NWRT Final Progress Report
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1. NWRT PROJECT NUMBER: 3-19-15

2. PROJECT TITLE: Fishery Independent Sampling of Cambridge Bay Arctic Char with Emphasis on the Lauchlan River Stock: Year 2 of 5

3. PROJECT LEADERS:

Les N. Harris
Fisheries and Oceans Canada
Freshwater Institute
501 University Cres., Winnipeg, MB, R3T 2N6
Ph: (204) 983-5143
Fax: (204) 984-2403
E-mail: Les.N.Harris@dfo-mpo.gc.ca

4. SUMMARY

This project involved the second year of fishery-independent sampling of Arctic Char from the Lauchlan River, NU using multi-mesh research gill-nets. Similar to 2018, multi-mesh gill nets were used to capture a representative sample of Arctic Char from this system that were sampled for a suite of biological characteristics (i.e., length, weight, age, sex and maturity). These data will be compared to those collected as part of the commercial plant sampling program (that typically over-represents larger and older fish) and will be added to the time series of fishery-independent data from this system. Valuable catch and effort information was also collected which can be used as a proxy for abundance and in stock assessment models for estimating biomass and sustainable harvest levels. In 2019, we also collected 200 Arctic stomachs and 30 tissue samples to be subsequently analyzed for micro-plastics, diet and contaminants. All told, the results of this work will add to the time series of data that will be key for assessing the sustainability of the Lauchlan River Arctic Char stock while contributing to our overall collective understanding of char biology and the health of char in the region.

5. PROJECT OBJECTIVES

In response to the above knowledge gaps, the purpose of this proposed research is to continue our fishery-independent sampling program for Arctic char from the Lauchlan River, NU. The specific objectives of this proposed research are to:

1. Continue the collection of fishery-independent data from Lauchlan River Arctic char to establish a time series of biological (including, length, weight and age) and catch-effort

data from this system. This will be done in tandem with the fishery-dependent data collection program in the region.

2. Collect stomach, tissue and genetic samples from all captured char. These will specifically be used for (1) assessing the frequency and prevalence of microplastics in the stomachs of Lauchlan River Arctic char, (2) investigating trends in mercury concentrations and other contaminants in sea-run (anadromous) Arctic char in the region (3) diet analyses and stable isotope analyses aimed at understanding the trophic relationships of char within the marine food web, and (4) assessing contributions of discrete stock to harvest in the mixed-stock fisheries in the region.
3. After five consecutive years, use these data to assess the sustainability of the Lauchlan River fishery and to set total allowable harvests for this location that will be incorporated into an updated version of the IFMP for Cambridge Bay Arctic char.

6. MATERIALS AND METHODS

Fishery-independent sampling of Lauchlan River Arctic char in 2019 focused on the biological sampling of char during downstream migration, after having spent the winter in freshwater. The study was designed and carried out in cooperation with the Ekaluktutiak HTO (EHTO) and two local field technicians chosen by the EHTO assisted with all aspects of the field component of the work. The field work portion of this project was conducted with little variance from the summary provided in the initial proposal and thus only a brief summary of our sampling is provided below. We do, however, expand on some preliminary data analyses that have commenced.

Field sampling:

Field sampling took place from July 10-16, 2019. Fish were captured using multi-mesh gillnets permitting the capture of Arctic char of all sizes and ages. Location and general environmental data such as position (determined by GPS), time of year, time of day, net depth, water temperature, weather and other environmental conditions were recorded for each net set. To estimate catch-per-unit-effort, the net type and soak time (number of hours the net was in the water fishing) were recorded. The fork length, round weight, gonad weight, sex and maturity stage were recorded for each fish. Additionally, structures for determining the age and stomach contents of each fish were all taken as well as tissues for contaminants (mercury and radium) and for future molecular assessments. Ages of sampled fish were determined by embedding, sectioning and reading the aging structures (i.e., otoliths).

Diet Analyses

All stomachs were persevered for subsequent diet analyses. Stomachs were weighed and stomach linings were weighed subsequent to diet items being removed. The degree of fullness (F = Full (distended); PF = partially full (obvious contents, not completely distended); NE = near empty (few contents); or E = empty) and state of digestion (I = Intact; PD = partially digested; D = digested (individual stomachs may include some intact and some digested prey items) were both recorded. Individual stomach contents were then identified to the lowest taxonomic level and contents were enumerated and weighed.

Marine Microplastics Assessments:
In 2019 Arctic char stomachs, marine water and sediment samples were collected to 1) quantify microplastic concentration across a range of environmental matrices (i.e. sediment, water, Arctic char; 2) determine concentrations of PCBs/PBDEs in these environmental and biological matrices; 3) investigate the relationship between PCBs/PBDEs and microplastic concentration across all matrices; and 4) investigate congener and concentration patterns between microplastics and PCB/PBDEs identified in the char gut and muscle tissue.

The char samples will be analyzed for PCB/PBDE and microplastic concentrations using Pyrolysis-Gas Chromatography Mass Spectrometry (Pyro-GC/MS0. The char samples will be divided into three different sample types: gut lining, gut contents, and muscle tissue. All three samples will be homogenized separately using a tissue homogenizer (Fischer and Scholz-Böttcher 2019, 2017), extracted using microwave assisted extraction (MAE) and analyzed via Pyro-GC/MS. Here, samples will be split in two to determine microplastic concentrations (via Pyro) and PCB/PBDE concentrations (via GC/MS).

Sediment samples will be subsampled for PCB/PBDE concentrations using a single-point Tenax extraction method (adapted from Harwood and Nutile 2020; Sinche et al., 2017). The remaining sediment samples will be analyzed for microplastic concentration via density separation and stereo microscopy. Once identified a representative sub-sample of suspected microplastics will be chemically identified using Raman Spectrometry. Water samples will also be quantified via stereo microscopy, and chemically identified using Raman Spectrometry.

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

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

where W and L are weight (g) and fork length (mm) respectively.

Histograms were used to display the frequency distributions of length, weight, age and condition. Weight-length relationships for Arctic Char were described using a linear regression model for both data sets. The weight-length relationship,

$$W_i = aL_i^b$$

was transformed into its logarithmic form expressed as:

$$\log(W_i) = log(a) + b * log(L_i) + \varepsilon_i$$

where *W* is the round weight (g), *L* is the fork length (mm), *a* is the y-intercept, *b* is the slope of the regression and ε_i is a normally distributed error term for the *i*th fish. The parameters *a* and *b* were calculated by least-squares regression.

Arctic char length at age was modeled using the von Bertalanffy growth function (Beverton and Holt 1957) expressed by the equation:

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

where L_t is the expected or average length at time t, L_∞ is the asymptotic average length, *k* is the Brody growth rate coefficient, and t_0 is the theoretical length at age 0 (Ricker 1975). Statistical differences in growth between sexes within years for each fishery and between first and last sampling years for each fishery were determined using analysis of the residual sum of the squares following Haddon (2001).

