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ASSESSMENT OF DOLLY VARDEN FROM THE RAT RIVER, NORTHWEST TERRITORIES 2009–2014

*Dolly Varden (*Salvelinus malma*) from the Rat River: spawning male (top), spawning female (middle) and non-spawning "silver" (bottom). Photos by Colin Gallagher.*

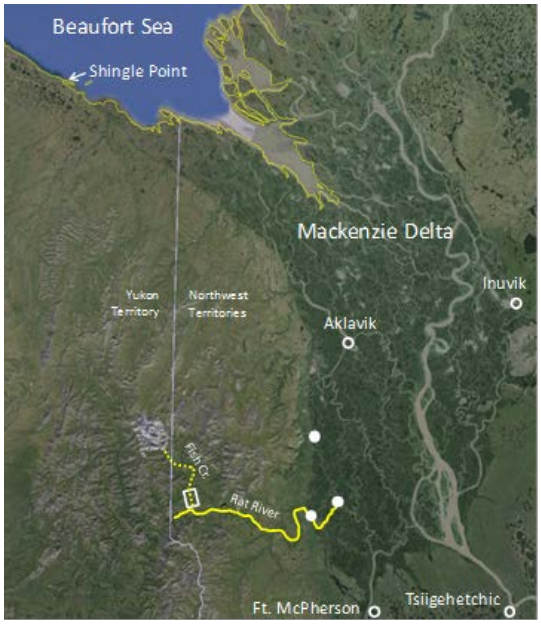

Figure 1. Location of the Rat River, Northwest Territories, harvest monitoring locations (closed circles), and where seining was conducted in Fish Creek (open box).

Context:

*Situated in the Gwich'in settlement Area (GSA), the Rat River is inhabited by anadromous Dolly Varden (*Salvelinus malma malma*) that are harvested by both Gwich'in and Inuvialuit beneficiaries. The harvest of Dolly Varden from the Rat River occurs during the summer at feeding areas along the coast (by the Inuvialuit) and during upstream migration in the Mackenzie Delta (by both Gwich'in and Inuvialuit). Dolly Varden stocks are co-managed under an Integrated Fisheries Management Plan (IFMP) whose signatories include Fisheries and Oceans Canada (DFO), Gwich'in Renewable Resources Board, Fisheries Joint Management Committee, and Parks Canada Agency. The Rat River Working Group, the co-management body that makes recommendations for harvest levels for Dolly Varden stocks in the GSA, has supported research activities that facilitate implementation of the IFMP, including studies to monitor harvest levels and assess population status.*

Population studies (e.g., abundance estimates, biological and genetic sampling) and coastal harvest monitoring activities allow for a comprehensive assessment of this stock. Data from research conducted on the Rat River (1995–2014) and along the Beaufort Sea coast (2011–2014) were used to assess the population. The science advice will be used to inform co-management partners on the status of Dolly Varden from the Rat River and the current estimated level of harvest.

SUMMARY

- Mark-recapture techniques were used to estimate abundance of Dolly Varden from the Rat River. The estimated population abundance of Dolly Varden (≥~305–365 mm) increased from 5,820 in 2010 to 11,919 in 2013. The estimates were based on recaptures obtained from seining at the spawning and overwintering area at the end of September in 2010 and 2013.
- Data from community harvest surveys (1972–2014), various sampling programs (1971–1994), and the Rat River Harvest Monitoring Program (RRHMP) (1995–2014) were incorporated into population models (depletion-based stock reduction analysis (DB-SRA), surplus production (SPM) and, statistical catch-at-age models (SCA)) to estimate maximum sustainable yield (MSY) and temporal changes in population abundance.
- The three models predicted the current population size was approximately between 10,509 and 12,205 fish for the fishable component of the population (≥440 mm), and 10,128 fish for all life stages.
- The DB-SRA, SPM and SCA models generated estimates of MSY with the inverse weighted average among the estimates providing a value (± 1 standard deviation [SD]) of 891 (81) fish.
- Biological information collected from the RRHMP and seining at the spawning and overwintering area every year between 2009 and 2014 demonstrated the presence of a wide range of sizes and that length structure of adults appeared relatively stable among years.
- The modal age of harvested fish ranged between 5 and 7 years every year between 2009 and 2014, with an increasing proportion among older ages (≥8 years) over time, suggesting improved survival of adults.
- A high proportion of spawners was observed among years when seining at the spawning and overwintering area (range = 38–81%). Biological data from the mark-recapture studies indicated females spawned in consecutive-years more often than males.
- Genetic mixed-stock fishery analysis of samples collected along the Beaufort Sea coast between 2011 and 2014 indicate that Dolly Varden from the Rat River were mainly harvested at Shingle Point, contributing between 5 and 29% to the harvests at this location among years.
- Estimates of effective population size (N_E) determined using genetic data suggest there are no immediate conservation concerns for the population.
- The reported annual harvest of Dolly Varden from the Rat River has been <400 fish since the voluntary closure of the subsistence fishery ended in 2009. Between 2011 and 2014, the estimated average harvest rate was 4.7%.
- The available information indicates that the population is currently stable and is sustainably harvested. There is increased confidence in the assessment given that multiple independent sources of information provided relatively similar trends for indicators and/or conclusions of stock status.

INTRODUCTION

Anadromous Dolly Varden from the Rat River is an important cultural and subsistence resource for both Gwich'in and Inuvialuit peoples mainly from the communities of Aklavik and Fort McPherson, NT (Figure1). Anadromous and stream resident life histories of Dolly Varden spawn and overwinter in Fish Creek, a tributary to the Rat River (Figure 1). The anadromous population is harvested in a mixed-stock fishery during the summer along the Beaufort Sea coast, mainly at Shingle Point (Figure 1). Additionally, Dolly Varden are harvested during their return migration in late summer/ fall in Aklavik and the Husky Channel in the Mackenzie Delta, and in the lower reaches of the Rat River (Figure 1). Declines in abundance in the Big Fish River and Rat River stocks, and limited critical freshwater habitat resulted in the listing of northern-form Dolly Varden in Canada as 'Special Concern' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2010. Concomitantly, an Integrated Fisheries Management Plan (IFMP) was developed in order to guide the co-management of anadromous Dolly Varden in the western Arctic over the next five years (2010–2015). The proper implementation of the IFMP and any future evaluation by COSEWIC requires updated assessments, including that for the Rat River.

ASSESSMENT

Abundance estimates (mark-recapture), catch-effort and biological data, three population models (depletion-based stock reduction analysis (DB-SRA), surplus production (SPM) and, statistical catch-at-age models (SCA)), genetic mixed-stock fishery analysis, and a genetic estimate of effective population size (NE) were evaluated. Annual fishery-dependent catch-effort and biological information (length, weight, sex/ maturity, and otolith for age estimation) was collected during the upstream migration of Dolly Varden since 1995 by the RRHMP from three traditional subsistence fishing locations (Big Eddy situated in Husky Channel, mouth of Rat River, and in the Rat River at a location named Destruction City) (Roux et al. 2012) (Figure 1). While the monitors were stationed at these locations from approximately the end of July to the beginning/ middle of September, they also collected harvest data, reported tag returns, collected tissue samples for genetics, and recorded daily environmental conditions. A seining program conducted at the spawning and overwintering area in Fish Creek at the end of September (Figure 1) (periodically since 1995 and annually since 2007) aimed to live-sample Dolly Varden in order to collect fishery independent biological information (length, reproductive status, 'non-spawner' or 'spawner', and sex if in spawning condition) and attach t-bar tags (or recapture tags from previous years) for a mark-recapture study. Harvest data were collected from the RRHMP, community harvest surveys (in Fort McPherson and Aklavik, NT), and through a combination of harvest reporting and genetic mixed-stock fishery analysis of Dolly Varden captured along the Beaufort Sea coast. Additionally, data from community harvest surveys (1972–2014) and various sampling programs (1971–1994) were used in combination with data from the RRHMP for population modelling. For the purpose of this assessment there was an emphasis on data collected between 2009 and 2014.

