Cruise Report - Group 3

RV Skagerak, University of Gothenburg
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Port of departure & return: Uddevalla Hamnterminal

Abstract

Hypoxia is a well known problem in marine water bodies and manual deep water oxygenation has been thought about several times. The BOX project (Baltic deep-water Oxygenation project) was a pilot project focusing on this issue conducted in the Byfjord, Sweden. Therefore, the fjord as well as the related the Havstensfjord are monitored regularly to document the impact of the BOX project. We conducted CTD analyses on transects in both fjords measuring pressure, depth, temperature, conductivity, salinity, dissolved oxygen, fluorescence and density, as well as a box core of the sediment. Furthermore, we took water samples of different depths, which were analysed for nutrient content. Vertical stratification could clearly be seen in the Byfjord with hypoxic bottom water despite a deep fluorescence maximum just below the thermocline. The Havstensfjord contained a relatively large mixed layer, but the bottom water was hypoxic as well. Nutrient concentrations were slightly increasing with depth in the Havstensfjord, while especially NO_2 and NO_3 concentrations were mostly decreasing with depth in the Byfjord. Monitoring the fjords of this pilot study is important to make suggestions for other hypoxic marine systems, such as the Baltic sea.

Keywords: hypoxia, Baltic sea, Byfjord, Havstensfjord, CTD, nutrients, oxygenation

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Cruise Personal

Supervisor:	Marcel du Plessis
Chief Scientist:	Marlene Wiechmann
Scientists:	Victor Spjern
	Tabea Meyerjuergens
	Nicole Eliassen
	Claudia Majtenyi Hill
	Therese Nitschke (onshore)
	Foteini Kappa (onshore)
	Johan Edholm (onshore)
	Mahmudul Hasan (onshore)
Sample analyst:	Hans Olsson

Laboratory responsible for nutrients analysis:
Sven Lovén Centre, Kristineberg (University of Gothenburg, The Sven Lovén Centre for Marine Sciences, Kristineberg 566, 450 34 Fiskebäckskil, Sweden)

Purpose

The Byfjord is a small fjord on the west coast of Sweden, with a length of 4 km, a width of 1.5 km and greatest depth at 51 m (Forth et al., 2015). At one end the Byfjord relates to the Havstensfjord by the strait of Sunninge. The maximum depth of the Havstensfjord is 46 m (Gustafsson & Nordberg, 2000). The connecting sill of both fjords has a depth of 13.5 m (Forth et al., 2015). The city of Uddevalla and the estuary of the Bäve river is located at the other end of the Byfjord, opposite to the sill. In the Byfjord weak vertical mixing in combination with high-density gradient leads to stagnant bottom waters and distinct vertical stratification (Brabandere et al., 2015). Further, oxygen deficits are developing in the bottom waters due to the stratification and the simultaneously occurring degradation of organic matter (Forth et al., 2015). Under anoxic conditions high nutrient releases (ammonium and phosphate) from sediment to bottom waters arise (Brabandere et al., 2015). The bottom water body of the Byfjord gets oxygenated naturally only every 3-5 years when dense and oxygenated seawater from the Havstensfjord reaches the fjord basin (Hansson et al., 2013, as cited in Brabandere et al., 2015). The hypoxia of the Byfjord is not only facilitated by the hydrodynamics of the system but also by eutrophication (and climate change, but that is beyond the scope of this study). Source of nutrient influx is the Bäve river that accounts for ~80 % of freshwater supply and the wastewater treatment plant located at the Bäve river estuary (Forth et al., 2015) (Brabandere et al., 2015). Hypoxia causes severe harm to marine ecosystems, e.g. increased phytoplankton growth, decline of water quality and increase of ammonium concentration that is poisoning fish.

Research about (engineered) oxygenation is therefore needed to counter the global problem of hypoxia in marine water bodies. The BOX project (Baltic deep-water Oxygenation project) conducted a pilot experiment in the Byfjord because the fjord has similar trophic conditions as the Baltic Sea (Forth et al., 2015). From October 2010 till December 2012 oxygen-rich surface water was pumped into the deep-water body of the Byfjord and it could be proved that engineered oxygenation improves the condition of the bottom water (Brabandere et al., 2015) (Stigebrandt et al., 2015) (Forth et al., 2015). This cruise was conducted within the scope of the BOX project, with the purpose to collect complementing data related to the relationship between the Byfjord and the Havstensfjord.