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

$$x = \frac{log\left(\frac{\mathrm{p}}{1-\mathrm{p}}\right) - \alpha}{\beta_1}$$

where *p* is the proportion mature (0.00-1.00) in length class (x) or age class (x). For determining *x* for 50% maturity, (i.e., *p* = 0.05) the above formula reduces to:

$$x = -\frac{\alpha}{\beta_1}$$

Finally, catch curve data were used to estimate the total annual survival rate (S), and thus the annual finite mortality (A) and instantaneous (Z) total mortality rates. We employed the methods of Chapman and Robson (1960) which is based on the assumption that the descending limb of the curve showing catches at each age follows a geometric probability distribution. Briefly, the natural log of age class frequency was plotted against age for each year. Least squares regression was then used to fit a curve to descending limb of the catch curve (from modal year class plus one year to the oldest year class where n>1). Instantaneous mortality rate (Z), annual survival rate (S) and annual mortality rate (A) were then calculated as follows: Z=positive slope of regression, S=e^{-z}, A=1-S (Ricker 1975).

The Chapman-Robson estimate of the annual survival rate is:

$$\hat{S} = \frac{T}{n + T - 1}$$

where *n* is the total number of fished observed on the descending limb of the curve, *T* is the total recorded age of fish on the descending limb of the catch curve. The parameters S and A were calculated as described above for each year of sampling for both fishery-dependant and independent data.

7. RESULTS:

Sample size

The Lauchlan River was sampled using multi-mesh gill nets from July 10-16th, 2019 and during that time 170 Arctic Char were captured and sampled. The number of Arctic char captured per day ranged from 24-43 (**Figure 1**). We also captured and sampled an additional 30 anadromous lake trout. The migratory behaviour of this unique life history strategy for this species will be assessed using otolith microchemistry (examining the distributions of strontium in the bones of each individual). Of the 170 Arctic char that were sampled, 87 were males and 83 were females. The majority were mature (n=103) meaning that they have spawned at least once in their life. The remaining fish that were sampled were all immature (n=67), which means they have not yet attained sexual maturity.

Biological Data Summary

Individual fork lengths ranged from 455 mm to 900 mm, with an average fork length of 661 mm Males were significantly larger than females in 2019 ($t = 6.7183$, $df = 144.74$, $p < 0.05$). Individual fork lengths for males ranged from 511 mm to 900 mm, with an average fork length of 723 mm. Fork lengths for females ranged from 445 mm to 846 mm, with an average fork length of 643 mm. The fork length distribution of Arctic char sampled in 2019 is shown in **Figure 2**. There appears to be a bi-modal distribution in fork length, but further analyses are need in order to better understand what might be driving this bi-modal distribution. We also calculated the length at 50% maturity (L50) to use as an index for reproductive potential. For the calculation of L50, we combined sexes. In 2019, across all samples combined, the overall L50 at Lauchlan River was 636 mm (**Figure 3**).

Individual weights ranged from 900g to 6300g with an average weight of 2908 g. Males were significantly heavier (mean = 3614 g) than females (mean = 2206 g, $t = 7.0161$, $df = 178.93$, p-value = 4.537e-11,). Males ranged in weight from 53 g to 6600 g and females ranged from 82 g to 9100 g. The weight distribution of Arctic char sampled in 2019 is shown in **Figure 4.** Similar to fork length, there appears to be a bi-modal distribution in fork length, but further analyses are need in order to better understand what might be driving this bi-modal distribution. The relationship between fork length and weight is shown in **Figure 5**. There was not significant difference in the weight-length relationship between males and females ($P > 0.05$).

Mean condition factor (sexes combined) was 0.95 with individuals ranging in condition from 0.62 to 1.48. Males were in slightly better condition than females (0.96 vs. 0.95), a difference that was not statistically significant ($t = -0.98103$, $df = 162.22$, p-value = 0.328). The frequency distribution of condition factor was unimodal (**Figure 6**).

Ages of Arctic char collected as part of fishery-independent sampling of Lauchlan River Arctic char in 2019 ranged from 7 to 320 (sexes combined) with a mean age of 3.2 across all individuals. There was no significant difference in the average age between males and females (t = 0.01561, df = 156.36, p-value = 0.9876). The frequency distribution of condition factor was bi-modal with peaks at 10 and 14 years of age (**Figure 7**). Age at 50% maturity A50), also used to understand reproductive potential, across all samples combined was (**Figure 8**). Length-at-age was modelled using the von Bertalanffy growth function. The population growth rate for the 2019 Lauchlan River fishery-independent data is shown in **Figure 9** and the growth parameters were: t0=*2.62*, L_∞ = 785 mm and k = 0.20.

Finally, full recruitment of Arctic Char to the fishery-independent sampling of Lauchlan River char was 14 years of age. Instantaneous mortality rate (Z) calculated following the methods of Chapman and Robson (1960) was 0.193. This results in annual mortality (A, the percentage of a stock not surviving annually) and survival rates (S, the percentage of a stock surviving annually) of 17.6% and 82.4% respectively.

Diet:

Currently the stomachs of Arctic char are still being processed and only preliminary results can be discussed. Of the 203 Arctic char stomachs assessed, 85 of these contained no prey items (i.e., they were empty). Unidentified amphipods and fish remains appeared to be the most commonly fond prey items. Work is still ongoing to identity prey items to lower taxonomic levels

Marine microplastics

During the summer of 2019, Arctic char were collected from the Lauchlan River. A total of 127 char gastrointestinal (GI) tracts and muscle tissues were collected as well as relevant biodata (sex, maturity, length, weight, otoliths). Char samples for microplastic analyses ranged in size from 900 to 6150g and 458 to 900mm with an age range of seven to 30 years. GI tracts and muscle tissues were wrapped in combusted aluminum foil and stored at -20oC. Additionally, surface water samples (5 sites, n=3; + 3 blanks) were taken with a peristaltic pump with three stacked in-line filters (500µm, 212µm, 104µm). Sediment samples were taken (5 sites, n=3; + 3 blanks) using a 20L stainless steel dredge and/or stainless steel scoop. Sediment samples were kept cool in the field. Sediment samples were frozen upon return to Cambridge Bay; sediment and char samples were shipped frozen to the University of Toronto. While we do not have any preliminary data to share at this time, method development is ongoing and positive.

8. DISCUSSION/MANAGEMENT IMPLICATIONS

The Arctic char harvested at the Lauchlan River are considered by some to be the best quality char in the Cambridge Bay region (Stephane Lacasse, Kitikmeot Foods Ltd. pers. comm). The fishery here also occurs early in the summer (first week of July) thereby bringing Arctic char into the fish plant early within the season for processing. Combined, these factors rendered Lauchlan River Arctic char a highly sought after resource. The quota at the Lauchlan River, however, was reduced from 9100 kg to 2400 kg in 2005, largely in part due to concerns over the number of char that were counted (n = 10,850) in a 1983 enumeration. This reduction in quota rendered the fishery economically unviable due to the rising costs of transportation and its distance from the community of Cambridge Bay. As such, fishing stopped here in 2008 despite keen interest form Kitikmeot Foods Ltd. in continuing harvesting at this location.

In 2017, Fisheries and Oceans Canada (DFO) along with the Integrated Fisheries Management Plan (IFMP) working group (composed of DFO, the EHTO, local resource users and elder and youth representatives) and the NWMB agreed to increase the quota for 5 years (to a minimum of 5000 kgs – the quota number that Kitikmeot Foods would harvest), after which the stock will be assessed to evaluate whether harvest at the new level is sustainable or if the quota could potentially be increased to historic levels. At that time, it was also decided that a 5-year fishery-independent and –dependent sampling programs be established for the collection of biological and catch-per-unit-effort data. Furthermore, as recommended within the DFO Exploratory Fisheries Protocol, upon commencement of fishing at a waterbody that has never been fished or one that has had a lapse in fishing, biological, CPUE, and total harvest data should be collected every year for a minimum of five years before stocks are assessed and recommendations are made about the biological viability of a commercial fishery. The data collected as part of this research will form the backbone of the stock assessment subsequent to the five year data collection period and the results from this work will be used for updating the IFMP (DFO 2014) for this fishery and for potentially refining management strategies that are considerably outdated for this species in the region.

