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Information to support the Qasigiyat Arctic Char Assessment

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Arctic Char (*Salvelinus alpinus* (Linneaus)) are widely distributed throughout the Arctic and are an important commercial and subsistence resource for Inuit. Arctic Char found in Qasigiyat Lake, are an important resource for the community of Pangnirtung, Nunavut. They have been harvested under a stage II exploratory licence since 1989. The initial quota for Qasigiyat Lake was established based on test fishery data collected in 1982 and 1984.

Fisheries and Oceans Canada (DFO) Resource Managers requested an updated summary of information collected from Cumberland Sound Arctic Char stocks. A Regional Advisory Process meeting was held to evaluate the status of the Qasigiyat Lake (Ptarmigan Fiord) Arctic Char stock and recommendations for long-term plans for this fishery. The results of the assessment indicate that current harvest levels appear to be sustainable.

Renseignements à l'appui de l'évaluation de l'omble chevalier de Qasigiyat

RÉSUMÉ

L'omble chevalier *Salvelinus alpinus* (Linneaus) est largement réparti dans l'Arctique et constitue une ressource commerciale et de subsistance importante pour les Inuits. L'omble chevalier du lac Qasigiyat est une ressource importante pour la communauté de Pangnirtung, au Nunavut. Depuis 1989, il est pêché en vertu d'un permis exploratoire de stade II. Le quota de pêche initial pour le lac Qasigiyat a été établi selon les données recueillies en 1982 et en 1984, issues de pêches expérimentales.

Les gestionnaires des ressources de Pêches et Océans Canada (MPO) ont demandé un sommaire à jour des renseignements recueillis au sujet des stocks d'ombles chevaliers de la baie Cumberland. Une réunion dans le cadre du processus consultatif régional a eu lieu pour évaluer l'état du stock d'ombles chevaliers du lac Qasigiyat (fjord Ptarmigan) et les recommandations relatives aux plans à long terme concernant la pêche de cette espèce. Les résultats de l'évaluation indiquent que les niveaux de prises actuels semblent être durables.

INTRODUCTION

Arctic Char, (*Salvelinus alpinus*) are the most northerly freshwater fish and have a circumpolar distribution (Scott and Crossman 1998). This species is abundant within the Canadian Arctic and is an important subsistence resource for local Inuit (Priest and Usher 2004). Within Cumberland Sound there are multiple stocks of Arctic Char. Specifically this report is focused on the stock found in Qasigiyat Lake (Ptarmigan Fiord) (Figure 1).

Qasigiyat is Inuktitut for Harbour Seals, so the direct translation of this waterbody name is Harbour Seals Lake (Ptarmigan Fiord). Historically Qasigiyat has been spelled numerous ways (e.g., Qasigiat, Qasigijjat); the Pangnirtung Hunters and Trappers Organization (HTO) provided the spelling used in this report. This waterbody has been harvested under a stage II exploratory licence since 1989 by the community of Pangnirtung. The objective of a stage II exploratory licence is to determine whether a species/stock can sustain a commercially viable operation and to collect biological data to build a preliminary database on stock abundance and distribution (DFO 2010). The initial quota for Qasigiyat Lake was established from test fishery data collected in 1982 and 1984 (McGowan 1985). Test fishery data collection on a waterbody was initiated by interested community groups such as HTOs (Kristofferson and McGowan 1981). Qasigiyat Lake was originally a winter fishery but in recent years has transitioned to a summer fishery, due to poor ice conditions preventing safe travel to the lake. In winter, fishing occurs in the lower lake (Figure 2), but in the summer fishing occurs in the inter-tidal zone at the mouth of the river as fish migrate from salt water to fresh water. In the summer the fishermen have a narrow time window within which they capture fish migrating from the saltwater environment to the freshwater environment.

It has been documented that there are two life history forms of Arctic Char present in Qasigiyat Lake - resident and anadromous (Loewen 2008). It is common for Arctic Char populations to exhibit different life history forms as the species is considered very adaptable and plastic (Johnson 1980). The two life history forms differ in their migration behaviour, and age and size at first maturity (Loewen et al. 2009). The resident life history form typically resides in freshwater environments, and matures at an earlier age and smaller size compared to the anadromous life history form. It is important to consider the presence of the different life forms, as both may be subjected to harvest whether directly (as targeted catch) or indirectly (as by-catch). It is understood that resident and anadromous Arctic Char are able to reproduce successfully with each other (J.-S. Moore, University of British Columbia. pers. comm.). Thus, harvest of one life history form will have effects on the other. For the purpose of this report all fish captured whether anadromous or resident forms were used in all analyses unless otherwise stated. However, the focus of the current assessment is on anadromous Arctic Char as they are targeted by the fishery.

Qasigiyat Lake is not commonly fished for subsistence as it is too far from the community of Pangnirtung. However, it is located in close proximity to good caribou and polar bear hunting grounds; thus, when in the area people will opportunistically fish for subsistence (P. Kanayuk, Pangnirtung, Nunavut, pers. comm.).

The purpose of this report is for the Science section of DFO to provide an updated summary of information collected from Cumberland Sound Arctic Char stocks. In this Regional Advisory Process (RAP) DFO Science is assessing the status of the Qasigiyat Lake (Ptarmigan Fiord) Arctic Char stock and recommending a long-term plan for this fishery.

MATERIALS AND METHODS

STUDY AREA

Qasigiyat Lake (Ptarmigan Fiord) is located on the south side of Cumberland Sound (64° 37.657' N, 66° 18.670' W) (Figure 1). The lake is in close proximity to the marine environment with a surface area of 1.2 km^2 and with a perimeter of 4.5 km (Figure 2). Qasigiyat Lake has a large deep region (>21 m), reduced littoral habitat and steep lake shoreline making the lake more characteristic of a fiord (Loewen 2008). Qasigiyat Lake is slightly elevated above the marine environment (approximately 2-3 m). There are two rivers that connect the lake to the fiord. These rivers are short with lengths of 0.11 km and 0.39 km (Loewen et al. 2009). Given the slight elevation of the lake above sea level and the short river lengths, during high tide events it is common for Qasigiyat Lake to be inundated by salt water from Ptarmigan Fiord (Loewen et al. 2009). There are a few shallow ponds attached to Qasigiyat Lake (not shown on maps) that are thought to be possible rearing grounds for Arctic Char (Loewen 2008).

HARVEST INFORMATION

Qasigiyat Lake was originally a winter fishery (commercial harvest) but in recent years has transitioned to a summer fishery, due to poor ice conditions preventing safe travel to the lake. The quota for Qasigiyat Lake was 1,000 kg from 1982 until licence year 2003/2004, in licence year 2004/2005 the quota was raised to 1,500 kg. As mentioned above Qasigiyat Lake is not commonly fished for subsistence harvest.

DATA SOURCES

In this assessment there are three types of data presented from Qasigiyat Lake: test fishery data 1982 and 1984; fishery-independent data 2003, 2004, 2006, 2007, 2009 and 2010; and fishery-dependent data 1989 to 2011. The test fishery and fishery-independent data are reported by calendar year. The fishery-dependent data corresponds to the licence year which runs from April 1 the first year to March 31 the following year.

Test fishery data from 1982 and 1984 (McGowan 1985), has been included in the assessment as a historical reference point (Table 2, Table 3). The test fishery data from Qasigiyat Lake was collected by Resource Development Officers (Government of the Northwest Territories) from Pangnirtung. The objective of the test fishery was to set an initial quota for the waterbody and collect baseline biological data for the waterbody (Kristofferson and McGowan 1981).

Fishery-independent data were collected by DFO Science (Central and Arctic Region) in 2003, 2004, 2006, 2007, 2009 and 2010. Fishery-independent data collection is designed to minimize biases in sampling by using a variety of mesh sizes, consistent sampling procedures, and consistent timing of sampling (Begg 2005). Attempts were made to sample during the upstream migration but this was not always possible; thus, sampling did not always coincide with the migration. Each year nets of variable mesh sizes were used to collect a representative sample of fish from the population; see Table 1 for detailed information.

The fishery-independent data collected were catch effort, and biological data which included: fork length (mm), round weight (g), sex, gonad weight (g), maturity, and aging structure from each fish caught. The primary sources of data used for the assessment were the fishery-independent data as it was the only recent source for catch-effort and biological information.

Fishery-dependent data were compiled from the DFO Fisheries Management and Harvest Information System (FMHIS) database from 1989/1990 to 2010/2011. These data include exploratory harvest information in round weight (kg) for Qasigiyat Lake (Table 3). These data come from trade records supplied to DFO by the Pangnirtung Fisheries Ltd. There is uncertainty with the fishery-dependent data as reporting may not have been complete each year. The fishery-dependent data did not include catch effort or biological information. Prior to 2007, Pangnirtung Fisheries Ltd. would not purchase Arctic Char that weighted less than 1.8 kg (4 lbs). This selective purchasing of fish is known as high grading and results in data biased to older and larger fish. Thus, the fishery-dependent data should be used with caution as it does not necessarily represent the actual catch by fishers (Hilborn and Walters 1992).

The residents of Pangnirtung harvest Arctic Char annually for subsistence purposes from various waterbodies within Cumberland Sound. A harvest study was undertaken in Nunavut (Priest and Usher 2004) which reported that Pangnirtung residence took on average 35,065 individual Arctic Char annually for subsistence purposes. However, there is reason to believe that some commercial harvest was mistakenly reported as subsistence in this study. Therefore, it is likely that the annual subsistence harvest of Arctic Char by the community of Pangnirtung was below the reported harvest over the period of the study (1996-2001). Currently subsistence harvest of Arctic Char from Qasigiyat Lake is done opportunistically resulting in annual harvest levels of approximately 150 kg (330 lbs) (P. Kanayuk, Pangnirtung, Nunavut, pers. comm.). Due to the lack of recorded information, subsistence harvest has not been included in this assessment.

