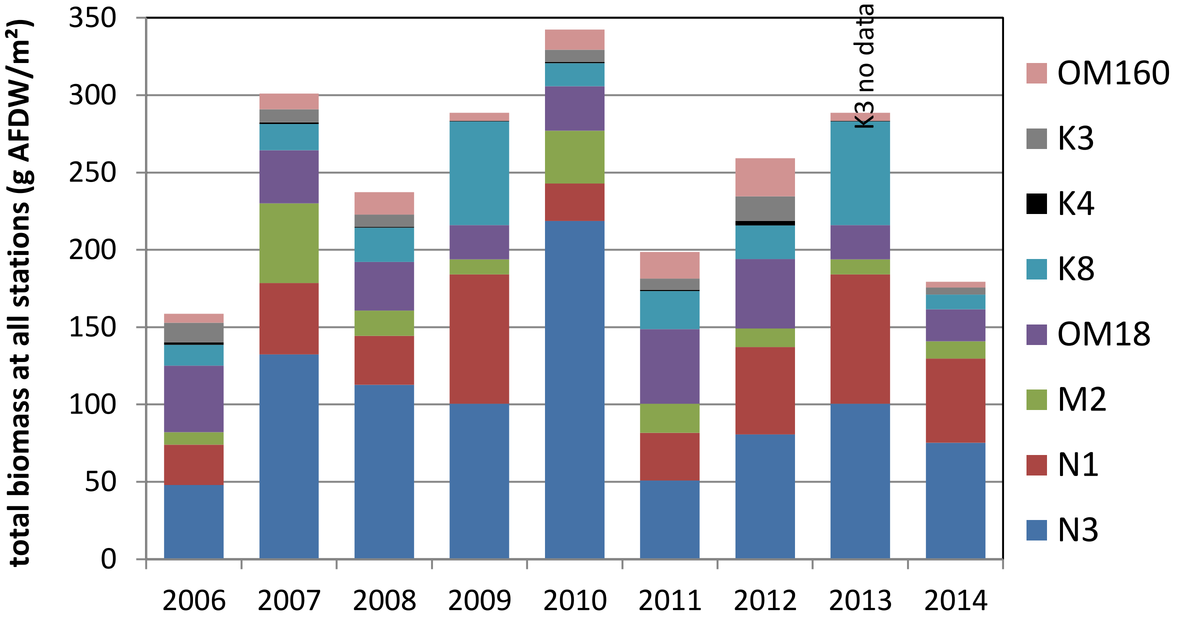

Fig. 43: Biomass of macrozoobenthos at 8 monitoring stations from 2006 to 2014. The stations are plotted from west to east (Kiel Bay = OMBMPN3 to Pomeranian Bay = OM160).

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 117 species, 17 are classed as threatened (1, 2, 3, G) (Fig. 44). Five species are still classed as being near threatened. Currently, 61 species are classed as being of least concern. Data are deficient for 18 species, and 16 taxa on the Red List were not evaluated.

Macoma calcarea (chalky macoma) is critically endangered. As in previous years, low densities (50 ind./m²) were detected in Kiel Bay (OMBMPN3). One specimen was dredged from the south of Mecklenburg Bay (OM18) where the species has been detected irregularly since monitoring began. Species that are classed as endangered (category 2) were also found at the westernmost station (OMBMPN3), including *Buccinum undatum* (common whelk) and *Mya truncata* (blunt gaper). Specimens of *Arctica islandica* (ocean quahog; category 3, vulnerable) were observed at all western stations (OMBMPN3, OMBMPN1, OMBMPM2, OM18) 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 11 species observed in 2014 were distributed across almost all sea areas: 10 species in Kiel Bay (OMBMPN3), 3 in Fehmarnbelt (OMBMPN1), 2 at Darss Sill (OMBMPK8), and one each in Mecklenburg Bay (OM18) 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).

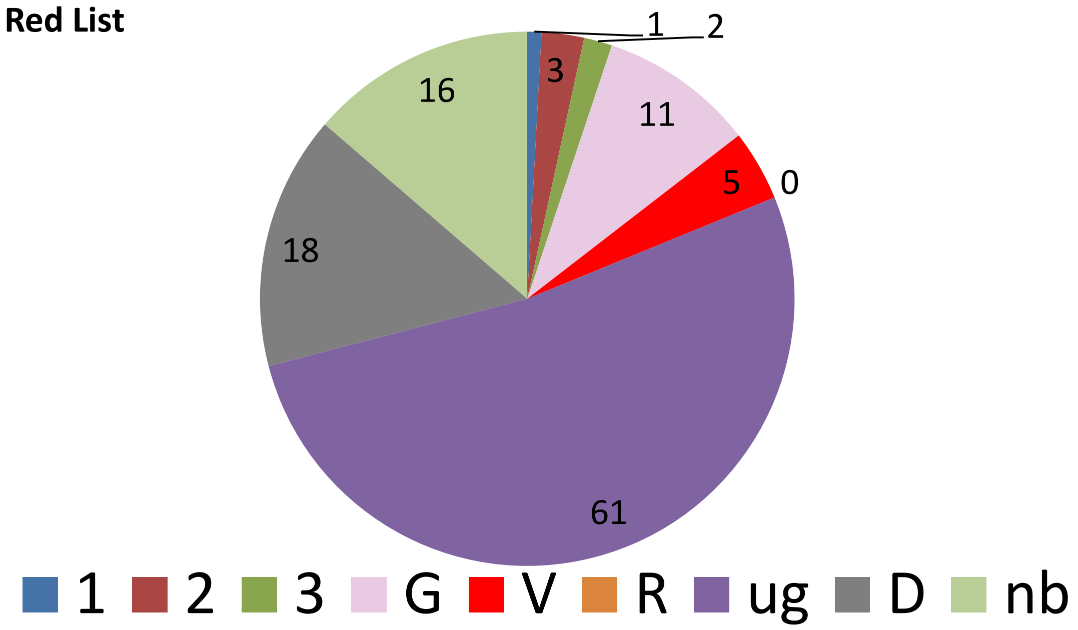

Fig. 44: Percentage of red list categories (RACHOR et al. 2014) in relation to macrozoobenthos in autumn 2014 (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, UG=least concern, D=data deficient, nb=not evaluated).

