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Report from SMHI's marine monitoring cruise with R/V Svea

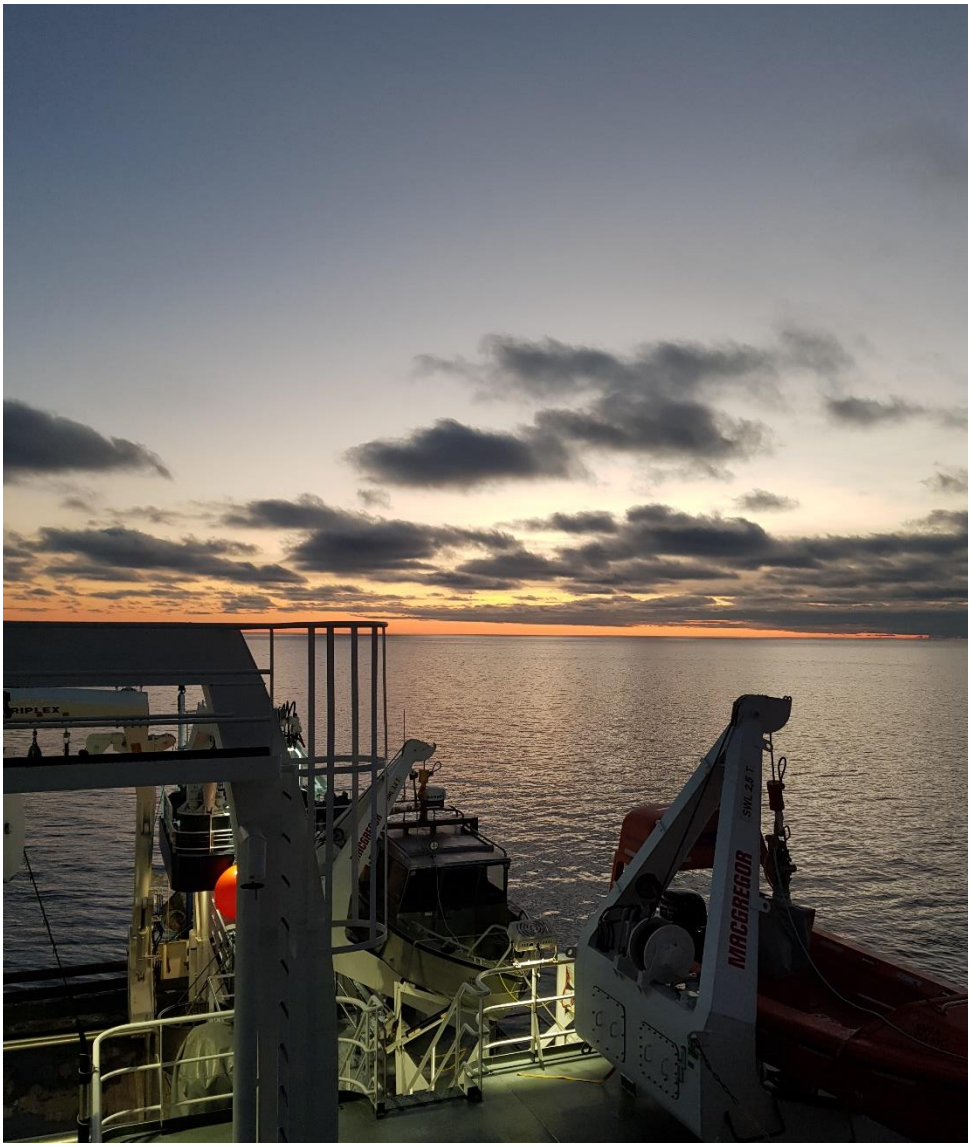

Photo: Ola Kalén, SMHI

Survey period: 2022-12-05 to 2022-12-16

Principals: Swedish Meteorological and Hydrological Institute (SMHI),
Umeå Marine Sciences Centre (UMF),
Swedish Agency for Marine and Water Management (SwAM)

Cooperation partners: Swedish University of Agricultural Sciences (SLU),
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SUMMARY

During the cruise, which is part of the Swedish pelagic monitoring program, the Skagerrak, Kattegat, the Sound, the Baltic Proper and the Gulf of Bothnia were visited. In the Gulf of Bothnia, SMHI and Umeå Marine Research Center (UMF) carried out a joint mapping of nutrients.

The cooling of the surface water had now gained momentum in all investigated areas. But temperatures above normal were noted in the Baltic Proper and the Bothnian Sea, while the temperature in the Skagerrak and Kattegat were partly lower than normal. The salinity in the surface water was normal in the Skagerrak, the Kattegat and the Gulf of Bothnia, while levels higher than normal were noted in parts of the Baltic Proper and the Bothnian Sea.

In the Skagerrak and Kattegat, the concentration of nutrients had increased markedly in the surface water since November, but the levels of all nutrients were within the normal range for the month. In the Baltic Proper, the concentration of nutrients had increased in the surface layer since November, above all there had been a strong increase in inorganic nitrogen. In both the Eastern and Western Gotland basins, higher values of inorganic nitrogen and silicate than normal were measured below 100 meters depth. At station BCSIII-10 the concentration of phosphate and inorganic nitrogen was instead below normal and the entire water column was oxygenated. In the Bornholm Basin, the Hanö Bight and in the Arkona Basin, the concentrations of nutrients were mostly normal. In the Bothnian Sea, concentrations were slightly lower than normal in the eastern parts and at some of the stations in the northern parts. In the deep water, the levels were mostly normal, but in the central parts, levels were found high above normal. The phosphate levels in the surface water were lower than normal in the eastern parts and at some stations in the northern parts of the area. The phosphate content increased with depth and the levels in the deep water were much above normal at some stations. Silicate levels were generally higher in the surface water in the western and central parts of the area compared to the eastern. Here, too, the levels increased with depth and at many stations levels above normal were noted in the deep water.

In the Bothnian Bay, levels of inorganic nitrogen were below normal. In the deep water, the nitrogen content increased and showed great variation, normal levels and both lower and higher levels than normal. The phosphate content in the surface water was low, which is normal for the time of year. The levels increased with depth and in the deep water higher levels than normal were found. Silicate levels above normal were noted in the surface and in the deep water the levels increased further and here too the levels were higher than normal.

