Parasite Community of Arctic Char, *Salvelinus alpinus*, from Lake Hazen and Craig Lake, Quttinirpaaq National Park, Nunavut

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PARASITE COMMUNITY OF ARCTIC CHAR, *Salvelinus alpinus*, FROM LAKE HAZEN AND CRAIG LAKE, QUTTINIRPAAQ NATIONAL PARK, NUNAVUT

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ABSTRACT

Gallagher, C.P., Dick, T.A., Babaluk, J.A., and Reist, J.D. 2009. Parasite community of Arctic char, *Salvelinus alpinus*, from Lake Hazen and Craig Lake, Quttinirpaaq National Park, Nunavut. Can. Tech. Rep. Fish. Aquat. Sci. 2854: vi + 24 p.

Arctic char (*Salvelinus alpinus*) from Lake Hazen and Craig Lake in Quttinirpaaq National Park, Ellesmere Island, Nunavut were examined to: 1) determine the parasite species present in the char, 2) describe the differences in parasite community among known specimens of juveniles, small-, large-, and unknown-form char sampled from Lake Hazen, 3) determine whether any parasites were acquired from the marine environment, 4) describe the diet of the char, and 5) determine whether parasites affect gonad development. A total of five parasite species were found: *Diphyllobothrium dendriticum*, *D*. *ditremum*, *Eubothrium salvelini*, *Philonema agubernaculum*, and *Salmincola edwardsii*. All five parasite species were recovered from both the small- and large-form char in Lake Hazen, although large-form char had higher mean intensity and mean abundance values for each species. Differences in mean intensity and abundance reflect differences in diet and habitat use, yet overlapping values suggest that feeding patterns and habitat use between small- and large-form chars are not exclusive. No parasites from the marine environment were recovered. The most abundant diet items were chironomids and Arctic char (a list of chironomid species found in char stomachs is presented). Parasite species were more abundant in the Lake Hazen sample, and the paucity of parasites from Craig Lake char may be a result of lower abundances and infection level of intermediate hosts in this lake. The level of infection by *Diphyllobothrium* spp. appears to negatively affect gonad development of Arctic char from Lake Hazen.

Key words: Arctic char; chironomids; diet; Ellesmere Island; Lake Hazen; Craig Lake; parasites.

RÉSUMÉ

Gallagher, C.P., Dick, T.A., Babaluk, J.A., and Reist, J.D. 2009. Parasite community of Arctic char, *Salvelinus alpinus*, from Lake Hazen and Craig Lake, Quttinirpaaq National Park, Nunavut. Can. Tech. Rep. Fish. Aquat. Sci. 2854: vi + 24 p.

Une enquête a été réalisée sur l'omble chevalier (*Salvelinus alpinus*) des lacs Hazen et Craig, dans le parc national du Canada Quttinirpaaq, sur l'île d'Ellesmere (Nunavut), en vue de : 1) déterminer quelles sont les espèces de parasites présentes chez l'omble chevalier, 2) décrire les différences entre les communautés de parasites trouvées dans les spécimens connus d'omble juvénile ou des formes de petite taille, de grande taille ou de forme inconnue prélevés dans le lac Hazen, 3) déterminer si certains parasites sont d'origine marine, 4) définir le régime alimentaire de l'omble et 5) déterminer si les parasites influent sur le développement des gonades. Un total de cinq espèces de parasites ont été détectées : les *Diphyllobothrium dendriticum*, *D*. *ditremum*, *Eubothrium salvelini*, *Philonema agubernaculum* et *Salmincola edwardsii*. Ces cinq espèces ont été prélevées sur des ombles de formes de petite taille et de grande taille du lac Hazen, malgré que les valeurs d'intensité et d'abondance moyennes soient plus élevées chez l'omble de forme grande taille, et ce pour toutes les espèces de parasites. Les différences d'intensité et d'abondance moyennes reflètent des différences d'habitudes alimentaires et d'utilisation de l'habitat, quoique des valeurs qui se recoupent tendent à indiquer que l’alimentation et l’utilisation de l’habitat ne sont pas exclusives entre les ombles de forme petite taille et de forme grande taille. Aucun parasite d’origine marine n’a été prélevé. Les aliments les plus abondants étaient les chironomes et l’omble chevalier (une liste des espèces de chironomides trouvées dans l’estomac des ombles est disponible). L’abondance d’espèces de parasites étaient plus grande dans l’échantillon du lac Hazen, et le peu de parasites dans l’omble du lac Craig pourrait être dû à un niveau d’abondance et à un taux d’infection plus faibles chez les hôtes intermédiaires de ce lac. Le taux d’infection par *Diphyllobothrium* spp. semble avoir des effets néfastes sur le développment des gonades de l’omble chevalier du lac Hazen.

Mots-clés: omble chevalier; chironomides; régime alimentaire; île d’Ellesmere; lac Hazen; lac Craig; parasites.

INTRODUCTION

Arctic char (*Salvelinus alpinus*) often demonstrate anadromous and resident life history types within lakes at higher latitudes of their circumpolar distribution (Johnson 1980). Different sympatric forms (e.g., ecological or morphological type) are often found among resident or landlocked Arctic char populations. These forms often differ in phenotype, with different life-history traits and exploit different foraging niches (Jonsson and Jonsson 2001). Identifying and studying Arctic char forms within lakes is important to improve our understanding of Arctic freshwater food webs, char diversity and speciation, and to ensure proper management and conservation of the species.

Methods used in other studies to discriminate Arctic char forms have included combinations of growth, diet, population structure, $\delta^{13}C$ and $\delta^{15}N$ stable isotopes, and habitat use (see Hindar and Jonsson 1982; Hammar 2000; Guiguer et al. 2002; Power et al. 2002; Power et al. 2005). Parasite information has also been used for differentiating among ecologically segregated forms of resident Arctic char within lakes because parasite transmission is a reflection of feeding habits and habitat use. Parasites have been used to confirm the ecological segregation of resident Arctic char forms within several lakes (Frandsen et al. 1989; Dorucu et al. 1995; Knudsen et al. 1997; Hammar 2000; Knudsen et al. 2004), as well as between sea-run (anadromous) and resident (non-anadromous) life-history types (Dick and Belosevic 1981).

Arctic char is the only fish species present in Lake Hazen and Craig Lake (Hunter 1960). However, at least two morphologically (Reist et al. 1995) and ecologically (Guiguer et al. 2002) distinct forms of Arctic char are known to inhabit Lake Hazen. The small-form char is dark in colour, feeds on benthic invertebrates and is slower growing relative to the large-form char, which has lighter colouration and feeds on both chironomids and other char (Reist et al. 1995; Guiguer et al. 2002). Lake Hazen large-form char were once thought to be anadromous (Hunter 1960; Johnson 1983). However, more recent research suggested that both the large-form and small-form were non-anadromous (Babaluk et al. 1997; 2001). A third form (mature at smaller sizes than the small- and large-forms) of Lake Hazen char was also recently captured (authors' unpublished data). Based on a single, limited sampling, Arctic char from Craig Lake do not appear to exhibit morphological variation (Babaluk et al. 2007).

The objectives of this study were to examine Arctic char from Lake Hazen and Craig Lake in order to: 1) determine the parasite species present in the char, 2) describe the differences in parasite community among known specimens of juveniles, small-, large-, and unknown-form char sampled from Lake Hazen, 3) determine whether any parasites were acquired from the marine environment, 4) describe the diet of the char, and 5) determine whether parasites (i.e., *Diphyllbothrium* spp.) affect gonad development.

MATERIALS AND METHODS

STUDY AREA

Quttinirpaaq National Park is located at the northern end of Ellesmere Island, Nunavut (Fig. 1, inset). The Park, with an area of 37 775 km^2, is the second largest national park in Canada and is described in detail in Parks Canada (1994). Lake Hazen (81°50'N, 70°25'W, Fig. 1), is the largest lake in the park and the Canadian Arctic Archipelago with a surface area of 537.5 km^2 (Inland Waters Directorate 1973). The lake is extremely oligotrophic with no macrophytes and low phytoplankton (Johnson 1990) and zooplankton productivity (McLaren 1964). A total of thirty-four species of benthic invertebrates have been reported from the lake (Oliver 1963). Craig Lake (81°52'N, 68°47'W) is a small lake that drains via Salor Creek into the north-east end of Lake Hazen (Fig. 1). Other than some limited information on the char in the lake (Babaluk et al. 2007) and its water chemistry (Babaluk et al. 1999), little is known about Craig Lake.

