UNIVERSITY OF TROMSØ UIT

NORWEGIAN COLLEGE OF FISHERIES SCIENCE

Habitat choice of juvenile coastal cod

The role of macroalgae habitats for juvenile coastal cod (*Gadus morhua* L.) in Porsangerfjorden and Ullsfjorden in Northern Norway

Christer Michaelsen

Master's Degree Thesis in Fisheries Science
Field of Study – Fisheries biology (60 credits)

November 2012

Abstract

Habitat choice of small juvenile coastal cod (*Gadus morhua* L. 1758) was investigated in a field study in Porsangerfjorden and Ullsfjorden in Northern Norway. A towed video rig was used to record video along depth transects in the subtidal zone. Depth, algae cover and occurrence of 0-group, 1-group and 2+ group cod was registered. Beach seine and angling was used to estimate relative abundances of cod and sample fish for length measurement and diet analysis. The occurrence of juvenile cod was significantly higher in areas with algae cover of 20% or more. In addition there seemed to be a depth preference for depths between 10-20 m. There was a difference in the degree of association to macroalgae between the various age groups of cod. The diet analysis showed variations in between the various age groups of cod. My findings suggest that macroalgae habitats play a vital role as nursing grounds for juvenile coastal cod by providing refuge from predators and lucrative feeding opportunities. There was observed an ontogenic shift in diet composition among juvenile coastal cod, which suggests that the role of macroalgae habitats is different for various age groups of juvnile cod. 0-group seemed more closely associated with the macroalgae than older individuals. Overgrazing of macroalgae by sea urchins may affect the survival of juvenile coastal cod by limiting the extent of nursing grounds. The recruiment of norwegian coastal cod north of 62°N is probably affected by the condition and extent of macroalgae habitats along the coast of Norway.

Key words: *Norwegian coastal cod, juvnile cod, habitat, macroalgae, diet*

Acknowledgements

I would like to thank my supervisor Prof. Torstein Pedersen at the Institute of Arctic and Marine Biology, University of Tromsø. I also would like to thank Trond Ivarjord and the crew onboard RV «Johan Ruud» and RV «Hyas» for valuable assistance during the field surveys.

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1 Introduction

1.1 Norwegian coastal cod north of 62° N

The norwegian coastal cod (NCC) stock north of 62° N consists of stationary populations of Atlantic cod (*Gadus morhua* Linnaeus 1758) that spawn at several locations along the norwegian coast (Jakobsen, 1987). These populations are genetically separate from each other, and from the Northeast Arctic cod (NEAC), which reside in adjacent and overlapping areas (Berg and Albert 2003). Since the mid 1990s there has been a decrease in the biomass of coastal cod north of 62° N, and recruitment since 2001 has been low (ICES, 2011). The proportion of NCC versus NEAC is increasing from north to south along the norwegian coast. The abundance of NCC is however increasing from south to north (Berg and Albert, 2003). Low recruitment is a main cause of the deteriorating condition of the coastal cod populations (ICES, 2011). This may be linked to the destructive grazing by sea urchins in near shore vegetated areas, which have resulted in a decimation of near shore macroalgae communities (Norderhaug and Christie, 2009). Areas with a high abundance of macroalgae, like kelp forests, are belived to provide nursing grounds for coastal cod (Løken *et al.,*1994).

1.2 Life history of coastal cod

The life history of coastal cod is different from that of oceanic cod, e.g. the Northeast Arctic cod stock. NCC and NEAC differ with regard to geographical spawning patterns, migration and settling behaviour of the juveniles. The eggs and larvae of NEAC are transported long distances from the spawning grounds, whereas the progeny of NCC commonly is retained within a limited geographical area (Jakobsen, 1987; ICES, 2005). If progeny of NEAC is transported into fjord areas, they are likely to settle in deep areas where they can be expected to be exposed to high rates of predation (Løken *et* al., 1994). The difference in settling strategy might be important in maintaining the stock structure between the two types of cod (Berg and Albert, 2003). Spawning of NCC takes place along most of the norwegian coastline, and the regularity of the spawning in some areas suggest that there are local self recruiting stocks of cod (Jakobsen, 1987, Knutsen *et al.,* 2007). Small fjords are typical spawning sites used by NCC, and upon spawning the eggs are released into the pelagic. After spawning, a significant proportion of the fertilized eggs is retained within a limited geographical area. Local hydrographic conditions affect the vertical distribution of the pelagic eggs, which in turn may have an effect on the transport or retention of eggs (Knutsen et al., 2007, Myksvoll et al., 2011). After the eggs hatch, the cod larvae have limited mobility and are subject to passive transport. After metamorphosisfrom larva to juvenile, the coastal cod juveniles settle in shallow near shore areas (Espeland, 2010). When settling, the coastal cod in Northern Norway has a body length of approximately 40 mm (Sandeseng, 2006). Predation represent a major cause of mortality during the early life of Atlantic cod. Newly settled cod is most vulnerable to predation from other fish (Keats et al., 1987; Berg and Pedersen, 2001). Bottom dwelling ambush predators, such as sculpins, and cruising predators such as larger gadoids, are both major predators on 0-group cod (Laurel et al., 2006). For juvenile cod of age 1 and older, other fish still represent a threat, but seabirds and seals may also actively forage on these individual (Nøstvik and Pedersen, 1999). It has been suggested that there are ontogenic habitat shifts among coastal cod juveniles. Berg and Albert (2003) conducted a field study where cod was sampled by trawling, which is limited to deep areas with flat bottom topography. They rarely caught cod of 2 years of age or younger. This indicated that the depth distribution and habitat associations of juveniles of 2 years or younger were different from that of older individuals, and the authors suggested that small juvenile coastal cod reside in shallow near shore habitats.

The life stages of fish from metamorphosis until sexual maturation is referred to as the juvenile period (Balon, 1984). Norwegian coastal cod north of 62°N have been found to mature sexually between 2 and 10 years of age, with a median maturation age of 5.7 years (Berg and Albert, 2003). The juveniles may however start to join larger conspecifics in search for food at an earlier age (Løken *et al.*, 1994). The spawning season of coastal cod varies, but it has been suggested that a peak concentration of spawning can be found in late April (Kjesbu, 1989). The offspring is referred to as 0-group until 1st January the year after spawning. Within a cohort there are variations in length and growth due to different time of spawning, hatching and first feeding. The growth pattern of coastal cod is varying between different sub populations of coastal cod (Berg and Pedersen, 2001; Berg and Albert, 2003). The growth during the juvenile period is considerable, and ontogenic shifts in behaviour is very likely.

1.3 Macroalgae communities

Fishery scientists are well aware of the importance of habitat in mediating growth and survival in fish populations (Werner, 2002). Coastal ecosystems at high latitudes accommodate highly productive and diverse communities (Steneck *et al.*, 2002). These communeties are characterized by seasonal variations and large fluctuations in biomass. Kelp forests and densely vegetated habitats are restricted to shallow areas, where macroalgae can get sufficient light, suitable substrate and adequate shelter. The biomass production of macroalgae in well suited areas can be considerable, and a multitude of epiphytes and fauna can be found associated with kelp forests (Christie *et al.*, 2003). Important species of macroalgae along the norwegian coast include brown algae (*Phaeophycaea*) such as *Laminaria spp.*, *Fucus spp.* and *Desmarestia spp.* (Sjøtun *et al.*, 1993). Since the early 1970s destructive grazing by sea urchins has occurred frequently along the norwegian coast (Hagen, 1995; Sivertsen, 2006; Norderhaug and Christie, 2009). This has reduced the extent of kelp beds and macroalgae habitats, and in many areas the barrens caused by the grazing have not been revegetated. Kelp and other macrophytes provide refuge and feeding opportunities for small fish (Norderhaug *et al.*, 2005). A reduction in the extent of macroalgae may in turn lead to lower abundances of the species that depend on vegetation for refuge and food (Steneck *et al.*, 2002; Christie *et al.*, 2009). Vegetation is believed to play significant role in reducing mortality amongst juvenile cod by providing refuge and feeding opportunities, and several studies have investigated the habitat preferences of juvenile gadoids (Keats *et al.*, 1987; Borg *et al.*, 1997; Grant and Brown, 1997; Gregory and Anderson, 1997). The studies have been conducted in both field and laboratory conditions. There has however not been conducted any field studies that directly investigate the relationship between juvenile coastal cod and macroalgae habitats in northern Norway.

1.4 Aims and hypotheses

The aims of the current study was to investigate the choice of habitat and distribution of juvenile coastal cod in Porsangerfjorden and Ullsfjorden in northern Norway. There was a special emphasis on the role of macroalgae habitats for various age groups of juvenile coastal cod. The following hypotheses were formulated:

Hypothesis$_1$: *There is a higher occurence of juvenile cod in areas with macroalgae cover than in areas without.*

Hypothesis$_2$: *Areas with macroalgae cover are used as refuge for juvenile coastal cod.*

Hypothesis$_3$: *Areas with macroalgae cover are used as foraging grounds for juvenile coastal cod.*

Hypothesis$_4$: *Association with macroalgae is different between various age groups of juvenile coastal cod.*

Hypothesis$_5$: *Juvenile coastal cod has depth preferences.*

Hypothesis$_6$: *Depth preference differs between various age groups of juvenile coastal cod.*

2 Materials and methods

2.1 Description of sampling area

This study was based on field sampling from two fjord systems in northern Norway, namely Porsangerfjorden in Finnmark (Figure 1) and Ullsfjorden in Troms (Figure 2). Juvenile cod was observed and abundance estimated by using a towed video rig. In addition beach seine hauls and angling were performed to make relative abundance estimates and sample fish for body size measurements and stomach analysis. Sampling was conducted during the summer and autumn of 2010 and 2011 (Table 1). Locations for sampling was chosen with the criteria that the whole expanse of the fjords should be covered, and that different types of habitats should be included. In Porsangerfjorden, all stations except Strandbukt and Hamnholmen, were sampled using all three methods. Beach seine hauls were not performed on these two stations. In Ullsfjorden all stations were sampled using video. Seven out of a total of eleven stations were sampled using angling, but none of the stations were sampled with beach seine (Table 1). All sampling was carried out in daylight. Hydrographic data was aquired from the University in Tromsø´s project «Havmiljø data fra NordNorske fjorder».

Porsangerfjorden, being one of the largest fjords in Norway, is approximately 110 km in length and has widths ranging from 5 km across in the inner part to about 15 km across in the outer parts (Figure 1). The entrance is facing north and there is no distinct sill (Hegseth *et al.*, 1995). The outermost parts of the fjord are directly exposed to the Barents Sea and the shoreline here mainly consists of rock and cobble. The depth in the outer parts of the fjord runs down to 300 meters. Located 20 km from the entrance is an island named Tamsøy. This island forms a natural barrier against the ocean to the north. South of Tamsøy is a basin with depths down to 150 m, that forms the middle part of the fjord. In the inner parts of Porsangerfjorden there are two separate basins, namely Austerbotn and Vesterbotn. These areas are scattered with several large islands and rocky islets. The water temperatures in Austerbotn differs from the rest of Porsangerfjorden, with bottom temperatures down to -1º C (Svendsen, 1990). The general characteristics of the various parts of Porsangerfjorden differ with regard to wave exposure and substrate charachteristics.

Ullsfjorden is the smaller of the two investigated fjords with an approximate length of 44 km, stretching from Karlsøy in the north to the innermost station Straumen in the south (Figure 2).

The mouth of Ullsfjorden is partly sheltered from the open ocean by several large islands. In the innermost part of the main fjord there is a sharp and narrow threshold (Straumen), marking the entrance to Sørfjorden, a subsidiary fjord. There is a strait coming into Ullsfjorden from the west, Grøtsundet, about 20 km from the innermost part of the fjord (Figure 2). The western shores of Ullsfjorden are lined with steep mountains and the shoreline is mostly covered by rock. The eastern shoreline in the south of the fjord is however dominated by sand and cobble. Further out on the eastern side of the fjord the shoreline consists of larger cobble and rocks.

