Fish diets and food webs in the Northwest Territories: Dolly Varden (*Salvelinus malma*)

D.B. Stewart, N.J. Mochnacz, T.J. Carmichael, C.D. Sawatzky, and J.D. Reist

Central and Arctic Region
Fisheries and Oceans Canada
Winnipeg, MB R3T 2N6

2009

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2912

Fisheries and Oceans Canada   Pêches et Océans Canada

Canada

Fish diets and food webs in the Northwest Territories: Dolly Varden (*Salvelinus malma*)

D.B. Stewart, N.J. Mochnacz, T.J. Carmichael, C.D. Sawatzky, and J.D. Reist

Central and Arctic Region
Fisheries and Oceans Canada
Winnipeg, MB R3T 2N6

2009

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2912

Fisheries and Oceans Canada   Pêches et Océans Canada

Canada

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2912

2009

FISH DIETS AND FOOD WEBS IN THE NORTHWEST TERRITORIES: DOLLY VARDEN (*Salvelinus malma*)

by

D.B. Stewart[1], N.J. Mochnacz, T.J. Carmichael, C.D. Sawatzky, and J.D. Reist

Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, Manitoba
R3T 2N6

[1] Arctic Biological Consultants, 95 Turnbull Drive, Winnipeg, MB, R3V 1X2

Cat. No. Fs 97-4/2912E ISSN 0706-6473

Correct citation for this report is:

Stewart, D.B., Mochnacz, N.J., Carmichael, T.J., Sawatzky, C.D., and Reist, J.D. 2009. Fish diets and food webs in the Northwest Territories: Dolly Varden (*Salvelinus malma*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2912: vi + 33 p.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Stewart, D.B., Mochnacz, N.J., Carmichael, T.J., Sawatzky, C.D., and Reist, J.D. 2009. Fish diets and food webs in the Northwest Territories: Dolly Varden (*Salvelinus malma*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2912: vi + 33 p.

Dolly Varden prey on a variety of aquatic invertebrates and fishes, and on terrestrial invertebrates when the opportunity presents. They forage near the surface of the substrate and seldom feed on infaunal benthos, or on midwater or surface taxa. Small fish in fresh water eat predominately immature stages of aquatic insects. Prey size and the proportion of fish in the diet increases as the Dolly Varden grow larger. Anadromous Dolly Varden do not feed extensively in fresh water. In coastal waters they eat mostly amphipods, mysids and fish, although insects—predominately chironomid larvae, are eaten in areas strongly influenced by freshwater. The diet of anadromous fish in fresh water is similar to that of juveniles and residuals that remain there year-round, except that a higher proportion of the anadromous fish have empty stomachs. Humans are a key predator on larger anadromous Dolly Varden that are predictably available in confined areas of fresh water and vulnerable to mixed-stock coastal fisheries. Piscivorous fishes, including larger Dolly Varden, may be the key predators on smaller juveniles and eggs. The ability of northern-form Dolly Varden to withstand competition from other species is not well understood. This document provides generalized freshwater and marine food webs for the species and reviews knowledge of its interactions with predators, prey, and competitors. Dietary differences related to geographical location, habitat type, life history stage, season, predation, and competition are discussed.

Key words: diet; life history; habitat use; fresh water; marine; stream-resident; riverine; anadromous; Salmonidae; feeding behaviour; Beaufort Sea; Yukon, Alaska; North Slope.

RÉSUMÉ

Stewart, D.B., Mochnacz, N.J., Carmichael, T.J., Sawatzky, C.D., and Reist, J.D. 2009. Fish diets and food webs in the Northwest Territories: Dolly Varden (*Salvelinus malma*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2912: vi + 33 p.

Le Dolly Varden fait sa proie de divers poissons et invertébrés aquatiques, ainsi que d'invertébrés terrestres lorsque l'occasion se présente. Il pêche près de la surface du substrat et se nourrit rarement de benthos, ou de taxons à mi-eau ou à la surface. Les petits poissons d'eau douce mangent surtout des insectes aquatiques immatures. La taille des proies et la proportion de poissons dans le régime alimentaire augmentent au même rythme que la taille du Dolly Varden. Le Dolly Varden anadrome ne se nourrit pas beaucoup en eau douce. Dans les eaux côtières, il se nourrit principalement d'amphipodes, de mysidacés et de poissons, mais aussi des insectes — surtout des larves de chironomes – dans les zones fortement influencées par les eaux douces. Le régime des poissons anadromes en eau douce est semblable à celui des juvéniles et des poissons résiduels qui y restent toute l'année, sauf qu'une proportion plus élevée de poissons anadromes ont l'estomac vide. Les êtres humains sont des prédateurs clés des Dolly Varden anadromes de plus grande taille auxquels on s'attend dans les zones confinées d'eau douce et qui sont vulnérables aux pêches de stocks mélangés dans les eaux côtières. Les poissons piscivores, y compris le Dolly Varden de plus grande taille, pourraient être les prédateurs clés des juvéniles et des oeufs. On ne comprend pas bien la capacité de la forme nordique du Dolly Varden à résister à la concurrence des autres espèces. Le présent document mentionne des réseaux trophiques marins et d'eau douce généralisés pour l'espèce et examine les connaissances de ses interactions avec les prédateurs, les proies et les compétiteurs. On discute également des différences alimentaires liées à l'emplacement géographique, au type d'habitat, au stade du cycle biologique, à la saison, à la prédation et à la concurrence.

Mots clés : régime alimentaire; cycle biologique; utilisation de l'habitat; eau douce; marine; résident en ruisseau; fluvial; anadrome; salmonidés; comportement alimentaire; mer de Beaufort; Yukon, Alaska; versant nord.

1.0 INTRODUCTION

Renewed interest in natural gas pipeline development along the Mackenzie Valley has raised the prospect that fish species in the watershed may be impacted by changes to their habitat. The proposed pipeline would extend from near the Beaufort Sea coast to markets in the south (http://www.mackenziegasproject.com/). Fishes in the Mackenzie River depend upon the integrity of their aquatic habitats, so it is important to summarize knowledge that can be used to assess potential impacts of this development proposal and others, and to facilitate efforts to avoid and mitigate these impacts.

This report reviews knowledge of the diet of the northern-form of Dolly Varden, *Salvelinus malma* (Walbaum in Artedi, 1792). These prized food fish have been harvested in quantity from the Rat and Big Fish river systems, Mackenzie Delta, and other rivers and coastal waters along the North Slope (Jessop et al. 1974; Sparling and Stewart 1986; Sandstrom 1995; Stewart 1996; Papik et al. 2003; Ayles et al. 2007). They inhabit the Gayna, Peel, Rat, and Big Fish river systems in the northwest corner of the Northwest Territories (NT) (Mann and Tsui 1977; Reist et al. 2002; Mochnacz and Reist 2007; Sawatzky et al. 2007); the Babbage, Firth, and Fish rivers of the Yukon (YT) North Slope (Sandstrom 1995; Sandstrom et al. 1997); the Peel River watershed in the Yukon interior (N. Millar, Yukon Department of the Environment, pers. comm. 2009); and rivers on the Alaskan North Slope (Craig 1984). The limits of their distribution in western Alaska (AK) and Asia remain a matter of debate.

The nomenclature of fish in these areas is somewhat confused, as they were often referred to in earlier literature as the “western form of Arctic char, *Salvelinus alpinus* (Linnaeus, 1758)” (e.g., McPhail 1961; Jessop et al. 1973; McCart 1980). Consequently, many of the cited reports discuss “Arctic Char” or “*Salvelinus alpinus*” that are now considered Dolly Varden. As well, some reports that discuss “Dolly Varden” south of the Great Bear River have not been cited as these fish are likely Bull Trout (*Salvelinus confluentus*) (Reist et al. 2002).

Dolly Varden exhibit both **non-anadromous** and anadromous life history types in response to the local environmental conditions, and it is not uncommon for a river system to support more than one life history type (Armstrong and Morrow 1980; McCart 1980; Babaluk and Reist 1996; Stewart et al. 2009). Most non-anadromous Dolly Varden are prevented from undertaking seasonal migrations into coastal waters by either distance or impassable barriers that confine them to lakes (**lacustrine-isolated**) or streams (**stream-resident—isolated**). Some non-anadromous fish (**riverine—residual**) have access to the sea but remain in fresh water throughout their lives. These latter fish are typically males that follow an alternative reproductive strategy, whereby they mature earlier and at a smaller size than their anadromous

[1] Terms in bold type are defined in the Glossary.

counterparts. They participate in spawning with anadromous pairs following a ‘sneaker’ reproductive strategy. Most adults and older juveniles with access to the sea migrate into productive coastal brackish and marine habitats during the summer to feed (**anadromous)**. Anadromous fish are larger than non-anadromous fish of the same age and tend to mature later in life. Fry of all life history types are reared in freshwater, where spawning occurs and all life stages overwinter. All life histories and life stages are closely associated with groundwater inflows into small streams. These inflows maintain suitable incubation and rearing conditions through the winter, and prevent small areas of streams from freezing, thereby providing overwintering habitat in streams that otherwise freeze to the bottom over long reaches.

Very little is known of the species’ diet within the Mackenzie watershed outside the summer season, about energy flow, or predation rates. This limits the ability to assess the effects of environmental changes on the species, particularly impacts related to pipeline development and climate change. This report presents a generic food web for Dolly Varden, based largely on data from the Mackenzie River watershed within the NT. It reviews knowledge of how the species’ diet varies with geographical location, habitat type, season, life history stage, and competition. It also considers predation pressures and identifies knowledge gaps. Similar reports have been prepared for other fishes that inhabit the Mackenzie River watershed. Stewart et al. (2009) provide a recent review of habitat use by Dolly Varden.

2.0 FOOD WEB

Quantitative data from Dolly Varden populations in the Northwest Territories (NT), and Yukon (YT) were used to construct the generic food webs for the freshwater and marine environments (Appendices 1-3). Most of these studies were conducted during the summer, and they often combined the juvenile and adult dietary data. These limitations make it difficult to compare dietary differences among populations, life stages, and seasons. They also limit what can be said about the energetic importance of each pathway.

The methods used to quantify Dolly Varden diet are not always directly comparable among studies. Most studies have used percent frequency of occurrence based only on stomachs that contained food. Where studies calculated percentages based on all stomachs examined, including those that were empty, the data were re-calculated to base all percentages only on stomachs with food. Some studies have used percentage by volume to quantify stomach contents. Griffiths et al. (1975) did this using Hynes’ (1950) points method, while Bryan et al. (1973) used the method of Borgeson (1963).

The frequency of occurrence of taxa in fish stomachs, expressed as a percentage, is not a good measure of the biomass or caloric content of the stomach contents (McCart 1980; Stevens and Deschermeier 1986). This measure tends to over-emphasize small, widely occurring species that occur frequently in the diet but may contribute less food energy than larger species that are found less frequently in the stomach contents. However, comparisons of percent occurrence and percent volume data using anadromous fish from studies in both fresh and coastal waters suggest that items found most frequently in the diet also contribute most to the volume and probably to the food value (Appendix 4).

Based on these data, generalized food webs have been constructed for freshwater (Figure 1) and marine (Figure 2) environments. Aspects of these food webs, including predators and dietary differences related to life history stage, habitat, and season are discussed below, as are the effects of inter- and intra-specific competition.