This is the second year of fishery independent sampling at the Lauchlan River and more thorough and comparative analyses can proceed in subsequent years after multiple years of data have been collected. All told, the data collected as part of this research will be used to evaluate trends (trend analyses) in age, length, weight and condition (and analyses employing these data) among years at the Lauchlan River using both fishery-dependent (commercial plant sampling) and –independent (those data collected here) data as a means to assess potential responses to commercial harvest over time. Trend analyses based on fishery-independent and –dependent will allow us to assess if Arctic Char have been adversely impacted by recent harvests in these systems (e.g., if the biological characteristics in Lauchlan River char have not been altered drastically as a result of the fishery this system). Additionally, data collected in the field (fork length, weight, sex and maturity) will allow for the assessment of the age and length structure, growth rate, sex ratios, physical condition, age-at-maturity, egg-number-per-female (fecundity), reproductive potential and mortality rates for these Arctic char populations. Finally, these data, along with catch and effort data, can subsequently be used in more derived analyses such as in stock assessment modelling exercises (e.g., depletion corrected average catch (DCAC) and surplus production models, Tallman et al. 2013) that aim to estimate safe removal levels and limit reference points. It is difficult to predict which data poor methods models will be suitable for assessing the sustainability of Lauchlan River char but the results from future data-poor assessments will be used to potentially refine management strategies and quotas for the fisheries. All told, the results of this work will add to the time series of data that will be key for assessing the sustainability of the Lauchlan River Arctic Char stock (through a Regional Advisory Process now planned for 2024) while contributing to our overall collective understanding of char biology in the region.

Finally, microplastics in the marine environment can be devastating for aquatic species and ecosystems as a whole. In 2019, we collected several hundred stomachs from Lauchlan River Arctic char and a multitude of water and sediment samples in order to have them analyzed for marine microplastics, specifically prevalence and frequency. Arctic Char will be used as a study organism to assess plastics as a source of flame-retardants to the Arctic and Arctic wildlife. Arctic char are ideal for testing these questions since they constitute important fishery (both subsistence and commercial) and they are keystone species. Due to COVID-19, we are behind schedule, but are looking at beginning analysis at the start of 2021.We will use these data to determine whether or not microplastics are correlated with greater concentrations of PCB/PBDEs in Arctic char samples and evaluate any congener patterns present across matrices. If congeners found in char tissue are similar to those found co-located on the plastics, this will suggest a relationship between microplastics and legacy contaminants. This work will ultimately contribute to a greater understanding of whether microplastics may be a vector for legacy contaminants in the Arctic, using PCB/PBDEs as a case study. We will report the results of this work back to the NWMB and the community of Cambridge Bay once laboratory analyses have been completed. This work will undoubtedly be important for shedding light on potential pollutants in the Cambridge Bay marine environment and how potential pollutants and contaminants may impact the health and condition of char in the region. This has been identified as an NWMB priority.

The Cambridge Bay commercial fishery is the first Arctic Char fishery in Canada that has a finalized Integrated Fisheries Management Plan (IFMP). This plan involved the work and support of a variety of stake holders including community elders, youth, fish processing plant representatives, the Ekaluktutiak Hunters and Trappers Organization (EHTO) and DFO. The aim of the IFMP is to guide the conservation and sustainable use of the commercial resources. Thus, the IFMP was developed to manage the Cambridge Bay Arctic char commercial fishery and it combines the best available science for this species in the region with industry data on capacity and methods for harvesting that species. The IFMP is considered an "evergreen" documented meaning it is to be updated as new data become available and when assessments of the fishery have been completed. The Cambridge Bay IFMP has several long-term objectives that strive conserve Arctic Char stocks through sustainable use and effective fishery management. Within these, improving knowledge of Arctic Char biology and stock discrimination in general has been identified as a top priority. Thus, the data collected as part of this research will be used directly for meeting this objective and for updating the management plan for this fishery accordingly given novel information on the biology of Arctic char in the region.

9. REPORT BY INUIT PARTICPIPANTS

Attached as a separate document.

10. REPORTING TO COMMUNITY RESOURCE USERS

Numerous telephone and email communications took place with the EHTO manager (Beverly Maksagak) and the EHTO president (Bobby Greenley) to discuss the project and as a means to incorporate local knowledge into the timing of sampling at the Lauchlan River and field camp logistics. Meetings in Cambridge Bay occurred in February 2019 where we discussed and presented this project at the at the EHTO annual general meeting. Approval for the project was also received at that time. Additionally, we met with the HTO in June 2019 as part of our pre-season fishing meetings and we met with board members multiple times throughout the summer while in Cambridge Bay when we were conducting our field work. The results of our 2019 field season were also presented at the Kitikmeot Regional Wildlife Boards annual general meeting (AGM) in September 2019 and to the community of Cambridge Bay at the Polar Knowledge Canada Science Days community feast held in March 2020. Summary reports for the Ekaluktutiak HTO and residents of Cambridge Bay have also been distributed.

