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Harvest, catch-effort, and biological information of Arctic Char, *Salvelinus alpinus*, collected from a long-term subsistence harvest monitoring program in Tatik Lake (Kuujjua River), Northwest Territories

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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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TABLE OF CONTENTS

ABSTRACT

Data collected from a fishery-dependent monitoring program between 1992 and 2015 and supplemental information collected in 1978 and 1987 were used to inform a population assessment of anadromous Arctic Char (*Salvelinus alpinus*) from the Kuujjua River, Northwest Territories. The stock is important for the subsistence and economy of residents from the hamlet of Ulukhaktok in the Inuvialuit Settlement Region. Arctic Char from the Kuujjua River stock are harvested during summer when feeding along the coast in a mixed-stock fishery, and during winter (under-ice) while overwintering in Tatik Lake. The monitoring program conducted during the winter fishery employed subsistence fishers from Ulukhaktok to collect harvest, catch-effort, and biological data for the majority of the duration of the fishery. Catch-effort in Tatik Lake varied without trend although the frequency of relatively high values (> 125 Arctic Char/100 m/24 hours) increased from 2006 to 2015. The biological data reveal the winter fishery harvests Arctic Char mainly between 500 and 700 mm, 1,000 and 3,500 g, and 8 and 12 years of age. Mean length and weight increased from 533 to 633 mm and 1,893 to 3,354 g, respectively, between 2008 and 2012, and have been relatively stable through 2015. Mean age increased from 8.3 to 10.3 years between 2010 and 2012 and was then stable through 2015 with the consistent presence of fish ≥ 15 years of age. The von Bertalanffy growth parameters of Arctic Char from Tatik Lake were L_{∞}= 703, K= 0.42, and t_0= 2.61, with no statistically significant difference between sexes. The mean length of fish 9 to 12 years of age increased beginning in 2008 and continued through 2015. Over the time-series, mean length and weight, and length-at-age followed a quasi-cyclic pattern. Condition factor remained relatively high (K ≥ 1.2) and stable from 2008 to 2015, which suggests feeding opportunities were favorable for growth during this period. The annual mortality rate between 2011 and 2015 was stable (~ 30%). Where comparisons were possible, some similarities were observed between the biological data collected from the 1992-2015 monitoring, and data collected from this same fishery in 1978 and 1987. Collectively, the catch and monitoring data through 2015 indicate that the Kuujjua River population is not experiencing overfishing and the current stock status is healthy.

INTRODUCTION

Anadromous Arctic Char (*Salvelinus alpinus*) is an important subsistence resource for the residents of the hamlet of Ulukhaktok, Northwest Territories (Lewis et al. 1989, Paylor et al. 1998, Joint Secretariat 2003) with the majority of the total reported harvest occurring during the summer along the coast near the community and in Prince Albert Sound (HCWG 2004, DFO unpublished data) (Figure 1). Multiple stocks contribute to this coastal harvest in summer with populations that include the Kuuk, Kagloryuak, Naloagyok, and Kagluk, rivers, which drain directly into Prince Albert Sound, and the Kuujjua River and Mayoklihok Lake, which drain into Minto Inlet. Results of t-bar tagging studies in 1992 and 1993 suggested the Kuujjua River stock contributed substantially to the summer mixed-stock fishery in the Ulukhaktok area (Paylor et al. 1998). In addition to summer, char from the Kuujjua River stock are also harvested while overwintering in Tatik Lake (N 71.2°, W 116.57°; locally known as 'Fish Lake'). The fishery for Arctic Char on Tatik Lake is the most important winter fishery for the community. The contribution of the Kuujjua River stock to both summer and winter fisheries underscores the importance of this population to the subsistence and economy of Olokhaktomiut.

In addition to subsistence, anadromous Arctic Char are harvested in a small-scale commercial fishery. Commercial fishing of Kuujjua River Arctic Char was initiated in 1979 (annual quota was 600 kg) where the harvest occurred at the same time as subsistence fisheries during the summer (coastal) and winter (Tatik Lake) (Lewis et al. 1989). The quota was kept low to protect the stock and minimize possible negative impacts to the subsistence fishery (Lewis et al. 1989). No commercial fishing was reported in the 1990s. Beginning in the early 2000s a small commercial fishery was implemented for the Ulukhaktok coastal area under an Exploratory Fishery Stage I licence (DFO 2001) with a quota of 500 individual char that are all locally sold within the community or territory.

The headwaters of the Kuujjua River drain a large expanse of northern Victoria Island. The river flows in a south-west direction for over 350 km and in the lower reaches, on Diamond Jenness Peninsula, widens into three separate lakes (Third, Second, and Tatik) (Figure 1). In addition to Arctic Char, Tatik Lake is inhabited by Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus clupeaformis*) (Stewart and Bernier 1982). Harwood et al. (2013) report a waterfall between Second and Third lakes that may restrict upstream movements of fish. The distance of river migration between overwintering and summer marine feeding habitat for Arctic Char is at least 16 km, although riverine migrations of spawning individuals may be greater given that the community has identified locally named Red Belly Lake (N 70.997°, W 117.081°) (Figure 1), situated approximately 47 river km from Tatik Lake, as another spawning location.

The winter fishery, described in Lewis et al. (1989) and Harwood et al. (2013), occurs primarily in the months of October and November using gill nets set under the ice. Fisheries monitoring information was collected from the subsistence harvest in Tatik Lake between 1966 and 1978, and from a summer sport fishery (angling) at the mouth of the river between 1966 and 1975. Total harvest averaged approximately 3,400 Arctic Char (Lewis et al. 1989). Biological sampling of the winter subsistence fishery occurred in 1978 and 1987 (Lewis et al. 1989). Harwood et al. (2013) described how community concerns around reduced catches and sizes of Arctic Char in 1990 prompted the initiation of an annual community-based monitoring program for Tatik Lake. The collection of harvest and catch-effort information began in 1991, and biological sampling was added in 1992. The fishery on Tatik Lake was voluntarily closed by the Olokhaktomiut Hunters and Trappers Committee between 1993 and 1995 to promote stock recovery (HCWG 2004). The sampling program was suspended in 1993 but re-instated in 1994 for monitoring purposes. Data from the program were used to assess trends in relative abundance and population demographics.

Harwood et al. (2013) assessed the population of Arctic Char from the Kuujjua River using data collected between 1991 and 2009 and concluded the stock had been stable at the harvest levels reported from the lake during the monitoring period (mean number of Arctic Char harvested ± SD = 1,261 ± 1.17) and also demonstrated some improved fitness linked to enhanced environmental productivity associated with earlier breakup of sea ice in Amundsen Gulf in spring. Since 2010, the annual monitoring program has continued although no assessment of the population has been conducted.

OBJECTIVES

The objectives were to use data collected from multiple sampling programs to inform the population assessment of Arctic Char from Tatik Lake; specifically to:

- summarize harvest, catch-per-unit-effort (CPUE) (1991–2015), and biological (1992–2015) data collected from the Tatik Lake Char Monitoring Program;
- compare biological data collected between 1992 and 2015 to data collected from the Tatik Lake winter subsistence fishery in 1978 and 1987; and,
- examine temporal trends in CPUE and biological information up to 2015 to obtain an indication of stock status.

METHODS

HARVEST MONITORING

The methods for harvest monitoring and biological sampling are described in Harwood et al. (2013). Briefly, two harvesters from the community of Ulukhaktok (not always the same combination of people every year) were employed to record fishing effort information on a standardized form for themselves and others at nearby camps on Tatik Lake during the approximately three week peak of the winter fishery (October–November). The responsibilities of the monitors were to record the daily total number of Arctic Char captured from individual subsistence gill nets, the soak time of each net, and the length and mesh size (stretch) of each net. Nets were set under the ice and typically fished for 24 hours. A randomly chosen subsample of the catch was processed for biological information (annual target sample size of 200): length (± 1 mm), weight (± 25 g), sex (2000, 2004–2011, 2013–2015 only), mesh size (except in 1997–1999 and 2003), and otoliths for age estimation. In some years, the community monitors recorded maturity (2013 and 2014 were the only reliable data in recent years), which was categorized as either ‘immature’ or ‘mature’, with an ‘immature’ fish being either sexually immature or a mature resting fish that had not spawned in the current year, while a ‘mature’ fish was one that had spawned in the current year. Maturity was recorded in this manner because of the difficulties in confidently distinguishing between immature and resting gonads.

The harvest number reported by monitors was not intended to be a full enumeration of the total harvest of Arctic Char from the Kuujjua River system. The best estimate of total harvest for the lake was obtained from the annual community survey that asks Olokhaktomiut fishers to voluntarily share their seasonal harvest information by location and species. Additionally, the proportion of the summer harvest derived from the Kuujjua River stock is unknown given the lack of information on its contribution to the mixed-stock coastal summer fisheries.

AGE ESTIMATION

The methods for estimating ages are described in Gallagher et al. (2021). Briefly, age estimation using otoliths collected between 1992 and 2010 was conducted by an age reader using the whole otolith method. Otoliths collected in 2010 and thereafter were examined by a different age reader using a combination of whole and thin-section otolith preparation methods. A between-reader comparison of paired age data using historical (1992–2010) and contemporary (≥ 2010) otolith preparation methods revealed that thin-sectioning otoliths produced a higher proportion of older ages (> 12 years) compared to whole. Therefore, comparing age frequency distribution, longevity, and mortality data should be done cautiously (Gallagher et al. 2021). However, no effects on von Bertalanffy growth parameters were found (Gallagher et al. 2021).

CATCH-EFFORT AND BIOLOGICAL INFORMATION

The number of Arctic Char harvested during the monitoring program was tabulated from individual catch records. CPUE data from each net set was calculated separately for each sampling year and mesh size, as the number of Arctic Char captured per 100 m of net fished per 24 hours. In some years the mesh size was not recorded, however it was assumed that these ‘unknown’ records in 2003 (n = 50) and 2013 (n = 5) were collected using the 114 mm mesh as this was either the most likely mesh utilized in the fishery or the only mesh size recorded for that year. A non-parametric statistical test (Mann-Whitney) was used to evaluate for differences in CPUE between 114 and 127 mm mesh. Comparisons were not made for the 102 and 140 mm mesh sizes due to low sample sizes (n = 15 and 8, respectively). The relatively low number of catch-effort records in 2009 (n = 12) and 2010 (n = 14) and short duration of monitoring efforts in 2009 (Figure 2) may not have provided a representative sample for those years; therefore results must be interpreted with caution.

A Shapiro-Wilk test was used to determine whether the lengths and ages of Arctic Char among mesh sizes were normally distributed. Testing for effects of mesh size on length depended on whether the data followed a parametric (t-test) or non-parametric (Mann-Whitney) distribution in years with sufficient sample sizes for comparison (114 vs. 127 mm mesh in 1992, 2000 and 2010; 102 vs. 114 mm in 2004). Differences in length and age between sexes were evaluated using the Mann-Whitney test. A Kruskal-Wallis test was used to examine for differences in age between females and males.

The length-weight relationship was examined using the total sample and separately for females and males among years. Data were $\log_{10}$ transformed to linearize the relationship for analysis of covariance (ANCOVA) testing of weight between sexes using length as a covariate. Fulton’s condition factor was calculated as:

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

where W = weight in grams and L = fork length in millimeters, with results plotted against sampling year. The proportion of females and males were calculated and statistically tested in each sampling year to determine if there was a departure from a binomial proportion of 0.5 (i.e., 1:1) (Rohlf and Sokal 1995). The proportion of individuals within each maturity category was tabulated for both sexes to estimate age-at-maturity. It was not possible to determine age-at-50%-maturity because sexually immature and adult resting fish were not distinguished.

Parameters of the von Bertalanffy growth model:

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

where L_t is the expected length at time t, L_∞ is the asymptotic average length, K is the Brody growth rate coefficient, and t_0 is the modelling artefact representing time or age when the average length was zero (Ricker 1975), was generated using the combined data collected between 2010 and 2015 with the R (R Core Team 2015) package 'FSA' (Simple Fisheries Stock Assessment Methods) (Ogle 2016). To determine whether parameters L_∞, K, and t_0 were significantly different between males and females, pairs of candidate models of the same type were compared in a hierarchical framework where complex models were tested against simpler models with fewer parameters using an *F*-test on the residual sum of squares (RSS) (Ogle 2016). Comparisons were conducted until a simpler model did not fit the data as well as a more complex one and the model with the lowest RSS was selected if multiple models with the same parameters fit the data as well as a more complex model. All statistical results were considered significant for p values ≤ 0.05.

The survival rate (S) was calculated for each sampling year using the age data according to Robson and Chapman (1961):

$$S = \left(\frac{T}{\sum N + T - 1}\right)$$

$$T = \sum_{x=0}^{k} x(N_x)$$

where N = total number of fish fully recruited to the gear (modal age +1), and x is the sequential coded age (first age is 0, second is 1, third is 2, etc.) of those fully recruited. The standard error of S (SE_S):

$$SE_S = \sqrt{S\left(S - \frac{T-1}{\sum N + T - 2}\right)}$$

and 95% confidence intervals = S ± 1.96(SE_S) were also estimated. Additionally, annual mortality (A, 1-S) and instantaneous mortality (Z, $-\log_e(1-A)$) were calculated. Robson and Chapman estimates presented in Harwood et al. (2013), for data collected between 1992 and 2009, used the modal age as the first fully recruited age class (rather than mode + 1), therefore estimates are slightly different than what are reported here.

Biological data (i.e., length, weight, condition factor, and age) collected from the subsistence fishery in Tatik Lake in 1978 and 1987 (both years in the month of October) (Lewis et al. 1989) were compared to data collected between 1992 and 2015 as a benchmark prior to the reported decline of the fishery in 1990 (note, raw data for 1987 was not available to generate some of the graphics e.g., boxplots and scatterplots).

