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Population Abundance and Biological Characteristics of Dolly Varden (*Salvelinus malma*) from the Rat River Collected from a Mark-recapture Program: 2015–2022

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Foreword

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

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ABSTRACT

A long-term fisheries-independent program is used to monitor and assess the population of anadromous Dolly Varden (*Salvelinus malma*) from the Rat River, Northwest Territories, Canada. Data collected from a seining and mark-recapture program performed (2015–2022) in the upper reaches of the Rat River watershed (Fish Creek area where fish spawn and overwinter) were analyzed and compared to the available time-series describing longer-term variability and indications of changes in the population. Seining was performed in fall when anadromous fish display vivid spawning colouration, which differs considerably between sexes, or non-spawning colouration, which consist of fish that are either sexually immature juveniles or resting adults. Population estimates using a Petersen model (single year census) based on recaptures from two independent sources (i.e., 1] fisheries-dependent Rat River Harvest Monitoring Program, and 2] seining) were as high as approximately 30,000 fish but was followed by abrupt decline to < 7,500 fish by 2019–2022. Catch-effort data from seining, which had a moderate positive correlation with population abundance estimates from both sources of tag recaptures, was exceptionally high in 2017 (91.3 fish captured per seine haul) and became considerably low by 2022 (10.8 fish captured per seine haul). The mean fork length of the total sample of fish seined increased between 2015 (mean = 487 mm) and 2019 (mean = 537 mm), where the length frequency distributions of male and female spawners tended to be consistent among years while those of non-spawners gradually shifted towards larger sizes over time. Subsequently, mean size declined (≤ 483 mm) and the majority of the sample was comprised of juvenile non-spawners < 350 mm. Males demonstrated a higher rate of growth compared to females. Females spawning in alternate years had a higher rate of growth compared to females spawning in consecutive years. An almost equal proportion of females spawned in alternate versus consecutive years while the large majority of males spawned in alternate years. The prevalence of alternate-year spawning behaviour in females decreased as the size of fish increased. Female spawners tended to be the most prevalent life history encountered among years (~ 43–72%; mean = 52%) except in 2015 and 2022 when non-spawners were more frequent in the catch (49 and 66%, respectively). Male spawners were relatively infrequent and typically accounted for ~ 15% of the catch. As of 2022, anadromous Dolly Varden from the Rat River appear to be in a state of low abundance after experiencing a period of relatively higher population productivity between approximately 2013 and 2017.

INTRODUCTION

Monitoring of fish populations using standardized annual fisheries-independent approaches are important for developing a time-series of data to evaluate for changes in stock productivity indicators to advise management decisions. Fisheries-independent data collected for the Rat River stock of anadromous Dolly Varden (*Salvelinus malma*) (dhik'ii; Gwich'in) (iqalukpik; Inuvialuktun) has provided a valuable source of information for co-management decision-making to ensure the sustainable harvest and conservation of this culturally important population for both Gwich'in and Inuvialuit people from communities in the Mackenzie Delta area of the Northwest Territories (DFO et al. 2019).

The Rat River stock of Dolly Varden is natal to Fish Creek, a headwater tributary (transboundary between Yukon Territory and Northwest Territories) to the Rat River situated in the Richardson Mountains, southwest of the hamlet of Aklavik (Figure 1). Dolly Varden from the stock are highly philopatric and genetically distinct from other populations, and demonstrate a complex life cycle (Appendix 1) (Harris et al. 2015, Gallagher et al. 2018). Dolly Varden are relatively short-lived (few attain ages ≥ 10 years) and exhibit partial migration where one component of the population remains in freshwater for their entire life (stream-resident; almost exclusively males) while the other undertakes seasonal feeding migrations (anadromous; both females and males but predominantly females) between Fish Creek and the Beaufort Sea (Gallagher et al. 2019, Morrison et al. 2019). Anadromous Dolly Varden from the Rat River can spawn in consecutive or alternate years and can skip ocean migration (i.e., forgo migration and remain in the Fish Creek watershed during summer) once or multiple times during their lifetime (Gallagher et al. 2018). While spawning occurs primarily in the fall, there is strong evidence that a component of the adult population will spawn during summer (Gallagher et al. 2018). Although both males and females have similar silver colouration during migration, they display vivid and contrasting colouration and morphology when in spawning condition. Anadromous males display secondary spawning characteristics (e.g., kype, enlarged teeth) to defend territory from other males that are looking to access females staging at redds whereas the stream-resident males will attempt to spawn with anadromous females using a sneaker strategy to reduce the chance of negative encounters with anadromous males.

The anadromous stock is harvested for subsistence using single mesh gill nets during migration either in summer when feeding along the Yukon coast (i.e., a mixed-stock fishery) or between late summer and fall when migrating (returning upstream) in the Mackenzie Delta or lower Rat River. There has been a long history of work dating back to the 1980s among Gwich'in communities, co-management bodies, and Fisheries and Oceans Canada (DFO) to collect information to monitor the stock given that important declines in population abundance were identified by harvesters. The desire to conserve the stock and advance sustainable harvesting measures to ensure fishing for future generations prompted the establishment of programs to collect fisheries data and a co-management working group (Rat River Working Group established in 1995) that uses the results from programs, along with Indigenous knowledge, to help guide decision-making. The working group provides recommendations on harvest level (i.e., voluntary), establishes rules on gear types and best practices for handling fish, and makes research recommendations for stocks in the Gwich'in Settlement Area (Lea et al. 2021).

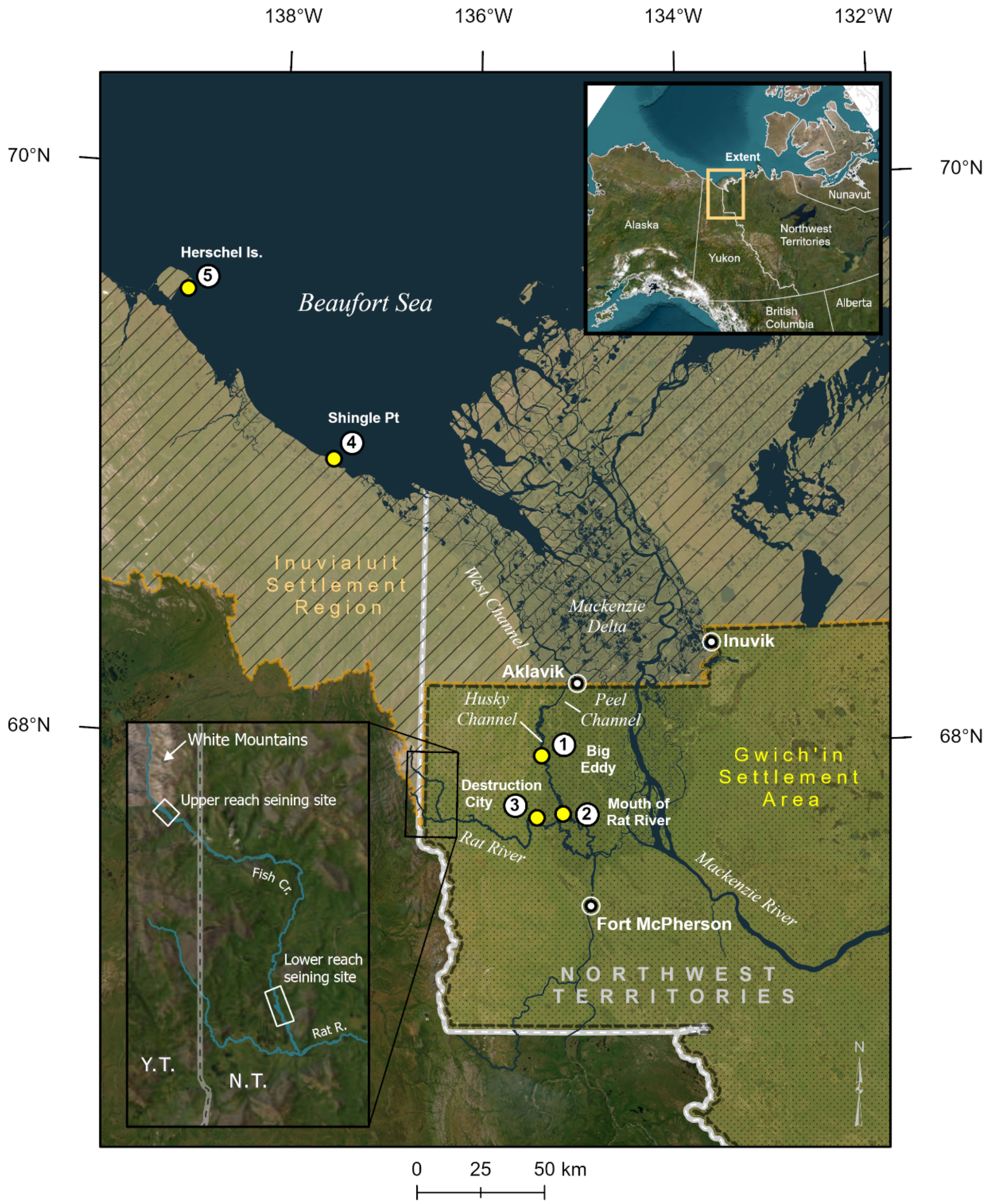

Figure 1. Locations in the Inuvialuit Settlement Region and Gwich'in Settlement Area where data are collected as part of the mark-recapture study for anadromous Dolly Varden from the Rat River stock. Insert on lower left is an image of Fish Creek, the spawning and overwintering tributary of the Rat River stock, showing the location of the upper and lower reaches where seining was conducted and fish were tagged (end of September). The reporting of recaptured fish in subsistence fisheries (coastal or inland) were either made to the Aklavik Hunter and Trapper Committee or Ehdiitat Renewable Resource Council in Aklavik or to fisheries monitoring program situated in the Mackenzie Delta at (1) Big Eddy in (Husky Channel), the Rat River at (2) the mouth and (3) Destruction City, and the coast at (4) Shingle Point and (5) Herschel Island.

An annual fisheries-independent mark-recapture program for the Rat River stock has been implemented to primarily track changes in population abundance over time. Established in 1995, the program occurs in the fall in the headwaters of the Rat River, in a tributary called Fish Creek, where Dolly Varden congregate for spawning. Fish are captured using a seine net deployed in shallow pools, tagged, and released. This document presents the results of the seining and mark-recapture program between 2015 and 2022 (note, data from previous years are summarized in Sandstrom et al. 2009 and Gallagher et al. 2020). Specifically, this document presents:

- Calculated population abundance estimates for 2014–2019 and 2022 based on two separate methods of recapture and compared to prior estimates;
- Tabulated catch-effort data and summarized biological characteristics of the population for 2015–2020 and 2022 from live-sampling conducted in Fish Creek at spawning and overwintering locations in September (length, sex, maturity/reproductive status, and growth) and compared to data collected in previous years.

Data were examined for trends over time and compared with results from previous years to characterize longer-term variability and indicators of changes in the population that inform the current stock status of anadromous Dolly Varden from the Rat River. The outcomes provide information to characterize the biological properties of the population and status of the stock, which help co-management decision-makers implement the Integrated Fisheries Management Plan (IFMP; DFO et al. 2019) for Dolly Varden.