In the central basins of the Baltic Proper, hydrogen sulphide was measured from 70-80 m and in the remaining basins no hydrogen sulphide was measured. But in Hanö Bight and the Bornholm Basin, a lack of oxygen was noted from a depth of 70 meters. The lowest oxygen concentration was found at Hanö Bight and BY4 in the Bornholm Basin with 0.2-0.3 ml/l at 70 m. The oxygen content in the bottom water varied between about 5 ml/l in the Kattegat and 3 ml/l in the Sound, which is relatively low but just within the normal range. In the open Skagerrak, the oxygen situation was

good and at the coastal station Släggö the concentration had increased from 3 ml/l in November to just over 5 ml/l.

No lack of oxygen was noted in the Gulf of Bothnia. But low levels, close to oxygen deficiency, were noted at the coastal station Gavik-1. Levels just above 4 ml/l were also noted in the southwestern part of the Bothnian Sea.

SMHI's next regular cruise with R/V Svea is planned for 10th – 17th January, starting and ending in Lysekil.

RESULTS

The cruise was carried out on board the R/V Svea and started in Kalmar on the 5th of December and ended in Lysekil on the 16th of December. A crew exchange was carried out in Gävle harbor on 11 December.

During the first part of the cruise, from Kalmar to Gävle, personnel from the Umeå Marine Research Center (UMF) participated as part of coordination of SMHI's and UMF's part of the national marine environmental monitoring program. In the Gulf of Bothnia, the annual winter mapping of nutrients was carried out. SMHI staff performed CTD, water and net sampling and some analyses, while UMF crew carried out all analyzes of nutrients and biological parameters. In the Gulf of Bothnia, two stations were cancelled; US7 as well as F2, in order to keep the schedule.

During the second part of the cruise, from Gävle to Lysekil, the Baltic Proper and the Skagerrak and Kattegat were visited. A storm with northerly winds descended over the Baltic Proper with average winds just above 20 m/s and considerably higher gusts. When the cruise passed through the Eastern Gotland Basin, the waves were so high that sampling could not be carried out and two stations had to be cancelled; BY20 and BY15. During the passage to the east through the Bornholm Basin and Hanö Bight, the wind had decreased somewhat and was about 15-17 m/s but easterly. Only during the last day of the cruise in the Kattegat and Skagerrak did the winds become somewhat weaker.

At three stations in the Skagerrak and Kattegat, extra sampling of water for phytoplankton samples was carried out for Stockholm University.

Svea's instrument for measuring profiles while underway, the Moving Vessel Profiler (MVP), was run during the day between the sampling stations, approx. 300 profiles were collected. In the Gulf of Bothnia, the measurements had to be interrupted due to ice forming on MVP's cable and winch. The system could be restarted again in the southern Baltic Sea when there was no longer a risk of ice formation. The Ferrybox system and the ADCP were run continuously throughout the expedition.

This report is based on data that has undergone an initial quality control. When additional quality control has been performed, certain values may change. Data from this cruise is published as soon as possible on the data host's website, this usually takes place within a week after the cruise has ended. Some analyses are made after the cruise and are published later.

Data can be downloaded from SHARKweb here:
https://www.smhi.se/en/services/open-data/national-archive-for-oceanographic-data/download-data-1.153150

The Skagerrak

The temperature in surface water had dropped by between 6-8 degrees since the last cruise in November and was now below normal at three of the seven stations in the area. The lowest temperature, about 4 degrees, was at station P2 and Släggö in the mouth of the Gullmars fjord. At the Å-transect with five stations from the coast to the open sea, the temperature varied between 5-7 degrees and was below normal at the westernmost (Å17) and the easternmost (Å13) station. The salinity in the surface layer was normal at all stations and varied between just under 26 psu at station P2 to just over 30 psu at station Å17. At all stations except the westernmost Å17, there was a thermocline around five meters with cold well-mixed surface water of 3.5-4.0 degrees, at Å17 the thermocline was somewhat shallower. At most stations there was a layer below the thermocline at a

depth between 20-50 m with water that had temperatures around 10 degrees, which is above normal. Then the temperature decreased again and was normal in the deep water, between 7-9 degrees.

The concentration of nutrients had increased significantly in the surface water since November at all stations except station P2. Here, in the transition between several different water masses, the levels of inorganic nitrogen and phosphorus had instead decreased since November, a consequence of the water here now having a different origin with a lower salinity than in November. Levels of all nutrients were within the normal range for this time of the year.

The oxygen situation in the deep water was good at all stations, concentrations between 5.2 - 5.6 ml/l. All stations had normal values for the season. At the Släggö station, the concentration had increased from 2.9 ml/l in November to 5.3 ml/l

Chlorophyll fluorescence is a measure of plankton activity measured with a sensor mounted on the CTD. No strong chlorophyll fluorescence peaks were measured, but at all stations low activity was noted in the well-mixed surface layer down to the depth of the thermocline.

The Kattegat and the Sound

Similar to the Skagerrak, the surface temperature had decreased considerably since the cruise in November and was now below normal at the two northernmost stations, N14 and Fladen. The temperature was around 4 degrees in the Kattegat and about 5 degrees in the Sound. This was about 8 degrees colder compared to November. The salinity was normal at all stations, around 23 psu in Kattegat and 16 psu in the Sound. In Kattegat, the thermocline at about 10 m, which was about five meters deeper than in Skagerrak. Here too, there was an intermediate layer with a temperature above 10 degrees, which is above normal. In the Kattegat, the salinity below the thermocline was above normal. In the Sound there was a clear salinity stratification with a surface layer of water flowing out of the Baltic Sea with a salinity of around 16 psu and a layer of water flowing into the Baltic Sea below that with a salinity of around 30 psu.

Nutrient concentrations were normal in Kattegat surface water and had increased at all stations since sampling in November. At Fladen, the concentration of inorganic nitrogen was slightly lower than normal, as at P2 in Skagerrak, otherwise the concentrations were within normal. In the Sound the levels were higher than in the Kattegat, which is also normal.