COLLECTION AND ANALYSIS METHODS

Between June 14-21, 1992, 219 Arctic char were collected from Lake Hazen at four sites: Blister Creek, Henrietta Nesmith Glacier, Mesa Creek, and the Ruggles River outlet (Fig. 1). All fish were captured by either multi-mesh, nylon, multi-filament gillnets (gangs of 10, 12.5, 16, 19, 22, and 25 mm bar-mesh and 10, 19, 33, 45, 55, and 60 mm bar-mesh) set under the ice, or by angling through the ice with un-baited lures. A sample of 50 char from Craig Lake were collected on June 16, 1992 by angling through the ice with un-baited lures.

All char were frozen in the field immediately after capture and transported to Fisheries and Oceans Canada (Winnipeg) for subsequent processing. Sub-samples of 95 fish from Lake Hazen (25 from the Blister Creek area, 21 from the Henrietta Nesmith Glacier area, 24 from the Mesa Creek area, and 25 from near the outflow of the Ruggles River) and 25 from Craig Lake were processed for parasites. Each specimen from Lake Hazen was assigned to a group: juvenile, small-form, large-form or unknown-form. The criteria used to assign a specimen to a group are provided in Reist et al. (1995) and Guiguer et al. (2002). Craig Lake char were not categorized to morphotype and only designated as juvenile or adult. Biometrics assessed included fork length and weight of thawed individuals, assessment of sex and maturity, and gonad weight. Otoliths were collected for age determination. Ages were determined using the technique described in Reist et al. (1995) and criteria described by Nordeng (1961) and Chilton and Beamish (1982).

Viscera, eyes, and gill arches were removed for examination. The external surface of the body, mouth, and body cavity were also examined for parasites. The following were separately examined for parasites using a dissecting microscope: gills, stomach, swim bladder, gonads, urinary bladder, spleen, heart, eyes, brain, liver, esophagus, caecae, and intestine divided into foregut, midgut and hindgut. Each tissue (heart, liver and spleen) was cut open or compressed using a trichinoscope. Organs with a lumen were opened and the contents scraped into a petri dish. This material was stirred and 100 mL aliquots decanted into a second petri dish for observation with a dissecting microscope. Parasites were enumerated by species, then fixed and stained or cleared for identification purposes. Prevalence (%), mean intensity and mean abundance (Margolis et al. 1982) were calculated for each parasite species from both lakes. Encysted cestode plerocercoids were enumerated and identified as *Diphyllobothrium* spp.

Stomach contents were identified to the lowest taxonomic level possible, and all fish remains were identified as Arctic char. Chironomids from select stomachs contents (Lake Hazen = 9, Craig Lake = 1) were identified by a specialist in chironomid taxonomy (see Appendix 1). The prevalence of each food item in the diet was quantified as percent frequency of occurrence, which is the percentage of char stomachs that contained a particular prey type.

The gonadosomatic index (GSI) was calculated as follows:

$$GSI = (\text{gonad weight} \div \text{total fish weight}) \times 100$$

and plotted against the frequency of *Diphyllobothrium* spp. to infer whether infection levels inhibited gonad maturation in Lake Hazen Arctic char.

Non-parametric Mann-Whitney U tests or Kruskall-Wallace tests (H) were performed on the abundance of parasite species between juveniles and small-form, and small-form and large-form char from Lake Hazen using SPSS Statistics (version 14) to determine if differences were statistically significant.

RESULTS

Arctic char processed for parasites from Lake Hazen ranged in fork length from 151 to 735 mm and were between 6 and 33 years of age. The sample consisted of 10 juveniles, 34 small-form, 46 large-form, and 5 adult fish of unknown-form. The 25 char from Craig Lake ranged in length from 210 to 297 mm and between 8 to 27 years of age. The Lake Hazen sample was mainly collected using gillnets and is, therefore, a more representative sample of the population with a larger size range than the Craig Lake sample which was collected by angling.

PARASITES

Five parasite species, comprised of three cestodes, one nematode, and one crustacean, were identified from Arctic char from Lake Hazen and Craig Lake (Table 1). Species found in Lake Hazen were: *Diphyllobothrium dendriticum*, *D*. *ditremum*, *Eubothrium salvelini*, *Philonema agubernaculum*, and *Salmincola edwardsii*. Arctic char from Craig Lake were only infected with *Diphyllobothrium* spp. plerocercoids and *P*. *agubernaculum* in adults while no parasites were detected in juveniles. *Diphyllobothrium dendriticum* and *D*. *ditremum* were mostly found to infect the esophagus, stomach, caecae and foregut while encysted pleorcercoids were mainly detected on the stomach and caecae. The nematode *P*. *agubernaculum* was more ubiquitous as it principally infected the swimbladder, liver, stomach, caecae, foregut and hindgut. The cestode *E*. *salvelini* was found more often in stomach, foregut and caecae while *S*. *edwardsii* was only collected from the gills.

In Lake Hazen, the prevalence of *Diphyllobothrium* spp. (*D*. *ditremum*, *D*. *dendriticum* and plerocercoids combined) in juvenile char was 70%, and was similar between both small-

(88.2%) and large-form (93.5%) char (Table 1). The mean intensity and abundance of *Diphyllobothrium* spp. were lowest in juveniles, followed by small-form char, then increased substantially in large-form char. Statistically significant differences in the abundance of *Diphyllobothrium* spp. were observed between juveniles and small-form ($U = 55.5$, $p < 0.01$), and small- and large-form char ($U = 424.5$, $p < 0.01$). *Diphyllobothrium* spp. frequency in small-form char was typically ≤215 and did not vary considerably with length with the exception of three fish which had >500 plerocercoids (Fig. 2). However, *Diphyllobothrium* spp. varied considerably with length in large-form char (Fig. 2). Large-form char up to ~400 mm had *Diphyllobothrium* spp. infections that were typically <100 and these increased substantially in most larger-sized fish. Among large-form char >400 mm in length, infections were wide-ranging, with some samples having no signs of infection and others with >1000 plerocercoids. The abundance of *Diphyllobothrium* spp. among age classes of large-form Arctic char also varied considerably as uninfected and heavily infected char were both observed in fish >20 years (Fig. 3). *Diphyllobothrium* spp. infections of >2000 were only observed in char between 401-615 mm in length and 18-23 years of age. One unknown-form char had no *Diphyllobothrium* spp. infections, two had ≤3 while the remaining two had 40 and 286 plerocercoids, respectively.

Diphyllobothrium spp. were found infrequently in the Craig Lake sample relative to that from Lake Hazen as the prevalence was 28.0% in Craig Lake and 88.4% in Lake Hazen (Table 1). The highest infection in a single fish from Craig Lake was nine *Diphyllobothrium* spp. plerocercoids.

Infections of *E. salvelini* were not significantly different between juveniles and small-form char ($U = 162.0$, $p > 0.05$), yet were significantly higher in large-form char ($U = 583.0$, $p < 0.01$) (Table 1, Fig. 4, 5). Although the differences were statistically significant, the majority of small- and large-form char had overlapping frequencies of *E. salvelini*. Infections typically numbered <20 although three fish (two large-form and one unknown-form), which were ≥20 years of age, had relatively high infections (71, 109, and 123) (Fig. 4, 5).

Philonema agubernaculum was detected infrequently in Lake Hazen char and, although mean intensity and mean abundance appeared to be higher in large-form char, no statistically significant differences were observed among juveniles, small- and large-form char ($H(2) = 0.363$, $p > 0.05$) (Table 1, Figs. 6, 7). Infection levels were much lower in Craig Lake char than in Lake Hazen char, with only one nematode found in a single sample (Table 1).

Salmincola edwardsii occurred infrequently in Lake Hazen Arctic char. This crustacean was not detected on juvenile or unknown-form char but was present on small- and large-form char. The prevalence, mean intensity and mean abundance were higher in large-form char compared to the small form (U = 584.0, $p < 0.01$) (Table 1). Infections of *S. edwardsii* were only found in char >350 mm in length (Fig. 8) and 12 years of age (Fig. 9). Infections >10 were only observed in large-form char ≥492 mm in length and ≥22 years of age.

