ARROW LAKES RESERVOIR

ANGLER CREEL SURVEY 2018

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BRITISH COLUMBIA
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Executive Summary

Access point angler surveys have been conducted 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 19 years after the beginning of a large scale nutrient program in 1999. Sampling covers 5 days/month at three sites, and site-specific estimates are expanded to the whole reservoir using overflight boat counts. This report summarizes 2018 (calendar year) results, as part of the monitoring for FWCP Large Lakes Action Plan objectives 1 (*Ensure a productive and diverse aquatic ecosystem)* and 3 (O*ptimize recreational angling opportunities, participation and local benefits* (FWCP 2012; Appendix 7 lists sub-objectives).

Total angling effort for ALR in 2018 was estimated at 12,100 angler days, or 59,400 rod-hours. This level of effort is a slight increase from 2015-2017 (the lowest years on record), but still below 2001-2014. Estimated catch of Bull Trout, Rainbow Trout, Kokanee, and Burbot combined (including released fish) was 11,810 fish; of these 7,620 were retained for a harvested weight of 7.5 tonnes. Annual expenditures based on daily values from a federal angler survey were about $0.78 million for spending wholly attributable to the fishery, or $2.8 million including major purchases partly attributable to the fishery. Residents of British Columbia comprised 92% of interviewed anglers.

Bull Trout catch in 2018 was estimated as 3,300 fish, of which 52% were retained for a weight harvest of 4,600 kg. Catch rate (CPUE) for anglers targeting Bull Trout was 0.08 fish/rod hour. Rainbow Trout catch was 3,100 fish, of which 56% were retained for a weight harvest of 1,600 kg; CPUE was 0.05 fish/rod hour. No hatchery clipped Rainbow Trout were recorded. Kokanee catch was 4,760 fish of which 70% were kept for a harvest of 300 kg; CPUE was 0.53 fish/rod hour. The average weight of harvested Kokanee (92 g) in 2018 was the smallest since records began in 1998. Burbot catch was 700 fish, of which 89% were kept for a harvest of 1,000 kg; CPUE was 0.44 fish/rod hour. The 2018 harvest of Bull Trout increased over 2014-2017 to a level closer to earlier in the nutrient program, and their average size was the largest in the time series; however, the number and average size of piscivorous Rainbow Trout declined in 2018, and Kokanee harvest remained low. Overall, the 2018 harvests showed an improvement for Bull Trout, decline for piscivorous Rainbow Trout, and were similar to 2017 for Kokanee and Burbot.

Relative condition factor (K_n) of Bull Trout showed a strong increase in 2017 after four consecutive years of remaining near the pre-nutrient addition level; in 2018 it declined slightly from the 2017 average, as expected given a decline in Kokanee spawning escapement. Condition of piscivorous Rainbow Trout was stable although sample size was very low. The decline in K_n and decrease in piscivorous Rainbow harvest coincide with a weaker spawning escapement of Kokanee in 2018. Preliminary results of predator diet sampling are included in Appendix 6.

Acknowledgements

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- Arrow Lakes Power Corporation. Arrow Lakes Power Corporation is jointly owned, on a 50/50 basis, by Columbia Power and Columbia Basin Trust (CBT) Arrow Lakes Power Development Corporation (an indirect subsidiary of CBT).

Field data were collected by:

- Carlos Berger, Carmen Berger, Deb Imeson, Kayla Keraiff, Delaney Marken, 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.

Dr. Carl Schwarz (Simon Fraser University) kindly computed estimates of angler effort, catch and harvest for the three main access sites (Shelter Bay, Nakusp, Castlegar) and the overflight-expanded estimates for the whole reservoir. Thanks to Jeff Burrows (MFLNRORD), Crystal Klym (FWCP) and Eva Schindler (MFLNRORD) for providing comments on a draft version.

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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 about 29,000 hectares in early October (late growing season), although 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 an enhanced substrate for Kokanee spawning, and Rainbow Trout spawning and juvenile rearing, 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 (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 zooplankton production and higher Kokanee production that will in turn support growth and survival of Bull Trout and piscivorous Rainbow Trout in the reservoir. Productive fish stocks are expected to benefit angling and bring economic benefits to local communities and the province in accordance with the FWCP Large Lakes Action Plan Objective 3: O*ptimize recreational angling opportunities, participation and local benefits* (FWCP 2012).

Creel surveys have been conducted annually at selected access locations since 1976. They provide essential information for evaluation and monitoring of the actions listed under Objectives 1 and 3 of the FWCP plan, and the status indicators for Bull trout, piscivorous Rainbow Trout, Kokanee, and Burbot.[4] Specific objectives of the angler survey 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 fishery, and a measure of the contribution of fin-

[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. Current ALR Kokanee objectives are listed in FWCP (2012); the interim fry production target for 2017 was 3.8 million. Fry production from the spawning channel has ranged from 114,000 to 20 million between 1999-2016 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). There is also annual variation of P inputs from tributaries.

[4] These include status indicators 13-15,20-22, 26-29, and 33-35 (FWCP 2012; Appendix 7).

clipped Rainbow Trout released into the reservoir from 2005 to 2010.[5] This report summarizes results for the 2018 calendar year. Multi-year analyses with greater detail are provided in Arndt and Schwarz (2011) and Arndt (2014a); previous results are provided in Sebastian et al. 2000, Arndt 2002, 2004a, Arndt 2014b, Arndt 2015, Arndt 2016, Arndt 2017, Arndt 2018).

Preliminary results of ongoing Bull Trout and piscivorous Rainbow Trout diet sampling are also included in Appendix 6 of this report.

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. Angler effort, catch and harvest estimates were computed specifically for the three access locations, and expanded to the whole reservoir using overflight boat counts following methods detailed in Arndt and Schwarz (2011) and Beliveau et al. (2015). No flights were conducted in 2018, so expansion factors were based on the ratio of total active/interviewed boats in previous years using the time proportional method described in Arndt (2014a). 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).

Relative condition factor (K_n) of Bull Trout and piscivorous Rainbow Trout were 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).

[5] Hatchery fish were released by the Freshwater Fisheries Society of British Columbia in cooperation with the Ministry of Forests, Lands and Natural Resource Operations. 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 1,187 anglers from 584 angling parties[6] (including repeat contacts) were interviewed at the three major access locations in 2018 (Table 1). Residents of BC comprised 92% of the anglers, with non-resident Canadians (primarily from Alberta) making up the remainder. Nakusp and Shelter Bay had a higher percentage of anglers from outside the province than Castlegar. Residency percentages for 2018 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, 20% of interviewed parties in 2018 had 5 or less years of fishing experience on ALR, 33% from 6-20 years, and 47% over 20 years. The percentage with over 20 years of experience has increased from 32% in 2014 (Arndt 2015) with corresponding reductions in anglers with ≤ 5 years of experience. Among the three sites, Shelter Bay had the lowest proportion with ≤ 5 years and the highest with over 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; in many cases, there are less experienced anglers in the party. However, the trend to more experienced anglers means that decreases in catch rates over this period cannot be attributed to reduced fishing efficiency.

Table 1. Number of anglers sampled and residence category percentages for three main access locations in the Arrow Lakes Reservoir creel survey in 2018.

Year	Location	No. Anglers Sampled	Resident (%)	Non-Resident Canadian (%)	Non-Canadian (%)
2018	Shelter Bay	354	88.7	11.3	0.0
	Nakusp	394	88.2	11.8	0.0
	Castlegar	439	97.7	2.3	0.0
	All Sites	1,187	91.9	8.1	0.0

[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.

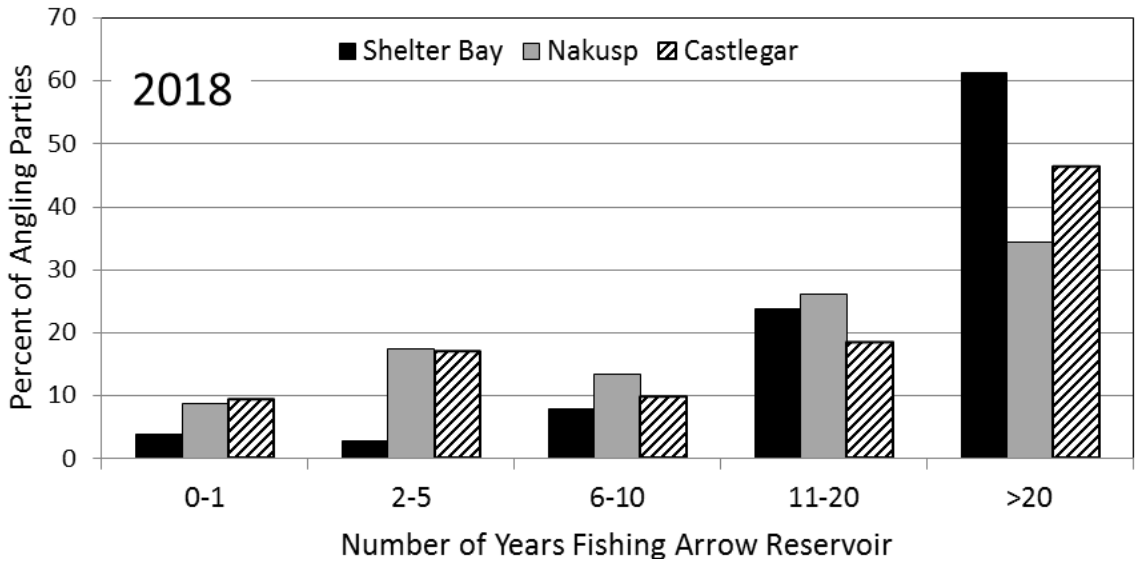

Figure 1. Percentage of interviewed angling parties by fishing experience category (years of experience fishing Arrow Reservoir for the most experienced party member) for three main sampled locations on Arrow Lakes Reservoir in 2018.

3.2 Species Targeted and Caught by Location

Species targeted for the three sampled locations (pooled) are listed in Table 2. About 85% of the 2018 effort was targeting Bull Trout and/or Rainbow Trout, with only 10% targeting Kokanee, or Kokanee and other species. Burbot remained the smallest component of the fishery, detected only at the Nakusp access.

Catch at each sampled location differed by species and month (Figure 2). Shelter Bay was primarily a Bull Trout and Rainbow Trout fishery with no sampled Kokanee harvest in 2018. Nakusp had the most diverse fishery including the four main species. Lower Arrow catch at Castlegar was dominated by Kokanee and Rainbow in warmer months and by smaller numbers of Bull Trout and Rainbow Trout during cooler months.

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 2014 to 2018.

	Angler-days					Rod-hours				
Species Sought	**2014**	**2015**	**2016**	**2017**	**2018**	**2014**	**2015**	**2016**	**2017**	**2018**
Bull or Rainbow Trout	54.2	52.7	66.8	60.6	64.7	58.4	56.6	66.8	64.0	69.2
Bull trout only	2.1	2.2	4.2	5.7	7.5	2.1	2.6	4.2	7.2	8.3
Rainbow trout only	6.2	11.8	5.3	6.6	8.5	5.2	11.2	5.6	6.0	7.9
Kokanee or Rainbow	11.5	12.8	6.0	10.4	6.4	10.7	11.7	5.5	7.6	4.5
Kokanee only	10.7	10.4	5.2	3.4	7.2	8.7	8.6	4.6	3.1	5.2
Burbot	0.6	1.5	1.1	1.3	2.4	0.5	1.5	1.0	1.0	1.9
Kokanee or Bull trout	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.3
Anything[1]	14.7	8.6	11.5	11.5	2.9	14.4	7.8	12.3	10.5	2.8

[1] includes anglers listing 3 or more targeted species

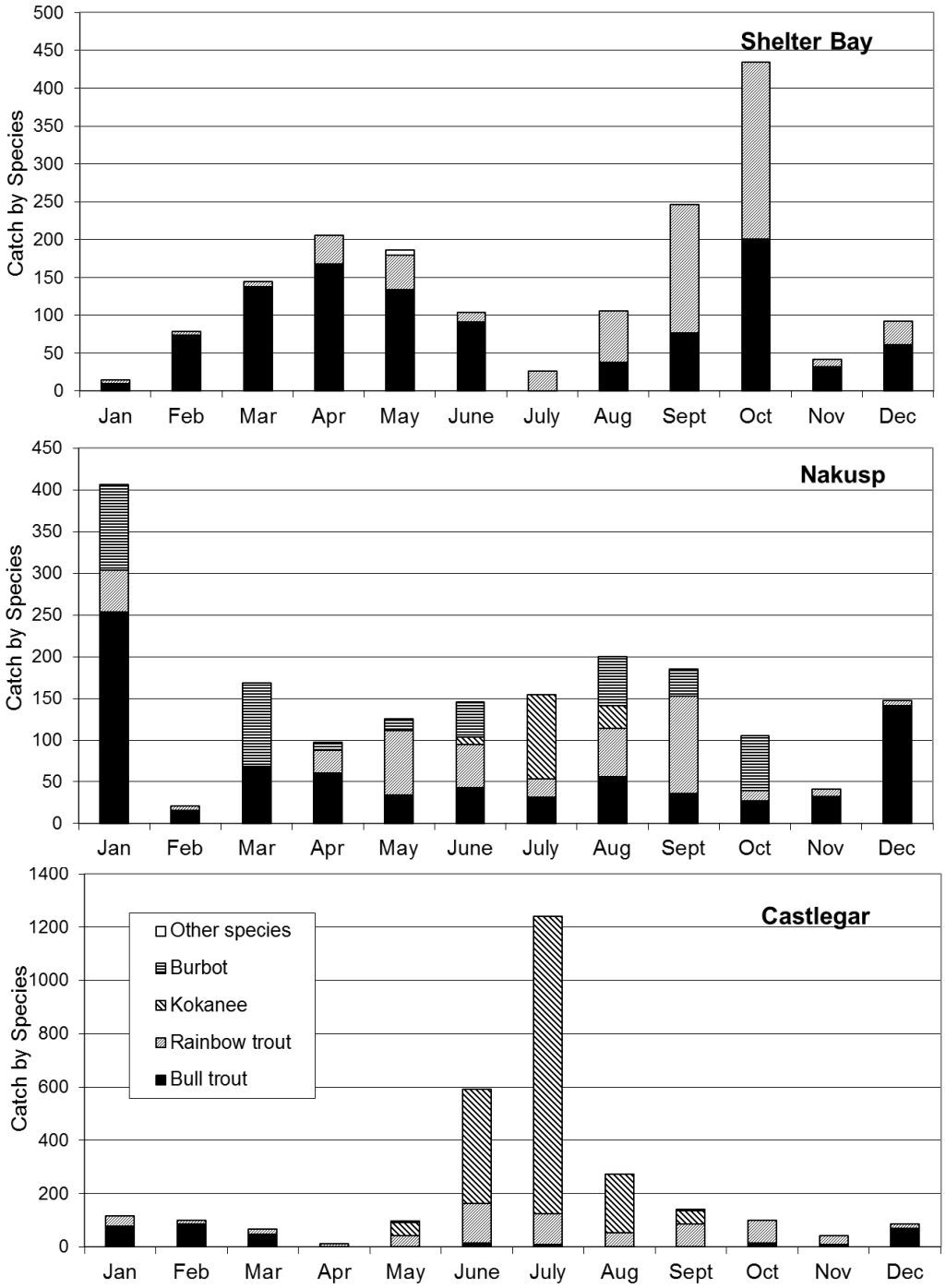

Figure 2. Monthly catch estimates (including released fish) by species at three access locations on Arrow Lakes Reservoir in 2018. Note differences in the Y-axes.