The oxygen content in the bottom water varied between about 5 ml/l in the Kattegat and 3 ml/l in the Sound, which is relatively low but just within the normal range.
Just as in Skagerrak, some plankton activity was noted in the upper layer down to the thermocline from the chlorophyll fluorescence sensor.

The Baltic Proper

The temperature in the surface layer in the Baltic Proper was still above normal at half of the stations and varied between 7–8 degrees. The surface water had thus cooled down about 4 degrees since the cruise in November. The salinity in the surface layer varied between 6.8 psu in the Northern Baltic Proper and 8.1 psu in the Arkona Basin. In November the salinity was above normal in the Bornholm Basin and here it had decreased since then and was now only slightly above normal at station BY5 in the Bornholm Basin with 7.7 psu. The salinity was above normal also at the two stations that could be sampled in the Eastern Gotland Basin and at the southern station in the Western Gotland Basin (BY38 Karlsödjupet).

West and north of Gotland, the water was well mixed down to 30–40 m, below that there was an intermediate layer with older, colder water down to about 70 m. Below that, the temperature increased about one degree and was above normal in the deep water. In the Eastern Gotland Basin there were high waves and a strong storm and only two stations in the southern part could be sampled and the profiles looked similar to those in the Western Gotland Basin. In the Bornholm Basin and Hanö Bight, the water was well mixed down to 40 m and from 70–80 m the temperature increased and was slightly above normal. Even in the Arkona Basin, the water was well mixed down to 40 m, i.e. about 5 m from the bottom.

The concentration of nutrients had increased in the surface layer since November, above all there was an increase in inorganic nitrogen where levels were below normal at several stations in November but now normal at most stations. The levels of inorganic nitrogen varied between 1.4-2.9 µmol/l. Highest at the mapping station Tröskeln Åland Sea and lowest at BY38. The concentration of phosphate varied between 0.3-0.6 µmol/l. The lowest levels were measured in the Western Gotland Basin and there the concentration was below normal. The levels of silicate had increased a little since November and varied between 10.0-13.0 µmol/l and were within the normal range, with the exception of the station Tröskeln Åland Sea which had a concentration of 16 µmol/l.

Below the halocline, the concentration of all nutrients increased. In both the Eastern and Western Gotland Basins, higher values of inorganic nitrogen and silicate than normal were measured below 100 meters depth. In the Eastern Gotland Basin, only the two southernmost stations could be sampled and no results are therefore available from the deep areas in the middle of this basin. In November, the level of phosphate was higher than normal below 100 m in the entire basin. In December, phosphate concentrations above normal were measured from 70 m at station BY10 south of the deeper parts. This coincides with the oxygen concentration falling below the reporting limit. At station BCSIII-10, a little further southwest of BY10, the concentration of phosphate and inorganic nitrogen was instead below normal and the entire water column was oxygenated. Only near the bottom there was a lack of oxygen. In the Bornholm Basin, the Hanö Bight and in the Arkona Basin, the concentrations of nutrients were mostly normal. At station BY1 in Arkona and at station BY4 in the Bornholm Basin, a thin layer with low oxygen levels was measured at depths of 40 and 70 m, respectively, and in connection with this the concentrations of nutrients deviated from the normal. It was clearest at station BY4, where the oxygen was completely consumed at 70 m, so a peak in phosphate and silicate was measured together with a minimum in inorganic nitrogen, a clear example of how microbial activity affects the concentrations of nutrients in the transition between oxygenated and oxygen-free water.

In the Western Gotland Basin and Northern Baltic Proper, hydrogen sulfide was measured from 70-80 m, in the Eastern Gotland Basin from 70 m, and in the remaining basin, no hydrogen sulfide was measured. But in Hanö Bight and the Bornholm Basin, the oxygen concentration was below 2 ml/l from 70 m, which is defined as acute oxygen deficiency. The lowest oxygen concentration was at Hanö Bight and BY4 in the Bornholm Basin with 0.2-0.3 ml/l at 70 m.

Fluorescence measurements from the CTD showed plankton activity in the surface layer above the thermocline at all stations, very low values were measured below the thermocline. The highest activity was measured in the Arkona Basin. No major peaks in chlorophyll fluorescence were observed.
More information about the algal situation can be found in the AlgAware report for December: https://www.smhi.se/publikationer/publikationer/algrapporter (only available in Swedish).

The Bothnian Sea and Ålands Sea

The temperature in the surface water was higher than normal for the season in the eastern part of the Bothnian Sea, where the temperature varied around 5.5 degrees. In the other areas the temperature was slightly lower, 3-5 degrees and thus normal for the time of year. In general, the surface water had started to cool down and from a depth of 25-50 meters warmer water was found, up to 7 degrees warm. After that, the temperature dropped towards the bottom to 3-4 degrees at the deeper stations.

The salinity in the surface water was largely normal for the time of year, but lower levels were noted along the Swedish coast and higher than normal levels were noted closer to the Finnish coast in the southeastern parts. The surface salinity varied between 4.8 and 5.7 psu. The salinity stratification largely followed the temperature variations in the deep water and the salinity was around 6-7 psu in the bottom water, slightly lower salinities were noted in the deep water along the Swedish coast. At some stations the salinity of the deep water was above normal.

The levels of dissolved inorganic nitrogen in the surface water in the Åland Sea were around 2.1-2.7 µmol/l, which is normal or slightly lower than normal. In the Bothnian Sea, concentrations were lower than normal in the eastern parts and at some of the stations in the northern parts. The levels varied between 1.5–3.0 µmol/l. In the deep water, the levels were mostly normal, but in the central parts, levels were found high above normal.

The phosphate levels in the surface water were lower than normal in the eastern parts and at some stations in the northern parts of the area. The levels varied between 0.1-0.4 µmol/l throughout the area. The phosphate content increased with depth and the levels in the deep water were much above normal at some stations. Silicate levels were generally higher in the surface water in the western and central parts of the area compared to the eastern. The levels in the surface varied between 13-24 µmol/l. Here too, the levels increased with depth and at many stations levels above normal were noted in the deep water.

