

# 2014

## Effects of a new bridge on an intertidal mudflat in the Outer Barsnesfjord, Western Norway



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**Front page.** Main sampling site at the outer Barsnesfjord the 1st of March 2014 at 16:16. Picture taken by Torbjorn Dale.

## Foreword

I would like to thank my Norwegian supervisors Torbjørn and Matthias, without your practical and emotional support it would not have been possible to carry out this bachelor thesis. I also would like to thank my Dutch supervisors Tjibbe and Francois who always came with new and challenging ideas that helped me forward in my thinking process and Per Johannessen at the University of Bergen who identified all the species. Again, without you all it would not have been possible. In addition I would like to thank Tom Dybwad and Marte Rosnes for their time; you gave me a big insight in how the Norwegian government system works and a valuable deeper insight about management systems. Finally I want to thank all my family, friends and my mentor Angelique Kuiper who stood by me during good and bad times, words cannot express how grateful I am for all the support I received from you all.

Sogndal 10-6-2014

Martine Venneman

## Abstract

A new bridge is going to be built in Sogndal (west-Norway) over the sill of Barsnesfjord which is a part of the Sognefjord due to the fact that the current bridge is no longer safe nor able to deal with the increasing traffic. This research is a pilot study and uses macro-benthos from the intertidal mudflat to qualify the ecosystem and make a status quo of the ecosystem before the bridge is build. The samples (4 samples of 0.1 m<sup>2</sup> and 4 of 0.01 m<sup>2</sup>) were taken on the first of March, meaning that it are winter values. 7 species and 173 individuals were found in the 6 analysed samples. The Shannon-Wiener index, commonly used for ecosystem qualification, showed that the status of the ecosystem is 'bad' or 'very bad'. This is most likely due to natural causes such as a change in salinity throughout the year. The EU Water Framework Directive contains a list of indexes that should be used but no index have been developed to describe natural ecosystems this extreme. The predictions are that the new bridge is not going to influence this. What could be influenced is the renewal of the deep water of the Barsnesfjord due to the design of the new bridge. The size of this possible effect depends on how much the water is constricted and on how much the sill is swallowed. Due to the fact that no research has been done on the macro-benthos of this intertidal mudflat further research is recommended.

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## 1. Introduction

Norway is the home to fjords which are only found in glaciated areas such as Norway, Iceland, Greenland and Alaska. Fjords are the result of glacial erosion and follow river valleys formed prior to the glaciations. These river valleys have now reached sea level which makes fjords large estuaries. There is a great variety in between fjords in Norway for various reasons. The most obvious one is the size and depth; less obvious differences are in the location, currents and tidal differences (Ramberg & all, 2008). Another factor which causes the high variation in fjords is due to sills. Sills are underwater hills and are a leftover from the glaciers. Sills can be quite high; the sill that separates the Sogndalsfjord and the Barsnesfjord rises quickly from more than 100 meters to -9 meters. Because of these sills, the water flow is very much different than when there was no sill because they cause a restriction in the water flow and also causes the fact that all fjords are unique to some extent (Dale, Life in the Barsnes fjord, 2014). The Norwegian Coastal Current, which is one of the main drivers for the hydrologic system, originates from the freshwater runoff from the Baltic and from the Norwegian mainland. Most currents are driven by density differences which, in saltwater, mainly depends on salinity differences while freshwater density differences are caused by temperature differences. Important to note is that freshwater at its highest density cannot be heavier than seawater. Another important source for (surface) currents is the wind direction (Saetre, 2007).

### 1.2 Ecosystems in fjords

Fjords have rich and varied marine ecosystems and have a high freshwater transport; 40% of the freshwater runoff from the mainland is flowing into the fjords. The freshwater discard is clearly seasonal even though there are large fluctuations between years. Freshwater is forced by gravity out to the coast, flowing in a brackish upper layer due to the fact that freshwater mixes with salt water due to wind and tide. Differences in mixing can occur due to natural reasons or anthropic reasons (Saetre, 2007).

Conditions of the water directly influence the life in the fjord and a change of the water leads to changes in species that live in narrow niches. An example of this is the macro-benthos. Macro-benthos is defined as benthic organisms that are larger than 1 mm in size (Herman *et al.*, 1999) and among them are crustaceans, polychaetes and molluscs. The macro-

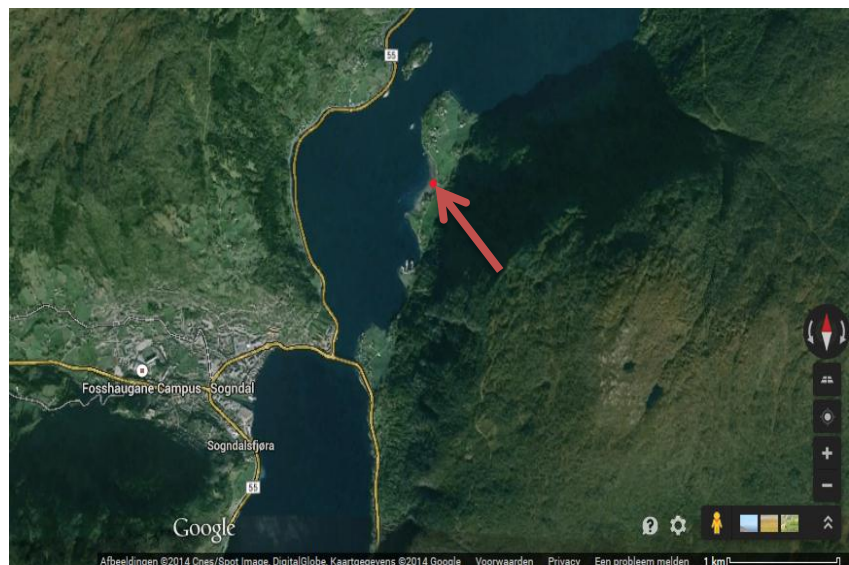


Figure 1 Red arrow shows location of the mudflat. Google maps 2014.

benthos community consists of many species, each of which occupies a narrow environmental niche, defined by variables such as sediment type, hydrography (which includes salinity, temperature, oxygen, etc.) and inundation time. Several studies have already indicated that changes in the environmental conditions can lead to changes in abundance, growth and reproduction of at least some species of the macro-benthos community (Compton, et al., 2013).

Not much is known about the mudflats in Norway and especially not about intertidal mudflats in Norwegian fjords. Mudflats in fjords such as the Barsnesfjord, which is located where the red dot is on figure 1, may contain less species than mudflats close to the open sea due to the change between nearly freshwater during spring, summer and autumn and a higher salinity in wintertime. In addition to this the sun is blazing during summer while the surface is frequently exposed to temperatures down to -10. Due to the high salinity changes and temperature differences it is expected that only a few species are living there. Birds have been spotted on the mudflat and it is suggested that they use it for foraging, and there are suspicions that the mudflat is used as a nursing ground for flatfish since other mudflats in the Sogndalsfjord contain many young flatfishes (Dale, Life in the Barsnes fjord, 2014). This makes the mudflat in the Barsnesfjord interesting enough to research.

### **1.3 New bridge**

A new bridge will be built nearby Sogndal which is shown in figure 2. Sogndal is a small city (population between 3000 to 4000) and is situated at the inner part of the Sogndalsfjord, a branch of the Sognefjord. The bridge is build due to the fact that the old bridge is no longer sufficient due to safety measures while the design of the bridge was chosen because it was a money issue and a matter of personal taste. The Barsnesfjord itself is used for recreation, fishing and leads into a salmon river. This bridge is a part of the main road, road 5 which connects to road 55 which goes up north (NIVA, 2003).

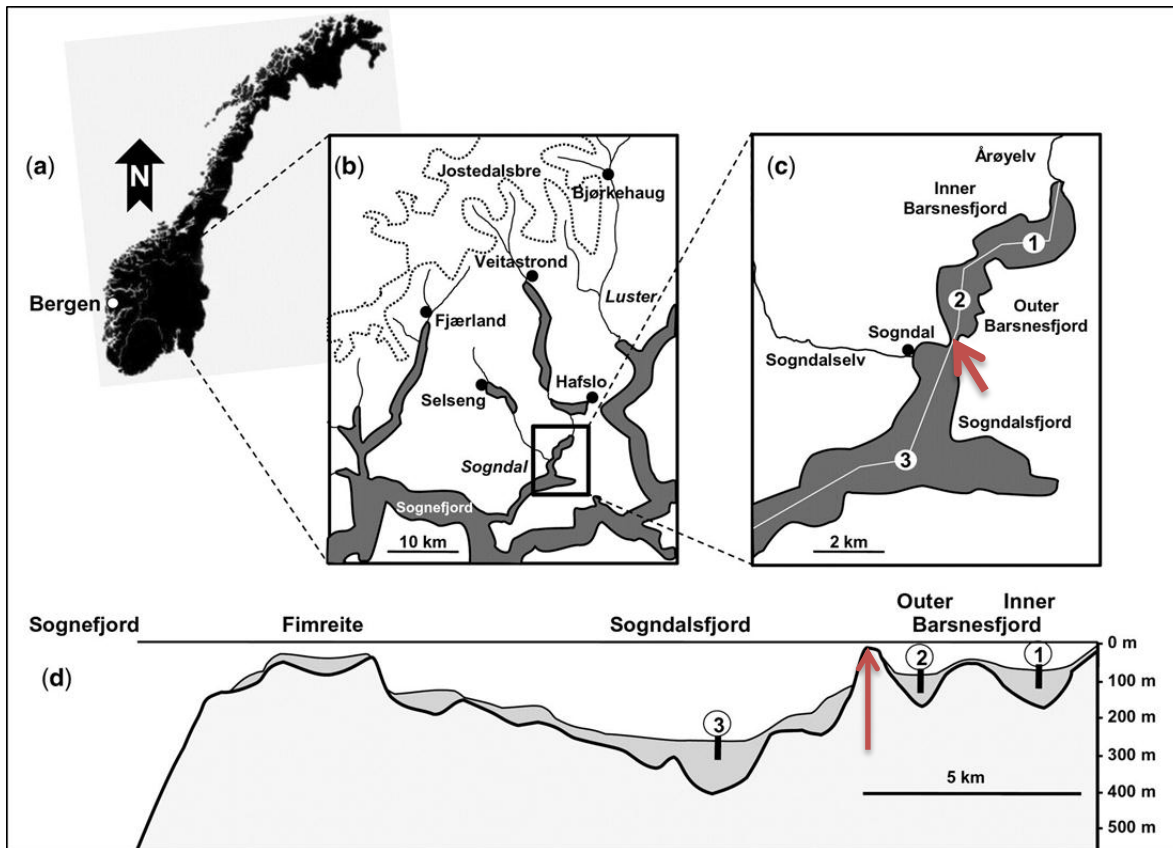


Figure 2 Picture a, b and c show the area where the Barsnesfjord is located. The location of the bridge lies on the sill between 2 and 3 and is indicated with a red arrow. The depth of this part is 9 meters deep during high tide (Paetzel, M; Dale, T, 2010).