Scientific Objectives

1. How does the water column hydrography (& nutrients) differ between the two fjords? Is there any evidence of water exchange over the sill?

2. Can you observe a difference in the vertical stratification between the two fjords? What implications does the stratification have on the water mass exchange between the surface and the deep and distribution of properties, such as nutrients?

3. What is the distribution of dissolved oxygen and nutrients in depth and space, and between the two fjords? What can be said about the connection between DO and fjord health (e.g. hypoxia)?

Cruise Overview

Intentions

We planned for a transect (A) along the Byfjord and the Havstensfjord with ten stations and water samples taken at every station. One box core was planned for station 10, and optional one for station 4. After this main transect three additional transects were planned. One in the Havstensfjord (B) and two inside the Byfjord (C and D), all perpendicular to transect A. On these additional transects only CTD measurements were planned, as well as a second box core inside the Byfjord at the location of station 4. We deemed that transect A with the water samples was the most important to get an overview over the conditions along both of the fjords and to see comparable characteristics in nutrients and CTD data. The following transects were meant to allow a better spatial understanding of the processes. Therefore transect A was planned to occur first, in the event of time-loss.

The two box cores were supposed to allow further insight about the bottom environment.

Instruments and operation procedures

The instruments at hand were a Sea- Bird SBE 9 (CTD) with 12 Niskin bottles, as well as a small Box corer (ca. 30cmx30cm). The CTD measures pressure, depth, temperature, conductivity, salinity, dissolved oxygen (DO), fluorescence and density with several sensors attached to a metal frame. The data is sent to the ship in real time via a conducting cable. The Niskin bottles, 12 plastic tubes connected to the metal CTD frame that close remotely on both ends, collect water samples at appointed depths. The water samples were analyzed for NO_2, NO_3, NH_4, PO_4 and SiO_2 content.

The box corer consists of a heavy frame with a liner that sinks into the soft bottom sediment, and two small spades, that swing underneath the sample when retrieving the box core. On the boat, the outer frame and spades are removed, leaving the sediment in the liner for observation and sampling.

Figure 1. *Lowering the CTD into the water. (Picture: Cloudy Majtenyi Hill)*

For each station with CTD and water sampling, the CTD was lowered into the water to bottom level, with measurements taken on the way down (Figure 1). On the basis of these real time measurements, depths were appointed for the water samples. Depending on the overall depth of each station, we determined three or four water sample depths. While retrieving the CTD the Niskin bottles closed at the appointed depths. The labelled sampling tubes as well as a syringe with an attached filter (22 µm) were flushed twice and then filled (Figure 2). One 15mL vial of water was collected at each depth to be sent for nutrient analysis.
One box core was obtained as described above at station 10. We performed only a rough visual inspection of the first 10-20 cm (Figure 3).

Figure 2. *Water samples. (Picture: Cloudy Majtenyi Hill)*

Figure 3. *Box core at station 10 from above (left) as well as the upper 10cm of the sediment (right). (Photographs: Cloudy Majtenyi Hill, Marlene Wiechmann)*

Narrative

The weather was partly cloudy with temperatures around 16°C, with small showers in the afternoon. Due to Covid-19 restrictions, the participation was lower than expected with five participants onboard. The roles were assigned onboard, consisting of one chief scientist and four assisting scientists.
The planned coordinates were given to the ship crew, but as the coordinates were in the wrong format, the stations had to be confirmed visually on board.
The chief scientist communicated to the ship crew when to go to the next station and what measurements were to be taken at that location. The assisting scientists, together with the chief scientist, circulated the practical onboard tasks (see Cruise Plan).

Transect A
The ship departed from the dock at 9:15 CET. CTD measurements were taken at each station. Two Niskin bottles were closed for each determined depth, as some bottles had failed to close on previous cruises.

Transect B & C
At Station 15, a problem with the coordinates occurred, resulting in a slight adjustment to the planned route. Neither a second box core nor an additional perpendicular transect (D) inside The Byfjord could be taken due to a lack of time. The ship got back to the dock around 3 pm.

Oxygen calibration
A preparation for oxygen calibration (Winkler method) was demonstrated onboard at Station 4 by the supervisor. This consisted of filling two glass vials of water from the Niskin bottles, one with bottom water and one with surface water. For each vial 1 mL of manganese chloride and 1 mL of sodium hydroxide was added. This resulted in an orange precipitate for the surface water, and a white precipitate for the bottom water. The vials would later be used for calibration by titration.

