Yukon

SR-23-11

Fisheries Status Report

Little Atlin Lake

June 2023

Fisheries Status Report
Little Atlin Lake

Government of Yukon
Fish and Wildlife Branch
SR-23-11

Authors
Pascale-Laure Savage, Robert Perry and Cameron L. Sinclair

Acknowledgements
Caitlin January, Kenji Tatsumi, Jaylene Goorts, Carcross/Tagish Renewable Resource Council

Copies available from:
Government of Yukon
Fish and Wildlife Branch, V-5
Box 2703, Whitehorse, Yukon Y1A 2C6
Phone 867-667-5721
Email: environmentyukon@gov.yk.ca
Online: Yukon.ca and open.yukon.ca

Suggested citation:
Savage, P.-L. et al. 2023. Fisheries Status Report: Little Atlin Lake. Yukon Fish and Wildlife Branch Report SR-23-11 Whitehorse, Yukon, Canada.

Abstract

Little Atlin Lake, in south-central Yukon, experiences high recreational fishing pressure, due to its popular Northern pike fishery and its proximity to the growing Yukon capital of Whitehorse. Between 2003 and 2023 the Department of Environment has conducted seven Angler Harvest Surveys and two Lake trout Monitoring surveys to detail fish population dynamics and recreational harvest pressure.

The following Fisheries Status Report provides a detailed review and analysis of this data and summarizes key findings. Using these key findings, we develop a monitoring plan and make management recommendations that will help to ensure sustainable fish populations as well as a recreational fishery for Little Atlin Lake. Species considered include Northern pike, lake trout and lake whitefish.

[This page intentionally left blank]

Contents

Figures

Tables

Executive Summary

Recreational Angling

- Angler surveys for Little Atlin indicate the proportion of summer anglers targeting Northern pike is significantly higher than either lake trout or lake whitefish. Over 45% of summer anglers (open water season from mid-May to early September) target Northern pike. Approximately 20% target lake trout or lake whitefish. While the remaining 35% are generalists, choosing not to target any single species.
- Little Atlin Lake experienced a significant increase in angler effort, with an estimated 43% increase in summer angling effort (total # of hours fished) between 1998 and 2020. In recent years (2015, 2018 and 2020) the angler effort may have plateaued, as angler effort has not greatly increased.
- We observed a significant rise in fishing pressure during the weekdays in comparison to the weekend.
- The rise in angling pressure on Little Atlin Lake is likely a consequence of Yukon's growing population. Little Atlin, being near Whitehorse, is conveniently reachable for its angling community.
- In general, many anglers practice live release when fishing on Little Atlin Lake. Despite this, with an increase in effort, it is likely that fish mortalities are also increasing due to fish handling and recovery practices.

Lake trout Status

- In 2015, we captured an average of 0.33 lake trout/net compared to 0.08 Lake trout/net in 2021. As such, estimated density and population size dropped by 65% between 2015 (4,200 Lake trout) and 2021 (1,500 Lake trout). However, there was also a drop in the confidence of the 2021 estimate. While our sampling effort was consistent between years, the numbers of fish caught in 2021 was reduced. This led to greater uncertainty in our results.
- The mean fork length of lake trout was similar between 2015 (554 ± 12 mm) and 2021 (521 ± 36 mm).
- In summer, anglers caught an average of less than one lake trout per day. Fewer than 10% of anglers reported catching more than one lake trout per visit, and fewer than 5% reported catching two or more lake trout per visit.
- With an average depth of 10.6m there is little suitable habitat for lake trout in Little Atlin Lake and therefore, the lake trout population is naturally small.

Northern Pike Status

- For Northern pike, younger fish are becoming more prevalent and the frequency of Northern pike >8 years has declined by over 75% in the catch composition.

- Mean ages in both 2018 and 2020, were younger than the mean age in 2008 and 2015. When comparing among sample years, mean age significantly differed. Northern pike harvested in 2018 were significantly younger than those harvested in 2008, and those harvested in 2018 and 2020 were significantly younger than those harvested in 2015.
- There is an increase in Northern pike annual mortality across survey years. The annual mortality rate for Northern pike aged 6 and up (The age when fish are fully recruited to summer angling gear) increased from 33% to 57% between 2008 and 2020.
- The Little Atlin Northern pike fishery is predominantly a recreational, live release fishery. Catch rates for Northern pike remain good on Little Atlin. On average, anglers catch one fish per hour and harvest one fish per trip. No anglers reported harvesting more than the bag limit of four fish.
- We are uncertain whether this population is declining. Our uncertainty stems from the Northern pike's abilities to offset population losses through increases to its recruitment and survivorship. This phenomenon is known as compensatory mortality.
- We found that angler non-compliance with the regulations has been consistent across survey years. 6% of summer anglers will harvest Northern pike over the maximum length of 750 mm total length (716 mm fork length).

Lake Whitefish Status

- Lake whitefish angling has grown in popularity, with a rise in anglers targeting lake whitefish since 2015. Estimates of catch and harvest have also increased.
- Since 2015, anglers targeting lake whitefish catch an average of two lake whitefish per visit and harvest one.
- The catch composition for lake whitefish has become increasingly smaller and younger. However, shifts to a younger catch composition are normal in newly established fisheries.
- This change in harvest composition was not reflected in the SPIN (Summer Profundal Index Netting) data, where no changes in mean fork length or length frequency distribution were observed. Additionally, while catch rates during SPIN surveys declined between survey years, the results suggest that lake whitefish densities in Little Atlin Lake have not significantly changed; however, this may warrant further monitoring.

Introduction

Background

Little Atlin Lake, located in south-central, Yukon, is a popular fishing destination for many Yukon residents, likely due in part to its proximity to Whitehorse. The First Nations (Taku River Tlingit and the Carcross Tagish) and the local Renewable Resource Council (CTRRC), have expressed concerns regarding an increase in the number of people fishing at Little Atlin Lake, alleging that the increased pressure may not be sustainable and that the current regulations are no longer adequate. They expressed concerns regarding the status of the lake trout (*Salvelinus namaycush)* population.

In response, we launched a program in 2022 to sample Little Atlin Lake's fish population and to monitor its fishery. Additionally, we conducted a review of all our archived fisheries data, collected intermittently between 1990 and 2020, to determine if we could identify temporal changes.

This report summarizes the results of our review and analyses. The report briefly describes the challenges and data gaps regarding our knowledge of the lake's ecology and the species that inhabit its waters, with a focus on lake trout (*Salvelinus namaycush*), Northern pike (*Esox Lucius)*, and lake whitefish (*Coregonius clupeaformis)*. We then summarize the lake's sport fishery, describing angler preferences and the current level of fishing pressure per focal species. Finally, we analyze available field data to determine if there are population changes occurring for any of these three species.

Study Objectives

- Develop lake and species-specific regulations;
- provide a plan to monitor fish populations, their health, growth rates, habitat use and relative abundances; and
- provide analyses to support recommended regulatory changes.

Study Area

Little Atlin Lake is in south-central Yukon, within the Traditional Territories of the Carcross/Tagish First Nation and the Taku River Tlingit First Nation (Figure 1). This lake is in the headwaters of the Yukon River watershed and drains into the Lubbock River, which flows into Atlin Lake, BC. Situated near the communities of Marsh Lake and Tagish, Little Atlin is approximately 90 km southeast of Yukon's most populous centre, Whitehorse. The lake is approximately 22 km long and 3.2 km at its widest point. With a maximum depth of 49 m (average 10.6m) (Figure 1) and a surface area of 4032 ha, we consider this lake to be in category D (Table 1). Public access to Little Atlin Lake is limited to a single boat ramp and associated parking lot, located on the eastern shore, which is accessible from Yukon Highway 7. The lakeshore is scattered with private residences and has one commercial lodge, Little Atlin Lodge. Currently, this lodge does not offer guided recreational angling. Public campgrounds are located at Snafu and Tarfu lakes. Overnight camping is common at the Little Atlin Lake boat ramp.

Table 1. Yukon lake size classifications

SIZE CATEGORY	SIZE RANGE (HA)
A	< 100
B	101 – 1,000
C	1,001 – 2,500
D	2,501 – 5,000
E	5,001 – 15,000
F	15,001 – 65,000

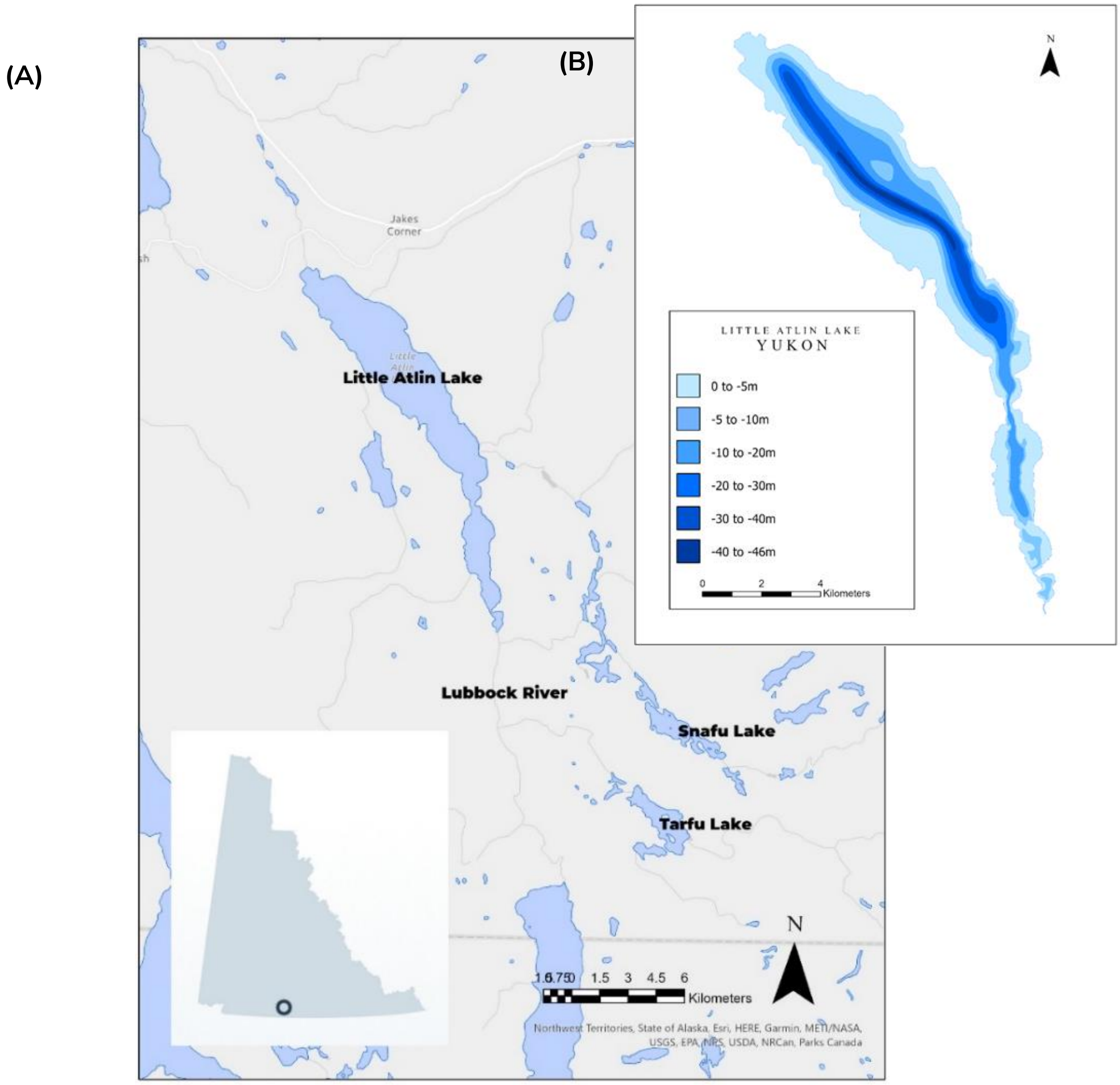

Figure 1. Location of Little Atlin Lake (A) and the lake's bathymetric profile (B).

Data Gaps

Habitat

The current bathymetric profile for Little Atlin Lake (Figure 1) was created in the late 1990s, and new technology exists to provide higher resolution bathymetry data. During our 2021 Summer Profundal Index Netting (SPIN) survey it was discovered that several depth isolines were incorrect. This has implications for sample design and Lake trout population estimates. Additionally, to properly understand the effects of climate change, we require accurate bathymetry data to calculate the available thermal habitat.

Fisheries

The available fisheries data for Little Atlin Lake is presented for lake trout, Northern pike, and lake whitefish, however we have identified deficiencies within the data. These deficiencies include:

- limited data on ages of harvested lake trout prior to 2015;
- in certain instance, small numbers for sampled fish;
- limited data on targeted effort (hours anglers are spending targeting one species);
- a standardized methodology to measure Northern pike abundance; and
- limited information pertaining to winter recreational harvest and subsistence harvest.

Methods

We used both fisheries dependent and independent data. Fisheries dependant data comprises data that was collected by surveying anglers and includes (a) annually collected data on the number of hours fished, (b) the numbers of individuals in a fishing party, and (c) the numbers of fish caught, kept, and released by species. It also consists of data on harvested fish, such as, the fish's length, weight, sex, and age. Other data collected includes some social and demographic information such as the angler's place of origin, their age and sex, fishing methodology, and their species preference.

Fisheries-independent data does not come from the fishery but, instead, comes from our standardized sampling program. In general, this information is collected through our Summer Profundal Index Netting Program (SPIN) surveys. The collected data includes catch-per-unit-effort-data (CPUE, the number of fish caught per hour), the length and weight of all captured fish and some of the sampled fish's age data.

Fisheries-dependent data can have biases associated with its use. For example, anglers have preferences regarding where they fish and what size of fish they harvest. Such predispositions can skew data, giving inflated catch rates or skewed size distributions. This may result in an incorrect assessment pertaining to a fisheries status.

However, these datasets can be used to corroborate the results of the other. Thus, in combination, the various analyses can be used to detect the presence of population changes.

Fisheries Independent Data

Population Estimates

Population estimates were only derived for lake trout because it is the one species for which we have a calibrated population model. To collect data for these estimates we used the SPIN netting protocol, developed by the Government of Ontario (Sandstrom and Lester 2009). This standardized sampling was developed so that the density of harvest-sized fish (>300 mm) could be compared among lakes. This protocol can also be used for temporal comparisons to assess a population's status through time.

For both survey years (2015 and 2020), gillnets were set randomly on the bottom and at differing depths throughout the lake to capture lake trout and determine catch-per-unit-of-effort (CPUE). In 2015, 67 nets were set, with 70 nets set in 2021. Each 64 m gillnet was made up of 8 panels of monofilament web with mesh sizes from 57 mm to 127 mm. We set each net for 2 hours.

The numerical CPUE was calculated using catch numbers adjusted to account for net selectivity bias (adjusted for fish whose size reduces the probability of their capture; Sandstrom and Lester 2009). Given our standardized protocols, in this instance, CPUE can be used as an index of abundance, and changes in CPUE are assumed to represent changes in abundance of lake trout.

We also calculated a lake-wide biomass CPUE for lake trout, as the kilograms of lake trout (300 mm and up) caught per net, using Cochran's area weighted mean and standard deviation for random stratified samples (Cochran 1977, Krebs 1999, Barker et al. 2014). Lake trout biomass CPUE was not adjusted for net selectivity bias. Numerical CPUE was converted to density (lake trout/ha) based on an empirical relationship between CPUE and fish density that has been established for Ontario lakes (Sandstrom and Lester 2009; Government of Yukon 2023). From this, absolute abundance was estimated (i.e., the total population size), multiplying density by lake size (number of lake trout/ha x lake area (ha) = number of lake trout in lake).

We did not compare age distributions between 2015 and 2020. SPIN sets are short in duration (approx. 2 hours). As such, most fish remain alive in the net and were released back to the water once measured for weight and length. This means that little age data exists for comparisons because we did not sacrifice fish to collect otoliths for aging.

Fisheries Dependent Data

Angler Harvest Survey Program

We use creel surveys to assess fisheries dependent data. During a creel survey, recreational anglers are interviewed, and their daily catch and fishing hours are recorded. We also determine the species they sought, measure their catch's length and weight, and, when provided permission from anglers, we sample calcified structures (e.g., bones, scales, or otoliths) so harvested fish can be aged.

For Little Atlin Lake, creel surveys were single point access and were conducted daily between 8:00 am and 10:00 pm for the summer season (mid-May to early-September). The number of sampling days per season were randomly selected to capture 30% of the summer recreational fishery. Sampling days were stratified by weekdays and weekends, which were proportionally represented. Estimates of effort (hours fished), catch rate (catch per unit effort, CPUE), and catch (number of fish caught per species), were calculated for each survey year.

Effort is reported in fishing hours and was estimated for each survey day (daily), stratum (weekends and weekdays) and season (year) following methods described in McCormick et al. 2017). Whereby, daily effort (total fishing hours per survey day, $\hat{E}_d$) was estimated as:

$$\hat{E}_d = T_d \bar{A}_d,$$

where T_d is the total recorded fishing hours in a day and $\bar{A}_d$ is the mean number of anglers counted per sample day. We assigned a mean daily effort to incomplete interviews (i.e., angling parties that were not interviewed, but presence recorded), and used the mean rather than the total number of anglers to estimate daily effort to account for unknown numbers of anglers in a party. This lowered our precision and increased error. However, it allowed us to account for effort missed during the sample day, improving our estimates of total effort.

Stratum effort (total fishing hours on weekends and weekdays, $\hat{E}_k$) was estimated as:

$$\hat{E}_k = N_k \frac{\sum_{d=1}^{n_k} \hat{E}_d}{n_k},$$

where N_k is the number of days in a stratum and n_k is the number of days sampled per stratum. These estimates were additive and summed to estimate total effort for the season ($\hat{E}$). Similarly, within-stratum variance was estimated from the average daily effort and summed to determined seasonal variance. Equations for variance estimators are found in Su and Clapp (2013) and McCormick et al. (2017).

Catch rates were estimated using the daily estimator method (Su and Clapp 2013). Whereby daily catch rates ($\hat{R}_d$) were calculated by dividing the total number of fish caught by the total number of anglers interviewed each day. The daily catch rates were then used to estimate both the stratum ($\hat{R}_k$) and season ($\hat{R}$) CPUE using the following equation:

$$\hat{R}_k = \sum_{d=1}^{n} \left(\frac{\hat{E}_d}{\sum_{d=1}^{n} \hat{E}_d} \right) \hat{R}_d,$$

where $\hat{E}_d$ and $\hat{R}_d$ can be interchanged with $\hat{E}_k$ and $\hat{R}_k$. Due to the multi-step approach to estimating stratum and seasonal catch rates, variance was more challenging to calculate. We therefore used a non-parametric resampling method (bootstrap) to calculate confidence intervals using upper and lower quantiles of the distribution of catch rates estimated.

Lastly, daily catch (number of fish caught, $\hat{C}_d$) and stratum catch ($\hat{C}_k$), were also estimated using the daily estimator method following the two equations below:

$$\hat{C}_d = \frac{\hat{R}_d}{\hat{E}_d}, \text{ and } \hat{C}_k = N_k \frac{\sum_{d=1}^{n} \hat{C}_d}{n_k}.$$

Total catch for the season was determined by summing the stratum catch estimates.

The above equations were used to estimate both total and targeted catch rates. Total CPUE is calculated for individual species by dividing the number of fish caught by the total number of fishing hours, irrespective of the species being targeted. Targeted CPUE is calculated using directed effort, therefore only the hours spent targeting a specific species are summed.

The creel survey questionnaire developed in the Yukon does not breakdown the number of angler fishing hours per species, therefore, unless an angler is only targeting one species, we were unable to quantify targeted effort for angling parties fishing for multiple species in a day. Despite this, where possible, we chose to present targeted CPUE values generated from anglers pursuing a single species. While it reduced our sample size (i.e., number of interviews), the estimates are thought to be a more accurate representation of catch rates.

Mortality Estimates

Using catch-at-age data from the angler harvest program, annual catch curves were plotted (i.e., total catch vs age) for Northern pike (all survey years) and lake whitefish (2015, 2018 and 2020). The age at which the peak catch occurred (i.e., highest rate of capture) was the age at which fish were considered fully recruited to the fishing gear. Fish fully recruited to the fishing gear (gill net) are the ones that are large enough to be captured. For Northern pike this was between 5 and 6 years of age depending on survey year, and for Lake whitefish between 8 and 9. Where possible we used all ages following the youngest peak observed across survey years (6 years old for Northern pike and 9 years old for Lake whitefish) to estimate rates of instantaneous (Z) and annual (A) mortality from the descending limb of each catch-curve using the Chapman and Robson estimator (Robson and Chapman 1960, 1961) with a bias correction factor (Smith et al. 2012):

$$Z = log_e\left(\frac{1+\bar{T} - T_c - \frac{1}{n}}{\bar{T} - T_r}\right) - \frac{(n-1)(n-2)}{n[n(\bar{T}-T_r)+1][n+n(\bar{T}-T_r)-1]},$$

where n is the total number of fish observed on the descending limb of the catch curve (i.e., total catch), $\bar{T}$ is the mean age recruited to the gear, and T_r is the age of full recruitment to the gear. A was calculated as:

$$A = 1 - e^{-Z}$$

No estimates of mortality could be generated from harvested Lake trout due to insufficient sample size from the creel surveys.

Fish Attribute Data (size, age, and growth)

Most fish sampled during the SPIN surveys were only sampled for length and weight, then returned to the water. In certain instances, lake trout and lake whitefish that died during capture in the nets were also sampled for sex, and their otoliths were extracted. This practice resulted in sampling bias and generated limited age data from these surveys. Therefore, SPIN data was only used to examine for changes in size (length) composition and growth through time.

Fork length (FL, mm), round weight (RWT, g), age and sex were collected from harvested fish sampled during creel surveys (i.e., voluntary angler submissions). These data were used to provide information on the age and size structure of lake trout, Northern pike, and lake whitefish harvested by anglers during the summer.

Prior to analyses, obvious outliers were identified through visual inspection of scatterplots of the log-transformed relationships between FL, RWT and age. All outliers were further investigated, and data points with both a high leverage (Cook's distance greater than the cut off (4/ (n-k-1); n = sample size, k = number of independent variables) and high residual (studentized residual greater than 3) (Fox 1997) were either corrected or removed from the dataset. Less than 2% of data were removed, most of which (n = 35) were RWT values.

