REPORT OCEANOGRAPHY No. 71, 2021

The Swedish National Marine Monitoring Programme 2020

Hydrography, Nutrients, Phytoplankton

Ann-Turi Skjevik, Karin Wesslander, Lena Viktorsson

Front: The image illustrates salinity profiles from all CTD-observations made by SMHI during 2020. The colour shows the salinity, from low to high, blue-yellow. Image is made with ODV (Schlitzer, R., Ocean Data View, https://odv.awi.de, 2020).

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Summary

Despite a year of pandemic, the environmental monitoring in the pelagic could be done largely as planned in 2020. It was the warmest year on land since national statistics started in 1860. This was also shown in the sea where especially the surface temperature in winter was higher than usual. In the Baltic Sea, the lowest winter temperature was two degrees above normal and the maximum distribution of sea ice was the lowest ever measured. The autumn was also warm and in November the surface water in the Baltic Sea was about 1 degree warmer than normal.

In the Kattegat, there were signs of the spring bloom in February with high chlorophyll levels and high species diversity. In March, the nutrients were largely depleted in the surface water and the spring bloom of diatoms was over for this time. At one occasion, in April, toxins were reported in mussels along the West Coast that exceeded the warning limit. In the Skagerrak, the spring bloom started a little later than in the Kattegat, and in the Baltic Sea even later. In April, the spring bloom was observed in the Western Gotland Basin with high chlorophyll concentrations and typical dinoflagellates species for the season. In the Gulf of Bothnia, there was an early spring bloom of diatoms in April. This early bloom may have been an effect of the mild winter. The bloom of cyanobacteria in the Baltic Sea started already in May when cyanobacteria were observed at several stations. In August, cyanobacteria were also observed along the West Coast. These had probably been transported out with water from the Baltic Sea. A late bloom of the microzooplankton *Noctiluca scintillans* was observed at several sites along the West Coast in December. *N. scintillans* turns the water red during blooms and when it is dark, its fluorescence causes beautiful bioluminescence.

Throughout the year high levels of silicate were observed in the Baltic Sea and low levels of DIN in the surface waters of the Gulf of Bothnia. Otherwise, the levels of nutrients did not deviate much from normal.

In the bottom water of the Baltic Sea, no direct improvement of the oxygen situation was seen. In December 2019, there was a small inflow to the Baltic Sea that temporarily raised oxygen levels in the southern and south-eastern parts at the beginning of 2020. But this increase in oxygen was consumed quickly. In the East Gotland Basin, there was an acute lack of oxygen from 80 m and hydrogen sulphide was measured from depths exceeding 125 m. In the Western Gotland Basin, acute oxygen deficiency was found from 70 m and completely oxygen-free conditions from 80 m. An effect of stagnation in the deep basin parts is, in addition to increased levels of hydrogen sulphide, also increased levels of ammonium. Ammonium levels in the deep water increase in both the Eastern and Western Gotland Basins. The highest concentration of ammonia was observed in the eastern parts, but in the western parts they were above normal levels and closer to the levels in the eastern parts than they have been before. In the Kattegat, oxygen concentrations just above the limit for acute oxygen deficiency were found at some stations during August-October.

Sammanfattning

Trots ett år med pandemi så kunde miljöövervakningen i pelagialen göras i stort sett som planerat under 2020. Det blev det varmaste året på land sedan nationell statistik startade 1860. Detta visade sig även i havet där i synnerhet yttemperaturen vintertid var högre än normalt. I Östersjön blev den lägsta vintertemperaturen två grader över det normala och den maximala utbredningen av havsis var den lägsta som någonsin uppmätts. Även hösten var varm och i november var ytvattnet i Östersjön ca 1 grad varmare än normalt.

I februari observerades de första tecknen på att vårblomningen hade startat i Kattegatt, med höga klorofyllhalter och hög artdiversitet. I mars var näringsämnena i stort sett slut i ytvattnet och vårblomningen av kiselalger var över för denna gång. Vid ett tillfälle, i april, rapporterades gifter i musslor längs Västkusten som översteg varningsgränsen. I Skagerrak startade vårblomningen aningen senare än i Kattegatt och i Östersjön ännu något senare. I april observerades vårblomningen i västra Gotlandsbassängen med hög klorofyllkoncentration och för våren typiska dinoflagellater. I Bottenviken var det en tidig vårblomning av kiselalger i april. Denna tidiga blomning kan ha varit en effekt av den milda vintern. En början på blomningen av cyanobakterier i Östersjön startade redan i maj då cyanobakterier observerades vid flera stationer. I augusti observerades ytansamlingar av cyanobakterier även längs Västkusten, vilka hade transporterats ut med vatten från Östersjön. En sen blomning av microzooplanktonet *Noctiluca scintillans* observerades vid flera platser längs Västkusten i december. *N. scintillans* färgar vattnet rött när den massförekommer och när det är mörkt orsakar dess fluorescens vacker mareld.

Generellt så var det under året höga halter av kisel i Östersjöns och låga halter av DIN i Bottniska Vikens ytvatten. I övrigt avvek inte halterna av näringsämnen från det normala.

I Östersjöns bottenvatten syntes ingen direkt förbättring av syresituationen. I december 2019 skedde ett mindre inflöde till Östersjön som höjde syrenivåerna tillfälligt i de södra och sydöstra delarna i början av året. Men denna syreökning konsumerades snabbt. I Östra Gotlandsbassängen var det akut syrebrist från 80 m och svavelväte uppmättes från 125m. I Västra Gotlandsbassängen var det akut syrebrist från 70 m och helt syrefritt från 80 m. En effekt av stagnation i de djupa bassängdelarna är förutom ökade halter av svavelväte även ökade halter av ammonium. Ammoniumhalterna ökar i både Östra- och Västra Gotlandsbassängerna. Högst koncentration återfanns i de östra delarna men i de västra delarna är de över det normala och närmre de högsta koncentrationerna i de östra delarna än vad de varit tidigare. I Kattegatts bottenvatten var syrenivåerna som lägst under augusti-oktober då det vid några stationer var strax över gränsen för akut syrebrist.

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1 The monitoring programme

The current Swedish marine monitoring programme of the pelagic has been in place since 1994, with only smaller changes. The focus of the programme is eutrophication and oxygen deficiency, and has been since the end of the 1970's. Historically, the programme focused on fishery hydrography, while plankton and chlorophyll was added in the 1980's and extended zooplankton sampling was introduced in 2007. The data from the Swedish marine monitoring are 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)[1] and the Marine Strategy Framework Directive 2008/56/EC (MSFD)[2].

In 1991 SMHI published an investigation of the Swedish marine monitoring programme, its station network and sampling frequency (Rahm et al 1991[3]). In 1992 an international evaluation panel recommended implementation of the changes suggested by SMHI (SNV Report 4170[4]) and a revised monitoring programme started in 1994. This led to significant change, mainly in the frequency of expeditions so that a number of stations are now sampled monthly and additional stations are sampled at high frequency (bi-weekly) in all basins. The high frequency stations were introduced to better monitor changes in biological parameters that change rapidly, especially during spring and summer.

In addition to the monthly and high frequency stations, a denser network of stations was set up 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, 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 stations 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 also started with the revision of the programme 1994. For the oxygen mapping there are no fixed stations, instead stations vary from year to year since sampling is performed in combination with fisheries cruises led by 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). Thus, the oxygen mapping, with focus on the deep water is performed during the autumn because it's the season with the most severe oxygen deficiency. Since many countries around the Baltic Sea also perform BIAS-cruises in their national waters and take oxygen samples during these cruises the coverage of autumn oxygen data is generally good, the combined results from all countries are presented in a

[1] Water Framework Directive

[2] Marine Strategy Framework Directive

[3] Rahm L., Sjöberg B., Håkansson B., Andersson L., Fogelqvist E., 1991. *Utredning om Optimering av utsjö-monitoringprogrammet vid SMHI.*

[4] 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.

separate SMHI report on the Oxygen situation[5]. 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 two coastal stations were added to support the work associated with the EU Water Frame Work Directory; N14 Falkenberg and Ref M1V1. Recently two stations have been added on the west coast to monitor the gradient from the Gullmar fjord to the open sea. The two new stations are Alsbäck (in the fjord) and BroA (outside the sill). Together with the station Släggö they represent the gradient from fjord to archipelago. Also, in the Baltic Proper, stations have been added to represent a gradient from coast to open sea. The station H4 in Himmerfjärden together with B1 and BY31 represent the gradient there. 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, in Swedish, is published by the Swedish Agency for Marine and Water Management[6].

In addition to the national pelagic programme, municipalities and counties perform monitoring in coastal waters. In the open sea there are several fixed platforms mainly run by SMHI, including wave buoys, coastal buoys and one offshore buoy. Two cabled platforms are currently under development; west of Gothenburg and in the Sound between Denmark and Sweden. SMHI and the Swedish maritime administration are also responsible for a network of stations measuring sea water level. Many of these stations also measure surface water temperature. In 2020 three bottom mounted systems that measure salinity, temperature and oxygen was installed at Laholm Bay, Hanö Bight and Understen in the entrance to the Bothnian Sea from the Baltic Proper.

The first oceanographic measurements in Swedish waters were done on the initiative of Gustav Ekman who in 1877 initiated a mapping of all Swedish seas with the warships HMS Alfhild and HMS Gustav af Klint. The data from this first mapping were not analysed until 1901 by Otto Petterson. Otto Petterson 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 aim to explain what controlled the variations in herring stocks. The first Swedish research vessel R/V Skagerrak I was used and the measurements were mainly salinity, temperature and oxygen. Stations were sampled at 1-2 cruises per year and after a few years alkalinity and pH were added to the measurements. 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, in some periods the measurements were only performed during summer and in others only in spring. This makes it difficult to create continuous time series and trend analyses with data from this period. Furthermore, conditions are relatively more stable in the deep basins of the Baltic Sea than in surface waters and for these areas data are better fitted for long trend analysis. Although the frequency still varied between one and three visits per year, the network of stations was roughly the

[5] Hansson M., Viktorsson L., Oxygen Survey in the Baltic Sea 2020 - Extent of Anoxia and Hypoxia, 1960-2020, REPORT OCEANOGRAPHY No. 70, 2020

[6] SwAM, *Beskrivning av delprogrammet Fria vattenmassan,* Version 3:1, 2019-02-14

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 was made of both physical and chemical parameters as well as biological, including bottom fauna.

1969-1970 was the International Baltic Year and this is why many of the station are still have names starting with BY. In 1978 the Programme for Environmental Control (Programmet för Miljökontroll, PMK) was started and the following year HELCOM started its Baltic Monitoring Programme (BMP). The Swedish commitment in BMP 1979 included nutrients, oxygen, salinity and temperature and all countries around the Baltic Sea started sharing data. The programme continued until 1993 when it was revised as described above.

2 Performance in 2020 and description of the current programme

The marine monitoring programme of the pelagic in Sweden consists of 36 standard stations distributed in the seas surrounding Sweden, deep blue and red dots in Figure 1. The visiting frequency is monthly at most standard stations (blue) but bi-weekly at six stations (red). Concentrations of winter nutrients in the surface layer (light blue) and oxygen during autumn (white) are mapped once per year at additional stations. Coastal stations that are part of gradient studies are shown in orange. The number of visits at the standard stations during 2020 is presented in Figure 2. In 2020 only a few visits were cancelled, despite the challenges of 2020 caused by the pandemic.

The responsible institutes for performing the monitoring are: Umeå Marine Sciences Centre, Stockholm University, the University of Gothenburg, Kalmar county coastal committee (Kalmar läns kustvattenkommitté, KVK) and SMHI. The programme is financed by the Swedish government through SwAM and SMHI.

SMHI used the Swedish research vessel R/V Svea for the regular monthly cruises, the nutrient mapping of the Gulf of Bothnia in December 2019 and 2020. SMHI also performed the late summer/autumn oxygen surveys with R/V Svea in cooperation with SLU Aqua; the third quarter International Bottom Trawl Survey (IBTS Q3) in Kattegat/Skagerrak in August/September and the Baltic International Acoustic Survey (BIAS) in September/October in the Baltic. Positions sampled are shown in white in Figure 1, in total 49 stations were visited in Kattegat/Skagerrak and 29 stations were visited in the Baltic Proper during these cruises. The samples, together with data from most countries around the Baltic Sea and Swedish monthly monitoring data from August-October, is used for SMHIs annual report on the calculated area of anoxic and hypoxic bottoms in the Baltic Proper[5]. The winter mapping of nutrients in the Skagerrak was performed by SMHI in cooperation with the first quarter International Bottom Trawl Survey (IBTS Q1) led by SLU Aqua in January-February. During this cruise nutrients, salinity, temperature and oxygen were sampled at 41 stations in the Skagerrak and the Kattegat.

Stockholm University used M/S Fyrbyggaren for sampling at the offshore stations BY31 Landsortsdjupet and BY29/LL19. The smaller vessels R/V Limanda and R/V Electra were used for sampling at station B1. The station U19 Norra Randen was sampled with an unspecified vessel, 'ship of opportunity'.

Umeå Marine Sciences Centre used KBV181, KBV201, R/V Botnica for their sampling. At some occasions Umeå Marine Sciences Centre also used a hoovercraft for the sampling during winter when sea ice did not permit sampling from a ship.

The University of Gothenburg have sampled zooplankton at Alsbäck, BroA and Släggö and primary production together with chlorophyll-a, salinity, temperature and Secchi depth at BroA and Släggö. These visit stations and visits are not presented in Figure 2.

