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Faculty of Biosciences, Fisheries and Economics

Department of Arctic and Marine Biology

Do diet of long rough dab (*Hippoglossoides platessoides*) differ between fjords with and without red king crab (*Paralithodes camtschaticus*)?

A study of summer diet

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BIO-3950 Master thesis in Biology May 2017

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Front page photo of long rough dab at lab

by Kristoffer Kiærbech.

Abstract

The purpose of this study is to describe the diet of long rough dab in three different fjords with and without red king crab. The hypothesis is that red king crab are influencing the diet and possible also growth of long rough dab. By the applying objectives it is assumed to give an answer to if red king crab is influencing different aspects of the diet and growth in long rough dab.

By the applied frequency of occurrence and weight % analyses there were found small differences in the long rough dab diet. There was a dominance of different Crustacea and some Polychaeta prey groups. The main differences between the fjords was high dominance by fish, Bivalvia and Pandalidae in Porsanger, and little dominance of fish and Bivalvia prey groups in Balsfjord. A diet shift with increased predator length were recognized in both Balsfjord, Kvænangen and Porsanger long rough dab diet. The shift in Balsfjord were from a Crustacea dominance to Polychaeta and Crustacea dominance. Kvænangen with the opposite result. Porsanger having the most diverse diet in regard to prey groups contributing to the energy budget. The diet shift is towards a more fish and Pandalidae dominated diet.

There were found small differences in growth in the three populations of long rough dab, with Porsanger material being in slightly better condition. There is by this study not found indication of an impact of red king crab on diet and growth in long rough dab. Though there is assumed that the low size of the cod stock in Porsanger, might let the long rough dab to include more fish and Pandalidae into their diet. This is relative high energetic prey which might held the growth rate up in a situation where the ecosystem are in change. In a situation with a large cod stock in a fjord area, there might possible be a larger influence of red king crab on the diet and growth in a population of long rough dab.

Keywords: Long rough dab, *Hippoglossoides platessoides*, diet, growth, red king crab influence.

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Tromsø, May 2017

Kristoffer Kiærbech

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1 Introduction

Long rough dab (*Hippoglossoides platessoides*) is a common demersal fish species along the Norwegian coast and the Barents Sea. By biomass it is recognized as one of the 10 most abundant species in the Barents Sea (Walsh 1996).

Long rough dab and red king crab (*Paralithodes camtschaticus*) are both species where it is a considerable knowledge on diet (Klemetsen 1993, Mikkola 1996, Fuhrmann et al. 2017), and population dynamics (Walsh 1996, Jørgensen & Nilssen 2011), and for the red king crab also its impact on benthic communities (Jørgensen & Nilssen 2011, Oug et al. 2011).

The red king crab which is native to the north Pacific is a large invertebrate species. In its native area, it has been an economic important species. For a long time, Russian scientists thought of introducing the crab to the Barents Sea for fishery purpose. First attempts to establish red king crabs in Barents Sea in the 1930's failed due to challenges under the transport (crabs that not survived the transport) (Pinchukov & Sundet 2011, Christiansen et al. 2015). However, during the 1960' and 1970's Russian scientists made new attempts on introducing the red king crab to the Barents Sea (with crabs from Okhotsk Sea) for fishery purposes (Jørgensen & Nilssen 2011, Christiansen et al. 2015). This time they sampled high numbers of all life stages of the crab from Peter the Great Bay in Okhotsk Sea, and transported them to Murmansk at Kola Peninsula where they were released (Jørgensen & Nilssen 2011). For a long time, decades, the stock of the crab were low. After years of acclimation to the Barents Sea condition the stock increased and spread out. Areas from Cape Kanin in the east to North Cape in Norway where "soon" reached (Jørgensen & Nilssen 2011). In Varanger-fjord, the area in Norway where the crab has been longest, it has been performed studies at benthos communities to investigate how benthos communities were affected by the crab. The short answer is that there where a change to smaller and thinner, larger and more active species, and sediment changes were also registrated (Oug et al. 2011).

These changes in the benthic invertebrate community give rise to questions about whether the diet of benthic fishes are affected. This study is investigating the diet to the flatfish long rough dab from three fjords. Porsanger-fjord which have had high densities (stock size estimated to 531 773 individuals in 2010) and presence of the crab for the longest (Fuhrmann et al. 2015), Balsfjord which has had very low densities of the crab, and Kvænangen also with low density of crabs (2017 E. Nilssen, UiT, pers.comm).

1.1 Description of long rough dab (taxonomy, distribution, life style stocks)

Long rough dab (*Hippoglossoides platessoides*) is a species in the flounder family, Pleuronectidae. Ecologically, the long rough dab is one of the species of flatfishes contributing to the flux of energy through the food web (due to its biomass and part of other fish species diet) (Klemetsen 1982, Klemetsen 1993, Walsh 1996, Kolsum 2011).

Long rough dab is an arcto-boreal, right-eyed flounder species. It is a common and widely distributed species inhabiting shelf waters on both sides of the North Atlantic between 42 ^{o} N and 80 ^{o} N (Walsh 1996). From Cape Cod (41^{o}41N, 70^{o}12W), Labrador and Newfoundland in west/south west, long rough dab is found up to 70 ^{o} N at both sides of Greenland, via Svalbard to large parts of the Barents Sea. Long rough dab is found along the coastline of Norway, the North Sea, Skagerrak, English Channel and at Faroe Islands. In Barents Sea and in north Norwegian fjords it very abundant (Klemetsen 1993, Mikkola 1996, Walsh 1996). With an estimated biomass of 150 000 – 200 000 tons in the Barents Sea, it is the fifth largest fish species according to biomass in that area (Walsh 1996).

The literature divide the species in two subspecies according to which part of the distribution area they inhabit. *Hippoglossoides platessoides platessoides* (Fabricius) inhabit the north-east coast of North – America, while *Hippoglossoides platessoides limandoides* (Bloch) inhabit the coast of north west coast of Europe including the Barents Sea (Mikkola 1996, Walsh 1996).

1.2 Feeding ecology of long rough dab.

Pleuronectids in general are demersal fish. Their feed on a wide range of prey including fish and invertebrate benthos like polychaetas, crustaceans, molluscs and echinoderms (Klemetsen 1993). Some species are more generalized predators, while others are more specialized predators. Long rough dab is considered as a generalized predator feeding on a wide range of prey groups throughout the year (Klemetsen 1993, Mikkola 1996). Echinoderms, crustaceans (especially Euphausiidae, Isopoda, different shrimps like *Pandalus* sp.), both Sedentaria and Errantia Polychaeta, molluscs (especially Bivalvia) and some fish is part of the diet (Lande 1976, Klemetsen 1993, Ntiba & Harding 1993, Mikkola 1996). The amount of fish included in the diet of long rough dab differ considerably between areas (Lande 1976, Klemetsen 1993, Ntiba & Harding 1993, Mikkola 1996).

The diet of long rough dab is known to change from place to place, throughout the year and between the individual fish size (Lande 1976, Klemetsen 1993, Ntiba & Harding 1993, Mikkola 1996). From different parts of the North Sea it is known to be dominated by Polychaetes, Echinodermata, fish and to some extant Crustacea. Amphipods, bivalves or Ophiuoridea has been reported as dominating prey (Klemetsen 1993, Ntiba & Harding 1993). In Borgenfjord in Trøndelag a dominance of echinoderms, Mysidae and Bivalvia was registrated (Lande 1976).

The diet of long rough dab may change with size. In Icelandic waters, small long rough dab were found to feed at benthos, predominantly Crustacea, Ophiuoridea and Polychaeta (Palson (1985) cited in Klemetsen 1993). Larger long rough dab diet shifted to Ophiuoridea and fish. A shift towards Ophiuoridea and fish (especially capelin) has also partly been observed in large dab in the Barents Sea (Simacheva & Glukhov (1985) cited in Klemetsen 1993). In Borgenfjord the shift has been seen especially with larger long rough dab preying on larger bivalves than smaller long rough dab (Lande 1976). For the Ullsfjord system, Mikkola (1996) found Crustacea, Echinodermata and Polychaeta as dominating prey in the diet of long rough dab.

Mouth size to the fish increases with increasing size of the fish. With increasing mouth size, the fish get opportunity to consume larger preys (Sharf et al. 2000). This increase in prey size selection by increasing predator length is faster than the elimination of smaller prey sizes already included in the diet of the predator (Sharf et al. 2000). This possibility for a larger predator to choose larger preys might give rise to a difference in diet based on the predator length. It will also give an advantage in an environment where the preferred prey species are changing its size ranges due to heavier or reduced predation from other predators.

The literature points out that depending upon the competitive status in an ecosystem, long rough dab may either be a specialist or more of a generalist feeder (Klemetsen 1993). The realized niche of long rough dab could become more specialized when it inhabits a more diverse community of different demersal fish and large crab species (Lande 1976, Ntiba & Harding 1993). In less diverse communities of demersal fish and crab species where competition is lower, the realized niche of the long rough dab tends to be more generalized (Klemetsen 1993). Balsfjord in the 1970ies was an example of a fjord with only cod (*Gadus morhua*) and long rough dab as abundant demersal fish species, and Klemetsen (1993) found the long rough dab to be a generalist predator. In later years (from 2000 and on) there has been an increase of especially haddock (*Melanogrammus aeglefinnus*) and plaice

(*Pleuronectes platessa*) in the demersal fish community in Balsfjord (Kolsum 2011, 2017 E. Nilssen, UiT, pers.comm.). Fish communities in more open fjords like Kvænangen and Porsanger are some more diverse in respect to abundant demersal fish species (Kolsum 2011). Cod and especially long rough dab are still recognized to be some of the more abundant demersal fish species (Klemetsen 1993, Mikkola 1996, Nilsen et al. 2008, Kolsum 2011, Mc Bride et al. 2016). Due to the low diversity of demersal fish species in Northern Norwegian fjords, it is assumed that long rough dab predate as a generalist predator (Klemetsen 1993). The realized niche of long rough dab should by this be wide or showing a large numbers of prey taxa (Klemetsen 1993).

As a benthic fish species, long rough dab is an important species linking production of benthic and semi-pelagic biomass to predator fish species like cod. As a prey for other fish species it is known to contribute in the diet of cod and haddock (Klemetsen 1982, Mikkola 1996, Kolsum 2011).

There are many ways to perform diet studies on fish (Hyslop 1980). The occurrence method is one simple approach to analyse the diet of a fish species. By counting the number of stomachs with a certain prey taxa, it is possible to calculate the occurrence by percentage either by divide on the total stomach examined (imprecise) or by the number of stomachs with content (more precise) (Hyslop 1980). It give a short picture of what taxa a given fish species prey on. The problem with the occurrence methods is that it do not necessary tell something about what really contribute energetically (Hyslop 1980). Gravimetric methods are often also used in diet studies (Hyslop 1980). Together with isotope analyses of fish tissue it may be used to look at the position of the species in the food web and the flow of energy and matter through the food web (Nilsen et al. 2008). In this study, the prey weight % is used to assess the important taxa in three different fjord systems at a window of time (summer) and possibly influence by presence of the red king crab. Isotope analyses were not applied on the material - of this study.

1.3 Demographics and growth

Similar to some other fish species (i.e. cod – *Gadus morhua*, haddock – *Melanogrammus aeglefinus*), long rough dab in the Barents Sea are migrating south and west-ward for spawning. There may be local stocks of the species in local fjords along the coast where recruitment is predominately local, but some recruitment from the Barents Sea stock is possible (Fossen 1996, Mikkola 1996, Walsh 1996). Many factors are contributing to the growth and recruitment to the different stocks, making each stock or population somewhat different with respect to expected growth rate, maturation, life expectancy and population dynamics (Bagenal 1957, Fossen 1996, Mikkola 1996, Walsh 1996). Food level variability may affect both growth rate and survival (Mikkola 1996, Walsh 1996,). To little food, food with low energetic qualities over time or absence of food in important stages of the fish lifecycle may give lower growth and possible higher mortality. For example, would a high mortality through the larval stages and early juvenile stages give lower recruitment to the adult part of the stock. This would further give lower biomass of the stock due to lower numbers of fish and lower growth rate (Bagenal 1957, Walsh 1996)). Earlier studies have shown that females tend to be larger than males when it comes to maturation. It is also shown for different locations that females grows larger than males (Mikkola 1996). This difference in size when it comes to mature individuals is often referred to that larger individual has space for more gonads than smaller individuals, and would by becoming larger contributing more to next generation of the species (Bagenal 1957, Fossen 1996, Mikkola 1996). To investigate a possible size difference between genders, there were made analyses between genders and fjords.

Fish growth is dynamic. The diet of the fish is related to what type of prey that is in the environment. The environment is dynamic, where changes in the prey species community might give large variability in growth and survival of individual fish. Ultimately, this might be measured as a change in growth (and mortality) at population level. Maturation is also known to impact on further growth rate after maturation (Bagenal 1957, Fossen 1996, Mikkola 1996). Thus, the growth and condition in a population are by this dependent on age, gender, nutrient or preys and season. A study by Mikkola (1996) in the Ullsfjord and Sørfjord systems showed, differences in the expected growth between genders, with females becoming larger than males.

Data on length and weight at age might therefore be used as an indicator on variance in condition between populations or individuals. For this study, information about condition might give information about how different populations of long rough dab grow before, under and after establishment of red king crab.

1.4 Red king crab

The red king crab is native to the northern Pacific from Korea, Japan and Kamchatka along the Aleutian Islands, Alaska to Vancouver Island (Jørgensen & Nilssen 2011, Oug et al. 2011, Fuhrmann et al. 2015). In its native area, the crab is part of the regional ecosystem and share resources with a number of other bottom dwelling invertebrates and flatfishes (Fuhrmann et al. 2017). After its introduction to the Barents Sea (from the Murman coast), the red king crab has taken an invasive species lifestyle. This means a long establishment period (1960's and 1970's), and when adapted to the condition in the Barents Sea region, the stock size went into an explosive growth period. In this period the crab stock both expanded in number of individuals and distribution area (Jørgensen & Nilssen 2011, Matishov et al. 2012).

In the first couple of decades there where a slow increase in the crab population with establishment eastward along the coast and north/northeast ward direction, where the crab first appeared in Norwegian waters in 1977 (Jørgensen & Nilssen 2011, Oug et al. 2011). From 1992 and onward the red king crab established in the Varanger area close to the Russian boarder. With a self-sustaining population in the area it dispersed further into the Varanger area (Oug et al. 2011). In the late 1990's there was a rapid increase in adult crab stock, from around 0.5 million individuals to over 2 million individuals. During the next two decades, the crab invaded new areas further westward along the coast, with catches of crabs as far south as Balsfjord (2016 T. Pedersen, UiT, pers.comm.). Single crabs have been taken further south (Pinchukov & Sundet 2011, Christiansen et al. 2015). Stock size has been estimated to be up to estimated 21 million adults (2003) in the Norwegian zone (Oug et al. 2011, Matishov et al. 2012). Per 2011 (2017) the main distribution of the crab is from Cape Kanin in the Russian part of the Barents Sea to the Loppa/Kvænangen area in Norway. However, the king crab stock is still steadily increasing in numbers and reaches new areas along the coast (Oug et al. 2011).

Becoming a commercially valuable species, there has from 1994 been a fishery after red king crab. The fishery has for long time been regulated in two parts, where the "free" fishing west of Nordkapp had intention to reduce further invasion. East of Nordkapp there has been a quota regulated area (Oug et al. 2011).

As one of the largest marine decapods, the red king crab is known to feed on a variety of benthic epifauna and infauna (Fuhrmann et al. 2017). In the literature, the red king crab is referred to as being a generalist and opportunistic feeder, which might give it advantage in competition with local species (Fuhrmann et al. 2017). Diet studies performed on red king crab show that polychaetas, bivalves, echinoderms as Echinoidea and Ophiuoridea with different size distributions are the chosen food items for the crab (Oug et al. 2011, Fuhrmann et al. 2017). The prey which may be of less importance are very small and thin or large animals with a higher degree of movement (Oug et al. 2011).

