CTD and nutrient sampling in the Byfjorden and Havstensfjorden on the west coast of Sweden onboard the R/V Skagerak

Björklund, E., Borus David, K., Bridge, T., Fleet, F., Jing, S., Johansson, M., Kuijt, A., Morgan, L., Möller, H., Nyquist, N., Rasmussen, M., Stolpmann, L.

ABSTRACT

The research cruise during the MAR440 course called: "CTD and nutrient sampling in the Byfjorden and Havstensfjorden on the west coast of Sweden onboard the R/V Skagerak" was undertaken during the 24th September 2019 in Byfjorden, Havstensfjorden, Sweden. The aims of the research project were to sample different sites and depths to determine the differences in water column characteristics and nutrient composition between Byfjorden and Havstensfjorden. The specific aims were to determine:
1) If there is evidence of water exchange over the sill;
2) If there is any difference in vertical stratification between the fjords;
3) If the vertical water exchange is affected by the difference in vertical stratification;
4) The vertical and horizontal distribution of dissolved oxygen and nutrients;
5) The relationship between dissolved oxygen and hypoxia in the fjord;
6) If there is a difference in sediment and benthic communities in the deep basins between the fjords.
The six sites were located in Byfjorden and Havstensfjorden with a maximum distance of 7.97km from the mouth of the Bäveån river. We sampled six sites, performed six CTD casts, 34 nutrient samples, eight dissolved oxygen samples and two sediment samples.

Keywords: CTD, Nutrient samples, Dissolved oxygen, Box Corer, Hypoxia, Byfjorden, Havstensfjorden
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Reference: University of Gothenburg, MAR440, 8 pages

1 Cruise personell

Table 1. Cruise personell and roles on board.

Name	Role
Emilia Björklund	Student, scientist
Katja Borus David	Student, scientist
Thomas Bridge	Student, scientist
Frederick Fleet	Student, scientist
Sun Jing	Student, scientist
Mariela Johansson	Student, scientist
Anne Kuijt	Student, scientist
Linnea Morgan	Student, scientist
Henrik Möller	Student, scientist
Nils Nyquist	Student, scientist
Matilda Rasmussen	Student, scientist
Lea Stolpmann	Student, scientist
Sebastiaan Swart	Instructor, supervisor
Louise Biddle	Instructor, supervisor
Hans Olsson	Lab technician, Kristineberg

Table 2. Station assignments during the cruise.

Station	CTD Room	Water samples	Sediment samples
1	Lea, Fred, Nils	Tom, Linnea, Emilia, Anne, Katja	Sunjing, Mariela, Matilda
2	Sunjing, Mariela, Matilda	Lea, Fred, Nils,Anne, Katja	Tom, Linnea, Emilia
3	Tom, Linnea, Emilia, Anne, Katja	Sunjing, Mariela, Matilda, Lea, Fred, Henrik	-
4	Matilda, Fred, Anne	Tom, Linnea, Emilia, Sunjing, Mariela, Lea, Katja	Nils, Anne, Katja, Lea, Fred, Matilda, Mariela
5	Linnea, Tom, Emilia, Sunjing, Katja	-	Anne, Lea, Fred
6	Fred, Nils, Katja, Anne	Matilda, Tom, Linnea, Emilia, Sunjing	-

2 Scientific objectives

The research project aims to determine the difference in water column hydrography and nutrient composition between Byfjorden and Havstensfjorden. The specific objectives of the research cruise was to determine:
a) If there is evidence of water exchange over the sill;
b) If there is any difference in vertical stratification between the fjords;
c) If the vertical water exchange is affected by the difference in vertical stratification;
d) The vertical and horizontal distribution of dissolved oxygen and nutrients;
e) The relationship between dissolved oxygen and hypoxia in the fjord;
f) If there is a difference in sediment and benthic communities in the deep basins between the fjords.
This follows the operation of a water pump in Byfjorden between October 2010 and December 2012, aimed at oxygenating the deep water by pumping surface water down, locking phosphate within the sediment[1].