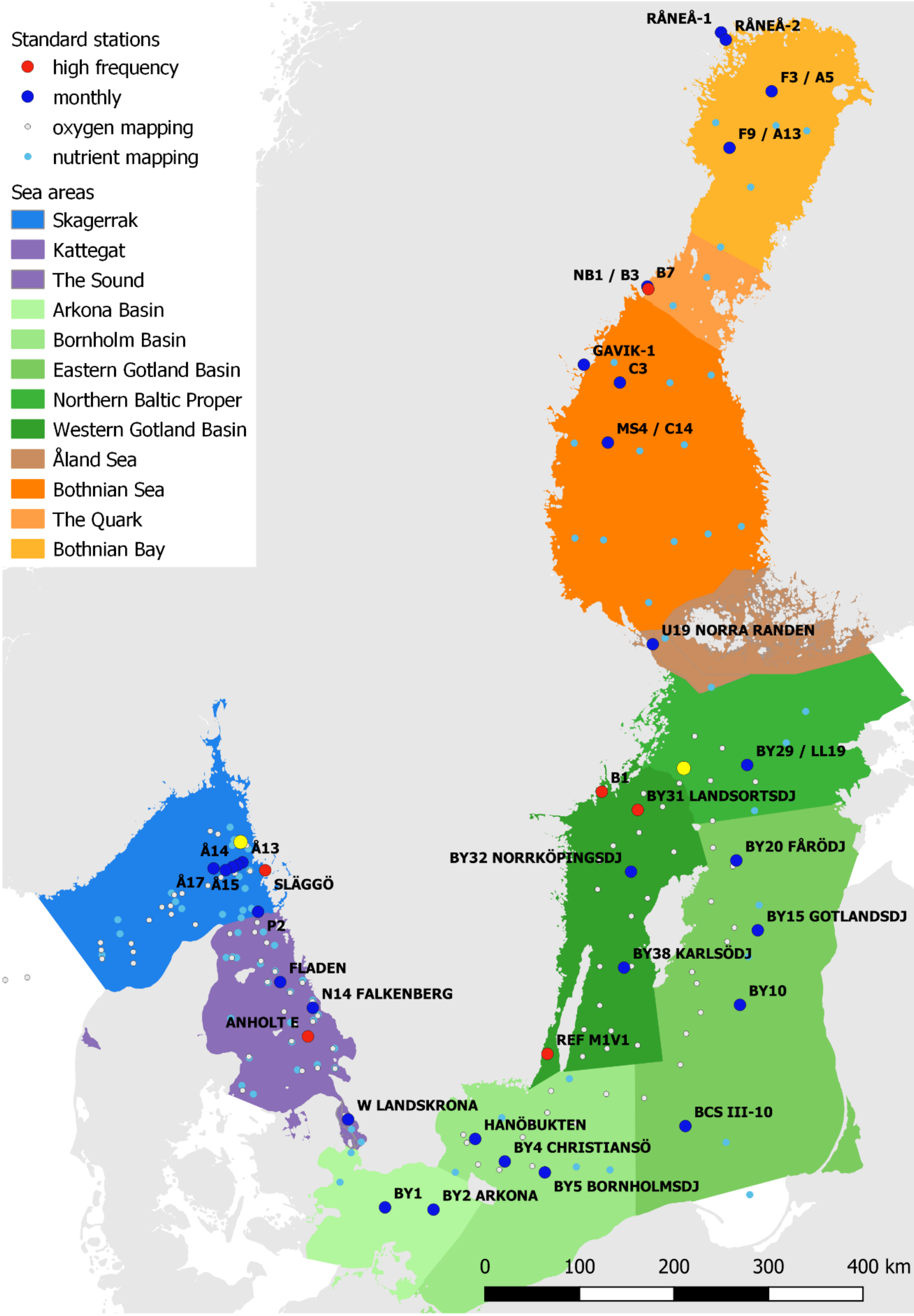

Figure 1. Monitoring stations visited during 2020. Blue – stations visited monthly, red – stations visited two times per month or more frequently, white – stations visited for oxygen mapping, lightblue – stations visited for nutrient mapping, yellow – positions of the Huvudskär buoy in the Northern Gotland Basin and the Väderöarna buoy in Skagerrak.

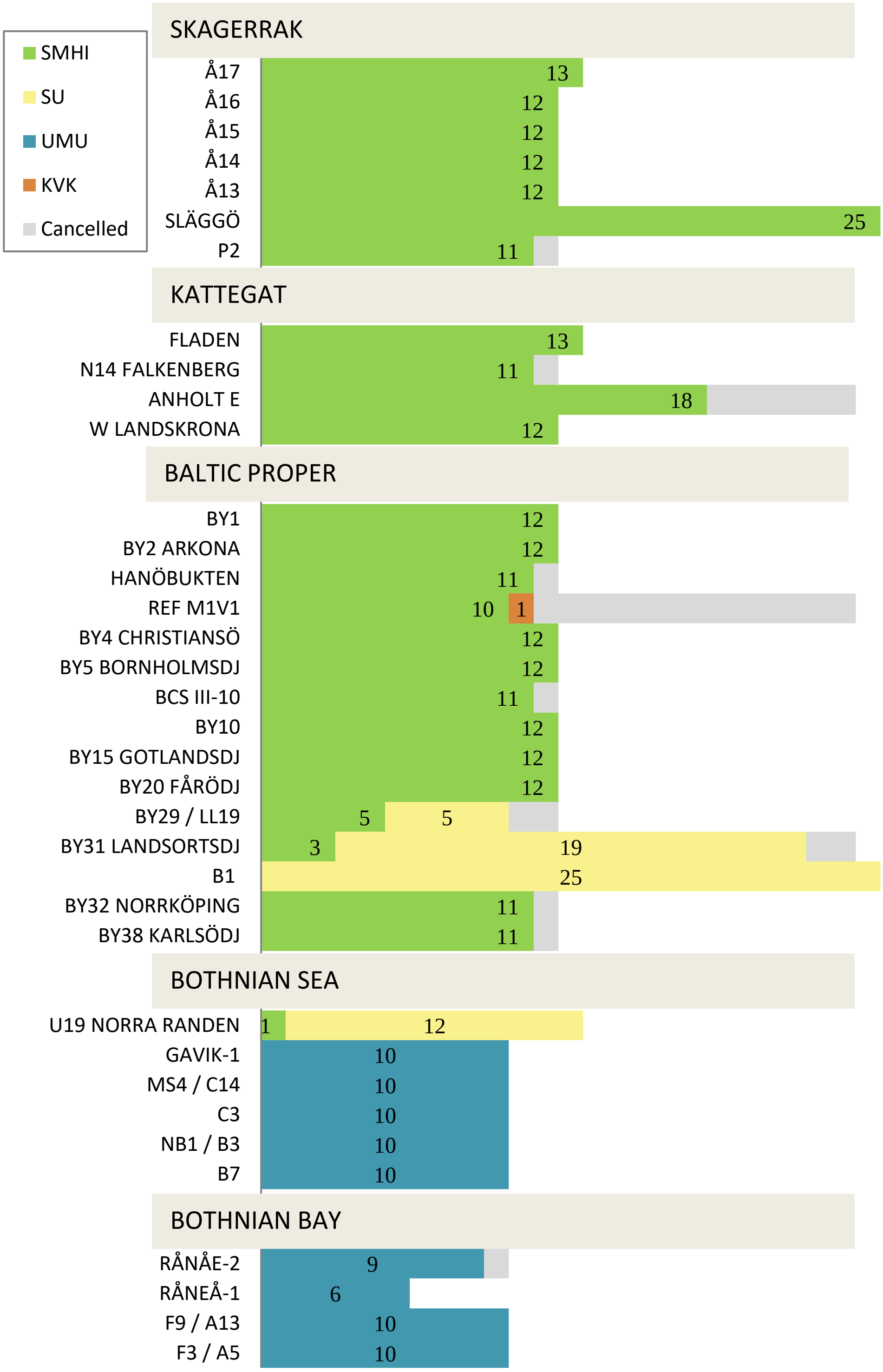

Figure 2. Number of visits at each standard monitoring station during 2020.

3 Weather

The year of 2020 became the warmest year since the first publication of national statistics in 1860. With exception of the south eastern parts of Sweden the precipitation was also higher than normal. The high precipitation led to high river flows and flooding.

In both January and February, the mild winter from the end of 2019 continued and the mean temperature was 2-6 degrees above normal (normal period 1961-1990). Two storms passed in February, Ciara the 9-10 and Dennis on the 16th. Both storms passed over Scandinavia on a north-easterly track. In March and April, the mean temperature continued to be above normal. The weather was windy in March and on the 12th the storm Laura past over the southern parts of Sweden and wind gusts of 37.8 m/s were recorded at Hanö. May was colder than normal, 2-4 degrees below the normal period. June was very warm, mean was 2-5 degrees above the normal period. The highest June temperature in 50 years was recorded at Skellefteå airport on the 25th with 34 degrees. In July the weather shifted and the mean temperature was 1-2 degrees below normal. Storms passed the southern parts during 5-6 of July and gusts of 28.1 m/s were recorded at Väderöarna. In August the weather got warmer and the mean temperature was again above normal. The autumn and the start of the winter was mild, several temperature maxima records were broken on the 2nd of November. Lows passed over the country in a north-easterly track and the precipitation was above normal.

4 Oceanographic conditions

Annual cycles of the surface water (0-10m), vertical sections from the Skagerrak to the Western Gotland Basin and time series from 1960-2020 are presented in Appendices I-IV. In the text, we often refer to a normal condition or value and by this we mean the average +/- one standard deviation for the period 2001-2015. There is also extra material, as vertical profiles for each station from the stations sampled by SMHI, in the cruise reports available at the SMHI webpage[7].

The Swedish seas have large variations especially in salinity, which gives the seas their different characteristics, Figure 3. The Skagerrak on the west coast has almost open ocean salinities >30 psu, with lower salinities closer to the coast due to river runoff and the Baltic current bringing the outflowing Baltic water northward along the Swedish west coast. 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 naturally sensitive to increases in nutrient input leading to a eutrophic state and oxygen deficiency in the deep basins. The Gulf of Bothnia in the north is the freshest sea in Swedish waters with salinities <7 psu. It is an oligotrophic sea with other levels of and ratios between nutrients than the Baltic Proper.

To illustrate the highly variable seas around Sweden a selection of parameters and stations from the different sea areas are presented in Figure 4, where mean values of surface water (0-10 m) at each sampling occasion are displayed. Besides the different salinities mentioned above, other parameters show differences between the areas. For example, the concentration of phosphate is much lower in the northern parts while the concentration of dissolved inorganic nitrogen is higher. It is also visible from the chlorophyll concentrations that the spring bloom occurs at different times. In the Gulf of Bothnia, the spring bloom is generally not as distinct as in the other areas.

[7] Cruise reports from SMHI

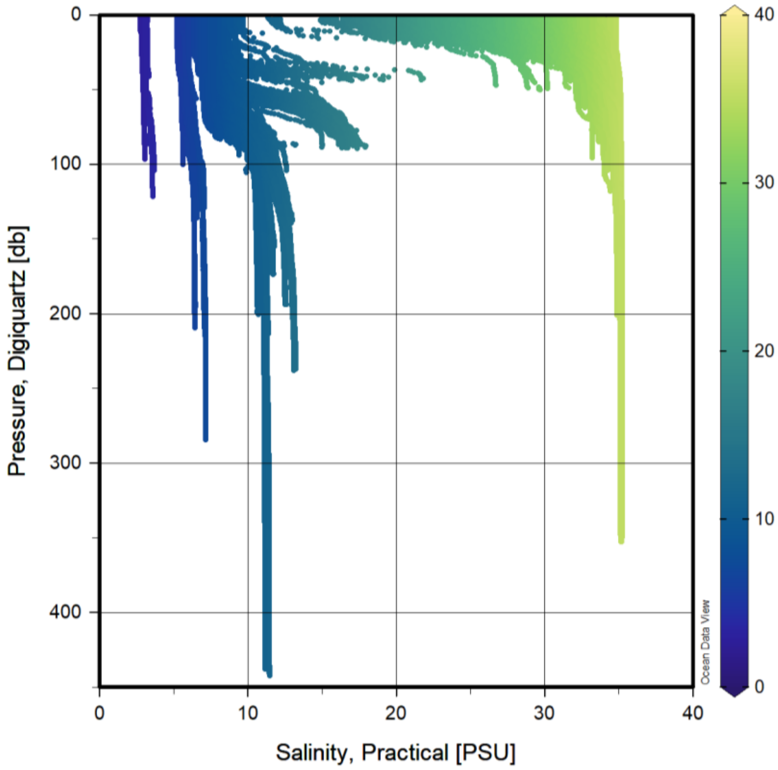

Figure 3. All salinity profiles from the SMHI monitoring cruises during 2020, colours refer to the salinity.

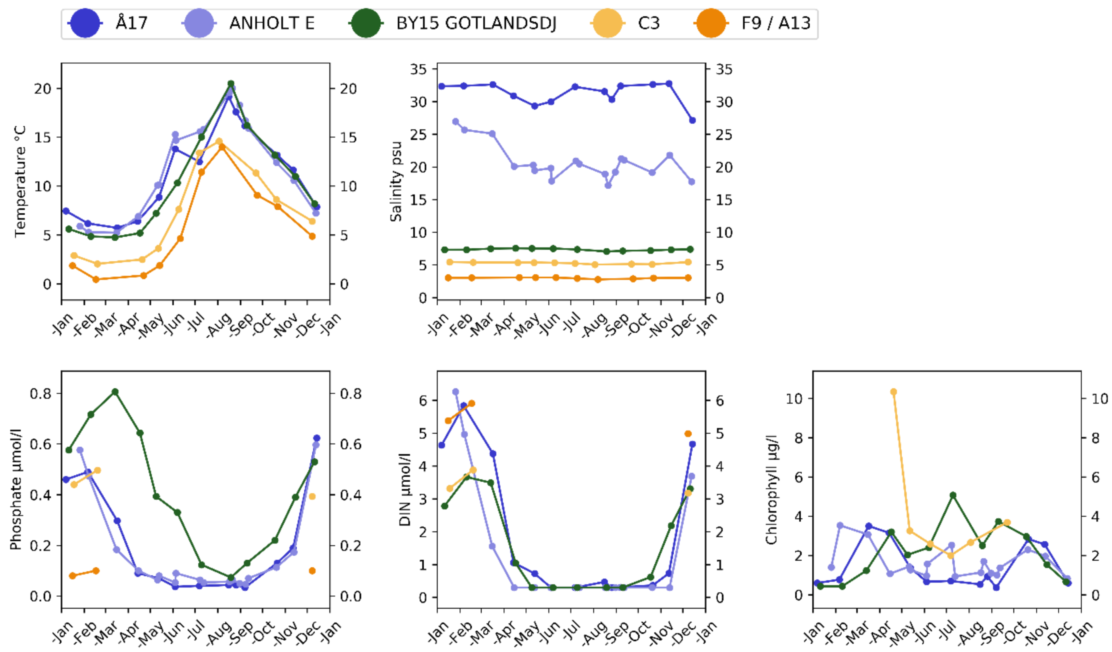

Figure 4. Selection of parameters from the different sea areas around Sweden: the Skagerrak (Å17), the Kattegat (Anholt E), the Baltic Proper (BY15), the Bothnian Sea (C3) and the Bothnian Bay (F9/A13). All parameters are mean values of surface water (0-10 m) during 2020.