RESULTS

FISHERY TIMING AND GEAR TYPE

The monitoring program at Tatik Lake typically started in approximately mid-October and concluded by late October (1994–2004) or mid-November (2005–2015). Exceptions were in 1996 when monitoring was conducted early (mainly September) and in 2006 when the program included additional sampling in mid-December (see Harwood et al. 2013 for explanation). In some years (1991–1992, 1998, 2009, and 2012) the monitoring efforts were of short duration compared to the other years (several days to approximately one week) (Figure 2).

The mesh sizes used in the fishery were 102 mm (4”), 114 mm (4.5”), 127 mm (5.0”), and 140 mm (5.5”), with the 114 mm and 127 mm being the most prevalent, accounting for 90.1% and 7.4%, respectively, of the catch-effort records between 1991 and 2015. The length of net used by the large majority (89% of catch-effort records) of harvesters was 45.7 m (50 yards).

REPORTED HARVEST AND CATCH-EFFORT

Between 1992 and 2004, the annual number of harvested Arctic Char that were enumerated by Tatik Lake monitors was predominantly < 250, with the exception of 1999 (1,201 fish) (Figure 3). The number of char enumerated after 2004 was consistently > 400, except for 2009 and 2010 when < 300 fish were counted by the monitors (Figure 3).

No effect of mesh size (114 vs. 127 mm) on CPUE was observed ($U = 33873$, $p = 0.8$). CPUE in the most consistently used mesh size (114 mm) ranged from < 10 to > 30 fish/100 m/24 hours (Table 1; Figure 4). CPUE appears to have varied without trend over time, however, the frequency of high CPUE sets (> 125 Arctic Char/100 m/24 hours) has increased from an average of 0.4% between 1992 and 2005 to an average of 4.4% after 2006 (Figure 4).

BIOLOGICAL INFORMATION

Biological information of Arctic Char from Tatik Lake was mainly collected from fish captured using 114 mm mesh (82% of total) with the exception of 1994, 1995, and 2010 where most of the sampled fish were from 127 mm mesh gill nets (Table 2). The only year when samples were obtained from the 102 mm mesh was 2004.

Length

Effects of mesh size on fork length were observed in only two sampling years, 1992 ($U = 68.5$, $p < 0.0001$) (114 mm < 127 mm mesh) and 2010 ($U = 1691$, $p = 0.045$) (114 mm < 127 mm mesh) while none were observed in 2000 ($t = 0.77$; d.f. = 190; $p = 0.87$) and 2004 ($U = 3751$, $p = 0.44$). Length data from all mesh sizes were combined due to the low number of significant differences detected and because of the high degree of overlap in length distributions among mesh sizes (data not shown).

Among years where sex information was collected, statistically significant differences in length between females and males were observed in only three of 12 sampling years (range of mean difference = 10–35 mm) (Table 3). Given no obvious or consistent pattern of one sex being larger, male and female data were pooled.

Arctic Char harvested from the winter fishery in Tatik Lake were mainly distributed among 500–700 mm sizes (Figure 5). The proportion of large-size Arctic Char (≥ 700 mm) gradually increased from 1% to 5% of the sample between 1992 and 1999, and increased dramatically between 2000 and 2006 (range = 16–34%). This was followed by a decrease until 2010 (11–0.5%) and a dramatic increase thereafter (range = 11–37%) (Figure 5). Between 1992 and 2015 mean length demonstrated a quasi-cyclic pattern an increasing trend in size from 1992 to 2002 followed by a decline until 2008 and a subsequent increasing trend to 2015 (Table 4; Figure 6).

Lengths of Arctic Char collected in 1978 and 1987 had a similar distribution to those collected in early 1990s, and early 2000s/ ≥ 2012, respectively (Figure 5). Arctic Char ≥ 700 mm accounted for 6.8% and 20% in 1978 and 1987, respectively of the sampled catch.

Weight and condition

The weight of Arctic Char harvested among years was predominantly between 1,000 and 3,500 g and was highly correlated with length (Figure 7), although the correlation was weaker in

2005. ANCOVA revealed no significant differences between males and females except in 2014 when males (mean = 3,399 g) were heavier than females (mean = 2,847) (Table 3). Similar to length, weight varied in a corresponding quasi-cyclic pattern among years (Table 4; Figure 8).

Age

Effects of mesh size on age were only observed in 1992 ($U = 247$, $p < 0.001$) (114 mm < 127 mm mesh. Among years when sex information was collected, statistically significant differences in age between females and males were observed (~ 1–2 year difference) in only three of the 12 sampling years (Table 3; 2007, 2009, and 2015). Given there were no consistent effects of mesh size and sex on age, all age data were pooled.

Arctic Char sampled from Tatik Lake were mainly between 8 and 12 years of age (Figure 10). Age frequency distributions using data from 1992–2009 appeared relatively consistent and stable among years. Mean values were similar between 1992 and 2007, ranging between 9 and 11 years, which was followed thereafter by a slight decrease to approximately 8 years (Table 4; Figure 11). Age frequency distributions using data from 2010–2015 were similar among years apart from an absence of samples > 15 years in 2010 (Figure 10). The oldest individual observed was a 29 year old in 2015.

Ages for fish sampled during the 1978 and 1987 winter subsistence fishery were mainly distributed between 10–13 and 12–16 years, respectively. The distribution of the 1978 sample was similar to the one in 1994 while the 1987 sample was predominantly distributed among older ages (Table 4; Figures 10, 11).

Growth

The von Bertalanffy growth parameters (with 95% CI) for Arctic Char from Tatik Lake (2010–2015) were L_∞= 703 (690–723), K = 0.42 (0.22–0.33), and t_0 = 2.61 (0.96–2.63). No statistically significant differences were detected between males and females ($p > 0.05$). Length increased from an average of 443 mm at age 5 years to 663 mm at age 11 years whereas further changes in mean length among older fish were relatively small (Figure 12). Length among ages 8–12 years between 1992 and 2015 revealed a quasi-cyclic pattern in growth with an increase between 1992 and ~2001/2002 was followed by a gradual decline until ~2008 and subsequently followed by another period of increase (Figure 13).

Mean weight-at-age increased at similar rates for males and females until age 11, however, greater variation/ differences between sexes in mean weight were evident among older ages (Figure 14). Among age classes 9 to 12 years, mean weight increased by a factor of 1.5 between the early 1990s and recent years (Figure 15). Length and weight among ages 8–12 years in the 1978 and 1987 samples were both similar to values observed in the early 1990s.

Mortality

Between 1992 and 2009, annual mortality decreased from 0.59 to 0.44 (apart from a relatively low value in 1992 (0.42)), (Table 5; Figure 16). Annual mortality rates have remained stable and relatively low (~0.3) from 2010 to 2015, with the exception of one higher estimate in 2010 (0.47), (Figure 16). Annual mortality in 1978 (0.48) and 1987 (0.47) were similar to most of the estimates between 1998 and 2010.

Sex ratio and maturity

In sampling years where sex information was recorded (2000–2015, periodically), females and males were found in equal proportion nearly half of the time. Statistically significantly higher proportions of females were observed in 2000 (68%), 2006 (75%), 2009 (61%), 2014 (57%), and 2015 (61%) while significantly more males were captured in 2008 (65%) and 2011 (89%) (Figure17). Note, the high prevalence of males in 2011 is suspect as it appears unrealistic based on what is typically observed. No difference in the proportion of females and males was observed in 1978 and 1987.

In 2013 and 2014, the majority (87.9% of n = 356) of fish sampled were either immature or resting adults. When the combined sample of all mature individuals was examined among age classes, the majority of Arctic Char current-year spawners was between 10 and 13 years of age (Figure 18). Males may attain sexual maturity at an earlier age (6 years) compared to females (10 years) (Figure 18), although a larger sample size would be required to more confidently assess patterns in maturation.

DISCUSSION

The annual Tatik Lake Char Monitoring Program has provided a relatively long time-series of fisheries data for Arctic Char that has been used to assess trends in harvest, catch-effort, and biological variables. Catch-effort in Tatik Lake has varied without trend among years although the frequency of relatively high CPUE values has noticeably increased since 2006. This suggests that relative abundance of Arctic Char in Tatik Lake may have increased in recent years compared to the 1990s and early 2000s. The harvest pressure since annual monitoring was initiated in 1991 does not appear to have had a negative effect on stock abundance.

The biological data reveal the harvesters mainly remove fish between 500 and 700 mm. Fluctuations in annual mean size and somatic condition factor have been previously attributed to enhanced feeding opportunities associated with earlier clearance of sea ice in spring (Harwood et al. 2013). The increasing trend in mean sizes observed since 2008 for Arctic Char in Tatik Lake combined with a sustained high condition factor suggests environmental conditions have been favorable for feeding and growth since 2008. This assumption is supported by the mean length-at-age of fish between 9 and 12 years of age that have been increasing since 2008. The increase in size in recent years did not appear associated with reduced mortality given there was essentially consistent mortality values from 2010 through 2015.

The fishery harvests mainly Arctic Char between 8 and 12 years of age, including individuals older than age 20. The presence of older ages in the population is a positive indicator of stock status that suggests the harvest pressure is currently not so high as to negatively impact the older (typically larger) component of the population. The demographic properties and length-at-age were similar between males and females. The years when sizes were relatively high (2000–2004 and 2012–2015) would presumably have conferred added reproductive benefits to females given the positive correlation between size and both fecundity and egg diameter (Power et al. 2005). The higher prevalence of large-sized females in a long-lived population such as Tatik Lake could have improved the productivity of the population by the increase in egg production and the larger egg sizes that improve probability of offspring survival (Quinn et al. 2004, Hixon et al. 2014).

Some similarities were observed between the biological data collected from 1992–2015 and data collected in 1978 and 1987. The average length and weight in 1978 were similar to those in 1994–1995 and 2008–2010, which were ranges of years when length and weight averages were low. Alternatively, the size distribution in 1987 demonstrated the presence of a relatively high proportion of large-size individuals (> 700 mm) during the period of time when the reported decline in stock status was beginning to be noticed by subsistence harvesters (DFO 2016). The reported decrease in size over the five years between 1987 and 1992–1995 is similar in timing (i.e., number of years) to the decrease in size observed between 2002 and 2008 (i.e., 6 years). The lack of a continuous time-series of biological and harvest data for Tatik Lake prior to 1992 limits our ability to infer whether the lengths from the earlier years would be considered relatively high or low for the population at that time.

The biological characteristics of Arctic Char in Tatik Lake are similar to nearby Mayoklihok Lake, situated ~ 50 km east of Tatik Lake, which also drains into Minto Inlet (Figure 1). Sampled in 2013 using similar gill nets, the size and age distribution of Arctic Char from Mayoklihok Lake were principally between 450–700 mm and 8–14 years of age, respectively, with a small number of individuals > 20 years of age (DFO unpublished data). Furthermore, annual mortality was 0.31 and asymptotic size was ~ 650 mm. The similarities in the demographic properties between these two systems may be a result of fish moving between river systems. It is common for Arctic Char to exhibit straying behavior where fish natal to one river system and not reproducing in the current year will overwinter in a different system after it's summer ocean migration (i.e., overwintering dispersion) (reviewed in Moore et al. 2014). In the Cambridge Bay area of Victoria Island, rates of straying by Arctic Char based on mark-recapture data ranged between 7–54% with 85% of recaptures occurring within 60 km of the tagging site (Dempson and Kristofferson 1987). However, the paucity of genetic or tagging information to elucidate stock structure, and breeding and overwintering dispersion of Arctic Char in the Ulukhaktok area limits any speculation of movement between Tatik and Mayoklihok lakes. Confirming the extent of inter-annual straying behavior by Arctic Char from Tatik Lake would be beneficial for management as any possible changes in stock status could be explained by harvests in other nearby overwintering lakes (Moore et al. 2014).

The quasi-cyclic temporal pattern observed for mean length and weight, and length-at-age of Arctic Char from Tatik Lake is similar to Arctic Char from the Hornaday River (Harwood 2009, Gallagher et al. 2017). Situated ~ 340 km southwest from Tatik Lake, the anadromous Hornaday River stock feeds in the coastal waters of Darnley Bay during summer. Similar to Tatik Lake, the Hornaday River population has been monitored annually since the early 1990s mainly for assessment purposes. Both stocks have demonstrated a near concomitant change in mean length and weight values among decades with troughs (early 1990s and late 2000) and peaks (mid-2000s and mid-2010s) of the curve occurring in relatively similar years (see Harwood 2009, Gallagher et al. 2017). Although further research is necessary to evaluate the relationship in trends between populations, the results could suggest broad-scale environmental factors are influencing the temporal trend in growth of Arctic Char over a wide geographic region in the western Canadian Arctic.

Biological and catch indices through 2015 indicate the Kuujjua River (Tatik Lake) population is not experiencing overfishing and that the current stock status is healthy. The reported harvest has been relatively consistent among years and it appears the current level of harvest (winter and summer fisheries) has not had a negative effect on the population. The fishery in Tatik Lake appears to be sustainable, a conclusion similar to that found by Harwood et al. (2013) using data up to 2009. The catch-effort data has demonstrated an increase in the frequency of relatively high values since 2006, the size distributions have been stable while the proportion of large-size fish (> 700 mm) has been increasing since 2010. Age distribution is stable, with the consistent presence of fish ≥ 15 years, and the mortality rate appears to be stable and relatively low. The time-series of population assessment data available for Tatik Lake could be used in population models to better inform how harvest has affected the population and establish reference points for fisheries management. This would serve the continued efforts of the Ulukhaktok Char Working Group (formerly the Holman Char Working Group) to conserve this stock and ensure its long term viability for subsistence use (HCWG 2004).

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TABLES AND FIGURES

Table 1. Median catch-per-unit-effort (CPUE) (number of fish/100 m/24 hours) of Arctic Char, with number of net sets in brackets, from Tatik Lake, NT during the winter fishery among mesh sizes and sampling years.

