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### Biological assessment of the Baltic Sea 2020

Jörg Dutz, Anke Kremp, Michael L. Zettler

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Schriftleitung / Editorship: Dr. Sandra Kube ([sandra.kube@io-warnemuende.de](mailto:sandra.kube@io-warnemuende.de))

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Adresse der Autoren:

<sup>1</sup> Leibniz Institute for Baltic Sea Research (IOW), Seestraße 15, D-18119 Rostock-Warnemünde, Germany

Corresponding author: [joerg.dutz@io-warnemuende.de](mailto:joerg.dutz@io-warnemuende.de)

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## Abstract

In 2020, a total of 153 **phytoplankton** species were recorded on 4 annual monitoring cruises reported here, marking a species diversity comparable to previous years. Mean annual phytoplankton biomass was lower in 2020 than in 2018 and 2019, but close to the 20-year mean. The spring bloom of 2020 was represented by only two cruises, taking place in February and May, thus missing the peak of the bloom season that is usually captured by the March cruise. As in previous years, in 2020 a diatom dominated spring bloom started in February at the southernmost station in Kiel Bight. While “travelling” successively northward, dominance changed from diatoms (*Skeletonema marinoi*) to the ciliate *Mesodinium rubrum*. By May, the now dinoflagellate dominated bloom was already declining. The late spring community contained high biomass shares of small, unidentified gymnodinoids as well as colonial cyanobacteria. The summer phytoplankton community was unusual in 2020 as in the Belt Sea and the Arkona Basin it contained high biomass shares of the diatom *Dactyosolen fragilissimus*. The toxic invasive dinoflagellate *Alexandrium pseudogonyaulax* was a dominant species in the Belt Sea. Cyanobacteria dominated the northern Basins, but total phytoplankton biomass was, generally low. The phytoplankton growth period extended well into the autumn when high biomass levels were found in the southern sea areas, made by diatoms of the genera *Pseudosolenia*, *Cerataulina* and potentially toxic *Pseudo-nitzschia* spp. The 2020 phytoplankton sedimentation pattern was similar to the previous year with diatoms dominating the settling matter in spring and autumn and dinoflagellate/cyanobacteria sedimentation pulses occurring in summer.

The **zooplankton** was characterized by a low stock size which continued a series of years of low stock size that started around 2010. This decline is primarily based on a decreasing abundance of rotifers in spring and cladocerans in autumn, and to a lesser degree on copepods. While the abundance of copepods was lower than usual in the Kiel Bight in 2020, cladocerans and rotifers were less abundant than usual in the Bay of Mecklenburg and the Arkona Basin. The total zooplankton density of  $4.8 \times 10^4$  ind.  $m^{-3}$  was the lowest value recorded since 20 years and accounts for only 1/6 of the long-term average. Due to the low abundance of rotifers and cladocerans, copepods dominated the zooplankton in all areas, with *A. longiremis* as a major species. In total, fifty-four different zooplankton taxa were identified in the Kiel Bight, the Bay of Mecklenburg and the Arkona Basin. The species composition resembled the inventory of the previous year with a strong influence of species with a broad salinity tolerance and characteristic of the brackish waters. Nevertheless, halophilic organisms like the copepods *Calanus* spp., *Centropages typicus* or the cladoceran *Penilia avirostris* were regularly observed albeit as single findings. The anthomedusae *Lizzia blondina* and *Staurosarsia gemmifera* are non-indigenous species and were found in the Bay of the Mecklenburg.

The 118 species found in the **macrozoobenthos** in 2020 mark a low to medium diversity. The species number found at the eight monitoring stations ranged between 10 and 66. In most regions, the oxygen supply in bottom waters in the current year was always higher than 2 ml/l. However, in the Mecklenburg Bay we detected oxygen values below 0.5 ml/l in September. After a dramatic decrease of diversity and abundance in the Fehmarnbelt area in 2018, a complete

recovering was observed in 2019 and 2020. During the autumn sampling in 2020, the benthic fauna appeared to be affected by the oxygen situation of that year's summer. At both stations, very low numbers were observed. At all other stations the diversity was similar or slightly increased compared to the last years. Depending on the region, the abundances ranged from 293 to 16.230 ind. m<sup>-2</sup>, and the biomass (ash free dry weight) from 0.9 g m<sup>-2</sup> to 66.4 g m<sup>-2</sup>. Seventeen species of the German Red List (Categories 1, 2, 3 and G) were observed at the eight monitoring stations. With seven, the number of invasive species in 2020 was low. *Melita nitida*, a species of amphipod, originally from North America and arriving in the southern Baltic Sea around 2013, was observed for the first time at the monitoring station in the Pomeranian Bay. *Rhithropanopeus harrisi*, also originally from North America, can be observed at the Oderbank since 2006. Finally, as a cryptic neozoan species, the ascidian *Molgula manhattensis* was observed in the Kiel Bay.

## 1 Introduction

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

The biological monitoring is one element of the international environmental monitoring programme of the Helsinki Commission (HELCOM) in which the IOW's predecessor institute had participated since its launch in 1979. Besides marine biology, the monitoring programme includes an extensive programme of hydrographic and chemical investigations (NAUMANN et al. 2021). The establishment of the IOW in 1992 assured the continuance of re-unified Germany's contribution to the HELCOM Monitoring Programme. International monitoring results are collected, discussed and published by HELCOM Periodic Assessments (HELCOM 1987, 1990, 1996, 2002). Moreover, specialized Thematic Assessments are published, for example on the influence of climatic change (HELCOM 2013a), endangered species (HELCOM 2013b) and eutrophication (HELCOM 2014, HELCOM 2018a). In a similar manner, short reports known as the 'Baltic Sea Environment Fact Sheets' (formerly 'Indicator Fact Sheets') are published annually (e.g. ÖBERG 2017, WASMUND et al. 2018a).

On a national level, the German coastal states coordinate their measurements in the 'Arbeitsgemeinschaft Bund/Länder-Messprogramm Nord- und Ostsee' (BLANO). The collected data are transferred annually to ICES (International Council for the Exploration of the Sea, see <http://www.ices.dk/indexnofla.asp>) via the national database MUDAB (<https://geoportal.bafg.de/MUDABAnwendung/>). One of the main tasks is the national coordination of the contributions to the EU's Marine Strategy Framework Directive (MSFD) (see [www.meeresschutz.info/msrl.html](http://www.meeresschutz.info/msrl.html)). The MSFD (EUROPEAN UNION 2008; Directive 2008/56/EG) creates the regulatory framework for the necessary measures in all EU member states to achieve or maintain the 'good environmental status' in all European waters by 2020.

In order to determine the 'good environmental status', HELCOM relies on indicators. Members of the Biological Oceanography section of the IOW have been involved in the development or at least contributing to the following HELCOM 'Core' and 'Pre-core' indicators in connection with descriptors for biodiversity (D1), non-native species (D2), food web (D4) or eutrophication (D5); see for example HELCOM (2013c, 2020):

- Zooplankton mean size and biomass
- State of the soft-bottom macrofauna communities
- Trends in arrival of new non-indigenous species
- Chlorophyll-a
- Diatom/Dinoflagellate Index
- Seasonal succession of dominating phytoplankton groups
- Cyanobacterial bloom Index

These indicators are applied on the international (HELCOM) and/or national level for the evaluation of the status of the marine environment. The monitoring data collected by IOW provide a solid basis to develop some of these indicators and to assess the state of the environment in the frame of 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 2020 hydrographic-hydrochemical assessment of the Baltic Sea that has already been published (NAUMANN et al. 2021).

Dr. ANKE KREMP wrote the chapters on phytoplankton, chlorophyll and sedimentation; Dr. JÖRG DUTZ wrote the chapter on zooplankton; Dr. MICHAEL L. ZETTLER wrote the chapter on macrozoobenthos.

## 2 Material and Methods

### 2.1 Sampling Strategy

The tasks undertaken by IOW in the monitoring programme are prescribed by the BSH (Bundesamt für Seeschifffahrt und Hydrographie), and they follow the 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. The methods are set out in the HELCOM COMBINE manual (HELCOM 2017a). Fig. 1 shows the locations of the biological monitoring stations. They are labelled 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 internal IOW station numbers are given in Table 1.

Five cruises represent different phases of the growth season and were, in 2020, conducted in February (29.01. - 10.02., referred to as TF0220), March (17.03. - 27.03., TF0320), May (05.05. - 15.05., TF0520), August (17.07. - 30.05., TF0720) and November (12.11. - 23.11., TF1120).

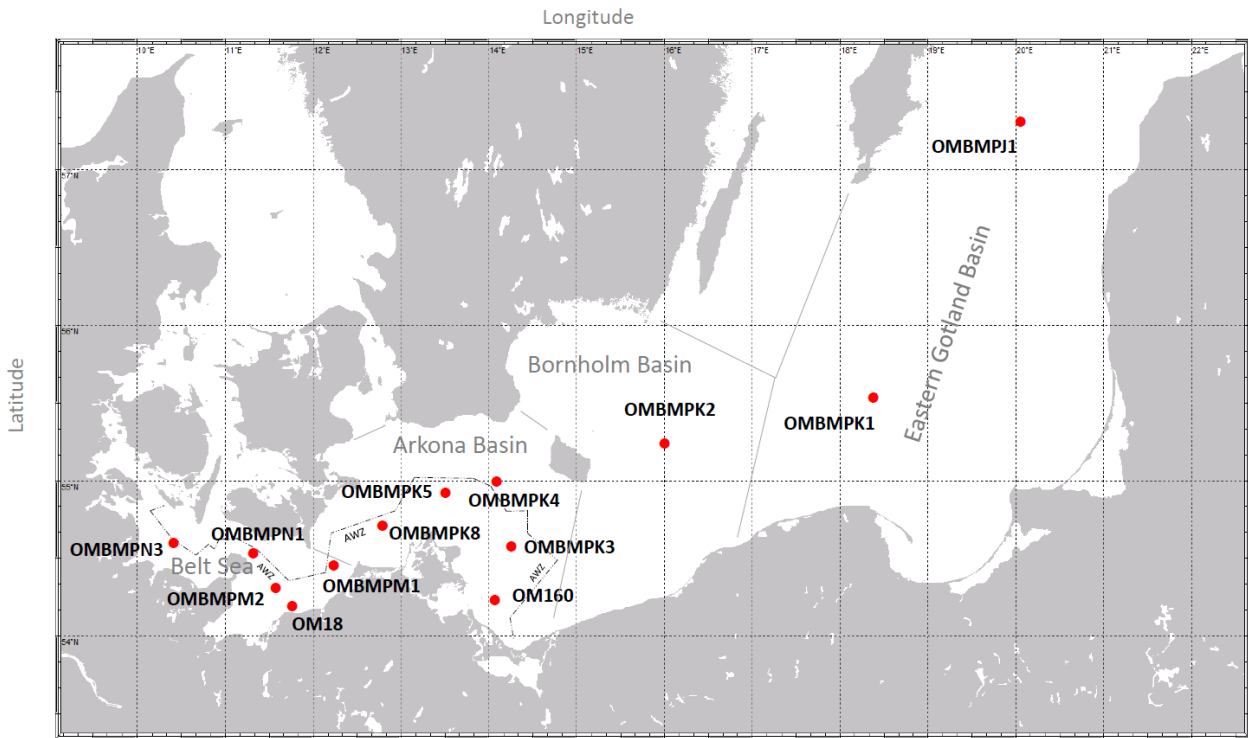
Within the regular monitoring programme, plankton samples should be collected both on outbound (northward) and inbound (southward) tracks of the cruises, if possible. There is a lag of about 7 to 12 days between sampling at a given station during outbound and inbound (return) journey. Five cruises yield a maximum of 10 samples per station per year. Samples at stations OMBMPN<sub>3</sub> (Kiel Bay), OMBMPK<sub>4</sub> (Arkona Basin) and OMBMPK<sub>1</sub>/OMBMPJ<sub>1</sub> (Eastern Gotland Basin) are taken on the outward leg only.

Sediment traps are installed in the Arkona Basin sampling area near station OMBMPK<sub>5</sub> (see station AB in Fig. 1).

Zooplankton samples are generally taken at five stations in the German Exclusive Economic Zone (EEZ) during outward and return journeys on the scheduled cruises (Table 1). In 2020, however, bad weather conditions in February and the cancellation of the March cruise due to the COVID-19 lockdown reduced the number of the samples. Due to strong winds in November 2020, sampling could not be conducted on the return journey at stations OMBMPM<sub>2</sub> and OMBMPM<sub>1</sub> (Bay of Mecklenburg) in February and OMBMPK<sub>5</sub> (Arkona Basin).

Samples of macrozoobenthos are usually collected at eight stations once a year. In 2020, sampling was conducted in November (see Table 1 and Table 3).





*Fig. 1: Station grid for biological sampling in the Baltic Sea with depiction of the border of the Exclusive Economic Zone Germany (AWZ) and the borders between the main HELCOM basins.*

## 2.2 Chlorophyll a

As chlorophyll a represents a share of the biomass of all plant cells, including phytoplankton, its concentration is indicative of the total biomass of phytoplankton. For rough estimates, 1 mg chlorophyll *a* equates to 50 mg of algal organic carbon as assumed by EILOLA et al. (2009) and HOPPE et al. (2013) in the Baltic Sea. Nevertheless, this relationship can be highly variable depending on season, phytoplankton physiological status, bloom phase and environmental conditions (LIPS et al. 2014, SPILLING et al. 2014, PACZKOWSKA et al. 2017). Therefore, a conversion is usually not done, and the concentration of chlorophyll a is used directly as parameter describing phytoplankton bulk biomass or production.

Table 1: Sampling statistics (number of sampling events) for the different parameters specified for regular monitoring stations in 2020 (Chl = Chlorophyll *a*, PP = Phytoplankton, ZP = Zooplankton; B = Benthos).

Station number	IOW-station number	Latitude	Longitude	Sea area	Chl	PP	ZP	B
<b>Belt Sea</b>								
OMBMPN <sub>3</sub>	TF0360	54°36,0'N	10°27,0'E	Kiel Bay	4	4	4	1
OMBMPN <sub>1</sub>	TF0010	54°33,1'N	11°19,2'E	Fehmarnbelt	-	-	-	1
OMBMPM <sub>2</sub>	TF0012	54°18,9'N	11°33,0'E	Bay of Mecklenburg	7	7	7	1
OM18	TF0018	54°11,0'N	11°46,0'E	Bay of Mecklenburg	-	-	-	1
OMBMPM <sub>1</sub>	TF0046	54°28,0'N	12°13,0'E	Bay of Mecklenburg	7	7	7	-
<b>Arkona Basin</b>								
OMBMPK <sub>8</sub>	TF0030	54°43,4'N	12°47,0'E	Arkona Basin, west	4	5	-	1
OMBMPK <sub>5</sub>	TF0113	54°55,5'N	13°30,0'E	Arkona Basin, central	7	7	7	-
OMBMPK <sub>4</sub>	TF0109	55°00,0'N	14°05,0'E	Arkona Basin east	4	6	4	1
<b>Pomeranian Bay</b>								
OMBMPK <sub>3</sub>	TF0152	54°38,0'N	14°17,0'E	Pomeranian Bay	-	-	-	1
OM160	TF0160	54°14,4'N	14°04,1'E	Pomeranian Bay	-	-	-	1
<b>Bornholm Basin</b>								
OMBMPK <sub>2</sub>	TF0213	55°15,0'N	15°59,0'E	Bornholm Basin	6	6	-	-
<b>Gotland Basin</b>								
OMBMPK <sub>1</sub>	TF0259	55°33,0' N	18°24,0' E	Eastern Gotland Basin	3	3	-	-
OMBMPJ <sub>1</sub>	TF0271	57°19,2' N	20°02,8' E	Eastern Gotland Basin	4	4	-	-

Samples for the determination of chlorophyll *a* (Chl*a*) concentrations were collected together with phytoplankton samples at standard depths of 1, 5, 10, 15 and 20 m, and occasionally at other depths with a rosette water sampler. 200-500 ml of the seawater were filtered through glass-fibre filters (Whatman GF/F) that were flash-frozen in liquid nitrogen (-196°C) and stored at -80°C for a maximum of three months. 96 % ethanol was used for the extraction, as specified by HELCOM (2017b). Several methods are available for determining concentrations of Chl*a* as reviewed in WASMUND et al. (2011). The method to measure Chl*a* currently used by IOW does not consider phaeopigment, which contains various constituents (phaeophytin, phaeophorbide), essentially regarded as degradation products of Chl*a* and sometimes measured separately. Phaeopigments are not major players in the open sea and were thus disregarded by the current Chl*a* analyses.

### 2.3 Phytoplankton

Sampling and analysis procedures followed HELCOM (2017c). Generally, two phytoplankton samples were taken at each station: A composite sample was 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, one sample was taken from below the upper pycnocline (usually from a depth of 20 m). If distinctive fluorescence maxima were present in deeper layers, additional samples were taken from that depth. The water

samples (200 ml) were fixed with 1 ml of acid Lugol's solution and stored until analysis (6 months at most).

The biomass of individual phytoplankton species was analysed microscopically using the standard method according to UTERMÖHL (1958). During counting, individuals were classified not just according to taxa, but also to size classes in line with HELCOM guidelines (OLENINA et al. 2006; HELCOM 2017c). To obtain a statistically acceptable estimate, at least 50 individuals of the most abundant species had to be counted. Thus for the most common species, a statistical counting error of around 28 % can be assumed. In this study generally at least 500 individuals were counted per sample to reduce the statistical error to < 10 %. Species- and size class specific biovolumes were multiplied by the number of counted individuals to obtain the biovolume of a particular species. Assuming a density of 1 g cm<sup>-3</sup> the figure of biovolume equates to the biomass (wet weight).

The counting, calculation and data output were facilitated by the software "OrgaCount", (AquaEcology Oldenburg). For the data of the cruise in February 2020, the species and biovolume list PEG\_BVOL2019 was used. The phytoplankton samples of the March, May, July/August and November cruises were analysed according to the PEG\_BVOL2020, which was confirmed by PEG during the meeting in April 2020. The latest biovolume file can be downloaded from: <https://helcom.fi/wp-content/uploads/2020/01/HELCOM-Guidelines-for-monitoring-of-phytoplankton-species-composition-abundance-and-biomass.pdf>

## 2.4 Sedimentation

Within the IOW Arkona Basin sampling area, rates of vertical particle flux (sedimentation) were measured throughout the year. To collect settling material from the pelagic zone and record the amount and quality of sinking phytoplankton from the surface layer to the sea floor, a programmable sedimentation trap (type SM 234) with a collection area of 0.5 m<sup>2</sup> and equipped with 21 sampling bottles was moored in the Arkona Basin at 54°53,020'N/13°51,718'E. Water depth at the mooring station was 45 m and the funnel of the trap located at 35 m, below the pycnocline. After three to four months, samples were retrieved via a recovery line attached to the surface float of the mooring. Sampling intervals were set to successively collect settling material over a period of seven to 10 days. The collected material was processed to facilitate elemental analyses, determination of the natural isotopic composition of nitrogen and carbon as well as microscopic analyses of phytoplankton taxonomic composition. Usually the trap was exchanged three - four times a year for continuous collection of settling material. Due to the cancellation of the March cruise (caused by Covid pandemic), when the exchange of the trap was scheduled, sampling was interrupted from 23.4. to 17.6.2020. Apart from this, the sampling worked according to the plan without any technical or logistical problems at the preprogrammed intervals.

## 2.5 Mesozooplankton

Zooplankton sampling followed the recommendations of the HELCOM COMBINE manual (HELCOM 2018 b). Vertical net tows were conducted with a WP-2 net of 100 µm mesh size equipped with an operating/closing mechanism released by a drop messenger and a T.S.K Flowmeter (Tsurumi-Seiko Co. Ltd., Yokohama, Japan). The net was operated with a hauling speed of 0.5 m/s. In the case of a well-mixed water column, zooplankton was sampled with a single net catch taken from a few meters above the sea floor to the surface. In case a halocline or a thermocline formed through saline inflows or the seasonal warming of the surface during spring - autumn stratified, hauls were taken in the respective water layers. Net angles greater than 30° were avoided during sampling. The samples were preserved in Borax-buffered 4 % aqueous formaldehyde solution and stored at cool/dark conditions until processing in the laboratory. In total, 42 zooplankton samples were collected at 29 stations. Table 2 provides the details about the specific depth layers sampled over the season at the monitoring stations.

Table 2: Sample statistics of zooplankton hauls on monitoring cruises between January and November 2020.

Station	Period				
	29.01. - 09.02.	No cruise	09.05. - 18.05.	14.07. - 27.07.	12.11. - 24.11.
	Depth from -to (m)	Depth from -to (m)	Depth from -to (m)	Depth from -to (m)	Depth from -to (m)
OMBMPN3	14 - 0	-	15 - 0	15 - 0	15 - 9 - 0
OMBMPM2	21 - 0	-	18 - 0	22 - 0	23 - 8 - 0
	-	-	21 - 0	23 - 0	22 - 0
OMBMPM1	26 - 11 - 0	-	25 - 9 - 0	25 - 15 - 0	25 - 8 - 0
	-	-	25 - 0	25 - 0	25 - 0
OMBMPK5	44 - 24 - 0	-	44 - 0	43 - 0	44 - 34 - 0
	45 - 0	-	44 - 24 - 0	43 - 0	-
OMBMPK4	44 - 31 - 0	-	45 - 20 - 0	45 - 26 - 0	45 - 36 - 0

The sample analysis followed the established HELCOM guidelines (HELCOM 2018b). In short, a minimum number of individuals was identified and counted microscopically in a Bogorov chamber. Several subsamples from the total sample were analysed. With the exception of nauplii and tintinnids, at least 100 individuals from three taxa were counted. The abundance (ind. m<sup>-3</sup>) was calculated from the counts and the volume of seawater filtered by the net. The identification of the zooplankton species followed an internal IOW species list of the long-term record of the species inventory as well as the zooplankton atlas of the Baltic Sea (TELESH et al. 2009) and an internal species list of the ZEN HELCOM working group. The taxonomic classification of identified specimens is based on the World Register of Marine Species (WoRMS 2021). In the case of *Bosmina* spp. and *Synchaeta* spp., identification to the species level is unresolved; their abundances were, therefore, recorded on the level of the genus. In line with the standards of the

Integrated Taxonomic Information System (ITIS 2021), Bryozoa were listed as Gymnolaemata and Mysidacea as Lophogastridae. The databases of the information system on Aquatic Non-Indigenous Species (AquaNIS 2021) and of the European Network on Invasive Species (NOBANIS 2021) served as references for the classification of invasive species.

## 2.6 Macrozoobenthos

In November 2020, benthos investigations were undertaken at eight 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 cm<sup>2</sup> and 1060 cm<sup>2</sup>, weighing 38 kg - 70 kg, and 23 kg respectively). Three hauls were taken 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 % buffered formalin (HELCOM 2017a). Additionally, at all stations, a “Kieler Kinderwagen” botanical dredge with a 1 m rectangular mouth and a mesh size of 5 mm was deployed. Especially in relation to vagile and rarer species, the dredge yielded finds that would have been missed using only the grab sampler.

Further processing of samples was undertaken in the laboratory. After rinsing each haul, taxa were sorted under a binocular microscope at 10-20 x magnification and, except for a few groups (e.g., Nemertea, Halacaridae), were determined to species level. As much as possible, nomenclature complied with the ‘World Register of Marine Species (WoRMS)’ (<http://www.marinespecies.org/index.php>). Abundance and biomass were also recorded (ash free dry weight, afdw). To ensure comparability of weight determinations, HELCOM guidelines were followed (HELCOM 2017a), and samples were stored for three months before processing. Wet, dry, and ash-free dry weights were measured on a microbalance. The whole procedure of sorting and analysis follows the standard operating procedure (SOP) of the accredited benthos analytical laboratory of the IOW.

*Table 3: Station list of macrozoobenthic investigations in November 2020.*

	date	depth	north	east	sea area
OMBMPN3	12.11.2020	18.5	54° 36.00	10° 27.00	Kiel Bay
OMBMPN1	12.11.2020	28.5	54° 33.20	11° 20.00	Fehmarnbelt
OMBMPM2	12.11.2020	25.0	54° 18.90	11° 33.00	Mecklenburg Bay
OM18	12.11.2020	20.5	54° 11.00	11° 46.00	Mecklenburg Bay, south
OMBMPK8	13.11.2020	22.8	54° 44.00	12° 47.40	Darss Sill
OMBMPK4	13.11.2020	48.3	55° 00.00	14° 05.00	Arkona Basin
OMBMPK3	14.11.2020	31.4	54° 38.00	14° 17.00	Pomeranian Bay, north
OM160	14.11.2020	14.9	54° 14.50	14° 04.00	Pomeranian Bay, central

## 2.7 Quality Assurance (QA)

### Chlorophyll *a*

As an internal quality assurance measure, every tenth chlorophyll sample is taken twice and analysed separately to test parallel deviations. The results are entered into the range control chart. The fluorometer is calibrated every six months. As an external quality assurance measure, IOW regularly participates in chlorophyll comparisons within QUASIMEME AQ-11 (chlorophyll in seawater). The Rounds 2020.1 and 2020.2 were passed with very good results.

### Phytoplankton

From every tenth sample, two abundant 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 (<https://helcom.fi/wp-content/uploads/2020/01/HELCOM-Guidelines-for-monitoring-of-phytoplankton-species-composition-abundance-and-biomass.pdf>). Expert identification of phytoplankton species depends on the analyst's level of knowledge. PEG therefore runs annual training courses and undertakes regular ring test. Two annual PEG meetings in 2020 took place online in April and October 2020 and were attended by representatives of all Baltic Sea States except Russia. Specific training sessions were not organized in 2020, as physical examination of samples and discussion with taxonomy experts were not possible due to the Covid-situation. Nevertheless, nomenclatural issues were discussed at the two online meetings as well as technical procedures of data transfer. Susanne Busch, phytoplankton analyst at the IOW, took part in the phytoplankton proficiency test organized every three to four years by the Finnish Environment Institute, and passed with excellent results. Like every year, the biovolume list of species and size classes was updated during the HELCOM PEG meeting in April 2020 to assure up-to date taxonomy and biovolume information. Samples taken in January/February 2020 were counted based on the previous ICES and HELCOM biovolume file PEG\_BIOVOL2019, while the new list was adopted for the counting of all cruise samples collected in 2020 thereafter, i.e. following biovolume file PEG\_BIOVOL2020.

### Mesozooplankton

The quality assurance followed the protocol for internal quality control concerning documentation and analyses provided by HELCOM (2018b). The duplicate analysis of every 20<sup>th</sup> zooplankton sample was done as an intra laboratory routine to check the reliability of the zooplankton analysis. The validity of counting results and assessment of their accuracy was similarly tested. Deviations were well below the threshold value for critical errors. Data stored in databases was quality-checked and validated.

### Macrozoobenthos

The IOW macrozoobenthos working group has participated in all QA measures to date. The results of the latest ring test from spring 2018, presented by the UBA in March 2019, confirmed the high quality of the macrozoobenthos analyses. Internal double checks of four samples of the 2020 monitoring season confirmed high accuracy.



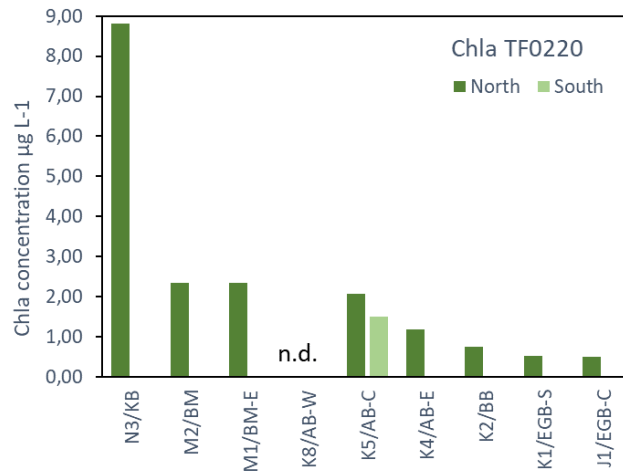


Fig. 2: Chla concentrations ( $\mu\text{g L}^{-1}$ ) at sampling stations along the S-N (dark green) and N-S (light green) legs of the February cruise TF0220.

The results reflect the typical spatial pattern of the spring bloom succession in the Baltic Sea, where phytoplankton development cascades from southwest to northeast over a period of several weeks. However, the rapid and distinct decline of Chla values towards the Bay of Mecklenburg and Arkona Basin nevertheless confirms an isolated early start of the bloom in Kiel Bight. Like the year before, Chla was approximately four-fold lower at the remaining Belt Sea stations at that time and further declined towards the Bornholm and Gotland basins, reflecting the above mentioned typical northward delay of the seasonal succession in the Baltic Sea. Unfortunately, data from the southward journey of the cruise (the return leg), which represents the second sampling occasion, was only obtained from Station OMBMP-K5 in central Arkona Basin, and it remains unclear, how fast biomasses increased during the two weeks of the cruise. Here, the Chla concentration was even lower on the way back.

Spatial biomass distribution along the sampling transect (Fig. 3) generally reflected Chla distribution. Total phytoplankton biomass values of nearly  $2400 \mu\text{g L}^{-1}$  were measured at station N3 in the Kiel Bight, where the spring bloom had started. The community here was mainly dominated by diatoms, constituting approximately 70 % of the total biomass. *Skeletonema marinoi* was the most prominent diatom species here, followed by centric diatoms (Fig. 4). Dinoflagellates, specifically *Tripes muelleri* (Fig. 4 a) contributed significantly to biomass in Kiel Bight, as well as in Bay of Mecklenburg. In the eastern part of the Belt Sea at station M1, the ciliate *Mesodinium rubrum*, together with its cryptophyte prey *Teleaulax* sp. (Fig. 4 b), increased in biomass share compared to Kiel Bight. The two species typically co-occur as they represent a predator-prey system where *Mesodinium rubrum* utilizes (and depends on) the chloroplasts of *Teleaulax*. Diatom share at the Stations M2 and M1 were low compared to the blooming community in Kiel Bight.



