Determining Deep-Sea Fish Community Structure in the Arctic: Using Species Assemblages, Stomach Contents, Parasite Infracommunities and Stable Isotopes to Evaluate Trophic Interactions

By

Chandra Chambers

A Thesis submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

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Winnipeg

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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Determining Deep-Sea Fish Community Structure in the Arctic: Using Species Assemblages, Stomach Contents, Parasite Infracommunities and Stable Isotopes to Evaluate Trophic Interactions

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ABSTRACT

Little is known about deep-sea Arctic fish communities, especially relating to species distributions, basic biology and ecology. Surveys usually focus on commercially exploitable species such as Greenland halibut (*Reinhardtius hippoglossoides*) and shrimp (*Pandalus* spp.). Most community studies on Arctic food web dynamics often overlook underlying patterns such as shifting trophic position with environmental change. This is the first study in which the fish/invertebrate food web of the deep-sea Arctic is described in terms of predator-prey and host-parasite relationships. The objectives of this thesis were to determine factors that affect community dynamics and trophic relationships within deep-sea fish communities of Davis Strait and Baffin Bay and involved 1) recognizing broad feeding patterns by combining fish groups, regardless of phylogenetic relationships, by size and/or age class as well as similar ecologies, 2) determining factors that affect community dynamics and trophic relationships in benthic Arctic marine communities and 3) assessing the trophic position of individual species based on stomach content analysis, parasite assemblages and stable isotope data. Four hypotheses were generated, involving fish community composition with changing environmental variables, the effectiveness of trophic guilds in the construction of deep-sea Arctic food webs, the value of using parasites and stable isotopes in combination with stomach content analysis, and the role of size and age class in determining trophic position.

Species within this region are distributed along one or more environmental gradients such as latitude, longitude, temperature and depth, resulting in continually shifting species composition throughout the system. Traditional methods of trophic evaluation, namely guild determination and food web construction, were not appropriate

for deep-sea Arctic communities due to the prevalence of generalist feeding throughout. These results are different from previous reports on tropical or temperate marine environments in which fish species can be separated into clear trophic levels. A multivariate approach combining stomach contents and endohelminths demonstrated that habitat utilization and diet best described trophic relationships within the region; fish species were divided into trophic 'groups' based on their ability to utilize benthic and pelagic zones. I provide, for the first time, an analysis of endohelminth communities of deep-sea species that supports dietary information. Data from parasite infracommunities revealed that, at best, they can be used to describe the preferred habitat zone of individual fish species without stomach content analysis and, at the very least, they give strong support to diet data. Due to the broad overlap of dietary preferences, tissue values of $\delta^{13}C$ and $\delta^{15}N$ stable isotopes were not as useful to describe trophic position; these values could not be used to designate a species to a clearly defined trophic position. However, the use of differences in $\delta^{13}C$ and $\delta^{15}N$ values were used to reveal similar patterns of habitat utilization and feeding strategies to those seen for diet and parasite analyses. There was no significant relationship between fish size and stable isotope signature; diets of different fish size classes overlap and/or prey species contain similar isotopic signatures in the deep-sea.

I have provided Arctic science with the first insights into community dynamics within deep-sea Arctic habitats. Hopefully, better decisions will be possible regarding the health and structural integrity of marine Arctic communities in the face of environmental change. Marine resource managers can no longer consider single-species populations when assessing the health of marine communities as the data from this thesis clearly show a marine system in which the life histories of its species are inextricably intertwined. Clearly for the future, disturbances such as single or multiple species overfishing and/or global warming must be considered in the context of the National Marine Fisheries Policy of 'Ecosystem-Based Management'.

ACKNOWLEDGEMENTS

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DEDICATION

For my grandfather, Mr. Anthony S. Dudek. You left us too early but loved us for a lifetime. Thank you for believing in me.

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CHAPTER 1: GENERAL INTRODUCTION

Background

Little is known regarding assemblage and parasite-host relationships of deep-sea fish species in the eastern Arctic. Many commercially important species such as redfish (*Sebastes* sp.), Greenland halibut (*Reinhardtius hippoglossoides*) and roughhead grenadier (*Macrourus berglax*) have been studied extensively in terms of food preference and parasite assemblages, but data on community structure and food web dynamics is limited. Many species in the deep-sea environment have been overlooked in the literature making it difficult to assess community structure and food web dynamics relative to commercial fisheries.

Of particular interest are the poorly studied snailfish of the genera *Liparis*, *Paraliparis*, and *Rhodichthys*, eelpouts of the genus *Lycodes*, and deep-sea sculpins of the genera *Artediellus*, *Cottunculus* and *Triglops*. Their diet, parasites and life history characteristics such as reproduction and early development are not well documented. Most of these species are reported from the stomach contents of predators such as Greenland halibut or American plaice (*Hippoglossoides platessoides*) (Arthur and Albert 1992a,b, Boje et al. 1997, Bray 1979, 1987, Bray and Gibson 1986, Gibson and Bray 1986, Khan et al. 1980, Khan et al. 1982, Margolis and Arthur 1979, McDonald and Margolis 1995, Rubec 1988, Scott and Bray 1989, Wierzbicka 1990, Wierzbicka 1991a,b). These fish, as food, likely have a significant influence on the populations of top predators.

Fish Assemblages in the deep-sea Environment

Ocean taxa have different physiologies and behaviours and utilize different habitats (Gartner et al. 1997). Often fish species are categorized based on habitat type (Fig. 1.1). Benthic species have physical contact with the bottom and are not particularly mobile (Gartner et al. 1997) and include fishes of the families Bathysauridae, Bathypteroidae and Zoarcidae (Gartner et al. 1997). The diet of these fishes is comprised of polychaetes, anemones, echinoderms, and other benthic fishes (Gordon and Mauchline 1990).

Demersal fishes spend most of their lives near the ocean floor (within about five meters) and move actively over the bottom. The term benthopelagic is sometimes used synonymously with demersal; however, it is most often used for those species that spend only part of their life cycle near the bottom (Gartner et al. 1997). Demersal fishes are present in the Macrouridae, Synaphobranchidae, Halosauridae and Ophidiidae families and feed mainly on organisms that swim freely and habitually near the ocean floor (Gordon and Mauchline 1990).

Pelagic fishes frequent mid-water environments and can be further separated into epipelagic (species existing above 200 m), mesopelagic (species existing between 200 and 1000 m) and bathypelagic (species existing primarily below 1000 m) (Gartner et al. 1997). Mesopelagic species include fish of the families Myctophidae, Stomiidae, Gonostomiidae and Sternoptychidae. In addition, these species often undergo diurnal vertical feeding migrations. Bathypelagic fishes are found in the Eurypharyngidae and Saccopharyngidae families (Gartner et al. 1997). Pelagic species feed on organisms living well off the sea bed (Gordon and Mauchline 1990).

Classifying deep-sea fishes by habitat type is often difficult, as deep-sea fishes tend to be opportunistic and many species alternate between habitats on a regular basis (Dayton and Hessler 1972). However, these definitions may serve as a basis to understand relationships between fishes in such little-understood environments.

The Baffin Bay/Labrador Sea region is unique in that it is subject to several current systems, each with a different temperature and direction of flow (Jones et al. 2003, Kiilerich 1939, Tang et al. 2004). The West Greenland Current (WGC) flows south to north along the eastern portion of this region, exposing species to warm, northerly flowing waters. Conversely, the Polar Current (PC) flows in a north to south direction, exposing species on the western side of Davis Strait and Baffin Bay to colder Arctic waters (Fig. 1.2). These two major current systems may produce two separate and distinct ecological communities; one with more warm-tolerant species and the other with more cold-tolerant species. By contrast, the unique physical characteristics and branching current systems in the region suggests the likelihood of more complex biological systems.

Jorgensen et al. (2005) concluded that up to seven benthic species assemblages exist in the Baffin Bay/Davis Strait/Labrador Sea region based on environmental characteristics such as depth, temperature, latitude and longitude. The area comprised of Northwest Greenland and parts of Baffin Island has a major assemblage in shallow (approximately 300 m) and cold (average 2.6°C) waters. This assemblage is characterized by Greenland halibut (*R. hippoglossoides*), two primary indicator species (i.e., species unique to a particular assemblage such as *Triglops nybelini*, *Artediellus atlanticus*) and several secondary indicator species (i.e., those nearly exclusive to one assemblage) including *Leptoclinus maculatus*, *Lycodes vahlii*, *Anarhichas minor*, *Leptagonus* *decagonus*, *Raja radiate* and *Careproctus reinhardti*. Each assemblage is characterized by its own primary and secondary indicator species with unique associations to depth and temperature. Given these findings, it is likely that these assemblages maintain similar but distinct community dynamics and trophic patterns.

Parasite-host relationships in relation to diet and habitat type

Parasites are frequently used as indicators of ecological relationships among hosts (Arthur and Arai 1980, Campbell et al. 1980, Lester et al. 2001, Mackenzie 1985, Malek 2003, Zhokhov 2001). Examples of these associations are 1) feeding and migration patterns of species such as Atlantic argentine (*Argentina silus*) (Scott 1969), Atlantic salmon (*Salmo salar*) (Lund and Heggberget 1992), Atlantic herring (*Clupea harengus*) (Mackenzie 1985, McGladdery and Burt 1985), Pacific salmon of the genus *Onchorhynchus* (Margolis 1965), American plaice (*Hippoglossoides platessoides* (Scott 1975) and pollock (*Theragra* sp.) (Avdeev et al. 1989), as well as trophic relationships (Huxham et al. 1995, Johnson et al. 2004), 2) feeding behaviour and phylogenetic linkages (Campbell et al. 1980, Urawa 1989) and 3) stock identification (Mackenzie and Abaunza 1998, Marcogliese et al. 2003). Campbell et al. (1980) recognized that helminth life cycles and the specificity of a parasite species for intermediate and definitive hosts were useful to link prey and predator. For example, Arctic marine fishes are important intermediate hosts for nematode species that complete their life cycle in seals or toothed whales. When the definitive hosts of these parasites are known it is possible to construct food webs of Arctic marine communities without actual diet data.

Access to a host is determined by diet and living conditions as well as evolutionary and zoogeographical factors (Noble 1973). Behaviour of the fish, community diversity and population density are important in determining the parasite load (Campbell et al. 1980). Riley (1951) found that only about one tenth of the organic matter produced in the euphotic (surface) zone penetrates below 200 m. Similarly, Vinogradov (1968) reported that at depths of 1000 to 2000 m, the amount of plankton was one quarter that of the surface. This general decrease of plankton and nekton with depth in oceanic waters (Noble 1973) means that less nutrients reach the ocean floor. However, there are a large number of animals living on the bottom or immediately above the bottom (Noble 1973) and many of these organisms are important as intermediate hosts of fish parasites. The distribution and abundance of these intermediate hosts are important in the maintenance of deep-sea fish parasite communities.

Parasite-host relationships of the deep-sea environment

Ecological factors (Grabda 1989, Holmes 1979, Kennedy and Bush 1994, Leong and Holmes 1981, Wisniewski 1958, Wootten 1973), host specificity (Carney and Dick 2000, Choudhury and Dick 1998, Dogeil 1964, Hålvorsen 1971, Kennedy and Bush 1994), and fish host factors such as feeding rate, vagility and physiology affect the shape of fish parasite communities (Chubb 1970, Johnson et al. 2004, Kennedy 1990). Marine food webs are shaped primarily by stratification of the water column which consequently also affects the transfer of fish parasites to their hosts (Klimpel and Ruckert 2005). For example, Klimpel and Ruckert (2005) showed that water stratification in the North Sea affected the infection rate of gadiform species as a result of feeding on pelagic hyperiid amphipods which were intermediate hosts for the nematode, *Hysterothylacium aduncum*.

Noble (1973) recognized that little was known regarding the broad ecological aspects of deep-water parasite-host relationships. This problem still exists today, as scientists interested in parasites of marine species often confine their efforts to shallow waters or to the description of new species rather than to understanding actual parasite-host relationships within the deep ocean environment. Those fish species that have been described in terms of parasites and diet usually represent commercially important species such as salmon (*Onchorhynchus* spp., *Salmo* spp.), Atlantic cod (*Gadus morhua*), Atlantic herring (*Clupea harengus*) and Greenland halibut. In order to determine whether or not deep-sea habitats differ from other habitat types in terms of parasite composition, abundance and life cycle characteristics, further research is required with an emphasis on food web and community interactions.

Preliminary studies have revealed general information regarding parasite occurrence and diet in deep-sea fishes. Campbell et al. (1980), Noble (1973) and Noble and Collard (1970) found that carnivorous benthic fishes are infected with relatively large numbers of parasites, perhaps because of the high diversity of food present on the ocean floor. In addition, benthic animals tend to be larger and more active than mid-water species because of this increased food availability (Campbell et al. 1980). The kinds, numbers and availability of food determine the frequency of ingestion of infected intermediate hosts (Noble 1973). We would expect benthic species then to have higher incidences and heavier infections of parasites.

Bathy- and mesopelagic fishes tend to harbour fewer numbers and types of parasites than do other ecological groups of fishes (Campbell et al. 1980, Noble and Collard 1970). These species are often faced with higher energy demands and decreased food abundance (Noble 1973). Most of their energy must be conserved for obtaining food and for reproduction (Noble 1973). Thus, Noble (1973) suggested the possibility that these species cannot sustain high numbers of parasites, particularly those that would demand a considerable share of available energy. However, lower parasite loads in these organisms could be simply due to the lower incidence of infected intermediate hosts (Noble 1973). Alternatively, perhaps mid-water fishes have as many parasites per unit weight as benthic fishes but benthic fish are larger and harbour more parasites species (Noble 1973).

The role of mesopelagic species in parasite transmission

Most mesopelagic species migrate to the surface, or near the surface, at night (Haedrich 1997, Noble 1973, Pearcy and Laurs 1966, Pearcy et al. 1977, Willis and Pearcy 1982). Here, the type and availability of food items as well as parasites may be quite different from those found in the deep-sea environment. Collard (1970) suggested that mesopelagic fishes (primarily of the family Myctophidae) serve as intermediate hosts, transporting parasites to predatory fishes in the deeper zones. There is little evidence to support this hypothesis, as studies of this nature are rare. However, the majority of parasites found in mesopelagic fishes are larvae. More research is required regarding the relationship between parasitism and diet in the deep-sea environment.

Food webs and food web construction

Food webs represent descriptions of biological communities that focus on trophic interactions between consumers and their resources (e.g. predators and their prey) (Cohen 1990, De Ruiter et al. 2005). Each interaction represents the transfer of nutrients and energy, shaping the structure and function of the community as a whole. Cohen (1990) likens a food web to a street map of a city (in this case, an ecological community), helping to picture how a community works just as a street map provides a helpful overview of a complex city.

Food webs are an important component of Arctic systems since what-consumes-what in an energy limited environment is important, especially if single species are exploited, as the feeding equilibrium among species can be altered. While it is important to know the species present, for example using a deep-water trawl, it is equally, if not more important to know how these species interrelate to each other. An obvious interaction is through food webs and the degree of overlap of food items consumed among species.

The concept of food webs has been known for some time (Cohen 1977, 1978, DeAngelis 1992, DeAngelis et al. 1982, Pimm 1982, Valiela 1984) and may be studied in various ways; by food consumption, parasite infracommunities (Carney and Dick 2000, Arias-Gonzalez and Morand 2006, Hernandez et al. 2007, Marcogliese et al. 2006), stable isotope ratios (Bunn et al. 1989, Forsberg et al. 1993), and more recently using a combination of the three (Johnson et al. 2004).

Food webs are usually determined through diet analysis. A major disadvantage of diet analysis is that it provides data at a particular point in time (Sholto-Douglas et al. 1991) but fails to provide any long-term data. For example, prey species such as certain crustaceans have a seasonal abundance and if sampling occurs during times other than the period of peak abundance an important diet item could be missed or reduced in importance within a food web. The solution is to collect diet data throughout the year but this is costly and often impossible in Arctic marine systems. Complimentary methods such as parasites and stable isotopes that reflect a longer time frame should aid in the construction of more accurate food webs.

Parasite infracommunities and stable isotope ratios have been used to augment diet data from freshwater (Johnson et al. 2004) and marine (Bulman et al. 2001, Davenport and Bax 2002) fishes. Johnson et al. (2004) reported that parasite infracommunities more accurately predicted trophic interactions than stomach contents in freshwater yellow perch (*Perca flavescens*). This type of data is particularly important for Arctic marine communities, as fish species are important intermediate hosts for several nematode species that complete their life cycle in marine mammals such as seals or toothed whales. With knowledge of the definitive hosts of these parasites it is possible to construct food webs for Arctic marine communities without direct observation of the gut contents of marine mammals.

Animals are similar in isotopic composition to their diets (Fry 1988, Kline et al. 1998, Monteiro et al. 1991, Peterson and Fry 1987, Sholto-Douglas et al. 1991, Thomas and Cahoon 1993, Wainright et al. 1993). When whole food webs are examined, differences in the way an animal processes isotopes of carbon, nitrogen and sulphur can be detected (Peterson and Fry 1987). At each trophic level, an organism is enriched in the heavier isotope relative to its diet (DeNiro and Epstein 1978). This enables scientists to place species accurately into positions along a food web. Nitrogen is considered to be the best indicator of trophic position as animals are usually enriched by 3.4 $^{0}/_{00}$ relative to their prey (McCutchan et al. 2003, Minagawa and Wada 1984, Post 2002). ^{14}N is more abundant and excreted in higher amounts than the stable isotope ^{15}N, leading to the organism being enriched in ^{15}N relative to their food (Peterson and Fry 1987). Thus the $^{15}N/^{14}N$ ratio, or $\delta^{15}N$, is a function of the trophic level occupied by an animal. The carbon isotope ^{13}C is considered less effective when determining actual trophic position but remains an important descriptor of interactions within food webs. Because the ratio of $^{13}C/^{12}C$ of organic matter produced from primary production is different for various plant species, the origin of the carbon ingested by an animal can be traced (Peterson and Fry 1987, Fry and Sherr 1984).

Such analyses complement other methods of studying diets in that the stable isotopic compositions of tissues represent a measure of the assimilated diet, both in the long- and short-term (Kline et al. 1998, Monteiro et al. 1991, Sholto-Douglas et al. 1991, Thomas and Cahoon 1993, Wainright et al. 1993). Dayton and Hessler (1972) stated that deep-sea environments differ from other ecological communities in that trophic levels appear to merge. Thus, the roles of most predators are not as distinguishable from those of decomposers (Dayton and Hessler 1972). As a result, in the case of deep-water marine fishes, where different food items appear to be limited in areas and feeding location is less clear-cut, stable isotopes may be less helpful (DeNiro and Epstein 1978). However, if combined with parasite analyses, stable isotopes may give better insights to feeding strategies.

Importance of age and size relationships

One major determinant of food web structure is the body size of its component species (Cohen et al. 1993, Memmott et al. 2000, Warren and Lawton 1987, Woodward and Hildrew 2002). Woodward and Hildrew (2002) recognized that detailed food webs including the ontogenetic dietary shifts of component species are rare. The authors assessed the importance of body size within and among species of the Broadstone Stream (UK) food web and found that this food web was affected primarily by seasonal and ontogenetic shifts in the size spectrum. Body size along with seasonal changes in prey abundance accounted for most of the changes in predator diets and consequently, trophic position.

Age and size relationships are important variables when determining if and when food preferences shift for an individual species (Monteiro et al. 1991, Sholto-Douglas et al. 1991). In general, larger fishes tend to take a greater proportion of larger food items than do smaller fishes as their energy requirements increase. These fish may ingest different types and quantities of food items and often move higher up in the food web (Cohen et al. 1993, Gordon and Swan 1996, Mauchline and Gordon 1985, Orr and Bowering 1997). This in turn, affects the numbers and types of predators a fish will have (Cohen et al. 1993) and the transmission dynamics of parasites within its community (Bush et al. 1993).

Since fishes usually undergo a shift in food size preference over time, it is difficult to assign each species a specific position along a food web. Instead, it may be more advantageous to assign species to positions based on size class, assuming the availability of prey species is limited and that deep-sea fishes are generalist feeders.

Biology and ecology of key by-catch species within the Davis Strait/Baffin Bay region

Descriptions of key by-catch species examined in this study (distribution/habitat, diet, predation, parasites, reproduction and growth) as well as length/weight comparisons can be found in Appendices 1-4.

Objectives

This study was designed to evaluate trophic structure in the deep-sea Arctic environment and the effectiveness of food web construction in benthic habitats. This involved 1) determining factors that affect community dynamics and trophic relationships in benthic Arctic marine communities, 2) recognizing broad feeding patterns by combining fish groups, regardless of phylogenetic relationships, by size and/or age class as well as similar ecologies, and 3) assessing the trophic position of individual species based on stomach content analysis, parasite assemblages and stable isotope data.

Four hypotheses were proposed:

Hypothesis 1: If trophic guilds within a system represent differences in feeding behaviour and food item preference, the analysis of stomach contents for deep-sea species will reveal the presence of several trophic guilds within the Arctic marine environment. From this, accurate food webs can be created.

Hypothesis 2: If differences in parasite infracommunities and stable isotope ratios are a reflection of food item consumption, then trophic guilds based on food item prevalence will be identical, or nearly so, to those based on parasite prevalence and stable isotope ratios.

Hypothesis 3: If trophic position is dependent on feeding mode as a reflection of body size and age class, differences in feeding habits, parasite communities and stable isotope ratios will occur with increasing size and age class.

Hypothesis 4: If fish species diversity decreases with increasing latitude, then the number of trophic guilds will be smaller and contain more species in higher latitudes. Fish species in higher latitudes will feed on a wider variety of food items due to the increased availability of prey species in the absence of predators found in more southerly arctic marine environments. This will be reflected by an increase in parasite infracommunity diversity as well as increase in the heavier isotopes of carbon and nitrogen (^{13}C and ^{15}N).

Figure 1.1. Bathymetric zones of the oceanic environment. (Adapted from Angel, 1997).

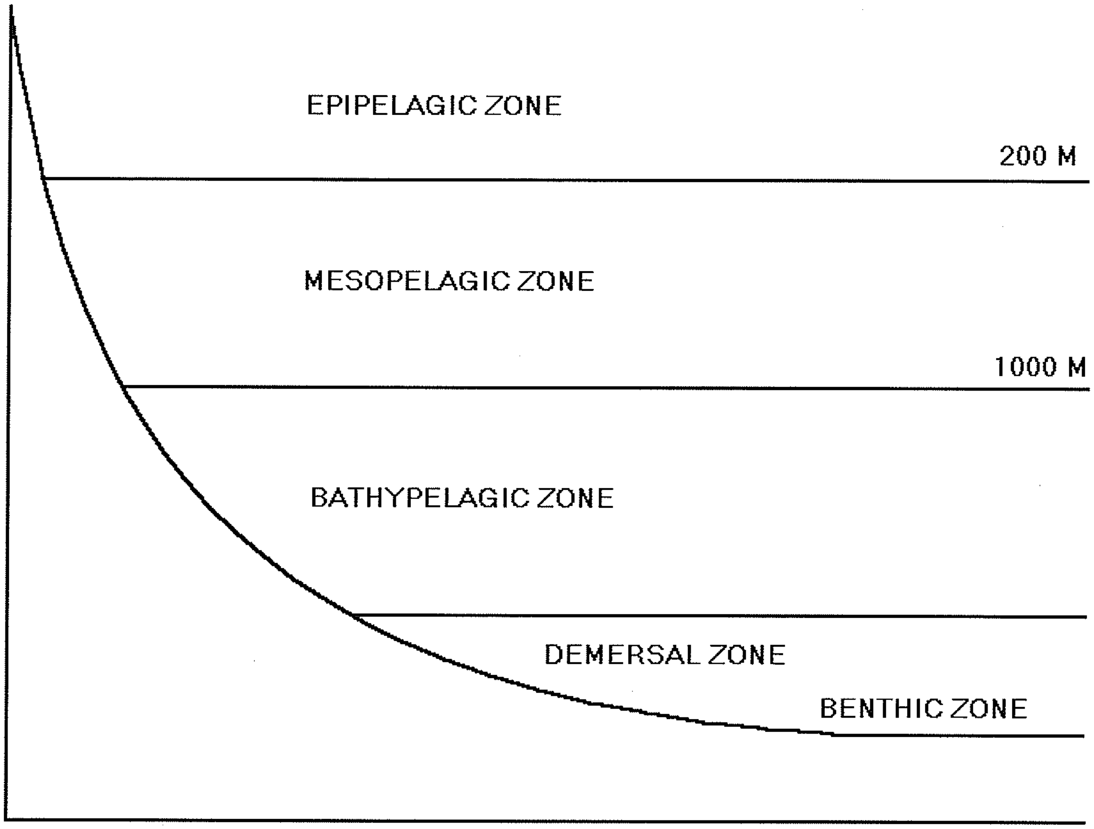
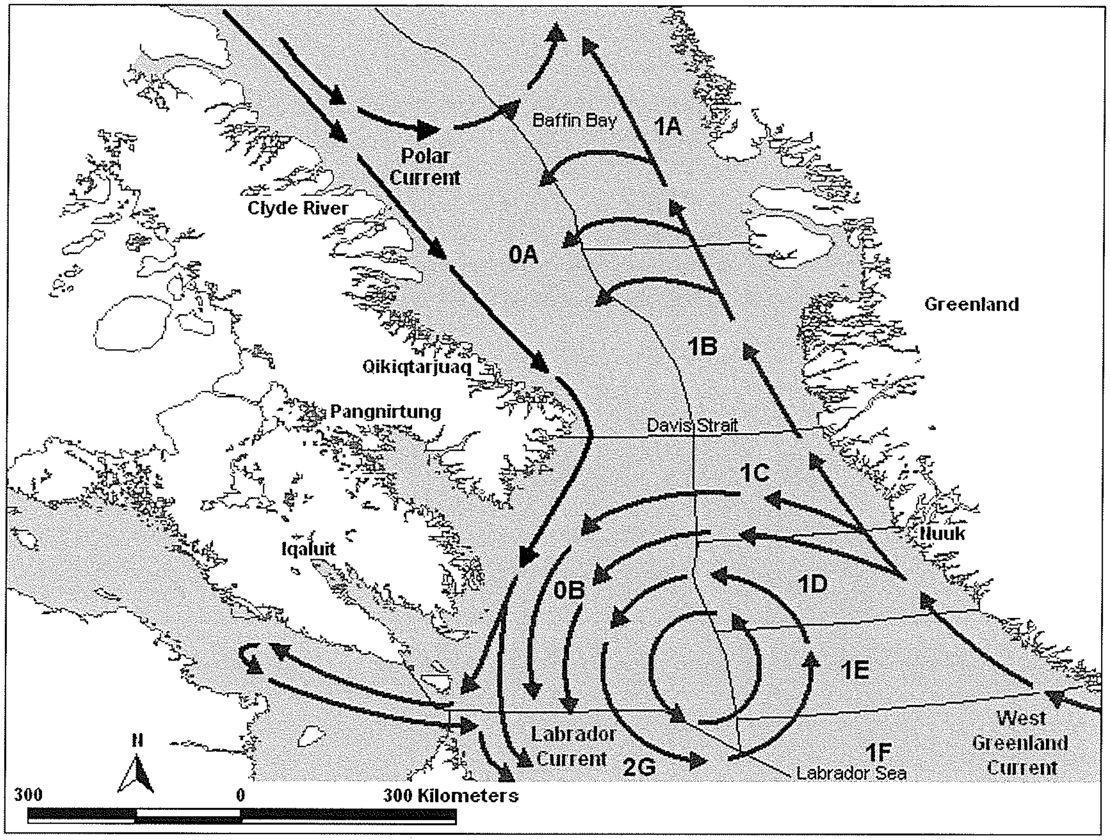

EPIPELAGIC ZONE
200 M
MESOPELAGIC ZONE
1000 M
BATHYPELAGIC ZONE
DEMERSAL ZONE
BENTHIC ZONE

Figure 1.2. Map of current flow through NAFO management areas within Baffin Bay and Davis Strait. (Adapted from Treble, 2002). Red arrows represent warmer waters of the West Greenland Current, blue arrows indicate colder waters of the Polar Current and purple arrows represent the moderate temperatures of the Labrador Current and mixing of the West Greenland and Polar currents.


Baffin Bay
1A
Polar Current
Clyde River
0A
Greenland
1B
Qikiqtarjuaq
Pangnirtung
Davis Strait
1C
Nuuk
Iqaluit
0B
1D
1E
N
Labrador Current
2G
1F
Labrador Sea
West Greenland Current
300
0
300 Kilometers

CHAPTER 2: GENERAL MATERIALS AND METHODS

Study Area

This project was conducted in conjunction with the Greenland Halibut Otter Trawl Survey in the North Atlantic Fisheries Organization (NAFO) Subareas 0 and 1. It was a cooperative project of the University of Manitoba Department of Zoology, Fisheries and Oceans Canada, Greenland Institute of Natural Resources, University of Copenhagen, Nunavut Wildlife Management Board and Baffin Island communities adjacent to the survey locations.

During September to November 2000 to 2004, a stratified random survey was conducted throughout NAFO subareas 0 (divisions A and B) and 1 (divisions A, C and D) located between 61 and 75 degrees north latitude, 75 and 55 degrees west longitude within Davis Strait and Baffin Bay (Fig. 2.1). Samples were collected using an A722 GRT stern trawler (MV Paamiut) equipped with an Alfredo III bottom otter trawl with rock hopper ground gear. Mesh size was 140 mm with a 30 mm mesh liner in the cod end. The region was stratified by depth and the number of stations per stratum was proportional to its geographic area. The target was one set per 1030 km^2 (300 nm^2) with a minimum of two sets per stratum as described in Bowering (1987), Treble (2000) and Treble et al. (2001). Exceptions included depth range 401-500 in 0A South in 2001, 0A North in 2004 and 1CD in 2004 due to adverse weather conditions. Stratification schemes of subareas are provided in Tables 2.1 to 2.3. The number of tows completed within each depth range from 2000 to 2004 is listed in Table 2.4. Surveys conducted in different years occurred in the same time period (September – October) to decrease variation between years. Similarly, surveys within the same year were completed consecutively to ensure the least amount of seasonal variation. At each tow, environmental and biological data were collected, including species data (total weight and number of each species), geographical position (latitude and longitude), tow length (distance and time), wing spread, depth and temperature. Near-bottom temperatures were measured in 0.1°C increments using a Seamon sensor (Starr-Oddi, 104 Reykjavik, Iceland) mounted on a trawl door. Salinity measurements were not conducted during the trawls and as such were not included in this study. More detailed information about trawl gear is provided in Jorgensen (1998). Trawling occurred over a 24-hour period with maximum tow duration of 30 minutes. Average towing speed was 3.0 knots (kn).

Sample Collections

Two thousand six hundred and twenty two specimens representing twenty-six fish species were collected for stomach content and parasite infracommunity analysis. In addition to Greenland halibut (*Reinhardtius hippoglossoides*), these included sculpins (*Cottunculus microps*, *Artediellus atlanticus*, *Myoxocephalus scorpius*, *Triglops nybelini*), blue hake (*Antimora rostrata*), eelpouts (*Lycodes eudipleurostictus*, *L. mcallisteri*, *L. paamiuti*), blacksmelts (*Bathylagus euryops*), lanternfish (*Lampanyctus macdonaldi*, *Benthosema glaciale*), Arctic cod (*Arctogadus glacialis*, *Boreogadus saida*), snailfish (*Careproctus reinhardti*, *Liparis fabricii*, *Paraliparis bathybius, Rhodichthys regina*), black dogfish (*Centroscyllium fabricii*), grenadier (*Macrourus berglax*, *Coryphaenoides rupestris*), rocklings (*Gaidropsarus argentatus*, *G. ensis*), American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes mentella*), and eels (*Synaphobranchus kaupi*).

Prior to sampling, fish species known to obtain total lengths greater than 250 mm were separated into four size classes based on minimum and maximum recorded lengths listed in Scott and Scott (1988) and Okamura et al. (1995). The initial objective was to collect an equal number of samples from each size class to obtain a more accurate assessment of food size and type. Not all size classes were represented within the study area and consequently, a minimum of 30 specimens of each species were collected, representative of the size classes found within the study area. Immediately following capture, specimens were frozen at -18°C and stored until necropsied. Data were collected on length (total, standard, fork {when appropriate}), total weight, stomach contents, parasites and gonad weight. Fish and organs were weighed using a Delta Range Mettler PM460 scale to the nearest 0.001 g. Stomach contents of fishes were collected in order to determine diet and possible modes of transmission of parasite species. Fish with empty stomachs (34.1% of fish examined) were not included in diet analyses. Organs and tissues of each fish were examined separately to compile a list of parasites within each host species and organ as well as for the determination of parasite loads. Samples for stable isotope analysis were also collected from each fish for determination of trophic information.

Necropsy Procedures

The mouth lining and body surface of each fish were examined for ectoparasites before the necropsy began. The eyes, heart, gills, stomach, intestine, pyloric caecae, gonads, liver, urinary bladder and kidneys were then removed and placed in separate Petri dishes with 0.6% saline for examination. Separation of each organ prevented mixing of contents and inaccurate determination of parasite distribution within the host. During separation of each organ, examination of the mesentery was done as larval nematodes and/or acanthocephalans are often found encysted in this tissue. Surfaces of the heart, kidneys and liver were examined before being flattened under glass. Flattening allows for the detection of transparent or concealed parasites within thick tissue such as the liver. In addition, a section of muscle was examined from each fish for encysted parasites.

The eyes, stomach, intestine, urinary bladder and caecae were carefully cut open and scraped into a Petri dish containing 0.6% saline. The contents were gently separated and examined for parasites under a Nikon SMZ-1 dissecting microscope. Stomach contents were identified, enumerated and stored in 70% ethanol for future reference. Copepods and nematodes were similarly placed in 70% ethanol for future clearing and identification. Trematodes, cestodes and acanthocephalans were fixed in AFA for 48 hours. Parasites were then placed in 70% ethanol for storage prior to staining and mounting. Individual parasite species within each organ were enumerated.

Staining and mounting of parasites

Staining and mounting procedures were used according to Humason (1962). Semichon's acetocarmine was used for the staining of trematodes, cestodes and acanthocephalans. Specimens were placed in the acetocarmine solution for 20 minutes to one hour (depending on the thickness/size of the specimen). Once properly stained, the parasite was washed in 70% ethanol and placed into a Petri dish containing acidic 70% ethanol for one to five minutes or until excess stain was removed. The parasite was then washed with basic 70% ethanol for an equal amount of time to neutralize the acid. Each specimen was dehydrated completely through several one-hour changes each of 70%, 80%, 95% and 100% ethanol. Following complete dehydration, each parasite was transferred to xylene or Slide Brite© until the cuticle became clear. Specimens were then mounted onto slides with Permount©.

Nematodes were cleared in 5% glycerol, using methods described in Hays et al. 1998. After fixation, each specimen was added to a Petri dish containing glycerol and trace amounts of powdered copper sulphate to prevent mould growth. The Petri dish was then covered and kept dry at room temperature. As the alcohol slowly evaporated, the specimen cleared and was eventually left in pure glycerine. Specimens were then mounted in glycerine and identified.

Keys used in the identification of fish, parasite and prey species

Fishes were identified using various keys and descriptions found in Able and McAllister (1980), Andriyashev (1954), Möller 2001a,b, Nielsen and Bertelsen (1992), Okamura et al. (1995), Scott and Scott (1988) and Whitehead et al. (1986). Parasites were identified using keys and descriptions found in Bray (1979, 1987), Bray and Campbell (1995), Bray and Gibson (1986, 1991,1995), Campbell and Munroe (1977), Campbell et al. (1982), Cone 1995, Dick and Choudhury (1995), Gibson and Bray (1982, 1986), Hogans (1986), Hunninen and Cable (1943), Klassen et al. (1989), Koie (1981), Miller (1941), Nickol (1995), Rubec (1988), Scott and Bray 1989, Skrjabin (1964) and Zdzitowiecki and Cielecka (1998). Original literature was also used in the identification of parasites. For example, the monogenean *Macruricotyle newfoundlandiae* was identified using the original description in Campbell et al (1982). In addition, the original description of the digenean trematode, *Gonocerca phycidis*, was obtained from Manter (1925).

Food items were identified using keys and descriptions found in Hartman and Fauchald (1971), Kathman et al. (1986), Sars (1890, 1899) and Squires (1990). Authorities for fish and invertebrate food items were obtained from IT IS (Integrated Taxonomic Information System; http://www.itis.gov/). Parasite authorities were obtained from Bray (1979, 1987), Bray and Campbell (1995), Bray and Gibson (1986, 1991,1995), Campbell and Munroe (1977), Campbell et al. (1982), Cone 1995, Dick and Choudhury (1995), Gibson and Bray (1982, 1986), Hogans (1986), Hunninen and Cable (1943), Klassen et al. (1989), Koie (1981), Miller (1941), Nickol 1995, Rubec (1988), Scott and Bray 1989, Skrjabin (1964) and Zdzitowiecki and Cielecka (1998).

Assessing Trawl Data

It is worth noting that although trawl data provide invaluable information about marine communities, several factors may contribute to inaccuracy or imprecision. These factors include inefficiency of sampling gear, fish avoidance behaviour and bias in terms of sampling location. Inconsistencies of wing spread and trawl height are the most common examples of gear inefficiency (Koeller 1991). Additionally, swept area often increases with depth, resulting in overestimated density estimates for deep water compared to those in shallow water. In addition, lack of stability in trawl performance due to unstable bottom contact by the ground gear can occur and is normally caused by uneven bottom conditions. This will lead to imprecise survey indices (Walsh et al. 1993).

A variety of fish behaviour problems are possible when sampling in the marine environment. In trawl surveys, it is assumed that fishes behave according to certain patterns. However, trawl avoidance and 'unavailability' (i.e., species existing higher or lower in the water column than the gear) may occur to varying degrees during sampling.

Many of these difficulties can be circumvented by altering sweep angles, using more precise gear and decreasing tow duration; however, factors such as fish avoidance behaviour are inevitable. Despite this, trawl data collection remains an important, and in fact, the only method of evaluating deep-sea marine communities.

Table 2.1. Stratification scheme for NAFO Subarea 0, Division B used in the 2000 and 2001 surveys. A conversion factor of 3.430 was used to calculate square kilometers from square nautical miles (Bowering 1987, Treble et al. 2001).

Stratum	Sq. N Miles	Approx. # Units	Sq. Km	Depth (m)
3	2616	748	8972.9	401-500
4	4671	1335	1602.2	501-750
5	2070	592	7100.1	751-1000
6	1975	564	6774.3	1001-1250
7	1641	469	5628.6	1251-1500
10	1566	448	5371.4	401-500
11	2311	661	7926.7	501-750
12	943	270	3234.5	751-1000
13	343	98	1176.5	1001-1250
24	1449	414	4970.1	401-500
25	2130	609	7305.9	501-750
Total	**21715**		**60,063.2**	

Table 2.2. Stratification scheme for NAFO Subarea 0, Division A South used in the 2001 and 2004 surveys. A conversion factor of 3.430 was used to calculate square kilometers from square nautical miles (Bowering 1987, Treble et al. 2001).

Stratum	Sq. N Miles	Approx. # Units	Sq. Km	Depth (m)
024	281	90	963.8	401-500
025	1527	510	5237.6	501-750
030	1004	330	3443.7	751-1000
031	832	280	2853.8	1001-1250
032	391	130	1341.1	1251-1500
033	305	100	1046.2	501-750
034	156	50	535.1	401-500
040	1296	480	4445.3	1251-1500
041	546	200	1872.8	1001-1250
042	443	160	1519.5	751-1000
043	472	170	1619.0	501-750
044	289	110	991.3	401-500
045	268	100	919.2	501-750
046	281	110	963.8	751-1000
047	686	250	2353.0	1001-1250
048	653	240	2240.0	1251-1500
049	547	200	1876.2	1251-1500
050	491	190	1684.1	1001-1250
051	437	160	1499.0	751-1000
052	477	180	1636.1	501-750
053	214	80	734.0	401-500
054	649	240	2226.1	501-750
055	253	100	867.8	401-500
056	125	60	428.8	401-500
057	416	190	1426.9	501-750
058	220	100	754.6	501-750
059	377	170	1293.1	751-1000
060	422	190	1447.5	1001-1250
061	471	210	1615.5	1251-1500
Total	**14,529**		**49,834**	

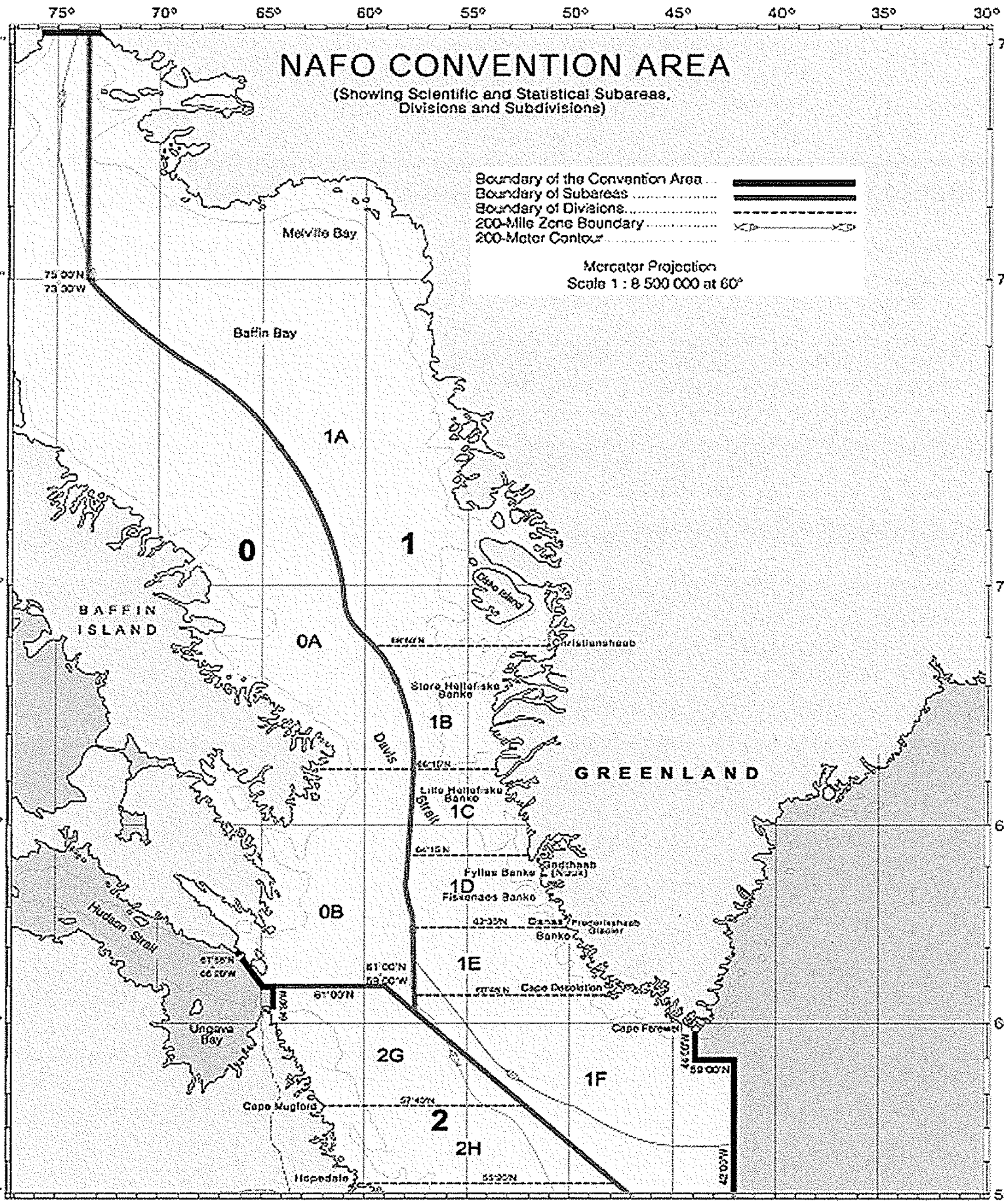
Table 2.3. Stratification scheme for NAFO Subarea 0, Division A North used in the 2004 survey. A conversion factor of 3.430 was used to calculate square kilometers from square nautical miles (Bowering 1987, Treble et al. 2001).

Stratum	Sq. N Miles	Approx. # Units	Sq. Km	Depth (m)
062	114	40	391.0	401-500
063	569	190	1951.7	501-750
064	1586	530	5440.0	751-1000
065	683	230	2342.7	1001-1250
066	576	190	1975.7	1251-1500
067	674	220	2311.8	501-750
068	1051	350	3604.9	751-1000
069	1602	540	5494.9	751-1000
070	507	170	1739.0	751-1000
071	81	30	277.8	1001-1250
072	1274	420	4369.8	1001-1250
073	421	140	1444.0	1251-1500
074	1429	520	4901.5	751-1000
075	53	20	181.8	1001-1250
076	999	360	3426.6	751-1000
077	898	330	3080.1	751-1000
078	732	270	2510.8	1001-1250
079	401	150	1375.4	1250-1500
080	1033	380	3543.2	501-750
081	1224	450	4198.3	501-750
082	968	350	3320.2	501-750
083	583	210	1999.7	751-1000
084	320	120	1097.6	401-500
085	822	300	2819.5	301-400
086	302	110	1035.9	401-500
087	494	180	1694.4	501-750
088	348	130	1193.6	401-500
089	1234	450	4232.6	301-400
090	838	310	2874.3	401-500
091	818	300	2805.7	501-750
Total	**22,634**		**77,634**	

Table 2.4. Number of tows conducted in each depth range during the 2000, 2001 and 2004 surveys. Subarea 0B was sampled in 2000 and 2001. Subarea 0A South was sampled in 2001 and 2004. Subarea 0A North was sampled in 2001 and 2004. Subareas 1A and 1CD were sampled in 2004. 'S' denotes south, 'N' denotes north.

		Depth Range (m)				
		<500	501-750	751-1000	1001-1250	1251-1500
Year	Subarea					
2000	0B	12	14	12	8	6
2001	0B	9	5	8	7	4
	0AS	1	16	6	6	11
2004	0AS	4	11	12	11	16
	0AN	1	5	14	10	6
	1A	12	22	13	18	10
	1CD	0	4	13	18	10

Figure 2.1. Map of NAFO management areas within Baffin Bay and Davis Strait (NAFO, 2008; used with permission). Data used for analysis were collected from 0A, 1A, 0B, 1C and 1D between 2000 and 2004.


NAFO CONVENTION AREA
(Showing Scientific and Statistical Subareas, Divisions and Subdivisions)
Boundary of the Convention Area
Boundary of Subareas
Boundary of Divisions
200-Mile Zone Boundary
200-Meter Contour
Mercator Projection
Scale 1 : 8 500 000 at 60°
75°
70°
65°
60°
55°
50°
45°
40°
35°
30°
78°
75°
70°
65°
60°
55°
Melville Bay
Baffin Bay
75°00'N
73°30'W
1A
0
1
Disko Island
BAFFIN ISLAND
0A
68°50'N
Christianshaab
Store Hellefiske Banke
1B
Davis Strait
GREENLAND
66°15'N
Lille Hellefiske Banke
1C
64°15'N
Godthaab (Nuuk)
Fyllas Banke
1D
Fiskenaes Banke
0B
62°30'N
Danas Banke
Frederikshaab Glacier
Hudson Strait
61°55'N
66°20'W
61°00'N
59°00'W
1E
60°45'N
Cape Desolation
61°00'N
64°30'W
Ungava Bay
Cape Farewell
2G
44°00'W
59°00'N
1F
Cape Mugford
57°40'N
2
2H
Hopedale
55°20'N
42°00'W

CHAPTER 3: USING ENVIRONMENTAL VARIABLES TO PREDICT THE STRUCTURE OF DEEP-SEA ARCTIC FISH COMMUNITIES

Introduction

Efforts to exploit Arctic marine fisheries are increasing as landings of the world's marine fisheries have plateaued and for some species catches have declined (Hutchings and Myers 1995, Zhao et al. 2003). The Arctic Ocean is heterogeneous, due in part to latitude, variability in ocean currents, salinity and depth, so marine fish populations will likely vary both regionally and locally. Eight ecoregions have been designated for the Canadian Arctic compared to six for the Pacific region and seven for the Atlantic region (Powles et al. 2004). Consequently, the need to know how Arctic marine fish communities are structured overall and locally is essential for long term sustained fisheries. In the face of past exploitation, effective management decisions require an understanding of the biological and ecological processes that drive community dynamics. Food webs are traditionally used for this purpose; however, they are often incomplete and do not account for factors such as changes in latitude, longitude, depth and/or temperature.

In 1999, Fisheries and Oceans Canada launched their Greenland Halibut Arctic Survey, an ongoing project aimed at investigating Greenland halibut populations throughout Davis Strait and Baffin Bay. Their secondary objective was to survey by-catch populations in order to discern which species represent important prey items and/or competitors of Greenland halibut. Before more detailed trophic studies could be undertaken, a simple species inventory was required, focusing on species diversity with changing environmental variables.

Several authors have investigated community structure using multivariate statistical methods. In recent years, the effects of changing environmental conditions on terrestrial (Kitahara and Fujii 2005), freshwater (Amsinck et al. 2006), estuarine (Juareguizar et al. 2004) and marine invertebrates (Cai et al. 2007, Mannin and Bucklin 2005) and fish (Bertolo and Magnan 2006, Kochzius 2007, McField et al. 2001, Pusch et al. 2004) have been of great interest, either in terms of human impacts or trophic evaluation.

The first objective discussed in Chapter 1 involved determining factors that affect community dynamics and trophic relationships in benthic Arctic marine communities. That objective was the primary focus of this chapter; to investigate the role of environmental variables on marine fish community composition using multivariate analytical methods in order to predict changes in trophic structure within the Davis Strait/Baffin Bay region. More specifically, to determine 1) if environmental variables could be used to predict fish species composition within Davis Strait and Baffin Bay and 2) if this information is applicable to the construction of Arctic food webs.

Methods

Data Analysis

Trawl data collected in the 2000-2004 surveys were used in this analysis. Sampling methods are described in detail in Chapter 2. Distance measures of latitude and longitude, bottom depth and water temperature chosen for comparison with abundances of 145 fish species (Table 3.1). Latitude and longitude coordinates were converted to northing and easting UTM (Universal Transverse Mercator) distance measures using the conversion software GeoTrans2 (Northrop Grumman Information Technology, 2002). Easting values were further converted to make distance measures comparable to each other by calculating the distance west of each transect from the midpoint of UTM zone 23. Fish abundance for each tow was log transformed and organized into a covariance matrix in order to meet assumptions of linearity and to avoid giving equal weights to abundant and rare species. Environmental data for each tow were also logged and standardized in a correlation matrix. Redundancy analysis (RDA) of environmental data with species abundance was run using the statistical software CANOCO 4.53.

Results

Fourty-two per cent of the total redundancy in species abundance is predicted from variation in the environment (Table 3.2). Eigen values (E) and the cumulative proportion of canonical variance accounted for by each canonical axis (CSE) indicate that most of the variation is accounted for in the first two axes with E values of 0.321 and 0.071 and CSE values of 76.0 and 92.8% respectively.

Scatter plot results (Fig. 3.1) illustrate how species data are constrained by the environmental data. Temperature and latitude are negatively correlated along RDA Axis 1 indicating that community composition differs between high latitude areas with low temperatures and low latitude areas with higher temperatures. Longitude is also negatively correlated with temperature but less so than latitude as indicated by its shorter vector length. Depth also influences community composition, and is accounted for along RDA Axis 2.

The proportional differences (by number) of twenty common by-catch species in five depth ranges within NAFO subareas 0A and 0B between 2000 and 2001 are shown in Figure 3.2. In subarea 0A *B. saida* dominated in shallow waters whereas *S. mentella* had the highest proportion at the same depths in 0B. Two species dominated in tows greater than 600 m within subarea 0A, the most abundant of which was the snailfish, *L. fabricii*. Rocklings (*G. ensis*) also dominated these tows, and increased in proportion with increasing depth. The increase of *G. ensis* corresponded to a decreases of *L. fabricii*. In 0B, more species were present overall and no one species dominated at depths greater than 800 m. *Synaphobranchus kaupi* and *A. rostrata* were not collected from 0A but there was a definite increase in proportion with depth in 0B. Lanternfish, *L. macdonaldi* and *B. glaciale*, decreased in proportion with increasing depth in 0B. Though *G. ensis* represented a smaller proportion of the by-catch overall in subarea 0B, it followed a similar pattern to that of 0A in terms of increasing proportion with increasing depth.

Figures 3.3 and 3.4 represent generalized food webs based on known diet preferences, demonstrating the differences in fish community structure in southern vs. northern latitudes. Several fish species are absent to the north (0A; Fig. 3.4) compared to the south (0B; Figure 3.3), including *S. kaupi*, *C. fabricii*, *A. rostrata*, *C. rupestris* and *B. euryops*.

Discussion

The distribution of fish species differed within and between subareas and consequently, the Davis Strait/Baffin Bay region may be composed of several 'distinct' communities. Although many species were common throughout the study area, several others varied in abundance according to one or more environmental variables. Redundancy analysis comparing fish species abundance with environmental variables supports this hypothesis and provides an explanation for observed changes in community structure. Species with low LC scores, i.e. those species closest to the origin of the ordination, were not significantly correlated with any of the four environmental variables; they were ubiquitous throughout Arctic waters regardless of environmental change. Re-examination of the raw data confirmed that these fishes were relatively abundant throughout the study area and may be considered 'core' species (e.g. Greenland halibut, polar sculpin) whereas others are relatively rare (e.g. Greenland shark, *Somniosus microcephalus*). Several species, many of which represent key predators or prey, vary along environmental gradients such as depth, temperature and/or latitude. The presence or absence of these species, or 'variants', within deep-sea environments may affect shifts in the trophic position of many individuals, effectively altering the community dynamic.

These findings corroborate those of Jorgensen et al. (2005). *Macrourus berglax*, *A. rostrata*, *C. rupestris* and *S. kaupi* were closely associated with each other in low latitude/high temperature areas, whereas *A. atlanticus*, *L. fabricii* and *B. saida* were most closely associated with high latitude/low temperature areas (Fig. 3.1). Differences in depth were also comparable to Jorgensen et al. (2005). For example, *S. mentella* was most closely associated with shallow water and more strongly correlated with low latitude/high temperature areas, whereas *P. bathybius* and *R. hyperborea* were more closely associated with deep waters and high latitude/low temperature areas.

Communities in higher Arctic latitudes differ from those to the south in that organisms such as lanternfish (*L. macdonaldi*) and grenadier (*C. rupestris*) begin to reach the limits of their geographical distribution, likely due to physiological limits with respect to temperature or habitat preferences with respect to spawning or feeding. For example, lanternfish such as *L. macdonaldi* are an important food item for *C. rupestris*. It is possible that populations of *C. rupestris* follow their food source and will remain further south due to the increased availability of prey. As the abundance of southern species declines, those tolerant of decreasing temperatures or those with diet items that remain abundant throughout the Arctic (such as *L. fabricii* and *G. ensis*) become more important within the community as predator and prey species. Consequently, species interactions and food web structure are altered and certain species may replace others in terms of trophic importance. Figures 3.3 and 3.4 represent generalized food webs based on known diet preferences, constructed to demonstrate this shift in community structure between northern (0A) and southern (0B) communities. A number of fish species within each trophic level are lost to the north (0A), including important predator and prey species, such as *S. kaupi*, *C. fabricii*, *A. rostrata*, *C. rupestris* and *B. euryops*. As expected, some species are replaced by others of a similar trophic position (e.g. *A. glacialis*, *C. reinhardti*); however, the number of species and linkages decreases overall.

According to RDA results, longitude has less influence on community composition than the temperature/latitude gradient; however, it remains an important descriptor of community structure in terms of changes in current flow and physical characteristics of the ocean bottom (Tang et al. 2004). For example, shelf length on the Canadian side of Baffin Bay/Davis Strait is shorter than that of the Greenland side (Tang et al. 2004). Consequently, the distribution of deep- and shallow-water species at similar latitudes will differ in accordance with shelf association at different longitudes. This pattern was also noted by Jorgensen et al. (2005). The Davis Strait/Baffin Bay region is unique in that it is subject to several current systems, each with a different temperature, salinity and direction of flow (Jones et al. 2003, Kiilerich, 1939, Tang et. al. 2004). For example, the West Greenland Current (WGC) flows south to north along the eastern portion of this region, exposing species to warmer, more saline northerly flowing waters. Conversely, the Polar Current (PC) flows in a north to south direction, exposing species on the western side of Davis Strait and Baffin Bay to colder Arctic waters. The Arctic Ocean receives 11% of the world river runoff in addition to freshwater flux due to sea ice melt (Shiklomanov et al. 2000). Consequently, species along the Canadian side of Davis Strait and Baffin Bay are exposed to a less saline environment, especially to the north (Cuny et al. 2005). Two such different current systems in a relatively small geographical area may produce two separate and distinct ecological communities; one with more warm-tolerant species adapted to higher salinities and the other with more cold-tolerant species adapted to lower salinities. The absence of significant differences between these two areas may be explained by a high degree of current 'mixing' within this relatively narrow region, resulting in areas more similar in terms of environmental conditions than previously thought. For example, as the WGC travels north, warm water 'branches off' from the main direction of flow to circulate and mix with the colder waters to the west. Similarly, as the PC travels south, its colder waters mix with the warmer eastern waters.

As a result, the temperature and salinity gradients are less discrete from east to west than from south to north with the exception of shallow shelf waters along the west coast of Greenland (Cuny et al. 2005), and species composition is similar. Though the effects of current movement may have an important impact on species distribution in relatively shallow shelf waters (i.e., <800 m), temperature and salinity are known to stabilize and remain relatively uniform at greater depths (Cuny et al. 2005, Tang et al. 2004). As a result, species distribution at greater depths will not be affected.

Redundancy analysis confirmed that approximately 42 per cent of species distribution can be predicted using a combination of the four environmental variables; latitude, longitude, temperature and depth. As latitude increases, proportions of by-catch species at depth change drastically. As species are lost from the system, predators become increasingly dependent on the remaining organisms to meet daily dietary requirements and the removal or depletion of a common food source could result in partial or complete collapse of the system. With this information, it is now possible to predict community composition in different areas along the Davis Strait/Baffin Bay and to construct food webs representative of these communities. Because community structure appears to change gradually along environmental gradients, it may prove difficult to separate out distinct trophic communities and construct a corresponding food web for each. Alternatively, it may be more useful to describe the region in terms of shifting trophic position with assemblage along the temperature/latitude and depth gradients rather than attempt to construct several different food webs that may not encompass all of the variation seen in this dynamic environment.

Table 3.1. List of fish species within Davis Strait and Baffin Bay in 2000-2004 surveys for which abundances were compared with four environmental variables (latitude, longitude, temperature and depth) in redundancy analysis. Families are listed in alphabetical order.

Species

- Agonidae
  - *Leptagonus decagonus* (Bloch & Schneider)
- Alepocephalidae
  - Alepocephalidae gen. sp.
  - *Alepocephalus agassizii* Goode & Bean
  - *Alepocephalus bairdii* Goode & Bean
  - *Alepocephalus* sp.
  - *Bajacalifornia megalops* (Lutken)
  - *Bathytroctes* sp.
  - *Xenodermichthys copei* (Gill)
- Ammodytidae
  - *Ammodytes* sp.
- Anarhichadidae
  - *Anarhichas denticulatus* (Kroyer)
  - *Anarhichas minor* Olafsen
- Anoplogasteridae
  - *Anoplogaster cornuta* (Valenceinnes)
- Bathylagidae
  - *Bathylagus euryops* Goode & Bean
- Bythitidae
  - *Bythites fuscus* Reinhardt
- Ceratiidae
  - *Ceratias holboelli* Kroyer
- Chiasmodontidae
  - *Chiasmodon niger* Johnson
- Chimaeridae
  - *Hydrolagus affinis* (de Brito Capello)
- Clupeidae
  - *Clupea harengus* Linnaeus
- Cottidae
  - *Artediellus atlanticus* Jordan & Evermann
  - *Artediellus uncinatus* (Reinhardt)

Species Continued...

  - *Liparis tunicatus* Reinhardt
  - *Liparis* sp.
  - *Paraliparis bathybius* (Collett)
  - *Paraliparis copei* Goode & Bean
  - *Paraliparis garmani* Burke
  - *Rhodichthys regina* Collett
- Lophiformes
  - Lophiformes gen. sp.
- Lotidae
  - *Gaidropsarus argentatus* (Reinhardt)
  - *Gaidropsarus ensis* (Reinhardt)
  - *Gaidropsarus* sp.
  - *Molva dypterygia* (Pennant)
- Macrouridae
  - *Coryphaenoides brevibarbis* (Goode & Bean)
  - *Coryphaenoides guentheri* (Vaillant)
  - *Coryphaenoides rupestris* Gunnerus
  - Macrouridae gen. sp.
  - *Macrourus berglax* Lacepede
  - *Nezumia bairdii* (Goode & Bean)
  - *Nezumia* sp.
  - *Trachyrhynchus murrayi* Gunther
- Melamphaidae
  - *Poromitra crassiceps* (Gunther)
  - *Scopelogadus beani* (Gunther)
- Moridae
  - *Antimora rostrata* (Gunther)
  - *Lepidion eques* (Gunther)
- Myctophidae
  - *Benthosema glaciale* (Reinhardt)
  - *Lampanyctus macdonaldi* (Goode & Bean)
  - Myctophidae gen. sp.

Species Continued...

- Pleuronectidae
  - *Glyptocephalus cynoglossus* (Linnaeus)
  - *Hippoglossoides platessoides* (Fabricius)
  - *Hippoglossus hippoglossus* (Linnaeus)
  - *Reinhardtius hippoglossoides* (Walbaum)
- Psychrolutidae
  - *Cottunculus microps* Collett
  - *Cottunculus thompsoni* (Gunther)
- Rajidae
  - *Bathyraja spinicauda* (Jensen)
  - *Malacoraja spinacidermis* (Barnard)
  - *Raja bathyphila* (Holt & Byrne)
  - *Raja fyllae* (Lutken)
  - *Raja hyperborea* (Collett)
  - *Raja radiata* (Donovan)
  - *Raja* sp.
- Saccopharyngidae
  - *Saccopharynx ampullaceus* (Harwood)
- Scorpaenidae
  - *Sebastes marinus* (Linnaeus)
  - *Sebastes mentella* Travin
  - *Sebastes* sp.
- Scyliorhinidae
  - *Apristurus profundorum* (Goode & Bean)
- Serrivomeridae
  - *Serrivomer beanii* Gill & Ryder
- Stephanoberyciformes gen sp.
- Sternoptychidae
  - *Argyropelecus hemigymnus* Cocco
  - *Argyropelecus olfersi* (Cuvier)
- Stichaeidae
  - *Leptoclinus maculatus* (Fries)

  - *Icelus bicornis* (Reinhardt)
  - *Icelus spatula* Gilbert & Burke
  - *Gymnocanthus tricuspis* (Reinhardt)
  - *Myoxocephalus scorpius* (Linnaeus)
  - *Triglops pingelii* Reinhardt
  - *Triglops nybelini* Jensen
- Cyclopteridae
  - *Cyclopteropsis macalpini* (Fowler)
  - *Cyclopterus lumpus* Linnaeus
  - *Eumicrotremus derjugini* Popov
  - *Eumicrotremus spinosus* (Fabricius)
- Etmopteridae
  - *Centroscyllium fabricii* (Reinhardt)
- Eurypharyngidae
  - *Eurypharynx pelecanoides* Vaillant
- Gadidae
  - *Arctogadus glacialis* (Peters)
  - *Boreogadus saida* (Lepechin)
- Gonostomatidae
  - *Cyclothone braueri* Jespersen & Taning
  - *Cyclothone microdon* (Gunther)
  - *Cyclothone* sp.
  - *Gonostoma bathyphilum* (Vaillant)
  - *Gonostoma* sp.
- Liparidae
  - *Careproctus micropus* (Gunther)
  - *Careproctus reinhardti* (Kroyer)
  - *Liparis fabricii* Kroyer
  - *Liparis gibbus* Bean
  - *Myctophum punctatum* Rafinesque
  - *Notoscopelus kroeyeri* (Malm)
- Myxinidae
  - *Myxine* sp.
  - Myxinidae gen. sp.
- Nemichthyidae
  - *Nemichthys scolopaceus* Richardson
  - Nemichthyidae gen. sp.
- Notacanthidae
  - *Notacanthus chemnitzii* Bloch
  - *Polyacanthonotus rissoanus* (De Filippi & Verany)
- Notosudidae
  - *Scopelosaurus lepidus* (Krefft & Maul)
- Oneirodidae
  - *Oneirodes eschrichtii* Lutken
- Osmeridae
  - *Mallotus villosus* (Muller)
- Paralepididae
  - *Arctozenus risso* (Bonaparte)
  - *Magnisudis atlantica* (Kroyer)
  - *Paralepis coregonoides* Risso
  - Paralepididae gen. sp.
- Platytroctidae
  - *Holtbyrnia anomala* Krefft
  - *Holtbyrnia macrops* Maul
  - *Holtbyrnia* sp.
  - *Maulisia microlepis* Sazonov & Golovan
  - Platytroctidae gen. sp.
  - *Sagamichthys schnakenbecki* (Krefft)
- Stomiidae
  - *Borostomias antarcticus* (Lonnberg)
  - *Chauliodus sloani* Bloch & Schneider
  - *Malacosteus niger* Ayres
  - *Rhadinesthes decimus* (Zugmayer)
  - *Stomias boa* (Risso)
  - Stomiidae gen. sp.
- Synaphobranchidae
  - *Synaphobranchus kaupi* Johnson
- Trachichthyidae
  - *Hoplostethus atlanticus* Collet
- Zoarcidae
  - *Lycenchelys muraena* (Collett)
  - *Lycenchelys* sp.
  - *Lycodes adolfi* Nielsen & Fossa
  - *Lycodes esmarkii* Collett
  - *Lycodes eudipleurostictus* Jensen
  - *Lycodes mcallisteri* Moller
  - *Lycodes paamiuti* Moller
  - *Lycodes pallidus* Collett
  - *Lycodes reticulatus* Reinhardt
  - *Lycodes seminudus* Reinhardt
  - *Lycodes squamiventer* Jensen
  - *Lycodes vahlii* Reinhardt
  - *Lycodonus mirabilis* Goode & Bean
  - *Melanostigma atlanticum* Koefoed
- New Species No 1
- New Species No 2

Figure 3.1. Scatter plot results from RDA of fish abundance and environmental data. Axis 1 corresponds to a cold-to-warm temperature gradient whereas Axis 2 corresponds to a deep-to-shallow depth gradient. T = Temperature, D = Depth, Ln = Longitude, Lt = Latitude. Mb: *M. berglax*, Ar: *A. rostrata*, Cr: *C. rupestris*, Sk: *S. kaupi*, Sme : *S. mentella*, Aa : *A. atlanticus*, Bs: *B. saida*, Lf: *L. fabricii*, Rah: *R. hyperborea*, Pb: *P. bathybius*. Total redundancy in species predicted from variation in the environment = 0.422. Eigen values (E) and cumulative proportion (%) of canonical variance (CSE) accounted for by each axis: Axis 1 = 0.321, 76.0 %; Axis 2 = 0.071, 92.8%, Axis 3 = 0.025, 98.6%, Axis 4 = 0.006, 100.0%.

