Faculty of Biosciences, Fisheries and Economics

Department of Arctic and Marine Biology

Soft-bottom communities in Balsfjord

Stable over time or under change?

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Nina Elisabeth Henriksen

BIO-3950 Master thesis in Biology December 2015

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http://www.lyngen.name/henriktind/henriktind.html 09.12.15

Front page foto of Balsfjord (Svartnes area)

by Geir Jenssen 2008

http://www.lyngen.name/henriktind/henriktind.html 09.12.15

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Now it’s time to start a new chapter. I am ready!!

Tromsø, December 2015

Nina Elisabeth Henriksen

Summary

The soft-bottom macrofauna (>1 mm) was investigated at three different locations in Balsfjord; Andersdal, Svartnes and Tennes. The Svartnes data was then merged with Eivind Ougs long-term series from 1977-1994. The data showed that there were large variation between the three different stations in number of taxa and individuals found. A total of 59 taxa and 1514 (0.7 m^2) individuals were found. The polychaeta *Maldane sarsi* and *Galathowenia oculata* were the dominate taxa at all three stations in number of individuals but the echinoderm *Ctenodiscus cripatus* dominated in biomass at Andersdal and Tennes. Andersdal was found to have the most number of taxa and individuals. Svartnes was the most divers with Shannon-Wiener index of 2.54 followed by Tennes with 1.99 and Andersdal with 1.69. The long-term study showed that species assemblage had changed little, but that the number of individuals had decreased from 1994 to 2013. *Tubificoides cruspisetosus* that was found in large numbers in 1994, was found in only one of the grab samples at Svartnes, represented by only one individual. Long-term monitoring in Balsfjord is now more important than ever since 3 small red king crab *Paralithodes camtschaticus* was captured in October 2014 at Tennes, especially considering the potential effect this invasive species has on the ecosystem.

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Introduction

In northern Norway there is a long standing tradition for the study of marine benthic fauna. In earlier times the focus of the research was to describe and systemise the fauna. In the 1900's the Petersens grab was developed and quantitative sampling of the bottom fauna was possible (Nilsen, 2001; Gray and Elliot, 2009). Petersen and Jensen had in the early 1900's observed that most benthic fish had benthic animals as their main food source. Since there were large variations in the fishery yield, Petersen and Jensen cohered the large variation in fishery yield with the abundance of benthic biomass, thus conducting the first production estimate on benthic organisms (Petersen, 1918; Nilsen, 2001).

The first systematic description of the marine fauna around Tromsø was published in 1906 by Hans Kiær (Kiær, 1906). In recent years the focus has been concentrated on the environmental and ecological aspects of the marine environment and especially related to benthos. Studies on the effect of shrimp fisheries, which was banned in 1982, and the potential for commercial aquaculture in the fjord have been conducted. Many recipient studies have been made in the Tromsø area from the beginning of the 1970`s (Holte and Oug, 1996; Reigstad and Wassmann, 1996; Larsen, 1997; Oug, 1998; 2000; Holte, 2004; 2005; Nilsen et al., 2006). I would especially like to mention Eivind Oug's long-term series conducted in Balsfjord at Svartnes from 1977-1994 (Oug, 2000), where bottom communities were investigated in the deep basin at Svartnes (185m). Ougs long-terms series from 1977-1994 (Oug, 2000) is the only long-term investigation in Balsfjord and one of the few in northern Norway, undertaken on the benthic communities.

Balsfjord is one of the most well studied fjord systems in northern Norway, From the mid-1970s Balsfjord has been the subject to many research investigations and in 1977 the Balsfjord Project was started, which has given us great knowledge of the ecology of this semi enclosed fjord ecosystem (Eilertsen et al., 1981). The project was a collaboration between research fields that concentrated on fish, shellfish, plankton and hydrography. A large part of the project was an ecological investigation on the plankton communities with emphasise on topography and the physical environment in Balsfjord. It has been observed that north Norwegian deep basin sill fjords have low oxygen levels and can often be anoxic due to oxygen-consuming degradation of organic materials in the deeper basins. However due to inflow of deep water in spring observations in Balsfjord over several years have showed that the deep basins do not experience anoxia and that the oxygen levels are around 70-80% (Eilertsen et al., 1981; Larsen, 1997).

The red king crab *Paralithodes camtschaticus* is among the largest arthropods in the world, weighing over 10 kg and having a carapace length of 22 cm (Jørgensen, 2005). They are native to the North Pacific Ocean and the Bering Sea, but during the period of 1961-1969 Russian scientists transferred them to the Barents Sea from Okhotsk Sea to try to establish commercial fishery in this area (Orlov and Ivanov, 1978). The first appearance of the crab in Norwegian waters was in 1977 (Nilssen, 2003) as bycatch in fishing net, yet by 1992 the red king crab was found in abundance within Varangerfjorden, Finnmark. As an introduced species it has adapted very well to the conditions found here. The crab has now become abundant along the coast of Finnmark and is steadily increasing in numbers further down the coast of Norway and further into the Barents Sea (Jørgensen and Primicerio, 2007). The population is estimated to have increased from 3.5 million crabs, carapace larger the 70 mm in length, in 2003 to 5 million individuals in 2008 (Jørgensen and Spiridonov, 2013). In 1994 a research fishery for the red king crab was initiated, and in 2003 a commercial fisheries was established (Windsland, 2014). In 2008 close to 2000 tons of red king crab were taken off the coast of northern Norway (Hvingel et al., 2012).

Red king crab has become a valuable marine resource for the Norwegian fishing industry (Windsland, 2014), but this is an introduced species that have the potential to threat the native ecosystem (Didham et al., 2005; Jørgensen and Primicerio, 2007; Oug et al., 2011). The effect an alien species will have on an ecosystem is unpredictable due to the complex interactions such as competition, for both food and space, and predation along with the indirect activity that the invasive species have on the native fauna through modification of the environment (Oug et al., 2011). The red king crab is known to be an opportunistic omnivorous feeder of the most abundant benthic prey (Cunningham, 1969; Sundet et al., 2000; Jørgensen, 2005; Jørgensen and Primicerio, 2007; Oug et al., 2011). Their diet is area-specific and usually consist of one food or species group abundant to the area (Jewett and Feder, 1982). Cunningham (1969) observed that the king crab had two distinct ways of feeding, grasping and tearing apart larger prey or by scooping up organisms from the soft sediments using the chelae. Scooping of sediment seems to be the most observed in areas where lager prey are not available. Stomach analysis from previous studies done in areas invaded by the king crab, have shown that their diet is diverse and contain organism from the phylum of molluscs, echinoderms, annlids and chordates but the dominate prey classes were bivalves and polychaetes. In addition algae, gastropods and echinoderms were found in many of the stomach samples (Sundet et al., 2000). Observations also show that composition of prey items vary seasonally, such as high abundance of bivalves and echinoderms in spring/summer and polychaetes in autumn/winter (Jørgensen, 2005). During spring epibenthic species like the green sea urchin *Strongylocentrotus droebachiensis* and the Iceland scallop *Chlamys islandica*, were found to be particularly important prey items for the red king crab in the Varanger area (Jørgensen, 2005; Oug et al., 2011).

The digging activity of the red king crab may have an effect on the benthic communities. Oug et al. (2011) found that there was a reduction in soft-bottom infauna (animals that live within the sediments) and epifauna (animals that live on the sediment) in areas where the king crab had reworked the sediment, the quality of the sediment layers was also degraded due to biological activity leading to hypoxic conditions in the surface layers. The result of this study suggest that the red king crab has a negative effect on the resident species assemblages by removing organisms that have key functions in the sediment, such as bio-irrigation and sediment reworking.

As there is a potential threat of an invasion of the red king crab in Balsfjord, the monitoring of the bottom fauna is now of even greater importance. By comparing new data collected with Ougs long–term series, we can discuss potential effects the invasive crab may have on the fauna of a fjord like Balsfjord and other fjords invaded. The long-term series from Svartnes in Balsfjord gives us very good historical data if the king crab should invade the area. Since there at present are no well documented data prior to an invaded fjords in northern Norway, this data set gives us an unique opportunity to establish the effect that invasive king crab have on the soft bottom communities.

There have been individual observations of red king crab in the Tromsø area. One mature female with roe was captured outside of Polaria in Tromsøsundet (Figure 1) (Espen Rafter pers. com.) and 3 relatively small crabs (one male and two female) were caught at the Tennes station during our cruise in Balsfjord on the 27th October 2014. Since Balsfjord has been subject to extensive studies from the 1970s, we have the opportunity to document with good historical data the potential effect of the red king crab on the benthic communities.

In this study the spatial variation in the benthic communities between three different localities Andersdal, Svartnes and Tennes, in Balsfjord will be compared. Species composition and abundance at the three localities will be investigated by grab sampling and beam trawling.

Furthermore, I will use Ougs long-term series from Svartnes to investigate variations over time based on his data from 1977-1994 with focus on biomass, species composition in form of number of taxa, diversity and dominate species. What changes are there, and are these changes due to environmental conditions? And how stable are the soft-bottom communities in Balsfjord?

By merging my data into Ougs long-term series we will establish a background for discussing species composition at the soft-bottom communities in Balsfjord. This is important if we would like to add future samples to Ougs in order to monitor the potential effect the red king crab, *Paralithodes camtschaticus*, has on the soft bottom communities, with special attention to the deepest basin at Svartnes.

Material and Methods

Study area

The coastline of northern Norway is characterized by the large amount of deep fjords that can penetrate many kilometres inland. The water masses in this region are regarded as the transitional zone between boreal and Arctic areas (Holte, 2004). Compared to fjords in the southern part of Norway, the northern fjords are categorized by the sill depths at the opening of the coastal zone. This makes the fjords influenced by the water mass exchange from the Norwegian Coastal Current (NCC) and Norwegian Atlantic Current (NAC) (Wassmann et al., 1996; Holte, 2004). The NCC and the NAC flows along the Lofoten islands, following the bathymetry along the north Norwegian coastal zone (Wassmann et al., 2000). In contrast to open fjords that have homogeneous water masses that experience extensive exchange with the surrounding open ocean, sill fjords are generally weakly stratified and experience large scale advective water mass exchanged (Oug, 2000).

The study was carried out in Balsfjord (69°20`N, 19°0`E) approximately 10 km south of the city of Tromsø (Figure 1), northern Norway. The fjord reaches about 50 km inland and is 5 km at its widest point. Balsfjord is a relatively narrow sill fjord with shallow sills of abort 10 m water depth at Tromsøysund and Sandnessundet, and 35 m depth at Rystraumen (Figure 1).

These sills separate the fjord from the open costal water and is therefore subject to limited deep water exchange in the deeper basins. The deepest part of the fjord is located at Svartnes and has a maximum depth of 195 m. The Svartnes area is located in the central part of the fjord and is approximately 12 km long. The relatively flat bottom consists mainly of finely grained mud (Oug, 2000).