DIET

Food items collected from Arctic char analyzed for parasites from Lake Hazen and Craig Lake are listed in Table 2. Food items for all Lake Hazen and Craig Lake char from the 1992 collection including those analyzed for parasites are shown in Appendices 1 and 2, respectively. A list of chironomid species found in selected Lake Hazen and Craig Lake char stomachs is presented in Appendix 3. The most frequently detected food item in Lake Hazen and Craig Lake char stomachs were chironomids (larvae and pupae). Acari (Arachnidae) were found only in the stomachs of small-form char (5.9%). Cannibalism was noted in all forms of Lake Hazen char, yet occurred predominantly in large-form char (30.4%) (Table 2). Empty stomachs were mostly detected in large-form char (26.1%). *Apatania zonella* (Trichoptera) larvae were found in two juvenile char stomachs from Craig Lake. Although not noted in Table 2, mermithid nematodes were found in stomachs and digestive tracts of 6.3% and 20.0% of the char from Lake Hazen and Craig Lake, respectively. Mermithids were from the body cavity of the insect food items and while a source of nutrients they are not considered part of the parasite fauna of char.

GONAD DEVELOPMENT

The majority of GSI values in the sample were ≥2%, which indicates these fish would not spawn in the current year. All high (>300) *Diphyllobothrium* spp. abundance values were associated with low (<1.5%) GSI in both sexes from each morphotype (Fig. 10).

DISCUSSION

The number of parasite species recovered from Lake Hazen and Craig Lake Arctic char (n = 5 and 2, respectively) was low relative to other lake-resident char populations in the Canadian

Arctic (Beverley-Burton 1978; Dick 1984). The low number may be a reflection of the decreased diversity of invertebrates suitable as intermediate hosts for parasites in Lake Hazen and Craig Lake (Oliver 1963; McLaren 1964). All parasites except the crustacean, *S. edwardsii*, are endoparasites, acquired by ingesting infected copepods or infected fish. *S. edwardsii* is an ectoparasite and has a direct life-cycle involving Arctic char that does not require an intermediate host. Although the majority of char parasite infections are acquired by consuming copepods, none were detected in stomach contents from any of the samples. However, Guiguer et al. (2002) reported that copepods were detected at low frequency of occurrence in juvenile and small-form char. Copepods may have been present in the stomach yet missed during examination for parasites.

The most abundant parasite in Lake Hazen char was the cestode *Diphyllobothrium ditremum*. *Diphyllobothrium* spp. are acquired by eating infected copepods or already infected conspecifics (Vik 1964; Curtis 1984). High numbers of *Diphyllobothrium* spp. in char are associated with a non-migratory life-history type (Dick and Belosevic 1981) and a piscivorous feeding habit (Curtis 1984; Fransden et al. 1989; Hammar 2000), although Knudsen et al. (1997) found high infection levels in a form of char that occupied the pelagic habitat and fed mainly on copepods. Studies have found that high levels of *Diphyllobothrium* spp. plerocercoids appear to have a negative effect on gonad development (Curtis 1984; Hammar 2000) and increases char mortality (Henricson 1977; Halvorsen and Anderson 1984). Results from Lake Hazen also indicate that high *Diphyllobothrium* spp. abundance affects gonad development, as no sexually mature char were found with relatively high infections (>300) (Fig. 10).

The level of *Diphyllobothrium* spp. infection cannot be used to discriminate between small- and large-from Arctic char in Lake Hazen. Large-form char had overlapping *Diphyllobothrium* spp. values with small-form fish. Some large-form char with fish remains in their stomachs had no *Diphyllobothrium* spp. The majority of large-form char >400 mm in length had infections >350 except for four samples with infections of <20. Very low levels of *Diphyllobothrium* spp. in Arctic char can be an indicator of anadromous behaviour (i.e., few accumulated plerocercoids because they have migrated to sea recently and expelled any freshwater cestodes), while heavy infections indicate the fish have not migrated to sea (non-anadromous). However, laser ablation ICP-MS analysis of the strontium distribution in the otoliths from the four char with low levels of infection, indicated the fish were not anadromous (J.A. Babaluk, unpubl. data). This could be explained by large-form char with very few infections not eating as many fish as did heavily infected char, although one of these did have a conspecific in the stomach. The capacity for resistance to infection is also poorly known and may account for the paucity of *Diphyllobothrium* spp. in some large-form char.

Three small-form char showed relatively high *Diphyllobothrium* spp. infection levels, which suggest a long-term piscivorous feeding habit. It is possible that these individuals were misidentified, and their *Diphyllobothrium* spp. infections >250 would suggest a high probability of these individuals belonging to the large-form morphotype. One of these small-form char with high infections did have fish remains in the diet.

While all parasite species were recovered from both the small- and large-form char in Lake Hazen, and parasite species presence/absence or abundance levels could not discriminate between small- and large-form char, it does appear that large-form char have higher variation and generally higher mean intensity and abundance values, particularly for *Diphyllobothrium* spp. (Table 1). The mean intensity of *Diphyllobothrium* spp. in large-form char was 689.8 ± 760.4 compared to 262.9 ± 455.3 in small-form char, while mean abundance was 195.0 ± 502.8 and 54.1 ± 222.1 in large- and small-form char, respectively. This high variation is a reflection of both the aggregated nature in the dispersal of parasites in fish and the diet, which overlap between small- and large-form char. The overlap in parasites and diet suggests that the ecological niche between the forms is neither exclusive nor widely disparate.

Applying $\delta^{15}N$ stable isotope analysis in conjunction with parasite and diet data would provide further confirmation of the trophic status of Arctic char and may be useful in discriminating samples that are intermediate between small- and large-form (fish categorized by phenotypic appearance). Stable isotopes analysis ($\delta^{15}N$ and $\delta^{13}C$) had been performed on six samples (five small-form and one unknown-form) from Lake Hazen for the study by Guiguer et al. (2002). The $\delta^{15}N$ and $\delta^{13}C$ of small-form char ranged from 8.8 and 10.4‰, and -18.4 and -19.1‰, respectively, while *Diphyllobothrium* spp. abundance ranged from 0-11. The unknown-form sample had $\delta^{15}N$ and $\delta^{13}C$ values of 8.7 and -22.5‰, respectively, with *Diphyllobothrium* spp. abundance equal to 3. Stomach contents from the six Arctic char did not contain any conspecifics. The $\delta^{15}N$ values indicate that Arctic char examined for stable isotopes occupied a lower trophic level while the diet and low abundance of *Diphyllobothrium* spp. confirmed the interpretation of results obtained from stable isotopes analysis.

Juvenile Arctic char had relatively low instances of infection. Using $\delta^{13}C$ and $\delta^{15}N$ stable isotopes, Guiguer et al. (2002) concluded that juveniles from Lake Hazen were more dependent on zooplankton while small-form char increasingly relied on chironomids, and were eventually able to occupy different habitats once they reached sizes above the predation risk threshold (250 mm). Low infection levels reflect the predominantly pelagic (i.e., zooplankton) food items consumed by juveniles. A single juvenile had a conspecific in its stomach, which suggests that char may be a large-form individual.

One of the five unknown-form Arctic char had 286 *Diphyllobothrium* spp., 123 *E. salvelini* and a conspecific in its stomach, and it is likely the fish is a large-form char. The remaining unknown-form samples had either no or very low parasite infections.

Salmincola edwardsii infections corroborate results from Amundsen et al. (1997) and Poulin et al. (1991) where larger-sized fish were infected. *S. edwardsii* infected Arctic char from Lake Hazen that were >350 mm. This parasitic copepod typically infects the gills of larger-sized char because these fish circulate more water over the gills, increasing the probability of acquiring infection (Amundsen et al. 1997). Poulin et al. (1990) found that copepodites of *S. edwardsii* reside close to the bottom, indicating that large-form Arctic char can occupy benthic habitats in the lake.