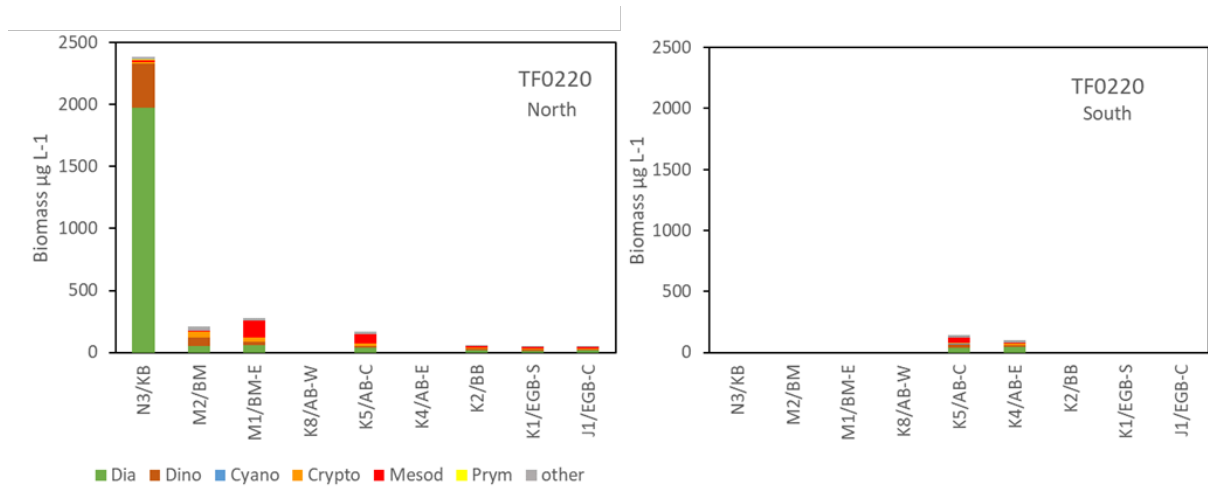


Fig. 3: Total phytoplankton biomass ( $\mu\text{g L}^{-1}$ ) and contribution of major taxa measured from samples taken during northward and southward transects of TF0220. Dia = Diatoms, Dino = Dinoflagellates, Cyano = Cyanobacteria, Crypto = Cryptophytes, Mesod = *Mesodinium rubrum*, Prym = Prymnesiophytes

Biomass composition east of the Bay of Mecklenburg was generally dominated by *Mesodinium rubrum* co-occurring with *Actinocyclus* sp., together constituting half of the biomass. In Arkona Basin, additionally gymnodinoid dinoflagellates and unidentified unicells were abundant, whereas *Teleaulax* co-occurred in Bornholm and Eastern Gotland Basins, respectively. Generally, biomass levels, composition and dominance patterns encountered during the February cruise of 2020 resembled the pattern observed in the two previous years (e.g. ZETTLER et al. 2020, WASMUND et al. 2019a).



Fig. 4: Micrographs of net samples representing typical species assemblages encountered on TF0220 at A) Station N3 (Kiel Bight): *Skeletonema marinoi*, *Actinocyclus* sp., and *Tripos muelleri* and B) Station K2 (Bornholm Basin) *Mesodinium rubrum* and *Teleaulax* sp.

Table 5: The 10 most abundant phytoplankton taxa (percentage of total phytoplankton biomass) and total number of taxa recorded in different sea areas (upper 10 m, data from individual stations pooled) in February 2020.

TF0220

<b>Belt Sea</b>		<b>Arkona Basin</b>	
Species	% Biomass	Species	% Biomass
<i>Skeletonema marinoi</i>	21.41	<i>Mesodinium rubrum</i>	30.38
<i>Centrales</i>	15.16	<i>Actinocyclus</i>	18.00
<i>Tripos muelleri</i>	7.15	<i>Gymnodiniales</i>	9.75
<i>Thalassiosira</i>	7.03	<i>Unicell spp.</i>	7.23
<i>Mesodinium rubrum</i>	5.49	<i>Dactyosolen fragilissimus</i>	6.34
<i>Rhizosolenia delicatula</i>	5.40	<i>Teleaulax</i>	5.55
<i>Rhizosolenia flaccida</i>	3.31	<i>Heterocapsa rotundata</i>	3.32
<i>Proboscia alata</i>	3.16	<i>Plagioselmis prolunga</i>	2.28
<i>Protoperidinium depressum</i>	2.91	<i>Hemiselmis</i>	2.09
<i>Dactyosolen fragilissimus</i>	2.74	<i>Eutreptiella</i>	2.01
<b>Total number of taxa</b>	<b>78</b>	<b>Total number of taxa</b>	<b>46</b>
<b>Bornholm Basin</b>		<b>Eastern Gotland Basin</b>	
Taxon	% Biomass	Taxon	% Biomass
<i>Actinocyclus</i>	24.26	<i>Mesodinium rubrum</i>	29.04
<i>Mesodinium rubrum</i>	23.10	<i>Actinocyclus</i>	28.07
<i>Teleaulax</i>	14.79	<i>Teleaulax</i>	12.27
<i>Gymnodiniales</i>	11.71	<i>Gymnodiniales</i>	11.82
<i>Unicell spp.</i>	4.54	<i>Unicell spp.</i>	5.05
<i>Eutreptiella</i>	3.53	<i>Woronichinia</i>	2.03
<i>Protoperidinium</i>	2.87	<i>Plagioselmis prolunga</i>	1.78
<i>Chaetoceros castracanei</i>	1.84	<i>Dinophysis acuminata</i>	1.31
<i>Cyclotella</i>	1.81	<i>Pterosperma</i>	1.14
<i>Plagioselmis prolunga</i>	1.43	<i>Peridiniella catenata</i>	0.94
<b>Total number of taxa</b>	<b>35</b>	<b>Total number of taxa</b>	<b>42</b>

In February 2020, differences in phytoplankton species composition and relative contribution to phytoplankton biomass were pronounced between the Belt Sea and the remaining study area (Table 5). While the Belt Sea stations were almost entirely dominated by diatoms, the Arkona, Bornholm and Eastern Gotland Basin communities shared high biomass contributions of *Mesodinium rubrum*, *Teleaulax*, and *Gymnodiniales* besides the diatom *Actinocyclus* sp. With 78 taxa, species diversity was significantly higher in the Belt Sea compared to the other sea areas where total numbers of taxa ranged between 35 in Bornholm Basin and 46 in Eastern Gotland Basin.

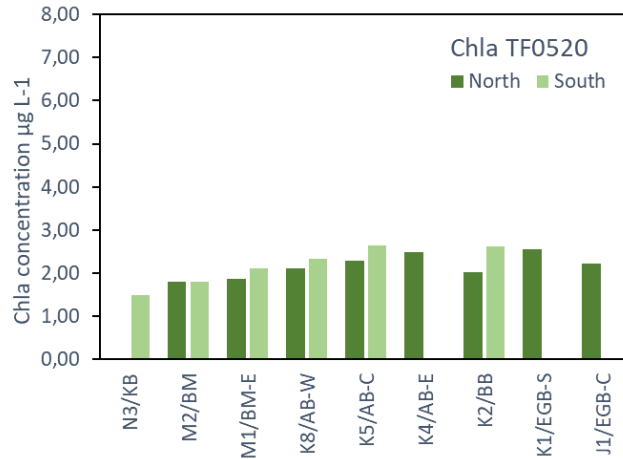


Fig. 5: Chla concentrations ( $\mu\text{g L}^{-1}$ ) at sampling stations along the S-N (dark green) and N-S (light green) transects of the May cruise TF0520.

In **May 2020**, the phytoplankton spring bloom was still ongoing throughout the study area as indicated by Chla levels ranging from  $1.5 \mu\text{g L}^{-1}$  at the southernmost station N3 in Kiel Bight to  $2.65 \mu\text{g L}^{-1}$  in central Arkona Basin at station K5 (Fig. 5). Chla values were even higher on the southward journey of the cruise and generally exceeded the ones measured at the same time of the year in previous years (WASMUND et al. 2019a, ZETTLER et al. 2020). Nevertheless, they reflect an already declining bloom even at the northernmost stations: Spring biomass of up to  $6000 \mu\text{g L}^{-1}$  are usually encountered during the March cruises of the BSH/IOW monitoring programme. Thus, the peak of the 2020 spring bloom was obviously missed as a result of the cancelled March cruise.

The decline of the bloom was reflected by relatively low total phytoplankton biomass concentrations (Fig. 6) which were in the same range or lower than in 2019 (ZETTLER et al. 2020). The highest total phytoplankton biomasses, were ranging between  $500$  and  $641 \mu\text{g L}^{-1}$  was measured at the northernmost stations, K2 to J1, located in the Bornholm and Gotland basins. Like Chla levels, total phytoplankton biomasses in Arkona Basin had even increased two weeks later on the southward journey. The phytoplankton biomass was, at most stations, dominated by dinoflagellates and prymnesiophytes. Diatoms were a minor component at all stations. Prymnesiophytes constituted 36 % of the biomass in Arkona Basin in May (Fig. 6, Table 6), while dinoflagellates dominated the communities of the northern stations contributing 30 – 40 % of the biomass there.

Generally, regional differences in species composition and relative contribution to the phytoplankton biomass (Table 6) were less pronounced in May than in February. Belt Sea communities were relatively diverse in terms of biomass share, with Prymnesiales, several dinoflagellates and cryptophytes contributing most of the biomass (Fig. 7 a). In Arkona Basin these taxa contributed nearly 80 % to the community. In the northern Basins, taxon diversity was generally higher in May compared to January, while in the south (Belt Sea) less taxa were encountered.

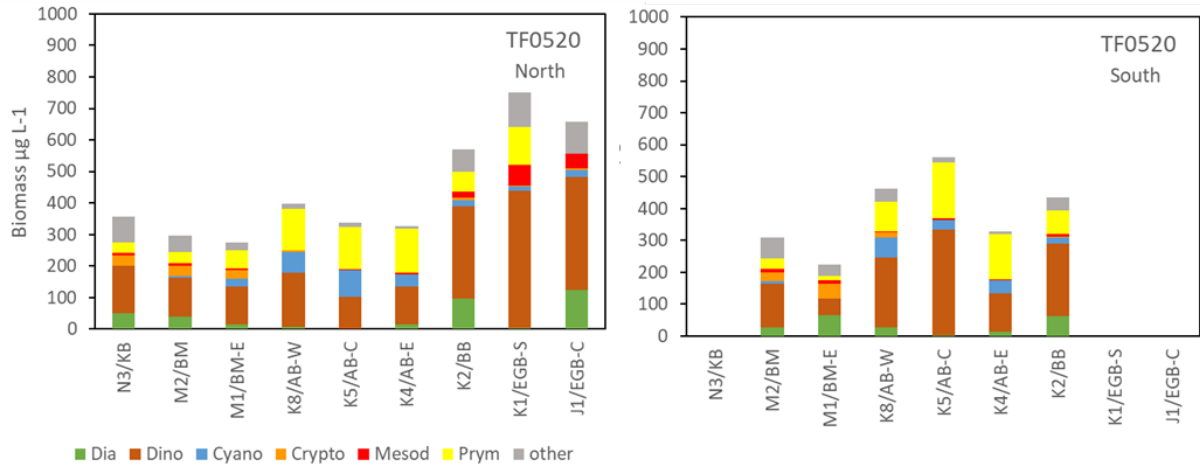


Fig. 6: Total phytoplankton biomass ( $\mu\text{g L}^{-1}$ ) and contribution of major taxa measured from samples taken during northward and southward transects of TF0520 in May 2020.

Dominating dinoflagellates in the Belt Sea were *Peridiniella danica*, different unidentified photo- and heterotrophic Gymnodiniales as well as *Tripos muelleri* (previously *Ceratium tripos*). The northern basins were, as typical for these regions, dominated by phototrophic Gymnodiniales (Table 6, Fig. 7 b). Unlike in previous years, when dominant Gymnodiniales mostly consisted of *Gymnodinium corollarium*, (SUNDSTRÖM et al. 2009) these dinoflagellates could not be assigned to a known species. Efforts are being made by IOW scientists to bring this dinoflagellate in culture to characterize it morphologically and genetically for further identification.

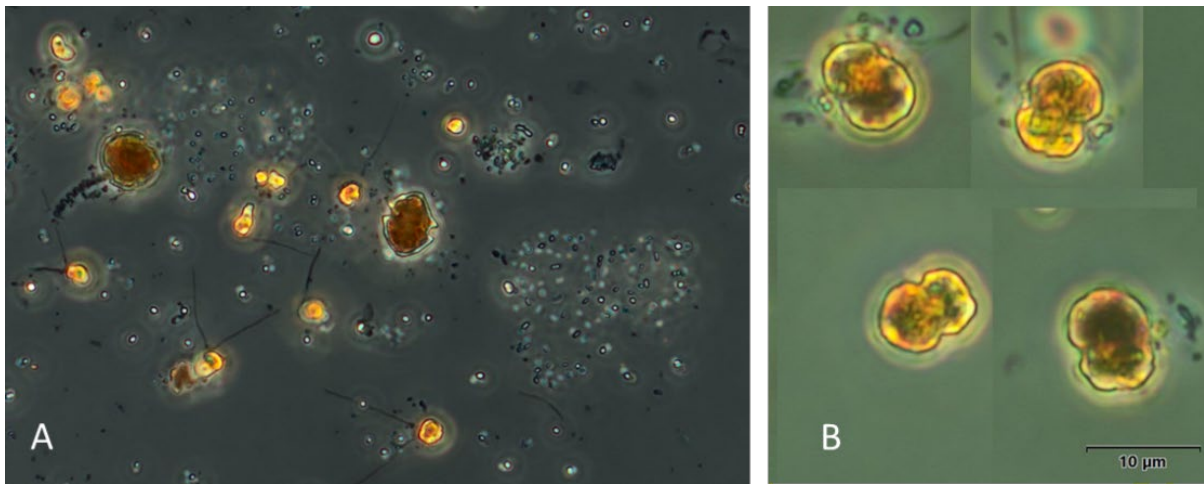


Fig. 7: Light micrographs of (a) a typical phytoplankton community at Station K4 in Arkona Basin dominated by Prymnesiales, colonial cyanobacteria and dinoflagellates, and (b) unidentified small sized Gymnodiniales from Station K2 in Bornholm Basin, taken in May 2020.

Table 6: The 10 most abundant phytoplankton taxa (percentage of total phytoplankton biomass) and total number of taxa recorded in different sea areas (upper 10 m, data from individual stations pooled) in May 2020.

TF0520

<b>Belt Sea</b>		<b>Arkona Basin</b>	
Taxon	% Biomass	Taxon	% Biomass
<i>Prymnesiales</i>	14.31	<i>Prymnesiales</i>	36.05
<i>Peridiniella danica</i>	13.71	<i>Peridiniella danica</i>	26.34
<i>Gymnodiniales</i>	10.78	<i>Gymnodiniales</i>	13.18
<i>Tripos muelleri</i>	9.80	<i>Aphanocapsa</i>	3.12
<i>Leucocryptos marina</i>	6.93	<i>Aphanothece</i>	2.77
<i>Plagioselmis prolunga</i>	6.75	<i>Peridinales</i>	2.44
<i>Unicell spp.</i>	3.73	<i>Kryptoperidinium triquetrum</i>	1.90
<i>Coscinodiscus radiatus</i>	3.43	<i>Coelosphaerium minutissimum</i>	1.86
<i>Scrippsiella spp. CPX</i>	3.36	<i>Unicell spp.</i>	1.53
<i>Teleaulax</i>	2.55	<i>Cyanodictyon planctonicum</i>	1.46
<b>Total number of recorded taxa</b>	<b>54</b>	<b>Total number of recorded taxa</b>	<b>39</b>
<b>Bornholm Basin</b>		<b>Eastern Gotland Basin</b>	
Taxon	%Biomass	Taxon	% Biomass
<i>Gymnodiniales</i>	28.89	<i>Gymnodiniales</i>	22.48
<i>Prymnesiales</i>	13.77	<i>Dinophysis acuminata</i>	13.61
<i>Chaetoceros similis</i>	13.51	<i>Prymnesiales</i>	10.72
<i>Kryptoperidinium triquetrum</i>	13.47	<i>Mesodinium rubrum</i>	6.41
<i>Peridiniella danica</i>	4.09	<i>Peridiniella danica</i>	4.75
<i>Unicell spp.</i>	3.28	<i>Kryptoperidinium triquetrum</i>	4.40
<i>Dinophysis norvegica</i>	3.02	<i>Chaetoceros similis</i>	4.20
<i>Mesodinium rubrum</i>	2.76	<i>Flagellates</i>	4.19
<i>Katablepharis remigera</i>	2.57	<i>Dinophysis norvegica</i>	4.01
<i>Ebria tripartita</i>	1.63	<i>Peridiniella catenata</i>	3.07
<b>Total number of taxa</b>	<b>48</b>	<b>Total number of taxa</b>	<b>52</b>

Interestingly, biomass shares of diatoms were low at all stations and sea areas during May, which is different from the previous year, when diatoms were prominent members of the late spring communities, particularly in the southern part of the studied transect (Zettler et al. 2020). The cyanobacteria genera *Aphanocapsa* and *Aphanothece* were among the 5 most important taxa in the Arkona Basin in terms of biomass share which is unusual.

In May, phytoplankton diversity was generally lower in the southern basins (Belt Sea and Arkona Basin) with a total number of 54 and 39 recorded taxa compared to the northern ones (Table 6) with 48 and 52, respectively. The numbers in the southern basins were lower in May than during the February cruise (78 and 46 in February, see Table 5). In the northern Basins, on the other hand, the numbers of recorded taxa had increased between February and May (Table 5 and Table 6). This development represents the typical temperature driven south to north progression of the spring bloom in the Baltic Sea.

Due to lack of data from March 2020, it is not possible to compare the spatial and temporal dynamics of the 2020 spring bloom to previous years. As indicated above, the bloom started early in the Belt Sea and had reached higher biomass here by February compared to 2019. This observation adds evidence to the general trend of an extended growth period in the southern Baltic Sea and specifically an earlier beginning of the spring bloom in relation to the ongoing warming of surface waters (WASMUND et al. 2019a, b). Based on the biomass composition data from the February and May cruises of 2019 and 2020, dinoflagellates, prymnesiophytes and *Mesodinium rubrum* likely played a more important role in 2020 than in the previous year, particularly in the northern parts of the study area (ZETTLER et al. 2020). This would corroborate the general trend of increasing dinoflagellate proportions in relation to diatoms as a consequence of changing climate conditions (KLAIS et al. 2011).

### 3.1.1.2 Summer bloom

In July 2020, at the time of the TF0720 monitoring cruise, Chl $a$  concentrations (Fig. 8) ranged between 2.4  $\mu\text{g L}^{-1}$  and 3.8  $\mu\text{g L}^{-1}$  and remained relatively stable during the cruise with similar Chl $a$  levels detected for the northward and southward journey. Highest values were measured in central and northern Arkona Basin (Stations K5, K4).

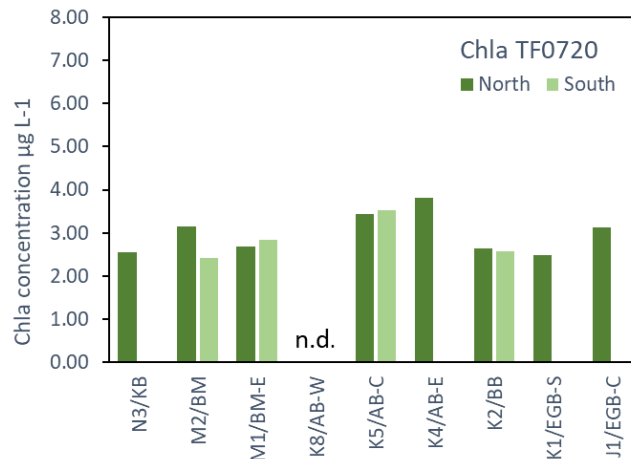


Fig. 8: Chl $a$  concentrations ( $\mu\text{g L}^{-1}$ ) at sampling stations along the S-N (dark green) and N-S (light green) transects of cruise TF0720 in July 2020.

Chl $a$  dynamics was generally reflected by total biomass levels, particularly in the Belt Sea and the Arkona Basin, where communities were dominated by dinoflagellates and diatoms and the contribution of cyanobacteria to total biomass was low. Cyanobacteria dominated northern stations in Bornholm and Gotland basins and had relatively lower biomass levels compared to Chl $a$  values. Such discrepancy between biomass and Chl $a$  levels likely reflects taxon specific C: Chl $a$  ratios (WASMUND et al. 2019a). For example, in the Belt Sea and Arkona Basin area the diatom *Dactyosolen fragilissimus* had a high share (40 – 70 %) of the total phytoplankton biomass (Table 7). The large cells of this species are sparsely pigmented and the amount of Chl $a$  per cell volume is low compared to most other species of the community (Fig. 9). Total biomass in July 2020 ranged between a minimum of 320  $\mu\text{g L}^{-1}$  measured on the southward return journey

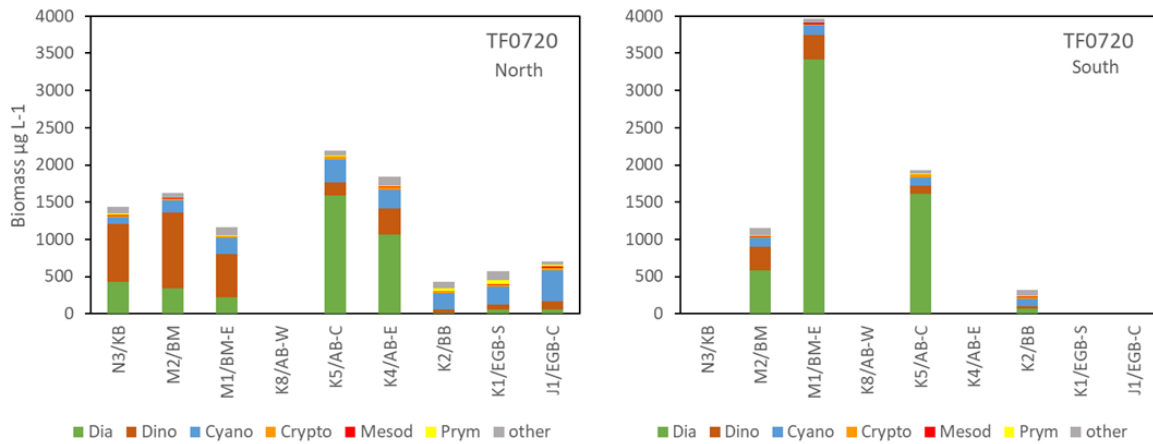


Fig. 9: Total phytoplankton biomass ( $\mu\text{g L}^{-1}$ ) and contribution of major taxa measured from samples taken during northward and southward transects of TF0720 in July 2020.

10 days later at station K2 in Bornholm Basin and a maximum of nearly  $4000 \mu\text{g L}^{-1}$  at station M1 in the Arkona Basin (Fig. 9). At most stations biomass levels were approximately twice as high as in summer 2019. In the Belt Sea, summer phytoplankton communities were dominated by dinoflagellates during the northward transect, when toxic *Alexandrium pseudogonyaulax* (Fig. 10 a) together with *Tripos muelleri* had become abundant and constituted 35 to 65 % of the total biomass at these stations here. *A. pseudogonyaulax* has recently invaded the Baltic Sea and forms now recurrent blooms during summer in the southern sea areas (WASMUND et al. 2017a, KREMP et al. 2019, ZETTLER et al. 2020).

As indicated above, an unusual bloom of the diatom *Dactyosolen fragilissimus* (Fig. 10 b) developed at the time of the monitoring cruise in the Belt Sea in July 2020, causing a sudden biomass peak at station M1 that was captured on the southward transect of the cruise (Fig. 9). Within 10 days, community composition in the Belt Sea had thus changed from dinoflagellate to diatom dominance and this change was accompanied by a three-fold increase in biomass to almost  $4000 \mu\text{g L}^{-1}$ . Summer diatom blooms are somewhat unusual in the Baltic Sea where cyanobacteria and dinoflagellates typically constitute warm water communities. Further research is needed to better understand whether the observed diatom bloom in the Belt Sea was the result of specific hydrographic and hydrochemical settings, or whether it reflects a general trend possibly related to changing climate conditions.

Phytoplankton communities of Bornholm and Gotland Basins consisted - as typical for this time of the year, largely of Cyanobacteria, dinoflagellates and Prymnesiophytes. Cyanobacteria contributed on average (all three stations) 30 % of biomass (Table 7). Besides *Aphanizomenon*, *Nodularia spumigena* was the most common cyanobacteria species. Both species are known for their potential to produce potent hepato- and neurotoxins. Generally, cyanobacterial summer blooms are a characteristic feature of the seasonal phytoplankton cycle in the Baltic Sea and are expected to build up high biomass. Under the conditions of climate change their biomass has increased and the rise is expected to continue (OLOFSSON et al. 2020). In 2020, their absolute biomass and biomass contribution in the central Baltic was comparable to previous years.

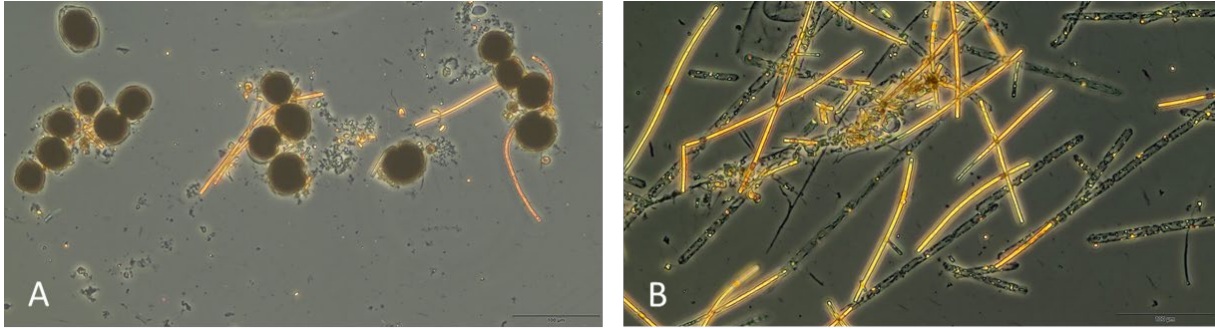


Fig. 10: (A) Light micrographs of (A) an *A.pseudogonyaulax* dominated community at Station M2 in Belt Sea and (B) *Dactyosolen fragilissimus* (= *Rhizosolenia fragilissima*) together with *Aphanizomenon* at Station K5 in July 2020.

Table 7: The 10 most abundant phytoplankton taxa (percentage of total phytoplankton biomass) and total number of taxa recorded in different sea areas (upper 10 m, data from individual stations pooled) in July 2020.

TF0720

<b>Belt Sea</b>		<b>Arkona Basin</b>	
Taxon	% Biomass	Taxon	% Biomass
<i>Rhizosolenia fragilissima</i>	41.20	<i>Rhizosolenia fragilissima</i>	70.76
<i>Alexandrium pseudogonyaulax</i>	17.52	<i>Aphanizomenon</i>	9.43
<i>Tripos muelleri</i>	7.88	<i>Kryptoperidinium triquetrum</i>	4.86
<i>Cerataulina bergonii</i>	4.76	<i>Gymnodiniales</i>	2.47
<i>Aphanizomenon</i>	4.45	<i>Tripos muelleri</i>	1.46
<i>Proboscia alata</i>	2.60	<i>Unicell spp.</i>	1.44
<i>Gymnodiniales</i>	1.93	<i>Plagioselmis prolonga</i>	1.26
<i>Prorocentrum cordatum</i>	1.76	<i>Nodularia spumigena</i>	0.86
<i>Dolichospermum</i>	1.74	<i>Pseudanabaena limnetica</i>	0.69
<i>Prorocentrum micans</i>	1.62	<i>Teleaulax</i>	0.62
<b>Total number of taxa</b>	<b>82</b>	<b>Total number of taxa</b>	<b>55</b>
<b>Bornholm Basin</b>		<b>Eastern Gotland Basin</b>	
Taxon	% Biomass	Taxon	% Biomass
<i>Aphanizomenon</i>	23.22	<i>Aphanizomenon</i>	13.89
<i>Unicell spp.</i>	8.07	<i>Nodularia spumigena</i>	11.43
<i>Nodularia spumigena</i>	7.25	<i>Aphanothece paralleliformis</i>	10.20
<i>Prymnesiales</i>	7.15	<i>Gymnodiniales</i>	8.14
<i>Plagioselmis prolonga</i>	6.22	<i>Actinocyclus</i>	7.29
<i>Pseudanabaena limnetica</i>	6.19	<i>Prymnesiales</i>	5.41
<i>Chroococcales</i>	5.31	<i>Chroococcales</i>	5.21
<i>Gymnodiniales</i>	4.45	<i>Unicell spp.</i>	4.53
<i>Katablepharis remigera</i>	4.20	<i>Katablepharis remigera</i>	3.24
<i>Ebria tripartita</i>	4.01	<i>Ebria tripartita</i>	3.09
<b>Total number of taxa</b>	<b>38</b>	<b>Total number of taxa</b>	<b>55</b>



Phytoplankton diversity of the summer community, as expressed by total number of taxa encountered at the time of sampling, was comparable to the spring community with >80 taxa detected in the Belt Sea and approx. 50 in the Gotland Basin (Table 7). Again, the lowest number occurred in the Bornholm basin, which, however is only represented by one station, compared to the other sea areas.

