
# REPORT

# FROM R/V OCEANOGRAF

# RESEARCH CRUISE

**Scientific cruise leaders:**

**03.06. – 23.06.2024 Agata Weydmann-Zwolicka**

**23.06. – 05.07.2024 Ryszard Kuczyński**

# Content

## 1. Scientific background of the cruise

According to the surface circulation model, Baltic water flows out through the Danish Straits and along the Swedish coast, and part of it further flows along the coast of Norway with the Norwegian Coastal Current to the tip of the Scandinavian Peninsula, where it flows into the Barents Sea. In summer, this brackish water stays on the surface for a long time, carrying possible pollution, a relatively high load of nutrients, dissolved organic matter delivered by rivers and planktonic organisms from the Baltic Sea, enriching the fully saline Nordic Seas this way. The forecasted further freshening of the Baltic Sea in the coming century will probably intensify the observed phenomena.

The aim of the cruise was to study the physico-chemical properties of water masses, possible pollution and organisms transported from the Baltic Sea northward to the Nordic Seas.

The project idea was based on the joint scientific cruise of two Polish research vessels – OCEANOGRAF (University of Gdańsk) and OCEANIA (Institute of Oceanology Polish Academy of Sciences). We used the unique opportunity of two research vessels working in a coordinated way along the same transect, from the mouth of the Baltic Sea to the Norwegian Sub-Arctic, Lofoten. OCEANOGRAF took the coastal route, while OCEANIA went along the outer shelf.

Additionally, the cruise was among the activities of the European University of the Seas (SEA-EU), an alliance of 9 coastal European universities, including the University of Gdańsk and NORD University from Bodø.

## 2. European University of the Seas

The cruise was among the activities of the European University of the Seas (SEA-EU), which is the European Commission's European Universities initiative, an alliance of 9 coastal European universities: Cadiz, Western Brittany, Kiel, Gdańsk, Split, Malta, Algarve, Naples and NORD, as well as two Associated University Partners. SEA-EU works to co-create, together with more than 75 stakeholders, the future of European Higher Education and to enhance scientific co-operation between the SEA-EU universities, of which the planned cruise is a great example.

SEA-EU was started in 2019 with six European universities; in 2022, three new universities, including the Norwegian NORD University in Bodø, joined the alliance. This expansion of SEA-EU to the north gave impetus to research covering northern European waters and that is how the idea of the reported cruise was born.

## 3. Cruise itinerary

The complete itinerary of the cruise by r/v Oceanograf (note that sampling details are given in Chapter 4: Sampling program, materials and methods):

03.06.2024: Official beginning of the cruise in Gdynia (Poland)

03.06 – 05.06: Transit between Gdynia and Kiel [leg 1]

05.06 – 07.06: Stay in Kiel (Germany); outreach activities, embarkment of international scientific team

07.06. – 13.06: Transit and sampling between Kiel and Bergen (4 sampling stations) [leg 2]:

08.06: Sampling and measurements at station S1 (Swedish Territorial Waters)

09.06: Sampling and measurements at station S2 (Swedish Territorial Waters)

10.06: Bad weather conditions, no sampling due to strong wind and high waves

11.06: Sampling and measurements at station S3 (position changed due to strong wind and high waves), time 4:00 UTC

12.06: Sampling and measurements at station S4, time 10:15 UTC

13.06 – 14.06: Stay in Bergen; change of crew members and some members of scientific team

14.06 – 19.06: Transit and sampling between Bergen – Bodø (5 sampling stations) [leg 3]:

15.06: Sampling and measurements at station S5, time 13:40 UTC

16.06: Sampling and measurements at station S6, time 11:35 UTC

17.06: Sampling and measurements at station S7, time 8:46 UTC

18.06: Sampling and measurements at station S8, time 6:17 UTC

19.06: Sampling and measurements at station S9, time 4:35 UTC

19.06 – 23.06: Stay in Bodø; outreach activities, change of the leader of the scientific team and members

23.06. – 02.07: Transit and sampling between Bodø and Malmö (7 sampling stations) [leg 4]:

23.06: Sampling and measurements at station B0, time 19:06 UTC

25.06: Sampling and measurements at station B1, time 13:12 UTC

26.06: Sampling and measurements at station B2, time 7:35 UTC

27.06: Sampling and measurements at station B3, time 4:12 UTC

28.06: Sampling and measurements at station B4, time 2:00 UTC

29.06: Sampling and measurements at station B5, time 13:25 UTC

30.06: Sampling and measurements at station B6, time 4:50 UTC

02.07: Stay in Malmö (Sweden); outreach activities, change of some members of the scientific team

02.07. – 05.07: Transit between Malmö and Sopot [leg 5]

05.07: Official welcome in Sopot (Poland)

05.07: Back to Gdynia

## 4. Sampling program, materials and methods

The whole cruise from Gdynia (Poland) and to Bodø (Norway) and back took place between 03.06.2024 and 05.07.2024. Within the Norwegian Territorial Waters, r/v Oceanograf sampled seven stations on the way from Gdynia to Bodø between 11-06-2024 and 19-06-2024 (stations S) and seven on the way back between 23-06-2024 and 30-06-2024 (stations B) (Table 1, Fig. 1). Due to stormy conditions, some changes in timing, order and exact positions of the sampling stations had been made from the plan.

