

**Angler Residence, Targeted species, Catch Rate and Size
of Angler-Harvested Fish
from Arrow Lakes Reservoir in 2019**

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Executive Summary

Access point angler surveys have occurred at selected locations in Arrow Lakes Reservoir (ALR) since 1976 to monitor the effects of BC Hydro dams and fishery compensation efforts. They provide a valuable long term index of angling effort and harvest from the years of dam construction to 20 years after the beginning of a large scale nutrient program in 1999. Sampling covers 5 days/month at three access locations.

This report summarizes 2019 (calendar year) results for angler residence and experience, targeted species, catch rate, and fish size, as part of the monitoring for FWCP Large Lakes Action Plan objectives for conservation and sustainable use. Overflight boat counts were conducted in 2019 – 2020 to revise the expansion factors for whole lake catch and harvest estimates; since analysis of these data was not complete at the time of writing, angler effort, catch and harvest estimates for 2019 will be provided in a future report.

A total of 1,428 anglers from 663 angling parties (including repeat contacts) were interviewed at the three major access locations in 2019. Residents of BC comprised 93% of the anglers, with non-resident Canadians (primarily from Alberta) making up most of the remainder. Overall, 19.4% of interviewed parties in 2019 had 5 or less years of fishing experience on ALR, 32.5% from 6-20 years, and 48.1% over 20 years. About 85% of the 2019 effort was targeting Bull Trout and/or Rainbow Trout, with only 13% of angler-days targeting Kokanee, or Kokanee and other species. There has been a trend towards decreased effort for Kokanee and small Rainbow Trout since 2015, coinciding with a reduction in Kokanee size (caught in the creel) to about 20 cm in recent years. However, 'Kokanee only' effort increased in 2019 at the Castlegar access; this may be a response to an increase in the daily limit from 5 to 15 fish. Burbot remained the smallest component of the fishery, detected only at the Nakusp access.

The average size of harvested Bull Trout of 59 cm (2.4 kg) was slightly below 2018 (which was the largest in the time series since 1998); the highest recorded weight in 2019 was 6.8 kg, and catch rate was 0.072 fish/rod-hour. The average size of harvested Rainbow Trout of 39 cm (1.0 kg) was similar to previous years; highest recorded weight was 5.75 kg, and catch rate was 0.066 fish/rod-hour. Nineteen piscivorous Rainbow Trout ≥ 50 cm were sampled in 2019, which is one more than 2018 and about half of 2017. Average size of harvested Kokanee was 21 cm (129 g). This is slightly larger than 2016 - 2018 but remains below most years since 1998. Average CPUE for Kokanee was 0.833, the highest in more than a decade. Average size of Burbot was 66 cm (1.7 kg). This is similar to the last two years, and slightly larger than 2010 – 2016. Catch rate for Burbot was 0.382 fish/rod-hour.

Relative condition factor (K_n) of Bull Trout in 2019 declined from the two previous years to 5% above the pre-nutrient average for all Bull Trout, and 10% above for larger (>60 cm) Bull Trout. This value is consistent with the long term relationship between Kokanee spawning escapement and Bull Trout K_n . Average condition of piscivorous Rainbow Trout was higher than expected at 22% above pre-nutrient, however the sample size was low (n=14). Stomach samples were collected from 87 Bull Trout and seven Rainbow Trout; slightly less than half of the predators had fish in the gut, with most consumed fish being Kokanee.

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Field data were collected by:

- Carmen Berger, Deb Imeson, Lynda Schmidt, and Aleah Soukoroff at the Lower Arrow (Castlegar) locations;
- Sara Hogaboam, Glen Olson and Gail Olson at Nakusp;
- Brian Barney and Darlene Riehl at Shelter Bay.

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1.0 INTRODUCTION

Arrow Lakes Reservoir (ALR) is located in the West Kootenay Region of British Columbia with Hugh Keenleyside Dam and Arrow Lakes Generating Station at the outlet, and two hydroelectric facilities upstream (Mica and Revelstoke dams).¹ Reservoir area is 49,500 ha at full pool and about 29,000 hectares in late growing season (early October). Water levels and residence time can fluctuate considerably over the course of a single year and among years. Water management in the reservoir is strongly influenced by requirements of the Columbia River Treaty. The fish community in ALR includes 24 species (McPhail and Carveth 1992), with the recreational fishery mainly targeting Bull Trout *Salvelinus confluentus*, Rainbow Trout *Oncorhynchus mykiss*, Kokanee *Oncorhynchus nerka*, and Burbot *Lota lota*.

The Fish and Wildlife Compensation Program (FWCP) currently funds two large-scale projects in ALR related to the impacts of dams. Hill Creek Spawning Channel was built in 1981 to provide spawning habitat for Kokanee and Rainbow Trout, and rearing habitat for juvenile Rainbow Trout, as compensation for lost access to spawning habitat above Revelstoke Dam. The number of adult Kokanee admitted to the channel is regulated to achieve a specified annual fry production target.² A second compensation initiative, the ALR Nutrient Restoration Program, began in 1999 to address nutrient losses related to upstream dams (with 25% of funding provided by Arrow Lakes Power Corporation). Phosphorus and nitrogen (limiting nutrients) are dispensed into the upper reservoir during the growing season (late April to September) with the goal of increasing primary production (Pieters et al. 2003, Bassett et al. 2018).³ Increased primary production is expected to translate into higher zooplankton and Kokanee production that will in turn support growth and survival of Bull Trout and piscivorous Rainbow Trout in the reservoir. Productive fish stocks should benefit angling and bring economic benefits to local communities and the province in accordance with the FWCP Large Lakes Action Plan objectives to support conservation and sustainable use.

Angler surveys have been conducted annually at selected access locations since 1976 to provide information for evaluating and monitoring sub-objectives listed in the FWCP action plan, including status indicators for Bull trout, piscivorous Rainbow Trout, Kokanee, and Burbot.⁴ Specific objectives are to provide: estimates of angling effort, harvest, catch rate, and size for the four main species, an index of feeding conditions for apex predators, estimates of the social and economic value of the

¹ Keenleyside dam was completed in 1968, with the Arrow Lakes Generating Station becoming operational in 2002. Mica and Revelstoke dams were completed in 1973 and 1984 respectively.

² Lindsay's (1994) outline of ALR fishery objectives in the early 1990s noted a need to balance adequate Kokanee density for piscivore prey with a Kokanee size suitable for the popular fishery. Updated ALR Kokanee objectives are listed in FWCP (2012); an interim fry production target since 2014 is 3.8 million. Fry production from the spawning channel ranged from 114,000 to 20 million between 1999-2013 due to changing objectives and two years of poor egg to fry survival.

³ Annual phosphorus (P) additions were held constant at 52.8 tonnes with 232.3 – 268 tonnes nitrogen (N) from 1999 to 2003. Since 2004, loadings have been modified based on lower trophic level variables to target optimal phytoplankton size for effective carbon transfer to zooplankton, the food source for kokanee, with total annual P ranging from 14.5 - 49.5 tonnes and N from 177-279 tonnes (Bassett et al. 2016, MFLNRORD file data). Note: 14.5 tonnes of P was added due to City of Castlegar water quality concerns in 2012. There is also annual variation of P inputs from tributaries; estimates from 1999 to 2018 range from 7 to 28 tonnes of P (data on file, FLNRORD).

⁴ These include sub-objectives listed in Figure 7 of FWCP (2019): maintain sufficient abundance of forage fish to meet targets for large piscivores, maximize abundance of large Kokanee, maximize viability of Bull Trout, insectivorous and piscivorous Rainbow Trout, and Burbot.

fishery, and a measure of the contribution of fin-clipped Rainbow Trout released into the reservoir from 2005 to 2010.⁵

Previous results up to 2018 are summarized in Arndt (2019) and references therein. This report summarizes angler characteristics, catch rate and fish size results for the 2019 calendar year. Estimates of angler effort, total catch and harvest of fish in 2019 will be included in a future report, because the expansion factors for these estimates may be revised based on overflight boat counts which continued into 2020.

2.0 METHODS

Anglers were interviewed at the end of their fishing trip by technicians stationed at three primary access locations (Shelter Bay, Nakusp, Castlegar). Five days per month were sampled (3 weekdays, 2 weekend/holidays) providing coverage of about a sixth of the total days in a year, and slightly less than a quarter of the weekend/holidays. Sampling aimed to cover the complete angler day as detailed in Arndt 2014a, and was randomized within the day types with all three access locations sampled on the same day.

Catch per unit effort was computed for each species by the ratio of means method (Malvestuto 1996) using the rod-hours of effort of anglers who reported targeting that species (Arndt and Schwarz 2011). Overflight boat counts (Beliveau et al. 2015) were completed starting in April 2019 and continuing into 2020. These data were not yet analysed at the writing of this report, and therefore the 2019 catch and harvest estimates (using 2019 expansion data) will be reported in the 2020 report.

