Fisheries and Oceans Canada — Pêches et Océans Canada
Ecosystems and Oceans Science — Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2023/015

Central and Arctic Region

Ulukhaktok, Northwest Territories coastal Arctic Char (*Salvelinus alpinus*) subsistence (1993–1997 and 2011–2015) and commercial (2010–2015) fisheries: Catch-per-unit-effort and biological sampling

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February 2023

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.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-47021-4 Cat. No. Fs70-5/2023-015E-PDF

Correct citation for this publication:

Lea, E.V., Gallagher, C.P., Carder, G.M., Matari, K.G.A., and Harwood, L.A. 2023. Ulukhaktok, Northwest Territories coastal Arctic Char (*Salvelinus alpinus*) subsistence (1993–1997 and 2011–2015) and commercial (2010–2015) fisheries: Catch-per-unit-effort and biological sampling. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/015. iv + 41 p.

Aussi disponible en français :

*Lea, E.V., Gallagher, C.P., Carder, G.M., Matari, K.G.A., et Harwood, L.A. 2023. Pêche de subsistance (de 1993 à 1997 et de 2011 à 2015) et pêche commerciale (de 2010 à 2015) de l'omble chevalier (*Salvelinus alpinus*) dans les eaux côtières près d'Ulukhaktok, dans les Territoires du Nord-Ouest : captures par unité d'effort et échantillonnage biologique Secr. can. des avis sci. du MPO. Doc. de rech. 2023/015. iv + 43 p.*

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ABSTRACT

The summer coastal Arctic Char (*Salvelinus alpinus*) fishery is an important cultural, subsistence, and commercial resource for the community of Ulukhaktok in the Inuvialuit Settlement Region, Northwest Territories. Anadromous Arctic Char are caught while they are feeding along the coast during summer, generally early-July to late-August. A community-based harvest monitoring program was conducted during 1993–1997 and 2011–2015 to collect catch-per-unit-effort (CPUE) and biological data from the coastal subsistence fishery. The community has also conducted a small-scale Arctic Char commercial fishery, licensed as a Stage 1 Exploratory Fishery with catch and biological data reporting requirements. Median CPUE in the subsistence fishery ranged from 19.2 to 32.8 Arctic Char/100 m net/24 h, with no trends over time in either sampling period or overall. There was an increase in the length and weight of Arctic Char harvested in the coastal fishery between sampling periods, with the majority of fish between 500 mm and 650 mm, and 1,500 g to 3,000 g in 1993–1997, and between 550 mm and 800 mm and 2,500 g and 5,000 g in 2011–2015. The majority of Arctic Char harvested in the subsistence fishery were between 8 and 13 years. Annual mortality during 2011 to 2015 was relatively stable at a low level (0.17–0.3). In addition to changes in size, there was evidence of increases in growth rate (length-at-age) between 1993–1997 and 2011–2015. Biological data collected from the commercial fishery were similar to those collected from the subsistence fishery although the commercial catch was comprised of a higher proportion of large (≥ 700 mm) fish which is expected given some differences in gear types. The available information suggests that the populations contributing to the coastal summer fishery are sustainable at present harvest levels. The collection of biological and CPUE data from subsistence and commercial fisheries continues to be a priority for the Ulukhaktok Char Working Group, to support their use of adaptive co-management and enable the sustainable management of their Arctic Char fisheries. Continued monitoring and research, that include both Indigenous Knowledge and scientific methods are required to better understand, characterize, and assess the stocks that contribute to this mixed-stock coastal fishery.

INTRODUCTION

Ulukhaktok (formerly known as Holman Island), Northwest Territories, is a coastal community located on western Victoria Island in the Inuvialuit Settlement Region (ISR; Figure 1). Anadromous and landlocked Arctic Char (*Salvelinus alpinus*) are important cultural and subsistence resources for the community, with seasonal harvesting occurring in various lake, river, and coastal sites in the area (Lea et al. 2023). Community members have a continued dependence and preference for traditional foods such as Arctic Char (OHTC et al. 2016), which make up a significant component of their diets (Paylor et al. 1998).

Anadromous Arctic Char spawn, rear, and overwinter in large lakes and rivers, and migrate to coastal waters during summer to feed (Dempson and Kristofferson 1987). Landlocked or resident Arctic Char stay within lake systems and do not migrate to the coast (Johnson 1980). While harvest from within lakes and rivers are generally assumed to be comprised of a single stock (with an unknown degree of mixing due to straying; see Moore et al. 2014), harvest from coastal areas are considered to be comprised of fish from different river systems (i.e., mixed-stock fisheries). In the Western Arctic gillnets are the predominate gear used to catch Arctic Char. However, fishing rods are sometimes used in summer and traditional jiggling hooks are used under the ice in spring. In the Ulukhaktok area landlocked Arctic Char are harvested from lakes in the area, predominantly during spring (Lea et al. 2023). Anadromous Arctic Char are caught in coastal areas (generally from Kidjvik to Anialik) during summer, and the Kuujjua River (i.e., Tatik Lake, also known locally as Fish Lake) and Prince Albert Sound during late-fall and early winter (Figure 1; Lea et al. 2023). The coastal fishery is likely comprised of fish from the Kuujjua River (Paylor 1998, L. Harwood, DFO, pers. comm.) as well as rivers that flow into Prince Albert Sound and Minto Inlet (Figure 1).

In 1996 the Olokhaktomiut Hunters and Trappers Committee (OHTC), Fisheries Joint Management Committee (FJMC) and Department of Fisheries and Oceans (DFO) formed a co-management working group under the Inuvialuit Final Agreement (IFA; Canada 2005) focused on Arctic Char in the Ulukhaktok area. The Ulukhaktok Char Working Group (UCWG; formerly the Holman Char Working Group) developed a community-based fisheries management plan for Arctic Char fisheries in the area (HCWG 2004). The UCWG meets annually to review all available scientific and Indigenous Knowledge, identify research and monitoring priorities, assess results from harvest and monitoring programs, and make decisions on the management of Arctic Char fisheries. Fisheries monitoring has been conducted at Tatik Lake during late-fall since 1992 (Harwood et al. 2013, Gallagher et al. 2021a) and along the coast during summer (this report). These programs rely on community harvesters to collect biological and catch information that are used to assess stock status (Bell and Harwood 2012).

In addition to subsistence fisheries, there has been effort over the years to assess the feasibility of, and provide opportunities for, small-scale commercial Arctic Char fisheries in the Ulukhaktok coastal area and Prince Albert Sound. Test fisheries were first conducted in the Ulukhaktok coastal area in 1982 and 1983 (Lewis et al. 1989). During the early 2000s, there was renewed interest in fisheries development and since 2006 a small fishery (henceforth referred to as a ‘commercial fishery’) has been authorized through a Stage I Exploratory Fishery Licence under DFO’s New Emerging Fishery Policy (DFO 2008), with a quota of 500 Arctic Char that can be sold locally (within the Northwest Territories). Recommendations for data collection from exploratory Arctic Char fisheries were developed by VanGerwen-Toyne and Tallman (2011) and individuals fishing under the licence were required to record their harvest and some basic biological information.

OBJECTIVES

The objectives of this research document were to analyze data collected from both the subsistence and commercial mixed-stock coastal fisheries in order to support the population assessment of Ulukhaktok Arctic Char. Specific tasks are to:

- Summarize catch-per-unit-effort (CPUE) and biological data collected from the subsistence fishery during 1993–1997 and 2011–2015;
- Compare trends in annual CPUE and biological information between the two separate sampling periods (1993–1997 and 2011–2015) to determine if there has been a change in the subsistence fishery;
- Summarize biological data collected from the Stage I Exploratory fishery and compare it to the subsistence fishery to inform future monitoring.

METHODS

ULUKHAKTOK COASTAL HARVEST MONITORING PROGRAM

From 1993–1997 and 2011–2015, one to two harvesters from Ulukhaktok were selected by the OHTC to be monitors and to record catch-effort and biological information from the coastal summer (July-August) subsistence Arctic Char fishery. The monitors recorded and sampled fish caught from their own nets as well as from others. The intention was not to conduct an enumeration of total harvest as this was the objective of the concurrent community harvest surveys (Lea et al. 2023). Harvesters used monofilament gillnets, set perpendicular to shore that were typically checked every 12–24 h. Harvesters used 89 mm, 102 mm, 114 mm, and 127 mm stretched mesh gillnets that were 20–50 m in length. Occasionally fishing rods were also used to harvest Arctic Char.

Data collected to calculate CPUE included stretched mesh size and net length, date, location, soak time, and the number of Arctic Char caught. In 1996 and 1997, harvesters were provided with a logbook to record their cumulative catch (total number of fish) and effort (total hours) instead of their individual net set records (Paylor 1998), limiting comparisons between 1993–1997 and 2011–2014 time periods (CPUE records were not collected in 2015).

Biological information collected from Arctic Char included location and date of capture, mesh size, fork length (± 1 mm), round weight (± 50 g), sex (male or female), maturity ('mature' current-year spawner or 'immature' non-spawner; collected only in 2011, 2012, 2013 and 2015), and sagittal otoliths to estimate age. Sample sizes were variable during 1993–1997 (range = 53–249), and were between 200 and 300 during 2011–2015 (except for 2012 when only 35 samples were collected). Tissue samples (e.g., muscle, stomachs and fin clips) were also collected during 2011–2015 to be available for future analysis.

Methods used to estimate fish ages are described in Gallagher et al. (2021b). Briefly, age estimation using otoliths collected between 1993 and 1997 was conducted by an age reader using the whole otolith method (Nordeng 1961). Otoliths collected in 2011 and thereafter were read by a different age reader using a combination of whole and thin-section otolith preparation methods. A between-reader comparison of paired age data from Tatik Lake using historical (whole) and contemporary (combination of whole and thin-section) otolith preparation methods revealed differences in age frequency distribution, longevity, and mortality, although no effects on von Bertalanffy growth parameters were found (see Gallagher et al. 2021b).

COMMERCIAL FISHERIES

Although the commercial fishery has been underway since 2000, sampling Arctic Char harvested in this fishery occurred in 2010 and 2012–2015. Individuals selected by the OHTC to fish under the licence were required to record net mesh size (mm) and length (yards), the date and location, and fork length (mm) and round weight (g) of each fish caught under the commercial fishing licence. There was direct spatial and temporal overlap between the commercial fishery and the subsistence harvest monitoring program from 2010 to 2015.

ANALYSIS

Ulukhaktok Coastal Harvest Monitoring Program

Analysis was done on the basis of year and gill net mesh size. In order to standardize the analysis only data from Arctic Char harvested using 114 mm stretch mesh nets were used, given that it was the dominant mesh size. Mesh size was not recorded for 78 samples in 1996, however, it was assumed that all of these were harvested with 114 mm stretched mesh gillnets and they were also included in the analysis.

Sets with duration ranging between 1 h and 48.5 h were considered valid for calculating CPUE (number of fish caught in 100m of net in 24 hours), excluding less than 10% of the data from the analysis. The annual median value was calculated, given data were not parametrically distributed, and box-plots were generated. Low sample sizes (in 2011–2013), inconsistent records, and different approaches (individual vs. cumulative records) limited the extent to which we could conduct statistical analyses of CPUE among years and between sampling periods. Also, the low sample sizes in 2011 (n = 22), 2012 (n = 13), and 2013 (n = 22) are not considered representative of the summer coastal fishery and this limits our ability to draw conclusions.

Length, weight, age, and condition factor were summarized (mean ± SD, length and age frequency distributions, and box plots) separately for females and males and the pooled samples, by year. Fulton's condition factor (K) was calculated:

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

where W = weight in g and L= fork length in mm. Testing for differences in length, condition factor, and age between sexes within each year depended on whether the data followed a parametric (t-test) or non-parametric (Mann-Whitney or Kruskal-Wallis) distribution. Weight data were log10 transformed to linearize the relationship so that analysis of covariance (ANCOVA) could be used to test for differences, with fork length as a covariate. Because age data were non-parametric, a Kruskal-Wallis test was used to assess differences in age. A Kruskal-Wallis test was also used to test for differences in fork length and weight between the 1993–1997 and 2011–2015 sampling periods. Because different age readers and otolith preparation methods were used between the sampling periods, it was not possible to statistically compare fish age distributions between decades so we visually compared graphs.

Length-weight relationships were examined separately for females and males using scatterplots fit with a power regression. Length-at-age and weight-at-age plots were generated for the total sample and for each sex. The total sample (sexes combined) was also compared between the 1993–1997 and 2011–2015 sampling periods. Mean length at ages 8, 9, 10, 11 and 12 years were examined for each year between 1993–1997 and 2011–2015.

The ratio of males to females was tested for a significant departure from a binomial proportion of 0.5 (i.e., 1:1) (Rohlf and Sokal 1995). The frequency of male and female Arctic Char classified as ‘mature’ (i.e., current-year spawners) among age classes was tabulated for those years with adequate sample sizes (2011, 2013, and 2015) to determine age at maturity. It was not possible to calculate age-at-50%-maturity because the frequency of immature and adult resting fish in the catches was unknown.

Survival rate (S) (Robson and Chapman 1961) was calculated for each sex and the total sample:

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

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

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. Annual mortality (A, 1-S) and instantaneous mortality (Z, $-\log_e(1\text{-}A)$) were calculated. Neither survival nor mortality was estimated in 2012 due to low sample size and these statistics could not be calculated separately for males and females in 2014 due to issues with sex identification.

Commercial Fishery

Samples were collected from the fishery in 2010 and 2012 to 2015. Both 114 mm and 127 mm mesh gillnets were used in 2010, 2012, and 2013. Length frequency distributions and boxplots for length and weight data were analysed. A Kruskal-Wallis test was used to determine if length differed between mesh sizes. Length-weight relationships were examined using scatterplots fit with a power regression.

RESULTS

ULUKHAKTOK COASTAL HARVEST MONITORING PROGRAM

Fishery timing and gear types

The coastal harvest monitoring program typically started in early-July and ended in late-August (Figure 2), with a few notable exceptions: in 1993, the program began in mid-August and ended mid-September; in 1994 it ended on September 30th; 2012 had the shortest duration, from late July to early August; and in 1997, it started in late-June. Fishing and/or sampling periods appear to be more sporadic during 2011–2015 compared to 1993–1997. Although no CPUE records were kept in 2015, biological samples were collected from July 15 to August 8.

The predominant mesh size in the fishery was 114 mm (95.2% of all samples collected; 79.4% of all CPUE records) (Tables 1 and 2). Other mesh sizes reported were 89 mm, 102 mm, 127 mm, and 139 mm mesh gillnets. Six fish caught using a fishing rod were sampled in 2013.

Catch-per-unit-effort

Set duration ranged from 0.25 h to 600 h, with values > 48.5 h assumed to be cumulative net sets. Excluding the years with low sample sizes (n < 20 in 2012 and 2013), the median CPUE for 114 mm mesh gillnets ranged from 19.2–32.8 Arctic Char/100 m net/24 h (Table 1). CPUE varied without obvious trends within or between sampling periods (Figure 3).

Biological characteristics

Length

Arctic Char fork length ranged from 240 mm to 940 mm with most distributed between 550 and 850 mm (Table 3; Figures 4, 5). Mean length was significantly smaller for samples harvested in 1993–1997 (most between 500 and 650 mm) compared to 2011–2015 (most between 550 and 800 mm) (Kruskal Wallis, U = 114707, p < 0.001) (Table 3; Figure 5). Additionally, there was a higher proportion of larger fish (≥ 700 mm) in the later sampling period, averaging 43% (range= 34–54%) of samples from 2011–2015, compared to an average of 6.0% (range = 1.5–15.1%) from 1993–1997.

Female and male fork lengths were normally distributed for some years but not others (Figure 6). Males were significantly larger than females in five of ten years (1997, 2011, 2013, 2014, and 2015) (Appendix Table A1).

Weight and Condition

Arctic Char weight ranged from 150 g to 9,100 g with most distributed between 1,500 g and 3,000 g during 1993 to 1997, and between 2,500 g and 5,000 g during 2011 to 2015 (Table 3; Figure 7). Weight was significantly smaller for Arctic Char harvested in 1993–1997 compared to 2011–2015 (Kruskal Wallis, U = 124155, p < 0.001). There was a significant increase in mean weight, variation, and proportion of heavier fish (> 3,000 g) in the later sampling period (Figure 7). Weight was highly correlated with length (r^2 = 0.79–0.91, Figure 8). Males were significantly different from females at a given length in three of ten sampling years (2011, 2013, 2014) (Table 3; Figure 9; Appendix Table A1).

Mean condition factor ranged between 1.2 and 1.3 with no significant difference between males and females (Table 3; Figure 10; Appendix Table A1).

Age

Arctic Char ages ranged between 4 and 24 years, with a majority of the distribution between 8 and 13 (Table 3; Figures 11, 12). The 2011–2015 samples showed a wider range of ages and higher maximum and mean ages relative to 1993–1997 (Table 3; Figures 11, 12). Median age was also relatively stable at approximately 11 years between 2011 and 2015 (Figure 12). No significant differences were detected in age between females and males, with the exception of 2014 (F > M) (Table 3; Figures 12, 13; Appendix Table A1).

Growth

Males grew faster than females starting at approximately age 10 for both methods/time periods (Figures 14, 15). Growth rate (length-at-age) was higher for the 2011–2015 samples compared to 1993–1997, particularly for ages 6 to 13 (Figures 16, 17), although this should be interpreted cautiously for ages > 11 years given differences observed between age estimation methods that were used in each time period (Gallagher et al. 2021b). Mean length at ages 8 to 12 increased during 1993–1997 while remaining relatively stable from 2011–2015 (Figure 17).

Males were heavier than females at a given age during 2011–2015 (Figure 18). Mean weight for ages 8 to 12 years had a pattern similar to length, with higher values for the 2011–2015 sampling period relative to 1993–1997 (Figure 19). Mean weight also increased during 1993–1997 for all ages, while it was relatively stable for ages 8–10 and increasing for ages 11 and 12 during 2011–2015 (Figure 19).

Mortality

Annual mortality values for 2011–2015 (range = 0.17–0.3) were considerably lower than for 1993–1997 (range = 0.3–0.69) (Table 4, Figure 20). Mortality estimates for females and males were similar for all years during 2011 and 2015 (where sample sizes allowed for calculation) (Table 4).

