Kootenay Lake North Arm Nutrient Restoration Program

(COL-F20-F-3007-DCA)

2019-20 (F20) Activity Report

1 April 2019 to 31 March 2020

Prepared for: Fish & Wildlife Compensation Program (FWCP)

Prepared by: Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Resource Management (FWCP – Section)

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Prepared with financial support from the Fish & Wildlife Compensation Program, on behalf of its program partners BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and Public Stakeholders

Executive Summary

Nutrient additions occurred in the North and South Arms of Kootenay Lake following the same tug and barge method as in 2018 (Peck et al. 2019). Note: the South Arm program is funded by the Kootenai Tribe of Idaho (additional information is listed in the Acknowledgements). In the North Arm a total of 40.0 MT of phosphorus and 234.4 MT of Nitrogen were added in the form of liquid agricultural grade fertilizers (additions began in early May and ceased near the end of September). In the South Arm, 196 MT of Nitrogen was added between early July and ceased beginning of September; reduced loading in 2019 occurred due to increased ambient nitrogen inputs from the Kootenay River.

Daphnia (the preferred food source to Kokanee) biomass was higher than the long-term trends. The *Daphnia* biomass has been high since the decrease in Kokanee. The release on predation pressure on Zooplankton has allowed the biomass to increase as well as the individual size of individual *Daphnia.* Mysid densities in Kootenay lake increased in both the North and South Arms, however more substantially in the South Arm These higher results occurred mainly in the August samples, although 2019 was predominantly higher than the 1993-2018 monthly means

In 2019, there were approximately 63,300 spawners that returned to the north end of Kootenay Lake to Meadow Creek (33,700) and Lardeau River (30,600). Spawner results continue as a decrease from the historic time series, however is the highest return since 2015. Considering the mean fecundity and sex ratio measured at Meadow Creek Spawning Channel, this equates to an approximate egg deposition of 22 million eggs (additional details are provided in the Meadow Creek project update). This is roughly 20% of the 1980-2019 long term average for annual egg deposition, however as exceptional egg to fall fry survival has occurred over the previous 5 years the 2020 fall fry estimate is likely be near 12 million fry, which is within 1 SD of the post nutrient era mean (1993-2011 – pre-collapse era).

The in-lake abundance in 2019 has not deviated from trends since 2013, particularly for the Age 1-3 age class. The Age 0 class has not shown the same decrease as the older age classes likely due to the high egg to fry survival rates as well as egg plants into Meadow Creek Channel. The Age 1-3 in lake abundance shows a slight improvement from 2017 and is similar to the 2018 estimate. An increase in kokanee biomass was primarily due to the highest Age 2 abundance since 2013. Kokanee age 0 to 1 survival has not improved since 2013, however, age 1 to 2 kokanee survival in 2019 remains high which is a great sign for kokanee recovery.

Bull Trout redd counts were completed or partially completed in eight tributaries with a total count of 423 redds. Unusually high fall precipitation compromised viewing conditions for redd counts on some of the tributaries this year so that not all scheduled streams were able to be completed. An analysis of the relationships between redd numbers and discharge for all streams is currently under review.

Table of Contents

Introduction

Kootenay Lake has been influenced by the construction of Duncan Dam in 1967, (which raised the water level in Duncan Lake and flooded the lower Duncan River) and construction of Libby dam in 1973, (creating Koocanusa Reservoir and flooding a large section of the Kootenai River in the US). An invasive species was also introduced to the lake in 1949; *Mysis diluviana*. The dams have impacted native fish populations by permanently changing the hydrograph and nutrient loading to Kootenay Lake, flooding and/or blocking migration to spawning and rearing habitat and decreasing downstream lake productivity, a process referred to as oligotrophication. Kokanee stocks declined significantly through the 1980s as a result of the decreased productivity. To address the nutrient losses in Kootenay Lake, a bottom-up approach was taken with the addition of nutrients (nitrogen and phosphorus in the form of liquid fertilizer) to increase phytoplankton populations that are suitable for the production of *Daphnia*, a main food source for kokanee. Nutrients additions have occurred in the North Arm since 1992 and are added from the end of April through early to mid-September. Nutrient additions began (nitrogen only) in the South Arm in 2004.

Goals and Objectives and Linkage of FWCP Action Plans and specific actions

The goals and objectives of the nutrient restoration program are a priority one habitat-based action described in the Columbia Region reservoir and large lakes plan. The following is a snapshot from the plan with the description of the Kootenay and Arrow nutrient restoration programs.

8	Habitat-based	**COLRLL.ECO.HB.08.01 Implementation of Kootenay Lake and Arrow Lakes Nutrient Restoration Programs-P1**	**1**	Kootenay Lake Arrow Lakes	Fish	Implement and adaptively manage nutrient restoration programs in Kootenay Lake and Arrow Lakes Reservoir to sustain in-lake productivity at levels sufficient to support secondary productivity (forage for Kokanee).	Successfully demonstrate improved health and productivity of reservoirs.	Directed
9	Habitat-based	**COLRLL.ECO.HB.09.01 Operation of Meadow Creek and Hill Creek spawning channels-P1**	**1**	Kootenay Lake Arrow Lakes	Fish	Support the maintenance and operation of the Meadow Creek and Hill Creek spawning channels to ensure sufficient kokanee production in Kootenay Lake and Arrow Lakes Reservoir.	Improved Kokanee productivity to support a healthy and resilient reservoir ecosystem.	Directed
10	Monitoring and Evaluation	**COLRLL.ECO.ME.10.01 In-season Monitoring of Kootenay Lake and Arrow Lakes Nutrient Restoration Programs-P1**	**1**	Kootenay Lake Arrow Lakes	Fish	Implement in-season monitoring and evaluation of indicators and trends in ecosystem components (e.g. water chemistry, plankton, Kokanee) related to the Kootenay Lake and Arrow Lakes Reservoir nutrient restoration programs.	Improved understanding of indicators and annual trends of in lake productivity.	Directed

- **Habitat-based Actions** – These actions will conserve, restore, and enhance reservoir and large lake habitats. Examples include habitat creation, restoration, and enhancement; enhancing habitat connectivity; nutrient restoration; and invasive species prevention.
- **Monitoring and Evaluation** – These actions will monitor and evaluate reservoir and large lake projects supported by the FWCP to understand the effectiveness of habitat- or species-based actions.