Invasive species is on general basis considered to be major threats to local biodiversity, by affecting the ecosystems in unpredictable ways (Oug et al. 2011, Fuhrmann et al. 2017). According to Oug et al. (2011) invasive species might act as habitat modifiers through their activities, like digging for prey items, and by that changing the living condition for the native fauna. The red king crabs structuring of benthic ecosystems are known from Norwegian areas (Oug et al. 2011). In the Varanger and Porsanger areas there are localities which has got a change in species composition where medium and large sized slow moving species like bivalves and others has decreased as a response to crab invasion (Jørgensen & Nilssen 2011, Oug et al. 2011). The size distribution of benthic species diverging to larger active species, smaller and short lived species, and in some cases reducing the size of already present species (Oug et al. 2011). Species performing different functions in the sediment (e.g. sediment digging, sediment "cleaners" or eater, predators) are observed disappearing (Oug et al. 2011, Fuhrmann et al. 2017). The structure of the benthic ecosystem has changed to ward lower biomass of benthic invertebrates, while the production may have been less affected (Fuhrmann et al. 2017).

The change in biodiversity and size range of prey may affect the diet in for example long rough dab to favorize prey species/individuals with lower and/or higher sizes because of the elimination of the prey sizes of benthos species preferred by the crab. The medium sized prey for long rough dab become less important due to less individuals of these species. To summarize the factors that affect prey size in flatfish: predator or fish length, prey size distribution in environment (either as a consequence of predation by other species or naturally dynamics of the different populations of prey) (Oug et al. 2011).

1.5 Objectives and approach

To sum up. As mentioned the red king crab do perform ecological structuring of benthic ecosystems. Long rough dab is flexible in respect to prey choice, and in a scenario where red king crab is present in high densities, changes in diet and growth of long rough dab may be expected. Expectation 1: the preferred size range of prey for long rough dab would include high numbers of small sized and large sized preys (not to the extent that it eat larger preys than the red king, but more of for instance active benthos species which move around fast), and lower numbers of medium sized preys because the red king crab is expected to structure the benthic ecosystem to be composed of smaller sized species by predation. Expectation 2: due to the flexibility of long rough dab niche there may be a change in diet from benthos to more (epi)pelagic and fish fauna. Expectation 3: the growth rate is dependent on prey choice, and if expectation 1 is the case the growth rate may be lower in the presence of high abundance of red king crab. If expectation 2 is true there may be a lower if any drop in expected growth rate, because the long rough dab might end up eating prey organisms like shrimps or fish with enough energy to sustain the growth.

The expectations give rise to this study's objectives which are to test if; i) diet of long rough dab differ between fjord systems with and without red king crab, ii) long rough dab prey on smaller prey in areas with red king crab, iii) there are a change in diet with increasing predator length, iv) there are differences in growth rate in fjords with red king crab and without red king crab.

In the diet part, both frequency of occurrence and weight % of taxa will be estimated to investigate which taxa are present in the diet and which taxa are energetically important (making an influence in the flow of energy). Analyses of prey to predator weights ratios is performed to answer to objective ii) if long rough dabs prey choices is influenced by the presence of the red king crab. As part of growth rate investigation, a length at age comparison between areas and between genders will be made.

2 Material and Method

2.1 Materials and area of sampling

The sampling of long rough dab was performed in June 2015 for Balsfjord and Kvænangen fjords and in August 2015 for Porsanger fjord, on board research vessel Johan Ruud (Table 1, Figure 1, 2, 3). A shrimp trawl were used, with a trawl time ca 30 minutes (Table 1).

The catch was sorted into species and long rough dab in various categories were picked out, small (less than 20 cm), medium (20 – 30 cm) and larger (over 30 cm) sizes to get a representative material from all length groups with respect to diet. Fish samples were put in bags with five to 20 individuals in each bag, marked with given station name and total content of fish, dated and frozen at – 18 ^{o} C.

Table 1. Stations information together with number of long rough dab sampled during field work. UTC: standard time zone (Universal time), local time is UTC + 1 (standard) UTC + 2 (summertime). Numbers of fish is the amount of fish picked out to this study (the total number of fish on board RV Johan Ruud would therefore be higher than the numbers used in the table).

Area	**Station**	**Date**	**UTC**	**Latitude**	**Longitude**	**Depth (m)**	**Number of fish**
Balsfjord	Tennes	22.06.2015	10:10:06 – 10:43:06	69º 19.3712N	019º 22.4002E	118.63 - 120.48	**40**
Balsfjord	Svartnes	22.06.2015	08:47:15 – 09:13:39	69º 21.8187N	019º 04.9272E	179.99 - 181.99	**38**
Kvænangen	Spildra	24.06.2015	07:43:48 – 08:18:21	69º 58.8004N	021º 34.2773E	196.98 - 201.48	**5**
Kvænangen	Skorpa	24.06.2015	09:03:42 – 09:37:21	69º 54.3105N	021º 41.2827E	180.67 - 184.63	**72**
Porsanger	Sandholmen	21.08.2015	12:23:42 – 12:50:09	70º 26.0009N	025º 19.4915E	124.47 - 133.22	**49**
Porsanger	Auskarholmen	21.08.2015	08:24:21 – 08:53:06	70º 20.7287N	025º 14.6479	169.77 - 171.52	**12**
Porsanger	Brenna	21.08.2015	10:46:57 – 11:22:39	70º 32.0952N	025º 36.3521E	200.38 - 203.73	**9**
Porsanger	Reinøy	21.08.2015	07:09:33 – 07:45:21	70º 18.3348N	025º 16.5422E	69.53 - 97.77	**28**
Sum							**253**

The North Norwegian coastline is characterized with large and deep fjords, which often has sills at different depth. Some fjords have more than one sill, making the hydrography more complicated (Larsen 1997). For this study Balsfjord, Kvænangen and Porsanger fjords has been the source of the material.

Figure 1. Map of Balsfjord. Green marking = Tennes, red marking = Svartnes. (Map view from www.Norgeskart.no, station and aquaculture markings made in paint).

Figure 2. Map of Kvænangen. Green marking = Spildra, red marking = Skorpa, yellow marking = areas with periodic organic input from aquaculture (http://www.fiskeridir.no/Akvakultur/Registre-og-skjema/Akvakulturregisteret).

(Map view from www.Norgeskart.no, station and aquaculture markings made in paint).

Figure 3. Map of Porsanger, black marking = Brenna, grey marking = Sandholmen, red marking = Auskarholmen and green marking = Reinøy. (Map view from www.Norgeskart.no, station and aquaculture markings made in paint).

Balsfjord is around 60 km long and is oriented in a south-east direction from Tromsø (Figure 1). It has a complex sill depth of 35 m (with further shallow sills in Tromsøysund and Sandesund) and a maximum depth in the fjord of 195 m (Klemetsen 1993). The deep water of the fjord is colder than the coastal water along the coast outside the fjord. Below cm 50 m depth, there are small variations in temperature, with annually deep water temperature normally below 5 ^{o}C (Klemetsen 1993). The fjord has large areas of deep water floors sustaining different communities of especially soft bottom benthos. Until 1984 there were a fishery after shrimps in the fjord. After shrimp fishery were closed there has been a slight increase in biomass and size of Pandalidae species (Hopkins & Nilssen 1990). Cod is together with long rough dab, haddock and plaice the most common demersal fishes in Balsfjord.

Kvænangen is a subarctic fjord system with a length at 80 km (depending on the reference). It is oriented in a northwest – southeast direction. A number of smaller fjords contribute to the exchange of water to the main fjord. As for the Porsangerfjord, Kvænangen has a deep outer sill at 200 meter. This make the outer fjord basin more influenced by the coastal current than the inner basins of the fjord. The islands Spildra and Skorpa is placed in this outer fjord basin, were the stations are placed close by (Figure 2). Further inward there are two shallow sills at 7 meter and 3 meter giving rise to two smaller basins with lower temperatures. The innermost basin get covered with ice each winter due to high runoff of fresh water and limited exchange of water with the outer basins (Larsen 1997). Larsen (1997) found that Kvænangen benthos community is dominated by annelids, specially polychaetes. The fjord has good environment, except for some influence for aquaculture in some areas (http://www.fiskeridir.no/Akvakultur/Registre-og-skjema/Akvakulturregisteret). Aquaculture farms marked in Figure 2.

Porsangerfjord is a subarctic fjord system which is one of the largest fjords in Finnmark (Figure 3). The fjord has a slightly warmer, deeper outer part and a colder deeper inner part with a number of smaller and larger islands separating these two parts (Fuhrmann et al. 2017). While the outer section has a subarctic and boreal species composition, the inner part sustain more typical cold water and arctic species. The red king crab was established in Porsangerfjord around 2000, and from 2008 there has been a fishery for the crab. After the decline in the local cod stock in 1990's, the crab fishery has become the most important source of income for the fishery (Fuhrmann et al. 2017). Now the entire fjord system sustain a quota-regulated fishery with after the red king crab yielding around 450 tons annually (Fuhrmann et al. 2017).

2.2 Laboratory procedures

The analyses in the laboratory where done during autumn 2015, spring and autumn 2016 and January 2017. In the laboratory the fish samples where thawed in cold water with some ice to reduce degradation of stomach content. To minimize degradation of stomach content, small number (up to 8 fishes), where thawed simultaneously. Each fish were length measured to nearest half cm total length (Figure 4), and weighted to the nearest 0.1 gram.

The stomach where dissected out by cutting at the pharynx and at the pyloric caeca (Figure 5). More stomach information is given in section 2.2.2.

The sex of each individual fish were determined by inspecting the gonads, and the maturity stage was assessed (Table 2). For more details about sex determination, see section 2.2.1. The otoliths were dissected by cutting the skull open over the brain region. The otoliths which are positioned below and slightly behind the brain were taken out, and cleaned in lukewarm water. The otoliths were stored in small vials with ethanol (70%) and marked the same station name and number as the individual fish it come from. Section 2.2.3 gives more detailed information about work on otolith.

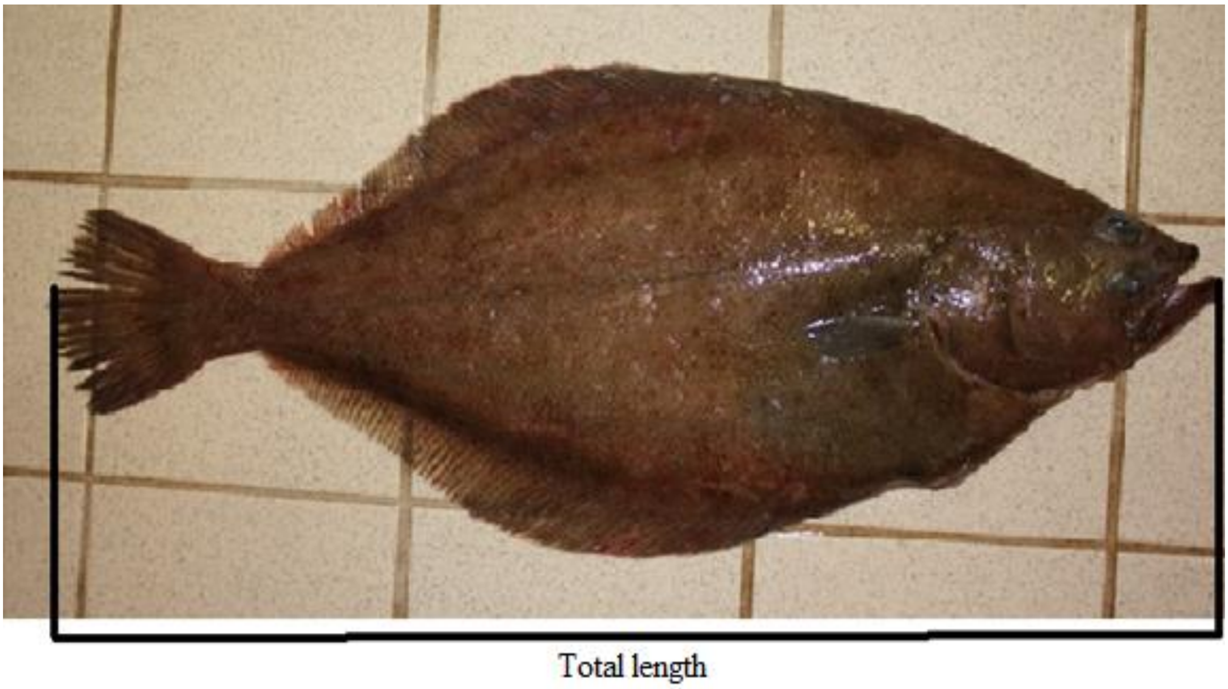

Figure 4. Total length measurement on long rough dab.

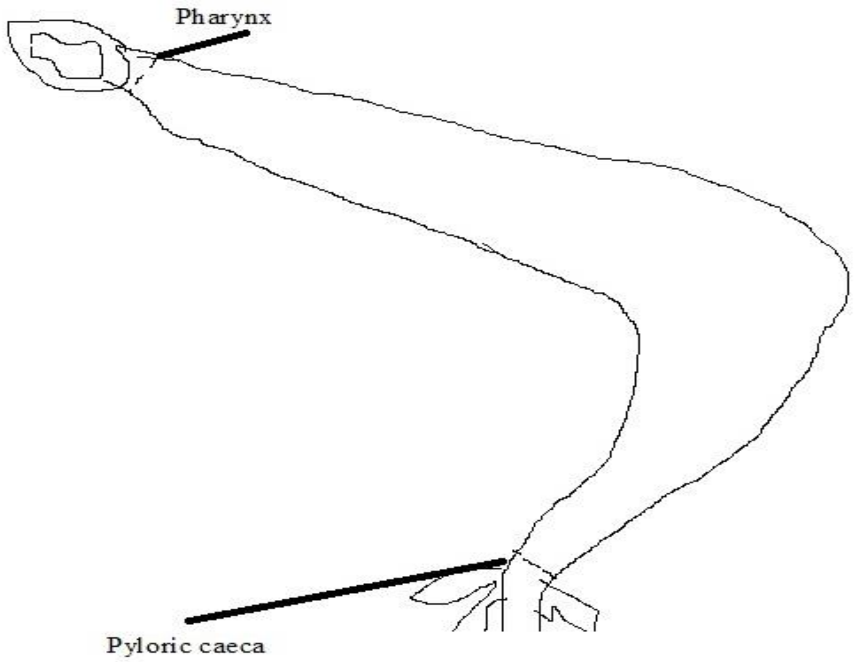

Figure 5. Description of dissection of the stomach from the rest of the digestive system.

2.2.1 Gender and maturation

From earlier work on long rough dab done by Mikkola (1996) and others there is a standard stage description for determining maturity on the species, and this table with code, stage and description was used as a base for identification of maturity staging (Mikkola 1996). The stages were numbered from 0 – 5, where 0 is describing a non-determined individual while 4 is spawned. Stage 5 was seldom used, but as described in Table 2, this stage was used when there was uncertainty between stage 1 – 4.

Gender and maturity were assessed by visually inspecting the gonads. To find the gonads, the fish was sectioned along the “ventral” fins from anus and back to tail fin. This opened up the abdominal cavity where the gonads are placed. It might be difficult to find the individual fish gender, especially on immature individuals. On maturing and spawning individuals it is easier either because eggs or sperms are running after a light touch at the abdomen or by the inspection of colour of the gonads. Females typical have orange to red coloured gonads, while males have white coloured gonads.

The female ovary runs from anus, alongside the abdominal cavity in the direction of the tail fin. In small and immature females the ovary is small, and often transparent threads extending backward to the tail. The males has two small testes laying in the back of the abdominal cavity. In males smaller than 12 cm, the testes appear as thin treads which are difficult to discover (Mikkola 1996).