Mark-Recapture Population Abundance

A mark-recapture approach was used to estimate population abundance. Dolly Varden (≥~305–365 mm) were caught using a seine net and tagged at the spawning/ overwintering area in 2009, 2010, and 2013. Recaptures were obtained the following year from either the RRHMP or seining. The Petersen model with Chapman modifier was used to estimate population size with 95% confidence intervals calculated based on the assumption that the probability of recapture followed a Poisson distribution. The Poisson approximation was used because the number of recaptures among years was consistently <50, and the ratio between number of recaptures and

number of tagged was <0.1 (Seber 1982). To better meet the assumptions required to use the Petersen model, corrections were made to account for recruitment and tag loss. Tag returns from the RRHMP were used to estimate abundance in order to be consistent with the methods used in earlier years.

Abundance estimates of Dolly Varden from the Rat River were 6,625 (95% CI = 4,199–12,769) in 2009, 9,310 (95% CI = 6,137–17,351) in 2010, and 14,891 (95% CI = 9,091–32,052) in 2013 (Figure 2). Estimates based on the recapture of tagged fish from seining at the spawning and overwintering area at the end of September were 5,792 (95% CI = 4,494–9,612) in 2009, 5,820 (95% CI = 3,286–14,403) in 2010, and 11,919 (95% CI = 7,773–23,638) in 2013 (Figure 2). Estimates using recaptures from the RRHMP during the upstream migration were greater than estimates generated using recaptures from seining, although 95% confidence intervals were smaller for those estimates based on seine recaptures. However, in most years both methods of recapture demonstrated relatively similar values and temporal trends which increases the level of confidence in the population estimates. The RRHMP abundance estimates varied without trend from 2007 to 2013 at levels similar to those for 1995, 1997 and 2001 and well above the lowest value observed in 2004. Both methods indicated an increase in abundance between 2010 and 2013.

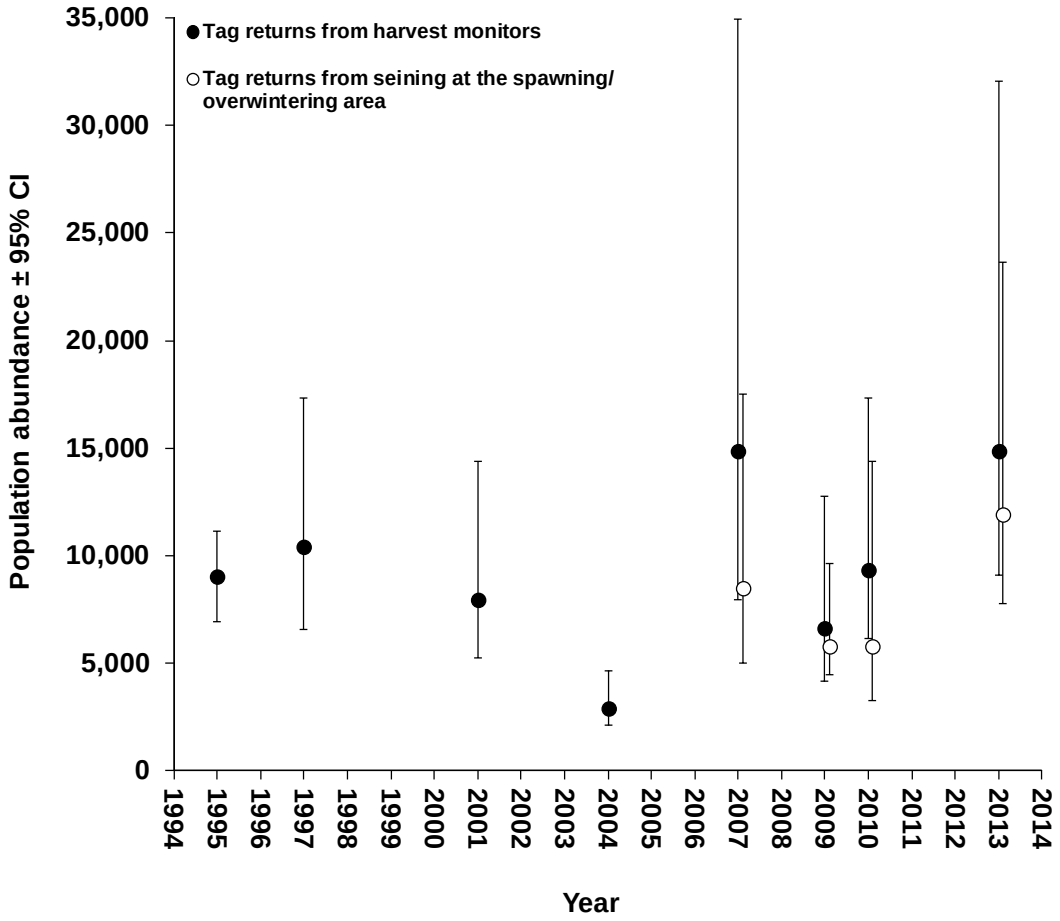

Figure 2. Population abundance estimates of Dolly Varden (≥~305–365 mm) from the Rat River between 1996 and 2013 generated by mark-recapture studies.

Harvest Monitoring

Median catch-per-unit-effort (CPUE) for Dolly Varden captured at Big Eddy and mouth of Rat River locations (102 and 114 mm mesh sizes combined) varied in a sinusoidal pattern, with high values in the late 1990s and from 2011–2012, and low values from 2002–2006 and 2013–2014 (Figure 3). Dolly Varden were mainly between 350–550 mm (Figure 4) and 560–1,900 g. Since 1995 the median length has varied in a sinusoidal pattern, with low values from 1995–1998 and 2004–2009, and relatively higher values from 1999–2003 and 2010–2014 (Figure 5). Except for the year 2012, the proportion of sizes ≥550 mm observed from 2010–2014 is greater than was observed between 2003 and 2009 (Figure 6). Additionally, there has been an increase in the proportion among the largest size classes (≥600 mm) since 2010, suggesting improved survival (Figure 6). Ages ranged between three and 13 years. The proportion of older ages (≥8 years) increased between 2009 and 2014 (Figure 7), resulting in a decrease in annual mortality from 0.67 to 0.45. Since 1995, non-spawners typically accounted for >60% of fish sampled during the upstream migration while female and male current-year spawners were usually <20% and <5%, respectively (Figure 8). The proportion of current-year spawners in the harvest monitoring program from 2009-2014 ranged between 9% and 67%.

Seining at the Spawning and Overwintering Area

Dolly Varden captured by seining were mainly distributed between 400 and 600 mm. Females in spawning condition ranged between 325 mm and 685 mm and were particularly abundant between 450 mm and 575 mm in length (Figure 4). Anadromous male spawners were larger in size, attaining up to 730 mm in length with a higher proportion among larger sizes (≥550 mm). Non-spawners were primarily distributed among sizes ≤475 mm, suggesting that most of these were juveniles while larger ones were presumed to be resting adults. The median length of female spawners was more stable than for male spawners and non-spawners (Figure 5) with an increased proportion of larger sizes (≥550 mm) occurring in 2010 and following years (Figure 6). Non-spawners and female spawners each typically comprised between 30 and 65% of the sample while males were considerably smaller (~≤10%) (Figure 8). A higher prevalence of current-year spawners was observed in the seining than the harvest monitoring program.