Year	Mesh (mm)					Total
	102	114	127	140	Unknown	
2015	-	32.8 (46)	-	-	-	32.8 (46)
2014	-	15.3 (97)	-	-	-	15.3 (97)
2013	-	26.2 (53)+	-	-	-	26.2 (53)
2012	-	48.1 (28)	-	-	-	48.1 (28)
2011	21.9* (1)	39.4 (80)	43.7 (14)	-	-	39.4 (95)
2010	-	27.3 (10)	32.9 (4)	-	-	27.3 (14)
2009	-	61.2 (12)	-	-	-	61.2 (12)
2008	-	24.1 (53)	-	-	-	24.1 (53)
2007	-	21.9 (45)	-	-	-	21.9 (45)
2006	-	22.2 (48)	-	-	-	22.2 (48)
2005	-	19.7 (81)	13.2 (2)	-	-	19.7 (83)
2004	23.6 (11)	3.3 (32)	-	-	30.6 (2)	6.6 (45)
2003	6.4 (3)	9.3 (53)+	-	-	-	8.4 (56)
2002	-	37.4 (36)	39.5 (2)	-	-	37.5 (38)
2001	-	14.0 (25)	-	-	-	14.0 (25)
2000	-	23.6 (15)	23.8 (10)	-	-	23.6 (25)
1999	-	32.8 (67)	-	-	-	32.8 (67)
1998	-	26.9 (21)	-	-	-	26.9 (21)
1997	-	18.8 (18)	26.8 (7)	-	-	25.0 (25)
1996	-	39.2 (50)	-	-	-	39.2 (50)
1995	-	12.0 (37)	-	4.3 (8)	19.3* (1)	9.6 (46)
1994	-	34.6 (7)	48.4 (18)	-	34.6* (1)	45.5 (26)
1992	-	8.5 (16)	6.6 (7)	-	-	6.6 (23)
1991	-	6.6 (12)	2.2 (13)	-	-	4.4 (25)

* actual CPUE value

+Assumed n = 50 and 5 ‘unknown’ in 2003 and 2013, respectively, were captured using 114 mm mesh.

Table 2. Number of Arctic Char from Tatik Lake, NT sampled for length and weight, and the number of aged otoliths (brackets) among mesh sizes.

Year	Mesh size (mm)				Total
	102	114	127	Unknown	
2015	-	94 (87)	-	-	94 (87)
2014	-	189 (169)	-	-	189 (169)
2013	-	195 (191)	-	-	195 (191)
2012	-	200 (195)	-	-	200 (195)
2011	-	199 (183)	-	-	199 (183)
2010	-	26 (26)	172 (170)	2 (2)	200 (198)
2009	-	200 (188)	-	-	200 (188)
2008	-	200 (192)	-	-	200 (192)
2007	-	200 (191)	-	-	200 (191)
2006	-	124 (122)	-	-	124 (122)
2005	-	200 (193)	-	-	200 (193)
2004	62 (59)	130 (128)	8 (8)	-	200 (195)
2003	-	200 (190)+	-	-	200 (190)
2002	-	186 (178)	-	-	186 (178)
2001	-	200 (180)	-	-	200 (180)
2000	-	117 (105)	83 (79)	-	200 (184)
1999	-	200 (194)+	-	-	200 (194)
1998	-	200 (196)+	-	-	200 (196)
1997	-	200 (196)+	-	-	200 (196)
1996	-	200 (192)	-	-	200 (192)
1995	-	-	200 (196)	-	200 (196)
1994	-	8 (8)	257 (232)	-	265 (240)
1992	-	90 (85)	20 (19)	-	110 (104)

+mesh size not recorded and assumed to be from 114 mm mesh.

Table 3. Mean length, weight, and age (SD in brackets) of female (F) and male (M) Arctic Char sampled during the winter fishery in Tatik Lake, NT (2000–2015). Differences between females and males (statistically significant values highlighted in grey) were tested using Kruskal-Wallis (length and age) and analysis of covariance (weight).

Sample type	Year	Female	Male	N = (F/M)	Test statistic & p-value
Length (mm)	2015	642 (89)	645 (104)	51/28	U = 713, p = 0.34
	2014	611 (85)	662 (78)	105/79	U = 2702, p < 0.0001
	2013	610 (71)	632 (91)	96/99	U = 4062, p = 0.08
	2011	585 (80)	600 (74)	21/179	U = 1773, p = 0.7
	2010	551 (44)	565 (52)	98/102	U = 4299, p = 0.09
	2009	600 (76)	584 (57)	122/78	U = 4393, p = 0.36
	2008	540 (63)	529 (59)	71/129	U = 4162, p = 0.29
	2007	596 (62)	572 (82)	87/113	U = 3905, p = 0.01
	2006	606 (58)	602 (95)	53/18	U = 405, p = 0.3
	2005	608 (73)	627 (74)	111/88	U = 4222, p = 0.1
	2004	632 (64)	659 (73)	99/101	U = 4027, p = 0.002
	2000	641 (65)	637 (94)	75/35	U = 1209, p = 0.5
Weight (g)	2015	3,445 (1,260)	3,521 (1,564)	51/28	F = 0.5; d.f. = 1,80; p = 0.47
	2014	2,847 (1,278)	3,399 (1,280)	105/79	F = 5.1; d.f. = 1,181; p = 0.025
	2013	2,909 (1,060)	3,292 (1,491)	95/99	F = 0.92; d.f. = 1,191; p = 0.3
	2011	2,714 (1,264)	2,801 (1,176)	22/178	F = 0.06; d.f. = 1,196; p = 0.8
	2010	2,088 (612)	2,273 (748)	98/102	F = 0.02; d.f. = 1,197; p = 0.9
	2009	2,611 (1,050)	2,368 (758)	122/78	F = 0.27; d.f. = 1,107; p = 0.6
	2008	1,978 (830)	1,847 (762)	71/129	F = 0.001; d.f. = 1,197; p = 0.9
	2007	2,619 (892)	2,362 (1,112)	86/113	F = 1.67; d.f. = 1,196; p = 0.2
	2006	2,567 (839)	2,039 (692)	24/14	F = 0.74; d.f. = 1,35; p = 0.4
	2005	2,262 (930)	2,572 (1,070)	111/87	F = 1.86; d.f. = 1,195; p = 0.2
	2004	2,817 (873)	3,242 (1,160)	99/101	F = 1.13; d.f. = 1,197; p = 0.3
	2000	3,187 (1,007)	3,169 (1,689)	75/35	F = 0.27; d.f. = 1,107; p = 0.6
Age (years)	2015	12.0 (3.6)	10.4 (2.6)	51/28	U = 517, p = 0.04
	2014	10.5 (2.7)	11.6 (3.5)	94/71	U = 2842, p = 0.1
	2013	10.4 (2.7)	9.9 (2.7)	94/97	U = 4364, p = 0.3
	2011	11.1 (4.3)	9.6 (2.4)	19/164	U = 1368, p = 0.4
	2010	8.1 (1.5)	8.4 (1.7)	96/102	U = 4537, p = 0.4
	2009	9.1 (2.0)	8.1 (1.7)	112/76	U = 3133, p = 0.02
	2008	8.0 (2.2)	7.9 (2.3)	65/127	U = 3981, p = 0.6
	2007	10.3 (2.1)	9.4 (2.1)	82/109	U = 3342, p = 0.03
	2006	11.2 (1.7)	11.0 (1.6)	52/18	U = 442, p = 0.7
	2005	10.2 (1.6)	11.1 (2.1)	105/87	U = 3574, p = 0.08
	2004	10.0 (1.6)	11.1 (1.9)	97/98	U = 4621, p = 0.7
	2000	9.7 (1.8)	9.7 (1.5)	71/32	U = 1052, p = 0.5

Number of samples where sex was not recorded: n = 11 in 2015; n = 5 in 2014; n = 53 in 2006; n = 1 in 2005; and n = 90 in 2000.

Table 4. Mean length, weight, Fulton's condition factor, age[a] among years (SD in brackets) of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 and 1987[b], and between 1992 and 2015.

Year	Fork length (mm)	Weight (g)	Condition factor	Age (years)
2015	648 (95)	3,506 (1,363)	1.23 (0.19)	11.9 (4.1)
2014	634 (85)	3,093 (1,296)	1.15 (0.16)	11.0 (3.2)
2013	621 (82)	3,104 (1,309)	1.23 (0.24)	10.2 (2.7)
2012	633 (82)	3,354 (1,435)	1.25 (0.23)	10.3 (2.8)
2011	598 (75)	2,792 (1,183)	1.23 (0.18)	9.8 (2.7)
2010	558 (49)	2,182 (689)	1.22 (0.14)	8.3 (1.6)
2009	594 (69)	2,516 (952)	1.16 (0.16)	8.7 (1.9)
2008	533 (61)	1,893 (787)	1.20 (0.11)	7.9 (2.2)
2007	582 (75)	2,473 (1,028)	1.18 (0.13)	9.8 (2.2)
2006	599 (75)	2,364 (1,098)	1.16 (0.12)	11.1 (1.7)
2005	616 (74)	2,395 (1,001)	1.00 (0.23)	10.6 (1.9)
2004	646 (70)	3,032 (1,047)	1.09 (0.08)	11.1 (1.8)
2003	621 (87)	2,660 (1,221)	1.05 (0.14)	10.3 (1.8)
2002	655 (77)	3,160 (1,226)	1.07 (0.18)	10.5 (1.8)
2001	628 (79)	3,049 (1,264)	1.16 (0.15)	10.7 (2.1)
2000	639 (72)	3,177 (1,189)	1.17 (0.20)	9.7 (1.7)
1999	592 (65)	2,835 (1,054)	1.31 (0.13)	9.5 (1.7)
1998	569 (67)	2,407 (1,031)	1.24 (0.14)	9.8 (1.7)
1997	580 (54)	2,219 (746)	1.10 (0.12)	9.4 (1.7)
1996	586 (56)	2,652 (848)	1.29 (0.19)	9.9 (1.5)
1995	553 (65)	2,219 (861)	1.25 (0.14)	9.5 (1.5)
1994	552 (60)	2,285 (797)	1.30 (0.17)	9.8 (1.5)
1992	534 (70)	1,821 (796)	1.16 (0.14)	10.2 (1.8)
1987	640	3,036	1.16	13.8
1978	555 (82)	2,260 (1,166)	1.23 (0.14)	10.4

[a] Two different age readers and age estimation protocols were used to estimate age (Reader 1: 1978, 1987, and 1992–2012; Reader 2: 2010–2015).

[b] Lewis et al. 1989.

Table 5. Robson-Chapman estimates of survival (S) (95% confidence intervals in brackets), annual mortality (A), and instantaneous mortality (Z) of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT 1978 and 1987, and 1992-2015+.*

Year	S	A	Z
2015	0.70 (0.08)	0.30	0.36
2014	0.68 (0.06)	0.32	0.38
2013	0.68 (0.06)	0.32	0.38
2012	0.70 (0.05)	0.30	0.35
2011	0.68 (0.05)	0.32	0.39
2010	0.53 (0.06)	0.47	0.63
2009	0.57 (0.07)	0.44	0.57
2008	0.64 (0.06)	0.36	0.45
2007	0.61 (0.06)	0.39	0.50
2006	0.47 (0.11)	0.53	0.77
2005	0.53 (0.07)	0.47	0.63
2004	0.47 (0.08)	0.53	0.76
2003	0.51 (0.11)	0.49	0.68
2002	0.44 (0.11)	0.56	0.82
2001	0.52 (0.09)	0.48	0.66
2000	0.51 (0.07)	0.49	0.68
1999	0.52 (0.08)	0.48	0.66
1998	0.52 (0.07)	0.48	0.65
1997	0.48 (0.12)	0.51	0.71
1996	0.46 (0.07)	0.54	0.77
1995	0.45 (0.08)	0.55	0.80
1994	0.41 (0.09)	0.59	0.90
1992	0.58 (0.12)	0.42	0.55
1987	0.53 (0.07)	0.47	0.64
1978	0.52 (0.12)	0.48	0.65

* Lewis et al. 1989

+Two different age readers and protocols were used to estimate age (Reader 1: 1978, 1987, and 1992–2009; and Reader 2: 2010–2015).