In this section we also present a time series from 2001-2021 for the nutrients DIN (dissolved inorganic nitrogen), phosphate and silicate in the surface water, 0-10 m, from one station per sea area, Figure 5. The shadowed grey area in the figure highlights the time period that the mean period is based on in this report, 2001-2015. The shadowed green area highlights the year 2020. In appendix II longer timeseries are presented, 1960-2020.

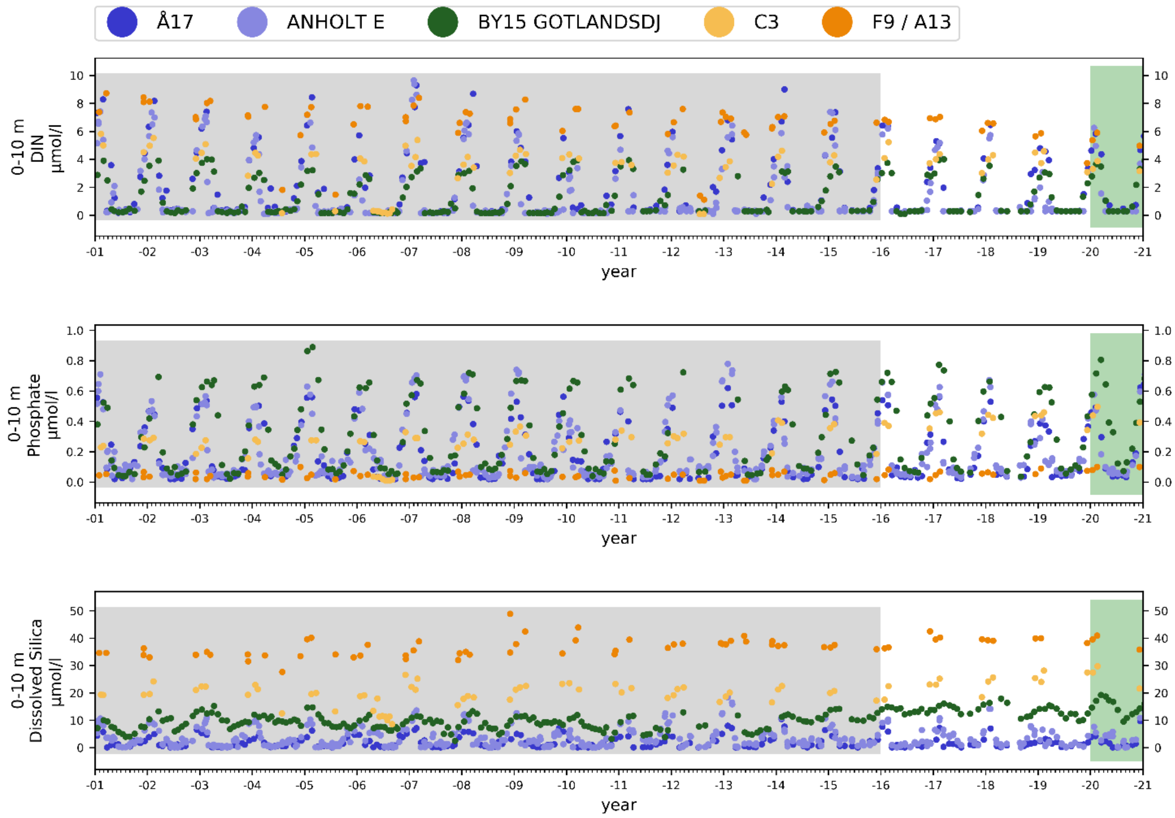

Figure 5. The averaged concentration of DIN, phosphate and silicate in the surface layer, 0-10 m, at the monitoring stations Å17 in Skagerrak, Anholt E in Kattegat, BY15 in the Eastern Gotland Basin, C3 in the Bothnian Sea and F9/A13 in the Bothnian Bay. The shadowed grey area highlights the time period that statistics is based on in this report, 2001-2015. The shadowed green area highlights the year 2020.

4.1 Skagerrak, Kattegat and the Sound

4.1.1 Temperature and salinity

In 2020 the surface water temperature was above or within the 15-year mean, except at a few stations in July due to a passing low with strong winds. The lowest temperatures were measured in March and were 2-3 degrees above the normal minimum winter temperature, which normally occurs in February. The highest surface water temperatures were measured in August, just above 19 degrees. The salinity was within the normal range (mean +/-1 standard deviation), except at the beginning of the year.

The lowest surface water temperatures are normally recorded in the beginning of the year between January to March. In 2020 the unusually warm winter resulted in less cooling of the ocean and unusually high winter temperatures, Figure 6. At all stations, from Skagerrak to the Sound, with measurements in February and March the surface water was warmer than normal (more than two standard deviations above the mean values for 2001-2015). In Kattegat the surface waters were warmer than normal also in January. In spring the surface water temperature was normal. In June-July the weather was warm and data from land-based stations as well as buoys showed that the temperature in the surface water peaked at around 23 degrees in the end of June, see Figure 7. However, just when the July cruise started the previous high pressure moved away and strong winds resulted in mixing of the surface water and lowered the temperature. Thus, the data from the July cruise shows normal or below normal surface water temperature, showing how fast conditions in the sea can change and the value of complementary measurements with higher resolution (satellite, buoys and land-based stations), see Figure 7. After the mixing and cooling of the water in July warm weather followed and in August the surface water temperature was normal or above normal. This resulted in a large difference between the temperature in July and August, largest at stations Å17 in the open Skagerrak where the temperature difference was almost 10 degrees between the two visits.

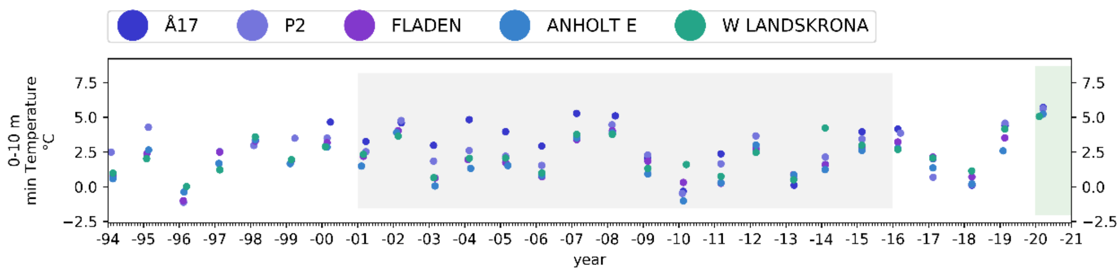

Figure 6. Lowest temperature in the first quarter of the year at two stations in the Skagerrak, two in the Kattegat and one in the Sound, the winter 2020 was unusually warm and the lowest temperature was around 5 degrees, which is ca 2-3 degrees above normal.

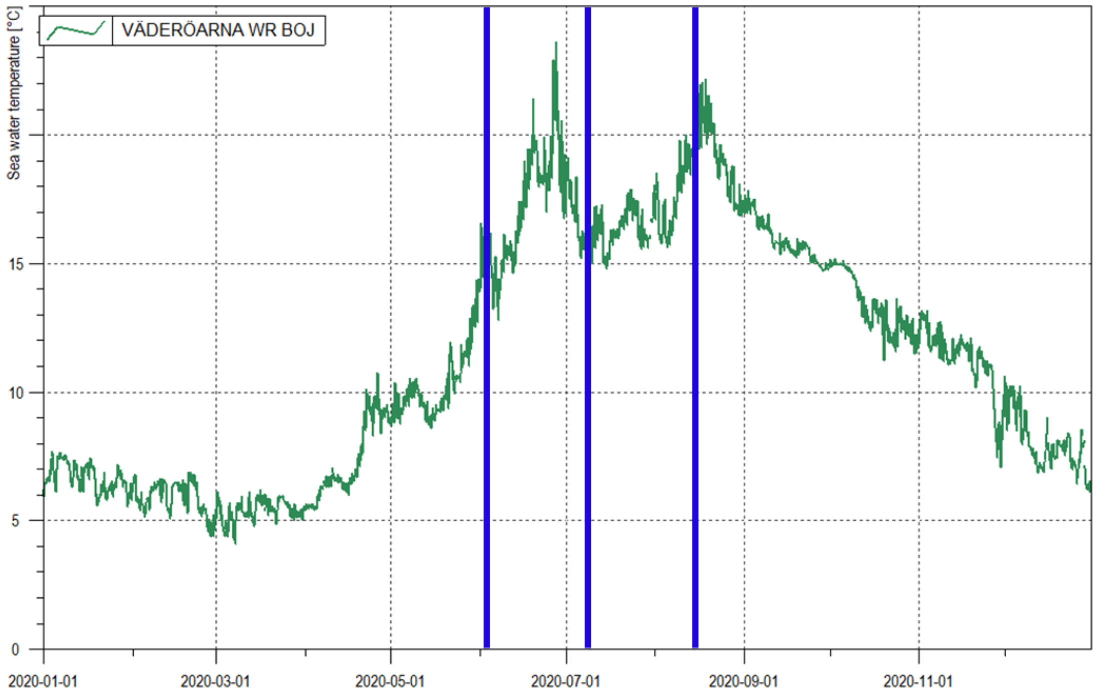

Figure 7. Surface water temperature from the buoy at Väderöarna. Measured at 0.5 m depth, the blue lines show the time of the cruises in June, July and August. This illustrates that the temperature from monthly cruises does not necessarily catch the highest and lowest temperatures during summer.

In Skagerrak the surface salinity was mostly within the normal range (mean +/-1 standard deviation), see examples of selected stations that showed the most deviations from normal in Figure 8. The lowest salinity was measured in December at station Å17, at this time the salinity was unusually low at all stations in the Å-transect with surface salinity between 27-28 psu. This is well below normal at station Å17, but within the normal range at the other stations in the Å-transect. The highest salinity in Skagerrak was measured in March with values between 32-33 psu in the Å-transect, with the highest measurements at stations Å14 and Å15, 33.4-33.6 psu, which is above normal. At station P2, outside Marstrand, the surface salinity is highly variable and measured salinities in 2020 was above the normal range in February, June, August and September and below the normal range in May, July, October and December. The variations are similar to those at the Å-transect, but with a larger fluctuation. At the coastal station Släggö, the surface salinity was above normal from January until May, with exception of March when it was normal. After May the surface salinity at Släggö was within the normal range but towards the lower end.

The highest surface salinity in Kattegat in 2020 was measured in January at the southernmost station Anholt E; 27 psu which is well above the normal range, see Figure 8. After this the salinity decreased and towards the end of the year it was below normal (August, October and December) with the lowest measurement in December at 18 psu.

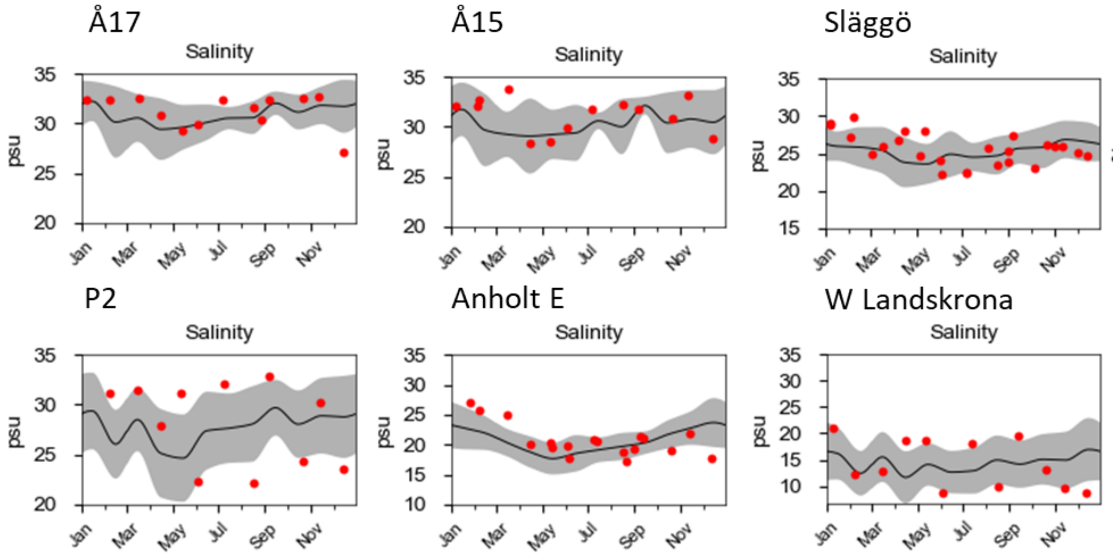

Figure 8. Surface (0-10 m) salinity at four selected stations. From left top row, Å17, Å15, Släggö and bottom row P2, Anholt E and W Landskrona. Red dots shows monthly measurements, black line the avareage from the period 2001-2015 and the grey area +/-1 std. At the station W Landskrona in the Sound and the station P2 in Skagerrak the variability in both temperature and salinity is high. In the Sound the conditions in the surface water reflects the surface current, with high salinities when water is flowing into the Baltic Sea and low salinities when water flows out. At P2 the conditions are highly variable because the station is positioned in an area where water masses from the Kattegat (water properties influenced by the Baltic Sea), the Skagerrak and the North Sea (via the Jutland current) meet. This makes it in general difficult to interpret the results from these two stations.

In both Skagerrak and Kattegat there is a halocline, usually at 10-15 m depth, Figure 9. In November the stratification in the Å-transect was weaker than the rest of the year, due to higher surface salinity. In January when the surface salinity was above normal in Kattegat and at some of the stations in Skagerrak (Å15, Å13, P2) the halocline was also weak with only a small salinity increase at 20-30 m depth. In general, the halocline was weakest between January to March and became sharper from April through the summer and fall. Since the surface layer in Kattegat is less saline (ca 20-25 psu) compared to the surface layer in the Skagerrak (ca 30 psu) the halocline is usually stronger in Kattegat compared to the Skagerrak, Figure 9.

