Lotic Environmental

Specialists in Freshwater Ecosystems

Kootenay Lake Fisheries Advisory Team Workshop Summary, May 15/16, 2018

Final Report

October 2018

Prepared for
BC Ministry of Forests, Lands, natural Resource Operations and Rural Development
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Suggested Citation

McPherson, S. 2018. Kootenay Lake Fisheries Workshop Summary, May 15/16, 2018. Prepared by Lotic Environmental Ltd. for the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Nelson.

Acknowledgements

I wish to thank all of the scientists and managers comprising the Kootenay Lake Fisheries Advisory Team for their valued input. Their fisheries knowledge and expertise specific to Kootenay Lake were used directly to prepare this report. I would also like to express my appreciation to Jeff Burrows and Matt Neufeld, for their guidance, review, and technical contributions to this report.

It has been a pleasure facilitating this important process. Please do not hesitate to contact me with any inquiries about this document.

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Cover photos: Kootenay Lake (left), Kokanee (top right, Fish and Wildlife Compensation Program), Gerrard rainbow trout (bottom right, Barrie Kovish).

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1 Introduction

Kootenay Lake supports one of British Columbia's most important large lake sport fisheries. The trophy sized Gerrard Rainbow Trout (Gerrard) are prized by anglers, and are important economically and recreationally. Bull Trout, which also grow to a large size, are highly valued as well. The Gerrard fishery is in decline, with poor fish condition, and few large fish. Current data indicates that a leading cause for this is an imbalance between predator (Gerrard and Bull Trout) and prey (Kokanee) abundance.

The objective of the Kootenay Lake Fisheries Advisory Team (KLAT) is develop and implement the Kootenay Lake Action Plan (the Plan), which is aimed at recovering populations of Kokanee, Gerrard, and Bull Trout. The Team has met and developed plans over the last few years, starting in 2015, with two workshop summary reports (Lotic Environmental Ltd 2015[1],[2]); and resuming in 2016, with the development of the Kootenay Lake Action Plan (Redfish Consulting Ltd 2016; the 2016 Action Plan)[3]. The 2016 Action Plan was comprehensive, identifying actions, tools, triggers/measures/targets; rationale, benefits/risk; and rank.

Following two years of Action Plan implementation, the Region invited the KLAT to participate in a workshop on May 15/16 2018, in Nelson BC. The objectives of the workshop were to:

1. Review associated biological response,
2. Review any additional new data.
3. Provide recommendations on actions required to aid fish population recovery

KLAT are members based on their fisheries science and management expertise/responsibility pertinent to benefitting Kootenay Lake fisheries. The KLAT are representatives from: the Ktunaxa Nation; Freshwater Fisheries Society of BC (FFSBC); BC Wildlife Federation; BC Ministry of Environment (BC MoE); and BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). Members in attendance at the May 15/16 workshop are identified in Appendix A.

This report is a summary of the May 2018 workshop. An overview map of Kootenay Lake, showing locations of relevance is provided below (Figure 1).

[1] Lotic Environmental Ltd. 2015. Kootenay Lake fisheries meeting summary, March 12/13, 2015. Prepared for the Ministry of Forests, Lands and Natural Resource Operations.

[2] Lotic Environmental Ltd. 2018. Kootenay Lake Fisheries Meeting Summary, October 2, 2015. Prepared for the Ministry of Forests, Lands and Natural Resource Operations.

[3] Redfish Consulting Ltd. 2016. Kootenay Lake Action Plan. Prepared for the Ministry of Forests, Lands and Natural Resource Operations

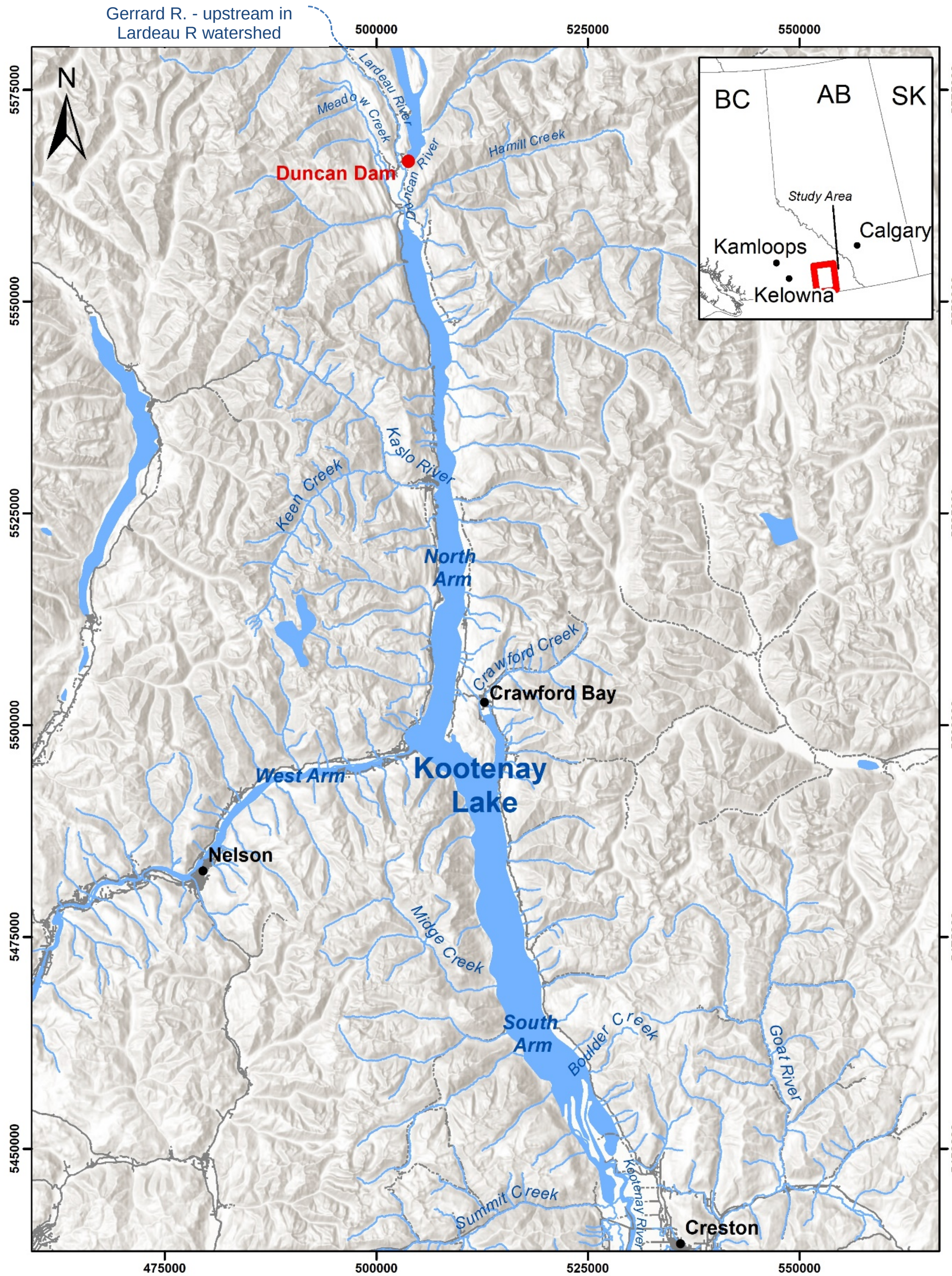


Figure 1. Kootenay Lake, and locations of relevance

2 Background information and biological response update

Historical background information and data were presented, showing the biological responses since implementation of the 2016 Plan. Presentations were all encompassing, including: Kokanee and piscivore spawner and in-lake estimates, piscivore fishery trends, other piscivore in-lake sampling data, Kootenay Lake Kokanee dynamics with a stock recruitment approach, and the nutrient restoration program Appendix B. This information was presented by Matt Neufeld, Tyler Weir, David Johner, Jeff Burrows, Eva Schindler, Hillary Ward, Kristen Peck, Rob Bison and Steve Arndt.

Highlights of these presentations are largely provided in this section, with some material also nestled in subsequent sections (Section 3 - Review of actions, triggers, and 2016 – 2018 implementation; Section 4 - Effective actions taken since 2015 - round-table discussion; and Section 5 - Areas requiring potential improvement/updates – guided by key questions).

2.1 *Kokanee*

2.1.1 Kootenay Lake spawner numbers, potential egg deposition, fry production (Matt)

Kokanee spawner count data has been collected since 1964 (and since 1980 for comparable modern lake and tributary conditions) for both the Lardeau River and Meadow Creek populations (north arm tributaries). In 2011, the number of observed spawners was 1.7 million fish. Since 2011, spawner numbers have been declining steadily, with the lowest count on record in 2017 at 12,074 fish (Figure 2). In 2018, Kokanee spawners are not expected to recover, with spawner predictions between 30,000 and 40,000.