Table 2. Description of maturity stages. After Mikkola (1996).

Code	Stage	Description
0	Not determined	
1	Immature	The gonads are small. Not visible egg/sperm
2	Maturely	The gonads are bigger in volume. Egg/sperm sac may be visible, but not running
3	Spawning	Gonads are running. Small pressure on the abdomen and egg/sperm are running
4	Spawned	The gonads are small, relaxed and bloodshot. Regenerating starts, gonads some bigger and fuller than stage 1.
5	Unsertain	Only used if uncertainty between stage 1 and 4

2.2.2 Stomach measurements and identification of stomach content

Three measurements on stomach weight were taken. Total stomach weight were found first and is the weight of the stomach and its content. The total weight were measured to the closest 0.1 gram. Thereafter, the content of each stomach were weighted. This measurement where calculated as the sum of each prey group weight found in each individual stomach. The total empty weight of the stomach content where measured to the nearest 0.0001 gram due to measurements of the different preys were performed on a very precise weight. Empty stomach weight were calculated as: the total stomach weight minus the weight of the stomach content. Due to the precision level of stomach content weight, the weight of the empty stomach were to the nearest 0.0001 gram.

The stomach was opened with a scissor section from the pharynx section to the pyloric ceca section (Figure 5).

The stomach content was then identified down to the lowest taxa possible. For some prey, family were the lowest taxa. For other prey it was possible to identify prey to species level. For each prey taxa found in a stomach, the number of individuals of that taxa, the size of each individual in that taxa present (to the closest mm), weight of the taxa, and digestion level where written on prepared sheets with information on the other measurements on the fish. The krill (Euphausiidae) group were either categorized as small krill (*Thyssanoessa* sp) or krill, but might in fact consist of three species. Due to the advanced level of digestion on much of the krill material it was decided that it was best to have only one group of krill in the further analyses, Euphausiidae. After working through the stomach content, the content where put in vials with 70 % ethanol. Each stomach sample where marked with fish number, station, date of station sampling. Some parasites were found in some stomachs and then were stored in vials with ethanol for identification by parasitologists.

Table 3. Code for identification of degree of digestion on prey in the stomach of long rough dab. After Mikkola (1996).

Code	**Stadium**	**Description**
0	Not observed	Empty
1	Fresh	Digestion not visible
2	Some digested	Digestion started, species still easy to identify
3	Half digested	Prey still in one part. Proceeded digestion, species difficult to identify
4	Almost digested	Difficult to identify, at the best to group looking at connected bodyparts or eyes
5	Digested	The content is unidentified. Identification at the best to phyla

2.2.3 Otolith sampling and reading

After opening of the skull at least one, if possible two otoliths where sampled from each individual fish. For otolith reading, the otoliths were placed in small petri dish and placed under the stereomicroscope. The magnification were moved manually, with only light from below the otolith. This give a shadow over the otolith, which make it easier to read of the structures in the otolith (Figure 6). Wide opaque summer zones and narrow translucent (light coloured) winter zones (Figure 6) were often visible. Birthdate were set to 1 January, but birth (hatching) is mainly April to May in northern Norwegian fjords and Barents Sea (February to August in the total distribution area) (Fossen 1996). The age of the individual fish was determined by counting the number of the transparent winter zones (Rollefsen 1933). The otoliths were stored in small vials with etanol and given the same name and number as the individual fish it come from.

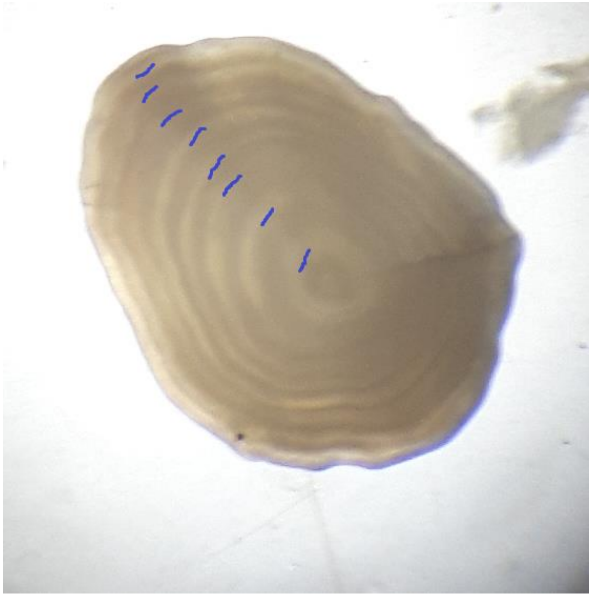

Figure 6. Otoliths from Long rough dab. Blue marks: winter zones. In this otolith, there are 8 winter zones, which make this long rough dab 8 years old.

2.3 Statistical analyses

All numerical data sampled on the laboratory where punched in Excel sheets. From each individual, information about sampling area, station and date for sampling, length, weight, stomach weights, prey items with weight, length, number and digestion degree, and the individual fish's age and number of otoliths sampled from each fish. To ease the statistical analyses process, the original taxa were grouped into larger categories. For the length, weight and age distribution of the material from the different fjords, the raw Excel file was the main input.

To make use of the length of each individual prey, for each long rough dab each prey item got its own line (prey record) in one Excel sheet. Prey records could with lack length measurement on an individual prey item, and have more than one individual prey within the same category. For each prey recording, an average weight per individual prey were calculated for prey weights based on several individuals.

For statistical analyses on the data, the statistic program Systat (version 2013) where used. Excel were also used for making some figures and tables.

2.3.1 A) Frequency of occurrence of prey taxa

One Excel sheet were made to calculate frequency of occurrence and present – absent prey data for multivariate analyses. Information about each individual fish with its prey item were plotted. To investigate if frequency of different taxa differed between fjords, the lowest taxa possible were used. Each time one individual fish had eaten for instance an Oweniidae (or other taxa in this family) it got the number 1 (present). For all other taxa which the individual fish did not eat got the number of 0 (absent). Based on this a figure with frequency of overall taxa in a fjord were made.

Frequency of occurrence (FOC %) was calculated as (%) (Equation 1): (Number of stomachs with a given taxa in the fjord / Number of stomach with content in the same fjord) * 100. Due to low frequencies of many taxa and for the possibility to compare frequency of occurrence with weight %, the taxa in frequency of occurrence were also grouped according to the 13 taxa used for weight analyses (info about 13 taxa in 2.3.1 B).

Frequency of occurrence were compared as: the overall frequency of prey taxa in the fjord, and as frequency of occurrence within the length groups 10 – 19 cm, 20 – 29 cm and 30 – 39 cm. Frequency of occurrence was calculated each length group as (Equation 2): (Number of stomachs with a given taxa in the given length group in the fjord / Number of stomach with content in the same length group in the same fjord) * 100.

For all frequency of occurrence calculations empty stomachs were excluded (Hyslop 1980).

2.3.1 B) Stomach content, weight of taxa

Due to low weight and frequency of many taxa, the number of taxa were grouped into 13 main prey groups for the prey weight analyses for the different fjords. The 13 groups used for frequency of occurrence and weight comparisons: <u>others</u> (including Edwardsiidae, *Ctenodiscus crispatus*, Cumacea, Ophiuoridea, unidentified crustacea and unidentifiable content), <u>Bivalvia</u> (including *M. baltica*, *Yoldiella* sp., *Yoldia* sp. and *Chlamys islandica*), <u>Anelida Uid</u> (including all polychaetes which were too degraded to be classified otherwise), <u>Polychaeta Sedentaria</u> (including Terebellidae, Ampharetidae, Trichobranchidae, Capitellidae, except for Oweniidae), <u>Polychaeta Errantia</u> (including Orbiniidae and Syllidae), <u>Oweniidae</u> (including unidentified Oweniidae, *Owenia* sp., *Myriochele* sp. and *Galatownia* sp.), <u>Other fish</u> (including flatfish, capelin and other fish), <u>Stichaeidae</u> (including primary *Lumpenus* spp. and *Leptoclinus* sp.), <u>Mysidae</u> (identification only to group Mysidae), <u>Euphausiidae</u>

(including *Thysanoessa* spp. and *Meganyctiphanes* sp.), Amphipoda (including *Gammarus* sp., Hyperidae, Amphartidae and other Gammaroidea), Isopoda (including *Idotea* sp., *Idotea granulosa* and *Idotea pelagica*) and Pandalidae (including *Pandalus* sp. and P*andalus borealis*, possibly only one species).

Each fjord were compared with regard to 1: the overall composition of prey taxa by weight % in the fjord, 2: weight % composition at length groups 10 – 19 cm, 20 – 29 cm and 30 – 39 cm.

Weight % of each prey group was calculated as: (Weight of a given prey group in a fjord / Total prey weight in the fjord) * 100.

For comparison of weight % of length groups, was calculated: (Weight of a given prey group in a given length group in a fjord / Total prey weight in that length group in the same fjord) * 100.

Naturally, predators with empty stomach would not contribute to the weight % calculations due to no prey weight input.

The condition (weight at length) of long rough dab in the three fjords were compared. This were done by converting the length and weight to ln(length) and ln(weight) and plotting ln(length) versus ln(weight). Linear regressions (ln(weight)=a + b*ln(length)) of the material from each fjord were calculated, and regression lines were plotted showing the material from the different fjords overlaying over each other to visualize differences between the fjords with regard to condition.

2.3.2 Prey size

In the introduction it was an objective that long rough dab in the Porsanger fjord might be dominated by on average smaller and larger size groups (eg Oweniidae (small), Isopoda (small), Euphausiidae (large), Pandalidae (large), small fish or Bivalvia (intermediate)), while the intermediate prey size group was expected to be less important (many Bivalvia species). A possible change might only be a change in the sizes of the species already present in the fjord. To investigate this the information on the individual prey weight and length were adjusted to take into consideration lifestyle. The prey groups which is thought to be negatively influenced by the red king crab are slow-moving and sessile benthos (and by this influencing the prey size groups in long rough dab diet), which also is known to have some species important for long rough dab.

Prey were categorized into five main lifestyles 1: semipelagic which included Pandalidae and Euphausiidae, 2: fish which included all fish (flatfish, capelin, other fish, *Lumpenus* spp. and *Leptoclinus* sp.), 3: moving active benthos which include Errant polychaetes, Mysidae, Amphipoda and Isopoda, 4: slow-moving benthos including Sedentary polychaetes, Oweniidae, echinoderms and Edwardsiidae, 5: sessile benthos including only bivalves. Unidentified were a sixth lifestyle category, but would in the end come from one of the other groups.

Prey/predator weight ratios were calculated and the frequency of natural logarithm of these ratios ($\log_{10}$(Preyw/Predw)) were plotted for each fjord and main prey categories. The main lifestyle groups used for indicating differentiation in size distribution of preys due to king crab were the slow-moving and sessile benthos and these two groups were lumped into a "super-category" when presented in plots. This category were marked blue in plots to distinguish it from other preys with for instance a semipelagic lifestyle. By plotting the $\log_{10}$ of ration of the weight of prey (Preyw) and predator weight (Predw), the $\log_{10}$(Preyw/Predw) would be expected to be approximately log normal distributed. Prey/predator ratios with a 1/100 size of the predator would get $\log_{10}$ of -2, 1/1000 of predator size $\log_{10}$ would give -3, 1/10000 of predator size $\log_{10}$ of -4 etc. (Degel & Gislason 1988). What prey sizes that are preferred by the predator is species specific, dependent on prey type and might be influenced by which type of potential preys there in the environment. Mainly, the average prey size would probably have a $\log_{10}$ weight of around -3 or -4, which would correspond to about 1/1000 – 1/10000 of the predator weight (Degel & Gislason 1988).

2.3.3 Empty stomachs

To investigate if the proportion of empty stomachs in the material differ between length groups and fjords, Chi-square tests were applied. Material from each fjord were divided in 10 cm length classes. "10 – 30 cm" for all individuals under 20 cm (with the smallest individual being 9 cm), "20 – 30 cm" (for individual size range 20 – 29,5 cm) and "30 +" cm (for individual size range above 30 cm).

The described Chi-square test were also applied to the material without considering different length groups. This were done to investigate if the result would be different from the analyses considering length groups differences. The material were compared between the three fjords. Chi-square test and p – values calculated in a separate Excel sheet, and in Systat.

Chi-square test: a test which intention is to test how likely it is that an observed distribution is due to chance. It will measure how well the observed distribution of data fits with the distribution that is expected if the variable are independent.

2.3.4 Growth

For growth analyses, length at age information is important. Lengths were plotted versus age in graphs. First expected growth for males and females were calculated (in Systat) and showed in figure together with estimated growth rate (line) (length growth) both for males and females in all three fjords. Later there were made a length at age and weight at age plot, only showing overall growth pattern in the three fjords.

Mortality is only touched in this investigation by examining number of age groups present in each fjord. Together with the estimated growth pattern, there might be an indicator for how mortality status is. Calculation is still recommended for more detailed examination of the demographic status.

To look at the growth in another way, von Bertalanffeys growth model (VBGM) were estimated by Systat. Mikkelsen et al. (2016) were used as a guide line for the calculation. The Bertalanffeys model were fitted to the length and weight data with the assumption that growth might be described by VBGM equation: $L_t = L_\infty(1-e^{-k(t-t0)})$. L_t: average length, $L\infty$: asymptotic maximum length, K: von Bertalanffy growth coefficient, t_0: was fixed to 0. Applying nonlinear regression, the data were fitted to VBGM model by Systat.

For growth analyses both individuals with empty and filled stomachs were included.

3 Results

The numbers of individuals differed between the length groups, both within each fjord and between fjords (Table 4). The Porsanger material were larger than Balsfjord and Kvænangen material (Appendix Figure 1 A, B).

Table 4. Number (n) of individuals of long rough dab in 10 cm length interval in each fjord sampled. Number of individuals picked out for this study.

Fjord	10 -19 Cm	20 29 Cm	30 39 Cm	Total nr fish
Balsfjord	13	40	25	78
Kvænangen	30	40	7	77
Porsanger	30	51	17	98

There lowest numbers of empty stomachs where in Balsfjord (Figure 7). There are relatively more empty stomachs especially in Porsanger than in Balsfjord. Based on the total stomach material the proportion of empty stomachs differed significantly between the three fjord systems (Pearson Chi Square 12.589, p = 0.002) (Figure 7).

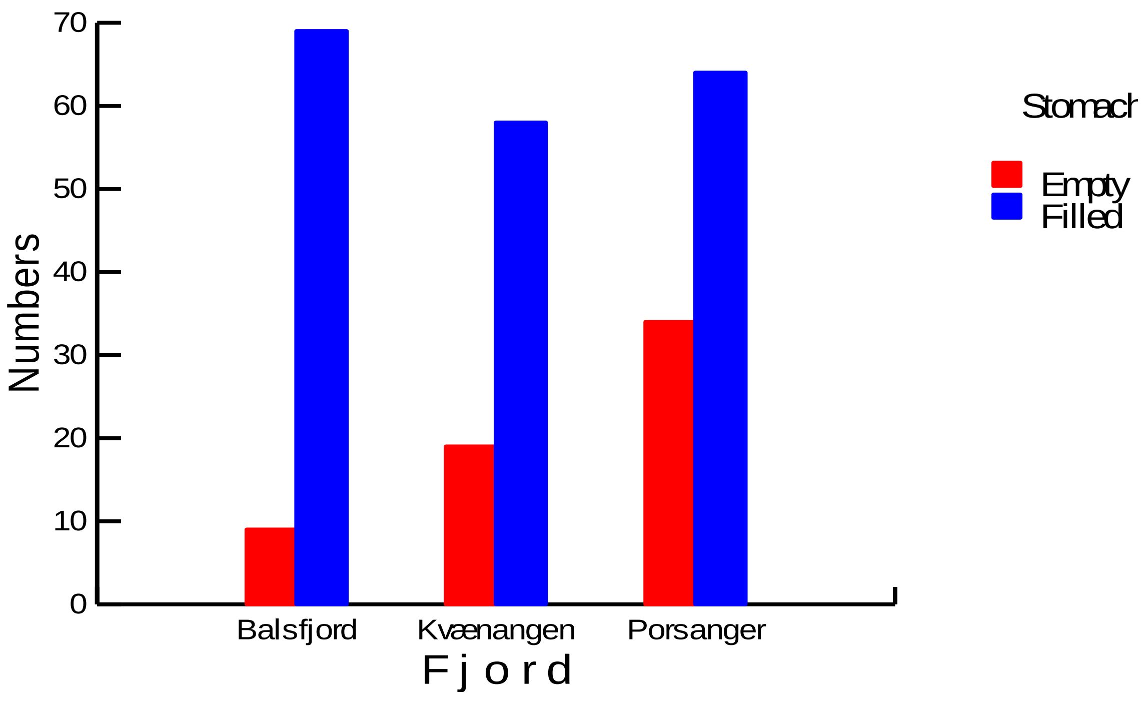

Figure 7. Empty and filled stomachs in the material from the three fjords sampled.