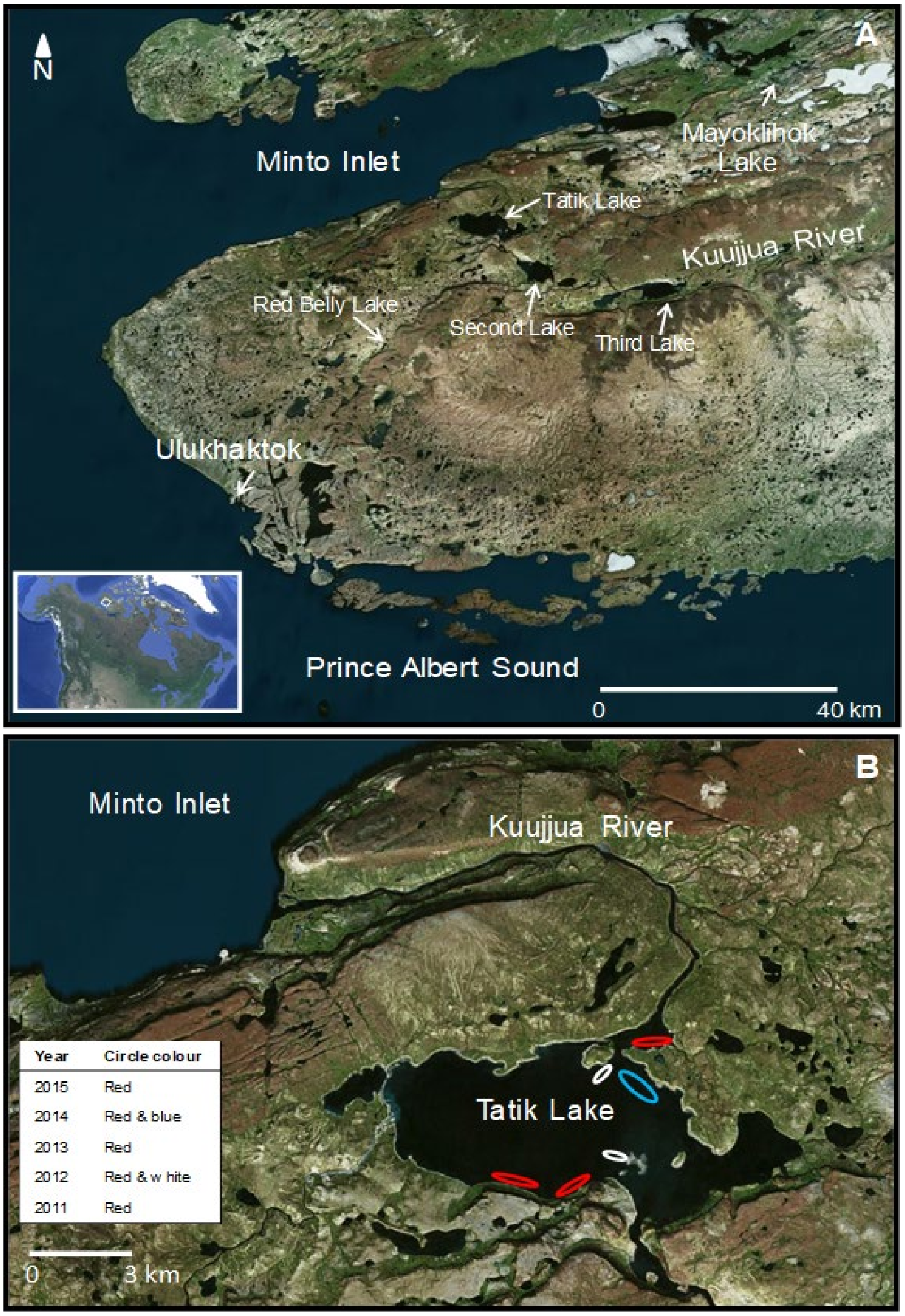

Figure 1. Location of A) Tatik Lake on the Kuujjua River system, Victoria Island, Northwest Territories and B) locations where subsistence harvest occurred in Tatik Lake between 2011 and 2015, and presumably in earlier years. Images provided by Google Earth.

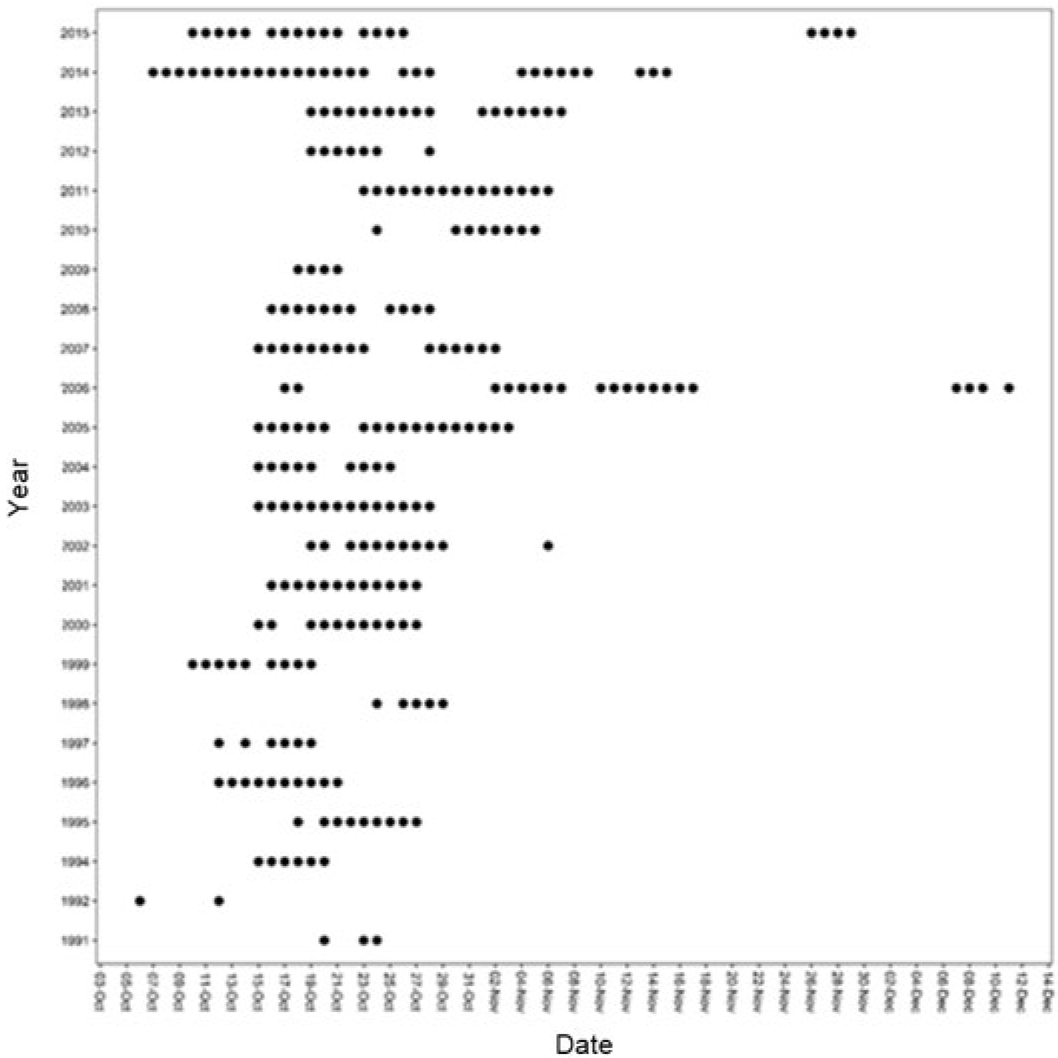

Figure 2. Days when catch-effort information was recorded in the Tatik Lake Char Monitoring Program between 1991 and 2015.

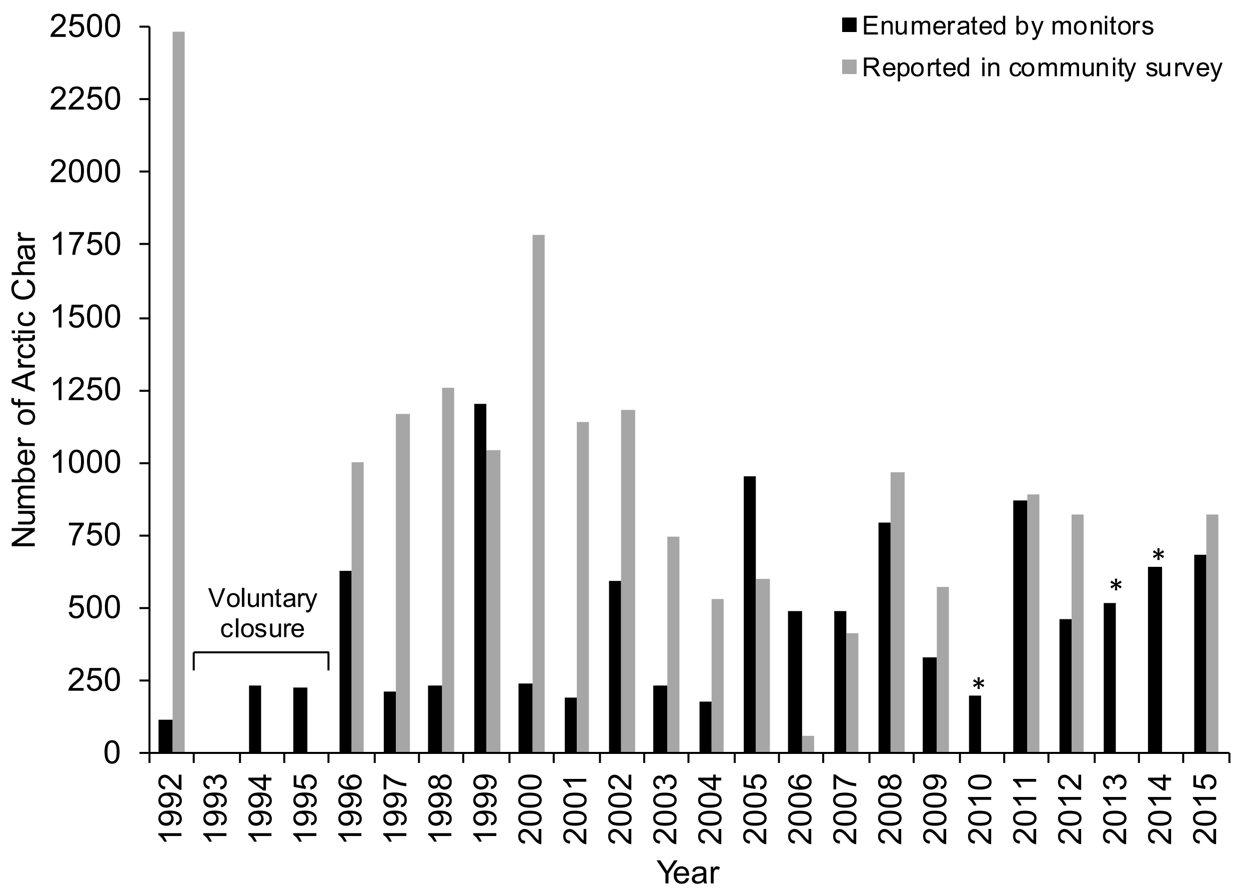

*Figure 3. Number of Arctic Char enumerated by the Tatik Lake harvest monitors compared to the number harvested char from the lake reported in community surveys (Inuvialuit Harvest Survey 1992–2002, Joint Secretariat 2003; Fisheries and Oceans Canada survey 2003–2015, Harwood et al. 2013, E. Lea, DFO, unpublished data) between 1992 and 2015. *Community survey not conducted in 2010 and incomplete in 2013 and 2014.*

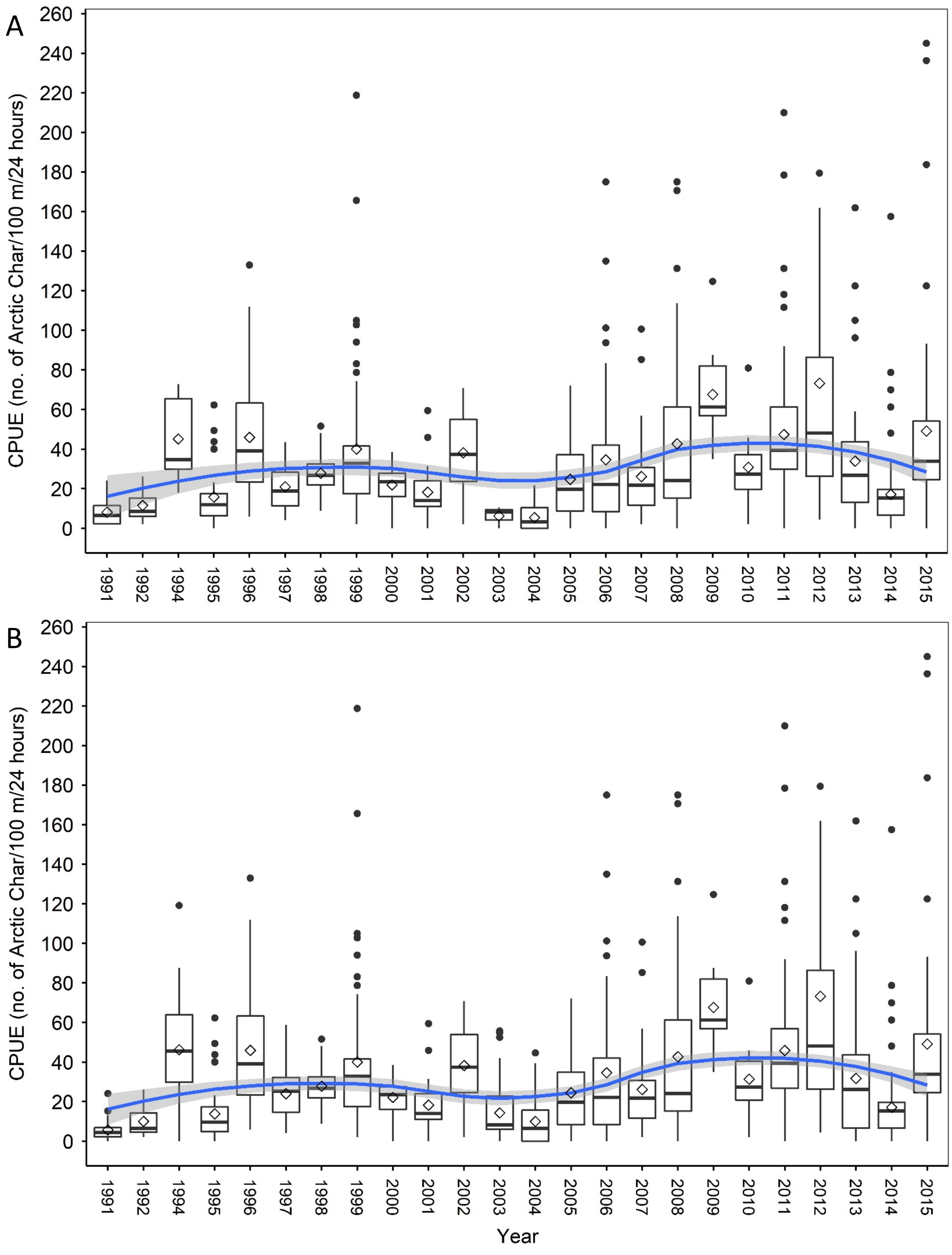

Figure 4. Box plot of catch-per-unit-effort (CPUE) (median, quartiles, outliers (●; values ≥ 1.5 x IQR), and ◊ mean) of Arctic Char captured in A) 114 mm mesh and B) all mesh sizes combined from gill nets used by harvesters in Tatik Lake, NT from 1991 to 2015. A loess regression (blue line) with 95% CI was fitted to the data. Note: one outlier in 2012 in the 114 mm mesh size had a CPUE equal to 293 (not shown).

