ELISABETH MANN BORGESE – Berichte

Baltic Sea Long-term Observation Programme

Cruise No. EMB 298

4 August – 15 August 2022,

Rostock – Sassnitz - Rostock (Germany)

HELCOM/long-term

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2022

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1 Summary

1.1 Summary in English

The cruise of r/v Elisabeth Mann Borgese No. 298 was done in the frame of the HELCOM monitoring and the IOW long-term observation of the Baltic Sea from August 4th to 15th 2022. The weather was characterized by a moderate to fresh breeze that often weakened during the day. Only on the third day, a strong breeze of 6 bft caused some discomfort by higher waves. Air temperature was relatively low for August with 15.4 °C to 22.5 °C. We investigated 96 stations (including 5 mandatory repetition stations) with the majority on the thalweg transect from the western Baltic Sea to the eastern and western Gotland Basin, completed 5 multicorer hauls for surface sediment sampling, and a transverse ScanFish transect across the central eastern Gotland Basin. Thereby, we put some effort in order to obtain samples for project work in the frame of Carbostore, to study the reaction of different carbon reservoirs of the Baltic Sea on anthropogenic environmental changes, and a DAM initiative to establish an archive of eDNA samples.
The monitoring revealed that the nutrient situation of surface waters was as expected for a typical summer of recent years. The inorganic nitrogen was depleted in the upper waters of the Baltic Proper, whereas phosphate was available at a significant concentration with a mean of 0.1 µmol/L in the upper 10 m and a maximum of 0.44 µmol/L. Diazotrophic cyanobacteria are favoured by this nutrient situation and were observed at high abundance. The oxygen concentration in bottom waters of the Kiel and the Mecklenburg Bight stations were below 2 mL/L, but in the Arkona Basin oxygen was measured between 2.3 mL/L in the central and up to 5.5 mL/L in the western Arkona Basin. In the deep Gotland Sea oxygen had completely vanished and euxinic conditions intensified in deep waters below the halocline at about 80 m. Thereby, the western basin appeared better in bottom waters with a hydrogen sulphide concentration expressed in an oxygen equivalent concentration between -1.8 to -3.8 mL/L, whereas the eastern basin was between -2 and almost -10 mL/L oxygen on the sampled stations. An exception was observed in the Słupsk furrow, between the Bornholm Basin and the eastern Gotland Basin, where bottom water partly showed an oxygen concentration of 3-4 mL/L.

1.2 Zusammenfassung

Die Reise des F/S Elisabeth Mann Borgese Nr. 298 wurde im Rahmen des HELCOM Monitorings und der IOW Langzeit Überwachung der Ostsee vom 4. bis zum 15. August 2022 durchgeführt. Die Wetterbedingungen zeichneten sich durch mäßige bis frische Winde aus, die über Tag oft abnahmen. Nur am dritten Tag war es etwas unangenehmer, als ein starker Wind mit 6 bft für höhere Wellen sorgte. Die Lufttemperaturen waren für August mit 15.4 °C bis 22.5 °C relativ niedrig. Wir untersuchten 96 Stationen (dabei sind 5 Pflichtwiederholstationen eingeschlossen) mit einem überwiegenden Anteil auf dem Talwegschnitt von der westlichen Ostsee zum östlichen und westlichen Gotland Becken, absolvierten 5 Multicorer Beprobungen des Oberflächen-sediments und einen quer zum Talweg gelegten ScanFish Schnitt über das zentrale östliche Gotland Becken. Dabei wurden auch einige Anstrengungen unternommen, Proben für die Projektarbeiten im Rahmen von Carbostore, zur Untersuchung der Reaktion verschiedener Kohlenstoffspeicher in der Ostsee auf anthropogene Umweltveränderungen, und einer DAM Initiative zum Aufbau einer eDNA Probenbank, zu bekommen.

Die Untersuchungen im Rahmen des Monitorings ergaben, dass eine für die letzten Jahre typische Nährstoffsituation im Oberflächenwasser im Sommer vorlag. Anorganischer Stickstoff war im Oberflächenbereich verbraucht, wogegen Phosphat noch mit einer signifikanten Konzentration von im Mittel 0.1 µmol/L und einem Maximum von 0.44 µmol/L in den oberen 10-Metern zur Verfügung stand. Diazotrophe Cyanobakterien sind bei dieser Nährstoffsituation begünstigt und wurden in hoher Abundanz vorgefunden. Die Sauerstoffkonzentration im Bodenwasser der Kieler und Mecklenburger Bucht waren unterhalb von 2 mL/L, aber lagen im zentralen noch bei 2.3 mL/L und im westlichen Arkona Becken bei bis zu 5.5 mL/L. In der tiefen Gotlandsee unterhalb der Haloklinen war Sauerstoff vollständig aufgezehrt und die euxinische Bedingungen hatten sich verstärkt. Dabei zeigte das westliche Becken noch etwas niedrigere Konzentrationen von Schwefelwasserstoff im Bodenwasser, die umgerechnet in negative Sauerstoffäquivalente, von -1.8 bis -3.8 mL/L variierten, wogegen das östliche Becken zwischen -2 und -10 mL/L Sauerstoff auf den untersuchten Stationen aufwies. Eine Ausnahme wurde in der Słupsker Rinne beobachtet, in der Sauerstoff mit einer Konzentration von 3-4 mL/L im Bodenwasser gemessen wurde.

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 Cruise participants

Name	Discipline	Institution
Kuss, Joachim, Dr.	Marine Chemistry, Chief Scientist	IOW
Kolbe, Martin	Phys. Oceanography, CTD	IOW
Muche, Yannik	Phys. Oceanography, CTD	IOW
Sadkowiak, Birgit	Marine Chemistry, Nutrients	IOW
Jeschek, Jenny	Marine Chemistry, Oxygen	IOW
Klostermann, Birgit	Marine Chemistry, Nutrients support	IOW
Fechtel, Christin	Biol. Oceanogr., Plankt. and Microbiol.	IOW
Schell, Antonia	Marine Geology	IOW
Ruth, Linda	Marine Geology	IOW
Alfke, Fenna	Marine Geochemistry	Uni-Oldenburg
Dr. Dürwald, Alexandra	Microbiology	Uni-Greifswald
Reddy, Kaylim	Biological Oceanography	IOW

2.3 Participating Institutions

IOW	Leibniz Institute for Baltic Sea Research Warnemünde
ICBM	Institute for Chemistry and Biology of the Marine Environment, Uni-Oldenburg

Uni-Greifswald, Institute of Pharmacy

3 Research Programme

3.1 Description of the Work Area

The working area for IOW's contribution to the HELCOM monitoring comprised German territorial waters with the German Exclusive Economic Zone and bordering sea areas. Therefore, basic hydrographic data, major nutrients, phyto- and zooplankton parameters were determined. Moreover, the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) extends the investigated sites by its long-term observation programme of the Baltic Sea. This contributes with station work in parts of the Belt Sea, the Arkona Sea, and the Bornholm Sea, as well as the eastern and western Gotland Sea. Project work in the frame of Carbostore and a DAM (Deutsche Allianz Meeresforschung) initiative to establish an archive of eDNA samples was added to the cruise's work programme. Therefore, several multicorer deployments and additional CTD-rosette casts were done to provide samples for the projects. However, a major focus is always on the thalweg transect, which reflects the main path of inflowing North Sea water via the Belt Sea, Arkona Sea, Bornholm Sea, along the Słupsk channel to the eastern Gotland Basin and further to the northern and western Gotland Sea, bringing episodically haline oxygen rich water to the central basins. This transect was supplemented by an east-west ScanFish transect in the eastern Gotland Basin to provide data for hydrographic modelling purposes. An overview of the location of CTD stations and the ScanFish transect is shown in Fig. 3.1. In addition, the list of stations is given in Chapter 6.

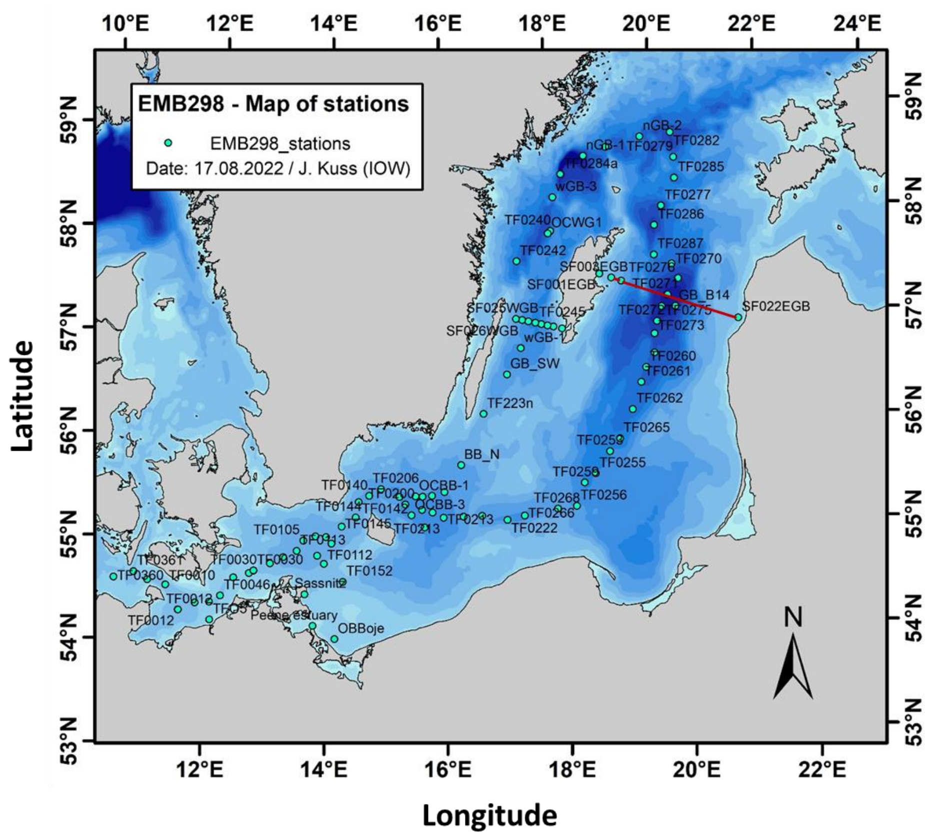

Fig. 3.1 Map of stations (green dots) and the ScanFish transects (red lines) of the cruise EMB 298 from 4th August – 15th August 2022; for clarity, a couple of station names are not shown; for the details of the sampled stations the reader is referred to the list of stations in Chapter 6.