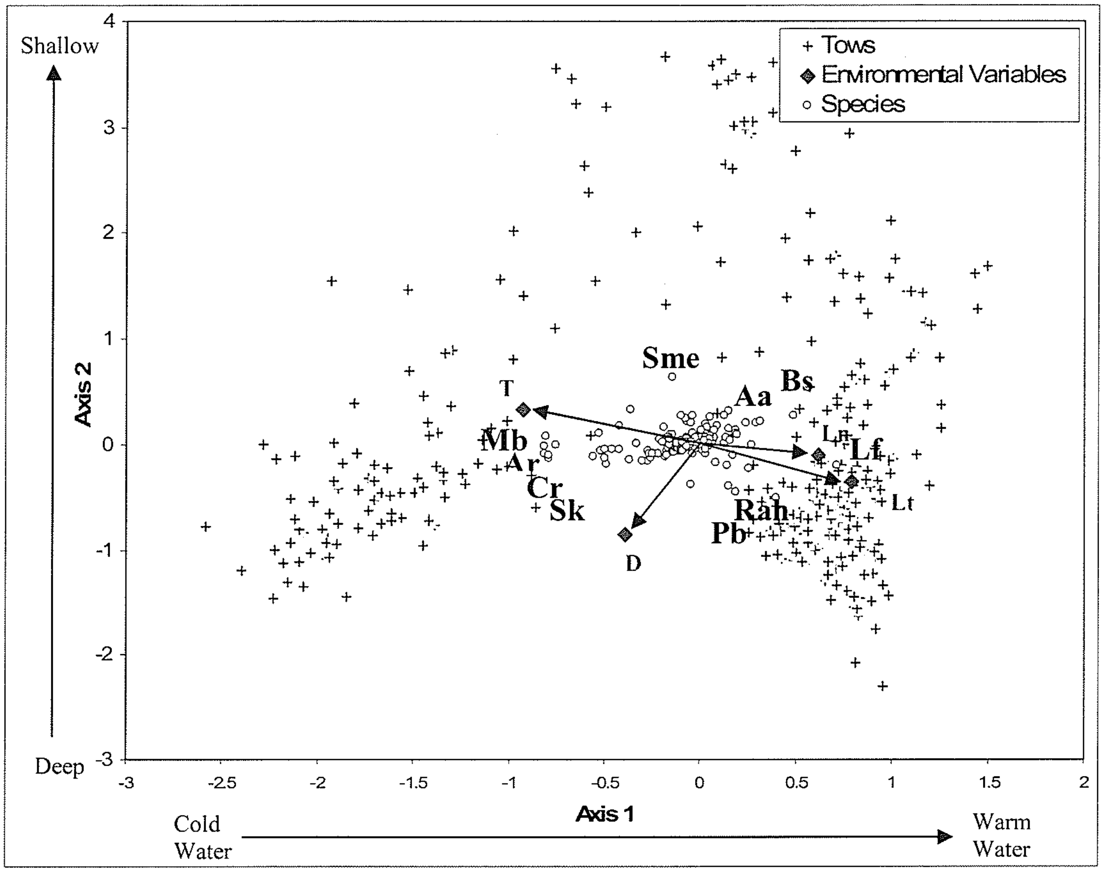
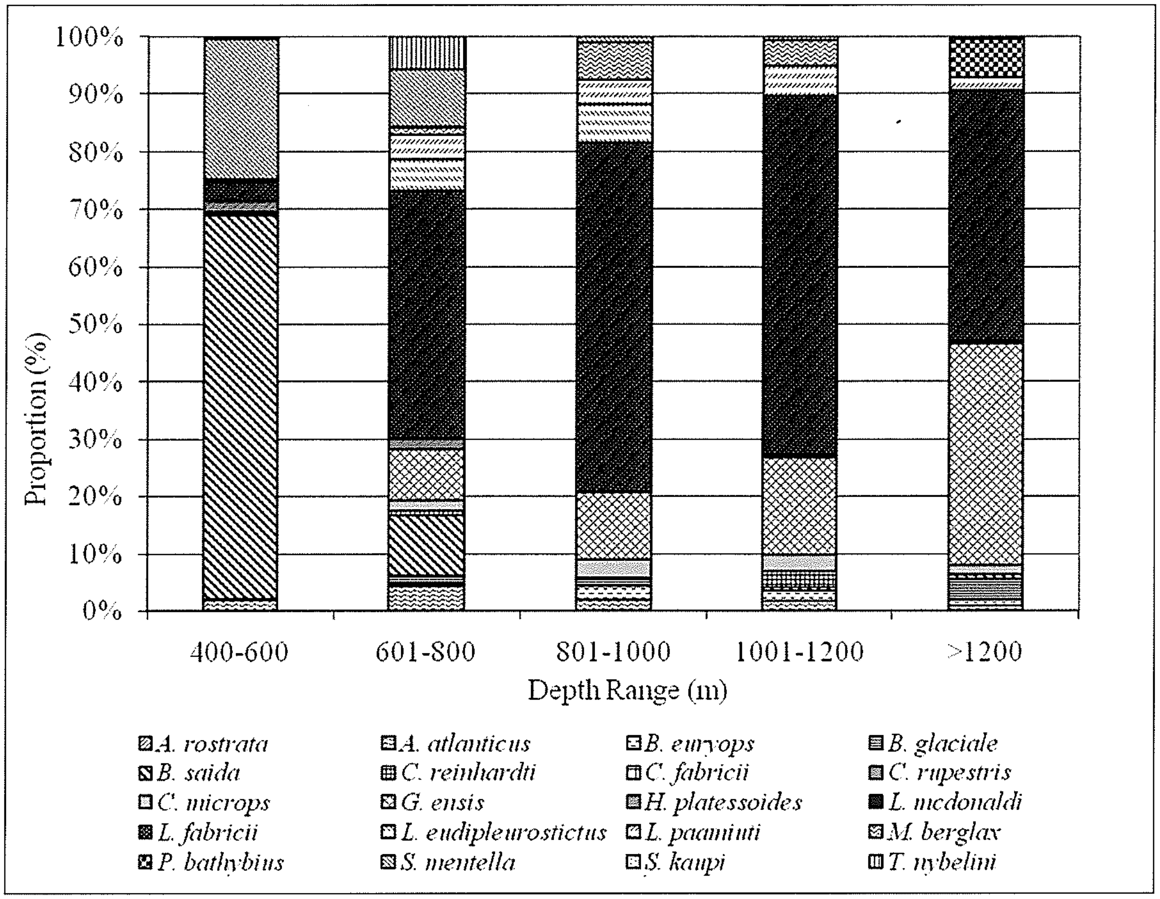
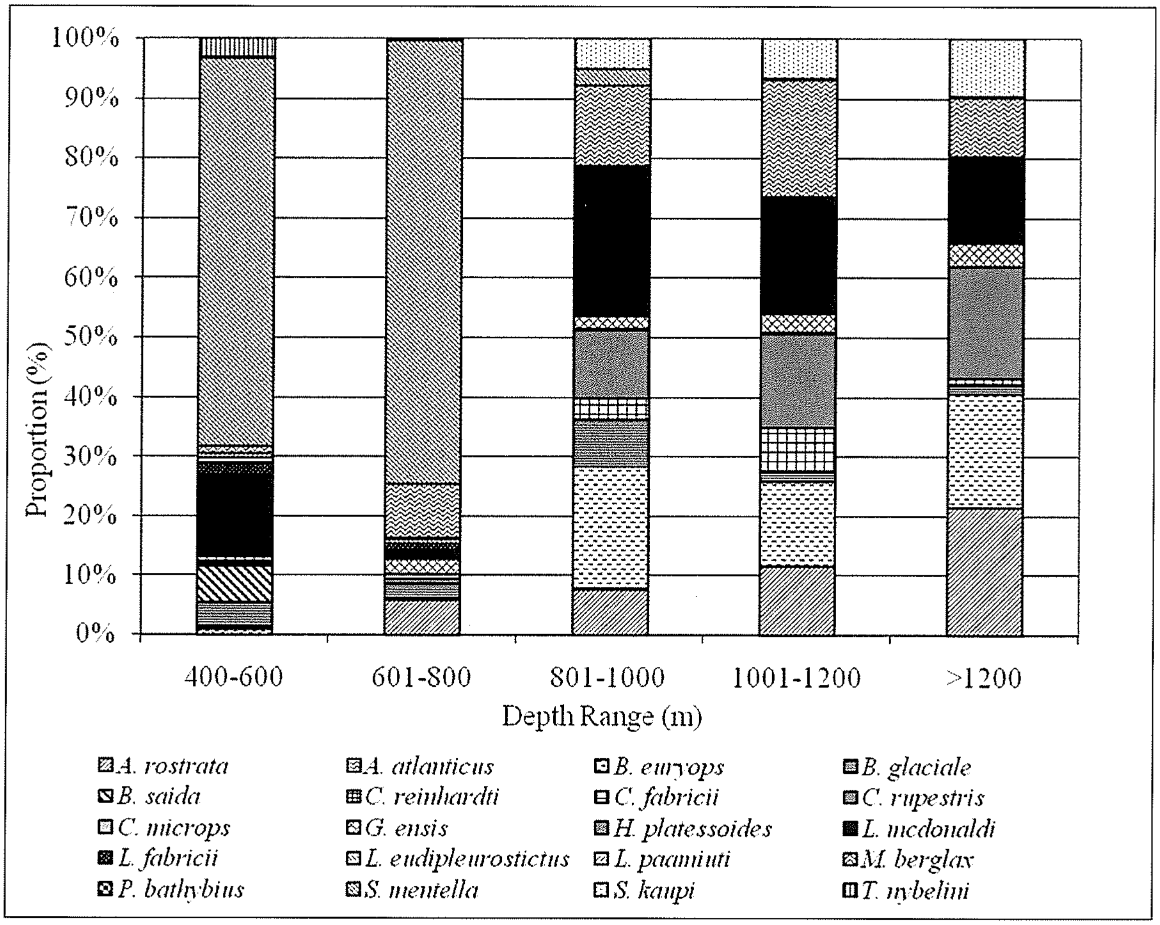

Shallow
Deep
Axis 2
4
3
2
1
0
-1
-2
-3
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Axis 1
Cold Water
Warm Water
+ Tows
◆ Environmental Variables
○ Species
T
D
Mb
Ar
Cr
Sk
Sme
Aa
Bs
Ln
Lf
Lt
Rah
Pb

Figure 3.2. Proportion of the twenty most common by-catch species over five depth ranges (400-600, 601-800, 801-1000, 1001-1200, >1200) within a) NAFO subarea 0A and b) NAFO subarea 0B, in 2000 and 2001.



a) NAFO Subarea 0A



b) NAFO Subarea 0B

Figure 3.3. Generalized food web representing common predator and prey fish species in NAFO subarea 0B based on stomach content data from 2000-2001 samples. Dietary information for *Gonatus fabricii* was obtained from Nesis (1965), Kristensen (1983) and observations from 2000-2004 surveys.

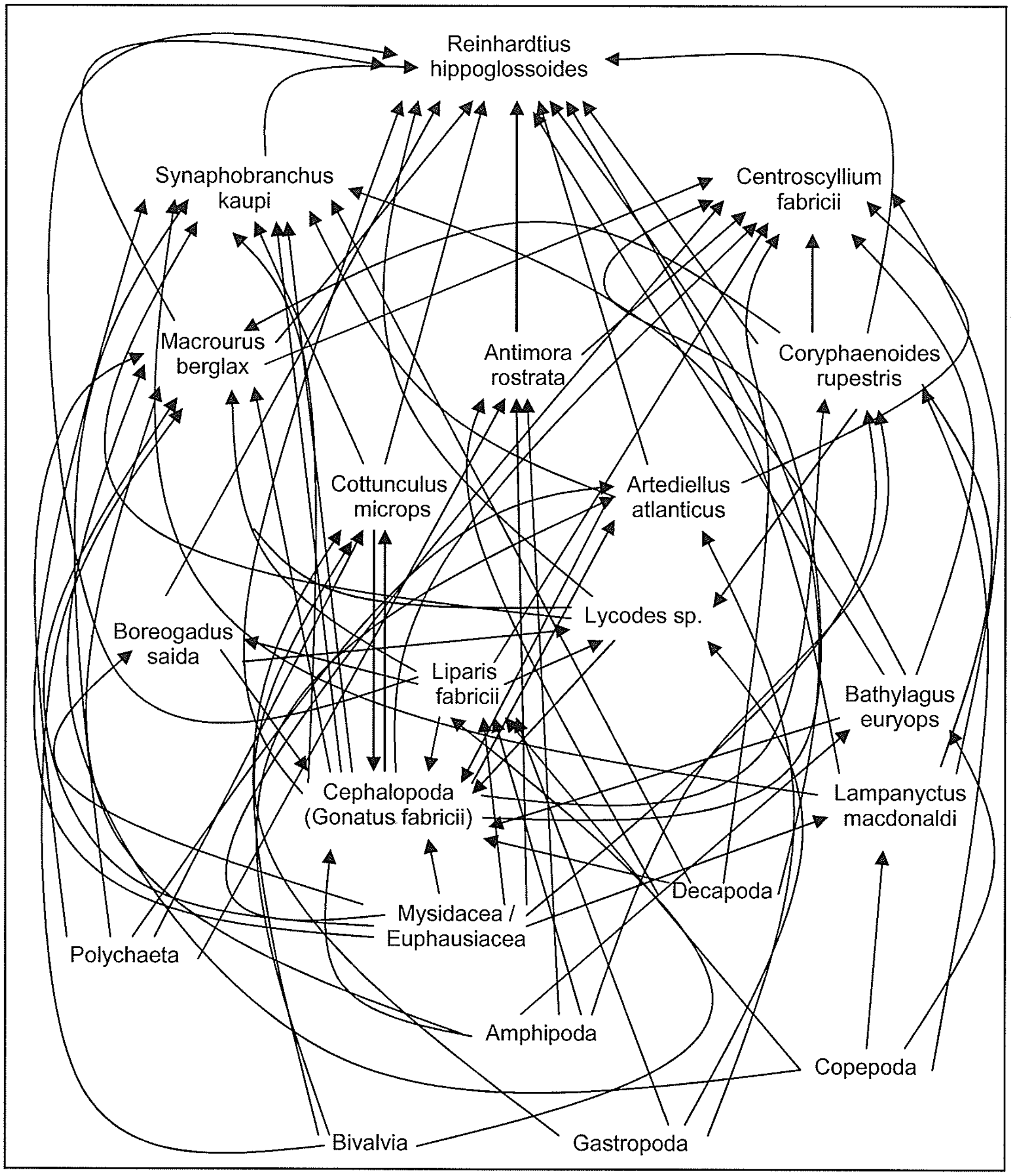
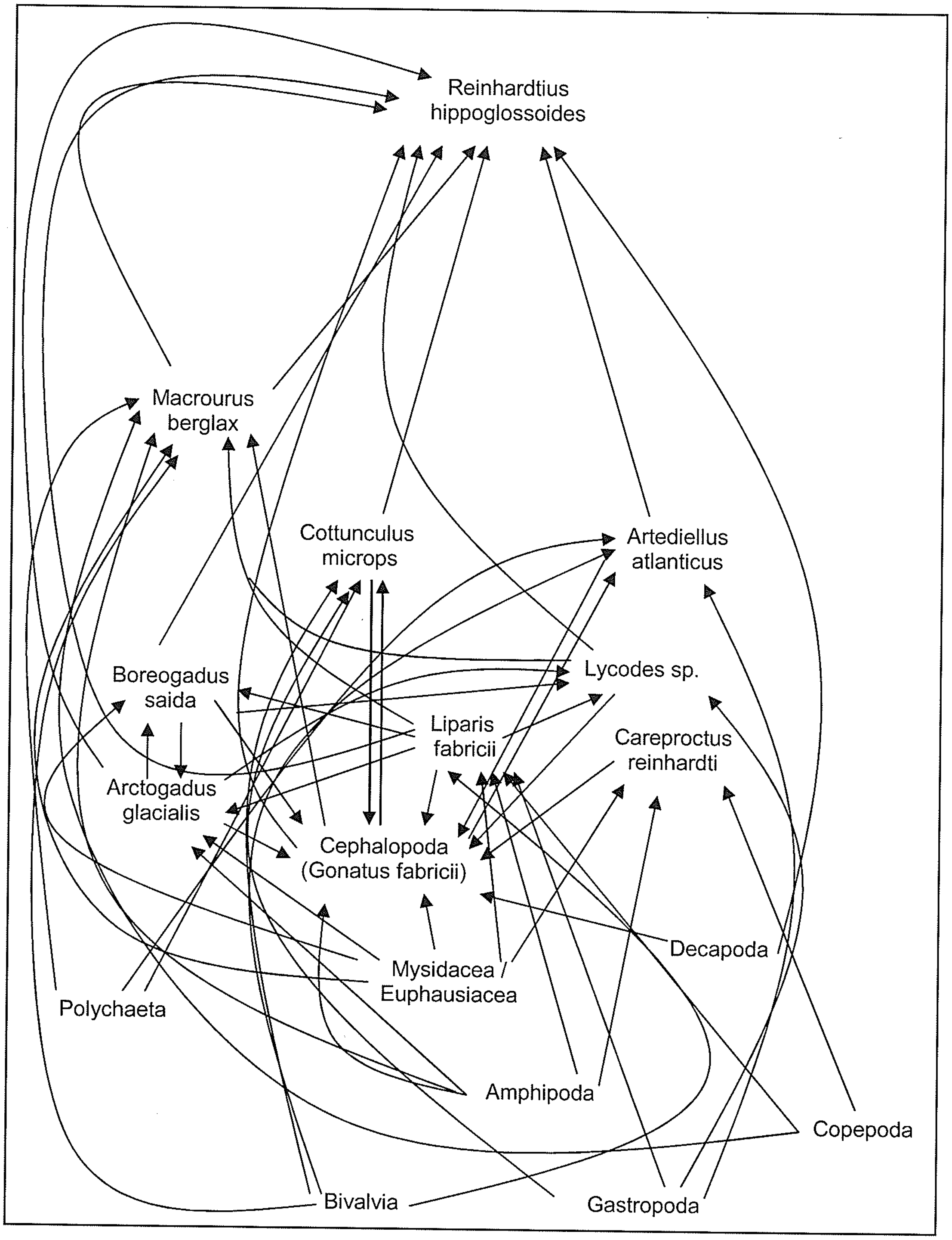

Reinhardtius hippoglossoides
Synaphobranchus kaupi
Centroscyllium fabricii
Macrourus berglax
Antimora rostrata
Coryphaenoides rupestris
Cottunculus microps
Artediellus atlanticus
Lycodes sp.
Boreogadus saida
Liparis fabricii
Bathylagus euryops
Cephalopoda (Gonatus fabricii)
Lampanyctus macdonaldi
Decapoda
Mysidacea / Euphausiacea
Polychaeta
Amphipoda
Copepoda
Bivalvia
Gastropoda

Figure 3.4. Generalized food web representing common predator and prey fish species within in NAFO subarea 0A based on stomach content data from 2000-2001 samples. Dietary information for *Gonatus fabricii* was obtained from Nesis (1965), Kristensen (1983) and observations from 2000-2004 surveys.


Reinhardtius hippoglossoides
Macrourus berglax
Cottunculus microps
Artediellus atlanticus
Boreogadus saida
Lycodes sp.
Liparis fabricii
Careproctus reinhardti
Arctogadus glacialis
Cephalopoda (Gonatus fabricii)
Decapoda
Mysidacea / Euphausiacea
Polychaeta
Amphipoda
Copepoda
Bivalvia
Gastropoda

CHAPTER 4: TROPHIC STRUCTURE OF DEEP-SEA BENTHIC FISH COMMUNITIES – THE USE OF TROPHIC GUILDS AND MULTIVARIATE ANALYSIS

Introduction

Although new Arctic marine fisheries are being developed without a comprehensive national policy (Dick and Chambers 2005) the Strategic Framework for Nunavut Fisheries (2004) indicated the need for a multi species approach to develop fundamental knowledge of Arctic fish communities. In order to maintain a stable marine Arctic ecosystem with an on-going commercial fishery, the accumulation of basic biological knowledge is required, both at the species and community levels and should include food webs information. This is particularly important for northern regions as species diversity decreases with increasing latitude and many organisms reach the limits of their geographical distribution.

Contrary to most tropical species, Arctic fishes tend to be generalist feeders, selecting prey items that are readily available within their respective habitat zones (i.e., position in the water column). Benthic species tend to feed on sedentary organisms or other benthic species, whereas benthopelagic fishes feed on benthic prey as well as pelagic species. While deep-sea fishes share several common food items, there are differences in food availability among these habitat types or ‘zones’.

The use of trophic guilds to describe community interactions and construct food webs is well documented (Alvim and Peret 2004, Angel and Ojeda 2001, Bulman et al. 2001, Davenport and Bax 2002, Luczkovich et al. 2002). Some studies have focussed on a subset of species to predict trophic structure within a community, while others have incorporated the majority of species within a study area. For example, Bulman et al. (2001) classified seventy marine species on the southeastern Australian shelf into trophic guilds using the Bray-Curtis Dissimilarity Index with stomach content data. Similarly, Luczkovich et al. (2002) used published and observed dietary information to determine trophic guild structure of fishes and macroinvertebrates of a seagrass food web in the northeastern Gulf of Mexico. Hierarchical classification has been effective in describing tropical systems in which most species exhibit specialised feeding behaviour; however, in deep-sea Arctic habitats, feeding strategies are largely unknown and such methods may be inappropriate. If large overlaps of prey species (i.e., generalist feeding strategies) exist within these communities, a clear separation of trophic levels based on food items and/or parasite species may be difficult.

The concept of resource partitioning has been expanded over the years, following Root's (1967) definition of a trophic guild as 'a group of species that exploit the same class of environmental resources in a similar way' regardless of taxonomic differences. Later, the concept of trophic guild and food web structure was revised to include ontogenetic shifts in niche utilization and the importance of body size with respect to guild association, particularly in marine environments (Cohen et al. 1993, Garrison and Link 2000, Haedrich and Merrett 1992, Jennings et al. 2002, Munoz and Ojeda 1998, Piet et al. 1999, Werner and Gilliam 1984, Woodward and Hildrew 2002). Consequently, studies focussing on the trophic structure of fish communities should consider all aspects of habitat utilization in order to provide accurate dietary information.

Although stomach content analyses reveal accurate diet data, they often represent only short-term information (Sholto-Douglas et al. 1991). Methods that incorporate longer term information, in addition to stomach contents, would aid in the construction of more accurate food webs. Parasite infracommunities and stable isotope ratios are useful in this respect and have been used to augment stomach content data for freshwater fishes (Johnson et al. 2004) and marine (Bulman et al. 2001, Davenport and Bax 2002) ecosystems. For example, Johnson et al. (2004) found that parasite infracommunities more accurately predicted trophic interactions than stomach contents alone in yellow perch (*Perca flavescens*) from Canadian Shield lakes.

Parasites are frequently used as indicators of ecological relationships between hosts (Arthur and Arai 1980, Holmstad et al. 2004, Lester et al. 2001, Mackenzie 1985, Malek 2003, Zhokhov 2001). Some examples demonstrate 1) feeding and migration patterns of Atlantic argentine (*Argentina silus*) (Scott 1969), Atlantic salmon (Lund and Heggberget 1992), Atlantic herring (*Clupea harengus*) (Mackenzie 1985, McGladdery and Burt 1985) and pollock (Avdeev and Avdeev 1989), as well as trophic relationships (Huxham et al. 1995, Johnson et al. 2004), and 2) feeding behaviour and phylogenetic linkages (Campbell et al. 1980, Urawa 1989). Campbell et al. (1980) recognized that helminth life cycles and the specificity of a parasite species for intermediate and definitive hosts were useful to link prey and predator. For example, Arctic marine fishes are important intermediate hosts for several nematode species that complete their life cycle in marine mammals such as seals or toothed whales. With knowledge of the definitive hosts of these parasites it is possible to construct food webs for Arctic marine communities without direct observation of the gut contents of marine mammals.

The remainder of the thesis focuses on the last two general objectives stated in Chapter 1; 2) recognizing broad feeding patterns by combining fish groups, regardless of phylogenetic relationships, by size and/or age class as well as similar ecologies, and 3) assessing the trophic position of individual species based on diets, parasite assemblages and stable isotope data. Hypotheses 1 and 2 were generated from these objectives and are, in part, investigated in this chapter.

The specific objectives of this chapter were to 1) determine if hierarchical clustering (guild formation) is an effective method of trophic evaluation in deep-sea Arctic fish communities using diet and parasite data with size class, and 2) evaluate the application of endohelminth communities (parasite species transmitted in the food) as indicators of trophic position in deep-sea marine fishes.

Methods

Species and samples

One thousand one hundred and one samples representing twenty-six fish species from Subarea 0B (Fig. 4.1) were collected for stomach content and parasite infracommunity analysis and are listed in Table 4.1. In addition to Greenland halibut (*Reinhardtius hippoglossoides*), these include sculpins (*Cottunculus microps*, *Artediellus atlantics*, *Triglops nybelini*), blue hake (*Antimora rostrata*), eelpouts (*Lycodes eudipleurostictus*, *L. esmarkii*, *L. vahlii*, *L. paamiuti*, *L. reticulatus*), blacksmelts (*Bathylagus euryops*), lanternfish (*Lampanyctus macdonaldi*, *Benthosema glaciale*), Arctic cod (*Boreogadus saida*), snailfish (*Liparis fabricii*), black dogfish (*Centroscyllium fabricii*), grenadiers (*Macrourus berglax*, *Coryphaenoides rupestris*), rocklings (*Gaidropsarus argentatus*, *G. ensis*), American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes mentella*), and eels (*Synaphobranchus kaupi*). The total sample sizes for each species are listed in Table 4.1.

Species of the same genera for which fewer than 30 individuals were collected were grouped for analysis (e.g. *L. esmarkii*, *L. vahlii* and *L. reticulatus* will now be referred to as '*Lycodes* spp.'); *G. argentatus* was grouped with *G. ensis* and will now be referred to as '*Gaidropsarus* spp.'). *Antimora rostrata*, *C. fabricii*, *C. rupestris*, *Gaidropsarus* spp., *H. platessoides*, *M. berglax*, *R. hippoglossoides*, *S. mentella* and *S. kaupi* are known to reach maximum lengths of >250 mm, and were separated into 'taxa' based on size classes. A maximum value of 1 meter was used as a base for size class partitioning (as the largest fish collected was 1 m in length); class 1 = 0-250 mm, 2 = 251-500 mm, 3 = 501-750 mm, 4 = 750-1000 mm.

Trophic guild construction

Food Groups

Food items were identified and assigned to one of ten major food groups, based on known biology and habitat preferences, as follows; Benthic Invertebrates (BI: Bivalvia, Gastropoda, Echinodermata), Copepoda (CO), Benthic Crustaceans (BC: other amphipods, isopods, ostracods), Pelagic Amphipoda (family Hyperiidae, PA), Polychaeta (PO), Cephalopoda (CE), Pelagic Crustaceans (PC: mysids, euphausiids, decapods), Pelagic Fish (PF: lanternfish, cod), Benthopelagic Fish (BPF: grenadier, Greenland halibut, rocklings), and Benthic Fish (BF: eelpouts, sculpins). The abundance (per cent by number) of each food group was calculated for all fish taxa and analysed using cluster analysis. Cluster analysis was performed using SYNTAX 5.1 (Podani 1997).

Parasite Communities

Thirty endohelminth species found in fish hosts of this area are listed in Table 4.3. Cluster analysis of parasite abundance data was used to determine the value of parasite infracommunities as predictors of trophic guild structure. Cluster analysis was performed using Syn-Tax 5.1 (Podani 1997).

Using Parasite Communities to Predict Guild Structure

Average parasite and food abundances found in the trophic guilds produced by hierarchical classification were combined for RDA to determine the value of parasites as predictors of food preference within specified trophic guilds. In this analysis, parasite abundance values were treated as environmental variables, food group abundances were defined as species variables and guilds represented the sample values.

Using Food Group and Parasite Abundance for Individual Trophic Evaluation

Parasite and food abundances of individual taxa were combined for RDA to determine the value of parasite communities as predictors of trophic position without prior guild designation. In the analysis parasite abundance values were treated as environmental variables, food group abundances were defined as species variables and taxa represented the sample values.

Results

Trophic Guild Construction

Food Groups

The trophic guild structure of subarea 0B based on food group abundance is illustrated in Figure 4.2. Using the Bray-Curtis Dissimilarity Index fishes were clustered into eleven guilds based on a dissimilarity score of 0.5 (Table 4.3). Eight of these contained two or more taxa (guilds 1-7, 10) and three corresponded to one taxon (guilds 8, 9 and 11). Although some food groups maintained similar abundances throughout (pelagic crustaceans), guilds corresponded either to a distinct combination of food group abundances or a relatively high abundance of one particular food item. For example, guild 1 fishes tended to have low abundances of all food groups, while species in guild 10 maintained high abundance values for pelagic amphipods. Similarly, guild 11 (*R. hippoglossoides*, size class 4) was separated based on the presence of a single food group with a relatively high abundance value (benthopelagic fishes).

Parasite Communities

Hierarchical clustering of parasite infracommunity data resulted in a different guild structure than that of food group abundance. At the same dissimilarity score (0.5), few groups were apparent, and those grouped together were known to differ in terms of food group preference. For example, *C. fabricii* (size class 2) and *L. macdonaldi* are known to have different diets (Table 4.3) but were grouped together here based on the absence or low abundance of most parasite infections.

Using Parasite Communities to Predict Guild Structure

Redundancy analysis of food group and parasite abundance within the trophic guilds defined by hierarchical clustering (Fig. 4.2, Table 4.3) revealed no significant correlations (Table 4.4). Ninety-five per cent of the variation was contained along axis 1 (eigenvalue = 0.952) and Monte Carlo test for significance yielded an f-ratio of 0 and p-value of 1.0.

Using Food Group and Parasite Abundance for Individual Trophic Evaluation

Redundancy analysis for food group and parasite abundance with individual fish taxa yielded significant correlations. In many cases, parasite species are significantly correlated with one or more food groups and these, in turn, are significantly correlated with fish taxa (Fig. 4.4). The parasite species, *S. furciger* (SF), *Stenakron vetustum* (STK), *L. rachion* (LR) and *Echinorhynchus* sp. (AC), are closely associated with food groups such as benthic invertebrates (BI), benthic crustaceans (BC), pelagic crustaceans (PC) and polychaetes (PO) and are significant along axis 1 (eigenvalue = 0.405). *Neophasis burtii* and, to a lesser extent, *L. elongatum*, are closely associated with pelagic amphipods (PA) and are significant along axis 2 (eigenvalue 0.317). Monte Carlo test for significance yielded an f-ratio of 18.859 and p-value of 0.086. Three trophic groups are apparent in Figure 4.4; trophic group 1 consists of parasites *S. furciger*, *Stenakron vetustum*, *L. rachion*, *Echinorhynchus* sp., Trematoda larvae, *Lepidapedon* sp., *L. steenstrupi*, *Philobythos* sp., *G. macrouri*, *Capillaria* sp., and *G. phycidis*, the food groups benthic invertebrates, benthic crustaceans, pelagic crustaceans, polychaetes and copepods and are closely associated with benthic fish species *Lycodes* sp., *C. rupestris* (size class 2), *C. microps*, *L. paamiuti*, *L. eudipleurostictus*, *M. berglax* (size classes 2 and 3), *A. atlanticus* and *Gaidropsarus* sp. (both size classes). Trophic Group 2 consists of parasite species, *D. varicus*, *F. felis*, *H. levinseni*, *Lecithaster gibbosus*, *Lecithophyllum* sp., *Otodistomum* sp., *Podocotyle* sp., *P. squamatus*, Bothriidae sp., Cestoda sp. plerocercoids, *G. squali*, *Gilquinia* sp. plerocercoids, *Spathebothrium* sp., *Contracaecum* larvae, *Pseudoterranova* sp. larvae, *Anisakis* sp. larvae, and Acanthocephala sp. larvae, in addition to the food groups Cephalopoda, pelagic fishes, benthopelagic fishes and benthic fishes. These species are closely associated with all remaining fish species with the exception of *L. fabricii* and *T. nybelini*. Trophic Group 3 includes parasite species *N. burtii* and *L. elongatum*, the food group pelagic amphipods and fish species *T. nybelini* and *L. fabricii*.

Discussion

Trophic Guild Construction

The concept of trophic guilds has become increasingly important in ecology, allowing scientists to compare the functional organization of animal assemblages in different geographic regions (Burns 1989, Cartes et al. 2002, Garrison and Link 2000, Grossman 1986, Livingston 1982, Munoz and Ojeda 1997, 1998, Terborgh and Robinson 1986). Most aquatic and marine studies focus on tropical or warm-water systems in which fish species tend to have distinct habitat preferences and the overlap of feeding habits is limited. As deep-sea Arctic habitats have fewer prey species and less niche specialization than tropical marine ecosystems, there is a tendency for these systems to contain a larger number of generalist feeders. While this makes separation of species into trophic guilds difficult, it was believed that the use of habitat zone of both predator and prey species to assess differences in feeding preference would be more effective. Bulman et al. (2001) and Davenport and Bax (2002) found this method of prey categorization useful in that cluster analysis of food categories based on habitat zone provided functional guilds of fish species off the eastern Australian shelf. My goal was to use a similar method with stomach content data to determine the guild structure of Arctic marine communities.

Caution must be taken when interpreting results of hierarchical clustering. Most clustering algorithms will give rise to a hierarchy regardless of whether or not objects are hierarchically interrelated (Legendre and Legendre 1998); however, validation is possible by comparing cluster results to the raw data and determining whether such similarities and/or differences reflect patterns observed in cluster analysis. A cut-off point of 0.5 was used to define the trophic guilds described in Figure 4.2 because it appeared as though fish species were assigned to guilds based on observable patterns in the data set (Table 4.3). Benthic fishes such as *M. berglax*, *Gaidropsarus* sp., *A. atlanticus* and most eelpouts (genus *Lycodes*) in guild 6 were known to consume similar food items, as did taxa in guild 3 (*B. euryops*, *L. macdonaldi*, *S. mentella* size class 1). A closer look at individual food group abundance revealed that in several cases, taxa that differed in the abundance of important food groups were placed into the same guild. For example, the lanternfish *B. glaciale* feeds almost exclusively on copepods and was grouped with Arctic cod (*B. saida*) based on the high abundance of copepods in both diets. However, *B. saida* does not feed exclusively on one or two food groups but rather on a combination of several food groups in addition to copepods which would normally place the species into a different trophic level. In addition, while no fish were found in cod stomachs of this particular subarea, cannibalism has been observed on several occasions in *B. saida* of surrounding waters (Chambers, pers. obs.).

While copepod abundance is high in the diet, hierarchical clustering may obscure less obvious but equally important trophic information that would place individuals into realistic trophic positions within the food web. One explanation for the ambiguous results seen in diet-based cluster analyses is that stomach content data provide information on feeding habits within a short time period. This, in addition to the fact that several deep-sea species have a tendency to eject stomach contents upon capture, lead to the conclusion that additional methods of analysis were necessary for an accurate evaluation of trophic structure in this region. Parasites allow linkages to be made among fish species in terms of predator- prey relationships and may do so without the need for direct observation of stomach content. For example, benthic species such as sculpins and eelpouts were the only hosts infected with trematode metacercariae, and as such are considered important prey species for piscivorous fish or marine mammals in higher trophic positions. Ascarid larval nematodes in fish are also a good example, as they can be identified to genus and are accurate predictors of marine mammals in the area. *Anisakis* species utilize odontocete or 'toothed' whales as definitive hosts (Hays et al. 1998) whereas *Contracaecum* sp. and *Pseudoterranova* sp. complete their life cycle within seals such as *Phoca vitulina* (Borgsteede et al. 1990). The ability of nematode larvae to infect a wide range of fish hosts may also be a reflection of marine mammal distribution. For example, *Contracaecum* sp. and *Pseudoterranova* sp. show little host specificity for their larval stages and have been reported from several species throughout the north Atlantic (Dick and Choudhury, 1995).

In the past, parasite data have provided supportive evidence for dietary investigations of fish species and in at least one case were proven to be more accurate in terms of describing fish trophic position (Johnson et al. 2004). Assuming guild formation using food group data was accurate, cluster analysis using parasite data should reflect guild structure (Fig. 4.2). The lack of group structure for parasite cluster analysis (Fig. 4.3) at the same dissimilarity score (0.5) suggests that either parasites are not as useful in describing trophic relationships in this environment, or more likely, that guild structure using food group abundance does not adequately describe the trophic position of deep-sea Arctic species. Clustering analysis included fishes with host-specific parasites, whether or not transmission was through an intermediate host common to all fish diets. If these species were removed from the analysis a simpler, more interpretable evaluation of trophic structure would be possible, but this omission would mask important predator-prey relationships.

Using Parasite Communities to Predict Guild Structure

Redundancy analysis using average food group and parasite abundance within each guild in Figure 4.3 was carried out to determine whether in any instance, parasite species could be used as predictors of feeding strategy. Parasites were not significantly correlated with food group abundance in the pre-defined guilds, indicated by an eigenvalue close to 1.0 along the first axis (0.952, Table 4.4). Monte Carlo test for significance generated an f-ratio of zero and p-value of 1.0, confirming that guild construction is not an ideal method of trophic evaluation for deep-sea Arctic fish species.

A potentially important constraining factor in this study is the method used to group food items. The preferred habitat zone (i.e., benthic, benthopelagic, pelagic) of prey items was used as the basis for food groups as opposed to taxonomic similarity. The idea was that in a system likely comprised of predominantly generalist feeders, the availability of prey species would take precedence over all other variables involved in prey selection. Consequently, trophic guilds and intra-guild parasite communities would reflect the position that each fish species occupies in the water column. This is a valid hypothesis; however, it fails to take zone shifting of species, i.e., the ability of certain species to utilize more than one zone within the water column, into account. For example, benthic species such as sculpins and eelpouts lack a swim bladder and as a result maintain contact with the ocean floor and are able to feed only on other benthic species. Conversely, benthopelagic (or demersal) species such as dogfish inhabit the zone just above the ocean floor (within a few meters) and are able to access prey both in the water column and along the bottom. In doing so, benthopelagic species will compete with benthic species while maintaining their ability to feed on prey that are less accessible to their benthic counterparts.

Using Food Group and Parasite Abundance for Individual Trophic Evaluation

Due to the failure of hierarchical clustering to depict trophic structure accurately and to test the usefulness of food groups based on habitat zone in trophic studies of this region, the concept of guilds was abandoned and individual taxa were analysed in terms of food groups and parasite abundance. RDA revealed the presence of three groups in the community (Fig. 4.4), the two most prominent of which reflected positive correlations between parasite and food group abundance with habitat zone. Trophic Group 1 was characterized by benthic fish taxa and were most closely associated with benthic food groups such as benthic crustaceans, benthic invertebrates and polychaetes. Parasite data supported food group and species associations in that the parasite species correlated with this group are transmitted through predominantly benthic intermediate hosts. For example, *Lycodes* spp. fed mainly on benthic invertebrates such as brittle stars (Ophiuroidea), and had the highest infections of *S. furciger* that utilize brittle stars as second intermediate hosts (Schell 1970). Trophic group 2 consisted of all benthopelagic/pelagic fish species in the study and was characterized by short vector lengths (i.e., closer proximity to the origin of the ordination). Short vector lengths of food and parasite species in this group indicated a high level of generalist feeding and infection by parasites with little or no host specificity such as *D. varicus* (Bray 1979). Trophic group 3 included the shallow-water species *T. nybelini* and the common gelatinous snailfish, *L. fabricii*, both of which fed extensively on pelagic amphipods (family Hyperiidae). These fish species were considered specialist feeders and in the absence of other parasite species, were likely categorized based on low abundances of rare parasites. Both eigenanalysis and Monte Carlo test results (listed in Fig. 4.4) confirmed that parasite species are significant predictors of food group abundance in fishes of subarea 0B, indicating that in the benthic marine communities of the Arctic, over 72% of food group consumption can be predicted by parasite infracommunity structure.

To date, the description of natural communities in terms of guild structure and species interactions has been relatively successful but in most cases, these communities have species that feed on relatively small numbers of prey items. These communities are readily partitioned into distinct trophic guilds based on specific feeding niches. By contrast, in Arctic benthic marine communities food web complexity decreases at higher latitudes and prey species are lost, but predators become less specialized in their selection of food species resulting in overlap of trophic position. In other words, trophic structure is more dependent on prey availability and habitat zone. Consequently, the most effective means of community assessment is to separate species based on their ability to exploit prey species within the different habitat zones.

Table 4.1. Total sample size and letter codes of twenty-three fish species collected from NAFO Subarea 0B in 2000 and 2001 for stomach content and parasite infracommunity analysis.

Latin Name	Common Name	Letter Code	N
Antimora rostrata (Gunther)	Blue Hake	Ar	48
Artediellus atlanticus Jordan & Evermann	Hookear Sculpin	Aa	45
Bathylagus euryops Goode & Bean	Goitre Blacksmelt	Beu	63
Benthosema glaciale (Reinhardt)	Glacier Lanternfish	Bg	60
Boreogadus saida (Lepechin)	Arctic Cod	Bs	94
Centroscyllium fabricii (Reinhardt)	Black Dogfish	Cf	40
Coryphaenoides rupestris Gunnerus	Roundnose Grenadier	Cr	54
Cottunculus microps Collet	Polar Sculpin	Cm	37
Gaidropsarus argentatus (Reinhardt)	Arctic Rockling	Ga	15
Gaidropsarus ensis (Reinhardt)	Three-Beard Rockling	Ge	47
Hippoglossoides platessoides (Fabricius)	American Plaice	Hp	21
Lampanyctus macdonaldi (Reinhardt)	Rakery Beaconlamp	Lm	85
Liparis fabricii Kroyer	Gelatinous Snailfish	Lf	58
Lycodes esmarkii Collet	Esmark's Eelpout	Les	10
Lycodes eudipleurostictus Jensen	Double-Line Eelpout	Leu	49
Lycodes paamiuti Möller	Lycodes sp.1	Lyp	55
Lycodes reticulatus Reinhardt	Arctic Eelpout	Lyr	6
Lycodes vahlii Reinhardt	Vahl's Eelpout	Lyv	11
Macrourus berglax Lacepede	Roughhead Grenadier	Mb	45
Reinhardtius hippoglossoides (Walbaum)	Greenland Halibut	Rh	119
Sebastes mentella Travin	Deepwater Redfish	Sme	38
Synaphobranchus kaupi Johnson	Slatjaw Cutthroat Eel	Sk	64
Triglops nybelini Jensen	Mailed Sculpin	Tn	32

Table 4.2. Names and letter codes of thirty parasite species recovered from twenty-three fish species within NAFO Subarea 0B in 2000 and 2001. ‘Trematoda larvae’ refer to at least two species of digeneans, all of the family Opecoelidae. Identification to genus and species was not possible.

Parasite Species	Code
Derogenes varicus (Müller)	DV
Fellodistomum felis (Olsson)	FF
Glomericirrus macrouri (Gaevskaja)	GM
Gonocerca phycidus Manter	GP
Hemiurus levinseni Odhner	HL
Lecithaster gibbosus (Rudolphi)	LEC
Lecithophyllum sp.	LI
Lepidopedon elongatum (Lebour)	LE
Lepidapedon rachion (Cobbold)	LR
Lepidapedon sp.	LEP
Lepidophyllum steenstrupi Odhner	LS
Neophasis burti Bray & Gibson	NB
Otodistomum sp.	OF
Podocotyle sp.	POD
Prosorhynchus squamatus Odhner	PS
Steringophorus furciger (Olsson)	SF
Stenakron vetustum Stafford	STK
Trematoda sp. Larvae	TL
Bothriidae sp.	BO
Cestoda sp. Plerocercoid	CP
Philobythos sp.	PHY
Gilquinia squali (Fabricius)	GS
Gilquinia sp. Plerocercoid	GQP
Spathebothrium sp.	SPA
Contracaecum Larvae	CL
Pseudoterranova Larvae	PL
Anisakis Larvae	ANL
Capillaria sp.	CAP
Acanthocephala Larvae	ACL
Echinorhynchus sp.	AC

Table 4.3. Average abundance of ten food groups for each fish taxa within the eleven trophic guilds defined using hierarchical clustering. PA = Pelagic Amphipods, CO = Copepoda, BI = Benthic Invertebrates, BC = Benthic Crustaceans, POL = Polychaeta, CEP = Cephalopoda, PC = Pelagic Crustaceans, PF = Pelagic Fish, BPF = Benthopelagic Fish, BF = Benthic Fish. Size classes were defined as: 1 = 0-250 mm, 2 = 251-500 mm, 3 = 501-750 mm, 4 = 750-1000 mm.

Guild	Taxon	Size Class	PA	CO	BI	BC	POL	CEP	PC	PF	BPF	BF
1	*A. rostrata*	1	0.06	0.06	0	0	0.13	0.13	0.31	0	0	0
	A. rostrata	2	0	0.03	0	0.03	0.16	0	0.34	0	0	0
	H. platessoides	2	0.33	0	0	0	0.07	0	0.20	0	0	0.20
	R. hippoglossoides	1	0.40	0	0	0	0.07	0.13	0.53	0	0	0
	R. hippoglossoides	2	0.21	0.03	0	0.04	0.01	0.19	0.34	0.01	0.01	0.08
	C. fabricii	2	0	0	0	0	0	0.21	0.42	0.17	0	0.17
	R. hippoglossoides	3	0.04	0	0	0.18	0	0.07	0.39	0.04	0	0.04
2	*C. rupestris*	1	0	0.31	0	0.06	0	0	0.94	0	0	0
	C. rupestris	3	0	0	0	0	0	0	0.70	0	0	0
	Gaidropsarus sp.	2	0.07	0.17	0.17	0.50	0	0.03	1.40	0	0	0.03
3	*B. euryops*	1	0.05	0.51	0.02	0.03	0.02	0	0.08	0	0	0
	L. macdonaldi	1	0	0.27	0	0	0	0	0.08	0	0	0
	S. mentella	1	0.12	0.31	0	0.04	0	0.15	0.19	0	0	0
4	*B. glaciale*	1	0.03	1.25	0	0	0	0	0	0	0	0
	B. saida	1	0.27	2.02	0	0.02	0	0.02	0.81	0	0	0
5	*C. fabricii*	3	0	0	0.06	0	0	0.88	0.24	0	0	0.29
	S. mentella	2	0.08	0	0.08	0	0	0.75	0	0	0	0
	S. kaupi	2	0	0	0	0.05	0.35	0.55	0.10	0.10	0	0.15
	S. kaupi	3	0	0	0.02	0.02	0.18	0.41	0.05	0	0	0.09
6	*A. atlanticus*	1	0.02	0.13	0.58	0.76	0.27	0.31	0.16	0.02	0	0.11
	M. berglax	1	0	0.82	0.55	1.64	0.27	0.36	0.27	0	0	0

	L. eudipleurostictus	1	0.06	0.14	1.45	2.04	0.24	0.14	0.14	0	0	0.04
	L. paamiuti	1	0.02	0.04	1.29	2.47	0.24	0.04	0.27	0	0	0
	M. berglax	2	0.03	0.29	1.38	0.79	0.47	0.12	0.79	0	0	0.12
	Gaidropsarus sp.	1	0.03	0.33	0.07	1.37	0.03	0.07	0.27	0.17	0.03	0.03
7	*C. microps*	1	0	0.19	0.22	2.54	0.11	0.14	3.16	0	0	0
	Lycodes sp.	1	0.07	0	8.70	3.81	0.33	0	4.67	0	0	0
8	*H. platessoides*	1	0	0	0.17	0.33	0.17	0	0	0	0	0
9	*C. rupestris*	2	0	7.07	0	0.37	0	0.11	4.59	0	0.04	0
10	*L. fabricii*	1	4.02	0.48	0.10	0.05	0	0	0.02	0	0	0
	T. nybelini	1	9.81	0.09	0.03	0	0.03	0	0	0	0	0
11	*R. hippoglossoides*	4	0	0	0	0	0	0	0	0	1.00	0

Table 4.4. Eigenvalues and Monte Carlo for significance between food group and parasite abundances found in trophic guilds defined by the Bray-Curtis Dissimilarity Index.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.952	0.036	0.007	0.004
Sum of all canonical Eigenvalues:				0.999
F-Ratio:				0
P-Value				1.000

Figure 4.1. Map of the Davis Strait/Baffin Bay region defining the boundaries of NAFO Subarea 0, Division B sampled in 2000 and 2001 (Treble, 2002).

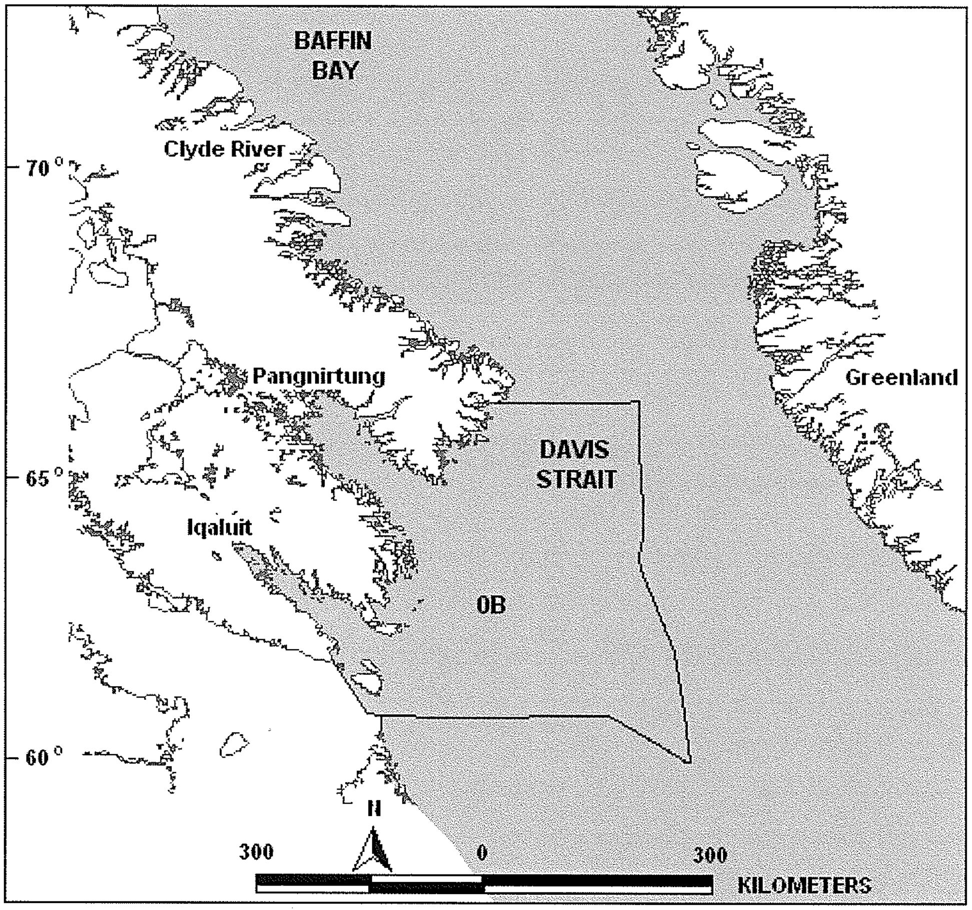

BAFFIN
BAY
Clyde River
70 °
Pangnirtung
Greenland
DAVIS
STRAIT
65 °
Iqaluit
0B
60 °
N
300
0
300
KILOMETERS

Figure 4.2. Eleven trophic guilds within NAFO Subarea 0B based on food group abundance for thirty-two fish taxa using the Bray-Curtis Dissimilarity Index. Guild 1: *Antimora rostrata* (1), *A. rostrata* (2), *Hippoglossoides platessoides* (2), *Reinhardtius hippoglossoides* (1, 2, 3), *Centroscyllium fabricii* (2); Guild 2: *Coryphaenoides rupestris* (1, 3), *Gaidropsarus* spp.; Guild 3: *Bathylagus euryops*, *Lampanyctus macdonaldi*, *Sebastes mentella* (1); Guild 4: *Benthosema glaciale*, *Boreogadus saida*; Guild 5: *C. fabricii* (3), *S. mentella* (2), *Synaphobranchus kaupi* (2, 3); Guild 6: *Artediellus atlanticus*, *Macrourus berglax* (1, 2), *Lycodes eudipleurostictus*, *L. paamiuti*, *Gaidropsarus* spp. (1); Guild 7: *Cottunculus microps*, *Lycodes* spp.; Guild 8: *H. platessoides* (1); Guild 9: *C. rupestris* (2); Guild 10: *Liparis fabricii*, *Triglops nybelini*; Guild 11: *R. hippoglossoides* (4). Numbers in brackets beside species/taxa denote the size class of each taxon. No size class indication denotes species that only attain sizes within size class 1. Size classes were defined as: 1 = 0-250 mm, 2 = 251-500 mm, 3 = 501-750 mm, 4 = 750-1000 mm.

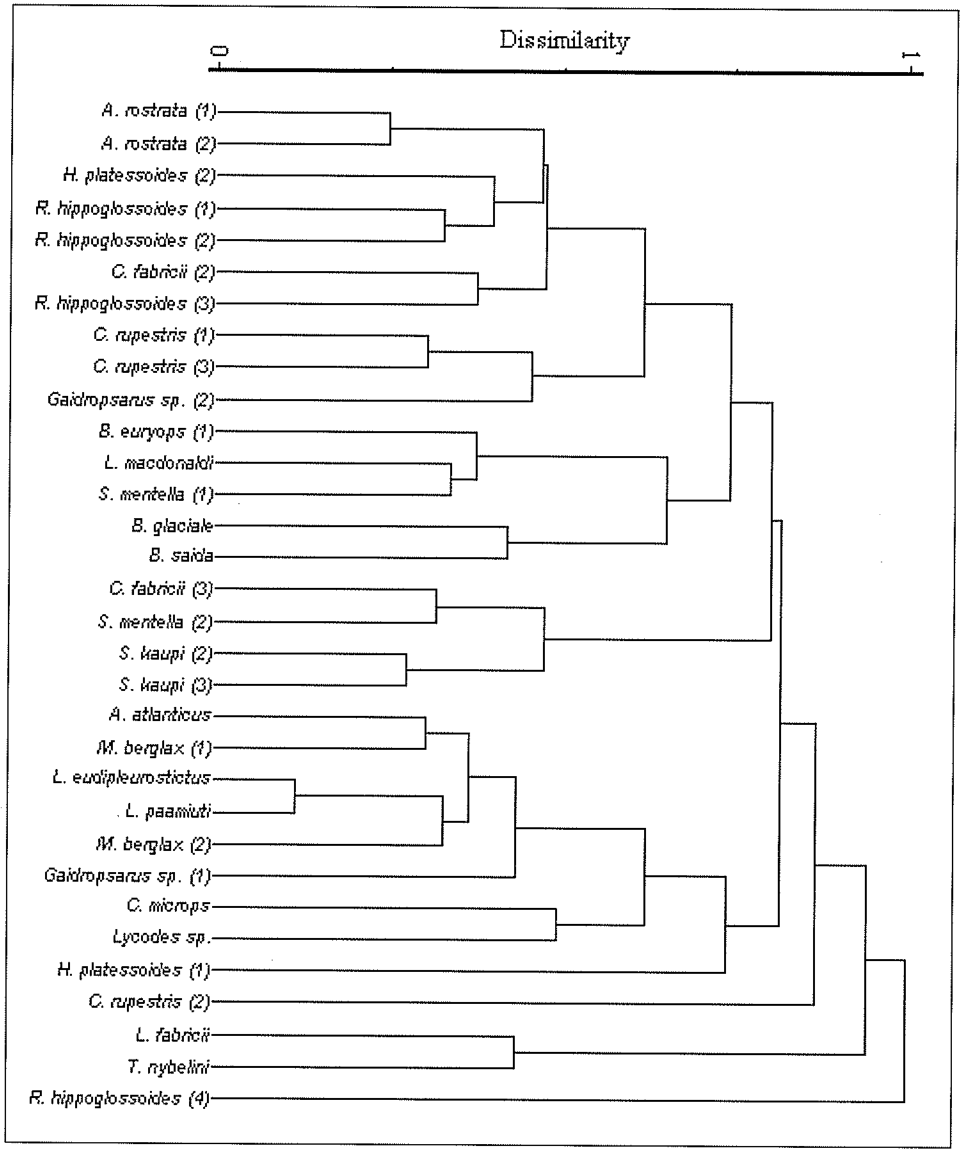

Dissimilarity
0
1
A. rostrata (1)
A. rostrata (2)
H. platessoides (2)
R. hippoglossoides (1)
R. hippoglossoides (2)
C. fabricii (2)
R. hippoglossoides (3)
C. rupestris (1)
C. rupestris (3)
Gaidropsarus sp. (2)
B. euryops (1)
L. macdonaldi
S. mentella (1)
B. glaciale
B. saida
C. fabricii (3)
S. mentella (2)
S. kaupi (2)
S. kaupi (3)
A. atlanticus
M. berglax (1)
L. eudipleurostictus
L. paamiuti
M. berglax (2)
Gaidropsarus sp. (1)
C. microps
Lycodes sp.
H. platessoides (1)
C. rupestris (2)
L. fabricii
T. nybelini
R. hippoglossoides (4)

Figure 4.3. Eighteen trophic guilds within NAFO Subarea 0B based on parasite abundance for thirty-two fish taxa using the Bray-Curtis Dissimilarity Index. Guild 1: *Antimora rostrata* (1); Guild 2: *Coryphaenoides rupestris* (3), *Bathylagus euryops*; Guild 3: *Sebastes mentella* (2); Guild 4: *Reinhardtius hippoglossoides* (1); Guild 5: *A. rostrata* (2), *Synaphobranchus kaupi* (3); Guild 6: *Hippoglossoides platessoides* (2), *R. hippoglossoides* (4); Guild 7: *S. kaupi* (2), *Macrourus berglax* (2); Guild 8: *Centroscyllium fabricii* (2), *Lampanyctus macdonaldi*, *H. platessoides* (1); Guild 9: *S. mentella* (1), *Benthosema glaciale*; Guild 10: *Boreogadus saida*, *Gaidropsarus* spp. (1); Guild 11: *Artediellus atlanticus*; Guild 12: *C. rupestris* (2), *Triglops nybelini*; Guild 13: *Gaidropsarus* spp. (2); Guild 14: *C. fabricii* (3), *Cottunculus microps*, *Lycodes* spp.; Guild 15: *M. berglax* (2), *L. eudipleurostictus*, *L. paamiuti*; Guild 16: *R. hippoglossoides* (3), *C. rupestris* (1); Guild 17: *Liparis fabricii*; Guild 18: *R. hippoglossoides* (2). Numbers in brackets beside species/taxa denote the size class of each taxon. No size class indication denotes species that only attain sizes within size class 1. Size classes were defined as: 1 = 0-250 mm, 2 = 251-500 mm, 3 = 501-750 mm, 4 = 750-1000 mm.

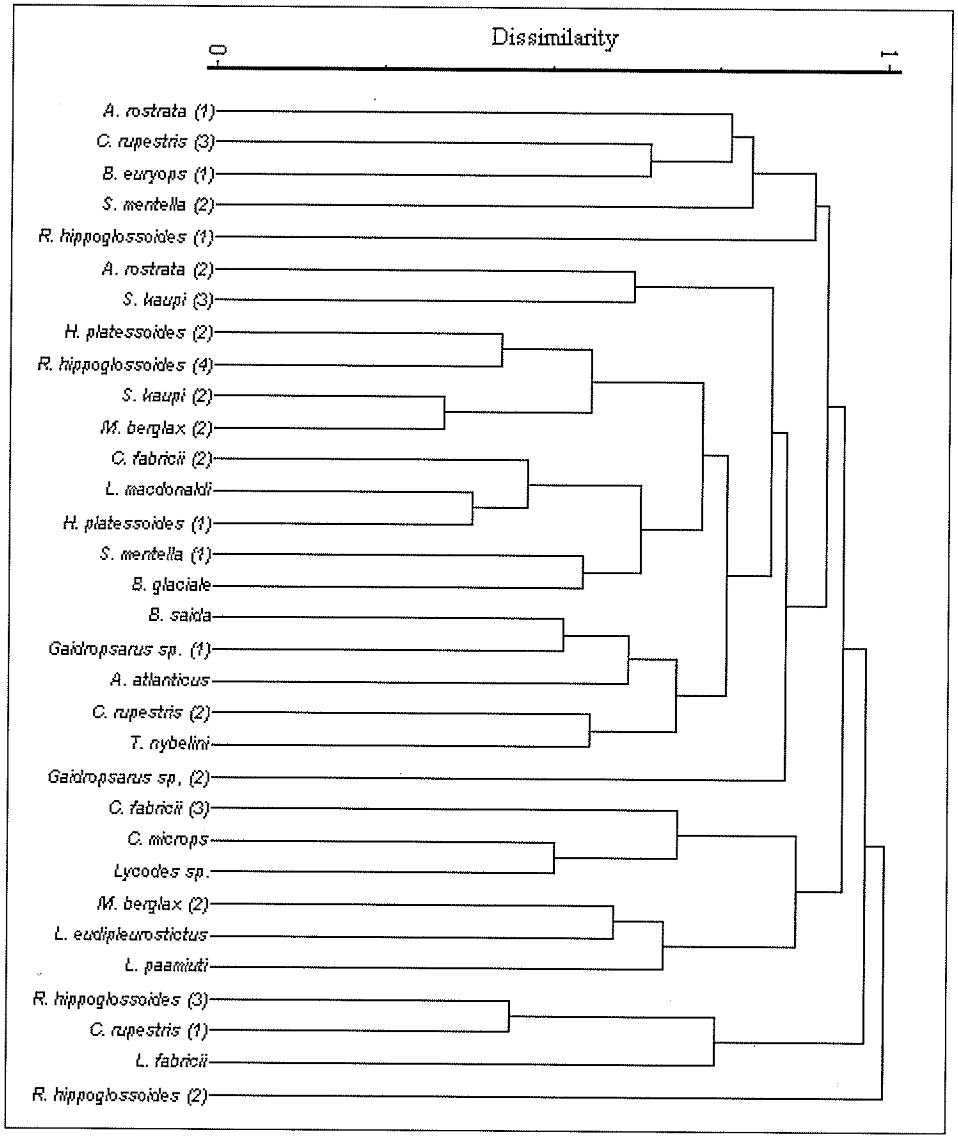
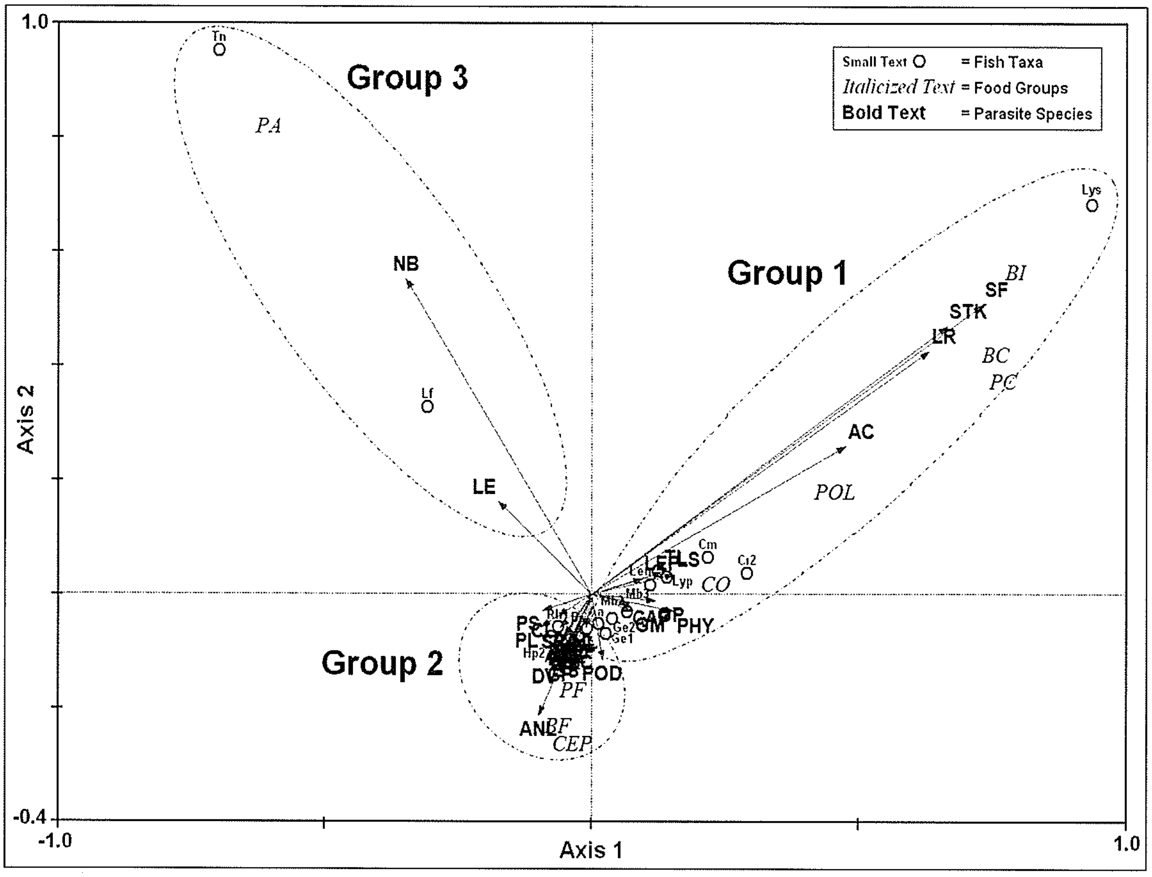

Dissimilarity
0
1
A. rostrata (1)
C. rupestris (3)
B. euryops (1)
S. mentella (2)
R. hippoglossoides (1)
A. rostrata (2)
S. kaupi (3)
H. platessoides (2)
R. hippoglossoides (4)
S. kaupi (2)
M. berglax (2)
C. fabricii (2)
L. macdonaldi
H. platessoides (1)
S. mentella (1)
B. glaciale
B. saida
Gaidropsarus sp. (1)
A. atlanticus
C. rupestris (2)
T. nybelini
Gaidropsarus sp. (2)
C. fabricii (3)
C. microps
Lycodes sp.
M. berglax (2)
L. eudipleurostictus
L. paamiuti
R. hippoglossoides (3)
C. rupestris (1)
L. fabricii
R. hippoglossoides (2)

Figure 4.4. RDA scatterplot illustrating the relationship of food group and parasite abundance for twenty-three fish taxa in subarea 0B. PA = Pelagic Amphipods, CO = Copepoda, BI = Benthic Invertebrates, BC = Benthic Crustaceans, POL = Polychaeta, CEP = Cephalopoda, PC = Pelagic Crustaceans, PF = Pelagic Fish, BPF = Benthopelagic Fish, BF = Benthic Fish. Letter codes for fish taxa are listed in Table 4.2 and for parasites in Table 4.3. Eigenvalues of the first four axes were 0.405, 0.317, 0.210 and 0.033, respectively. Sum of all canonical eigenvalues was 0.996. Monte Carlo test for significance yielded an f-ratio of 18.859 and a p-value of 0.086.


Small Text O = Fish Taxa
Italicized Text = Food Groups
Bold Text = Parasite Species
Group 1
Group 2
Group 3
Axis 1
Axis 2
1.0
-0.4
-1.0
1.0
Tn
PA
NB
Lf
LE
Lys
BI
SF
STK
LR
BC
PC
AC
POL
Cm
Cl2
Len
Lyp
CO
Mb
Mba
CAP
GM
PHY
Ge2
Ge1
An
Rh
PS
PL
Hp2
DV
POD
PF
AN
BF
CEP

CHAPTER 5: USING STABLE ISOTOPES OF CARBON AND NITROGEN TO PREDICT TROPHIC STRUCTURE IN DEEP-SEA ARCTIC FISH COMMUNITIES

Introduction

Understanding community dynamics and trophic structuring in marine systems, particularly in the Arctic, is essential in the context of environmental change. Alterations in climate regimes and subsequent shifts in water temperature, salinity and current systems will have significant effects on the range extensions of fish species, inter- and intra- specific competition as well as rates of extinction. Such changes would also be confounded by impacts of increased shipping activity and by commercial exploitation of single or multiple species. Without baseline knowledge of structural dynamics, it will be difficult to detect changes in community components or contribute to conservation and reclamation strategies once changes begin to accumulate.

Although stomach contents continue to be primary indicators of ecological relationships among species, a major disadvantage is that they provide dietary information at only one particular point in time (Sholto-Douglas et al. 1991). Endohelminth communities are often used to supplement dietary investigations, providing longer term information and revealing predator-prey linkages that may otherwise be overlooked (Campbell 1980). Though the analysis of parasite data is useful for trophic linkage determination between species, it also has potential limitations. For example, some parasite species maintain seasonal fluctuations within their fish hosts (Burreson and Olson 1974, Hakalahti et al. 2006, Simkova et al. 2004) and as a result, their usefulness as indicators of ecological relationships may depend on appropriate sampling times. In addition, some small mesopelagic fishes harbour few or no endohelminth parasites. Consequently, additional longer-term methods are being implemented in trophic studies to supplement diet data and provide a clear understanding of trophic relationships within whole communities.

Recently, trophic studies in marine habitats have included analysis of carbon and nitrogen isotopes in conjunction with diet data in order to corroborate findings for trophic structuring within an ecosystem (Davenport and Bax 2002, Johnson et al. 2004). Stable isotope ratios in animal tissues are useful for constructing food webs as animals are similar in isotopic composition to their diets (Kline et al. 1998, Monteiro et al. 1991, Peterson and Fry 1987, Post 2002, Sholto-Douglas et al. 1991, Thomas and Cahoon 1993, Wainright et al. 1993). As a consequence, stable isotope analysis is becoming an important research tool for the examination of trophic relationships within freshwater (Johnson et al. 2004, Kline et al. 1998) and marine environments (Davenport and Bax 2002, Michener and Lajtha 2007, Monteiro et al. 1991, Sholto-Douglas et al. 1991, Thomas and Cahoon 1993), providing a continuous measure of an animal's trophic position, i.e., a measure of the assimilated diet, both in the long- and short-term (Kline et al. 1998, Monteiro et al. 1991, Sholto-Douglas et al. 1991, Thomas and Cahoon 1993, Wainright et al. 1993, Post 2002).

Though stable isotope analysis often plays a key role in trophic studies, Dayton and Hessler (1972) suggested that deep-sea environments differ from other ecological communities in that the trophic levels may merge. As a result, the roles of predators are not always distinguishable from those of decomposers and stable isotopes may be less helpful. This idea has not yet been tested but remains an important question in deep-sea ecology.

Results in Chapter 1 indicate that trophic guilds are not appropriate for the construction of food webs in deep-sea Arctic communities but elements of Hypotheses 1 and 2 are still valid; namely that parasites and stable isotope ratios should reflect diet preference and that if trophic position is dependent on feeding mode as a reflection of body size and age class, differences in feeding habits, parasite communities and stable isotopes will occur with increasing size and age class. Consequently, the objectives of this chapter were to determine if 1) stable isotopes of carbon and nitrogen could distinguish trophic position in deep-sea Arctic fishes and 2) stable isotopes of carbon and nitrogen are reflective of diet preferences and endohelminth infections in deep-sea fish species within the Davis Strait/Baffin Bay region.

Methods

Study Area and Species Collected

The study area included NAFO Subarea 0 (divisions A and B, Fig. 5.1). Sampling methods are described in detail in Chapter 2. Data used in this chapter included sample collections from 2000, 2001 and 2004. Two thousand one hundred and eighteen samples representing nineteen fish species were collected and lengths, weights, sex, stomach contents and parasite species identified and enumerated (Table 5.1). A minimum of 10 samples from each species were randomly selected within each subarea for stable isotope analysis, for a total of 320. These included Greenland halibut (*Reinhardtius hippoglossoides*), sculpins (*Cottunculus microps*, *Artediellus atlanticus*, *Triglops* *nybelini*), blue hake (*Antimora rostrata*), eelpouts (*Lycodes eudipleurostictus*, *L. paamiuti*), blacksmelts (*Bathylagus euryops*), lanternfish (*Lampanyctus macdonaldi*, *Benthosema glaciale*), Arctic cod (*Boreogadus saida*), snailfish (*Liparis fabricii*), black dogfish (*Centroscyllium fabricii*), grenadiers (*Macrourus berglax*, *Coryphaenoides rupestris*), rocklings (*Gaidropsarus ensis*), American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes mentella*), and eels (*Synaphobranchus kaupi*).

Stable Isotope Determination

Methods for stable isotope analysis were adopted from Thomas and Cahoon (1993). A dorsolateral sample of muscle tissue from each fish was collected and dried in an oven at 40°C. Once dry, samples were ground into a fine powder and used directly for carbon and nitrogen analyses. δ^{13}Carbon and δ^{15}nitrogen isotopic analyses on the muscle (protein) were accomplished by continuous flow ion ratio mass spectrometry (CF-IRMS) using a GV-Instruments® IsoPrime attached to a peripheral temperature controlled EuroVector® elemental analyzer (EA) (University of Winnipeg Isotope Laboratory, *UWIL*). 1.0 mg samples of oven-dried fish muscle were loaded into tin capsules and placed in the EA auto-sampler in accompaniment with internally calibrated carbon/nitrogen standards (Pharma cottonseed and casein proteins: δ^{13} C = -22.95 and -26.98 ‰ Vienna PeeDee Belemnite (VPDB); δ^{15} N = 5.00 and 5.94 ‰ Air, respectively). Batch files were set up as follows: 4 casein, 4 pharma, 10 samples (every 5th sample duplicated and every 15th sample was done in triplicate), 4 cottonseed, 4 casein, etc....

Carbon and nitrogen isotope results are expressed using standard delta (δ notation in units of *per mil* (‰). The delta values of carbon (δ^{13} C_{cell}) and nitrogen (δ^{15} N_{cell}) represent deviations from a standard, such that $\delta_{sample} = [(R_{sample}/R_{standard})-1]*10^3$ where R is the $^{13}C/^{12}C$ or $^{15}N/^{14}N$ ratio in the sample and the standard. The standards used for carbon and nitrogen isotopic analyses are VPDB and IAEA-N-1 (IAEA, Vienna), respectively.

Analytical precision, determined from the analysis of duplicate samples, was ± 0.16 ‰ for $\delta^{13}C$ and ± 0.18 ‰ for $\delta^{15}N$. Accuracy was obtained through the analysis of laboratory standards used for calibration of results.

Using the equation: $\delta^{13}C' = \delta^{13}C + D (I + 3.90/1+287/L)$ where $\delta^{13}C'$ represents the lipid-normalized value of the sample, D represents the isotopic difference between protein and lipid, I represents a constant (-0.207) and L represents the proportional lipid content of the sample, Kiljunen et al. (2006) determined that fish muscle contained zero extractable lipid at a C:N ratio of approximately 3.0. No sample in this data set contained a C:N ratio of 3.0 or greater and consequently, lipid extraction was not required.