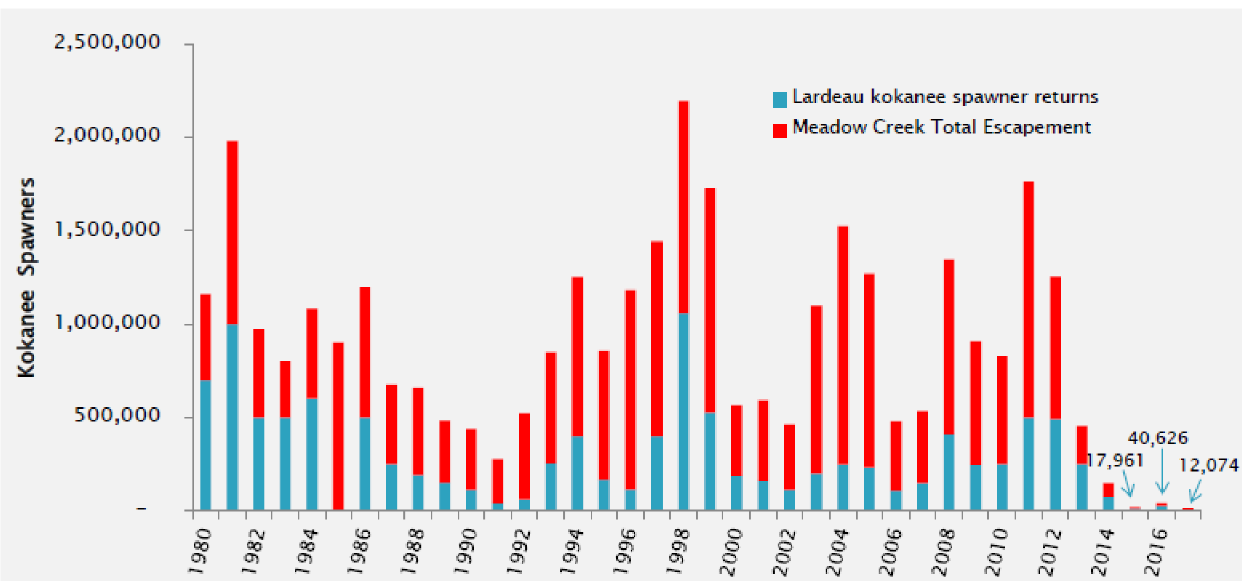


Figure 2. Total Kokanee escapement, North Arm Kootenay Lake 1980-2017 (FLNRORD, data on file).

Other indications of declining Kokanee population status, from spawning stream monitoring data were:

- Kokanee spawner biomass has been low since 2015, with 2017 biomass at <0.5 kg/ha. In contrast, the highest spawner biomass was >5 kg/ha in 2008.
- Egg deposition has been lower than normal in recent years. Approximately 150 million eggs were deposited in 2011, and there were less than 25 million in 2015 to 2017 (including supplemented transplants from outside of Kootenay Lake).

Kokanee data from spawning tributaries that indicate normal and/or compensatory life-stages during recent years were:

- Since 2014, spawner fork length has been the highest of all years sampled. In 2017, mean spawner fork length was 300 mm.
- Egg to fry survival has been normal or (higher than normal) since 2012. In 2017, egg to fry survival was 40%.
- Finally, spring fry to fall fry survival is typical and not low.

2.1.2 Kokanee in-lake estimates (Tyler/David)

Kokanee in-lake abundance data from fall acoustic surveys showed a marked decline in age 1 to 3+ aged fish since 2012 (Figure 3). Abundance in 2017 for age 1 to 3+ Kokanee was the lowest of all years sampled (< 0.5 million fish). This was a contrast to 2012, which had approximately 2.4 million age 1-3+ Kokanee, and to 2009, which had greater than 15 million.

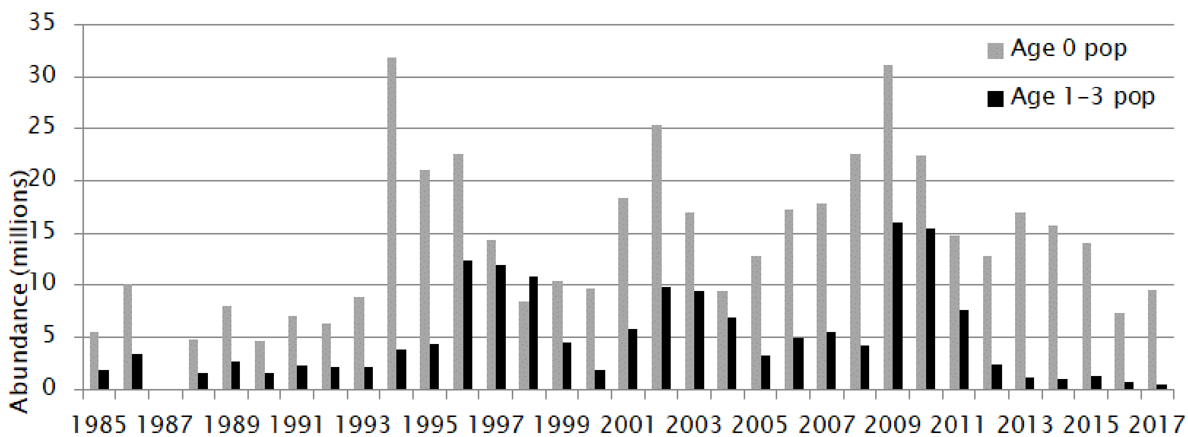


Figure 3. Acoustic abundance trends for age 0 and age 1-3+kokanee from fall surveys of Kootenay Lake (2017 data are preliminary).

Other items of potential concern for Kokanee evident from in-lake monitoring results were:

- Kokanee biomass density estimates showed a decline in in-lake values since 2011. In 2011 Kokanee biomass was approx. 8 kg/ha, and in 2017 biomass was <1 kg/ha (Figure 4).
- Size and condition (Fulton's K) of age 1 Kokanee has been well below average since 2013, which was unexpected given the abundant zooplankton available over this period. This could be a symptom of a change in feeding behaviour required to avoid predation.
- Age at maturity has been dominated by age 3 and has not shifted to age 2. Low densities and excellent zooplankton resources should have led to rapid growth and earlier

maturation. No change in age at maturity is likely a result of poor age 1 size/growth. Kokanee that survived beyond age 1 grew exceptionally well.

- Age 0-1 survival has been consistently at an all-time low since 2012 (~5-7%).

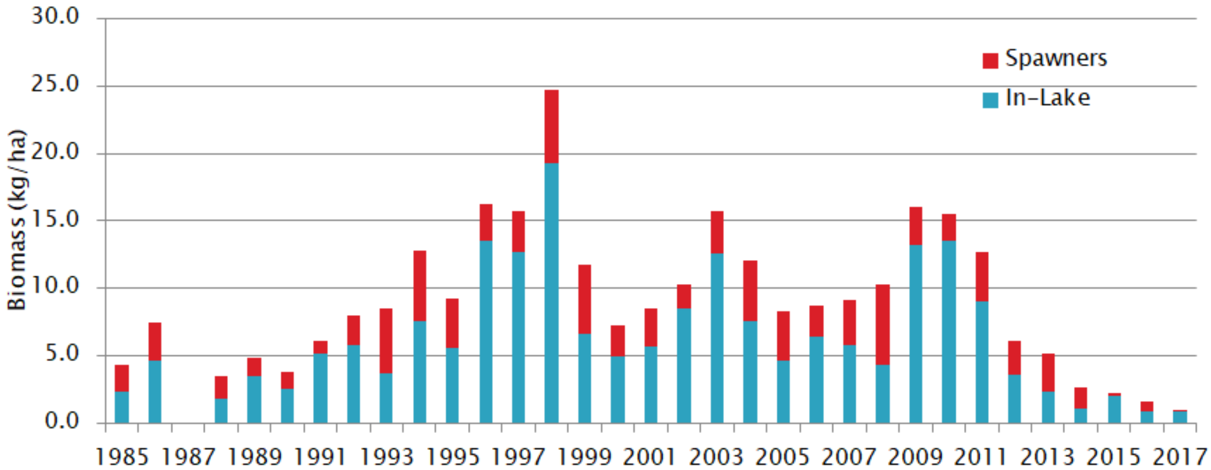


Figure 4. Kokanee biomass density estimate for Kootenay Lake.

Kokanee results that indicated normal values relative to the historical dataset were:

- Age 0 Kokanee abundance was within the normal range of previous years sampled. 2017 values were nearly 10 million fish (Figure 3).
- Age 0 Kokanee mean fork length has been above average since 2012 (2015 and 2016 were record highs), indicating fry have been benefiting from the increased zooplankton availability.
- Age 2 and older Kokanee (in-lake and spawner) size has been at record highs in recent years, indicating the expected compensatory growth has occurred during the period of reduced abundance.

2.2 *Piscivores (Matt)*

2.2.1 Gerrard Rainbow Trout – spawner abundance trends and biological data

From data collected at Gerrard River and throughout the Lardeau River, there were several indications of declines in the Gerrard Rainbow Trout population in recent years:

- Spawner abundance has declined in the last two years. Spawner abundance peaked in 2012 (~1500 fish), and this steadily declined to be ~300 fish in 2016 and ~190 fish in 2017 (Figure 5).
- Juvenile (age 1+) numbers were low following a very similar trend to spawner numbers.
- Gerrard Rainbow Trout spawner size has declined. Mean fork lengths in 2016 and 2017 were 58 and 53 cm, respectively; whereas, the range from 1979 to 2015 was 72 – 83 cm.