**Table 1** Sampling stations within the Norwegian Territorial Waters, sampled during the cruise of r/v Oceanograf.

| **Station no.** | **Station name** | **Sampling date** | **Latitude** | **Longitude** |
|---|---|---|---|---|
| 1. | S3 | 2024-06-11 | 57° 58,120 N | 8° 02,044 E |
| 2. | S4 | 2024-06-12 | 59° 07,102 N | 5° 17,003 E |
| 3. | S5 | 2024-06-15 | 60° 53,180 N | 4° 36,882 E |
| 4. | S6 | 2024-06-16 | 62° 46,613 N | 6° 07,689 E |
| 5. | S7 | 2024-06-17 | 64° 04,535 N | 8° 42,521 E |
| 6. | S8 | 2024-06-18 | 65° 46,212 N | 11° 19,939 E |
| 7. | S9 | 2024-06-19 | 67° 42,041 N | 13° 32,795 E |
| 8. | B0 | 2024-06-23 | 67° 12,123 N | 14° 03,800 E |
| 9. | B1 | 2024-06-25 | 64° 04,300 N | 8° 42,400 E |
| 10. | B2 | 2024-06-26 | 62° 46,365 N | 6° 07,414 E |
| 11. | B3 | 2024-06-27 | 60° 53,115 N | 4° 36,522 E |
| 12. | B4 | 2024-06-28 | 59° 05,366 N | 5° 19,147 E |
| 13. | B5 | 2024-06-29 | 57° 56,586 N | 6° 44,497 E |
| 14. | B6 | 2024-06-30 | 58° 31,230 N | 9° 12,067 E |

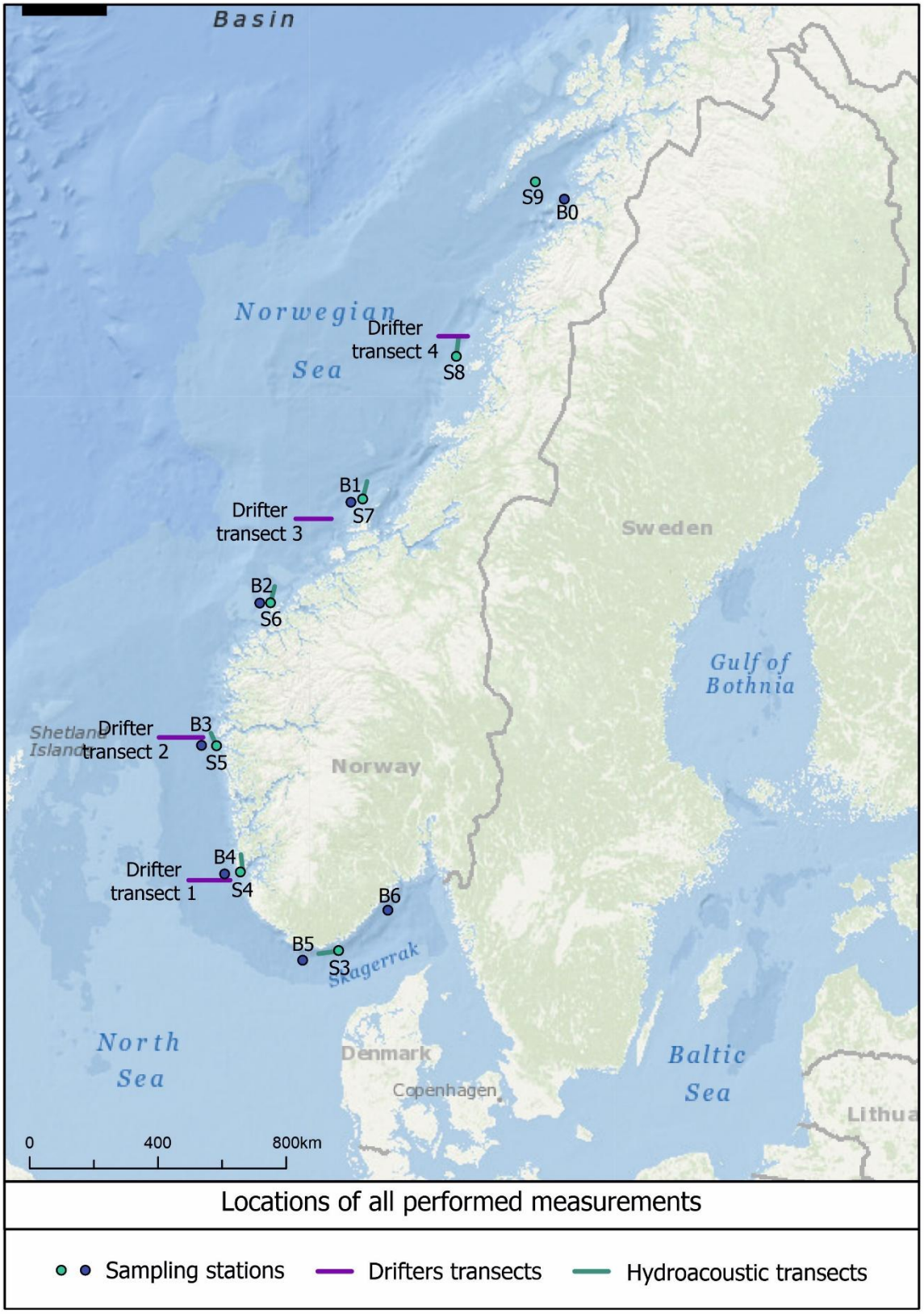


**Fig. 1** The map with marked locations of the sampling stations and measurements performed within the Norwegian Territorial Waters from r/v Oceanograf.