Station Log (24th September 2020)

Station	Latitude (°N)	Longitude (°E)	Time (CET)	Sample	Sampling Depth (m)	Maximum depth (m)	Transect
1	58.3415	11.89883	9:44	CTD	-	29	A
				WS	23.3 , 14 , 12 , 5		
2	58.3385	11.8895	10:07	CTD	-	40	A
				WS	37.3 , 22 , 12 , 4		
3	58.33617	11.88233	10:32	CTD	-	43	A
				WS	41.4 , 20 , 10 , 3		
4	58.33233	11.8685	10:58	CTD	-	43	A/C
				WS	44.3 , 24 , 14 , 4		
5	58.32883	11.85567	11:17	CTD	-	21	A

				WS	19 , 14 , 8 , 2		
6	58.3235	11.835	11:35	CTD	-	15	A
				WS	13.3 , 8 , 2		
7	58.32117	11.82317	11:50	CTD	-	24	A
				WS	21.8 , 17 , 14 , 6		
8	58.31967	11.8115	12:31	CTD	-	28	A
				WS	25.8 , 22 , 18 , 8		
9	58.316	11.79933	12:46	CTD	-	30	A/B
				WS	29 , 24 , 16 , 6		
10	58.31383	11.78683	13:00	CTD	-	37	A
				WS	34 , 20 , 16 , 8		
				BC	37		
11	58.32233	11.78583	13:30	CTD	-	26	B
12	58.31983	11.79317	13:41	CTD	-	26	B
13	58.31333	11.80683	13:53	CTD	-	24	B
14	58.33467	11.86383	14:17	CTD	-	35	C
15	58.3275	11.87733	14:29	CTD	-	19	C
16	58.33083	11.8725	14:36	CTD	-	19	C