3.3 Angling Effort and Potential Expenditures

Total angling effort (95% confidence limits) estimated for the whole reservoir in 2018 was 12,100 (2,300) angler-days, 57,700 (11,400) angler-hours, and 59,400 (11,400) rod-hours (Apendix 2a). This is an increase from 2017 to about 80% of the 2014 effort (15,200 angler-days, 71,700 angler-hours, 74,600 rod-hours). Although this is still low relative to 2014 and earlier, the increase is somewhat surprising given the fact that smoke from forest fires was quite dense in late August and September, and the Lower Arrow area was on fire evacuation notice for about one month. The fire situation clearly reduced fishing in the Lower Arrow, and probably reduced effort in Nakusp and Shelter Bay due to smoke. Site-specific trends since 1987 are shown in Figure 3.

When average spending per angler-day (Fisheries and Oceans Canada 2012) is applied to the angler-day estimates above, annual spending on the ALR fishery projects to $0.78 million for direct expenditures (transportation, food, lodging, fishing services and equipment) and $1.8 to $2.8 million including major purchases wholly or partially attributable to fishing (fishing, boating and camping equipment, vehicles, land, buildings).[7]

3.4 Catch, Harvest and Fish Size

Whole reservoir catch estimates varied by species with a total harvest of 7,620 fish weighing 7.5 tonnes in 2018. Numerically the harvest was dominated by Kokanee, but by weight Bull Trout comprised the largest component. Catch rate (CPUE) ranged from a low of 0.05 fish/h for Rainbow Trout to 0.53 fish/h for anglers seeking Kokanee. Note that Rainbow Trout CPUE combines rod-hours of anglers targeting piscivorous Rainbow Trout with those targeting the smaller ecotype. (Table 3)

Table 3. Catch and harvest estimates (± 95% confidence limits), and catch per unit effort (CPUE) for the recreational fishery in Arrow Lakes Reservoir in 2018.

Species	Number Caught[1]	Number Kept[1]	% Kept[2]	Harvest[3] (kg)	CPUE[4] (fish/h)
Bull Trout	3,300 (890)	1,780 (400)	52	4,630	0.076
Rainbow Trout	3,070 (740)	1,880 (610)	56	1,590	0.053
Kokanee	4,760 (2,360)	3,350 (1,660)	70	310	0.526
Burbot	680 (360)	610 (320)	89	1,010	0.435
Total	11,810	7,620	-	7,540	-

[1] Estimates are expanded to the whole reservoir using overflight boat counts, so are higher than the sum of the three locations in Figures 4, 8, 13, 16.
[2] Computed from three sampled locations raw data.
[3] Number kept x mean weight of sampled fish.
[4] Based on angling parties that report targeting the species; three sampled locations pooled.

[7] Values are $64.79/angler-day for directly attributable expenditures, $149.96/angler-day including wholly attributable major purchases, and $228.95/angler-day including wholly or partially attributable major purchases [derived from The Survey of Recreational Fishing in Canada 2010 (Fisheries and Oceans Canada 2012; Annexes A.6, 9, 10, 11)]. Results of the 2015 survey were not yet posted at the writing this report.

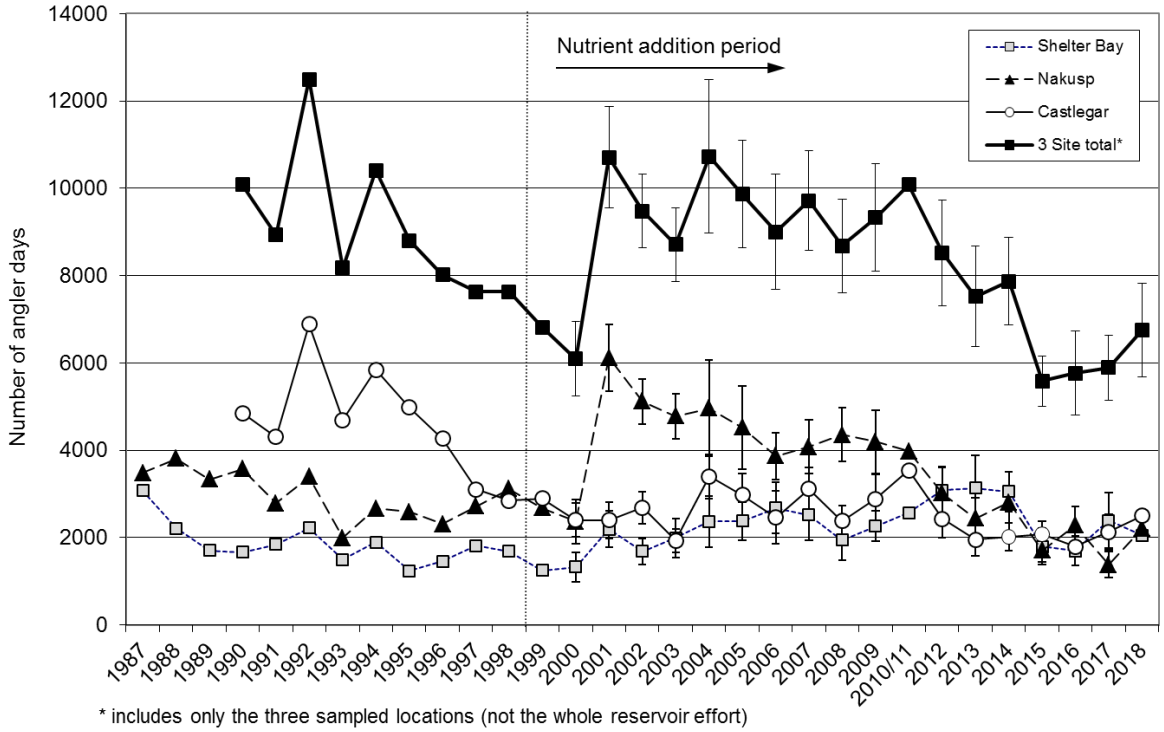

Figure 3. Trends in annual angler days at three sampled access locations on Arrow Lakes Reservoir from 1987 to 2018. Bars indicate 95% confidence limits around estimates since 2000. January to March 2010 are pooled with April to December 2011 for the 2010/11 total. Castlegar records for 1987-1989 are not available. Data prior to 1987 are summarized in Appendix 5.

3.4.1 Bull Trout

Whole reservoir estimates of Bull Trout catch in 2018 increased to 3,300 fish, and the harvest number increased to almost 1,800 (Table 4; Figure 4a). This level of harvest is a 50% increase over the last three years, and is within the range of harvests between 2001 and 2013. Rod-hours of effort doubled at Nakusp, and remained similar to 2017 at Castlegar and Shelter Bay (Figure 4b). Catch rate (CPUE) was highest at Shelter Bay (Figure 4c), but anglers from this site continued to release most of their Bull Trout catch (Figure 5). This may be a reflection of the higher proportion of experienced anglers (B. Barney, creel technician, pers. comm.; Figure 1) that target larger fish, although it could also be an indication of a higher proportion of small bull trout in the Shelter Bay vicinity. The average size of harvested Bull Trout was largest at Castlegar where the release rate was lowest (3.4 kg, compared to about 2.2 and 2.6 kg at Nakusp and Shelter Bay).

The average size of harvested Bull Trout in 2018 (60 cm and 2.6 kg) was the largest in the time series that starts in 1998 (Appendix 3a). Length ranged from 36 - 84 cm, with the frequency distribution suggesting good recruitment of younger fish into the fishery, following the pattern in 2017 (Figure 6). The highest recorded weight was 8.3 kg (Appendix 3a); this is the first time a Bull Trout over 7 kg has been sampled since 2012. The number of sampled Bull Trout over 2.0 kg also increased by about 50% over last year (Figure 7).

Table 4. Number of Bull Trout caught, retained for harvest, and catch rate (fish/rod-hour) from Arrow Lakes Reservoir from 2004 to 2018.

Bull Trout	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010/11**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Catch[1]	3,630	3,600	3,860	3,220	2,830	3,120	3,960	4,240	4,260	2,590	1,530	2,340	3,090	3,300
Harvest[1]	2,140	2,070	1,970	1,980	1,550	1,780	2,060	1,850	1,820	1,050	730	1,270	1,190	1,780
CPUE	0.065	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

[1] Estimates are expanded to whole reservoir using overflight boat counts, so are greater than the sum of the three locations in Figure 4.

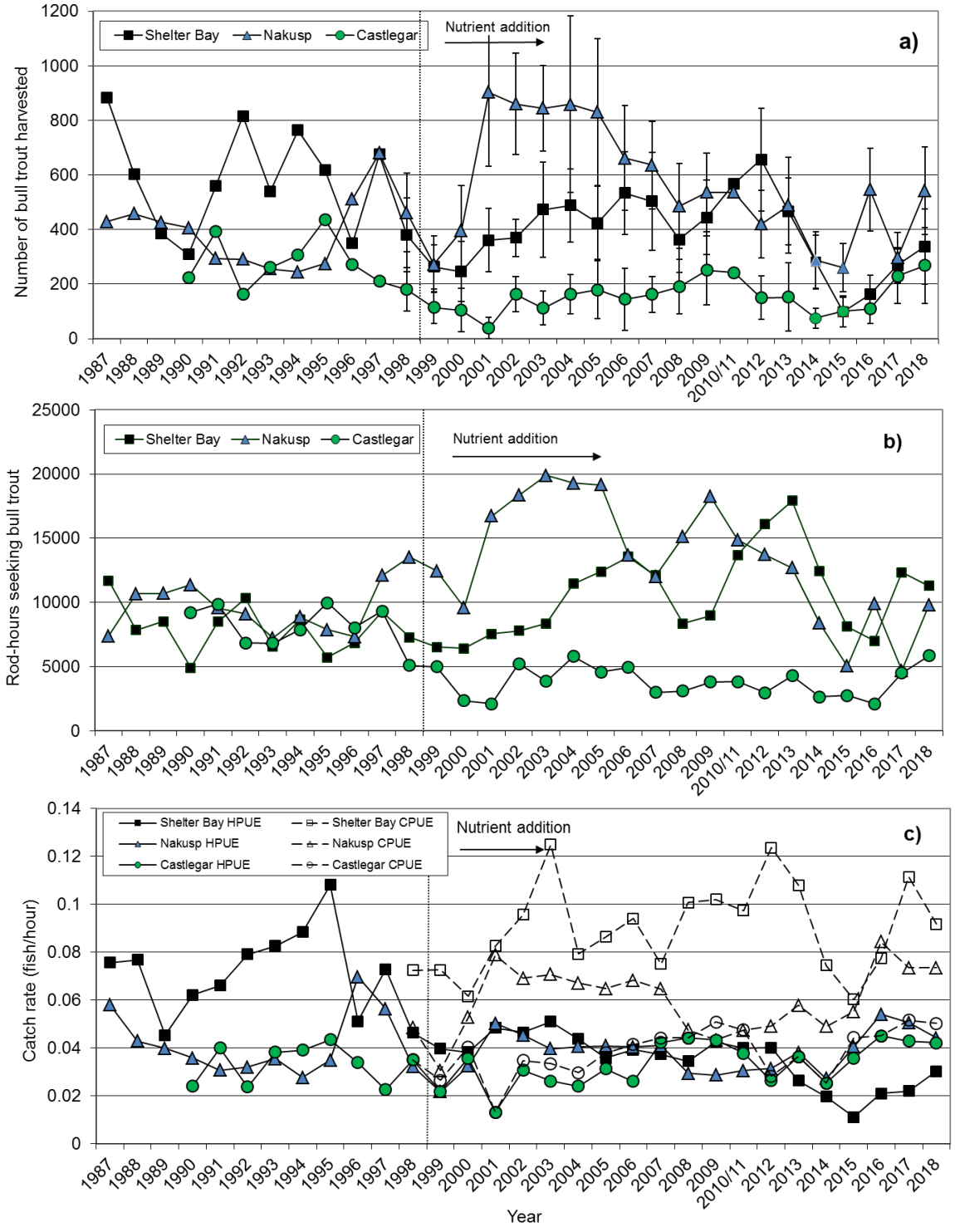

Figure 4. Trends in (a) harvested number, (b) targeted rod-hours, and (c) catch rate of Bull Trout from three access locations on Arrow Lakes Reservoir from 1987 – 2018. Brackets around harvest estimates after 1998 indicate 95% confidence limits. Catch rate after 1998 is shown for both harvested fish (HPUE) and for harvested and released fish combined (CPUE). January to March 2010 is pooled with April to December 2011 to obtain a 12 month period. Castlegar data are not available before 1990.

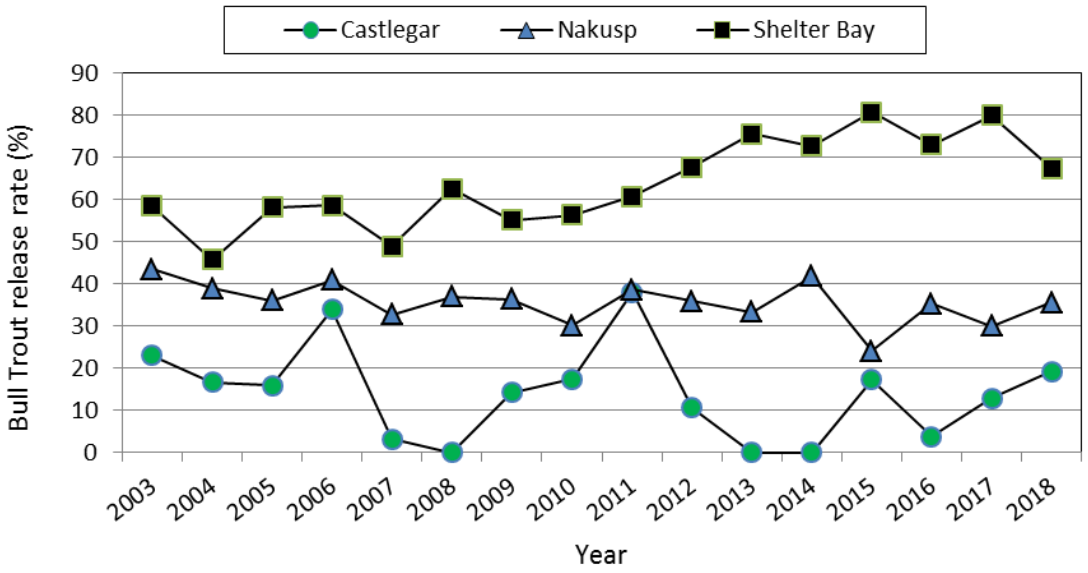

Figure 5. Percentage of Bull Trout released by anglers at three locations in Arrow Lakes Reservoir.