The following is the link to the Columbia region reservoir and large lakes plan.
https://fwcp.ca/app/uploads/2019/08/Action-Plan-Columbia-Region-Reservoirs-Large-Lakes-Aug-21-2019.pdf

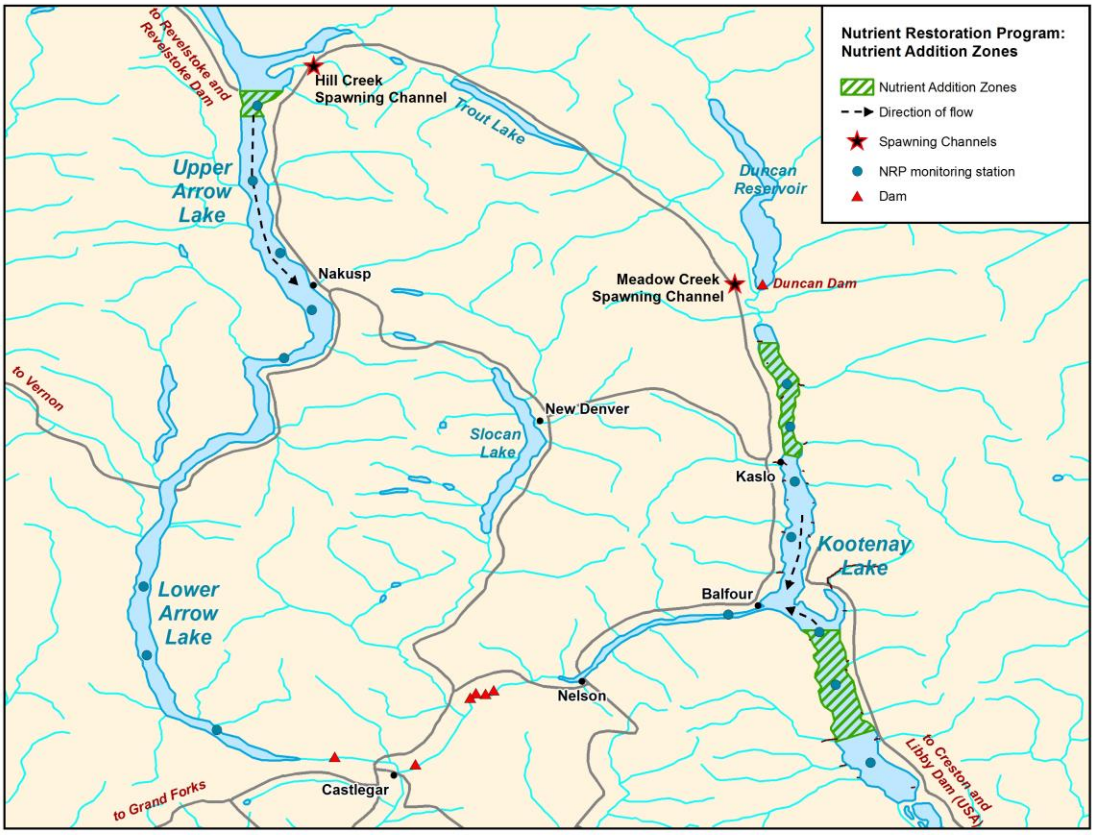


Figure 1. Map of Kootenay Lake with the North and South Arm nutrient addition zones and monitoring stations identified (described in the legend on the map).

Methods

Methods for nutrient additions and the sampling of various trophic levels for the nutrient restoration programs are listed in Peck et al. 2019. The trophic levels monitored as components of the program are physical limnology, phytoplankton, zooplankton, mysids (sampled April to October) in – lake kokanee (hydroacoustics and trawling - September), kokanee spawner enumeration (September) and bull trout redd counts (October).

Results

Nutrient additions occurred in the North and South Arms of Kootenay Lake following the same tug and barge method as in 2018. In the North Arm a total of 40.0 MT of Phosphorus and 234.4 MT of Nitrogen were added in the form of liquid agricultural grade fertilizers, 10-34-0 and 28-0-0. The schedule was affected once, in late June when a truck broke down and was unable to meet the barge in time for the scheduled dispensing trip. Fertilization began early May and ceased end of September. This was later than other years and was due to contract delays.

In the South Arm, a total of 196 MT of Nitrogen was added as liquid agricultural grade fertilizer, 28-0-0. Fertilization began early July and ceased beginning of September. This was the second year of reduced loading due to increases in ambient Nitrogen from Kootenay River. The South Arm nutrient strategy is currently under review with the International Kootenai(y) Ecosystem Restoration Team, through partnered funding with the Kootenai Tribe of Idaho.

Daphnia (the preferred food source to Kokanee) biomass was higher than the long-term trends. The *Daphnia* biomass has been high since the decrease in Kokanee (Fig. 2). The release on predation pressure on Zooplankton has allowed the biomass to increase (Fig. 2) as well as the individual size of individual Daphnia (Fig. 3)

