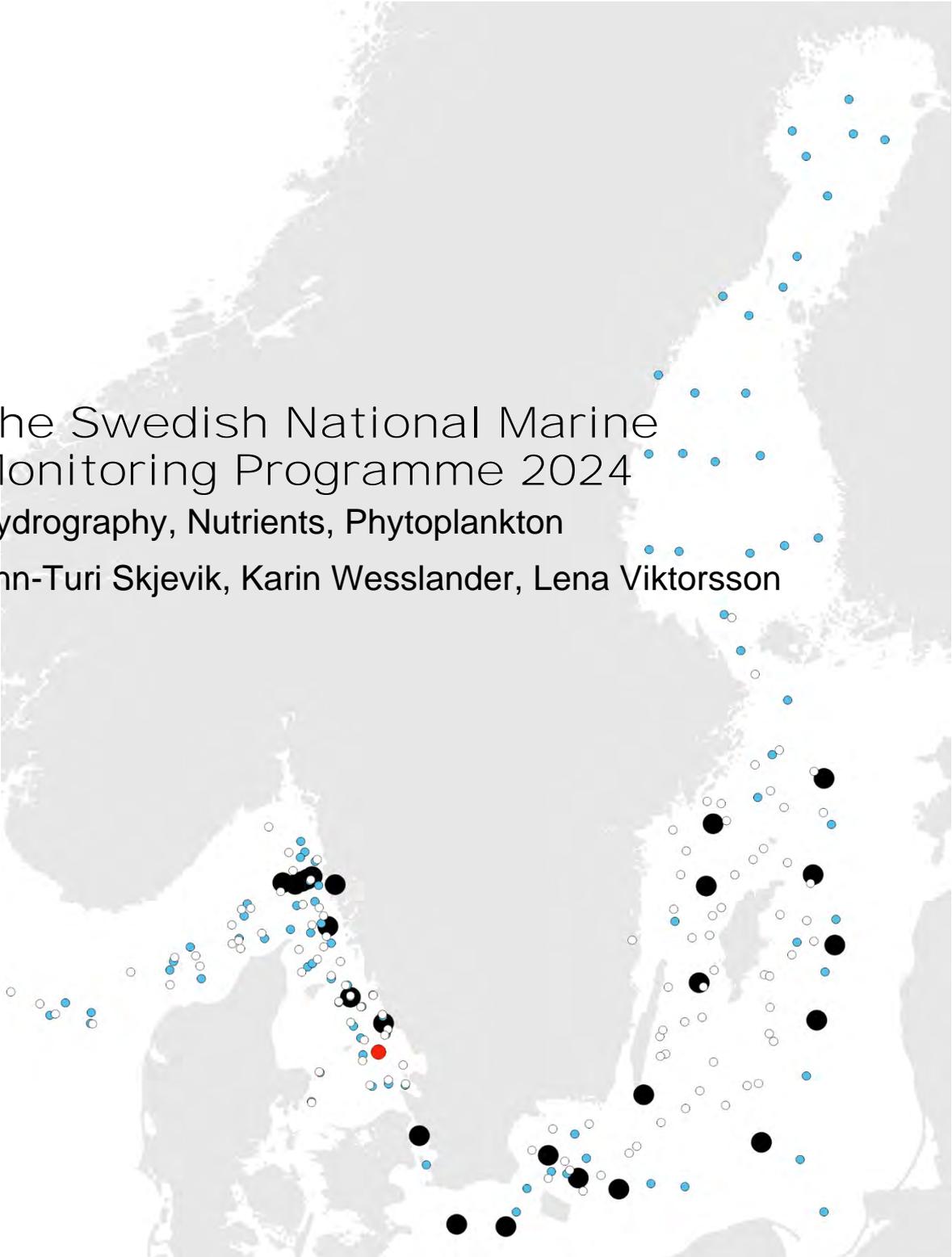


## The Swedish National Marine Monitoring Programme 2024

Hydrography, Nutrients, Phytoplankton

Ann-Turi Skjevik, Karin Wesslander, Lena Viktorsson



Front: Map of the stations visited by SMHI in the national monitoring programme in 2024. Black dots: stations visited monthly, red dots: stations visited more than 12 times, white dots: stations visited for oxygen mapping during BIAS (Baltic Proper) and during IBTS (Kattegat and Skagerrak), small blue dots: stations visited for winter nutrient.

REPORT OCEANOGRAPHY No. 81, 2025

# The Swedish National Marine Monitoring Programme 2024 Hydrography, Nutrients, Phytoplankton

Ann-Turi Skjevik, Karin Wesslander, Lena Viktorsson

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Contractor / Utförare

SMHI  
601 76 Norrköping

Contact / Kontakt

Lena Viktorsson  
011-495 80 00

---

Client / Kund

Havs- och vattenmyndigheten  
Box 11930  
404 39 Göteborg

Contact / Kontakt

Karl Norling  
010-698 60 00

[karl.norling@havochvatten.se](mailto:karl.norling@havochvatten.se)

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Author / Författare

Ann-Turi Skjevik, Karin Wesslander, Lena Viktorsson (SMHI)

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Control / Granskare

Martin Hansson, Maria-Pia Birkett, Maria Karlberg, Jörgen Öberg (SMHI)

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## Summary

Surface water temperatures across all monitored Swedish marine areas ranged from winter lows of ~2–3.5°C (January–March) to summer maxima of ~18–19°C in August. During the winter, water columns were generally well mixed down to 20–60 m depending on region, with deeper mixed layers where the halocline was deeper. Seasonal warming began in April–May, producing a summer thermocline at 10–20 m.

Oxygen conditions in the deep water varied substantially. In 2024, oxygen in both the Sound and in the Kattegat were alarmingly low with concentrations around 2 ml/l in September which is the limit for acute hypoxia. In the Baltic Sea, deep stratified basins with long-term stagnation continued to suffer from severe anoxia and elevated hydrogen sulphide, with no major inflows in 2024 to improve the situation; only a small inflow in December provided limited local effects. Deep-water salinity and temperature remained near constant throughout the year where stratification prevented mixing.

The spring bloom occurred between February–March in the Skagerrak and the Kattegat and between March–April in the Baltic Proper. The DIN in the surface water was depleted in May in the Baltic Proper and in April in the Skagerrak and Kattegat. Phosphate reached annual minima during summer but rarely reached full depletion in the Baltic Proper.

In the Skagerrak and Kattegat, the winter biomass was low and dominated by diatoms. The spring bloom occurred in February–March in the Kattegat but was weaker and started later in the Skagerrak. A minor *Pseudochattonella* event occurred at Släggö in March. Summer biomasses were generally low. In June, a diatom bloom occurred at both the Kattegat stations and station Å17. During autumn diatom blooms occurred, (coccolithophorid and dictyophyceae), with highest biomasses in the Kattegat.

In the Baltic Proper, the spring bloom was dominated by diatoms (*Skeletonema*, *Peridiniella*) and Aphanizomenon filaments were present early in the year. In May–June, species diversity increased, including potentially toxic *Dinophysis acuminata*, *Mesodinium rubrum* and all three major filamentous cyanobacteria (*Aphanizomenon*, *Nodularia* and *Dolichospermum*). Summer brought surface accumulations of cyanobacteria, especially in the southeastern Baltic, dominated by *Nodularia*. Chlorophyll was elevated at many stations. Autumn saw declining cyanobacteria but strong diatom presence in the south, with marine species (*Dactyliosolen*, *Cerataulina*) being abundant.

## Sammanfattning

Ytvattentemperaturen i alla övervakade svenska havsområden varierade från vinterminimum på cirka 2–3,5°C (januari–mars) till sommarmaximum på omkring 18–19°C i augusti. Under vintern var vattenpelaren generellt väl omblandad ned till 20–60 meters djup beroende på område, med djupare blandningslager där haloklinen låg djupare. Den säsongsmässiga uppvärmningen började i april–maj och gav upphov till en sommartermoklin på 10–20 meters djup.

Syreförhållandena i djupvattnet varierade kraftigt. I både Öresund och Kattegatt var syrenivåerna alarmerande låga under 2024, runt 2 ml/l i september, vilket motsvarar gränsen för akut hypoxi. Allvarlig anoxi och höga svavelvätehalter dominerade fortsatt de djupa och långvarigt stagnanta bassängerna i Östersjön. Inga större inflöden inträffade och det lilla inflödet i december gav endast begränsade lokala effekter. Djupvattnets salthalt och temperatur var nära konstant över året där skiktningen förhindrade omblandning.

Vårblomningen inträffade under februari–mars i Skagerrak och Kattegatt och under mars–april i Egentliga Östersjön. DIN i ytvattnet var uttömt i april på västkusten och i maj i Egentliga Östersjön. Fosfat nådde sina årliga minimum under sommaren men blev sällan helt uttömt i Egentliga Östersjön.

I Skagerrak och Kattegatt var den totala biomassan låg under vintern och dominerades då av kiselalger. En mindre *Pseudochattonella*-händelse noterades vid Släggö i mars. På sommaren var biomassan generellt låg. En kiselalgsblomning förekom i juni vid båda stationerna i Kattegatt och vid stationen Å17 i Skagerrak. Under hösten observerades blomningar av kiselalger (kalkflagellater och kiselflagellater) med högst biomassa i Kattegatt.

I Egentliga Östersjön dominerades vårblomningen av kiselalger (*Skeletonema*, *Peridiniella*) och *Aphanizomenon*-filament förekom tidigt. Under maj–juni ökade artdiversiteten och inkluderade potentiellt toxiska *Dinophysis acuminata*, *Mesodinium rubrum* och alla tre stora trådbildande cyanobakterier (*Aphanizomenon*, *Nodularia*, *Dolichospermum*). Sommaren medförde ytansamlingar av cyanobakterier, särskilt i sydöstra Östersjön, dominerade av *Nodularia*. Klorofyllhalten var förhöjda vid många stationer. Under hösten minskade cyanobakterierna, men kiselalger var fortsatt talrika i söder, där marina arter (*Dactyliosolen*, *Cerataulina*) blev vanliga.

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**Appendix I** Seasonal plots for each station. Data from 2024 are averaged for the surface layer, 0-10 m.

**Appendix II** Time series for each station. Data from the surface layer and bottom layer are presented for the time period 1960-2024.

