ELISABETH MANN BORGESE – Berichte

Baltic Sea Long-term Observation Programme

Cruise No. EMB 264

4 May – 14 May 2021,

Rostock – Rostock (Germany)

HELCOM/long-term

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Chief Scientist

Leibniz-Institute for Baltic Sea Research Warnemünde

2021

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1 Cruise Summary

1.1 Summary in English

The cruise of r/v Elisabeth Mann Borgese No. 264 from May 4th to 14th 2021 was done in the frame of the HELCOM monitoring and the IOW long-term observation of the Baltic Sea. At moderate and partly stormy winds and relative low air temperatures of 5.0°C to 12.8°C the workplan was fulfilled. The work was interrupted on 5th May because of winds up to 9 bft. The different sea areas were investigated with a total of 74 stations (4 repetitions included) and two ScanFish transects. In addition, the profiling mooring GODESS was recovered. The major task constituted the hydrographic, hydrochemical and biological monitoring in German territorial waters and bordering sea areas as well as on the thalweg transect, from the Belt Sea to northern and western Gotland Sea.

Preliminary results show that spring bloom was terminated as nitrate was depleted, usually down to 40 m depth in the Baltic Proper, but phosphate was still available of about 20% of the winter values in surface waters. In the Baltic Proper between 40 m and 80 m depth, the concentrations of phosphate and nitrate were similar and reflected in clear excess of phosphate over nitrate considering a Redfield ratio of 16:1. Thus in case of upwelling, a clear advantage for diazotrophic cyanobacteria is preformed in these waters. The oxygen status in bottom waters of the Belt Sea was good. The Arkona Sea already showed a decreased bottom water oxygen concentration but still above the threshold of 3 mL/L, whereas the Bornholm Sea and the deep Gotland Sea waters were sulphidic at the time of measurement. However, the Słupsk furrow, which is the deep water connection between the Bornholm Basin and the Gotland Basin was oxic in May 2021. But in the deep Basins the stagnation mainly continued and hydrogen sulphide accumulation went on, in the Gotland Deep to -6.34 mL/L oxygen equivalents. Accordingly, nitrate was not found and phosphate further accumulated in the bottom waters of the Gotland, Fårö, Landsort, and Karlsö Deeps in May 2021 like in previous years. However, Fårö Deep had a relative stable hydrogen sulphide concentration in 2018/2019 as intermittent weaker inflows transferred some oxygen via an intermediate depth level of the eastern Gotland Basin to the deep waters of the Fårö Deep, but the situation was clearly worse in May 2021.

1.2 Zusammenfassung

Die Reise des F/S Elisabeth Mann Borgese Nr. 264 vom 4. bis 14. Mai 2021 wurde im Rahmen des HELCOM Monitorings und der IOW Langzeit Überwachung der Ostsee durchgeführt. Bei mäßigen und zum Teil stürmischen Winden sowie relativ niedrigen Lufttemperaturen von 5.0°C bis 12.8°C wurde das Arbeitsprogramm absolviert. Am 5. Mai wurde die Arbeit aufgrund von Windstären bis zu 9 bft unterbrochen. Die verschiedenen Seegebiete wurden anhand von insgesamt 74 Stationen (einschließlich 4 Wiederholstationen) und mit zwei ScanFish-Schnitten untersucht. Darüber hinaus konnte die profilierende Verankerung GODESS geborgen werden. Die Hauptaufgabe stellte aber das hydrographische, chemische und biologische Monitoring in den deutschen Territorialgewässern und den angrenzenden Meeresgebieten sowie der Talweg Schnitt von der Beltsee bis in die nördliche und westliche Gotlandsee dar.

Vorläufige Ergebnisse zeigen, dass die Frühjahrsblüte abgeschlossen war, da Nitrat vollständig bis zu einer Tiefe von etwa 40 m aufgebraucht war, wobei Phosphat noch zu etwa 20% des Winterwertes im Oberflächenwasser zur Verfügung stand. In der zentralen Ostsee zwischen 40

und 80 m Tiefe waren die Konzentrationen von Nitrat und Phosphat ähnlich und widerspiegelten damit einen deutlichen Überschuss von Phosphat im Vergleich zu Nitrat im Vergleich zu dem Redfield Verhältnis von 16:1. Damit ist im Falle einer Auftriebssituation in diesem Wasser ein Vorteil für stickstofffixierenden Cyanobakterien vorgeprägt. Die Arkonasee zeigte schon eine verminderte Sauerstoffkonzentration, aber noch oberhalb des Grenzwertes von 3 mL/L, wogegen die Bodenwässer der Bornholm- und der Gotlandsee zum Messzeitpunkt sulfidisch waren. Dagegen zeigte der Verbindungsweg des Tiefenwassers zwischen der Bornholm- und der Gotlandsee, Słupsker Rinne, oxische Bedingungen im Mai 2021. In den tiefen Becken setzte sich die Stagnationsphase aber fort und führte zur weiteren Anreicherung von Schwefelwasserstoff, im Gotlandtief bis auf eine Konzentration äquivalent zu -6.34 mL/L Sauerstoff. Entsprechend konnte im Bodenwasser der Gotland-, Fårö-, Landsort-, und Karlsötiefs im Mai 2021 kein Nitrat nachgewiesen werden, wie auch schon in den vergangenen Jahren. Das Fårötief zeigte noch eine relativ stabile Schwefelwasserstoffkonzentration in den Jahren 2018/2019, da zwischenzeitlich schwächere Einströme etwas Sauerstoff über die mittleren Wasserschichten des östlichen Gotlandbeckens in das Tiefenwasser des Fårötiefs transportiert hatten, aber bis zum Mai 2021 hat sich die Situation auch dort deutlich verschlechtert.

2 Participants

2.1 Principal Investigators

Name	Institution
Kuss, Joachim, Dr. (Marine Chemistry)	IOW
Mohrholz, Volker, Dr. (Hydrography)	IOW
Dutz, Jörg, Dr. (Zooplankton)	IOW
Kremp, Anke, Dr. (Phytoplankton)	IOW

2.2 Scientific Party

Name	Discipline	Institution
Kuss, Joachim, Dr.	Marine Chemistry, Chief Scientist	IOW
Kolbe, Martin	Phys. Oceanography, CTD and ScanFish	IOW
Dierken, Madleen	Marine Chemistry, Nutrients	IOW
Floth-Peterson, Mareike	Marine Chemistry, GODESS mooring	IOW
Otto, Stefan, Dr.	Marine Chemistry, Greenhouse gases	IOW
Krapf, Karina	Phys. Oceanography, CTD	IOW
Fechtel, Christin	Biol. Oceanogr., Plankton and Microbiol.	IOW

2.3 Participating Institutions

IOW Leibniz Institute for Baltic Sea Research Warnemünde

3 Research Program

3.1 Description of the Work Area

The contribution of the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) to the HELCOM monitoring comprised measurements in German territorial waters with the German Exclusive Economic Zone and bordering sea areas. Therefore, basic hydrographic data, major nutrients, phytoplankton and zooplankton parameters were determined. Moreover, IOW extends the investigated sites by its long-term observation programme of the Baltic Sea. This contributes with station work in parts of the Danish, Swedish, Polish, and Latvian territorial waters and their respective Exclusive Economic Zones. Thereby, the major focus is always on the thalweg transect, which reflects the main path of inflowing North Sea water through the belts and sounds to the Arkona Sea, via the Bornholmsgat to the Bornholm Sea, along the Słupsk channel (Bornholm Sea) to the eastern Gotland Sea Basin. The inflow may proceed within several months further to the northern and western Gotland Sea, episodically bringing haline oxygen rich water to the central basins. This work was supplemented by two east-west ScanFish transects at the Island of Gotland to provide data for hydrographic modelling purposes. An overview of the location of CTD stations and ScanFish transects are shown in Fig. 3.1. In addition, the list of stations is given in Chapter 6.

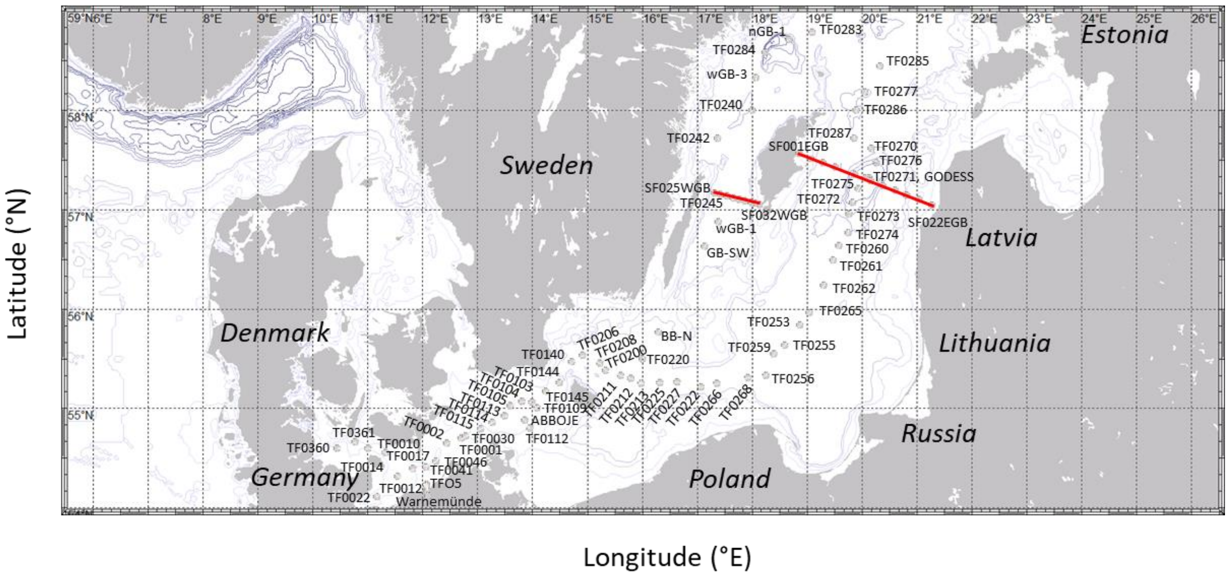

Fig. 3.1 Map of stations (grey dots) and the Scan fish transects (red lines) of the cruise EMB 264 from 4th – 14th May 2021; the details of the sampled stations are listed in Chapter 6.

3.2 Aims of the Cruise

The cruise EMB 264 was carried out as a joined cruise of the environmental monitoring programme of the Federal Maritime and Hydrographic Agency (BSH) and the Baltic Sea long-term observation programme of IOW. It was the third cruise in 2021 of five expeditions performed annually.

The acquired data are used for the regular national and international assessments of the state of the Baltic Sea, and provide the scientific basis for measures to be taken for the protection of the Baltic Sea ecosystem. The hydrographic and hydrochemical conditions as well as the development status of phytoplankton and zooplankton abundances are investigated. Microbiological aspects, acidification, and trace gases were additionally studied in the frames of the long-term observation of the Baltic Sea. A special focus of the long-term observation is always the occurrence or absence of inflow events that both have major consequences for the state of the Baltic Sea's hydrochemistry and its ecosystem. The oxygen entrained by the Major Baltic Inflows (MBI) that occurred between 2014 and 2016 vanished and euxinic conditions prevail in deep waters. Some inflow events of weak intensity during 2020 layered in the intermediate waters of the eastern Gotland Sea basin (Kuss and Fisch, 2020), but these had no effect on bottom waters.