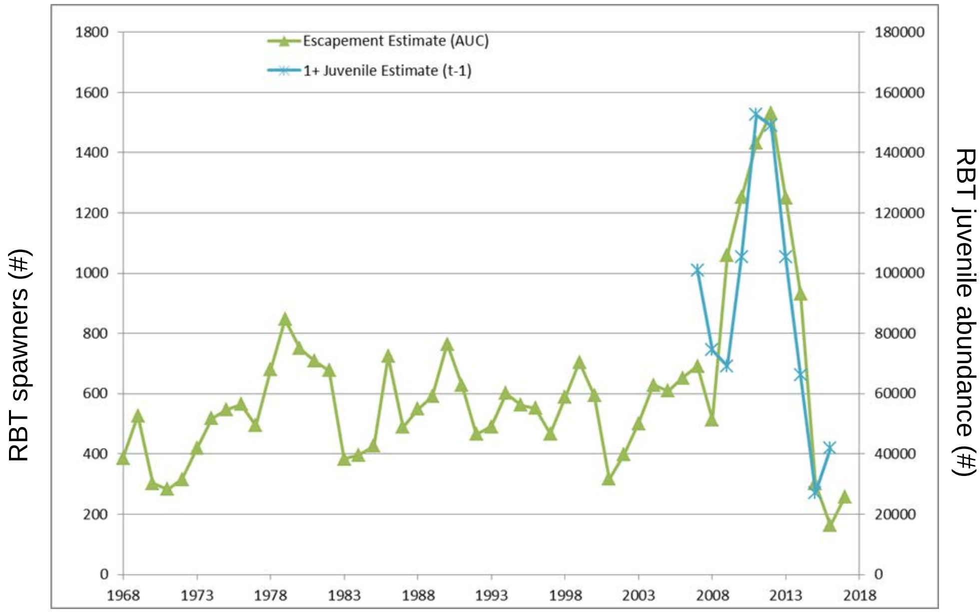


Figure 5. Gerrard Rainbow Trout escapement (spawner) and juvenile abundance estimates (juvenile estimates from Andrusak, adult escapement from Nelson FLNRORD).

Spawner mean age was relatively stable, at 5.8-5.9 years in 2016 and 2017. Although the current in-lake (age 1-4) survival is unknown, as a result of the declining juvenile supply, future in-lake abundance reductions are possible.

2.2.2 Bull Trout –spawner abundance trends and biological data

Bull Trout spawner abundance, as measured in index tributaries, found 2017 to be similar to 2013 (~3500 fish; Figure 6). 2017 showed a large increase since 2015 (~1250 fish). It is unclear whether this represents changes in spawning frequency, or actual changes to in-lake bull trout abundance. In 2017, the most spawners were in Hamill Creek and Kaslo River, representing over half of all spawners of those streams counted (index streams).

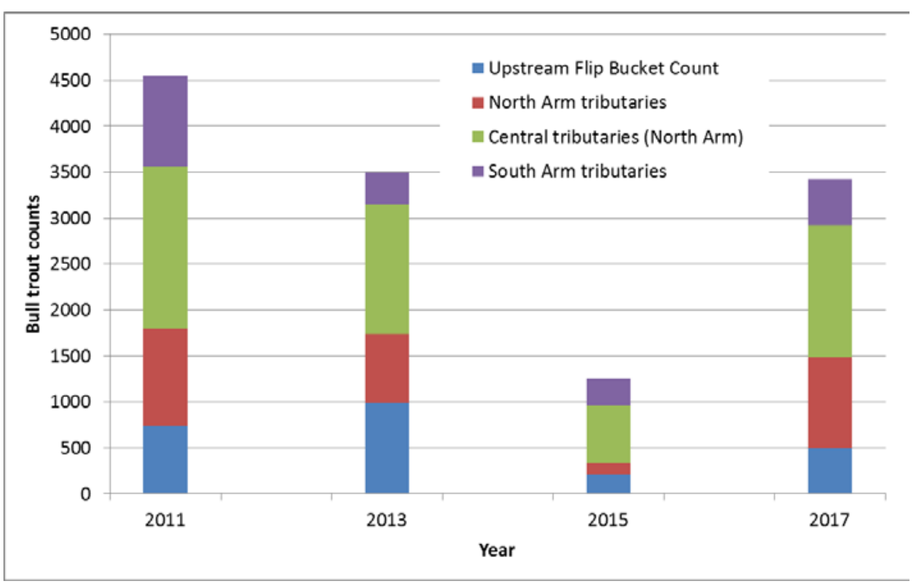


Figure 6. Kootenay Lake Bull Trout escapement estimates.

2.2.3 Rainbow Trout fishery trends and inferred in-lake abundance

Kootenay Lake Rainbow Trout (KLRT) creel survey data showed a decline in effort from 2013 to 2016 (~40,000 - ~15,000 angler days per year, respectively; Figure 7). The recent communication/outreach and daily quota increases have only resulted in slightly more harvest. This was evident by a reduction in release rate from 65% in 2014/15 to 55% in 2016/17. The catch per unit effort data (CPUE), indicated ~ 1 rainbow trout caught per rod day.

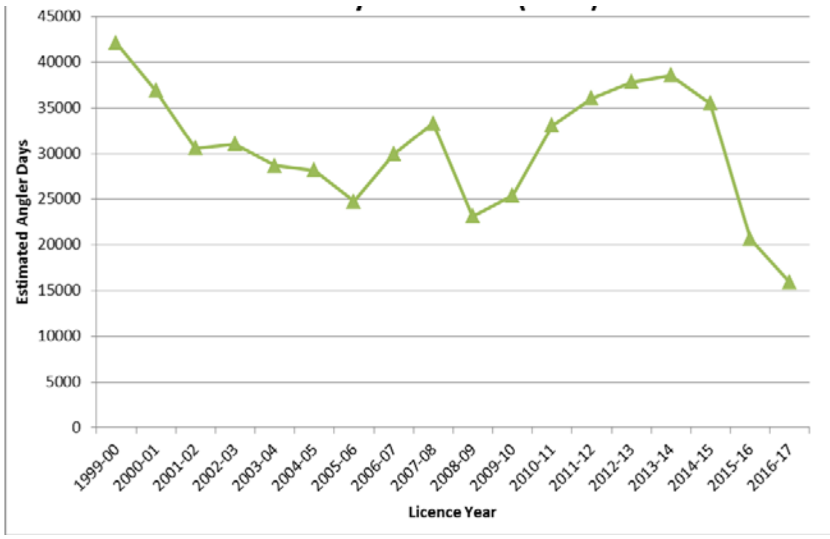


Figure 7. Kootenay Lake fishing effort (from KLRT data).

Other Rainbow Trout catch trends from KLRT data were:

- The Rainbow Trout CPUE increased over time for all size classes (Figure 8). This was matched by the increase in < 2 kg age class CPUE since 2013.
- The large size classes (2 to >7 kg) are now gone, with the catch being generally small fish.
- Since 2015, there has been a departure between the CPUE and catch trends. While the CPUE has increased, the estimated numbers of fish caught has declined.

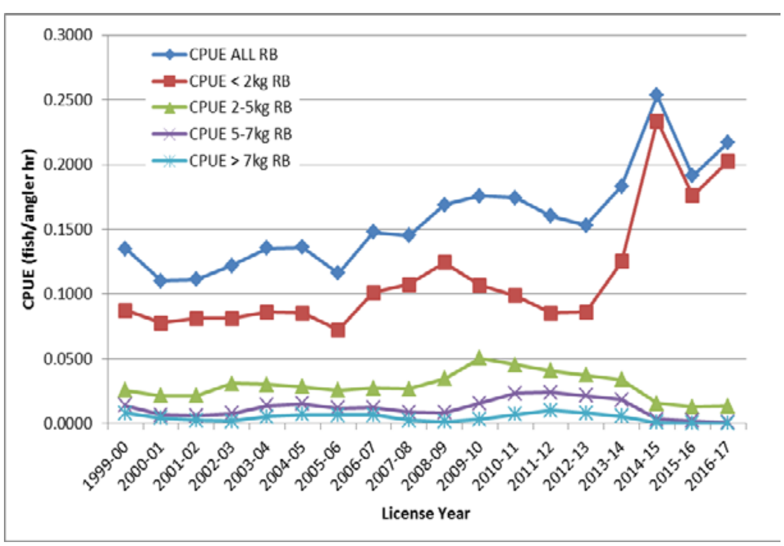


Figure 8. Rainbow Trout catch per unit effort (KLRT data)

2.2.4 Bull Trout fishery trends and inferred in-lake abundance

The general Bull Trout CPUE has increased over time (Figure 9). However, similarly to Rainbow Trout, the largest size classes (5 to >7 kg) are now gone, and the catch is now mostly small fish (<2 kg). Since 2015, there has also been declining numbers of Bull Trout caught overall.

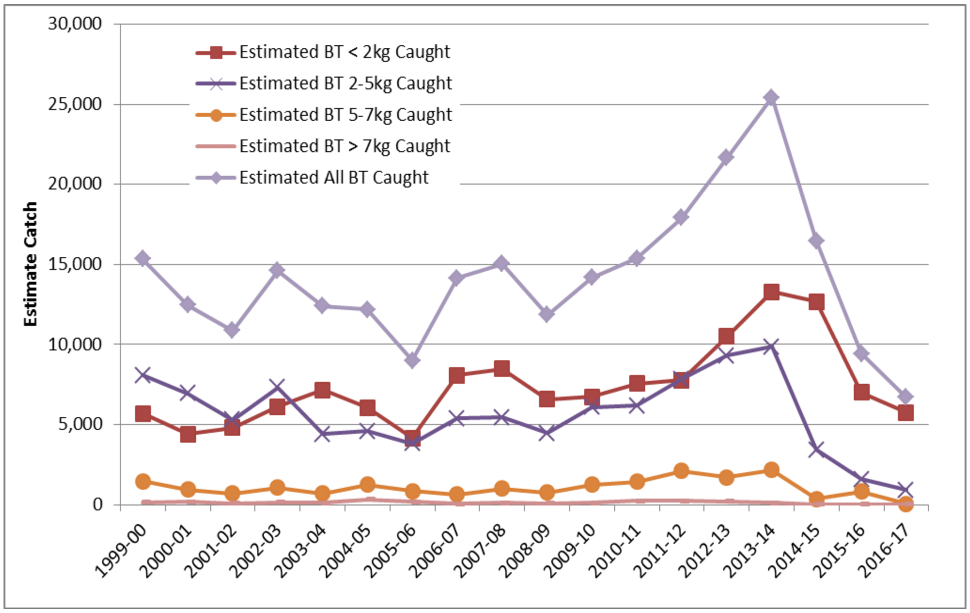


Figure 9. Bull Trout catch trend data.