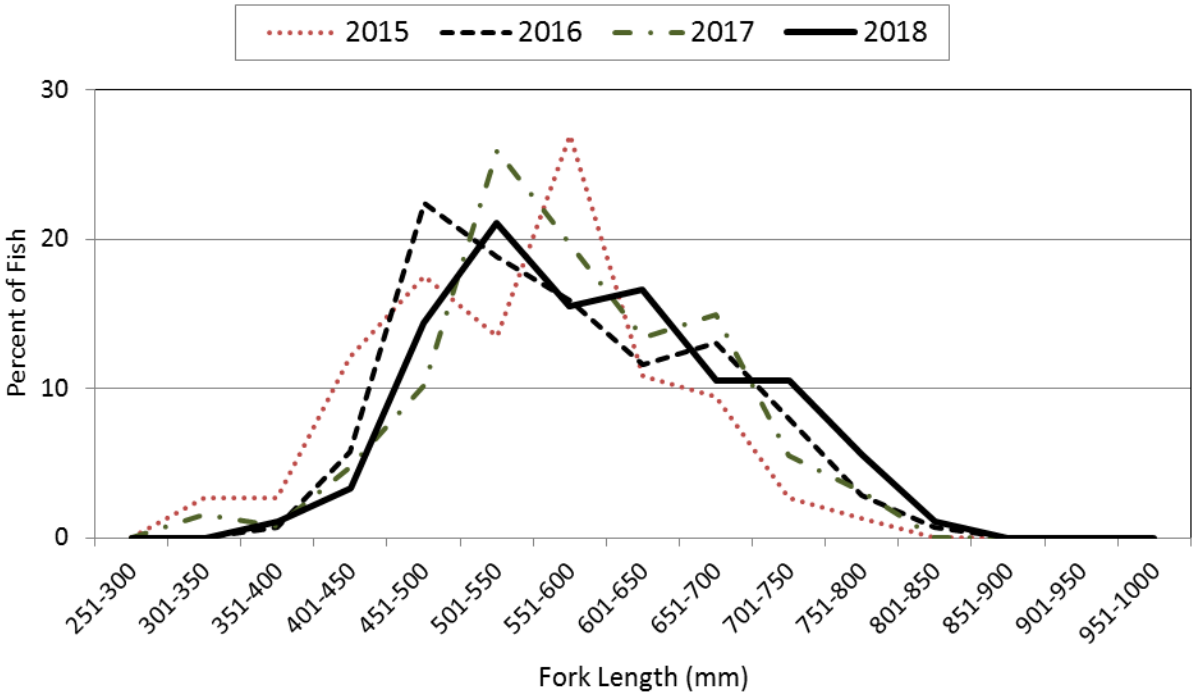

Figure 6. Length frequency distribution of angled Bull Trout from Arrow Lakes Reservoir from 2015 to 2018.

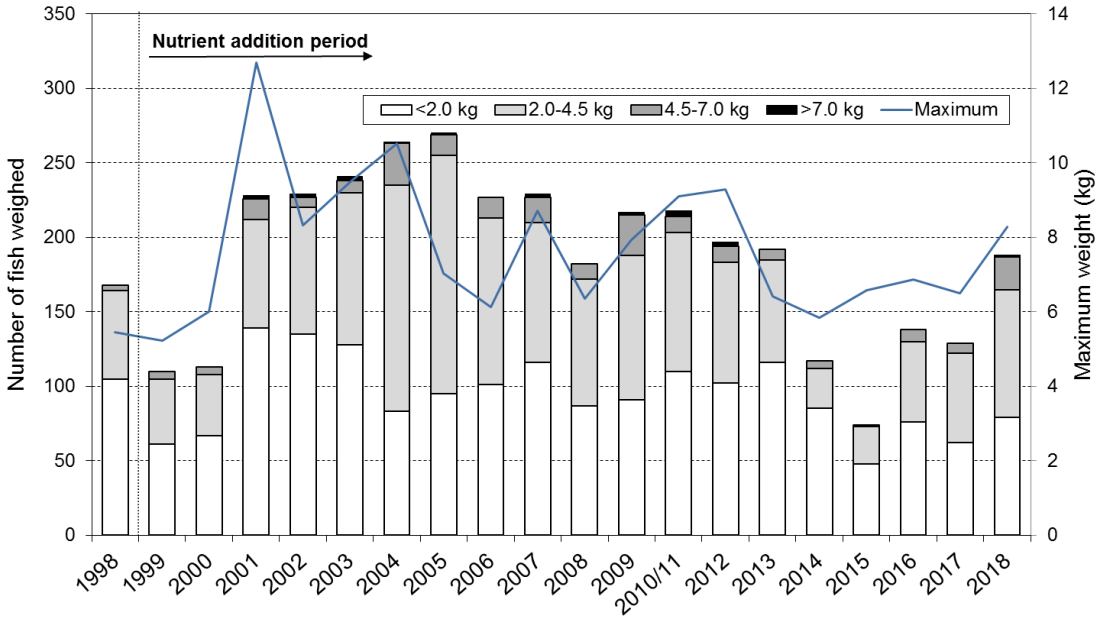

Figure 7. Number of weighed Bull Trout by size category sampled at three access locations in Arrow Lakes Reservoir from 1998 to 2018. Data from January to March 2010 are pooled with April to December 2011 because the 2010/11 fiscal year was not sampled.

3.4.2 Rainbow Trout

The 2018 catch estimate for Rainbow Trout (insectivorous and piscivorous ecotypes combined) of 3,070 declined from the two previous years, however the harvest of 1,880 increased (Table 5; Figure 8a). Rod-hours seeking Rainbow Trout have been relatively stable at Castlegar, but remained low compared to past years at Nakusp and Shelter Bay (Figure 8b). Average catch rate (CPUE) for Rainbows was the lowest observed since 1998 at 0.53 fish/hr (Table 5; Figure 8c). The percentage of released Rainbow Trout was about 70% at Shelter Bay, and remained near 30% at the other two sites (Figure 9). The high release rate at Shelter Bay appears to be a result of anglers selecting for larger fish, since average size of retained fish at that site (2.2 kg) is about twice as large as Nakusp and Castlegar (0.8 and 0.9 kg, respectively). No hatchery clipped Rainbow Trout were sampled in 2018.

Table 5. Number of Rainbow Trout caught and retained, and catch rate (fish/rod-hour) from Arrow Lakes Reservoir from 2004 to 2018.

	2004	2005	2006	2007	2008	2009	2010/11	2012	2013	2014	2015	2016	2017	2018
Catch[1]	6,580	5,400	5,990	5,940	4,950	3,330	7,530	4,410	4,540	5,090	2,420	3,310	3,820	3,070
Harvest[1]	4,300	3,410	4,020	4,150	3,610	4,730	5,200	2,420	2,270	2,750	1,270	1,940	1,700	1,880
CPUE	0.064	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

[1] Estimates are expanded to whole reservoir using overflight boat counts, so are greater than the sum of the three locations in Figure 8.

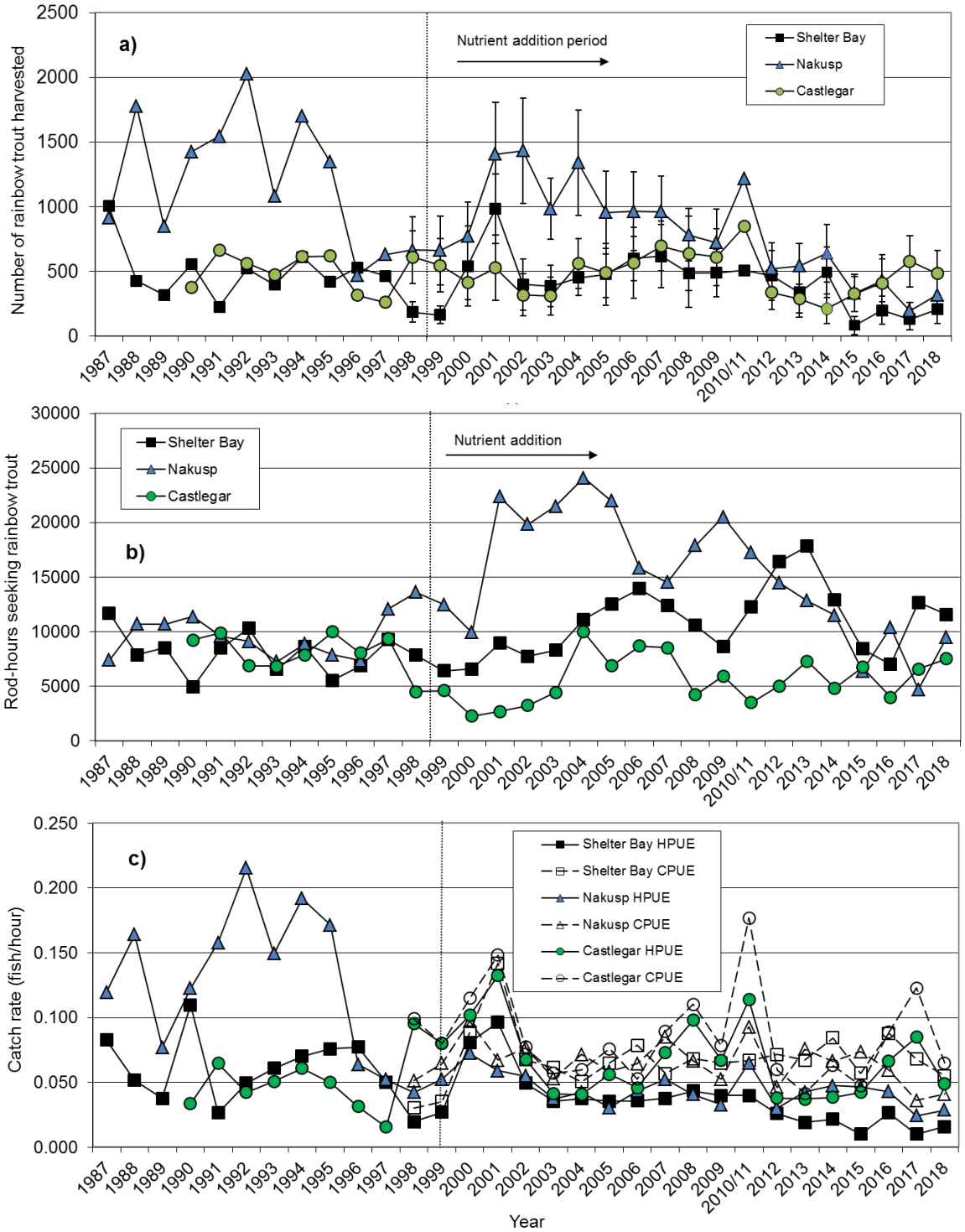

Figure 8. Trends in (a) harvested number, (b) targeted rod-hours, and (c) catch rate of Rainbow Trout from three locations in Arrow Lakes Reservoir from 1987 – 2018. Brackets around harvest estimates after 1998 indicate 95% confidence limits. Catch rate after 1998 is shown for both harvested fish (HPUE) and for harvested and released fish combined (CPUE). January to March 2010 is pooled with April to December 2011 to obtain a 12 month period. Castlegar records are not available for 1987-1989.

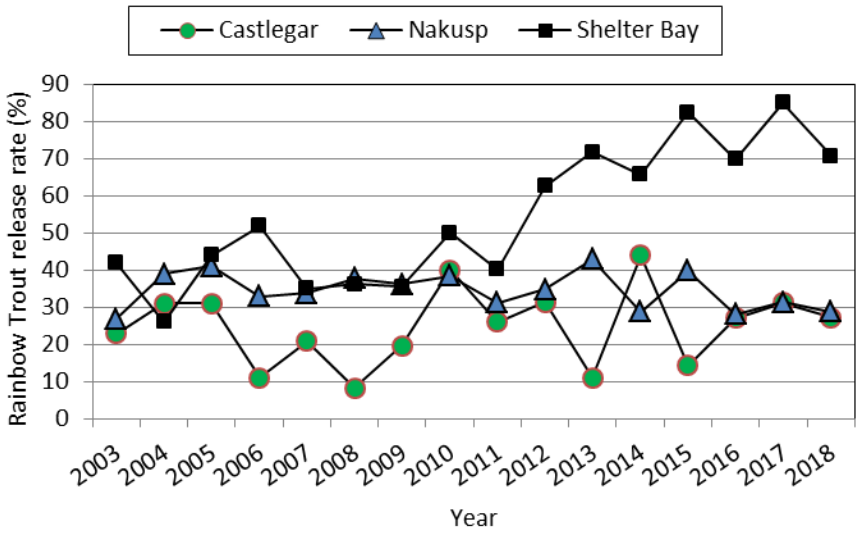

Figure 9. Percentage of Rainbow Trout released by anglers at three locations in Arrow Lakes Reservoir.

Length distribution of harvested Rainbow trout in 2018 was similar to 2015 and 2016 (Figure 10). Although the modal length of smaller Rainbows was greater than 2017, the average weight declined from 1.1 to 0.85 kg because there were fewer sampled piscivorous fish ≥ 50 cm (Figures 11). Only 11 Rainbow Trout over 2 kg were sampled in 2018 compared to 29 in 2017 (Figure 12). The largest recorded weight decreased slightly to 6.25 kg, although there were anecdotal reports of fish up to 9 kg (20 lb) on non-creel days.

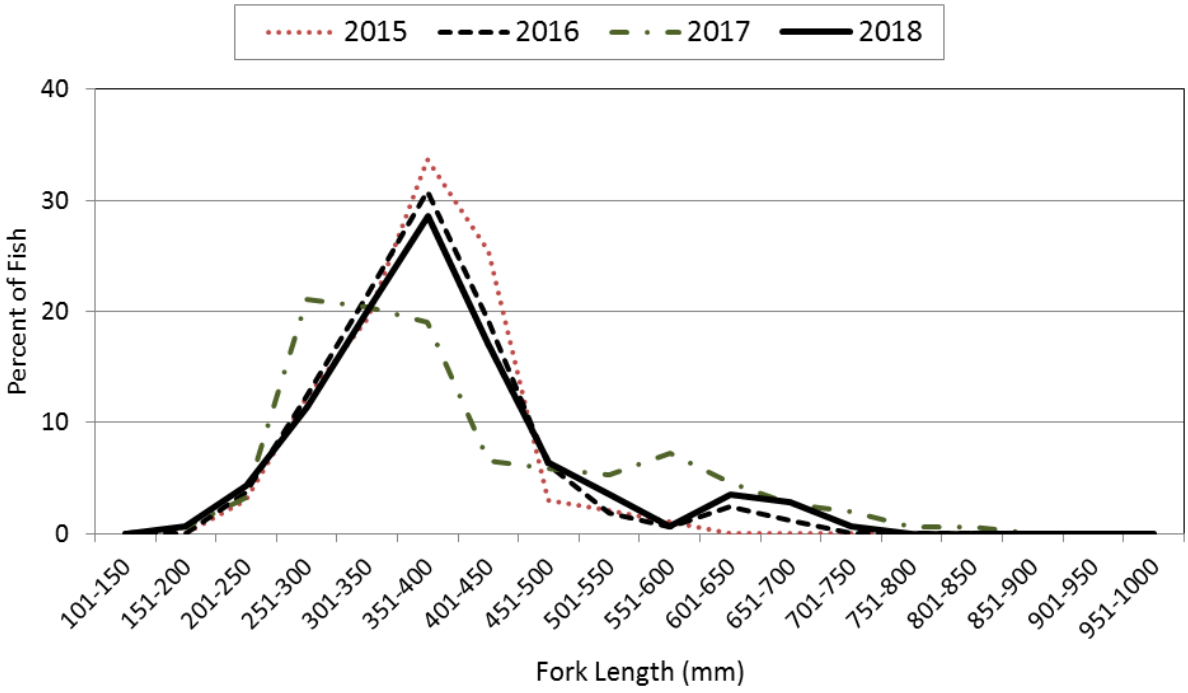

Figure 10. Length frequency of Rainbow Trout angled from Arrow Lakes Reservoir from 2015 to 2018.