11. REFERENCES

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FIGURES

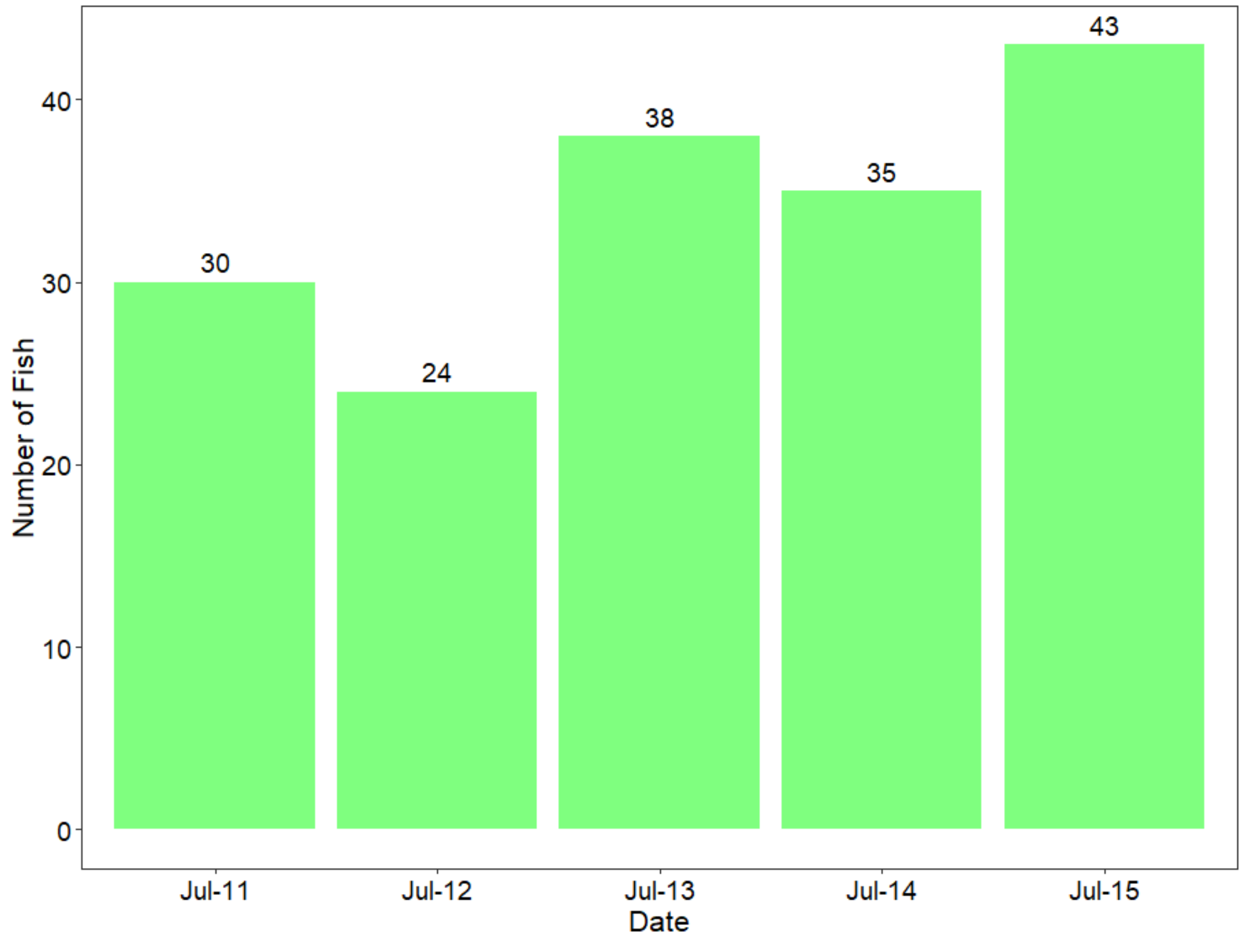

Figure 1. Daily counts of Arctic char captured during fishery-independent sampling of Arctic char at the Lauchlan River in 2019.

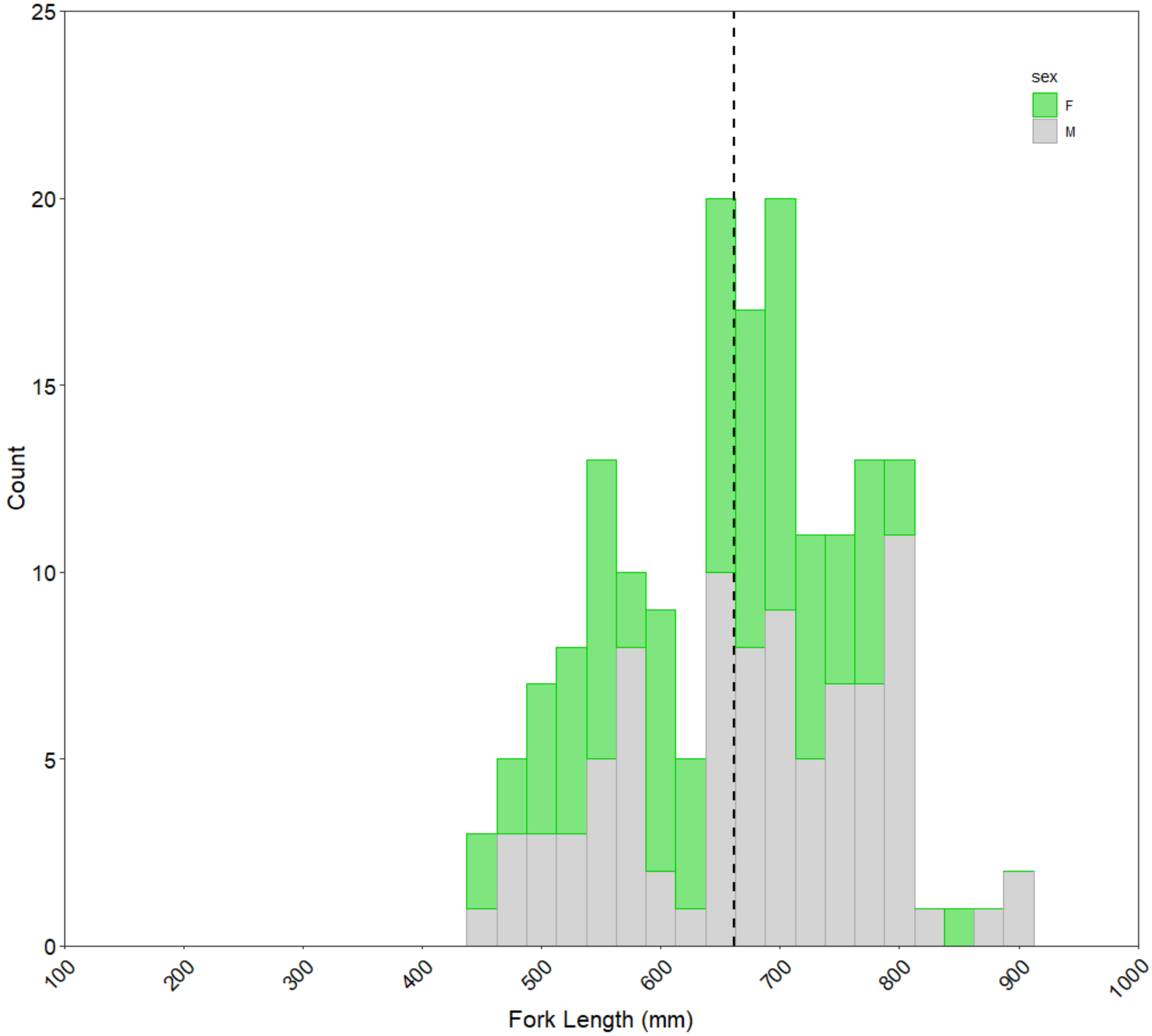

Figure 2. Frequency distributions of fork length (mm) collected from fishery-independent sampling of Arctic char at the Lauchlan River in 2019. Females are shown in green and males are shown in grey. The mean fork length for each year (sexes combined) is shown as a black dotted line.