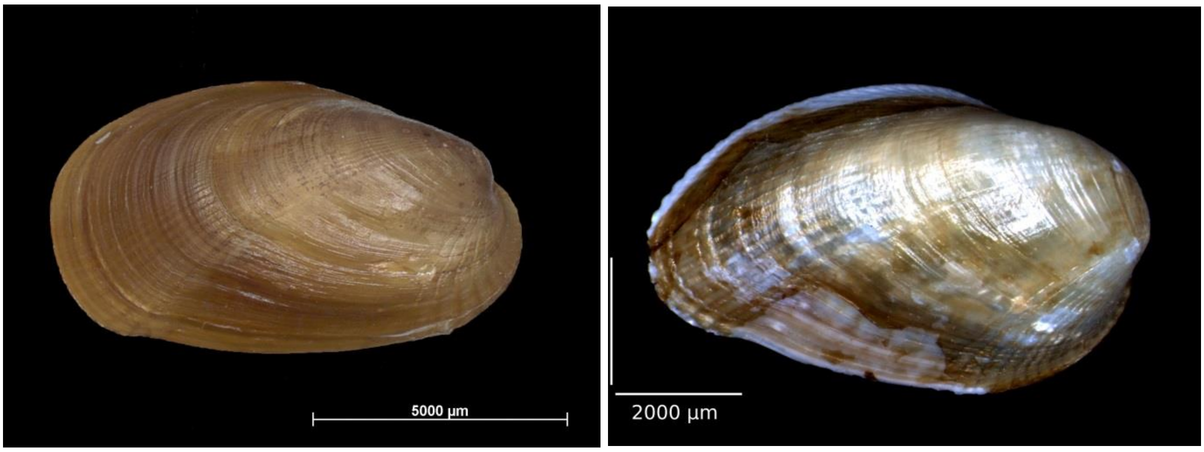

Fig. 45: *Musculus niger* (left) and *Musculus subpictus* (right): Bivalve species which are categorised as endangered in Germany's Red List. The pictured specimens come from the entrance to Fehmarnbelt.

4.3.5 Invasive Species

The role of invasive species in the open Baltic Sea is negligible (ZETTLER et al. 2014). Only 4 species were observed at our 8 monitoring stations in 2014. *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 2014 we observed the following abundances of *M. viridis*: 7 ind./m^2 at Darss Sill (OMBMPK8); 37 ind./m^2 in the north of the Pomeranian Bay (OMBMPK3); and 280 ind./m^2 in the central Pomeranian Bay (OM160). In 2014 *M. neglecta* was also observed at the Oder Bank (OM160): 10 ind./m^2. In contrast to a year earlier, *Mytilopsis leucophaeata* was not observed again in 2014. As was supposed a year earlier, this species will very probably be unable to establish itself there (WASMUND et al. 2014).

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, Mecklenburg Bay and the Arkona Basin (Fig. 1) were gathered in 2013 in order to continue the time series which exists since 1979. Data from sediment traps deployed in the Arkona Basin give information on particle dynamics. Also satellite data are used to trace the phytoplankton bloom development. 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.

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 could be closed by additional informationen from the coastal monitoring of the IOW in Heiligendamm, 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 2014, including a seasonal indicator, is shown in Table A2 (Annex). The ranking according to their biomass in 2014 is also given.

Spring bloom: The phytoplankton biomass was still low in February 2014, except for station OMBMPN3, where relatively high biomass of *Ceratium tripos* was found; this species even increased in the Mecklenburg Bay by the month of March, which is unusual as it is considered an autumn species (Fig. 6a, 10 a). Other sources (coastal station Heiligendamm, nutrient data acc. to Table 5, CO_2 partial pressure data) revealed that the spring bloom took place from 20.2. to 19.3.2014 in Mecklenburg Bay, which is much earlier than in 2013. Therefore it was not registered during the March-cruise, but *Rhizosolenia setigera* and *Skeletonema marinoi* still occurred in relatively high biomasses. Surprisingly, *Coscinodiscus concinnus* accumulated in deeper water layers at some stations, but on 13.2.2014 at station OMBMPM2 in the surface layer (Fig. 6a, c). After the decline of the diatoms (also by parasite infections, Fig. 6d) and of *Ceratium tripos,* a late-spring bloom of *Dictyocha speculum* appeared (Fig. 6g, 8, 13 c). This species is counted under Chrysophyceae in Fig. 8. Such late-spring bloom was found also in some earlier years. After the exhaustion of the nutrients (starting with phosphorus depletion in Kiel Bay) by the spring bloom, silicate concentrations increased surprisingly by May. Nevertheless, *Dictyocha speculum* occurred mostly in its “naked” form without the typical silicon skeleton (Fig. 6 e-g).

The Arkona Basin differed clearly from the western Baltic with regard to the phytoplankton development. The spring bloom was fully developed here during the cruise in mid of March with *Skeletonema costatum* (Fig. 13 b), *Thalassiosira* spp. and *Chaetoceros* cf. *wighamii*. *Dictyocha speculum* did not occur in the Arkona Basin, but *Mesodinium rubrum* has grown parallel to the diatom bloom, and it became the dominating species after the collapse of the diatom bloom at the beginning of May 2014 (in Fig. 8-10 counted as „Ciliophora (mixotr.)“, Fig. 14 a).

The diatom *Achnanthes taeniata*, unusual in the western Baltic but dominating in 2011, as well as the newly recorded *Peridiniella danica*, which was the dominating dinoflagellate in 2011, were again relatively unimportant in 2014. The dominant diatom in mid of March 2014 in Mecklenburg Bay and the Arkona Basin was the usual *Skeletonema marinoi. Dictyocha speculum* occurred much stronger than in the previous years.

Strong blooms of *Mesodinium rubrum* developed in the Bornholm Basin and Eastern Gotland Basin by the beginning of May 2014 (Fig. 10).

Summer bloom: The samples from summer are based on only one cruise and cannot reflect the total diversity. The typical diatom summer bloom could be found in Kiel Bay, Lübeck Bight and the central Mecklenburg Bay (Fig. 8 a-c), mainly composed of *Dactyliosolen fragilissimus* and accompanied by the remarkable dinoflagellate *Alexandrium pseudogonyaulax* (Fig. 11 b, 14b, 14c). The latter was first found in our samples in 2010 and shows an increasing trend. *Ceratium*-species and *Coscinodiscus granii*, forming blooms in autumn, start their growth already in summer. During the period of the summer cruise (end of July), the nitrogen-fixing cyanobacteria *Aphanizomenon* sp. and *Nodularia spumigena* were only sparsely developed in the western Baltic, but bloom-forming in some areas of the Eastern Gotland Basin (Fig. 7).

Autumn bloom: The autumn bloom was dominated by *Ceratium*-species in the western Baltic (Kiel Bay, Lübeck Bight and Mecklenburg Bay, Fig. 12 a, 15 a), however not by the typical *C. tripos* but by *C. fusus*. Also the otherwise rare dinoflagellate *Polykrikos schwartzii* was important. By the 17.11.2014, *C. tripos* has strongly declined at station OMBMPM2.

To the east, *Ceratium* spp. decrease but diatoms normally increase. Accordingly, no dinoflagellate bloom could be recorded at Darss Sill (Stat. OMBMPM1) and in the Arkona Basin. The share of *Coscinodiscus granii* increases and that of *Cerataulina pelagica* decreases easterly. *Coscinodiscus radiatus* appeared in a few specimens in the depth samples, as already found in 2012. In the Bornholm Basin, we observed an almost pure bloom of *Coscinodiscus granii*, to a lesser degree also in the Eastern Gotland Basin.