The parasite species richness in Craig Lake is considerably poor relative to Lake Hazen. Due to low infection levels, parasite data were not plotted against length and age. Variation has been observed in Arctic char parasite species diversity and abundance among other neighbouring lakes (Kennedy 1977; Dick 1984), and could be a result of different invertebrate species abundance and/or composition, infection levels among intermediate hosts or feeding habits of char between lakes. The low *Diphyllobothrium* spp. infection levels in Craig Lake also indicate Arctic char are likely non-piscivorous. Further sampling across all size ranges of char during the open water season may yield additional parasite species.

The parasites recovered from Arctic char in Lake Hazen and Craig Lake all have a freshwater lifecycle, and there is no evidence that any of the fish sampled have migrated to the sea. However, these results do not exclude the possibility of anadromy, as the samples were taken during spring. Investigations to infer anadromy using parasites should sample Arctic char during the return migration in the late summer or fall season as marine parasites would be expelled soon after entering freshwater. Other studies on Lake Hazen char have not found evidence of anadromy (Babaluk et al. 1997; 2001).

High infections of *Diphyllobothrium* spp. plerocercoids appear to inhibit reproduction in Arctic char from Lake Hazen. Large-form char are especially susceptible to acquiring higher levels of infection due to their piscivorous diet. Consequently, this may result in some large-form char having a more limited opportunity to reproduce over their life time relative to small-form char. Gonad development in female large-form char may be more affected than males as more energy and space in the body cavity are required which become inhibited with very heavy infections.

The results from Lake Hazen and Craig Lake indicated that most parasites found in Arctic char were transmitted through copepods and that although variable, infections by *Diphyllobothrium* spp. indicated ecological segregation between small- and large-form char. The higher frequency of *Diphyllobothrium* spp. in large-form char reflected a piscivorous feeding habit and although this results in a higher growth rate (Reist et al. 1995), it appears to hinder the reproductive potential of the fish.

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Table 1. Prevalence (%) (P), mean intensity (± SD) (I) and mean abundance (± SD) (A) of parasite species among juveniles, and small-, large-, and unknown-forms of Arctic char in Lake Hazen and Craig Lake, Nunavut.

		Lake Hazen					Craig Lake		
		Juveniles	Small-form	Large-form	Unknown-form	Total	Juveniles	Adults	Total
Cestoda									
Diphyllobothrium ditremum	P	40.0	20.6	28.3	40.0	27.4	0	0	0
	I	30.3 ± 36.1	262.9 ± 455.3	689.8 ± 760.4	21.5 ± 26.2	422.0 ± 639.7	0	0	0
	A	12.1 ± 26.0	54.1 ± 222.1	195.0 ± 502.8	8.6 ± 17.6	115.5 ± 380.3	0	0	0
Diphyllobothrium dendriticum	P	0	5.9	15.2	0	9.5	0	0	0
	I	0	149.5 ± 207.2	239.0 ± 275.9	0	219.1 ± 253.0	0	0	0
	A	0	8.8 ± 50.8	36.4 ± 133.0	0	20.8 ± 98.0	0	0	0
D. *ditremum* & D. *dendriticum* combined*	P	70.0	88.2	93.5	80.0	88.4	0	50.0	28.0
	I	20.6 ± 30.6	156.9 ± 347.3	669.2 ± 826.9	82.8 ± 136.6	404.3 ± 681.8	0	3.4 ± 3.3	3.4 ± 3.3
	A	14.4 ± 26.9	138.4 ± 329.6	625.6 ± 816.2	66.2 ± 124.0	357.5 ± 653.7	0	1.7 ± 2.8	1.0 ± 2.3
Eubothrium salvelini	P	20.0	29.4	50.0	20.0	37.9	0	0	0
	I	9.0 ± 8.5	5.3 ± 5.6	14.8 ± 25.4	123 ± 0	14.8 ± 27.9	0	0	0
	A	1.8 ± 4.7	1.6 ± 3.8	7.4 ± 19.3	24.6 ± 55.0	5.6 ± 18.5	0	0	0
Nematoda									
Philonema agubernaculum	P	10.0	17.6	15.2	20.0	15.8	0	7.1	4.0
	I	1.0 ± 0	1.5 ± 0.8	4.3 ± 5.8	1 ± 0	2.7 ± 4.1	0	1.0 ± 0	1.0 ± 0
	A	0.1 ± 0.3	0.3 ± 0.7	0.7 ± 2.6	0.2 ± 0.4	0.4 ± 1.9	0	0.1 ± 0.3	0.04 ± 0.2
Crustacea									
Salmincola edwardsii	P	0	23.5	47.8	0	31.6	0	0	0
	I	0	3.9 ± 2.1	7.5 ± 8.7	0	6.6 ± 7.7	0	0	0
	A	0	0.9 ± 1.9	3.6 ± 7.1	0	2.1 ± 5.3	0	0	0
n=		10	34	46	5	95	11	14	25

* includes encysted plerocercoids.

Table 2. Percent frequency of occurrence of food items collected from Arctic char from Lake Hazen and Craig Lake that were examined for parasites.

	Lake Hazen				Craig Lake	
	Juveniles	Small-form	Large-form	Unknown-form	Juveniles	Adult
Chironomidae	80.0	79.4	43.5	60.0	90.9	71.4
Apatania zonella	0.0	0.0	0.0	0.0	18.2	0.0
Acari	0.0	5.9	0.0	0.0	0.0	0.0
Arctic char	10.0	5.9	30.4	20.0	0.0	0.0
Empty stomach	10.0	11.8	26.1	20.0	20.0	28.6
n=	10	34	46	5	11	14

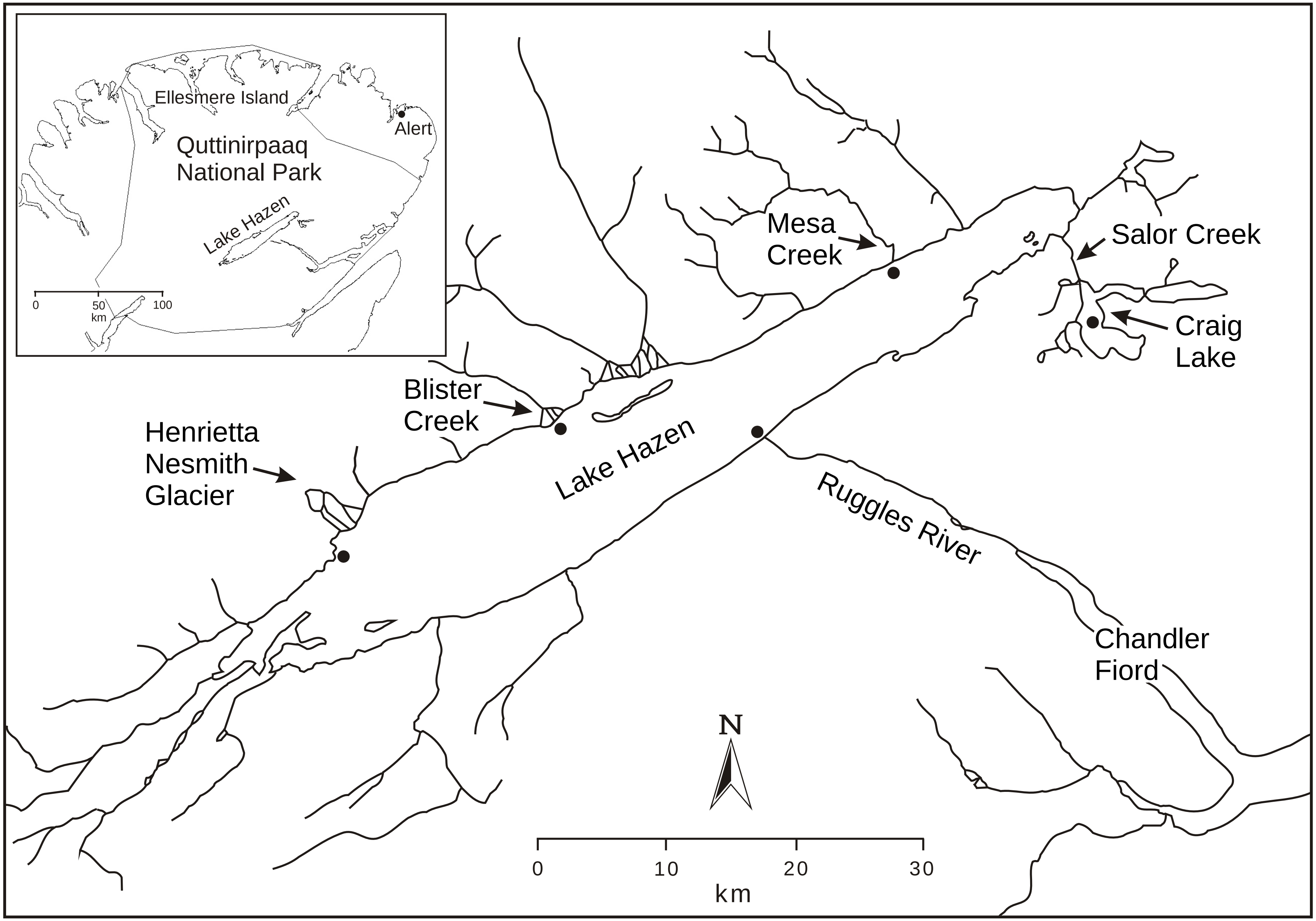


Figure 1. Map of the Lake Hazen and Craig Lake area, Quttinirpaaq National Park, Nunavut showing Arctic char capture locations (dots), June, 1992.