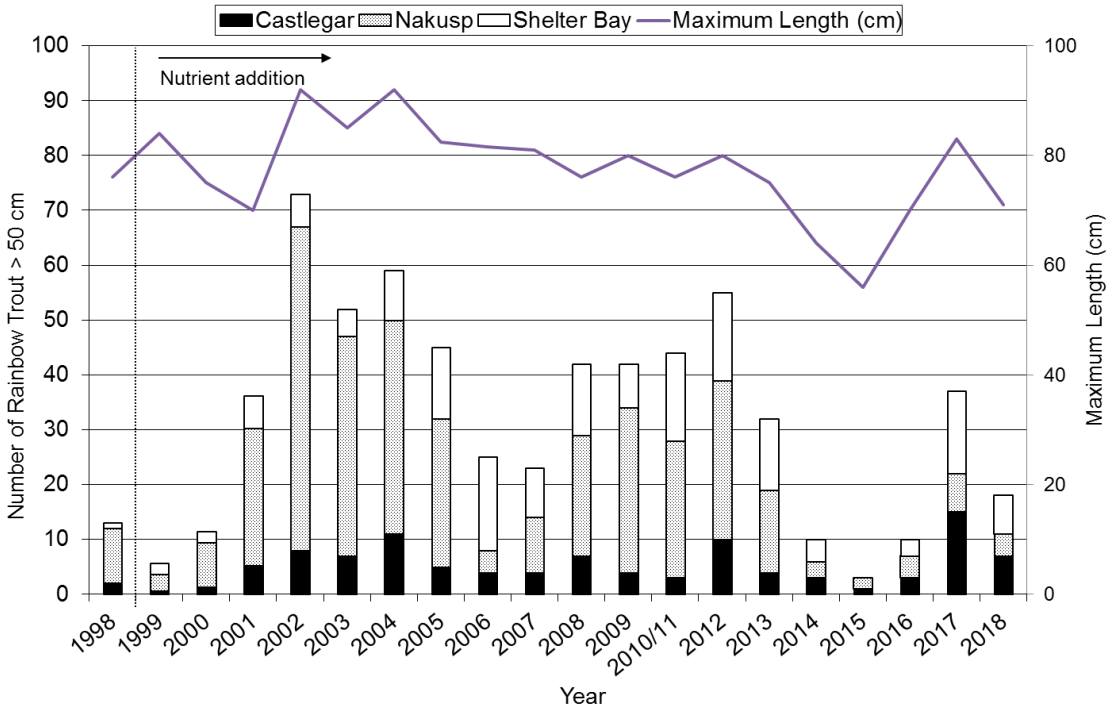

Figure 11. Number of Rainbow Trout ≥ 50 cm and maximum sampled length at three access locations in Arrow Lakes Reservoir from 1998 to 2018. January to March 2010 is pooled with April to December 2011. Castlegar values for 1999-2001 (data not available) were estimated as the average proportion of the total from the three following years.

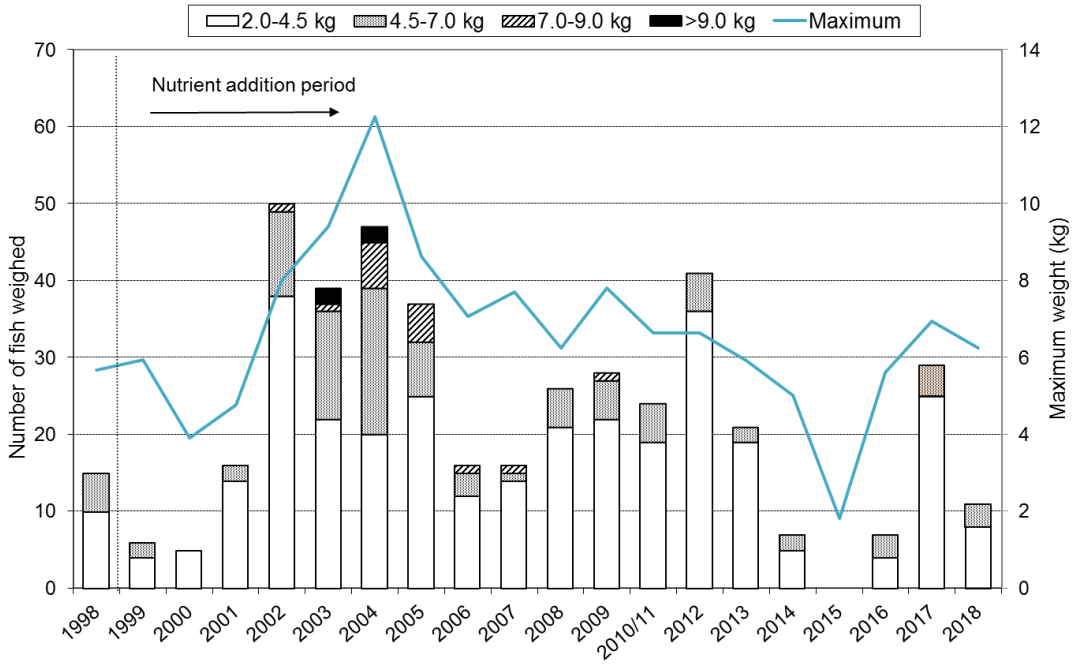

Figure 12. Number of sampled Rainbow Trout over 2 kg by size category at three access locations in Arrow Lakes Reservoir from 1998 to 2018. January to March 2010 was pooled with April to December 2011.

3.4.3 Kokanee

Kokanee catch in 2018 remained relatively low (similar to the last six years), and harvest decreased slightly (Table 6). Recent harvests have been a small fraction of those in the 1980s and 1990s (when Castlegar harvests alone ranged from 16,000 – 35,000 Kokanee), and are even well below years near the beginning of the nutrient program (Figure 13a). The long term harvest decrease reflects declines in both CPUE and rod-hours of effort (Figure 13b,c). Low Kokanee effort in turn appears to be strongly influenced by the small size of Kokanee (Figure 14). Average CPUE for the year was the highest observed since 2004 (Table 6), but was countered by the small size. An increase in average size from 20 to 24 cm would be expected to double the Kokanee angler-days in an average year.

Average size of Kokanee in 2018 (20 cm, 92 g) was the smallest on record, similar to the last two years (Appendix 3c); the length distribution was unimodal (Figure 15). Scale ages of angled Kokanee were not available at the time of writing, however, spawning Kokanee from nearby Deer Creek in September averaged only 22.3 cm and were a mix of age 2+ (60%) and 3+ fish (40%; MFLNRORD file data). Therefore it is likely that harvested fish (taken mostly before the spawning season) were comprised of both age-2+ and 3+ age classes.

Table 6. Number of Kokanee caught and retained, and catch rate (fish/rod-hour) from Arrow Lakes Reservoir from 2004 to 2018.

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010/11**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Catch[1]	15,650	11,540	3,250	11,980	5,870	8,250	7,930	3,220	2,640	6,920	4,390	5,620	4,600	4,760
Harvest[1]	9,040	7,070	2,410	9,260	4,990	6,070	5,670	2,200	2,300	5,790	3,110	3,700	3,660	3,350
CPUE	0.558	0.476	0.135	0.375	0.243	0.391	0.474	0.296	0.254	0.288	0.310	0.518	0.391	0.526

[1] Estimates are expanded to whole reservoir using overflight boat counts, so are greater than the sum of the three locations in Figure 13.

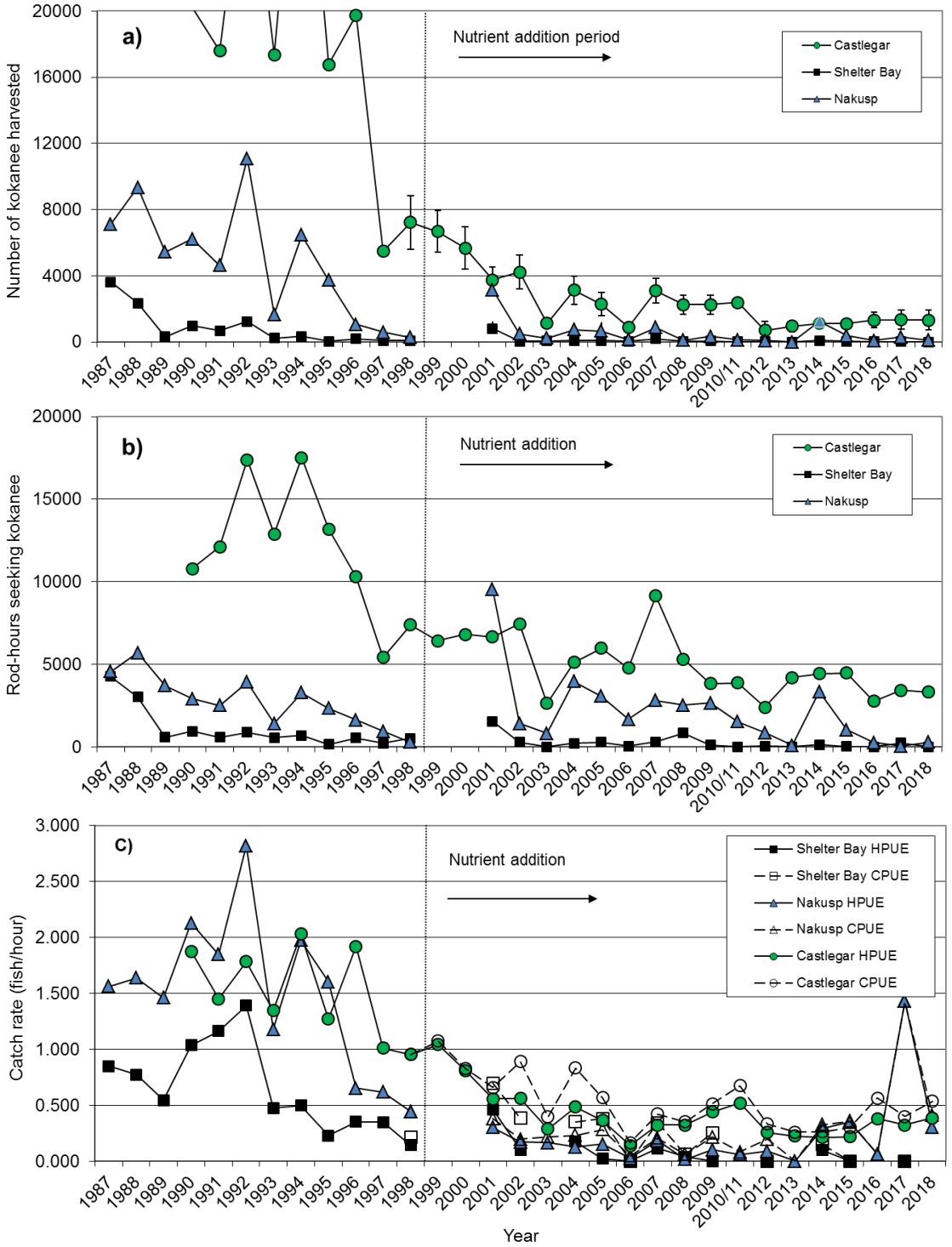

Figure 13. Trends in (a) harvested number, (b) targeted rod-hours, and (c) catch rate of Kokanee from three access locations in Arrow Lakes Reservoir from 1987 – 2018. Brackets around harvest estimates after 1998 are 95% confidence limits. Catch rate after 1998 is shown for both harvested fish (HPUE) and for harvested and released fish combined (CPUE). January to March 2010 is pooled with April to December 2011 to obtain a 12 month period. Castlegar records are not available for 1987-1989. *Only one fishing party reported targeting Kokanee from Nakusp in 2017.*

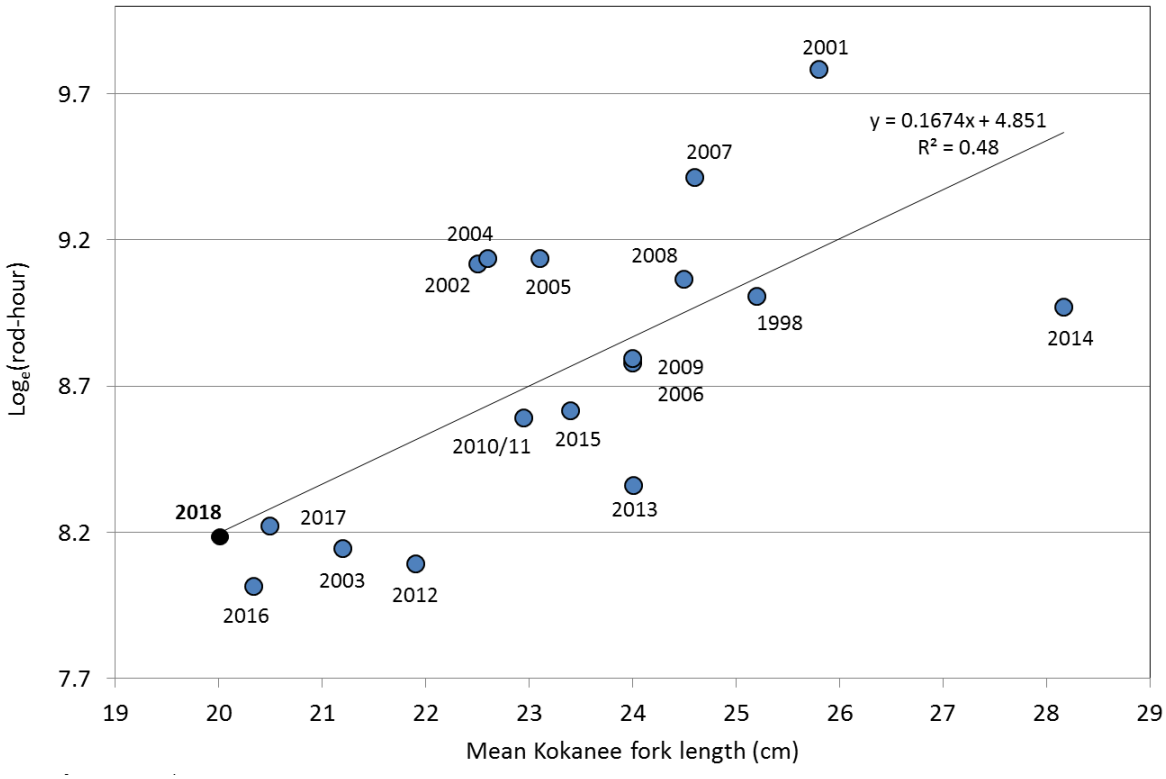

Figure 14. Relationship between the amount of kokanee-targeted effort (Castlegar, Nakusp and Shelter Bay pooled) and mean length of harvested kokanee in Arrow Lakes Reservoir from 1998 to 2018. January to March 2010 are pooled with April to Dec 2011 to obtain a 12 month period.

