

# Changes in plankton community in the Byfjord during the BOX project

Report for Göteborg University

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## Summary

From the available dataset, and with knowledge of the limitations of hypothesis testing of spatial changes in phytoplankton communities due to anthropogenic impact, we cannot find any visible structural difference in the plankton communities between the Byjord and the Havstensfjord areas from August 2010 to December 2012. This was tested with both uni- and multivariate statistical tests. The effect from the water pumps that is seen in physical parameters (oxygen concentration in bottom water, etc) cannot be found in the structure or biodiversity of the plankton communities.

## Background

The BOX project aims to oxygenize sea bottoms and hence decrease the leakage of phosphorus. This is achieved by pumping water from surface to bottom layers. A parallel study of the planktonic community was conducted to find any changes in Byfjorden due to the pumping.

Data from plankton samples has been collected and analyzed with the question whether there has been any change in the plankton community due to the anthropogenic pumping or if there has been general changes in the plankton community without coupling to the pumping. As an unreplicated control area has plankton data from the close by Havstensfjord area been used.

## Introduction

### Ecological studies on the plankton community

Ecological studies of plankton community due to anthropogenic changes are unfortunately a rather undeveloped biological discipline without a commonly accepted best practice. The present study is mostly using methods from the study of benthic communities.

Below we discuss some of the problems we have encountered during this study and how we have dealt with those issues.

- The studied water is in constant movement in the fjord system and is not easily connected to a specific geographical area. Every water mass is influenced by several environmental or physical parameters, that each, or in conjunction, can affect the plankton community. This adds statistical noise to the data – a common problem in ecological studies. In this study the retention time for the water is approximately 1 week in the Byfjord and Havstensfjord each (Daniel Hansson and Anders Stigebrandt pers. com)
- The spatial heterogeneity in water mass is higher than the sampling procedure is designed for. The method to minimize this is to take depth-integrated samples with a hose from e.g. 0-10 meters depth. But the area of the hose is still very small compared to the area that we extrapolate the results.
- Analysis of phytoplankton is very dependent on the skills of the analyzer. An experienced, or one with special interest in some plankton group, can easily skew the data, and the results, in multiparametric analyses and diversity index. A smart solution in this study was that the two experts analyzing the samples took one depth strata each. Those strata (0-10 m and 10-20 m) were analyzed independently.

- Smaller species is not analyzed to species level and is grouped in large “trash-bin”-groups, e.g. *Flagellates*. This is often unavoidable since small organisms need special methods (EM, fluorescence, etc.) which are in contradiction with the need of preservation with Lugol’s acidic solution.
- The use of the analytical parameters Abundance and Biovolume is tricky. Depending on the hypothesis we can choose to study the abundance of the organisms or their biovolumes. In the first case we risk to give small, abundant organisms to much weight, but this parameter is good for studies of internal community changes. In the second case we risk to give large, voluminous organisms to much weight in the analyses, but this parameter is crucial for studies of energy-fluxes and plankton production. This dilemma was a problem with the occurrence of the large dinoflagellate *Noctiluca* in some of the samples. There is also a scientific problem using a-priori knowledge to “trim” the data-set or to weighting in the diversity indices.

Despite the problems, it should be possible to find patterns in a plankton community. But we must be aware of the limitations of the methods and interpret the results with caution. Phytoplankton ecology is, as earlier said, very complex and not well understood but still an important and interesting field in marine ecosystems.

### **Report update - December 2012**

New data on nutrients and phytoplankton abundances from 2012 was partially included in this report. Some analyses were not updated (the physical parameters such as salinity and nutrients) and left unchanged representing data from 2010 and 2011. Data on plankton biovolumes from 2012 was not analyzed because of lack of data.



## Results - discussion

### Physical parameters

The water pumps were started in the end of October 2010 and were shut off in January 2011 when sea-ice caused the pumps to stop. The pumps were restarted in June 2011 and were functional the rest of the period. A small inflow of new deep-water was registered in May 2011.