Because we didn't have enough ages collected in individual surveys, we combined the ages gathered from both creel and SPIN surveys to fit age-at-length data to Von Bertalanffy Growth Curves (VBGC). Asymptotic average lengths (Linf) and growth rate coefficients (K) parameters were estimated for each species. How the age-at-length data were grouped prior to fitting VBGCs was specific to each species and based on the sample sizes available. Where possible we explored differences across survey years, sex, and generated average parameter values for the individual populations.

All analyses were performed using R 4.3.0 (R Core Team 2022).

Recreational Angling Overview

Overview

For Little Atlin Lake, angler (creel) surveys were conducted in 1990, 1998, 2008, 2015, 2018 and 2020. However, the 1990 data were removed from our analyses due to inconsistent data collection methods.

Species Targeted

The principal species targeted by anglers in Little Atlin Lake are northern pike, lake trout and lake whitefish. While all three species are considered popular sport fish, the proportion of summer anglers targeting Northern pike relative to both lake trout and lake whitefish is significantly higher, X^2 (3, N =310) = 141.092 p <0.0001; pairwise comparisons p<0.0001). With over 45% of summer anglers specifically targeting Northern pike, Little Atlin Lake can be considered a Northern pike fishery (Figure 2).

Up to 20% of anglers reported that they actively targeted lake trout or lake whitefish. Since 1998, the overall proportion of anglers targeting lake trout has remained constant with no significant changes being observed among years ($X^2(1, N = 1{,}370) = 0.175$, $p = 0.676$). In contrast, anglers targeting whitefish steadily increased, from 2% targeting whitefish in 1998 to 20% in 2020 ($X^2(1, N = 1{,}144) = 46.7$, $p < 0.0001$; Figure 2).

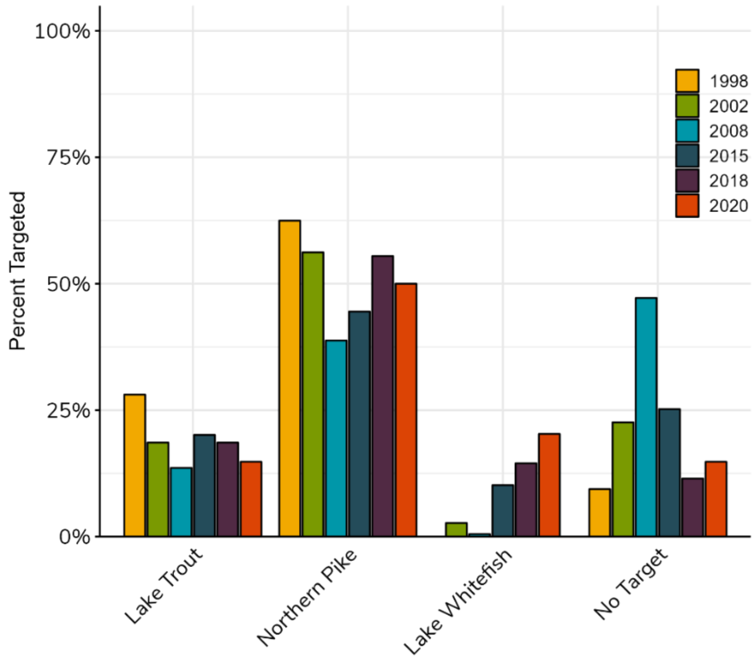

Figure 2. Percentage of reported species targeted by angling parties interviewed during angler harvest surveys between 1998 and 2020. Targeted data was not recorded in 1990.

Overall Recreational Angling Effort

Little Atlin Lake experienced a significant increase in angler effort, with an estimated 43% increase in summer angling effort (total # of hours fished) between 1998 and 2020 (Regression: Adj-R^2 = 0.90, $p<0.01$; Table 2, Figure 3). In recent years (2015, 2018 and 2020) the angler effort may have plateaued, as angler effort has not increased (Kruskal-Wallis: $H (2) = 2.6$, $p = 0.27$, Figure 3 and Table 2).

Total fishing effort at Little Atlin Lake rose significantly during the weekdays, but not weekends, between 1998 and 2020 (**Error! Reference source not found.**).

Table 2. Summary of creel survey sample effort and estimated fishing efforts (number of anglers and total effort in hours) on Little Atlin Lake by survey year.

Year	1998	2002	2008	2015	2018	2020
# Days Surveyed	34	36	35	40	40	41
# Completed Interviews	143	175	180	178	237	225
# Incomplete Interviews	11	14	35	42	38	16
Estimated # Anglers	891	953	1,164	1,169	1,462	1,362
Estimated Total Effort (±95% CI)	3,412 (±894)	3,303 (±776)	3,982 (±1,059)	4,895 (±1,223)	5,090 (±1,277)	4,865 (±1,171)

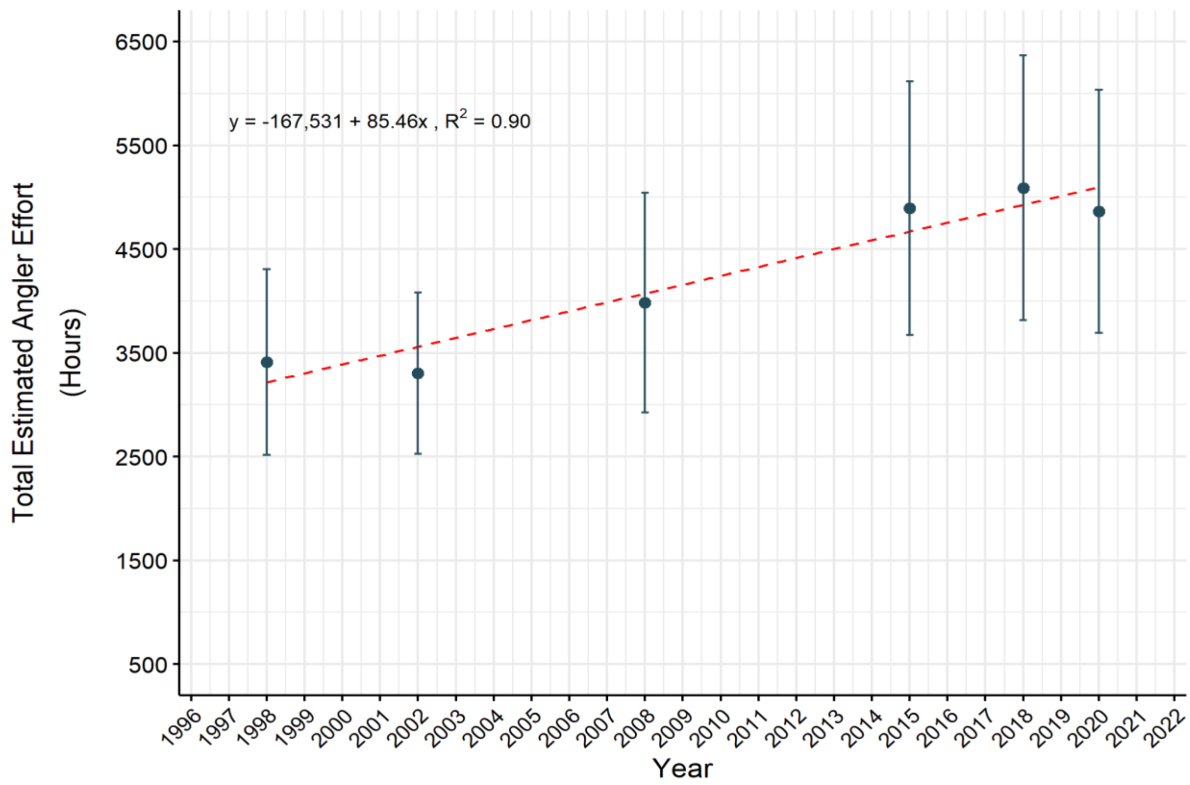

Figure 3. Estimated total summer angling effort (hours) for Little Atlin Lake by angler harvest survey year. Error bars represented 95% confidence intervals, and the red dashed line corresponds to the linear relationship observed between total effort and time as the population of Whitehorse grows.

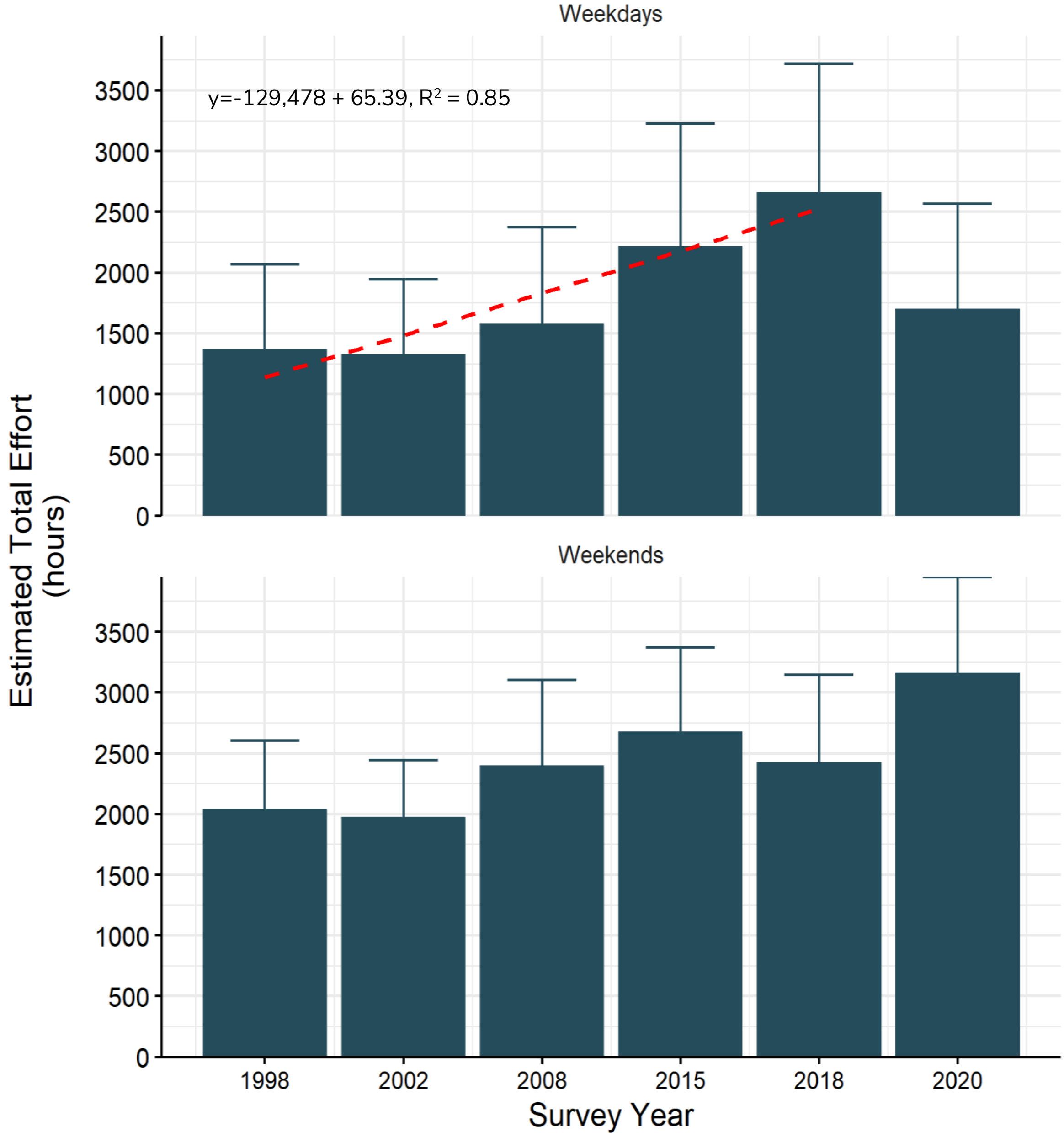

Figure 4. Estimated total fishing effort (hours) by strata (weekdays and weekends). Error bars represent 95% confidence intervals, and the red dashed line indicates a positive linear relationship in increasing total effort on weekdays between 1998 and 2018.

Discussion: Recreational Angling

The rise in angling pressure (Table 2) at Little Atlin Lake is a consequence of Yukon's growing population and the subsequent rise in Whitehorse's population. Little Atlin Lake, being near Whitehorse, is conveniently located for the angling community. Other factors that may be contributing to the increasing effort include the quality of the boat launch, its proximity to Snafu and Tarfu Parks campgrounds, and a growing interest in the whitefish and pike fisheries.

With an excess of 45% of anglers targeting Northern pike, and only 20% seeking lake trout and lake whitefish, respectively, Little Atlin Lake is primarily a Northern pike fishery. This is not surprising given the reported low lake trout catch rates. With a substantial portion of the lake being shallow and a mean depth of 10.6 m, bathymetric data suggests that Little Atlin Lake has little suitable lake trout habitat, but a great deal of shallow, vegetated habitat near shorelines for Northern pike (Figure 1).

It is worth noting that in 2016 the Department of Environment in conjunction with the Yukon Fish and Game Association gave lessons on how to angle for lake whitefish both during the winter and open water season. Additionally, a public video was released demonstrating summer angling techniques. It was hoped that by diversifying Little Atlin Lake's sport fishery, it would remove pressure from the preferred species of Northern pike and lake trout. This effort may have been successful as creel surveys have indicated an 18% rise in anglers who are targeting lake whitefish.

It is also interesting that there is evidence of an increasing number of anglers opting to fish on the weekdays rather than the weekends (Figure 4). This may suggest that anglers are attempting to avoid crowding and/or they are ensuring that they secure spots in the neighbouring campgrounds at Tarfu and Snafu lakes prior to the weekend rush.

The results of our survey indicate that the concerns of the Carcross / Tagish Renewable Resource Council, suggesting that the angling pressure on Little Atlin Lake is growing, are warranted. As such, it is important that we closely monitor this lake, to ensure that Little Atlin Lake remains a quality fishery.

Lake Trout Status

Fisheries independent data (SPIN Program)

SPIN surveys for Little Atlin Lake

SPIN surveys for Little Atlin Lake were conducted between 7 and 10 July 2015 and between 19 and 21 July 2021. In 2015, a total of 67 nets were randomly set based on strata (depth), while 70 were placed in 2021. Each set was set for approximately 2 hours. Captured fish were measured for length, weighed, and returned to the water.

During both surveys water temperatures and dissolved oxygen were also measured, and in 2021 water samples were collected confirming Little Atlin Lake is a low nutrient lake (oligotrophic). Average water temperature during our SPIN survey in 2015 was 17°C, and for 2021 it was 15.5°C.

Lake Trout Monitoring Program (CUE and density estimates)

In 2015, we captured an average of 0.33 fish/net compared to 0.08 fish/net in 2021, resulting in a 65% decline in estimated density and population size between the two surveys. However, associated with this decrease, is a drop in the confidence of the 2021 estimate. This is due to the small sample number we acquired in comparison to 2015 (Table 3). In general, the precision of our estimates was low and should be considered with caution.

Regardless, our estimates indicate that the Little Atlin Lake trout population is small and has declined. Due to the confidence surrounding our 2021 results we did not find a significant difference between sample years for either our density or population estimates.

Table 3. Summary of population, density and catch per unit effort (CPUE, number of fish per net) estimates generated for the Lake trout population of Little Atlin Lake using the 2015 and 2021 SPIN data.

Survey Year	Population Estimate	Density Estimate (lower, upper 95% CI)	Mean CPUE (95% CI)	Net Count (N)
2015	4,200	2.1 kg/ha (0, 8.5)	0.33±0.25	67
2021	1,500	0.7 kg/ha (0, 6.7)	0.08±0.05	70

Lake Trout Monitoring Program (Length Data)

The Lake trout captured during the 2015 and 2021 SPIN surveys had mean fork lengths that were not statistically different (T-test: t (16.871) =1.72, p = 0.104; Figure 5). However, fork length was slightly smaller and more variable from fish captured in 2021 compared to those from 2015 (Figure 5). We applied similar fishing effort during both years, but fewer fish were captured in 2021 (15 fish in 70 net set) than in 2015 (44 fish in 67 net sets). The smaller sample size in 2021 created greater variability that year.

During both surveys, the proportion of lake trout larger than 586 mm (regulation size limit converted from total length) was 20%. Which suggests that our current regulations protect a possible 20% of the Little Atlin lake trout population from harvest.

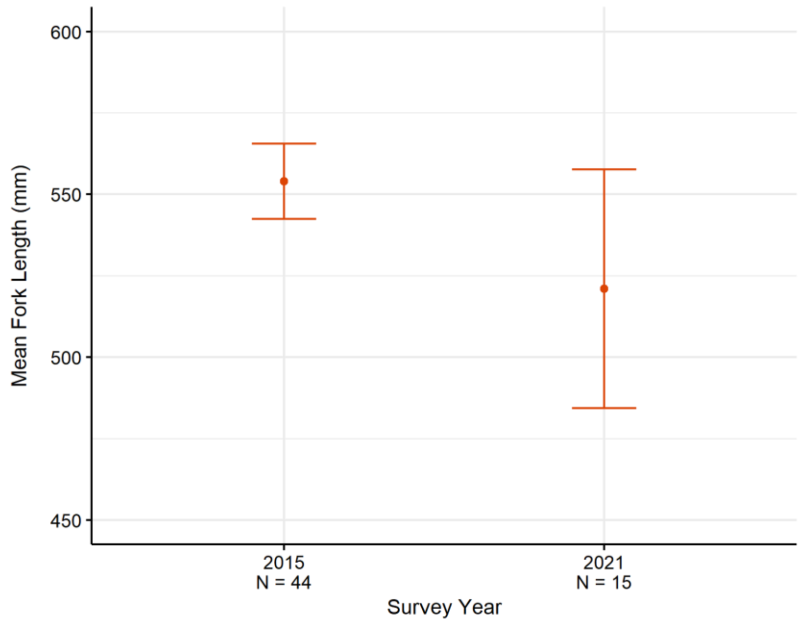

Figure 5. Mean fork length (mm) of lake trout sampled during the 2015 and 2021 SPIN surveys. Bars are 95% confidence intervals.

Fisheries Dependent Data (Creel Program)

Recreational Catch and Harvest Pressure (catch per unit effort)

The lake trout fishery for Little Atlin Lake is predominantly a spring fishery (mid-May until the end of June) with a small resurgence occurring in the fall (Figure 6). This is the result of spring littoral and surface water temperatures being below 15°C, which ensures lake trout, are present in the upper water column. As we move towards the summer, surface temperatures increase and lake trout retreat to deeper waters, becoming more difficult to catch. This change in habitat use influences angler CPUE as summer progresses through the summer. Therefore, we estimated CPUE for the spring lake trout fishery only (Figure 7).

We chose to report total CPUE instead of targeted CPUE to account for the proportionally small number of anglers who only target lake trout (Figure 2). Most spring anglers are targeting both lake trout and Northern pike, and both species can be caught in similar water depth during spring. This results in a higher by-catch of lake trout by those anglers targeting Northern pike. At Little Atlin Lake, anglers catch a lake trout on average every 4-5 hours in the spring. The catch rate remained relatively consistent over the past 20 years. Spring CPUE has ranged from 0.15 to 0.29 fish/hour (Figure 7). In 2015, catch rates increased, deviating from the overall mean, this increase is the result of an inflated estimate of CPUE due to a high number of incomplete surveys (25%). Average fishing effort (hours) is calculated for each fishing day and this value is assigned to all incomplete surveys for the purpose of extrapolation. If there is a high number of incomplete surveys, uncertainty increases in our estimates of effort and subsequently catch rates, resulting in a possible inflation of true catch and effort values.

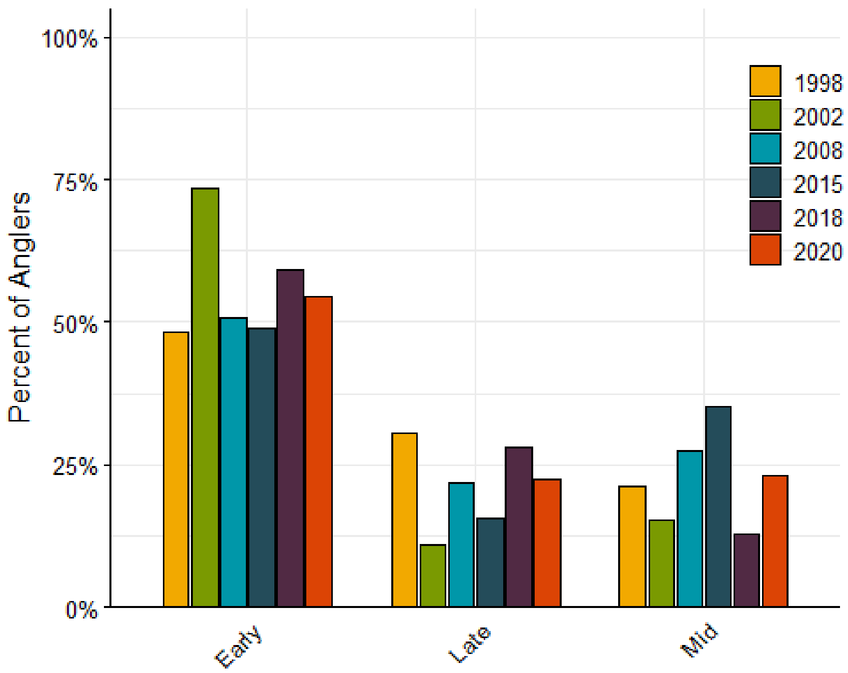

Figure 6. The percentage of anglers who reported targeting lake trout during the early, mid and late summer months on Little Atlin Lake. In 1990, targeted data were not collected.