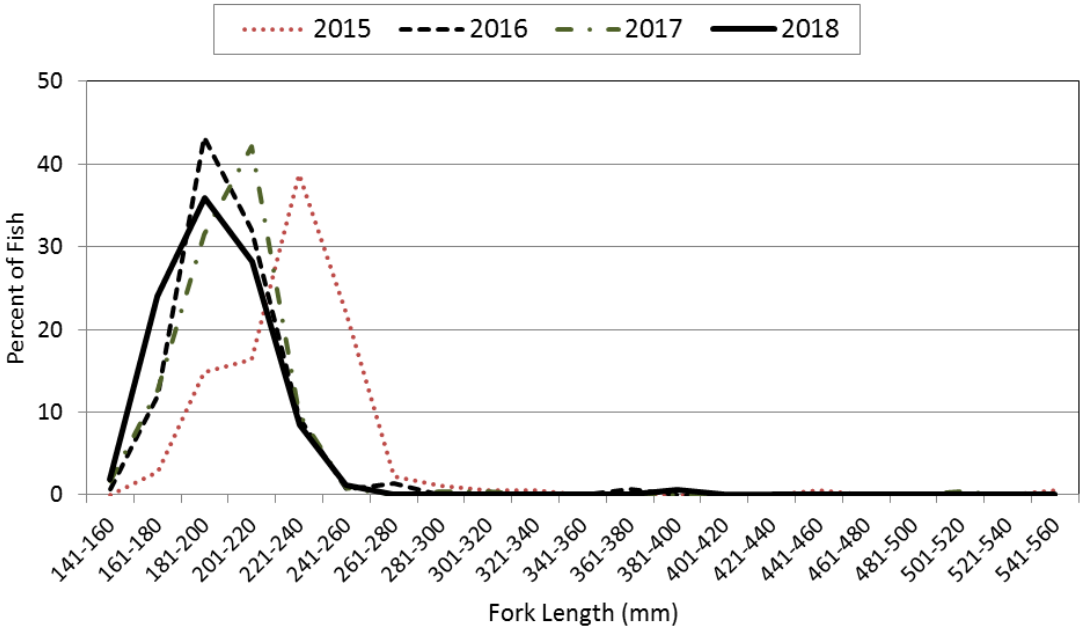

Figure 15. Length frequency distribution of Kokanee angled from Arrow Lakes Reservoir from 2015 to 2018.

3.4.4 Burbot

The total Burbot harvest estimate for the reservoir in 2018 was 610 fish weighing 1,010 kg (Table 3). As is usually the case, all creel-recorded Burbot were from the Nakusp access, where harvest was about 350 fish, similar to 2002-2011 and 2017 (Figure 16a). Anecdotal information suggests that Burbot angling also occurs out of private residences in Beaton Arm (B. Barney, pers. comm.), and other unsampled locations such as McDonald Creek Provincial Park (M. Neufeld, MFLNRORD, pers. comm.). Unsampled harvest, rod-hours, and burbot size may be different in Arrow reservoir than our overflight-expanded estimates, due to the limited scope of our access sampling and the apparently very specific locations of burbot fishing.

Length of Burbot in 2018 ranged from 49 to 92 cm, with a mean size of 65 cm and 1.7 kg; size distribution is similar to 2017 but with slightly fewer large fish (Figure 17, Appendix 3d).

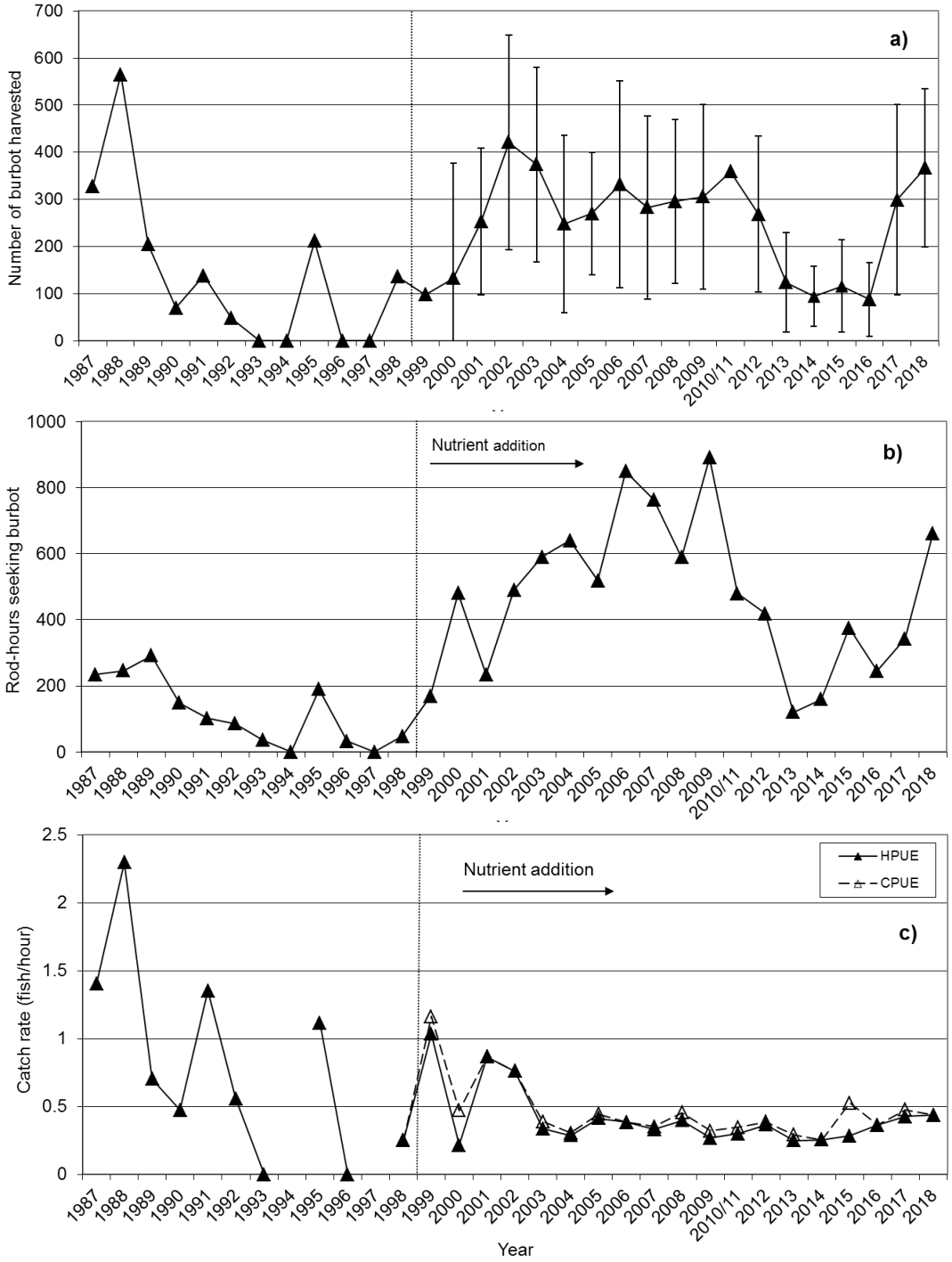

Figure 16. Trends in the (a) number of fish kept, (b) directed rod-hours, and (c) catch rate for Burbot anglers launching from Nakusp in Arrow Lakes Reservoir from 1987-2018. Brackets around harvest estimates after 1998 indicate 95% confidence limits. Catch rate after 1998 is shown for both harvested fish (HPUE) and including released fish (CPUE). January to March 2010 is pooled with April to December 2011 to obtain a 12 month period.

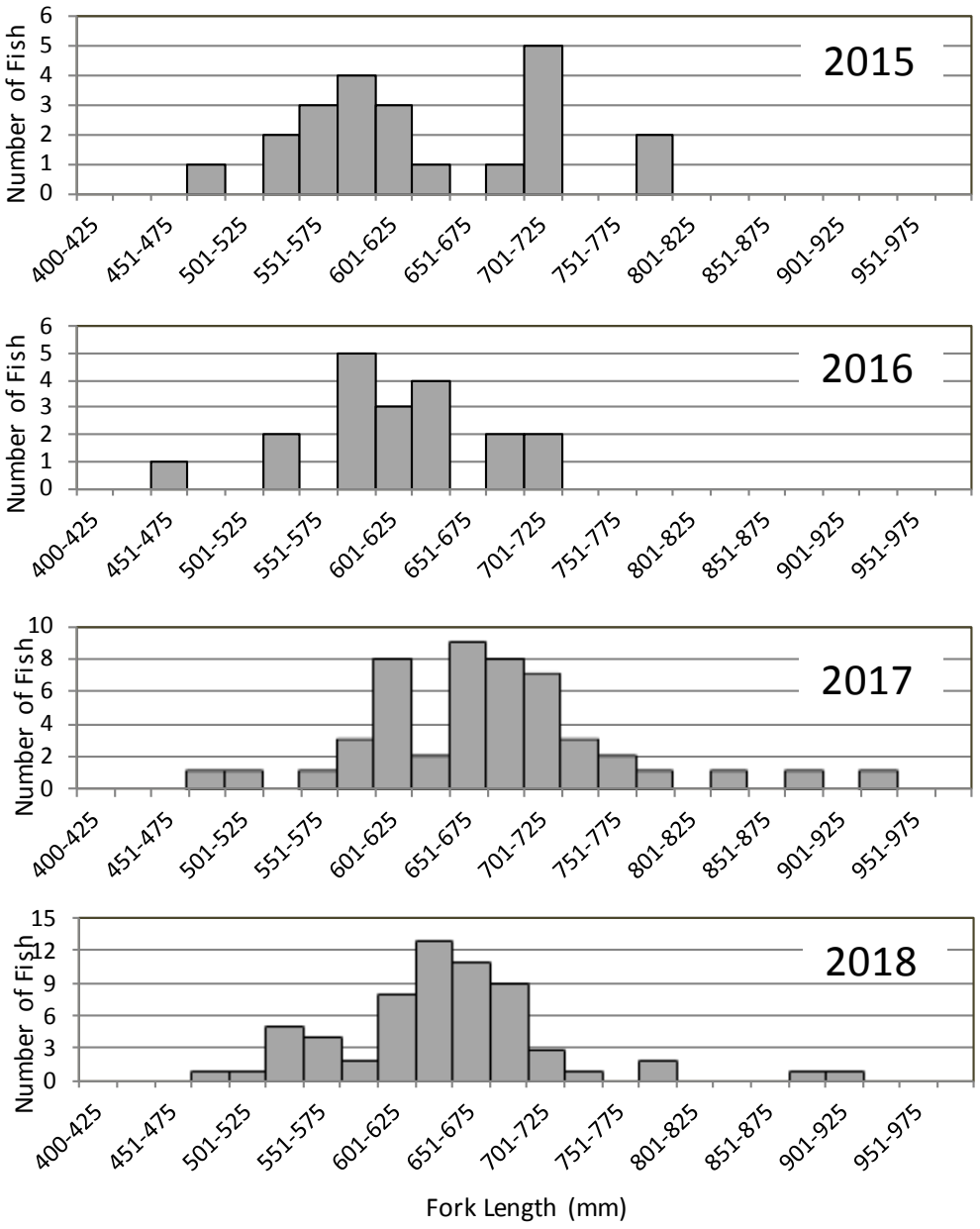

Figure 17. Length frequency distribution of Burbot angled from Arrow Lakes Reservoir from 2015 to 2018.

3.5 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 (Appendix 6, 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 suitability (abundance and size) at the top trophic level. Bull Trout K_n increased substantially in 2017 after remaining near the pre-nutrient average for four years (Figure 18). The change in average K_n from near 1.0 (2013 - 2015) to 1.13 (in 2017) implies increased growth rates, higher survival (Korman et al. 2017), and a greater probability of spawning (Thorley and Andrusak 2017). In 2018, K_n declined slightly to 1.08, while remaining well above the pre-nutrient average. This value is also somewhat higher than expected based on Kokanee spawning escapement (Figure 19). The pattern in Bull Trout condition from this survey generally agrees with condition trends observed for Bull Trout sampled in Revelstoke Reach, where it also appears to follow trends in Kokanee abundance (Golder et al. 2018).

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 (1.1; n=33) was above the pre-nutrient level similar to that of Bull Trout (Figure 20). The 2018 average is similar to 2017 with a reduced sample number (n=14). The return to higher condition for both apex predators in 2017 implies a significant improvement in prey suitability, which apparently has declined only slightly in 2018 in spite of a significant drop in Kokanee index spawner counts. Kokanee counts for 2018 may be an underestimate of actual escapement, because wildfires delayed most of the counts (by air) until late September, possibly missing the period of peak abundance.[8]

[8] Index stream Kokanee escapement is estimated by multiplying the peak count by 1.5. Estimates remained at about 100,000 fish for the upper basin and 200,000 for the whole reservoir from 2013 – 2016; returns increased to 320,000 (upper) and 685,000 (total) in 2017, and declined to 155,000 (upper) and 245,000 (total) in 2018 (MFLNRORD data on file).

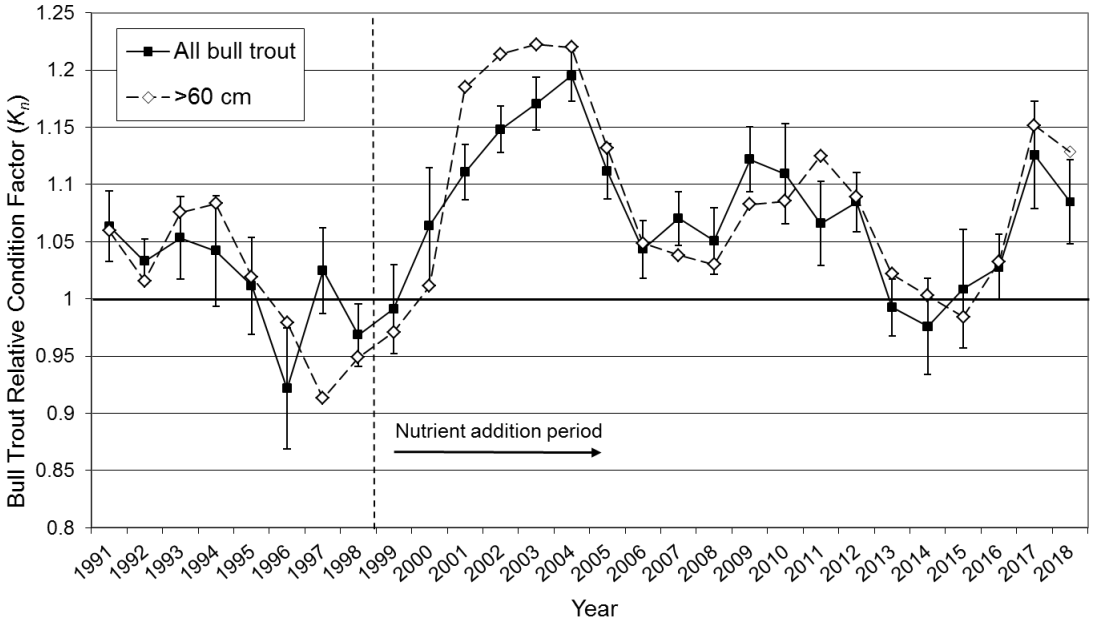

Figure 18. Mean annual condition factor (K_n; ± 95% confidence limits) relative to the average pre-nutrient weight at length (K_n=1) for all bull trout, and for bull trout over 60 cm in Arrow Lakes Reservoir from 1991 to 2018. Annual sample size for all bull trout ranges from 33 to 267.