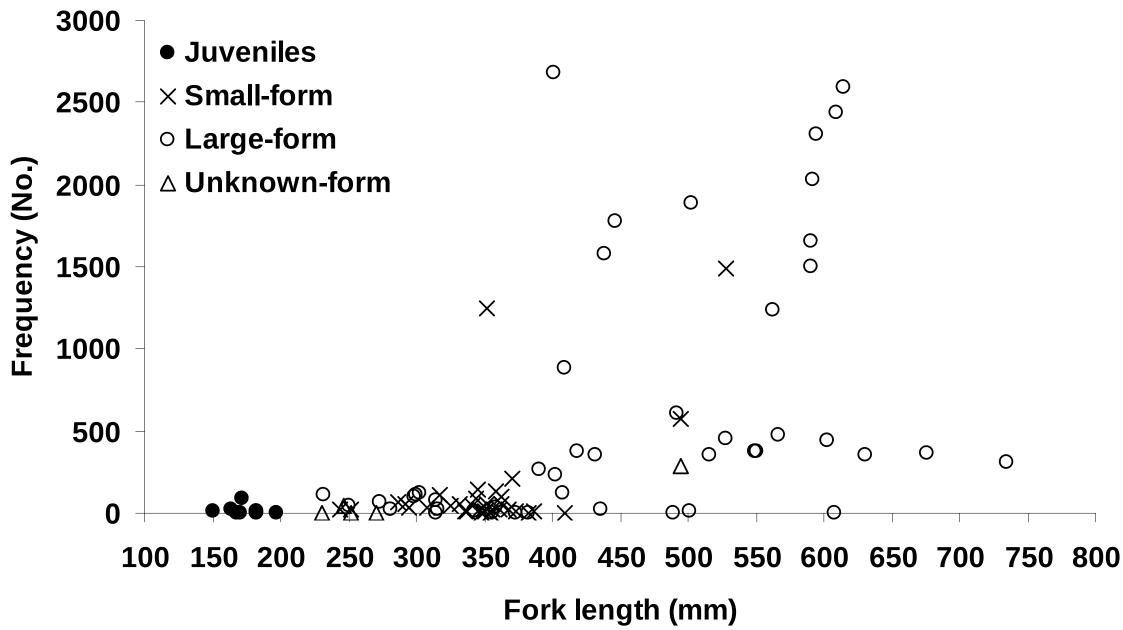


Figure 2. Frequency of *Diphyllobothrium* spp. plotted against fork length of juveniles, small-form, large-form, and unknown-form Arctic char from Lake Hazen.

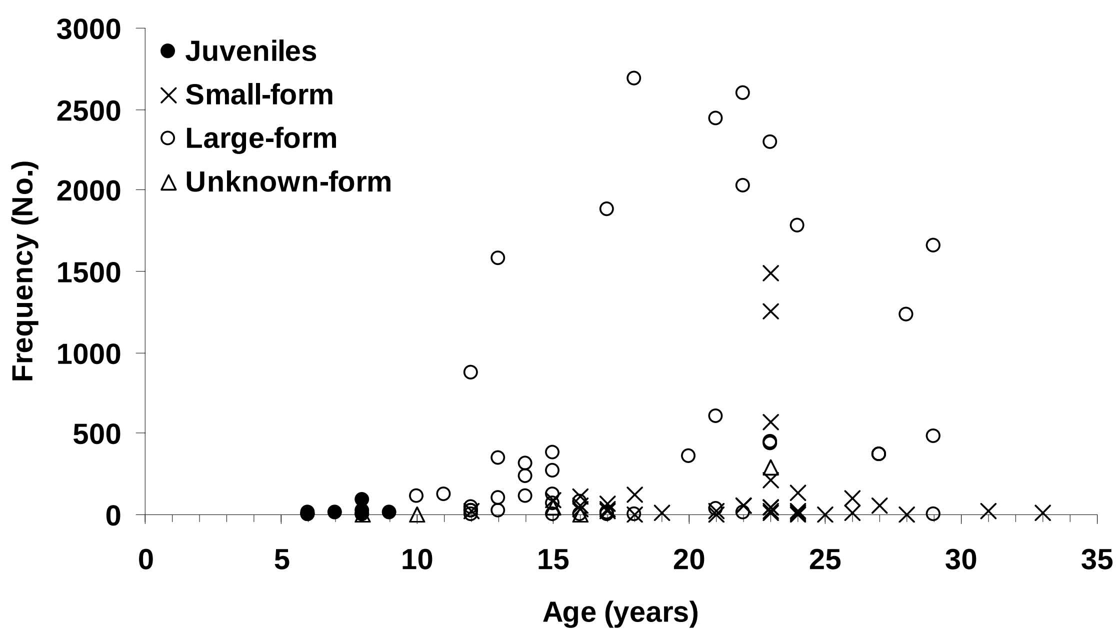


Figure 3. Frequency of *Diphyllobothrium* spp. plotted against age of juveniles, small-form, large-form, and unknown-form Arctic char from Lake Hazen.

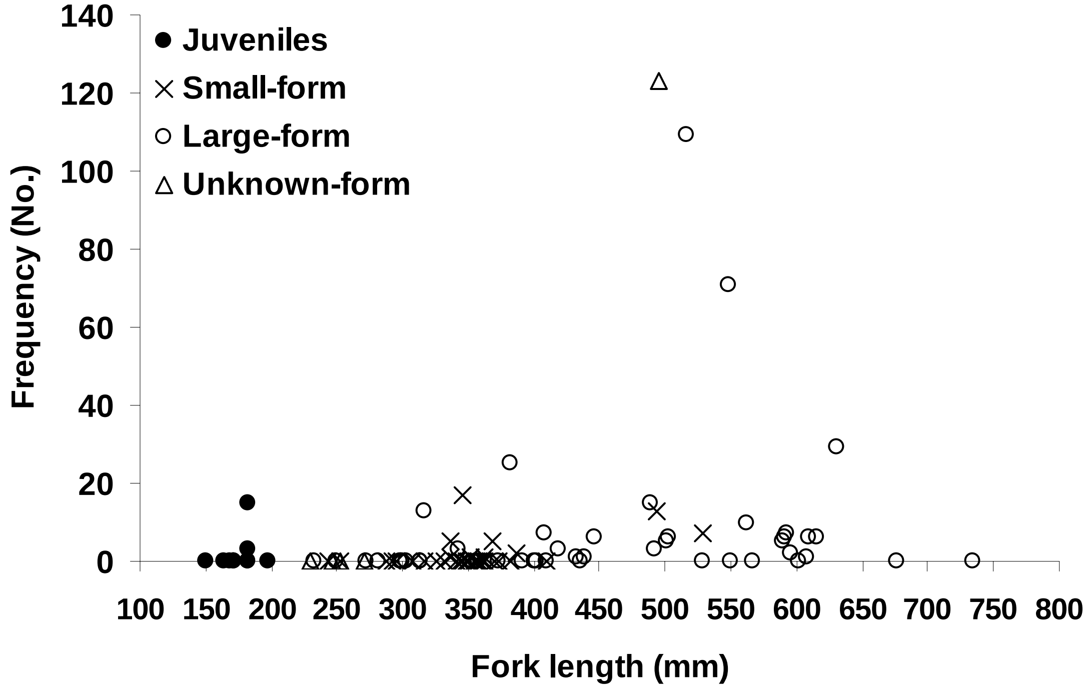


Figure 4. Frequency of *Eubothrium salvelini* plotted against fork length of juveniles, small-form, large-form, and unknown-form Arctic char from Lake Hazen.

