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Information to support the assessment of Arctic Char, *Salvelinus alpinus*, from the Isuituq River system, Nunavut

Informations à l'appui de l'évaluation de l'omble chevalier (*Salvelinus alpinus*) dans le réseau hydrographique de la rivière Isuituq, au Nunavut.

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ABSTRACT

Arctic Char, *Salvelinus alpinus*, is widely distributed throughout Northern Canada and is an important subsistence and commercial resource throughout much of its range. In the Cumberland Sound region of Nunavut (NU), this species is abundant in numerous waterbodies, several of which likely have commercial potential. Sustainability of harvest levels, however, must first be demonstrated prior to the transition to commercial status. This is typically done through an assessment of data collected as part of an exploratory fishery (STAGE II), which precedes the commercial stage (STAGE III) of a fishery. Data collected as part of the exploratory fishery may be complimented with several years of data collected through fishery independent research surveys conducted by Fisheries and Oceans Canada (DFO). Here, we present harvest data collected from subsistence and exploratory fisheries and population parameter data collected from DFO research initiatives in the Isuituq River system, NU specifically at Clearwater Fiord (waterbody code PG080; 66°37’ N, 67°52’ W). This fishery at Clearwater Fiord is currently fished under an exploratory licence, and in this assessment, the commercial potential of this fishery is evaluated. Since the inception of the exploratory fishery, harvest has varied between 2298.45 kg to 3378.91 kg per year with total landings for this exploratory period equal to 32151.37 kg round weight per year. Subsistence harvest, in this system is likely low, but variable (157-1255 fish per year). Subsistence harvest information, however, encompasses only a short time series and has likely been overestimated in some years. Population parameter data (weight, length, condition and age) for Isuituq Arctic Char show a high degree of temporal variation. A lack of negative biological trends in the majority of the parameters examined suggests the Isuituq stock is healthy and is withstanding current harvest levels. That is, the Isuituq fishery appears to be stable and is likely fished at or below the sustainable rate of harvest which suggests that this fishery could transition to commercial status at the current harvest levels. Small increases in quota could be implemented followed by careful monitoring of the fishery. To allow better assessment of the Isuituq Arctic Char stock and the sustainability of the fishery, population abundance should be determined for this system and information to address whether harvest represents a mixed-stock fishery should be collected.

RESUMÉ

L’omble chevalier (*Salvelinus alpinus*) est présent à grande échelle dans tout le Nord canadien et représente une importante ressource pour la subsistance et le commerce dans presque toute cette aire de répartition. Dans la région de la baie de Cumberland, au Nunavut (NU), cette espèce est abondante dans de nombreux cours d’eau, dont plusieurs présentant possiblement un potentiel commercial. Il est toutefois nécessaire d’établir la durabilité des niveaux de capture avant d’autoriser la transition vers la pêche commerciale. Dans cette perspective, il faut habituellement procéder à une évaluation des données recueillies dans le cadre de la pêche exploratoire (PHASE II), qui constitue l’étape préalable à la pêche commerciale (PHASE III). Les données recueillies dans le cadre de la pêche exploratoire peuvent être supplémentées au moyen de données émanant de relevés d’études indépendantes sur cette pêche couvrant plusieurs années et ayant été menées par Pêches et Océans Canada (MPO). Le présent document rapporte les données recueillies par l’entremise des activités de pêche de subsistance et de pêche exploratoire, de même que des données sur les paramètres de population provenant des initiatives de recherche dirigées par le MPO dans le réseau de la rivière Isuituq, NU, et plus particulièrement dans le fjord Clearwater (code de cours d’eau PG080; 66°37’ N, 67°52’ O). L’omble chevalier du fjord Clearwater est actuellement pêché en vertu d’un permis de pêche exploratoire, et la présente évaluation a pour but d’analyser le potentiel commercial associé à cette espèce. Depuis le début de la pêche exploratoire, la capture a varié entre 2 298,45 kg et 3 378,91 kg par année, et les prises totales comprises dans cette période exploratoire sont égales à un poids brut de 32 151,37 kg par an. Dans le réseau hydrographique concerné, la capture de subsistance est susceptible d’être peu importante, mais variable (157 à 1 255 poissons par an). Les données sur la capture de subsistance ne couvrent cependant que de brèves séries chronologiques et ont probablement été surestimées lors de certaines années. Les données relatives aux paramètres de population (poids, longueur, condition et âge) de l’omble chevalier de la rivière Isuituq présentent un degré de variation important en fonction du temps. L’absence de tendances biologiques négatives pour la majorité des paramètres examinés donne à penser que le stock de la rivière Isuituq est sain et résiste aux niveaux de capture actuels. Ainsi, la pêche dans la rivière Isuituq semble être stable et est probablement égale ou inférieure au niveau de capture durable, ce qui signifie que la pêche pourrait passer à la phase commerciale en fonction des niveaux de capture actuels. Des quotas légèrement supérieurs pourraient être établis à la condition que la pêche fasse subséquemment l’objet d’un suivi attentif. Pour qu’il soit possible d’évaluer avec plus d’exactitude le stock d’omble chevalier de la rivière Isuituq et la durabilité de la pêche, il conviendrait d’établir l’abondance de la population dans ce réseau hydrographique et d’obtenir des informations permettant de déterminer si la capture représente une pêche de stocks mélangés.

INTRODUCTION

Arctic Char (*Salvelinus alpinus*) is one of the most widely distributed northern freshwater fishes (Scott and Crossman 1998) and this species has a long history of harvest in a variety of fisheries. For the Inuit peoples of Nunavut, Arctic Char have historically been, and continue to be, an important subsistence resource (Priest and Usher 2004). In the Cumberland Sound region of the territory, and specifically for the community of Pangnirtung, numerous waterbodies are important for the subsistence harvest of this species. The potential for several of these waterbodies to support a commercial fishery has been questioned, however, before a commercial fishery is initiated, the sustainability of the harvest must be evaluated. This is typically done by operating a fishery under an exploratory licence for five or more consecutive years. The specific objective of the exploratory stage is to determine whether the harvested stock or population can sustain the level of fishing pressure by collecting and analysing biological and catch and effort data (DFO 2010). Essentially this stage assesses the resilience of a stock to sustained fishing pressure and if resilience to the exploitation is demonstrated, the commercial stage may be reached. Some of the Arctic Char producing waterbodies in the Cumberland Sound region including Kingnait Fiord are currently being fished under exploratory licences (DFO 2009).

The feasibly of a commercial fishing operation in the Isuituq River system in Cumberland Sound (Fig. 1, 2) is presently being assessed. Typically, the majority of fishing in this area commences in late summer and early fall at the head of Clearwater Fiord at a location locally know as “Isuituq” (waterbody code PG080; 66°37' N, 67°52' W; Fig. 2). Arctic Char move up the Isuituq River system to spawn and overwinter and several other waterbodies in, or close to, the Isuituq system have been fished in the past under commercial licences and for subsistence purposes (e.g., waterbody codes PG062 (66°36’ N, 67°54’ W), PG086 (66°37’ N, 67°45’ W) and PG092 (66°45’ N, 68°08’ W); Fig. 2), but to a much lesser extent than at the head of Clearwater Fiord where char congregate prior to moving into the river. Additionally, several nearby waterbodies in the Ranger River system and Millut Bay, have been fished in the past for subsistence and commercial purposes (e.g., water body codes PG003 (66°43’ N, 67°46’ W), PG034 (66°34’ N, 67°56’ W) and PG087 (66°43’ N, 67°48’ W); Fig. 2). This assessment only evaluates, specifically, data from the area at the head of Clearwater Fiord (i.e., “Isuituq”) during the July/August period before the Arctic Char move into the river system.

As with most of the waterbodies in Cumberland Sound, the Isuituq system has a long history of subsistence fishing, but since 1997 an exploratory fishing licence has been issued for Isuituq (at the head of Clearwater Fiord) with an annual quota of 2500 kg. Under an exploratory licence the harvesters are expected to collect five years of data and samples during the course of the fishery. In the case of the Isuituq fishery, no data were collected during the first five years of the fishery and it has therefore retained the status of an exploratory fishery.

There is interest in converting several Cumberland Sound waterbodies, including the Isuituq River, from exploratory to commercial fisheries and before doing so, stock assessment research data, in addition to data collected under an exploratory licence, is often assessed.The community of Pangnirtung requested direct assistance from DFO Science Branch in acquiring suitable information to assess the commercial potential of the stock. The principle of this is to collect biological and catch effort data, to compliment that collected by exploratory fisheries. Subsequently these data are used to gain an accurate understanding of the biology, life history and stock structure of this harvested species. More importantly, stock assessment data are used to assess the response of the population to the level of exploitation. Unfortunately in Cumberland Sound, for most waterbodies, scientific information on the biology of Arctic Char and its response to harvest is still quite scarce or is generally outdated (e.g., Moore 1975a, b).

DFO has collected data on several Cumberland Sound waterbodies over the last few years. In order to effectively manage these fisheries, Fisheries and Aquaculture Management (FAM) sector of DFO has requested a report on the current status of the Arctic Char from these Cumberland Sound systems. In the Isuituq River system, DFO has been collecting biological and catch and effort data as part of a research-oriented (scientific) fishing effort since 2002. As such, this, waterbody is one of few in the Cumberland Sound region that has sufficient data necessary for stock assessment analyses and thus is a prime candidate for FAMs request. In this assessment, we present six years (2002-2006, 2008) of biological and catch and effort data for Arctic Char harvested from the Isuituq River system, specifically at Clearwater Fiord (PG080). We examine trends in biological characteristics of anadromous Isuituq River Arctic Char across a six year research-oriented fishery time series to evaluate the current status of this stock. The objective is to assess and report on the current status of Isuituq system Arctic Char to provide advice on the transition of the exploratory fishery to that of a commercial fishery. Additionally, the data presented in this assessment provide a benchmark for future stock assessment surveys; information vital to understanding responses to exploitation.

MATERIALS AND METHODS

HARVEST INFORMATION

Several sources of harvest and fisheries assessment data were included in this assessment including subsistence harvest data and fishery independent research data.

Subsistence harvest data are reported as the number of fish caught per year. Although the Isuituq area has a long history of subsistence harvest, unfortunately only five years (1996-2000) of subsistence catch data, provided by the Nunavut Wildlife Harvest Study (Priest and Usher 2004), have been recorded. While the time series of subsistence harvest is limited, these data do provide an idea of the numbers of fish harvested in Isuituq subsistence fisheries and the variability of such catches. Unfortunately no length or weight data were recorded and ageing structures were not collected in these fisheries.

Several years of research survey sampling have been conducted by DFO in the Isuituq system. These data form the foundation of the present assessment and were used to model population parameters of Isuituq Arctic Char.

Several years of fishery harvest data are available (reported as kilograms of Arctic Char harvested per year) through the Pangnirtung fish plant sampling program but were not used in this assessment. This information is mainly available for the head of Clearwater Fiord from 2005 and 2006, but limited data are also available for other waterbodies on the Isuituq system. These data were compiled from commercial fish plant trade records in the community of Pangnirtung. Unlike the subsistence catch data, there are some length and weight data for Arctic Char caught under the exploratory licence. Prior to 2007, Pangnirtung Fisheries Ltd. would not purchase Arctic Char weighing less than 1.82 kg (4 lbs, K. Ulrich, Pangnirtung Fisheries Ltd., Pangnirtung, NU, pers. comm.). This selective purchasing of fish (i.e., “high grading”) results in data biased to older and larger fish and as such, the plant sampling data do not accurately represent what is truly captured by fishermen harvesting under an exploratory licence.

FISH COLLECTION AND BIOLOGICAL SAMPLING

The information presented in this document is based primarily on data obtained from DFO research surveys conducted from 2002-2006 and in 2008. For all years, sampling commenced towards the end of July or the beginning of August (Table 1) in estuarine habitat at the mouth of the Isuituq River in Clearwater Fiord (waterbody code PG080; Fig. 2). At this location, Arctic Char congregate in the summer prior to commencing upstream migrations to spawning and over-wintering areas in the Isuituq system. All life history stages, to some degree, however, are likely present at Isuituq during summer fisheries. To collect a representative sample of the population, research multi-mesh gill nets were fished consisting of the following stretched mesh sizes: 38.1 mm (1.5-inch), 50.8 mm (2.0-inch), 63.5 mm (2.5-inch), 76.2 mm (3.0-inch), 88.9 mm (3.5-inch) and 101.6 mm (4.0-inch). Additionally, in each year of the assessment, research nets with the same mesh size (139.7 mm, 5.5-inch) used for subsistence and exploratory or commercial fisheries were also fished to collect information on sizes and ages of Arctic Char likely to be exploited in commercial and subsistence fisheries of the area. Research multi-mesh gill nets were 54.9 m in length with 9.1-m-long panels while fishery equivalent nets ranged in length from 24.4 - 45.7 m. Where available, harvest data (number of fish or kg harvested) from additional fisheries (subsistence and exploratory) is also presented and compared to the fishery-independent research data.

Arctic Char captured in the Isuituq research survey were sampled for fork length (± 1 mm), round weight (± 1 g), sex, maturity, gonad weight (± 1 g) and sagittal otoliths were collected for ageing purposes. The capture net and mesh size were recorded for each fish and catch and effort data (hours fished and number of fish captured) were recorded throughout the duration of fishing.