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## 1 The monitoring programme – history and development

The current Swedish marine monitoring programme of the pelagic zone started in 1994 after a major revision in 1991, with only smaller changes after that. Historically, the marine programme in Sweden focused on fisheries and hydrography, while biological parameters were added later. Since the end of the 1970's focus of the programme has been eutrophication and oxygen deficiency. Phytoplankton and chlorophyll were added in the 1980's and extended zooplankton sampling was introduced in 2007. Data from the Swedish marine monitoring is widely used in research and management for e.g. trend analysis, modelling, climate studies and assessments for EU directives such as the Water Framework Directive 2000/60/EC (WFD)<sup>1</sup> and the Marine Strategy Framework Directive 2008/56/EC (MSFD)<sup>2</sup>. The long time series with high quality data from fixed positions has been essential for the understanding of the Swedish seas and development of the current models used for both research and management of our open seas.

In 1991 SMHI published an investigation of the Swedish marine monitoring programme, the corresponding station network and sampling frequency (Rahm et al 1991<sup>3</sup>). In 1992 an international evaluation panel recommended implementation of the changes suggested by SMHI (SNV Report 4170<sup>4</sup>) and a revised monitoring programme started in 1994. This led to significant changes, mainly in the frequency of cruises. The number of cruises increased while the number of stations decreased. This was mainly done to achieve time series with a frequency and length that is suitable for trend analysis. The current program consists of 36 standard stations of which four are sampled 24 times per year and 32 are sampled 10-12 times per year (10 times per year in the Gulf of Bothnia). The high frequency stations (sampled 24 times per year) were introduced to better monitor changes in biological parameters which change rapidly, especially during spring and summer.

In addition to the monthly and high frequency stations, a denser network of stations was determined to map winter nutrient pools, to allow estimates of the potential spring phytoplankton production. Winter nutrient mapping is normally done in the Skagerrak and the Kattegat in January and in the Baltic Proper in February, while in the Gulf of Bothnia mapping has usually been performed in December. Nutrient mapping in the Skagerrak is done during the International Bottom Trawl Survey (IBTS Q1, quarter 1) and positions for sampling vary from year to year.

In the Kattegat and the Baltic Proper, where oxygen deficiency had been documented during parts of the year, an autumn mapping of oxygen was implemented as part of the revision of the programme in 1994. For the oxygen mapping there are no fixed stations, instead the sampling stations vary from year to year. The oxygen mapping is performed in combination with fisheries cruises led by the Swedish University of Agricultural Sciences (SLU). In the Baltic Sea oxygen is mapped during the Baltic International Acoustic Surveys (BIAS) programme in September-October, while the oxygen mapping in the Kattegat is done during the IBTS Q3 (quarter 3). The oxygen mapping, with focus on the deep water, is performed during the autumn when the most severe oxygen deficiency occurs. Since many countries around the Baltic Sea also perform BIAS-cruises in their national waters and take oxygen samples during

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<sup>1</sup> [Water Framework Directive](#)

<sup>2</sup> [Marine Strategy Framework Directive](#)

<sup>3</sup> Rahm L., Sjöberg B., Håkansson B., Andersson L., Fogelqvist E., 1991. *Utredning om Optimering av utsjö-monitoringprogrammet vid SMHI.*

<sup>4</sup> Report / Swedish Environmental Protection Agency, ISSN: 0282-7298 ; 4170, 1993. *Swedish National Marine Monitoring Programme, Report of an Evaluation Panel.* Stored at the library of SwAM.

these cruises, the coverage of autumn oxygen data is generally good and the combined results from all countries are presented in a separate annual SMHI report on the oxygen situation<sup>5</sup>. The good spatial resolution of oxygen data during the most severe period of the year is essential for the calculations of the maximum extent of anoxic and hypoxic bottoms in the Baltic Sea.

In recent years coastal stations have been added to the programme. In 2007 the coastal stations N14 Falkenberg (Kattegatt) and Ref M1V1 (Baltic Proper) was added to support the work associated with the EU Water Frame Work Directory. The latter station was excluded from the program and replaced by the station BY39 Ölands södra udde in 2023. This replacement station is part of the winter monitoring and represent the transition area between the Western Gotland Basin and the Hanö Bay/Bornholm Basin. Recently two stations have been added to monitor the gradient from the Gullmar fjord to the open sea, the station Alsbäck (in the fjord) and BroA (outside the sill). Together with the station Släggö they represent the gradient from fjord to archipelago. However, due to budget cuts BroA was removed again in 2023. Furthermore, additional stations have been added to represent a gradient from coast to open sea in the Baltic Proper, where the station H4 in Himmerfjärden together with B1 and BY31 represent the gradient in this region. In the Bothnian Sea two coastal stations have been added, U19 Norra Randen (NR) north of Stockholm and Gavik-1 in the northern part of the Bothnian Sea. In the Bothnian Bay two stations have been added, Råneå-1 and Råneå-2. A full description of the current national monitoring programme of the pelagic zone is published, in Swedish, by the Swedish Agency for Marine and Water Management<sup>6</sup>.

In addition to the national pelagic programme, municipalities and counties perform monitoring in coastal waters. Oceanographic data is also collected from platforms that are not part of the national monitoring program. These platforms include four smaller wave buoys (Väderöarna, Brofjorden, Knolls grund and Finngrundet), three coastal buoys (Koster fjord (GU), Norrbyn (UmU) and Askö (SU)), one offshore buoy (Huvudskär) and two ferryboxes (R/V Svea and Tavastland). One cabled platform is operational in the Sound between Denmark and Sweden (Flinten 7). SMHI and the Swedish maritime administration are responsible for a network of stations measuring sea water level and many of these stations also measure surface water temperature.

The first oceanographic measurements in Swedish waters were performed on the initiative of Gustaf Ekman who in 1877 initiated a mapping of all Swedish seas with the warships HMS Alfhild and HMS Gustaf af Klint. The data from this first mapping was not analysed until 1901 by Otto Pettersson, who was the permanent secretary of the Hydrographic-Biologic Commission 1901-1930 and the initiator of the formation of the International Council for the Exploration of the Sea (ICES). In 1948 the Hydrographic-biologic commission became the National Board of Fisheries (Fiskeristyrelsen) with the main purpose to explain which oceanographic conditions controlled the variations in herring stocks. The first Swedish research vessel R/V Skagerrak I was used and mainly salinity, temperature and oxygen were measured. Stations were sampled during 1-2 cruises per year and after a few years alkalinity and pH measurements were added. In the 1950's, the frequency of cruises increased and from 1958 the Swedish monitoring became part of an internationally coordinated sampling effort. During the 1960's nutrients entered the picture; first phosphorus, then nitrogen and finally silica. However, the frequency was still variable between years. During some periods the

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<sup>5</sup> [Hansson M., Viktorsson L., Oxygen Survey in the Baltic Sea 2024 - Extent of Anoxia and Hypoxia, 1960-2024, REPORT OCEANOGRAPHY No. 80, 2025](#)

<sup>6</sup> [Beskrivning av delprogrammet Fria vattenmassan version 3:1 2019-02-04, Havs- och vattenmyndigheten](#)

measurements were only performed during summer, in other periods only in spring. Thus, creating continuous time series and trend analyses from this data was difficult to achieve. Furthermore, conditions are more stable in the deep basins of the Baltic Sea than in the surface waters, so for these areas data from the deep basins are better suited for long trend analysis. Although the frequency still varied between one and three visits per year, the network of stations was roughly the same as today. At the end of the 1960's monitoring became more structured. The Skagerrak and the fjords were visited 4 times per year, the Kattegat and the Sound five times per year, the Baltic Proper four times per year and the Bothnian Bay two times per year. Sampling included both physical and chemical parameters as well as biological, including benthic fauna.

1969-1970 was the International Baltic Year, thus many of the stations still have names starting with BY. In 1978 the Programme for Environmental Control (Programmet för Miljökontroll, PMK) started and the following year HELCOM started the Baltic Monitoring Programme (BMP). The Swedish commitment in BMP 1979 included nutrients, oxygen, salinity and temperature and all countries around the Baltic Sea shared the data. The programme continued until 1993 when it was revised as described. The current programme is part of Sweden's commitment within HELCOM and OSPAR.

## 2 Performance in 2024 and description of the current programme

This report describes the results of the data collected by SMHI within the monitoring program and covers monthly stations in the Skagerrak, the Kattegat and the Baltic Proper, winter nutrient surveys in the same regions and the Gulf of Bothnia as well as oxygen surveys in the Baltic Proper and the Kattegat. The oxygen surveys (August-October) and the winter nutrient mapping was performed during the fisheries cruises by SLU-aqua (IBTS Q1, IBTS Q3 and BIAS).

The stations sampled in 2024 are shown in Figure 1. The number of visits to the standard stations during 2024 is presented in Figure 2. Some station visits in the Skagerrak had to be cancelled due to bad weather in January, April and December 2024, see Figure 2. Due to security reasons three stations in the Eastern Gotland basin were cancelled in April and BY13 was visited as a replacement for BY15. During the winter nutrient survey of the Baltic the two stations in the mouth of the Gulf of Finland had to be cancelled due to time limitations. The CTD-profiles acquired by the ship-board CTD at the stations Å14 and Å16 in the Skagerrak are currently being replaced by CTD-profiles acquired by the Moving Vessel Profiler (MVP) on R/V Svea, thus these profiles are not included in the result presented in Figure 2. During most cruises there are complementary CTD-profiles every 5<sup>th</sup> minute from the stations Å13-Å17, also referred to as the Å-transect. The number of visits to the station Anholt E in the Kattegat decreased from 24 to 17, since this station is only sampled bi-monthly. This occurs when the SMHI cruise with R/V Svea starts and ends in Lysekil and during the IBTS cruises in February and August/September.

In December 2021 SMHI and Umeå Marine Sciences Centre (UMSC) performed a joint cruise onboard R/V Svea as a test which resulted in a successful and now a well-established cooperation. This cruise cover both the stations in the nutrient survey of the Gulf of Bothnia as well as the regular monthly sampling from the UMSC part of the national programme. In 2024, pH and alkalinity sampling were added to five of the stations; two in the Skagerrak, one in the Kattegat and two in the Baltic Proper. Simultaneously, depth resolution decreased at the previously sampled stations. This change was implemented to improve the monitoring of the carbonate system. pH was measured only with the spectrophotometric method at these added locations whereas at the previously sampled stations, pH was measured with both a pH electrode and the spectrophotometric method.