Some of the physical parameters that can affect the plankton community differ consistently between the Byfjord and Havstensfjord for both surface and deep-water, see Table 1 and Figure 2 and 3. The difference was tested with pairwise t-tests between samples from the two localities taken the same date and depth.

The surface water (0-10m) differs significantly between Byfjord and Havstensfjord in concentration of ammonia, nitrate, silicate, oxygen and salinity. See Fig. 2.

The deeper (10-20) water differs significantly between Byfjord and Havstensfjord in concentration of ammonia, silicate, oxygen and the parameter temperature. See Fig. 3.

Table 1 Physical parameters in Byfjord compared to Havstensfjord (2010-08-02 to 2011-12-19, n=27). Positive values in pairwise difference means higher value in the Byfjord and negative values higher values in Havstensfjord. No statistical difference in the yellow cells.

	Pairwise t-tests, p-values, n=27					
	Ammonia	Nitrate	Silicate	Oxygen	Salinity	Temperature
Surface water (0-10m)	0,005	0,008	0,000	0,040	0,001	0,718
Deeper water (10-20m)	0,000	0,469	0,000	0,000	0,134	0,035

	Pairwise difference (mean value, in respective units)					
	Ammonia	Nitrate	Silicate	Oxygen	Salinity	Temperature
Surface water (0-10m)	1,20	0,98	4,63	-0,38	-0,12	N/A
Deeper water (10-20m)	5,29	N/A	7,83	-1,46	N/A	0,47

The high peak of ammonia in the Byfjord surface water during end of 2010 and spring 2011 was compared to historical values and were found 8 times from 1990 and onwards, mostly during the 1990's.

The difference in oxygen concentration in surface water was more pronounced when the pumps were shut down (spring 2011).

The nutrients in surface waters followed a clear seasonal trend.