The bridge will be located on a sill at the shallowest and narrowest part where 2 fjords meet, see figure 2. The water depth at the sill is 9 meters deep during high tide. On the northern part of the Barsnesfjord is the Årøy River which is the main supply for freshwater and brings in  $1\text{ km}^3$  of water each year. The surface of the Barsnesfjord is  $4.5\text{ km}^2$  (Dale, T; Hovgaard, P, 1993) and the tidal difference is 1 to 1.5 m (Dale, Personal com., 2014).



## 2. Problem description

The building of the new bridge will most likely bring changes in the hydrography in the Barsnesfjord and due to this the environmental department of the government has ordered a research on the effects (Dale, Life in the Barsnes fjord, 2014). The company to do this research is NIVA and they made 2 reports, one from 2003 and one from 2010. The one of 2003 is based on a model of hydrography (NIVA, 2003) which partly works with 5 different parameters.

These values are:

1. Inflow area (width \* depth)
2. Water flow (surface area of the Barsnesfjord)
3. Tidal difference
4. Amount of turbulence
5. Length of the constrictions

The other report is based on hydrography samples (NIVA, Ny Loftesnesbru i Sogndal Vurdering av miljokonsekvensar i sjoen (Rapport nr 5899-2010), 2010). Since the hydrological conditions are very important to macro-benthos, the reports of NIVA have great value. Predictions have been made on the model of 2003 which are that if there would be any effects, the effects should be positive for the ecosystem. This is due to the fact that the bridge narrows the inlet of water and if the same amount of water flows through, the turbulence of the water is higher therefore bringing in more oxygen in the deeper part of the Barsnesfjord. However, the model was underestimating the values of the current speed and the amount of water that went through and because of that, new hydrographic measurements were taken. (NIVA, Ny Loftesnesbru i Sogndal Vurdering av miljokonsekvensar i sjoen (Rapport nr 5899-2010), 2010). The report of 2010 contained the first designs of the bridge showing large land infills which may lead to water restriction and thus to changes in the hydrography which leads to a change in life (Dale, Life in the Barsnes fjord, 2014).

Both reports of NIVA are not complete environmental impact assessments which match the standards of the European Union (NIVA, 2010), (NIVA, 2003). A great number of laws and legislations of the EU are being integrated within Norway step by step, including marine legislation and the water framework directive ( Norwegian Ministry of Foreign Affairs, 2010).

Two professors of the College University Sogn a Fjordane in Sogndal (Høgskulen i Sogn og Fjordane) had great worry about the possible hydrographic change of the Barsnesfjord. They formed an independent research carried out by the students of the international course "From Mountain to Fjord". In order to get a better view, various samples were taken which were diatoms samples, sediments cores, foraminifera, macro-benthos and hydrography samples were taken. In the final presentation it was shown that the diatoms, sediment cores foraminifera and the macro-benthos all were related to the hydrographic conditions. In

other words, if the hydrography changes, it is expected that it has a strong impact on at least sediment, diatoms, foraminifera and macro-benthos. The results from the “From Mountain to Fjord” course will be put a report to the municipality written by Torbjørn Dale. In addition to this research, the mudflats will be researched for macro-benthos and the results will be added into the report by Dale. By making a good status quo of a certain area it should be possible to measure change in that area in the years to come. Important to note is that this is the first research done on this mudflat (Dale, Life in the Barsnes fjord, 2014).

### **3. Goals**

The goal of my bachelor thesis is to provide data on macro-benthos in the intertidal mudflats in the outer Barsnesfjord and contribute to the knowledge of the Sognefjord and the decision making process of the bridge. This leads to the following questions:

- Which macro-benthos species live in the in the intertidal mudflat in the Barsnesfjord?
- What will happen to the macro-benthos in the mudflat when the new bridge is built based on results of this thesis, literature research and expert knowledge?
- What is the current policy and how can the answers of the previous questions contribute to the current policy?

The tools used to answer these questions can be found in the methods.

## 4. Methods

Each of the sub questions need their own method in order to be answered. This chapter explains by sub question how the questions should be answered and which materials are needed.

### 4.1 Area description

The air temperatures in Sogndal varies throughout the year ranging from 26.2 °C at its highest measured on the 24th July, 2013 and -11.6 °C measured on the 6th December 2013 (Yr, 2014). These change in temperature combined with the weather have got a large effect on the amount of freshwater in the fjord. High amounts of freshwater runoff take place in May, June and July and low amounts take place from December till March (Saetre, 2007). This can be explained by the changing of the change of the seasons or to be more exact, the building up of snow during autumn & winter and the melting of the snow during spring and summer (Dale, Life in the Barsnes fjord, 2014).

The researched intertidal mudflat lies a few kilometres north-east of Sogndal. The intertidal mudflat has not been researched in the past. What is researched is the temperature and salinity of the water throughout the season in various places in the Barsnesfjord. Graph in appendix I figure I shows that the average water temperature in the measured near the Årøy River in layers 0, 20 and 40 cm is at its lowest between January and March and highest in July and August. The water is likely to freeze in the coldest months, giving a water temperature of 0 degrees (Dale, Unpublished data, 2014).

Salinity changes as well; figure II in appendix I shows a high salinity can be found at 40 cm deep from November to May while the water is almost from May to November. At 0 cm it is fresher from November to May then the 40 cm layer but it follows a similar pattern. All these measurements were taken at the same location of the temperature measurements (Dale, Unpublished data, 2014).

In addition to this, both salinity and temperature changes with the depth but also with the season according to figure III and IV in appendix I. One of the biggest changes is that the salinity. In September it takes almost 20 meters before reaching maximum salinity and the surface water is almost fresh (From Mountain to Fjord, 2013) while the upper layer in February, around the date when all the samples were taken, was around 23‰ and it took less than 1 meter to reach maximum density. Most interesting is that the oxygen concentration (purple line in gram/l) also varies, showing that a renewal of the deep water, an phenomena that only takes place in wintertime (Dale, Unpublished data, 2014).

The main samples were taken on the 1<sup>st</sup> of March 2014 at new moon with the second lowest point in the month; 11 cm above 0-level. For comparison, the highest low water is 61 cm above 0-level, meaning that the mudflat would not have been exposed at that time. The complete tidal table can be found in appendix III figure VII.

## 4.2 Research design for macro-benthos

A pre-pilot study was done on the 26<sup>th</sup> of February 2014 in order to determine the local conditions, how the sediment was, which method to use, how many animals there were in there, etc. Special attention was given to the small Gastropod *Hydrobia* spp.. Due to the fact that it is one of the few Gastropods and feeds on diatoms and therefore it is used as an indicator species. Due to the results that were obtained from the pre-pilot study the final research design has been written in combination with standards described by the ISO 16665:2014 'Water quality Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna'. This guide is being described by the EU Water Framework Directive (Vannportalen, 2014).

The main samples were taken on the 1<sup>st</sup> of March 2014 at low tide by using a transect from the upper part of the mudflat to the lowest part of the mudflat as can be seen in figure 3. Pictures from Google earth of the location can be found in appendix I. This area has a length of roughly 110 meters and at 16, 50 and 86 meters small sediment samples were taken by using a small sediment core due to the silt rich ground. At 100 meters a bigger sediment core were taken together with the macro benthos samples. From there a 20 meter transect will be followed in a 90° angle from the previous transect, following the shoreline (roughly). There samples of macro-benthos (0.1 m<sup>2</sup>), *Hydrobia* spp.. (0,01m<sup>2</sup>) and sediment core samples

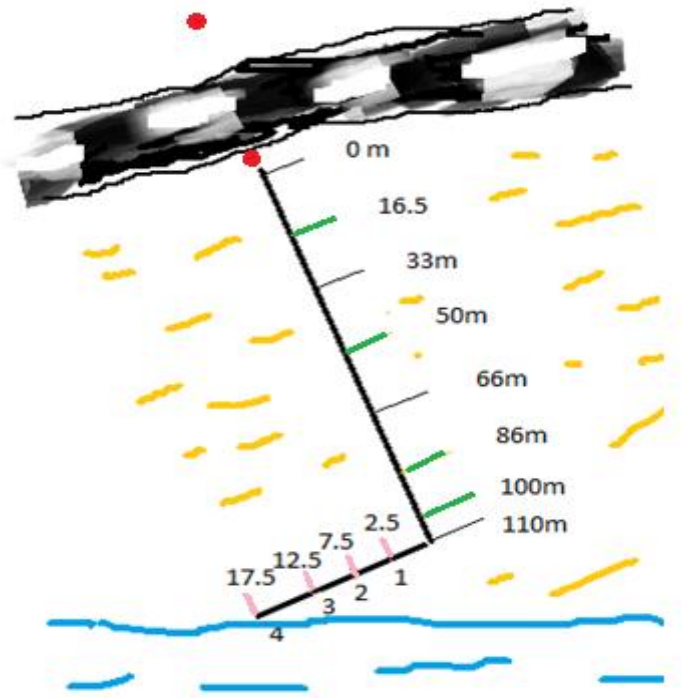


Figure 2 The sampling side at the Barsnesfjord. The green lines show where the samples have been taken. The small sediment samples have been taken at 16.5m, 50m, 86m and at 100 m. The bigger sediment samples, biological samples and *Hydrobia* sp. samples have been taken in a 90 degree angle from the main transect, every 5 meters marked in pink. Blue line indicates were the low low waterline is and the yellow the exposed mudflat



Figure 4 Sampling location at 17.08 after the samples were taken.

(approx. 15 cm deep) will be taken at 2.5, 7.5, 12.5 and 17.5 m. The samples were being taken at new moon so that the lowest part of the mudflat is exposed at low tide when the sampling was.

The samples were taken by foot and using a shovel to take a sample of 0, 1 m<sup>2</sup> (0.33 by 0.33 by 0.15), while sediment cores were is taken with plastic cores of around 15 cm and *Hydrobia* spp.. samples will be taken with a Van Veen grab of 0.01m<sup>2</sup>. Figure 4 shows the sampling location after the samples were taken.

The 0.1 m<sup>2</sup> sample were sieved with a mesh size of 5 and 1mm by following the design described in (Hovegaard, 1973). The samples were washed out in the aquaculture centre nearby with salt water. The 0.01 m<sup>2</sup> sample were washed at the school with fresh water and geological sieves of 1 mm and 0,1 mm in order to catch all the *Hydrobia* spp..