3.2 Aims of the Cruise

The cruise EMB 298 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 the IOW. It was the fourth cruise in 2022 as one 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 of phyto- and zooplankton populations are investigated. Microbial habitats, acidification and greenhouse gases were additionally studied in the frames of the long-term observation of the Baltic Sea and by projects. 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 hydrochemistry and the ecosystem. The oxygen entrained by the Major Baltic Inflows that occurred between 2014 and 2016 vanished and euxinic conditions intensified in deep waters. Baroclinic inflows of warm water of summer 2018 caused a record high bottom water temperature in the Gotland Deep in 2019 but did not improve the oxygen situation significantly. Only one indication of a small inflow was observed on EMB 298 in August 2022 in the Słupsk Furrow, between the Bornholm and the eastern Gotland Basin.

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 and manually released samplings in near-bottom and surface waters. Then other CTD casts were carried out to meet the additional water sample requirements on the respective stations. Net sampling and depth of visibility determinations by means of a Secci disk were done on selected stations. The project Carbostore investigates how different carbon reservoirs in the North Sea and Baltic Sea react to anthropogenic environmental changes. Therefore, many additional water samples and three multicorer hauls were taken. Moreover, surface water was sampled in German territorial and EEZ waters for a DAM initiative that plans to establish an eDNA sample archive and investigates the metabolic pathways of bacteria by a metagenomic and metaproteomic approach. For details 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 determined by daily comparison with Winkler titration.

Nutrients

Nitrate, nitrite, phosphate, and silicate were analyzed using standard colorimetric 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 by spectrophotometry after its conversion to methylene blue (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 sensors (duplicate installation) recorded oxygen values that are validated by daily Winkler titration from 3 water sampling bottles released according to a specific time-regime, each by triplicate analysis.

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 water column. 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 microbial habitat of the redoxcline

Insights into the redoxcline microbial food web is obtained by well resolved sampling in 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. Dr. 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 an 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. Dr. Gregor Rehder).

Establishment of an eDNA-archive and Metaproteogenomic analyses (DAM project)

For a bio-archive of microorganisms and metazoans in the North and the Baltic Sea, biomass is collected by filtering seawater either through a 0.2 µm or a 0.45 µm filter to obtain respectively bacterial and metazoan DNA (CREATE project). All samples are frozen directly and stored at -20 °C and are available for further processing like DNA extraction and sequencing.

For metaproteogenomic analyses, surface water samples of 60 L were taken by a CTD-Rosette system. Subsequently, the water was filtered through 10 µm, 3 µm and 0.2 µm filters, respectively. Filters were stored at -80 °C. Macro- and microalgae were found on the 10 µm and 3 µm filters and bacteria were harvested on the 0.2 µm filter for metagenomic and metaproteomic analyses and furthermore for the determination of bacterial metabolic activity. (Responsible scientists: Prof. Dr. Matthias Labrenz, IOW, Dr. Alexandra Dürwald, Uni-Greifswald, Dr. Anneke Heins, MPI-Bremen).

3.3.2 Underway measurements

Just a Surface water Monitoring Box (JSMB)

The JSMB system (Krüger and Ruickoldt, 2021) is used for continuous measurements in a pumped sea surface water flow of temperature salinity conductivity, calculated sound velocity, real sound velocity, Chl_a, turbidity and optional many more parameters. The measurement ranges, the accuracy or alternatively the sensitivity of the measurements are as follows: conductivity with a range of 0 to 70 mS/cm, and an accuracy of 0.003 mS/cm, temperature (-3 to 35 °C, 0.002 °C), salinity (2 to 42, 0.005), sound velocity (1375 to 1625 m/s, 0.025 m/s), turbidity (0 to 25 NTU, 0.013 NTU sensitivity), and chlorophyll_a (0 to 50 µg/L, 0.025 µg/L sensitivity). The system was used during transect for recording of these parameters in surface water that was pumped from below the ship's hull. Preliminary data of temperature, salinity, chlorophyll_a and turbidity are shown in Figure 5.2 (Responsible scientists: Dr. Robert Wagner, Johann Ruickoldt).

ScanFish

An undulating CTD-system with fluorometer and oxygen sensor was tugged on one transect. The transect was transverse versus the thalweg in the eastern Gotland Basin with the Gotland Deep station in the center.

The ScanFish is a towed platform in wing shape allowing to accumulate CTD data of the water column in an undulating manner from the surface close to the bottom. 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 (Responsible scientists: Dr. Robert Wagner, Martin Kolbe).

Air-borne phytoplankton observation

The Maritime Safety and Security Lab of the DLR Neustrelitz cooperates with the IOW Warnemünde in regards to remote detection of toxic Cyanobacteria in patches of phytoplankton. In the future, a satellite derived early warning system is planned to detect harmful algae from space. During the August 2022 campaign, several overflights of r/v *Elisabeth Mann Borgese* while taking phytoplankton samples were done by a twin engine Do 228 research plane of the DLR. On board of this plane, a high-resolution hyperspectral HYSpex sensor is installed. It was intended to pass the EMB vessel around the time, samples were taken in order to detect algae with the sensor and produce a spectral curve of that algae later on. In a future step, this data will be compared with lower resolution (30 m) hyperspectral data of the DESIS sensor on board of the International Space Station ISS and other satellite imagery. It is planned to repeat the procedure in 2023 in order to collect more data. (Responsible scientist: Dr. Carsten Mönnig, German Aerospace Center, Earth Observation Center, German Remote Sensing Data Center, Neustrelitz, Germany)

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 the (Deutscher Wetterdienst (DWD), 2022) for the respective days.

Thursday, 04 August 2022: The weather forecast for the day was first light and variable winds, otherwise west to northwest about 3 bft, for a time thundery gusts at a sea of 0.5 m wave height. We left the pier at 8 o'clock in the morning and reached the first station TFO5 at 9:30 at a sunny sky and calm wind conditions. The first CTD-cast with sensor measurements of conductivity, temperature, depth, oxygen, fluorescence and turbidity was on the schedule. Water sampling for oxygen Winkler determinations, the nutrients nitrate, nitrite, phosphate, silicate, ammonium, total nitrogen and total phosphorous as well as for the dissolved and particulate natural organic matter analyses was done. The depth of visibility was determined by the traditional Secci disk. Moreover, sampling for an eDNA archive as well as to investigate bacteria's metabolic activity by examination of metagenomics and metaproteomics was subsequently performed. After completing the station work a security exercise followed and all were well prepared by the instructions they had received after breakfast. The next station was TF0012 again with CTD, water sampling for chemical parameters, Secci depth determination, and first plankton net hauls. Moreover, water samples were taken from surface waters for additives of personal care products and pharmaceuticals, especially hormones. We observed the DO 228 during its overflight with the high-resolution hyperspectral HYSpex sensor on-board. After lunch the TF0012 was completed. On the TF0010 Fehmarn Belt station a CTD cast and the first sampling on this cruise to study the storing capacity of the Baltic Sea's and the North Sea's water column and sediments for carbon were done. TF0014 followed with a CTD cast, and in the Kiel Bight again all nutrient parameters and net hauls were done on TF0360 and a final CTD cast of the day on TF0361.

Friday, 05 August 2022: The weather forecast for the day was northwesterly winds of 3 to 4 bft, increasing to 5 bft, thundery gusts, at a sea state of 1 meter. Early in the morning, we started with the thalweg stations TF0017 and TF0041 with just a CTD cast on each. We found that surface waters were relatively well mixed and scheduled an intercomparison measurement for the next station. On TF0046, air pressure and water temperature with the high precision thermometer SBE RT35 was measured for comparison. From a time-series of three water bottles, each for salinity and for oxygen, water samples were taken for comparison with the respective sensors at the selected depth horizon. After we passed the Kadet channel we completed TF0002 and subsequently TF0001 by CTD casts. TF0030 followed with a couple of net hauls and water sampling for chlorophyll, then TF0115, TF0114, TF0113, TF0105, TF0104, ABBOJE, and late in the evening TF0112 were completed to fulfil the monitoring obligations.

Saturday, 06 August 2022: The weather forecast for the day expected wind from northwest of 5 bft, for a time shifting west, decreasing 3 to 4 bft, at a sea of 1 meter wave height. In the night a CTD cast on TF0152 was completed and early in the morning at half past four we reached the most southern station OBBoje. Then the transit to Sassnitz followed to exchange one person of the scientific crew. To save some time, this was done by the rubber boat. One scientist already completed her work. The new person planned special culture experiments on samples from the Gotland Deep station. But prior to boarding the ship, he needed to be tested for Covid-19 but was negative. The boat reached the ship at 8:40 and we headed north for TF0103 in the central Arkona Sea. We passed the beautiful sunlit chalk cliffs of the Island of Rügen. Then the TF0109 followed with phytoplankton net hauls to sample and identify present phytoplankton species. We observed the last overflight at ideal blue sky conditions of the DO 228 with the Hyperspectrometer on-board. Then station TF0145 with a CTD cast and TF0144 with an additional intercomparison measurement was done. Because of elevated wind force of 5-6 bft the mixed layer was extended to above 10 m, so well suitable conditions for stable sensor readings in the sampled horizon were found. Then the stations TF0142, TF0140, TF0206 were completed.