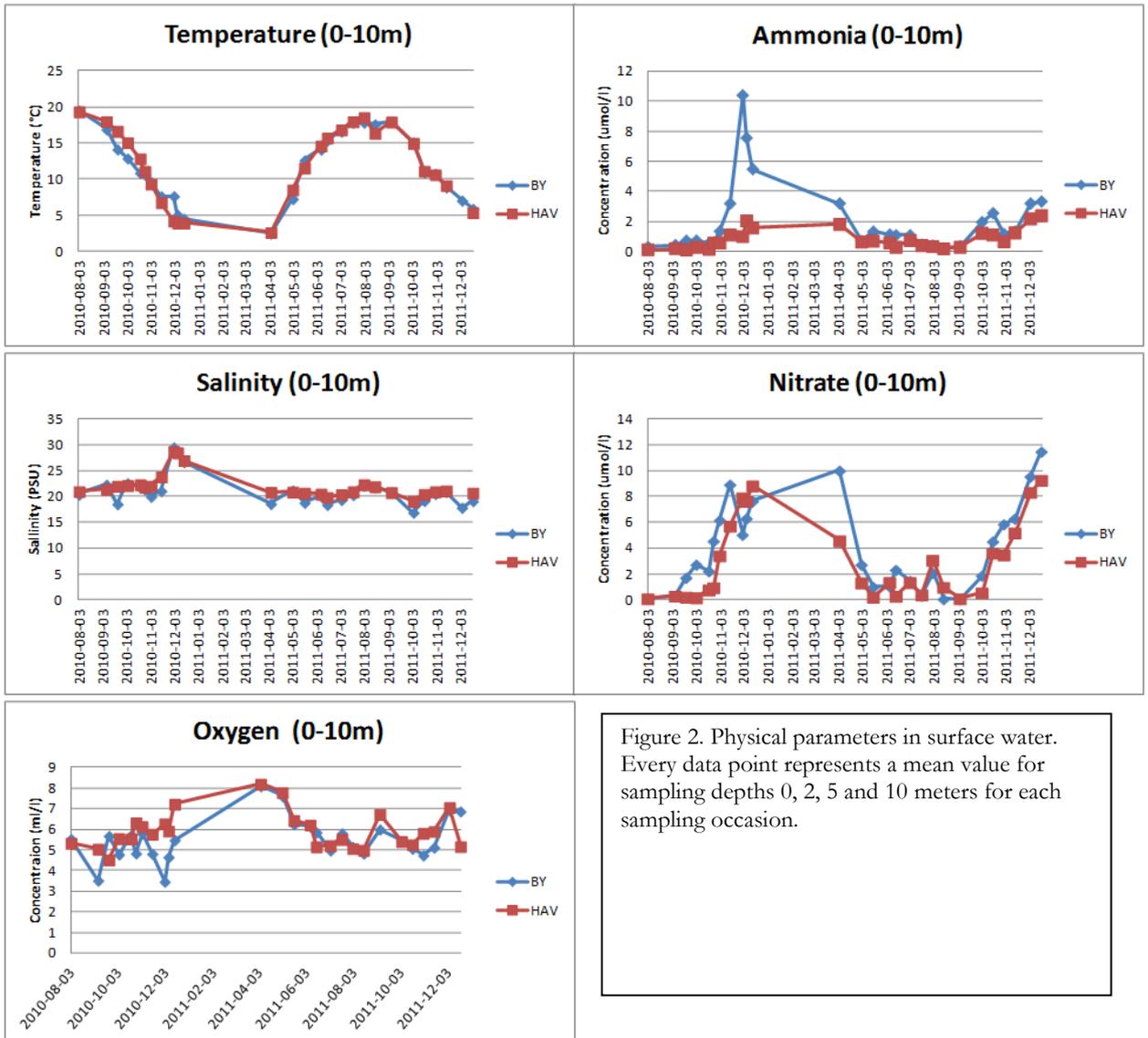


Figure 2. Physical parameters in surface water. Every data point represents a mean value for sampling depths 0, 2, 5 and 10 meters for each sampling occasion.

Several parameters differs between the localities for deeper water, see Fig. 3. Oxygen concentrations are significantly lower in the Byfjord but the difference decrease when the pumps are working – during and after June 2011.

Hydrogen sulphide is measured in the Byfjord during the first period but is eliminated after the first period of pumping (December 2010).