No lack of oxygen was noted in the Bothnian Sea nor in the Åland Sea, which is normal. But low levels, on the limit of oxygen deficiency, i.e. 4 ml/l, was noted at the coastal station Gavik-1. Levels just above 4 ml/l were also noted in the southwestern part of the Bothnian Sea. In general, the oxygen levels were lower at the stations centrally located in the basin. Otherwise, oxygen levels at the bottom of around 5-8 ml/l were noted.

Plankton activity, assessed on the basis of chlorophyll fluorescence measured with a CTD probe, was low throughout the investigated area. The Secchi disk depth was measured to 10 m. The turbidity measured with the CTDn turbidity meter showed high particle concentrations at most stations in the deeper parts of the Bothnian Sea. This could also be observed in the images from the camera mounted on the CTD rosette, which displays real-time video.

The Bothnian Bay and Northern Quark

The stratification in the Bothnian Bat and Northern Quark is weaker than in the Bothnian Sea, but a weak temperature and salinity stratification was found deeper down at a depth of around 40-60 meters. At some stations in the center of the basin there was also a near-surface stratification, probably due to cooling and runoff.

The temperature in the surface water was normal for the season and varied between 3.5 – 4.6 degrees. The salinity in the surface was lower than normal 2.7-3.7 psu. Lowest at the stations closest to the Swedish coast. The salinity of the deep water was normal.

The content of dissolved inorganic nitrogen was below normal and varied between 5.1-5.6 µmol/l. In the deep water, the nitrogen content increased and showed some variation, normal levels and both lower and higher levels than normal. The phosphate levels in the surface water were very low, which is normal for the time of year. The levels increased with depth and in the deep-water higher levels than normal were found. The silicate content in the surface water is naturally high due to the large runoff to the Gulf of Bothnia. However, levels above normal were noted and they varied around 40 µmol/l. In the deep water the levels increased further and here too the levels were higher than normal.

No lack of oxygen was noted in the Bothnian Bay or Northern Quark, which is normal. The concentrations in the bottom water were above 7 ml/l at all stations.

Plankton activity, assessed on the basis of chlorophyll fluorescence measured with a CTD probe, was low throughout the investigated area. The Secchi disk depth was measured to 5-6 m. The turbidity measured with the CTDn turbidity meter showed lower particle concentrations in the deeper parts of the Bothnian Bay compared to the Bothnian Sea.

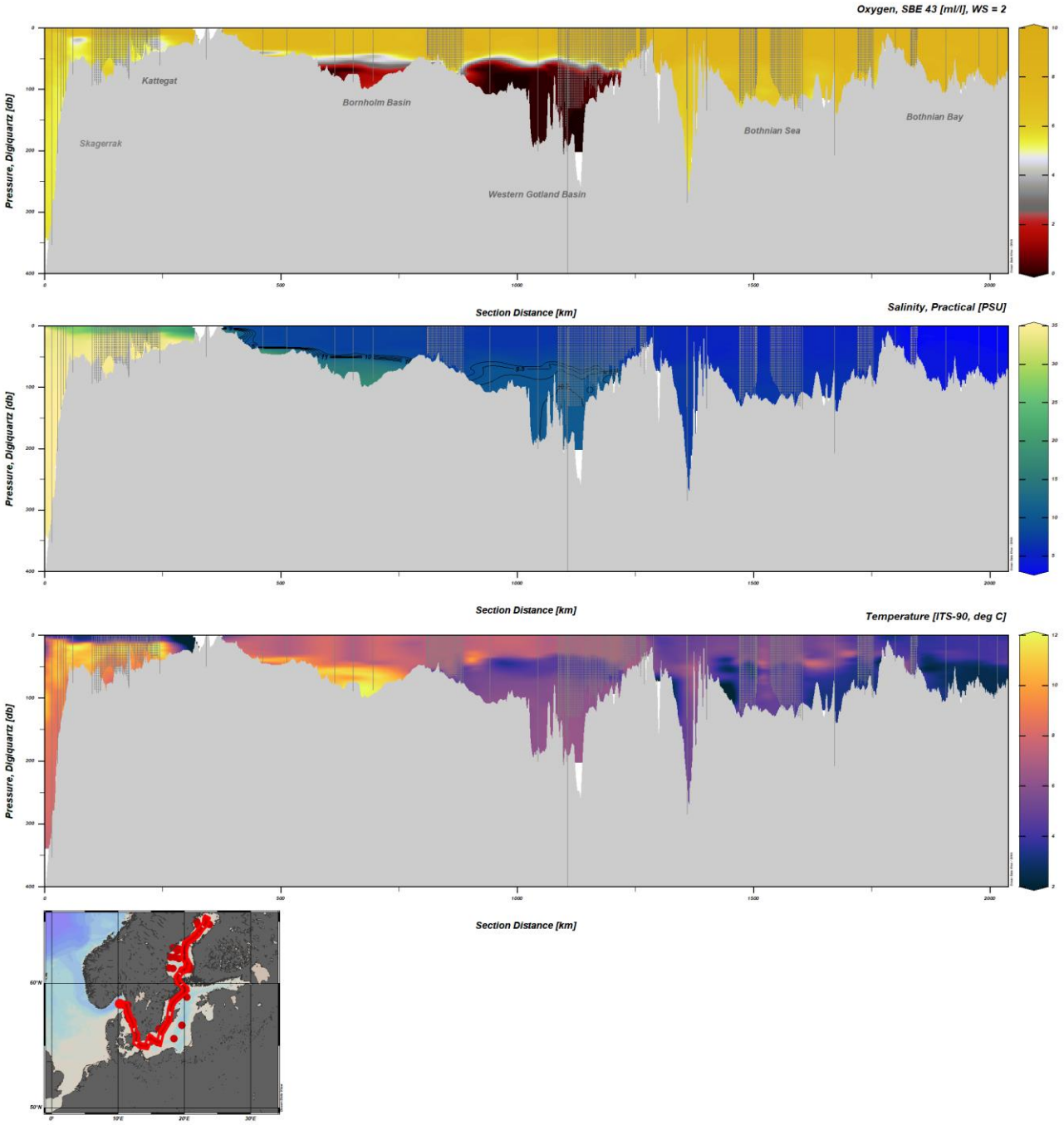

Figure 1. Transect showing CTD and MVP measurements of dissolved oxygen, salinity and temperature from Skagerrak, Kattegat, the Sound, further into the Baltic Proper, Western Gotland Basin, Ålands Sea and Gulf of Bothnia. Vertical lines show the positions where data is collected, also shown in the map.