The scientific plan during the cruise covered three main research areas (Work Packages, WPs):

1) oceanographic conditions,
2) chemistry of seawater and atmosphere,
3) pelagic organisms.

The research was focused on describing environmental conditions in the epipelagic zone, including oceanographic conditions, the concentration of nutrients, dissolved organic matter, and marker pigments in the Baltic surface waters. We used the combined forces of an interdisciplinary research group and a magnitude of methods including the classical water column measurements and sampling at the planned stations. Sampling and oceanographic measurements was focused in the upper part of the water column, with exact depth depending on a bottom depth at a certain station and meteorological conditions. Seawater samples were collected using a bathometric Seabird rosette or 10 l Niskin bottle.

The following analyses, of which final results have been obtained, were performed in the laboratories of the University of Gdańsk and Institute of Oceanology of the Polish Academy of Sciences, as well as in the cooperating SEA-EU universities.

Please note that some samples have not been analyzed yet, so we are not able to present the complete results.

### 4.1. Oceanographic conditions

16 surface drifters were deployed along four offshore-oriented transects (Fig. 1). Table Z1 reports type of drifters, deployment coordinates and dates, drifter lifetimes.

The drifters belonged to two different categories: 10 units were CARTHE (see below) drifters provided by the Institute of Marine Science of the Italian National Research Council. They are low-cost instruments tracking currents centered 40 cm below the surface. Their design was developed by the University of Miami for the Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE; Novelli et al., 2017). They operated with Globalstar telemetry and were located every 10 minutes.

The other 16 units were CODE (see below) drifters, originally designed by Russ Davis (Scripps Institution of Oceanography, University of California at San Diego) for the Coastal Ocean Dynamics Experiment (CODE; Davis, 1985). Provided by the Parthenope University, they

track currents centered 50 cm below the surface. They operated with Iridium telemetry with location every hour.

For intercalibration and for sampling optimization, the two different kinds of drifters were deployed inhomogeneously along the four transects (see Fig. 1). CARTHE deployments were concentrated in the southernmost locations in order to take full advantage of the Globalstar primary coverage, which barely extends into the Barents Sea, whereas Iridium coverage reaches way further north.

**Table 2** Drifter deployment and last transmission details.

| | DEVICE ID | DRIFTER TYPE | DEPLOYMENT DATE AND TIME (UTC) | DEPLOYMENT COORDINATES | LAST TRANSMISSION DATE AND TIME (UTC) | LAST TRANSMISSION COORDINATES |
|---|---|---|---|---|---|---|
| TRANSECT 1 | 0-4005791 | CARTHE | 13/06/2024 - 04:20 | 60° N, 3°30' E | 22/09/2024 - 01:36:49 | 71.06° N, 28 °E |
| | 0-4705745 | CARTHE | 13/06/2024 - 06:00 | 60° N, 3°50' E | 04/08/2024 - 16:28:14 | 63.75° N, 8.66° E |
| | 0-4706824 | CARTHE | 13/06/2024 - 07:20 | 60° N, 4°10' E | 19/06/2024 - 02:32:24 | 60.37° N, 4.24° E |
| | 0-4708258 | CARTHE | 13/06/2024 - 08:45 | 60° N, 4°30' E | 20/06/2024 - 15:06:31 | 60.43° N, 4.9° E |
| TRANSECT 2 | 0-4712768 | CARTHE | 15/06/2024 - 02:05 | 61 °N, 3°55' E | 04/07/2024 - 20:11:49 | 62.95° N, 6.95° E |
| | 0-4716064 | CARTHE | 15/06/2024 - 04:00 | 61° N, 3°30' E | 12/08/2024 - 03:07:39 | 65° N, 10.85° E |
| | 0-4716076 | CARTHE | 15/06/2024 - 05:30 | 61° N, 3°04' E | 25/09/2024 - 05:31:24 | 71.82° N, 27.51° E |
| | 0-4616098 | CARTHE | 15/06/2024 - 06:58 | 61° N, 2°40' E | 31/08/2024 - 20:30:42 | 68.31° N, 15.23° E |
| TRANSECT 3 | 0-4716100 | CARTHE | 16/06/2024 - 23:51 | 63°30.1' N, 6°29.2' E | 06/09/2024 - 08:16:34 | 69.79° N, 18.12° E |
| | 300534065169240 | CODE | 17/06/2024 - 01:15 | 63°30' N, 6°50.4' E | 20/06/2024 - 15:00:00 | 63.76° N, 8.22° E |
| | 300534065162270 | CODE | 17/06/2024 - 02:18 | 63°30' N, 7°10' E | 10/07/2024 - 13:00:00 | 64.83° N, 10.73° E |
| | 0-4716101 | CARTHE | 17/06/2024 - 03:37 | 63°30' N, 7°30' E | 10/08/2024 - 00:55:00 | 64.1° N, 9.2° E |
| TRANSECT 4 | 300534066619210 | CODE | 18/06/2024 - 00:41 | 65°30' N, 9°30' E | 29/06/2024 - 04:00:00 | 66.98° N, 13.2° E |
| | 300534065163230 | CODE | 18/06/2024 - 01:43 | 65°30' N, 9°50' E | 06/07/2024 - 12:00:00 | 68.24° N, 14.62° E |
| | 300534065160240 | CODE | 18/06/2024 - 02:48 | 65°30' N, 10°10' E | 24/06/2024 - 15:00:00 | 66.77° N, 12.46° E |
| | 300534066616220 | CODE | 18/06/2024 - 03:49 | 65°30' N, 10°30' E | 06/07/2024 - 00:00:00 | 65.81° N, 11.97° E |