3.3 Agenda of the Cruise

3.3.1 Station work

The work on the stations usually started with a CTD cast and already programmed sampling on standard depth levels. Manual releases in near-bottom waters and close to the sea surface completed the sampling. Then other CTD casts followed on demand to meet the additional water sample requirements. On selected stations, water sampling was carried out for oxygen, basic dissolved inorganic nutrients, total nutrient concentrations, as well as net sampling for phytoplankton and zooplankton species were carried out. Moreover, determinations of chlorophyll and the depth of visibility by means of a Secci disk were also done. For the detailed list of deployed gears see list of stations in Chapter 6.

CTD and Sampling
The CTD-system "SBE 911plus" (SEABIRD-ELECTRONICS, USA) was used to measure the variables: Pressure, Temperature (2x SBE 3), Conductivity (2x SBE 4), Oxygen concentration (2x SBE 43), Chlorophyll-a fluorescence (683 nm), Turbidity, Photosynthetic active radiation in water (PAR), and above the sea (SPAR).
The rosette water sampler was equipped with 13 Free Flow bottles of 5 L volume each. The CTD sensors were checked during the cruise by comparison measurements. In detail, for temperature a high precision thermometer SBE RT35 was used. Salinity samples were taken for measurement after the cruise by means of a salinometer. Slope and offset of the oxygen sensors SBE 43 are checked daily by potentiometrically titrated water samples according to Winkler (Winkler, 1888).

Nutrients
Nitrate, nitrite, phosphate, and silicate were analyzed on filtered water samples using standard spectrophotometric methods by means of an autoanalyser (FlowSys, Alliance-Instruments, Ainring, Germany) and ammonium was determined manually as indophenole blue (Grasshoff et al., 1999) from unfiltered water on-board. Total and total dissolved nitrogen and phosphorous samples as well as particulate and dissolved organic matter samples were prepared and stored deep frozen for digestion and analysis in the IOW nutrients and natural organic matter labs, respectively.

Oxygen and hydrogen sulphide

Oxygen was analyzed by Winkler titration and hydrogen sulphide was determined spectrophotometrically by the methylene blue reaction (Grasshoff et al., 1999). To continue the oxygen profiles in anoxic waters and for comparison, H_2S concentration was converted to negative oxygen values according to its reduction capacity: $H_2S + 2\ O_2 \rightarrow H_2SO_4$. During CTD casts the SBE 43 oxygen sensor (duplicate installation) recorded oxygen values that are validated by daily Winkler titration of triplicate samples each from 3 water sampling bottles released according to a specific time-regime.

Plankton sampling

Plankton sampling was performed by means of a rosette sampler (combined with CTD) as well as with a small phytoplankton net and the zooplankton nets WP2 and Apstein. Samples were taken in a tight follow up of depths levels in order to get representative data from the euphotic zone. The traditional method to estimate water transparency/primary production by means of a Secci disk is also applied here. (Responsible scientists: Dr. Anke Kremp, Dr. Jörg Dutz).

Long-term observation of the microbiological habitat of the redoxcline

Insights into the redoxcline microbial food web is obtained by well resolved sampling of the range of the redoxcline at Gotland Deep and Landsort Deep stations on each monitoring cruise. Therefore, in the redoxcline as well as 6 depths above and below, respectively, in depth intervals of 2 m, samples were taken by CTD/water sampling bottles and prepared for microbiological analysis (FISH and DNA) and determination of pigments. (Responsible scientist: Prof. Klaus Jürgens)

Long-term investigations of CH_4, N_2O and the marine carbonate system

Sampling for simultaneous CH_4 and N_2O observation is carried out on 4 stations (TF0113, TF0213, TF0271, TF0286) in the frame of the accompanying project for long term data collection. All samples were taken in septum-sealed 250 mL water bottles and fixed with 200 µL or in case of hydrogen sulphide presence with 500 µL saturated $HgCl_2$-solution to prevent microbiological activity and stored dark. On the same stations and depths also CT, AT, and pH were sampled for their long-term observation. These samples were fixed by the same method and were also stored dark. (Responsible scientist: Prof. Gregor Rehder).

Sensor tests in the frame of the projects DArgo2025 and C-SCOPE

As part of the research project DArgo2025, optical nitrate and hydrogen sulphide data were acquired with two sensors (OPUS, TriOS GmbH; SUNA, Sea-Bird Scientific). Both were tested during CTD casts as well as underway by using the ship's clean seawater supply system. Moreover, a HydroC pCO_2 sensor was attached to the CTD in preparation for analyses within the C-SCOPE research project. Data from these sensors will be made available by the respective research project's data management upon publication of the intended analyses. (Responsible scientist: Dr. Henry Bittig)

ScanFish

An undulating CTD-system with fluorometer and oxygen sensor was tugged on 2 transects, transverse versus the thalweg, one in the eastern and one in the western Gotland Basin. The ScanFish is a towed platform in wing shape allowing to accumulate CTD data of the water column in an undulating manner from surface to about 230 m maximum depth. This can be achieved by adjusting cable length to current diving depth with up to 1000 m cable. It offers a payload to accommodate a pumped Seabird CTD application consisting of a Seabird SBE911+ probe, temperature (SBE3), conductivity (SBE4) (salinity) and oxygen (SBE43) sensor. Additionally, a Wetlabs FLNTU is installed for chlorophyll and turbidity recording. The central ScanFish controller supports DSL data transfer protocols and speed, making it very flexible to interface with additional sensors and devices.

4 Narrative of the Cruise

This paragraph is aimed to give an impression of the work on board during the campaign. It is a day by day report that includes the forecasted weather and sea condition as predicted by Deutscher Wetterdienst (DWD, 2021) for the respective days.

Tuesday, 04 May 2021: The weather forecast for the first day of the cruise was moderate wind from the south of 5 to 6 bft, in the southern Belt Sea with an increasing tendency to 7, shifting southwest to west with shower squall and a sea state with waves of 1.5 m height. After one and a half hour of steaming time, we arrived at the first station TFO5. It is usually termed as test station for CTD performance and the chemical parameters. The samples and data are however relevant and already needed. The visibility depth was determined by the traditional method by using a Secci disk. The value is also used to optimize the filtration volume for organic matter analysis. Moreover, water sampling for oxygen determinations, the inorganic nutrients nitrate, nitrite, phosphate, silicate, ammonium, total as well as total dissolved nitrogen and phosphorous, and for dissolved and particulate natural organic matter analyses was done. All was in perfect order. The next station was TF0012 still in the Mecklenburg Bight, again with CTD and water sampling for chemical parameters accompanied by Secci depth, as well as first plankton net hauls by using the small phytoplankton net and the WP2 plankton net with a closing mechanism. On TF0010 after the CTD cast, early intercomparison measurements for oxygen, salinity, temperature, and pressure were done to secure the correctness and stability of the sensors or in case to adjust the sensor reading after the cruise. The TF0014 and the work-intensive TF0360 already in the Kiel Bight followed, the latter with sampling and sample preparation for all the parameters as investigated on the second station that will be measured on-board or in the IOW labs after the cruise. The additional sampling of zooplankton by repetitive WP-2 net hauls enabled considerable enrichment of live organisms that were stored in ambient seawater in a bucket supplied by bubbling air. The last station of this day was TF0361 in the evening, still in the Kiel Bight.

Wednesday, 05 May 2021: The weather was expected to be bad, with strong south-westerly winds of about 7 bft in the Western Baltic Sea, later shifting west and decreasing a little, thundery gusts, at a sea state in the beginning of about 3 meters. After fulfilling the TF0022 in the Lübeck Bight at night by a standard CTD-Cast with a bottom water oxygen sample, subsequently the TF0017 in the early morning in harsh weather conditions could finally be completed. We headed to Warnemünde to deliver the live-sample of zooplankton in the morning that was taken on TF0360. But then we decided to stay in Warnemünde until the stormy wind and the sea state have decreased that already made the CTD cast on TF0017 challenging. However, because of the Corona pandemic it was neither allowed to leave the ship or to allow guests to come on board.

Thursday, 06 May 2021: The weather seemed to have significantly improved. The forecast reads westerly winds of 6 to 7 bft, then decreasing to 4 bft with shower squalls, at a sea with first 2.5 m wave height. We left Warnemünde at noon after an excellent “seaman’s Sunday” lunch, going back to the station chain from Mecklenburg Bight to the central Arkona Sea to continue on station TF0041 by a CTD cast. The TF0046 followed with CTD casts and water sampling for nutrients and oxygen. Then plankton net hauls with the small phytoplankton net and the WP-2 and a Secci depth determination were carried out. Subsequently, we went across Darss Sill and then via TF0002 and TF0001. The latter is located close to the pile-platform Darss Sill of the Marine environmental monitoring network (MARNET). We took additional comparison values for the sensors attached to the platform in 7 and 19 m depths. Then station work on TF0115, TF0114, and TF0113 followed. The TF0113 was a main station and the last one of the day, where we obtained a huge amount of water and plankton samples from the central Arkona Basin.

Friday 7 May 2021: The weather forecast for the western Baltic Sea announced westerly winds of about 4 bft, increasing a little with shower squalls, and the sea was expected to calm down again to a sea of 1 m wave height. Over midnight we went in south-eastern direction to the TF0112. We started the station work early in the day with water sampling for nutrients and oxygen determinations. Then headed to the station close to the MARNET platform “Arkona Basin”, termed ABBOJE. The visit of ABBOJE was mainly aimed to provide comparison values for the sensors in various depth layers, especially of the two oxygen sensors in 7 m and 40 m depths. Thereafter, TF0105, TF0104 and TF0103 were completed with respective CTD casts for the temperature, salinity, oxygen, fluorescence and turbidity profiles and sampling for dissolved inorganic nutrient measurements. The next station was TF0109, again with a comprehensive program including ammonium as well as total and total dissolved nitrogen and phosphorous and natural organic matter sampling and sample preparation. The biological sampling comprised water sampling and several plankton net hauls. Then TF0145 followed with standard inorganic nutrients nitrate, nitrate, phosphate and silicate that were measured on board in due time after sampling and filtration. From station TF0144 we passed the Bornholmsgat to the next station TF0140. The Bornholmsgat station TF0242 could not be permitted by the Swedish coast guard because of heavy ship traffic. Next were TF0206 as well as TF0208 with standard CTD casts. On station TF0200 a mixed layer oxygen as well as either oxygen or hydrogen sulphide determinations in bottom waters were on the schedule. It turned out that the bottom water in the Bornholm Basin was currently anoxic with a detectable hydrogen sulphide concentration. Then the TF0211, TF0214 and TF0212 followed before we reached the Bornholm Deep station TF0213 with the ambitious programme including gases like dinitrogen oxide and carbon dioxide, all the nutrient parameters and organic matter that was investigated already on previous main stations of this cruise. As a precautionary measure to reach a German port in due time, in case of a Covid-19 infected person onboard, the next station TF0225 was scheduled for Saturday after breakfast to stay in a circle of one-day travel until the last Covid-19 test of the cruise was done.

Saturday 8 May 2021: Forecast for the southern Baltic Sea was wind from West of about 4 bft, partly light and variable winds, later south 5 to 6 bft and misty at a sea of 1.5 m wave height. During the morning we fulfilled mainly pure CTD casts to investigate the water column structure along the thalweg TF0225, TF0227, and TF0222 with regard to temperature, salinity, oxygen, chlorophyll and turbidity by sensors attached to the rosette system. Bevor lunch we had to do our fourth Corona test, that turned out to be negative for all persons onboard. Thus we could speed up the schedule and leave the circle of reaching a German port within a day. Then the physical measurements by CTD casts were continued first along the Słupsk furrow eastwards on TF0266, TF0268, TF0256, and subsequently northward in the eastern Gotland Basin via TF0259, TF0255, TF0253, and TF0265. However, on the main stations TF0222 and TF0259 additionally water sampling was done for basic inorganic nutrients, ammonium, total nitrogen and total phosphorus as well as oxygen or hydrogen sulphide determinations on water samples from selected depths and mandatorily in bottom waters. In the afternoon we had excellent sunny weather that was used by the scientific crew for a coffee break on the work deck. However, the outside temperature of 7°C was still relative low.