Sex ratio and maturity

Females and males were found to be in equal proportion for all nine years except for 1996 and 2014 (females < males) and 2015 (females > males) (Table 3, Figure 21). The majority of Arctic Char captured in 2011–2015 classified as 'mature' (i.e., current-year spawner) were between 8 and 13 years (Figure 22).

COMMERCIAL FISHERY

Sample size, fork length (mm), and round weight (g) are summarized in Table 5. There were significant differences in mean fork length between mesh sizes ($p < 0.001$) in each year, although not in a consistent pattern (2010: 114 < 127 mm, U =10067; 2012: 114 > 127 mm, U = 5532; and 2013: 114 > 127 mm, U = 5405).

Mean fork length ranged between 629 mm and 740 mm, with a majority of the individuals between 600 mm and 800 mm (Table 5, Figures 23, 24). Mean weight ranged between 4,036 g and 5,003 g, with a majority between 3,000 g and 5,500 g (Table 5, Figure 25). Correlation in the length-weight relationship was variable among years (r^2 0.41 to 0.62) (Figure 26).

DISCUSSION

The collection of biological and catch data from Ulukhaktok's coastal subsistence fishery continues to be essential for monitoring trends and assessment of Arctic Char caught in the summer mixed-stock fishery. Both the subsistence and commercial fisheries consistently harvested large, relatively old Arctic Char in recent years. While there were significant differences in the demographics of females and males in some years, there were no observed trends among the years sampled. The majority of Arctic Char classified as current-year spawners were 8 to 13 years old, however, further research is required to assess age-at-maturity and spawning frequency. Given variation in some of the approaches used to compile CPUE records, our ability to make firm conclusions relating to temporal shifts in these data remain limited. The monitoring program depends on the community's summer harvest; as such, timing and effort of catch-effort records and biological samples were variable based on ice conditions, the timing of char runs, coastal weather, or other factors.

With an abundance of Arctic Char available in proximity to the community during summer, the commercial fishery has provided local economic opportunities for several years (Lea et al. 2023). The fishery has implemented logbooks for the collection of biological and catch data, as recommended for new emerging Arctic Char fisheries (VanGerwen-Toyne and Tallman 2011). The coastal commercial and subsistence harvests of Arctic Char take place concurrently, with direct spatial and temporal overlap, thereby effectively sampling the same mixed populations of fish along the coast. Not surprisingly, given this overlap, Arctic Char caught in these fisheries had similar characteristics (e.g., length and weight distributions), although the commercial fishery had a slightly higher proportion of larger fish (≥ 700 mm) which is expected given that they were using 114 mm and 140 mm mesh nets in some years. Data collected from the subsistence harvest monitoring program were more comprehensive, and also better standardized in terms of equipment used and training provided. While the collection of biological data (e.g., length, weight) from the commercial fishery may not be essential (i.e., the harvest monitoring program can provide sufficient samples from the concurrent subsistence fishery), it would be useful to maintain the collection of CPUE records in order to bolster available data for assessment purposes.

Interpretation of data collected from these coastal fisheries are not directly relevant to the assessment of Kuujjua River char because these are likely mixed-stock fisheries. However, past tagging studies suggest a relatively high contribution of Kuujjua River Arctic Char to the coastal subsistence harvest (Paylor 1998, L. Harwood, DFO, unpublished data) with the Kuuk and Kagloryuak Rivers likely also contributing to some degree (L. Harwood, DFO, pers. comm.). Arctic Char caught in the coastal fisheries also tend to have a high proportion of larger (Figure 27) and older (Figure 28) fish compared to the Tatik Lake (Kuujjua River) fishery (Gallagher et al. 2021a), suggesting contributions from other stocks. Indigenous Knowledge from the community indicates that some of the fish caught in the coastal fishery are from the Kuuk River, given their larger size, different colouration, and direction caught in the net (Joshua Oliktoak, Community of Ulukhaktok, pers. comm). Further research, drawing on both Indigenous Knowledge and scientific methods, is required to better understand stock contributions to the coastal fisheries and the characteristics of Arctic Char populations in the area (population size, temporal and spatial extent of migrations, demographics, genetics, life history, etc.).

The collection of biological data during two time periods separated by more than a decade (1993–1997 and 2011–2015) provides an opportunity to determine if there have been changes over time. While Arctic Char sampled during 2011–2015 attained older ages, we cannot be certain if the higher frequency of older age classes was the result of different age estimation methods, an increase in longevity, or a combination of both. Given that Gallagher et al. (2021b) report differences in age reading methods between the two sampling periods for fish > 11 years of age, we are unable to compare age-related metrics (e.g., mortality) between time periods. Nevertheless, there was evidence of improved growth rates in fish ≤11 years between 1993–1997 and 2011–2015 and there was a higher proportion of larger (length and weight) fish in the coastal harvest observed during 2011–2015. Local observations from Inuvialuit harvesters are consistent with these results, with fishers reporting a higher proportion of large fish in Ulukhaktok coastal waters during 2011–2015 (John Alikamik, Community of Ulukhaktok, pers. comm.). Data collected through community interviews suggests that the coastal subsistence fishery harvested fewer Arctic Char during 2011–2015 compared to the 1990s (Lea et al. 2023). Although the sampling takes place in different seasons, the length patterns observed during coastal monitoring aligned with those observed for char sampled from Tatik Lake during early winter, which demonstrate a ‘sinusoidal’ pattern (peak followed by a trough) over the time series (Gallagher et al. 2021a), with average length and weight values in the 1990s lower than in the 2010s. This pattern could potentially be linked to directional changes caused by climate change, and/or by natural fluctuations in ecosystem productivity, which have been reported for other Arctic Char and marine mammal populations in the Western Arctic (see Harwood et al. 2015, Gallagher et al. 2017, Nguyen et al. 2017, Harwood et al. 2020).

There have been a multitude of indisputable ecosystem changes in the Ulukhaktok coastal area linked to climate change and observed through both Indigenous Knowledge and scientific research. For habitats used by anadromous Arctic Char in the Ulukhaktok area, these have included changes in the timing and duration of seasonal ice cover, weather and water conditions in both freshwater and coastal environments, quantity, quality and distribution of available prey, among others, all with potential influence on Arctic Char growth, ecology and life history.

Although variable among years, the window for summer coastal feeding continues to expand over time with earlier break-up during spring, and later freeze-up in fall (Melling et al. 2005, Harwood et al. 2020). While there were no temporal trends related to body condition of Arctic Char harvested in coastal waters during summer, Harwood et al. (2013) showed a correlation between the timing of spring sea ice clearance and somatic condition of fish in fall, suggesting enhanced prey quality and/or quantity during summer coastal feeding in years with earlier break-up. The greater size-at-age in younger fish suggests that there has been an improvement in growing conditions for char, although the complexities behind the factors driving these changes, including their interactions and thresholds, are not well understood at this time. A shift in Arctic Char diet has also been observed in the Ulukhaktok coastal area, from one dominated by Arctic Cod (ice-associated) to one that includes other species such as Sandlance, Capelin and Themisto spp. (John Alikamik, Community of Ulukhaktok, pers. comm., Harwood et al. 2015, DFO unpublished data).

Changes observed in the Arctic are wide-ranging, complex, and interconnected, highlighting the importance of applying scientific and Indigenous Knowledge approaches to the continued monitoring and research of key ecosystem components such as Arctic Char (Knopp et al. 2010). As stated by Joshua Oliktoak (February 2016), a well-respected Inuvialuit harvester and knowledge holder from Ulukhaktok, the land is "*our life, our travel, our food, and to preserve it in its natural state is getting harder and harder to do… due to global warming that is changing the land and the ocean*" (DFO 2016). These observations of change over time underscore the importance of the continued collection of harvest, catch-effort, and biological data through long-term community-based monitoring programs to support local decision-making through the UCWG.

CONCLUSIONS

Biological indicators such as length, weight, and length-at-age of Arctic Char harvested in the coastal fishery, as well as a prevalence of large and older ages (> 15), suggest that the populations contributing to the coastal summer fishery are healthy. The summer subsistence and commercial (Stage 1 Exploratory) fisheries near Ulukhaktok harvested a wide range in size (mainly 550–850 mm; 1,000–6,000 g) and age (predominantly distributed between 8 and 13 years). Mean length and weight values have been stable at approximately 690 mm and 3,900 g, respectively, since 2011. Results indicate Arctic Char captured in 2011–2015 attain larger sizes and grow faster compared to the 1990s. Median age has also been relatively stable at approximately 11 years between 2011 and 2015. The ongoing collection of Indigenous Knowledge and advancement of scientific research continue to be a priority for the UCWG to support a better understanding of Arctic Char biology and life history, trends in abundance, and the factors that are driving variability in the coastal environment. Results support the continuation of the commercial fishery to provide local economic opportunities in the community, following the leadership of the UCWG and community with future fisheries management decisions.

ACKNOWLEDGEMENTS

We gratefully acknowledge community harvesters who have participated in this program, particularly the harvest monitors hired through the OHTC, including Jack Akhiatak, Peter Alikamik, Clayton Banksland, the late Brian Kudlak, Kelly Nigiyok, Larry Olifie. We also gratefully acknowledge the long-term support from the OHTC Board and staff, the UCWG, and FJMC, including Don Dowler and Michael Papst. The UCWG and OHTC verified and supported the results presented in this report. The coastal harvest monitoring program has been supported through implementation funds under the IFA and DFO Fisheries Management. We greatly appreciate Adriana Rivas Ruiz's assistance with producing a map for this report. We would like to acknowledge the DFO Arctic Aquatic Research Division Fish Age Determination Lab for providing otolith age readings over the years. We thank various DFO staff for program support, including Véronique D'Amours-Gauthier, Sarah Buckle, Amanda Joynt, and Larry Dow. Finally, we thank Margaret Treble for her helpful review of this report.

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TABLES AND FIGURES

Table 1. Median catch-per-unit effort (number of fish/ 100m net /24 hours) of Arctic Char, with the number of net sets in brackets, from the summer coastal subsistence fishery near Ulukhaktok among mesh sizes and sampling years, 1993–1997 and 2011–2015.*

Year	Mesh (mm)				Total
	102	114	127	140	
2014	-	32.8 (48)	-	-	32.8 (48)
2013	-	43.7 (13)	-	-	43.7 (13)
2012	-	7.5 (13)	-	-	7.5 (13)
2011	-	21.2 (22)	-	-	21.2 (22)
1997	22.2 (2)	22.1 (57)	17.0 (11)	-	22.0 (70)
1996	29.2 (1)	31.1 (177)	19.1 (24)	10.3 (11)	29.1 (213)
1995	-	28.3 (128)	177.1 (2)	22.5 (4)	28.3 (134)
1994	50.0 (60)	30.0 (44)	85.7 (27)	-	50.0 (131)
1993	-	19.2 (45)	-	-	19.2 (45)

*Only gill nets that soaked between 1 and 48.5 hours.

Table 2. Number of Arctic Char sampled among gill net mesh sizes and angling from the summer coastal subsistence fishery near Ulukhaktok, 1993–1997 and 2011–2015.

Year	Mesh size (mm)					Angling	Total
	89	102	114	127	139		
2015	-	-	236 (221)	-	-	-	236 (221)
2014	-	-	299 (292)	-	-	-	299 (292)
2013	-	-	194 (192)	-	-	6 (6)	200 (198)
2012	-	-	35 (33)	-	-	-	35 (33)
2011	-	-	207 (206)	-	-	-	207 (206)
1997	-	-	53 (52)		-	-	53 (52)
1996	-	-	152 (145)+	16(10)	-	-	168 (155)
1995	-	-	131 (119)	-	-	-	131 (119)
1994	20 (19)	16 (15)	191 (167)	15 (14)	7(7)	-	249 (222)
1993	-	-	104 (87)	20 (0)	-	-	104 (87)

+Mesh size not recorded for 78 samples and assumed to be from 114 mm mesh.

Table 3. Arctic Char mean length, weight, condition factor, and age (SD in brackets) for female (F), male (M), and total (sexes combined), sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015.*

Sample type	Year	Female	Male	n = (F / M)	Total	n =
Length (mm)	2015	673 (115)	713 (116)	133 / 94	686 (118)	236
	2014	678 (72)	757 (72)	150 / 33	686 (78)	299
	2013	645 (87)	680 (94)	104 / 96	661 (92)	200
	2012	686 (110)	684 (121)	16 / 19	685 (114)	35
	2011	651 (87)	690 (103)	99 / 107	672 (98)	207
	1997	575 (87)	637 (84)	21 / 32	612 (90)	53
	1996	592 (51)	603 (65)	68 / 100	598 (60)	168
	1995	553 (64)	561 (59)	58 / 67	559 (59)	131
	1994	562 (86)	551 (95)	118 / 130	564 (89)	249
	1993	506 (67)	524 (92)	52 / 49	512 (82)	103
Weight (g)	2015	4,006 (1,520)	4,708 (1,843)	132 / 93	4,253 (1,701)	234
	2014	3,695 (1,056)	5,026 (1,032)	150 / 33	3,878 (1,191)	299
	2013	3,297 (1,225)	4,019 (1,444)	104 / 95	3,640 (1,379)	199
	2012	3,934 (1,540)	4,213 (2,068)	16 / 19	4,086 (1,825)	35
	2011	3,309 (1,190)	4,111 (1,594)	99 / 107	3,749 (1,502)	207
	1997	2,493 (1,466)	3,077 (1,193)	21 / 32	2,845 (1,326)	53
	1996	2,642 (840)	2,908 (1,073)	68 / 100	2,801 (992)	168
	1995	2,126 (671)	2,254 (678)	58 / 67	2,202 (690)	131
	1994	2,427 (967)	2,390 (1,206)	118 / 130	2,489 (1,105)	249
	1993	1,813 (927)	1,997 (1,005)	52 / 50	1,878 (974)	104
Condition factor	2015	1.3 (0.3)	1.2 (1.2)	132 / 93	1.3 (0.3)	234
	2014	1.2 (0.2)	1.2 (0.4)	150 / 33	1.2 (0.2)	299
	2013	1.2 (0.2)	1.2 (0.2)	104 / 95	1.2 (0.2)	199
	2012	1.2 (0.3)	1.2 (0.2)	16 / 19	1.2 (0.2)	35
	2011	1.2 (0.3)	1.2 (0.3)	99 / 107	1.2 (0.3)	207
	1997	1.2 (0.2)	1.2 (0.2)	21 / 32	1.2 (0.2)	53
	1996	1.2 (0.2)	1.3 (0.2)	68 / 100	1.3 (0.2)	168
	1995	1.2 (0.2)	1.3 (0.2)	58 / 67	1.2 (0.2)	131
	1994	1.3 (0.3)	1.3 (0.3)	118 / 130	1.3 (0.3)	249
	1993	1.3 (0.2)	1.3 (0.2)	52 / 49	1.3 (0.2)	103
Age (y)†	2015	13.2 (4.4)	14.3 (4.9)	124 / 87	13.7 (4.6)	219
	2014	12.9 (2.4)	14.2 (3.7)	149 / 32	12.5 (3.3)	292
	2013	11.8 (3.6)	11.6 (3.2)	101 / 91	11.7 (3.4)	192
	2012	14.0 (4.3)	12.8 (3.8)	16 / 17	13.4 (4.0)	33
	2011	12.2 (3.4)	12.5 (3.7)	98 / 107	12.4 (3.5)	206
	1997	9.6 (2.1)	10.3 (2.1)	21 / 31	10.0 (2.1)	52
	1996	9.8 (1.2)	9.5 (1.6)	56 / 89	9.6 (1.5)	145
	1995	9.7 (1.4)	9.4 (1.5)	56 / 83	9.5 (1.4)	119
	1994	10.7 (2.3)	9.9 (2.4)	82 / 99	10.4 (2.3)	167
	1993	9.4 (1.4)	9.8 (1.9)	43 / 42	9.6 (1.6)	87

**Number of samples where sex was not recorded: n = 9 in 2015; n = 116 in 2014; n = 1 in 2011; n = 6 in 1995, n = 1 in 1994; n = 2 in 1993.*

†The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

Table 4. Robson-Chapman estimates of survival (S) (95% confidence intervals in brackets), annual mortality (A), and instantaneous mortality (Z) for Arctic Char females, males and total (sexes combined) from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015.

Year	Female			Male			Total		
	S	A	Z	S	A	Z	S	A	Z
2015	0.82 (0.04)	0.18	0.20	0.86 (0.04)	0.14	0.15	0.83 (0.03)	0.17	0.18
2014	0.76 (0.05)	0.24	0.22	NA	-	-	0.75 (0.04)	0.25	0.29
2013	0.77 (0.05)	0.23	0.26	0.75 (0.07)	0.25	0.29	0.70 (0.05)	0.30	0.35
2011	0.79 (0.05)	0.21	0.23	0.80 (0.04)	0.20	0.22	0.80 (0.03)	0.20	0.23
1997	0.62 (0.21)	0.38	0.48	0.61 (0.18)	0.39	0.50	0.61 (0.15)	0.39	0.49
1996	0.43 (0.14)	0.57	0.85	0.52 (0.12)	0.48	0.65	0.48 (0.09)	0.52	0.74
1995	0.33 (0.21)	0.67	1.10	0.56 (0.10)	0.44	0.59	0.34 (0.14)	0.66	1.08
1994	0.65 (0.08)	0.35	0.43	0.59 (0.11)	0.41	0.53	0.59 (0.07)	0.41	0.52
1993	0.46 (0.19)	0.54	0.77	0.53 (0.15)	0.47	0.63	0.50 (0.12)	0.50	0.69

[+]Low sample sizes in 2012 precluded analyses for all samples; low sample sizes of males in 2014 precluded analyses.

Table 5. Mean length and weight (SD in brackets), total sample size (n =), and number caught in 114 mm and 127 mm stretch mesh gillnets for Arctic Char harvested in commercial fisheries during summer near Ulukhaktok, 2010–2015.