### Salinity

The salinity was determined from measured temperatures and water density by using a monogram. Temperature was measured by using a normal thermometer and the density by using a densimeter with a scale ranging between 0.998 and 1.052 g/cm<sup>3</sup>.

## Type of research design

Due to the fact that this is the first time that the intertidal mudflat is researched and forms a fundament of further research, this study should be considered as a pilot study by following the ISO standards (Standard Norge, 2014).

### 4.3 Analyses of macro-benthos samples

In order to get a sense of uniformity, the same analyses were being done as stated by the water framework directive for soft bottom. The water framework directive is a document which contains standards and goals to manage the water system, freshwater or saltwater, in a proper way. It also contains procedures on how to take samples for example soft bottom (Rijkswaterstaat, 2014) which are the documents that are going to be used in this research. The same documents contain standards and indexes used in the Norwegian water systems (Direktoratsgruppa for gjennomføringen av vanddirektivet, 2009).

### Identification species in the Barsnesfjord

In order to identify the species in the mudflats, it is necessary to take the samples by following the research design. The samples were being stored with ~75% alcohol. In the lab, the species that were living on the moment that they were caught were picked out, sorted and identified. Identification was done by Per Johannesssen of the University of Bergen..

### Shannon Wiener diversity index (H')

The Shannon-wiener index is the most common index used in benthic research (Kaurin, 2011). The index takes the species richness and proportion of each species within the ecosystem into account. Because of this, it rather depends on the proportion of the numbers than a sample size (Maryland Sea Grant, 1999). The Shannon Wiener index can be calculated by using the following formula:

$$H' = -\sum(p_i) * (\log_2 p_i)$$

The result of the formula gives a number between 1 and 5, 5 being a healthy and diverse ecosystem and a low number being an unhealthy ecosystem. If only 1 species is found the outcome will be 0. Table 1 shows the outcome of the formula scale from very good to very bad of the H' index.

Table 1 Values of the Shannon Wiener index showing what the state is of the ecosystem.

Parameter	Very good	Good	Moderate	Bad	Very bad
H'	<3.8	3.0-3.8	1.9-3.0	0.9-1.9	>0.9

### 4.4 Policy

In order to understand how the current policy works literature research and interviews were done. Since most of the literature of the Norwegian policy was in Norwegian supervisor Torbjorn Dale did a translation of the most important processes.

## 5. Results

The results exist out of an ecology part and policy part. The ecology part describes the results of the amount of animals found, number species, densities and the indexes used to interpret the results. The second part will answer the question about the existing policy and the implementation of this bachelor thesis.

### 5.1 Pre-Pilot study

A pre-pilot study was performed on the 26<sup>th</sup> of February 2014 at low tide and showed that the first 100 m had such a high clay density that it was impossible to wash out. Further away from land the sediment changes; the sediment contained more sand and less silt. Because of the dense sediment it was decided to sample in a transect with an angle of 90° at 110 meters to avoid the dense sediment. At the waterline the salinities and temperatures on various depths were measured and are described in table 2.

Table 2 Depth, temperature and salinity at the mudflat on the 26th of February

Depth (cm)	Temperature (C°)	Salinity (‰)
0	5.3	21
20	5.6	22
40	5.9	25

### 5.2 Biological samples

On the first of March the main samples were taken. Out of the 8 samples that were taken, (4 of 0, 1 m<sup>2</sup> and 4 of 0, 01 m<sup>2</sup>) only 6 were analysed. The 6 samples contained 7 different species and 173 individuals as seen in table 3. Most species only occur in one or two samples and only one species, *Chiromidae s.*, appears in all the samples. This species is also the one with the highest abundance.

Table 3 Table contains the amount of the species and in which sample they are found. The 'H' behind a number such as '1-H' means that it is found in the Hydrobia sample of sample 1.

Species name	Amount of individuals	Found in sample
<b>Phylum Mollusca</b>		
<i>Mytilus edulis</i>	7	1
<i>Hydrobia ulvae</i>	3	1; 3
<b>Phylum Annelida</b>		
<i>Oligochaeta</i>	9	1; 3
<i>Polydora sp.</i>	13	1; 2; 2-H
<i>Hediste diversicolor</i>	1	3
<b>Phylum Arthropoda</b>		
<i>Chiromidae spp.</i>	139	1; 1-H; 2; 2-H; 3
<i>Crangon crangon</i>	1	3
<b>Total amount of individuals</b>	173	



The distribution of the macro-benthos in the samples is shown in table 4. In the table it becomes clear that the amount of species and abundance of the species varies strongly. The first sample of 0,1 m<sup>2</sup> contains 117 individuals while the second sample only has got 9 individuals in the 0,1 m<sup>2</sup> sample and the third sample only contains 10 individuals at the same size.

For convenience the density is also expressed in square meters due to the fact that square meter is a well-used unit. However, there is too little data to prove if the calculated numbers are correct or not. For that reason only the amount sampled are used in further calculations.

Table 4 Shows how much and which species are in which sample and in which density. The Hydrobia samples (1-h, 2-h and 3-h) have a sample size of 0.01m<sup>2</sup>; the other samples have got a sample size of 0.1m<sup>2</sup>.

Species name	Sample 1	Sample 1-h	Sample 2	Sample 2-h	sample 3	sample 3-h
<b>Phylum Mollusca</b>						
<i>Mytilus edules</i>	7					
<i>Hydrobia ulvae</i>	2				1	
<b>Phylum Annelida</b>						
<i>Oligochaeta</i>	7				2	
<i>Polydora sp.</i>	8		3	1		1
<i>Hediste diversicolor</i>					1	
<b>Phylum Arthropoda</b>						
<i>Chiromidae spp.</i>	93	16	6	25	5	
<i>Cragon cragon</i>					1	
<b>Total amount of individuals</b>	117	16	9	26	10	1
<b>Total amount of individuals at 1m<sup>2</sup></b>	1170	1600	90	2600	100	100

In addition to the biology samples also temperature and salinity samples were taken. Results are in table 5.

Table 5 Depth, temperature and salinity at the mudflat on the 1<sup>st</sup> of March

Depth (cm)	Temperature (C°)	Salinity (‰)
0	5.9	27
20	5.8	26
40	5.9	26

### Shannon Wiener diversity index (H')

When the Shannon Wiener index is applied it becomes clear the state of the ecosystem is 'bad' in the 0, 1 m<sup>2</sup> sample due to the fact that the values are between 0.9 and 1.9. The results of the 0,01 m<sup>2</sup> samples are very bad due to the fact that it is below 0.9 very bad in

the Hydrobia sample as seen in table 4 and using table1 from the Norwegian WFD as a reference.

Table 2 Results of the Shannon Wiener index.

Sample	H index of 0.1 m <sup>2</sup>	H index of 0.01 m <sup>2</sup>
1	1,11	0
2	0,92	0,24
3	1,13	0

### 5.3 The implementation phase

This chapter places the results from the biological part into a larger management framework and tells how the results will be implemented. To do this, first the past and the present situation will be described after which the description of implementation phase follows. The EU Water Framework Directive is an important tool in this chapter since it is the connecting element between biology and management. In order to make clear about which bridge is being discussed, 3 terms are used.

The old bridge is the bridge that is going to be replaced while bridge 1 is the first design of the new bridge (2010). Bridge 2 is the revised design of the new bridge which comes from 2013.

#### Past events

The reason why the new bridge is build is due to the fact that the old bridge is no longer sufficient due to safety measures and the increasing amount of traffic that is passing the bridge. The process of the building of the new bridge (bridge 1) started before 2003 before the first report of NIVA (published in 2003) came out. The major past events concerning the bridge will be in chronological order.

#### 2003

First report of NIVA came out (NIVA, 2003). The Norwegian district highway authorities were considering building a new bridge over the mouth of the Barsnesfjord. The design of the new bridge was a suspension bridge combined with an extended causeway (rock fills) which would narrow the mouth of the Barsnesfjord. This might lead to a restriction of the water flow which was the reason for NIVA to investigate. The report that NIVA wrote was not a full environmental impact assessment (NIVA, 2003). Based on this model the conclusions of NIVA were that if the same amount of water would flow through a narrower space, the turbulence (and thus the oxygen concentrations) would increase and the oxygen would be taken to a greater depth. This would improve the conditions for life in the fjord. Additional effects are longer periods with ice conditions, lower salinity with altered stratification but the effects of this was considered minor (NIVA, 2003).

## 2007 - 2008

Various EU legislations for marine policy have been adopted in the Norwegian law and legislation over time due to the fact that Norway is not a part of the EU but is closely associated to the EU. The law and legislation that Norway implemented from the EU includes the EU Water Framework Directive (Norwegian Ministry of Foreign Affairs, 2010). The EU Water Framework Directive entered into force in Norway in 2008. The directive's main objective is to ensure good status of surface and ground water by 2021. Norwegian authorities issued a corresponding water regulation (Vannforskriften) that ensures the national implementation of the directive (NIVA, EU Water Framework Directive, 2013).

Around the same time the first articles appeared in the local newspaper that was written about the building of a new bridge. These newspaper articles started to worry the local people which reacted by sending the letters to the local newspaper to express their worries and requesting more information. Torbjørn Dale came into contact with the plans of the new bridge in this way (Dale, Personal com., 2014).

## 2010

The improved report of NIVA. In the report of 2010 the model of 2003 underestimated various values on which the model was based (NIVA, 2010). For the report in 2010 direct hydrographic measurements were taken and showed that the current values in 2010 were higher than in the model of 2003. Bridge 1 includes a reduced inlet by making it narrower and shallower compared to the old bridge. This report states that the effects on the water exchange between the Barsnesfjord and the Sogndalsfjord were not be significantly affected (NIVA, Ny Loftesnesbru i Sogndal Vurdering av miljøkonsekvensar i sjoen (Rapport nr 5899-2010), 2010). The report also contained drawings of the bridge design shown in figure 5.

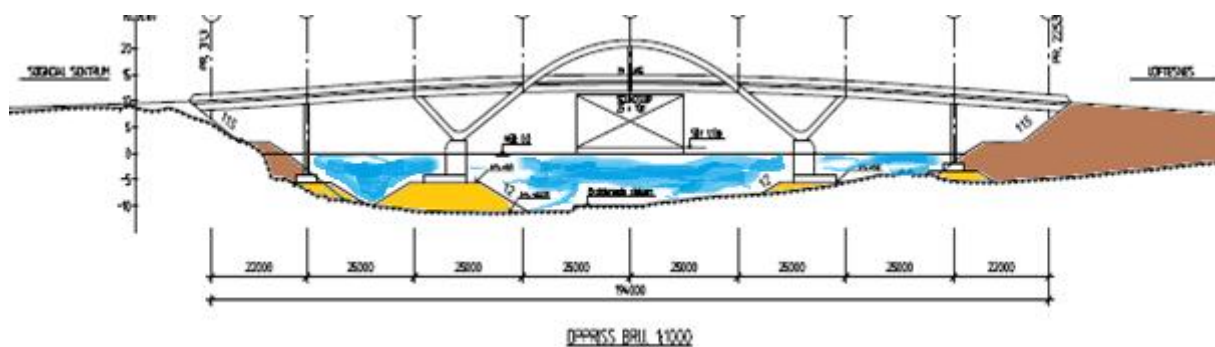


Figure 5 The bridge design of bridge 1 out of the report of NIVA 2010. Brown areas are land infills while the yellow areas are pillars (NIVA, 2010).