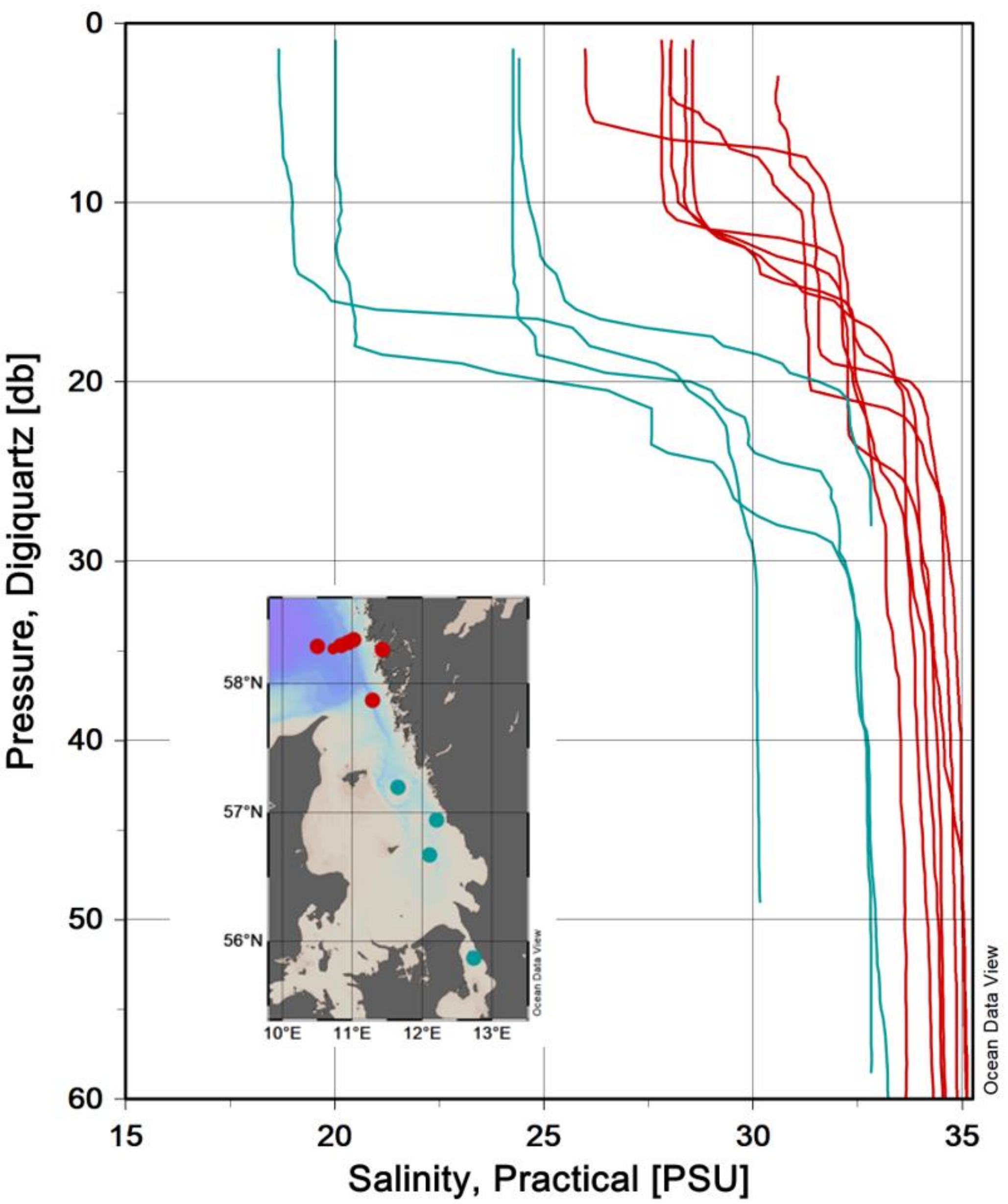

Figure 9. Salinity profiles from Skagerrak (red) and Kattegat (bluegreen), April 2020. The profiles illustrate the difference in stratification in the two areas. The halocline is deeper in the Kattegat compared to the Skagerrak and the difference in salinity above and below the halocline is larger in the Kattegat compared to the Skagerrak.

4.1.2 Oxygen conditions in the bottom water

In the Sound there was oxygen deficiency (<4ml/l) in the bottom water from July-December, with the lowest concentrations, just above 2 ml/l, in August-October. Oxygen deficiency was also observed at station Anholt E in southern Kattegat in July and August and at the coastal station N14 Falkenberg in August. In the Skagerrak there are no oxygen deficiency in the open sea, but at the coastal station Släggö oxygen deficiency was observed in the bottom water from August-December, Figure 10.

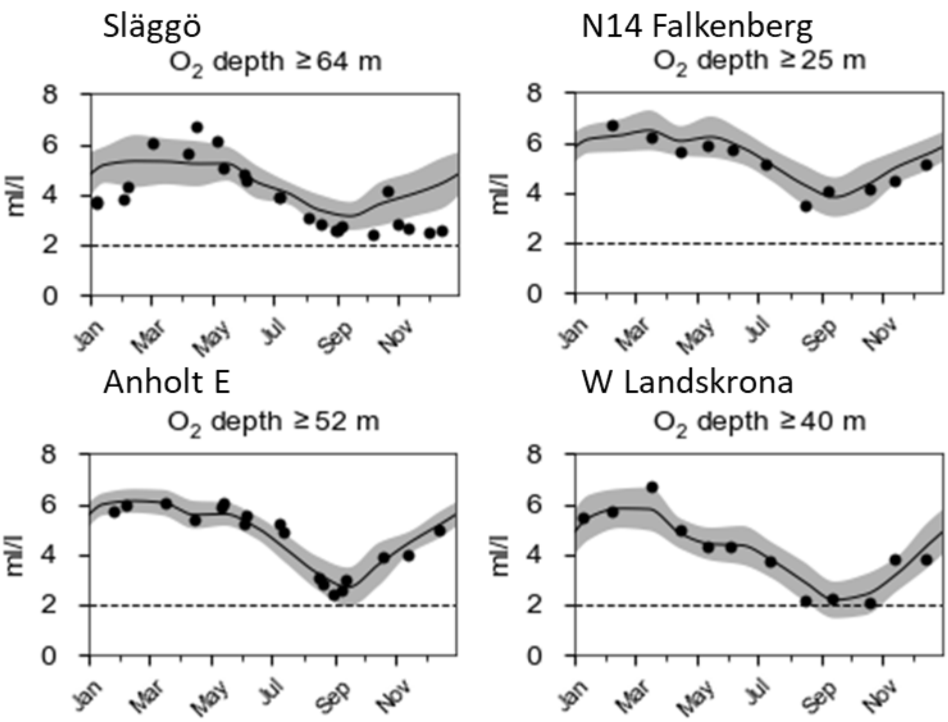

Figure 10. Oxygen concentration in bottom water at four stations, from top left: Släggö, N14 Falkenberg, Anholt E, W Landskrona.

4.1.3 Nutrients

The temporal variation of nutrients in the Skagerrak and Kattegat surface water followed the seasonal variation with a few deviations from the normal ranges in concentration (average 2001-2015). In the beginning of the year, in January, the concentrations were mostly within normal ranges except from the Å-section in Skagerrak where DIN and phosphate where a little below normal, Figure 11.

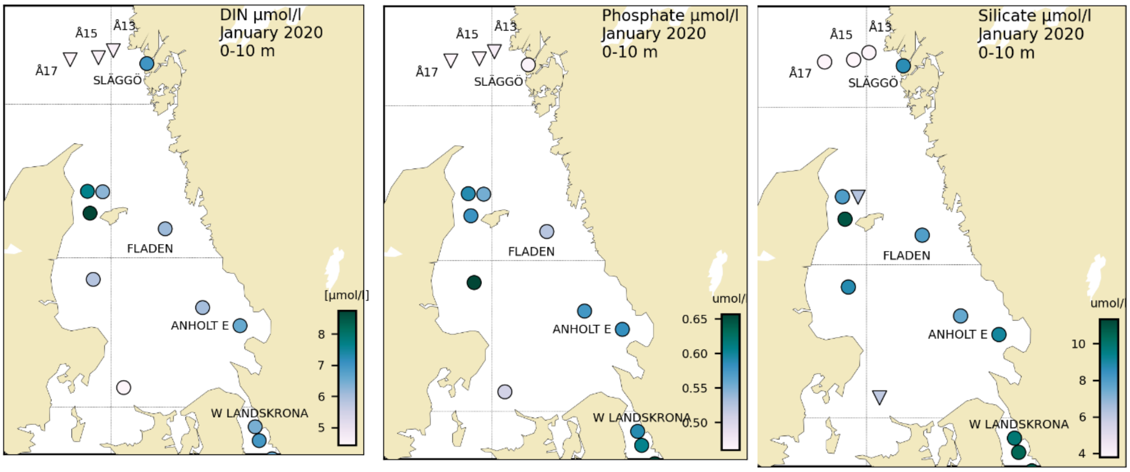

Figure 11. The averaged concentration of DIN, phosphate and silicate in the surface layer, 0-10 m, in January at the monitoring stations in Skagerrak and Kattegat. ○ concentration is within the mean ± 1 *standard deviation, Δ concentration is* $>$ 1 *standard deviation from the mean and ∇ concentration is* $<$ 1 *standard deviation from the mean. The statistical mean is based on basin data from the time period 2001-2015.*

The sharp decrease in nutrients in the first part of the year, which indicates the beginning of the spring bloom, occurred between February and March and this is a normal situation.

The concentration of phosphate continued to decrease during the summer to just above the detection limit (0.02 µmol/l). In October, the levels of phosphate had begun to increase and it continued to do so throughout the year even though the increase was slower than usual. The year ended with phosphate concentrations above average, particularly in the Skagerrak. Unlike phosphate the concentration of dissolved inorganic nitrogen (DIN) was completely depleted in the surface waters at most stations from June to September and continued to be low also during the autumn and did not increase until November-December. The silicate concentrations were above average at many stations during both the spring period and in December. During summer the silicate levels decreased and reached the detection limit (0.1 mmol/l) in July, at this time diatom blooms were observed. July was actually the month with the least amount of nutrients in the surface layer, in Skagerrak this layer was down to 50 m and in Kattegat down to 15-20 m, Figure 12.

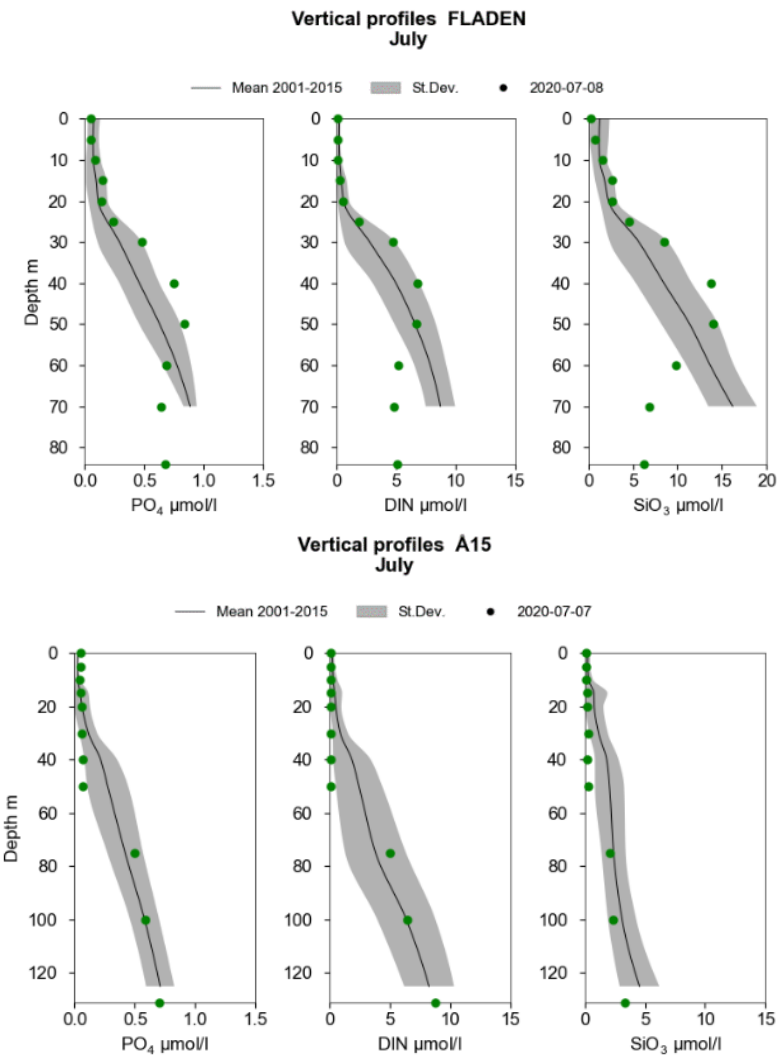

Figure 12. Vertical profiles of nutrients from monitoring station Fladen in Kattegat and Å15 in Skagerrak, July 2020.

Nutrient concentrations below the halocline in the Skagerrak were mostly within the normal ranges, most deviations were seen at stations Å15 and Å17 where DIN was significantly below normal (3 µmol/l lower in March) in, January-March and in November-December. Phosphate and silicate were also lower than normal, but not as much below normal as nitrogen. In Kattegat deviations from normal in the deeper waters was associated with changes in the depth of the halocline, causing surface characteristic nutrient concentrations to spread deeper than normal, at Anholt E and Fladen in March and only at Fladen in December. As in Skagerrak, lower than normal DIN concentrations were found in February in Kattegat at station Fladen below 40 m.

The ranges of nutrients in the Sound is somewhat different from Kattegat because it is affected by the water flowing through the Sound. If the main flow is out from the Baltic Sea the properties are more alike those in the Arkona Basin and if the main flow is in to the Baltic Sea the properties are more like Kattegat but often there is a mixture of the water properties. In 2020, phosphate concentrations were below normal several times and the silicate concentration were pending between above and below normal.

4.1.4 Phytoplankton

The total cell numbers were low in January and February in the Kattegat and Skagerrak areas. There were however signs of the coming spring bloom at Anholt E in the Kattegat in February considering the enhanced chlorophyll concentrations and the high species diversity, Figure 13.