All Arctic Char were aged using sectioned otoliths. Ages were determined by two age readers; one from 2002-2006 and the second in 2008. Given concerns regarding inter-reader discrepancies in age determination, a random subsample of 30 fish per year was re-aged by the second reader to assess the consistency of ageing throughout the assessment. Paired t-tests (or nonparametric alternatives) were used test for systematic differences between the ages provided by the different readers (Campana *et al.* 1995). Two measures of precision were then calculating for comparing age determinations. First, average percent error (APE, Beamish and Fournier 1981) was expressed as:

$$APE = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{\left|x_{ij} - x_j\right|}{x_j}\right]$$

where, where x_{ij} is the *i*th age determination of the *j*th fish, x*j* is the mean age of the *j*th fish, *R* is the number of times each fish is aged and N is the total number of fished aged. As recommended by Chang (1982), APE was then essentially expressed as a coefficient of variation (CV) for testing the reproducibility of age determination between readers using the following equation:

$$CV_j = 100 \times \frac{\sqrt{\sum \frac{\left(X_{ij} - X_j\right)^2}{R-1}}}{X_j}$$

where CV_j is the coefficient of variation for the $_j$th. CV_j can be averaged across fish to produce a mean CV. Finally, the ages provided by the two readers were plotted for a qualitative inspection of age discrepancies.

DATA ANALYSIS

Catch-Per-Unit-Effort (CPUE)

Catch and effort data were recorded and these data were used to calculate catch-per-unit-effort (CPUE) for both multi-mesh (across all mesh sizes) nets and separately for fishery nets. CPUE was calculated separately for each net type (research multi-mesh vs. fishery) as the number of fish landed per 9.29 m^2 (100 ft^2) per 24 hours of fishing. Univariate, generalized linear models (GLMs; SPSS vers. 15.0) were used to test for differences in CPUE between gear types and a Bonferroni post-hoc test was used to test for significant differences among years.

Biological Analysis

Arctic Char sex ratios were calculated for each year of the fishery. Significant differences among years was tested using non-parametric Chi-square tests (α = 0.05). The same procedure was used to test for differences in the frequency of maturity stages (immature, mature or resting) among years.

Comparisons of trends (trend analyses) in age, length and weight structure (and analyses employing these data) were used to assess the response of Isuituq Arctic Char to the effects of fishing. Mean weight, length and age were compared between sexes for each year using two-sample t-tests (α = 0.05). Analysis of variance (ANOVA, α = 0.05) or the non-parametric alternative (Kruskal-Wallis ANOVA on ranks) was used to test for differences in mean weight, length and age across years. A post hoc sequential Bonferroni procedure (Rice 1989), or Dunn's post-hoc test for non-normal data with unequal sample sizes, was used to test for the significance of pairwise comparisons. The same procedures were also used to test for differences between gear types (sexes combined where there were no significant differences) in length and age of fish captured across years. The frequency distributions of length and age were also compared among years. Two-sample Kolmogorov-Smirnov Goodness of Fit tests (with Bonferroni adjustments of alpha (0.05) for pairwise comparisons) were used to test for pairwise yearly differences in frequency distributions.

Fulton's relative condition factor (K; Ricker 1975) was calculated as:

$$K = \frac{W \times 10^5}{L^3}$$

where W and L are weight (g) and fork length (mm) respectively. Condition was summarized as the annual mean determined from individual specimens and was also compared across years.

The weight-length relationships for Arctic Char were described using the linear regression model. The weight-length relationship,

$$W = aL^b$$

was transformed into its logarithmic form expressed as:

$$\log_{10} W = a + b(\log_{10} L)$$

where W is the round weight (g), L is the fork length (mm), a is the y-intercept and b is the slope of the regression. The parameters *a* and *b* were calculated by least-squares regression separately for males and females in each sampling year.

Arctic Char length at age (by sex and year) was modeled using the von Bertalanffy growth function expressed by the equation:

$$L_t = L_\infty \left(1 - e^{-K(t - t_0)}\right)$$

where L_t is the estimated length at time t, L_∞ is the maximum length, K is the body growth coefficient and t_0 is the theoretical length at age 0 (Ricker 1975). Statistical differences in growth between sexes within years and between sampling years (2002 and 2008) were determined using analysis of the residual sum of the squares following Haddon (2001).

To compare potential differences in maturity indices (sexes combined) across sampling years, the length and age at 50% maturity (L_{50} and A_{50} respectively) was determined from non-linear, logistic regression. The proportion mature within a given length or age class was modeled as:

$$P_i = \frac{a}{1 + e^{-\left(\frac{x - x_0}{b}\right)}}$$

where *Pi*, the proportion mature (0.00-1.00) for each length class (*x*) or age class (*x*). Additionally, the age at first maturity was determined and compared among years.

Finally, following Ricker (1975), instantaneous mortality (Z), annual survival (S) and annual mortality rates (A) were determined from catch curves for each sampling year. Briefly, the natural log of age class frequency was plotted against age for each year. Least squares regression was then used to fit a curve to descending limb of the catch curve (from modal year class plus one year to the oldest year class where n>1). Instantaneous mortality rate (Z), annual survival rate (S) and annual mortality rate (A) were then calculated as follows: Z=positive slope of regression, $S=e^{z}$, A=1-S (Ricker 1975). Given the low sample sizes of the multi-mesh nets, catch curves were only plotted for data obtained in commercial (139.7 mm) gill nets.

RESULTS AND DISCUSSION

HARVEST

Accurate information on total harvest is essential for assessing the status of the stock and for implementing a sustainable harvest rate that is economically viable. The fishery at the head of Clearwater Fiord likely targets a mixture of Arctic Char stocks from the Isuituq (PG080 and PG092) and Ranger (PG003, PG034 and PG087) river systems and other nearby river systems (PG062 and PG086). This, however, has yet to be tested quantitatively. In a fishery where several populations are potentially exploited (i.e., a mixed-stock fishery), an accurate description of what populations are being harvested and to what extent is essential, both of which are unknown for Isuituq. Future molecular genetic research initiatives will likely resolve some of the current unknowns regarding the exploitation of mixed-stocks.

Harvest information in the Isuituq system is provided by six years of fishery-independent research sampling (discussed below), although the time series for these data is relatively short (2002-2006, 2008, Table 2). Exploratory/commercial fishery harvest data are also available for several waterbodies in this system. These data, with the exception the fishing location at Isuituq, encompass only a few sporadic years (Table 2). Therefore, only harvest records for Isuituq (PG080) are considered in this assessment. Harvest from this fishery was relatively consistent and ranged from 2298.45 kg (1997) to 3378.91 kg (1998) and has averaged 2679.28 kg of Arctic Char per year since 1997. Using an average char weight of 2537.3 g (average weight of char caught using 139.7 mm nets for all years combined in this assessment) this corresponds to a harvest of 906 and 1332 fish for 1997 and 1998 respectively. Trends in these data, however, should be interpreted with caution given they were based on fishing to a quota of 2500 kg of Arctic Char in each year. This quota has not been modified since the origin of this fishery but it is consistent with those implemented in Arctic Char commercial/exploratory fisheries of the area (e.g., DFO 2005). It is however, smaller than those implemented in other Nunavut fisheries (DFO 2004). It should also be noted that Ijaruvung Lake (PG003) to the north of Isuituq also has a long history of commercial fishing including several years of harvest records, but as it drains to the Ranger River system, it is not included in this assessment. It is however possible, given that a mixture of populations are most likely harvested (i.e., this is a mixed-stock fishery) in Clearwater Fiord, that some Ranger River system fish are potentially captured in the Isuituq exploratory fishery. Without mark-recapture or molecular data, this remains an unknown.

A short time series (1996 – 2000) of subsistence harvest data is also available (Priest and Usher 2004, Table 1). Subsistence harvest was highly variable among years and ranged from 157 char in 1996 to 1255 char in 2000 (Table 2). Although this harvest is inconsistent from year to year, the high levels in some years, suggests that subsistence harvest can be quite substantial in this system and may have as pronounced an impact on the stock as commercial and exploratory harvest. For example, using an average char weight of 2537.3 grams (described above) an estimated 3184.0 kg of char were harvested in the Isuituq subsistence fishery in 2000. These data however, should be interpreted with caution as the information presented in the subsistence harvest study may not reflect true subsistence harvest but likely also accounts for some commercial and exploratory harvest. It is thought that the subsistence harvest data presented in the harvest study greatly overestimate the true subsistence harvest in the Isuituq system (M. Kisa, Pangnirtung resident, pers. comm.). If these data represent the true subsistence harvest, changes in this harvest could potentially have important consequences to the Isuituq Arctic Char stock. Pangnirtung residents however, have indicated that this is not a primary subsistence fishing location given the distance from the community and fishing at Isuituq most often occurs opportunistically when in the area for other purposes (i.e., hunting caribou, M. Kisa, Pangnirtung resident, pers. comm.). As such, it is likely that subsistence fishing at Isuituq is negligible, but updated subsistence harvest information will be vital in assessing subsistence harvest impacts on the stock in addition to exploratory/commercial harvests.

As mentioned above, no information is currently available on population sizes in this system. This is unfortunate as no estimate of the current exploitation rate can be calculated in order to effectively guide future management decisions (e.g., establishing quotas for exploitable biomass). If the current fishery appears to be withstanding present harvest levels, given the scientific uncertainty (unknown population sizes, mixed-stock fishery unknowns, etc.), small increases in quota could potentially be implemented followed by careful monitoring of the fishery. Ideally, a balance between exploitation rate and stability of the fishery would be determined. This is often considered to be a precautionary approach to management (DFO 2006) followed by adaptive management of the fishery (Kristofferson 2002, Kristofferson and Berkes 2005).

CATCH-PER-UNIT-EFFORT (CPUE) AND ABUNDANCE

Direct estimates of abundance are critical for fisheries stock assessments and the establishment of quotas, but in most Arctic systems, such data are rarely available. This is also the case for Isuituq Arctic Char. In the absence of abundance data, however, CPUE can be used as a useful estimate of relative stock size (Hilborn and Walters 1992). Changes in CPUE, assessed using the same fishing gear and methods, can therefore indicate changes in stock abundance. Unfortunately, for this assessment, there are no effort data available from subsistence and exploratory/commercial fisheries and therefore estimates of CPUE could not be calculated for these fisheries. In the future, data used to calculate CPUE should be collected from these fisheries to assist evaluations of this stock. Additionally, attempts to estimate abundance directly using, for example, weirs counts and/or mark-recapture methods, should be initiated. These methods have worked on Salmonines in other northern systems (Kristofferson *et al.* 1986, DFO 2004, Harwood *et al.* 2009) and such data could be valuable for future Isuituq Arctic Char assessments.

DFO research CPUE was calculated for 2002-2006, but not for 2008 as no effort data were available for that sampling year. CPUE was also calculated separately per gear type (i.e., experimental multi-mesh and fishery mesh size gill nets), given the differences in fishing effort and the unequal proportion of fish caught in each. Overall, trends in CPUE were quite similar between gill net types, but CPUE was highly variable among years within each (Table 3, Fig. 3). With the exception of 2003, where catch rates were abnormally high, CPUE appears to be relatively constant across sampling years, especially towards the end of the assessment.

There was no difference in CPUE between gear types ($t=0.39$; df 1, 167; $p=0.834$), but overall significant yearly differences within each was found (Multi-mesh net: $F=30.19$; df = 4, 90; $p<0.001$; Fishery mesh (139.7 mm): $F=16.02$; df = 4, 77; $p<0.001$). For both gear types, overall CPUE differences among years appears to be an artefact of the high catch rates in 2003 as CPUE in this sampling year was always significantly different from all other years ($p<0.05$, Table 4).

Overall, for multi-mesh nets, CPUE ranged from 2.71 Arctic Char/9.29 m^2 of mesh/24 hours in 2002 to 91.70 Arctic Char/9.29 m^2 of mesh/24 hours in 2003 and averaged 21.77 Arctic Char/9.29 m^2 of mesh/24 hours across all years. For fishery mesh size nets, CPUE ranged from 3.20 Arctic Char/9.29 m^2 of mesh/24 hours in 2005 to 62.99 Arctic Char/9.29 m^2 of mesh/24 hours in 2003 and averaged 19.42 Arctic Char/9.29 m^2 of mesh/24 hours across all years. As mentioned above, the high catch rates from 2003 have inflated the overall average CPUE for both net types.

Problems associated with using CPUE estimates for indices of abundance are well acknowledged (e.g., Maunder *et al.* 2006). For instance there are several assumptions that are rarely met and estimates can be temporally variable depending on factors such as timing of sampling, fish aggregation and or movement into the sampling area and potential environmental effects (e.g., temperature differences). In the present assessment, variability in CPUE is highlighted by the elevated estimates calculated for the 2003 sample. The high CPUE in 2003 is difficult to explain given the gear type (139.7 mm nets and multi-mesh nets), methods, location and time of fishing (late-July to early-August) were relatively consistent across years. Additionally, environmental variables (e.g., water temperature and weather) were also relatively consistent across years (T. Loewen, Fisheries and Oceans Canada, Winnipeg, MB, pers. comm.).