Sample type	Year	Mean (SD)	Total n =	114 mm n =	127 mm n =
Length (mm)	2015	740 (84)	202	202	-
	2014	697 (73)	288	288	-
	2013	691 (82)	293	194	99
	2012	752 (84)	273	173	100
	2010	674 (87)	369	269	100
Weight (g)	2015	4,655 (1,112)	202	202	-
	2014	4,188 (1,148)	294	294	-
	2013	4,223 (1,560)	294	194	100
	2012	5,003 (1,394)	273	173	100
	2010	4,036 (1,449)	369	269	100

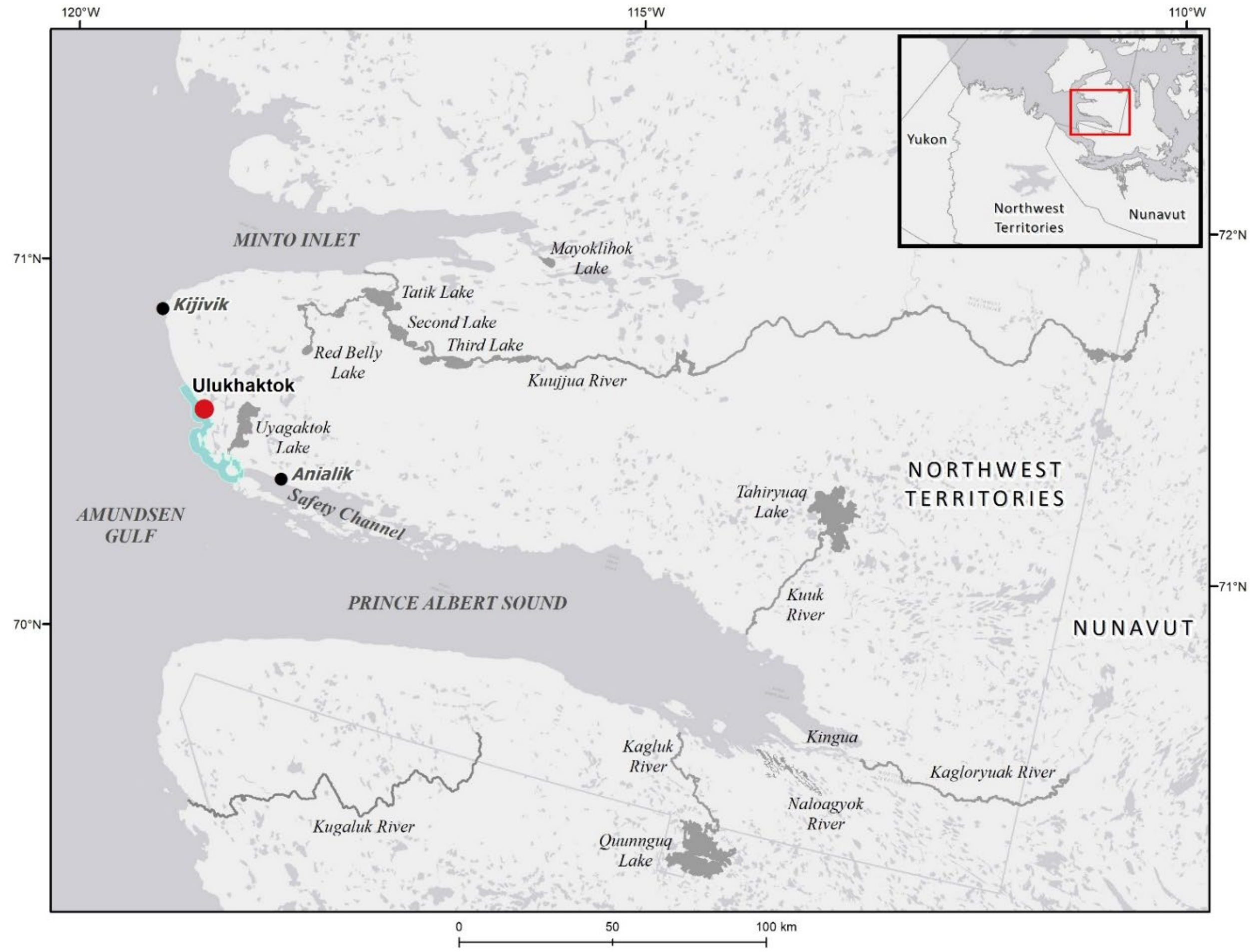

Figure 1. Coastal fishing area around Ulukhaktok, NT, highlighting the geographical extent of the coastal monitoring program extending from Kijivik to Anialik, with the majority occurring near the community (highlighted in blue). The coastal harvest is presumed to be comprised of Arctic Char from the Kuujjua River system (including Tatik Lake) with contributions from other river systems in Prince Albert Sound (e.g., Kuuk, Kagloryuak, Naloagyok, and Kagluk Rivers) and possibly others into Minto Inlet and Amundsen Gulf.

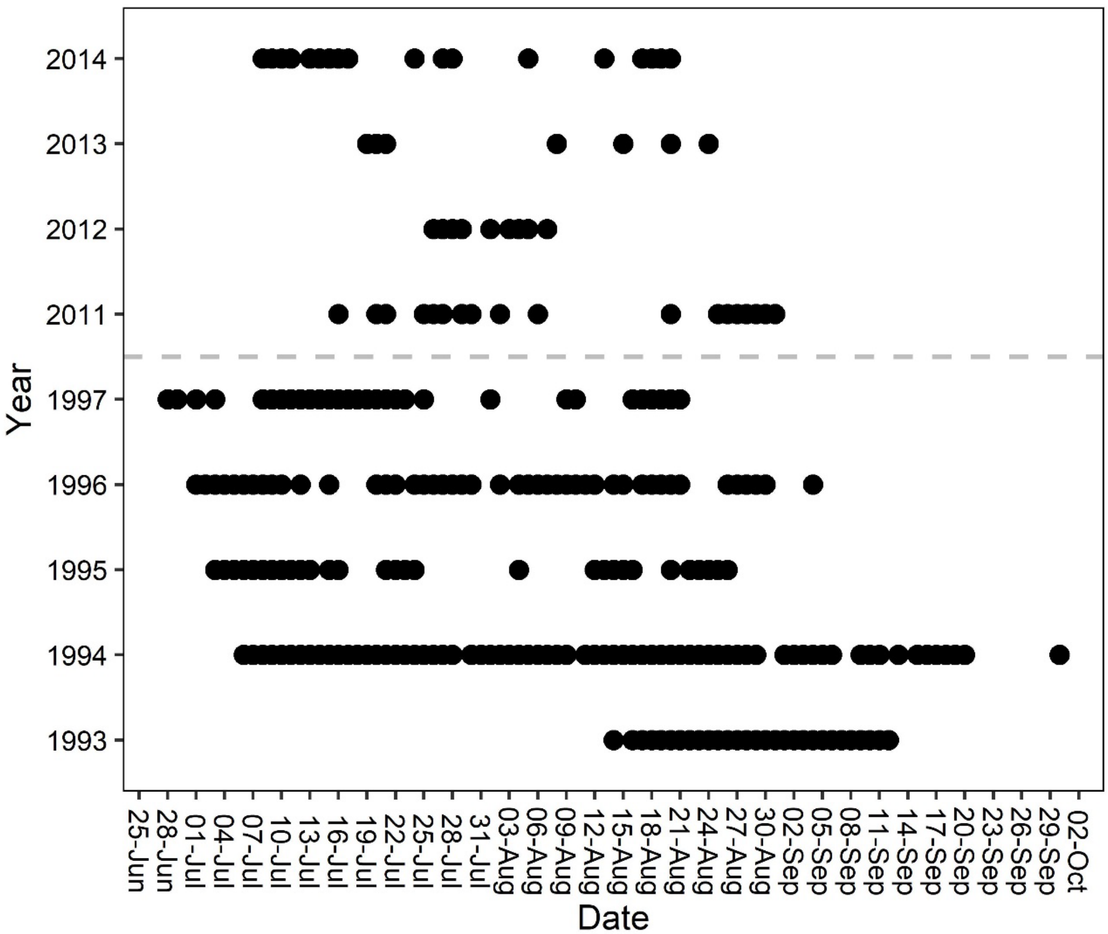

Figure 2. Chronology of the catch-effort records of Arctic Char harvested from the summer coastal subsistence fishery near Ulukhaktok 1993–1997 and 2010–2014. No Catch-Per-Unit-Effort data was collected in 2015.

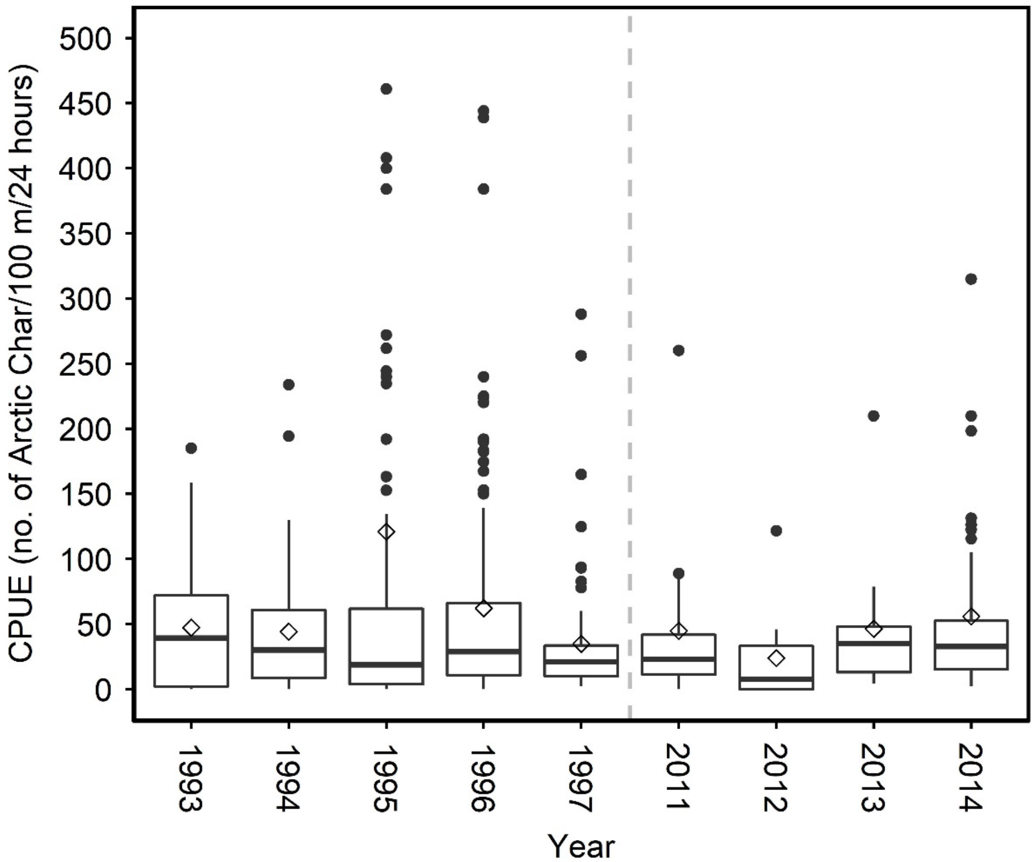

Figure 3. Catch-per-unit-effort (CPUE) box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for Arctic Char captured in 114 mm mesh from gill nets set between 1 and 48.5 hours along the coast near Ulukhaktok, 1993–1997 and 2011–2014. Note: outliers in 1995 = 1008, 1440, 2040 (x 2), 2088, and outlier in 1996 = 576. No CPUE data was collected in 2015.

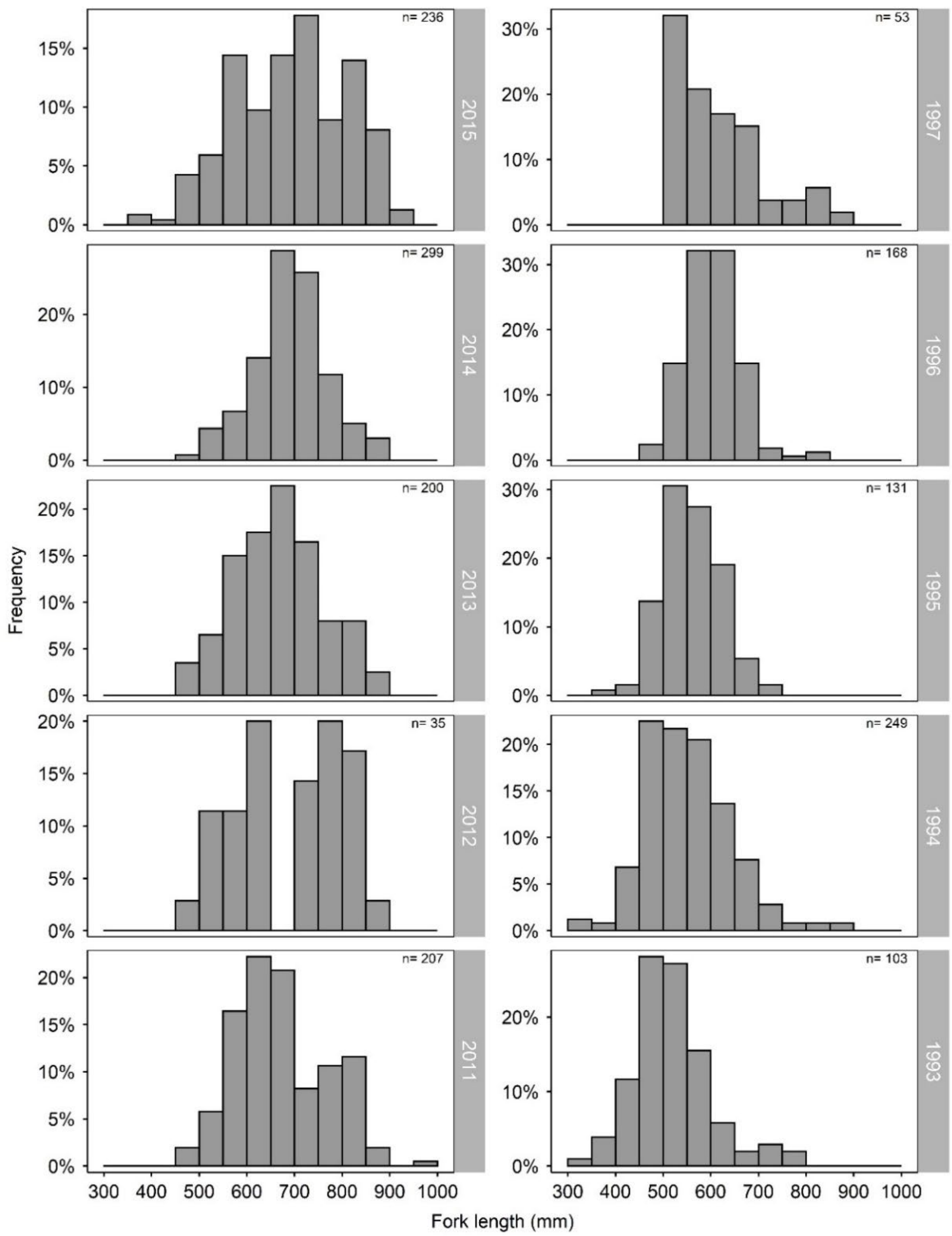

Figure 4. Arctic Char fork length frequency distribution for the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. Note: n = 1 fish < 300 mm in 1993 not included in the figure.

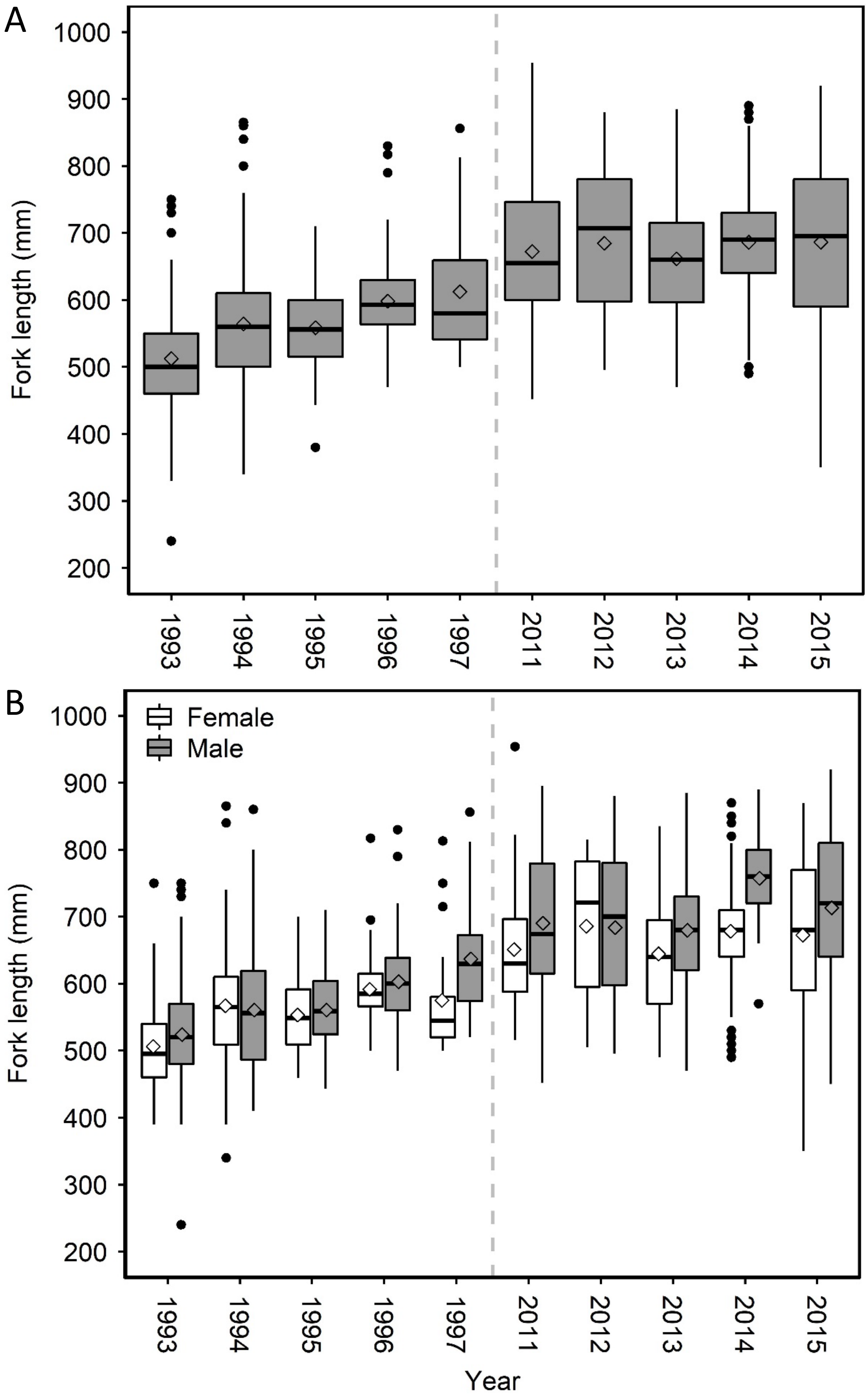

Figure 5. Fork length box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for A) total sample and B) female and male Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015.