Trophic Evaluation – Food Groups and Parasite Communities

Food items were identified and assigned to one of ten major food groups, based on known biology and habitat preferences, as follows; Benthic Invertebrates (BI: Bivalvia, Gastropods, Echinodermata), Pelagic Amphipods (PA: family Hyperiidae), Copepoda (CO), Benthic Crustaceans (BC: other amphipods, isopods, ostracods, cumaceans), Polychaeta (PO), Cephalopoda (CE), Pelagic Crustaceans (PC: mysids, euphausiids, decapods), Pelagic Fish (PF: lanternfish, cod), Benthopelagic Fish (BPF: grenadier, Greenland halibut, rocklings), and Benthic Fish (BF: eelpouts, sculpins). The abundance (per cent by number) of each food group was used in the analyses.

Parasites were fixed in AFA, stored in 70% ethanol, stained, mounted on slides and identified as in Chapter 4. Abundance values (% by number) for the 22 endohelminths were calculated and used in the multiple regression analyses.

Calculations and Statistical Analyses

Average stable isotope values of $\delta^{13}C$ and $\delta^{15}N$ (Table 5.3) were plotted on the same graph for nineteen fish species within Davis Strait and Baffin Bay. Each species was assigned to one of three general feeding groups, which included benthic, benthopelagic, and pelagic. Multidimensional Scaling (MDS) was then performed using Syn-Tax 5.1 in order to visualize relationships between species and feeding groups relative to the data. MDS is a type of ordination used in data visualization to investigate similarities or dissimilarities in data (Borg and Groenen 2005, Cox and Cox 2001). To test the assigned feeding groups the global optimization routine of non-hierarchical clustering package in cluster analysis was performed using Syn-Tax 5.1 (Podani 1997). This was used to iteratively determine three groups. Global optimization partitions individuals into *p* mutually exclusive groups (or clusters). The number of clusters is determined *a priori*, which for these data was three groups (benthic, benthopelagic, and pelagic). The iterative search is a relocation process, similar to *k*-means clustering, beginning with a random partition. The routine produces the selected number of groups, such that group membership is optimized by minimizing the ratio of within-group distances to between-group distances. Because solutions from random partitions are not unique, the process was repeated 50 times. Horn distance was selected because of the efficient manner in which it weights partial overlaps (Horn, 1966). In all cases data were not normally distributed, requiring the use of nonparametric statistics. To determine whether groups were significantly different a Kruskal-Wallace test was used with Dunn's procedure for multiple groups, for both the assigned groups and optimal groups using XLStat (Addinsoft, 2006). Mann-Whitney tests in XLStat (Addinsoft, 2006) were used in order to determine whether the assigned groups were distinguishable from optimized groups based on the frequency distributions of carbon and nitrogen.

The percentage of all ten food item groups was used to construct a 100% stacked column histogram in order to compare diet types of fish species. Lastly, $\delta^{13}C$ and $\delta^{15}N$ were individually plotted against total length (mm) for each species and R^2 values were calculated.

A stepwise multiple regression analysis was employed using SPSS (version 15.0) in order to test the effectiveness of $\delta^{13}C$ and $\delta^{15}N$ as predictors of diet composition and parasite infracommunities. Multiple regression allows the simultaneous testing and modelling of multiple independent variables, with the model:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots. + \varepsilon.$$

Where y is the dependent variable and x is the independent variable(s).

$\beta_0, \beta_1, \beta_2, \beta_3$, etc. (parameters) are estimated by obtaining:

$$\hat{Y}_1 = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 \ldots$$

Where b = regression coefficient. The estimation is done according to linear least squares. The model is: $Y = X\beta + e$. The solution is: $b = (X'X)^{-1}X'Y$.

Carbon and nitrogen were tested separately and together with ten food groups and twenty-two parasite species (Table 5.2). Assumptions of normality and linearity, homoscedasticity and independence of the data were met, determined by examination of the response scatterplot.

Results

Stable isotope analysis of carbon revealed δ^{13}C signatures from -10.9 to -27.5 (Fig. 5.2). Strictly benthic species such as *C. microps*, *M. berglax*, *A. atlanticus* and *L. eudipleurostictus* maintained the least negative values (<-19), whereas the most depleted values of δ^{13}C (> -21.0) were found in *T. nybelini*, *B. euryops*, *B. glaciale* and *L. macdonaldi*. δ^{15}N values were highest (>15.0) for *R. hippoglossoides* and most of the strictly benthic species (*C. microps*, *M. berglax*, *A. atlanticus*, *L. eudipleurostictus*) (Fig. 5.2). The lowest δ^{15}N values (<12.5) were found in *C. rupestris*, *L. macdonaldi*, *B. glaciale*, *A. rostrata*, *L. fabricii* and *S. kaupi*.

When δ^{15}N was plotted against δ^{13}C using the average values for each species (Fig. 5.2) three possible trophic groups emerged; 1) species with low δ^{13}C and δ^{15}N values (*B. glaciale*, *B. euryops* and *L. macdonaldi*), 2) species with intermediate values of δ^{13}C and δ^{15}N (*R. hippoglossoides*, *B. saida*, *L. fabricii*, *T. nybelini*, S. kaupi, *C. rupestris*, *S. mentella*, *G. ensis*, *H. platessoides*, *C. fabricii*, *A. rostrata*) and 3) species with high δ^{13}C and δ^{15}N values (*C. microps*, *A. atlanticus*, *L. eudipleurostictus*, *L. paamiuti* and *M. berglax*). Multidimensional scaling (MDS) based on Bray-Curtis similarities resulted in a similar pattern in that benthic, benthopelagic and pelagic species were clustered together (Fig. 5.3).

A δ^{13}C vs. δ^{15}N scatterplot for all fish samples analysed is presented in Figure 5.4. All individuals were assigned to one of three groups; benthic, benthopelagic or pelagic based on the presumed habits of the species. The three groups were distinguishable, with some overlap, using a Kruskal-Wallis test with Dunn's procedure for multiple comparisons. There was visibly more overlap between benthopelagic and pelagic species than between benthopelagic and benthic species (Figure 5.4).

Results of a global optimization routine using Horn distance are presented in Table 5.3. Kruskal-Wallis multiple pairwise comparisons using Dunn's procedure found significant differences between all three groups with a Bonferroni corrected significance level of 0.0167. Definitive group assignment was determined when 50% or more of the individuals from each species were included based on the global optimization results. Mann-Whitney pairwise tests between natural groups and global optimized groups for benthic, benthopelagic, and pelagic groups determined that the distributions of carbon and nitrogen values between the natural and optimized groups were not statistically different, with exception of the pelagic nitrogen group.

The proportion of diet categories found in the stomachs of nineteen fish species studied, in order of fish group (i.e., benthic – pelagic) is presented in Figure 5.5. The diet of benthic species was characterized by benthic invertebrates and benthic crustaceans while that of benthopelagic species was characterized by pelagic amphipods, cephalopods and to a lesser extent, pelagic crustaceans and benthopelagic fish. Pelagic species were characterized by large amounts of copepods and pelagic crustaceans in the diet.

The proportion of endohelminths found in the nineteen fish species examined, in order of fish group (i.e., benthic – pelagic) is presented in Figure 5.6. Most endohelminth species were prevalent among fish trophic groups; however, *G. macrouri* and Trematoda larvae were most abundant in benthic species. Benthopelagic fishes maintained the largest number of non-host specific endohelminths, with particularly high abundances of

Cestoda plerocercoids, *Contracaecum* larvae and *Anisakis* larvae. Pelagic species were the least parasitized, with most fish containing either few, no or host-specific parasites.

Multiple regression using $\delta^{15}N$ as a predictor of food groups indicated that few food groups in the diet can be predicted using nitrogen isotope signals (Table 5.5). Nitrogen isotope values were able to predict two groups: Benthic Invertebrates and Benthic Crustacea, with f-ratios of 9.798 and 11.056, respectively and p-values of .005 and .003, respectively. $\delta^{13}C$ was a better predictor of diet as it was significantly correlated with Benthic Invertebrates (f-ratio 13.35, p-value 0.001), Benthic Crustacea (f-ratio 7.235, p-value 0.013), Polychaeta (f-ratio 11.498, p-value 0.003) and Pelagic Crustacea (f-ratio 4.586, p-value 0.043). When $\delta^{15}N$ and $\delta^{13}C$ were combined, three food groups were predicted; Benthic Invertebrates (f-ratio 8.276, p-value .002), Benthic Crustacea (f-ratio 6.36, p-value .007) and Polychaeta (f-ratio 5.518, p-value 0.011).

Based on multiple regression analysis, $\delta^{15}N$ was a poor predictor of parasite infracommunities with no significant relationships (Table 5.6) but $\delta^{13}C$ was a significant predictor of six parasite species: *Glomericirrus macrouri* (f-ratio 5.272, p-value 0.031), *Gonocerca phycidis* (f-ratio 6.395, p-value 0.019), Cestoda plerocercoids (f-ratio 4.391, p-value 0.047), *Anisakis* larvae (f-ratio 4.616, p-value 0.042), *Capillaria* sp. (f-ratio 11.521, p-value 0.002) and *Echinorhynchus* sp. (f-ratio 9.712, p-value 0.005). When values for $\delta^{15}N$ and $\delta^{13}C$ were combined they predicted the abundance of *Capillaria* sp. (f-ratio 6.258, p-value 0.007) and *Echinorhynchus* sp. (f-ratio 5.26, p-value 0.014).

A plot of $\delta^{13}C$ against total length revealed low or no correlation with low R^2 values. Five species (*C. fabricii*, *C. microps*, *G. ensis*, *L. fabricii*, *S. kaupi*) from subarea

0B had R^2 values > 0.2 but none were > 0.7. In subarea 0A three species (*G. ensis*, *L. paamiuti* and *S. mentella*) had R^2 values > 0.2 but none > 0.39.

Discussion

Traditionally, stable isotopes of carbon and nitrogen have been used to define trophic categories within a system, allowing ecologists to separate food webs into their respective components and determine the supporting linkages. In most cases, the isotope values of a fish species, particularly nitrogen, reflect its diet, whether it be small zooplankton, larger invertebrates or fish. In communities dominated by specialist feeders, each species will have unique isotopic signatures and as a consequence, trophic position is more readily predicted.

Dayton and Hessler (1972) and DeNiro and Epstein (1978) recognized that diet overlap is common in deep-sea environments, making it difficult to separate species into discrete trophic positions. My results corroborate this observation as isotope values of carbon and nitrogen were unable to separate species into discrete trophic units. Rather, $\delta^{13}C$ and $\delta^{15}N$ values separated species based on habitat preferences for feeding (Figs. 5.2, 5.3, 5.4), suggesting that habitat zone (i.e., benthic, benthopelagic, pelagic), is more important in the determination of trophic structure within deep-sea Arctic environments than are inter-specific partitioning within zones. For example, benthic species such as sculpins (*C. microps*, *A. atlanticus*) and eelpouts (*Lycodes* spp.) had the highest $\delta^{13}C$ and $\delta^{15}N$ signals (Figs. 5.2, 5.4) and fed primarily on benthic crustaceans and other benthic invertebrates (Fig. 5.5). Benthopelagic species such as *R. hippoglossoides* and *S. mentella*, which fed on a variety of benthic, benthopelagic and pelagic species, had intermediate $\delta^{13}C$ and $\delta^{15}N$ values, whereas pelagic/mesopelagic species such as lanternfish fed on copepods and small pelagic invertebrates and maintained the lowest $\delta^{13}C$ and $\delta^{15}N$ values.

It is generally accepted that a difference in trophic level occurs when the $\delta^{15}N$ of an animal is enriched by $3.4^{o}/_{oo}$ relative to its diet (DeNiro and Epstein 1981, Hobson and Welch 1992, Michener and Schell 1994, Minagawa and Wada 1984, Peterson and Fry 1987, Post 2002). The $\delta^{15}N$ values in this study ranged from 11.3 to 16.1 (Fig. 5.2), suggesting that at least three trophic levels of fishes occur within this community. However, using $\delta^{15}N$ to evaluate trophic level within such a system may be misleading as species with the highest $\delta^{15}N$ values were not necessarily the largest predators. Rather, smaller benthic fishes maintained the highest $\delta^{15}N$ values, likely due to the consumption of small invertebrate detritivores and other benthic invertebrates with higher $\delta^{15}N$ signals. Larger predators maintained intermediate $\delta^{15}N$ levels and fed on a variety of prey items including pelagic invertebrates with lower $\delta^{15}N$ signals. Consequently, in deep-sea Arctic environments, $\delta^{15}N$ is useful to predict the habitat preference of species (i.e. pelagic, benthopelagic, benthic) but is unable to predict individual trophic position as traditionally defined.

Carbon isotope values often reveal the original source of organic carbon to the food web and are generally used to distinguish feeding habitat preferences, where depleted carbon signals indicate a more pelagic feeding strategy (France 1995, Hobson et al. 2002, Le Loc'h and Hily 2005, Moller 2006). Contrary to the literature, $\delta^{13}C$ in my study was a better predictor of feeding strategy than $\delta^{15}N$; benthic species maintained the highest values of $\delta^{13}C$ ($> -19^{o}/_{oo}$), followed by benthopelagic (-21 to $-19^{o}/_{oo}$) and pelagic species (< -21$^{\circ}/_{oo}$; Fig. 5.2). This suggests that although carbon has been considered by some to not accurately predict trophic position (Hobson and Welch 1992, Hobson et al. 1995, Hobson et al. 2002, Iken et al. 2005), it is a valuable indicator of feeding strategy in environments where generalist feeding predominates and the separation of species into distinct trophic positions is difficult.

Takai et al. (2002, 2003) suggested that primary production in the pelagic environment has little bearing on demersal fishes as demersal species depend on carbon from benthic primary production. However, there is exchange of energy among the pelagic, sympagic (ice-associated) and benthic communities in the Arctic (Bauerfeind et al. 2005, Belicka 2002, Hobson et al. 1995, Werner and Auel 2005, Werner et al. 2004). For example, Belicka (2002) found that although deep-water habitats are less productive, some portion of pelagic primary production reaches bottom sediments despite ice cover and light limitations. Consequently, the carbon source for benthic species is likely a combination of pelagic, sympagic and demersal producers.

Fry and Sherr (1984) found that phytoplankton $\delta^{13}C$ ranges from -24 to -18$^{\circ}/_{oo}$, macroalgae from -27 to -8, sea grasses from -15 to -3 and microphytobenthose from -20 to -10$^{\circ}/_{oo}$. Though isotope values in the Arctic may differ slightly from those in temperate systems, $\delta^{13}C$ values in my study (range -22 to -18) suggest that any one or combination of phytoplankton, microphytobenthos or macroalgae could be carbon sources for Arctic marine species. It is worth noting that Thimdee et al. (2004) found organisms in deep waters off the coast of Thailand derived their carbon through planktonic sources; however, it is difficult to make comparisons between the two systems due to different environmental conditions.

Evidence thus far indicates that stable isotopes of carbon and nitrogen predict the preferred feeding habitat (i.e. pelagic, benthopelagic, benthic) of deep-sea Arctic fishes; however, their ability to predict specific diet and endohelminth communities is less clear-cut. Multiple regression analysis indicated that δ^{15}N and δ^{13}C values were unable to predict the majority of food groups (Table 5.4) but were able to predict benthic prey. Nitrogen values predicted two groups; Benthic Invertebrates and Benthic Crustacea, with f-ratios of 9.798 and 11.056 respectively and p-values of .005 and .003, respectively. δ^{13}C was a better predictor of diet revealing a significant correlation with Benthic Invertebrates (f-ratio 13.35, p-value 0.001), Benthic Crustacea (f-ratio 7.235, p-value 0.013), Polychaeta (f-ratio 11.498, p-value 0.003) and Pelagic Crustacea (f-ratio 4.586, p-value 0.043). When δ^{15}N and δ^{13}C were combined, they predicted three food groups; Benthic Invertebrates (f-ratio 8.276, p-value .002), Benthic Crustacea (f-ratio 6.36, p-value .007) and Polychaeta (f-ratio 5.518, p-value 0.011). Consequently, combining δ^{15}N and δ^{13}C with stomach content data can distinguish benthic feeding from that in other habitat zones but is less useful to distinguish between other zones.

Based on multiple regression analysis using parasite species, δ^{15}N was unable to predict parasite infracommunities (Table 5.5). By contrast, δ^{13}C values predicted six parasite species; *Glomericirrus macrouri* (f-ratio 5.272, p-value 0.031), *Gonocerca phycidis* (f-ratio 6.395, p-value 0.019), Cestoda plerocercoids (f-ratio 4.391, p-value 0.047), *Anisakis* larvae (f-ratio 4.616, p-value 0.042), *Capillaria* sp. (f-ratio 11.521, p-value 0.002) and *Echinorhynchus* sp. (f-ratio 9.712, p-value 0.005). The ability of δ^{13}C values to predict infections of *G. macrouri*, Cestoda plerocercoids and *Anisakis* larvae suggest that parasite infracommunities in addition to stable isotopes are useful for distinguishing benthic vs. other types of feeding within deep-sea Arctic environments. Consequently, a combination of carbon and nitrogen isotopes along with diet and parasite data can be used to separate benthic from benthopelagic species, but are less able to identify the trophic position of a species within deep-sea Arctic systems.

There is a general view in the literature that as an animal becomes larger it consumes larger and different food items. Consequently numerous reports show a high correlation between body size and diet (Cohen et al. 1993, Memmott et al. 2000, Moller 2006, Warren and Lawton 1987, Woodward and Hildrew 2002). Möller (2006) found for gadoids and Greenland halibut that trophic position increased significantly with fish length, indicating that a change in diet at a higher trophic level was correlated with size and age. This suggests that the $\delta^{15}N$ and $\delta^{13}C$ signatures within deep-sea Arctic food webs will change depending on the proportion of larvae/intermediate/adult individuals of each species in the diet and that food web structure will change with ontogenetic shifts in its component species. Supporting evidence for this comes from inshore species along the coast of Baffin Island. The sculpin species *Myoxocephalus scorpius* showed increasing $\delta^{15}N$ values with fish length, suggesting that clear separations can be made with respect to trophic level and age for an Arctic fish species (Appendix 6). Similarly, Cocheret de la Morinière et al. (2003) found that, for all carnivorous reef fishes tested in Spanish Water Bay in Curaçao (Caribbean Sea), there was a significant positive relationship between $\delta^{15}N$ content and fish size. In their study, comparison of gut content analysis with stable isotopes revealed that fish size and increasing $\delta^{15}N$ content were associated with decreasing dietary importance of small crustaceans and increasing consumption of decapod crabs or prey fishes. In addition, Badalamenti et al. (2002) found increasing $\delta^{15}N$

levels with fish length when examining fish species in an area recovering from intense commercial fishing. This was thought to be indicative of changing trophic level with age.

Data from my study, in contrast to the literature, did not support a strong positive correlation between length and $\delta^{15}N$ or $\delta^{13}C$ values for Arctic deep-sea species (Table 5.6). At best, regressions showed slight positive correlations of $\delta^{15}N$ with size and small R^2 values (i.e., less than 0.1). The regressions for most species showed a slight negative correlation between $\delta^{13}C$ and total length and R^2 values were not significant. These observations were similar to Ferraton et al. (2007) who reported no correlation between length and $\delta^{13}C$ or $\delta^{15}N$ of juvenile European hake (*Merluccius merluccius*) in the Mediterranean Sea. Jennings et al. (2001, 2002b) also reported that some species within the North Sea and Northeast Atlantic communities had a negative correlated or had a non-significant positive correlation of $\delta^{15}N$ with length. In these communities, the largest species did not always feed at the highest trophic levels, suggesting that body size is not always the best predictor of trophic position.

The absence of or a very weak correlation between size and trophic position suggests several possibilities. Large fish shift their diet to a lower trophic level or small benthic species shift to a diet with higher $\delta^{13}C$ or $\delta^{15}N$ signals. Perhaps, in deep water benthic communities, the type and location of prey in pelagic, benthopelagic and benthic zones are also important. For example, the prey species of a benthic micropredator (e.g. polychaetes), have higher $\delta^{15}N$ signatures than pelagic zooplankton. Consequently, the $\delta^{15}N$ signals of carnivorous species feeding on same-sized prey on the ocean bottom vs. pelagic environment would be higher. Based on these observations it appears that $\delta^{15}N$ and $\delta^{13}C$ are less useful in estimating the trophic position of individual species in the

Arctic benthic environment, relative to size, but quite useful to predict trophic position within the community in terms of feeding patterns.

Table 5.1. Latin names, common names and samples sizes of nineteen fish species analyzed for carbon and nitrogen stable isotopes collected within NAFO subareas 0A and 0B between 2000 and 2004.

Latin Name	Common Name	N
Antimora rostrata (Günther)	Blue Hake	25
Artediellus atlanticus Jordan & Evermann	Hookear Sculpin	25
Bathylagus euryops Goode & Bean	Goitre Blacksmelt	25
Benthosema glaciale (Reinhardt)	Glacier Lanternfish	25
Boreogadus saida (Lepechin)	Arctic Cod	24
Centroscyllium fabricii (Reinhardt)	Black Dogfish	24
Coryphaenoides rupestris Gunnerus	Roundnose Grenadier	24
Cottunculus microps Collet	Polar Sculpin	25
Gaidropsarus ensis (Reinhardt)	Three-Beard Rockling	27
Hippoglossoides platessoides (Fabricius)	American Plaice	25
Lampanyctus macdonaldi (Reinhardt)	Rakery Beaconlamp	24
Liparis fabricii Kroyer	Gelatinous Snailfish	25
Lycodes eudipleurostictus Jensen	Double-Line Eelpout	26
Lycodes paamiuti Møller	Lycodes sp.1	24
Macrourus berglax Lacepede	Roughhead Grenadier	29
Reinhardtius hippoglossoides (Walbaum)	Greenland Halibut	38
Sebastes mentella Travin	Deepwater Redfish	25
Synaphobranchus kaupi Johnson	Slatjaw Cutthroat Eel	29
Triglops nybelini Jensen	Mailed Sculpin	25

Table 5.2. Names and letter codes of thirty parasite species recovered from fish species within NAFO subareas 0A and 0B between 2000 and 2004.

Parasite Species	Code
Derogenes varicus (Müller)	DV
Fellodistomum felis (Olsson)	FF
Glomericirrus macrouri (Gaevskaja)	GM
Gonocerca phycidus Manter	GP
Hemiurus levinseni Odhner	HL
Lecithaster gibbosus (Rudolphi)	LEC
Lepidopedon elongatum (Lebour)	LE
Lepidapedon rachion (Cobbold)	LR
Podocotyle sp.	POD
Prosorhynchus squamatus Odhner	PS
Steringophora furciger (Olsson)	SF
Stenakron vetustum Stafford	STK
Trematoda sp. metacercariae	TL
Cestoda sp. Plerocercoid	CP
Philobythos sp.	PHY
Gilquinia squali (Fabricius)	GS
Contracaecum Larvae	CL
Pseudoterranova Larvae	PL
Anisakis Larvae	ANL
Capillaria sp.	CAP
Echinorhynchus sp.	AC
Acanthocephala Larvae	ACL

Table 5.3. Composition of optimized benthic, benthopelagic and pelagic fish groups (%) based on carbon and nitrogen isotope values. Definitive group assignment was assumed when 50% or more of the individuals from each species were included based on global optimization. Results of Mann-Whitney pairwise test between natural and global benthic, benthopelagic and pelagic groups for carbon were 0.812, 0.397 and 0.905, respectively and for nitrogen, 0.356, 0.218 and 0.002, respectively.

Species	Group (based on mean C & N)	n	Benthic	Benthopelagic	Pelagic
Cottunculus microps	Benthic	48	97.92	2.08	0
Lycodes paamiuti	Benthic	15	93.33	6.67	0
Macrourus berglax	Benthic	51	86.27	13.73	0
Lycodes eudipleurostictus	Benthic	37	81.08	18.92	0
Artediellus atlanticus	Benthic	38	78.95	21.05	0
Gaidropsarus ensis	Benthopelagic	69	47.83	46.38	5.80
Hippoglossoides platessoides	Benthopelagic	33	42.42	54.55	3.03
Triglops nybelini	Benthopelagic	47	4.26	63.83	31.91
Reinhardtius hippoglossoides	Benthopelagic	59	15.25	62.71	22.03
Liparis fabricii	Benthopelagic	55	14.55	58.18	27.27
Synaphobranchus kaupi	Benthopelagic	23	4.35	56.52	39.13
Boreogadus saida	Benthopelagic	31	16.13	51.61	32.26
Centroscyllium fabricii	Benthopelagic	34	17.65	50.00	32.35
Sebastes mentella	Benthopelagic	40	17.50	42.50	40.00
Antimora rostrata	Benthopelagic	42	4.76	47.62	47.62
Coryphaenoides rupestris	Pelagic	26	0	38.46	61.54
Bathylagus euryops	Pelagic	25	4.00	24.00	72.00
Benthosema glaciale	Pelagic	22	0	27.27	72.73
Lampanyctus macdonaldi	Pelagic	17	0	11.76	88.24

Table 5.4. Results of a standardised multiple regression analysis using stable isotopes of carbon, $\delta^{13}C$ (C), nitrogen, $\delta^{15}N$ (N), and a combination of $\delta^{13}C$ and $\delta^{15}N$ as predictors of ten food item groups. Values in bold indicate significant p-values.

Isotope	variable	R^2	F-ratio	p-value
N	Pelagic Amphipoda	0.001	0.012	0.915
	Copepoda	0.025	0.586	0.452
	Benthic Invertebrates	0.299	9.798	**0.005**
	Benthic Crustacea	0.325	11.056	**0.003**
	Polychaeta	0.121	3.151	0.089
	Cephalopoda	0.049	1.189	0.287
	Pelagic Crustacea	0.058	1.403	0.248
	Pelagic Fish	0.105	2.692	0.114
	Benthopelagic Fish	0.007	0.162	0.691
	Benthic Fish	0.023	0.545	0.468
C	Pelagic Amphipoda	0.054	1.320	0.262
	Copepoda	0.023	0.530	0.474
	Benthic Invertebrates	0.367	13.354	**0.001**
	Benthic Crustacea	0.239	7.235	**0.013**
	Polychaeta	0.333	11.498	**0.003**
	Cephalopoda	0.091	2.301	0.143
	Pelagic Crustacea	0.166	4.586	**0.043**
	Pelagic Fish	0.023	0.542	0.469
	Benthopelagic Fish	0.014	0.328	0.572
	Benthic Fish	0.076	1.887	0.183
C/N	Pelagic Amphipoda	0.089	1.070	0.360
	Copepoda	0.030	0.345	0.712
	Benthic Invertebrates	0.429	8.276	**0.002**
	Benthic Crustacea	0.366	6.360	**0.007**
	Polychaeta	0.334	5.518	**0.011**
	Cephalopoda	0.095	1.154	0.334
	Pelagic Crustacea	0.166	2.196	0.135
	Pelagic Fish	0.106	1.306	0.291
	Benthopelagic Fish	0.047	0.544	0.588
	Benthic Fish	0.076	0.903	0.420

Table 5.5. Results of a standardised multiple regression analysis using $\delta^{13}C$ (C), $\delta^{15}N$ (N) and a combination of $\delta^{13}C$ and $\delta^{15}N$ as predictors of infection by twenty-two parasite species. Values in bold indicate significant p-values.

Isotope	variable	R^2	F-ratio	p-value
N	*D. varicus*	0.058	1.427	0.244
	F. felis	0.004	0.086	0.771
	G. macrouri	0.041	0.990	0.330
	G. phycidis	0.048	1.172	0.290
	H. levinseni	0.020	0.458	0.506
	L. gibbosus	0.093	2.357	0.138
	L. elongatum	0.007	0.161	0.692
	L. rachion	0.009	0.206	0.692
	Podocotyle sp.	0.008	0.183	0.673
	P. squamatus	0.058	1.427	0.244
	S. furciger	0.130	3.433	0.077
	S. vetustum	0.004	0.097	0.758
	Trematoda Meta.	0.053	1.296	0.267
	Cestoda Plero.	0.078	1.946	0.176
	Phylobythos sp.	0.032	0.754	0.394
	G. squali	0.003	0.066	0.799
	Contracaecum L.	0.009	0.202	0.658
	Pseudoterranova L.	0.038	0.904	0.352
	Anisakis L.	0.034	0.815	0.378
	Capillaria sp.	0.034	0.807	0.378
	Acanthocephala L.	0.001	0.034	0.856
	Echinorhynchus sp.	0.029	0.695	0.413
C	*D. varicus*	0.030	0.704	0.410
	F. felis	0.040	0.962	0.337
	G. macrouri	0.186	5.272	**0.031**
	G. phycidis	0.218	6.395	**0.019**
	H. levinseni	0.010	0.227	0.638
	L. gibbosus	0.002	0.050	0.824
	L. elongatum	0.002	0.035	0.853
	L. rachion	0.012	0.276	0.605
	Podocotyle sp.	0.001	0.021	0.886
	P. squamatus	0.050	1.219	0.281
	S. furciger	0.004	0.094	0.761
	S. vetustum	0.015	0.348	0.561
	Trematoda Meta.	0.026	0.618	0.440
	Cestoda Plero.	0.160	4.391	**0.047**
	Phylobythos sp.	0.040	0.958	0.338
	G. squali	0.023	0.530	.0474
	Contracaecum L.	0.011	0.262	0.613
	Pseudoterranova L.	0.041	0.988	0.330
	Anisakis L.	0.167	4.616	**0.042**
	Capillaria sp.	0.334	11.521	**0.002**
	Acanthocephala L.	0.012	0.286	0.598
	Echinorhynchus sp.	0.297	9.712	**0.005**
C/N	*D. varicus*	0.197	2.703	0.089

F. felis	0.044	0.506	0.609
G. macrouri	0.189	2.559	0.100
G. phycidis	0.220	3.105	0.065
H. levinseni	0.066	0.771	0.475
L. gibbosus	0.162	2.133	0.142
L. elongatum	0.018	0.199	0.821
L. rachion	0.047	0.544	0.588
Podocotyle sp.	0.008	0.094	0.911
P. squamatus	0.070	0.826	0.451
S. furciger	0.158	2.064	0.151
S. vetustum	0.015	0.167	1.847
Trematoda Meta.	0.055	0.638	0.538
Cestoda Plero.	0.165	2.168	0.138
Phylobythos sp.	0.163	2.148	0.141
G. squali	0.024	0.269	0.766
Contracaecum L.	0.013	0.144	0.867
Pseudoterranova L.	0.051	0.587	0.564
Anisakis L.	0.170	2.254	0.129
Capillaria sp.	0.363	6.258	**0.007**
Acanthocephala L.	0.013	0.146	0.865
Echinorhynchus sp.	0.323	5.260	**0.014**

Table 5.6. Comparison of R^2 and slope of carbon and nitrogen vs. total fish length for each species by location. Minimum and maximum stable isotope values are included. Total refers to results for 0A and 0B data combined. N/A refers to a species' absence within the location.

Species	Location	n	R^2C	Slope C	Min. C	Max C	R^2N	Slope N	Min. N	Max N
A. rostrata	0B	25	0.110	0.005	-21.16	-18.01	0.024	0.005	9.41	18.72
	0A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
A. atlanticus	0B	12	0.051	-0.008	-19.80	-16.75	0.087	0.015	14.12	20.15
	0A	13	0.111	-0.009	-21.90	-17.41	0.477	0.021	15.31	19.99
	Total	25	0.024	-0.005	-21.90	-16.75	0.087	0.015	14.12	20.15
B. euryops	0B	25	0.005	-0.004	-26.59	-5.68	0.083	-0.015	9.01	16.50
	0A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
B. glaciale	0B	12	0.001	-0.003	-23.42	-20.50	0.001	0.095	8.55	17.50
	0A	13	0.025	0.023	-25.29	-20.63	0.408	0.112	9.47	15.11
	Total	25	0.002	-0.007	-25.29	-20.50	0.151	0.087	8.55	17.50
B. saida	0B	11	0.038	0.004	-22.25	-18.77	0.292	0.017	13.15	18.73
	0A	13	0.002	-0.002	-22.93	-14.45	0.147	0.014	11.97	16.92
	Total	24	0.000	0.001	-22.93	-14.45	0.265	0.018	11.97	18.73
C. fabricii	0B	24	0.272	0.007	-23.35	-17.21	0.318	0.011	10.28	19.21
	0A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C. rupestris	0B	24	0.195	0.002	-22.55	-18.92	0.011	0.001	8.28	17.95
	0A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C. microps	0B	12	0.374	-0.017	-20.46	-16.23	0.00008	0.000	13.88	20.56
	0A	13	0.002	-0.001	-21.23	-16.91	0.023	-0.005	15.23	22.50
	Total	25	0.071	-0.007	-21.23	-16.23	0.006	-0.003	13.88	22.50
G. ensis	0B	15	0.695	0.021	-24.67	-17.13	0.502	0.021	5.91	16.84
	0A	12	0.346	0.007	-22.28	-18.52	0.659	0.028	11.25	22.84
	Total	27	0.479	0.015	-24.67	-17.13	0.495	0.024	5.91	22.84
H. platessoides	0B	13	0.007	-0.001	-20.06	-17.33	0.168	-0.008	12.26	16.13
	0A	12	0.072	0.005	-21.86	-17.33	0.049	0.004	12.75	16.75
	Total	25	0.000	0.000	-21.86	-17.33	0.001	0.000	12.26	16.75

L. macdonaldi	0B	24	0.022	-0.009	-25.55	-20.14	0.256	0.051	8.82	18.16
	0A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
L. fabricii	0B	12	0.518	0.021	-21.33	-19.77	0.163	0.016	12.98	16.56
	0A	13	0.150	-0.013	-22.59	-19.65	0.214	-0.005	14.14	17.07
	Total	25	0.000	0.000	-22.59	-19.65	0.023	-0.006	12.98	17.07
L. eudipleurostictus	0B	13	0.054	0.003	-19.67	-17.27	0.000	0.001	14.30	21.03
	0A	13	0.089	-0.011	-22.02	-15.93	0.044	0.010	15.28	23.46
	Total	26	0.055	-0.007	-22.02	-15.93	0.030	0.008	14.30	23.46
L. paamiuti	0B	13	0.047	0.008	-22.90	-17.26	0.116	-0.017	11.59	18.89
	0A	11	0.670	-0.002	-20.89	-17.39	0.220	0.040	16.28	26.62
	Total	24	0.018	-0.004	-22.90	-17.26	0.014	0.010	11.59	26.62
M. berglax	0B	17	0.135	0.003	-22.36	-15.42	0.194	0.003	12.30	17.53
	0A	12	0.046	0.001	-22.26	-17.30	0.417	0.004	16.14	19.34
	Total	29	0.072	0.003	-22.36	-15.42	0.090	0.003	12.30	19.34
R. hippoglossoides	0B	20	0.091	0.001	-24.87	-19.34	0.246	0.002	12.72	17.50
	0A	18	0.023	-0.004	-25.04	-8.57	0.037	0.001	13.13	17.99
	Total	38	0.000	0.000	-25.04	-8.57	0.165	0.002	12.72	17.99
S. mentella	0B	15	0.127	0.009	-22.85	-10.86	0.016	-0.002	9.91	17.02
	0A	10	0.389	0.005	-21.76	-19.20	0.635	0.011	12.99	16.86
	Total	25	0.061	0.005	-22.85	-10.86	0.112	0.006	9.91	17.02
S. kaupi	0B	29	0.279	-0.018	-26.23	-8.54	0.002	0.001	9.82	17.57
	0A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
T. nybelini	0B	12	0.061	0.012	-22.86	-19.61	0.562	0.051	12.59	17.19
	0A	13	0.058	-0.022	-23.93	-17.11	0.105	-0.019	11.91	16.04
	Total	25	0.013	-0.009	-23.93	-17.11	0.038	0.012	11.91	17.10

Figure 5.1. Map of the Davis Strait/Baffin Bay region defining the boundaries of NAFO Subarea 0, divisions A and B where sampling took place between 2000 and 2004 (Adapted from Treble, 2002).

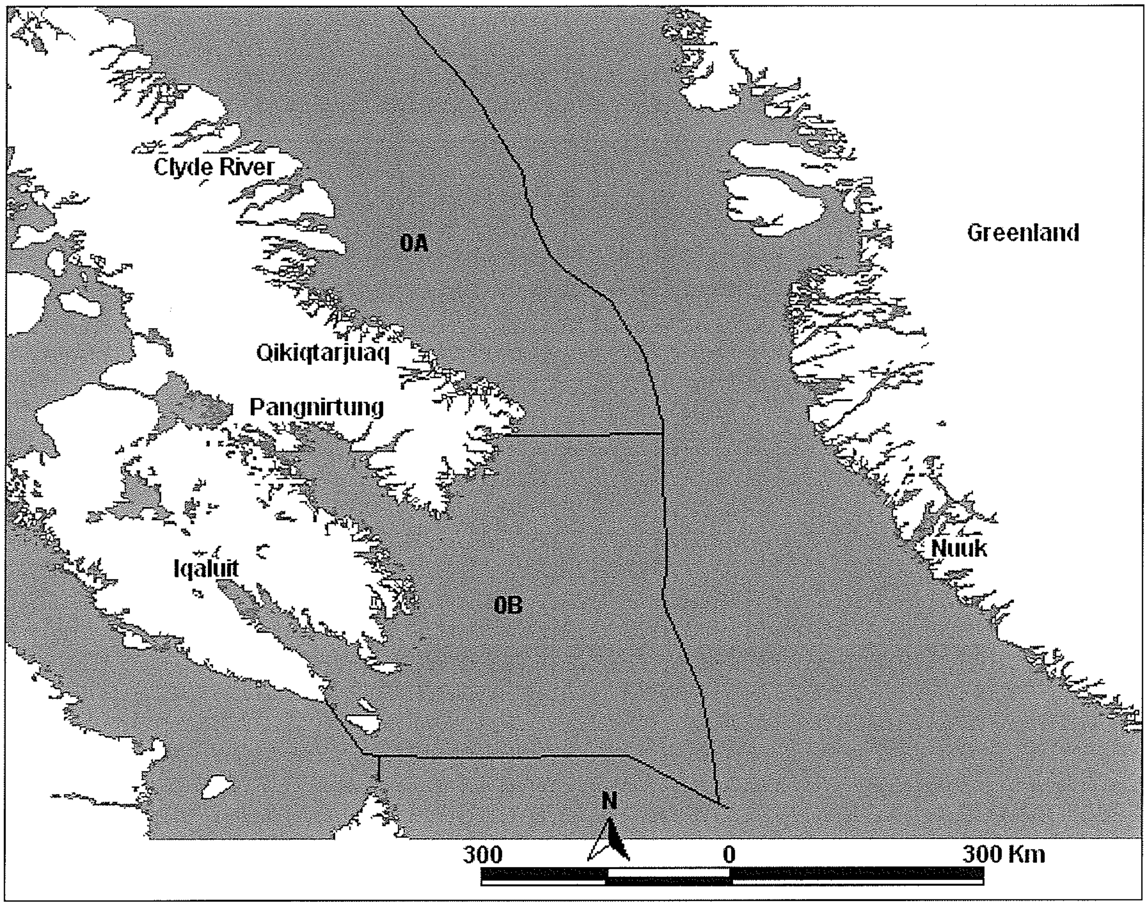
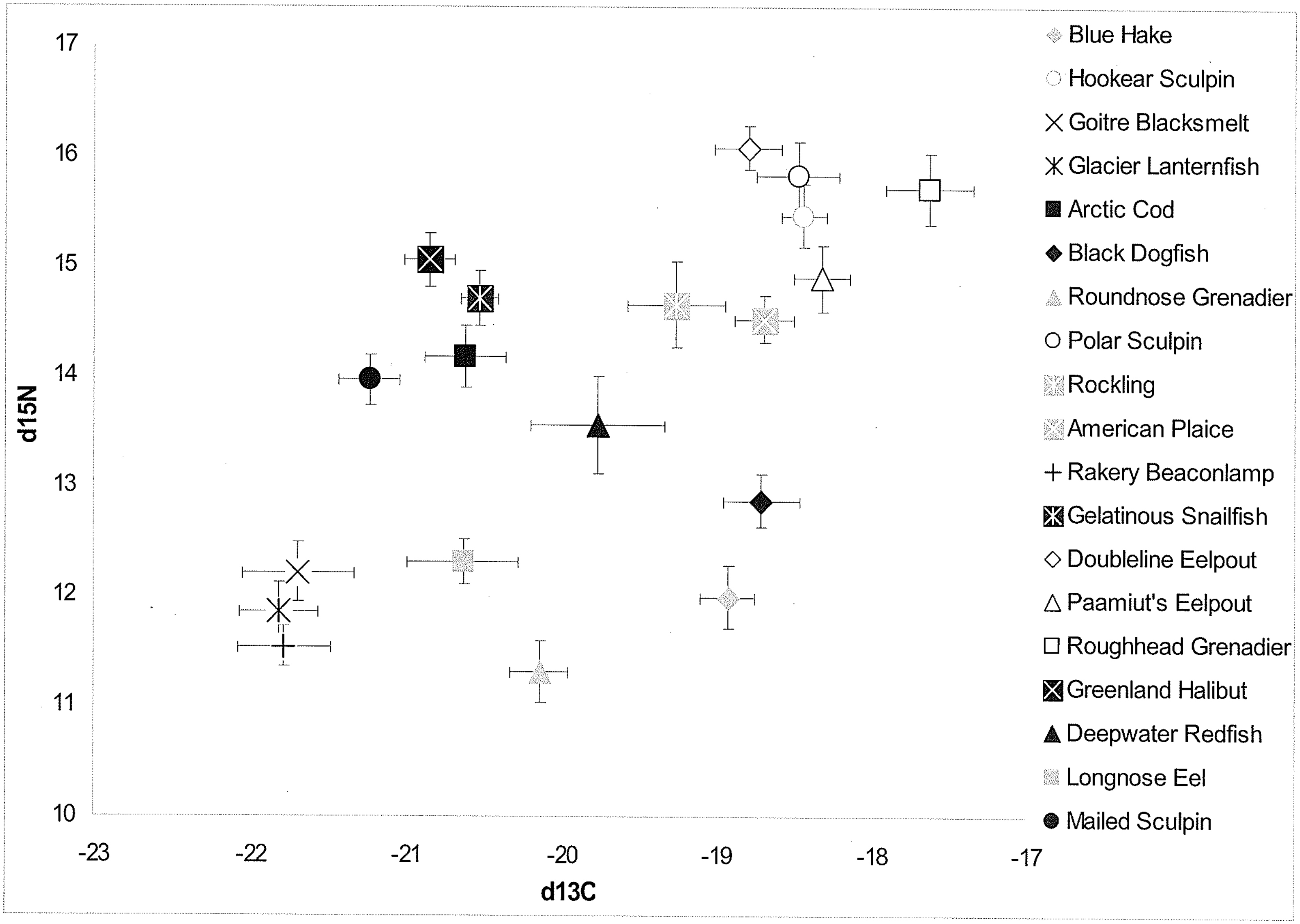
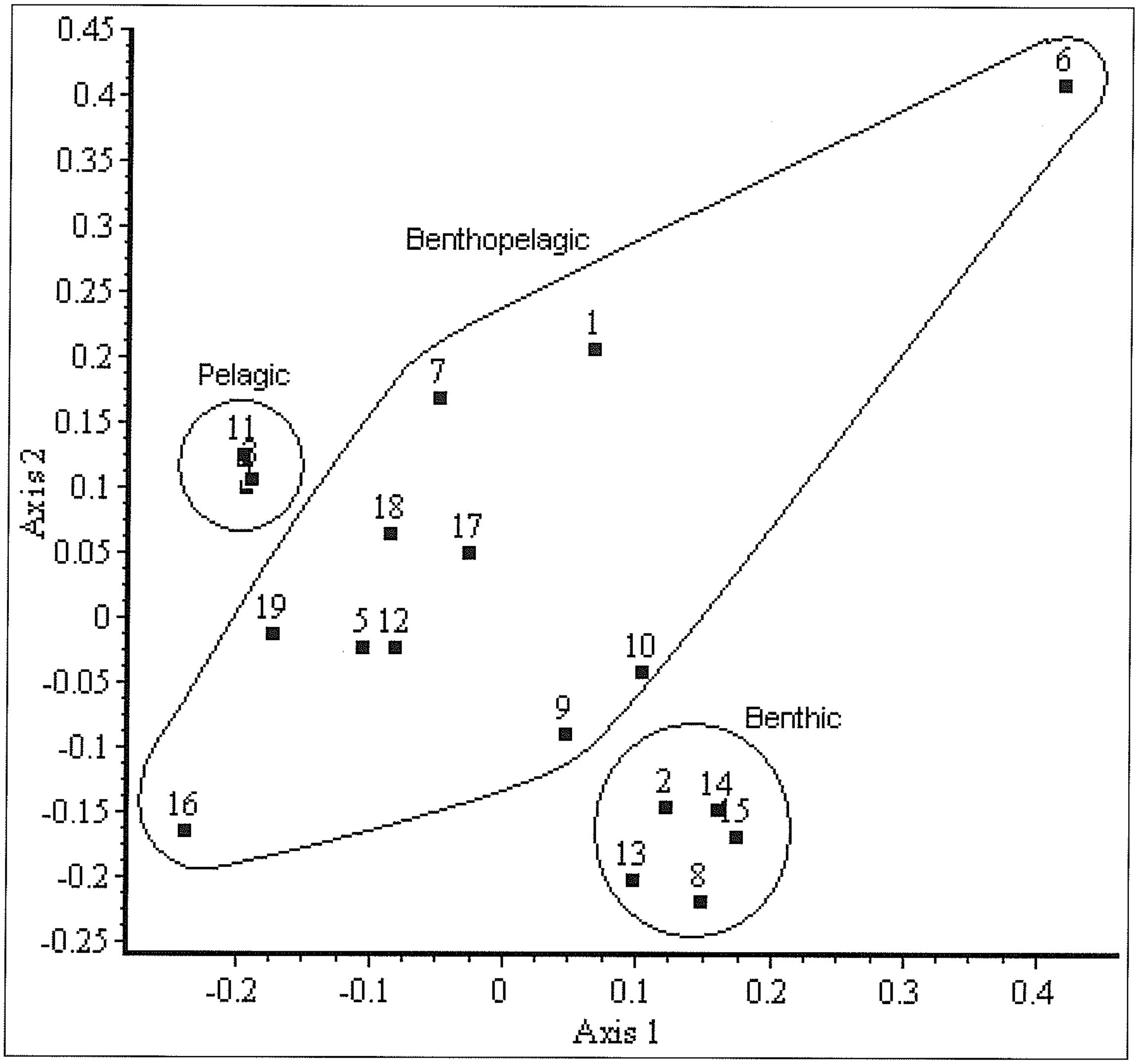

Clyde River
0A
Greenland
Qikiqtarjuaq
Pangnirtung
Nuuk
Iqaluit
0B
N
300
0
300 Km

Figure 5.2. Scatterplot of average $\delta^{15}N$ vs. average $\delta^{13}C$ for nineteen fish species collected within Davis Strait and Baffin Bay between 2000 and 2004. Lines indicate standard error bars.



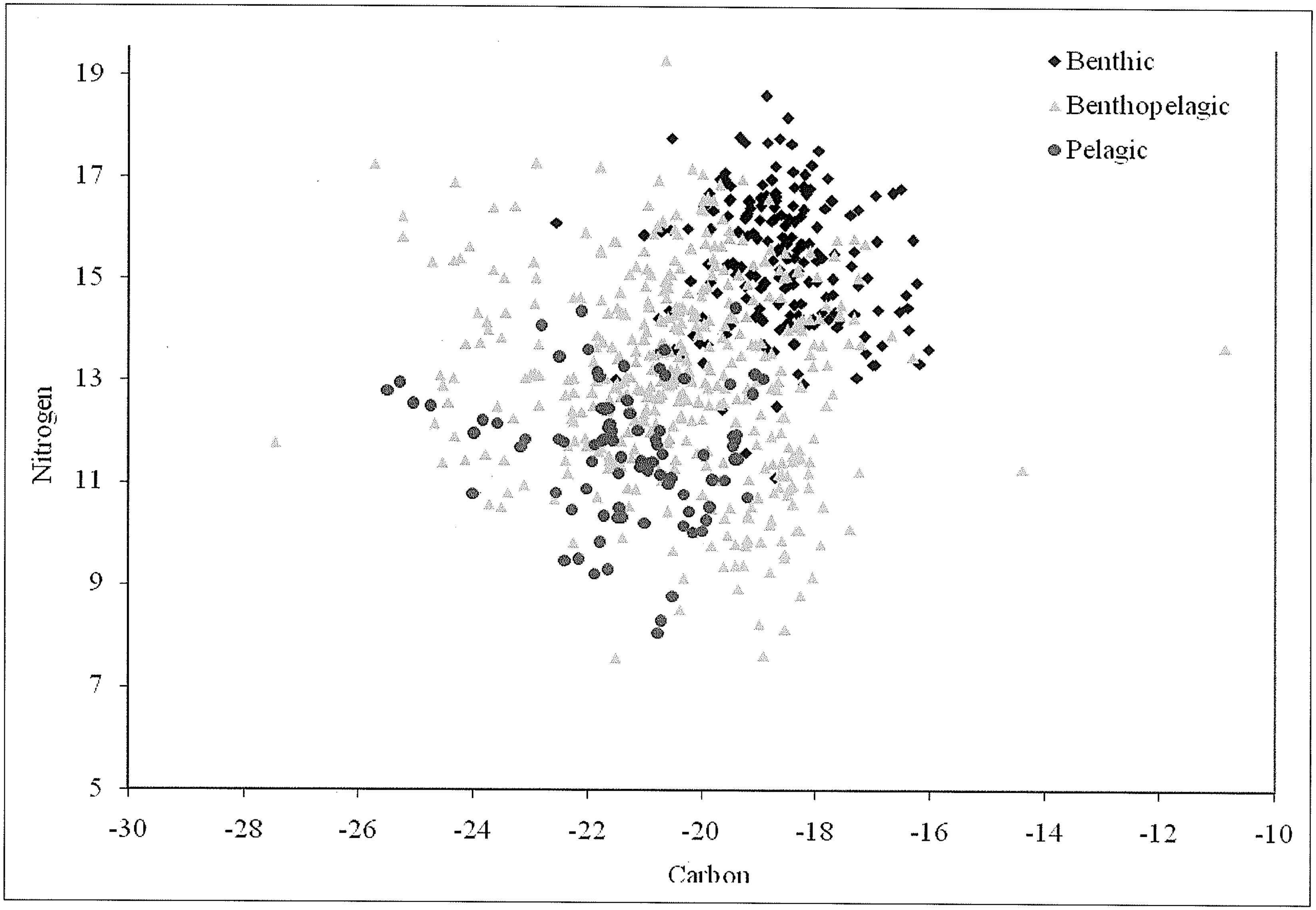
d15N
17
16
15
14
13
12
11
10
d13C
-23
-22
-21
-20
-19
-18
-17
Blue Hake
Hookear Sculpin
Goitre Blacksmelt
Glacier Lanternfish
Arctic Cod
Black Dogfish
Roundnose Grenadier
Polar Sculpin
Rockling
American Plaice
Rakery Beaconlamp
Gelatinous Snailfish
Doubleline Eelpout
Paamiut's Eelpout
Roughhead Grenadier
Greenland Halibut
Deepwater Redfish
Longnose Eel
Mailed Sculpin

Figure 5.3. Results of non-metric multidimensional scaling (MDS) using principle coordinates analysis based on Bray-Curtis similarities of average carbon and nitrogen isotope values for nineteen fish species within Davis Strait and Baffin Bay. MDS indicates three groups corresponding to benthic, benthopelagic and pelagic species.



Axis 2
Axis 1
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.2
-0.1
0
0.1
0.2
0.3
0.4
Benthopelagic
Pelagic
Benthic
6
1
7
11
18
17
19
5
12
10
9
16
2
14
15
13
8

Figure 5.4. Scatterplot results of $\delta^{13}C$ vs. $\delta^{15}N$ for all samples. Kruskal-Wallis multiple pairwise comparisons using Dunn's procedure found significant differences among the three groups with a Bonferroni corrected significance level of 0.0167 for carbon and nitrogen.



◆Benthic
▲Benthopelagic
●Pelagic
Nitrogen
19
17
15
13
11
9
7
5
Carbon
-30
-28
-26
-24
-22
-20
-18
-16
-14
-12
-10

Figure 5.5. Proportion of ten food groups found in stomachs of nineteen fish species within the Davis Strait/Baffin Bay region from 2000-2004. Species = Ar: *A. rostrata*, Aa: *A. atlanticus*, Beu: *B. euryops*, Bg: *B. glaciale*, Bs: *B. saida*, Cf: *C. fabricii*, Cr: *C. rupestris*, Cm: *C. microps*, Ge: *G. ensis*, Hp: *H. platessoides*, Lm: *L. macdonaldi*, Lf: *L. fabricii*, Leu: *L. eudipleurostictus*, Lyp: *L. paamiuti*, Mb: *M. berglax*, Rh: *R. hippoglossoides*, Sme: *S. mentella*, Sk: *S. kaupi*, Tn: *T. nybelini*. Food Groups = PA: Pelagic Amphipods, CO: Copepods, BC: Benthic Crustaceans, PO: Polychaeta, CE: Cephalopoda, PC: Pelagic Crustaceans, PF: Pelagic Fish, BPF: Benthopelagic Fish, BF: Benthic Fish.

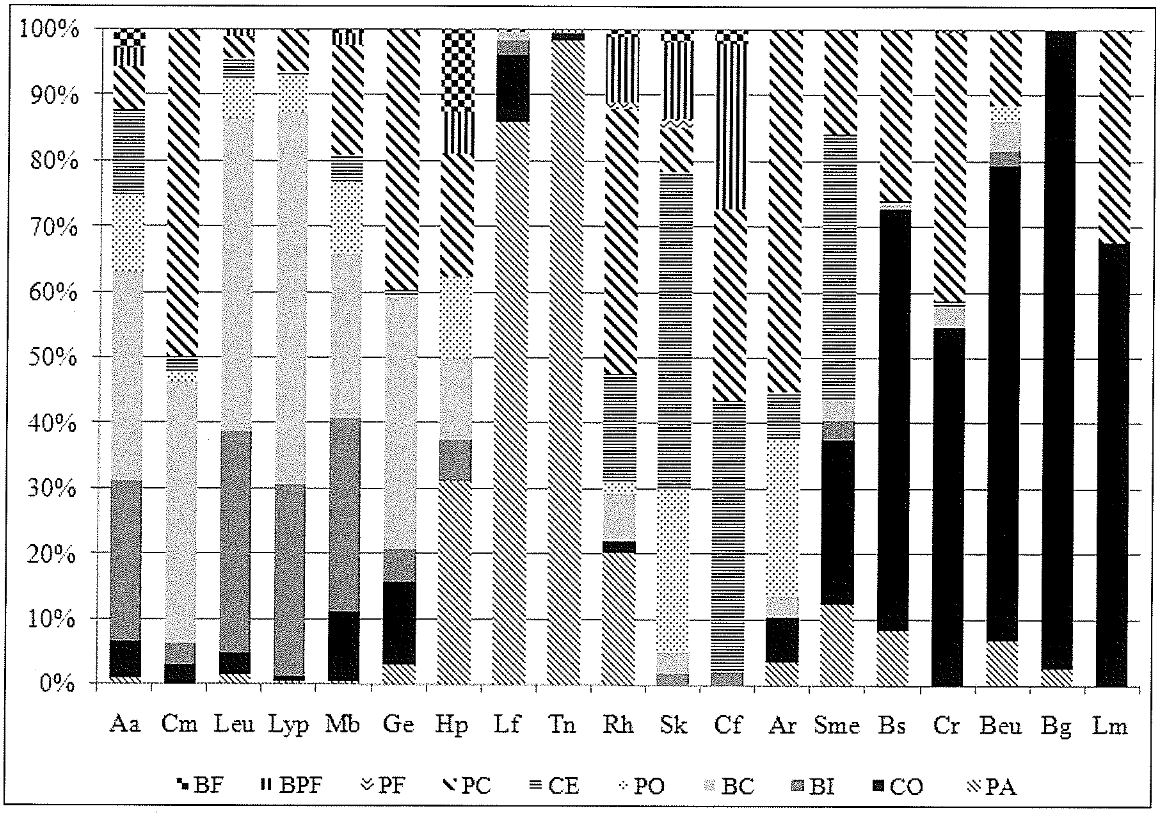
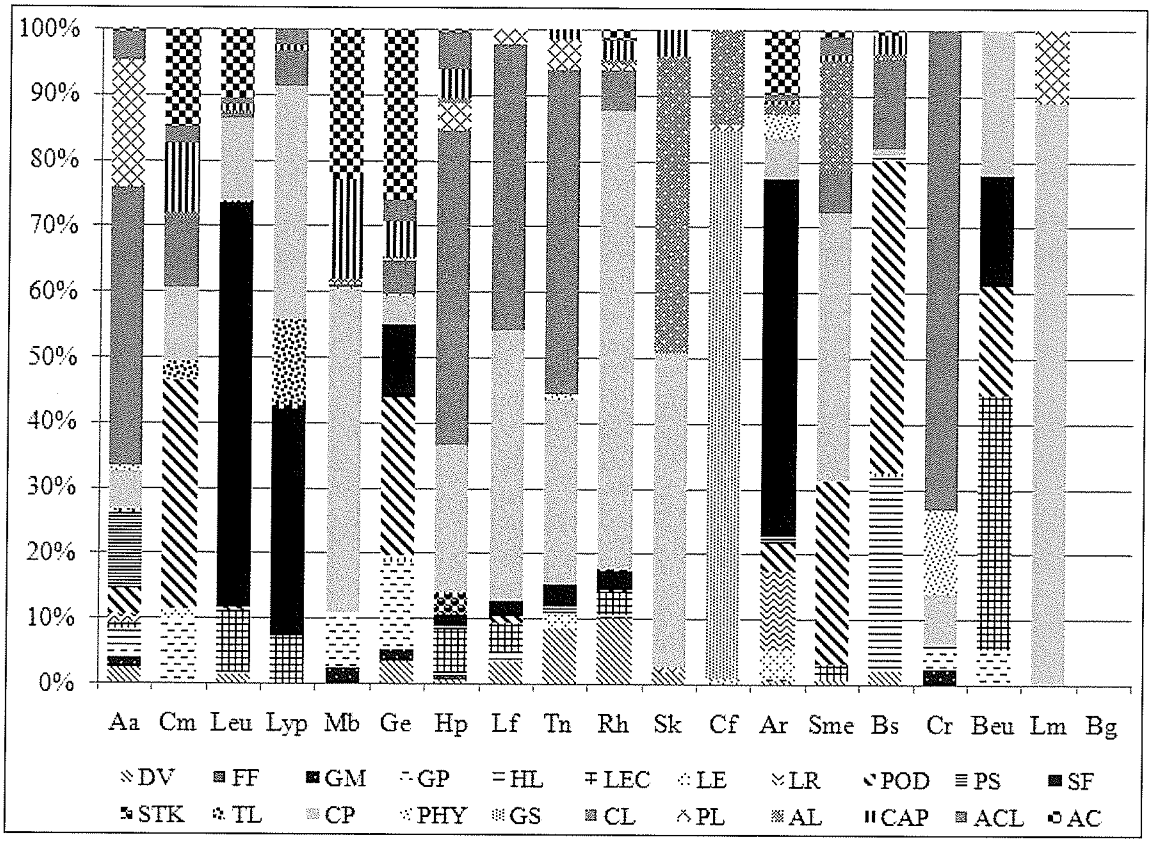

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aa
Cm
Leu
Lyp
Mb
Ge
Hp
Lf
Tn
Rh
Sk
Cf
Ar
Sme
Bs
Cr
Beu
Bg
Lm
BF
BPF
PF
PC
CE
PO
BC
BI
CO
PA

Figure 5.6. Proportion of twenty-two parasite species found in nineteen fish species within the Davis Strait/Baffin Bay region from 2000-2004. Species = Ar: *A. rostrata*, Aa: *A. atlanticus*, Beu: *B. euryops*, Bg: *B. glaciale*, Bs: *B. saida*, Cf: *C. fabricii*, Cr: *C. rupestris*, Cm: *C. microps*, Ge: *G. ensis*, Hp: *H. platessoides*, Lm: *L. macdonaldi*, Lf: *L. fabricii*, Leu: *L. eudipleurostictus*, Lyp: *L. paamiuti*, Mb: *M. berglax*, Rh: *R. hippoglossoides*, Sme: *S. mentella*, Sk: *S. kaupi*, Tn: *T. nybelini*. Parasite names are listed in Table 5.2. NOTE: no endohelminths were found in any *B. glaciale* specimens.


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aa
Cm
Leu
Lyp
Mb
Ge
Hp
Lf
Tn
Rh
Sk
Cf
Ar
Sme
Bs
Cr
Beu
Lm
Bg
DV
FF
GM
GP
HL
LEC
LE
LR
POD
PS
SF
STK
TL
CP
PHY
GS
CL
PL
AL
CAP
ACL
AC

CHAPTER 6: USING ENVIRONMENTAL VARIABLES TO PREDICT DIET PREFERENCE AND ENDOHELMINTH INFECTIONS OF DEEP-SEA ARCTIC FISH SPECIES

Introduction

Several factors including age, geographical location, habitat preferences, and reproductive status, are involved in diet preference of and endohelminth diversity in fishes. For example, most fish species undergo some type of dietary shift during their ontogeny and in most cases move higher up the food chain (Cohen et al. 1993, Memmott et al. 2000, Møller 2006, Warren and Lawton 1987, Woodward and Hildrew 2002). Though fish size is an important component in prey selection, environmental factors such as latitude, longitude, water temperature, salinity and depth contribute on a more basic level due to the physiological tolerance limits and preferences of each species. Each fish species exists within a unique set of environmental conditions and as a result has evolved different survival mechanisms, feeding strategies and diet preferences. As a consequence, those species will have a distinct assortment of prey items available to them and will be vulnerable to unique combinations of parasitic infections (Campbell et al. 1980).

There are a number of studies on the feeding strategies of marine fishes in tropical systems (Barletta and Blaber 2007, Bonaldo et al. 2007, Kotrschal and Thomson 1986, Layman et al. 2005) due to the high level of diversity and feeding specificity of constituent species. Less is known about the Arctic marine environment; however, researchers are beginning to describe community structure in this dynamic environment (Chambers and Dick 2005, 2007, He 2005, Jorgensen et al. 2005, Møller 2006, Prokopowicz and Fortier 2002). For example, Jorgensen et al. (2005) defined several fish assemblages throughout Davis Strait and Baffin Bay, concluding that the northern Baffin Bay region contained more fish assemblages with fewer species than the more speciose southern Davis Strait. Each assemblage differed based on temperature and depth in addition to latitude and longitude. Chambers and Dick (2007) found similar results, concluding that a combination of four environmental variables (latitude, longitude, temperature and depth) significantly influenced the distribution of fish species throughout Davis Strait and Baffin Bay. As species assemblages change along these environmental gradients, the trophic position of individual fish species will also change.

The distribution of invertebrate prey species also affects the trophic structure of marine communities, influencing the trophic position of species throughout the food web. For example, differences in copepod (Prokopowicz and Fortier 2002) and decapod (Chambers pers. obs., He 2005) species distributions have been found throughout Arctic waters of Baffin Bay and Davis Strait, attributed to environmental characteristics and the physiological limits of each species. Though deep-sea fish species of the eastern Arctic tend to be generalist feeders (Chambers and Dick 2005) the distribution of copepods and other invertebrate species will nevertheless contribute to the shape and dynamics of their communities.

While there are numerous single-species studies in marine environmental research, few attempt to synthesize available data in the context of an entire ecosystem. Additionally, while many assumptions have been made with respect to the distribution and environmental preferences of endohelminth and/or diet species of deep-sea Arctic fishes, few authors have incorporated both endohelminth and diet data in the context of trophic relationships within this system. This chapter combines endohelminth, diet and environmental data in order to describe trophic relationships of deep-sea Arctic species with changing environmental conditions.

This chapter incorporates different aspects of the original objectives; environmental variables, parasite, diet data and fish age and size classes are used again but they are combined in order to investigate differences in trophic patterns throughout the study area. Here, the objectives were to determine if 1) environmental variables (latitude, longitude, temperature and depth) could be used to predict feeding habits and endohelminth infections of deep-sea fish species in the Davis Strait/Baffin Bay region, 2) total fish length in conjunction with environmental variables was a better predictor of feeding habits and endohelminth infections than environmental variables alone, and 3) feeding habits and parasite infracommunities of fish species differed between subareas within Davis Strait and Baffin Bay.

Methods

Study Area and Sample Collections

Study area included NAFO subareas 0 (divisions A and B) and 1 (divisions A, C and D). Sampling methods are described in detail in Chapter 2. Data used in this chapter included sample collections from 2000, 2001 and 2004. Stomach content and parasite infracommunity data for 2,541 samples and 23 fish species (Table 6.1) were analyzed. Species evaluated were Greenland halibut (*Reinhardtius hippoglossoides*), sculpins (*Cottunculus microps*, *Artediellus atlanticus*, *Triglops nybelini*), blue hake (*Antimora rostrata*), eelpouts (*Lycodes eudipleurostictus*, *L. mcallisteri*, *L. paamiuti*), blacksmelts (*Bathylagus euryops*), lanternfish (*Lampanyctus macdonaldi*, *Benthosema glaciale*), cod

(*Boreogadus saida*), snailfish (*Careproctus reinhardti, Liparis fabricii, Paraliparis bathybius, Rhodichthys regina*), black dogfish (*Centroscyllium fabricii*), grenadier (*Macrourus berglax, Coryphaenoides rupestris*), rocklings (*Gaidropsarus ensis*), American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes mentella*) and eel (*Synaphobranchus kaupi*). Fish species data (diet and parasites) were combined in order to detect changing distribution patterns in prey and parasite species with environmental variables.

Data Analysis

Food Groups – Community

Food items were identified and assigned to one of ten major food groups as follows; Benthic Invertebrates (BI: Bivalvia, Gastropods, Echinodermata), Copepoda (CO), Benthic Crustaceans (BC: other amphipods, isopods, ostracods), Pelagic Amphipoda (family Hyperiidae, PA), Polychaeta (PO), Cephalopoda (CE), Pelagic Crustaceans (PC: mysids, euphausiids, decapods), Pelagic Fish (PF: lanternfish, cod), Benthopelagic Fish (BPF: grenadier, Greenland halibut, rocklings), and Benthic Fish (BF: eelpouts, sculpins).

The total number of each food group in all individual samples were combined with five environmental variables (latitude, longitude, temperature, depth and fish length) for Redundancy analysis (RDA) and Monte Carlo significance test. It is usually more effective to use raw data in statistical analyses than it is to use calculated data (i.e., abundance, mean intensity) as real patterns within the dataset will be more easily detectable. Consequently, total numbers (or raw data) were used in the multivariate analyses. Two analyses were carried out: one RDA excluding total fish length and one including total fish length for environmental variables. Monte Carlo tests for significance were performed for both.

Parasite Infections – Community

The total number of each parasite species (Table 6.2) within each fish host (Table 6.1) was combined with five environmental variables (latitude, longitude, temperature, depth and total fish length) for Redundancy analysis (RDA) and Monte Carlo significance test. Two analyses were carried out; one RDA excluding total fish length and one including total fish length for environmental variables. Monte Carlo tests for significance were performed for both.

Environmental variables with diet and parasitic infections – Individual Fish Species

Two analyses were performed for each of twenty-three fish species. One RDA involved using the five environmental variables (latitude, longitude, temperature, depth and total fish length) with all food groups found in each particular fish species (i.e. previously defined food groups not recovered from any stomachs of a particular species were excluded). The second RDA included the five environmental variables (latitude, longitude, temperature, depth and total fish length) with all parasite species collected from individuals of each particular species.

Food Groups and Parasitic Infections – Subarea Comparisons

Food group and parasite data were separated into three subarea comparisons: 0A vs. 0B (north vs. south), 0A vs. 1A (northwest vs. northeast) and 0B vs. 1CD (southwest vs southeast). Only fish species common to both subareas being compared were used in the analysis. For example, though *A. rostrata*, *C. fabricii*, *C. rupestris* and *L. macdonaldi* were common species within subarea 0B they were not included in the analysis of 0B vs.

0A due to their absence in subarea 0A. The total number of each food group and parasite species in fish species common to the two subareas were analysed. A two-tailed t-test for significance was performed for each subarea comparison in order to determine whether there were significant differences in food group consumption and/or parasite infections between subareas. In order to avoid bias in terms of variable size differences within species, equal proportions of size classes were used from each species.

Results

Food Groups – Community

A significant correlation between food group consumption and a combination of depth, temperature, latitude and longitude when fish species were combined for redundancy analysis with food groups and environmental variables (f-ratio of 24.798 and p-value of 0.002, Fig. 6.2). 93.2% of the variance was contained within the first two axes. Most food groups remained close to the origin of the ordination, regardless of a close association with one or more environmental variable. Benthic invertebrates (BI), Copepoda (CO) and pelagic amphipods (PA) were more closely associated with shallower depths, lower temperatures and slightly more western latitudes while cephalopods (CE) were more closely associated with higher temperatures. Most fish prey groups (benthopelagic and benthic) were associated with deeper waters and higher latitudes whereas polychaetes, pelagic fish, benthic crustaceans and to a greater degree pelagic crustaceans, were more closely associated with higher latitudes, eastern longitudes and to a lesser extent, deeper waters.

Total fish length was also determined to be an important factor in food group consumption (Fig. 6.3). The analysis yielded an f-ratio higher than that without total length (30.521 vs 24.798), with a total redundancy of 0.061 and a p-value of 0.002. 95% of the variance was contained within the first two axes. Larger food item groups are more closely associated with greater total lengths (benthopelagic fish and benthic fish), whereas other food item groups are influenced by other environmental variables in addition to total fish length. Cephalopods, pelagic fish, polychaetes and pelagic crustaceans were more closely associated with greater total length, depth, and latitude. Benthic crustaceans were more closely associated with higher latitudes while benthic invertebrates appear to be less affected by changing environmental variables. Copepods and pelagic amphipods were more closely associated with shallower waters, smaller fish and lower temperatures.

Parasite Infections – Community

Parasite species redundancy analysis followed a similar pattern to that for food item groups in that a combination of environmental variables including total fish length was an accurate predictor of parasite infections with an f-ratio of 67.457 (Fig. 6.5) vs. 23.603 (Fig. 6.4; total length not included), though p-values were equal (0.002). 88.4% of the variance was contained within the first two axes compared to 90.5% when total fish length was included. Many parasite species were associated with larger fish (Fig. 6.5) and total length appeared to be most important in predicting the abundance of species such as cestode plerocercoids, *Gonocerca phycidis* and *Echinorhynchus* spp. Parasites such as trematode metacercariae and *Hemiurus levinseni* were more closely associated with hosts at higher latitudes and eastern longitudes while *Lepidophyllum steenstrupi* and

Phylobythos spp. were more abuundant in hosts at lower latitudes and deeper waters. *Lepidapedon rachion* preferred hosts in deeper waters at higher latitudes while *Lecithophyllum* sp. preferred hosts at higher temperatures and western longitudes.

Food Groups and Parasitic Infections – Subarea Comparisons

Differences in food group consumption were more pronounced for north (0A) vs. south (0B) comparisons (Table 6.3). There were significant differences in seven of the ten food groups within fish stomachs between subareas 0A and 0B; significantly more copepods, benthic crustaceans, polychaetes, pelagic crustaceans, pelagic fish and benthic fish were consumed in subarea 0A (p-values 0.0011, 0.0001, 0.0018, 0.0038, 0.0018 and 0.0104, respectively), while significantly more cephalopods were consumed in subarea 0B (p-value 0.0116). Copepods and cephalopods were consumed in larger numbers in 0A (Table 6.4; p-values 0.0470 and 0.0002) when compared to 1A, while polychaetes were more abundant in fishes from 1A (p-value 0.0022). When the two southern subareas were examined (Table 6.5), benthic crustaceans and polychaetes were found in significantly higher numbers in fishes from 1CD (p-values 0.0008, 2.6141E-06).