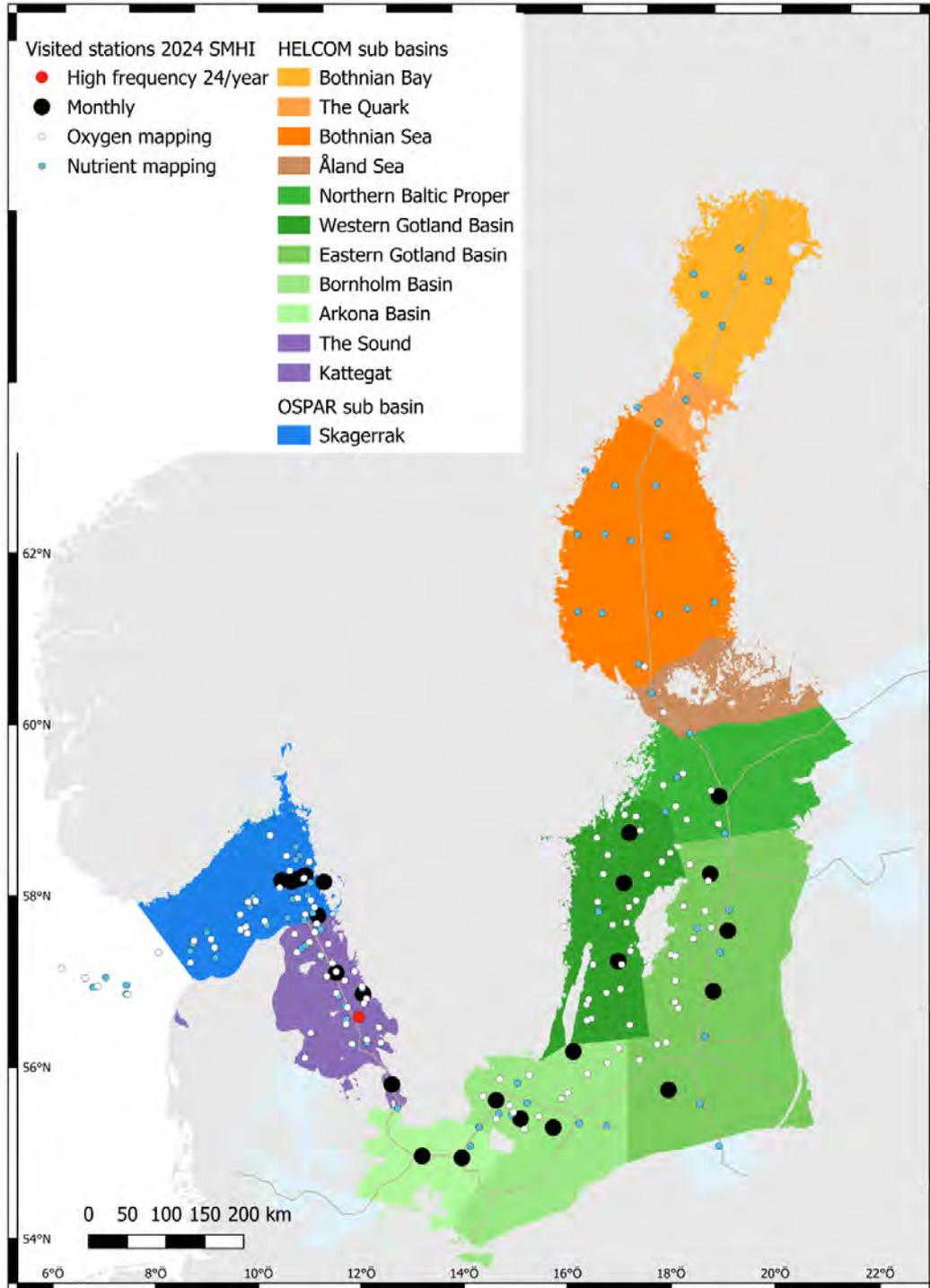


Figure 1. Map of the stations visited by SMHI in the national monitoring programme in 2024. Black large dots: stations visited monthly, red dots: stations visited more than 12 times, white dots: stations visited for oxygen mapping at BIAS (Baltic Proper) and IBTS (Kattegat and Skagerrak), small blue dots: stations visited for winter nutrient mapping.

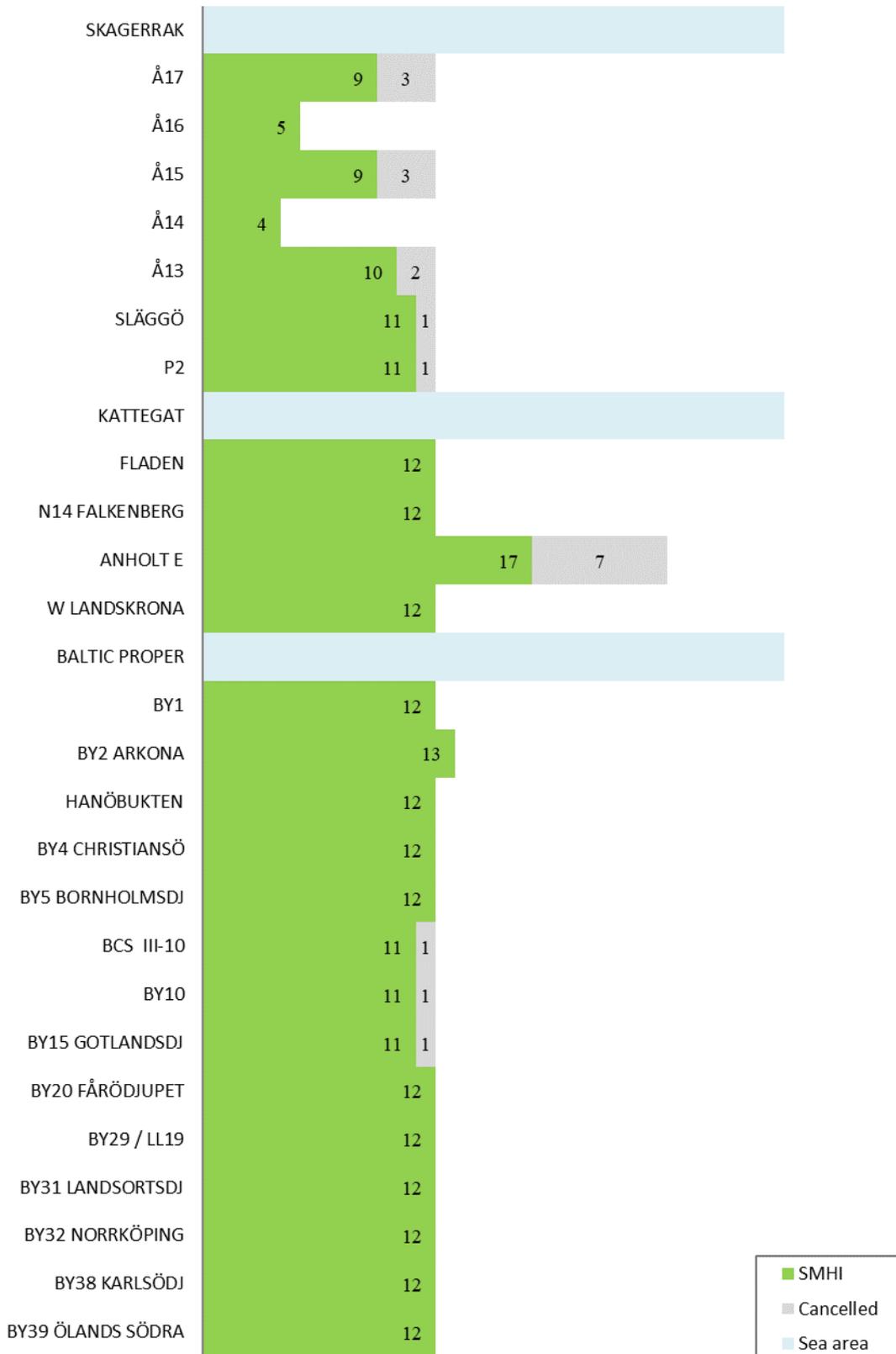


Figure 2. Number of visits at each standard monitoring station in 2024. Only SMHI standard stations are shown. In addition, mapping stations were visited in December (Bothnian Sea and Bothnian Bay), January (Skagerrak and Kattegat), and February (Baltic Proper).

### 3 Oceanographic conditions

Annual cycles of the surface water (0-10m) in 2024 and time series from 1960-2024 are presented in Appendices I and II. In the text, reference to normal condition or normal values refer to the average +/- one standard deviation for the period 1991-2020. There is additional material, such as vertical profiles for each station sampled by SMHI, in the cruise reports available at the SMHI webpage<sup>7</sup>.

Large variations, especially in salinity, generates different characteristics of the Swedish seas, see Figure 3. The Skagerrak generally has almost open ocean salinities >30 psu. Closer to the Swedish western coast, salinities are lower due to river runoff and outflowing Baltic water. The Baltic Proper has typical fjord-like hydrography with a strong stratification separating the deep water from the surface water. This makes the Baltic Proper sensitive to excessive nutrient input, leading to a eutrophic state and oxygen deficiency in the deep basins. The Gulf of Bothnia is less saline with salinities <7 psu. It is an oligotrophic sea with different nutrient levels and ratios compared to the Baltic Proper.

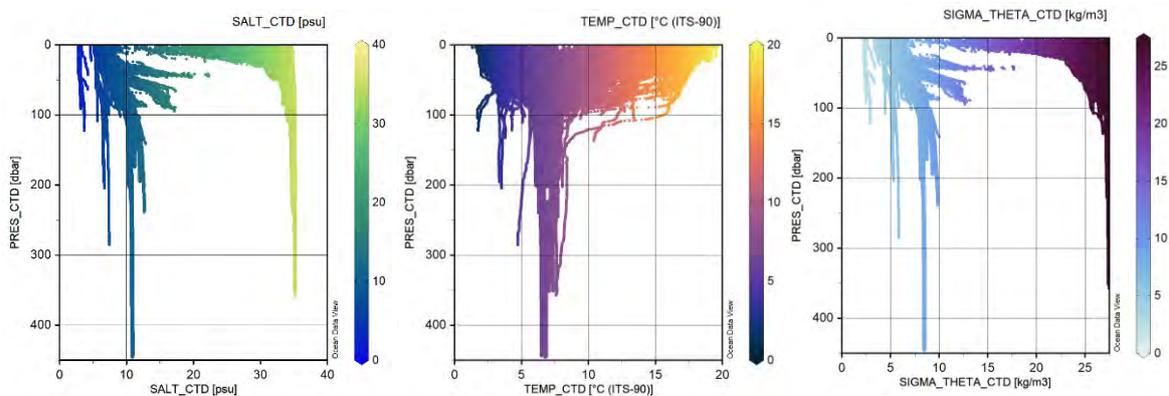


Figure 3. All temperature, salinity and density profiles from the SMHI monitoring cruises in 2024.