Highlights are the marine species *Noctiluca scintillans* (Fig. 12 b) and *Spatulodinium pseudonoctiluca* (Fig. 12 c), found in Lübeck Bight and Mecklenburg Bay in November 2014. They indicate that an inflow of North Sea water occurred obviously already before the Major Baltic Inflow from December 2014.

Chlorophyll: The concentrations of chlorophyll *a* are compiled in Tab. 6. The annual maximum (10.35 mg m^{-3}) was found as usual during the time of the spring bloom which was registered in mid of March in the Arkona Basin. In the western Baltic, the spring bloom was missed; therefore we find the maximum values in autumn in this area. The bloom of *Dactyliosolen fragilissimus* in July in the western Baltic was not reflected in the chlorophyll-a-data (Fig. 17 b) because these large diatom cells are very poor in chlorophyll.

Sedimentation: The total annual flux of particulate organic matter in the Arkona Basin was extremely high with an unusual seasonal distribution in the year 2014. Whereas rates in the first half of the year were low and the spring peak seems to be missed, a first maximum appeared in June which was followed by increasing peaks over the rest of the year. The flux within these peaks and the total annual flux for single elements amounted to rates which were up to 5 times higher than in previous years and cannot be caused by the vertical sinking of microalgae alone. The high carbon content of more than 12 % (weight) of the material excluded resuspended sediment as the primary source. Microscopic examination showed the material to consist of intact and broken fecal pellets in the millimeter range which seem to derive from the heavy colonization of the trap lid by barnacles. Thus, the absolute annual flux in 2014, amounting to 3.0 mol C, 429 mmol N, 1.2 mol Si and 9.3 mmol P $m^{-2}\ a^{-1}$ at a mass flux of 293 g dry mass $m^{-2}\ a^{-1}$ cannot be considered to reflect the true vertical transport of detrital material and can quantitatively not be compared with previous periods. Elemental ratios and isotopic signature of the material seem to have been affected as well, as most of them display continuous trends over the year that correspond to the increase of fecal material in the collection cups. Few phases of low δ15N values of 2-4 permill in the material during June/July may indicate periods of nitrogen fixation.

The qualitative composition of the microalgae over the year is, however, quite well reflected in the material, although the preference of diatoms may as well be an effect of the preferential digestion of forms without frustules. Diversity within the diatoms and dinoflagellates remained in the same high range as in the previous year and just the number of identifiable flagellates decreased.

Zooplankton

In 2014, as part of a long-term investigation into zooplankton in the Baltic Sea, samples for the analysis of abundance and species composition were collected at 67 locations within Germany's Exclusive Economic Zone (EEZ), as well as in the Bornholm and Gotland Basins. During the taxonomic analysis, a total of 49 zooplankton taxa were identified. Species diversity was thus as high as in previous years.

Compared with 2013, the range of species in 2014 showed little change. Shifts in the frequency of different species were more evident, however. Among the copepods, mainly *Pseudocalanus* spp., *Temora longicornis*, *Centropages hamatus*, *Paracalanus parvus*, *Acartia bifilosa* and *Acartia longiremis* as well as the cyclopoid copepod *Oithona similis* occurred regularly, and often within the study area's pelagic zone. Compared with the previous year, we observed a markedly greater abundance of *Temora longicornis* and *Centropages hamatus. Calanus* spp. occurred mainly in the Arkona and Bornholm Basins. The Cladocera were dominated by *Bosmina* spp. and *Evadne nordmanni. Podon leuckartii* displaced *P. intermedius* as the third commonest species. *Evadne spinifera* and *E. anonyx* were observed in isolated samples from Kiel Bay for the first time. The marine species *Evadne spinifera* is rarely found in the Baltic; its presence in Kiel Bay is probably due to an inflow of saline water from the Skagerrak. *Evadne anonyx* is an invasive species in the Baltic that has probably been introduced from the Caspian Sea. No other invasive species were found.

In its seasonal development, the zooplankton community exhibited a succession of Copepod and Polychaete larvae in the winter followed by a community dominated by Rotatoria, Copepods and Cladocera in the spring and summer. In 2014, there was a very distinct seasonal increase in total abundance in the Arkona and Bornholm Basins, due mainly to the sharp increase in the concentration of *Bosmina* spp. from west to east.

High numbers of Rotatoria were observed mainly in the Arkona, Bornholm and southern Gotland Basins. Unlike 2013, they occurred only during the spring. *Oithona similis* and *Pseudo/Paracalanus* dominated the ecologically important group of Copepods in the Bays of Kiel and Mecklenburg. It was striking how the genus *Pseudocalanus* was replaced by *Paracalanus parvus* as the dominant species in the adult population. In the Arkona Basin, the concentration of Copepods at times grealty exceeded that of 2013. This increase was largely due to greater numbers of *Temora longicornis* and *Centropages hamatus* during the summer months. A shift in the composition of the dominant species was observed in the Arkona and Bornholm Basins: from *Acartia bifilosa*, *Acartia longiremis* and *Oithona similis* in 2013 to *Temora longicornis*, *Centropages hamatus* and *Acartia longiremis* in 2014.

Despite the higher zooplankton concentration in the Arkona and Bornholm Basins, in its long-term development, total zooplankton remained low and comparable with previous years. At 1.9 x 10^5 individuals m^{-3} for total plankton and 1.4 x 10^4 individuals m^{-3} for adult Calanoida, values fell short of the long-term means of 3.9 x 10^5 individuals m^{-3} and 2.49 x 10^4 individuals m^{-3} respectively.

Macrozoobenthos

This study presents the results of macrozoobenthos monitoring in the southern Baltic Sea in November 2014. The following parameters were measured: species richness, and the abundance and biomass of organisms per station. Compared to previous years, the 117 species recorded at the 8 monitoring stations were considered to be a moderate number. Long-lasting oxygen deficiency caused a loss of biodiversity and abundance at two stations in the Bay of Mecklenburg. Depending on the region, abundances varied between 183 and 10,899 ind./m². In terms of biomass, similarly high variations were observed (1.7 g in the Arkona Basin to 75.2 g AFDW/m² in Kiel Bay). Due to the high species number (24) and salinity (22.1 psu) in the central Arkona Basin, it can be assumed that a minor inflow reached the central Arkona Basin in autumn 2014, bringing some marine species with it (even before the Major Baltic Inflow of December 2014). For example, some euhaline species like the bivalves *Abra alba* and *Corbula gibba*, the polychaete *Nephtys caeca*, 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, 17 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 Bays of Kiel and Mecklenburg, for instance. Two species on the HELCOM Red List (KONTULA et al. 2013) were observed: *Macoma calcarea* (VU) and *Mya truncatula* (NT).