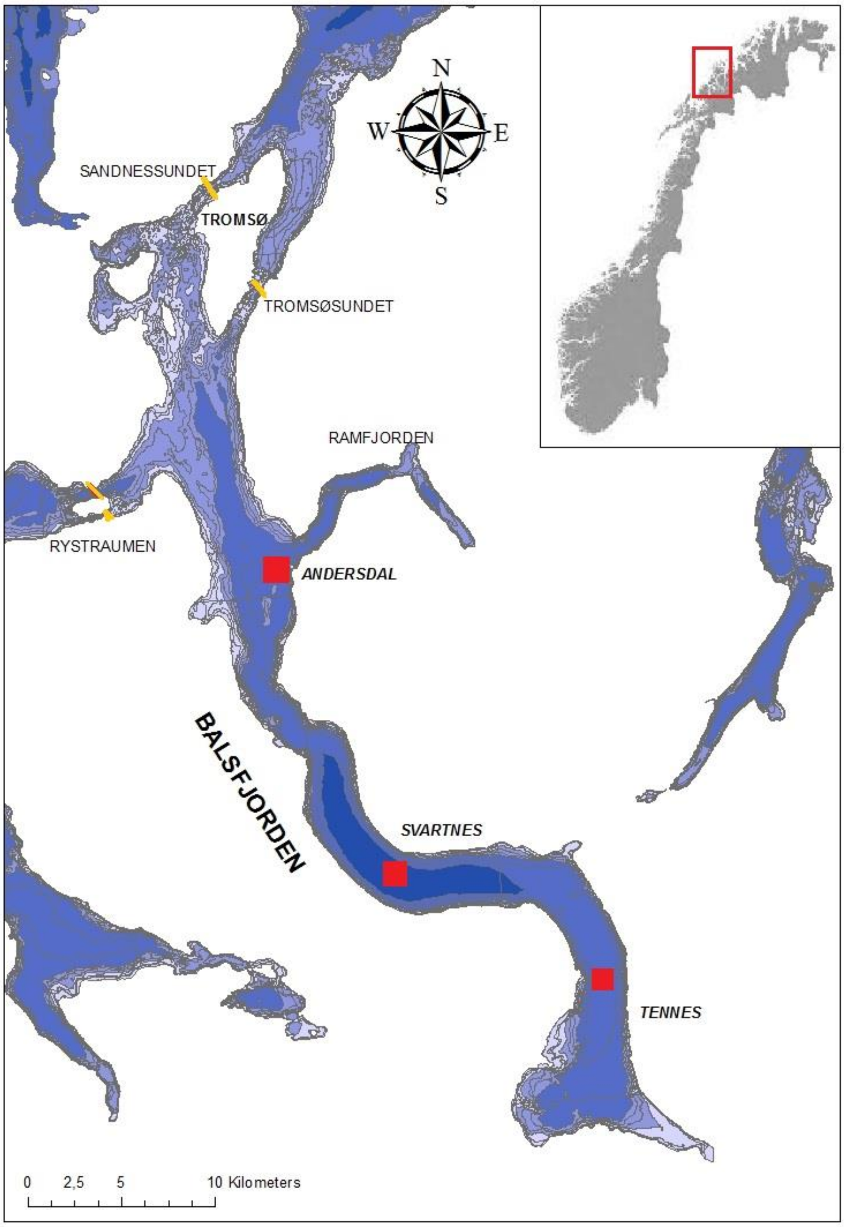

Figure 1: Map of Balsfjord, Northern Norway with sampling stations Andersdal (St.3), Svartnes (St.2) and Tennes (St.1) marked with red squares. Sills are marked with yellow lines. Grab samples collected 6th and 7th November 2013 at all three stations. Beam sledge collected on 27th October 2014 at all three stations.

Sampling

Field sampling took place during the 6th and 7th November 2013 on board RV *John Ruud* and RV *Hyas*, and on the 27th October 2014 on board RV *John Ruud*. For more specific station data see Table 1. Three stations in Balsfjord were selected (Figure 1) for sampling with 2 different gears. A 0.1 m^2 van Veen grab was used for quantitative sampling of the infauna (>

1mm) and a 2 m beam trawl fitted with an outer mesh of 20 mm and an inner mesh of 4 mm was used for semi-quantitative sampling of the epifauna (> 4mm). The beam trawl was fitted with a chain mat to exclude large stones and debris from the net (Jennings et al., 1999). Active trawling time was 5 min with an average speed of 1 knot (1.85km h^{-1}). Due to that beam trawl was not available for the cruise in 2013, beam trawl samples were just collected on the 27th October 2014.

Andersdal station is located near the entrance of Ramfjord and has a depth of 120 meters (Figure 1). Svartnes station is located in the centre of Balsfjord with the deepest basin depth of 195 meter. Tennes is the station located in the inner most part of Balsfjord and has a depth of approximately 120 meters. At each station five replicate grab samples were collected and grabs that were over 70% full were taken. The samples were sieved through 4 mm and 1 mm round- mesh screens to collect all living animals < 1mm. They were then preserved in 4 % buffered formaldehyde solution for further identification in the lab.

Table 1: Stationary data for sampling conducted in Balsfjord.

Gear	Station	Station nr	Date	Latitude	Longitude	Depth
Grab	Tennes	1	06.11.2013	69°20.2'N	19°21.2'E	125m
	Svartnes	2	06.11.2013	69°22.2'N	18°59.7'E	186m
	Andersdal	3	07.11.2013	69°31.1'N	19°04.3'E	120m
Beam trawl	Tennes	1	27.10.2014	69°17.4'N	19°22.5'E	125m
	Svartnes	2	27.10.2014	69°21.8'N	19°06.5'E	186m
	Andersdal	3	27.10.2014	69°31.2'N	19°01.0'E	120m

Environment

Svartnes in Balsfjord is classified as a cold water area with bottom temperatures from approximately 1-7°C during the year (Eilertsen et al., 1981). The water column is in spring, from October until late April, almost homogenous due to vertical mixing of the water masses. In summer the water masses are stratifies, due to a sharp and shallow pycnocline produced by freshwater runoff and heating of the surface water (Eilertsen et al., 1981; Wassmann et al., 2000). The water masses are aerobic and the oxygen levels are estimated around 70 to 80 % in the bottom water (Eilertsen et al., 1981; Oug, 2000). Primary production is estimated at about

100 gC m^{-2} per year with two production peaks, one in late March/early April and a second peak around August/September (Eilertsen and Taasen, 1984). Most of the production in the fjord is mineralized in the pelagic food webs, in short food chains or exported out of the fjord due to advection episodes (Reigstad and Wassmann, 1996). The little organic matter that reaches the bottom of the fjord consists of detritus and faecal pellets making the sediment in the deep basin nutrient poor.

Hydrography

Hydrographical data (temperature, salinity, density) were presented from the permanent CTD station located in the Svartnes area where they have monthly sampling throughout the year. A similar hydrographic dataset for all three stations are available from Andersdal (Haugbergnes), Svartnes and Tennes as presented in Rahman Mankettikkara's doctor thesis (Mankettikkara, 2013).

Trends could be studied by plotting a long term bottom temperature series from December 1977 to June 2014. The graph is divided in four panels of 10 year intervals (Figure 2). The temperature varied from 0.4 – 4.6 ^{o}C with colder and warmer periods (Figure 2). The mean temperature based on data from 1977-2014 was calculated and plotted as a dotted line through the graph. The month number is shown to see which months are represented at the different temperatures. Sampling Dates for Ougs long-term series (red dots) and own samples (green dots) are indicated in Figure 2 (also see Appendix 1 and 2). There was no data available for 1978 and 1979.

There were three periods in the 1980s that were particularly cold, 1981, 1985 and 1988. Followed by a relatively warm period from 1989 to 1993 were temperatures ranged from 2.7-4.6^{o}C. From 1995 to 2000 the bottom temperature was unstable with large fluctuations before it stabilised above mean temperature until 2011. A periods with fluctuating temperatures are again seen between 2011 and 2014. However from 1995 to 2014, there were no cold periods like those that were found in the 1980s.

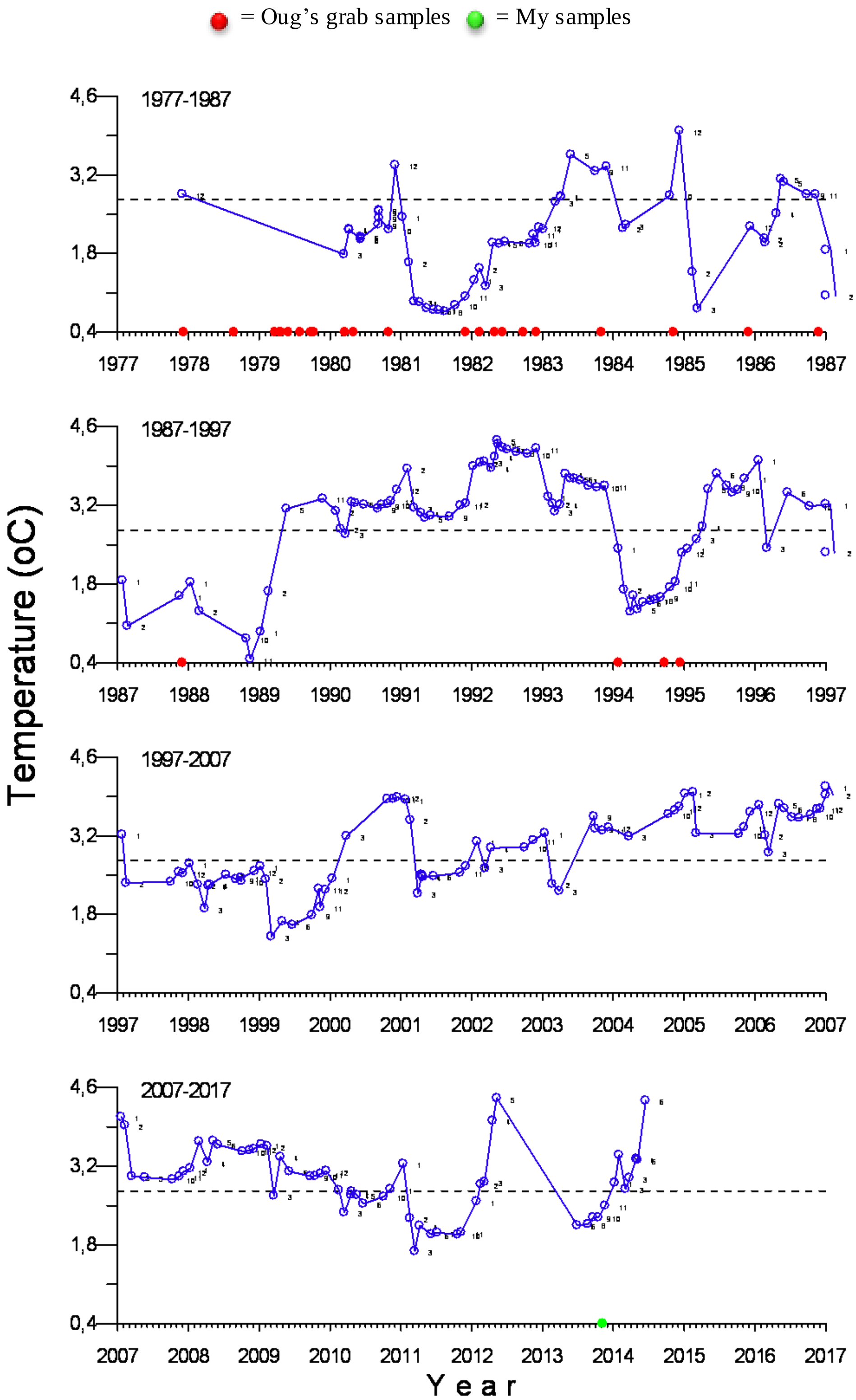

Figure 2: Bottom temperature (°C) in Balsfjord at Svartnes from 1977- 2014 in ten year intervals, 1977-1987, 1987-1997, 1997-2007 and 2007-2017. Mean bottom temperature indicated by the dotted line. The number besides each blue circle represents the number of the month.

Laboratory work

Due to time constraint, two out of five replicates from Andersdal and Tennes, and three out of five replicates from Svartnes were randomly selected for species identification. The samples were washed in running water in a 1 mm sieve for 24 hours before submerging the sample in ethanol with Rose Bengal stain, and left to stain for a few hours. The samples were transferred to a 1 mm sieve and washed with running water to remove the excesses ethanol and Rose Bengal stain. The samples were then transferred into a petri dish in spoon size fractions. Using a stereo microscope the animals were then sorted from the residual sediments and into family, before being identified down to the lowest possible taxon.