Our estimates of CPUE appear to be lower than those calculated for other research programs on Baffin Island (Kristofferson and Sopuck 1983, DFO 2005, Gallagher and Dick 2010). Overall, the consistency of our CPUE estimates (with the exception of 2003), especially in the latter years of the assessment, suggests that population sizes have remained relatively constant at this fishing location. It should be noted that our CPUE estimates, at best, reflect that the relative abundance of Arctic Char at the mouth of the Isuituq River (i.e., in Clearwater Fiord (PG080) in late-July/early-August appears to be constant. Our estimates do not necessarily reflect the relative abundance of the Isuituq River population given uncertainties regarding which, and to what extent, populations are being harvested in Clearwater Fiord.

BIOLOGICAL EVALUATION

Sex Ratios and Maturity

Over the duration of the research program, the sex ratio remained relatively constant and no statistical differences were found across all years (χ^2=6.18, df = 5, p=0.290). In every sampling year, males were more abundant than females (Table 5) and the male to female sex ratio averaged 1.33 and varied from 1.15 (2008) to 1.71 (2002; Table 5). These ratios are within ranges reported for other Arctic Char systems (Hunter 1976, Johnson 1983) including some in Cumberland Sound (Moore 1975a). The temporal stability of the sex ratio in this assessment may be evidence of the stock stability (Morgan 2008) of Isuituq Arctic Char. Shifts in sex ratio have been implicated as a compensatory response to exploitation (Silliman and Gutsell 1958).

Significant differences (χ^2=585.44, df = 585.44, p<0.001) in the percentage of maturity stages were evident among years (Table 5) and no trend could be qualitatively deduced. Post hoc analysis (comparisons of residual converted z-scores, z ±1.96 corresponding to α = 0.05) showed that significance among stages within years was variable, a result due to an underrepresentation or overrepresentation of most maturity classes in all years (data not shown). Considering mature fish only, for example, the percentage of mature fish ranged from 2.56% (2006) to 92.44% (2008, Table 5). On average, resting fish were most prevalent in catches (51.7%) followed by mature (28.3%) and immature fish (20.0%). These percentages, however, were extremely variable depending on the sampling year (Table 5), possibly a result of the variation in the timing of sampling. For example, if different life history stages congregate at the mouth of the Isuituq River en route to upstream spawning and wintering locations at different times of the year, then slight deviations in the timing of yearly sampling could explain the marked differences in maturity stages observed. Overall, the high prevalence of non-spawning fish (resting and immature) in most years is not surprising given all Arctic Char of all maturity stages are known to feed in Cumberland Sound (Moore and Moore 1974, Moore 1975b). Higher proportions of resting and immature fish could also be explained if a proportion of the current year spawners do not go migrate to marine/estuarine habitats in the year in which they spawn. This however, has yet to be confirmed.

Understanding the reproductive biology of a species (e.g., age and size at maturity) helps determine stock productivity and therefore a population's resilience to exploitation or other anthropogenic disturbances (Morgan 2008). In the current assessment, length (L_{50}) and age (A_{50}) at 50% maturity was used as a reproductive potential index. These measures were calculated (sexes combined) only for data collected from 139.7 mm mesh nets given the limited samples sizes produced from the multi-mesh nets. L_{50} ranged from 427 mm in 2003 to 515 mm in 2002 (Fig. 4). In the latter years of the assessment, L_{50} remained relatively stable, especially from 2004-2006. With respect to maturity at age, A_{50} varied between 8.2 in 2005 and 11.6 in 2003 (Fig. 5). Although A_{50} was also variable across all years, as with the L_{50} data, this index of maturity appears to be quite stable in the latter years of the assessment. Numerous studies provide evidence of trends for declining age and length at maturity in moderate to heavily exploited fish stocks (e.g., Olsen *et al.* 2004, 2005, Kendall *et al.* 2009). The consistency of maturity indices provided here, albeit over a short time series, offer subtle evidence for the stability of this stock and its ability to sustain the current harvest levels.

Overall, the mean age at first maturity was 8.3 for males and 8.7 for females (Table 5). Although these means were relatively close, age at first maturity was quite variable between years and between sexes and no trend was apparent across years or within sexes. Hegge *et al*. (1991) found in a highly exploited population of Arctic Char in Norway, maturity was attained by age six. The mean age of first maturity in Isuituq River Char is thus higher than that known for a heavily fished stock. Additionally, there was no indication that age at maturity was decreasing over the duration of the assessment, especially during the last four years of the study. In the face of exploitation, a decrease in age at maturity is expected as a compensatory response to harvest. This has been shown in several cases where field experimental manipulations of fish removal were used on other north temperate fish species to assess responses to exploitation (e.g., Healy 1975, Mills *et al.* 1995). Although this index appears stable in this assessment, the continued collection of maturity data for future comparisons would likely better resolve the effects of exploitation on maturity in the Isuituq system.

Biological Characteristics of Arctic Char

Weight

Individual Arctic Char weight ranged from 29.5 g (2006) to 5298 g (2008) and was variable among years and between sexes and net type within years (Table 6a). Overall, males were statistically heavier than females in each sampling year ($p<0.01$ for each yearly comparison by sex) with the exception of 2005 ($t=1.498$; df = 210; $p=0.136$). Furthermore, within each year, there were significant differences ($p<0.01$) in the weight of fish captured with multi-mesh and fishery size (139.7 mm) mesh with the latter capturing heavier fish on average ($p<0.001$, Fig. 6a). Among years, both male weight and female weight varied significantly (males: $H=122.33$; df = 5; $p<0.001$; females: $H=87.39$; df = 5; $p<0.001$). Nine of 15 and eight of 15 pairwise yearly comparisons, for males and females respectively, were significant subsequent to Dunn’s post hoc procedure ($p<0.05$, Table 7a). Additionally, there were significant differences among years in the weights of fish captured in each net type (139.7 mm nets: $H=175.34$; df = 5; $p<0.001$; multi-mesh nets: $H=35.16$; df = 5; $p<0.001$). Following Dunn’s post-hoc test, 11 of 15 and three of 15 pairwise yearly comparisons were significantly different for 139.7 mm nets and multi-mesh nets respectively ($p<0.05$, Table 7b).

Mean round weight appears to be relatively stable across the duration of the assessment (Table 6a, Fig. 6a) although annual variation is evident. The mean weights reported here (in 139.7 mm mesh gill nets) are consistent with weights for other Nunavut Arctic Char fisheries (DFO 2004) including data from Cumberland Sound (Moore 1975a). Mean weight is higher in the final year of the assessment compared to data from 2002. Long-term declines in mean weight can be indicative of heavy exploitation (Dempson *et al.* 2008) and given that this index does not appear to be declining in the current assessment, the fishery seem to be stable given the current harvest levels.

Length

Individual fork length ranges from 145 mm (2006) to 758 mm (2002), but mean fork length was also quite variable depending on the year, sex and gear type employed (Table 6b). Males were significantly longer than females within each year ($p<0.01$) with the exception of 2005 ($t=1.159$; df = 210; $p=0.248$). Additionally, each year, there were statistical differences in the length of fish captured with multi-mesh and 139.7 mm gill nets with the latter capturing larger fish on average ($p<0.01$, Figure 6b). Fork length also varied significantly among years for both sexes (males: $H=127.88$; df = 5; $p<0.001$; females: $H=83.10$; df = 5; $p<0.001$) and the majority of the pairwise yearly comparisons were significant different for both males (8 of 15) and females (8 of 15, $p<0.05$, Table 7c). Fork length also varied significantly among years for Arctic Char captured in both net types (139 mm nets: $H=169.34$; df = 5; $p<0.001$; multi-mesh nets: $H=40.42$; df = 5; $p<0.001$). The majority of pairwise yearly comparisons in fork length were significant for the 139.7 mm nets (12 of 15), but not the multi-mesh nets (5 of 15, $p<0.05$, Table 7d). The length data, to a considerable extent, strikingly mirrors that of the weight data for both net types (i.e., both weight and length are characterized by the same increases and decreases across years). As with the weight data, no clear trend in mean fork length across sampling years was resolved and although annual variation is noticeable, mean fork length remained relatively stable across years.

Length-frequency distributions were unimodal with modal lengths relatively stable across years (Fig. 7). The modal values for length ranged between 550-650 mm. There is considerable variability in the shapes of the length distributions from year to year. This variability is reflected in the pairwise comparisons (2 sample Komolgorov-Smirnov tests) that indicate several of the yearly distributions were significantly different ($P<0.001$, Table 8). Importantly however, there were no consistent shifts in modal lengths.

The distributions were typically skewed towards the larger sizes (Fig. 7) and as such, there was weak representation of the smaller size classes throughout all years of the study. Therefore, in some years, the distributions appear to be truncated. This was caused due to the higher proportion of fish that were captured using the 139.7 mm mesh nets (Table 1) therefore over-representing the number of larger sized fish captured in each year. This raises concerns regarding future sampling protocols with respect to sample mesh sizes. To truly obtain an accurate representation of the population (in terms of length, weight and age), it is recommended that multi-mesh nets (that also include a 139.7 mm mesh panel) be used solely for future research surveys. Information on the biological characteristics of the harvested animals could be attained from the plant sampling program currently under development. Since length and age distributions become truncated in severely exploited populations (Johnson 1980) it is vital that gear types be used that will collect biological data that accurately represent current population indices. This should greatly reduce misinterpretation of the data. Given the relatively stability (and lack of negative biological trends) across years observed in our length data, however, it does appear that present harvest levels this system have had a negligible impact on the length structure of Isuituq Char.

The relationships between fork length and round weight for each sex within sampling year are presented in Fig. 8 and the parameters for these linear regressions are presented in Table 9. The length-weight relationships of Arctic Char were similar among years (Fig. 8). Likewise, males and females had similar weight length relationships, suggesting that condition varied little temporally or by sex.

Condition

Given the overall stability in weight and length data, it is not surpirising that relative condition factor (K) appears relatively constant (although significantly different: $F=8.75$; df = 5, 1197; $p<0.001$) across years (Fig. 6d). For both 139.7 mm mesh size nets and and multi-mesh nets, condition remained relatively stable (Fig. 6d) varying from from 1.14 in 2002 to 1.24 in 2005 (data not shown). Although temporal variation is apparent, condition factor did not vary annually as much as mean weight, length or age (Fig. 6d). Additionally, differences in condition between the two net types was not as pronounced as that shown for the other three biological measures. Condition factor is often used as an index of fish health (Van Den Avyle 1993). Dramatic changes in condition were not observed across years, thus, it appears that the Isuituq fishery has had a minimal effect on Arctic Char condition in this system. In fisheries where high harvest rates have adversly affected population structure, significant changes in mean condition often accompany increases in exploitation (Langeland 1986). This was not the case in our study, although, in the absence of abundance data, exploitation rates could not be determined and therefore specific fishing intensity could not be quantified. As mentioned above, estimates of abundance will be critical for future assessments.

Age

Ages were determined by one reader for the first five years of the assessment (2002-2006) and by a second for 2008. The second age reader randomly re-aged 30 samples from each of the first five years of the assessment. Discrepancies in ages provided by the two readers were apparent, although non-significant ($t=0.281$; df = 89; $p=0.780$) and no trend in these differences could be found (Fig. 9). Age comparisons were scattered around the 1:1 line and therefore both over- and under-estimates of age between readers was prevalent. The overall, average percent error (APE) was 7.23% while the average coefficient of variation was %10.22. Errors in ageing can greatly affect the estimation on population parameters (Beamish and McFarlane 1995) Accurate, consistent ageing is required for reliable fisheries stock assessments and subsequent interpretations. It is therefore recommended that all years be re-aged if further assessments of Isuituq System Arctic Char are required.

Arctic Char ranged in age from 3 years (2005 and 2006) to 22 years (2003) and overall averaged 10.2 (2005) to 14.0 (2008, Table 6c). Age varied between sampling year, sexes and gear type employed, but average age and range in ages was similar between 2002 and 2008 (Table 6c). Within each year, males and females were of similar age ($p \geq 0.05$), with the exception of 2004 ($t=2.418$; df = 177; $p=0.017$). Alternatively, Arctic Char captured in 139.7 mm nets were older in every year ($p < 0.001$) with the exception of 2003 ($t=0.48$; df = 212 $p=0.648$). Among years, average age differed for both sexes (males: $H=182.85$; df = 5; $p<0.001$; females: $H=112.83$; df = 5; $p<0.001$) and the majority of the pairwise yearly comparisons were significantly different for both sexes (Table 7e). Average age also differed significantly among years depending on the net type used (139 mm nets: $H=233.01$; df = 5; $p<0.001$; multi-mesh nets: $H=125.87$; df = 5; $p<0.001$). The majority of pairwise yearly comparisons of average age were significant for the 139.7 mm nets (10 of 15), but not the multi-mesh nets ($p<0.05$, Table 7f).

Mean age among years (Fig. 6c) shows similar trends with respect to both average weight and length although with more annual variation in comparison to the latter two. Overall, from 2002 to 2006 average age declined yearly and then increased to initial levels in the final year of the assessment. As such no trend in age data for the full assessment could be found and importantly no trends indicative of over-exploitation could be resolved. Given the annual variation, and the uncertainty surrounding estimates of age for some years, interpreting changes in mean age possibly induced by exploitation is presently difficult to do. Although it does appear mean age was declining in the first five years of the assessment caution is needed when interpreting these data. As such, length, weight and condition data may provide more reliable indicators of stock health and resilience to the current levels of exploitation.