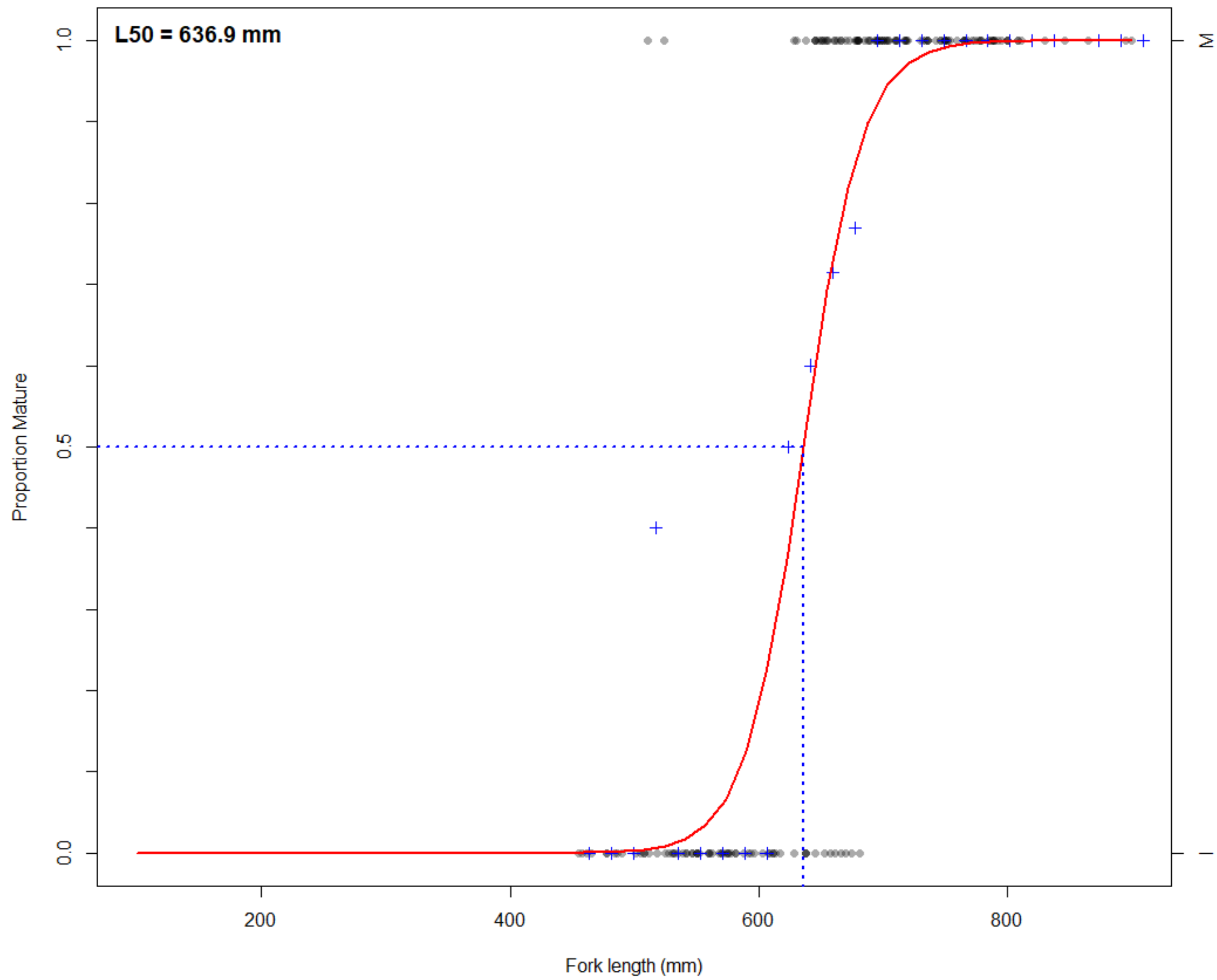

Figure 3. Length at 50% maturity (L50) for Arctic Char (sexes combined) captured at the Lauchlan River, NU, in 2018 as part of our fishery-independent sampling program. The length at 50% maturity for Arctic char sampled in 2019 was 636.9 mm.

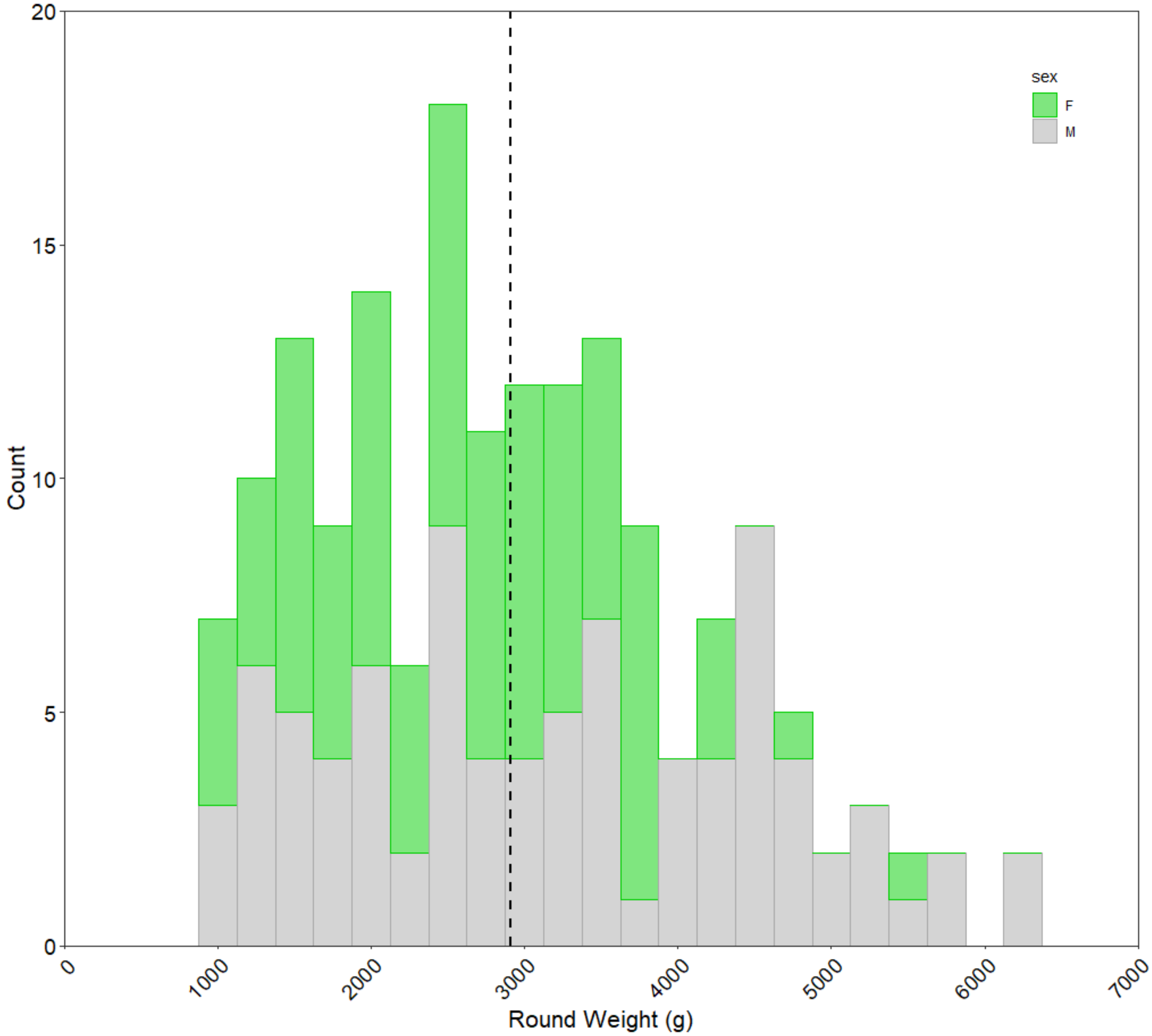

Figure 4. Frequency distributions of round weight (g) collected from fishery-independent sampling of Arctic char at the Lauchlan River in 2019. Females are shown in green and males are shown in grey. The mean round weight for each year (sexes combined) is shown as a black dotted line.