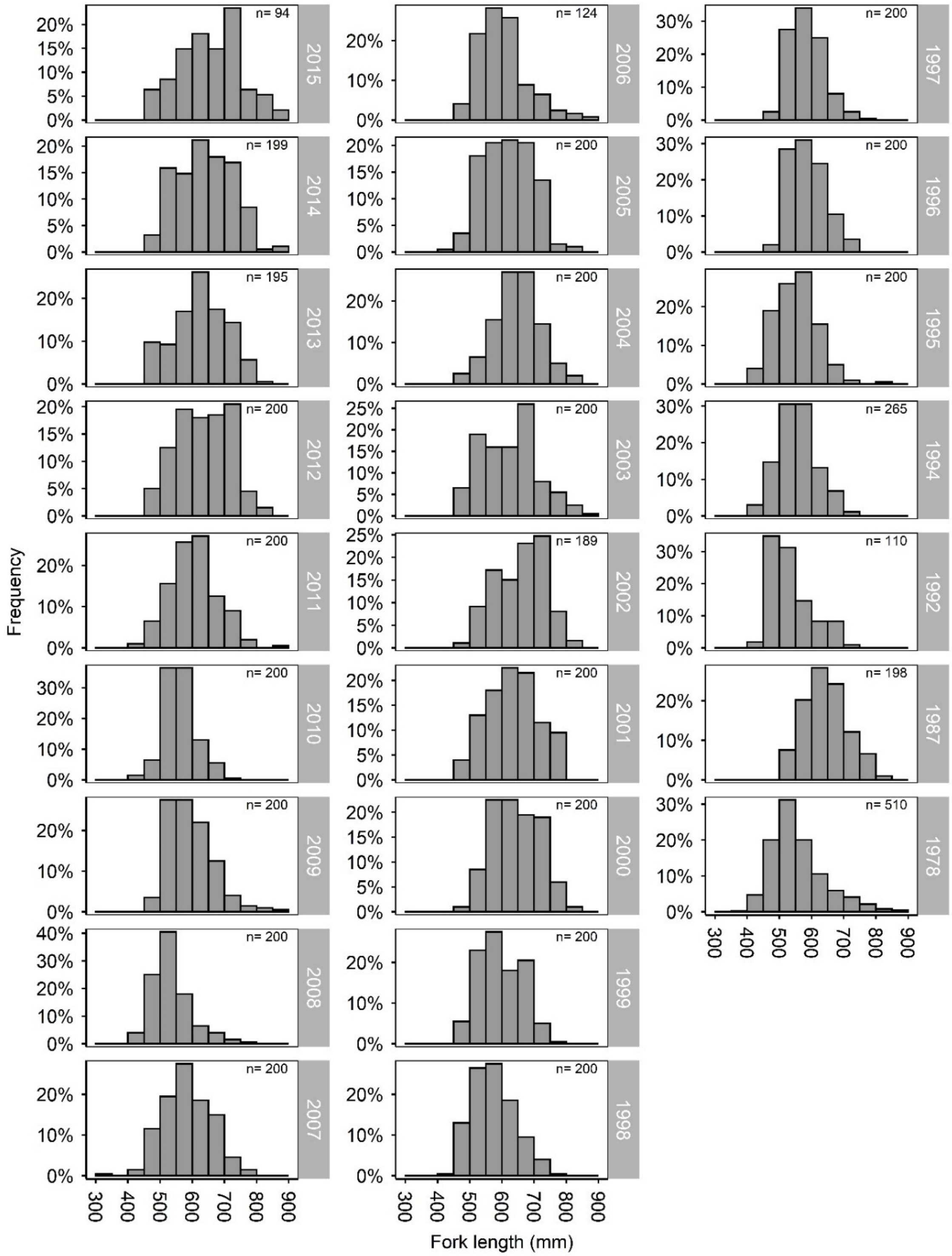

Figure 5. Fork length frequency distribution of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 and 1987 (Lewis et al. 1989), and between 1992 and 2015. Note, n = 1 fish < 300 mm in 1992 not included in the Figure.

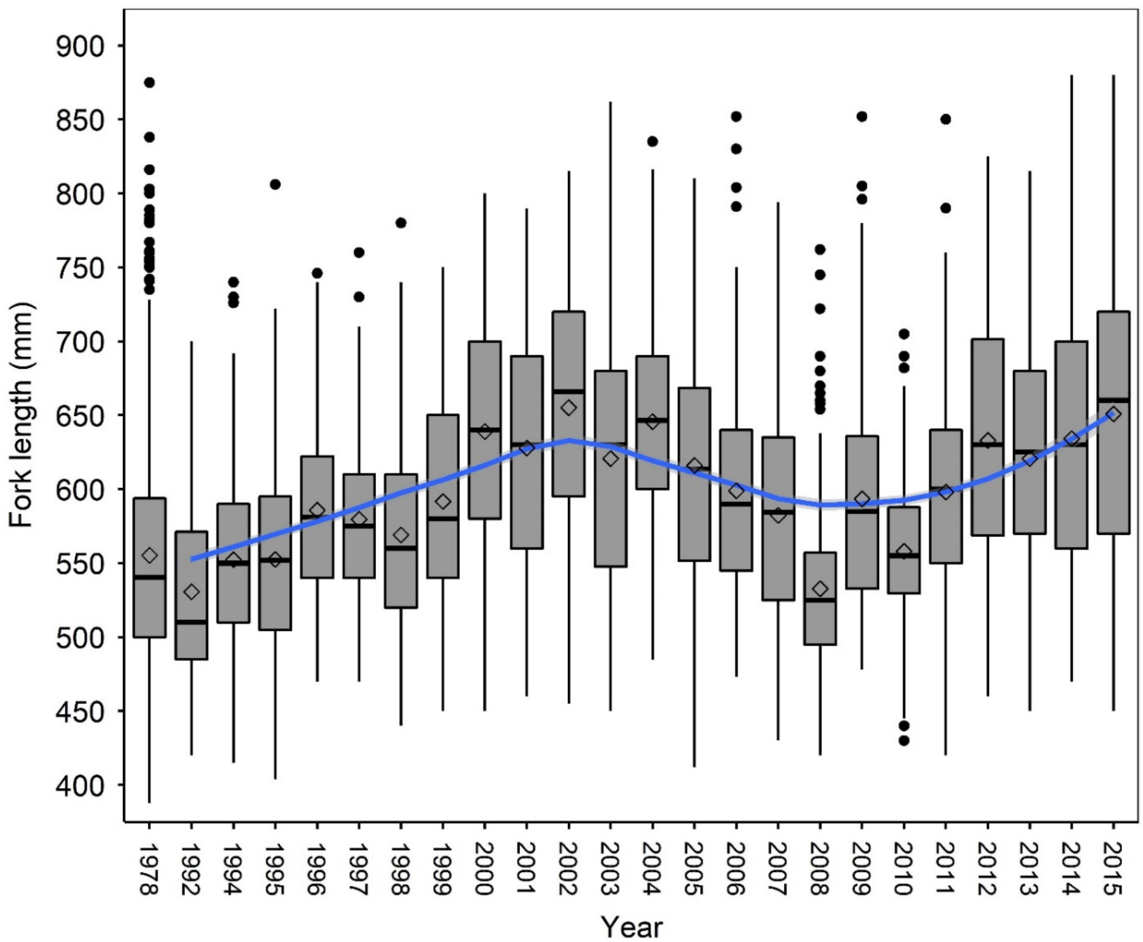

Figure 6. Box plot (median, quartiles, outliers (●; values ≥ 1.5 x IQR), and ◊ mean) of fork length of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 (Lewis et al. 1989), and between 1992 and 2015. A loess regression (blue line) with 95% CI was fitted to the 1992-2015 data.

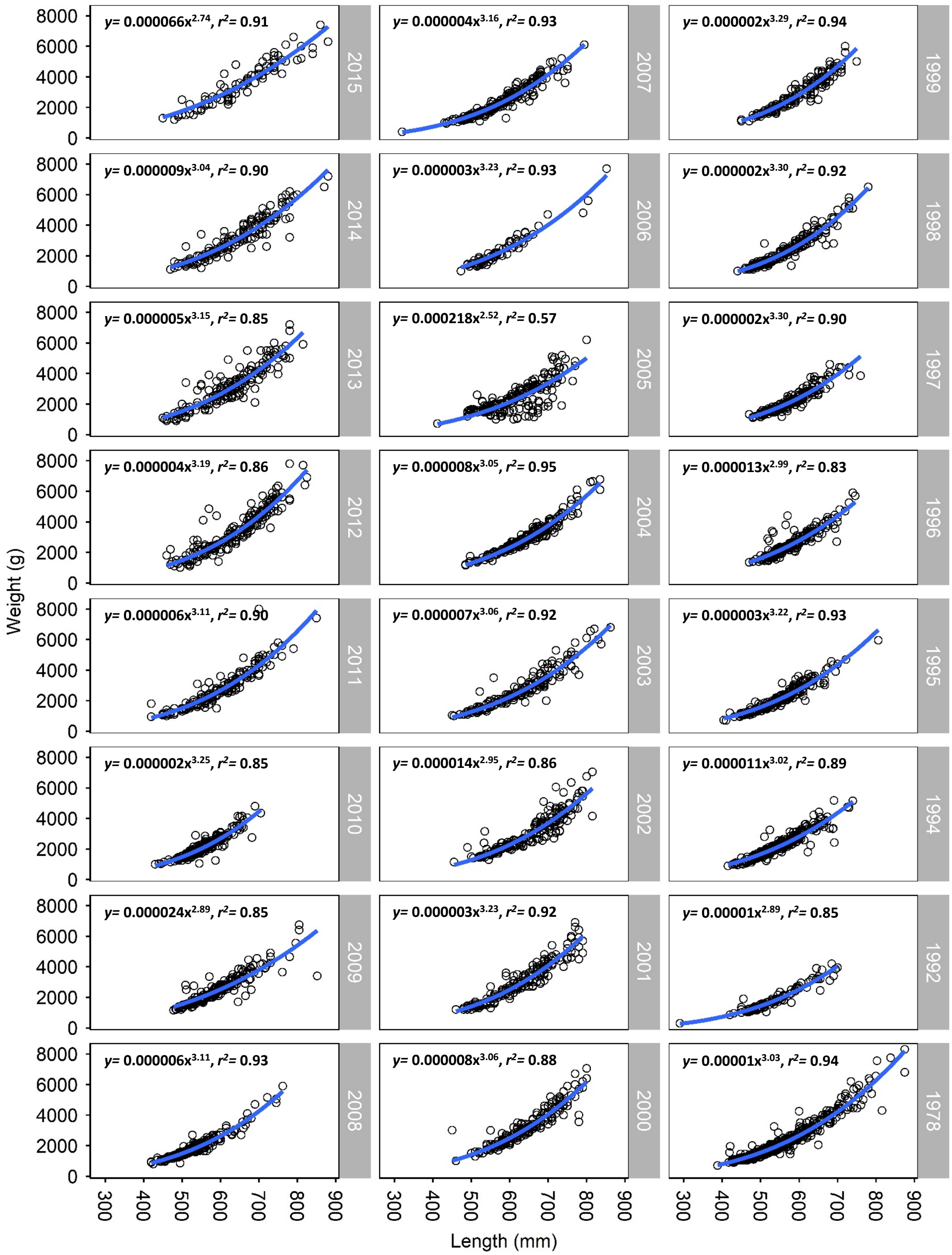

Figure 7. Scatter plot of fork length and weight of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978, and between 1992 and 2015.