Growth and Repeat-Spawning

The growth of males was higher than females, based on the recapture of 71 females and 19 males in the RRHMP and seining (Figure 9). Growth based on length-at-age data from the 2009-2014 RRHMP found males had higher annual growth rates compared to females and demonstrated little inter-annual variation.

Both the tagging and recapture events typically provided biological data where the reproductive status of a fish was known at both times. Annual change in reproductive status can provide information on the prevalence of consecutive-year spawning, consecutive-year non-spawning, or a change from non-spawner to spawner (and vice versa). Based on the recapture of 55 females and 8 males (in spawning condition when tagged in previous year), a higher proportion of females (51%) spawned in consecutive years compared to males (13%).

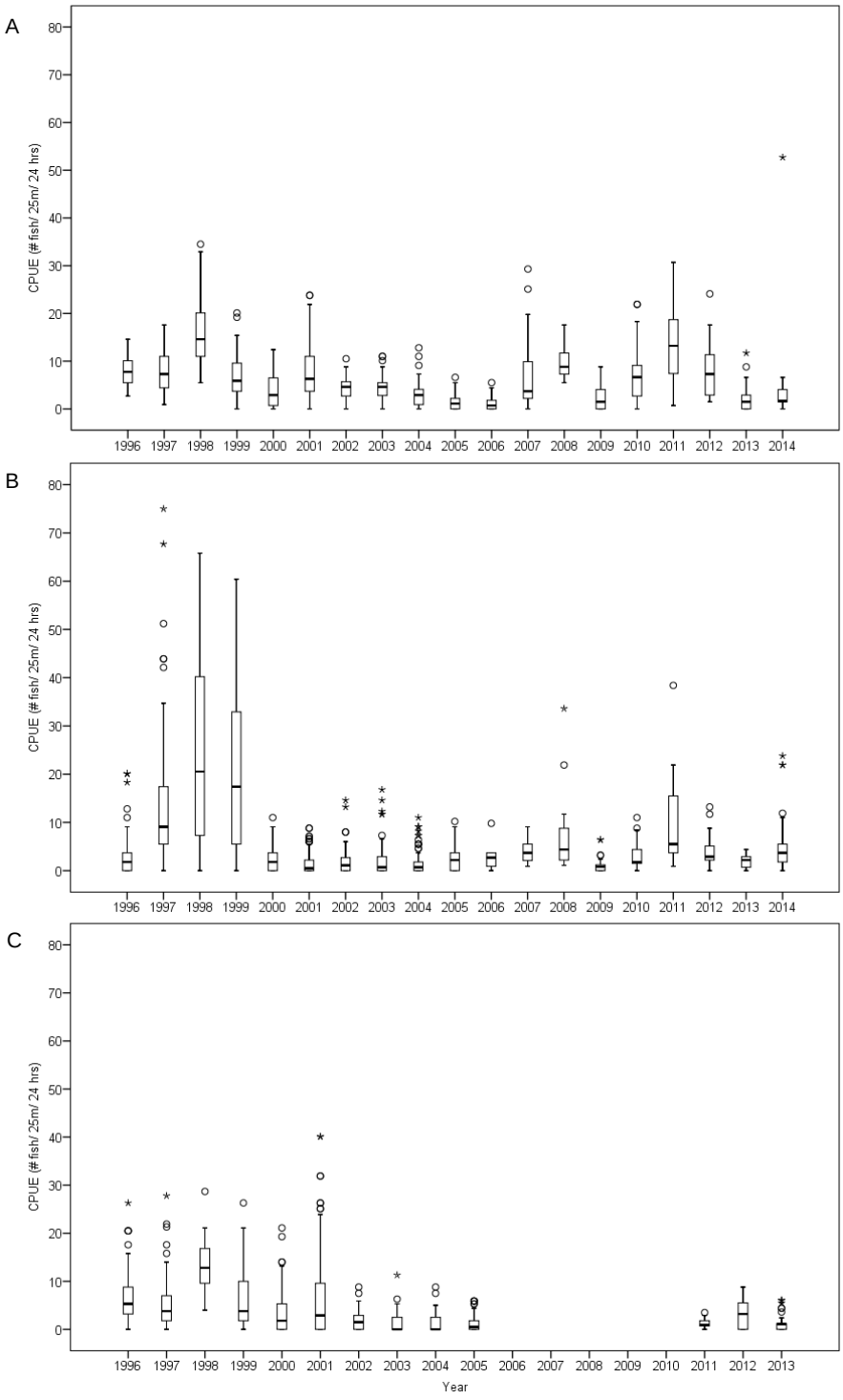

Figure 3. Catch-per-unit-effort (median, quartiles and outliers (○, ★; values ≥1.5 x and 3 x interquartile range, respectively) of Dolly Varden captured in 102 and 114 mm mesh gill nets in the Rat River Harvest Monitoring Program at: A) Big Eddy, B) mouth of Rat River, and C) in the Rat River at a location named Destruction City. Note: one outlier in 2011 at mouth of Rat River had a CPUE equal to 132 (not shown). CPUE data for Destruction City 2006–2010 were omitted.