METHODS

CAPTURE AND RECAPTURE OF FISH AT THE SPAWNING AND OVERWINTERING AREA

Between 2015 and 2022 (except in 2021), seining was conducted annually at the spawning and overwintering area for Dolly Varden in Fish Creek at the end of September, to collect fishery-independent biological information (live sampling) and attach up to 500 individually coded t-bar tags to Dolly Varden for a mark-recapture study to estimate population abundance. The seine net and technique used to capture fish were consistent with previous work described by Sandstrom et al. (2009), where seining was conducted in pools located in the lower reach of Fish Creek (N 67.76582, W 136.30533) near the start of an aufeis field, down to just above a rock slide area that is situated approximately three kilometers from its confluence with the Rat River (Figure 1 and 2).

A helicopter was used to transport a crew of four or five (Table A1) individuals and all their equipment to the spawning and overwintering area in Fish Creek, in late September-early October. The base of operations was in Inuvik, NT and community participants, typically from Aklavik, were picked up en route to the tagging site. Two single day-trips were typically planned in order to perform the work and tag up to 500 fish. On the first day, a visual reconnaissance from the helicopter was performed by the front passenger, who was experienced with the work, to identify and assess the spatial distribution of pools that have relatively high numbers of large-bodied fish, which were presumed to be Dolly Varden. Arctic grayling (*Thymallus arcticus*) can also occupy the same pools, and in years when large-bodied Arctic grayling are highly prevalent, it becomes more challenging to confidently identify and target pools that consist primarily of Dolly Varden. The helicopter would fly low to the ground, at relatively slow speeds, along the creek with the passenger window facing the stream. The crew lead would decide which pools are best to attempt to seine given the amount of time left in the day and the distance between pools deemed to have high likelihood of success. There were instances when a crew could seine the same pool again immediately afterward if it was felt the first seine might have missed a considerable number of fish that escaped during the first attempt. Additionally, the same pool could be seined again on a different day in the same year. Weather conditions in Inuvik, the Mackenzie Delta, and the Richardson Mountains were the most important factors in determining access to a site and the amount of time spent working at the site. Late September is a challenging time to fly in the area, given the transition between autumn and winter, which increases the instances of low clouds, fog, and sometimes freezing rain. Other factors influencing work at the site included water velocity, crew experience, and the extent of time needed to move among groups of pools by helicopter. Sometimes water velocity was too high to effectively seine and a decision was made to wait a number of days for the air temperature to drop and water velocity to decrease. Near-freezing conditions reduced the extent of water flowing in the area, which decreased stream level and velocity, thereby making it easier to deploy the seine net and improve efficiency of fish capture.

Figure 2. Image of the lower reach of Fish Creek illustrating the area where seining occurred. Image taken towards the south-east (facing downstream) through a helicopter window (i.e., glare in lower right quadrant) on October 5, 2019. Fish Creek's confluence with the Rat River is far in the background and is barely visible.

The only exception was in 2021 when seining at the spawning area did not occur after the helicopter-based visual reconnaissance, performed by experienced crew members (S. Lord and R. McLeod) on September 30, 2021, yielded only a small number (i.e., a total of a dozen) of large-bodied fish in the area between the rock slide and the upper aufeis. The observation was considered extremely unusual and it was deemed that the amount of fish observed did not merit the effort to attempt to seine and tag fish. A visual survey was performed in the upper reach of

Fish Creek (next paragraph) and very few large-bodied fish were also observed there. A subsequent survey flight was performed on October 22, 2021 from the mouth of the Rat River to the upper reach of Fish Creek in order to record video and assess if there was evidence of slumping or beaver activity that would have resulted in a barrier to fish passage that could explain why so few large-bodied fish (presumed anadromous) were observed at the spawning area. By October 22, there was some ice cover in the spawning area. In the open-water areas, the crew did observe more fish than on September 30, but too few to attempt tagging. Regardless, the icy conditions so late in October would have made seining impossible.

In addition to sampling conducted in the lower reach, seining was also performed at the upper reach of Fish Creek (N 67.90375, W 136.51607) in 2015, 2017–2019, and 2022. Sampling the upper reach was supplemental to the main objective of maximizing the number of intended tags deployed in a given year in the lower reach area, which was more densely occupied by the anadromous life history type. The main objective of sampling the upper reach was to obtain tissue and biological data from resident Dolly Varden to describe the resident life history type of the Rat River population. The visit to the upper site was typically performed at the end of a day spent tagging/sampling at the lower reach of Fish Creek and was often hurried, which resulted in limited seines (Table 1). In some years, a lack of time and/or poor weather did not allow access to the upper site (i.e., 2016, 2020). It is noted that the sample of resident Dolly Varden obtained from the upper site in September 2016 was collected using a backpack electrofisher, by a team conducting activities not directly linked to the seining program (K. Maier, Gwich'in Renewable Resources Board).

To capture Dolly Varden for the tagging study, a seine net was used to sweep a series of pools in the river where fish were congregated. Each fish captured in the net was identified to species and measured for fork length. The life history type of each Dolly Varden was visually identified and, for anadromous fish, the reproductive status was recorded ('non-spawner' or 'spawner') along with the sex if it was in spawning condition. Non-spawners (also termed 'silvers') are either sexually immature smolts or resting adults that are silver in colour whose sex typically cannot be confidently distinguished through external visual examination. Each anadromous fish was examined for the presence of a tag near the base of the dorsal fin and, if present, the tag number and colour were recorded. If a Dolly Varden lacked a tag and was ≥ 300 mm, it was tagged with an individually coded plastic t-bar tag at the base of the dorsal fin and then released back into the water. Injuries (scars or recent wounds) from predators observed on individual fish were also noted.

Table 1. Location, dates, number of pools seined, and the numbers of anadromous Dolly Varden from the Rat River captured and tagged in the lower and upper reaches of the spawning and overwintering areas in Fish Creek, a tributary to the Rat River between 2015 and 2022. The total number of juveniles (pre-smolt) (freshwater juvenile [FWJ], ≤ 230 mm) and resident life-history type (Res) are included, with the number of resident dead-sampled in brackets.

Location	Year	Dates	Number of pools seined	Number of anadromous fish caught	Number of anadromous fish tagged	FWJ	Res
Lower reach	2022	Sept. 30, Oct. 6, 7	32	324	297	65	14 (1)
Lower reach	2021	NA	-	-	-	-	-
Lower reach	2020	Sept. 29, Oct. 15	11	161	148	0	0
Lower reach	2019	Sept. 26, Oct. 5	20	545	493	26	0
Lower reach	2018	Sept. 18, 24	20	750	500	0	0
Lower reach	2017	Sept. 27, 28	7	639	480	0	0
Lower reach	2016	Sept. 21, 30	11	545	495	0	0
Lower reach	2015	Oct. 1, 2	13	541	496	18	2 (2)
Upper reach	2022	Oct. 7	5	1	0	3	10 (10)
Upper reach	2021	NA	-	-	-	-	-
Upper reach	2020	NA	-	-	-	-	-
Upper reach	2019	Sept.26	1	3	3	8	26 (20)
Upper reach	2018	Sept. 24	4	17	0	7	31 (24)
Upper reach	2017	Sept. 28	1	19	19	12	39 (20)
Upper reach	2016	NA	-	-	-	-	20 (20)*
Upper reach	2015	Oct. 2	1	1	0	12	30 (20)

* Electrofishing on September 22, 2016

RECAPTURE OF TAGGED FISH IN HARVEST MONITORING PROGRAMS

Tagged Dolly Varden from the Rat River were recovered in fisheries-dependent harvest monitoring programs along the Beaufort Sea coast when fish were feeding, or inland when the fish were migrating back to Fish Creek (Figure 1). Fishing at coastal sites (e.g., Shingle Point) typically occurs from mid-July until early August, and from late July to early September for inland sites (Figure 1). Additionally, tags were also directly reported to the Aklavik Hunters and Trappers Committee or Ehdiitat Renewable Resources Council by harvesters fishing in locations where monitors were not stationed (e.g., fishery in Aklavik). Although these tag returns were accounted for, they were not used in calculations for population abundance estimates (i.e., in the calculation of marked versus unmarked). Note, no tags were reported to the Tetlit Renewable Resources Council in Fort McPherson between 2015 and 2022. The large majority of recaptured fish in the Rat River Harvest Monitoring Program were comprehensively sampled for biological information, including length, sex, and maturity.

The harvest monitors collecting biological data from recaptured Dolly Varden recorded sexual maturity as either ‘mature’ or ‘immature’, where ‘mature’ is a fish that would spawn in the current year, whereas ‘immature’ is a fish that is either a sexually immature juvenile or resting adult. In order to standardize reproductive status between the seining and harvest monitoring programs when examining annual spawning frequency, ‘mature’ and ‘spawner’ were considered analogous, while ‘immature’ and ‘non-spawner’ were considered analogous.

POPULATION ABUNDANCE

Two recapture methods were used to generate separate estimates of population abundance for Dolly Varden from the Rat River between 2015 and 2022: 1) Rat River Harvest Monitoring Program and 2) seining and mark-recapture program (note, recapture data from seining in 2023 was used to estimate 2022 abundance). Prior to 2007, only estimates based on recaptures reported by the monitoring program were available. Since 2007, two estimates were possible since the approach to start seining the spawning area on an annual basis (rather than every three years) (Gallagher et al. 2020). The Petersen model was used to estimate abundance, based on the assumption that fish tagged in a given year would be susceptible to recapture in the following year (i.e., a single year census).

Most of the assumptions of the Petersen model were met. However, corrections were made to address annual recruitment into the tagged population and tag loss (see Sandstrom et al. 2009, Gallagher et al. 2011). Both recapture methods assumed all tags were available (excluding fish that experience natural mortality) and that tagged and untagged individuals were randomly mixed by the following year. For the recaptures from the subsistence fishery, it was assumed that most if not all available tags were vulnerable for recapture given that monitoring was conducted over the majority of the migration period (approximately six weeks; late July to early September). It was also assumed that the number of tagged and untagged fish captured in the subsistence fishery was accurately recorded, as trained harvest monitors were instructed to collect this information in field log sheets (Sandstrom et al. 2009). For recaptures obtained during the fall seining, contrary to recaptures from the fishery, it was assumed that the large majority of the population was distributed within a relatively small geographic area and that sampling could therefore be conducted over a short period of time (typically a few days). The estimate generated from fall seining (carried out after the subsistence fishing period) assumed that all Rat River tags recaptured in the subsistence fisheries had been reported.