Cruise Track

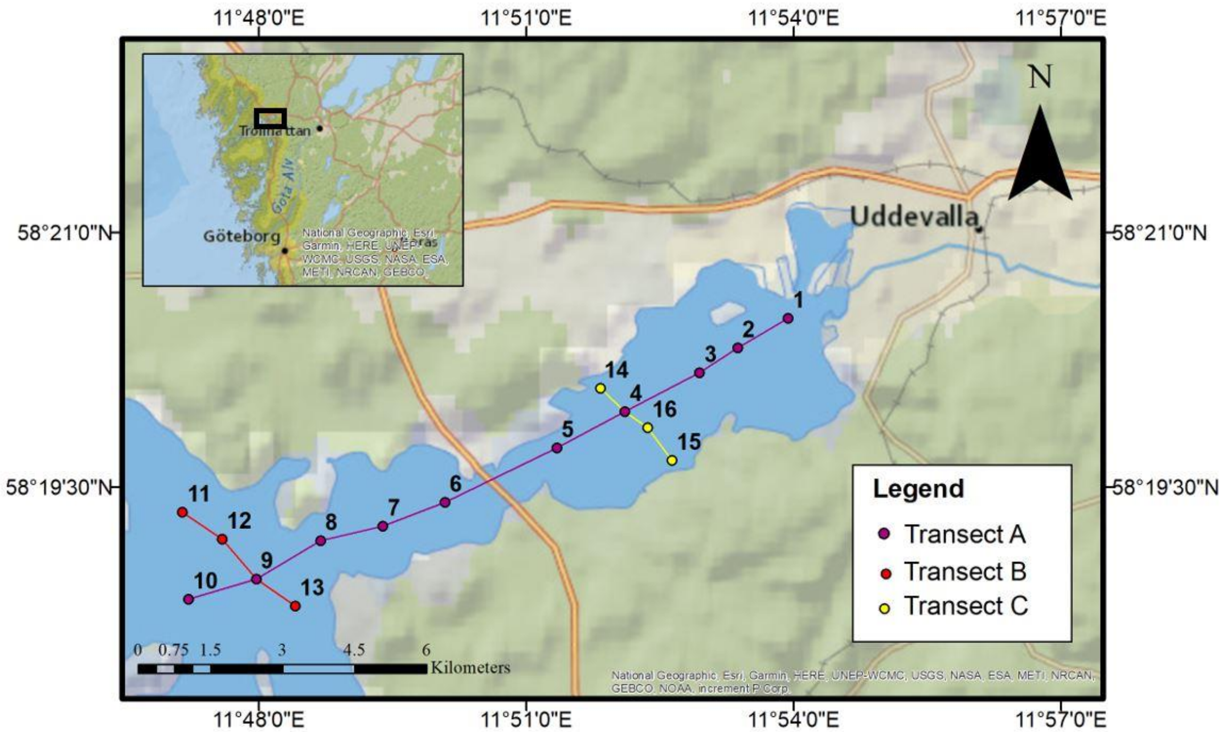
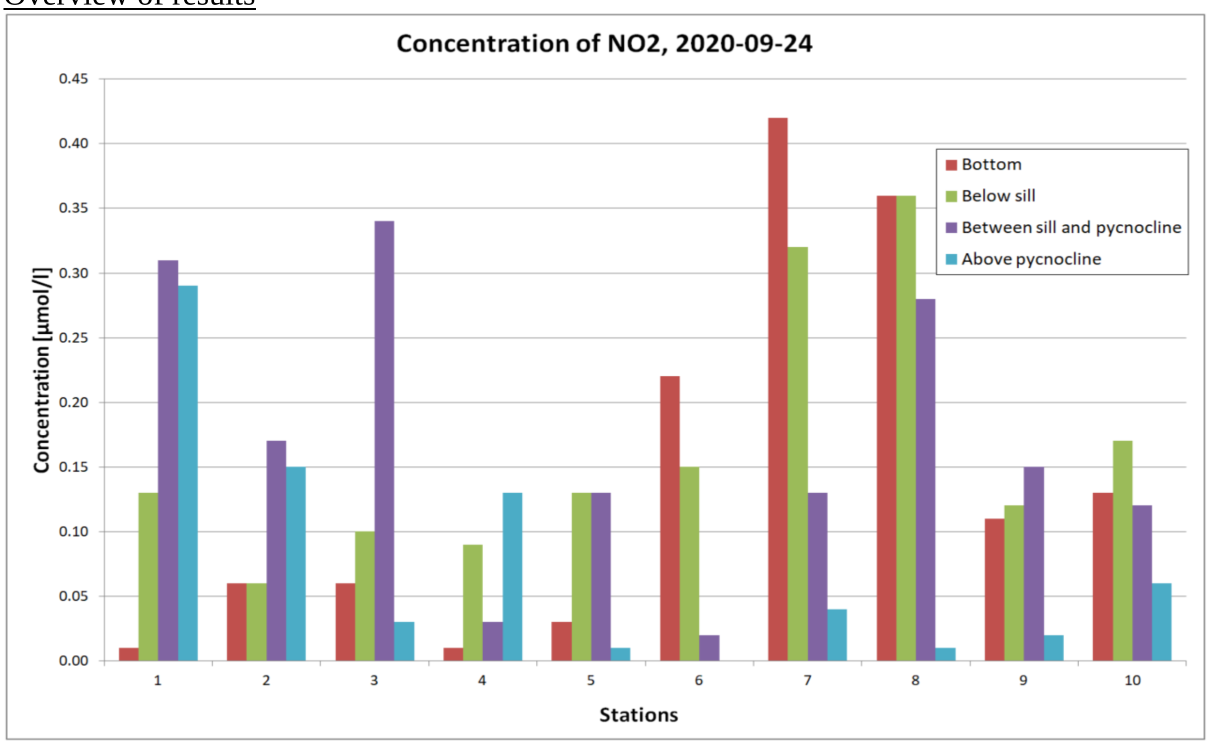