2.1 PREDATORS

During their lives, Dolly Varden are preyed upon by a variety of invertebrates, fishes, birds, and mammals. All life history stages of the Dolly Varden are vulnerable to predation in the small areas of spring-fed stream habitat that they use for spawning, rearing, and overwintering. Indeed, the concentrations of these fish draw some unlikely predators, such as wolves. Some fish spend their entire lives in fresh water, either by ‘choice’ in the case of residual males, or by necessity where barriers prevent migrations to and from the sea. Anadromous fish are also vulnerable to predation in shallow freshwater streams as they migrate downstream to feed at sea in the spring and early summer (June-July) and return upstream in late summer and early fall (August-September). They are also vulnerable to predation by brackish and marine species that inhabit river deltas and coastal waters.

Large anadromous Dolly Varden occasionally eat small juvenile Dolly Varden (80-120 mm FL) in streams (McCart et al. 1972; Jessop et al. 1973; Bain 1974; Craig 1977a; Stephenson 2003) or coastal waters (Griffiths et al. 1975). They also eat Dolly Varden eggs (McCart et al. 1972; Bain 1974; Jessop et al. 1973; Stephenson 2003). Residual males and adults from isolated populations also eat Dolly Varden eggs and fish (Bain 1974), which probably include Dolly Varden. Egg-eating behaviour may be related in part to spawning success, since southern form satellite (= riverine-residual) males in coastal streams on the Shiretoka Peninsula, Hokkaido, Japan that had not participated successfully in spawning were observed eating Dolly Varden eggs (Kitano

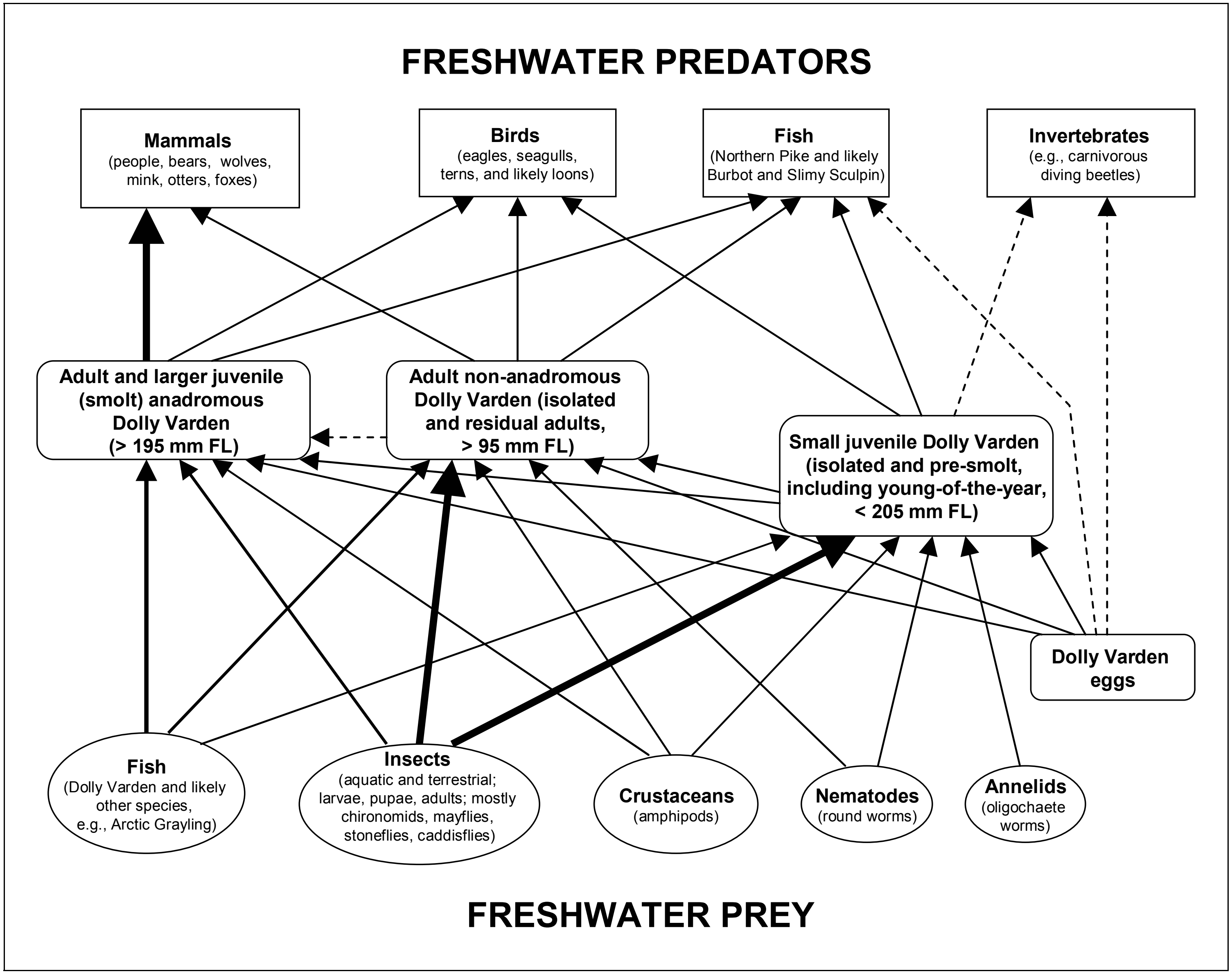

Figure 1. Generalized food web for Dolly Varden in fresh water showing the direction of energy flow. Bold lines indicate major food pathways, in comparison to thinner lines; solid lines indicate demonstrated and dashed lines indicate putative pathways.

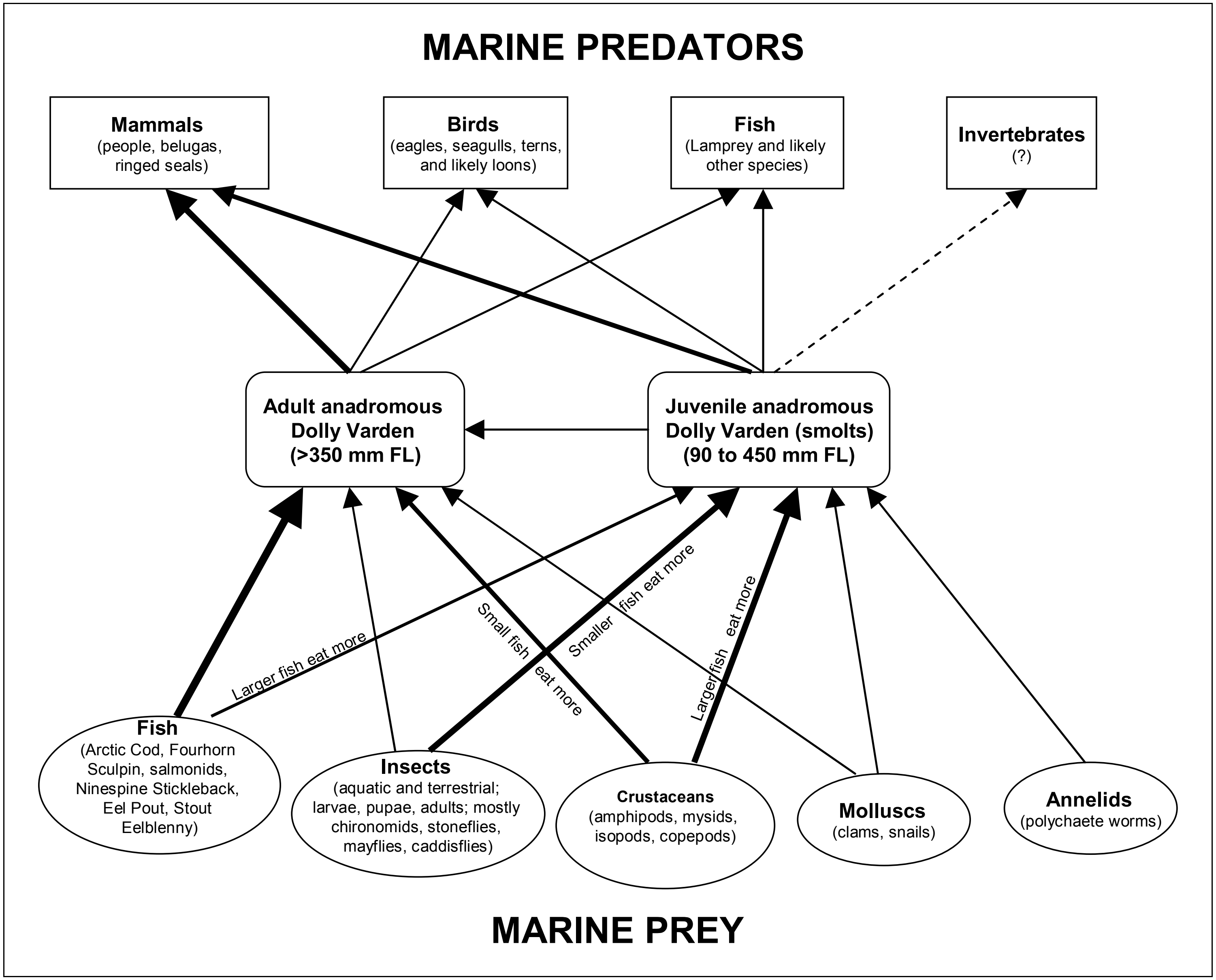

Figure 2. Generalized food web for anadromous Dolly Varden in coastal waters showing the direction of energy flow. Bold lines indicate major food pathways, in comparison to thinner lines; solid lines indicate demonstrated and dashed lines indicate putative pathways.

1996). Little is know about predation by macro-invertebrates on Dolly Varden eggs and fry, although it is likely.

Predation of Dolly Varden in the Northwest Territories by other freshwater fish species is not well known. Burbot (*Lota lota*) and Northern Pike (*Esox lucius*) likely predate anadromous Dolly Varden in the lower reaches of the Rat River and in the Mackenzie River channels and estuary (Gwich'in Elders 1997; DFO 2001). Slimy Sculpins (*Cottus cognatus*) may eat eggs and juveniles at nursery and rearing areas in the Fish Creek tributary of the Rat River (DFO 2001).

Wolves (*Canis lupus*), grizzly bears (*Ursus arctos*), mink (*Neovision vision*), golden eagles (*Aquila chrysaetos*), and possibly black bears (*Ursus americanus*), feed on Dolly Varden at the Fish Creek spawning and overwintering site in the Rat River (Gwich'in Elders 1997; Norton 1997; S. Sandstrom, pers. comm. in DFO 2001). Wolf predation on overwintering Dolly Varden in the region may not be unusual, as it also occurs at the Fish Hole Creek spawning area of the Babbage River, Yukon (Bain 1974). A wolf pack remained in that area for about a month in the winter, and blood spots along the shoreline indicated that they were successful in capturing Dolly Varden. Up to 20 grizzly bears have been observed along the Rat River during the spawning period (R. Gruben, COSEWIC ATK Subcommittee, pers. comm. 2008).

Grizzlies and large piscivorous birds have also been observed fishing for Dolly Varden overwintering in the Canning River of Alaska (Craig 1977a). Eagles catch Dolly Varden as the fish surface or pass through rapids or shallow areas (Gwich'in Elders 1997). Northern Pike, seagulls (*Larus* spp.), and foxes (*Vulpes* spp.) also catch and eat Dolly Varden (Gwich'in Elders 1997).

The river otter (*Lutra canadensis*) may be an important predator on juvenile Dolly Varden (southern form) in southeastern Alaska (Dolloff 1993). Their impact on northern-form Dolly Varden populations is unknown, but otter activity has been observed along the Big Fish and Rat rivers (Norton 1997) and at rivers on the Alaskan North Slope (Craig 1977a) and in the Alaskan interior (Armstrong and Morrow 1980).