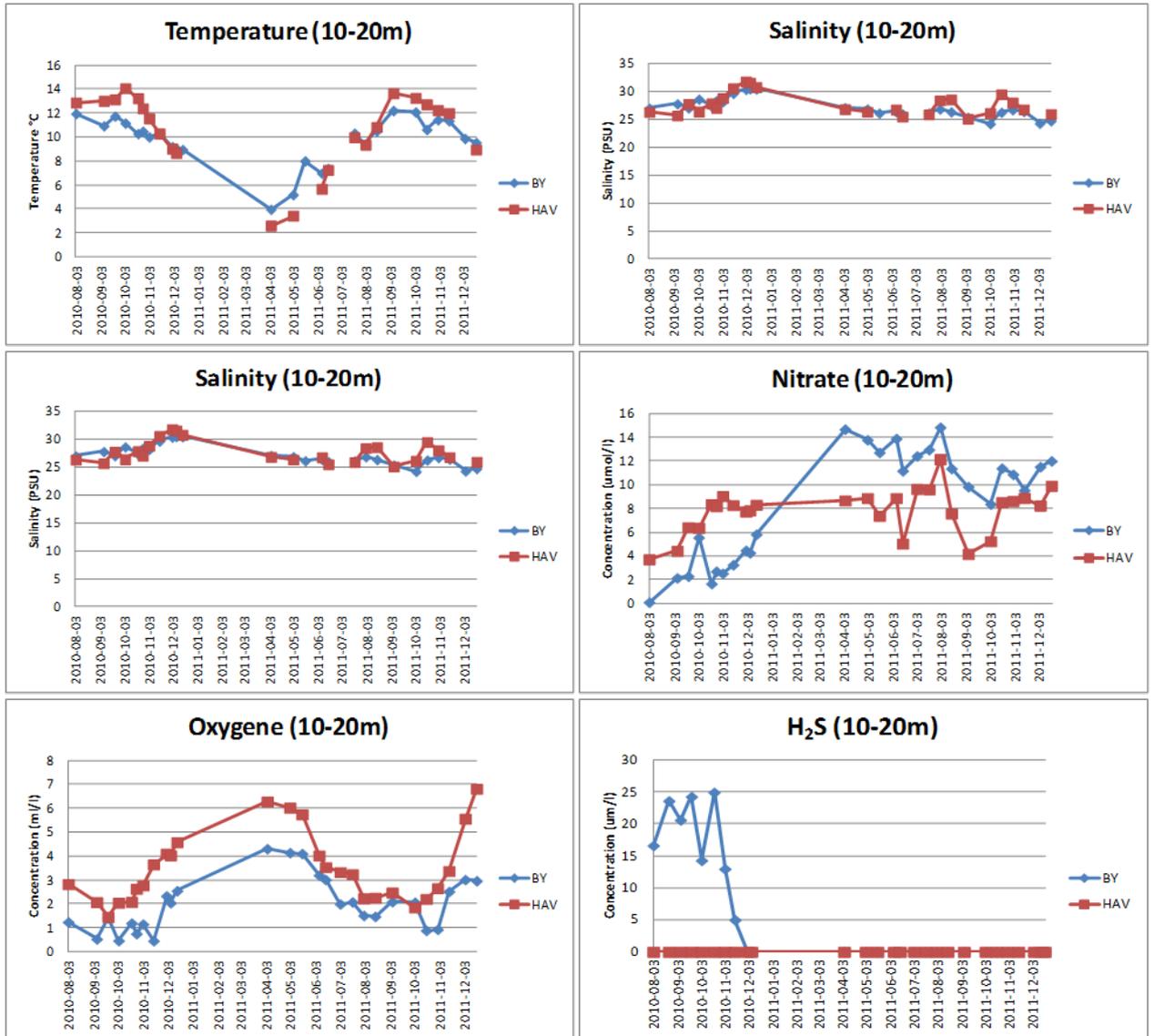


Figure 3. Physical parameters in deeper water. Every data point represents a mean value for sampling depths 10, 15 and 20 meters for each sampling occasion.

## Phytoplankton

### ***Species diversity***

In the species diversity calculation the genus "trash-bin" was used as an equal taxonomic value as species. This was based on the assumption that we underestimate the number of species in the analyses and the genus "trash-bin" represents true, but undetermined, species. Species from both surface and deeper water was included in the analysis of diversity.

For every sample following diversity indexes were calculated; Total number of Species and Shannon-Wiener index (which also include the abundance of each species). The interpretation weight in this report is on Species number and the rationale for this is that it is a "clean" index with no assumptions on the data and in accordance with Ockham's razor theorem. The Shannon-Wiener index is presented as an traditionally used index.

During 2010-08-02 to 2012-12-05 the total of species found during the time studied was 168 species in the Byford and 197 in Havstensfjord. This is 15 % less species in the Byford. Whether this is coupled to the pumping is not possible to distinguish from natural explanations, e. g. estuarine conditions. A general rule is that water with higher salinity has more species and the more estuarine Byford hence are expected to have fewer species.

The species diversity, measured as total species number in each sample, declined during the period, see Fig 4, but there was no difference between the localities (pairwise t.-test,  $n=27$ ,  $p=0,09$ ). No clear connection between pumping and species diversity was found. No coupling between improvement of physical parameters (pumping) and diversity are found or could be distinguished from natural changes in physical parameters.