2.2 Video survey

Video sampling was carried out using a 16′ rigid inflatable boat (RIB) in Porsangerfjorden and research vessel FF Hyas in Ullsfjorden. The video platform consisted of a fin stabilized steel rig (Figure 3). The camera was a wide angle, high resolution videocamera (LH Camera model PRO) with a sensitivity of 0.1 lux. The camera was tilted about 20 degrees down, with two parallel lasers for providing reference points for length measurement. The distance between the lasers were 18 cm, and they were adjusted so that they appeared horizontally in the middle of the video frame. A live video feed was available through a kevlar reinforced cable. The rig was towed using a steel wire or only the reinforced cable. Towing depths were limited by the cable length of 50 m. Video was recorded on a digital video recorder and stored for later analysis. During towing, an eccosounder was used for registering depth and a handheld GPS to record position and towing speed. Start time, stop time and position was registered for each transect. Video was recorded in realtime and without artificial light. Two to four transects were sampled per station (Table 1). Most transects were recorded starting in the tidal zone and towing out towards greater depths. On some locations the transectes were recorded starting from the deepest end of the transect and towing upwards to the tidal zone. The rig was ideally towed 0.5 meters above the seabed, which gave a horizontal coverage of approximately 2 meters in the mid part of the frame (in the plane of the lasers). Towing commenced until depths of about 40 m were reached. In shallow areas where it was not possible to reach depths of 40 m, recording was stopped after 30 minutes. Towing speed was ideally kept at 1 knot per hour, but there was some variation in towing speed due to varying wind and current. Total recording time per station varied from 450 seconds to 4250 seconds. Mean towing length per station in Porsangerfjorden was 2440 second (SD = 820), whereas mean towing length in Ullsfjorden was 1660 seconds (SD = 1140 seconds).

Table 1: Overview of sampling localities in Porsangerfjorden and Ullsfjorden.

Station number	Fjord	Station	Date	Year	Type	Transects	Latitude N	Longitude E
1	Porsangerfjorden	Kåfjord	18.08	2010	Angling		70 52.234	25 44.011
			18.08	2010	Beach seine		70 52.234	25 44.011
			01.09	2011	Angling		70 52.234	25 44.011
			01.09	2011	Video	2	70 52.234	25 44.011
2		Strandbukt	29.08	2011	Angling		70 44.570	25 37.370
			29.08	2011	Video	3	70 44.570	25 37.370
3		Repvåg	03.08	2010	Angling		70 45.117	25 40.155
			16.08	2010	Beach seine		70 45.117	25 40.155
			17.08	2010	Angling		70 45.117	25 40.155
			29.08	2011	Angling		70 45.117	25 40.155
			29.08	2011	Video	3	70 45.117	25 40.155
4		Ytre Svartvik	17.08	2010	Beach seine		70 40.056	25 23.523
			29.08	2011	Angling		70 40.056	25 23.523
			29.08	2011	Video	3	70 40.056	25 23.523
5		Smørfjord	06.08	2010	Angling		70 31.780	25 05.700
			17.08	2010	Angling		70 31.780	25 05.700
			17.08	2010	Beach seine		70 31.780	25 05.700
			30.08	2011	Angling		70 31.780	25 05.700
			30.08	2011	Video	3	70 31.780	25 05.700
6		Hamnholmen	31.08	2011	Angling		70 24.010	25 18.800
			31.08	2011	Video	3	70 24.010	25 18.800
7		Indre Billefjord	06.08	2010	Angling		70 19.597	25 06.685
			19.08	2010	Beach seine		70 19.597	25 06.685
			31.08	2011	Angling		70 19.597	25 06.685
			31.08	2011	Video	3	70 19.597	25 06.685
8		Trollholmsund	06.08	2010	Angling		70 18.148	25 10.849
			18.08	2010	Beach seine		70 18.148	25 10.849
			31.08	2011	Angling		70 18.148	25 10.849
			31.08	2011	Video	3	70 18.148	25 10.849
9		Reinøya øst	19.08	2010	Beach seine		70 16.042	25 20.612
			31.08	2011	Angling		70 16.042	25 20.612
			31.08	2011	Video	3	70 16.042	25 20.612
10		Brenna	19.08	2010	Beach seine		70 29.046	25 39.042
			31.08	2011	Angling		70 29.046	25 39.042
			31.08	2011	Video	2	70 29.046	25 39.042
11	Ullsfjorden	Reinøya nord	15.06	2010	Angling		69 58.221	19 52.993
			29.09	2010	Angling		69 58.221	19 52.993
			03.10	2011	Video	3	69 58.221	19 52.993
12		Nordeide	15.06	2010	Angling		69 55.071	19 47.068
			03.10	2011	Video	3	69 55.071	19 47.068
13		Blåmannsneset	16.06	2010	Angling		69 46.820	19 43.437
			29.09	2010	Angling		69 46.820	19 43.437
			03.10	2011	Video	3	69 46.820	19 43.437
14		Kavlberget	04.10	2011	Video	3	69 43.392	19 41.643
15		Straumen	17.06	2010	Angling		69 36.516	19 43.857
			04.10	2011	Video	3	69 36.516	19 43.857
16		Hjellnes	17.06	2010	Angling		69 36.617	19 44.732
			01.10	2010	Angling		69 36.617	19 44.732
			04.10	2011	Video	3	69 36.617	19 44.732
17		Bakkeby	30.09	2010	Angling		69 40.792	19 45.973
			04.10	2011	Video	3	69 40.792	19 45.973
18		Mikkelvik	16.06	2010	Angling		69 47.573	19 54.493
			30.09	2010	Angling		69 47.573	19 54.493
			04.10	2011	Video	3	69 47.573	19 54.493
19		Sør Lenangen	04.10	2011	Video	3	69 50.504	19 58.306
20		Eidstrand	05.10	2011	Video	3	69 53.704	20 06.153
21		Nord Lenangen	05.10	2011	Video	4	69 55.152	20 10.883

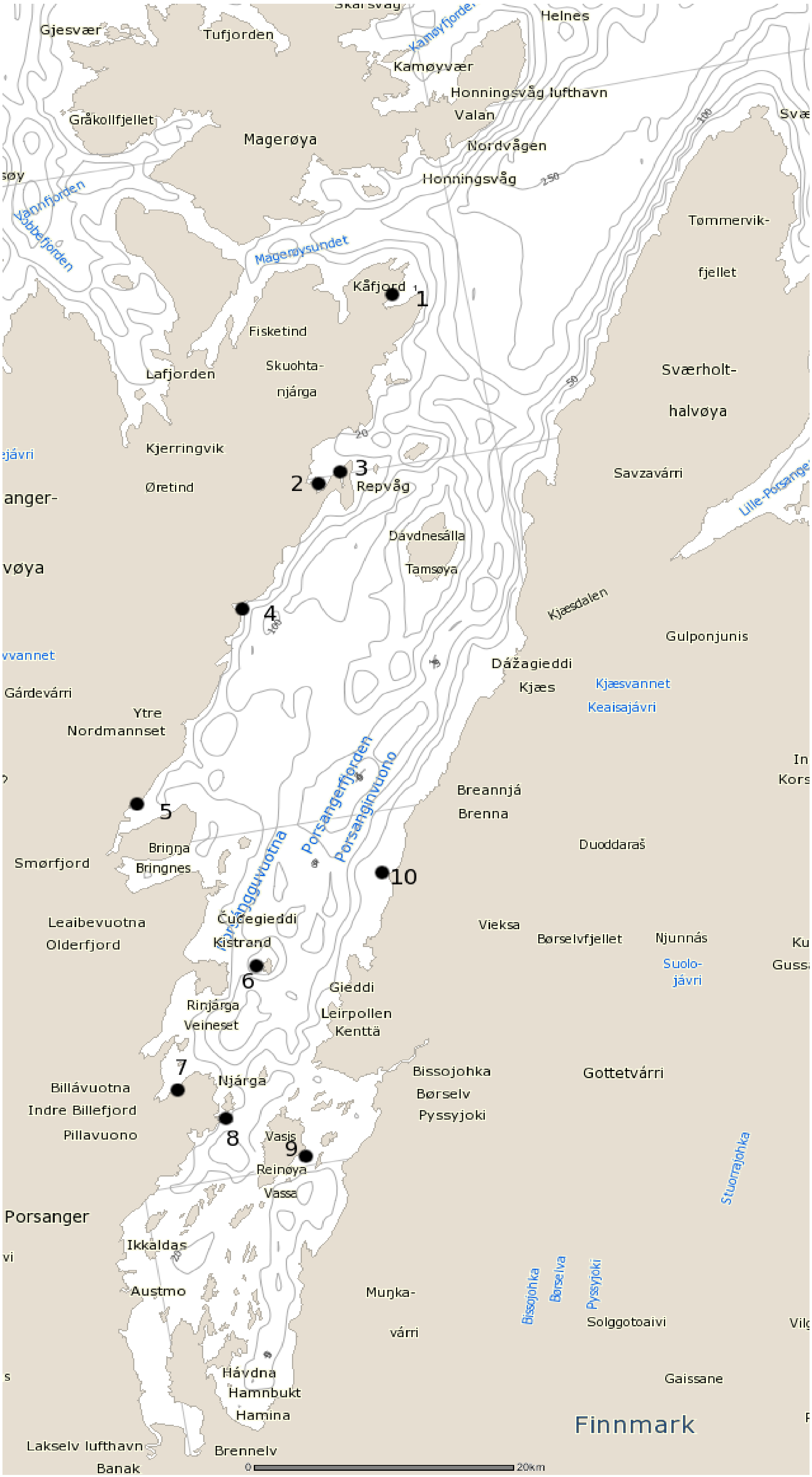

Fig. 1: Map of Porsangerfjorden (www.mareano.no). Sampling localites marked with numbers. Depth curves show 20 m, 50 m, 100 m, 150 m, 200 m and 300 m. (Map from www.mareano.no)

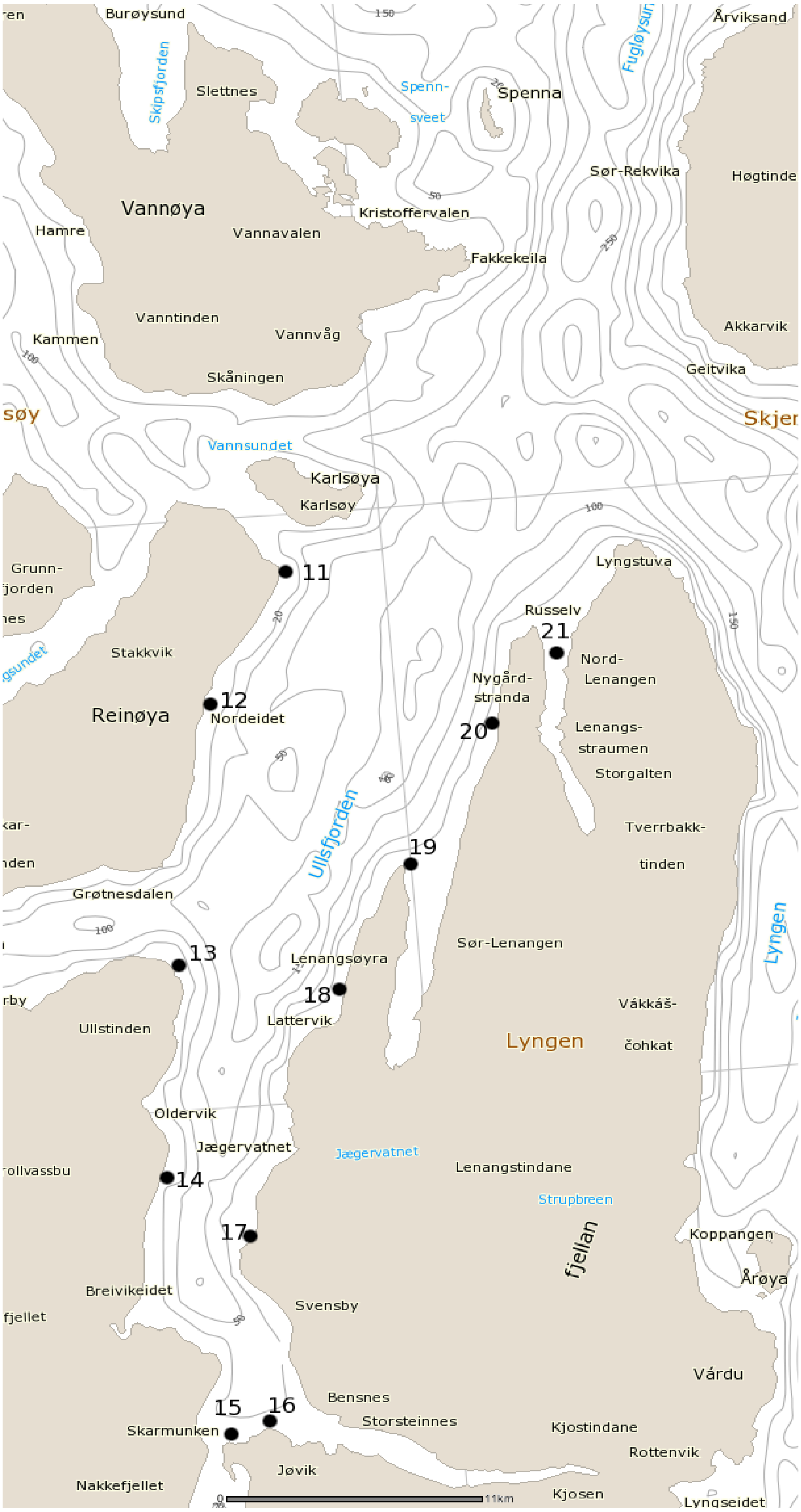

Fig. 2: Map of Ullsfjorden (www.mareano.no). Sampling localities marked with numbers. Depth curves show 20 m, 50 m, 100 m, 150 m, 200 m and 300 m.(Map from www.mareano.no)