In line with expectations, the number of invasive species found during the 2014 sampling campaign was low: only 4 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 280 ind./m².

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ANNEX (for multi-page tables)

Table A1

The 10 most abundant phytoplankton taxa (percentage of total phytoplankton biomass) in the different sea areas (upper 10 m): averages from the three cruises 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 80-81 !

February-May	(%)	July/August	(%)	October/November	(%)
Kiel Bight (Stat. OMBMPN3)					
Phytopl. Biomass in µg/l	700	Phytopl. Biomass in µg/l	3003	Phytopl. Biomass in µg/l	1040
Dictyocha speculum	46.7	Dactyliosolen fragilissimus	88.7	Ceratium fusus	39.6
Ceratium tripos	25.3	Alexandrium pseudogonyaulax	4.3	Ceratium tripos	17.8
Rhizosolenia setigera	5.8	Cerataulina pelagica	1.6	Polykrikos schwartzii	8.7
Teleaulax	3.1	Ceratium tripos	1.4	Dinophysis norvegica	7.8
Mesodinium rubrum	2.3	Plagioselmis prolonga	0.4	Ceratium lineatum	3.3
Actinocyclus	1.9	Prorocentrum micans	0.3	Thalassiosira	2.5
Dinophysis norvegica	1.4	Proboscia alata	0.3	Protoperidinium	1.8
Protoperidinium pellucidum	1.1	Coscinodiscus radiatus	0.3	Dinophysis acuminata	1.6
Thalassiosira	1.1	Actinocyclus	0.3	Prorocentrum micans	1.4
Coscinodiscus radiatus	1.0	Prymnesiales	0.3	Teleaulax	1.3
Lübeck Bight (Stat. OMO22)					
Phytopl. Biomass in µg/l	516	Phytopl. Biomass in µg/l	4890	Phytopl. Biomass in µg/l	1119
Dictyocha speculum	62.7	Dactyliosolen fragilissimus	89.5	Ceratium fusus	39.9
Ceratium tripos	6.9	Alexandrium pseudogonyaulax	3.3	Polykrikos schwartzii	23.8
Skeletonema marinoi	6.7	Ceratium tripos	3.2	Ceratium tripos	4.9
Rhizosolenia setigera	6.0	Coscinodiscus radiatus	1.1	Dinophysis norvegica	4.4
Teleaulax	2.0	Dolichospermum	0.3	Cerataulina pelagica	2.9
Mesodinium rubrum	1.4	Plagioselmis prolonga	0.3	Dictyocha speculum	2.6
Thalassiosira	1.2	Katablepharis remigera	0.3	Teleaulax	2.5
Gyrodinium spirale	1.0	Prymnesiales	0.3	Ceratium lineatum	2.4
Protoperidinium pellucidum	0.7	Guinardia delicatula	0.2	Gyrodinium spirale	2.1
Chaetoceros curvisetus	0.6	Aphanizomenon	0.1	Dinophysis acuta	1.3
Central Mecklenburg Bay (Stat. OMBMPM2)					
Phytopl. Biomass in µg/l	444	Phytopl. Biomass in µg/l	1806	Phytopl. Biomass in µg/l	859
Dictyocha speculum	30.5	Dactyliosolen fragilissimus	73.8	Cerataulina pelagica	26.6
Ceratium tripos	21.0	Ceratium tripos	8.7	Ceratium fusus	26.0
Coscinodiscus concinnus	15.4	Alexandrium pseudogonyaulax	4.4	Ceratium tripos	13.7
Rhizosolenia setigera	5.2	Nodularia spumigena	1.8	Polykrikos schwartzii	12.3
Teleaulax	4.6	Aphanizomenon	1.7	Coscinodiscus granii	3.2
Mesodinium rubrum	3.0	Actinocyclus	1.3	Ceratium lineatum	1.8
Gyrodinium spirale	2.4	Plagioselmis prolonga	0.8	Ditylum brightwellii	1.1
Skeletonema marinoi	2.2	Prymnesiales	0.8	Teleaulax	1.0
Protoperidinium pellucidum	1.1	Katablepharis remigera	0.6	Prorocentrum micans	0.9
Chaetoceros decipiens	0.6	Guinardia delicatula	0.3	Dinophysis norvegica	0.8
Eastern Mecklenburg Bay (Stat. OMBMPM1)					
Phytopl. Biomass in µg/l	255	Phytopl. Biomass in µg/l	202	Phytopl. Biomass in µg/l	1355
Dictyocha speculum	53.9	Ceratium tripos	33.2	Coscinodiscus granii	61.0
Ceratium tripos	8.9	Nodularia spumigena	10.2	Cerataulina pelagica	20.6
Teleaulax	5.7	Aphanizomenon	7.2	Ceratium tripos	4.3
Mesodinium rubrum	5.3	Prymnesiales	6.6	Ceratium fusus	2.3