### 4.2. Chemistry of seawater and atmosphere

The concentration of dissolved organic carbon (DOC) in the surface (0 m) and sub-surface (25 m , and deep (50 m) water layers was measured using the high-temperature catalytic oxidation on a VarioTOC Cube (Elementar GmbH) carbon analyzer equipped with a nondispersive infrared (NDIR) detector and calculated as described in Twardowski et al. (2004) and Helms et al. (2008). The concentrations of silicate (dSi) were measured using the molybdenum blue method (Grasshoff et al., 1999). The precision of measurements (RSD) was 3.0%.

### 4.3. Pelagic organisms

For the analysis of phytoplankton community composition, abundance and biomass, water samples were taken at each sampling station according to methods recommended by HELCOM. For quantitative phytoplankton surveys, one integrated sample (200 ml) was taken at each

station from the fixed depths of 0 to 10 m using a water sampler (a Niskin bottle from the depths of 0-1 m, 2.5 m, 5 m, 7.5 m and 10 m or with a bathometric rosette). The samples were preserved with Lugol's solution. For a qualitative analysis, additional samples were taken using a hand-towed plankton net.

Additionally, the composition of the autotrophic protist pigments composition was established with use of the HPLC method based on separation chlorophylls and carotenoids present in the mixture of appropriate prepared extracts, their qualification and quantification as described in Parsons et al. 1984. The pigments were separated, qualified and quantified according to the methodology described in Stoń-Egiert and Kosakowska (2005).

To determine the variability of the backscattering properties of near-surface biological aggregates in the northern direction within the waters of the North Sea (southern coast of Norway) and the Norwegian Sea (western coast of Norway) hydroacoustic data were collected at a frequency of 120 kHz using split-beam echosounder SIMRAD EK80 operating in CW mode, along the research transects shown in Figure 1. The length of each transect was approximately 12 nautical miles. Detailed information on the individual hydroacoustic transects are presented in Table 2. The collected hydroacoustic data were analyzed using Echoview 5.4 (Myriax Software, Hobart, Tasmania) and Sonar5-Pro version 605.

**Table 3** Detailed information on the performed hydroacoustic transects.

| Transect | Latitude Start | Longitude Start | Latitude End | Longitude End | Dates and hours of data acquisition |
|---|---|---|---|---|---|
| C1 | 57°57.06″N | 07°53.23′E | 57°55.29′N | 07°28.51′E | 11.06.2024 13:55 – 16:56 |
| C2 | 59°08.19′N | 05°20.98′E | 59°22.21′N | 05°17.90′E | 12.06.2024 17:15 – 20:15 |
| C3 | 60°53.41′N | 04°36.75′E | 61°03.43′N | 04°27.59′E | 15.06.2024 19:21 – 22:23 |
| C4 | 62°46.86′N | 06°07.89′E | 62°59.18′N | 06°14.77′E | 16.06.2024 16:20 – 19:20 |
| C5 | 64°05.05′N | 08°42.76′E | 64°17.54′N | 08°50.06′E | 17.06.2024 13:15 – 16:15 |
| C6 | 65°46.36′N | 11°20.02′E | 65°58.93′N | 11°23.80′E | 18.06.2024 13:00 – 16:00 |

## 5. Results

Main results obtained within the performed three Work Packages are presented below. Moreover, we plan to publish a joint paper in a well-recognized peer-reviewed scientific journal that will cover the results from the whole cruise, from the Baltic Sea to sub-Arctic.

### 5.1 Oceanographic conditions

Drifter trajectories lasted from a few days up to three months, approximately. Their trajectories are shown in the spaghetti plot of Figure 2. All units were deployed in the coastal current, of Baltic origin. Figure 2 shows that they all tracked a swift northeastward current flowing along the Norwegian coast, the so-called Norwegian Coastal Current. Their trajectories suggest that all drifters remained confined over the continental shelf along their whole voyage, all the way up to the Barents Sea. This confirms that the Norwegian Coastal Current is well separated from the Norwegian Atlantic Slope Current, apart from possible, minor interactions between the two in correspondence of the Lofoten Escarpment.