## 2013

Beginning in January a discussion with Matthias Paetzel and Torbjørn Dale, 2 teachers of the College University Sogn a Fjordane in Sogndal, took place about the subject of the science project for the international course called "From Mountain to Fjord". Torbjørn took the opportunity to do research about the building of the new bridge, catching the attention of

authorities which decided to support the project with a minor grant (Dale, Personal com., 2014).

The From Mountain to fjord student group made an investigation about the situation in the Barsnesfjord in autumn 2013 in order to determine how the situation was before the building of the new bridge. Samples were taken by using a corer for sediment and a grab of 0.1 m<sup>2</sup>. The corer was to take sediment samples which were analyzed for the sediment itself, diatom species and abundance and foraminifera species and abundance. The samples with the corer were taken in the deeper part of the inner Barsnesfjord. The grab was used to sample macro-benthos and were taken on the sill between the inner and outer Barsnesfjord at ~30 meters depth. The results were presented to the local community by an oral presentation but some of the results will be included in the project report which will be published in 2014-2015 (Dale, Personal com., 2014).

## 2014

November: planed start on the building of the bridge.

### 5.4 Present events

The most important current event related to the bridge, is the starting of the building of the bridge. Even though the building of the bridge is the most important one, more events are taking place such as the current management system. This part describes the proposed bridge design (bridge 2) and the current management system.

#### Bridge design 2

The new bridge design seems to be very familiar to the design of bridge 1 presented in 2010. The big difference however was that the infills are smaller and the pillars have got a different design as well making them narrower while they are going deeper into the sediment as shown in figure 6. The design of the bridge has been altered to reduce the environmental effects (Dale, Personal com., 2014).

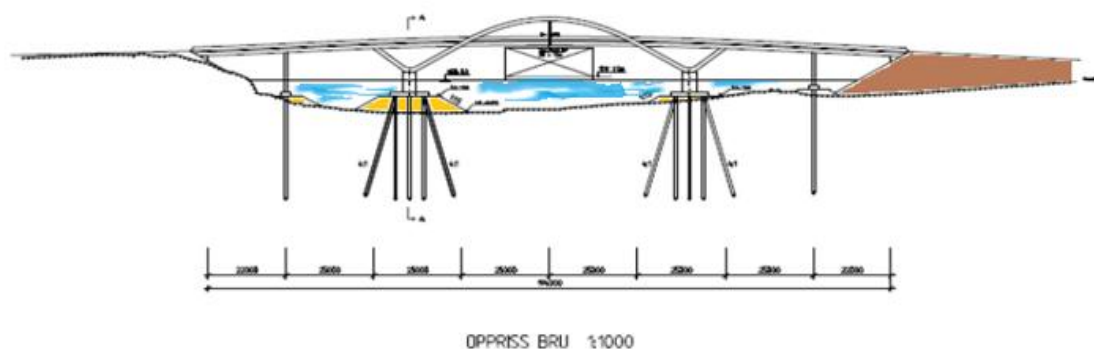


Figure 6 Bridge 2: the revised bridge design presented by the Norway district highway authorities in 2013.

## Present-day policy

Policy is defined as the making of goals which are achieved by using tools in a set time (Gemeente Utrecht, 2007). The most relevant policy for this research is the EU Water Framework Directive due to the fact that it is very much related to the ecology and for the fact that it is active throughout the country with the same standards (NIVA, EU Water Framework Directive, 2013).

The goal of the EU Water Framework Directive is to reach 'Good status' of surface and ground water by 2021. NIVA is an organisation which measures the water quality and such and provide the following tools/services (NIVA, EU Water Framework Directive, 2013):

- Characterizing and classifying water bodies and intercalibrating classification methods
- Monitoring ecological and chemical status
- Recommending mitigation and restoration measures

In addition to this a part of the county, Fylkesmann (County Governor) which also deals with the environmental part, checks if the law and legislation is followed and can give advice and/or protest if necessary to enforce the law and legislation (Dybwad, 2014).

## Decision making process

In Norway there are 3 different levels of organization: State, county and municipality. In addition to this the county level is divided into 2 parts; Fylkeskommune (county municipality) and Fylkesmann (County Governor). Fylkeskommune is chosen by the people while the Fylkesmann is elected by the state and has the role to see if the Fylkeskommune and municipality are doing their jobs. Both the Fylkeskommune and the Fylkesmann play a role in the process (Dale, Personal com., 2014) .

It was the municipality of Sogndal which started the process by writing the plan for a new bridge which was then sent out to both the Fylkesmann and the Fylkeskommune. The job of the Fylkesmann was to check the part on the environment which leads the research of NIVA. (Dybwad, 2014). After the research of NIVA and the designs of the bridge were made, the plans were then send out to the Norwegian district highway authorities (Dale, Personal com., 2014).

The role of the Norwegian district highway authorities is to coordinating efforts to develop proposals for the National Transport Plan. The plan is finally approved by the Parliament (Norwegian distict highway authorities, 2014) and then send back again to the municipality with money to build a bridge. After that the plan is send for one last time to the Fylkesmann before the building phase can begin (Dale, Personal com., 2014) .

## **Contributing to the policy and other future events**

The results for the biology part were have no direct effect on the building of the bridge due to the fact that the bridge itself is already in the making (Dale, Life in the Barsnes fjord, 2014). However, the thesis does lay a foundation for the following future projects and reports:

- A report will be written by Torbjørn Dale and Matthias Paetzel which combines the results from the previous From Mountain to Fjord courses and this bachelor thesis's to document the present situation
- Similar science projects will be done with the international "From Mountain to Fjord" course after the bridge is built in order to see if the bridge had environmental effects
- A contribution to the process to make the Sognefjord a sanctuary

The purpose of the reports that are written by Torbjørn Dale, Matthias Paetzel and the From Mountain to Fjord project is to gain knowledge and pass that knowledge on to authorities such as the municipality and the county. In that way information is being contributed which can help forming a foundation for major projects such as making the Sognefjord a sanctuary. Each of these points are explained in more detail in a separate paragraph.

### ***Report by Torbjørn Dale and Matthias Paetzel***

The report by Torbjørn Dale and Matthias Paetzel will contain 3 different subjects.

1. The biological data From Mountain to Fjord data from 2013 and the highlights of this bachelor thesis
2. The hydrographical data from the From Mountain to Fjord course together with 5 additional samples at 4 stations to collect winter data related to inflows
3. Turbidity samples including concentrations, size and sharpness of particles during the placing of the land infills.

The biological data collected with the From Mountain to Fjord course showed interesting trends about how the biology reacts on the hydrographical conditions. One of these trends show a decreased amount of oxygen which may have led to killing events in the shallower parts of the Barsnesfjord due to the lack of oxygen. This may increase in the future which can influence the upper parts of the fjords as well. More information about the hydrological events over the last hundred years can be found in the bachelor thesis of Sabrina Kaufmann (Kaufmann, 2014) This bachelor thesis itself will also contribute to the general knowledge but may help to uncover patterns between a change in hydrography and the type/amount of macro-benthos.

Due to the fact that the land infill's is made out of blasted materials, it is possible that these materials, if they are small enough and are sharp enough, form a potential hazard to the gills of the salmon. The particles in the water samples will be analyzed to see what type of sediment there is in the water column and if it forms a potential danger (Dale, Personal com., 2014).

In addition to the particle analyzes, the supposed effects of the constriction, such as effects on deep water renewal will be added together with the conclusions from the From Mountain to Fjord course in 2013 and the highlights from this thesis. The report itself is expected around summer (Dale, Personal com., 2014).

### *From Mountain to Fjord projects*

The coordinator from the from mountain to Fjord program, Matthias Pretzel has announced to work on macro-benthos in mudflats in future projects. It is planned that this will happen after the bridge has been built but it is not yet decided if it also will be measured during the construction phase. The samples will be taken as they have been taken in this in thesis in a similar way with similar analyses meaning that there will be summer values which will most likely be different then the winter values. By doing so it becomes possible to build a more reliable dataset which allows a comparison between the situation before the new bridge and after and see if the bridge had an effect on the environment (Paetzel, 2014)

### *Sognefjord sanctuary*

Plans have been made to conserve the entire Sognefjord area by turning into a sanctuary (Dybwad, 2014). The goal of the protection is to make people and nature work together so the area can be protected better. Current protection only takes place on land while the new conservation plans include life in the fjords as well. One of the issues the sanctuary solves is that it becomes clear who the owner is of the ground and, since it is protected, it also is controlled what happens on the ground. Because of the protection, a stricter control would take place in new projects and in order to do this, a lot of new information is needed because relatively little is known about the underwater life in the Sognefjord. In addition to the stricter control, new laws and legislation will be applied which may lead to resistance of the local community and companies. This is due to the increased amount of rules that come with the new environmental protection and may have a major impact on many activities taking place in and around the fjord. The first steps to realize this project will being taken in 2015 – 2016 (Dybwad, 2014).

## 6. Discussion

Whenever biological effect studies are done, the main question is if the measured changed is due to natural variation or the actual change tried to measure. Another typical problem is the general lack of information about the environment before the expected impact. As a general rule in statistics, the more data available, the better and more reliable the result is. This study deals with a small sample size in a unique environment where little is known about the ecology including macro-benthos. This means that the available data is very little and that interpretation the data is difficult. What is known, is that the conditions in the intertidal mudflat most likely are natural and not due to pollution (Dale, Life in the Barsnes fjord, 2014).

In the recent years quite a lot of research has been done on macro-benthos by Rygg & Norling (2013) in order to give an upgrade on existing indexes used in the EU Water Framework Directive. The locations where they did their sampling are shown in figure V in appendix II. The results of the individual stations are unknown but various indexes are done on all the found species, giving information the ISI, NSI, AMBI and density (Rygg & Norling, 2013).

A master thesis was written in 2011 to test the sensitivity of various indexes that are given in the EU Water Framework Directive. This research shows that the indexes that are developed for Norway, were less influenced by spatial variability than indexes used in Sweden. This in addition to the fact that different indexes measure different things on a different way, it is considered valuable to use all the indexes given by the EU Water Framework directive if possible (Kaurin, 2011).