Sunday 9 May 2021: The weather was fine – a bit hazy but sunny - and the sea was calm in the morning and we expected southerly winds of 4 to 5 bft that may temporarily increase slightly, at times misty with a sea of 1.5 m wave height. We continued the northward transect by the stations TF0262, TF0261, TF0260, TF0274 and TF0273. We decided to go first to the GODESS station to recover the mooring and do the two remaining southern stations afterwards, because of an expected increase of the wind speed and wave height during the day. At 10:00 o'clock the mooring was released by a hydrophone. After several minutes, the floats were visible at the surface and the mooring weight and the base unit with the winch were recovered. However, the profiling sensor package with the steering and storing unit was missing, because the winch rope was cut off. The recovery was finished at 11:00 o'clock. We then headed south to catch up the CTD casts on TF0272 and TF0275 bevor we went to the main station TF0271 Gotland Deep with many CTD casts, for hydrographic, chemical, and biological parameters. Also samples were taken for analyses of Greenhouse gases and the carbonate system of seawater. Several net hauls with various nets were carried out and water samples for microbiological analyses on filtrated particles were taken from the redoxcline. Late in the evening we went in south-easterly direction to reach the start point of the ScanFish transect near the Latvian coast.

Monday 10 May 2021: For the central Baltic Sea wind was expected from south to south-eastern direction of 4 to 5 bft, with temporarily elevated wind force at a sea of 1.5 m wave height. We started in the night at half past twelve and deployed the ScanFish. At a distance of about 40 miles from the coast the transect began and was orientated in west-north-westerly direction. This allowed to carry out the transect across the eastern Gotland Sea at almost tailwind. This was the best choice at moderate wind speed and a considerable wave height. The ScanFish did the undulation between the surface and the seafloor, down to 230 m depth in central basin very well. Sensors were basically the same as used on a CTD-rosette system (conductivity, temperature, depth, oxygen, fluorescence and turbidity). At 14:30 we recovered the ScanFish close to the Island of Gotland. A final CTD cast with intercomparison measurements was done, then we headed in eastern direction to do CTD casts on TF0276 and further North on TF0270 as well as on TF0287, before we reached the Fårö Deep station TF0286 late in the evening to fulfil the whole parameter set. This was again one of our main stations along the thalweg, however considerably shallower then Gotland Deep and Landsort Deep. The latter was on the schedule for next day in the afternoon.

Tuesday 11 May 2021: In the night we continued with stations along the thalweg in northern direction TF0277 and TF0285. To save some time, we then skipped a few far northern stations and did the direct transit to the western Gotland Basin. The stations TF0283 and nGB-1 were completed and subsequently we went to the deepest site of the Baltic Sea, the Landsort Deep station TF0284 with a depth of 460 m. All nutrient parameters oxygen/hydrogen sulphide, dissolved and particulate organic matter were sampled for analysis. The measurements were partly carried out on-board, other samples were stored deep frozen for analyses in the IOW laboratories. Because of many investigated depth layers, sampling was distributed on three CTD casts for the deeper, the medium and the upper water column, respectively. A fourth one was solely dedicated to the redoxcline and the range above and below in 2 m depth steps. Also the Secci depth was determined. Then we continued the route to the stations wGB-3, TF0240 and TF0242 with respective CTD casts and oxygen intercomparison measurements. Then we approached the next ScanFish transect on SF032WGB close to the west coast of the Island of Gotland.

Wednesday 12 May 2021: In nice weather with a fresh breeze we deployed the ScanFish at 5 o'clock in the morning close to the southern tip of the Island of Gotland and started the transect across the western Gotland Sea Basin. The weather was forecasted to be stable at south-easterly winds of 3 to 4 bft, shifting northeast and were expected to partly increase during the day. Around noon we recovered the ScanFish in some distance to the Island of Oland, to continue the station work on the Karlsö Deep Station TF0245 about one hour back on the transect. Then several CTD casts with oxygen intercomparison on the stations wGB-1, GB_SW, TF223 and BB_N followed until late in the evening. However, a longer transit was used for a nice barbeque in the sunny, but still a bit cold evening.

Thursday 13 May 2021: In the night we sampled the station TF0220 and at 2:00 o'clock in the morning we arrived on the first repetition station at Bornholm Deep (TF0213) for CTD casts and several net hauls. We reached the Arkona Sea in the morning in foggy conditions and forecasted wind from northwest of 3 to 4 bft, shifting west. Then CTD casts on TF0113, TF0030 close to the peninsula of Zingst, TF0046 already behind Darss Sill in the Belt Sea, and finally the TF0012 in the Mecklenburg Bight followed with net hauls as well as Secci depth determinations and water sampling before midnight. Close to the coast we waited for the clearance to the port.

Friday 14 May 2021: Early in the morning we entered Rostock harbour and docked at the pier of Rostock-Marienehe at about 8 o'clock in the morning. All the lab staff was carried from board at once by a small container and loaded on the Institute's lorry. Also the valuable samples and data were taken from board to the IOW.

5 Preliminary Results

The results presented in the following section are preliminary and many samples taken are to be analysed and interpreted during the next weeks and months. The aim of this section is to give a first impression on the collected data set. An advanced data analysis will follow when the validated data sets are available.

5.1 Meteorological conditions

A deep depression crossed northern Europe during the beginning of the campaign. The 4th May was characterized by moderate wind from southern direction but during the night the wind force increased to 8 partly 9 bft from southwest at 980 hPa in the Mecklenburg Bight. We decided to stop working and to enter a save place until the next day. During the next days, we basically had moderate wind that calmed down on 7th, 8th, 11th and 13th May. After the storm the air temperature decreased partly to 5°C with a cloudy sky in the first half of the cruise. During sunny periods in the second half, temperatures were partly above 10°C and reached a maximum of 12.8°C (Fig. 5.1). However, the time period of the cruise appeared rather windy and cold for a May month. The detailed development of the onboard measured wind speed, humidity, wind direction, air pressure, air temperature and global radiation are shown in Fig. 5.1.

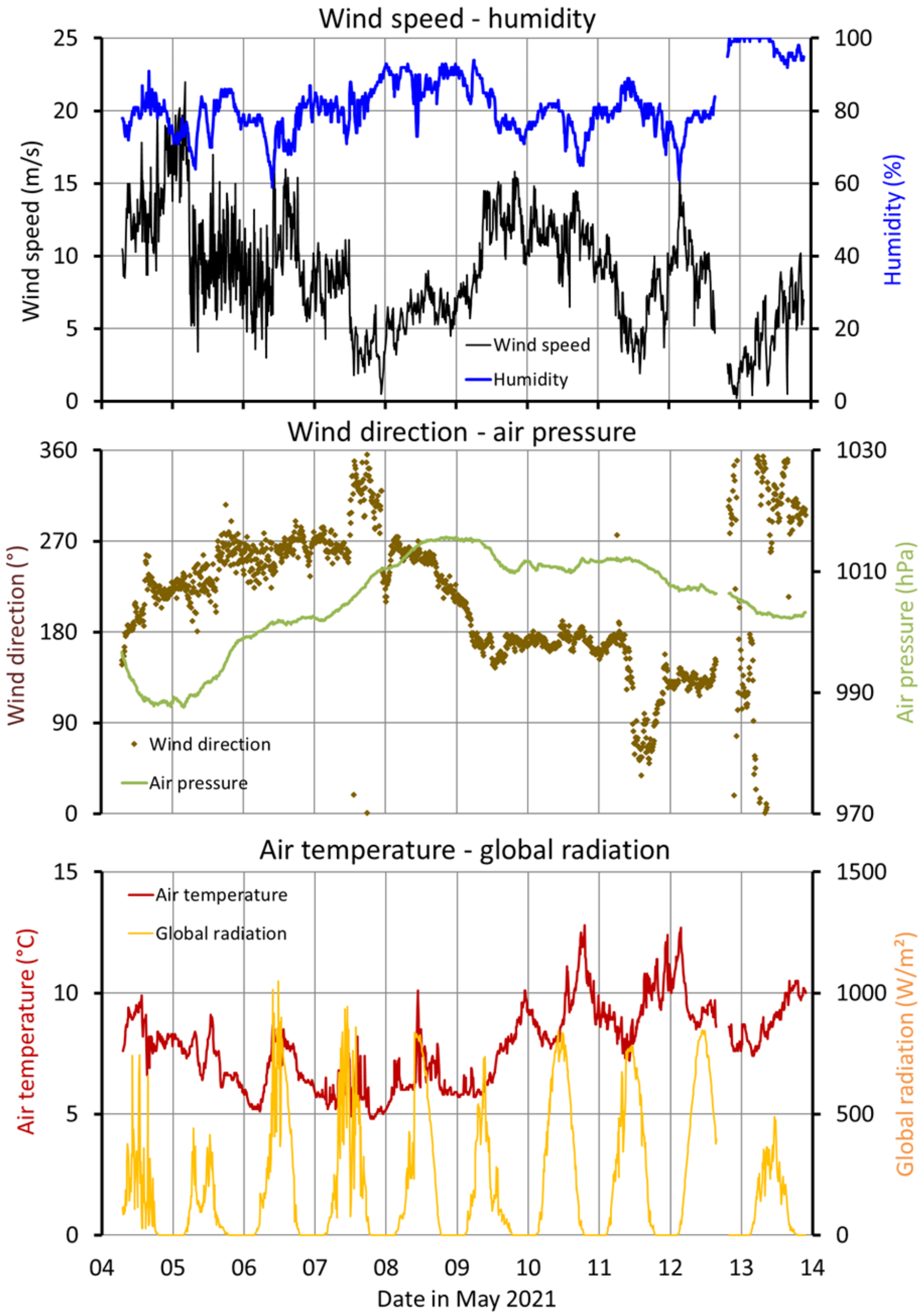

Fig. 5.1 Wind speed and humidity (upper panel), wind direction and air pressure (panel in the middle), as well as air temperature and global radiation (lower panel) measured on-board by the automatic weather station of the DWD.

Also the surface water temperature was low during the campaign. We had about 8°C in the Belt Sea and 6°C in the Baltic Proper, respectively, shown as the meteorological surface water temperature in Fig. 5.2. The upper water showed a deep mixed layer during the first half of the cruise caused by the storm. In the last few days the surface water temperature increased and the water column started to stabilize.