It was tested if proportion of empty stomachs differed between length interval within fjords. There were found to be no significant differences in numbers of empty stomachs between different length groups in the different fjords. A hypothesis on an equal number of empty stomachs between length groups may not be discarded (Figure 8). Though there are some different numbers in the different fjords (Figure 8). Due to low numbers of expected empty stomachs in the Balsfjord material, the statement has to be understood carefully (loglikelihood $x^2 = 3.6$, df = 2, p ≈0.17). The Balsfjord material is the fjord with the lowest number of empty stomachs, with low numbers in all length groups, and a X^2-test indicated no differences (X^2= 3.6, df = 2, p = 0.17). The Porsanger material has highest numbers of empty stomachs in length groups 10 – 19 cm and 20 – 29 cm, but no differences between length groups (loglikelihood $x^2 = 1.6$, df = 2, p ≈0.45). The Kvænangen material has a high number of empty stomachs in length group 20 – 29 cm, and lowest number of empty stomachs in the length groups under 20 cm and over 29 cm, and it could be that there are some difference between length groups (loglikelihood $x^2 = 5.8$, df = 2, p ≈0.055).

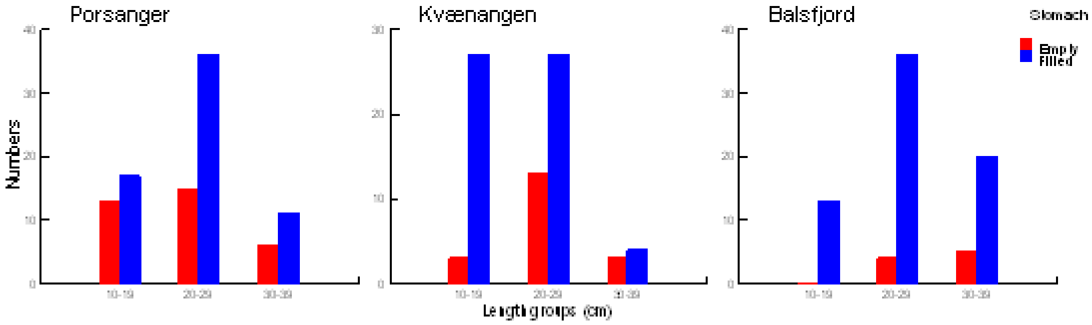

Figure 8. Differences in numbers of empty and filled stomachs in respect to length groups and fjords.

The total numbers of taxa found in Balsfjord, Kvænangen and Porsanger (Figure 9, Appendix Table 1). Many polychaete taxa were not so frequent, but Oweniidae family with its genera *Owenia*, *Myriochele* and *Galatownia* and unidentified Polychaetes either identified to Sedentaria or Errantia were frequent prey items. Twelve taxa were observed at all stations. There were a number of unique taxa which only were observed in one fjord. Balsfjord had 7 unique taxa, Kvænangen 7 taxa and Porsanger 6 taxa. In total, it was observed 24 taxa in Balsfjord, 26 taxa in Kvænangen and 24 taxa in Porsanger.

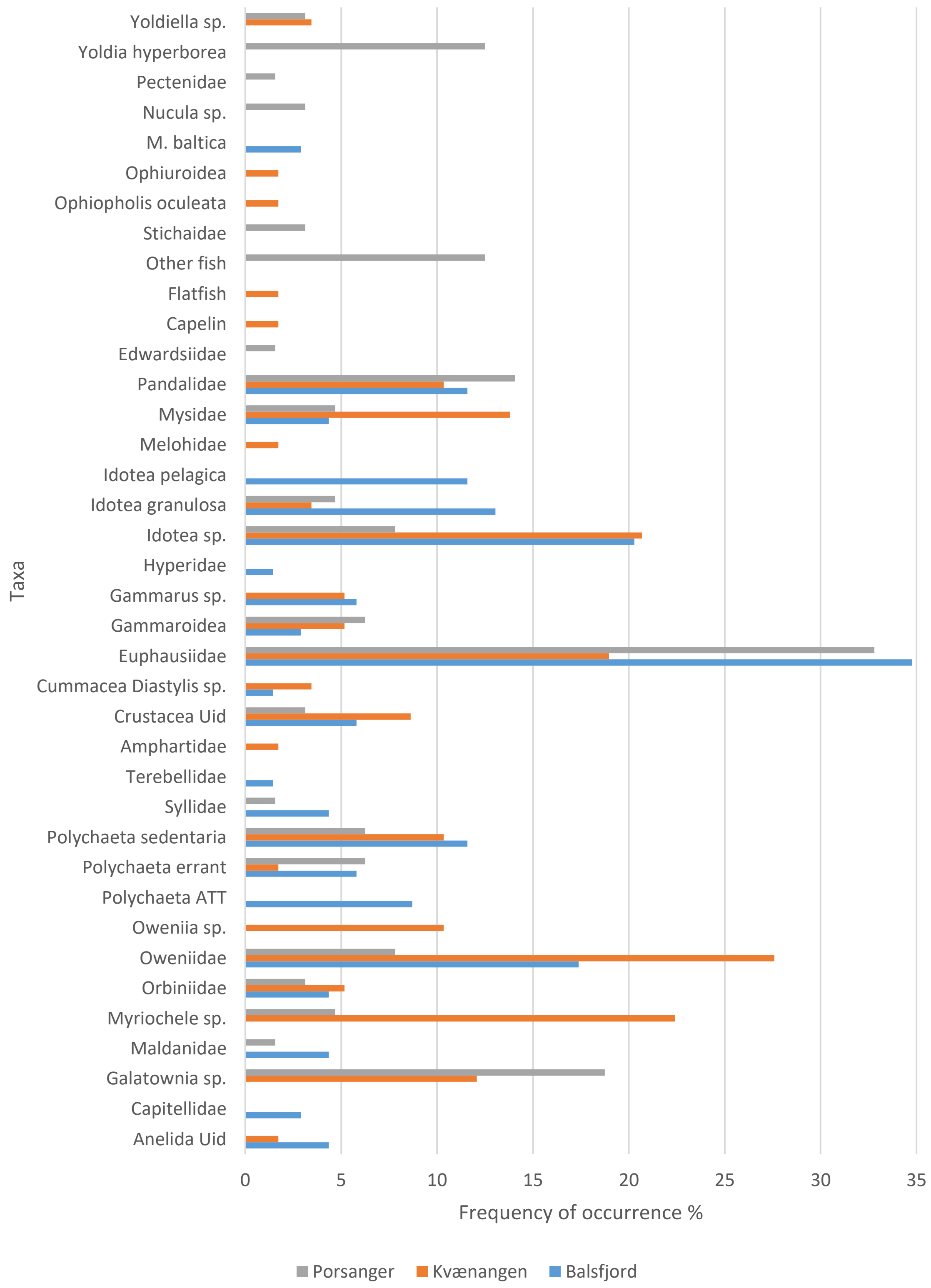

Figure 9. Full taxa list on frequency of occurrence (%) of different prey taxa found in Porsanger (n = 64), Kvænangen (n = 58) and Balsfjord (n = 69).

Frequency of occurrence (FOC %) of prey groups were lumped into 13 prey groups at a higher taxonomic level to compare between length groups and fjords are shown in Figure 10 (Figure 11). Oweniidae, Euphausiidae, Pandalidae and others had the highest frequency of occurrence (FOC %) in all three fjords examined. While Oweniidae has highest FOC % in Kvænangen, especially the Polychaete Sedentaria has high FOC % in Balsfjord. Mysidae has relative high FOC % in the Kvænangen material compared to the other fjords, but of less FOC % importance locally. Different forms of fish where only observed preyed upon in Kvænangen and Porsanger. The taxa others has FOC % in the range 12 – 21 % in each fjords, but comprise of many taxa which has by its own low contribution either by frequency or by weight (Figure 10, 13, 14 A - C).

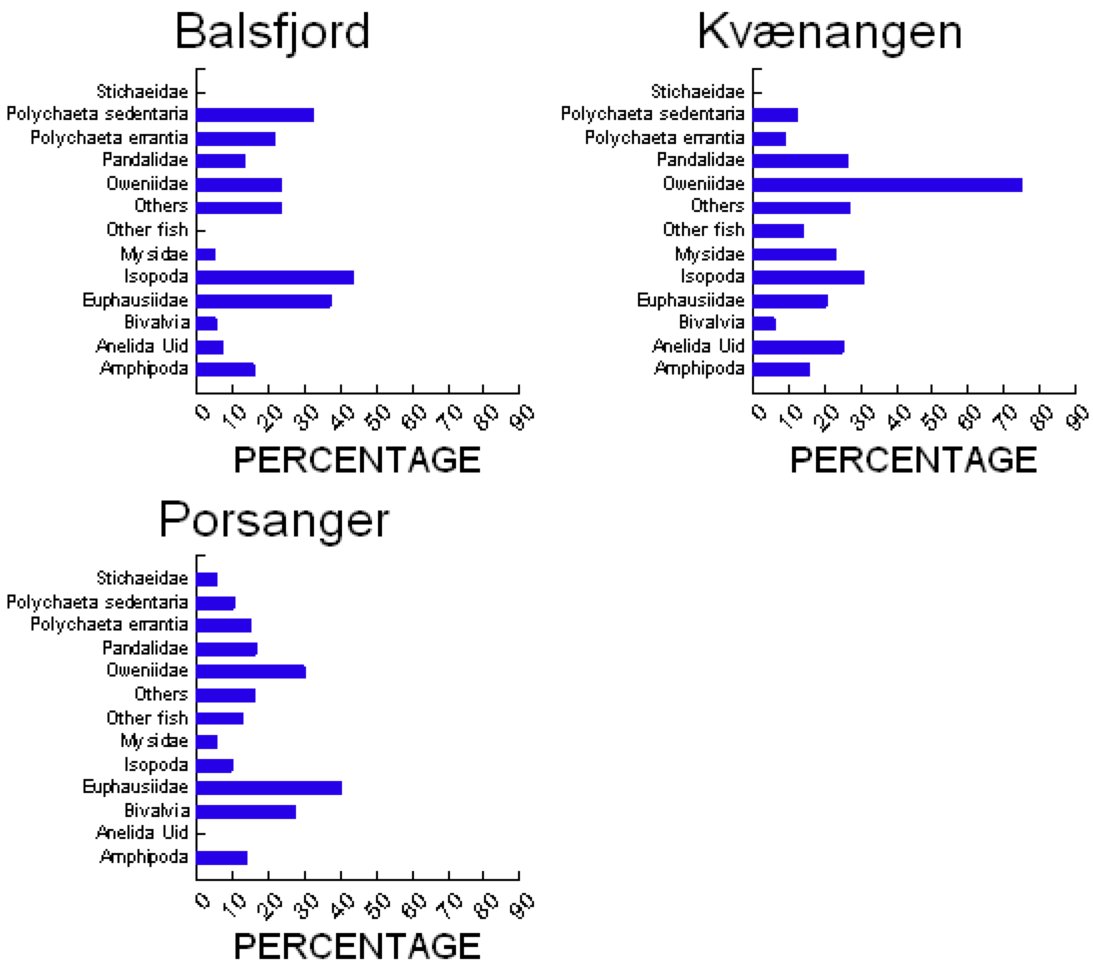

Figure 10. Frequency of occurrence % of grouped taxa based on filled stomachs from Balsfjord, Kvænangen and Porsanger.

There were small differences between fjords with regard to the FOC % of the different prey groups (Figure 11). While long rough dab in Balsfjord prey little Bivalvia and do not prey on fish, these two groups were more frequent in Kvænangen and Porsanger. There was clearly a difference by length groups. While Euphausiidae, Bivalvia, Mysidae and Amphipods, for Balsfjord also Oweniidae tend to be less important by FOC % with increasing length, the different taxa of fish and polychaetes tend to have higher FOC % by increasing length. Isopoda was frequent for all length groups in Porsanger. In Balsfjord, Isopoda was less frequent in the 30 – 39 cm length group. In Kvænangen, there are lower numbers of important taxa than in the other fjords. For the 30 – 39 cm length group there was only 4 taxa present. There was little material from Kvænangen in this length group.

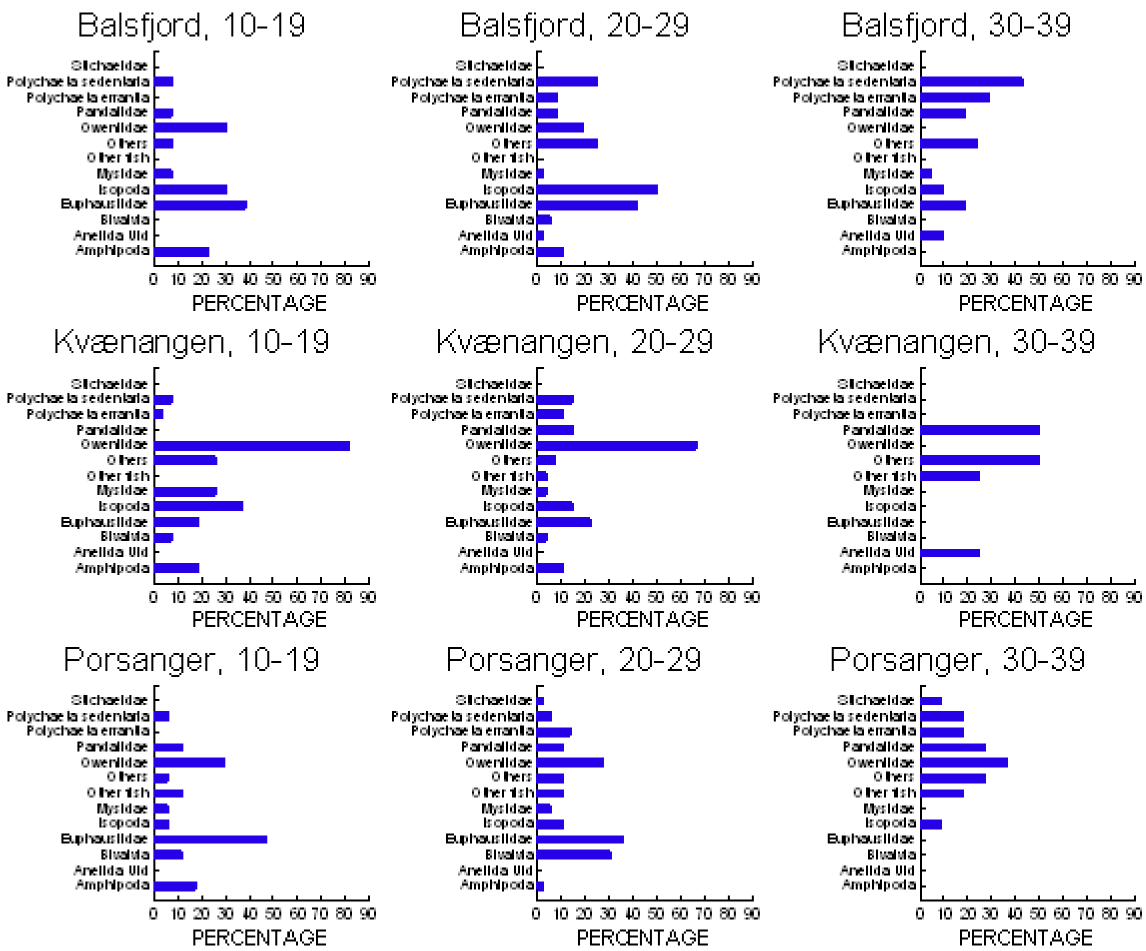

Figure 11. Frequency of occurrence % of grouped taxa (based on empty stomachs) in three fjords according to length groups.