In 2009 OSPAR brought out a document about intertidal mudflats with a map showing the records of all the intertidal mudflats in Europe. This map shows that the data of Norway is delivered mostly on the coast and the Oslo fjord. The place which would be of most interest for comparison would be the Hardangerfjord below the Sognefjord (see figure V in appendix II) due to the fact that the Hardangerfjord is relatively long and lies on a similar place to the Sognefjord (OSPAR, 2009). The study done there is not traceable by Google but it is known that the University of Bergen did research there in the fifties and sixties, suggesting that the information might be available only on paper (Dale, Personal com., 2014).

Research on macro-benthos also has been performed near Tromsø above the polar circle. Interesting enough the location with the poorest amount of species (8 species, 53 individuals  $0.1\text{m}^2$ ) is closer to the sea while the location which is more similar to the Barsnesfjord (more influence from freshwater) contains more species and individuals than the one near the sea. The explanation given is that the locations near the sea are exposed to wave action and thus contain less species than locations without the wave action (Oug, 2001)



## Lab work

The reason why the 0.5 mm sieve was used for the 0, 01 m<sup>2</sup> (or *Hydrobia* samples) was to catch *Hydrobia* spp.. However, all the *Hydrobia* that were caught, were found in the 0, 1 m<sup>2</sup> sample with the 1 mm sieve. An explanation for this would be that the samples sieved with the 0.5 mm sieve still contained a lot of sediment. The sediment had the same shape, size and colour as a *Hydrobia* meaning that it was very easy to overlook them, even when taking a close look to every sand grain. In addition to that, it is also very much possible that there simply were no *Hydrobia* in the 0.01m<sup>2</sup> samples considering the fact that only 3 *Hydrobia* were found in all the samples. It should be noted that the highest densities of *Hydrobia ulvae* that had been recorded were 300,000 /m<sup>2</sup> (BIOTIC, 2003).

A great number of ISO standards have been adapted in this research but not all of them. The reason for this was that the ISO standards came in rather late and after the lab work was finished. Sediment and sample descriptions were not made because of this. It is strongly recommended to study the ISO standards thoroughly before sampling.

## Species distribution

Literature shows that the species *M. edules* (Kautsky, 1982), *H. diversicolor* (Smith, 1956), *H. ulvae* (Komendantov, 2009) are saltwater species which are able to live in salinities down to 6‰ while some species of *Chiromidae* are able to tolerate up to 42‰ (Bervoets, Wils, & Verheyen, 1996). The subclass Oligochaeta contains many species which makes it likely that at least some of these species can tolerate low salinity. A paper describes that some species can tolerate salinities down to 10.5‰ and lower (Chapman, P.M & Brinkhurst, R.O, 1980).

A phenomenon that could explain the species distribution is called patchiness. Patchiness forms a spatial pattern due to various energy inputs, climatic effects, and disturbances, quality of the sediment and species interactions that result in spatially patchy structures or gradients. This spatial variance, such as temperature, time emerged and salinity, in the environment creates diversity in communities of organisms even if the landscape looks homogenous (Legendre & Fortin, 1989). Additional to this, the spatial scales of patchiness in the variables being measured are often not known before the sampling is done. This means that the scale of the patchiness is not revealed in the sampling design (Hurlbert, 1984) even though limited predictions can be made. The bigger the variation in the landscape, the bigger the chance between samples. Variation on the mudflat exists mainly out of differences in oxygen, salinity, temperatures, porosity, organic content, submersion time and the effects of the seasons. The effect of salinity and other hydrographical conditions are most likely the biggest influence considering the graphs that show the differences in the upper layers but also show the seasonal effects throughout the fjord.

## Analyses

The EU Water Framework Directive contains a great number of indexes that should be made. The list includes:

- Shannon Wiener index –diversity index
- Es100 – diversity index
- NSI – Norwegian diversity index
- ISI – sensitivity index
- AMBI –sensitivity index
- DI – density index for areas with low species
- NQI1 – Norwegian sensitivity and diversity index

A problem which some indexes have such as the ES100 (and with that the ISI & NSI index) is that they require 100 individuals to perform the analyses (Rygg & Norling, 2013). In addition to that the ES100 index is based on a calculation that the highest 5 species and the lowest 5 species are used (Kaurin, 2011). This means that one needs to have a minimum of 10 species as well; something that this research did not find meaning that the data does meet the requirements.

Another problem which was encountered was with the AMBI index. The AMBI index is based for a part on expert judgement (Rygg & Norling, 2013) meaning that species have to be put into a class from 1 to 5 with 1 being sensitive species and 5 being opportunistic species (Kaurin, 2011). In the case of the species identified, only 4 were identified on a species level, 3 on genus level and one on subclass level. For this it could be argued for to use the species on genus level but misses the sensitivity of the system. With for example the *Chiromidae spp.* it is known that some species in this genus can tolerate up to 42 ‰ even though *Chiromidae spp.* is typically known to be freshwater species. By not knowing what this species is, it is hard to determine how sensitive this species and thus it could be classified but the classification would feel meaningless in this case. For this reason and the given time limitation, the choice was not to do the AMBI index and the related other index, the NQI1 (Kaurin, 2011).

The DI seems to have a lot of potential since it is an index developed for systems with a natural poor habitat. However, the document where it is referred to from the EU Water Framework Directive (Vannportalen, 2014) does not contain information about it (Rygg & Norling, 2013). For this reason this index was not used.

### Validity of the research

As discussed before, the ISO 16665-2014 was not completely on various subjects. These subjects are a description of the sediment before and after sieving, recording of the location with a GPS, colouring of the samples and sediment research. Even though these factors are very important, they do not influence or compromise the results of this research. This is due to the fact that the research area was chosen to be found back easily and the samples were sorted out with utmost care and patience even though colouring would have made it less time consuming. In addition to this is the fact that sediment research and descriptions are interesting and can form additional prove if the environment changed after a few years but it does not compromise the research that has been done (note: sediment samples have been

taken but were not worked up due to time restriction. For the moment they are stored in a fridge for future research).

Another issue is the fact that only the Shannon Wiener index was performed. Again, there was worked with the data that was available which did not give more space to do more indexes which lead to the fact the lack of indexes does not compromise the research. On the contrary, it shows were more indexes are needed.

### **Functionality of the EU Water Framework Directive in the intertidal mudflat**

The EU Water Framework Directive reshaped a great amount of previous management systems to match the European standards. The framework provides new standards for a 'good environmental status' which are adapted to the Norwegian water system in addition to this, the directive also contains standards for biological sampling. The question on what a 'good environmental status' is, is still under debate and is considered a learning process, meaning that the guidelines and standards are still developing as more knowledge comes in (Rosnes, 2014).

As (Kaurin, 2011) found out, the fact that one index works in one environment (or in one country) does not mean it works everywhere. The low  $H'$  index in the intertidal mudflat from the Barsnesfjord is most likely due to natural circumstances (Dale, Personal com., 2014) and there is a need to classify ecosystems as extreme as the one in the Barsnesfjord. The intertidal mudflat in the Barsnesfjord may very well be in one of the most extreme ecosystems in Norway due to the unique hydrography (Dale, Personal com., 2014).

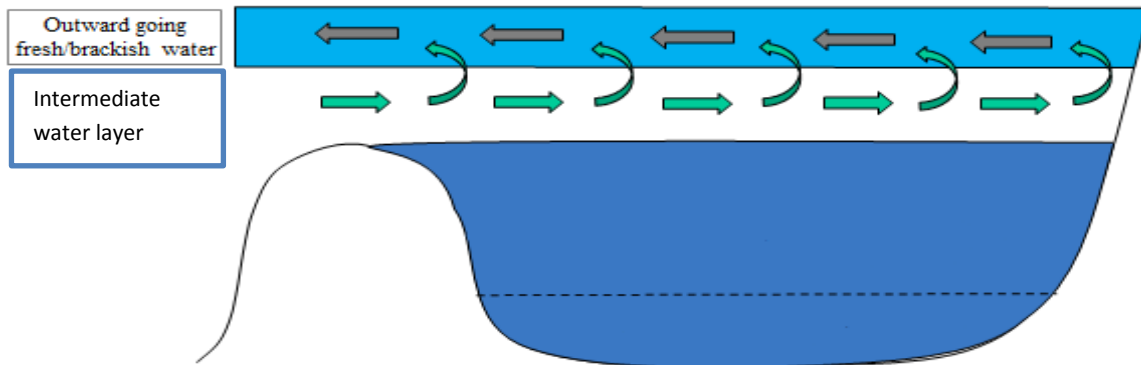
### **Influence of the result on the building process on bridge**

The decision process of the bridge was a long and complicated process and this thesis took place at the very end of this process. Because of this it was not possible to contribute directly to the decision-making process but it will contribute to the general knowledge of the entire Sognefjord as well as present the status before eventual impacts from the new bridge.

### **Hydrography**

The freshwater does not mix well with the salt water in the fjords due to a lack of energy input such as wind and waves. In addition to that, the Barsnesfjord is a large body of water and needs a lot of energy to be mixed. Because of the lack of mixing, layers in start to form as seen in figure 7. This figure shows 3 layers: the blue freshwater layer that flows out from the fjord towards the sea, the white layer which represents the intermediate water layer with the compensation current and contains fresh/brackish water. The compensation current replaces the saltwater that flows out and with that the water level in the fjord is stable. This does not take the tidal difference nor any sea-level rise into account. It is known that the tidal currents are strong due to the strong restriction and that the tide has got a strong influence on the different water layers (Dale, Life in the Barsnes fjord, 2014).

Figure 7 the top light blue layer shows the freshwater layer that flows from the river, into the fjord and eventually into the sea. The white layer is the intermediate water layer with the compensation current and replaces the freshwater that flows out. The arrows indicate that there is some mixing taking place (From Mountain to Fjord, 2013)



The thickness of the freshwater layer changes by the year; this is best seen in figure 8 which shows how much the depth of the freshwater in the outer Barsnesfjord (same place as were samples on the intertidal mudflat were taken) changes. The average is 2.8 meter but the variety is high due to natural causes as wind and precipitation (Dale, Life in the Barsnes fjord, 2014).

