# Comparing the Effects of the BOX Project Between Byfjorden and Havstensfjorden

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**Abstract** A further analysis of the long-standing impact of the previously conducted BOX project was studied after a day of collecting water samples and CTD data from the site of the project in Byfjorden and the neighboring Havstensfjorden. The general consensus acknowledges that the formerly experimented on fjord reverted back to its anoxic state in the deep waters that were previously pumped; however, a comparison of the two fjords allowed for a deeper understanding of this return to "normal". By using Havstensfjorden as a baseline, we were able to distinguish that there is a difference in the hydrography of the two fjords.

**Keywords** Nutrient Analysis, CTD, Hypoxia, Anoxia, Oxygenation, BOX project

The Baltic deepwater oxygenation (BOX) project was conducted in Byfjorden by Stigebrandt et al. wherein a pump was utilized to bring more oxygenated surface water into the hypoxic and anoxic deep water of the fjord. The experiment ran from November 2010 to April 2013 and looked specifically at the water compositions and ecological effects. The results were successful; phosphate levels were reduced and organisms were observed repopulating dead zones. Additionally, deep water remained oxygen rich from the time of the pump being turned off in December 2012 till August 2013. Further analysis years later has shown the same waters to have reverted to pre-BOX project conditions.

The objective of this experiment is to further examine the effects that the BOX project had on Byfjorden by comparing its waters to that of Havstensfjorden. The two fjords are separated by a shallow sill with a depth of approximately 13m. The latter fjord's greater availability to exchanging waters allows for a more apt representation of Byfjorden's composition pre-BOX project. Hence, water samples and CTD measurements were collected throughout the two bodies of water across ten stations of varying depths. From the water samples, nitrate, phosphate, and oxygen concentrations were evaluated; the CTD system allowed for additional oxygen measurements to be recorded.

The group objective was to collect CTD samples from 6 main stations and 4 additional ones situated between the main stations. This was done to acquire extensive sample data to understand the current situation of both Byfjorden and Havstensfjorden. As visible in the cruise track chart below (*Figure 1*), the number of sample sites were decided upon with the intention of collecting a sufficient number of samples from both fjords. This would facilitate a comparative quantitative and qualitative analysis of their characteristics. Stations 1, 2, 3, 10 and 9 are located in Byfjorden while stations 4, 5, 6, and 7 are located in Havstensfjorden. Station 8 is located on the shallow sill separating the two fjords. The group also collected box core samples from stations 6 and 10, which were situated in Havstensfjorden and Byfjorden respectively.