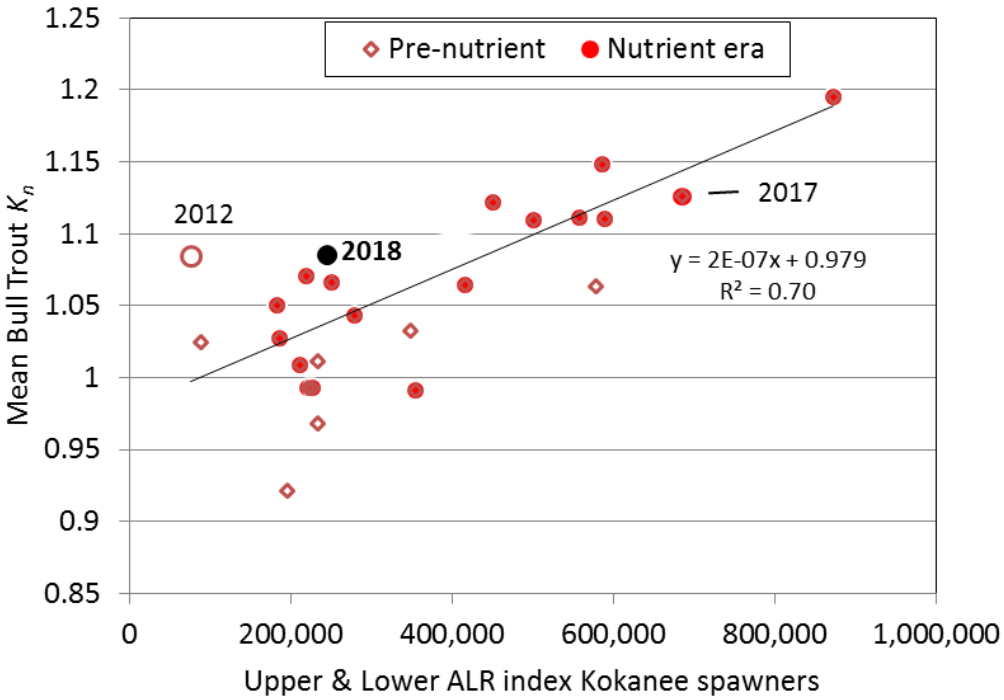

Figure 19. Relationship between mean relative condition factor (K_n) of Bull Trout and index stream Kokanee spawner estimates for Upper and Lower Arrow Lakes Reservoir. Year 2012 was not used for the regression because a large proportion of age-3 Kokanee delayed spawning (see Arndt 2014b). A similar plot using only Upper Arrow Kokanee index streams is provided in Appendix 4.

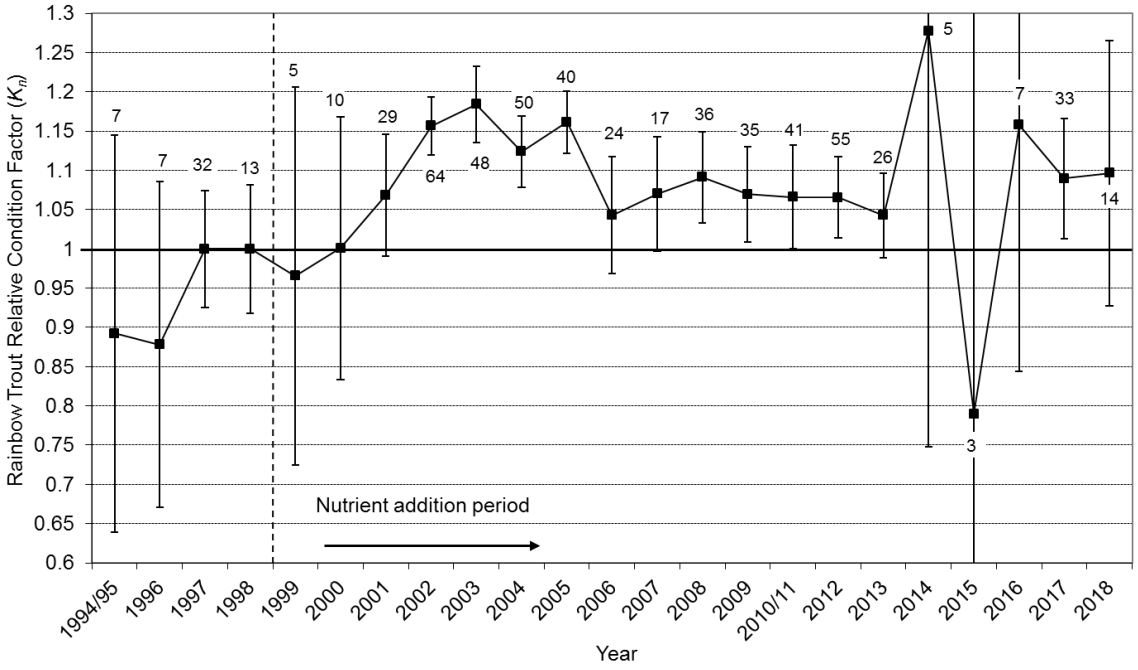

Figure 20. Mean annual condition factor (K_n; ± 95% confidence limits) relative to the average pre-nutrient weight at length (K_n=1) of piscivorous Rainbow Trout in Arrow Lakes Reservoir from 1994 to 2018. Numbers indicate sample size.

4.0 SUMMARY AND CONCLUSIONS

In 2018, ALR supported 12,100 angler-days, providing important recreational opportunities for local, provincial and some non-resident anglers, and a food harvest of 7.5 tonnes. Expenditures related to the fishery were estimated at up to $2.8 million including major purchases wholly or partially attributable to the fishery. This level of angling effort is an increase compared to the previous three years, although still below the early years of the nutrient restoration program (Figure 3, also see top panel Appendix 5).

Numerical harvests for Bull Trout in 2018 increased to a level approaching harvests prior to 2014, however, Rainbow Trout and Kokanee harvests remained well below those earlier in the nutrient program. The Kokanee fishery remains a small fraction of that in the 1980s and early 1990s (Figure 13). The small size of Kokanee in recent years is unusual because density and biomass in the reservoir have been relatively low (MFLNRORD file data); average length of harvested fish was only slightly less than Kokanee spawners in Deer Creek, suggesting that the harvest was comprised of similar age classes to the spawners (2+ and 3+).

A large part of angling effort prior to the nutrient program was targeting Kokanee (Fig. 13b), and the decline in Kokanee effort is a significant component of the overall decline. One hypothesis is that changes in angler demographics or species preferences may be the reason for reduced interest in Kokanee fishing, however, a 2016 discrete choice survey of ALR stakeholders suggests an alternative explanation. The largest group of respondents were classified as “casual consumptive anglers” who expressed an “overall preference for high quality Kokanee fishing experiences”; both Kokanee catch rates and size were important to this group (Nelitz and Beardmore 2017). A positive relationship of Kokanee effort to size has also been documented by this creel survey (Fig. 14). Comments of respondents also indicated an interest in fishing opportunities suitable for introducing children to fishing. Therefore there may be potential for increased angler-days on ALR, if Kokanee size and catch rate could be increased (Nelitz and Beardmore 2017, p. 38).

In 2017, there was a strong improvement in Bull Trout and piscivorous Rainbow Trout catch and size. In 2018, Bull Trout catch continued to improve but piscivorous Rainbow Trout catch declined; condition (K_n) of Bull Trout also declined slightly. These changes coincide with a spawning escapement of over 700,000 Kokanee in 2017 (more than triple the annual escapements for the last five years) and a decline in Kokanee escapement in 2018 (<300,000). The quality of the fishery for the apex predators, particularly the large Rainbow Trout, is linked to Kokanee escapement (see Appendix 6 for more detail).

ALR fishery yield by weight continued to increase in 2018, although it is still below the 2001 – 2011 range (Figure 21). Fishery yield in a given year is comprised of four main species, from more than one trophic level, produced over varying time periods. The majority of yield in most years is from Bull Trout, which are at the fourth trophic level, with harvested fish ranging from age-4 to over 10, (MFLNRORD unpublished data). Therefore it is not expected to be directly linked to the nutrient

conditions in a single year. Yield is also to some extent a reflection of fishing effort and release rates.[9] Nevertheless in general, periods of higher yield imply higher primary production at the lowest trophic level, and/or improved transfer efficiency from lower to upper trophic levels (e.g., Giacomini et al. 2013).

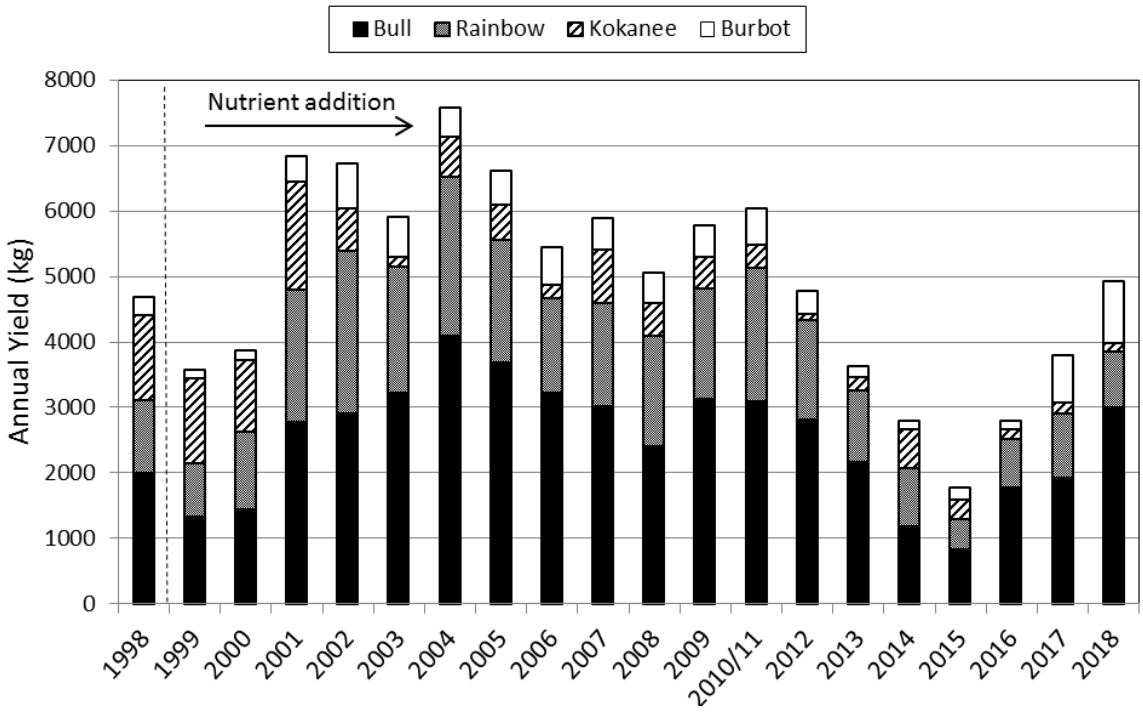

Figure 21. Annual fishery yield estimates by species for fish harvested by anglers from three primary access locations in Arrow Lakes Reservoir (Shelter Bay, Nakusp, Castlegar) from 1998 to 2018. Estimates are not expanded to account for other access points to allow a longer time series (overflight counts of total boats did not start until 2003).

Several hypotheses have been suggested to explain variable fish production in ALR since the beginning of the nutrient program. These include: region-wide weather patterns, a weather or disease-related Kokanee mortality event in 2012, increased entrainment (of nutrients and subsequent production at all trophic levels) and reduced Kokanee survival related to high flows and reduced water residence time, variable spawning channel fry production, and variable nutrient additions starting in 2004.[10] Analyses of these hypotheses are ongoing using existing data; however, an adaptive management experiment may be necessary to address some questions (Hansen et al. 2015). In such an experiment, inputs under management control (e.g., amount and timing of phosphorus added from fertilizer, spawning channel

[9] A decrease in release rates cannot account for the increased yield in 2017 (see Figures 5,9).

[10] Annual Kokanee production estimated with hydroacoustic/trawl data and spawner escapement estimates (incremental growth method; Hayes et al. 2007) was highest in the first five years of the nutrient program (1999-2003) when phosphorus additions were over 50 tonnes/year.

fry production) should be held constant at specified levels for a period of time while maintaining ongoing monitoring. Four years for each experimental treatment would allow completion of one Kokanee life cycle for the majority of fish maturing at age 3+. [11]

Some initiatives towards improved understanding of ALR compensation initiatives are underway. For example, predator diet samples, collected from 2003 – 2006, were added to the creel survey again for 2014 - 2018. This sampling should be continued through periods of contrasting Kokanee abundance and size structure to resolve questions related to optimal prey size and density. Data analysis is ongoing as time permits (see Appendix 6). As previously noted, a survey of stakeholder views on ALR fishery management objectives was completed in 2017 as a separate MFLNRORD initiative (Nelitz and Beardmore 2017).

Overflight boat counts conducted from 2003–2005 and in 2011-2012 provided the expansion factors used for whole reservoir effort, harvest and catch estimates. The pattern of air/interviewed boat ratios in the 2011-2012 flights was very similar to the earlier flights, so all boat count data between 2003 and 2012 have been included when computing a common monthly correction factor for the three access sites (Arndt 2014a). 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 are occurring in the 2019/20 fiscal to ensure that the interviewed/total boat expansion ratios are accurate.

[11] Hill Creek fry production and phosphorus targets have been held constant since 2014, recognizing some variation due to weather and other factors beyond program control.

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6.0 APPENDICES

APPENDIX 1. Angler residence composition on Arrow Lakes Reservoir from 1976 to 2018. 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

[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. Arrow Lakes creel survey 2017 and 2018 estimates using a common monthly correction factor (derived from aerial boat counts and the time proportional method) applied to all zones to adjust for boats returning to non-sampled access sites (see Arndt 2014a).