FISH COLLECTION AND BIOLOGICAL SAMPLING

Test Fishery

The test fishery data were collected during March in both 1982 and 1984 (McGowan 1985). The nets used were 139.7 mm gill nets, thus this sampling targeted the portion of the population that was vulnerable to a commercial fishery (Kristofferson and McGowan 1981). The data collected from individual fish included: catch effort data, fork length (cm), round weight (g), sex, and sagittal otoliths for aging (McGowan 1985). The objective of the test fishery was to gather baseline biological information for comparison with future studies to assess population structure responses to harvest over time (Kristofferson and McGowan 1981). Catch-Per-Unit-Effort (CPUE) data were collected in March and are not considered comparable to the more recent CPUE data collected in August/September. Thus, the CPUE data from the test fisheries are not used in this assessment.

Fishery-Independent Sampling

Fishery-independent data, from scientific sampling undertaken by DFO, were collected between August and early September in 2003, 2004, 2006, 2007, 2009 and 2010. Sampling locations were primarily in the lake (freshwater environment), but in 2007 and 2009 fish were caught in the inter-tidal zone (marine environment) as well as in the lake (see Table 1 and Figure 3 for details).

Different mesh-sized nets were used to collect a representative sample of the population. They included two types of experimental gillnets: stretched multi-mesh and stretched single mesh (38.1 mm) nets. Multi-mesh nets ranged in mesh size from stretched 38.1 mm (1.5 inch) to stretched 101.6 mm (4.0 inch). In addition, stretched 139.7 mm (5.5 inch) gillnets were also set along with the experimental gillnets (multi-mesh net or stretch 38.1 mm net). This was to provide samples for direct comparison to the exploratory fishery which used 139.7 mm nets. The combination of nets used varied from year to year; see, Table 1 for details. Multi-mesh nets catch a larger size range of fish compared to the single mesh size nets (38.1 mm nets and 139.7 mm) and provide a better size and age representation of the entire population.

For each fish captured catch effort data were recorded and the fish were sampled for fork length (± 1 mm), round weight (± 1 g), sex, maturity, gonad weight (± 1g) and sagittal otoliths.

Samples from 2003, 2004, 2006, 2007 and 2009 were aged using section otoliths. Ages were either determined or verified by the same age reader for all years.

Fishery-Dependent Sampling

Fishery-dependent data were compiled from the FMHIS database which provides trade record information (round weight in kg) on the fish that were caught under an exploratory fishing licence during the licence year (i.e., April 1 the first year to March 31 the following year). The weights of fish harvested in the winter are reported as round weight; whereas, weights of fish harvested in the summer months are reported as dressed weight. A conversion factor of 1.1 is used to convert dressed weight to round weight (T. Loewen, DFO, Winnipeg, MB, pers. comm.).

DATA ANALYSES

For most of the analyses sexes have been combined (pooled) as it has been shown that basic biological parameters (e.g., length, weight) do not vary in Arctic Char from males to females (Dempson and Green 1985) so sexes are combined where appropriate. In contrast, gear type used greatly affects the size of the fish caught (e.g., small mesh sizes catch a higher proportion of small sized fish). When the gear type used is known to influence results gear type has been kept separate otherwise gear has been combined.

Catch-Per-Unit-Effort (CPUE)

Catch and effort data were recorded for every net set and included: date net set, time net set, date net lifted, time net lifted, number of fish captured from each mesh size, and total number of fish in the net. These data were then used to calculate the CPUE which may be used as an index of abundance (Hubert 1996). For the fishery-independent data CPUE was calculated separately for each net type (multi-mesh nets, 38.1 mm nets, 139.7 mm nets) to show catch rate differences between gear types. As well, CPUE was calculated for pooled gear types to show the general trend in CPUE over the years. CPUE data were presented as number of fish caught per hour per for a 100 m long, 1.83 m high net. The number of fish captured in each mesh size was not always recorded, so standardization by mesh size could not be done for fishery-independent data.

Weight-Length Relationship

The weight-length analysis shows the relationship between fish fork length and weight and can be used as a measure of condition (Anderson and Neumann 1996). The weight-length relationship was graphed as a scatter plot by year and a power trend-line was fitted. The equation for the power trend-line is:

$$y = ax^b$$

where, y = round weight (g), x = fork length (mm) and a and b are parameters. This power equation provides information on the weight-length relationship as the fish grows. The parameter b changes in relation to the robustness of the fish as length increases; if $b > 3.0$ then fish are more robust as length increases, if $b < 3.0$ the fish are less robust as length increases and if $b = 3.0$ the shape of the fish does not change with increasing length (Anderson and Neumann 1996).

Length-Frequency Distribution

The annual length-frequency distributions are presented as histograms by gear type (multi-mesh nets, 38.1 mm nets, 139.7 mm nets), sexes combined.

Age-Frequency Distribution

Annual age-frequency distribution histograms are presented by gear type (multi-mesh nets, 38.1 mm nets, 139.7 mm nets), sexes combined.

Trend Analysis

Comparisons of trends (trend analysis) of mean fork length (mm), mean otolith age (year), mean round weight (g) and mean condition factor (K) were used to assess the response of the Qasigiyat Lake Arctic Char to harvest pressure. For these analyses sexes were combined, but gear types (multi-mesh nets, 38.1 mm nets, 139.7 mm nets) were kept separate. Mean fork length, mean age, mean round weight and mean condition factor for each year of the fishery-independent data are summarized and compared to the historical test fishery data.

Condition factor (K) is an index of the condition (well-being) of a fish which standardizes weight-length interactions (Anderson and Neumann 1996). The formula used for condition factor (K) was:

$$K = (W \times 10^5)/L^3$$

where, W = round weight (g), L = fish fork length (mm) (Kristofferson and McGowan 1985, Anderson and Neumann 1996).

Length-at-Age

Mean fork length at age is presented as a line graph, where years and sexes are kept separate but gear types (multi-mesh nets, 38.1 mm nets, 139.7 mm nets) are combined (it is not necessary to account for gear selectivity in this analysis). Plotting the growth of the sexes separately highlights any differences in length-at-age between the sexes.

Sex and Maturity

Arctic Char sex ratios (defined as the proportional representation of males to females in the catch) were calculated for each year of the fishery-independent data and compared to the 1982 and 1984 test fishery data. Sex ratios were calculated for all gear types combined and for 139.7 mm nets alone.

The percentage of different maturity stages (immature, mature, resting, unknown), mean age of mature fish, and age at first maturity for the fishery-independent data were determined. There was no maturity stage information provided from the test fishery data so no comparison with more recent data could be made.

In addition, scatter plots of percent mature at a given age are presented, using fishery-independent data from 2003, 2004, 2006, 2007 and 2009. A sigmoidal four parameter curve was added as a trend-line to the data using Sigma Plot.

RESULTS

HARVEST INFORMATION

The test fishery data were collected during the winter in 1982 and 1984 (Table 2). Sampling was limited to the lake (freshwater environment) with the quota being filled within 24 hours (McGowan 1985).

Unlike the test fishery data, the fishery-independent data were collected in the summer (August – September). In most years samples were collected from the lake (freshwater environment); but in 2007 and 2009 data were also collected from the inter-tidal zone (Figure 3, Table 1). The number of fish captured ranged from n = 129 in 2004 to n = 211 in 2010. The proportion of fish captured in the different gear types varied from year-to-year. In some years the majority of the catch came from the experiment nets (multi-mesh nets and 38.1 mm nets), in other years the majority of the catch came from the 139.7 mm nets, see Table 1 for details.

Historically this waterbody was a winter fishery, but since the 1997/1998 licence year it has developed into a summer fishery (Table 3). The present quota for the Qasigiyat Lake waterbody is 1,500 kg (3,300 lbs) which has been in effect since 2004/2005 (Table 3). Since then there have been no recorded harvesting above the quota. Prior to this, when the quota was set at 1,000 kg (2,200 lbs) harvesting in excess of the quota was recorded for 7 out of 16 years (Table 3).

The total harvest removed from Qasigiyat Lake (Ptarmigan Fiord), since 1982 from all sources (i.e., test fishery data, fishery-independent data and fishery-dependent data), was 25,781 kg (56,717.9 lbs) round weight. Over the last 12 years (licence year 1999/2000 until 2010/2011) the average annual harvest from known records (fishery-independent data and fishery-dependent data) was 981.8 kg (2,160 lbs) round weight (calculated from Table 3).

DATA ANALYSES

Catch-Per-Unit-Effort (CPUE)

There is no trend in the CPUE data (Figure 4). No trend indicates that there has been no change in the catch rates and thus, no change in the abundance of Arctic Char in Qasigiyat Lake. There is a large amount of variability in the CPUE from the fishery-independent data between the different gear types (multi-mesh nets, 38.1 mm nets and 139.7 mm nets) (Figure 4). The multi-mesh nets from 2010 had the highest CPUE across all years. In contrast, the multi-mesh nets and 38.1 mm nets in all other years expect 2009 and 2010, had lower CPUE compared to 139.7 mm nets, with 2007 recording the lowest catch rates overall (Figure 4). To see the overall trend in CPUE, gear type was pooled. The pooled CPUE shows similar results (no trend) with less variation overall. The highest CPUE was recorded in 2010 and lowest in 2003, 2007 and 2009.