Lamprey (*Lethenteron japonicum*) scarring is common among anadromous Dolly Varden in the Rat (Sparling and Stewart 1986; Cosens and Dueck 2001; DFO 2001), Big Fish (Sparling and Stewart 1986), and Babbage (Sandstrom et al. 1997) rivers. Scarring rates of 9.5% (10 of 105) and 23.5% (20 of 85) were observed on fish returning to the Big Fish and Rat rivers, respectively, in the fall (Sparling and Stewart 1986). These high incidences of scarring may reflect the relatively small sample sizes and clumping in the captures of scarred fish. The incidence of scarring of anadromous Dolly Varden captured at a weir on the Big Fish River as they moved upstream in the fall of 1991 was 4% (58 of 1475; Sandstrom et al. 1994). The incidence of lamprey scars on anadromous Dolly Varden returning to the Babbage River, Yukon in 1991 and 1992 was about 1% (i.e., 32 of 3541; 26 of 2323) (Sandstrom et al. 1997). Scarred anadromous juveniles and adults ranged in fork length from 225 to 602 mm (Sparling and Stewart 1986; Sandstrom et al. 1994, 1997).

Seals, such as the ringed seal (*Pusa hispida*), may be a significant predator of Dolly Varden in estuaries and coastal waters, although the fish are seldom found in seal stomach contents. The incidence of seal scars on anadromous fish that were sampled as they returned to the Big Fish River was 4% (4 of 105) in the fall of 1986 (Sparling and Stewart 1986), and 6% (92 of 1475) in the fall of 1991 (Sandstrom et al. 1997). The injured fish ranged in fork length from 395 to 600 mm (Sparling and Stewart 1986; Sandstrom et al. 1997).

Beluga whales (*Delphinapterus leucas*) occasionally consume Dolly Varden (Seaman et al. 1982). While captured belugas often have empty stomachs, one taken in western Alaska had eaten 11 Dolly Varden ranging in fork length up to 500 mm.

Human harvesters are a very significant predator of the Dolly Varden. Not only are these fish sought after for food, they are also predictably available in confined areas, including the spring-fed areas where they spawn and overwinter, the small rivers travelled in spring and fall by anadromous migrants, and shallow nearshore coastal waters. The anadromous fish, which grow to a larger average size, are most sought after by harvesters. These fish can be vulnerable to harvest at numerous locations, both in fresh water and along the coast by mixed-stock fisheries. Past harvesting has likely depleted the Dolly Varden stock in the Rat River, and careful management is required to restore this stock and avoid over-exploitation of it and other stocks in future (DFO 2001, 2003a, 2003b, 2003c).

2.2 PREY

Dolly Varden feed opportunistically on a wide variety of freshwater and marine invertebrates and fishes, and on terrestrial insects that fall into the water (McCart 1980). Plant material and detritus are also common in the stomachs of Dolly Varden in freshwater and at sea. These materials, and minute invertebrates such as water mites (Cl. Arachnida), are likely ingested accidentally while foraging for other bottom-dwelling taxa. They probably contribute little to the diet except possibly in very unproductive waters.

Predation pressure by Dolly Varden in fresh water may be temperature-related. In laboratory studies of Japanese Dolly Varden, their feeding rates on caddisfly larvae (*Glossosoma* sp.) were low at 3°C which coincided with the mean winter stream temperature, and low above 18°C which was near the maximum summer temperature (Kishi et al. 2005). Feeding rates were high at 12°C. Top-down effects on the abundance of caddisfly larvae were only evident at this intermediate temperature. This suggests that thermal habitat alteration, which could result from climatic warming, could change the food web structure of stream communities inhabited by Dolly Varden via combinations of direct and indirect trophic effects.

2.2.1 Young-of-the-year

Young-of-the-year typically remain in the vicinity of their natal springs during their first summer (Glova and McCart 1974; Craig 1978; Armstrong and Morrow 1980; McCart 1980), and are relatively inactive except when feeding (Armstrong and Morrow 1980). Their growth rate increases significantly with the switch to exogenous feeding in the spring, peaking in summer (July and August) and slowing again in the fall (September) (Radtke et al. 1996). Major foods for newly emerged alevins are the several developmental stages of midges and mayflies, as well as other insects and various small crustaceans that are captured on or near the bottom (Appendix 1; Jessop et al. 1973; Glova and McCart 1974; Craig 1977a; Armstrong and Morrow 1980).

The diet of fry collected from the Firth River, Yukon (42 to 71 mm; Glova and McCart 1974) and Canning River system of Alaska (34 to 70 mm; Craig 1977a) was similar to that of older stream-dwelling fish, but the fry fed on fewer taxa and smaller individuals. Their diet consisted of immature stages of **benthic** aquatic invertebrates, mostly Diptera larvae (especially chironomids and tipulids), and Plecoptera and Ephemeroptera nymphs. Few fish had empty stomachs (4 of 127; Glova and McCart 1974; Craig 1977a).

One of the reasons that fry and small juveniles often remain in the vicinity of their natal springs may be the richer food supply offered by these habitats (Bain 1974; Ward and Craig 1974; Craig 1978). The CS-10 spring channel on Alaska's Canning River system, for example, supports 1,279 to 6,642 organisms/m², whereas the braided channels of the Marsh Fork of the Canning River only support 3 to 1,077 organisms/m² — predominately chironomid larvae and Ephemeroptera nymphs (Ward and Craig 1974; Craig 1978). The stabilizing influence of spring water inflows may account for the relatively high density of benthic organisms there. Similar mechanisms may influence the abundance of invertebrates in Fish Hole Creek and the main channel of the upper Babbage River (Bain 1974).

2.2.2 Small juveniles (pre-smolts)

In streams, small pre-smolt Dolly Varden, feed mostly on aquatic insect larvae, particularly midges (Chironomidae), caddisflies (Trichoptera), and stoneflies

(Plecoptera) (Appendix 1; McCart et al. 1972; Bain 1974; Glova and McCart 1974; Craig 1977a,b; Stevens and Deschermeier 1986). They also eat the adults of these and other insects that fall into the streams. Pre-smolt juveniles can range in fork length from about 70 to 204 mm (Bain 1974).

In the Babbage River, Yukon (Bain 1974) and in the Canning, Hulahula, Aichilik, and Kongakut rivers on the Alaskan North Slope (AEL file data cited in McCart 1980; Stevens and Deschermeier 1986), chironomid larvae were found in the majority of fish stomachs that contained food. Ephemeroptera and Plecoptera nymphs, and Simuliidae and Tipulidae were also common dietary items. Fewer fish had eaten terrestrial insects, nematodes, amphipods, fish, or fish eggs. Juveniles as small as 118 mm FL and 10 g had eaten fish, likely young-of-the-year Arctic Grayling (*Thymallus arcticus*) (Stevens and Deschermeier 1986). In the Babbage and Canning river systems, the juveniles tended to eat smaller food organisms, fewer adult and terrestrial insects, and fewer fish and fish eggs than did the larger riverine-residual males (Bain 1974; AEL file data cited in McCart 1980). A number of taxa that occurred in benthic samples from these two rivers were not found in the diet, including Amphipoda, Hydracarina, Oligochaeta, and Tricladida (McCart 1980).

Parasitism of juvenile southern-form Dolly Varden by the nematode *Philonema agubernaculum* reduced the fish's ability to capture salmon fry in the laboratory (Moles 2003). The introduction of this or other parasites into stocks where they are not already present could alter predator-prey interactions and thereby stock health.

2.2.3 Large anadromous juveniles (smolts)

The age and length at **smoltification** varies. Some juvenile Dolly Varden migrate to sea for the first time at age 1, most at age 2 to 4, and some at age 5 (McCart et al. 1972; Yoshihara 1973; Bain 1974; Griffiths et al. 1975; Craig 1977a; McCart 1980; Craig and Haldorson 1981; Gillman and Sparling 1985; Bond and Erickson 1987, 1989; DeCicco 1991; Underwood et al. 1996; Sandstrom and Harwood 2002). They range in fork length from 90 mm (Griffiths et al. 1975) to about 443 mm (Sandstrom et al. 2001). Juveniles that have migrated to sea are typically about twice the length of stream-residents the same age (McCart et al. 1972; Glova and McCart 1974). Because of their growth spurt following smoltification the anadromous fish spend a relatively short time in the intermediate size classes (Craig 1977a).

Most growth by anadromous Dolly Varden smolts (140 to 260 mm FL) occurs during the short summer season (Craig 1984; Underwood et al. 1996; Fechhelm et al. 1997). The fish feed heavily on mysids and amphipods (e.g., *Diaporeia affinis=Pontoporeia affinis, Onisimus* spp., *Gammaracanthus loricatus*) in the coastal waters, which are very productive relative to the freshwater habitats where they overwinter (Appendix 2). Midge larvae, polychaete worms, isopods and euphasids are also eaten (Fechhelm et al. 1997).

Growth rates of smolts in the Prudhoe Bay region of Alaska peaked in mid-summer, and were lower earlier and later in the season (Fechhelm et al. 1997). This was in contrast to the quick early summer growth reported for juvenile Broad Whitefish (*Coregonus nasus*) and Arctic Cisco (*C. autumnalis*) in the region (Fechhelm et al. 1992; Griffiths et al. 1992).

The diet of anadromous Dolly Varden in Nunaluk Lagoon, on the Yukon coast at the mouth of the Firth River, changed as the fish grew (Figure 3; Appendix 2; Griffiths et al. 1975). Small fish (≤300 mm FL) that were caught exclusively in the lagoon or delta regions, ate mostly insect larvae and pupae — particularly chiromonid larvae, and some fish and crustaceans. Crustaceans, particularly amphipods and small epibenthic isopods, were important foods for Dolly Varden of intermediate size (300 to 500 mm FL) during their transition to piscivory. As they grew, the proportion of crustaceans in their diet declined while the proportion of fish increased, such that the largest Dolly Varden (>500 mm) ate almost exclusively fish, mostly Fourhorn Sculpin (*Myoxocephalus quadricornis*).

Bain (1974) found that 81.7% of the juvenile Dolly Varden captured in October at the Babbage River overwintering site had empty stomachs. Chironomid larvae were the most common item in the stomachs of juveniles that had eaten.

The dietary changes that accompany smoltification are evident in the stable isotope signatures of anadromous Dolly Varden (Kline et al. 1998). The carbon-13 and nitrogen-15 signatures in muscle tissue of fish from Alaska's Sagavanirktok River Delta varied in response to size-related changes in diet. Smaller individuals (250 to 300 mm FL) fed at a broader range of trophic levels than larger fish (>300 mm), and used a broader range of feeding niches. Some smaller individuals fed entirely on freshwater or marine biota, others on a mixture of both. They ranged in trophic level from 3 to 5, whereas the large fish were mostly level 5 or high level 4 — a higher number indicates predation on food items that are higher in the food chain.

2.2.4 Adults

Along the North Slope of Alaska, the food resources accessible to fish in spring-fed streams ($0.1x10^7$ g) are very small relative to those in coastal waters ($180x10^7$ g wet wt) (Craig 1989). Fish food in these streams consists almost entirely of **benthos** with a small amount of drift, whereas in coastal environments it consists of **epibenthos** such as mysids and amphipods. The accessible foods in these environments are similar, 0.9 g/m^2 for spring-streams and 1.2 g/m^2 for coastal waters, but the habitat surface area of the spring streams (1 km²) is tiny compared to that of the coastal waters (1,500 km²). Other stream types (i.e., tundra, coastal plain, mountain) have less accessible food per unit area (0.1 to 0.24 g/m²) but intermediate surface areas (126 to 966 km²).