Rhizosolenia setigera	4.4	Plagioselmis prolonga	3.1	Mesodinium rubrum	1.1
Gyrodinium spirale	2.4	Katablepharis remigera	3.0	Teleaulax	1.0
Plagioselmis prolonga	0.9	Pyramimonas	2.5	Prorocentrum minimum	0.9
Actinocyclus	0.8	Cyclotella	2.5	Coscinodiscus radiatus	0.6
Thalassiosira	0.6	Alexandrium pseudogonyaulax	2.2	Pyramimonas	0.6
Katodinium rotundatum	0.4	Teleaulax	2.1	Ceratium lineatum	0.5
Western Arkona Basin (Stat. OMBMPK8)					
Phytopl. Biomass in µg/l	427	Phytopl. Biomass in µg/l	305	Phytopl. Biomass in µg/l	1185
Skeletonema marinoi	52.2	Ceratium tripos	26.6	Coscinodiscus granii	83.2
Mesodinium rubrum	16.9	Nodularia spumigena	12.3	Cerataulina pelagica	3.0
Thalassiosira	4.3	Aphanizomenon	8.3	Actinocyclus	1.8
Chaetoceros	3.4	Prymnesiales	5.7	Ceratium tripos	1.3
Dictyocha speculum	3.3	Katodinium rotundatum	5.4	Prorocentrum minimum	1.1
Chaetoceros wighamii	1.6	Actinocyclus	5.1	Ebria tripartita	1.1
Teleaulax	1.4	Plagioselmis prolonga	4.9	Teleaulax	0.9
Rhizosolenia setigera	0.9	Pseudanabaena limnetica	3.9	Coscinodiscus radiatus	0.7
Scrippsiella COMPLEX	0.8	Coscinodiscus granii	3.7	Prymnesiales	0.6
Gyrodinium spirale	0.6	Pyramimonas	3.1	Mesodinium rubrum	0.6
Central Arkona Basin (Stat. OMBMPK5)					
Phytopl. Biomass in µg/l	616	Phytopl. Biomass in µg/l	264	Phytopl. Biomass in µg/l	520
Skeletonema marinoi	50.7	Ceratium tripos	36.4	Coscinodiscus granii	74.2
Mesodinium rubrum	19.6	Pyramimonas	10.0	Ceratium tripos	5.4
Thalassiosira	8.9	Mesodinium rubrum	5.8	Actinocyclus	2.9
Chaetoceros wighamii	4.2	Nodularia spumigena	5.8	Teleaulax	2.0
Chaetoceros	1.3	Pseudanabaena limnetica	5.5	Mesodinium rubrum	1.1
Teleaulax	1.0	Plagioselmis prolonga	5.1	Plagioselmis prolonga	0.9
Actinocyclus	0.6	Teleaulax	4.8	Cerataulina pelagica	0.8
Scrippsiella COMPLEX	0.5	Aphanizomenon	4.3	Chaetoceros danicus	0.7
Achnanthes taeniata	0.5	Katodinium rotundatum	4.2	Protoperidinium	0.7
Chaetoceros ceratosporus var. ceratosporus	0.4	Actinocyclus	3.6	Ebria tripartita	0.7
Eastern Arkona Basin (Stat. OMBMPK4)					
Phytopl. Biomass in µg/l	751	Phytopl. Biomass in µg/l	203	Phytopl. Biomass in µg/l	473
Skeletonema marinoi	50.9	Ceratium tripos	17.2	Coscinodiscus granii	83.3
Mesodinium rubrum	21.6	Actinocyclus	16.5	Actinocyclus	2.7
Thalassiosira	8.2	Pseudanabaena limnetica	13.6	Coscinodiscus radiatus	2.5
Chaetoceros wighamii	6.4	Plagioselmis prolonga	7.5	Teleaulax	1.7
Actinocyclus	1.4	Teleaulax	4.6	Hemiselmis	0.8
Chaetoceros pseudobrevis	1.0	Aphanizomenon	2.7	Plagioselmis prolonga	0.7
Dictyocha speculum	1.0	Pseudopedinella	2.6	Mesodinium rubrum	0.7
Teleaulax	0.7	Pyramimonas	2.1	Dictyocha speculum	0.6
Scrippsiella COMPLEX	0.5	Mesodinium rubrum	1.9	Eutreptiella	0.4
Chaetoceros ceratosporus var. ceratosporus	0.3	Katablepharis remigera	1.3	Katodinium rotundatum	0.4
Bornholm Basin (Stat. OMBMPK2)					
Phytopl. Biomass in µg/l	786	Phytopl. Biomass in µg/l	162	Phytopl. Biomass in µg/l	1332
Mesodinium rubrum	92.5	Unicell spp.	34.9	Coscinodiscus granii	87.8
Actinocyclus	0.9	Actinocyclus	11.2	Actinocyclus	6.2
Katodinium glaucum	0.7	Prymnesiales	10.5	Mesodinium rubrum	0.9
Prymnesiales	0.5	Mesodinium rubrum	7.1	Teleaulax	0.8
Teleaulax	0.5	Pseudanabaena limnetica	5.5	Plagioselmis prolonga	0.5
Dinophysis acuta	0.3	Plagioselmis prolonga	5.1	Katodinium rotundatum	0.3
Coscinodiscus radiatus	0.3	Cyanonephron styloides	3.6	Hemiselmis	0.3
Dinobryon balticum	0.3	Teleaulax	3.6	Eutreptiella	0.2
Thalassiosira	0.2	Nodularia spumigena	2.8	Prymnesiales	0.2
Plagioselmis prolonga	0.2	Pyramimonas	1.9	Pyramimonas	0.2

Southern Gotland Basin (Stat. OMBMPK1)					
Phytopl. Biomass in µg/l	996	Phytopl. Biomass in µg/l	332	Phytopl. Biomass in µg/l	552
Mesodinium rubrum	89.0	Prymnesiales	17.9	Coscinodiscus granii	70.3
Dinophysis acuta	2.3	Unicell spp.	16.2	Actinocyclus	21.5
Actinocyclus	1.7	Cyanonephron styloides	15.1	Teleaulax	1.9
Peridiniella catenata	1.2	Pyramimonas	8.0	Gymnodiniales	1.5
Gyrodinium spirale	0.6	Mesodinium rubrum	7.5	Plagioselmis prolonga	0.8
Amylax triacantha	0.6	Aphanizomenon	5.9	Coscinodiscus radiatus	0.7
Teleaulax	0.5	Plagioselmis prolonga	5.7	Mesodinium rubrum	0.6
Prymnesiales	0.4	Teleaulax	4.4	Chaetoceros danicus	0.4
Dinophysis acuminata	0.3	Nodularia spumigena	3.8	Pyramimonas	0.2
Nodularia spumigena	0.3	Aphanothece	2.9	Hemiselmis	0.2
Eastern Gotland Basin (Stat. OMBMPJ1)					
Phytopl. Biomass in µg/l	508	Phytopl. Biomass in µg/l	1184	Phytopl. Biomass in µg/l	496
Mesodinium rubrum	84.1	Nodularia spumigena	46.4	Coscinodiscus granii	67.3
Peridiniella catenata	2.4	Prymnesiales	15.5	Mesodinium rubrum	14.2
Scrippsiella COMPLEX	2.1	Aphanizomenon	10.8	Dinophysis norvegica	5.0
Actinocyclus	1.5	Aphanothece	3.0	Dinophysis acuta	1.3
Teleaulax	1.0	Aphanocapsa	2.0	Prymnesiales	1.2
Aphanizomenon	0.8	Plagioselmis prolonga	1.9	Plagioselmis prolonga	0.9
Coscinodiscus granii	0.7	Pyramimonas	1.6	Katodinium rotundatum	0.8
Amylax triacantha	0.5	Aphanothece paralleliformis	1.5	Teleaulax	0.8
Peridiniella danica	0.3	Cyanonephron styloides	1.4	Katablepharis remigera	0.6
Plagioselmis prolonga	0.3	Pseudanabaena limnetica	1.0	Eutreptiella	0.5

Table A2

Phytoplankton taxa list of 2014, with class affiliation, biomass rank (for all stations including central Baltic, all depths) and seasonal occurrence from the five monitoring cruises.

Continued on page 83-85.