For identification of the animals some of the literature available was given to me by Mona Furhman and Emma Källgren, and a reference sample on polychaetes provided by Eivind Oug was used. For list of literature see Table 2. Where identification was difficult, for example if only small fragments of the animal were found, the fragments were sorted as "unidentified". Identification of especially the polychaetes was time consuming and laborious work and due to time limitation not all animals were sorted down to species. Literature was also in some cases hard to come by due to that most identification keys were British and Danish and do not include arctic species that are found in north Norwegian fjord. From each sample all individuals were counted and weighed (mg) for further analysis to determined species composition and total density.

Table 2. List of literature used in identification of taxa.

Phylum	**Author**
Annelida	Baker (1983) George and Hartmann-Schroder (1985) Hayward et al. (1990) Holthe (1986;1992) Kirkegaard (1992;1996) Nygren et al. (2013) Oug (2011) Parapar (2006)
Arthropoda	Sars (1966) Hayward et al. (1990)
Mollusca	Hayward and Ryland (1990)
Echinodermata	Moen and Svendsen (2004)

Data treatment

The bottom temperature data at Svartnes, abundance data from Balsfjord, total number of individuals, taxa and biomass (Andersdal, Svartnes and Tennes) and Ougs (Oug, 2000) time series of benthic data (number of individuals per grab) was plotted for analysis and graphical presentation. 16 most dominate taxa from Ougs long-term series and the 20 most dominate taxa from my data (2013) in number of individuals was compared to see if there have been changes in dominating taxa from 1977-2013.

For measuring biodiversity, how the total number of individuals was divided among the different taxa, the heterogeneity in the different grabs, the Shannon-Wiener (H') index and Pielou's evenness index was applied.

Shannon-Wiener diversity index (H')

To measure the diversity at the three different localities in Balsfjord, the Shannon-Wiener diversity index (H') was used. This is the most common nonparametric measure used in benthic studies. This way we can measure how the number of individuals are divided among the different taxa at the different localities.

The Shannon-Wiener index (H') is expressed by the equation:

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where $p_i = n_i / N$ (n_i being the number of individuals of the *i*th species and N the total number of individuals) *s* is the total number of species (Gray and Elliot, 2009).

Pielou's evenness index (J')

Species evenness refers to how close in numbers a community is. The more even the numbers between the different taxa (grabs) are, the more even the community. The evenness in a community can be expressed by Pielou's evenness eqution:

$$J = H' / H'_{max}$$

where H' max represents the maximum possible diversity achieved if all taxa are equally abundant. In a community the J' values range from 0 to 1 where 1 would give a perfect evenness (Zar, 1984).

Bray-Curtis index

Bray-Curtis dissimilarity index is widely used in multivariate analysis of station/species assemblage data and used to find patterns in this data. In marine ecology the Bray-Curtis index is often used to determine dissimilarities (similarities) and distance between samples and species (Quinn et al., 2002). It quantifies the differences between the samples. The Bray-Curtis index is bound between 0 and 1. If the values are close to 0 it means that the samples are similar but if they are close to 1 it means that they are dissimilar. Bray-Curtis index:

$$D = \sum_{i=1}^{s} \left| \frac{x_{1j} - x_{2j}}{(x_{1j} + x_{2j})} \right|$$

Where x_{1j}, $x_{2j}$are the abundance of species *j* in sites 1 and 2, and s is the number of species.

Ranking correlation (Spearman)

Spearman's ranking correlation coefficient is a nonparametric statistical method that measure the relationship between two variables (Zar, 1984). It measures how well the relationship between to variables can be. In the Spearman rank correlation index the values between +1 to -1 are use, for positive and negative association.

Multivariate analysis

Multivariate data can be analysed by many different methods. In my thesis I have used a measurement of similarities to find patterns in station/taxa composition. By using both Bray-Curtis and ranking correlation (Spearman) it was possible to look for patterns in the species composition. Bray-Curtis is density dependent while Spearman ranking is not. A cluster analysis was used to shows how the species occur in natural groups or clusters. Average linkage was selected to measure the distance between the clusters while multidimensional scaling was used shows the distance between the species and how they occur together in the samples over time.

Multi-dimensional scaling (MDS) is a nonparametric measure that reduces the data set into one to five dimensions by use of a dissimilarity or similarly matrix. The object of this analysis is to reduce the data into a two-dimensional representation making it easier to interpret the results. This analysis reduces the distance between the samples to see how they occur together in the sample.

Principle component analysis (PCA) is a linear transformation method and the main purpose is to identify and find patterns in our data set by reducing the dimensions without loss of information. Principle component analysis (PCA) was used to show the pattern between grabs samples over time and the species that occur in the samples. In the PCA analysis the most dominant species were selected to reduce the complexity of the data set.

Software used

Calculations were done in Microsoft ® Excel® for Windows (Microsoft Corp. Redmond, WA, USA). All graphs and statistical analysis was done by using SYSTAT 13 for Windows (Crane Software International Ltd, Chicago, USA). The map was made by using ArcGIS Desktop Advanced, 10.1 (Esri Inc. USA).

Results

Spatial variation

A complete list of taxa with full name and abundance data identified in Balsfjord for Andersdal, Svartnes and Tennes November 2013 is shown in Appendix 3 and the 20 most dominant taxa are shown in Table 2 in ranking order. To eliminate rare species interference, the 20 most dominant taxa were selected for further analysis (Table 3). For simplicity, I chose to use abbreviations for the taxa, these are shown in Table 3 (also see Appendix 3).

From the taxa list in Table 3 *Maldane sarsi* and *Galathowenia ocultata* are the two dominate (species) taxa at all stations. Some of the lager taxa rank higher at Svartnes then at the two other stations. *Ampharetidae* sp. and *Nephtys ciliata* are ranked as 4 and 6 at Svartnes. But at Andersdal and Tennes *Ampharetidae* sp. is ranges as 8 and *N. ciliata* as 13 at Andersdal and 10 at Tennes. *Aratacama proboscidae* is another taxa that is ranked much higher at Svartnes (7) then Andersdal (15) and Tennes (12). Svartnes see to stand out with other value score for some of the taxa then the other two stations.

The number of taxa or species found in each grab samples varied from station to station. In total 59 taxa and 1514 individuals were recorded (Figure 3A and B). The number for individuals found in each grab did not vary much except for in the samples from Svartnes which we can see from Figure 3A stands out as very different form the other stations. In Andersdal and Tennes 673 and 641 individuals were found in total, whereas at Svartnes only 200 individuals were found. Since the total number of taxa for each stations do not vary much, 51 to 54 taxa, this indicates that many taxa are represented with few individuals especially in the Svartnes grab samples. Andersdal had a total number of 54 taxa collected, whereas Svartnes and Tennes had 51 and 50 taxa approximately (Figure 3B). The Polychaeta *Maldanidae sarsi* (total of 729 individuals) and *Galathowenia oculata* (total 331 individuals) were the most dominant in number of individuals.

Table 3: The 20 most dominant taxa based on number of individuals found in grab ($0.1m^2$) samples from Andersdal, Svartnes and Tennes November 2013. Numbers ①-⑮ from most abundant to least abundant.

Taxa	Abbr.	Andersdal	Svartnes	Tennes
Nematea/ Nemertina	Nematea	⑮	⑪	⑨
POLYCHAETA				
Maldane sarsi (Malmgren, 1865)	Mal sar	①	②	①
Galathowenia (Myriochele) oculata (Zachs, 1923)	Gal ocu	②	①	②
Trichobranchidae sp.	Tri sp.	④	③	⑦
Maldane sp.	Mal sp.	③	⑪	③
Myriochele heeri (Malmgren, 1867)	Myr hee	⑥	⑤	④
Terebellidae sp.	Ter sp.	⑤	⑪	⑤
Ampharetidae sp.	Amph sp.	⑧	④	⑧
Chaetozone setosa (Malmgren, 1867)	Cha set	⑦	⑦	⑧
Lumbrineris mixochatea (Oug, 1998)	Lum mix	⑧	⑧	⑪
Nephtys ciliata (O.F. Müller, 1776)	Nep cil	⑬	⑥	⑩
Spiophanes spp.	Spio spp.	⑭	⑪	⑥
Prionospio sp.	Prio sp.	⑬	⑪	⑨
Owenia fusiformis (Delle Chiaje, 1844)	Owe fus	⑨	⑪	⑫
Paranoidae spp.	Par spp	⑪	⑪	⑪
Artacama proboscidae (Malmgren, 1866)	Art pro	⑮	⑦	⑫
Heteromastus filiformis (Claparède, 1864)	Het fil	⑫	⑨	⑫
Aglaphamus malmgreni (Théel, 1879)	Agl mal	⑭	⑩	⑩
MOLLUSCA				
Bivalvia sp.	Biv sp.	⑪	⑧	⑧
ECHINODERMATA				
Ctenodiscus crispatus (Retzius, 1805)	Cte cri	⑩	⑩	⑪

**sp. one species*

***spp. more than one species*

As seen in Figure 3A and 3B the variation in number of individuals and taxa per grab and station vary especially for Svartnes which is very different in numbers of individuals from the other stations. Andersdalen and Tennes were more even in numbers and taxa. There were also large differences in taxa between the grabs at Svartnes. However, both Shannon-wiener (H') index and Pielou's eveness index (J') show that Svartnes has higher index values than Andersdal and Tennes. This can be seen in Figure 3C and 3D were we register that the Shannon-Wiener index (H') and Pielou's index of evenness (J') for Svartnes is higher than at Andersdalen and Tennes, indicating a more even distribution of individuals (J'). Values of the Shannon-Wiener diversity index range from 1.40 at Andersdal to 2.54 at Svartnes. Andersdal had the lowest values in general of the 3 stations while Tennes had values of 1.69 and 1.99.

Pielou's index of evenness (J') was highest at Svartnes in Grab I at 0.89 which had the lowest number of individuals. Andersdal Grab II had the lowest evenness (J') index at 0.45.

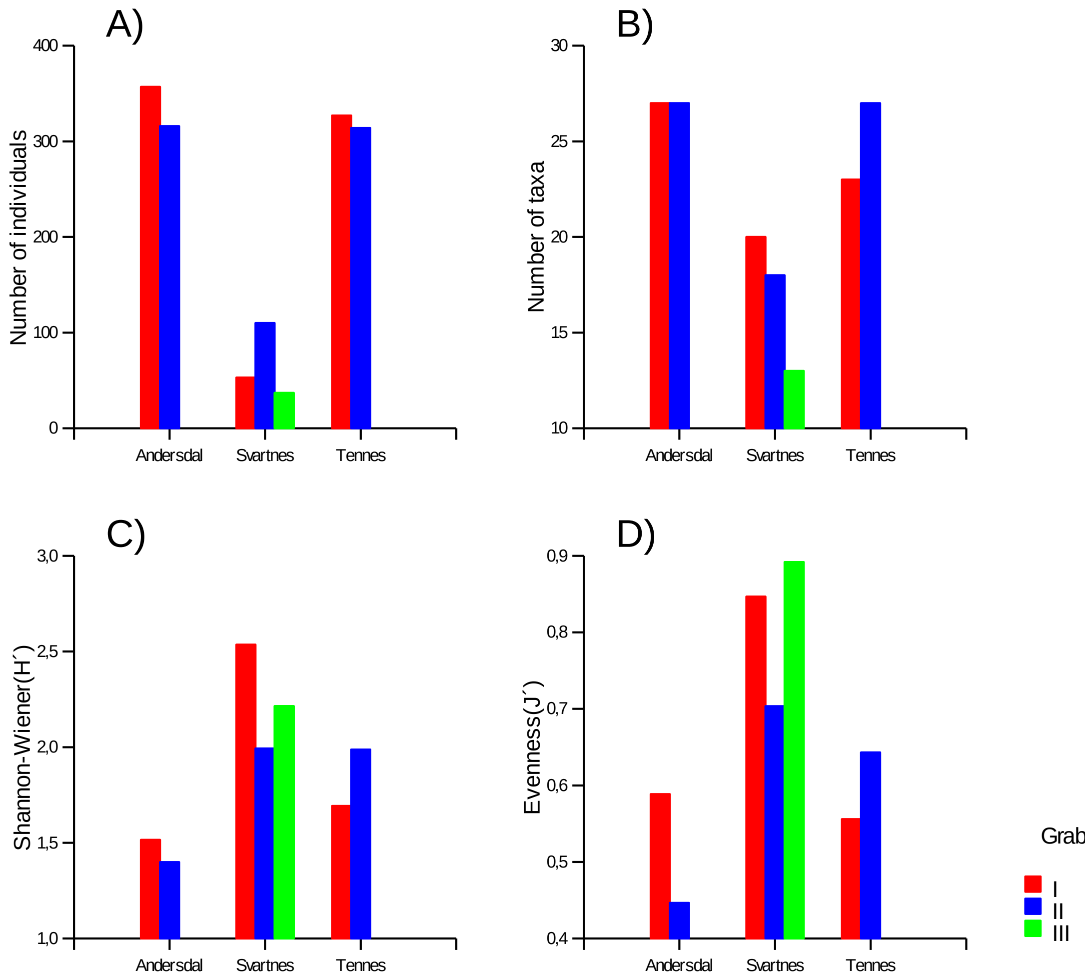

Figure 3: A) The total number of individuals and B) taxa for all grabs taken 2013 is showed. C) Shannon-Wiener diversity index (H') and D) Pielou's evenness index (J') for grabs taken in November 2013 at Andersdal, Svartnes and Tennes.