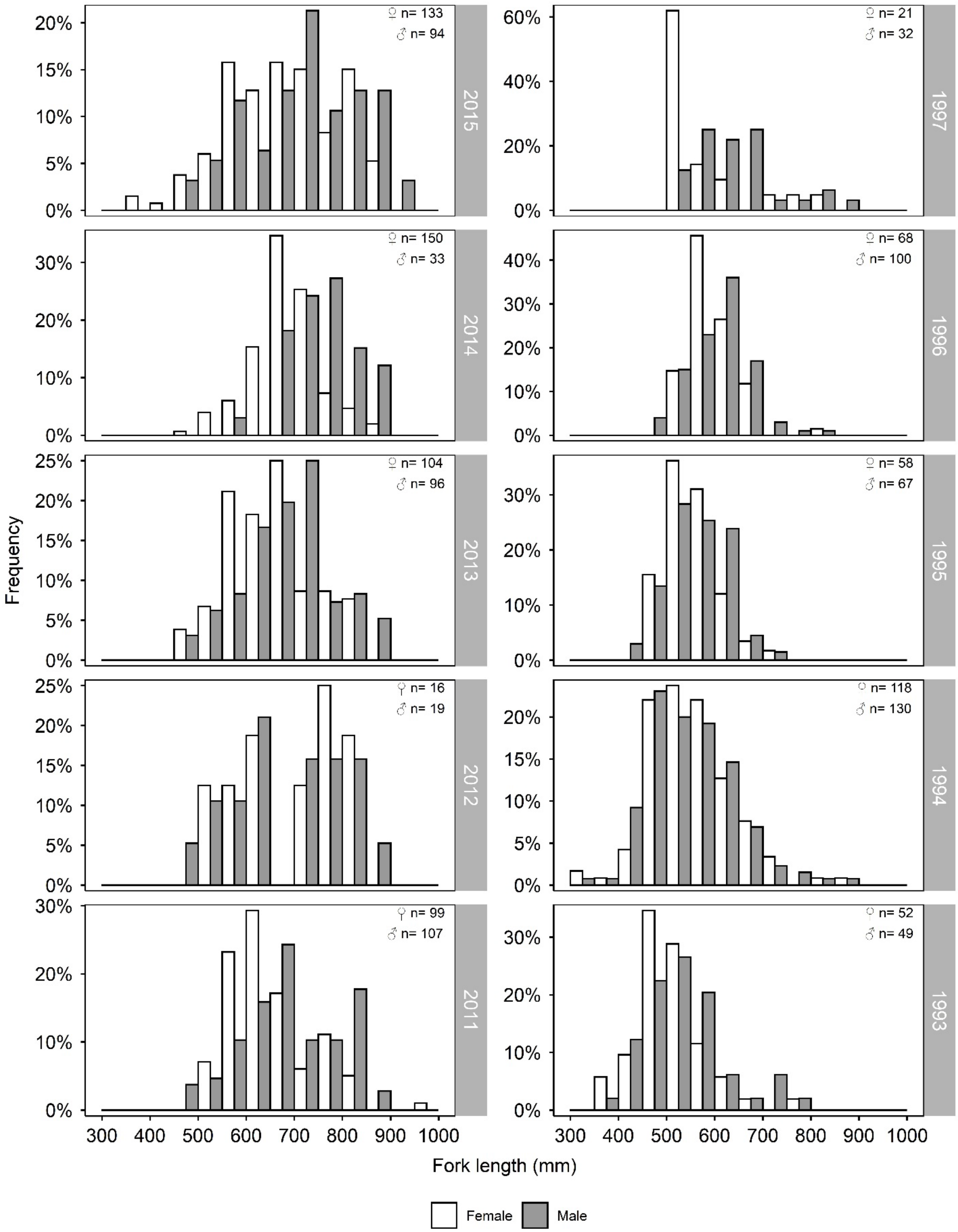

Figure 6. Fork length frequency distribution of female and male Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. Note: n = 1 male < 300 mm in 1993 was not included in the figure.

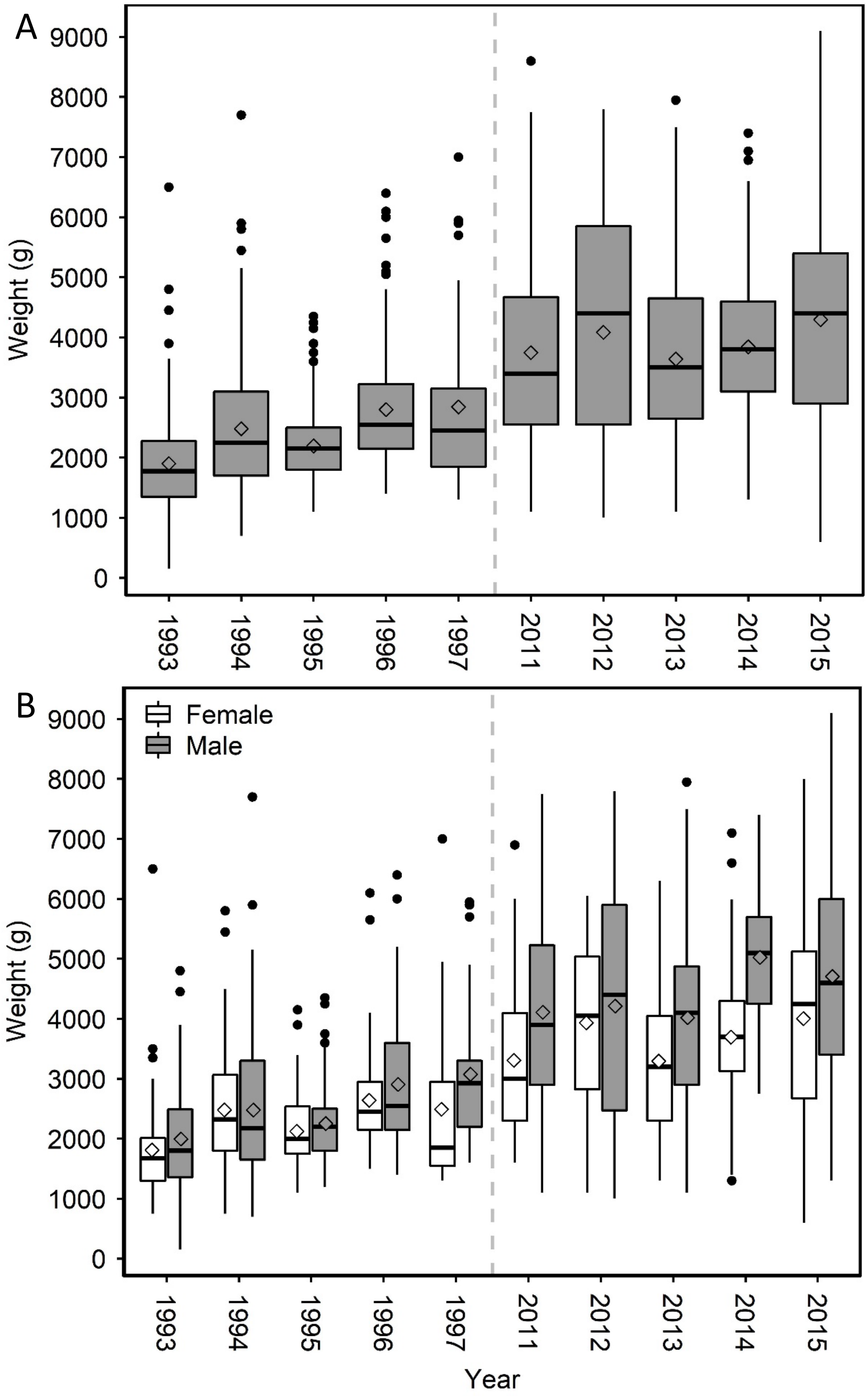

Figure 7. Weight (g) box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for A) total sample and B) female and male Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015.

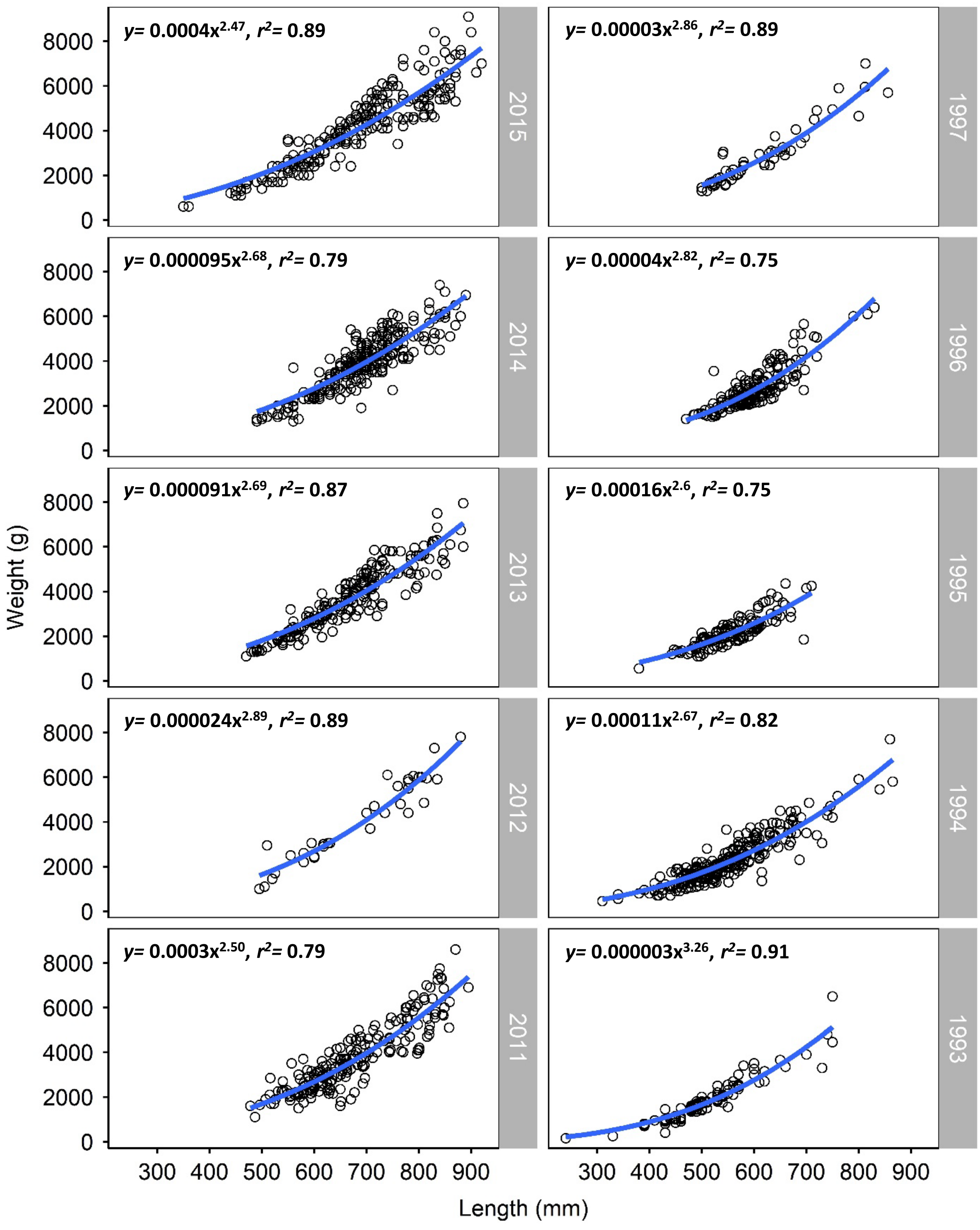

Figure 8. Length-weight relationship fit with a power regression for Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015.

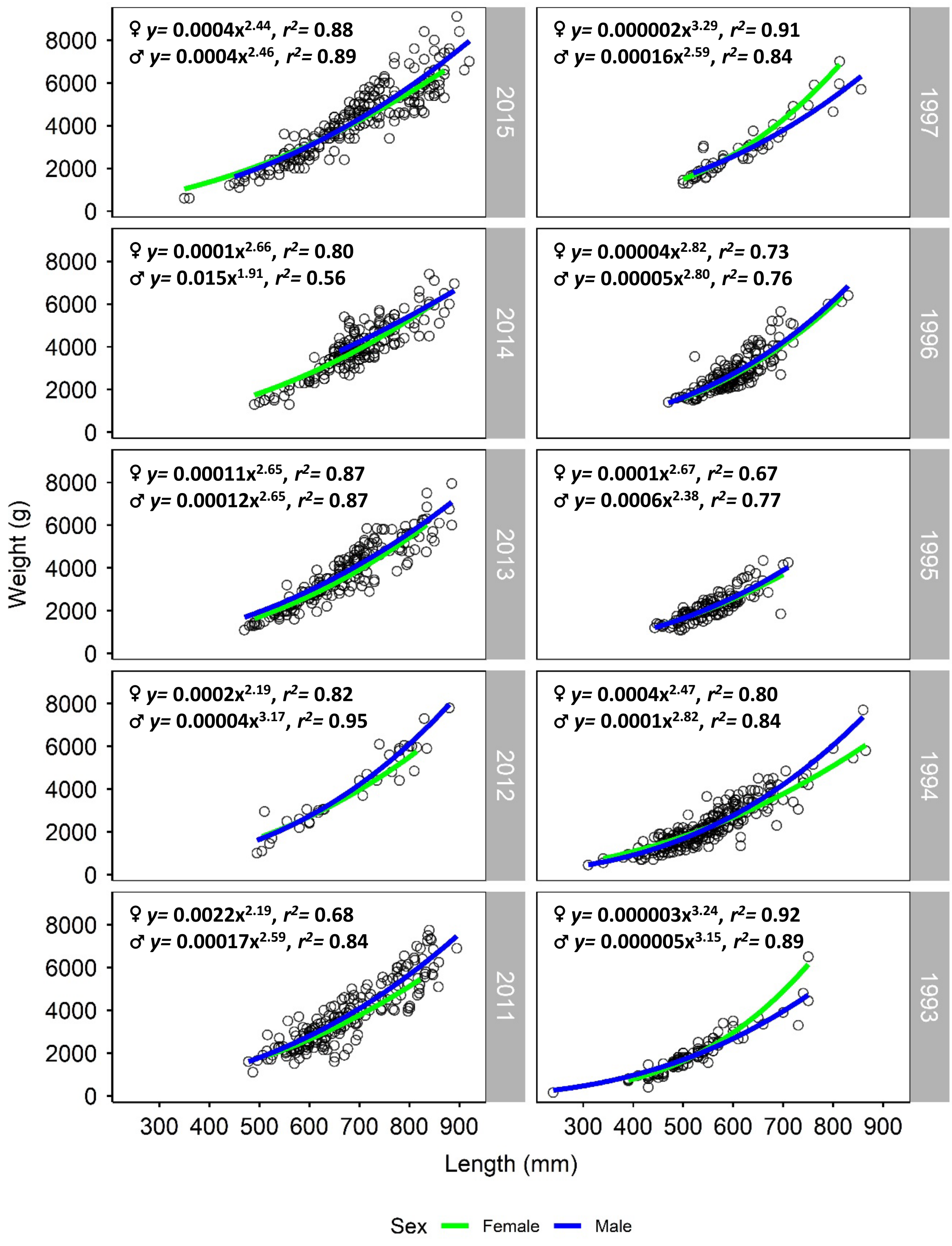

Figure 9. Length-weight relationship fit with a power regression for female and male Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015.

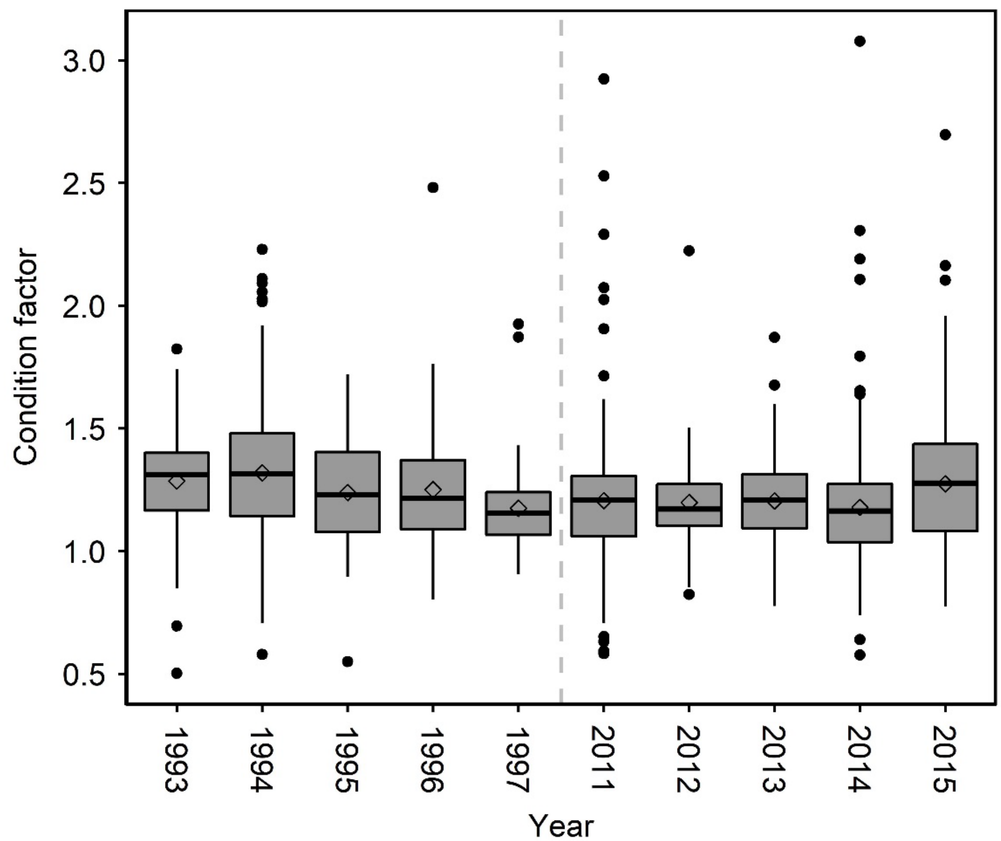

Figure 10. Condition factor box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015.