Relative condition factor (K_n) of Bull Trout and piscivorous Rainbow Trout was computed in relation to the average weight of pre-nutrient fish as: $K_n = (W/W')$; where W is the weight of an individual fish, and W' is the length-specific weight for that fish as predicted by a weight-length equation for fish sampled prior to the beginning of the nutrient addition program (detailed in Arndt and Schwarz 2011). Average annual K_n was computed for all sizes pooled, and for a subset of Bull Trout >60 cm, because larger predators typically require larger or more energy dense prey (Kerr 1971, Rand and Stewart 1998, Shuter et al. 2016).

Clerks collected stomach samples opportunistically from Bull Trout (any size) and piscivorous Rainbow Trout (≥ 50 cm). With angler permission, the entire viscera was removed, sealed in a plastic zip-lock bag, and frozen until lab analysis. Predator species, fork length, and weight were recorded for each sample. Samples were thawed in the Ministry lab at 333 Victoria Street and stomach contents from the esophagus to the beginning of the intestine were examined. Consumed fish were identified to species if possible, and consumed invertebrates to the lowest possible taxon.

⁵ Hatchery fish were released by the Freshwater Fisheries Society of British Columbia in cooperation with the Province of BC. Prior to 2001, the FWCP funded a hatchery at Hill Creek.

3.0 RESULTS AND DISCUSSION

3.1 Angler Residence and Experience

A total of 1,428 anglers from 663 angling parties⁶ (including repeat contacts) were interviewed at the three major access locations in 2019 (Table 1). Residents of BC comprised 93% of the anglers, with non-resident Canadians (primarily from Alberta) making up most of the remainder. Nakusp and Shelter Bay had a higher percentage of anglers from outside the province than Castlegar. Residency percentages for 2019 were similar to those in ALR over the past two decades (Appendix 1), and to a province-wide mailed survey in 2010 (90.6% resident, 5.4% non-resident Canadian and 4.0% non-Canadian participation in freshwater fisheries; Fisheries and Oceans Canada 2012, Annex A.6).

Overall, 19.4% of interviewed parties in 2019 had 5 or less years of fishing experience on ALR, 32.5% from 6-20 years, and 48.1% over 20 years. These percentages are unchanged from 2018, although the percentage with > 20 years of experience has increased from 32% in 2014 (Arndt 2015). Among the three sites, Shelter Bay had the lowest proportion with ≤ 5 years and the highest with > 20 years (Figure 1). Note that years of experience is recorded only for the most experienced angler in each fishing party, so these percentages do not apply to all anglers; the overall proportions would have a higher percentage of less experienced anglers.

Table 1. Number of anglers sampled and residence category percentages for three main access locations sampled in Arrow Lakes Reservoir creel survey in 2019.

| Year | Location | No. Anglers Sampled | Resident (%) | Non-Resident Canadian (%) | Non-Canadian (%) |
|------|-------------|---------------------|--------------|---------------------------|------------------|
| 2019 | Shelter Bay | 540 | 90.7 | 9.3 | 0.3 |
| | Nakusp | 357 | 88.8 | 10.9 | 0.6 |
| | Castlegar | 531 | 97.3 | 2.7 | 0.0 |
| | All Sites | 1428 | 92.7 | 7.2 | 0.3 |

⁶ An angling party typically means one or more anglers in a single boat, although it can be one or more shore anglers fishing from the sampled access location.

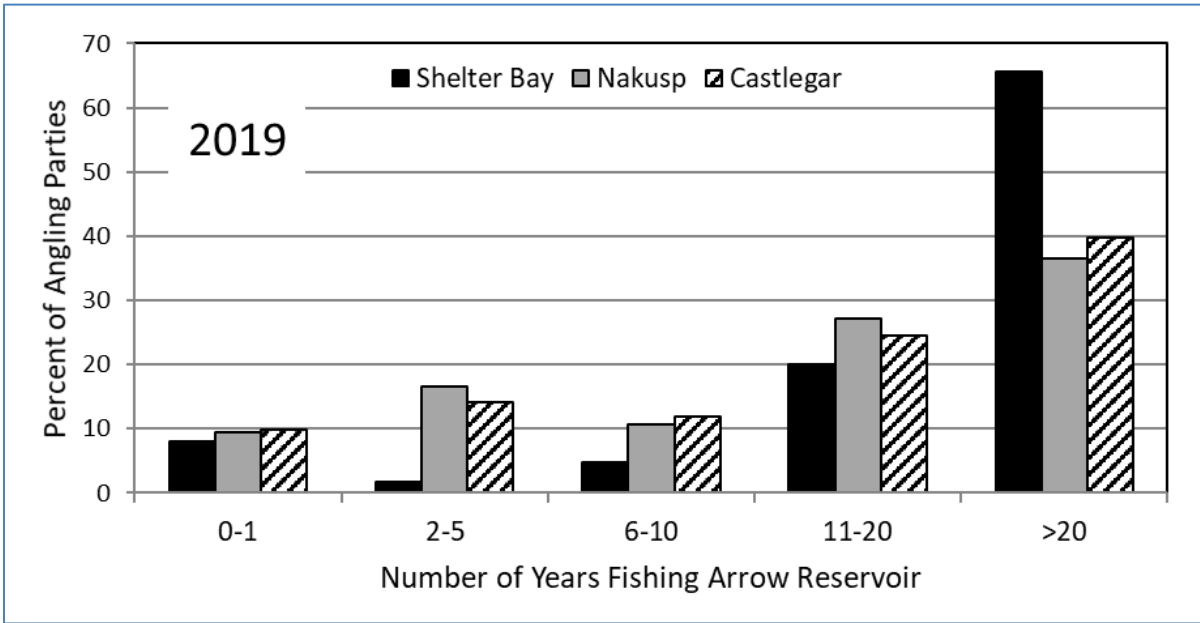


Figure 1. Percentage of interviewed angling parties by fishing experience category (years of experience fishing Arrow Lakes Reservoir for the most experienced party member) for three main sampled locations on Arrow Lakes Reservoir in 2019.

3.2 Species Targeted

Species targeted for the three sampled locations (pooled) are listed in Table 2. About 85% of the 2019 effort was targeting Bull Trout and/or Rainbow Trout, with only 13% of angler-days targeting Kokanee, or Kokanee and other species. There has been a trend towards decreased effort for Kokanee and small Rainbow Trout since 2015, and a corresponding increase in the proportion of Bull Trout effort. However, 'Kokanee only' effort increased in 2019, perhaps in response to a regulation change increasing the daily limit from 5 to 15 Kokanee. Burbot remained the smallest component of the fishery, detected only at the Nakusp access.

Table 2. Percentage of sampled angler-days and rod-hours by species sought category, based on sampling at three main access locations in Arrow Lakes Reservoir from 2015 to 2019.

| Species Sought | Angler-days | | | | | Rod-hours | | | | |
|-----------------------|-------------|------|------|------|------|-----------|------|------|------|------|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Bull or Rainbow Trout | 52.7 | 66.8 | 60.6 | 64.7 | 69.2 | 56.6 | 66.8 | 64.0 | 69.2 | 73.5 |
| Bull trout only | 2.2 | 4.2 | 5.7 | 7.5 | 6.1 | 2.6 | 4.2 | 7.2 | 8.3 | 6.5 |
| Rainbow trout only | 11.8 | 5.3 | 6.6 | 8.5 | 7.9 | 11.2 | 5.6 | 6.0 | 7.9 | 7.0 |
| Kokanee or Rainbow | 12.8 | 6.0 | 10.4 | 6.4 | 2.6 | 11.7 | 5.5 | 7.6 | 4.5 | 2.4 |
| Kokanee only | 10.4 | 5.2 | 3.4 | 7.2 | 10.2 | 8.6 | 4.6 | 3.1 | 5.2 | 7.0 |
| Burbot | 1.5 | 1.1 | 1.3 | 2.4 | 1.4 | 1.5 | 1.0 | 1.0 | 1.9 | 1.0 |
| Kokanee or Bull trout | 0.0 | 0.0 | 0.5 | 0.5 | 0.4 | 0.0 | 0.0 | 0.5 | 0.3 | 0.3 |
| Anything ¹ | 8.6 | 11.5 | 11.5 | 2.9 | 2.3 | 7.8 | 12.3 | 10.5 | 2.8 | 2.1 |

¹ includes anglers listing 3 or more targeted species

3.3 Fish Size and Catch Rates

3.3.1 Bull Trout

The average size of harvested Bull Trout in 2019 (59 cm and 2.4 kg) was slightly below 2018 (which was the largest in the time series since 1998; Appendix 2a). Length in 2019 ranged from 40 – 87.5 cm (Figure 2). The highest recorded weight was 6.8 kg (Figure 3), and catch rate was 0.072 fish/rod-hour (Table 3).