2.2.5 In-lake sampling (diet, genetics, age structure, fecundities, age at lake entry, etc.)

To better inform recovery actions, the piscivore monitoring program was expanded in 2015 to include: genetic structure of mixed stock Rainbow Trout fishery (% Gerrard versus insectivores in catch), age structure, diet, maturation rate (% ripe) by ecotype, fecundity, and age at entry to lake. A summary of results are as follows:

- Genetics from 921 fish (from across 18 reference samples, and 6 mixed stock (i.e. in the lake), identified that approximately 75% of the catch were Gerrards. These results have been relatively stable since 2015.
- Morphometric measures and diet confirmed genetics:
  - Kokanee were a significant portion of diet only for Gerrards, while *Mysis* and zooplankton were more important for insectivores
  - Piscivores had a larger mouth to head ratio (i.e., to eat Kokanee).
- Scale analysis of data available in 2015-2016, suggested expected in-lake age structure, despite the lack of large fish (Figure 10).

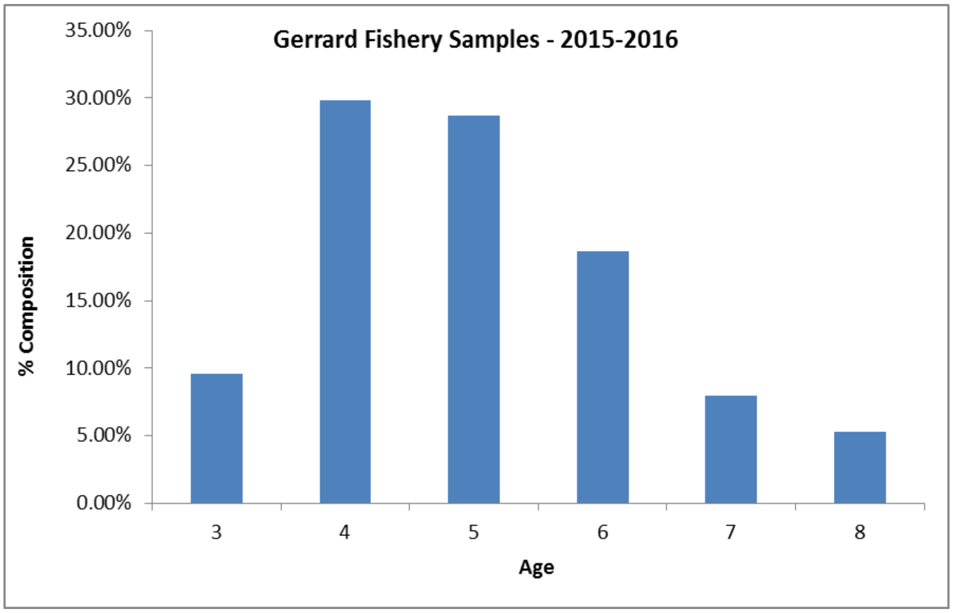


Figure 10. Gerrard age structure from scale analysis (2015-2016).

- Gerrard fecundity showed a significant decrease from historic samples, concurrent with fish size. In 1966-2004 fecundity was as high as 14,000 eggs, while in 2015-16 fecundity was <2000 eggs.
- Piscivore monitoring of diet composition, measured as % composition by mass, revealed the following:
  - In 2015 to 2017, Kokanee made up a higher proportion of the Bull Trout diet (68%), than the Rainbow Trout diet (22%). Insects were the highest proportion of the Rainbow Trout diet (36%).
  - There were seasonal shifts in diet, with Bull Trout consuming more Kokanee in the spring (90%) than fall (65%). The fall Bull Trout diet was supplemented by Mysis. Rainbow Trout diet was more diverse, or opportunistic; in the spring it was mostly insects (40%), followed by Mysis (26%), and Kokanee (28%). In the fall, the Rainbow Trout diet shifted to *Mysis* (35%), Kokanee (27%), and zooplankton (18%).
  - Rainbow Trout diet under conditions of low Kokanee abundance was different than under higher Kokanee abundance (measured historically). Specifically, there is a current shift to *Mysis* and zooplankton to offset low Kokanee availability (Figure 11). This outcome has implications for Kokanee recovery, namely, that even at unchanged future predator density, Rainbow Trout consumption of Kokanee will likely increase concurrent with Kokanee abundance increases.

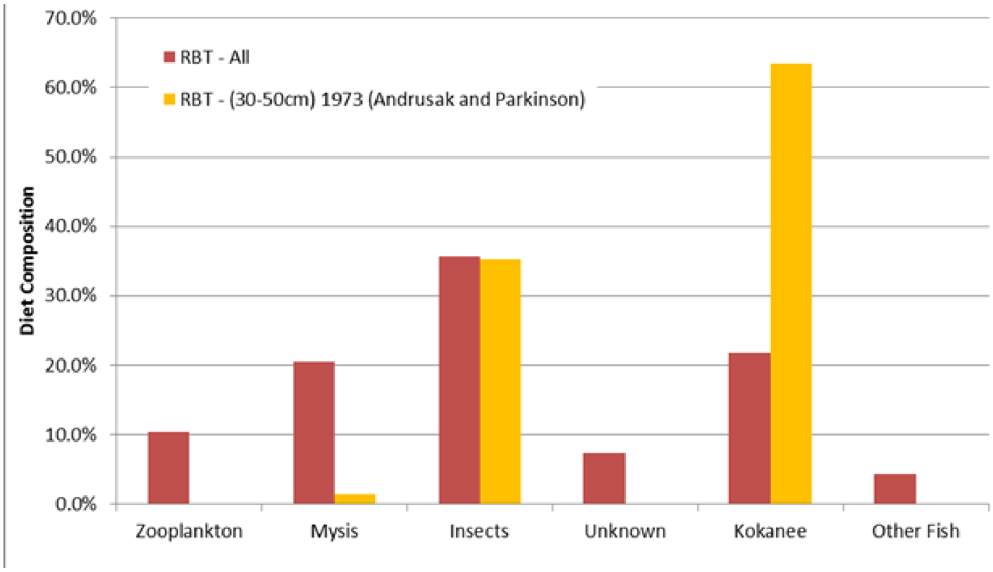


Figure 11. Rainbow Trout diet composition in 2015-2017 (RBT – all), and in 1973, corresponding with low and high Kokanee abundance, respectively.

- Gerrard rearing origin and age at lake entry were reviewed using otolith microchemistry. The study is still underway, and includes both Gerrards and insectivores to validate the approach, provide contrast, and identify if signatures differ between groups. The hypothesis is that: if fry in excess to Lardeau River capacity do not contribute to Gerrards caught in the lake fishery, then high Gerrard abundance and Kokanee collapse is driven by a change to Gerrard in-lake survival (between age 1+ and 3). If fry do contribute to Gerrards caught in the lake fishery, then a change in survival did not necessarily contribute to Kokanee collapse.
  - **POST WORKSHOP INFO:** Following the workshop a participant provided that the hypothesis about Gerrard juveniles may not be the only plausible explanation for the Kokanee decline. It is presented because it is the only data available. For example, could be Bull Trout or Sturgeon or other predators that responded to increased productivity over time. Sturgeon eat a lot of kokanee.

2.3 *Nutrient restoration program update (Kristen)*

The nutrient restoration program replaces nutrients lost behind upstream reservoirs, restoring the lake to natural productivity. Nutrient additions commenced in the North Arm in 1992, and in the South Arm in 2004. Monitoring has been ongoing since the start of the nutrient additions, and has included: water temperature, Secchi depth, water quality, phytoplankton, primary production, zooplankton, mysids, Kokanee hydroacoustics (two surveys per year), Kokanee trawl (fall survey), Kokanee spawner escapement in Duncan/Lardeau and South Arm tributaries, and Bull Trout redd surveys (in 2011, 2013, 2015 and 2017, tributaries in addition to the Kaslo and Keen tributaries). The Kokanee and Bull Trout redd count information was presented in other sections of this document. Key nutrient monitoring results were:

- Phytoplankton (both edible and inedible) bio-volume (mm^3/L) has been consistent, with seasonal variation within a sampling season.
- Zooplankton biomass, presented as annual mean *Daphnia* biomass from April to October, reveal higher than average values since 2012. *Daphnia* is a preferred food source for

Kokanee and these results indicate that there is above average food available. *Daphnia* has increased likely due to a lack of grazing pressure from Kokanee.

- Mysids and Kokanee both eat zooplankton. In the absence of high Kokanee biomass, there is a risk that the mysid population could increase. However, the monitoring results indicate that the mysid standing crop biomass has been stable.
- Kokanee spawner counts were conducted in South Arm tributaries (Crawford, Boulder, Goat, Summit, and Midge creeks). These tributaries, in 2017, made up 5 to 10 % of Kokanee spawners from Kootenay Lake.