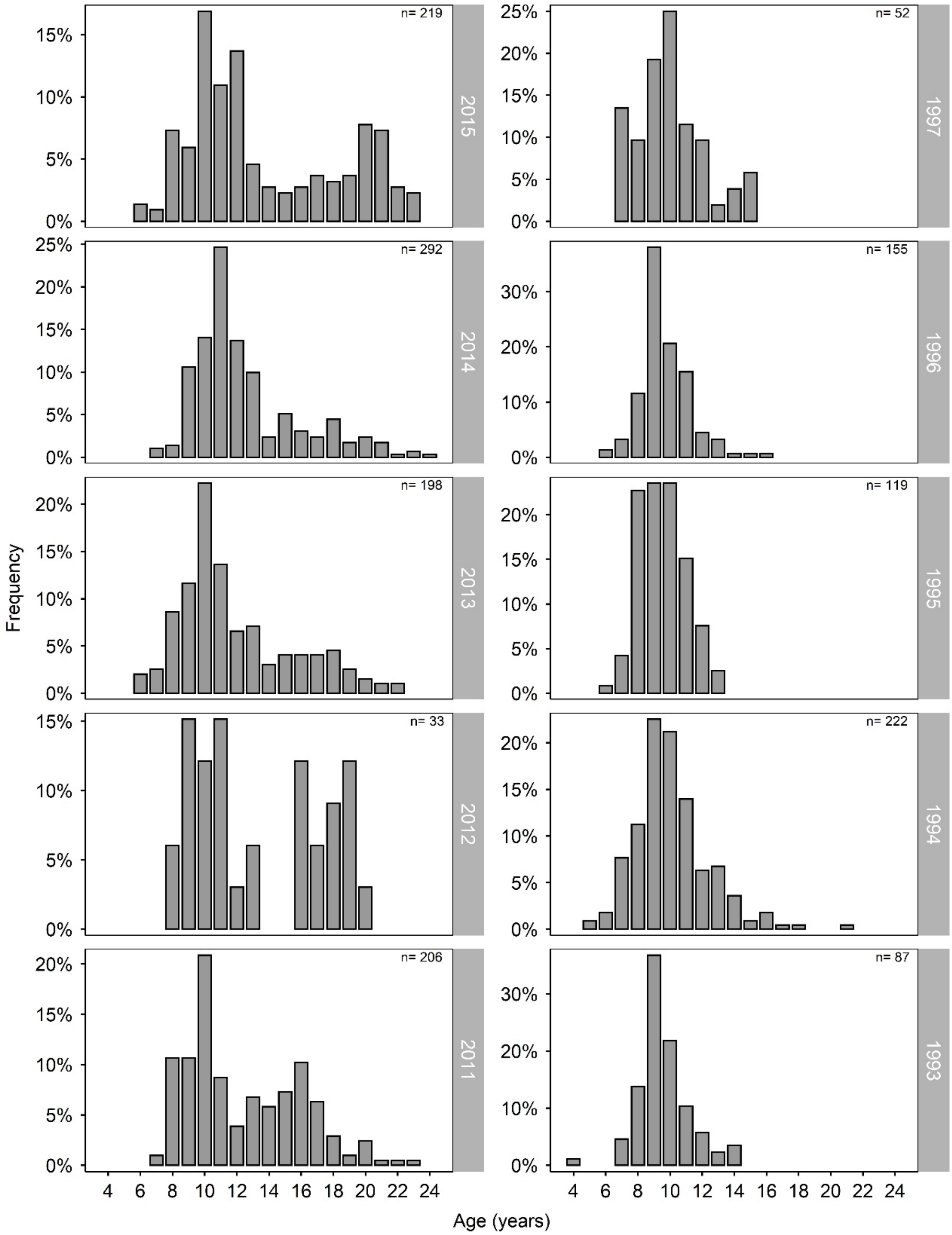

Figure 11. Age frequency distribution of Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

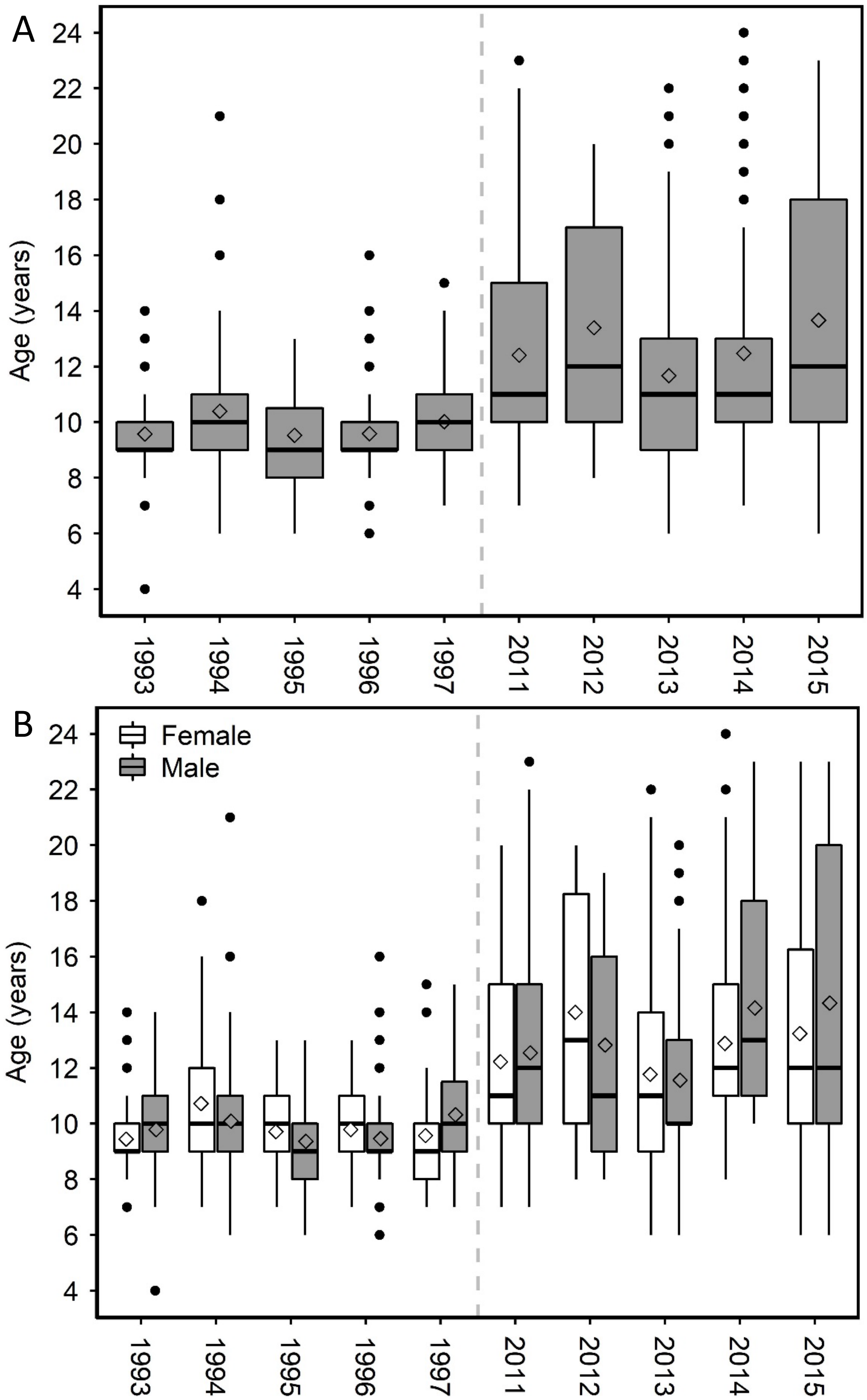

Figure 12. Age (years) box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for A) total sample and B) female and male Arctic Char from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

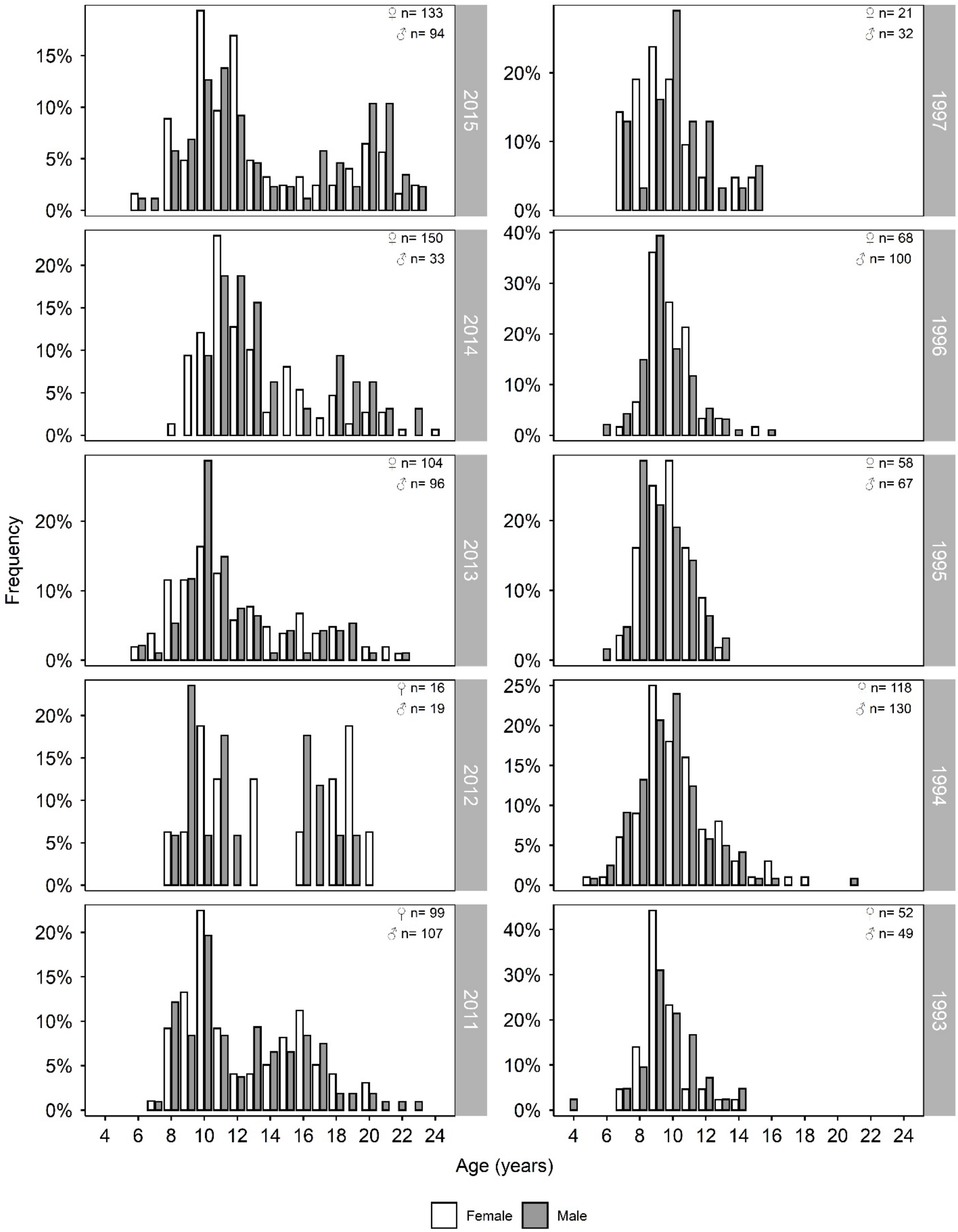

Figure 13. Age frequency distribution of female and male Arctic Char sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok 1993–1997 and 2011–2015. The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

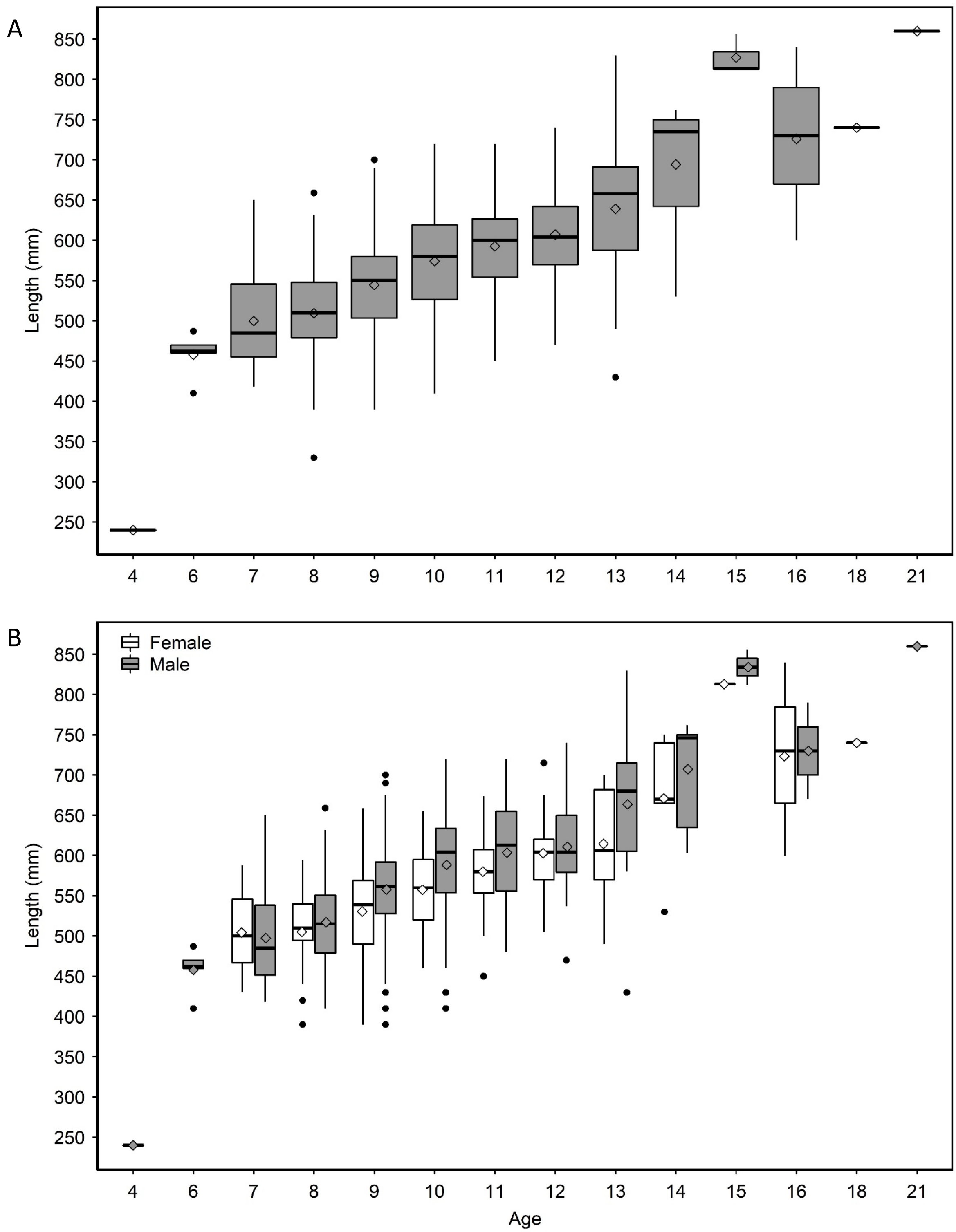

Figure 14. Length-at Age box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for A) total sample and B) female and male Arctic Char from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997.