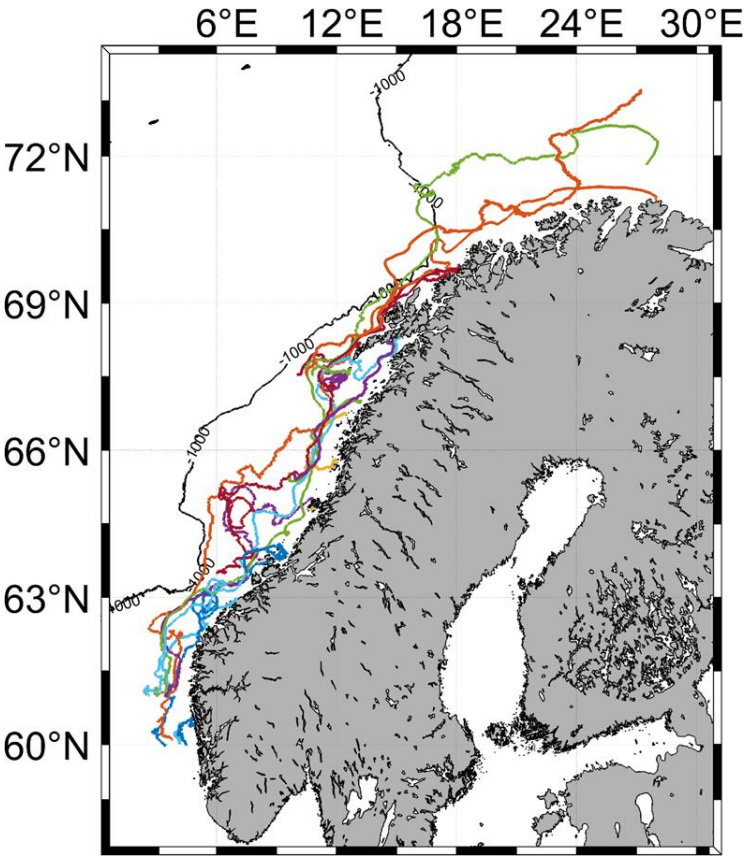


**Fig. 2** Trajectories of all drifters deployed during the experiment.

Studying oceanographic conditions and ocean currents along the way of the brackish waters from the Baltic Sea to the Nordic Seas was mainly based on the measurements of seawater physical parameters such as salinity and temperature with the use of CTD probe (Figs 3 & 4).