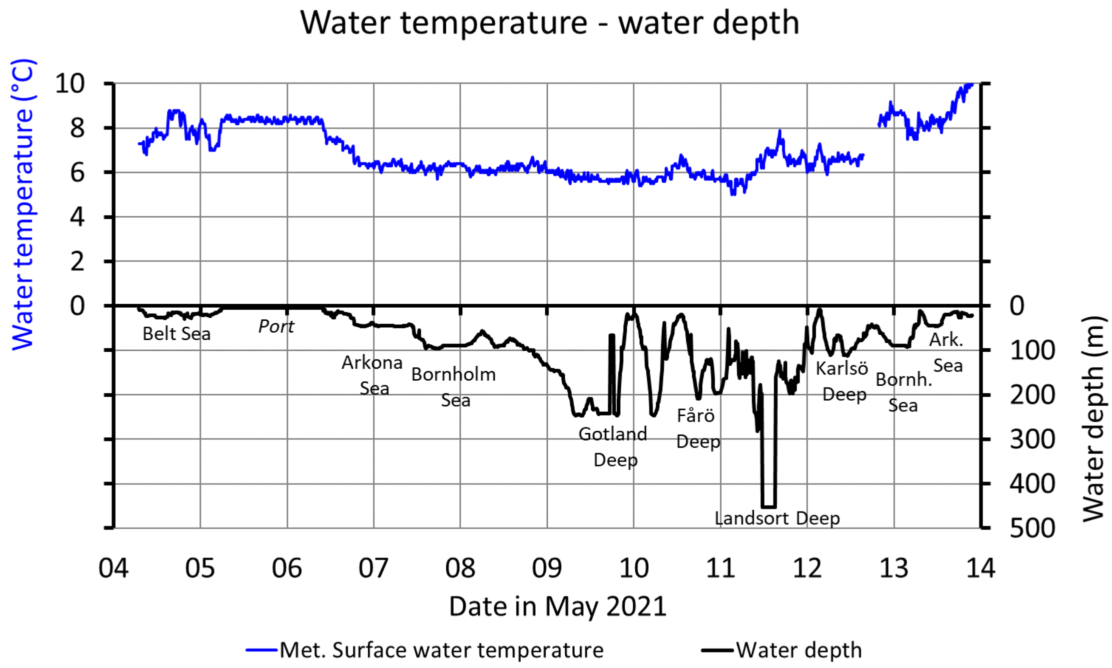

Fig. 5.2 Recording of not finally validated meteorological surface water temperature with the corresponding water depth and sea area during the cruise EMB 264 of r/v Elisabeth Mann Borgese from May 4th to May 14th.

5.2 Nutrient situation in the western Baltic Sea in May 2021

In the Belt Sea, the nutrient situation was characterized by the depletion of nitrate and significant residues of phosphate of about 20% of the winter maximum in surface waters. In the bottom range, nitrate was about 25% and phosphate about 50% of the winter situation. Similarly, in the Arkona Sea where the upper 20 m were depleted of nitrate, whereas phosphate remained at about 0.26 µmol/L. In bottom waters, both could be up to about 1 µmol/L. In the Bornholm Sea nitrate depletion reached 40 m depth at an average phosphate concentration of 0.30 µmol/L without a significant depth gradient. In the eastern Gotland Sea nitrate could be quantified in 60 to 80 m depth between 1 and 5 µmol/L in the Gotland Deep, and its depletion to an undetectable concentration above and below this depth interval, while phosphate clearly increased below 50 m depth (0.55 µmol/L) to the bottom water layer (5.7 µmol/L). In the Fårö Deep the nitrate concentrations showed maximum values at 70 and 80 m depth of 4.1 µmol/L, whereas phosphate increased from 0.36 µmol/L in 40 m depth to 3.0 in 100 m and 4.7 µmol/L close to the bottom in 190 m. At Landsort Deep site the nitrate maximum of 4.4 µmol/L was in 60 m and phosphate increased from 0.34 µmol/L in 40 m depth to 3.5 µmol/L in 100 m depth and then remained almost constant to 3.7 µmol/L in 437 m in the bottom water. Thereby, in the Landsort Deep, nitrate was already depleted in 80 m depth and below at sulfidic conditions. Due to the coarse depth-resolution in the Karlsö Deep only in 60 m, 4.7 µmol/L nitrate was found. In depths 20 m below and above, respectively, and further on, no nitrate was found. Phosphate increased to the bottom to 3.9 µmol/L in 107 m depth.

Also nitrite contributed significantly to the oxidized nitrogen species with 10% on average. Looking at the intermediate waters between 40 m and 80 m depth of the Baltic Proper, phosphate was on average 1.1 µmol/L and nitrate 1.3 µmol/L. This resulted in average nitrate/phosphate ratio of close to one. That in turn reflected a clear excess of phosphate over nitrate considering a Redfield ratio of 16:1 as the favourite N:P uptake ratio in phytoplankton. Thus in case of upwelling, a clear advantage for diazotrophic cyanobacteria is preformed in the deeper waters (Wasmund et al., 2012).

In the deep basins the stagnation phase and subsequent oxygen depletion with subsequent increase of hydrogen sulphide in deep waters was on-going since 2016. Nitrate was basically depleted and phosphate was accumulated there again (Table 5.1). Anoxic condition lead on one side to remineralisation of organic matter until the oxidation state of ammonium only, and on the other side remaining nitrate is used as oxidant until its depletion. So nitrate was below the detection limit in May 2021 in the bottom waters of the Gotland, Fårö, Landsort, and Karlsö Deeps similarly as in previous years. Thereby, the phosphate concentration showed some variability with an increasing tendency in the Gotland Sea bottom waters and almost stable conditions on different levels in the Fårö, Landsort, and Karlsö Deeps in recent years (Table 5.1).

Table 5.1 Nitrate plus nitrite (upper part) and phosphate concentrations (lower part) in the bottom layer (µM) in May 2021 in comparison to former years.

Area	2021	2020	2019	2018	2017	2016
Gotland Deep	**n.d.**	0.18	n.d.	n.d.	n.d.	12.53
Farö Deep	**n.d.**	-	n.d.	n.d.	7.91	4.89
Landsort Deep	**n.d.**	-	n.d.	n.d.	n.d.	n.d.
Karlsö Deep	**n.d.**	-	n.d.	n.d.	n.d.	n.d.

Area	**2021**	2020	2019	2018	2017	2016
Gotland Deep	**5.70**	5.35	4.70	4.87	5.20	2.46
Farö Deep	**4.70**	-	5.07	4.25	2.63	2.59
Landsort Deep	**3.73**	-	4.45	2.85	n.d.	3.23
Karlsö Deep	**3.90**	-	3.40	3.50	3.65	4.75

n.d.: below detection limit - : no data

5.3 Baltic thalweg transect

The recorded sensor profiles on the stations between the Kiel Bight along the thalweg to the Landsort Deep in the western Gotland Sea were combined to contour plots of salinity and temperature (Fig. 5.3) as well as of oxygen, fluorescence, and turbidity (Fig. 5.4). It is aimed as an overview of the hydrographic and the hydrochemical state of the Baltic Proper during the cruise EMB 264 in May 2021. From the Belt Sea (TF0360) with a temperature of 8.4°C in surface water to 6.1°C in bottom water and a respective salinity of 16.8 and 20.3 to the Landsort Deep (TF0284) of 5.1°C in the surface and 6.6°C in the deep with a respective salinity of 6.0 and 11.2 in 250 m reflects the two dimensional picture of the gradient system (Fig. 5.3).

The halocline deepens from the Arkona Basin at about 40 m to 60 m depth in the Bornholm Basin and via the eastern Gotland Sea at ~70 m with some spatial variability, to the Landsort Deep station at 65 m depth. The thermocline showed a clear spatial variability and a trend throughout the campaign, as warming of the upper water continued after the storm. So in the central Arkona Sea we had a mixed layer depth of 32 m on 6^{th} May and a thermocline at 13 m on 13^{th} May. Remaining winter water of about 4°C (the blue ribbon in Fig. 5.3) was present in the Arkona Sea at 35-40 m, in the Bornholm Sea between 50-60 m in the eastern Gotland Sea in general between 45-55 m. Below the cold layer, the water showed a temperature of 6 to 8°C and in the Bornholm Sea up to even 8.5°C in the bottom range at corresponding elevated salinity.

The mixed layer oxygen concentration was close to the equilibrium with the atmosphere, at the respective surface water temperature and reached almost the depth level of the halocline. Within the halocline, the oxygen concentration decreased sharply to mostly an undetectable level. It should be mentioned that H_2S is not considered in this figure, since the oxygen sensor is unable to record “negative oxygen”. However, waters that reflected slightly positive oxygen values of ~ 1 mL/L can be identified as blue and dark blue patches between 600 and 800 km of the transect, which seemed to move down the southern slope of the eastern Gotland Sea basin (Fig. 5.4, upper panel). The origin of the water body is likely the Bornholm Basin that was anoxic at the time of the cruise. But Slupsk furrow that is situated between Bornholm Basin and eastern Gotland Basin was oxic, and served as a transition reservoir of the inflow water (see Fig. 5.5). These regions frequently obtain water from the western Baltic Sea with elevated salinity to be episodically released to the eastern Gotland Basin. It is mostly intruded at a depth interval of 80 to 140 m in the central Eastern Gotland Basin, but this time it didn’t reach deeper as about 120 m. Interestingly, turbidity was slightly increased in that interval, which is noticeable as a light blueish colour shading. Turbidity could indicate resuspension near the seafloor, as in the transition between the Belt Sea and the Arkona Sea right after the storm. But in deeper waters as in this context it likely showed precipitates after former intrusions of oxygenated waters. Partly this is caused by precipitation of fine particles of elemental sulphur (Kamyshny et al., 2013) and likely manganese(IV) and iron(III) oxyhydroxides and phosphates play a role too (Dellwig et al., 2010). Because of the low temperatures in April and the windy periods prior to the EMB 264, a distinct chlorophyll maximum did not develop, except perhaps on stations in the Bornholm Sea and later in the Landsort Deep area. However, the patchy structure is depicted in the panel in the middle of Fig. 5.4 with chlorophyll_a concentration of up to 2 mg/L. Some fluorescent matter is visible in the halocline region that likely reflected older material that was already sunken out of euphotic waters and accumulated in the density gradient.

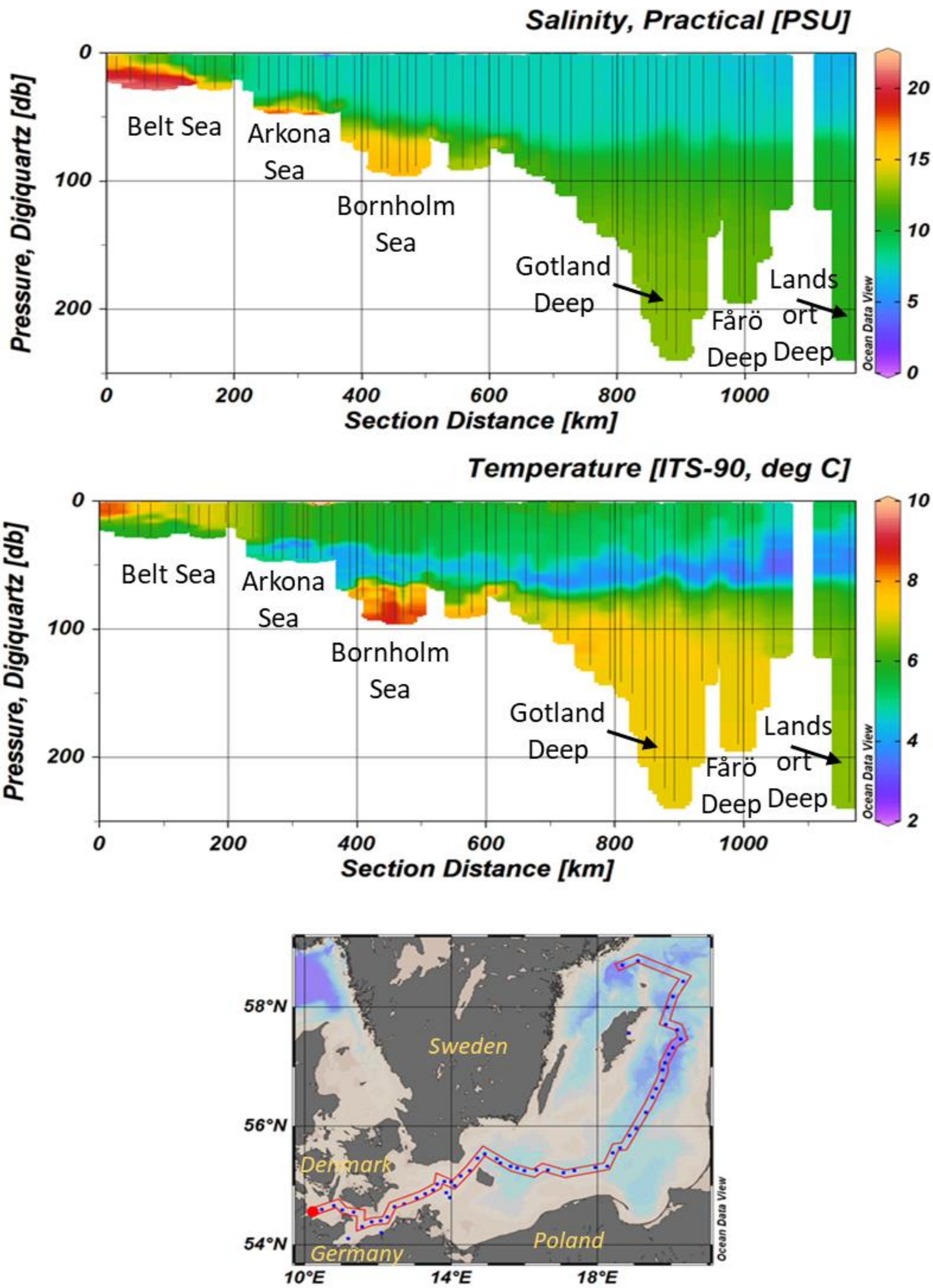

Fig. 5.3 Distribution of temperature and salinity along the thalweg of the Baltic Sea from the Kiel bight to the western Gotland Basin. The figure is based on not finally validated CTD data on selected stations in the upper 250 m, measured between May 4th and May 14th. The plot was done by using ODV 5 (Schlitzer, 2018).