3 Cruise overview

The ship left the Uddevalla docks around 10:30 (UTC+1) and arrived back at approximately 14:00 (UTC+1). The initial goal was to sample five stations, a deep and a shallow location in both Byfjorden and Havstensfjorden, as well as a single sample location in Byfjorden closer to the freshwater input. With an availability of extra time, we were able to add a station on the sill between Byfjorden and Havstensfjorden and perform a CTD drop. The first station was the deep sampling location in Byfjorden, here we took four oxygen samples, ten nutrient samples, and a box core sediment sample. Station two was located closer to the sill in Byfjorden, four nutrient samples were taken. Station three was located on the Havstensfjord side of the sill, and five nutrients samples were collected. The fourth station was the deep sampling location in Havstensfjorden, here four oxygen samples, nine nutrient samples, and a box core sediment sample were taken. At station five, we only performed a CTD drop to examine the water column properties and did not take any water samples. At station six, we took six nutrient samples.

4 Diary cruise narrative

We went to sea on the 24th of September 2019 to take samples in Byfjorden and Havstensfjorden on the west coast of Sweden. It was a calm day and we had sunny weather up until lunch when it got cloudy with minimal wind. An immediate problem arose when the Skagerak was refused permission to dock up-river, forcing the group behind schedule as we met the docked boat on foot. The original plan was to take four samples in total and more if we had the time. We planned two sampling stations in Byfjorden and two in Havstensfjorden. Sampling took place at the deeper parts of the fjords and on each side of the sill. We started at the station closest to Uddevalla and worked our way out to the station furthest from the docks. After taking samples at all four stations, we added a CTD drop at the sill and a CTD drop with water samples close to the harbour, totalling six stations. The day went smoothly, in part due to the good communication with the crew on the ship. A misunderstanding about the CTD drop at station 4 lead to confusion on board as some sub-groups had started their lunch break, but we managed to solve the situation easily. Throughout the day our sub-groups switched between the tasks onboard. At points this meant people lost the station they should have been on, again this was easily resolved. To avoid this happening it would be easier to assign sub-groups tasks where they remain for the duration of the cruise.

5 Stations activities log

At each station, the first step was to deploy the CTD from the side of Skagerak. From the downcast, we were able to assess the changes in oxygen, temperature and salinity with depth. As we recovered the CTD, niskin bottles were fired every five meters to collect water samples at desired depths. These samples were used for oxygen calibration and nutrient analysis. For the sampling of dissolved oxygen, we chose to collect samples from above the pycnocline, within the pycnocline, and below the pycnocline. The oxygen samples were fixed onboard so that they could be titrated in the lab on a later date. The oxygen samples will be used to calibrate the CTD measurements. When the CTD was onboard we fixed the dissolved oxygen samples

Table 3. Station coordinates and time of sampling tab:stationassignment

Station	WGS84	SWEREF99 TM (N,E)	SYSTEM UPLOAD TIME	TIME ZONE
1: Byfjorden (deep)	58° 20' 7,4" N 11° 52' 50,5" E	6470283, 317388	Sep 24 2019 10:36:09	UTC + 1 (Europe/Stockholm)
2: Byfjorden (sill)	58° 19' 43,2" N 11° 51' 23,7" E	6469603, 315942	Sep 24 2019 11:16:07	UTC + 1 (Europe/Stockholm)
3: Havstensfjorden (sill)	58° 19' 16,6" N 11° 49' 8,0" E	6468883, 313696	Sep 24 2019 11:45:09	UTC + 1 (Europe/Stockholm)
4: Havstensfjorden (deep)	58° 18' 56,8" N 11° 47' 16,4" E	6468356, 311853	Sep 24 2019 12:12:52	UTC + 1 (Europe/Stockholm)
5: Inside the sill	58° 19' 34,2" N 11° 50' 50,4" E	6469349, 315388	Sep 24 2019 13:20:48	UTC + 1 (Europe/Stockholm)
6: Byfjorden (docks)	58° 20' 26,4" N 11° 53' 53,1" E	6470825, 318433	Sep 24 2019 13:39:46	UTC + 1 (Europe/Stockholm)