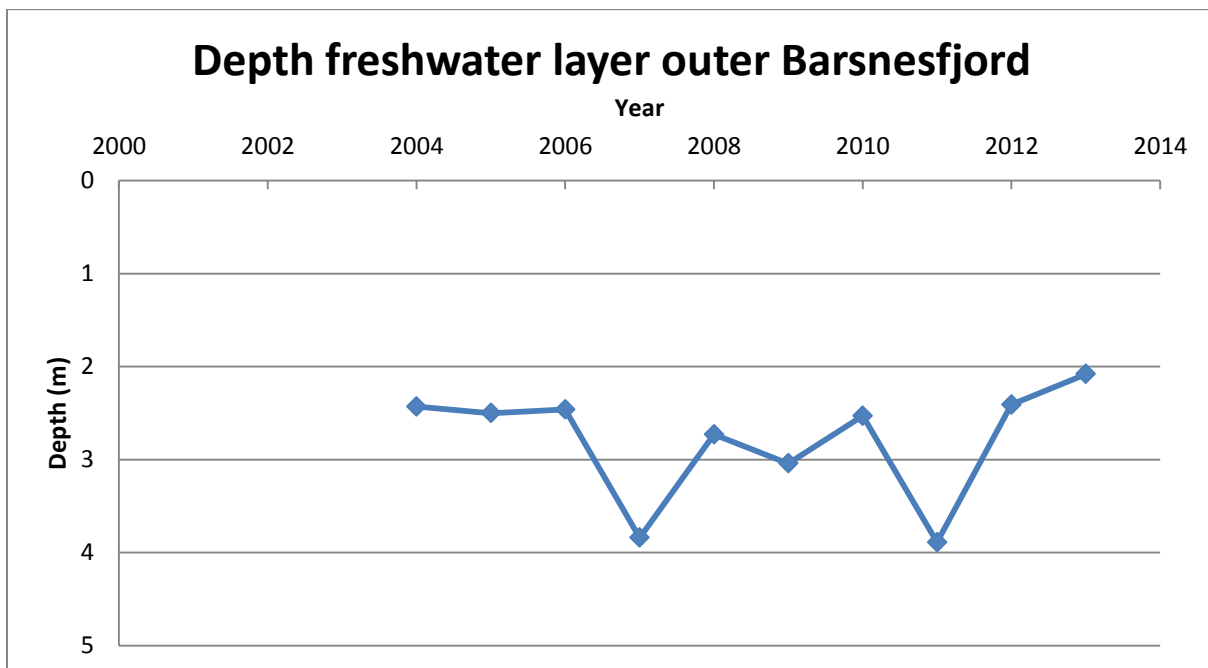


Figure 8 Depth of the freshwater layer taken once a year in the end of August or early September (Dale, Unpublished data, 2014).

Another important factor which is influencing the entire fjord is deep water renewal. Deep water renewal is the process in which the water in the deepest part is been replaced by water from outside of the sill. The deep water contains the oxygen on which the deep part of the fjord depends on. Deep water renewal is an episodic event that takes place only in

wintertime that is influenced by factors as water density, wind and currents. When the deep water renewal is taking place, the 'old' water is lifted up and is taken out by the surface currents as seen in figure 9. The deep water is replaced by water from the intermediate water layer from the Sogndalsfjord. The Sogndalsfjord forms the main driver in the deep water renewal (Dale, Personal com., 2014).

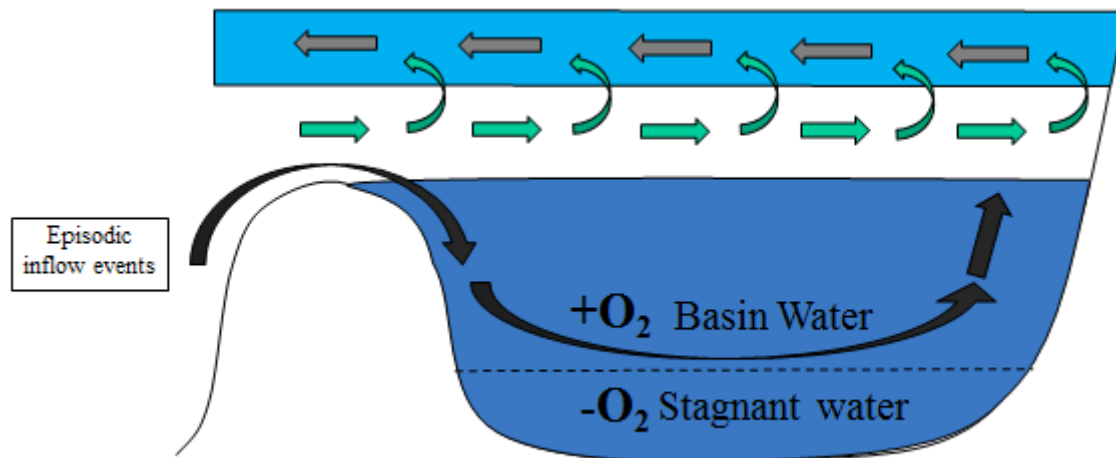


Figure 9 Process of deep water renewal. The basin water gets replaced by new water while the 'old' and oxygen poor water is lifted up and carried out (From Mountain to Fjord, 2013).

In order for deep water renewal to take place, it is important that the new and heavy water can come over the sill. If the height of the sill is being increased, chances are that deep water renewal will happen less frequent (Dale, Personal com., 2014). Historic data shows that the renewal took place on an average of once every 1.5 years between 1916 – 1956, before the building of the first bridge. In the period from 2001 – 2013 inflows took place every 3 years. There are various causes for this such as the building of the first bridge, climate change and other factors. Because of the low amount of inflows in the recent years, there is a reduced amount of oxygen in the fjord which could have an effect on the entire fjord (Kaufmann, 2014).

### Research design

The research design was chosen due to the fact that it fitted the purpose; providing data on macro-benthos in the intertidal mudflats and contribute to the knowledge of the Barsnesfjord which is a part of the Sognefjord. The position of the sampling stations were chosen due to the fact that a transect is easy to do with untrained students and the same location of the sampling can easily found back. The area along the transect on which the biology samples were taken was fairly uniform but did continue down the mudflat, having a small difference in height and came across a very small creek. This means that the effect of patchiness is high and should give a good overview of the species capable of living in these conditions. The ISO file states that it is an approach used when it is not feasible or appropriate to work in strata (Standard Norge, 2014).

## **7. Possible consequences of the new bridge**

There is a wide range of various possibilities what would happen to the ecosystem when the new bridge is going to be build. The report of NIVA (NIVA, 2010) claims that by changing the design of bridge 1 into bridge 2 and the removal of the legs of the old bridge, there will be no significant changes in the water flow.

The local expert Torbjørn Dale is uncertain about the effects of the plans because it is still not known how much constriction and how much shallower it will be, especially because of the fact that the new bridge could influence the inflow of deep water. As stated before, the amount of deep water inflow that takes place in the fjord is already reducing. Because of that even the smallest change can have big effects on the oxygen effects in the deep part of the fjord (Dale, Unpublished data, 2014).

Because of the changes that have been done on the bridge design such as less infilling and less shallowing of bridge 2 compared to bridge 1, it is expected that the water flow above the sill (which exist out of the tidal flow and the fresh/brackish water flow) is not influenced by the new bridge. The deep water inflow could be reduced if the threshold is raised (Dale, Unpublished data, 2014).

## 8. Conclusions

The main question that this study wanted to answer was which species there live in the Barsnesfjord and how many. This study shows that a low amount of species and individuals living in the intertidal mudflat which may be explained by the strong change in salinity throughout the season. The environment is so extreme that only a few species can survive there.

Another question that was asked was what the current policy was and how can there be contributed to this policy. The management system that is meant to monitor the environmental status, the EU Water Framework Directive, does not have the right indexes to properly describe this ecosystem. Due to the quality of the data that was collected it was not possible to do many of these indexes prescribed by the EU Water Framework Directive or that due to expert judgment it was considered not feasible enough to do so. If they were done, the indexes would say that the environmental condition is 'bad' or 'very bad' while this is most likely the natural state of the intertidal mudflat in wintertime. This means that there is a need to develop an index especially for environments like this.

Plans of the bridge itself also have changed dramatically. Where the first report from 2003 showed the consequences of major constrictions, the report of 2010 contained new measurements of the hydrographic conditions and a design of the bridge which promises no significant effects on the hydrography. The bridge design in 2013 showed that the infills and size of the pillars have been reduced to reduce the effects in the environment.

If there are any effects on the ecosystem, it is likely that they take place in the deeper part of the Barsnesfjord and it is predicted that there are no effects in the upper part of the Barsnesfjord. The deeper part of the Barsnesfjord depends for oxygen on the deep water inflow of the Sogndalsfjord which has been decreasing after the old bridge was build. The inflow of deep water depends of the density of the water, wind conditions and the height of the threshold. If any of these factors change, it could have big effects on the oxygen conditions in the deeper part of the Barsnesfjord.

In short it could be argued for that the complicated decision process works. The bridge design was changed from a bridge with a high impact (positive or not) to a bridge design with an expected low environmental effect. The EU Water Framework Directive is proper tool to measure the environmental status in many conditions but does miss the tools to proper qualify the status of the natural low species/individuals environments like the intertidal mudflats of the Barnesfjord.

## 9. Recommendations

A number of recommendations can be made in order to improve the quality of future research. As cliché as it may sound, further research is strongly recommended for determining the possible effects of the bridge. Only further research can prove if there were or were not any changes due to the new bridge. In addition to that, the extreme hydrographic environment makes it interesting enough to research it on its own. When doing further research, there is a list of things which can be strongly recommended to use or to do:

- When doing research is sure to study the ISO 16665-2014 thoroughly and do the research as the book prescribes.
- This present research only contains winter values. For a proper overview it is recommended to add in summer values as well
- Add in sediment research and do that as described in the ISO 16665-2013
- Take the sample on the same spot for a better comparison
- When possible, add in the indexes that the EU Water Framework Directive describes
- Do further research on the functional traits of the macro-benthos. This may hold an answer why new species appear or disappear
- Build a dataset of all the collected data and share the data