The Chapman modification of the Petersen equation was used to estimate population size (*N*):

$$N = \frac{(M+1)(C+1)}{(R+1)} - 1$$

where *M* = number of individuals marked, *C* = total number of individuals captured while trying to collect marked fish, and *R* = number of individuals marked that were recaptured. The uncertainty of *N* is determined by calculating the variance (*Var*):

$$Var = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} - 1$$

Seber (1982) recommends the Poisson distribution to calculate 95% confidence intervals (C.I.) if $R/C < 0.1$ and $R/M < 0.1$, which applies in this study. To calculate the intervals, coefficients were determined based on the frequency of R, according to Seber (1982), and applied to the product of M and C to determine the lower and upper limits. To control for the issue of recruitment of unmarked individuals into the component of the population being evaluated (i.e., due to growth between sample 1 and sample 2), the lower end of the size range was adjusted upwards using the established growth relationship observed from recaptures to exclude those fish in the recapture event that would have been too small for tagging in sample 1.

CATCH-EFFORT

The catch-effort from seining was calculated as the total number of fish captured per total number of seine hauls performed in the lower reach of Fish Creek in a given year. Catch-effort could not be calculated for 2007 as the number of seine hauls was not recorded for that year.

BIOLOGICAL INFORMATION

Length

Length frequency distributions were created to compare non-spawners, female spawners, and male spawners among years. Boxplots were used to visualize the results from 2015–2022 in the longer time-series of data (extending to 1995) to better visualize temporal changes in trends among the reproductive categories and the total combined sample. Summary statistics for length (mean, median, minimum and maximum) were tabulated among non-spawners, female spawners, male spawners, and the total combined samples. Logarithmically (base 10) transformed fork length was assessed for parametric or non-parametric distribution and a Wilcox test was used to statistically compare between pairs of reproductive categories (i.e., non-spawners, female spawners, and male spawners). A Kruskall-Wallis was used to test for significant differences among years within a category.

Annual Growth

The length and reproductive status data collected from both the tagging and Rat River Harvest Monitoring programs permitted an analysis of growth of Dolly Varden from the Rat River. Tagged fish, at-large for 0.9 to one year, that were recaptured and measured in both sampling programs were used to characterize the annual growth of individual fish and annual spawning frequency.

Data with discrepancies in the sex of the fish between capture and recapture (n = 1) and where recaptured lengths were smaller than when tagged (i.e., only if difference > 5 cm; n = 5) were omitted. There were four instances when the discrepancy in annual growth was ≤ 5 cm and these were assumed to have a growth of zero from one year to the next. Growth was plotted against length at capture and fitted with a linear regression. Length at capture was also plotted against length at recapture to illustrate the annual change in length of Dolly Varden. Analysis of covariance (ANCOVA) was used to test for differences in growth between sexes (all years combined and regardless of reproductive status from one year to the next) using length at capture as a covariate. Effects of change in annual reproductive status (i.e., skip spawner or consecutive-year spawner) on growth were examined for both females and males. Levene's test and normality checks were performed to ensure assumptions of the ANCOVA tests were met.

Annual Spawning Frequency

Tagged Dolly Varden sampled for sex and maturity when recaptured in the following year by harvest monitors or seining, were used to tabulate the spawning frequency for males and females (note: samples with discrepancies in length [length at capture > recapture] were included assuming reproductive status was properly recorded upon recapture). Consecutive-year spawners were individuals that were recaptured in spawning condition (i.e., either preparing to spawn in approximately the following month if recaptured by harvest monitors or in spawning condition if recaptured while seining) in consecutive years. Alternate-year spawners were fish in spawning condition the first year and were recorded as a non-spawner in the following year. Other categories of annual change in reproductive status were tabulated, such as tagged fish that were non-spawners/'immature' the first year and recaptured as spawners or non-spawners. If consecutive year non-spawning individuals were detected, sex information could only come from recaptures in the harvest monitoring program (i.e., sex was recorded during comprehensive dead-sampling) while those from the seining program (live-sampling) had their sex categorized as 'unknown'.

Proportion Among Reproductive Categories

The proportion of male and female spawners and non-spawners captured while seining was tabulated among years. Additionally, the ratio of female to male spawners, and the percent total of spawners (regardless of sex) was calculated. A bar graph illustrating the percent contribution among reproductive categories was created to view changes in the reproductive composition since sampling began in 1995.

RESULTS AND DISCUSSION

SEINING

From 2015 to 2019, the total catch of Dolly Varden was > 500 with larger catches in 2017 (n = 639) and 2018 (n = 750), followed by years when the number of fish encountered decreased (< 325 fish; Table 1). The 2017 sampling year was exceptional given the high catch-effort value (91.3) (i.e., number of fish captured for the number of seine hauls performed), which contrasted with a declining trend in catch-effort from 2018 (37.5) to 2022 (10.8) (Figure 3). High water velocity in Fish Creek impacted the ability to effectively seine in 2016 and 2020. Specifically, the work performed on the first day at the site in both years resulted in relatively small numbers and the seining was stopped after < 10 hauls because conditions were too challenging. In 2016, the subsequent site visit occurred at the end of September and water levels were lower, resulting in improved catches (n = 101 day 1 vs. n = 404 day 2). In 2020, the earliest date possible to return to the site was in mid-October, which is considered late. By mid-October, ice had formed on the banks of Fish Creek and would break up and clog the seine net as the crew deployed the net, which rendered the net nearly inoperable. After two attempts, the crew stopped and returned home (Dolly Varden captured: n = 142 day 1 vs. n = 19 day 2). It is also noted that the aerial visual reconnaissance of the pools performed on day 1 in 2020 indicated there were not many fish occupying the site that day.

The small number of fish tagged in 2020 (n = 148) and the lack of seining and tagging in 2021 resulted in no population estimates available via the tagging program for either year. Although a relatively high number of tags from 2020 were recaptured the following year in the Rat River Harvest Monitoring Program (n = 18), the considerably smaller number of fish tagged in 2020 relative to other years reduced our confidence in using the information to generate a population estimate that would provide robust advice.

The small number of anadromous Dolly Varden seined while targeting the resident life history type, at the upper reach of Fish Creek, were similar to the sizes of anadromous fish encountered in the lower reach (Table 2). Residents were clearly more prevalent at the upper reach location, although three were encountered at the lower site among years, which is consistent with earlier results presented in Gallagher et al. (2020).

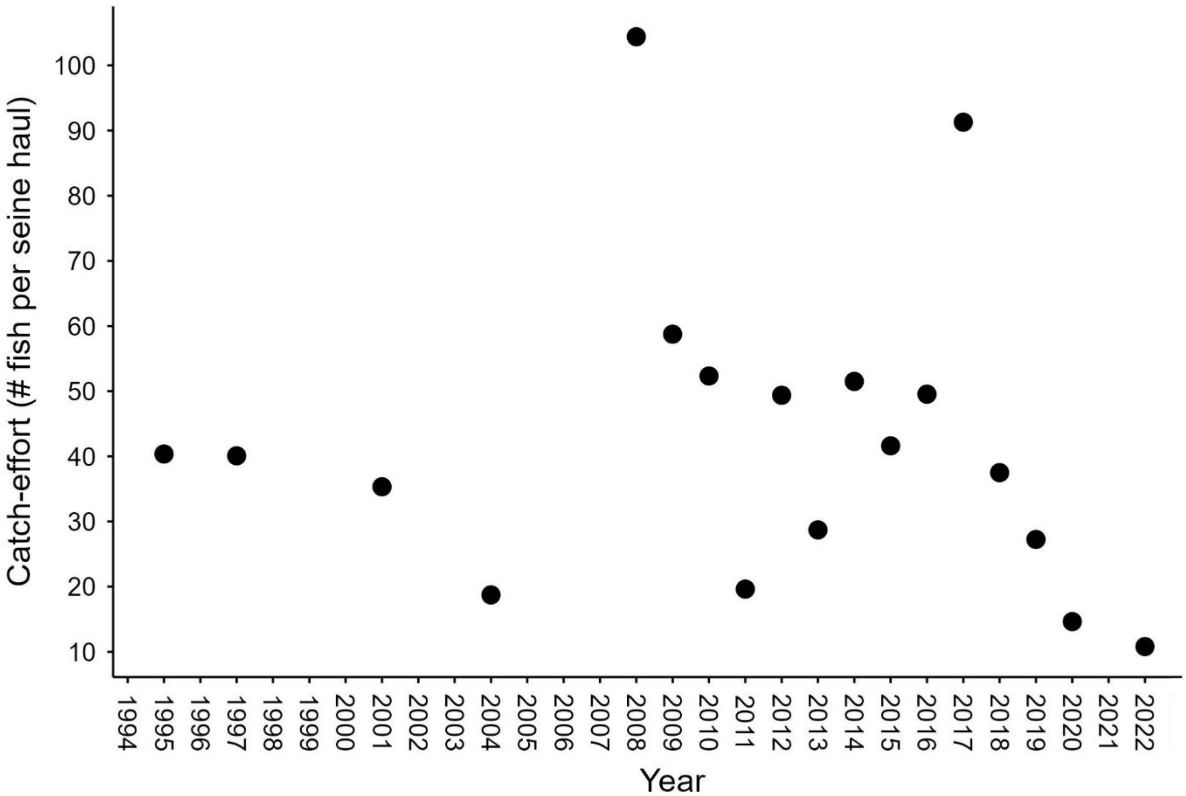

Figure 3. Catch effort (# fish per seine haul) of anadromous Dolly Varden seined at the spawning and overwintering area (lower reach) in Fish Creek between 1995 and 2022.

Table 2. Mean (± standard deviation), median, range, and sample size (n =) of fork length (mm) of anadromous Dolly Varden from the Rat River identified as non-spawners, and female and male spawners captured in the lower (above dashed line) and upper reaches (below dashed line) of Fish Creek at spawning and overwintering locations. Sampling performed using a seine net between late September and early October, 2015–2022.

Year	Non–spawner				Female spawner				Male spawner				Total			
	Mean	Median	Range	n	Mean	Median	Range	n	Mean	Median	Range	n	Mean	Median	Range	n
2022	376 ± 75	356	216–684	214	499 ± 62	485	375–646	103	536 ± 40	518	497–594	7	419 ± 92	425	216–684	324
2021	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2020	373 ± 74	354	295–665	62	529 ± 54	536	350–616	70	612 ± 64	628	455–731	28	483 ± 112	504	295–731	160
2019	531 ± 86	540	306–700	115	534 ± 47	532	420–681	376	570 ± 68	556	430–705	53	537 ± 60	535	306–705	544
2018	504 ± 73	506	312–664	118	526 ± 55	525	388–715	543	595 ± 79	600	396–735	89	531 ± 66	529	312–735	750
2017	515 ± 74	512	314–755	187	523 ± 54	520	390–667	365	569 ± 77	560	448–715	86	527 ± 66	520	314–755	638
2016	484 ± 71	470	325–730	169	513 ± 51	510	340–720	287	575 ± 74	575	385–750	89	514 ± 69	510	325–750	545
2015	454 ± 84	460	290–655	265	511 ± 58	510	390–680	202	536 ± 90	540	340–720	74	487 ± 83	490	290–720	541
2022	201	–	–	1	–	–	–	–	–	–	–	–	201	–	–	1
2021	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2020	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2019	–	–	–	–	490	–	–	1	434 ± 83	434	375–492	2	452 ± 67	490	375–492	3
2018	–	–	–	–	509 ± 36	510	463–572	8	541 ± 56	546	440–614	9	526 ± 49	529	440–614	17
2017	–	–	–	–	444 ± 18	438	428–471	6	497 ± 67	492	370–615	13	481 ± 61	471	370–615	19
2015	–	–	–	–	–	–	–	–	465	–	–	1	465	–	–	1

*sampling did not occur in 2021

POPULATION ABUNDANCE

Estimates of abundance based on the recaptures from the Rat River Harvest Monitoring Program were relatively high from 2014 to 2018 (~ 14,500–30,000) and decreased abruptly thereafter with the values in 2019 and 2022 equal to ~ 7,500 and ~ 5,200, respectively (Table 3; Figure 4). Confidence intervals were very wide for the high population estimates from 2014–2018, with upper values > 90,000 in some years. Similarly, the estimates from seining at Fish Creek indicated an increasing pattern in abundance from 2014 (~ 8,700) to 2017 (~ 28,900), which was followed by a smaller, yet relatively high value in 2018 (~ 17,400), and a pronounced decline by 2019 (~ 5,300), that did not differ greatly from the estimate in 2022 (~ 6,300) (Table 3; Figure 4). In most years, the estimate from the harvest monitoring was higher, sometimes considerably, compared to the estimate from seining in the same year. Estimates from both recapture methods tended to be more similar to each other in years when abundance was < 15,000 (although see 2017). There has been an increasing trend in abundance regardless of recapture method since 2007, which appeared to have peaked in 2017 at values that exceeded all prior estimates since 1995 when the mark-recapture program began (Figure 4).