first, with the following procedure: We attached a hose to the spigot on the Niskin bottle and allowed water to rinse through, letting water flow. We rinsed the Winkler bottles and caps, allowing the bottle to overflow three times. We filled the bottles to the rim, ensuring no air bubbles were present. One millilitre of $MnCl_2$ and one millilitre of NaOH were added to precipitate and fix the oxygen in the water sample. After adding both reagents, the cap was placed on the Winkler bottle and we shook the bottle gently for approximately 1 minute.

After fixing the oxygen, we proceeded with the nutrient samples. We took nutrient samples every five meters at stations one through four and six, using the following procedure: First, we rinsed the syringe with water from the niskin bottle and allowed it to overflow twice. We filled it with the water sample, inserted the plunger and ensured there was no excess water in the syringe. The filter was then attached to the syringe, and vials filled with the filtered water, rinsing the syringe between samples.

At stations one and four, we also took sediment samples using a box corer. The crew were responsible for deploying and retrieving the box corer. Once the box corer was back onboard, we took qualitative observations of the sample, noting properties such as colour, texture, and smell. We then used a shovel to move the sediment sample into a sieve, which was used to filter out the mud. Once the mud was filtered out, we looked through the remaining sediment to see if there were any living organisms in the sediment sample.

6 Operations

The CTD gives a vertical profile of the water column as well as measuring conductivity, temperature, pressure and oxygen. For every station, the CTD was deployed from the surface all the way down to just above the bottom while sampling the data. This was done for 6 stations. Bottom samples of sediments and infauna was collected with a box corer for two stations. The box corer was deployed down to the bottom and when it hits the bottom it closes and samples the sediment and are brought up to the surface. The size of the box corer was approximately 25*25*45cm. The sediment and infauna were then analyzed. For infauna the alive organisms were counted and speciated and for the sediment, the color, the grain size and the smell were recorded. We collected eight samples of oxygen in the two deepest stations (1 and 4) and 34 samples of nutrients from the niskin bottles of our CTD among all stations (except for Station 5). At each station, we collected the following water samples:
Station 1: 4 samples of oxygen and 10 samples of nutrients.
Station 2: 4 samples of nutrients.
Station 3: 5 samples of nutrients.
Station 4: 4 samples of oxygen and 9 samples of nutrients.
Station 5: no samples.
Station 6: 6 samples of nutrients.

Table 4. Data collection activities at each station.

Station	CTD	Oxygen	Nutrients	Box corer
1	X	X	X	X
2	X		X	
3	X		X	
4	X	X	X	X
5	X			
6	X		X	

Figure 1. Cruise chart, station numbers represent the actual sampling order.

Thanks

Thank you to our supervisors Sebastiaan Swart and Louise Biddle for guideance throughout the project. Also, thank you to the crew of Skagerak who made all sampling and this cruise possible.

References

1. Stigebrandt, A. *et al.* An experiment with forced oxygenation of the deepwater of the anoxic by fjord, western sweden. *Ambio* **44**, 42–54 (2015).