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## Appendix I

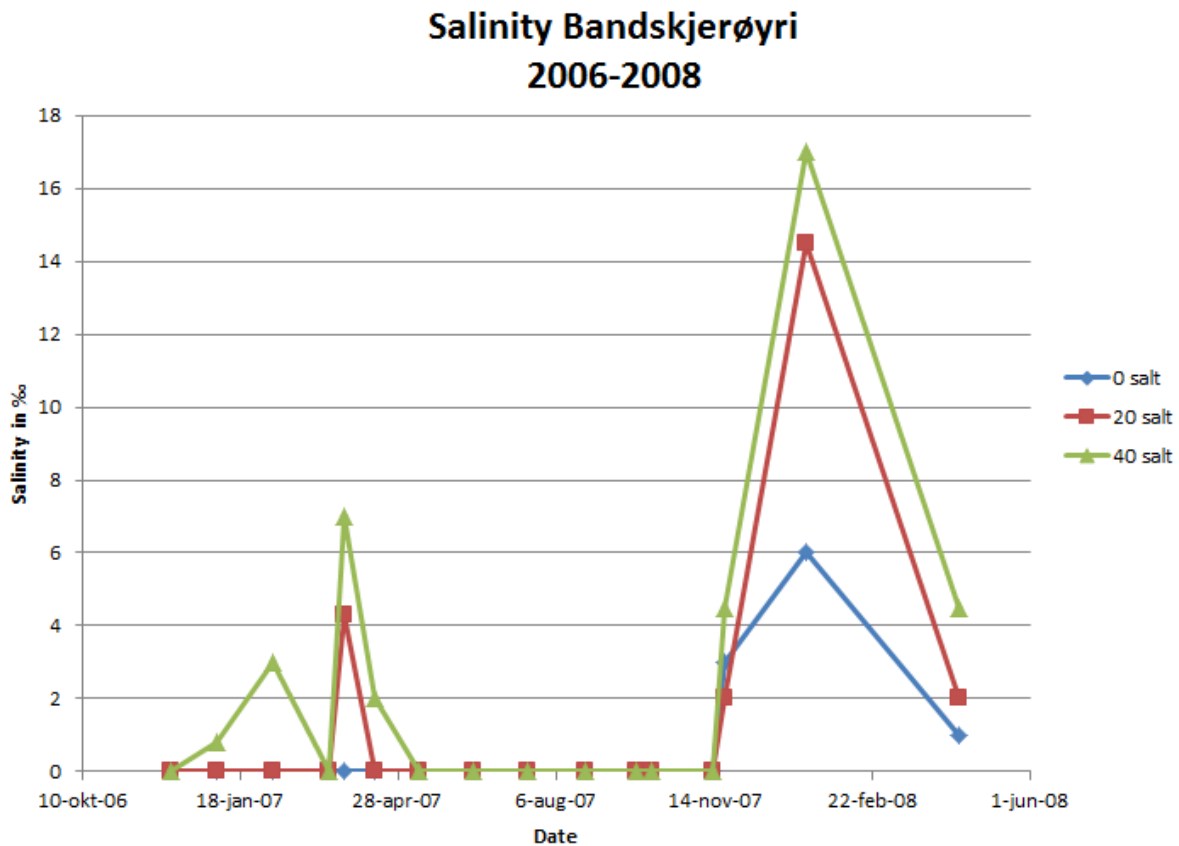


Figure I

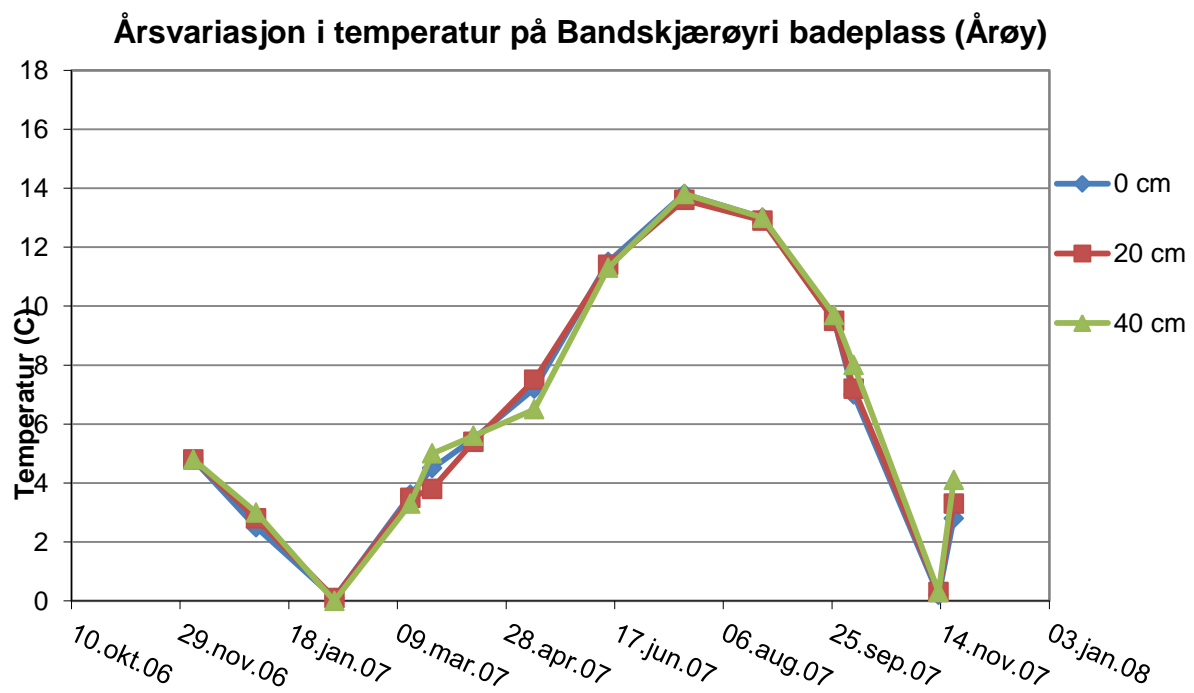


Figure II

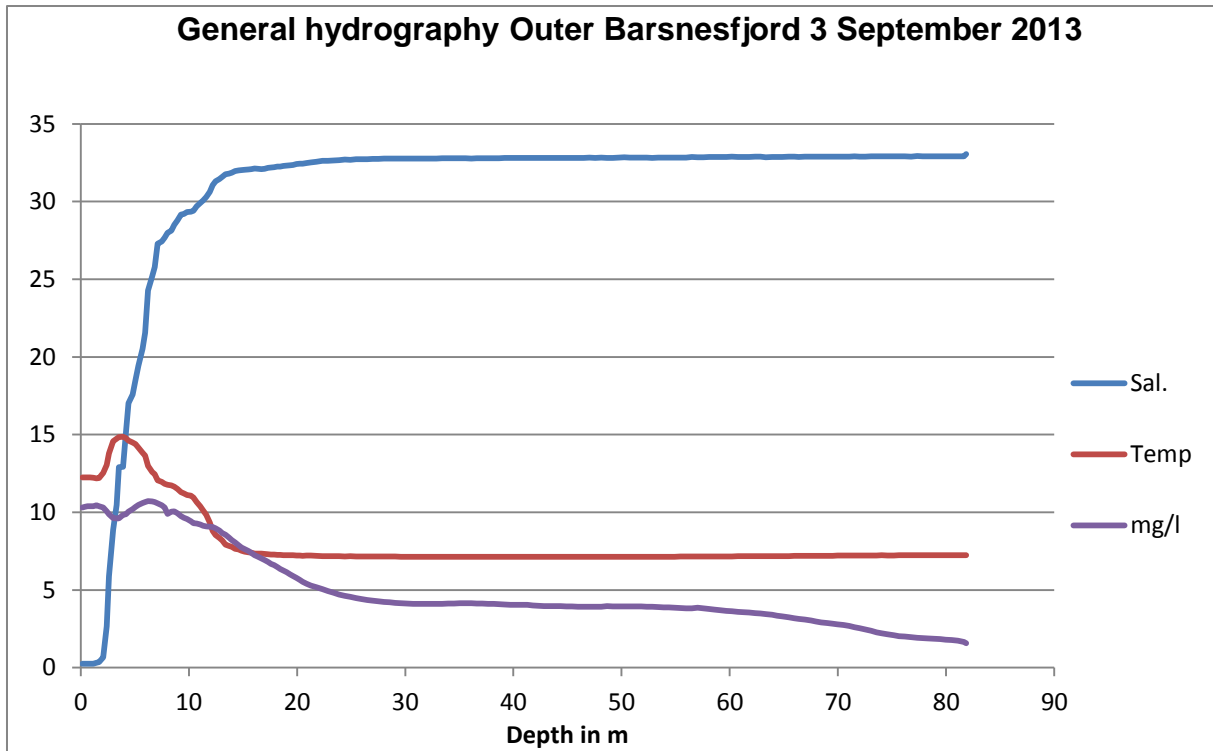


Figure III

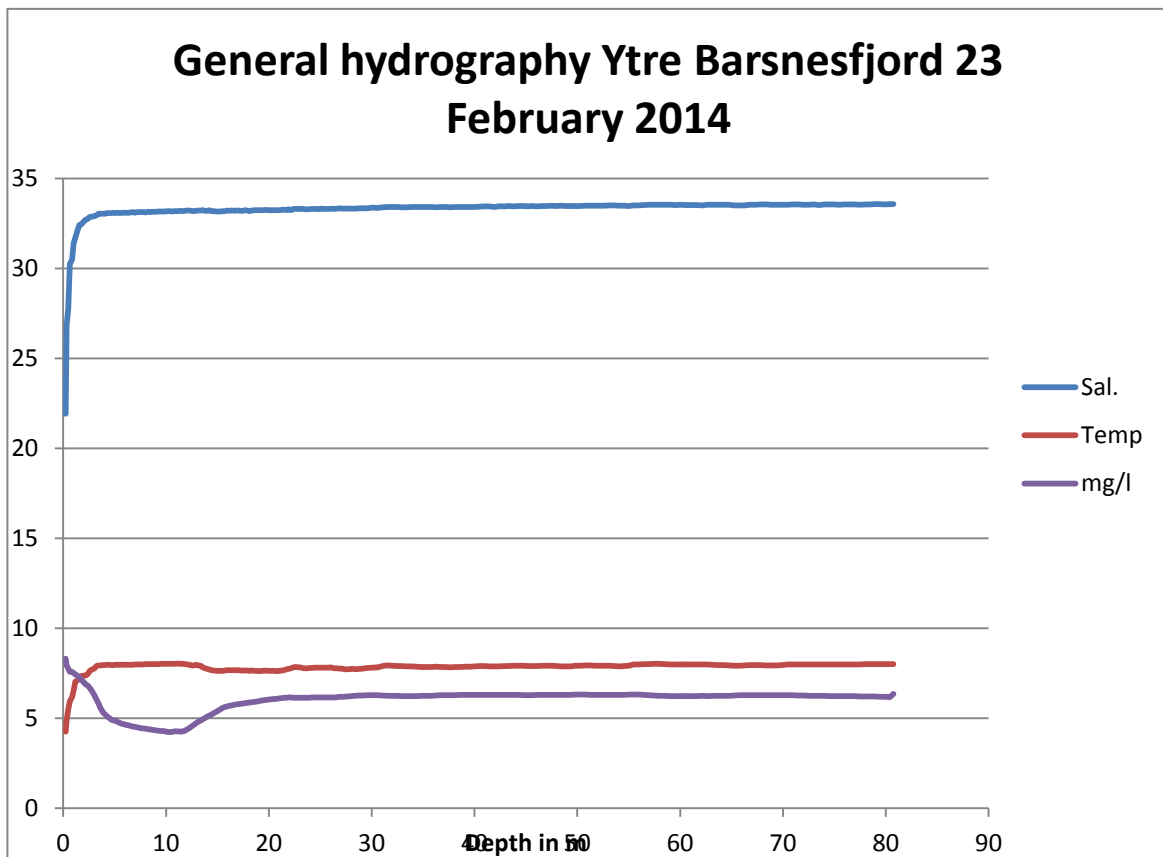


Figure IV

## Appendix II



Figure V (Rygg & Norling, 2013)