2.2.4.1 *Stream-resident (isolated)*: Isolated, stream-resident, juvenile and adult Dolly Varden in the Yukon's upper Babbage River (Bain 1974) and in Alaska's Canning River system ate mostly immature stages of benthic aquatic insects (McCart and Craig 1973 — Shubilik Spring, ~50 to 235 mm FL, n = 123; McCart and Craig 1973 — unnamed spring, ~54 to 164 mm FL, n = 81; Craig 1977b — Saderochit Spring, ~80 to 210 mm FL, n = 58). Trichopteran and chironomid larvae and plecopteran and ephemeropteran nymphs were the taxa found most frequently in the stomachs examined. Amphipods and terrestrial insects were also eaten but the latter were apparently absent from fish captured in Shubilik Spring. Fish remains were found in several of the upper Babbage River Dolly Varden (Bain 1974). Most of the fish from these four populations had food in their stomachs at capture (i.e., 91% or 368 of 405) (McCart and Craig 1973; Bain 1974; Craig 1977b). They were sampled between March and November.

2.2.4.2 *Riverine (residual)*: Residual males that remain in rivers despite having access to the sea eat mostly insects, fish, and fish eggs (Bain 1974; McCart 1980). As adults, these fish range in size from about 128 to 395 mm (Bain 1974). A majority (66%, 99 of 150) of those sampled from the Babbage River, Yukon in May to September (Bain 1974), and from the Canning River, Alaska (AEL file data cited in McCart 1980) had food in their stomachs. Chironomid larvae, small fish, fish eggs, Trichoptera and Plecoptera were the taxa found most frequently. Terrestrial insects from surface drift were also common in the diet, and some Ephemeroptera, Simuliidae and Tipulidae were eaten. A number of taxa that occurred in benthic samples were not found in the stomachs, including Amphipoda, Hydracarina, Nematoda, Oligochaeta, and Tricladida (McCart 1980). The residual fish were larger than the pre-smolt juveniles that shared the streams, and ate more large food organisms. The high proportion of eggs in the diet of residual Dolly Varden in the upper Babbage River was likely an artefact of sampling during the species' spawning period (Bain 1974).

2.2.4.3 *Anadromous*: Once they have migrated to sea, anadromous fish appear to feed mostly in the marine environment. During the short summer season at sea, they must accumulate the energy reserves necessary for growth, reproduction, migration, and winter survival (Craig 1989). As adults, anadromous Dolly Varden can range in fork length from about 347 mm (Bain 1974) to 720 mm (Glova and McCart 1974). The condition of upstream anadromous migrants reflects the quality and availability of food in the ocean (Harwood 2001). The time these fish spend feeding at sea depends largely on when river break-up occurs, since the timing of upstream migrations is quite consistent from year-to-year (Sandstrom 1995). The earlier the migration, the more food energy they can accumulate before returning to fresh water to spawn and overwinter. Early break-up in the spring of 1988, for example, may have resulted in particularly favourable feeding conditions in coastal waters that summer (Harwood 2001). Current-year spawners typically return upstream earlier in the fall than non-spawners and consequently have less opportunity in a spawning year to replenish their fat stores (Glova and McCart 1974; Griffiths et al. 1975; McCart 1980; Sandstrom 1995; Reist et al. 2001).

Anadromous Dolly Varden using coastal waters of the Beaufort Sea feed primarily on amphipods (e.g., *Gammarus setosus*), mysids, and fish (Appendix 2; Yoshihara 1973; Furniss 1975; Griffiths et al. 1975, 1977; Kendel et al. 1975; Bendock 1977; Craig 1977a; Craig and Griffiths 1978 cited in McCart 1980; McCart 1980; Craig and Haldorson 1981; West and Wiswar 1984; Bond and Erickson 1987; Knutzen and Jewett 1988). These taxa typically constitute the majority of the stomach contents regardless of whether the stomach analysis measured frequency of occurrence, volume, or wet weight (Appendix 4). The invertebrate prey species are typically found on or near the surface of the substrate, seldom in the **infaunal** benthos (McCart 1980). In areas where there is a strong freshwater influence, such as Nunaluk Lagoon, Yukon, insects are also eaten, especially chironomid larvae (Griffiths et al. 1975; McCart 1980). Whether these insects are taken as drift, or by fish moving into fresh water to feed, is unknown.

As anadromous Dolly Varden grow larger, they prey upon larger items and the proportion of fish in their diet increases. In Nunaluk Lagoon, Yukon, fish <300 mm in FL ate mostly chironomid larvae and some crustaceans, fish, and other taxa (Figure 3; Appendix 3; Griffiths et al. 1975; McCart 1980). Fish in the intermediate length classes, 301 to 500 mm FL, ate more amphipods and fish and fewer chironomids, and fish >500 mm FL ate predominately fish. These dietary differences likely reflect size-related differences in both foraging habitats and in the ability to capture and handle larger prey. The smaller fish tended to remain closer to the river outlet than the larger fish (Griffiths et al. 1975). Similar dietary differences have been observed between small (≤350 mm FL) and large (≥350 mm) Dolly Varden in the Prudhoe Bay area of Alaska (Knutzen and Jewett 1988).

While in coastal waters of the Beaufort Sea, anadromous Dolly Varden eat a variety of fish species including, Arctic Cisco, Least Cisco (*C. sardinella*), Arctic Cod (*Boreogadus saida*), Arctic Lamprey, Dolly Varden, Fourhorn Sculpin, Arctic Grayling, Ninespine Stickleback (*Pungitius pungitius*), Stout Eelblenny (*Anisarchus medius*), whitefish (*Coregonus* sp.), and eelpout (F. Zoarcidae) (Furniss 1975; Bendock 1977; Griffiths et al. 1975, 1977; Kendel et al. 1975; Craig 1977a; McCart 1980; West and Wiswar 1984). They feed voraciously when suitable prey is available. Indeed, Craig

(1977a) captured a female Dolly Varden (476 mm FL) with 62 Arctic Cod, ranging from 37 to 85 mm, crammed into her stomach.

Despite the richness of the marine feeding environment relative to that of their freshwater habitats, a significant proportion of the anadromous Dolly Varden captured in coastal waters have empty stomachs (Yoshihara 1973, 31%; Furniss 1975, 27%; Griffiths et al. 1975, 33%; Kendel et al. 1975, 49%; Bendock 1977, 44%; Bond and Erickson 1987, 32%). On Amchitka Island, Alaska, the proportion of southern-form Dolly Varden that had fed before capture decreased with size (Palmisano and Helm 1971).

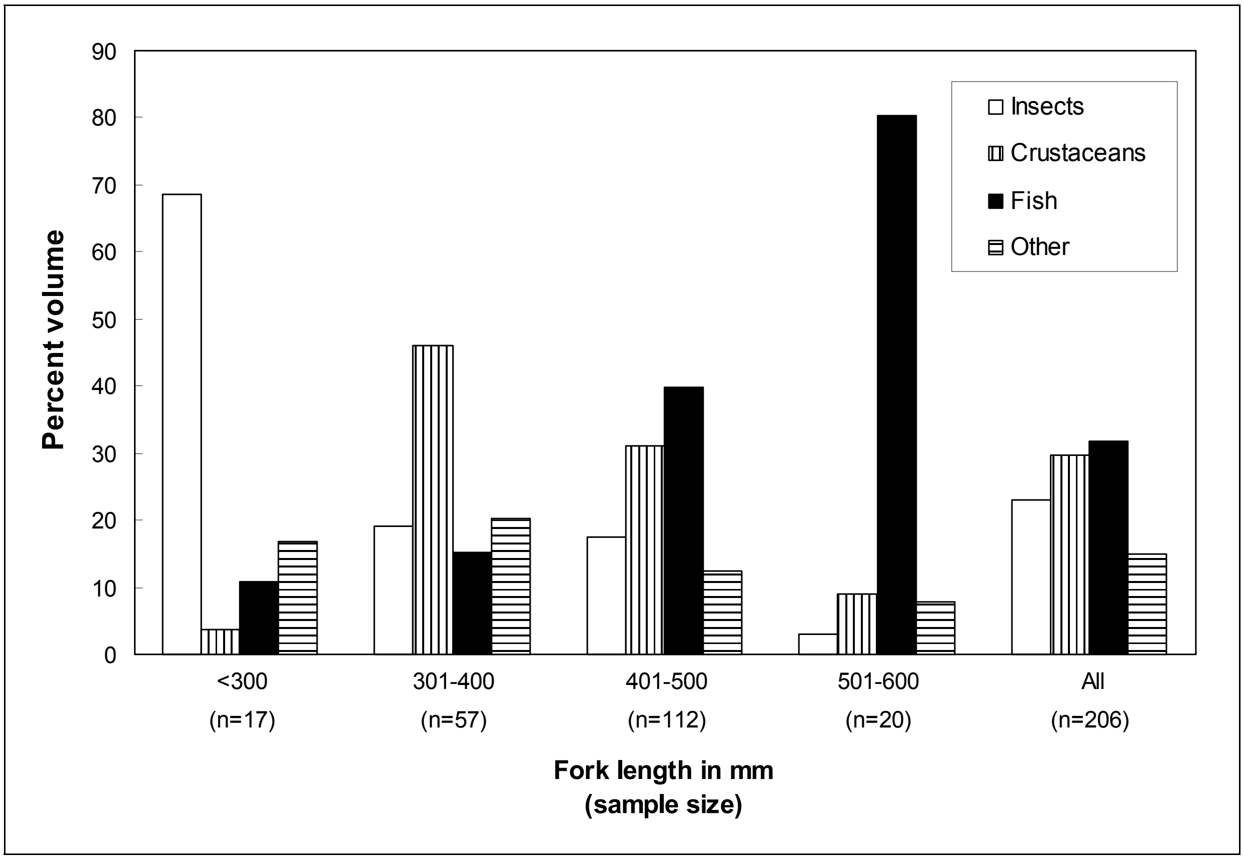

Figure 3. Comparison of the percent volumes of major food groups in the stomachs of anadromous Dolly Varden of different size ranges from Nunaluk Lagoon, Yukon (Data from Griffiths et al. 1975).

During the upstream migration and during the spawning and overwintering period anadromous Dolly Varden feed very little (Appendix 3). When they are caught after returning to freshwater in the fall, anadromous Dolly Varden often have empty stomachs (McCart et al. 1972; Stein et al. 1973b; Bain 1974; Glova and McCart 1975; Craig 1977a,c; McCart 1980; Sparling and Stewart 1986). Of 2,260 anadromous fish sampled from freshwater systems along the North Slope of Canada and Alaska, 79% had empty stomachs (McCart 1980). This proportion increased to over 95% in late winter (May). In contrast, only 18% of the 1,816 non-anadromous juvenile and residual fish sampled had empty stomachs when captured. In freshwater, chironomid larvae, unidentified insects, plant material, and fish remains were the most frequently-occurring items in the anadromous fish that had eaten before capture (Appendix 4; McCart 1980). Their diet occasionally included smaller Dolly Varden and Dolly Varden eggs (McCart et al. 1972; Jessop et al. 1973; Bain 1974; Stephenson 2003). Of 346 Dolly Varden harvested in the fall at the spawning sites on the Big Fish River, only two contained food (Stephenson 2003). One had eaten a smaller Dolly Varden and the other 23 fish eggs. In the Rat River, NT, spawning adults fed mostly on fish, including members of their own species, while few (8.8%) of the non-spawning adults and juveniles had fed, and those that had contained insects (Jessop et al. 1973).