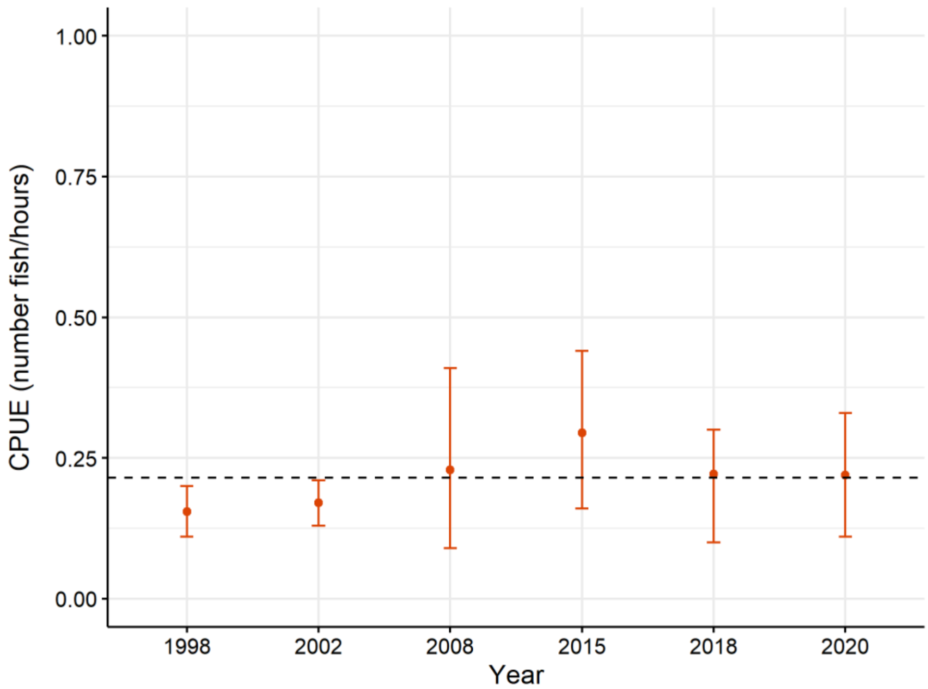

Figure 7. Spring catch per unit effort (CPUE) trends for lake trout sampled during summer angler surveys between 1998 and 2020.

Recreational Catch and Harvest Rates

We estimated lake trout catch for the full summer season. On average, summer anglers catch less than one lake trout per visit (Table 4). Total summer catch estimates for the lake trout fishery have been variable across survey years, for instance in 2015 nearly three times the number of lake trout were estimated caught compared to the prior survey in 2008 (Figure 8). This variability might be attributable to environmental conditions that enhanced the quality of fishing.

Fewer than 10% of anglers reported catching more than the average of one lake trout per day, and fewer than 5% reported catching two or more lake trout (Figure 4). Catch numbers exceeding four lake trout in a day have only been reported by 7 anglers (2 in 2015 and 5 in 2020). For all survey years combined, only two parties reported catching more than 10 lake trout during a trip (14 Lake trout in 2015 and 13 in 2020) (outliers).

Despite the variability in total catch estimates, the harvest estimates have remained relatively constant among all survey years, ranging from 68 to 116 individuals, with an average of 90 lake trout retained per summer (Figure 8). Anglers are limited to a catch and possession limits of 1:1, therefore with higher total catches the proportion of lake trout live released concurrently increases. In 2018 and 2020, relatively equal proportions of lake trout were retained and released.

Table 4. Summary of lake trout caught and retained per angler per visit (fishing day) for each survey year.

Survey Year	Average Catch/Day	Max Catch/Day	% Anglers Catching >2/Day	Average Retention	Max Retention
1998	0	4	2%	0	4
2002	1	4	2%	0	2
2008	0	4	1%	0	1
2015	1	14*	5%	0	2
2018	0	4	1%	0	1
2020	1	6	3%	0	2

**The 2015 max catch is based on two interviews, during which the angling parties reported catching 13 and 14 lake trout per angler. When these two outliers are removed, the max angler catch/day for 2015 is 6 lake trout.*

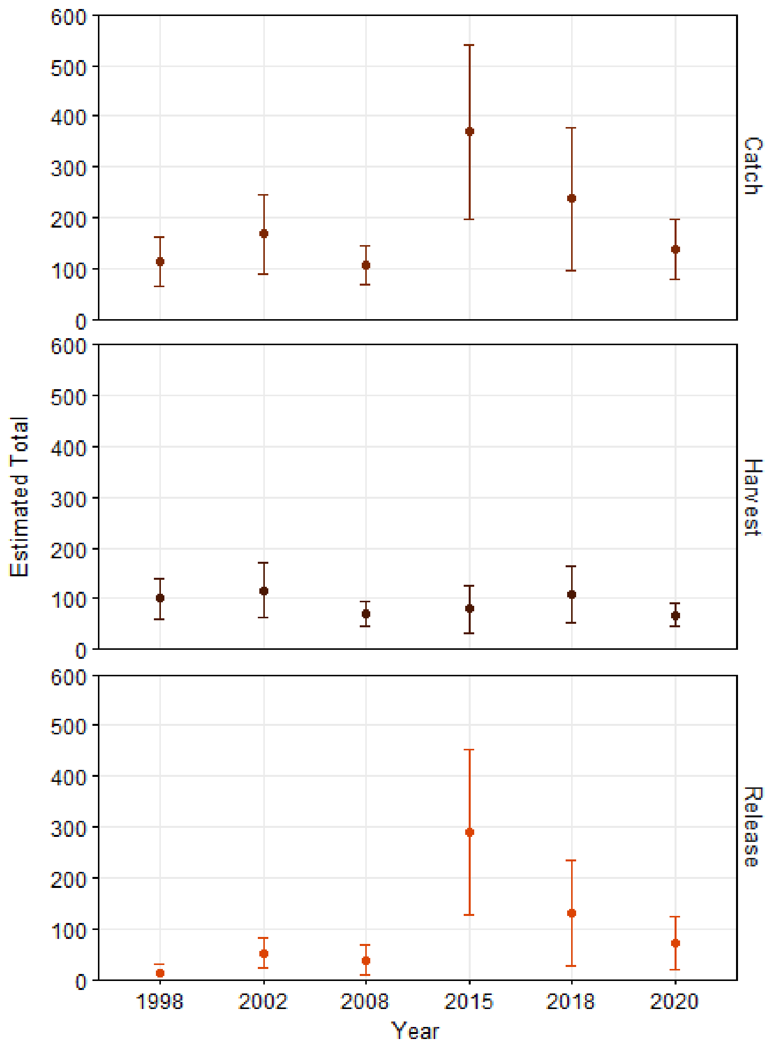

Figure 8. Estimate number of lake trout caught, harvested, and released during the summer angling season at Little Atlin Lake during survey years conducted between 1998 and 2020. Bars indicate 95% confidence intervals.

Harvest Size Structure

Between 1998 and 2020, 172 lake trout fork lengths were collected through our angler survey programs. Harvested lake trout ranged in fork length (FL) from 380 mm to 650 mm.

In 1997, a newly established regulation prohibited the retention of Lake trout greater than 586 mm in fork length (650 mm total length, Hansen et al. 2020). As such, to ensure equivalence among years when comparing age and length composition, we chose to omit all samples that were greater than the 586 mm length limit. This resulted in the elimination of 28 samples from the data set.

We did not find significant differences among sample years when we compared the size and age structure of harvested lake trout between 1998 and 2020. No significant differences in mean fork lengths (ANOVA: $F(5,138) = 0.306$, $p = 0.909$; Figure 9) were detected among years. However, this result must be interpreted with caution, small sample sizes coupled with large variability in the data, may have led to spurious conclusions based on weak statistical tests (e.g., n = 11 for 2015). Because we did not find a significant difference in fish size among sample years, we chose to combine the length data to provide an overview of the length frequency distribution of angler harvested catch for Little Atlin Lake trout (Figure 10).

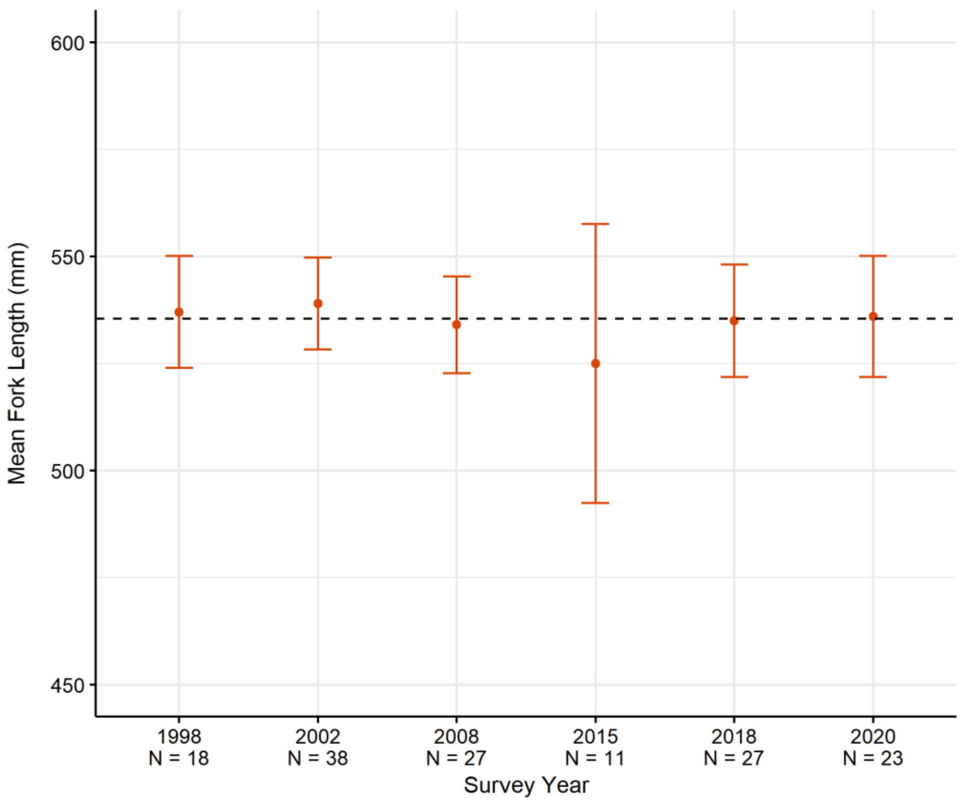

Figure 9. Mean fork length (mm) of harvested Little Atlin lake trout by survey year. Bars indicate 95% confidence intervals, and the dashed line is the overall fork length mean of 536 mm.

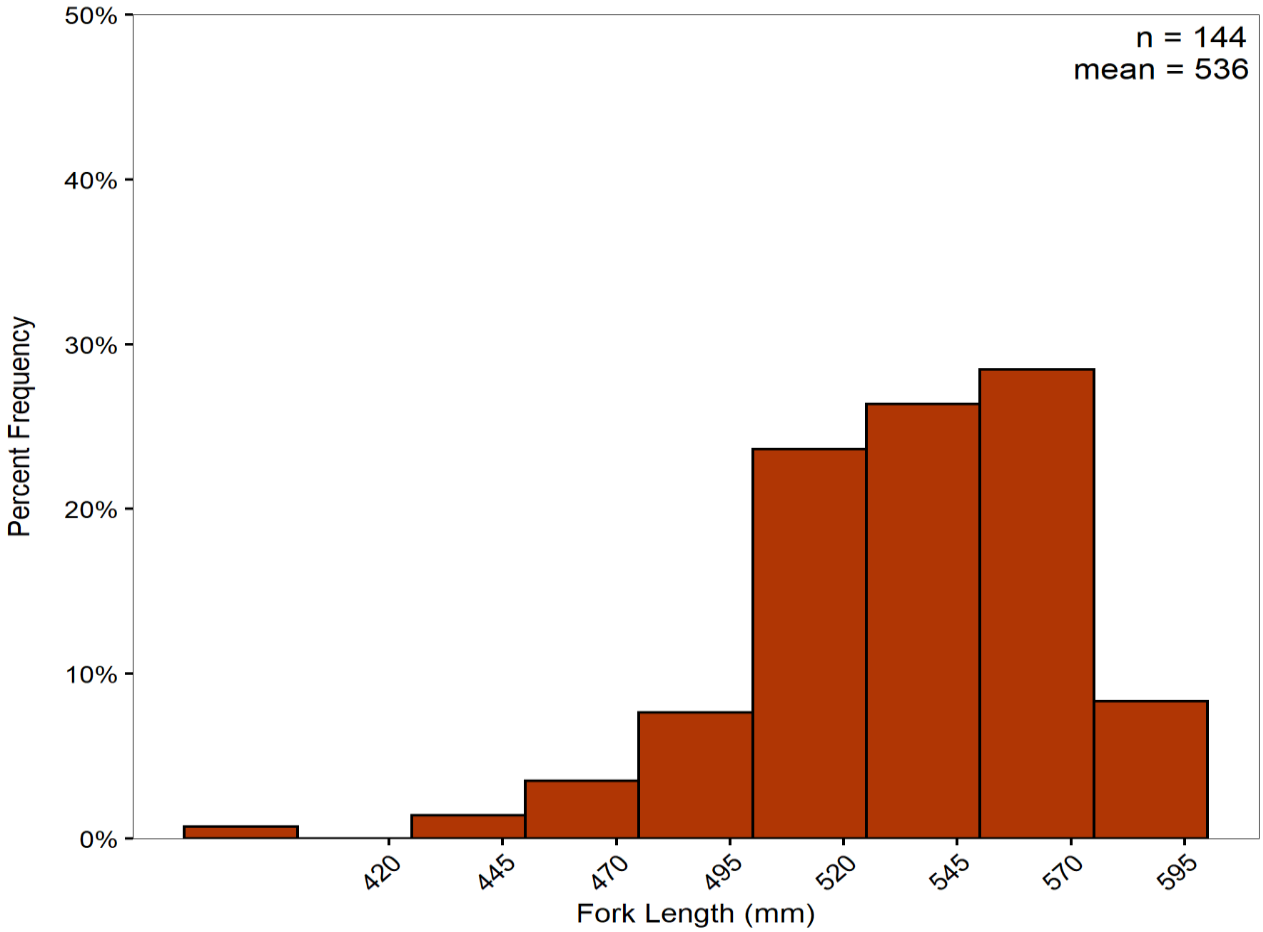

Figure 10. Length frequency distribution of angler harvested catch for Little Atlin lake trout; all years included (1998, 2002, 2008, 2015, 2018 and 2020). n = sample size.

Harvest Age Distribution

Otoliths (ear stones) were opportunistically sampled from lake trout during angler surveys conducted between 2002 and 2020 to age harvested fish. The range of lake trout ages among survey years was between 7 and 25 years old.

In 2002, only 4 otoliths were collected, from a possible 44 samples. Due to this small sample and the potential for bias, we chose to omit the 2002 age data from our analyses. No significant differences in mean age (ANOVA: F (66) = 0.525, p = 0.667; Figure 11) were observed across survey years.

Though not statistically significant, the proportion of fish that were either immature, or were at the age of first maturity, made up a sizable portion of the harvest (Figure 12). There was also a slight drop in the mean age of the sampled fish in the latter two sampling years. Our ability to conclusively determine if these observations are of biological significance is hindered due to inadequate sample sizes and high variability in the data.

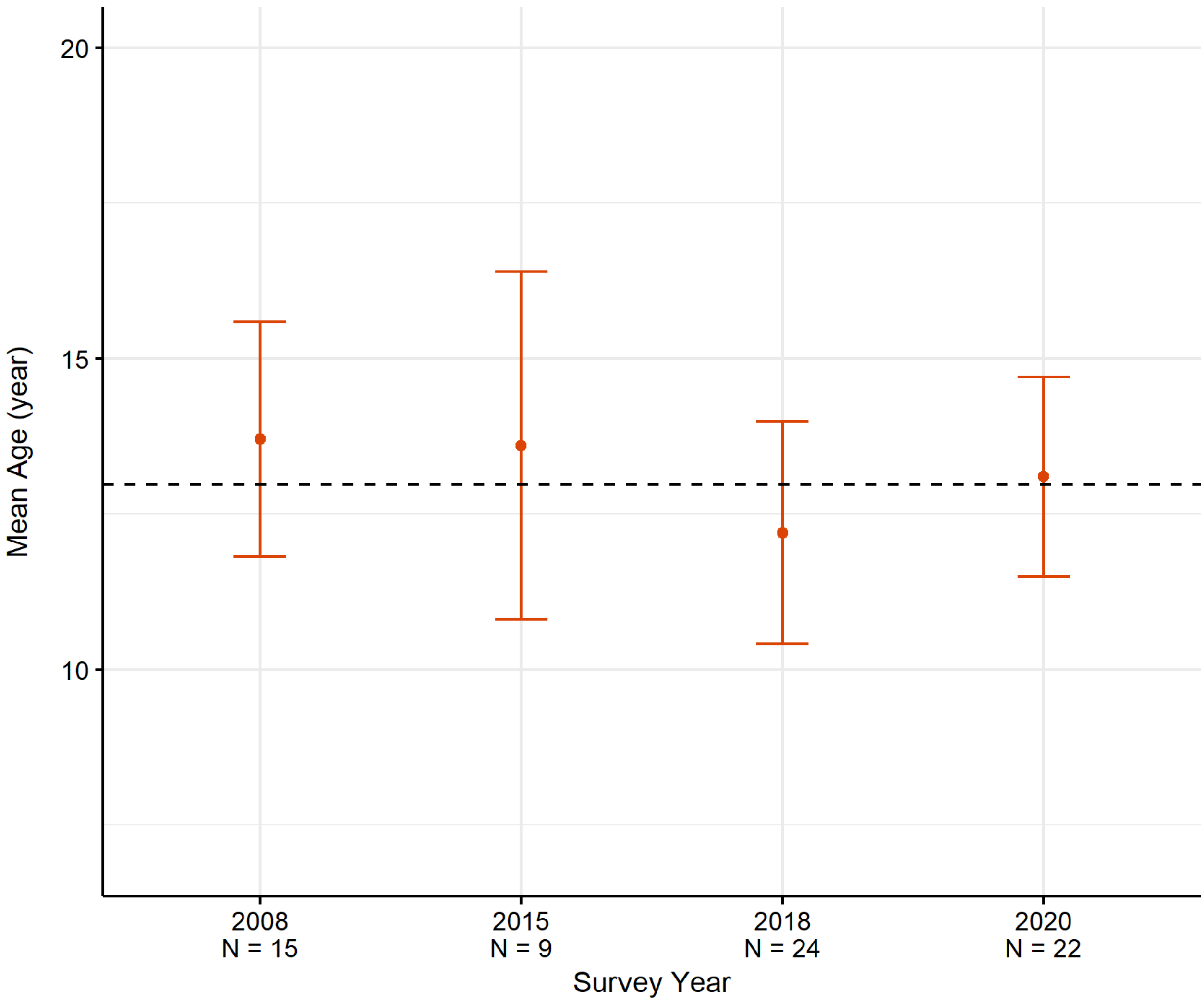

Figure 11. Mean ages by angler survey year of harvested Little Atlin lake trout. Bars indicate 95% confidence intervals, and the dashed line is the overall mean age of 13. N = sample size.

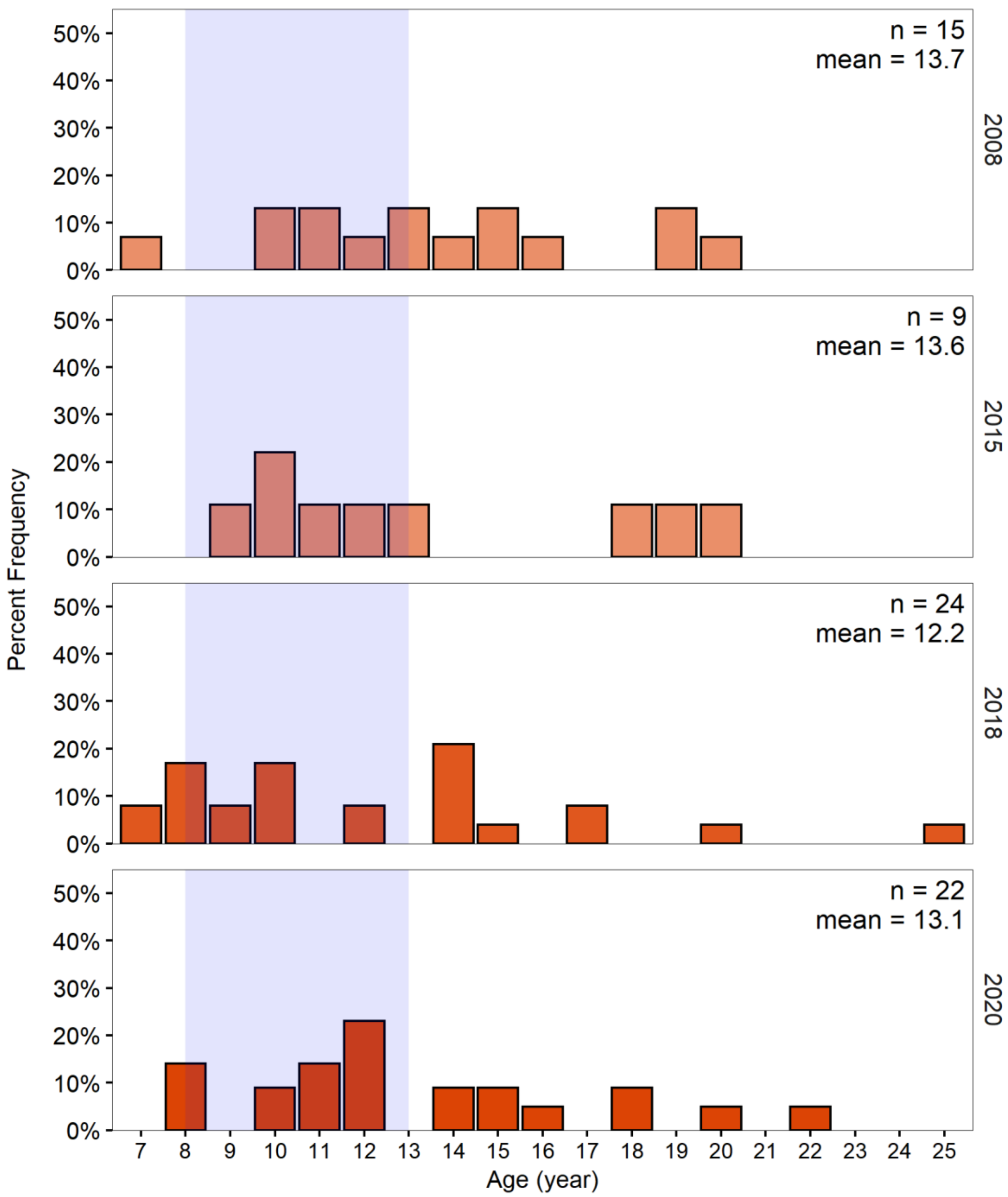

Figure 12. Age frequency distributions of harvested Little Atlin lake trout collated by survey year. The shaded blue bar illustrates the zone when lake trout first became sexually mature (ages 8-13). n = sample size.