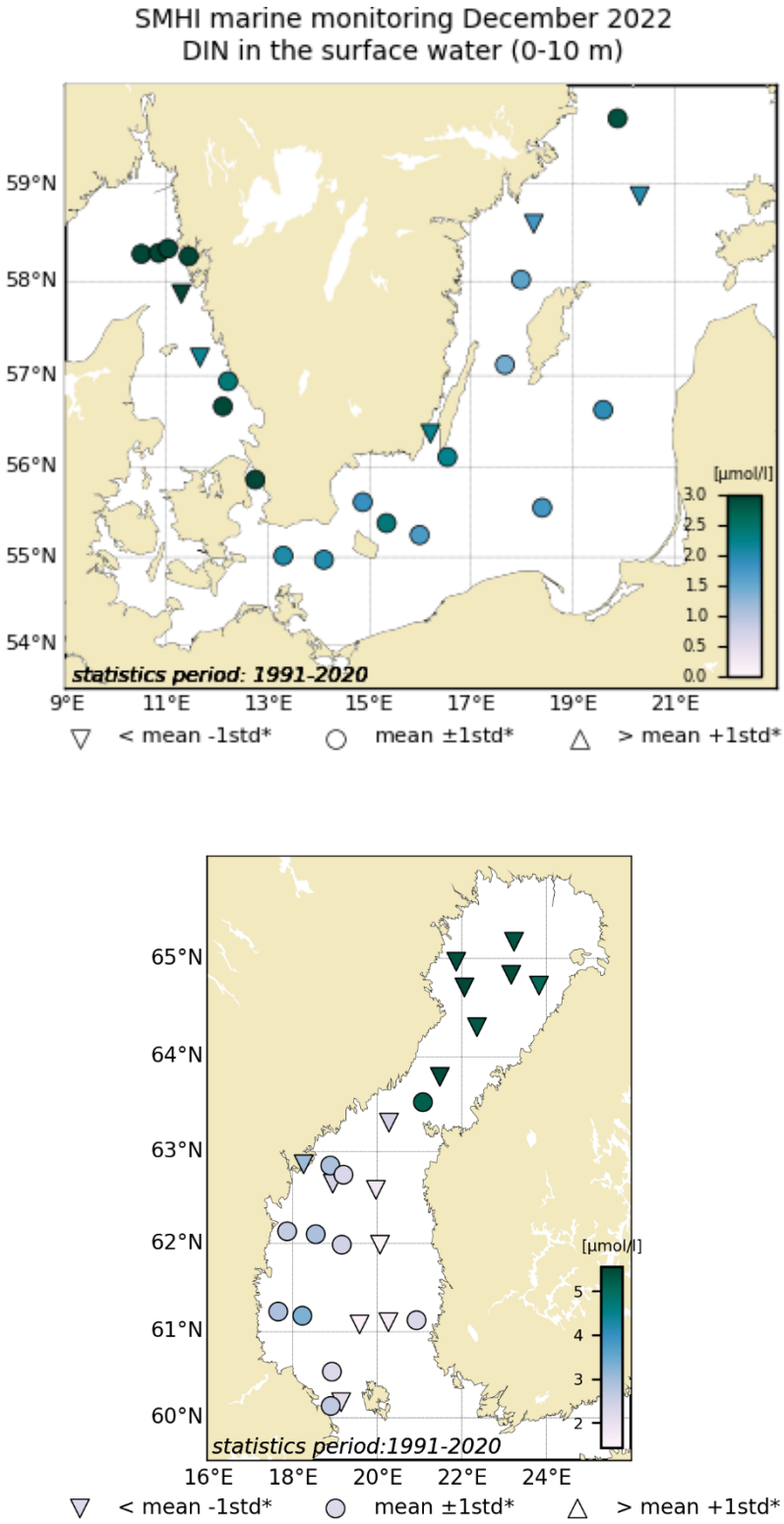

Figure 2. Concentration (µmol/l) of dissolved inorganic nitrogen in the surface water (0-10m). Note the different color scales.