To investigate which effect that influenced the presence - absence of prey taxa in the material, a multidimensional scaling (MDS) analyses were performed (Figure 12). It seems that a fjord effect is of little importance with regard to differences in taxa composition between the three fjords (p = 0.11). On the other hand, there was a size effect with regard to composition of taxa present (p = 0.045). Lastly, there were low catches of large (30 cm – 39 cm) long rough dab in Kvænangen and of 7 individuals only 4 had eaten prey.

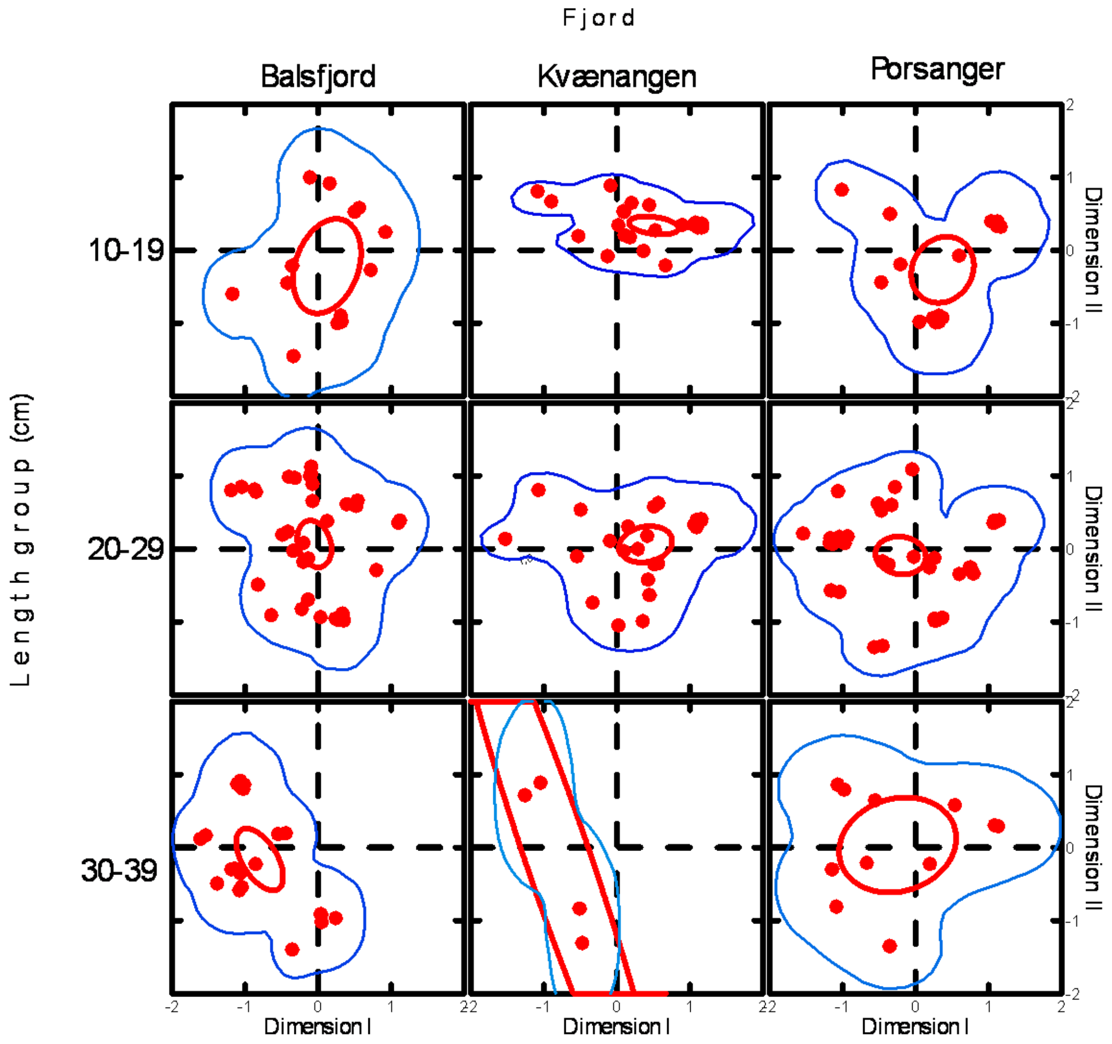

Figure 12. MDS – analyses of present absent data on long rough dab at different length groups in the three fjords sampled. Each dot represent an individual fish, red = 95 % CI, 95 % kernel.

The weight % results give a somewhat different picture than the frequency of occurrence %. Taxa with large individual body weight like Pandalidae, Euphausiidae, Bivalvia and different fish has a higher importance even if they do not dominate frequency data. Smaller taxa by weight is of less importance despite of their high frequencies. Amphipoda and Isopoda are examples of typically frequent prey by occurrence, but with rather low contribution to weight %. Oweniidae which had FOC % around 80 in Kvænangen only constitute 17 % of prey weight in Kvænangen. Other taxa which get less weight % are other small weighted taxa like Amphipoda, Isopoda and Mysidae (Figure 13).

In Balsfjord the four groups Pandalidae, Euphausiidae, Polychaeta Sedentaria and Polychaeta Errantia constitute 87.3 % of the weight %. In Kvænangen, Pandalidae is the dominant prey taxa with 54.1 %. Together with Oweniidae and others it constitutes 79 % of the prey weight. In Porsanger, the Euphausiidae is of almost no importance compared especially with Balsfjord. In Porsanger, weight % were dominated by Bivalvia (18.9 %), Stichaidae (15.9 %) other fish (16.71 %) and Pandalidae (29.4 %). Comparing fjords, the % weight of Crustacea groups decreases toward east, and the % weight of Bivalvia and fish increasing east-ward (Figure 13). Echinoderms were overall of almost no importance. *Ctenodiscus crispatus* (2.9 weight %) was only found in one fish in Balsfjord and a couple of Ophiuoridea (0.6 weight %) found in Kvænangen (Figure 9).

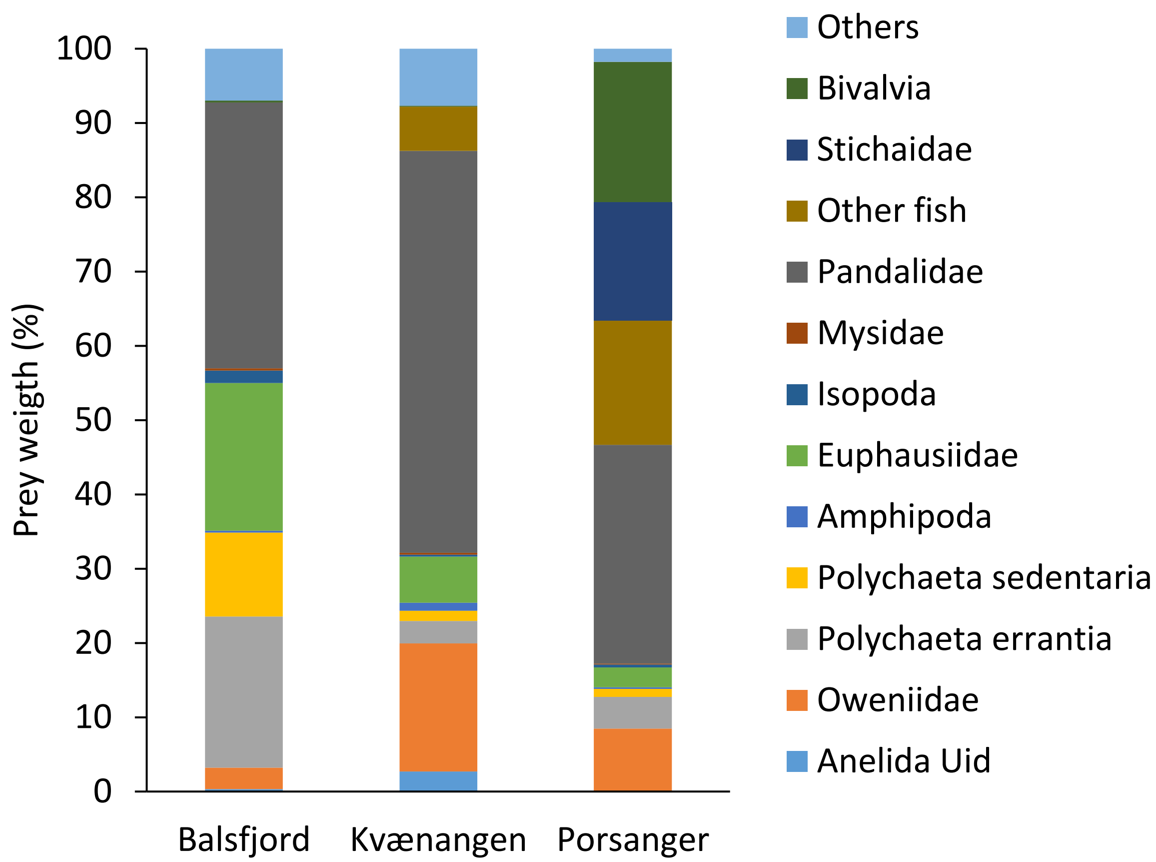

Figure 13. Total prey weight % of the grouped taxa in the sampled areas.

In the weight % analyses there were a clear diet shift in relation to fish (predator) length (Figure 14 A – C). This was even more pronounced than shown by FOC % (Figure 11).

In Balsfjord, the diet for 10 – 19 cm long rough dab is mostly dominated by Pandalidae (65 %) and to lesser extent Euphausiidae (18 %) and Oweniidae (8 %) (Figure 14 A). In length group 20 – 29 cm, Pandalidae weight % decreases (33 %) while Euphausiidae (32 %) and Polychaeta Sedentaria (10 %) increases in weight %. In length group 30 cm +, the dominating groups are Polychaeta Errantia (36 %), Pandalidae (32 %), Polychaeta Sedentaria (13 %). Euphausiidae contributing with only 10 %. The other taxa only contributing up to 20 % together on all length groups. No fish taxa were observed in the diet of long rough dab in Balsfjord.

In Kvænangen (Figure 14 B) the diet of the length group 10 – 19 cm were dominated by Oweniidae (75.9 %), where specially *Myriochele* sp and *Galatownia* sp and Oweniidae in general were contributing to the weight % (Figure 9, 14 B). Other groups with lesser importance are Euphausiidae (4.9 %), Mysidae (4 %) and Isopoda (3.4 %). The weight %

dominance of Oweniidae diminishes further up in length groups. For the length group 20 – 29 cm, Oweniidae (20.2 %) is replaced by Pandalidae (32.6 %), others (14.2 %), Euphausiidae (14.9 %) and Errant polychaeta (7.4 %). For length group 30 – 39 cm, Pandalidae (83 %) dominate the weight %. Other fish (7.9 %) and unidentified Anelida (5.5 %) make some contribution to the weight %. Low number of individuals in 30 cm + length group (n = 7, which of 4 had eaten preys) is thought to have a large effect on the result (Table 4, Figure 14 B).

When it come to the contribution to weight %, the Porsanger material has in general more groups contributing with more than 15 % in weight % in all length groups (Figure 14 C). In length group 10 – 19 cm is dominated by Bivalvia (33.4 %), Other fish (28.7 %) (which mostly is Stichaidae, but with no clear identification is placed in other fish), Euphausiidae (16.5 %) and Pandalidae (8.8 %). For the length group 20 – 29 cm, is dominated by Pandalidae (38.4 %), Bivalvia (29.1 %), and to some extent Oweniidae (11.4 %) and Other fish (7.3 %). Stichaidae is also present in this length group. The 30 – 39 cm length group is dominated by Stichaidae (37 %), Other fish (30.7 %), Pandalidae (17.1 %) and to a lesser extent Polychaeta Errant (6.9 %).

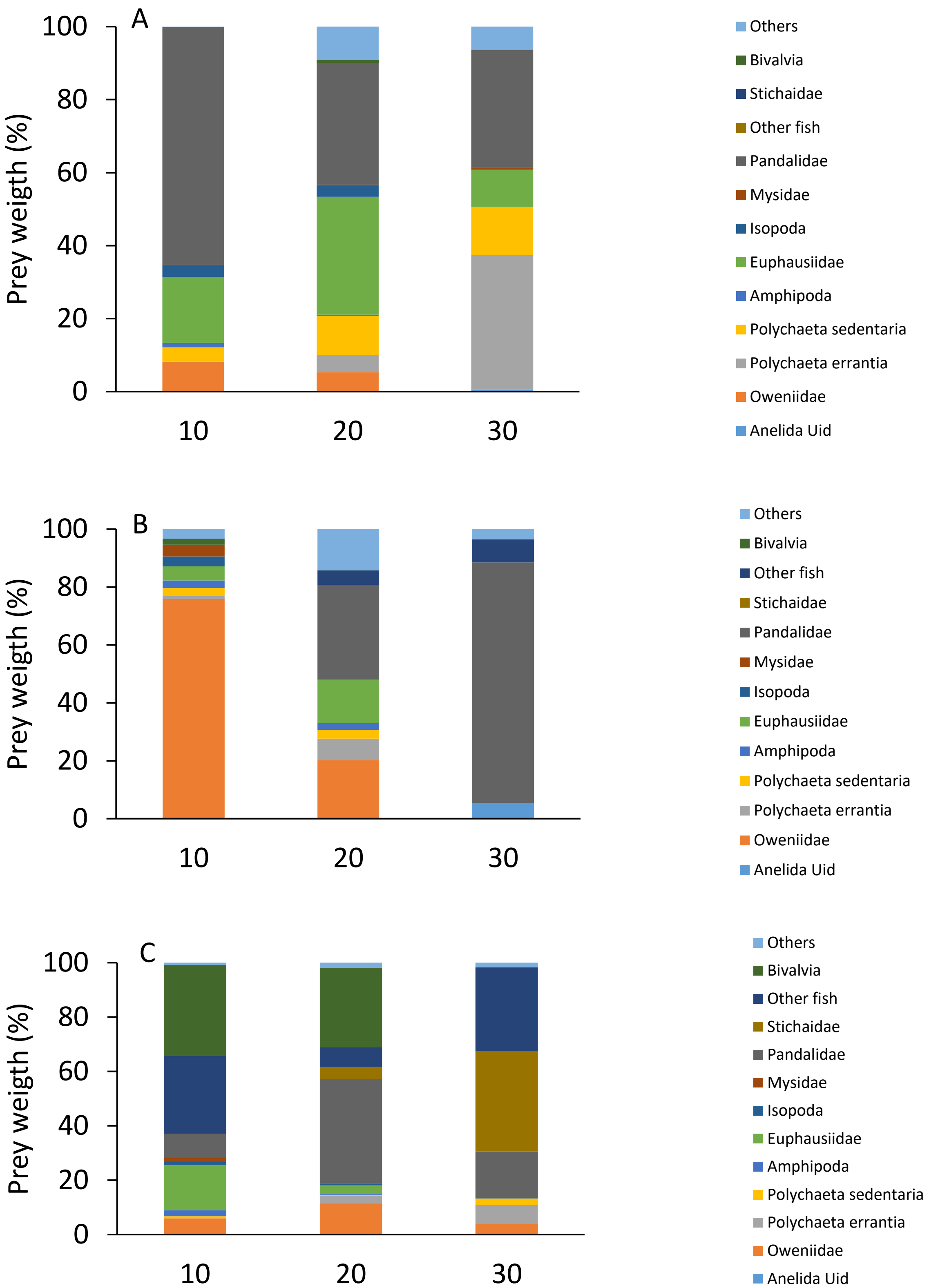

Figure 14. Prey weight % of grouped prey taxa at different length groups in A: Balsfjord, B: Kvænangen and C: Porsanger. Length groups 10: 10 – 19 cm, 20: 20 – 29 cm and 30: 30 – 39 cm.