### 3.1.1.3 Autumn bloom

In November 2020, high Chl $a$  values in the southern basins, ranging from 2.0 to 6.0  $\mu\text{g L}^{-1}$ , reflect an ongoing autumn phytoplankton bloom (Fig. 11). These values are among the highest measured in 2020 and are only exceeded by concentrations measured in the Kiel Bight in February. Though peak November values exceed the ones measured in 2019, Chl $a$  concentrations of the November cruise are within the same range as in autumn 2019. Chl $a$  values in Bornholm and Gotland Basins were comparatively low, suggesting that the autumn bloom was restricted to Belt Sea and Arkona Basin.

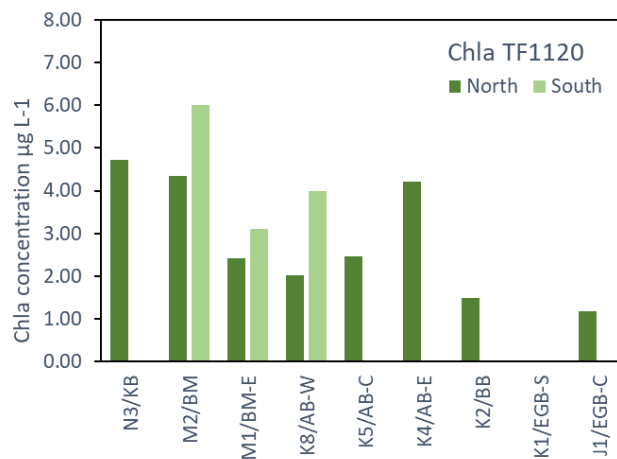


Fig. 11: Chl $a$  concentrations ( $\mu\text{g L}^{-1}$ ) at sampling stations along the S-N (dark green) and N-S (light green) transects of the November cruise TF1120.

High Chl $a$  levels corresponded to respective total phytoplankton biomass (Fig. 12) which were nearly as high as the ones measured on average during summer. Autumn biomass was dominated by diatoms, with *Cerataulina pelagica* (Fig. 13 a) contributing approximately 50 % of biomass at the Belt Sea and Arkona Basin stations (Table 8). In the Belt Sea *Pseudosolenia calcar-avis* was responsible for the second largest fraction of the biomass, followed by several potentially toxic *Pseudo-nitzschia* species. Dinoflagellates belonging to the genus *Ceratium* were other prominent members of the Belt Sea autumn community.

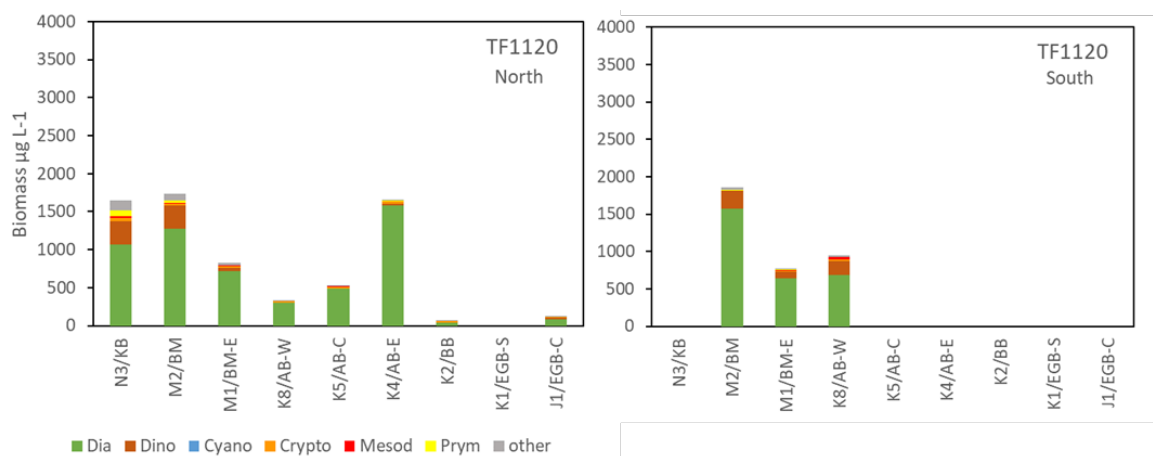


Fig. 12: Total phytoplankton biomass ( $\mu\text{g L}^{-1}$ ) and contribution of major taxa measured from samples taken during northward and southward transects of TF1120 in November 2020.

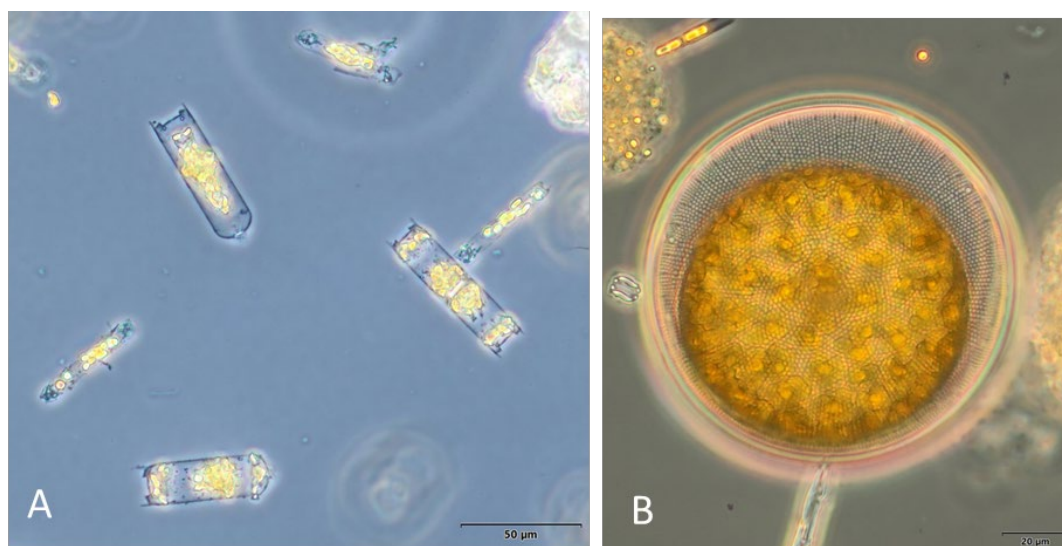


Fig. 13: Light micrographs of (A) *Cerataulina pelagica* from station M2 in Belt Sea and (B) *Coscinodiscus granii* from Eastern Arkona Basin Station K4 in November 2020.

In the Arkona Basin, diatoms *Cerataulina pelagica*, *Dactyosolen fragilissimus* (Fig. 13 a) and *Pseudosolenia calcar-avis* constituted the major part of the biomass, i.e. > 85 % leaving limited resource space for other taxa, e.g. dinoflagellates and species belonging to *Gymnodiniales* as well as *Tripos muelleri*. The northern sea areas had different communities: The phytoplankton at Bornholm Basin was diverse, with 5 – 20 % shares of *Coscinodiscus granii*, *Gymnodiniales*, *Ebria tripartita*, *Teleaulax*, *D. fragilissimus*, *Micranthodinium claytonia* and *Plagioselmis prolunga* (Table 8). The Gotland basin community contained, besides dominant (>70 % biomass share) *Coscinodiscus granii* (Fig. 13 b), still cyanobacteria - *Nodularia spumigena* being 10th in terms of biomass contribution. Total number of taxa in the different sea areas was in the same range as during the spring and summer cruises and followed the same pattern of highest diversity in the western sea areas and significantly lower taxon numbers in the northern basins.

Table 8: The 10 most abundant phytoplankton taxa (percentage of total phytoplankton biomass) and total number of taxa recorded in different sea areas (upper 10 m, data from individual stations pooled) in July 2020.

TF1120

<b>Belt Sea</b>		<b>Arkona Basin</b>	
Taxon	% Biomass	Taxon	% Biomass
<i>Cerataulina bergonii</i>	46.93	<i>Cerataulina bergonii</i>	49.35
<i>Pseudosolenia calcar-avis</i>	12.81	<i>Rhizosolenia fragilissima</i>	30.73
<i>Pseudo-nitzschia</i>	8.25	<i>Pseudosolenia calcar-avis</i>	5.72
<i>Pseudo-nitzschia seriata</i> GRP	7.19	Gymnodiniales	2.41
<i>Ceratium tripos</i>	4.01	<i>Ceratium tripos</i>	1.56
<i>Rhizosolenia setigera f. pungens</i>	3.34	<i>Ebria tripartita</i>	1.45
Gymnodiniales	2.10	<i>Unicell spp.</i>	1.29
<i>Rhizosolenia setigera</i>	1.89	<i>Teleaulax</i>	1.12
<i>Ceratium fusus</i>	1.88	<i>Pyramimonas</i>	0.75
<i>Mesodinium rubrum</i>	1.48	<i>Prorocentrum micans</i>	0.74
<b>Total number of taxa</b>	<b>87</b>	<b>Total number of taxa</b>	<b>67</b>
<b>Bornholm Basin</b>		<b>Eastern Gotland Basin</b>	
Taxon	% Biomass	Taxon	% Biomass
<i>Coscinodiscus granii</i>	19.45	<i>Coscinodiscus concinnus</i>	64.64
<i>Unicell spp.</i>	9.11	<i>Coscinodiscus granii</i>	8.31
Gymnodiniales	8.93	<i>Tripos longipes</i>	4.68
<i>Ebria tripartita</i>	7.35	<i>Synedra nitzschioides</i>	2.87
<i>Teleaulax</i>	7.14	<i>Unicell spp.</i>	2.26
<i>Rhizosolenia fragilissima</i>	6.18	<i>Teleaulax</i>	2.12
<i>Micracanthodinium claytonii</i>	5.71	<i>Merismopedia punctata</i>	1.67
<i>Plagioselmis prolunga</i>	5.22	<i>Mesodinium rubrum</i>	1.58
<i>Heterocapsa rotundata</i>	4.69	Flagellates	1.40
<i>Hemiselmis</i>	3.09	<i>Nodularia spumigena</i>	1.04
<b>Total number of taxa</b>	<b>48</b>	<b>Total number of taxa</b>	<b>51</b>

### 3.1.2 Species diversity, non-indigenous species and harmful algal blooms

In 2020 altogether 153 phytoplankton species/taxa were recorded in monitoring samples from 0 - 10 m water depth, three more than in 2019. A complete list of recorded species with biomass ranks and total biomass values can be found in supplementary Table Appendix 1. Diatoms were the most important biomass producers, specifically *Dactyosolen fragilissimus* and *Pseudosolenia calcar-avis* (biomass ranks 1 and 3) in the southern sea areas, and *Coscinodiscus granii* (biomass rank 2) growing in the low salinity northern parts of the monitored area. These were followed by species belonging to Gymnodiniales (Dinophyceae) forming high biomass blooms during spring in the northern basins and by the toxic or potentially toxic species, *Pseudo-nitzschia* spp. (biomass rank 5), *Alexandrium pseudogonyaulax* (biomass rank 6) *Aphanizomenon flos-aquae* (biomass rank 8).

Table 9: Occurrence of toxic/ bloom forming and invasive phytoplankton taxa in 2020. + = present, ++ = abundant (1-10 % biomass share), +++ = very abundant (> 10 % biomass share), ++++ = bloom (>50 % biomass share). *Dinophysis* spp includes *D. acuminata*, *D. norvegica*, *D. acuta*; *Pseudo-nitzschia* spp. contains records of *P. pseudodelicatissima* group, *P. pungens*, *P. seriata* and *P. multiseriata*.

Species/Station	IOW and BSH/ cruise	TF0360 N3	TF0012 M2	TF0046 M1	TF0030 K8	TF0113 K5	TF0109 K4	TF0213 K2	TF0259 K1	0271 J1
<b>Cyanophyceae</b>										
<i>Dolichospermum</i> <i>spp.</i>	TF0720	+	++*	++*		+	+	++*	+	+
<i>Nodularia</i> <i>spumigena</i>	TF0520				+					
	TF0720	++	++	++*		++*	+	++*	+++	+++
<i>Aphanizomenon</i> sp.	TF0120					++*		+	+	+
	TF0520			+	+	+	+	++*	++	++
	TF0720	++	++*	++*		++	+++*	+++*	++	+++
	TF1120									+
<b>Dinophyceae</b>										
<i>Alexandrium</i> <i>pseudogonyaulax</i>	TF0720	+++	+++*	+++*		++*	+	+		
	TF1120			+						
<i>Prorocentrum</i> <i>cordatum</i>	TF0720	++*	++*	++*		++*	+			+
	TF1120	+	++	+++	+++	++		+		
<i>Dinophysis</i> spp ( <i>D. acuminata</i> , <i>D. norvegica</i> , <i>D.</i> <i>acuta</i> )	TF0220	++	++	++						++
	TF0520							++*	+++	+++
	TF0720	+	+			++*	+	++	++	++
	TF1120		++*	+	+					+
<b>Bacillariophyceae</b>										
<i>Pseudo-nitzschia</i> <i>spp.</i>	TF0120	+	+					+		
	TF0520			+						
	TF0720	+	++*	++*						
	TF1120	++	+++*	+++*	+++					

Table 9 shows occurrences of toxic and potentially harmful taxa at sampled stations in 2020. Under conditions of Climate Change, when temperatures of surface waters rise, the risk of harmful algal bloom formation increases (WELLS et al. 2015). Particularly warm water adapted species such as filamentous cyanobacteria and dinoflagellates are expected to benefit from increased summer surface temperatures (OLOFSSON et al. 2020), though this relationship seems to be species and basin specific in the Baltic Sea and cannot be generalized (KAHRU et al. 2020, OLOFSSON et al. 2020). In 2020, several HAB (harmful algal bloom) taxa contributed significant biomass shares to the phytoplankton community. Unlike in 2019 though, they never dominated community biomass (>50 % of biomass). HAB taxa in 2020 included cyanobacteria, *Nodularia spumigena* and *Aphanizomenon*, which were most prominent in the summer months in the

brackish northern parts of the monitored transect, as well as *Dolichospermum spp.* contributing minor biomass shares. Dinoflagellates, such as *Prorocentrum cordatum*, which is - apart from being toxic - an invasive species, and toxic *Alexandrium pseudogonyaulax* reached relatively high biomasses in the southern parts of the study area in summer. *A. pseudogonyaulax* produces a potent toxin (Goniodomin) and is currently spreading in Northern European waters. This is due to its efficient nutritional strategy, to rising sea surface temperatures, and accumulating seed populations that anchor the species in their new habitats (KREMP et al. 2019). The ongoing establishment of a permanent population of *A. pseudogonyaulax* in the Baltic Sea may have negative effects on invertebrates and fish populations and potentially disturb food web transfer efficiency here (BLANDA et al. 2016). *Dinophysis* species were found in February and November in the western Baltic and reached high biomass shares during summer in the Bornholm and Gotland basins. In 2020, Domoic acid producing *Pseudo-nitzschia spp.* were most abundant during autumn, contributing significant shares of the total phytoplankton biomass. Domoic acid can be transferred through the marine food web, especially benthic compartments and cause mortalities at higher trophic levels (LUNDHOLM et al. 1994). In 2020, the distribution and seasonal dynamics of harmful algal bloom species were comparable to 2019. *A. pseudogonyaulax* did not reach bloom concentrations in the western Baltic in 2020.

### 3.1.3 Long-term trends

#### Biomass

Average phytoplankton biomass values of 2020 were significantly lower than in 2019, and remained below the 20 year - mean (Fig. 14). It is possible that some bias occurred due to omission of the March cruise, which usually captures the height of the spring production in Mecklenburg Bight and Arkona Basin. On the other hand, the 2020 annual biomass mean per station of  $753 \mu\text{g L}^{-1}$  just slightly fell below the 20 year mean of  $771 \mu\text{g L}^{-1}$ .

The ratio of diatoms and dinoflagellates in the phytoplankton community affects ecosystem functions, specifically food web transfer and biogeochemical cycles. A high proportion of diatoms compared to dinoflagellates specifically in the spring bloom is an indication for a good environmental status (WASMUND et al. 2017b) as it supports food web transfer. On the other hand, sedimentation of large diatom blooms may enhance oxygen consumption in bottom waters leading to anoxic conditions in the sediments, which support the internal phosphorus loading (VAHTERA et al. 2007). In contrast to diatoms, dinoflagellates typically disintegrate in the water column or form resting stages that resist remineralisation in bottom sediments (SPILLING et al. 2018). Dinoflagellate dominance in summer is often related to harmful algal blooms which can disrupt trophic transfer.

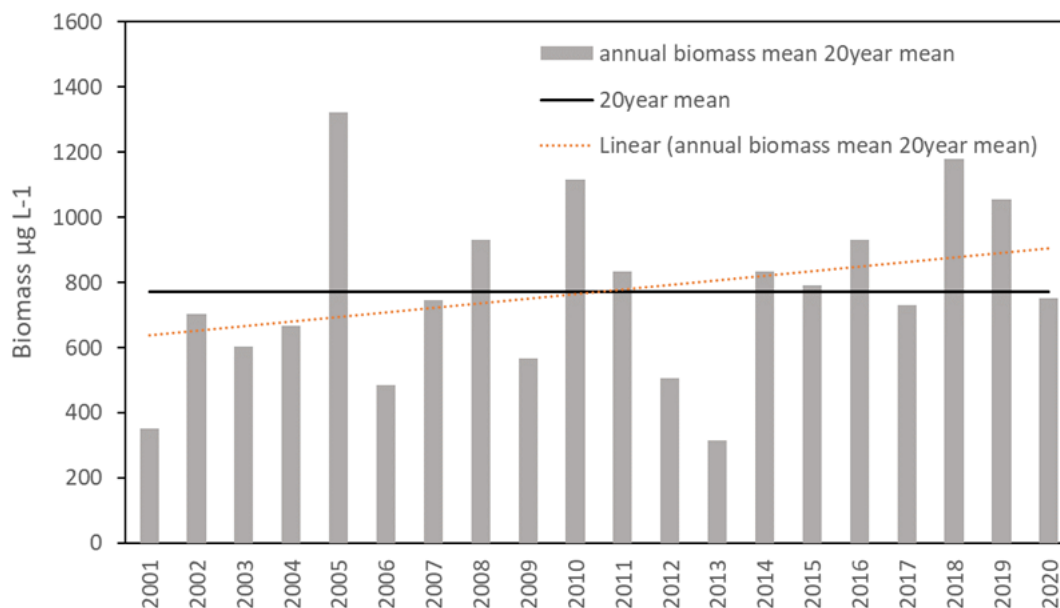


Fig. 14: Mean annual biomass values (all stations and samplings) for the period between 2001 and 2020

### Diatom/Dinoflagellate ratio

Despite the lack of early spring (March cruise, TFO320) data, the 2020 Diatom/Dinoflagellate biomass ratio of 7.18 was higher but in the same range as during the previous year, and thus significantly higher than the 20-year mean of 3.14 (Fig. 15). This further corroborates the trend of an increasing importance of diatoms (in relation to dinoflagellates) in contributing to the total annual biomass production during the past decade. The current trend contrasts the situation of the 1990s and early 2000s, when particularly in the more northern basins of the Baltic Sea, including the Gotland Basin, dinoflagellates were on the rise and dominated specifically the Baltic spring bloom community (KLAIS et al. 2011). In 2020, monitoring data show that diatoms have become the dominant primary producers of the spring and autumn periods again. Furthermore, the year 2020 was characterized by high biomass shares of diatoms in the summer community - which is an unusual phenomenon and remains to be studied.

### Cyanobacteria biomass

As in 2019, average cyanobacteria biomass measured in 2020 per sampling and station, 57.27 µg L<sup>-1</sup> (Fig. 16) was well above the long-term mean of 31.48 µg L<sup>-1</sup> and higher than during the previous years. This is likely due to the high cyanobacteria share, particularly *Aphanizomenon* and *Nodularia*, in the summer community of the more northern basins which is typical for warm summers such as 2020.

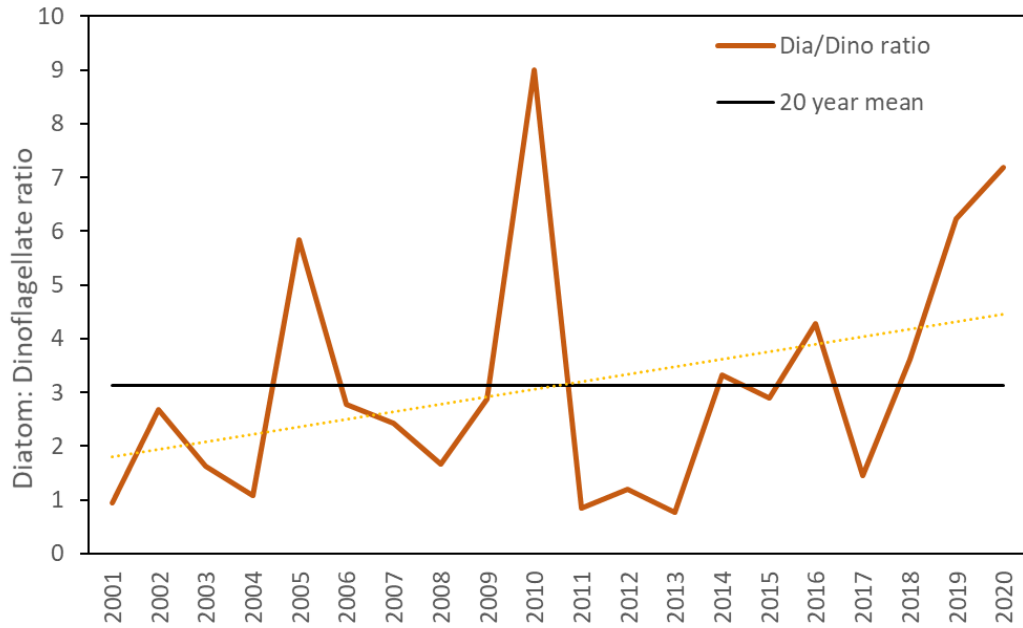


Fig. 15: Mean annual ratio of diatoms to dinoflagellates per sampling and station based on biomass concentrations ( $\mu\text{g L}^{-1}$ ). The black line marks the 20-year mean, dotted line = trendline.

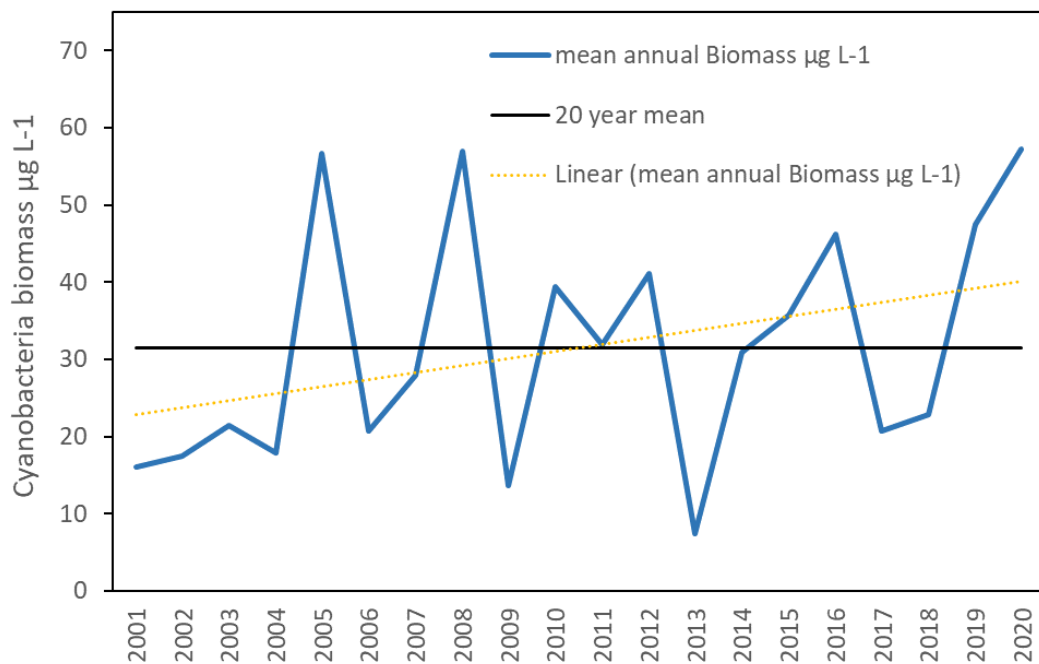


Fig. 16: Mean annual averages of cyanobacterial biomass for the period 2000-2020 per sampling and station ( $\mu\text{g L}^{-1}$ ). The black line marks the 20-year mean, dotted line = trendline.

### 3.1.4 Phytoplankton sedimentation

Microscopic analysis of phytoplankton settling out from the photic zone into a sediment trap moored in Arkona Basin throughout 2020 reflected the typical dynamics of seasonal pelagic community succession (Fig. 17). Altogether 42 phytoplankton taxa were encountered in 2020 in

settling material, which is in the range of preceding years (40 in 2016 - 49 in 2019). The relative frequency of settled phytoplankton was slightly lower for most taxa compared to 2019. Unfortunately, the period between early April and late May was not sampled in 2020 due to the cancelled March monitoring cruise when the trap was supposed to be exchanged. A new trap was only moored at the end of May. Thus, late spring, which usually coincides with the end of the spring bloom and a major seasonal sedimentation pulse, was missed in 2020.

As in previous years, **diatoms** were found to be the most diverse phytoplankton group in sediment trap material, comprising 21 species. This is expected, as diatoms are covered by silicified frustules, which support sinking. Two distinct periods of diatom sedimentation occurred in 2020. The first, in March/April followed the spring bloom in the Arkona Basin and was dominated by typical cold-water species such as *Thalassiosira* spp. and *Skeletonema marinoi*. It seems that the time window without sedimentation records coincided to some extent with a low sedimentation period between spring and summer bloom. Diatom sedimentation was low in June and July, and settling diatoms consisted of *Cylindrotheca closterium* and *Dactyosolen fragilissimus*. Diatom diversity and relative frequency of settling matter increased again in late summer and remained high until October, reflecting the unusual prevalence of diverse diatoms in the 2020 summer and autumn phytoplankton: specifically, *Dactyosolen fragilissimus*, *Pseudosolenia calcar-avis* and *Actinocyclus octonarius*. Late autumn and early winter phytoplankton sedimentation was characterized by high amounts of *Coscinodiscus granii*, which was one of the most abundant taxa of the phytoplankton community at that time, and *Actinocyclus octonarius*.

**Dinoflagellates** were found in settled material only from June on. Apparently, the main period of dinoflagellate sedimentation after the spring bloom was just missed, because it coincided with the April to June time window when settling material could not be collected. This is however just the time when encysted spring bloom dinoflagellates usually settle out from the water column. Interestingly, typical spring bloom taxa, such as *Peridiniella catenata* and *Dinophysis norvegica* dominated settling matter in late June/early July together with *Heterocapsa triquetra*, which were among the 10 most abundant - in terms of biomass - taxa of the spring phytoplankton community. All three have heavy armours that should enhance their sedimentation and possibly their resuspension.

In 2020, highest dinoflagellate sedimentation rates were observed during the summer months from late July on, *Tripos muelleri* and *Prorocentrum cordatum*, as common summer species in the area, added to the settling material. In autumn, *Prorocentrum* spp, *Dissodinium pseudolunula*, and *Tripos muelleri* constituted most of the dinoflagellate taxa in sedimentation traps. These records however may be more related to resuspension than to sedimentation from the water column – since none of these taxa was particularly abundant in plankton samples.

In 2020, **cyanobacteria** sedimentation started somewhat earlier than in 2019 and occurred in 2 distinct pulses, in June and August. Settling cyanobacteria consisted mostly of diazotrophic filamentous taxa: *Dolichospermum*, *Aphanizomenon* and *Nodularia spumigena*. In late summer and autumn, colonial cyanobacteria, *Merismopedia* and *Snowella*, increased in sedimentation



samples. An early summer cyanobacteria sedimentation peak suggests that cyanobacterial growth and bloom formation started earlier than usual in the study area.

**Chlorophytes and flagellates** were present in sediment trap samples in spring and summer at relatively low frequencies. In summer and autumn samples, like in 2019, the harmful raphidophyte *Heterosigma akashiwo* was identified. This species was not yet encountered in the plankton samples taken during the respective time window. The sediment trap record is the only indication of the species being present in the phytoplankton community during 2020.

Due to a dysfunction of the sedimentation trap, caused by extensive *Balanus* growth as well as by significant sediment resuspension, absolute measurements of **particulate organic matter and elements as well as isotopic signatures** are flawed and cannot be interpreted with confidence. We thus refrain from their presentation and discussion.