To illustrate the large variation in the seas surrounding Sweden, a selection of parameters at stations from the various sea areas are presented in Figure 4. Here, mean values in the surface water (0-10 m) at each sampling occasion in 2024 are shown. Besides the difference in salinity, other parameters also vary between the areas. For example, the various onset of the spring bloom can be seen from the chlorophyll and inorganic nutrients concentrations.

<sup>7</sup> [Cruise reports from SMHI](#)

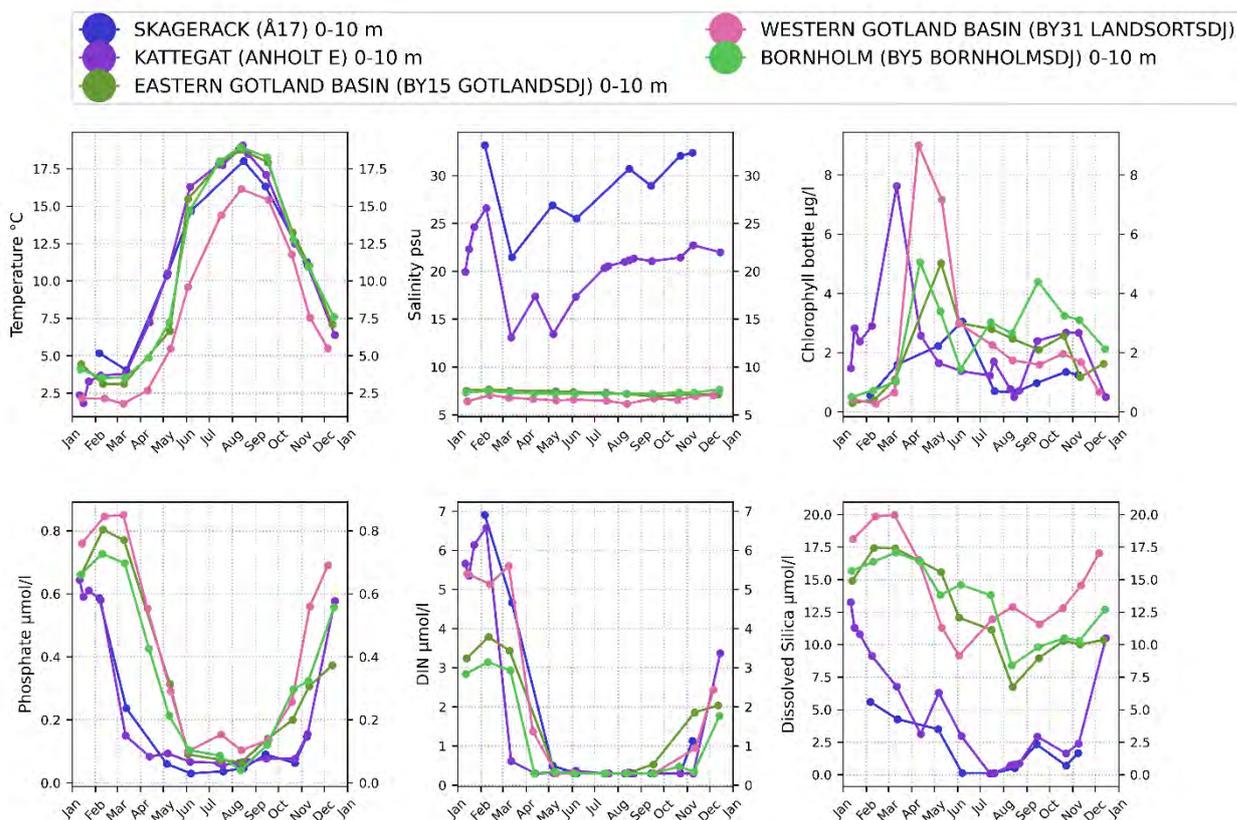


Figure 4. Temperature, salinity, chlorophyll, phosphate, dissolved inorganic nitrogen and dissolved silica from the various sea areas around Sweden: the Skagerrak (Å17), the Kattegat (Anholt E), the Eastern Gotland Basin (BY15), the Western Gotland Basin (BY31) and the Bornholm Basin (BY5). All parameters are mean values of surface water (0-10 m) from 2024.

### 3.1 Skagerrak, Kattegat, and the Sound

#### 3.1.1 Temperature and salinity

In the Skagerrak, the Kattegat and the Sound, along the Swedish coast, the surface water, 0-10 m, was coldest in January when the temperature dropped to 2-2.5°C. At the coastal station Släggö it was even colder, with a temperature measurement of 1.7°C in January. In February, temperatures increased to above normal and in March it returned to normal values again. Normal temperatures prevailed until June when it became warmer than normal in Kattegat. The rest of the summer had normal temperatures and the maximum was observed in August with surface temperatures reaching 18-19°C. The cooling of the surface water progressed for the rest of the year and in December temperatures had dropped to 6-7°C which is normal.

The salinity of the surface water varied from the lowest in spring, with values of 20 psu in the Skagerrak and 13-18 psu in the Kattegat. The highest values occurred in the beginning of the year, with values of 33.5 psu in in the Skagerrak and 25-30 psu the Kattegat. In March, the salinity was below normal at all stations.

The conditions in the Sound are strongly affected by the water exchange between the Baltic Sea and the Kattegat, which is reflected in the salinity, which has no seasonal pattern. The salinity in the Sound varied between 7.5 psu and 22 psu.

The stratification in the upper layer along the stations in the Å-transect in Skagerrak depends largely on the east-west position of the Baltic current that brings water with less salinity from the Baltic Sea. Hence, even though the five monitoring stations along the transect are located close to each other, large variations are seen especially in the surface water. However, in the beginning of the year, the surface water was generally well-mixed down to 20-30 meters and

as the surface water heated, a thermocline was developed. In June, the thermocline was at its shallowest, 10 meters, and coincided with a shallow halocline. As summer continued, a larger water layer heated and the depth of the thermocline increased. After the temperature peak in August the surface water started to cool down. For the rest of the year there was a layer of warmer water below the surface layer remaining from the summer.

There are typically small seasonal variations in the deep waters of the Skagerrak. This due to the effects of weather events such as fluctuations in air temperature and wind mixing, which does not reach far below the surface layer. Along the Å-transect, below 100 meters, the temperature was around 7-8°C, and the salinity around 35 psu throughout the year. In the Kattegat, which is shallower than the Skagerrak, the seasonal variations in the deep water resemble those at comparable depths in the Skagerrak. The conditions were most stable below 40 meters, with temperatures ranging between 5-13°C and salinity between 33-34.5 psu.

Figure 5 below presents monthly measurements from one station each in the Kattegat, the Skagerrak and the Sound.

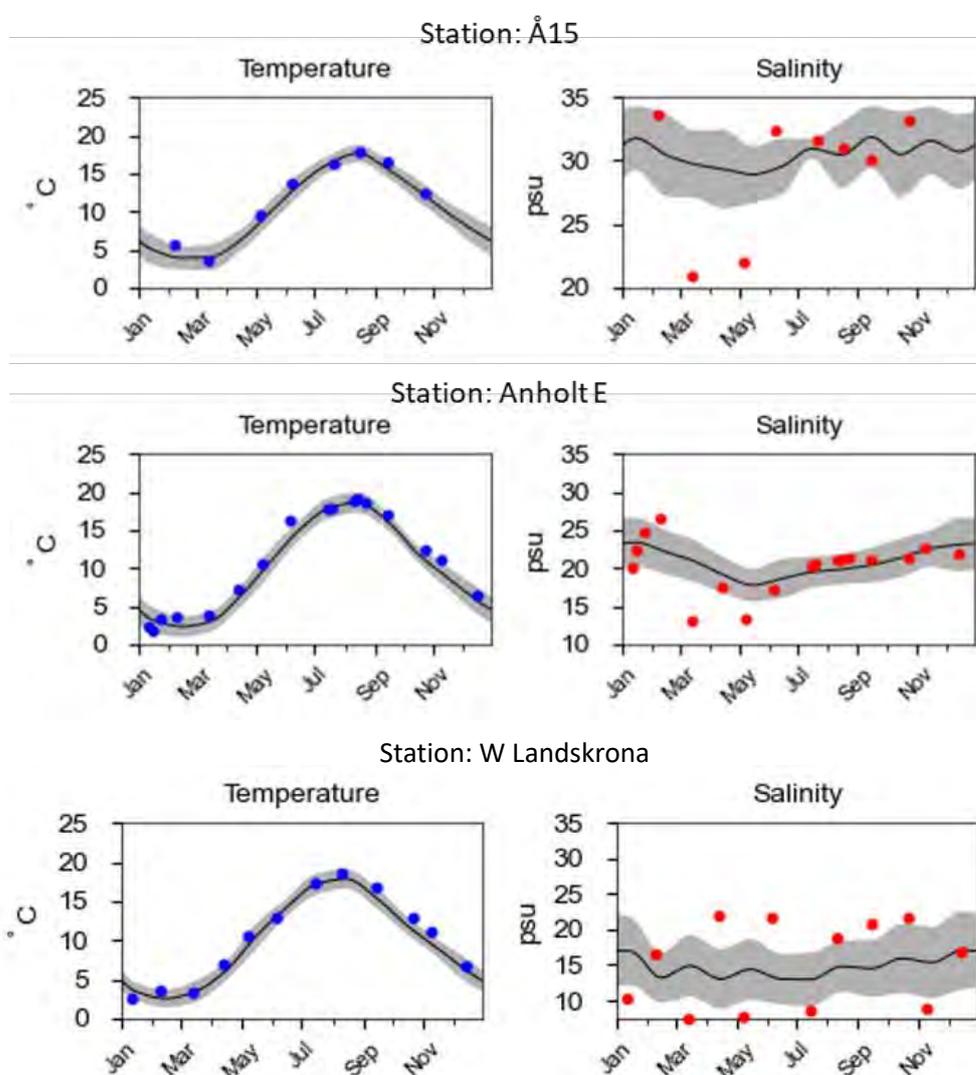


Figure 5 Surface(0-10 m) temperature (left) and salinity (right) at Å15 in the Skagerrak (upper panel), Anholt E in the Kattegat (middle panel) and W Landskrona in the Sound (lower panel). Monthly measurements (dots) throughout 2024 are shown in relation to the average value for the period 1991-2020 (black line) and +/- 1 standard deviation (grey area).