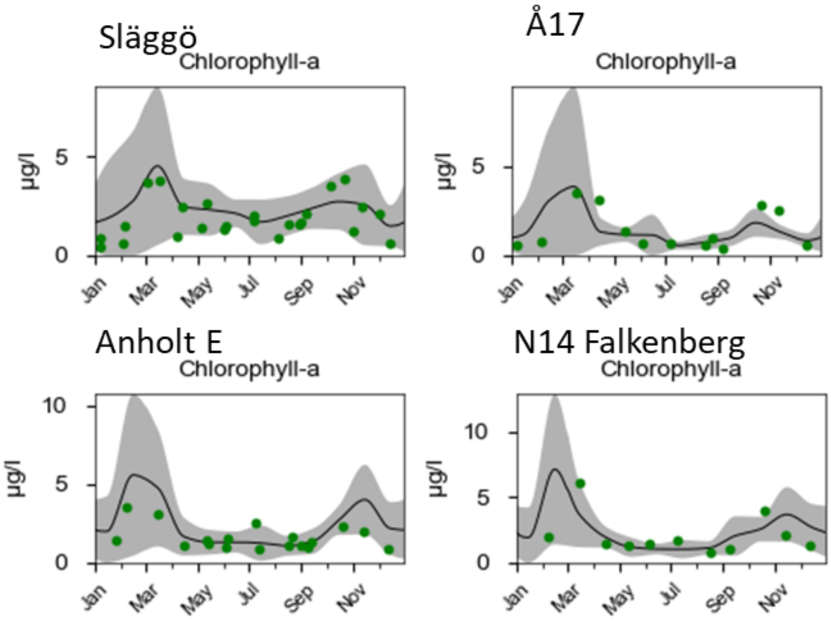

Figure 13. Integrated chlorophyll, 0-10 m, at from top left, Släggö and Å17 in Skagerrak and Anholt E and N14 Falkenberg in Kattegat. The black line is the mean value 2001-2015 and the grey field is ± 1 standard deviation.

The nutrients in the Kattegat were almost all consumed in March, Figure 14, which is why the diatom spring bloom probably was at the end at Anholt E and N14 Falkenberg. The chlorophyll concentrations were above normal for this month at N14 Falkenberg, partly caused by the diatom *Skeletonema marinoi.* Several other diatoms were also abundant, amongst others, the potentially toxic species *Pseudo-nitzschia seriata*. In the Skagerrak, nutrients were still available insinuating that the spring bloom was in an earlier stage compared to the Kattegat. The chlorophyll concentrations were high although within the standard deviations.

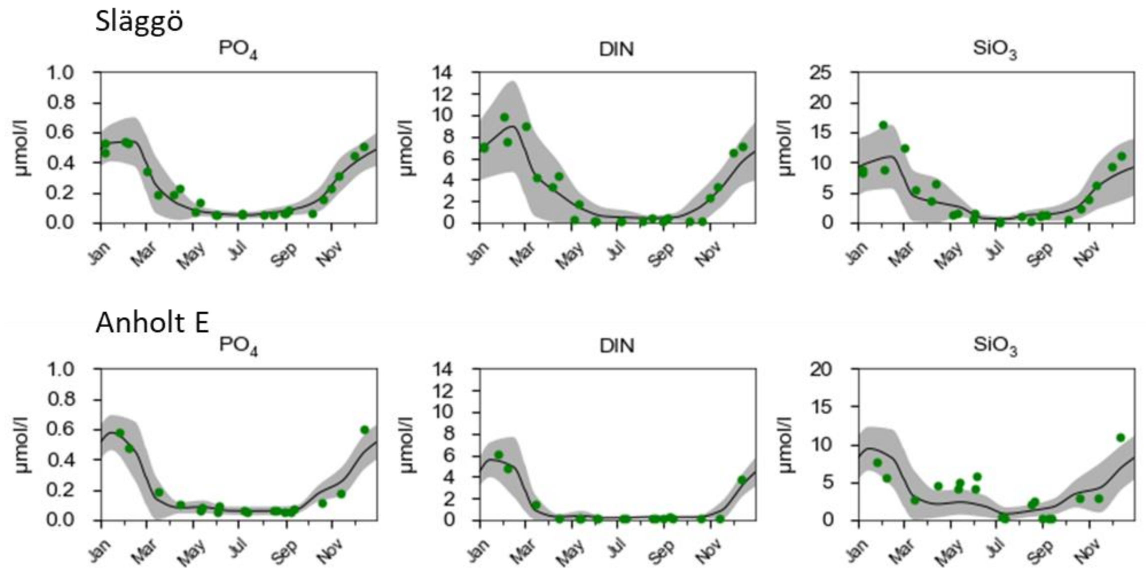

Figure 14. The concentration of phosphate, DIN and silicate in the surface, 0-10 m, from Släggö in coastal Skagerrak (top) and Anholt E in Kattegat. The black line is the mean value 2001-2015 and the grey field is ± 1 standard deviation.

The Swedish Food Agency reported only one incident of toxins in bivalves above the warning limits during 2020. PST (paralytic shellfish toxins) were found in Japanese oysters in April at the Bohus coast. PST is produced by the dinoflagellate genus *Alexandrium,* which was observed above the warning limits a few times during the year, although not on the same occasion as the toxin was found in oysters.

High chlorophyll concentrations, Figure 13, at Å17 in the Skagerrak in April were mainly caused by the dinoflagellate *Tripos muelleri* (previously called *Ceratium tripos*).

High cell numbers of diatoms were found in the Skagerrak in May and in both Kattegat and Skagerrak in June. The dinoflagellate *Tripos muelleri* was abundant in June.

At the first visit at Anholt E in the Kattegat during the July cruise, the chlorophyll concentrations were above normal for this month, Figure 13. The diatom *Proboscia alata*, a typical summer diatom in the Kattegat and Skagerrak areas, was abundant. By now phosphate, nitrogen and silicate were almost or totally consumed in the whole area.

In August surface accumulations of cyanobacteria transported from the Baltic Sea were observed during the cruise. Accumulations were also reported from several sights along the west coast 9th-17th of August. The potentially toxic diatom genus *Pseudo-nitzschia*, Figure 15, was abundant as well as the coccolithophorid *Emiliania huxleyi* at all stations except Å17 in the Skagerrak.

Figure 15. The potentially toxic diatom Pseudo-nitzschia seriata *was abundant in the Skagerrak in March and various species of the genus* Pseudo-nitzschia *were numerous in the Skagerrak and Kattegat areas in August. Photo: Ann-Turi Skjevik*

Diatoms kept dominating the samples during autumn from September to November and a diatom bloom was observed in October. The nutrients were still as low as the July concentrations in November at all stations except Släggö where they started to reach winter levels. The chlorophyll concentrations were above normal for the month at Å17 in November, mostly caused by diatoms and the silica flagellate *Octactis speculum.*

A late bloom of the microzooplankton *Noctiluca scintillans* was observed from many locations at the Swedish west coast in December which caused much attention from the media. *N. scintillans* colors the ocean red when blooming and its fluorescence causes beautiful bioluminescence when it is dark during the night.

4.2 Baltic Proper

4.2.1 Temperature and salinity

The winter 2020 was warm and the temperature in the surface water never reached the normal minimum winter temperatures in February-March, Figure 17. The lowest temperatures were recorded in March, ranging from 4.2 degrees in the Northern Baltic Proper to 5.3 degrees in the Arkona and Bornholm basins. The minimum winter temperatures in 2020 were around 2 degrees above the 15-year mean (mean is 1.7-2.8 degrees; standard deviation is ca 1 degree).

After the unusually warm start of the year the surface temperatures from March to July were close to normal. In August the year's highest temperatures were recorded and the surface water temperature was then 19-20 degrees at all stations. This temperature was around 1.2 degrees above the 15-year mean value for August. A warm autumn followed and although the water cooled down from the high August temperatures the surface temperature stayed above normal at many stations. In November the surface temperature was about 1 degree above normal at all stations. See Figure 16.

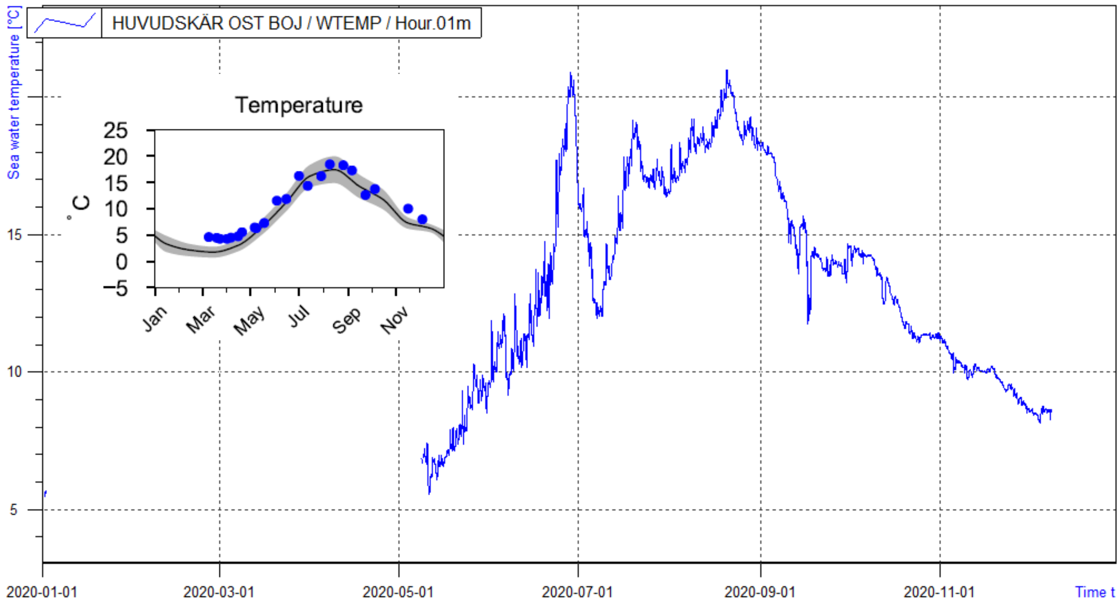

Figure 16. Water temperature from 1 m from the buoy at Huvudskär. The insert shows the averaged surface temperature, 0-10 m, sampled during monitoring cruises at the station BY31.

The temperature and salinity profiles, Figure 18, shows that it is evident that the high temperature (and salinity) is not limited to the surface water but is observed from the surface down to the bottom.

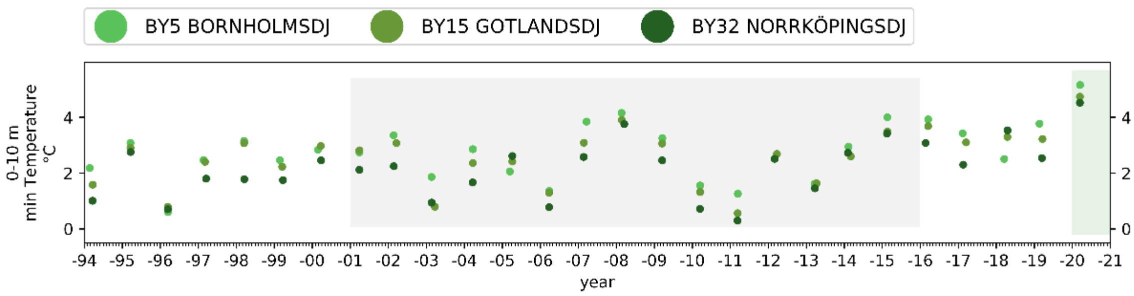

Figure 17. Lowest temperature in the first quarter of the year at three stations in the Baltic Proper, the winter 2020 was unusually warm and the lowest temperature was around 5 degrees, which is ca 2-3 degrees above normal.

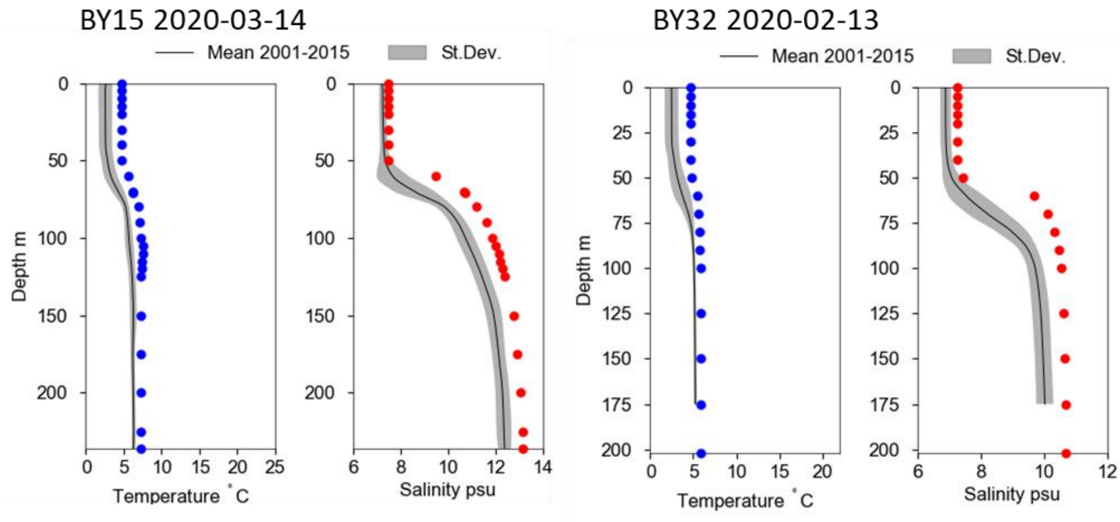

Figure 18. Temperature and salinity profiles from BY15 and BY32 illustrating that temperature and salinity was above normal in the entire water columns at most visits.

Surface salinity was mostly above normal, a trend that is seen after the inflow in 2014-2015, Figure 19. In Arkona, Bornholm and the Eastern Gotland Basin the salinity was above normal from March to the December, with only a few exceptions. In the Northern Baltic Proper the surface salinity was normal from the end of August until the end of the year. Just like temperature the high salinity was not limited to the surface water but was seen at almost all depths, from the surface to the bottom, Figure 18. Since the only source of salt is the inflows from the Kattegat the source of this increased salinity must be the large saline inflow in 2014 and the series of medium or small inflows that followed during the following years. The inflowing water was also warmer than normal, and the saline and warm inflow of 2014-2015 has resulted in a warmer and more saline deep water in the Baltic Proper compare to the period prior to the inflow, Figure 20.