Harvest Growth Rates

To model lake trout age-at-length, we pooled all samples collected from our SPIN and creel program (n = 116) and then plotted them separated by males (n = 59) and females (n = 53). Fish ages ranged from 7 to 36 years. The absence of any lake trout younger than 7 limited our ability to fit our data to a VBGC. To compensate for this, we added an additional 44 immature lake trout samples, ranging from 2-4 years, collected from 11 Yukon lakes with similar productivity and species compositions. To use the samples in this manner, we assumed that the aggregate would represent an average, from which the growth parameters of immature fish from Little Atlin Lake would be captured (Madenjian et al. 1998).

We also assumed that sexual size dimorphism does not occur prior to the onset of sexual maturity (that is, the sexes do not grow at different rates; Reyes-Gavilán et al. 1997, Englmaier et al. 2021) and therefore used the data to model growth for both sexes. Subsequently, VBGC were fitted to the data to establish overall growth coefficients for male and female lake trout (Figure 13). While both male and female lake trout appear to grow at similar rates (K = 0.3), females reach larger sizes than males. Neither sex had average asymptotic lengths greater than the current regulation size limit of 586 mm (Female Linf = 585 mm and Male Linf = 561.3 mm).

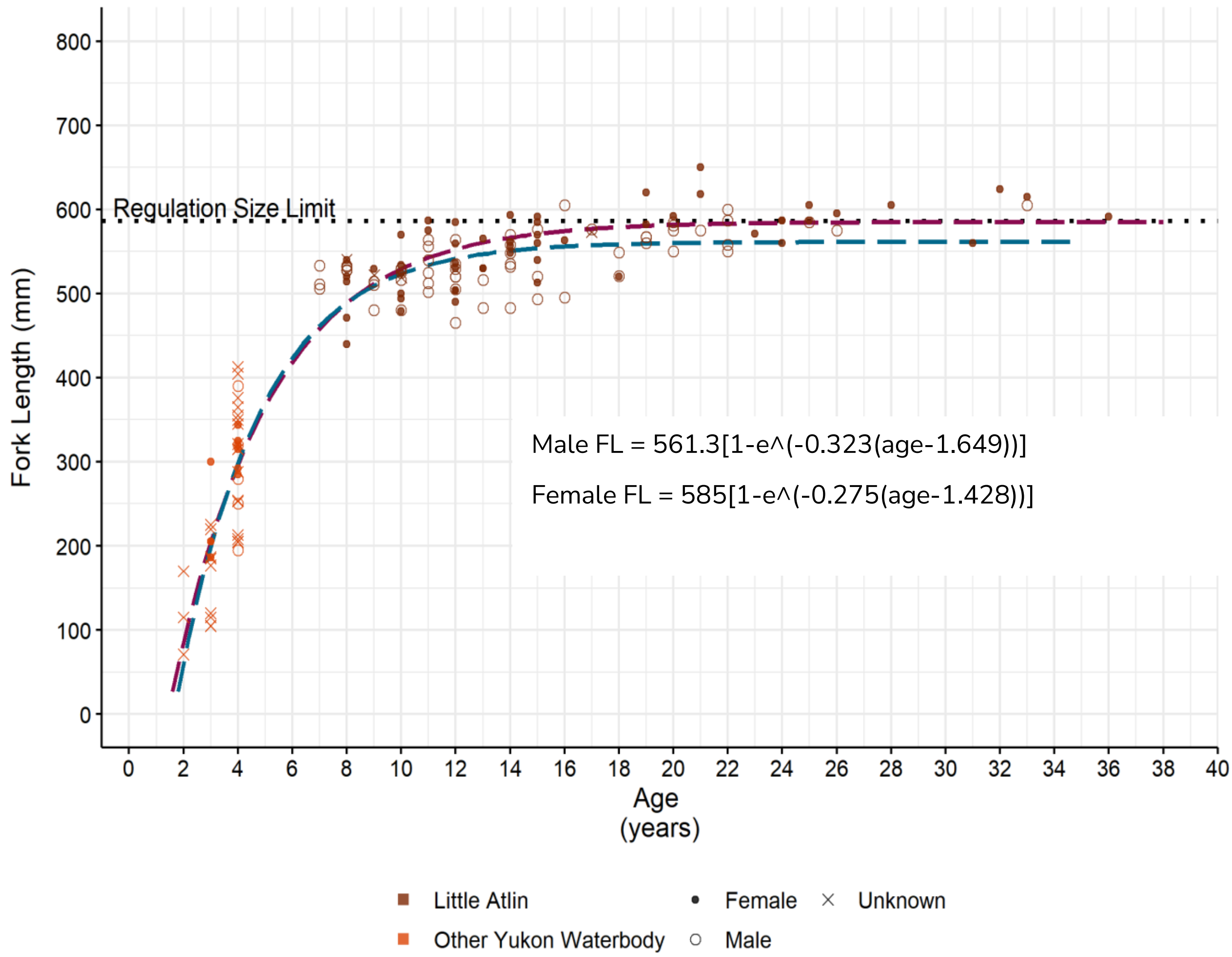

Figure 13. Length-at-age data were plotted by sex (female and male) for the Little Atlin lake trout using data from 2002 to 2021 (n=116) and immature fish age data (2-4 years, n=44) collected from 11 other Yukon waterbodies with similar productivity and species composition. A von Bertalanffy growth curve was fitted to both the female (red line, FemaleFL) and male (blue line, MaleFL) data, independently. The regulation size limit of 650 mm total length has been converted to fork length (586 mm FL; Hansen et al. 2020) and is identified by the hatched line.

Discussion: Lake Trout Status

Fisheries independent sampling

Our estimates of population size from the SPIN sampling indicate the lake trout population in Little Atlin Lake is small, relative to other Yukon lakes. This is likely due to habitat limitations. This finding is consistent with previous work done on Little Atlin. Millar et al. (2012) found the population was small and they also contributed its size to habitat limitations. Based on our bathymetry results, Little Atlin Lake does not have a large amount of deep-water habitat for lake trout. As such, this small population may be vulnerable to over-exploitation and therefore special regulative protections and frequent monitoring may be warranted.

For example, when we compared our 2015 SPIN population estimate to the recent 2021 results, we found a 64% drop in population size, with an accompanying drop in the number of individual lake trout caught per hour (Table 3). While there is great uncertainty in our population estimates, it does point to a lake trout population that may be in decline. Lending support to this assertion, when we compared the mean lengths of the lake trout sampled in the 2015 SPIN program with those sampled from 2021, we noticed that the average catch size had declined by 3.3 cm, a small drop of approximately 6%. While this drop was not statistically significant, in combination with our population results, it is concerning. Comparable size declines have been documented in other fisheries, where fish populations have been determined to be over harvested (Van Den Avyle and Hayward 1999).

Fisheries dependent sampling

Our creel results were ambiguous in comparison to our netting data. Nevertheless, during the past 20 years, the summer fishing effort on Little Atlin has increased (Figure 3) and so too has the numbers of anglers seeking lake trout (Figure 2). Nevertheless, since 2015, lake trout anglers have predominantly practiced live release fishing and therefore, the proportion of lake trout harvest has remained relatively consistent throughout the surveyed years (Figure 8). While this conservation practice has undoubtedly helped to offset the influences of the increased fishing effort, it may have also led to an increase in inadvertent mortalities associated with the practice.

There are associated mortalities with live release which occur due to the influences of warmer water temperatures, extended handling times and poor hook placements (Sitar et al. 2017). This is particularly true for cold water species, such as lake trout. For much of the summer, lake trout tend to spend their time in deep, cold waters, in the thermocline. Typically, when angled, they are pulled up from these cold water refugia into shallow, warmer waters. The combination of the handling time, pressure change (barotrauma) and the shock of warmer water can be detrimental to a successful live release.

Between 1998 and 2015, spring CPUE rates trended slightly upwards, followed by a slight decline following 2015 (Figure 7). In association with this trend, the lake trout catch numbers also increased until 2015, albeit the trending was not as consistent. There is a strong concordance between catch and release numbers throughout the surveys. However, results for the 2008 creel and all creels prior, indicate that the numbers released always fell below those that were harvested. Since 2015, this trend has reversed, with numbers released exceeding those harvested. This angler behavioural shift was an outcome of a regulative change that occurred in 2004/2005.

At that time, Little Atlin Lake was reclassified from Conservation to Special Management Waters. In association with this reclassification, the lake trout retention limit was dropped from two to one. Thus, to ensure that they could continue fishing throughout the duration of their trips, most anglers released their fish, retaining only one.

The 2005 reduction in harvest limit was implemented as a proactive measure to address concerns about increasing angling pressure on Little Atlin's vulnerable Lake trout population (*personal communications*, Chair of CTRRC). It was hoped by reducing the bag limit, the harvest numbers would drop.

In accordance with our creel results, the limit reduction has not had the desired effect, as harvest numbers have remained constant (Figure 7). Overall, results from our six creels indicate that harvest numbers have ranged between 68 and 116, with an average of 90 lake trout retained per summer. It is likely that any compensatory gains realized by the reduction in bag limit were offset due to the substantial increase in fishing effort (Table 2). Further, on average, most anglers only catch one lake trout per trip (Table 4) and therefore, the current bag limit is unlikely to have an effect in reducing harvest as effort continues to grow.

When we examined the trends in overall catch numbers across creel years, we noticed that, in association with catch rates, the reported catch in the last two creels (2018 and 2020) have been trending downwards, when compared to the harvest peak in 2015. Whether this decline is indicative of a stock decline or a return to the long-term average, we cannot say. Regardless, it is an indication that the Little Atlin lake trout fishery requires close monitoring.

In general, when we examined the age and length composition from the angler's catch our findings were inconclusive. Due to Little Atlin's small population size, anglers do not catch many lake trout (Table 4). As such, few fish are harvested and fewer still, are sampled. This lack of samples leads to large variability and little confidence in the collated data, leading to Type II errors (Quinn and Keough 2002). Wherein, the population might be experiencing a significant change, but we cannot find significance because the sample sizes are too small to overcome the data's variability.

When we compared the average fish length among our six creels, we did not observe any significant trends. While body size of angler harvest ranged from 380 and 650mm, mean lengths fluctuated closely around the overall average of 536mm (Figure 9).

The above stated, our length measurements indicate that 80% of Little Atlin's harvested lake trout fall beneath the current maximum length limit for a harvestable fish (Figure 13). Specifically, when we modelled lake trout growth for Little Atlin, neither sex had an average asymptotic length greater than the current regulation size limit of 586 mm (Female Linf = 585 mm and Male Linf 561.3 mm).

Therefore, the current regulation is not effective in protecting the majority of Little Atlin's spawning stock, allowing anglers to harvest almost everything. This is concerning as lake trout from small oligotrophic lakes have been shown to attain maturity at older ages (8-12 years) and smaller body sizes (Trippel 1993). In the case of Little Atlin, the age at first maturity begins when the fish are 489 mm in length.

Additionally, during our examination of fish length, we identified that 14% of the angler's harvest fish above the maximum length limit of 650 mm total length (586 mm fork length) and 2% of anglers retain more than the allowable bag limit. Given that 80% of the lake trout population is subject to harvest, these out-of-compliance anglers are inadvertently placing greater stress on the resource, as they are directly harvesting from the remaining, largest spawners.

Conclusion

While there are uncertainties with our SPIN results, our estimates of density and CPUE indicate the population of Little Atlin lake trout is small and may be in decline. Additionally, when examining the fisheries dependent data, we found that angler effort has increased over the years and with it, both the number of fish caught and released has grown. This is concerning because there is a portion of lake trout that die after being released, so as the number of fish released increases so too will unintentional mortalities. Given that many of these caught fish fall below the maximum size limit and that, on average, anglers catch only one fish per trip, it is unlikely the current regulative size and bag limits protect the stock. As such, it may be advisable to enact revised slot-size guidelines or regulations that protect immature and maturing fish and safeguard this small population. The slot limit should consider the size-at-sexual maturity for lake trout. By so doing, it would minimize the harvest of fish that are immature or newly maturing, thereby ensuring most fish are given a spawning opportunity, before they are susceptible to harvest. It has been documented that failing to protect these smaller, younger fish may cause a population to be vulnerable to collapse (Myers and Mertz 1998). The upper bound of the slot would also consider the maximum size that lake trout at Little Atlin Lake can achieve.

Northern Pike Status

Fisheries Dependent Program (Creel Program)

Recreational Catch and Harvest Pressure (catch per unit effort)

Targeted CPUE for Northern pike varied little between 1998 and 2018; anglers were catching an average of one fish per hour. However, in 2020, we observed a decline in targeted catch rate relative to the prior survey year, dropping from 1.1 fish per hour in 2018 to 0.8 fish per hour in 2020, representing a 30% decline (Figure 14). While the mean daily targeted CPUE was significantly different among survey years (Kruskal-Wallis: H (11) =1,287.2, p <0.001), no significant differences were detected when a pairwise comparison test was applied at an alpha level of 0.05 (Dunn's test bonferroni adjusted p >0.05). This suggests that our small sample sizes for targeted CPUE resulted in a type II error (i.e. a false negative, Quinn and Keough 2002). In a pairwise comparison test, the smallest un-adjusted p-value detected was between 2018 and 2020 and was significant at al alpha level of 0.1 (p = 0.07). Despite being small, this is the largest percent drop in CPUE recorded in 20 years and warrants further monitoring.

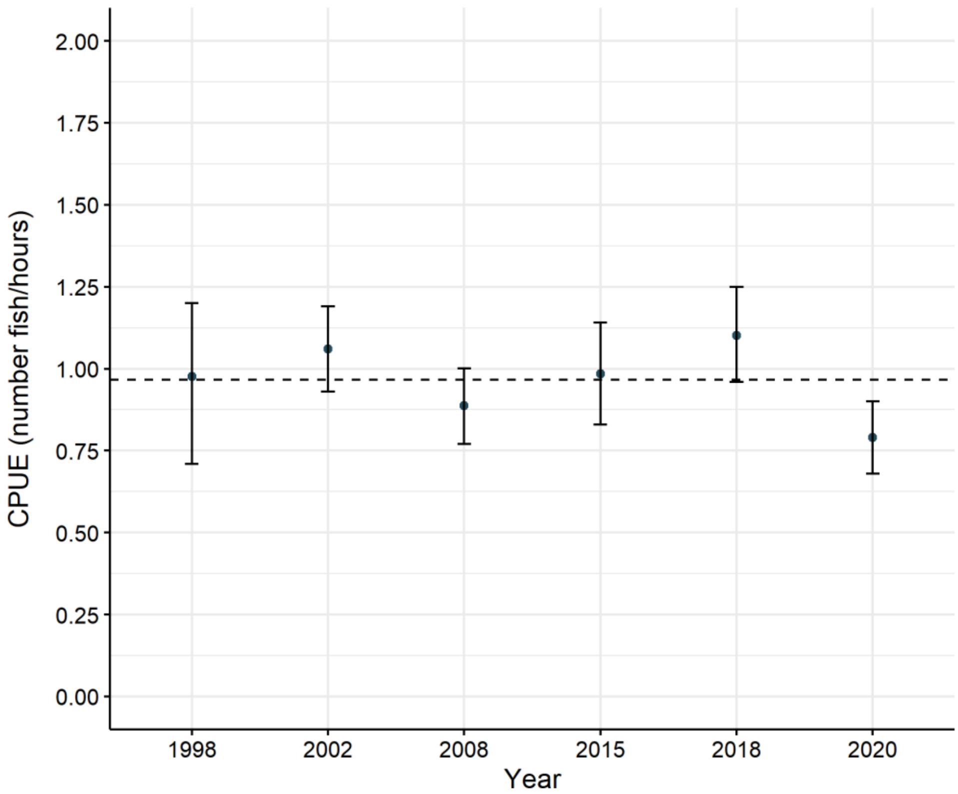

Figure 14. Estimates of Northern pike targeted catch per unit effort (CPUE) in Little Atlin Lake by angler survey year. Targeted data was not recorded in 1990.

Recreational Catch and Harvest Rates

The Little Atlin Lake Northern pike fishery is predominantly a live release, recreational fishery (Figure 15). Current catch and possession limits for Northern pike on Little Atlin Lake are 4 and 4, respectively. Anglers on Little Atlin Lake catch an average of 3 to 4 Northern pike per visit, but only retain one (Table 5). Most anglers report catching below four Northern pike per visit, with those catching more, ranging from 9%-14% (Figure 16, Table 5).

Between 1998 and 2018, in association with the rising fishing effort, catch and harvest estimates were also trending upwards (Figure 3). However, in 2020, we observed a 40% decline in total catch of Northern pike. This decline in catch represents the first since 2002 and is noteworthy because targeted effort had not significantly changed between 2018 and 2020 (Mann-Whitney W=12, p = 0.679), and no decline of this magnitude had been previously observed

Importantly, as effort on Little Atlin Lake increased between 1990 and 2018, so did the numbers of fish released and harvested. Combined, intentional and unintentional mortality, may be creating pressure on the population. For example, the numbers of fish harvested almost doubled between 2008 (389±151) and 2015 (760±243). Moreover, with the increase in the numbers of pike caught there has also been a concurrent increase in the numbers of fish released (Figure 15). Depending on hook placements and handling practices, released fish occasionally die later, albeit unintentionally (Arlinghaus et al. 2008).

Table 5. Summary of Northern pike caught and retained per angler per visit (fishing day) for each survey year.

Survey Year	Average Catch/Day	Max Catch/Day	% Anglers Catching >4/Day	Average Retention	Max Retention
1998	4	55	14%	1	4
2002	3	20	10%	1	4
2008	3	23	10%	1	4
2015	4	40	14%	1	4
2018	4	47	11%	1	6
2020	3	34	9%	1	4

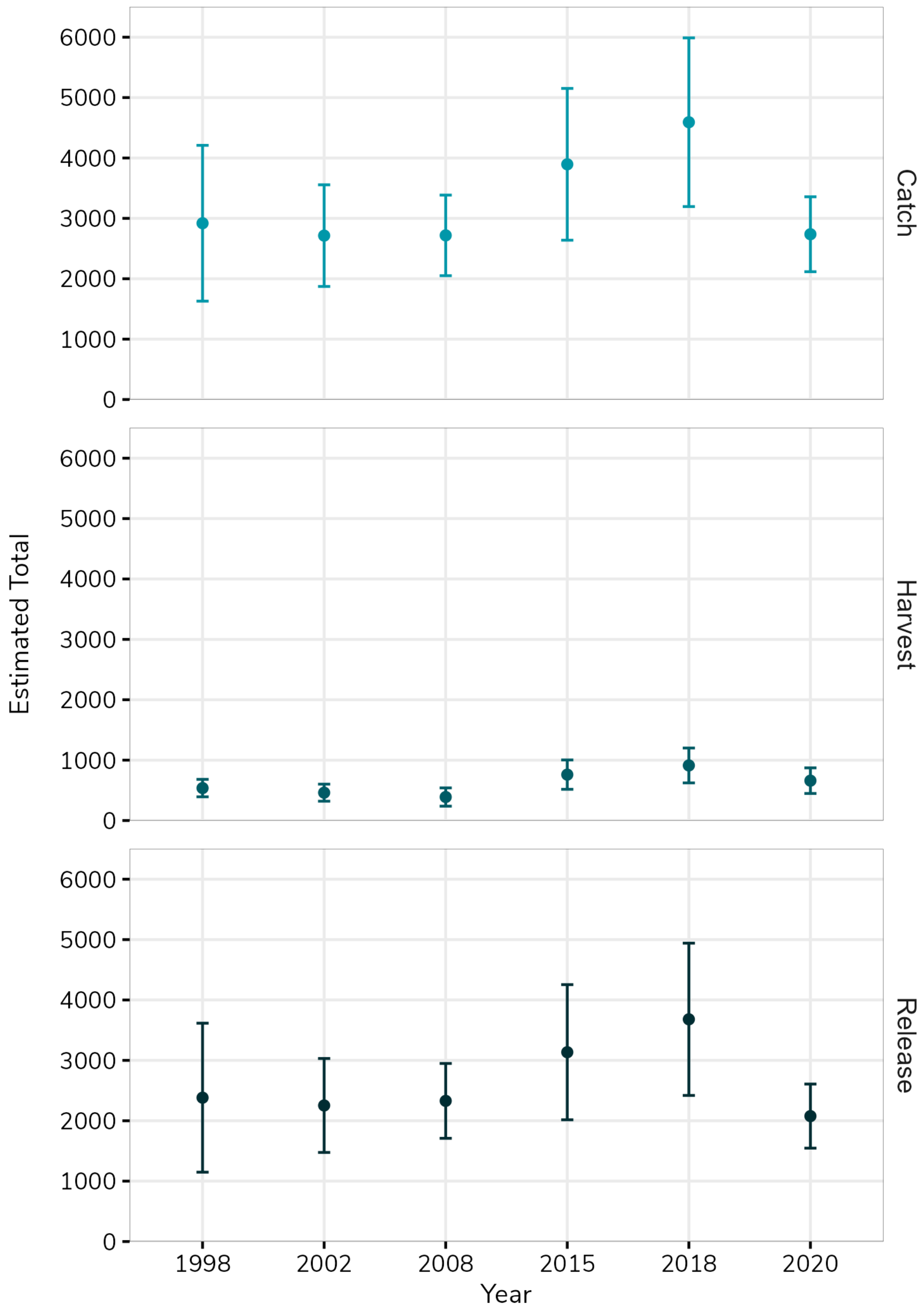

Figure 15. Estimates of Northern pike caught, harvested, and released during the summer angling season at Little Atlin Lake during survey years conducted between 1990 and 2020. The bars represent 95% confidence intervals.