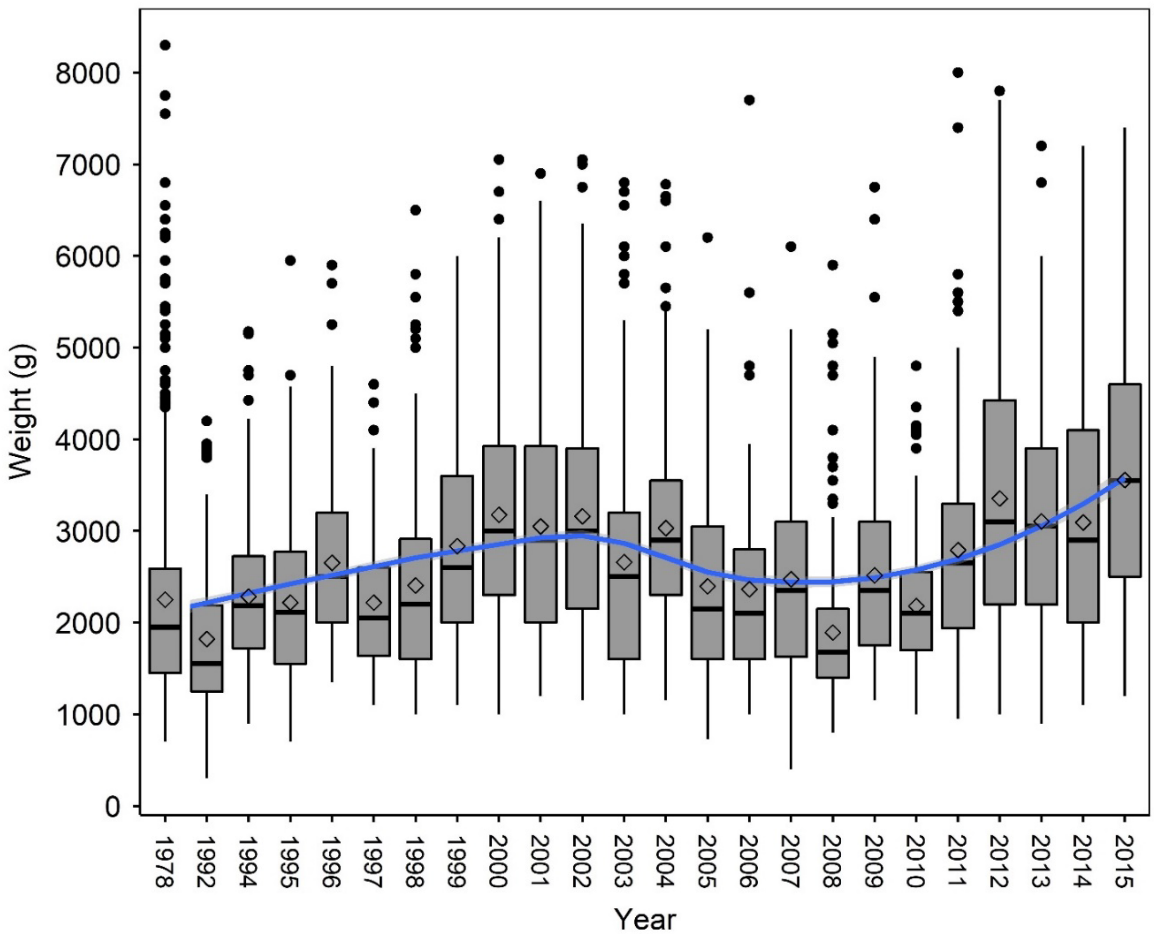

Figure 8. Box plot (median, quartiles outliers (●; values ≥ 1.5 x IQR), and ◊ mean) of weight of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 (Lewis et al. 1989), and between 1992 and 2015. A loess regression (blue line) with 95% CI was fitted to the 1992–2015 data.

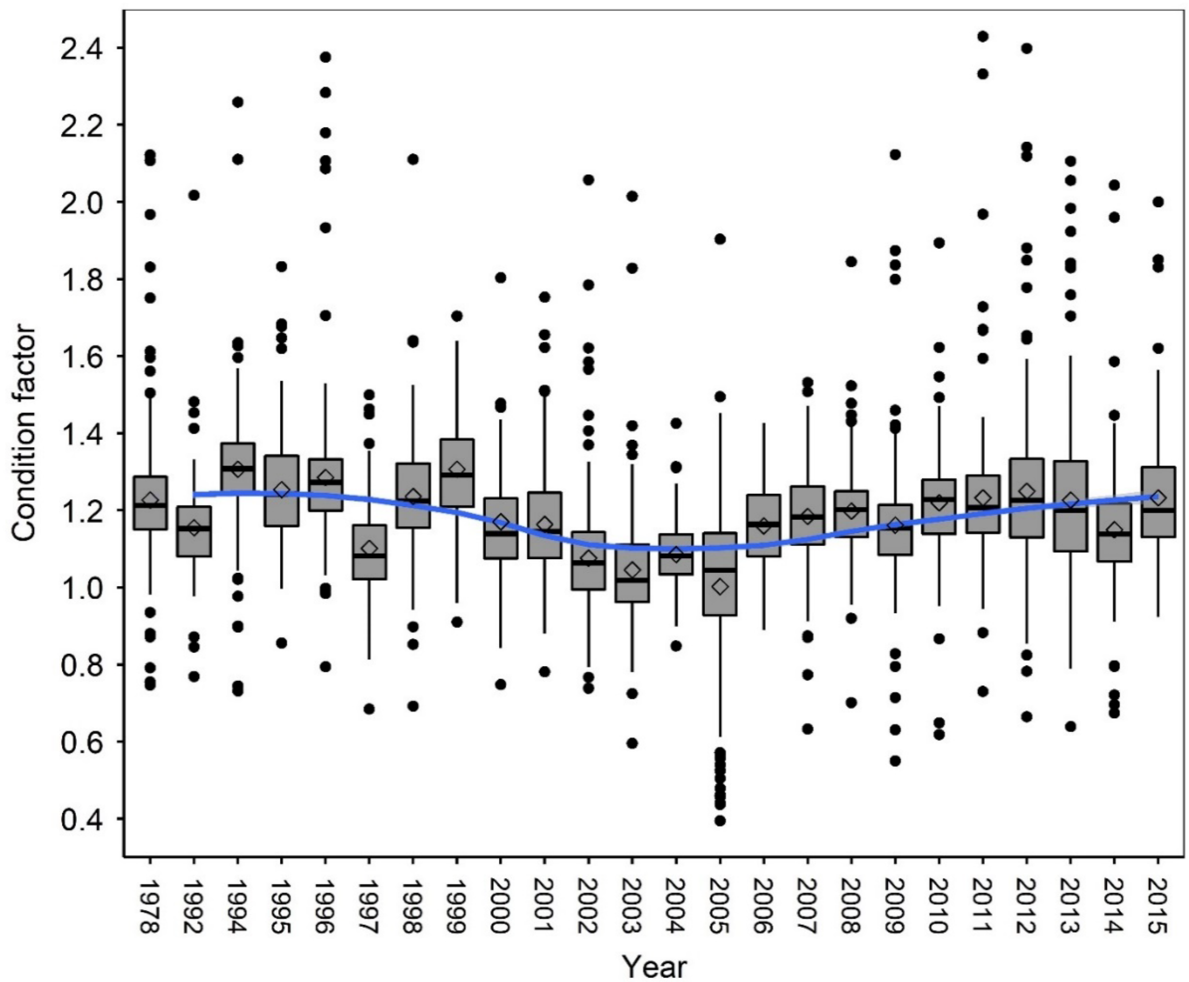

Figure 9. Box plot (median, quartiles outliers (●; values ≥ 1.5 x IQR), and ◊ mean) of condition factor of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 (Lewis et al. 1989), and between 1992 and 2015. A loess regression (blue line) with 95% CI was fitted to the 1992–2015 data.

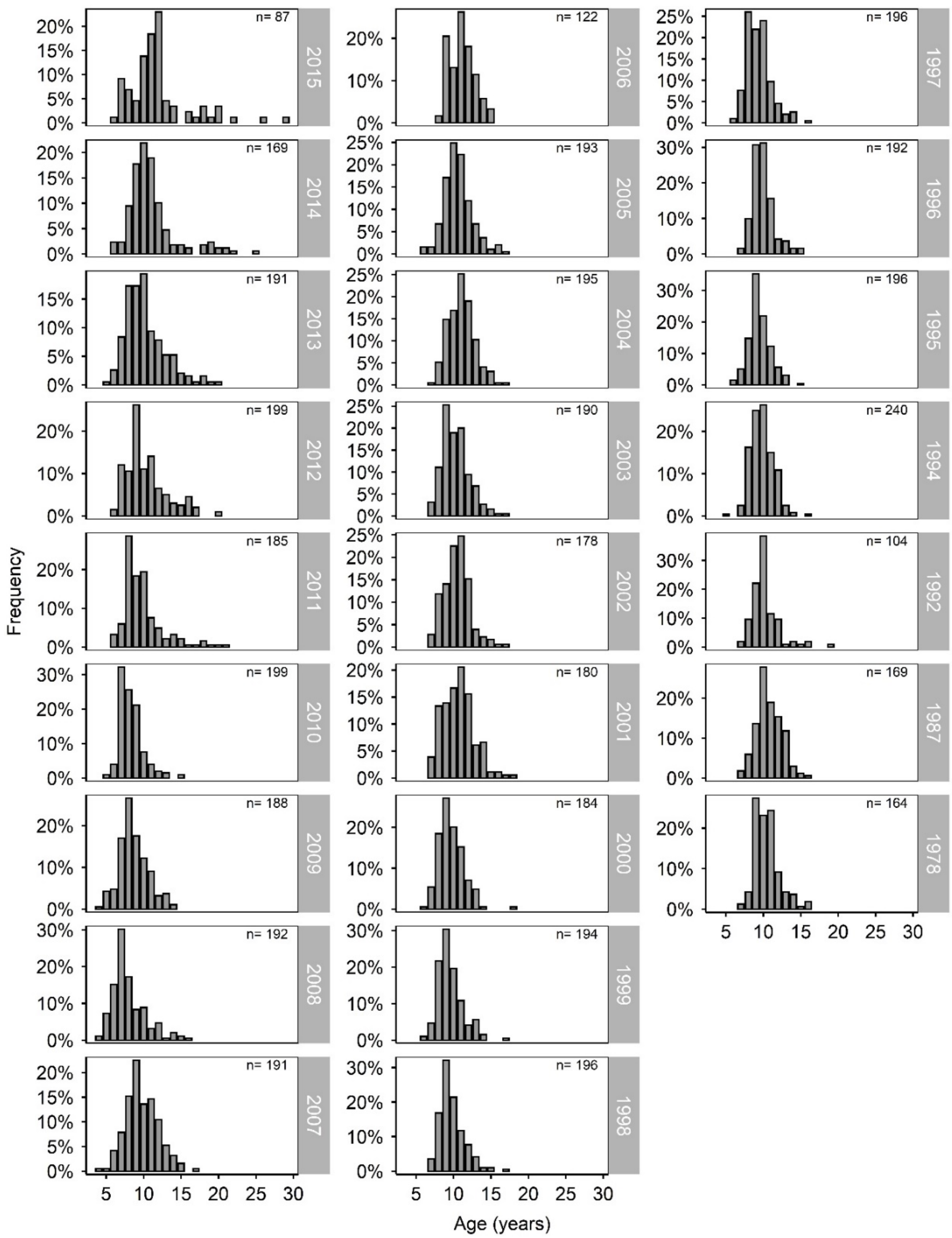

Figure 10. Age frequency distribution of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 and 1987 (Lewis et al. 1989), and between 1992 and 2015. Two different age readers and age estimation protocols were used to estimate age (age Reader 1: 1978, 1987, and 1992–2009; age Reader 2: 2010–2015).

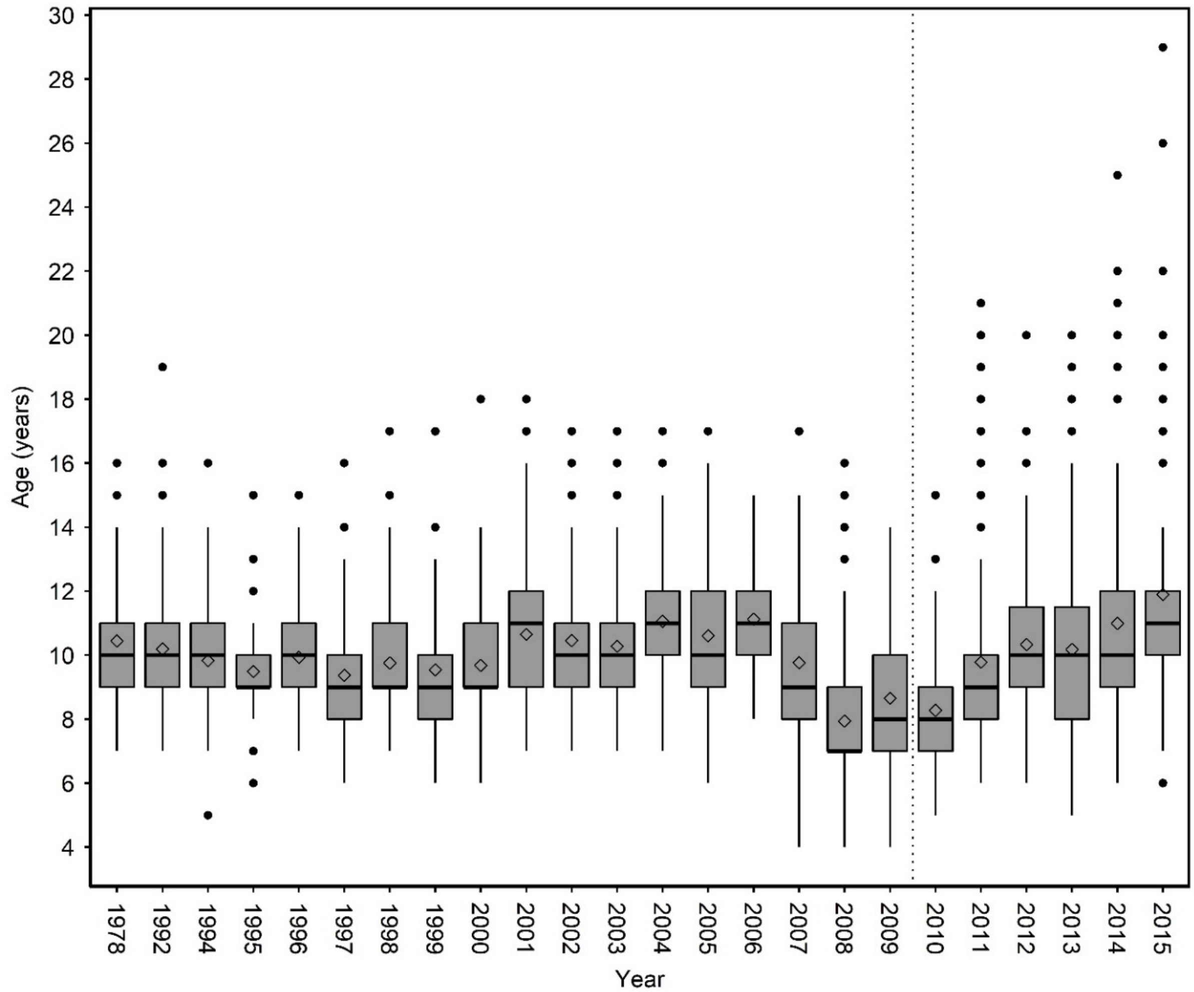

Figure 11. Box plot (median, quartiles (●; values ≥ 1.5 x IQR), and ◊ mean) of age of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 (Lewis et al. 1989), and between 1992 and 2015. Two different age readers and age estimation protocols were used to estimate age (dotted vertical line; age Reader 1: 1992–2009, and Reader 2: 2010–2015).