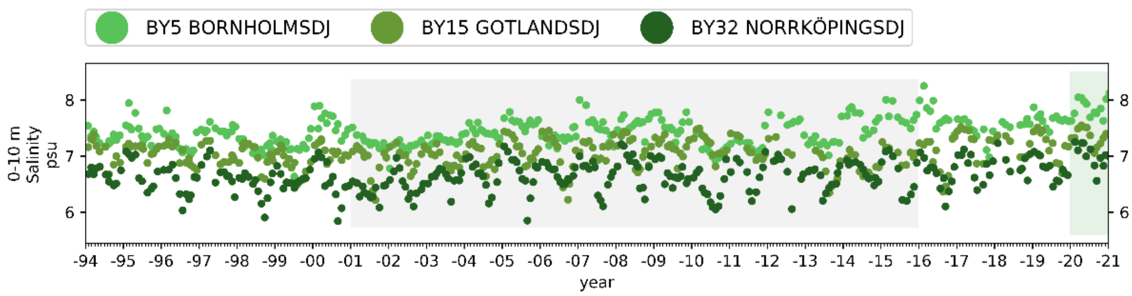

Figure 19. Salinity in the surface water (0-10 m) at three stations in the Baltic Proper.

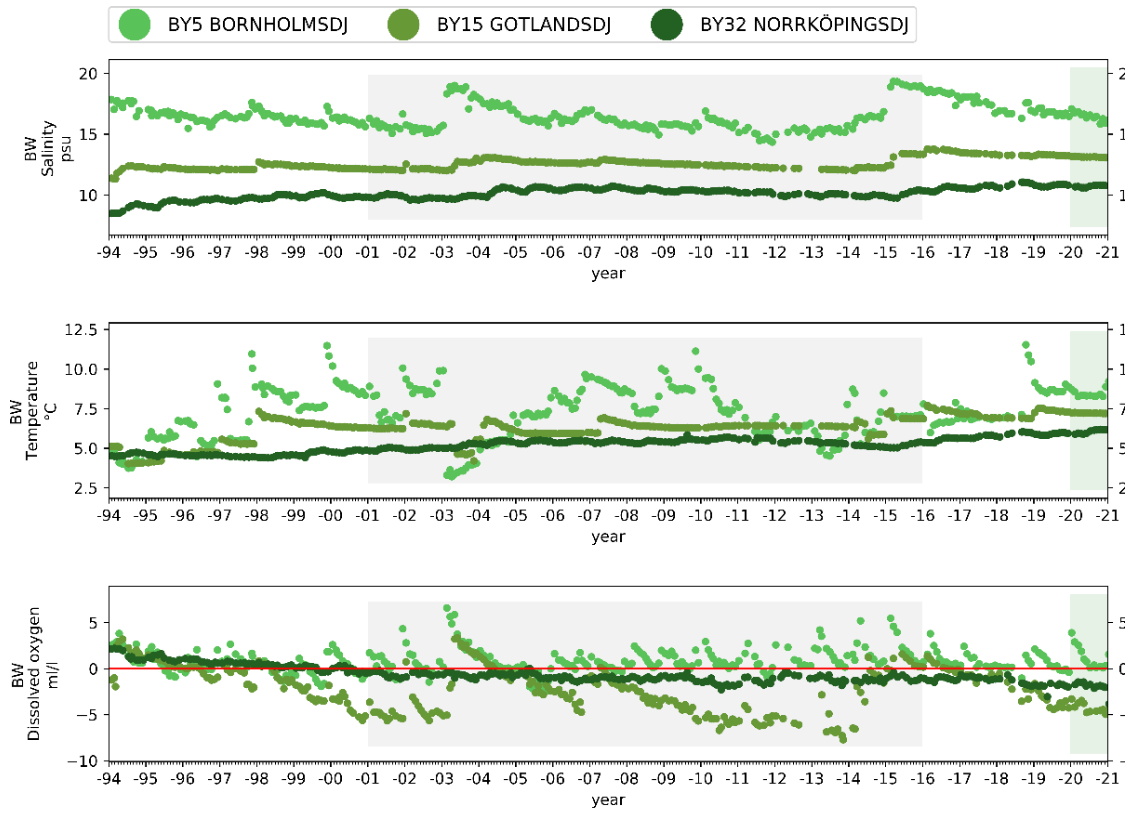

Figure 20. Bottom water salinity, temperature and dissolved oxygen at BY5 (≥80 m), BY15 (≥225 m) and BY32 (≥75 m).

The halocline in the Baltic Proper is situated between 50-70 m, shallowest in the southern Bornholm Basin and deepest in the Western Gotland Basin. In February 2020 the halocline was around 10 m shallower than normal in the Hanö bight and the northern part of the Bornholm Basin (seen at BY4 but not at BY5). In February, unusually sharp haloclines were also noted in the Western Gotland Basin (stations BY38 and BY32) and in March in the Eastern Gotland Basin (stations BY10 and BY15). The sharp and shallow haloclines resulted in oxygen concentrations lower than normal at the depths normally above or at the start of the halocline. In November 2019 an inflow of ca 40 km^3 through the Sound was registered[8]. This inflow was seen as increased salinity (20 psu) in the bottom water in Arkona in December 2019 and in January 2020 in the Bornholm Basin. Higher than normal salinity was observed in the Eastern Gotland Basin just below the halocline in March, this could also be a trace from the inflow in December 2019. A deeper than normal halocline was only observed at one station, BY29 in the Northern Baltic Proper, in February, April and May.

4.2.2 Oxygen conditions in the bottom water

There was no substantial improvement of the oxygen conditions in the bottom waters during 2020. In January the bottom water in Bornholm Basin was well oxygenated, due to an inflow in the end of 2019. After this the oxygen concentration decreased each month and was close to zero again in June and remained so until December. The same decrease was seen in Hanö bight, but was interrupted in December 2020 when the

[8] Östersjöns in- och utflöden 2019, smhi.se

oxygen concentration increased slightly. In Hanö bight a bottom rig with oxygen, salinity and temperature sensors was deployed in May, the data from the rig shows how the oxygen concentration varies between the monthly visits, see Figure 21.

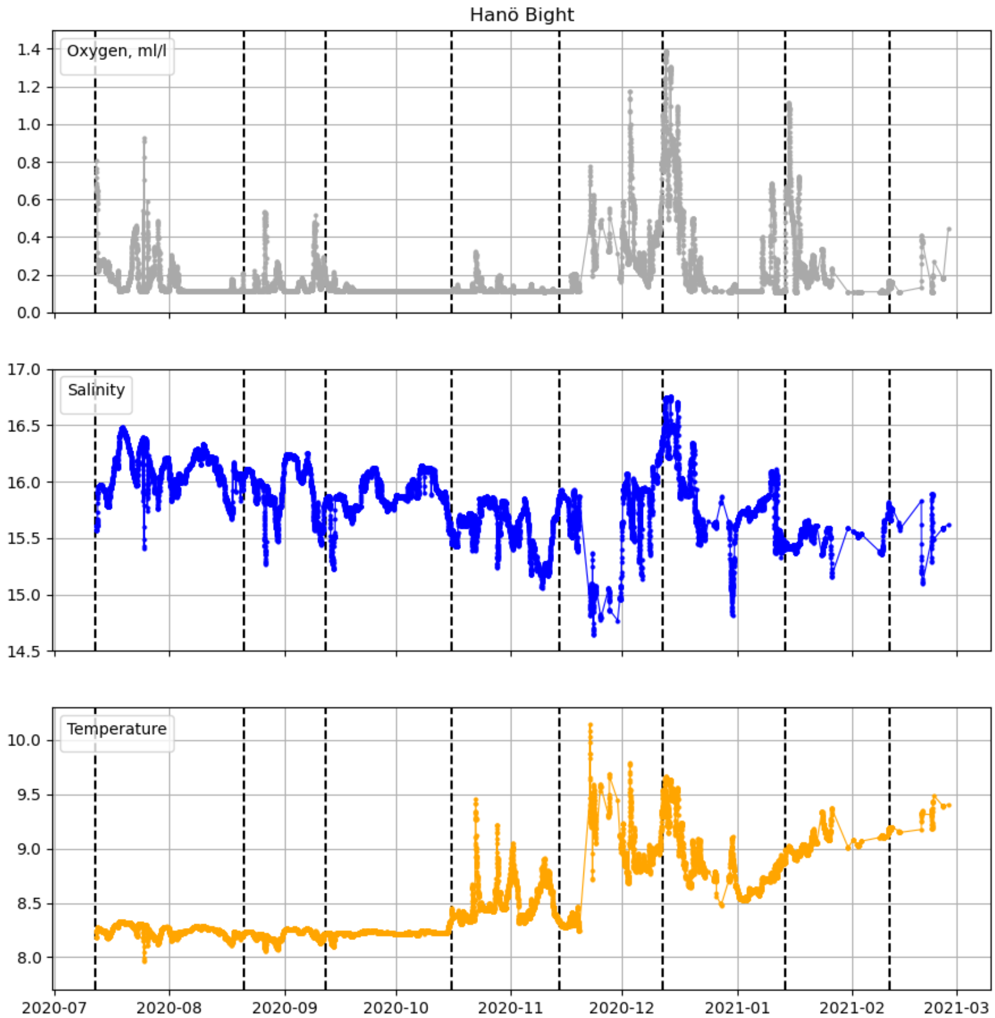

Figure 21. Data from the oxygen, salinity and temperature sensors deployed at Hanö Bight at 80 m. Vertical lines illustrates the time for the monitoring cruises.

In the southern part of the Eastern Gotland Basin (station BCS III-10) there were also signs of the inflow that occurred in December 2019 with oxygen concentrations just above 2 ml/l in January. Like in the Bornholm Basin the oxygen then decreased but remained at around 1 ml/l until October and in November it had decreased to almost zero. At the station BY10 there was small amounts of oxygen between 80-100 m in February and in May-August, likely connected to the same inflow that could be seen in the bottom water at BCS III-10 in January. Similarly, at station BY15 in the Gotland Deep there was a layer with hypoxic water (<2ml/l) at around 80-125 m underneath a thin layer of anoxic water. Below 125 m the water was anoxic again and toxic hydrogen sulphide was observed. North of the Gotland Deep and into the Western Gotland Basin the water remains hypoxic from 70-80 m depth and anoxic from 80-90 m depth.

The areal extent of anoxia and hypoxia remains elevated during 2020. The preliminary results for 2020 shows that anoxia affected 18% of the bottom areas and 31% suffered from hypoxia. Hence, the anoxic and hypoxic conditions have decreased somewhat compared to the record years 2018-2019. However, the decrease in hypoxia is small. The decrease in anoxia noted during 2020 in the southern Baltic Proper can be connected to the inflow that occurred during 2019. The positive development in the Gulf of Finland is most likely due to changes in stratification and mixing since no inflows has reached this area. The pool of hydrogen sulphide is increasing in both the Western- and Eastern Gotland Basin[5].

In the Arkona Basin the oxygen concentration followed the normal annual cycle with highest concentrations in early winter and deteriorating conditions during summer and autumn with the lowest oxygen concentrations observed in August and September (<2ml/l, hypoxic). After this the oxygen concentration increased every month until December.

4.2.3 Nutrients

The seasonal cycle of nutrients in the surface water followed overall a normal situation. The results from the winter mapping cruise in February, when all mapping stations are visited, showed mainly higher silicate levels in the surface layer while the levels of DIN and phosphate were normal at most stations, Figure 22.

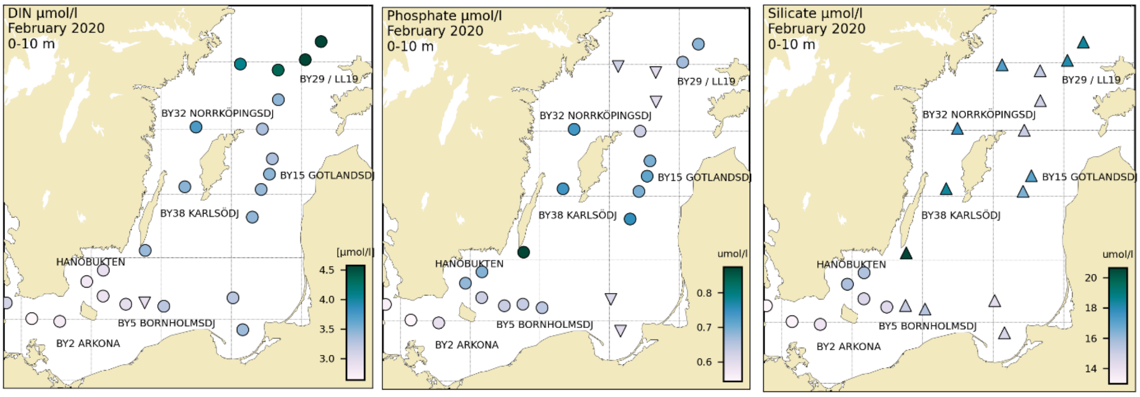

Figure 22. The averaged concentration of DIN, phosphate and silicate in the surface layer, 0-10 m, in February at the monitoring stations in the Baltic Proper. ○ concentration is within the mean ± 1 standard deviation, Δ concentration is > 1 standard deviation from the mean and ∇ concentration is <1 standard deviation from the mean. The statistical mean is based on basin data from the time period 2001-2015.

The major decrease in nutrients, related to the spring bloom, was observed in April in all sea basins in the Baltic Proper, about one month later than in the Kattegat. Most obvious was the decrease in DIN that dropped rapidly to concentrations near the detection limit (0.1 µmol/l). The concentration of DIN was depleted from April to September down to the halocline. While DIN was depleted in the surface layer the concentration of phosphate was not and there were hence favourable conditions for cyanobacteria blooms to grow. The phosphate concentration in spring where above normal in the southern and eastern parts, from the surface layer down to the halocline. The concentration of silicate decreased later in summer and was high in the south and the east for almost the entire year, Figure 23.

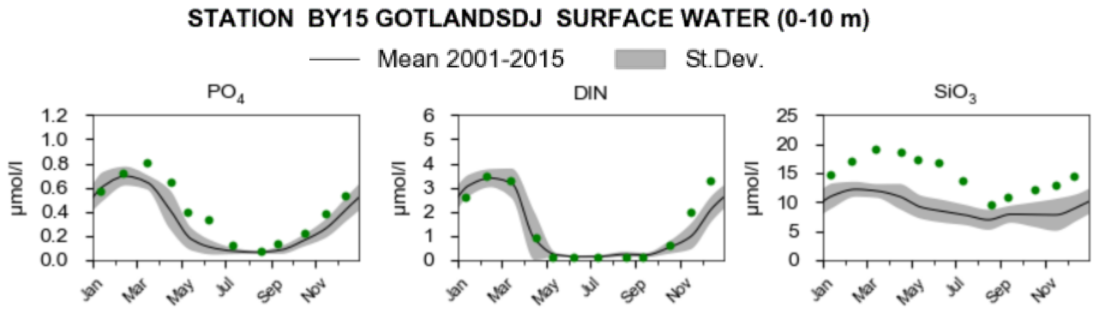

Figure 23. The averaged concentration of phosphate, DIN and silicate in the surface layer, 0-10 m, in 2020 at the monitoring station BY15 in the Eastern Gotland Basin.