Artname (Gesamtliste)	Klasse	Rang	Feb.	März	April/Mai	Juli	Nov.
Achnanthes taeniata	Bacillarioph.	78		X			
Actinocyclus sp.	Bacillarioph.	10	X	X	X	X	X
Alexandrium pseudogonyaulax	Dinophyceae	23				X	
Amphidinium crassum	Dinophyceae	103				X	X
Amphidinium sphenoides	Dinophyceae	101	X	X	X	X	X
Amylax triacantha	Dinophyceae	63		X	X	X	
Anabaenopsis sp.	Cyanobact.	147				X	
Apedinella radians	Chrysophyc.	91	X	X		X	X
Aphanizomenon sp.	Cyanobact.	24	X	X	X	X	
Aphanocapsa spp.	Cyanobact.	37	X	X	X	X	X
Aphanothece paralleliformis	Cyanobact.	71	X	X	X	X	X
Anathece spp.	Cyanobact.	57	X		X	X	
Attheya septentrionalis	Bacillarioph.	97	X	X		X	X
Botryococcus spp.	Chlorophyc.	135	X			X	
Calliacantha spp.	Craspedoph.	149		X			
Centrales	Bacillarioph.	72	X		X	X	X
Cerataulina pelagica	Bacillarioph.	9		X		X	X
Ceratium fusus	Dinophyceae	11	X	X		X	X
Ceratium lineatum	Dinophyceae	38	X	X			X
Ceratium longipes	Dinophyceae	61		X		X	X
Ceratium tripos	Dinophyceae	6	X	X	X	X	X
Chaetoceros affinis	Bacillarioph.	90				X	
Chaetoceros brevis	Bacillarioph.	74		X			
Chaetoceros ceratosporus	Bacillarioph.	81		X			
Chaetoceros circinalis	Bacillarioph.	131				X	
Chaetoceros contortus	Bacillarioph.	114				X	X
Chaetoceros convolutus	Bacillarioph.	117					X
Chaetoceros curvisetus	Bacillarioph.	77	X	X	X	X	X
Chaetoceros danicus	Bacillarioph.	60	X	X	X	X	X
Chaetoceros debilis	Bacillarioph.	132		X	X		
Chaetoceros decipiens	Bacillarioph.	86		X			X
Chaetoceros impressus	Bacillarioph.	46	X	X	X	X	X
Chaetoceros lorenzianus	Bacillarioph.	121		X			
Chaetoceros pseudobrevis	Bacillarioph.	84		X			
Chaetoceros similis	Bacillarioph.	109	X	X	X	X	X
Chaetoceros socialis	Bacillarioph.	108		X		X	X
Chaetoceros spp.	Bacillarioph.	30	X	X	X	X	X
Chaetoceros subtilis	Bacillarioph.	116		X		X	

Artname (Gesamtliste)	Klasse	Rang	Feb.	März	April/Mai	Juli	Nov.
Chaetoceros throndsenii	Bacillarioph.	139				X	
Chaetoceros wighamii	Bacillarioph.	19		X			
Chrysophyceae	Chrysophyc.	65	X		X	X	X
Cladopyxis claytonii	Dinophyceae	76	X	X	X	X	X
Cocconeis sp.	Bacillarioph.	144				X	
Coelosphaerium minutissimum	Cyanobact.	80			X	X	
Coscinodiscus concinnus	Bacillarioph.	7	X	X	X		
Coscinodiscus granii	Bacillarioph.	2				X	X
Coscinodiscus radiatus	Bacillarioph.	22	X	X	X	X	X
Craspedophyceae	Craspedoph.	58	X	X	X	X	X
Cyanodictyon planctonicum	Cyanobact.	88			X	X	
Cyanonephron styloides	Cyanobact.	47			X	X	
Cyclotella spp.	Bacillarioph.	54				X	X
Cylindrotheca closterium	Bacillarioph.	112	X	X		X	X
Cymbomonas tetramitiformis	Prasinophyc.	98			X	X	X
Dactyliosolen fragilissimus	Bacillarioph.	3	X	X	X	X	X
Desmodesmus communis	Chlorophyc.	138	X				
Detonula confervacea	Bacillarioph.	89	X	X			
Diatoma tenuis	Bacillarioph.	143		X			
Dictyocha speculum	Dictyochoph.	5	X	X	X	X	X
Dinobryon balticum	Chrysophyc.	82	X	X	X		
Dinobryon faculiferum	Chrysophyc.	113		X	X	X	
Dinobryon spp.	Chrysophyc.	126		X		X	
Dinophysis acuminata	Dinophyceae	53	X	X	X	X	X
Dinophysis acuta	Dinophyceae	35			X		X
Dinophysis norvegica	Dinophyceae	20	X	X	X	X	X
Dinophysis rotundata	Dinophyceae	118					X
Dissodinium pseudolunula	Dinophyceae	110				X	X
Ditylum brightwellii	Bacillarioph.	56		X			X
Dolichospermum spp.	Cyanobact.	69				X	
Ebria tripartita	Ebriophyc.	36	X	X	X	X	X
Euglenales	Euglenoph.	145		X			
Eutreptiella braarudii	Euglenoph.	94	X	X			
Eutreptiella spp.	Euglenoph.	43	X	X	X	X	X
Guinardia delicatula	Bacillarioph.	34	X	X	X	X	X
Gymnodiniales	Dinophyceae	8	X	X	X	X	X
Gyrodinium spirale	Dinophyceae	25	X	X	X	X	X
Gyrodinium spp.	Dinophyceae	123		X			
Hemiselmis sp.	Dinophyceae	48	X	X	X	X	X
Heterocapsa rotundata	Dinophyceae	29	X	X	X	X	X
Heterocapsa triquetra	Dinophyceae	130				X	X
Katablepharis remigera	Incertae sedis	39	X	X	X	X	X
Katablepharis sp.	Incertae sedis	124		X			
Katodinium glaucum	Dinophyceae	41	X	X	X	X	X
Koliella spp.	Chlorophyc.	148	X				
Laboea strobila	Oligotrichea	83	X	X	X	X	X
Lemmermanniella pallida	Cyanobact.	99	X		X	X	
Lemmermanniella parva	Cyanobact.	122				X	
Lennoxia faveolata	Bacillarioph.	129			X	X	