The shapes of the age distributions and the range of ages differed among years and appear to be skewed towards older ages in all years; a result of the size selectivity of the 139.7 mm mesh size nets (Fig. 10). Additionally, most (11 of 15) yearly pairwise comparisons of age frequency distributions were significant (P<0.001, Table 8). Age-frequency distributions were unimodal with modal lengths relatively consistent across sampling years (Fig. 10). Modal values ranged from 10 -14 and no trend in modal age, or the age-frequency distributions themselves, could be resolved. It does appear that older fish were more frequently captured in 2008, which again may, in part, be attributed to inconsistencies in ageing.

Truncations in age distributions, through the removal of older age classes, are often associated with fishing and exploitation (Berkeley *et al.* 2004). Truncations in age distribution were not obvious in this assessment and older (> 18 years of age) fish were captured in all years. Age, as well as length, distributions are known to be relatively stable in Char populations, even under heavy exploitation, and may be noticeable only in the final stages of population reduction (Johnson 1989). As such, changes in mean weight, length, age and condition are likely better indicators of stock health in Isuituq River Arctic Char (Dempson *et al.* 1998). The periodic collection of age data in the future will be valuable for monitoring changes in age structure possibly associated with commercial exploitation of Isuituq Char.

All years considered, Arctic Char were recruited to the survey gear at age 3 (2005, 2006), age 9 (2008), but in most years were recruited at age 7 (2002-2004). The younger ages of recruitment in some years is undoubtedly a result of the multi-mesh nets used in then the present study that allowed for the capture of smaller younger fish. The overall average (age 6), however, is consistent with studies of other commercially exploited char populations (Dempson *et al.* 2008, DFO 2004).

Population growth rates are shown in Fig. 11 as plots of mean fork length on age. Qualitatively, growth of Isuituq River Arctic Char was similar among years for both sexes. Once modeled (incorporating only comparable ages among years) using von Bertalanffy growth equations (Fig. 12), significant differences (assessed by analyses of residual sums of the squares) in growth rates between sexes were only detected in 2004 and 2005 (Table 10; p<0.05). Additionally, significant difference between the first year (2002) and the last year (2008) of the assessment with the latter having significantly larger (F = 4.63; df = 20, 23; p<0.05) length at age (Table 8, Fig. 12). In general, however, growth patterns appear to be relatively similar among years with the exception of 2003. Fish sampled in this year appear to grow slower at younger ages. Overall, these data suggest growth rate of Arctic Char has remained relatively stable in this system.

<u>Mortality</u>

Mortality estimates can provide useful points of reference for assessing the impacts of fishing on the exploited population. This is especially true if comparisons in mortality can be made to historical, pre-exploitation estimates (e.g., Gallagher and Dick 2010). Unfortunately, these are the first estimates of mortality in this system and therefore no such comparisons can be made. These mortality data however, will provide a useful benchmark for future comparisons.

Full recruitment of Arctic Char to the commercial (139.7 mm) net sizes used in this assessment varied among years and ranged from 10 (2005) to 15 (2003) years of age (Fig. 13). Instantaneous mortality (Z) was highly variable among years and ranged from moderately low (0.27 in 2002) to relatively high (0.68 in 2004; Fig. 13). No trends in mortality (annual or instantaneous) or survival could be resolved from these data but overall, it does appear that annual survival is relatively high in this system. The mortality rates calculated in this assessment, overall appear to be higher than those reported for other Baffin Char fisheries (Gallagher and Dick 2010 and references therein). Even though overall mortality appears to be high, given the lack of trends in the length, weight and age data it appears Isuituq Char population(s) can sustain current mortalities rates. If the fishery were having a detrimental effect on the Isuituq Char population, we would expect mortality rates to increase with time. Indeed, this was not the case and trends showing consistent increases in mortality were not found.

CONCLUSIONS

Isuituq, at the head of Clearwater Fiord in Cumberland Sound, has a long history of subsistence fishing for Arctic Char. Since 1997 Arctic Char in this system have also been fished under an exploratory licence. The exploratory stage is designed to determine sustainability of the harvest level, establish initial quotas for a potential a commercial fishery, identify any potential problems a commercial fishery may encounter, and to collect biological data that can be used for fisheries stock assessment purposes. Often however, the biological data required for meaningful fisheries stock assessments are lacking or absent subsequent to the exploratory stage of a fishery. As such, in many of these systems, DFO establishes fisheries research concurrently to ensure valuable stock assessment data are collected. In the Isuituq River system DFO conducted research-based sampling from 2002-2006 and then again in 2008 to collect data to be used for stock assessment purposes. This provided DFO with the information vital for studying stock dynamics and the impacts of exploitation.

Given the data assessed in this document, there is no indication that Isuituq Arctic Char have been adversely impacted by recent exploitation in this system. That is, the biological characteristics of this population have not been altered drastically as a result of current harvest levels in this system. This is supported by several analyses. First, the exception of 2003, catch-per-unit-effort data remained relatively stable across all assessment years. This was especially true in the latter years of the assessment. Second, the relatively stability observed in mean weight, length, age and condition all provide evidence that Isuituq River Arctic Char are presently not being over-exploited. The overall stability found in the distributions of length and age across years was also quite apparent and can also be used as a proxy for stock health and/or stability. Last, the high catches of mature fish (in both net types), suggests sufficient numbers of Arctic Char in this system are reaching reproductive age and likely recruitment overfishing is not a concern. This could also be an artifact of the size selectivity of the 139.7 mm mesh gill nets. Often, improving the status of the stock requires that more Arctic Char reach reproductive age to ensure a strong likelihood of spawning several times (Gallagher and Dick 2010). This appears to be the case in the Isuituq system.

With no abundance data available, however, exploitation rates cannot be determined and thus quantifying sustainable harvest levels for this system is difficult to do. For the effective management of this fishery, attempts to estimate population size should be initiated. Having these data will allow for the estimation of exploitation rates and the establishment of limit reference points and sustainable harvest levels. Unfortunately, the exploitation rates that are sustainable will undoubtedly vary from system to system and using harvest rates from other studies should be approached with caution. For example, harvest rates of 5-10% are suggested to be sustainable in some depending on the Arctic Char system (Kristofferson *et al.* 1991). In others, harvesting at a rate of 11% is excessive and will likely lead to population decline (Johnson 1980). In the absence of abundance data we cannot calculate a sustainable level of harvest. The thorough collection of CPUE data by fishermen harvesting under exploratory licences would assist in inferring changes in abundance. Given the stability of the majority of data presenting in this assessment the current harvest levels appear to pose a low or moderate risk to Isuituq Arctic Char. If harvest levels remain at the current levels, this fishery could be moved from the exploratory to commercial status.

Small increases in quota could be implemented followed by careful monitoring of the fishery. Ideally, a balance between harvest rate and stability of the fishery would be determined as the fishery evolves. Given the costs associated with conducting such work, monitoring of the fishery can be done periodically (when time and money permit), to act as a “check” on the status and health of Isuituq Arctic Char given that biological benchmarks are now in place. This would be best conducted as a combined effort between subsistence fishers, commercial fishers and DFO research personnel. Such an approach is often considered precautionary and would be followed by adaptive co-management of the fishery (Kristofferson 2002). Such an approach is typically implemented to try to avoid serious or irreversible harm to the stock when there is a lack of full scientific certainty.

The time series of biological data included in this assessment was, however, relatively short and the collection of subsequent data after several more years of exploitation will be valuable for future reassessments of the fishery. Our assessment data do, however, now provide a benchmark that defines the early stages of exploitation of Arctic Char from the Isuituq River system. It is recommended that stock assessment data continues to be collected periodically (or annually if funding permits) in subsequent years in order to evaluate future impacts of Arctic Char exploitation and harvest in this system and as a way to monitor the potential development and evolution of this fishery. The benchmarks provided by this assessment will be useful for future evaluations of Isuituq Arctic Char population status which will be vital for the future management of this stock.

RECOMMENDATIONS

- If current harvest levels continue, this fishery could transition from an exploratory fishery to a commercial fishery.
- Abundance should be determined via weir or tagging-based population estimates.
- Age data should be interpreted cautiously. In regards to a future assessment, the re-ageing of these benchmark data should be considered.
- A program should be implemented that would allow for the recording and reporting of catch-per-unit-effort data from the exploratory fishery. This could be implemented as a requirement of the fishery if commercial status is attained.
- Initiatives to resolve the genetic population structure of Arctic Char in this fishery should be perused. This will also include determining how many other putative stocks are being harvested and to what extent (i.e., mixed-stock fishery analysis).

- Research (experiment multi-mesh nets that include a 139.7 mm panel) gill nets should be used solely for future research surveys conducted by DFO. This will allow for a better representation of the Isuituq Arctic Char population.

- Monitoring of this fishery should continue (periodically or annually) if funding permits. This could also potentially be done as part of a fisheries plant sampling program with assistance from local fisherman and fisheries plant personnel.

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TABLES

Table 1. Sample dates and the number of fish captured per net type for each year of sampling

Sampling Year	Start Date	End Date	Number of Fish Captured	
			139.7mm Net	Multi-Mesh Net
2002	3 August	6 August	164	35
2003	3 August	4 August	160	62
2004	30 July	1 August	162	27
2005	12 August	13 August	171	42
2006	15 August	17 August	159	36
2008	21 July	25 July	159	26

Table 2. Available harvest information for Arctic Char from the Isuituq River system, 1997 to 2009. PG080 = Isuituq. Harvest is reported in kg round weight. The quota for all years of the exploratory fishery was 2500 kg.

Year	DFO Research Harvest		Exploratory Harvest (PG080)	Subsistence Harvest
	# Fish	Round Wt (kg)	Round Wt (kg)	# Fish
1996				157
1997			2298.45	1180
1998			3378.91	290
1999			3159.48	950
2000			2328.61	1255
2001				
2002	199	459.08	2589.54	
2003	222	404.52	2738.93	
2004	189	495.78	2491.36	
2005	213	462.43	2458.51	
2006	195	412.96	2446.25	
2007			2958.41	
2008	186	549.34	2690.04	
2009			2612.88	
Average	**200.67**	**464.02**	**2679.28**	**766.40**
Totals	**1204**	**2784.11**	**32151.37**	**3832**

Table 3. Catch-per-unit-effort (CPUE = the number of fish landed per 9.29 m^2 (100 ft^2) per 24 hours of fishing) and total hours fished for both net types (multi-mesh and fishery mesh) across all years of research sampling at the mouth of the Isuituq River (Clearwater Fiord), NU.

Year	Multi-mesh		Fishery Mesh (139.7mm)	
	Mean CPUE	**Total Hours Fished**	**Mean CPUE**	**Total Hours Fished**
2002	2.71	43.63	23.03	11.95
2003	91.70	1.77	62.99	19.70
2004	3.86	16.38	3.51	143.00
2005	3.56	26.33	3.20	120.07
2006	7.05	12.98	4.38	70.10
Average	21.77	20.22	19.42	72.96

*Table 4. Yearly pairwise comparisons of CPUE shown for multi-mesh (above diagonal) and fishery mesh (139.7 mm; below diagonal) gill nets (non-significant; NS and significant; *, Bonferroni corrected alpha = 0.005).*

	2002	**2003**	**2004**	**2005**	**2006**
2002		NS	NS	NS	NS
2003	NS		*	*	*
2004	NS	*		NS	NS
2005	NS	*	NS		NS
2006	NS	*	NS	NS	

Table 5. Sex and maturity information for Isuituq River Arctic Char caught in research sampling, 2002-2006, 2008. Data are pooled for the 139.7 mm and multi-mesh gill nets given the small sample sizes of the latter.

	Sex	Maturity			Age at First Maturity	
Year	**M:F**	**% Immature**	**% Mature**	**% Resting**	**Male**	**Female**
2002	1.73	31.2	6.5	62.3	8	12
2003	1.17	23.2	7.1	69.7	10	10
2004	1.33	11.6	49.7	38.6	8	8
2005	1.19	24.1	11.3	64.6	8	7
2006	1.44	26.2	2.6	71.3	8	7
2008	1.15	4.1	92.4	3.5	8	8
Average	**1.33**	**20.0**	**28.3**	**51.7**	**8.3**	**8.7**

Table 6. Mean weight (A), mean length (B) and mean age (C) of Arctic Char from the Isuituq River, NU. Means, ranges, 95% confidence intervals (C.I.) and sample sizes (N) are shown for males (M) and females (F) and for different gill net types (commercial size (139.7 mm) and experimental multi-mesh gill nets).