Appendix

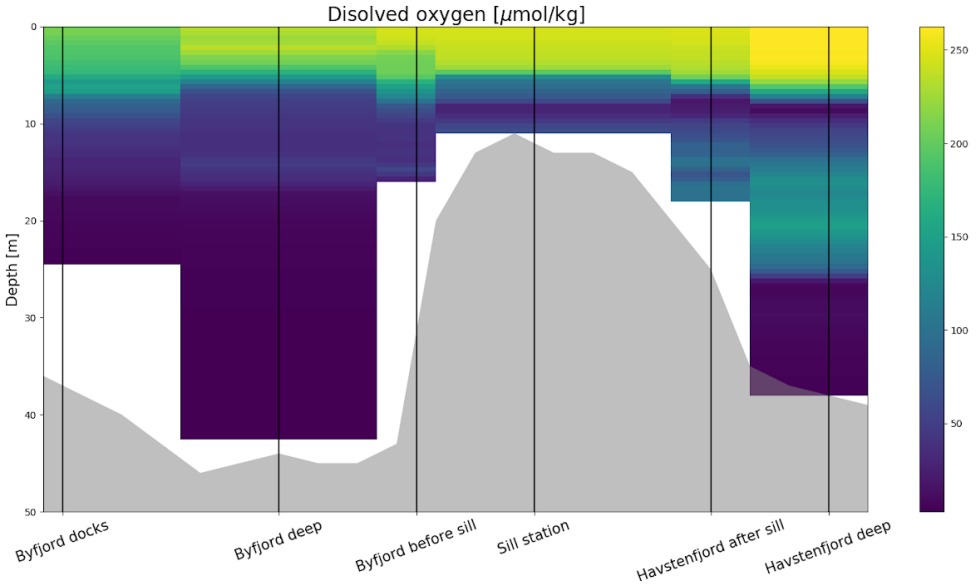

Figure 2. Dissolved oxygen by depth per station.

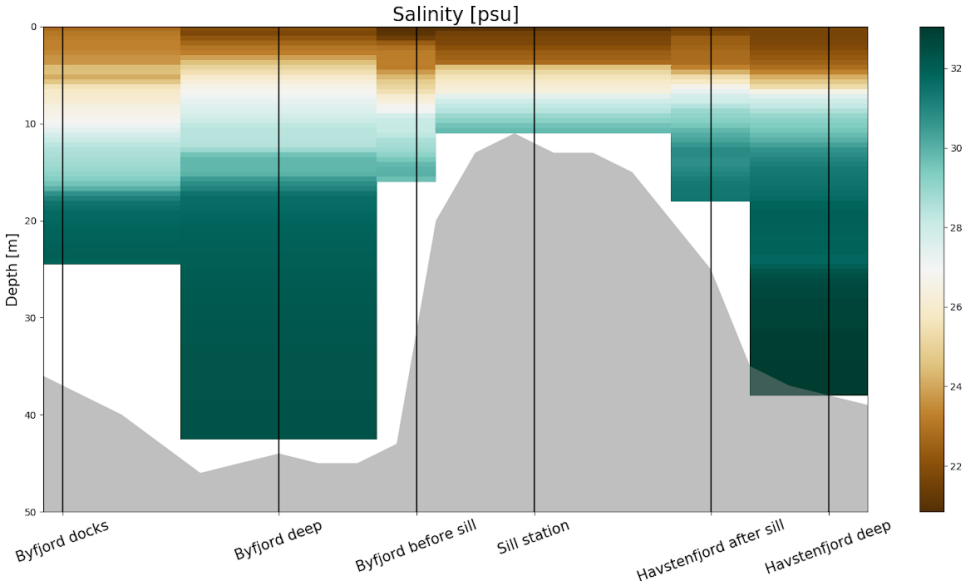

Figure 3. Salinity (PSU) by depth per station.