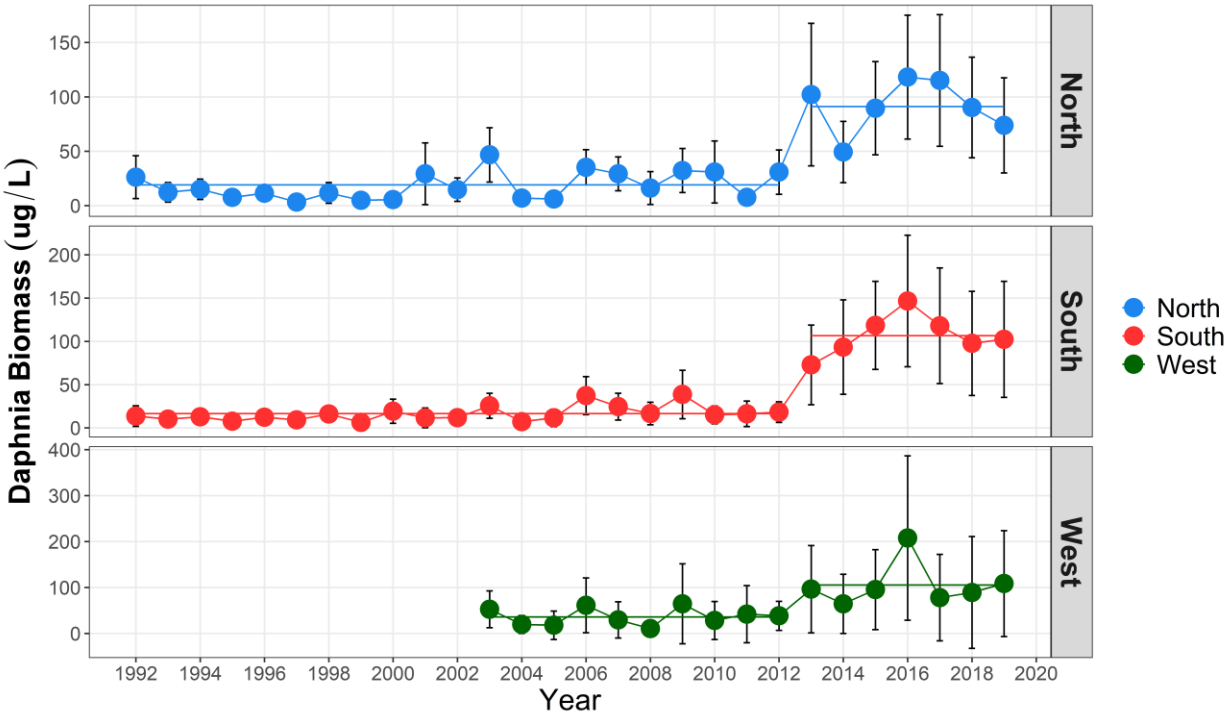


Figure 2. Kootenay zooplankton *Daphnia* biomass (ug/L) annual monthly mean (April – October), biomass (ug/L) by Arm. Horizontal lines are the Arm means for the time series (1992-2019).

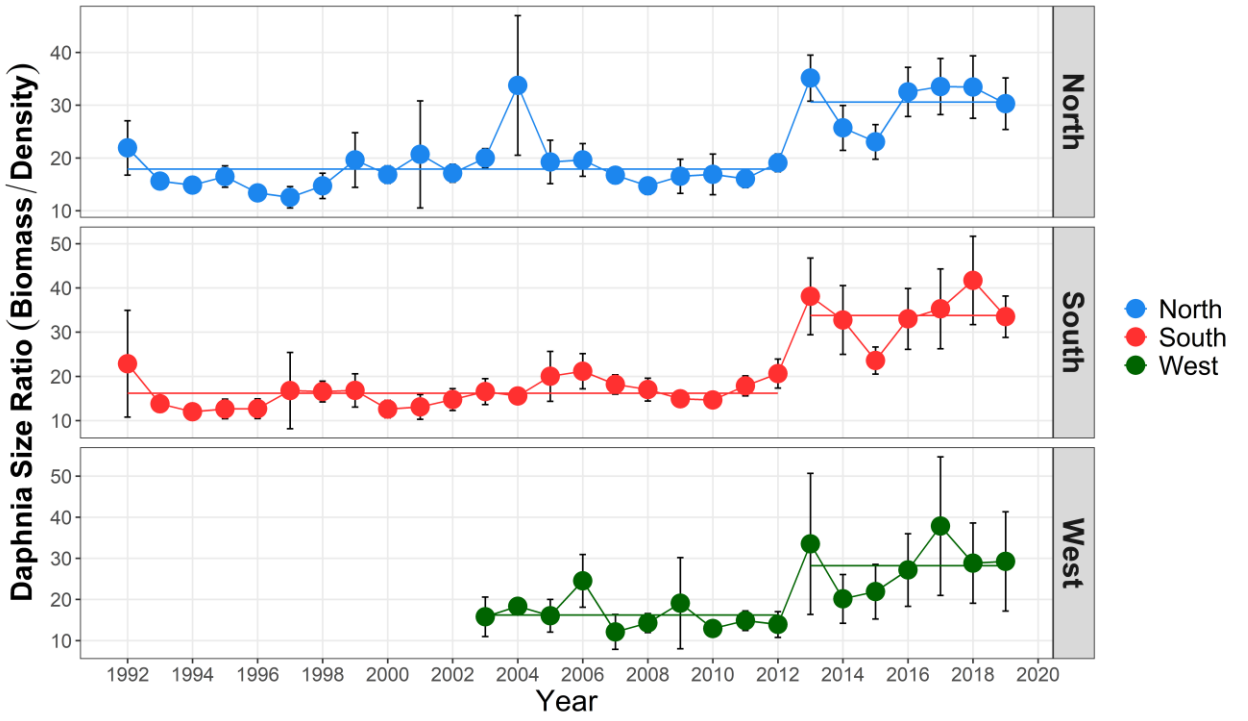


Figure 3. Kootenay zooplankton *Daphnia* size *(*biomass/density) annual monthly mean (April – October), by Arm. Horizontal lines are the arm means for the time series (1993-2019: North and South Arms, 2003-2019: West Arm).

Mysid densities in Kootenay lake increased in both the North and South Arms, however more substantially in the South Arm (Fig. 4). These higher results occurred mainly in the August samples, although 2019 was predominantly higher than the 1993-2018 monthly means (Fig 5). The highest result was 1304 ind/m^2, at KL5 (the furthest north station in the South Arm), the sample was mainly immature individuals.