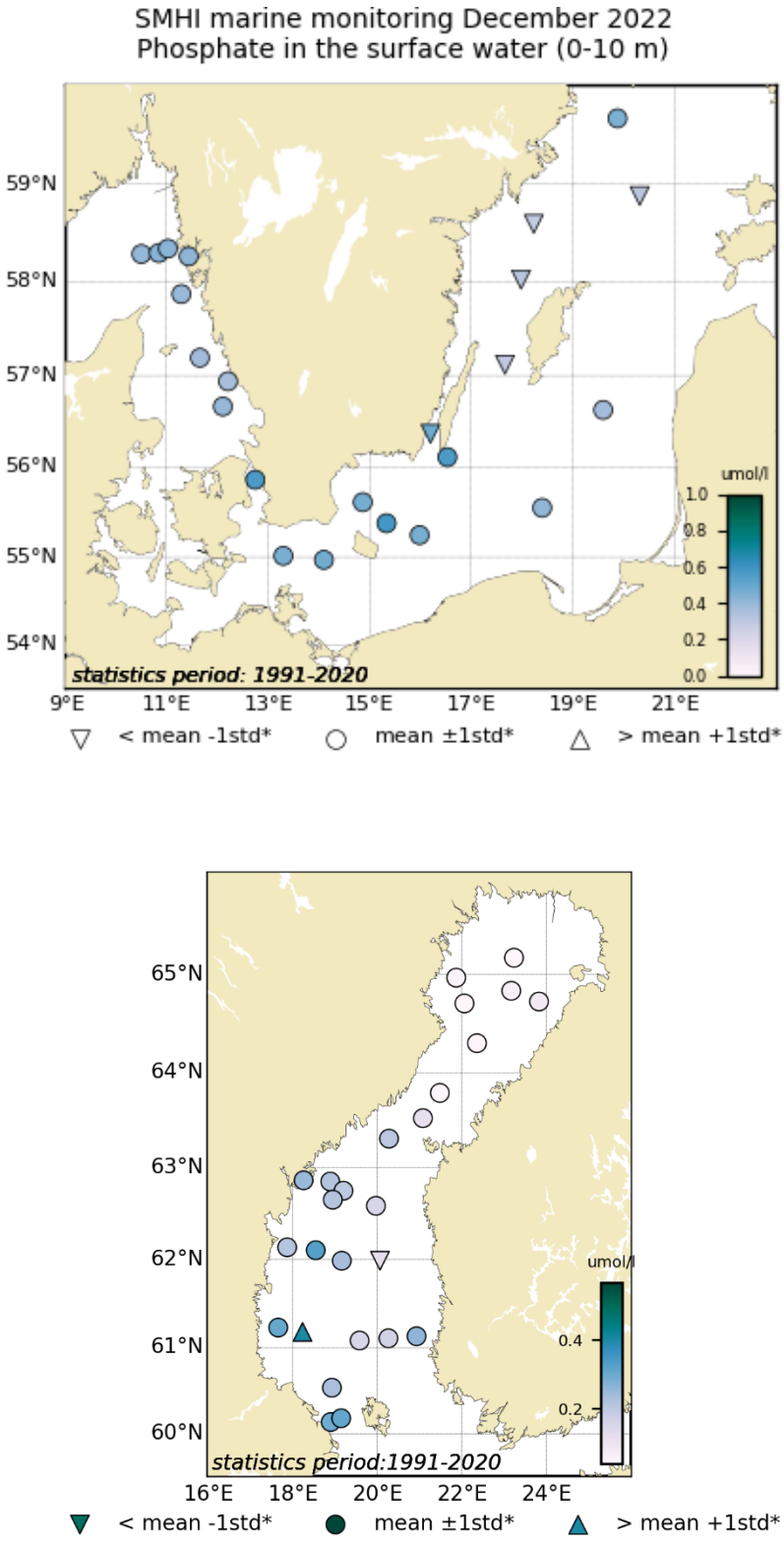

Figure 3. Concentration (µmol/l) of phosphate in the surface water (0-10m). Note the different color scales.

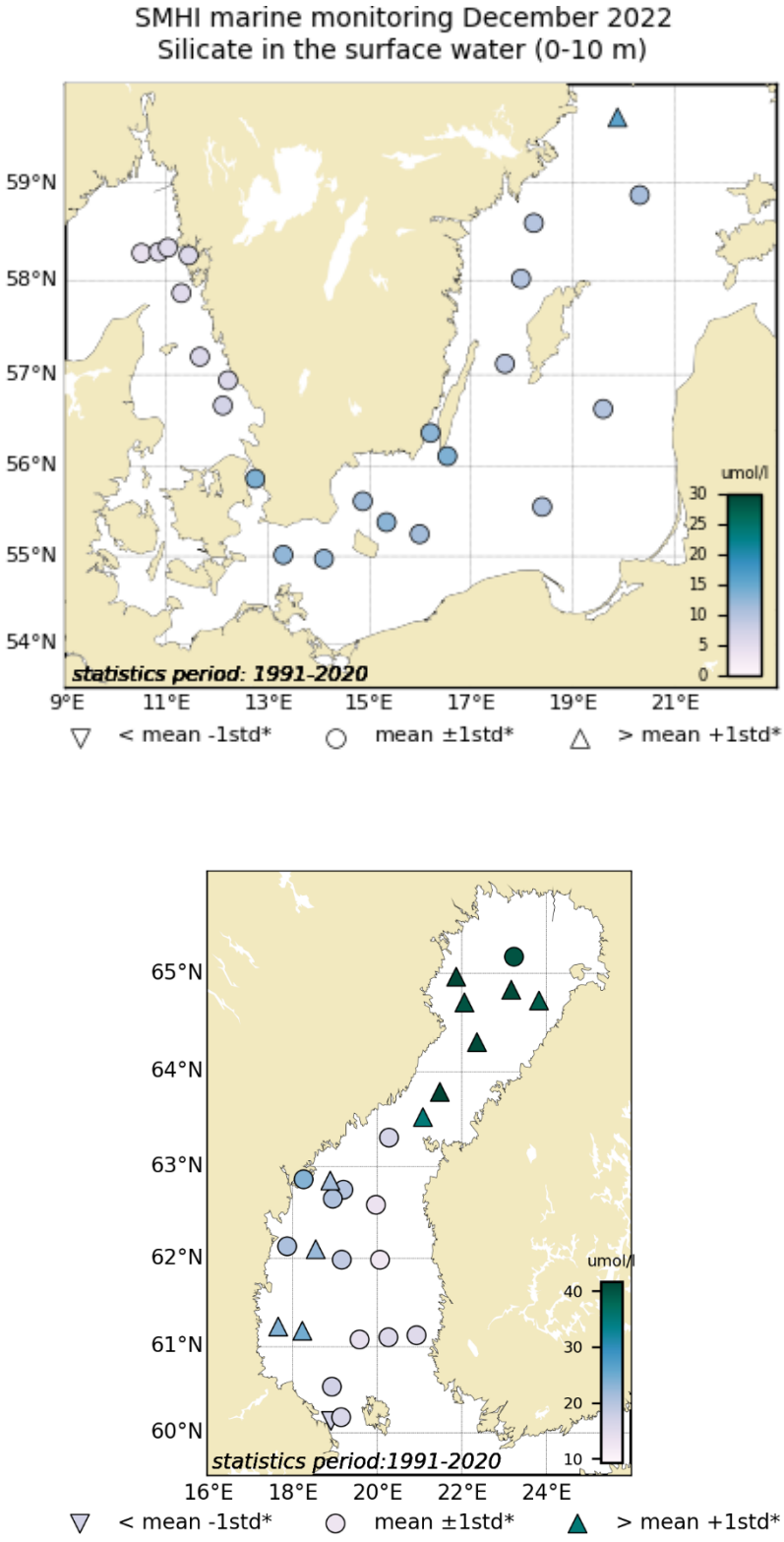

Figure 4. Concentration (µmol/l) of silicate in the surface water (0-10m). Note the different color scales.