Year 2017

	Site									
	ALL sites		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total
variable										
Angler Hours	52862	5482	20613	2854	11524	1661	20724	4090	32249	4277
Bull Kept	1192	140	343	76	459	96	391	55	850	109
Bull Rel	1899	449	51	25	214	68	1633	443	1848	450
Bull Total	3092	510	394	91	673	136	2024	483	2697	490
Burbot Kept	613	217	0	0	613	217	0	0	613	217
Burbot Rel	68	51	0	0	68	51	0	0	68	51
Burbot Total	681	232	0	0	681	232	0	0	681	232
Kokanee Kept	3659	756	2890	732	751	273	19	17	769	272
Kokanee Rel	938	217	864	215	0	0	74	22	74	22
Kokanee Total	4597	847	3754	796	751	273	92	31	843	273
Num Angler	10673	1002	4042	502	2518	345	4113	566	6631	672
Num Rods	10873	984	3936	475	2778	360	4159	570	6937	674
Other Kept	0	0	0	0	0	0	0	0	0	0
Other Rel	51	27	24	23	0	0	27	14	27	14
Other Total	51	27	24	23	0	0	27	14	27	14
Rainbow Kept	1696	312	1123	240	345	67	228	85	573	126
Rainbow Rel	2124	516	425	97	270	112	1429	495	1699	503
Rainbow Total	3821	632	1549	274	615	146	1657	500	2272	512
Rod hours	53637	5367	20044	2717	12635	1709	20958	4051	33593	4231

Year 2018

	Site									
	ALL sites		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total
variable										
Angler Hours	57720	5687	21129	2949	17411	2592	19180	2495	36591	4194
Bull Kept	1783	203	392	113	869	129	522	112	1391	173
Bull Rel	1518	326	106	35	341	162	1071	260	1412	317
Bull Total	3301	445	498	123	1210	232	1593	312	2803	412
Burbot Kept	613	162	0	0	613	162	0	0	613	162
Burbot Rel	63	45	0	0	63	45	0	0	63	45
Burbot Total	676	182	0	0	676	182	0	0	676	182
Kokanee Kept	3352	832	3105	766	247	146	0	0	247	146
Kokanee Rel	1407	478	1312	441	95	71	0	0	95	71
Kokanee Total	4758	1180	4416	1078	342	172	0	0	342	172
Num Angler	12068	1138	4601	633	3841	527	3627	407	7468	806
Num Rods	12288	1129	4411	594	4094	531	3783	413	7877	817
Other Kept	6	6	6	6	0	0	0	0	0	0
Other Rel	30	16	10	9	10	9	10	9	20	13
Other Total	36	17	16	11	10	9	10	9	20	13
Rainbow Kept	1877	305	911	202	612	140	354	95	966	192
Rainbow Rel	1195	154	300	90	164	59	731	111	895	127
Rainbow Total	3072	372	1211	250	777	151	1084	137	1861	237
Rod hours	59365	5678	20720	2810	18621	2670	20023	2560	38645	4307

Common monthly correction factor used for all basins based on proportional presence of interviews during overflight

SE Totals have been adjusted (approximately) for se of correction factor

APPENDIX 2b. Arrow Lakes creel survey 2017 and 2018 estimates for the specific sample sites.

Year 2017

	Site									
	ALL sites		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total
variable										
Angler Hours	30225	2620	11135	1323	6503	744	12587	2684	19090	2434
Bull Kept	796	75	229	50	296	47	270	32	567	49
Bull Rel	1245	303	42	21	120	35	1084	301	1204	304
Bull Total	2041	329	271	64	416	67	1354	325	1770	318
Burbot Kept	299	101	0	0	299	101	0	0	299	101
Burbot Rel	34	23	0	0	34	23	0	0	34	23
Burbot Total	333	108	0	0	333	108	0	0	333	108
Kokanee Kept	1633	264	1342	283	278	95	14	12	291	95
Kokanee Rel	435	90	385	88	0	0	50	14	50	14
Kokanee Total	2068	289	1727	291	278	95	64	20	341	96
Num Angler	5891	373	2127	207	1376	149	2389	317	3764	292
Num Rods	6015	359	2075	196	1531	155	2409	313	3940	284
Other Kept	0	0	0	0	0	0	0	0	0	0
Other Rel	23	11	7	7	0	0	16	8	16	8
Other Total	23	11	7	7	0	0	16	8	16	8
Rainbow Kept	906	120	578	98	196	33	131	41	328	57
Rainbow Rel	1145	208	266	60	114	45	765	197	879	197
Rainbow Total	2050	256	844	108	310	63	896	217	1206	218
Rod hours	30723	2563	10838	1266	7174	764	12711	2643	19884	2378

Year 2018

	Site									
	ALL sites		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total	Est Total	SE Total
variable										
Angler Hours	34004	3202	12070	1385	10666	1992	11268	1331	21934	2556
Bull Kept	1148	121	268	70	542	80	338	69	881	101
Bull Rel	1002	224	73	26	253	153	676	148	929	219
Bull Total	2150	305	341	76	795	204	1014	189	1809	284
Burbot Kept	367	84	0	0	367	84	0	0	367	84
Burbot Rel	59	43	0	0	59	43	0	0	59	43
Burbot Total	425	117	0	0	425	117	0	0	425	117
Kokanee Kept	1426	324	1321	298	105	61	0	0	105	61
Kokanee Rel	582	189	550	177	32	22	0	0	32	22
Kokanee Total	2007	461	1871	420	137	69	0	0	137	69
Num Angler	6747	534	2498	258	2197	323	2053	194	4249	408
Num Rods	6937	523	2447	246	2351	325	2139	188	4490	404
Other Kept	5	4	5	4	0	0	0	0	0	0
Other Rel	18	10	6	6	5	4	7	7	12	8
Other Total	23	11	11	7	5	4	7	7	12	8
Rainbow Kept	1009	148	484	90	318	74	207	56	525	106
Rainbow Rel	724	80	167	43	115	47	443	56	557	74
Rainbow Total	1733	174	650	102	433	88	650	74	1083	130
Rod hours	35127	3184	12026	1350	11386	2028	11714	1331	23101	2570

APPENDIX 3a. Size statistics for Bull Trout in the Arrow Lakes Reservoir creel survey from 1998 to 2018. 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.

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

APPENDIX 3b. Size statistics for Rainbow Trout in the Arrow Lakes Reservoir creel survey from 1998 to 2017.

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

APPENDIX 3c. Size statistics for Kokanee in the Arrow Lakes Reservoir creel survey from 1998 to 2017.

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

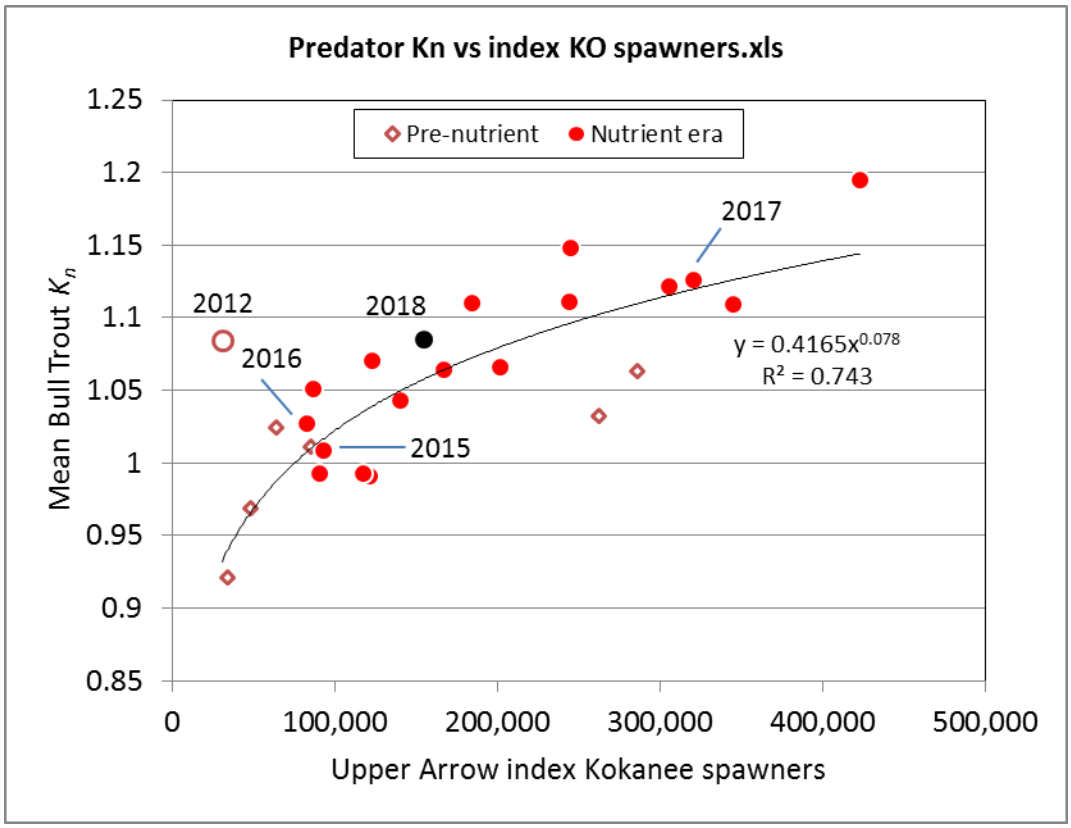
* 2010 data January to March only; 2011 data April to December only.

APPENDIX 3d. Size statistics for Burbot in the Arrow Lakes Reservoir creel survey from 1998 to 2017.

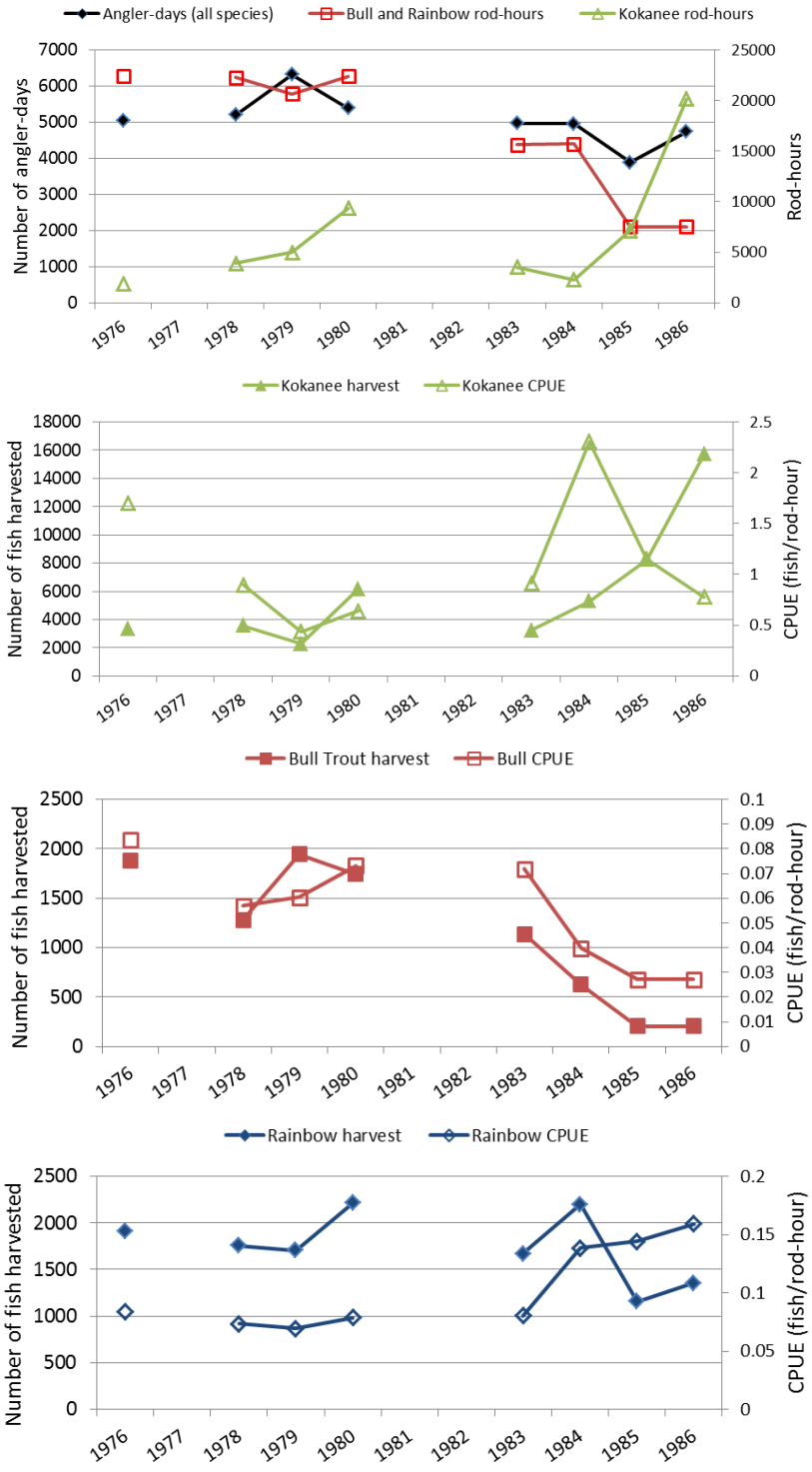
		Fork Length (cm)			Weight (g)	
Year	**N**	**Mean ± 95% c.l.**	**Range**		**Mean ± 95% c.l.**	**Range**
1998	5	73.2 ± 19.8	60 - 90		2,019 ± 1,588	900-4,130
1999	18	59.1 ± 4.7	41 - 76		1,264 ± 239	454-2,223
2000	6	60.0 ± 4.8	52 - 65		1,196 ± 419	700-1,700
2001	39	63.1 ± 2.3	50 - 86		1,596 ± 190	737-3,345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

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

APPENDIX 4. 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 19 because in most years the majority of Bull Trout samples come from the Upper Arrow creel sites (Shelter Bay and Nakusp).



APPENDIX 5. Estimated angler-days, rod-hours, harvest, and CPUE (fish/rod-hour) in Upper Arrow Reservoir from 1976 – 1986. Full year data are not available for Lower Arrow (or the Castlegar access) and the specific sample locations for the Upper Arrow estimates are unknown. Data from Sebastian et al. (2000).



APPENDIX 6. Arrow Lakes Reservoir Predator diet sampling update.

Introduction

A key objective of the nutrient restoration program in ALR is to "ensure sufficient abundance of forage fish to meet targets for large piscivores" (FWCP 2012); however, since the beginning of the program in 1999, the response of the two apex predators, Bull Trout and Rainbow Trout, has been highly variable in terms of catch, size and condition factor. This highlights a need to better understand the prey conditions that promote efficient nutrient transfer to upper trophic levels. Since reservoir carrying capacity for Kokanee is limited, there is an interaction between Kokanee density and their growth (size) and survival to spawning, such that high fry production can lead to reduced spawner escapement (MFLNRORD, unpublished data). Prey suitability for predators, and *bottom-up* trophic efficiency, may relate to Kokanee size and age structure (Kerr 1971, Giacomini et al. 2013), which is influenced by Hill Creek Spawning Channel because of its high fry production capacity. There has also been heightened interest in the role of predators in structuring prey communities from the *top down*, since the decline of Kokanee in nearby Kootenay Lake in 2014, and in other northwest lakes with similar fish communities (e.g., Beauchamp and Van Tassel 2001; Hanson et al. 2010).