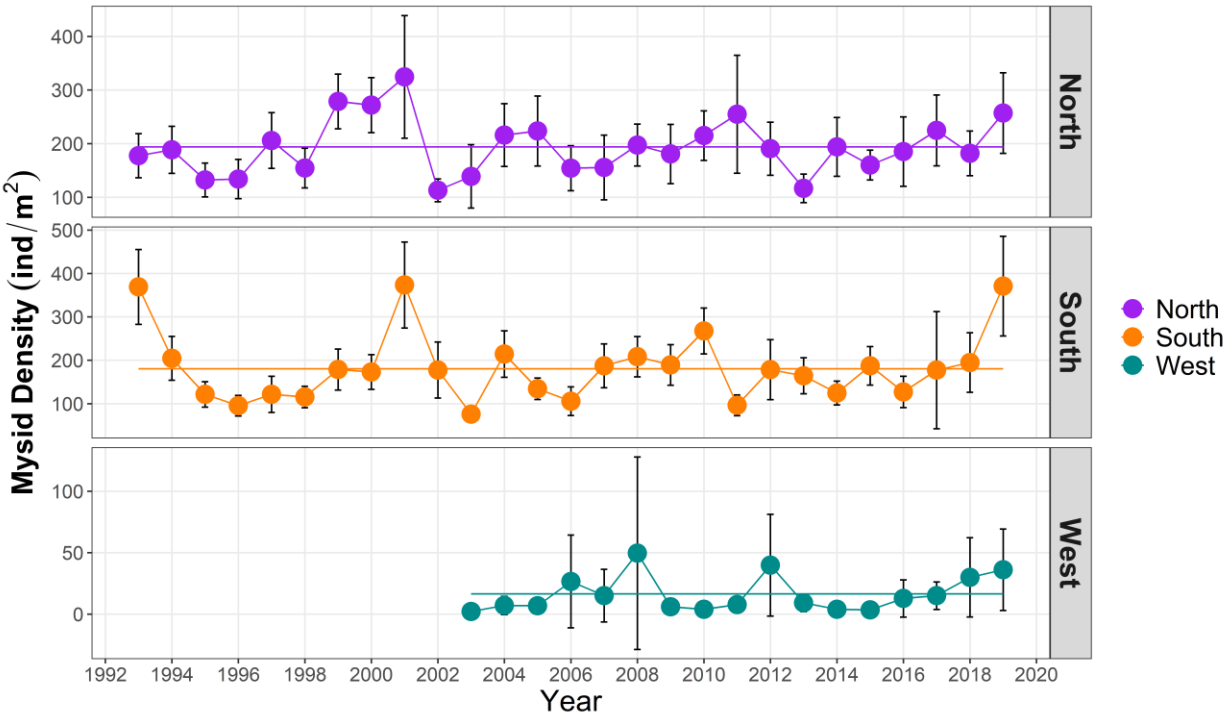


Figure 4. Kootenay mysid annual monthly mean (April – October), density (ind/m^2) by arm. Horizontal lines are the arm means for the time series (1993-2019: North and South Arm, 2003-2019: West Arm).

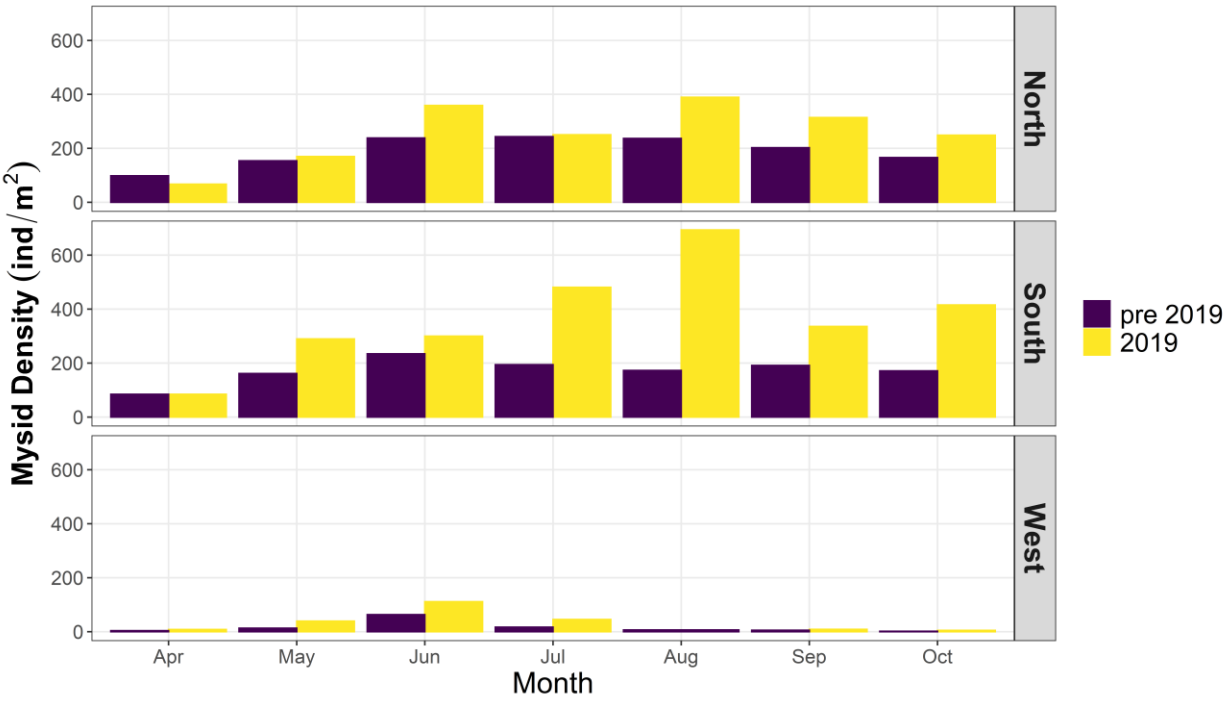


Figure 5. Kootenay mysid monthly mean (April – October), density (ind/m^2) by arm. Comparison between the 2019 monthly means (yellow bars) and 1993-2018 monthly mean (purple bars)