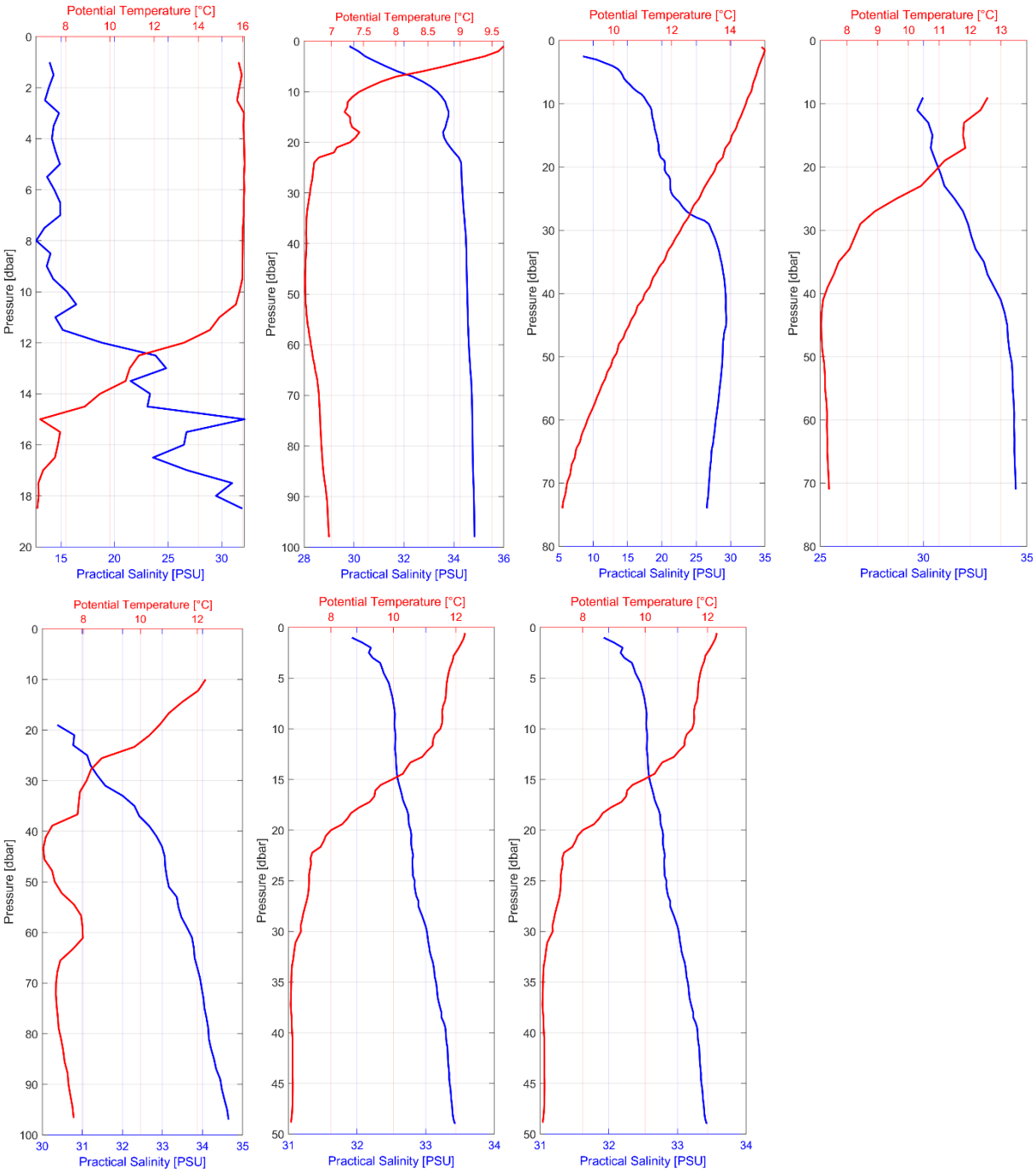


**Fig. 3** Temperature and salinity vertical profiles at stations S: S3, S4, S5, S6 (upper row) and S7, S8, S9 (lower row).

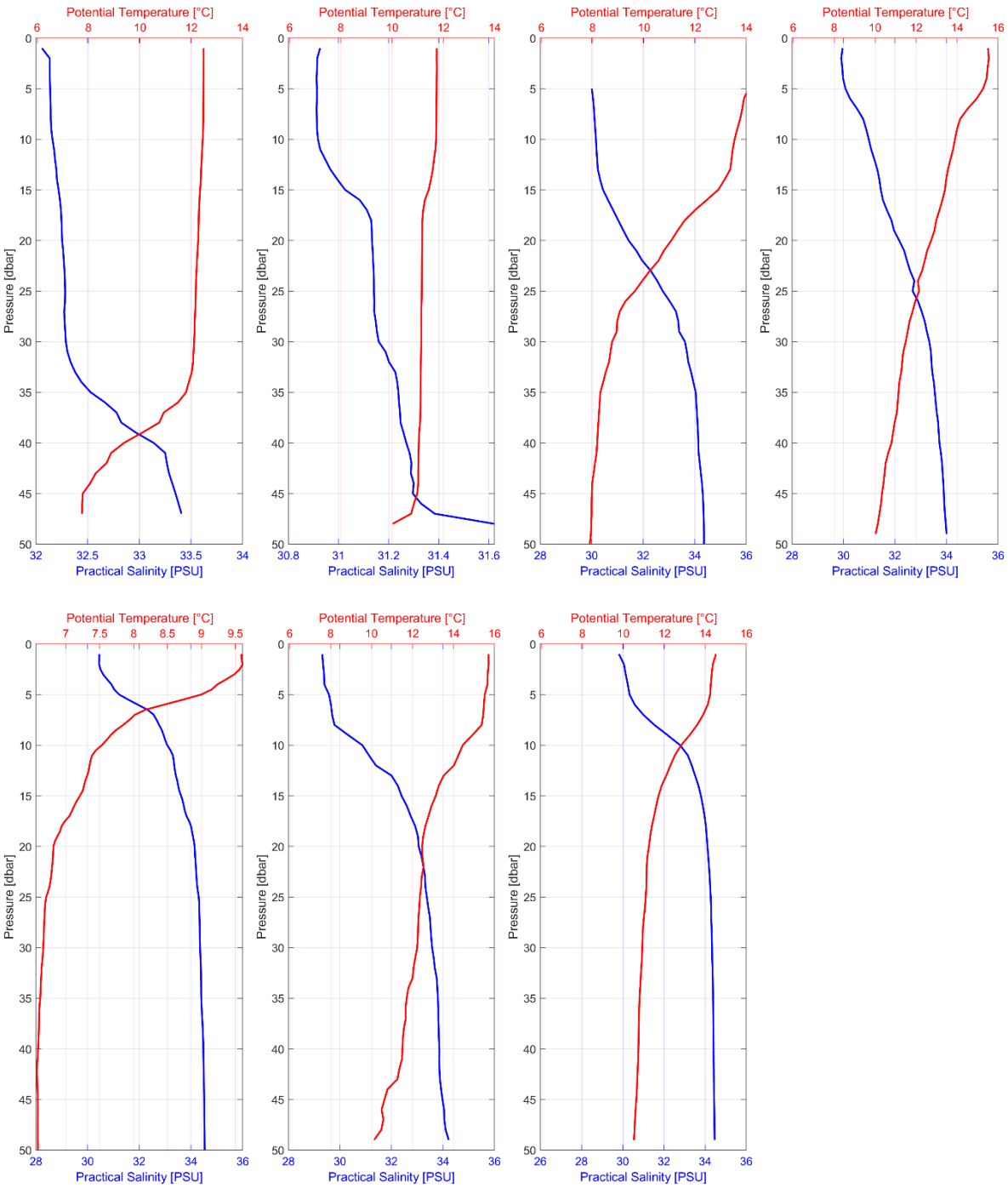


**Fig. 4** Temperature and salinity vertical profiles at stations B: B0, B1, B2, B3 (upper row) and B4, B5, B6 (lower row).

## 5.2 Chemistry of seawater and atmosphere

The highest concentrations of silicate and phosphate along the Norwegian coast were recorded in the subsurface (25 m) and deep (50 m) layers at stations S4 and S6 (Fig. 5). The concentrations of DOC varied from 120 µmol $dm^{-3}$ (50 m, station S3) to 233 µmol $dm^{-3}$ (25 m, station S9).