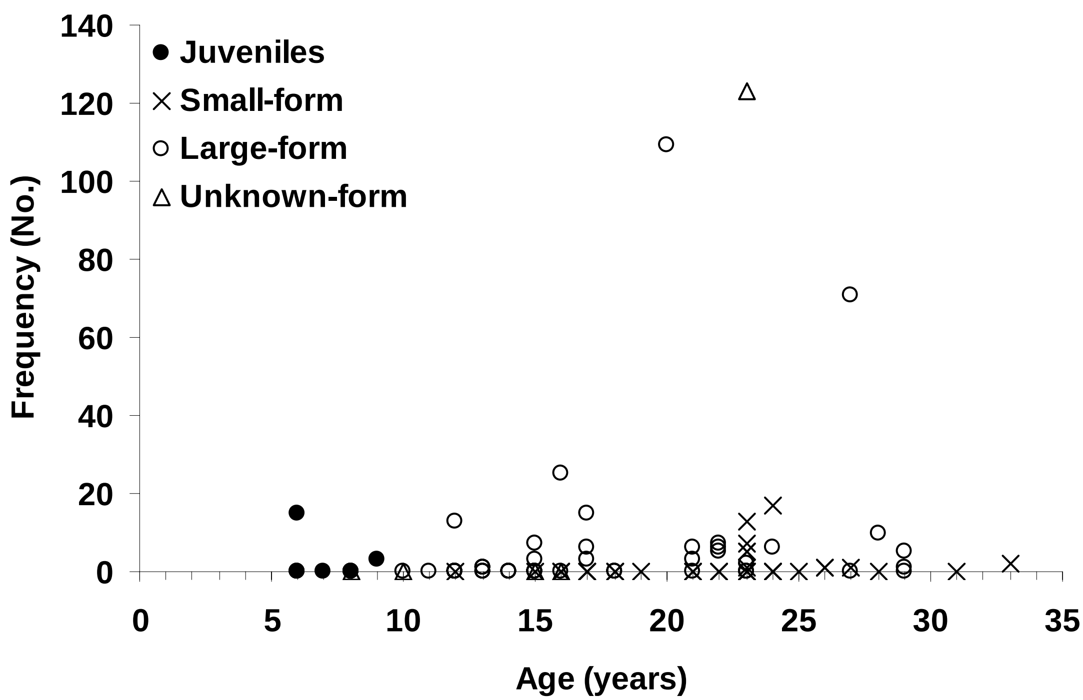


Figure 5. Frequency of *Eubothrium salvelini* plotted against age of juveniles, small-form, large-form and, unknown-form Arctic char from Lake Hazen.

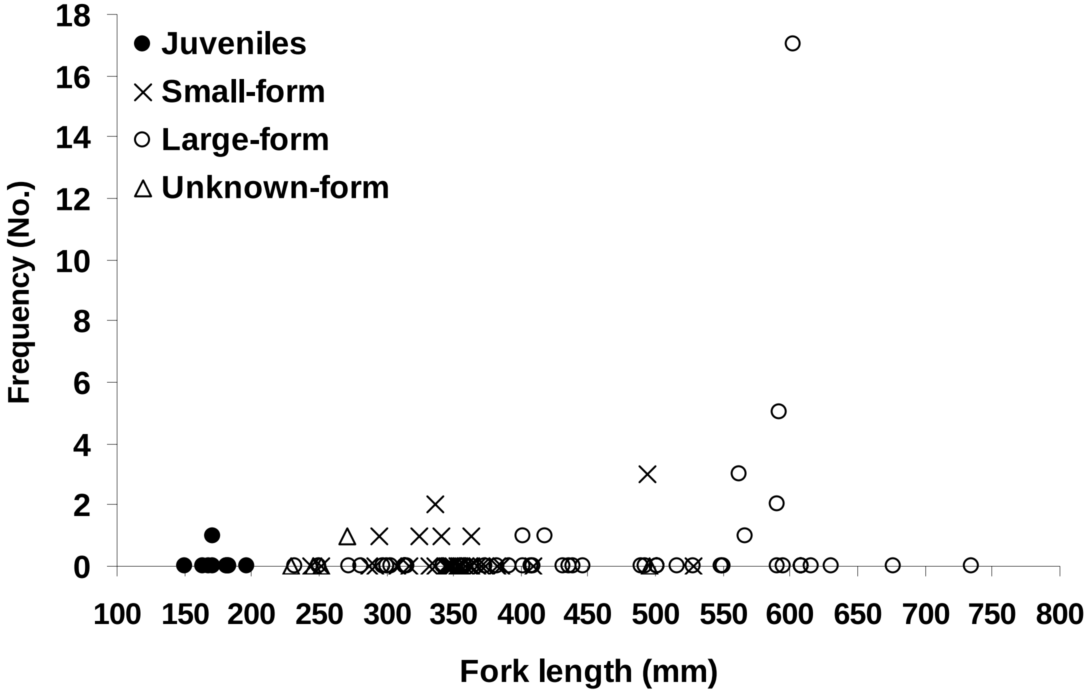


Figure 6. Frequency of *Philonema agubernaculum* plotted against fork length of juveniles, small-form, large-form, and unknown-form Arctic char from Lake Hazen.

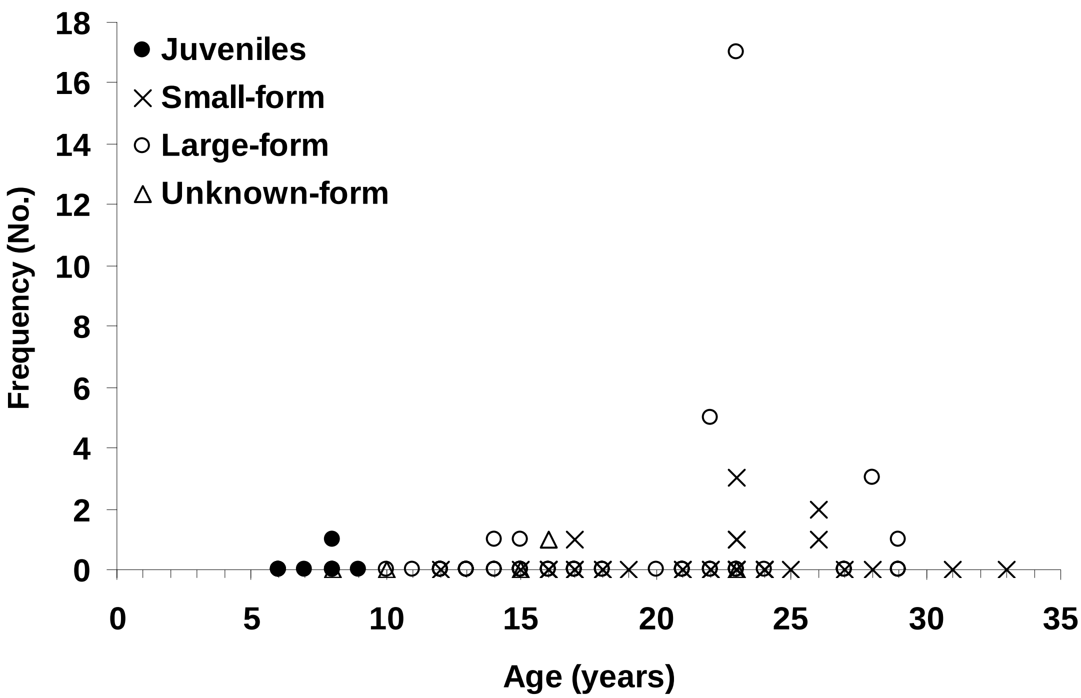


Figure 7. Frequency of *Philonema agubernaculum* plotted against age of juveniles, small-form, large-form, and unknown-form Arctic char from Lake Hazen.