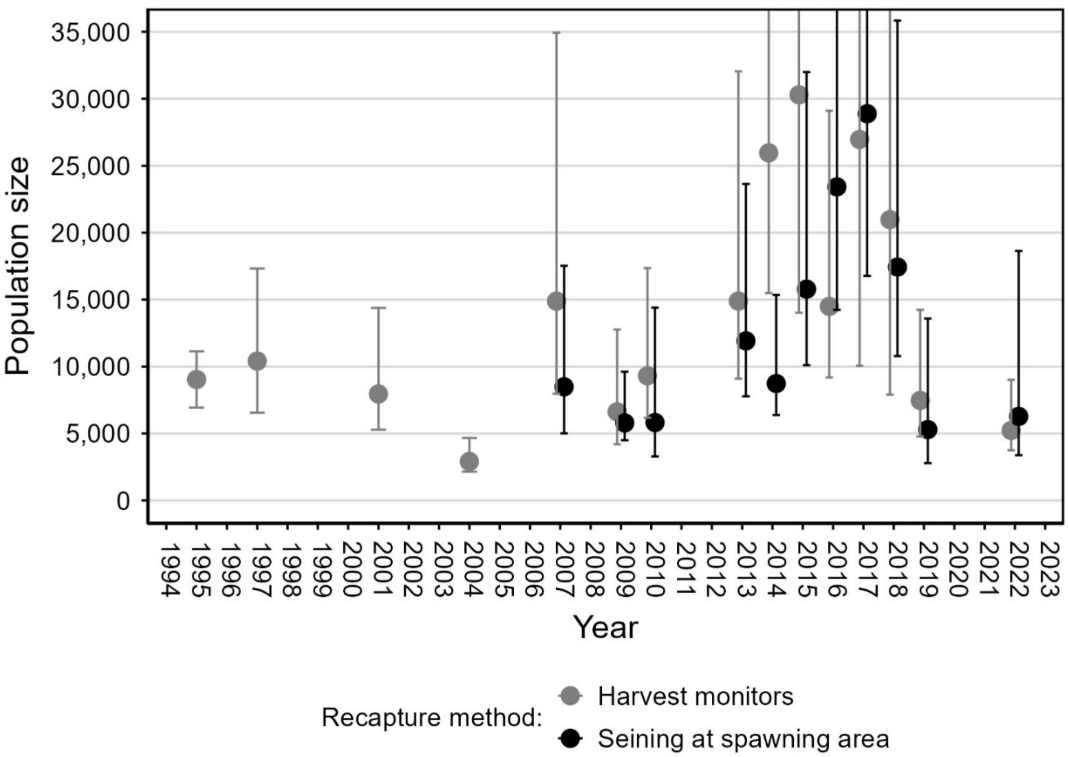

Figure 4. Population abundance estimates of anadromous Dolly Varden from the Rat River between 1995 and 2022. Given the very high 95% confidence intervals observed in 2014–2018, the y-axis (population size) was limited to 35,000 for easier visualization of the trend in abundance. Grey points are estimates based on recaptures from harvest monitors and black points are estimates based on recaptures from seining.

Table 3. Calculations of the Petersen model used to estimate the population abundance and 95% confidence intervals (C.I.) (Poisson distribution) of anadromous Dolly Varden from the Rat River in 2014–2019 and 2022 based on the recapture of fish by the harvest monitoring program (subsistence gill nets) and seining at the spawning and overwintering area.

Parameter	Harvest Monitoring Program							Seining Program						
	2014	2015	2016	2017	2018	2019	2022	2014	2015	2016	2017	2018	2019	2022
Minimum fork length (mm) of tagged Dolly Varden included in recapture sample	300	305	325	314	333	306	300	300	305	325	314	333	306	300
Estimated length (mm) of the smallest tagged fish the following year rounded to nearest 5 mm	400	400	400	390	400	400	420	400	400	400	390	400	400	420
Recapture year	2015	2016	2017	2018	2019	2020	2023	2015	2016	2017	2018	2019	2020	2023
Total catch > minimum size examined in recapture year (C*) [see Table A2]	739	471	486	292	229	261	465	471	533	649	759	539	107	203
Number of tags observed in recapture event (R*)	12	6	14	4	4	15	23	23	14	11	11	13	8	7
Number of tags applied†	499	496	495	499	500	496	297	499	496	495	499	500	496	297
Estimated annual tag loss rate (%)††	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Reported previous year tags recaptured in subsistence fishery†††	4	8	10	0	5	1	5	16	14	24	4	9	16	28
Number of tags available for recapture (M*)	455	448	445	459	455	455	268	443	442	431	455	451	440	245
Abundance estimate (N*)	25,960	30,296	14,492	26,960	20,975	7,471	5,227	8,733	15,781	23,421	28,884	17,433	5,295	6,278
Lower 95% C.I.	15,488	14,017	9,190	10.054	7,901	4,725	3,571	6,383	10,099	14,232	16,788	10,780	2,792	3,382
Upper 95% C.I.	54,208	90,643	29,109	107,533	84,501	14,370	9,018	15,347	31,989	53,007	62,492	35,844	13,586	18,630
Percent of population tagged > minimum size	1.9	1.6	3.4	1.9	2.4	6.6	5.7	5.7	3.1	2.1	1.7	2.9	9.4	4.7
Percent of tags observed in recapture event (following year)	2.6	1.3	3.1	0.9	0.9	3.3	8.6	5.2	3.2	2.5	2.4	2.9	1.8	2.9

†Tag colours: 2014 = Blue; 2015 = Orange, 2016 = Yellow, 2017 = Blue, 2018 = Orange, 2019 = Yellow, 2020 = Yellow, 2022 = Yellow and Blue
†† See Sandstrom et al. 2009
††† Harvest Monitoring Program: tags reported from Shingle Point or elsewhere in the Mackenzie Delta; Seining Program: tags reported from all subsistence fisheries.
* parameter of the Petersen equation to estimate population abundance

Population abundance estimates were positively correlated with catch-effort from seining (Figure 5). The Pearson correlation between catch-effort and abundance for tags reported from the harvest monitoring program and the fall seining program was equal to 0.54 and 0.58, respectively. Catch-effort has varied considerably over the available time series of data and has seemingly mirrored the temporal pattern in population abundance. The peak in catch-effort in 2017 corresponded with a high population abundance and the low catch-effort values in 2004 and 2022 were associated with low abundances. Catch-effort data from seining, as it is for gill nets and other fishing gear, should be treated cautiously as an indicator of abundance, given that stream conditions can affect catchability. Furthermore, the seining crew composition and level of experience can vary among years, which can influence how the seine is deployed and how fish are corralled into the net. Regardless, the accumulation of years of data suggests the catch-effort information from seining can be a useful coarse indicator of relative abundance for the stock.

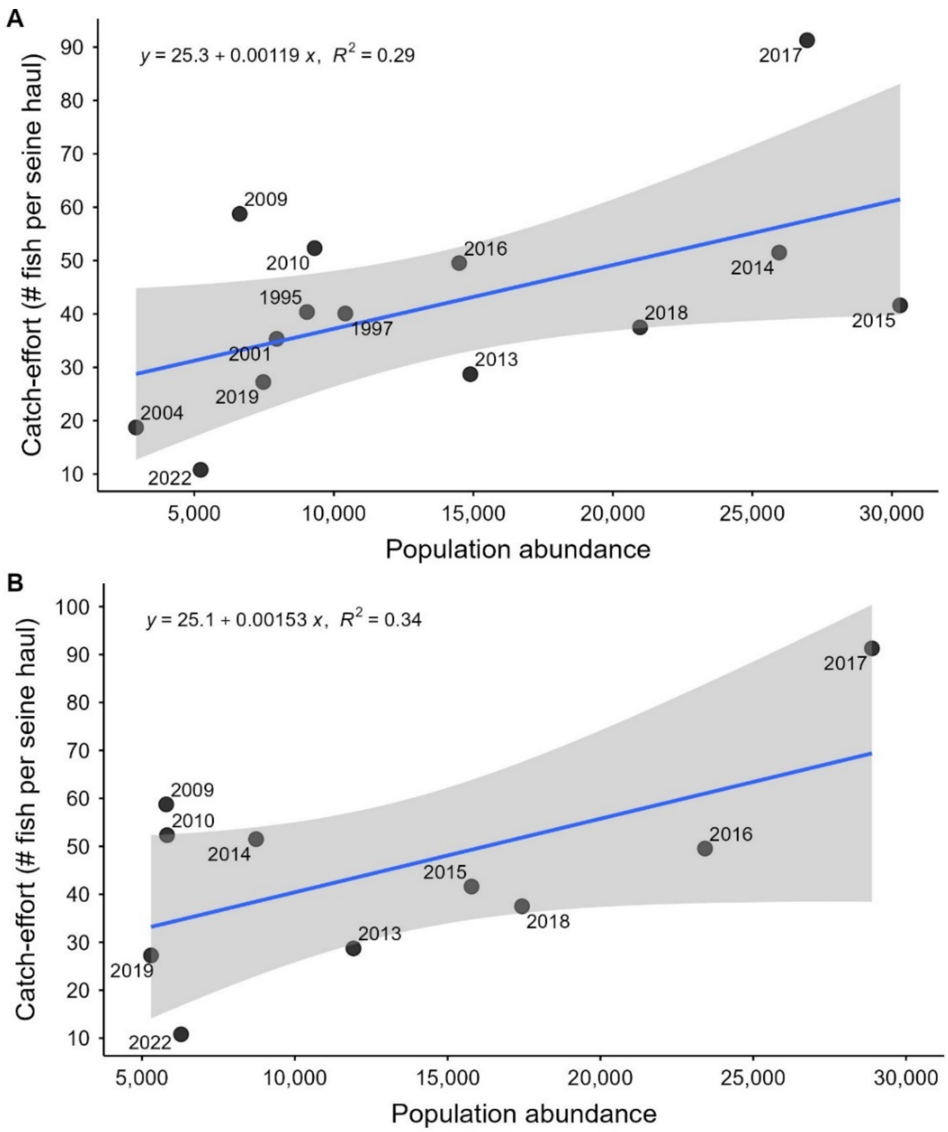

Figure 5. Linear regression between catch-effort from seining and mark-recapture population abundance estimates generated using recapture of tagged Dolly Varden, 1995–2022, from A) the Rat River Harvest Monitoring Program and B) Fall Seining and Tagging Program. Blue line is the linear regression fitted to the data and the grey shaded area is the 95% confidence interval.