The surface concentration of silicate and phosphate in the Arkona-, Bornholm- and Eastern Gotland basins were higher during 2020 than in 2019. On the other hand, the concentration of silicate in the Western- and Northern Gotland basins were lower during 2020 than in 2019.

The concentration of nutrients increases in the deep water, below the halocline, due to remineralisation of organic matter and in the deep parts of the Baltic Proper the concentration is also affected by the stagnation of water. The condition of nutrients in the deep water during 2020 where mainly normal except from the concentration of ammonia. The levels of ammonia in the bottom water have increased in both the Eastern- and Western Gotland basins, Figure 24. Highest concentration was observed in the Eastern Gotland Basin but in the Western Gotland Basin the ammonia levels are now above normal in the water mass below the halocline, Figure 25.Hydrogen sulphide and phosphate also increase in the deep waters, but have not yet reached record high concentrations, like ammonia have.

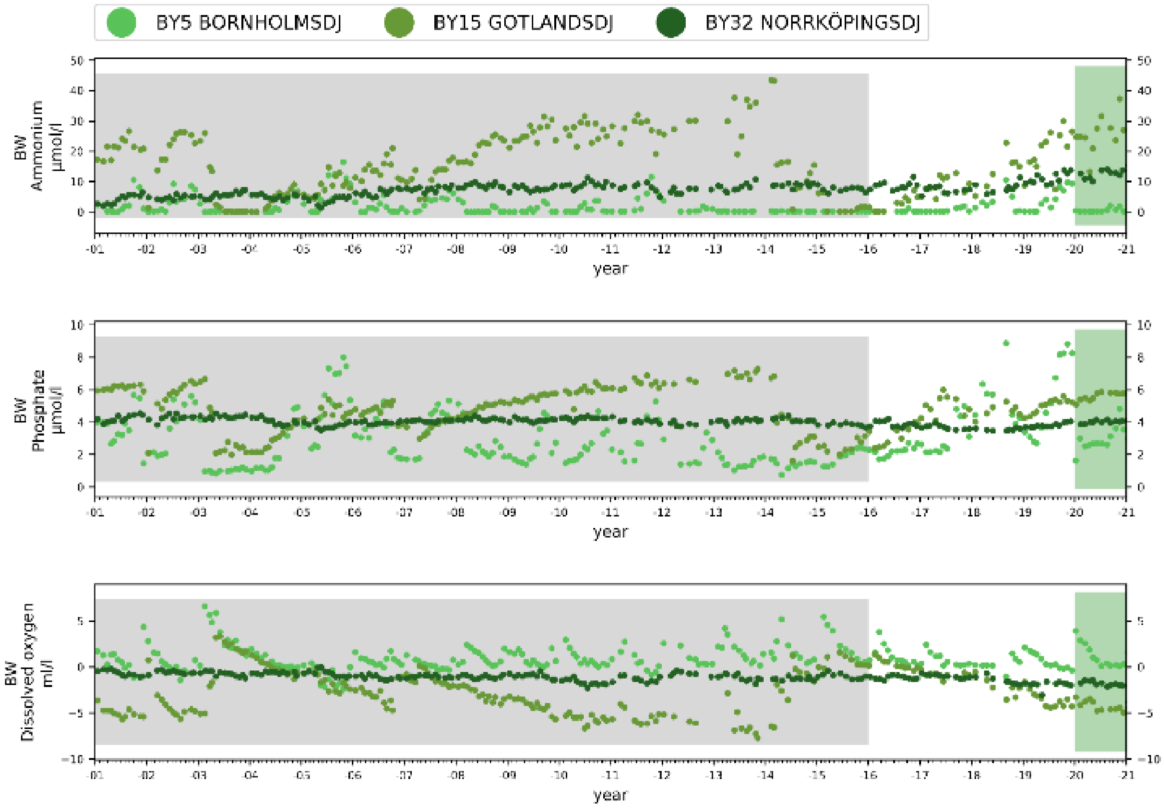

Figure 24. The concentration of ammonia, phosphate and dissolved oxygen in the bottom water at the monitoring stations BY5 in the Bornholm Basin ≥80 m, BY15 in the Eastern Gotland Basin ≥225 m and BY32 in the Western Gotland Basin ≥175 m. The shadowed grey area highlights the time period that statistics is based on in this report, 2001-2015. The shadowed green area highlights the year 2020.

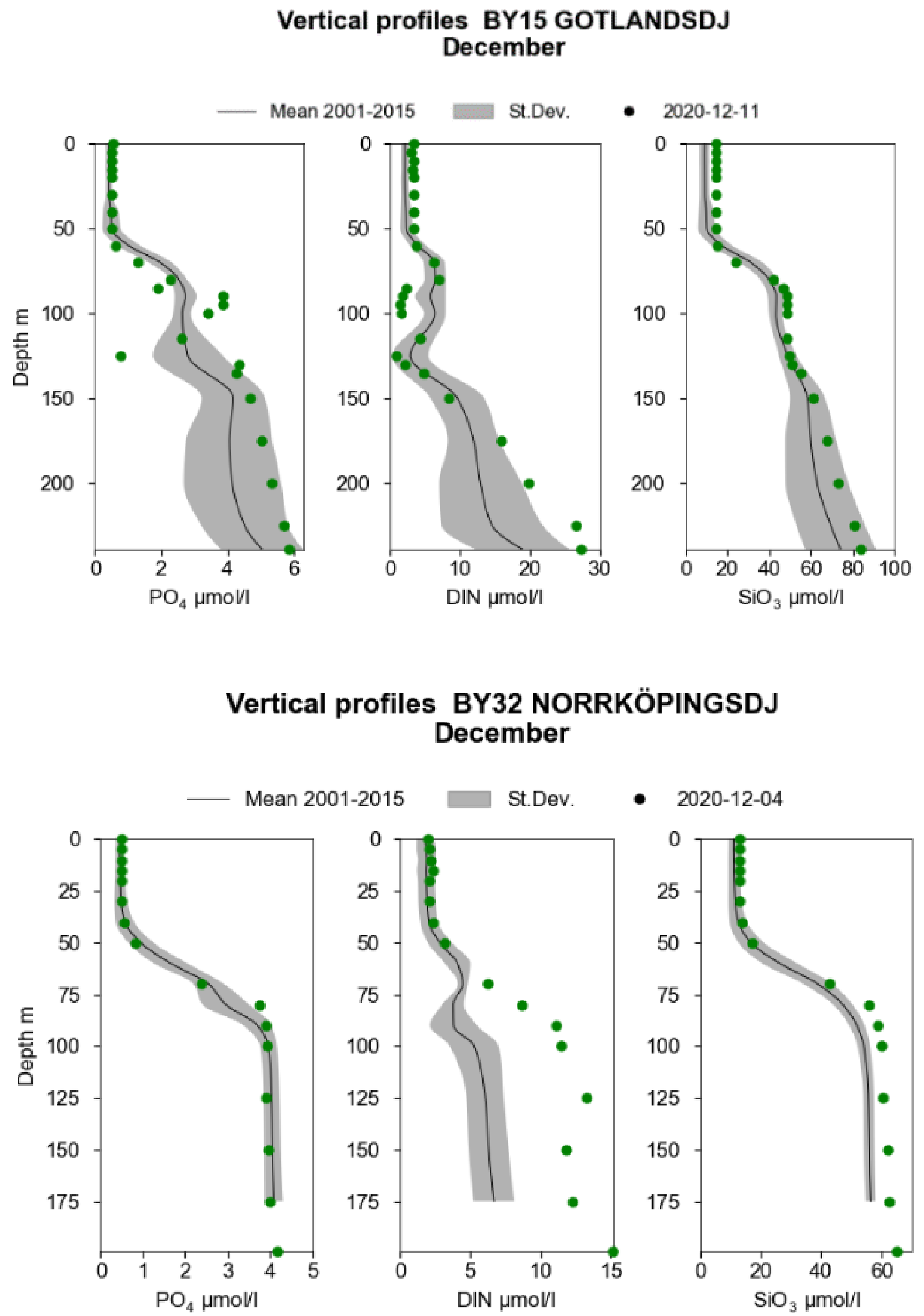

Figure 25. Vertical profiles of nutrients from the monitoring stations BY15 in the Eastern Gotland Basin and BY32 in the Western Gotland Basin, December 2020.

4.2.4 Phytoplankton

In January the chlorophyll concentrations were above normal for the month at BY1 and BY2 in the Southwestern Baltic, Figure 26, partly caused by the diatom *Dactyliosolen fragilissimus*. The overall phytoplankton situation was otherwise calm during the winter with small cells of various species.

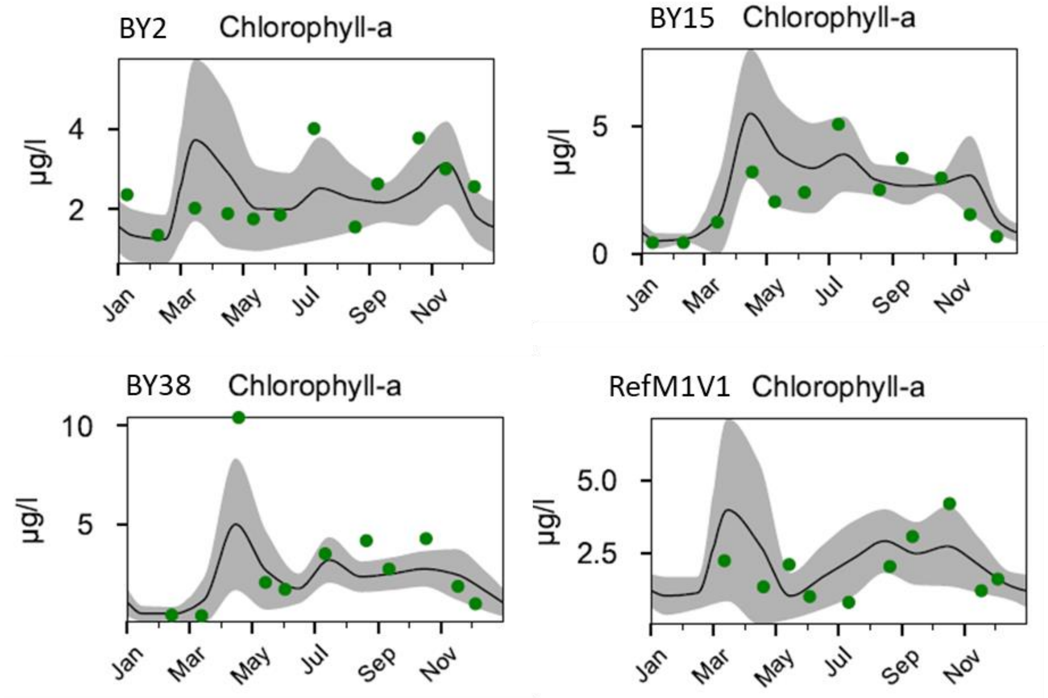

Figure 26. Integrated chlorophyll, 0-10 m, at from top left, BY2, BY15, BY38 and REF M1V1 in the Baltic Proper. The black line is the mean value 2001-2015 and the grey field is ± 1 standard deviation.

Both the number of species and the total cell numbers were low in February and March.

In April spring bloom was observed in the Western Gotland Basin. High chlorophyll concentrations were found at BY32 and BY38 and at the latter, the typical spring dinoflagellate *Peridiniella catenata* dominated the phytoplankton sample. The species diversity was high in the southern Baltic, especially at BY5 were high cell counts of the diatom *Skeletonema marinoi* and the dinoflagellate *Heterocapsa triquetra* were found.

The species diversity was high at the Baltic phytoplankton stations in May. The filamentous cyanobacterium *Aphanizomenon flosaquae* was already abundant at several stations with the highest amounts at the stations BCSIII-10, BY15, BY38 and BY29. These stations are located in the Southeastern Baltic and northwards, which is where the cyanobacteria blooms were first spotted from the satellite observation system BAWS (Baltic Algae Watch System) last year.

High amounts of *A. flosaquae* were found at most of the phytoplankton stations in June and the first observation of the potentially toxic cyanobacterium *Nodularia spumigena* was made at BY5. The first detections of surface accumulations by the Baltic Algal Watch System - BAWS were made in the middle of the month.

In July the chlorophyll concentrations were above normal for the month at the stations BY1, BY2, BY15 and BY20. All of the three cyanobacteria known to form the massive surface accumulations during summer, *A. flosaquae, N. spumigena* and *Dolichospermum sp.*, were present in all phytoplankton samples, Figure 27.

Figure 27. A typical sample from the cyanobacteria surface accumulations in the Baltic Sea in July contains the cyanobacteria Aphanizomenon flosaquae *(arrow head),* Nodularia spumigena *(arrow) and* Dolichospermum *sp (star).*

At BY15, BY38 and at REFM1V1, the amounts of cyanobacteria were high in August, and surface samples at BY10 and BY32 were dominated by *N. spumigena.* In the southern and eastern Baltic, there were few or none filamentous cyanobacteria in the samples. There were, however, high cell numbers of the dinoflagellate *Prorocentrum cordatum* at BY2.

In September the chlorophyll concentrations were above normal at BY15 in the Eastern Gotland Basin. The diatom *Chaetoceros castracanei* was abundant as well as various small species and low amounts of cyanobacteria, both *A. flosaquae* and *N. spumigena*.

The species diversity was rather high in October with predominantly small species in low cell numbers. The chlorophyll concentrations were however above normal for this month at several stations.

Further on through the autumn, chlorophyll concentrations were low, nutrients were elevated towards winter levels and phytoplankton were accordingly found in low diversity.