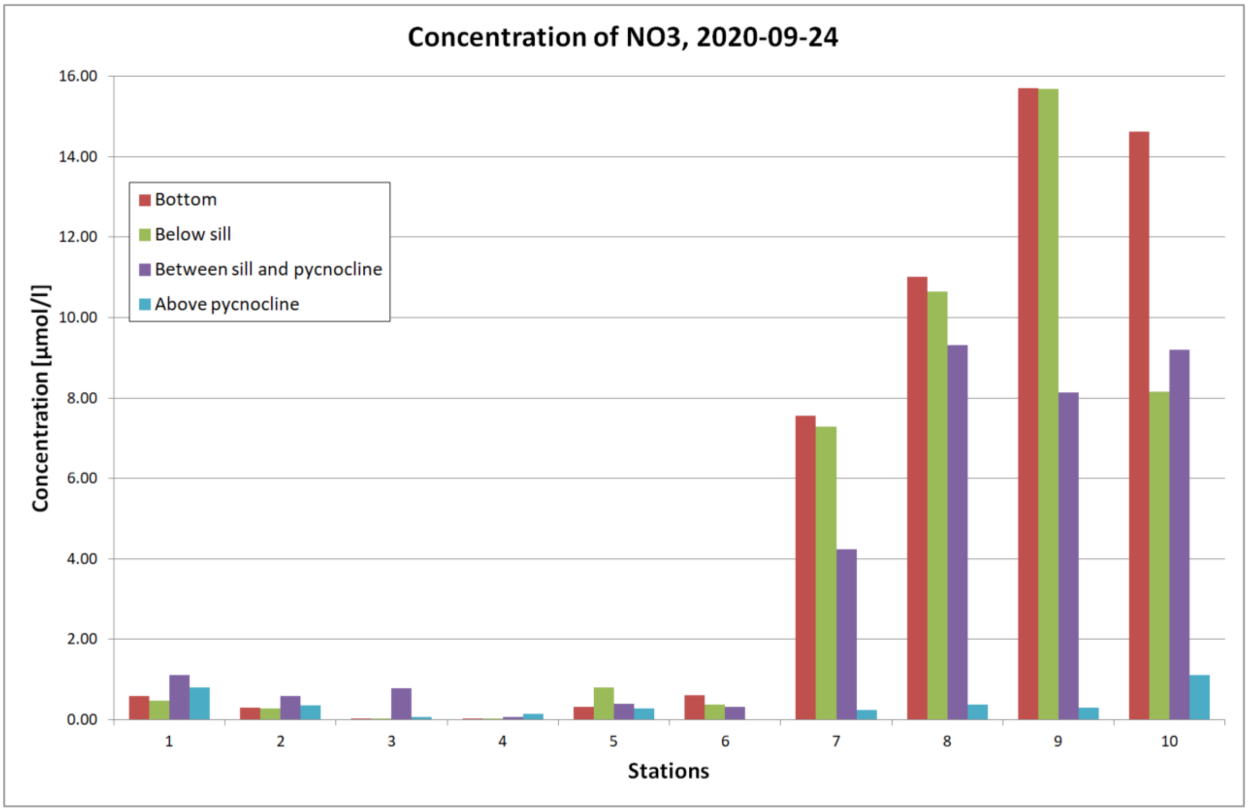
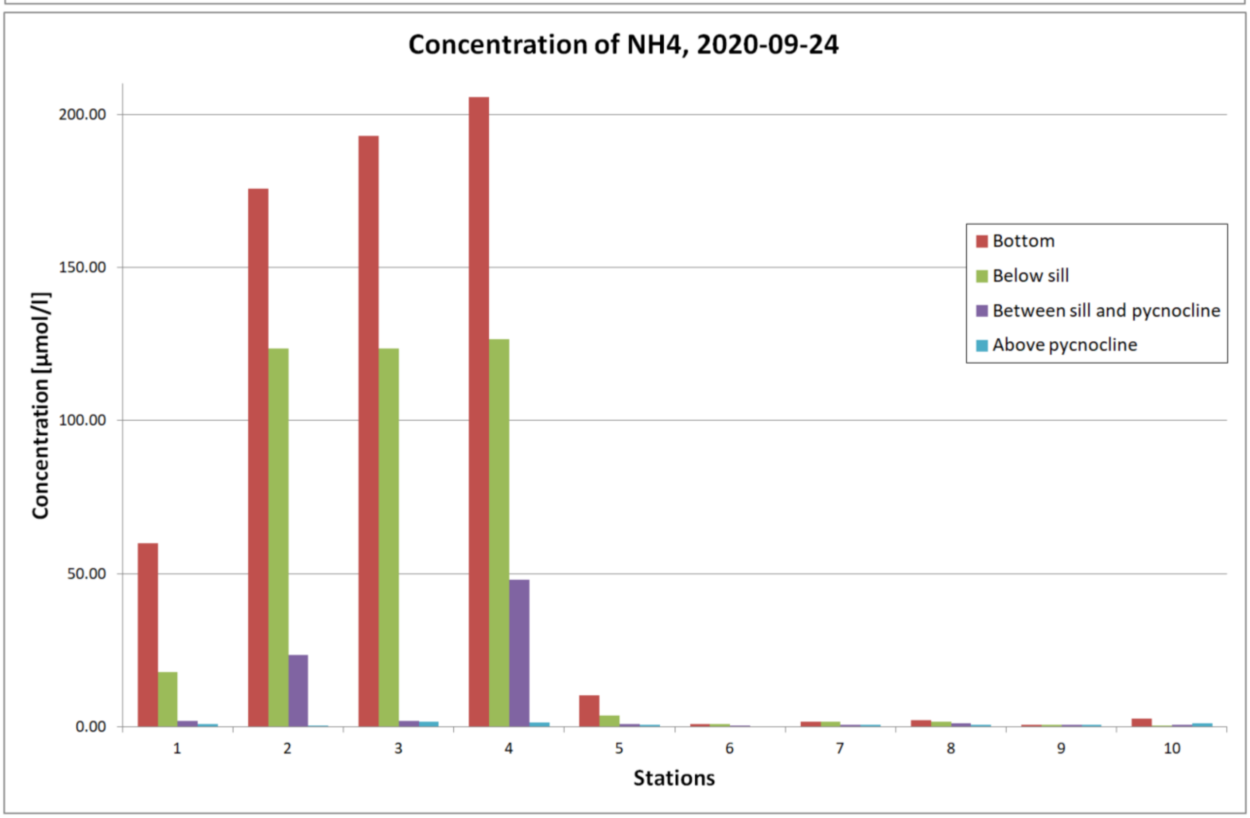