  POST WORKSHOP INFO:

  - o Although historic South Arm spawner data are limited, South Arm Kokanee are not believed to have comprised this high of a proportion of total spawners in recent history. This suggests that South Arm spawning Kokanee survived at a higher rate than North Arm spawners for one or more cohorts. The reason(s) are unknown, but could include reduced competition from formerly strong North Arm stocks (including significantly increased egg to fry survival resulting from much larger spawners), and possibly lower Bull Trout numbers. There is currently insufficient data to determine whether South Arm spawner replacement is consistently higher than that of North Arm spawners, or what years it has been.
  - o This seems to assume the South Arm fry remain in South Arm. These could be strays from North Arm or Libby entrainment. Genetics could help answer these questions.
- Over the years of nutrient restoration program, there has been annual variation in phosphorus inputs to the lake (fertilizer and input from the Kootenai/y River and Duncan River provide the annual input). Figure 12 illustrates the pattern of Kokanee spawners, *Daphnia* biomass, and phosphorus inputs to the lake since 1992. The figure illustrates the pattern shift of *Daphnia* increasing from 2013 through 2017, while Kokanee spawners decreased from previous years. When Kokanee populations increase, it is expected that the trend in *Daphnia* biomass will decrease as there would be additional grazing pressure.

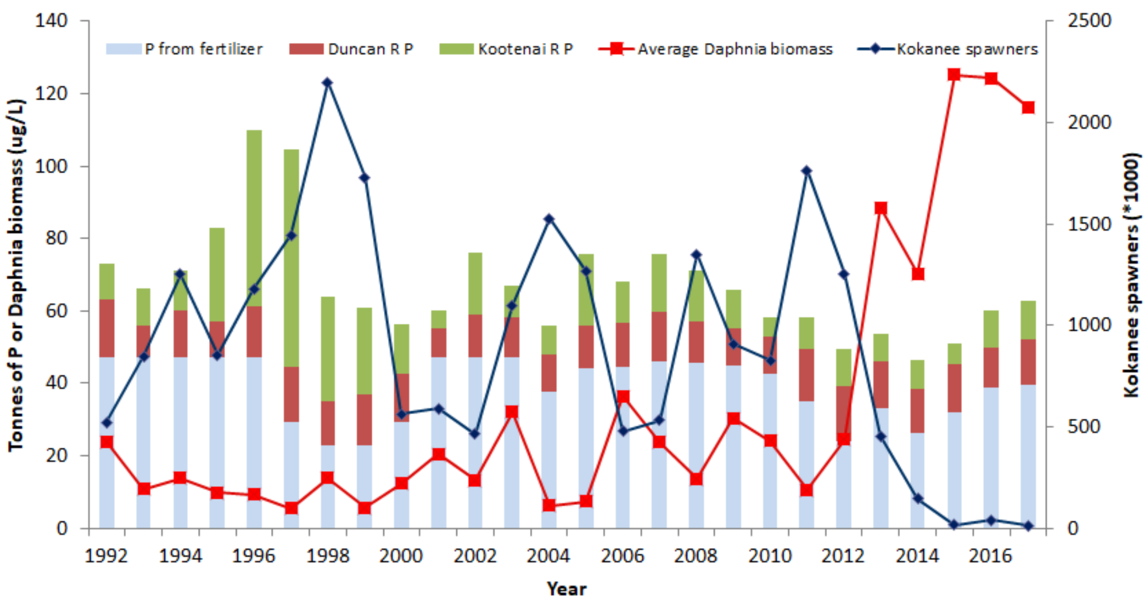


Figure 12. Kootenay Lake phosphorus loading, *Daphnia* and Kokanee (FLNRORD data on file).

3 Review of actions, triggers, and 2016 – 2018 implementation

Action 1 - Kokanee supplementation

Trigger (to enact an improvement action): <65-140 thousand spawners; age 0-1 survival of <11%.

Action:
> 5 million eyed eggs were stocked annually in Meadow Creek in 2016 and 2017 (Table 1).

Implementation details:
An important consideration was the genetic source suitability of the stocked eggs. The 2016 Action Plan identified suitable genetic sources as Whatshan, Kinbasket Reservoirs and Lussier River. Since 2016, more than half of transplanted Kokanee departed from these recommended sources.

Table 1. Kokanee supplementation before (2015) and after development of the Action Plan (2016, 2017). Highlighted locations were not specifically identified in the Action Plan.

Year	Source Location	Eyed egg number	% Contribution	Total
2015	Hill Creek	477,398	43%	1,113,006*
	Koocanusa (Lussier and Norbury)	493,371	44%	
	Interior Brood Lakes	142,237	13%	
2016	Whatshan	603,164	9%	6,759,574**
	Fairmont (Columbia)	1,569,888	23%	
	Hill Creek	1,381,059	20%	
	Koocanusa (Lussier, Norbury, and Bull)	1,203,857	18%	
	Interior Brood Lakes	2,001,606	30%	
2017	Whatshan	240,270	3%	8,701,893**
	Fairmont (Columbia)	1,238,740	14%	
	Hill Creek	6,496,339	75%	
	Interior Brood Lakes	726,544	8%	

Legend: *Combined eyed egg and fry planting
**Eyed eggs only

Monitoring results:
There are several questions the monitoring program should answer, including: are stocking efforts meeting with success, what is success, is survival similar to wild Kokanee, and is there an increase in overall Kokanee survival?

1. **Spawning channel**
   a. Supplementation (egg stocking) is significant contributor to overall egg supply (30-60% of all eggs) in the past two years.
   b. The egg deposition crash has roughly corresponded with escapement.

c. Transplanted eyed egg-to-fry survival in Meadow Creek was 60-90%; this was as good as or better than typical channel survival.

d. Although fall fry supply had decreased, it was not too far outside historic lows (Figure 13).

e. As of fall 2017, in-lake Kokanee 0-1 survival remained low (~5%), despite the start of Kokanee supplementation (Figure 14).

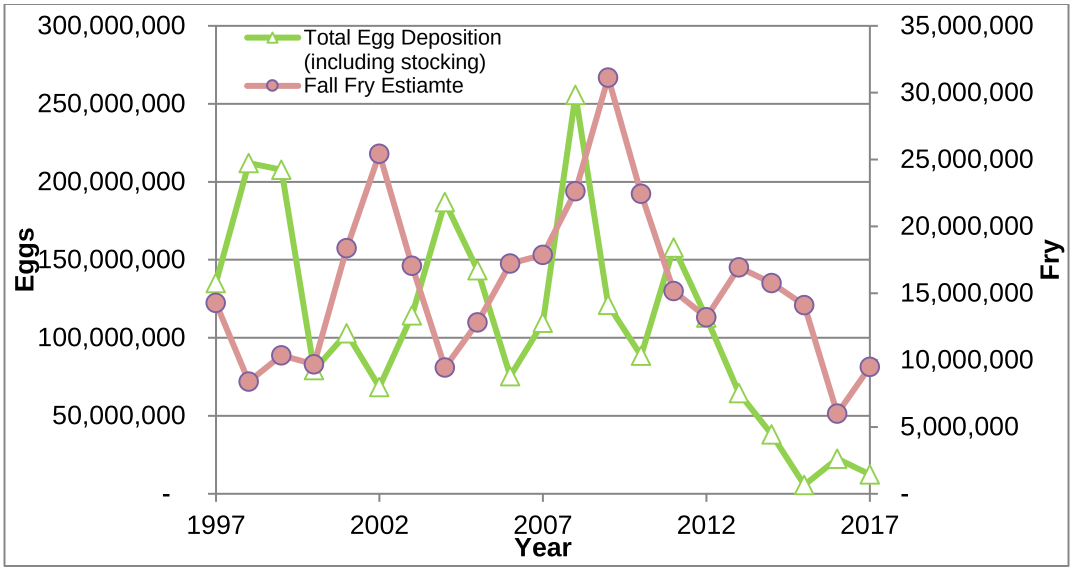


Figure 13. Kokanee egg deposition versus fall fry estimates, 1997-2017.

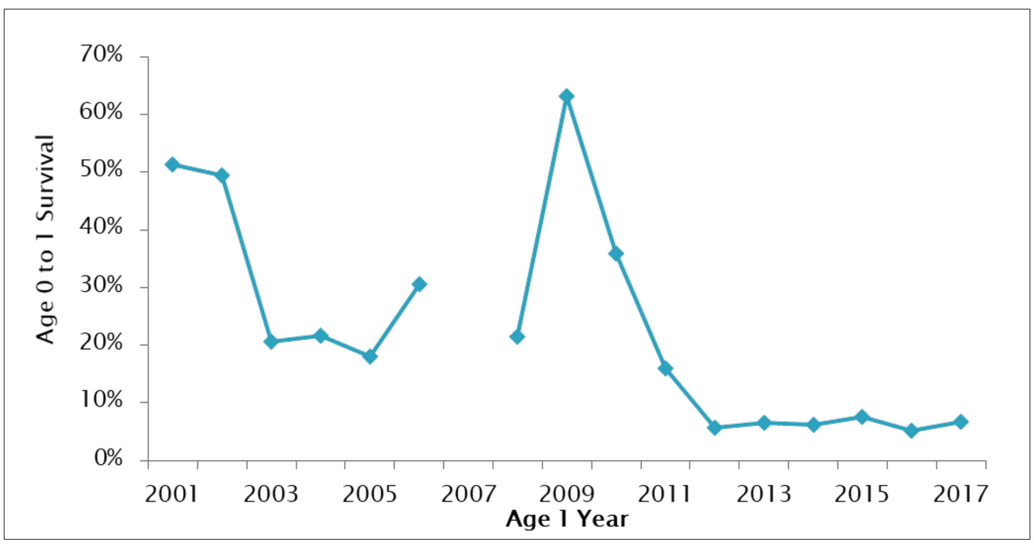


Figure 14. In-lake Kokanee age 0-1 survival.

2. It takes two years from when eggs are planted to see if **a signal is received in the lake.** In-lake monitoring of stocked Kokanee survival was presented as a sampling matrix (Table 2a,b):

a. The 2015 cohort (1 million combined fry/eggs) was heat marked (or thermal marked - TM). These fish will spawn in 2018 and 2019.

b. The 2016 cohort (6.8 million eggs) were not heat marked, but there is 2018 funding to look at the feasibility of genetics analysis to evaluate this year class survival

c. The 2017 cohort (8.7 million eggs) were, for the most part, heat marked. The 2019 trawl will be the first data available for this cohort, although effort will be made to extract otoliths from the fry caught in the trawl in 2018.