All recorded video was reviewed in full length on a desktop computer after the video survey was completed. Each transect was divided in 10 second long samples, resulting in a total of 4318 samples. The horizontal coverage width of the video recordings was calculated by measuring the distance between the laser points in centimeters on the video monitor with a ruler during review, and applying the following formula.

$$\text{Horizontal coverage (cm)} = \frac{\text{[Videomonitor width (cm)]}}{\text{[Distance between laser points on screen (cm)]}} * \text{[Known distance between lasers (cm)]}$$

The calculation of the horizontal coverage assumed that the field of view was flat, and did not take into account any optic distortion from the camera. Area covered per transect was estimated by multiplying the horizontal coverage width in meters with towing length per 10-second sample. In the statistical analysis, a towing speed of 1 knot per hour was assumed, which gives a towing length of ~5 m per 10 seconds. In each sample, depth, macroalgae type and coverage in percent, and cod abundance and occurence were registered in a standardized data matrix / spreadsheet. Algae cover was judged visually in each sample using a ruler. The laser points was used for estimating cod size during review of the video recordings, by comparing fish length with the known distance between the lasers.

The variables depth, algae species and algae cover were divided into categories. Calcareous algae species were not included in the algae cover mapping. The categories were defined with the criterion that each should contain a sufficient number of samples. Chi-square tests (Zar, 1998, p. 487) were applied to test if distribution of samples between categories were equal between groups of stations or fjords. The chi-square test assumes that the sample is selected randomly from the population and that all expected values are five or more. Open Office Calc was used for calculations and plotting of figures. Various age groups of cod were defined on the basis earlier studies (Berg and Pedersen, 2001; Larsen and Pedersen, 2002). 0-group was defined as fish with body length <12 cm. 1-group was defined as fish with body length between 12-22 cm. 2+ group was including all fish with body length >22 cm. In some tests, the 1-group and 2+ group were pooled and referred to as 1+ group. The proportion of samples with cod present was calculated for each depth and algae cover category. Confidence intervals (95%) for proportions was calculated using a formula given by Zar (1998, p. 528). Chi-square tests (Zar, 1998, p. 487) were applied to test if proportion of occurrence of cod was equal between various locations, algae cover categories and depth intervals.

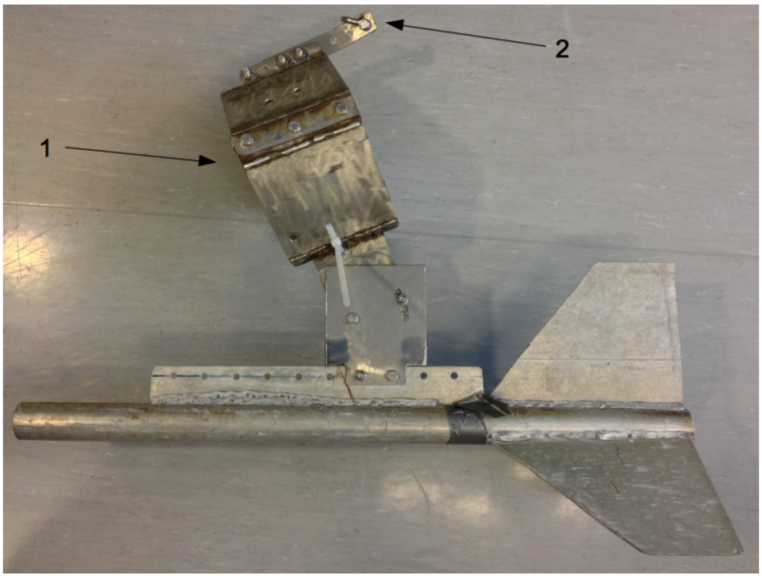

Fig. 3: Towed video rig used to record video of bottom habitats in the sub tidal zone. (1) Camera and lasers, (2) cable attachment.

2.3 Beach seine survey

Sampling with beach seine was carried out by using an inflatable rubber dinghy equipped with an outboard engine and eccosounder. The beach seine used was 30 meters long and had a maximum height of 3 meters. The mesh size was ca. 4 mm in the central cod end. In each end of the seine there a 20 m of rope attached. The lower rope on the seine was led filled so it would sink, and the upper rope had floatings. The seine was set from a point on the shore and motored out in an arch with the dinghy. The other end of the seine was landed ashore about 30 meters from the first rope. The area covered during each sweep was ideally 300 m^2. Two replicate hauls were taken on each station. Fish caught with the beach seine was counted and measured consecutively. All cod was stored in 70% ethanol for later analyses. In the statistical analysis, the two hauls from each station were pooled. Abundances per 1000 m^2 was calculated assuming that 600 m^2 was sampled at each station. Only 0-group cod was included in the abundance estmates from the beach seine survey.

2.4 Angling survey

Angling was carried out from a rubber dinghy, using a light spinning rod with 0.25 mm diameter nylon line and a jig consisting of five fly fishing hooks of size 10 with rubber baits and a 100 gram brass sinker. The distance between the rubber baits was 10 cm. An eccosounder was used to register depth. At each station, angling was performed consecutively in five depth intervals with five minutes angling time per interval. Additional fishing time was added when fish was caught and had to be reeled in and unhooked. Depth intervals were

2-5 m, 5-10 m, 10-20 m, 20-30 m and 30-50 m. The positions for angling were ideally along a line perpendicular to the shoreline. An anchor was used to keep the position with the dinghy during angling. Position for each depth interval was recorded with a handheld GPS and depth of each fish caught was registered. All fish were packed individually and frozen for later analysis. Abundance estimates based on angling assumes that all fish have equal probability of capture (Gutowsky *et al.*, 2011). Catch per unit effort (25 minutes of angling) were esimated per station.

2.5 Diet analysis

Fish caught by beach seine and angling were length measured and analysed in a laboratory after the field surveys were completed.. The same age groups as defined in the video survey were used. A total of 61 0-group and 81 1+ group cod were included in the diet analysis. Prey items were identified down to lowest possible taxonomic level. In the statistical analysis, the prey were categorized into eleven taxonomic/functional groups. Frequency of occurrence was calculated for each prey category based on the total number of stomachs with stomach content for each station. Empty stomachs were counted, but not included in the frequency of occurrence analysis. A chi-square test (Zar, 1998, p. 487) was applied to test if frequencies of occurrence for various prey categories were equal between different stations, fjords and age groups of cod.

3 Results

3.1 Topography of sampling locations and seawater temperature

The depth category composition was similar between the various stations in both Porsangerfjorden and Ullsfjorden (Table 2). In Porsangerfjorden 58% of the videosamples had depths of 20 m or less. The composition of depth categories in Ullsfjorden was similar with 59% of the samples having depths of 20 m or less. The average depth gradients were however steeper in Ullsfjorden than in Porsangerfjorden, resulting in longer transect lengths in Porsangerfjorden (Figure 4). Hydrographic data for Porsangerfjorden from 05.07.11, showed that there was a decrease in temperature from 11°C in the surface to 6.5°C at 20 m depth (Appendix 4). Hydrographic data for Ullsfjorden from 17.10.11, showed that there was a temperature of 7°C, and little variation from the surface and down to 50 m (Appendix 5).

3.2 Algae cover

The video mapping of macroalgae showed different patterns of algae cover in Porsangerfjorden and Ullsfjorden, and the distribution of samples in the various algae cover categories differed between the two fjords ($\chi^2 = 344.99$, df = 4, $p < 0.001$) (Table 3). There was 745 samples (~33%) with 20% algae cover or more, and 1691 samples (~67%) with less than 20% algae cover in Porsangerfjorden (Table 3). The algae cover categories 20-40% and >80% constituted the majority of samples with algae cover of 20% or greater. In Porsangerfjorden the three innermost stations (Reinøya Øst, Trollholmsund and Indre Billefjord) had very low algaecover with less than 10% of samples had 20% algae cover or more (Figure 5). From the station Hamnholmen and outwards in Porsangerfjorden, all localities had more than 20% of the samples with algae cover of 20% or more. From Ytre Svartvik in the mid part of Porsangerfjorden and outwards to Kåfjord, there was a gradual decrease in proportion of samples with algae cover of 20% or more. Brenna was the only station in Porsangerfjorden with algae cover of 20% or greater in more than 50% of the samples (Figure 5). In Ullsfjorden, there was 1041 samples (~58%) with 20% or more algae cover and 742 (~42%) samples with less than 20% algae cover, and the majority of samples with algae cover of 20% or greater, belonged to the categories 20-40% and 40-60%. The stations Bakkeby, Noreide and Nord Lenangen in Ullsfjorden all had more than 50% of samples with algae cover of 20% or more (Figure 5). Blåmannsneset was the only station in Ullsfjorden which had no samples with algae cover of 20% or more.

There was a variety of macroalgae species found in both fjords, the most abundant belonging to the phylum *Phaeophyceae* (brown algae), but species from phyla *Chlorophyceae* (green algae) and *Rhodophyceae* (red algae) were also observed. Brown algae such as *Fucus spp.* (*Phaeophyceae*) were abundant in the tidal zone and *Chorda filum* was found in the subtidal zone of most stations in Porsangerfjorden (Table 4). At intermediate depths (10-20 m), *Laminaria saccharina* and *Desmarestia spp.* was frequently observed in both fjords. At depths from 20 m and deeper, red algae were frequently found in Ullsfjorden, and to a lesser degree in Porsangerfjorden (Table 4). The occurrence of various species of macroalgae were significantly different between Porsangerfjorden and Ullsfjorden ($\chi^2 = 581.93$, df = 9, $p < 0.001$). The most noticable difference was found in the shallow sub tidal zone, where *Alaria esculenta* and *C. filum* were more frequent in Porsangerfjorden than Ullsfjorden. On the other hand, there was a higher occurrence of red algae and *Desmarestia spp.* in Ullsfjorden than in Porsangerfjorden (Table 4). The species of macroalgae found at the three innermost stations in Porsangerfjorden (Reinøya øst, Trollholmsund and Indre Billefjord) were primarily *Fucus spp.* and *C. Filum,* which were located in the tidal zone and shallow sub tidal zone. The station Brenna had a high abundance of *Laminaria digitata* in the depth interval 5-10 m. This species of macroalgae was also abundant on the station Nord Lenangen in Ullsfjorden.

Table 2: Total number of samples in various depth categories and number of samples with 0-group, 1-group and 2+ group present.

	Porsangerfjorden				Ullsfjorden			
Depth category (m)	0-group	1-group	2-group +	Total samples	0-group	1-group	2-group +	Total samples
0-10	13	7	6	802	6	13	6	454
10-20	18	4	2	618	32	38	21	588
20-30	9	3	1	759	8	11	4	435
>30	1	1	0	256	0	1	2	306
	41	15	9	2435	46	63	33	1783

Table 3: Total number of samples in various algae cover categories and number of samples with 0-group, 1-group and 2+ group present.

	Porsangerfjorden				Ullsfjorden			
Algaecover (%)	0-group	1-group	2-group +	Total samples	0-group	1-group	2-group +	Total samples
0-20	2	3	2	1631	4	10	14	742
20-40	8	5	0	202	10	21	7	352
40-60	5	4	3	194	19	19	2	329
60-80	15	3	2	117	7	9	9	179
80-100	11	0	2	291	6	4	1	181
	41	15	9	2435	46	63	33	1783

Table 4: Number of samples with various species of macro algae present. Note that several species may occur in same sample.