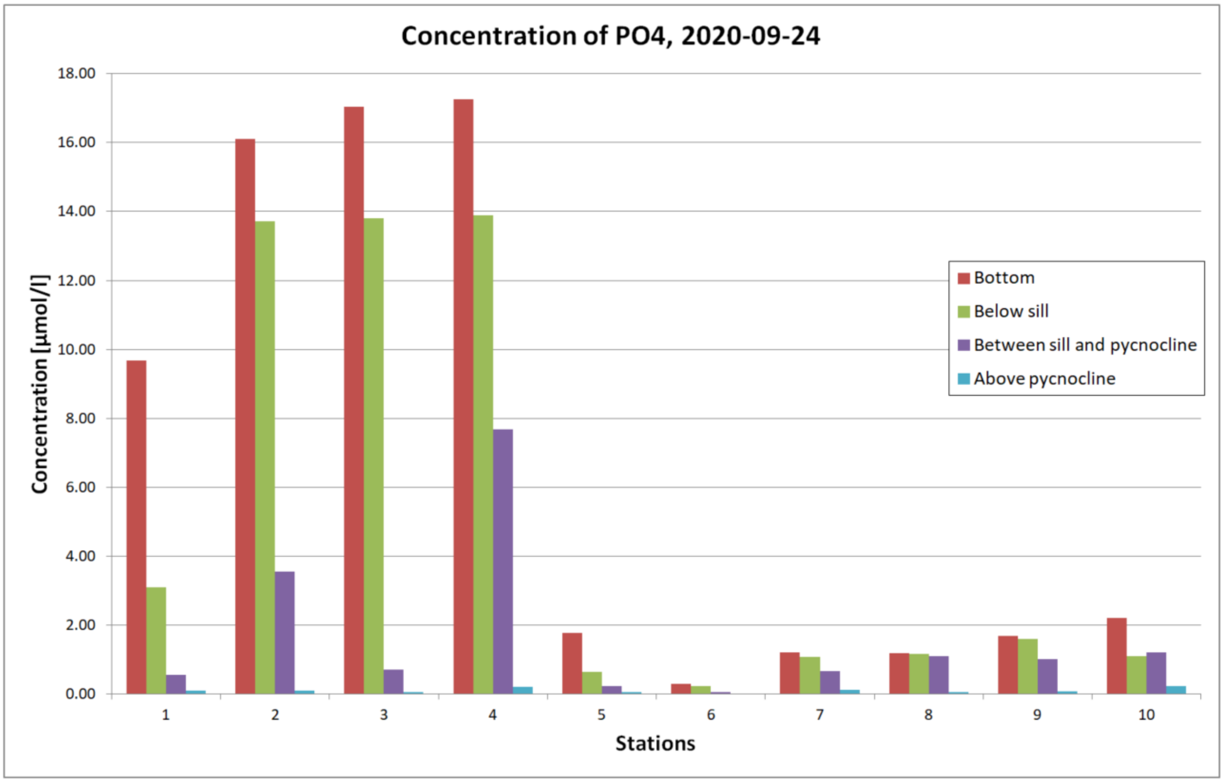
Figure 4. *Location of cruise stations within The Byfjord and The Havstensfjord. Station ID is indicated for each individual station. Transects A, B & C are denoted by corresponding coloured lines.*