Differences in parasite infections were seen in all subarea comparisons. When comparing subarea 0A with 0B (Table 6.6), *H. levinseni*, *Podocotyle* sp., cestode plerocercoids and *Contracaecum* larvae were significantly more abundant in 0A (p-values 0.0010, 0.0280, 0.035 and 0.0106, respectively) while *Lecithophyllum* sp. and *Echinorhynchus gadi* were more abundant within subarea 0B (p-values 0.0010 and 0.0018). When comparing 0A to 1A (Table 6.7), *Lecithaster gibbosus*, *Steringophorus furciger*, cestode plerocercoids and *Pseudoterranova* larvae were significantly higher in number within 0A (p-values 0.0046, 0.0114, 0.0001 and 0.0035, respectively), while

Capillaria sp. and *E. gadi* were significantly higher in 1A (p-values 0.0019, 0.0060). When comparing the southern subareas (0B vs. 1CD) (Table 6.8), *L. gibbosus*, *Lecithophyllum* sp., and *Phylobythos* sp. were significantly higher in 0B (p-values 0.0097, 0.0001, 0.0002) while *G. phycidis*, *L. elongatum*, *Podocotyle* sp. and *Capillaria* sp. were significantly higher in 1CD (p-values 0.0008, 0.0168, 0.0308, 0.00003).

Discussion

Food Groups and Parasite Infections - Community

Our ability to evaluate ecosystems in terms of their breadth, health and dynamic is based solely on the amount of reliable data that is available for study. In most tropical and many temperate systems, an overwhelming amount of data is available with respect to species inventories, biology and ecology; however, in the deep-sea Arctic, comprehensive knowledge of ecosystem function is just beginning to accumulate.

Jorgensen et al. (2005) defined several fish species assemblages throughout Davis Strait and Baffin Bay using a combination of cluster analysis and a Bayesian multinomial logit model. They found that northern regions contained more fish assemblages with fewer species than the southern, more speciose regions. Each assemblage was defined by temperature and depth in addition to latitude and longitude. Chambers and Dick (2007) found similar results, concluding that a combination of water temperature, latitude, longitude and bottom depth strongly influenced the distribution of fish species in the Davis Strait/Baffin Bay region. Fish species were distributed along a low latitude/high temperature to high latitude/low temperature gradient while some were more highly correlated with depth. The proportions of fish species differed between northern and southern regions at each depth range, resulting in unique assemblages of species throughout the region.

The initial objective of this chapter was to determine whether or not diet and parasite infracommunities differed in fish between subareas of Davis Strait and Baffin Bay, and if so, the secondary objective was to determine if it was possible to predict dietary patterns and parasite infections using environmental data. A redundancy analysis using food group (Figs. 6.2, 6.3) and parasite (Figs. 6.4, 6.5) data from fishes within these assemblages showed that a combination of latitude, longitude, temperature and depth significantly predicted food group consumption and parasite infections in a similar manner. Examination of the food group RDA output (Fig. 6.2) showed 93 % of the variance contained within the first two axes, suggesting that diet preference is influenced almost exclusively by these four environmental variables. The addition of total fish length to the RDA (Fig. 6.3) confirmed what has been shown for fish communities globally; larger food groups such as fish were more abundant in the diet of larger taxa while smaller food groups such as copepods were more abundant in smaller taxa. Though total length affected food group abundance within fish diets, the amount of variance contained within the first two axes increased by only 2%, indicating that total length was not the most important variable affecting food group consumption. This corroborates stable isotope results in Chapter 5, in which increasing $\delta^{15}N$ values did not always reflect increasing total fish lengths. Though increases in size will allow fish to feed on a wider variety of larger prey items due to physiological adaptations such as larger gape size (Juanes et al. 2002, King 2005, Werner 1977) (e.g. benthopelagic and benthic fish; Fig.

6.3), other factors related to evolutionary adaptations in Arctic environments are more important in determining prey type.

Similar results were seen for parasite species; 88 % of the variation was contained within the first two RDA axes when total fish length was not used and 91% when used. As a fish grows and more prey items become available, it will become vulnerable to different or additional parasitic infections. Most food groups and parasites came out close to the origin of the ordination, indicating that although they may be associated with one or more environmental variables, many are common throughout the study area. Nevertheless, many species were closely associated with paticular environmental characteristics. For example, the digenean *H. levinseni* was closely associated with high latitudes, whereas *L. steenstrupi* and *Phylobythos* sp. were found in larger numbers in fish at greater depths (Figs. 6.2, 6.3). Consequently, if certain environmental variables are known, it is possible to predict the food groups most abundant in fish diets and parasite infections most likely to be found. As a result, assumptions can be made with respect to prey species and the parasite community distributions within the different regions of the Davis Strait and Baffin Bay. For example, using figure 6.2, we can predict that pelagic crustaceans will represent an important part of fish diets at high latitudes, whereas benthic invertebrates such as isopods will be more important in fish diets at greater depths. Fish at higher latitudes will be more likely to have infections of *H. levinseni* while fish at greater depths are more likely to carry infections of *L. steenstrupi.*

It is not surprising that environmental variables influence the availability of food and parasite species within this or any other marine environment. All animal species have a set of physiological limits and barriers which provide them with natural boundaries and exclude them from particular geographical regions, at large and small scales. In some cases, the distribution of entire taxonomic groups (e.g. family Squalidae) may vary according to physiological limits, whereas in others, a genus will be ubiquitous but there will be species differences according to environmental conditions. Prokopowicz and Fortier (2002) found differences in *Calanus* (Copepoda) species distribution and abundance within Baffin Bay based on temperature and depth preferences. *Calanus glacialis*, an Arctic water species, was more numerous on the western side of Baffin Bay due to the influence of strong Arctic surface waters. By contrast, *C. finmarchicus*, a boreal Atlantic species that tolerates wider temperature ranges, was able to survive in areas where Arctic and Atlantic waters mix. *Calanus hyperboreas* was more numerous in deep-water habitats and was found to be the most abundant species within the region. The presence and abundance of several parasite species have also been shown to vary with environmental conditions. Marcogliese and Cone (1997) found that parasite diversity in the American eel (*Anguilla rostrata*) was influenced by pH gradients within Nova Scotia rivers. Goater et al. (2005) found that helminth community structure in whitefish (*Coregonus clupeaformes*) was influenced by one or more gradients of water colour, phosphorous concentration and productivity level. Additionally, Hakalahti et al. (2006) found that hatching, transmission and/or development of the ectoparasite *Argulus coregoni* and the trematode *Diplostomum spathaceum* were controlled by surrounding environmental temperatures.

Food Groups and Parasite Infections – Subarea Comparisons

Since 1950, the western North Atlantic has been divided into sections based on a combination of international boundries (Canada, Greenland, France, USA) and stock distributions of cod and other marketable fish species. There are seven divisions between the northern limit of Baffin Bay and Cape Hatteras (numbered 0-6), each one further subdivided into two or more subareas (A, B, C, etc.). Though differences in the distribution and catch rates of commercial species have been reported between subareas (Jorgensen 1998, 2002, Treble 2002, Treble and Bowering 2002, Treble et al. 2000, Treble and Jorgensen 2002), no comparative studies with respect to ecosystem function and trophic structure have been attempted.

The last objective of this chapter was to determine if there were differences in food group consumption and parasite infections between subareas. Though latitude and longitude were found to influence diet and parasite infracommunities significantly in combination with other environmental factors, the ability to make generalizations regarding biota in each subarea may be important for future work in the north Atlantic, particularly with respect to ecosystem-based management.

Differences in diet were most pronounced in northern (0A) vs. southern (0B) comparisons. Significantly more cephalopods were consumed in the south, while significantly more copepods, crustaceans, polychaetes and fish were consumed in the north. Kristensen (1977) found decreasing abundance of *G. fabricii* towards Baffin Bay, suggesting that this species is more abundant, particularly smaller body sizes, in southern waters. However, this pattern could be due to higher temperatures or the higher prevalence of cephalopod predators within southern regions (Chambers and Dick 2007).

Species such as *A. rostrata*, *C. fabricii*, *C. rupestris* and *S. kaupi* had greater numbers of *G. fabricii* in their diet but were not found in northern subareas such as 0A. Consequently, a higher proportion of cephalopods in the diet of southern species was expected. Converseley, there were higher numbers of 'small-bodied' predators in northern Baffin Bay, leading to an increased consumption of copepods and other crustaceans, polychaetes, and small fish.

Differences in food group consumption between eastern and western subareas of Davis Strait and Baffin Bay were also apparent and likely due to assemblage differences with various depth and shelf characteristics. Lee et al. (2005) acoustically mapped the ocean bottom throughout Davis Strait and Baffin Bay, confirming that extended shallow waters exist off the coast of Greenland due to the large extension of the ocean shelf. Jorgensen et al. (2005) found that there were different species assemblages in eastern vs. western Baffin Bay due to these extended shallow water habitats, illustrated by a greater diversity of smaller benthic species such as sculpins and alligatorfish. Consequently, benthic food groups such as polychaetes and benthic crustaceans would be expected to predominate.

Differences in parasite infections were also seen between subareas, reflecting patterns of host distribution and feeding strategy. Fish species in subarea 0A were infected by higher numbers of cestode plerocercoids (Table 6.6), a taxon that uses pelagic crustaceans as intermediate hosts. This is not unexpected, as significantly higher abundances of pelagic crustaceans were seen in the diets of 0A fish. Additionally, *Podocotyle* sp. infections were significantly higher in fish from 1CD than 0B. *Podocotyle* sp. is known to use amphipods as a second intermediate hosts (Klimpel et al. 2006), a prey item found in significantly higher numbers in fish stomachs from 1CD. Though abundances of various parasite species increase or decrease within certain areas, most species are present throughout the Davis Strait/Baffin Bay region. The fact that most fish are generalist feeders in the Arctic results in low host specificity of its constituent parasite fauna, suggesting that habitat preference of fish hosts is the most important factor determining parasite communities within the system. This corroborates the findings of Klimpel et al. (2006), who reported that parasite species diversity in Arctic marine fishes depends on a combination of host feeding behaviour, availability of hosts (both intermediate and final), depth and host migration. The authors postulated that a higher degree of generalist feeding in fish species would encourage low host specificity of parasites and result in the infection of numerous host species.

Low parasite host specificity is a result of generalist feeding, which can be used to make broad conclusions regarding food web patterns within Arctic marine systems. Endohelminth data have been a valuable supplement to diet as a predictor of fish trophic position both regionally and locally, more so than stable isotopes. Results from Chapter 5 illustrate that although stable isotopes can be used to determine feeding strategies of deep-sea Arctic fishes, they are less useful in distinguishing species differences along latitudinal or other environmental gradients. Generalizations about the abundance of parasite species within individual subareas and along environmental gradients within Davis Strait and Baffin Bay can be made as patterns of infections closely follow patterns of fish host distribution and habitat utilization. Each location within this region can be described in terms of expected predator/prey relationships and as a result, most and least likely parasite-host relationships. While individual subarea differences are valid for some generalizations, descriptions of species assemblages and food web dynamics based on environmental gradients within the entire system will be more valuable for evaluations of the marine Arctic.

Generalist feeding predominates in Arctic marine fish species but one needs to be careful not to generalize too much. It is inaccurate to assume that all similar benthic fish taxa in the Arctic maintain similar feeding strategies. Chambers et al. (Appendix 6) found that the diet of shallow water species such as *M. scorpius* consisted primarily of two *Gammarus* spp. (Amphipoda). This contrasts with its deep-sea counterparts (*C. microps*, *A. atlanticus*), with a similar life history, but with a diet of mostly bivalves and polychaetes, even in environments with high amphipod abundance. Perhaps these differences relate to nutrient or lipid content of prey species. The data support the observation that trophic interactions are affected by changing environmental variables and that each microcommunity (or assemblage) maintains a unique trophic structure with distinct predator-prey relationships.

Table 6.1. Latin names, common names and letter codes of twenty-three fish species collected within NAFO subareas 0 (divisions A and B) and 1 (divisions A, C and D) between 2000 and 2004.

Latin Name	Common Name	Letter Code
Antimora rostrata (Günther)	Blue Hake	Ar
Artediellus atlanticus Jordan & Evermann	Hookear Sculpin	Aa
Bathylagus euryops Goode & Bean	Goitre Blacksmelt	Beu
Benthosema glaciale (Reinhardt)	Glacier Lanternfish	Bg
Boreogadus saida (Lepechin)	Arctic Cod	Bs
Careproctus reinhardti (Kroyer)	Sea Tadpole	Car
Centroscyllium fabricii (Reinhardt)	Black Dogfish	Cf
Coryphaenoides rupestris Gunnerus	Roundnose Grenadier	Cr
Cottunculus microps Collet	Polar Sculpin	Cm
Gaidropsarus ensis (Reinhardt)	Three-Beard Rockling	Ge
Hippoglossoides platessoides (Fabricius)	American Plaice	Hp
Lampanyctus macdonaldi (Reinhardt)	Rakery Beaconlamp	Lm
Liparis fabricii Kroyer	Gelatinous Snailfish	Lf
Lycodes eudipleurostictus Jensen	Double-Line Eelpout	Leu
Lycodes paamiuti Møller	Paamiut's Eelpout	Lyp
Lycodes mcallisteri Reinhardt	Mcallister's Eelpout	Lym
Macrourus berglax Lacepede	Roughhead Grenadier	Mb
Paraliparis bathybius (Collet)	Black Seasnail	Pb
Reinhardtius hippoglossoides (Walbaum)	Greenland Halibut	Rh
Rhodichthys regina Collet	Threadfin Seasnail	Rr
Sebastes mentella Travin	Deepwater Redfish	Sme
Synaphobranchus kaupi Johnson	Slatjaw Cutthroat Eel	Sk
Triglops nybelini Jensen	Mailed Sculpin	Tn

Table 6.2. Names and letter codes of twenty-nine parasite species collected from twenty-three fish species collected in NAFO subareas 0 (divisions A and B) and 1 (divisions A, C, and D) between 2000 and 2004.

Parasite Species	Code
Derogenes varicus (Müller)	DV
Fellodistomum felis (Olsson)	FF
Glomericirrus macrouri (Gaevskaja)	GM
Gonocerca phycidis Manter	GP
Hemiurus levinseni Odhner	HL
Lecithaster gibbosus (Rudolphi)	LEC
Lecithophyllum sp.	LI
Lepidopedon elongatum (Lebour)	LE
Lepidapedon rachion (Cobbold)	LR
Lepidapedon sp.	LEP
Lepidophyllum steenstrupi Odhner	LS
Neophasis burtii Bray & Gibson	NB
Otodistomum sp.	OF
Podocotyle sp.	POD
Prosorhynchus squamatus Odhner	PS
Steringophorus furciger (Olsson)	SF
Stenakron vetustum Stafford	STK
Trematoda sp. Larvae	TL
Bothriidae sp.	BO
Cestoda sp. Plerocercoid	CP
Phylobythos sp.	PHY
Gilquinia squali (Fabricius)	GS
Gilquinia sp. Plerocercoid	GSP
Contracaecum Larvae	CL
Pseudoterranova Larvae	PL
Anisakis Larvae	AL
Capillaria sp.	CAP
Acanthocephala Larvae	ACL
Echinorhynchus sp.	AC

Table 6.3. Results of a two-tailed test for significance between ten food groups found in twenty-three fish species collected in NAFO subareas 0A and 0B between 2000 and 2004. Sample size of fish examined in 0A was 832, and 781 in 0B.

Food Group	Subarea	Mean	St.D.	DF	P-value
Pelagic Amphipods	0A	0.9760	4.2198	1607.6	0.3610
	0B	0.7939	3.7825		
Copepoda	0A	1.8305	10.9669	1059.3	0.0011
	0B	0.5032	3.9890		
Benthic Crustaceans	0A	1.1683	2.9469	1490.8	0.0001
	0B	0.6850	2.0595		
Benthic Invertebrates	0A	0.2764	1.1539	1610.4	0.2955
	0B	0.3342	1.0620		
Cephalopoda	0A	0.0445	0.2804	1457.5	0.0116
	0B	0.0858	0.3673		
Polychaeta	0A	0.1563	0.5326	1312.7	0.0018
	0B	0.0896	0.2947		
Pelagic Crustaceans	0A	0.9784	4.7808	1038.1	0.0038
	0B	0.4673	1.6527		
Pelagic Fish	0A	0.0745	0.5694	969.1	0.0018
	0B	0.0102	0.1598		
Benthopelagic Fish	0A	0.0132	0.1143	1490.2	0.1629
	0B	0.0064	0.0798		
Benthic Fish	0A	0.0709	0.4116	1152.9	0.0104
	0B	0.0307	0.1800		

Table 6.4. Results of a two-tailed test for significance between ten food groups found in twenty-three fish species collected in NAFO subareas 0A and 1A between 2000 and 2004. Sample size of fish examined in 0A was 507 and 212 in 1A.

Food Group	Subarea	Mean	St.D.	DF	P-value
Pelagic Amphipods	0A	1.4517	5.3238	653.5	0.1607
	1A	1.0094	3.0291		
Copepoda	0A	0.7239	3.1319	698.9	0.047
	1A	0.4104	1.0782		
Benthic Crustaceans	0A	1.8107	3.7763	353.9	0.5128
	1A	2.033	4.2963		
Benthic Invertebrates	0A	0.355	1.3875	527.4	0.791
	1A	0.3302	1.0278		
Cephalopoda	0A	0.0493	0.2425	660.4	0.0002
	1A	0.0047	0.0687		
Polychaeta	0A	0.1598	0.4357	272.4	0.0022
	1A	0.3302	0.7506		
Pelagic Crustaceans	0A	1.5523	6.2068	476.3	0.0915
	1A	2.3066	5.1079		
Pelagic Fish	0A	0.0789	0.6725	594.3	0.7151
	1A	0.0943	0.436		
Benthopelagic Fish	0A	0.0217	0.1458	482.7	0.4683
	1A	0.0142	0.1184		
Benthic Fish	0A	0.0986	0.5051	605.2	0.5576
	1A	0.0802	0.3202		

Table 6.5. Results of a two-tailed test for significance between ten food groups found in twenty-three fish species collected in NAFO subareas 0B and 1CD between 2000 and 2004. Sample size of fish examined was 488 in 0B and 178 in 1CD.

Food Group	Subarea	Mean	St.D.	DF	P-value
Pelagic Amphipods	0B	0.084	0.7631	629.7	0.8008
	1CD	0.073	0.353		
Copepoda	0B	0.5615	4.0974	607.3	0.1024
	1CD	0.236	0.9628		
Benthic Crustaceans	0B	0.3033	1.1598	241	0.0008
	1CD	0.7697	1.6833		
Benthic Invertebrates	0B	0.1311	0.5831	350.8	0.3606
	1CD	0.1742	0.5186		
Cephalopoda	0B	0.127	0.4443	317.3	0.1731
	1CD	0.1798	0.4399		
Polychaeta	0B	0.0676	0.2672	189.9	2.61E-06
	1CD	0.382	0.8505		
Pelagic Crustaceans	0B	0.6414	2.3764	299	0.4568
	1CD	0.8034	2.5201		
Pelagic Fish	0B	0.0225	0.243	326.1	0.2791
	1CD	0.0449	0.2334		
Benthopelagic Fish	0B	0.0123	0.1103	206.5	0.0742
	1CD	0.0449	0.2334		
Benthic Fish	0B	0.0533	0.2338	262.5	0.0859
	1CD	0.0955	0.2947		

Table 6.6. Results of a two-tailed test for significance between parasites recovered from twenty-three fish species collected in NAFO subareas 0A and 0B between 2000 and 2004. Sample size of fish examined was 832 in 0A and 781 in 0B.

Parasite	Subarea	Mean	St.D.	DF	P-value
Derogenes varicus	0A	0.9952	4.3397	1300.2	0.6281
	0B	0.8553	6.8871		
Fellodistomum felis	0A	0.0036	0.06	1049.4	0.1402
	0B	0.0115	0.1382		
Glomericirrus macrouri	0A	0.1382	1.5252	1462	0.1964
	0B	0.0551	1.0245		
Gonocerca phycidus	0A	0.6599	6.1281	1042.6	0.111
	0B	0.2996	2.1423		
Hemiurus levinseni	0A	0.8305	3.1511	1108.8	0.001
	0B	0.1319	1.2717		
Lecithaster gibbosus	0A	0.5613	4.1583	1419.8	0.5642
	0B	0.7055	5.709		
Lecithophyllum sp.	0A	0.0012	0.0347	791.8	0.001
	0B	0.0602	0.3859		
Lepidopedon elongatum	0A	0.2356	4.9102	832.7	0.1862
	0B	0.0102	0.1516		
Lepidapedon rachion	0A	0.0204	0.3339	1010.6	0.2502
	0B	0.0064	0.1072		
Lepidapedon sp.	0A	0.0012	0.0347	783.8	0.3427
	0B	0.0243	0.6799		
Lepidophyllum steenstrupi	0A	0.0096	0.2774	1261.3	0.6801
	0B	0.0051	0.1431		
Neophasis burtii	0A	0.0998	2.8775	831.8	0.3367
	0B	0.0038	0.0619		
Podocotyle sp.	0A	1.9507	17.7266	1004.7	0.028
	0B	0.5288	5.5949		
Prosorhynchus squamatus	0A	0.0781	0.883	1422.1	0.4418
	0B	0.0499	0.5628		
Steringophorus furciger	0A	0.7416	5.0836	1271.2	0.2013
	0B	1.1857	8.3643		
Stenakron vetustum	0A	0.0048	0.1096	794.7	0.0956
	0B	0.0704	1.0938		
Trematoda sp. Larvae	0A	1.1731	23.3896	834.8	0.1659
	0B	0.0474	1.0797		
Cestoda sp. Plerocercoid	0A	6.6887	24.8158	1457.5	0.0305
	0B	3.5557	32.5051		
Philobythos sp.	0A	0.0096	0.1624	1227	0.6109
	0B	0.0064	0.0798		
Gilquinia sp. Plerocercoid	0A	0.0024	0.049	1520.6	0.5975
	0B	0.0013	0.0358		
Contracaecum Larvae	0A	5.8714	44.2029	938.2	0.0106
	0B	1.8207	10.9108		
Pseudoterranova Larvae	0A	0.4327	5.7119	938.4	0.2106
	0B	0.1767	1.4113		
Anisakis Larvae	0A	0.1971	2.3751	1064.9	0.2172
	0B	0.0883	0.8748		
Capillaria sp.	0A	2.2596	12.3808	1581	0.0896
	0B	1.169	13.3439		
Acanthocephala Larvae	0A	0.2368	1.5906	1353.6	0.6952
	0B	0.1972	2.3658		
Echinorhynchus sp.	0A	0.5625	3.0509	975.6	0.0018
	0B	1.5506	8.3018		

Table 6.7. Results of a two-tailed test for significance between parasites recovered from twenty-three fish species collected in NAFO subareas 0A and 1A between 2000 and 2004. Sample size of fish examined was 507 in 0A and 212 in 1A.

Parasite	Subarea	Mean	St.D.	DF	P-value
Derogenes varicus	0A	1.3116	5.3177	468.6	0.7609
	1A	1.4292	4.4498		
Fellodistomum felis	0A	0.0059	0.0768	506	0.0833
	1A	0	0		
Glomericirrus macrouri	0A	0.2268	1.9494	602.2	0.062
	1A	0.0566	0.4091		
Gonocerca phycidus	0A	1.0848	7.8241	715.4	0.6696
	1A	1.2642	3.4375		
Hemiurus levinseni	0A	0.3984	1.8669	445.5	0.5127
	1A	0.3066	1.6451		
Lecithaster gibbosus	0A	0.6746	4.9769	516.4	0.0046
	1A	0.0425	0.3274		
Lecithophyllum sp.	0A	0.002	0.0444	506	0.3178
	1A	0	0		
Lepidopedon elongatum	0A	0.3491	6.2442	712.9	0.7697
	1A	0.2547	2.393		
Lepidapedon rachion	0A	0.0355	0.4341	317.2	0.0213
	1A	0.1368	0.572		
Lepidophyllum steenstrupi	0A	0.0158	0.3553	589.2	0.502
	1A	0.0047	0.0687		
Neophasis burtii	0A	0.1637	3.6862	506	0.3178
	1A	0	0		
Podocotyle sp.	0A	2.8402	22.5585	697.7	0.4068
	1A	1.7925	11.1799		
Prosorhynchus squamatus	0A	0.0237	0.2072	332	0.8155
	1A	0.0283	0.256		
Steringophorus furciger	0A	0.9132	5.5286	635.1	0.0114
	1A	0.2453	1.3859		
Stenakron vetustum	0A	0.0059	0.1332	536.6	0.6931
	1A	0.0094	0.0969		
Trematoda sp. Larvae	0A	1.8738	29.9487	696.7	0.849
	1A	2.1934	14.9087		
Cestoda sp. Plerocercoid	0A	8.6824	28.3424	674.7	0.0001
	1A	3.1132	8.5917		
Philobythos sp.	0A	0.002	0.0444	506	0.3178
	1A	0	0		
Contracaecum Larvae	0A	3.645	44.0357	578.7	0.4114
	1A	1.9764	7.9043		
Pseudoterranova Larvae	0A	0.2998	2.2194	515.2	0.0035
	1A	0.0094	0.1374		
Anisakis Larvae	0A	0.1696	1.9878	525.7	0.102
	1A	0.0236	0.1806		
Capillaria sp.	0A	3.1953	15.0339	243.4	0.0019
	1A	11.1179	35.4207		
Acanthocephala Larvae	0A	0.2919	1.9655	711.6	0.1501
	1A	0.1462	0.743		
Echinorhynchus sp.	0A	0.9448	4.0823	273.9	0.006
	1A	2.3585	6.9476		

Table 6.8. Results of a two-tailed test for significance between parasites recovered from twenty-three fish species collected in NAFO subareas 0B and 1CD between 2000 and 2004. Sample size of fish examined was 488 in 0B and 178 in 1CD.

Parasite	Subarea	Mean	St.D.	DF	P-value
Derogenes varicus	0B	1.2971	8.6627	443.8	0.8459
	1CD	1.1798	6.1231		
Fellodistomum felis	0B	0.0184	0.1745	363	0.6001
	1CD	0.0112	0.1499		
Glomericirrus macrouri	0B	0.0861	1.2947	227.7	0.6011
	1CD	0.1742	2.1041		
Gonocerca phycidus	0B	0.4611	2.6958	212.6	0.0008
	1CD	1.8483	5.2026		
Hemiurus levinseni	0B	0.0164	0.1424	421.6	0.6138
	1CD	0.0112	0.1057		
Lecithaster gibbosus	0B	0.9221	6.5943	531.9	0.0097
	1CD	0.1292	0.8767		
Lecithophyllum sp.	0B	0.0922	0.4814	547.2	0.0001
	1CD	0.0056	0.075		
Lepidopedon elongatum	0B	0.0225	0.3757	205.5	0.0168
	1CD	0.1742	0.8082		
Lepidapedon rachion	0B	0.0471	0.7926	647.7	0.538
	1CD	0.0225	0.2366		
Lepidophyllum steenstrupi	0B	0.0164	0.2558	220.1	0.6276
	1CD	0.0337	0.4497		
Neophasis burtii	0B	0	0	177	0.3119
	1CD	0.4045	5.3218		
Podocotyle sp.	0B	0.4652	3.1011	179.9	0.0308
	1CD	3.8539	20.6863		
Prosorhynchus squamatus	0B	0.0307	0.3751	359.7	0.7727
	1CD	0.0393	0.3253		
Steringophorus furciger	0B	0.8033	5.5689	218.6	0.2863
	1CD	1.6461	9.9679		
Stenakron vetustum	0B	0.1045	1.3772	263.7	0.8329
	1CD	0.1348	1.7251		
Trematoda sp. Larvae	0B	0	0	177	0.1579
	1CD	0.0112	0.1057		
Cestoda sp. Plerocercoid	0B	5.1291	40.9896	302.7	0.0957
	1CD	11.3258	42.8326		
Philobythos sp.	0B	0.0656	0.3895	487	0.0002
	1CD	0	0		
Gilquinia squali larvae	0B	0.002	0.0453	177.3	0.3338
	1CD	0.0674	0.8994		
Contracaecum Larvae	0B	2.7336	15.4911	203.8	0.1633
	1CD	6.4719	34.398		
Pseudoterranova Larvae	0B	0.1967	1.6508	183.7	0.3768
	1CD	0.6854	7.2915		
Anisakis Larvae	0B	0.1701	1.1255	267.8	0.0107
	1CD	0.4663	1.3784		
Capillaria sp.	0B	1.8033	16.851	237.8	0.00003
	1CD	10.4775	25.0609		
Acanthocephala Larvae	0B	0.2602	2.9783	554.2	0.2726
	1CD	0.1067	0.4927		
Echinorhynchus sp.	0B	2.3053	9.9963	267.4	0.3282
	1CD	3.309	12.2663		

Figure 6.1. Map of NAFO management areas within Baffin Bay and Davis Strait. (NAFO, 2008). Data used for analysis were collected from 0A, 1A, 0B, 1C and 1D between 2000 and 2004.

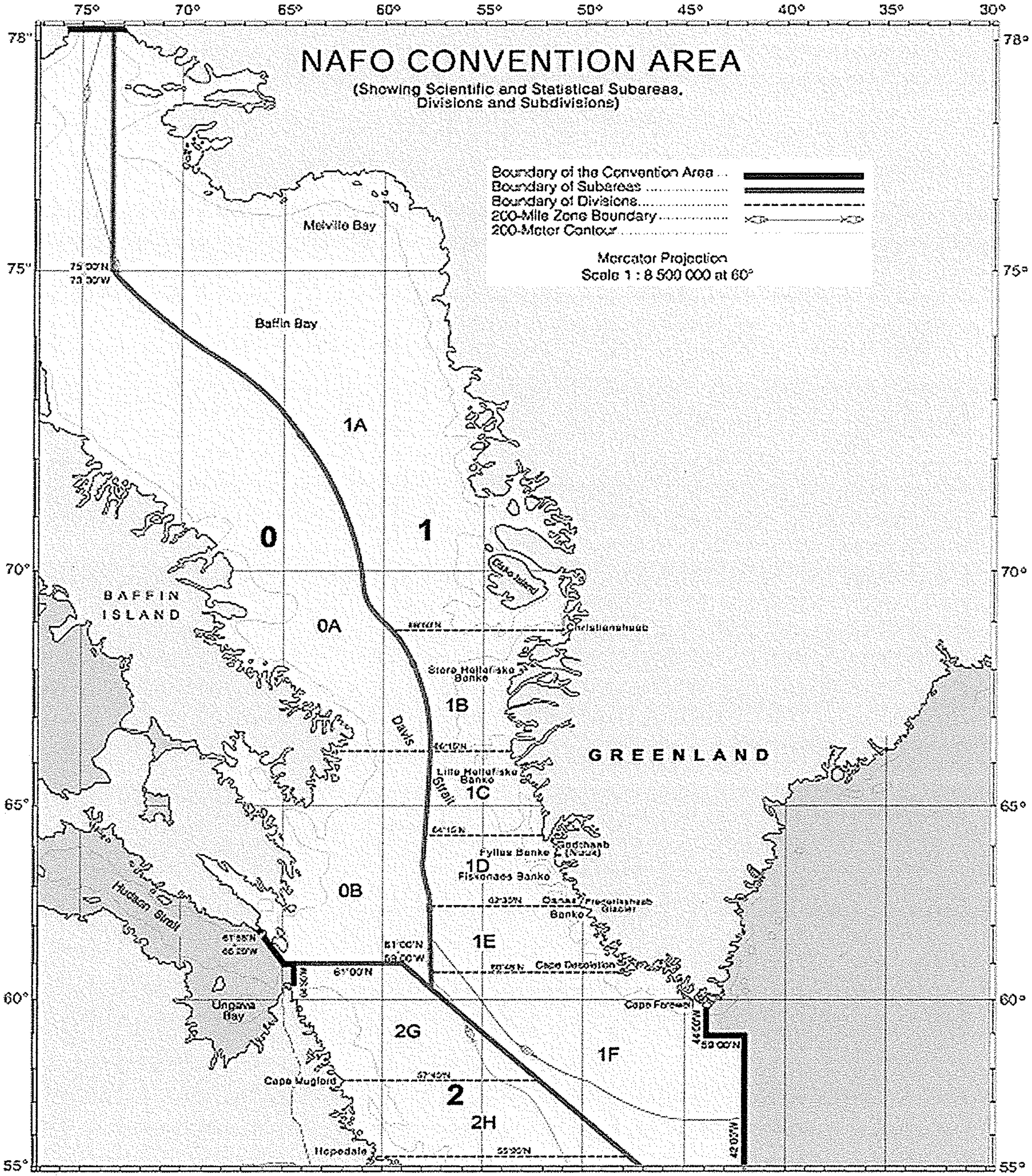
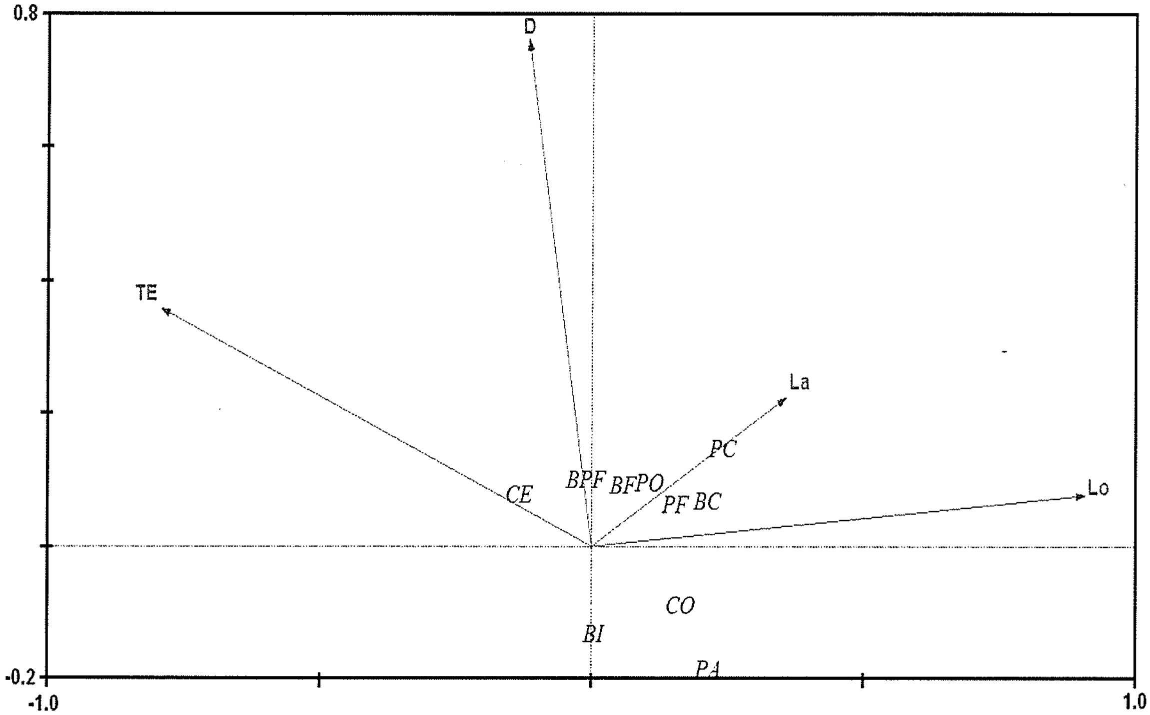

NAFO CONVENTION AREA
(Showing Scientific and Statistical Subareas, Divisions and Subdivisions)
Boundary of the Convention Area
Boundary of Subareas
Boundary of Divisions
200-Mile Zone Boundary
200-Meter Contour
Mercator Projection
Scale 1 : 8 500 000 at 60°
Melville Bay
Baffin Bay
75°00'N
73°30'W
1A
0
1
BAFFIN ISLAND
0A
Disko Island
Christianshaab
Store Hellefiske Banke
1B
Davis Strait
GREENLAND
Lille Hellefiske Banke
1C
64°15'N
Godthaab (Nuuk)
Fyllas Banke
1D
Fiskenaes Banke
0B
62°30'N
Danas Banke
Frederikshaab Glacier
Hudson Strait
61°00'N
59°00'W
1E
61°00'N
Cape Desolation
Ungava Bay
Cape Farewell
44°00'W
59°00'N
2G
1F
Cape Mugford
57°40'N
2
2H
Hopedale
55°20'N
42°00'W
75°
70°
65°
60°
55°
50°
45°
40°
35°
30°
78°
75°
70°
65°
60°
55°

Figure 6.2. RDA scatterplot illustrating the relationship between food groups of twenty-three Arctic marine fish species and four environmental variables. 'La' refers to latitude, 'Lo' to longitude, 'TE' to temperature and 'D' to depth. CO refers to Copepoda, CE to Cephalopoda, PA to Pelagic Amphipods, PC to Pelagic Crustaceans, BC to Benthic Crustaceans, BI to Benthic Crustaceans, PO to Polychaeta, BF to Benthic Fish, BPF to Benthopelagic Fish, and PF to Pelagic Fish. Monte Carlo test for significance yielded an F-ratio of 24.798 and P-value of 0.002.



0.8
-0.2
-1.0
1.0
D
TE
La
Lo
PC
BPF
BFPO
CE
PF
BC
CO
BI
PA

Figure 6.3. RDA scatterplot illustrating the relationship between food groups of twenty-three Arctic marine fish species and five environmental variables. 'La' refers to latitude, 'Lo' to longitude, 'TL' to total fish length, 'TE' to temperature and 'D' to depth. CO refers to Copepoda, CE to Cephalopoda, PA to Pelagic Amphipods, PC to Pelagic Crustaceans, BC to Benthic Crustaceans, BI to Benthic Crustaceans, PO to Polychaeta, BF to Benthic Fish, BPF to Benthopelagic Fish, and PF to Pelagic Fish. Monte Carlo test for significance yielded an F-ratio of 30.521 and P-value of 0.002.

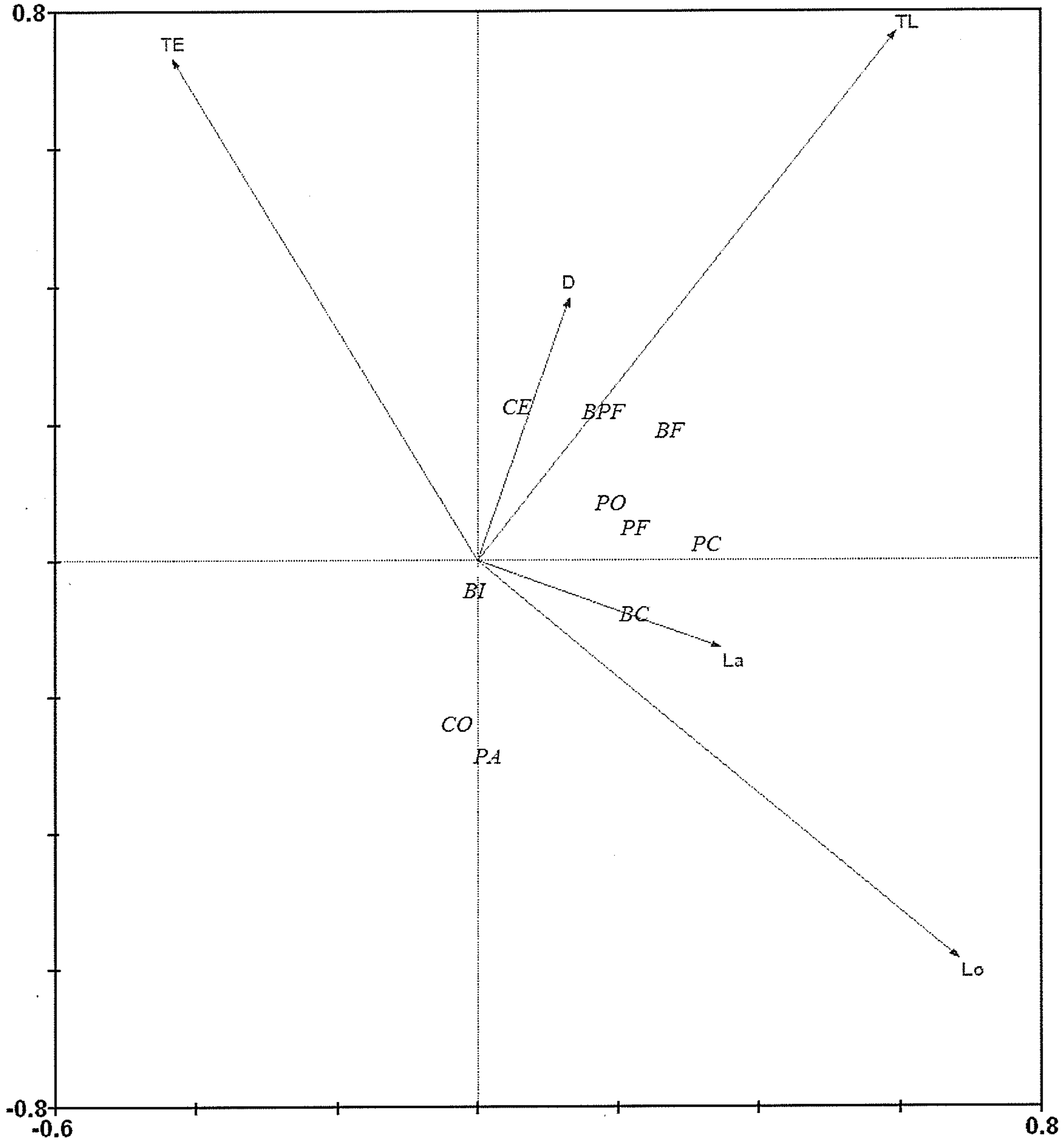

0.8
-0.8
-0.6
0.8
TE
TL
D
CE
BPF
BF
PO
PF
PC
BI
BC
La
CO
PA
Lo

Figure 6.4. RDA scatterplot illustrating the relationship between endohelminths of twenty-three Arctic marine fish species and four environmental variables. 'La' refers to latitude, 'Lo' to longitude, 'TE' to temperature and 'D' to depth. Parasite species codes are listed in Table 6.2. Monte Carlo test for significance yielded an F-ratio of 23.603 and P-value of 0.002.

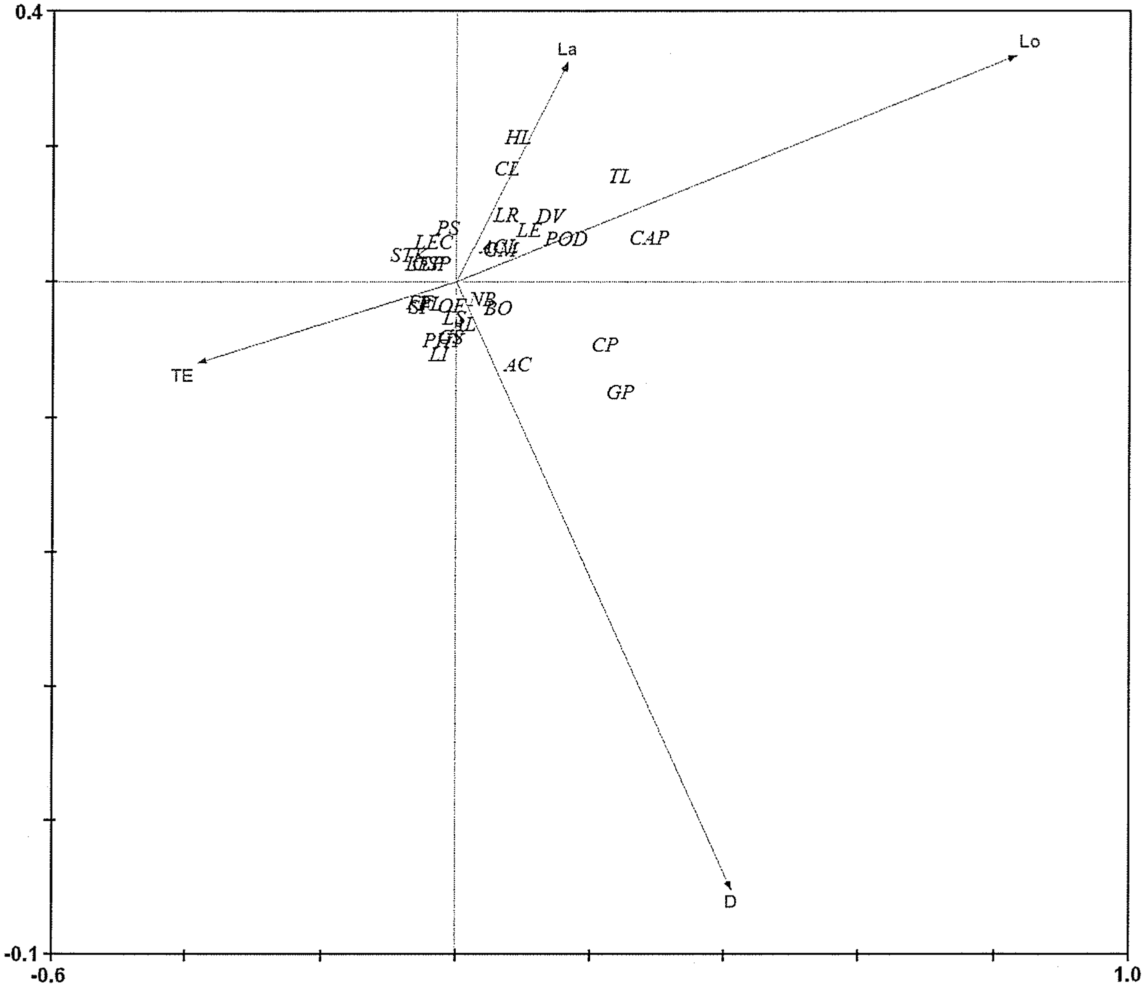
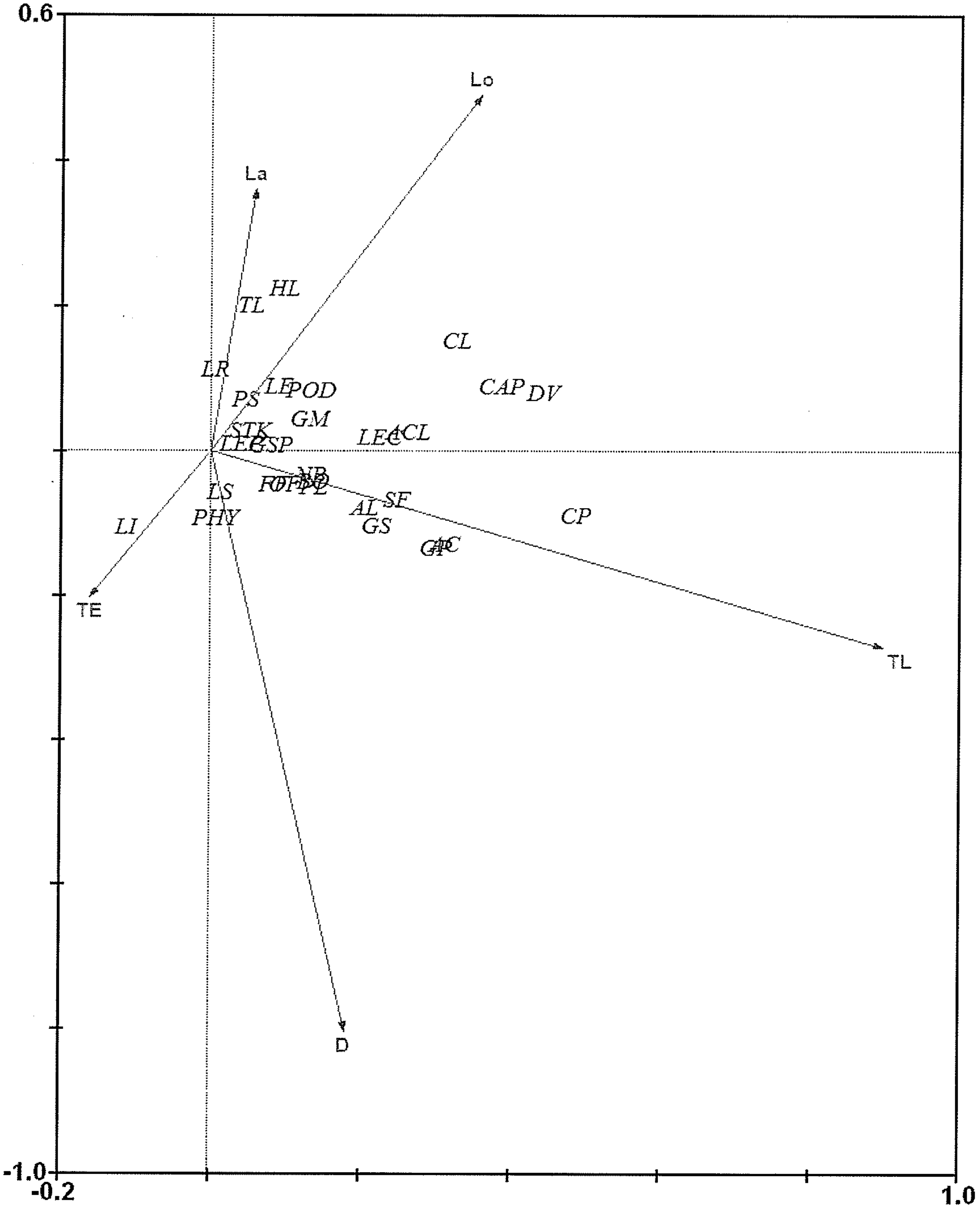

0.4
-0.1
-0.6
1.0
La
Lo
TE
D
HL
CL
TL
LR
DV
PS
LE
LEC
POD
CAP
NB
BO
CP
AC
GP
LI

Figure 6.5. RDA scatterplot illustrating the relationship between endohelminths of twenty-three Arctic marine fish species and five environmental variables. 'La' refers to latitude, 'Lo' to longitude, 'TL' to total fish length, 'TE' to temperature and 'D' to depth. Parasite species codes are listed in Table 6.2. Monte Carlo test for significance yielded an F-ratio of 67.457 and P-value of 0.002.


0.6
-1.0
-0.2
1.0
Lo
La
HL
TL
CL
LR
LE
POD
CAP
DV
PS
GM
STK
LEC
ACL
LEB
CSP
NB
FO
FF
BO
PL
LS
SF
AL
CP
PHY
GS
LI
GP
AC
TE
TL
D

CHAPTER 7: GENERAL DISCUSSION

Community studies in the Arctic marine environment are often monospecific or focus on subsistence and commercially important species with management implications. Single-species investigations are valuable as stepping stones to a broader understanding of Arctic systems, but the isolation of a species or population overlooks complex evolutionary and ecological interactions and obscures the dynamic of the system as a whole (Pianka 1987). Hall and Raffaelli (1991) stated that the primary goal of ecological studies is to understand the nature of species interactions in order to explain the observed patterns and dynamics of communities. Food webs and food web theory have been used to describe community interactions worldwide. Undoubtedly, they contribute to our understanding of practical problems such as wildlife management and toxicology (Cohen et al. 1993), but their accuracy depends on factors such as duration of study, geographical scale, species distributions, number of species included in the study, frequency of sampling and intensity with which samples are analyzed (Paine 1988). The resulting food webs then depend on the spatial, temporal, allometric and taxonomic scales set out by individual researchers (Peters 1988).

Traditional food web studies are difficult in benthic deep-sea Arctic communities because of limited sampling window, restricted sampling areas in terms of physical characteristics of the ocean bottom, biased sampling gear and perhaps the most important, these areas are speciose and community composition changes with environmental variability over a relatively small geographic area. Consequently, understanding community composition and how it changes with the physical characteristics of its environment must be a priority before any other ecological or biological studies can proceed. This idea became the underlying theme of the thesis. Before the four hypotheses discussed in Chapter 1 could be addressed, a greater understanding of community structure and species composition in Arctic marine waters was necessary. In particular, how abiotic factors affect species displacement in the context of physiological limits and preferences. A combination of latitude, longitude, temperature and depth strongly influenced the distribution of fish species in the Davis Strait/Baffin Bay region. Most species were distributed along latitude/temperature gradients while depth or longitudinal gradients were more important to others. Fish distribution along these gradients signified gradually changing species composition relative to physical and environmental characteristics. Because of this gradually shifting community composition, trophic studies within the region should focus on shifting trophic dynamics rather than fixed food web constructs. This is a significant finding as the majority of communities worldwide are described in terms of energy transfer through fixed food webs. Such descriptions may be useful in small, static communities, but in most marine environments and particularly in the Arctic, pathways will disappear and appear based on geographical position.

A significant component of the thesis dealt with how best to describe the trophic structure of deep-sea Arctic fish communities in this complex environment. Theoretically, if one particular area was chosen, traditional methods of food web construction should result in an accurate description of trophic patterns within that community. Hypothesis 1 was: if trophic guilds within a community represent differences in feeding behaviour, diet analysis would reveal the presence of several trophic guilds within the Arctic marine environment and from this a fixed food web could be developed. Traditional methods, such as trophic guild determination, as the basis of food web construction are not appropriate for Arctic communities due to the prevalence of generalist feeding and infections by non-host specific parasites. Instead, a multivariate approach focusing on habitat utilization (benthic, benthopelagic, pelagic) best described the dynamic of these Arctic marine communities. Benthic and benthopelagic species were separated out based on food group consumption and endohelminth infections, as well as those species preferring shallower habitats by more specific dietary requirements. Single linkages in complex food webs are useful when examining specific predator/prey relationships, but they contribute little to the mechanics of these ever-changing 'microcommunities'. More effective methods of understanding trophic relationships in deep-sea Arctic communities require the identification of trophic groups through habitat utilization.

Trophic relationships are most commonly determined through diet analysis. This is a useful method to determine trophic linkages, but in most cases, it provides only short-term information and fails to elucidate the full spectrum of a species' diet (Sholto-Douglas et al. 1991). Hypothesis 2 focussed on the importance of parasite communities and stable isotope data in defining trophic linkages. Chapters 4 and 5 investigated both methods and found that, within the context of trophic 'groups' based on habitat utilization, both methods provided information regarding feeding strategy, although endohelminth communities represented a more precise tool in the determination of trophic relationships. Results from Chapter 4 indicated that trophic groups were separated based on utilization of food groups within certain habitat zones (benthic, benthopelagic) and were parasitized by endohelminths whose intermediate hosts utilized the same zones. Consequently, parasite infections which indirectly provide longer term diet data can be used to support or replace diet data when describing trophic relationships in the Arctic deep-sea. Similarly, stable isotope analyses from many environments can supplement information on diet (Kline et al. 1998, Monteiro et al. 1991, Sholto-Douglas et al. 1991, Thomas and Cahoon 1993, Wainright et al. 1993). Because animals are similar in isotopic composition to their diets, it is often possible to determine an individual's diet and assign it a specific trophic level. However, my interpretation in Chapter 4 supports Dayton and Hessler's (1972) belief that in deep-sea environments, trophic levels merge and the specific roles of predators are not as distinguishable from those of detritivores. Stable isotopes may not be as useful in the deep sea as in other environments in terms of describing the individual trophic position of an individual species. The purpose of Chapter 5 was to test this idea and determine how useful stable isotopes are in the description of trophic relationships within the Arctic deep-sea. Although stable isotopes did not show the separation of taxa into clear trophic positions, differences in carbon and nitrogen isotopes did depict patterns in habitat utilization and feeding strategy. Preference for benthic vs. benthopelagic habitats defined carbon and nitrogen isotopic signatures more so than fish size, suggesting that similar isotope ratios were due to comparable diets within each habitat zone. So, although stable isotopes are useful in defining species in terms of habitat preference, parasite and stomach content data are most useful in determining trophic relationships within the Arctic deep-sea.

Chapter 6 represented an extension of hypotheses 1 and 2 with a focus on environmental impacts. The first five chapters illustrated that a) fish community composition (i.e., assemblage) is significantly affected by changing environmental factors within a relatively small area, and b) diet, parasite and stable isotope data can be used to predict feeding preferences for habitat groups (benthic, benthopelagic, pelagic) in Arctic marine waters. The next obvious question was whether or not environmental variables significantly affected prey consumption of fish within this region and if so, which variables were best at predicting diet. An examination of food group preference with environmental variables (Chapter 6) illustrated that environmental variables such as latitude, longitude, temperature and depth were the best predictors of food group preference in deep-sea Arctic fish species. Changing environmental variables determine species distribution and community composition at every trophic level, influencing the types of prey available within each microcommunity. Many larval fish remain closely inshore before swimming or being passively transported offshore as adults or juveniles (Scott and Scott 1988). Consequently, inshore fish predators will have exclusive access to these individuals as food items while strictly off-shore species will be forced to feed on other fish and invertebrates. Other prey types will have a more gradual increase or decrease along environmental gradients, further shaping the pool of available prey species at each geographic position. My results also support the idea that fixed food webs are not appropriate for Arctic marine systems as a whole. Rather, assessing benthic communities along shifting environmental gradients is more effective when defining trophic relationships within this unique environment.

Grouping prey species based primarily on habitat utilization is useful in regions that are less well-known and speciose, especially the small invertebrates. Paine (1988) stated that the aggregation of lower-level organisms such as small invertebrates is useful because they are smaller, less observable, less well known ecologically and likely more similar in terms of trophic position. A limitation, especially in large oceanic environments, is the possible existence of different feeding strategies within one taxonomic group. For example, within the Copepoda, several species of calanoids are carnivorous (e.g. genus *Euchaeta*) (Yen 1991). Though *Euchaeta* spp. was rare in my study, the regular occurrence of this genus in a fish's diet may alter its trophic position and make the determination of trophic position more difficult. Consequently, grouping all Copepoda together into one trophic group may compromise descriptions of trophic position. Paine (1988) discussed this problem in terms of food web construction, stating that aggregation of taxa into more 'convenient' units excludes the treatment of species from web structure and alters the intrinsic nature of community structure. There are problems in grouping taxa for trophic studies, but until detailed studies are available for each species within this and other environments, I believe grouping the more speciose taxa for the purpose of trophic evaluation is valid.

Hypothesis 3 dealt with age and body size as a reflection of trophic position, i.e. feeding preferences, parasite communities and stable isotopes will differ with increasing body size. Fish species were divided into taxa based on size (chapter 4) and results showed that although larger food groups were slightly more abundant in larger fish taxa, deep-sea Arctic fishes remained generalist feeders with overlapping diet preferences. No significant relationship was found between fish size and carbon or nitrogen isotope ratios (chapter 5) but in both chapters, habitat utilization was the most important factor in determining trophic relationships. Fish size was found to influence food group preference for most fish species (chapter 6) but it was not the best indicator of diet preference. When data were combined, fish size and age were found to be less important in diet selection and determination of trophic position than previously assumed. The diet of most fish species remained similar throughout their ontogeny even though larger fish fed on larger prey. This is likely due to the propensity of Arctic species for generalist feeding as a result of low levels of competition. Results in this chapter contrast with the majority of reports in the literature. Similar studies in different marine or freshwater environments have found that fish undergo large dietary shifts during their ontogeny, usually due to larger gape size (Juanes et al. 2002, King 2005, Werner 1977). Though increasing gape size allows fish to expand their diet to include larger prey such as fish and large invertebrates, it does not significantly affect individual trophic position as indicated by food group consumption, stable isotopes or parasite infracommunities.

Hypothesis 4 discussed species diversity with latitude, postulating that if species diversity decreases with increasing latitude, the number of trophic guilds will be smaller and contain more species at higher latitudes. Though the concept of guilds was rejected in Chapter 4, the idea put forth is important with respect to changing dynamics in Arctic communities. If the diversity of large-bodied predator species decreases with increasing latitude, the remaining fish species at higher latitudes will feed on a wider variety of food items due to the increased availability of prey in the absence of predators. In the Davis Strait/Baffin Bay region, larger-bodied predators such as *C. fabricii*, *S. kaupi*, *C. rupestris* and *A. rostrata* disappear to the north. This reduction in predator diversity may influence changes in food group consumption seen in Chapter 6. In the northern subarea (0A), a larger number of food item groups were consumed by the remaining fish species, including copepods, benthic crustaceans, polychaetes, pelagic crustaceans, pelagic fish and benthic fish. Consequently, this hypothesis may be altered to state that species assemblages and in turn, food webs, will contain fewer species with increasing latitude.

These food webs will likely be more complex in terms of number of linkages per constituent species as remaining taxa broaden their diets and become associated with a larger number of prey items.

It is apparent that deep-sea communities of the eastern Arctic are complex. Changing physicochemical variables within the Davis Strait and Baffin Bay have resulted in continually changing species composition and trophic structure with latitude and longitude, so much so that it may be impossible to use traditional methods of trophic evaluation for the illustration of energy transfer. Rather, identification of shifting patterns within the system in the context of habitat utilization and species assemblage becomes more important, allowing scientists and resource managers to make more accurate predictions regarding community health and reactions to intensifying pressures such as commercial fishing and global warming.

LITERATURE CITED

Able, K.W. 1978. Ichthyoplankton of the St. Lawrence estuary: composition, distribution, and abundance. Journal of the Fisheries Research Board of Canada. 35: 1518-1531.

Able, K.W. and W. Irion. 1985. Distribution and reproductive seasonality of snailfishes and lumpfishes in the St. Lawrence River estuary and the Gulf of St. Lawrence. Canadian Journal of Zoology. 63:1622-1628.

Able, K.W. and D.E. McAllister. 1980. Revision of the snailfish genus *Liparis* from Arctic Canada. Canadian Bulletin of Fisheries and Aquatic Sciences. 208: 52.

Addinsoft, 2006. XLSTAT 2006 Version 2006.2. New York.

Albikovskaya, L.K. 1988. Some aspects of the biology of glacier lanternfish (*Benthosema glaciale*) over the slopes of Flemish Cap and Eastern Grand Bank. NAFO Science Council Studies. 12: 37-42.

Albikovskaya, L.K. and O.V. Gerasimova. 1993. Food and feeding patterns of cod (*Gadus morhua* L.) and beaked redfish (*Sebastes mentella* Travin) on Flemish Cap. Northwest Atlantic Fisheries Organization Scientific Council Studies. 19: 31-39.

Altukhov, K.A. 1979. The reproduction and development of the arctic cod, *Boreogadus saida* in the White Sea. Journal of Ichthyology. 19(1): 104-113.

Alvim, M.C. and A.C. Peret. 2004. Food resources sustaining the fish fauna in a section of the upper Sao Francisco River in Tres Marias, MG, Brazil. Brazilian Journal of Biology. 64(2): 195-202.

Amsinck, S.L., A. Strzelczac, R. Bjerring, F. Landkildehus, T.L. Lauridsen, K. Christoffersen and E. Jeppesen. 2006. Lake depth rather than fish planktivory determines Cladoceran community structure in Faroese lakes – evidence from contemporary data and sediments. Freshwater Biology. 51(11): 2124-2142.

Anderson, J.T. 1994. Feeding ecology and condition of larval and pelagic juvenile redfish *Sebastes* sp. Marine Ecology Progress Series. 104(3): 211-226.

Andriyashev, A.P. 1949. On the species composition and distribution of sculpins of the genus *Triglops* Reinh. in the northern seas. Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva Akademii Nauk SSSR. 1: 194-209. (Translated from Russian).

Andriyashev, A.P. 1954. Fishes of the northern seas of the USSR. Moscow &

Leningrad: Izdatel'stvo Akademii Nauk Soyuza Sovetskii Sotsialisticheskii Republik. [Translated from Russian by the Israel Program for Scientific Translations, Jerusalem, Translation No. OTS 63-11160, 1964.]

Andriyashev, A.P. 1964. Fishes of the northern seas of the USSR. Pp 566 *In* E.N. Pavlovskii [Ed.]. Keys to the fauna of the USSR, Volume 53. Translated by the Israel Programme of Scientific Translation, Jerusalem.

Andriyashev, A.P. 1970. Cryopelagic fishes of the Arctic and Antarctic and their significance in polar ecosystems. Pp. 297-304 *In* M.W. Holdgate [ed.]. Antarctic Ecology, Volume 1. Academic Press, New York.

Angel, A. and F.P. Ojeda. 2001. Structure and trophic organization of subtidal fish assemblages on the northern Chilean coast: the effect of habitat complexity. Marine Ecology Progress Series. 217: 81-91.

Angel, M.V. 1997. What is the deep sea? Pp. 2-37 *In* D.J. Randall and A.P. Farrell (Eds.). Deep-Sea Fishes. Academic Press, San Diego.

Arctic Council. 2004. Arctic Marine Strategic Plan, Final Draft. Pp. 1-13.

Arias-Gonzalez, J.E. and S. Morand. 2006. Trophic functioning with parasites: a new insight for ecosystem analysis. Marine Ecology Progress Series. 320: 43-53.

Arthur, J.R. and E. Albert. 1992a. Parasites of Greenland halibut (*Reinhardtius hippoglossoides*) from the Atlantic Ocean off Canada. Bulletin of the Canadian Society of Zoologists. 23(2): 26. (31st Annual Meeting Canadian Society of Zoologists, St. Francis Xavier University, 13-17 May 1992. Program and Abstracts).

Arthur, J.R. and E. Albert. 1992b. Parasites as biological tags for Greenland halibut (*Reinhardtius hippoglossoides*) from the Atlantic Ocean off Canada. 67th Annual Meeting American Society of Parasitologists, 4-8 August 1992, Philadelphia, PA. Program and Abstracts. Pp. 63.

Arthur, J.R. and H.P. Arai. 1980. Studies on the parasites of Pacific herring (*Clupea harengus pallasi* Valenciennes): a preliminary evaluation of parasites as indicators of geographical origin for spawning herring. Canadian Journal of Zoology. 58(4): 521-527.

Atkinson, D.B., W.R. Bowering, D.G. Parsons, Sv.Aa. Horsted and J.P. Minet. 1982. A review of the biology and fisheries for roundnose grenadier, Greenland halibut and northern shrimp in Davis Strait. NAFO Scientific Council Studies. 3: 7-27.

Avdeev, V.V., G.V. Avdeev and B.I. Lebedev. 1989. The study of population pattern and migration routes of the Sea of Okhotsk pollock by parasitologic (sic) indication technique. Pp. 67-75 *In* Avdeev, V.V., G.V. Avdeev and B.I. Lebedev (Eds.). Investigation in parasitology: collection of papers. Dal'nevostochnoe otdelenie AN SSSR. Vladivostok. 1989: 1-164.

Backus, R.H. 1951. New and rare records of fishes from Labrador. Copeia. 4: 288-294.

Backus, R.H. 1957. The fishes of Labrador. Bulletin of the American Museum of Natural History. 113: 273-338.

Badalamenti, F., G. D'Anna, J.K. Pinnegar and N.V.C. Polunin. 2002. Size-related trophodynamic changes in three target fish species recovering from intensive trawling. Marine Biology. 141: 561-570.

Bagenal, T.B. 1955. The growth rate of the long rough dab *Hippoglossoides platessoides* (Fabr.) – a correction. Journal of the Marine Biological Association of the United Kingdom. 34(3): 643-647.

Bakay, Y.I. 1990. On infestation of marine redfishes (*Sebastes* genus) of the North Atlantic by the copepod *Sphyrion lumpi* (Kroyer, 1845). Pp. 27-36 *In* L.W. Reimer [Ed.]. Proceedings of the International Workshop on *Sphyrion lumpi* 3-5 October 1989, Gustrow (Lahnwitz), GDR. Institut fur Biologie, Padagogische Hochschule Gustrow.

Barret, B.E. 1968. First occurrence of Greenland halibut (*Reinhardtius hippoglossoides*) in the Bay of Fundy. Journal of the Fisheries Research Board of Canada. 25: 2721-2722.

Barletta, M. and S.J.M. Blaber. 2007. Comparison of fish assemblages and guilds in tropical habitats of the Emblay (Indo-West Pacific) and CAETE (Western Atlantic) estuaries. Bulletin of Marine Science. 80(3): 647-680.

Barsukov, B.B. and G.P. Zakharov. 1972. Morphological and biological peculiarities of Acadian redfish. Commercial fishes of the Northwest Atlantic and their dwelling conditions. Trudy PINRO. 28: 143-173.

Barsukov, V.V., N.I. Litvinenko and V.P. Serebryakov. 1984. Manual for the identification of redfish species of the North Atlantic and adjacent areas. USSR Ministry of Fisheries. Atlantic Scientific Research Institute of Fisheries and Oceanography, Kaliningrad, USSR. Pp. 28. [Translated from Russian in Canadian Translations of Fisheries and Aquatic Sciences. 5168, 1985].

Bauerfeind, E., Leip, T., R.O. Ramseier. 2005. Sedimentation at the permanently ice-covered Greenland continental shelf (74°57.7'N/12°58.7'W): significance of biogenic and lithogenic particles in particulate matter flux. Journal of Marine Systems. 56: 151:166.

Beebe, W. 1933. Deep-sea fishes of the Bermuda oceanographic expeditions. No. 2. Family Alepocephalidae. Zoologica. 16: 15-147.

Belicka, L.L., R.W. Macdonald and H.R. Harvey. 2002. Sources and transport of organic carbon to shelf, slope, and basin surface sediments of the Arctic Ocean. Deep-sea Research I. 49: 1463-1483.

Berestovskiy, E. G. 1990. Feeding in the skates, *Raja radiata* and *Raja fyllae*, in the Barents and Norwegian Seas. Journal of Ichthyology. 29(8):88-96.

Bergstad, O.A. and J.D.M. Gordon. 1994. Deep-water ichthyoplankton of the Skagerrak with special reference to *Coryphaenoides rupestris* GUMMERUS, 1765 (Pisces, Macrouridae) and *Argentina silus* (ASCANIUS, 1775) (Pisces, Argentinidae). Sarsia. 79: 33-43.

Bergstad, O.A. and A.S. Hoines. 1998. Do herring (*Clupea harengus* L.) spawners influence the migratory tendency of cod (*Gadus morhua* L.)? ICES Journal of Marine Science. 55(2): 325-328.

Bertolo, A. and P. Magnan. 2006. Spatial and environmental correlates of fish community structure in Canadian Shield lakes. Canadian Journal of Fisheries and Aquatic Sciences. 63(12): 2780-2792.

Bjelland, O., O.A. Bergstad, J.E. Skjaeraasen and K. Meland. 2000. Trophic ecology of deep-water fishes associated with the continental slope of the eastern Norwegian Sea. Sarsia. 85: 101-117.

Boily, F. and D.S. Marcogliese. 1995. Geographical variations in abundance of larval anisakine nematodes in Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) from the Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Sciences. 52(Supplement 1): 105-115.

Boje, J., F. Riget and M. Koie. 1997. Helminth parasites as biological tags in population studies of Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)), in the north-west Atlantic. ICES Journal of Marine Science. 54(5): 886-895.

Bonaldo, R.M., J.P. Krajewski, C. Sazima and I. Sazima. 2007. Dentition damage in parrotfishes feeding on hard surfaces at Fernando de Noronha Archipelago, southwest Atlantic Ocean. Marine Ecology Progress Series. 342: 249-254.