To the frequency distributions of $\log_{10}$ prey-predator weight ratios of long rough dab, show no large differences between Balsfjord, Kvænangen and Porsanger (Figure 15). There are no significant differences in size of slow-moving and sessile benthos prey between the three fjords. On the other hand the other prey groups (eg epipelagic, active benthos, fish) seem to be smaller in Porsanger. The filling of stomach seems not to be influenced (Appendix Figure 2).

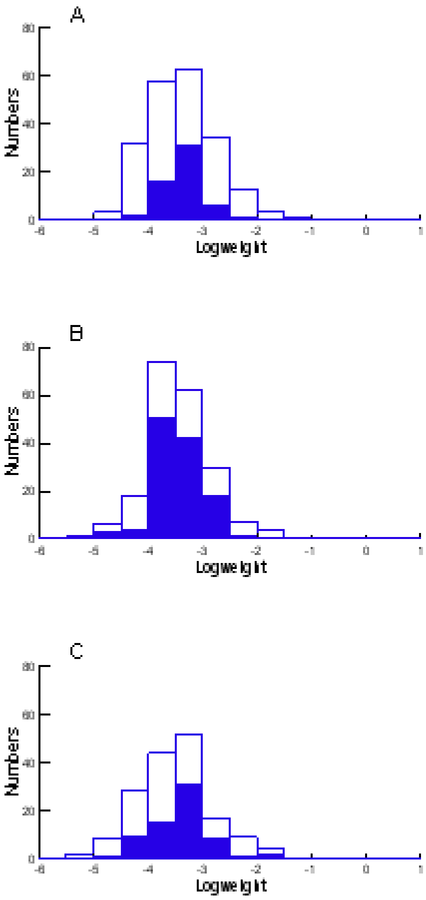

Figure 15. Frequency distributions of numbers of prey ratios (log10(Prey weight/Predator weight)). Marked in blue: slow-moving benthos and sessile benthos. White marked: all other prey groups which are not mentioned for the blue marking. A: Balsfjord, B: Kvænangen and C: Porsanger.

There is relative wide distribution in both length and weight at a given age in all three fjords (Figure 16, 17). Long rough dab from Porsanger and Balsfjord have similar length at age up to the age of 7 – 8 were length of long rough dab from Balsfjord are stagnating (Figure 16, 17, Appendix Figure 3 A and B). The Porsanger long rough dab has the longest length at ages under 5 years and over 10 years. Long rough dab from Balsfjord are longest at age from 5 to 8 years. Long rough dab from Kvænangen is smallest in all age groups except for the 10 year group. Based on this it seems that long rough dab from Balsfjord and Porsanger has the best growth rate. On the other side it seems like long rough dab from Kvænangen and Porsanger might have a slightly higher maximum length. Analyses of variance of age groups between 4 and 8 year confirm the given picture (Appendix Table 2).

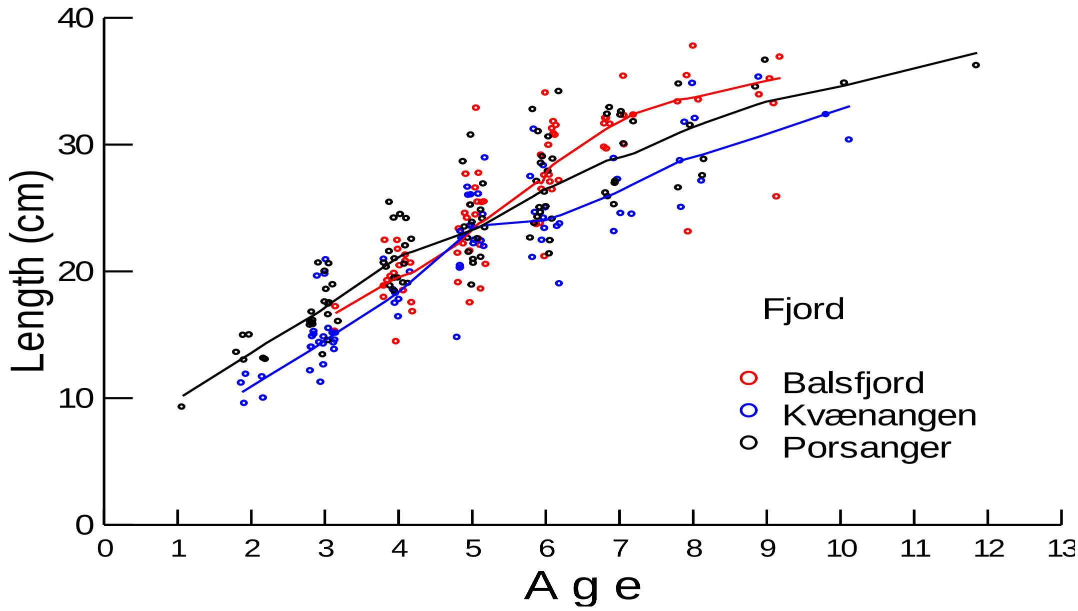

Figure 16. Length at age of long rough dab in various fjords. Smoother line for each fjord. Red: Balsfjord, blue: Kvænangen and black: Porsanger.

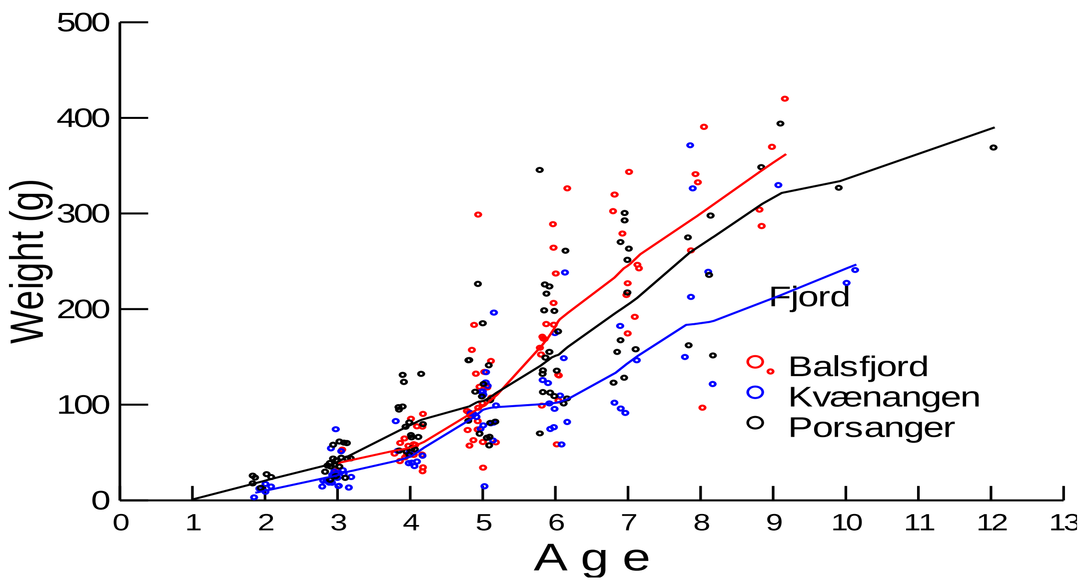

Figure 17. Weight at age of long rough dab in various fjords. Smoother line for each fjord. Red: Balsfjord, blue: Kvænangen and black: Porsanger.

To check if diet and prey size distribution were influencing the condition of long rough dab, the log transformed fish weight and log transformed fish length were plotted against each other for Balsfjord, Kvænangen and Porsanger (Figure 18). There are small differences in the three fjords when it comes to the condition. Still, it is indicated that long rough dab from Porsanger is in somewhat better condition than long rough dab from Balsfjord and Kvænangen (Figure 18). For the smallest long rough dab, there seems like Porsanger long rough dab is pronounced better condition than the other fjords (p= 0.0001) (Figure 18). By applying of a model: ln(weight) = constant + fjord-effect + b*ln(weight), b corresponds to factor llen in the table: the slopes of each fjord are basically the same, with main difference being the height of the slope. Porsanger has highest slope with Balsfjord slightly lower, Kvænangen having the lowest position of the slope (p< 0.0001). Fjord effect $F_{2.248} = 19.8$, p < 0.0001 (Appendix Table 2).

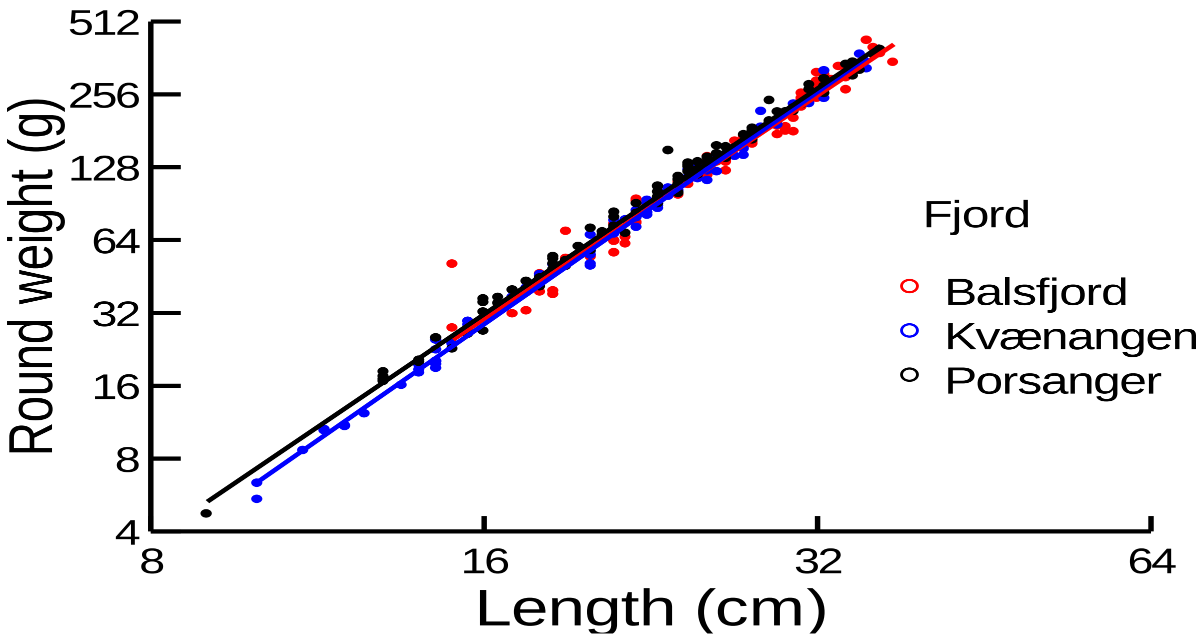

Figure 18. Plot of logarithm of fish length versus logarithm of fish weight for different fjords. Line shows linear regressions. Red: Balsfjord, black: Kvænangen and blue: Porsanger.

In all three fjords examined, females tend to grow larger and become some older than males (Figure 19 A, B and C). For the estimated growth of males and females in the different fjords, there seem like males from Balsfjord is the only fjord were males are estimated to become larger than females (Linfint values) (Table 5). For long rough dab in Kvænangen and Porsanger the females tend to be definitely larger than males. The estimated growth is a combination of K and Linf. A conclusion of which fjord population having best estimated growth should be drawn carefully, but Linfint values drops east-ward while K values increases east-ward (Table 5).

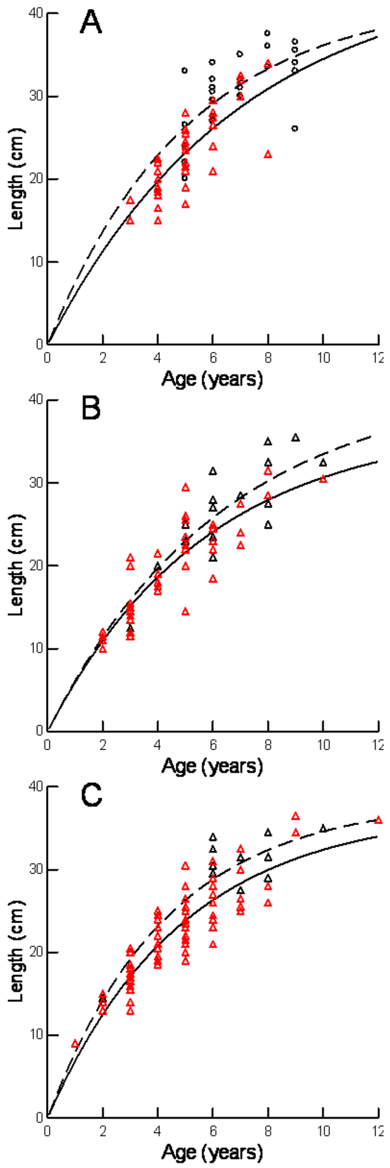

Figure 19. Length at age for females (black markings) and males (red markings) with calculated von Bertalanffeys growth function. A: Balsfjord, B: Kvænangen and C: Porsanger. Dotted line: female, smooth line: males.

Table 5. CI values is 95 % confidence interval of Linfinity and K for the estimated growth for both males (2) and females (1) from Balsfjord, Kvænangen and Porsanger. GPI (growth performance index) = logK + 2logL$_{\infty}$.

Fjord	Sex	Linfint	CIlow	CIhigh	K	CI low	CI high	R2
Balsfjord	1	41,99	31,55	52,44	0,197	0,094	0,3	0,525
Balsfjord	2	45,34	28,12	62,56	0,143	0,062	0,224	0,603
Kvænangen	1	42,28	28,9	55,66	0,157	0,072	0,242	0,74
Kvænangen	2	37,18	29,47	44,89	0,174	0,116	0,231	0,793
Porsanger	1	38,41	29,6	47,23	0,231	0,105	0,358	0,81
Porsanger	2	37,17	32,68	41,69	0,205	0,161	0,248	0,781

4 Discussion

Based on the material, there might be questioned if the quality of all analyses might be influenced by little material. In the diet part, there were some length groups in some fjords with relative small numbers of individuals, giving rise to some chance of bias (Figure 14 B as example). But the overall picture is thought to be given precise enough. On the growth analyses, there are also limitations due to this study primary is a diet study. Long rough dab in age 4 to 8 years has the most individuals giving the most precise estimates (Appendix Figure 1). Another challenge is ageing of individual fish. On the other hand that bias is "applied" to each age group, masking the effect of wrong otolith reading.

Eating in trawl is a much-stated issue by others (Hyslop 1980, Klemetsen 1982, Klemetsen 1993, Mikkola 1996, Kolsum 2011). From studies were shrimp trawls has been used, shrimps are often given higher weight values due to the eating of shrimps in the trawl (Mikkola 1996, Kolsum 2011). By investigation the digestive state of especially the Pandalidae and Euphausiidae taxa, eating in trawl is considered to be of no problem. Fish on the other hand might have some influence by eating in the trawl. Some of the benthic species like Amphipoda, Isopoda and Oweniidae is not considered to be influenced by this issue.