Weight-Length Relationship

For the weight-length relationships only fishery-independent data were used; because the test fishery data provided only a summary and the fishery-dependent data had no weight or length information available. From the weight-length relationships in all years (2003, 2004, 2006, 2007, 2009 and 2010) it appears that Qasigiyat Lake Arctic Char increase in round weight faster than fork length, meaning fish robustness increases with fork length (Figure 5). This observation is support by the b parameter in the power trend-line which in all years, except 2010, has a value above 3.0. The R^2 values (top right-hand corner on each graph) are all close to 1 indicating that the power trend-line is a good fit to the data.

Length-Frequency Distribution

Fishery-independent data were used in this analysis as all other data sets were lacking the appropriate information. The length-frequency distributions show annual variation within and among gear types (multi-mesh nets, 38.1 mm nets, 139.7 mm nets) (Figure 6). In some years (2007, 2009 and 2010), there is a large amount of overlap in the length-frequencies between gear types; in other years (2004 and 2006), there is very little overlap of the length-frequency data. The modal size of the distributions fluctuates between years. In 2004 and 2006 there is a bimodal distribution while in all other years show unimodal distributions of varying ranges (Figure 6). In 2003, 2004 and 2006 fishing occurred exclusively in the lake (Table 1) and aimed to capture resident fish. Additionally, in 2004 and 2006 smaller mesh gill nets were used. This most likely explains the higher frequencies of smaller-size (< 300 mm) Arctic Char seen in those years relative to 2007, 2009 and 2010.

From the length-frequency graphs the multi-mesh nets captured fish from all length ranges, while the 139.7 mm nets only captured fish that were of sellable size (larger fork length) (Figure 6). In 2004 and 2006, the 38.1 mm nets captured predominately smaller fish with a maximum fork length of 575 mm and 610 mm respectively.

Lastly, the range in fork length of the Arctic Char from all years except 2010 was consistent. Fish captured from all gear types ranged in fork length from 75 mm to 700 mm. In contrast, fish fork length in 2010 ranged from 195 mm to over 700 mm. The peak of the bell curve in fork length consistently ranged between 550 mm to 600 mm in all sample years except in 2004, when the peak in length distribution was at 275 (mm).

Age-Frequency Distribution

For the age-frequency distributions, fishery-independent data from 2003, 2004, 2006, 2007 and 2009 were used. The ages for the 2010 samples were not available for this assessment. Between sampling years there is some variability in the distributions (Figure 7). The age data from 2003 and 2004 are mostly represented by younger age classes (age 9 or younger), whereas the data for 2006, 2007and 2009 are represented mostly by older age classes (age 9 or older). This difference in age distribution is likely the result of gear selectivity, not a representation of population changes. The range of ages remains consistent from year-to-year indicating that there is no change in the age structure of the Qasigiyat stock. In all years fish ranged from age 3 to 19. From these graphs age classes can be followed throughout the years. Specifically, 1995 may have been a strong year class, appearing in 2003 as age class 8, 2004 as age class 9, age class 11 in 2006 and age class 14 in 2009. In addition to determining strong year classes, the age data shows that the 139.7 mm nets are catching fish ages 5 to 16, while experimental nets (multi-mesh and 38.1 mm) are catching fish ages 2 to age 16.

Trend Analysis

Fishery-independent data and test fishery data were used for the trend analysis (Figure 8).

Mean fork length (mm) for fish captured in 139.7 mm nets is consistent over time ranging from 529.6 mm in 2007 to 646 mm in 1984 (Figure 8-A). There is very little variability in mean fork length from year to year for the 139.7 mm nets. The 38.1 mm nets capture the lowest mean fork lengths 216 mm and 219.6 mm, in 2004 and 2006, respectively. In contrast there is a lot of variability between the mean fork length of fish captured in the multi-mesh nets across the years. Overall mean fork length shows no trend or a slight increasing trend over time, indicative of a sustainable fishery and perhaps an improving stock.

Mean age of Qasigiyat Lake Arctic Char is highly variable between the gear types, with 139.7 mm nets catching older fish and 38.1 mm nets catching younger fish (Figure 8-B). Despite the differences by gear type, the mean age appears to be stable over time from 2003 to 2010. It should be noted that strong year classes influence the average age data when those year classes are highly represented in the data set (e.g., many age 8 fish in 2003, but not many age 9 fish in 2003 will affect the average age calculation). Strong year classes were noted in some years and the potential of these influences has been taken into account when interpreting these results. Mean age from the test fishery are higher than the recent fishing period (2003-2009) (Figure 8-B). The change in average age from the 1980s to recent period is likely due to increased growth that could be a result of a fishing-up-effect (Ricker 1975), changing environmental conditions or both. It is noted that the mean age from recent sampling is high and stable and therefore indicative of a sustainable fishery.

Mean round weight (g) of fish captured in 139.7 mm nets appears to be variable with a possible increasing trend, with 2007 being an exception (Figure 8-C). In 2007, there was a decrease in the mean weight of fish captured in the 139.7 mm nets followed by an increase in 2009 and 2010. Round weight from the 139.7 mm nets ranged from 1,910.4 g in 2007 to 3,212.9 g in 2010. In contrast, fish captured in the multi-mesh nets show a large amount of variability in mean round weight, ranging from 900 g in 2003 to 2,418.9 g in 2010. Fish captured in the 38.1 mm nets had the lowest mean weights of less than 500g in both 2004 and 2006. Overall the mean round weight appears to be increasing over time, indicative of a sustainable fishery and perhaps improving stock.

The mean condition factor (K) for this population appears to be stable over time. Although there is some annual variability, overall there is no trend (Figure 8-D). The 139.7 mm nets have a mean condition factor of 1.0 in 1982 and a mean condition factor of 1.35 in 2010. It cannot be said if this change in mean condition factor is a true indication of an increase in robustness of the population or more likely simply a by-product of the seasonal sampling variation. It is theorized that anadromous Arctic Char only feed in the salt water and do not feed in fresh water which would result in natural seasonal variation in body condition (well-being); where an individual would have a lower condition factor in late winter (pre-feeding) compared to late summer (post-feeding).

Length-at-Age

The mean length-at-age could only be graphed for the fishery-independent data from 2003, 2004, 2006, 2007 and 2009. No age data were available from 2010. From the graphs of Figure 9, it appears that length-at-age among years is consistent. Fish aged 9 -10 years primarily fall within the size range of 450 mm to 650 mm (Figure 9). In general, females appear to be longer than males when younger than age 9; while, males appear to be longer than females when older than age 9. This difference in fish length is not statistically different (Figure 9), but may be biologically significant. Lastly, fish fork length asymptotes at approximately age 11.

Sex and Maturity

Sex ratio data for Qasigiyat Lake Arctic Char are presented in Table 4, for both test fishery data and fishery-independent data. The sex ratio of the fishery-independent data was determined for all gear types combined, and 139.7 mm nets alone. All mature individuals with fork lengths less than 375 mm were removed from this analysis as they were considered to be part of the resident life history form and thus not part of the stock targeted by the fishery (i.e., anadromous fish). These individuals were only removed from this analysis as they mature younger and at a smaller size which may results in underestimates of sex and maturity for the targeted harvest population.

The ratio of males to females for all gear types combined ranged between 0.9 in 2003 to 3.5 in 1984. The higher the ratio the more males there are compared to females in the catch. The mean sex ratio for all years was 1.9, meaning that overall there were more males caught than females. The sex ratio of the 139.7 mm nets represents the sex ratio of the harvested portion of the population. Overall there are more males than females captured in 139.7 mm nets shown by a sex ratio of 2.4.

For the comparison of maturity stage, only fishery-independent data are presented, as the test fishery data did not provide this information. The majority of fish captured in all years were considered mature, preparing to spawn, resting, or having spawned at least once. On average, immature fish made up 23.9% of the catch, ranging from 13.2% in 2009 to 39.4% in 2004 (Table 4). Current year spawners on average made up 49.9% of the catch, ranging from 36.1% in 2003 to 59.6% in 2006. Resting fish on average made up 22.7% of the catch, ranging from 17.9% in 2006 to 30.2% in 2009.

For the mean age of mature fish, only fishery-independent data were used from the following years 2003, 2004, 2006, 2007 and 2009 (Table 4). The mean age of mature females ranged from age 10 to age 11.2, in 2003 and 2004 respectively; whereas, the mean age of mature males ranges from age 10 to age 10.6 in 2003 and 2009 respectively. The mean age across all years is similar for the sexes, males = 10.3 and females = 10.5. The age at first maturity for females ranged from 5 to 8 in 2003 and 2009, respectively. The age at first maturity for males ranges from 5 to 8 in 2003 and 2009, respectively.

Only current year spawners from fishery-independent data were used to determine age at 50% maturity. The age at 50% maturity appears to be stable over time ranging from age 6.5 in 2004 to age 7.75 in 2007 (Figure 10). The lowest mean age at 50% maturity were recorded in 2004 and 2006. During these years 38.1 mm nets were used for sampling; these nets capture fish with smaller fork lengths, thus biasing the results. This bias is most likely the reason for the younger age at 50% maturity recorded for 2004 and 2006 compared to other years. The 4-parameter sigmoidal trend line is a good fit to the data as R^2 values are close to 1.

DISCUSSION

The results from this assessment indicate that the Qasigiyat Lake (Ptarmigan Fiord) Arctic Char stock appears to be stable under present harvest levels. Consistency among years in CPUE data, weight-length relationships, length-frequency distributions, age-frequency distributions, mean trend data and maturity ratios support this conclusion.