### 3.1.2 Oxygen conditions in the bottom water

In the open sea parts of the Skagerrak, the bottom water oxygen conditions are generally good. This was also the case in 2024. Along the Å-transect, the water depth varies from 100 to 350 meters, and the oxygen concentration was around 6 ml/l with only minor seasonal variations linked to temperature variation. At the coastal station Släggö, with water depth shallower than ~70 meters, larger variations occur in the bottom water, and the oxygen concentration can drop to 2 ml/l during autumn. In 2024, the lowest concentration of oxygen in the bottom water was around 3 ml/l from July-October with the lowest observation in October when it was 2.7 ml/l, see Figure 6.

In the Kattegat and the Sound, there are greater variations in the bottom water compared to the Skagerrak, and the lowest concentrations are usually observed during autumn. Since the Kattegat is relatively shallow, with an average depth of 50 meters, and has a significant water exchange, the water tends to mix or be replaced during autumn and winter. At the end of summer in 2024 oxygen levels in both the Sound and in the Kattegat were alarmingly low. At the end of summer hypoxia occurred at all stations south of Läsö in the Kattegat (concentrations between 3.0-3.5 ml/l). At two coastal stations (W Landskrona and Yttre Laholmsbukten) the concentration was below the limit for acute hypoxia (2 ml/l), where the low oxygen concentration severely affects the benthic fauna. Figure 6 shows the annual cycles of bottom water oxygen at stations Anholt E and W Landskrona. At the station Anholt E, it was 2.51 ml/l and at station W Landskrona in the Sound, it was 1.81 ml/l.

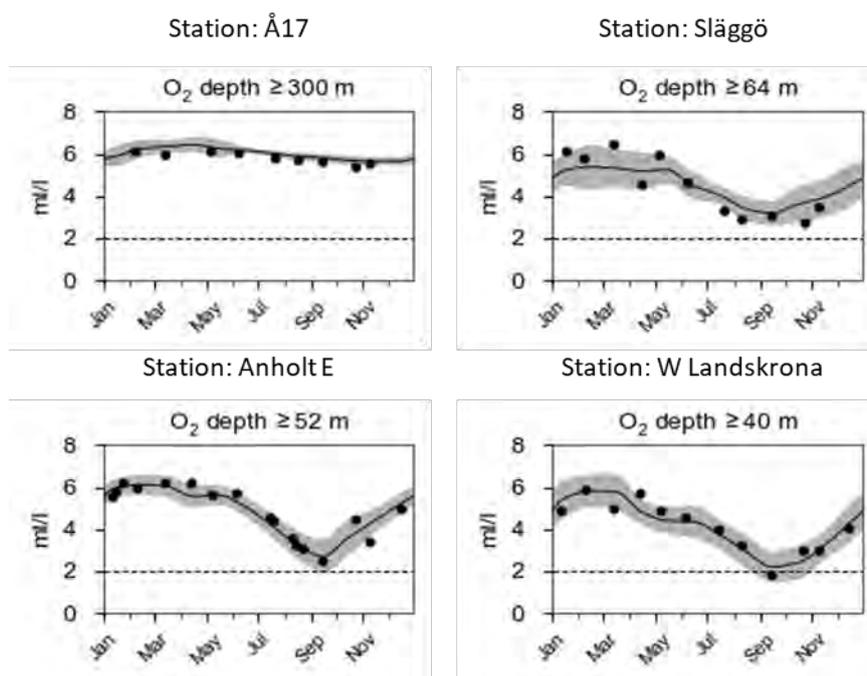


Figure 6. Concentration of oxygen in the bottom water at the open sea stations Å17 in the Skagerrak and Anholt E in the Kattegat and at the coastal station Släggö in the Skagerrak and W Landskrona in the Sound. Monthly measurements (circles) from 2024 are shown in relation to average values for the period 1991-2020 (black line) and  $\pm 1$  standard deviation (grey area).

### 3.1.3 Nutrients

The spring bloom of 2024 occurred between February and March in both the Skagerrak and the Kattegat. At the beginning of the year, the concentration of both total and inorganic nitrogen in the surface water was within normal ranges, while total phosphorus and phosphate were close to, or above their normal concentration. In February, many stations in the Skagerrak showed a peak in surface water nitrate concentration. The highest value was measured at station P2 with 13  $\mu\text{mol/l}$ , which is about 3 standard deviations above the median

value. Figure 7 presents the annual cycle of surface water nutrients data from three Skagerrak stations, showing the onset of the spring bloom and the gradual increase in nutrient concentration during fall.

From April to September, concentrations of phosphate and dissolved inorganic nitrogen were generally very low to depleted above the thermocline mostly located between 15-20 meters, but occasionally deeper. In September, very low concentrations of both phosphate and nitrate were unusually measured down to 50 m depth.

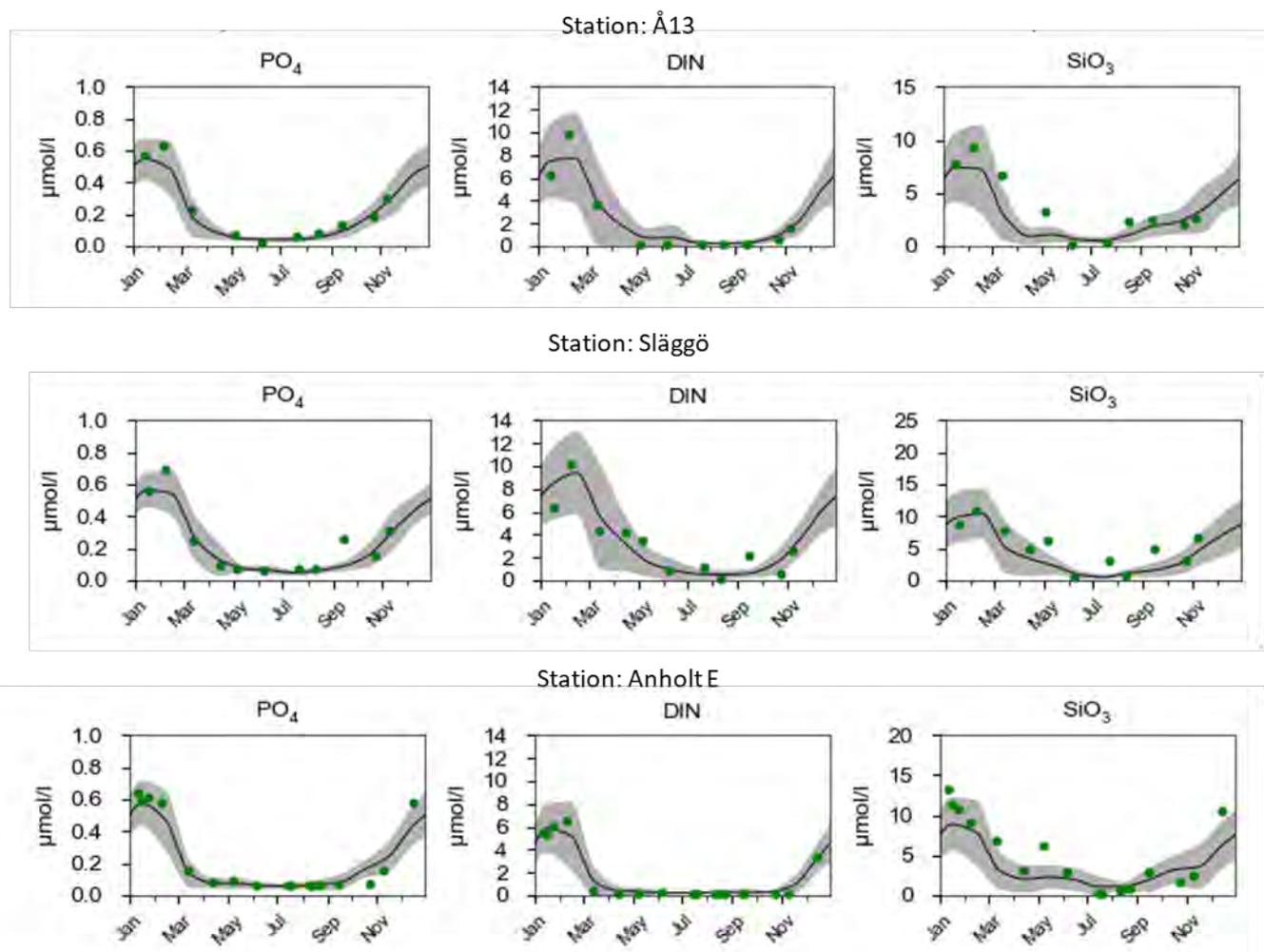


Figure 7. Concentrations of phosphate, DIN, and silicate in the surface layer, 0-10 m, at three stations: Å13 and Släggö in the Skagerrak; Anholt E in the Kattegat from 2024. Monthly measurements (dots) from 2024 are shown in relation to average value for the period 1991-2020 (black line) and +/- 1 standard deviation (grey area). Nutrients were more or less consumed at Anholt E in March.

### 3.1.4 Phytoplankton

Potentially harmful species are marked with \*.

The total phytoplankton biomass was generally low in January, see Figure 8, although diatoms were relatively abundant at both the Skagerrak and the Kattegat stations with the diatom chains *Skeletonema marinoi* and *Pseudo-nitzschia* spp.\* being the most numerous.

The *S. marinoi* and *Pseudo-nitzschia* spp.\* cell numbers increased in February at Anholt E and N14 Falkenberg in the Kattegat while the numbers were low in the Skagerrak area. The spring bloom occurred at Anholt E in March with a high total biomass and consequently high chlorophyll concentrations. The total biomass was lower at N14 Falkenberg, indicating an earlier start of the spring bloom between the February and March samplings. As shown in

Figure 7, at Anholt E, nutrients were more or less consumed at both of the Kattegat stations. At the Skagerrak stations in March, nutrients levels were average and the biomass and chlorophyll concentrations were low, see Figure 9. A minor *Pseudochattonella* bloom was observed at Släggö. The species *Pseudochattonella* spp.\* (Figure 10) is a flagellated species known to be potentially harmful for fish. The chlorophyll concentration was rather high at N14 Falkenberg mainly caused by small flagellated species and the diatom *S. marinoi*.

In May, high total biomass was found at Anholt E, whereas all other phytoplankton stations showed low concentrations. In June however, a diatom bloom was observed at both the Kattegat stations and at Å17 in the Skagerrak, which was dominated by relatively large typical summer diatom species.

From July throughout September, biomasses were low in the Kattegat and the Skagerrak areas, even at Släggö, although elevated levels of chlorophyll were observed in July at this station.