Biomass ranged from the highest in Andersdal with 25.2 g per grab, where we also found the highest number of individuals and taxa, to the lowest at 1.36 g at Tennes (Figure 4A). Biomass ranged between 1.62 g to 9.30 g. The high biomass value in Andersdal is mostly due to the high weight of asteroidae *Ctenodiscus crispatus*. Apart from *C. cripatus*, polychaeta make up the largest group in biomass collected at all three station. The total biomass is much lower at Svartnes then at Andersdal and Tennes, but when *C. crispatus* is removed the biomass evens out (Figure 4B). The high biomass value in grab II at Tennes is due to one large individual of the polychatea *Nepthys ciliata*. The Echinodermata *Ctenodiscus crispatus* were the most dominate in biomass in the samples (total biomass 44.35 (g)) followed by the polychaete *Nephtys ciliata* (total biomass 5.86(g)). Other common species found in all samples were the polychaeta *Galathowenia oculata, Trichobranchidae sp., Myriochele heeri, Terebellidae sp., Ampharetidae sp., Chaetozone setosa* and *Lumbrineris mixochatea*. Bivalves were also common and present in almost all the samples. Except for grab II at Tennes due to *N. ciliate*, the biomass does not very much at the three different localities.

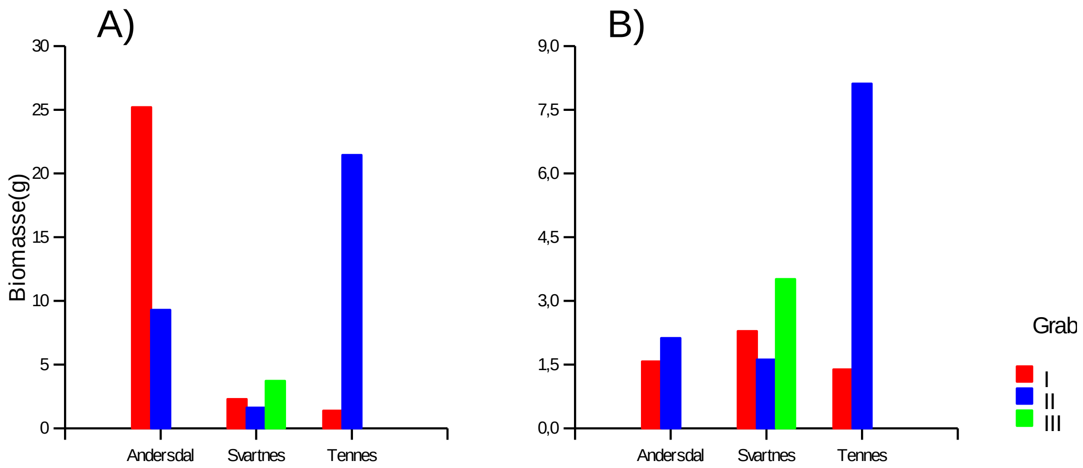

Figure 4: A) Total biomass (g) from the three stations Andersdal, Svartnes and Tennes. B) Biomass for all three stations were *Ctenodiscus crispatus* is excludered form total biomass (g).

Community analysis

From the data presented in Figure 3A and 4A it may look like Svartnes is different from Andersdalen and Tennes, which is confirmed by the help of a cluster tree presented in Figure 5. Here we can see the similarities between the different grabs at each locality. All three grabs at Svartnes are grouped closed together, as are the samples from Anderdal. But the grabs from Tennes are found at the opposite ends of the cluter tree, far apart, where Tenne IIis more similar to Andersdalen II then Tennes I. This plot shows that there is a similarity between the grabs collected at Andersdal and Svartnes, but that grabs from Tennes are very different, probably because of the one large individual of *N. ciliate*.

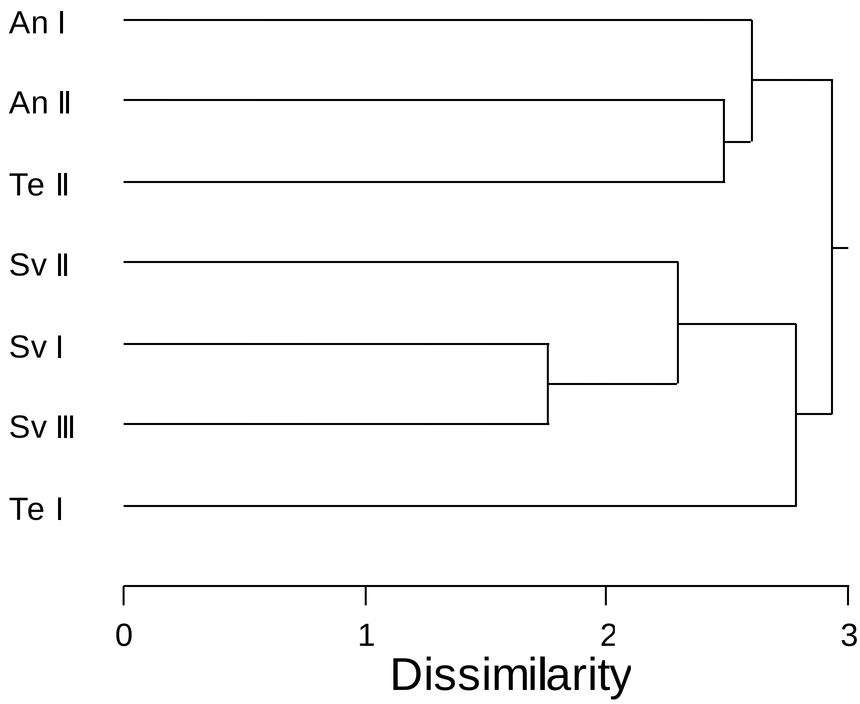

Figure 5: Cluster (average linkage) dendogram base on Bray-Curtis dissimilarity indices of the 20 most dominat taxa found at Andersdal (An I-II), Svartnes (Sv I-III) and Tennes (Te I-II).

To study the similarities between the 20 dominant taxa and how they occur together I chose to calculate a Bray-Curtis triangular similarity matrix based on the data collected at Andersdalen, Svartnes and Tennes. This data was then analysed by a multi-dimensional scaling (MDS) plot which is presented in Figure 6. No clear taxa groups could be identified, but Nematea and *Spiophanes* spp seem to form a group associated with *Nephtys ciliate*, *Bivalvia* sp., *Chaetozone setosa*, *Ampharetidae* sp, *Trichobranchidae* sp., *Terebellidae* sp. and *Myriochele heeri* at the positive side of Dimension I. While *Aglaphamus malmgreni* and *Prionospio* sp. form a second group found at the negative side of the Dimension I. A third group consisting of *Heteromastus filiformis*, *Owenia fusiformis*, *Ctenodiscus crispatus*, and *Paranoidae* spp. is found at the positive side of Dimension II. *Maldane sarsi* and *Galathowenia oculata* seem to form a fourth group quite separate from the other groups. A cluster tree based on Bray-Curtis matrix with average linkage also shows the same four groups that were apparent in the MDS (Figure 7).

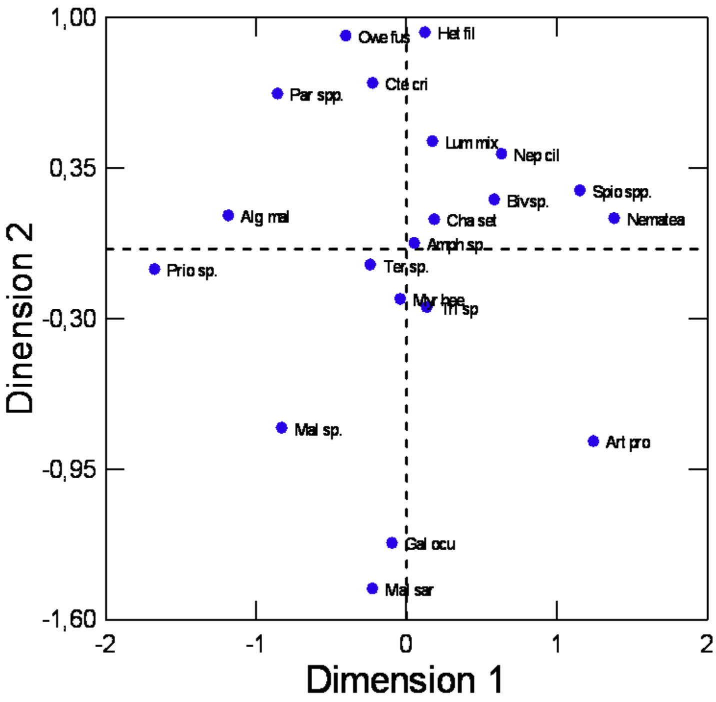

Figure 6. Multi-dimensional scaling (MDS) based on Bray-Curtis matrix of the 20 most dominate taxa in grab samples from November 2013 Andersdal, Svartnes and Tennes. Stress: 0.169 and RS: 0.849.

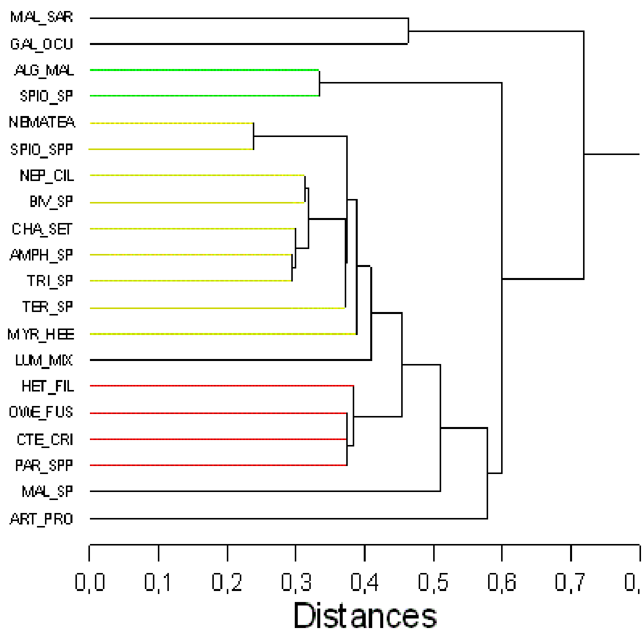

Figure 7: Cluster dendogram formed by group average linkages showing the 20 most dominant taxa based on Bray-Curtis matrix for the grabs samples from November 2013 Andersdal, Svartnes and Tennes.