## Arkona Basin 2020

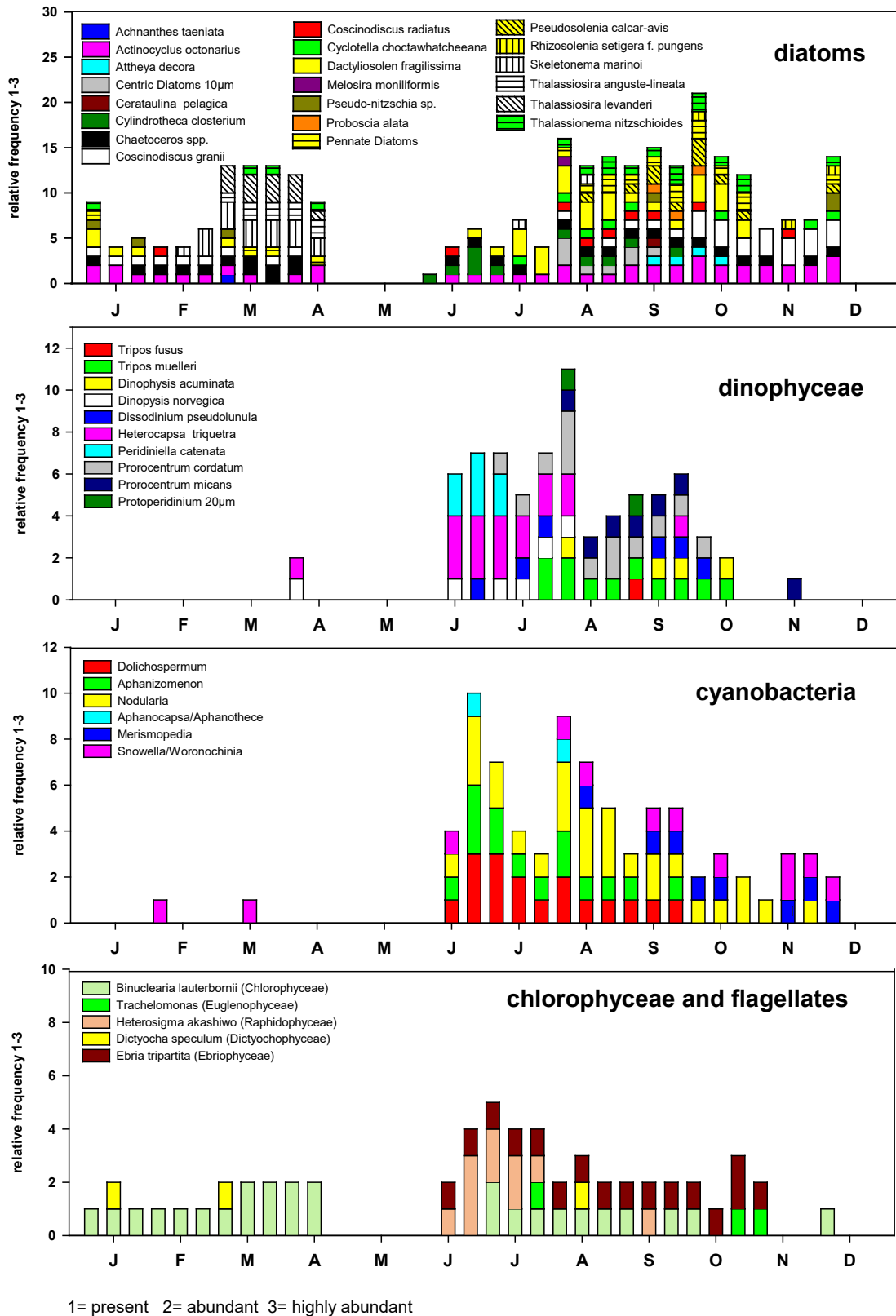


Fig. 17: Relative frequency of selected taxa of diatoms, dinoflagellates, cyanobacteria and green algae/flagellates in sinking organic material in 2020 (sediment trap at the Arkona Basin station).

## 3.2 Mesozooplankton

### 3.2.1 Species composition and non-indigenous species

In 2020, 54 taxa were observed in the Kiel Bight, the Bay of Mecklenburg and the Arkona Basin (Table Appendix 2). The species inventory was dominated by the commonly encountered taxa in the western Baltic Sea. The number of taxa resembled largely the previous years (2018 - 2019: 44 - 50 taxa) and remained again below the decadal peak of 63 - 73 taxa during the period 2016 - 2017 (WASMUND et al. 2017a, 2018b). The lack of sampling in March had a little effect on the species inventory because very few species are restricted in their seasonal occurrence to early spring only.

The species composition resembled the inventory of the previous year with a strong influence of species with a broad salinity tolerance and characteristic of the brackish waters. Nevertheless, halophilic organisms occurred regularly. They included the copepods *Calanus* spp., *Centropages typicus*, the cladoceran *Penilia avirostris*, chaetognaths of the family Sagittidae spp. or the coelenterates *Lizzia blondina*, *Stauridiosarsia gemmifera* or *Euphysa aurata*. These species were primarily found on single occasions in the Kiel Bight and the western Bay of Mecklenburg.

The seasonal variation of the species richness was pronounced in 2020 with a minimum in May and maxima in early spring and autumn (Fig. 18). This is a regularly observed pattern in the western Baltic Sea and caused by the presence of benthic larvae of Polychaeta, Echinodermata and Crustacea or diverse jellyfish species in early spring and autumn. In addition, thermophilic plankton such as the copepod *Acartia tonsa* or the cladocerans *Bosmina* spp., *Podon intermedius*, *Pleopis polyphemoides* or *Penilia avirostris* shows a temporally restricted occurrence during the summer/autumn (see Table Appendix 2). The number of taxa was generally higher in the Kiel Bight and the Bay of Mecklenburg (32 - 39 taxa) compared to the Arkona Basin (29 - 31 taxa). This is caused by the restriction of many meroplankton taxa (*Pectinaria* spp., *Asterias* spp., *Ophiura* spp., *Echinus* spp., Gymnolaemata) and halophilic holoplankton taxa (*Calanus* spp., *Paracalanus parvus*, *Crangon crangon*, *Penilia avirostris*, Ostracoda, Isopoda) and jellyfish (*Lizzia blondina*, *Rathkea octopunctata*, *Stauridiosarsia gemmifera*, *Euphysa aurata*) to the more western areas with a stronger influence of saline water (stations OMBMP-N1, -M2 and -M1).

The analysis of the spatial and temporal variation of the zooplankton lacks results for March in all areas. This may affect the interpretation of the relative composition or dominance based on maximal abundances observed during a year. The seasonal development of many taxonomic groups, however, is largely in a transition from the low overwintering stocks observed in February to their late spring and summer maxima. This is valid for the usually dominating calanoid copepods, rotifers and cladocerans which display their peak abundance in May-August. Larger stocks of zooplankton in March have been observed in Kiel Bight and the Bay of Mecklenburg only in some exceptional years due to the early occurrence of the cyclopoid copepod *Oithona* spp. In addition, *Fritillaria borealis* is common in spring in the Bay of Mecklenburg and the Arkona Basin. In case of *Oithona* spp., the lacking sampling in March has mainly implications for the analysis of the species' seasonal timing and less for the analysis of the general zooplankton

composition and dominance. In agreement with this, *Oithona* spp. did not display large differences in their maximal abundance between 2020 and the previous years. The stock of *F. borealis*, in contrast, may be underestimated. However, the lack of spring estimates is not expected to skew the description of the overall composition because the species usually contributes less than 10 % to the zooplankton stock in a restricted period.

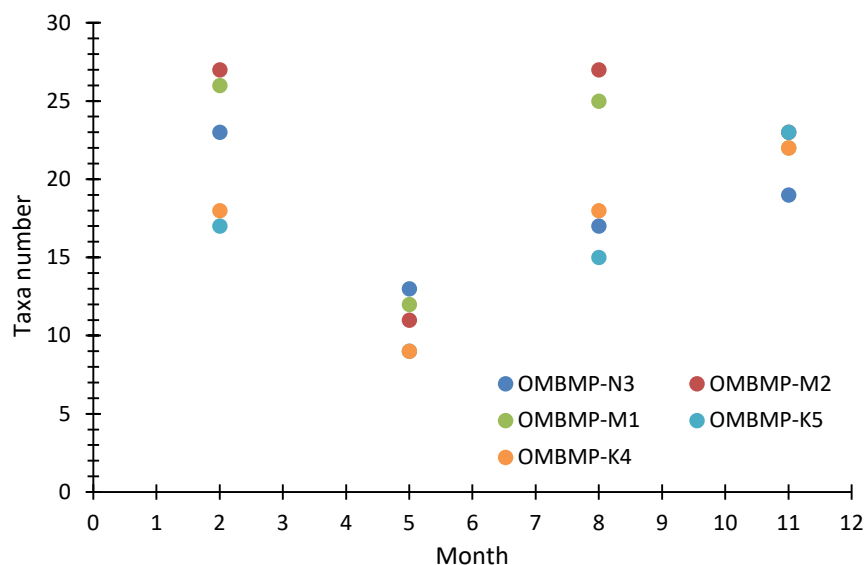


Fig. 18: Seasonal variation of the number of taxa recorded at different stations in the investigation area in 2020.

Based on the maximal concentrations, zooplankton abundance was low and ranged from  $2.3$  to  $5.6 \times 10^4$  ind.  $m^{-3}$  in the Arkona Basin (OMBMP-K4) and the Kiel Bight (OMBMP-N3), respectively (Fig. 19 a). Compared to previous years, this stock size was generally low, particularly in the Bay of Mecklenburg and the Arkona Basin (vgl. WASMUND et al. 2017a, 2018b, 2019a). Copepods dominated the zooplankton at all stations in 2020 (Fig. 19 a, Fig. 20 a-i). With an average abundance of  $1.7 - 2.9 \times 10^4$  ind.  $m^{-3}$  they contributed to 52 – 72 % to the stock. Their dominance resulted from an unusual low abundance of rotifers and cladocerans in 2020. Rotifers were already low in abundance in the previous year and with maximal  $1.0 \times 10^3$  ind.  $m^{-3}$  they contributed to only 0.4 - 3.9 % to the community (Fig. 20). However, cladocerans were also considerably less abundant (max.  $9.2 \times 10^3$  ind.  $m^{-3}$ ) than in preceding years and accounted for only 19.8 % of the stock. Contributions ranging from 32 to 58 % have been observed in previous years, particularly during 2017-2019. The copepods achieved their maximum in spring (Fig. 19 b). Apart from these groups, only bivalve larvae and the group of ‘others’ showed a higher contribution to the plankton. The latter consisted mainly of tintinnids, which were abundant in the Kiel Bight (Fig. 19 a, Fig. 20 a).

### Copepoda

The Copepoda are an important group that forms a vital trophic link between the primary production and higher trophic levels and serves as food for many commercially relevant fish species and their larvae (ALHEIT et al. 2005, BERNREUTHER et al. 2018). Because rotifers and

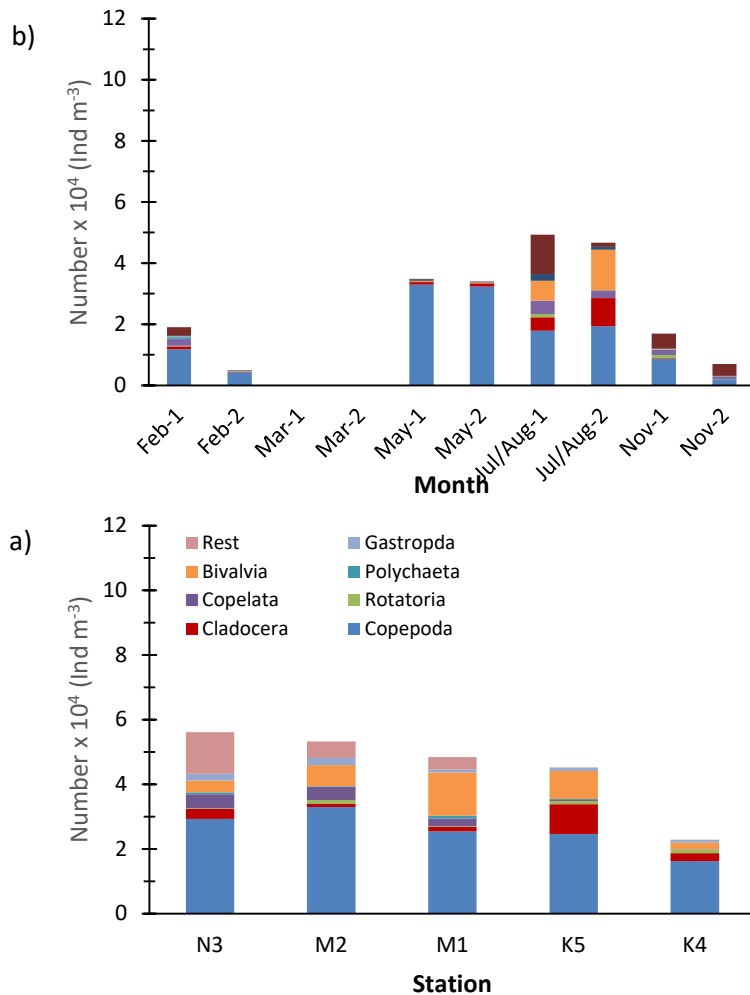


Fig. 19: Spatial and seasonal variation of the maximal abundance of the mesozooplankton groups (a, b) and of adults of calanoid and cyclopoid copepods (c, d) in the investigation area; continued on page 36.

cladocerans were relatively scarce in 2020, copepods were the numerically dominant group in all areas (Fig. 19 a, Fig. 20). Maximum concentrations are usually observed in late spring and summer and the year 2020 is no exception from this general pattern (Fig. 19 b). While the maximum abundance in the Arkona Basin (1.7 - 2.6 x 10<sup>4</sup> ind. m<sup>-3</sup>, OMBMP-K5 and -K4) was similar to the preceding years, the copepod stocks were about 50 % lower than those in the period 2017 - 2019 in the Kiel Bight and Bay of Mecklenburg (2.6 - 3.2 x 10<sup>4</sup> ind. m<sup>-3</sup>, OMBMP-N3 - M1).

In the Kiel Bight (OMBMP-N3) and the central Bay of Mecklenburg (OMBMP-M2), cyclopoid copepods (28 – 29 %, 1.5 - 1.6 x 10<sup>4</sup> ind. m<sup>-3</sup>) - exclusively represented by the genus *Oithona similis* - and calanoid copepods (24 – 33 %, 1.3 - 1.7 x 10<sup>4</sup> ind. m<sup>-3</sup>) contributed equally to the stock of copepods (Fig. 20 a, c). The contribution of *Oithona*, however, rapidly declined towards the Arkona Basin (2.9 - 3.2 %, 0.7 - 1.3 x 10<sup>3</sup> ind. m<sup>-3</sup>), which resulted in an unusual dominance of calanoid copepods (Fig. 20 e, g, i). However, the decline of *Oithona* towards the Baltic Proper is a regularly observed phenomenon in the western Baltic Sea.

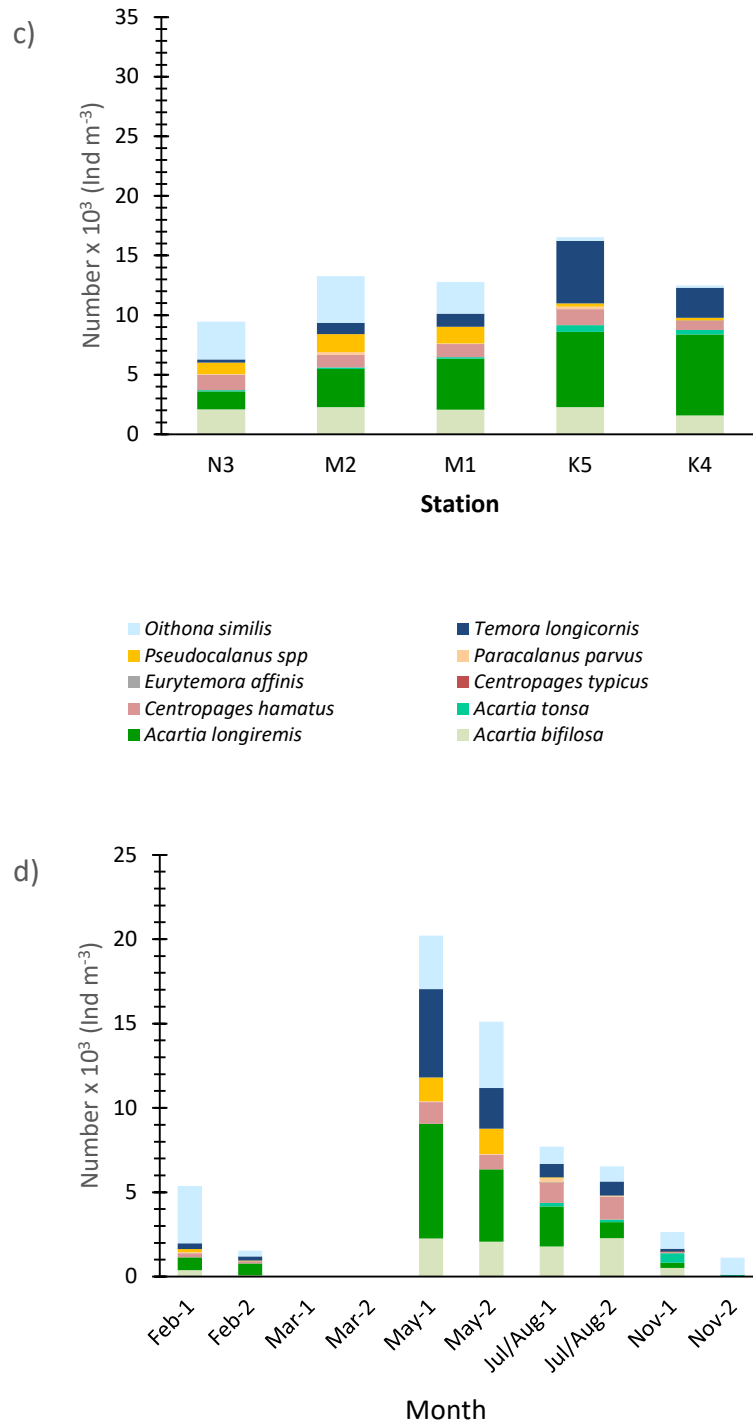


Fig. 19: continued.

Among the adult calanoid copepods, the genus *Acartia* was dominating in all areas (Fig. 19 c, Fig. 20 b-j). *Acartia longiremis* was the major species in this genus and contributed 24-55 % to the stock of calanoid copepods (Fig. 20 b-j). Its abundance increased from the Kiel Bight to the Bay of Mecklenburg and the Arkona Basin ( $1.5 - 6.7 \times 10^3$  ind. m<sup>-3</sup>). *Acartia bifilosa* was dominating in the Kiel Bight (33.2 %, Fig. 20 a), but its contribution to the calanoid copepod stock gradually decreased along the salinity gradient to 12.9 %, although its abundance remained rather constant ( $1.5 - 2.3 \times 10^3$  ind. m<sup>-3</sup>).

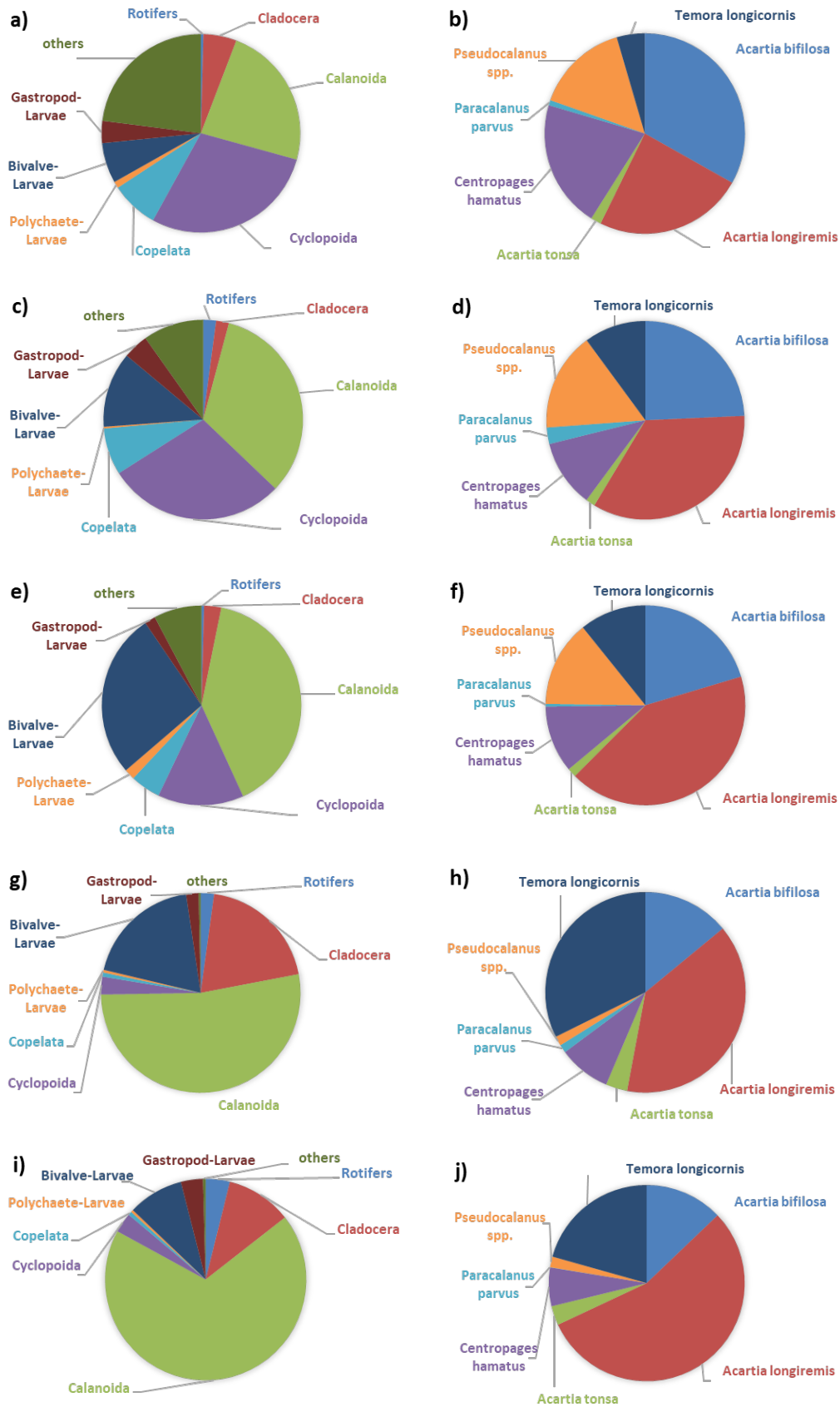


Fig. 20: Relative composition of the mesozooplankton groups (a-i) and adults of calanoid copepods (b-j) in 2020 (a-b: Kiel Bight (OMBMP-N3), c-d: Bay of Mecklenburg (OMBMP-M2) e-f: Bay of Mecklenburg (OMBMP-M1), g-h: Arkona Basin (OMBMP-K5), i-j: Arkona Basin (OMBMP-K4)).

The shift in the dominance among the two sibling species is commonly observed in the zooplankton community composition of the western Baltic Sea. Both species had their maximum in late spring and summer (Fig. 19 d). As usual, *A. tonsa* contributed only little to the zooplankton stock (1.5 - 3.2 %, 105 - 560 ind. m<sup>-3</sup>).

Among the other calanoid copepod species, *Temora longicornis* ranked third in 2020. The species contributed 4.5 - 32.2 % to the stock and occurred primarily in the Arkona Basin (2.5 - 5.2 x 10<sup>3</sup> ind. m<sup>-3</sup>) during late spring. The species is usually also common in the Bay of Mecklenburg, but the abundance was low in 2020 (0.9 - 1.1 x 10<sup>3</sup> ind. m<sup>-3</sup>). *Pseudocalanus* spp. and *Centropages hamatus* occurred at their usual concentrations (1.4 - 1.5 x 10<sup>3</sup> ind. m<sup>-3</sup>). They primarily contributed to the copepod stock in the Kiel Bight and Bay of Mecklenburg (10.8 - 20.6 %) and had their seasonal maximum during late spring and summer, respectively (OMBMP-N<sub>3</sub>, -M<sub>2</sub>, -M<sub>1</sub>; Fig. 19 b, Fig. 20 b, d). In contrast, the abundance of *Paracalanus parvus* was unusual low in 2020 (4 - 250 ind. m<sup>-3</sup>). The species can be common in the Kiel Bight, but was only of minor importance in 2020. Other copepod species were generally rare. *Centropages typicus*, *Eurytemora affinis* or *Calanus* spp. were only observed as single specimen.

#### *Cladocera*

With the exception of *Evadne nordmanni*, the density of cladocerans was generally low in 2020. *Bosmina* spp. was usually the single most important genus contributing significantly to the zooplankton stock in summer by concentrations that can exceed 0.5 - 1.0 x 10<sup>5</sup> ind. m<sup>-3</sup>. In 2020, the cladocerans contributed only 2.8 - 19.8 % to the zooplankton stock (Fig. 20). *Bosmina* spp. was largely restricted to the Arkona Basin (OMBMP-K<sub>4</sub>, -K<sub>5</sub>) where it occurred at 1.2 - 8.5 x 10<sup>3</sup> ind. m<sup>-3</sup> in summer. *E. nordmanni* was found in all areas usually during summer at 0.9 - 2.6 x 10<sup>3</sup> ind. m<sup>-3</sup>. *Podon intermedius* and *P. leuckartii* were unusually rare (17-310 ind. m<sup>-3</sup>). Nevertheless, they occurred in a typical succession with *P. leuckartii* followed by *P. intermedius* during spring to summer at all stations. *Pleopis polyphemoides*, in contrast, was only observed in the Kiel Bight, where it occurred similar to *Penilia avirostris* in small numbers.

#### *Rotifera*

Rotifers can be seasonally very abundant, but their numbers were very low in 2020 (200 - 1100 ind. m<sup>-3</sup>, Fig. 19 a, b). Already in 2019, the abundance was considerably lower compared to preceding years ranging from 1.8 - 6.1 x 10<sup>4</sup> ind. m<sup>-3</sup>. However, exceptional low stocks are not uncommon and have been observed already before in 2017. The genus *Synchaeta* spp. dominated in all areas, with highest numbers in the Arkona Basin (909-1000 ind. m<sup>-3</sup>). Specimen of the genus *Keratella* occurred at numbers of 3-6 ind. m<sup>-3</sup> in all areas except the Kiel Bight. With *K. cruciformis* and *K. quadrata* two species were observed and *K. cochlearis*, which was observed in previous years, were not encountered.

#### *Copelata*

Copelata contributed to 0.6 - 7.8 % to the stock (Fig. 20). They are represented by *Fritellaria borealis* and *Oikopleura dioica* in the western Baltic Sea. *F. borealis* usually occurs in spring in the Bay of Mecklenburg and the Arkona Basin. Due to the lack of sampling in March, the stock



size of 39-191 ind. m<sup>-3</sup> is likely underestimated, because the species usually achieves 1.6 - 7.2 x 10<sup>3</sup> ind. m<sup>-3</sup>. *O. dioica* is more confined to the Kiel Bay and the Bay of Mecklenburg and occurs primarily in autumn. *O. dioica* occurred at usual concentrations of 2.0 - 4.0 x 10<sup>3</sup> ind. m<sup>-3</sup>.

#### *Other zooplankton*

Meroplankton contributed to 11 – 30 % to the stock (Fig. 20). As usual, bivalve larvae were the most abundant group outnumbering the gastropod and polychaete larvae. Other groups such as cirripede or echinoderm larvae were, in contrast, rare. Bivalve larvae occurred primarily in summer at 0.2 - 1.3 x 10<sup>4</sup> ind. m<sup>-3</sup> in the Bay of Mecklenburg (OMBMP-M<sub>2</sub>, -M<sub>1</sub>) and Arkona Basin (OMBMP-K<sub>5</sub>, -K<sub>4</sub>) and contributed up to 36 % to the zooplankton stock (Fig. 19 a, b, Fig. 20). Polychaete larvae and gastropod were restricted to the Kiel Bight (OMBMP-N<sub>3</sub>) and the Bay of Mecklenburg (OMBMP-M<sub>2</sub>, -M<sub>1</sub>). While the abundance of polychaetes was unusual low (91-862 ind. m<sup>-3</sup>), gastropods occurred at their usual concentrations (0.8 - 2.2 x 10<sup>3</sup> ind. m<sup>-3</sup>).

#### *Non-indigenous species (NIS)*

In 2020, the anthomedusae *Lizzia blondina* and *Staurosarsia gemmifera* were found again in the Bay of the Mecklenburg. The species is now regularly found in the area albeit at low numbers. Both species occur regularly around the coasts of the British Isles and the southern North Sea. They have also been recorded from the Skagerrak and the Kattegat (RUSSEL 1970, GREVE et al. 2004). *Acartia tonsa* is a regular member of the zooplankton in the western Baltic Sea. It is considered as non-indigenous species (NIS) since its introduction during the 1920s into the Baltic Sea (OJAVEER & KOTTA 2015). It was found at all stations, but at considerably low numbers. Apart from NIS, other species of marine origin occurred in the samples and are likely transported with saline water into the Kiel Bight. These include the cladoceran *Penilia avirostris* (RUSSEL 1970, GIESKES 1971, GREVE et al. 2004) or *Calanus* spp. and *Centropages typicus* which occur primarily in the North Sea and the Kattegat (CPR-TEAM 2004).

### **3.2.2 Seasonal zooplankton variation in the sub-areas**

#### **Kiel Bight (OMBMP-N<sub>3</sub>)**

The seasonal development of zooplankton in the Kiel Bight (OMBMP-N<sub>3</sub>) is usually characterized by an early increase of the stock size in March compared to the later start of the season in April-May in the Baltic Proper. The lack of sampling in March, thus, impedes clear statements about the timing and phenology of zooplankton in spring 2020. In the past, the seasonal variation in stock size in the Kiel Bight has been very variable, particularly regarding the size of the overwintering stock and the abundance in late spring. In this respect, the year 2020 has been a rather usual year. The overwintering stock of 1.5 x 10<sup>4</sup> ind. m<sup>-3</sup> is comparable to period 2017 - 2019 (Fig. 21) and continue are period of higher stock size compared to the beginning of the decade. This applies also to the observed spring and summer concentrations of zooplankton which were in the usual range of 3.1-3.4 x 10<sup>4</sup> ind. m<sup>-3</sup> (Fig. 21). Thus, the previous year 2019 was an exceptional year with very high zooplankton abundance (> 6 x 10<sup>4</sup> ind. m<sup>-3</sup>) during May (see ZETTLER et al. 2020).