Borg, I. and P. Groenen. 2005. Modern Multidimensional Scaling: theory and applications. 2nd Edition. Springer-Verlag, New York. Pp. 614

Borgsteede, F.H.M., H.G.J. Bus, J.A.W. Verplanke and W.P.J. Van Der Burg. 1991. Endoparasitic helminths of the Harbour Seal, *Phoca vitulina*, in the Netherlands. Netherlands Journal of Sea Research, 28(3): 247-250.

Bourgeois, C.E. and I.H. Ni. 1984. Metazoan parasites of Northwest Atlantic redfishes (*Sebastes* spp.). Canadian Journal of Zoology. 62: 1879-1885.

Bowering, W.R. 1983. Age, growth, and sexual maturity of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in the Canadian Northwest Atlantic. Fisheries Bulletin. 81: 599-611.

Bowering, W.R. 1987. Distribution and abundance of Greenland halibut in Davis Strait (NAFO Subareas 0 and 1) from a Canadian research vessel survey in 1986. NAFO SCR Doc. 87/22, Ser. No. N1305. Pp. 1-10.

Bowering, W.R. and G.R. Lilly. 1992. Greenland halibut (*Reinhardtius hippoglossoides*) off southern Labrador and northeastern Newfoundland (northwest Atlantic) feed primarily on capelin (*Mallotus villosus*). Netherlands Journal of Sea Research. 29(1-3): 211-222.

Bowman, R.E., C.E. Stillwell, W.L. Michaels and M.D. Grosslein. 2000. Food of northwest Atlantic fishes and two common species of squid. NOAA Tech. Memo. NMFS-NE 155, 138 p.

Bradstreet, M.S.W., K.J. Finely, A.D. Sekerak, W.B. Griffiths, C.R. Evans, M.F. Fabijan and H.E. Stallard. 1986. Aspects of the biology of Arctic cod (*Boreogadus saida*) and its importance in Arctic marine food chains. Canadian Technical Report of Fisheries and Aquatic Sciences. 1491: 1-193.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs. 27: 325-349.

Bray, R.A. 1979. Digenea in marine fishes from the eastern seaboard of Canada. Journal of Natural History. 19: 377-405.

Bray, R.A. 1987. A revision of the family Zoogonidae Odhner, 1902 (Platyhelminthes: Digenea): Subfamily Lepidophyllinae and comments on some aspects of biology. Systematic Parasitology. 9: 83-123.

Bray, R.A. and R.A. Campbell. 1995. Fellodistomidae and Zoogonidae (Digenea) of deep-sea fishes of the NW Atlantic Ocean. Systematic Parasitology. 31: 201-213.

Bray, R.A. and D.I. Gibson. 1986. The Zoogonidae (Digenea) of fishes from the north-east Atlantic. Bulletin of the British Museum of Natural History. Zoological Series. 51: 127-206.

Bray, R.A. and D.I. Gibson. 1991. The Acanthocolpidae (Digenea) of fishes from the north-east Atlantic: the status of *Neophasis* Stafford, 1904 (Digenea) and a study of North Atlantic forms. Systematic Parasitology. 19: 95-117.

Bray, R.A. and D.I. Gibson. 1995. The Lepocreadiidae (Digenea) of fishes from the north-east Atlantic: a review of the genus *Lepidapedon* Stafford, 1904. Systematic Parasitology. 31: 81-132.

Brubacher Development Strategic Inc. 2004. A Strategic Framework for Nunavut Fisheries. Pp. 1-54.

Bruun, A.F. 1937. Contributions to the life histories of the deep-sea eels: Synaphobranchidae. Dana-Report. 9: 31.

Bulman, C, F. Althaus, X. He, N.J. Bax and A. Williams. 2001. Diets and trophic guilds of demersal fishes of the south-eastern Australian shelf. Marine and Freshwater Research. 52: 537-548.

Bunn, S.E., D.R. Barton, H.B.N. Hynes, G. Power & M.A. Pope. 1989. Stable isotope analysis of carbon flow in a tundra river system. Canadian Journal of Fisheries and Aquatic Sciences. 46: 1769–1775.

Burns, T.P. 1989. Lindeman's contradiction and the trophic structure of ecosystems. Ecology. 70(5): 1355-1362.

Burreson, E.M. and R.E. Olson. 1974. Seasonal variations in the populations of two hemiurid trematodes from the Pacific Staghorn sculpin, *Leptocottus armatus* Girard, in and Oregon estuary. The Journal of Parasitology. 60(5): 764-767.

Bush, A.O., R.W. Heard, Jr. and R.M. Overstreet. 1993. Intermediate hosts as source communities. Canadian Journal of Zoology. 71: 1358-1363.

Cabana, G. And J.B. Rasmussen. 1996. Comparison of aquatic food chains using nitrogen isotopes. Proceedings of the National Academy of Sciences (USA). 93: 10844-10847.

Cai, W., C. Li, X. Jia, Q. Lin and J. Gan. 2007. Multivariate analysis and evaluation on the community structure of phytoplankton in west Guangdong waters. Acta Hydrobiologica Sinica. 31(2): 155-161.

Campbell, R.A. 1992. A new digenetic trematode, *Gibsonia borealis* sp.n. (Lepocreadiidae: Lepidapedinae), parasitic in the rattail *Macrourus berglax* from the Flemish Cap off Newfoundland. Journal of Helminthological Society of Washington. 59(1): 5-8.

Campbell, R.A., R.L. Haedrich and T.A. Munroe. 1980. Parasitism and ecological relationships among deep-sea benthic fishes. Marine Biology. 57: 301-313.

Campbell, R.A., S.J. Correia and R.L. Haedrich. 1982. A new monogenean and cestode from the deep-sea fish, *Macrourus berglax* Lacepede, 1802, from the Flemish Cap off Newfoundland. Proceedings of the Helminthological Society of Washington. 49: 169-175.

Campbell, R.A. and T.A. Munroe. 1977. New hemiurid trematodes from deep-sea benthic fishes in the western North Atlantic. Journal of Parasitology. 63(2): 285-294.

Cannon, T.C., D.R. Glass and C.M. Prewitt. 1991. Habitat use patterns of juvenile Arctic cod in the coastal Beaufort Sea near Prudhoe Bay, Alaska. American Fisheries Society Symposium. 11: 157-162.

Cardinale, M. 2000. Ontogenetic diet shifts of bull-rout, *Myoxocephalus scorpius* (L.), in the south-western Baltic Sea. Journal of Applied Ichthyology. 16:231-239.

C.A.R.E. 2006. Manual on generalized age determination: procedures for groundfish. Committee of Age Reading Experts. Canada/U.S. Groundfish Committee. Pp. 52.

Carney, J.P. and T.A. Dick. 2000. Helminth communities of yellow perch (*Perca flavescens* (Mitchill)): determinants of pattern. Canadian Journal of Zoology. 78: 538–555.

Cartes, J.E., P. Abello, D. Lloris, A. Carbonell, P. Torres, F. Maynou and L. Gil de Sola. 2002. Feeding guilds of western Mediterranean demersal fish and crustaceans: an analysis based on a spring survey. Scientia Marina. 66(2): 209-220.

Chambers, C.A. and T.A. Dick. 2005. Trophic structure of one deep-sea benthic community in the eastern Canadian Arctic: application of food, parasites and multivariate analysis. Environmental Biology of Fishes. 74: 365-378.

Chambers, C.A. and T.A. Dick. 2007. Using environmental variables to predict the structure of deep-sea Arctic fish communities: implications for food web construction. Arctic, Antarctic and Alpine Research. 39(1): 2-8.

Chen, Y., D.A. Jackson and H.H. Harvey. 1992. A comparison of von Bertalanffy and polynomial functions in modeling fish growth rate. Canadian Journal of Fisheries and Aquatic Sciences. 49: 1228-1235.

Chernova, NV, CF von Dorrien, AV Neyelov and L. Saldanha. 1992. Benthic fish investigations. Pp. 101-109 *In* Rahcor, E. [Ed]. Scientific Cruise Report of the 1991 Arctic Expedition ARK VIII/2 of RV. Polar-stern. Ber Polarforsch. 115.

Choudhury, A., and Dick, T.A. 2000. Richness and diversity of helminth communities in tropical freshwater fishes: empirical evidence. Journal of Biogeography. 27: 935–956.

Chubb, J.C. 1970. The parasite fauna of British freshwater fish. Symposium of the British Society for Parasitology. 8: 119–144.

Cocheret de la Morinière, E., B.J.A. Pollux, I. Nagelkerken, M.A. Hemminga, A.H.L. Huiskes and G. Ven der Velde. 2003. Ontogenetic dietary changes of coral reef fishes in the mangrove-seagrass-reef continuum: stable isotopes and gut-content analysis. Marine Ecology Progress Series. 246: 279-289.

Cohen, D.M. 1964. Family Bathylagidae, pp. 34-38. *In* Fishes of the western North Atlantic. Memoirs. Sears Foundation Marine Research. 1(4). Yale University, New Haven.

Cohen, D.M., T. Inada, T. Iwamoto and N. Scialabba. 1990. Gadiform fishes of the world (Order Gadiformes). FAO Species Catalogue, FAO Fisheries Symposium. 125(10): 442

Cohen, J.E. 1977. Food webs and dimensionality of trophic niche space. Proceedings of the National Academy of Sciences of the United States of America. 74: 4533-4536.

Cohen, J.E. 1978. Food Webs and Niche Space. Princeton University Press, Princeton, NJ, USA. Pp. 189.

Cohen, J.E. 1990. Food webs and community structure. Pp. 1-22 *In* J.E. Cohen, F. Briand and C.M. Newman (Eds.). Community Food Webs. Data and Theory. Biomathematics Volume 20. Springer-Verlag. Berlin. Pp. 308.

Cohen, J.E., R.A. Beaver, S.H. Cousins, D.A. DeAngelis, D.A. Goldwasser, L. Heong, K.L. Holt, R.D. Kohn, A.J. Lawton, J.H. Martinez, N. O'Malley, R. Page, L.M. Patten, B.C. Pimm, S.L. Polis, G.A. Rejmanek, M. Schoener, T.W. Schoenly, K. Sprules, W.G. Teal, J.M. Ulanowicz, P.H. Warren, H.M. Wilbur and P. Yodzis. 1993. Improving food webs. Ecology. 74: 252-258.

Cohen, J.E., S.L. Pimm, P. Yodzis and J. Saldanas. 1993. Body sizes of animal predators and animal prey in food webs. Journal of Animal Ecology. 62: 67-78.

Collard, S.B. 1970. Some aspects of host-parasite relationships in mesopelagic fishes. *In* S.F. Snieszko (Ed.), A Symposium on Diseases of Fishes and Shellfishes. American Fisheries Society Special Publications. 5: 41-56.

Cone, D.K. 1995. Monogenea (Phylum Platyhelminthes). Pp. 289-328 *In* P.T.K. Woo (Ed.). Fish Diseases and Disorders. Volume 1: Protozoan and Metazoan Infections. CAB International, Wallingford.

Cortés, E. 1997. A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes. Canadian Journal of Fisheries and Aquatic Sciences. 54: 726-738.

Cox, M.F. and M.A.A. Cox. 2001. Multidimensional Scaling. Chapman and Hall, London. Pp. 308

Coyle, K.O., J.A. Gillispie, R.L. Smith and W.E. Barber. 1997. Food habits of four demersal Chukchi Sea fishes. American Fisheries Society Symposium. 19: 310-318.

Cuny, J., P.B. Rhines and R. Kwok. 2005. Davis Strait volume, freshwater and heat fluxes. Deep-Sea Research I. 52: 519-542.

Dannevig, A. 1919. Fish-eggs and larvae. Pp. 1-80 *In* J. Hjort (Ed.) Canadian Fish. Expedition 1914-15. Investigators of Canada. Department of Naval Service Canada. King's Printer, Ottawa.

Davenport, S.R. and N.J. Bax. 2002. A trophic study of a marine ecosystem off southeastern Australia using stable isotopes of carbon and nitrogen. Canadian Journal of Fisheries and Aquatic Sciences. 59: 514-530.

Dawe, E.G., W.R. Bowering and J.B. Joy. 1998. Predominance of squid (*Gonatus* spp.) in the diet of Greenland halibut (*Reinhardtius hippoglossoides*) on the deep slope of the northeast Newfoundland continental shelf. Fisheries Research (Amsterdam). 36(2-3): 267-273.

Dayton, P.K. and R.R. Hessler. 1972. Role of biological disturbance in maintaining diversity in the deep-sea. Deep-Sea Research. 19: 199-208.

DeAngelis, D.L. 1992. Dynamics of Nutrient Cycling and Food Webs. Chapman & Hall, London. Pp. 270.

DeAngelis, D.L., W. Post and G. Sugihara. 1982. Current Trends in Food Web Theory. Oak Ridge National Laboratory, Oak Ridge, TN. ORNL-5983.

Deblois, E.M. and G.A. Rose. 1995. Effect of foraging activity on the shoal structure of cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences. 52(11): 2377-2387.

Deblois, E.M. and G.A. Rose. 1996. Cross-shoal variability in the feeding habits of migrating Atlantic cod (*Gadus morhua*). Oecologia (Heidelberg). 108(1): 192-196.

Dempson, J.B., M. Shears and M. Bloom. 2002. Spatial and temporal variability in the diet of anadromous Arctic charr, *Salvelinus alpinus*, in northern Labrador. Environmental Biology of Fishes. 64: 49-62.

DeNiro, M.J. and S. Epstein. 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochimica et Cosmochimica Acta. 42: 495-506.

De Ruiter, P.C., V. Wolters and J.C. Moore. Dynamic Food Webs. 2005. Dynamic Food Webs. Multispecies Assemblages, Ecosystem Development and Environmental Change. Theoretical Ecology Series. Elsevier Inc. Burlington, MA, USA.

Dick, T.A. and C.A. Chambers. 2005. Fishing in Canadian Arctic Marine Waters: A need for national policies and priorities. Meridian. Canadian Polar Commission. Pages 1-5.

Dick, T.A and A. Choudhury. 1995. Phylum Nematoda. Pp. 415-446 *In*, P.T.K. Woo (Ed.). Fish Diseases and Disorders. Volume 1. Protozoan and Metazoan Infections. CAB International, Wallingford.

Dogiel, V.A. 1964. Ecology of the parasites of freshwater fishes. Pp. 1–47 *In* V.A. Dogiel, G.K. Petrushevski, and Y.I. Polyanski (Eds.). Leningrad University Press, Leningrad. Parasitology of fishes. [Translation by Z. Kabata. 1970. T.F.H. Publications Inc., Hong Kong.]

Du Buit, M.H. 1978. Alimentation de quelques poissons téléostéens de profondeur dans la zone du seuil de Wyville Thomson. Oceanologica Acta. 1(2): 129-134.

Du Buit, M.H. 1995. Food and feeding of cod (*Gadus morhua* L.) in the Celtic Sea. Fisheries Research (Amsterdam). 22(3-4): 227-241.

Dunbar, M.J. 1947. Marine young fish from the Canadian eastern Arctic. Bulletin. Fisheries Research Board of Canada. 73: 1-11.

Dunbar, M.J. and H.H. Hildebrand. 1952. Contribution to the study of the fishes of Ungava Bay. Journal of the Fisheries Research Board of Canada. 9: 83-128.

Ebeling, E. and S. Alshuth. 1989. Food preferences and diseases of *Myoxocephalus scorpius* in the German bight. p. 1-6. ICES, C.M. 1989/G:48, demersal Fish Committee, Ref. MEQC.

Ennis, G.P. 1970a. Age, growth and sexual maturity of the shorthorn sculpin, *Myoxocephalus scorpius*, in Newfoundland waters. Journal of the Fisheries Research Board of Canada. 2782155-2158.

Ennis, G.P. 1970b. Reproduction and associated behaviour in the shorthorn sculpin, *Myoxocephalus scorpius*, in Newfoundland waters. Journal of Fisheries Research Board of Canada. 27: 2037-2045.

Fahay, M.P. 1983. Guide to the early stages of marine fishes occurring in the western North Atlantic Ocean, Cape Hatteras to the southern Scotian Shelf. Journal of Northwest Atlantic Fisheries Science. 4: 423.

Fedorov, V.V. 1984. Cottidae. Pp. 1243-1260. *In* P.J.P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen and E. Tortonese (Eds.) Fishes of the North-eastern Atlantic and the Mediterranean. UNESCO, Paris. Vol. 3.

Ferraton, F., M. Harmelin-Vivien, C. Mellon-Duval and A. Souplet. 2007. Spatio-temporal variation in diet may affect condition and abundance of juvenile European hake in the Gulf of Lions (NW Mediterranean). Marine Ecology Progress Series. 337: 197-208.

Fjosne, K. and J. Gjosaeter. 1996. Dietary composition and the potential of food competition between 0-group cod (*Gadus morhua* L.) and some other fish species in the littoral zone. ICES Journal of Marine Science. 53(5): 757-770.

Forsberg, B.R., C.A.R.M. Araujo-Lima, L.A. Martinelli, R.L. Victoria & J.A. Bonassi. 1993. Autotrophic carbon sources for fish of the Central Amazon. Ecology. 74: 643–652.

France, R.L. 1995. Differentiation between littoral and pelagic food webs in lakes using carbon isotopes. Limnology and Oceanography. 40: 1310-1313.

Fry, B. 1988. Food web structure on Georges Bank from stable C, N, and S isotopic compositions. Limnology and Oceanography. 33: 1182-1190.

Fry, B. and E. Sherr. 1984. d13C measurements as indicators of carbon flow in marine and freshwater ecosystems. Contributions in Marine Science. 27: 15-47.

Garrison, L.P. and J.S. Link. 2000. Dietary guild structure of the fish community in the northeast United States continental shelf ecosystem. Marine Ecology Progress Series. 202: 231-240.

Gartner, J.V. Jr., R.E. Crabtree and K.J. Sulak. 1997. Pp.115-182 *In* D.J. Randall and A.P. Farrell (Eds.). 1997. Deep-Sea Fishes. Academic Press, San Diego, California.

Gaston, A.J., D.K. Cairnes, R.D. Elliot and D.G. Noble. 1985. A natural history of Digges Sound. Canadian Wildlife Service. Rep. Ser. 46: 63p.

Geistdoerfer, P. 1976. Alimentation de deux Macrouridae de l'Atlantique nord:

Macrourus berglax et *Coryphaenoides rupestris* (Teleostei, Gadiformes). Revue des Travaux de l'Institut des Peches Maritimes. Nantes 40: 579-580.

Geistdoerfer, P. 1979. Recherches sur l'alimentation de Macrourus berglax Lacepede 1801 (Macrouridae, Gadiformes). Annales de l'Institut Oceanographique, Paris. 55: 135-144.

Gibson, D.I. and R.A. Bray. 1982. A study and reorganization of *Plagioporus* Stafford, 1904 (Digenea: Opecoelidae) and related genera, with special reference to forms from European Atlantic waters. Journal of Natural History. 16: 529-559.

Gibson, R.N. and R.A. Bray. 1986. The Hemiuridae (Digenea) of fishes from the northeast Atlantic. Bulletin of the British Museum of Natural History Zoology. 51: 125p.

Gibson, R.N. and L. Robb. 1996. Piscine predation on juvenile fishes on a Scottish sandy beach. Journal of Fish Biology. 49 :120-138.

Gjosaeter, J. 1973. The food of the myctophid fish, *Benthosema glaciale* (Reinhardt), from western Norway. Sarsia. 52: 53-58.

Gjosaeter, J. 1981. Growth, production and reproduction of myctophid fish, *Benthosema glaciale* (Reinhardt) from western Norway. Sarsia. 52: 1-14.

Goater, C.P., R.E. Baldwin and G. J. Scrimgeour. 2005. Physico-chemical determinants of helminth component community structure in whitefish (*Coregonus clupeaformes*) from adjacent lakes in Northern Alberta, Canada. Parasitology. 131: 713-722.

Gordon, J.D.M. and J. Mauchline. 1990. Depth related trends in diet of a deep sea bottom living fish assemblage of the Rockall trough. Pp. 439-452 *In* Trophic Relationships in Marine Environment, Barnes, M. and R.N. Gibson (Eds.), Aberdeen University Press, Aberdeen.

Gordon, J.D.M. and S.C. Swan. 1996. Validation of age readings from otoliths of juvenile roundnose grenadier, *Coryphaenoides rupestris*, a deep-water macrourid fish. Journal of Fish Biology. 49 (Supplement A): 289-297.

Grabda, J. 1989. Marine Fish Parasitology. An Outline. Polish Scientific Publishers, Warszawa. Pp. 306.

Grall, J. F. Le Loc'h, B. Guyonnet and P. Riera. 2006. Community structure and food web based on stable isotopes (δ^{15}N and δ^{13}C) analysis of a North Eastern Atlantic maerl bed. Journal of Experimental Marine Biology and Ecology. 338(1): 1-15.

Green, J.M. and D.H. Steele. 1977. Observations on marine life beneath sea ice, Resolute

Bay, N.W.T. Pp. 79-86 *In* Proceedings of the Circumpolar Conference on Northern Ecology. National Research Council, Ottawa.

Greer-Walker, M. and J.H. Nichols. 1993. Predation on *Benthosema glaciale* (Myctophidae) by spawning mackerel (*Scomber scombrus*). Journal of Fish Biology. 42(4): 618-620.

Grey, M. 1956. The distribution of fishes found below a depth of 2000 meters. Fieldiana. Zoology. 36(2): 98-319.

Grigor'ev, G.V. 1972. On the reproduction of rock grenadier from the North Atlantic. Journal of the Fisheries Research Board of Canada. Trudy PINRO 28: 107-115. (Translated from Russian). Translation Serial No. 2529.

Grigor'ev, G.V. and V.P. Serebryakov. 1981. Eggs of roundnose grenadier, *Coryphaenoides rupestris* Gunnerus 1765. Journal of Northwest Atlantic Fishery Science. 2: 73-74.

Grossman, G.D. 1986. Food resource partitioning in a rocky intertidal fish assemblage. Journal of Zoology. 1: 317-355.

Haddon, M. 2001. Modelling and quantitative methods in fisheries. Chapman and Hall, USA. Pp. 406.

Haedrich, R.L. 1974. Pelagic capture of the epibenthic rattail *Coryphaenoides rupestris*. Deep-Sea Research. 21: 977-979.

Haedrich, R.L. 1997. Distribution and Population Ecology. Pp. 79-106 *In* D.J. Randall and A.P. Farrell (Eds.). 1997. Deep-Sea Fishes. Academic Press, San Diego, California.

Haedrich, R.L. and N.R. Merrett. 1992. Production/biomass ratios, size frequencies, and biomass spectra in deep-sea demersal fishes. Pp. 157-182 *In* G.T. Rowe and V. Pariente (Eds.). Deep-Sea Food Chains and the Global Carbon Cycle. Kluwer Academic Publishers, Netherlands.

Hakalahti, T., A. Karvonen and E.T. Valtonen. 2006. Climate warming and disease risks in temperate regions – *Argulus coregoni* and *Diplostomum spathaceum* as case studies. Journal of Helminthology. 80: 93-98.

Hall, A.J., J. Watkins and P.S. Hammond. 1998. Seasonal variation in the diet of harbour seals in the south-western North Sea. Marine Ecology Progress Series. 170: 269-281.

Hall, S.J. and D. Rafaelli. 1991. Food-web patterns: lessons from a species-rich web. Journal of Animal Ecology. 60: 823-842.

Halliday, R.G. 1970. Growth and vertical distribution of the glacier lanternfish, *Benthosema glaciale* in the Northwestern Atlantic. Journal of the Fisheries Research Board of Canada. 27: 105-116.

Hålvorsen, O. 1971. Studies of the helminth fauna of Norway. XVIII. On the composition of the parasite fauna of coarse fish communities in the River Glomma, southwestern Norway. Norwegian Journal of Zoology. 19: 181–192.

Hartman, O. and K. Fauchald. 1971. Deep-water benthic polychaetous annelids off New England to Bermuda and other North Atlantic areas. Part II. Allan Hancock Monographs in Marine Biology. Number 6. University of Southern California Press, Los Angeles. Pp.184-307.

Hays, R., L.N. Measures and J. Huot. 1998. Capelin (*Mallotus villosus*) and herring (*Clupea harengus*) as paratenic hosts of *Anisakis simplex*, a parasite of beluga (*Delphinapterus leucas*) in the St. Lawrence estuary. Canadian Journal of Zoology. 76: 1411-1417.

He, P. 2005. Characteristics of bycatch of porcupine crabs, *Neolithodes grimaldii* (Milne-Edwards and Bouvier, 1894) from deepwater turbot gillnets in the northwest Atlantic. Fisheries Research. 74(1-3): 35-43.

Hernandez, A.D., J.F. Bunnell and M.V.K. Sukhdeo. 2007. Composition and diversity patterns in metazoan parasite communities and anthropogenic disturbance in stream ecosystems. Parasitology. 134(1): 91-102.

Hobson, K.A. and H.E. Welch. 1992. Determination of trophic relationships within a high Arctic food web using $\delta^{13}C$ and $\delta^{15}N$ analysis. Marine Ecology Progress Series. 84: 9-18.

Hobson, K.A., W.G. Ambrose Jr. and P.E. Renaud. 1995. Sources of primary production, benthic-pelagic coupling, and trophic relationships within the Northeast Water Polynya: insights from $\delta^{13}C$ and $\delta^{15}N$ analysis. Marine Ecology Progress Series. 128: 1-10.

Hobson, K.A., A. Fisk, N. Karnovsky, M. Holst, J.M. Gagnon and M. Fortier. 2002. A stable isotope ($\delta^{13}C$, $\delta^{15}N$) model for the North Water food web: implications for evaluating trophodynamics and the flow of energy and contaminants. Deep-Sea Research. Part 2. Topical Studies in Oceanography. 49: 5131-5150.

Hogans, W.E. 1986. *Paeonocanthus antarcticensis* (Copepoda: Sphyriidae) parasitic on the bathypelagic fish *Bathylagus euryops* in the northwest Atlantic Ocean. Sarsia. 71: 305-307.

Holmes, J.C. 1979. Parasite populations and host community structure. Pp. 144 *In*

B.B. Nickol (Ed.). Host–parasite interfaces. Academic Press, New York.

Honda, H. and M. Kan-no. 1997. Size selective feeding and its limitations for the black rockfish, *Sebastes inermis*, in a demersal fish assemblage of Onagawa Bay, northeastern Japan. Environmental Biology of Fishes. 50(2): 183-193.

Hop, H., D.S. Danielssen and J. Gjosaeter. 1993. Winter feeding ecology of cod (*Gadus morhua*) in a fjord of southern Norway. Journal of Fish Biology. 43(1): 1-18.

Hop, H., J. Gjosaeter and D.S. Danielssen. 1992. Seasonal feeding ecology of cod (*Gadus morhua* L.) on the Norwegian Skagerrak coast. ICES Journal of Marine Science. 49(4): 453-461.

Hop, H., H.E. Welch and R.E. Crawford. 1997. Population structure and feeding ecology of Arctic cod schools in the Canadian high Arctic. American Fisheries Society Symposium. 19: 68-80.

Horn, H.S. Measurement of "overlap" in comparative ecological studies. American Naturalist. 100: 419-424.

Hully, P.A. 1984. Myctophidae, Pp. 429-483. *In* P.J.P. Whitehead, M.L. Bauchot, J.C. Hureau, J. Nielsen and F. Tortonese [Eds.], Fishes of the North-eastern Atlantic and the Mediterranean, Volume 1. UNESCO, Paris.

Humason, G.L. 1962. Animal Tissue Techniques. Third Edition. W.H. Freeman and Company, San Francisco. Pp. 465-505.

Hunninen, A.V. and R.M. Cable. 1943. The life history of *Lecithaster confusus* Odhner (Trematoda: Hemiuridae). Journal of Parasitology. 29: 71-79.

Hunter, J.G., S.T. Leach, D.E. McAllister and M.B. Steigerwald. 1984. A distributional atlas of records of the marine fishes of Arctic Canada in the National Museums of Canada and Arctic Biological Station. Syllogeus. 52: 35.

Hussain, S. M. 1992. The reproductive biology of the lantern fish *Benthosema fibulatum* from the northern Arabian Sea. Fisheries Research (Netherland). 13: 381 - 393.

Hussy, K., M.A. St. John and U. Bottcher. 1997. Food resource utilization by juvenile Baltic cod *Gadus morhua*: a mechanism potentially influencing recruitment success at the demersal juvenile stage? Marine Ecology Progress Series. 155: 199-208.

Hutchings, J.A. and R.A. Myers. 1995. The biological collapse of Atlantic cod off Newfoundland and Labrador: an exploration of historical changes in exploration, harvesting technology, and management. Pp. 37-93 *In* R. Arnason and L. Felt (Ed.), The North Atlantic Fisheries: Successes, Failures, and Challenges. Volume

3. An Island Living Series, B. Bartmann (Ed.). Charlottetown: The Institute of Island Studies.

Huxham, M., D. Raffaelli and A. Pike. 1995. Parasites and food web patterns. Journal of Animal Ecology. 64: 168-176.

Iken, K., B.A. Bluhm, and R. Gradinger. 2005. Food web structure in the high Arctic Canada Basin: evidence from δ^{13}C and δ^{15}N analysis. Polar Biology. 28: 238-249.

Iwamoto, T. 1975. The abyssal fish *Antimora rostrata* (Gunther). Comparative Biochemistry and Physiology. 52B: 7-11.

Jennings, S., J.K. Pinnegar, N.V.C. Polunin and T.W. Boon. 2001. Weak cross-species relationships between body size and trophic level belie powerful size-based trophic structuring in fish communities. Journal of Animal Ecology. 70: 934-944.

Jennings, S., J.K. Pinnegar, N.V.C. Polunin and K.J. Warr. 2002a. Linking size-based and trophic analyses of benthic community structure. Marine Ecology Progress Series. 226: 77-85.

Jennings, S., S.P.R. Greenstreet, L. Hill, G.J. Piet, J.K. Pinnegar and K.J. Warr. 2002b. Long-term trends in the trophic structure of the North Sea fish community: evidence from stable-isotope analysis, size spectra and community metrics. Marine Biology. 141: 1085-1097.

Jensen, A.S. 1948. Contributions to the ichthyofauna of Greenland. Spolia Zoologica Musei Hauniensis. 9: 1-182.

Jensen, AS. 1952a. On the Greenland species *Artediellus*, *Cottunculus*, and *Gymnocanthus* (Teleostei, Seleparei, Cottidae). Meddelser om Grönland. 142: 1-21.

Jensen, A.S. 1952b. Recent finds of Lycodinae in Greenland waters. Meddelser om Gronland. 142(7): 1-28.

Jensen, I.B. and D. Jensen. 1991. Marine fishes of Igloolik, N.W.T. Arctic Canada. Pp. 1-140 *In* Jorgensen, M. [ed.]. Arctic Biology Course 1989, Igloolik NWT Canada. Zoologisk Museum, University of Copenhagen, Copenhagen.

Jensen, T. 1997. Experimental infection/transmission of sculpins (*Myoxocephalus scorpius*) and cod (*Gadus morhua*) by sealworm (*Pseudoterranova decipiens*) larvae. Parasitology Research. 83: 380-382.

Jensen, T. And K. Andersen. 1992. The importance of sculpin (*Myoxocephalus scorpius*) as intermediate host and transmitter of the sealworm *Pseudoterranova decipiens*. International Journal of Parasitology. 22: 665-668.

Johnson, M.W., R.H. Hesslein and T.A. Dick. 2004. Host length, age, diet, parasites and stable isotopes as predictors of yellow perch, (*Perca flavescens* Mitchill), trophic status in nutrient poor Canadian Shield lakes. Environmental Biology of Fishes. 71(4): 379-388.

Jones, E.P., J.H. Swift, L.G. Anderson, G. Lipizer, M. G. Civitarese and K.K. Falkner. 2003. Tracing Pacific water in the North Atlantic Ocean. Journal of Geophysical Research. 108: 13-1 – 13-10.

Jorgensen, O.A. 1998. Survey for Greenland halibut in NAFO Divisions 1C-1D. Northwest Atlantic Fisheries Organization SCR Document 98/25. Pp. 1-26.

Jorgensen, O.A. 2002. Survey for Greenland halibut in NAFO Divisions 1A-1D, 2001. Northwest Atlantic Fisheries Organization SCR Document 02/30. Pp. 1-40.

Jorgensen, O.A., C. Hvingel, P.R. Moller and M.A. Treble. 2005. Identification and mapping of bottom fish assemblages in Davis Strait and southern Baffin Bay. Canadian Journal of Fisheries and Aquatic Sciences. 62: 1833-1852.

Juanes, F., J.A. Buckel and F.S. Scharf. 2002. Feeding ecology of piscivorous fishes. Pp. 267-283 *In* P.J.B. Hart and J.D. Reynolds (Eds.). The handbook of fish biology and fisheries. Volume 1. Fish Biology. Blackwell Scientific Publications, London.

Juareguizar, A.J., R. Menni, R. Guerrero and C. Lasta. 2004. Environmental factors structuring fish communities of the Rio de la Plata estuary. Fisheries Research. 66(2-3): 195-211.

Kathman, R.D., W.C. Austin, J.C. Saltman and J.D. Fulton. 1986. Identification manual to the Mysidacea and Euphausiacea of the Northeast Pacific. Canadian Special Publication of Fisheries and Aquatic Sciences. 93 Pp.

Kawaguchi, K. and J. Mauchline. 1982. Biology of myctophid fishes (family Myctophidae) in the Rockall Trough, northeastern Atlantic. Biological Oceanography. 1(4): 337-373.

Kelly, C.J., M. Clarke and P.L. Connolly. 1997. Catch and discards from a deep water trawl survey in 1996. Fishery Leaflet 175. Dublin: Marine Institute.

Kelly, C.J., P.L. Connolly and J.J. Bracken. 1996. Maturity, oocyte dynamics and fecundity of the roundnose grenadier from the Rockall Trough. Journal of Fish Biology. 49 (Supplement A): 5-17.

Kennedy, C.R. 1990. Helminth communities in freshwater fish: structured communities or stochastic assemblages? Pp. 131– 156 *In* G.W. Esch, A.O. Bush, and J.M. Aho (Eds.). Parasite communities: patterns and processes. Chapman and Hall, New York.

Kennedy, C.R., and Bush, A.O. 1994. The relationship between pattern and scale in parasite communities: a stranger in a strange land. Parasitology. 109: 187–196.

Khan, R.A., M. Dawe, R. Bowering and R.K. Misra. 1982. Blood Protozoa as an aid for separating stocks of Greenland halibut, *Reinhardtius hippoglossoides*, in the Northwestern Atlantic. Canadian Journal of Fisheries and Aquatic Sciences. 39: 1317-1322.

Khan, R.A., H. Munehara, K. Ryan, and J.W. Lawson. 1997. Influence of *Haemobaphes cyclopterina* and *H. intermedius* (Copepoda) on Arctic cod (*Boreogadus saida*) and tidepool sculpins (*Oligocottus maculosus*), respectively. Canadian Journal of Zoology. 75: 1280-1284.

Khan, R.A., J. Murphy and D. Taylor. 1980. Prevalence of a trypanosome in Atlantic cod (*Gadus morhua*) especially in relation to stocks in the Newfoundland area. Canadian Journal of Fisheries and Aquatic Sciences. 37: 1467-1475.

Khan, N.Y. and D.J. Faber. 1974. A comparison of larvae of the deepwater fourhorn sculpin, *Myoxocephalus quadricornis* L., from North America. I. Morphological Development. Pp. 703-712 *In* J.H.S. Blaxter (Ed.). The Early Life History of Fish. Proceedings of International Symposium, 17-23 May 1973. Dunstaffnage Marine Research Laboratory of the Scottish Marine Biological Association. Oban, Scotland. Springer-Verlag, New York. Pp. 765.

Kiilerich, A.B. 1939. The Godthaab Expedition 1928 – a theoretical treatment of the hydrographical observation material. Meddelser om Gronland. 78(5): 1-148.

Kiljunen, M., J. Grey, T. Sinisalo, C. Harrod, H. Immonen and R.I. Jones. 2006. A revised model for lipid-normalizing $\delta^{13}C$ values from aquatic organisms, with implications for isotope mixing models. Journal of Applied Ecology. 43: 1213-1222.

King, A.J. 2005. Ontogenetic dietary shifts of fishes in an Australian floodplain river. Marine and Freshwater Research. 56(2): 215-225.

Kinzer, J., R. Bottger-Schnack and K. Schulz. 1993. Aspects of horizontal distribution and diet of myctophid fish in the Arabian Sea with reference to the deep water oxygen deficiency. Deep-Sea Research Part II Tropical Studies in Oceanography. 40(3): 783-800.

Kitahara, M. and K. Fujii. 2005. Analysis and understanding of butterfly community composition based on multivariate approaches and the concept of generalist/specialist strategies. Entomological Science. 8(2): 137-149.

Klassen, G.J., M. Beverly-Burton and A. Locke. 1989. A revision of *Entobdella* Blainville (Monogenea: Capsalidae) with particular reference to *E. hippoglossi* and *E. squamula*: the use of ratios in taxonomy and key to species. Canadian Journal of Zoology. 67: 1869-1876.

Klemetsen, A. 1993. The food of the long-rough dab (*Hippoglossoides platessoides limandoides* Bloch) in Balsfjorden, north Norway. Sarsia. 78(1): 17-24.

Klimpel, S. and S. Ruckert. 2005. Life cycle strategy of *Hysterothylacium aduncum* to become the most abundant anisakid fish nematode in the North Sea. Parasitology Research. 97: 141-149.

Klimpel, S., H.W. Palm, M.W. Busch, E. Kellermanns and S. Ruckert. 2006. Fish parasites in the Arctic deep-sea: poor diversity in pelagic species vs. heavy parasite load in a demersal fish. Deep-Sea Research. 53: 1167-1181.

Kline, T.C Jr., W.J. Wilson and J.J. Goering. 1998. Natural isotope indicators of fish migration at Prudhoe Bay, Alaska. Canadian Journal of Aquatic Sciences. 55: 1494-1502.

Kochzius, M. 2007. Community structure of coral reef fishes in El Quadim Bay (El Quseir, Egyptian Red Sea coast). Zoology in the Middle East. 42: 89-98.

Koeller, P.A. 1991. Approaches to improving groundfish survey abundance estimates by controlling the variability of survey gear geometry and performance. Journal of Northwest Atlantic Fishery Science. 11: 51-58.

Koie, M. 1981. On the morphology and life-history of *Podocotyle reflexa* (Creplin, 1825) Odhner, 1905, and a comparison of its developmental stages with those of *P.atomon* (Rudalphi, 1802) Odhner, 1905 (Trematoda, Opecoelidae). Ophelia. 20(1): 17-43.

Kotrschal, K. and D.A. Thomson. 1986. Feeding patterns in eastern tropical Pacific blennioid fishes teleostei (Tripterygiidae Labrisonidae Chaenopsidae Blenniidae). Oecologia. 70(3): 367-378.

Kozlova, T.A. 1997. Seasonal cycles in total chemical composition of two Lake Baikal benthic-pelagic sculpins (*Cottocomephorus*, Cottoidei). Journal of Fish Biology. 50: 734-743.

Kristensen, T.K. 1977. Hatching, growth and distribution of juvenile *Gonatus fabricii* (Mollusca: Cephalopoda) in Greenland waters. Astarte. 10: 21-28.

Kristensen, T.K. 1983. *Gonatus fabricii*. Pp. 159-173 *In* P.R. Boyle (Ed.). Cephalopod Life Cycles. Volume 1: Species Accounts. Academic Press, London.

Lawrence, M.J., G. Lacho, and S. Davies. 1984. A survey of the coastal fish of the southeastern Beaufort Sea. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 1220.

Layman, C.A., K.O. Winemiller, D.A. Arrington and D.B. Jepsen. 2005. Body size and trophic position in a diverse tropical food web. Ecology. 86(9); 2530-2535.

Lee, C.M., V. Soukhovtsev, J. Abriel, M. Scotney, J.I. Gobat, K. Van Thiel and B. Petrie. 1995. An observational array for high-resolution, year-round measurements of volume, freshwater and ice flux variability in Davis Strait. Cruise Report for R/V Knorr 179-5, 22 September – 4 October 2004. Pp. 51.

Legendre, P. and L. Legendre. 1998. Numerical Ecology. Second English Edition. Developments in Environmental Modelling 20. Elsevier, Amsterdam. Pp. 378-380.

Le Loc'h, F. And C. Hily. 2005. Stable carbon and nitrogen isotope analysis of *Nephrops norvegicus/Merluccius merluccius* fishing grounds in the Bay of Niscay (Northeast Atlantic). Canadian Journal of Fisheries and Aquatic Sciences. 62(1): 123-132.

Leong, T.S. and J.C Holmes. 1981. Communities of metazoan parasites in open water fishes of Cold Lake, Alberta. Journal of Fish Biology. 18: 693–713.

Lester, R.J.G., C. Thompson, H. Moss and S.C. Barker. 2001. Movement and stock structure of narrow-barred Spanish mackerel as indicated by parasites. Journal of Fish Biology. 59(4): 833-842.

Lile, N.K. 1998. Alimentary tract helminths of four pleuronectid flatfish in relation to host phylogeny and ecology. Journal of Fish Biology. 53: 945-953.

Livingston, R.J. 1982. Trophic organization on fishes in a coastal seagrass system. Marine Ecology Progress Series. 7: 1-12.

Luczkovich, J.J., G. P. Ward, J.C. Johnson, R.R. Christian, D. Baird, H. Neckles and W.M. Rizzo. 2002. Determining the trophic guilds of fishes and macroinvertebrates in a seagrass food web. Estuaries. 25(6): 1143-1164.

Luksenberg, J.A. and T. Pedersen. 2002. Sexual and geographical variation in life history parameters of the shorthorn sculpin. Journal of Fish Biology 61: 1453-1464.

Lund, R.A. and T.G. Heggberget. 1992. Migration of Atlantic salmon, *Salmo salar* L., parr through a Norwegian fjord: potential infection path of *Gyrodactylus salaris*. Aquaculture and Fisheries Management. 23(3): 367-372.

Mackenzie, K. 1985. The use of parasites as biological tags in population studies of herring *Clupea harengus* in the North Sea and to the north and west of Scotland UK. Journal du Conseil, Conseil International pour l'Exploration de la Mer. 42(1): 33-64.

Mackenzie, K. and P. Abaunza. 1998. Parasites as biological tags for stock discrimination of marine fish : a guide to procedures and methods. Fisheries Research. 38(1) : 45-56.

Malek, M. 2003. Parasites as indicators of feeding behaviour in gobies. Bulletin of the European Association of Fish Pathologists. 23(5): 219-222.

Manning, C.A. and A. Bucklin. 2005. Multivariate analysis of the copepod community of near-shore waters in the western Gulf of Maine. Marine Ecology Progress Series. 292: 233-249.

Mansfield, A.W. 1967. Seals of Arctic and eastern Canada. Bulletin of the Fisheries Research Board of Canada. Pp. 137: 35.

Manter, H.W. 1925. Some marine fish trematodes of Maine. Journal of Parasitology. 12: 11-18.

Marcogliese, D.J. and D.K. Cone. 1997. Parasite communities as indicators of ecosystem stress. Parasitologia. 39: 27-232.

Marcogliese, D.J., E. Albert, P. Gagnon and J.M. Sevigny. 2003. Use of parasites in stock identification of the deepwater redfish (*Sebastes mentella*) in the Northwest Atlantic. Fishery Bulletin. 101 : 183-188.

Marcogliese, D.J., A.D. Gendron, C. Plante M. Fournier and D. Cyr. 2006. Parasites of spottail shiners in the St. Lawrence River: effects of municipal effluents and habitat. Canadian Journal of Zoology. 84(10): 1461-1481.

Margolis, L. 1965. Parasites as an auxiliary source of information about the biology of Pacific salmons (genus *Onchorhynchus*). Journal of the Fisheries Research Board of Canada. 22(6): 1387-1395.

Margolis, L. 1965. Systematic and biological studies of macrourid fishes (Acanthini: Teleostei). Deep-Sea Research. 12: 299-322.

Margolis, L. and J.R. Arthur. 1979. Synopsis of the parasites of fishes of Canada. Bulletin of the Fisheries Research Board of Canada. 199: 1-269.

Margolis, L, G.W. Esch, J.C. Holmes, A.M. Kuris and G.A. Schad. 1982. The use of ecological terms in parasitology: report of an *ad hoc* committee of the American Society of Parasitologists. Journal of Parasitology 68: 131-133.

Marshall, N.B. 1965. Systematic and biological studies of the macrourid fishes (Anacanthini-Teleostei). Deep-Sea Research. 12: 299-322.

Marshall, N.B. and T. Iwamoto. 1973. Family Macrouridae. Pp. 496-665 *In* Fishes of the western North Atlantic. Memoirs. Sears Foundation Marine Research. 1(6). Yale University, New Haven.

Martell, D.J. and G. McClelland. 1992. Prey spectra of pleuronectids (*Hippoglossoides platessoides*, *Pleuronectes ferrugineus*, *Pleuronectes americanus*) from Sable Island Bank. Canadian Technical Report of Fisheries and Aquatic Sciences. 1895: i-vi, 1-20.

Martell, D.J. and G. McClelland. 1994. Diets of sympatric flatfishes, *Hippoglossoides platessoides*, *Pleuronectes ferrugineus*, *Pleuronectes americanus*, from Sable Island Bank, Canada. Journal of Fish Biology. 46(1): 8-17.

Matallanas, J. 1999. New and rare snailfish genus *Paraliparis* from the Weddell Sea with the description of two new species. Journal of Fish Biology. 54(5): 1017-1028.

Mauchline, J. and J.D.M. Gordon. 1984a. Diets and bathymetric distributions of the macrourid fish of the Rockall Trough, northeastern Atlantic Ocean. Marine Biology. 81: 107-121.

Mauchline, J. and J.D.M. Gordon. 1984c. Occurrence and feeding of berycomorphid and percomorphid teleost fish in the Rockall Trough. Journal du Conseil. Conseil International pour l'exploration de la Mer. 41: 239-247.

Mauchline, J. and J.D.M. Gordon. 1985. Trophic diversity in deep-sea fish. Journal of Fish Biology. 26: 527-535.

Mauchline, J., O.A. Bergstad, J.D.M. Gordon and T. Brattegard. 1994. The food of juvenile *Coryphaenoides rupestris*, 1795 (Pisces, Macrouridae) in the Skagerrak. Sarsia. 79: 163-164.

McCutchan, J.H., Jr., W.M. Lewis, Jr., C. Kendall and C.C. McGrath. 2003. Variation in trophic shift for stable isotope rations of carbon, nitrogen and sulphur. Oikos. 102(2) 378-390.

McDonald, T.E. and L. Margolis. 1995. Synopsis of the Parasites of Fishes of Canada: Supplement (1978-1993). Canadian Special Publication of Fisheries and Aquatic Sciences. 22:1-266.

McField, M.D., P. Hallock and W.C. Jaap. 2001. Multivariate analysis of reef community structure in the Belize barrier reef complex. Bulletin of Marine Science. 69(2): 745-758.

McGladdery, S.E. and M.D.B. Burt. 1985. Potential of parasites for use as biological indicators of migration, feeding and spawning behavior of northwestern Atlantic herring (*Clupea harengus*). Canadian Journal of Fisheries and Aquatic Sciences. 42(12): 1957-1968.

McLellan, T. 1977. Feeding strategies of the macrourids. Deep-Sea Research. 24: 1019-1036.

Memmott, J., N.D. Martinez and J.E. Cohen. 2000. Predators, parasitoids and pathogens: species richness, trophic generality and body size in a natural food web. Journal of Animal Ecology. 69: 1-15.

Michalsen, K. and K.H. Nedreaas. 1998. Food and feeding of Greenland halibut (*Reinhardtius hippoglossoides*, Walbaum) in the Barents Sea and east Greenland waters. Sarsia. 83(5): 401-407.

Michaud, J., L. Fortier, P. Rowe and R. Ramseier. 1996. Feeding success and survivorship of Arctic cod larvae, *Boreogadus saida*, in the Northeast Water polynya (Greenland Sea). Fisheries Oceanography. 5(2): 120-135.

Michener, R.H. and D.M. Schell. 1994. Stable isotope ratios as tracers in marine aquatic foodwebs. Pp. 138-157 *In* Lajtha, K and R.H. Michener (Eds.), Stable isotopes in ecology and environmental sciences. Blackwell, Oxford.

Michener, R. and K. Lajtha. 2007. Stable isotopes in ecology and environmental science. Second Edition. Blackwell, Oxford. Pp. 566.

Midtgaard, T., K. Andersen and O. Halvorsen. 2003. Population dynamics of sealworm, *Pseudoterranova decipiens* sensu lato, in sculpins, *Myoxocephalus scorpius*, from two areas in Norway between 1990 and 1996. Parasitology Research. 89: 387-392.

Milinsky, G.I. 1944. On the biology and fisheries of the long rough dab in the Barents Sea. Trudy PINRO. 8: 388-415.

Miller, M.J. 1941. A critical study of Stafford's report on "Trematodes of Canadian Fishes" based on his trematode collection. Canadian Journal of Research. 19: 28-52.

Minagawa, M. and Wada, E. 1984. Stepwise enrichment of $\delta^{15}N$ along food chains: further evidence and the relation between $\delta^{15}N$ and animal age. Geochimica et Cosmochimica Acta. 48: 1135–1140.

Minet, J.P. 1973. Age and growth of the American plaice, *Hippoglossoides platessoides*, off Cape Breton Island in ICNAF Subdivision 4Vn. ICNAF Research Bulletin. 10: 99-105.

Miya, M. 1995. Some aspects of the biology of *Bathylagus ochotensis* (Pisces: Bathylagidae) in Sagami Bay, central Japan. Bulletin of Marine Science. 56(1): 173-184.

Møller, P.R. 2001a. A new zoarcid, *Lycodes mcallisteri*, from eastern Arctic Canada (Teleostei: Perciformes). Ichthyological Research 48: 111-116.

Møller, P.R. 2001b. Redescription of the *Lycodes pallidus* species complex (Pisces, Zoarcidae), with a new species from the Arctic/North Atlantic Ocean. Copeia (4):972-996.

Møller, P.R. 2006. Lipids and stable isotopes in marine food webs in West Greenland. Trophic relations and health implications. Doctoral Thesis. National Environmental Research Institute. Ministry of the Environment. Denmark.

Møller, P.R. and O.A. Jorgensen. 2000. Distribution and abundance of eelpouts (Pisces, Zoarcidae) off West Greenland. Sarsia. 85(1): 23-48.

Monteiro, P.M.S., A. G. James, A.D. Sholto-Douglas and J.G. Field. 1991. The $\delta^{13}C$ trophic position isotope spectrum as a tool to define and quantify carbon pathways in marine food webs. Marine Ecology Progress Series. 78: 33-40.

Moore, I.A. and J.W. Moore. 1974. Food of shorthorn sculpin, *Myoxocephalus scorpius*, in the Cumberland Sound Area of Baffin Island. Journal of the Fisheries Research Board of Canada. 31: 355-359.

Moran, J.D.W., J.R. Arthur and M.B.D. Burt. 1996. Parasites of sharp-beaked redfishes (*Sebastes fasciatus* and *Sebastes mentella*) collected from the Gulf of St. Lawrence, Canada. Canadian Journal of Fisheries and Aquatic Sciences. 53(8): 1821-1826.

Morrison, C.M. and G. Shum. 1983. Epitheliocystis in American plaice, *Hippoglossoides platessoides* (Frabricius). Journal of Fish Diseases. 6: 303-308.

Munoz, A.A., and F.P. Ojeda. 1997. Feeding guild structure of a rocky intertidal fish assemblage in central Chile. Environmental Biology of Fishes. 49: 471-479.

Munoz, A.A., and F.P. Ojeda. 1998. Guild structure of carnivorous intertidal fishes of the Chilean coast: implications of ontogenetic dietary shifts. Oecologia. 114: 563-573.

Nafpaktitis, B.G., R.H. Backus, J.E. Craddock, R.L. Haedrich, B.H. Robison and C. Karnella. 1977. Family Myctophidae. Pp. 13-265 *In* Fishes of the western North Atlantic. Memoirs of the Sears Foundation Marine Research, 1(7). Yale University, New Haven.

Nesis, K.N. 1965. The distribution and nutrition of young squid, *Gonatus fabricii* (Licht.) in the Labrador Sea and the Norwegian Sea. Oceanology. 5(1): 102-108.

Nesis, K.N. 1983. A hypothesis of the origin of western and eastern Arctic ranges of marine bottom animals. Biologiya Morya. 5: 3-13.

Nesis, K.N. 2001. West-Arctic and East-Arctic distributional ranges of cephalopods. Sarsia. 86(1): 1-11.

Nevinsky, M.M. and V.P. Serebryakov. 1973. American plaice, *Hippoglossoides platessoides platessoides* Fabr., spawning in the Northwest Atlantic area. ICNAF Research Bulletin. 10: 23-36.

Ni, I.H. and W. Templeman. 1985. Reproductive cycles of redfishes (*Sebastes*) in Southern Newfoundland Waters. Journal of Northwest Atlantic Fishery Science. 6(1): 57-63.

Nickol, B.B. 1995. Phylum Acanthocephala. In Woo, P.T.K. (Ed.). Fish Diseases and Disorders. Volume 1: Protozoan and Metazoan Infections. CAB International, Wallingford. Pp. 447-474.

Nielsen, J.G. and E. Bertelsen. 1992. Fisk: i gronlandske farvande. Atuakkiorfuk, Nuuk. Pp. 65.

Noble, E.R. 1973. Parasites and fishes in a deep-sea environment. Advances in Marine Biology. 11: 121-195.

Noble, E.R. and S.B. Collard. 1970. The parasites of midwater fishes. American Fisheries Society Special Publications. 5: 57-68.

Norderlaug, K.M., H. Christie, J.H. Fossa and S. Frederiksen. 2005. Fish-macrofauna interactions in a kelp (*Laminaria hyperborean*) forest. Journal Marine Biological Association of the United Kingdom. 185: 1279-1286.

Northrop Grumman Information Technology. 2002. Geographic Translator (GEOTRANS) Version 2.2.2. Northrop Grumman Information Technology. Beeches Technical Campus, Rome, NY.

Ntiba, M.J. and D. Harding. 1993. The food and the feeding habits of the long rough dab, *Hippoglossoides platessoides* (Fabricius 1780) in the North Sea. Netherlands Journal of Sea Research. 31(2): 189-199.

Nyssen, F., T. Brey, G. Lepoint, J.M. Bouquegneau, C. De Broyer and P. Dauby. 2002. A stable isotope approach to the eastern Weddell Sea trophic web: focus on benthic amphipods. Polar Biology. 25: 280-287.

Okamura, O., K. Amaoka, M. Takeda, K. Yano, K. Okada and S. Chikuni. 1995. Fishes collected by the R/V Shinkai Maru around Greenland. Japan Marine Fishery Resources Research Center. Pp. 181.

Orlov, A.M. 1997a. Role of fishes in predator diets of the Pacific slope of the northern Kuril Islands and southeastern Kamchatka. Alaska Sea Grant Report. 97(1): 209-229.

Orlov, A.M. 1997b. Ecological characteristics of the feeding of some Pacific predatory fish of south-east Kamchatka and northern Kuril Islands. Russian Journal of Aquatic Ecology. 6(1-2): 59-74.

Orr, D.C. and W.R. Bowering. 1997. A multivariate analysis of food and feeding trends among Greenland halibut (*Reinhardtius hippoglossoides*) sampled in Davis Strait, during 1986. ICES Journal of Marine Science. 54: 819-829.

Packer, D.B., L. Watling and R.W. Langton. 1994. The population structure of the brittle star *Ophiura sarsi* Lutken in the Gulf of Maine and its trophic relationship to American plaice (*Hippoglossoides platessoides* Fabricius). Journal of Experimental Marine Biology and Ecology. 179(2): 207-222.

Paine, R.T. 1988. Food webs: road maps of interactions or grist for theoretical development? Ecology. 69: 1648-1654.

Palsson, O.K. 1997. Predator-prey interactions of demersal fish species and capelin (*Mallotus villosus*) in Icelandic waters. Alaska Sea Grant Report. 97(1): 105-126.

Parsons, L.S. 1976. Distribution and relative abundance of roundnose, roughhead and common grenadiers in the Northwest Atlantic. ICNAF Selected Papers. 1: 73-88.

Pearcy, W.G. and R.M. Laurs. 1966. Vertical migration and distribution of mesopelagic fishes off Oregon. Deep-Sea Research. 13: 153-166.

Pearcy, W.G., E.E. Krygier, R. Mesecar and F. Ramsey. 1977. Vertical distribution and migration of oceanic micronekton off Oregon. Deep-Sea Research. 24: 223-245.

Pechenik, L.N. and F.M. Troyanovskii. 1970. Trawling resources of the North-Atlantic continental slope. Murmansk. Translated from Russian. Israel Program for Scientific Translations, Jerusalem, 1971.

Pedersen, S.A. 1994. Shrimp trawl catches and stomach contents of redfish, Greenland halibut and starry ray from West Greenland during a 24-hour cycle. Polar Research. 13(2): 183-196.

Pedersen, S.A. and F. Riget. 1993. Feeding habits of redfish (*Sebastes* spp.) and Greenland halibut (*Reinhardtius hippoglossoides*) in west Greenland waters. ICES Journal of Marine Science. 50(4): 445-459.

Persson, L. 1999. Trophic cascades: abiding heterogeneity and the trophic level concept at the end of the road. Oikos. 85: 385-397.

Peters, R.H. 1988. Some general problems for ecology illustrated by food web theory. Ecology. 69(6): 1673-1676.

Peterson, B.J. and B. Fry. 1987. Stable isotopes in ecosystem studies. Annual Review of Ecology and Systematics. 18: 293-320.

Pianka, E.R. 1987. The subtlety, complexity and importance of population interactions when more than two species are involved. Revisita Chilena de Historia Natural. 60: 351-361.

Piet, G.J., Pet, J.S., W.A.H.P. Guruge, J. Vijverberg and W.L.T. Van Densen. 1999. Resource partitioning along three niche dimensions in a size-structured tropical fish assemblage. Canadian Journal of Fisheries and Aquatic Sciences. 56: 1241-1254.

Pietsch, T.W. 1993. Systematics and distribution of cottid fishes of the genus *Triglops* Reinhardt (Teleostei: Scorpaeniformes). Zoological Journal of the Linnean Society. 109(4): 335-393.

Pimm, S.L. 1982. Food Webs. Chapman & Hall. London. Pp. 219.

Pitt, T.K. 1964. Fecundity of the American plaice, *Hippoglossoides platessoides* (Fabr.) from Grand Bank and Newfoundland areas. Journal of the Fisheries Research Board of Canada. 21: 597-612.

Pitt, T.K. 1966. Sexual maturity and spawning of the American plaice, *Hippoglossoides platessoides* (Fabricius), from Newfoundland and Grand Bank areas. Journal of the Fisheries Research Board of Canada. 23:651-672.

Pitt, T.K. 1982. American plaice. Underwater World. Department of Fisheries and Oceans, Ottawa. Pp. 6.

Podani, J. 1997. SYN-TAX 5.1: A new version for PC and Macintosh computers. Coenises. 12: 149-152.

Podrazhanskaya, S.G. 1971. Feeding and migrations of the roundnose grenadier, *Macrourus rupestris*, in the Northwest Atlantic and Iceland waters. ICNAF Redbook. Part 3. 115-123.

Polis, G.A. and D.R. Strong. 1996. Food web complexity and community dynamics. American Naturalist. 147: 813-846.

Post, D.M. 2002. Using stable isotopes to estimate trophic position: models, methods and assumptions. Ecology. 83(3): 703-718.

Powles, H., V. Vendette, R. Siron and R. O'Boyle. 2004. Proceedings of the Canadian Marine Ecoregions Workshop, Pp. 1-47.

Powles, P.M. 1965. Life history and ecology of American plaice (*Hippoglossoides platessoides* F.) in the Magdalen Shallows. Journal of the Fisheries Research Board of Canada. 22: 1565-1566.

Prokopowicz, A. and L. Fortier. 2002. Population structure of three dominant *Calanus* species in North Water Polynya, Baffin Bay. Polar Research. 23: 241-252.

Pusch, C., P.A. Hulley and K.H. Kock. 2004. Community structure and feeding ecology of mesopelagic fishes in the slope waters of king George Island (South Shetland Islands, Antarctica). Deep-Sea Research Part 1:Oceanographic Research Papers. 51(11): 1685-1708.

Rass, T.S. 1967. Certain regularities in the distribution of deep-water fishes. Tikhii okean 3 (Pacific Ocean 3). USSR Academic Science (Moscow).

Rass, T.S. and A.A. Kashkina. 1967. Bathylagid fishes of the North Pacific (Pisces, Bathylagidae). Trudy Instituta Okeanologii. 84: 209-221. Translated from Russian, U.S. National Museum Translations. 58, 1967.

Reilly, C.A., E.T. Wyllie and S. Ralston. 1992. Interannual variation and overlap in the diets of pelagic juvenile rockfish (genus: *Sebastes*) off central California. US National Marine Fisheries Service Fishery Bulletin. 90(3): 505-515.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191. Pp. 382.

Riley, G.A. 1951. Oxygen, phosphate, and nitrate in the Atlantic Ocean. Bingham Oceanographic College. Bulletin. 13: 1-126.

Rodriguez, M.E., A. Punzon and J. Paz. 1995. Feeding patterns of Greenland halibut (*Reinhardtius hippoglossoides*) in Flemish Pass (northwest Atlantic). Northwest Atlantic Fisheries Organization Scientific Council Studies. 23: 43-54.

Root, R. B. 1967. The niche exploitation pattern of the blue-gray gnatchatcher. Ecological Monographs. 37: 317-350.

Rounick, J.S. and M.J. Winterbourn. 1986. Stable carbon isotopes and carbon flow in ecosystems. BioScience. 36: 171-177.

Rubec, L.A. 1988. *Neobrachiella rostrata* (Copepoda: Lernaeopodidae) on the gills of the Greenland halibut, Reinhardtius hippoglossoides from the Gulf of St. Lawrence. Canadian Journal of Zoology. 66: 504-507.

Runge, J.A. and Y. de Lafontaine. 1996. Characterization of the pelagic ecosystem in surface waters of the northern Gulf of St. Lawrence in early summer: the larval redfish - Calanus - microplankton interaction. Fisheries Oceanography. 5(1): 21-37.

Saemundsson, B. 1927. Synopsis of the fishes of Iceland. Reykjavik. *Cottus scorpius*. Rit Visindafelags Islendinga. Reykjavik, Prentsmidjan, Gutenberg II: 1-64.

Saemundsson, B. 1949. Marine Pisces. Pp 72-124 *In* A. Frioriksson et al. (Eds.), The Zoology of Iceland. 4: 72-124. Ejnar Munksgaard, Copenhagen.

Saldanha, L. and M.-L. Bauchot. 1986. Synaphobranchidae (including Nettodaridae and Simenchelyidae). Pp. 586-592. *In* P.J.P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nelsen and E. Tortonese (Eds.). Fishes of the North-Eastern Atlantic and the Mediterranean. UNESCO, Paris. Vol. 2.

Santos, M.B., G.J. Pierce, R.J. I.A.P. Patterson, H.M. Ross and E. Mente. 2001. Stomach contents of bottlenose dolphins (*Tursiops truncatus*) in Scottish waters. Journal of the Marine Biological Association of the United Kingdom. 81: 873-878.

Sars, G.O. 1890. An account of the Crustacea of Norway. Volume I. Amphipoda. Bergen and Oslo, Copenhagen.

Sars, G.O. 1899. An account of the Crustacea of Norway. Volume II. Isopoda. Bergen, Christiania.

Savvatimsky, P.I. 1969. The grenadier of the North Atlantic. Trudy PINRO. Pp. 3-72. [Translated from Russian by the Fisheries Research Board of Canada Translation Series, 2879, 1974].

Savvatimsky, P.I. 1971. Studies of the age and growth of roundnose grenadier (*Macrourus rupestris* Gunn.) in the North Atlantic, 1967-1970. ICNAF Redbook. Part 3: 125-131.

Savvatimsky, P.I. 1972. The age of the rock grenadier in the Northwest Atlantic and a possible influence of fisheries on its population numbers. Fisheries Research Board of Canada. Serial No. 2879, Trudy PINRO. 28: 116-127.

Savvatimsky, P.I. 1984. Biological aspects of roughhead grenadier (*Macrourus berglax*) from long-line catches in the eastern Grand Bank area, 1982. NAFO Scientific Council Studies. 7: 45-51.

Savvatimsky, P.I. 1994. Age structure of roughhead grenadier (*Macrourus berglax* L.) in the Northwest Atlantic, 1985. NAFO Scientific Council Studies, 20: 53–64.

Schell, S.C. 1970. How to know the trematodes. WM. C. Brown Company Publishers, Dubuque, Iowa. Pages 1-355.

Scott, J.S. 1969. Trematode populations in the Atlantic argentine, *Argentina silus*, and their use as biological indicators. Journal of the Fisheries Research Board of Canada. 26: 879-891.

Scott, J.S. 1973. Variation in the food of American plaice (*Hippoglossoides platessoides*) with fish length and locality in the Scotian Shelf and Gulf of St. Lawrence. Technical Report of Fisheries Research Board of Canada. 411: 15p.

Scott, J.S. 1975. Geographic variation in incidence of trematode parasites of American plaice *Hippoglossoides platessoides* in the Northwest Atlantic. Journal of the Fisheries Research Board of Canada. 32(4): 547-550.

Scott, J.S. 1982a. Depth, temperature and salinity preferences of common fishes of the Scotian Shelf. Journal of Northwest Atlantic Fisheries Science. 3: 29-39.

Scott, J.S. 1982b. Digenean parasite communities in flatfishes of the Scotian Shelf and southern Gulf of St. Lawrence. Canadian Journal of Zoology. 60: 2804-2811.

Scott, J.S. and S.A. Bray. 1989. Helminth parasites of the alimentary tract of Atlantic halibut (*Hippoglossus hippoglossus* L.) and Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)) on the Scotian Shelf. Canadian Journal of Zoology. 67: 1476-1481.

Scott, W.B. and M.G. Scott. 1988. Atlantic Fishes of Canada. University of Toronto Press, Toronto, Ontario. 1-731.

Sherwood, G.D. and G.A. Rose. 2005. Stable isotope analysis of some representative fish and invertebrates of the Newfoundland and Labrador continental shelf food web. Estuarine, Coastal and Shelf Science. 63: 537-549.

Shiklomanov, I., A. Shiklomanov, R. Lammers, B. Peterson and C. Vorosmarty. 2000. They dynamics of river water inflow to the Arctic Ocean. Pp. 113-119 *In* Lewis, E. (Ed.). The freshwater budget of the Arctic Ocean. Proceedings of the NATO

Advanced Research Workshop, Tallin, Estonia, 27 April – May 1998. Kluwer Academic Publishers, Norwell, Massachusetts, USA.

Sholto-Douglas, A.D., J.G. Field, A.G. James and N.J. van der Merwe. 1991. $^{13}C/^{12}C$ and $^{15}N/^{14}N$ isotope ratios in the Southern Benguela ecosystem: indicators of food web relationships among different size-classes of plankton and pelagic fish; differences between fish muscle and bone collagen tissues. Marine Ecology Progress Series. 78: 23-31.

Simkova, A., J. Jarkovsky, B. Koubkova, V. Barus and M. Prokes. 2004. Associations between fish reproductive cycles and the dynamics of metazoan parasite infection. Parasitology Research. 95(1): 65-72.

Skrjabin, K. I. 1964. Keys to the trematodes of animals and man. University of Illinois Press, Urbana. Pp.351.

SPSS Inc. 2001. SPSS 11.0.1 for Windows. SPSS Inc. Chicago, IL.

Squires, H.J. 1990. Decapod Crustacea of the Atlantic coast of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences. 221: 477 Pp.

St. Pierre, J.F. and Y. de Lafontaine. 1995. Fecundity and reproduction characteristics of beaked redfish (*Sebastes fasciatus* and *S. mentella*) in the Gulf of St. Lawrence. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 2059. Pp. 32.

Stafford, J. 1904. Trematodes from Canadian fishes. Zoologischer Anzeiger. 27: 481-495.

Stein, D.L. and K.W. Able. 1986. Liparidae. Pp. 1275-1283. *In* P.J.P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen and E. Tortonese (Eds.) Fishes of the North-eastern Atlantic and the Mediterranean. UNESCO, Paris. Vol. 3.

Sufke, L., D. Piepenburg and C.F. von Dorrien. 1998. Body size, sex ratio and diet composition of *Arctogadus glacialis* (Peters, 1874) (Pisces: Gadidae) in the Northeast Water Polynya (Greenland). Polar Biology. 20: 357-363.

Sulak, K.J. and Y.N. Shcherbachev. 1997. Zoogeography and systematics of six deep-living genera of synaphobranchid eels, with a key to taxa and description of two new species of *Ilyophis*. Bulletin of Marine Science. 60(3):1158-1194.

Sulgostowaska, T., B. Jerzewska and J. Wicikowski. 1990. Parasite fauna of *Myoxocephalus scorpius* (L.) and *Zoarces viviparus* (L.) from environs of Hel (south-east Baltic) and seasonal occurrence of parasites. Acta Parasitologica Polonica. 35: 143-148.

Svetovidov, A.N. 1986. Review of the three-bearded rocklings of the genus

Gaidropsarus Rafinesque, 1810 (Gadidae) with description of a new species. Journal of Ichthyology. 26(1):114-135.

Takai, N., N. Hirose, T. Osawa, K. Hagiwara, T. Kojima, Y. Okazaki, T. Kuwae, T. Taniuchi and K. Yoshihara. 2007. Carbon and trophic position of pelagic fish in coastal waters of south-eastern Izu Peninsula, Japan, identified by stable isotope analysis. Fisheries Science. 73: 593-608.

Tang, C.C.L., C.K. Ross, T.Yao, B. Petrie, B.M. DeTracey and E. Dunlap. 2004. The circulation, water masses and sea-ice of Baffin Bay. Progress in Oceanography. 63: 183-228.

Templeman, W. 1963. Distribution of sharks in the Canadian Atlantic (with special reference to Newfoundland waters). Bulletin of the Fisheries Research Board of Canada. 140: 77.

Templeman, W. 1973. Distribution and abundance of the Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in the Northwest Atlantic. ICNAF Research Bulletin. 10:93-98.

Terborgh, J. and S. Robinson. 1986. Guilds and their utility in ecology. Pp. 65-90 *In* J. Kikkawa and D.J. Anderson (Eds.). Community Ecology. Pattern and Process. Blackwell, Oxford.

Ter Braak, C. J. F. and P. Šmilauer. 2002. CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power (Ithaca NY, USA), 500 Pp.

Thimdee, W., G. Deein, C. Sangrungruang and K. Matsunaga. 2004. Analysis of primary food sources and trophic relationships of aquatic animals in a mangrove-fringed estuary, Khung Krabaen Bay (Thailand) using dual stable isotope techniques. Wetlands Ecology and Management. 12: 135-144.

Thomas, C.J. and L.B. Cahoon. 1993. Stable isotope analyses differentiate between different trophic pathways supporting rocky-reef fishes. Marine Ecology Progress Series. 95: 19-24.

Treble, M.A., 2002. Analysis of data from the 2001 Trawl Survey in NAFO Subarea 0. NAFO SCR Doc. 02/47, Ser. No. N4659, 1-29.