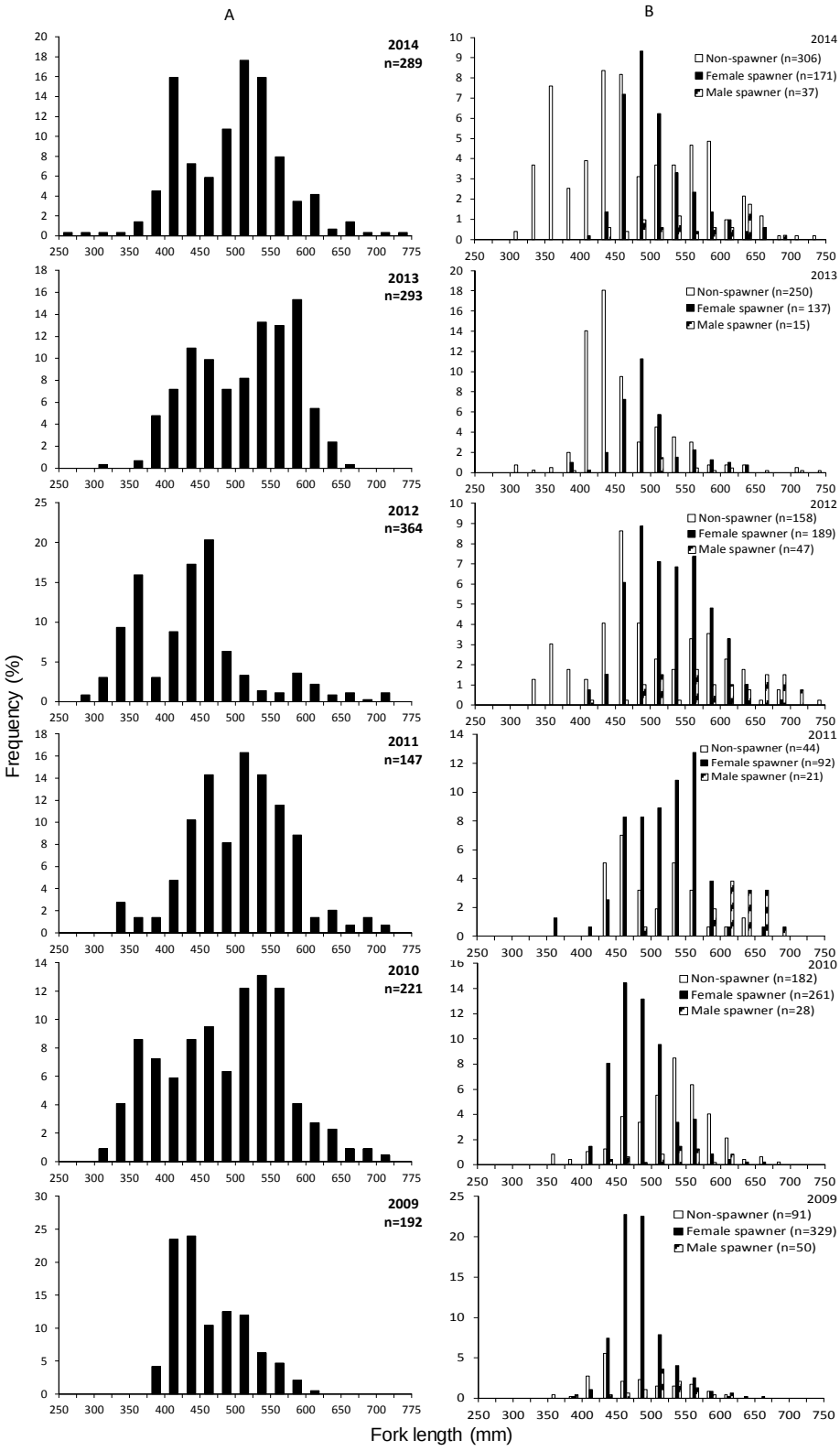

Figure 4. Length frequency distribution of Dolly Varden captured between 2009 and 2014: A) in the Rat River Harvest Monitoring Program, and B) when seining at the spawning and overwintering area (identified as non-spawners, female spawners, and male spawners).

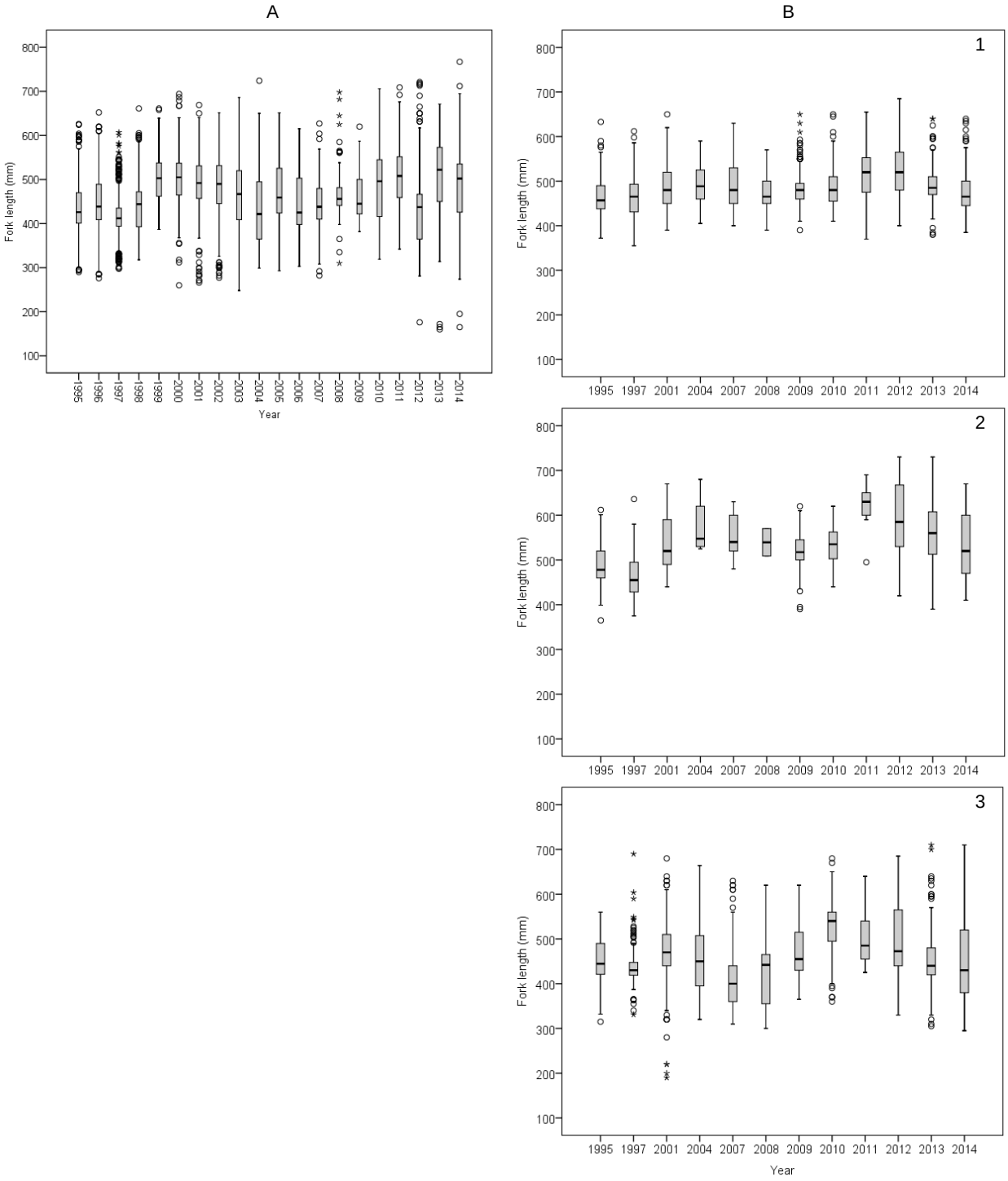

Figure 5. Fork length (median, quartiles and outliers (○, ✶; values ≥1.5 x and 3 x interquartile range, respectively)) of Dolly Varden between 1995 and 2014: A) captured in the Rat River Harvest Monitoring Program, and B) captured while seining at the spawning and overwintering area (identified as: 1) female spawners, 2) male spawners, and 3) non-spawners).

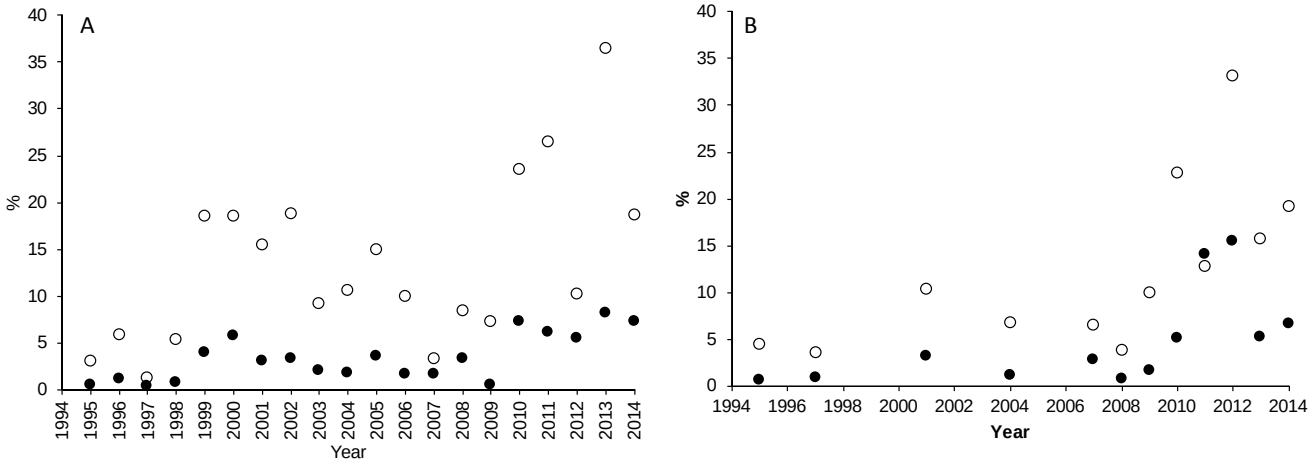

Figure 6. Proportion (%) of sizes ≥550 (○) and ≥600 (●) mm of Dolly Varden captured between 1995 and 2014: A) in the Rat River Harvest Monitoring Program, and B) when seining at the spawning and overwintering area.