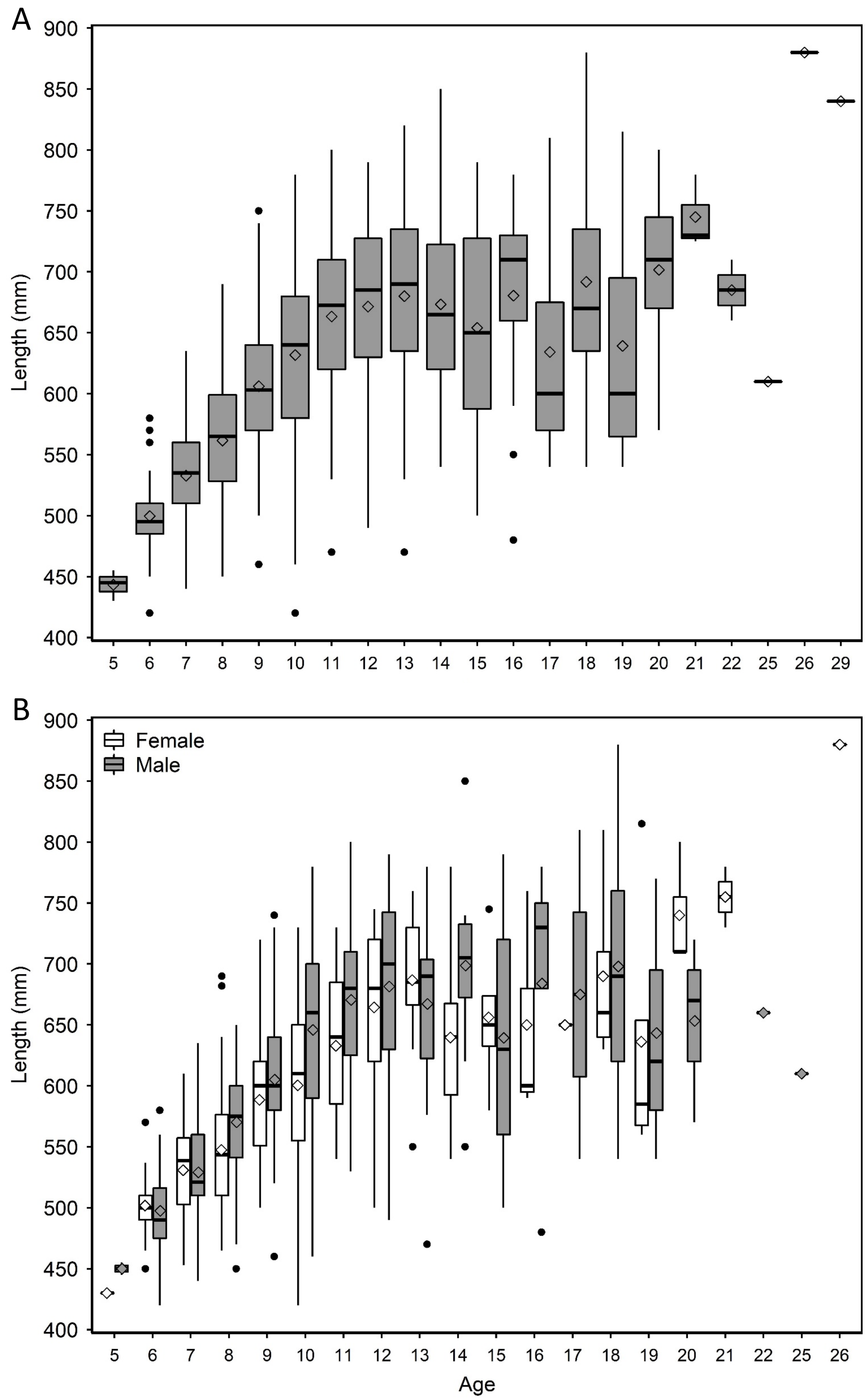

Figure 12. Box plot (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) of length-at-age of A) total sample and B) of female and male Arctic Char sampled from the subsistence fishery in Tatik Lake, NT between 2010 and 2015.

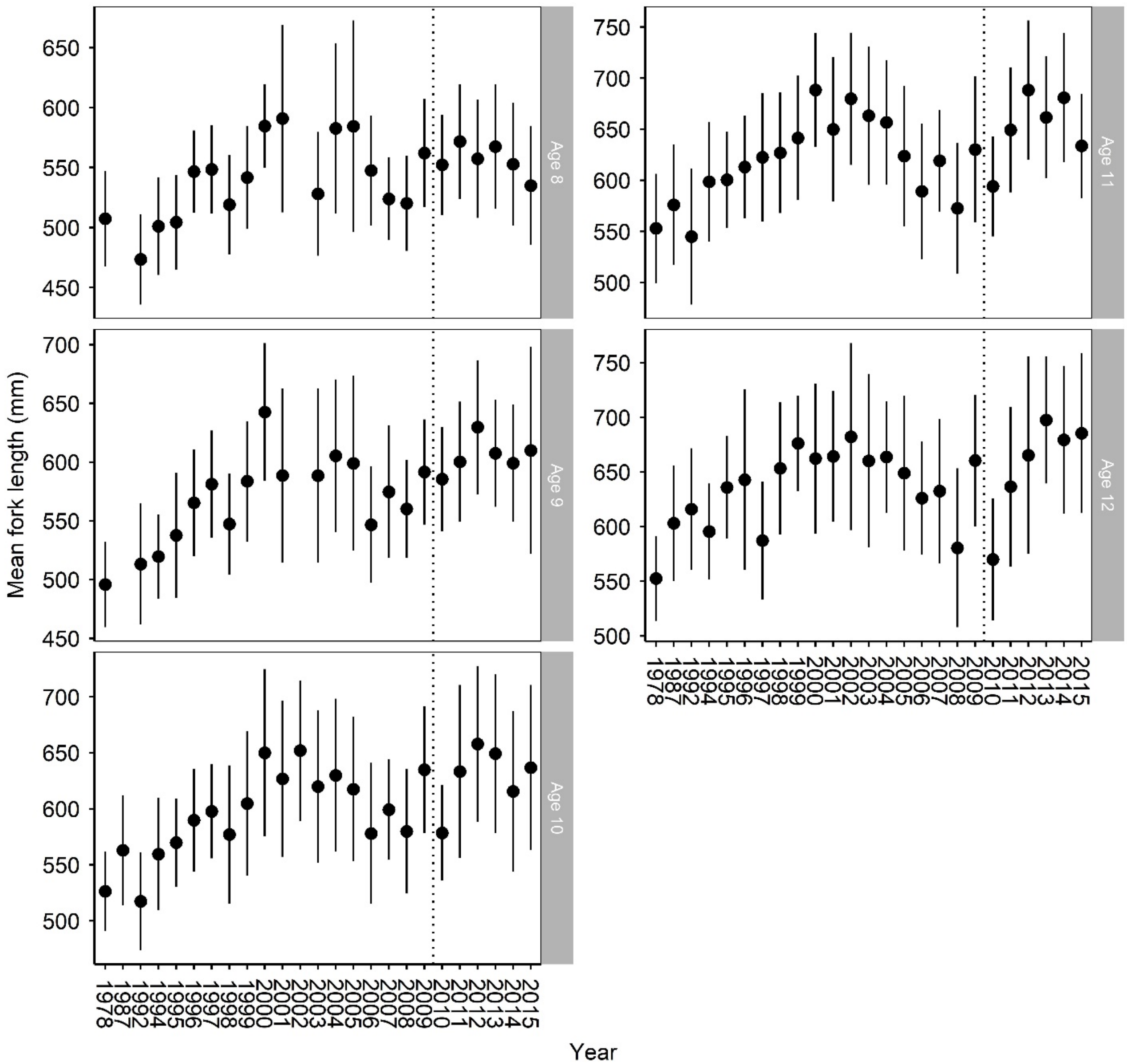

Figure 13. Mean length (± SD) of ages 8, 9, 10, 11 and 12 among years of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 and 1987 (Lewis et al. 1989), and between 1992 and 2015. Two different age readers and age estimation protocols were used to estimate age (dotted vertical line; age Reader 1: 1978, 1987, and 1992–2009, and age Reader 2: 2010–2015). No Arctic Char < 10 years were observed in the 1987 sample.

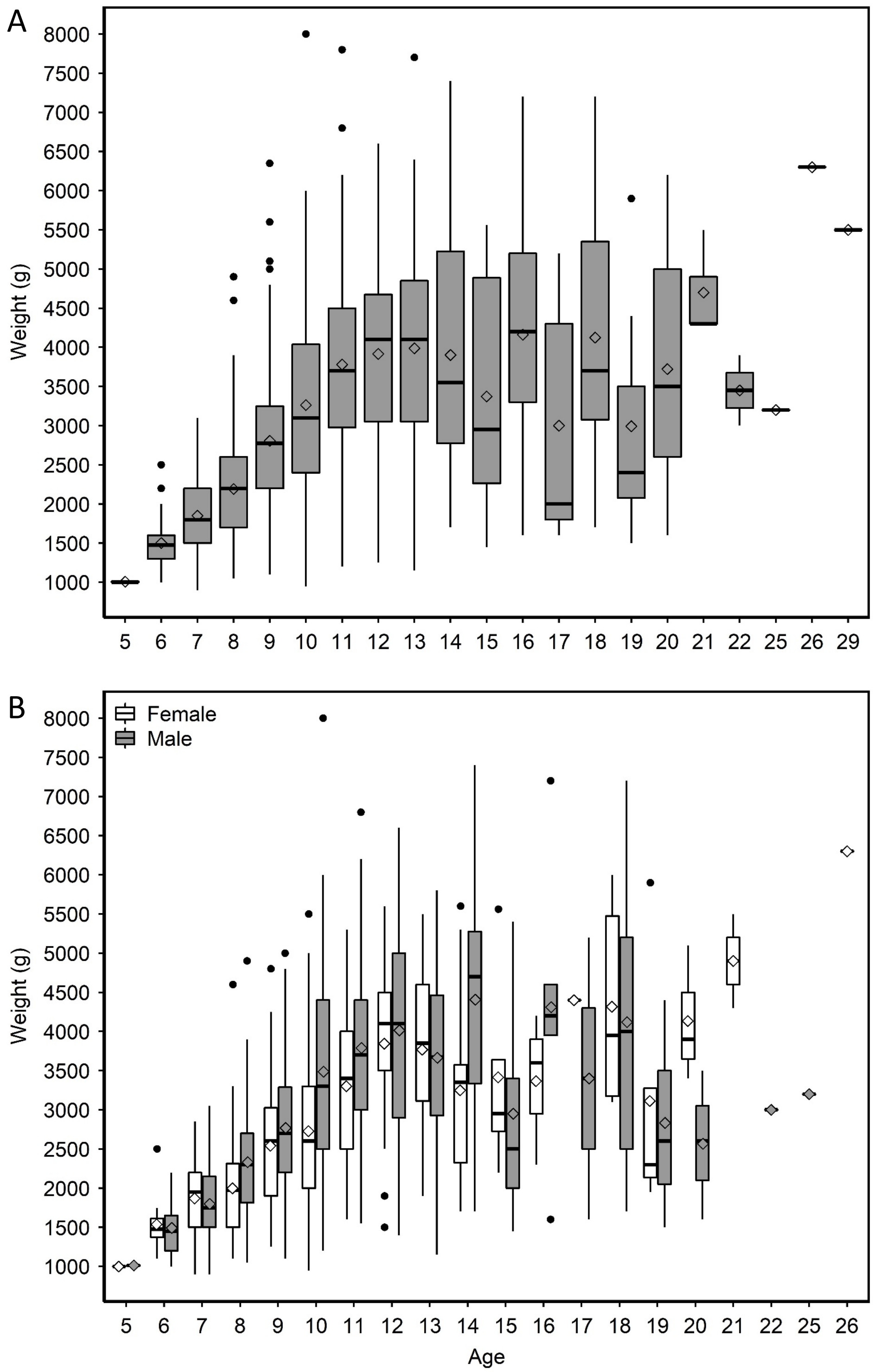

Figure 14. Box plot (median, quartiles, outliers (● values ≥1.5 x IQR, and ◊ mean) of weight-at-age of A) total sample and B) of female and male Arctic Char sampled from the subsistence fishery in Tatik Lake, NT between 2010 and 2015.