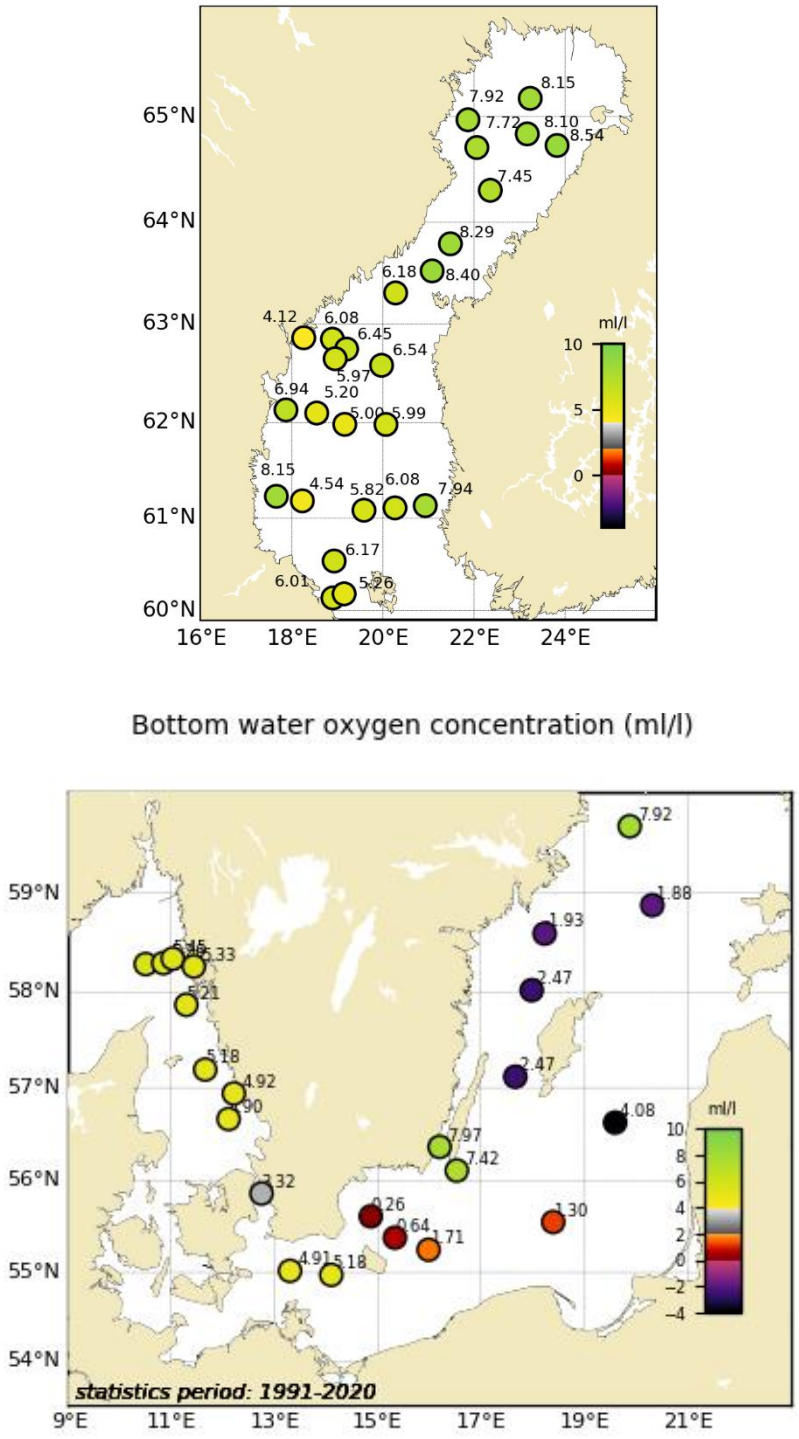

Figure 5. Oxygen concentration (ml/l) in the bottom water.