LENGTH

The fork length of anadromous Dolly Varden sampled in the lower reach of Fish Creek between 2015 and 2022 ranged between 216 and 720 mm. In each year, the average length of male spawners (range of means = 536–612 mm) was greater than either female spawners (range of means = 499–534 mm) or non-spawners (range of means = 376–504 mm) (Table 3). The smallest male in spawning condition was 340 mm, yet sizes were mainly distributed among those ≥ 500 mm (Figure 6). Similarly, small females < 400 mm in spawning condition were observed, although most sizes were primarily distributed among 450–575 mm size classes (Figure 6). From 2015 to 2019, distributions of male and female spawners tended to be consistent while those of non-spawners gradually shifted towards larger sizes. In a remarkable change from one year to the next, the large majority of non-spawners in 2020 were small in size (< 350 mm) while male spawners were relatively large compared to other years (Figure 6). In 2022, the length distribution of non-spawners was bimodal with a relatively high proportion of fish < 350 mm (similar to 2020) and a second peak in sizes 300–400 mm while the mean size of male spawners had decreased, although sample size was small (n = 7) (Figure 6). Statistically significant differences in size were observed between non-spawners and female spawners (W = 666,654, $p < 0.001$), non-spawners and male spawners (W = 102,316, $p < 0.001$), and female spawners and male spawners (W = 280,830, $p < 0.001$). Fork length differed significantly among years for non-spawners ($X^2 = 389$, df = 6, $p < 0.001$), female spawners ($X^2 = 60.3$, df = 6, $p < 0.001$), and male spawners ($X^2 = 30.2$, df = 6, $p < 0.001$).

When examining the size of the total combined sample of Dolly Vaden captured among years of seining, we observe a gradual increase in mean length between 2014 and 2019, followed by a substantive change to smaller sizes in subsequent years (Figure 7A). Gradual annual increase in mean length followed by a decline was also apparent from 2007 to 2014. When examining temporal patterns among the three reproductive categories, the increase in mean length starting in 2014 and subsequent shift to smaller sizes was very apparent for non-spawners (Figure 7B). Interestingly, the size distribution of female spawners has remained fairly consistent among all sampling years, while those of male spawners were more variable, particularly between 2012 and 2020 when wider distribution in sizes was evident compared to earlier years (Figure 7B).

The increase in size of Dolly Varden up to 2019 followed by a noticeable decline is consistent with length data for the stock collected through the Rat River Harvest Monitoring Program (Gallagher et al. 2026).The lower mean sizes in recent years are attributable to a large number of small immature fish that are three and four years of age (based on length-at-age data in Gallagher et al. 2026) and possibly an indication of a pulse of juvenile recruitment into the population following the decline in abundance. The temporal consistency in the size of female spawners over the available time-series indicates that female size at maturity may not be strongly influenced by changes in abundance (i.e., population density) (see Johnston and Post 2009). The greater variation in size over time observed for non-spawners is likely a result of changes in the proportion of resting adults versus immature juveniles in the population present during seining. Strong interannual differences in rates of survival and mortality of resting adults and juveniles, and year class strength will presumably be expressed in the size distribution of small non-spawners.

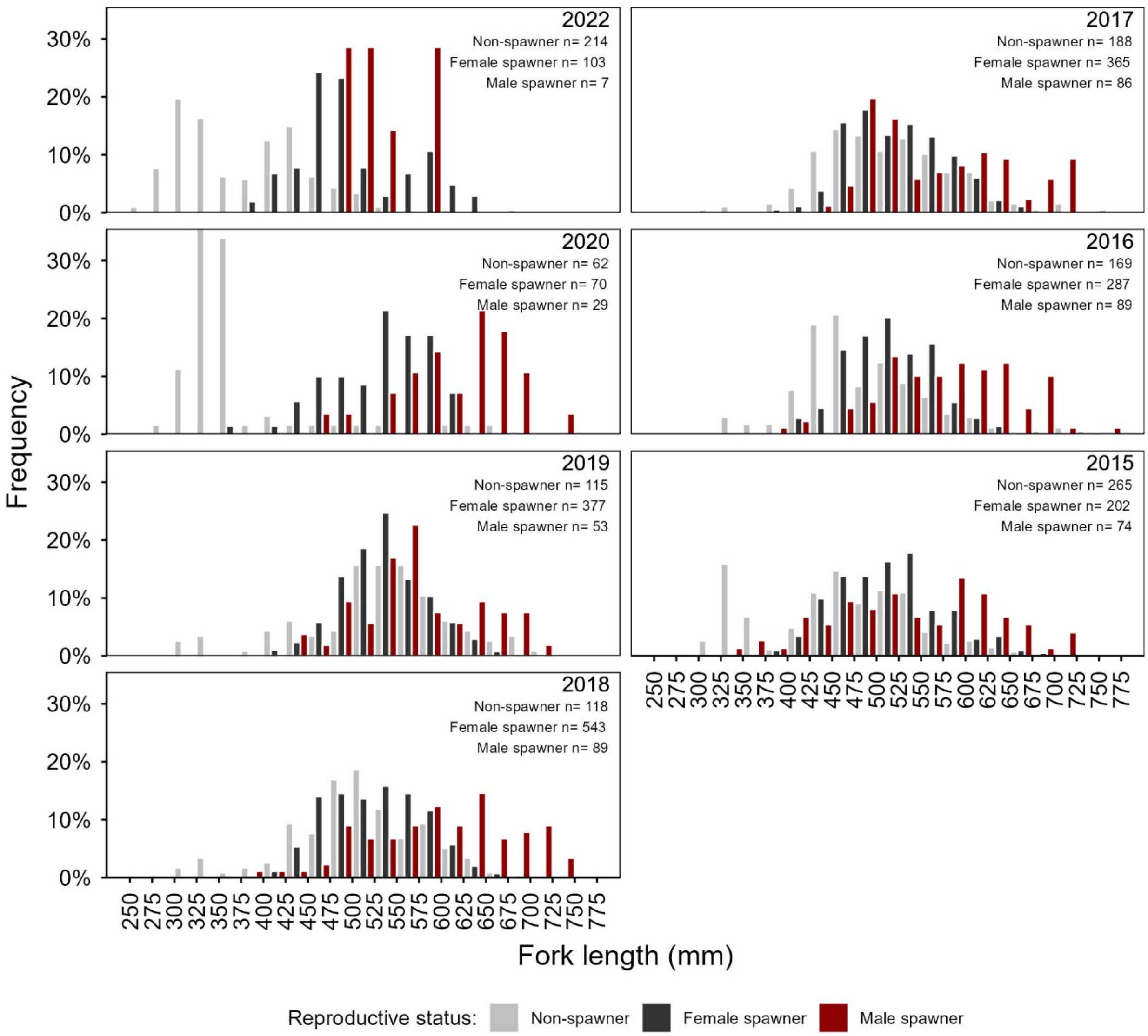

Figure 6. Length frequency distribution of anadromous Dolly Varden from the Rat River captured by seine net at the spawning and overwintering area (lower reach) in Fish Creek (2015–2022) and identified as non-spawner (grey), female spawner (black), and male spawner (red). Note: in 2022, 4 non-spawners were < 250 mm. n is sample size.

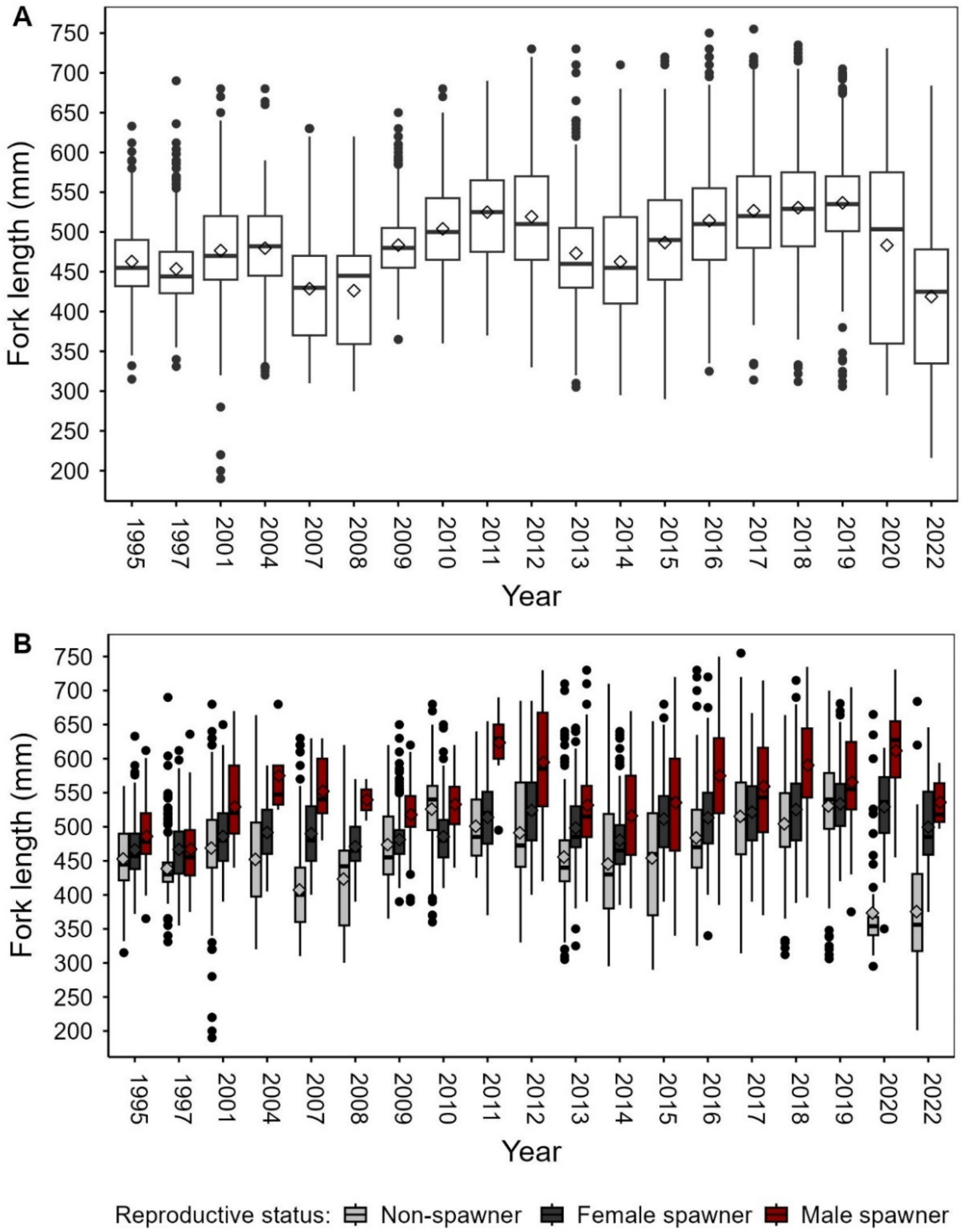

Figure 7. Box plot of fork length (median [–], mean [◊], quartiles, and outliers [●]) of anadromous Dolly Varden from the Rat River, captured by seine net at the spawning and overwintering area (lower reach) in Fish Creek (1995–2022). A) the total sample and B) fish identified as non-spawners (grey), female spawners (black), and male spawners (red).