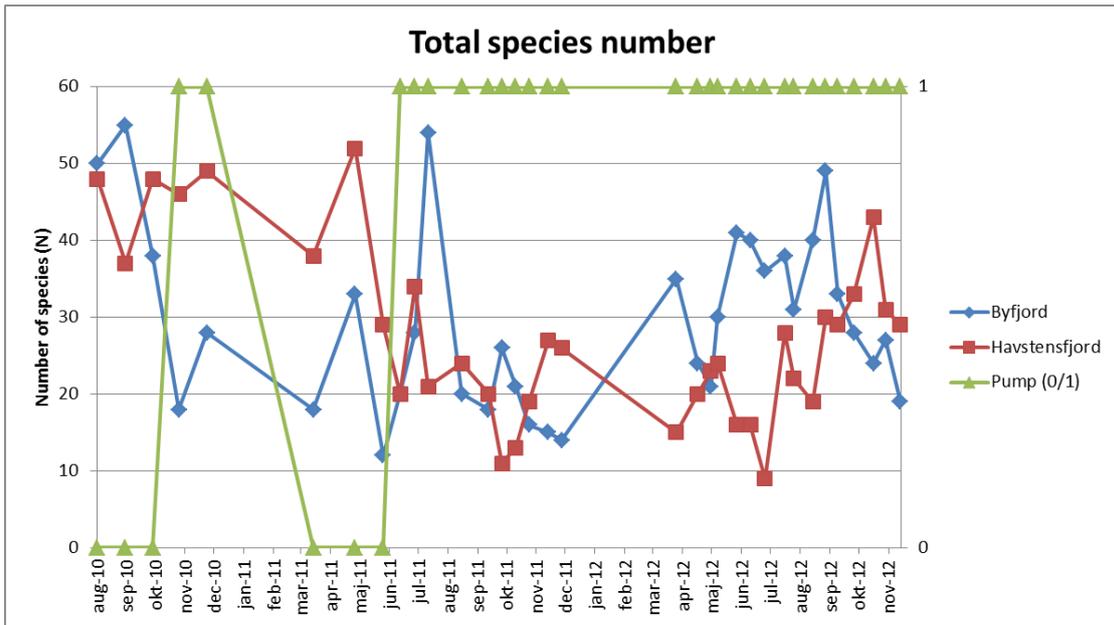


Figure 4 Total number of species found in each location and sampling date. Pumping in the Byfjord is indicated with 0 or 1 in the diagram. The analyses are based on species in the surface water samples (0-10m).

The pattern of species diversity over time is similar for Species number and Shannon-Wiener (Figure 5).