Treble, M.A. and O.A. Jorgensen. 2002. Summary of results for Greenland halibut from trawl survey in NAFO Division 0B, 2000. Northwest Atlantic Fisheries Organization SCR Document 02/60. Pp. 1-8.

Treble, M.A. and R. Bowering. 2002. The Greenland halibut (*Reinhardtius* *hippoglossoides*) fishery in NAFO Division 0A. Northwest Atlantic Fisheries Organization SCR Document 02/46. Pp. 1-10.

Treble, M.A., W.B. Brodie, W.R. Bowering and O.A. Jorgensen. 2000. Analysis of Data from a trawl survey in NAFO Division 0A, 1999. NAFO SCR Doc. 00/31, Ser. No. N4260. Pp. 1-19.

Treble, M.A., W.B. Brodie, W.R. Bowering and O.A. Jorgensen. 2001. Analysis of data from a trawl survey in NAFO Division 0B, 2000. NAFO SCR Doc. 01/42, Ser. No. N4420. Pp. 1-19.

Urawa, S. 1989. Parasites as biological indicators contributing to salmonid biology. Scientific Reports of the Hokkaido Salmon Hatchery. 43: 53-74.

Valiela, I. 1984. Marine ecological processes. Springer Verlag, New York. Pp. 546.

Valtysson, H.T. 1995. Feeding habits and distribution of eelpout species (*Lycodes* sp.) (Reinhardt) (Pisces: Zoarcidae) in Icelandic waters. Postgraduate thesis, Department of Biology, University of Iceland, Reykjavik.

Vander Zanden, M.J. and J.B. Rasmussen. 1999. Primary consumer $\delta^{13}C$ and $\delta^{15}N$ and the trophic position of aquatic consumers. Ecology. 80: 1395-1404.

Van Guelpen, L. 1986. Hookear sculpins (genus *Artediellus*) of the North American Atlantic: taxonomy, morphological variability, distribution, and aspects of life history. Canadian Journal of Zoology. 64: 677-690.

Vinogradov, M.E. 1968. Vertical distribution of the oceanic zooplankton. Akademii Nauk SSSR Institut Okeanologii. Pp. 339. [Translated from Russian by the Israel Program for Scientific Translations, Jerusalem, 1970].

Von Dorrien, C.F. 1996. Reproduction and larval ecology of the Arctic fish species *Artediellus atlanticus* (Cottidae). Polar Biology. 16: 401-407.

Wainright, S.C., M.J. Fogarty, R.C. Greenfield and B. Fry. 1993. Long-term changes in the Georges Bank food web: trends in stable isotope compositions of fish scales. Marine Biology. 115: 481-493.

Walker, M.G. and J. H. Nichols. 1993. Predation on *Benthosema glaciale* (Myctophidae) by spawning mackerel (*Scomber scombrus*). Journal of Fish Biology. 42: 618-620.

Walsh, S.J. 1994. Recruitment variability in populations of long rough dab (American plaice) *Hippoglossoides platessoides* (Fabricius) in the north Atlantic. Netherlands Journal of Sea Research. 32(3-4): 421-431.

Walsh, S.J., A. Koeller and W.D. McKone (Eds.). 1993. Proceedings of the International Workshop on Survey Trawl Mensuration, Northwest Atlantic Fisheries Centre, St. John's Newfoundland, March 18-19, 1991. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 1911.

Warren, P.H. and J.H. Lawton. 1987. Invertebrate predator-prey body size relationships: an explanation of upper triangularity in food webs and patterns in food web structure. Oecologia. 74: 231-235.

Wenner, C.A. and J.A. Musick. 1977. Biology of the morid fish *Antimora rostrata* in the western North Atlantic. Journal of the Fisheries Research Board of Canada. 34: 2362-2368.

Werner, E.E. 1977. Species packing and niche complementarity in three sunfishes. American Naturalist. 111: 553-578.

Werner, E.E. and J.F. Gilliam. 1984. The ontogenetic niche and species interactions in size-structured populations. Annual Review of Ecology and Systematics. 15: 393-425.

Werner, I, H. Auel and R. Kiko. 2004. Occurrence of *Anonyx sarsi* (Amphipoda: Lysianassoidea) below Arctic pack ice: as example for cryo-benthic coupling? Polar Biology. 27: 474-481.

Werner, I. and H. Auel. 2005. Seasonal variability in abundance, respiration and lipid composition of Arctic under-ice amphipods. Marine Ecology Progress Series. 292: 251-262.

Wheeler, A. 1969. The fishes of the British Isles and North-west Europe. Michigan State University Press, East Lansing. Pp. 613.

Whitehead, P.J.P., M.L. Bauchot, J.C. Hureau, J. Nielsen and E. Tortonese. 1986. Fishes of the north-eastern Atlantic and the Mediterranean. Volumes I-III. United Nations Educational, Scientific and Cultural Organization, Paris.

Wierzbicka, J. 1990. Parasitic protozoa of a Greenland halibut *Reinhardtius hippoglossoides* (Walbaum, 1792). Acta Ichthyologica et Piscatoria. 20: 91-98.

Wierzbicka, J. 1991a. Parasite fauna of the Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum, 1792) from Labrador area. Acta Ichthyologica et Piscatoria. 21: 21-29.

Wierzbicka, J. 1991b. Parasite fauna of the Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum, 1792) in different age groups. Acta Ichthyologica et Piscatoria. 21: 31-41.

Willis, J.M. and W.G. Pearcy. 1982. Vertical distribution and migration of fishes of the lower mesopelagic zone off Oregon. Marine Biology. 70: 87-98.

Wisniewski, W.L. 1958. Characterization of the parasitofauna of an eutrophic lake. Acta Palaeontologica Polonica. 6: 1–64.

Woodward, G. and A.G. Hildrew. 2002. Body-size determinants of niche overlap and intraguild predation within a complex food web. Journal of Animal Ecology. 71: 1063-1074.

Wootten, R. 1973. The metazoan parasite-fauna of fish from Hannigfield Reservoir, Essex, in relation to features of the habitat and host populations. Journal of Zoology. 171: 323–331.

Yanulov, K.P. 1962. On the reproduction of the rough-head grenadier (*Macrourus berglax* Lacepede). Zoologichesky Zhurnal. 41: 1259-1262.

Yen, J. 1991. Predatory feeding behavior of an Antarctic marine copepod, *Euchaeta antarctica*. Polar Research. 10(2): 433-442.

Zamarro, J. 1992. Feeding behaviour of the American plaice *(Hippoglossoides platessoides*) on the southern Grand Bank of Newfoundland. Netherlands Journal of Sea Research. 29(1-3): 229-238.

Zdzitowiecki, K. and D. Cielecka. 1998. Digenea of the fish, *Macrourus holotrachys* (Gadiformes, Macrouridae), from the North Scotia Ridge, sub-Antarctic. Acta Parasitologica. 43(4): 200-208.

Zhao, X., J. Hamre, F. Li, X. Jin and Q. Tang. 2003. Recruitment, sustainable yield and possible ecological consequences of the sharp decline of the anchovy (*Engraulis japonicus*) stock in the Yellow Sea in the 1990s. *Fisheries Oceanography*. 12(4/5): 495- 501.

Zhokhov, A.E. 2001. Studies of transition to feeding the mollusk *Dreissena polymorpha* (Bivalvia, Dreissenidae) in cyprinid fishes from the Rybinsk Reservoir with use of the parasite *Aspidogaster limacoides* (Aspidogastrea, Aspidogastridae). Voprosy Ikhtiologii. 41(5): 651-655.

Zubchencko, A.V. 1975. On the fauna of Macrouridae parasites in North Atlantic. Trudy Polyarnyi Nauchno-Issledovatelskii I Proektnyi Institut Morskogo Rybnogo Khozaistva I Okeanografii im N.M. Knipovicha (PINRO). 35: 234-238.

Zubchenko, A.V. 1980. Parasitic fauna of Anarhichadidae and Pleuronectidae families of fish in the Northwest Atlantic. ICNAF Selected Papers. 6: 41-46.

APPENDIX 1: BIOLOGY AND ECOLOGY OF KEY FISHES FROM DAVIS STRAIT AND BAFFIN BAY

Introduction

Little is known about the basic biology and ecology of deep-sea Arctic marine fish. Many commercially important species such as Atlantic cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*) and the roughhead grenadier (*Macrourus berglax*) have been studied extensively in terms of food preference and parasite assemblages; however, by-catch species have been overlooked in the literature due to their relative unimportance. Of particular interest are the poorly studied snailfish (genera *Liparis, Paraliparis* and *Rhodichthys),* eelpouts of the genus *Lycodes*, deep-sea sculpin (genera *Artediellus*, *Cottunculus* and *Triglops*). In addition to the diet and parasites of these fish, simple life history characteristics such as growth rate, reproductive strategy and development remain unclear. Most of these species have been found in the stomachs of top predators such as Greenland halibut or American plaice (*Hippoglossoides platessoides*) (Arthur and Albert 1992a,b, Boje et al. 1997, Bray 1979, 1987, Bray and Gibson 1986, Gibson and Bray 1986, Khan et al. 1980, Khan et al. 1982, Margolis and Arthur 1979, McDonald and Margolis 1995, Rubec 1988, Scott and Bray 1989, Wierzbicka 1990, 1991a,b). Thus, depending on their importance in the diet, they may have significant influence on populations of these top predators. In order to understand the population structure and stability of commercially important species, we must first understand the dynamics of the community from which they come.

This report includes a summary of known literature regarding the distribution/habitat, diet, predation, parasites growth and reproduction of twenty-six Arctic marine fish species as well as recently collected information. In many cases, the information given here represents the first ever description of a species in terms of basic biology and ecology. All summaries include known literature as well as information collected in the Davis Strait/Baffin Bay region during 2000 to 2004.

In the following section, I describe the known distribution, diet, predators, parasites, reproduction and growth of fish species chosen for this study, using both published information and data collected from the present study. Summaries of food items, parasites and length/weight data can be found in Appendices 2, 3 and 4.

Class Elasmobranchii

Order Squaliformes

Family Squalidae

***Centroscyllium fabricii* (Reinhardt) – Black Dogfish**

Distribution/Habitat

This species occurs only in the Atlantic Ocean, from Iceland, Faroe Islands and the British Isles to Senegal and discontinuously to the southwest of Africa (Scott and Scott 1988). *Centroscyllium fabricii* occurs most frequently off bottom, occasionally forming schools (Scott and Scott 1988). It can be found to depths of 275 to 1600 m, but is most common at depths greater than 400 m in Canadian waters (Scott and Scott 1988). This species occurs at bottom temperatures of 3.5 to 4.5°C. During winter, it has been known to occur near the surface in the northern part of its range (Scott and Scott 1988).

Diet

Centroscyllium fabricii feeds primarily on cephalopods, pelagic crustaceans, jellyfish and small fish such as *Sebastes* sp. (Jensen 1948, Scott and Scott 1988). Several new species of crustaceans and fish prey are listed in Appendix 2.

Predation

No information available prior to this study.

Parasites

Eight species were known to parasitize *C. fabricii*, including three protozoans, one trematode, and four copepods (Margolis and Arthur 1979, McDonald and Margolis 1995). In this study, eight additional species were found to parasitize *C. fabricii*, including one trematode, one monogenean, three cestodes, and the larvae of three nematodes. Parasites of this species are listed in Appendix 3.

Reproduction and Growth

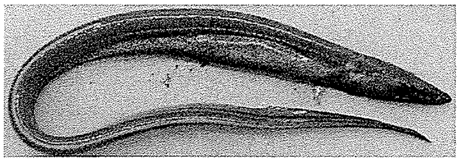
Centroscyllium fabricii is an ovoviviparous species (Templeman 1963). There is little information regarding growth and development; however, mature females have been found up to 84 cm in length (Templeman 1963). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Class Actinopterygii

Order Anguilliformes

Family Synaphobranchidae

Synaphobranchus kaupi Johnson - Kaup's Arrowtooth Eel/ Longnose Eel



Distribution/Habitat

Synaphobranchus kaupi is a benthic species occurring in deep water up to 3000 m or more (most commonly between 800 and 2000m (Sulak and Shcherbachev 1997). Scott and Scott (1988) claimed that water temperature may be a limiting factor for this species which had not been found in waters below 1.4°C; however, Sulak and Shcherbachev (1997) listed its temperature range between -1 and -10°C. The distribution of *S. kaupi* is wide, occurring worldwide between 60°N and 40°S latitude.

Diet

This species feeds mainly on decapods, Natantia and amphipods; however, it is also known to prey upon fishes and cephalopods (Saldanha and Bauchot 1986). A summary of the diet of this species can be found in Appendix 2.

Predation

Little information is available regarding predation of this species; however, Du Buit (1978) reported *S. kaupi* in the stomach of a benthic species *Coryphaenoides rupestris*.

Parasites

McDonald and Margolis (1995) reported two nematodes (*Contracaecum* sp., *Hysterothylacium* sp.) and one copepod species (*Lophoura gracilis*) as parasites of *S. kaupi*. In this study, two more nematodes were found in this species, in addition to two trematodes and cestode pleroceroids. For a more detailed list see Appendix 3.

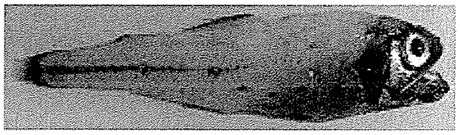
Reproduction and Growth

Little information regarding reproduction and growth is available for this species. Spawning males and females have been observed in summer months, most commonly in June. These individuals were 47 to 60.5 cm long in waters deeper than 700 m (Scott and Scott 1988). This species is believed to achieve lengths of approximately 74 cm. Bruun (1937) found that young pass through a leptocephalus stage lasting 18-22 months. During this phase the eyes are characteristically telescopic (Scott and Scott 1988). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Order Myctophiformes

Family Myctophidae

Benthosema glaciale (Reinhardt) - Glacier Lanternfish



Distribution/Habitat

Benthosema glaciale is a mesopelagic species, occurring in temperatures of zero to 18°C. It is most abundant at 4 to 16°C (Scott and Scott 1988). *Benthosema glaciale* can be found from surface waters to depths up to 530m. During the day, it is found mainly below 457m, while at night, it is most abundant at 46 to 91m (Scott and Scott 1988). Older fish are found at greater depths at night than are younger fish (Scott and Scott 1988). *Benthosema glaciale* occurs in the northwest Atlantic from Davis Strait, west Greenland, Labrador, Newfoundland and the Scotian Shelf to Cape Hatteras (Scott and Scott 1988). It is the most common myctophid north of 40°N in the North Atlantic (Albikovskaya 1988) and makes up a major portion of the deep scattering layer (Greer-Walker and Nichols 1993).

Diet

The diet of *B. glaciale* consists mainly of calanoid copepods and euphausiids (Hully 1984, Gjosaeter 1973, Kawaguchi and Mauchline 1982). In addition, Kawaguchi and Mauchline (1982) found various amphipods, decapods, and fish in the stomachs of *B. glaciale* collected in the Rockall Trough. Other benthic invertebrates may also be important. Kinzer et al. (1993) found that myctophids of the genus *Benthosema* in the Arabian Sea also consume ostracods, decapods, amphipods, cladocerans, polychaetes and fish larvae. Retrieval of stomach contents by Chernova et al. (1992) support these findings. A summary of food items can be found in Appendix 2.

Predation

Benthosema glaciale is important in the diets of many commercial and non-commercial fishes (Scott and Scott 1988). It may be important to species such as Greenland halibut, Atlantic cod and American plaice (Albikovskaya and Gerasimova 1993, Bergstad and Hoines 1998, DeBlois and Rose 1995, 1996, Fjosne and Gjosaeter

1996, Hop et al. 1992, 1993, Hussy et al. 1997). Walker and Nichols (1993) found *B. glaciale* to be common in the stomachs of mackerel (*Scomber scombrus*).

Parasites

Two parasite species have been recorded from *B. glaciale*, one cnidarian and one copepod (McDonald and Margolis 1995). In this study, one cestode, one nematode and an additional copepod were found to parasitize this species. See Appendix 3.

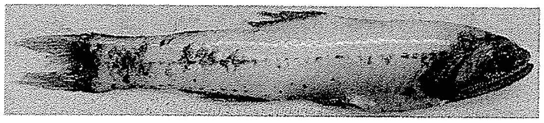
Reproduction and Growth

Females mature between the ages of 2+ years, and lengths of 37 mm or longer (Halliday 1970, Kawaguchi and Mauchline 1982). Those with ripening eggs were found in January and February (Albikovskaya 1988, Halliday 1970), which suggests that spawning occurs in spring and early summer (Halliday 1970). Males are also known to reach maturity at 2+ years of age (Halliday 1970). Gjosaeter (1981) suggested that maturation of this species is related more to length than age, stating that 45 to 50 mm is the lower limit of size at which first spawning occurs. Kawaguchi and Mauchline (1982) concurred.

Halliday (1970) found the mean length of juveniles to be 17.3 mm in July. At one, two and three years of age, mean lengths were 24.6, 37.5 and 46 mm, respectively. Fish of 4+ years were 52 and 58 mm (Halliday 1970). Albikovskaya (1988) determined that growth is rapid during the first two to three years, decreasing markedly thereafter. The largest specimen of *B. glaciale* was found by Gjosaeter (1973) off the coast of Norway, and measured 103 mm in length.

Egg size and number have not been reported for this species; however, Hussain (1992) found that mature ovaries of the related species, *B. fibulatum*, contained large numbers of varying egg sizes. Three groups of eggs were observed; those less than 0.06 mm, developing eggs around 0.07 mm and mature eggs 0.4 to 0.66 mm. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

***Lampanyctus macdonaldi* (Goode & Bean) – Rakery Beaconlamp**



Distribution/Habitat

Lampanyctus macdonaldi is a mesopelagic species in temperate to subpolar waters (Scott and Scott 1988). It occurs throughout the North and South Atlantic oceans between 550 and 1000 m (Scott and Scott 1988). Juveniles are most common at depths between 60 and 175 m, whereas adults occur in deeper waters (Nafpaktitis et al. 1977).

Diet

Copepods appear to be important in the diet of *L. macdonaldi*; however, Kawaguchi and Mauchline (1982) suggested that this species is an opportunistic feeder. In the present study, copepods were the most prevalent food item; however, cumaceans and mysids were also present in the diet. A summary of food items known for this species can be found in Appendix 2.

Predation

This species has been found in the stomachs of a number of shark species, such as *Etmopterus spinax* and *Centroscymnus crepidater* (Gordan and Mauchline 1990), as well as trachichthyids, such as *Hoplostethus atlanticus* (Mauchline and Gordon 1984c). In this study, *S. kaupi* and *G. argentatus* were found to feed on *L. macdonaldi*.

Parasites

No published information was available prior to this study; however, only one parasite was found for this species. The plerocercoids of an unknown cestode species were found in the stomach and intestine.

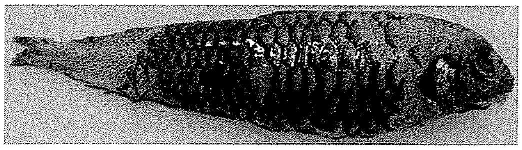
Reproduction and Growth

Kawaguchi and Mauchline (1982) proposed that spawning begins in late June or early July, based on larvae found in the Rockall Trough. These larvae were at the earliest stages of development in mid-July. Metamorphosis begins in September, and larval development lasts approximately two months (Kawaguchi and Mauchline 1982). Mature females have been found at four to five years in age and lengths of approximately 123 mm (Kawaguchi and Mauchline 1982). The authors found one mature female with 7020 eggs with an average diameter of 0.5 mm. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Order Salmoniformes

Family Bathylagidae

Bathylagus euryops Goode & Bean – Goitre Blacksmelt



Distribution/Habitat

Bathylagus euryops is a bathypelagic species occurring in temperate and subarctic regions of the North Atlantic (Scott and Scott 1988). In the northern part of its range, this species is found at depths between 20 and 500 m as postlarvae and between 500 and 1800 m as juveniles and adults (Cohen 1964, Scott and Scott 1988). *Bathylagus euryops* occurs from the Davis Strait off the coast of Greenland to the south and east coasts of Ireland, the Faroe Islands, Denmark Strait and southward to Bermuda (Cohen 1964). It is also found along the Labrador coast, northern Newfoundland, the southern edge of Grand Bank, Georges Bank and off Long Island (Scott and Scott 1988).

Diet

Little is known regarding the diet of *B. euryops*; however, Beebe (1933) found small crustaceans in the stomachs of samples from Bermuda. Several new food items were found for this species in the present study, including several copepod species, ostracods, hyperiid and other amphipods, isopods, mysids and echinoderms. A summary of food items for this species can be found in Appendix 2.

Predation

Rass and Kashkina (1967) concluded that piscivorous fish and marine mammals prey upon *B. euryops*; however, more information is needed. In this study, *R. hippoglossoides* was a predator of *B. euryops*.

Parasites

One copepod (*Paeonocanthus antarcticensis*) has been described from this species (McDonald and Margolis 1995). In this study, several additional parasites were found in *B. euryops*, including six trematodes, two adult cestodes as well as plerocercoids. A summary of the parasites of this species can be found in Appendix 3.

Reproduction and Growth

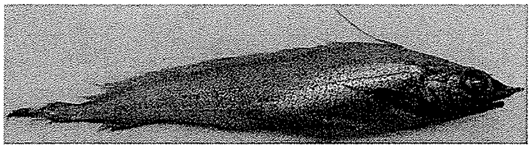
There is little information regarding growth or reproduction of this species. Cohen (1964) found that younger specimens were most abundant in the spring, whereas older specimens were taken in summer and fall months. Adults can grow to 19 cm (Scott and Scott 1988).

Reproduction and growth may be similar to the closely related *B. ochotensis*. Miya (1995) collected small larvae of *B. ochotensis* in November from the Sagami Bay in Central Japan. These specimens had most likely just completed yolk absorption. Larvae tend to occur at shallower depths than adults and larger juveniles, at approximately 400 to 450 m (Miya 1995). Females of this closely related species are considered mature at lengths greater than or equal to 100 mm (Miya 1995). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Order Gadiformes

Family Moridae

Antimora rostrata (Günther) – Blue Hake



Distribution/Habitat

Antimora rostrata is a benthopelagic species, occurring over mud bottoms (Scott and Scott 1988). It is most common at depths of 1300 to 2500 m (Wenner and Musick 1977); however, it can be found at depths between 457 and 2904 m (Scott and Scott 1988, Grey 1956). This species is the dominant member of the benthic fish community at the former depth range (Gordon and Mauchline 1990, Wenner and Musick 1977). Wenner and Musick (1977) showed that fish length positively influences depth of capture for this species. In addition to size, sex also influences depth preference. Iwamoto (1975) found that males are most common in shallower waters, while females are most abundant at greater depths. *Antimora rostrata* has been found in 2.7°C water (Cohen 1977); however, little is known about temperature preferences. This species occurs worldwide in all oceans and is widely distributed in the North Atlantic (Grey 1956, Scott and Scott 1988).

Diet

Food items of *A. rostrata* include benthic invertebrates such as crustaceans and cephalopods (Scott and Scott 1988). Obtaining information on diet composition is difficult for this species, as in most cases, the stomach is everted upon capture due to inflation of the swim bladder. However, several new food items were identified for this species, including fish, copepods, amphipods, and other crustaceans as well as polychaetes. A list of food items found in this species can be found in Appendix 2.

Predation

No information is available regarding predators of *A. rostrata*; however, it is assumed that they are prey of large predatory fish inhabiting the same areas (Scott and Scott 1988). In this study, *A. rostrata* was found in stomachs of *R. hippoglossoides*.

Parasites

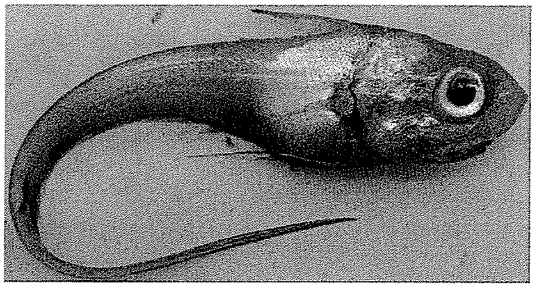
Eight species were known to parasitize *A. rostrata*, including four protozoans, two trematodes and two copepods (Bray and Campbell 1995, Hogans 1986, McDonald and Margolis 1995). In this study, eleven additional trematodes, two monogeneans, one cestode (in addition to plerocercoids), three nematodes and two acanthocephalans were found to parasitize *A. rostrata*. These parasites are listed in Appendix 3.

Reproduction and Growth

Mature specimens of *A. rostrata* are rarely encountered; however, Wenner and Musick (1977) found two females with enlarged gonads in the western North Atlantic. One female weighed 1.3 kg and measured 51.2 cm standard length. This specimen contained an estimated 1,351,300 eggs between 0.22 and 0.33 mm in diameter. The other female weighed 1.4 kg at 60.6 cm and contained 760,000 eggs between 0.6 and 0.85 mm in diameter. Iwamoto (1975) found specimens to be mature at 65 cm total length or more. Adults may grow to 54.6 cm in length, and males are, on average, smaller than females (Wenner and Musick 1977). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Family Macrouridae

Coryphaenoides rupestris Gunnerus - Roundnose Grenadier



Distribution/Habitat

Coryphaenoides rupestris is a slope-dwelling species (Kelly et al. 1996), inhabiting deep waters from 400 to 1200m (Grey 1956, Scott and Scott 1988). Some have been reported to depths of 2500m (Atkinson et al. 1982), and occurrence above 500 m is rare (Grey 1956). Juveniles are most common at depths of 1000 m, and it has been suggested that a vertical migration takes place in conjunction with seasonal fluctuations in fall months (Pechenik and Troyanovskii 1970). Parsons (1976) found that greatest concentrations of *C. rupestris* occurred at temperatures between 3.5 and 4.5°C. This species undertakes diurnal vertical feeding migrations (Savvatimsky 1969, Haedrich 1974), and juveniles become bathypelagic after their first year (Bergstad and Gordon 1994).

In the eastern North Atlantic, *C. rupestris* occurs from Greenland, Iceland, and the coast of Norway through the Irish Sea to the Bay of Biscay. In the western North Atlantic, it occurs along the Davis Strait, Labrador, Newfoundland and Grand Bank to Cape Hatteras (Scott and Scott 1988).

Diet

This species feeds on various small crustaceans, squid and fishes, depending on locality (McLellan 1977, Scott and Scott 1988). Throughout life, copepods remain an important component in the diet. As the fish increases in size, amphipods, mysids, euphausiids and decapods become more important (Gordon and Swan 1996). Mauchline and Gordon (1984a) found a predominance of decapods in the diet of *C. rupestris* in the Rockall Trough. This species is a benthopelagic or pelagic feeder (Haedrich 1974, Mauchline et al. 1994, Mauchline and Gordon 1984a), undertaking significant vertical feeding migrations (Haedrich 1974). Feeding is seasonal, done mainly in autumn and winter (Scott and Scott 1988). A list of food items for this species can be found in Appendix 2, including several new food items from the present study.

Predation

Coryphaenoides rupestris has been found in the stomachs of whales (Rass 1967), Greenland halibut and redfish (Atkinson et al. 1982, Scott and Scott 1988). Redfish tend to feed on younger, smaller individuals (Scott and Scott 1988). This species may be important in the diets of many other fish species; however, more research is required. In this study, larger individuals of this species were found to be cannibalistic. *Reinhardtius hippoglossoides* also fed on this species.

Parasites

Forty-one different parasites have been collected from *C. rupestris*, including a large number of protozoans and trematodes. Parasites from Monogenea, Cestoda, Nematoda, and Copepoda have also been found (Bray 1979, 1987, Gibson and Bray 1986, Margolis and Arthur 1979, McDonald and Margolis 1995). In the present study, one new trematode in addition to one monogenean, one nematode and a copepod were identified as parasites of *C. rupestris*. See Appendix 3.

Reproduction and Growth

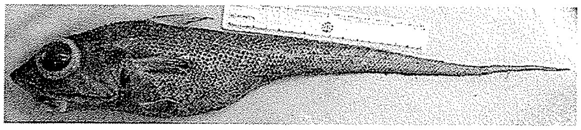
Time and place of spawning are not yet known; however, several hypotheses have been proposed. The most widely accepted explanation is that spawning occurs in Icelandic waters. Eggs and larvae are carried by the Irminger Current to waters south of Greenland (Scott and Scott 1988). Baffin Island waters are reached by way of the West Greenland Current, and to Labrador and eastern Newfoundland by way of the Polar and Labrador currents (Scott and Scott 1988). At 40 to 50 cm in length, the grenadiers begin a return migration (Atkinson et al. 1982), spawning at depths below 850 m (Savvatimsky 1969).

Savvatimsky (1972) found spawning males and post-spawning females at the end of October, to depths between 580 and 850 m. Kelly et al. (1996, 1997) found spawning individuals throughout the year but noted that most fish were spent or recovering in April and ripe and spawning between July and November. Podrazhanskaya (1971) found pre-spawning individuals in May and post-spawning individuals in August. These studies suggest that *C. rupestris* spawns in spring and autumn (Geistdoerfer 1976, Marshall 1965); however, Grigor'ev (1972) proposed that this species spawns intermittently throughout the year. Geistdoerfer (1979) agreed that *C. rupestris* is a serial spawner.

Females produce an estimated 16,500 eggs (Marshall and Iwamoto 1973), and Marshall (1965) noted that small, medium and large eggs are found together in ripe ovaries. Eggs appear to be fertilized at the time of spawning (Marshall 1965), and measure about 2.3 mm in diameter (Grigor'ev and Serebryakov 1981). Fertilized eggs were mesopelagic from October to December, whereas juveniles were at these depths between December and February (Bergstad and Gordon 1994).

Information regarding growth rate and development is scarce; however, Savvatimsky (1971) found that fish between nine and fourteen years of age were immature. These specimens measured 60 to 70 cm in length and weighed between 0.4 and 0.8 kg. This species is considered slow-growing, late maturing and long-lived (Scott and Scott 1988). Specimens have been found up to 60 years of age (Kelly et al. 1997). Females of the species tend to grow at a faster rate than males (Atkinson et al. 1982). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Macrourus berglax **Lacepede - Roughhead Grenadier**



Distribution/Habitat

Macrourus berglax is a subarctic species inhabiting temperatures of zero to 3.5°C (usually above 2°C) and bottom depths of 200 to 1000m (Andriyashev 1954, Savvatimsky 1984, Marshall and Iwamoto 1973). It is most abundant down to 600m. (Marshall and Iwamoto 1973). This species is found in the eastern North Atlantic off southern Greenland, Iceland and northern Norway. In the western North Atlantic, it is present from Davis Strait along the continental slope, Newfoundland, Grand Bank, Nova Scotia, Sable Island Bank, Brown Bank, and Georges Bank (Scott and Scott 1988).

Diet

Macrourus berglax feeds on various benthic invertebrates including bivalve molluscs, shrimp, starfishes, as well as a few fishes (McLellan 1977, Savvatimsky 1984, Scott and Scott 1988). Composition of diet also appears to vary according to size. Larger roughhead grenadiers prefer bivalves, shrimp and fishes, whereas smaller grenadiers feed mainly on small bivalves, starfishes, shrimps and polychaetes (Scott and Scott 1988). Several new food items were found in this species, including various crustaceans, echinoderms and cephalopods listed in Appendix 2.

Predation

Macrourus berglax has been found in the stomachs of cod (Savvatimsky 1969) and Greenland halibut (Scott and Scott 1988). It is assumed to be important in the diets of several other species found in the same region (Scott and Scott 1988). It was also found in the stomachs of *R. hippoglossoides*. In this study, larger individuals of this species were cannibalistic.

Parasites

Fifty-one species are known to parasitize *M. berglax* (Bray 1979, Campbell 1992, Campbell et al. 1982, Gibson and Bray 1986, Margolis and Arthur 1979, McDonald and Margolis 1995, Zubchenko 1975). Parasites of *M. berglax* are similar to those for *C. rupestris*, though a larger number of copepods and protozoans have been found. I found nine additional trematode species, two cestodes, two nematodes and an acanthocephalan juvenile to parasitize *M. berglax*. See Appendix 3.

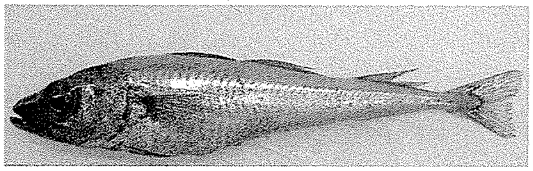
Reproduction and Growth

Macrourus berglax is thought to spawn in winter and early spring (Marshall and Iwamoto 1973, Savvatimsky 1984). At spawning, eggs are 3.4 to 3.85 mm in diameter; however, smaller eggs 0.5 to 2.75 mm may also be contained in the ovary at this time. Yanulov (1962) estimated the number of eggs to be 25,000 and suggested that eggs are laid intermittently over a long spawning period. Spawning grounds are not known at this time.

Macrourus berglax is a slow-growing, late-maturing, long-lived species (Scott and Scott 1988). Females tend to grow faster than males after age seven (Savvatimsky 1984, 1994, Scott and Scott 1988). Savvatimsky (1984) found 15 year-old females to be 65 to 75 cm in length and weigh 1.56 to 2.54 kg. Females 17 to 25 years of age were 67 to 89 cm in length (Savvatimsky 1971). Southern populations grow larger than their northern counterparts (Savvatimsky 1984). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Family Gadidae

***Arctogadus glacialis* (Peters) - Arctic Cod**



Distribution/Habitat

This species is endemic to the Arctic (Andriyashev 1964), occurring in the North Atlantic off the coast of Greenland and in the Arctic Ocean (Cohen et al. 1990). This species is cryopelagic, i.e., a pelagic species associated with sea-ice biota for at least part of its life cycle (Andriyashev 1970, Sufke et al. 1998).

Diet

The diet of *A. glacialis* consists of pelagic prey such as copepods (especially calanoid copepods), amphipods, mysids, ostracods and chaetognaths (Sufke et al. 1998). Less common food items include foraminiferans, euphausiaceans and tanaidaceans (Sufke et al. 1998). In this study, small fish species were also found in the diet. A detailed list of food items can be found in Appendix 2.

Predation

No information is available at this time; however, it is assumed that predators of this species are similar to those of *B. saida*. In this study, *A. glacialis* was found in stomachs of *Lycodes eudipleurostictus* and *R. hippoglossoides*.

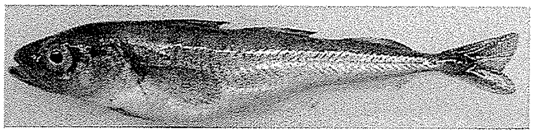
Parasites

Hemiurus levinseni was the only known parasite of this species (Gibson and Bray 1986). I found two additional trematodes and three nematode species to parasitize *A. glacialis*, listed in Appendix 3.

Reproduction and Growth

Information regarding reproduction and growth of this species is limited; however, Sufke et al. 1998) observed specimens up to 34.5 cm in length off the coast of Greenland. Individuals less than 10 cm in length live in swarms or schools of specimens of the same relative size (Sufke et al. 1998). Sufke et al. (1998) also found that females mature faster than males and are longer-lived. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Boreogadus saida (Lepechin) - Polar Cod



Distribution/Habitat

Boreogadus saida is pelagic, forming huge schools at depths of 100 to 300m and temperatures of –1.85 to 3.6°C (Backus 1957, Jensen and Jensen 1991, Scott and Scott 1988). Juveniles have also been found in large numbers at surface depths of 1-2m (Cannon et al. 1991). *Boreogadus saida* is a circumpolar species, occurring off the northern coast of USSR, in the Bering Sea, Chukchi Sea, Barents Sea, Scandinavia, Greenland, and throughout the Canadian Arctic. In the Canadian Atlantic, it is present along the Baffin Island region and Davis Strait into Hudson Strait and Hudson Bay, to Labrador, Strait of Belle Isle, Gulf of St. Lawrence, northern Newfoundland and Grand Bank (Scott and Scott 1988).

Diet

Boreogadus saida feeds primarily on plankton, eating mainly pelagic invertebrates (Coyle et al. 1997, Jensen and Jensen 1991, Scott and Scott 1988). Small individuals feed on copepods including nauplii and eggs, consuming more of amphipods, mysids, euphausiids and various fish species as they grow (Bradstreet et al. 1986, Jensen and Jensen 1991, Michaud et al. 1996, Scott and Scott 1988). Large cod are occasionally cannibalistic (Scott and Scott 1988). A list of food items for this species can be found in Appendix 2.

Predation

Many species utilize the polar cod, including marine mammals such as the harp seal, bearded seal, ringed seal, beluga whale and narwhal (Scott and Scott 1988). Fish predators include Atlantic salmon (*Salmo salar*), Arctic char (*Salvelinus alpinus*), Atlantic cod, Greenland halibut and Greenland cod (*Gadus ogac*). Seabirds and man are also important predators of *B. saida* (Jensen and Jensen 1991, Scott and Scott 1988). Due to its importance in the diet of so many species, *B. saida* is vitally important to the Arctic marine food web (Jensen and Jensen 1991). In this study, larger *B. saida* were cannibalistic. This species was also found in the stomachs of *G. ensis*, *C. reinhardti*, *L. eudipleurostictus*, *L. mcallisteri*, *M. berglax*, *M. scorpius* and *R. hippoglossoides*.

Parasites

Twenty-three parasite species were reported to parasitize *B. saida* previous to this study, the majority of which were trematodes (Bray 1979, Gibson and Bray 1986, Jensen and Jensen 1991, Khan et al. 1997, McDonald and Margolis 1995). I found an additional seven trematodes, one cestode, three nematode, two acanthocephalans and one copepod to also inhabit *B. saida*. See Appendix 3.

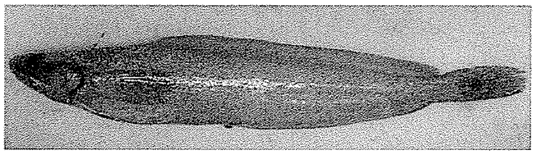
Reproduction and Growth

Boreogadus saida is believed to spawn under the ice from December to March, and in some regions in late fall (Altukhov 1979, Scott and Scott 1988). Mature females produce 21,000 eggs or more, ranging from 1.5 to 1.9 mm in diameter (Andriashev 1954, Scott and Scott 1988). Hatching occurs after about 80 days (Altukhov 1979). Young-of-the-year are planktonic, whereas older fish are found either dispersed throughout the water column, near the bottom and under ice, or in large schools (Bradstreet et al. 1986). In their study, Bradstreet et al. (1986) found young-of-the-year to be more concentrated in the eastern Arctic, within 50 meters of inshore water. Growth of young is relatively rapid and varies depending on location (Bradstreet et al. 1986, Jensen et al. 1991). Jensen et al. (1991) found that growth stops during winter months, and is not solely regulated by the availability of light.

Bradstreet et al (1986) recognized that this species is relatively short-lived, rarely attaining a length of more than 300 mm or an age of seven years. Cod off the Labrador coast tend to grow faster than those from Arctic waters, living up to six years of age, as opposed to ten in the Arctic (Scott and Scott 1988). Jensen et al. (1991) stated that *B. saida* rarely exceeds five years of age. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Family Lotidae

Gaidropsarus argentatus (Reinhardt) – Silvery Threebeard Rockling



Distribution/Habitat

Gaidropsarus argentatus occurs in temperatures between 0.5 and 3.1°C and depths of 400 to 2260 m. It is usually found between 400 and 500 m (Scott and Scott 1988). In the eastern North Atlantic, it ranges from Greenland to Iceland, the Norwegian

Sea to the Faroe Islands. In the western North Atlantic, this species is found from Greenland, south to Baffin Island and Labrador to Grand Bank (Scott and Scott 1988).

Diet

The diet of *G. argentatus* consists of various fish, amphipods, euphausiaceans and decapods (Svetovidov 1986). Several new food items were found for this species, including various amphipods, fish and cephalopods. A summary of food items for this species can be found in Appendix 2.

Predation

The only known predator of *G. argentatus* is Greenland halibut.

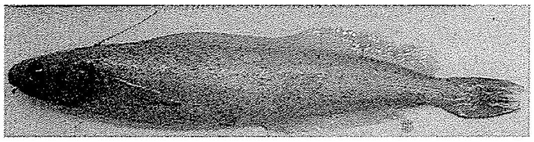
Parasites

There are no previous records of parasites of *G. argentatus*; however, I found eleven different trematodes, one cestode, four nematodes and two acanthocephalans parasitizing this species. For a list, see Appendix 3.

Reproduction and Growth

There is no information regarding growth and reproduction of this species. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Gaidropsarus ensis (Reinhardt) - Threebeard Rockling



Distribution/Habitat

Gaidropsarus ensis is a deepwater species, found at depths of 1500 m and temperatures of -0.2 to 2.47°C (Scott and Scott 1988). It ranges from Baffin Bay and Greenland to Labrador, Flemish Cap, Grand Bank, and from the Scotian Shelf to Cape Hatteras (Scott and Scott 1988).

Diet

The diet of *G. ensis* consists of various fish species, crustaceans and molluscs (Svetovidov 1986). Many new food items were found for this species, including fish, crustaceans (especially amphipods), molluscs and polychaetes. For a more detailed list, see Appendix 2.

Predation

There is no published information; however, this study found *G. ensis* in the stomachs of *R. hippoglossoides*.

Parasites

Three parasites have been reported from *G. ensis*, including two protozoans and one copepod (*Sphyrion lumpi*) (McDonald and Margolis 1995). In this study, sixteen new trematodes, three cestodes, four nematodes, two acanthocephalans and one copepod was found to parasitize *G. ensis*. See Appendix 3.

Reproduction and Growth

Information regarding growth and reproduction of this species is unavailable. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Order Scorpaeniformes

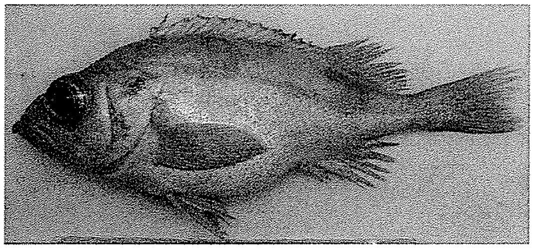
Family Scorpaenidae

Redfishes

In the Canadian Atlantic, there are three species of *Sebastes*, all difficult to distinguish (Scott and Scott 1988). Juveniles of all three are pelagic (Honda and Kan-no 1997, Reilly et al. 1992), adopting a benthic lifestyle over rocky or clay-silt bottom in the adult stage (Scott and Scott 1988). Redfish are pelagic or bathypelagic feeders (Anderson 1994). Adults rise off the bottom at night to feed, whereas larvae feed during the day (Anderson 1994).

Prey items vary with season, increasing in number during late spring and summer due to increased prey abundance (Albikovskaya and Gerasimova 1993, Anderson 1994). As redfish larvae grow, they switch from smaller food types such as euphausiid or copepod eggs and nauplii to cyclopoid and later calanoid copepods and copepodites (Anderson 1994, Runge and de Lafontaine 1996). Pelagic crustaceans such as amphipods, copepods and euphausiids are the primary food for adults (Albikovskaya and Gerasimova 1993, Scott and Scott 1988); however, prey items also include hyperiids, shrimp, chaetognaths, ctenophores, squid, polychaetes, and anchovy (Albikovskaya and Gerasimova 1993).

Sebastes mentella Travin - Deepwater Redfish



Distribution/Habitat

Sebastes mentella is thought to ascend higher up in the water column to feed than any other *Sebastes* sp. (Scott and Scott 1988). It occurs at the greatest depths, from 350 to 700m, occasionally reaching 1100m (Scott and Scott 1988). *Sebastes mentella* is the most widely distributed of the genus, occurring throughout the North Atlantic except the North Sea and Gulf of Maine (Barsukov et al. 1984). It predominates in northern waters such as Baffin Island, and moves further out to sea (Scott and Scott 1988).

Diet

Redfish have extensive diets including amphipods, mysids, isopods, euphausiids, fish and other invertebrates. For a list see Appendix 2 (Anderson 1994, Runge and de Lafontaine 1996, Scott and Scott 1988).

Predation

Predators of redfish include Atlantic halibut, Greenland sharks, thorny skates, redfish, Greenland halibut, Atlantic cod, swordfish, harbour seals (Albikovskaya and Gerasimova 1993, Du Buit 1995, Fjosne and Gjosaeter 1996, Hop et al. 1992, Hop et al. 1997, Michalsen and Nedreaas 1998, Pedersen 1994, Pedersen and Riget 1993, Scott and Scott 1988). In this study, *S. mentella* was occasionally cannibalistic. It was also found in the stomachs of *C. fabricii*, *S. kaupi*, *G. argentatus*, *A. atlanticus* and *M. berglax*.

Parasites

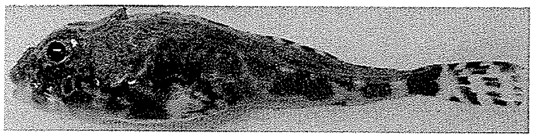
Thirty-four parasite species have been reported from *S. mentella*, the majority of which are trematodes (Bakay 1990, Bourgeois and Ni 1984, Bray and Gibson 1996, Margolis and Arthur 1979, McDonald and Margolis 1995, Moran et al. 1996). In this study, an additional seven trematodes, two cestodes, one nematode and one acanthocephalan were identified in *S. mentella*. For a summary, see Appendix 3.

Reproduction and Growth

Sebastes mentella is also ovoviviparous, often spawning earlier in the season and in deeper water than the other two *Sebastes* species (Barsukov and Zakharov 1972, Scott and Scott 1988). St. Pierre and de Lafontaine (1995) found that redfish spawning is relatively short-lived and occurs in late May to early June for the Gulf of St. Lawrence population. The authors go on to state that fertilization and embryogenesis most likely occur between January and April. Females produce 1500 to 70,000 eggs, numbers increasing with body size (St. Pierre and de Lafontaine 1995). Males reach sexual maturity at a fork length of approximately 18.5 cm, whereas females tend to mature at a smaller size than those of *S. marinus*, at about 29.5 cm (Ni and Templeman 1985). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Family Cottidae

Artediellus atlanticus Jordan & Evermann - Hook-Ear Sculpin



Distribution/Habitat

Artediellus atlanticus has been found between -1.7 and 3°C, but normally occurs in temperatures below 0°C (Von Dorrien 1996). It is present in waters around the coasts of North America from Cape Cod to southeastern Baffin Island (Scott and Scott 1988), with reports from Greenland, Iceland, Svalbard, Scotland, the Faro Islands, Norway, Barents Sea, Kara Sea, and Laptev Sea (Andriyashev 1954, Fedorov 1984, Jensen 1952a, Van Guelpen 1986, Von Dorrien 1996). It is a benthic species during all life stages (Von Dorrien 1996), usually on soft bottom to depths of 384 m (occasionally to 795 m) (Jensen 1952a, Scott and Scott 1988, Van Guelpen 1986). Larger fish most often occupy deeper, colder waters (Scott and Scott 1988).

Diet

Published information regarding the diet of *A. atlanticus* is limited; however, several benthic invertebrates have been identified as important food items. These include small fish (as well as their eggs and larvae), copepods, ostracods, amphipods, cumaceans, decapods, isopods, mysids, bivalves, cephalopods, gastropods, echinoderms and annelids. This species is occasionally cannibalistic. For a more detailed list see Appendix 2.

Predation

No published data are available; however, in this study, *A. atlanticus* was found in the stomachs of *R. hippoglossoides*. In addition, this species was occasionally cannibalistic.

Parasites

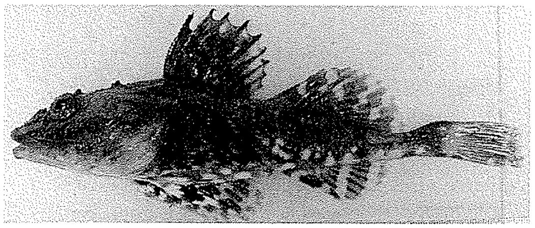
There is no published information; however, I found sixteen trematode species, four cestodes, four nematodes and two acanthocephalans parasitizing *A. atlanticus*. See Appendix 3.

Reproduction and Growth

Jensen (1952a), Van Guelpen (1986) and Von Dorrien (1996) found that males of this species tend to be larger than females. Males and females have been reported to lengths of 10.9 and 10.6 respectively (Van Guelpen 1986). Von Dorrien (1996) reported the largest specimen, at 13 cm.

Spawning is thought to occur from May to November for *A. atlanticus* (Able 1978, Andriashev 1954, Backus 1957, Van Guelpen 1986, Jensen 1952a). Jensen (1952a) found that mature females of 95 and 105 mm in length contained 57 to 71 eggs respectively, all approximately 4.0 mm in diameter. Able (1978) suggested that since they were not found in ichthyoplankton catches in the St. Lawrence estuary, *A. atlanticus* larvae are benthic. Support for this theory comes from a laboratory study conducted by Von Dorrien (1996). I showed that age at maturity varied for different populations of *A. atlanticus*. For example, 80 per cent of females from the Barents Sea were stage IV at maturity, as opposed to those from the Svalbard, where only half were at this stage. Von Dorrien (1996) also found that female gonads accounted for more than half of the gutted body wet weight. In this study, more than 100 eggs were incubated; however, most did not develop. By mid-November, only 15 developing embryos remained. Eggs hatch after seven months, and larvae are at an advanced developmental stage resembling their parents (Von Dorrien 1996). These larvae showed strictly benthic behaviour throughout development, and began to feed after three to four weeks post-hatching. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Myoxocephalus scorpius (Linnaeus) – Shorthorn Sculpin



Distribution/Habitat

Myoxocephalus scorpius is considered an inshore species, preferring cool shoal waters over smooth and weedy bottoms in northern (40°N - 80°N) waters (Fedorov 1984, Scott and Scott 1988). Maximum depth for this species was found to be 145 m; however, it is rarely found below 37 m (Scott and Scott 1988).

Diet

This species is an extremely generalist feeder, eating crab, shrimp, amphipods, sea urchins, marine worms and other benthic invertebrates in addition to small fish such as gobies, herring or cod (Cardinale 2000, Ebling and Alshuth 1989, Gibson and Robb 1996, Wheeler 1969). In this study, gammarids represented the majority of the diet. For a more detailed list see Appendix 2.

Predation

Eggs of this species are occasionally preyed upon by other fish species, despite male guarding behaviour (Scott and Scott 1988). Predators on larvae and adults include sea birds, whales, dolphins, gadids, seals, sharks and skates (Bowman et al. 2000, Hall et al. 1998, Santos et al. 2001). In this study, adults were occasionally cannibalistic.

Parasites

This species is heavily parasitized. Margolis and Arthur (1979) listed several parasites including two protozoans, two myxosporidians, six trematodes, one cestode, three nematodes and four hirudinoideans. For a detailed list see Appendix 3.

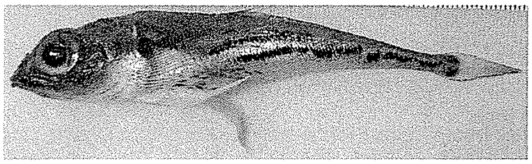
Reproduction and Growth

This species spawns in late November or early December and may last for approximately one month in Newfoundland waters (Ennis 1970a,b). Off Iceland Saemundsson (1949) reported that spawning takes place later, in January or February in the south and west or in May and June in the north and east. In Newfoundland, spawning occurred over rocky bottom at depths of 6 to 11 m (Fahay 1983). Eggs are 2 to 2.5 mm in diameter, are red-yellow to pinkish in colour and contain an oil globule. They are laid in v-shaped crevices, are adhesive and kept clean and well aerated my males (Ennis 1970a,b). Males guard the eggs until hatching, while females move into deeper waters. Development of the embryos takes approximately three months, usually in temperatures of about 0°C. Larvae are 7 to 9 mm long (Fahay 1983) and tend to remain near the bottom.

Males mature earlier than females and tend to be smaller. Males mature at four to six years of age while females mature between six and eight years of age (Ennis

1970a,b). Size, age at maturity, maximum size attained and length of life often differ between habitats (Saemundsson 1949). This species may live to fifteen years. Observed maximum length was 50.6 cm for females and 42.2 cm for males (Ennis 1970a,b). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Triglops nybelini **Jensen – Bigeye/Mailed Sculpin**



Distribution/Habitat

Triglops nybelini occurs at temperatures between -0.1 and -1.8°C (Pietsch 1993) and depths between 135 and 930 m (Scott and Scott 1988, Pietsch 1993). It is more common between 200 and 600 m, and is occasionally found in inshore waters (Scott and Scott 1988). This species is nearly circumpolar in distribution, not found in the North Pacific and Bering Sea. It is present from the Beaufort Sea to Baffin Island, Ungava Bay, Labrador, from Baffin Bay to Greenland, Barents Sea, Kara Sea and Laptev Sea (Scott and Scott 1988).

Diet

Little published information is available for *T. nybelini* in Canadian waters (Scott and Scott 1988). In Soviet Seas, this species feeds predominantly on planktonic crustaceans such as *Themisto* spp. and *Calanus hyperboreus* (Andriyashev 1954). This was also true in the present study; however, other food items were occasionally present.

These included euphausiids, isopods, gastropods, echinoderms and polychaetes. For a detailed list of food items, see Appendix 2.

Predation

Little information is available regarding predation of this species; however, it is a known food item of seabirds such as the thick-billed murre (Gaston et al. 1985). *Triglops* sp. have also been found in the stomachs of American plaice (Klemetsen 1993, Martell and McClelland 1992). In this study, *T. nybelini* was also found in stomachs of *R. hippoglossoides*.

Parasites

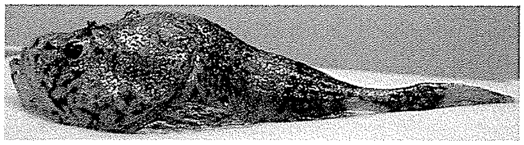
No published information was available; however, in this study, thirteen trematodes, three cestodes, four nematodes, two acanthocephalans and one copepod were found to parasitize *T. nybelini*. See Appendix 3.

Reproduction and Growth

Information regarding reproduction and growth of this species is limited; however, in Greenland waters, most specimens collected in June appeared to be spent females (Scott and Scott 1988). Eggs are demersal and Andriashev (1949) found that the number of eggs spawned ranges from 100 to 2739 for the genus *Triglops*. One female obtained from the Kara Sea in August contained 307 eggs measuring 2.8 mm in diameter (Andriashev 1954). Thus, it has been suggested that this species spawns in summer (Andriashev 1949, Scott and Scott 1988). Females tend to be somewhat larger than males (Pietsch 1993). Males possess a prominent urogenital papilla (Pietsch 1993). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Family Psychrolutidae

Cottunculus microps Collett - Polar Sculpin



Distribution/Habitat

Cottunculus microps is a benthic species occurring in temperatures of 1.3 to 4°C (Scott and Scott 1988) and depths between 170 and 896 m (Andriyashev 1954, Scott and Scott 1988). Its range includes the North Atlantic Ocean, Arctic Ocean and Barents Sea (Andriyashev 1954, Scott and Scott 1988).

Diet

Little published information is available regarding the diet of *C. microps*; however, benthic invertebrates including polychaetes, amphipods and other crustaceans are known food items (Andriyashev 1954). I found many new food items for the species, including several crustaceans, cephalopods and echinoderms. For a list of food items see Appendix 2.

Predation

No published information is available; however, in this study *C. microps* was found in stomachs of *R. hippoglossoides*.

Parasites

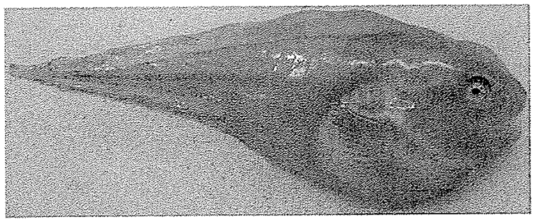
Five species were known to parasitize *C. microps* prior to this study (Bray 1979, Margolis and Arthur 1979, McDonald and Margolis 1995). I found ten additional trematodes, one monogenean, three cestodes, three nematodes, two acanthocephalans and one copepod parasitizing *C. microps*. See Appendix 3.

Reproduction and Growth

There is little information regarding growth and reproduction for this species; however, Andriashev (1954) reported that specimens from the Barents Sea contained ripening eggs in June and July. These specimens contained between 124 and 220 eggs approximately 4.5 mm in diameter. Growth rate in unknown for this species; however, they have been reported to lengths of 30 cm (Jensen 1952a). Scott and Scott (1988) observed that females tend to be longer than males. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Family Liparidae

Careproctus reinhardti Kroyer– Sea Tadpole



Distribution/Habitat

This species ranges from the Gulf of St. Lawrence north to Baffin Bay and Davis Strait, Greenland and eastward to Jan Mayen Islands, Novaya Zemlya and the Kara Sea.

Diet

Little published information is available regarding the diet of *C. reinhardti*. Stien and Able (1986) reported unspecified benthic crustaceans from the stomachs of *C.*

reinhardti. An extensive diet was found for *C. reinhardti* in this study, including crustaceans (mostly amphipods), cephalopods and polychaetes. For a detailed list, see Appendix 2.

Predation

Although information on predators is scarce, Berestovski (1990) found *C. reinhardti* in the stomachs of the skate, *Raja radiata,* in the Barents and Norwegian Seas. Fish of the genus *Careproctus* have been found in stomachs of *R. hippoglossoides*, along with several other species from the family Liparidae and as such, this species is also assumed to be a food item of the predator.

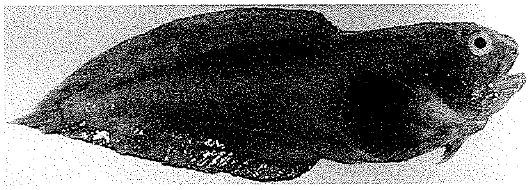
Parasites

McDonald and Margolis (1995) reported one trematode from this species, *Stenakron vetustum*. I found an additional eight trematodes, one cestode, two nematodes, two acanthocephalans and one copepod. See Appendix 3.

Reproduction and Growth

Little is know regarding reproduction and growth of this species; however, Able and Irion (1985) found mature females at 12 cm or more with eggs larger than 4 mm, suggesting that eggs and larvae are demersal. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Liparis fabricii Kroyer - Gelatinous Snailfish



Distribution/Habitat

Liparis fabricii is a circumpolar benthic species occurring in temperatures of -1.5 to 0.56°C and depths between 49 and 100 m (Able and McAllister 1980, Scott and Scott 1988). This species is occasionally pelagic (Able and McAllister 1980, Backus 1957, Scott and Scott 1988). It is a circumpolar species, found in arctic seas of Alaska, Canada, Greenland, Iceland, Europe and the USSR (Scott and Scott 1988). In Canada, it is found from Yukon to northern Ellesmere Island, Baffin Island, Labrador and Grand Bank (Backus 1957). Adults and juveniles are presumed to be planktonic in the Gulf of St. Lawrence (Able and Irion 1985).

Diet

This species is known to feed on invertebrates such as amphipods (Green and Steele 1977), mysids, euphausiids, gammarids, other crustaceans and polychaetes (Able and McAllister 1980, Scott and Scott 1988). I found it to be occasionally cannibalistic. For a detailed list of food items see Appendix 2.

Predation

Liparis fabricii has been found in the stomachs of Atlantic cod, seals, and seabirds including terns and murres (Able and McAllister 1980). *Liparis fabricii* was found in stomachs of *M. berglax*, *B. saida*, *G. ensis* and *R. hippoglossoides* in my study. It was occasionally cannibalistic.

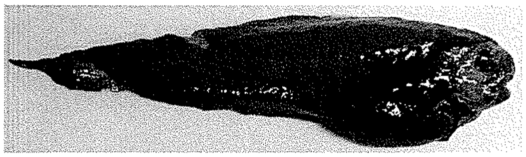
Parasites

No published information was available; however, I found eleven trematodes, two cestodes, four nematodes and one copepod species to parasitize *L. fabricii*. See Appendix 3.

Reproduction and Growth

There is little information regarding growth and reproduction of this species. Andriashev (1954) suggested that spawning occurs in September and October after observing females that contained eggs 2.1 to 2.7 mm in diameter. The author also noted that 485 to 735 eggs per female. In addition, young 12 to 31 mm in length have been reported off Labrador and Baffin Island in July and August (Dunbar 1947). Young are planktonic in the St. Lawrence River and Gulf of St. Lawrence (Able and McAllister 1980), the Strait of Belle Isle (Dannevig 1919) and off Labrador (Backus 1951, 1957, Able and Irion 1985). Able and McAllister (1980) reported that males tend to be larger than females. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Paraliparis bathybius **(Collett) – Black Seasnail**



Distribution/Habitat

Paraliparis bathybius occurs in temperatures usually below 0°C at depths of 600 to 4000m (Nielsen and Bertelsen 1992). It is usually bathypelagic and can be found in

Western Greenland in the Davis Strait and the Norwegian Sea (Andriyashev 1954, Grey 1956, Okamura et al. 1995).

Diet

The diet of *P. bathybius* consists of various amphipods, gastropods and mysids (Stein and Able 1986). Decapods and polychaetes were also found in stomachs in the present study. For a list of food items see Appendix 2.

Predation

There was no information available prior to this study. Though no specimens were found in stomachs of other species, it is likely that predators of *L. fabricii* and other snailfish also feed on *P. bathybius*.

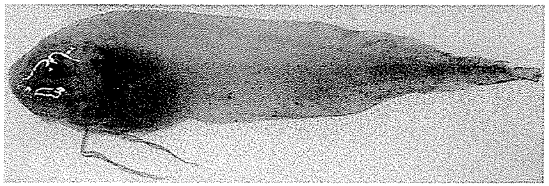
Parasites

No published information was available; however, I collected one trematode and one cestode from *P. bathybius*. See Appendix 3.

Reproduction and Growth

No information is available at this time; however, ovaries of several size classes or "generations" have been found in the ovaries of other *Paraliparis* species, including *P. balgueriasi* and *P. hureaui* from the Weddell Sea (Matallanas 1999). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Rhodichthys regina **Collett - Threadfin Seasnail**



Distribution/Habitat

Rhodichthys regina occurs at depths between 1150 and 2400 m (Grey 1956, Nielsen and Bertelsen 1992) around Greenland and the Norwegian Sea (Okamura et al. 1995). It is present in the west around Baffin Bay and the Davis Strait, and in the east from the Laptev Sea and north of Novaya Zemlya (Grey 1956). This species tends to occur in waters with temperatures below 0°C (Grey 1956).

Diet

Bjelland et al. (2000) reported shrimp/prawn remains of the infraorder Caridea (Decapoda) as well as unidentified foraminiferans as food items for *R. regina*. I found copepods, several amphipods, mysids, echinoderms and polychaetes in stomachs of this species. See Appendix 2.

Predation

No information available prior to this study. Though no specimens were found in stomachs of other species, it is likely that predators of *L. fabricii* and other snailfish also feed on *R. regina*.

Parasites

No information was available in the literature; however, I found five trematodes, one cestode and one nematode to parasitize *R. regina*. See Appendix 3.

Reproduction and Growth

As described for *P. bathybius*. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

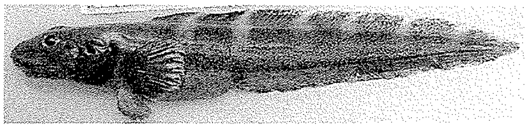
Order Perciformes

Family Zoarcidae

EELPOUTS

This family consists of benthic to bathypelagic marine coldwater fishes found in the Arctic, Antarctic, Atlantic and Pacific Oceans (Scott and Scott 1988). Eelpouts are important food items for many commercial species such as Atlantic cod, Atlantic halibut and Greenland halibut (Scott and Scott 1988).

Lycodes eudipleurostictus Jensen - Doubleline Eelpout



Distribution/Habitat

Lycodes eudipleurostictus is found in temperatures from zero to 4.9°C and depths between 188 and 975 m (Møller and Jorgensen 2000, Nielsen and Bertelsen 1992). It is present off the coasts of Greenland to Iceland, Beaufort Sea, Norwegian Sea and northwestern Barents Sea to Severnaya Zemlya (Møller and Jorgensen 2000, Okamura et al. 1995).

Diet

Valtysson (1995) found various fish, polychaetes, echinoderms, molluscs and sponges in the stomachs of *L. eudipleurostictus*. I found several species of amphipods in the diet as well as decapods, isopods, mysids, pycnogonids, ostracods and cumaceans. For a list of known food items see Appendix 2.

Predation

No information regarding predation of this species is available; however, it is assumed to be an important food item for commercial species such as Atlantic cod, Atlantic halibut and Greenland halibut. In this study, *L. eudipleurostictus* was often found in stomachs of *R. hippoglossoides*.

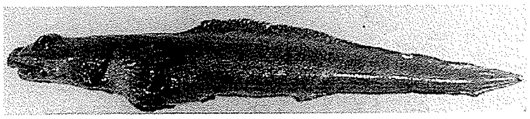
Parasites

Two species of parasites from *L. eudipleurostictus* have been described, including one annelid and one protozoan. In this study, sixteen trematodes, one cestode, four nematodes, two acanthocephalans and one copepod were recovered from this species. See Appendix 3.

Reproduction and Growth

Very little information is available regarding growth and reproduction of this species; however, Møller and Jorgensen (2000) found ripening gonads in females greater than 23 cm and males greater than 29 cm in length. The number of eggs per female ranged from 120 to 300, with diameters 2.7 to 8 mm (Jensen 1952b, Møller and Jorgensen 2000). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Lycodes paamiuti Möller – Paamiut's Eelpout



Distribution/Habitat

Lycodes paamiuti is found in the North Atlantic from Davis Strait to the Greenland and Norwegian seas (Møller 2001b). It occurs at depths between 350 and 1300 m and temperatures below 4°C (Møller 2001b).

Diet

Little published information is available for this species; however, it is assumed to have eating habits and prey species similar to other *Lycodes* species of similar size. I found that assumption to be true compared to the diet of *L. eudipleurostictus*. For a detailed list, see Appendix 2.

Predation

No information has been published with regard to predation of *L. paamiuti*. In this study, it was found in stomachs of *S. kaupi*, *M. berglax* and *R. hippoglossoides*.

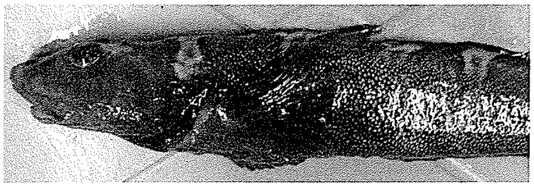
Parasites

No information was available in the literature; however, this study found seven trematodes, three cestodes, two nematodes and two acanthocephalans parasitizing *L. paamiuti*. See Appendix 3.

Reproduction and Growth

Little information is available at this time. This species is known to reach lengths of 22 – 24 cm (Møller 2001b) and it is possible that females are smaller than males. Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Lycodes mcallisteri Möller – Peter's Eelpout



Distribution/Habitat

This species occurs in the Northwest Atlantic from Baffin Bay to Hudson Strait (63°N to 70°N latitude) (Møller 2001a). It is found at depths from approximately 300 – 700 m in temperatures between 1 and -1°C.

Diet

Published information regarding the diet of this species is lacking; however, in this study the diet of *L. mcallisteri* was similar to other *Lycodes* species. See Appendix 2.

Predation

No information has been published with regard to predation of *L. paamiuti*. In this study, it was found in stomachs of *M. berglax*.

Parasites

No information was available in the literature; however, I found five trematodes, one cestode, three nematodes and one copepod parasitizing *L. mcallisteri*. See Appendix 3.

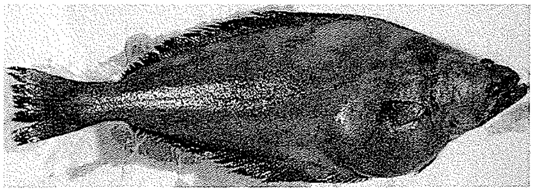
Reproduction and Growth

Little is known regarding reproduction and growth of this species. It has been known to reach sizes of 23 to 37.5 cm, with males often larger than females (Møller 2001a). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

Order Pleuronectiformes

Family Pleuronectidae

Reinhardtius hippoglossoides (Walbaum) - Greenland Halibut/Turbut



Distribution/Habitat

Reinhardtius hippoglossoides occurs at bottom temperatures of -0.5 to 6.0°C, with preferred temperatures of zero to 4.5°C (Scott and Scott 1988). Total depth range is 90 to 1600 m, with larger fish occurring in deeper waters (Scott and Scott 1988). *Reinhardtius hippoglossoides* is considered partly pelagic, spending much of its time off the bottom (Scott and Scott 1988). It is found in the Atlantic and Pacific Oceans. In the northeast Atlantic, it occurs around Iceland and the Greenland Sea to the Arctic Ocean, Barents and Norwegian seas to the Faroe-Shetland Ridge (Scott and Scott 1988). In the northwest Atlantic, *R. hippoglossoides* is present from Smith Sound in western Greenland, along the Labrador coast, Newfoundland banks and the Gulf of St. Lawrence to the southern edge of the Scotian Shelf and Georges Bank (Scott and Scott 1988). It rarely inhabits the Bay of Fundy (Barret 1968).

Diet

The list of prey items of Greenland halibut is extensive, including various invertebrates and fishes (Atkinson et al. 1982, Bowering and Lilly 1992, Dawe et al. 1998, Orlov 1997a, b, Palsson 1997, Rodriguez et al. 1995, Scott and Scott 1988). Over

30 new food items were found for this species in the present study. For a detailed description see Appendix 2.

Predation

The Greenland shark is considered the most important predator of *R. hippoglossoides*, although other fish such as cod, salmon and other Greenland halibut also feed on them (Bowering 1983, Dunbar and Hildebrand 1952, Scott and Scott 1988). Marine mammals such as the beluga whale, narwhal, and hooded seal are also known predators (Mansfield 1967, Bowering 1983), as well as humans.

Parasites

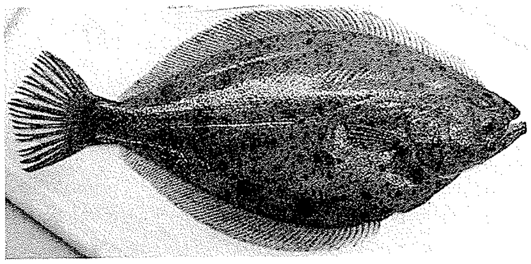
Fifty-four parasite species are known from *R. hippoglossoides*, including several protozoans, trematodes, cestodes, nematodes, acanthocephalans, and copepods. One representative each of Annelida, Monogenea and Isopoda are also listed (Arthur and Albert 1992a, b, Boje et al. 1997, Bray 1979, 1987, Bray and Gibson 1996, Gibson and Bray 1986, Khan et al. 1980, 1982, Margolis and Arthur 1979, McDonald and Margolis 1995, Rubec 1988, Scott and Bray 1989, Wierzbicka 1990, 1991a, b). In this study, eleven additional trematodes, one monogenean, one cestode, two nematodes and two copepods were found to parasitize *R. hippoglossoides* (Appendix 3).