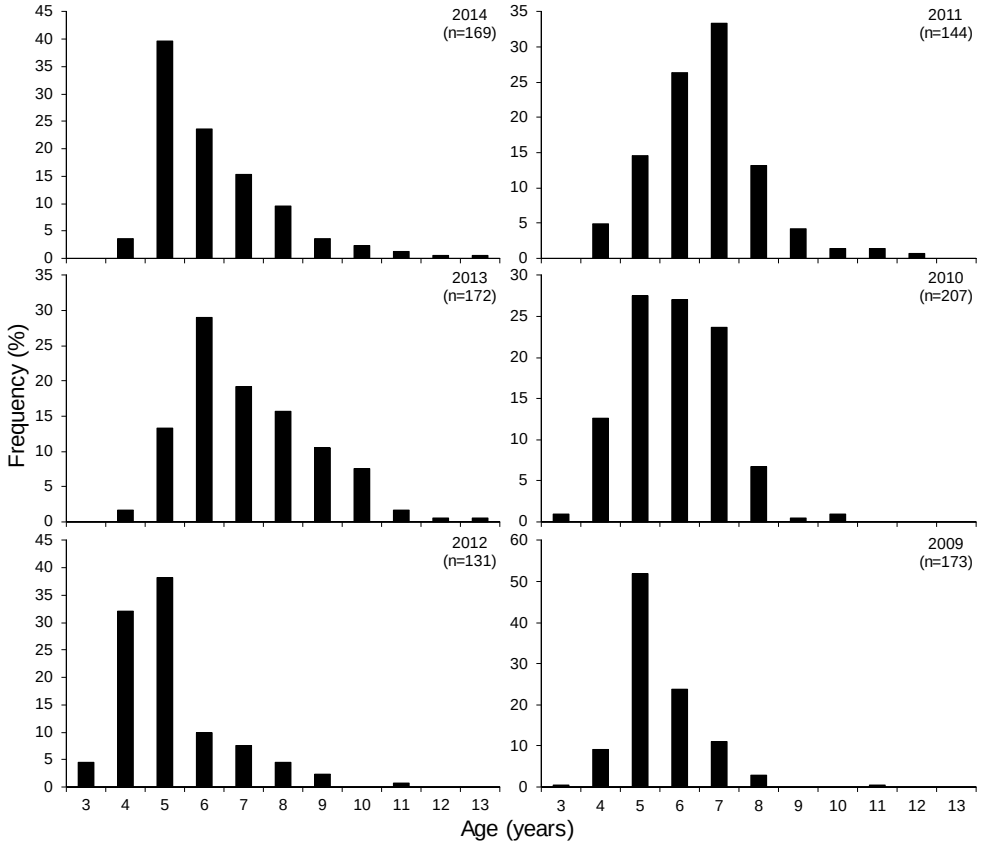

Figure 7. Age frequency distribution of Dolly Varden from the Rat River captured in the Rat River Harvest Monitoring Program (2009–2014).

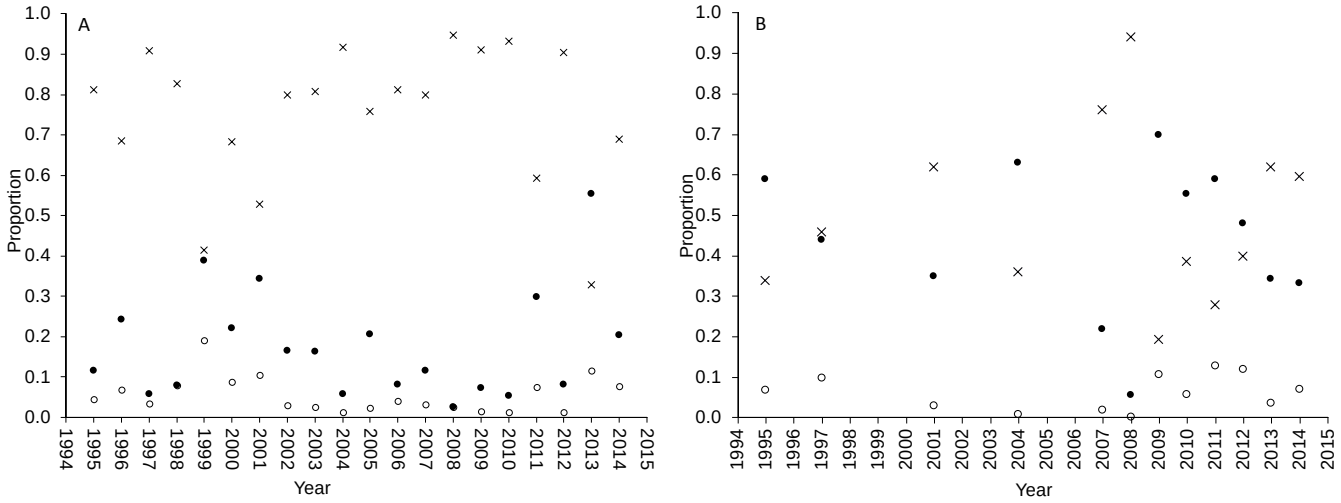

Figure 8. Proportion of anadromous Dolly Varden captured between 1995 and 2014 and identified as non-spawners (X), female spawners (●), and male spawners (○): A) in the Rat River Harvest Monitoring Program, and B) when seining at the spawning and overwintering area.

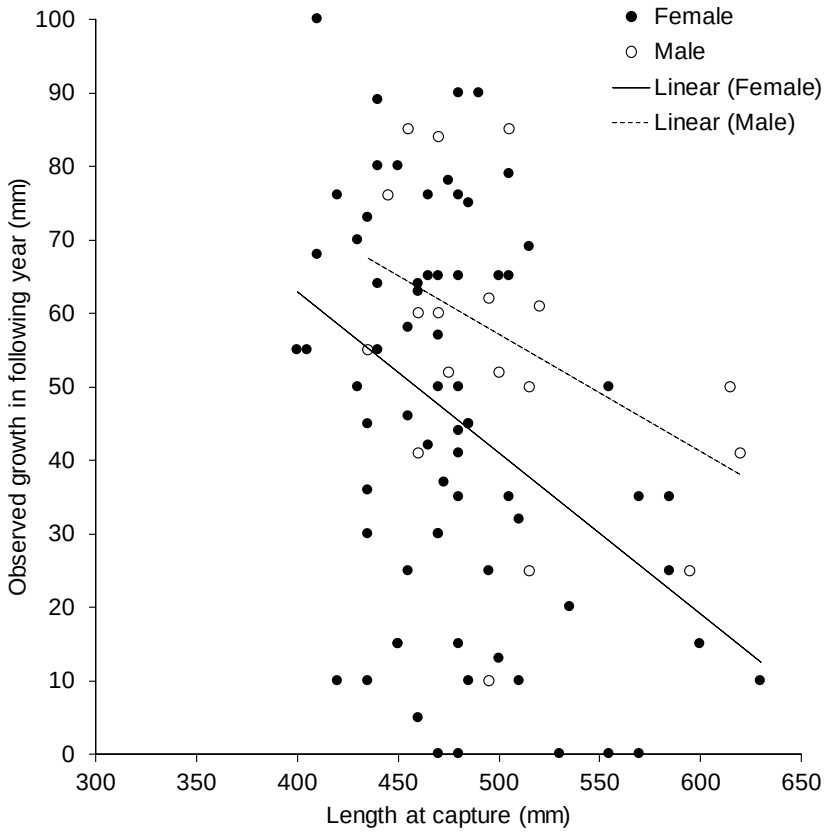

Figure 9. Observed annual growth of female (●) and male (○) Dolly Varden from the Rat River based on mark and recapture studies between 2009 and 2014.