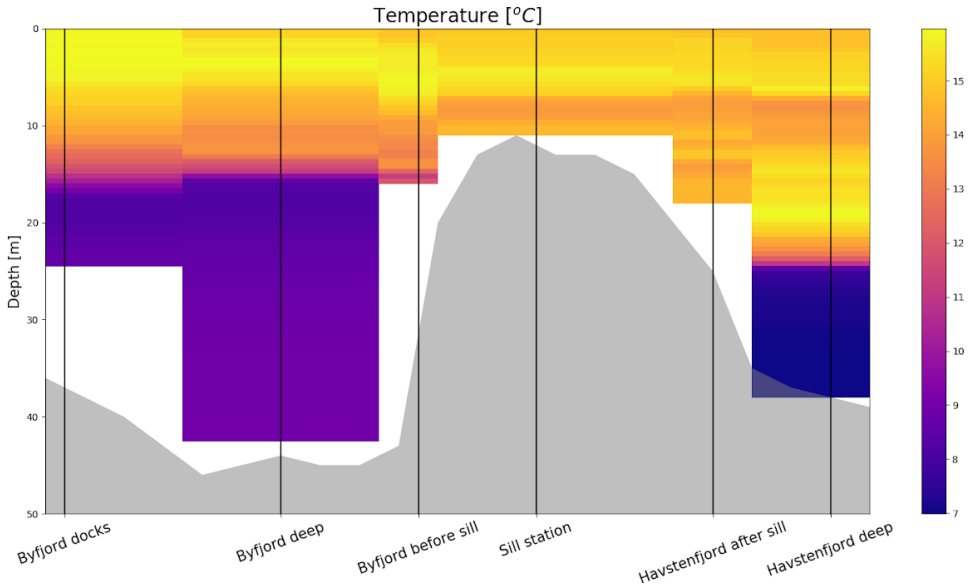

Figure 4. Temperature (°C) by depth per station.

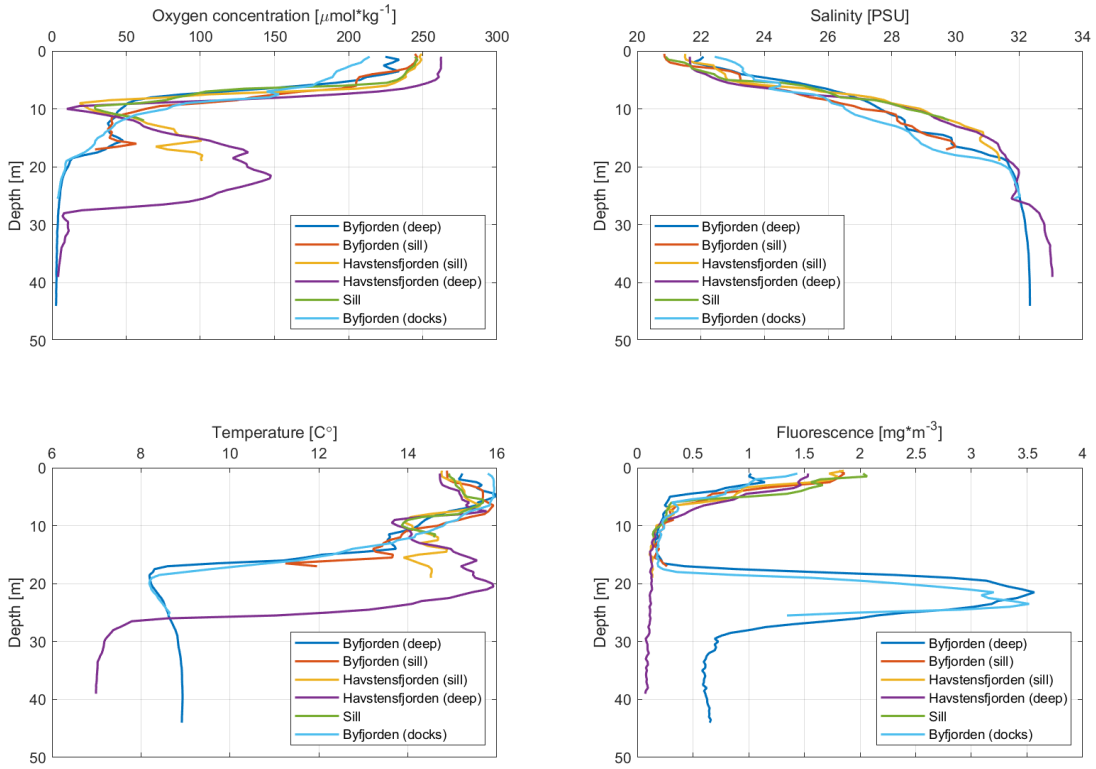

Figure 5. Line plots comparing a) Oxygen concentration (mol*kg^{-1}); b) Salinity (PSU); c) Temperature (°C) and d) Fluorescence (mg*m^3) by depth per station.