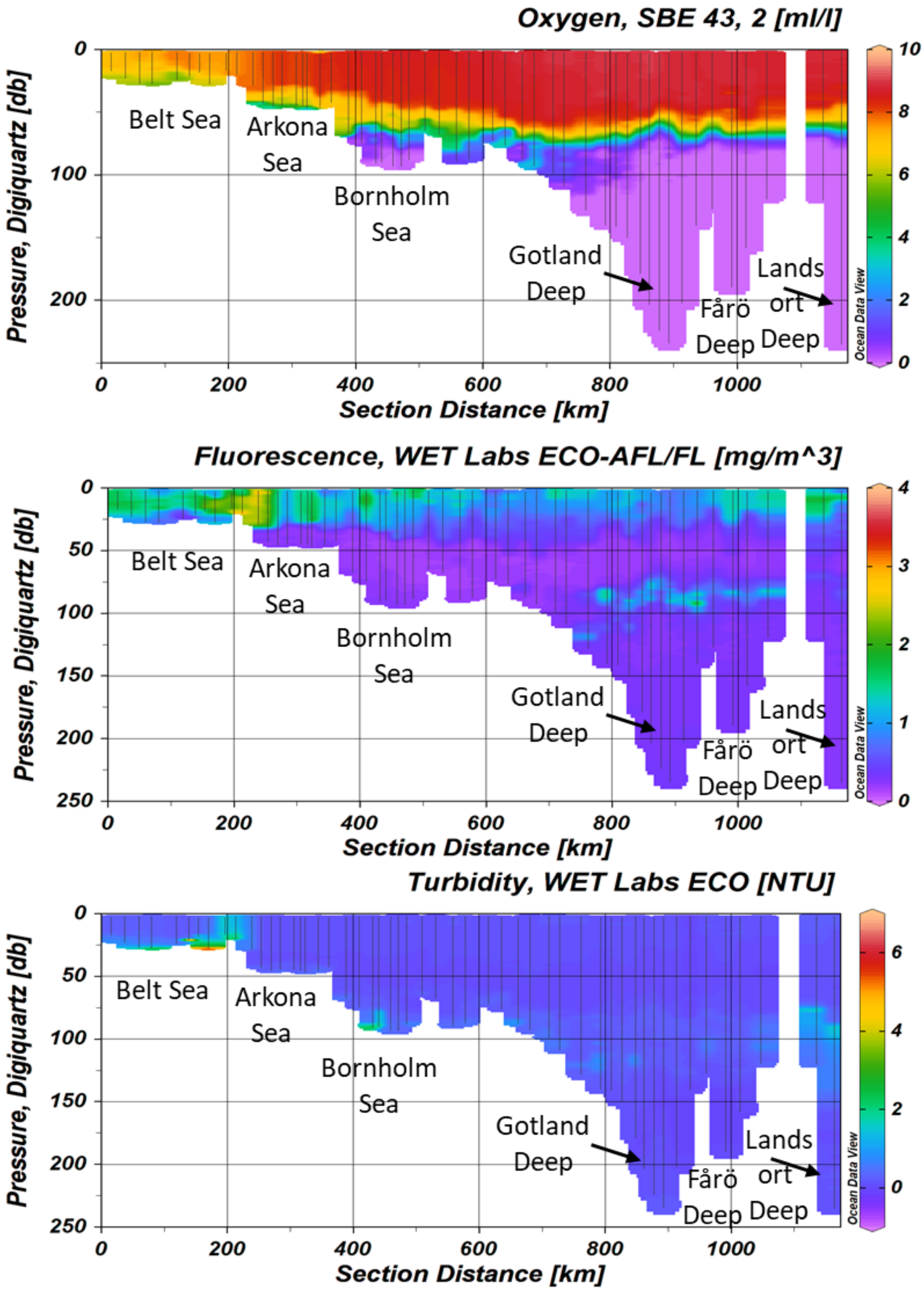

Fig. 5.4 Distribution of oxygen, fluorescence and turbidity along the thalweg of the Baltic Sea from the Kiel bight to the northern Gotland Basin. The figure is based on not finally validated sensor data (see 3.3.1 Station work) on selected stations (see Fig. 5.3) in the upper 250 m, measured between May 4th and May 14th. The plot was done by using ODV 5 (Schlitzer, 2018).

5.4 Development of Baltic Sea water masses – comparison to previous cruises

5.4.1 Surface water temperature

The surface water temperature along the cruise track of EMB 264 was already shown (Fig. 5.2). Here we compare the values determined during EMB 264 at selected Baltic Sea monitoring stations to the temperatures of recent years from 2016 to 2020 and the long-term mean values 1971-1990 in May (Table 5.1). Surface water temperatures in May 2021 were similar to 2017 and generally at the lower end of recent years as shown in Table 5.2. Moreover, the surface water temperatures of May 2021 of the Bornholm and Gotland Seas were close to the low long-term averages. So the surface water temperature was 1 K lower on the Mecklenburg Bight station and between 2.1 and 2.2 K lower on the respective stations in the Arkona, Bornholm and eastern Gotland Sea Basins. However, in the Mecklenburg Bight it was still 3.4 K and in the Arkona Sea 2.5 K warmer in comparison to the long-term average determined for 1971-1990.

Table 5.2 Temperature in the surface layer (°C) in May 2021 in comparison to former years.

Area	**2021**	2020	2019	2018	2017	2016	1971-1990
Mecklenburg Bight	**8.1**	9.1	9.2	8.2	8.1	11.3	4.7
Arkona Basin	**6.8**	9.0	7.4	7.1	7.0	9.8	4.3
Bornholm Basin	**6.4**	8.5	7.4	8.4	6.1	8.9	6.1
Gotland Deep	**5.3**	7.5	6.6	7.4	5.8	8.7	5.6
Farö Deep	**5.3**	-	7.2	8.6	5.0	7.9	5.2
Karlsö Deep	**6.2**	-	6.4	8.1	7.0	8.1	6.8

5.4.2 Deep water salinity and temperature

The temperatures in the bottom waters of the Bornholm, Gotland, Fårö, Landsort, and Karlsö Deeps in May 2021 were relatively similar to the last two years (within ± 0.4 K), ignoring the data gaps in 2020. Obviously, the temperatures reflected an increasing tendency since 2016 after the Major Baltic Inflow (MBI) in 2014/2015 (Table 5.3). The difference between May 2021 and the reference period of 1.9 ± 0.3 K on average appears huge. However, the difference to the selected 20-year period of the last century confirms a general increase that appears to reflect a basic climate change consequence, but was certainly interrupted many times by MBIs.

Table 5.3 Temperature in the bottom layer (°C) in May 2021 in comparison to former years.

Area	**2021**	2020	2019	2018	2017	2016	1971-1990
Bornholm Deep	**8.45**	8.31	8.64	6.93	6.92	6.24	6.12
Gotland Deep	**7.21**	7.23	7.45	6.91	7.14	7.53	5.62
Farö Deep	**7.24**	-	7.24	6.77	7.07	6.81	5.2
Landsort Deep	**6.67**	-	6.39	6.27	-	5.85	4.76
Karlsö Deep	**6.04**	-	5.67	5.66	5.51	5.21	4.18

The development of salinity in bottom waters over several years is also determined by MBIs. From maximum values at the time the inflow had reached the respective sites, an almost steady decrease of salinity occurred (Table 5.4). In the Gotland Deep the decline of salinity proceeded since 2016, and in the rear part of the thalweg since 2017/2018 (Landsort Deep). The change of salinity was for the Gotland Deep -0.75 since 2016, for the Farö Deep -0.46 since 2017, and for the Landsort Deep bottom water -0.21 since 2018. Karlsö Deep showed a different development with a smooth salinity increase until 2019 in the bottom water. That may indicate a slower, but longer lasting influence of the MBI, but also could mean a basically stable salinity between May 2018 and 2021 with slight fluctuations only.

Table 5.4 Salinity in the bottom layer in May 2021 in comparison to former years.

Area	**2021**	2020	2019	2018	2017	2016
Gotland Deep	**13.02**	13.15	13.32	13.29	13.45	13.77
Farö Deep	**12.43**	-	12.65	12.69	12.9	12.7
Landsort Deep	**11.25**	-	11.29	11.46	-	10.99
Karlsö Deep	**10.39**	-	10.43	10.4	10.24	9.87

5.4.3 Oxygen

The oxygen concentration in the bottom waters of the deep basins clearly worsen since May 2016, in the Gotland Deep to -6.34 mL/L, in the Fårö Deep to -3.57 mL/ and in the Landsort Deep to -1.98 mL/L. In the Karlsö Deep the concentration of -2.47 mL/L was close to 2019. However, in 2020 no values were available, except for the Gotland Deep. The negative oxygen equivalents of hydrogen sulphide concentration (Table 5.5, Fig. 5.5) showed a slight improvement at this site. The Fårö Deep likely had received some oxygen by smaller inflows in 2019 that allowed an entrainment of the weakly oxygenated waters to the deep waters of the Fårö Deep to keep the situation stable at that time (Naumann et al., 2020), but in May 2021 a clear decrease to -3.57 mL/L oxygen equivalents was measured.

Table 5.5 Bottom water oxygen concentration (mL/L) of Baltic Sea deeps during this cruise (Jul-20) compared to the summer values of the last five years.