In 2019, there were approximately 63,300 spawners that returned to the north end of Kootenay Lake to Meadow Creek and Lardeau River. Roughly 33,700 were enumerated at Meadow Creek, both in the spawning channel and downstream. Another ~ 30,600 were counted in the Lardeau system. This is still a substantial decrease from the historic time series (Fig. 6A), however is the highest return since 2015 (Fig. 6B). Considering the mean fecundity and sex ratio measured at Meadow Creek Spawning Channel, this equates to an approximate egg deposition of 22 million eggs. This is roughly 20% of the 1980-2019 long term average for annual egg deposition (data not shown); however as exceptional egg to fall fry survival has occurred over the previous 5 years the 2020 fall fry estimate is likely be near 12 million fry, which is within 1 SD of the post nutrient era mean (1993-2011 – pre-collapse era).

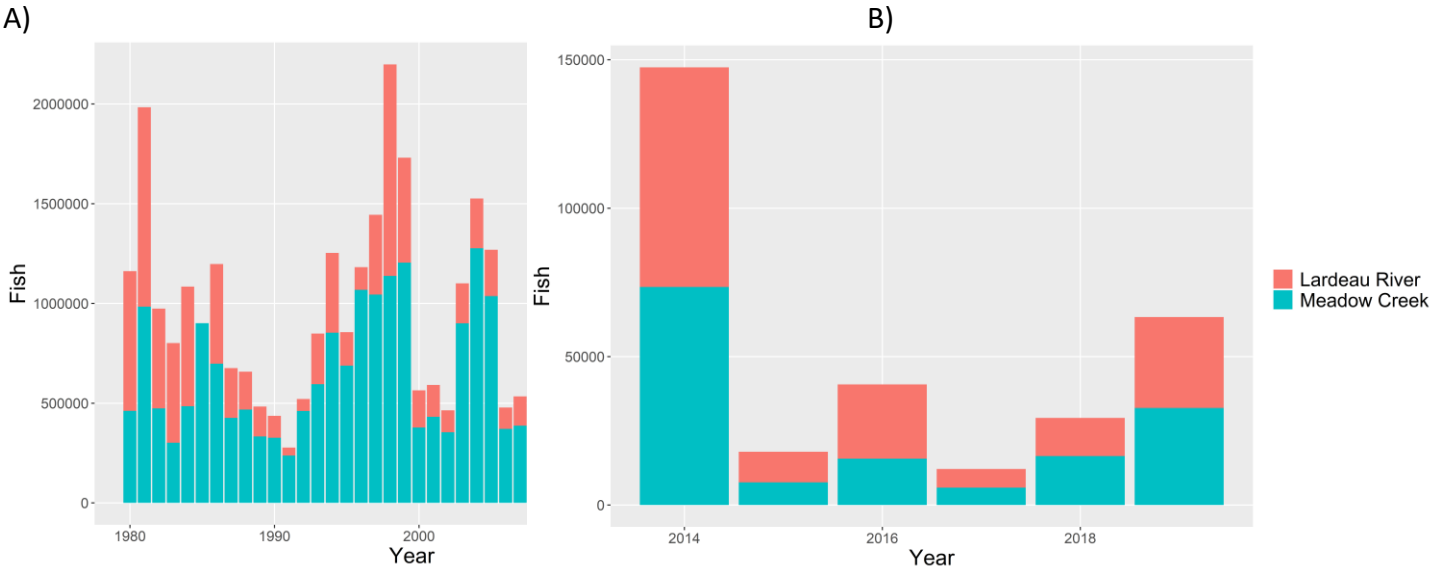
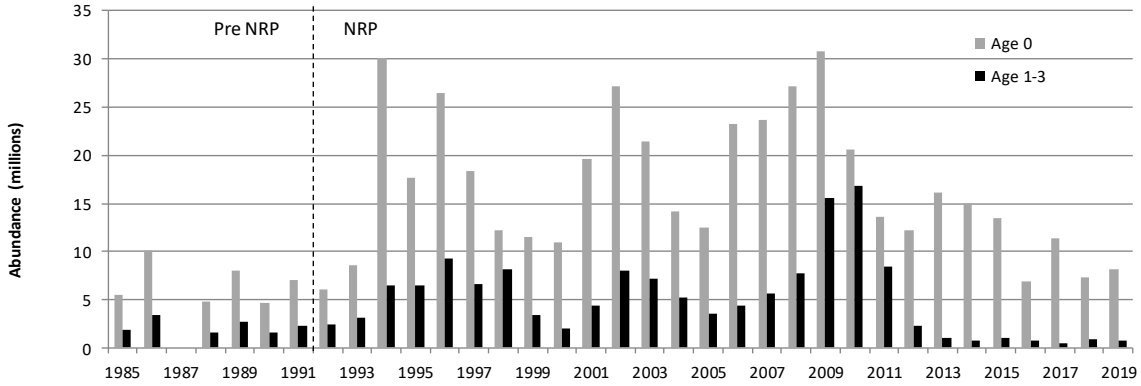


Figure 6. Number of Spawners returned to North Arm of Kootenay Lake. Red bars are Lardeau River spawners and blue bars are Meadow Creek spawners (spawning channel and creek combined). A) 1980-2019 B) 2014-2019.

The in-lake abundance in 2019 has not deviated from the recent trends since 2013, particularly for the Age 1-3 age class (Fig 7). The Age 0 class has not shown the same dramatic drop as the older age classes likely due to the high egg to fry survival rates as well as egg plants into Meadow Creek Channel. The 2019 Age 1-3 in lake abundance shows a slight improvement from 2017 and is similar to the 2018 estimate.