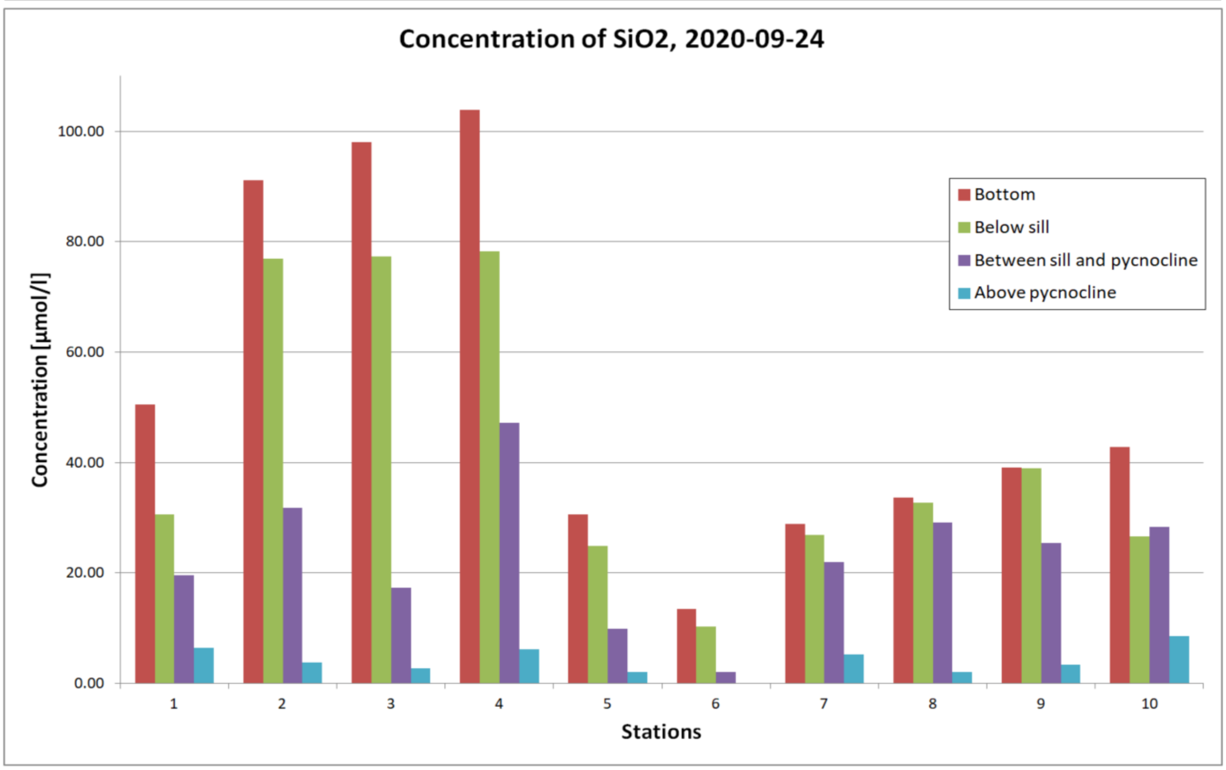
Overview of results




Concentration of NO3, 2020-09-24
Concentration [µmol/l]
Stations
Bottom
Below sill
Between sill and pycnocline
Above pycnocline
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1
2
3
4
5
6
7
8
9
10


Concentration of NH4, 2020-09-24
Concentration [µmol/l]
Stations
Bottom
Below sill
Between sill and pycnocline
Above pycnocline
200.00
150.00
100.00
50.00
0.00
1
2
3
4
5
6
7
8
9
10





Figures 5-9. *Bar plots showing the concentration of each nutrient for all 10 stations at the water bottom, just below the sill depth, between sill and pycnocline and above pycnocline. If concentrations were under the detection limit for* NO_2*,* NO_3 *and* NH_4 *we set the half of the detection limit as the actual concentration value. At station 6 there are no values for the depth "Above pycnocline".*