The CPUE data (gear types combined) shows no decreasing trend from 2003 to 2009, and if assumed to be an index of abundance, then this implies that the stock is able to support present harvest levels (Hubert 1996). Catch rates appear to be much lower with the fishery-independent data than they were with the test fishery data. This difference in catch rates is most likely attributed to the difference in sampling season and sampling methods. Records from the test fishery indicate that the nets were set in areas where Arctic Char were believed to be congregating in the lake over winter thus, resulting in faster catch rates in 1982 and 1984. For comparative purposes it is vital that sampling is unbiased (Begg 2005). Focusing fishing effort where fish are congregating will result in biased higher catch rates. In looking solely at the fishery-independent data (2003 to 2010) for catch rate and CPUE, there is very little variability from 2003 to 2009; however, the catch rate in 2010 is 6-fold higher, shown with a shorter net soak time and a higher CPUE. This difference in catch rates in 2010 may be a result of different fishing locations or timing of sampling with timing of fish migration. In general, the overall trend indicates stability in CPUE and catch rates, thus stability in stock structure.

The weight-length relationships indicate that the Qasigiyat Lake Arctic Char stock is gaining robustness with increased fork length, thus it can be concluded that the stock is healthy. The weight-length relationship appears to be consistent suggesting that the condition of the stock has not changed over time. Stocks that are stressed (e.g., over harvest, climate change) typically have a reduced condition or robustness, meaning the fish are skinnier and less healthy.

Length-frequency distributions reflect interactions between rates of reproduction, recruitment, growth and mortality of the age-groups (Anderson and Neumann 1996). Monitoring the change in length-frequency over time can help in understanding the dynamics of a fish population and can help in identifying problems such as year class failure, slow growth or excessive annual mortality (Anderson and Neumann 1996). The length-frequency distributions for Qasigiyat Lake Arctic Char show a constant annual range in fork length. There is variability in the length-frequency distributions which is most likely a product of the timing of sampling, gear type used and how that correlated with the return migration of Arctic Char to the freshwater environment. There is natural annual variability in the timing of Arctic Char migration back to the freshwater environment (Moore 1975b); this is attributed to the variability of the environmental cues that signal fish to return. Depending on environmental signaling and the timing of the fishery-independent data collection, different portions of the population may have been sampled in different years as Arctic Char in Cumberland Sound are believed to have stratified migrations. Stratified migrations occur when a species migrates in groups such as, small fish first, big fish last or males first, females last. The behaviour of stratified migration is noted in many migrating fish species (Moore 1975a, VanGerwen-Toyne et al. 2008). Despite the variability in length distribution, the general consistency in fish length ranges supports the statement that Qasigiyat Lake Arctic Char has a stable stock structure that is able to sustain present harvest levels.

The mean trend data for length, weight and condition factor indicate that the stock structure is stable. No trend in mean fork length indicates that the range in fork length for the stock is not changing, thus supporting the conclusion of a stable stock structure. The mean trend in weight and condition factor data mimics that of the length data. A stable mean condition factor indicates that fish are able to feed well in their environment potentially resulting in overall reproductive health. Condition factor is an important variable in determining reproductive potential (Marteinsdottir and Begg 2002).

Age-frequency distributions allow for the comparison of relative abundance of age-groups (year classes) within the catch. Consecutive years of age data allow the abundance of year-class to be tracked through time. Tracking year classes through time and comparing them to other year classes of the same population provides general information on year-class strength, year-class abundance, and year-class mortality over time (Smith 1994). The range in age of this population appears to be stable. In more recent years (2009) there is a higher proportion of older fish compared to earlier years (2003). This slight shift in age structure composition is most likely a result of strong year classes aging in the population. This hypothesis is supported by the lack of variation in mean age of fish caught in 139.7 mm nets and an increase in mean age of fish captured in multi-mesh nets. Lastly, the age at 50% maturity shows little variation providing further evidence of stability in the population structure. As previously mentioned, in 2004 and 2006 the experimental nets used were comprised of only the smallest mesh size (38.1 mm) and it has been shown with the length frequency data that the length of fish captured is highly correlated to the mesh size being used. Since fish length and age are correlated, smaller mesh will target younger fish in the population. In addition, there is evidence of two life history forms of Arctic Char residing in Qasigiyat Lake - resident and anadromous (Loewen 2008). Although only the anadromous form is directed for under the stage II exploratory licence, the habitat of the two populations overlap in the lake environment and thus both forms are susceptible to capture in the fishery-independent data. If both forms are present in the fishery-independent data then the variation in age data for 2004 and 2006 may be caused by an over representation of the resident life form which matures at a smaller size and younger age compared with the anadromous life form (Loewen 2008).

Additionally, the oldest age and mean age of Qasigiyat Lake Arctic Char are younger than other Arctic Char populations within Cumberland Sound. Arctic Char from the Isuituq stock have a maximum age of 22 years, which is approximately 5 years older compared to the Qasigiyat Lake population (Harris and Tallman 2010). In addition, the mean age from the Isuituq population ranges from 10.2 to 14.0, from 2005 and 2008 respectively (Harris and Tallman 2010), which is higher than the mean ages (10.0 to 11.2, 2003 and 2004 respectively) from Qasigiyat Lake Arctic Char.

The length-at-age analysis of Qasigiyat Lake Arctic Char qualitatively appears to be consistent among years; which is indicative of a stable stock structure and a healthy population. The plateau in growth at around age 11 may represent a shift in energy allocation. It is not uncommon for organisms to divert energy from growth to reproduction at older ages and larger sizes, resulting in slower or no growth. This phenomenon may be exaggerated in the Arctic where food resources for fish are often more limited compared to temperate environments (Gross et al. 1988). The Qasigiyat Lake population appears to reach an asymptotic length of approximately 600 mm around 10 years of age. This differs from other populations within Cumberland Sound who do not appear to reach a growth plateau (Harris and Tallman 2010).

Lastly, the sex and maturity data are consistent among years. The ratio of more males to females in this population is consistent with other findings in the Cumberland Sound area (Moore 1975a). No change in the sex ratio indicates that the population is able to maintain its stock structure under present harvest levels. In addition, there is a large portion of the population that is classified as mature and able to reproduce. Having a large portion of the population being mature results in long-term stock sustainability as it is commonly believed that due to the extreme conditions of the environment within which Arctic Char live, that they do not reproduce annually. Individual fish are believed to reproduce every 2-3 years when they have acquired sufficient reserves (Johnson 1980). A stock structure that has a large number of mature individuals who are older is a sign of a healthy stock, and stable stock structure.

From the data presented it appears that there is sufficient information to assess the stock structure of Qasigiyat Lake Arctic Char. All of the analyses show stability which indicates no stock structure change. It can be concluded from this analysis that the present harvest level of Qasigiyat Lake (Ptarmigan Fiord) Arctic Char is sustainable. Traditional Knowledge from the fishers of Pangnirtung, support the statement that the current harvest level for Qasigiyat Lake is sustainable. The fishers suggest that the portion of the harvest removed by DFO Science for the purpose of fisheries independent data should be added to the quota.

RECOMMENDATIONS

The recommendations for the long-term plan are as follows:

1) a) Continued assessment of this stock requires that CPUE and biological samples are collected for fish harvested under the exploratory licence (fishery-dependent data), according to DFO protocols (DFO 2010, VanGerwen-Toyne and Tallman 2011).

   b) Scientific sampling data (i.e., fishery-independent data) are collected to provide an independent comparison to Arctic Char caught by the fishery (i.e., fishery-dependent data). It is imperative that this sampling continues within Cumberland Sound collaboratively between the local HTO of Pangnirtung and DFO.

   c) It is recommended that sampling be as consistent as possible; same methods, same sampling equipment, same location and same time of year.

2) The possibility and usefulness to adjust the timing of sampling to specific environmental cues (such as neap tides) should be examined, as this determines Arctic Char movements in Cumberland Sound systems, according to local harvesters.

3) Pangnirtung fishers note that the upper lake may be important for the persistence of this stock, by providing critical habitat to different life stages. It is recommended that baseline information (fishery-independent data) from the upper lake be collected.

4) Traditional Knowledge from experienced fishers and elders in the community is available but needs to be written down. Local fishermen have a wealth of information and we recommend that this information be collected, documented and incorporated into all fishery plans, including science sampling plans.

5) A collaborative approach between the Pangnirtung HTO, Pangnirtung fishers and DFO to develop long term research plans should be undertaken for the Cumberland Sound area, with emphasis on stocks the community considers to be high priority.

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Table 1. Summary of fishery-independent data. includes sample dates, gear type used, number of nets set, total soak time, number of fish captured for each net type, total number of fish captured categorized per year. Total soak time was calculated by adding all the hours that each net type was left to soak for each set.

Sampling Year	***Start Date***	***End Date***	***Number of fish captured***		***experimental (exp.) net mesh sizes (mm)***	***Number of nets set***		***Total soak time (hours)***	***Total numb of fish captured***	***Location fished***
			139.7 mm nets	**exp. mesh**		***139.7 mm nets***	**exp. mesh**			
2003	September 5	September 8	48	156	38.1 – 101.6	1	4	443.7	204	Lake
2004	September 7	September 8	57	72	38.1	2	2	116.3	129	Lake
2006	August 20	August 21	140	44	38.1	4	2	156.8	184	Lake
2007	August 1	August 4	121	60	38.1 – 101.6	7	3	558.1	181	Inter-tidal zone
2009	August 20	August 23	72	120	38.1 – 101.6	4	4	295.7	192	Inter-tidal zone/Lake
2010	September 4	September 5	64	147	38.1 - 101.6	1	2	57.4	211	Lake

Table 2. Summary of test fishery data (from McGowan 1985) including sample dates, location fished, number of fish captured in 139.7 mm nets, total number of fish captured per year.