Sunday, 07 August 2022: For the day westerly winds of 4 bft were forecasted, decreasing a little at a wave height of 1 meter. In the night, on station TF0208 a profile for Carbostore was the only sampling for this site. Just a CTD-profile with the available sensor data is required for the thalweg transect on TF0200. The intercomparison measurements of the day was done on TF0210, then a standard profile with sampling for inorganic nutrients and oxygen, a CTD-profile on TF0211, at 6 o'clock in the morning at 16 °C air temperature we reached the TF0214. On TF0214 the first multicorer deployment was done. But first, a CTD cast was carried out with water sampling for oxygen and again a water column profile for Carbostore. A CTD cast on TF0212 and then the major station TF0213 - Bornholm Deep with a work-filled programme followed with sampling for natural organic matter, total nitrogen, total phosphorus and dissolved nutrients as well as multiple phytoplankton and zooplankton net hauls, water sampling for chlorophyll and greenhouse gases. The next stations TF0225 and TF0227 just required a CTD-cast. In the evening on TF0222 inorganic nutrients, nitrate, nitrite, phosphate, silicate and ammonium were measured as well as oxygen in upper waters and hydrogen sulphide in the bottom range. Then the thalweg stations TF0266, TF0268, TF0256 with just a CTD profile on each were completed.

Monday, 08 August 2022: The weather forecast read, wind first southwest to west 3 bft, otherwise light and variable winds, locally shower at a sea 0.5 meter wave height. During the night the station TF0259 was done with a CTD-cast, water sampling for nutrients, oxygen and hydrogen sulphide, several phytoplankton net hauls were carried out and a surface and a bottom water sample for the Carbostore project were taken. In the morning at a cloud covered sky, a series of stations with just a standard CTD profile on each was started: the TF0255, TF0253, TF0265, TF0262, TF0261, TF0260, TF0274, TF0273 with respective sensor recordings of salinity, temperature, oxygen, chlorophyll, and turbidity. Then TF0272 and TF0275 were completed before we reached the Gotland Deep station. At about 9 o'clock in the evening we began with a CTD cast on TF0271, likely the most important station for the surveillance of the Baltic Sea. We had four CTD casts to sample the chemical parameters – nutrient, oxygen/hydrogen sulphide, trace gases - at a good resolution in the water column of 245 m depth, as well as simultaneously carried out phytoplankton net catches with the small net. Then we moved away a few hundred meters to do a multicorer haul and continued afterwards with a CTD for the Carbostore project and for the investigation of magnetotactic bacteria in the redoxcline. Then a CTD for biological parameters and finally a CTD dedicated to the microorganisms of the redoxcline were carried out.

Tuesday, 09 August 2022: The weather forecast of the day was winds shifting southwest at about 3 bft, later increasing 4 to 5 bft, and a sea of 1 meter wave height. In the early morning at sunrise we completed the GB_B14 east of the central Gotland Deep station, but still more than 240 m deep. After breakfast a ScanFish transect from Latvian coast to Swedish coast of Gotland across the eastern Gotland Basin was planned. After solving some technical problems and data connection issues, the ScanFish operated fine and the CTD data of the undulating system were visualized and stored. In the evening a barbeque was organized as dinner. It was really a warm and calm evening with a flat sea and beautiful sun down and the crew members and the scientific party enjoyed the event together. Unfortunately, the ScanFish transect ended at station SF020EGB as the contact to the ScanFish was lost due to a low internal battery voltage. So we made a CTD-cast instead, as well on the last station of the transect SF022EGB.

Wednesday, 10 August 2022: The weather forecast was wind of southern to southwestern direction of 3 to 4 bft, increasing a little, at a sea of 1 meter. Early in the morning at 4 o'clock we started with the first station of the day TF0276 by a CTD-cast and sampling for the Carbostore project. Then stations TF0270, TF0287 followed both with a CTD profile before we reached the Fårö Deep station TF0286 with a comprehensive measurement and sampling programme on this major station. It was a sunny warm day with sometimes a thin layer of clouds. On the following stations TF0277, TF0285, and TF0279, CTD-casts were carried out. After dinner we reached the most northern station of the campaign TF0282, almost 59° North and in the night nGB-2. The wind increased a bit and at elevated wave height the ship wobbled.

Thursday, 11 August 2022: The weather was expected to be with wind from south to southwest with 4 to 5 bft, decreasing a little, at a wave height of 1 meter. During the night the stations TF0283 and nGB-1 were completed. The replacement station TF0284a for the Landsort Deep station further north that was not approved by Sweden this time, was scheduled after breakfast. The water depth of 360 m on the station 284a appeared still deep compared to the nearby Landsort Deep station of about 460 m depth. The programme reflected a comprehensive set of parameters, oxygen/hydrogen sulphide, inorganic nutrients and total nitrogen and total phosphorus, ammonia, and samples for natural organic matter analysis. For the Carbostore project a water column profile from the surface to the bottom waters represented by 8 depths and a multicorer deployment to obtain also the structure of the sediment below. Then CTD-casts were done on stations wGB-3 and TF0240. Again a multicorer haul was done, in this case for organic chemical investigations on OCWG1 accompanied by a CTD-profile. Unfortunately, four attempts finally ended without a successful sediment sampling. The next station was scheduled after midnight.

Friday, 12 August 2022: The weather forecast for the day was wind first from south to southwest of about 4 bft, light and variable winds later, at a sea of 1 meter wave height first. We reached the TF0242 after midnight and half past 12:00 the CTD cast was completed. Then we headed in south-eastern direction to reach the southern tip of the island of Gotland to start the ScanFish transect in the western Gotland Basin. The ScanFish was deployed on SF032WGB after recharging the internal battery on deck and a successful pre-flight check. However, it turned out that the normal flap operations seem to consume battery power despite external power supply was established via the winch cable. So, after a few miles the system failed due to low battery power. We recovered the ScanFish and continued the stations SF030WGB, SF029WGB, SF028WGB, SF027WGB, SF026WGB, and SF025WGB by CTD casts. The station TF0245 Karlsö Deep was inserted into the row after the SF029WGB to do water sampling for nutrient analyses and an oxygen/hydrogensulphide profile that was initially foreseen after the ScanFish transect. Then we went about 20 n.m. south to reach the wGB-1 with a CTD cast and some water sampling for the Carbostore project, then station work on GB_SW and TF223n was done.

Saturday, 13 August 2022: The weather was forecasted with southerly winds of about 3 bft, shifting east, at a sea state of 0.5 meter wave height. In the night BB_N and TF0220 with a CTD cast on each only, and after breakfast a multicorer on OCBB-2 after a standard CTD cast was done. The first repetition station with biological and physical investigations was the TF0213. Then again multicorer deployments were done after a CTD on OCBB-3, OCBB-1 in the Bornholm Basin. The multicorer haul were successful and the last station for nutrient measurements was the TF0213. On OCB-3, we then received a call to focus on a waste water accident in the river Odra that might had influence on the near coastal area of the Island of Usedom. We decided to go there and to take samples to check for some water constituents.

Sunday, 14 August 2022: The weather forecast was wind from northeast to east 3 to 4 bft, for a time increasing a little, at a sea state of 0.5 meter wave height. At 5 o'clock in the morning, we saw the first signs of a river plume in the recording of the JSMB, a clearly lower salinity and elevated chl_a concentrations in the water, but no signs of dead fish or a special smell in the air. We stopped close to the estuary of the river Peene that most likely may show some peculiarities, because of the release of a substance that caused the fish kill in the Odra. Due to the shallow environment and the draught of 3.6 m of the ship, we decided to use the rubber boat to get closer to the potential contaminated water plume at the mouth of the Peene. We sampled on three stations close to and 1 n.m. away on a western and an eastern position to cover a potential plume. We brought remaining bottles for salinity, nutrients, the carbonate system with pH, and for organic contaminants. The sampling trip lasted about one hour. We had mostly sunny weather during the whole day with relatively calm winds. The last four repetition stations were in the Arkona Sea TF0113 as a biological station with water sampling and several net hauls, as well as TF0030, near the Darss Sill TF0046, and finally in the Mecklenburg Bight TF0012.

Monday, 15 August 2022: On the sunny warm day we docked at 8:00 in the morning at the peer and began to unload our equipment, mostly stowed in one container that was heaved from board and put on a lorry. As well samples, partly cooled or frozen were carried from board and brought to the institute.

5 Preliminary Results

The results presented in the following sections 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 of the actual state of the western and central Baltic Sea in August 2022. An advanced data analysis will follow when the validated data sets are available.

5.1 Meteorological conditions

In the beginning of the cruise, a stable high-pressure bridge between the northeast shifted Azores High and an extensive East European bottom high established across Central Europe. North of this high-pressure bridge a frontal zone pulls disturbances eastward and influenced the northern part of Europe with their cold fronts. In the following days, the high-pressure bridge stretched from the Azores across the British Islands to northern Europe with anticyclonic extension to Central Europe. Extensive activity of low-pressure systems located over western Russia. The last two days were determined by a blocking high-pressure system over central and northern Fennoscandia. Between this and an extended high altitude low pressure system in southern Central Europe an eastern flow prevailed from Central Russia through Central Europe to Great Britain (Deutscher Wetterdienst, 2022). The development of the on-board measured wind speed, the air temperature and the surface water temperature (upper panel) as well as the wind direction and humidity (lower panel) during the cruise are shown in Fig. 5.1.