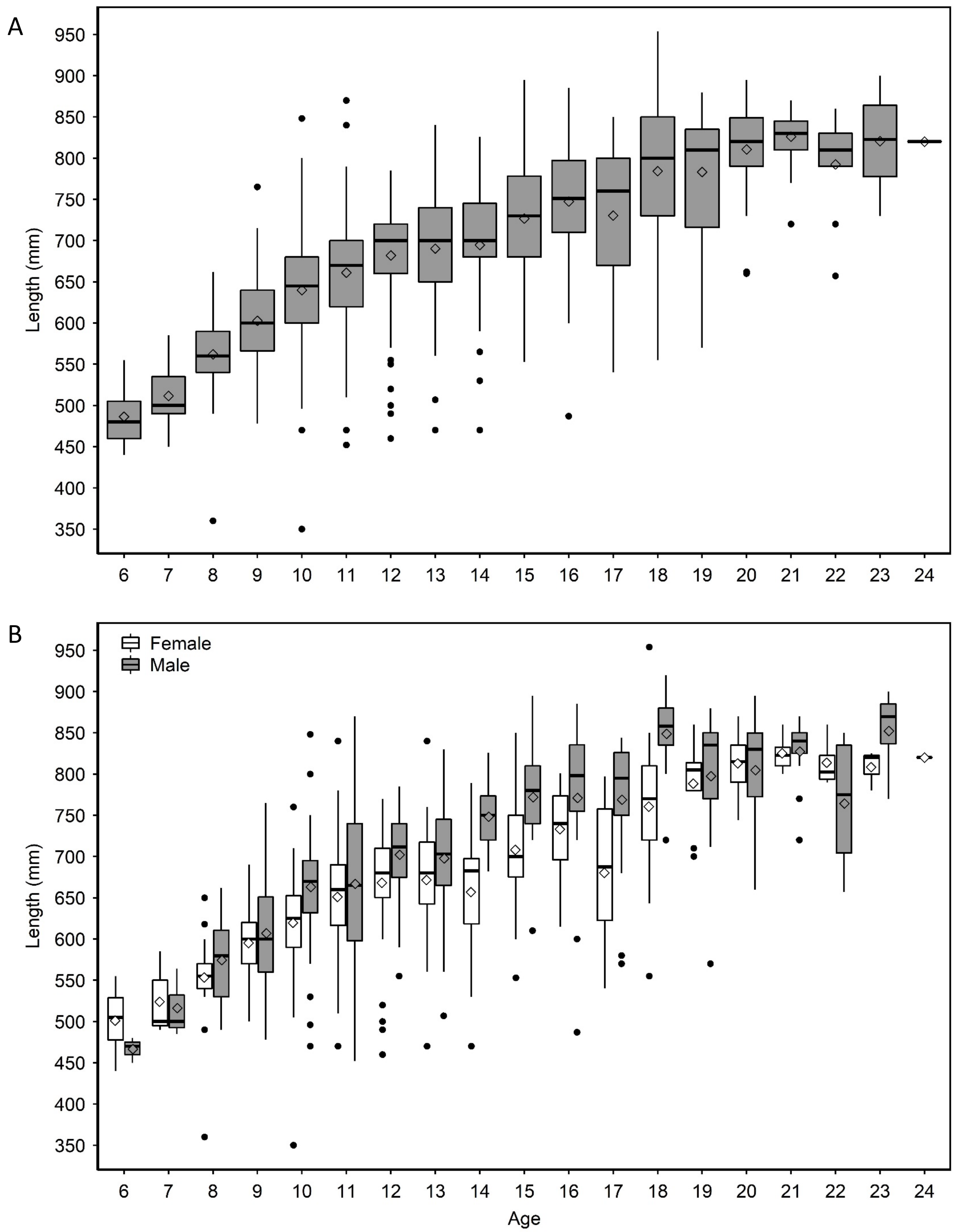

Figure 15. Length-at-age box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for A) total sample and B) female and male Arctic Char from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 2011–2015.

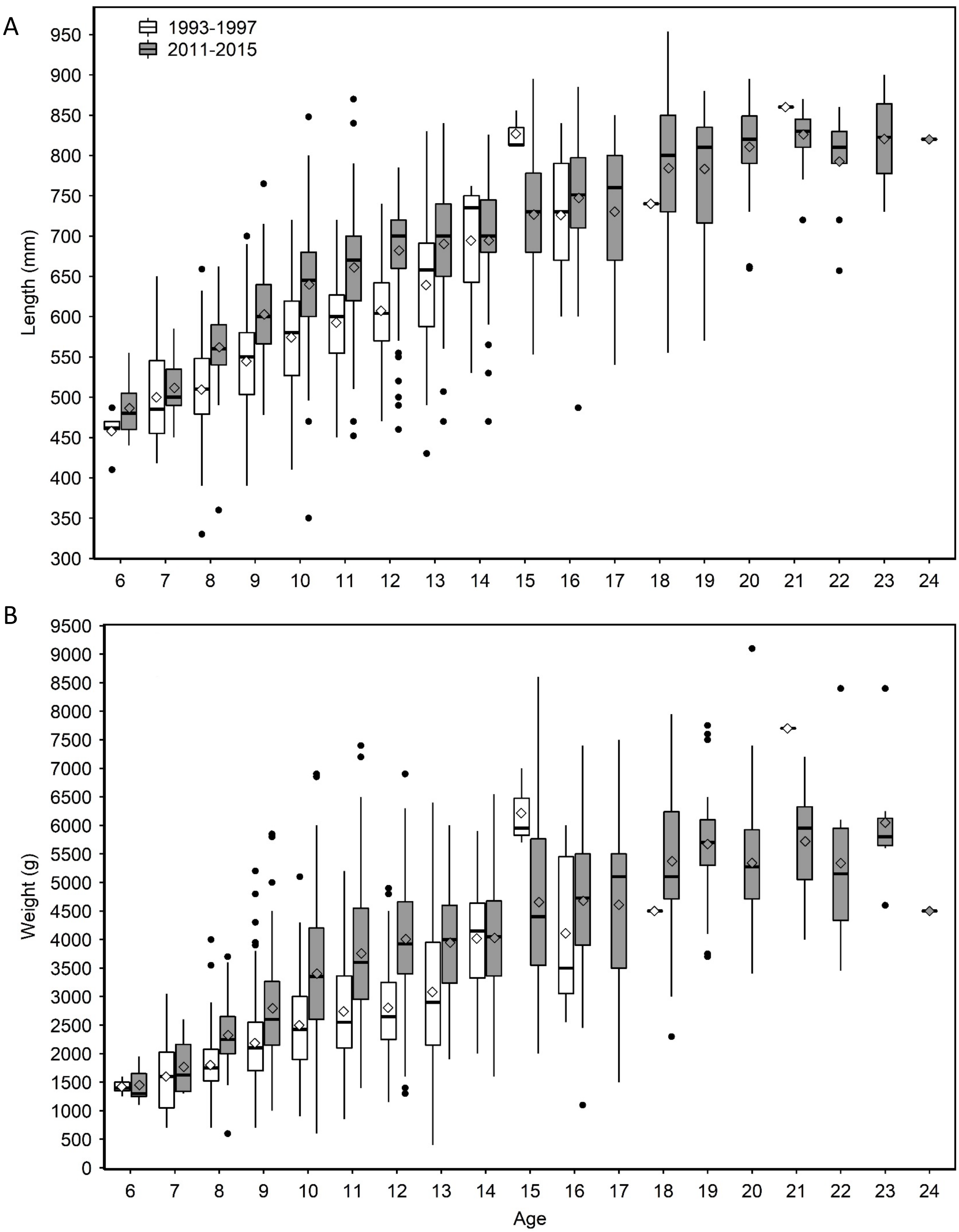

Figure 16. Box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for Arctic Char A) length- and B) weight-at-age from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

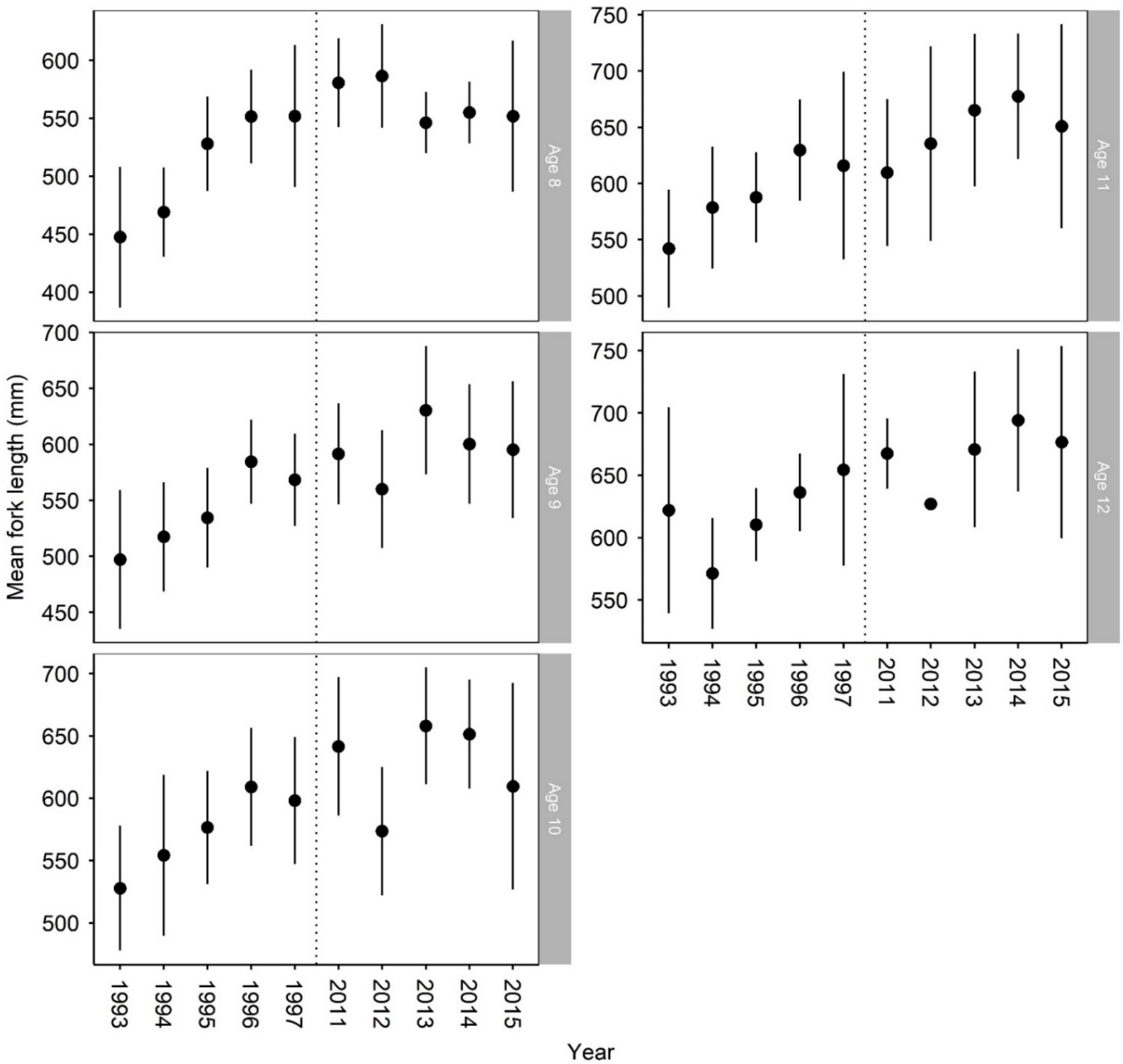

Figure 17. Mean length (± 1 standard deviation) for Arctic Char aged 8, 9, 10, 11 and 12 years from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011-2015. The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

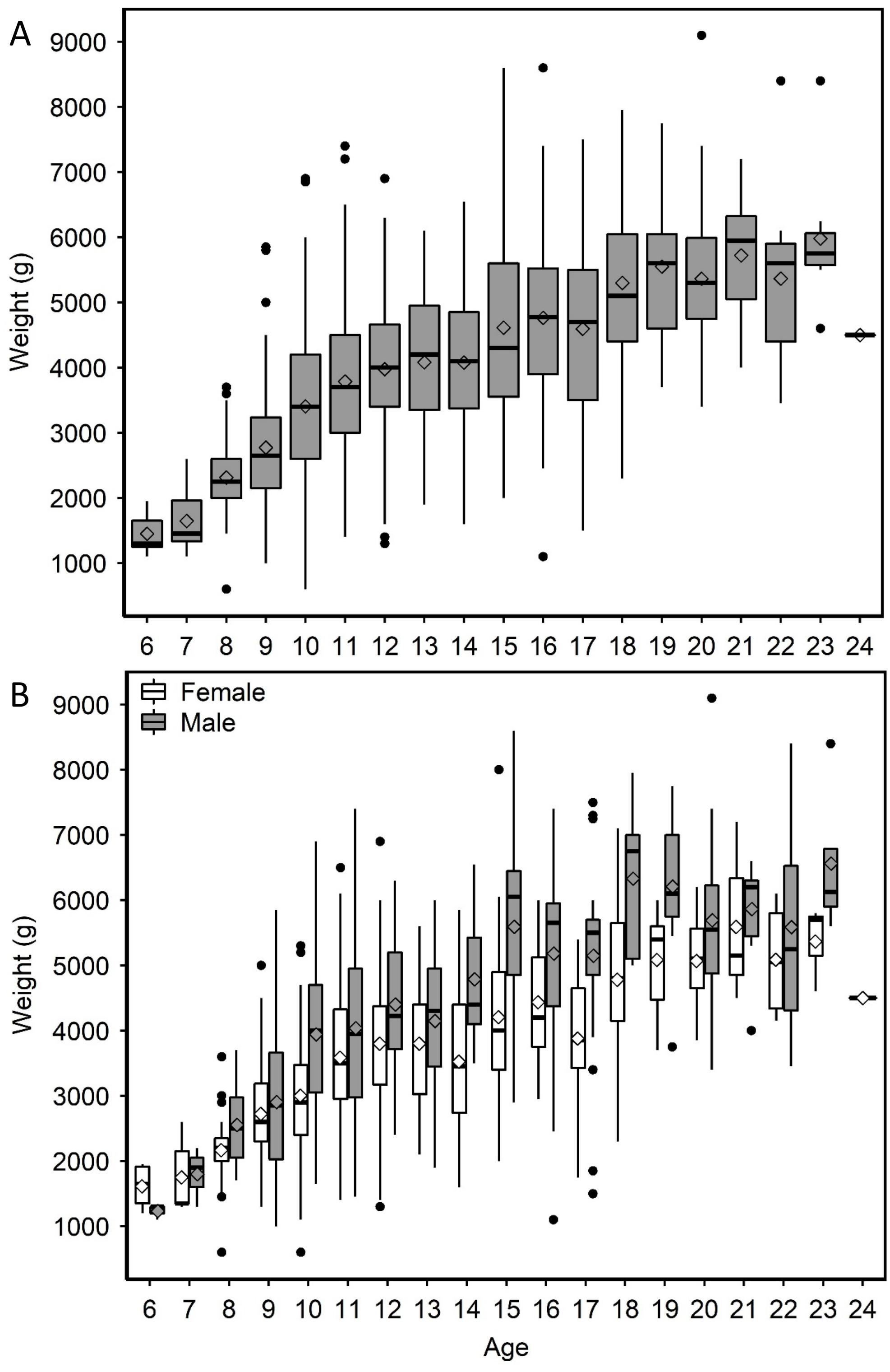

Figure 18. Weight-at-age box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for A) total sample and B) female and male Arctic Char from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 2011–2015.

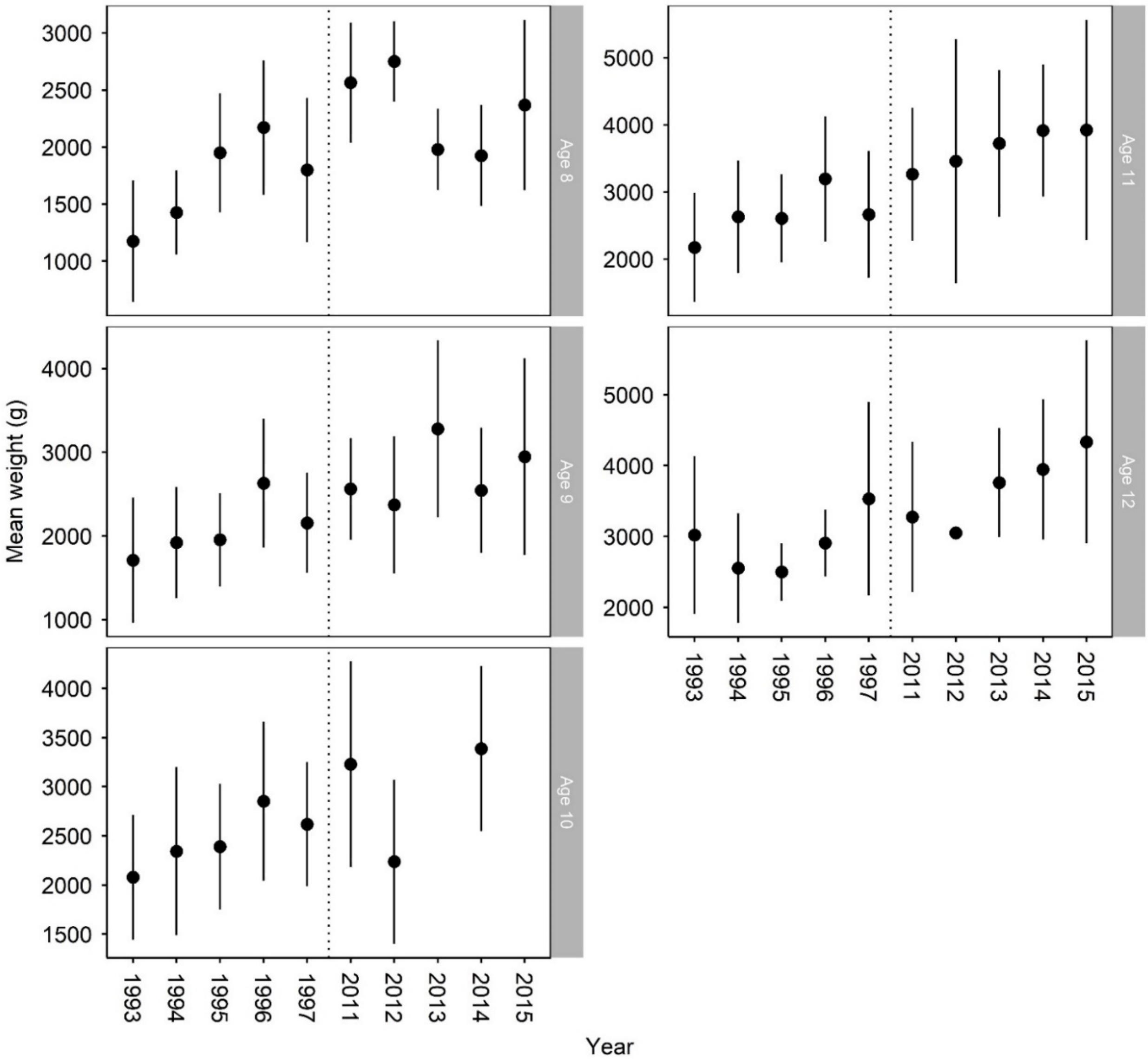

Figure 19. Mean weight (± 1 standard deviation) for Arctic Char aged 8, 9, 10, 11 and 12 years from the summer coastal subsistence fishery near Ulukhaktok, 1993–1997 and 2011- 2015. The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