Sampling Year	**Start Date**	**End Date**	**Number of fish captured**	**Total soak time (hours)**	**Location fished**
1982	March 16	March 16	528	24	Lake
1984	March 12	March 12	395	24	Lake

Table 3. Summary of available harvest information from all sources (fishery-independent, fishery-dependent) detailing quota, number of fish captured and weight (kg) where available, by year. Data for the exploratory harvest landings was compiled from Fisheries Management and Harvest Information System (FMHIS) and from McGowan (1985). Exploratory Harvest Landings captured in the summer months (7 and 8) were converted to round weight by a factor of 1.1 to account for removed viscera. When 0 appears as the harvest by weight, there was no recorded harvest for that licence year.

Year	Harvest Month	Quota		Harvest by weight		Source	Fishery-independent data	
		kg	lb	kg	lb		number	weight (kg)
1982	3	454	998.8	908	1997.6	McGowan 1985		
1984	3	1000	2200	1088	2393.6	McGowan 1985		
1989/1990	1, 3	1000	2200	2027.6	4460.7	FMHIS		
1990/1991	3	1000	2200	680	1496	FMHIS		
1991/1992	2, 3	1000	2200	1791.9	3942.2	FMHIS		
1992/1993	1, 3	1000	2200	900.2	1980.4	FMHIS		
1993/1994	1, 3, 7	1000	2200	2370.1	5214.2	FMHIS		
1994/1995	1, 3	1000	2200	1094.1	2407	FMHIS		
1995/1996	1, 2	1000	2200	795.5	1750	FMHIS		
1996/1997	5	1000	2200	915	2013	FMHIS		
1997/1998	8	1000	2200	501.5	1103.3	FMHIS		
1998/1999	8	1000	2200	927.4	2040.2	FMHIS		
1999/2000		1000	2200	0	0	FMHIS		
2000/2001	8	1000	2200	858.2	1888	FMHIS		
2001/2002	7, 8	1000	2200	1616.6	3556.5	FMHIS		
2002/2003	8	1000	2200	1492	3282.4	FMHIS		
2003/2004	8	1000	2200	668.5	1470.7	FMHIS	204	114
2004/2005	8	1500	3300	916.5	2016.3	FMHIS	129	73
2005/2006	8	1500	3300	1067.6	2348.7	FMHIS		
2006/2007	7	1500	3300	1100	2420	FMHIS	184	172
2007/2008	7, 8	1500	3300	1299.3	2858.5	FMHIS	181	142
2008/2009		1500	3300	0	0	FMHIS		
2009/2010	7, 8	1500	3300	1510	3322	FMHIS	192	193
2010/2011	7, 8	1500	3300	1253	2756.6	FMHIS	211	255
Total				**25,781**	**56,717.9**		**1098**	**949**

Table 4. Summary of the sex and maturity of anadromous Arctic Char captured in Qasigiyat Lake from fishery-independent data. Data from 139.7 mm nets and multi-mesh nets have been pooled. Mature fish under the fork length of 375 mm were considered to be residents and thus removed from the maturity analysis.

	Sex					Maturity Percentage				Mean Age of Mature		Age at first Maturity	
Year	**Male**	**Female**	**Unknown**	**Ratio M:F All nets**	**Ratio M:F 139.7 mm Nets**	**Immature**	**Mature**	**Resting**	**Unknown**	**M**	**F**	**M**	**F**
1982	62	28		2.2	2.2								
1984	78	22		3.5	3.5								
2003	87	95	1	0.9	2.0	21.9	36.1	21.9	0.5	10	10	5	5
2004	72	37	0	2.0	1.9	39.4	39.4	21.1	0	10.3	11.2	6	6
2006	123	55	0	2.2	2.6	22.5	59.6	17.9	0	10.3	10.8	6	8
2007	96	80	1	1.2	1.6	26.6	49.7	23.2	0.6	10.1	10.4	6	8
2009	103	78	1	1.3	2.0	13.2	56.0	30.2	0.5	10.6	10.3	8	7
2010	125	85	0	1.5	3.1	19.5	58.6	21.9	0				
Average	93.3	60.0	0.5	1.9	2.4	23.9	49.9	22.7	0.27	10.3	10.5	6.2	6.8

Figure 1. Map of Cumberland Sound with Qasigiyat Lake (Ptarmigan Fiord) marked with ✦ and the community of Pangnirtung marked with ★.

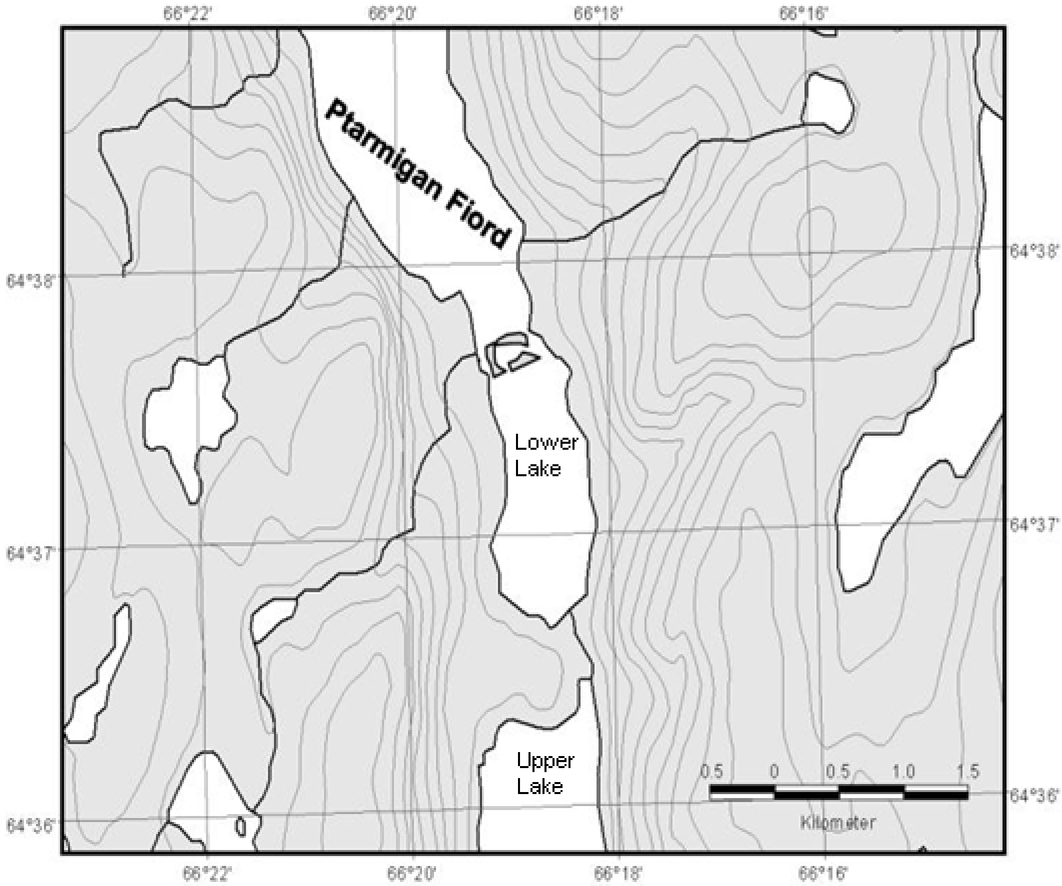

Figure 2. The map of Qasigiyat Lake, Ptarmigan Fiord, Nunavut, showing the lake basin both lower and upper lakes and the proximity to the marine environment (Loewen 2008).

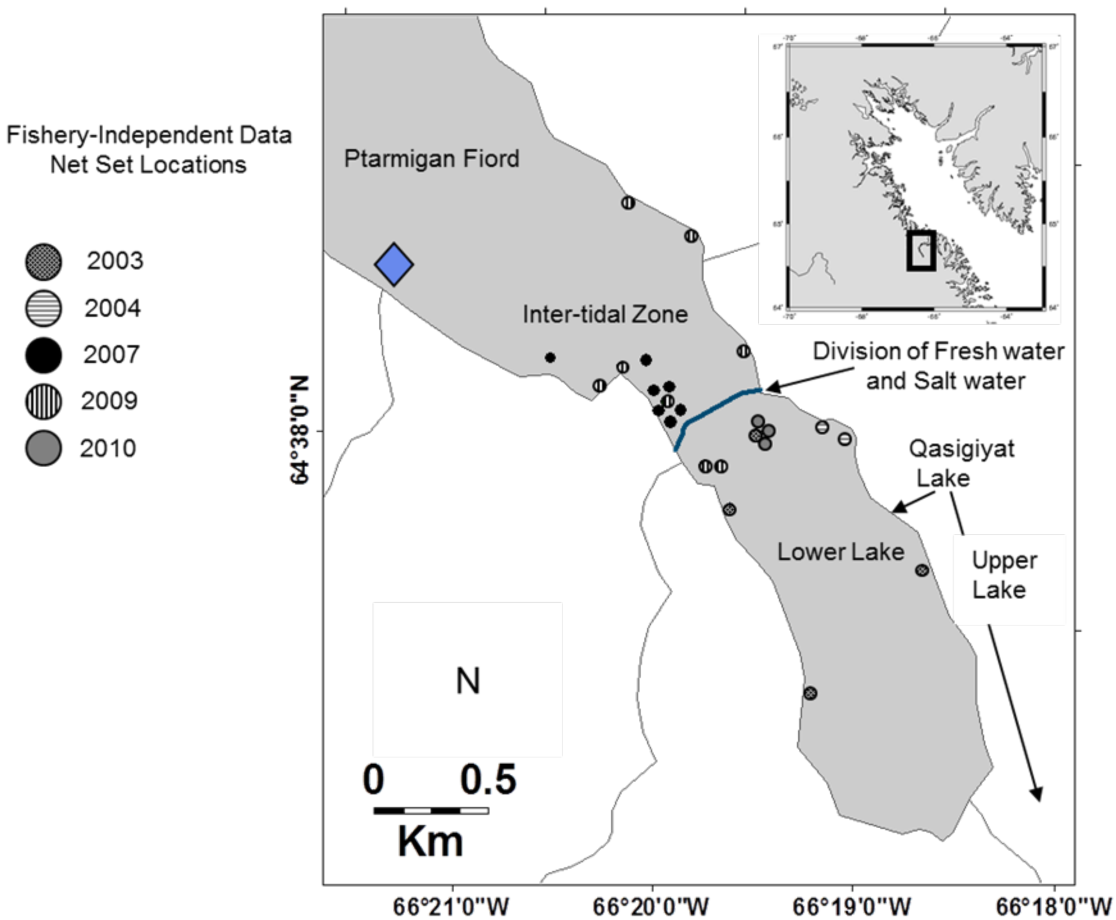

Figure 3. Map of Qasigiyat Lake, with fishing locations noted. The net set locations for fishery-independent data presented by collection year. The common fishing location used by fishermen is marked with ◆. There is a cabin close to this location so it makes it easy to camp while fishing. The 2006 net set location data are not available. Map made by S. Wiley (Fisheries and Oceans, 501 University Crescent, Winnipeg, MB).