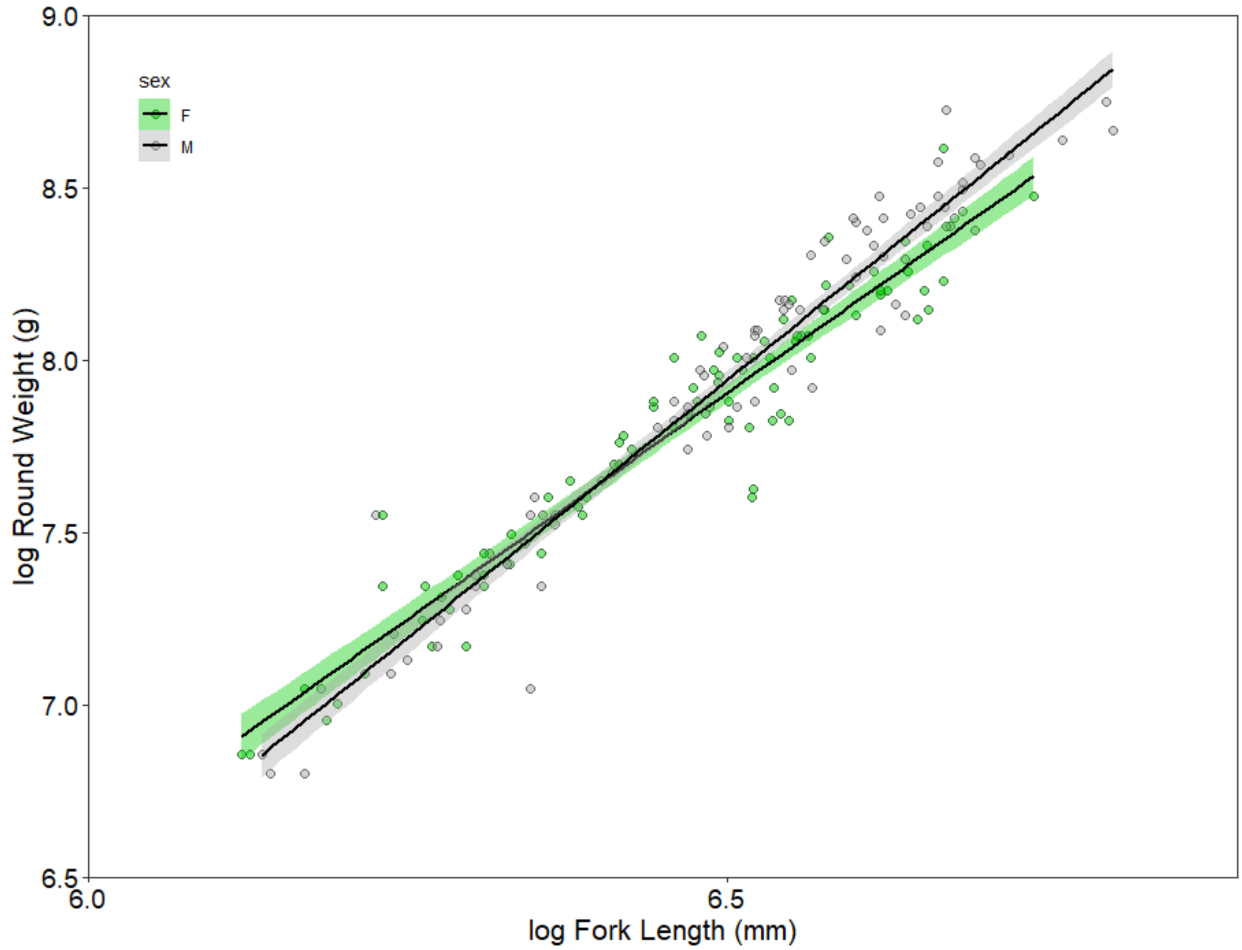

Figure 5. Weight-length relationship of Lauchlan River Arctic Char collected from fishery-independent sampling in 2019.

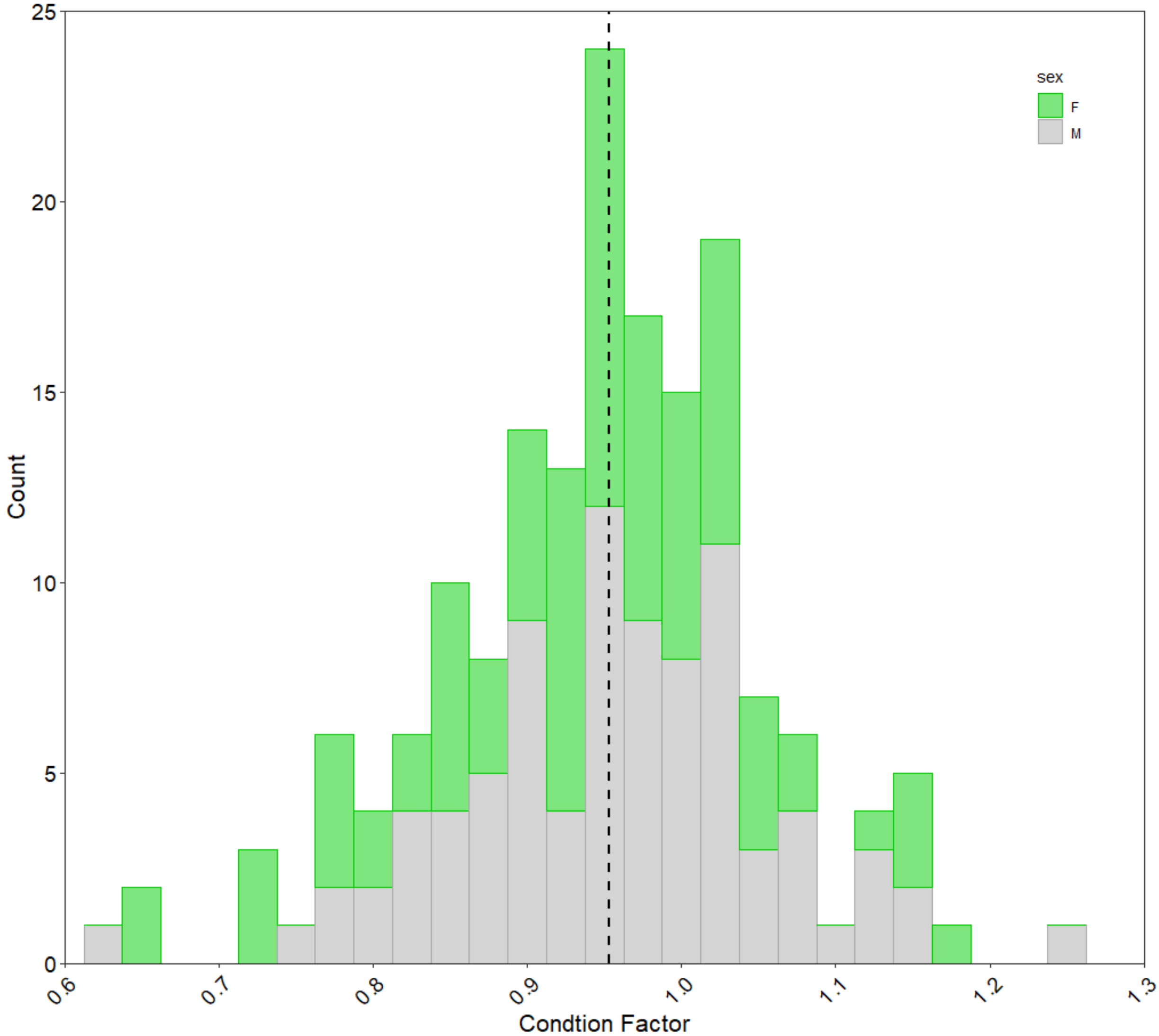

Figure 6. Frequency distributions of condition factor collected from fishery-independent sampling of Arctic char at the Lauchlan River in 2019. Females are shown in green and males are shown in grey. The mean round weight for each year (sexes combined) is shown as a black dotted line.