A — **Weight (g)**

Year	M	F	139.7	Multi	All	Range	95% C.I.	N
2002	2536	1912	2520	1309	**2307**	**300 - 4700**	**2186 - 2428**	**199**
2003	1980	1629	1925	1562	**1822**	**400 - 4450**	**1714 - 1930**	**219**
2004	2895	2261	2844	1298	**2623**	**546 - 4763**	**2487 - 2758**	**189**
2005	2270	2076	2350	1497	**2181**	**100 - 4427**	**2052 - 2309**	**212**
2006	2327	1817	2419	787	**2118**	**29.5 - 4113**	**1978 - 2258**	**194**
2008	3403	2694	3169	1868	**2598**	**54.5 - 5298**	**2461 - 2735**	**184**

B — **Length (mm)**

Year	M	F	139.7	Multi	All	Range	95% C.I.	N
2002	598	545	598	486	**579**	**300 - 758**	**566 - 591**	**199**
2003	539	509	535	504	**526**	**305 - 700**	**515 - 537**	**219**
2004	611	564	610	476	**591**	**364 - 739**	**580 - 602**	**189**
2005	552	536	561	480	**545**	**203 - 733**	**531 - 558**	**212**
2006	553	507	572	369	**534**	**145 - 735**	**518 - 550**	**194**
2008	654	610	633	515	**616**	**189 - 751**	**605 - 628**	**185**

C — **Age (otolith years)**

Year	M	F	139.7	Multi	All	Range	95% C.I.	N
2002	13.6	13.3	14.0	11.0	**13.5**	**7 - 21**	**13.0 - 13.9**	**183**
2003	14.1	13.5	13.8	13.7	**13.8**	**7 - 22**	**13.4 - 14.2**	**214**
2004	12.8	11.9	12.9	9.8	**12.4**	**7 - 20**	**12.1 - 12.8**	**179**
2005	10.1	10.2	10.5	9.0	**10.2**	**3 - 18**	**9.9 - 10.5**	**206**
2006	10.7	10.5	11.4	7.1	**10.6**	**3 - 18**	**10.2 - 11.0**	**194**
2008	13.8	14.2	14.2	12.5	**14.0**	**9 - 21**	**13.7 - 14.4**	**176**

*Table 7. Yearly pairwise comparisons (Dunn's post-hoc test for non-parametric Kruskal-Wallis ANOVA on ranks) of weight by sex (A) and net type (B), length by sex (C) and net type (D) and age by sex (E) and net type (F) for Isuituq Arctic Char. For sexes, males are above the diagonal and females below. For net type, multi-mesh nets are above the diagonal and fishery mesh (139.7 mm) gill nets are below (non-significant; NS and significant; *, alpha = 0.05).*

A **Sexes by Weight**

	2002	2003	2004	2005	2006	2008
2002		NS	NS	NS	NS	*
2003	NS		*	NS	*	*
2004	NS	*		*	*	*
2005	NS	*	NS		NS	*
2006	NS	NS	*	NS		*
2008	*	*	*	*	*	

B **Net Type by Weight**

	2002	2003	2004	2005	2006	2008
2002		NS	NS	NS	NS	NS
2003	NS		NS	NS	*	NS
2004	NS	*		NS	NS	NS
2005	NS	NS	*		*	NS
2006	NS	*	*	NS		*
2008	*	*	*	*	*	

C **Sexes by Length**

	2002	2003	2004	2005	2006	2008
2002		*	NS	*	*	*
2003	*		*	NS	NS	*
2004	NS	*		*	*	*
2005	NS	NS	NS		NS	*
2006	NS	NS	*	NS		*
2008	*	*	*	*	*	

D **Net Type by Length**

	2002	2003	2004	2005	2006	2008
2002		*	NS	*	NS	*
2003	NS		*	NS	*	*
2004	NS	NS		*	*	NS
2005	NS	NS	NS		*	*
2006	*	*	*	*		*
2008	NS	NS	NS	NS	*	

E **Sexes by Age**

	2002	2003	2004	2005	2006	2008
2002		NS	NS	*	*	NS
2003	NS		NS	*	*	NS
2004	NS	*		*	*	NS
2005	*	*	*		NS	*
2006	*	*	NS	NS		*
2008	NS	NS	*	*	*	

F **Net Type by Age**

	2002	2003	2004	2005	2006	2008
2002		NS	*	*	*	NS
2003	*		NS	*	*	NS
2004	NS	*		*	*	*
2005	NS		NS		*	*
2006	*	*	*	NS		*
2008	NS	NS	*	*	*	

Table 8. Yearly pairwise comparisons (2 sample Komolgorov-Smirnov tests) of length (above diagonal) and age (below diagonal) distributions for Isuituq Arctic Char. Values shown are the KS statistic. Bold values are significant at the Bonferroni adjusted alpha of 0.0033.

	2002	**2003**	**2004**	**2005**	**2006**	**2008**
2002		0.093	**0.209**	**0.468**	**0.376**	0.143
2003	**0.363**		**0.215**	**0.508**	**0.388**	0.097
2004	**0.115**	0.354		**0.368**	**0.248**	**0.238**
2005	**0.225**	0.165	**0.222**		0.126	**0.605**
2006	**0.221**	0.173	**0.233**	0.077		**0.479**
2008	**0.232**	**0.546**	**0.233**	**0.413**	**0.425**	

Table 9. Linear regression parameter: a (y-intercept), b (slope), and r^2 (coefficient of determination) for length-weight relationships (by sex within sampling year) of Isuituq River Arctic Char.

Year	**Sex**	**N**	***a***	***b***	***r^2***
2002	**Male**	126	-4.68	2.91	0.89
	Female	73	-4.11	2.69	0.81
2003	**Male**	51	-4.31	2.77	0.83
	Female	101	-4.85	2.97	0.94
2004	**Male**	108	-5.21	3.10	0.96
	Female	81	-4.82	2.96	0.92
2005	**Male**	115	-4.82	2.97	0.97
	Female	97	-4.96	3.02	0.97
2006	**Male**	115	-4.90	3.90	0.98
	Female	80	-5.12	3.08	0.98
2008	**Male**	91	-5.56	3.23	0.84
	Female	80	-4.50	2.85	0.83

Table 10. von Bertalanffy growth equation parameters (K = growth coefficient; t_0 = theoretical length at age 0; L_∞ = maximum length) for Arctic Char collected from the Isuituq River, 2002-2008.

Year	Sex	*K*	t_0	L_∞	Age Range
2002[b]	**Male**	0.122	0.65	758	7-20
	Female	0.166	1.62	655	7-21
2003	**Male**	0.161	3.68	700	7-22
	Female	0.143	2.20	655	7-21
2004[a]	**Male**	0.208	3.63	735	7-17
	Female	0.162	0.90	682	7-20
2005[a]	**Male**	0.179	1.57	733	3-16
	Female	0.181	0.12	664	4-18
2006	**Male**	0.168	1.29	735	4-19
	Female	0.233	3.38	645	7-16
2008[b]	**Male**	0.168	2.03	751	10 - 21
	Female	0.097	2.99	733	9 - 20

[a] statistical difference in growth rate between sexes in 2004 ($F = 4.13$; df = 8, 11; $p = 0.02$) and 2005 ($F = 3.97$; df = 20, 23; p = 0.0.02).
[b] statistical difference in growth rate between the first (2002) and the last (2008) year of the study ($F = 4.63$; df = 20, 23; $p = 0.0072$).

FIGURES

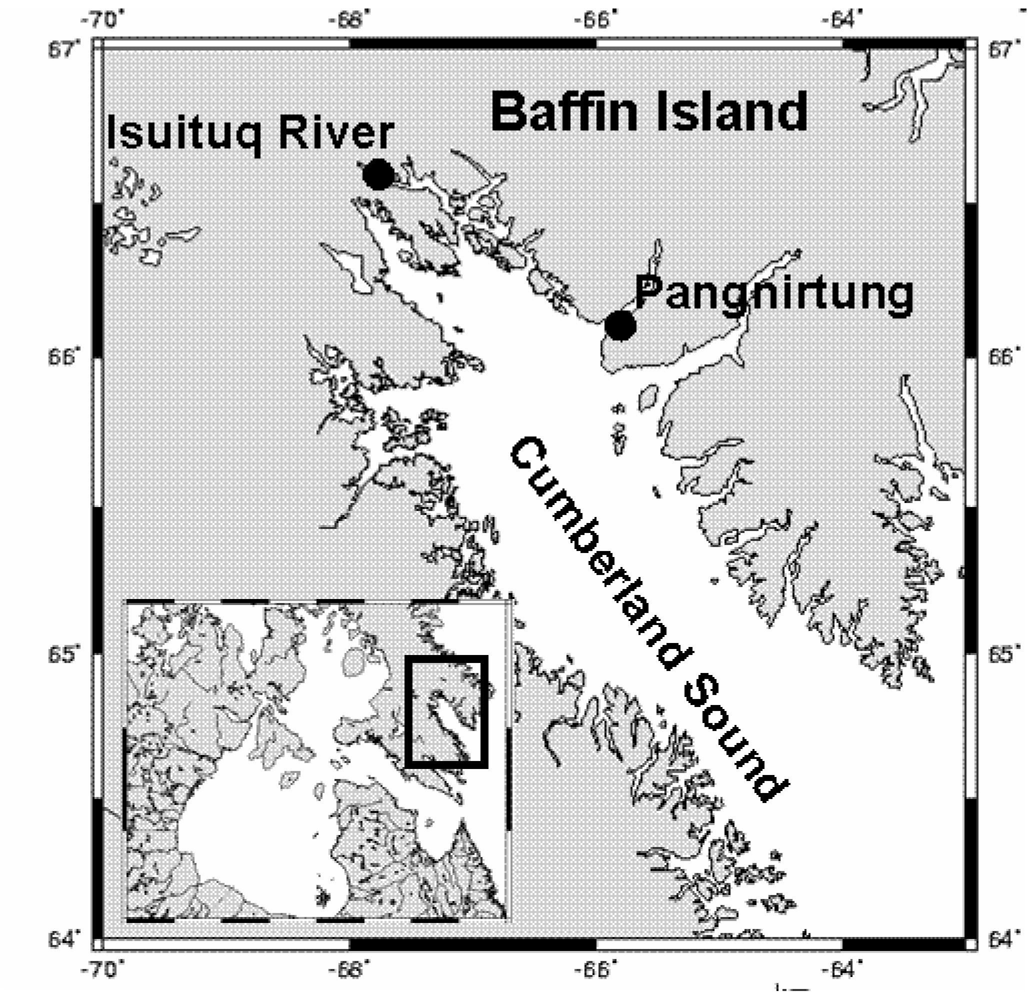

Figure 1. Cumberland Sound showing the location of the Isuituq River system. Also shown is the community of Pangnirtung (primary resource users of the Arctic Char from the Isuituq system).

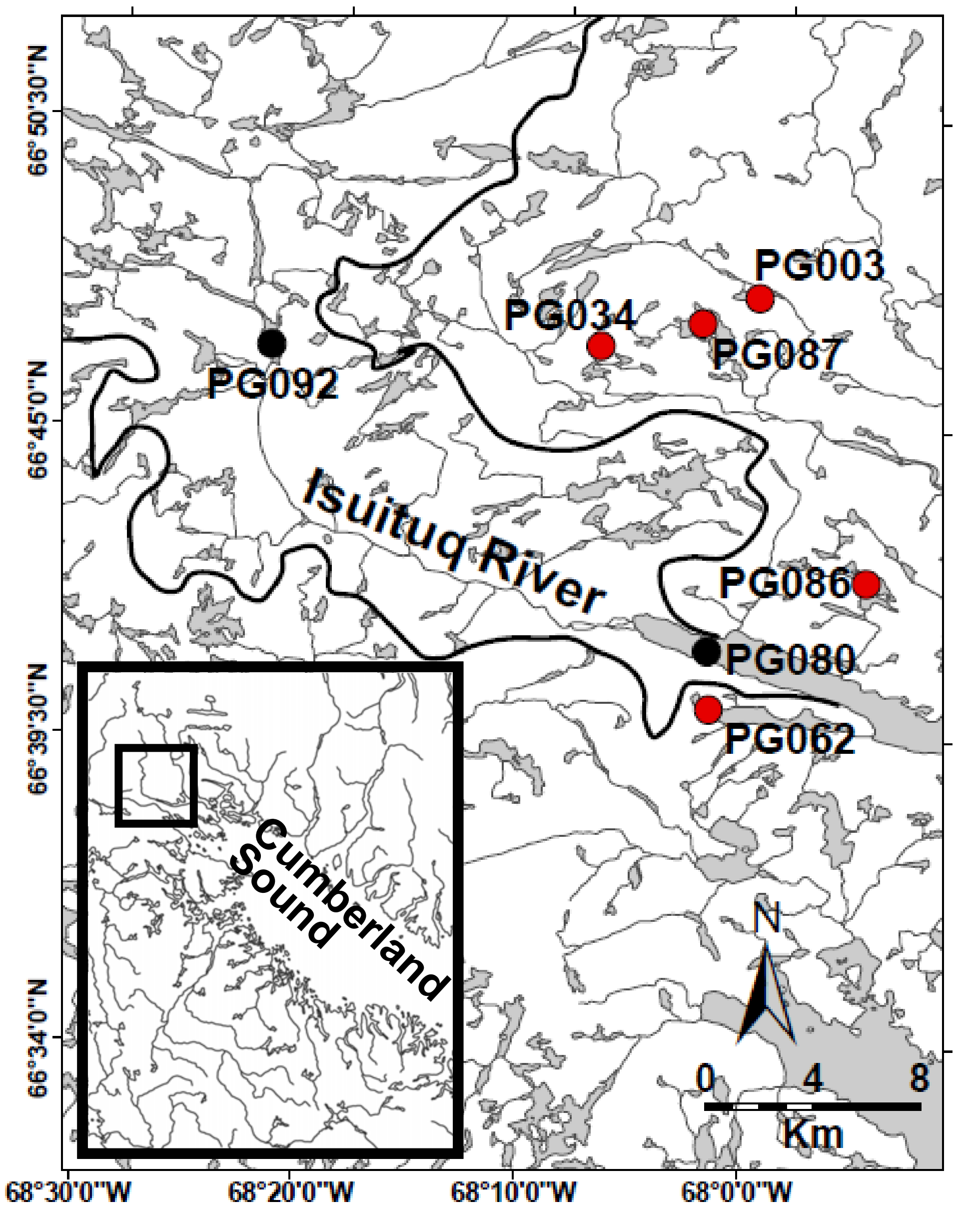

Figure 2. The Isuituq River system in Cumberland Sound. Also shown are several of the waterbodies of the area that have been fished for commercial or subsistence purposes. These waterbodies likely contribute fish to the mixed-stock harvest at Isuituq. Black circles represent fisheries in the Isuituq system and red circles show fisheries in other nearby systems including the Ranger River system to the east. PG003 = Ijaruvung Lake and PG080 = Isuituq. The rest are unnamed waterbodies.