Modelling

Three models were used to estimate total abundance and biomass, maximum sustainable yield (MSY), abundance (N_{MSY}), biomass (B_{MSY}), fishing mortality (F_{MSY}), and exploitation rate (U_{MSY}) at MSY:

1) Depletion-based stochastic stock reduction analysis (DB-SRA);
2) Surplus production model (SPM); and
3) Statistical-catch-at-age model (SCA).

The DB-SRA used reported harvest and basic biological data to reconstruct population dynamics from 1986–2014. Both the SPM and SCA reconstructed population dynamics from 1995-2014 using harvest and catch-effort data as well as growth, recruitment, and natural mortality. Age data were incorporated into the SCA. MSY (± 1 SD) and U_{MSY} (± 1 SD), respectively, were estimated as: 1,251 (307) and 18.1% (6.3%), using DB-SRA; 767 (271) and 6.9% (1.5%), using SPM; and 759 (185) and 12.2% (2.6%) using SCA. The inverse-variance weighted average of each parameter estimated by the three models was calculated in order to generate a single estimate (Table 1). Results indicated that harvest is currently below MSY. The models generated different estimates of either fishable (component of the population vulnerable to fishing gear; ≥440 mm) or total abundance (includes all ages of fish) for 2014, with the DB-SRA (fishable), SPM (fishable) and SCA (total) predicting approximately (± 1 SD) 12,205 (4,616), 10,509 (5,254), and 10,128 (1,714) Dolly Varden, respectively (Figure 10). All three models suggested a declining trend in population abundance until approximately early 2000s, which was followed by either an increase (DB-SRA and SPM) or stable trend (SCA) until 2014. The DB-SRA model suggested overfishing (F_t/F_{MSY} was >1) was occurring in the late 1990s while both the SPM and SCA indicated overfishing in years ≤2005 (B_t/B_{MSY} and N_t/N_{MSY} were < 1) (Figure 10). The DB-SRA and SPM models suggest the population is currently not experiencing overfishing and the stock status is healthy, while the SCA suggests the population is currently (only observed in 2014) experiencing overfishing (F_t/F_{MSY} >1).

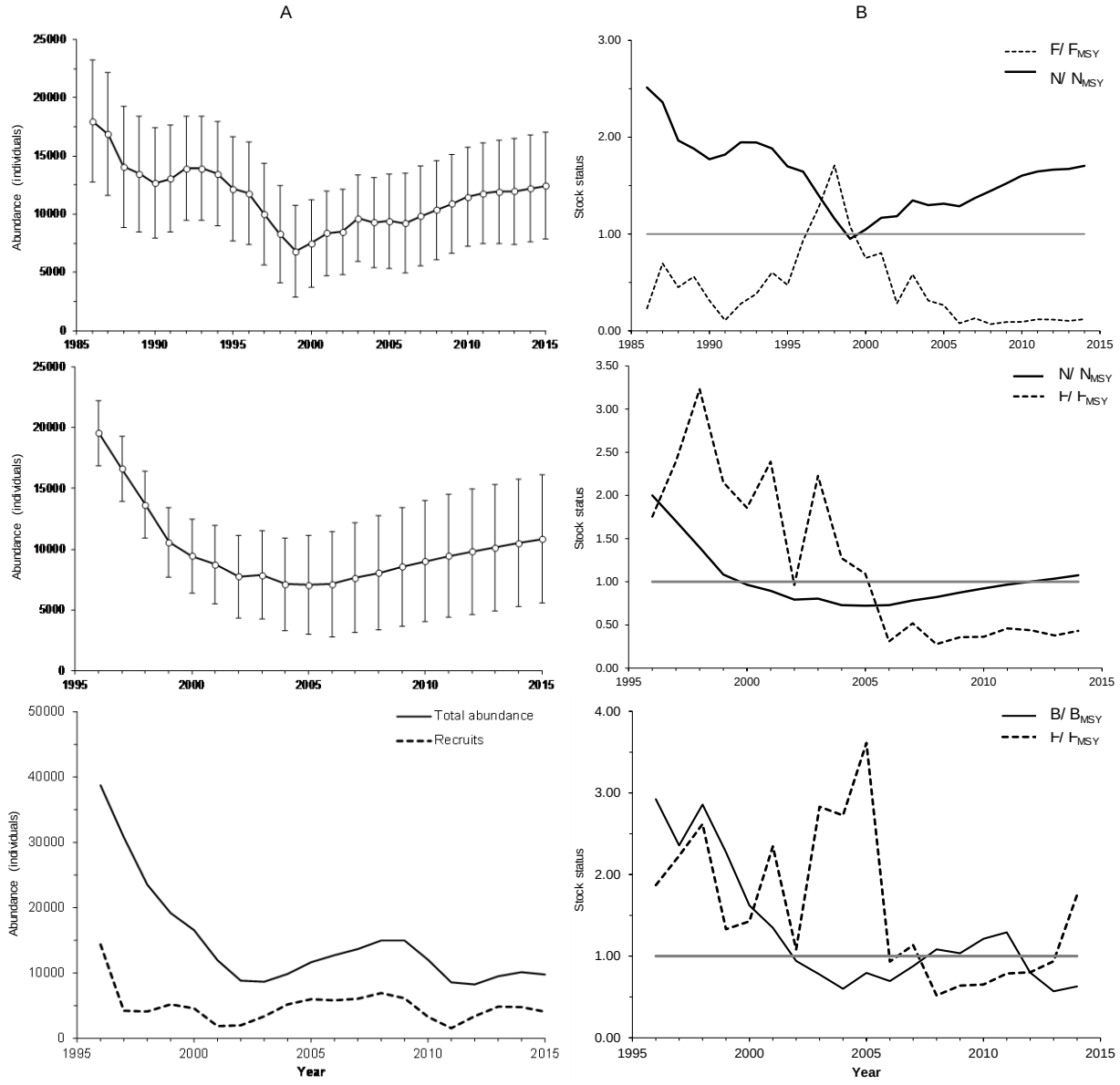

Figure 10. Rat River Dolly Varden: A) Estimates (mean ± SD) of abundance of harvestable-size (≥440 mm) from Depletion Based-Stock Reduction Analysis (top panel) and Surplus Production (middle panel) models, and total abundance from a Statistical Catch-at-Age model (lower panel); and B) stock exploitation history, shown by posterior median trends in stock status (N/N_{MSY} or B/B_{MSY}) and fishing status (F/F_{MSY}) from Depletion Based-Stock Reduction Analysis (top panel), Surplus Production (middle), and Statistical Catch-at-Age (lower panel) models (the critical reference to the stock status is delineated by the grey line). For lower panel in A, abundance of both total population and age-1 recruits were estimated.

Table 1. Median (standard deviation in brackets) of inverse weighted average of the maximum sustainable yield (MSY), abundance (N_{MSY}), biomass (B_{MSY}), fishing mortality (F_{MSY}) and exploitation rate (U_{MSY}) at MSY.