Until now I have not related my taxa to the different grabs and locations. I have chosen to use PCA on ranked data while this is a robust method on non-normally distributed data (E.M. Nilssen, pers.com (Quinn et al., 2002)).

The results from PCA of the different grabs (resented in Figure 8A and B) shows a clear difference between the localities but not between the grabs, except for Tennes with response to species composition.

Svartnes I, II and III are positively correlated with the taxa *Artacama proboscidae* and *Ampharetidae* sp. which is negatively correlated with the taxa on the positive side of the plot. Tennes II is positively correlated with the taxa *Bivalvia* sp, *Nematea* and *Spiophanes* spp. found at the positive side of axis I and II. Tennes I is positively correlated with the taxa *Aglaphamus malmgreni* which is located at the negative side of axis I. Andersdal I and II with taxa to the far left on axis I is positively correlated with the taxa *Galathowenia oculata*, *Maldane sarsi*, *Heteromastus filiformis*, *Owenidae fusiformis*, *Terebellides* sp and *Myriochele heeri*. A total of 57% of the variance is explained in the plot (Factor I 33%, Factor II 24%).

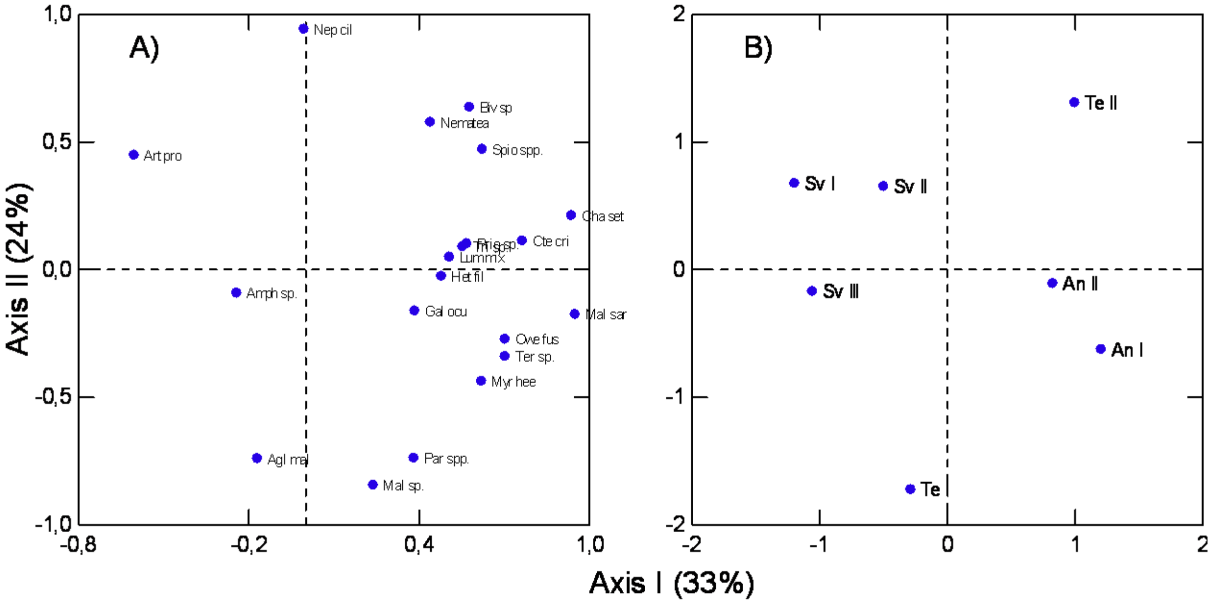

Figure 8: Principle component analysis (PCA) based on 20 dominate taxa by numbers in ranking correlation from grab stations November 2013. A) Species B) Station grabs.

Beam trawl samples of the macrofauna were collected at Andersdal, Svartnes and Tennes in October 2013. The most to least abundant taxa in biomass are represented in Table 4. In total 20 taxa were found.The most taxa were found at Tennes (20 taxa) while Andersdal had the second most (18) and Svartnes had the fewest taxa found (16). *Ctenodiscus crispatus* dominated the fauna at all stations. The sea star *Leptasterias muelleri* which is considered an arctic species, was the second most dominant taxa in the samples even thought it was not found at Andersdal. The deep water shrimp *Pandalus borealis* also dominated at Svartnes and Tennes. While the Echinodermata *Strongylocentrotus droebachiensis* was just found at Andersdal it had high biomass. *Ophiura ophiura* was also found at all stations in high biomass.

Table 4: Taxa found in beam trawl in ranking order from most ① to least ⑳.

Taxa	Andersdal	Svartnes	Tennes
Ctenodiscus crispatus	①	①	①
Leptasterias muelleri		②	③
Pandalus borealis	③	⑤	②
Septem carinata		③	⑥
Ophiuroidae sp.	②	④	④
Strongycentrotus droebachiensis	④		
Gastropoda	⑦	⑦	⑦
Scaphopoda	⑥	⑪	⑨
Polychatea	⑧	⑯	⑧
Actinaria	⑤		⑪
Yoldiella sp.			⑤
Arthropoda	⑨	⑫	⑩
Sipuncula	⑰	⑥	⑲
Pycnogonidae	⑪	⑧	
Amphipoda	⑭	⑩	⑰
Bivalvia ind.	⑩		⑯
Echniodermata		⑨	
Paguridae			⑫
Bryozoa	⑫	⑬	⑭
Astartidae	⑱		⑬
Cumacea	⑬		⑮
Hydrozoa	⑯		⑱
Nematea		⑭	
Isopoda	⑮	⑮	⑳

Long-time variation Svartnes

To look at the long-term variation at Svartnes, Eiving Ougs data from 1977-1994 is presented with my data from 2013. For all taxa from 1977-1994, see Oug (2000).

In Table 5 Ougs data and my data of the most dominant taxa found at Svartnes in the time period of 1977-1994 and 2013 is shown. The 16 most dominant taxa found from 1977-1994 and the 20 most dominant taxa found in 2013 are marked with numbers from 1-20 from the most abundant to least abundant taxa. From Table 5 we can see that polychaetas *Galathowenia oculata* (*Myriochele oculata* in Ougs time-series) and *Maldane sarsi* are the taxa dominating the samples at Svartnes in Ougs long-term series and in the 2013 samples. The oligochaete *Tubificoides cruspisetosus* that was the 4th dominating taxa in the 1977-1994 samples, yet are not among the dominant taxa in 2013. Only one individual was found at Svartnes. Many of the taxa found in 2013 who are not among the dominant taxa in 1977-1994 samples, can be due to that some taxa were in the 2013 samples just sorted to family level compared to Oug where most of the taxa were sorted to species level.

The number of individuals from the 16 most abundant taxa from 1977-2013 are presented in Figure 9. There is a decreases in numbers of individuals for most of the taxa. Expect for *M. heeri* and *T. stroemi* that increase in numbers, *M. sarsi* and *N. ciliata* have only a small decrease in numbers. Some of the dominant taxa from Ougs long-term series were not found in the samples from 2013. These taxa are *C. longocirriata*, *Maldane* indet, and *Chone* sp.

Table 5: The 16 most abundante taxa found in grab (individuals per 0.1m^2) samples from Balsfjord at Svartnes from 1977-1994 (Ranked Oug data) with ranked numbers ①- ⑳ from most abundant to least abundant based on number of individuals. Also shown are in ranking order data collected at Svartnes in November 2013. Abbr. = abbreviation of species names used in plots.

Taxa	**Abbreviation**	**Ranked Oug data**	**Ranked Nina data**
Nemertina ind.	Neme	⑯	⑯
POLYCHAETA			
Galathowenia (Myriochele) oculata (Zachs, 1923)	Myr ocu	①	①
Levinsenia gracilis (Tauber, 1879)	Lev gra	⑤	⑰
Lumbrineris mixochaeta (Oug, 1998)	Lum mix	⑦	⑩
Chaetozone setosa (Malmgren, 1867)	Cha set	⑥	⑧
Maldane sarsi (Malmgren, 1865)	Mal sar	②	②
Prionospio cirrifera (Wirén, 1883)	Pri cir	⑨	⑱
Heteromastus filiformis (Claparède, 1864)	Het fil	⑩	⑮
Myriochele heeri (Malmgren, 1867)	Myr hee	③	⑤
Cossura longocirrata (Webster & Benedict, 1887)	Cos lon	⑧	⑳
Maldane indet	Mal ind	⑬	③
Nephtys ciliata (O.F. Müller, 1776)	Nep cil	⑭	⑪
Terebellides stroemi (M.Sars, 1835)	Ter str	⑫	④
Apistobranchus tullbergi (Théel, 1879)	Api tul	⑮	⑳
Chone sp	Cho sp	⑪	⑳
OLIGOCAETA			
Tubificoides cruspisetosus (Baker 1983)	Tub cus	④	⑲
POLYCHAETA Groups			
Terebellidae sp.	Ter sp.	⑳	⑥
Ampharetidae sp.	Amph sp.	⑳	⑦
Spiophanes spp.	Spio spp.	⑳	⑪
Prionospio sp.	Prio sp.	⑳	⑫
Owenia fusiformis (Delle Chiaje, 1844)	Owe fus	⑲	⑭
Paranoidae spp.	Par spp	⑳	⑭
Artacama probiscidae (Malmgren, 1866)	Art pro	⑰	⑮
ECHINODERMATA			
Ctenodiscus crispatus (Retzius, 1805)	Cte cri	⑱	⑬

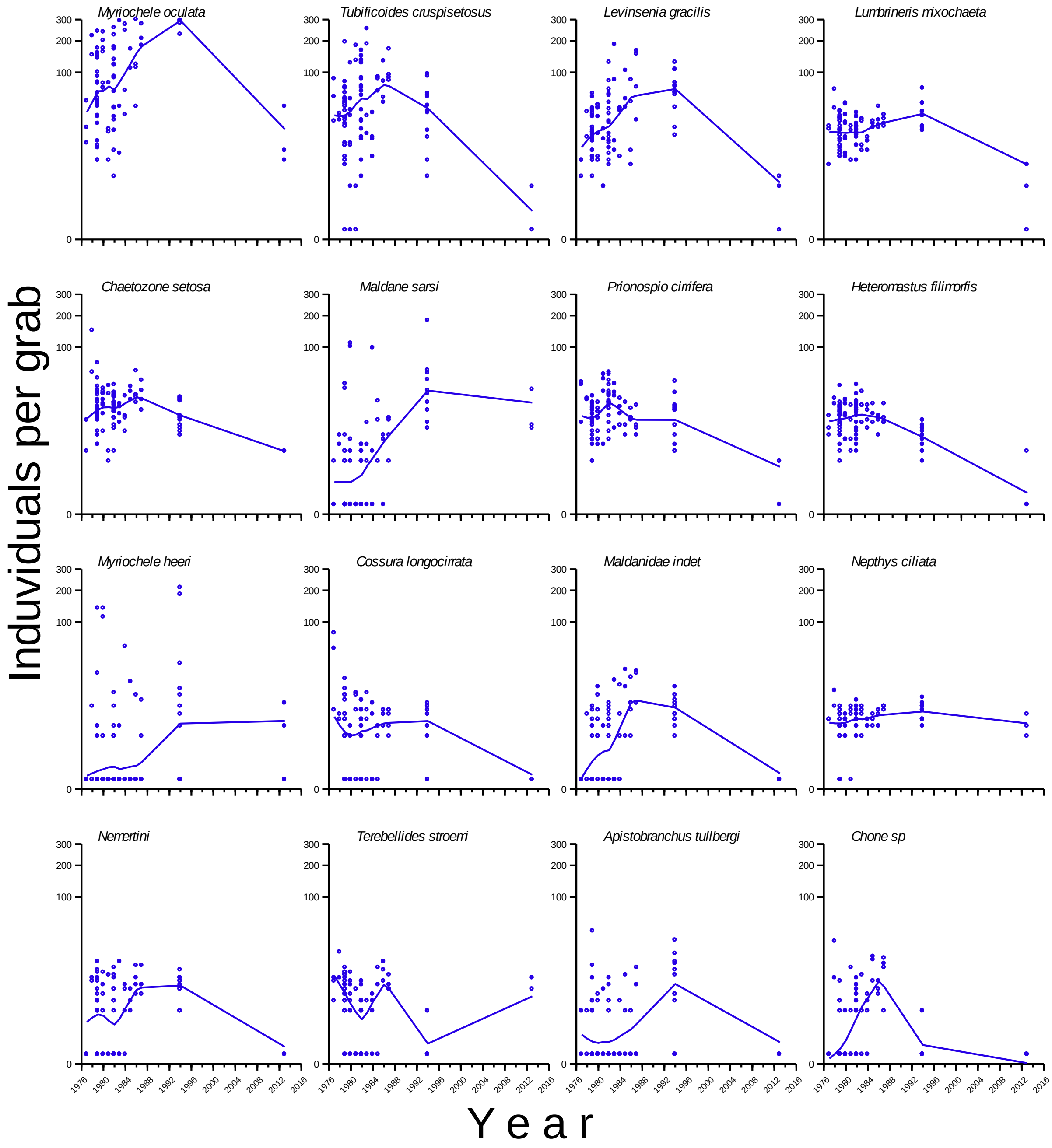

Figure 9: Number of individuals (√) per grab of the 16 most dominant species from Ougs (Oug, 2000) long-term series from 1977-2013 in ranking order. Cleveland smoother te=0.25 (Cleveland and Devlin, 1988). 0.01 added to all numbers.