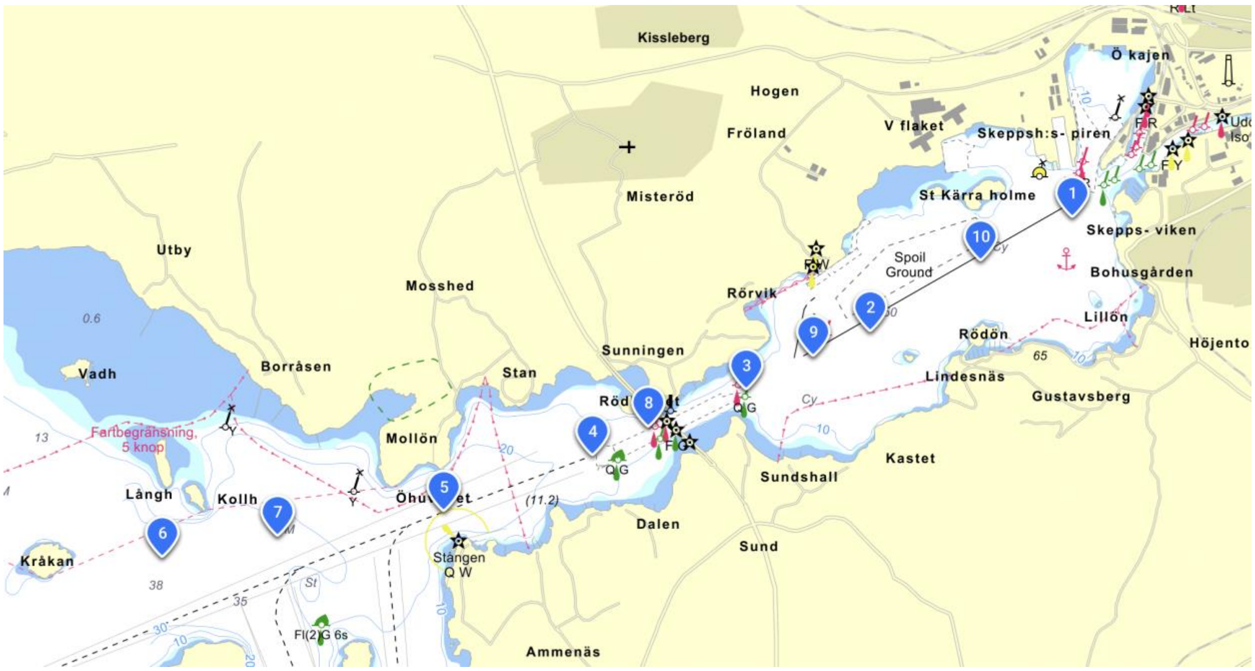

*Figure 1. Cruise track chart from Havstensfjorden (Stations 6 , 7, 5, 4) to Byfjorden (Stations 3, 9, 2, 10,1).*

Ship personnel present during the excursion included Captain Joakim and Master Deck Crew Anders and Christian, who actively helped with the scientific subjects. Other indirect steward crew members consisted of one cook, mess attendants, deck watch officers and two chief scientists.

The 12 members of our group boarded the Skagerrak ship in the Port of Uddevalla at approximately 09:45 on 22 September 2021. The crew members of the ship gave us a quick tour and we all signed a safety declaration. The experiment was carried out in stable weather conditions; cloudy skies and no rainfall with temperature between 12-13°C and wind speed at approximately 2,5m/s (www.yr.no). The group was divided into 3 sub-groups that rotated between the following on-ship stations: CTD sampling, CTD monitoring, and sample labelling. The sub-group on the sample labelling station was also responsible for communicating with the ship's crew members. Overall, the execution of the project went well without any major challenges. The following information can be found in the contents of Table 1. We had slight confusion while en route to the first station regarding the sampling depths which led to a minor change in the labeling system. This was resolved rather quickly and the organization of the different tasks went well for the rest of the trip. After finishing up on the sixth station, we decided to add the four additional stations on our way back as we had more time than expected. On these additional stations we only recorded the CTD profile, and no nutrient samples were taken. We also decided to do sediment samplings with a box core: one at station 6 and two at station 10. In the first box core sample at station 6, we found organisms. At station 10, no organisms were found in the initial box core sample. The procedure was repeated and a second box core was collected to ensure that there were not any organisms at the station. We returned to the port at approximately 15:00.