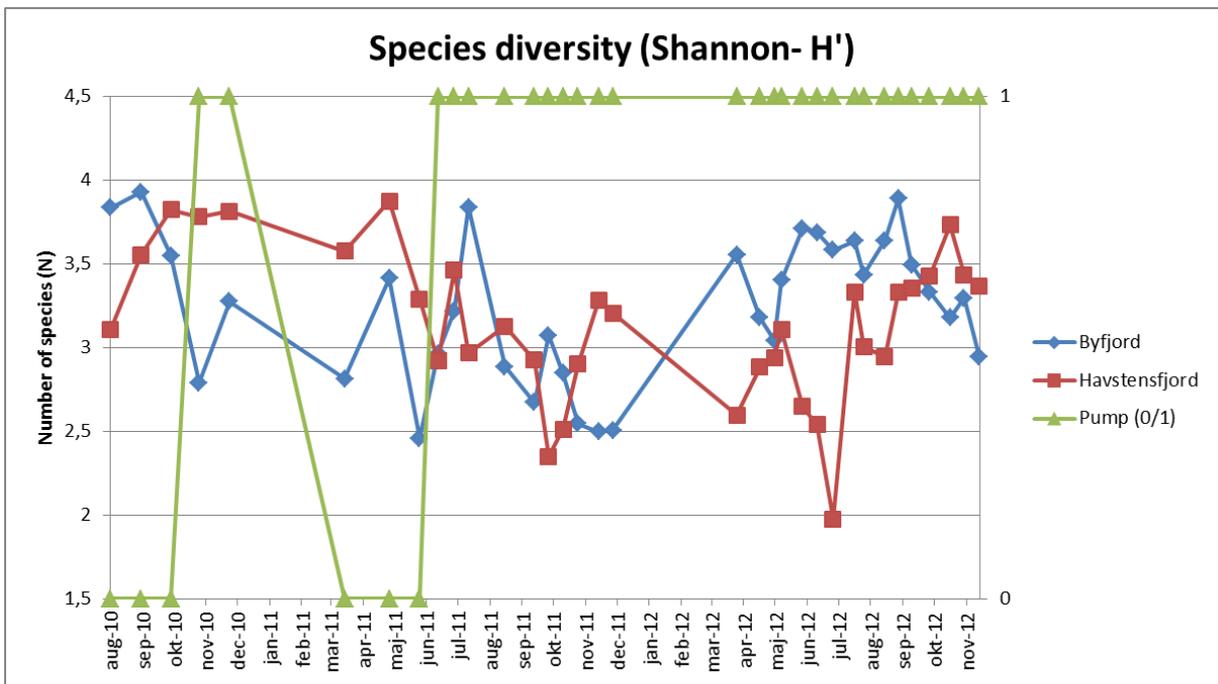


Figure 5 Shannon-Wiener diversity index. A higher value indicates higher biodiversity. Pumping is indicated by 0 or 1 (off or on). The analyses are based on species in the surface water samples (0-10m).

An alternative to the univariate methods above, multivariate methods can analyze differences in the whole plankton community. Multi-dimensional Scaling (MDS) was applied the data set for the parameters abundance and biovolume. No visible difference was found between the parameters. Different transformations were applied to the dataset before MDS, but also here the differences were small.

The ordinations (visualizations) of the data showed no consistent difference between the two localities but showed that there was greater similarity between samples taken at the same date than between the localities, i.e. samples taken at the same date are more similar. This is visible in Fig 6.

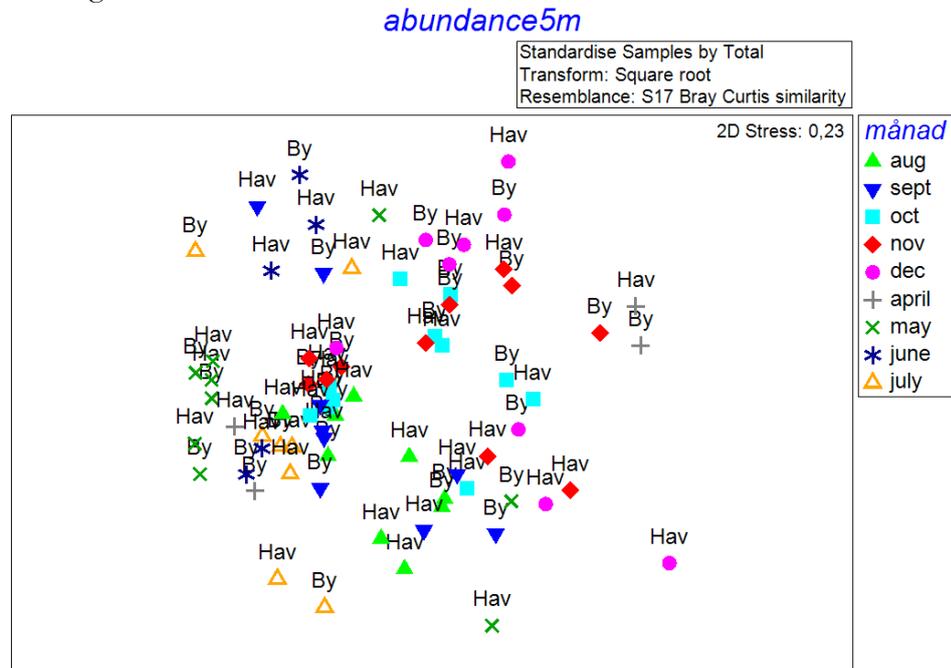


Figure 6 MDS plot for the phytoplankton communities in the Byfjord and the Havstensfjord in regard to sampling date. Data from 2010-08-02 to 2012-12-05 were used. Distance between the samples indicates the similarity of the communities – smaller distances means similar communities. The 2-D stress is very high and should not be interpreted as a whole – but the pattern shows that samples taken the same date, irrespective of locality, is similar each other.