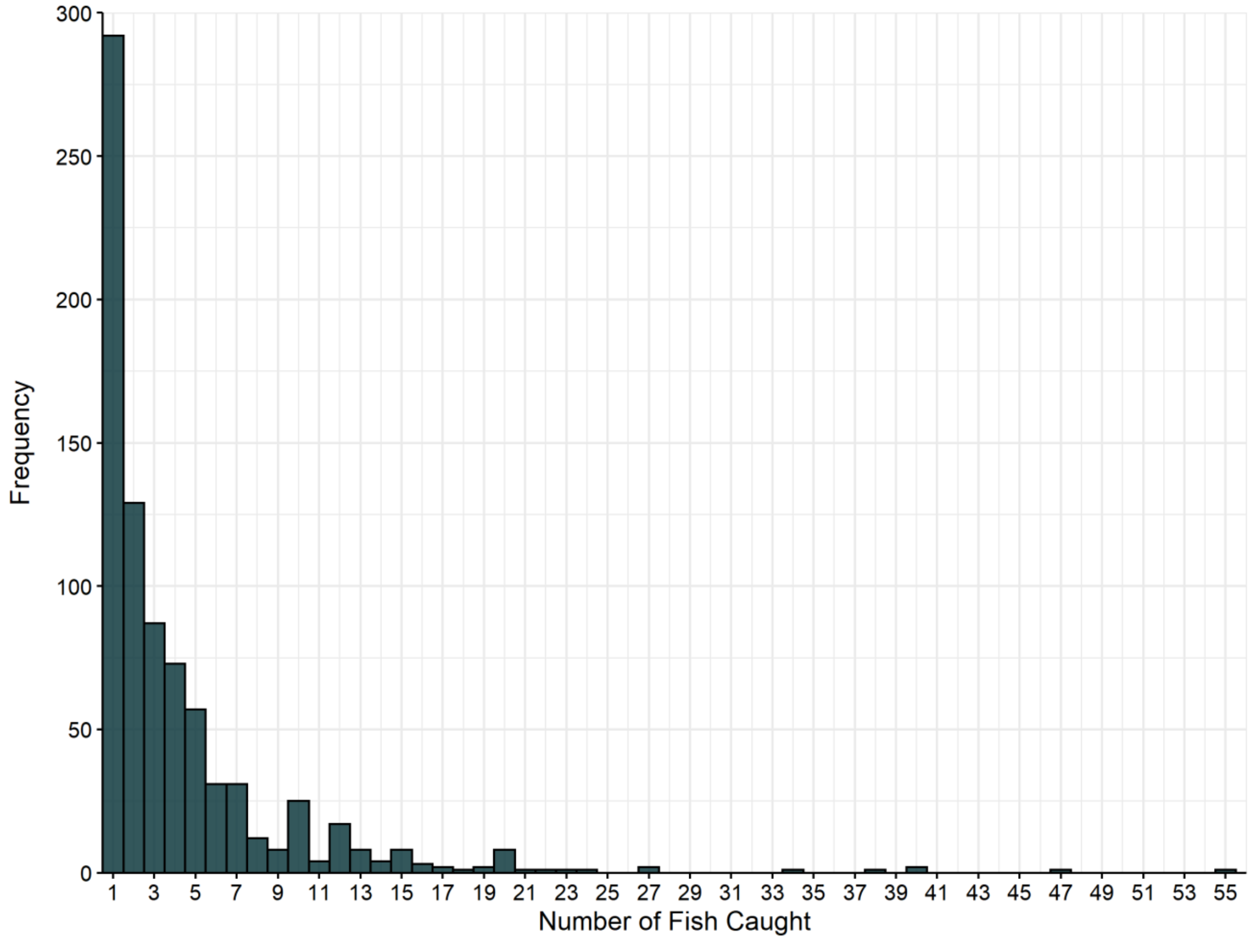

Figure 16. There were no significant differences in mean angler catch among survey years (ANOVA, F (5,968) =1.777, p = 0.115). Therefore, data was pooled across survey years (1998, 2002, 2008, 2015, 2018 and 2020) to demonstrate the frequency of reported numbers of Northern pike caught per angler per day on Little Atlin Lake.

Harvest Size Structure

Northern pike sampled during our summer angler surveys ranged in fork length from 385 mm to 1070 mm. However, since 1997, fishing regulations have prohibited the retention of Northern pike greater than 716 mm in fork length (750 mm total length). Therefore, to ensure comparability among sample years, 52 of the 915 samples were excluded from additional analyses because they exceeded the maximum size limit.

No significant changes in mean lengths were observed among sample years (ANOVA, F (5,857) =2.134, p = 0.06; Figure 17), annual mean fork lengths hovered above and below the overall mean length of 602±4.3 with no significant trends detected (Adj-R^2 = 0.00, F (1,861) =0.42, p = 0.5162). Moreover, the frequency distribution of overall length among sample years varied little (Figure 18).

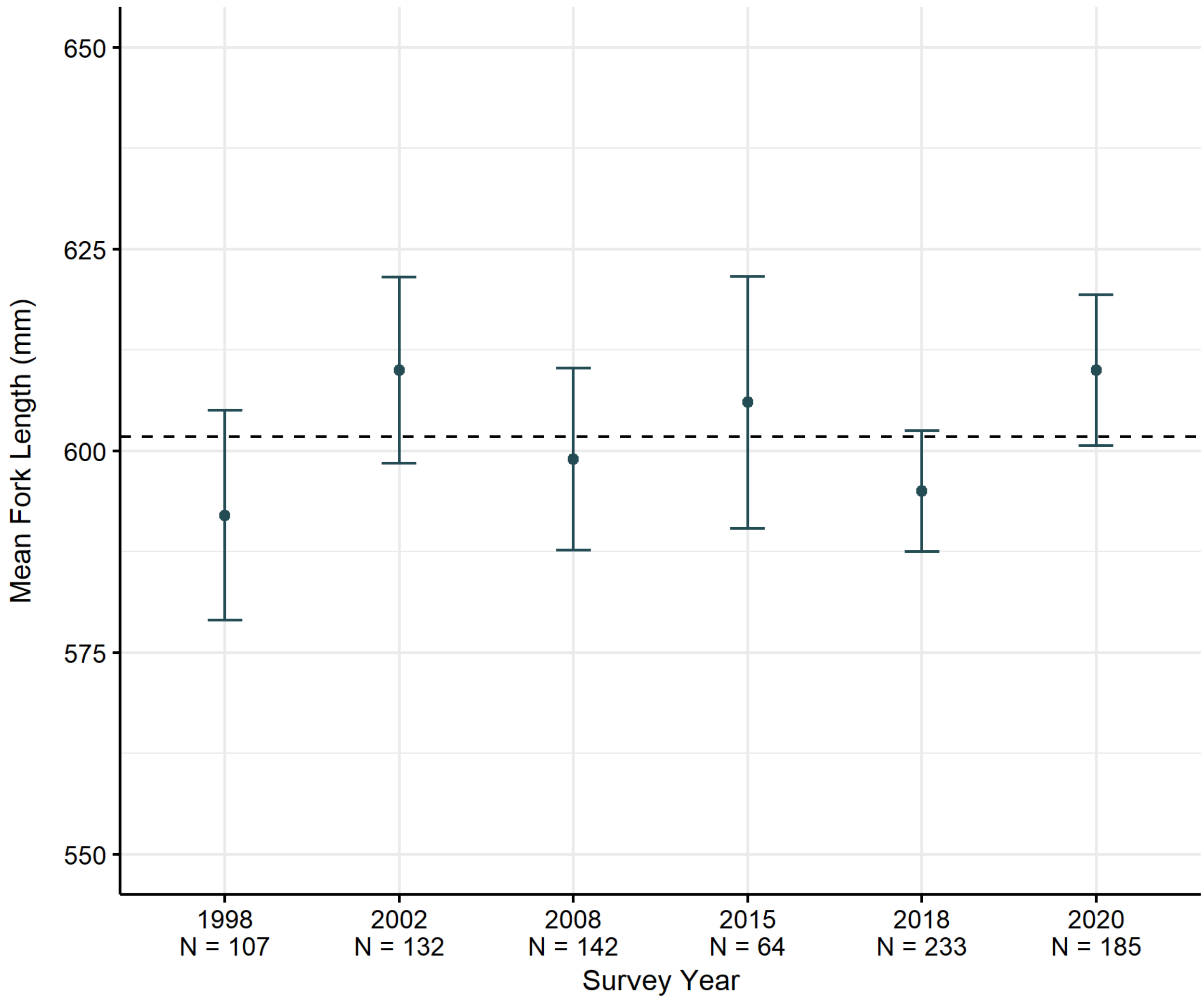

Figure 17. Mean fork length (mm) by angler survey year of harvested Little Atlin Northern pike. Bars indicate standard error, and the dashed line is the mean population fork length (602 mm).

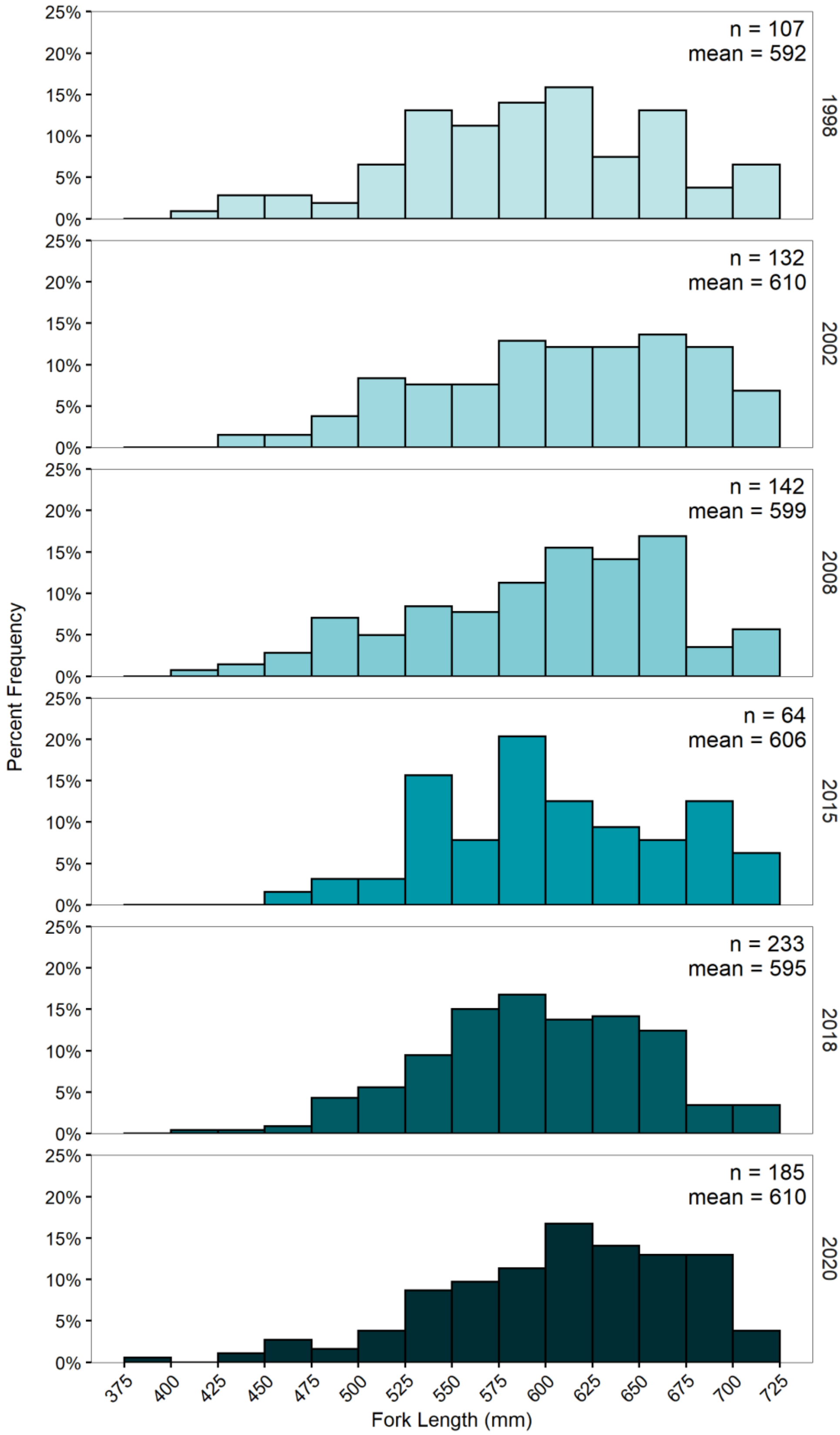

Figure 18. Length frequency distributions of Little Atlin Northern pike by angler harvest survey year. n = sample size. Fish that fall within the 700 to 725 mm bin are smaller than or equal to 716 mm in fork length (750 mm total length regulation size).

Harvest Age Distribution

Age structures for Northern pike were only collected in 2008, 2015, 2018 and 2020. Northern pike harvested between 2008 and 2020 have ranged in ages from 3 to 17 years. Mean ages in both 2018 and 2020, were younger than the mean ages in 2008 and 2015. When comparing among sample years, mean age significantly differed (ANOVA, $F(3,602) = 7.778$ $P<0.0001$; Figure 19). Northern pike harvested in 2018 were younger than those harvested in 2008 (Tukey's test: $p <0.05$) and those harvested in 2018 and 2020 were younger than those harvested in 2015 (Tukey's test: $p <0.01$).

When we graphically compared the age distribution of Northern pike harvested between 2008 and 2020, we noticed the population has seemingly truncated (Figure 20). Whereby, younger fish are becoming more prevalent in the catch composition and the frequency of Northern pike >8 years has declined by over 75%.

Our observed changes in age composition are supported by a concurrent increase in annual mortality (A), across survey years (Table 6). The annual mortality rate for Northern pike aged 6 and up (the age when fish are fully recruited to summer angling gear) increased from 33% to 57% between 2008 and 2020.

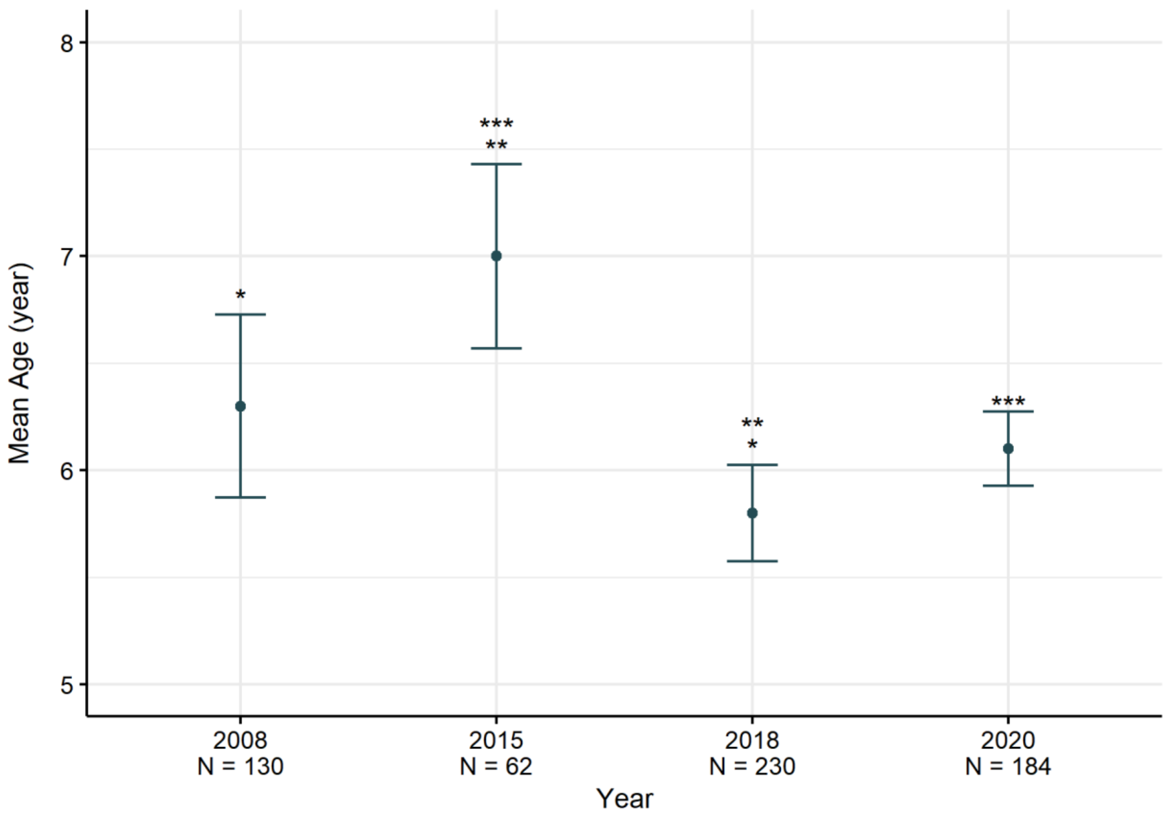

Figure 19. Mean age by angler survey year of harvested Little Atlin Northern pike. Bars indicate 95% confidence intervals and asterisk denotes which sample years were found to be significantly different. No age structures were collected prior to 2008.

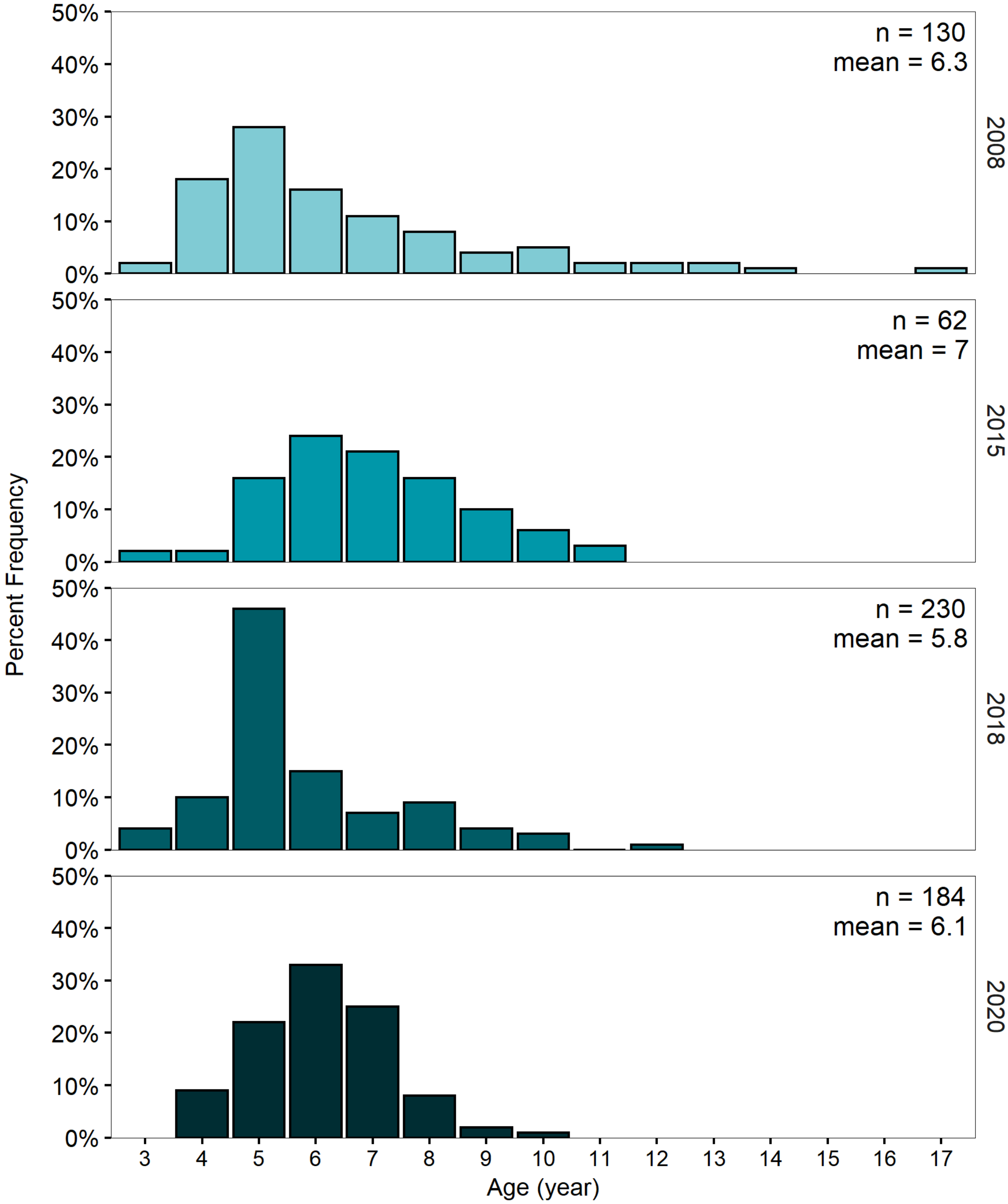

Figure 20. Age frequency distributions of Little Atlin Northern pike by angler survey year. n = sample size. No age structures were collected prior to 2002.

Table 6. Summary of instantaneous (Z) and annual (A) mortality rates (Chapman and Robson 1960) for Northern pike captured in Little Atlin Lake by survey year.

Year	N	Z (95% CI)	A (95% CI)
2008	130	0.41 (0.35, 0.46)	33% (27%, 40%)
2015	62	0.49 (0.34, 0.63)	39% (30%, 47%)
2018	230	0.51 (0.39, 0.62)	40% (34%, 46%)
2020	184	0.852 (0.58, 1.12)	57% (51%, 64%)

Harvest Growth Rates

To compare growth among sample years we used Northern pike length-at-age data sampled from the 2008, 2018 and 2020 creel surveys and fitted them with von Bertalanffy growth curves (VBGC). Because fish sampled prior to 2008 were not sampled for age, they were excluded from the comparison. Additionally, we confined our comparisons to only those years where there were at least 100 samples, this excluded the 2015 sample (N = 66). Other studies have found that sample sizes greater than 100 will improve the precision of the growth coefficient (K) by 29%, depending on the species (Kritzer et al. 2011).

A higher growth coefficient (K) was observed in 2020 (0.37, n = 194) when compared to 2018 (0.23, n = 242) and 2008 (0.24, n = 136) (Figure 21). Overall, males grew at a slower rate (K = 0.19) than females (K = 0.28) but, on average, attained a larger size (male Linf = 744.4 mm, female Linf = 735.9 mm).

Length and age data were natural-log transformed and an analysis of covariance (ANCOVA) with age as the covariate was used to explore age-corrected differences in length among survey years for each sex. Length-at-age coefficients were significantly different among the 2008, 2018 and 2020 surveys for both females (ANCOVA, $F_{(2,298)} = 3.32$, $p < 0.05$) and males (ANCOVA, $F_{(2,238)} = 5.95$, $p < 0.05$). For female Northern pike, a pairwise comparison test (post-hoc EMM, bonferroni adjusted) suggested age corrected lengths have significantly increased between 2008 and 2018 (bonferroni adjusted p = 0.0212). For males, we found that age corrected lengths have significantly changed between 2018 and 2020 (bonferroni adjusted p = 0.0166) as well as 2008 and 2020 (bonferroni adjusted p = 0.00402). These results indicate Northern pike at Little Atlin Lake are growing at faster rates.