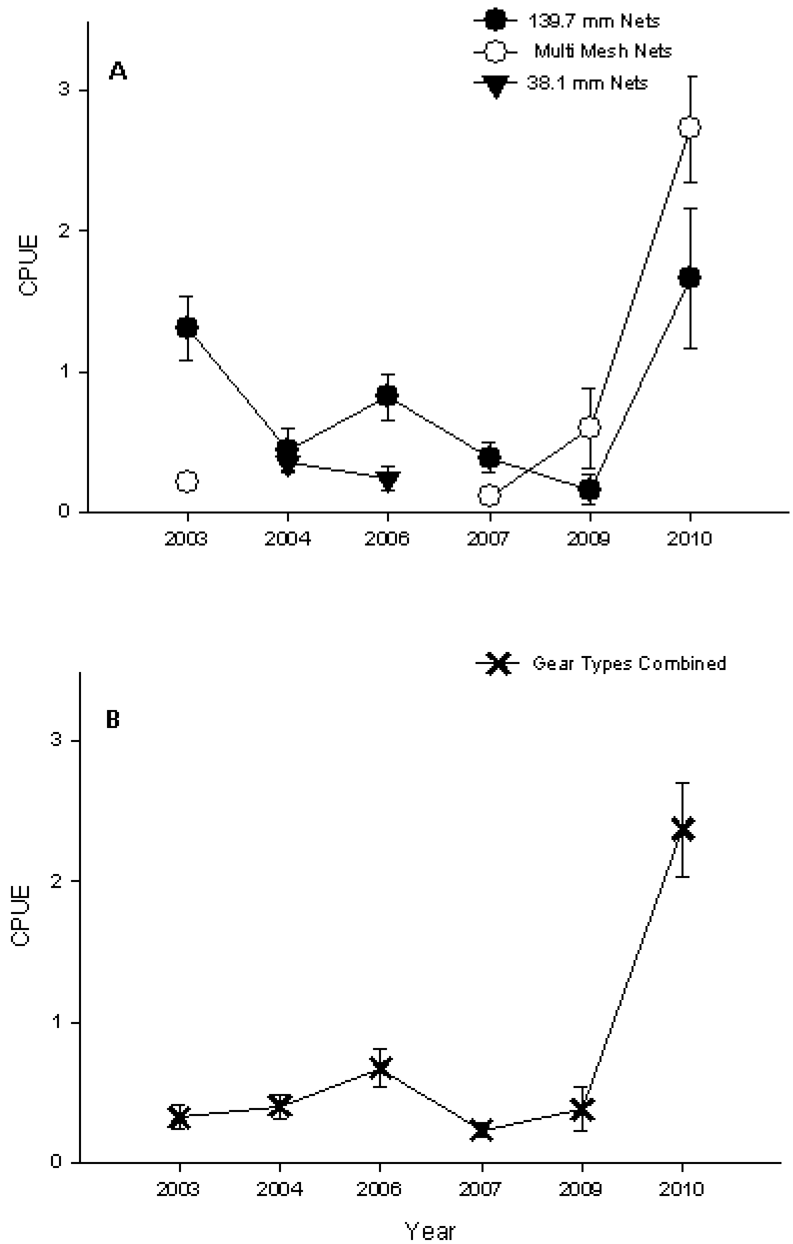

Figure 4. Mean catch-per-unit-effort (CPUE) by year, and gear type (139.7 mm nets and multi-mesh nets) (A), and by year for gear types pooled (B). Standard error bars included. Data was from the fishery-independent sampling. CPUE was reported as fish caught per 100m net (net height 1.83 m) per hour.

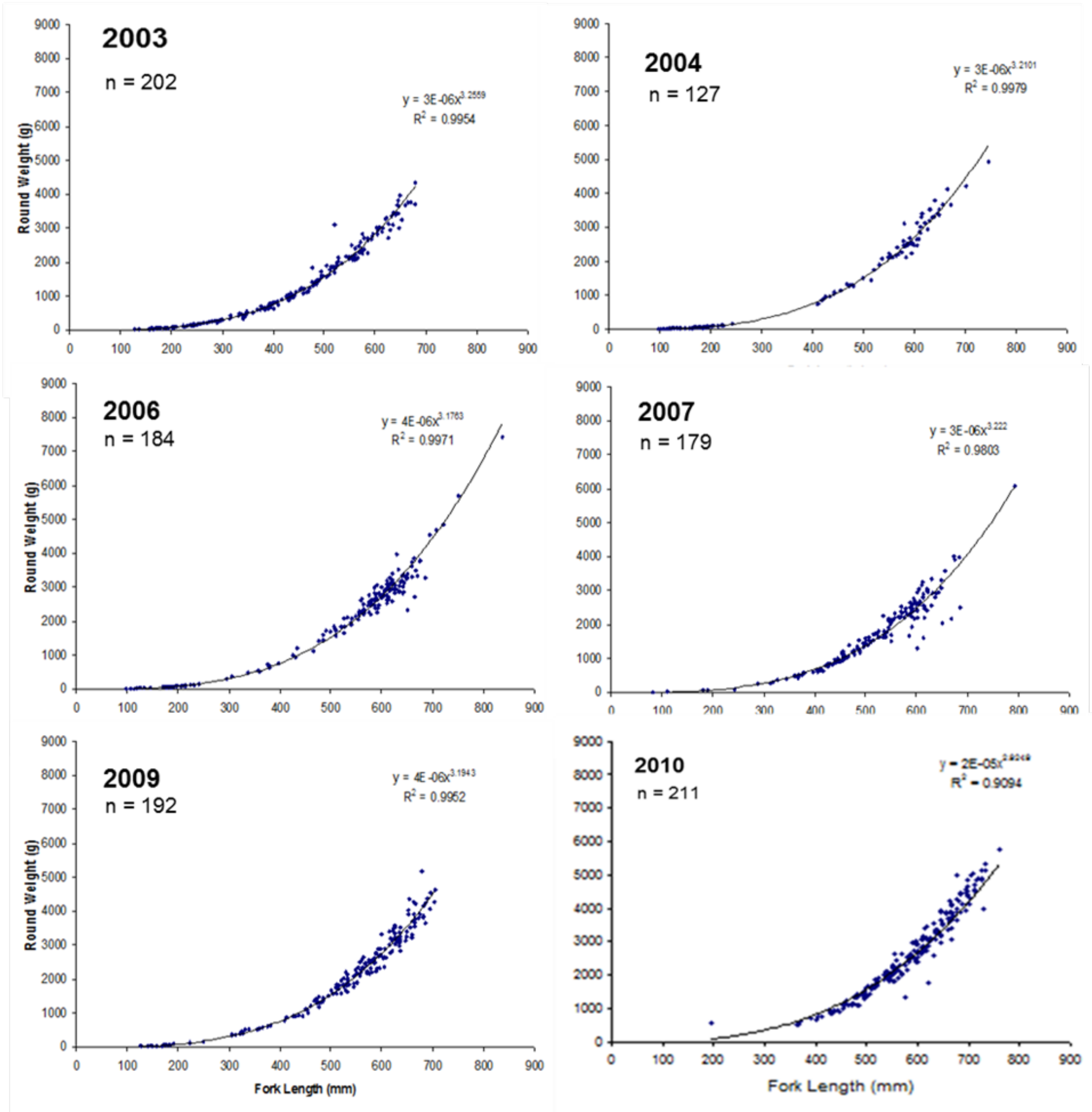

Figure 5. Weight-length relationship of Qasigiyat Lake (Ptarmigan Fiord) Arctic Char from fishery-independent data. Sexes and gear type have been pooled. Power trend-lines have been applied to each graph, the equation of the power line and the associated R^2 value are presented on each graph. n = sample size.