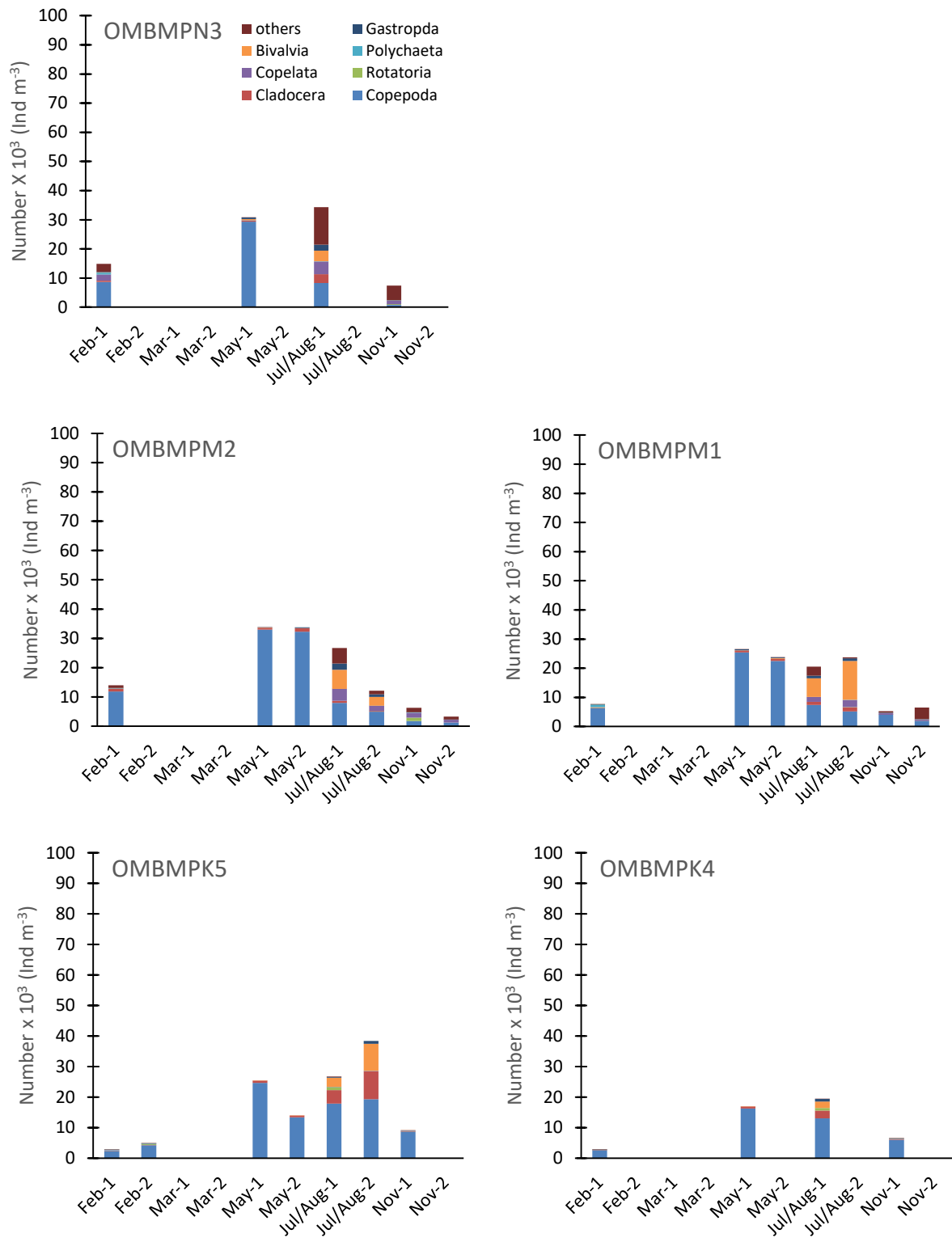


Fig. 21: Seasonal variation of the main taxonomic groups of the mesozooplankton at different stations in the investigation area in 2020.

The composition of the zooplankton community resembled previous years (Fig. 20, Fig. 21 a). As usual, copepods dominated the community (max.  $2.9 \times 10^4$  ind.  $m^{-3}$ ) due to the higher salinity in the area. Calanoids and cyclopoids contributed equally to the stock, which contrasts with the period 2016-2019 when calanoid copepods generally dominated with a higher abundance than 2020. The group of 'others' were prominent in summer ( $1.3 \times 10^4$  ind.  $m^{-3}$ ) caused by a high abundance of Tintinnidae. This group occurs regularly at the Kiel Bight during summer. The abundance of Copelata (max.  $4.3 \times 10^3$  ind.  $m^{-3}$ ) was in the range of those densities usually observed in the area ( $1.7 - 10.7 \times 10^3$  ind.  $m^{-3}$ ). The stocks of cladocerans and rotifers as typical members of brackish communities were, in contrast, low (3026 and 234 ind.  $m^{-3}$ , respectively). The meroplankton was dominated by bivalve larvae (max.  $3.6 \times 10^3$  ind.  $m^{-3}$ ) followed by gastropods (max.  $2.0 \times 10^3$  ind.  $m^{-3}$ ) and polychaetes ( $0.6 \times 10^3$  ind.  $m^{-3}$ ). The abundance of polychaetes was lower than usual ( $1.4 - 2.2 \times 10^3$  ind.  $m^{-3}$ ). The genus *Oithona* spp. exclusively represented the cyclopoids and was the single most important taxon of the copepoda (Fig. 22 a). *Acartia bifilosa* dominated together with *A. longiremis* and *Centropages hamatus* among the calanoid copepods (Fig. 22 b). The species share was, however, lower than usual (33 %,  $2.2 \times 10^3$  ind.  $m^{-3}$ ), while *A. longiremis* (24 %,  $1.5 \times 10^3$  ind.  $m^{-3}$ ) displayed an unusual high contribution since it barely contributed more than 10 % to the calanoid stock in the past. Following a higher density during the period 2017-2019, the abundance of *Pseudocalanus* spp., *Paracalanus parvus* and *Temora longicornis* were low ( $< 1.0 \times 10^3$  ind.  $m^{-3}$ ).

The winter abundance of the total zooplankton was generally high ( $1.4 \times 10^4$  ind.  $m^{-3}$ , Fig. 21). Copepods and Copelata dominated the stock ( $8.6$  and  $2.1 \times 10^3$  ind.  $m^{-3}$ ). Polychaete larvae were less abundant than usual ( $600 \times 10^3$  ind.  $m^{-3}$ ), while an exceptional high concentration of the plathelminth *Aleurina* spp. was observed ( $2.3 \times 10^3$  ind.  $m^{-3}$ ). The Cladocera were represented by *Evadne nordmanni* occurring in low numbers (483 ind.  $m^{-3}$ ). *Oithona* ( $4.7 \times 10^3$  ind.  $m^{-3}$ ) and *Pseudo/Paracalanus* ( $1.9 \times 10^3$  ind.  $m^{-3}$ ) had high stocks among the copepods. All other species were rare.

In May, the zooplankton abundance increased to  $3.1 \times 10^4$  ind.  $m^{-3}$ . This increase is usually based on the copepods, which alone contributed already to  $2.9 \times 10^4$  ind.  $m^{-3}$  to the total stock (Fig. 21). The Cladocera, consisting of *Evadne nordmanni* and *Podon leuckartii* were rare (473 ind.  $m^{-3}$ ), similar to the meroplankton (63 - 537 ind.  $m^{-3}$ ). *Oithona* spp. remained as the dominant copepod species ( $1.6 \times 10^4$  ind.  $m^{-3}$ ), but the stocks of *Acartia* ( $6.6 \times 10^3$  ind.  $m^{-3}$ ), with *A. bifilosa* as the main species, *Centropages* to ( $2.6 \times 10^3$  ind.  $m^{-3}$ ) and *Pseudo/Paracalanus* (to  $3.6 \times 10^3$  ind.  $m^{-3}$ ) increased by a factor 2 - 10. *Temora longicornis*, in contrast, declined (315 ind.  $m^{-3}$ ). *Acartia bifilosa* ( $2.1 \times 10^3$  ind.  $m^{-3}$ ) and *Oithona similis* ( $3.6 \times 10^3$  ind.  $m^{-3}$ ) were dominating the stock of adult copepods, but *A. longiremis* was abundant as well ( $1.5 \times 10^3$  ind.  $m^{-3}$ ).

The zooplankton stock remained high from late spring to summer ( $3.4 \times 10^4$  ind.  $m^{-3}$ ). The composition changed in response to the warming of the seawater. While copepods were still dominating, their abundance decreased considerably ( $8.3 \times 10^3$  ind.  $m^{-3}$ ). The single most abundant group were Tintinnidae ( $1.3 \times 10^4$  ind.  $m^{-3}$ ). The stocks of Cladocera increased, with *Evadne nordmanni* ( $2.6 \times 10^3$  ind.  $m^{-3}$ ) and *Podon intermedius* (237 ind.  $m^{-3}$ ) as the major species.

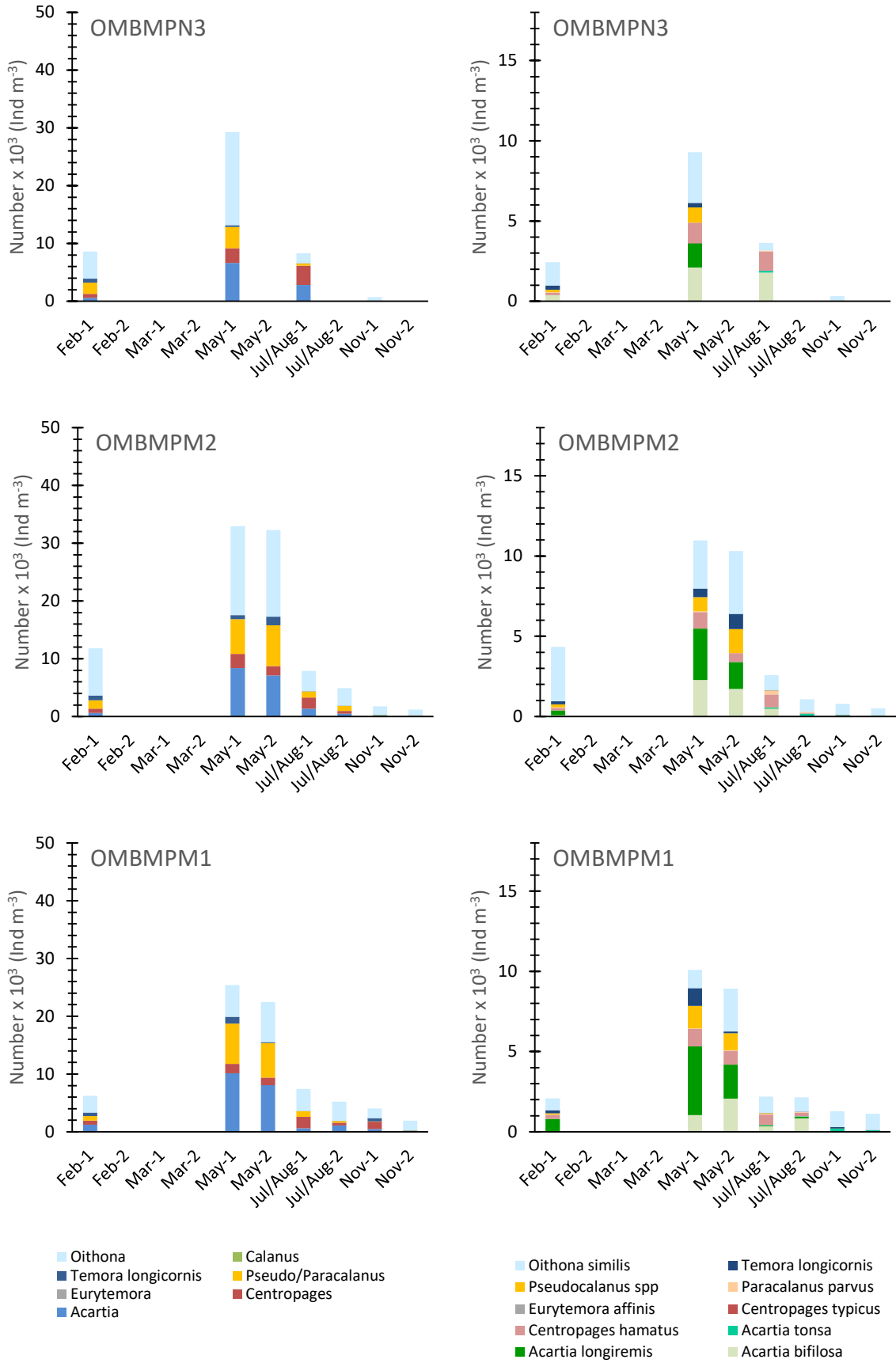


Fig. 22: Seasonal variation of the abundance and composition of juvenile (left) and adult stages of copepods (right) of different genera in 2019. Note the different scale in the abundance of juveniles and adults (continued on page 42).

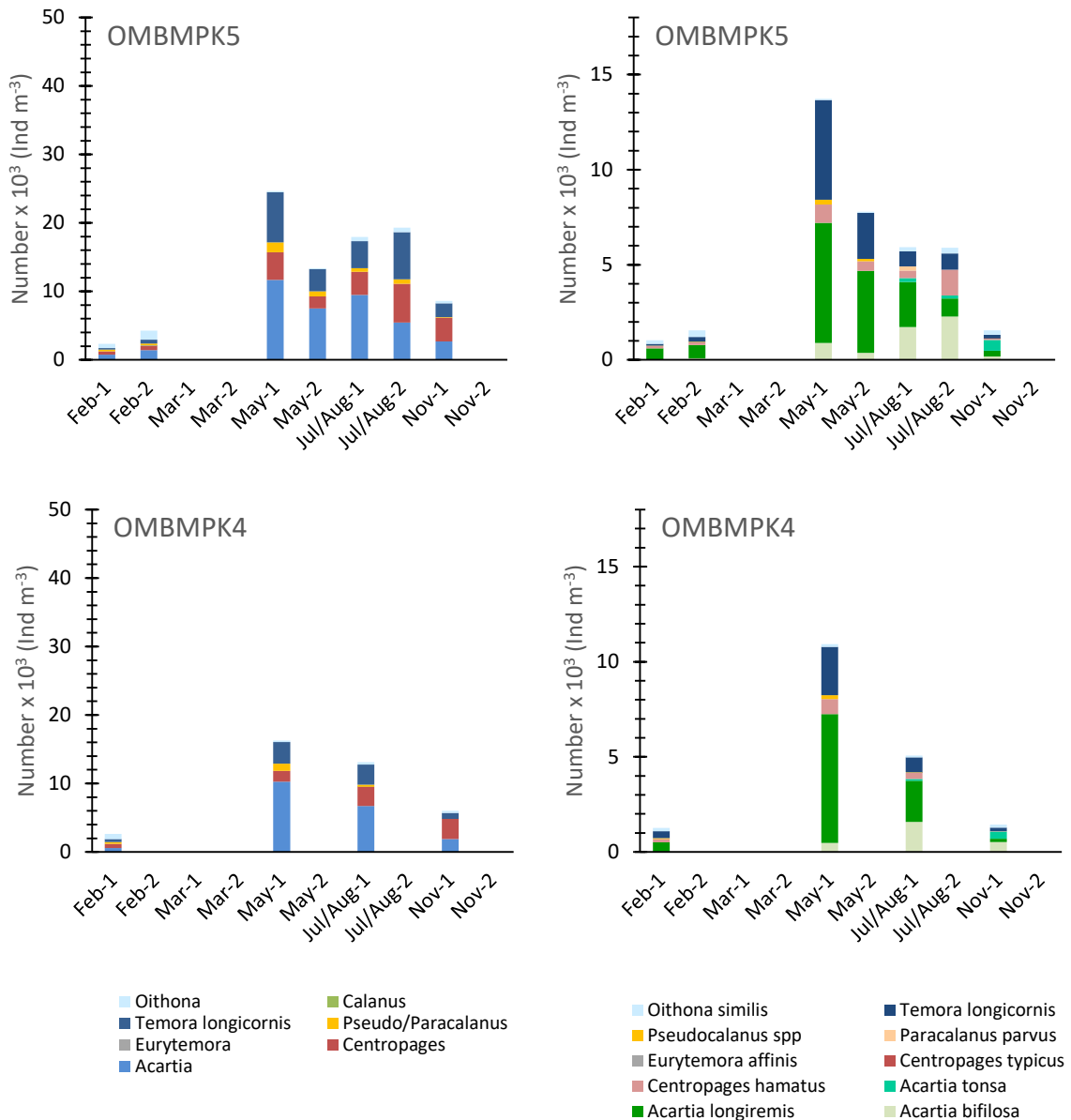


Fig. 22: continued.

Also Copelata, represented by the species *Oikopleura dioica*, became an important member of the community ( $4.4 \times 10^3$  ind.  $m^{-3}$ ). The meroplankton stocks increased primarily due to bivalves ( $3.7 \times 10^3$  ind.  $m^{-3}$ ) and gastropods ( $2.1 \times 10^3$  ind.  $m^{-3}$ ), while bryozoan and polychaete larvae were rare ( $< 200$  ind.  $m^{-3}$ ). While *Oithona* spp., as usual, declined during the second half of the year ( $1.7 \times 10^3$  ind.  $m^{-3}$ ), the stocks of *Acartia* and *Centropages* were still large ( $2.8$  and  $3.3 \times 10^3$  ind.  $m^{-3}$ ). *Acartia bifilosa* ( $1.8 \times 10^3$  ind.  $m^{-3}$ ) and *Centropages hamatus* ( $1.2 \times 10^3$  ind.  $m^{-3}$ ) were the main species among adults. *Pseudo/Paracalanus* and *Temora* largely disappeared.

The autumn stock was rather low compared to previous years ( $7.4 \times 10^3$  ind.  $m^{-3}$ ). *Oikopleura dioica* ( $1.3 \times 10^3$  ind.  $m^{-3}$ ) and bryozoan larvae ( $4.7 \times 10^3$  ind.  $m^{-3}$ ) were most abundant. All other taxa were rather rare. *Oithona* spp. dominated among the copepods, but its abundance was low ( $623$  ind.  $m^{-3}$ ).

### Bay of Mecklenburg (OMBMP-M2 and M1)

The restrictions in the description of the seasonal timing of zooplankton caused by lacking samples from March described for the Kiel Bight apply also to the Bay of Mecklenburg (OMBMP-M2 and M1) and do not allow any conclusions about the seasonal timing. The Bay usually shows a strong resemblance the Kiel Bight regarding the zooplankton composition and the seasonal development. The more eastern station (OMBMP-M2), however, shows usually - to a variable degree - the characteristics of a transition to the Baltic Proper. This might involve for instance the appearance of brackish rotifers or cladocerans or the decline of stocks of true marine species. The zooplankton abundance (max.  $4.9 - 5.3 \times 10^4$  ind.  $m^{-3}$ ) was lower than in the period 2017 - 2019 ( $6.7 - 13.7 \times 10^4$  ind.  $m^{-3}$ ), despite a higher overwintering stock size.

The copepods ( $1.7 - 1.9 \times 10^4$  ind.  $m^{-3}$ ) and bivalve larvae ( $0.7 - 1.3 \times 10^4$  ind.  $m^{-3}$ ) dominated the zooplankton community at both stations and their contribution increased towards the more eastern station (33 to 40 % and 12 to 27 %, respectively; Fig. 20 and Fig. 21). The cyclopoid *Oithona* spp. ( $0.7 - 1.5 \times 10^4$  ind.  $m^{-3}$ ), *Oikopleura* among the Copepoda ( $2.4 - 4.0 \times 10^3$  ind.  $m^{-3}$ ) and the gastropod larvae ( $0.8 - 2.1 \times 10^3$  ind.  $m^{-3}$ ), in contrast, declined. Rotifers and Cladocera were a minor component in the Bay of Mecklenburg ( $< 1.1$  and  $1.4 \times 10^3$  ind.  $m^{-3}$ , respectively). *Oithona* ( $0.7 - 1.5 \times 10^4$  ind.  $m^{-3}$ ), *Acartia* ( $0.8 - 1.1 \times 10^4$  ind.  $m^{-3}$ ) and *Pseudo/Paracalanus* ( $6.9 - 7.1 \times 10^3$  ind.  $m^{-3}$ ) were the dominant copepods, but the contribution of *Oithona* declined considerably towards the east. Among the adult copepods, *A. longiremis* ( $3.2 - 4.2 \times 10^3$  ind.  $m^{-3}$ ) replaced *A. bifilosa* ( $2.1 - 2.3 \times 10^4$  ind.  $m^{-3}$ ) as the major species. *Centropages hamatus* and *Pseudocalanus* spp. ( $1.1 - 1.5 \times 10^3$  ind.  $m^{-3}$ ) remained abundant, while the abundance of *Temora longicornis* increased compared to the Kiel Bight ( $0.9 - 1.1 \times 10^3$  ind.  $m^{-3}$ ).

The overwintering stocks were high ( $0.7 - 1.4 \times 10^4$  ind.  $m^{-3}$ ), particularly among the copepods which clearly dominated ( $0.6 - 1.2 \times 10^4$  ind.  $m^{-3}$ , Fig. 21). Polychaete larvae occurred at the usual densities (118 - 862 ind.  $m^{-3}$ ). The cladocera were represented by *Evadne nordmanni* and *Podon leuckartii* and were slightly more abundant than in the previous years (197 - 977 ind.  $m^{-3}$ ). Other groups contributed with less than 100 ind.  $m^{-3}$  to the zooplankton stock. Among the copepods, *Oithona* was most abundant ( $2.9 - 8.1 \times 10^3$  ind.  $m^{-3}$ ) followed by *Pseudo/Paracalanus* ( $0.7 - 1.4 \times 10^3$  ind.  $m^{-3}$ ) and *Acartia* ( $0.6 - 1.2 \times 10^3$  ind.  $m^{-3}$ ). *Oithona similis* ( $0.7 - 3.4 \times 10^3$  ind.  $m^{-3}$ ) and *Acartia longiremis* (303-758 ind.  $m^{-3}$ ) were dominating the adult community (Fig. 22).

Similar to the Kiel Bight, the zooplankton increase towards late spring ( $2.3 - 3.4 \times 10^4$  ind.  $m^{-3}$ ) was primarily based on a tripling of the copepod stocks which achieved  $2.3 - 3.3 \times 10^3$  ind.  $m^{-3}$  (Fig. 21, Fig. 22). *Evadne nordmanni* (197 - 977 ind.  $m^{-3}$ ) and *Podon leuckartii* (197 - 977 ind.  $m^{-3}$ ) were still abundant, but occurred at a lower density than the previous years. The rotifers, in particular *Synchaeta*, are regularly observed in May, particular at station -M1. In 2020, the group was not observed. This might indicate that the influence of brackish water on the zooplankton composition was low. However, the genus abundance in eastern waters was also unusually low (see chapter Arkona Basin). The meroplankton abundance remained low, polychaete larvae disappeared and were replaced by gastropod (146 - 352 ind.  $m^{-3}$ ) and bivalve larvae (48 - 274 ind.  $m^{-3}$ ). *Oithona* ( $0.5 - 1.5 \times 10^4$  ind.  $m^{-3}$ ), *Acartia* ( $0.7 - 1.1 \times 10^4$  ind.  $m^{-3}$ ) and *Pseudo/Paracalanus*

( $6.0 - 7.1 \times 10^3$  ind.  $m^{-3}$ ) were still the dominant genera among the copepods, with *Acartia* gaining in importance towards the eastern station –M1. The contribution of *Centropages* and *Temora* was lower than usual ( $0.2 - 2.4 \times 10^3$  ind.  $m^{-3}$ ). *A. bifilosa* ( $1.0 - 2.2 \times 10^3$  ind.  $m^{-3}$ ), *A. longiremis* ( $1.6 - 4.2 \times 10^3$  ind.  $m^{-3}$ ) and *Oithona similis* ( $1.1 - 3.9 \times 10^3$  ind.  $m^{-3}$ ) dominated the adult copepods at stations OMBMP-M2 and –M1, respectively, but *A. longiremis* became more prominent at OMBMP-M1.

In summer, the zooplankton abundance was lower at OMBMP-M2 than at OMBMP-M1 due to variable stocks of meroplankton, but the stocks remained high (Fig. 21). Similar to the Kiel Bight, the stocks of copepods declined ( $4.9 - 7.9 \times 10^3$  ind.  $m^{-3}$ ), and the meroplankton gained in importance ( $0.4 - 1.4 \times 10^4$  ind.  $m^{-3}$ ). Bivalve larvae replaced the copepods as most abundant group ( $0.3 - 1.3 \times 10^4$  ind.  $m^{-3}$ ). *Oikopleura dioica*, among the Copepata, ( $1.7 - 4.0 \times 10^3$  ind.  $m^{-3}$ ) and gastropod larvae ( $0.8 - 2.2 \times 10^3$  ind.  $m^{-3}$ ) were similarly abundant, while Cladocera were more important at station M1 only ( $0.3 - 1.5 \times 10^3$  ind.  $m^{-3}$ ). *Evadne nordmanni* was still the dominant species, and similar to the Kiel Bight, *Podon leuckartii* was replaced by *P. intermedius*. Only a few *Synchaeta* were observed, while Tintinnidae were abundant ( $2.8 - 4.8 \times 10^3$  ind.  $m^{-3}$ ). Among the copepods, *Oithona* still remained the dominant taxon ( $2.9 - 3.8 \times 10^3$  ind.  $m^{-3}$ ), *Acartia* ( $0.5 - 1.3 \times 10^3$  ind.  $m^{-3}$ ) and *Centropages* ( $\times 10^3$  ind.  $m^{-3}$ ) were abundant as well. *O. similis*, *C. hamatus* and *A. bifilosa* were dominating the adult copepods ( $0.3 - 1.1 \times 10^3$  ind.  $m^{-3}$ ).

The zooplankton abundance was low in autumn. Copepods ( $1.1 - 4.0 \times 10^3$  ind.  $m^{-3}$ ) and *Oikopleura dioica* ( $0.5 - 1.7 \times 10^3$  ind.  $m^{-3}$ ) were the major groups. All other zooplankton declined in abundance and had a minor contribution to the stocks. *Oithona similis* dominated the stock of copepods ( $1.0 - 1.7 \times 10^3$  ind.  $m^{-3}$ ).

#### **Arkona Basin (OMBMP-K4 and –K5)**

The total zooplankton stock showed maximum size of  $2.3$  to  $4.6 \times 10^4$  ind.  $m^{-3}$  (OMBMP-K4, -K5; Fig. 21) and was considerably lower than the zooplankton abundance of  $4.4 - 14.0 \times 10^4$  ind.  $m^{-3}$  during the period 2016 - 2018, but also lower than in 2015-2016 when stock sizes were at minimum in the past decade ( $2.7 - 8.2 \times 10^4$  ind.  $m^{-3}$ ). Low stocks were already observed during 2019 due to unusual low densities of rotifers during May. In 2020, the cladocerans occurred at an unusual low abundance, primarily based on low densities of *Bosmina* spp. during the summer. This observation is not affected by the lacking March sampling. Both groups have their maxima during late spring and summer.

Due to the low abundance of these two important brackish-water zooplankton taxa, copepods were the dominating group during most of the seasons (Fig. 21). With maximum concentrations of  $1.7 - 2.5 \times 10^4$  ind.  $m^{-3}$ , calanoid copepods contributed to 53 - 69 % to the zooplankton stocks (Fig. 20 c-f). The cyclopoid copepod *Oithona* spp. was only of minor importance in the Arkona Basin ( $742 - 1339$  ind.  $m^{-3}$ , 3 %). The Cladocera accounted for 11 - 20 % of the stock. Although by one order of magnitude lower than usual, *Bosmina* spp. was the most abundant taxon ( $8.4 \times 10^3$  ind.  $m^{-3}$ ) followed by *Evadne nordmanni* ( $2.6 \times 10^3$  ind.  $m^{-3}$ ). *Podon intermedius* and *P. leuckartii* were rare ( $310$  and  $107$  ind.  $m^{-3}$ ). In the autumn, the bivalve larvae achieved high concentrations as well (max.  $8.8 \times 10^3$  ind.  $m^{-3}$ ). The rotifers and gastropods showed only occasionally elevated

concentrations (800 - 1000 ind. m<sup>-3</sup>), while the Copelata and other meroplankton occurred at concentrations larger than 300 ind. m<sup>-3</sup>. The calanoid copepods consisted mainly of *Acartia longiremis* (6.3 - 6.7 x 10<sup>3</sup> ind. m<sup>-3</sup>) and *Temora longicornis* (2.5 - 5.2 x 10<sup>3</sup> ind. m<sup>-3</sup>) which together contributed to 71 - 75 % of the calanoid copepods. *A. bifilosa* and *Centropages hamatus* occurred regularly (0.7 - 2.2 x 10<sup>3</sup> ind. m<sup>-3</sup>), while all other species contributed less than 3.5 % to the stock.

Winter stocks were typically low (2.8 - 4.9 x 10<sup>3</sup> ind. m<sup>-3</sup>) and dominated by the copepods (2.3 - 4.2 x 10<sup>3</sup> ind. m<sup>-3</sup>, Fig. 21). Polychaete larvae had a minor contribution only (90 - 200 ind. m<sup>-3</sup>) as well as *Fritellaria borealis* (Copelata, 87 - 191 ind. m<sup>-3</sup>). All other taxa were rare. The copepods mainly consisted of the genera *Oithona*, *Centropages*, *Acartia* and *Temora* (< 840 ind. m<sup>-3</sup>), and among the adults *Acartia longiremis* and *Temora longicornis* (359 - 508 ind. m<sup>-3</sup>) dominated (Fig. 22).