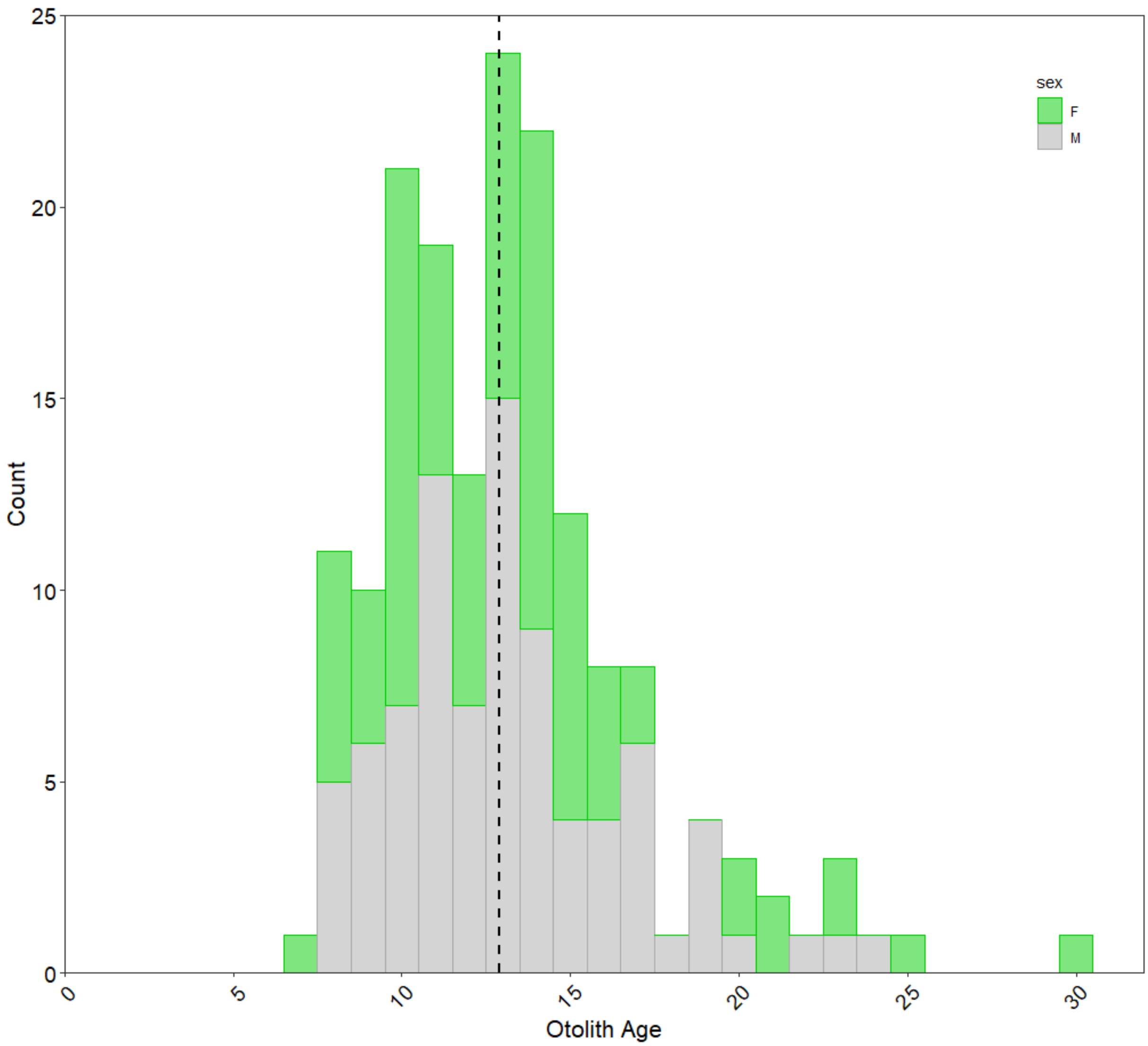

Figure 7. Frequency distributions of age collected from fishery-independent sampling of Arctic char at the Lauchlan River in 2019. Females are shown in green and males are shown in grey. The mean round weight for each year (sexes combined) is shown as a black dotted line.

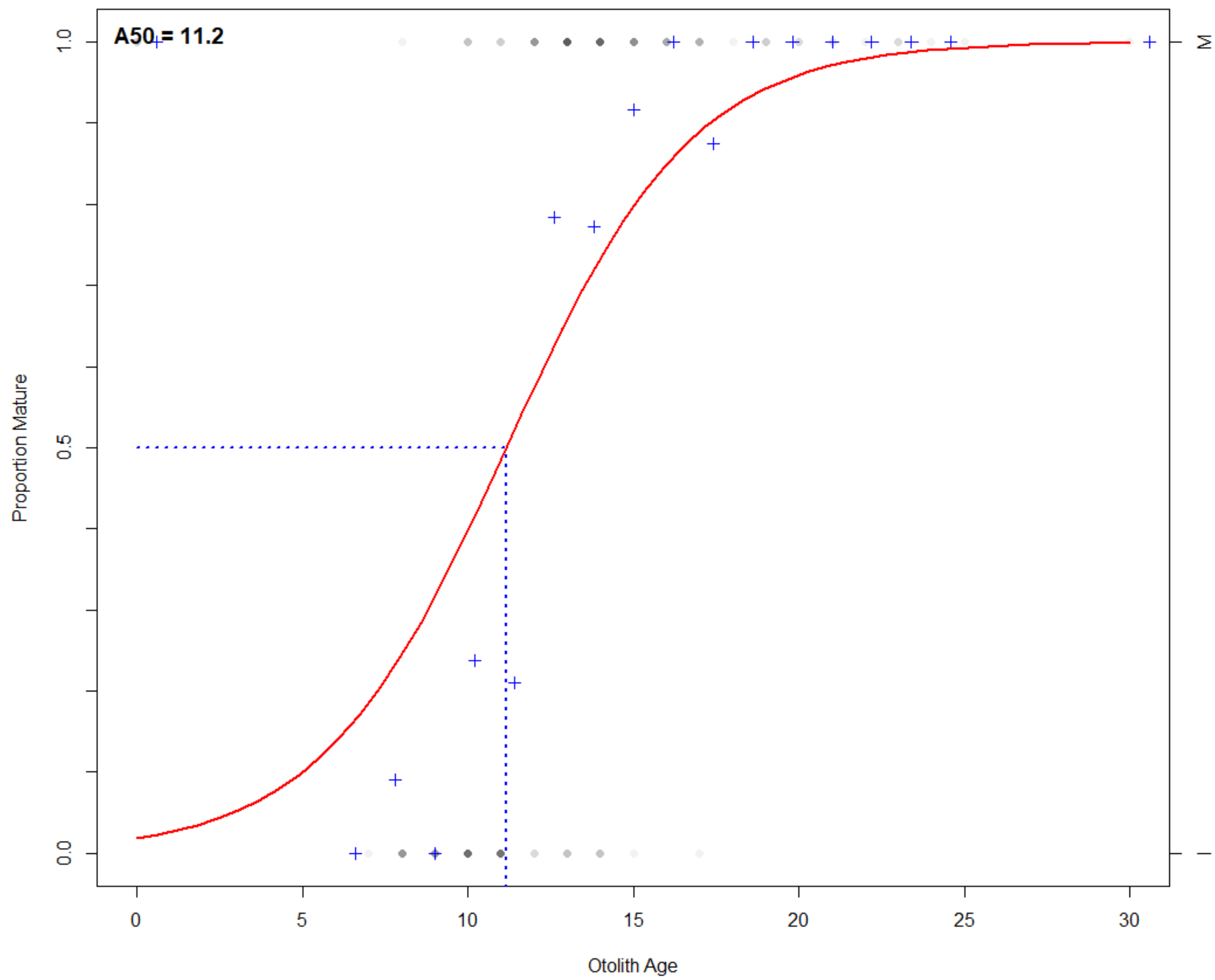

Figure 8. Age at 50% maturity (A50) for Arctic Char (sexes combined) captured at the Lauchlan River, NU, in 2018 as part of our fishery-independent sampling program. The age at 50% maturity for Arctic char sampled in 2019 was 11.2.