The result from the PCA of Ougs long-term series combined with my data is presented in Figure 10 (taxa) and Figure 11 (single grabs).We can see that *M. heeri, M. sarsi* and *M. (G). oculata* are found relatively close together in the bottom right corner. As seen in Figure 6 of the taxa from 2013, this taxa seem to make a community of species that often are found together. Most of the taxa are found in the right upper corner, positively correlated to each other. Only *C. longocirrata* and *P. cirrifera* are found to the left side of the plot grouped close together. 27% of the variance is explained along Factor I and 16% along Factor II, in total 43% of the variance is explained along Factor I and II.

We can see that all the samples from 1994 are grouped close together in the right corner indicating that these samples are similar in content of taxa (Figure 10). The long-time taxa plot (Figure 11) indicate that the 1994 grab samples were dominated by the maldane species- *M. sarsi* and *M. (G). oculata*. and oweniidae *M. heeri,* The samples from 2013 are grouped together in the bottom left corner together with the samples from 1977, indicating that the samples from 1977 and 2013 are similar and characterised by the same taxa or lack of some taxa. Apart from the samples from 1978, 1986 and 1987 that all are fond in the upper part of the plot, none of the other years seem to show any patterns and are scattered over the whole plot. There seems to be a circular trend though the plot were it would now seem as if the communities are similar to the samples taken at the start of the long-tern series started by Oug in 1977.

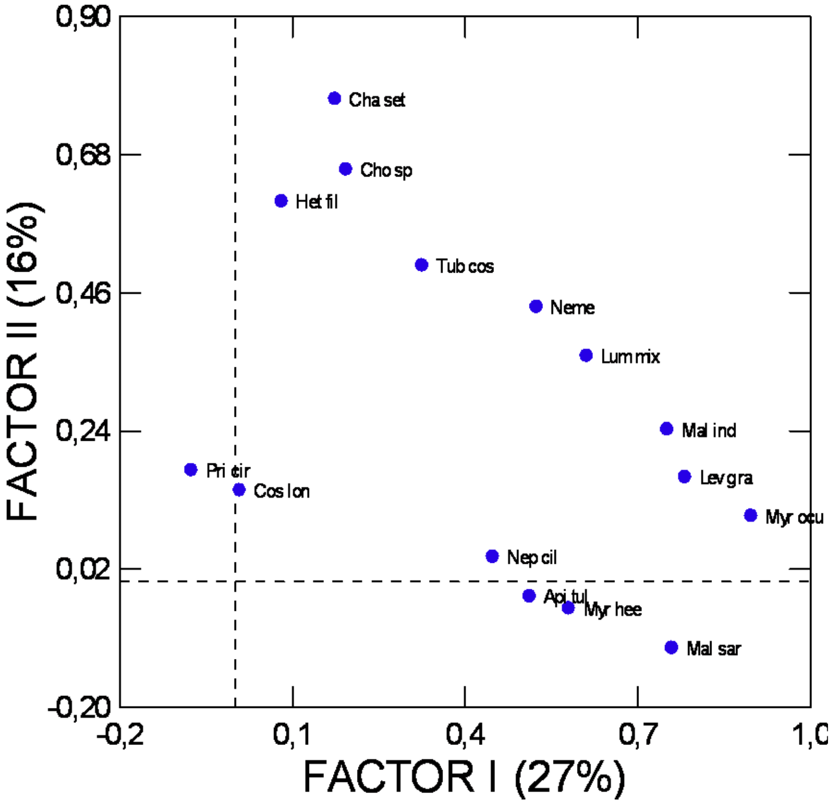

Figure 10: PCA plot of the dominant taxa in ranking correlation of grab taken at Svartnes in 1977-2013.

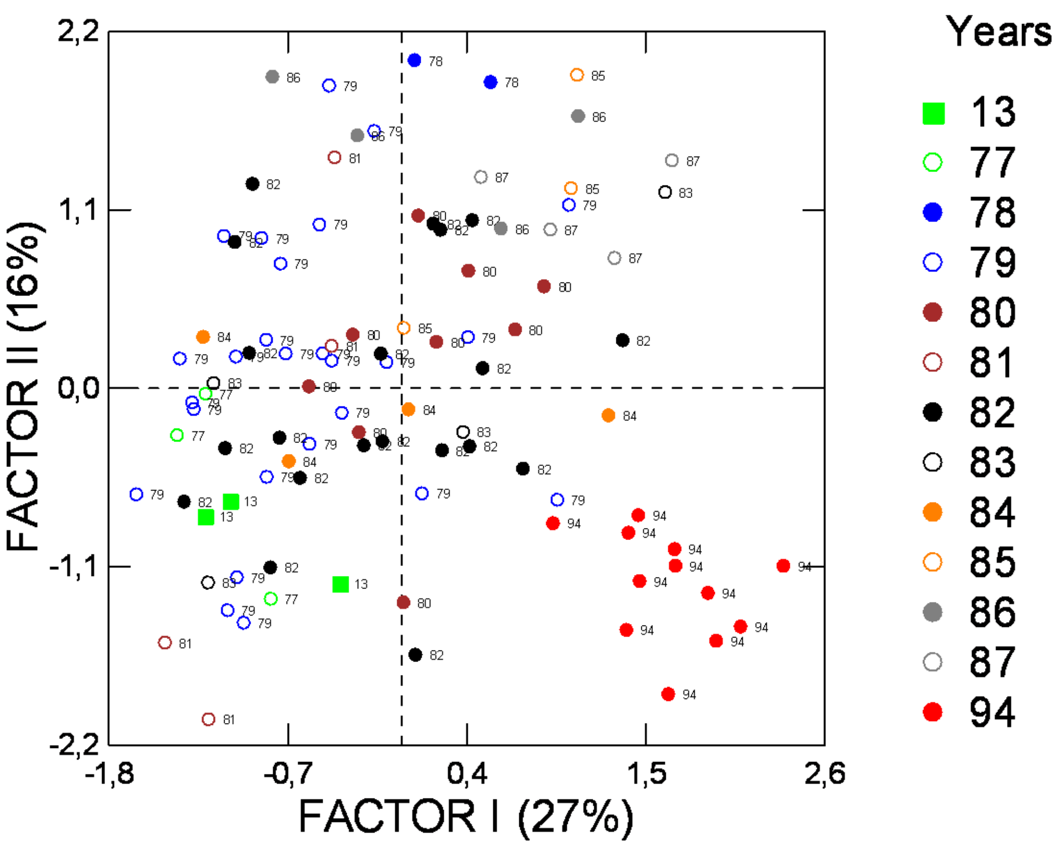

Figure 11. PCA of grabs samples baes on ranking correlated data from years 1977-2013.

Discussion

In the present study I investigated the spatial variation of soft bottom benthic communities at three different localities Andersdal, Svartnes and Tennes in Balsfjord using data from the long-term variation at Svartnes from 1977 to 2013 as well as point data from November 2013. I have focused on the most dominant taxa found in Balsfjord. I hope to show the importance of continuing Ougs (2000) long-term time series at Svartnes to monitor environmental and community changes, especially now that the red king crab has been observed in the fjord.

Sampling

When sampling benthos there are many different aspects to consider before sampling begins. Underwood and Chapman (2005) states that clear aims and hypothesis make for good results and valid conclusions. Since time and money are limited resources it is important that research is conducted in the best possible way. But error may occur even if all precursors are taken. It is therefore important to have a clear agenda. It is well known that benthic animals are extremely patchy in distribution and abundance (Gray and Elliot, 2009). Patchiness is caused by external and internal processes that effect the existing assemblage. Large-scale (trawling and dredging) and small-scale (waves and tides) disturbance contribute to changes in these assemblage. However unpredictability and variable patterns in recruitment and interactions like competition and predation are probably some of the most important contributors to patchy distribution (Underwood and Chapman, 2005). It is therefore important to have this in mind when sampling benthos. Many factors could contribute to loss of materials when sampling benthic fauna and especially when sampling micro fauna. It is therefore important to use equipment that are the right size for the investigation. For example investigating young recruits sieves < 1 mm should be used (Oug, 2000).

It is uncertain if the fullness of the grabs had an impact on the taxa and numbers of individuals collected. Since we only took grab samples that were over 70 % full, it is difficult to say if there can be great difference in abundance between these samples and the ones that were 100% full. Most of the grabs were at least 85% full. Since the number of individuals per grab do not vary dramatically we are confident that loss of material is minimal. We are confident the sampling undertaken in November 2013 is coherent with earlier sampling done by Oug (2000) through his long-term time series, therefore ensuring that no great difference should occur because of sampling. When it comes to epifauna, grabs seldom capture the larger individuals like *Ctenodiscus cripatus* and *Ophiura* sp. Since these taxa are particularly interesting as food source for the red king crab, other equipment is needed to samples these large individuals. We therefor used a beam trawl to capture the echinoderms. Compared to the grab which is quantitative the bream trawl is semi-quantitative. However when size of the beam and sampling area is known biomass can be estimated.

Taxonomy

Some studies have shown that the use of surrogates to reveal patterns of biodiversity can be used to reduce the time and money constraint in benthic studies (Olsgard et al., 2003). However this entails the use of species richness among higher taxonomic levels like genera and family. By just identifying to higher taxa there will be great loss of information about the functional trait of species. To have a thorough understanding of the marine system, basic knowledge of ecosystem functions need to be investigated. Sorting down to the lowest possible taxa gives a much better indication of the fauna and species functions. It is very apparent in the diversity index (H') were Andersdal has the lowest diversity. The low diversity value at Anderdal is most likely due to identification problems of particularly difficult species. In these cases the individual would be sorted in higher taxonomic groups. This was particularly the case for the polychaetes *Amphateridae* sp., *Terebellides* sp. and *Trichobranchidae* sp. Identification was difficult in maldanidae for the head was usually underdeveloped making it next to impossible to sort down to species. Vegetative reproduction was observed in individuals of this taxa, which has also been observed in *Maldane saris* in the Antarctic (Wrzesinski and Hartmann-Schroeder, 1994). The mechanisms to why this vegetative reproduction occurs is not understood.