	Fucus serratus	Chorda filum	Alaria esculenta	Laminaria saccharina	Laminaria digitata	Laminaria hyperborea	Desmarestia spp.	Phaeophyceae spp.	Chlorophyceae spp.	Rhodophyceae spp.
Porsangerfjorden	2	88	66	568	207	3	256	557	18	46
Ullsfjorden	0	21	1	357	77	10	456	375	45	381
Total	2	109	67	925	284	13	712	932	63	427

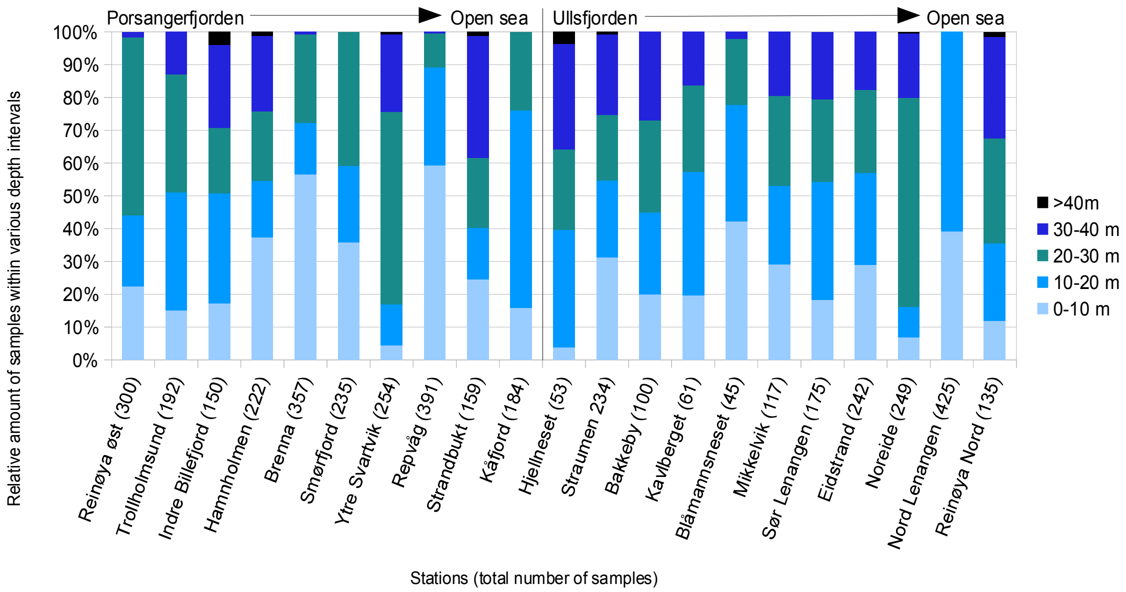

Fig. 4: Depth category composition of stations from video survey. Stations listed from innermost location and outwards. Number of 10-second samples for each station shown in brackets.

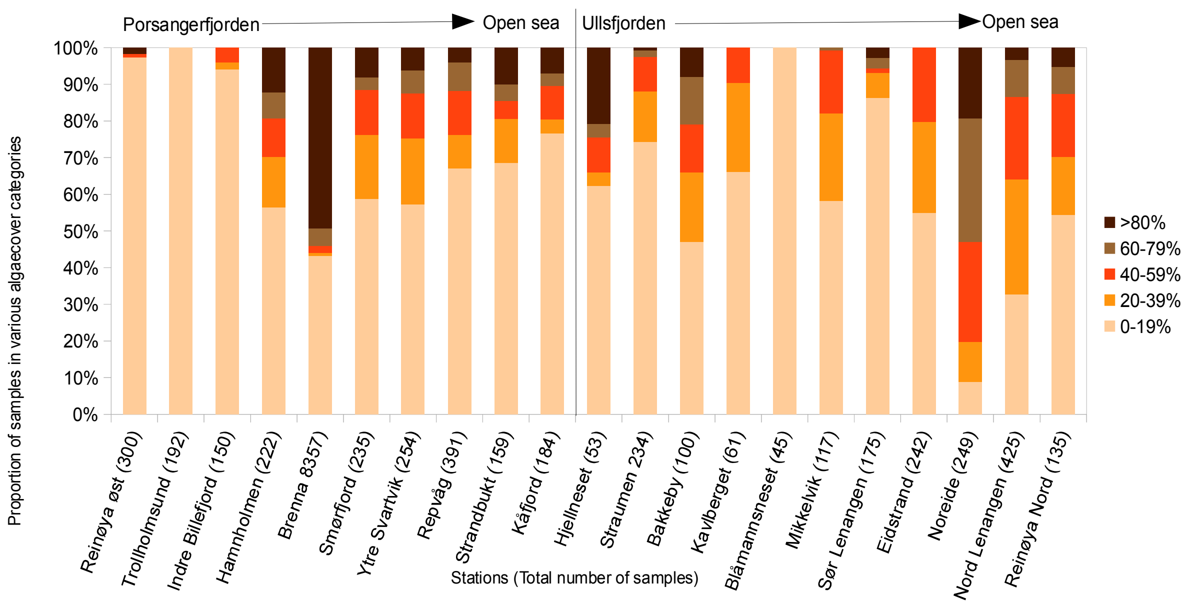

Fig 5: Algae cover category compostition shown for each station. Stations listed from innermost location and outwards. Number of 10-second samples for each station shown in brackets.

3.3 Depth distribution of algae cover

In Porsangerfjorden the depth interval 0-10 m had the highest proportion of samples with algae cover of 20% or more (Figure 6). The tree innermost stations (Reinøya øst, Trollholmsund and Indre Billefjord) did however only have algae cover lower tidal and upper sub tidal zone. For all stations in Porsangerfjorden (pooled), there was a gradual decrease of algae cover towards greater depths. Algae cover greater than 80% was not found at depths below 30 m (Figure 6). In Ullsfjorden, the largest proportion of samples with algae cover of 20% or more was at depths of 20 m or more (Figure 6). At these depths, the most frequently occurring species of macroalgae were red algae and *Desmarestia spp*. Samples with 80% algae cover were found in all depth intervals in Ullsfjorden (Figure 6). A majority of samples in Ullsfjorden with algae cover of 20% or greater were in the coverage categories of 20-40% and 40-60%. In the depth interval 0-10 m there was a higher proportion of samples (pooled samples for each fjord) with algae cover of 20% or more in Porsangerfjorden than Ullsfjorden ($\chi^2 = 28.33$, df = 1, $p < 0.001$). In the depth interval 10-20 m ($\chi^2 = 31.03$, df = 1, $p < 0.001$), 20-30 m ($\chi^2 = 133.06$, df = 1 , $p < 0.001$) and >30 m ($\chi^2 = 85.02$, df = 1, $p < 0.001$) there was a higher proportion of samples with algae cover of 20% or more in Ullsfjorden than in Porsangerfjorden.

3.4 Occurrence of juvenile cod in Porsangerfjorden and Ullsfjorden

The results from the video surveys showed that there was a higher occurrence of 0-group and 1+ group cod in Ullsfjorden (7.7% of samples) than in Porsangerfjorden (2.6%) (Table 3). The difference was significant for both 0-group ($\chi^2 = 204.45$, df = 1, $p < 0.001$) and 1+ group cod ($\chi^2 = 293.20$, df = 1, $p < 0.001$). 0-group cod was observed on five of ten stations in Porsangerfjorden (Figure 7). There were no observations on the four innermost stations. In Ullsfjorden, 0-group cod was observed on seven of eleven stations sampled. The majority of the observations were made in the innermost and outermost parts of Ullsfjorden. 1+ group cod was observed on five of ten stations in the video survey in Porsangerfjorden, and there was no observations on the four innermost stations (Figure 8). In the video survey in Ullsfjorden, observations of 1-group and older cod was made on nine of eleven sampled stations. Aggregations of ten or more individuals of 0-group cod per sample were observed in both Porsangerfjorden and Ullsfjorden. For 1-group and 2+ group cod, aggregations of ten individuals or more individuals per sample were only observed in Ullsfjorden (Appendix 2).

In the beach seine survey in Porsangerfjorden, 0-group cod was caught on all sampled stations. Abundance estimates from the beach seine survey ranged from 2 to 33 0-group cod per 1000 m2 (Figure 7). In the angling survey in Porsangerfjorden 1+ group cod was caught on all sampled stations. Catches ranged from 1 to 3 cod per 25 minutes (Figure 8). In the angling survey in Ullsfjorden, fish was caught on five of seven sampled stations. Catches ranged from 1 to 4 cod per 25 minutes (Figure 8).

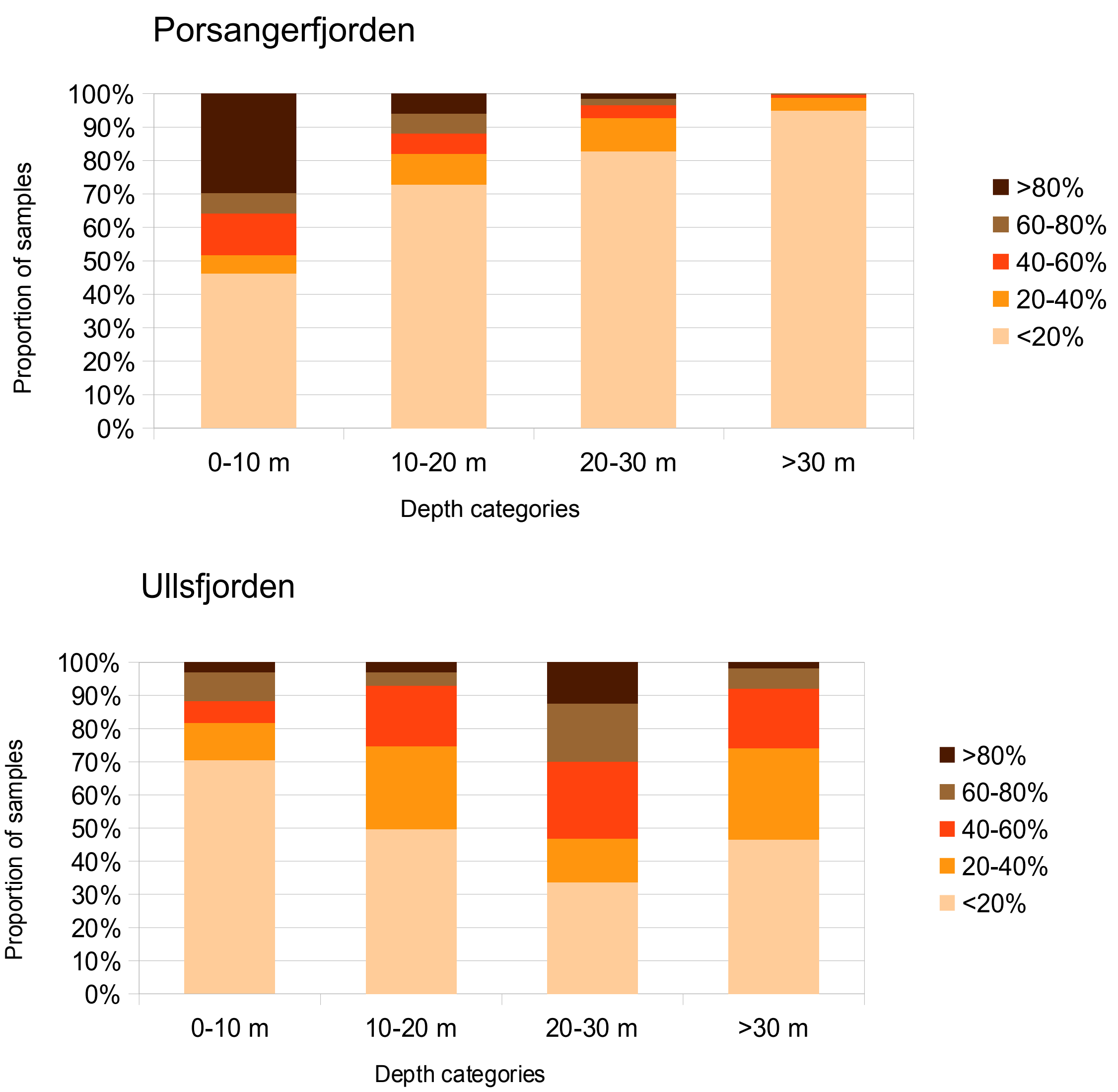

Fig. 6: Depth distribution of algae cover categories in Porsangerfjorden and Ullsfjorden.