Table 1. Station and Activities Log

| Activity Identifier | Station | Date | Start Time (GMT +2) | Latitude | Longitude | Event Description | Comments |
|---|---|---|---|---|---|---|---|
| CTD 1 | 1 | 2021-09-22 | 10:39 | 58°20'469'N | 11°53,988'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| Nutrient Samples 1 | 1 | 2021-09-22 | 10:39 | 58°20'469'N | 11°53,988'E | Nutrient samples at 4 different depths. | ---------------------- |
| CTD 2 | 2 | 2021-09-22 | 11:05 | 58°19,939'N | 11°52,316'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| Nutrient Samples 2 | 2 | 2021-09-22 | 11:05 | 58°19,939'N | 11°52,316'E | Nutrient samples at 7 different depths. | ---------------------- |
| CTD 3 | 3 | 2021-09-22 | 11:36 | 58°19,698'N | 11°51,291'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| Nutrient Samples 3 | 3 | 2021-09-22 | 11:36 | 58°19,698'N | 11°51,291'E | Nutrient samples at 4 different depths. | ---------------------- |
| CTD 4 | 4 | 2021-09-22 | 12:00 | 58°19,404'N | 11°49,993'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| Nutrient Samples 4 | 4 | 2021-09-22 | 12:00 | 58°19,404'N | 11°49,993'E | Nutrient samples at 4 different depths. | ---------------------- |
| CTD 5 | 5 | 2021-09-22 | 12:20 | 58°19,183'N | 11°48,716'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| Nutrient Samples 5 | 5 | 2021-09-22 | 12:20 | 58°19,183'N | 11°48,716'E | Nutrient samples at 5 different depths. | ---------------------- |
| CTD 6 | 6 | 2021-09-22 | 12:40 | 58°18,856'N | 11°46,455'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| Nutrient Samples 6 | 6 | 2021-09-22 | 12:40 | 58°18,856'N | 11°46,455'E | Nutrient samples at 6 different depths. | ---------------------- |
| Box Core 1 | 6 | 2021-09-22 | 12:40 | 58°18,856'N | 11°46,455'E | 1 box core sample collected and observed. | Organisms (worms) found. |
| CTD 7 | 7 | 2021-09-22 | 13:12 | 58°19,084'N | 11°47,352'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| CTD 8 | 8 | 2021-09-22 | 13:34 | 58°19,537'N | 11°50,683'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| CTD 9 | 9 | 2021-09-22 | 13:46 | 58°19,820'N | 11°51,844'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| CTD 10 | 10 | 2021-09-22 | 14:19 | 58°20,252'N | 11°53,243'E | Salinity, temperature, depth, oxygen, and fluorescens recorded. | ---------------------- |
| Box Core 2 | 10 | 2021-09-22 | 14:19 | 58°20,252'N | 11°53,243'E | 2 box core samples collected and observed. | No organisms found. |

The preliminary results suggest a difference in the water column hydrography between Byfjorden and Havstensfjorden, especially in oxygen and nutrient composition. The salinity gradient in the two fjords is however quite similar, as can be seen in *Figure 2*.

In *Figure 3*, presenting the oxygen gradient for Byfjorden and Havstensfjorden, there is a visible difference in the oxygen level between the two fjords. Byfjorden is less oxygenated than Havstensfjorden. This indicates that Havstensfjorden has a greater influx of oxygenated water than Byfjorden. The water in Byfjorden becomes anoxic just a few meters below the sill which also indicates that the sill has a big impact on the low exchange of water between the two fjords. In *Figure 4* we can also see that there is a high level of phosphate in station 2, the deepest area in Byfjorden, which coincides with previous knowledge about anoxic deep waters. Phosphate is no longer retained in the sediment due to the lack of oxygen in the deep waters. The remaining stations maintain a consistent amount of phosphate (< 5 mmol/L) as their depths increase.

Nitrate levels are visible in the graph of *Figure 5*. Stations 2 and 3 peak at the same depth of 15m; however, we observe a dramatic decline in nitrate at station 2, likely caused by lack of oxygen and subsequent denitrification of the deep waters. In contrast, stations 5 and 6 display a higher level of deep water nitrate (past ~15m depth) that reduces closer to the surface also as a result of consumption by phytoplankton.