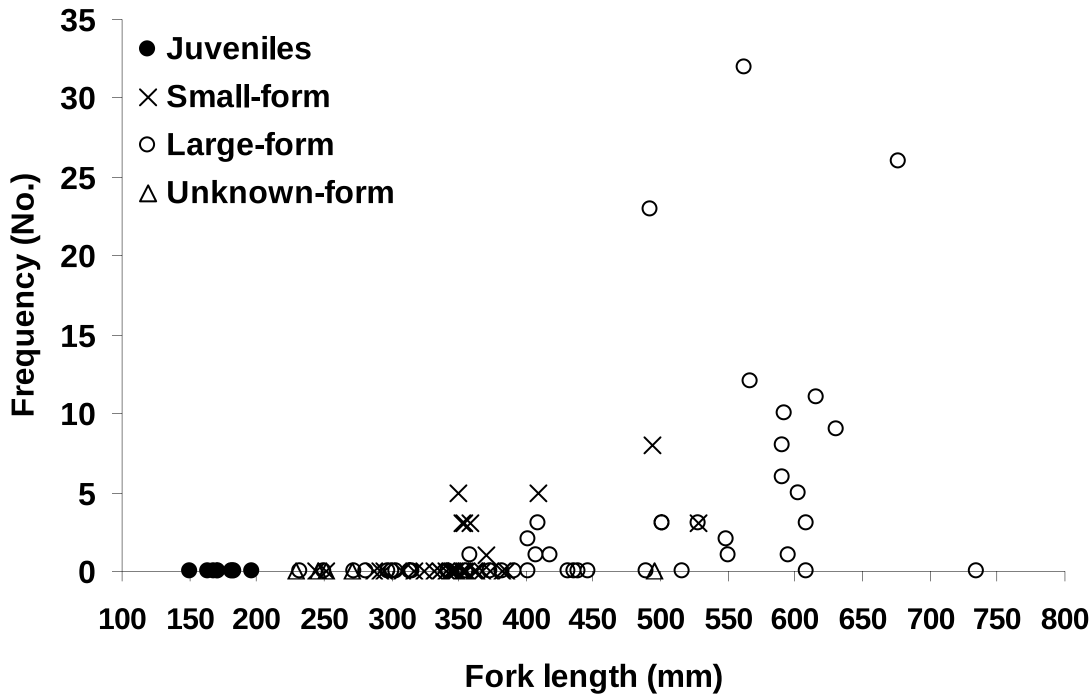


Figure 8. Frequency of *Salmincola edwardsii* plotted against fork length of juveniles, small-form, large-form, and unknown-form Arctic char from Lake Hazen.

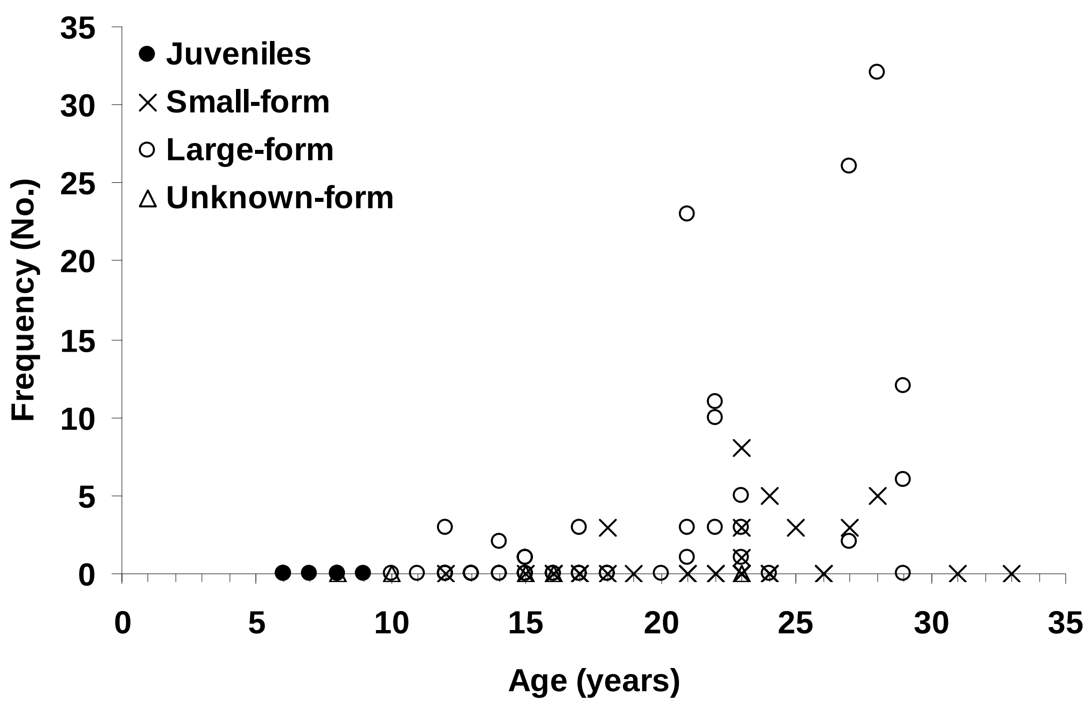


Figure 9. Frequency of *Salmincola edwardsii* plotted against age of juveniles, small-form, large-form, and unknown-form Arctic char from Lake Hazen.