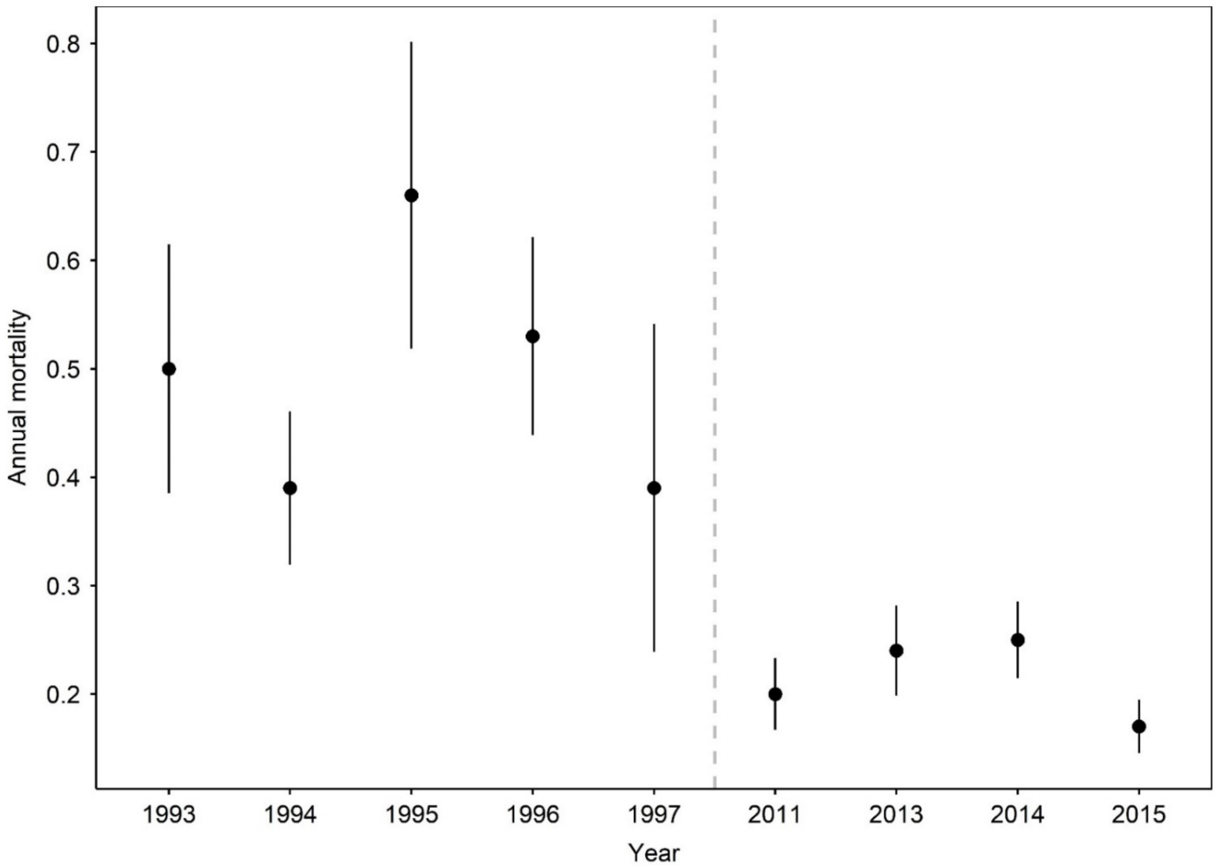

Figure 20. Annual mortality with 95% confidence intervals for Arctic Char from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.

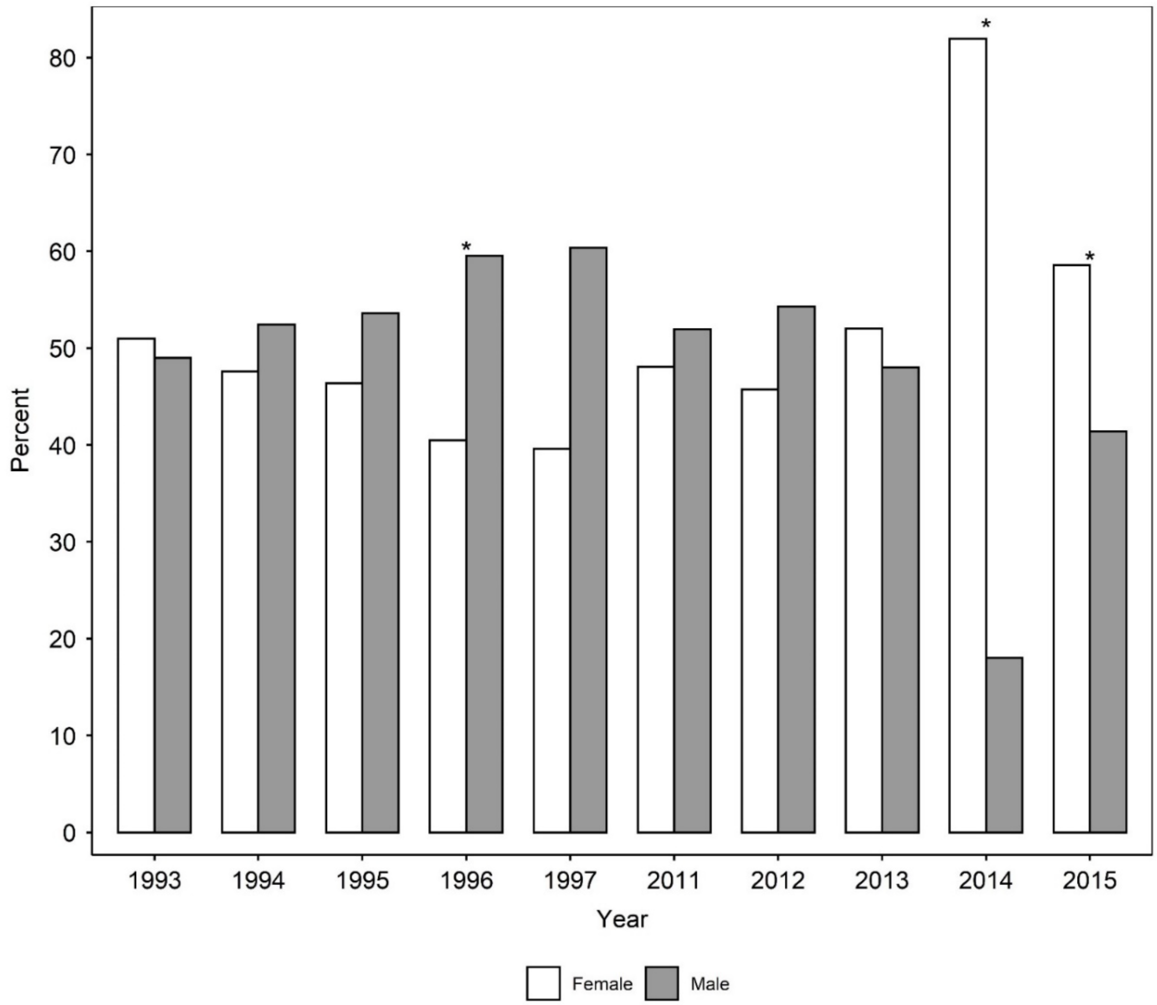

Figure 21. Percent female and male for Arctic Char from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. Asterisks indicate significant departure from a binomial proportion of 0.5.

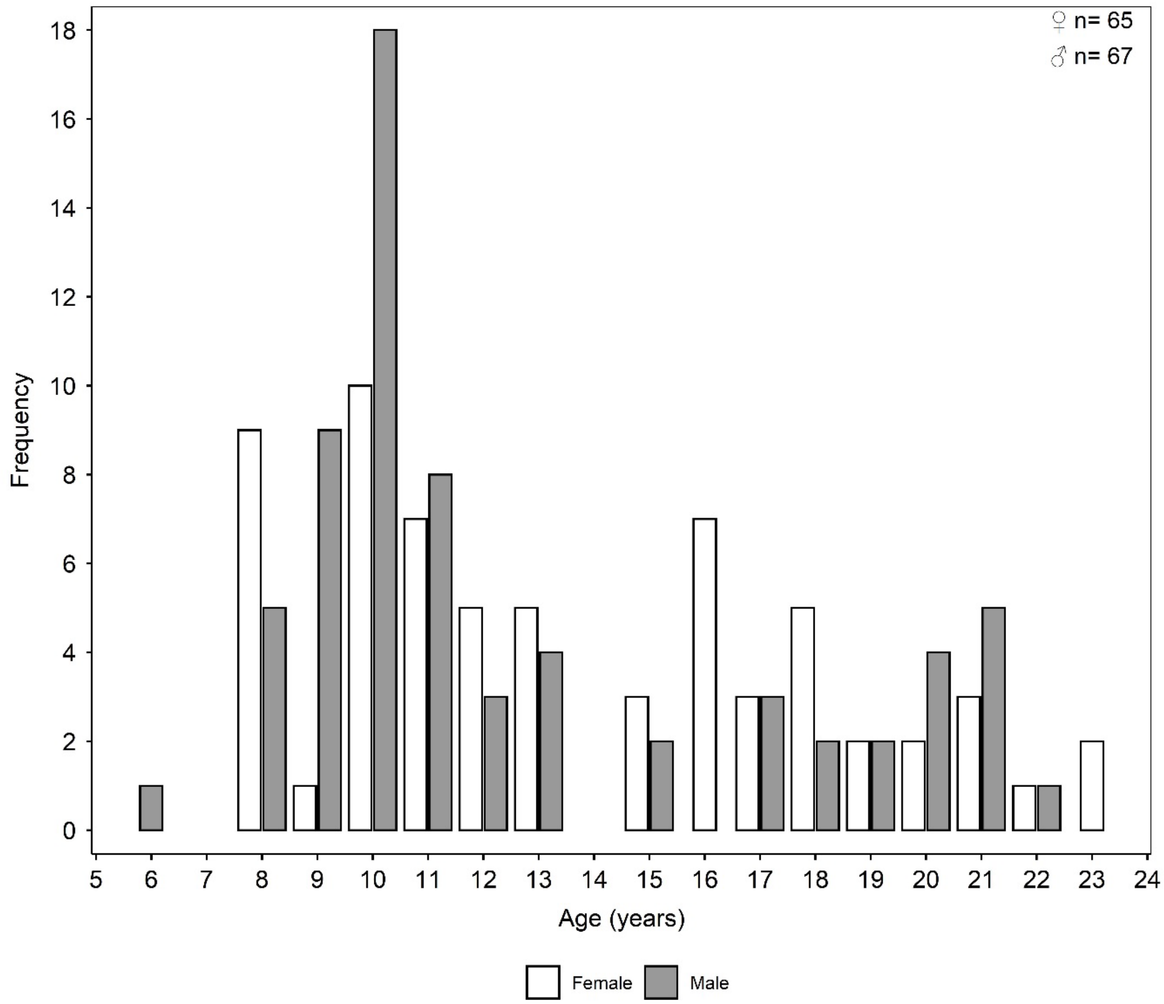

Figure 22. Frequency of 'mature' (i.e., current-year spawners) male and female Arctic Char among age classes sampled from the summer coastal subsistence fishery (114 mm mesh gillnets) near Ulukhaktok in 2011, 2013, and 2015.

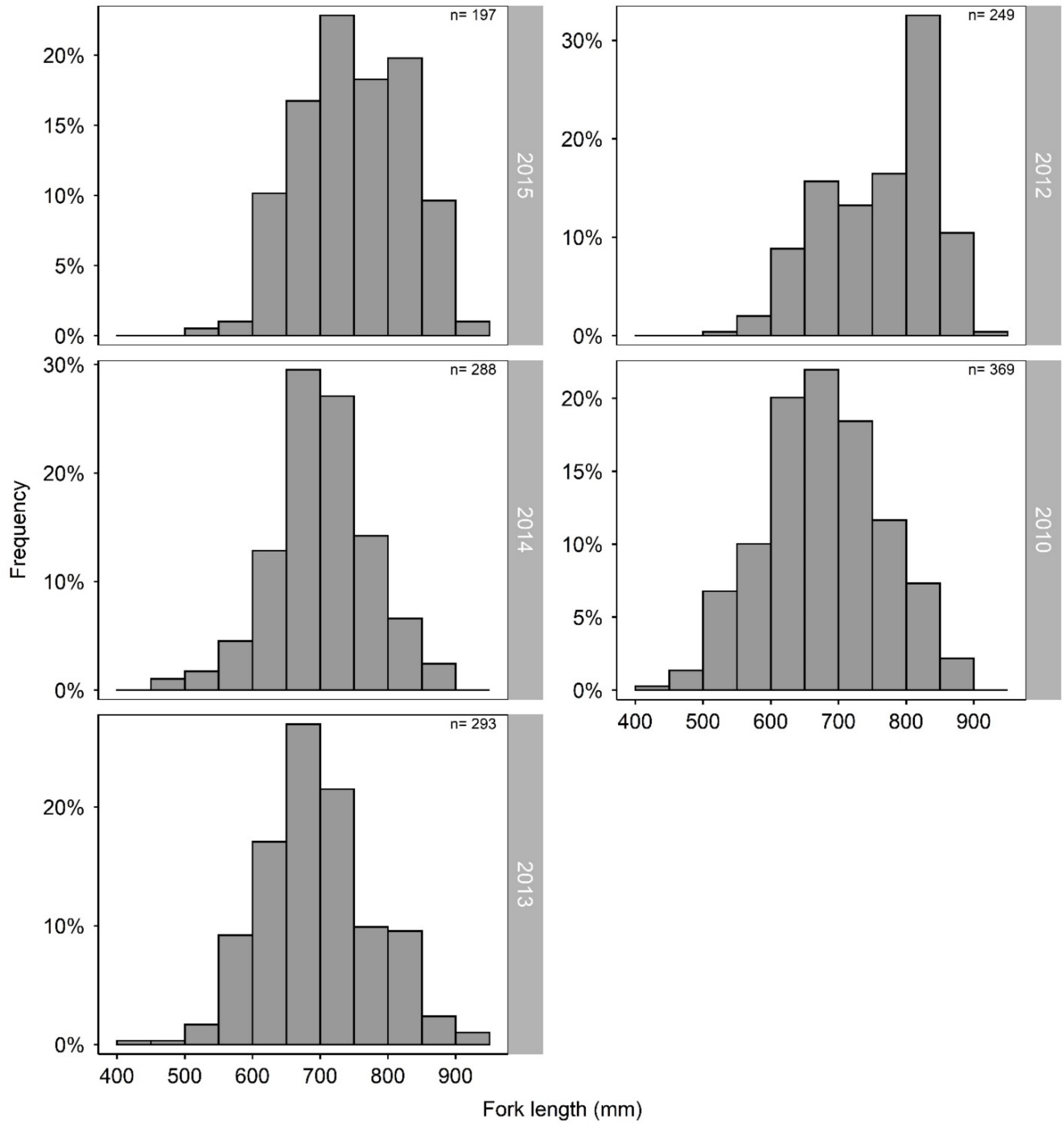

Figure 23. Fork length (mm) frequency distributions for Arctic Char harvested in the summer coastal commercial fishery near Ulukhaktok, 2010–2015.

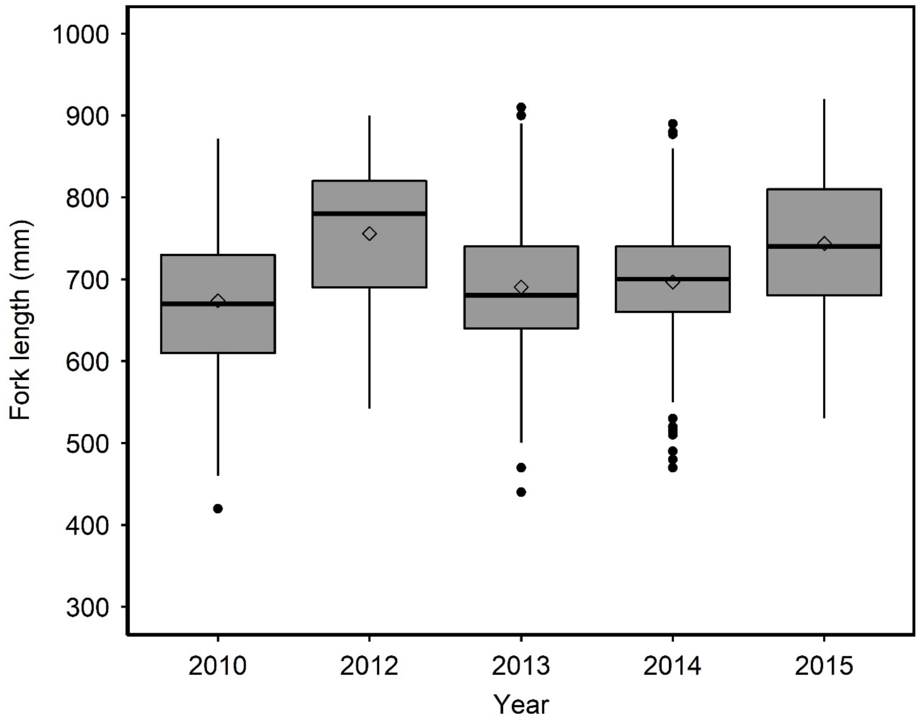

Figure 24. Fork length (mm) box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for Arctic Char harvested in the summer coastal commercial fishery near Ulukhaktok, 2010–2015.