Resent research has suggested that in addition to taxonomy a practical alternative can be to adopt trait-based estimates of important geochemical processed in the marine system (Queiros et al., 2013). Since there are still large gaps in our knowledge of the different species that contribute to the sediment reworking, only a few have been investigated and calculated in this manner. But this is very interesting research that we should keep in mind in the future.

Spatial variation

The variance between Andersdal, Svartnes and Tennes in terms of number of taxa and individuals was found to be large. The low numbers of individuals and biomass found at Svartnes compared to Andersdal and Tennes might have to do with the difference in depth. Svartnes is the deepest part of Balsfjord (180-190m) which may explain the difference in numbers and taxa found. For less nutrient reaches the deep basin floor at Svartnes compared to the more shallow part at Andersdal (120m) and Tennes (125m) (Wassmann et al., 1996; Oug, 2000).

Maldanidae and oweniidae were the most dominate species numbers wise, found at all three stations while the echinoderms (*Ctenodiscus crispatus*) were the most dominant in biomass. These taxa generally seem to dominate in biomass in soft bottom fjords in north Norwegian fjords (Jørgensen, 2005; Nilsen et al., 2006; Oug, 2011b; Fuhrmann et al., 2015). Kendra et al (2010) found that over a five year period of investigation on the soft bottom macrofauna in Hornsund (Svaldbard) *Maldane sarsi* was found to be one of the dominant species.

Svartnes has the lowest number of individuals per grab samples but the highest diversity index (H') indicating few individuals per taxa but quite many taxa present. Andersdal had the highest number of individuals and taxa but the lowest diversity index (H'). Since there are no available research data from Andersdal and Tennes, it is difficult to discuss if there numbers are low or high. Recipient studies have been done but the reports are not available for the public. I can only compare with similar research done in other nearby fjords in northern Norway like for instance Ullsfjord and Sørfjord (Nilsen et al., 2006) which are in agreement with my finding on taxa. In Sørfjorden Nilsen found polychaeta to be the most abundant group in number for individuals.

The species assemblage at Andersdal differed from Svartnes and Tennes by that more taxa were found. Even though more taxa was found the identification was difficult and higher taxonomical groups were used. Andersdal was found to have the lowest diversity index (H' 1.53) of the three locations. In NIVAs report on classification of environmental quality of fjords (Oug, 2003), Andersdal would be classified as an area of poor quality (H' 0.9-1.9), while Svartnes and Tennes fall under moderate quality (H' 1.9-3.0).

The Shannon-Wiener index is influenced by number of taxa and number of individuals found in the grab samples. Identification of taxa will therefor influence the index a great deal. The lower down the species are classified the more accurate the calculations are. This might explain the low index found at Andersdal.

Finding the right statistical tool for presenting and analysing data is not an easy task. There are so many different statistical applications that one should be aware of how they transform your data and how your data is graphically presented. The importance of choosing the right statistical method and transformation for my species and abundance data have been shown by van Son and Halvorsen (2014). They argue that two or more statistical methods should be used parallel to enhance artefacts in the data. This I found to be in agreement with my results from spatial variation at the three localities in Balsfjord. Analysing my data by two different methods (MDS and PCA) gave the same result.

The results from both the MDS and PCA analysis show that the rare species contribute to the largest differences in the grabs.

The PCA plot (Figure 8A) shows that *Artacama proboscidea* is situated on the negative side of axis I positively correlated with the Svartnes stations (Figure 8B). This is in agreement with the raw data where *A. proboscidea* was only found in the samples from Svartnes. The two grab samples from Tennes are located opposite of each other in the PCA plot, which is more than likely due to the rare taxa of Bivalvia and *Aglaophamus malmgreni* being found in opposing grab samples, making them very different from each other. Andersdal is the location where the samples are most homogeneous and dominated by the taxa maldanidae and oweniidae, where also the highest number of individuals were found.

The large gap in the time series from 1994 to 2013 of 29 years at Svartnes, and the difference in size of material in Ougs long-term samples and my material at Svartnes from 2013 make it difficult to make a comparison. Oug usually sampled more than once every year and in the mean density table from Ougs long-term series (Oug, 2000) he shows that his samples contained higher individual numbers then in my samples form 2013 which contained much lower number of individuals, even though most of the same taxa were found. This situation of low individual numbers but no reduction in taxa has been seen in other fjords, but there are no good explanations to why these situations occur (E. Oug pers.comm.). Only a new long-term series can say if the samples collected in November 2013 at Svartnes are representative for the situation in that area or if 2013 was an untraditional year in terms species assemblage.

Little is known about the biology of each of the different single species (Fauchald and Rouse, 1997). A literature search gave very little information, especially when it comes to lifecycle, recruitment and the larva development. Most benthic animals release eggs and sperm into the water column where they develop into larva that drift in the pelagic zone until they develop, sink down and become sessile.

Polychaetes are known to regenerate parts of their bodies if damaged in some way. But some polychaetes are known to have vegetative reproduction like maldanidae and especially *Maldane sarsi*. From my samples I found several maldanidae that reproduced this way. One can only speculate to why this type of reproduction does occur. Similar vegetative reproduction has also been observed in the Antarctic (Wrzesinski and Hartmann-Schroeder, 1994). However, studies have been done on polychaete feeding guilds and metabolism (Jumars and Fauchald, 1977; Fauchald and Jumars, 1979; Jumars et al., 2015; Pagliosa, 2005).

We know that Svartnes is a relatively homogeneous area which has restricted water exchange and circulation. Oug (2000), Wassmann (1996) and Reigstad (2000) have shown that Balsfjord is a special fjord were most of the production is exported out of the fjord and very little of the production reaches the bottom. But advective episodes have been shown to influence the spring bloom and the pelagic-benthic coupling by introducing pulses of organic matter (Noji et al., 1993; Reigstad and Wassmann, 1996). Oug (2000) found that where there was an increase in density advection had also taken place, enriching the nutrient supply. The low numbers of individuals that were found in my samples in November 2013 can maybe be explained by a decrease in nutrient supply to the deep basin area at Svartnes. However, recruitment may also have contributed to the low levels of individuals in my samples. Even though little is known about the recruitment of polychaetes we know that they release larva into the water column in spring and summer and larva can therefore colonise seasonally. But we know very little about the conditions that trigger the reproduction and what effects recruitment. The best time to investigate recruitment will be in February/ March when the larva have settled and survived. We know very little about which factors are involved in recruitments and explaining potential differences in good or bad recruitment to the benthic communities. But we do know that nutrient supply plays a large part in both recruitment and survival. Recruitment seems to come in pulses. It has been observed that in some year recruitment of some species are extreme and the year class outcompeting other species. This year the mussel *Mytilus edulis,* which is a typical Norwegian mussel found along the whole coast of Norway, has been observed to grow in large numbers, covering the rocks along the coast of southern Norway (E. Oug per. obser.). This phenomenal has also been observes in the Tromsø area, where the rocky shorelines are covered in large numbers of very small individuals mussels. Another examples of recruitment appearing in pulses, are the huge amounts of red slime that was reported by the fishermen from Arnøy, northern Troms this summer (2015). The fishermen reported red slime covering their fishing gear this fall. The red slime is now believed to be jellyfish in large abundance (www.imr.no). This has never been seen before in this large quantities. The vast bloom of this jelly fish was so enormous that it was spotted on an echo sounder covering large areas near the sea floor bottom. Why this bloom has occurred and what consequences this large biomass of organic material will have on the bottom fauna in these area is very uncertain.

Competition is another biological factor that can also influence the number of individuals. Environmental disturbance in an area which may alter the species composition dramatically. Opportunistic, fast growing and short lived species are known to colonise areas that have been disturbed (Dolbeth et al., 2011).

We know that there are long-lived and short-lived benthic species. Most of the polychaetes are short-lived, not more than 3 years (Britaev et al., 2002), and will probably respond to short- term ecological changes faster than more long lived species.

Since polychaetes are easily affected by ecological changes they could be used as environmental markers. In polluted areas with high concentrations of organic matter, opportunistic and pollutant tolerant species like *Hetermastus filiformis, Chaetozone setosa* and *Cossura longocirrata*. are known to dominate the infauna. (Larsen, 1997; Rygge, 1997; Holte and Oug, 1996; Holte, 2005). Dominance of opportunistic taxa have also been seen in Alaksa, were a long-term study investigated the influence of ballast water dispersal on benthic faunal structure (Blanchard et al., 2002). Since there has been a decrease in numbers of the small species like *H. filiformis* and *C. setosa* at Svartnes from 1994 to 2013, this might be explained by pelagic-benthic coupling and that very little of the production has reached the bottom fauna.

The seasonal effect is also a factor in species assemblage and density. To investigate the seasonal effect, samples need to be collected throughout the year, which was not the case in my study. However, Oug conducted in 1994 a seasonal sampling effort to check for seasonal changes, but no particular patterns of seasonality was observed (Oug, 2000).

Possible effects of red king crab invasion

Varangerfjorden in 1994 show that the invasive red king crab reduced the soft bottom fauna, especially echinoderms, molluscs and burrowing polychaetes (Oug et al., 2011). Both Varangerfjorden (Oug et al., 2011) and Porsangerfjorden (Fuhrmann et al., 2015) are examples of areas invaded by the king crab have reduced biomass and that small species like oweniidae and maldanidae have increased and now dominated the species assemblage in the area. Due to the observation of red king crab in Balsfjord, Tennes and Ramfjord, we can assume that the same ecological changes found in other invaded fjords like Varangerfjorden and Porsangerfjorden will also be expected in Balsfjord if the invasion persists.

In the event of a red king crab invasion we should expect to find a reduction in the larger taxa of polychaetes and an increase in the smaller taxa. Species richness and diversity would also be expected to decrease under an invasion, like what has been observed in Varangerfjorden (Oug et al., 2011) and Porsangerfjorden (Fuhrmann et al., 2015).

It is now widely accepted that invasive species are one of the direct causes of biodiversity losses. But the question is whether the invasive species takes opportunistic advantages of ecosystem changes, such as habitat disturbance instead of being the driving force of change themselves (Didham et al., 2005). The red king crab is opportunistic and feeds on the most abundant prey items. From the studies carried out in Varangerfjord (Oug et al., 2011), Porsangerfjord (Fuhrmann et al., 2015) and Alaska, Kodiak Island (Jewett and Feder, 1982) the red king crab food items are area specific, were it feeds on the most abundant prey. Since the most abundant food item in Balsfjord is echimoderms (Figure 4 and 8) such as the mud star *Ctenodiscus crispatus* and brittle stars *Ophiura,* it is safe to assume that if an invasion persist this species will be reduced in biomass.

Only the establishment of long-term monitoring series can give us the answers if changes in an ecosystem are natural changes or driven by environmental changes. When it comes to predicting long-term changes in marine benthic communities one needs to take into account the cyclic changes that also occur (Gray and Christie, 1983). And especially in the case of an invasion of the red king crab that has been personally observed in the fjord, it is more important than ever to follow up the long-term series Oug has started. With this long-term series that already is in place, there is a unique opportunity for a long-term series that will tell us how the crab alters an ecosystem.

Conclusion

Based on the results from this thesis the large gap in the sampling between1994 to 2013, it is difficult to show if the variation in soft-bottom communities in Balsfjord, with particular interest in the Svartnes area, has undergone changes due to natural cycles or if other environmental changes has occurred. However investigating if these variations are natural changes in an ecosystem or if climate change or invasive species has an impact on an ecosystem, it is important to establish long-term series that investigate the whole ecosystem functions. This is now more important the ever when considering the rapid change in climate and all industrial advances that are threatening the ecosystems.

It is also recommend to take sediment samples for carbon and nitrogen measurements in order to see the impact when species that have important biogenetic activity in the sediment are reduced. This may result in poor oxygen supply to the deeper sediment layers. However, only further sampling over time can determine the impact of the red king crab, it is therefore highly recommended to continue the long-term study in Balsfjord.