### ***Biovolumes***

The surface water in Byfjord had in October 2010 a high presence of the large dinoflagellate *Noctiluca* which gave a very high biovolume measure that occasion (14 mm<sup>3</sup>/liter). Otherwise it was mostly low biovolumes during the study except early autumn 2011.

Compared to Swedish environmental status limits for biovolumes of marine phytoplankton (NFS 2008:1), which is 2.0 mm<sup>3</sup>/lit, the both fjords had GOOD status except for early autumn 2011. No difference between the fjords was found for biovolumes (pairwise t-test, n=27, p=0,57).

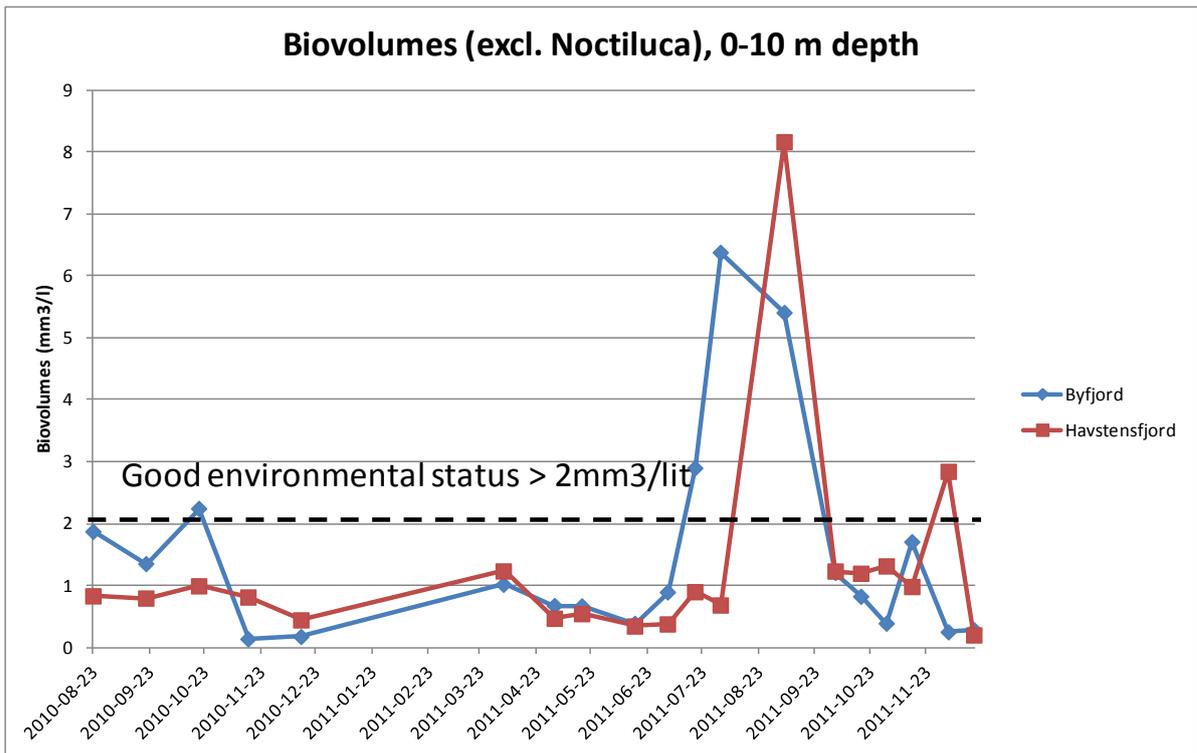


Figure 7. Biovolumes of phytoplankton in surface water (0-10 m) during the BOX project. The limit for GOOD environmental status is indicated by the dotted line (2, 0 mm<sup>3</sup>/lit).