GROWTH

The annual growth of tagged anadromous Dolly Varden was assessed based on 145 recaptures obtained between 2015 and 2022 (i.e., n = 82 from harvest monitors and n = 63 from seining; two fish were recaptured twice in separate years) (Figure 8). The annual change in length from one year to the next was described with the linear equation:

$$\textit{Length (mm)}_{year2} = 193 + 0.285 \times \textit{Length (mm)}_{year1}$$

Males (n = 33) had a higher rate of growth compared to females (n = 99) (F (1, 131) = 34.2, p < 0.001) (Figure 9). Females that spawned in alternate years (‘spawner to non-spawner’) had a higher rate of growth compared to females that spawned in consecutive years (‘spawner to spawner’) (F (1, 67) = 22.5, p < 0.001) (Figure 10). Female non-spawners recaptured as spawners the following year were mainly distributed among 450–575 mm sizes and had the lowest growth rate compared to consecutive- and alternate-year spawners whereas fish < 400 mm (presumably first time spawners when recaptured) had a higher growth that was more consistent with juveniles (i.e., small sized consecutive-year non-spawners) (Figure 10). Males spawning in alternate years demonstrated highly variable growth as indicated by the wide confidence intervals in the regression.

The overall pattern in annual growth of Rat River Dolly Varden from 2015–2019, which differs between sexes and affected by annual spawning frequency, is consistent with results from earlier years (Sandstrom et al. 2009, Gallagher et al. 2020). The low rate of growth in females, which were tagged as non-spawners and recaptured the following year as spawners, is a result of not having migrated to sea in the year after tagging and remaining in freshwater in order to spawn, which prevented the opportunity to accumulate energy to invest into substantive growth (Gallagher et al. 2018). The large majority of females demonstrating this annual change in reproductive status were obtained from seining (n = 24) rather than harvest monitoring (n = 3). The three individuals captured in the harvest monitoring during their return from the ocean had an annual growth > 50 mm while the 24 individuals from seining demonstrated annual growth < 20 mm.

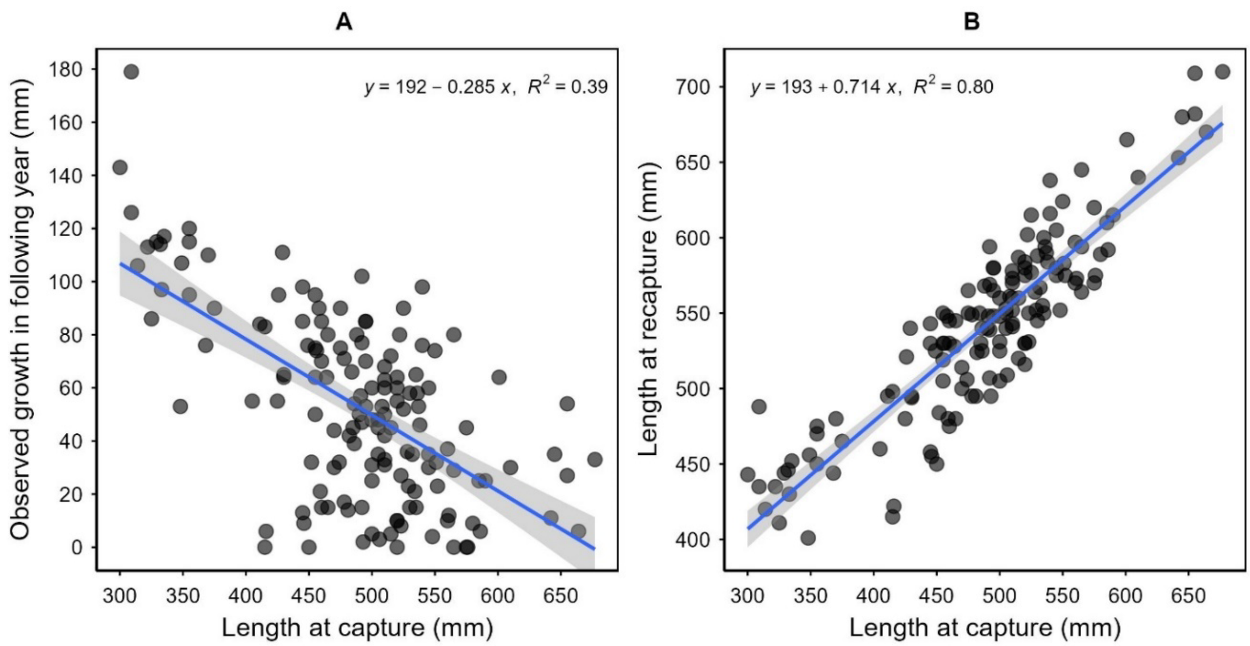

Figure 8. A) Observed annual growth and B) length at capture and recapture of Dolly Varden from the Rat River, based on mark-recapture studies between 2015 and 2022. Linear regression (blue solid line) and 95% confidence intervals (grey shaded area) are illustrated.

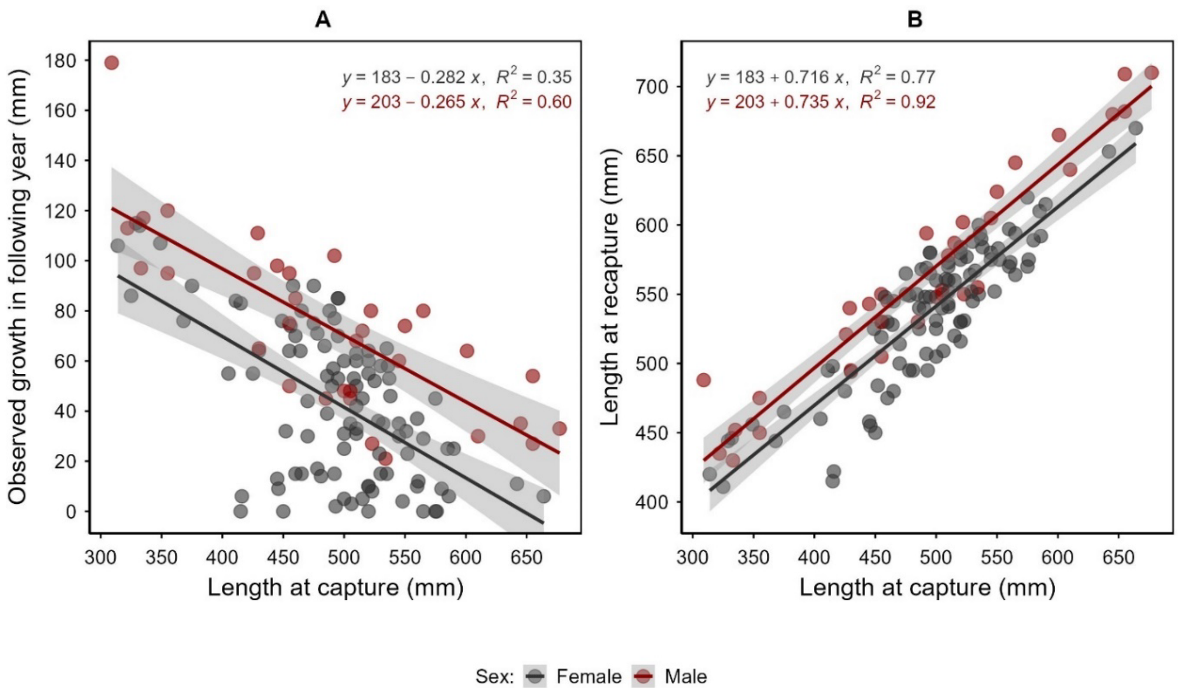

Figure 9. A) Observed annual growth and B) length at capture and recapture of female (grey points) and male (red points) Dolly Varden from the Rat River based on mark-recapture studies between 2015 and 2022. Linear regressions (solid line) and 95% confidence intervals (grey shaded area) are illustrated.