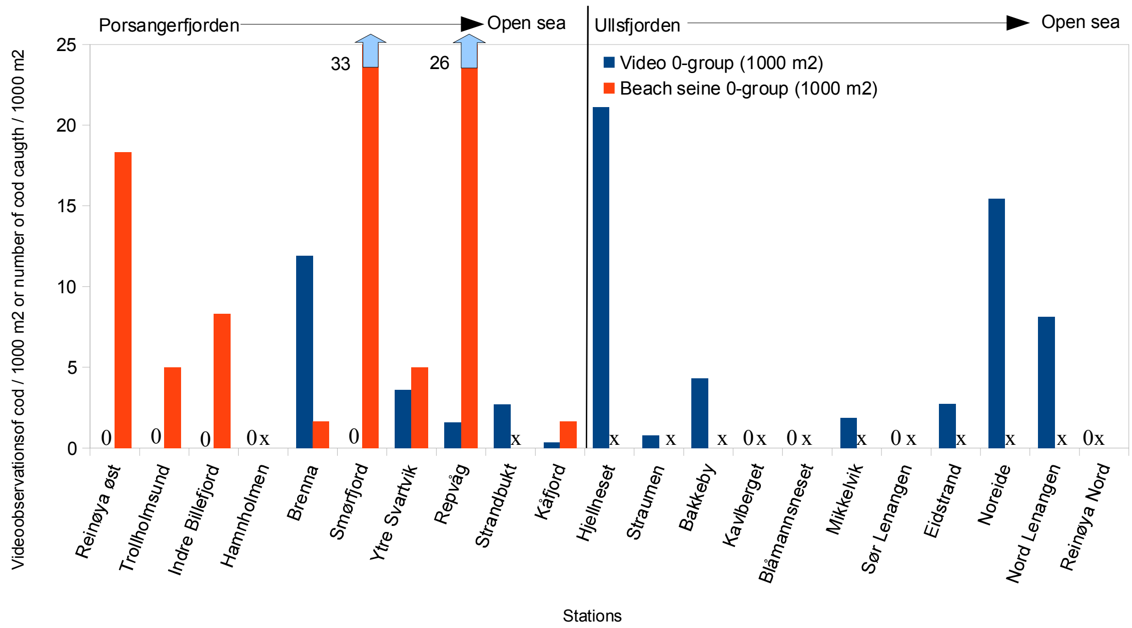

Fig. 7: Estimated abundance of 0-group cod (≤12 cm) from videos survey and beach seine survey. 0 indicates no fish observed/caught. X indicates that the location was not sampled. Sampling with beach seine was performed in August 2010, and only in Porsangerfjorden.

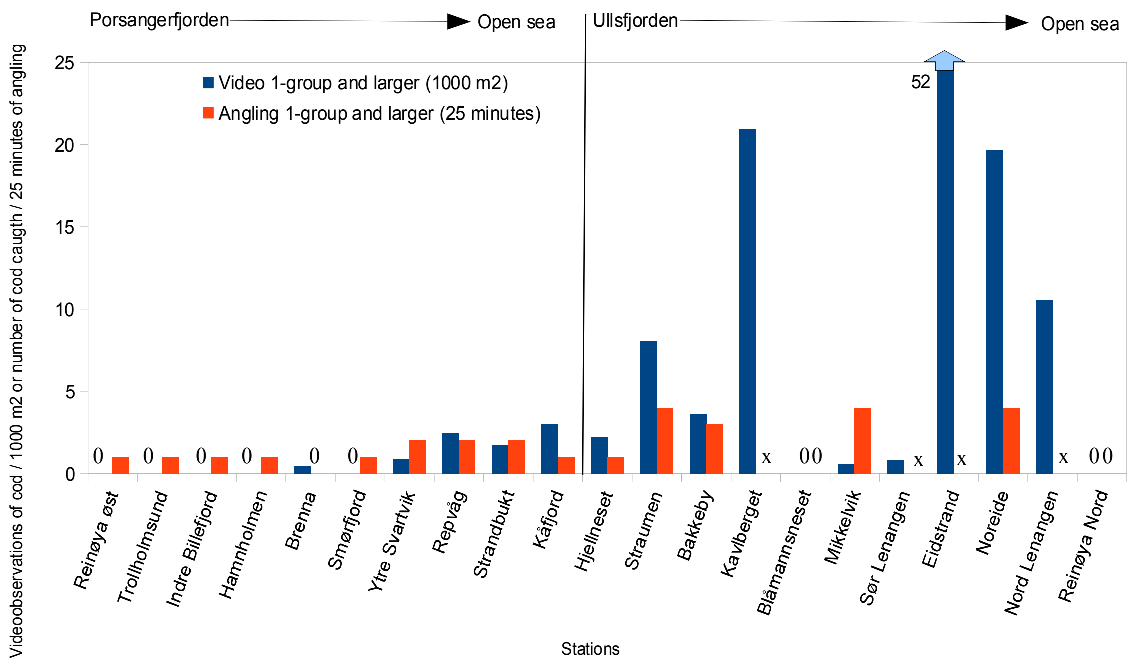

Fig. 8: Estimated abundance of 1-group cod and larger (>12 cm) from videos survey and beach seine survey. 0 indicates no fish observed/caught. X indicates that location was not sampled. Angling survey in Porsangerfjorden was performed in August and September 2011. In Ullsfjorden angling was performed in June, September and October 2010. Each angling transect had 25 minutes effort.

3.5 Occurrence of juvenile cod in relation to algae cover

There was a significant difference in proportion of samples with 0-group cod present between various algae cover categories in both Porsangerfjorden ($\chi^2 = 149.43$, df = 4, $p < 0.001$) and Ullsfjorden ($\chi^2 = 41.77$, df = 4, $p < 0.001$). Samples with 20% algae cover or more had a higher proportion of samples with 0-group cod present in both fjords (Figure 9). There were very few occurrences of juvenile cod in video samples with less than 20% algae cover (Table 3). In Porsangerfjorden there was a pronounced peak in occurrence of 0-group cod in samples with 60-80% algae cover (Figure 9). In Ullsfjorden the proportion of samples with 0-group cod present was not significantly different between the four algae cover categories with algae cover of 20% or greater ($\chi^2 = 3.78$, df = 3, $p > 0.05$) (Figure 9).

In Porsangerfjorden there was a significantly higher proportion of samples with 1-group cod in samples with 20-40%, 40-60% and 60-80% algae cover than in the <20% category ($\chi^2 = 33.97$, df = 4, $p < 0.001$) (Figure 9). In samples with algae cover of 80% or more, there were no observations of 1-group cod in Porsangerfjorden (Table 2). In Ullsfjorden there was a significantly higher proportion of samples with 1-group cod present in algae cover categories 20-40%, 40-60%, 60-80% and >80% than in the <20% category ($\chi^2 = 32.16$, df = 4, $p < 0.001$) (Figure 9). In Porsangerfjorden there was not enough observations of 2+ group cod in any of the algae cover categories to test for significance (less than 5 observations in one or more of the algae cover categories) (Table 3). In Ullsfjorden the algae cover categories with sufficient number of observations of 2+ group cod to test for significance were the categories <20%, 20-40% and 60-80% algae cover. There was a significantly higher proportion of samples with 2+ group cod present the algae cover category 60-80% than the category <20% algae cover ($\chi^2 = 10.90$, df = 1, $p < 0.05$). The difference between the 20-40% algae cover category and the <20% algae cover was however not significant ($\chi^2 = 0.38$, df = 1, $p > 0.05$).

3.6 Occurrence of juvenile cod in relation to depth

There was a significant difference in proportion of samples with 0-group cod present between the various depth intervals in Porsangerfjorden ($\chi^2 = 9.17$, df = 3, $p < 0.05$). There was a higher occurrence of 0-group cod at depths between 10-20 m (Figure 10). In Ullsfjorden there was a similar depth distibution of 0-group cod as in Porsangerfjorden, with a significantly higher proportion of samples with 0-group cod present in the depth interval 10-20 m than the other depth intervals ($\chi^2 = 28.71$, df = 3, $p < 0.001$) (Figure 10).

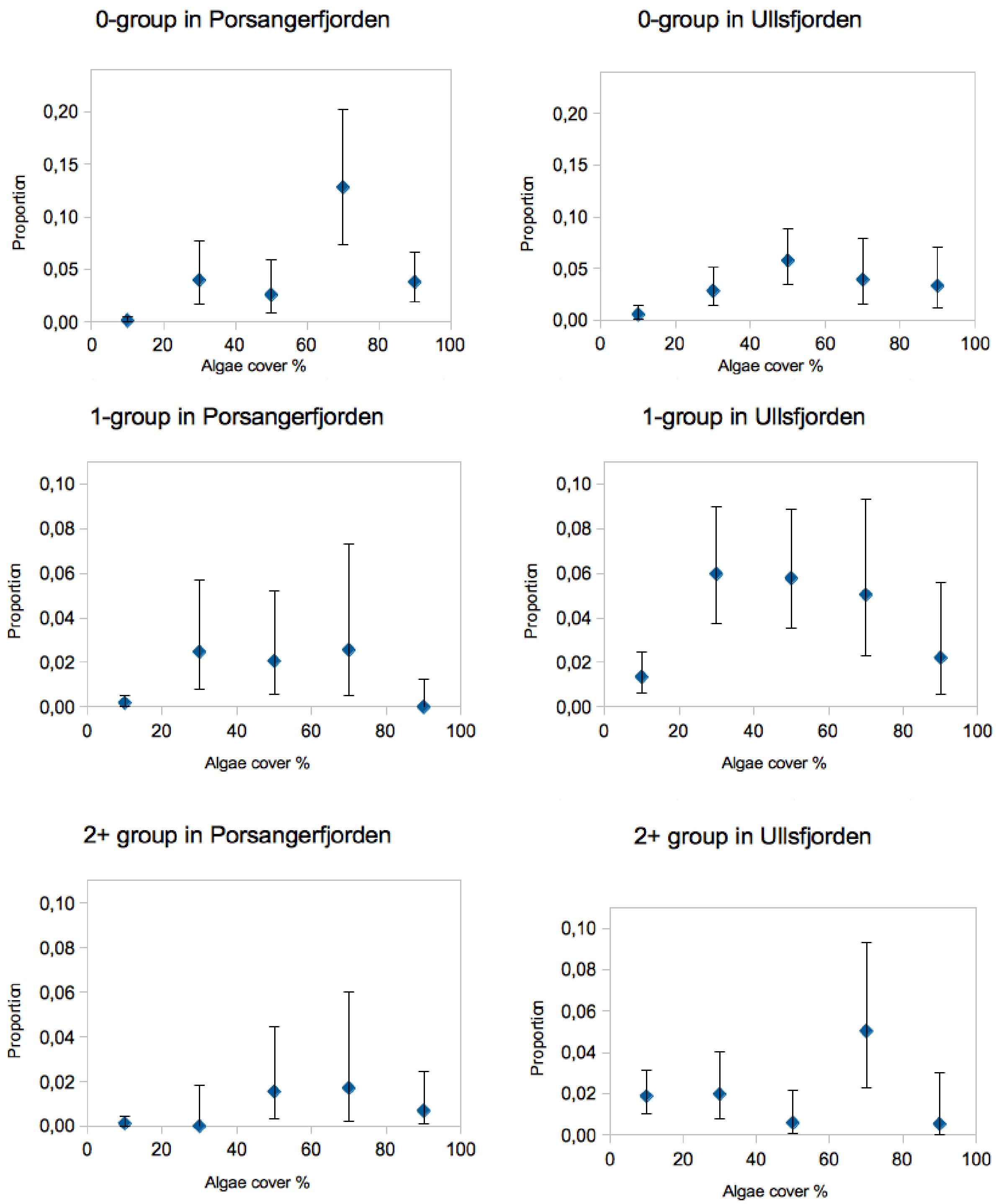

Figure 9: Relationship between algae cover and proportion of samples with of juvenile cod present (0-group: <12 cm bodylength; 1-group: 12-22 cmbodylength; 2+ group: >22 cm bodylength). Algaecover categories: 0-20%, 20-40%, 40-60%, 60-80% and 80-100%. Bars show 95% confidence interval.