A)



B)

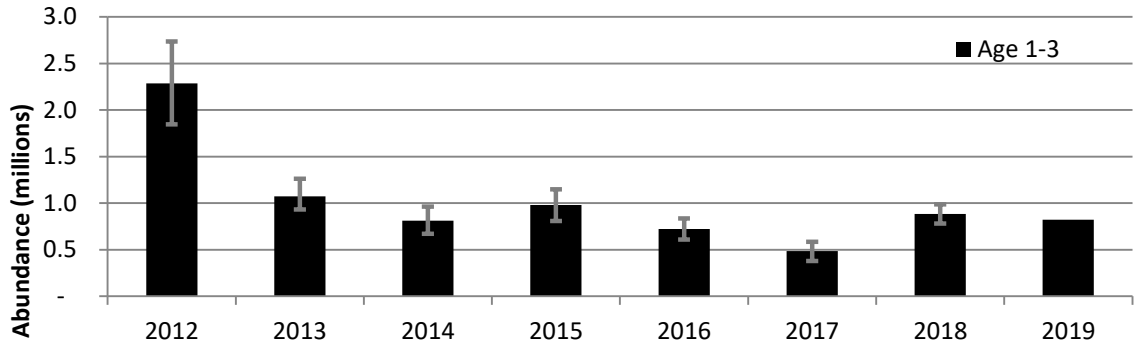


Figure 7. Acoustic abundance trends for Age 0 and Age 1-3 kokanee from fall surveys of Kootenay Lake from 1985-2019 (A) and Age 1-3 only for 2012-2019 (B). 2019 data are preliminary.

The Standing crop in-lake kokanee biomass from acoustic survey and spawner biomass (Lardeau and Meadow Creek) are shown in Figure 8.The substantial increase in 2019 biomass was primarily due to the highest Age 2 abundance since 2013.

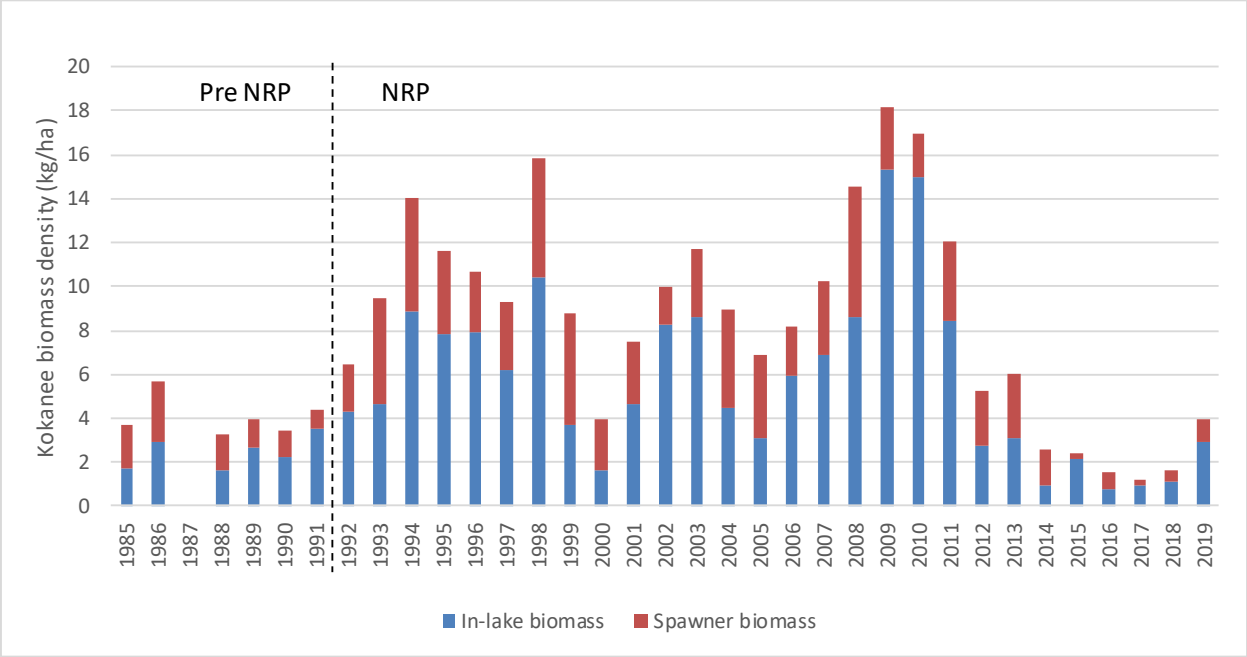


Figure 8. In-lake and spawner kokanee biomass density (kg/ha) estimates for Kootenay Lake.

The spawner return for 2020 has been predicted from a regression model between large acoustic targets from the fall survey and following year spawner numbers. In the fall of 2019, there were the highest number of these large acoustic targets since 2013 resulting in a predicted estimate for Meadow Creek and Lardeau combined in 2020 of ~100,000 spawners (Fig. 9).

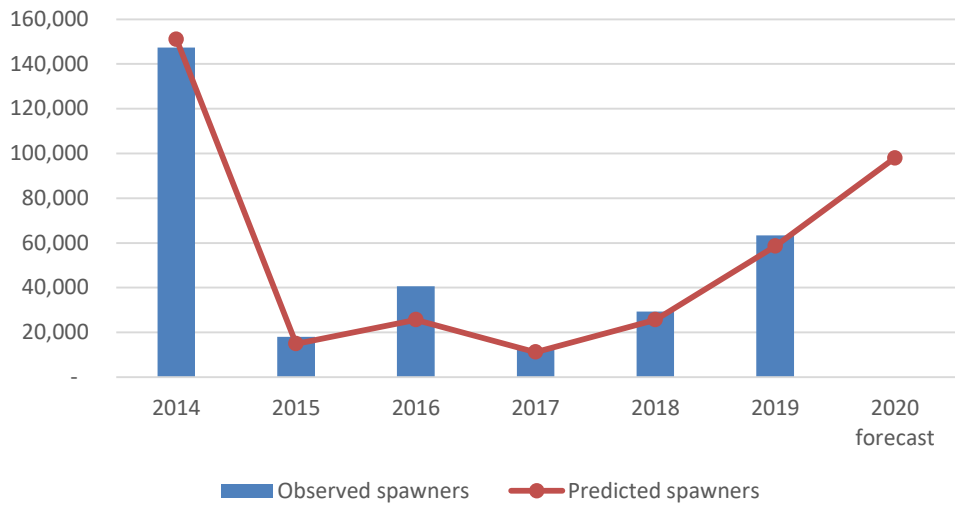


Figure 9. Observed (2014-2019) and predicted spawners (2014-2020) for Kootenay Lake.