In October-November a diatom, a coccolithophorid and a dictyophyceae bloom occurred in both areas and the highest biomass values were found in the Kattegat. In December, while nutrients were available the biomass values and chlorophyll concentrations were generally low.

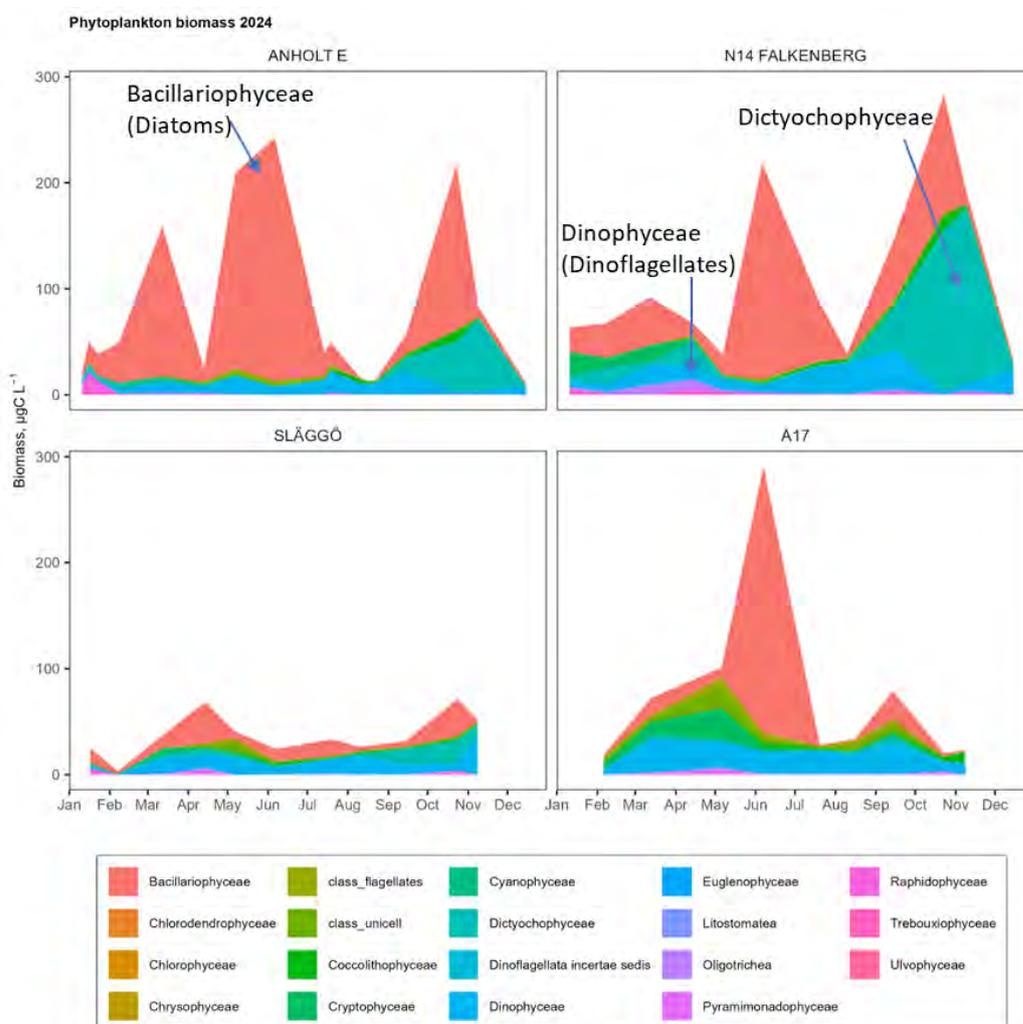


Figure 8. Phytoplankton biomass ( $\mu\text{g/l}$ ) at Anholt E and N14 Falkenberg in the Kattegat and Släggö and Å17 in the Skagerrak.

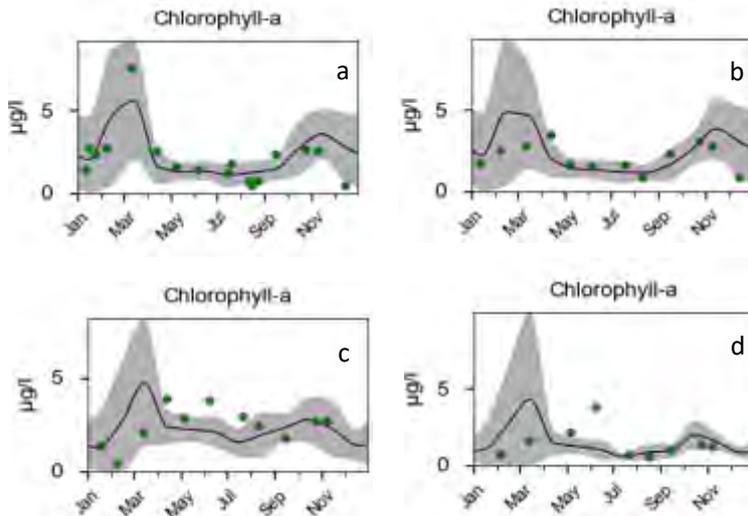


Figure 9. Integrated (0-10 m) chlorophyll a ( $\mu\text{g/l}$ ) from Anholt E (a) and N14 Falkenberg (b) in the Kattegat and Släggö (c) and Å17 (d) in the Skagerrak. Monthly measurements (dots) from 2024 are shown in relation to average value for the period 1991-2020 (solid line) and  $\pm 1$  standard deviation (grey area).

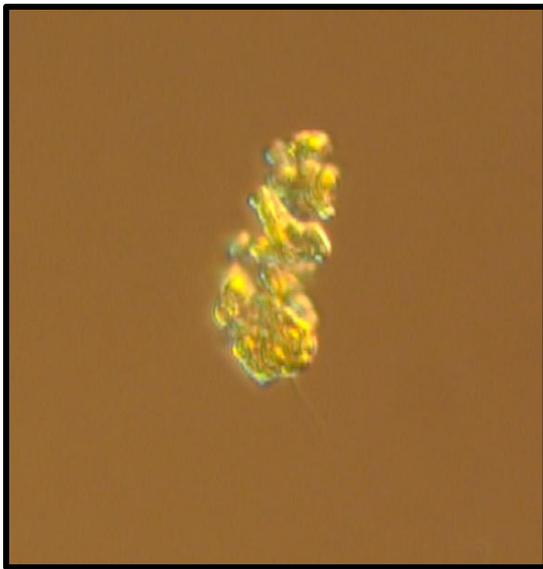


Figure 10. The flagellate *Pseudochattonella* sp. Is potentially harmful for fish since it may cause gill damage. A minor bloom was found at Släggö in April. Photo by: A-T. Skjevik.

## 3.2 Baltic Proper

### 3.2.1 Temperature and salinity

The temperature in the surface water, 0-10 m, was fairly stable between January and March, which was the coldest period of the year. The lowest temperatures were 3.5°C in the southern regions (Arkona and Bornholm basins), 3°C in the eastern regions and 2 °C in the western regions. The water column during this period was well mixed down to the halocline at 40-60 m depth. Below the halocline the temperature was higher than at the surface. The seasonal warming of the surface layer was first seen in April in the southern parts and in May the warming was seen in the entire Baltic Proper. In June the surface temperature was above normal at most stations. The maximum temperature in August measured around 19°C. The summer thermocline was at 10-20 m. Surface water temperatures began to decrease in the autumn, although the surface temperature was above normal at many stations both in September and November. In December surface temperature was within the normal range of 6-7.5°C.

In 2024 the salinity in the surface water varied between normal and below normal in the southern areas. In the Eastern Gotland Basin and the Northern Baltic Proper the surface salinity was above normal for the first half of the year. In the Western Gotland Basin, the surface salinity was above normal for the second half of the year.

Figure 11 presents monthly measurements of temperature and salinity from three stations in the Baltic Proper.

The halocline in the Baltic Proper is situated around 60 m but with seasonal and geographic fluctuations. In the Arkona and the Bornholm basins, which are shallower, the halocline is located at about 40-50 m. Salinity and temperature are less variable below the halocline. In the Arkona and the Bornholm basins, the variability in the deep water is slightly larger because of the influence from salt water inflows from the Kattegat. During 2024 the temperature was above normal in the deep basins in the Baltic Proper while the salinity was mostly within normal ranges. The salinity is steadily decreasing in the stagnant water below the halocline while the temperature has remained relatively constant since 2021, see Figure 12.

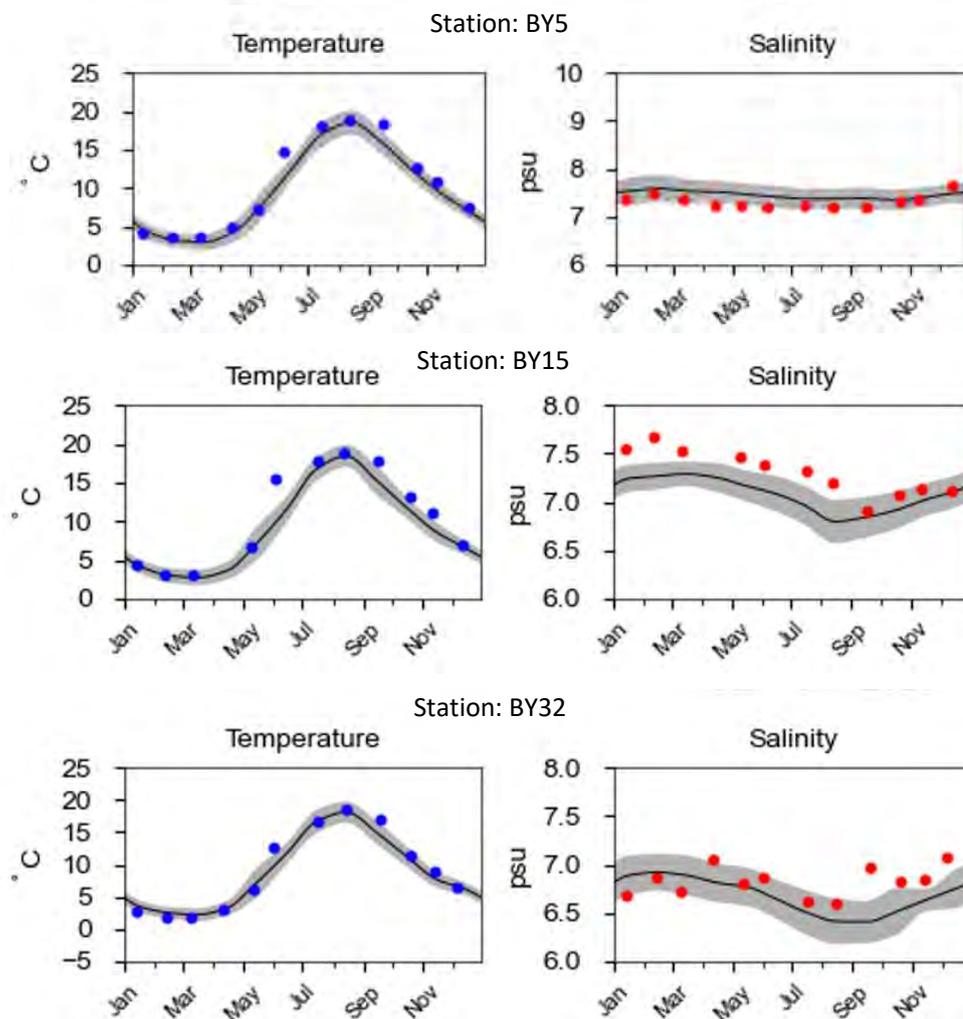


Figure 11. Surface (0-10 m) temperature (left) and salinity (right) at BY5 in the Bornholm Basin (upper panel), BY15 in the Eastern Gotland Basin (middle panel) and at BY32 in the Western Gotland Basin (lower panel). Monthly measurements (dots) from 2024 are shown in relation to the average value for the period 1991-2020 (black line) and +/- 1 standard deviation (grey area).