Table 2a. Egg plant / fry stocking sampling matrix and identification method. TM=thermal mark; DNA = genetic analysis.

stocking type	Metric	2016 fall	2017 fall	2018 fall	2019 fall	2020 fall	2021 fall
ee	survival/abundance as age 1+ (trawl sample analysis)		n=0	DNA	TM		
ee	survival/abundance as age 2+ spawner			TM	DNA	TM	
ee	survival/abundance as age 3+ spawner				TM	DNA	TM
ee	survival to spawn (using cumulative age 2-4 spawner abundance)					TM	DNA
fry	Fall age 0 abundance	n=2	n/a				
fry	survival/abundance as age 1+ (trawl sample analysis)	ns	n=0	n/a			
fry	survival/abundance as age 2+ spawner		ns	TM	n/a		
fry	survival/abundance as age 3+ spawner			DNA	TM	n/a	
fry	survival to spawn (using cumulative age 2-4 spawner abundance)				DNA	TM	n/a

Table 2b continued. Egg plant / fry stocking sampling matrix.

Stocking Type	Brood year	fry year	Heat Marked	Number	comment
ee	2015	2016	Y	477,000	TM Band - III_III
ee	2016	2017	N	6,800,000	
ee	2017	2018	Y (89%)	8,700,000	TM Band - IIII
ee	2018	2019		tbd	
fry	2014	2015	N	92,541	All -> Crawford, DNA from spawners
fry	2015	2016	Y	635,000	TM Band - III_III (30,000 -> Crawford
fry	2016	2017	N	80,000	All -> Crawford

* Hatchery fry are closer in size to the smallest wild age 1 at time of stocking in spring
DNA = no heat mark, would require DNA analysis (if a viable method)
n/a = no TM, DNA not likely possible
ns = not sampled

POST WORKSHOP INFO: Otoliths from the 2016 and 2017 trawl caught fish >~90 mm have been analyzed for temperature marks, but the data have been inconclusive. Overall, the team was not yet 100% confident in the ability to identify thermal marks. Sampling age 0 otoliths was planned for 2018 in addition to older age classes. Analysis of reference samples of known TM'd fish was planned for further evaluation of the method. Ultimately, it was expected that spawner samples would be the most informative as survival to spawn was identified as the most viable metric to evaluate overall success.

Action 2 – Meadow Creek Kokanee egg incubation

Trigger: None

Action: Upgrade Meadow Creek hatchery to increase incubation capacity above 5 million.

Implementation details:
1. Completed actions - ~1 million eggs were incubated in 2017; FFSBC has also increased capacity to ~8 million through upgrades/staff and facility planning (this may not sustainable indefinitely).
2. Meadow Creek is considered a poor/last option for incubation. This is because there are no alarms, there are egg quality issues, and cold water pushes egg plants to occur late.
3. Egg supply is more limiting than incubation space, as there are only so many wild eggs available by source; and collection/egg management is also intensive and uses a lot of resources.

Action 3 - Kokanee Angling Closure

Trigger: <140,000 spawners; age 0-1 <11%

Action: Maintained Kokanee daily quota=0. Implemented in 2015, and continued to 2018

Action 4 - Nutrient Program

Trigger: None

Action - Continued implementation of current program (late April through early to mid-September)

Action 5 - Mysis Removal

Trigger: Explore feasibility, removal if density > 463 ind/m^2 (2 SD > mean).

Action: Evaluate feasibility of *Mysis* removal

Implementation details:
The KLAT evaluated options of a removal program in 2016. A feasibility review is now in development.

Action 6 - Predator Management - Rainbow Trout

Trigger: <140,000 Kokanee spawners; age 0-1 Kokanee survival <11%

Action: Increase harvest, through Recreational Fishery Regulations

Implementation details:

1. Implemented Rainbow Trout daily harvest quota increase (increased to 4 fish/day in 2015 and then 5/d in 2018; still only 1>50cm)
2. KLRT Rainbow Trout harvest rate increased ~14% between 2015 and 2017, as a result of regulations and outreach combined.
3. Effort declines resulted in a decrease in overall Rainbow Trout harvest (from ~9,000 to 4,000 in the same period).
4. Additional predator removal options briefly mentioned but not defined in Action Plan.

Action 7 - Predator Management – Bull Trout

Trigger: <140,000 kokanee spawners; age 0-1 survival <11%

Action: Increase harvest through Recreational Fishery Regulations

Implementation details:

1. Regional biologists recommended a harvest increase to 2 Bull Trout / day (only 1 >50 cm) in 2015. Due to stakeholder opposition, management decided not to proceed.
2. In 2018, the daily catch quota increase was approved at 2 Bull Trout / day (only 1 >50 cm).
3. It is now too soon to estimate changes in release rate that would indicate success.
4. Additional predator removal options briefly mentioned but not defined in Action Plan.

Action 8 – Predator conservation – Gerrard Rainbow Trout

Trigger 1: 50 -100 spawners; ***action not triggered***

Action 1: Reduce exploitation though regulations

Trigger 2: <50 - 100 spawners in two consecutive years; ***action not triggered***

Action 2a: Hatchery Supplementation "Gene Banking" to sustain Gerrard populations if population collapse imminent.

Action 2b: Reduce exploitation though regulations.

Action 9 - Predator conservation – Bull Trout

Trigger: Escapement < 50 spawners in Kaslo River and < 500 spawners in lake-wide index; ***action not triggered.***

Action: Reduce exploitation though regulations.

4 Effective actions taken since 2015 - round-table discussion

1. There has been public support of the Action Plan because the actions are connected to clear and accountable tools, triggers, and measures. It is good to have it clearly laid out in this way.
2. FLNRORD's KLRT questionnaire does a good job of estimating fishing effort. People have not gone fishing more. There were 38,000 anglers in 2012 and ~17,000 in 2017. There have been fewer guided trips, fewer locals fishing, less people catching and releasing the big fish. Now smaller fish mainly available, those angling to keep, or at least land, a very large rainbow are largely fishing elsewhere.
3. Angler composition – still people coming from elsewhere to fish; type of people might be different. Anecdotal evidence that people are moving over to Arrow Lakes to catch big fish.
4. What stands out is higher juvenile Rainbow Trout survival, less people on lake, less spawners.
5. Juvenile Rainbow Trout production has also been declining. Number of trout rearing in the lake (or trout at large) was estimated using the Peterson mark recapture method:

$$\text{Number of trout at large} = N_{\text{spawners at gerrard}} \times (N_{\text{lake sampled}} / N_{\text{lake maturing}})$$

   The method uses maturing gonads as a "mark." The number of trout are estimated by expanding the number of spawners by the ratio of trout sampled the previous year to the number ripe in that sample. The "Marking session" (spawning) occurs after "recapture session" (previous year of observations) reverse order compared to typical mark-recapture estimation projects.

   a. Using this method, the number of Rainbow Trout at large was 1,328 fish in 2016, and 5,461 in 2017. It is difficult to reconcile these numbers with apparent trout abundance estimated by KLRT questionnaire (calibrated by creel) of 50,000, for the consumption analysis, which indicates much higher trout numbers (Figure 15).

   b. The probability of spawning estimates by age class were provided (Table 3).

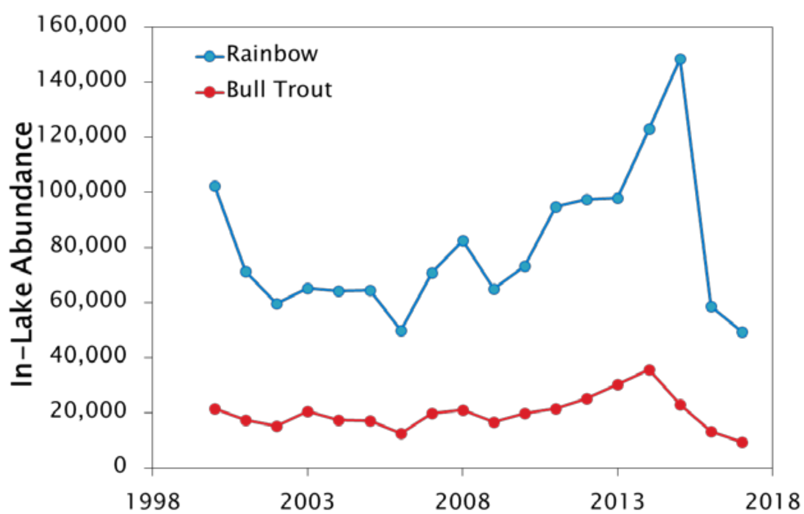


Figure 15. Predator abundance estimated by KLRT questionnaire (calibrated by creel).

Table 3. Probability of spawning estimates

age (SY-1)	spawner age	n	maturing	p(spawning)
2	3	18	1	6%
3	4	56	3	5%
4	5	52	8	15%
5	6	35	2	6%
6	7	15	2	13%
7	8	10	2	20%

Exploitation study
For rb > 50 mm =
22%

Table 2 p. 12
Andrusak and Thorley. 2014. [tag-telemetry to estimate fishing and natural mortality of large Bull Trout and Rainbow Trout on Kootenay Lake. Poisson Consulting Ltd. Redfish Consulting Ltd.]