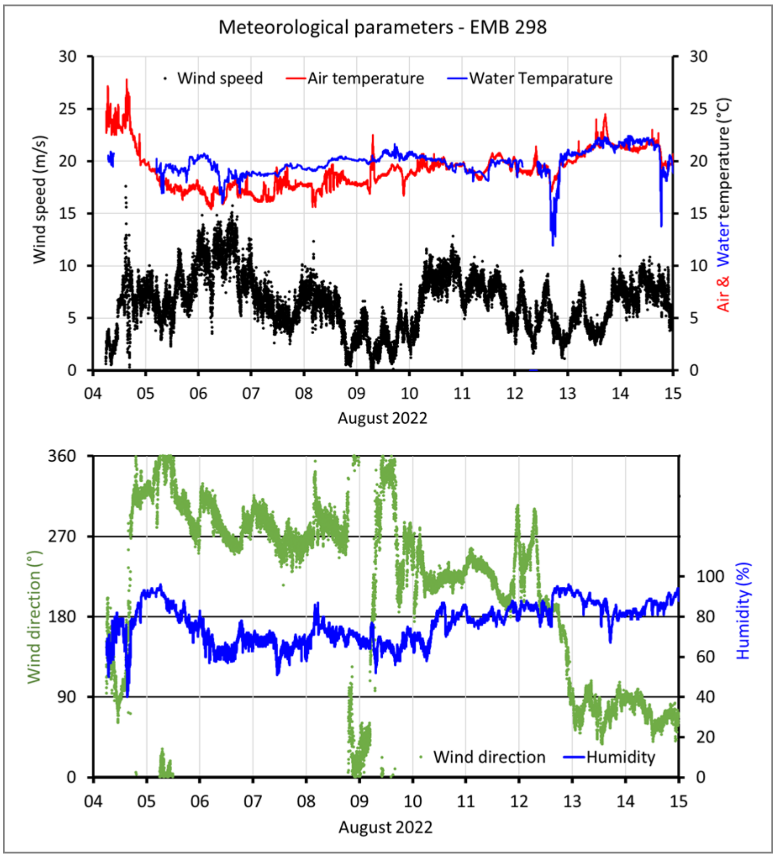

Fig. 5.1 Surface water temperature, air temperature, and wind speed (upper panel) as well as humidity and wind direction (lower panel) measured on-board by the automatic weather station of the DWD; surface water temperature was measured by the JSMB-thermosalinograph.

A moderate breeze of 4 bft on the first two days increased to a strong breeze of 6 bft on the third day. The following 10 days the wind basically changed between a moderate and fresh breeze (4-5 bft) but frequently calmed down during the day. The wind direction basically turned from a westerly (until 10th August) to a south-westerly (10th-13th August) and further to an easterly direction (until 15th August). Air temperature was relatively low for August and scattered around 17 °C (15.4-22.5 °C) during 5th-13th August, but was higher on the first (about 25 °C) and the last

two days (22 °C). The surface water temperature was about 20 °C but reached low values of about 12 °C (near Öland) and 14 °C (near Darss sill), likely caused by upwelling features. Slightly elevated values of up to 22.4 °C characterized the Pomeranian Bight and the southern Arkona Sea on the last two days. Salinity decreased in surface water from the Belt Sea of 11.8 to 5.8 in the western Gotland Sea basin (Fig. 5.1, upper panel).
Chlorophyll showed an elevated concentration in the eastern and western Gotland Basins and in the Pomeranian Bight at the end of the cruise. Likely the imprint of riverine water caused elevated chlorophyll_a concentration near the Odra outflow (Fig. 5.2). As well, turbidity was especially high in that shallow area (Fig. 5.2, upper panel).

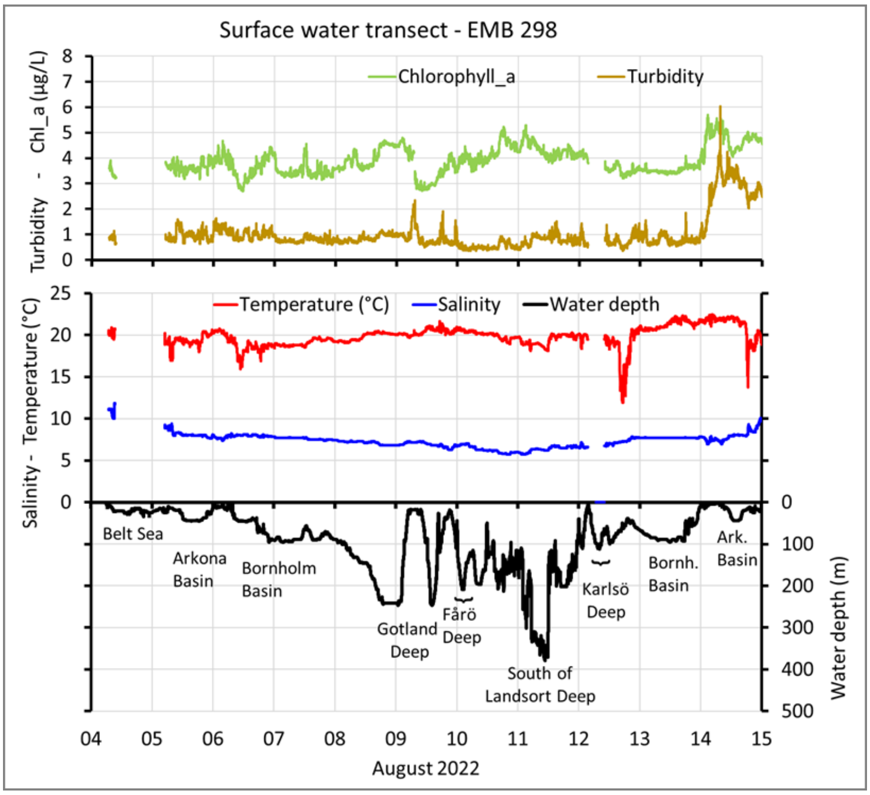

Fig. 5.2 Recording of chlorophyll and turbidity data (upper panel, drift corrected), compared to temperature and salinity in surface waters with the corresponding water depth and sea area during the cruise EMB 298 of r/v *Elisabeth Mann Borgese* from August 4th to August 15th.

5.2 Baltic thalweg transect

For an overview of the hydrographic and the hydrochemical state of the Baltic Proper during the cruise EMB 298, data of the CTD casts along the thalweg from the Kiel Bight to the eastern, via the northern and western Gotland Sea and back until the Bornholm Sea were combined to contour plots of salinity, temperature and oxygen for August 2022 (Fig. 5.3, with a small map of the selected stations in the upper panel).

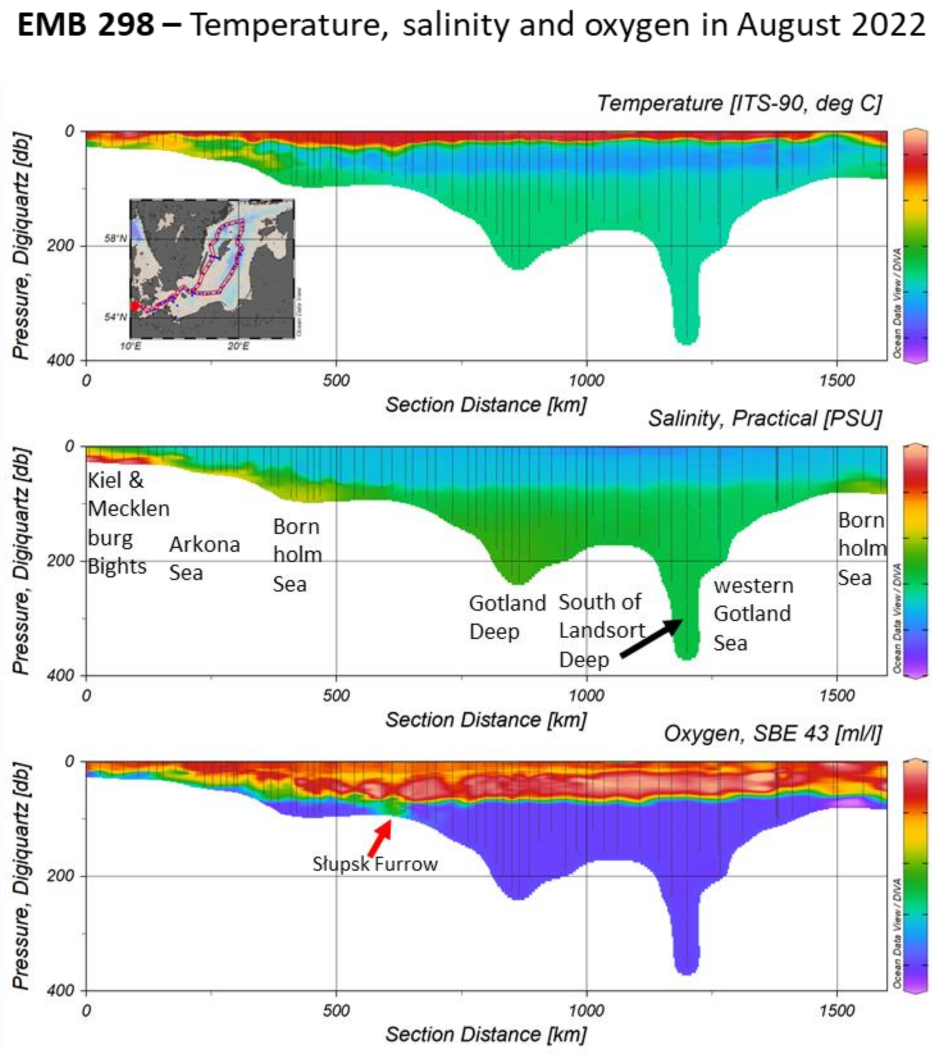

Fig. 5.3 Temperature, salinity and oxygen (without H_2S) along the thalweg of the Baltic Sea from the Kiel Bight via the eastern and western Gotland Basin back to the Bornholm Sea (4 Aug – 13 Aug 2022). The elevated oxygen concentration in the bottom water of Słupsk Furrow is indicated by a red arrow. The figure is based on the preliminary data of the CTD casts (vertical grey lines) by using ODV 5 (Schlitzer, 2018).