Area:	**2021**	2020	2019	2018	2017	2016
Gotland Deep	**-6.34**	-6.47	-5.47	-3.26	-3.44	0.08
Farö Deep	**-3.57**	-	-2.53	-2.53	0.38	0.05
Landsort Deep	**-1.98**	-	-1.33	-0.16	-	-1,05
Karlsö Deep	**-2.47**	-	-2.55	-2.1	-1.56	-1.13

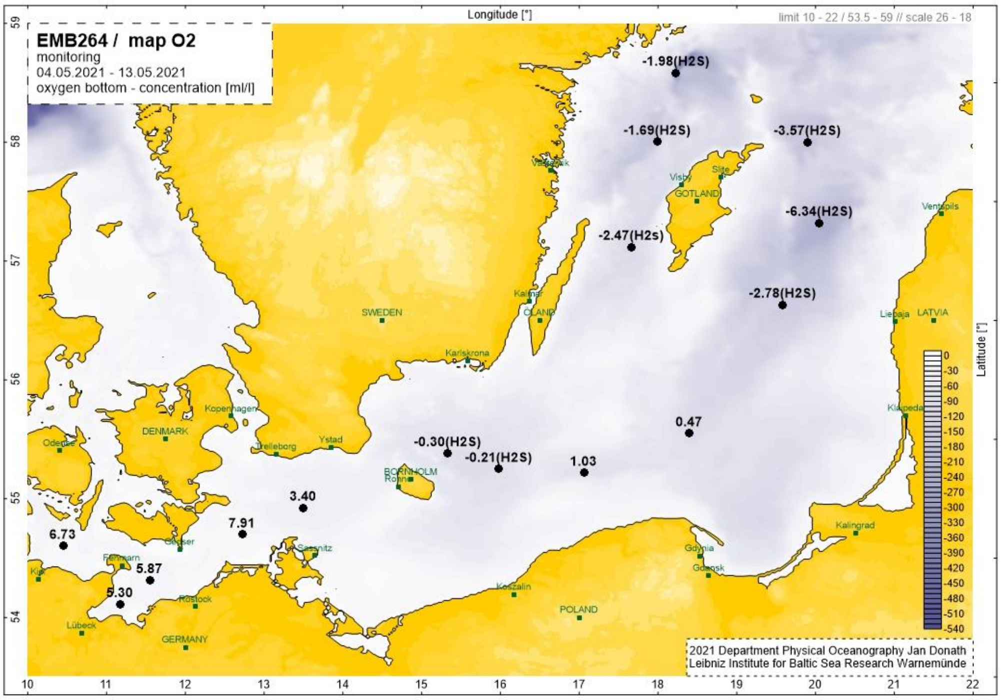

Fig. 5.5 Oxygen concentration (mL/L) in bottom waters of selected Baltic Sea stations (H_2S is included as negative oxygen).

The oxygen concentration in bottom waters varied on the sampled stations in the study area between 7.91 mL/L oxygen and a high hydrogen sulphide concentration corresponding to -6.34 mL/L oxygen equivalents in May 2021 (Fig. 5.5). The oxygen concentration in bottom waters of the investigated Belt Sea stations was between 5.30 and 6.73 mL/L and reflected a good status at that time. In the Arkona Sea, behind the well ventilated shallow Darss Sill station (7.91 mL/L), an oxygen concentration of only 3.4 mL/L was measured in the bottom water. It appeared at that time a bad precondition to keep the oxygen concentration high enough during the summer. The value was already close to the ~3 mL/L (4 mg/L) threshold value for a good status according to the German evaluation scheme for stratified waters. The ongoing stagnation phase in the deep basins basically leads to a worsening situation in terms of bottom water oxygen, since hydrogen sulphide continued to accumulate. Even the Bornholm Sea showed slight sulphidic conditions of -0.2 to -0.3 mL/L oxygen equivalents in May 2021. However, in the southern Gotland Sea bottom waters some remains of oxygen at concentrations of 1.03 and 0.47 mL/L were measured. But at the Gotland Deep site especially strong hydrogen sulphide accumulation occurred that reflected an oxygen deficit of -6.34 mL/L. An improving tendency was measured via the Farö Deep of -3.57 mL/L to the Landsort Deep of about -1.98 mL/L, and a bit worse the Karlsö Deep of 2.47 mL/L negative oxygen equivalents of the measured hydrogen sulphide concentration in bottom waters.

6 Station List of EMB264

6.1 Overall Station List

Station No.		Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/ Recovery
Elisabeth Mann Borgese	**IOW**	**2021**		**[UTC]**	**[°N]**	**[°E]**	**[m]**	Max sampl. depth
EMB264_1-1	TFO5	4-May	Secchi disk	07:29	54.2316	12.0754	9.7	In water
EMB264_1-2	TFO5	4-May	CTD	07:29	54.2315	12.0755	9.6	In water
EMB264_1-2	TFO5	4-May	CTD	07:54	54.2322	12.0768	9.6	CLmax:11m
EMB264_2-1	TF0012	4-May	CTD	09:53	54.3154	11.5506	21.9	In water
EMB264_2-1	TF0012	4-May	CTD	10:05	54.3151	11.5504	21.8	CLmax:23m
EMB264_2-2	TF0012	4-May	Plank. net	09:53	54.3153	11.5505	21.9	In water
EMB264_2-3	TF0012	4-May	Secchi disk	10:03	54.3151	11.5505	21.6	In water
EMB264_2-4	TF0012	4-May	WP-2 Plank. net	10:25	54.3150	11.5500	21.9	In water
EMB264_2-4	TF0012	4-May	WP-2 Plank. net	10:27	54.3150	11.5500	22.1	CLmax:8m
EMB264_2-5	TF0012	4-May	WP-2 Plank. net	10:29	54.3149	11.5503	21.9	In water
EMB264_2-5	TF0012	4-May	WP-2 Plank. net	10:31	54.3149	11.5503	21.9	CLmax:21m
EMB264_3-1	TF0010	4-May	CTD	12:13	54.5521	11.3204	25.2	In water
EMB264_3-1	TF0010	4-May	CTD	12:30	54.5518	11.3201	25.4	CLmax:26m
EMB264_3-2	TF0010	4-May	CTD	12:57	54.5518	11.3199	25.4	In water
EMB264_3-2	TF0010	4-May	CTD	13:04	54.5518	11.3199	25.5	CLmax:25m
EMB264_3-2	TF0010	4-May	CTD	13:07	54.5518	11.3200	25.7	In water
EMB264_3-2	TF0010	4-May	CTD	13:09	54.5518	11.3200	25.6	CLmax:25m
EMB264_4-1	TF0014	4-May	CTD	14:26	54.5950	11.0149	25.3	In water
EMB264_4-1	TF0014	4-May	CTD	14:42	54.5945	11.0153	25	CLmax:26m
EMB264_5-1	TF0360	4-May	CTD	16:50	54.6000	10.4507	14.9	In water
EMB264_5-1	TF0360	4-May	CTD	17:06	54.5995	10.4506	14.8	CLmax:16m
EMB264_5-2	TF0360	4-May	WP-2 Plank. net	17:29	54.6001	10.4496	15.1	In water
EMB264_5-2	TF0360	4-May	WP-2 Plank. net	17:30	54.6001	10.4495	14.7	CLmax:14m
EMB264_5-3	TF0360	4-May	WP-2 Plank. net	17:34	54.5999	10.4499	15.1	In water
EMB264_5-3	TF0360	4-May	WP-2 Plank. net	17:37	54.5998	10.4500	14.7	CLmax:14m
EMB264_5-4	TF0360	4-May	WP-2 Plank. net	17:46	54.5997	10.4500	14.7	In water
EMB264_5-4	TF0360	4-May	WP-2 Plank. net	17:47	54.5998	10.4502	15	CLmax:14m
EMB264_6-1	TF0361	4-May	CTD	19:09	54.6664	10.7789	20.6	In water
EMB264_6-1	TF0361	4-May	CTD	19:17	54.6658	10.7786	21.1	CLmax:22m
EMB264_7-1	TF0022	5-May	CTD	00:24	54.1102	11.1760	19.6	In water
EMB264_7-1	TF0022	5-May	CTD	00:30	54.1101	11.1753	20	CLmax:21m
EMB264_8-1	TF0017	5-May	CTD	03:21	54.3916	11.8241	18.7	In water
EMB264_8-1	TF0017	5-May	CTD	03:27	54.3916	11.8243	19.1	CLmax:20m
EMB264_9-1	TF0041	6-May	CTD	11:26	54.4065	12.0621	15.9	In water
EMB264_9-1	TF0041	6-May	CTD	11:38	54.4067	12.0615	16.3	CLmax:17m
EMB264_10-1	TF0046	6-May	CTD	12:36	54.4697	12.2412	25.6	In water
EMB264_10-1	TF0046	6-May	CTD	12:45	54.4697	12.2408	25.4	CLmax:26m
EMB264_10-2	TF0046	6-May	Plank. net	12:37	54.4698	12.2411	25.7	In water
EMB264_10-3	TF0046	6-May	Secchi disk	12:46	54.4697	12.2407	25.6	In water
EMB264_10-4	TF0046	6-May	WP-2 Plank. net	12:56	54.4695	12.2407	25.1	In water
EMB264_10-4	TF0046	6-May	WP-2 Plank. net	12:58	54.4695	12.2407	25.2	CLmax:26m
EMB264_11-1	TF0002	6-May	CTD	14:23	54.6505	12.4513	15.1	In water
EMB264_11-1	TF0002	6-May	CTD	14:32	54.6500	12.4507	15.1	CLmax:15m
EMB264_12-1	TF0001	6-May	CTD	15:49	54.6958	12.6995	18.5	In water
EMB264_12-1	TF0001	6-May	CTD	16:17	54.6962	12.6988	18.3	CLmax:19m
EMB264_13-1	TF0115	6-May	CTD	17:51	54.7947	13.0599	27.7	In water
EMB264_13-1	TF0115	6-May	CTD	18:06	54.7950	13.0588	27.1	CLmax:28m
EMB264_14-1	TF0114	6-May	CTD	19:14	54.8599	13.2768	43.2	In water
EMB264_14-1	TF0114	6-May	CTD	19:23	54.8600	13.2763	42.9	CLmax:42m
EMB264_15-1	TF0113	6-May	CTD	20:23	54.9250	13.5013	45.2	In water
EMB264_15-1	TF0113	6-May	CTD	20:32	54.9252	13.5007	45.3	CLmax:45m
EMB264_15-2	TF0113	6-May	Plank. net	20:25	54.9251	13.5009	45.1	In water
EMB264_15-3	TF0113	6-May	Secchi disk	20:42	54.9252	13.5009	44.7	In water
EMB264_15-4	TF0113	6-May	WP-2 Plank. net	20:54	54.9251	13.5004	45.2	In water
EMB264_15-4	TF0113	6-May	WP-2 Plank. net	20:57	54.9251	13.5006	45.4	CLmax:33m