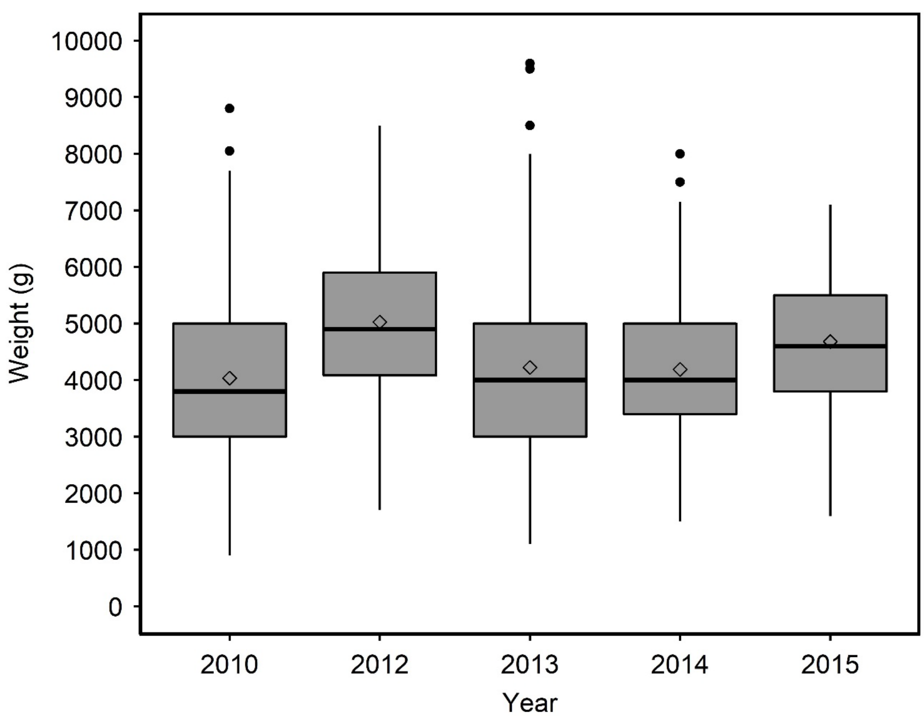

Figure 25. Weight (g) box plots (median, quartiles, outliers (● values ≥ 1.5 x IQR, and ◊ mean) for Arctic Char harvested in the summer coastal commercial fishery near Ulukhaktok, 2010–2015.

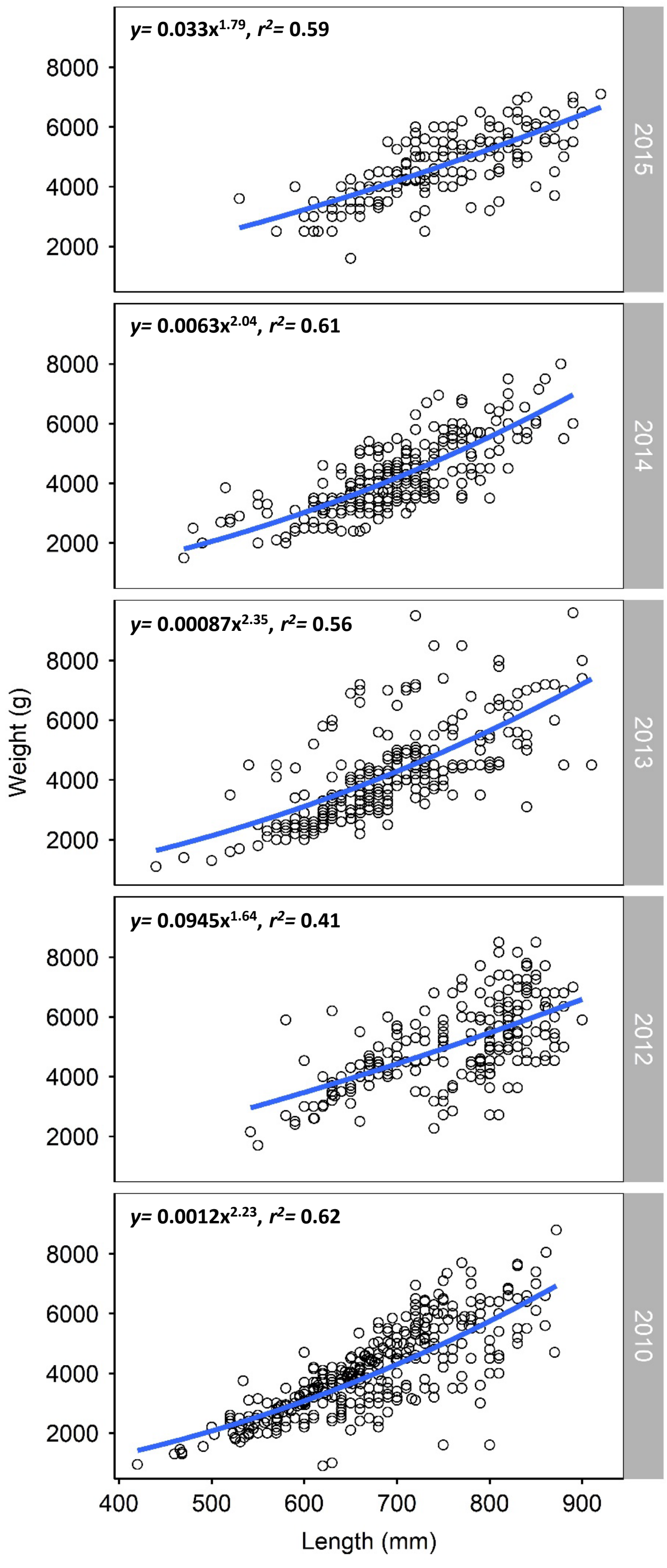

Figure 26. Length-weight relationship fit with a power regression for Arctic Char harvested in the summer coastal commercial fishery near Ulukhaktok, 2010–2015.

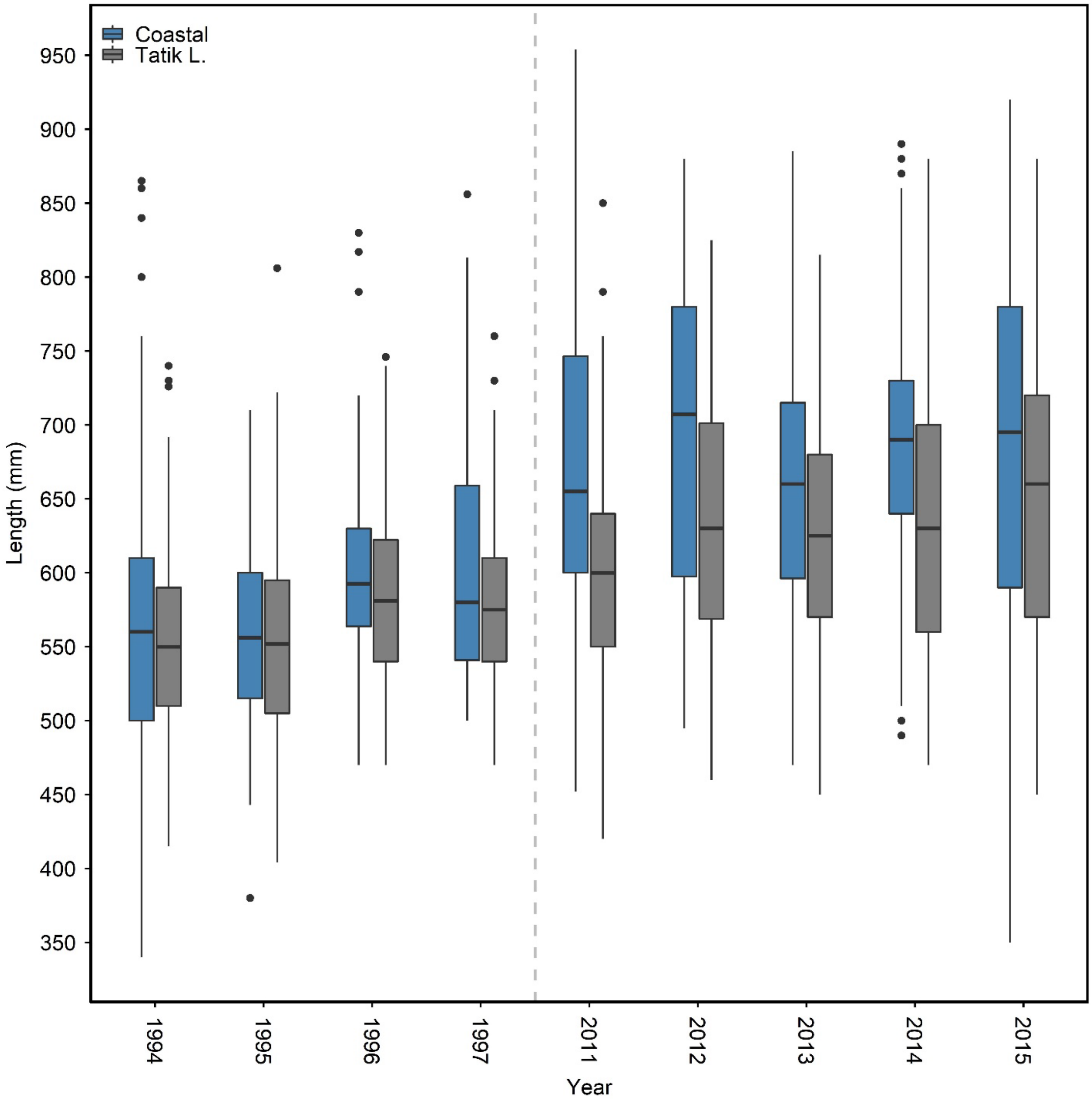

Figure 27. Box plot (median, quartiles, outliers (● values ≥ 1.5 x IQR) of fork length of Arctic Char sampled from the summer coastal and Tatik Lake winter (Gallagher et al. 2021a) subsistence fisheries monitoring programs (using gill nets with 114 mm mesh) near Ulukhaktok 1994–1997 and 2011–2015.

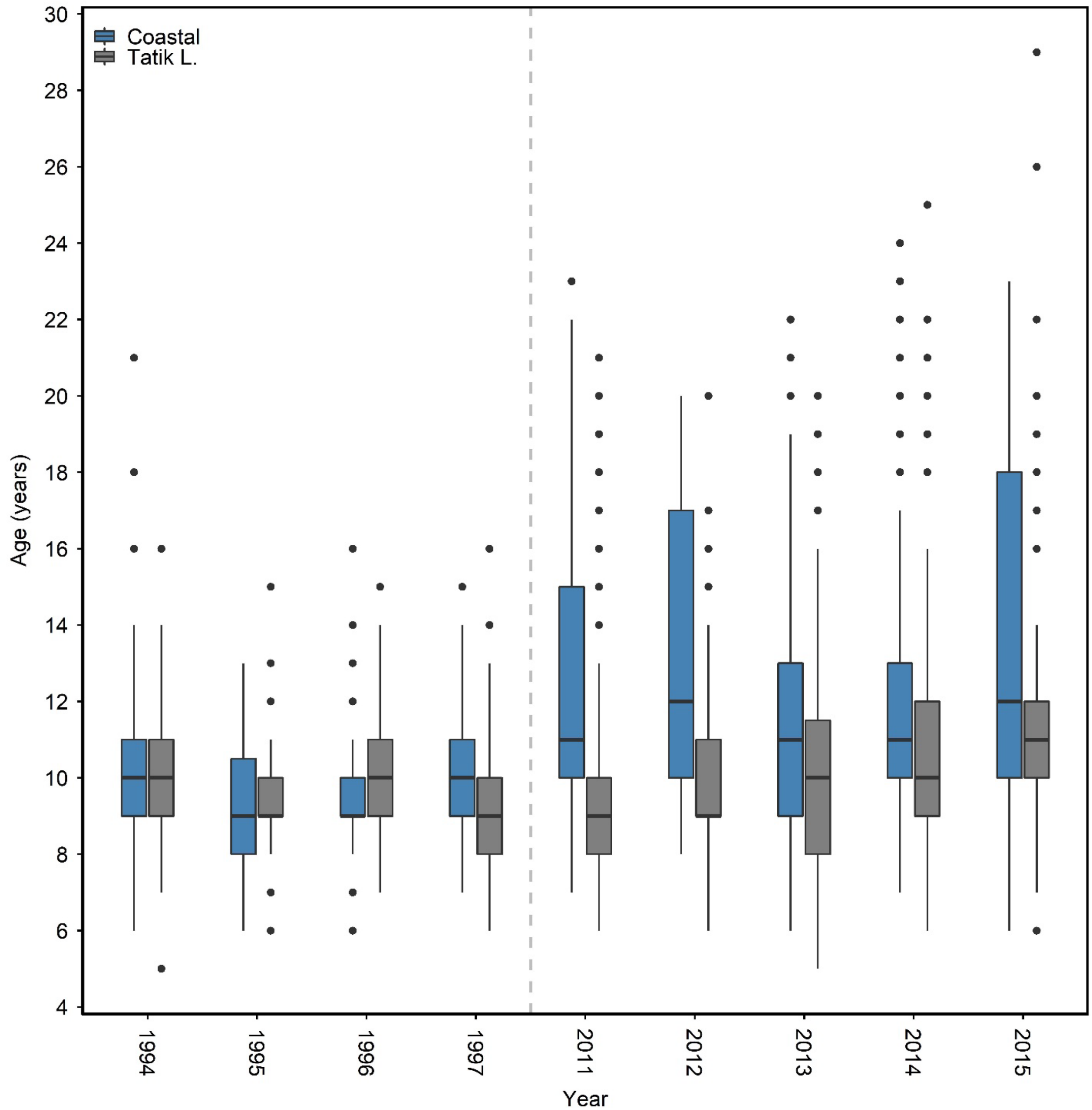

Figure 28. Box plot (median, quartiles, outliers (● values ≥ 1.5 x IQR) of age of Arctic Char sampled from the summer coastal and Tatik Lake winter (from Gallagher et al. 2021a) subsistence fisheries monitoring programs (using gill nets with 114 mm mesh) near Ulukhaktok 1994–1997 and 2011–2015.

APPENDIX

Table A1. Mean fork length, weight, condition factor, and age (Standard Deviation [SD] in brackets) of female (F) and male (M) Arctic Char sampled from the summer coastal subsistence fishery (114 mm stretch mesh gillnets) near Ulukhaktok, 1993–1997 and 2011–2015. Differences between females and males were tested using two sample t-test (length), Kruskal-Wallis (length, age and condition), and analysis of covariance (weight); significant differences are highlighted in grey.*

Sample type	Year	Female	Male	n = (F / M)	Test statistic & *p*-value
Fork Length (mm)	2015	673 (115)	713 (116)	133 / 94	t = -2.6; d.f.= 225, p = 0.01
	2014	678 (72)	757 (72)	150 / 33	U = 1019, p < 0.001
	2013	645 (87)	680 (94)	104 / 96	t = -2.89; d.f. = 198, p = 0.04
	2012	686 (110)	684 (121)	16 / 19	t = 0.051; d.f.= 33, p = 0.96
	2011	651 (87)	690 (103)	99 / 107	U = 3908, p = 0.001
	1997	575 (87)	637 (84)	21 / 32	U = 165, p = 0.002
	1996	592 (51)	603 (65)	68 / 100	U = 2417, p = 0.18
	1995	553 (64)	561 (59)	58 / 67	t = -0.73; d.f. = 123, p = 0.48
	1994	562 (86)	551 (95)	118 / 130	U = 4287, p = 0.56
	1993	506 (67)	524 (92)	52 / 49	U = 1119, p = 0.22
Weight (g)	2015	4,006 (1,520)	4,708 (1,843)	132 / 93	F = 0.17; d.f.=1,222; p = 0.69
	2014	3,695 (1,056)	5,026 (1,032)	150 / 33	U = 866, p < 0.001
	2013	3,297 (1,225)	4,019 (1,444)	104 / 95	F = 5.65; d.f. = 1,190; p = 0.02
	2012	3,934 (1,540)	4,213 (2,068)	16 / 19	F = 0.24; d.f. =1,32; p = 0.63
	2011	3,309 (1,190)	4,111 (1,594)	99 / 107	F = 5.61; d.f. = 1,203; p = 0.02
	1997	2,493 (1,466)	3,077 (1,193)	21 / 32	F = 0.49; d.f. =1,50; p = 0.49
	1996	2,642 (840)	2,908 (1,073)	68 / 100	F = 1.03; d.f. =1,149; p = 0.31
	1995	2,126 (671)	2,254 (678)	58 / 67	F = 1.42; d.f. = 1,122; p = 0.24
	1994	2,427 (967)	2,390 (1,206)	118 / 130	F = 0.06; d.f. = 1,187; p = 0.81
	1993	1,813 (927)	1,997 (1,005)	52 / 50	F = 1.65; d.f. = 1,99; p = 0.2
Condition factor	2015	1.3 (0.3)	1.2 (1.2)	132 / 93	U = 663, p = 0.3
	2014	1.2 (0.2)	1.2 (0.4)	150 / 33	U = 2650, p = 0.52
	2013	1.2 (0.2)	1.2 (0.2)	104 / 95	U = 3968, p = 0.08
	2012	1.2 (0.3)	1.2 (0.2)	16 / 19	U = 115, p = 0.22
	2011	1.2 (0.3)	1.2 (0.3)	99 / 107	U = 4774, p = 0.22
	1997	1.2 (0.2)	1.2 (0.2)	21 / 32	U = 398, p = 0.26
	1996	1.2 (0.2)	1.3 (0.2)	68 / 100	U = 2537, p = 0.37
	1995	1.2 (0.2)	1.3 (0.2)	58 / 67	U = 1828, p = 0.57
	1994	1.3 (0.3)	1.3 (0.3)	118 / 130	U = 4751, p = 0.52
	1993	1.3 (0.2)	1.3 (0.2)	52 / 49	U = 1411, p = 0.46
Age (y)†	2015	13.2 (4.4)	14.3 (4.9)	124 / 87	U = 4766, p = 0.15
	2014	12.9 (2.4)	14.2 (3.7)	149 / 32	U = 1851, p = 0.046
	2013	11.8 (3.6)	11.6 (3.2)	101 / 91	U = 4552, p = 0.91
	2012	14.0 (4.3)	12.8 (3.8)	16 / 17	U = 108, p = 0.31
	2011	12.2 (3.4)	12.5 (3.7)	98 / 107	U = 5038, p = 0.63
	1997	9.6 (2.1)	10.3 (2.1)	21 / 31	U = 245, p = 0.13
	1996	9.8 (1.2)	9.5 (1.6)	56 / 89	U = 2044, p = 0.06
	1995	9.7 (1.4)	9.4 (1.5)	56 / 83	U = 1499, p = 0.15
	1994	10.7 (2.3)	9.9 (2.4)	82 / 99	U = 2838, p = 0.06
	1993	9.4 (1.4)	9.8 (1.9)	43 / 42	U = 756, p = 0.18

*Number of samples where sex was not recorded: n= 9 in 2015; n=116 in 2014; n= 1 in 2011; n= 6 in 1995, n=1 in 1994; n= 2 in 1993.

† The age reader and method used to determine ages differed between 1993–1997 and 2011–2015.