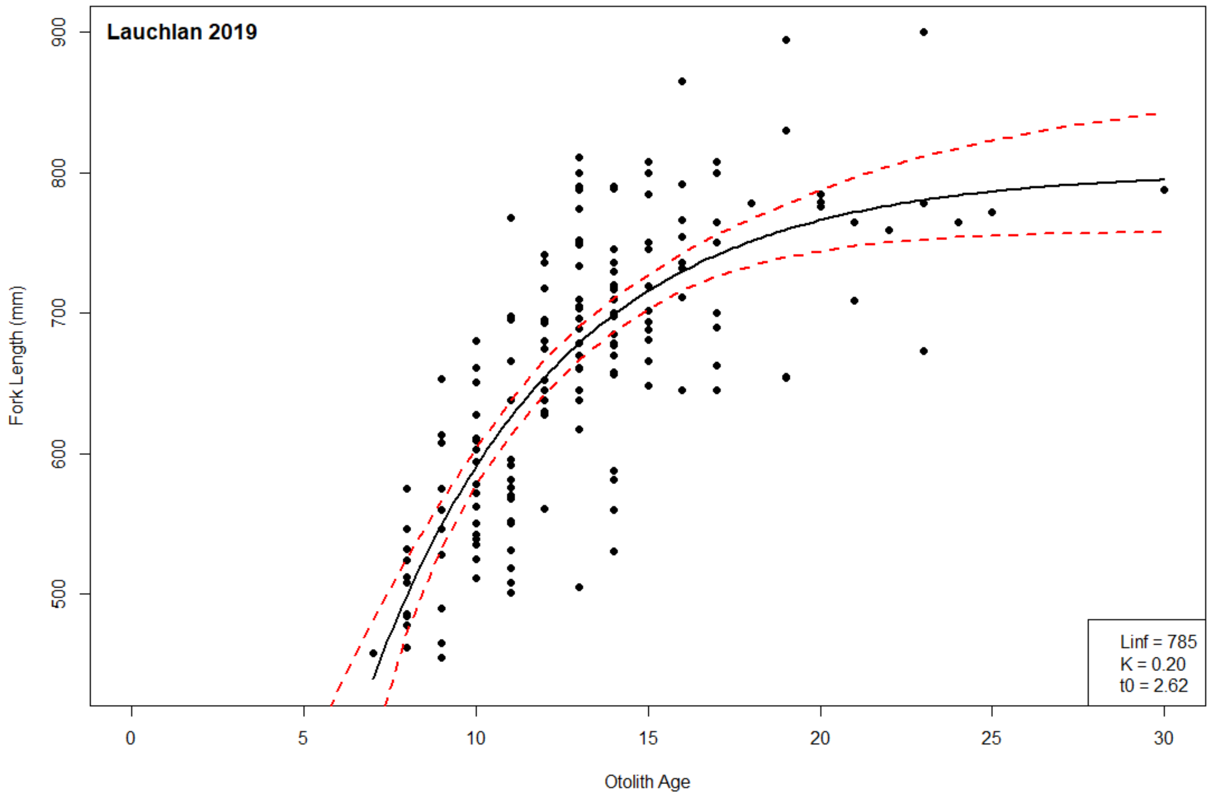

Figure 9. von Bertalanffy growth curve fitted to lengths at age for Lauchlan River, NU Arctic Char collected as part of the fishery-independent sampling program in 2019. von Bertalanffy growth parameters are shown in the bottom right corner of the plot.

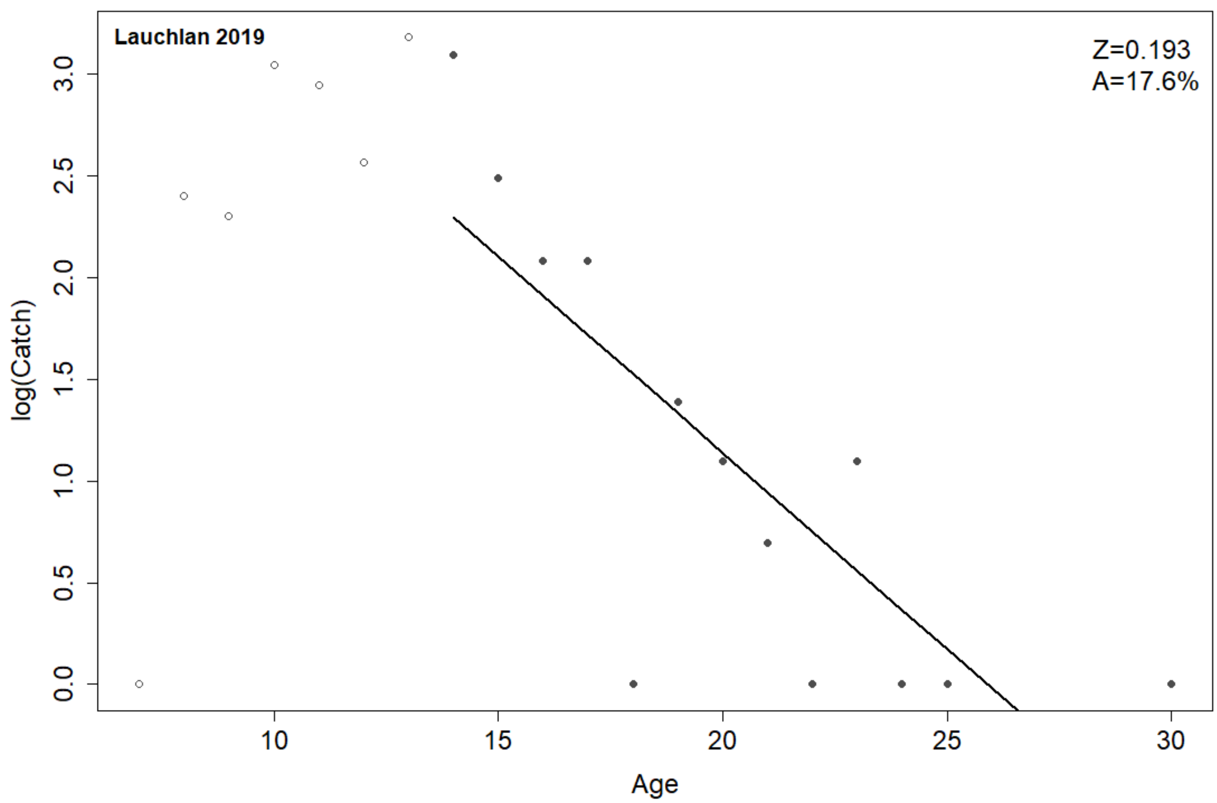

Figure 10. Age frequency catch curves for Lauchlan River, NU Arctic Char collected as part of the fishery-independent sampling program in 2019 Catch curve parameters (calculated using the Chapman-Robson method) instantaneous mortality (Z) and annual mortality (A) are shown in the top right corner of the plot.