Kokanee survival trends based on acoustic size partitioning in illustrated in Figure 10. The survival trend for age 0 to age 1 remains basically unchanged since 2013. The age 1 to age 2 survival increased substantially in 2018, validated by increased spawner numbers in 2019. The age 1 to age 2 survival remains high and was validated by a relatively large trawl catch of Age 2 fish in fall 2019

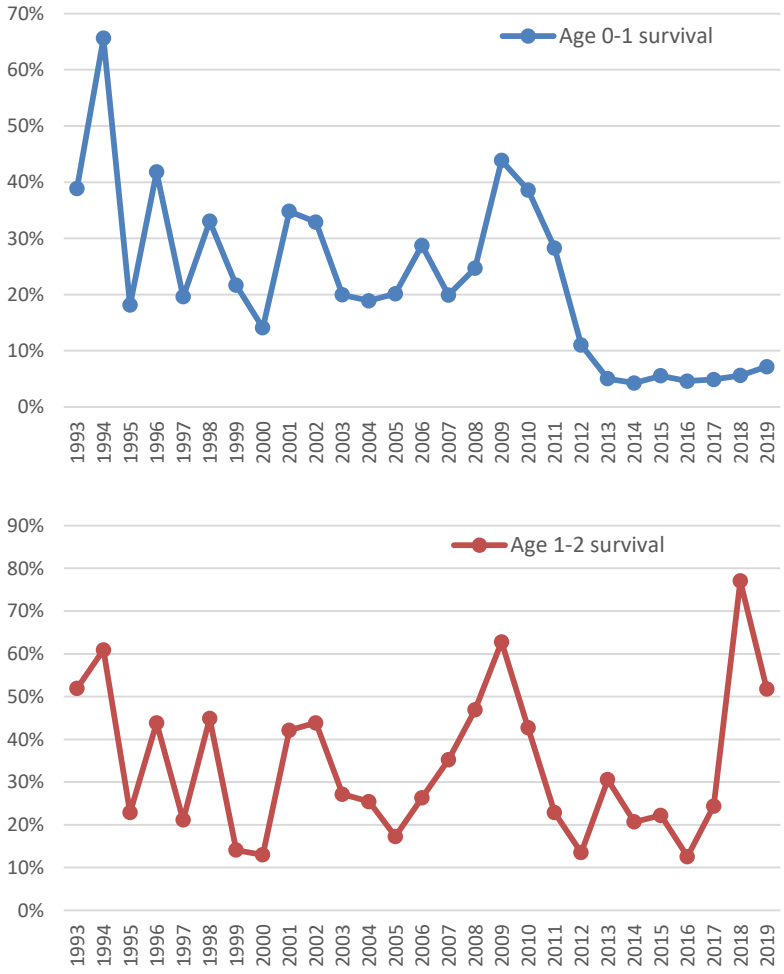


Figure 10. Age 0 to Age 1 (blue) survival rates and Age 1 to Age 2 (red) survival rates by year 1993-2019 for Kootenay Lake.

A total of 423 bull trout redds were counted in eight tributaries in 2019 (Table 1). Unusually high fall precipitation (Fig. 11) compromised the redd counts on some of the tributaries and resulted in not all scheduled streams were able to be completed. There were also some logistical issues on Midge Creek due to the timing of the helicopter. An analysis of the relationships between redd numbers and discharge for all streams in the time series is currently under review.

Table 1. Summary of Bull Trout redd count results for Kootenay Lake tributaries in 2019.

Stream Name	2019 Redd Count	Comments	Previous Count Date range
Upstream Flip Bucket Fish Count - Duncan Dam	na	five transfers with no counts	-
Hamill (including Clint)	na	cancelled due to weather conditions	29 Sep - 15 Oct
Poplar	0	count incomplete due to high flows	2 Oct - 12 Oct
Meadow Creek (including Matt)	38		28 Sep - 4 Oct
North Arm tributaries			
Crawford	91	upper/mid sections only; lower too high to count	3 Oct - 17 Oct
Kaslo-mainstem	131	HCTF data	1 Oct - 5 Oct
Kaslo-Keen Creek	33	HCTF data	1 Oct - 5 Oct
Coffee	14	count delayed to allow flow to decline	5 Oct - 17 Oct
Central tributaries (North Arm)	269		
Midge-mainstem & Kutetl	57	2 km missed	3 Oct - 12 Oct
Midge-Seeman (incl. Wurttenberg)	47		3 Oct - 12 Oct
Midge-Conway	1		3 Oct - 12 Oct
Midge - Total	**105**		3 Oct - 12 Oct
Cultus	11		4 Oct - 13 Oct
South Arm tributaries	**116**		
TOTAL REDD COUNT	**423**		

Figure 11. Photographs of Crawford Creek – on the left is the upper reach on October 16, and on the right is the lower reach 2 days later.

Discussion and Recommendations

Daphnia biomass continues to be higher than the long term average due to the current state of low kokanee numbers in the lake. Conclusions from a peer review of phytoplankton and zooplankton populations indicated that nutrient additions have been successful over the duration of the project by providing sufficient zooplankton as a food source for kokanee (Schindler et al. 2020). There are signs of kokanee recovery with the improvement of age 1 to 2 survival and a predicted higher number of spawners (in the North Arm) for the fall of 2020. There were also a higher number of spanwers in 2019 compared to 2018. Bull trout redd count conditions were not as suitable in some tributaries in 2019 due to higher discharge in some tributaries.