Artname (Gesamtliste)	Klasse	Rang	Feb.	März	April/Mai	Juli	Nov.
Leptocylindrus danicus	Bacillarioph.	146				X	
Leptocylindrus minimus	Bacillarioph.	128				X	
Leucocryptos marina	Incertae sedis	64	X	X	X	X	X
Licmophora sp.	Bacillarioph.	142			X		
Melosira arctica	Bacillarioph.	106		X			
Merismopedia punctata	Cyanobact.	141					X
Merismopedia spp.	Cyanobact.	119	X		X		X
Mesodinium rubrum	Litostomatea	1	X	X	X	X	X
Microcystis wesenbergii	Cyanobact.	140	X				
Monoraphidium contortum	Chlorophyc.	125	X	X	X	X	X
Monoraphidium minutum	Chlorophyc.	150	X				
Nitzschia paleacea	Bacillarioph.	104				X	X
Nodularia spumigena	Cyanobact.	15			X	X	
Oocystis spp.	Chlorophyc.	87	X	X	X	X	
Pennales	Bacillarioph.	105	X	X	X	X	X
Peridiniales	Dinophyceae	32	X	X	X	X	X
Peridiniella catenata	Dinophyceae	31	X	X	X		
Peridiniella danica	Dinophyceae	50		X	X		
Plagioselmis prolonga	Cryptophyc,	21	X	X	X	X	X
Planctonema lauterbornii	Chlorophyc.	79	X	X	X	X	X
Planktolyngbya spp.	Cyanobact.	127				X	
Polykrikos schwartzii	Dinophyceae	17		X			X
Proboscia alata	Bacillarioph.	26	X			X	X
Prorocentrum micans	Dinophyceae	44	X	X		X	X
Prorocentrum minimum	Dinophyceae	51		X	X	X	X
Protoperidinium bipes	Dinophyceae	136		X		X	
Protoperidinium divergens	Dinophyceae	75					X
Protoperidinium pallidum	Dinophyceae	92		X			
Protoperidinium pellucidum	Dinophyceae	42		X	X		
Protoperidinium spp.	Dinophyceae	40	X	X	X	X	X
Protoperidinium steini	Dinophyceae	115		X			
Prymnesiales	Prymnesioph.	18	X	X	X	X	X
Pseudanabaena limnetica	Cyanobact.	33	X			X	X
Pseudo-nitzschia delicatissima group	Bacillarioph.	137				X	
Pseudo-nitzschia pungens	Bacillarioph.	62		X		X	X
Pseudo-nitzschia seriata group	Bacillarioph.	111				X	X
Pseudo-nitzschia spp.	Bacillarioph.	100				X	X
Pseudopedinella spp.	Chrysophyc.	59	X	X	X	X	X
Pterosperma spp.	Prasinophyc.	93		X		X	X
Pyramimonas spp.	Prasinophyc.	28	X	X	X	X	X
Rhizosolenia hebetata f. *semispina*	Bacillarioph.	68	X	X			
Rhizosolenia pungens	Bacillarioph.	45				X	X
Rhizosolenia setigera	Bacillarioph.	16	X	X		X	X
Romeria spp.	Cyanobact.	120				X	
Scenedesmus spp.	Chlorophyc.	134	X				
Scrippsiella complex	Dinophyceae	27	X	X	X	X	X
Skeletonema marinoi	Bacillarioph.	4	X	X	X	X	X
Skeletonema subsalsum	Bacillarioph.	133	X				
Snowella spp.	Cyanobact.	70	X	X	X	X	X

Artname (Gesamtliste)	Klasse	Rang	Feb.	März	April/Mai	Juli	Nov.
Spatulodinium pseudonoctiluca	Dinophyceae	96					X
Teleaulax spp.	Cryptophyc,	13	X	X	X	X	X
Telonema spp.	Incertae sedis	52	X	X	X	X	X
Tetrastrum spp.	Chlorophyc.	102	X		X		X
Thalassionema nitzschioides	Bacillarioph.	73	X	X	X	X	X
Thalassiosira anguste-lineata	Bacillarioph.	85		X			
Thalassiosira baltica	Bacillarioph.	95	X	X			
Thalassiosira eccentrica	Bacillarioph.	66				X	X
Thalassiosira hyperborea	Bacillarioph.	107		X			
Thalassiosira punctigera	Bacillarioph.	55	X		X	X	X
Thalassiosira spp.	Bacillarioph.	12	X	X		X	X
Trachelomonas spp.	Euglenoph.	67	X	X		X	X
Unidentified	-	14	X	X	X	X	X
Unidentified flagellata	-	49	X	X	X	X	X
Anzahl der Taxa: insgesamt 150			80	97	72	105	89

Table A3
Seasonal occurrence of taxa found in the investigation area in 2014 with information on original description, taxonomic rank and serial number according to the Integrated Taxonomic Information System (ITIS).

	Rang	TSN	Feb	März	Mai	Aug	Nov
Protozoa							
Tintinnidae	Familie	46743		o	o	o	o
Annelida							
Polychaeta - Trochophora	Unterstamm	914166	o	o	o	o	o
Polychaeta - others	Unterstamm	914166	o	o	o	o	o
Harmothoe spp. Kinberg, 1855	Gattung	64502	o	o	o	o	o
Arthropoda - Crustacea							
Copepoda							
Acartia bifilosa Giesbrecht, 1881	Art	86095	o	o	o	o	o
Acartia longiremis Lilljeborg, 1853	Art	86087	o	o	o	o	o
Acartia tonsa Dana, 1849	Art	86088	o	o	o	o	o
Calanus spp. Leach, 1819	Art	85263	o	o	o		o
Calanus helgolandicus (Claus, 1863)	Art	85276		o			
Centropages hamatus Lilljeborg, 1853	Art	85766	o	o	o	o	o
Eurytemora affinis Poppe, 1880	Art	85863	o	o	o	o	o
Euterpina acutifrons Dana, 1849	Art	86546			o		
Limnocalanus macurus G.O. Sars 1863	Art	85775	o	o			o
Microsetella spp. Brady & Robertson, 1873	Gattung	86208	o	o	o	o	o
Oithona similis Claus, 1866	Art	88805	o	o	o	o	o
Paracalanus parvus Claus, 1863	Art	85323	o	o	o	o	o
Pseudocalanus spp. Boeck, 1872	Gattung	85369	o	o	o	o	o
Temora longicornis O.F.Müller, 1785	Art	85877	o	o	o	o	o
Phyllopoda							
Bosmina spp. Baird, 1845	Gattung	83936		o	o	o	o
Evadne nordmanni Lovén, 1836	Art	86546	o	o	o	o	o
Evadne anonyx G.O. Sars, 1897	Art			o			
Evadne spinifera P. E. Müller, 1867	Art	83964				o	
Podon intermedius Lilljeborg, 1853	Art	83965				o	o
Podon leuckartii G. O. Sars, 1862	Art	83966	o	o	o	o	o
Pleopsis polyphaemoides (Leuckart,1859)	Art	684626		o	o	o	o
other Crustacea							
Crangon crangon Linnaeus, 1758	Art	107552				o	
Carcinus maenas Linnaeus, 1758	Art	107381				o	
Gammaridea Latreille, 1802	Unterordnung	93295	o		o		
Balanus spp. Da Costa, 1778	Gattung	89600	o	o	o	o	o

Table A3 continued.