The warm mixed layer of about 20 °C with a thickness of 5 to 20 m is clearly visible in red in Fig. 5.3 (upper panel). The thermocline is steep and reaches temperature below 5 °C already in the range between 25 and 30 m depth. The layer of cold winter water shows a thickness of about 50 m in the Gotland Basin, but is less pronounced and thinner in the Bornholm Sea and vanishes in the shallower western Baltic Sea. The deep water is warmer at a temperature of 6-7 °C.

The low salinity of 6-8 in upper waters extends down to 70 m (light blue, Fig. 5.3, middle panel) that is primarily influenced by freshwater supply from the large drainage area of the Baltic sea. The strong halocline below marks the winter mixing depths and is a permanent feature in the central basins. A high salinity of partly above 20 (red) was observed in August 2022 in bottom waters of the Kiel Bight and Mecklenburg Bight. In Baltic Sea deep waters at greater depths than 120 m, the salinity ranged between 11 and 13.

The oxygen concentration distribution in upper waters was about 6-8 mL/L (reddish, Fig. 5.3, middle panel). It is mainly determined by its lower solubility at elevated surface water temperature in August 2022 in contact with the atmosphere. In the halocline the supply of oxygen decreases and oxygen consumption processes dominate and deplete oxygen below 80 m to an undetectable concentration. An exception was observed in the Słupsk furrow, between the Bornholm Basin and the eastern Gotland Basin, where bottom water partly showed oxygen concentration of 3-4 mL/L. The signal was noticeable on the two stations TF0222 and TF0266 (marked by a red arrow, Figure 5.3, lower panel) but an elevated concentration of oxygen was also seen on TF0259, 2.8 mL/L right above the bottom's depth of 86 m, and of 3.7 mL/L between 75 and 80 m depth, indicating an inflowing oxic water parcel.

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

5.3.1 Surface water temperature

The surface water temperatures during the cruise EMB 298 were already shown (Fig. 5.2). Here we compare the values determined at selected Baltic Sea monitoring stations to the temperatures of the last summers from 2017 to 2021 and to the long-term mean values 1971-1990 measured during the respective July/August cruises in the 1970ies and 1980ies (Table 5.1). Surface water temperature values in August 2022 reflect almost mean values of recent years, but are overall about 2 °C higher than the long term averages of the chosen two decades of the last century (right column). But the differences change clearly with region: Bornholm Deep and Landsort Deep were less than 1 °C warmer, but temperature in the Mecklenburg Bight, Gotland, Fårö, and Karlsö Deeps were 2.6-2.9 °C higher than the long-term comparison value determined for 1971-1990. So surface water clearly depends on the actual weather situation of the region. A comparison appears difficult based on a few data points. However, a general warming trend over decades is again supported.

Table 5.1 Surface water temperature (°C) of Baltic Sea areas of this cruise (Aug 22) compared to the last five years and to a former long-term average (rightmost column).

Temperature (°C)	Aug 17	Aug 18	Aug 19	Jul 20	Jul 21	**Aug 22**	1971-1990
Mecklenb. Bight (TF0012)	18.2	22.5	18.9	17.1	19.7	**20.6**	17.7
Arkona Basin (TF0113)	17.3	21.7	19.9	16.0	20.0	**18.6**	17.0
Bornholm Deep (TF0213)	17.6	22.0	18.9	16.0	20.9	**18.5**	17.6
Gotland Deep (TF0271)	17.5	23.0	17.8	19.1	21.8	**19.8**	17.1
Fårö Deep (TF0286)	18.2	23.1	16.9	16.9	21.4	**19.9**	17.0
Landsort Deep (TF0284)	16.8	23.1	18.5	16.1	20.8	**18.7**	18.2
Karlsö Deep (TF0245)	16.9	24.5	18.6	16.3	21.6	**19.5**	16.9

5.3.2 Deep water salinity and temperature

The salinity of the bottom water layer measured in August 2022 is shown in comparison to data from the cruises in August 2017 to July 2021 (Table 5.2). It appears that the salinity is still decreasing since August 2017 in the investigated deeps Gotland Deep, Fårö Deep, and Landsort Deep. At that time the strong inflow of 2014/2015 reached the northern part of the western Gotland Basin, whereas the salinity peak in Karlsö Deep, the end of the thalweg, was likely noticeable in August 2018. However, bottom water salinity in the Landsort Deep had increased in July 2020 showing some additional entrainment of saltier water. Even more complex is the salinity development in the Karlsö Deep in the summer of recent years as salinity basically had scattered around 10.5, but was clearly lower with 10.26 in August 2022. The salinity of the Gotland Deep bottom water decreased significantly from August 2019 to August 2022 by about 0.13/yr summing up to 0.41. Lower salinity close to the bottom improves the chance of inflowing water to reach the bottom water layer. But with regard to the strong oxygen deficits, the salinity of 12.87 appear still high in August 2022 in comparison to pre-inflow time in August 2014 when the salinity was 12.25 (Kuss, 2019).

Table 5.2 Bottom water salinity of Baltic Sea deeps of this cruise (Aug 22) compared to the last 5 years.

Salinity	Aug 17	Aug 18	Aug 19	Jul 20	Jul 21	Aug 22
Gotland Deep	13.47	13.27	13.28	13.13	13.00	12.87
Fårö Deep	12.82	12.75	12.63	12.55	12.42	12.13
Landsort Deep	11.54	11.46	11.38	11.53	11.23	10.92*
Karlsö Deep	10.39	10.70	10.45	10.59	10.52	10.26

* Value measured on 284a in 359 m depth

The temperatures in the bottom waters of the Bornholm, Fårö, Landsort, and Karlsö Deeps were 0.34, 0.04, 0.11, and 0.12 °C lower compared to summer last year (Table 5.3). In the Gotland Deep bottom waters the temperature was very similar (within one-hundreds) as in previous 2 years. However, despite a slight decrease, the bottom water temperatures of August 2022 confirm the finding that temperatures in recent years are clearly above the long-term averages of 1971-1990. In August 2022 the differences ranged between 1.60 and 2.00 °C, with an average of 1.84 °C higher temperatures in bottom waters, compared to 1971-1990.

Table 5.3 Bottom water temperature (°C) of Baltic Sea deeps of this cruise (Aug 22) compared to the last 5 years and to a former long-term average.

Temperature (°C)	Aug 17	Aug 18	Aug 19	Jul 20	Jul 21	**Aug 22**	1971-1990
Bornholm Deep	6.97	6.97	8.54	8.31	8.42	**8.08**	6.12
Gotland Deep	6.95	6.9	7.37	7.22	7.21	**7.22**	5.62
Fårö Deep	6.98	6.76	7.19	7.3	7.23	**7.20**	5.20
Landsort Deep	6.36	6.28	6.5	6.89	6.66	**6.55 ***	4.76
Karlsö Deep	5.58	5.83	5.68	5.97	6.17	**6.05**	4.18

* Value measured on 284a in 359 m depth

5.3.3 Oxygen

The oxygen concentration in the bottom water clearly worsen since July 2020 after a slight improvement in July 2021. The respective hydrogen sulphide concentrations were recalculated to negative oxygen concentration values for the Gotland Deep of -9.72 mL/L, the Fårö Deep of -5.55 mL/L, the Landsort Deep of -2.87 mL/L, and the Karlsö Deep to -3.80 mL/L. This reflects an striking oxygen deficits for the Gotland Deep, reaching almost -10.0 mL/L oxygen.

Table 5.4 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.

Oxygen (mL/L)	Aug 17	Aug 18	Aug 19	Jul 20	Jul 21	**Aug 22**
Gotland Deep	0.06	-4.29	-6.15	-7.88	-7.17	**-9.72**
Fårö Deep	< d.l.	-3.52	-4.68	-4.17	-4.91	**-5.55**
Landsort Deep	< d.l.	-0.82	-2.08	-1.74	-1.60	**-2.87***
Karlsö Deep	< d.l.	-3.10	-2.93	-3.48	-2.43	**-3.80**