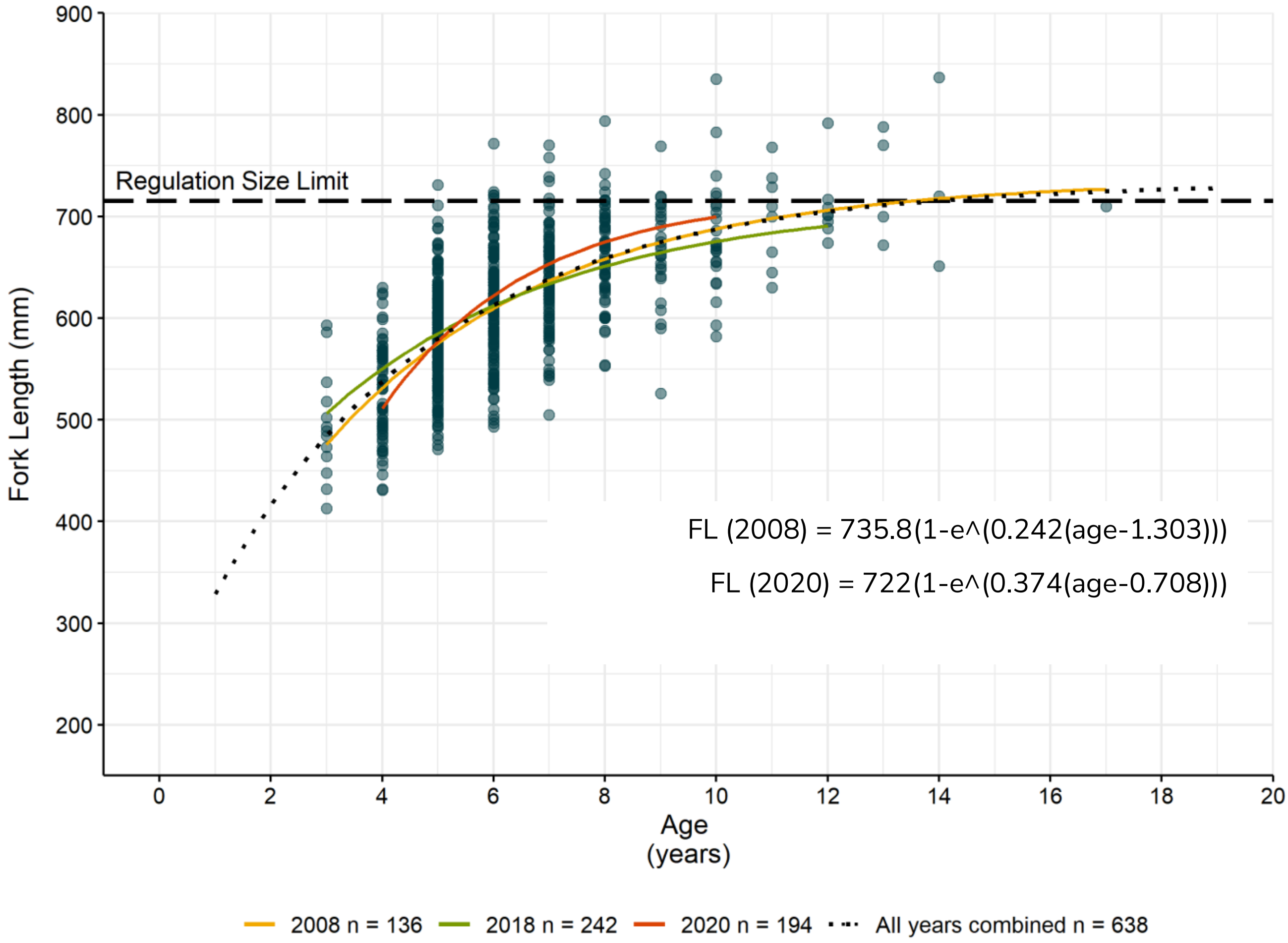

Figure 21. A von Bertalanffy growth curve was fitted (black dotted line) for the Little Atlin Northern pike population using length-at-age data from 2008 to 2020 (n=638) collected from annual summer angler surveys. Each year was subsequently fitted with von Bertalanffy growth curves to detect temporal changes in growth. For comparison, equations for 2008 and 2020 are presented. The regulation size limit of 750 mm total length (715 mm FL) is identified by the dashed line.

Discussion: Northern Pike Status

Our analysis of creel data from the Little Atlin Northern pike fishery indicates that both effort and catch have increased among survey years and with this increase the Northern pike population may be showing early signs of harvest stress. For instance, our results indicate the numbers of anglers increased between 1990 and 2018 and with this increase was an associated increase in numbers of Northern pike caught, released, and harvested (Figure 15). While mortalities have increased due to the increased harvest, it is likely there are also increases in incidental mortalities related to the practice of live release. Typically, the mortalities associated with live release occur when poor hook placements cause fatal injuries (Arlinghaus et al. 2008). In combination, these additional mortalities may be increasing pressures on the resource.

There is some evidence to indicate this is the case. For example, in 2020 a decline in catch rates (CPUE) occurred relative to 2018 (Figure 14). The lower catch rate led to a decline in the numbers of fish caught and released. Whether this decline is indicative of a one-time anomaly or an overall trend, it is too early to say. However, others have described similar declining CPUE trends in fisheries that are experiencing excessive harvest pressures (Anderson et al. 2008; Barnett et al. 2017; Ahrens et al. 2020; Bergström et al. 2022). They contributed the decline to thinning densities of fish.

Our analysis of the pike's growth further supports the possibility of a thinning population. We found that Northern pike are exhibiting increased growth rates. When we compared growth rates from 2008, to those in 2018 and 2020 we found significant rate increases for both males and females in the latter years. Such increases have been linked to density dependent effects for this species. As a population begins to thin, competition for resources diminishes and those remaining, benefit (Jacobson 1993; Margeneau et al. 1998).

Additionally, when we graphically examined the age composition among the yearly harvested catch we identified a trend towards larger numbers of younger fish, with the frequency of Northern pike older than 8 years of age declining. In association with this trend, the mean catch age has also gotten younger. We found significant differences existed between the 2008 and 2015 mean ages when compared to 2018 and 2020 (Figure 12). Accompanying the decline in mean age, mortality rates have also been increasing (Table 6). This is concerning as shifts in age compositions and higher mortality rates have been associated with populations that may be experiencing excessive angling pressure (Post et al. 2002).

Our uncertainty, regarding whether this population is declining, stems from the Northern pike's abilities to offset population losses through increases to its recruitment and survivorship. This phenomenon is known as compensatory mortality. It occurs because of a decreasing population density, which leaves more resources for the remaining population. This increase in resources promotes better growth and energy stores for reproductive output. This allows for better survivorship and stronger recruitment. The phenomenon of compensatory mortality has been documented for young Northern pike (Colby et al. 1987).

In accordance with our results the Little Atlin Northern pike fishery is predominantly a recreational, live release fishery. While there are incidents of excessive catch, on average, anglers catch one fish per hour and harvest one fish per trip. No anglers reported harvesting more than the allowable bag limit of four fish.

One cause for concern, we did find that angler non-compliance with the regulations has been consistent across survey years. Generally, 6% of summer anglers will harvest Northern pike that are over the maximum length limit of 750 mm total length (716 mm fork length). Given this is a consistent trend, it points to the need for public education and greater enforcement.

Conclusion

Northern pike is the principal fish sought by anglers fishing Little Atlin Lake. We found the pike fishery has grown in popularity. Consequently, mortalities have increased and as the older fish are removed, we are seeing younger fish in the catch composition. These younger fish may be benefitting, as we also witnessed increased growth rates for pike in the later survey years. Northern pike are a robust and resilient species and have been managed using various strategies across North America (Paukert et al. 2001), which are only effective if anglers comply. Most anglers are respecting the current regulations, however, consistently we find that 6% of their harvested catch violates the maximum size restrictions. This combination of non-compliance and increasing mortality may be placing additional stress on the population. Given the recent decline in catch rates, it may be that the current regulations are not adequately protecting Little Atlin's Northern pike population. As such, a recommendation to establish a sampling plan may be warranted. In addition, to increase compliance and reduce the numbers of mortalities associated with catch and release, a public outreach program, designed to educate anglers on best handling practices should be established.

Lake Whitefish Status

Fisheries independent Program

Population Estimate

Presently, we do not target lake whitefish for population surveys. However, our SPIN sampling protocol for lake trout is standardized which allows us to coarsely examine catch per unit effort estimates for lake whitefish bycatch. The number of lake whitefish caught per net during the 2015 and 2021 SPIN survey diminished from 8.7±3.25 to 5.6±1.98, respectively. However, we did not find a significant difference in catch rates between years (Mann-Whitney, W= 2128 p = 0.35). Nevertheless, given the increased popularity of lake whitefish angling, the observed decline in catches during the 2021 survey warrants further monitoring.

Size Composition for Lake Whitefish Sampled during SPIN

Fork lengths of lake whitefish captured during the 2015 and 2021 SPIN surveys, ranged from 201 mm to 475 mm, with means of 351±6 mm and 347±6 mm, respectively. No significant differences in mean lengths (T-test: t (708.4) = 0.897 p = 0.3701;Figure 24), nor in length frequency distribution (KS-test: p = 0.13; Figure 25) were observed between the two survey years.

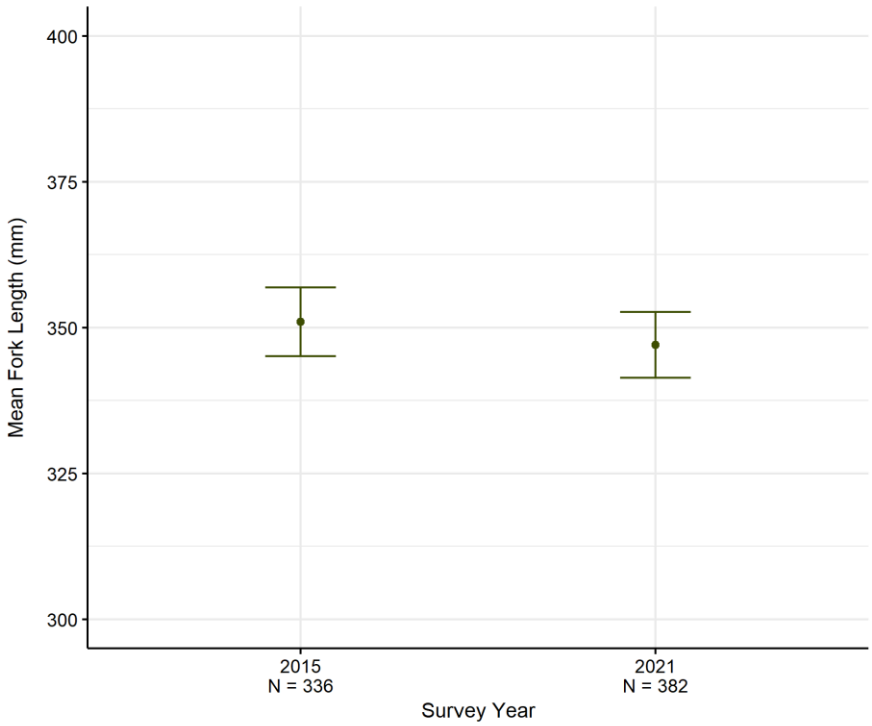

Figure 22. Mean fork length (mm) of lake whitefish sampled during the 2015 and 2021 SPIN surveys. Bars indicate 95% confidence intervals. N = sample size.

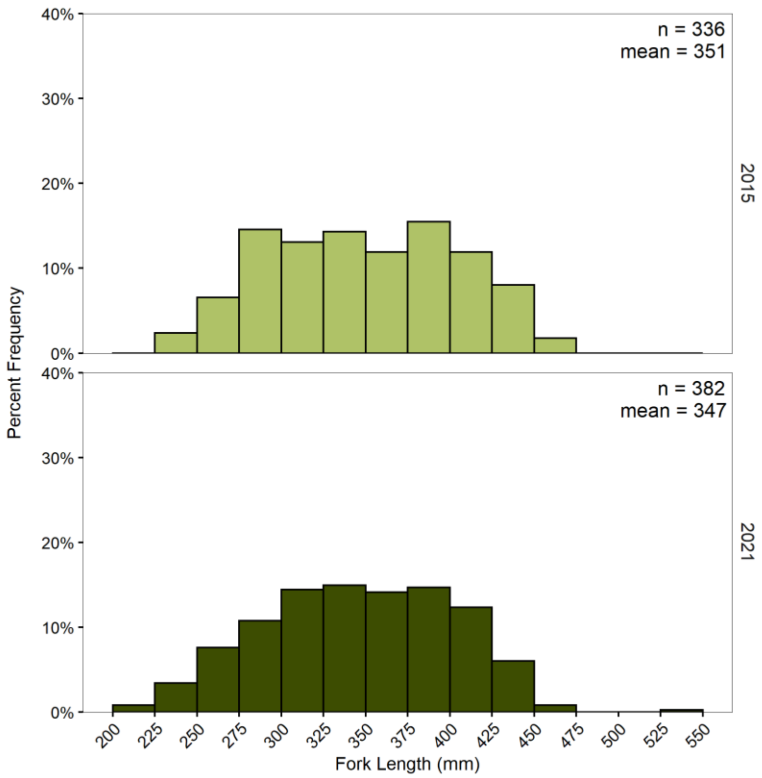

Figure 23. Length frequency distributions of lake whitefish captured in Little Atlin Lake during the 2015 and 2021 SPIN surveys. n = sample size.

Fisheries Dependent Program (Creel Program)

Prior to 2008, lake whitefish was not a popular sport fish among anglers. Fewer than five fish were sampled during the 1998, 2002 and 2008 creel surveys, and these years were not included in any analyses due to insufficient sample sizes.

Catch Length (Angler Harvest)

Lake whitefish harvested by anglers ranged in fork length from 337 to 475 mm. Fish sampled in 2015 were significantly larger than those sampled in 2020 (ANOVA, $F_{(2,199)}$ =5.323, p = 0.006; Tukey's test: p <0.05; Figure 24Figure 17). Accompanying the mean size difference was a significant shift in the harvested length frequency distribution, with anglers harvesting an overall higher proportion of smaller size classes in 2020 (KS-test, p<0.05; Figure 25). However, these results should be interpreted with caution given the small number of samples in 2015 (n=32) and 2018 (n = 55) relative to 2020 (n = 112).

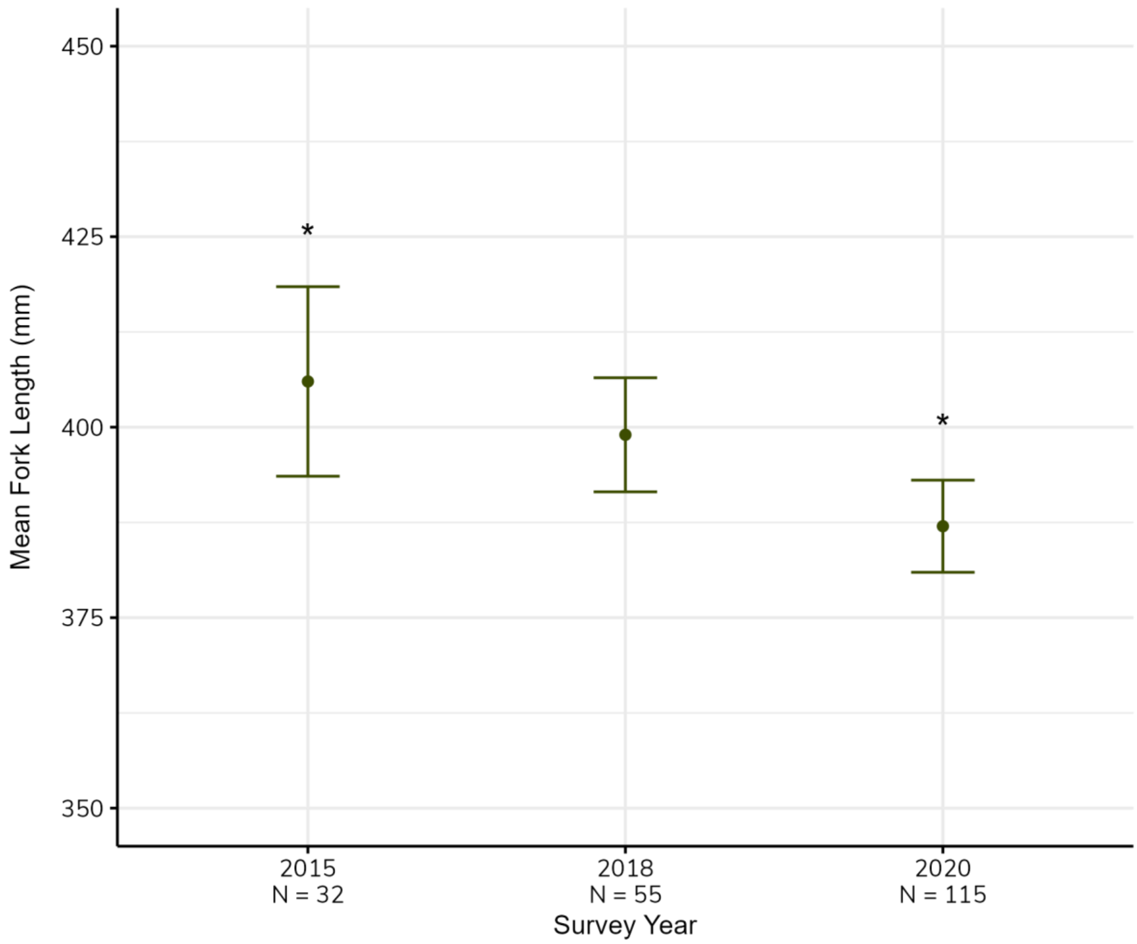

Figure 24. Mean fork length (mm) of lake whitefish by angler survey year. Bars are 95% confidence intervals and asterisks denote which two surveys were found to be significantly different from one another. N = sample size.

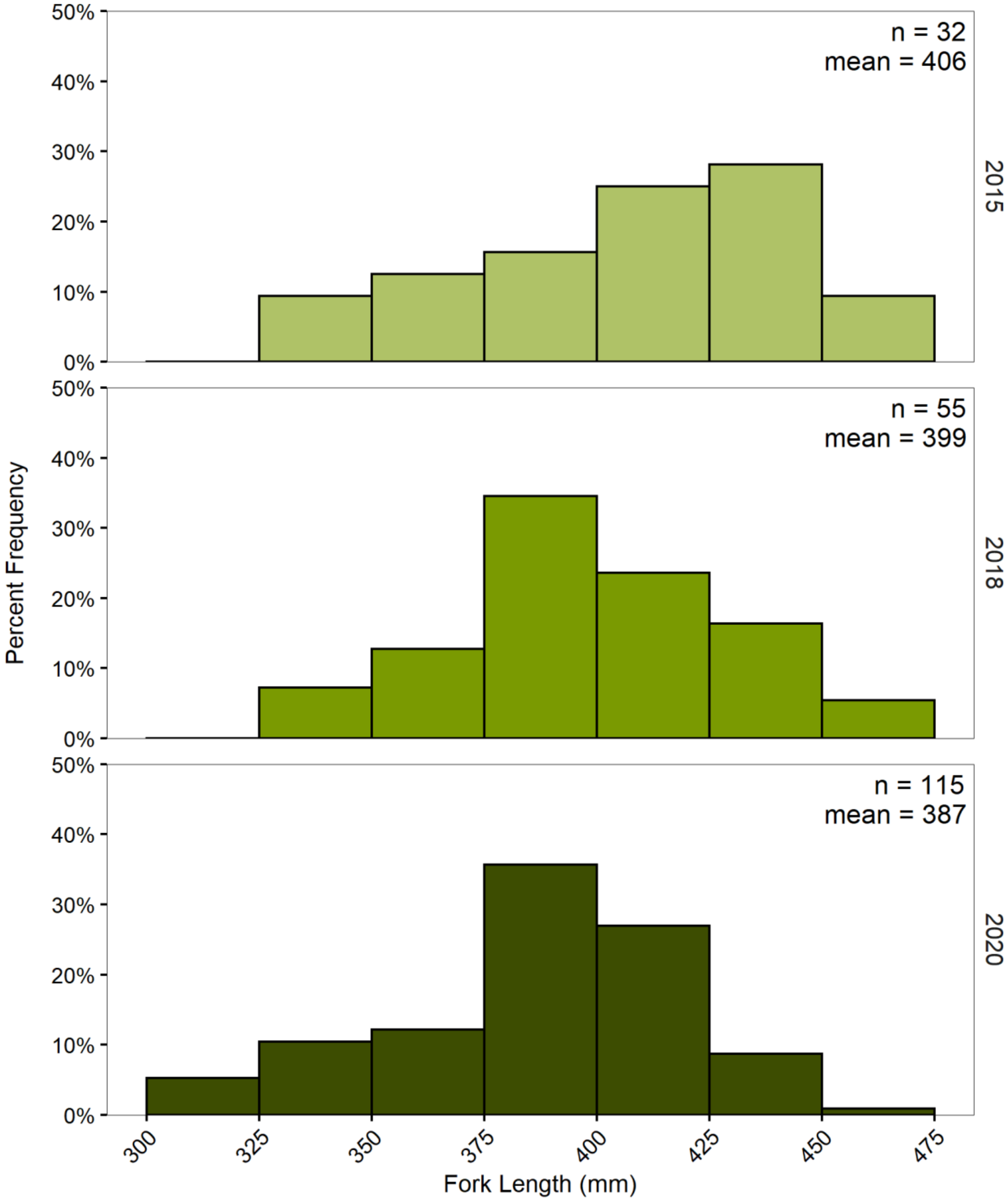

Figure 25. Length frequency distributions of angler catch for Little Atlin Lake whitefish, collated by survey year. n = sample size.

Catch Age Distribution (Angler Harvest)

Harvested lake whitefish ranged in age from 5 to 25 years. In association with the change in mean fork length we identified significant difference in mean age among surveys years (ANOVA, F (2,187) =3.607 p<0.05; Figure 26), whereby lake whitefish harvested in 2015 (mean age = 12.9±1.8) were significantly older than those harvested in 2020 (mean age = 10.7±0.7; Tukey's test: p<0.05).