2.3 COMPETITORS

Competition is an important determinant of the structure of salmonid communities (Andrew et al. 1992). Detailed studies have been conducted on the interactions of southern-form Dolly Varden, with other salmonids, but no similar studies were found for the northern form. The applicability of data from these studies to northern form populations is uncertain but they serve to illustrate ecological changes that can occur.

During the summer, **allopatric** populations of southern-form Dolly Varden in coastal lakes of British Columbia used all habitats (i.e., littoral, epipelagic, pelagic, epibenthic) and exhibited generalist feeding behaviours, opportunistically using different habitats as prey abundance shifted between sampling periods (Andrusak 1968; Andrusak and Northcote 1971; Andrew 1985; Andrew et al. 1992). In sympatry with Cutthroat Trout (*Oncorhynchus clarkii*), which in allopatry occupy surface habitats, the Dolly Varden shifted to deeper pelagic and epibenthic habitats not occupied by trout. The Cutthroat Trout fed on surface and planktonic prey, while the Dolly Varden fed primarily upon benthic prey (Andrusak and Northcote 1971). When Dolly Varden from populations in sympatry with Cutthroat Trout were stocked into fishless lakes, they initially became highly planktivorous and later ate mainly benthic organisms (Hume and Northcote 1985). Over the next 8 years, they significantly increased their utilization of shallow-dwelling zoobenthos and increased their vertical distribution relative to that in sympatry (Hindar et al. 1988). These shifts suggest that there is competition for habitat resources between the species, and that the effect of this competition is greater on the Dolly Varden.

Laboratory experiments found the trout to be more aggressive under higher light levels, similar to those found in surface waters, than at low light levels (Andrew 1985; Andrew et al. 1992). At higher light levels they also reacted sooner to prey and swam faster than the Dolly Varden, which reacted sooner at low light levels (Henderson and Northcote 1985). Dolly Varden were more successful capturing benthic prey at low light intensities (Schutz and Northcote 1972). Spatial and dietary segregation of **sympatric** populations weakens during the winter (Rempel and Northcote 1989).

The overall distribution of northern-form Dolly Varden likely reflects their ability to colonize marginal, recently-deglaciated streams. In southeastern Alaska, anadromous southern-form Dolly Varden have typically been the first salmonids to colonize recently deglaciated streams (Milner and Bailey 1989; Milner et al. 2000). The extent to which the ability of Dolly Varden to colonize new habitats is related to their diet and foraging ability is unknown. In southeastern Alaska, they are the dominant fish species in moderate- (mean gradient = 5.5%) and high-gradient (mean gradient = 12.9%) stream zones (Bryant et al. 2004). Coho Salmon (*Oncorhynchus kisutch*) are the dominant species in the low-gradient zones (mean gradient = 3.1%), but are also present in higher gradient zones. Coho Salmon have been reported from the North Slope (Craig and Haldorson 1986; Babaluk et al. 2000). If their numbers increase they may compete successfully with Dolly Varden for low-gradient stream habitat.

Differences in their summer growth patterns suggest that Dolly Varden smolts from the Beaufort Sea have adapted a life history strategy that minimizes competition with juveniles of the two other most abundant anadromous species in this region, Arctic Cisco and Broad Whitefish (Fechhelm et al. 1997). The minimal overlap of Dolly Varden and Arctic Char (*Salvelinus alpinus*) distributions in northern Canada (Sawatzky et al. 2007) suggests that northern-form Dolly Varden effectively exclude Arctic Char from North Slope streams, while the char do the same for Dolly Varden in lower-gradient tundra streams and lakes. The two species do occur together in the Becharof Lake drainage of western Alaska, where the Dolly Varden frequents stream habitats and the Arctic Char lacustrine habitats (Scanlon 2000).

Bull Trout might expand their range northward in the Mackenzie River watershed in response to climatic warming (Reist 1994; Mochnacz 2002; Stewart et al. 2007). Their impact on northern-form Dolly Varden populations, should they become sympatric, is uncertain. Juvenile southern-form Dolly Varden that are sympatric with Bull Trout in the Thutade Lake watershed of British Columbia, showed extensive dietary overlap (Hagen and Taylor 2001). However, the Dolly Varden occupied deeper, faster water and foraged more during the daytime in the drift than did the Bull Trout, which used shallower, slower water and made more night-time foraging attempts towards the substrate. Bull Trout have a larger gape and consumed relatively larger prey than Dolly Varden of the same size, which ate a higher proportion of adult winged insects. Both species make extensive use of groundwater inflows for spawning and overwintering.

3.0 SUMMARY

Dolly Varden prey on a variety of aquatic invertebrates and fishes and will eat terrestrial invertebrates when the opportunity presents. They forage near the surface of the substrate and seldom feed on infaunal benthos or on midwater or surface taxa. Their selection of food items appears to be related to availability, size, and ease of capture of a particular food item. Small fish eat small organisms, predominately immature stages of aquatic insects. Prey size and the proportion of fish in the diet increases as the Dolly Varden grow larger. Plant material and detritus are consumed but likely have little food value.

Anadromous Dolly Varden do not feed extensively in fresh water. In coastal waters they feed mostly on amphipods, mysids and fish, although insects — predominately chironomid larvae, are eaten in areas strongly influenced by fresh water. The diet of anadromous fish in fresh water is similar to that of juveniles and residuals that remain there year-round, except that a higher proportion of the anadromous fish caught have empty stomachs.

Dolly Varden are very vulnerable to predation by humans and other species because they are predictably available in confined areas, including the spring-fed areas of streams where they spawn and overwinter, the small rivers travelled in spring and fall by anadromous migrants, and shallow nearshore coastal waters. Humans are a key predator on adult and large juvenile anadromous Dolly Varden. These valued food fish can be vulnerable to harvest at numerous locations, both in fresh water and along the coast by mixed stock fisheries. Piscivorous fishes, including larger Dolly Varden, may be the key predators on smaller juveniles and eggs. The ability of northern-form Dolly Varden to withstand competition from other species is not well understood.

4.0 ACKNOWLEDGEMENTS

This work is a result of the Sensitive Fish Species Project of the Northern Energy Development Research Program at Fisheries and Oceans Canada. The work was funded through a Government of Canada interdepartmental initiative to fund research in the Mackenzie River Valley and Beaufort Sea areas. This interdepartmental initiative is led by Indian and Northern Affairs Canada. Marge Dyck, Kerry Macdonald, and Jane Martin at the Eric Marshall Aquatic Research Library assisted with gathering literature for this review. Nathan Millar of the Yukon Department of the Environment and Cecile Stewart of Arctic Biological Consultants reviewed the manuscript. Donna Laroque of DFO Winnipeg assisted with publication. Their contributions improved this report and we thank them.

5.0 REFERENCES

Andrew, J.H. 1985. Habitat shifts and behavioural interactions between sympatric and experimentally allopatric cutthroat trout and Dolly Varden char. M.Sc. Thesis, University of British Columbia, Vancouver, B.C. vii + 114 p.

Andrew, J.H., Jonsson, N., Jonsson, B., Hindar, K., and Northcote, T.G. 1992. Changes in use of lake habitat by experimentally segregated populations of cutthroat trout and Dolly Varden. Ecography **14**: 245-252.

Andrusak, H. 1968. Interactive segregation between Dolly Varden (*Salvelinus malma*) and cutthroat trout (*Salmo clarki*) in small coastal British Columbia lakes. M.Sc. Thesis, University of British Columbia, Vancouver, B.C. viii + 76 pp.

Andrusak, H., and Northcote, T.G. 1971. Segregation between adult cutthroat trout (*Salmo clarki*) and Dolly Varden (*Salvelinus malma*) in small coastal British Columbia lakes. J. Fish. Res. Board Can. **28**: 1259-1268.

Armstrong, R.H., and Morrow, J.E. 1980. The Dolly Varden charr, *Salvelinus malma*. *In* Charrs: Salmonid fishes of the genus *Salvelinus*. *Edited by* E.K. Balon. Dr. W. Junk bv Publishers, The Hague, Netherlands. pp. 99-140.

Ayles, B., Bell, R., and Hoyt, A. 2007. Adaptive fisheries co-management in the Western Arctic. *In* Adaptive co-management: Collaboration, learning, and multi-level governance. *Edited by* D. Armitage, F. Berkes, and N. Doubleday. UBC Press, Vancouver, B.C. pp. 125-150.

Babaluk, J.A., and Reist, J.D. 1996. The use of strontium distribution in Dolly Varden and Arctic char otoliths from Ivvavik National Park for determining life history and stock differences. Unpublished report prepared for Parks Canada by Department of Fisheries and Oceans, Winnipeg, MB. 32 p.

Babaluk, J.A., Reist, J.D., Johnson, J.D., and Johnson, L. 2000. First records of sockeye (*Onchorhynchus nerka*) and pink salmon (*O. gorbuscha*) from Banks Island and other records of Pacific salmon in Northwest Territories, Canada. Arctic **53**(2): 161-164.

Bain, L.H. 1974. Life histories and systematics of arctic char (*Salvelinus alpinus*, L.) in the Babbage River system, Yukon Territory. Canadian Arctic Gas Study Limited (Calgary), Biological Report Series **18**(Chapter I): xvi + 156 p.

Bendock, T.N. 1977. Beaufort Sea estuarine fishery study. Alaska Department of Fish and Game, Sport Fish Division, Fairbanks, Alaska. pp. 670-729 [Contract # 03-5-022-69].

Bond, W.A., and Erickson, R.N. 1987. Fishery data from Phillips Bay, Yukon, 1985. Can. Data Rep. Fish. Aquat. Sci. **635**: v + 39 p.

Bond, W.A., and Erickson, R.N. 1989. Summer studies of the nearshore fish community at Phillips Bay, Beaufort Sea coast, Yukon. Can. Tech. Rep. Fish. Aquat. Sci. **1676**: vi + 102 p.

Borgeson, D.P. 1963. A rapid method for food-habitat studies. Trans. Am. Fish. Soc. **92**: 434-435.

Bryan, J.E., Walker, C.E., Kendel, R.E., and Elson, M.S. 1973. Freshwater aquatic ecology in northern Yukon Territory, 1971. Environmental-social Committee, Northern Pipelines, Task force on Northern Oil Development Report No. **73-21**: vii + 64 p.

Bryant, M.D., Zymonas, N.D., and Wright, B.E. 2004. Salmonids on the fringe: abundance, species composition, and habitat use of salmonids in high-gradient headwater streams, southeast Alaska. Trans. Am. Fish. Soc. **133**: 1529-1538.

Cosens, S., and Dueck, L.[Chairpersons] 2001. Proceedings of the RAP meeting on Rat River Dolly Varden. Canadian Science Advisory Secretariat, Proceedings Series **2001/26**: 16 p.

Craig, P., and Haldorson, L. 1986. Pacific salmon in the North American Arctic. Arctic **39**: 2-7.

Craig, P.C. 1977a. Ecological studies of anadromous and resident populations of Arctic char in the Canning River drainage and adjacent coastal waters of the Beaufort Sea, Alaska. Arctic Gas Biological Report Series **41**(Chapter 1): xi + 116 p.

Craig, P.C. 1977b. Arctic char in Sadlerochit Spring, Arctic National Wildlife Range. Arctic Gas Biological Report Series **41**(Chapter 2): vi + 29 p.

Craig, P.C. 1977c. Fisheries investigations in the Shaviovik River drainage, Alaska, with emphasis on Arctic char in the Kavik River. Arctic Gas Biological Report Series **41**(Chapter 3): vi + 28 p.

Craig, P.C. 1978. Movements of stream-resident and anadromous Arctic char (*Salvelinus alpinus*) in a perennial spring on the Canning River, Alaska. J. Fish. Res. Board Can. **35**(1): 48-52.