Reproduction and Growth

This species is believed to spawn in the Davis Strait in winter or early spring at depths between 650 and 1000 m (Bowering 1983, Templeman 1973). Females may produce 30,000 to 300,000 eggs, depending on body length, and egg diameter is 4.0 to 4.5 mm when fertilized (Scott and Scott 1988). Eggs and small larvae occur at depths between 600 and 1000 m; however, larvae soon rise to surface waters (around 30 m) where they remain until a length of about 70 mm is reached (Scott and Scott 1988). Throughout this growing period, young are carried by current action southward to the continental shelf, Labrador and Newfoundland, as well as northward along the Davis Strait (Bowering 1978, 1983). They eventually descend to greater depths; however, they are not as closely associated with the bottom as other flatfish species (Scott and Scott 1988). Bowering (1983) found large numbers of young in the Baffin Bank region, suggesting this may be a nursery area for this species.

Males and females have similar growth rates to the ages of five to seven or lengths of approximately 45 cm (Scott and Scott 1988). At this point, females grow faster and tend to be longer-lived (Scott and Scott 1988). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

***Hippoglossoides platessoides* (Fabricius) - American Plaice**



Distribution/Habitat

Hippoglossoides platessoides is a demersal species (Klemetsen 1993), preferring water temperatures of slightly below zero to 1.5°C (Scott and Scott 1988). However, it has been found up to 13°C (Scott 1982a). This species prefers sand or mud bottoms to depths of 73 to 274 m or more (Scott and Scott 1988). *Hippoglossoides platessoides* occurs in the eastern North Atlantic from Iceland and Spitsbergen to the British Isles and English Channel (Scott and Scott 1988). In the western Atlantic, it occurs in deep water from Frobisher Bay, Baffin Island, western Hudson Bay (Hunter et al. 1984), along the Labrador coast, Newfoundland banks, Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy, and Gulf of Maine to Rhode Island (Scott and Scott 1988).

Diet

This species has an extensive list of prey items from published literature (Klemetsen 1993, Martell and McClelland 1992, 1994, Ntiba and Harding 1993, Packer et al. 1994, Palsson 1997, Powles 1965, Scott 1973, Scott and Scott 1988, Zamarro 1992). Food items vary with size and locality, but in general include crustaceans such as mysids and amphipods, polychaetes, cnidarians, echinoderms, molluscs and fish such as capelin (*Mallotus villosus*), sand lance (*Ammodytes* sp.) and mailed sculpin (*Triglops nybelini*) (Klemetsen 1993, Martell and McClelland 1992, Powles 1965, Scott 1973, Scott and Scott 1988). Six new food items were identified for this species in the present study and are listed in Appendix 2.

Predation

Predators of American plaice include cod, halibut and Greenland sharks, though other large fishes are assumed to feed on them as well (Scott and Scott 1988). In this study, *H. platessoides* was found in stomachs of *R. hippoglossoides*.

Parasites

Sixty-six parasite species are known from *H. platessoides*, including several protozoans, trematodes, cestodes, nematodes, acanthocephalans, and copepods. One representative each of Annelida and Monogenea are also listed (Boily and Marcogliese

1995, Bray 1979, 1987, Bray and Gibson 1986, Gibson and Bray 1986, Lile 1998, Margolis and Arthur 1979, McDonald and Margolis 1995, Morrison and Shum 1983, Scott 1982b, Stafford 1904, Zubchenko 1980). In my study, three additional trematodes, two cestodes, one nematode, one acanthocephalan and one copepod were also found to parasitize *H. platessoides* (Appendix 3).

Reproduction and Growth

This species spawns at depths to 182 m, beginning in February and extending into August, depending on location (Nevinsky and Serebryakov 1973, Pitt 1966, Scott and Scott 1988, Walsh 1994). Spawning migrations are not common; however, Milinsky (1944) found that the Barents Sea population is an exception. The number of eggs produced by a female depends on body size and age to a lesser extent (Bagenal 1955, Pitt 1964). For example, females approximately 40 cm in length produce an average of 250,000 to 300,000 eggs, whereas one 70 cm in length can produce up to 1.5 million (Pitt 1964). Eggs are 1.5 to 2.8 mm in diameter, depending on the population, and are free-floating near the surface (Scott and Scott 1988, Walsh 1994). Fertilized eggs are carried great distances, and time to hatching depends on water temperature (Scott and Scott 1988). Upon hatching, young are 4 to 6 mm in length, and 18 to 34 mm at transformation (Fahay 1983). Larval growth takes approximately three to four months, after which larvae settle in oceanic nursery areas in offshore banks to mix with older juveniles and adults (Milinsky 1944, Walsh 1982).

Growth rate varies among populations; however, all are slow-growing and long-lived (up to 25 years of age) (Pitt 1982, Scott and Scott 1988, Walsh 1994). Males mature faster than females (at 4 to 5 years as opposed to 5 or more years for females); however, they grow more slowly and are not as long-lived (Minet 1973, Scott and Scott 1988). Length, weight, temperature and depth data as found in the literature have been summarized in Appendix 4 along with that found in the present study.

APPENDIX 2. FOOD ITEMS OF TWENTY-SIX FISH SPECIES WITHIN DAVIS STRAIT AND BAFFIN BAY– A COMPENDIUM OF PRESENT STUDY AND PUBLISHED DATA

Common Name	Black Dogfish	Longnose Eel
Latin Name	*Centroscyllium fabricii*	*Synaphobranchus kaupi*
Species ID#	27	152
Food Items	FISH	FISH
	Melamphaidae	Centriscidae
	*Scopelogadus beani***	*Macroramphosus scolopax*
	Sebastidae	Myctophidae
	Sebastes sp.*	*Lampanyctus macdonaldi***
	*Sebastes mentella***	Sebastidae
	Zoarcidae	*Sebastes mentella***
	Lycodes sp.**	Zoarcidae
	Fish sp.**	*Lycodes paamiuti***
	INVERTEBRATES	Fish sp.*
	Cnidaria	INVERTEBRATES
	Crustacea*	Malacostraca
	Decapoda**	Amphipoda**
	Oplophoridae	Euphausiacea
	Acanthephyra sp.**	Decapoda*
	Pandalidae	Hippolytidae
	Pandalus sp.**	*Bythocaris gracilis***
	Pasiphaeidae	Isopoda**
	Pasiphaea sp.**	Mysidacea**
	Euphausiacea	Mysidae
	Euphausiidae	*Boreomysis* sp.**
	*Thysanopoda acutifrons***	Mollusca
	Mysidacea**	Bivalvia**
	Mysidae	Cephalopoda
	*Ambylops abbreviata***	Gonatidae
	Mollusca	*Gonatus fabricii***
	Bivalvia**	Sepiolidae
	Cephalopoda*	*Rossia* sp.
	Gonatidae	Annelida
	*Gonatus fabricii***	Polychaeta**
	Annelida	
	Polychaeta**	

*Previously published and found in present study

**New record, found in present study

Glacier Lanternfish
Benthosema glaciale
290

- FISH
- Larvae
- INVERTEBRATES
- Crustacea
  - Copepoda
    - Calanoida
      - Acartiidae
        - *Acartia clausi*
      - Aetideidae
        - *Aetideus armatus*
        - *Udeuchaeta* sp.
      - Calanidae*
        - *Calanus finmarchicus*
        - *Calanus helgolandicus*
        - *Calanus hyperboreus**
      - Centropagidae
        - *Centropages typicus*
      - Clausocalanidae
        - *Pseudocalanus elongatus*
      - Eucalanidae
        - *Rhincalanus nasutus*
      - Euchaetidae
        - *Euchaeta norvegica*
        - *Pareuchaeta norvegica*
      - Heterorhabdidae
        - *Heterorhabdias sp.*
        - *Mesorhabdus brevicaudatus*
      - Lucicutiidae
        - *Lucicutia sp.*
      - Metridinidae
        - *Metridia lucens*
        - *Metridis* sp.
        - *Pleuromamma* sp.
        - *Pleuromamma robusta*
    - Cyclopoda sp.
  - Ostracoda
      - Halocyprididae
        - *Conchoecia borealis*
        - *Conchoecia* sp.
  - Malacostraca
    - Amphipoda
      - Hyperiidae
        - *Parathemisto oblivia*
        - *Themisto compressa**
        - *Themisto libelula*
    - Decapoda
      - Sergestidae
        - *Sergestes* sp. larvae
      - Decapoda sp. larvae
    - Mysidacea**
      - Mysidae
        - *Boreomysis* sp.**
    - Euphausiacea
      - Euphausiidae
        - *Meganyctiphanes norvegicus*
        - *Thysanoessa* sp.
    - Mysidacea
- Annelida
  - Polychaeta
- Chaetognatha
      - Oikopleuridae
        - *Oikopleura* sp.
      - Sagittidae
        - *Sagitta* sp.

Rakery Beaconlamp
Lampanyctus macdonaldi
283

- INVERTEBRATES
- Crustacea*
  - Copepoda
    - Calanoida
      - Aetideidae
        - *Valdiviella brevicornis*
      - Augaptilidae
        - *Euaugaptilus sp.*
      - Calanidae*
        - *Calanus hyperboreus***
        - *Calanus finmarchicus*
      - Euchaetidae
        - *Euchaeta norvegica*
        - *Euchaeta sp.*
      - Lucicutiidae
        - *Lucicutia sp.*
      - Metridinidae
        - *Metridia* sp.
        - *Pleuromamma abdominalis*
        - *Pleuromamma gracilis*
        - *Pleuromamma robusta*
        - *Pleuromamma* sp.
      - Megacalanidae
        - *Bathycalanus princeps*
      - Scolecitrichidae
        - *Scottocalanus persecans*
    - Cyclopoda sp.
  - Ostracoda
      - Halocyprididae
        - *Conchoecia* sp.
  - Malacostraca
    - Amphipoda
      - Hyperiidae
        - *Metacyphocaris helgae*
        - *Themisto compressa*
        - *Scina* sp.
    - Cumacea
      - Diastylidae
        - *Diastylis rathkei***
    - Decapoda larvae
    - Euphausiacea
      - Euphausiidae
        - *Thysanopoda acutifrons*
    - Mysidacea*
      - Eucopiidae
        - *Eucopia* sp.
      - Mysidae
        - *Boreomysis sp.***
        - *Boreomysis tridens*

- Mollusca
- Chaetognatha
- Tunicata

Goitre Blacksmelt *Bathylagus euryops* 202	Blue Hake *Antimora rostrata* 432
INVERTEBRATES	FISH
Crustacea*	Notosudidae
Copepoda**	*Scopelosaurus lepidus***
Calanoida	Fish sp.**
Calanidae	INVERTEBRATES
*Calanus hyperboreus***	Crustacea*
*Calanus finmarchicus***	Copepoda
Euchaetidae	Calanoida
*Euchaeta glacialis***	Calanidae
Ostracoda**	*Calanus hyperboreus***
Cypridinidae	Malacostraca
*Philomedes brenda***	Amphipoda
Malacostraca	Calliopiidae
Amphipoda**	*Apherusa* sp.**
Hyperiidae**	Hyperiidae
*Themisto abyssorum***	*Hyperia medusarum***
*Themisto compressa***	Lysinassidae**
*Themisto libellula***	Decapoda**
Lysianassidae**	Pandalidae
*Onisimus litoralis***	*Pandalus* sp.**
Euphausiacea	Mysidacea**
Euphausiidae	Mollusca
*Thysanopoda acutifrons***	Bivalvia
Isopoda**	Cephalopoda
Mysidacea	Gonatidae
Mysidae	*Gonatus fabricii***
*Boreomysis sp.***	Annelida
Echinodermata	Polychaeta**
Ophiuroidea**	

Roundnose Grenadier
Coryphaenoides rupestris
481

- FISH
- Bathylagidae
- Marouridae
  - Coryphaenoides rupestris**
- Cottidae
- Myctophidae
- Alepocephalidae
  - _Xenodermichthys copei_
- Paralepididae
  - _Notolepis rissoi_
- Synaphobranchidae
  - _Synaphobranchus kaupi_
- INVERTEBRATES
- Ctenophora
  - Salpidae gen. sp.
- Crustacea
  - Copepoda*
    - Calanoida
      - Aetideidae
        - _Aetideopsis multiserrata_
      - Calanidae
        - _Calanus hyperboreus_*
        - _Calanus finmarchus_**
      - Euchaetidae
        - _Eucheata norvegica_
        - _Eucheata_ sp.
      - Metridinidae
        - _Pleuromamma robusta_
      - Phaennidae
        - _Xanthocalanus profundus_
    - Cyclopoida sp.
  - Ostracoda
  - Cirripedia (Larvae)
  - Malacostraca
    - Amphipoda*
      - Ampeliscidae
        - _Ampellisa_ sp.
        - _Haploops tubicola_**
      - Lysianassidae**
        - _Anonyx nugax_**
        - _Eurytenes gryllus_**
        - _Onisimus_ sp.**
        - _Orchomenella_ sp.**
      - Oediceridae
        - _Arrhis_ sp.**
    - Cumacea
      - Diastylidae
        - _Diastylis rathkei_**
    - Decapoda
      - Pandalidae
        - _Pandalus_ sp.
      - Pasiphaeidae
        - _Pasiphaea tarda_
      - Oplophoridae
        - _Hymenodora glacialis_**
    - Euphausiacea
      - Euphausiidae
        - _Meganyctiphanes norvegica_
        - _Thysanopoda acutifrons_**
    - Isopoda
      - Tanaidae
        - _Tanaidacea_ sp.
    - Mysidacea*
      - Chironomidae
        - _Hemimysis_ sp.
      - Mysidae
        - _Ambylops abbreviata_**
        - _Boreomysis_ sp.*
- Mollusca
  - Bivalvia
  - Gastropoda
  - Cephalopoda*
    - Gonatidae
      - _Gonatus fabricii_**
- Echinodermata
  - Ophiuroidea
    - Ophiuridae
      - _Ophiocten_ sp.
  - Spatangoidea
  - Holothuroidea
- Annelida
  - Polychaeta*
- Chaetognatha
  - Larvacea

Roughhead Grenadier

Macrourus berglax

474

- FISH
- Ammodytidae
  - *Ammodytes* sp.
- Gadidae*
  - *Boreogadus saida***
- Liparidae**
  - Liparis fabricii**
- Lotidae
  - *Gaidropsarus* sp.**
- Macrouridae*
  - *Macrourus berglax***
- Osmeridae
  - *Mallotus* sp.
- Rajidae
- Sebastidae
  - *Sebastes* sp.
  - *Sebastes mentella***
- Zoarcidae*
  - *Lycenchelys* sp.**
  - *Lycodes* sp.**
  - *Lycodes mcallisteri***
  - *Lycodes paamiuti***
- Fish sp.**
- INVERTEBRATES
- Crustacea*
  - Copepoda*
    - Calanoida
      - Calanidae
        - *Calanus sp.***
        - *Calanus hyperboreus**
        - *Calanus finmarchus***
      - Euchaetidae
        - *Euchaeta glacialis***
  - Ostracoda**
      - Cypridinidae
        - *Philomedes brenda***
  - Malacostraca
    - Amphipoda*
      - Ampeliscidae
        - *Haploops* sp.**
        - *Haploops tubicola***
        - *Haploops setosa***
      - Calliopiidae
        - *Apherusa* sp.**
      - Epimeridae
        - *Epimera loricata***
      - Eusiridae**
        - *Eusirus* sp.**
        - *Eusirus cuspidatus***
        - *Eusirus homi***
      - Gammaridae**
        - *Gammarus* sp.**
        - *Lilljeborgia* sp.**
      - Hyperiidae**
        - *Hyperia* sp.**
        - *Hyperia galba***
        - *Themisto libellula***
      - Lysinassidae*
        - *Anonyx* sp.**
        - *Anonyx lilljeborjia***
        - *Anonyx nugax***
        - *Eurytenes gryllus***
        - *Nannonyx* sp.**
        - *Onisimus* sp.**
        - *Onisimus normani***
        - *Orchomene serratus***
        - *Orchomenella* sp.**
      - Oediceridae**
        - *Arrhis phyllonyx***
      - Pardaliscidae
        - *Halice abyssi***
      - Photidae**
        - *Autonoe* sp.**
      - Stegocephalidae**
        - *Andania abyssi***
        - *Stegocephalus* sp.**
      - Stenothoidae**
        - *Stenothoe* sp.**
    - Cumacea**
      - Diastylidae
        - *Diastylis rathkei***
    - Decopoda*
      - Crangonidae
        - *Sclerocrangon ferox***
      - Galatheidae
        - *Munida* sp.**
      - Hippolytidae
        - *Bythocaris gracilis***
      - Pandalidae
        - *Pandalus borealis**
      - Pasiphaeidae
        - *Pasiphaea sp.***
      - Oplophoridae
        - *Hymenodora glacialis***
    - Euphausiacea**
    - Isopoda*
      - Eurycopidae
        - *Eurycope* sp.**

Macrourus berglax Continued...	Arctic Cod Arctogadus glacialis 452
Aegidae**	FISH
Aega sp.**	Fish sp.
Gnathidae	INVERTEBRATES
Gnathia sp.**	Crustacea
Lophogastridae	Copepoda
*Gnathophausia zoea***	Calanoida
Munnidae**	Calanidae
Munnopsidae**	Calanus hyperboreus**
Paranthuridae	Euchaetidae
Calathura sp.**	Eucheata glacialis**
Tanaidae**	Malacostraca
Mysidacea*	Amphipoda*
Eucopiidae	Hyperiidae
Eucopia sp.**	*Themisto* sp.**
Mysidae	*Themisto abyssorum***
Boreomysis sp.**	*Themisto libellula***
*Erythrops microps***	Decapoda**
Erythrops sp.**	Euphausiacea
Pseudomma sp.**	Mysidacea*
Echinodermata*	Mysidae
Asteroidea*	*Boreomysis* sp.**
Holothuroidea**	Tanaidacea
Ophiuroidea*	Ostracoda
Ophiothricidae	Annelida
Ophiocantha sp.	Polychaeta
Mollusca	Chaetognatha
Bivalvia*	
Cephalopoda*	
Oegopsida	
Gonatidae	
*Gonatus fabricii***	
Octopoda	
Octopodidae	
Octopus sp.**	
Gastropoda*	
Buccinidae	
Buccinum sp.	
Annelida*	
Polychaeta*	

Polar Cod
Boreogadus saida
451

- FISH
- Gadidae
  - *Boreogadus saida**
- Fish sp.
- Eggs/Larvae**
- Liparidae
  - *Liparis fabricii***
- INVERTEBRATES
- Protozoa
  - Tintinnidae
    - *Tintinnus* sp.
- Crustacea*
  - Copepoda*
    - Nauplii
    - Eggs
    - Calanoida
      - Acartiidae
        - *Acartia longiremis*
      - Aetideidae
        - *Derjuginia tolli*
      - Calanidae*
        - *Calanus glacialis*
        - *Calanus hyperboreus**
        - *Calanus finmarchicus**
      - Centropagidae
        - *Limnocalanus macrurus*
      - Clausocalanidae
        - *Microcalanus pusillus*
        - *Pseudocalanus minutus*
      - Euchaetidae
        - *Euchaeta glacialis*
      - Oithonidae
        - *Oithona atlantica*
        - *Oithona similis*
      - Temoridae
        - *Eurytemora* sp.
  - Cirripdia
  - Malacostraca
    - Amphipoda*
      - Hyperiidae*
        - *Parathemisto* sp.
        - *Themisto* sp.**
        - *Themisto abyssorum***
        - *Themisto compressa***
        - *Themisto libellula***
      - Lysianassidae**
      - Oedicerotidae
        - *Monoculodes* sp.
    - Cumacea
      - Leuconidae
        - *Eudorella* sp.
        - *Leucon* sp.
    - Decapoda
      - Hippolytidae
        - *Eualus gaimardii*
      - Majidae
        - *Hyas* sp.
      - Paguridae
    - Isopoda**
    - Mysidacea
      - Mysidae
        - *Boreomysis* sp.**
    - Euphausiacea
      - Euphausiidae
        - *Thysanoessa inermis*
    - Mysidacea
      - Mysidae
        - *Mysis oculata*
        - *Pseudomma truncatum*
- Mollusca
  - Bivalvia*
  - Cephalopoda**
    - Gonatidae
      - *Gonatus fabricii***
  - Gastropoda (Larvae)
- Annelida
  - Polychaeta
- Chaetognatha
  - Larvacea

Silvery Three-Beard Rockling
Gaidropsarus argentatus
455

- FISH
- Lotidae
  - *Gaidropsarus* sp.**
- Myctophidae
  - *Lampanyctus macdonaldi***
- Sebastidae
  - *Sebastes mentella***
- Zoarcidae
  - *Lycodes* sp.**
- Fish sp.*
- INVERTEBRATES
- Crustacea*
  - Copepoda
    - Calanoida
      - Calanidae
        - *Calanus hyperboreus***
  - Malacostraca
    - Amphipoda*
      - Ampeliscidae
        - *Haploops tubicola***
      - Calliopiidae
        - *Apherusa* sp.**
      - Eusiridae
        - *Eusirus cuspidatus***
        - *Eusirus holmi***
      - Gammaridae
        - *Lilljeborgia* sp.**
      - Lysinassidae**
        - *Eurytenes gryllus***
        - *Onisimus* sp.**
      - Stegocephalidae**
    - Decopoda*
      - Hippolytidae
        - *Bythocaris gracilis***
      - Oplophoridae
        - *Hymenodora glacialis***
      - Pandanlidae
        - *Pandalus* sp.**
    - Euphausiacea
    - Isopoda**
      - Eurycopidae
        - *Eurycope* sp.**
    - Mysidacea**
      - Mysidae
        - *Ambylops abbreviata***
        - *Boreomysis* sp.**
        - *Erythrops microps***
        - *Pseudomma affine***
- Mollusca
  - Cephalopoda**
    - Gonatidae
      - *Gonatus fabricii***
  - Gastropoda**
- Annelida
  - Polychaeta**

Three-Beard Rockling
Gaidropsarus ensis
453

- FISH
- Gadidae
  - *Boreogadus saida***
- Gobiidae
- Labridae
- Liparidae
  - *Liparis fabricii***
- INVERTEBRATES
- Crustacea
  - Copepoda*
    - Calanoida
      - Calanidae
        - *Calanus hyperboreus***
        - *Calanus finmarchus***
      - Euchaetidae
        - *Euchaeta glacialis***
  - Ostracoda**
  - Malacostraca
    - Amphipoda*
      - Ampeliscidae**
        - *Haploops tubicola***
      - Calliopiidae**
        - *Apherusa* sp.**
      - Eusiridae**
        - *Eusirus* sp.**
        - *Eusirus cuspidatus***
        - *Eusirus homi***
        - *Rhachotropis* sp.**
      - Gammaridae**
        - *Gammarus* sp.**
        - *Lilljeborgia* sp.**
        - *Maera* sp.**
      - Hyperiidae
        - *Hyperia galba***
        - *Themisto sp.***
        - *Themisto abyssorum***
        - *Themisto compressa***
        - *Themisto libellula***
      - Lysinassidae**
        - *Anonyx* sp.**
        - *Anonyx nugax***
        - *Aristias microps***
        - *Haplonyx sp.***
        - *Haplonyx albidus***
        - *Onisimus* sp.**
        - *Onisimus litoralis***
        - *Orchomene* sp.**
        - *Orchomenella* sp.**
        - *Tryphosa* sp.**
      - Photidae**
      - Podoceridae**
        - *Dulichia* sp.**
      - Stegocephalidae**
        - *Andania* sp.**
        - *Andania abyssi***
        - *Stegocephalus* sp.**
      - Stenothoidae
        - *Stenothoe* sp.**
    - Cumacea**
      - Diastylidae
        - *Diastylis rathkei***
      - Pseudocumatidae
        - Pseudocuma sp.**
    - Decapoda*
      - Hippolytidae
        - *Bythocaris gracilis***
      - Pasiphaeidae
        - *Pasiphaea sp.***
      - Oplophoridae
        - *Acanthephyra* sp.**
        - *Hymenodora glacialis***
    - Euphausiacea**
      - Euphausiidae
        - *Thysanopoda acutifrons***
    - Isopoda*
      - Eurycopidae
        - *Eurycope* sp.**
        - *Eurycope cornuta***
      - Aegidae**
        - *Aega* sp.**
      - Gnathidae
        - *Gnathia* sp.**
        - *Paragnathis formica***
      - Munnopsidae**
      - Tanaidae**
    - Mysidacea*
      - Mysidae
        - *Boreomysis* sp.**
        - *Erythrops microps***
        - *Erythrops* sp.**
        - *Parerythrops* sp.**
        - *Pseudomma affine***
        - *Pseudomma* sp.**
- Mollusca
  - Bivalvia**
  - Cephalopoda*
    - Gonatidae
      - *Gonatus fabricii***
  - Gastropoda**
- Echinodermata
  - Asteroidea*
- Annelida
  - Polychaeta**

Deepwater Redfish
Sebastes mentella
794

- FISH
- Engraulidae
- Sebastidae
    - *Sebastes* sp.
    - *Sebastes mentella***
- Fish sp.**
- INVERTEBRATES
- Dinophyta
- Ctenophora
- Crustacea*
    - Copepoda*
        - Calanoida
            - Calanidae
                - *Calanus finmarchicus*
                - *Calanus glacialis*
                - *Calanus hyperboreus**
                - Eggs
                - Nauplii
            - Oithonidae
                - *Oithona similis*
        - Cyclopoida
            - Nauplii
    - Malacostraca
        - Amphipoda*
            - Hyperiidae*
                - *Themisto* sp.*
                - *Themisto compressa***
                - *Themisto libellula***
            - Gammaridea
            - Lysinassidae**
        - Decopoda*
            - Pandalidae
                - *Pandalus borealis*
                - *Pandalus montagui*
            - Pasiphaeidae
                - *Pasiphaea* sp. **
        - Euphausiacea
        - Mysidacea*
            - Mysidae
                - *Boreomysis* sp.**
- Mollusca
    - Bivalvia
    - Cephalopoda*
        - Gonatidae
            - *Gonatus fabricii***
    - Gastropoda
        - Limacinidae
            - *Limacina* sp.
- Echinodermata**
- Annelida
    - Polychaeta*
- Chaetognatha

Hook-Ear Sculpin
Artediellus atlanticus
810

- FISH
- Cottidae
  - *Artediellus atlanticus***
- Psychrolutidae
  - *Cottunculus* sp.**
- Sebastidae
  - *Sebastes mentella***
- Fish sp.**
- Eggs/Larvae**
- INVERTEBRATES
- Crustacea*
  - Copepoda*
    - Calaniidae
      - *Calanus hyperboreus***
      - *Calanus finmarchus***
  - Ostracoda
    - Cypridinidae
      - *Philomedes brenda***
  - Malacostraca
    - Amphipoda*
      - Ampeliscidae**
        - *Haploops tubicola***
      - Aoridae**
      - Eusiridae
        - *Eusirus* sp.**
        - *Eusirus cuspidatus***
      - Gammaridae
        - *Gammarus* sp.**
        - *Lilljeborgia fissicornis***
      - Hyperiidae*
        - *Themisto* sp.**
        - *Themisto libellula***
      - Lysinassidae**
        - *Anonyx* sp.**
        - *Anonyx nugax***
        - *Eurytenes gryllus***
        - *Onisimus* sp.**
      - Oediceridae**
      - Photidae**
      - Podoceridae
        - *Erichthonius tolli***
      - Stegocephalidae**
        - *Andania* sp.**
        - *Andania abyssi***
        - *Stegocephaloides* sp.**
    - Cumacea
      - Diastylidae
        - *Diastylis rathkei***
      - Pseudocumatidae
        - Pseudocuma sp.**
    - Decopoda
      - Oplophoridae
        - *Acanthephyra* sp.**
    - Isopoda*
      - Cirolanidae
        - *Cirolana borealis***
      - Eurycopidae
        - *Eurycope* sp.**
        - *Eurycope producta***
      - Gnathidae
        - *Gnathia maxillaris***
    - Mysidacea*
      - Mysidae
        - *Ambylops abbreviata***
        - *Boreomysis* sp.**
        - *Parerythrops* sp.**
- Mollusca
  - Bivalvia*
  - Cephalopoda*
    - Oegopsida
      - Gonatidae
        - *Gonatus fabricii***
    - Octopoda
      - Octopodidae
        - *Octopus* sp.**
  - Gastropoda*
    - Prosobranchia**
- Echinodermata
  - Asteroidea*
  - Crinoidea
  - Echinoidea
  - Ophiuroidea*
- Annelida
  - Polychaeta*
  - Oligochaeta**

Shorthorn Sculpin
Myoxocephalus scorpius
108

- FISH
- Agonidae
  - *Agonus cataphractus*
- Ammodytidae
- Clupeidae
  - *Clupea harengus*
- Cottidae
  - *Myoxocephalus* sp.
- Gadidae
  - *Boreogadus saida***
- Gasterosteidae
  - *Gasterosteus aculeatus*
- Gobiidae
  - *Pomatoschistus minutus*
- Osmeridae
- Pleuronectidae
- INVERTEBRATES
- Crustacea
  - Copepoda*
    - Calaniidae
      - *Calanus* sp.**
      - *Calanus finmarchus***
  - Malacostraca
    - Amphipoda*
      - Calliopiidae**
        - *Apherusa* sp.**
      - Hyperiidae**
        - *Themisto libellula***
      - Gammaridae
        - *Gammarus* sp.**
        - *Gammarus campylops***
        - *Gammarus setosa**
      - Lysinassidae**
        - *Onisimus edwardsi***
        - *Onisimus litoralis***
        - *Orchomenella minuta***
    - Decapoda
      - Crangonidae
        - *Crangon allmanni*
        - *Crangon* sp.
        - *Sclerocrangon* sp.
      - Hippolytidae
        - *Lebbeus polarus*
      - Majidae
        - *Hyas* sp.
      - Nephropsidae
        - *Nephrops norvegica*
      - Palaemonidae
        - *Leander* sp.
      - Portunidae
        - *Macropipus holsatus*
    - Isopoda
      - Chaetiliidae
        - *Mesidotea entomon*
        - *Mesidothea*
    - Mysidacea
      - Mysidae
        - *Mysis mixta*
        - *Praunus flexosus*
- Mollusca
  - Bivalvia*
    - Mytilidae
      - *Modiolus barbatus*
  - Gastropoda*
    - Trochidae
      - *Margarites umbilicalis*
- Annelida
  - Polychaeta
    - Nereididae
      - *Nereis pelagica*

Polar Sculpin
Cottunculus microps
829

- FISH
- Eggs/Larvae**
- INVERTEBRATES
- Crustacea*
  - Copepoda*
    - Calaniidae*
      - *Calanus hyperboreus**
      - *Calanus finmarchus***
    - Euchaetidae
      - *Euchaeta glacialis***
  - Malacostraca
    - Amphipoda*
      - Ampeliscidae**
        - *Haploops setosa***
      - Caprellidae**
      - Calliopiidae**
        - *Apherusa* sp.**
        - *Haliragoides inermis***
      - Epimeridae
        - *Epimera loricata***
      - Eusiridae**
        - *Eusirus* sp.**
        - *Eusirus cuspidatus***
        - *Eusirus homi***
        - *Rhachotropis* sp.**
      - Gammaridae**
        - *Gammarus* sp.**
        - *Liljeborgia* sp.**
      - Hyperiidae*
        - *Hyperia* sp.**
        - *Hyperia galba***
        - *Hyperia medusarum***
        - *Themisto compressa***
      - Lysinassidae*
        - *Anonyx* sp.**
        - *Anonyx lilljeborjia***
        - *Anonyx nugax***
        - *Aristias* sp.**
        - *Aristias microps***
        - *Eurytenes* sp.**
        - *Eurytenes gryllus***
        - *Haplonyx albidus***
        - *Nannonyx* sp.**
        - *Onisimus* sp.**
        - *Onisimus litoralis***
        - *Onisimus normani***
        - *Onisimus plantus***
        - *Orchomene* sp.**
        - *Orchomene ambylops***
        - *Orchomene pectinatus***
        - *Orchomenella* sp.**
      - Oediceridae
        - *Arrhis phyllonyx***
      - Pardaliscidae
        - *Pardalisca* sp.**
      - Phoxocephalidae
        - *Harpinia* sp.**
      - Podoceridae
        - *Dulichia* sp.**
        - *Erichthonius* sp.**
        - *Erichthonius tolli***
      - Stegocephalidae**
        - *Andania* sp.**
        - *Andania abyssi***
        - *Stegocephaloides* sp.**
      - Syrrhoidae**
    - Cumacea**
      - Diastylidae
        - *Diastylis rathkei***
      - Pseudocumatidae
        - *Pseudocuma* sp.**
    - Decapoda
      - Hippolytidae
        - *Bythocaris gracilis***
      - Hyppolytidae**
      - Oplophoridae
        - *Acanthephyra* sp.**
      - Pasiphaeidae
        - *Pasiphaea* sp.**
    - Euphausiacea*
      - Euphausiidae
        - *Thysanopoda acutifrons***
    - Isopoda*
      - Aegidae
        - *Aega* sp.**
      - *Calathura* sp.**
      - Eurycopidae
        - *Eurycope* sp.**
        - *Eurycope phallangium***
      - Gnathidae
        - *Gnathia maxillaris***
      - Munnopsidae**
      - Munnidae**
      - Tanaidae**
    - Mysidacea*
      - Mysidae
        - *Ambylops abbreviata***
        - *Boreomysis* sp.**
        - *Erythrops* sp.**
        - *Erythrops microps***
        - *Pseudomma affine***
  - Pycnogonida**
- Mollusca
  - Bivalvia*
  - Cephalopoda*
    - Gonatidae
      - *Gonatus fabricii***
  - Gastropoda*
    - Prosobranchia**
- Echinodermata**
  - Holothuroidea**
  - Ophiuroidea**
- Annelida
  - Polychaeta*

Arctic Mailed Sculpin
Triglops nybelini
815

- INVERTEBRATES
- Crustacea*
  - Copepoda
    - Calaniidae
      - *Calanus hyperboreus**
      - *Calanus finmarchus***
  - Malacostraca
    - Amphipoda*
      - Hyperiidae
        - *Themisto* sp.*
        - *Themisto abyssorum***
        - *Themisto compressa***
        - *Themisto libellula***
    - Decapoda
    - Euphausiacea**
      - Euphausiidae
        - *Thysanopoda acutifrons***
    - Isopoda**
- Mollusca
  - Bivalvia
  - Gastropoda**
- Echinodermata**
  - Ophiuroidea**
- Annelida
  - Polychaeta**

Sea Tadpole
Careproctus reinhardti
28

- FISH
- Gadidae
  - *Boreogadus saida***
- INVERTEBRATES
- Crustacea**
  - Copepoda*
    - Calaniidae
      - *Calanus hyperboreus***
      - *Calanus finmarchus***
  - Malacostraca
    - Amphipoda**
      - Ampeliscidae**
      - Calliopiidae**
      - Eusiridae
        - *Eusirus homi***
        - *Rhachotropis* sp.**
      - Gammaridae**
      - Hyperiidae**
        - *Hyperia* sp.**
        - *Themisto* sp.**
        - *Themisto abyssorum***
        - *Themisto compressa***
        - *Themisto libellula***
      - Lysinassidae**
        - *Anonyx* sp.**
        - *Anonyx nugax***
        - *Haplonyx* sp.**
        - *Hippomedon* sp.**
        - *Onisimus* sp.**
        - *Onisimus edwardsi***
        - *Onisimus litoralis***
        - *Onisimus normani***
        - *Orchomene serratus***
        - *Orchomenella* sp.**
      - Oediceridae
        - *Oediceros* sp.**
      - Pardaliscidae
        - *Halice abyssi***
      - Stegocephalidae**
        - *Andania abyssi***
        - *Stegocephalus* sp.**
        - *Stegocephalus inflatus***
      - Stenothoidae**
    - Cumacea
      - Diastylidae
        - *Diastylis rathkei***
      - Pseudocumatidae
        - *Pseudocuma* sp.**
    - Decapoda**
      - Hippolytidae
        - *Eualus* sp.**
    - Isopoda**
    - Mysidacea**
      - Mysidae
        - *Boreomysis* sp.**
- Mollusca
  - Cephalopoda**
    - Gonatidae
      - *Gonatus fabricii***
- Annelida
  - Polychaeta**

Gelatinus Snailfish
Liparis fabricii
859

- FISH
- Liparidae
  - *Liparis fabricii***
- Eggs/Larvae**
- INVERTEBRATES
- Crustacea*
  - Copepoda*
    - Calaniidae
      - *Calanus* sp.**
      - *Calanus hyperboreus***
      - *Calanus finmarchus***
    - Euchaetidae
      - *Euchaeta glacialis***
  - Ostracoda**
    - Cypridinidae
      - *Philomedes brenda***
  - Malacostraca
    - Amphipoda*
      - Hyperiidae*
        - *Hyperia* sp.**
        - *Hyperia galba***
        - *Themisto* sp.**
        - *Themisto abyssorum***
        - *Themisto compressa***
        - *Themisto libellula***
      - Gammaridae
        - *Gammarus* sp.
        - *Halirages fulvocinctus*
        - *Stegocephaloides christianiensis*
      - Lysinassidae
        - *Onisimus normani***
    - Decapoda
      - Pandalidae
        - *Pandulus borealis*
    - Euphausiacea
    - Mysidacea*
      - Mysidae
        - *Ambylops abbreviata***
        - *Boreomysis* sp.**
        - *Mysis oculata*
        - *Pseudomma roseum**
- Mollusca
  - Bivalvia**
  - Cephalopoda*
  - Gastropoda**
- Echinodermata
  - Ophiuroidea**
- Annelida
  - Phascolosomatidae
    - *Phascolosoma* sp.
  - Polychaeta*
- Chaetognatha

Black Seasnail
Paraliparus bathybius
855

- INVERTEBRATES
- Crustacea*
  - Copepoda
    - Calaniidae
      - *Calanus hyperboreus***
  - Malacostraca
    - Amphipoda*
      - Hyperiidae**
        - *Hyperia galba***
        - *Themisto* sp.**
        - *Themisto abyssorum***
        - *Themisto compressa***
        - *Themisto libellula***
      - Lysinassidae**
        - *Callisoma crenata***
        - *Onisimus* sp.**
    - Decopoda**
      - Oplophoridae
        - *Hymenodora glacialis***
    - Mysidacea*
      - Mysidae
        - *Boreomysis* sp.**
- Mollusca
  - Gastropoda
- Annelida
  - Polychaeta**

Threadfin Seasnail
Rhodichthys regina
852

- INVERTEBRATES
- Foraminifera
- Crustacea*
  - Copepoda
    - Calaniidae
      - *Calanus hyperboreus***
  - Malacostraca
    - Amphipoda**
      - Ampeliscidae**
        - *Haploops* sp.**
        - *Haploops tubicola***
      - Hyperiidae**
        - *Themisto* sp.**
        - *Themisto abyssorum***
        - *Themisto compressa***
      - Lysinassidae**
        - *Eurytenes gryllus***
        - *Haplonyx* sp.**
        - *Orchomenella* sp.**
        - *Tryphosa* sp.**
      - Stegocephalidae**
        - *Andania* sp.**
    - Decapoda
      - Caridea
    - Mysidacea**
      - Mysidae
        - *Boreomysis* sp.**
- Echinodermata**
- Annelida
  - Polychaeta**

Doubleline Eelpout
Lycodes eudipleurostictus
736

- FISH
- Gadidae**
  - *Arctogadus glaciale***
  - *Boreogadus saida***
- Fish sp.*
- INVERTEBRATES
- Porifera
- Crustacea
  - Copepoda
    - Calaniidae
      - *Calanus* sp.**
      - *Calanus hyperboreus***
  - Ostracoda**
    - Cypridinidae
      - *Philomedes brenda***
  - Malacostraca
    - Amphipoda**
      - Ampeliscidae**
        - *Haploops* sp.**
        - *Haploops tubicola***
      - Eusiridae
        - *Eusirus cuspidatus***
        - *Eusirus homi***
      - Epimeridae
        - *Epimera loricata***
      - Hyperiidae**
        - *Hyperia* sp.**
        - *Hyperia medusarum***
        - *Themisto* sp.**
        - *Themisto abyssorum***
        - *Themisto compressa***
        - *Themisto libellula***
      - Gammaridae
        - *Gammarus* sp.**
        - *Lilljeborgia* sp.**
      - Lysinassidae**
        - *Anonyx* sp.**
        - *Anonyx nugax***
        - *Hippomedon* sp.**
        - *Onisimus* sp.**
        - *Onisimus normani***
        - *Orchomene* sp.**
        - *Orchomene pectinatus***
        - *Orchomenella* sp.**
      - Podoceridae
        - *Ericthonius tolli***
      - Stegocephalidae**
        - *Andania* sp.**
    - Cumacea**
      - Diastylidae
        - *Diastylis rathkei***
      - Pseudocumatidae
        - *Pseudocuma* sp.**
    - Decapoda**
    - Isopoda**
      - Aegidae**
      - Paranthuridae
        - *Calathura* sp.**
      - Eurycopidae
        - *Eurycope* sp.**
        - *Eurycope producta***
      - Gnathidae
        - *Gnathia maxillaris***
      - Munnopsidae**
        - *Munnopsis typica***
      - Tanaidae**
    - Mysidacea**
      - Mysidae
        - *Boreomysis* sp.**
        - *Erythrops microps***
        - *Pseudomma affine***
- Pycnogonida**
- Mollusca*
  - Bivalvia**
  - Cephalopoda**
    - Gonatidae
      - *Gonatus fabricii***
  - Gastropoda**
- Echinodermata*
  - Asteroidea**
  - Ophiuroidea**
- Annelida
  - Polychaeta*

Pamiut's Eelpout
Lycodes paamiuti
87

- INVERTEBRATES
- Crustacea**
  - Copepoda
    - Calaniidae
      - *Calanus* sp.**
      - *Calanus hyperboreus***
  - Ostracoda**
    - Cypridinidae
      - *Philomedes brenda***
  - Malacostraca
    - Amphipoda**
      - Ampeliscidae**
        - *Haploops* sp.**
        - *Haploops tubicola***
        - *Haploops setosa***
      - Caprellidae
        - *Aegina echinata***
      - Eusiridae
        - *Eusirus* sp.**
        - *Eusirus cuspidatus***
      - Gammaridae
        - *Gammarus* sp.**
        - *Gammaracanthus* sp.**
        - *Lilljeborgia* sp. **
      - Hyperiidae
        - *Themisto* sp. **
        - *Themisto compressa***
      - Lysinassidae**
        - *Aristias* sp.**
        - *Anonyx nugax***
        - *Eurytenes gryllus***
        - *Onisimus* sp.**
        - *Onisimus normani***
        - *Orchomene* sp.**
        - *Orchomenella* sp.**
      - Paramphithoidae sp.**
      - Podoceridae
        - *Ericthonius* sp.**
        - *Ericthonius tolli***
      - Stegocephalidae**
        - *Andania* sp.**
        - *Andania abyssi***
      - Stenothoidae
        - *Stenothoe* sp.**
      - Syrrhoidae
        - *Bruzelia tuberculata***
    - Cumacea
      - Diastylidae
        - *Diastylis rathkei***
    - Decapoda**
    - Isopoda**
      - Apseudidae**
      - Colletteidae
        - *Haplocope* sp.**
      - Eurycopidae
        - *Eurycope* sp.**
        - *Eurycope producta***
      - Gnathidae
        - *Gnathia maxillaris***
        - *Paragnathis formica***
      - Paranthuridae
      - *Calathura* sp.**
    - Mysidacea**
      - Mysidae
        - *Boreomysis* sp.**
- Mollusca**
  - Bivalvia**
  - Cephalopoda**
    - Gonatidae
      - *Gonatus fabricii***
  - Gastropoda**
    - Prosobranchia**
- Echinodermata*
  - Ophiuroidea**
- Annelida
  - Polychaeta*

McAllister's Eelpout
Lycodes mcallisteri
86

- FISH
- Gadidae**
  - *Boreogadus saida***
- INVERTEBRATES
- Crustacea**
  - Copepoda
    - Calaniidae
      - *Calanus hyperboreus***
  - Malacostraca**
    - Amphipoda**
      - Ampeliscidae**
        - *Haploops* sp.**
      - Eusiridae**
        - *Eusirus cuspidatus***
      - Epimeridae
        - *Epimera loricata***
      - Gammaridae**
        - *Maera* sp.**
      - Hyperiidae**
        - *Themisto compressa***
      - Laphystiidae**
      - Lysinassidae**
        - *Anonyx nugax***
        - *Haplonyx* sp.**
        - *Lysianella* sp.**
        - *Onisimus* sp.**
        - *Onisimus litoralis***
        - *Orchomene* sp.**
        - *Orchomenella* sp.**
      - Oediceridae**
      - Stegocephalidae**
        - *Andania* sp.**
        - *Stegocephalus* sp.**
    - Isopoda**
      - Aegidae
        - *Aega* sp.**
      - Eurycopidae
        - *Eurycope producta***
      - Gnathidae
        - *Gnathia maxillaris***
        - *Gnathia* sp.**
      - Munnopsidae**
      - Trichoniscidae
        - *Haplophthalmus* sp.**
    - Decapoda**
      - Hippolytidae
        - *Eualus* sp.**
    - Mysidacea**
      - Mysidae
        - *Boreomysis* sp.**
- Pycnogonida**
- Mollusca**
  - Bivalvia**
- Echinodermata**
  - Ophiuroidea**
- Annelida
  - Polychaeta**

Greenland Halibut
Reinhardtius hippoglossoides
892

- FISH
- Agonidae gen. sp.
- Ammodytidae
  - _Ammodytes marinus_
- Anarhichadidae
  - _Anarhichas_ sp.
- Bathylagidae
  - _Bathylagus euryops_
  - _Leuroglossus schmidti_
- Chiasmodontidae
  - _Chiasmodon niger_
- Cottidae
  - _Artediellus atlanticus_**
  - _Cottunculus_ sp.**
  - _Icelus_ sp.
  - _Triglops_ sp.
  - _Triglops nybelini_**
- Eurypharyngidae**
  - _Eurypharynx pelecanoides_**
- Gadidae
  - _Arctogadus glacialis_*
  - _Boreogadus saida_*
  - _Gaidropsarus argentatus_
  - _Micromesistius poutassou_
- Hexagrammidae
- Liparidae*
  - _Careproctus cypselurus_
  - _Elassodiscus tremebundus_
  - _Elassodiscus obscurus_
  - _Elassodiscus_ sp.
  - _Paraliparis grandis_
  - _Paraliparis_ sp.
  - _Liparis_ gen. sp.
  - _Liparis fabricii_**
- Lotidae
  - _Gaidropsarus_ sp.**
  - _Gaidropsarus ensis_**
- Macrouridae*
  - _Macrourus berglax_*
  - _Coryphaenoides rupestris_
  - _Coryphaenoides cinereus_
  - _Nezumia bairdi_
- Melamphaidae**
  - _Scopelogadus beani_**
- Moridae
  - _Antimora rostrata_
- Myctophidae
  - _Benthosema glaciale_**
  - _Stenobrachius leucopsarus_
  - _Stenobrachius nannochir_
  - _Lampanychtus jordani_
- Nemichthyidae
- Notacanthidae
  - _Notacanthus chemnitzi_
- Notosudidae
  - _Scopelosaurus_ sp.
- Osmeridae
  - _Mallotus villosus_
- Phycidae
  - _Ciliata septentrionalis_
  - _Urophycis_ sp.
- Pleuronectidae
  - _Hippoglossoides platessoides_
  - _Reinhardtius hippoglossoides_*
- Psychrolutidae
  - _Cottunculus microps_
  - _Malacocottus zonurus_
- Rajidae
- Sebastidae
  - _Sebastes_ sp.*
  - _Sebastolobus macrochir_
  - _Sebastes mentella_**
- Squalidae
- Zoarcidae
  - _Lycenchelys_ sp.
  - _Lycodes_ sp. **
  - _Lycodes eudipleurostictus_**
  - _Lycodes paamiuti_**
  - _Lycodes vahli_
- Eggs/Larvae**
- INVERTEBRATES
- Cnidaria
- Crustacea
  - Copepoda
    - Calaniidae
      - _Calanus hyperboreus_**
  - Ostracoda**
  - Malacostraca
    - Amphipoda *
      - Amphilochidae**
      - Eusiridae
        - _Eusirus_ sp.**
        - _Eusirus cuspidatus_**
      - Hyperiidae*
        - _Themisto_ sp.*
        - _Themisto abyssorum_**
        - _Themisto compressa_**
        - _Themisto libellula_*
        - _Lycaeidae_ sp.
      - Lysianassidae
        - _Anonyx nugax_*
        - _Eurytenes gryllus_**
        - _Timetomyx_ sp.
      - Gammaridae
    - Cumacea**
      - Diastylidae**
        - _Diastylis rathkei_**
    - Decopoda
      - Hippolytidae
        - _Eualus_ sp.**
      - Oplophoridae
        - _Acanthephyra_ sp.**
        - _Hymenodora glacialis_**
      - Pasiphaeidae
        - _Pasiphaea tarda_*
        - _Pasiphaea multidentato_*
      - Pandalidae
        - _Pandalus borealis_*
        - _Pandalus montagui_*
      - Crangonidae
        - _Pontophilus norvegicus_
      - Lithodidae
    - Euphausiacea
      - Euphausiidae
        - _Meganyctiphanes norvegica_
        - _Sergestres arcticus_
    - Isopoda**
      - Eurycopidae
        - _Eurycope_ sp.**
    - Mysidacea*
      - Mysidae*
        - _Boreomysis_ sp.**
        - _Boreomysis artica_
- Mollusca
  - Cephalopoda*
    - Oegopsida
      - Chiroteuthidae
        - _Chiroteuthis_ sp.
      - Gonatidae
        - _Berryteuthis magister_
        - _Gonatus fabricii_*
    - Teuthida
    - Octopoda (eggs and adults)
      - Octopodidae
        - _Octopus vulgaris_
  - Bivalvia
    - Myidae

Reinhardtius hippoglossoides Continued…

            - *Mya arenaria*
    - Gastropoda*
        - Buccinidae
- Echinodermata
    - Asteroidea
        - Ophiolepidae
            - *Ophiura texturata*
- Annelida
    - Polychaeta*

American Plaice
Hippoglossoides platessoides
889

- FISH
- Ammodytidae
  - *Ammodytes lancea*
- Clupeidae
  - *Sprattus sprattus*
  - *Clupea harengus*
  - Larvae
- Gobidae
- Cottidae
  - *Triglops* sp.
  - *Triglops nybelini***
- Osmeridae
  - *Mallotus villosus*
- Gadidae
  - *Merlangius merlangus*
  - *Gadus morhua*
- Lotidae
  - *Gaidropsarus* sp.
- Fish sp.**
- INVERTEBRATES
- Cnidaria
  - Actinaria
    - Hormathiidae
      - *Actinauge longicornis*
- Crustacea*
  - Copepoda
    - Calanidae
      - *Calanus hyperboreus**
    - Cyclopoda
  - Malacostraca
    - Amphipoda*
      - Ampeliscidae
        - *Ampelisca macrocephala*
      - Aoridae
        - *Unicola irrorata*
      - Argissidae
        - *Argissa hamatipes*
      - Calliopiidae
        - *Halirages fulvocinctus*
      - Caprellidae
        - *Aeginina longicornis*
        - *Caprella* sp.
      - Corophiidae
        - *Corophium bonelli*
        - *Corophium crassicorne*
        - *Erichthonius rubicornis*
      - Eusiridae
        - *Rhachotropis lobata*
        - *Rhadoctropis macropus*
        - *Rhachotropis oculata*
        - *Eusirus* sp.
      - Haustoriidae
        - *Priscillina armata*
      - Hyperiidae
        - *Themisto* sp.
        - *Themisto compressa**
      - Ischyroceridae
        - *Ischyroceros anguipes*
      - Lysianassidae
        - *Anonyx lilljeborgii*
        - *Haplonyx* sp.**
        - *Hippomedon serratus*
      - Oedicerotidae
        - *Arrhis phyllonx*
        - *Monoculodes edwardsi*
        - *Monoculoides intermedius*
      - Photidae
        - *Leptocheirus pinguis*
        - *Photis* sp.
        - *Protomedeia fasciata*
      - Pleustidae
        - *Pleustes panopla*
        - *Pleustes glaber*
        - *Stenopleustes inermis*
      - Podoceridae
        - *Dyopedos* sp.
      - Pontogeneiidae
        - *Pontogeneia inermis*
      - Stenothoidae
        - *Metopa alderi*
        - *Metopa bruzelii*
        - *Metopa pusilla*
        - *Metopella augusta*
        - *Stenothoe brevicornis*
    - Cumacea
      - Bodotriidae
      - Diastylidae
        - *Diastylis rathkei*
        - *Diastylis sculpta*
        - *Diastylis quadrispinosa*
      - Leuconidae
        - *Eudorellopsis deformis*
      - Lampropidae
        - *Lamprops quadrireplicata*
      - Pseudocumidae
        - *Petalosarsia declivis*
    - Decopoda*
      - Crangonidae

Hippoglossoides platessoides Continued...

- *Crangon almani*
- *Crangon crangon*
- *Crangon septemspinosa*
- Hippolytidae
  - *Spirontocaris lilljeborgii*
- Nephtyidae
  - *Aglaophamus malmgreni*
  - *Pagurus bernhardus*
- Paguridae
- Pandalidae
  - *Dichelopandalus leptocerus*
  - *Lumbrineries* sp.
  - *Pandalus borealis*
- Portunidae
  - *Liocarcinus depurator*
- Euphausiacea
  - Euphausiidae
    - *Meganyctiphanes norvegica*
- Isopoda
  - Idoteidae
    - *Chiridotea* sp.
    - *Edotea montosa*
    - *Idotea phosporea*
  - Janiridae
    - *Janira alta*
- Mysidacea*
  - Mysidae
    - *Boreomysis* sp.**
    - *Erythrops erythropthalma*
    - *Mysis mixta*
    - *Neomysis americana*
    - *Pseudoma truncatum*
- Mollusca
  - Bivalvia*
    - Heterodontida
        - *Cerasotoderma pinnulatum*
      - Cardiidae
        - *Clinocardium ciliatum*
      - Petricolidae
        - *Petricola pholadiformes*
    - Myoida
      - Hiatellidae
        - *Hiatella arctica*
    - Nuculoida
      - Nuculidae
        - *Nuculoma tenuis*
        - *Nuculana pernula*
    - Pteroconchida
      - Anomiidae
        - *Anomia* sp.
      - Pectinidae
        - *Chlamys islandicus*
    - Veneroida
      - Semelidae
        - *Abra nitida*
  - Gastropoda
    - Archaeogastropoda
      - Trochacea
        - *Margarites costalis*
      - Buccinidae
        - *Buccinium undatum*
        - *Neptunea* sp.
    - Cephalaspida
      - Retusidae
        - *Retusa obtusa*
      - Cyclichnidae
        - *Cyclichna gouldii*
    - Naticacea
      - Naticidae
        - *Polinices* sp.
    - Neogastropoda
  - Cephalopoda
      - Gonatidae
        - *Gonatus fabricii***
- Echinodermata
  - Asteroidea**
  - Dendrochirotida
  - Molpadiida
  - Echinoida
      - Echinidae
        - *Echinus esculentus*
      - Scutellidae
        - *Echinarachnius parma*
      - Strongylocentrotidae
        - *Strongylocentrotus droebachiensis*
  - Euechinoidea
  - Ophiuroidea
      - Amphiuridae
        - *Amphiura Chiajei*
        - *Amphiura filiformis*
        - *Amphipholis squamata*
      - Ophiuridae
        - *Opiura albida*
        - *Ophiura sarsi*
- Annelida
  - Polychaeta*
    - Ampharetidae
      - *Ampharete lindstroemi*

Hippoglossoides platessoides Continued...

- *Amphicteis gunneri*
- *Sabellides borealis*
- Capitellidae
- Cirratulidae
- Flabelligeridae
  - *Pherusa affinis*
- Maldanidae
  - *Praxillura* sp.
- Nereididae
  - *Nephtys neotena*
- Onuphidae
  - *Onuphis conchylega*
- Opheliidae
  - *Ophelia limacina*
  - *Ophelina acuminata*
- Orbiniidae
- Owenidae
- Paraonidae
  - *Aricidea suecica*
- Pectinaridae
  - *Pectinaria granulata*
- Phyllodocidae
  - *Phyllodoce mucosa*
  - *Polyphysia crassa*
- Polynoidae
  - *Harmothoe* sp.
- Sabellidae
  - *Chone* sp.
  - *Euchone incolor*
  - *Potamilla reniformis*
- Scalibregmidae
  - *Scalibregma inflatum*
  - *Chaetozone chaetosa*
  - *Cossura longicirrata*
  - *Galathowena oculata*
  - *Spiophanes kroyeri*
- Scolopacidae
  - *Scolopos armiger*
- Spionidae
  - *Polydora* spp.
- Syllidae
  - *Exogone hebes*
- Terebellidae
  - *Trichobranchus glacialis*

APPENDIX 3. PARASITE SPECIES OF TWENTY-SIX FISH WITHIN THE DAVIS STRAIT AND BAFFIN BAY – A COMPENDIUM OF PRESENT STUDY AND PUBLISHED DATA

Common Name	Black Dogfish	Longnose Eel
Latin Name	*Centroscyllium fabricii*	*Synaphobranchus kaupi*
Species ID#	27	152
Parasites	APICOMPLEXA *Haemogregarina delagei* *Haemohormidium* sp. MASTIGOPHORA *Trypanosoma rajae* PLATYHELMINTHES (Trematoda) *Otodistomum cestoides* *Otodistomum felis*** (Monogenea) *Macruricotyle newfoundlandiae*** (Cestoda) *Gilquinia squali*** *Philobythos* sp. ** Cestoda gen. sp.** NEMATODA *Anisakis simplex* Larva** Anisakidae gen. sp.** *Pseudoterranova decipiens* Larva** ARTHROPODA (Copepoda) *Albionella centroscylli* *Albionella fabricii* *Lernaeopoda centroscyllii* *Ommatokoita* sp.	PLATYHELMINTHES (Trematoda) *Derogenes varicus*** *Lepidapedon* sp.* *Lepidapedon rachion*** (Cestoda) Cestoda gen. sp. Plerocercoid** NEMATODA *Anisakis simplex* Larva** *Contracaecum* sp. *Hysterothylacium* sp. *Capillaria* sp.** ARTHROPODA (Copepoda) *Lophoura gracilis*

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*Previously published and found in present study

**New record, found in present study

Glacier Lanternfish *Benthosema glaciale* 290	Rakery Beaconlamp *Lampanyctus macdonaldi* 283	Goitre Blacksmelt *Bathylagus euryops* 202
CNIDARIA *Hydrichthys sarcotretis* PLATYHELMINTHES (Cestoda) Cestoda gen. sp.** NEMATODA *Capillaria* sp.** ARTHROPODA (Copepoda) *Clavella adunca*** *Sarcotretis scopeli* Copepoda gen. sp.**	PLATYHELMINTHES (Cestoda) Cestoda gen. sp. Plerocercoid**	PLATYHELMINTHES (Trematoda) *Gonocerca phycidis*** Hemiuridae gen. sp.** *Lecithaster gibbosus*** *Lecithophyllum irelandeum*** *Podocotyle* sp.** *Steringophora* sp.** (Cestoda) Bothriidae sp.** *Pistana* sp.** Cestoda gen. sp. Plerocercoid** ARTHROPODA (Copepoda) *Paeonocanthus antarcticensis*

Blue Hake *Antimora rostrata* 432	Roundnose Grenadier *Coryphaenoides rupestris* 481
APICOMPLEXA	MICROSPORA
Haemohormidium terraenovae	*Loma branchialis*
Haemohormidium sp.	*Loma morhua*
MYXOZOA	MYXOZOA
Ceratomyxa sp.	*Auerbachia pulchra*
Myxidium coryphaenoidium	*Auerbachia* sp.
PLATYHELMINTHES	*Myxidium coryphaenoidium*
(Trematoda)	*Myxidium melanocetum*
*Derogenes varicus***	*Myxidium melanostigmum*
Dinosoma sp.**	*Myxidium profundum*
*Gonocerca phycidis***	*Myxoproteus californicus*
Lepidapedon sp.*	*Zschokkella hildae*
*Lepidapedon elongatum***	PLATYHELMINTHES
*Lepidapedon rachion***	(Trematoda)
*Lepidophyllum steenstrupi***	*Derogenes varicus**
Podocotyle sp.**	*Dolichoenterum* sp. Metacercaria
*Podocotyle reflexa***	*Glomericirrus macrouri**
*Prosorhynchus squamatus***	*Glomericirrus ulmeri*
*Steringophora furciger**	*Gonocerca crassa*
Trematoda sp. Metacercaria**	*Gonocerca macroformis*
(Monogenea)	*Gonocerca macrouri*
Dichlidophoridae**	*Gonocerca physidis**
*Macruricotyle newfoundlandiae***	*Hemiurus levinseni***
(Cestoda)	*Lepidopedon* sp.
Philobythos sp.**	*Paraccacladium jamiesoni*
Cestoda gen. sp. Plerocercoid**	*Parahemiurus merus*
NEMATODA	*Proctophantastes abyssorum*
Anisakis simplex Larva**	*Steringophora* sp.
Contracaecum/Phocascaris sp. Larva**	(Monogenea)
Capillaria sp.**	*Aporocotyle simplex*
ACANTHOCEPHALA	*Diclidophora macrouri*
Corynosoma sp. Juvenile**	*Macruricotyle newfoundlandiae***
*Echinorhynchus gadi***	(Cestoda)
ARTHROPODA	*Bothriocephalus* sp.
(Copepoda)	*Nybelinia* sp.
Lophoura tetraphylla	*Philobythos atlanticus**
Sphyrion lumpi	*Pseudophyllidea* gen.sp. Plerocercoid
	Scolex pleuronectis Plerocercoid*
	Cestoda gen. sp.**
	NEMATODA
	Anisakis simplex Larva*
	Contracaecum/Phocascaris sp. Larva*
	Hysterothylacium aduncum
	Hysterothylacium sp.
	Thynnascaris aduncum
	Capillaria sp.**
	ACANTHOCEPHALA
	Echinorhynchus gadi

Coryphaenoides rupestris Continued...	Roughhead Grenadier *Macrourus berglax* 474
ARTHROPODA	APICOMPLEXA
(Copepoda)	*Goussia caseosa*
Chondracanthodes radiatus	*Haemogregarina marshallairdi*
*Clavella adunca**	*Haemogregarina* sp.
Sphyrion lumpi	*Haemohormidium terraenovae*
Copepoda gen. sp.**	*Haemohormidium* sp.
	MASTIGOPHORA
	Cryptobia dahli
	Trypanosoma murmanensis
	Trypanosoma sp.
	MYXOZOA
	Auerbachia pulchra
	Davisia newfoundlandia
	Myxidium coryphaenoidium
	Myxidium melanocetum
	Zschokkella kudoi
	PLATYHELMINTHES
	(Trematoda)
	*Derogenes varicus**
	Derogenidae gen. sp. Metacercariae**
	Fellodistomum sp.
	Genolinea laticauda
	Genolinea sp.
	Gibonsia borealis
	*Glomericirrus macrouri**
	Gonocerca crassa
	*Gonocerca phycidis**
	Gonocerca sp.
	*Hemiurus levinseni**
	*Lecithaster gibbosus***
	Lecithophyllum botryophorum
	Lepidapedon elongatum
	Lepidapedon sp.
	*Podocotyle atomon***
	*Podocotyle reflexa***
	*Prosorhynchus squamatus***
	*Steganoderma formosum***
	*Stenakron vetustum***
	Steringophora sp.**
	*Steringophora furciger**
	Trematoda sp. Metcercaria**
	(Monogenea)
	Cyclocotyloides pinguis
	Diclidophora sp.
	*Macruricotyle newfoundlandiae**
	(Cestoda)
	*Bothriocephalus scorpii***
	Parabothriocephalus macruri
	*Philobythos atlanticus**

Macrourus berglax Continued...	Arctic Cod *Arctogadus glacialis* 452
Pseudophyllidea gen. sp.	PLATYHELMINTHES
Scolex pleuronectis Plerocercoid*	(Trematoda)
Cestoda gen. sp. Procercoid**	*Derogenes varicus***
NEMATODA	*Hemiurus levinseni**
Anisakis sp. Larva*	*Steringophora furciger***
Capillaria sp.**	NEMATODA
Capillaria (Procapillaria) gracilis	*Anisakis simplex* Larva**
Contracaecum/Phocascaris sp. Larva*	*Contracaecum/Phocascaris* sp. Larva**
Hysterothylacium aduncum	*Pseudoterranova decipiens* Larva**
Hysterothylacium sp.	*Capillaria* sp.**
Pseudoterranova decipiens Larva**	
Spinitectus sp.	
ACANTHOCEPHALA	
Corynosoma sp. Juvenile**	
*Echinorhynchus gadi**	
Echinorhynchus sp.	
ARTHROPODA	
(Copepoda)	
Chondracanthodes radiatus	
Chondracanthodes tuberofurcatus	
Clavella adunca	
Clavellomimus macruri	
Lateracanthus quadripedis	
Lophoura bouvieri	
Sphyrion lumpi	
Copepoda gen. sp.**	

Polar Cod _Boreogadus saida_ 451	Silvery Three-Beard Rockling _Gaidropsarus argentatus_ 455
APICOMPLEXA	PLATYHELMINTHES
Haemohormidium terraenovae	(Trematoda)
MASTIGOPHORA	_Derogenes varicus_**
Trypanosoma murmanensis	_Fellodistomum felis_**
MYXOZOA	_Glomericirrus macrouri_**
Myxidium bergense	_Gonocerca phycidis_**
PLATYHELMINTHES	_Hemiurus levinseni_**
(Trematoda)	Hemiuridae gen. sp.**
Brachyphallus crenatus	_Lepidapedon elongatum_**
Derogenes varicus *	_Podocotyle_ sp. **
Dinosoma sp.**	_Podocotyle reflexa_**
Gonocerca phycidis**	_Prosorhynchus squamatus_**
_Hemiurus levinseni_*	_Steringophora furciger_**
Hemiuridae gen. sp.**	(Cestoda)
_Lecithaster gibbosus_*	Cestoda gen. sp. Plerocercoid**
Lepidapedon elongatum**	NEMATODA
Podocotyle sp.**	_Anaskis simplex_ Larva**
_Podocotyle reflexa_*	_Contracaecum/Phocascaris_ sp. Larva**
Prosorhynchus squamatus**	_Pseudoterranova decipiens_ Larva**
Prosorhynchus squamatus Metacercaria	Capillaria sp.**
Trematoda sp. Metacercaria**	ACANTHOCEPHALA
(Cestoda)	_Corynosoma_ sp. Juvenile**
Bothriocephalus scorpii**	_Echinorhynchus gadi_**
Cestoda gen. sp. Plerocercoid*	
NEMATODA	
Anaskis simplex Larva**	
Anisakidae gen. sp.	
Contracaecum/Phocascaris sp. Larva**	
Pseudoterranova decipiens Larva*	
Capillaria sp.**	
Nematoda gen. sp.	
ACANTHOCEPHALA	
Corynosoma sp. Juvenile**	
Echinorhynchus gadi**	
ANNELIDA	
Hirudinea gen. sp.	
ARTHROPODA	
(Copepoda)	
Clavella adunca**	
Copepoda gen. sp.*	

Three-Beard Rockling	Deepwater Redfish
Gaidropsarus ensis	*Sebastes mentella*
453	794
APICOMPLEXA	CNIDARIA
Haemogregarina sp.	*Hydrichthys sarcotretis*
Haemohormidium terraenovae	APICOMPLEXA
PLATYHELMINTHES	*Haemohormidium terraenovae*
(Trematoda)	MYXOZOA
*Derogenes varicus***	*Ceratomyxa macrospora*
*Glomericirrus macrouri***	*Myxidium incurvatum*
*Gonocerca phycidis***	*Myxidium sphaericum*
*Hemiurus levinseni***	PLATYHELMINTHES
Hemiuridae gen. sp.**	(Trematoda)
*Lecithaster gibbosus***	*Anomalotrema koiae*
*Lepidapedon elongatum***	*Brachyphallus crenatus*
*Lepidophyllum steenstrupi***	*Crepidostomum* sp.
Opecoelidae gen. sp.**	*Derogenes varicus**
Podocotyle sp. **	*Gonocerca phycidis***
*Podocotyle atomon***	*Hemiurus levinseni**
*Podocotyle reflexa***	*Hemiurus* sp.
*Prosorhynchus squamatus***	Hemiuridae gen. sp.**
Steringophora sp.**	*Lecithaster gibbosus**
*Steringophora furciger***	*Lecithophyllum* sp.**
Trematoda sp. Metcercaria**	*Lecithophyllum botryophorum*
(Cestoda)	*Lepidapedon* sp.**
*Bothriocephalus scorpii***	*Lepidapedon elongatum***
Phylobythos sp.**	Opecoelidae gen. sp.
Cestoda gen. sp. Plerocercoid**	*Podocotyle* sp. **
NEMATODA	*Podocotyle atomon***
Anaskis simplex Larva**	*Podocotyle reflexa**
Contracaecum/Phocascaris sp. Larva**	*Steganoderma formosum*
Pseudoterranova decipiens Larva**	(Monogenea)
Capillaria sp.**	*Microcotyle* sp.
ACANTHOCEPHALA	(Cestoda)
Corynosoma sp. Juvenile**	*Abothrium* sp.
*Echinorhynchus gadi***	*Bothriocephalus scorpii*
ARTHROPODA	*Eubothrium* sp.
(Copepoda)	*Gilquinia* sp. Procercoid**
*Clavella adunca***	*Grillotia* sp. Plerocercoid
Sphyrion lumpi	*Phylobythos* sp.**
	Scolex pleuronectis Plerocercoid*
	Trypanorhyncha gen. sp. Plerocercoid
	NEMATODA
	Anaskis simplex Larva*
	Anisakis sp. Larva
	Contracaecum/Phocascaris sp. Larva*
	Hysterothylacium aduncum
	Pseudoterranova decipiens Larva*
	Capillaria sp.**
	ACANTHOCEPHALA
	Acanthocephala gen. sp.
	Corynosoma sp. Juvenile**

Sebastes mentella Continued...	Hook Ear Sculpin *Artediellus atlanticus* 810
*Echinorhynchus gadi**	PLATYHELMINTHES
Neoechinorhynchus rutiti	(Trematoda)
ARTHROPODA	*Derogenes varicus***
(Copepoda)	*Glomericirrus macrouri***
Chondracanthus nodosus	*Gonocerca phycidis***
*Clavella adunca***	*Hemiurus levinseni***
Peniculus clavatus	Hemiuridae gen. sp.**
Sphyrion lumpi	*Lecithaster gibbosus***
Copepoda gen. sp.**	*Lepidapedon elongatum***
	*Lepidapedon rachion***
	*Neophasis burti***
	Podocotyle sp.**
	*Podocotyle atomon***
	*Podocotyle reflexa***
	*Prosorhynchus squamatus***
	Prosorhynchus squamatus Metacercaria**
	*Steringophora furciger***
	Trematoda sp. Metcercaria**
	(Cestoda)
	*Bothriocephalus scorpii***
	Phylobythos sp.**
	Cestoda gen. sp. Plerocercoid**
	Cestoda gen. sp.**
	NEMATODA
	Anaskis simplex Larva**
	Contracaecum/Phocascaris sp. Larva**
	Pseudoterranova decipiens Larva**
	Capillaria sp.**
	ACANTHOCEPHALA
	Corynosoma sp. Juvenile**
	*Echinorhynchus gadi***