4.1 Frequency of occurrence, compared with earlier studies.

Earlier studies have investigated the frequency of occurrence of prey taxa and given information about total taxa found in its study area (Klemetsen 1993, Mikkola 1996). In studies including frequency of occurrence, the calculations differs with some only including filled stomachs and other including both filled and empty stomachs. To be able to compare with earlier studies on long rough dab in Balsfjord, frequency of occurrence was based on only stomach with content (Hyslop 1980, Klemetsen 1993). There are different length groups in different studies, and might be subject of some bias (Mikkola 1996, Sharf et al. 2000).

4.1.1 General picture of frequency of occurrence

From the objectives (objective i) were to detect any differences between the fjords and between length groups ie to confirm a diet shift (objective iii). This was analysed by both frequency of occurrence (FOC %) and prey weight %.

There were found to be small differences between the fjords with regard to FOC % of the various prey groups (objective i) (Figure 10). Different groups of Polychaetes and Crustaceans like Euphausiidae, Isopoda, Pandalidae and Amphipoda all contributed on a significant level (above 10 %) to the FOC %. Except for some differences in the values of FOC % on the mentioned groups, the largest difference is the presence of different fish species in the diet of long rough dab in Kvænangen and especially Porsanger (Figure 10). Bivalvia which has low FOC % in Balsfjord and Kvænangen has higher FOC % in Porsanger. Other diet studies has observed Echinoderms as important to some degree either by FOC % or by weight %. This study found echinoderms to be of no importance in summer diet of long rough dab, with only two observed fish with echinoderm prey (Figure 9, Appendix Table 1) (Lande 1976, Klemetsen 1993, Ntiba & Harding 1993, Mikkola 1996).

The diet shift (objective iii) in FOC % with increasing length for Balsfjord and Porsanger is primary a decrease in the contribution of Crustacea and an increase in contribution of Polychaeta to the FOC %. For Porsanger, fish also contribute more to FOC % by increased size. In Kvænangen the shift goes from a high FOC % of Polychaete prey group to high FOC % of Crustacean prey groups in larger long rough dab.

When it come to the presence – absence of all taxa registrated (Figure 9), Balsfjord had 24 taxa which of 7 were unique for the fjord, Kvænangen had 26 taxa where 7 taxa were unique and lastly, Porsanger with 24 taxa were 6 were unique for that fjord (Figure 9). In total there were 40 taxa registrated for this study. The numbers of taxa registered is equal to what Klemetsen (1993) and Mikkola (1996) found. Though, there is not investigated if all species are the same. Due to high degradation of many prey on species level, the higher taxa *Idotea* sp., *Pandalus* sp., Other fish and Oweniidae is quite high represented in FOC % (Appendix Table 1). This might influence the results of more precise taxa under those to be of less importance by the mentioned FOC % (Figure 9). In the analyses where the more generalized 13 taxa are used this bias is equalized.

Two sub-questions to the objectives were if long rough dab preyed on small red king crabs and small green sea urchins. Based on the overall taxa, long rough dab do not prey on small red king crab and small green sea urchins (Figure 9, Appendix Table 1).

4.1.2 Frequency of occurrence and comparison of Balsfjord with other fjords.

By frequency of occurrence (FOC %) the dominating prey groups were Isopoda and Euphausiidae, with other Crustacean and Polychaeta groups also being frequent (Figure 10). The group “others” was frequent, but each taxon behind it was of low contribution value

(Appendix Table 1). This study found 24 taxa in the summer diet of long rough dab (Figure 9, Appendix Table 1). The result fits what Klemetsen (1993) found, though Klemetsen (1993) also found highly variability in what taxa found at different parts of the year. As for Klemetsen (1993), this study found fish to be of minor contribution to long rough dab diet in Balsfjord. Opposite of this study, Klemetsen (1993) and Mikkola (1996) found echinoderms to be important. There might be possible that long rough dab compete about the benthic prey groups with haddock and plaice, which has become more abundant in Balsfjord the last 10 – 20 years (2017 E. Nilssen, UiT, pers.comm.). From Ullsfjorden and Sørfjorden systems the diet of long rough dab is known to be dominated by Polychaetes and Crustacea in the inner cold Njosken area, while echinoderms dominating further out in Sørfjord and Ullsfjord (Mikkola 1996). The result of Mikkola (1996) at least supporting that Crustacea is important prey groups for long rough dab. Klemetsen (1993) also observed Polychaeta as dominating.

There was found a diet shift with increased length of long rough dab, with an increase of larger prey groups like Pandalidae and Euphausiidae with increased length (Figure 11, Table 6). Other Polychaetes also making an increased contribution to diet by increased fish length. This picture fits with what Mikkola (1996) found from station Njosken, were Crustacea and Polychaete increased by FOC % with increasing fish length. Mikkola (1996) also found a clear seasonality in prey importance, were Crustaceans actually was even more dominating in the winter diet of long rough dab. Polychaetes were of lower importance during winter feeding, while fish and echinoderms primarily was observed during February and March (Mikkola 1996).

Table 6. Prey groups in different studies which has some dominance by FOC %. This study, orange text had high dominance in 10 – 19 cm, black text had a FOC % dominance in 30 – 39 cm length group. In columns for Klemetsen (1993) and Mikkola (1996) it is not considered which length group it represents.

This study – Balsfjord	**Klemetsen**	**Mikkola**
Oweniidae	Ophiuoridea	Crustacea
Polychaeta Sedentaria	Oweniidae	Polychaeta
Polychaeta Errantia	Maldanidae	Echinoderms
Amphipoda	*Nepthys* sp	
Euphausiidae		
Isopoda		
Pandalidae		

4.1.3 Frequency of occurrence in Kvænangen compared to other fjords.

By FOC % the dominating taxa in Kvænangen were different forms of Oweniidae. Other polychaetes had only minor contribution to FOC %. Crustacea taxa were important to FOC % with a diverse taxa composition (Figure 10). There were some fish in the diet, flat fish among others. The diet of long rough dab in Kvænangen showed most similarities to the February diet registered at Njosken when it comes to diversity, but the high importance of Oweniidae might be similar to the summer diet at Njosken (but the overall diversity of important polychaete in Kvænangen is low).

With increasing length, Oweniidae or other specific polychaete taxa became of no importance at length group 30 cm +. At length group 30 – 39 cm there were only four prey groups present and the diet was dominated in terms of FOC % by Pandalidae, Others, Other fish and unidentified Anelida. This is quite different from the material from Balsfjord and Porsanger. This bias to four taxa is primary related to a low numbers of individual in that length group (Figure 11, Table 4). For the two length groups between 10 – 29 cm, there were at least some correspondence to the diet Mikkola (1996) registered at Njosken March and June.

4.1.4 Frequency of occurrence Porsanger compared to other fjords.

In Porsanger Euphausiidae, Bivalvia and Oweniidae had relative high FOC % (Figure 10). Other Crustacea and Polychaeta prey groups also contributed to the diet. Of the three fjords examined Fish and Bivalvia was relatively important in Porsanger (Figure 10). The diet composition of long rough dab in Porsanger was slightly more diverse with regard to number of prey groups than Balsfjord and Kvænangen. Porsanger also had the highest numbers of empty stomachs, which make the overall appearance some similar Mikkola's (1996) March diet at Njosken. However, Mikkola (1996) found lower importance of both Polychaeta, Bivalvia and fish than this study does.

A shift in the diet from a Crustacea dominance to a more fish and Polychaeta groups were observed with increased fish length (FOC %) (Objective iii). Bivalves only contributing to smaller length group. The dominating prey groups at 30 – 39 cm is Oweniidae, Others and Pandalidae. All fish taxa are together of similar appearance to Sedentaria and Errant Polychaeta taxa alone (Figure 11). Except for the absence of fish in Mikkola (1996) and absence of echinoderms in this study, the diet at different length groups is similar to what was found in June at Njosken by Mikkola (1996).

4.2 Diet of long rough dab weight %.

A challenge with weight % comparisons with frequency of occurrence is that preys with high weight would out weight lighter prey taxa, even if the lighter prey taxa has higher occurrence in the material. Fish, Pandalidae and large Bivalvia are examples of larger-sized prey groups over-represented by weight %, while Amphipoda, Isopoda and Oweniidae are examples of small-sized prey groups under-represented by weight %.

4.2.1 General picture of weight %.

The general picture of the results on terms of prey weight % in this study was a dominance by especially Crustacea in general and Polychaeta groups in Balsfjord and Kvænangen, while the diet in Porsanger was more dominated by different fish groups, Bivalvia and Pandalidae (Figure 13) (objective i). The Euphausiidae and Polychaete prey groups contributed less to weight % in eastern fjords Kvænangen and Porsanger than in Balsfjord. There are no contribution of fish to the diet of long rough dab in Balsfjord, while fish contributing more to the diet in Porsanger. This difference in regard to preference to fish as prey might be explained by that in Balsfjord is a large stock of cod and haddock, while there in Porsanger is a small cod stock. In Balsfjord the cod stock keeps potential fish stocks which are of interest as prey for long rough dab low in biomass. In Porsanger the cod stock may be too small to really compete with long rough dab in regard to fish prey. As a “top” predator (cod) in the fish community this might be explained in more detail by trophic cascade (Frank et al. 2005).

The shift in the diet with increased length observed in FOC % is more pronounced when prey weight % is used (objective iii) (Figure 14 A – C). In Balsfjord, the Crustacean prey groups become less dominating in weight % by increased fish length, while different Polychaeta prey groups become more dominating by increased fish length. In Kvænangen the diet shift goes from a Polychaete dominated weight % to a Crustacea dominated weight %. In Porsanger the diet changed from a diet based on Bivalvia, Other fish and Euphausiidae, to a diet based on different fish groups and Pandalidae.

Analyses of prey- predator weight ratios (Figure 15) indicate that the size of slow-moving and sessile benthos preyed upon by the long rough dab do not differ much between Balsfjord, Kvænangen and Porsanger (objective ii). The overall prey size on the other side seems to be some smaller in Porsanger than in Balsfjord and Kvænangen, due to relative more smaller moving prey in the diet in Porsangerfjord. This might indicate that red king crab do not impact the prey sizes of long rough dab at this point in time. It is possible though that long rough dab uses the opportunity of a low cod stock in Porsanger to eat more fish and Pandalidae and less benthos, and by that not being impacted as much by the presence of the king crab.

4.2.2 Prey weight % Balsfjord compared to other fjords.

Pandalidae and Euphausiidae is the main source of energy for long rough dab in Balsfjord. Sedentary and Errante polychaetes was of some importance as energy source. Other prey groups were of minor importance despite these taxa had high importance in terms of FOC % analyses. Mikkola (1996) found a dominance of Crustacea, Polychaeta and others together with some fish in Njosken area. Mikkola (1996) study fit well into the results from Balsfjord from 2015. From outer parts of Sørfjord and Ullsfjorden systems, the echinoderms, polychaetes and crustacea dominated. In Balsfjord echinoderms, fish and bivalve were of minor or no importance in this study. This is contrary to earlier findings in Balsfjord, North Sea and Borgenfjord (Lande 1976, Klemetsen 1993, Ntiba & Harding1993).

There are clearly a diet shift in relation to increased fish size among long rough dab in Balsfjord (Figure 14 A). Crustacea prey groups are the main diet of small long rough dab, while large long rough dab has almost equal amount of Crustacea and different Polychaeta prey groups. This differ to some extent from earlier investigations were fish, echinoderms and to some extent bivalves have been recognized as more important with increased predator length (Lande 1976, Klemetsen 1993, Ntiba & Harding 1993, Mikkola 1996).

4.2.3 Prey weight % Kvænangen compared to other fjords.

Long rough dab in Kvænangen predate primarily on Pandalidae, while other prey groups as Oweniidae has minor contributions to the weight % (Figure 13). In the Sørfjord and Ullsfjord system there were also found high dominance of crustaceans at Njosken and Ullsfjord stations, but not to that extent found in Kvænangen. Polychaete importance in the flow of energy is equivalent to Njosken values (Mikkola 1996). In Balsfjord polychaete taxa had high FOC % (Klemetsen 1993). At Tennes, Klemetsen (1993) also found Oweniidae to be of relative abundant, but transformed to weight % Klemetsen (1993) result would probably be lower and not directly comparable to the result of this study. In Borgenfjord the echinoderms were the overall dominant prey taxa with crustaceans and molluscs the other abundant prey groups. Fish was registrated at a level comparable to Kvænangen material.

The diet shift of long rough dab in Kvænangen were from Oweniidae dominance (weight %) to Pandalidae dominance among large long rough dab (30 cm +) (Figure 14 B). This is a shift of opposite character than registered in Balsfjord (Figure 14 A), and quite different from Porsanger shift (Figure 14 C). Few large long rough dab in Kvænangen might bias the result. By this it is not plausible to state that Crustacea prey groups are the main prey groups for energy flow for large long rough dab. On the other side Pandalidae is registrated with larger (Balsfjord) or smaller (Porsanger) importance in the energy flow by this study. In the North Sea, it is also known that Pandalidae might have an overall importance of 80 % in periods of spring (Ntiba & Harding 1993). If not that large dominance of crustaceans, there are still possibilities to at least Pandalidae to have some contribution to the diet of larger predator sizes.

4.2.4 Prey weight % Porsanger.

The overall diversity when it comes to dominating prey groups between the fjords is highest in Porsanger. No prey group has more than 30 % of the prey weight % (Figure 13, 14 C). Different forms of fish contributed most to the weight %, while Pandalidae and Bivalvia as other important prey groups in the flow of energy. Oweniidae was the only polychaete taxa that was contributed to weight % (Klemetsen 1982). This is different from both Ullsfjord, Sørfjord and Balsfjord systems, were bivalves and fish was of low or no importance (Klemetsen 1993, Mikkola 1996 Figure 13). Lande (1976) found higher dominance of bivalves in the diet. In Borgenfjord and other areas echinoderms has been observed with high importance (Lande 1976, Klemetsen 1993, Mikkola 1996). The importance of echinoderms is not supported by this study (Figure 13, Appendix Table 1). From some areas in the North and Barents Sea, there were also known a high contribution of fish in long rough dab diet (Klemetsen 1993, Ntiba & Harding 1993). The importance of crustacean prey groups is supported by Mikkola (1996).

There was also observed a diet shift by increased fish length in Porsanger, were different fish groups and Pandalidae became more important to weight %. A shift to fish and crustacean by increasing length is also found in Barents Sea and North Sea (Klemetsen 1993, Ntiba &

Harding 1993). The low importance of echinoderms and high importance of crustacea is found at Njosken in Sørfjord (Mikkola 1996). Ntiba & Harding (1993) also found that there where a change of which fish species who were included in the diet. There was not possible to tell if that also is the case for Porsanger.

4.2.5 Prey size

The analyses showed no significant size difference between Porsanger and the other fjords with regard to prey-predator ratios of the slow-moving and sessile benthos species in the long rough dab diet (objective ii). On the other side, the overall prey-predator size-ratios including mobile prey in Porsanger seems to be some smaller compared to prey sizes from Balsfjord and Kvænangen (Figure 15). Analyses of the condition on the long rough dab from the three fjords seems quite similar. The Porsanger long rough dab is overall in slightly better condition-, i.e. higher weight at length, than long rough dab from Balsfjord and Kvænangen (Figure 18). This might indicate that long rough dab is not significant influenced by the presence of the red king crab, or the crab might push long rough dab to choose smaller mobile prey.

The diet of long rough dab is flexible, and it might be possible that a low cod stock in Porsanger might give the long rough dab opportunity to eat more fish and shrimps like Pandalidae. By this, long rough dab may escape from some of the changes performed by the red king crab in benthos communities. Fuhrmann et al. (2017) points out that by now there are little overlap in diet by king crab and flatfishes like long rough dab, supporting the idea of trophic cascade due to a small cod stock. In a scenario with a larger cod stock in Porsanger, the result might be different from this study results.