Table 3. Angling catch rate (fish/rod-hour) for Bull Trout from Arrow Lakes Reservoir from 2005 to 2019. Three access locations are pooled.

| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010/11 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|------|-------|-------|-------|-------|-------|---------|-------|-------|-------|-------|-------|-------|-------|-------|
| CPUE | 0.069 | 0.075 | 0.067 | 0.064 | 0.061 | 0.069 | 0.084 | 0.081 | 0.060 | 0.056 | 0.077 | 0.093 | 0.076 | 0.072 |

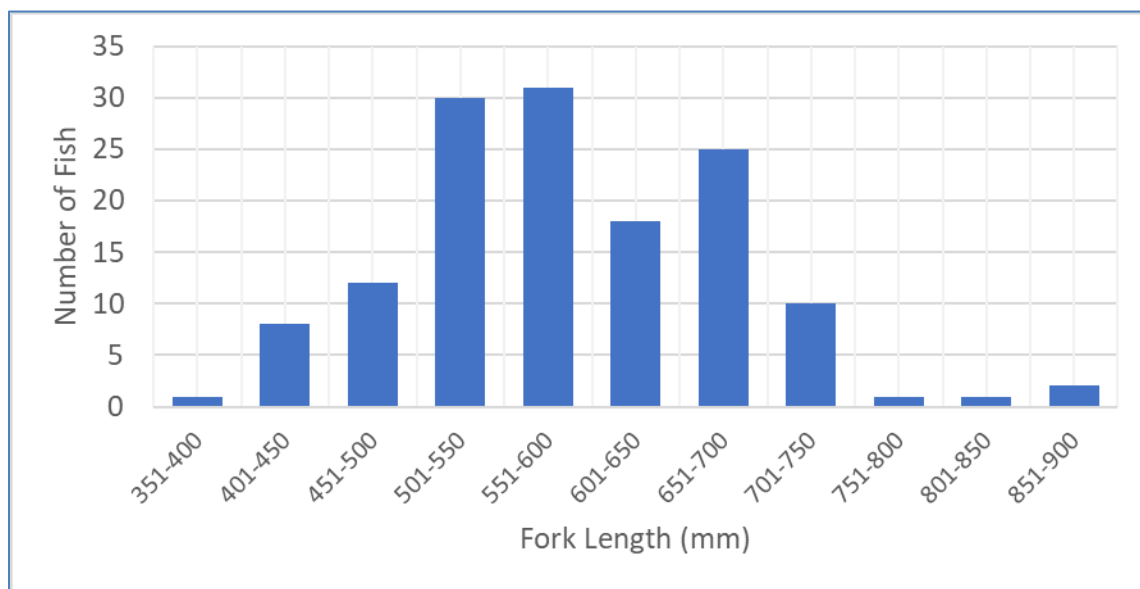


Figure 2. Length frequency distribution of angled Bull Trout from Arrow Lakes Reservoir in 2019.

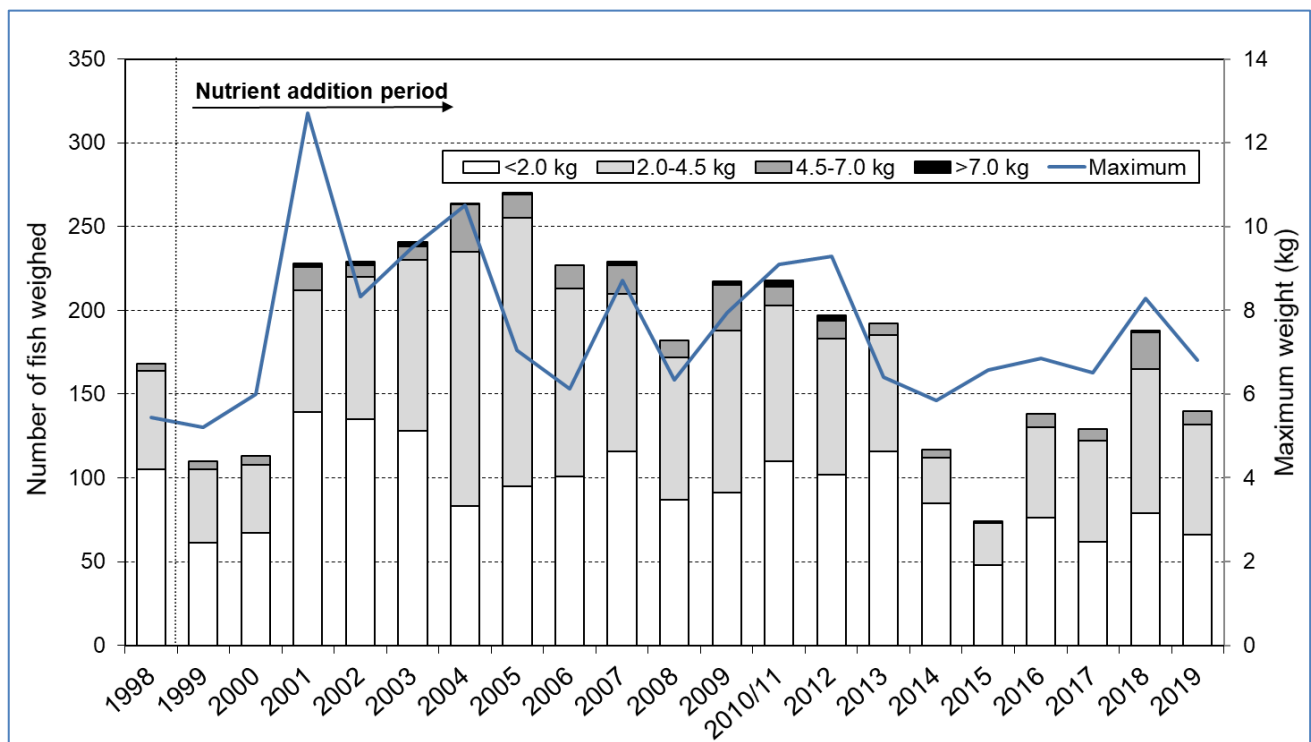


Figure 3. Number of weighed Bull Trout by size category sampled at three access locations in Arrow Lakes Reservoir from 1998 to 2019. Data from January to March 2010 are pooled with April to December 2011 because the 2010/11 fiscal year was not sampled.

3.3.2 Rainbow Trout

The average size of harvested Rainbow Trout in 2019 (39 cm and 1.0 kg) was similar to previous years (Appendix 2b). Length ranged from 24 – 75 cm (Figure 4). The highest recorded weight was 5.75 kg (Figure 5), and catch rate was 0.066 fish/rod-hour (Table 4). No hatchery clipped Rainbow Trout were sampled. Nineteen piscivorous Rainbow Trout \geq 50 cm were sampled in 2019, which is one more than 2018 and about half of 2017 (Figure 6).

Table 4. Angling catch rate (fish/rod-hour) for Rainbow Trout from Arrow Lakes Reservoir from 2005 to 2019.

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010/11 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|------|-------|-------|-------|-------|-------|---------|-------|-------|-------|-------|-------|-------|-------|-------|
| CPUE | 0.063 | 0.067 | 0.076 | 0.073 | 0.060 | 0.090 | 0.060 | 0.065 | 0.074 | 0.059 | 0.074 | 0.076 | 0.053 | 0.066 |

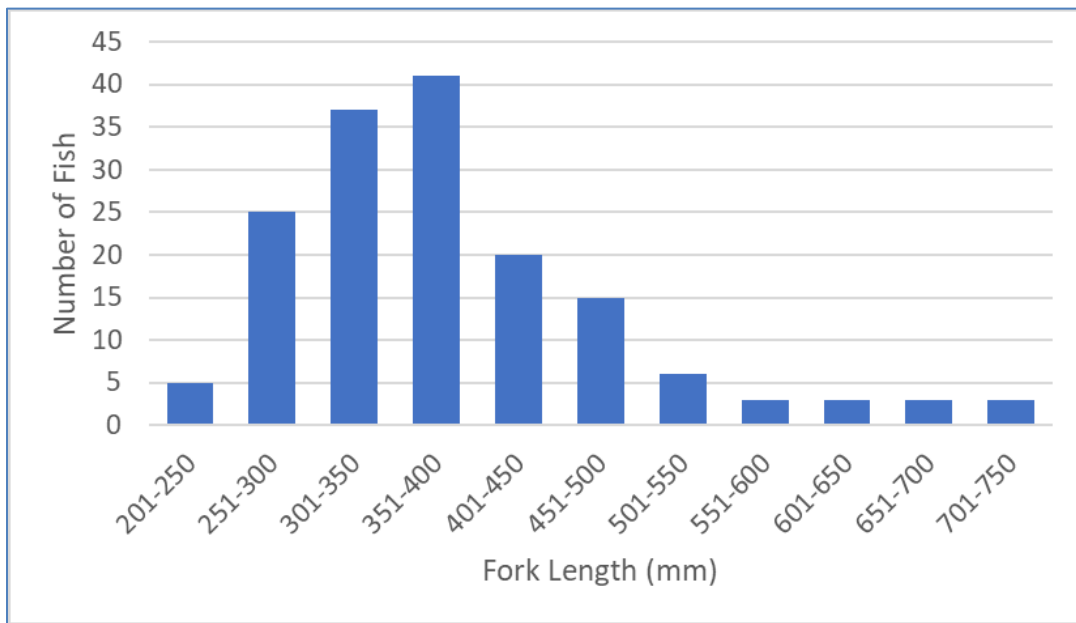


Figure 4. Length frequency of Rainbow Trout angled from Arrow Lakes Reservoir in 2019.