Fisheries management in FLNRORD have taken various steps to improve kokanee recovery (some steps are itemized in the Kootenay Lake Action Plan, 2016). These include kokanee eyed egg supplementation in Meadow Creek from 2015 – 2019, kokanee fry stocking in Crawford Creek and Meadow Creek – spring of 2016-2019, kokanee angling closure in the main lake – 2015-2019, liberalizing harvest rates of rainbow trout and bull trout in the main lake, opening a bull trout fishery on the Duncan River, June to September 2019, bull trout kelt fence installations for bull trout removal – Hamill Creek (2018) and Kaslo River (2018 and 2019). The most recent work (spring 2020) is the commencement of an angling incentive program to promote angling opportunities; this will hopefully continue to alleviate predation pressure on the kokanee.

Recommendations for the nutrient programs include continuing with nutrient additions to ensure *Daphnia* abundance is sufficient to provide food to kokanee and therefore supporting kokanee recovery. Consider Independent Science Review Panel' s review of the partnered Kootenai Tribe of Idaho South Arm nutrient restoration program through Kootenai Tribe of Idaho be applied to nutrient effectiveness review of North Arm program in F21 (the review was based on lake-wide results).Consider peer-review of phytoplankton/zooplankton CJFAS paper (Schindler et al. 2020) as a component of the nutrient effectiveness review in fall 2020/spring 2021.

Acknowledgements

This project was prepared with financial support Fish & Wildlife Compensation Program on behalf of its partners, BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations, and Public Stakeholders to conserve and enhance fish and wildlife in watersheds impacted by BC Hydro dams. Additional funding was provided by BCHydro Water License Requirements. Funding was also provided by the Kootenai Tribe of Idaho (KTOI) for the project. The KTOI receives funding from the Bonneville Power Administration through the Northwest Power and Conservations Council's Columbia Basin Fish and Wildlife Program. Thanks to the British Columbia Conservation Foundation and Fish and Wildlife Compensation Program for administering a portion of the funding provided by KTOI. A list of contributing personnel to the project is listed in Appendix 1.

References

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Appendix 1. Kootenay Lake NRP – Personnel - 2019

Project Focus	Personnel - Affiliation
Project co-ordination, management and scientific liaison	Marley Bassett - Resource Management, FLNRORD Kristen Peck - Resource Management, FLNRORD
Report compilation	Marley Bassett - Resource Management, FLNRORD Tyler Weir - Fish and Aquatic Habitat Branch, FLNRORD David Johner - Fish and Aquatic Habitat Branch, FLNRORD Rob Fox - Resource Management, FLNRORD
Report editing and review	Eva Schindler - Resource Management, FLNRORD Steve Arndt - Resource Management, FLNRORD
Fertilizer schedule, loading	Marley Bassett - Resource Management, FLNRORD Eva Schindler - Resource Management, FLNRORD Ken Ashley - BC Institute of Technology Rivers Institute
Fertilizer supplier	Alan Jelfs - Agrium
Fertilizer application	Graham Marine, Balfour, BC Crescent Bay Construction - Crescent Bay Construction
Physical limnology, water chemistry, phytoplankton, zooplankton and mysid sampling	Golder Associates Ltd. Staff - Golder Associates Ltd. Marley Bassett - Resource Management, FLNRORD Rob Fox - Resource Management, FLNRORD Dave Heagy BC Parks, ENV Tom Roos - BC Parks, ENV
Chemistry analysis	ALS Global staff - ALS Global
Chlorophyll analysis	ALS Global staff - ALS Global
Phytoplankton analysis	Advanced Eco-Solutions Inc.
Zooplankton and mysid analysis	Dr. Lidija Vidmanic, Limno-Lab Ltd., Vancouver
Kokanee acoustic surveys	Tyler Weir - Fish and Aquatic Habitat Branch, FLNRORD David Johner - Fish and Aquatic Habitat Branch, FLNRORD
Kokanee trawling	Golder Associates Ltd. Staff - Golder Associates Ltd. Tyler Weir - Fish and Aquatic Habitat Branch, FLNRORD David Johner - Fish and Aquatic Habitat Branch, FLNRORD
Kokanee aerial spawner surveys (Lardeau/lower Duncan River)	Marley Bassett - Resource Management, FLNRORD Murray Pearson – Resource Management, FLNRORD Mark Homis - Highland Helicopters
Kokanee ground spawner surveys (South Arm)	Rob Fox - Resource Management, FLNRORD Tim Davis - Resource Management, FLNRORD Katrina Caley - Ktunaxa Nation Council Stefan Himmer – Arctos Wildlife Services Eugene Volokov – Reel Adventures
Kokanee analysis and Reporting	Tyler Weir – Fish and Aquatic Habitat Branch, FLNRORD David Johner - Fish and Aquatic Habitat Branch, FLNRORD
Kokanee scale ageing	Morgan Davies - BC Provincial Aging Lab - FFSBC Carol Lidstone - Birkenhead Scale Analyses
Bull Trout Redd Counts	Greg Andrusak – Fish and Aquatic Habitat Branch, FLNRORD Steve Arndt – Resource Management, FLNRORD Rob Fox – Resource Management, FLNRORD Jeremy Baxter, Al Irvine, Jimmy Robbins – Mountain Water Research Ico DeZwart, Rachel Pennell – Masse Environmental Consulting Jeff Berdusco - BCCF Stefan Himmer – Arctos Wildlife Research Kerry Reed – Reel Adventures
Meadow Creek Spawning Channel monitoring	Murray Pearson – Resource Management, FLNRORD Steve Arndt – Resource Management FLNRORD
Regional support	Irene Manley – Resource Management, FLNRORD Jeff Burrows - Resource Management, FLNRORD Matt Neufeld - Resource Management, FLNRORD