6. Uncertain what the Rainbow Trout (age 1-4) in lake survival is.
   a. A tagging program using coded wire can give a direct estimate of survival. This would allow for a time series of information to be started.
   b. Acoustic tags produced survival rates. How do they compare?
   c. Need to be careful about using CPUE from KLRT to describe populations. Will plummet and see a lot less Rainbow Trout in the lake. Lots of small fish all the same size, and clumped into 1 size class.
      i. Get an age sample from a creel to verify, angler catch age structure.
      ii. People still buy the tag (for keeping a Rainbow Trout >50 cm), less because they expect a large trout and more to contribute funds for the fishery or fisheries management. This tag is important, as it gives survey data. Would have to go to a general survey without tag system. This data provides a time series of KLRT and angler and catch rates. Have found that guide and KLRT data are similar.
7. Incentives are needed to bring people back to the lake. Require an outreach to anglers to harvest more predators, as there are lots of Rainbow Trout and Bull Trout.
   a. People do not attend the public meetings, and are thus not getting the information. Lots of people are still throwing these fish back.
   b. Harvey put this out through the Fish & Wildlife Club. Can also put on society blog.
   c. Parasites on Rainbow Trout? Tape worm observed in creel caught fish. Certainly they are present; however, not as bad as in 2007 or 2008. This does also discourage people from harvesting.
8. Rob Bison presentation – Examining Kootenay Lake Kokanee dynamics with a stock recruitment approach:
   a. Recruitment anomalies evident. These may be related to fertilization of the lake.
   b. Rainbow Trout are reacting to the prey abundance, with weight dropping with time.
   c. Bull Trout not as apparent; do they impart a stabilizing effect on the dynamics?
   d. Predator covariates - why use catch and not CPUE?
      i. If corrected for fish size, CPUE resembles catch for predator abundance. Considers tolerance of anglers to fish given the size of the fish they are catching. Takes size response out of CPUE trend.
   e. Question moving forward – KLRT is currently the only metric for in-lake abundance. Are we collecting the correct data, how do we best use it?

f. Gerrard spawner abundance is not that low (Figure 16). Predator numbers seem only slightly lower than they were before, except their size and condition is much lower (Figure 17).

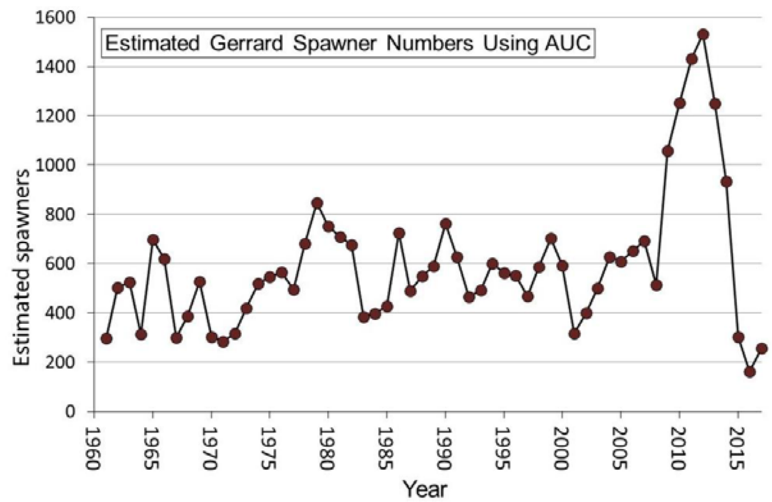


Figure 16. Gerrard spawner abundance

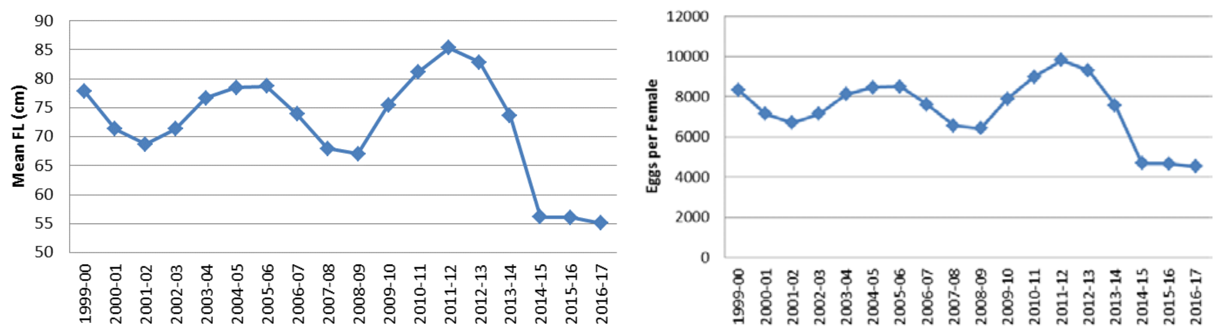


Figure 17. Cycles in Gerrard spawner mean fork length (left) and fecundity (right).

9. When fertilization began Kokanee increased, then predators increased. This is typical in large lakes. The predators soak up the Kokanee dynamics in growth, but not in terms of number.
10. Predator numbers/ consumptive potential waiting to soak up stocked fish. Would it have been better to get predators down by not supplementing Kokanee? Lake Pend Oreille did both - egg plant and reduce predators. Some discussion about what worked – both or just predator reduction?
11. Not just the number of anglers - it's also exposure, lower effort is getting older age classes. Catch rates are good, but still so low at <1 Rainbow Trout per day. Available age data has been partitioned. Catch consists of some 3 year olds, mostly 4 year olds, and fewer older years. No one is limiting out at 5 per day. However, back in 2000's, when fishing was good, people didn't harvest 5 large trout per year (the annual limit); limits did not reduce harvest because rates were so low.
12. There is an age shift in size distributions. An independent monitoring program using mark recapture should be undertaken to look at size at age.
13. The Kurota model projections suggested a need to harvest Gerrards – even harvest older and bigger ones. Also applies to Bull Trout. Seems Rainbow Trout respond fast. As soon as Kokanee come back the Rainbow Trout are expected to return.

14. Evidence of predator prey cycling dynamics evidenced at other lakes, for example: At Shushwap Lake the Rainbow Trout starve every 4 years; they double their fecundity in bursts. At Arrow and Quesnel lakes, the Rainbow Trout have a cycle of being in low numbers and small, and then as soon as the Kokanee came back, the Rainbow Trout come back.
15. Suggestion to put more emphasis on Bull Trout for reducing predation, as they are more plastic than Gerrards.
16. Bull Trout are consuming lots of Kokanee, even when there are not that many available:
    a. Bull Trout have an advantage over Rainbow Trout to find Kokanee, because they are a better predator at low light.
    b. Typically catch Bull Trout deep (+200 ft depth distribution). Bull Trout come to surface during the spring, where there are mysids and Kokanee.
17. Is fertilization a lever? Nutrients were deliberately reduced from 1997 through 2000 and zooplankton biomass decreased. Zooplankton biomass needs to be maintained to support Kokanee for recovery.
    a. While fertilizing, productivity of zooplankton varies (*Daphnia*). There is currently higher than long term average zooplankton biomass and productivity, since it is not getting grazed down.
18. Piscivore monitoring of diet composition, measured as % composition by mass, revealed the following (Figure 18):
    a. In 2015 to 2017, Kokanee made up a higher proportion of the Bull Trout diet (68%), than the Rainbow Trout diet (22%). Insects were the highest proportion of the Rainbow Trout diet (36%).
    b. There were seasonal shifts in diet, with Bull Trout consuming more Kokanee in the spring (90%) than fall (65%). The fall Bull Trout diet was supplemented by Mysis. Rainbow Trout diet was more diverse, or opportunistic; in the spring it was mostly insects (40%), followed by Mysis (26%), and Kokanee (28%). In the fall, the Rainbow Trout diet shifted to *Mysis* (35%), Kokanee (27%), and zooplankton (18%).
    c. Rainbow Trout diet under conditions of low Kokanee abundance was different than under higher Kokanee abundance (measured historically). Specifically, there is a current shift to *Mysis* and zooplankton to offset low Kokanee availability (Figure 11). This outcome has implications for Kokanee recovery, namely, that even at unchanged future predator density, Rainbow Trout consumption of Kokanee will likely increase concurrent with Kokanee abundance increases.
19. The Kurota model results hinted at an advantage for small rainbow survival over Kokanee after 2005 in the lake, perhaps due to new South Arm nutrient additions as the timing is the same (and we suspect other hypotheses are less likely – no evidence of angling regulation changing catch or harvest, limited evidence of Rainbow Trout fry surviving, some Lardeau evidence of one very strong parr cohort). However, it is not clear what advantage 1 – 3 year old Rainbow Trout would have over Kokanee.