Craig, P.C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Trans. Am. Fish. Soc. **113**: 265-282.

Craig, P.C. 1989. An introduction to anadromous fishes in the Alaskan Arctic. Biol. Pap. Univ. Alsk. **24**: 27-54.

Craig, P.C., and Griffiths, W. 1978. Beaufort Sea barrier island-lagoon ecological process studies. III. Ecology of fishes in Simpson Lagoon, 1977. *In* Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators. National Oceanic and Atmospheric Administration, Boulder, Colorado. Volume. **7**: 587-664.

Craig, P.C., and Haldorson, L. 1981. Beaufort Sea barrier island-lagoon ecological process studies: final report, Simpson Lagoon, Part 4. Fish. *In* Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators, Bureau of Land Management/National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Boulder, Colorado. Volume. **7**: 384-678.

DeCicco, A.L. 1991. Life history of anadromous Dolly Varden (*Salvelinus malma*) in north-western Alaska. *In* Proceedings of the Sixth ISACF workshop on Arctic char, 1990. *Edited by* J. Hammar. International Society of Arctic Char Fanatics, Information Series **5**. pp. 45-123.

de Graaf, D., and Machniak, K. 1977. Fisheries investigations along the Cross Delta Pipeline Route in the Mackenzie Delta. Arctic Gas, Biological Report Series **39**(Chapter IV): 109 p.

DFO (Canada. Department of Fisheries and Oceans) 2001. Rat River Dolly Varden. DFO Science, Stock Status Report **D5-61**: 15 p.

DFO (Canada. Department of Fisheries and Oceans) 2003a. Big Fish River Dolly Varden. DFO Science, Stock Status Report **D5-60**: 15 p.

DFO (Canada. Department of Fisheries and Oceans) 2003b. Babbage River Dolly Varden. DFO Science, Stock Status Report **D5-62**: 12 p.

DFO (Canada. Department of Fisheries and Oceans) 2003c. Firth River Dolly Varden. DFO Science, Stock Status Report **D5-63**: 12 p.

Dolloff, C.A. 1993. Predation by river otters (*Lutra canadensis*) on juvenile coho salmon (*Oncorhynchus kisutch*) and Dolly Varden (*Salvelinus malma*) in southeast Alaska. Can. J. Fish. Aquat. Sci. **50**: 312-315.

Fechhelm, R.G., Bryan, J.D., Griffiths, W.B., and Martin, L.R. 1997. Summer growth patterns of northern Dolly Varden (*Salvelinus malma*) smolts from the Prudhoe Bay region of Alaska. Can. J. Fish. Aquat. Sci. **54**: 1103-1110.

Furniss, R.A. 1975. Inventory and cataloguing of Arctic area waters. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1974-1975. Project F-9-7, Job G-II, Volume **16**: 47 p.

Gillman, D.V., and Sparling, P.D. 1985. Biological data on Arctic charr, *Salvelinus alpinus* (L.), from the Rat River, Northwest Territories, 1983. Can. Data Rep. Fish. Aquat. Sci. **535**: iv + 15 p.

Glova, G., and McCart, P.J. 1974. Life history of Arctic char (*Salvelinus alpinus*) in the Firth River, Yukon Territory. Canadian Arctic Gas Study Limited; Alaskan Arctic Gas Study Company. Biological report series no. **20**(Chapter 3): viii + 50 p.

Griffiths, W.B., Craig, P., Walder, G., and Mann, G. 1975. Fisheries investigations in a coastal region of the Beaufort Sea (Nunaluk Lagoon, Yukon Territory). Arctic Gas, Biological Report Series **34**(Chapter II): xvii + 219 p.

Griffiths, W.B., Den Beste, J.K., and Craig, P.C. 1977. Fisheries investigations in a coastal region of the Beaufort Sea (Katovik Lagoon, Alaska). Arctic Gas Biological Report Series **41**(Chapter 2): xiii + 190 p.

Griffiths, W.B., Gallaway, B.J., Gazey, W.J., and Dillinger, R.E.Jr. 1992. Growth and condition of Arctic cisco and broad whitefish as indicators of causeway-induced effects in the Prudhoe Bay region, Alaska. Trans. Am. Fish. Soc. **121**: 557-577.

Gwich'in Elders 1997. Gwich'in words about the land. Gwich'in Renewable Resource Board, Inuvik, NT. 212 p.

Hagen, J., and Taylor, E.B. 2001. Resource partitioning as a factor limiting gene flow in hybridizing populations of Dolly Varden char (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*). Can. J. Fish. Aquat. Sci. **58**: 2037-2047.

Harwood, L.A. 2001. Status of anadromous Dolly Varden (*Salvelinus malma*) of the Rat River, Northwest Territories, as assessed through a community-based sampling of the subsistence fishery, August-September 1989-2000. Canadian Science Advisory Secretariat (CSAS) Research Document **2001/090**: 30 p.

Henderson, M.A., and Northcote, T.G. 1985. Visual prey detection and foraging in sympatric cutthroat trout (*Salmo clarki clarki*) and Dolly Varden (*Salvelinus malma*). Can. J. Fish. Aquat. Sci. **42**: 785-790.

Hindar, K., Jonsson, B., Andrew, J.H., and Northcote, T.G. 1988. Resource utilization of sympatric and experimentally allopatric cutthroat trout and Dolly Varden charr. Oecologia **74**: 481-491.

Hume, J.M.B., and Northcote, T.G. 1985. Initial changes in use of space and food by experimentally segregated populations of Dolly Varden (*Salvelinus malma*) and cutthroat trout (*Salmo clarki*). Can. J. Fish. Aquat. Sci. **42**: 101-109.

Hynes, B.N. 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food fishes. J. Anim. Ecol. **19**(1): 36-58.

Jessop, C.S., Porter, T.R., Blouw, M., and Sopuck, R. 1973. Fish resources of the Mackenzie River valley. Special report: An intensive study of the fish resources of two main stem tributaries. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development Rep. **Special Report**: xiv + 148 p.

Jessop, C.S., Chang-Kue, K.T.J., Lilley, J.W., and Percy, R.J. 1974. A further evaluation of the fish resources of the Mackenzie River valley as related to pipeline development. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development Rep. **74-7**: xii + 94 p.

Kendel, R.E., Johnston, R.A.C., Lobsiger, U., and Kozak, M.D. 1975. Fishes of the Yukon coast. Beaufort Sea Project, Technical Report **6**: xi + 114 p.

Kishi, D., Murakami, M., Nakano, S., and Maekawa, K. 2005. Water temperature determines strength of top-down control in a stream food web. Freshwater Biol. **50**: 1315-1322.

Kitano, S. 1996. Size-related factors causing individual variation in seasonal reproductive success of fluvial male Dolly Varden (*Salvelinus malma*). Ecol. Freshw. Fish **5**: 59-67.

Kline, T.C.Jr., Wilson, W.J., and Goering, J.J. 1998. Natural isotope indicators of fish migration at Prudhoe Bay, Alaska. Can. J. Fish. Aquat. Sci. **55**: 1494-1502.

Knutzen, J.A., and Jewett, S.C. 1988. 1987 Endicott Enironmental Monitoring Program, Part IV. Chapter 2. Fish food habits (stomachs). Envirosphere Company, Anchorage, Alaska. iv + 29 p. + appendices [Draft Report].

Mann, G.J., and Tsui, P.T.P. 1977. Fall and early winter aquatic resource inventory Dempster Lateral Pipeline Route, Volume II. Stream and lake catalogue. Aquatic Environments Limited for Foothills Pipe Lines (Yukon) Ltd. v + 188 p. [Available from Eric Marshall Aquatic Research Library, 501 University Crescent, Winnipeg, Manitoba, Canada, R3T 2N6].

McCart, P., and Craig, P. 1973. Life history of two isolated populations of Arctic char (*Salvelinus alpinus*) in spring-fed tributaries of the Canning River, Alaska. J. Fish. Res. Board Can. **30**(8): 1215-1220.

McCart, P., Craig, P., and Bain, H. 1972. Report on fisheries investigations in the Sagavanirtok River and neighboring drainages. Report prepared for the Alyeska Pipeline Service Company. iii + 83 p. + Figures, Tables and References.

McCart, P.J. 1980. A review of the systematics and ecology of Arctic char, *Salvelinus alpinus*, in the western Arctic. Can. Tech. Rep. Fish. Aquat. Sci. **935**: vii + 89 p.

McPhail, J.D. 1961. A systematic study of the *Salvelinus alpinus* complex in North America. J. Fish. Res. Board Can. **18**(5): 793-816.

Milner, A.M., and Bailey, R.G. 1989. Salmonid colonization of new streams in Glacier Bay National Park, Alaska. Aquac. Fish. Manage. **20**: 179-192.

Milner, A.M., Knudsen, E.E., Soiseth, C., Robertson, A.L., Schell, D., Phillips, I.T., and Magnusson, K. 2000. Colonization and development of stream communities across a 200-year gradient in Glacier Bay National Park, Alaska, USA. Can. J. Fish. Aquat. Sci. **57**: 2319-2355.

Mochnacz, N.J. 2002. Bull trout distribution, life history, and habitat requirements in the southern and central Mackenzie River Valley, Northwest Territories. A report submitted to the Habitat Stewardship Program for Species at Risk, Government of Canada [Edmonton, AB]. ii + 52 p.

Mochnacz, N.J., and Reist, J.D. 2007. Biological and habitat data for fish collected during stream surveys in the Sahtu Settlement Region, Northwest Territories, 2006. Can. Data Rep. Fish. Aquat. Sci. **1189**: vii + 40 p.

Moles, A. 2003. Effect of parasitism by *Philonema agubernaculum* (Nematoda: Philometridae) on the ability of Dolly Varden to capture prey in fresh and salt water. Alsk. Fish. Bull. **10**(2): 119-123.

Norton, P. 1997. Proceedings of a workshop to examine the status, conservation and fishing practices, including mesh size, relative to the primary fishery resources of the Inuvialuit and Gwich'in, February 15-17, 1995, Inuvik, N.W.T. Can. Manuscr. Rep. Fish. Aquat. Sci. **2394**: iv + 30 p.

Palmisano, J.J., and Helm, W.T. 1971. Freshwater food habits of *Salvelinus malma* (Walbaum) on Amchitka Island, Alaska. Bioscience **15**: 637-641.

Papik, R., Marschke, M., and Ayles, G.B. 2003. Inuvialuit traditional ecological knowledge of fisheries in rivers west of the Mackenzie River in the Canadian Arctic. Canada/Inuvialuit Fisheries Joint Management Committee Report **2003-4**: v + 20 p.

Radtke, R.L., Fey, D.P., DeCicco, A.F., and Montgomery, A. 1996. Otolith microstructure in young-of-the-year Dolly Varden, *Salvelinus malma*, from American and Asian populations: resolution of comparative life history characteristics. Arctic **49**(2): 162-169.

Reist, J.D. 1994. An overview of the possible effects of climate change on northern freshwater and anadromous fishes. *In* Mackenzie Basin Impact Study (MBIS) Interim Report 2. *Edited by* S.J. Cohen. Environment Canada, Downsview, ON. pp. 377-385.

Reist, J.D., Papst, M.A., and Babaluk, J.A. 2001. Biodiversity, life history and management of the anadromous fish of the western Canadian Arctic. Unpublished report prepared by Fisheries and Oceans Canada, Winnipeg, MB. Draft MS, 76 p.