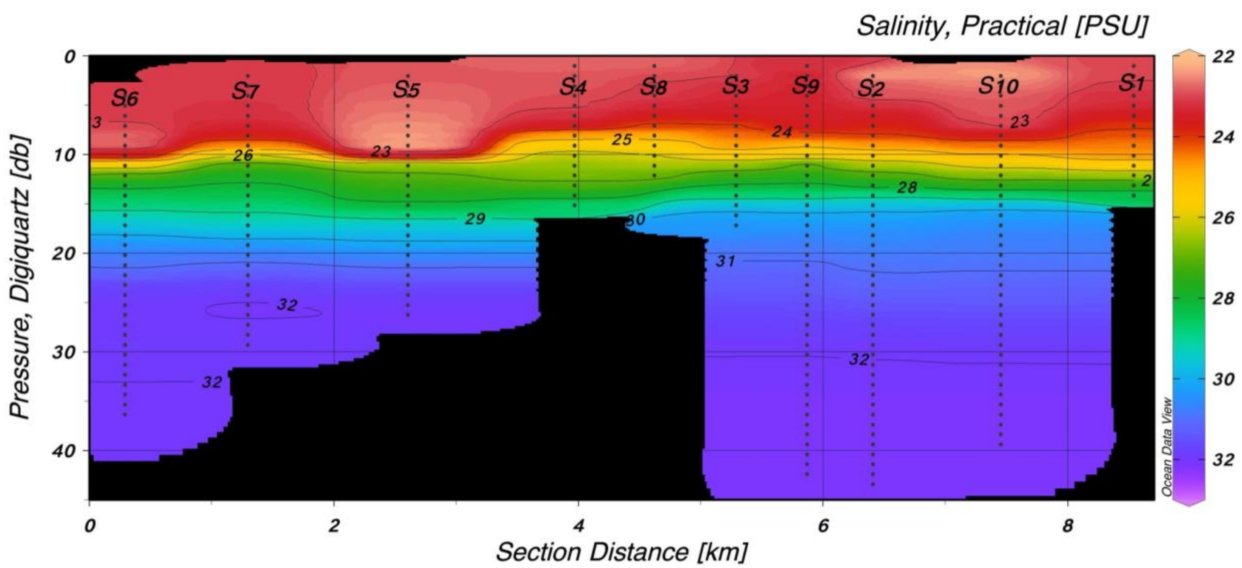


*Figure 2. The salinity data plotted against the pressure from Havstensfjorden to Byfjorden, where the dots mark the stations sampled.*