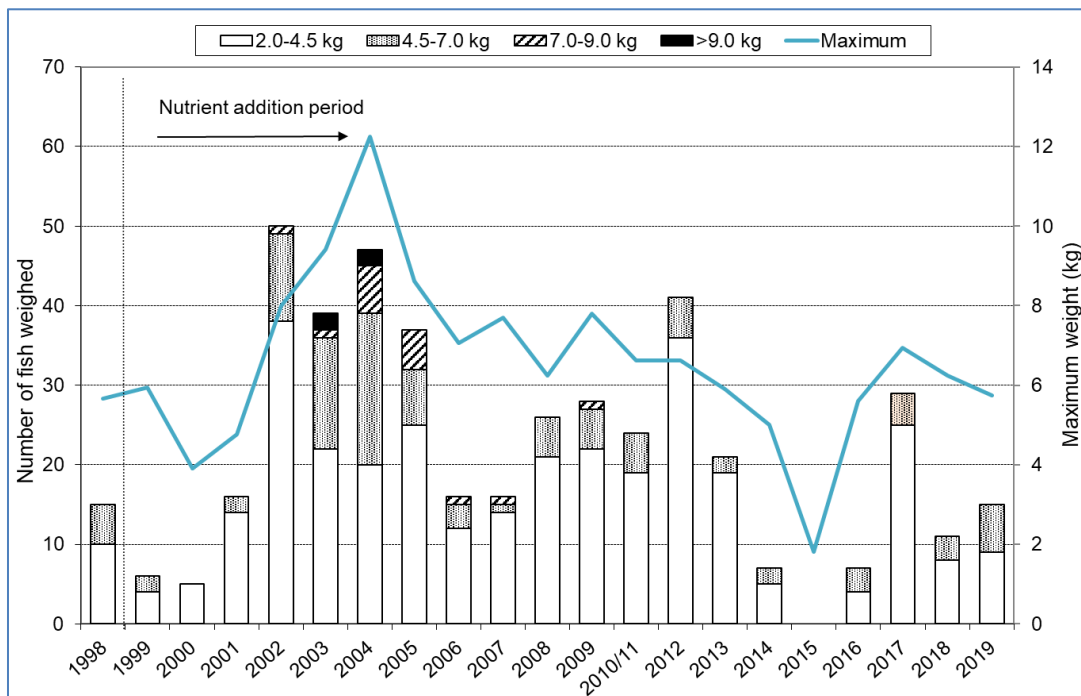


Figure 5. Number of sampled Rainbow Trout over 2 kg by size category at three access locations in Arrow Lakes Reservoir from 1998 to 2019. January to March 2010 was pooled with April to December 2011.

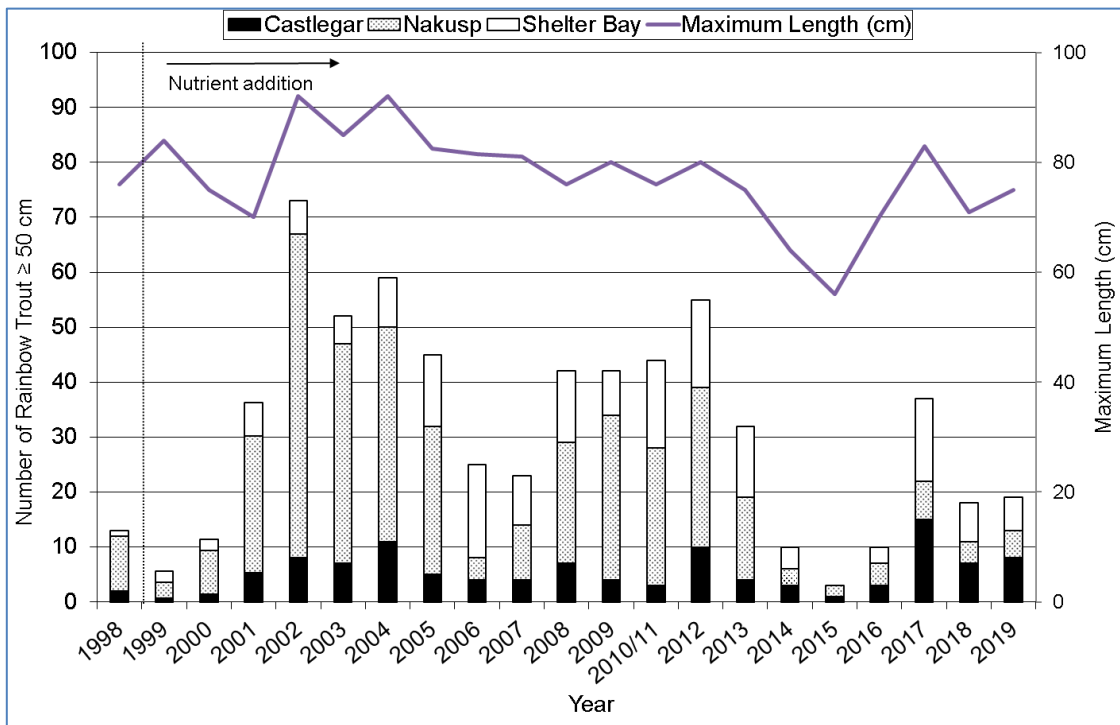


Figure 6. Number of piscivorous Rainbow Trout ≥ 50 cm and maximum sampled length at three access locations in Arrow Lakes Reservoir from 1998 to 2019. January to March 2010 is pooled with April to December 2011. Castlegar values for 1999-2001 (data not available) were estimated as the average proportion of the total from the three following years.

3.3.3 Kokanee

Average size of Kokanee in 2019 (21 cm, 129 g) was slightly larger than 2016 - 2018, but remains below most years since 1998 (Appendix 2c); the length distribution was unimodal (Figure 7). Despite their small size the majority of spawning Kokanee in 2019 were age-3 based on otoliths (MFLNRORD file data), and therefore it is likely that most of the harvested fish were also age-3 (scale ages not available). Average CPUE for the year was 0.833, which is the highest in more than a decade (Table 5). This may be related to the increased effort of 'Kokanee only' anglers who are presumably using methods more specific to catching Kokanee.

Table 5. Angling catch rate (fish/rod-hour) for Kokanee from Arrow Lakes Reservoir from 2005 to 2019.

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010/11 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|-------------|-------|-------|-------|-------|-------|---------|-------|-------|-------|--------|-------|-------|-------|-------|
| CPUE | 0.476 | 0.135 | 0.375 | 0.243 | 0.391 | 0.474 | 0.296 | 0.254 | 0.288 | 0.3100 | 0.518 | 0.391 | 0.526 | 0.833 |

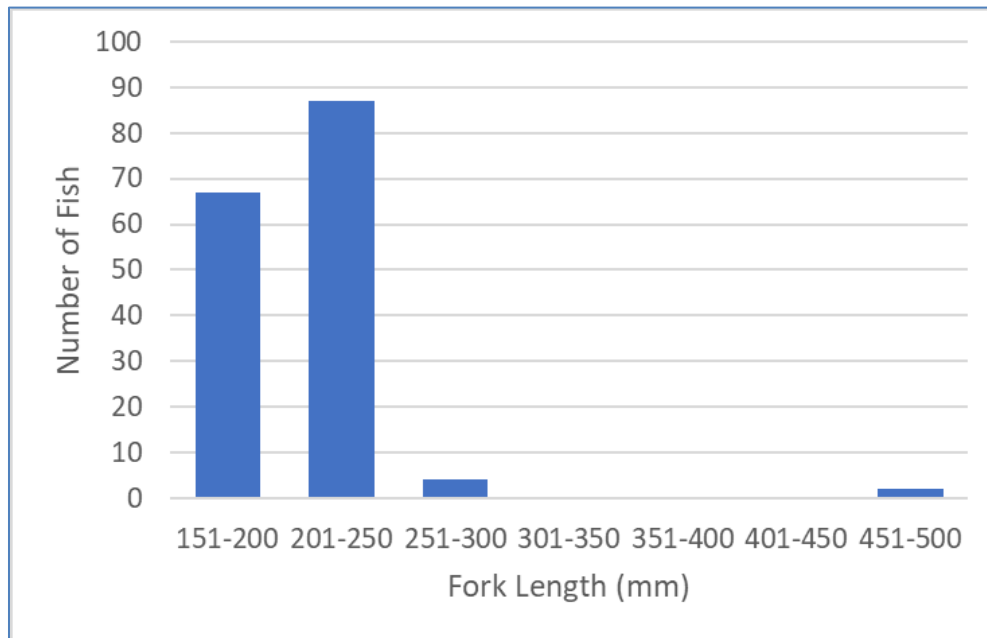


Figure 7. Length frequency distribution of Kokanee angled from Arrow Lakes Reservoir in 2019.