	Abundance	Biomass (kg)
MSY	891 (81)	1,007 (200)
N_{MSY}	6,828 (450)	-
B_{MSY}	-	6,512 (1,293)
F_{MSY}	0.12 (0.01)	0.15 (0.04)
U_{MSY}	0.1 (0.01)	0.14 (0.03)

Genetic Mixed-Stock Analysis

Genetic techniques were used to examine the mixed-stock subsistence fishery along the Beaufort Sea coast (summer 2011–2014) and in the Mackenzie River Delta and Rat River (summer/ fall 2012–2014) to determine the contribution of Dolly Varden from the Rat River at these locations. These results, in combination with total harvest information, provided data to estimate the harvest of Dolly Varden from the Rat River. Samples were analyzed against an established genetic baseline comprised of all known anadromous Canadian Dolly Varden stocks and a subset of Alaskan stocks from the North Slope. Samples from Firth River, Joe Creek, and Kongakut River systems were combined into a single reporting group because it was not possible to genetically differentiate these with the information currently available. Fifteen microsatellite DNA markers were assayed from 1,514 tissue samples collected along the Beaufort Sea coast (Herschel Island, Ptarmigan Bay, King and Sabine points, and Shingle Point) and 544 samples collected at harvest monitoring program locations in the Mackenzie River Delta and Rat River. Genetic mixed-stock analysis of Dolly Varden from each fishing site was performed to determine the genetic mix of the fish caught in these fisheries. A conditional maximum likelihood procedure implemented in the genetic stock identification program ONCOR (Kalinowski et al. 2007) was used to report contributions from each Dolly Varden source stock to each coastal fishing site. Simulation and assignment tests verified the accuracy and confirmed the results from the mixed-stock analysis.

The number of Dolly Varden from the Rat River estimated in the coastal harvest sample ranged between 21 and 42 fish where 97% were collected at Shingle Point (Table 2). The Rat River stock contributed between 5 and 29% to the annual harvest of Dolly Varden at Shingle Point with only a few samples identified at Herschel Island and Ptarmigan Bay; however, the error associated with the assignment test suggest the Herschel Island and Ptarmigan Bay results should be treated cautiously (Table 2). Nearly all (99% [95% CI = 96–100]) of the samples collected in the Mackenzie River Delta and Rat River were assigned to the Rat River stock.

Table 2. Percent contribution (%) (± 95% CI) and number (#) (± 95% CI) of Dolly Varden from the Rat River among multiple locations along the Beaufort Sea coast[†] in the Yukon 2011–2014.

Year	Herschel Island		Ptarmigan Bay		Shingle Point		Total
	%	#	%	#	%	#	#
2014	1 (0–4)	2 (0–6)	-	-	10 (7–13)	40 (29–52)	42
2013	0	0	-	-	29 (20–39)	33 (23–45)	33
2012	0	0	-	-	5 (3–8)	21 (10–33)	21
2011	0	0	1 (0–4)	1 (0–4)	12 (7–17)	22 (14–33)	23

[†] King and Sabine points 2011–2014: %= 0

- no genetic samples available (harvest in 2012, 2013, 2014 was 1, 12 and 0 fish, respectively)

Harvest

Between 2009 and 2014, the total reported harvest of Dolly Varden from the Rat River was <400 fish (Table 3). The stock was mainly harvested from the Mackenzie Delta and Rat River by Gwich'in harvesters (~79%) from the communities of Ft. McPherson and Aklavik. The estimated mean harvest rate (total number harvested in one year divided by the population estimate previous year based on recaptures from seining) for the Rat River stock from 2011–2014 was 4.7% (range= 2.7–6.5%).

Table 3. Harvest numbers of Dolly Varden from the Rat River stock reported among monitoring programs and community surveys for both Gwich'in and Inuvialuit peoples.

Year	Mackenzie River Delta/ Rat River				Beaufort Sea Coast	Total
	Rat River Harvest Monitoring (Gwich'in)	Ft. McPherson (Gwich'in)	Aklavik (Gwich'in)	Aklavik (Inuvialuit)	Aklavik (Inuvialuit)	
2014	180	96	15	56	42	389
2013	180	0	41	72	33	326
2012	150	112	38	45	21	366
2011	147	43	69	87	23	378*
2010	220	0	46	13	-	279†
2009	192	41	0	28	-	261†

* a sample of n= 9 was taken for scientific purposes from seining in Fish Creek in July 2011.
† coastal harvest is unknown therefore the total is incomplete

Effective Population Size

The effective size of a population (N_E) determines the rate at which genetic variability will be lost as a result of random genetic drift (the random change in allele/genotype frequencies across generations) and is a parameter that is typically less than the census population size (N_C). Decreases in N_E typically lead to decreases in genetic variation and increases in inbreeding, which may ultimately lead to reductions in overall fitness. Therefore, reductions in N_E may potentially have several adverse impacts on a population, especially those that are already small and isolated. Given that genetic variation is important for evolutionary potential, N_E should also be considered when evaluating the long-term plans for population persistence and conserving biological diversity within a species.

Samples were collected at the spawning and overwintering area in three separate sampling periods (1988, 1991, and 2011). For the estimation of N_E in Dolly Varden from the Rat River, two single-sample estimates (SS) (LDNe (Waples and Do 2008) based on linkage disequilibrium and COLONY (Jones and Wang 2010) based on sibship analyses) and two temporal-based estimates (MLNe (Wang 2001) and TempoFS (Jorde and Ryman 2007), both based on shifts in allele frequencies through time) were applied to a microsatellite DNA data set. The weighted harmonic mean when combining SS methods was 1038 (-95% CI= 282) and the weighted harmonic mean when combing temporal-based estimates was 541 (-95% CI = 198; note that +95% CI could not be calculated when combining means within methods due to some results of infinity). N_E, based on the grand harmonic mean (Waples and Do 2008) of all four estimates (i.e., combing both SS and temporal-based estimates) was 608 (-95% CI = 212). The results suggest there are no immediate conservation concerns (e.g., reductions in fitness as a result of inbreeding) for Dolly Varden from the Rat River and long-term population persistence is likely not compromised if effective population size remains the same.

Sources of Uncertainty

There is some uncertainty whether all the assumptions of the Petersen method were sufficiently met in order to achieve a suitable estimate of population size. For example not all areas of Fish Creek where Dolly Varden congregate at the end of September were sampled which could affect the assumption of equal catchability for all tagged fish.

The CPUE data from the fishery may not be an accurate index of abundance for the Rat River stock. Multiple factors can affect CPUE data in the Mackenzie Delta and Rat River among years and include the timing of the fishery relative to that of the upstream migration, weather conditions (e.g., wind), debris, flow velocity, gear type, and soak time of the net. These will have important effects on the modelling outputs used to assess the population and estimates of sustainable harvest levels.

The subsistence fishery along the coast can target different species based on fishing location and gill net mesh size. The fishery at Shingle Point mainly targets Arctic Cisco (*Coregonus autumnalis*) using small mesh gill nets (~89 mm, stretched), whereas Dolly Varden fisheries further west (e.g., Komakuk Beach and Herschel Island) use larger mesh sizes (~102 mm, stretched). Weather (e.g., wind speed and direction) and sea conditions (e.g., drifting ice and waves) affect the location and timing of fishing activity. The catches in the coastal fishery possibly vary in amount and stock composition due to environmental conditions that affect fish movements (e.g., migration timing, nearshore/ offshore movements). Variability in fishing effort, and the timing and location of fishing activity and sample collection may cause discrepancies in composition over seasonal and annual timeframes resulting in non-representative sampling of the coastal run.