* Value measured on 284a in 359 m depth; d.l.: O_2 detection limit

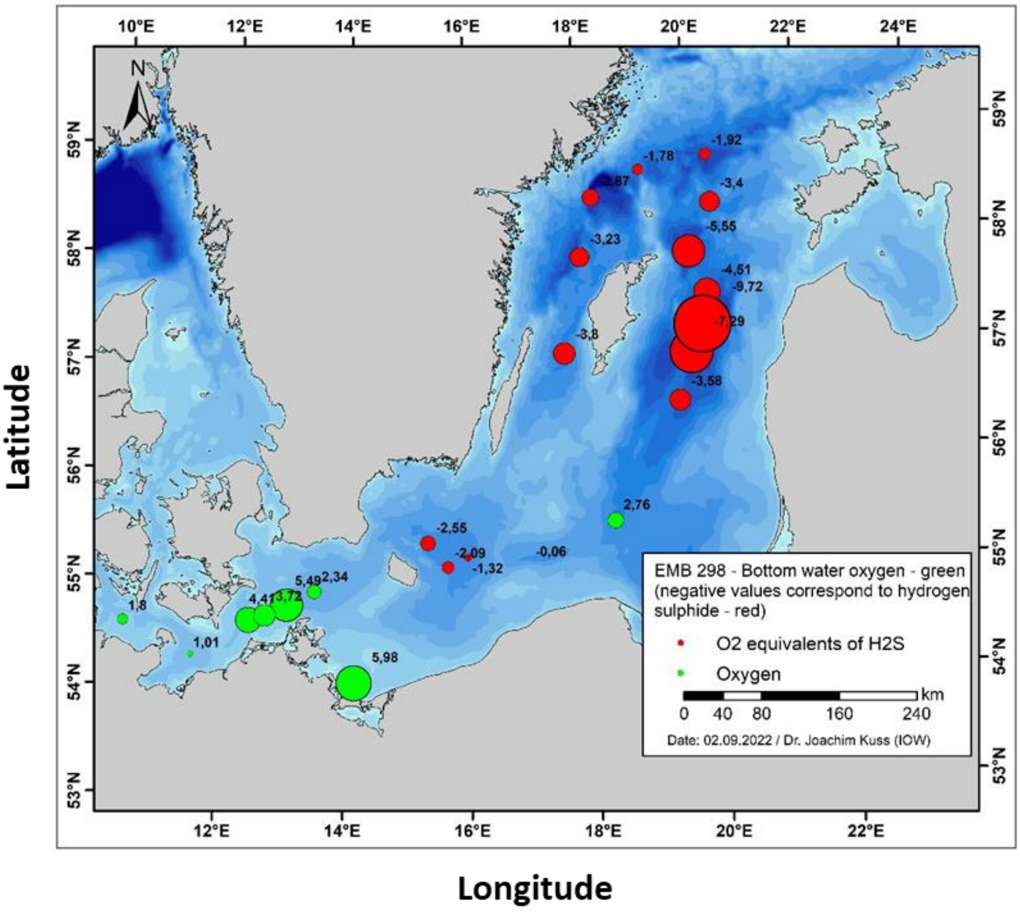

Fig. 5.4 Oxygen concentration (mL/L) in bottom waters of selected Baltic Sea stations (H_2S is included as negative oxygen).

The oxygen concentration in bottom waters of the Kiel Bight (1.8 mL/L) and in the Mecklenburg Bight (1.0 mL/L) were low, but in the Arkona Basin oxygen was measured between 2.3 mL/L in the central and up to 5.5 mL/L in the western Arkona Basin (Fig. 5.4). As well in the shallow area of the Oderbank area already belonging to the Bornholm Basin it was almost 6 mL/L bottom water oxygen. In August 2022, the deep parts of the Bornholm Basin were characterized by euxinic conditions with -1.3 to -2.6 mL/L oxygen equivalents. On station TF0222 in the Slupsk Furrow hydrogensulphide could hardly be detected close to the bottom, and further east a relative high oxygen concentration of 2.76 mL/L was measured in the bottom water at the entrance of the eastern Gotland Basin (Fig. 5.4). However, the deep Gotland Sea showed a strong oxygen deficit as mentioned before, thereby the western Basin was between -1.8 to -3.8 mL/L, whereas the eastern basin was between -2 and almost -10 mL/L on the sampled stations (Fig. 5.4).

Moreover, it was interesting to investigate the turbidity zones in intermediate and deeper waters in comparison to low oxygen waters, as it was observed that turbidity often marks the mixing or diffusion zones between sulphidic and oxygenated waters (Fig. 5.5, lower panel). 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). The density distribution (Fig. 5.5, upper panel) is basically determined by salinity (Fig. 5.3, middle panel), but also the warm mixed layer can be distinguished by its lower density. Interestingly, along the permanent halocline, the turbidity maxima can be seen that likely indicate former supply of oxygenated water in the range of the halocline (Fig. 5.5, lower panel). But also in deeper waters, indication of former inflows of oxygenated waters can be assumed. The patchiness of the chlorophyll_a fluorescence maxima in surface waters is well visible in Fig. 5.5 (middle panel) that despite the lack of nutrients, the primary production is still active.

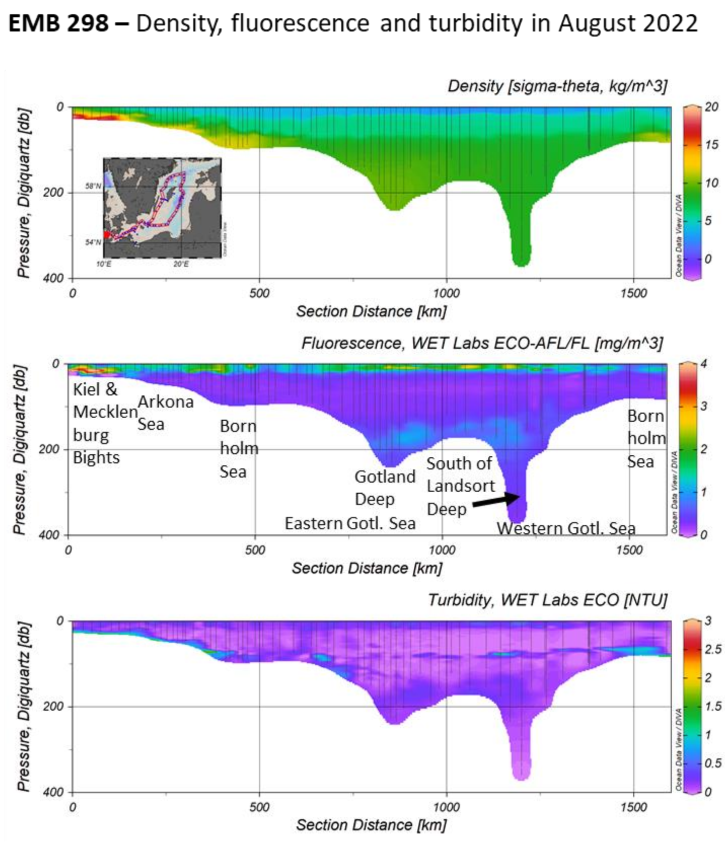

Fig. 5.5 Sensor measurements of density, fluorescence and turbidity along the thalweg transect (see Fig. 5.3). The figure is based on the preliminary data of the CTD casts (vertical grey lines) by using ODV 5 (Schlitzer, 2018).

5.3.4 Nutrients

In August 2022 the inorganic nitrogen is depleted in the upper waters of the Baltic Proper. Phosphate was available at an average concentration of 0.06 µmol/L and up to 0.15 µmol/L in the upper 5 m of the water column, and showed an average of 0.11 µmol/L between 5 and 10 m with a maximum of 0.44 µmol/L. Diazotrophic cyanobacteria are favoured by this nutrient situation and were observed at high abundance. In the central basins, nitrate was depleted in deep waters below about 80 in accordance with the depletion of oxygen. An exception was indeed the Slupsk furrow in the area of station TF0222, were oxygen was determined in deep waters and nitrate was about 10 µmol/L in the bottom water layer of about 10 m thickness. As well the oxygen imprint on station TF0259 enabled a nitrate concentration of 3.9 µmol/L in 88 m and still 2.62 in 80 m depth.

Because of the ongoing stagnation phase in deep waters of the Gotland Sea since 2017, the accumulation of hydrogen sulphide in deep waters was almost continuously ongoing. Nitrate was depleted and phosphate was slowly accumulating on a high level (Table 5.5). Anoxic condition lead to a total consumption of nitrate as remaining nitrate is used for oxidation, and remineralisation of organic nitrogen does not go beyond ammonium, and thus remineralization does not deliver nitrate anymore. So nitrate was not found in August 2022 in the bottom waters of the Gotland, Fårö, Landsort, and Karlsö Deeps like 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. Whereas, the Bornholm Sea is subjected to frequent episodic inflows of oxygenated waters that also replaced the bottom water and changed nutrient concentrations strongly. So nitrate concentrations varied during the summer cruises of recent years between the detection limit and up to 7.2 µmol/L (July 2020). This is also valid for the phosphate concentration that scattered from 2.6 to 11.7 µmol/L in bottom waters. In August 2022 nitrate was still detectable and phosphate showed a high concentration of 7.3 µmol/L in the bottom water of the Bornholm Deep, indicating anoxia (Table 5.5).

Table 5.5 Bottom water Nitrate (upper part) and phosphate (lower part) concentrations (µM) of Baltic Sea deeps of this cruise (Aug-19) compared to the last 5 years.

Nitrate (µM)	Aug 17	Aug 18	Aug 19	Jul 20	Jul 21	**Aug 22**
Bornholm Deep	1.1	< d.l.	2.3	7.2	< d.l.	**0.4**
Gotland Deep	< d.l.	< d.l.	< d.l.	< d.l.	< d.l.	**< d.l.**
Fårö Deep	< d.l.	< d.l.	< d.l.	< d.l.	< d.l.	**< d.l.**
Landsort Deep	< d.l.	< d.l.	< d.l.	< d.l.	< d.l.	**< d.l.**
Karlsö Deep	< d.l.	< d.l.	< d.l.	< d.l.	0.1	**< d.l.**

Phosphate (µM)	Aug 17	Aug 18	Aug 19	Jul 20	Jul 21	**Aug 22**
Bornholm Deep	2.7	8.3	7.0	2.6	11.7	**7.3**
Gotland Deep	4.7	5.3	4.7	5.6	6.3	**6.5**
Fårö Deep	3.4	4.4	4.6	4.4	5.3	**5.1**
Landsort Deep	2.8	3.0	3.4	3.3	4.0	**4.1**
Karlsö Deep	3.8	3.8	3.8	3.8	4.0	**4.2**