	Rang	TSN	Feb	März	Mai	Aug	Nov
Bryozoa							
Gymnolaemata Allman, 1856	Class	155471	o	o	o	o	o
Chaetognatha							
Sagittidae Claus and Grobben, 1905	Familie	158726	o	o			o
Chordata							
Fritellaria borealis Lohmann, 1896	Art	159675	o	o	o	o	o
Oikopleura dioica Fol 1872	Art	159669	o	o		o	o
Teleostei	Infraklasse	161105	o	o	o	o	
Echinodermata							
Asterias spp. Linnaeus, 1758	Gattung	157215					o
Ophiura spp. Lamarck, 1801	Gattung	157411				o	
Cnidaria & Ctenophora							
Ctenophora Eschscholtz, 1829	Stamm	53856	o	o			
Aurelia aurita Linnaeus, 1758	Art	51701		o			
Rathkea octopunctata M. Sars, 1835	Art	49387		o			
Euphysa aurata Forbes, 1848	Art	48976				o	o
Steenstrupia natans (M. Sars, 1835)	Art	48970				o	
Phoronida							
Phoronis muelleri Selys-Longchamps, 1903	Art	206663				o	
Platyhelminthes							
Alaurina spp. Metschnikoff, 1861	Art	54024	o	o		o	o
Acoelomorpha	Unterstamm	914172		o			
Molluska							
Bivalvia Linnaeus, 1758	Klasse	79118	o	o	o	o	o
Gastropoda Cuvier, 1797	Klasse	69459	o	o	o	o	o
Rotifera							
Synchaeta spp. Ehrenberg, 1832	Gattung	59255	o	o	o	o	o
Keratella quadrata O. F. Muller, 1786	Art	58352				o	o
Keratella cochlearis Gosse, 1851	Art	58360				o	
Keratella cruciformis Thompson, 1892	Art	58349					o

Table A4:

Distribution of macrozoobenthos at 8 stations in November 2014. In the right column the red list (RACHOR et al. 2014) 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).

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL2013
Amphipoda									
Caprella linearis	1								V
Corophium volutator								1	*
Crassicorophium crassicorne	1				1				*
Gammarus oceanicus					1		1		*
Gammarus salinus					1		1	1	*
Gammarus zaddachi							1		*
Pontoporeia femorata						1	1		V
Anthozoa									
Edwardsia danica	1			1					D
Sagartia sp.		1							nb
Ascidiacea									
Dendrodoa grossularia	1	1							V
Molgula manhattensis	1								D
Bivalvia									
Abra alba	1	1		1		1			*
Arctica islandica	1	1	1	1		1			3
Astarte borealis	1	1		1	1				G
Astarte elliptica	1	1				1			G
Astarte montagui	1								3
Cerastoderma glaucum							1	1	*
Corbula gibba	1	1	1	1		1			*
Hiatella arctica	1								*
Kurtiella bidentata	1	1		1					*
Macoma balthica				1	1	1	1	1	*
Macoma calcarea	1			1					1
Musculus discors	1								G
Musculus niger	1								G
Musculus subpictus	1								G
Mya arenaria					1		1	1	*
Mya truncata	1								2
Mytilus edulis	1	1		1	1		1	1	*
Parvicardium pinnulatum	1	1							D
Parvicardium scabrum	1								D
Phaxas pellucidus	1	1							*
Bryozoa									
Alcyonidium polyoum							1		D
Einhornia crustulenta			1		1	1	1	1	*
Electra pilosa		1							*
Eucratea loricata			1	1					V
Farrella repens	1								D
Flustra foliacea		1							*

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL2013
Cirripedia									
Amphibalanus improvisus							1	1	nb
Balanus crenatus		1							*
Cumacea									
Diastylis rathkei	1	1	1	1	1	1	1		*
Eudorellopsis deformis	1	1							*
Decapoda									
Carcinus maenas					1				*
Crangon crangon	1				1	1	1	1	*
Palaemon elegans					1				*
Rhithropanopeus harrisii								1	nb
Echinodermata									
Asterias rubens	1				1				*
Echinocyamus pusillus	1								G
Ophiura albida	1	1				1			*
Psammechinus miliaris	1								*
Gastropoda									
Aporrhais pespelecani	1								G
Buccinum undatum	1								2
Neptunea antiqua	1								G
Odostomia scalaris					1				*
Onoba semicostata		1							*
Peringia ulvae	1			1	1			1	*
Philine aperta	1								*
Retusa obtusa		1			1				*
Retusa truncatula	1	1							*
Hydrozoa									
Hartlaubella gelatinosa					1		1	1	D
Isopoda									
Jaera albifrons							1		*
Mysida									
Gastrosaccus spinifer	1				1				nb
Mysis mixta					1	1	1	1	nb
Neomysis integer					1	1	1		nb
Nemertea									
Lineus ruber	1			1	1				nb
Malacobdella grossa		1							nb
Nemertea	1		1		1				nb
Tubulanus polymorphus	1								nb
Oligochaeta									
Tubificidae		1	1		1		1	1	nb
Tubificoides benedii	1			1	1		1	1	*
Phoronida									
Phoronis sp.	1	1							nb
Polychaeta									
Alitta succinea					1	1		1	D
Ampharete acutifrons	1					1			*
Ampharete baltica	1	1			1	1			*

Taxa	N3	N1	M2	OM18	K8	K4	K3	OM160	RL2013
Arenicola marina					1				*
Aricidea suecica	1	1			1				*
Bylgides sarsi		1			1	1			*
Capitella capitata		1	1		1				*
Dipolydora quadrilobata	1	1		1	1	1			*
Eteone longa	1				1	1			*
Euchone papillosa	1								2
Eumida sanguinea	1								*
Exogone naidina	1								D
Flabelligera affinis	1								D
Harmothoe imbricata					1				D
Harmothoe impar	1				1				*
Hediste diversicolor		1						1	*
Heteromastus filiformis	1	1	1						*
Lagis koreni	1	1	1	1	1				*
Laonome kroyeri	1								D
Marenzelleria neglecta								1	nb
Marenzelleria viridis					1		1	1	nb
Nephtys caeca	1	1				1			*
Nephtys ciliata	1	1				1			*
Nephtys hombergii	1	1	1	1		1			*
Nereimyra punctata	1	1							G
Nicolea zostericola	1								*
Notomastus latericeus			1						*
Paradoneis eliasoni	1								*
Paraonis fulgens			1						*
Pherusa plumosa	1	1							D
Pholoe assimilis	1								D
Phyllodoce mucosa	1	1			1	1			*
Prionospio steenstrupi		1							*
Pseudopolydora antennata					1				D
Pseudopolydora pulchra	1	1							*
Pygospio elegans	1				1		1	1	*
Scalibregma inflatum	1								G
Scoloplos armiger	1	1			1	1			*
Spio goniocephala					1				*
Streblospio shrubsolii								1	V
Terebellides stroemii	1	1							*
Travisia forbesii					1				G
Trochochaeta multisetosa						1			D
Porifera									
Chalinula limbata		1							D
Haliclona oculata		1							D
Priapulida									
Halicryptus spinulosus							1		nb
Priapulus caudatus								1	nb
number of taxa 117	**69**	**43**	**13**	**17**	**42**	**24**	**22**	**22**	
Abundance (ind./m²)	**10899**	**2136**	**183**	**358**	**1904**	**425**	**2630**	**8486**	
Biomass (AFDW g/m²)	**75,2**	**54,5**	**11,2**	**20,6**	**9,5**	**1,7**	**4,7**	**3,8**	

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CONTENT

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