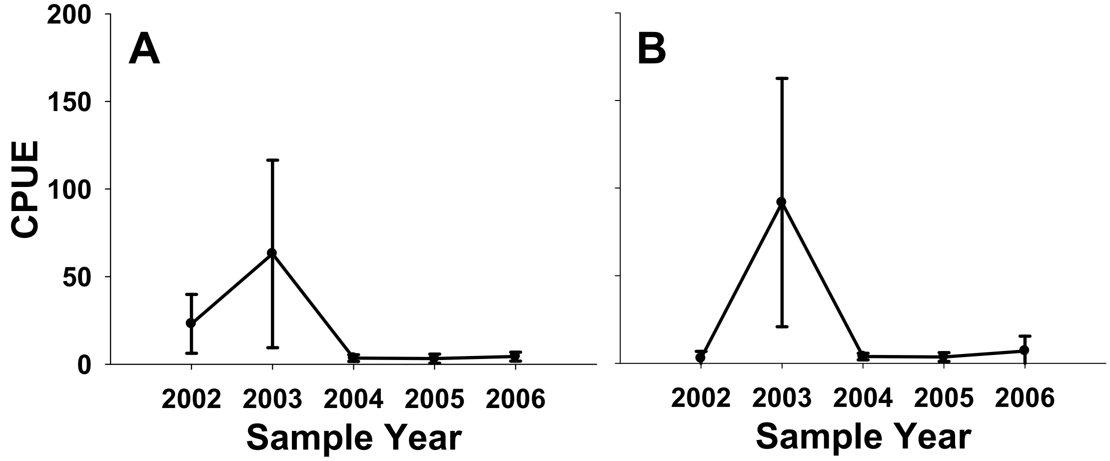

Figure 3. Mean catch-per-unit-effort (CPUE, number of Arctic Char/100 m^2 of mesh/24 h) for both fishery mesh size (139.7 mm, A) and multi-mesh (B) gill nets at the mouth of the Isuituq River, NU from 2006 to 2008.

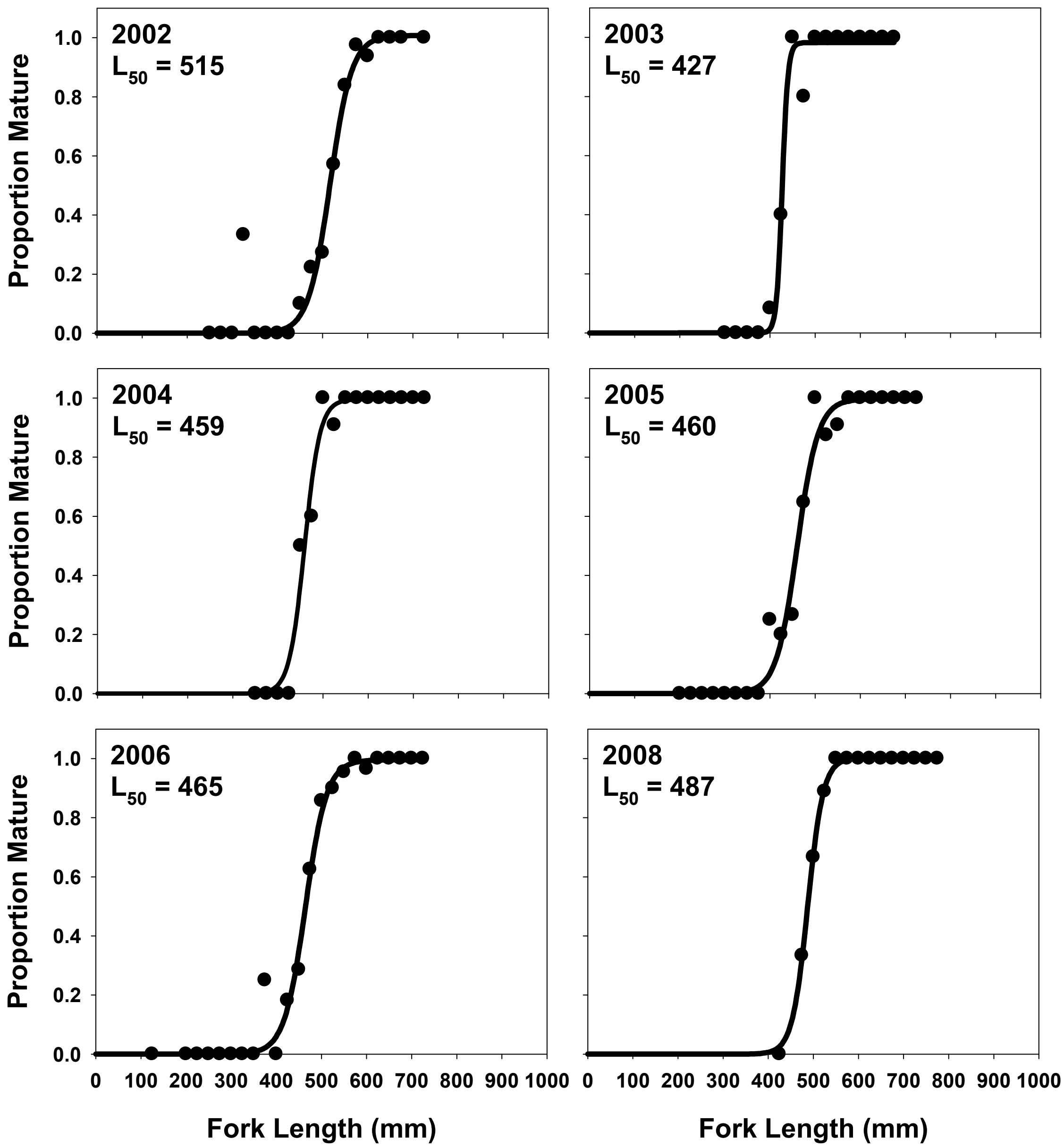

Figure 4. Length at %50 maturity (L_{50}) for Arctic Char (sexes combined) captured in the Isuituq River system, NU, using fishery size (139.7 mm mesh) gill nets, 2002-2008.

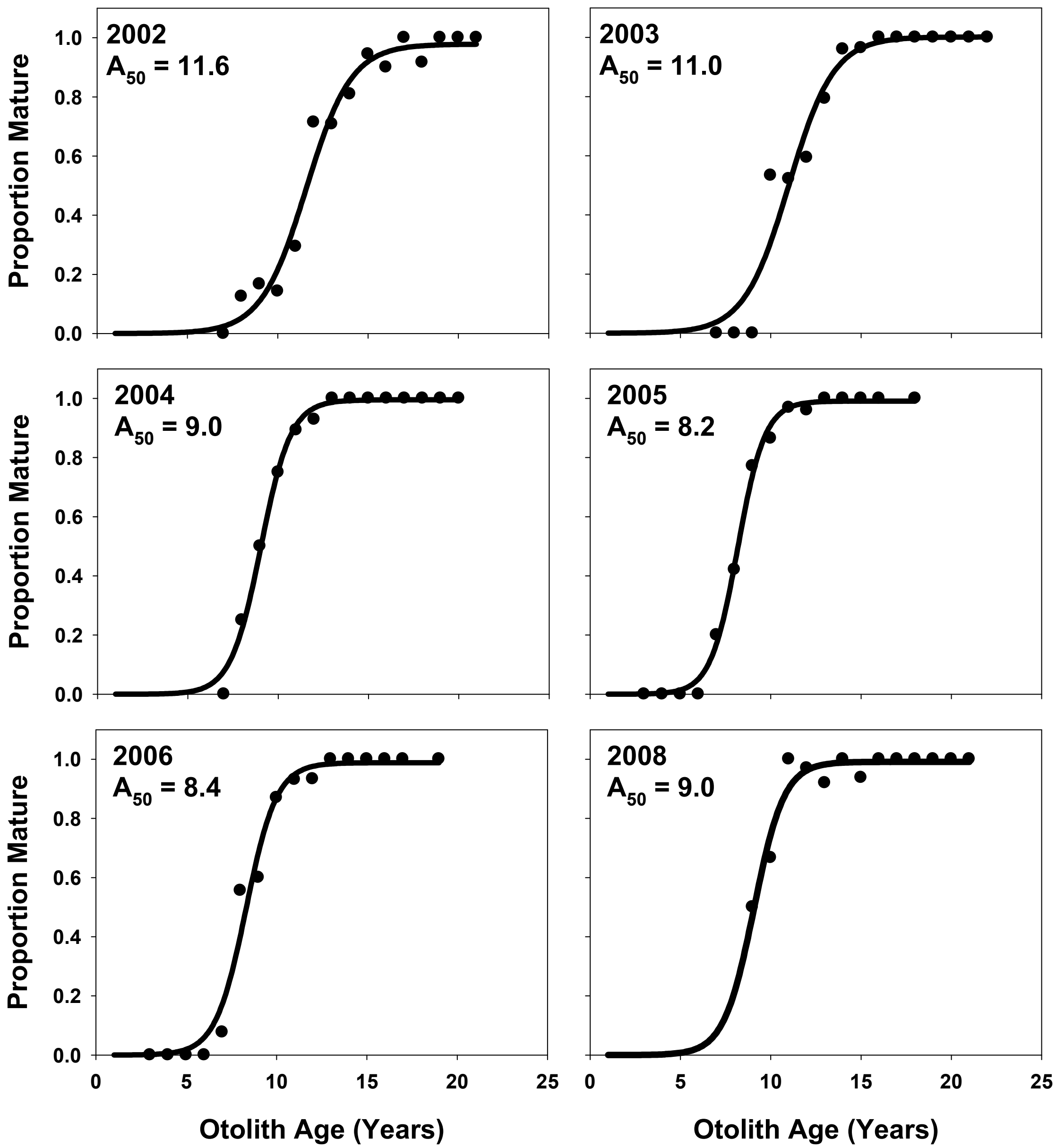

Figure 5. Age at %50 maturity (A_{50}) for Arctic Char (sexes combined) captured in the Isuituq River system, NU, using fishery size (139.7 mm mesh) gill nets, 2002-2008.

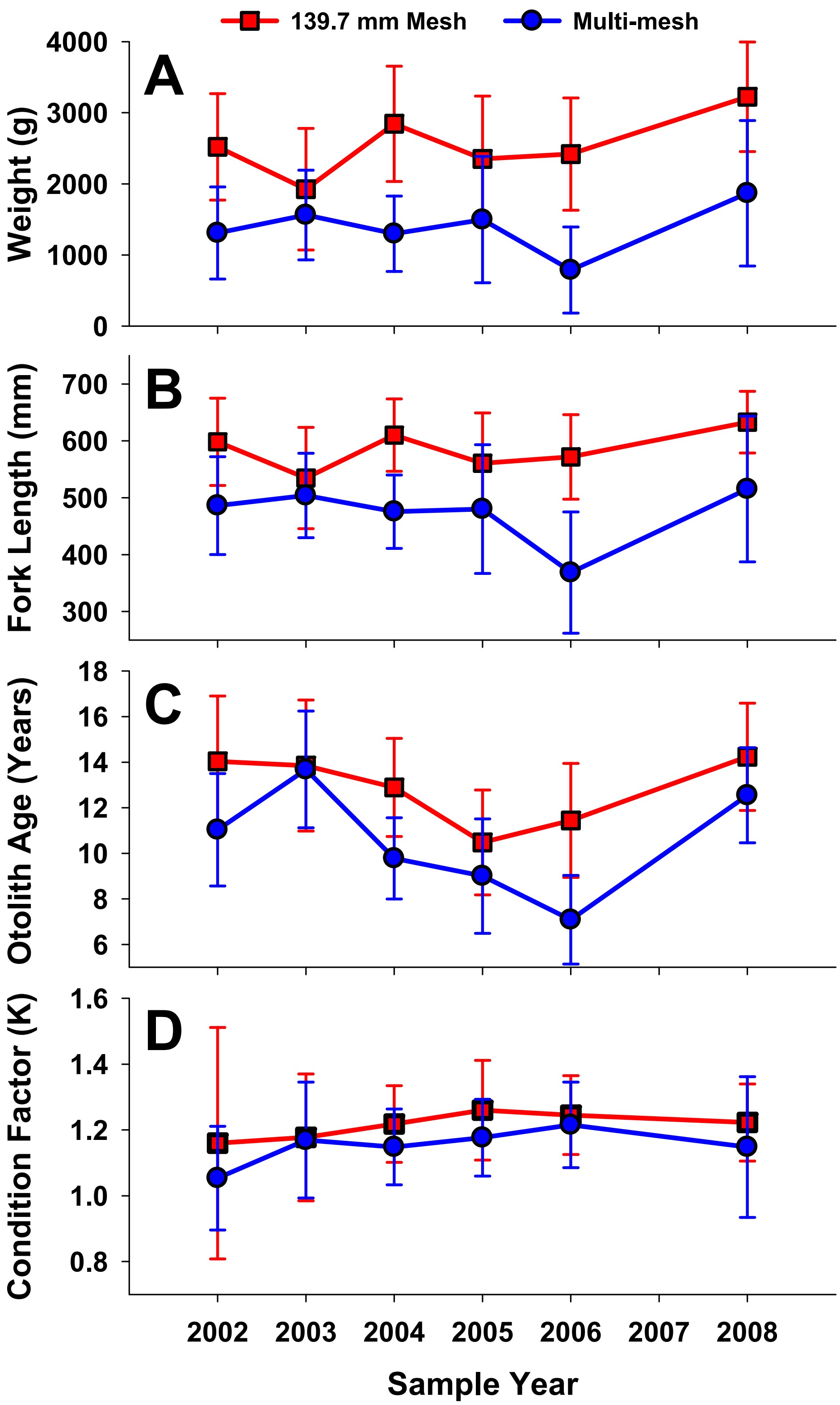

Figure 6. Mean weight (g), fork length (mm) age and condition (K) for Isuituq River Arctic Char shown by net type and year.