### Ratio autotrophic phytoplankton

The ratio of autotrophic (photosynthetic) phytoplankton was analyzed to see if there was a consistent difference in the plankton communities of the two fjords, see Fig. 9. The ratio was between the biovolume of autotrophic organisms divided by the total biovolume (including heterotrophic and mixotrophic species). The hypothesis stated was that the pumping effect could increase, or decrease, the numbers of autotrophs in the Byfjord compared to the Havstensfjord. The analysis showed that there was no difference in the ratio of autotrophs between the fjords during the study time (pairwise t-test,  $n=19$ ,  $p=0,97$ ). The one-time occurrence of *Noctiluca* was excluded in the analysis.

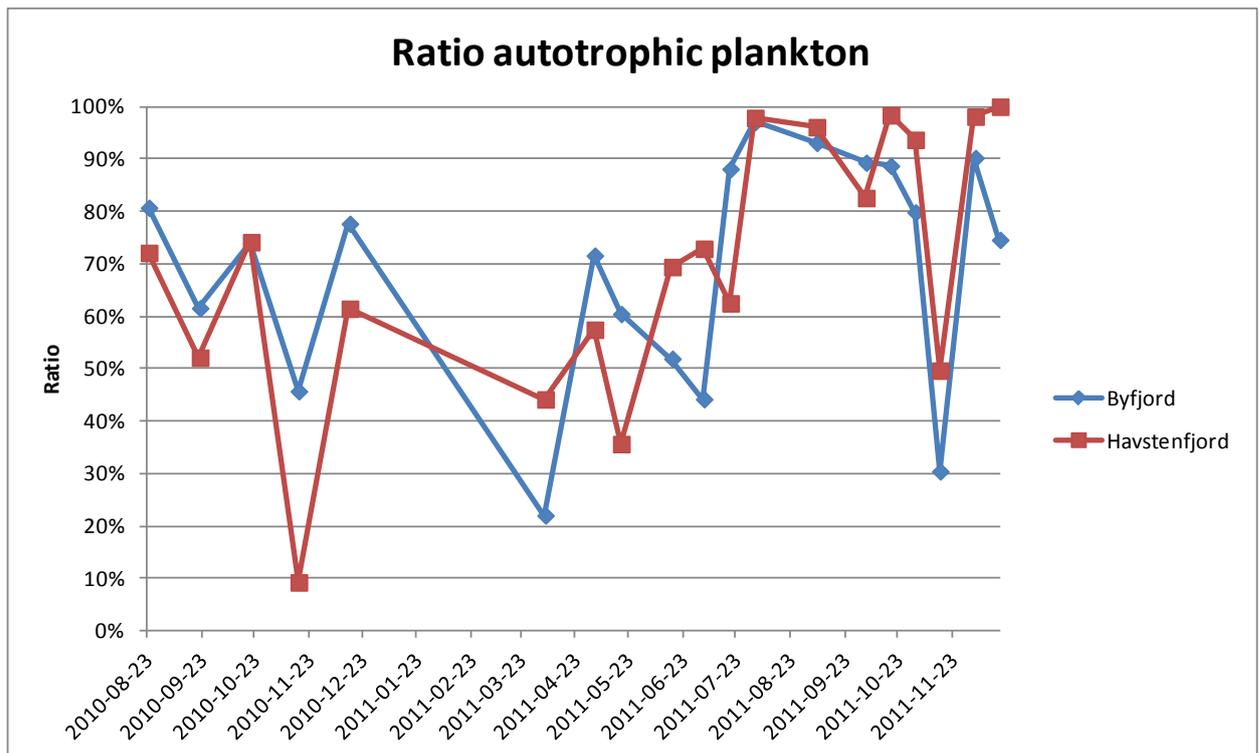


Figure 9. The ratio of autotrophic phytoplankton (compared to heterotrophic ones) in surface water (0-10m) during the BOX-project.

## References

Clarke, K.R., Warwick, R.M., 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2<sup>nd</sup> edition. PRIMER-E. Plymouth.

NFS 2008:1. Naturvårdsverkets föreskrifter och allmänna råd om klassificering och miljö kvalitetsnormer avseende ytvatten.