## Dissolved oxygen, temperature and salinity in the bottom water: Baltic Proper

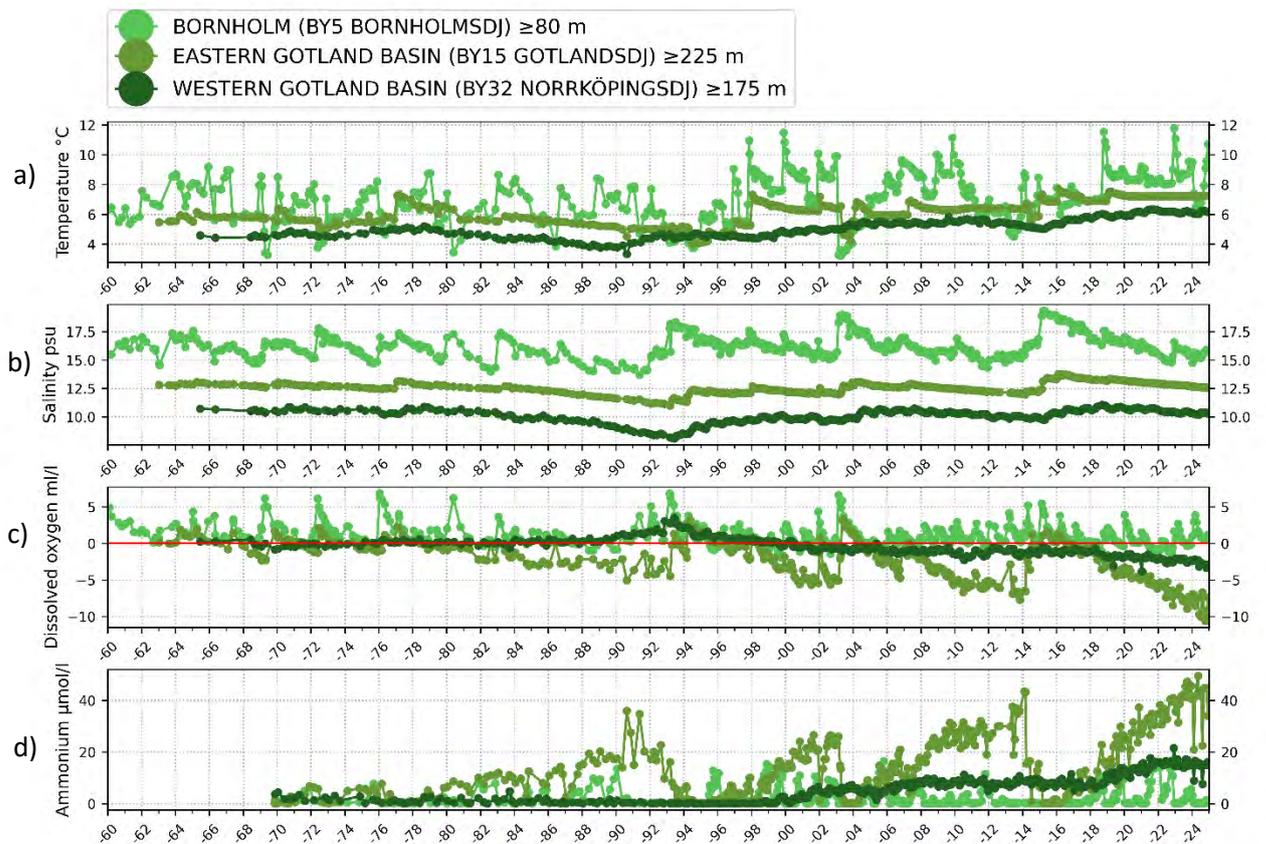


Figure 12. a) Temperature, b) salinity, c) dissolved oxygen and d) ammonium in the bottom water at three stations in the Baltic Proper representing the basins Bornholm Basin (BY5), Eastern Gotland Basin (BY15) and Western Gotland Basin (BY32).

### 3.2.2 Oxygen conditions in the bottom water

No major inflows to the Baltic Proper, which would have improved oxygen conditions in the bottom water, did occur during 2024. The largest inflow of 2024 happened in December and measured  $\sim 30 \text{ km}^2$ . However, the intermediate inflow in December 2023 reached the southern areas (the Arkona and the Bornholm basins) and intermediate depths in the Eastern Gotland basin in early 2024, Figure 13. The annual report on the oxygen situation published by SMHI<sup>5</sup> shows that the severe anoxia in the Baltic Proper continues and the concentration of hydrogen sulphide increases in all basins.

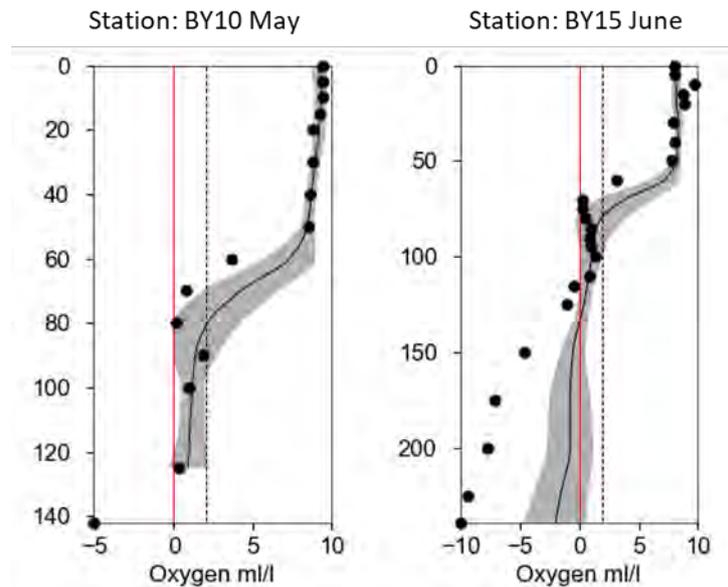


Figure 13. Profiles of dissolved oxygen and hydrogen sulphide (represented as negative values). The profiles show the effect of an intermediate inflow that interleaved at around 100 m. To the left station BY10 from the expedition in May 2024 and to the right station BY15 from the expedition in June 2024.

### 3.2.3 Nutrients

In the Baltic Proper a rapid decrease in the concentration of dissolved inorganic nitrogen indicates the occurrence of the spring bloom (Figure 14). In 2024 the spring bloom occurred during March and April. In the southern regions (the Bornholm and the Arkona basins) nitrate was fully depleted during the cruise in April, whereas in the central and northern parts there were still nitrate left in the surface waters in April and was fully depleted in May. Phosphate rarely fully depletes in the Baltic Proper and concentrations of phosphate decreased during the spring bloom and were lowest during the summer months of June to August. Phosphate started to increase again in September, whereas nitrate showed low concentrations in the southern regions until November and until October in the northern and central regions. This is unusually late and indicates a prolonged production season.

Due to the absence of large enough inflows to renew the deep water, concentrations of nutrients in the deep basins of the Baltic Proper continued to increase during 2024. In the Western Gotland Basin, dissolved inorganic nitrogen was historically present in the form of nitrate until the year 2000 after which the basin shifted to an anoxic state. Since the year 2000 ammonium has increased in the basin, and the concentrations measured during 2024 were almost double the mean value for the normal period (Figure 12, dark green station BY32). Since DIN consists mainly of ammonium, levels of ammonium (Figure 12 d) and DIN in the Eastern Gotland Basin follow the same pattern throughout the time series (1960-2023). In all deep basins around Gotland the concentrations of ammonium and hydrogen sulphide reached new maximum concentrations at almost every sampling visit.

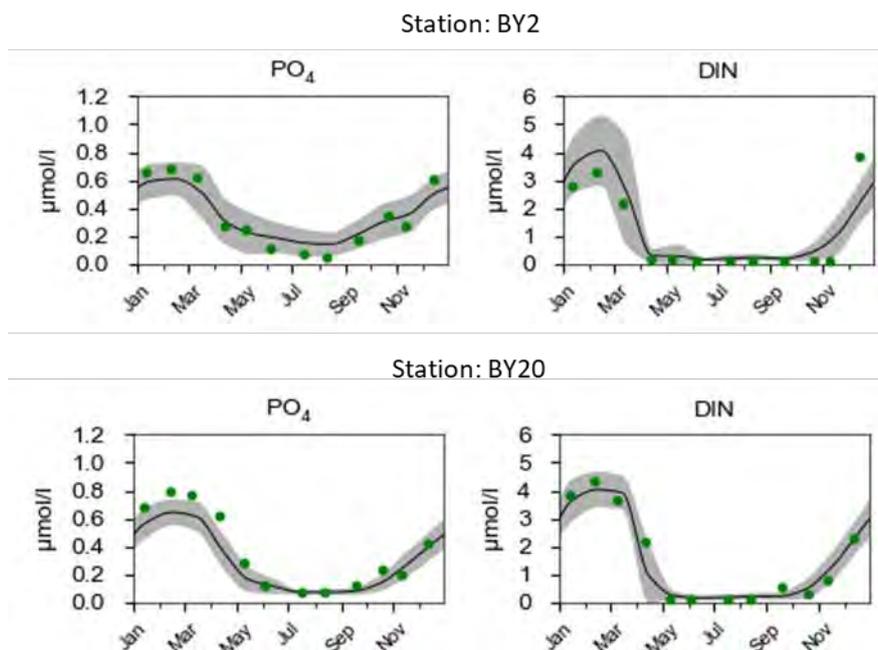


Figure 14. Concentrations of phosphate and dissolved inorganic nitrogen in the surface water (0-10 m) at stations BY2 in the Arkona Basin (top) and BY20 in the Eastern Gotland Basin (bottom). To the left: phosphate, right: dissolved inorganic nitrogen (DIN). Monthly measurements (dots) from 2024 are shown in relation to average value for the period 1991-2020 (black line) and +/- 1 standard deviation (grey area).