Reist, J.D., Low, G., Johnson, J.D., and McDowell, D. 2002. Range extension of bull trout, *Salvelinus confluentus*, to the central Northwest Territories, with notes on identification and distribution of Dolly Varden, *Salvelinus malma,* in the western Canadian Arctic. Arctic **55**(1): 70-76.

Rempel, R.S., and Northcote, T.G. 1989. Winter feeding and spatial distribution of lacustrine Dolly Varden charr and cutthroat trout populations. Physiol. Ecol. Jap. Spec. Vol. **1**: 323-336.

Sandstrom, S., Reist, J., and Carder, G. 1994. Summarization of biological data for Dolly Varden char (*Salvelinus malma*) (Walbaum) from the Northwest Territories and Yukon North Slope: 1980 to 1994. Report submitted to Inuvialuit Fisheries Joint Management Committee [Inuvik, NT] for Project 1994-2722-2200 Char Synthesis., 7 parts, variously paginated.

Sandstrom, S.J. 1995. The effect of overwintering site temperature on energy allocation and life history characteristics of anadromous female Dolly Varden char (*Salvelinus malma*), from the Yukon and Northwest Territory North Slope, Canada. M.Sc. Thesis, University of Manitoba, Winnipeg, MB. xii + 161 p.

Sandstrom, S.J., and Harwood, L.A. 2002. Studies of anadromous Dolly Varden (*Salvelinus malma*) (W.) of the Big Fish River, NT, Canada, 1972-1994. Can. Manuscr. Rep. Fish. Aquat. Sci. **2603**: vi + 31 p.

Sandstrom, S.J., Lemieux, P.J., and Reist, J.D. 1997. Enumeration and biological data from the upstream migration of Dolly Varden charr (*Salvelinus malma*) (W.), from the Babbage River, Yukon North Slope, 1990 to 1992. Can. Data Rep. Fish. Aquat. Sci. **1018**: iv + 132 p.

Sandstrom, S.J., Chetkiewicz, C.B., and Harwood, L.A. 2001. Overwintering habitat of juvenile Dolly Varden (*Salvelinus malma*) (W.) in the Rat River, NT, as determined by radio telemetry. Canadian Science Advisory Secretariat (CSAS) Research Document **2001/092**: 16 p.

Sawatzky, C.D., Michalak, D., Reist, J.D., Carmichael, T.J., Mandrak, N.E., and Heuring, L.G. 2007. Distributions of freshwater and anadromous fishes from the mainland Northwest Territories, Canada. Can. Manuscr. Rep. Fish. Aquat. Sci. **2793**: xiv + 239 p.

Scanlon, B. 2000. The ecology of the Arctic char and Dolly Varden in the Becharof Lake drainage, Alaska. M.Sc. Thesis, University of Alaska, Fairbanks, Alaska. xiv + 103 p.

Schutz, D.C., and Northcote, T.G. 1972. An experimental study of feeding behavior and interaction of coastal cutthroat trout (*Salmo clarki clarki*) and Dolly Varden (*Salvelinus malma*). J. Fish. Res. Board Can. **29**: 555-565.

Seaman, G.A., Lowry, L.F., and Frost, K.J. 1982. Foods of belukha whales (*Delphinapterus leucas*) in western Alaska. Cetology **44**: 1-19.

Sparling, P.D., and Stewart, D.B. 1986. Data from the monitoring of domestic/commercial fisheries for Arctic charr in the Big Fish and Rat River areas, Northwest Territories, 1986. Inuvik, NWT: Fisheries Joint Management Committee Report **87-002**: ii + 28 p.

Stein, J.N., Jessop, C.S., Porter, T.R., and Chang-Kue, K.T.J. 1973b. Fish resources of the Mackenzie River Valley, Interim Report II. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development Report. xvii + 260 p.

Stephenson, S.A. 2003. Local and scientific observations of Dolly Varden (*Salvelinus malma*) (W.) in the Big Fish River, Northwest Territories, Canada: 1995-2002. Can. Manuscr. Rep. Fish. Aquat. Sci. **2644**: v + 20 p.

Stevens, T.M., and Deschermeier, S.J. 1986. The freshwater food habits of juvenile Arctic char in streams in the Arctic National Wildlife Refuge, Alaska. U.S. Fish and Wildlife Service, Fairbanks, Alaska. iii + 11 p. [Fairbanks Fishery Resources Progress Report FY86-6].

Stewart, D.B. 1996. A review of the status and harvests of fish stocks in the Gwich'in Settlement Area. Can. Manuscr. Rep. Fish. Aquat. Sci. **2336**: iv + 41 p.

Stewart, D.B., Mochnacz, N.J., Sawatzky, C.D., Carmichael, T.J., and Reist, J.D. 2007. Fish diets and food webs in the Northwest Territories: bull trout (*Salvelinus confluentus*). Can. Manuscr. Rep. Fish. Aquat. Sci. **2800**: vi + 18 p.

Stewart, D.B., Mochnacz, N.J., Reist, J.D., Carmichael, T.J., and Sawatzky, C.D. 2009. Fish life history and habitat use in the Northwest Territories: Dolly Varden (*Salvelinus malma*). Can. Manuscr. Rep. Fish. Aquat. Sci.**2915**: vi + 63 p. .

Underwood, T.J., Millard, M.J., and Thorpe, L.A. 1996. Relative abundance, length frequency, age, and maturity of Dolly Varden in nearshore waters of the Arctic National Wildlife Refuge, Alaska. Trans. Am. Fish. Soc. **125**: 719-728.

Ward, D., and Craig, P. 1974. Catalogue of streams, lakes and coastal areas in Alaska along routes of the proposed gas pipeline from Prudhoe Bay, Alaska to the Alaskan/Canadian Border . Arctic Gas Biological Report Series **19**: xvi + 381 p.

West, R.L., and Wiswar, D.W. 1984. Fisheries investigations on the Arctic National Wildife Refuge, Alaska, 1984. U.S. Fish and Wildife Service, Fairbanks Fishery Resources Progress Report **FY85-1**: v + 47 p.

Yoshihara, H.T. 1973. Monitoring and evaluation of Arctic waters with emphasis on the North Slope drainages: Land and stream investigations, Part A: some life history aspects of Arctic char. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973. Project F-9-5, Job No. G-III-A. Volume **14**: ii + 81 p.

6.0 GLOSSARY

Allopatric fish do not inhabit the same waterbody.

Anadromous fish populations move downstream into marine waters to feed, and return upstream into fresh water to spawn and/or overwinter.

Benthic organisms are associated with the bottom substrate. They constitute the **benthos** and are **epibenthic** if they live at or just above the bottom substrate, or **infauna** if they inhabit the substrate.

Lacustrine populations remain in lakes throughout their lives.

Non-anadromous fish populations remain in fresh water year-round.

Riverine (residual) Dolly Varden remain in rivers and streams throughout their lives despite having access to the sea, and are typically small, early maturing males.

Smoltification is the physiological process undergone by salmonid fish, such as the Dolly Varden, that allows them to migrate from freshwater into seawater as part of their lifecycle.

Sympatric species occur in the same or overlapping areas.

Stream-resident (isolated) fish populations remain in streams throughout their lives and are prevented from migrating to sea by impassable barriers.

7.0 APPENDICES

Key to Appendices 1 and 2:

Where the life stage or terrestrial origin of taxa was provided it is denoted as follows: **A** = Adult, **L** = Larvae, **P** = Pupae, **N** = Nymph, **T** = Terrestrial origin.

+ = present in small amounts.

* = fish are considered to be age 0 until December 31 of the year they are hatched.

Notes:

a = % frequency of occurrence based only on fish with food in their stomachs.

b = % by volume based only on fish with food in their stomachs. Griffiths et al. (1975) used the Hynes (1950) point method; Bryan et al. (1973) used that of Borgeson (1963).

c = average % frequency of occurrence based only on fish with food in their stomachs, calculated from the reference material listed.

d = % by volume based only on fish with food in their stomachs, calculated from the reference material listed.

e = Diptera were mostly chironomids.

References:

1 = Stein et al. 1973b: 251.

2 = Jessop et al. 1973: 116; converted to % frequency of occurrence based on only fish with food in their stomachs by McCart (1980).

3 = Glova and McCart 1974: 47.

4 = Bond and Erickson 1987: 18.

5 = McCart 1980: 83. Average of dietary data from Bryan et al. 1973—Babbage and Firth rivers, YT.

6 = McCart 1980: 83. Average of dietary data from Aquatic Environments Limited file data for Little Fish Creek (Cache Creek) on Big Fish River, NT, and the Kongakut, Egaksrak, Ekaluakat, and Canning (CS-10) rivers; Stein et al. 1973b—Mackenzie River, NT; de Graaf and Machniak 1977—Mackenzie River, NT; Jessop et al. 1973—Rat River, NT; Bain 1974—Fish Hole Creek, Babbage River, YT; Glova and McCart 1974—Firth River, YT; Craig 1977a—Canning River, AK; Craig 1977c—Kavik River, AK; Yoshihara 1973 and McCart et al. 1972—Sagavanirktok River drainage; Kogl 1971—Colville River, AK.

7 = McCart 1980: 83. Average of dietary data from Craig 1977a—vicinity of Canning River mouth, Alaska; Yoshihara 1973—Sagavanirktok River delta and nearby coast, AK; Furniss 1975 and Bendock 1977—Prudhoe Bay, AK.

8 = McCart 1980: 83. Average of dietary data from Griffiths et al. 1975—Nunaluk Lagoon, Yukon; Griffiths et al. 1977—Katovik Lagoon and Bullen Point area, AK; Craig and Griffiths 1978—Simpson Lagoon, AK.

9 = Griffiths et al. 1975: 155, converted to percentages by McCart 1980.

10 = Bain 1974: 127.

11 = Bryan et al. 1973: 55, 56.

Appendix 1. Stomach contents of non-anadromous Dolly Varden from rivers in the Northwest Territories (NT) and Yukon (YT), expressed as percent frequency of occurrence based only on fish with food in their stomachs. See above for explanatory key.