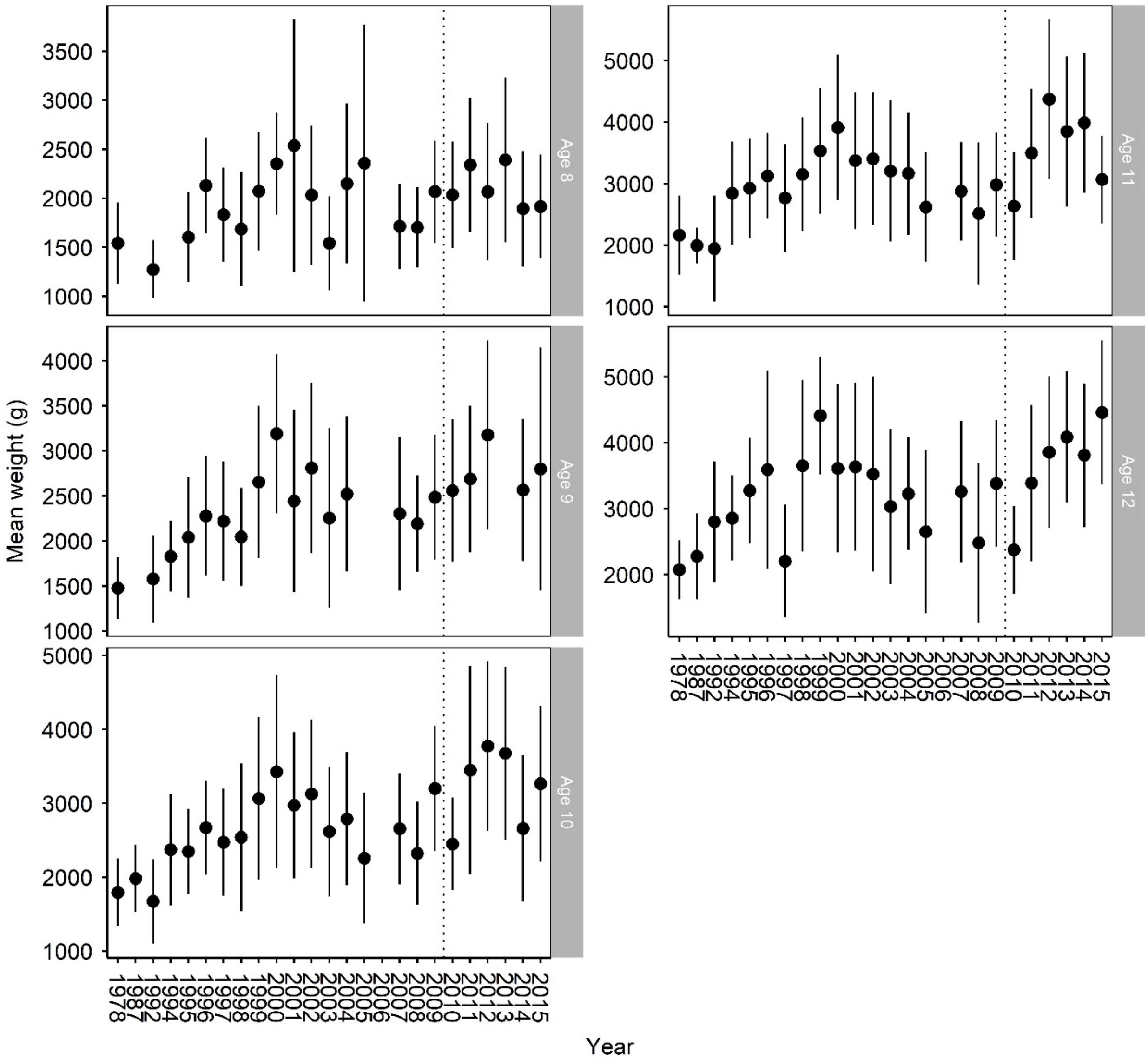

Figure 15. Mean weight (± 1 standard deviation) of ages 8, 9, 10, 11 and 12 among sampling years of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 and 1987 (Lewis et al. 1989), and between 1992 and 2015. Two different age readers and age estimation protocols were used to estimate age (dotted vertical line; age Reader 1: 1978, 1987, and 1992-2009, and age Reader 2: 2010–2015). No Arctic Char < 10 years were observed in the 1987 sample.

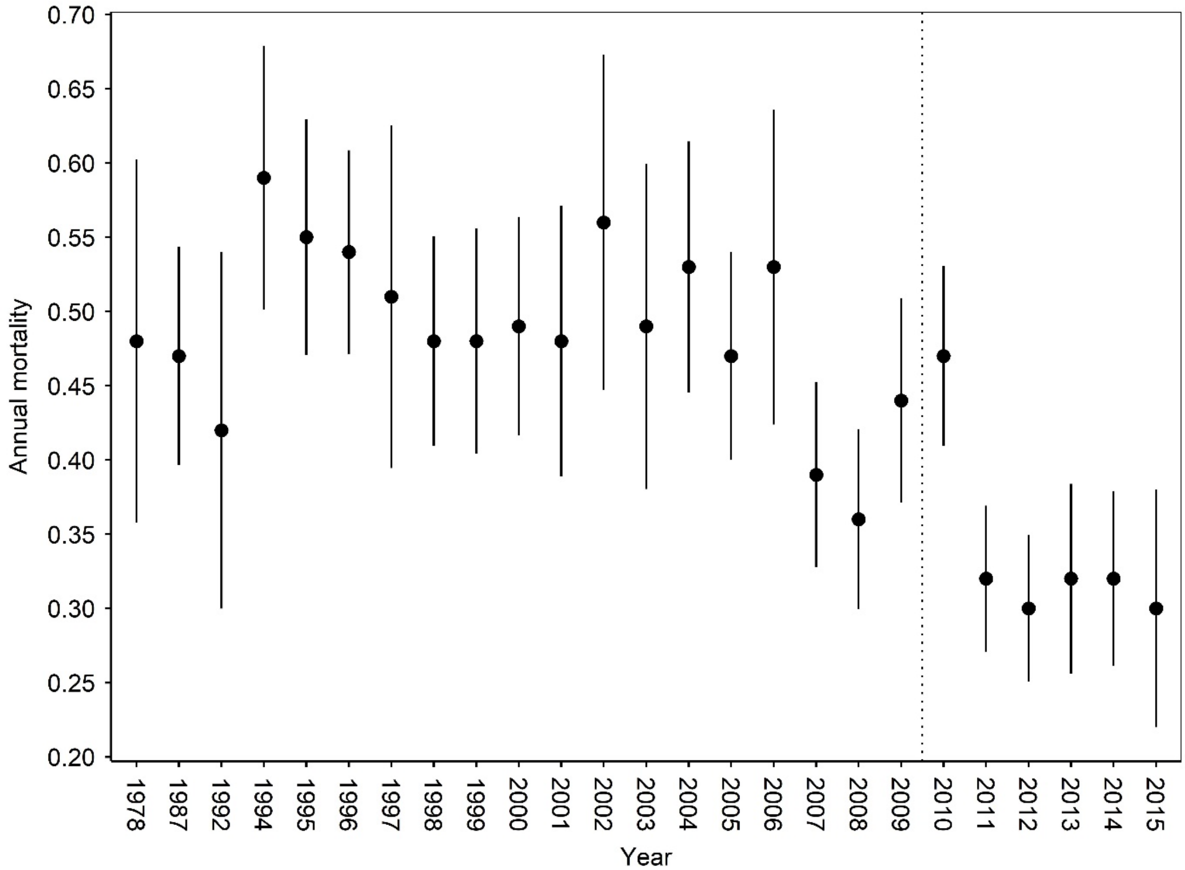

Figure 16. Annual mortality with 95% confidence intervals of Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 and 1987 (Lewis et al. 1989), and between 1992 and 2015. Two different age readers and age estimation protocols were used to estimate age (dotted vertical line; age Reader 1: 1978, 1987, and 1992–2009, and age Reader 2: 2010–2015).

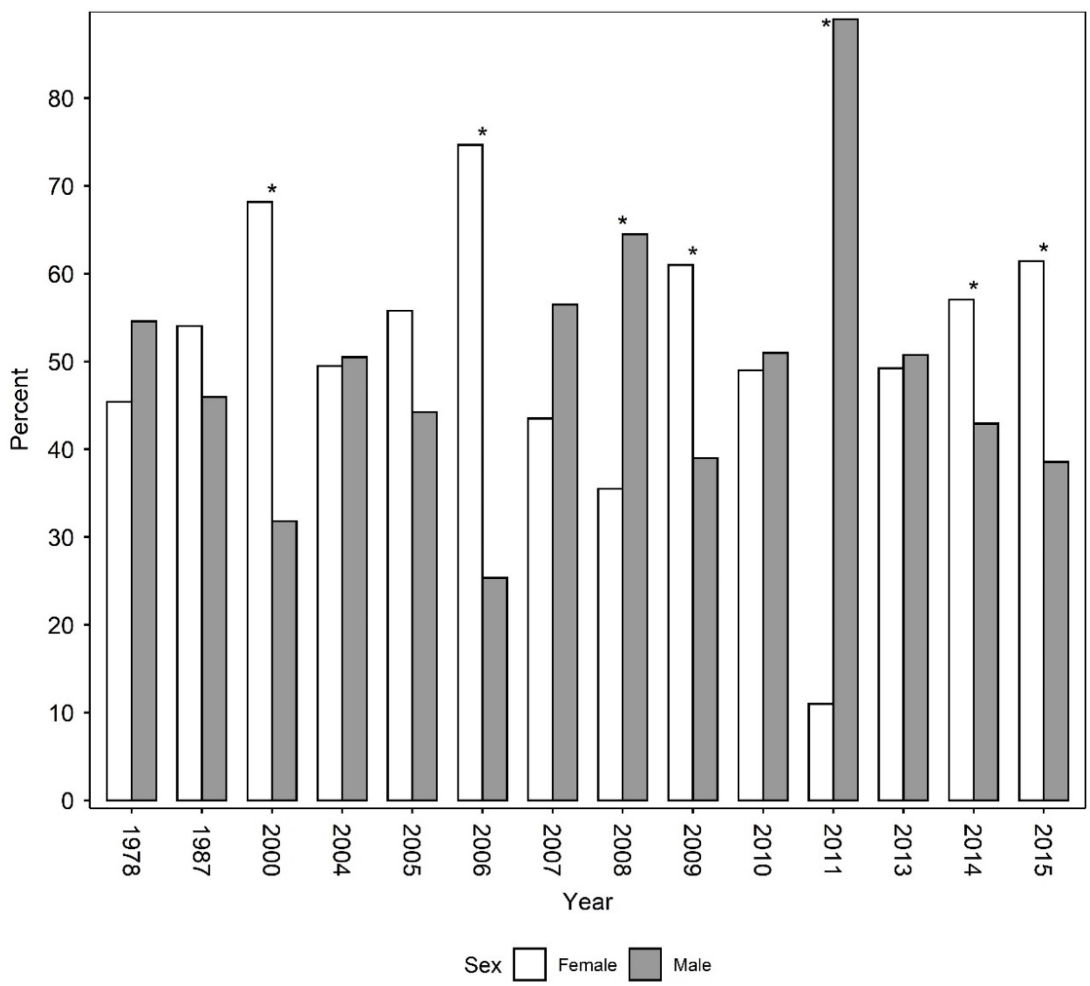

Figure 17. Percent female and male Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 1978 and 1987 (Lewis et al. 1989), and between 2000 and 2015. Asterisks indicate significant departure from a binomial proportion of 0.5.

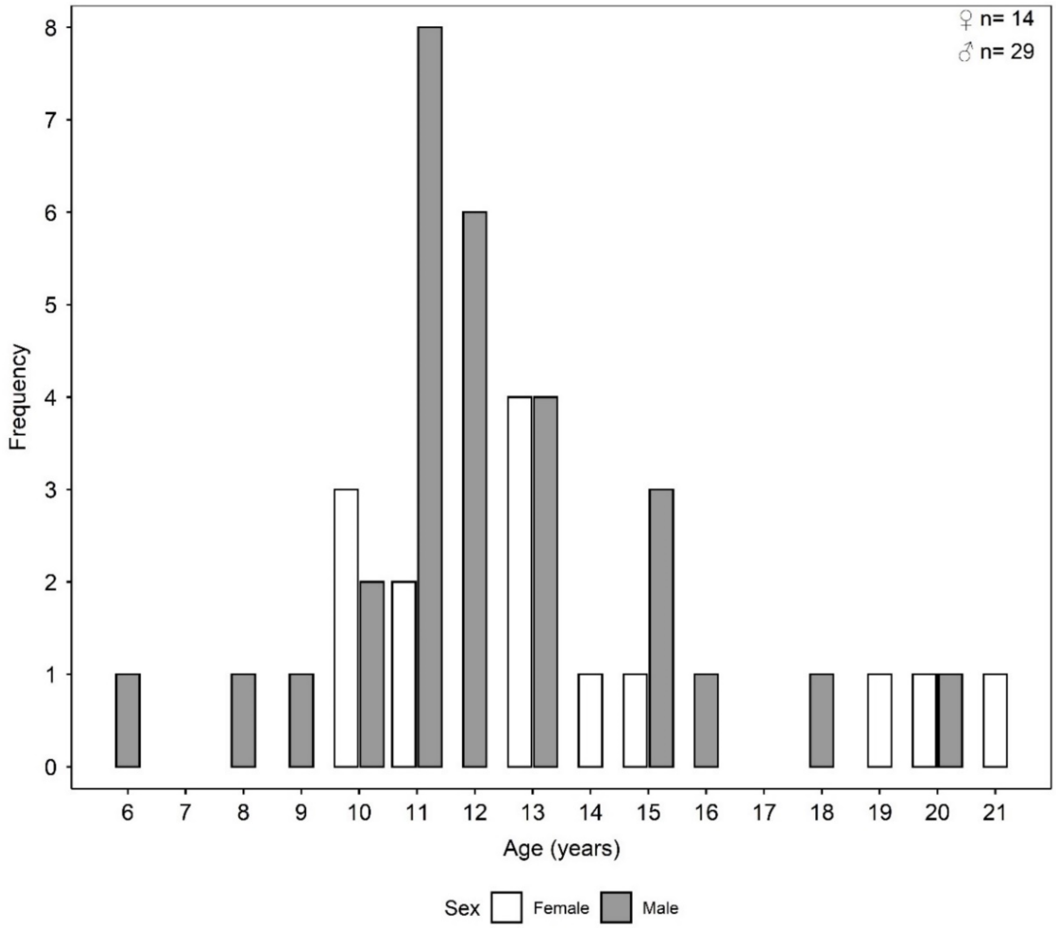

Figure 18. Frequency of male and female Arctic Char sampled from the subsistence fishery in Tatik Lake, NT in 2013 and 2014 that were categorized as 'mature' (i.e., current-year spawners) among age classes.