6 Station List EMB 298

6.1 Overall Station List

Station No.		Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/ Recovery
r/v *Elisabeth Mann Borgese*	**IOW**	**2022**		**[UTC]**	**[°N]**	**[°E]**	**[m]**	Max sampl. depth
EMB298-1	TFO5	04 Aug	CTD	7:42	54.2327	12.0762	10	CLmax: 12m
EMB298-2	TF0012	04 Aug	CTD	10:18	54.3158	11.5474	21	CLmax: 23m
EMB298-2	TF0012	04 Aug	CTD	10:38	54.3154	11.5467	21	CLmax: 23m
EMB298-2	TF0012	04 Aug	WP2	11:04	54.3160	11.5474	21	CLmax: 22m
EMB298-2	TF0012	04 Aug	WP2	11:11	54.3161	11.5475	21	CLmax: 22m
EMB298-2	TF0012	04 Aug	CTD	11:32	54.3159	11.5475	21	CLmax: 23m
EMB298-3	TF0010	04 Aug	CTD	13:52	54.5519	11.3187	25	CLmax: 27m
EMB298-4	TF0014	04 Aug	CTD	15:35	54.5941	11.0131	23	CLmax: 25m
EMB298-5	TF0360	04 Aug	CTD	18:12	54.6000	10.4504	15	CLmax: 17m
EMB298-5	TF0360	04 Aug	WP2	18:32	54.5998	10.4499	15	CLmax: 15m
EMB298-6	TF0361	04 Aug	CTD	20:15	54.6646	10.7758	21	CLmax: 23m
EMB298-7	TF0017	05 Aug	CTD	2:11	54.3915	11.8233	19	CLmax: 21m
EMB298-8	TF0041	05 Aug	CTD	3:44	54.4067	12.0616	16	CLmax: 18m
EMB298-9	TF0046	05 Aug	CTD	5:02	54.4692	12.2403	25	CLmax: 27m
EMB298-9	TF0046	05 Aug	WP2	5:23	54.4690	12.2395	25	CLmax: 6m
EMB298-9	TF0046	05 Aug	WP2	5:29	54.4692	12.2394	25	CLmax: 26m
EMB298-10	TF0002	05 Aug	CTD	7:27	54.6498	12.4497	15	CLmax: 16m
EMB298-11	TF0001	05 Aug	CTD	8:51	54.6964	12.7068	18	CLmax: 20m
EMB298-12	TF0030	05 Aug	CTD	9:35	54.7228	12.7826	20	CLmax: 22
EMB298-12	TF0030	05 Aug	CTD	10:03	54.7237	12.7827	20	CLmax: 22m
EMB298-13	TF0115	05 Aug	CTD	11:41	54.7966	13.0557	27	CLmax: 28m
EMB298-14	TF0114	05 Aug	CTD	13:03	54.8598	13.2763	42	CLmax: 43m
EMB298-15	TF0113	05 Aug	CTD	14:22	54.9250	13.4998	45	CLmax: 45m
EMB298-15	TF0113	05 Aug	WP2	14:40	54.9251	13.5000	45	CLmax: 45m
EMB298-15	TF0113	05 Aug	WP2	14:49	54.9250	13.5003	45	CLmax: 45m
EMB298-15	TF0113	05 Aug	WP2	14:55	54.9250	13.5003	45	CLmax: 45m
EMB298-15	TF0113	05 Aug	CTD	15:19	54.9252	13.5003	45	CLmax: 44m
EMB298-16	TF0105	05 Aug	CTD	16:36	55.0250	13.6066	44	CLmax: 45m
EMB298-17	TF0104	05 Aug	CTD	17:47	55.0681	13.8131	44	CLmax: 45m
EMB298-18	ABBOJE	05 Aug	CTD	19:22	54.8806	13.8453	43	CLmax: 44m
EMB298-19	TF0112	05 Aug	CTD	20:24	54.8029	13.9585	37	CLmax: surface
EMB298-19	TF0112	05 Aug	CTD	20:55	54.8039	13.9571	37	CLmax: 39m
EMB298-20	TF0152	05 Aug	CTD	23:06	54.6314	14.2807	28	CLmax: 29m
EMB298-21	OBBoje	06 Aug	CTD	2:47	54.0749	14.1540	12	CLmax: 13m
EMB298-22	Sassnitz	06 Aug	BOAT	5:58	54.5048	13.6438	6	Scientists exchange
EMB298-23	TF0103	06 Aug	CTD	11:13	55.0634	13.9881	44	CLmax: 45m
EMB298-24	TF0109	06 Aug	CTD	12:21	55.0010	14.0826	45	CLmax: 46m
EMB298-24	TF0109	06 Aug	WP2	12:40	55.0006	14.0822	46	CLmax: 46m
EMB298-25	TF0145	06 Aug	CTD	14:28	55.1668	14.2507	44	CLmax: 44m
EMB298-26	TF0144	06 Aug	CTD	16:00	55.2570	14.4901	41	CLmax: 5m
EMB298-26	TF0144	06 Aug	CTD	16:28	55.2570	14.4899	41	CLmax: 42m
EMB298-27	TF0142	06 Aug	CTD	18:01	55.4050	14.5370	58	CLmax: 59m
EMB298-28	TF0140	06 Aug	CTD	19:22	55.4657	14.7170	67	CLmax: 67m
EMB298-29	TF0206	06 Aug	CTD	20:46	55.5329	14.9166	75	CLmax: 74m
EMB298-30	TF0208	06 Aug	CTD	22:32	55.4559	15.2309	91	CLmax: 90m
EMB298-31	TF0200	06 Aug	CTD	23:48	55.3836	15.3314	90	CLmax: 90m
EMB298-32	TF0210	07 Aug	CTD	1:54	55.4564	15.6279	84	CLmax: 83m
EMB298-33	TF0211	07 Aug	CTD	3:11	55.3299	15.6150	95	CLmax: 94m
EMB298-34	TF0214	07 Aug	CTD	4:45	55.1603	15.6601	93	CLmax: 92m
EMB298-34	TF0214	07 Aug	MUC	5:08	55.1600	15.6599	93	CLmax: 95m

EMB298-35	TF0212	07 Aug	CTD	6:57	55.3010	15.7954	94	CLmax: 93m
EMB298-36	TF0213	07 Aug	CTD	8:14	55.2497	15.9828	90	CLmax: 88m
EMB298-36	TF0213	07 Aug	WP2	8:29	55.2499	15.9838	89	CLmax: 85m
EMB298-36	TF0213	07 Aug	WP2	8:38	55.2503	15.9836	89	CLmax: 85m
EMB298-36	TF0213	07 Aug	WP2	8:45	55.2500	15.9833	89	CLmax: 20m
EMB298-36	TF0213	07 Aug	WP2	8:51	55.2496	15.9832	89	CLmax: 55m
EMB298-36	TF0213	07 Aug	WP2	9:01	55.2496	15.9837	89	CLmax: 85m
EMB298-36	TF0213	07 Aug	CTD	9:24	55.2500	15.9827	89	CLmax: 23m
EMB298-36	TF0213	07 Aug	APNET	9:33	55.2501	15.9838	89	CLmax: 85m
EMB298-36	TF0213	07 Aug	APNET	9:53	55.2497	15.9825	89	CLmax: 85m
EMB298-36	TF0213	07 Aug	APNET	10:13	55.2498	15.9823	89	CLmax: 85m
EMB298-37	TF0225	07 Aug	CTD	12:04	55.2580	16.3210	64	CLmax: 64m
EMB298-38	TF0227	07 Aug	CTD	13:41	55.2623	16.6391	67	CLmax: 67m
EMB298-39	TF0222	07 Aug	CTD	15:51	55.2166	17.0669	90	CLmax: 89m
EMB298-40	TF0266	07 Aug	CTD	17:26	55.2521	17.3599	88	CLmax: 87m
EMB298-41	TF0268	07 Aug	CTD	20:04	55.3074	17.9300	74	CLmax: 73m
EMB298-42	TF0256	07 Aug	CTD	21:40	55.3269	18.2516	76	CLmax: 77m
EMB298-43	TF0259	07 Aug	CTD	23:41	55.5497	18.4004	89	CLmax: 88m
EMB298-43	TF0259	08 Aug	CTD	0:31	55.5498	18.3997	89	CLmax: 88m
EMB298-44	TF0255	08 Aug	CTD	2:00	55.6323	18.6010	94	CLmax: 93m
EMB298-45	TF0253	08 Aug	CTD	4:07	55.8403	18.8668	101	CLmax: 99m
EMB298-46	TF0265	08 Aug	CTD	5:38	55.9588	19.0475	111	CLmax: 109m
EMB298-47	TF0262	08 Aug	CTD	8:05	56.2344	19.3005	131	CLmax: 129m
EMB298-48	TF0261	08 Aug	CTD	10:22	56.4911	19.4798	143	CLmax:.140m
EMB298-49	TF0260	08 Aug	CTD	11:57	56.6337	19.5824	144	CLmax: 141m
EMB298-50	TF0274_	08 Aug	CTD	13:37	56.7682	19.7486	154	CLmax:. 150m
EMB298-51	TF0273	08 Aug	CTD	15:19	56.9518	19.7697	184	CLmax: 179m
EMB298-52	TF0272	08 Aug	CTD	16:42	57.0718	19.8290	209	CLmax: 204m
EMB298-53	TF0275	08 Aug	CTD	18:17	57.2100	19.9302	231	CLmax: 226m
EMB298-54	TF0271	08 Aug	CTD	19:47	57.3200	20.0506	242	CLmax: 236m
EMB298-54	TF0271	08 Aug	CTD	20:32	57.3198	20.0507	241	CLmax: 160m
EMB298-54	TF0271	08 Aug	CTD	21:13	57.3197	20.0506	241	CLmax: 91m
EMB298-54	TF0271	08 Aug	CTD	21:43	57.3195	20.0500	241	CLmax: 30m
EMB298-54	TF0271	08 Aug	MUC	22:05	57.3200	20.0498	241	CLmax: 245m
EMB298-54	TF0271	08 Aug	CTD	22:46	57.3195	20.0505	241	CLmax: 100m
EMB298-54	TF0271	08 Aug	CTD	23:28	57.3197	20.0483	241	CLmax: 236m
EMB298-54	TF0271	09 Aug	CTD	0:25	57.3215	20.0491	241	CLmax: 100m
EMB298-55	GB_B14	09 Aug	CTD	1:57	57.2029	20.1725	235	CLmax: 230m
EMB298-56	SF022EGB	09 Aug	CTD	6:25	57.0410	21.2719	18	CLmax: 20m
EMB298-57	SF022EGB	09 Aug	SF	8:06	57.0422	21.2717	18	SF-deployed
EMB298-57	SF005EGB	09 Aug	SF	18:41	57.4818	19.2373	65	SF-recovered
EMB298-58	SF005EGB	09 Aug	SF	18:51	57.4842	19.2274	64	SF-deployed
EMB298-58	SF003EGB	09 Aug	SF	19:46	57.5192	19.0593	37	SF-recovered
EMB298-59	SF003EGB	09 Aug	CTD	20:15	57.5166	19.0717	39	CLmax: 40m
EMB298-60	SF001EGB	09 Aug	CTD	21:26	57.5632	18.8523	20	CLmax: 21m
EMB298-61	TF0276	10 Aug	CTD	2:34	57.4698	20.2599	209	CLmax: 203m
EMB298-62	TF0270	10 Aug	CTD	4:11	57.6162	20.1670	144	CLmax: 141m
EMB298-63	TF0287	10 Aug	CTD	5:58	57.7145	19.8546	127	CLmax: 125m
EMB298-64	TF0286	10 Aug	CTD	8:20	58.0000	19.9003	196	CLmax: 191m
EMB298-64	TF0286	10 Aug	CTD	9:18	57.9991	19.9001	196	CLmax: 21m
EMB298-65	TF0277	10 Aug	CTD	11:02	58.1828	20.0508	163	CLmax: 159m
EMB298-66	TF0285	10 Aug	CTD	13:26	58.4424	20.3315	122	CLmax: 120m
EMB298-67	TF0279	10 Aug	CTD	15:13	58.6416	20.3463	164	CLmax: 160m
EMB298-68	TF0282	10 Aug	CTD	17:20	58.8834	20.3167	165	CLmax: 161m
EMB298-69	nGB-2	10 Aug	CTD	20:28	58.8662	19.7449	162	CLmax: 157m
EMB298-70	TF0283	10 Aug	CTD	0:19	58.7841	19.0961	176	CLmax: 175m
EMB298-71	nGB-1	11 Aug	CTD	2:36	58.7124	18.6694	244	CLmax: 237m
EMB298-72	TF0284a	11 Aug	CTD	6:04	58.5449	18.2354	331	CLmax: 361m