3.3.4 Burbot

As is usually the case, all recorded Burbot were from the Nakusp access. Length of Burbot in 2019 ranged from 49 to 96 cm, with a mean size of 66 cm and 1.7 kg (Figure 8). This is similar to the last two years, and slightly larger than 2010 – 2016 (Appendix 2d). Catch rate in 2019 was 0.382 fish/rod-hour (Table 6).

Table 6. Burbot catch rate (fish/rod-hour) from Arrow Lakes Reservoir from 2005 to 2019.

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010/11 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|-------------|-------|-------|-------|-------|-------|---------|-------|-------|-------|--------|-------|-------|-------|-------|
| CPUE | 0.476 | 0.135 | 0.375 | 0.243 | 0.391 | 0.474 | 0.296 | 0.254 | 0.288 | 0.3100 | 0.518 | 0.391 | 0.526 | 0.382 |

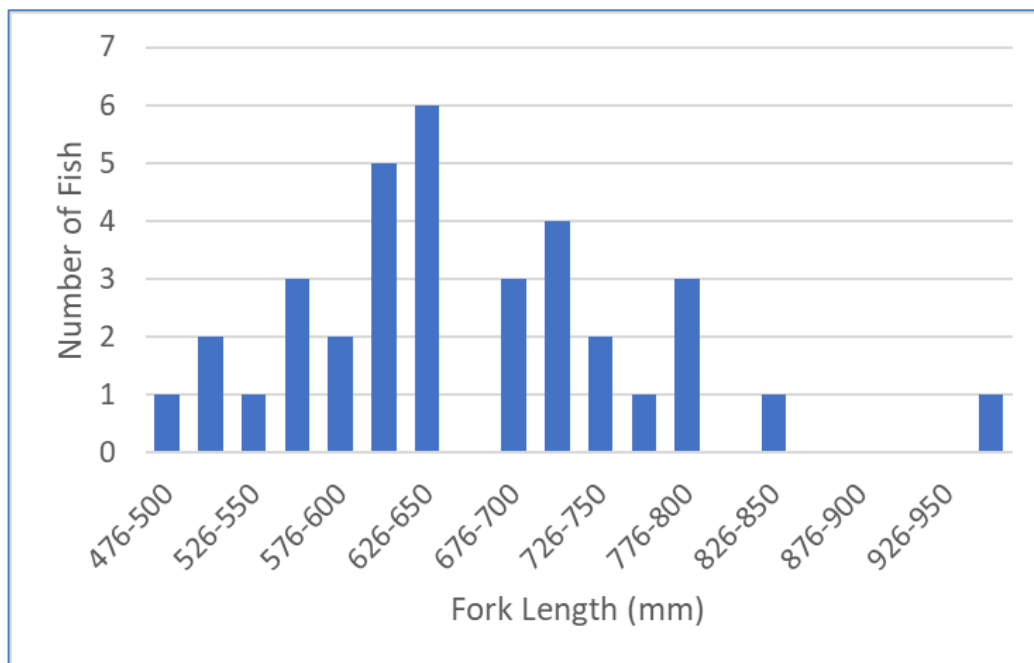


Figure 8. Length frequency distribution of Burbot angled from Arrow Lakes Reservoir in 2019.

3.4 Condition Factor of Apex Predators

Bull Trout and piscivorous Rainbow Trout, the two apex predators in the aquatic food web of ALR, feed primarily on Kokanee when they are available (Arndt 2004b; Clarke et al. 2005). Their condition factor relative to average weight at length prior to the nutrient program (K_n), provides an index of prey supply (abundance and size) at the highest trophic level in the aquatic food web. Bull Trout K_n increased substantially in 2017 after remaining near the pre-nutrient average for four years (Figure 9). The change in average K_n from near 1.0 (2013 - 2015) to 13% above pre-nutrient levels (1.13) in 2017 implies increased growth rates, higher survival (Korman et al. 2017), and a greater probability of spawning (Thorley and Andrusak 2017). Since then, K_n has declined to an average of about 5% above the pre-nutrient average for all Bull Trout, and 10% above for larger Bull Trout. This K_n value is expected based on the Kokanee spawning escapement in 2019 (Figure 10).⁷

Rainbow Trout K_n was fairly stable from 2006 – 2013 at 5-10% above the pre-nutrient average. From 2014-2016, the number sampled was too low to get a reliable average, but in 2017 the sample was adequate to show that Rainbow Trout K_n (1.10; n=33) was above the pre-nutrient level similar to that of Bull Trout (Figure 11). The 2019 average was 1.29 including one fish with very high (perhaps questionable) condition, or 1.22 excluding the unusual fish; both values are well above the pre-nutrient average, although sample size is low (n=14). The return to higher condition for both apex predators since 2017 implies an improvement in feeding conditions for the apex predators above the pre-nutrient level, although the last two years are moving downward again for Bull Trout.

3.5 Diet Samples

Eighty-seven Bull Trout and seven piscivorous Rainbow Trout stomach samples were collected and dissected in 2019, and data were entered in the Arrow predator diet database (Predator Diet_ 2015 update 21.mdb). Length range of diet-sampled Bull Trout ranged from 42 – 87.5 cm and for Rainbow Trout from 49 – 75 cm. Slightly less than half (45%) of the Bull Trout and Rainbow Trout (43%) had the remains of at least one fish in the gut. Most consumed fish were Kokanee. Bull Trout samples included a total of 51 Kokanee ranging from 13 – 23 cm, and one 30 cm fish of unknown species. Rainbow Trout samples included six Kokanee from 14 - 21.5 cm. A previous diet summary is included in Appendix 6 of the 2018 creel report (Arndt 2019), and more detailed analyses including multiple year comparisons will be conducted in future as time permits.

⁷ Index stream Kokanee escapement is estimated by multiplying the peak spawner count in nine regularly-counted streams by 1.5. After a historic low in 2012 of 76,000 for all index streams, estimates remained at about 100,000 fish for the upper basin and 200,000 for the total index from 2013 – 2016; returns increased to 320,000 (upper) and 685,000 (total) in 2017, declined to 155,000 (upper) and 245,000 (total) in 2018, and were 164,000 (upper) and 307,000 (total) in 2019 (MFLNRORD data on file).

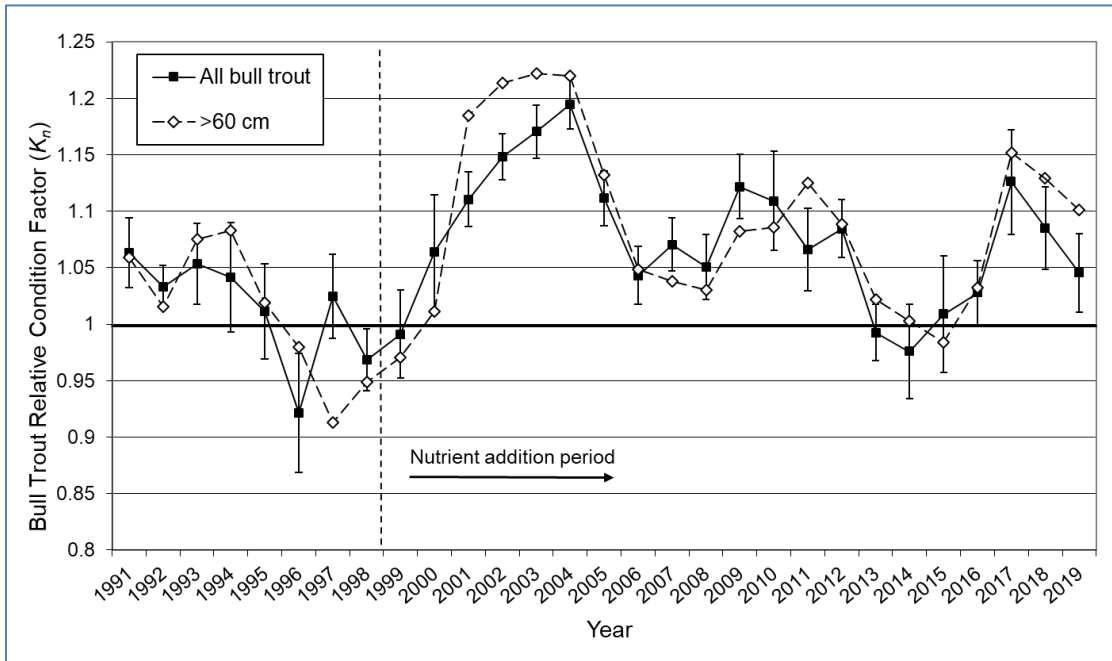


Figure 9. Mean annual condition factor (K_n ; \pm 95% confidence limits) relative to the average pre-nutrient weight at length ($K_n=1$) for all Bull Trout, and for Bull Trout over 60 cm in Arrow Lakes Reservoir from 1991 to 2019. Annual sample size for all Bull Trout ranges from 33 to 267.