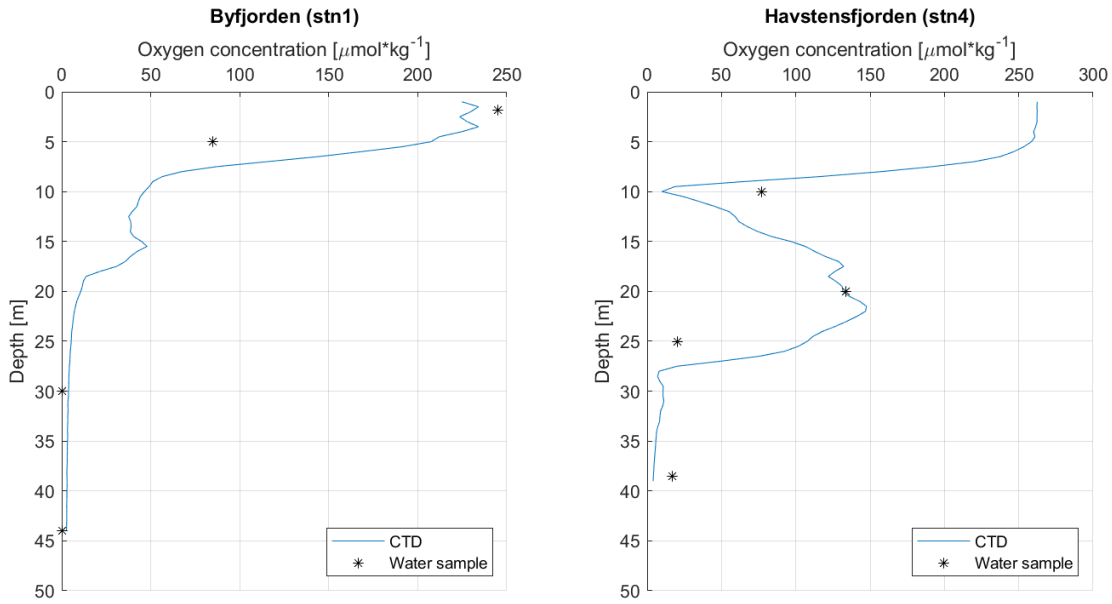

Figure 6. Line plots showing oxygen concentration (mol*kg^{-1}) by depth at Station 1 and Station 4. Scatter points show dissolved oxygen from water samples.