4.3 The Gulf of Bothnia (Bothnian Sea and Bothnian Bay)

4.3.1 Temperature and salinity

In the Bothnian Sea and Bothnian Bay the surface water temperatures were not as much above normal as in the other sea areas, however this area is normally ice covered in winter and the mild weather was instead reflected in the low ice extent. The continuous passing of lows on a north-easterly track broke the newly formed ice and pushed it to north of the Bothnian Bay. The winters maximum ice cover was recorded on March 5th with 37 000 km^2, which is the lowest maximum ice cover since the beginning of the 20th century. Temperature above normal was measured in February in the Bothnian Sea, but other than this the surface temperatures were within normal at the open sea stations. At the coastal stations in the Råne fjärd the highest temperatures in the area were recorded at close to 20 degrees in August. Here the surface water temperature was also above normal in June. Surface water salinity was within normal at all stations except two of the coastal stations, Gavik-1 in the Bothnian Sea and station B7 in the Quark where the salinity was above normal between January and April.

The Bothnian Bay is generally well mixed with only slightly higher salinity at the bottom than at the surface, in summer a thermocline develops when the surface water warms up. The Bothnian Sea has a week stratification with about 0.5 psu higher salinity at the bottom compared to the surface. There is a small increase in salinity and temperature in the bottom water in the Bothnian Sea that seems to reflect the inflow in 2014-2015, Figure 28.

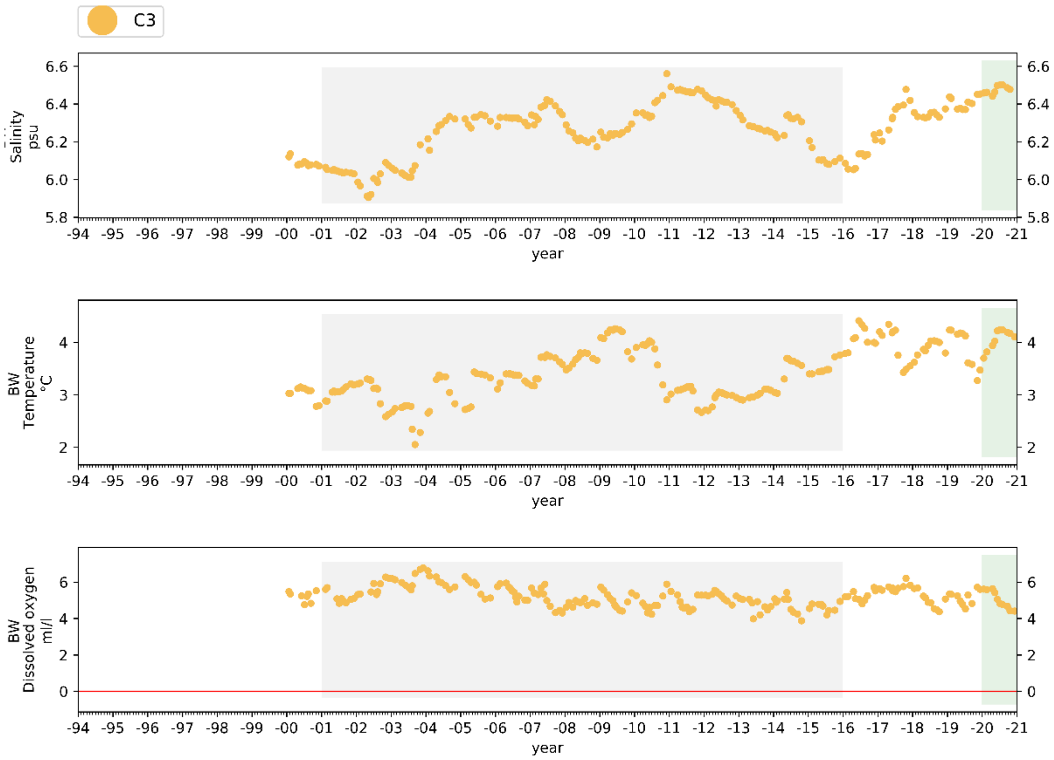

Figure 28. Bottom water data from station C3 in the Bothnian Sea, data is from ≥180 m. From top to bottom: salinity, temperature, dissolved oxygen.

4.3.2 Oxygen conditions in the bottom water

The bottom water in the Gulf of Bothnia is generally well oxygenated since the stratification is week, and the sea area is mainly oligotrophic. At the coastal stations Råneå-1, Råneå-2 and B7 the bottom water oxygen becomes lower during summer months and in 2020 the oxygen concentration in summer was just below normal at these stations. At the coastal station Gavik-1 in the Bothnian Sea the bottom water oxygen concentration was just above the limit for oxygen deficiency at 4 ml/l in October and December, which is below normal at this station. At the open sea station C3 the bottom water oxygen concentration was also below normal in October and December.

There is a trend with decreasing oxygen concentrations in the Bothnian Sea deep water (Figure 28), see e.g. Ahlgren et al 2017[9].

4.3.3 Nutrients

The winter concentrations of DIN in the surface water were below normal in the Bothnian Sea and Bothnian Bay while both phosphate and silicate were above normal, Figure 29. The Bothnian Bay has the lowest phosphate levels and the highest silicate levels of all Swedish open sea areas.

The decreasing concentrations of DIN in the Gulf of Bothnia have been observed since at least 2001, Figure 5, and phosphate levels have been higher in particular in the Bothnian Sea since 2014.

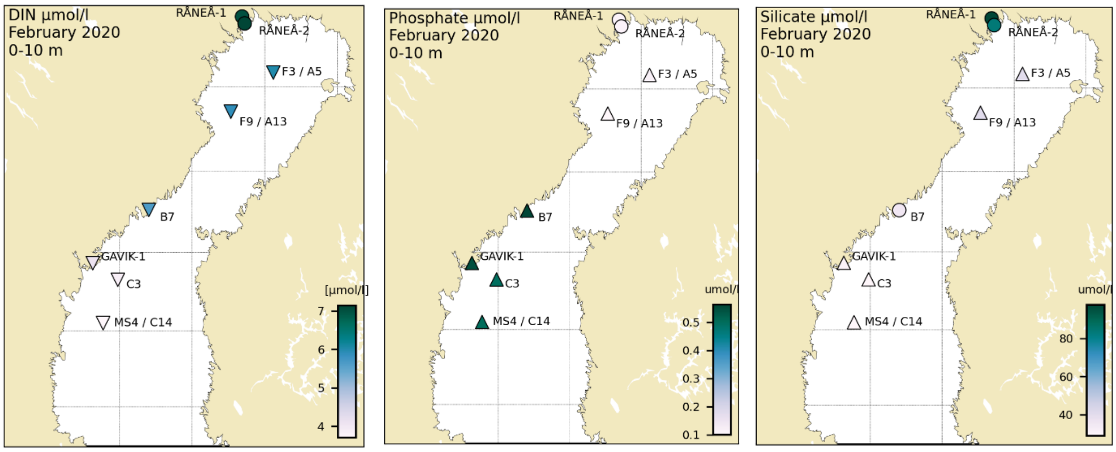

Figure 29. The averaged concentration of DIN, phosphate and silicate in the surface layer, 0-10 m, in February at the monitoring stations in the Gulf of Bothnia. ○ concentration is within the mean± 1 standard deviation, Δ concentration is >1 standard deviation from the mean and ∇ concentration is <1 standard deviation from the mean. The statistical mean is based on station data from the time period 2001-2015.

Inorganic nutrients were monitored each visit near the coast but only during winter in the open sea. The levels of DIN and phosphate at the coastal stations had dropped to lower levels in April and the lowest observations were in summer with levels just above the detection limit. The concentration of silicate was never a limiting factor in this sea area.

The Bothnian Bay is not very stratified and it is therefore little difference between the concentrations of nutrients in the surface layer and the bottom layer. The Bothnian Sea on the other hand is a little bit more saline and the stratification is stronger, even though it is not that stratified as the Baltic Proper, and there is a larger difference in nutrient concentrations between surface and bottom layer. Below the stratification the concentrations are higher, Figure 30.

[9] Ahlgren J., Grimvall A., Omstedt A., Rolff C., Wikner J., 2017, Temperature, DOC level and basin interactions explain the declining oxygen concentrations in the Bothnian Sea. Journal of Marine Systems 170 (2017) 22–30.

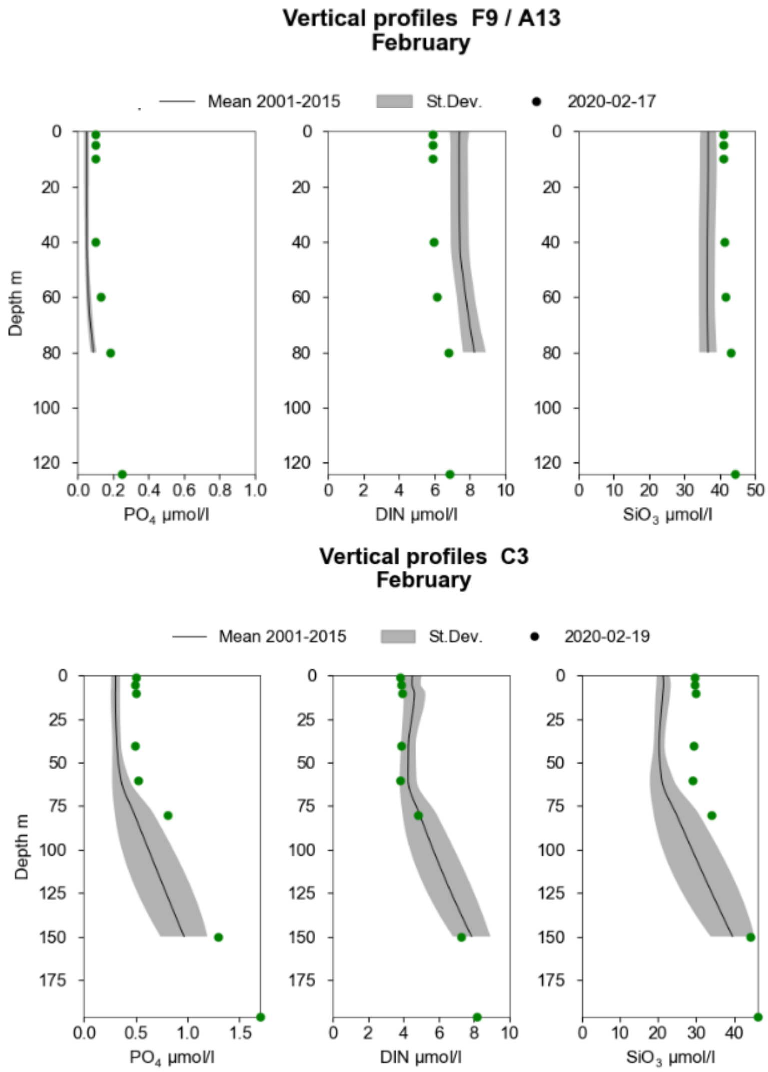

Figure 30. Vertical profiles of nutrients from the monitoring stations F9/A13 in the Bothnian Bay and C3 in the Bothnian Sea, February 2020.

4.3.4 Phytoplankton

An early spring bloom was observed at F9/A13 in April, dominated by diatoms, and the maximum biovolume was found in May and July. The early spring bloom may be an effect of the exceptionally mild ice winter with the lowest ice extension since the beginning of the 20th century. Diatoms dominated April-July with elevating amounts of flagellates during the summer months, June and July. The ciliate *Mesodinium rubrum* dominated the samples in August-September before the diatoms reentered and dominated throughout the autumn.

At Råneå-2, the outer most station in Råneå, spring bloom started in May with a maximum in June, which is normal for this area. Dinoflagellates dominated the samples in April and May while diatoms dominated in June. In July there was a higher diversity with several groups dominating amongst others diatoms and Prymniophyceae. The class Cryptophyceae dominated in August predominantly with the genus *Cryptomonas*. Another somewhat lower maximum was found in September mainly caused by the cyanobacterium *Planktothrix agardhii*, diatoms and the class Cryptophyceae. At RA1 in Råneå, the spring bloom probably occurred in June considering the species composition which was dominated by diatoms. The species diversity was high in July with a slight dominance of Chlorophytes. The biovolume maximum of the year was found in August, caused by the class Cryptophyceae, diatoms and cyanobacteria. The second highest total biovolume was found in September and was dominated by diatoms and cyanobacteria.

4.4 Time series

Although the focus of this report is on the measurements in the pelagic monitoring programme of the previous year (2020), we also present longer times series of the physical and chemical data held by the data host (SMHI). For salinity, temperature, oxygen, nutrients and chlorophyll we present time series 1960-2020 of surface waters (mean of 0-10 m) and bottom waters (depths defined for each station) for each sampling occasion in Appendix II. These time series show the general picture at each monitoring station and also gives a view of the change of measurement frequency over the years.

4.4.1 Content of nutrients in the Baltic Proper basins

In addition to the times series this report also show time series of calculated content of nutrient concentrations in each basin in the Baltic Sea.

In Appendix III the content of nutrients in each basin was calculated from the monthly sampling station, i.e. the same data set that was used for the time series 1960-2020 presented in Appendix II. The resulting time series of nutrient content shows large scale changes of the nutrient pools as well as differences between the basins.

Starting in the south with the Arkona Basin and the Bornholm Basins, a sudden increase in the content of both inorganic and total phosphorus is seen between 2004 and 2005 (Appendix III). This could be an effect of higher concentrations in the surface waters which could be a consequence of the inflow in the winter 2003-2004 that lifted phosphorus rich water from the deep basins in the Baltic Proper to surface waters. However, it should be noted that the total phosphorus method at the SMHI laboratory was changed at the same time which makes the changes in total phosphorus more difficult to connect to changes due to the inflow.

In the rest of the Baltic Proper the phosphorus content increased from 1994 until around 2000 when it starts to level out. The last three years show a tendency towards decreasing phosphorus content in the Eastern Gotland Basin, but it is still too early to determine if it is a persistent or temporary decline (Appendix III). The nitrogen content decreased from 1994 to the beginning of the 21st century (Appendix III). The drop in dissolved inorganic nitrogen is most drastic in the Western Gotland Basin for the sub-basins around stations BY31 and BY32 (Appendix III). The decrease in nitrogen content is most likely due to decreased loading of nitrogen from land while the absence of a decrease in phosphorus is explained by recycling of phosphate from sediment and decreased burial capacity of phosphorus in anoxic sediment. With continued efforts to reduce phosphorus and nitrogen loading the content should also decrease in the future.

In the Bothnian Sea the increasing phosphorus and silicate concentrations are clearly reflected in an increase in phosphorus and silicate content since year 2000. In the Bothnian Bay the silicate and phosphorus content is also increasing and here the nitrogen content is clearly decreasing over the same period (Appendix III).

5 SMHI Publications

SMHI publish seven reportseries. 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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