4.3 Growth of long rough dab.

With regard to the overall growth, there are small differences between the fjords (Figure 17, 18, 19, Appendix Figure 3 A, B). Long rough dab in Balsfjord and Porsanger being closest in length ate age with increasing age groups. For the analyses of age groups 4 to 8 years, long rough dab from Kvænangen was significant smaller.

Due to earlier studies has pointed out a difference in growth between genders, this was also investigated by this study (Bagenal 1957, Mikkola 1996) (Figure 19, Table 5). The finding of this study is that female tends to grow larger than males in all three fjords investigated.

Reproduction, fishery and predation are some factors influencing growth. Gonads are expensive to grow, with gonads by females being most expensive to produce (Mikkola 1996). Females would by this get higher fecundity by mature at larger size and age than males. By this males would grow slower earlier than females, and by that becoming smaller (Mikkola 1996). Increased fishery and predation pressure is known to reduce expected growth (Hunter et al. 2015). Long rough dab is not commercially fished on in Norwegian and Barents Sea water, but is predated by different fish species (i.e. cod, haddock) (Klemetsen 1982).

For comparing the condition of long rough dab in the three fjords, there were applied an analyses of logarithm of fish length versus logarithm of fish weight. This analyses indicated small differences between the three fjords (Figure 18). Though long rough dab in Porsanger has some higher condition. The condition of long rough dab is lowest shortly after spawning, with an increase of condition throughout the summer and autumn with a maximum point late autumn (Bagenal 1957, Mikkola 1996). Due to the later sampling period of long rough dab from Porsanger compared to Balsfjord and Kvænangen, there might be that the slightly better condition of Porsanger long rough dab is biased because of seasonal increase of the condition.

Analyses of empty filled stomachs showed no similarities in the numbers of empty stomachs between the three fjords (Figure 7). Taken in to consideration the fish length there are low differences with regard to empty stomachs (Figure 8). The high numbers of empty stomachs in Kvænangen and Porsanger seems not to influence the growth and condition on the long rough dab in Porsanger. A possible explanation is that long rough dab in Porsanger predate at prey with more energy (i.e. Pandalidae, fish) than long rough dab in Balsfjord (Figure 14 A – C).

4.4 Is long rough dab diet different, red king crab influence.

Objective i) were to investigate if there were difference between fjords with and without red king crab. By the applied Frequency of occurrence there was found small differences between the three fjords regardless of presence or absence of red king crab. The diet was dominated by different Crustacea and Polychaeta groups. The main difference was higher frequency of fish and Bivalvia in Kvænangen and especially Porsanger.

There was applied weight % for investigate what contribute to the flow of energy. There was expected that large sized prey groups would out weight smaller sized groups, which also was the case. The observed small difference between the three fjords in the FOC % analyses became larger with the applied weight %. While the Crustacea and Polychaeta had high contribution to weight % in Balsfjord and Kvænangen, the result was different in Porsanger. The Porsanger material had a more diverse prey composition with regard to dominating prey groups than the other two fjords. Fish and Bivalvia was of contributed most to weight % in Porsanger. Echinoderms was mostly absent from the diet of long rough dab in all three fjords.

Objective ii) were to investigate if long rough dab predated at smaller prey in a fjord with red king crab. The prey groups expected to change with presence of high densities of king crab (slow and sessile benthos) did not differ between the three fjords. The observed difference was primarily some smaller prey size of active benthos, epi-pelagic and fish groups in Porsanger.

Objective iii) were to test if there were a change in diet with increased predator (fish) length. Both the FOC % and weight % analyses showed a shift in the diet in all three fjords. Weight % showed that shift best. In Balsfjord the observed diet changed from primarily Crustacea dominated diet to a Crustacea and Polychaeta dominance. The diet shift in Kvænangen was of opposite character. In Porsanger fish and Pandalidae became more important with increased length. Two sub-questions were if small red king crab and small green sea urchins were present in the long rough dab diet. These two items are not preyed upon by long rough dab. An analysis of FOC % indicating a low fjord effect, but a higher effect by fish length. This might indicate other causes of the differences than red king crab by itself.

Objective iv) were to test if growth of long rough dab is influenced by the presence of red king crab. There are small differences between the three fjords in regard to growth. Porsanger and Balsfjord long rough dab being slightly larger than Kvænangen long rough dab. Porsanger long rough dab had the highest condition of the fish, but it is assumed to be influenced by a latter sampling date. Females were found to grow larger than males.

The diet and growth of long rough dab do not seem to be influenced much by the presence of red king crab. Though there might be possible that a small stock of cod in Porsanger have some trophic cascade effects in that ecosystem. A low sized cod stock giving rise to larger stocks of smaller fish species. Long rough dab might use this “new” space to predate more at epi-pelagic Pandalidae and small fishes like Stichaeidae. This might be a sort of escape from changes performed by the red king crab in benthic ecosystems. This might mean that: in a fjord with both high density of red king crab and a large cod stocks, there might be another result than this study.

5 Conclusion.

There are found small differences between the fjords, were the differences in FOC % mainly were a question of an effect by length (limited effect by fjord). By weight % there was a more pronounced difference between the fjords (objective i). On the slow-moving and sessile benthos (which was thought change in a fjord with red king crab) did not show difference between the three fjords. While other prey groups being some smaller in Porsanger long rough dab diet (objective ii).

There was a clear shift in diet by increased fish length in all three fjords. Larger sized prey is a part of this shift, for instance more Pandalidae and fish with increased size. Main difference between fjords are more of Bivalvia and fish prey in Porsanger than Balsfjord (objective iii).

There was small difference in growth in the three fjords. Long rough dab becoming larger in Porsanger and Balsfjord, some smaller in Kvænangen. The condition of long rough dab was best in Porsanger, though this may be a biased by later sampling of Porsanger material (objective iv).

There do not seem that red king crab influence diet and growth much in Porsanger compared to Balsfjord and Kvænangen (which has low density of red king crab). Though a small cod stock in Porsanger might have an influence. It is thought that the amount of fish and Pandalidae in diet of long rough dab in Porsanger is due to the low cod stock. Long rough dab in Porsanger might use that situation to escape from possible changes in benthos community. In a fjord with both a large cod stock and a high density of red king crab, the situation might give another result than this study.

6 Referenceses

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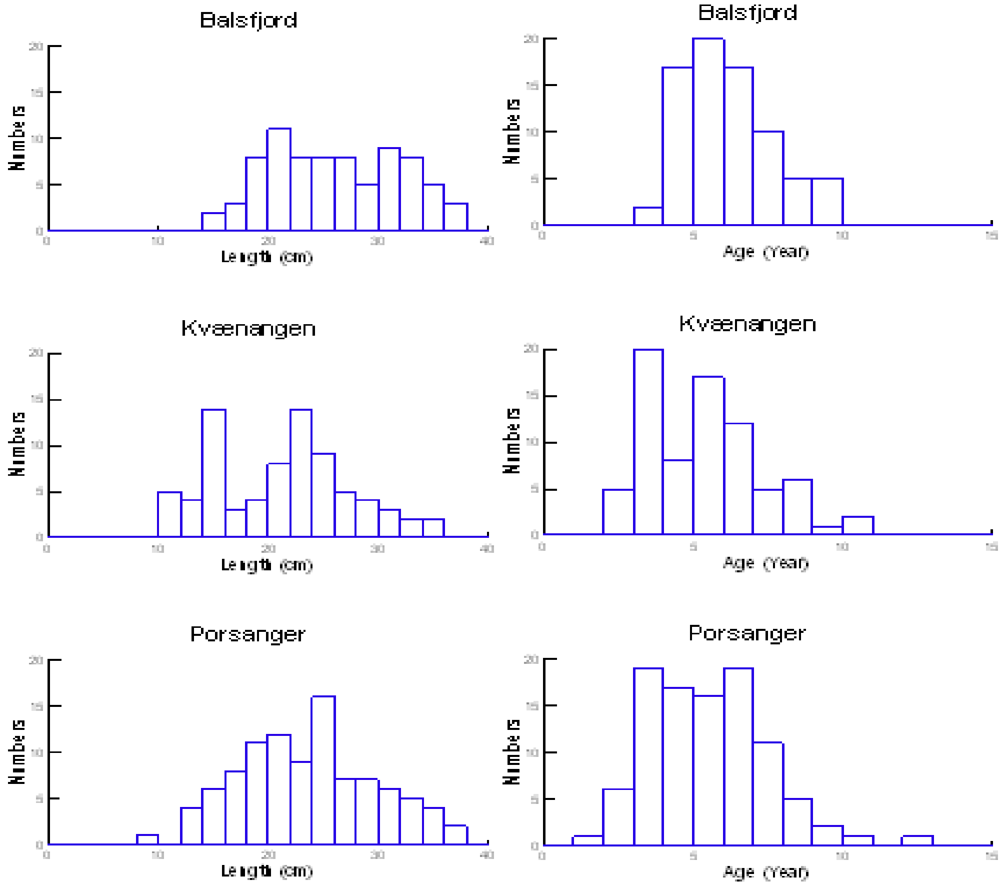
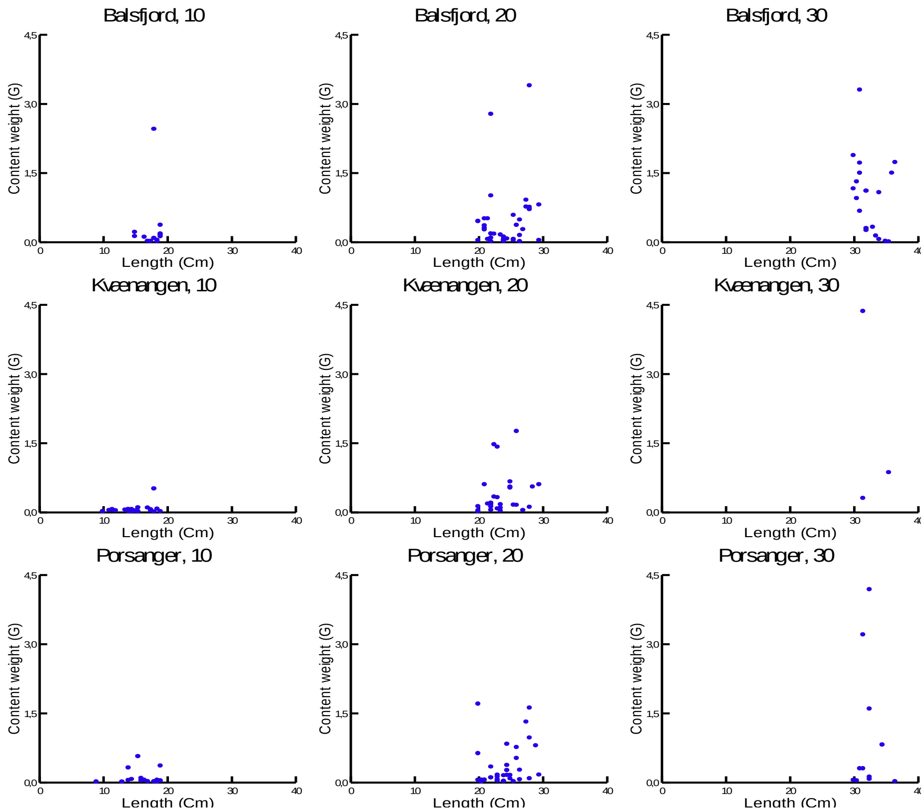
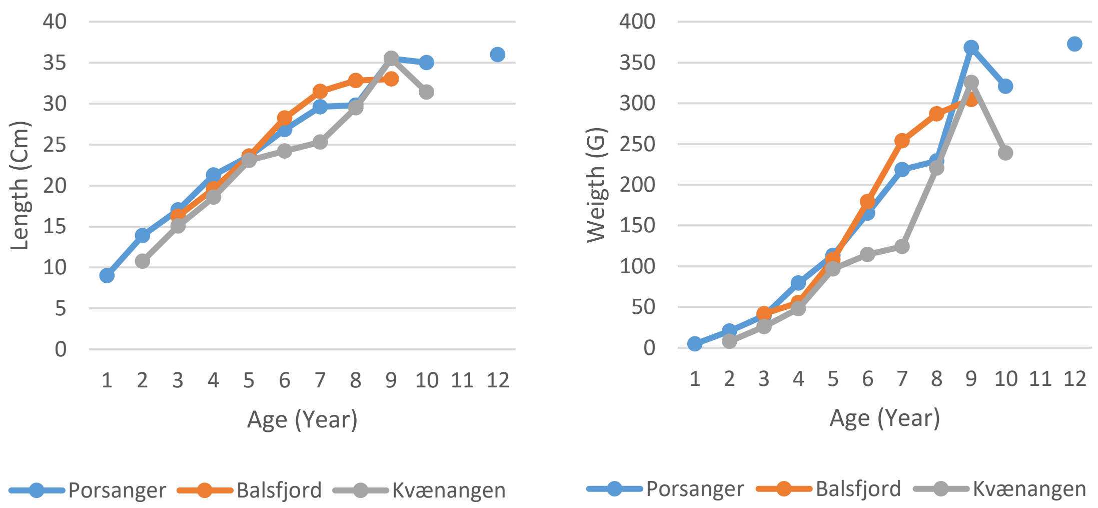
7 Appendix



Appendix Figure 1. A: Numbers of individuals long rough dab per 2 cm length interval. B: Numbers of individuals per age group.



Appendix Figure 2. Stomach content weight (g) plotted to fish length (cm).



A B

Appendix Figure 3. A: Average length per age group (long rough dab) in the three fjord areas sampled. B: Average length per age group (long rough dab) in the three fjord areas sampled.

Appendix Table 1. A detailed information about all taxa found in each fjord sampled for long rough dab.

Taxa	Balsfjord	Kvænangen	Porsanger
Anelida Uid	4,35	1,72	0

Capitellidae	2,9	0	0
Galatownia sp.	0	12,07	18,75
Maldanidae	4,35	0	1,56
Myriochele sp.	0	22,41	4,69
Orbiniidae	4,35	5,17	3,13
Oweniidae	17,39	27,59	7,81
Oweniia sp.	0	10,34	0
Polychaeta ATT	8,7	0	0
Polychaeta errant	5,8	1,72	6,25
Polychaeta sedentaria	11,59	10,34	6,25
Syllidae	4,35	0	1,56
Terebellidae	1,45	0	0
Amphartidae	0	1,72	0
Crustacea Uid	5,8	8,62	3,13
Cummacea *Diastylis* sp.	1,45	3,45	0
Euphausiidae	34,78	18,97	32,81
Gammaroidea	2,9	5,17	6,25
Gammarus sp.	5,8	5,17	0
Hyperidae	1,45	0	0
Idotea sp.	20,29	20,69	7,81
Idotea granulosa	13,04	3,45	4,69
Idotea pelagica	11,59	0	0
Melohidae	0	1,72	0
Mysidae	4,35	13,79	4,69
Pandalidae	11,59	10,34	14,06
Edwardsiidae	0	0	1,56
Capelin	0	1,72	0
Flatfish	0	1,72	0
Other fish	0	0	12,5
Stichaidae	0	0	3,13
Ophiopholis oculeata	0	1,72	0
Ophiuroidea	0	1,72	0
M. baltica	2,9	0	0
Nucula sp.	0	0	3,13
Pectenidae	0	0	1,56
Yoldia hyperborea	0	0	12,5
Yoldiella sp.	0	3,45	3,13

Appendix Table 2. Analyses of variance, growth at age in Balsfjord, Kvænangen and Porsanger.

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value	
FJORD$	194.9079	2	97.4540	10.0107	0.0001	0.0001
AGE	2093.1522	4	523.2881	53.7533	0.0000	< 0.0001
FJORD$*AGE	161.6926	8	20.2116	2.0762	0.0406	0.0406