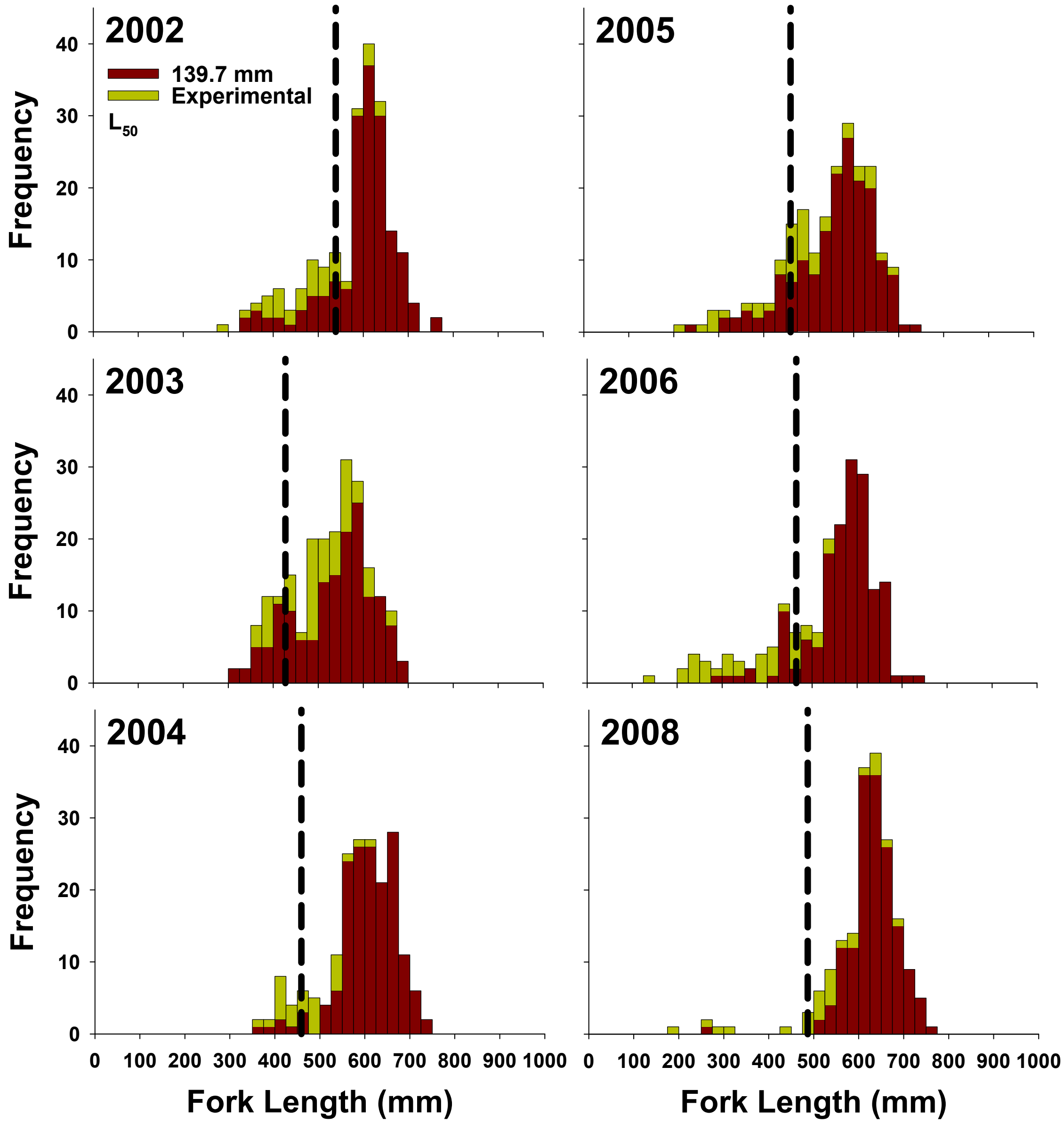

Figure 7. Fork length frequency distributions of Arctic Char captured by research survey gill-netting (using fishery size (139.7 mm) and multi-mesh gill nets) at the mouth of the Isuituq River, NU. Length at 50% maturity (L_{50}) is also shown.

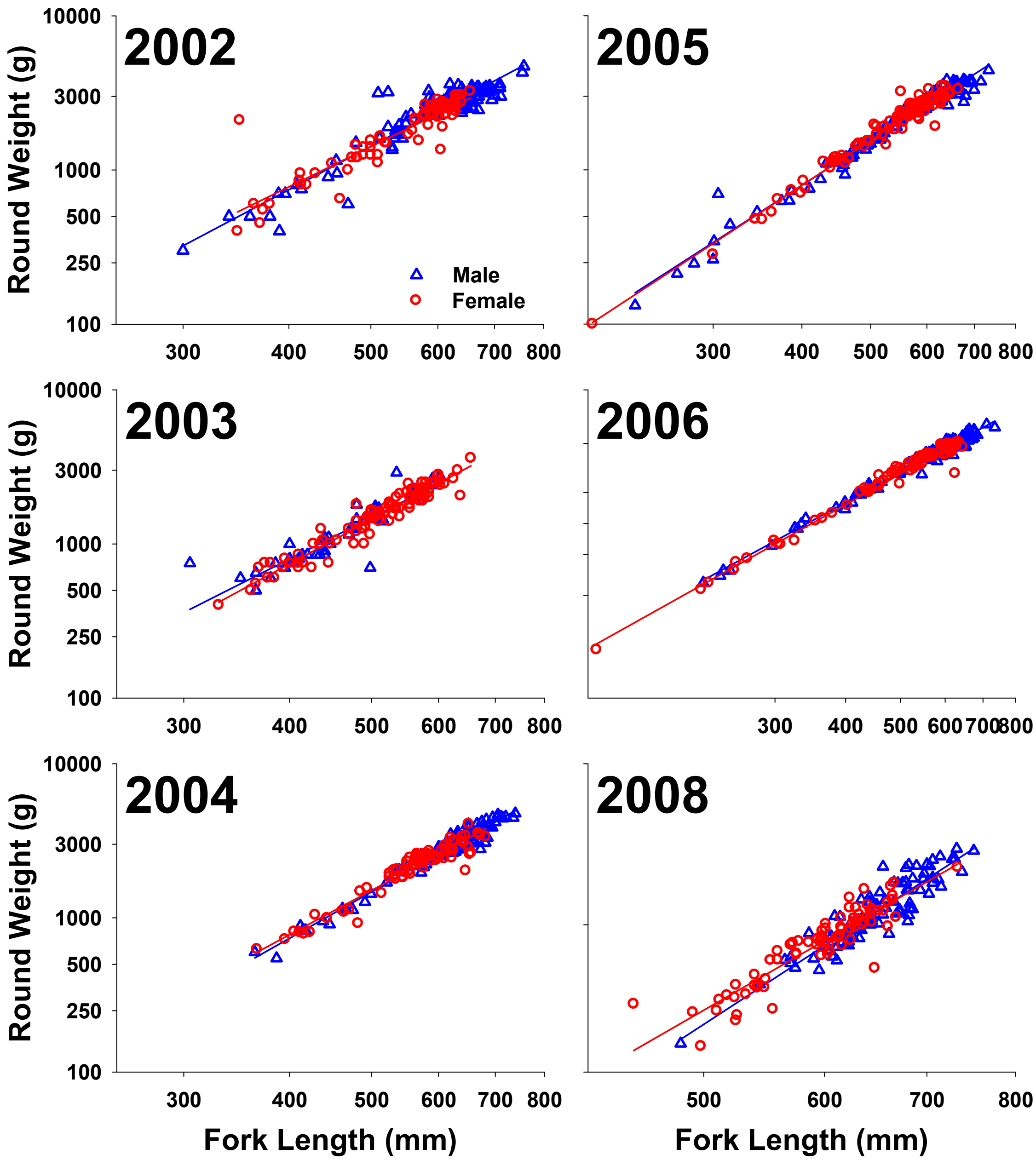

Figure 8. Weight-length relationships of Isuituq River Arctic Char by sex and among sampling year.

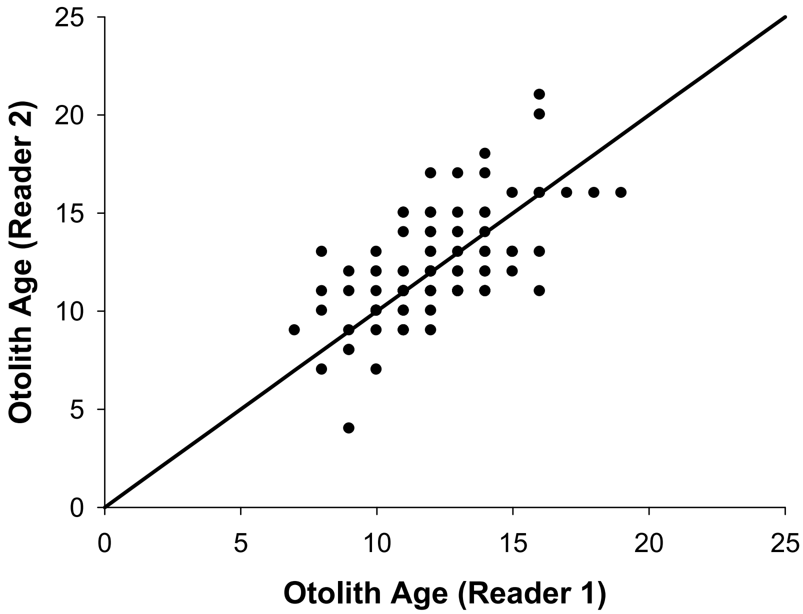

Figure 9. Age bias graph for each pairwise age comparisons presented of Isuituq River Arctic Char. Thirty fish from each of the first five years of the assessment were randomly re-aged by the second reader. The 1:1 equivalence (solid line) is also indicated.