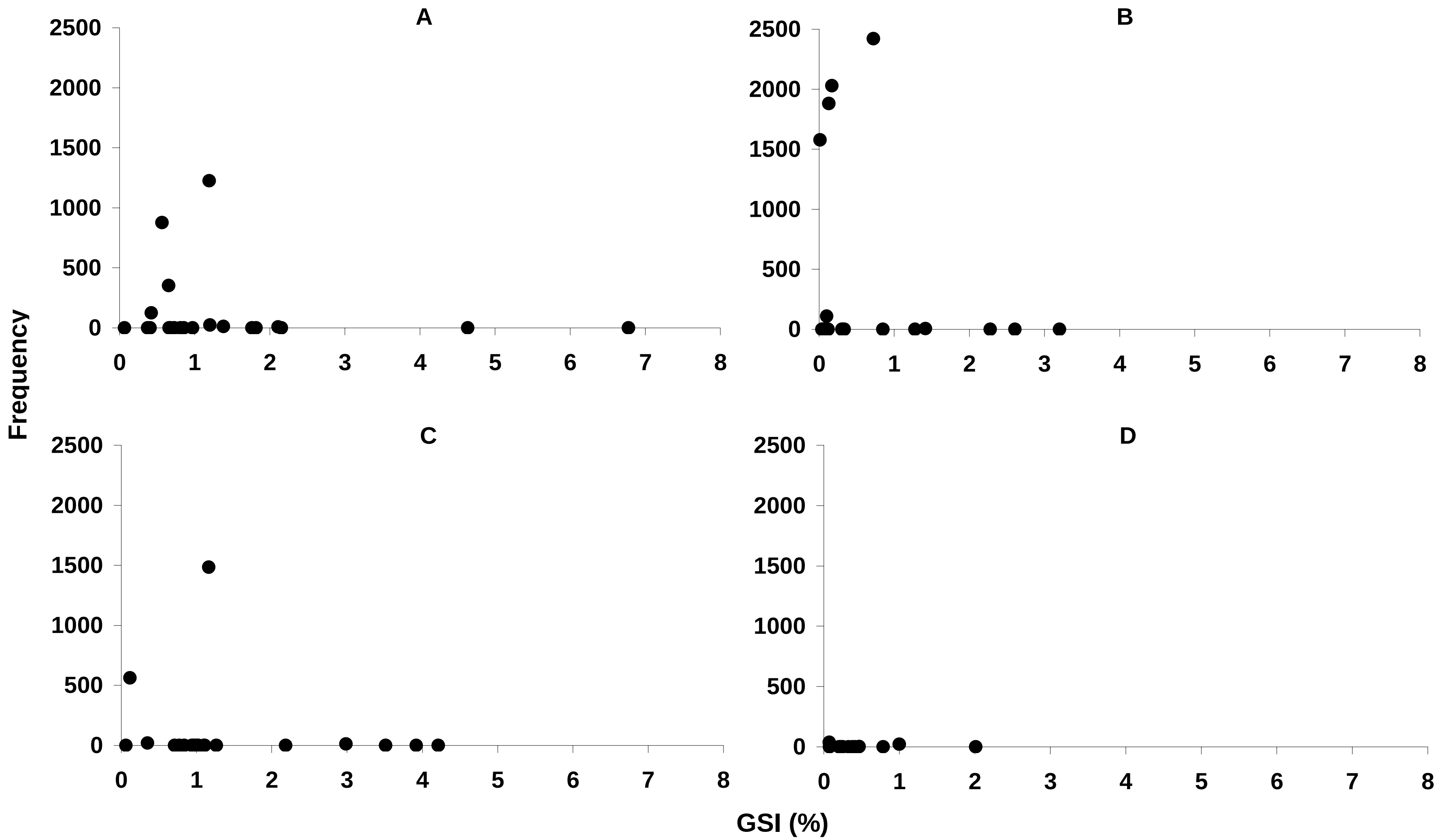
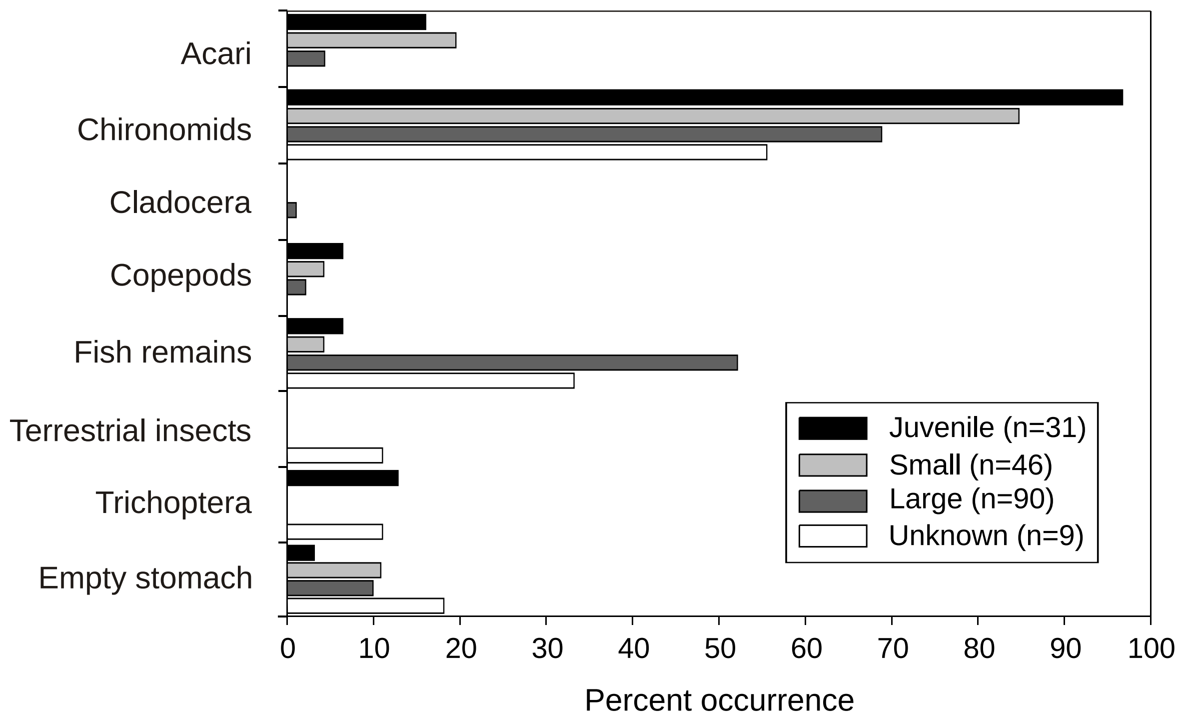
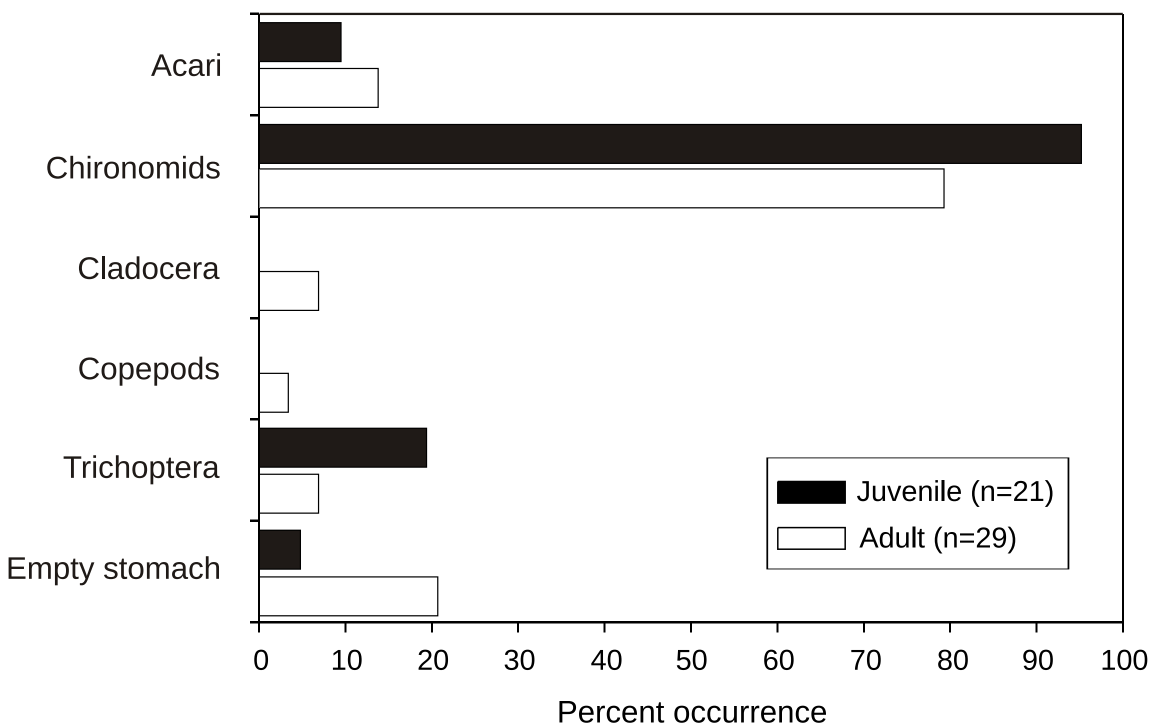


Figure 10. Frequency of *Diphyllobothrium* spp. plotted against the GSI of large-form female (A) and male (B), and small-form female (C) and male (D) Arctic char from Lake Hazen.



Appendix 1. Percent occurrence of food items in stomachs of Arctic char from Lake Hazen (n=176, including those sampled for parasites), June, 1992. Blank entries indicate zero occurrences of the item for the char form.



Appendix 2. Percent occurrence of food items in stomachs of Arctic char from Craig Lake (n=50, including those sampled for parasites), June, 1992. Blank entries indicate zero occurrences of the item for the char form.

Appendix 3. Chironomids (larvae and pupae) found in Arctic char stomachs from Lake Hazen (n = 9) and Craig Lake (n = 1), June, 1992.

Scientific name[1, 2]	Synonym[2]	Lake Hazen	Craig Lake
Arctopelopia cana			√
Chaetocladius sp.[3]		√	√
Heterotrissocladius oliveri	*H. subpilosus*[3]	√	
Heterotrissocladius maeaeri			√
Micropsectra sp.[3]			√
Micropsectra sedna	*Lauterbornia sedna*	√	
Micropsectra brundini		√	
Oliveridia tricornis	*Trissocladius tricornis*[3]	√	
Orthocladius charensis[3]		√	
Orthocladius lapponicus[3]		√	
Paracladius sp.		√	√
Procladius sp.[3]	*Psilotanypus* sp.		√
Protanypus sp.[3]		√	
Pseudodiamesa arctica[3]	*Diamesa arctica*	√	
Stictochironomus unguiculatus	*Chironomus unguiculatus*[3]	√	√
Tanytarsus sp.[3]	*Calopsectra* sp.		√

√ = reported present
[1] as identified by Bohdan Bilyj, Biotax, 12 Westroyal Road, Weston, ON, M9P 2C3
[2] Integrated Taxonomic Information System (ITIS) (http://www.itis.gov/index.html)
[3] also reported in the Lake Hazen area by Oliver (1963)