In May, stocks had increased to 1.4 - 2.6 x 10<sup>4</sup> ind. m<sup>-3</sup>. The zooplankton composition was generally monotonous (Fig. 21). Copepods primarily dominated (1.3 - 2.5 x 10<sup>4</sup> ind. m<sup>-3</sup>) followed by cladocerans (623 - 821 ind. m<sup>-3</sup>) and bivalve larvae (9 - 35 ind. m<sup>-3</sup>). Other taxa such as rotifers and other meroplankton were lacking. The genus *Acartia* was the main genus among the copepods (0.7 - 1.2 x 10<sup>4</sup> ind. m<sup>-3</sup>) followed by *Temora* (3.1 - 7.3 x 10<sup>3</sup> ind. m<sup>-3</sup>) and *Centropages* (1.6 - 4.0 x 10<sup>3</sup> ind. m<sup>-3</sup>). *Oithona* and *Pseudo/Paracalanus* were of minor importance. The adult copepods were dominated by *Acartia longiremis* (4.3 - 6.7 x 10<sup>3</sup> ind. m<sup>-3</sup>) and *Temora longicornis* (3.2 - 7.3 x 10<sup>3</sup> ind. m<sup>-3</sup>, Fig. 22). The cladocerans were represented by *Evadne nordmanni* (553 - 714 ind. m<sup>-3</sup>) and *Podon leuckartii* (69 - 107 ind. m<sup>-3</sup>).

The zooplankton stocks remained high during the summer (1.9 - 2.9 x 10<sup>4</sup> ind. m<sup>-3</sup>). Similar to spring, copepods dominated (1.3 - 2.5 x 10<sup>4</sup> ind. m<sup>-3</sup>) followed by cladocerans (2.5 - 9.2 x 10<sup>3</sup> ind. m<sup>-3</sup>) and bivalve larvae (2.1 - 8.8 x 10<sup>3</sup> ind. m<sup>-3</sup>), which had considerably increased stock sizes. The rotifers *Synchaeta* spp. (909 - 1000 ind. m<sup>-3</sup>), gastropod larvae (242 - 939 ind. m<sup>-3</sup>) and *Oikopleura dioica* (91 - 152 ind. m<sup>-3</sup>) were encountered in small numbers as well. *Acartia* was the major genus among the copepods (5.5 - 9.5 x 10<sup>3</sup> ind. m<sup>-3</sup>), but *Centropages* and *Temora* gained in importance (3.4 - 6.9 x 10<sup>3</sup> ind. m<sup>-3</sup>). *Pseudo/Paracalanus* and *Oithona* were still rare. *Acartia bifilosa* got more abundant (1.7 - 2.2 x 10<sup>3</sup> ind. m<sup>-3</sup>), while the stocks of *A. longiremis* decreased (0.9 - 2.4 x 10<sup>3</sup> ind. m<sup>-3</sup>). *Bosmina* spp. occurred at lower densities than usual (2.3 - 8.5 x 10<sup>3</sup> ind. m<sup>-3</sup>). *Evadne nordmanni* was still abundant (0.6 - 1.9 x 10<sup>3</sup> ind. m<sup>-3</sup>) and *Podon intermedius* replaced *P. leuckartii* (121 - 181 ind. m<sup>-3</sup>).

The autumn stocks were again low (6.4 - 9.2 x 10<sup>3</sup> ind. m<sup>-3</sup>) and were dominated by copepods (6.0 - 8.1 x 10<sup>3</sup> ind. m<sup>-3</sup>). All other taxa occurred at densities lower than 240 ind. m<sup>-3</sup>. The cladocerans were mainly represented by *Evadne nordmanni* (74 - 176 ind. m<sup>-3</sup>) and only few *Podon leuckartii* or *Bosmina* spp. (< 53 ind. m<sup>-3</sup>) occurred. *Oikopleura dioica* (139 - 310 ind. m<sup>-3</sup>) were other groups of importance. With bivalve, gastropod, polychaete and bryozoan larvae the meroplankton was divers, but occurred at low numbers (< 54 ind. m<sup>-3</sup>). *Acartia*, *Centropages* and *Temora* equally contributed to the copepods (0.8 - 2.9 x 10<sup>3</sup> ind. m<sup>-3</sup>), while *Oithona* and *Pseudo/Paracalanus* were rare.



### 3.2.3 Long-term trends

The year 2020 continued a series of years of low stock size of zooplankton that has started around 2010 (Fig. 23 a). Although the maximal abundance of the various taxa fluctuated considerably ( $0.5 - 4.5 \times 10^5$  ind.  $m^{-3}$ ), concentrations were generally below the long-term average in 10 out of 11 years. This is illustrated by the annual anomalies of the maximal abundance ( $B'$ ), which were calculated by subtracting the long-term annual average of the total zooplankton abundance in 1995-2020 ( $B$ ,  $\log_{10}$ -transformed) from the annual maximum total abundance ( $b$ ,  $\log_{10}$ -transformed) according to MACKAS & BEAUGRAND (2010):

$$B' (t) = \log_{10} [b(t)] - \log_{10} [B]$$

The anomalies were lowest in the recent decade (Fig. 23 b) and indicate that the short period of apparent recovery, which could be observed in 2017 – 2018, did not continue. The total abundance of  $4.8 \times 10^4$  ind.  $m^{-3}$  in 2020 was the lowest value recorded since 20 years and accounted for only 1/6 of the long-term average of  $3.1 \times 10^5$  ind.  $m^{-3}$ . Not all taxonomic groups showed the same trend, however. A decline is most pertinent for the groups of rotifers and cladocerans. The rotifers decreased considerably already in 2019, and their maximum abundance in 2020 was further reduced ( $1109$  ind.  $m^{-3}$ ). The largest decrease in 2020, however, was observed among the cladocerans. Compared to 2019, their stock achieved only 17 % ( $9219$  ind.  $m^{-3}$ ). A decline was also discernible for the Copepoda and the polychaete larvae, while copepods, bivalve larvae and gastropod larvae remained on the same low level observed during the preceding years.

Although the calanoid copepods increased slightly during 2020, the stock size also displayed a long-term decline since 2010 (Fig. 23 c). *A. longiremis* kept its high abundance compared to the previous years ( $6.7 \times 10^3$  ind.  $m^{-3}$ ). *Centropages hamatus* ( $1.4 \times 10^3$  ind.  $m^{-3}$ ) and *A. tonsa* ( $563$  ind.  $m^{-3}$ ) changed only little, as well. A large increase occurred in the stock size of *Temora longicornis* ( $5.2 \times 10^3$  ind.  $m^{-3}$ ), and to a lesser degree in *Pseudocalanus* spp. ( $1.5 \times 10^3$  ind.  $m^{-3}$ ). *A. bifilosa*, in contrast, declined slightly ( $2.3 \times 10^3$  ind.  $m^{-3}$ ) after being the most abundant calanoid copepod in 2019.

The causes for the decline of the total zooplankton stock can be manifold. In the North Sea, a reduction in the zooplankton abundance during the 1990s e.g. was attributed to a reduction in nutrient concentrations and to an increased predation by gelatinous plankton (GREVE et al. 2004). However, care needs to be taken in the interpretation of the present results because long-term trends are based on maximal concentrations observed in a rather infrequent sampling scheme. This does not allow a detailed analysis of potential causes. Rotifers and cladocerans, in particular, can have short periods of mass development that can be easily missed in infrequent sampling programmes. In addition, data about predator abundance, especially those of gelatinous zooplankton, are not available for the western Baltic Sea.

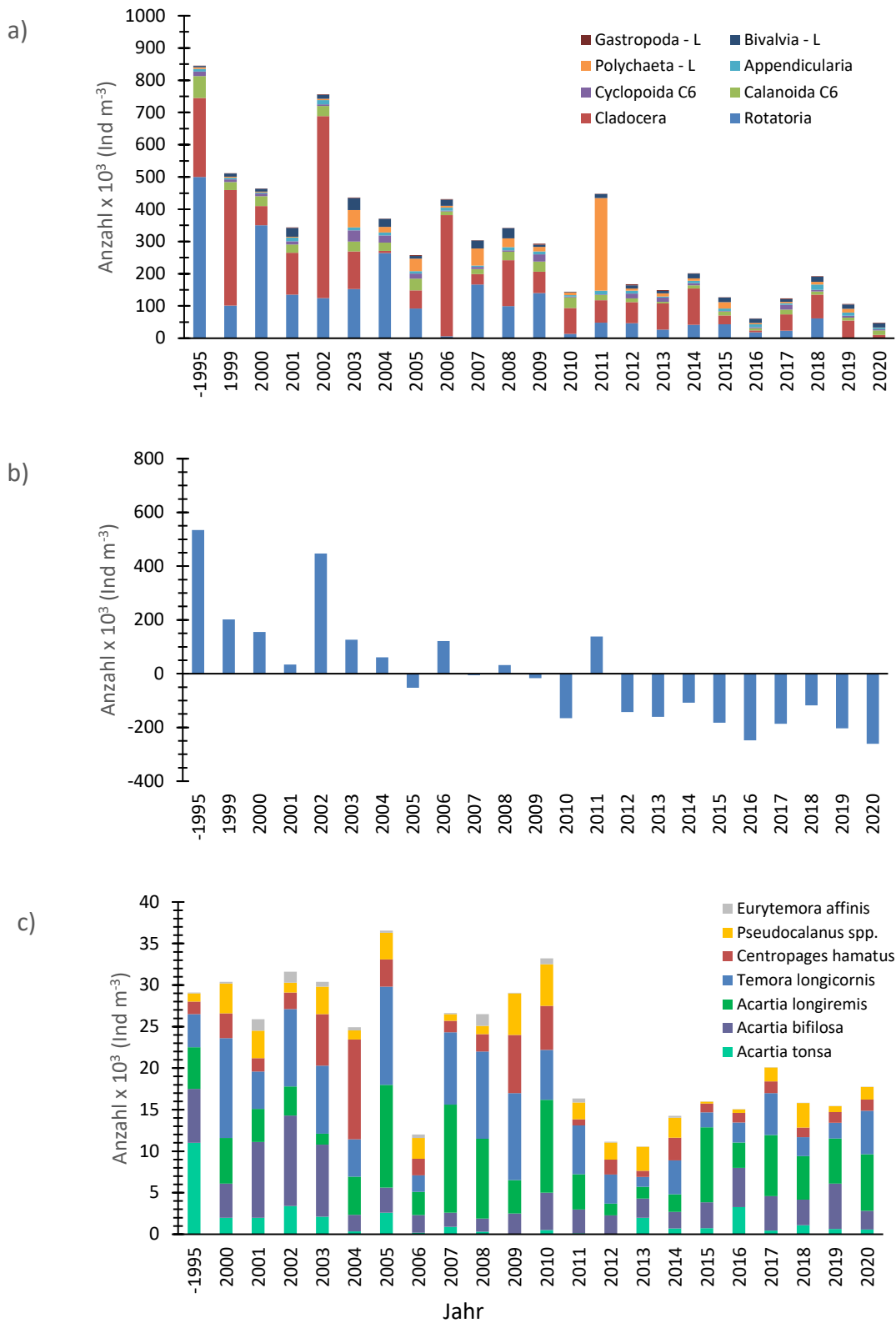


Fig. 23: Long-term trends in the maximal abundance of a) holoplanktonic taxa (Rotatoria, Cladocera, Cyclopoida, Calanoida, Copelata) and meroplanktonic taxa (Polychaeta, Bivalvia, Gastropoda), b) in the anomalies of the total zooplankton abundance and c) of seven calanoid copepod species in the years 1995 to 2020.

### 3.3 Macrozoobenthos

#### 3.3.1 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 done to determine associated parameters such as oxygen concentrations and near-bottom salinity (Table 10). Chemical parameters were measured in all samples taken during the five cruises per year (not content of this report, see NAUMANN et al. 2021). Except in the Mecklenburg Bay, a good oxygen supply could be observed at all stations almost all year round. Only in the Mecklenburg Bay the oxygen content was lower than  $0.5 \text{ ml l}^{-1}$  in September. When the benthos was sampled in November, the values were again above  $5 \text{ ml l}^{-1}$ .

*Table 10: Abiotic parameters at 8 monitoring stations in autumn 2020 (org=organic content of sediment in %, GS=mean grain size in  $\mu\text{m}$ ,  $\text{O}_2$ =oxygen content of near bottom water in  $\text{ml/l}$ , S=salinity at near bottom water in  $\text{psu}$ ).*

Station	Org %	GS ( $\mu\text{m}$ )	$\text{O}_2$ ( $\text{ml/l}$ )	S ( $\text{psu}$ )	Sediment characteristics
OMBMPN <sub>3</sub>	1.63	115	5.14	17.8	fine to middle sand
OMBMPN <sub>1</sub>	3.58	37	7.01	15.2	muddy sand
OMBMPM <sub>2</sub>	11.24	33	5.16	15.6	mud
OM18	1.62	86	5.23	21.7	muddy sand
OMBMPK <sub>8</sub>	0.50	216	7	7.9	fine sand
OMBMPK <sub>4</sub>	12.94	36	6.58	8.6	mud
OMBMPK <sub>3</sub>	0.29	209	6.79	8.1	fine sand
OM160	0.37	190	6.53	7.6	fine sand

For almost all stations the salinity ranged in an average value. The autumn bottom water salinity ranged from west to east between 21.7 and 7.6  $\text{psu}$  (Table 10). Surprisingly the bottom water values in autumn were highest in the Mecklenburg Bay (OM18) and not in the Kiel Bay.

#### 3.3.2 Macrozoobenthos at the stations

In November 2020, we deployed three Van Veen hauls to collect the samples from each of the 8 stations for macrozoobenthic analysis. In addition, a dredge was deployed at all stations to record rarer and vagile species. Our monitoring stations belong to four or five different macrozoobenthic communities along the salinity and depth gradient (see GOGINA et al. 2016).

Compared with the period 1991 to 2020, the number of species was low to medium at 118 (Table Appendix 3, Fig. 24 and Fig. 26). At five stations (N<sub>1</sub>, K<sub>8</sub>, K<sub>4</sub>, K<sub>3</sub>, 160) we observed slightly higher diversity as the median. Only at stations N<sub>3</sub>, M<sub>2</sub> and OM18 the diversity was lower as the median (Fig. 24). As in the years before the ocean quahog *Arctica islandica* reached high abundances and biomasses, especially at the western stations (Fig. 25).

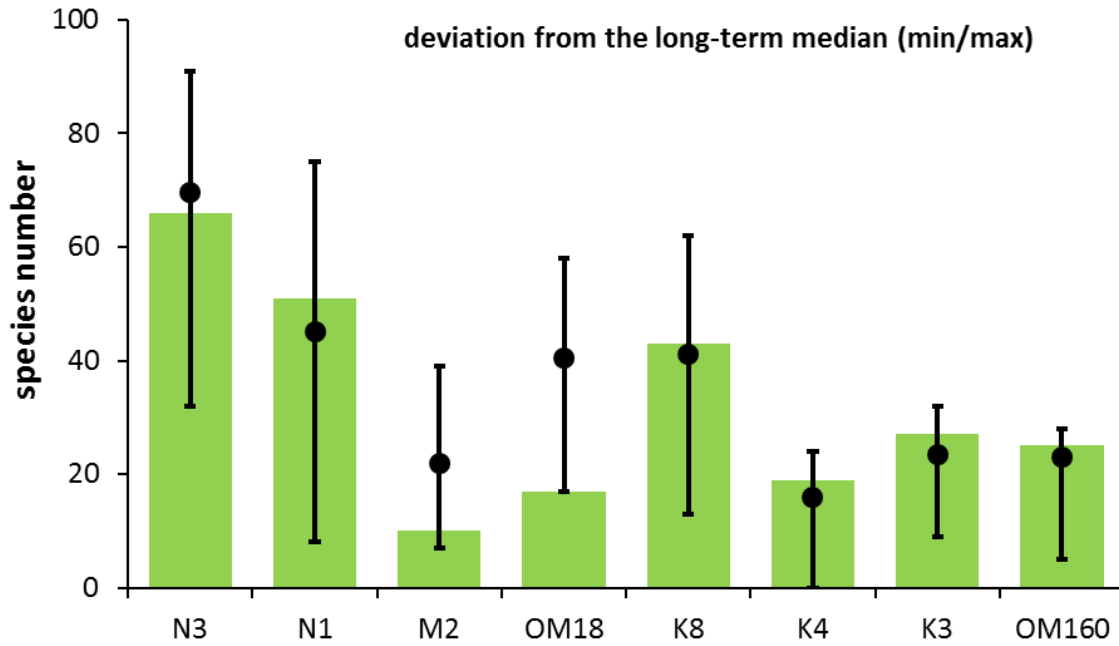


Fig. 24: Number of species (columns) of macrozoobenthos at 8 monitoring stations in November 2020. The median values of the years 1991 to 2020 are shown as dots; the minimum and maximum values are indicated as interval. The stations are plotted from west to east (Kiel Bay = N3 to Pomeranian Bay = OM160).



Fig. 25: The dredge sample of the Fehmarnbelt (N1) was dominated by *Arctica islandica* (alive and empty shells).

Whereas especially the eastern stations showed a general recovery of the benthic stock, at the stations in the bays of Mecklenburg and Kiel bays a decrease was observed. Additionally, for some stations new species (never observed during the last 20 years at these stations) were found. These species are listed below:

=>N3: *Sagartia* sp.

=>N1: *Clava multicornis*, *Hydractinia echinata*, *Aporrhais pespelecani*, *Tritia reticulata*, *Myrianida* sp., *Monocorophium insidiosum*

=>M2: none

=>OM18: none

=>K8: none

=>K4: *Malacobdella grossa*

=>K3: *Ampharete acutifrons*

=>OM16o: *Gastrosaccus spinifer*

Fig. 26 shows the taxa found at our 8 monitoring stations in 2020 as well as the total number of species found in measurements since 1991. Not just in 2020 (see ZETTLER et al. 2014, 2018, 2020), the Annelida (Polychaeta and Oligochaeta) emerged as the group that is richest in species, numbering 106; in 2020, 40 species were identified. Other species-rich groups in 2020 were Mollusca (23), Crustacea (19), Bryozoa (11) and Cnidaria (8).

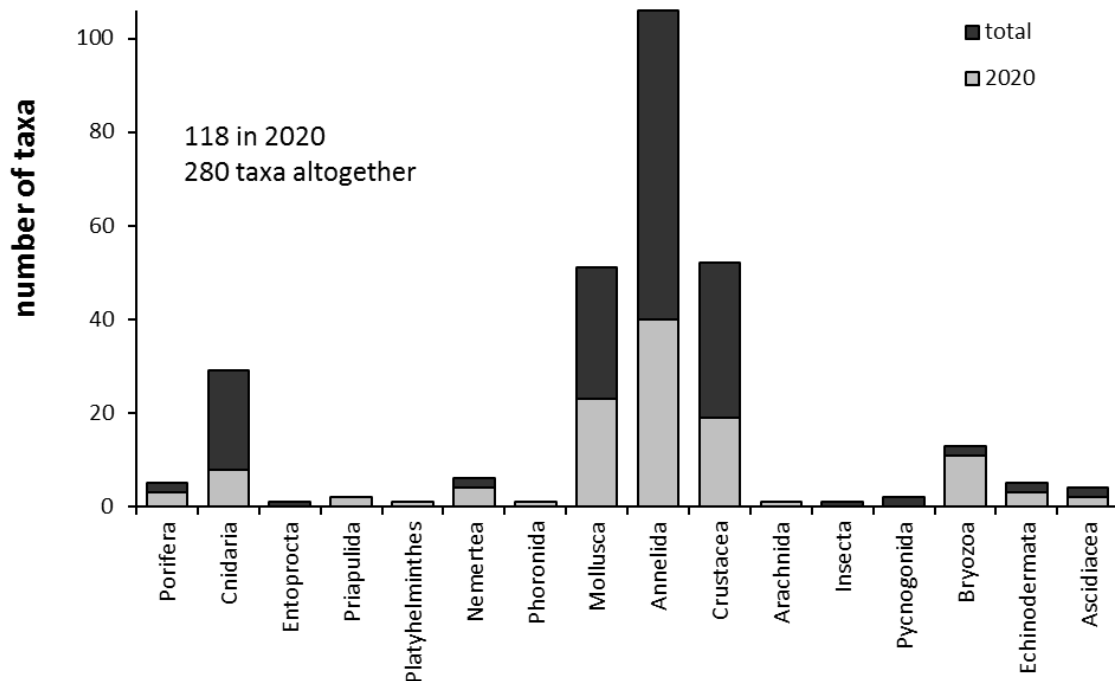


Fig. 26: Taxonomical classification of macrozoobenthos at 8 monitoring stations in November 2020 (grey). The species number of the entire monitoring from 1991 to 2020 is also indicated (black columns).

Depending on the sea area, abundances varied between 293 (Mecklenburg Bay) and 16.230 ind. m<sup>-2</sup> (Oderbank) (Fig. 27, Table Appendix 3). In the Mecklenburg Bay (M2 and OM18) and in the Kiel Bay (N3) the abundances had decreased or slightly decreased compared to previous years (Fig. 27). In the Arkona Basin (K4) the abundance was similar low as the last years. At the other three eastern stations (Drass Sill to Pomeranian Bay) we observed a significant increase in the abundance, sometimes twice as large as the long-term mean (K8 and OM160).

Which species was dominant in a given sea area varied greatly; it depended essentially on salinity and substrate. While the polychaetes *Dipolydora quadrilobata* and *Kurtiella bidentata* accounted for over 60 % of density in Kiel Bay (N3), *Kurtiella bidentata* and *Peringia ulvae* dominated the abundance in the southern Mecklenburg Bight (OM18). At the central Mecklenburg Bay (M2) the bivalve *Arctica islandica* and the polychaete *Lagis koreni* dominated the community. The phoronid *Phoronis* sp. reached more than 25 % of the total abundance at the station in the Fehmarnbelt area (N1) followed by the bivalve *Kurtiella bidentata* and the polychaete *Lagis koreni*. The Darss Sill (K8) was dominated by the spionid *Pygospio elegans* and mussel *Mytilus edulis*. Although in low abundances at all stations in the Arkona Basin (K4) the mud snail *Peringia ulvae* and the polychaetes *Ampharete acutifrons* and *Scoloplos armiger* were most frequent. In the Pomeranian Bay (OM160) *Pygospio elegans* and the mud snail *Peringia ulvae* accounted for high abundance. In the northern Pomeranian Bay (K3) the spionid *Pygospio elegans* (47 %) dominated the community.

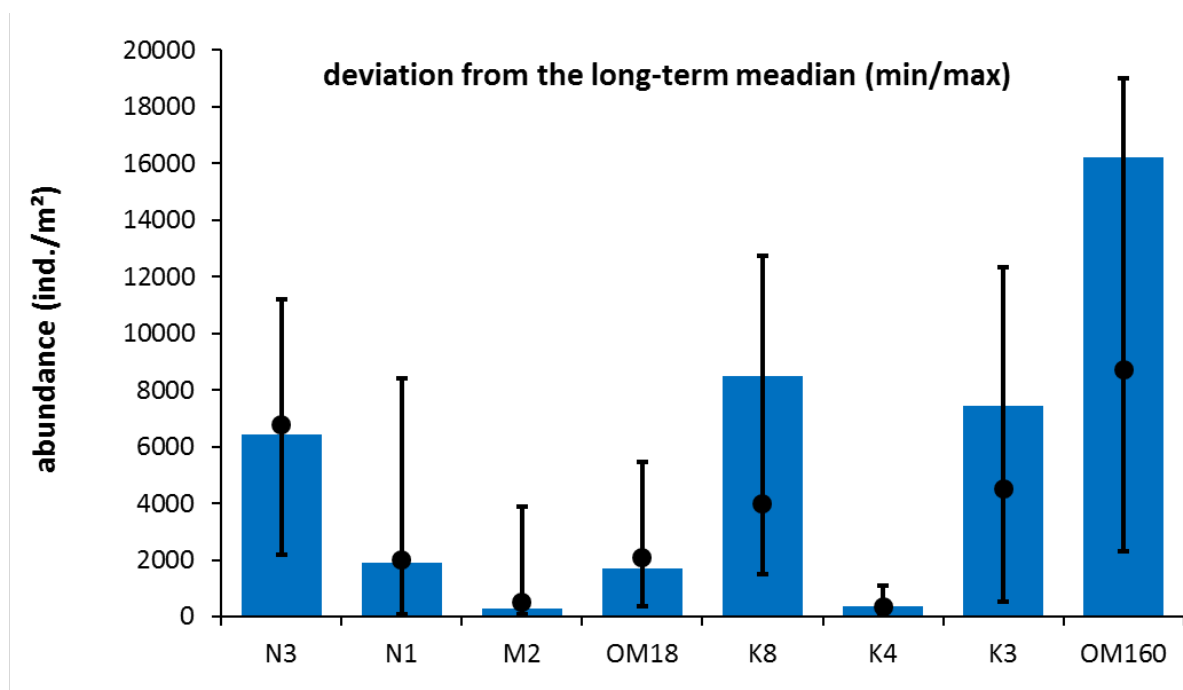


Fig. 27: Total abundances (columns) of macrozoobenthos at 8 monitoring stations in November 2020. The median values of the years 1991 to 2020 are shown as dots; the minimum and maximum values are indicated as interval.

Compared with their long-term averages six stations show similar or even higher total biomass than in the years before (Fig. 28). Significant lower than the long-term median were the values in the Kiel Bay (N3) and southern Mecklenburg Bay (OM18). Obviously due to grabbing of a hot spot of the patchily distributed *Mytilus edulis* at the Darss Sill (K8) the biomass value increased rapidly (Fig. 29).

The highest biomass was observed at the Darss Sill station (K8) (Fig. 28). 66.4 g afdw m<sup>-2</sup> was measured, consisting of 81.8 % *Mytilus edulis* (54.3 g afdw m<sup>-2</sup>) and 15.8 % *Astarte borealis* (10.5 g afdw m<sup>-2</sup>). At the station in the Fehmarnbelt the biomass was rather high; this is almost explainable with the dominance and patchy distribution of heavy adults of the ocean quahog. At Fehmarnbelt (N1), *Arctica islandica* contributed as much as 95 % to the biomass, where a total value of 42.3 g g afdw m<sup>-2</sup> was obtained. In the Kiel Bay (N3) the biomass has halved compared to the previous year. This decline was mainly caused by the loss of *Astarte borealis* and less or not at all by declines in *Arctica islandica*. Nevertheless, both types of bivalves accounted for 51 % and 38 % of the total biomass, respectively. In the Arkona Basin, (K4), *Limecola balthica* accounted for 42.2 % of the total biomass (0.4 g afdw m<sup>-2</sup>). In the north of the Pomeranian Bay (K3), 11.4 g of total biomass was measured, made up of 78.8 % *Mytilus edulis*. Further east in the central Pomeranian Bay (OM160; 9.6 g afdw m<sup>-2</sup>) *Mytilus edulis* (30.3 %) was also the dominant species together with *Mya arenaria* (23.6 %) and *Peringia ulvae* (22.8 %).

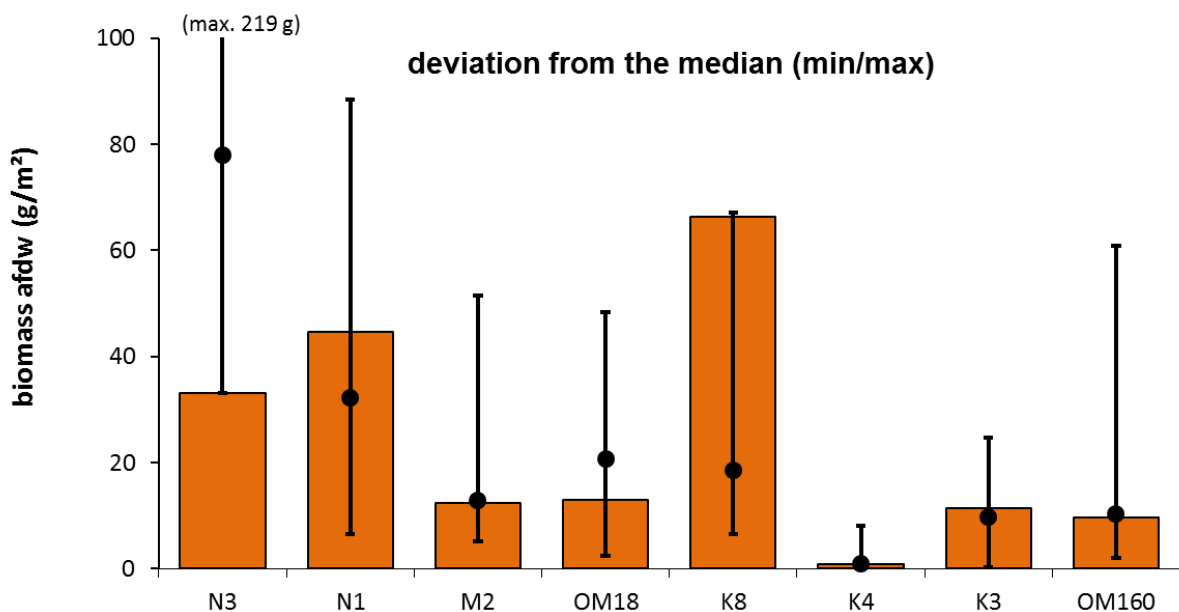


Fig. 28: Total biomasses (columns) of macrozoobenthos at 8 monitoring stations in November 2020. The median values of the years 1991 to 2020 are shown as dot and the minimum and maximum values are indicated as interval.



Fig. 29: In 2020 the dominant species of the dredge sample at the Darss Sill (K8) was *Mytilus edulis* (some *Asterias rubens* are also sighted).

Both for abundance and biomass, analysis of long-term data in part revealed considerable fluctuations that are illustrated as error bars (min/max) in the Fig. 27 and Fig. 28. Basically fluctuations relate to the population dynamics of long-living species (molluscs mostly). Another general influence is a population collapse following a phase of oxygen deficiency. Not least, however, the randomness of sampling and the clustered distribution of organisms are responsible for these fluctuations. Human induced direct effects were not evidently visible the analysed data. Nevertheless, impacts or effects on the benthic community of for example bottom trawling cannot be excluded, although and because it was not an object of the present study.