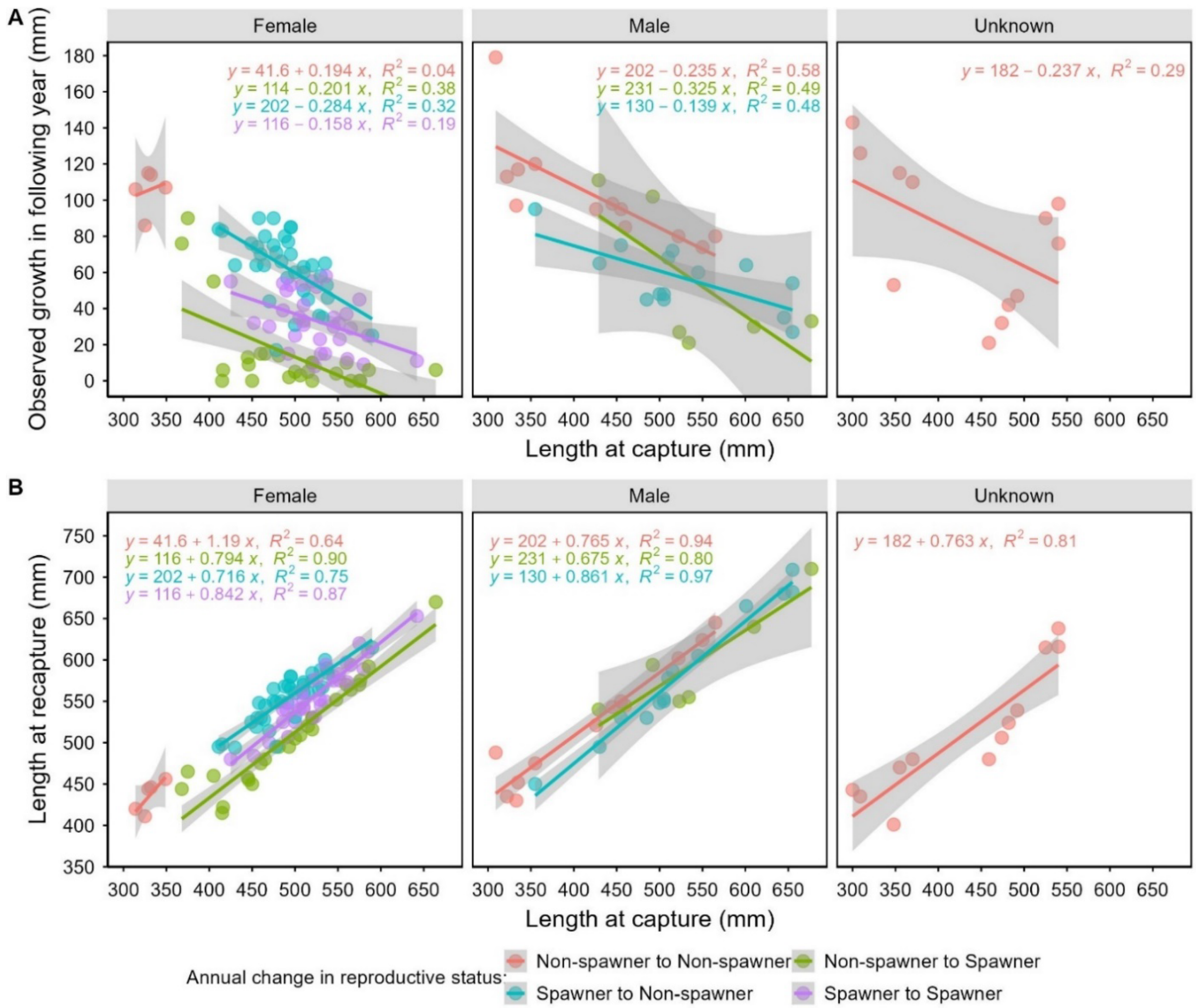

Figure 10. A) Observed annual growth and B) length at capture and recapture among female, male and sex unknown Dolly Varden from the Rat River among categories of reproductive status from one year to the next based on mark-recapture studies between 2015 and 2022. Linear regressions and 95% confidence intervals are illustrated. Reproductive status change: non-spawner to non-spawners are red, non-spawners to spawner are green, spawner to non-spawner are blue, and spawner to spawner are purple.

REPEAT AND SKIP SPAWNING, AND PROPORTION OF NON-SPAWNERS AND SPAWNERS

Among known mature individuals (i.e., identified as spawners when tagged), alternate- (52.1%) and consecutive-year (47.8%) spawning was detected in nearly equal proportions for females (Table 4). Alternatively, 93.4% of mature males (15 of 16) skipped spawning in the following year (Table 4). Female spawners tended to be the most prevalent life history encountered among years when seining the spawning and overwintering area (~ 43–72%; mean = 52%), except in 2015 and 2022 when non-spawners were more frequent (49 and 66%, respectively) (Table 5). Male spawners were relatively infrequent among years and typically accounted for ~ 15% of the catch with the exception of 9.7% and 2.1% in 2019 and 2022, respectively (Table 5). The proportion of non-spawners averaged 36% and was variable among years with values as low as 15.7% and as high as 66% observed in 2018 and 2022, respectively. See

Gallagher et al. (2018) for a more detailed explanation of why fewer male spawners are observed in the population and how spawning frequency and annual migration tactics are interrelated.

Female spawners considerably outnumbered male spawners by typically six times, although in 2022 a considerably higher number was observed (15.1x) (Table 5). Among years, spawners (regardless of sex) contributed the most to the composition of the catch (typically > 60%) apart from 2015 (50.9%) and 2022 (33.8%). The composition of female and male spawners, and non-spawners from 2015–2022 appeared consistent with earlier years with a seemingly sinusoidal pattern in the proportion of female spawners and non-spawners over time (Figure 11). Interestingly, a relatively high proportion (~ > 10%) of males were consistently observed from 2015–2020, which has not been observed in previous years.

Among adult females > 550 mm, spawning frequency was almost exclusively in consecutive years. One possible explanation is that fitness among larger/older fish is maximized by investing energy into reproduction given they are approaching senescence and annual growth rate for these size classes is low, thereby reducing the benefits that growth (e.g., greater fecundity) confers to smaller-sized fish that spawn more often in alternate years.

Table 4. Frequency among categories of annual change in reproductive status for female, male, and sex unknown anadromous Dolly Varden from the Rat River based on the recapture of tagged fish in the Rat River Harvest Monitoring Program and by seining at the spawning and overwintering area between 2015 and 2022.

Annual change	Female	Male	Unknown
Non-spawner to Non-spawner	5	12	12
Non-spawner to Spawner	27	6	-
Spawner to Spawner	34	1	-
Spawner to Non-spawner	37	15	-
Total	103	34	12

Table 5. Percent and number (in brackets) of live-sampled anadromous Dolly Varden from the Rat River identified as non-spawners, and female (F) and male (M) spawners captured at the lower reach of Fish Creek. Fish were captured using a seine net at spawning and overwintering locations in late September to early October between 2015–2020 and 2022. The ratio of female to male spawners, and percent spawners are calculated.*

Year	Non-spawner	Female spawner	Male Spawner	Total	F:M spawner	% spawner
2022	66.0 (214)	31.7 (103)	2.1 (7)	324	15.1:1	33.8
2020	38.5 (62)	43.4 (70)	18.0 (29)	161	2.4:1	61.4
2019	21.1 (115)	69.1 (377)	9.7 (53)	545	7.1:1	78.8
2018	15.7 (118)	72.4 (543)	11.8 (89)	750	6.1:1	84.2
2017	29.4 (188)	57.1 (365)	13.4 (86)	639	4.3:1	70.5
2016	31.0 (169)	52.6 (287)	16.3 (89)	545	3.2:1	68.9
2015	48.9 (265)	37.3 (202)	13.6 (74)	541	2.7:1	50.9

*sample size too low for upper reach

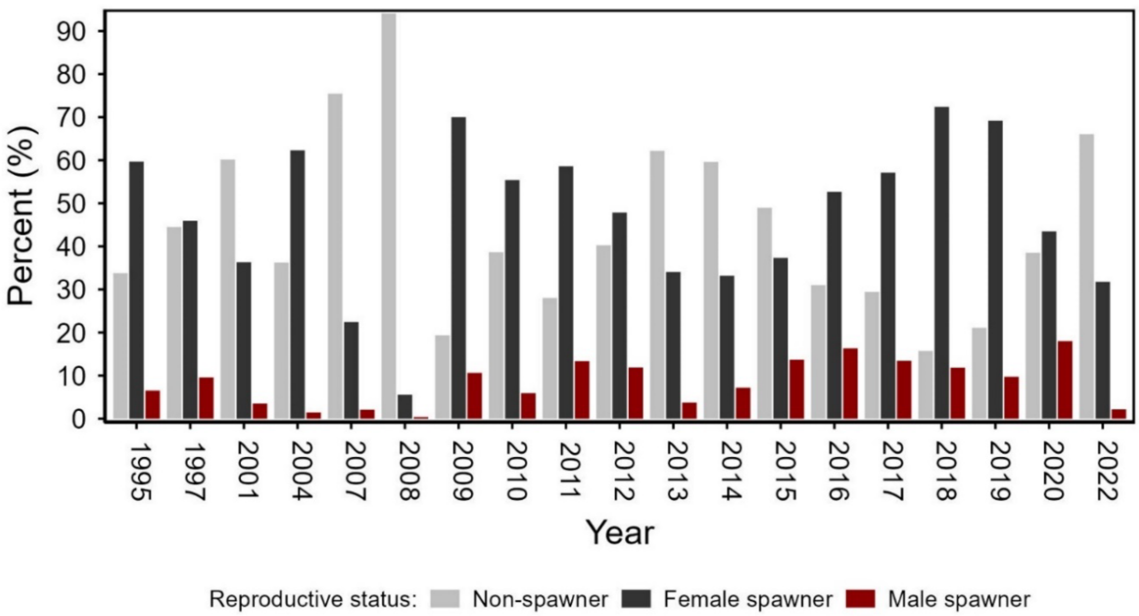

Figure 11. Percent of anadromous Dolly Varden from the Rat River captured by seine net at the spawning and overwintering area (lower reach) in September and or October (1995–2022) identified as non-spawners (light grey), female spawners (black) and male (red) spawners.

SUMMARY

The time-series of population abundance, catch-effort, and biological indicators for Dolly Varden from the Rat River obtained through a mark-recapture program performed between 2015 and 2022 indicated:

- Estimates of abundance based on the recaptures in the Rat River Harvest Monitoring Program were relatively high from 2014 to 2018 (~ 14,500–30,000) and decreased abruptly thereafter, with the values in 2019 and 2022 equal to ~ 7,500 and ~ 5,200, respectively
- Estimates of abundance, based on the recaptures from seining at Fish Creek, indicated an increasing pattern in abundance from 2014 (~ 8,700) to 2017 (~ 28,900) that was followed by a smaller, yet relatively high value in 2018 (~ 17,400) and a subsequent pronounced decline by 2019 to ~ 5,300 fish that did not differ considerably from the estimate in 2022 (~ 6,300).
- Catch-effort data from seining had a moderate positive correlation with population abundance estimates from both sources of tag recaptures.
- The mean length of the total combined sample increased between 2015 and 2019, where the length frequency distributions of male and female spawners tended to be consistent among years, while those of non-spawners gradually shifted towards larger sizes over time. Subsequently, mean size declined and the majority of the sample was comprised of juvenile non-spawners < 350 mm.
- The fewer fish captured, tagged, and aerially observed at the spawning area in Fish Creek between 2020 and 2022 is concomitant with a decline in population abundance, total harvest in subsistence fisheries, and catch-effort in both the Rat River Harvest Monitoring and seining programs.

- The years of low abundance (2020, 2022) were associated with increased presence of juvenile non-spawners < 350 mm, accompanied by an indication of a pulse of juvenile recruitment, given the bimodal juvenile size structure that would correspond with fish that are 3 and 4 years of age. A similar pattern was observed in 2007 and 2008, which preceded an increase in population abundance.
- Female spawners consistently outnumbered male spawners and the proportion among female and male spawners and non-spawners appeared consistent with previous sampling at Fish Creek. There was a seemingly sinusoidal pattern in the proportion of female spawners and non-spawners over time.
- The annual spawning frequency of females and males along, with the pattern in annual growth between males and females, and among categories of annual reproductive change within sexes, are consistent with data collected from the seining program in earlier years.

CONCLUSION

As of 2022, and based on the results from the seining and mark-recapture program and the Rat River Harvest Monitoring Program, anadromous Dolly Varden from the Rat River appear to be in a state of low abundance after experiencing a period of relatively higher population productivity between approximately 2013 and 2017. This appears to be the second notable decline since 1995, when fisheries-dependent and -independent programs coincided, after the first decline observed in 2004. However, it is important to underscore that “decline” is relative, given that in the greater context of time, the stock has experienced a more substantial decrease in abundance decades ago (Benson 2010). This most recent decline suggests the population can experience important fluctuations in abundance over short periods of time. The decline in 2004 was preceded by harvest rates that were considerably higher (up to 36%), which may have contributed to reductions in population abundance (Howland et al. 2012). It is unlikely that the recent decline is a product of harvest, given the low rate of removal experienced by the stock (i.e., typically < 5%). The role of freshwater and marine environmental factors on recruitment, growth, mortality, and migration tactics and timing of Dolly Varden and their implications for subsistence fisheries requires additional research.