Predator stomach sampling has been included in the creel survey to address these information gaps, and thereby work towards optimizing benefits from the nutrient restoration and spawning channel programs of the FWCP. The main goals of the work are to describe the diet, and quantify responses of predators to changes in prey density and size structure over time in ALR. This appendix briefly summarizes some of the progress made to date. Data collection and more detailed analyses, including estimates of daily ration, are ongoing.

Methods

Stomach samples were collected in 2003 – 2006, and again in 2014 – 2018 as part of the regular creel survey. 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. Stomach contents from the esophagus to the beginning of the intestine were examined in the lab after thawing. Consumed fish were identified to species if possible, and consumed invertebrates to the lowest possible taxon. Kokanee could be readily distinguished from other fish by the deep orange flesh colour, even when partially digested. Starting in 2004, lengths of fish prey were determined whenever possible, with lengths of partially digested Kokanee estimated to the nearest centimeter using a series of template photographs (graduated by 1 cm) to find the closest match. This method allowed a length estimate for over 80% of Kokanee, as long as the vertebral column was still intact. Kokanee weights at the time of consumption were estimated based on their fork length and length-weight regressions from annual trawl data.

Prey type was summarized both numerically (% frequency of occurrence) and as a proportion by weight in the diet. For data from 2004-2018, the prey:predator length ratio was computed for each consumed prey fish by dividing its fork length by the fork length of the predator that consumed it. Prey selection was examined by comparing the relative abundance of Kokanee in the diet to their relative abundance in the reservoir, by age class. Reservoir age proportions were based on hydroacoustic size bins (for age 0, age 1-3) and scale-determined ages of trawl caught Kokanee captured around October 1 (Basset et al. 2018). Ages of consumed Kokanee were assigned based on length at age data from the trawl. For the purposes of this report, prey selection is defined as

any difference in prey composition in the predator diet compared to the composition of available prey in the reservoir (Turesson et al. 2002). This can include passive selection resulting from differences in detection or capture success, or active selection where a predator chooses whether or not to attack after encountering a prey based on an ability to consider cost-benefit and optimize energy intake.

Results and Discussion

Prey type

A total of 458 Bull Trout and 188 Rainbow Trout stomach samples were obtained up to the end of 2018. Kokanee were by far the most common prey of both species, whether expressed as frequency of occurrence or weight proportion (Table A6-1). The dominance of Kokanee in the diet of both predator species was consistent for all years in this study (data not shown), and also with an earlier study on ALR which found Kokanee in 98% of non-empty Bull Trout stomachs (Sebastian et al. 2000).

Table A6-1. Diet summary for Bull Trout and piscivorous Rainbow trout in Arrow Lake Reservoir. Non-empty stomach samples (N) from 2003-2006 and 2014-2018 are pooled. Frequency of occurrence is the percentage of non-empty stomachs that contained the prey type; some fish consumed more than one prey type. Proportion by weight in this table is based on the remaining (undigested) portions at the time of examination.

			Prey Type					
	N		**Kokanee**	**Unidentified Fish**	**Mysids**	**Terrestrial insects**	**Aquatic insects**	**Fish eggs**
Bull Trout	252	% Frequency of occurrence	88.9	11.1	4.8	0.4	0	0
		% Proportion by weight	96.8	3.0	0.1	0.1	0	0
Rainbow Trout ≥50 cm	106	% Frequency of occurrence	84.0	0	9.4	12.3	1.9	0.9
		% Proportion by weight	97.7	0	0.2	2.1	<0.1	<0.1

Prey size and prey:predator length ratio

Consumed Kokanee ranged in length from 10 to 26 cm for Bull Trout and from 9 to 23 cm for Rainbow Trout. Prey:predator length ratio ranged from 0.14 to 0.48 for Bull Trout and 0.17 to 0.42 for Rainbow Trout. The ability of Bull Trout to consume fusiform prey up to half of their length was also observed by Beachamp and Van Tassel (2001) in Lake Billy Chinook, Oregon. For Rainbow Trout, our data agree with an earlier study in Kootenay and Quesnel lakes (Parkinson et al. 1989), which showed very few age 0 (< 8 cm) Kokanee consumed. However, our study differs from theirs in that their largest prey were less than one third of the Rainbow Trout length. This may be partially due to different methods, since in that study, prey lengths for Kootenay Lake were estimated

from (remaining undigested) prey volume. Different prey size structure may also be a factor because Quesnel Lake has both Kokanee and Sockeye Salmon, and only 5% of *O. nerka* were older than age 0 (Parkinson et al. 1989).

When prey length was compared for large and small predators (≤ 60 cm, > 60 cm) in ALR there was some evidence that larger predators eat larger prey, especially for Rainbow Trout (Fig. A6-1, left panels). When the data are converted to prey:predator length ratio, frequency distributions were more distinct between the size categories for both species (right panels), with larger predators eating smaller prey relative to their size. If capture success and bioenergetic cost-benefits of relative prey size remain similar as predators grow, the reduction in prey:predator length ratio for larger predators may be an indication that they are forced to consume prey below optimal size.

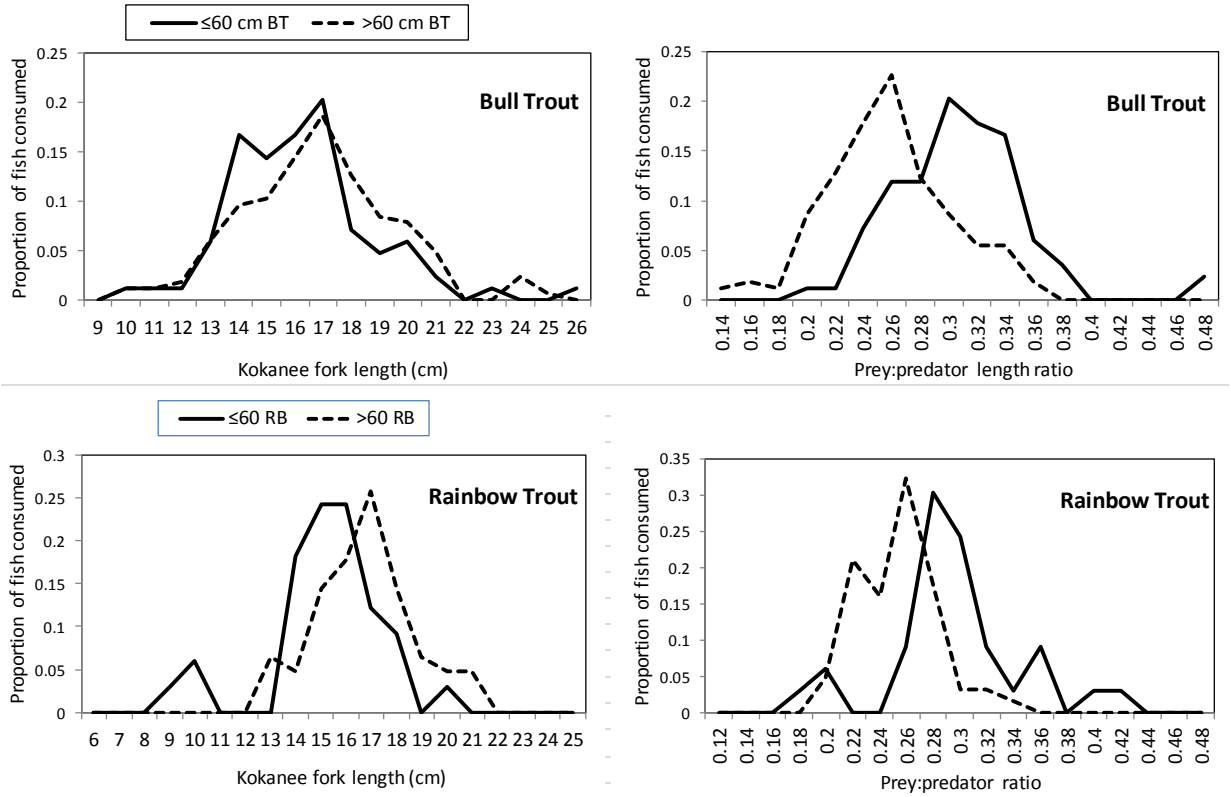


Fig. A6-1. Frequency distributions of fork length and prey:predator length ratio for Kokanee consumed by Bull Trout (upper panels) and Rainbow Trout (lower panels) in Arrow Lakes Reservoir (2004 – 2018 data pooled).

Prey selection by age

Relative abundance of Kokanee in the reservoir and in predator diets is shown for two years of higher predator sample size in Figure A6-2. Age-0 Kokanee were most abundant in the lake, but rarely observed in the stomachs of predators. Diets were comprised almost entirely of age 1 to 3 Kokanee. Further evidence of the importance of older (larger) Kokanee to the growth and condition of predators is provided by the positive relationship between Bull Trout condition and Kokanee spawner escapement from 1991 – 2018 (Fig. 19, main report; Appendix 4).

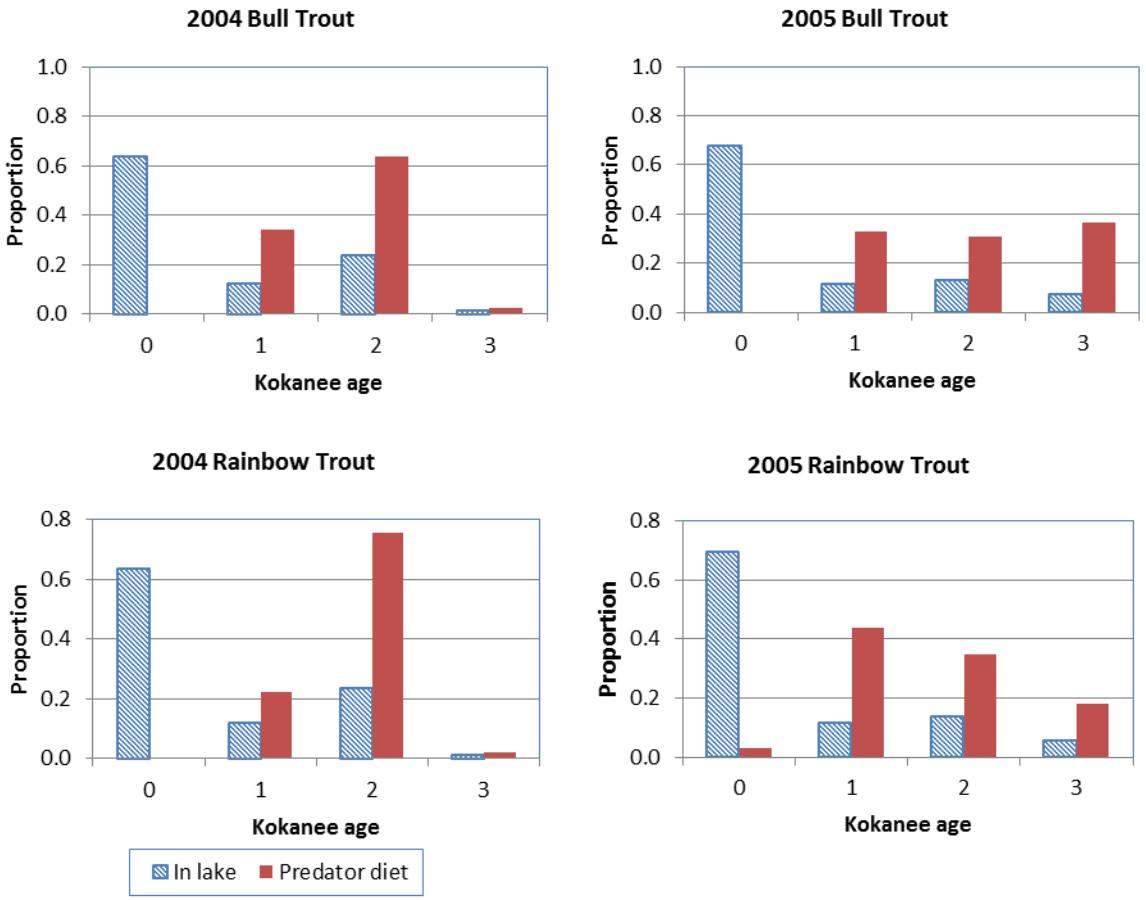


Fig. A6-2. Examples of relative age abundance for Kokanee in Arrow Lakes Reservoir during October 1, 2004 and 2005 hydroacoustic estimates (in reservoir) compared to age of Kokanee consumed by predators over 12-month periods from May to April around these estimates.

Preliminary Conclusions

Kokanee are the most important prey for Bull Trout and piscivorous Rainbow Trout in ALR, comprising over 95% of the diet by weight for both species. Age-0 Kokanee were found only rarely in the stomachs of Bull Trout > 40 cm, and Rainbow Trout > 50 cm, and there were indications that larger predators may be feeding on smaller than optimal prey. In addition, predator condition increases with increasing Kokanee spawner escapement. Therefore, Kokanee densities and nutrient applications that maximize survival to spawning will provide better feeding opportunities for apex predators in ALR. Fry production that strongly skews the age structure towards high densities of younger (smaller) fish with reduced survival to spawning is likely to reduce trophic efficiency. The importance of older Kokanee to Bull Trout in this study is similar to the work of Beachamp and Van Tassel (2001), who estimated that annual Bull Trout consumption removed 5–11% of age-0, 1–2% of age-1, and 9–59% of ages 2–3 Kokanee. Further analyses will investigate the relationships between annual differences in Kokanee size/age abundance and predator diet and condition. Estimates of daily ration for the predators are also in progress.

APPENDIX 7. Selected objectives, status indicators and actions related to the creel survey in Arrow Lakes Reservoir from FWCP draft Large Lakes Plan (FWCP 2012).

Objective 1: *Ensure a productive and diverse aquatic ecosystem.*
(status indicators include: Aquatic productivity status, Structure and function of ecological communities, Piscivorous rainbow trout, Insectivorous rainbow trout, Kokanee, Bull trout, Burbot)

Objective 3: O*ptimize recreational angling opportunities, participation and local benefits* (FWCP 2012, p. 19)

Sub-objectives:

1) **Productivity** - provide sufficient primary and secondary productivity to support **targets for higher trophic levels**.

Status indicator 1 Aquatic Productivity – Actions

- Continue the Kootenay Lake and Arrow Lakes nutrient restoration program to sustain in-lake productivity at levels sufficient to support fisheries management and ecosystem objectives, measures and targets

3) **Piscivorous rainbow trout** - Maximize the viability of large piscivorous rainbow trout.

4) **Kokanee** - Ensure sufficient abundance of forage fish to meet targets for large piscivores. … Maximize the abundance of large kokanee in support of **angling** and **harvest**.

5) **Bull trout** - Maximize the viability of bull trout.

Status indicators 3 to 6 for Bull Trout, Rainbow Trout, Kokanee and Burbot:

- Monitor status of multiple ecosystem components relative to current fisheries and ecosystem objectives, measures and targets to guide management actions for piscivorous Rainbow Trout, Bull Trout, Kokanee, and Burbot.
- Review possible management actions when results for piscivorous Rainbow Trout, Bull Trout, Kokanee or Burbot are outside the target range.
- Adjust targets for piscivorous Rainbow Trout, Bull Trout, Kokanee or Burbot as information becomes available or if management priorities change.

8) **Socio-economic value** - Optimize the monetary and non-monetary (angler days) values from the fishery.