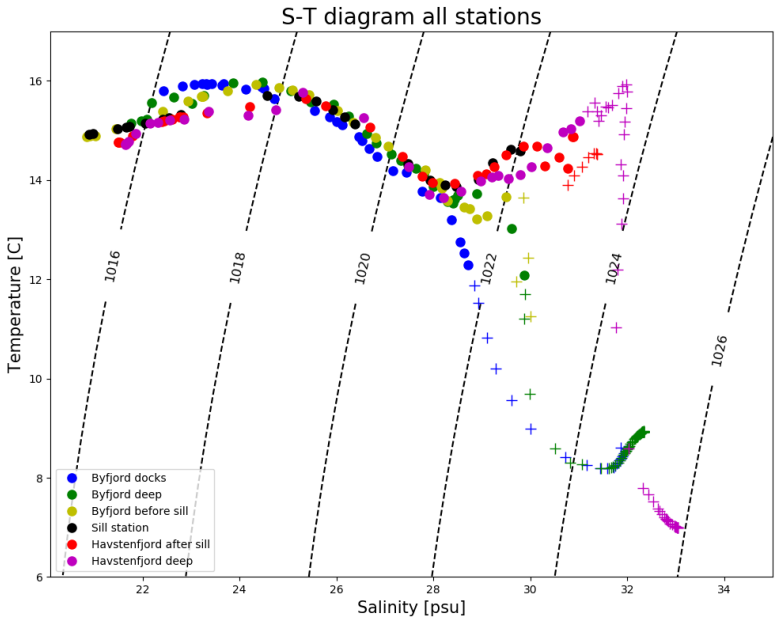

Figure 7. Temperature - Salinity (T-S) diagram of all stations. Isolines represent density.

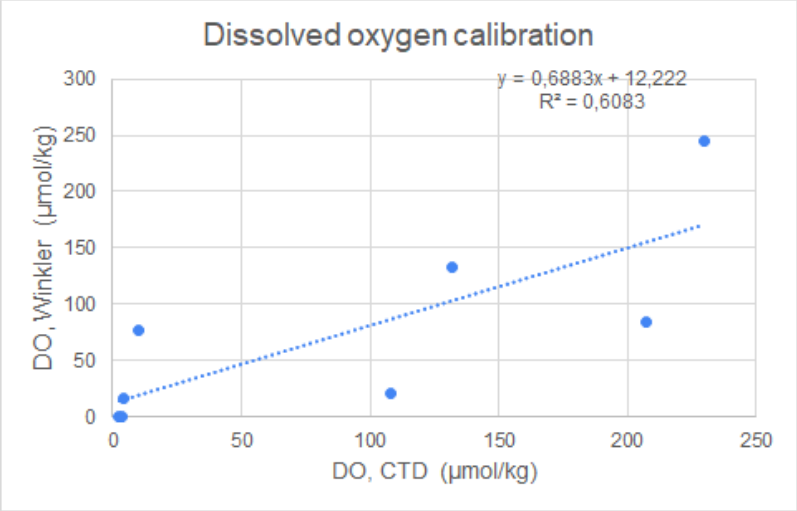

Figure 8. Dissolved oxygen calibration from in-situ samples. The R^2 value of linear regression is 0.6083.

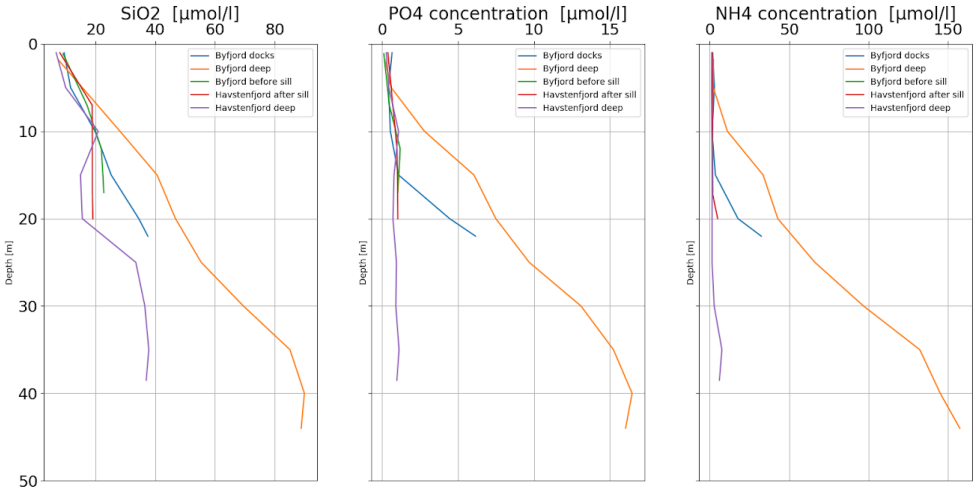

Figure 9. Nutrients profiles during the cruise. Here shows the three analysed compounds SiO_2 , PO_2 ,NH_4 .