### 3.3.3 Long-term trends

The Fig. 30 to Fig. 32 present a follow-up to the corresponding presentations of the monitoring report from 2019 and earlier (WASMUND et al. 2019a, ZETTLER et al. 2020) of long-term trends of species number, abundance and biomass of macrozoobenthos at the 8 monitoring stations. They mainly reflect the influence of changing O<sub>2</sub> conditions (cf. NAUMANN et al. 2021).

Fig. 30 shows the relative **number of species** (see also previous reports, e.g. WASMUND et al. 2019a, ZETTLER et al. 2020). As expected, species diversity falls from west to east (Kiel Bay N<sub>3</sub> to Pomeranian Bay OM160). During the considered period of the last 15 years, the station N1



(Fehmarnbelt) in some years was characterised by a severe loss of species due to oxygen deficiency. In 2008 and 2010, up to 50 % fewer species were found compared to the previous or subsequent years. In 2014 and 2016 again a dramatic loss in species number occurred also in the Bay of Mecklenburg (M2). The reasons for this decline are not well recognized yet. The oxygen conditions around the year 2016 cannot be used as an explanation, because no oxygen depletion was observed at all (at least during the sampling campaigns throughout the year). No further significant changes were observed. In the last year (2020) the overall diversity was low to medium (see also chapter 3.2.2). As already described above, the low-oxygen conditions in the Mecklenburg Bay in summer led to a loss of species and abundance (Fig. 35). The overall diversity was comparable low as in the years 2008 and 2014.

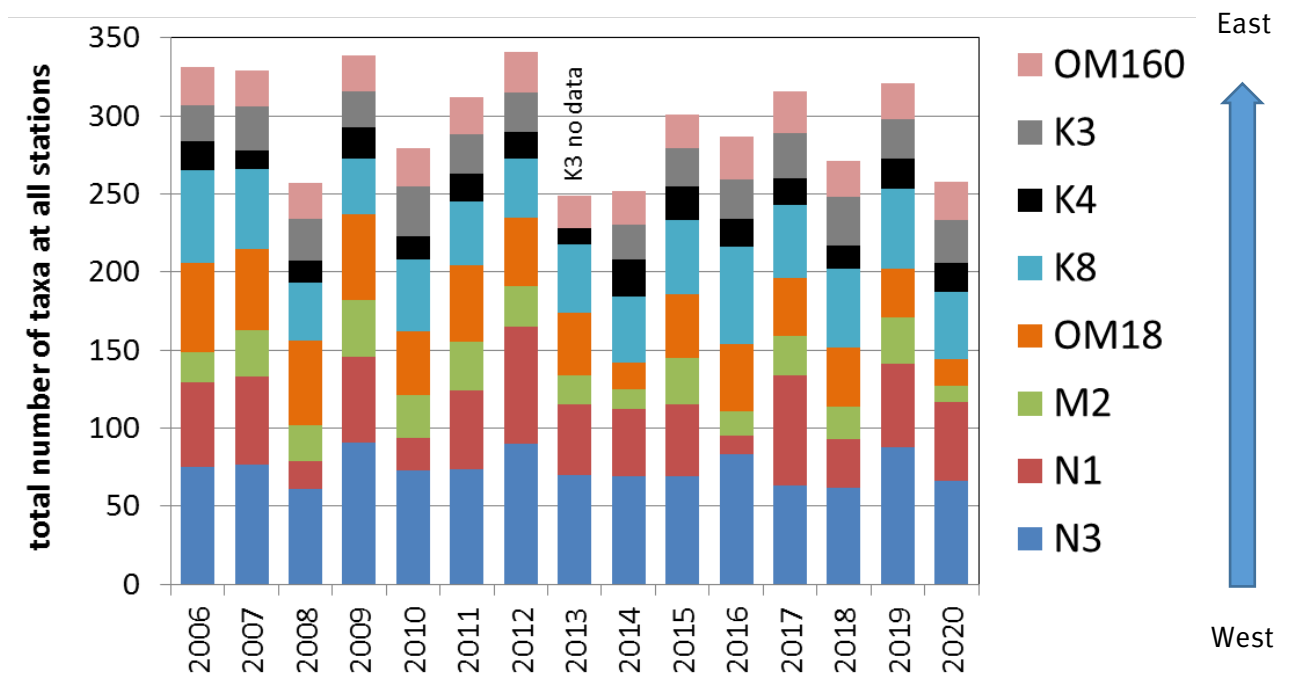


Fig. 30: Cumulative number of taxa of macrozoobenthos at 8 monitoring stations from 2006 to 2020. The stations are arranged within the columns from west to east (Kiel Bay = N3 to Pomeranian Bay = OM160).

In terms of **abundance**, the situation is similar (Fig. 31). Only the western (Kiel Bay) and the eastern most stations (Darss Sill, Pomeranian Bay, Oderbank) were characterised by high abundances. In some years, values fell below those of other years by more than 50 % - 2007 and 2008 at station N3, and 2010 and 2016 at station OM160, and 2015, 2016 and 2018 at station N1 in Fehmarnbelt for instance. Some significant variations also occurred at other stations, but they were based on substantially lower absolute values. At Fehmarnbelt (N1) and in the Bay of Mecklenburg (M2), oxygen deficiency in e.g. 2008, 2010 and 2014 caused a serious decline in abundance rates. A similar loss of abundance was observed for 2018 as well. At least at some other stations no significant decline was observed during the years. Although the stations in the Pomeranian Bay (OM160, K3) are also very variable interannually, they are least affected by lack of oxygen during the years. In 2020 the overall abundance of the stations in the Kiel and

Mecklenburg Bay were conspicuously low, whereas the values of the Dars Sill and the Pomeranian Bay were unusually high (Fig. 31). The latter is probably due to the increased density of *Mytilus edulis* and *Peringia ulvae*, respectively.

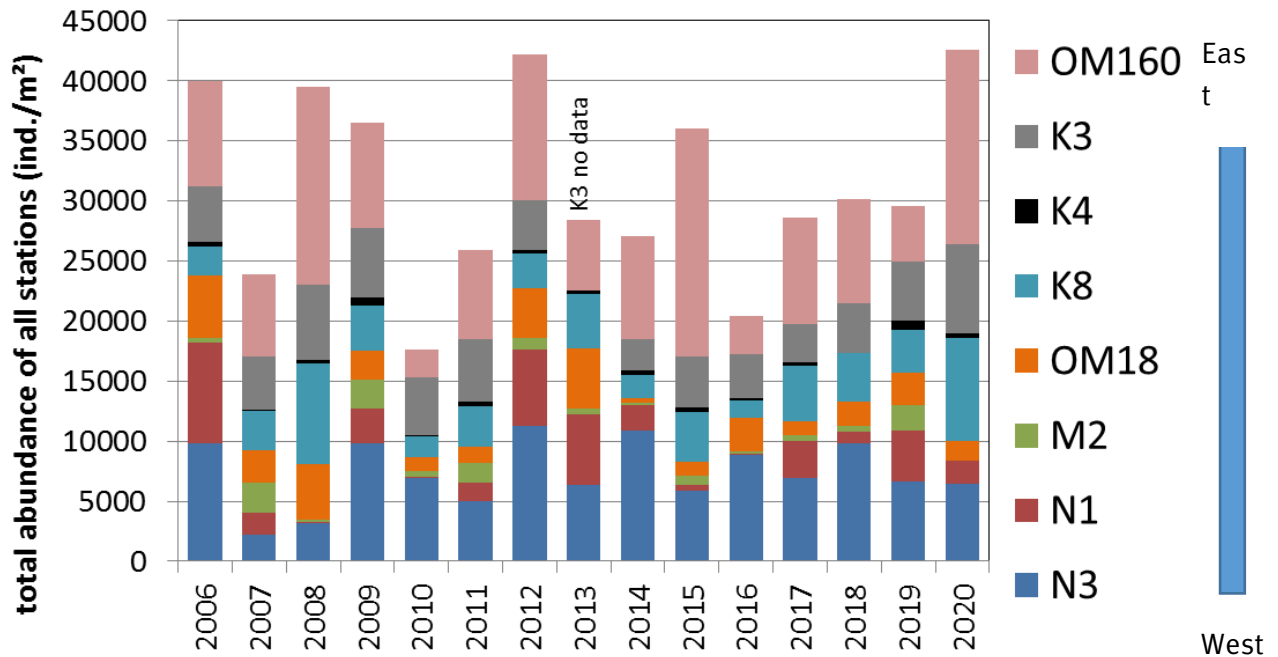


Fig. 31: Cumulative abundance of macrozoobenthos at 8 monitoring stations from 2006 to 2020. The stations are arranged within the columns from west to east (Kiel Bay = N3 to Pomeranian Bay = OM160).

Fig. 32 illustrates the long-term trend in **biomass**. Firstly, it is obvious that the highest values were observed in the west (Kiel Bay = N3) followed by the Bay of Mecklenburg (M2, OM18) and Fehmarnbelt (N1), and secondly it is obvious that biomass is not as strongly influenced as species numbers or abundance. Nevertheless, we can observe a clear decline during the last few years (compare 2007-2013 with 2014-2020). If this trend is significant cannot be answered so far. Also about the reasons for this decrease can only be speculated. For any reason the large bivalves seem to be reduced in abundance (and therefore biomass) since a few years. Similarly, variations can be significant, although at no station we did observe the sharp decline in biomass that we saw in species numbers and abundance due to oxygen deficiency at Fehmarnbelt (N1) in 2008 and 2010, and in Bay of Mecklenburg (M2, OM18) in 2014. The dominating species (bivalves of the genera *Arctica* and *Astarte*) with high individual weights buffer the loss of species and their weights for the total biomass. Overall, the total biomass observed in 2020 was except for the Dars Sill (K8) relatively low and in the range of the last 5 years.

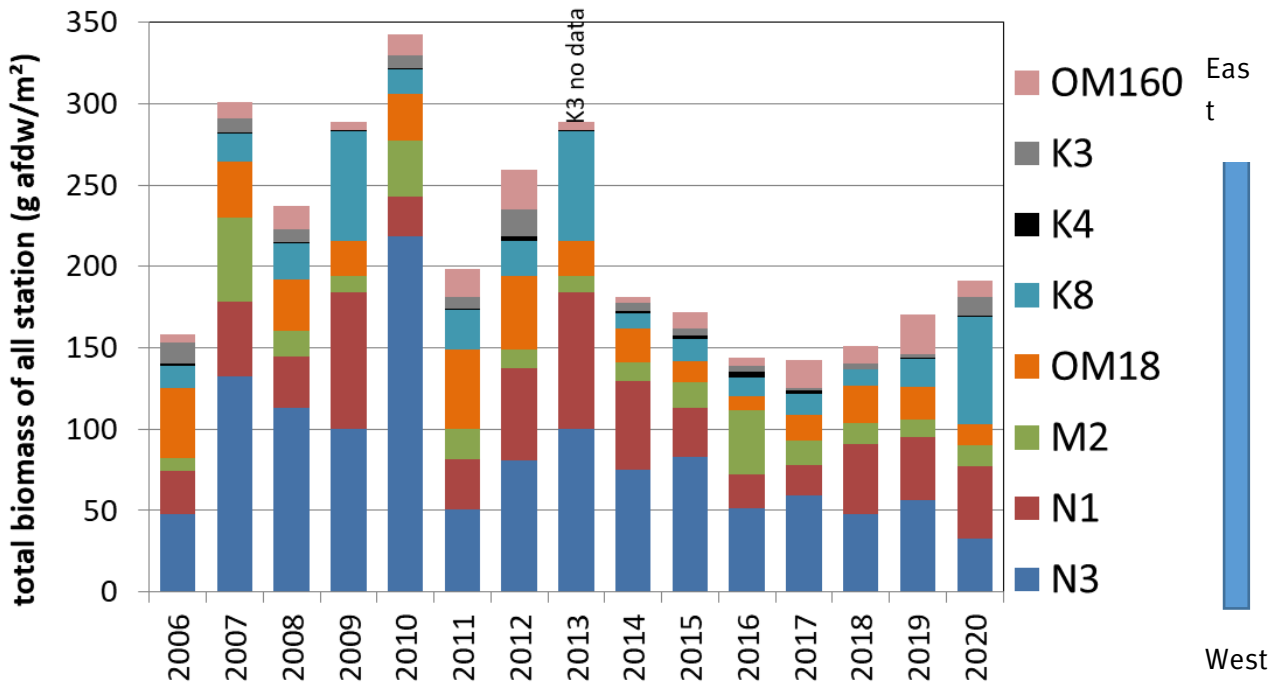


Fig. 32: Cumulative biomass of macrozoobenthos at 8 monitoring stations from 2006 to 2020. The stations are arranged within the columns from west to east (Kiel Bay = N<sub>3</sub> to Pomeranian Bay = OM160).

For a detailed assessment of long-term trends since 1980 we refer to our study on variation in benthic long-term data of transitional waters (ZETTLER et al. 2017) and to the monitoring reports of the preceding years (e.g. WASMUND et al. 2019a, ZETTLER et al. 2020). In these studies, the development of major macrozoobenthic parameters (abundance, biomass, species number) has been successfully interpreted relying on the modelling of the long-term fluctuations of salinity and oxygen, incorporation of the North Atlantic Oscillation index (NAOI) for winter, and the alliance of modelled and measured data along the 35 years of observation. The effects of oxygen deficiency on ecosystem functions, as well as temporal and spatial variations at selected monitoring stations, were published also in GOGINA et al. (2014).

### 3.3.4 Red List

This section refers to the Red List of bottom-dwelling invertebrates by RACHOR et al. (2013). Of a total of 118 species, 17 are classed as threatened (1, 2, 3, G) (Fig. 33, Table Appendix 3). Three species are classed as being near threatened. One species is categorised as extremely rare. Currently, 61 species are classed as being of least concern. Data are deficient for 17 species, and 19 taxa on the Red List were not evaluated. The anthozoan *Halcapa duodecimcirrata* is critically endangered. It was detected in the Arkona Basin (K<sub>4</sub>) in very low densities. A species that is classed as endangered (category 2) is *Mya truncata*, which was found in the Kiel Bay and Fehmarnbelt. Specimens of *Arctica islandica* (ocean quahog; category 3, vulnerable) were observed at all western stations (N<sub>3</sub>, N<sub>1</sub>, M<sub>2</sub>, and OM<sub>18</sub>) and in the deeper Arkona Basin (K<sub>4</sub>) at various levels of abundance. Montagu's Astarte (*Astarte montagui*) occurred in the Kiel Bay only. The hydrozoan species *Halitholus yoldiaearcticae* were observed in the Fehmarnbelt (N<sub>1</sub>).

Category G (probably vulnerable) includes species that cannot be assigned to category 1, 2 or 3 above, but which - based on current knowledge - are assumed to be endangered. They are declared to be at risk (uncategorized). The 13 species observed in 2020 were distributed across almost all sea areas: 8 species in Kiel Bay (N3), 5 at the Fehmarnbelt (N1), 1 at southern Mecklenburg Bay (OM18), 2 at the Darss Sill (K8), 1 in Arkona Basin (K4) and 2 in northern Pomeranian Bay (K3). The bryozoan *Farrella repens* (Fig. 34) belongs to this category D and was found in the Kiel Bay, Fehmarnbelt and the southern Mecklenburg Bay. 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). Only *Mya truncata* (near threatened) can be found on this list, but it has to be kept in mind that the current HELCOM list is relatively short and Kattegat-biased.

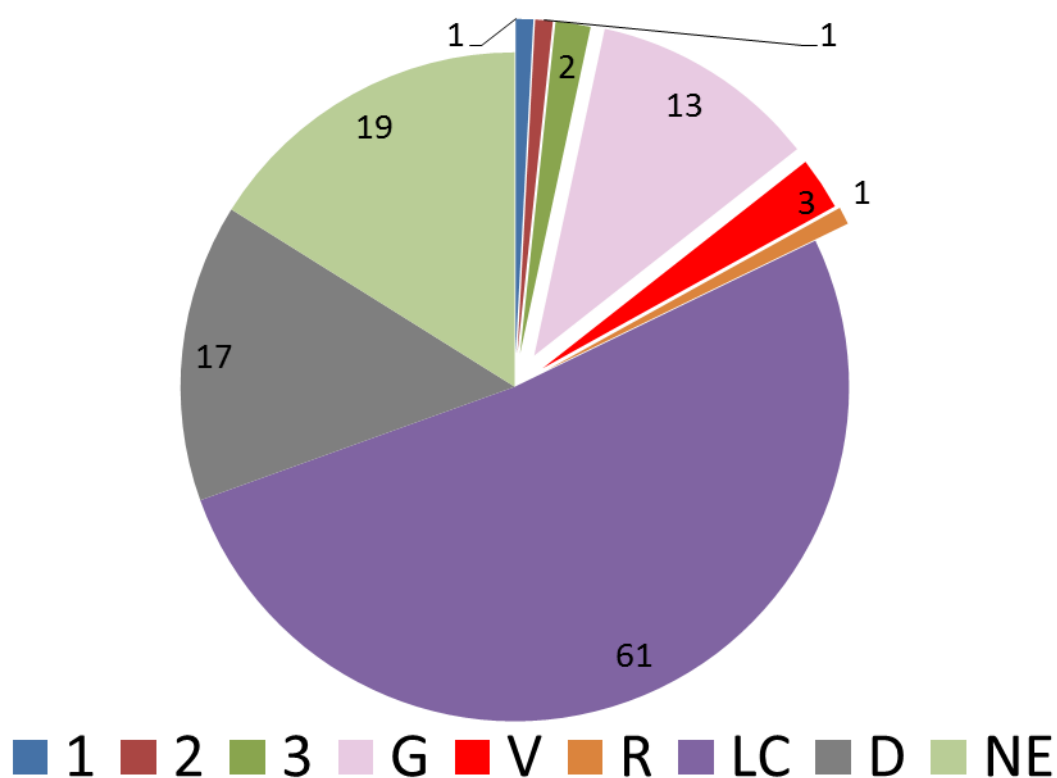


Fig. 33: Percentage of red list categories (RACHOR et al. 2013) in relation to macrozoobenthos in autumn 2020 (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, R=extremely rare, LC=least concern, D=data deficient, NE=not evaluated).

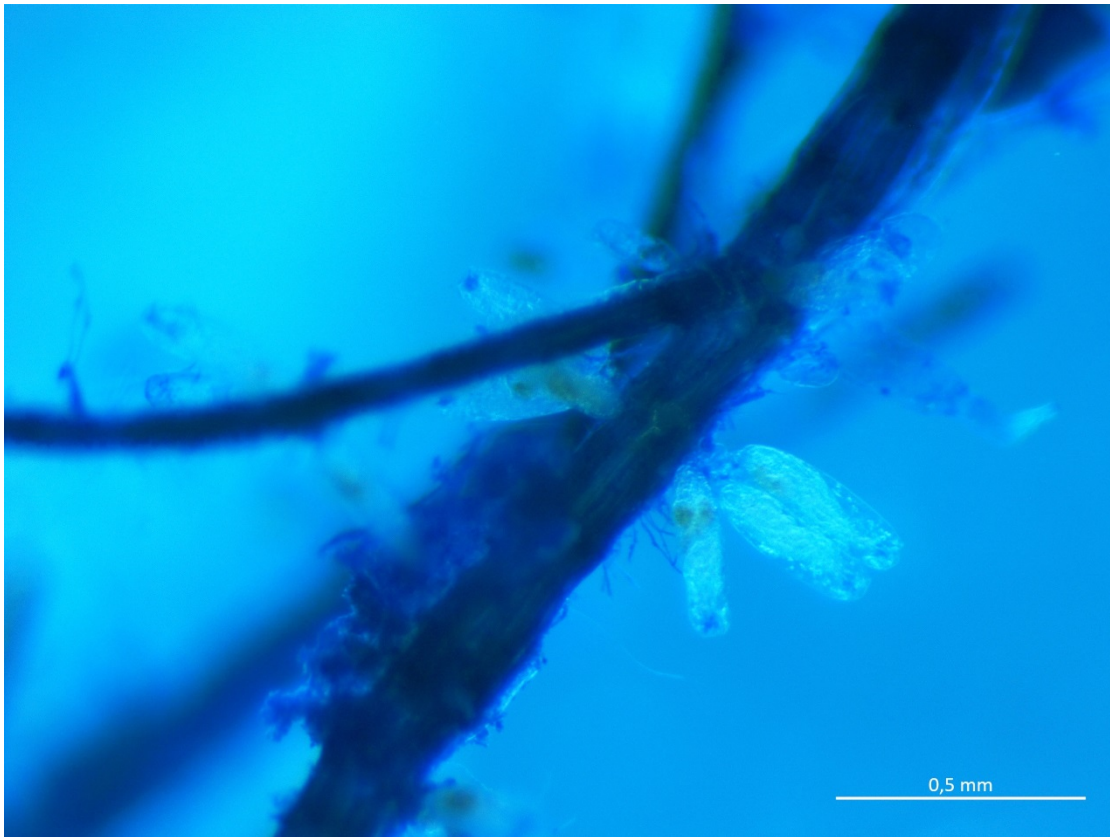


Fig. 34: The bryozoan species *Farella repens*, a red listed species of the category D (data deficient), found at the southern Mecklenburg Bay (OM18).

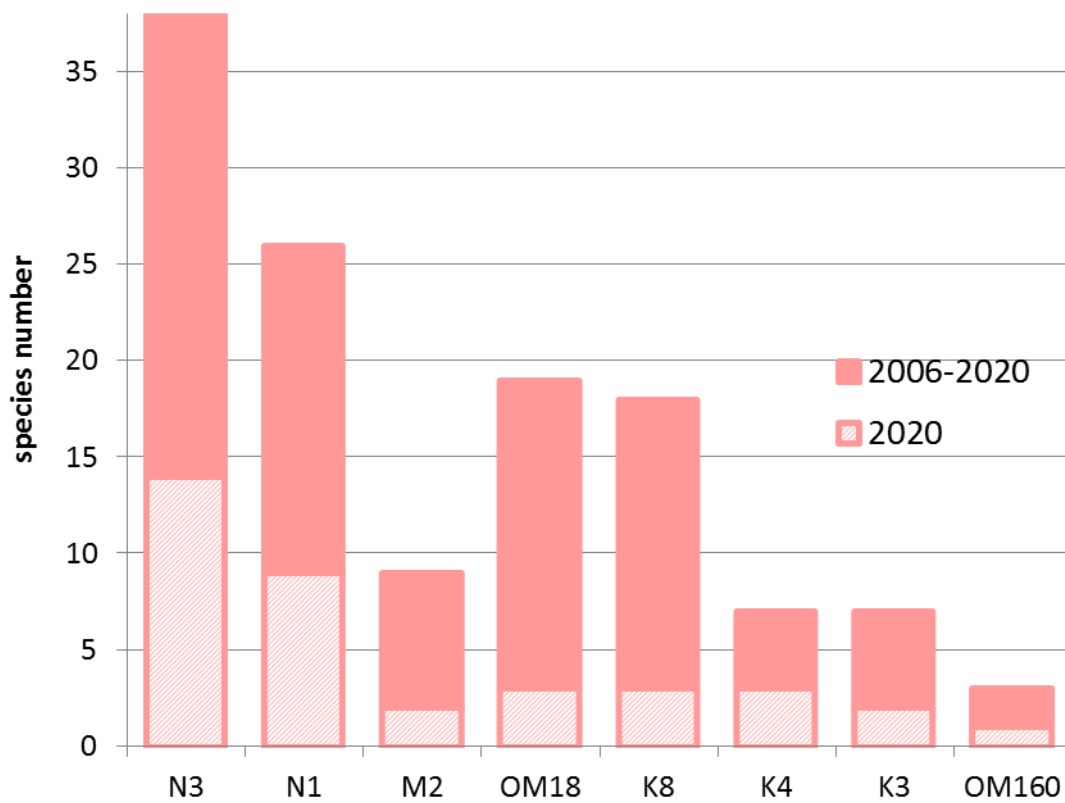


Fig. 35: Number of red listed species (categories 1, 2, 3, G, V and R) (RACHOR et al. 2013) at the 8 monitoring stations in 2020 and in total (2006-2020).

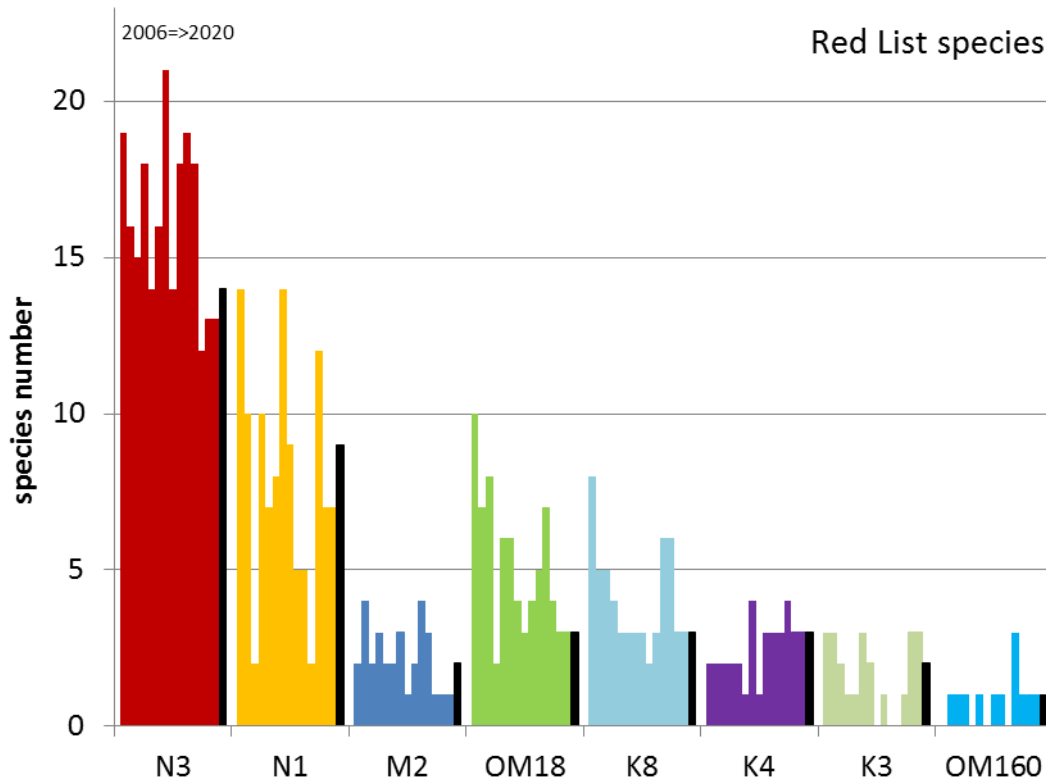


Fig. 36: Development of the number of red listed species (categories 1, 2, 3, G, V and R) (RACHOR et al. 2013) at the 8 monitoring stations from 2006 to 2020. The values of 2020 are highlighted in black colour.

In general the number of potentially occurring red listed species at the monitoring stations is decreasing systematically with the salinity gradient from the west to the east (Fig. 35 and Fig. 36). The percentage of red listed species in 2020 in comparison to observations in the whole investigation time (2006 to 2020) ranges between 16 and 43 % (Fig. 35). At all stations the number of red listed species was comparable to the previous years (Fig. 36). The strong salinity gradient and its effect on the distribution of red listed marine species are clearly visible. Both the number of records and the species number decrease with decreasing salinities from west to east.

### 3.3.5 Non-indigenous species (NIS)

The role of NIS in the open Baltic Sea is negligible (ZETTLER et al. 2014, 2018). Only seven species were observed at our 8 monitoring stations in 2020. *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 polychaete species 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. Additionally, the amphipod *Melita nitida* (Fig. 37) and decapod crab *Rhithropanopeus harrisi* (Fig. 38), find its origin in North America, were found at the Oderbank (OM160). Finally the ascidian species *Molgula manhattensis* was observed in

the Kiel Bay (N3). It is not clear if it is a neozoa species or a cryptic indigenous species (Lackschewitz et al. 2015).



*Fig. 37: The North American amphipod species Melita nitida was detected for the first time at the Oderbank as part of our 2020 monitoring programme (OM160). For determination and introduction history see Zettler & Zettler (2017).*



*Fig. 38: Rhithropanopeus harrisi, since 2006 a regular observed neozoa species on the Oderbank (OM160).*

## Summary

In 2020, the **phytoplankton** spring bloom was well developed in the western Belt Sea in early February as indicated by high Chl $a$  concentrations ( $\sim 9 \mu\text{g L}^{-1}$ ), and the biomasses, being dominated by diatoms, particularly *Skeletonema marinoi*. Eastwards, the beginning spring bloom mainly consisted of the ciliate *Mesodinium rubrum* and its cryptophyte prey, *Teleaulax* sp. The typical temporal delay in the spring bloom development towards the North was reflected in the number of taxa recorded: While altogether 78 species were found in the westernmost study area, the northern communities were much less diverse consisting of 35 to 45 taxa.

Phytoplankton data from May 2020 reflected a declining spring bloom, as total phytoplankton biomass, dominated by dinoflagellates in the North and prymnesiophytes in the south, was low. The late phase of the 2020 spring bloom was locally dominated by small unidentified gymnodinoid dinoflagellates and cyanobacteria of *Aphanocapsa* and *Aphanothece*. Like in February, taxon diversity decreased towards the North.