EMB264_15-5	TF0113	6-May	WP-2 Plank. net	21:02	54.9250	13.5006	44.9	In water
EMB264_15-5	TF0113	6-May	WP-2 Plank. net	21:04	54.9251	13.5006	45.4	CLmax:44m
EMB264_15-6	TF0113	6-May	CTD	21:20	54.9253	13.5009	45.2	In water
EMB264_15-6	TF0113	6-May	CTD	21:34	54.9250	13.5001	45	CLmax:43m
EMB264_16-1	TF0112	6-May	CTD	23:21	54.8030	13.9594	38.2	In water
EMB264_16-1	TF0112	6-May	CTD	23:34	54.8032	13.9581	38.2	CLmax:38m
EMB264_17-1	ABBOJE	7-May	CTD	00:18	54.8801	13.8598	43.8	In water
EMB264_17-1	ABBOJE	7-May	CTD	00:33	54.8801	13.8597	43.8	CLmax:43m
EMB264_18-1	TF0105	7-May	CTD	02:00	55.0248	13.6079	44.6	In water
EMB264_18-1	TF0105	7-May	CTD	02:11	55.0250	13.6073	44.6	CLmax:44m
EMB264_19-1	TF0104	7-May	CTD	03:12	55.0687	13.8135	44.3	In water
EMB264_19-1	TF0104	7-May	CTD	03:24	55.0688	13.8127	44.3	CLmax:44m
EMB264_20-1	TF0103	7-May	CTD	05:23	55.0632	13.9882	45.3	In water
EMB264_20-1	TF0103	7-May	CTD	05:33	55.0632	13.9883	45.2	CLmax:44m
EMB264_21-1	TF0109	7-May	CTD	06:25	55.0006	14.0837	46.3	In water
EMB264_21-1	TF0109	7-May	CTD	06:35	55.0003	14.0832	46.1	CLmax:46m
EMB264_21-2	TF0109	7-May	Secchi disk	06:29	55.0004	14.0834	46.4	In water
EMB264_21-3	TF0109	7-May	Plank. net	06:30	55.0004	14.0834	46.4	In water
EMB264_21-4	TF0109	7-May	WP-2 Plank. net	06:49	55.0001	14.0834	46.2	In water
EMB264_21-4	TF0109	7-May	WP-2 Plank. net	06:51	55.0001	14.0836	46.2	CLmax:29m
EMB264_21-5	TF0109	7-May	WP-2 Plank. net	06:55	55.0001	14.0835	46.3	In water
EMB264_21-5	TF0109	7-May	WP-2 Plank. net	06:58	55.0000	14.0837	46.1	CLmax:44m
EMB264_22-1	TF0145	7-May	CTD	08:18	55.1663	14.2505	44.8	In water
EMB264_22-1	TF0145	7-May	CTD	08:30	55.1668	14.2489	44.8	CLmax:44m
EMB264_22-2	TF0145	7-May	CTD	08:51	55.1672	14.2477	45	In water
EMB264_22-2	TF0145	7-May	CTD	09:04	55.1665	14.2474	45.1	CLmax:5m
EMB264_23-1	TF0144	7-May	CTD	10:08	55.2567	14.4902	42.3	In water
EMB264_23-1	TF0144	7-May	CTD	10:18	55.2570	14.4900	42.2	CLmax:42m
EMB264_24-1	TF0140	7-May	CTD	11:52	55.4664	14.7165	68.2	In water
EMB264_24-1	TF0140	7-May	CTD	12:03	55.4669	14.7165	68.7	CLmax:67m
EMB264_25-1	TF0206	7-May	CTD	13:01	55.5332	14.9158	75.4	In water
EMB264_25-1	TF0206	7-May	CTD	13:12	55.5332	14.9156	76	CLmax:74m
EMB264_26-1	TF0208	7-May	CTD	14:30	55.4524	15.2335	92.6	In water
EMB264_26-1	TF0208	7-May	CTD	14:42	55.4530	15.2333	92.5	CLmax:90m
EMB264_27-1	TF0200	7-May	CTD	15:27	55.3834	15.3329	91.1	In water
EMB264_27-1	TF0200	7-May	CTD	15:39	55.3836	15.3333	91.1	CLmax:89m
EMB264_28-1	TF0211	7-May	CTD	17:00	55.3302	15.6147	95.1	In water
EMB264_28-1	TF0211	7-May	CTD	17:16	55.3303	15.6150	95.2	CLmax:92m
EMB264_29-1	TF0212	7-May	CTD	18:07	55.3013	15.7985	95	In water
EMB264_29-1	TF0212	7-May	CTD	18:20	55.3027	15.7978	95.3	CLmax:93m
EMB264_30-1	TF0213	7-May	CTD	19:15	55.2503	15.9842	89.5	In water
EMB264_30-1	TF0213	7-May	CTD	19:25	55.2491	15.9839	89.6	CLmax:87m
EMB264_30-2	TF0213	7-May	Plank. net	19:16	55.2501	15.9842	89.4	In water
EMB264_30-3	TF0213	7-May	WP-2 Plank. net	19:41	55.2500	15.9830	89.8	In water
EMB264_30-3	TF0213	7-May	WP-2 Plank. net	19:47	55.2500	15.9827	90	CLmax:88m
EMB264_30-4	TF0213	7-May	Apstein Net	20:04	55.2497	15.9819	89.9	In water
EMB264_30-4	TF0213	7-May	Apstein Net	20:15	55.2502	15.9825	89.4	CLmax:88m
EMB264_30-5	TF0213	7-May	Apstein Net	20:27	55.2508	15.9824	89.8	In water
EMB264_30-5	TF0213	7-May	Apstein Net	20:36	55.2509	15.9817	89.3	CLmax:88m
EMB264_30-6	TF0213	7-May	CTD	20:55	55.2501	15.9801	89.6	In water
EMB264_30-6	TF0213	7-May	CTD	21:08	55.2505	15.9797	89.6	CLmax:87m
EMB264_30-7	TF0213	7-May	WP-2 Plank. net	21:19	55.2498	15.9819	89.5	In water
EMB264_30-7	TF0213	7-May	WP-2 Plank. net	21:23	55.2501	15.9819	89.4	CLmax:86m
EMB264_30-8	TF0213	7-May	WP-2 Plank. net	21:31	55.2499	15.9821	89.2	In water
EMB264_30-8	TF0213	7-May	WP-2 Plank. net	21:33	55.2500	15.9818	89.3	CLmax:86m
EMB264_30-9	TF0213	7-May	WP-2 Plank. net	21:43	55.2501	15.9823	89.7	CLmax:86m
EMB264_30-9	TF0213	7-May	WP-2 Plank. net	21:43	55.2501	15.9823	89.6	In water
EMB264_30-10	TF0213	7-May	WP-2 Plank. net	21:51	55.2504	15.9822	89.5	In water
EMB264_30-10	TF0213	7-May	WP-2 Plank. net	21:53	55.2505	15.9821	89.3	CLmax:86m
EMB264_31-1	TF0225	8-May	CTD	05:00	55.2590	16.3210	65	In water
EMB264_31-1	TF0225	8-May	CTD	05:12	55.2590	16.3207	65	CLmax:63m
EMB264_32-1	TF0227	8-May	CTD	07:17	55.2604	16.6414	68.2	In water
EMB264_32-1	TF0227	8-May	CTD	07:29	55.2605	16.6403	68.3	CLmax:67m
EMB264_33-1	TF0222	8-May	CTD	09:41	55.2166	17.0684	91.1	In water

EMB264_33-1	TF0222	8-May	CTD	09:52	55.2167	17.0671	90.9	CLmax:88m
EMB264_34-1	TF0266	8-May	CTD	11:07	55.2522	17.3596	88.7	In water
EMB264_34-1	TF0266	8-May	CTD	11:18	55.2523	17.3597	88.6	CLmax:86m
EMB264_35-1	TF0268	8-May	CTD	13:27	55.3073	17.9308	74.7	In water
EMB264_35-1	TF0268	8-May	CTD	13:39	55.3076	17.9306	73.2	CLmax:72m
EMB264_36-1	TF0256	8-May	CTD	14:55	55.3267	18.2524	77	In water
EMB264_36-1	TF0256	8-May	CTD	15:07	55.3267	18.2519	77.1	CLmax:75m
EMB264_37-1	TF0259	8-May	CTD	16:40	55.5500	18.3994	89.6	In water
EMB264_37-1	TF0259	8-May	CTD	16:53	55.5501	18.3997	89.3	CLmax:86m
EMB264_37-2	TF0259	8-May	Secchi disk	16:45	55.5502	18.3993	89.6	In water
EMB264_37-3	TF0259	8-May	Plank. net	16:46	55.5502	18.3993	89.6	In water
EMB264_38-1	TF0255	8-May	CTD	17:59	55.6335	18.5993	95.5	In water
EMB264_38-1	TF0255	8-May	CTD	18:11	55.6338	18.5998	94.9	CLmax:92m
EMB264_39-1	TF0253	8-May	CTD	19:45	55.8409	18.8678	100.3	In water
EMB264_39-1	TF0253	8-May	CTD	19:57	55.8398	18.8665	101.1	CLmax:98m
EMB264_40-1	TF0265	8-May	CTD	21:00	55.9582	19.0484	110.5	In water
EMB264_40-1	TF0265	8-May	CTD	21:14	55.9588	19.0472	109.6	CLmax:108m
EMB264_41-1	TF0262	8-May	CTD	23:05	56.2348	19.3016	132.1	In water
EMB264_41-1	TF0262	8-May	CTD	23:18	56.2343	19.3012	132.1	CLmax:128m
EMB264_42-1	TF0261	9-May	CTD	01:00	56.4920	19.4821	143.9	In water
EMB264_42-1	TF0261	9-May	CTD	01:15	56.4920	19.4816	143.6	CLmax:139m
EMB264_43-1	TF0260	9-May	CTD	02:24	56.6333	19.5843	145.4	In water
EMB264_43-1	TF0260	9-May	CTD	02:39	56.6324	19.5847	145.4	CLmax:140m
EMB264_44-1	TF0274_	9-May	CTD	03:48	56.7678	19.7529	155	In water
EMB264_44-1	TF0274_	9-May	CTD	04:07	56.7676	19.7525	155	CLmax:150m
EMB264_45-1	TF0273	9-May	CTD	05:21	56.9515	19.7710	184.3	In water
EMB264_45-1	TF0273	9-May	CTD	05:38	56.9516	19.7700	184.3	CLmax:179m
EMB264_moor	GODESS	9-May	Mooring	08:00	57.3200	20.1300	245.7	Releaser activated
EMB264_moor	GODESS	9-May	Mooring	09:00	57.3200	20.1300	244.3	Mooring on deck
EMB264_46-1	TF0272	9-May	CTD	11:31	57.0722	19.8302	210	In water
EMB264_46-1	TF0272	9-May	CTD	11:48	57.0718	19.8298	210	CLmax:204m
EMB264_47-1	TF0275	9-May	CTD	13:06	57.2100	19.9305	231.4	In water
EMB264_47-1	TF0275	9-May	CTD	13:31	57.2101	19.9300	230.9	CLmax:225m
EMB264_48-1	TF0271	9-May	CTD	14:40	57.3203	20.0500	242.5	In water
EMB264_48-1	TF0271	9-May	CTD	15:00	57.3198	20.0503	242.3	CLmax:234m
EMB264_48-2	TF0271	9-May	CTD	15:50	57.3200	20.0500	242	In water
EMB264_48-2	TF0271	9-May	CTD	16:04	57.3201	20.0502	241.4	CLmax:107m
EMB264_48-3	TF0271	9-May	CTD	16:50	57.3199	20.0503	241.7	In water
EMB264_48-3	TF0271	9-May	CTD	17:02	57.3198	20.0501	242.2	CLmax:28m
EMB264_48-4	TF0271	9-May	CTD	17:21	57.3199	20.0502	242.6	In water
EMB264_48-4	TF0271	9-May	CTD	17:30	57.3202	20.0501	65.8	CLmax:28m
EMB264_48-5	TF0271	9-May	CTD	18:09	57.3202	20.0506	64.6	In water
EMB264_48-5	TF0271	9-May	CTD	18:17	57.3203	20.0501	65.1	CLmax:24m
EMB264_48-6	TF0271	9-May	CTD	18:30	57.3204	20.0504	241.4	In water
EMB264_48-6	TF0271	9-May	CTD	18:42	57.3201	20.0502	241.4	CLmax:120m
EMB264_49-1	SF022EGB	9-May	ScanFish	22:56	57.0677	21.1500	26.4	In water
EMB264_49-1		9-May	ScanFish	23:11	57.0617	21.1657	27.9	CL:150m
EMB264_49-1		9-May	ScanFish	23:19	57.0714	21.1550	26.3	Start profile, 6 kn
EMB264_49-1		10-May	ScanFish	01:22	57.1486	20.8155	47.3	CL:200m
EMB264_49-1		10-May	ScanFish	01:28	57.1526	20.7968	49.2	CL:250m
EMB264_49-1		10-May	ScanFish	10:01	57.4632	19.3258	76.4	CL:400m
EMB264_49-1		10-May	ScanFish	10:07	57.4665	19.3101	74.8	CL:300m
EMB264_49-1		10-May	ScanFish	12:05	57.5383	18.9687	29.1	CL:150m
EMB264_49-1		10-May	ScanFish	12:34	57.5567	18.8811	23.5	End profile
EMB264_50-1	SF001EGB	10-May	CTD	13:03	57.5629	18.8514	20.1	In water
EMB264_50-1	SF001EGB	10-May	CTD	13:19	57.5625	18.8515	19.2	CLmax:20m
EMB264_51-1	TF0276	10-May	CTD	17:42	57.4701	20.2606	208.6	In water
EMB264_51-1	TF0276	10-May	CTD	18:00	57.4700	20.2604	208.6	CLmax:203
EMB264_52-1	TF0270	10-May	CTD	19:05	57.6176	20.1665	144.3	In water
EMB264_52-1	TF0270	10-May	CTD	19:21	57.6168	20.1672	145	CLmax:140m
EMB264_53-1	TF0287	10-May	CTD	20:35	57.7157	19.8535	130	In water
EMB264_53-1	TF0287	10-May	CTD	20:50	57.7152	19.8535	130.1	CLmax:127m
EMB264_54-1	TF0286	10-May	CTD	22:37	58.0004	19.9001	197	In water
EMB264_54-1	TF0286	10-May	CTD	22:52	58.0000	19.9005	195.9	CLmax:190m