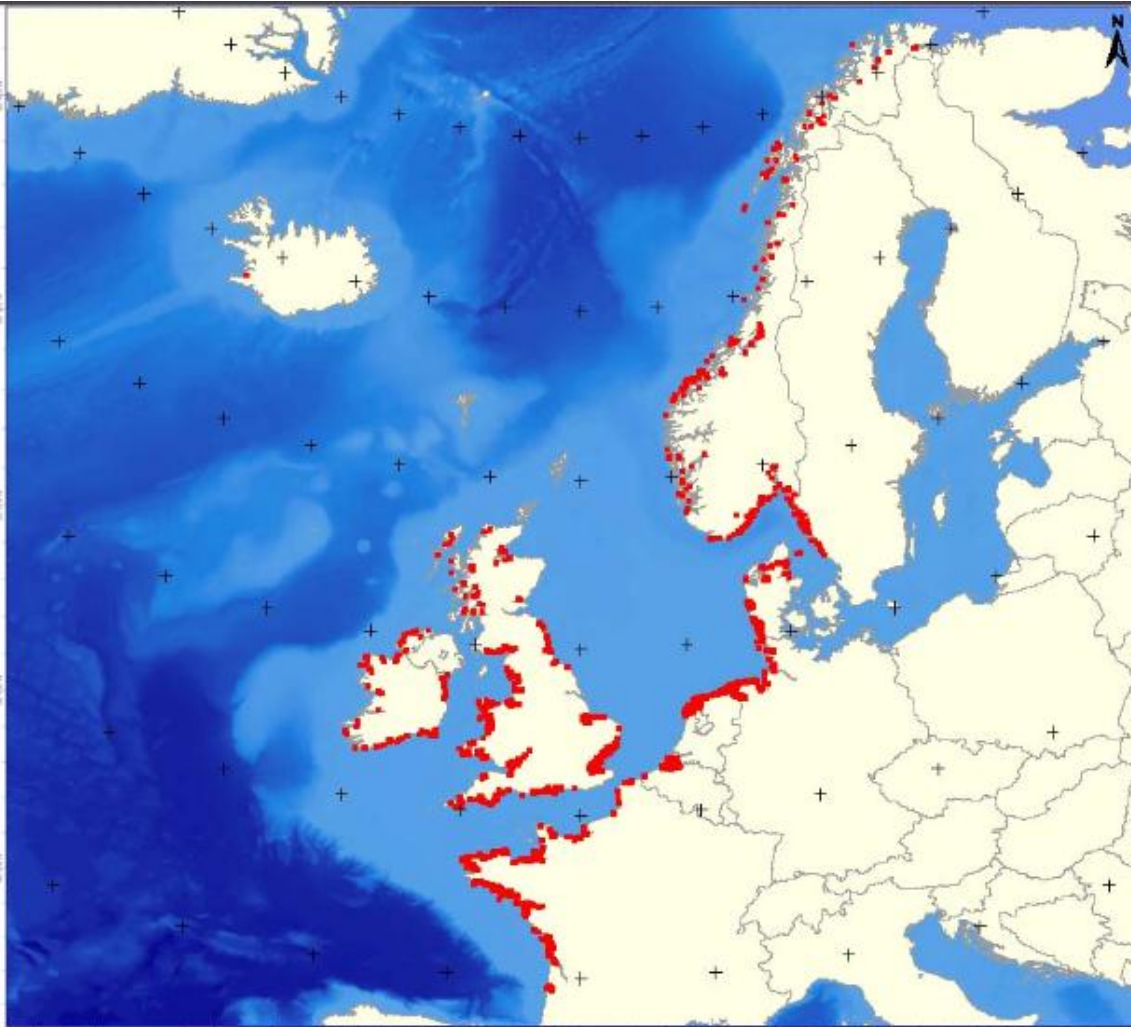


Figure VI (OSPAR, 2009). Black arrow indicating the position of the Barsnesfjord, green arrow indicating the Hardangerfjord.

# Appendix III

*Matr. Høh*

*11 cm above  
60°24' N 5°19' E  
2010 level*

## BERGEN 2014

### Tidspunkt og høyder for høy- og lavvann

Januar			Februar			Mars			April		
Tid	cm		Tid	cm		Tid	cm		Tid	cm	
1	0412 37	16	0448 48	1	0530 24	16	0528 35	1	0429 23	16	0432 32
On	1028 164	To	1107 152	Lø	1147 172	Sø	1147 152	Lø	1043 163	Sø	1048 144
	1640 32		1718 41		1801 15		1755 30		1658 11		1656 24
	2257 164		2327 146						2315 159		2309 142
2	0459 33	17	0519 45	2	0021 164	17	0008 146	2	0512 18	17	0503 27
To	1115 170	Fr	1140 154	Sø	0613 24	Ma	0557 33	Sø	1128 167	Ma	1120 147
	1728 26		1749 40		1234 172		1218 152		1740 9		1726 21
	2347 167				1844 16		1824 29				2341 145
3	0545 31	18	0000 147	3	0107 161	18	0041 146	3	0000 159	18	0534 24
Fr	1203 173	Lø	0549 44	Ma	0655 27	Ti	0628 33	Ma	0553 16	Ti	1153 148
	1815 24		1211 154		1320 168		1252 150		1213 166		1756 20
			1820 39		1928 23		1854 31		1821 11		
4	0037 166	19	0033 146	4	0153 154	19	0116 144	4	0043 156	19	0015 146
Lø	0630 33	Sø	0619 44	Ti	0738 34	On	0659 35	Ti	0633 19	On	0606 23
	1252 172		1243 153		1407 160		1327 147		1257 161		1228 147
	1903 26		1850 40		2012 32		1926 34		1900 18		1828 21
5	0127 162	20	0107 145	5	0240 146	20	0154 140	5	0126 150	20	0051 144
Sø	0715 37	Ma	0650 45	On	0822 43	To	0734 40	On	0713 25	To	0639 25
	1341 168		1316 150		1455 150		1407 141		1341 153		1306 144
	1951 31		1921 43		2058 43		2002 39		1938 28		1902 25
6	0218 155	21	0143 142	6	0327 136	21	0235 135	6	0208 142	21	0130 140
Ma	0802 44	Ti	0722 48	To	0911 53	Fr	0813 46	To	0753 34	Fr	0716 29
	1432 162		1352 147		1544 139		1451 135		1425 142		1348 138
	2042 39		1955 46		2150 54		2045 46		2018 39		1939 31
7	0309 147	22	0222 138	7	0417 128	22	0322 129	7	0251 133	22	0213 135
Ti	0853 53	On	0758 52	Fr	1013 62	Lø	0901 53	Fr	0837 44	Lø	0756 35
	1524 153		1432 142		1639 128		1544 129		1511 131		1436 131
	2138 48		2034 50		2255 63		2140 53		2101 51		2022 39
8	0402 139	23	0305 134	8	0516 121	23	0418 124	8	0336 123	23	0300 128
On	0951 61	To	0839 57	Lø	1135 67	Sø	1008 59	Lø	0931 54	Sø	0847 43
	1619 144		1517 137		1745 120		1647 123		1601 120		1530 124
	2240 57		2120 55				2258 59		2156 61		2119 49
9	0459 132	24	0354 130	9	0018 68	24	0525 121	9	0428 115	24	0356 122
To	1100 67	Fr	0932 63	Sø	0630 118	Ma	1143 61	Sø	1047 62	Ma	0956 50
	1720 132		1611 132		1305 67		1808 120		1702 111		1635 118
	2350 63		2221 60		1908 118				2320 68		2238 56
10	0604 128	25	0451 127	10	0136 67	25	0034 59	10	0536 110	25	0504 118
Fr	1219 69	Lø	1042 67	Ma	0750 121	Ti	0647 123	Ma	1227 63	Ti	1132 51
	1829 132		1715 129		1415 61		1320 54		1825 107		1755 115
			2337 62		2023 121		1936 125				
11	0101 65	26	0559 126	11	0234 62	26	0154 52	11	0057 67	26	0016 56
Lø	0716 129	Sø	1211 67	On	0851 127	On	0805 132	Ti	0706 111	On	0626 119
	1334 67		1832 128		1506 54		1430 42		1344 58		1305 45
	1942 131				2116 127		2047 135		1952 111		1923 120
12	0204 63	27	0059 60	12	0318 56	27	0254 42	12	0204 62	27	0137 49
Sø	0820 133	Ma	0716 130	On	0935 134	To	0906 143	On	0818 117	To	0745 127
	1435 61		1336 60		1548 47		1525 30		1437 51		1413 34
	2044 134		1952 133		2157 133		2142 145		2049 118		2031 130
13	0255 60	28	0210 53	13	0355 50	28	0344 32	13	0250 54	28	0236 39
Ma	0912 138	Ti	0825 139	To	1012 141	Fr	0956 155	To	0906 125	Fr	0846 138
	1524 55		1443 49		1624 40		1613 19		1519 43		1506 23
	2133 138		2059 142		2232 138		2230 154		2130 125		2124 140
14	0337 55	29	0308 44	14	0428 44	29	0428 44	14	0328 47	29	0325 28
Ti	0955 144	On	0922 150	Fr	1045 146		1045 146	Fr	0943 133	Lø	0937 148
	1606 49		1539 37		1656 35		1656 35		1554 36		1553 15
	2215 142		2155 138		2305 142		2305 142		2205 132		2211 147
15	0415 51	30	0359 35	15	0458 39	30	0458 39	15	0401 39	30	0410 20
On	1033 149	To	1013 160	Lø	1116 150		1116 150	Lø	1016 139	Sø	1023 155
	1644 45		1629 26		1726 32		1726 32		1626 29		1636 9
	2253 145		2245 159		2337 145		2337 145		2237 138		2254 152
		31	0446 28							31	0452 14
		Fr	1101 168							Ma	1107 158
			1716 18								1716 8
			2333 164								2336 153

Tidspunktene er gitt i norsk normaltid (UT + 1 time). Når sommertid gjelder må tidene økes med 1 time.

Figure VII Tidal table January to June

Effects of building activity on an intertidal mudflat in the Outer Barsnesfjord, Western Norway