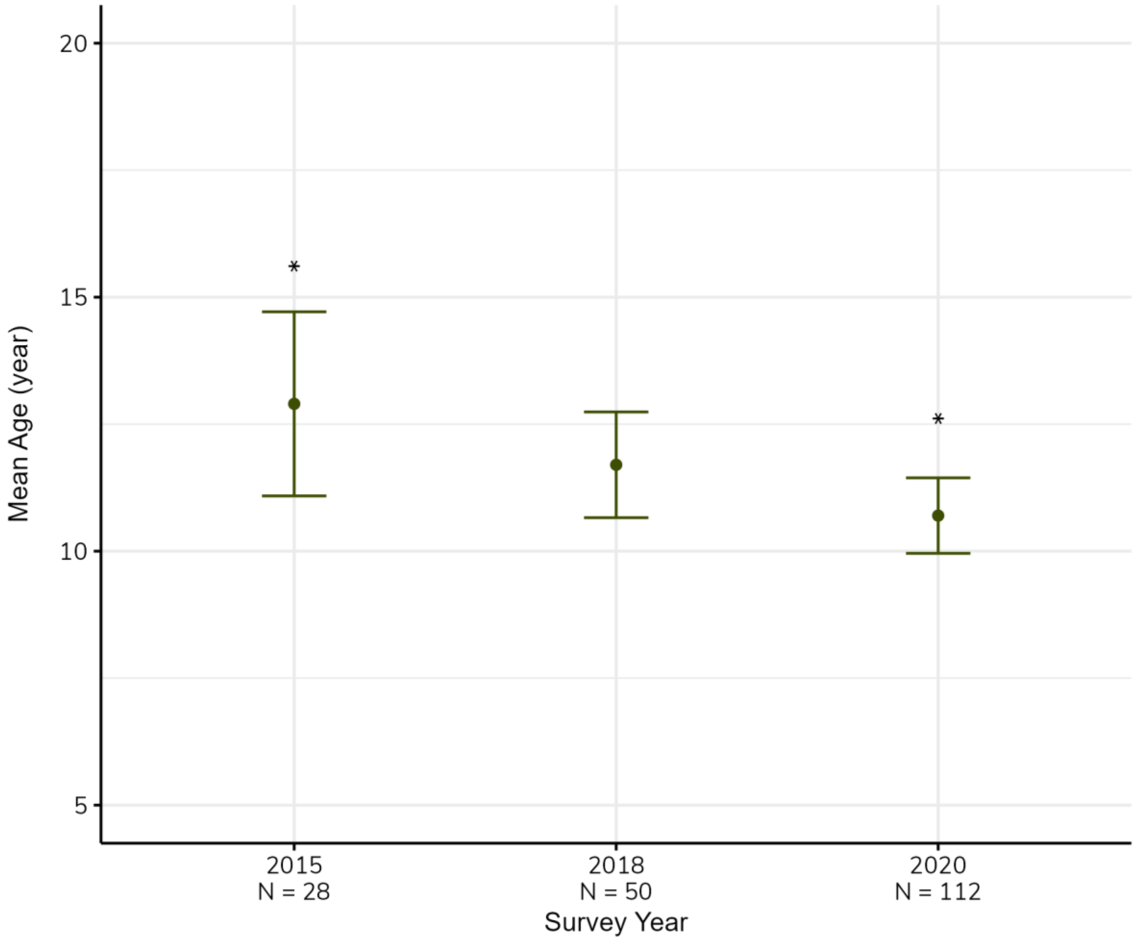

Figure 26. Mean ages of harvested lake whitefish from Little Atlin Lake by survey year. Bars indicate 95% confidence intervals and asterisks denote which two surveys were found to be significantly different from one another. N = sample size.

Mortality Rates

The mortality rate of lake whitefish aged 9 and up (fully recruited to summer angling gear) has not changed across survey years and is estimated at an average of 20% of the catch composition (Table 7).

Table 7. Summary of instantaneous (Z) and annual (A) mortality rates (Chapman and Robson 1960) for lake whitefish aged 8 years+ captured in Little Atlin Lake by survey year.

Year	N	Z (95% CI)	A (95% CI)
2015	28	0.206 (0.076, 0.33)	19% (14.19%, 23.10%)
2018	50	0.202 (-0.00041, 0.41)	18% (12.9%, 23.95%)
2020	112	0.263 (0.19, 0.33)	23% (18.51%, 27.84%)

Growth Rates

Length-at-age data was plotted for lake whitefish by combining samples from both the angler harvest and SPIN programs (n = 386; Figure 27). No comparisons across survey years were made due to small sample sizes (i.e., most survey years n < 60). The only years where we had over 100 samples were 2020 (creel) and 2021 (SPIN). The average asymptotic fork length (Linf) was 428.4 mm. No differences in growth rates (K) or Linf were observed between males and females.

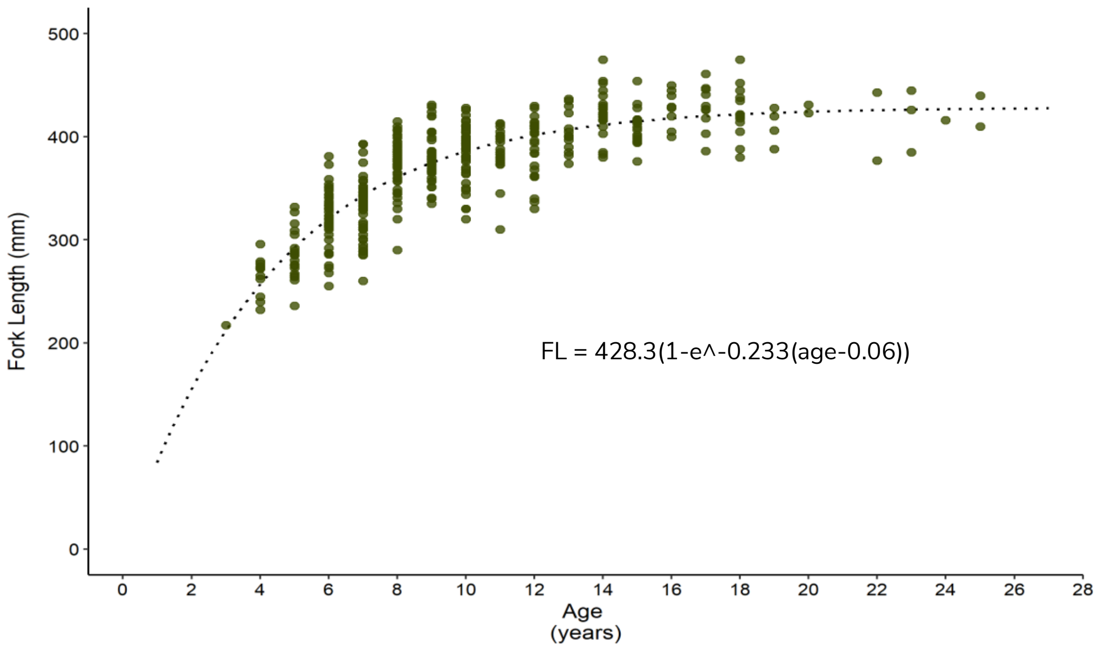

Figure 27. A von Bertalanffy growth curve was fitted (black dotted line) for the Little Atlin Lake whitefish population using length-at-age data from 2008 to 2021 (n=386).

Recreational Harvest Pressure

Catch per unit effort

Prior to 2015, fewer than 10 angling parties reported targeting lake whitefish during their interviews, and nearly all of these anglers could be considered generalists, targeting lake trout and Northern pike, as well. With so few anglers engaging in the whitefish fishery, there is no way to determine how many fishing hours were directed solely at the species. As such, targeted catch rates were challenging to estimate and were therefore omitted from Figure 28. Prior to 2015, anglers that reported catching lake whitefish, were angling for an average of four hours per visit and catching an average of one lake whitefish per visit. However, since 2015, anglers targeting lake whitefish have been catching an average of one fish per two hours. Nevertheless, this increase in CPUE was not statistically significant.

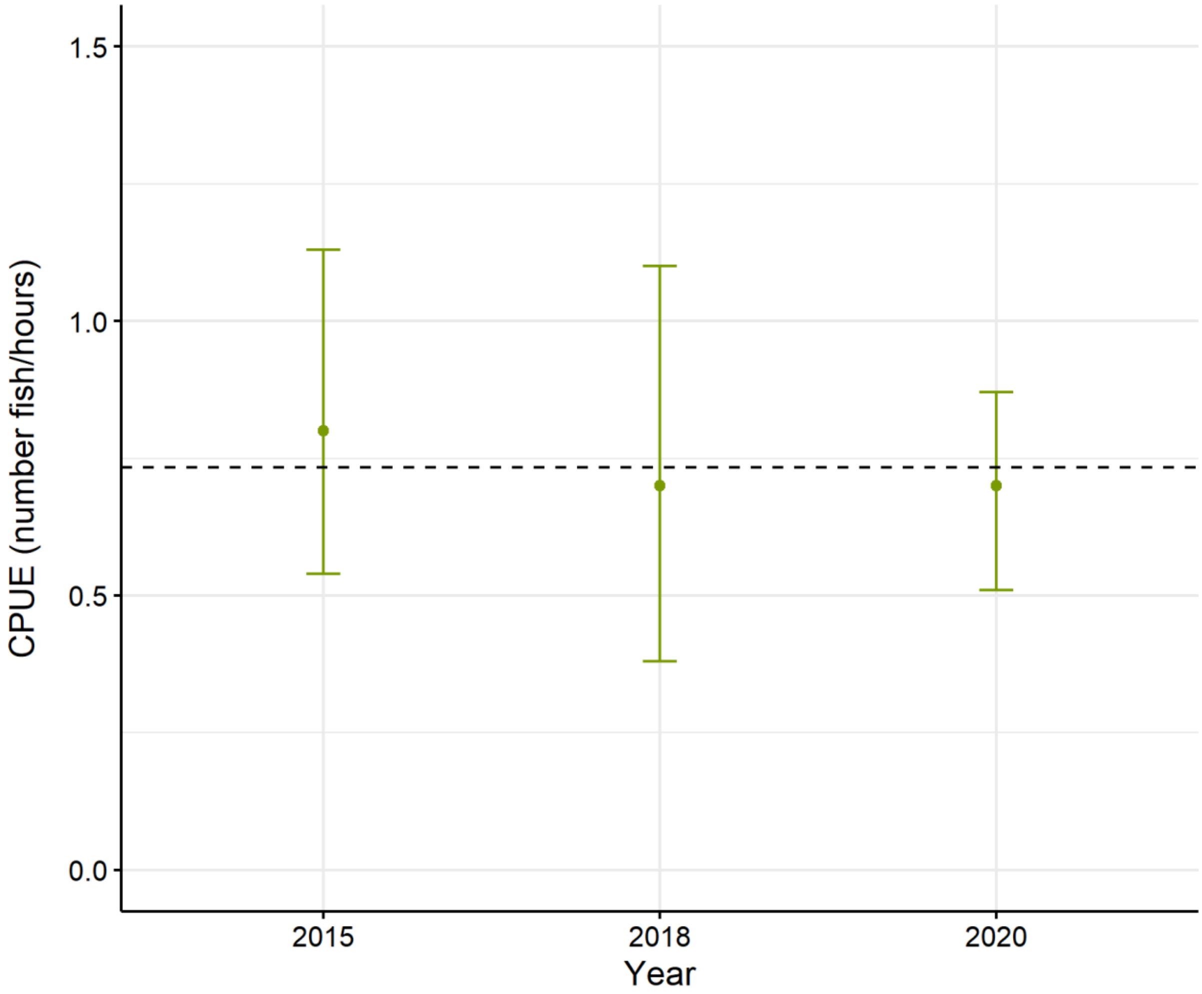

Figure 28. Estimates of targeted catch per unit effort (CPUE) for Little Atlin Lake whitefish, calculated using anglers harvest survey data from 2015, 2018 and 2020. Too few samples were collected in 1998, 2002 and 2018 to generate a meaningful estimate.

Catch and harvest rates

Lake whitefish angling at Little Atlin Lake has grown in popularity since 2015 (Figure 2). Both estimates of catch and harvest have increased (Figure 29). Since 2015, anglers catch an average of two lake whitefish per visit and harvest one (Table 8). One angling party reported catching upwards of 26 fish in a visit and fewer than 1% of anglers retain their daily bag limit of 5.

Estimated total catches have increased from an average of 40 fish in 2008, to over 700 by 2015. While total catch remains high (>500) a decline of 20% was observed between 2015 and 2020 (Figure 29). In general, the number of fish harvested has been increasing, with 2020 marking the first year since 1998 that harvested lake whitefish exceeded, both in number and proportion, estimates of released fish (Figure 29).

Table 8. Summary of lake whitefish caught and retained per angler per visit (fishing day) for each survey year.

Survey Year	Average Catch/Day	Max Catch/Day	% Anglers Catching >2/Day	Average Retention	Max Retention
1998	2	5	-*	1	2
2002	1	3	5%	0	1
2008	1	3	6%	0	1
2015	3	26	13%	1	5
2018	2	15	11%	1	5
2020	2	20	12%	1	5

**In 1998 only one angler caught more than two Lake whitefish.*

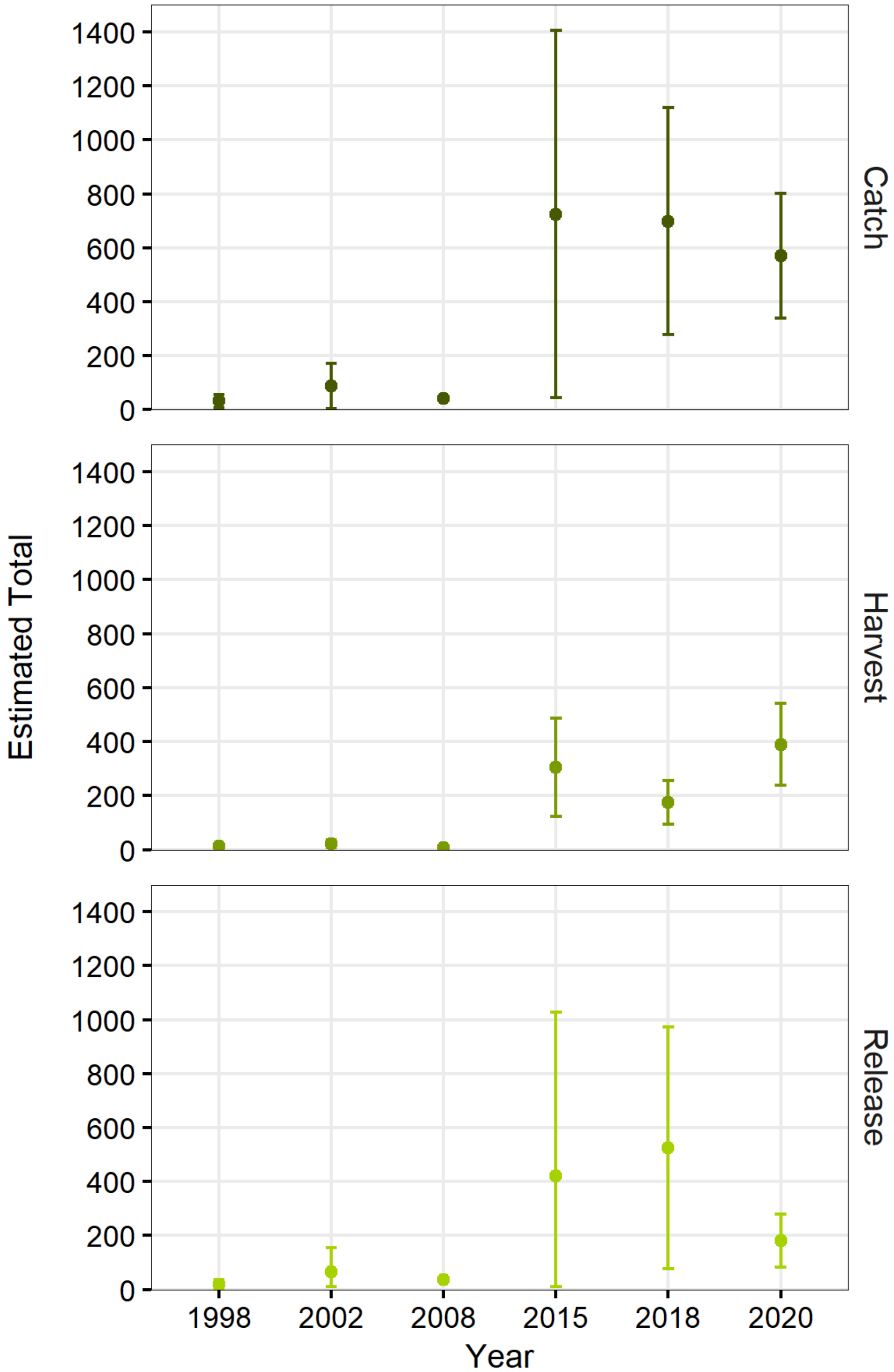

Figure 29. Estimate number of lake whitefish caught, harvested, and released during the summer angling season at Little Atlin Lake during survey years conducted between 1990 and 2020.

Discussion: Lake Whitefish Status

The lake whitefish fishery on Little Atlin Lake increased in popularity sometime after 2008. This shift in angler behaviour and interest was captured in our 2015 data. Since 2015, the number of fish caught seasonally has shown a slight decline but catch rates have remained stable. We have observed in recent years a higher proportion of anglers harvesting lake whitefish, but few anglers retaining their daily bag limit of five fish.

The catch composition for lake whitefish has become increasingly smaller and younger. However, shifts to a younger catch composition are normal in newly established fisheries (Johnson 1976). This change in harvest composition was not reflected in the SPIN data, whereby no changes in mean fork length or length frequency distribution was observed. Additionally, while catch rates during SPIN surveys declined between survey years, the results suggest that lake whitefish densities in Little Atlin Lake have not significantly changed but warrant ongoing monitoring.

Conclusion

To date, we have not observed any major changes from increased angler pressure on lake whitefish. This population may be able to sustain the current angling pressure. As a key prey species for lake trout and Northern pike, ensuring the lake whitefish population is sustainable is important for the overall health of Little Atlin Lake's fisheries. Therefore, we recommend improving our knowledge of the lake whitefish population in Little Atlin Lake by continuing to sample. Such information will guide future management decisions.

Concerns

To maintain sustainable freshwater fish populations, we must understand the factors that influence a lake's fish population. This includes understanding gaps in scientific knowledge and determining the threats associated with climate change on fish and their habitat; the fishery; and aquatic invasive species. By better understanding the above we can make better management recommendations for fish populations.

Climate Change

One of the principal concerns influencing fisheries is climate change. Climate change has been identified as a threat, with the Government of Yukon declaring a Climate Emergency in 2020. In addition, addressing climate change has been identified as a key component in Yukon's State of Environment Report, 2020 (Government of Yukon 2020a) and the Government of Yukon's Our Clean Future Plan (Government of Yukon 2020b).

In particular, understanding the effects of climate change on Yukon fish is key in the realization of these plans. Understanding the influence of climate change is important because it has been documented to influence fish reproduction, recruitment, growth rates, survival, and inter-species interactions, such as trophic linkages, competition and species assemblages (Lynch et al. 2016).

Fish Habitat

As stated above, temperature influences fish physiology, and these influences can affect all life stages by, altering spawning timing, egg and juvenile survival, as well as adult survival (Pankhurst and Munday 2011). Cold and cool water species, such as lake trout and Northern pike, are susceptible to changes in water temperatures. Warming temperatures can impose increased thermal stress on fish populations. For example, it can alter the availability and volume of optimal oxythermal habitat (THV) (Guzzo and Blanchfield 2017). This in turn can influence species abundance, altering their sustainable yields (Christie and Regier 1988).

While an earlier study predicted changes to THV for lake trout in Little Atlin Lake would likely be minimal (Mackenzie-Grieve and Post 2006a), it is important that we monitor water temperature. The effects of warming temperatures are not limited to altering lake trout habitat, but it may have implications for other aspects of their ecology (Guzzo and Blanchfield 2017). It may also influence cool water species such as Northern pike. For example, their habitat can be altered through changes to the extent and composition of macrophyte vegetation (Casselman and Lewis 1996, Lind et al. 2022).

By increasing our monitoring of water temperatures, we can develop predictive models of relative abundance and distribution for fish populations across the Yukon, as well as specifically for Little Atlin Lake.

Water Quality

Yukon lakes are primarily oligotrophic, which means they are cold, clear lakes, low in nutrients and therefore low in productivity. Our lakes are also subject to long cold winters, which have been associated with the slower growth rates and increased age at maturity of lake trout (Martin and Olver 1980).

Climate change can affect this by extending growing degree days and altering the rain cycle. This could increase nutrient levels such as phosphorus, and to a lesser extent nitrogen, leading to higher lake productivity (Matzinger and Schmid 2007). Indirectly this can affect fish population numbers, interspecies competition and, ultimately, sustainability of a population (Lynch et al. 2016).

Therefore, monitoring changes in lake productivity is important, as it may provide data that will help determine sustainable fish harvest estimates in the future. This type of monitoring has been previously recommended for lakes in the Yukon (Milligan 2018).

Recreational Harvest

Another challenge for fisheries managers is ensuring healthy, sustainable fish populations while also providing a quality fishery for anglers. Since the 1990's, recreational angling and, subsequently, fish harvest has steadily increased across the territory (Sinclair and Perry 2019).

This increase corresponds with an increase in Yukon's population, which has grown by 16% since 2013 (Government of Yukon 2020c).

While general catch and possession limits are aimed at maintaining sustainable fisheries, an ongoing analysis and assessment of harvest rates and their effects on lake-specific populations is required. To maintain a quality fishery, we must understand the influences that recreational harvest has on fish populations. If improperly managed, it can lead to losses in fish abundance (Post et al. 2002).

Incidental Mortality and Live Release

In addition to understanding the effects of harvest, we also consider the effects of incidental mortality associated with the practice of catch-and-release fishing, known in the Yukon as live release. Live release tends to increase when fisheries managers impose size restrictions, as anglers release fish that are of unsuitable sizes. Fisheries managers will often establish regulations that target certain sized fish for release. By imposing specific size limits to protect a portion of the breeding population, it is hoped that enough fish of breeding size will remain to ensure a sustainable, quality fishery.

However, the application of live release may have unintentional consequences. Unintended mortalities may occur due to bad hook placement in the fish (swallowing of the hook) or poor handling practices by the angler. Environmental factors can also influence unintended mortalities. For example, fish removed from deep water may experience stress due to changes in water temperature or pressure (Bartholomew and Bohnsack 2005, Arlinghaus et al. 2011). To minimize these mortalities managers will often implement public education programs that informs anglers of proper handling practices for releasing a fish.

Aquatic Invasive Species

Aquatic invasive species are foreign organisms such as fish, mussels, plants or bacterium that have been introduced into an ecosystem intentionally or unintentionally by humans and survive. Because they have not naturally evolved in the ecosystem, they have the potential to cause negative effects on the environment or native species. Yukon, as a place with minimal regulative protections, is highly vulnerable to these aquatic introductions.