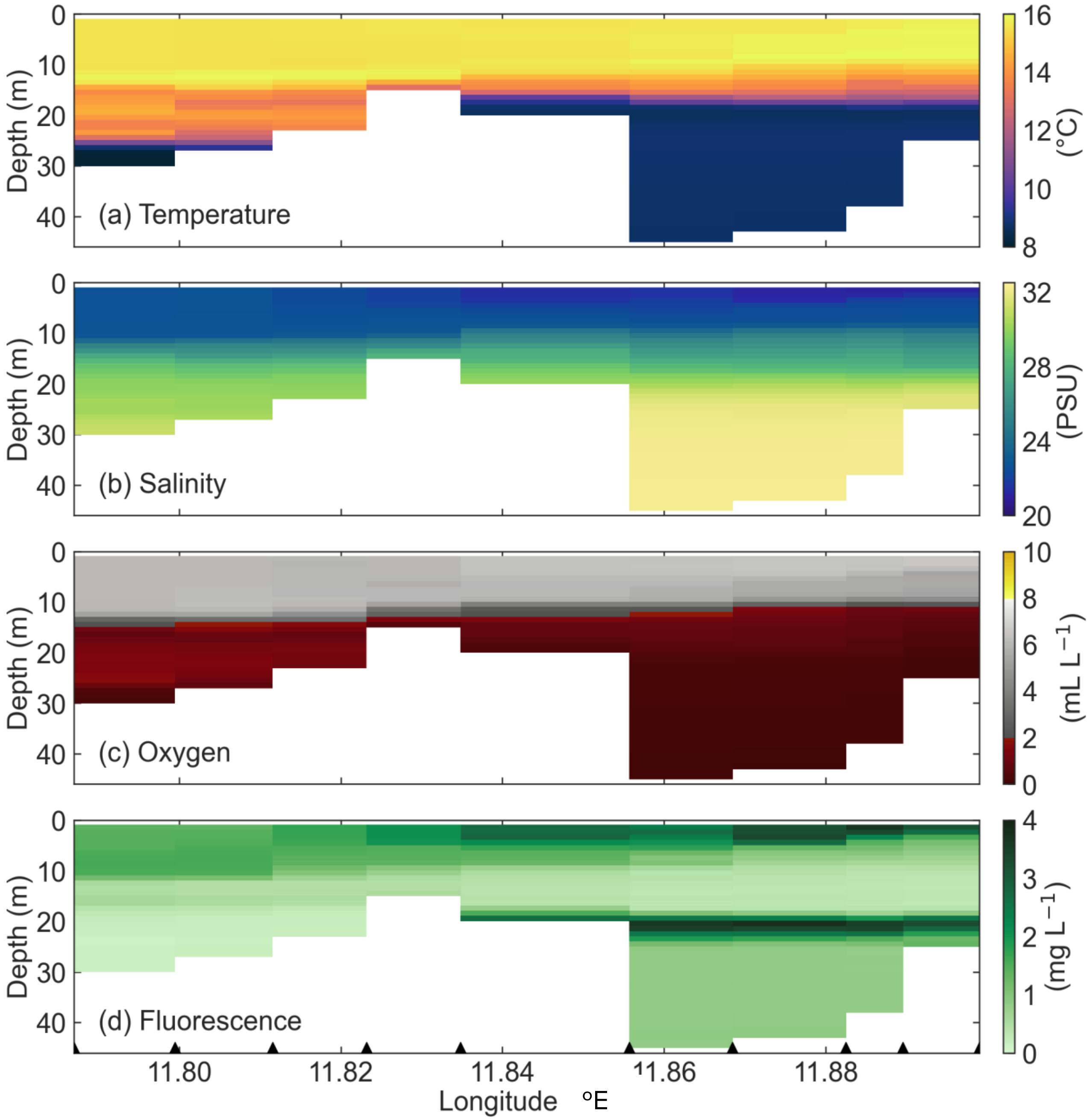


Figure 10. *Along-fjord transect of CTD measured (a) temperature, (b) salinity, (c) dissolved oxygen, and (d) fluorescence. Each station is marked by a black triangle in (d). Noticeable in (a-c) is a clear stratification within the Byfjord. A maximum of fluorescence (d) is visible at the lower end of the thermocline (a), despite hypoxic conditions (c).*

Further perspectives

One improvement that could be made in future cruises is ensuring confirmation of correct coordinate format prior to arrival onboard. In addition, a better awareness of time management during the cruise may help to improve efficiency and allow for more sampling. In terms of oxygen measurements, the possibility for calibration may possibly change our sampling depths slightly. However, since we sampled quite a range of samples at each station, that range would probably not change even with the possibility of calibrating oxygen. But we could definitely improve in taking water samples in more stable ranges than we did in the cruise. Moreover, if we would calibrate our samples and take similar depth samples as the other groups or previous monitoring programs, the data would actually be comparable, which would improve the reliability of the data.

References

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