	Mackenzie River, NT (Aklavik area)	Rat River, NT	Fish Hole Creek, Babbage River, YT		Upper Babbage River, YT		Lower Babbage River, YT		Firth River, YT	
Season	May-Nov	Jun-Sep	May-Sep		Mar-Sep		Jun-Sep		May-Sep	
Coordinates		67°37´10"N, 134°52´24"W	68º36'N, 138º43'W		68° 38' 14" N, 139° 21'		68º38'N, 139º20'W		69°33´N, 139°32´W	
Elevation (m asl)	< 20	< 30	~ 305		~220		< 200		< 500	
Life history type: P = small juveniles (pre-smolt); R = Riverine (residual); S = Stream-resident (isolated)	P	P	P	R	S	S	P	R	P	P, R
Life stage (J = juvenile; A = Adult)	J	J	J	A	J	A	J	A	J	J, A
Age range* (yoy = young-of-the-year)		yoy							YOY-1	~1-11
Length range (mm)	35-132	50-57	37-204	128-395	31-294		46-162	145-241	42-71	48-390
# of stomachs examined (# empty)	13 (0)	4 (0)	110 (6)	53 (14)	253 (27)	143 (22)	125 (48)	15 (4)	79(3)	209 (52)
Plant Material			5	5	1.3					
Invertebrates										
Ph. Nemata (round worms)					0.7	1.8	1.9			
Ph Annelida										
SubCl. Oligochaeta					4.0					
Ph. Arthropoda										
Cl. Arachinda (arachnids, water mites)	7.7				0.7	4.5				
Cl. Insecta (insects)					16.5 (T)	10.7 (T)	3.9 (T)	25.0 (T)	9.2 (T)	10.1 (T)
O. Coleoptera (beetles)					0.7 (L) 0.7 (A,T)	1.8 (L) 3.6 (A,T)				
O. Diptera (gnats, mosquitoes, flies)	61.5		44 2 (T)	13 5 (T)	6.6 (L)	0.9 (L)	1.9 (L) 1.9 (P)		43.4 (L) 7.9 (P) 10.5 (A)	51.6 (L) 13.4 (P) 3.2 (A)
F. Chironomidae (midges)	92.3	100	53 (L) 18 (P) 6 (A)	42 (L) 32 (P) 11 (A)	55.3 (L) 28.3 (P) 3.3 (A)	33.9 (L) 17.0 (P)	61.5 (L) 1.9 (P)	25.0 (L)		
F. Simuliidae (blackflies)				3		0.9 (P)	36.5 (L)			1.3 (L)

	Mackenzie River, NT (Aklavik area)	Rat River, NT	Fish Hole Creek, Babbage River, YT		Upper Babbage River, YT		Lower Babbage River, YT		Firth River, YT	
F. Tabanidae (deer and horse flies)	7.7									
F. Tipulidae (crane flies)	7.7		19	3	4.0 (L)		9.6 (L)		21.0 (L)	9.5 (L)
O. Ephemeroptera (mayflies)			9 (N)	25 (N)			36.5 (N)		3.9 (N)	14.0 (N)
O. Hymenoptera (bees and ants)						1.8 (A,T)				
O. Plecoptera (stoneflies)	30.8		12 (N)	8 (N) 3 (A)	2.6 (N)	4.5 (N)			9.2 (N)	11.5 (N)
F. Nemouridae (spring stoneflies)	7.7									
F. Perlidae (common stoneflies)	7.7									
F. Perlodidae (perlodid stoneflies)	7.7									
O. Trichoptera (caddisflies)			17 (L)	40 (L) 3 (A)	32.9 (L)	60.7 (L)	1.9 (L)	12.5 (L)		3.8 (L) 0.6 (A)
SubPh. Crustacea										
Cl. Malacostraca										
O. Amphipoda (e.g., *Gammarus lacutris, Hyalella azteca, Pontoporeia affinis)*)					1.3	2.7			3.9	3.8
Fishes			3	16		1.8		50.0		3.8
Fish eggs			1	66						0.6
Debris (includes unidentified organic an d inorganic matter)			5	3	33.4	7.4	32.5	27.5	1.3	31.8
Reference:	1	2	10	10	10	10	10	10	3	3
Notes:	a	a	a	a	a	a	a	a	a, e	a, e

Appendix 2. Stomach contents of anadromous Dolly Varden in coastal waters of the Yukon, expressed as percent frequency of occurrence, or percent by volume based only on fish with food in their stomachs. See above for explanatory key.

	Phillips Bay			"Nunaluk Lagoon"		
Season	Jun-Aug			Jun-Sep		
Coordinates	69°17´N, 138°30´W			69°33´N, 139°30´W		
Life stage (J = juvenile; A = Adult)	J, A	J	J, A (?)	J (?), A	A	J, A
Age range* (yoy = young-of-the-year)						
Length range (mm)	187-635	90-297	301-400	401-500	501-600	All
# of stomachs examined (# empty)	26 (32 of 101)	17	57	112	20	206 (68)
Plant Material	4			0.6		0.4
Invertebrates						
Ph. Arthropoda						
Cl. Insecta (insects)	8					
O. Diptera (gnats, mosquitoes, flies)		3.7 (P) 2.2 (A)	8.0 (P) 0.3 (A)	5.0 (P)	0.6 (P)	5.2 (P) 0.4 (A)
F. Chironomidae (midges)		57.8 (L)	5.3 (L)	8.1 (L)	0.3 (L)	14.1 (L)
F. Simuliidae (blackflies)			+ (L)		0.1 (L)	+ (L)
F. Tipulidae (crane flies)			0.3 (L)	0.6 (L)		0.2 (L)
O. Plecoptera (stoneflies)		4.9 (L)	5.0 (L)	3.7 (L)	1.9 (L)	3.2 (L)
O. Trichoptera (caddisflies)						+ (L)
SubPh. Crustacea						
Cl. Malacostraca						
O. Amphipoda (e.g., *Gammarus setosus, Gammaracanthus loricatus*)	77	3.7	24.0	14.9	1.6	15.3
O. Isopoda	15		9.8	13.7		9.3
O. Mysida	63		1.8	1.9		1.2
Cl. Maxillopoda						
SubCl. Copepoda	39		10.4	0.6	7.3	4.0
Ph. Mollusca						
Cl. Bivalvia (clams)	4					
Cl. Gastropoda (snails)	4					

	Phillips Bay	"Nunaluk Lagoon"				
Fishes	69		1.5	9.3	23.3	6.9
F. Salmonidae (salmonids)						
Coregonus autumnalis (Arctic cisco)				2.5	6.3	2.0
Salvelinus malma (Dolly Varden)				2.5	12.0	2.4
Thymallus arcticus (Arctic grayling)					4.1	0.4
F. Gasterosteidae (sticklebacks)						
Pungitius pungitius (ninespine stickleback)			0.6	5.6	1.6	2.8
F. Cottidae (sculpins)						
Myoxocephalus quadricornis (fourhorn sculpin)		10.9	13.1	19.9	33.1	17.3
Fish eggs						
Debris (includes unidentified organic and inorganic matter)	96	16.8	20.2	11.8	7.9	14.6
Reference:	4	9	9	9	9	9
Notes:	a	b	b	b	b	b

Appendix 3. Stomach contents of anadromous Dolly Varden in fresh waters of the Northwest Territories (NT) and Yukon (YT), expressed as percent frequency of occurrence or percent by volume based only on fish with food in their stomachs. See above for explanatory key.

	Rat River, NT		**Babbage River, YT**				**Firth River, YT**	
	dark phase (spawners)	**light phase (non-spawners)**	**Babbage River**	**Fish Hole Creek**				
Season	Jun-Sep	Jun-Sep	Aug	Aug	May-Sep	May-Sep	May-Sep	
Coordinates	67°37´10”N, 134°52´24”W		69°14´N 138°27´W	68°48´N, 138°47´W			69°33´N, 139°32´W	
	< 30			~305			< 500	
Life history type: A = anadromous; R = Riverine (residual); S = Stream-resident (isolated)	A	A	A?	A?	A	A	A	A?
Life stage (J = juvenile; A = Adult)	A	J, A	J, A	A	J	A	J, A	A
Age range* (YOY = young-of-the-year)							~3-15	
Length range (mm)	460-572	301-590	198-504	451-593		347-629	237-720	418-720
# of stomachs examined (# empty)	11 (3)	192 (175)	10 (5)	22 (20)	60 (49)	70 (61)	294 (233)	37 (23)
Ph. Arthropoda								
Cl. Insecta (insects)		+	2		9 (T)	11 (T)	3.2 (T)	39
O. Coleoptera (beetles)			<1					
F. Dytiscidae (predaceous diving beetles)		60.3						
O. Diptera (gnats, mosquitoes, flies)	0.1		<1				49.2 (L) 27.9 (P) 6.5 (A)	18
F. Ceratopogonidae (biting midges)		<1.5						
F. Chironomidae (midges)	0.1	<1.5	1 (L)	23 (L)	36 (L) 9 (A)	11 (L) 22 (P)		11 (L)
F. Muscidae (house flies)		14.7						
F. Simuliidae (blackflies)		14.7						
F. Tipulidae (crane flies)	<0.03					11	8.2 (L)	
O. Ephemeroptera (mayflies)						22	8.2 (N)	17
F. Baetidae	0.03							

	Rat River, NT		Babbage River, YT				Firth River, YT	
	dark phase (spawners)	**light phase (non-spawners)**	**Babbage River**	**Fish Hole Creek**				
O. Hemiptera (true bugs)								
F. Corixidae (water boatmen)		8.8						
O. Plecoptera (stoneflies)	2.8	<1.5	<1(N)				14.7 (N)	11 (N)
F. Nemouridae (spring stoneflies)	0.1							
F. Perlidae (common stoneflies)								
F. Perlodidae (perlodid stoneflies)	0.03							
O. Trichoptera (caddisflies)					9	11	6.5 (L) 1.6 (A)	
F. Brachycentridae		1.5						
SubPh. Crustacea								
Cl. Malacostraca								
O. Amphipoda (e.g., *Gammarus lacutris, Hyalella azteca, Pontoporeia affinis)*)							9.8	
Fishes	90.2		96	77	27		9.8	4
F. Salmonidae (salmonids)								
Salvelinus malma (Dolly Varden)	7.0							
Fish eggs			<1			44	3.3	
Debris (includes unidentified organic and inorganic matter)							32.8	
Reference:	2	2	11	11	10	10	3	11
Notes:	b	b	b	b	a	a	a	b

Appendix 4. Stomach contents of anadromous Dolly Varden in fresh or coastal waters of the Northwest Territories and North Slope of Yukon and Alaska, expressed as mean percent frequency of occurrence or mean percent by volume based only on stomachs containing food. See above for explanatory key.

	FRESHWATER		COASTAL	
	% occurrence	% volume	% occurrence	% volume
Life stage (J = juvenile; A = Adult)	J, A	J, A	J, A	J, A
Length range (mm)	195-710	198-720	130-685	190-703
# of stomachs examined (# empty)	2191 (~1750)	69 (48)	1412 (~694)	403 (>68)
Plant Material	18		1	<1
Invertebrates				
Ph. Arthropoda				
Cl. Arachinda (arachnids, water mites)	< 1			
Cl. Insecta (insects)	21 5 (T)	26	1	
O. Coleoptera (beetles)	2	< 1	<1	<1
O. Diptera (gnats, mosquitoes, flies)	4	12	2	1
F. Chironomidae (midges)	27 (L) 5 (P) 2 (A)	10 (L)	1	3
F. Tipulidae (crane flies)	4			
O. Ephemeroptera (mayflies)	2	11		<1
O. Hemiptera (true bugs)	<1			
O. Plecoptera (stoneflies)	11 (N) 1 (A)	7 (N)	1	
O. Trichoptera (caddisflies)	4			1
SubPh. Crustacea	< 1		6	1
Cl. Malacostraca				
O. Amphipoda (e.g., *Gammarus* spp)	2		32	34
O. Isopoda			15	3
O. Mysida			42	25

	FRESHWATER		COASTAL	
	% occurrence	% volume	% occurrence	% volume
Cl. Maxillopoda				
SubCl. Copepoda			<1	1
Ph. Mollusca			<1	<1
Fishes	16	33	18	15
F. Salmonidae (salmonids)				
Salvelinus malma (Dolly Varden)				< 1
Coregonus spp. (whitefish)				< 1
Coregonus autumnalis (Arctic cisco).				< 1
Thymallus arcticus (Arctic grayling)				< 1
F. Gadidae (cods)				
Boreogadus saida (Arctic cod)			7	
F. Gasterosteidae (sticklebacks)				
Pungitius pungitius (ninespine stickleback)				1
F. Cottidae (sculpins)				
Myoxocephalus quadricornis (fourhorn sculpin)				6
F. Stichaeidae (shannies)				
Anisarchis medius (stout eelblenny)				1
Fish eggs	7	< 1	< 1	
Debris (includes unidentified insect parts, baby lemmings, refuse, caribou hair, feathers, sticks, plastic ribbon, rocks)	8		9	9
Miscellaneous (e.g., parasitic nematodes)	1			
Reference:	6	5	7	8
Notes:	c	d	c	d