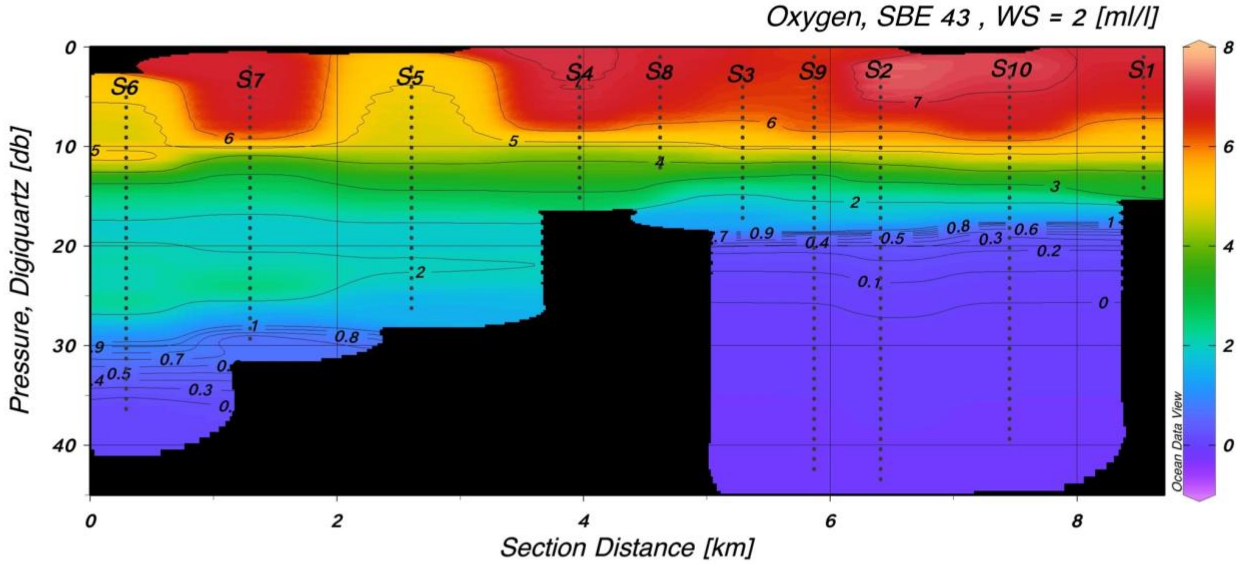


*Figure 3. The oxygen raw data plotted against the pressure from Havstensfjorden (S6, S7, S5 and S4) to Byfjorden (S3, S9, S2, S10 and S1), where the dots mark the stations sampled.*

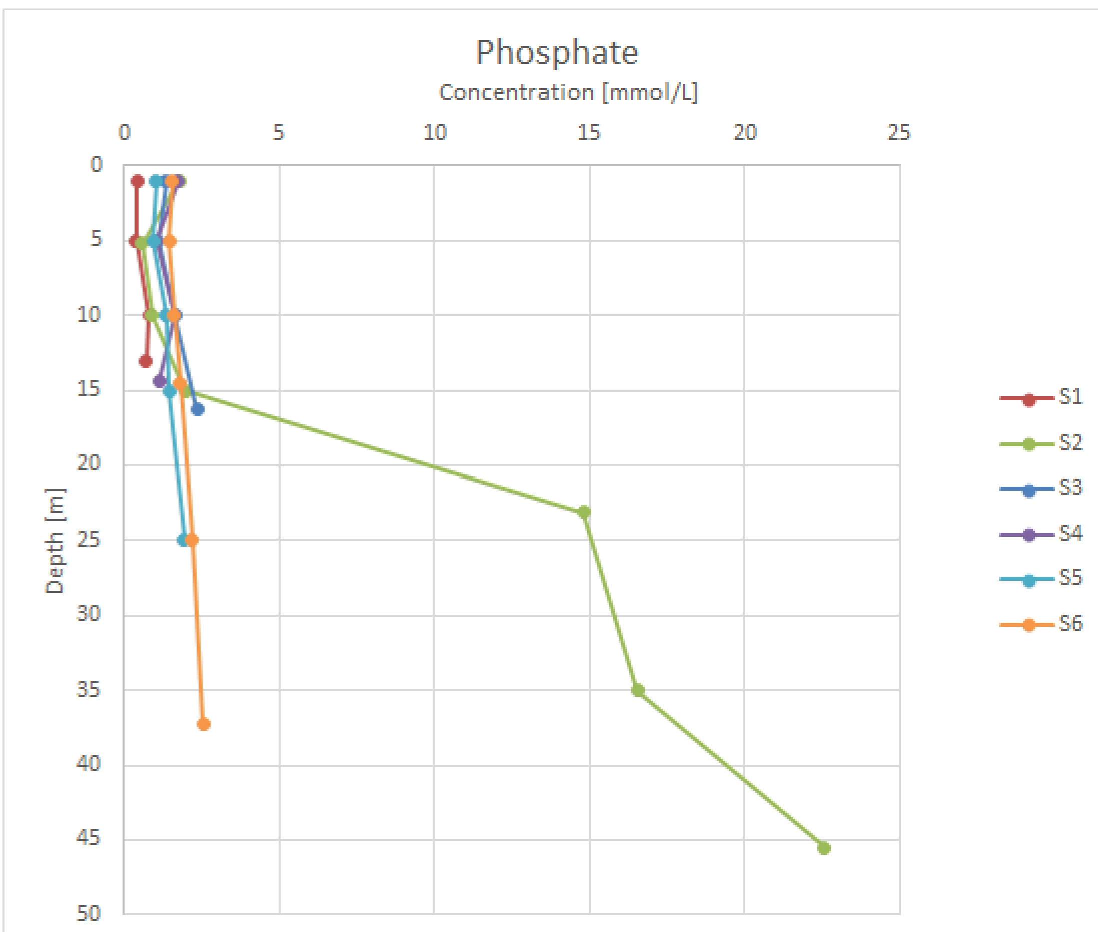


*Figure 4. The phosphate concentrations (calculated via a linear model of phosphate standards) plotted against the depth on all six stations where nutrient data was collected.*