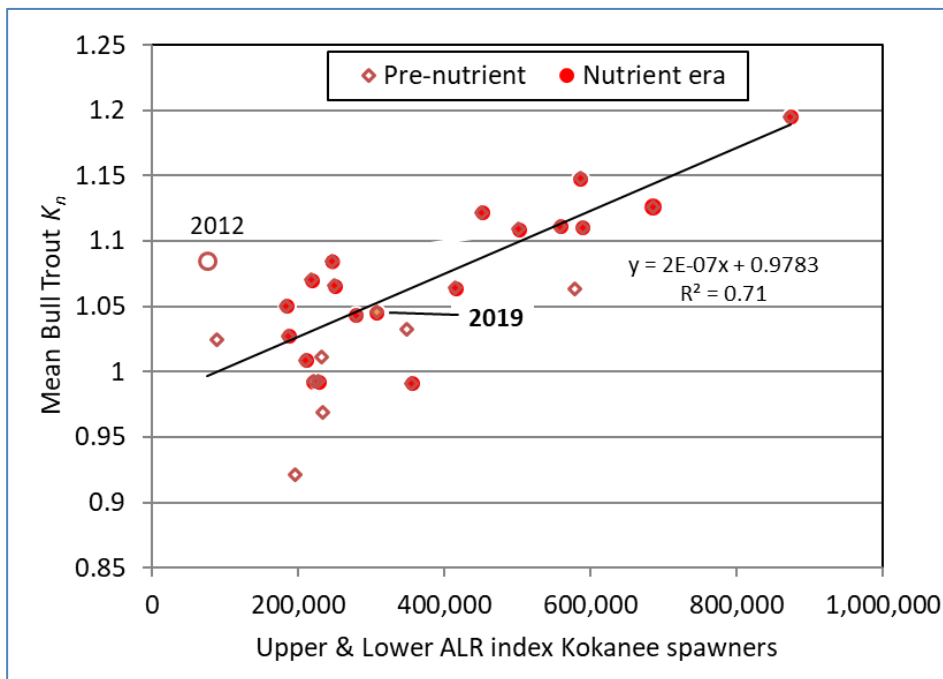


Figure 10. Relationship between mean condition factor (K_n) of Bull Trout and index stream Kokanee spawner estimates for Upper and Lower Arrow Lakes Reservoir. Year 2012 was not used for the regression because a large proportion of age-3 Kokanee delayed spawning (see Arndt 2014b). A similar plot using only Upper Arrow Kokanee index streams is provided in Appendix 3.

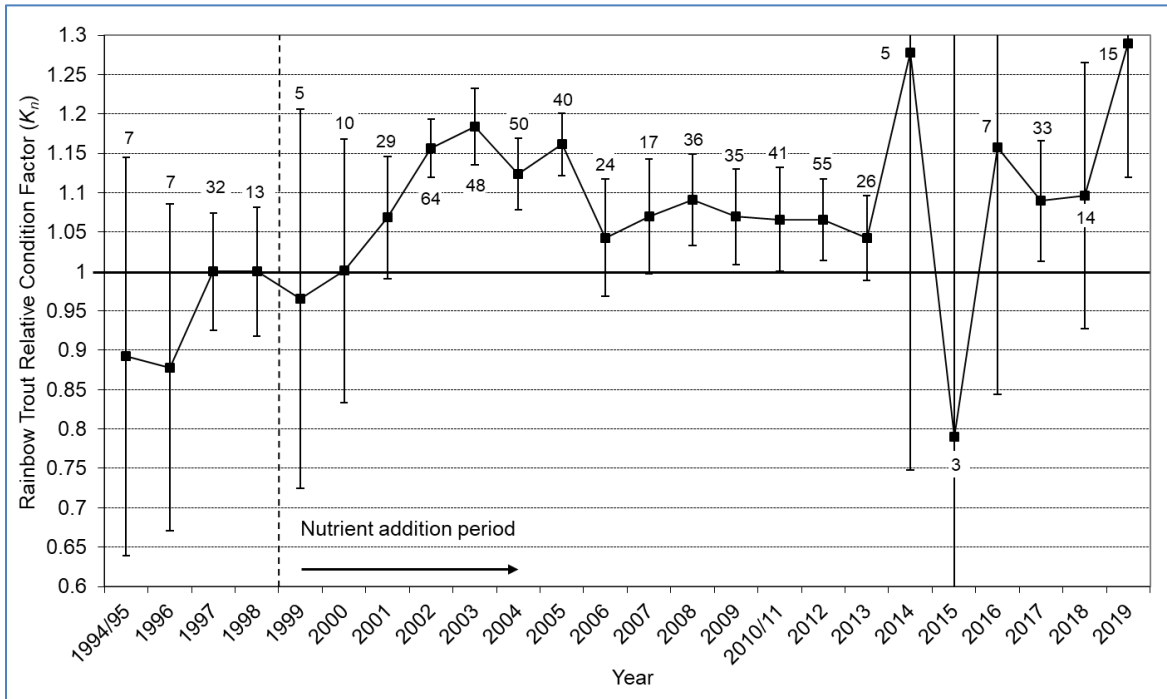


Figure 11. Mean annual condition factor (K_n ; \pm 95% confidence limits) relative to the average pre-nutrient weight at length ($K_n=1$) of piscivorous Rainbow Trout in Arrow Lakes Reservoir from 1994 to 2019. Numbers indicate sample size.

4.0 SUMMARY AND CONCLUSIONS

In 2019, the creel survey was completed successfully, with no substantial changes in angler characteristics (residence, experience, species targeted) or the size of harvested fish. Kokanee catch rate increased substantially with only a slight size increase; this might be related to greater targeted effort in the Lower Arrow near Castlegar because the daily limit was increased from 5 to 15 in 2019. The small size of Kokanee in recent years is unusual because density and biomass in the reservoir have been relatively low (MFLNRORD file data). The number of large Bull Trout and Rainbow Trout sampled decreased slightly in 2019 as did the condition factor of Bull Trout.

Overflight boat counts conducted from 2003–2005 and in 2011-2012 have provided the expansion factors used for whole reservoir estimates of effort, harvest and catch up to 2018. Given recent improvements to some of the smaller boat ramps on the reservoir and the possibility of unknown factors affecting angler access over time, overflight counts were completed again in the 2019/20 fiscal to ensure that the interviewed/total boat expansion ratios are accurate for the 2019 and 2020 catch and harvest estimates. These estimates will be provided in a future report.

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6.0 APPENDICES

APPENDIX 1. Angler residence composition on Arrow Lakes Reservoir from 1976 to 2019. Data up to 2009 are from Hill Creek Hatchery creel records (Thorp 1995) and Arndt and Schwarz (2011); 1995 to 1997 were not available. Number of access sites monitored was reduced from five to three in 1999.

| Year | Number of Anglers Interviewed | Resident (%) | Non Resident Canadian (%) | Non Resident Alien (%) |
|-------------------|-------------------------------|--------------|---------------------------|------------------------|
| 1976 | 852 | 97.0 | 2.0 | 1.0 |
| 1977 | 1,084 | 97.1 | 1.7 | 1.2 |
| 1978 | 1,006 | 95.1 | 3.0 | 1.9 |
| 1979 | 959 | 94.0 | 5.0 | 1.0 |
| 1980 | 1,253 | 93.0 | 5.0 | 2.0 |
| 1981 | 1,060 | 86.9 | 11.8 | 1.2 |
| 1982 | 977 | 90.0 | 8.0 | 2.0 |
| 1983 | 887 | 90.0 | 9.0 | 1.0 |
| 1984 | 751 | 89.0 | 10.0 | 1.0 |
| 1985 | 1,387 | 90.3 | 8.4 | 1.3 |
| 1986 | 916 | 85.0 | 12.0 | 3.0 |
| 1987 | 1,129 | 85.0 | 11.0 | 4.0 |
| 1988 | 1,089 | 88.0 | 8.0 | 4.0 |
| 1989 | 963 | 89.1 | 9.8 | 1.1 |
| 1990 | 900 | 88.6 | 9.8 | 1.6 |
| 1991 | 841 | 92.4 | 6.7 | 0.9 |
| 1992 | 898 | 87.9 | 10.7 | 1.4 |
| 1993 | 649 | 91.4 | 8.3 | 0.3 |
| 1994 | 807 | 90.0 | 9.3 | 0.7 |
| 1995 | - | - | - | - |
| 1996 | - | - | - | - |
| 1997 | - | - | - | - |
| 1998 | 1,463 | 95.6 | 3.4 | 1.0 |
| 1999 | 1,264 | 96.4 | 2.5 | 1.1 |
| 2000 | 1,071 | 94.3 | 4.2 | 1.5 |
| 2001 | 1,847 | 93.6 | 5.0 | 1.4 |
| 2002 | 1,694 | 94.8 | 4.3 | 0.9 |
| 2003 | 1,540 | 91.8 | 7.6 | 0.6 |
| 2004 | 1,896 | 92.7 | 5.8 | 1.5 |
| 2005 | 1,826 | 89.9 | 9.3 | 0.8 |
| 2006 | 1,624 | 93.8 | 5.7 | 0.5 |
| 2007 | 1,784 | 90.7 | 7.3 | 2.0 |
| 2008 | 1,535 | 90.4 | 9.3 | 0.3 |
| 2009 | 1,700 | 87.5 | 11.9 | 0.6 |
| 2010 ^a | 434 | 94.5 | 4.1 | 1.4 |
| 2011 ^a | 1,385 | 90.0 | 9.9 | 0.1 |
| 2012 | 1,545 | 92.0 | 7.7 | 0.3 |
| 2013 | 1,342 | 91.0 | 8.9 | 0.1 |
| 2014 | 1,414 | 88.3 | 11.7 | 0.0 |
| 2015 | 980 | 89.7 | 9.8 | 0.5 |
| 2016 | 1,028 | 94.1 | 5.9 | 0.0 |
| 2017 ^b | 1,092 | 93.7 | 5.9 | 0.4 |
| 2018 | 1,187 | 91.9 | 8.1 | 0.0 |
| 2019 | 1,428 | 92.7 | 7.2 | 0.3 |