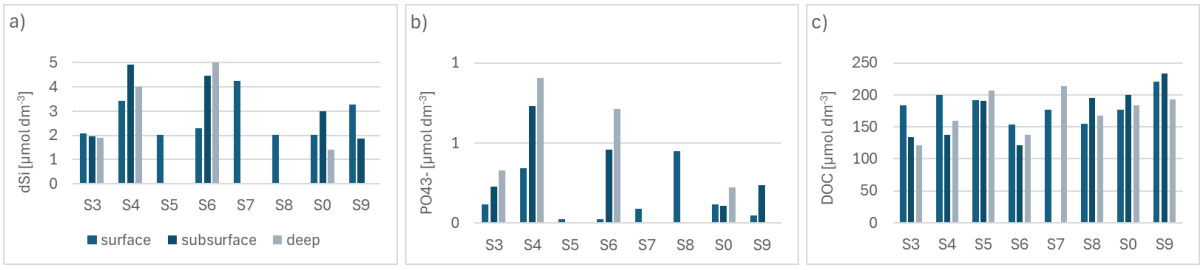


**Fig. 5** The concentrations of silicate (a), phosphate (b), and dissolved organic carbon (c) at sampling stations S3 – S9 in the depths of 1m (surface), 25m (subsurface), and 50 m (deep).

## 5.3 Pelagic organisms

To study the composition, diversity and fate of pelagic organisms transported with ocean currents from the Baltic Sea northwards, we collected phytoplankton samples and analyzed the marker pigment concentrations. The phytoplankton community biomass and composition differed at stations along the Norwegian coast, with the highest values reached at stations S4 and S5, and the dominant taxa belonging to Bacillariophyceae and Dinoflagellata (Fig. 6).

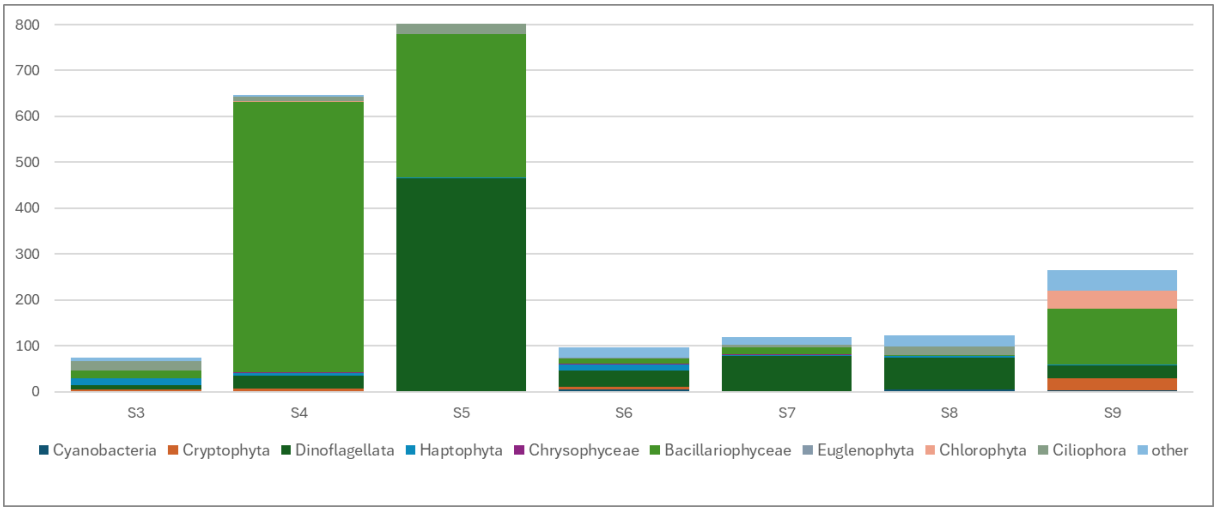


**Fig. 6** The biomass [µg $dm^{-3}$] of main taxa contributing to the phytoplankton community at stations along the Norwegian coast.

The analysis of the surface marker pigment concentrations in the surface waters (1 m), obtained by the HPLC method, confirmed the occurrence of diatoms (fucoxanthin), prochlorophytes (19'hex fucoxanthin), cryptophytes (alloxanthin) and cyanobacteria (zeaxanthin) in the phytocenosis in varying proportions between the stations along the Norwegian coast (Fig. 7).