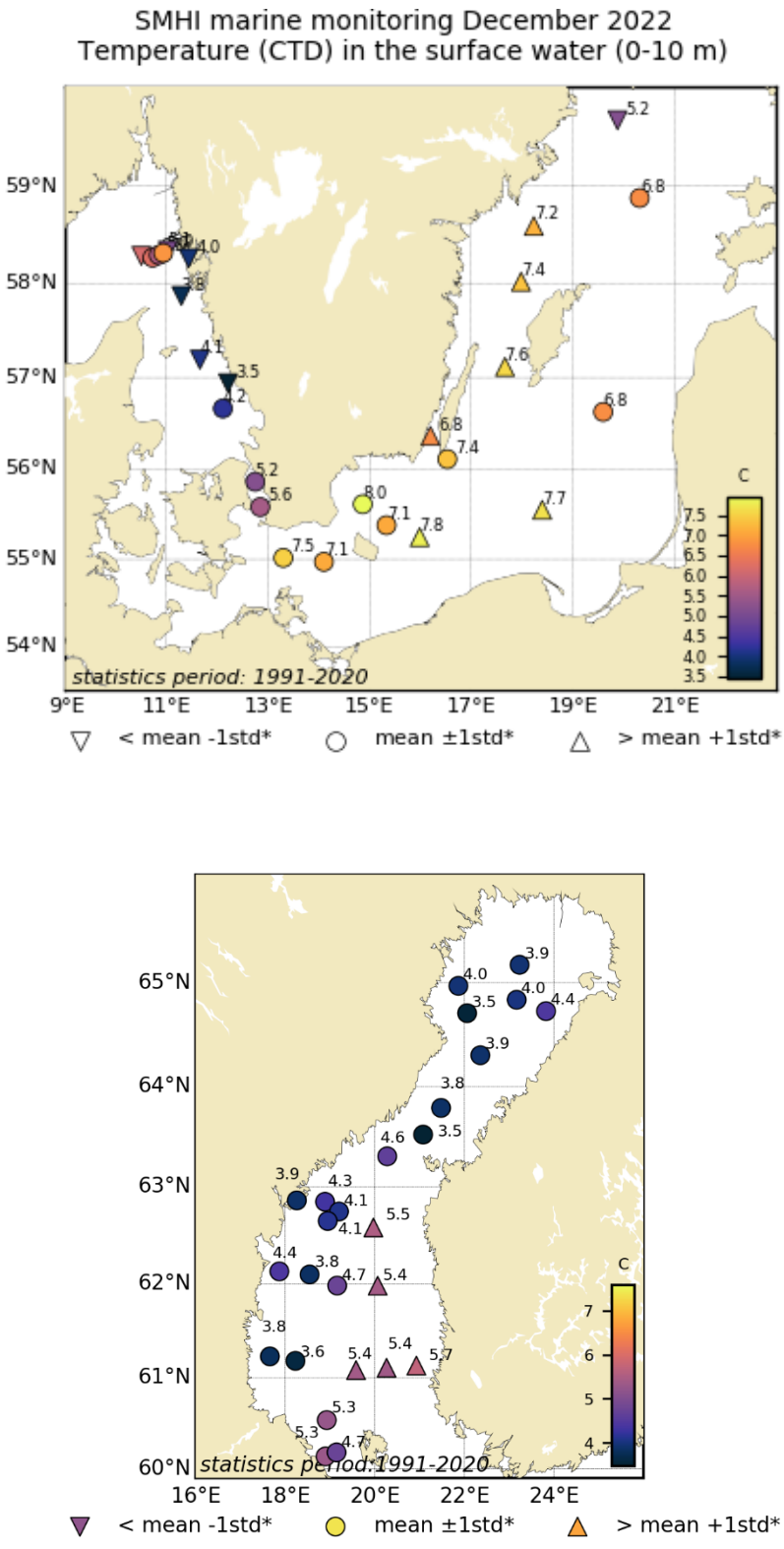

Figure 6. Temperature in the surface water (0-10m).

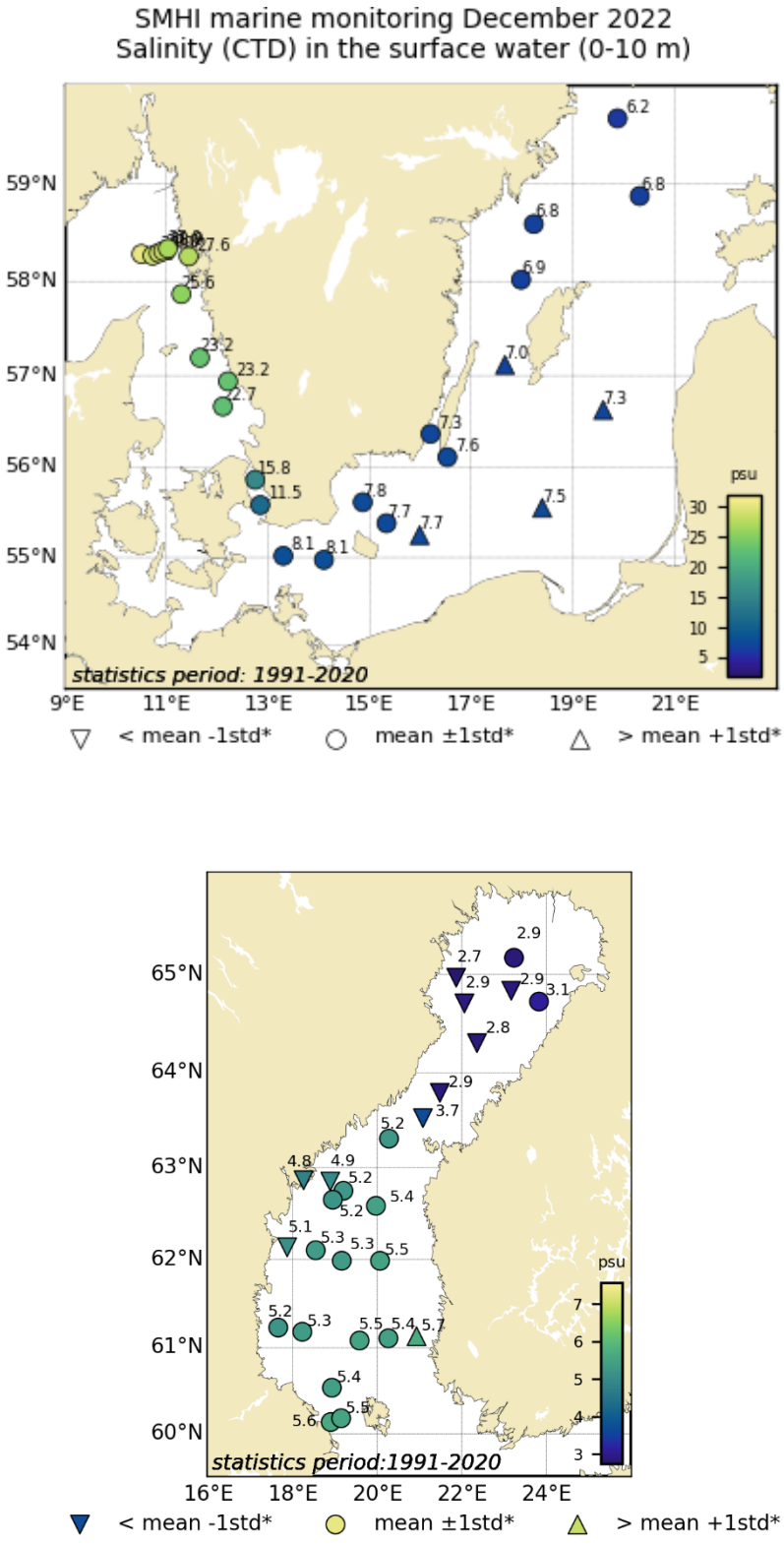

Figure 7. Salinity in the surface water (0-10m). Note the different color scales.

PARTICIPANTS

Name	Role	Institute
Martin Hansson	Chief scientist, leg 1, Oceanographer	SMHI
Örjan Bäck	Oceanographer	SMHI
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Madeleine Nilsson	Chemist	SMHI
Johan Kronsell	Oceanographer	SMHI
Ola Kalén	Oceanographer	SMHI
Kristin Andreasson	Chemist	SMHI

APPENDICES

- Track chart
- Table over stations, sampled parameters and number of sampling depths
- Vertical profiles for regular monitoring stations
- Monthly average surface water plots for regular monitoring stations

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