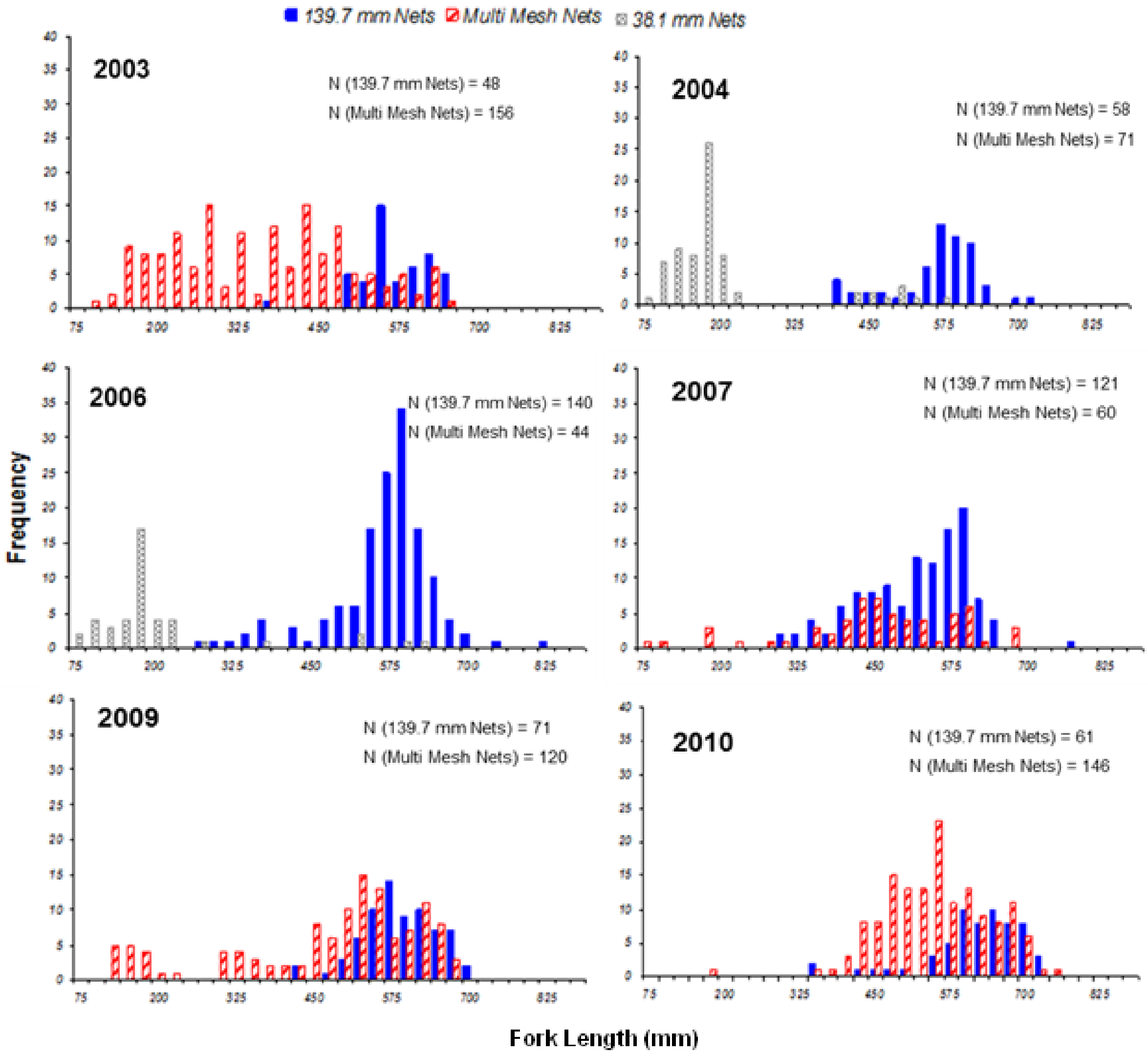

Figure 6. Length-frequency distributions of Arctic Char from Qasigiyat Lake (Ptarmigan Fiord) fishery-independent data by gear type. N=sample size.

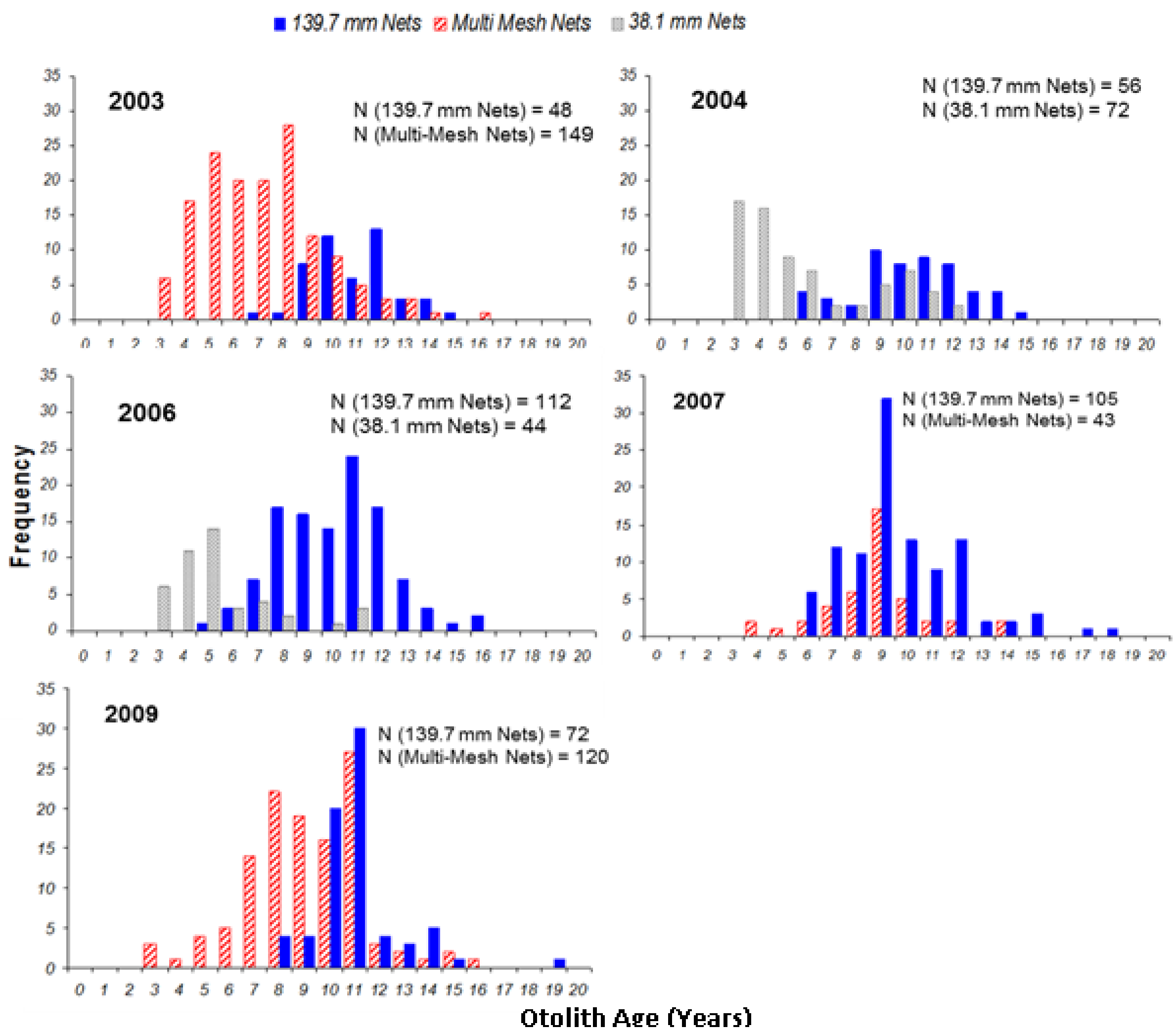

Figure 7. Age-frequency distributions of Arctic Char from fishery-independent data by net type. N=sample size.