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Appendix 1

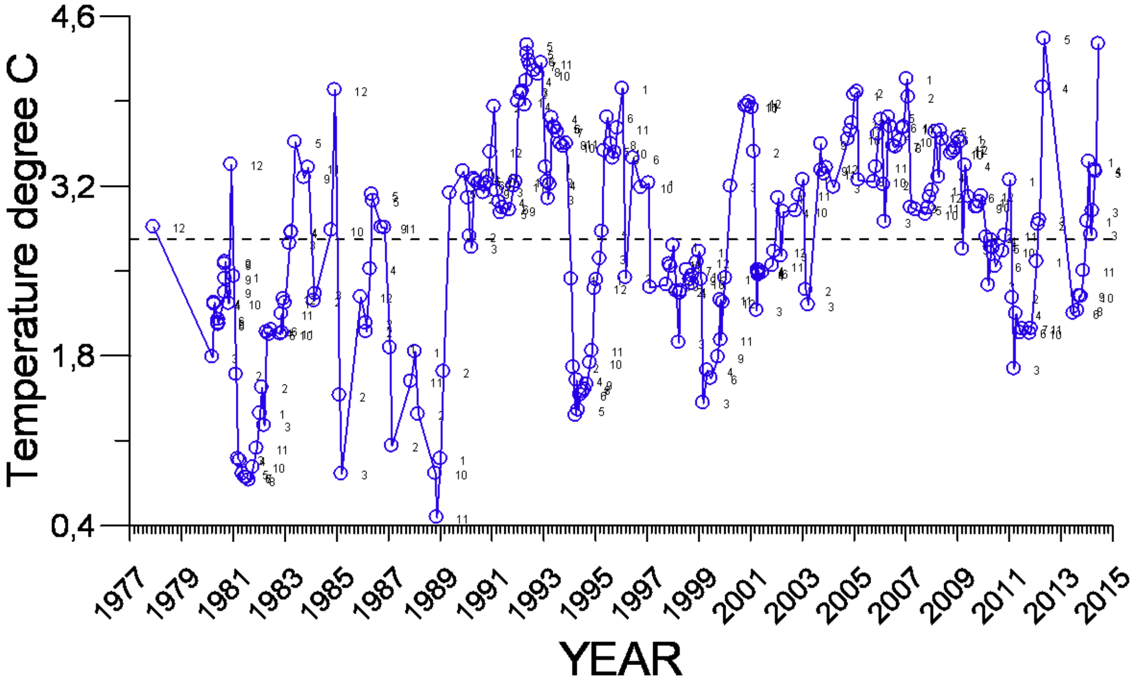

Figure of bottom temperature °C from 1977- 2014 in Balsfjord at Svartnes. Mean bottom temperature indicated by the dotted line. The numbers next to the squares indicate the month.

Appendix 2

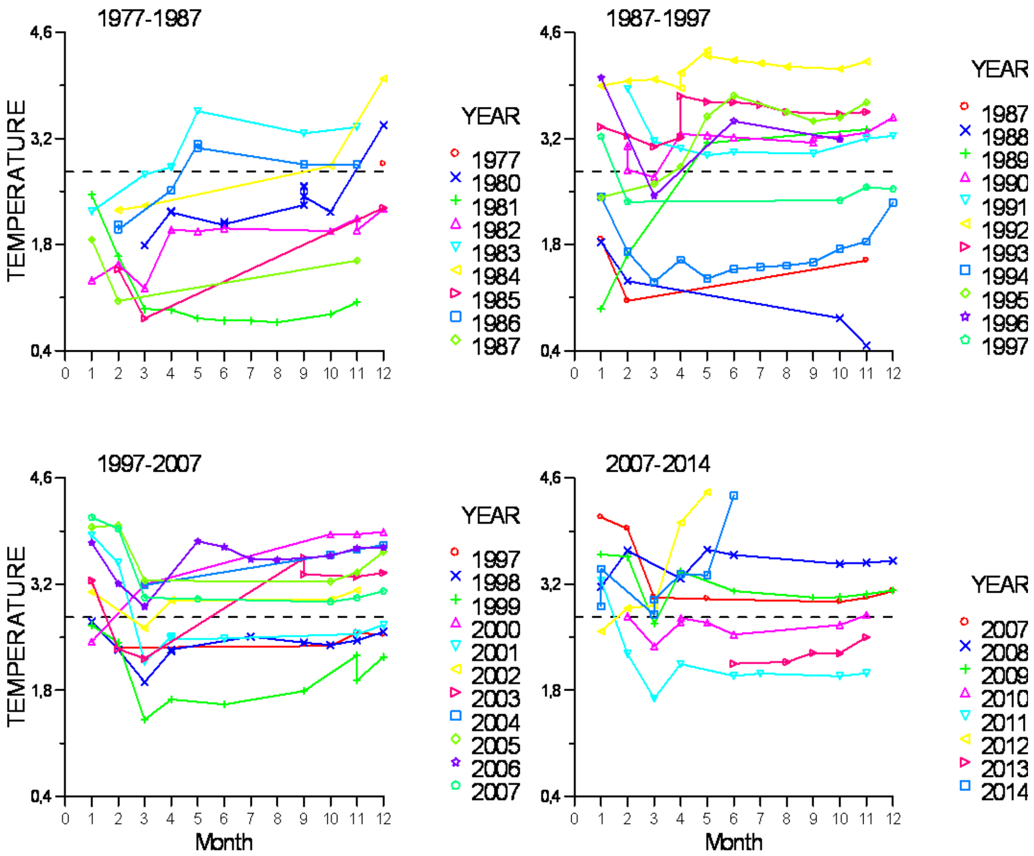

Figure of monthly variation in bottom temperature (°C) in ten year intervals from 1977-1987, 1987-1997, 1997-2007 and 2007-2014 in Balsfjord at Svartnes. Mean temperature indicated by the dotted line.

Appendix 3 Taxa list of numbers of individuals found in grab samples at Andersdal, Svartnes and Tennes in November 2013.

G R A B 2 0 1 3		**No. Individuals Grab**			**Andersdal**	**Andersdal**	**Svartnes**	**Svartnes**	**Svartnes**	**Tennes**	**Tennes**	
Phylum	**Class**	**Family**	**Species**	**Abbreviation**	**GI**	**GII**	**GI**	**GII**	**GIII**	**GI**	**GII**	**SUM**
Nematoda				Nema	1					2	2	5
Cnidaria			Actinaria sp.	Act sp.						1		1
Nemertea			Nemertea	Nematea		1				2	10	13
Annelida	Polychaeta	Polynoidae	*Polynoidae sp.* Kinberg, 1856	Poly sp.						2		2
Annelida	Polychaeta	Eteoninae	*Eteone longa* (Fabricius, 1780)	Ete lon	1	1						2
Annelida	Polychaeta	Nephtyidae	*Aglaophamus malmgreni* (Theel, 1879]	Agl mal		1			1	4		6
Annelida	Polychaeta	Nephtyidae	*Aglaophamus* sp.	Agl sp.	1							1
Annelida	Polychaeta	Nephtyidae	*Nephtys ciliata* (O F Müller, 1776)	Nep cil	1	1	2	4	1		4	13
Annelida	Polychaeta	Nephtyidae	*Nephtys paradoxa* Malm, 1874	Nep par							1	1
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris mixochaeta* Oug, 1998	Lum mix	2	7	1	4		1	1	16
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris* sp.	Lum sp	1							1
Annelida	Polychaeta	Orbiniidae	*Scoloplos (Scoloplos) armiger* (Müller, 1776)	Sco arm		2						2
Annelida	Polychaeta	Orbiniidae	*Orbiniidae* ssp.	Orb sp	2							2
Annelida	Polychaeta	Paraniodae	*Levinsenia gracilis* (Tauber, 1879)	Lev gra		1	1	2				4
Annelida	Polychaeta	Paraniodae	*Paranoidae* sp.	Par sp	5							5
Annelida	Polychaeta	Spionidae	*Polydora* sp.	Polydora sp						2		2
Annelida	Polychaeta	Spionidae	*Prionospio cirrifera* Wirén, 1883	Pri cir			1	1				2
Annelida	Polychaeta	Spionidae	*Prionospio* sp.	Prio sp.		2				1	7	10
Annelida	Polychaeta	Spionidae	*Spiophanes kroyeri* Grube, 1860	Spi kro	1							1
Annelida	Polychaeta	Spionidae	*Spiophanes* sp.	Spi sp.		1					12	13
Annelida	Polychaeta	Spionidae	*Spionidae* spp.	Spion spp						3		3
Annelida	Polychaeta	Cirratulidae	*Chaetozone setosa* Malmgren, 1867	Cha set	7	6	2	2	2	2	7	28
Annelida	Polychaeta	Cirratulidae	*Chatezone* sp.	Cha sp.		1						1
Annelida	Polychaeta	Capitellidae	*Capitella capitata* (Fabricius, 1780)	Cap cap						3		3

Appendix 3 (continue)

No. Individuals	(continue)				**Andersdal**	**Andersdal**	**Svartnes**	**Svartnes**	**Svartnes**	**Tennes**	**Tennes**	
Phylum	**Class**	**Family**	**Species**	**Abbreviation**	**GI**	**GII**	**GI**	**GII**	**GIII**	**GI**	**GII**	**SUM**
Annelida	Polychaeta	Capitellidae	*Capitella* sp.	Cap sp							3	3
Annelida	Polychaeta	Capitellidae	*Heteromastus filiformis* (Claparède, 1864)	Het fil	2	2		2				6
Annelida	Polychaeta	Capitellidae	*Notomastus latericeus* Sars, 1851	Not lac	1							1
Annelida	Polychaeta	Maldanidae	*Maldane sarsi* Malmgren, 1865	Mal sar	234	215	8	31	7	102	132	729
Annelida	Polychaeta	Maldanidae	*Maldanidae* sp.	Mal sp.	26					28		54
Annelida	Polychaeta	Maldanidae	*Praxillella gracilis* (M. Sars, 1861)	Par gra						2		2
Annelida	Polychaeta	Maldanidae	*Praxillura* sp. Verrill, 1879	Prax sp							1	1
Annelida	Polychaeta	Maldanidae	*Nicomache* sp. Malmgren, 1865	Nico sp							1	1
Annelida	Polychaeta	Opheliidae	*Ophelina acuminata* Örsted, 1843	Oph acu			1				1	2
Annelida	Polychaeta	Oweniidae	*Galathowenia oculata* (Zachs, 1923)	Gal ocu	27	29	8	40	5	139	83	331
Annelida	Polychaeta	Oweniidae	*Myriochele heeri* Malmgren, 1867	Myr hee	13	2		7	2	11	9	44
Annelida	Polychaeta	Oweniidae	*Owenia fusiformis* Delle Chiaje, 1844	Owe fus	4	3						7
Annelida	Polychaeta	Oweniidae	*Owenia* sp.	Owe sp.					5			5
Annelida	Polychaeta	Pectineriidae	*Pectinaria (Cistenides) hyperborea* (Malmgren, 1866)	Pec hyp	1	2			1			4
Annelida	Polychaeta	Ampharetidae	*Ampharetidae* sp.	Amp sp	3	6	8	2	4	5	4	32
Annelida	Polychaeta	Trichobranchidae	*Terebellides stroemii* Sars, 1835	Ter str	9	15	7	4	7	4	7	53
Annelida	Polychaeta	Terebellidae	*Artacama proboscidea* Malmgren, 1866	Art pro			4	2	0			6
Annelida	Polychaeta	Terebellidae		Ter sp	4	14		1		12	5	36
Annelida	Polychaeta	Sabellidae	*Euchone papillosa* (Sars, 1851)	Ech pap			1			1	3	5
Annelida	Polychaeta	Sabellidae	*Euchone* sp.	Euc sp.		2						2
Annelida	Oligichaeta	Sabellidae	*Tubificoides cruspisetosus* Baker 1983	Tub cru	0	0	1	0	0	0	0	1