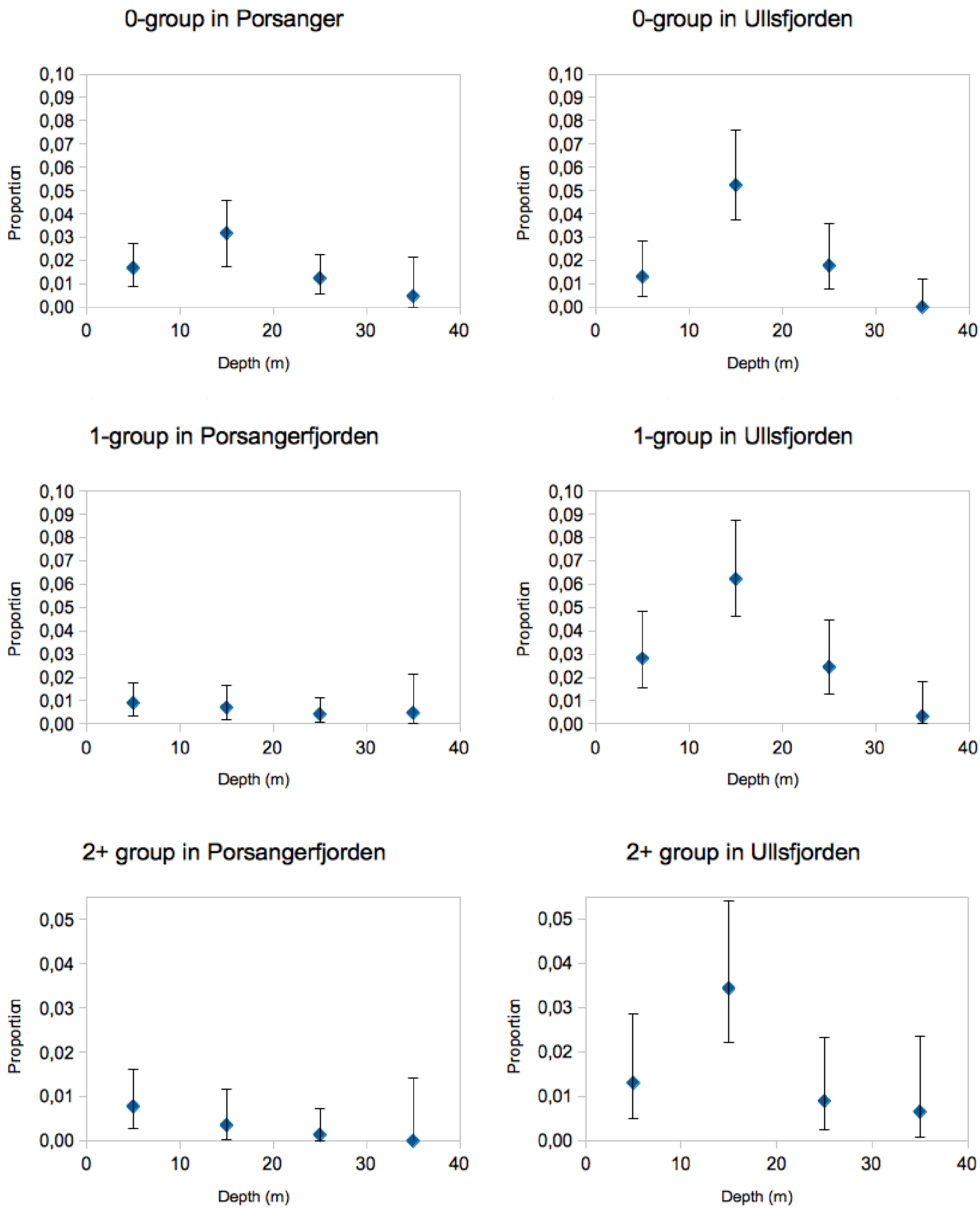

Figure 10: Relationship between depth and proportion of samples with of juvenile cod present (0-group: <12 cm bodylength; 1-group: 12-22 cmbodylength; 2+ group: >22 cm bodylength). Depth categories: 0-10 meters, 10-20 meters, 20-30 meters and >30 meters. Bars show 95% confidence interval.

In Porsangerfjorden, there was not a significant difference in proportion of samples with 1-group cod present between the depth interval 0-20 m (0-10 m and 10-20 m pooled) and the >20 m interval (20-30 m and >30 m pooled) ($\chi^2 = 1.38$, df = 1, $p > 0.05$). In Ullsfjorden, there was a significant difference in proportion of samples with 1-group cod present between the various depth categories ($\chi^2 = 23.56$, df = 3, $p < 0.001$). There was a higher proportion of samples with 1-group cod in the depth interval 10-20 m than the other depth categories (Figure 10). There was also a significant decrease proportion samples with 1-group cod from the depth category 20-30 m to the depth category >30 meters ($\chi^2 = 5.20$, df = 1, $p < 0.05$).

There was not enough observations of 2+ group cod in Porsangerfjorden to test for differences in the depth distribution (Table 2). However, there was a vague trend that proportion of samples with of 2+ group cod present decreased with increasing depth. In Ullsfjorden there was not enough occurrences of 2+ group cod at depths >30 meters to include this depth category in the significance test (Table 2). However, there was a higher porportion of samples with 2+ group cod in the depth interval 10-20 meters than in the depth intervals 0-10 meters and 20-30 meters ($\chi^2 = 9.82$, df = 2, $p < 0.05$) (Figure 10). Threre was not a significant difference in depth distribution of 0-group and 1-group cod in either Porsangerfjorden ($\chi^2 = 2.09$, df = 3, $p > 0.05$) or Ullsfjorden ($\chi^2 = 1.96$, df = 3, $p > 0.05$). The depth distribution of 1-group and 2+ group cod was also similar in both Porsangerfjorden ($\chi^2 = 1.33$, df = 3, $p > 0.05$) and Ullsfjorden ($\chi^2 = 1.88$, df = 3, $p > 0.05$).

3.7 Diet composition of juvenile cod

The mean body length of the 0-group cod sampled in the beach seine survey was 6.6 cm. In the angling survey, the mean body length was 26.8 cm when fish from all stations were pooled (Appendix 3). Diet of 0-group cod in Porsangerfjorden varied between the various stations (Table 5). None of the sampled 0-group cod had empty stomachs. The most frequently occurring prey group in the stomachs of 0-group cod was copepods. On the three innermost stations in Porsangerfjorden (Reinøya øst, Trollholmsund and Indre Billefjord), more than half of the sampled fish had copepods present in their stomach (Table 5). Copepods were also present in 38% of the stomachs from Smørfjord and 29% of the stomachs from Repvåg. In Repvåg the diet was more diverse than other stations, with 9 prey groups present. However, no prey group was present in more than 29% of the stomachs at Repvåg. There was a trend that fish and benthic invertebrates (*Anomura/Brachyura, Ophiuruidea, Polychaeta)* occurred more frequently on stations from Ytre Svartvik and outwards. There was a significant difference in frequency of occurrence of various prey groups in stomachs of 0-group cod between the inner (Reinøya øst, Trollholmsund and Indre Billefjord) and outer part of Porsangerfjorden (Smørfjord, Ytre Svartvik, Repvåg and Kåfjorden) ($\chi^2 = 18.53$, df = 10, $p < 0.05$). In Porsangerfjorden, fish occurred in 0-group cod stomachs on four of eight sampled stations (Table 5).

There was 6 empty stomachs (~11%) among the 1+ group cod sampled in Porsangerfjorden. There was a significant difference in frequency of occurrence of various pery groups of 0-group and 1+ group cod in Porsangerfjorden ($\chi^2 = 40.29$, df = 10, $p < 0.001$). The most frequent prey groups in stomachs of 1+ group cod were fish and *Crustacea spp.* (Table 5).

In Ullsfjorden there was 7 empty stomachs (~24%) among the 1+ group cod. On the station Bakkeby all sampled fish (n=3) had empty stomachs (Table 6). In the outer part of Ullsfjorden (Reinøya nord, Noreide and Mikkelvik) there was a higher occurrence of prey from the groups *Caridea, Anomura/Brachyura* and *Crustacea spp.* than in the inner part. In Ullsfjorden, the prey groups *Amphipoda* and *Copepoda* were only found in stomachs from the innermost station, Hjellneset.

The prey group *Anomura/Brachyura* occurred in a significanlty higher proportion of stomachs in Ullsfjorden than in Porsangerfjorden ($\chi^2 = 7.13$, df = 1, $p < 0.01$). Fish was only found in stomachs from the three outermost stations in Ullsfjorden, whereas in Porsangerfjorden, fish was present in stomachs from five of eight sampled stations. Cannibalism was only found in Porsangerfjorden (Appendix 1). The frequency of occurrence of various prey items in stomachs of 1+ group cod was similar between Porsangerfjorden and Ullsfjorden when all stations were pooled for each fjord ($\chi^2 = 15.21$, df = 10, $p > 0.05$). The frequency of empty stomachs from 1+ group cod was also similar between the two fjords ($\chi^2 = 1.63$, df = 1, $p > 0.05$).

Table 5: Frequency of occurence of various prey groups in diet of 0-group cod in Porsangerfjorden. Frequencies shown in percent. Values >0 and <50% colored in yellow and values ≥50% shown in red. All 0-group cod was sampled in August 2010.

	Porsangerfjorden →						**Open sea**	
	Reinøya øst	**Trollholmsund**	**Indre Billefjord**	**Smørfjord**	**Ytre Svartvik**	**Repvåg**	**Kåfjorden**	**Total**
Stomachs sampled	11	3	7	13	4	17	6	**61**
Empty stomachs	0	0	0	0	0	0	0	**0**
Prey occurence (%)								
Amphipoda	9	0	0	23	0	12	17	**9**
Copepoda	73	100	57	38	0	29	0	**43**
Mysida	0	0	29	38	0	6	0	**10**
Caridea	0	0	0	0	0	12	0	**2**
Anomura/Brachyura	0	0	0	0	25	12	17	**8**
Crustacea spp.	0	0	0	0	0	6	17	**3**
Ophiuroidea	0	0	0	0	25	0	0	**4**
Polychaeta	0	0	14	0	0	24	0	**5**
Fish	9	0	0	0	50	24	33	**17**
Other	18	33	0	15	0	0	0	**10**
Indet.	0	0	14	0	75	6	50	**21**

Table 6: Frequency of occurence of various prey groups in diet of 1-group cod and larger in Porsangerfjorden. Frequensies shown in percent. Values >0 and <50% colored in yellow and values ≥50% shown in red. In Porsangerfjorden, 1+ group cod for the diet analysis was sampled in August 2010 and August/September 2011.

	Porsangerfjorden →							Open sea	
	Reinøya øst	Trollholmsund	Indre Billefjord	Hamnholmen	Smørfjord	Ytre Svartvik	Repvåg	Kåfjorden	Total
Stomachs sampled	1	8	10	1	1	10	10	12	**52**
Empty stomachs	0	0	2	0	0	1	3	0	**6**
Prey occurence (%)									
Amphipoda	0	13	0	0	0	0	0	8	**3**
Copepoda	0	0	0	0	0	0	0	0	**0**
Mysida	0	0	0	0	0	0	0	0	**0**
Caridea	0	38	0	0	0	33	29	25	**18**
Anomura/Brachyura	0	38	0	0	100	22	14	0	**25**
Crustacea spp.	100	38	25	0	0	11	0	17	**13**
Ophiuroidea	0	0	0	0	0	11	0	0	**2**
Polychaeta	0	63	38	0	0	0	29	8	**20**
Fish	0	25	38	0	0	67	71	42	**35**
Other	0	0	0	0	0	22	29	8	**8**
Indet.	0	13	13	100	100	0	0	42	**38**

Table 7: Frequency of occurence of various prey groups in diet of 1-group cod and larger in Ullsfjorden. Frequensies shown in percent. Values >0 and <50% colored in yellow and values ≥50% shown in red. In Ullsfjorden, 1+ group cod for the diet analysis was sampled in June and September/October 2010.

	Ullsfjorden →						**Open sea**	
	Hjellneset	**Straumen**	**Bakkeby**	**Blåmannsneset**	**Mikkelvik**	**Noreide**	**Reinøya nord**	**Total**
Stomachs sampled	6	4	3	1	8	4	3	**29**
Empty stomachs	1	3	3	0	0	0	0	**7**
Prey occurence (%)								
Amphipoda	60	0	0	0	0	0	0	**9**
Copepoda	40	0	0	0	0	0	0	**6**
Mysida	0	0	0	0	0	0	0	**0**
Caridea	0	100	0	0	38	50	0	**27**
Anomura/Brachyura	40	0	0	0	100	75	0	**31**
Crustacea spp.	40	0	0	0	0	50	67	**22**
Ophiuroidea	0	100	0	0	13	0	0	**16**
Polychaeta	20	100	0	0	0	25	0	**21**
Fish	0	0	0	0	13	50	67	**18**
Other	20	0	0	0	63	0	0	**12**
Indet.	0	100	0	100	25	50	0	**39**

4 Discussion

4.1 Macro algae as refuge for small juvenile cod

The results from the current study show that juvenile cod was associated with macroalgae habitats. The association to macro algae of 2+ group cod did however not seem to be as strong as that of the two youngest age groups. These findings confirm earlier laboratory experiments and field studies which have investigated the association of juvenile cod to macroalgae (Keats *et al.* 1987; Borg, *et al.*, 1997; Gregory and Anderson, 1997; Cote *et al.*, 2001).