Alternative and more robust models (e.g., POPAN or Cormack-Jolly-Seber) should be investigated using the available time-series of tagging data. For example, models that can combine data from both recapture programs (e.g., stratified Petersen model) to generate one estimate would be an efficient use of the data and potentially produce a more precise estimate of abundance among years. Future work linking mark-recapture models to environmental data to investigate the relationship between abundance or survival and marine or freshwater variables would be beneficial in future population assessments for the Rat River stock to better inform co-management decision-makers on the potential drivers of population change and how it could affect subsistence harvesting.

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APPENDIX. TABLES AND FIGURES

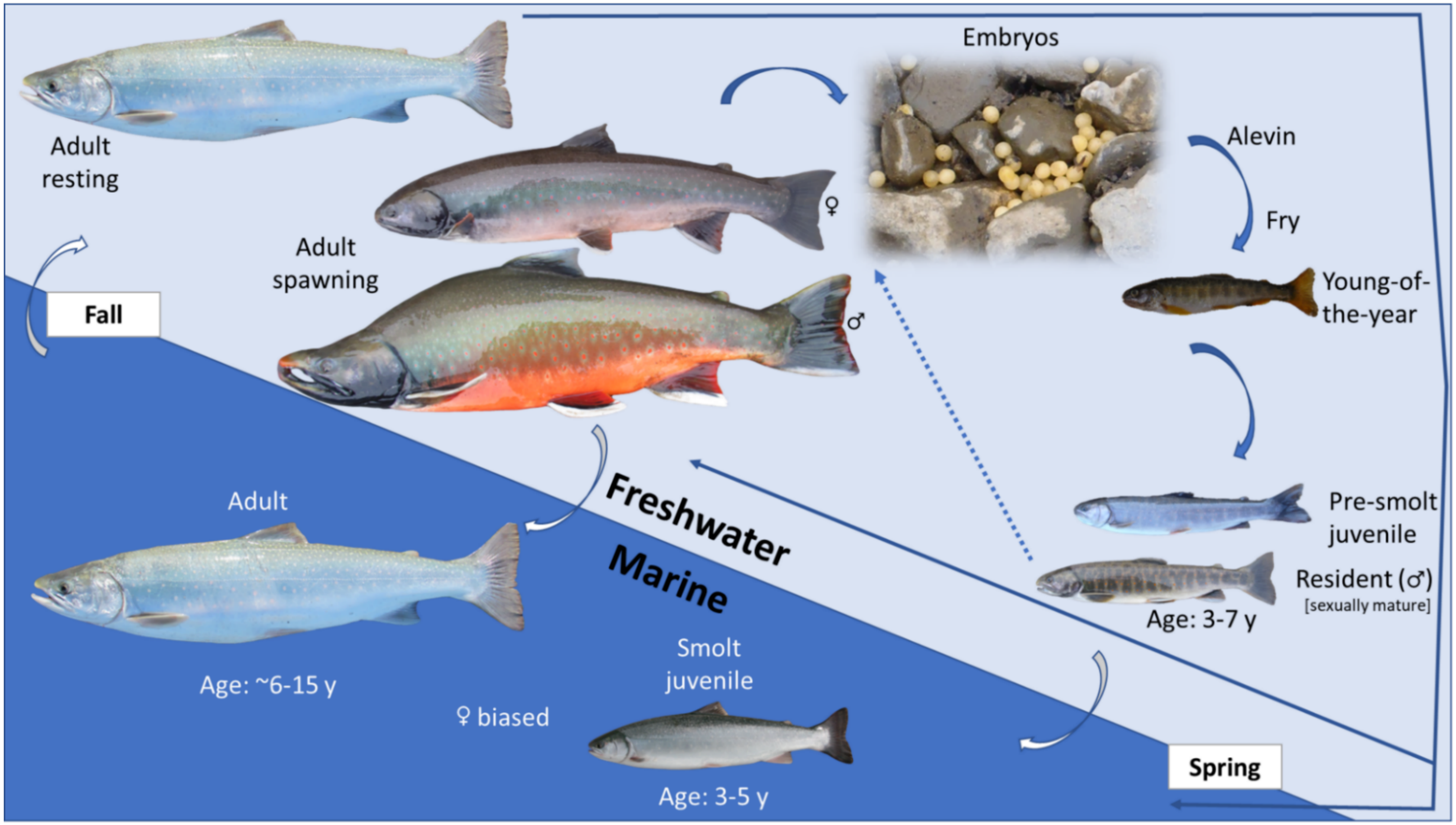

Figure A1. Life cycle of Dolly Varden from the Rat River. Embryos develop in gravel-cobble substrates with groundwater springs in Fish Creek and juvenile stages rear in the watershed. A component of males will adopt a resident life history tactic and remain and attain sexual maturity in freshwater, and will spawn with anadromous individuals. The anadromous component of the population begin seasonal migrations as juveniles to the Beaufort Sea starting between ages 3 and 5. After approximately two annual migrations anadromous fishes attain sexual maturity. Mature (i.e., intending to spawn in the current year), resting (i.e., sexually mature but does not spawn in the current year), and juvenile anadromous fish return to freshwater to reproduce and or overwinter in Fish Creek. Some anadromous fish (female and male) can skip ocean migration and remain in the Fish Creek watershed during summer and spawn in the following year, and conduct an ocean migration in the following spring. Photos by Colin Gallagher.

Figure A2. Images taken during seining and mark-recapture program in Fish Creek (Rat River), 2015–2022. Top Left Image: Rayna Vittrekwa, Ryan McLeod, and Doug Wilson (listed left to right). Top, Middle Image: crews tending to seine net in the lower reach of Fish Creek. Top, Left Image: Colin Gallagher, Ellen Lea, Ryan McLeod and Sarah Lord (listed left to right). Second row, Left Image: View of lower reach of Fish Creek by helicopter. Second row, Middle Image: Crew examining a seine catch in front of the helicopter. Second row, Right Image: Freddie Furlong holding a Dolly Varden. Third row left Image: Seining in lower reach of Fish Creek. Third row right Image: Dennis Semple holding a Dolly Varden. Bottom left Image: View of upper reach of Fish Creek by helicopter. Bottom middle Image: Crew tending to seine net in upper reach of Fish Creek. Bottom, right Image: Kris Maier holding a Dolly Varden.

Table A1. List of crew members and their affiliations (including Fisheries and Oceans [DFO] staff) that participated in seining at Rat River, 2015–2022.

LIST OF SEINING CREW PARTICIPANTS 2015–2022
2015: Kris Maier (Gwich'in Renewable Resources Board), Christie Morrison (University of Alberta), Ryan McLeod (DFO), Colin Gallagher (DFO).
2016: Blue Pascal (Aklavik), Freddy Furlong (Aklavik), Kris Maier (Gwich'in Renewable Resources Board), Ryan McLeod (DFO), Shannon MacPhee (DFO), Colin Gallagher (DFO).
2017: Dennis Semple (Aklavik), Freddie Furlong (Aklavik), Sarah Lord (Gwich'in Renewable Resources Board), Ellen Lea (DFO), Colin Gallagher (DFO).
2018: Riley Furlong (Aklavik), Graham MacDonald (Aklavik), Jamieson Wright (Aklavik), Sarah Lord (Gwich'in Renewable Resources Board), Michael Courtney (University of Alaska Fairbanks), Ellen Lea (DFO), Colin Gallagher (DFO).
2019: Jim Kaye (Aklavik), Sonny McDonald (Aklavik), Sarah Lord (Gwich'in Renewable Resources Board), Ryan McLeod (Aurora Research Institute), Ellen Lea (DFO), Colin Gallagher (DFO).
2020: Jessi Pascal (Ehdiitat Renewable Resources Council), Frankie Dillon (Aklavik), Sarah Lord (Gwich'in Renewable Resources Board), Ryan McLeod (Aurora Research Institute), Paden Lennie (Parks Canada).
2021: Steven Tetlichi (Fort McPherson), Ryan McLeod (Aurora Research Institute), Sarah Lord (Gwich'in Renewable Resources Board), Julienne Chipesia (Gwich'in Renewable Resources Board), Nick Bekolay (DFO), David Stewart (videographer)
2022: Doug Wilson (Fort McPherson), Ryan McLeod (Aurora Research Institute), Rayna Vittrekwa (Gwich'in Renewable Resources Board), Paden Lennie (Parks Canada), Nick Bekolay (DFO), Colin Gallagher (DFO).

Table A2. List of data from the Rat River Harvest Monitoring Program (FFHMP). Data was used to estimate proportions of tagged and untagged Rat River Dolly Varden (2014–2019, 2022).

LIST OF DATA FROM HARVEST MONITORS TO ESTIMATE PROPORTION OF TAGGED AND UNTAGGED FISH
2014 estimate: RRHMP 2015 reported 762 Dolly Varden harvested and 9 out of 297 measured fish were < 390 mm (i.e., 3.0%). Thus, 762 x 3.0% = 22.8 fish were theoretically too small, therefore 762 - 23 = 739 fish met size criteria.
2015 estimate: RRHMP 2016 reported 490 Dolly Varden harvested and 10 out of 263 measured fish were < 400 mm (i.e., 3.8%). Thus, 490 x 3.8% = 18.6 fish were theoretically too small, therefore 490 - 19 = 471 fish met size criteria.
2016 estimate: RRHMP 2017 reports 491 Dolly Varden harvested. 3 out of 276 measured fish were < 400 mm (i.e., 1.1%). Thus, 491 x 1.1% = 5.4 fish were theoretically too small, therefore 491 - 5 = 486 fish met size criteria.
2017 estimate: RRHMP 2018 reports 309 Dolly Varden harvested. 4 out of 224 measured fish were < 390 mm (i.e., 1.8%). Thus, 309 x 1.8% = 5.56 fish were theoretically too small, therefore 298 - 6 = 292 fish met size criteria.
2018 estimate: RRHMP 2019 reports 241 Dolly Varden captured (240 were harvested). 11 out of 241 measured fish were < 400 mm (i.e., 4.8%). Thus, 241 x 4.8% = 11.56 fish were theoretically too small, therefore 241 - 12 = 229 fish met size criteria.
2019 estimate : RRHMP 2020 reports 269 Dolly Varden captured (264 harvested). 8 out of 269 measured fish were < 400 mm (i.e., 3%). Thus, 269 x 4.8% = 13 fish were theoretically too small, therefore 269 - 13 = 256 fish met size criteria.
2022 estimate: RRHMP 2023 reports 535 Dolly Varden captured (390 harvested). 36 out of 278 measured fish were < 420 mm (i.e., 13%). Thus, 535 x 13% = 70 fish were theoretically too small, therefore 535 - 70 = 465 fish met size criteria.