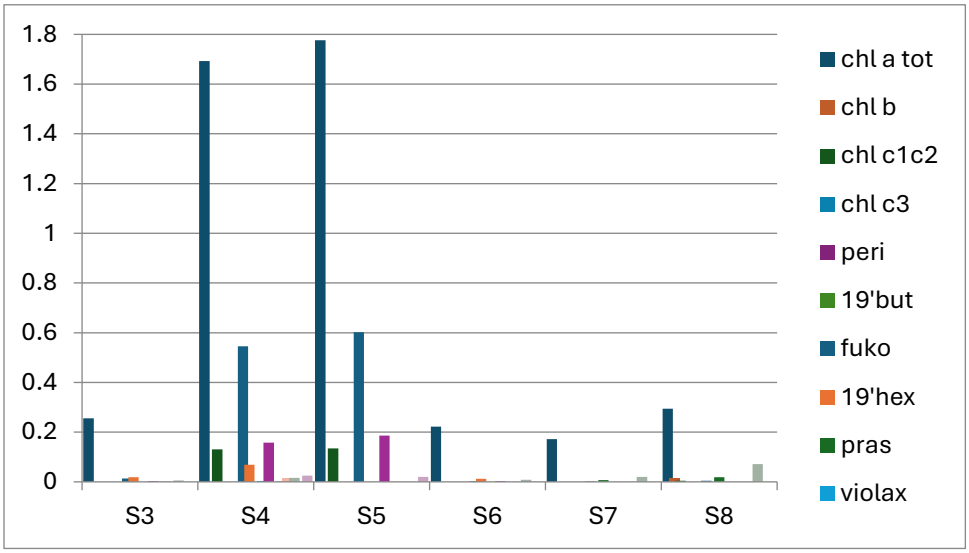


**Fig. 7** The results of the analysis of marker pigment concentrations, with pigment concentrations given in mg/L.

No trend in the average volume backscattering strength SV was observed on hydroacoustic transects conducted along the Norwegian coast close to the shoreline (Fig. 8). It is worth to remind that the volume backscattering strength depends both on the abundance of marine organisms and their individual backscattering properties, which are related to their size (e.g., for fish, backscattering increases with the individual length) (Simmonds and MacLennan, 2005). Thus, this observation may be related to the influence of fjord waters, which differ from open sea waters, and where the influence of Baltic waters is less significant.

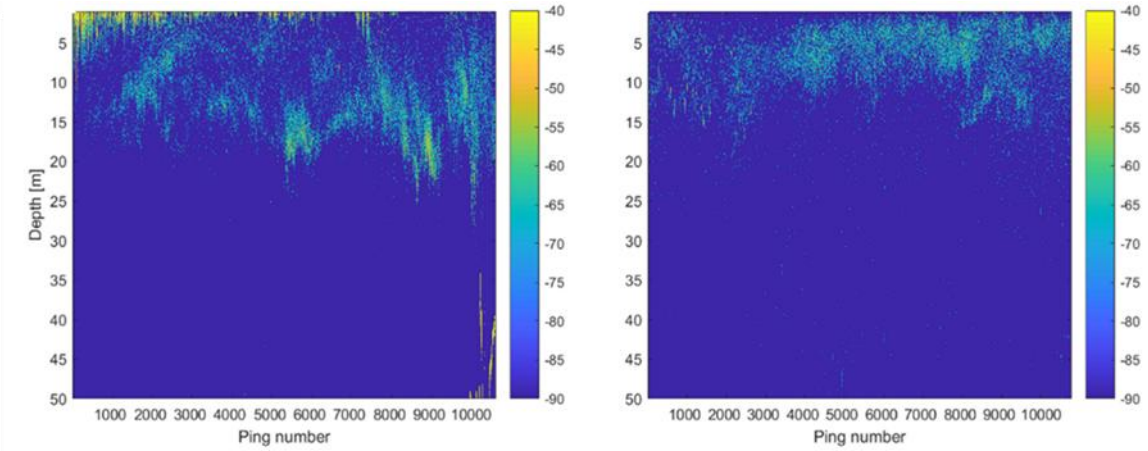


**Fig. 8** Examples of echograms for the hydroacoustic transects performed by r/v Oceanograf close to the shoreline (see Fig. 1 and Table 3 for the transects' locations).

## 6. Visited ports

Between 13.06.2024 and 14.06.2024 r/v Oceanograf visited the port of Bergen, where some scientists from the research team and ship's crew members, including the captains, changed.

Between 20.06.2024 and 23.06.2024 r/v Oceanograf visited the port of Bodø, where the international research team and the University of Gdańsk authorities were welcomed and had official meetings with the authorities of the city/port, NORD University and the European University of the Seas. There were also numerous outreach activities, including the tours of the ship for guests invited to the official welcome ceremony, as well as open tours for the students and researcher from the NORD University and Bodø citizens. Additionally, onboard r/v Oceanograf there was an exhibition WOMAN VIEW OF THE SEA, the initiative of combining scientific sea stories prepared by female researchers with the vision of female artists on the same subject, which was open for the public.

Moreover, some scientists from the r/v Oceanograf research team, including the leaders of the scientific team, changed in Bodø, too.

## 7. Acknowledgements

The cruise was organized within the activities of the European University of the Seas (SEA-EU). Dr hab. Agata Weydmann-Zwolicka was the scientific cruise leader between 03.06.2024 and 23.06.2024, and MSc Ryszard Kuczyński between 23.06.2024 and 05.07.2024.

The results presented in this report were prepared by: Enrico Zambianchi (Sapienza University of Rome, Italy; chapters 2.1 and 3.1), Daniel Rak (Institute of Oceanology Polish Academy of Sciences, chapter 3.1), Katarzyna Łukawska-Matuszewska (University of Gdańsk, chapter 3.2), Justyna Kobos (University of Gdańsk, chapter 3.3), Miłosz Grabowski (Institute of Oceanology Polish Academy of Sciences, chapter 3.3), and Joanna Stoń-Egiert (Institute of Oceanology Polish Academy of Sciences, chapter 3.3).

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