EMB264_54-2	TF0286	10-May	CTD	23:46	58.0000	19.9003	196.3	In water
EMB264_54-2	TF0286	10-May	CTD	23:52	58.0002	19.9002	195.9	CLmax:24m
EMB264_55-1	TF0277	11-May	CTD	01:08	58.1840	20.0509	162.9	In water
EMB264_55-1	TF0277	11-May	CTD	01:23	58.1835	20.0514	163.3	CLmax:158m
EMB264_56-1	TF0285	11-May	CTD	03:17	58.4418	20.3337	123.2	In water
EMB264_56-1	TF0285	11-May	CTD	03:30	58.4416	20.3335	122.7	CLmax:119m
EMB264_57-1	TF0283	11-May	CTD	07:39	58.7842	19.1002	125.9	In water
EMB264_57-1	TF0283	11-May	CTD	07:53	58.7832	19.1001	123.6	CLmax:120m
EMB264_58-1	nGB-1	11-May	CTD	09:21	58.7130	18.6702	240	In water
EMB264_58-1	nGB-1	11-May	CTD	09:42	58.7125	18.6699	244.3	CLmax:236m
EMB264_59-1	TF0284	11-May	CTD	11:34	58.5827	18.2327	452.8	In water
EMB264_59-1	TF0284	11-May	CTD	12:10	58.5833	18.2330	452.8	CLmax:440m
EMB264_59-2	TF0284	11-May	Secchi disk	11:38	58.5831	18.2331	452.8	In water
EMB264_59-3	TF0284	11-May	CTD	13:06	58.5834	18.2330	452.8	In water
EMB264_59-3	TF0284	11-May	CTD	13:20	58.5834	18.2333	452.8	CLmax:130m
EMB264_59-4	TF0284	11-May	CTD	14:00	58.5834	18.2335	452.8	In water
EMB264_59-4	TF0284	11-May	CTD	14:05	58.5834	18.2335	452.8	CLmax:17m
EMB264_59-5	TF0284	11-May	CTD	14:29	58.5834	18.2333	452.8	In water
EMB264_59-5	TF0284	11-May	CTD	14:46	58.5835	18.2331	452.8	CLmax:100m
EMB264_60-1	wGB-3	11-May	CTD	16:43	58.3259	18.0684	154.3	In water
EMB264_60-1	wGB-3	11-May	CTD	16:53	58.3263	18.0681	153.6	CLmax:153m
EMB264_61-1	TF0240	11-May	CTD	19:20	58.0002	17.9998	168.6	In water
EMB264_61-1	TF0240	11-May	CTD	19:35	58.0003	18.0006	167.9	CLmax:162m
EMB264_62-1	TF0242	11-May	CTD	22:13	57.7169	17.3666	142.3	In water
EMB264_62-1	TF0242	11-May	CTD	22:27	57.7167	17.3666	142.1	CLmax:137m
EMB264_63-1	SF032WGB	12-May	CTD	03:15	57.0520	18.1349	8.6	In water
EMB264_63-1	SF032WGB	12-May	CTD	03:24	57.0518	18.1351	8.2	CLmax:9m
EMB264_63-2	SF032WGB	12-May	ScanFish	03:35	57.0519	18.1329	9.9	Start profil, 6 kn
EMB264_63-2	SF025WGB	12 Mai	ScanFish	08:27	57.1652	17.3077	65.1	End profile
EMB264_64-1	SF025WGB	12-May	CTD	08:47	57.1629	17.3242	67.9	In water
EMB264_64-1	SF025WGB	12-May	CTD	09:00	57.1628	17.3248	67.6	CLmax:66m
EMB264_65-1	TF0245	12-May	CTD	10:16	57.1170	17.6662	110.7	In water
EMB264_65-1	TF0245	12-May	CTD	10:29	57.1169	17.6670	110.2	CLmax:107m
EMB264_66-1	wGB-1	12-May	CTD	12:17	56.8776	17.3894	95.5	In water
EMB264_66-1	wGB-1	12-May	CTD	12:30	56.8772	17.3899	95.2	CLmax:93m
EMB264_67-1	GB_SW	12-May	CTD	14:17	56.6259	17.1296	77.2	In water
EMB264_67-1	GB_SW	12-May	CTD	14:37	56.6251	17.1307	77.6	CLmax:75m
EMB264_68-1	BB_N	12-May	CTD	20:18	55.7628	16.2908	61.8	In water
EMB264_68-1	BB_N	12-May	CTD	20:28	55.7621	16.2902	61.2	CLmax:60m
EMB264_69-1	TF0220	12-May	CTD	22:25	55.5001	16.0002	80	In water
EMB264_69-1	TF0220	12-May	CTD	22:36	55.5000	16.0002	79.9	CLmax:78m
EMB264_70-1	TF0213	13-May	CTD	00:12	55.2503	15.9830	90	In water
EMB264_70-1	TF0213	13-May	CTD	00:24	55.2500	15.9832	89.3	CLmax:87m
EMB264_70-2	TF0213	13-May	Plank. net	00:14	55.2501	15.9831	89.3	In water
EMB264_70-3	TF0213	13-May	WP-2 Plank. net	00:45	55.2500	15.9832	89.6	In water
EMB264_70-3	TF0213	13-May	WP-2 Plank. net	00:50	55.2500	15.9833	89.6	CLmax:87m
EMB264_70-4	TF0213	13-May	WP-2 Plank. net	01:02	55.2500	15.9832	89.3	In water
EMB264_70-4	TF0213	13-May	WP-2 Plank. net	01:05	55.2501	15.9832	89.3	CLmax:87m
EMB264_70-5	TF0213	13-May	WP-2 Plank. net	01:14	55.2501	15.9832	89.6	In water
EMB264_70-5	TF0213	13-May	WP-2 Plank. net	01:17	55.2501	15.9832	89.3	CLmax:45m
EMB264_70-6	TF0213	13-May	WP-2 Plank. net	01:23	55.2500	15.9831	89.5	In water
EMB264_70-6	TF0213	13-May	WP-2 Plank. net	01:26	55.2501	15.9831	89.3	CLmax:87m
EMB264_70-7	TF0213	13-May	Apstein Net	01:44	55.2501	15.9832	90.6	In water
EMB264_70-7	TF0213	13-May	Apstein Net	01:53	55.2501	15.9831	89.4	CLmax:88m
EMB264_70-8	TF0213	13-May	Apstein Net	02:11	55.2500	15.9833	89.3	In water
EMB264_70-9	TF0213	13-May	Apstein Net	02:42	55.2501	15.9833	89.3	CLmax:88m
EMB264_71-1	TF0113	13-May	CTD	11:09	54.9248	13.5000	45.1	In water
EMB264_71-1	TF0113	13-May	CTD	11:18	54.9249	13.5000	45.4	CLmax:44m
EMB264_71-2	TF0113	13-May	Plank. net	11:10	54.9248	13.5000	45	In water
EMB264_71-3	TF0113	13-May	WP-2 Plank. net	11:32	54.9249	13.5000	45.4	In water
EMB264_71-3	TF0113	13-May	WP-2 Plank. net	11:34	54.9249	13.5000	44.5	CLmax:30m
EMB264_71-4	TF0113	13-May	WP-2 Plank. net	11:39	54.9249	13.5000	45.4	In water
EMB264_71-4	TF0113	13-May	WP-2 Plank. net	11:41	54.9249	13.5000	45	CLmax:42m
EMB264_72-1	TF0030	13-May	CTD	14:35	54.7233	12.7826	20	In water

EMB264_72-1	TF0030	13-May	CTD	14:44	54.7236	12.7827	20.1	CLmax:20m
EMB264_72-2	TF0030	13-May	CTD	15:07	54.7232	12.7832	20	In water
EMB264_72-2	TF0030	13-May	CTD	15:08	54.7232	12.7832	20	CLmax:5m
EMB264_73-1	TF0046	13-May	CTD	18:00	54.4697	12.2425	25.9	In water
EMB264_73-1	TF0046	13-May	CTD	18:11	54.4697	12.2422	26.1	CLmax:26m
EMB264_73-2	TF0046	13-May	Plank. net	18:06	54.4701	12.2424	26.1	In water
EMB264_73-3	TF0046	13-May	WP-2 Plank. net	18:24	54.4699	12.2420	26	In water
EMB264_73-3	TF0046	13-May	WP-2 Plank. net	18:26	54.4699	12.2420	26.1	CLmax:25m
EMB264_74-1	TF0012	13-May	CTD	21:02	54.3145	11.5511	22	In water
EMB264_74-1	TF0012	13-May	CTD	21:11	54.3148	11.5502	22	CLmax:22m
EMB264_74-2	TF0012	13-May	Plank. net	21:06	54.3147	11.5505	22	In water
EMB264_74-3	TF0012	13-May	WP-2 Plank. net	21:26	54.3150	11.5501	22	In water
EMB264_74-3	TF0012	13-May	WP-2 Plank. net	21:28	54.3149	11.5500	22	CLmax:23m

CLmax: Maximum rope/cable length
Secchi disk: Defined white disk with bore holes to determine water transparency
WP-2 Plank. net: Plankton net with closing mechanism and removable net bucket
Plank. net: Small Apstein net for phytoplankton sampling
CTD: CTD rosette system with fluorimeter, oxygen sensor, water sampler, and video camera
SF (ScanFish): Undulating CTD with fluorimeter and oxygen sensor mounted in a wing

7 Data and Sample Storage and Availability

All data gathered are saved on a data repository in the IOW immediately after the cruise. The processed and validated data will be stored in the ODIN data base (https://odin2.io-warnemuende.de) in due time after the cruise. According to the IOW data policy and to facilitate the international exchange of data, all metadata will be made available under the international ISO 19115 standards for georeferenced metadata.
The access to the data will be restricted for three years after the data acquisition, to protect the research process, including scientific analysis and publication. After that time the data will become openly available to any person or any organization who requests them, under the international Creative Commons (CC) data license of type CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/). For further details, refer to the IOW data policy document.

Table 7.1 Overview of data availability

Type	Database	Available	Free Access	Contact
Hydrographic data	ODIN	01.08.2021	01.08.2024	volker.mohrholz@io-warnemuende.de
Nutrient data	ODIN	01.06.2022	01.06.2025	joachim.kuss@io-warnemuende.de
Zooplankton results	ODIN	01.06.2022	01.06.2025	joerg.dutz@io-warnemuende.de
Phytoplankton results	ODIN	01.06.2022	01.06.2025	anke.kremp@io-warnemuende.de

8 Acknowledgements

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