^a 2010 surveyed from January to March only; 2011 from April to December

^b 2017 numbers do not include Revelstoke Reach April to September survey

APPENDIX 2a. Size statistics for Bull Trout in the Arrow Lakes Reservoir creel survey from 1998 to 2019. Data for 1998-2002 are from Arndt (2002, 2004a). Missing weights were estimated with a length-weight regression from 2013 on. The 2010 data are January to March only; 2011 data April to December only.

| Year | N | Fork Length (cm) | | Weight (g) | |
|-------|-----|---------------------|-----------|---------------------|--------------|
| | | Mean \pm 95% c.l. | Range | Mean \pm 95% c.l. | Range |
| 1998 | 169 | 56.9 \pm 1.7 | 38 – 85 | 1,948 \pm 160 | 500 – 5,450 |
| 1999 | 96 | 56.0 \pm 1.9 | 35 – 81 | 2,042 \pm 205 | 350 – 5,216 |
| 2000 | 105 | 53.3 \pm 2.1 | 28 – 82 | 1,914 \pm 223 | 425 – 6,000 |
| 2001 | 233 | 55.3 \pm 1.2 | 31 – 89 | 2,128 \pm 179 | 350 – 12,700 |
| 2002 | 231 | 55.0 \pm 1.1 | 29 – 82 | 2,076 \pm 149 | 123 – 8,325 |
| 2003 | 248 | 55.8 \pm 1.2 | 32 – 88 | 2,252 \pm 170 | 370 – 9,500 |
| 2004 | 263 | 59.2 \pm 1.1 | 37 – 88 | 2,710 \pm 168 | 600 – 10,517 |
| 2005 | 269 | 59.7 \pm 1.1 | 35 – 83 | 2,570 \pm 140 | 420 – 7,040 |
| 2006 | 240 | 59.2 \pm 1.2 | 38 – 83 | 2,396 \pm 158 | 405 – 6,123 |
| 2007 | 235 | 58.0 \pm 1.5 | 34 – 90 | 2,320 \pm 177 | 396 – 8,731 |
| 2008 | 181 | 58.4 \pm 1.4 | 30 – 82 | 2,309 \pm 182 | 340 – 6,350 |
| 2009 | 217 | 58.6 \pm 1.6 | 23 – 87 | 2,543 \pm 200 | 160 – 7,938 |
| 2010* | 107 | 60.2 \pm 1.8 | 41 – 95 | 2,639 \pm 291 | 808 – 9,100 |
| 2011* | 126 | 53.8 \pm 1.9 | 30 – 87 | 1,995 \pm 254 | 355 – 8,108 |
| 2012 | 224 | 56.4 \pm 1.3 | 25 – 88 | 2,284 \pm 191 | 226 – 9,296 |
| 2013 | 195 | 55.7 \pm 1.4 | 36 – 82 | 1,952 \pm 159 | 336 – 6,407 |
| 2014 | 117 | 55.2 \pm 1.5 | 32 – 78 | 1,837 \pm 202 | 259 – 5,851 |
| 2015 | 74 | 54.7 \pm 2.2 | 33 – 80 | 1,793 \pm 250 | 425 – 6,577 |
| 2016 | 138 | 57.6 \pm 1.7 | 40 – 84 | 2,172 \pm 204 | 592 – 6,861 |
| 2017 | 125 | 58.0 \pm 1.6 | 33 – 80 | 2,409 \pm 212 | 340 – 6,500 |
| 2018 | 188 | 59.8 \pm 1.4 | 36 – 84 | 2,601 \pm 210 | 420 – 8,288 |
| 2019 | 140 | 59.3 \pm 1.5 | 40 – 87.5 | 2,421 \pm 235 | 454 – 6,804 |

APPENDIX 2b. Size statistics for Rainbow Trout in the Arrow Lakes Reservoir creel survey from 1998 to 2019.

| Year | N | Fork Length (cm) | | Weight (g) | |
|-------|-----|---------------------|---------|---------------------|-------------|
| | | Mean \pm 95% c.l. | Range | Mean \pm 95% c.l. | Range |
| 1998 | 168 | 36.4 \pm 1.5 | 22 – 75 | 756 \pm 150 | 200 – 5,670 |
| 1999 | 150 | 35.8 \pm 1.4 | 23 – 84 | 597 \pm 105 | 100 – 5,942 |
| 2000 | 225 | 37.7 \pm 0.9 | 24 – 75 | 688 \pm 59 | 180 – 3,900 |
| 2001 | 400 | 37.7 \pm 0.8 | 22 – 70 | 690 \pm 60 | 85 – 4,762 |
| 2002 | 316 | 42.1 \pm 1.3 | 23 – 81 | 1,162 \pm 141 | 170 – 8,000 |
| 2003 | 281 | 40.8 \pm 1.4 | 20 – 85 | 1,144 \pm 177 | 140 – 9412 |
| 2004 | 383 | 39.0 \pm 1.4 | 17 – 92 | 1,034 \pm 167 | 70 – 12,247 |
| 2005 | 315 | 38.6 \pm 1.3 | 20 – 83 | 971 \pm 853 | 85 – 8,620 |
| 2006 | 362 | 37.0 \pm 1.0 | 18 – 82 | 679 \pm 78 | 85 – 7,065 |
| 2007 | 364 | 37.3 \pm 0.8 | 17 – 81 | 694 \pm 74 | 56 – 7,700 |
| 2008 | 313 | 39.8 \pm 1.1 | 19 – 76 | 885 \pm 104 | 91 – 6,237 |
| 2009 | 323 | 40.1 \pm 1.2 | 17 – 80 | 924 \pm 112 | 50 – 7,800 |
| 2010* | 21 | 52.0 \pm 5.7 | 34 – 73 | 2,349 \pm 924 | 510 – 6,633 |
| 2011* | 392 | 37.4 \pm 0.9 | 20 – 76 | 708 \pm 79 | 113 – 6,356 |
| 2012 | 228 | 41.9 \pm 1.5 | 21 – 80 | 1,149 \pm 163 | 56 – 6,634 |
| 2013 | 202 | 40.6 \pm 1.5 | 23 – 75 | 938 \pm 160 | 75 – 5,908 |
| 2014 | 235 | 38.2 \pm 0.8 | 23 – 64 | 651 \pm 74 | 85 – 5,012 |
| 2015 | 98 | 37.2 \pm 1.2 | 23 – 56 | 637 \pm 66 | 170 – 1,814 |
| 2016 | 162 | 38.0 \pm 1.3 | 21 – 70 | 709 \pm 125 | 85 – 5,600 |
| 2017 | 152 | 40.3 \pm 2.1 | 19 – 83 | 1,076 \pm 207 | 67 – 6,932 |
| 2018 | 140 | 39.4 \pm 1.7 | 20 – 71 | 846 \pm 163 | 78 – 6,250 |
| 2019 | 161 | 38.8 \pm 1.6 | 24 – 75 | 961 \pm 166 | 198 – 5,750 |

APPENDIX 2c. Size statistics for Kokanee in the Arrow Lakes Reservoir creel survey from 1998 to 2019.