The results from the video survey and beach seine survey showed different findings (Figure 7). The area sampled with the two different methods did only partially overlap. The beach seine sampled primarily the tidal zone (< 3 m), whereas the video sampling covered the sub tidal zone. On the stations Reinøya øst, Trollholmsund and Indre Billefjord, 0-group cod was caught in the beach seine survey but not observed on video. However, all three stations had a narrow belt of brown algae in the tidal and immediate sub tidal zone where 0-group cod was caught. Borg *et al.* (1997) investigated habitat choice of juvenile cod from Skagerak in a laboratory experiment, and found that the smallest size group (7-13 cm) had a preference for the brown alga *Fucus vesiculosus*. This species of macro algae have air filled vesicles which helps them float during high tide and create vertical and complex structures. *Fucus spp.* are common species along the Norwegian coast and were present on most sampled locations. In addition, the threadlike brown alga *Chorda filum* was found in the upper sub tidal zone on most stations in Porsangerfjorden, including Reinøya øst, Trollholmsund and Indre Billefjord. This suggests that the macroalgae that occupy the intertidal zone and immediate sub tidal zone can provide habitat and shelter for 0-group cod in areas where algae cover is absent at deeper water. In Ullsfjorden there was a more extensive algae cover at deeper water and a higher occurrence of juvenile cod than in Porsangerfjorden. The occurrence of 0-group and 1-group cod was notably higher when algae cover exceeded 20% in both fjords. This suggest that 0-group and 1-group cod require more than 20% algae cover to actively associate with macroalgae. The occurrence of 0-group and 1-group cod were similar between all algae cover categories in both fjords except for one case. In Porsangerfjorden there was a significant higher occurrence of 0-group cod in the algae cover category 60-80%. This peak in occurrence is most likely random, but it can be expected that 0-group cod will seek refuge in closely packed vegetation if the threat of predation pressure is high. Laurel and Brown (2006) investigated the effect of different types of predators and habitat types on swimming pattern of 0-group cod from Newfoundland. Their findings showed that the 0-group cod would change swimming pattern in relation to type of predator. In the presence of a bottom dwelling ambush predator (*Myxocephalus scorpius*), the 0-group cod would position themselves in the top layer of the vegetation to avoid predation. If confronted with by a cruising predator (2+ year old cod) the 0-group cod would choose a position closer to the bottom, within the vegetation, to avoid predation. It has been observed in earlier studies that larger conspecifics represent a major predator for 0-group cod (Keats *et* al., 1987; Kanapathippillai *et al.*, 1994). Shoaling amongst 0-group was only registered on a few occasions during my video survey (Appendix 2). An experimental study which investigated gap crossing behaviour of 0-group cod found that the presence of conspecifics increased the willingness to cross an open area, even with a predator present (Ryan *et al.*, 2012). It has been suggested that 0-group cod shoal during daytime to increase their chances of detecting and avoiding a potential predator (Grant and Brown, 1998). Schneider *et al.* (2008) showed that 0-group cod had scale dependent habitat association. At small scales (5 meters) 0-group cod was decoupled from eelgrass habitats. On larger scales (20-100 meters) there was however a strong association. They suggested that the decoupling from the habitat was due to the formation of shoals near the boundaries between tall and short eelgrass. The results from the current study did however show a strong coupling between 0-group cod and macroalgae at scales <5 m.

The relationship between algae cover and occurrence of 2+ group cod was not as clear as for 0-group and 1-group cod. This indicates that the larger size groups of juvenile cod have a different relationship with macroalgae, and are probably more loosely associated with them than smaller cod. Whereas 0- and 1-group cod probably depend on macroalgae for refuge from predators, the larger individuals may primarily associate with macroalgae because of favourable feeding conditions. Several studies have documented behavioural differences between different size groups of juvenile cod. Keats *et. al* (1987) found that 2-group cod swam away from algae cover when chased, whereas smaller cod swam into the algae cover. Persson *et al.* (2012) showed in an experimental study of Baltic cod that juveniles foraged more efficiently in sand habitats than in vegetated areas (*Zostera marina* and *Fucus vesiculosus*). They also investigated how juvenile cod responded to predators. The introduction of a chemical clue from a cannibal (predator) reduced feeding in all habitats, but most noticeably in the sand habitat. The results of Persson *et al.* (2012) suggest that the choice of habitat is a trade-off between the need for cover against predators and feeding opportunities. This supports my findings, that 0-group and 1-group cod rely on macroalgae as refuge, whereas this need is not as critical for 2 + group cod.

4.2 Depth distribution of juvenile cod

The highest occurrence of 0-group cod in Porsangerfjorden was found in the depth interval 10-20 m (Figure 9). The highest occurrences of 1-group and 2+ group cod was however in the depth interval 0-10 m. This suggests that different size groups of juvenile cod had different depth preferences between in Porsangerfjorden. As seen on the three innermost stations in Porsangerfjorden, the algae cover in the tidal zone was serving as habitat for 0-group cod. However, the highest proportion of samples with occurrence of 1-group and 2+ group cod was also found in the depth interval 0-10 m in Porsangerfjorden (Figure 9). These findings show that 1-group and 2+ group cod also actively use the shallow near shore areas, all the way up to the tidal zone.

In Ullsfjorden, macroalgae was most abundant at depths greater than 20 m. The occurrence of juvenile cod of all three size groups was however highest in the depth interval 10-20 m. This suggests that there was a true depth preference among juvenile cod in Ullsfjorden. The difference in depth distribution of juvenile cod in Porsangerfjorden and Ullsfjorden may be related to the depth distribution of algae cover in the two fjords. The upper sub tidal zone in Ullsfjorden had low algae cover, possibly due to grazing by sea urchins. In Porsangerfjorden there was a relatively high proportion of video samples with algae cover >20% in the depth interval 0-10 meters, and this may explain why the highest occurrence of 1-group and 2+ group cod was found in this depth category. Cannibalism was found amongst juvenile cod in Porsangerfjorden. This dictates that habitat segregation can be expected between 0-group cod and larger cod. However, 1-group cod may also be vulnerable to predation by larger conspecifics, which can contribute to explain why this age group also was observed to be closely associated with macroalgae.

Variability in water temperature between various depths may influence the depth distribution of juvenile cod. Lafrance *et al.* (2005) showed in a laboratory experiment that there was ontogenic shifts in temperature preferences of Atlantic cod from Newfoundland. They found that younger individuals preferred higher temperatures than older ones. On the station Reinøya øst in Porsangerfjorden there was no video observations of cod, but a relatively high number of 0-group cod was caught in the beach seine survey at this location. This may suggest that the bottom temperatures at depths below the sub tidal zone was too cold for larger juvenile cod. The hydrographic data from Porsangerfjorden was sampled two months before the video survey, and showed a significant decrease in temperature in upper 20 m of the water column (Appendix 4). The temperature gradient in Porsangerfjorden is strongest in the period July until September (Hegseth *et al.,* 1995), so it can be expected that there was distinct temperature gradient when the video survey was performed. The hydrographic data in Ullsfjorden was sampled about two weeks after the video survey was completed (Appendix 5). In Ullsfjorden the temperature gradient was less pronounced than in Porsangerfjorden. This means that temperature effects on the depth distribution of juvenile cod probably was minimal in Ullsfjorden.

4.3 Macroalgae habitats as foraging grounds

In the current study, there was a significant difference in diet composition of 0-group cod and 1+ group cod. In addition there were also local and regional differences in diet. Keats *et al.* (1987) concluded on the basis of diet analyses that the various age groups of juvenile cod on Newfoundland had different uses and benefits of macroalgae. 0-group cod was found to feed mainly on pelagic prey and use macroalgae for cover against predators, whereas larger cod foraged on benthic and epiphytic prey that was associated with the macroalgae. On the three innermost stations in Porsangerfjorden, where there was little algae cover, the 0-group cod seemed to depend on pelagic food items, such as copepods. A large part of this prey was most likely advected into the habitat. On the stations further out in the fjord, locally produced (non advected) benthic invertebrates such as *Anomura/Brachyura* and *Polychaeta,* constituted a significant part of the diet for 0-group. This indicates that 0-group cod is an opportunistic forager, and does not solely rely on pelagic food items. The sample size from the current study is however to small to make any strong conclusions about the feeding behaviour of juvenile cod in Porsangerfjorden and Ullsfjorden.

For 1-group cod and larger there was a significantly higher occurrence of the prey group *Anomura/Brachyura* in stomachs from Ullsfjorden than Porsangerfjorden, whereas fish occurred more frequently in Porsangerfjorden than Ullsfjorden. This may suggest that the availability of different type of prey differs between the two fjords, and hence be a manifestation of an opportunistic feeding pattern. Kanapathippillai *et al.* (1994) noted that cod in Ullsfjorden had a opportunistic rather than a generalist feeding pattern. In the current study, 1-group cod had generally fewer prey items than the 0-group cod. Most 1+ group stomachs contained no more than three different prey groups. A field study from Ullsfjorden found that the diet of juvenile cod (fish length 10-30 cm) was dominated by polychaetes, krill, prawn and other crustaceans (Kanapathippillai *et al.*, 1994). Kanapathippillai *et al.* (1994) observed an ontogenic shift in diet when the cod reached a body length of about 30 cm. My findings point in the same direction as the results as Keats *et al.* (1987), which is that juvenile cod gradually shifts feeding pattern from pelagic to epiphytic and benthic prey during the first two years of their life, although my results were not as conclusive as those of Keats *et al.*

Cod is an actively searching forager rather than an ambush predator (Laurel *et al.*, 2006). Visual detection of prey is important for efficient feeding, and dense algae cover may interfere with prey detection and foraging performance. Borg *et al.* (1997) found in a laboratory experiment that both 0-group and 1-group cod from Skagerak associated with *F. vesiculosus*. However, in their study, only 0-group cod associated with *Zostera marina* and *Cladophora sp.* The authors suggest that dense algae/macrophyte cover such as the *Z. marina* and *Cladophora sp.* may interfere with foraging, and that the need for cover from predators is not as pressing for 1-group as for 0-group cod. This effect of vegetation on foraging performance may have influenced the catchability of juvenile cod in my angling survey. This is because the rubber bait used, relied solely on visual detection. The error introduced would contribute to underestimation of 1-group and 2+ group cod in areas with dense algae cover and relatively higher catchability on locations with low algae cover.

My findings indicate that the role of macroalgae is different for various age groups of juvenile cod. When the juveniles are newly settled, their vulnerability to predators is considerable, and cover is needed to reduce the risk of predation. When the juvenile cod reaches a certain size, somewhere between 1 and 2 years of age, there seem to be a shift. Feeding opportunities are prioritized over refuge, and the association with macroalgae becomes weaker.

4.4 Impact of variability in macroalgae habitats on cod recruitment

Degradation of macroalgae habitats are widespread along the norwegian coastline (Sivertsen 1997). Destructive grazing by sea urchins is the main cause of this degradation. Heavy grazing often result in barren grounds which may persist for long periods. The impact this destruction of habitat have had on the recruitment of norwegian coastal cod may be substantial (Norderhaug and Christie, 2009).

There were localities in both Porsangerfjorden and Ullsfjorden where algae cover was strongly reduced, probably due to grazing by sea urchins. In Porsangerfjorden, the three innermost stations, Reinøya øst, Trollholmsund and Indre Billefjord, had less than 10% of video samples with 20% or more algae cover. In Ullsfjorden the two stations with least algae cover were Blåmannsneset and Sør Lenangen, which both had less than 20% of samples with 20% or more algae cover. Common for all five stations with minor algae cover was that the abundance of juvenile cod was low in the video samples (Figure 7 and Figure 8). The localities with the highest abundance of 0-group cod in Porsangerfjorden were bays and relatively sheltered areas with moderate depth gradients (Brenna, Repvåg, Strandbukt and Kåfjord). These stations had more than 20% of samples with algae cover of 20% or more. In Ullsfjorden, the stations with the highest occurrence of juvenile cod were Nord Lenangen, Eidstrand and Noreide. These three stations also had moderate depth gradients and high proportions of samples with algae cover of 20% or more. There was however two locations in Ullsfjorden (Hjellneset and Kavlberget), which had steep depth gradients, but with numerous observations of both 0-group and 1+ group cod. Both these stations had more than 30% of samples with 20% algae cover or more. This points in the direction that algae cover is one of the principal habitat requirements of juvenile cod.