EMB298-72	TF0284a	11 Aug	CTD	7:10	58.5449	18.2357	322	CLmax: 133m
EMB298-72	TF0284a	11 Aug	CTD	7:50	58.5449	18.2351	337	CLmax: 5m
EMB298-72	TF0284a	11 Aug	CTD	8:40	58.5452	18.2355	331	CLmax: 361m
EMB298-72	TF0284a	11 Aug	CTD	9:43	58.5453	18.2353	335	CLmax: 90m
EMB298-72	TF0284a	11 Aug	MUC	10:31	58.5449	18.2337	374	CLmax: 375m
EMB298-72	TF0284a	11 Aug	MUC	11:27	58.5446	18.2345	349	CLmax: 365m
EMB298-73	wGB-3	11 Aug	CTD	13:52	58.3254	18.0665	163	CLmax: 158m
EMB298-74	TF0240	11 Aug	CTD	16:33	58.0005	18.0001	167	CLmax: 163m
EMB298-75	OCWG1	11 Aug	CTD	17:24	57.9776	17.9559	201	CLmax: 196m
EMB298-75	OCWG1	11 Aug	MUC	17:51	57.9775	17.9561	201	CLmax: 200m
EMB298-75	OCWG1	11 Aug	MUC	18:16	57.9774	17.9562	201	CLmax: 200m
EMB298-75	OCWG1	11 Aug	MUC	18:37	57.9774	17.9558	201	CLmax: 200m
EMB298-75	OCWG1	11 Aug	MUC	19:05	57.9774	17.9562	201	CLmax: 200m
EMB298-76	TF0242	11 Aug	CTD	22:27	57.7184	17.3657	139	CLmax: 135m
EMB298-77	SF032WGB	12 Aug	CTD	3:40	57.0520	18.1351	9	CLmax: 10m
EMB298-78	SF031WGB	12 Aug	CTD	5:12	57.0726	17.9851	57	CLmax: 56m
EMB298-79	SF030WGB	12 Aug	CTD	6:03	57.0877	17.8774	78	CLmax: 76m
EMB298-80	SF029WGB	12 Aug	CTD	6:58	57.1022	17.7695	98	CLmax: 97m
EMB298-81	TF0245	12 Aug	CTD	7:51	57.1171	17.6654	110	CLmax: 108m
EMB298-82	SF027WGB	12 Aug	CTD	8:45	57.1339	17.5433	102	CLmax: 100m
EMB298-83	SF026WGB	12 Aug	CTD	9:34	57.1487	17.4314	74	CLmax: 73m
EMB298-84	SF025WGB	12 Aug	CTD	10:22	57.1612	17.3233	68	CLmax: 67m
EMB298-85	wGB-1	12 Aug	CTD	12:39	56.8767	17.3904	95	CLmax: 93m
EMB298-86	GB_SW	12 Aug	CTD	14:58	56.6258	17.1305	77	CLmax: 76m
EMB298-87	TF223n	12 Aug	CTD	18:19	56.2499	16.7001	56	CLmax: 56m
EMB298-88	BB_N	12 Aug	CTD	22:54	55.7581	16.2956	61	CLmax: 61m
EMB298-89	TF0220	13 Aug	CTD	3:23	55.5000	15.9998	79	CLmax: 79m
EMB298-90	OCBB-2	13 Aug	CTD	5:47	55.4653	15.7907	85	CLmax: 85m
EMB298-90	OCBB-2	13 Aug	MUC	6:02	55.4654	15.7912	85	CLmax: 85m
EMB298-91	TF0213	13 Aug	CTD	8:19	55.2501	15.9835	89	CLmax: 89m
EMB298-91	TF0213	13 Aug	WP2	8:36	55.2501	15.9835	89	CLmax: 85m
EMB298-91	TF0213	13 Aug	WP2	8:45	55.2500	15.9835	89	CLmax: 85m
EMB298-91	TF0213	13 Aug	WP2	8:54	55.2498	15.9837	89	CLmax: 85m
EMB298-91	TF0213	13 Aug	WP2	9:03	55.2498	15.9839	89	CLmax: 20m
EMB298-91	TF0213	13 Aug	WP2	9:11	55.2498	15.9837	90	CLmax: 48m
EMB298-91	TF0213	13 Aug	WP2	9:22	55.2498	15.9835	89	CLmax: 85m
EMB298-91	TF0213	13 Aug	APNET	9:38	55.2498	15.9833	89	CLmax: 86m
EMB298-91	TF0213	13 Aug	APNET	10:00	55.2501	15.9832	89	CLmax: 86m
EMB298-91	TF0213	13 Aug	APNET	10:20	55.2504	15.9831	89	CLmax: 86m
EMB298-92	OCBB-3	13 Aug	CTD	13:10	55.2774	15.4358	89	CLmax: 89m
EMB298-92	OCBB-3	13 Aug	MUC	13:28	55.2773	15.4361	89	CLmax: 90m
EMB298-93	OCBB-1	13 Aug	CTD	15:21	55.4607	15.5103	84	CLmax: 84m
EMB298-93	OCBB-1	13 Aug	MUC	16:12	55.4610	15.5096	84	CLmax: 85m
EMB298-94	Peene estuary	14 Aug	CTD	3:49	54.1993	13.7865	3	Sampling by Boat
EMB298-95	TF0113	14 Aug	CTD	13:45	54.9250	13.4989	44	CLmax: 45m
EMB298-95	TF0113	14 Aug	WP2	14:15	54.9250	13.4992	44	CLmax: 41m
EMB298-96	TF0030	14 Aug	CTD	17:34	54.7235	12.7826	20	CLmax: 21m
EMB298-97	TF0046	14 Aug	CTD	20:53	54.4692	12.2407	26	CLmax: 27m
EMB298-97	TF0046	14 Aug	WP2	21:03	54.4693	12.2409	25	CLmax: 25m
EMB298-98	TF0012	15 Aug	CTD	0:15	54.3153	11.5503	22	CLmax: 23m
EMB298-98	TF0012	15 Aug	WP2	0:25	54.3149	11.5507	22	CLmax: 9m
EMB298-98	TF0012	15 Aug	WP2	0:32	54.3147	11.5512	22	CLmax: 22m

CLmax: Maximum rope/cable length
MUC: Multi Corer with 4 tubes
WP2: Plankton net with closing mechanism and removable net bucket
APNET: Apstein net
CTD: CTD rosette system with Fluorimeter, Oxygen Sensor, Water Sampler, and 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 itself will be restricted for three years after data acquisition to protect the research process, including scientific analysis and publication. After that period the data becomes openly available to any person or 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	01.10.2022	01.10.2025	volker.mohrholz@io-warnemuende.de
Nutrient data	ODIN	01.02.2023	01.02.2026	joachim.kuss@io-warnemuende.de
Zooplankton data	ODIN	01.08.2023	01.08.2026	joerg.dutz@io-warnemuende.de
Phytoplankton data	ODIN	01.08.2023	01.08.2026	anke.kremp@io-warnemuende.de

8 Acknowledgements

We thank the captain and the crew of the r/v *Elisabeth Mann Borgese* for their efforts and support during the cruise, as well as the cruise participants of the Leibniz Institute for Baltic Sea Research in Warnemünde (IOW), who carried out the measurements as part of the HELCOM's Baltic Sea monitoring program and the IOW's long-term measuring program. We are grateful to all people who helped to prepare, conduct and finalize the cruise, especially our Cruise Coordinator Johann Ruickoldt. The cruise was funded by IOW and the Federal Maritime and Hydrographic Agency in Hamburg and Rostock.

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