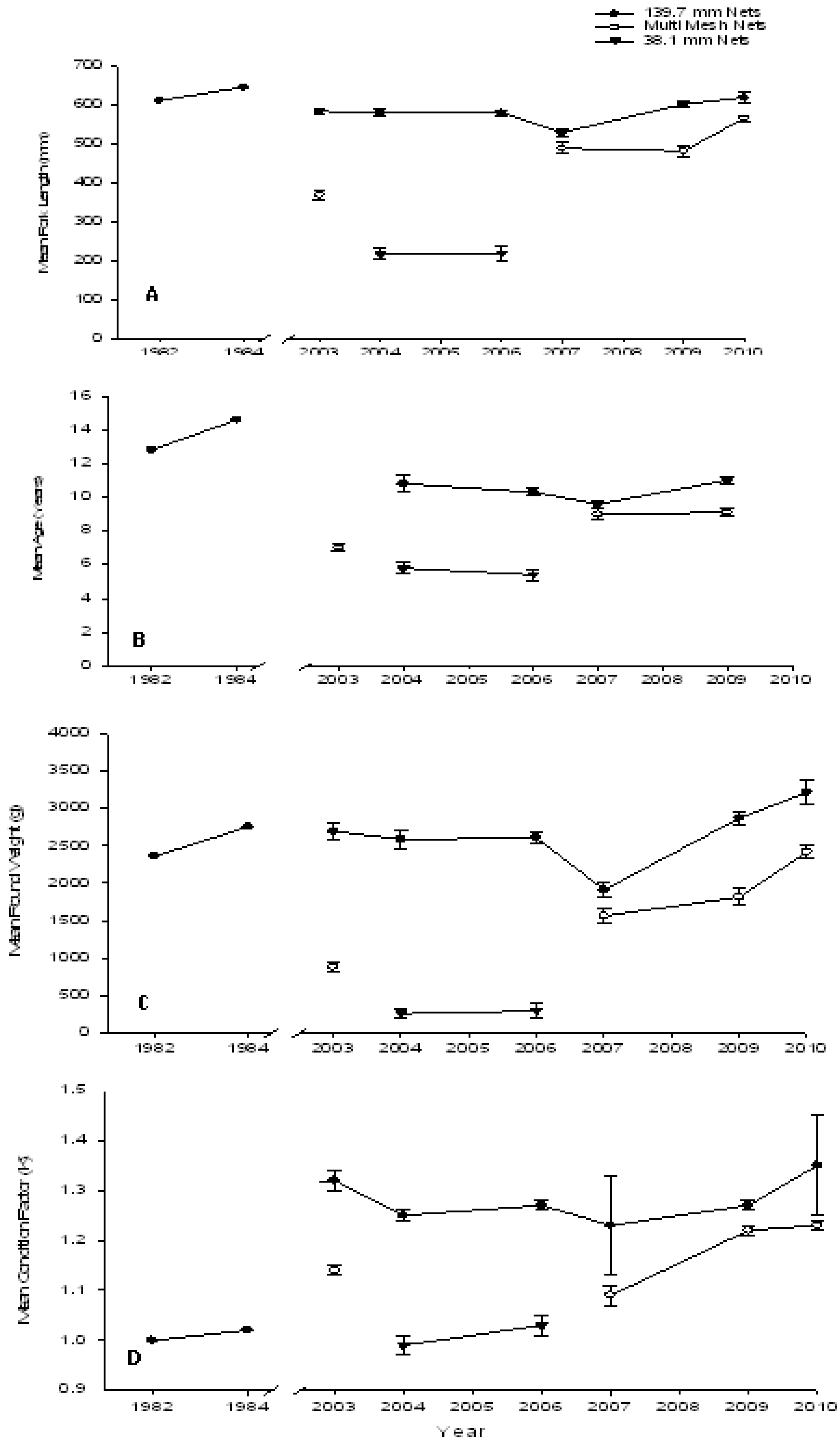

Figure 8. Trend analysis - plot of the means (fork length mm (A), age year (B), round weight g (C), condition factor K (D)) from both test fishery data (1982 and 1984) (McGowan 1985) and fishery-independent data (for the remaining years). Standard error bars of the mean included.

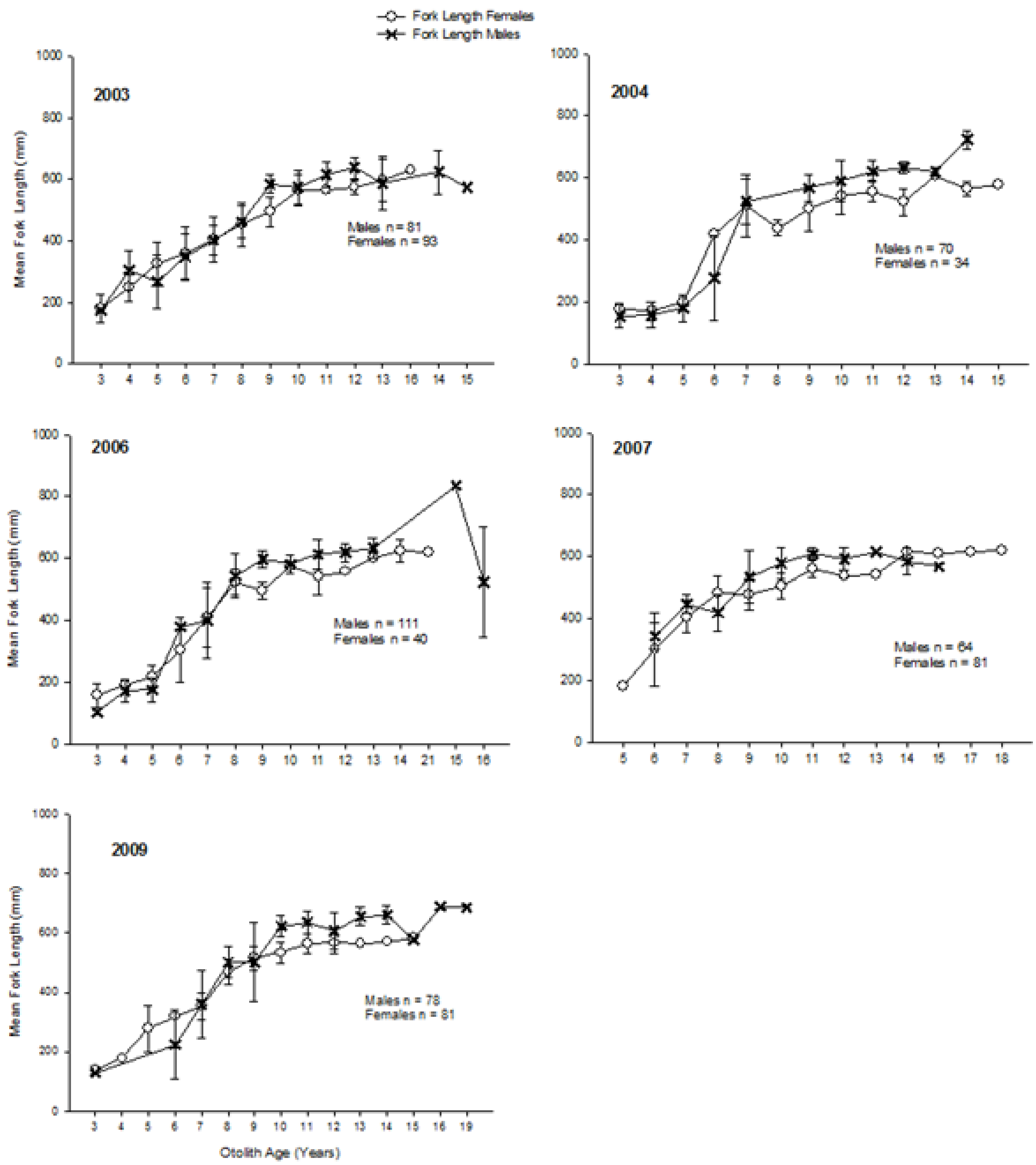

Figure 9.Mean fork length at age from fishery-independent data by year and sex. Standard deviation bars included. Note that the upper ranges of the x-axes are not consistent on each graph due to variation in maximum age values among the years.

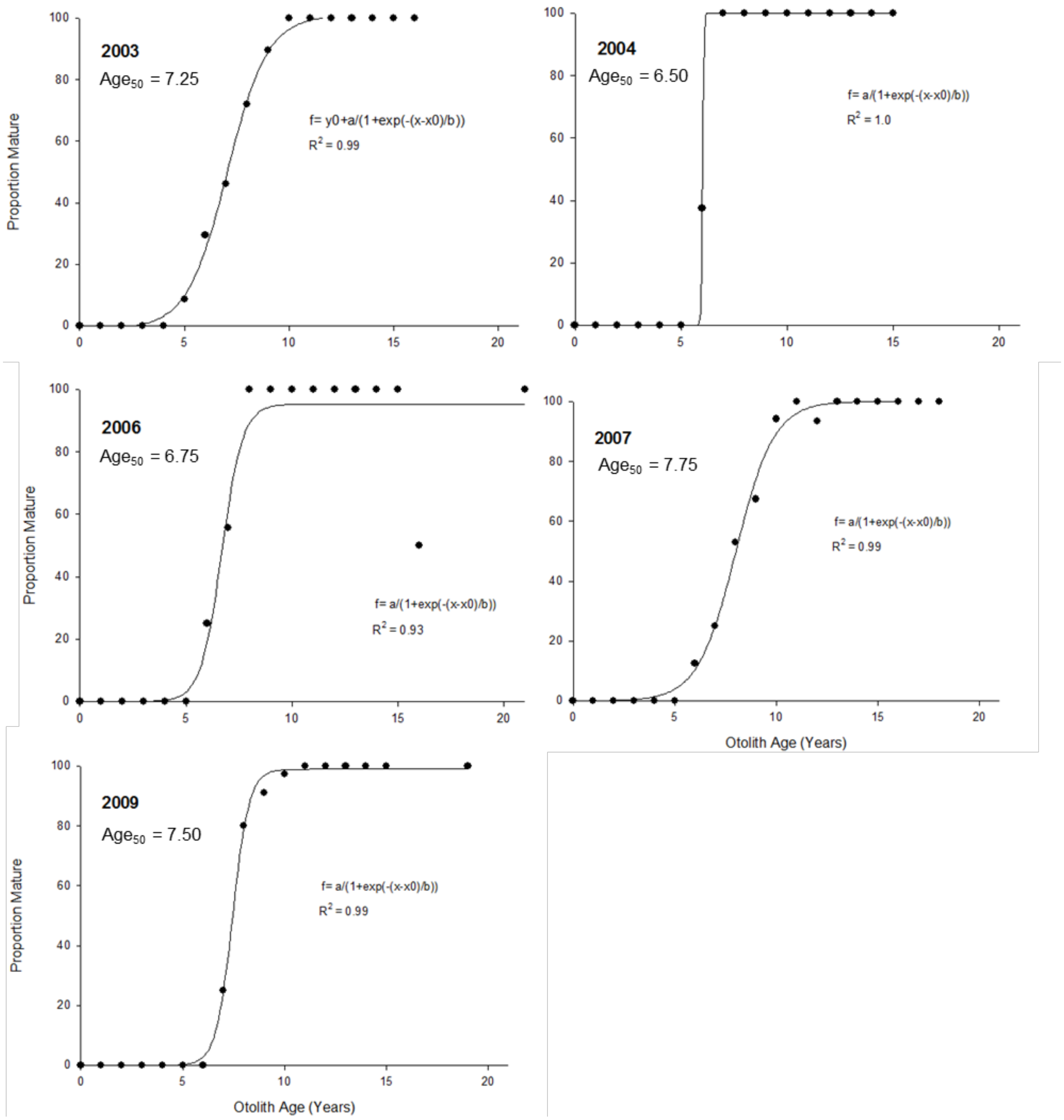

Figure 10. Proportion of mature fish at each age from fishery-independent data, gear types and sexes combined. The calculated age at 50% maturity is presented for each year.