In the SCA model, it was assumed that growth and natural mortality were constant, gear selectivity followed a constant logistic function, stock recruitment was best described using the Beverton-Holt model, and that harvest was reported without error. These assumptions are either unrealistic or not directly known and provide uncertainty in the results from the modelling. Also, the SCA model assumed that Dolly Varden spawned in consecutive-years after reaching sexual maturity. Therefore it is likely that the model would overestimate spawning stock biomass which would lead to an overestimate of abundance, MSY, and related parameters.

Uncertainty in the assignment test used in the genetic-mixed stock fishery analysis is due to the absence of unit-stock resolution between two river systems (Firth and Kongakut rivers) and the possibility that other source stocks may contribute to this fishery (e.g., Fish Creek near Komakuk Beach and in the Peel River drainage).

The total number of char harvested among all locations is unknown due to the voluntary nature of reporting harvest.

The same age reader and ageing method (whole) has been used to age Dolly Varden otoliths since the monitoring program began. However, new methods (e.g., thin sectioning) employed in recent years may provide more accurate estimates of ages. An age comparison study was carried out between the previous age reader and the current age reader who was experienced with both methods. The objective was to determine if differences existed between readers and/ or methods and to evaluate the impact that any differences may have on age-related metrics such as growth and mortality. Results indicated that for Dolly Varden >6 years of age, the current age reader tended to produce older age estimates, therefore, the proportion of older age classes in the population may have previously (before 2009) been underestimated, and the growth and mortality of the population overestimated.

CONCLUSIONS AND ADVICE

1) The Petersen (with the Chapman Modifier) mark-recapture population estimate of Dolly Varden from the Rat River (≥~305–365 mm) based on the recapture of tagged fish in the Rat River Harvest Monitoring Program was 6,625 (95% CI = 4,199–12,769) in 2009, 9,310 (95% CI = 6,137–17,351) in 2010, and 14,891 (95% CI = 9,091–32,052) in 2013. The population abundance has increased since a low observed in 2004 and is currently varying without trend. Mark-recapture abundance estimates based on the recapture of tagged fish from the harvest monitoring program during the upstream migration of Dolly Varden were greater than estimates generated using recaptures from seining.

2) The Petersen (with the Chapman Modifier) mark-recapture population estimate of Dolly Varden from the Rat River (≥~305–365 mm) based on the recapture of tagged fish using a seine net in September at the spawning and overwintering area was 5,792 (95% CI = 4,494–9,612) in 2009, 5,820 (95% CI = 3,286–14,403) in 2010, and 11,919 (95% CI = 7,773–23,638) in 2013. There is greater confidence in the estimates generated using recaptures from the seining due to the smaller 95% confidence intervals. Although there is lower confidence using tag returns from the fishery, the estimates provide an important index where the temporal trend is a useful means to evaluate stock status.

3) Three population models were considered for use in the assessment: DB-SRA, SPM, and SCA. The inverse weighted average (± 1 SD) of MSY derived from the models was 891 ± 81. The population abundance in 2014 (± 1 SD) derived from DB-SRA, SPM and SCA was 12,205 (4,616) (fishable component; ≥440 mm), 10,509 (5,259) (fishable component), and 10,000 (1,741) (all life stages), respectively. There was low confidence in the outputs of the DB-SRA model as the data were likely not suitable given the high variability in reported harvest between the 1980s and early 2000s while there was a higher degree of confidence in the results from the SCA, and in particular, the SPM models.

4) MSY could be used in combination with other indicators to guide co-management decisions. Harvest should not surpass MSY. Risk to the stock increases as harvest approaches MSY and given the amount of uncertainty in the models combined with the objective to work within a Precautionary Approach framework, harvest should be kept well below MSY in order to ensure a sustainable subsistence fishery and conservation of the stock. Models should be further developed to evaluate options for rebuilding the stock.

5) Genetic mixed-stock fishery analyses of samples collected along the Beaufort Sea coast indicate that between 2011 and 2014 coastal harvest of the Rat River stock was mainly at Shingle Point. The estimated number of char harvested with percent contribution to harvest and 95% CI in brackets was 22 (10% [95% CI = 7–17] in 2011, 21 (5% [95% CI = 3–8] in 2012, 33 (29% [95% CI = 20–30] in 2013, and 40 (10% [95% CI= 7–13] in 2014). Samples collected from the Husky Channel of the Mackenzie Delta and the Rat River indicate that between 2012 and 2014 the large majority (99%) of the harvested char were from the Rat River stock.

6) The reported annual harvest of Dolly Varden from the Rat River since the voluntary closure of the subsistence fishery was repealed in 2009 has been <400 fish. Based on the estimates of population abundance (tag returns from seining) and harvest from the fisheries at Shingle Point, Mackenzie Delta, and Rat River the mean annual harvest rate of the stock between 2011 and 2014 was 4.7% (range = 2.7–6.5%). Imprecision of the models employed for both mark-recapture population estimates and genetic mixed-stock

fishery analysis, reported harvest, and the level of inter-annual variation observed in the contribution of this stock to coastal fisheries increases the degree of uncertainty in regards to the rate of harvest.

7) The effective population size (N_E = 608 [-95% CI= 212]) suggests there are no immediate conservation concerns with respect to inbreeding and reduced fitness for the Rat River population.

8) Length data, which are a useful biological indicator of stock status, collected between 2009 and 2014 from the Rat River Harvest Monitoring Program and seining at the spawning/ overwintering area demonstrated the presence of a wide range of sizes that were mainly distributed between 400 and 600 mm. Median length and length structure among adults appeared relatively stable. The proportion of sizes >550 mm observed from 2009–2014 has increased since the decline in stock status observed in the mid-2000s. Additionally, there has been an increase in the proportion among the largest size classes (≥600 mm) since 2010.

9) Age data, also a useful biological indicator of stock status, collected between 2009 and 2014 from the Rat River Harvest Monitoring Program demonstrated the presence of a wide range of ages with modal age ranging between 5 and 7 years and an increasing proportion among older ages (≥8 years) over time, suggesting improved survival of adults.

10) While a higher proportion of current-year spawners was observed in seining at the spawning/ overwintering area (range = 38–81%) compared to the harvest monitoring program (range = 9–67%) in most years between 2009 and 2014, the relatively high proportion of current-year spawners observed in both sampling programs combined with the length structure data suggests productivity or reproductive capacity was not limited for the anadromous component of the population.

11) Growth information derived from the mark-recapture studies (change in length from one year to the next based on recapture of n = 71 females and n = 19 males) and age data collected from the fishery (length-at-age) between 2009 and 2014 revealed males grew faster than females. The length-at-age data demonstrated little inter-annual variation.

12) Biological data from the mark-recapture studies indicated females spawned in consecutive-years more often than males. Based on 63 samples of Dolly Varden (n = 55 females and n = 8 males), 51% of females and 13% of males tagged as spawners were recaptured in spawning condition the following year.

13) The available population estimates, biological, and harvest information suggest that the population is currently stable and is sustainably harvested. There is increased confidence in the assessment given that multiple independent sources of information (mark-recapture study, biological data, modelling, and effective population size) provided relatively similar trends for indicators and/ or conclusions of stock status.

14) In order to better evaluate how the reported harvest, which is an important metric used in the assessment of the Rat River population, varies among years, it is suggested to gather local knowledge/ observations in association with the harvest data to better understand how environmental conditions affected catches and effort in the fishery.

SOURCES OF INFORMATION

This Science Advisory Report is from the meeting held on February 10 and 11, 2015 on the Assessment of Dolly Varden, *Salvelinus malma malma*, from the Rat River, Northwest Territories. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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