For example, the introduction of zebra and/or quagga mussels could have detrimental effects to our lakes. In other locations, such as Ontario, the prolific numbers of zebra mussels have reduced lake trout spawning habitat and reduced their reproductive output by damaging deposited eggs (Marsden and Chotkowski 2001).

While a monitoring plan for invasive species has not been developed, in the interim, an education and public outreach program should be developed.

Recommendations

Regulatory History

Prior to presenting our recommendations for regulative changes, it is important to give the background on past regulative changes involving gear and the species catch, possession and size limits. Since the mid-1980's, there have been three differing sets of regulations placed on Little Atlin Lake through the Yukon Territorial Fisheries Regulations process (Table 9).

Between 1985 and 1995, Little Atlin was classified in the *General Waters* category, with no gear restrictions and liberal bag limits. This was followed by a reclassification into the *High-Quality Waters* category between 1996 and 2004, which imposed barbless hook restrictions and some small bag limit reductions. Since 2004, Little Atlin has been classified as Special Management C waters, retaining its barbless hook restrictions, but having a minimal limit for lake trout (see Table 9). Throughout this time, the size restrictions placed on Northern pike and lake trout have varied but, in all cases, they were designed to protect the largest spawners, thereby enhancing productivity. There have never been size limits placed on the lake whitefish population (Table 9).

Table 9. Regulative history for recreational angling at Little Atlin Lake for lake trout, Northern pike, and lake whitefish, including regulatory period, catch and possession limits, and size restrictions.

Species	*Regulatory period*	*Catch Limit*	*Possession Limit*	*Size Restriction*
Lake trout	2004-current	1	1	Must release all lake trout longer than 65cm (26")
	1996-2004	2	2	All lake trout between 65 and 100cm (26 to 39 in) in length must be released. Only one Lake trout in your catch or possession may be longer than 100cm (39 in.)
	1991-1996	3	6	Only one lake trout in your catch or possession may be longer than 65cm (39 in.)
	1985-1991	3	6	Of which only 1 may be over 80cm (31") in length
Northern pike	2004-current	4	4	Must release all pike longer than 75 cm (30")
	1996-2004	4	4	All pike between 75 cm and 105 cm (30 to 41 in) in length must be released. Only one pike in your possession may be longer than 105cm (41 in).
	1991-1996	5	10	Only one pike in your daily catch or possession may be longer than 75 cm (30 in.)
	1985-1991	5	10	No restriction
Lake whitefish	All periods	5	10	No restriction

Recommendations

Regulatory Recommendations

Slot Size Limits

The lake trout population in Little Atlin Lake is small and vulnerable to over-harvest. To help safeguard this population, added protections are required. To this end, we recommend establishing a slot limit for allowable harvest that is below the current length limit of 650 mm total length (586 mm fork length). Currently, the existing size regulation protects only 20% of the population and is above the average maximum length that this population can potentially achieve (males: 585mm FL, females: 561mm FL). As such, there is little protection for the younger, smaller recruits.

By establishing a slot size, we will create both an upper and lower length limit. The lower limit will protect immature fish until they reach sexual maturity, while the upper limit will protect the largest, most fecund fish. To be cautionary, we also recommend that the lower limit is set at a size which allows for growth beyond the onset of sexual maturity by two additional years. This will ensure that most fish are given at least one opportunity to spawn before reaching a harvestable size.

In Little Atlin Lake, lake trout reach maturity between 5 and 13 years of age, with an average of 8 years. Considering the additional two years of growth, the average fork length of a 10-year-old fish is 527 mm (583 mm total length). Therefore, we recommend a lower total length limit of 585 mm. The upper length limit should remain the same, at 650mm total length.

Initially, the new slot limit would reduce the harvestable catch by approximately 50%. However, over time, we believe the additional protections would allow more fish to reproduce, increasing recruitment. Inevitably, this would improve Little Atlin Lake's lake trout fishery. It is noteworthy, that the vast majority of anglers fish Little Atlin Lake for Northern pike, with few anglers targeting lake trout. Therefore, the impacts to anglers, given the new regulation, should be minimal (Figure 2).

Single Barbless Hooks

It is recognized, by recommending the establishment of a slot size, we will be increasing the numbers of fish that are live released and that this has the potential to increase unintentional mortality. Therefore, to aid in reducing these mortalities, we recommend a single barbless hook regulation. Such a regulation would eliminate the use of lures with multiple treble hooks. This regulation would reduce inadvertent damage due to multiple hook placements and subsequently, unintended mortalities. It will also aid in reducing the handling times for released fish.

Seasonal Closure

With only a small portion of Little Atlin Lake being deeper than 20m, it can be considered a shallow water lake. Typically, its waters warm quickly, with average temperatures tending to move beyond optimal for lake trout (8°C to 12°C) during the months of July and August. During this period, lake trout become habitat-limited, spending much of their time confined in the cold, deep waters that are near the thermocline. When they are captured, they tend to be pulled up from their cold water refugia into shallow, warmer waters. The shock of this warmer water, in combination with handling time and the pressure change (barotrauma) can be detrimental to a successful live release.

Given the above, we recommend closing the Little Atlin Lake trout fishery during the warmer summer months and extend the closure into the fall, avoiding the period when this population spawns. Specifically, we recommend closing the lake trout fishery from June 30th until November 30th. This would minimize live release during the warm water months. It would also reduce stress and disturbance to the fish during their spawning event.

Public Education Recommendations

To ensure greater public compliance and understanding with the new regulations, it is important to convey their importance for the preservation of the fishery and for the conservation of the affected species. Furthermore, while it is difficult to determine the exact numbers of fish that may die due to incidental mortalities from live-capture releases, we can work to minimize the number by improving the handling practices of anglers.

To do this, we recommend that the above regulative changes should be accompanied by a public education plan. The plan should include education components pertaining to the relevant biology of the species, the purpose of the regulations, and best live release practices and ethics. Specifically, the plan should include:

- Developing online resources to educate anglers regarding live release ethics (i.e instructional videos).
- Conducting public information sessions, providing an overview of these populations and their status and the purpose of the new regulations.
- Conducting social media, radio and news interviews and posts regarding these populations, the results of this report, and best practices.
- Interpretive signage should be placed around key access points.

Additionally, the education plan should be developed and implemented in partnership with other governments and stakeholders such as, Carcross / Tagish First Nation, Taku Tlingit First Nation, Yukon Fish and Game Association, the Carcross / Tagish Renewable Resource Council and the Yukon Fish and Wildlife Management Board.

Monitoring Recommendations

Lake Trout and Lake Whitefish Population Assessments and Angling Surveys

To ensure the regulative changes are effective, monitoring programs should continue for lake trout and lake whitefish. Additionally, monitoring of some habitat variables should occur, for example, water temperature and chemistry.

We also recommend the standardization of data collection. During the writing of this report, we determined that our archived age data was inadequate and biased due to the way it was previously collected. This paucity of data made it challenging to do analysis or draw inferences when we examined fish growth, maturation and age composition.

To understand the influences of increased fishing we also recommend conducting angler (creel) surveys. Continued monitoring of fisheries dependent data allows us to determine if populations are sustainable under current pressure levels. Conducting angler surveys also permits us to engage directly with anglers, to gather information about their attitudes, beliefs, their angling methods, and overall success. We also recommend that the angler surveys should be expanded to include the winter season. Presently, we do not conduct winter surveys, as such, data is lacking on this season. To ensure we understand the immediate influence of our new regulations on the Little Atlin Lake fishery we recommend that angler surveys are conducted with greater frequency according to the following schedule:

- **2024/2025**: Conduct a winter ice-fishing angler survey.
- **2025**: Conduct a summer angler survey.

Habitat

To quantify the available habitat for each species we recommend the establishment of long –term monitoring programs for both water temperature and chemistry. This information will help determine if habitat changes are occurring related to climate (eg. Changes in thermal habitat or lake nutrient levels). Furthermore, to determine the volume of habitat available we also recommend conducting a detailed bathymetric assessment. Specifically, we recommend;

- Conducting detailed bathymetric mapping in 2024.
- Monitoring for seasonal changes in water temperature across various depths, to determine changes in thermal habitat; and
- Conducting water chemistry analysis, focusing on nutrient levels, every 5 years.

Northern Pike Monitoring

At present, we lack a standardized inventory program for Northern pike. This means that we rely solely on the sports fishery to gather data and develop regulations for the species. This is problematic, as data gathered from anglers often has biases. For example, anglers tend to release younger, smaller fish, favouring the largest. Therefore, their catch composition is skewed to the largest and oldest fish. Anglers will also select fishing locations where the probability of success is great. Therefore, the numbers caught may give a false impression regarding abundance.

To address these biases, we recommend the implementation of a standardized monitoring program for Northern pike, using Little Atlin Lake as a pilot study. The lake is recognized as a quality pike fishing destination, and it is the area where we have gathered the most information for Northern pike. We are also aware that the public has many questions regarding the affects that the current sport fishery has on this population. Thus, by using Little Atlin, we would be able to test our new program while gathering information on Little Atlin Lake's Northern pike population abundance, their age structure, growth rates and condition.

- **2023/24**: Develop Northern pike population sampling program
- **2024**: Implement program on Little Atlin and few other lakes in the Yukon.

References

Ahrens, R.N., Allen, M.S., Walters, C. and Arlinghaus, R., 2020. Saving large fish through harvest slots outperforms the classical minimum-length limit when the aim is to achieve multiple harvest and catch-related fisheries objectives. *Fish and Fisheries*, *21*(3), pp.483-510.

Anderson, C.N., Hsieh, C.H., Sandin, S.A., Hewitt, R., Hollowed, A., Beddington, J., May, R.M. and Sugihara, G., 2008. Why fishing magnifies fluctuations in fish abundance. *Nature*, *452*(7189), pp.835-839.

Arlinghaus, R., Klefoth, T., Kobler, A. and Cooke, S.J., 2008. Size selectivity, injury, handling time, and determinants of initial hooking mortality in recreational angling for Northern pike: the influence of type and size of bait. *North American Journal of Fisheries Management*, *28*(1), 123-134.

Barnett, L.A., Branch, T.A., Ranasinghe, R.A. and Essington, T.E., 2017. Old-growth fishes become scarce under fishing. *Current biology*, *27*(18), pp.2843-2848.

Bartholomew, A., and J.A. Bohnsack. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Reviews in Fish Biology and Fisheries. 15: 129-154.

Bergström, U., Larsson, S., Erlandsson, M., Ovegård, M., Stabo, H.R., Östman, Ö. and Sundblad, G., 2022. Long-term decline in Northern pike (Esox lucius L.) populations in the Baltic Sea revealed by recreational angling data. *Fisheries Research*, *251*, p.106307.

Carcross / Tagish Renewable Resource Council. 2021. Carcross/Tagish Traditional Territory Community-Based Fish and Wildlife Work Plan 2020-2025.

Carl, L.M. 2008. Lake trout demographics in relation to burbot and coregone populations in the Algonquin Highlands, Ontario. Environmental Biology of Fishes 83(2): 127-138.

Cassleman, J.M., and C.A. Lewis. 1996. Habitat requirements of Northern pike (Esox lucious). Canadian Journal of Fisheries and Aquatic Sciences. 53(Suppl. 1): 161-174.

Chapman, D.G. and D.S. Robson. 1960. The Analysis of a Catch Curve. Biometrics 16:354-368.

Christie, G.C., and H.A. Reiger. 1988. Measures of optimal thermal habitat and their relationship to yields for four commercial fish species. Canadian Journal of Aquatic Sciences. 45: 301-314.

Clark, B.J., P.J. Dillon and L.A. Molot. 2004. Lake trout (Salvelinus namaycush) habitat volumes and boundaries in Canadian Shield Lakes. Chapter 6 in Boreal Watersheds: Lake trout Ecosystems in a Changing Environment. J.M. Gunn, R.J. Steedman and R.A. Ryder, Editors. Lewis Publishing, Boca Raton, Florida.

Colby, P.J., Ryan, P.A., Schupp, D.H. and Serns, S.L., 1987. Interactions in north-temperate lake fish communities. Canadian Journal of Fisheries and Aquatic Sciences, 44(S2), pp.s104-s128.

COSEWIC. 2018. COSEWIC assessment and status report on the Whitefish *Coregonus* spp., European Whitefish - Squanga Lake small-bodied population (*Coregonus lavaretus*), Lake whitefish - Squanga Lake large-bodied population (*Coregonus clupeaformis*), European

Whitefish - Little Teslin Lake small-bodied population (*Coregonus lavaretus*), Lake whitefish - Little Teslin Lake large-bodied population (*Coregonus clupeaformis*), European Whitefish - Dezadeash Lake small-bodied population (*Coregonus lavaretus*), European Whitefish - Dezadeash Lake large-bodied population (*Coregonus lavaretus*), Lake whitefish - Opeongo Lake small-bodied population (*Coregonus clupeaformis*), Lake whitefish - Opeongo Lake large-bodied population (*Coregonus clupeaformis*), Lake whitefish - Como Lake small-bodied population (*Coregonus clupeaformis*) and the Lake whitefish - Como Lake large-bodied population (*Coregonus clupeaformis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxxix + 42 pp. (Species at Risk Public Registry).

Crossman, E.J., and C.R. Harrington. 1970. Pleistocene Pike, Esox lucius and Esox sp., from the Yukon Territory and Ontario. Canadian Journal of Earth Science. 7:1130.

Diana, J.S. 1979. The feeding pattern and daily ration of a top carnivore, the Northern pike (Esox lucius). Canadian Journal of Zoology. 57: 2121-2127.

Englmaier, G.K., Antonov, A. and Weiss, S.J., 2022. General patterns of sexual dimorphism in graylings (Thymallus), with a comparison to other salmonid species. Reviews in Fish Biology and Fisheries, 32(2), pp.645-667.

Environment Yukon. 2010. Status of Yukon Fisheries 2010: An overview of the state of Yukon Fisheries and the health of fish stocks, with special reference to fisheries management programs. Yukon Fish and Wildlife Branch Report MR-10-01. Whitehorse, Yukon, Canada.

Evans, D.O. 2005. Effects of Hypoxia on scope-for activity of Lake trout: Defining a new dissolved oxygen criteria for protection of Lake trout habitat. Technical Report 2005-01. Habitat and Fisheries Unit, Aquatic Research and Development Section. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Fox, J. 1997. Applied regression analysis, linear models, and related methods. Sage Publications, Inc.

Government of Yukon. 2020a. Yukon State of the Environment Report 2020. Government of Yukon, Whitehorse, Yukon, Canada.

Government of Yukon. 2020b. Our Clean Future, A Yukon strategy for climate, energy and a green economy. Government of Yukon, Whitehorse, Yukon, Canada.

Government of Yukon. 2020c. Yukon Bureau of Statistics, Population Report, First Quarter 2020. Government of Yukon, Whitehorse, Yukon, Canada.

Government of Yukon. 2023. Lake Trout and Lake Whitefish Monitoring Program: 2021 Program Update (SR-23-07). Government of Yukon, Whitehorse, Yukon, Canada.

Guzzo, M.M. and Blanchfield, P.J. 2017. Climate change alters the quantity and phenology of habitat for Lake trout (Salvelinus namaycush) in small Boreal Shield lakes. Canadian Journal of Fisheries and Aquatic Sciences. 74(6):871-84.

Hansen, M.J., L.Chavarie, A.M.Muir, K.L. Howard, and C.Kreuger. 2020. Variation in Fork-to Total Length relationships of North American Lake trout populations. Journal of Fish and Wildlife Management. 11(1):263-272.

Havens, S., M. Lorne, P. Blanchfeld, M. Paterson and S, Higgins. 2014. Evaluation of eutrophication and water level drawdown on Lake whitefish (Coregonus clupeaformis) productivity; Fish habitat assessment. Canadian Technical Report of Fisheries and Aquatic Sciences No. 3110. Vi. + 40P.

Harvey, B. 2009. A biological synopsis of Northern pike (Esox lucious). Canadian Manuscript Report of Fisheries and Aquatic Sciences. 2885: V + 31p.

Jacobson, P.C., 1993. Analysis of factors affecting growth of Northern pike in Minnesota. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries.

Johnson, L., 1976. Ecology of arctic populations of lake trout, Salvelinus namaycush, lake whitefish, Coregonus clupeaformis, Arctic char, S. alpinus, and associated species in unexploited lakes of the Canadian Northwest Territories. Journal of the Fisheries Board of Canada, 33(11), pp.2459-2488.

Kennedy, W.A., 1953. Growth, maturity, fecundity and mortality in the relatively unexploited whitefish, Coregonus clupeaformis, of Great Slave Lake. Journal of the Fisheries Board of Canada, 10(7), pp.413-441.

Lind, L., Eckstein, R.L. and Relyea, R.A., 2022. Direct and indirect effects of climate change on distribution and community composition of macrophytes in lentic systems. *Biological Reviews*, *97*(4), pp.1677-1690.

Lindsay, C.C. 1964. Problems in zoogeography of the Lake trout, Salvelinus namaycush. Journal of the Fisheries Research Board of Canada 21(5): 977-994.

Lynch, A.J., B.J.E. Myers, C. Chu, L.A. Eby, J.A. Falke, R.P. Kovach, T.J. Krabbenhoft, T.J. Kwak, J. Lyons, C.P. Paukert and J.E. Whitney. 2016. Climate Change Effects on North American Inland Fish Populations and Assemblages. Fisheries, 41:7, 346-361.

Mackenzie-Grieve, J.L. and J.R. Post. 2006a. Projected impacts of climate warming on production of Lake trout (Salvelinus namaycush) in southern Yukon lakes. Canadian Journal of Fisheries and Aquatic Sciences. 63:788-797. Transactions of the American Fisheries Society. 135:727-738.

Mackenzie-Grieve, J.L. and J.R. Post. 2006b. Thermal habitat use by Lake trout in two contrasting Yukon Territory lakes.

Madenjian, C.P., Desorcie, T.J. and Stedman, R.M., 1998. Ontogenic and spatial patterns in diet and growth of Lake trout in Lake Michigan. *Transactions of the American Fisheries Society*, *127*(2), pp.236-252.

Margenau, T.L., Rasmussen, P.W. and Kampa, J.M., 1998. Factors affecting growth of Northern pike in small northern Wisconsin lakes. North American Journal of Fisheries Management, 18(3), pp.625-639.

Marsden, J.L., and M.A. Chotkowski. 2001. Lake trout spawning on artificial reefs and the effect of Zebra mussels: Fatal Attraction? Journal of Great Lakes Research. 27(1): 33-43.

Martin, N.V., and C.H. Olver. 1980. The lake charr: Salvelinus namaycush. In Charrs: salmonid fishes of the genus Salvelinus. E.K. Balon. Dr. W. Junk Publishers, The Hague, Netherlands. pp. 205-277.

Matzinger, A. and M. Schmid. 2007. Eutrophication of ancient Lake Ohrid: Global warming amplifies detrimental effects of increased nutrient inputs. American Society of Limnology and Oceanography. 52(1): 338-353.

Mee, J.A., Bernatchez, L., Reist, J.D., Rogers, S.M. and Taylor, E.B., 2015. Identifying designatable units or intraspecific conservation prioritization: a hierarchical approach applied to the Lake whitefish species complex (Coregonus spp.). Evolutionary Applications, 8(5), pp.423- 441.

McPhail, J.D. 2007. The Freshwater Fishes of British Columbia. University of Alberta Press. Edmonton, Alberta. 620p.

McCormick, J.L. and Meyer, K.A., 2017. Sample Size Estimation for On-Site Creel Surveys. *North American Journal of Fisheries Management*, *37*(5), pp.970-980.

Mertz, G. and Myers, R.A., 1998. A simplified formulation for fish production. Canadian Journal of Fisheries and Aquatic Sciences, 55(2), pp.478-484.

Milligan, H.E. 2018. Lake Productivity and sustainable fish harvest estimates: methods review (MR-18-04). Government of Yukon, Whitehorse, Yukon, Canada.

Pankhurst, N.W., and P.L. Munday. 2011. Effects of climate change on fish reproduction and early life history stages. Marine and Freshwater Research. 62: 1015-1026.

Paukert, C.P., Klammer, J.A., Pierce, R.B. and Simonson, T.D., 2001. An overview of Northern pike regulations in North America. Fisheries, 26(6), pp.6-13.

Pierce, R.B. 2010. Long-term evaluations of Northern pike experimental regulations in Minnesota Lakes. Minnesota Department of Natural Resources Investigational Report 556., Minnesota, USA.

Post J.R., M. Sullivan, S. Cox, N. Lester, C. Walters and E.A. Parkinon. 2002. Canada's recreational fisheries: The invisible collapse? Fisheries 27: 6-17.

Quinn, G.P. and Keough, M.J. 2002. Experimental design and data analysis for biologists. Cambridge university press.

Reyes-Gavilán, F.G., Ojanguren, A.F. and Braña, F., 1997. The ontogenetic development of body segments and sexual dimorphism in brown trout (Salmo trutta L.). Canadian Journal of Zoology, 75(4), pp.651-655.

Robson, D.S. and Chapman, D.G., 1961. Catch curves and mortality rates. Transactions of the American Fisheries Society, 90(2), pp.181-189.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin of the Fisheries Research Board of Canada 184. 966p.

Sinclair, C.L., and R. Perry. 2019. Review of the status of Yukon's commercial Lake trout and Lake whitefish fishing industry (MR-19-02). Government of Yukon, Whitehorse, Yukon, Canada.

Sitar, S.P., Brenden, T.O., He, J.X. and Johnson, J.E., 2017. Recreational postrelease mortality of Lake trout in lakes superior and huron. North American Journal of Fisheries Management, 37(4), pp.789-808.

Smith, M.W., Then, A.Y., Wor, C., Ralph, G., Pollock, K.H. and Hoenig, J.M., 2012. Recommendations for catch-curve analysis. North American Journal of Fisheries Management, 32(5), pp.956-967.

Tang, R.W., Doka, S.E., Gertzen, E.L. and Neigum, L.M., 2020. Dissolved oxygen tolerance guilds of adult and juvenile Great Lakes fish species. Fisheries and Oceans Canada= Pêches et Océans. Trippel, E.A., 1993. Relations of fecundity, maturation, and body size of Lake trout, and implications for management in northwestern Ontario lakes. North American Journal of Fisheries Management, 13(1), pp.64-72.

Van den Avyle, M .J., and R. S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127-166 in C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.