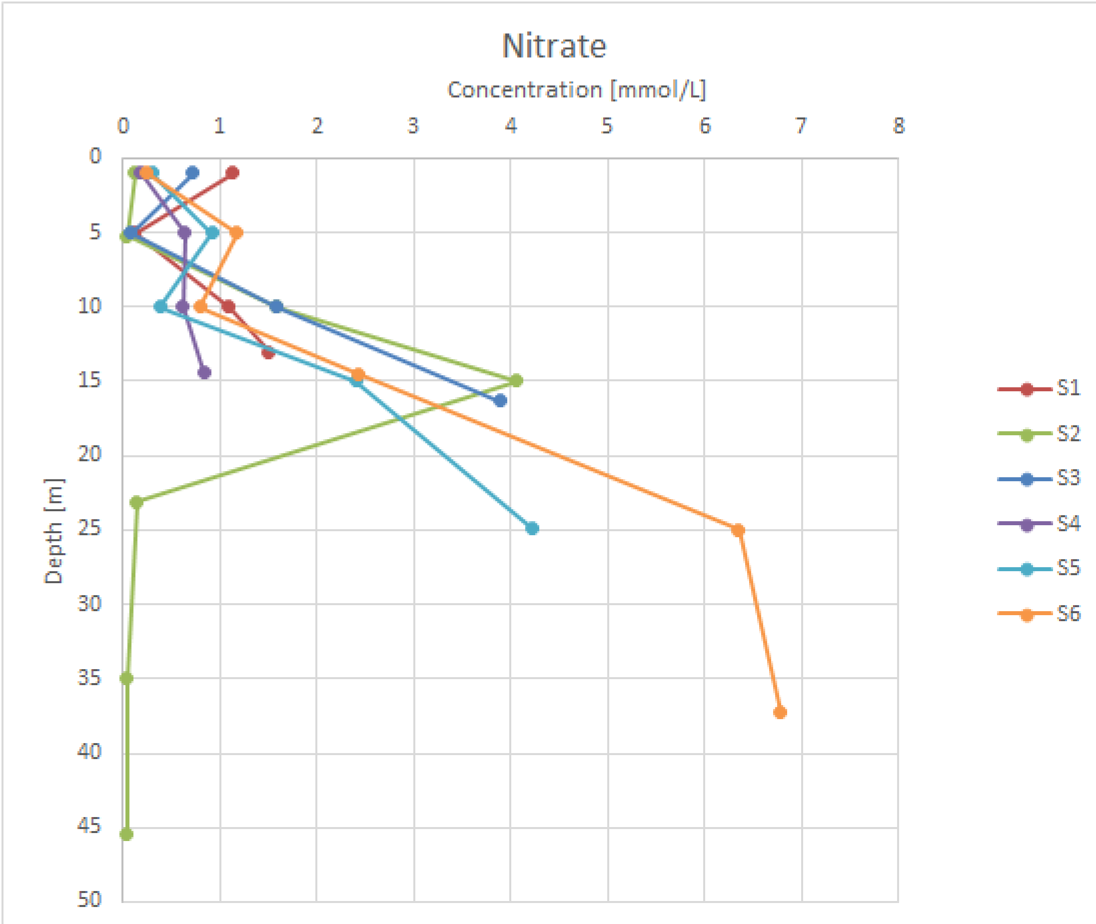


*Figure 5. The nitrate concentrations (calculated via a linear model of nitrate standards) plotted against the depth on all six stations where nutrient data was collected.*