In July, biomass of up to  $4000 \mu\text{g L}^{-1}$  corresponded to Chl $a$  concentrations of  $2.4$  to  $3.8 \mu\text{g L}^{-1}$ . The summer phytoplankton bloom of 2020, contained high biomass shares of diatoms at several stations in the Belt Sea and Arkona Basin. Here the diatom *Dactyosolen fragilissimus* contributed 40 to 70 % of the total phytoplankton biomass. Particularly in the Belt Sea, dinoflagellates, among them the toxic species *Alexandrium pseudogonyaulax*, produced high amounts of biomass. The northern stations were characterized by a high numerical dominance of cyanobacteria, but relatively low biomass levels. Nevertheless, total phytoplankton biomass was generally higher in 2020 compared to the previous year. The number of taxa recorded during the summer cruise ranged from 82 in the Belt Sea to 38 in Bornholm Basin.

The November cruise captured an autumn diatom bloom in the western study area, reaching Chl $a$  levels comparable to the spring bloom concentrations in 2020. Maximum biomass of nearly  $2000 \mu\text{g L}^{-1}$  was measured in the Bay of Mecklenburg. Significant phytoplankton production in late autumn reflects a general trend of an extended phytoplankton growth period.

In 2020 altogether 153 phytoplankton species/taxa were recorded in the monitoring samples, among them several non-indigenous and harmful species. The potentially toxic *Alexandrium pseudogonyaulax* and *Pseudo-nitzschia* spp. are now regular members of the Southern Baltic phytoplankton communities. Nevertheless, in 2020, their cell concentrations remained below bloom levels. While mean annual phytoplankton biomass in 2020 reflected the 20-year mean, the Diatom/Dinoflagellate ratio and mean annual cyanobacteria biomass were well above the 20-year mean, the same as in 2019.

Altogether 42 phytoplankton taxa were recorded in samples retrieved from **sedimentation** traps. The seasonal sedimentation pattern of phytoplankton reflected the growth dynamics of phytoplankton in the Arkona Basin with diatoms being the dominant group of the settling spring bloom. The typical dinoflagellate sedimentation peak after the spring bloom was not captured due to technical problems. Cyanobacteria sedimentation started earlier than usual, indicating an early onset of the summer cyanobacteria bloom.



A total of 42 **zooplankton** samples were collected on 29 stations. Due to the COVID-19 situation and bad weather, the March cruise was cancelled and the number of samples was lower than usual. Because very few species are restricted in their seasonal occurrence to early spring, only a minor effect is expected for the record of the species inventory.

The species richness of 54 taxa resembled largely the previous years, but remained below the decadal peak of 63 - 73 taxa during the period 2016-2017. Species with a broad salinity tolerance characterized the species composition. Halophilic organisms were nevertheless regularly found. The seasonal variation of the species richness was pronounced with a minimum in May and maxima in early spring and autumn. This was caused by the presence of benthic larvae of Polychaeta, Echinodermata and Crustacea or diverse jellyfish species in early spring/autumn and the occurrence of thermophilic organisms in autumn.

The zooplankton abundance ( $2.3$  to  $5.6 \times 10^4$  ind.  $m^{-3}$ ) was low in 2020, particularly in the Bay of Mecklenburg and the Arkona Basin. Copepods dominated the zooplankton at all stations in 2020 and contributed to 52-72 % to the zooplankton stock. This dominance resulted from an unusual low abundance of rotifers and cladocerans in the Bay of Mecklenburg and the Arkona Basin. The low abundance of rotifers was already observed in 2019. Copepods, in contrast, remained at the low abundance of the recent decade and did not further decrease, except for the Kiel Bight. Apart from these groups, only bivalve larvae and tintinnids showed a higher contribution ( $>10$  %) to the plankton.

The seasonal development of the zooplankton community in the Kiel Bight (OMBMP-N<sub>3</sub>) was characterized by a large overwintering stock. Copepods and Copelata dominated. The spring and summer concentrations of zooplankton were in the usual range of  $3.1$ - $3.4 \times 10^4$  ind.  $m^{-3}$ . As usual, copepods were most abundant and calanoids and cyclopoids contributed equally to the stock, but decreased already in summer when Cladocera and *Oikopleura dioica* became an important member of the community. The autumn stock was rather low compared to the previous years. On an annual basis, the cyclopoid *Oithona* spp. and the calanoids *Acartia bifilosa* dominated together with *A. longiremis* and *Centropages hamatus* were most abundant among the copepods.

In the Bay of Mecklenburg, the zooplankton abundance (max.  $4.9$  - $5.3 \times 10^4$  ind.  $m^{-3}$ ) was lower than usual. On an annual basis, copepods and bivalve larvae dominated the zooplankton community and their contribution increased towards the more eastern station. Rotifers and Cladocera were a minor component. *Oithona* spp., *Acartia* and *Pseudo/Paracalanus* were most abundant among the copepods, and *A. longiremis* replaced *A. bifilosa* as the major species. Similar to the Kiel Bight, the overwintering stock of zooplankton was large. The zooplankton increase towards late spring was primarily based on a tripling of the copepod stocks. The stock size in summer remained large and gained in importance when bivalve larvae replaced copepods as the most abundant taxon. Tintinnids were abundant as well. In autumn, zooplankton abundance was low and copepods and *Oikopleura dioica* were the major taxa.

Similar to the Bay of Mecklenburg, the total zooplankton stock was considerably lower than usual in the Arkona Basin. Particularly, cladocerans occurred at an unusual low abundance,

primarily based on low densities of *Bosmina* spp. during summer. Copepods were the dominating group, and calanoids contributed alone to 53 - 69 % to the zooplankton stocks. The group dominated the low overwintering stocks consisting of *Oithona*, *Centropages*, *Acartia* and *Temora*. The zooplankton composition remained monotonous following the spring increase. Copepods dominated followed by low stocks of cladocerans and bivalve larvae. The genus *Acartia* was the main genus among the copepods, stocks of adult copepods consisted largely of *Acartia longiremis*. The stocks remained high during summer and only the composition changed. Autumn stocks were again low.

The year 2020 continued the series of years of declining stock size of zooplankton that started around 2010. The total abundance of  $4.8 \times 10^4$  ind.  $m^{-3}$  was the lowest value recorded since 20 years and accounted only for 1/6 of the long-term average of  $3.1 \times 10^5$  ind.  $m^{-3}$ . The trend is primarily explained by a decline of rotifers and cladocerans. A decline was also discernible for the Copepoda and the polychaete larvae, while copepods, bivalve larvae and gastropod larvae remained on the same low level observed during the preceding years.

This study presents the results of **macrozoobenthos** monitoring in the southern Baltic Sea in November 2020. The following parameters were measured: species richness, and the abundance and biomass of organisms per station. Compared to previous years, the 118 species recorded at the 8 monitoring stations were considered to be a low to medium number. Depending on the region, abundances varied between 293 and 16.230 ind.  $m^{-2}$ . In terms of biomass, similar high variations were observed (0.9 g in the Arkona Basin to 66.4 g afdw  $m^{-2}$  at the Darss Sill).

In 2020 long-lasting oxygen deficiency was observed only in the Mecklenburg Bay.

Seventeen species of the German Red List (Categories 1, 2, 3 and G) were observed at the 8 monitoring stations. The anthozoan *Halcapa duodecimcirrata*, very rarely observed and critically endangered in German waters, was found in the Arkona Basin, for instance. *Mya truncata*, included in both, the Red Lists of Germany and of HELCOM, was found in the Kiel Bay and Fehmarnbelt.

In line with expectations, the number of non-indigenous species found during the 2020 sampling campaign was low: seven species were identified, among them long-established species like *Amphibalanus improvisus* (Cirripedia) and *Mya arenaria* (Bivalvia). The recently (since the 1980s and 1990s) introduced species *Marenzelleria viridis* and *M. neglecta* (Polychaeta) are locally important in the Pomeranian Bay. Additionally, the amphipod *Melita nitida* and decapod crab *Rhithropanopeus harrisi*, both find its origin in North America, were found at the Oderbank. Finally, as a cryptic neozoan species the ascidian *Molgula manhattensis* was observed in the Kiel Bay.

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## Appendix

Table Appendix 1: List of taxa recorded in 2020, distribution, biomass means per station and sampling and biomass ranks.

	TF0220	TF0520	TF0720	TF1120	Biomass	Rank
<i>Actinocyclus</i>	X	X	X	X	51.30	14
<i>Akashiwo sanguinea</i>				X	0.23	134
<i>Akashiwo sanguinea cf.</i>	X			X	0.35	124
<b><i>Alexandrium pseudogonyaulax</i></b>			<b>X</b>	<b>X</b>	<b>138.49</b>	<b>6</b>
<i>Amphidinium crassum</i>	X	X	X	X	0.72	106
<i>Amphidinium sphenoides</i>		X	X		0.48	111
<i>Amylax triacantha</i>				X	0.77	102
<i>Apedinella radians</i>	X				0.35	123
<b><i>Aphanizomenon</i></b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>111.76</b>	<b>8</b>
<i>Aphanocapsa</i>	X	X			6.01	64
<i>Aphanothece</i>	X	X	X		5.32	66
<i>Aphanothece paralleliformis</i>	X	X	X		16.12	37
<i>Attheya decora</i>			X		0.21	135
<i>Attheya longicornis</i>	X	X	X	X	0.16	140
<i>Binuclearia lauterbornii</i>			X		0.62	107
<i>Centrales</i>	X		X	X	49.15	15
<b><i>Ceartaulina pelagica</i></b>	<b>X</b>		<b>X</b>	<b>X</b>	<b>120.90</b>	<b>7</b>
<i>Tripes fusus</i>	X	X	X	X	0.44	114
<i>Tripes muelleri</i>	X				23.24	27
<i>Chaetoceros</i>	X	X	X	X	1.04	98
<i>Chaetoceros affinis</i>	X	X	X		0.03	148
<i>Chaetoceros castracanei</i>	X	X	X	X	1.89	88
<i>Chaetoceros contortus</i>			X		0.08	145
<i>Chaetoceros convolutus</i>				X	1.48	91
<i>Chaetoceros curvisetus</i>	X				0.37	121
<i>Chaetoceros danicus</i>	X	X	X	X	1.93	85
<i>Chaetoceros decipiens</i>			X		0.28	128
<i>Chaetoceros diadema</i>	X		X	X	0.39	120
<i>Chaetoceros minimus</i>			X		0.04	146
<i>Chaetoceros socialis</i>				X	0.41	119
<i>Chaetoceros subtilis</i>		X			0.31	126
<i>Chaetoceros wighamii</i>			X		0.32	125
<i>Choanoflagellata</i>	X	X	X	X	1.98	84
<i>Chroococcales</i>	X	X	X	X	12.22	48
<i>Coelosphaerium minutissimum</i>	X	X	X		4.48	71
<i>Thalassiosira anguste - lineata</i>	X		X	X	0.42	118
<b><i>Coscinodiscus granii</i></b>			<b>X</b>	<b>X</b>	<b>237.03</b>	<b>2</b>
<i>Coscinodiscus granii cf.</i>				X	6.02	63

<i>Coscinodiscus radiatus</i>	X	X	X		16.69	36
<i>Coscinodiscus radiatus cf.</i>			X		2.19	80
<i>Cyanodictyon</i>	X		X		0.02	150
<i>Cyanodictyon planctonicum</i>	X	X	X		6.53	62
<i>Cyanonephron styloides</i>	X				0.21	136
<i>Cyclotella</i>	X	X	X	X	3.95	73
<i>Cylindrotheca closterium</i>	X	X	X	X	0.43	117
<i>Cymbomonas tetramitiformis</i>			X		8.91	53
<b><i>Dactyliosolen fragilissimus</i></b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>685.82</b>	<b>1</b>
<i>Dinobryon</i>				X	0.50	110
<i>Dinobryon balticum</i>				X	1.30	94
<i>Dinobryon faculiferum</i>				X	0.76	104
<i>Dinophysis acuminata</i>	X	X	X	X	19.15	30
<i>Dinophysis acuta</i>	X	X		X	0.47	112
<i>Dinophysis norvegica</i>	X	X	X	X	20.13	28
<i>Diplopsalis spp. CPX</i>		X	X		0.09	142
<i>Ditylum brightwellii</i>				X	18.81	32
<i>Dolichospermum</i>			X		14.08	41
<i>Dolichospermum lemmermannii</i>	X	X	X		0.29	127
<i>Ebria tripartita</i>	X	X	X	X	8.91	52
<i>Thalassiosira punctigera</i>	X				2.50	77
<i>Eutreptiella</i>	X	X	X	X	7.63	58
<i>Flagellates</i>	X	X	X	X	12.34	46
<i>Gonyaulax cf.</i>	X	X	X		0.20	137
<i>Guinardia flaccida</i>	X	X	X	X	36.65	20
<b><i>Gymnodiniales</i></b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>142.28</b>	<b>4</b>
<i>Gyrodinium spirale</i>	X	X		X	19.97	29
<i>Hemiselmis</i>	X	X	X	X	5.72	65
<i>Heterocapsa rotundata</i>	X	X	X	X	8.65	54
<i>Katablepharis remigera</i>	X	X	X	X	18.87	31
<i>Katodinium glaucum</i>		X	X	X	0.74	105
<i>Koliella</i>	X				0.01	153
<i>Koliella spiralis</i>			X		0.03	149
<i>Heterocapsa triquetra</i>	X	X	X	X	37.51	19
<i>Laboea strobila</i>	X		X	X	1.75	89
<i>Lemmermanniella</i>			X		0.01	151
<i>Lemmermanniella pallida</i>	X	X	X	X	0.57	108
<i>Lemmermanniella parva</i>	X	X	X		2.11	82
<i>Lennoxia faveolata</i>	X	X			0.77	103
<i>Leptocylindrus danicus</i>	X		X	X	8.16	56
<i>Leptocylindrus minimus</i>	X	X	X	X	0.23	133
<i>Leucocryptos marina</i>	X	X	X	X	17.89	34
<i>Mesodinium rubrum</i>	X	X	X	X	67.72	12
<i>Micracanthodinium claytonii</i>	X	X	X	X	2.77	75
<i>Chaetoceros thronsdonii</i>			X		0.13	141

<i>Monoraphidium contortum</i>	X	X			0.01	152
<i>Nitzschia longissima</i>				X	0.19	139
<i>Nitzschia paleacea</i>				X	0.08	143
<i>Nodularia spumigena</i>		X	X		31.47	26
<i>Octactis speculum</i>	X		X		3.04	81
<i>Octactis speculum NK</i>		X	X	X	7.43	59
<i>Oocystis</i>	X				0.24	132
<i>Pennales</i>			X		0.43	116
<i>Peridinales</i>	X	X	X	X	13.46	42
<i>Peridiniella catenata</i>	X	X			4.17	72
<i>Peridiniella danica</i>		X	X	X	62.74	13
<i>Phaeodactylum tricornutum cf.</i>			X		0.08	144
<i>Phalacroma rotundatum</i>	X			X	0.25	129
<i>Plagioselmis prolunga</i>	X	X	X	X	35.07	21
<i>Planktolyngbya</i>			X		0.03	147
<i>Polykrikos schwartzii</i>				X	2.06	83
<i>Porosira glacialis</i>	X				8.32	55
<i>Proboscia alata</i>	X	X	X	X	34.27	24
<i>Prorocentrum cordatum</i>	X		X	X	15.59	38
<i>Prorocentrum micans</i>	X		X	X	14.14	40
<i>Protoperidinium</i>	X	X		X	9.47	51
<i>Protoperidinium bipes</i>		X			0.46	113
<i>Protoperidinium depressum</i>	X			X	12.33	47
<i>Protoperidinium divergens</i>	X			X	1.52	90
<i>Protoperidinium oblongum</i>	X		X	X	1.00	99
<i>Protoperidinium pallidum</i>		X			1.11	95
<i>Protoperidinium pellucidum</i>				X	1.42	92
<i>Protoperidinium thorianum</i>		X	X	X	0.92	101
<b>Prymnesiales</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>110.47</b>	<b>9</b>
<i>Pseudanabaena cf.</i>	X				0.44	115
<i>Pseudanabaena limnetica</i>	X		X		8.07	57
<i>Pseudanabaena limnetica cf.</i>			X		2.44	78
<i>Pseudochattonella</i>		X			0.24	131
<b>Pseudo-nitzschia</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>138.72</b>	<b>5</b>
<i>Pseudo-nitzschia delicatissima GRP</i>	X			X	2.58	76
<i>Pseudo-nitzschia seriata GRP</i>	X			X	15.32	39
<i>Pseudopedinella</i>	X	X	X	X	1.92	86
<b><i>Pseudosolenia calcar-avis</i></b>				<b>X</b>	<b>146.22</b>	<b>3</b>
<i>Pterosperma</i>	X	X	X	X	1.07	97
<i>Pyramimonas</i>	X	X	X	X	11.87	50
<i>Pyramimonas longicauda</i>				X	12.40	45
<i>Rhizosolenia delicatula</i>	X		X	X	18.08	33
<i>Rhizosolenia setigera</i>	X			X	31.71	25
<i>Rhizosolenia setigera f. pungens</i>	X		X	X	38.54	18
<i>Romeria</i>			X	X	0.25	130

<i>Scrippsiella</i> spp. CPX		X	X	X	12.74	43
<i>Skeletonema marinoi</i>	X	X	X	X	75.49	11
<i>Snowella</i>	X	X	X	X	4.64	69
<i>Spatulodinium pseudonociluca</i>				X	4.82	68
<i>Spatulodinium pseudonociluca</i> cf.				X	2.41	79
<i>Thalassionema nitzschioides</i>	X	X	X		17.85	35
<i>Teleaulax</i>	X	X	X	X	34.81	22
<i>Telonema</i>	X	X	X	X	12.43	44
<i>Thalassiosira</i>	X	X	X	X	43.03	17
<i>Thalassiosira baltica</i>		X		X	4.64	70
<i>Thalassiosira eccentrica</i>		X			0.55	109
<i>Thalassiosira gravida</i>	X			X	4.89	67
<i>Thalassiosira nordenskioldii</i>	X			X	1.38	93
<i>Trachelomonas</i>			X		0.20	138
<i>Tripes furca</i>	X				0.36	122
<i>Tripes fusus</i>		X	X	X	7.23	60
<i>Tripes lineatus</i>	X		X	X	7.14	61
<i>Tripes longipes</i>	X	X			2.82	74
<b><i>Tripes muelleri</i></b>		<b>X</b>	<b>X</b>	<b>X</b>	<b>106.51</b>	<b>10</b>
<i>Unicell</i> spp.	X	X	X	X	46.03	16
<i>Woronichinia</i>	X	X	X	X	1.91	87

Table Appendix 2: Seasonal occurrence of taxa found in the investigation area in 2020 with information on original description, taxonomic rank and taxonomic life science identifier according to the Aphia Database (AphiaID) of the world register of marine species (WoRMS).

	rank	AphiaID	Feb	March	May	Aug	Nov
<b>Protozoa</b>							
Tintinnidae Claparède & Lachmann, 1858	Family	183533	0			0	0
<b>Annelida</b>							
Polychaeta - Trochophora	Subphylum		0				
Polychaeta - others	Subphylum	883	0			0	0
<i>Harmothoe</i> spp. Kinberg, 1856	Genus	129491	0				
<i>Pectinaria</i> spp. Savigny in Lamarck, 1818	Genus	129437				0	
<b>Arthropoda - Crustacea</b>							
<b>Copepoda</b>							
<i>Acartia bifilosa</i> Giesbrecht, 1881	Species	345919	0		0	0	0
<i>Acartia longiremis</i> Lilljeborg, 1853	Species	346037	0		0	0	0
<i>Acartia tonsa</i> Dana, 1849	Species	345943				0	0
<i>Calanus</i> spp. Leach, 1816	Genus	104152	0				0
<i>Centropages hamatus</i> Lilljeborg, 1853	Species	104496	0		0	0	0
<i>Centropages typicus</i> Krøyer, 1849	Species	104499					0
<i>Cyclopoidea</i> Burmeister, 1834	Order	1101	0				0
<i>Eurytemora affinis</i> Poppe, 1880	Species	104872	0			0	
<i>Euterpina acutifrons</i> Dana, 1847	Species	116162			0		0
Harpacticoida G. O. Sars, 1903	Order	1102	0		0		0
<i>Microsetella</i> spp. Brady & Robertson, 1873	Genus	115341					0
<i>Oithona similis</i> Claus, 1866	Species	106656	0		0	0	0
<i>Paracalanus parvus</i> Claus, 1863	Species	104685	0		0	0	0
<i>Pseudocalanus</i> spp. Boeck, 1872	Genus	104165	0		0	0	0
<i>Temora longicornis</i> O.F.Müller, 1785	Species	104878	0		0	0	0
<b>Phyllopoda</b>							
<i>Bosmina</i> spp. Baird, 1845	Genus	106265				0	0
<i>Evadne nordmanni</i> Lovén, 1836	Species	106273	0		0	0	0
<i>Podon intermedius</i> Lilljeborg, 1853	Species	106276				0	0
<i>Podon leuckartii</i> G. O. Sars, 1862	Species	106277	0		0		
<i>Pleopis polyphemoides</i> (Leuckart, 1859)	Species	247981				0	0
<i>Penilia avirostris</i> Dana, 1849	Species	106272				0	
<b>other Crustacea</b>							
<i>Balanus</i> spp. Costa, 1778	Genus	106122	0		0	0	0
<i>Crangon crangon</i> Linnaeus, 1758	Species	107552				0	
Ostracoda Latreille, 1802	Class	1078				0	
Isopoda Latreille, 1817	Order	113				0	
Lophogastrida Boas, 1883	Order	149669	0				
<b>Bryozoa</b>							
Gymnolaemata Allman, 1856	Class	1795	0			0	0

Table Appendix 2 continued.

	Rang	TSN	Feb	März	Mai	Aug	Nov
<b>Chaetognatha</b>							
Sagittidae Claus and Grobben, 1905	Family	5953					0
<b>Chordata</b>							
<i>Fritellaria borealis</i> Lohmann, 1896	Species	103375	0				
<i>Oikopleura dioica</i> Fol 1872	Species	103407	0			0	0
Teleostei	Infraclass	293496	0		0	0	
<b>Echinodermata</b>							
<i>Asterias</i> spp. Linnaeus, 1758	Genus	123219				0	
<i>Ophiura</i> spp. Lamarck, 1801	Genus	123574				0	0
<i>Echinus</i> spp. Linnaeus, 1758	Genus	123386				0	
<b>Cnidaria &amp; Ctenophora</b>							
Anthothecatae Cornelius, 1992	Order	13551				0	
Ctenophora Eschscholtz, 1829	Phylum	1248	0			0	0
<i>Aurelia aurita</i> (Linnaeus, 1758)	Species	135306	0				
<i>Euphysa aurata</i> Forbes, 1848	Species	117561	0				
<i>Lizzia blondina</i> Forbes, 1848	Species	117345					0
<i>Rathkea octopunctata</i> (M. Sars, 1835)	Species	117848	0				0
<i>Stauridiosarsia gemmifera</i> (Forbes, 1848)	Species	565161				0	
<b>Phoronida</b>							
<i>Phoronis muelleri</i> Selys-Longchamps, 1903	Species	206663					0
<b>Platyhelminthes</b>							
<i>Alaurina</i> spp. Metschnikoff, 1861	Genus	142785	0		0	0	0
Leptoplanidae Stimpson, 1857	Family	142062					0
<b>Mollusca</b>							
Bivalvia Linnaeus, 1758	Class	105	0		0	0	0
Gastropoda Cuvier, 1797	Class	101	0		0	0	0
<b>Rotifera</b>							
<i>Synchaeta</i> spp. Ehrenberg, 1832	Genus	134958	0			0	0
<i>Keratella cruciformis</i> Thompson, 1892	Species	134991					0
<i>Keratella quadrata</i> O. F. Muller, 1786	Species	134992					0

Table Appendix 3: Distribution of macrozoobenthos at 8 stations in November 2020. In the right column the red list (RACHOR et al. 2013) species are indicated (1=critically endangered, 2=endangered, 3=vulnerable, G=probably vulnerable, V=near threatened, R=extremely rare, D=data deficient, \*=least concern, ne=not evaluated).

Taxa	N3	N1	M2	OM18	K8	K4	K3	160	RL
<b>Amphipoda</b>									
<i>Corophium volutator</i>								1	*
<i>Crassikorophium crassicorne</i>					1				*
<i>Gammarus oceanicus</i>					1		1		*
<i>Gammarus salinus</i>					1		1	1	*
<i>Gammarus zaddachi</i>							1	1	*
<i>Melita nitida</i>								1	ne
<i>Melita palmata</i>					1			1	V
<i>Microdeutopus gryllotalpa</i>	1				1		1	1	*
<i>Monocorophium insidiosum</i>		1							*
<b>Anthozoa</b>									
<i>Edwardsia danica</i>	1			1					D
<i>Halcampa duodecimcirrata</i>						1			1
<i>Sagartia</i> sp.	1								ne
<b>Arachnida</b>									
Halacaridae	1						1		ne
<b>Ascidacea</b>									
<i>Dendrodoa grossularia</i>	1	1							V
<i>Molgula manhattensis</i>	1								D
<b>Bivalvia</b>									
<i>Abra alba</i>		1							*
<i>Arctica islandica</i>	1	1	1	1		1			3
<i>Astarte borealis</i>	1				1				G
<i>Astarte elliptica</i>	1			1		1			G
<i>Astarte montagui</i>	1								3
<i>Cerastoderma glaucum</i>					1			1	*
<i>Kurtiella bidentata</i>	1	1		1			1		*
<i>Limecola balthica</i>					1	1	1	1	*
<i>Musculus niger</i>	1								G
<i>Musculus subpictus</i>	1								G
<i>Mya arenaria</i>	1				1		1	1	*
<i>Mya truncata</i>	1	1							2
<i>Mytilus edulis</i>	1	1		1	1	1	1	1	*
<i>Phaxas pellucidus</i>		1							*
<i>Varicorbula gibba</i>	1	1	1	1		1			*
<b>Bryozoa</b>									
<i>Alcyonidium diaphanum</i>	1								*
<i>Alcyonidium polyoum</i>	1				1				D
<i>Callopora lineata</i>	1								*
<i>Cribrilina punctata</i>	1								*
<i>Einhornia crustulenta</i>		1			1		1	1	*





Taxa	N3	N1	M2	OM18	K8	K4	K3	160	RL
<b>Oligochaeta</b>									
Tubificinae	1	1		1	1		1	1	ne
<i>Tubificoides benedii</i>					1		1	1	*
<b>Phoronida</b>									
<i>Phoronis</i> sp.	1	1							ne
<b>Platyhelminthes</b>									
Platyhelminthes					1			1	ne
<b>Polychaeta</b>									
<i>Alitta succinea</i>	1	1	1			1		1	D
<i>Ampharete acutifrons</i>	1		1			1	1		*
<i>Ampharete baltica</i>	1	1			1		1		*
<i>Arenicola marina</i>	1				1				*
<i>Aricidea suecica</i>	1	1			1				*
<i>Bylgides sarsi</i>		1			1	1			*
<i>Capitella capitata</i>	1				1				*
<i>Dipolydora quadrilobata</i>	1	1				1			*
<i>Eulalia bilineata</i>	1								G
<i>Fabriciola baltica</i>	1						1		G
<i>Harmothoe imbricata</i>		1							D
<i>Hediste diversicolor</i>	1				1			1	*
<i>Heteromastus filiformis</i>	1	1		1					*
<i>Lagis koreni</i>	1	1	1			1			*
<i>Marenzelleria neglecta</i>								1	ne
<i>Marenzelleria viridis</i>					1		1	1	ne
<i>Myrianida</i> sp.		1							ne
<i>Nephtys caeca</i>	1								*
<i>Nephtys ciliata</i>		1							*
<i>Nephtys hombergii</i>	1	1	1	1		1			*
<i>Nereimyra punctata</i>	1	1							G
<i>Paradoneis eliasoni</i>	1	1							*
<i>Pherusa plumosa</i>	1								D
<i>Pholoe assimilis</i>	1								D
<i>Pholoe baltica</i>	1								*
<i>Phyllodoce mucosa</i>		1							*
<i>Polydora ciliata</i>	1				1				*
<i>Polydora cornuta</i>	1	1		1	1				*
<i>Prionospio steenstrupi</i>		1							*
<i>Pygospio elegans</i>	1				1		1	1	*
<i>Scalibregma inflatum</i>		1							G
<i>Scoloplos armiger</i>					1	1	1		*
<i>Sphaerodoropsis baltica</i>	1								D
<i>Spio goniocephala</i>					1				*
<i>Spirorbis corallinae</i>	1								R
<i>Streptosyllis websteri</i>					1				D
<i>Terebellides stroemii</i>	1	1				1			*
<i>Travisia forbesii</i>					1		1		G

Taxa	N3	N1	M2	OM18	K8	K4	K3	160	RL
<b>Porifera</b>									
<i>Chalinula limbata</i>		1							D
<i>Haliclona oculata</i>	1								D
<i>Halisarca dujardini</i>	1								D
<b>Priapulida</b>									
<i>Halicryptus spinulosus</i>		1	1		1		1		ne
<i>Priapulus caudatus</i>		1							ne
<b>species number 118</b>	<b>66</b>	<b>51</b>	<b>10</b>	<b>17</b>	<b>43</b>	<b>19</b>	<b>27</b>	<b>25</b>	
<b>abundance (ind m<sup>-2</sup>)</b>	<b>6435</b>	<b>1906</b>	<b>293</b>	<b>1714</b>	<b>8498</b>	<b>381</b>	<b>7442</b>	<b>16230</b>	
<b>biomass (afdw g m<sup>-2</sup>)</b>	<b>33.0</b>	<b>44.6</b>	<b>12.3</b>	<b>12.9</b>	<b>66.4</b>	<b>0.9</b>	<b>11.4</b>	<b>9.6</b>	

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Sea 2020.

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Summary

Acknowledgements

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Appendix