In the inner parts of Porsangerfjorden, 0-group cod was caught in the narrow algae belt in the tidal zone. This algae belt consisted mostly of ephemeral macroalgae, such as *C. filum*. These algae degenerate in autumn and does not reappear until next spring (Rueness, 1998). The disappearance of the algae cover in the autumn can be expected to increase the mortality of 0-group cod in areas where there are no alternate refuge. In Ullsfjorden there was a higher proportion of perennial algae than in Porsangerfjorden (Table 4). Perennial algae such as *Laminaria spp., Desmarestia spp.*, persist over several years, and can be expected to be more stable habitats than those that are dominated by ephemeral macroalgae. Perennial macroalgae were most abundant at depths greater than 10 m, which were the depth interval with the highest occurrence of juvenile cod. This suggest that there may be a preference for the more stable habitats with large proportions of perennial macroalgae over habitats dominated by ephemeral macroalgae species.

Norwegian coastal cod is fragmented in sub populations, and recruitment to these populations are affected by migration and passive transport (Espeland, 2010). Jorde *et al.* (2007) found in a study performed in southern Norway that the genetic differentiation pattern indicated a patchy population structure with local coastal cod populations being limited in geographic extent to approximately 30 km or less. Pedersen *et al.* (2008) found that there was a latitudinal trend in mean displacement distances of coastal cod along the coast of Norway. The displacement distance was larger in fjords in Finnmark than in southern Norway. This suggests that coastal cod in northern Norway may migrate more frequently than in the south. A mark/recapture experiment in Ullsfjorden did however find that offspring of coastal cod were fairly stationary after release (Svåstrand *et al.*, 2000). In Porsangerfjorden the population may consists of several components which are distributed along the length of the fjord. Spawning grounds have historically been found along the whole extent of the fjord, but have the last decades been limited to the outer parts (Maurstad and Sundet, 1998). The reasons for a decrease in spawning activity in the inner parts of the fjord may be related to the reduction of suitable habitats for juvenile coastal cod. Nonetheless, my observations indicate that there is either local spawning, or transport and migration of larvae and juveniles to the inner parts of Porsangerfjorden. There was however a very low occurrence of 1+ group cod in the inner parts of the fjord, which is probably due to the absence of macroalgae habitats below the tidal zone. This suggest that there is either high mortality among 0-group and 1-group cod or high rates of migration of 1+ group cod away from the inner area of Porsangerfjorden. In Ullsfjorden there was a higher occurrence of juvenile cod than in Porsangerfjorden. This indicates that the condition of the local cod stock is better. There was also a higher occurrence of macroalgae in Ullsfjorden than in Porsangerfjorden. This suggests that there may be a direct connection between the state of macroalgae habitats and the recruitment of coastal cod stocks.

4.5 Conclusion

The results from the current study show that juvenile coastal cod is strongly associated with macroalgae in Porsangerfjorden and Ullsfjorden. The association seem to be grounded in the need for refuge. This need is however not as strong amongst 2+ group cod as for younger individuals. There was a significantly lower frequency of occurrence of juvenile cod when algae cover was less than 20%. This indicates that there need to be a certain amount of macroalgae in order make it beneficial for juvenile coastal cod. Macrophytes also represent productive and lucrative feeding grounds for all age groups of cod. There was observed an ontogenic shift in diet, from pelagic to benthic prey, as the size of the juvenile cod increased, This suggests that the role of the macroalgae habitats is different for various age groups of juvenile cod. The degree of association with macroalgae seems to be a tradeoff between the need for refuge from predators and the need for food. The habitat choice of juvenile cod did appear to be influenced by depth preferences. In Porsangerfjorden, there was size specific differences in depth distribution of juvenile cod. Looking at the importance of macroalgae habitats as nursing ground for juvenile cod, it is probable that recruitment of coastal cod populations is affected by the status and condition of local macroalgae communities. Overgrazing of macroalgae by sea urchins, may in turn influence the recruitment of coastal cod populations negatively.

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Electronic References

Mareano online maps. http://www.mareano.no/kart/viewer.php

Appendix 1

Frequency of occurrence of prey species in diet of juvenile cod

Prey species	Porsangerfjorden (n=108)	Ullsfjorden (n=22)
Amphipoda	7	0
Amphipoda, Gammaridea	2	3
Bivalvia	1	0
Brachyura indet.	3	0
Bryozoa	0	0
Caridea	8	3
Copepoda	16	0
Copepoda, Calanoida	9	2
Crustacea	11	5
Echinodermata	2	0
Fish indet.	17	4
Fish pelagic	2	1
Gadidae sp.	10	0
Galatheidae	0	3
Holothurioidea	4	0
Hyas coarctatus	3	4
Idotea baltica	0	1
Indet.	18	6
Insect nymph	4	0
Isopoda	1	0
Lacuna vincta	1	0
Limacina retroversa	0	4
Macroalgea	0	1
Mysida	8	0
Myxocephalus scorpius	1	1
Neptunea sp.	0	2
Ophiuroidea	2	2
Paguridae	5	6
Pandalus montagui	6	4
Pleuronectiformes	1	0
Polychaeta	15	3
Polychaeta (Terebellidae)	1	0
Rajidae	1	0

Appendix 2

Number of samples with various number of cod per sample

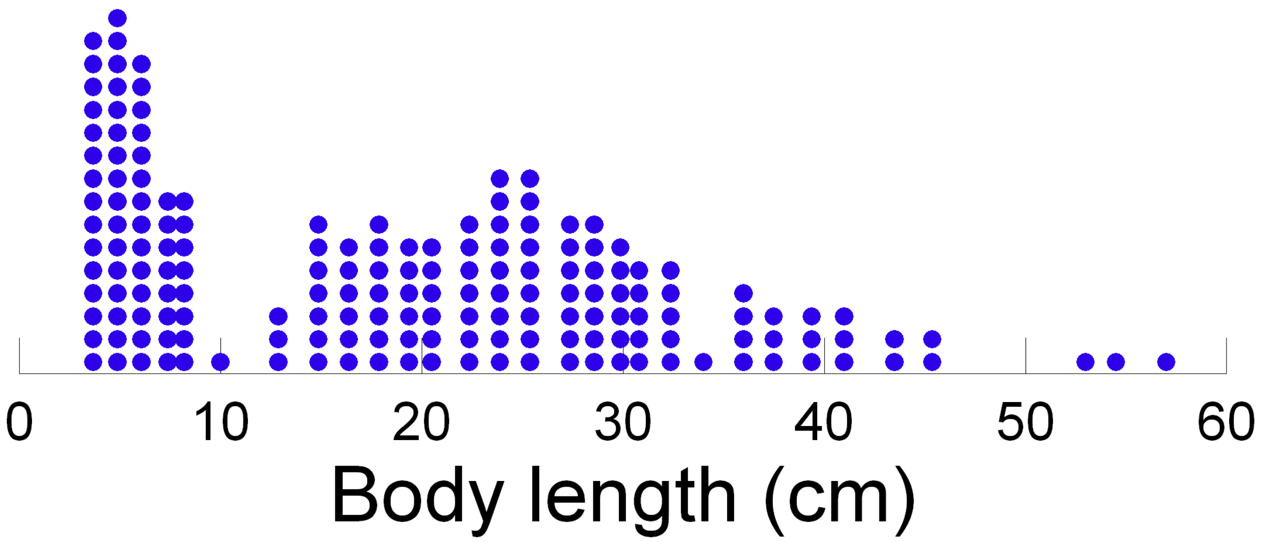
0-group (*n* cod/sample)	Porsangerfjorden	Ullsfjorden
1	25	25
2	6	8
3	5	0
4	1	3
5	2	3
6	0	1
7	0	2
8	0	1
9	0	1
10	1	1
11	1	0
25	0	1

1-group (*n* cod/sample)	Porsangerfjorden	Ullsfjorden
1	11	40
2	2	12
3	2	4
5	0	2
9	0	1
46	0	1

2+ group (*n* cod/sample)	Porsangerfjorden	Ullsfjorden
1	6	18
2	1	5
3	0	1
4	1	3
5	1	1
9	0	2
10	0	2

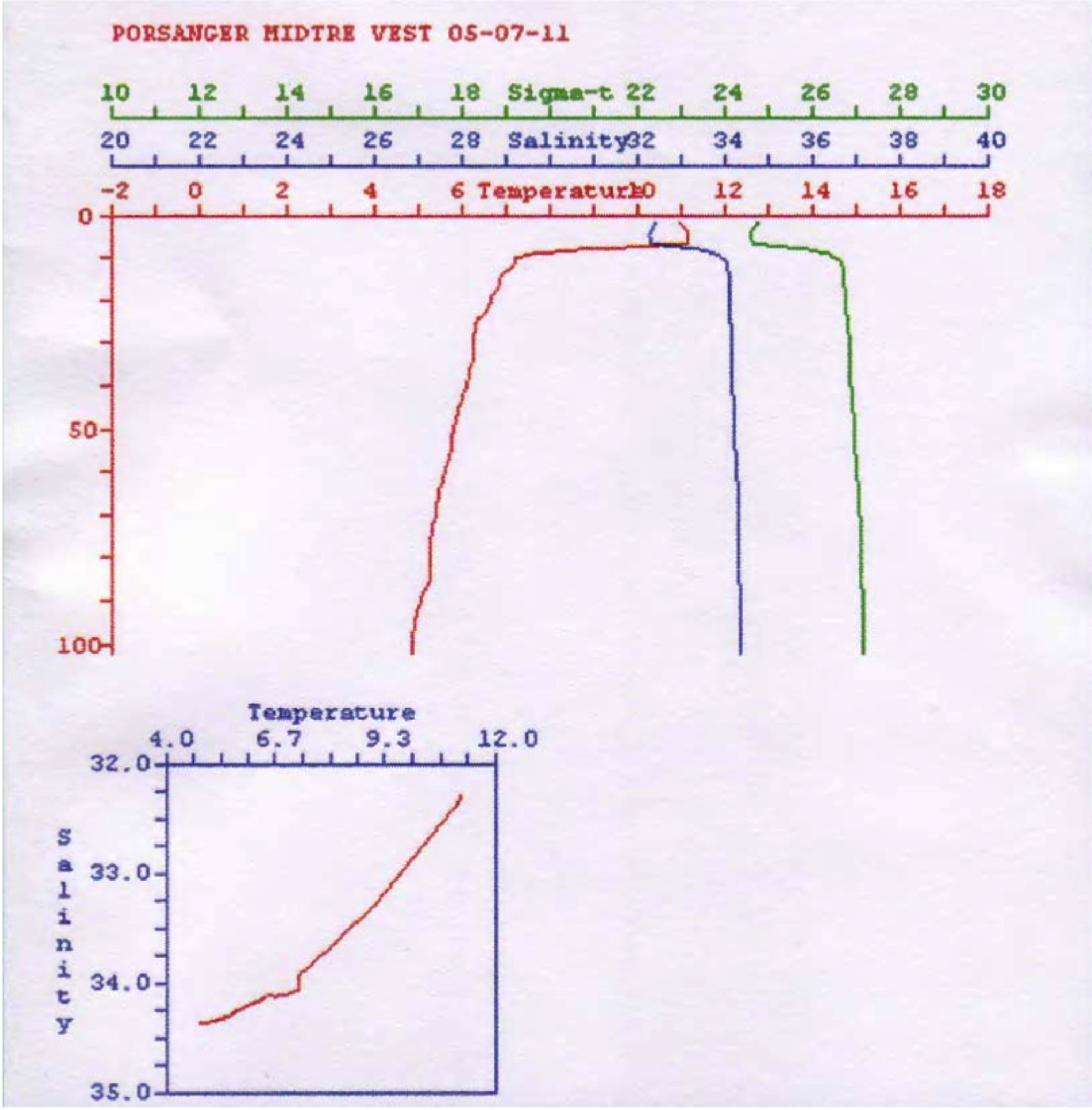
Appendix 3

Length distribution of juvenile cod from beach seine and angling survey.



Appendix 4

CTD plot from Porsangerfjorden 05.07.2011. Position N 70 29.5 E 025 25.0
Hydrographic data from Ulf Nordmann, University of Tromsø.



Appendix 5

CTD plot from Ullsfjorden 17.10.2011. Position N 69 43.1 E 019 45.5
Hydrographic data from Ulf Nordmann, University of Tromsø.