Shorthorn Sculpin *Myoxocephalus scorpius* 108	Bigeye/Mailed Sculpin *Triglops nybelini* 815
APICOMPLEXA	PLATYHELMINTHES
Dactylosoma beckeri	(Trematoda)
Eimeria lairdi	*Derogenes varicus***
Eimeria nucleocola	*Gonocerca phycidis***
Haemogregarina myoxocephali	*Hemiurus levinseni***
Haemogregarina sp.	Hemiuridae gen. sp.**
MASTIGOPHORA	*Lecithaster gibbosus***
Trypanosoma murmanensis	*Lepidapedon elongatum***
Trypanosoma sp.	*Lepidapedon rachion***
MYXOZOA	*Neophasis burti***
Ceratomyxa macrospora	*Podocotyle reflexa***
Myxidium incurvatum	*Prosorhynchus squamatus***
Myxidium oviforme	*Prosorhynchus squamatus* Metacercaria**
PLATYHELMINTHES	*Steringophora furciger***
(Trematoda)	Trematoda sp. Metcercaria**
*Brachyphallus crenatus***	(Cestoda)
*Derogenes varicus**	*Bothriocephalus scorpii***
Hemiuridae gen. sp.**	*Phylobythos* sp.**
*Lepidapedon rachion***	Cestoda gen. sp. Plerocercoid**
*Podocotyle atomon**	NEMATODA
*Podocotyle reflexa***	*Anaskis simplex* Larva**
Podocotyle sp. Metacercaria**	*Contracaecum/Phocascaris* sp. Larva**
Progonus muelleri	*Pseudoterranova decipiens* Larva**
*Prosorhynchus squamatus**	*Capillaria* sp.**
Prosorhynchus squamatus Metacercaria**	ACANTHOCEPHALA
Steganoderma formosum	*Corynosoma* sp. Juvenile**
Trematoda sp. Metcercaria**	*Echinorhynchus gadi***
(Monogenea)	ARTHROPODA
Gyrodactylus groenlandicus	(Copepoda)
(Cestoda)	Copepoda gen. sp.**
*Bothrimonus sturionis***	
Cestoda gen. sp. Plerocercoid**	
Cestoidea gen. sp.	
NEMATODA	
Contracaecum/Phocascaris sp. Larva**	
Pseudoterranova decipiens Larva*	
Capillaria sp.**	
ACANTHOCEPHALA	
Corynosoma sp. Juvenile**	
*Echinorhynchus gadi***	
ANNELIDA	
Johanssonia arctica	
Malmiana brunnea	
Malmiana scorpii	
Oceanobdella microstoma	
Platybdella olriki	
ARTHROPODA	
(Amphipoda)	
Lafystius sturionis	

Polar Deepsea Sculpin *Cottunculus microps* 829	Sea Tadpole *Careproctus reinhardti* 28
APICOMPLEXA	PLATYHELMINTHES
Haemohormidium terraenovae	(Trematoda)
PLATYHELMINTHES	*Derogenes varicus***
(Trematoda)	*Gonocerca phycidis***
Anisorchis opisthorchis	*Hemiurus levinseni***
*Derogenes varicus***	*Lecithaster gibbosus***
Derogenidae gen. sp. Metacercaria**	*Lepidapedon elongatum***
Gonocerca sp.	*Lepidapedon rachion***
*Gonocerca phycidis***	*Podocotyle reflexa***
Helicometra plovmornini	*Prosorhynchus squamatus***
*Lepidapedon elongatum***	*Stenakron vetustum*
*Lepidapedon rachion***	(Cestoda)
Podocotyle sp. **	Cestoda gen. sp. Plerocercoid**
*Podocotyle atomon***	NEMATODA
*Podocotyle reflexa***	*Contracaecum/Phocascaris* sp. Larva**
Prosorhynchus squamatus Metacercaria**	*Capillaria* sp.**
*Steringophora furciger***	ACANTHOCEPHALA
(Monogenea)	*Corynosoma* sp. Juvenile**
Monogenea gen. sp.**	*Echinorhynchus gadi***
(Cestoda)	ARTHROPODA
Phylobythos sp.**	(Copepoda)
Cestoda gen. sp. Plerocercoid**	*Clavella adunca***
Cestoda gen. sp.**	
NEMATODA	
Anaskis simplex Larva**	
Contracaecum/Phocascaris sp. Larva**	
Hysterothylacium sp.	
Capillaria sp.**	
ACANTHOCEPHALA	
Corynosoma sp. Juvenile**	
*Echinorhynchus gadi***	
ARTHROPODA	
(Copepoda)	
*Clavella adunca***	

Gelatinus Snailfish	Black Seasnail
Liparis fabricii	*Paralaparis bathybius*
859	855
PLATYHELMINTHES	PLATYHELMINTHES
(Trematoda)	(Trematoda)
*Derogenes varicus***	*Podocotyle* sp. **
*Hemiurus levinseni***	(Cestoda)
*Lecithaster gibbosus***	Cestoda gen. sp. Plerocercoid**
*Lecithophyllum irelandeum***	
*Lepidapedon elongatum***	
*Lepidapedon rachion***	
Podocotyle sp. **	
*Podocotyle atomon***	
*Podocotyle reflexa***	
*Prosorhynchus squamatus***	
*Steringophora furciger***	
(Cestoda)	
Cestoda gen. sp. Plerocercoid**	
Cestoda gen. sp.**	
NEMATODA	
Anaskis simplex Larva**	
Contracaecum/Phocascaris sp. Larva**	
Pseudoterranova decipiens Larva**	
Capillaria sp.**	
ARTHROPODA	
(Copepoda)	
Copepoda gen. sp.**	

Threadfin Seasnail *Rhodichthys regina* 852	Doubleline Eelpout *Lycodes eudipleurostictus* 736
PLATYHELMINTHES	MYXOZOA
(Trematoda)	*Myxidium sphaericum*
*Derogenes varicus***	PLATYHELMINTHES
*Gonocerca phycidis***	(Trematoda)
*Lepidapedon elongatum***	*Derogenes varicus***
*Steringophora furciger***	*Gonocerca phycidis***
Trematoda sp. Metcercaria**	*Hemiurus levinseni***
(Cestoda)	Hemiuridae gen. sp.**
Cestoda gen. sp. Plerocercoid**	*Lecithaster gibbosus***
NEMATODA	*Lepidapedon* sp.**
Capillaria sp.**	*Lepidapedon elongatum***
	*Lepidapedon rachion***
	*Lepidophyllum steenstrupi***
	Podocotyle sp.**
	*Podocotyle reflexa***
	*Prosorhynchus squamatus***
	*Stenakron vetustum***
	Steringophora sp.**
	*Steringophora furciger***
	Trematoda sp. Metcercaria**
	(Cestoda)
	Cestoda gen. sp. Plerocercoid**
	NEMATODA
	Anaskis simplex Larva**
	Contracaecum/Phocascaris sp. Larva**
	Pseudoterranova decipiens Larva**
	Capillaria sp.**
	ACANTHOCEPHALA
	Corynosoma sp. Juvenile**
	*Echinorhynchus gadi***
	ANNELIDA
	Platybdella olriki
	ARTHROPODA
	(Copepoda)
	*Clavella adunca***

Pamiut's Eelpout *Lycodes paamiuti* 87	McAllister's Eelpout *Lycodes mcallisteri* 86
PLATYHELMINTHES	PLATYHELMINTHES
(Trematoda)	(Trematoda)
*Derogenes varicus***	*Derogenes varicus***
*Lecithaster gibbosus***	*Gonocerca phycidis***
*Lepidapedon rachion***	*Lepidophyllum steenstrupi***
*Neophasis burti***	*Prosorhynchus squamatus***
*Stenakron vetustum***	Trematoda sp. Metcercaria**
*Steringophora furciger***	(Cestoda)
Trematoda sp. Metcercaria**	Cestoda gen. sp. Plerocercoid**
(Cestoda)	NEMATODA
Gilquinia squali Procercoid**	*Anaskis simplex* Larva**
Cestoda gen. sp. Plerocercoid**	*Contracaecum/Phocascaris* sp. Larva**
Cestoda gen. sp.**	*Capillaria* sp.**
NEMATODA	ARTHROPODA
Contracaecum/Phocascaris sp. Larva**	(Copepoda)
Capillaria sp.**	Copepoda ge. sp.**
ACANTHOCEPHALA	
Corynosoma sp. Juvenile**	
*Echinorhynchus gadi***	

Greenland Halibut
Reinhardtius hippoglossoides
892

- APICOMPLEXA
  - *Haemogregarina platessae*
  - *Haemohormidium terraenovae*
  - *Haemohormidium* sp.
- MICROSPORA
  - *Trypanosoma murmannensis*
  - *Trypanosoma* sp.
- MYXOZOA
  - *Ceratomyxa drepanopsettae*
  - *Ceratomyxa ramosa*
  - *Myxidium incurvatum*
  - *Myxidium sphaericum*
  - *Myxoproteus reinhardti*
  - *Myxoproteus* sp.
  - *Ortholinea divergens*
  - *Schulmania quadrilobata*
  - *Paramyxproteus reinhardti*
- PLATYHELMINTHES
- (Trematoda)
  - *Anomalotrema koiae*
  - *Brachyphallus crenatus*
  - *Derogenes varicus**
  - *Dinosoma triangulata*
  - *Dissosaccus laevis*
  - *Fellodistomum felis***
  - *Fellodistomum furcigerum*
  - *Genarchopsis mulleri*
  - *Glomericirrus macrouri***
  - *Gonocerca phycidus***
  - *Hemiurus levinseni**
  - *Lecithaster confusus*
  - *Lecithaster gibbosus**
  - *Neophasis burti***
  - *Otodistomum veliporum* Metacercaria
  - *Otodistomum* sp. Metacercaria
  - *Podocotyle* sp.**
  - *Podocotyle atomon***
  - *Podocotyle reflexa***
  - *Progonus muelleri*
  - *Prosorhynchoides gracilescens*
  - *Prosorhynchus squamatus***
  - *Rhipidocotyle* sp.**
  - *Steganoderma formosum**
  - *Stenakron vetustum**
  - *Steringophora* sp.**
  - *Steringophora furciger**
  - Trematoda sp. Metcercaria**
- (Monogenea)
  - *Entobdella* sp.
  - *Macruricotyle newfoundlandiae***
- (Cestoda)
  - *Bothriocephalus scorpii**
  - *Gilquinia squali* Procercoid**
  - *Grillotia erinacaus* Plerocercoid
  - *Grillotia* sp. Plerocercoid
  - *Phyllobothrium thridax* Plerocercoid
  - *Scolex pleuronectis* Plerocercoid
  - *Scolex* sp. Plerocercoid*
- NEMATODA
  - Aniskidae gen. sp. Larva
  - Aniskidae gen. sp.**
  - *Anisakis simplex* Larva*
  - *Anisakis* sp. Larva
  - *Contracaecum/Phocascaris* sp. Larva*
  - *Hysterothylacium aduncum*
  - *Pseudoterranova decipiens* Larva*
  - *Capillaria* sp.**
- ACANTHOCEPHALA
  - *Corynosoma strumosum* Juvenile
  - *Corynosoma* sp. Juvenile*
  - *Echinorhynchus gadi**
  - *Echinorhynchus laurentianus*
- ANNELIDA
  - *Johanssonia arctica*
- ARTHROPODA
- (Copepoda)
  - *Clavella adunca***
  - *Hatschekia hippoglossi*
  - *Neobrachiella robusta*
  - *Neobrachiella rostrata*
  - *Sphyrion lumpi*
  - Copepoda gen. sp.**
- (Isopoda)
  - *Aega psora*

American Plaice
Hippoglossoides platessoides
889

- SARCOMASTIGOPHORA
  - *Cryptobia bullocki*
- APICOMPLEXA
  - Eimeriorina gen. sp.
  - *Haemohormidium terraenovae*
  - *Haemohormidium* sp.
- MICROSPORA
  - *Pleistophora hippoglossoides*
- MASTIGOPHORA
  - *Trypanosoma murmanensis*
- MYXOZOA
  - *Ceratomyxa drepanopsettae*
  - *Davisia amoena*
  - *Leptotheca* sp.
  - *Myxidium bergense*
  - *Myxidium incurvatum*
  - *Myxidium sphaericum*
  - *Myxoproteus* sp.
  - Myxosporea gen. sp.
  - *Ortholinea divergens*
  - *Schulmania aenigmatosa*
- PLATYHELMINTHES
- (Trematoda)
  - *Anisoporus manteri*
  - *Brachiphallus crenatus*
  - *Cryptocotyle lingua* Metacercaria
  - *Derogenes varicus**
  - Digenea gen. sp.
  - *Diphterostomum microacetabulum*
  - *Fellodistomum felis***
  - *Fellodistomum furcigerum*
  - *Genolinea laticauda*
  - *Gonocerca phycidus**
  - *Gonocerca macriformis*
  - *Hemiurus communis*
  - *Hemiurus levinseni**
  - *Hemiurus* sp.
  - *Lecithaster gibbosus**
  - *Lepidapedon elongatum***
  - *Neophasis burti*
  - *Otodistomum veliporum* Metacercaria
  - *Podocotyle atomon*
  - *Progonus muelleri*
  - *Prosorhynchus squamatus**
  - *Pseudozoogonoides subaequiporus*
  - *Steganoderma formosum*
  - *Stenakron vetustum**
  - *Stenakron* sp.
  - *Stephanostomum baccatum* Metacercaria
  - *Steringophora* sp.**
  - *Steringophora furciger**
  - *Steringotrema ovacutum*
  - *Zoogonoides viviparus*
- (Monogenea)
  - *Aporocotyle simplex**
- (Cestoda)
  - *Bothrimonus sturionis*
  - *Gilquinia squali* Procercoid**
  - *Grillotia erinaceus* Plerocercoid
  - *Scolex pleuronectis* Plerocercoid*
  - Cestoda gen. sp.**
- NEMATODA
  - *Anisakis simplex* Larva*
  - *Anisakis* sp. Larva
  - *Ascarophis arctica*
  - *Capillaria* sp.**
  - *Capillaria/Procapillaria gracilis*
  - *Capillaris kabatai*
  - *Contracaecum osculatum* Larva
  - *Contracaecum/Phocascaris* sp. Larva*
  - *Cucullanus heterochrous*
  - *Hysterothylacium aduncum*
  - Nematoda gen. sp.
  - *Pseudoterranova decipiens* Larva*
- ACANTHOCEPHALA
  - *Corynosoma* sp. Larva**
  - *Corynosoma wegeneri* Juvenile
  - *Echinorhynchus gadi**
  - *Echinorhynchus laurentianus*
- ANNELIDA
  - *Johanssonia arctica*
- ARTHROPODA
- (Copepoda)
  - *Acanthochondria cornuta*
  - *Argulus megalops*
  - *Lernaeocerca branchialis*
  - *Neobrachiella rostrata*
  - Copepoda gen. sp.**

APPENDIX 4: MINIMUM AND MAXIMUM LENGTH, WEIGHT, TEMPERATURE AND DEPTH FOR TWENTY-SIX FISH SPECIES WITHIN THE DAVIS STRAIT/BAFFIN BAY REGION.

A) LITERATURE VALUES (Okamura et al. 1995, Scott and Scott 1988)
B) PRESENT STUDY
C) AVERAGE VALUES (Present Study)

a) Literature Values

Species	Min. Length(mm)*	Max Length (mm)	Min. Weight (g)	Max. Weight (g)	Min. Depth (m)	Max. Depth (m)	Min. Temp (oC)	Max. Temp (oC)
Antimora rostrata	NA	750	NA	NA	229	3000	NA	4.00
Arctogadus glacialis	NA	325	NA	NA	0	1000	NA	NA
Artediellus atlanticus	NA	150 (SL)	NA	NA	35	900	-1.70	4.00
Bathylagus euryops	37	190 (SL)	NA	NA	20 (PL), 500 (J&A)	1800	NA	NA
Benthosema glaciale	17.3	103 (SL)	NA	NA	0	1085	0.00	18.00
Boreogadus saida	5.5	400	NA	130	0	731	-0.70	3.60
Careproctus reinhardti	NA	300	NA	NA	150	1200	NA	NA
Centroscyllium fabricii	140	1070	NA	NA	180	1600	3.50	4.50
Coryphaenoides rupestris	5.1	700	NA	800	350	2500	1.00	4.50
Cottunculus microps	NA	300	NA	NA	165	1000	0.00	4.00
Gaidropsarus argentatus	NA	412	NA	NA	150	2260	0.00	3.10
Gaidropsarus ensis	2.4	420	NA	NA	0	1569	-0.20	2.47
Hippoglossoides platessoides	4	820	NA	6400	10	713	-0.50	13.00
Lampanyctus macdonaldi	NA	163	NA	NA	60	1000	NA	NA
Liparis fabricii	12	200	NA	NA	20	1750	-1.50	0.56
Lycodes eudipleurostictus	NA	445	NA	NA	25	464	NA	NA
Lycodes mcallisteri	NA	375	NA	NA	298	668	1.00	-1.00
Lycodes paamiuti	NA	240	NA	NA	350	1300	NA	NA
Macrourus berglax	NA	1100	NA	254	100	1000	<0	4.00
Myoxocephalus scorpius	7.4	900	NA	NA	0	145	0.00	3.20
Paraliparis bathybius	NA	253 (SL)	NA	NA	600	2824	NA	NA
Rhodichthys regina	NA	310 (SL)	NA	NA	1080	2365	NA	NA
Reinhardtius hippoglossoides	<70	1200	NA	7000	1	2000	-1.00	6.00
Sebastes mentella	NA	550	NA	NA	300	1100	0.20	1.20
Synaphobranchus kaupi	NA	1000	NA	NA	120	4800	-1.00	10.00
Triglops nybelini	27	170	NA	NA	135	930	-0.10	-1.80

* Minimum recorded lengths of fish caught (may not indicate minimum length after hatching)

SL=Standard Length, PL=Post Larval, J=Juvenile, A=Adult, NA=Not Available

b) Present Study

Species	Min. Length (mm)*	Max Length (mm)	Min. Weight (g)	Max. Weight (g)	Min. Depth (m)	Max. Depth (m)	Min. Temp (oC)	Max. Temp (oC)
Antimora rostrata	96.0	433.0	3.87	719.00	665	1468	0.79	4.39
Arctogadus glacialis	95.0	286.0	2.64	125.44	437	934	0.75	1.64
Artediellus atlanticus	55.8	195.0	1.69	115.25	341	1276	-0.41	3.50
Bathylagus euryops	74.9	191.0	2.19	70.52	700	1354	0.19	4.21
Benthosema glaciale	43.9	83.0	0.90	6.22	430	1442	0.10	3.60
Boreogadus saida	63.0	240.0	0.92	97.76	341	1166	0.03	1.70
Careproctus reinhardti	58.4	200.0	1.93	114.85	385	1381	-0.40	1.70
Centroscyllium fabricii	181.0	790.0	22.15	3456.00	619	1395	0.20	4.21
Coryphaenoides rupestris	151.0	869.0	10.03	837.00	713	1468	3.16	4.20
Cottunculus microps	45.0	268.0	1.06	361.26	450	1345	-0.40	4.21
Gaidropsarus argentatus	77.3	386.0	2.25	539.49	466	1419	-0.09	3.80
Gaidropsarus ensis	85.0	490.0	2.50	1064.00	630	1468	-0.09	3.90
Hippoglossoides platessoides	135.0	435.0	20.22	808.50	434	1413	0.03	5.53
Lampanyctus macdonaldi	79.0	185.0	2.48	36.06	703	1413	1.30	3.90
Liparis fabricii	51.3	460.0	1.42	77.05	341	1375	-0.04	3.80
Lycodes eudipleurostictus	82.0	381.0	1.33	279.31	385	934	-0.35	3.50
Lycodes mcallisteri	124.0	358.0	5.95	277.18	681	1337	0.20	1.20
Lycodes paamiuti	100.0	251.0	2.12	84.71	422	1381	0.20	3.80
Macrourus berglax	122.0	791.0	8.25	3909.22	519	1360	-0.35	4.97
Myoxocephalus scorpius	39.0	277.0	0.85	703.68	5	5	1.16	1.42
Paraliparis bathybius	20.4	235.0	17.03	81.23	967	1381	-0.04	0.80
Rhodichthys regina	136.0	212.0	7.83	46.99	624	1383	-0.04	2.30
Reinhardtius hippoglossoides	82.0	953.0	3.25	10644.00	385	1468	-0.35	4.31
Sebastes mentella	68.0	480.0	1.40	2000.00	437	1404	0.10	4.97
Synaphobranchus kaupi	230.0	607.0	6.07	293.91	477	1442	2.60	3.70
Triglops nybelini	68.0	156.0	1.68	36.83	341	967	-0.35	3.00

c) Present Study - Average Values

Species	Average Length (mm)	Average Weight (g)	Average Depth (m)	Average Temp. (oC)
Antimora rostrata	276.1	166.13	976	3.56
Arctogadus glacialis	154.9	30.48	566	1.24
Artediellus atlanticus	131.3	31.18	510	1.59
Bathylagus euryops	144.6	30.51	1029	2.65
Benthosema glaciale	64.3	3.01	771	1.96
Boreogadus saida	119.4	13.71	512	1.01
Careproctus reinhardti	134.4	35.03	740	0.93
Centroscyllium fabricii	506.4	805.67	1001	3.44
Coryphaenoides rupestris	346.5	148.83	1115	3.45
Cottunculus microps	161.4	95.33	829	1.26
Gaidropsarus argentatus	219.6	124.10	793	2.13
Gaidropsarus ensis	286.6	262.93	1107	1.77
Hippoglossoides platessoides	280.1	221.81	658	2.53
Lampanyctus macdonaldi	128.1	16.39	1062	3.43
Liparis fabricii	121.1	19.08	752	1.16
Lycodes eudipleurostictus	234.9	70.50	621	1.49
Lycodes mcallisteri	261.9	107.98	1076	0.51
Lycodes paamiuti	189.6	31.17	699	1.84
Macrourus berglax	410.0	506.77	965	2.18
Myoxocephalus scorpius	161.6	121.64	8	1.29
Paraliparis bathybius	190.0	36.03	1339	0.35
Rhodichthys regina	174.4	24.10	1302	0.24
Reinhardtius hippoglossoides	455.8	1333.11	849	2.05
Sebastes mentella	219.4	236.70	689	2.72
Synaphobranchus kaupi	482.2	116.36	1092	3.44
Triglops nybelini	111.4	12.55	513	1.09

APPENDIX 5. LITERATURE VALUES OF $\delta^{13}C$ AND $\delta^{15}N$ FOR INVERTEBRATES FOUND IN STOMACHS OF FISH SPECIES FOUND IN THE DAVIS STRAIT/BAFFIN BAY AREA

	Møller (2006)		Nyssen et al. (2002)		Sherwood & Rose (2006)		Grall et al. (2006)		Hobson & Welch (1992)	
	13C	15N	13C	15N	13C	15N	13C	15N	13C	15N
Bivalvia										
Chlamys islandica	-16.9	7.8								
Chlamys varia							-17.4	9.7		
Mya truncata									-19.0	9.5
Serripes groenlandica									-18.7	8.9
Hiatella arctica							-16.6	9.4	-18.9	9.8
Macoma calcarea									-17.5	10.8
Musculus discor									-20.5	7.9
Mollusca										
Buccinum sp.							-15.3	13.5		12.6
Gonatus fabricii	-18.1 - -18.8	10.4 - 13.1								
Copepoda										
Calanus finmarchus	-20.5	7.9								
Calanus hyperboreas	-19.4	8.4							-20.4	9.2
Mysidacea										
Mysidacea gen. sp.					-21.7	10.4				
Mysis oculata										10.3
Euphausiacea										
Euphausiacea gen. sp.					-20.6	9.3				
Meganyctiphanes norvegica	-19.0	8.5								
Decapoda										
Pandalus borealis	-17.4	10.0			-18.2	11.4				
Pasiphaea multidentata					-20.3	10.4				
Lebbius Polaris									-16.9	14.5
Eualus fabricii					-18.9	14.3				
Amphipoda										
Hyperiidae gen. sp.					-22.5	10.3				
Themisto libellula									-20.3	11.7

Onisimus glacialis					-18.2	11.4
Stegocephalus inflatus					-15.0	15.1
Ampelisca richardsoni	-27.1	6.6				
Eusiris perdentatus	-23.7	9.3				
Epimeria similis	-25.1	10.1				
Orchomenella pinguides	-22.3	10.9				
Polychaeta			-18.0	16.6		
Isopoda			-20.8	7.4		

APPENDIX 6

SHORTHORN SCULPIN (*Myoxocephalus scorpius* Linnaeus) FROM FROBISHER BAY, CANADA: BIOLOGY, DIET, PARASITES AND STABLE ISOTOPES

Introduction

The shorthorn sculpin (*Myoxocephalus scorpius*) is a benthic fish species associated with cool shoal marine waters, distributed on both sides of the Atlantic Ocean and in the Arctic where it ranges from Alaska through Hudson Bay to Baffin Island, Svalbard and the Kara Sea (Scott and Scott 1988). Scott and Scott (1988) described the general biology of this species and other reports deal with the food of sculpin (Moore and Moore 1974), growth and sexual maturity (Ennis 1970a) and parasites (Scott and Scott 1988, Sulgostowaska et al. 1990). Recently there has been an interest in the shorthorn sculpin as an intermediate host for the transmission of the sealworm (*Pseudoterranova decipiens*) (Jensen and Andersen 1992, Jensen 1997, Midtgaard et al. 2003). Shorthorn sculpin are a food source for Arctic char (*Salvelinus alpinus*) in northern Labrador (Dempson et al. 2002) and juvenile shorthorn sculpin have been found in Arctic char from Bay of Two Rivers and the Sylvia Grinnell estuary, Frobisher Bay, Nunavut (T.A. Dick, unpubl. data).

From the limited information on shorthorn sculpin food habits, its food preferences appear to be fairly broad (Moore and Moore 1974) and Norderhaug et al. (2005) described them as generalist feeding on a wide range of kelp-associated invertebrates.

The growth of shorthorn sculpin in the Canadian Arctic is described here, and data on food, parasites and stable isotopes are applied to provide insights on the feeding patterns and trophic position of shorthorn sculpin. The reproductive state of the shorthorn sculpin and liver as an energy storage organ were also evaluated. In addition, Gonadosomatic indices (GSI) and liver somatic indices (LSI) were investigated with respect to length, age and sexual maturity of this species. In addition, the effect of the acanthocepahalan *Echinorhynchus gadi* on growth is described.

Materials and Methods

Study area

The sample sites were at the north end of Frobisher Bay Baffin Island close to the community of Iqaluit. Site one was at Peterhead Inlet (63° 46’ N, 68° 42’ W), west of Iqaluit, and site two, about 10 km east, was close to Iqaluit at the Sylvia Grinnell River estuary (63° 43’ N, 68° 46’ W). Water temperature (to 10 meters) was measured using a YSI 650 MDS (Multiparameter Display System). All sample sites within Peterhead Inlet and the estuary were 10 meters or less and consequently, only one temperature reading was taken per site.

Sample collection

Shorthorn sculpin were collected in early July 2002 from the Sylvia Grinnell estuary (n= 21) and mid September 2005 from Peterhead Inlet (n = 80). Specimens were collected in the intertidal zone (approximate maximum intertidal range of 11.2 m) from intertidal pools (typically along concave depressions at the base of glacial erratics). Experimental gillnets (38, 64, 89, 114 and 139 mm stretched mesh) set and picked at low tide (approximately 12 hours) were used.

All specimens were frozen shortly after capture for later examination. Fish were thawed, measured, weighed and eviscerated. Sex was determined and the weight of the liver and gonads were recorded. Intact food items from the stomach and the intestine were identified and counted. Epaxial muscle was collected for stable isotope analysis, placed in aluminum tinfoil and dried for 48 hrs in an oven prior to analysis. The following organs were examined for parasites: esophagus, stomach, intestine divided into fore, mid and hind gut, liver, spleen and body cavity. Otoliths were removed, wiped cleaned and dried. Prior to counting the growth rings, the otolith was etched across the nucleus, pressure applied to crack the otolith through the nucleus and then heated over an alcohol burner. Rings were viewed under a dissecting microscope and all rings counted. Additional details on this method can be found in the Manual on Generalized Age Determination (C.A.R.E. 2006).

Stable isotope analysis

δ^{13}Carbon and δ^{15}Nitrogen isotopic analyses on the muscle (protein) were accomplished by continuous flow ion ratio mass spectrometry (CF-IRMS) using a GV-Instruments® IsoPrime attached to a peripheral temperature controlled EuroVector® elemental analyzer (EA) (University of Winnipeg Isotope Laboratory, *UWIL*, Manitoba). One mg samples of freeze-dried fish muscle were loaded into tin capsules and placed in the EA auto-sampler in accompaniment with internally calibrated carbon/nitrogen standards (Pharma and Casein proteins: $\delta^{13}C = -22.95$ and -26.98 ‰ VPDB (Vienna PeeDee Belemnite); $\delta^{15}N = 5.00$ and 5.94 ‰ air, respectively). Batch files were set up as follows: 4 casein, 4 pharma, 10 samples with every 5th sample duplicated and every 15th sample was done in triplicate. Carbon and nitrogen isotope results are expressed using standard delta (δ) notation in units *per mil* (‰). The delta values of carbon ($\delta^{13}C_{cell}$) and nitrogen ($\delta^{15}N_{cell}$) represent deviations from a standard, such that $\delta_{sample} = [(R_{sample}/R_{standard})-1]*10^3$ where R is the $^{13}C/^{12}C$ or $^{15}N/^{14}N$ ratio in the sample and the standard. The standards used for carbon and nitrogen isotopic analyses are VPDB and IAEA-N-1 (IAEA, Vienna), respectively.

Analytical precision, determined from the analysis of duplicate samples, was ± 0.16 ‰ for $\delta^{13}C$ and ± 0.18 ‰ for $\delta^{15}N$. Accuracy was obtained through the analysis of laboratory standards used for calibration of results.

Data analysis

The von Bertalanffy growth function [$L_{(t)} = L_{\infty}(1-e^{-k(t-t0)})$] was used to model the length-at-age of male and female shorthorn sculpin from Peterhead Inlet. The parameters for the model are t= age, $L_{(t)}$= length at age, L_{∞}= maximum length, K= body growth coefficient and t_0= theoretical age at which length is zero (Ricker 1975). To determine whether there was a statistically significant difference between male and female growth, an analysis of residual sum of squares (ARSS) was used to compare male and female von Bertalanffy curves (Chen et al. 1992, Haddon 2001). The four steps to perform the ARSS are: 1) calculate the residual sum of squares (RSS) from the male and female von Vertalanffy growth curves and the degrees of freedom (d.f.), 2) the RSS and d.f. are both added to produce the summed RSS and d.f., 3) the data from both curves are pooled and the RSS and d.f. for the new curve is calculated, and 4) an *F*-statistic is calculated:

$$F = \frac{(RSS_p - RSS_s)/(d.f._{RSSp} - d.f._{RSSs})}{RSS_s / d.f._{RSSs}}$$

$$= \frac{(RSS_p - RSS_s)/ 3(K - 1)}{RSS_s / (N - 3K)}$$

Where RSS_p and RSS_s are the residual sum of squares from the pooled and individual von Bertalanffy curves, respectively, K is the number of curves being compared and N is the total or pooled sample size.

Diet data were analyzed as follows: per cent frequency (number of a specific diet item divided by the total number of all diet items) and frequency of occurrence (% individuals with a specific diet item) (Cortés 1997).

Analysis of covariance was used to determine if there were differences in total weight and liver weight ($\log_{10}$ transformed) between sexes using length ($\log_{10}$ transformed) as a covariate. Indices were calculated for liver (liver somatic index, LSI) ([liver weight/ total weight – gonad weight] x 100) and gonads (gonadosomatic index GSI) ([gonad weight/ total weight] x 100). All statistical analyses were performed using SPSS for Windows v. 11.0.1 (SPSS 2001). Assumptions of all statistical tests (e.g. normality and homogeneity of variance) were checked before analysis and data was transformed when necessary in order to meet the assumptions.

Parasite prevalence, mean intensity and abundance for parasites were calculated according to Margolis et al. (1982). Fulton's condition factor (total weight x 10^5/ length^3) was calculated to determine if parasite burden influenced the health of the fish. A Kruskal Wallis test was used to determine if there was a difference in the mean size of *E. gadi* among the foregut, midgut and hindgut. A Bonferonni correction was then applied to conduct pairwise comparisons using the Mann Whitney test.

Results

Environmental conditions

Maximum intertidal range was 11.2 m at both sample sites. Vertical temperature profiles collected at high tide and location of gill net sets were at the edge of the low tide zone. The surface temperature in mid September was 1.42 °C at Peterhead Inlet and 1.16 °C at 10 m compared to the Sylvia Grinnell estuary where water temperature at the surface was 8.22 °C and at 4 m was -0.37 °C in late July.

Shorthorn sculpin growth characteristics

Figure A6.1 outlines the von Bertalanffy growth curve and Table A6.1 presents the von Bertalanffy growth function parameters of female and male shorthorn sculpin from Peterhead Inlet. The range of ages in the samples was 3-16 for females and 3-11 for males (Fig. A6.1) and no significant differences in growth were detected ($F(3, 17) = 3.09$, $p > 0.05$). Length weight relationship of logarithmically transformed data was expressed as Log_{10} weight (g) = 3.28 x log length (mm) – 5.44, $r^2 = 0.99$ for samples collected at Peterhead Inlet. There were no significant differences in weight between males and females ($F(1, 71) = 2.58$, $p > 0.05$) for samples collected at Peterhead Inlet.

The identification of sexually maturing individuals was based on GSI values > 2 at a length of 200 mm for females 6 years of age (Figs. A6.2 and A6.3) and a GSI value of >2 at a length of ~100 mm and 4 years of age for males (Figs. A6.4 and A6.5). LSI plotted against length of female and male shorthorn sculpin (Fig. A6.6) showed differences for the Peterhead Inlet samples. LSI and length were weakly correlated in females ($r^2 = 0.28$, $p < 0.001$) but no statistically significant correlations were detected for males. Significant differences in liver weight were detected between males and females (F(1,70)= 6.48, $p < 0.05$) and the LSI means and standard deviation for females and males were 6.52 ± 2.08 and 4.31 ± 1.19, respectively. The plot of LSI against GSI (Fig. A6.7) for the Peterhead Inlet sample shows a significant correlation for both female (r^2= 0.59, $p < 0.05$) and male (r^2= 0.19, $p < 0.05$) shorthorn sculpin.

Shorthorn sculpin diet

Food items recovered from shorthorn sculpin are outlined in Table A6.2. The three most common food items for sculpin from Peterhead Inlet were the amphipods: *Gammarus setosus*, *Onisimus litoralis* and *O. edwardsii*. Frequency of occurrence took into account the number of individual diet items /individual fish and ranking of diet items was *Gammarus setosus*, *Onisimus litoralis* and *Gammarus* sp.. Similarly, for the Sylvia Grinnell shorthorn sculpin sample, the ranking of the three most important diet items were different between the per cent frequency and frequency of occurrence. The most abundant diet by per cent frequency and frequency of occurrence were *G. setosus*, *O. edwardsii* and *O. litoralis*. Overall, *Gammarus setosus* and *Onisimus* spp. were the most important diet items, comprising 99.5 % of the total per cent frequency of food consumed by the shorthorn sculpin from Peterhead Inlet and comprising 97.3% of the total per cent frequency of food consumed by shorthorn sculpin from the Sylvia Grinnell estuary.

Shorthorn sculpin parasites

The most abundant parasite species found in shorthorn sculpin from Peterhead Inlet were the nematode, *Capillaria* sp., the acanthocephalan *Echinorhynchus gadi* and the trematode, *Prosorhynchus squamatus* (Table A6.3). Similar results were found for the

Sylvia Grinnell estuary samples (Table A6.3). The larval ascarid nematodes were present at low abundances, *Pseudoterranova* in shorthorn sculpin from Peterhead Inlet and *Anisakis* in sculpin from the Sylvia Grinnell estuary. Two other parasite species, *Derogenes varicus* and a cestode plerocercoid, were found in low numbers in shorthorn sculpin from both sample sites.

Echinorhynchus gadi had high prevalence values of 87.5 % and 100% and mean intensities of 34.71 and 28.33 in samples from Peterhead Inlet and Sylvia Grinnell River, respectively. The median size of *E. gadi* differed along the gut H(2)= 33.7, $p < 0.01$. There were no size differences between the foregut and midgut U(6109.5), $p > 0.05$, although comparisons between the hindgut and the midgut U(11943), $p < 0.01$, and foregut U(614), $p < 0.01$, indicated there were differences in size. Most of the worms were concentrated in the midgut and there was no evidence of pathology resulting from attachment by the proboscis. *Echinorhynchus gadi* was present in numbers as high as 139 and there was a low but significant effect of the parasite on condition factor (r_s= 0.22, $p < 0.05$), LSI (r_s= 0.3, $p < 0.05$) and GSI (r_s= 0.28, $p < 0.05$). There was an increase in the parasite numbers with host size and this appears to be related to increased diet intake of the intermediate host.

Capillaria sp. was found in some *Gammarus* sp. and *Onisimus* sp. specimens from the stomach contents of shorthorn sculpin.

Stable isotopes

Stables isotope ratios for carbon and nitrogen from the muscle samples of shorthorn sculpin from both sites are shown in Fig. A6.8. The nitrogen signal ranges between 12 and 17 ‰ and the carbon from approximately -16 to -20 ‰. The nitrogen signal for *G. setosus* and *O. litoralis* was between 6 and 7 ‰. The carbon signal ranged from -17 ‰ for *G. setosus* to -19 ‰ for *O. litoralis* and -20 ‰ for *T. libellula* (Fig. A6.8). A regression of total length on the nitrogen signal shows an increase in the nitrogen ratio from about 12 ‰ in shorthorn sculpin 50 mm in length to >17 ‰ for shorthorn sculpin over 300 mm in length (Fig. A6.9). Nitrogen stable isotope values were positively correlated with shorthorn sculpin lengths (Fig. A6.9).

Discussion

Age, Growth and Condition

When shorthorn sculpin growth characteristics were evaluated, there were no significant differences between the growth of males and females. The shorthorn sculpin in this study grew much slower and were longer lived than those from European waters (Luksenburg and Pedersen, 2002) and Ennis (1970a) reported that female shorthorn sculpin grew faster and were larger than males > 4 years of age, for specimens collected from Newfoundland waters. The maximum age of shorthorn sculpin in our samples was 16 years for females and 11 years for males and this was comparable to a report by Ennis (1970a) where the oldest females and males were 15 and 14 years, respectively.

The GSI values in this study were < 2 and 2-9 for immature and maturing females, respectively and <2 and 2-4 for immature and maturing males, respectively, for the period from early July to mid September. Ennis (1970b) found that shorthorn sculpin in Newfoundland waters spawned in late November and early December. Data on sexual maturing individuals were similar to that reported by Ennis (1970a), where females and males matured at 5-6 and 5 years, respectively and also agrees with a length of 15 cm for mature males and a length of 20 cm for mature females from Iceland waters (Saemundsson, 1927, cited in Ennis 1970a).

The LSI differed between juvenile and adults, between mature females and males. An increasing LSI with increasing fish size could suggest the liver as a site of energy storage. However, the high correlation of LSI with GSI indicates that most of the increase in LSI is likely associated with increased biosynthetic activity as eggs develop, especially as yolk is synthesized. Further support for this interpretation is the poor correlation of LSI and GSI in males. An unresolved question is whether a cold-water species such as shorthorn sculpin has obvious energy reserves or must feed constantly to survive. The absence of visceral fat and the small muscle mass relative to total body size (T. A. Dick, unpublished data) suggests that the shorthorn sculpin has limited energy reserves and relies primarily on available food as a survival strategy. However, stored lipids are important in freshwater sculpin species from Lake Baikal. For example, *Cottocomephorus inermis* stored lipids in the liver and total body lipids were depleted during spawning (Kozlova, 1997). Clearly more work is needed on the type and location of energy reserves in sculpin species, including the Arctic marine populations of shorthorn sculpin.

Diet

While shorthorn sculpin in this study fed mainly on amphipods, Scott and Scott (1988) reported that this species fed on crabs, shrimps, sea urchin, gobies, small cod, marine worms and possibly herring. Moore and Moore (1974) found shorthorn sculpin in the Cumberland Sound area of Baffin Island fed heavily on benthic gastropods, *Littorina saxatili*s and *Margarites umbilicalis,* the bivalve, *Modiolaria discors.* According to Moore and Moore (1974), shorthorn sculpin, under limited illumination, fed on brightly coloured plankton. Undoubtedly shorthorn sculpin are opportunistic generalist feeders in the bentholittoral zone but there must be some selectivity in feeding as there appears to be little overlap in the diet between shorthorn sculpin and anadromous Arctic char diets (T.A. Dick unpublished data), even though both species of fish frequented the intertidal zone in the study area.

Parasites

Fourteen species of metazoan parasites were collected from shorthorn sculpin and these data can be compared to the list provided by McDonald and Margolis (1995), where 13 metazoan parasitic species, five of which are annelids, were reported. *Brachyphallus crenatu*s, *Lepidapedon rachion,* Hemiuridae sp., *Bothrimomus sturionus*, *E. gadi*, *Corynosom*a sp., and *Capillaria* sp. appear to be new host records for North America. *Echinorhynchus gadi* and the ascarid, *Hysterothylacium adunca*, were reported from shorthorn sculpin from the south-east Baltic by Sulgostowaska et al (1990). The presence of the larval ascarid nematodes in the shorthorn sculpin is not new, as Jensen and Andersen

(1992), Jensen (1997) and Midtgaard et al. (2003) discussed the transmission of *Pseudoterronova decipiens* from shorthorn sculpin to seals.

Most of the parasite species were transmitted through diet. For example, the crustacean, *Themisto libellula*, transmits *Prosorhynchus squamatous* and *Bothrimonus sturionis*. *Capillaria* sp. is transmitted by *Gammarus* sp. and *Onisimus* sp. and *E. gadi* is also transmitted by *Gammarus* (Isinguzo and Dick, unpublish. data). *Brachyphallus crenatus* is transmitted by *Mysis oculata* and *M. mixta* (I. Isinguzo and T.A. Dick, unpublished.data).

The foregut and midgut appear to be a more suitable location in the host for the growth of *E. gadi*. *Echinorhynchus gadi* was found at intermediate prevalence and intensity of 13-20 % and 1-4, respectively in the shorthorn sculpin from Hel (south-east Baltic) by Sulgostowaska et al. (1990) and can be compared to prevalences of 88-100 % and intensities ranging from 28-35 in our study. It appears that *E. gadi* affects the growth of shorthorn sculpin.

Trophic Position

Stable isotopes ratios for $\delta^{15}N$ indicates a high trophic level for small and large shorthorn sculpin indicating the major diet type is similar. The ratio of $\delta^{13}C$ (–17 ‰ to -19 ‰) indicates *G. setosus* is a common food item of shorthorn sculpin and this is corroborated by the abundance of this diet item. The nitrogen values for shorthorn sculpin generally corresponds with literature values as it is within the range of published data for benthic fish species (Sherwood and Rose, 2005), although some of the values reported here are higher. If *G. setosus* is one of the main food items throughout the year, a shift of 7 ‰

in the $\delta^{15}N$ ratios for shorthorn sculpin seems high. Nitrogen stable isotopes values in this study for amphipods (*G. setosus* and *O. litoralis*) are lower at ~ 7 ‰ than that reported for amphipods ($\delta^{15}N$ 9.7 ‰) by Sherwood and Rose (2005). Nevertheless, the carbon signal for these two food items supports the range of $\delta^{13}C$ values reported from shorthorn sculpin in our study. Although fish, polychaetes and gastropods were rarely found in the diet of shorthorn sculpin, they may occur more frequently in the diet at other times of the year. Literature values for polychaetes are $\delta^{15}N = 16.6$ ‰ (Sherwood and Rose, 2005) and Grall et al. (2006) reported values of $\delta^{15}N$ as 11.2 ‰ to 15.7 ‰ for annelids and $\delta^{15}N$ as 9.2 ‰ to 13.5 ‰ for molluscs. The increase in nitrogen stable isotope values with increasing fish length suggests that larger shorthorn sculpin are consuming food with a higher nitrogen signal. Although rare in our samples, one of the largest shorthorn sculpin had an Arctic cod (*Boreogadus saida*) in its stomach. Clearly mixing dietary items of organisms with quite different stable isotope signals complicates the interpretation of the trophic position for a species.

Table A6.1. Von Bertalanffy growth function parameters of female (n= 41) and male (n= 34) *M. scorpius*.

	F	M
K	0.21	0.35
t_0 (mm)	0.36	1.34
L_∞ (mm)	277	259

Table A6.2. Total per cent frequency (%) and frequency of occurrence (%) of food items in *M. scorpius* sampled from Peterhead Inlet and the Sylvia Grinnell River estuary, Nunavut.

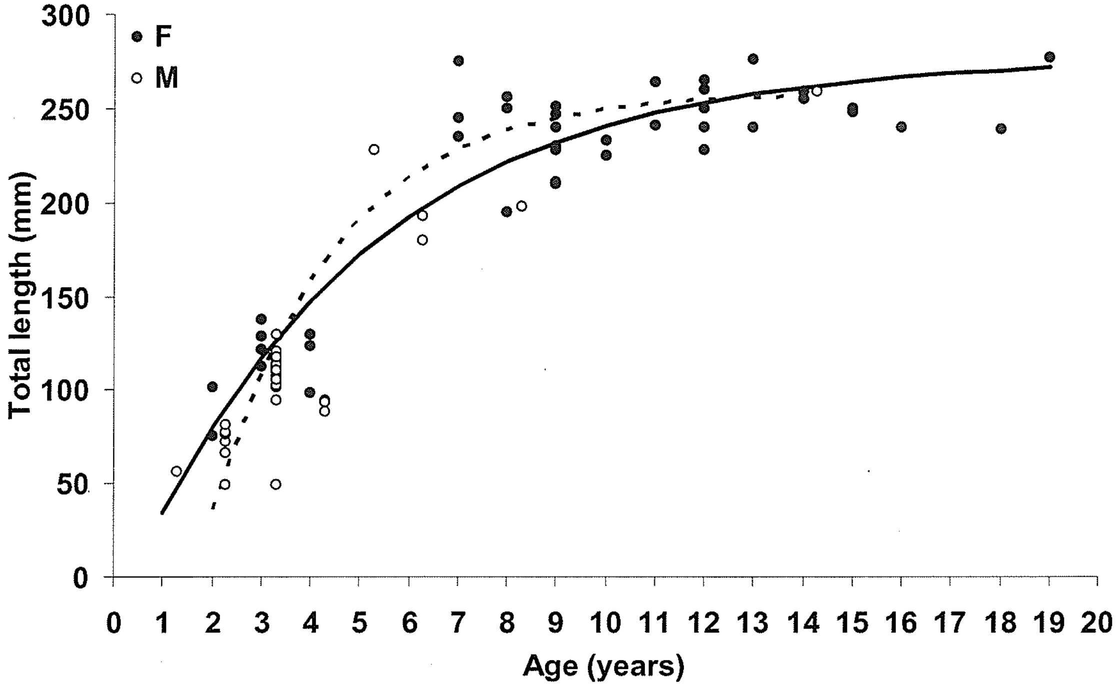
Food item	Peterhead Inlet (n= 80)		Sylvia Grinnell (n= 21)	
	Per cent frequency	Frequency of occurrence	Per cent frequency	Frequency of occurrence
Amphipoda				
Gammaracathus relictus (Sars)	0	0	1.23	19.0
Gammarus setosus (Dementieva)	63.97	70.0	35.95	71.4
Gammarus sp.	1.08	11.3	0	0
Themisto libellula (Lichtenstein)	0.09	3.8	0	0
Onisimus edwardsii (Kroyer)	4.52	7.5	33.50	23.8
Onisimus litoralis (Kroyer)	29.98	52.5	27.85	28.6
Copepoda				
Calanus hyperboreus (Kroyer)	0.11	3.8	0	0
Gastropoda				
Gastropoda sp.	0.23	2.5	0	0
Malacostraca				
Mysis oculata (Fabricius)	0	0	0.61	14.3
Polychaeta				
Polychaete	0	0	0.74	23.8
Actinopterygii				
Boreogadus saida (Lepechin)	0.03	1.3	0.12	4.8

Table A6.3. Prevalence (%), mean intensity (± SD) and abundance (± SD) of parasites in *M. scorpius* sampled from Peterhead Inlet and the Sylvia Grinnell River estuary, Nunavut.

Parasite	Peterhead Inlet (n= 80)			Sylvia Grinnell estuary (n= 21)		
	Prevalence	Mean intensity	Abundance	Prevalence	Mean intensity	Abundance
Trematoda						
Brachyphallus crenatus (Odhner)	5	2.75 ± 2.22	0.14 ± 0.74	0	0 ± 0	0 ± 0
Derogenes varicus (Muller)	48.8	2.51 ± 1.86	1.23 ± 1.81	81	4.53 ± 6.04	3.67 ± 5.70
Lepidapedon rachion (Cobbold)	1.3	2.00 ± 0.0	0.03 ± 0.22	0	0 ± 0	0 ± 0
Hemiuridae sp.	2.5	1.50 ± 0.71	0.04 ± 0.25	0	0 ± 0	0 ± 0
Podocotyle sp. larvae	1.3	2.00 ± 0.0	0.03 ± 0.22	0	0 ± 0	0 ± 0
Podocotyle atomon (Rudolphi)	8.8	3.43 ± 2.76	0.30 ± 1.24	0	0 ± 0	0 ± 0
Prosorhynchus squamatus (Odhner)	62.5	10.48 ± 15.66	6.55 ± 13.35	52.4	51.55 ± 54.98	27.0 ± 46.98
Prosorhynchus squamatus larvae	26.3	3.86 ± 2.74	1.01 ± 2.20	23.8	6.40 ± 6.31	1.52 ± 3.97
Unknown trematoda sp.	1.3	1.00 ± 0.0	0.01 ± 0.11	0	0 ± 0	0 ± 0
Trematoda sp. larvae	1.3	5.00 ± 0.0	0.06 ± 0.60	0	0 ± 0	0 ± 0
Cestoda						
Bothrimonus sturionis (Duvernoy)	25	2.40 ± 2.76	0.60 ± 1.71	0	0 ± 0	0 ± 0
Cestoda sp. plerocercoid	33.8	19.70 ± 24.07	6.65 ± 16.69	4.8	7.0 ± 0	0.33 ± 1.53
Nematoda						
Anisakis larvae	0	0 ± 0	0 ± 0	19	1 ± 0	0.19 ± 0.40
Pseudoterranova decipiens larvae* (Krabbe)	25	3.70 ± 2.60	0.93 ± 2.05	0	0 ± 0	0 ± 0
Capillaria sp.	91.3	98.18 ± 126.14	89.59 ± 123.62	100	111.86 ± 89.25	111.86 ± 89.25
Acanthocephala						
Corynosoma sp. larvae	13.8	2.08 ± 1.08	0.31 ± 0.85	0	0 ± 0	0 ± 0
Echinorhynchus gadi (Zoega)	87.5	34.71 ± 40.25	30.38 ± 39.36	100	28.33 ± 20.48	28.33 ± 20.48

* n= 73

Figure A6.1. Mean length at age and von Bertalanffy growth curves of female (solid line) and male (dashed line) *M. scorpius* collected from Peterhead Inlet.



● F
○ M
Total length (mm)
0
50
100
150
200
250
300
Age (years)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure A6.2. Gonadosomatic index plotted against total length of immature and mature female *M. scorpius* from Peterhead Inlet. Dashed line indicates shift from immature (below) to mature (above). Arrow indicates length of sexual maturity.

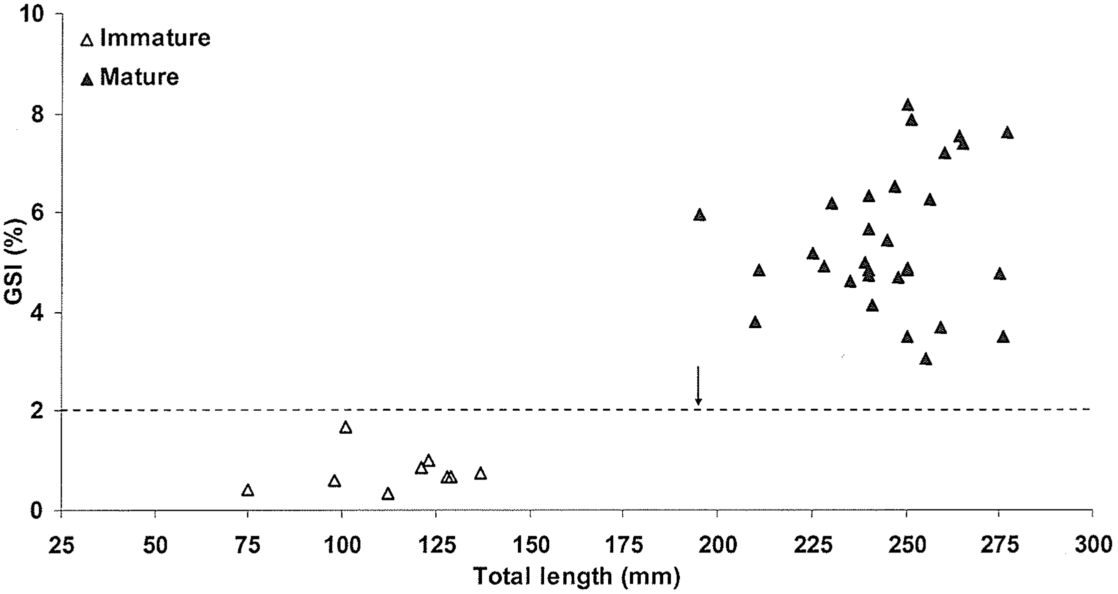
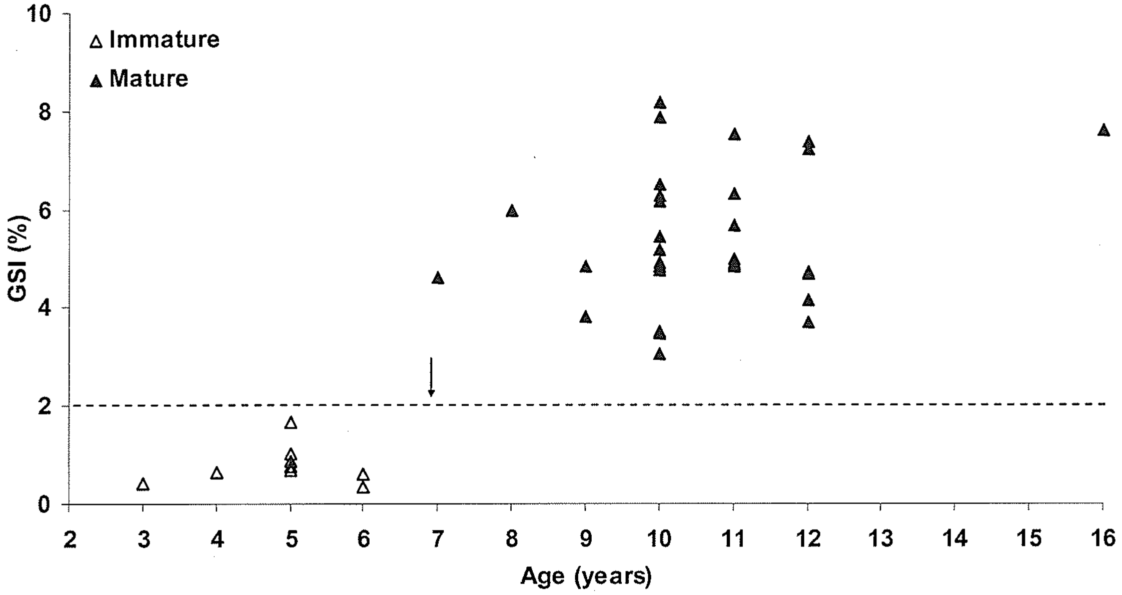

△ Immature
▲ Mature
GSI (%)
10
8
6
4
2
0
25
50
75
100
125
150
175
200
225
250
275
300
Total length (mm)

Figure A6.3. Gonadosomatic index plotted against age of immature and mature female *M. scorpius* from Peterhead Inlet. Dashed line indicates shift from immature (below) to mature (above). Arrow indicates age of sexual maturity.



△ Immature
▲ Mature
GSI (%)
0
2
4
6
8
10
Age (years)
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Figure A6.4. Gonadosomatic index plotted against total length for immature and mature male *M. scorpius* from Peterhead Inlet. Dashed line indicates shift from immature (below) to mature (above). Arrow indicates length at sexual maturity.

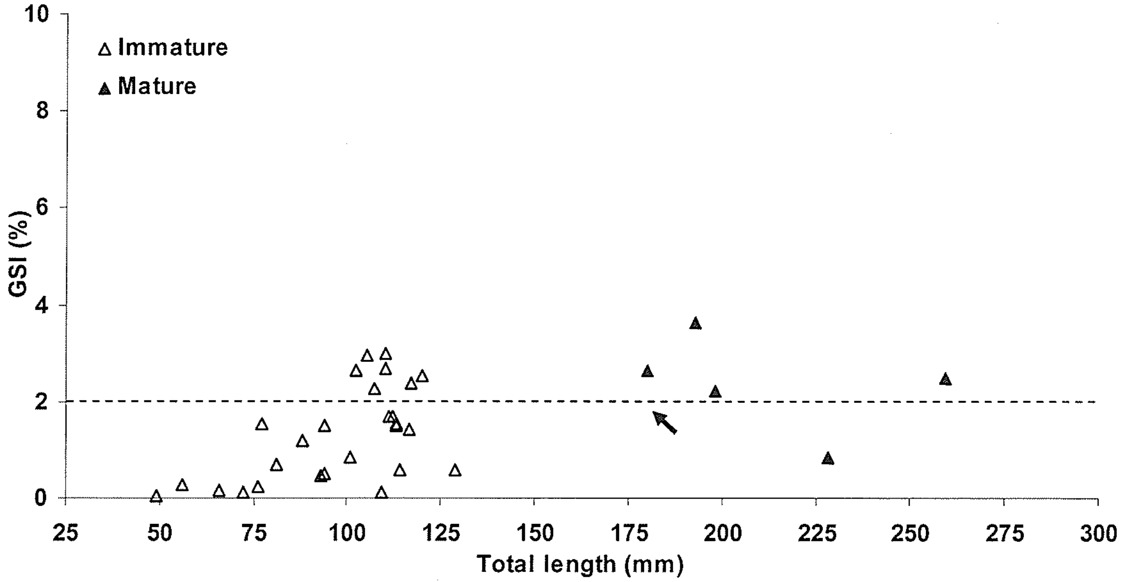

10
8
6
4
2
0
GSI (%)
△ Immature
▲ Mature
25
50
75
100
125
150
175
200
225
250
275
300
Total length (mm)

Figure A6.5. Gonadosomatic index plotted against age for immature and mature male *M. scorpius* from Peterhead Inlet. Dashed line indicates shift from immature (below) to mature (above). Arrow indicates age of sexual maturity.

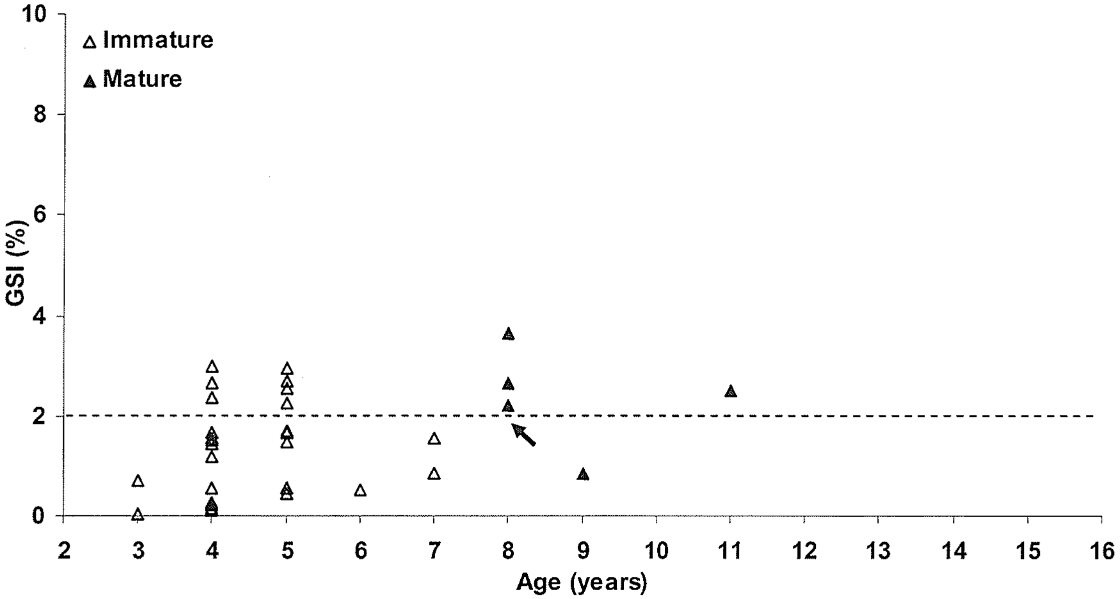
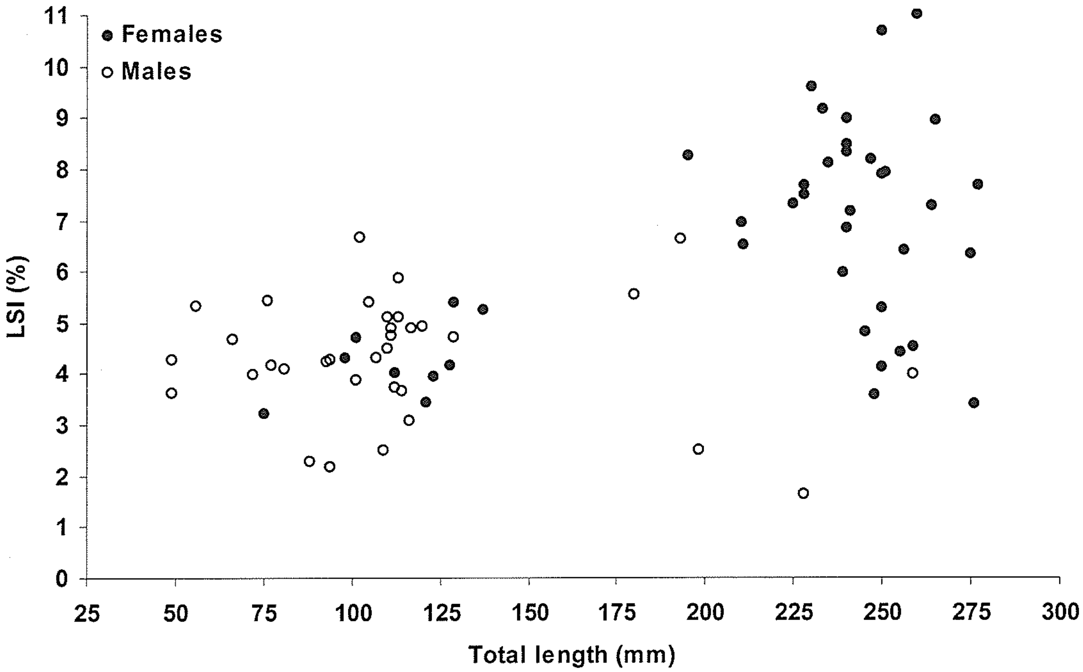

10
8
6
4
2
0
GSI (%)
△ Immature
▲ Mature
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Age (years)

Figure A6.6. Liver somatic index plotted against length of female and male *M. scorpius* from Peterhead Inlet.



● Females
○ Males
LSI (%)
0
1
2
3
4
5
6
7
8
9
10
11
25
50
75
100
125
150
175
200
225
250
275
300
Total length (mm)

Figure A6.7. Regression between liver somatic index and gonadosomatic index of female (solid line, $r^2 = 0.585$, $p < 0.05$) and male (broken line, $r^2 = 0.189$, $p < 0.05$) *M. scorpius* from Peterhead Inlet.

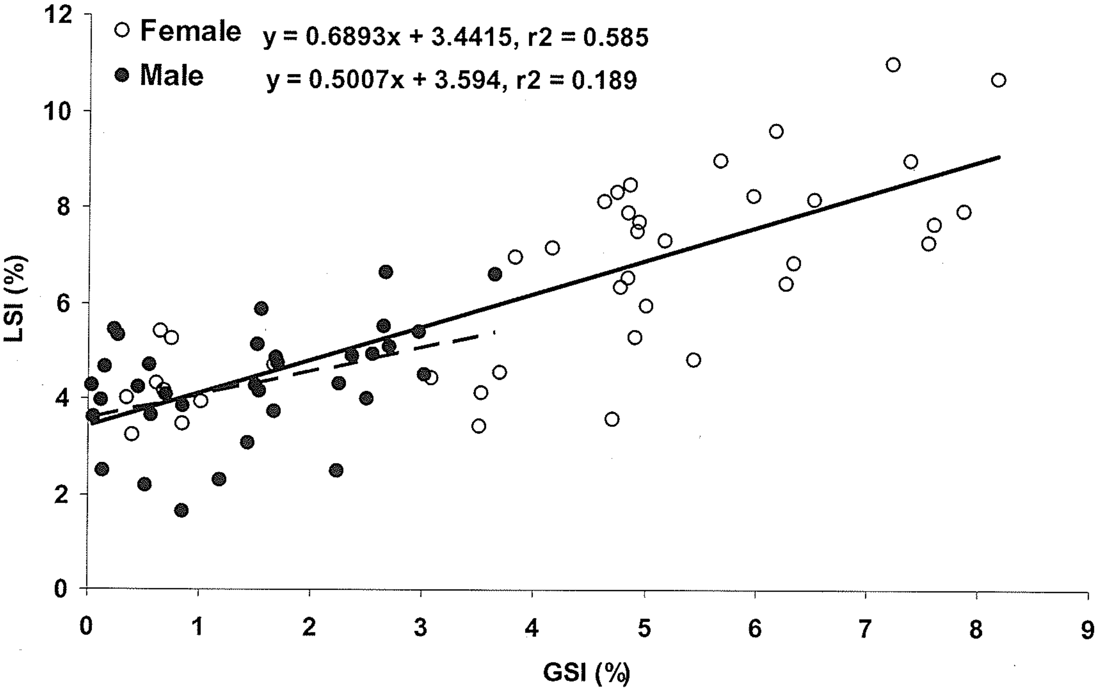

○ Female
● Male
y = 0.6893x + 3.4415, r2 = 0.585
y = 0.5007x + 3.594, r2 = 0.189
LSI (%)
GSI (%)
0
2
4
6
8
10
12
0
1
2
3
4
5
6
7
8
9

Figure A6.8. Stable isotope ratios of *M. scorpius* and important food items from Peterhead Inlet and the Sylvia Grinnell River estuary [Polychaete values are from Sherwood and Rose (2005), molluscs and annelids values are from Grall et all (2006)].

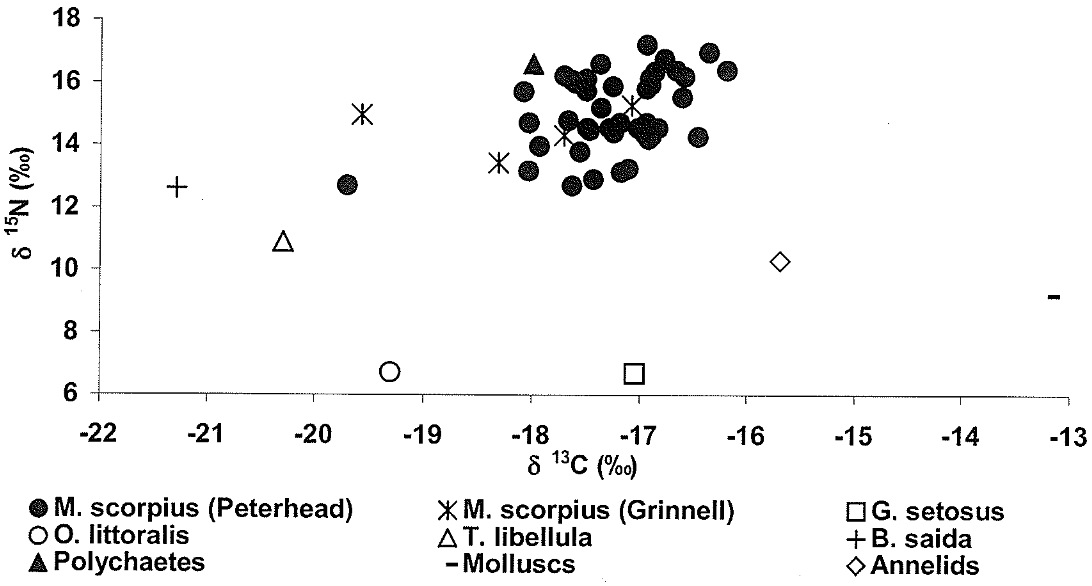
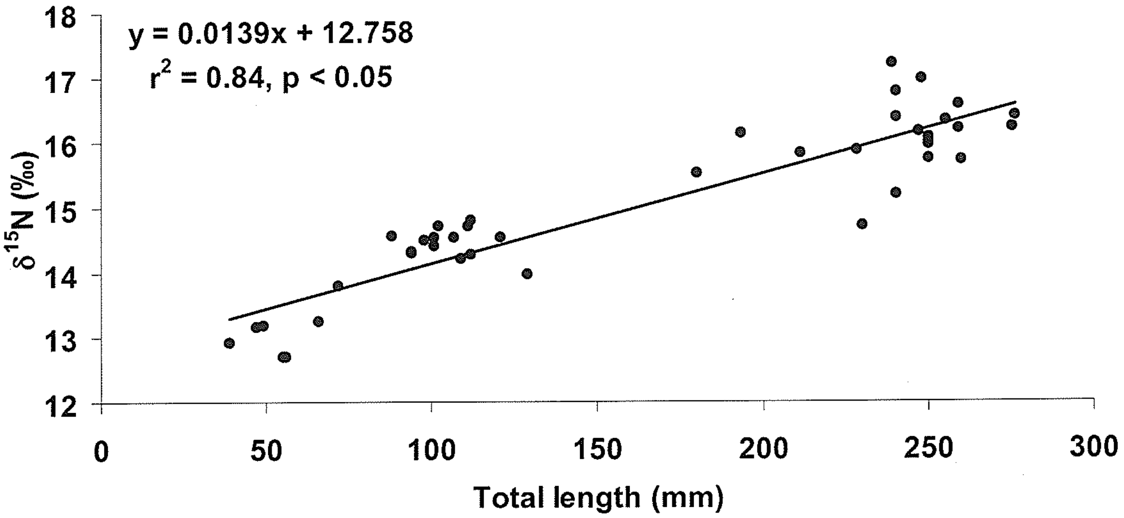

18
16
14
12
10
8
6
δ ¹⁵N (‰)
-22
-21
-20
-19
-18
-17
-16
-15
-14
-13
δ ¹³C (‰)
● M. scorpius (Peterhead)
○ O. littoralis
▲ Polychaetes
✳ M. scorpius (Grinnell)
△ T. libellula
- Molluscs
□ G. setosus
+ B. saida
◇ Annelids

Figure A6.9. Regression of total length and nitrogen isotope values from *M. scorpius* from Peterhead Inlet.


y = 0.0139x + 12.758
r2 = 0.84, p < 0.05
δ15N (‰)
18
17
16
15
14
13
12
0
50
100
150
200
250
300
Total length (mm)