| Year | N | Fork Length (cm) | | Weight (g) | | |
|-------|-----|---------------------|-----------|------------|---------------------|------------|
| | | Mean \pm 95% c.l. | Range | N | Mean \pm 95% c.l. | Range |
| 1998 | 104 | 25.2 \pm 0.9 | 18-34 | 59 | 172 \pm 13 | 75-400 |
| 1999 | 1 | 21.0 | N/A | 1 | 136 | N/A |
| 2000 | 2 | 28.5 | N/A | 2 | 275 | N/A |
| 2001 | 666 | 25.8 \pm 0.2 | 17-42 | 629 | 215 \pm 8 | 56-963 |
| 2002 | 123 | 22.5 \pm 0.7 | 16-41 | 109 | 138 \pm 19 | 28-708 |
| 2003 | 199 | 21.2 \pm 0.4 | 15-39 | 190 | 113 \pm 11 | 28-680 |
| 2004 | 349 | 22.6 \pm 0.5 | 13-50 | 340 | 155 \pm 13 | 28-1,417 |
| 2005 | 295 | 23.1 \pm 0.7 | 15-60 | 291 | 179 \pm 25 | 28-2,353 |
| 2006 | 158 | 24.0 \pm 0.7 | 16-47 | 148 | 203 \pm 23 | 56-1,275 |
| 2007 | 576 | 24.6 \pm 0.3 | 15-53 | 571 | 197 \pm 12 | 56-2,041 |
| 2008 | 343 | 24.5 \pm 0.4 | 17-55 | 338 | 207 \pm 15 | 50-1,650 |
| 2009 | 412 | 24.0 \pm 0.4 | 12-62 | 371 | 184 \pm 23 | 28-3,260 |
| 2010* | 31 | 25.8 \pm 0.5 | 23-28 | 31 | 164 \pm 10 | 115-220 |
| 2011* | 254 | 22.6 \pm 0.4 | 16-46 | 254 | 143 \pm 13 | 26-1,344 |
| 2012 | 105 | 21.9 \pm 0.7 | 17-36 | 105 | 132 \pm 15 | 42-550 |
| 2013 | 91 | 24.0 \pm 0.7 | 18 - 38 | 90 | 204 \pm 20 | 100 - 800 |
| 2014 | 357 | 28.2 \pm 0.3 | 21 - 58.5 | 357 | 247 \pm 13 | 45 - 2,100 |
| 2015 | 183 | 23.4 \pm 0.6 | 18 - 56 | 183 | 192 \pm 72 | 56 - 2,500 |
| 2016 | 150 | 20.3 \pm 0.4 | 16 - 37 | 150 | 109 \pm 7 | 56 - 504 |
| 2017 | 244 | 20.5 \pm 0.3 | 15 - 51 | 244 | 106 \pm 14 | 35 - 1,500 |
| 2018 | 167 | 20.0 \pm 0.3 | 16 - 40 | 173 | 92 \pm 12 | 35 - 1,100 |
| 2019 | 160 | 21.0 \pm 0.5 | 17 - 47 | 160 | 129 \pm 18 | 68 - 1,134 |

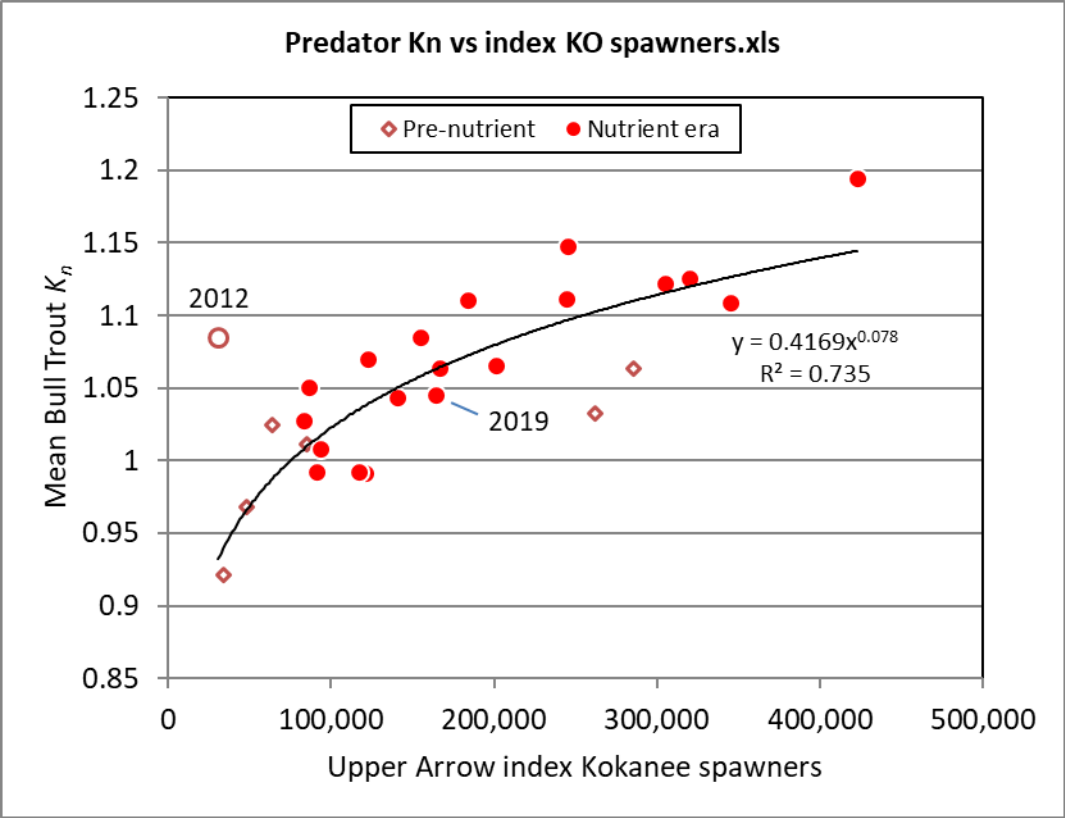
* 2010 data January to March only; 2011 data April to December only.

APPENDIX 2d. Size statistics for Burbot in the Arrow Lakes Reservoir creel survey from 1998 to 2019.

| Year | N | Fork Length (cm) | | Weight (g) | |
|-------|----|---------------------|-----------|---------------------|-------------|
| | | Mean \pm 95% c.l. | Range | Mean \pm 95% c.l. | Range |
| 1998 | 5 | 73.2 \pm 19.8 | 60 - 90 | 2,019 \pm 1,588 | 900-4,130 |
| 1999 | 18 | 59.1 \pm 4.7 | 41 - 76 | 1,264 \pm 239 | 454-2,223 |
| 2000 | 6 | 60.0 \pm 4.8 | 52 - 65 | 1,196 \pm 419 | 700-1,700 |
| 2001 | 39 | 63.1 \pm 2.3 | 50 - 86 | 1,596 \pm 190 | 737-3,345 |
| 2002 | 78 | 63.8 \pm 1.8 | 45 - 84 | 1,608 \pm 133 | 737-3,685 |
| 2003 | 73 | 63.0 \pm 1.5 | 50 - 79 | 1,601 \pm 105 | 680-3,175 |
| 2004 | 47 | 64.6 \pm 2.3 | 51 - 98 | 1,781 \pm 281 | 737-6,690 |
| 2005 | 55 | 66.1 \pm 1.9 | 53 - 84 | 1,944 \pm 187 | 1020-4,365 |
| 2006 | 64 | 65.9 \pm 1.8 | 46 - 86 | 1,685 \pm 142 | 963-3,628 |
| 2007 | 60 | 66.8 \pm 1.6 | 52 - 88 | 1,684 \pm 117 | 822-3,912 |
| 2008 | 55 | 64.2 \pm 1.9 | 51.5 - 87 | 1,569 \pm 145 | 878-3,515 |
| 2009 | 50 | 64.4 \pm 2.3 | 41.5 - 89 | 1,564 \pm 187 | 652-4,309 |
| 2010* | 16 | 60.9 \pm 4.1 | 46 - 76 | 1,392 \pm 277 | 963-2,948 |
| 2011* | 56 | 64.6 \pm 2.5 | 53 - 106 | 1,595 \pm 235 | 510-6,151 |
| 2012 | 51 | 60.3 \pm 1.5 | 47 - 72 | 1,305 \pm 75 | 680-1,899 |
| 2013 | 22 | 62.2 \pm 2.2 | 55 - 75 | 1,305 \pm 191 | 822 - 2,410 |
| 2014 | 20 | 62.6 \pm 4.5 | 51 - 92 | 1,435 \pm 323 | 709 - 3,742 |
| 2015 | 22 | 63.5 \pm 3.7 | 50 - 80 | 1,575 \pm 306 | 680 - 3,515 |
| 2016 | 19 | 61.6 \pm 3.0 | 46 - 72 | 1,450 \pm 175 | 907 - 2,098 |
| 2017 | 49 | 67.9 \pm 2.4 | 50 - 94 | 1,830 \pm 247 | 680 - 5,330 |
| 2018 | 62 | 65.0 \pm 2.0 | 49 - 92 | 1,650 \pm 213 | 567 - 5,443 |
| 2019 | 35 | 66.2 \pm 3.5 | 49 - 96 | 1,718 \pm 279 | 482 - 4,536 |

* 2010 data January to March only; 2011 data April to December only.

APPENDIX 3. Relationship between mean relative condition (K_n) of Bull Trout and Upper Arrow Lakes Reservoir index stream Kokanee spawner estimates. Year 2012 was not used for the regression because a large proportion of age-3 Kokanee delayed spawning (see Arndt 2014b). This graph is shown in addition to Figure 10 because in most years the majority of Bull Trout samples come from the Upper Arrow creel sites (Shelter Bay and Nakusp).



APPENDIX 4. Relationship between mean relative condition (K_n) of Bull Trout and mean fork length of Hill Creek Kokanee spawners (top). Lower graph compares Kokanee spawner size to the residuals from a regression using the number of index spawners to predict K_n (see Fig. 22 in Arndt and Schwarz 2011). After accounting for spawner abundance (line at 0), K_n tends to be highest when average Kokanee spawner size is between 23 and 25 cm.