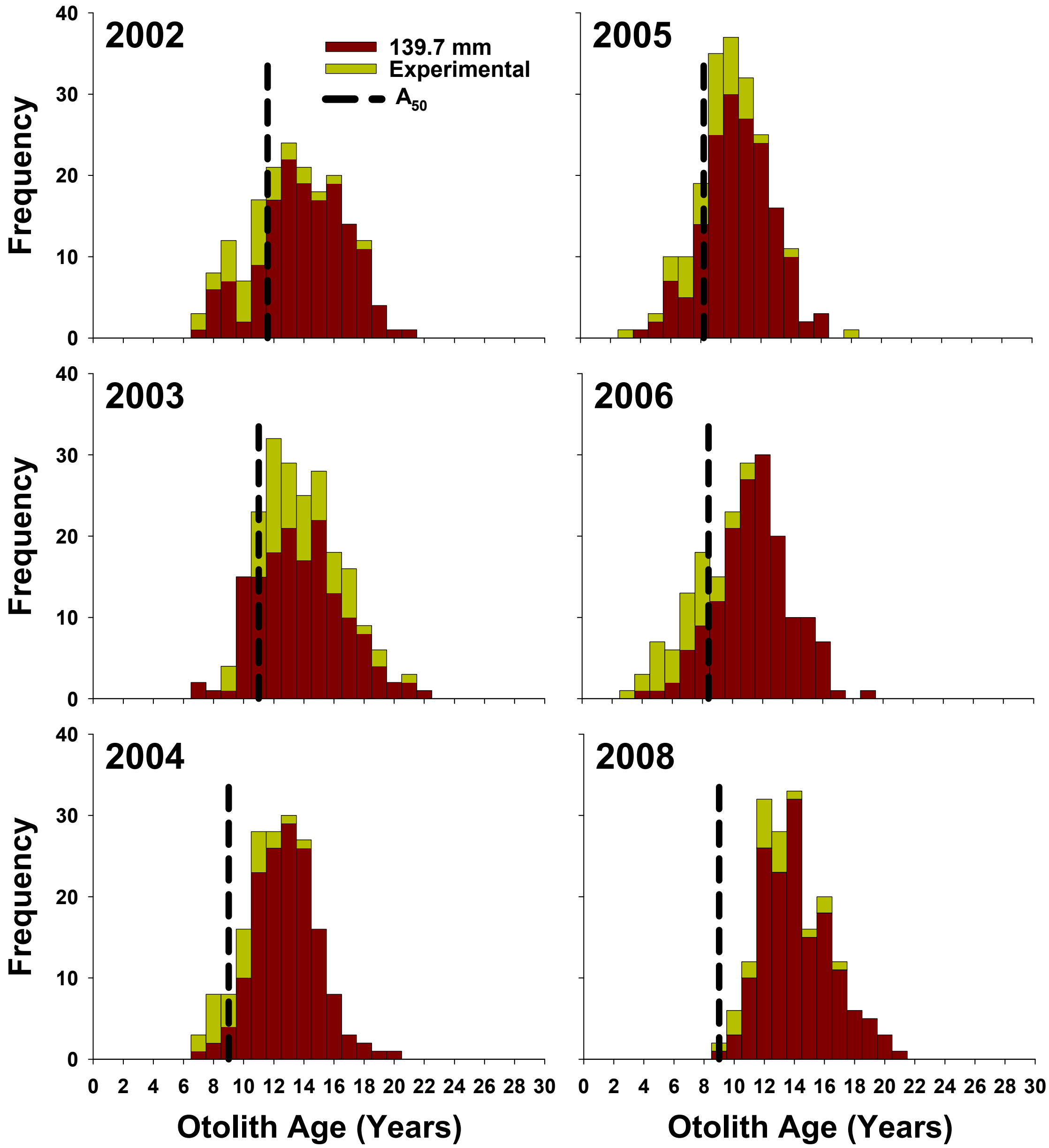

Figure 10. Age frequency distributions of Arctic Char captured by research survey gill-netting (using fishery size (139.7 mm) and multi-mesh gill nets) at the mouth of the Isuituq River, NU. Age at 50% maturity (A_{50}) is also shown.

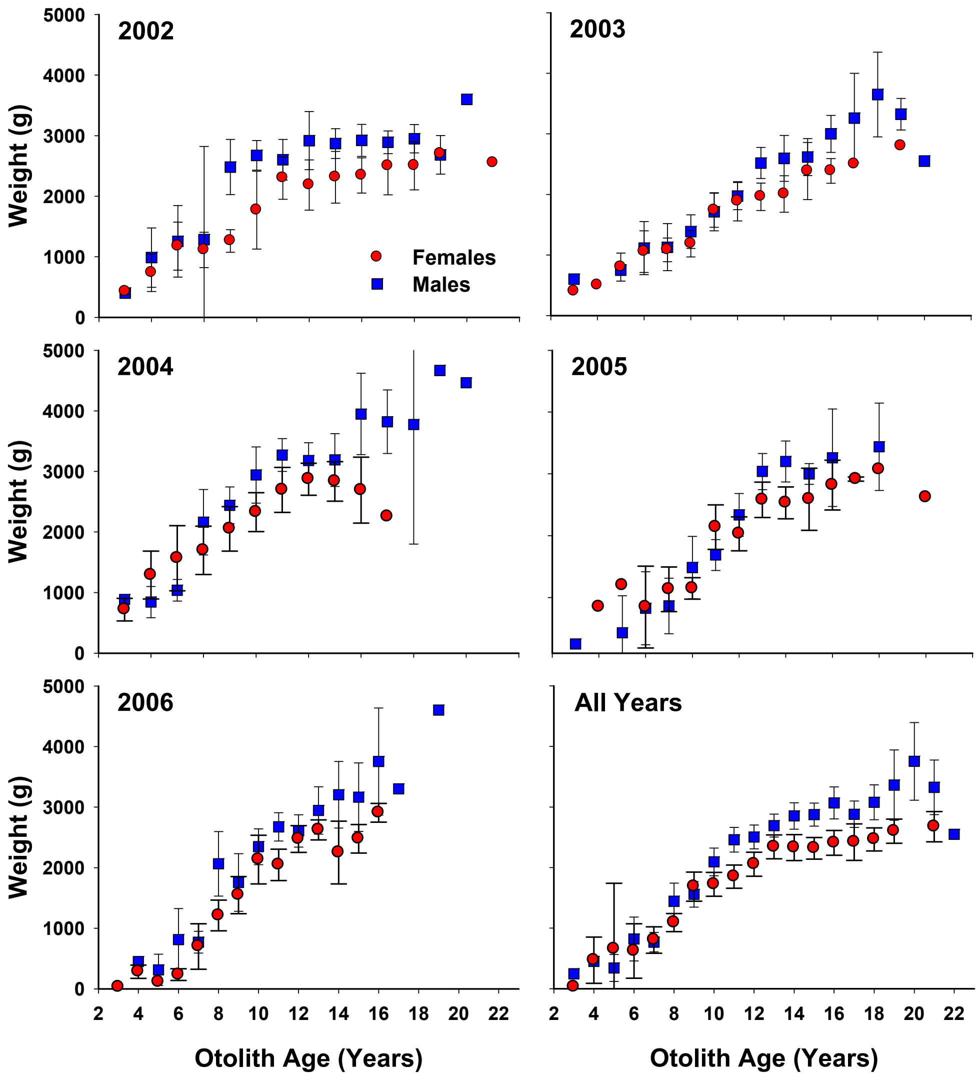

Figure 11. Mean length at age (± 2 standard deviations) of male and female Arctic Char from the Isuituq River, NU, 2002-2008.

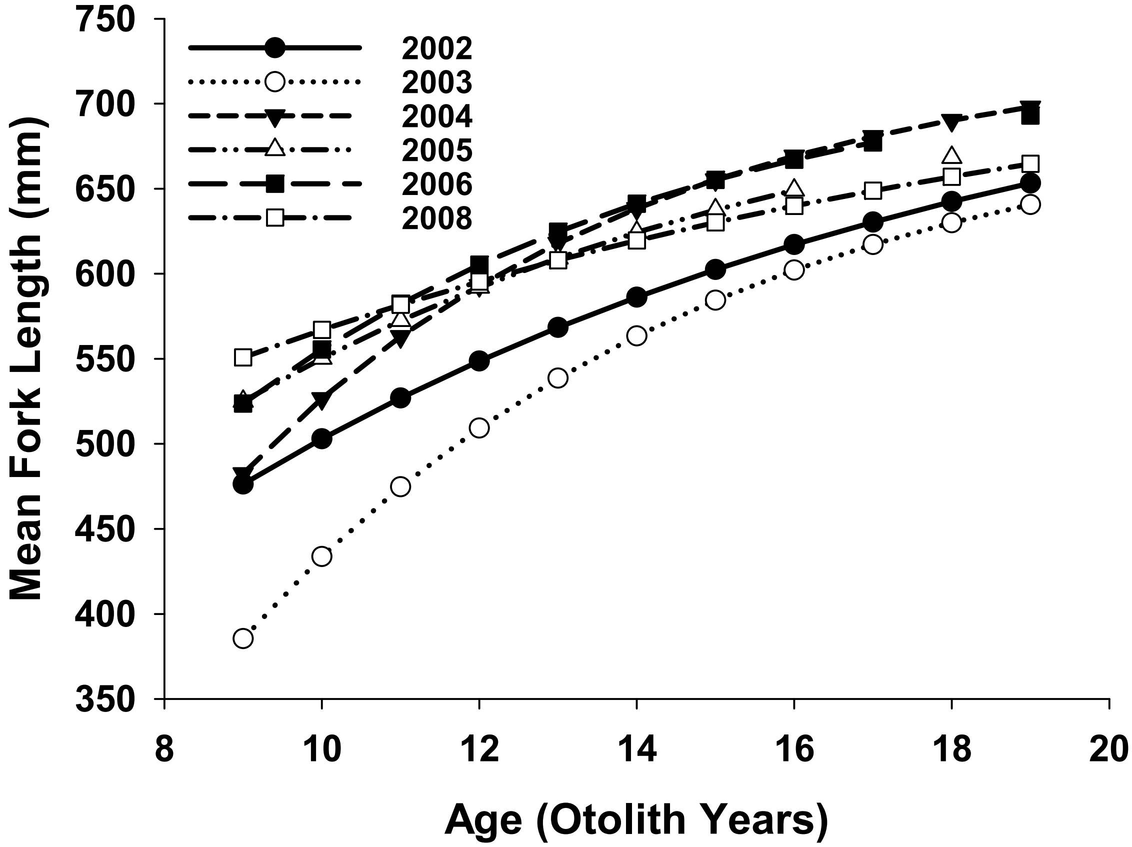

Figure 12. von Bertalanffy growth curves fitted to lengths at age (sexes combined) for Arctic Char sampled from research sampling in the Isuituq River, NU, 2002-2008.

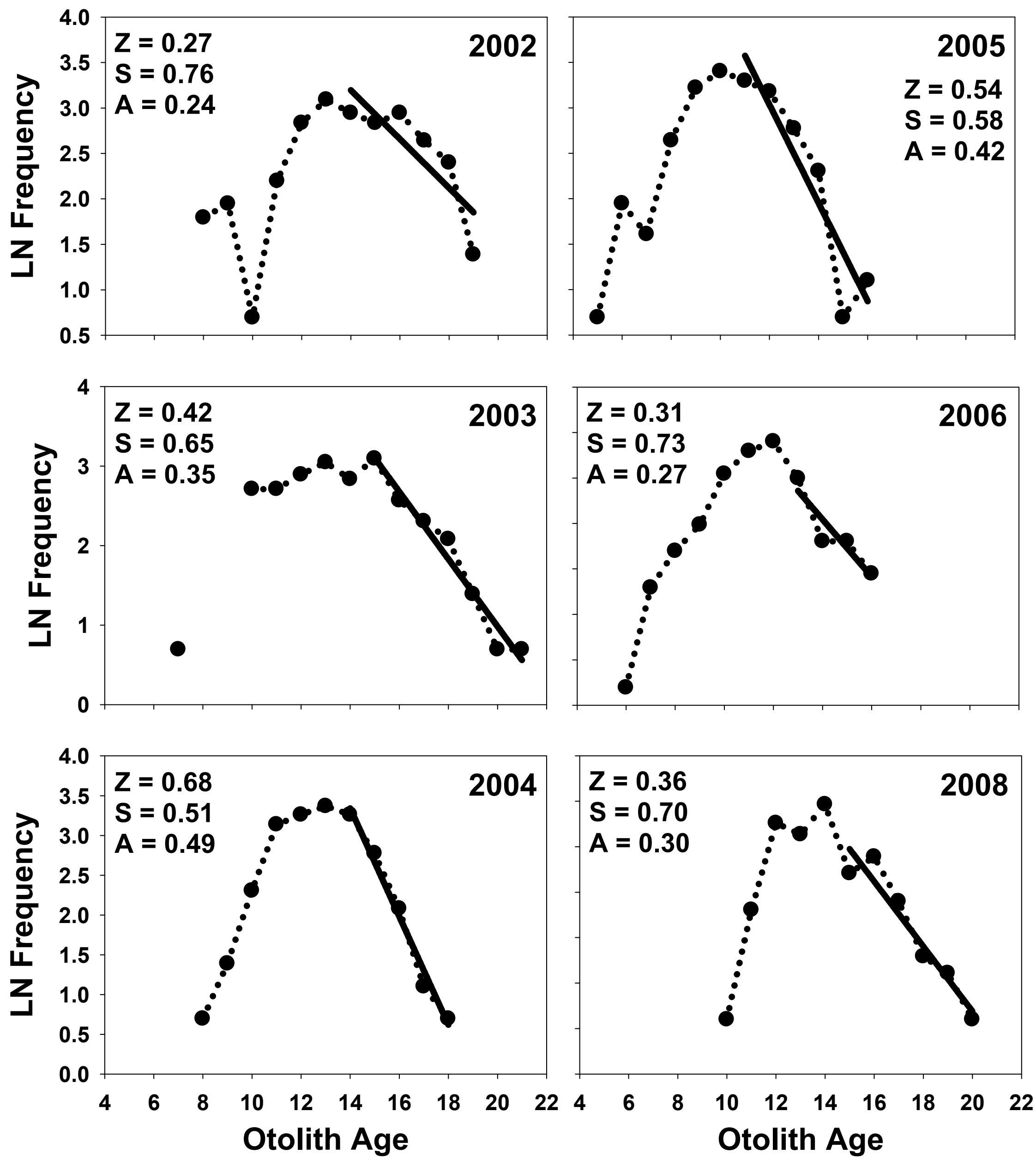

Figure 13. Age frequency catch curves for Arctic Char collected in the Isuituq River, NU, 2002-2008. Instantaneous mortality (Z), survival (S) and annual mortality (A) have been calculated where appropriate.