### 3.2.4 Phytoplankton

The text below is based on the phytoplankton analyses made for the AlgAware overview report and is based only on the samples analysed by SMHI, hence it does not include results from the full phytoplankton analyses made by Stockholm University within the monitoring program.

Low phytoplankton diversity, low chlorophyll concentrations (Figure 15) and high nutrient levels were generally observed in January-March in the Baltic Sea, see Figure 14 which shows the station BY2.

The spring bloom occurred between March and April at the Baltic stations. The start of the bloom was observed in March at the southern stations with high cell counts of the diatom *Skeletonema marinoi* and the dinoflagellate *Peridiniella catenata*. The spring bloom continued across all of the eastern, western and northern stations in April with diatoms, dominating the biomass. The filamentous cyanobacterium *Aphanizomenon flosaquae* was present at several stations with most abundance at BY5 in the southern Baltic.

Slightly elevated chlorophyll concentrations observed at several stations in May were partly caused by the potentially toxic dinoflagellate *Dinophysis acuminata*\* and the ciliate *Mesodinium rubrum*, amongst others. At BY5 in the southern region and at BCSIII-10 in the eastern Baltic Proper, *S. marinoi* was numerous this month, and further north, *P. catenata* was the most abundant species. The filamentous cyanobacterium *A. flosaquae* was present in low or moderate numbers at all stations except at BY39 southeast of Öland.

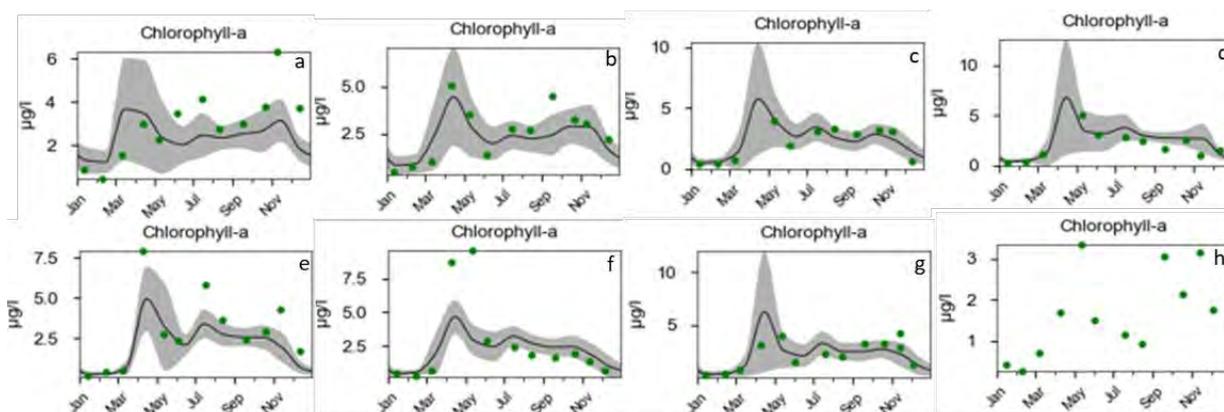


Figure 15. Integrated (0-10 m) chlorophyll a ( $\mu\text{g/l}$ ) from the stations BY2 (a), BY5 (b), BCSIII-10 (c), BY15 (d), BY29 (e), BY31 (f), BY38 (g) and BY39 (h). Monthly measurements (dots) from 2024 are shown in relation to average value for the period 1991-2020 (firm line) and  $\pm 1$  standard deviation (grey area).

The species diversity was very high in June, and all of the three filamentous cyanobacteria which dominate the cyanobacteria summer blooms in the Baltic were present in various amounts. *A. flosaquae* was the most abundant among the three species and was present at all stations. *Nodularia spumigena*\* and *Dolichospermum* spp. were found in low amounts. The potentially toxic dinoflagellate *D. acuminata*\* was present at all stations and was found with the highest cell numbers at BY31. The potentially harmful flagellate order Prymnesiales\* was also present at all stations and caused high chlorophyll fluorescence peaks at several stations.

During the July cruise, surface accumulations of cyanobacteria were mainly observed in the southern and eastern Baltic Sea, which coincided well with satellite analyses from the daily SMHI surveillance (see chapter on *Satellite observations of the summer cyanobacteria accumulations*). The most dense accumulations were found in the southeastern Baltic Sea, near station BCS III-10. Small accumulations were also noted in the northern Baltic Sea, near station BY29. *N. spumigena*\* was the most abundant cyanobacterium in the southern and eastern Baltic Sea, while a more consistent distribution of groups was observed in other parts of the Baltic Sea. At several stations, higher concentrations of filaments were noted in surface samples compared to the integrated samples (0-10 m), indicating that the filaments were mainly concentrated near the surface. The chlorophyll concentration was enhanced at many stations and the highest values were found at BY2 and BY29.

The three filamentous cyanobacteria were present in various amounts at BY39 in August, *A. flosaquae* being the most abundant of them. *A. flosaquae* was also present at most other stations. The diatom *Dactyliosolen fragilissimus*, usually thriving in higher salinity waters, dominated the cell counts at the southernmost stations.

In September diatoms were numerous in the southern Baltic and the amount of cyanobacteria decreased significantly compared to August. Enhanced filament numbers of *A. flosaquae* were however found at a few stations; BY2, BCSIII-10 and BY29. *N. spumigena*\* was present in low numbers at BY31. *D. fragilissimus*, unidentified dinoflagellates and small flagellates caused high chlorophyll concentrations at BY5. Similar to the two previous months, diatoms dominated the cell counts in the southern region of the Baltic in October, with species more associated with higher salinities. In addition to *D. fragilissimus*, this month *Cerataulina pelagica* was also numerous.

The species diversity was high in November and persistently high diatom biomasses partly caused the high chlorophyll concentrations at several stations, particularly in the most northern and southern areas.

Elevated nutrient levels and low chlorophyll concentrations dominated during December. Currently, no phytoplankton data from the December cruise is available for analysis.

Throughout the summer season, SMHI has a daily satellite surveillance of the cyanobacteria blooms called BAWs (Baltic Algae Watch System). BAWs is ongoing from mid-June until mid-September, or as long as blooms are visible. Summaries of each season are found at [smhi.se](https://www.smhi.se/vader/vader-till-havs/algsituationen---cyanobakterier/alger?map=year)<sup>8</sup>. In the summer of 2024, cyanobacteria blooms occurred throughout the Baltic Proper, in the Gulf of Finland and in the Bothnian Sea. For the image summary of the season, see Figure 16. The largest coherent occurrence of cyanobacteria was observed during the second part of July. It extended from the Southern Baltic to the eastern parts of the Gulf of Finland and the Northern Bothnian Sea. The most persistent occurrence was seen in the eastern part of the Gulf of Finland, with a duration of around 30 days.

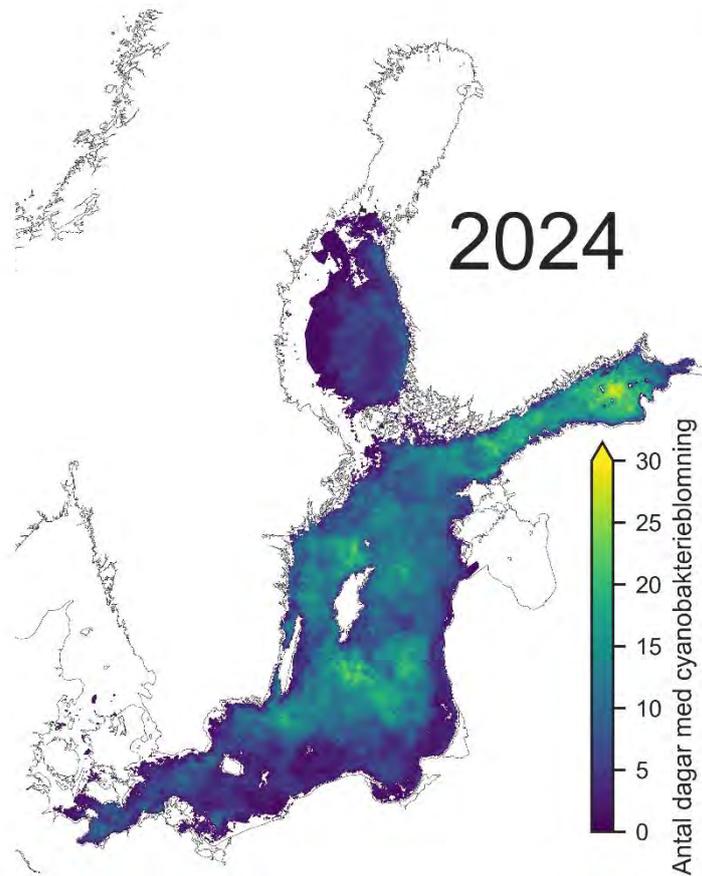


Figure 16. Number of days in 2024 with cyanobacteria bloom observed from satellite images.

<sup>8</sup> Summary of Baltic Sea Algal Watch 2025, <https://www.smhi.se/vader/vader-till-havs/algsituationen---cyanobakterier/alger?map=year>. Navigate to “Väder till havs” and then “Algsituationen – cyanobakterier”

#### 4 SMHI Publications

SMHI publish seven report series. Three of these, the R-series, are intended for international readers and are in most cases written in English. For the others the Swedish language is used.

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- 3 Stig Carlberg et al (1986)  
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- 4 Jan-Erik Lundqvist och Anders Omstedt (1987)  
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<sup>1</sup>Swedish Meteorological and Hydrological Institute, Sweden  
<sup>2</sup> Swedish Agency for Marine and Water Management  
<sup>3</sup>University of Gothenburg,  
<sup>4</sup>Geological Survey of Sweden  
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**SMHI**

Swedish Meteorological and Hydrological Institute  
SE 601 76 NORRKÖPING  
Phone +46 11-495 80 00 Telefax +46 11-495 80 01

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