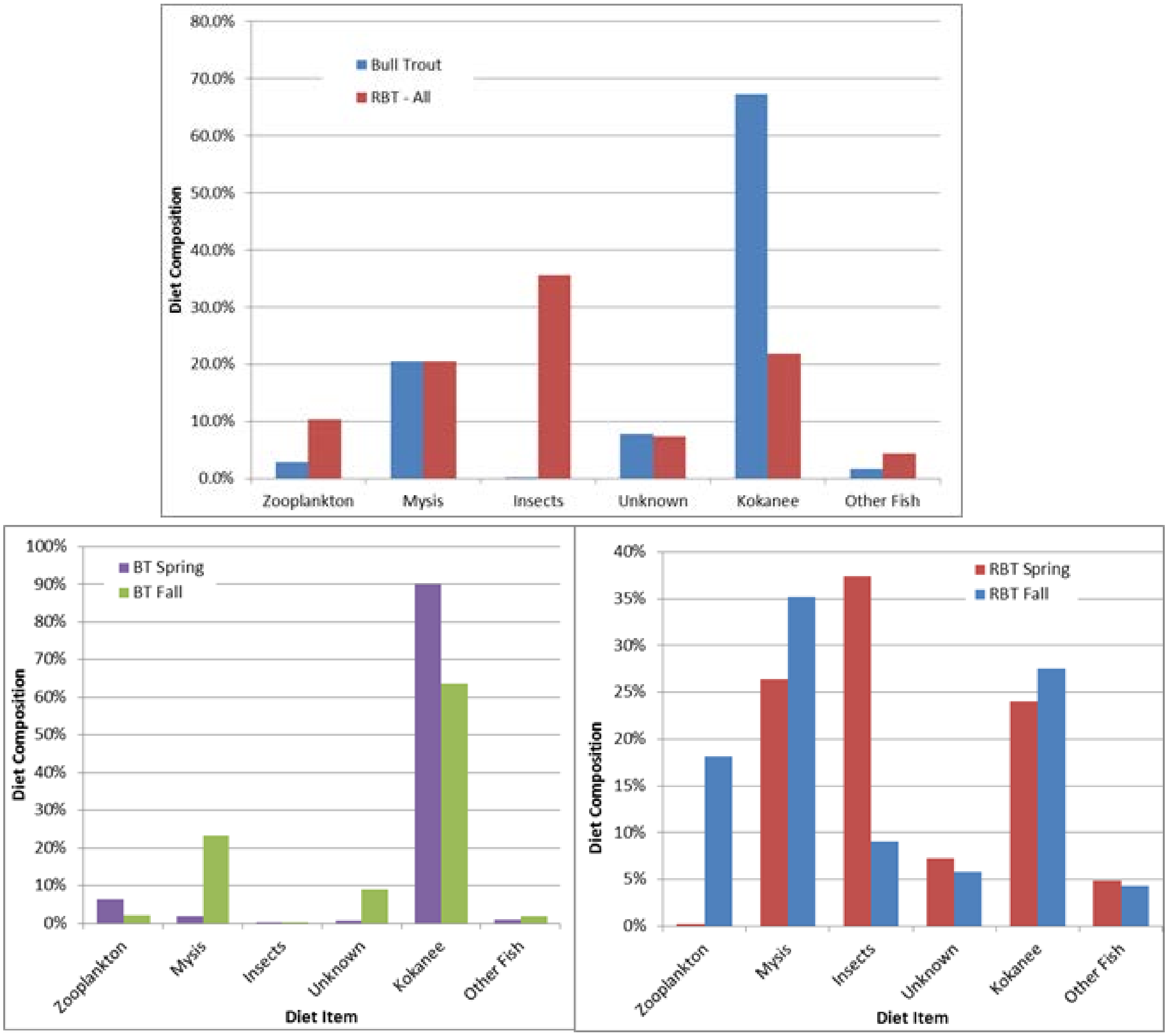


Figure 18. Piscivore monitoring (2015-17) diet composition - % composition by mass

5 Areas requiring potential improvement/updates – guided by key questions

5.1 *Should we stock Kokanee fry or eggs?*

1. Kokanee are surviving well from eyed eggs to emergent fry (40% in 2017).
2. However, age 0-1 survival is low at 5-7%.
3. Still waiting for results to show the success of fry stocking.
4. Raise fish to a larger sizes before planting? Is there an opportunity to increase capacity for the FFSBC? It would cost $10 million to build a new facility on Meadow Creek.

Stocking Kokanee eggs versus fry - group decision
Overall, eggs are surviving well coming out of the gravel (age 0-1 is the bottleneck). Therefore no need to change course right now, so continue to stock eggs as opposed to fry.

5.2 *What Kokanee sources are suitable to stock, and where are they suitable to stock?*

5.2.1 Stocking background

Matt provided background on stocking sources and genetic suitability to help inform this question:

1. Brood source options were initially screened for undesirable phenotypic expression that would make them clearly divergent from Meadow Creek, which included:
   a. Anadromy
   b. Shoal spawners
   c. Spawner age differences (i.e. 1+ or 5+ spawners etc.)
   d. Genetic analysis completed (some components after Action Plan developed)
2. Action Plan identified Whatshan, Kinbasket Reservoirs and Lussier River as sources.
3. 2016 and 2017 stocking departed from Action Plan recommendations (Table 4).
4. New genetic results suggested Hill Creek more appropriate than Koocanusa (Okanagan genetic component).
5. Kokanee egg stocking options and associated risks to genetic structure in Meadow Creek were presented as a decision making tool (Table 5). The order of risk is likely appropriate, no one can really identify risk level. Discussion around options included concerns over genetic risk, but also cost/benefit and risks associated with feeding predators

Table 4. Among-site Kokanee genetic differentiation between Kootenay Lake Meadow Creek, and all other site samples. Samples added this year indicated in *italics*.

Lake/River	Sampling Location	Kootenay Lake - Meadow Creek		
		F_{ST}[a]	*p*-value	significance[b]
Arrow Reservoir	*Burton Creek*	*0.1335*	*0.0006*	*
Arrow Reservoir	*Deer Creek*	*0.1382*	*0.0006*	*
Arrow Reservoir	*Drimmie Creek*	*0.1163*	*0.0006*	*
Arrow Reservoir	Hill Creek	0.0570	0.0002	*
Arrow Reservoir	*Mosquito Creek*	*0.1296*	*0.0006*	*
Arrow Reservoir	*Taite Creek*	*0.1126*	*0.0006*	*
Christina Lake	Sanders Creek	0.1280	0.0002	*
Christina Lake	Shore	0.2097	0.0002	*
Columbia River	Norns Creek	0.0732	0.0002	*
Cottonwood Lake	-	0.0653	0.0002	*
Deka Lake (2015)	Interior Plateau	0.0080	0.0044	NS
Kinbasket Reservoir	All[c]	0.0016	0.4211	NS
Kinbasket Reservoir	Bush Trawl	-0.0070	0.8605	NS
Kinbasket Reservoir	Columbia River	0.0065	0.2022	NS
Kinbasket Reservoir	Main Trawl	0.0053	0.4136	NS
Kinbasket Reservoir	Wood Trawl	0.0124	0.0437	NS
Koocanusa Reservoir	Lussier River	0.0481	0.0002	*
Koocanusa Reservoir	Norbury Creek	0.0428	0.0002	*
Kootenay Lake	*Crawford Creek*	*0.0104*	*0.6057*	NS
Kootenay Lake	*Goat River*	*0.0000*	*0.6640*	NS
Kootenay Lake	Lardeau River	0.0041	0.3111	NS
Kootenay Lake	Lower Duncan River	0.0009	0.7820	NS
Kootenay Lake	*Midge Creek*	*0.0920*	*0.0006*	*
Kootenay Lake	West Arm - Fisheries	0.1118	0.0002	*
Kootenay Lake	West Arm - Kokanee Creek	0.1503	0.0002	*
Kootenay	West Arm - Shore	0.1493	0.0002	*
Revelstoke Reservoir	*In Lake*	*0.0283*	*0.0006*	*
Revelstoke Reservoir	*Standard Creek*	*0.0201*	*0.0006*	*
Slocan Lake	Bonanza Creek	0.0352	0.0002	*
Slocan Lake	Wilson Creek	0.0270	0.0002	*
Sulphurous Lake (2015)	Interior Plateau	0.0252	0.0002	*
Whatshan Reservoir	Arrow Watershed	0.0097	0.0103	NS
Willistin Reservoir	Osolinka River	0.0544	0.0002	*

[a] Weir and Cockerham (1984) unbiased estimator of F_{ST} (θ)

[b] Indicative adjusted nominal level (5%) for multiple comparisons is : 0.000198

[c] Given small sample sizes of trawls, Kinbasket reservoir analyzed with all samples pooled and unpooled

Table 5. Kokanee egg stocking options and associated risks to genetic structure in Meadow Creek

Risk to Genetic Structure in Meadow Creek	Option	Description	Sources	Forecast Egg Supply
None	1	No Kokanee stocking	Only natural production	None
Low	2	Use only sources that are not significantly different	Whatshan, Kinbasket,	1,500,000
	3	Incorporate statistically significant different sources, but limit relative proportion of those stocks to be a maximum of 49% (i.e. 51% from mostly pure Kootenay Lake strains)	Above plus Hill Creek and Brood Lakes	3,000,000
	4	Incorporate statistically significant different sources, but limit relative proportion of those stocks to be a maximum of 49% (i.e. 51% from mostly pure Kootenay Lake strains) to Meadow Creek, remainder to Sout Arm Tribs	Above plus Hill Creek and Brood Lakes	3 million for Meadow; additional 6 million for South Arm
	5	Incorporate significantly different sources; no limit of relative proportion	Same as above	~ 9 million
High	6	Incorporate anywhere you can get eggs efficiently (notable include Koocanusa Tribs) no limits on relative contribution (potentially above FFSBC capacity to collect)	Above plus Lussier, Norbury	> 9 million

2018 Brood Collection fo KL - Order of Preference

Suitability	Collection Location	Potential Egg Supply
Most Suitable	Whatshan/Kinbasket (Fairmont); same as MC	1,500,000
	Bridge Lake (100% MC; F2 generation from ~150 F)	1,000,000
	Deka Lake (85% MC and 15% Hill; F2 generation from ~150 F)	400,000
	Hill Creek	6,000,000
	Sulphurous Lake (100% Hill; F2 Generation from ~150 F)	250,000
Least Suitable	Koocanusa (Lussier/Norbury/Bull)	1,500,000
		10,650,000
		Likely above FFSBC capacity to collect

5.2.2 Stocking discussion

In support of no stocking or multistep approach:

1. Stocking could simply feed the predators, prolonging their survival and the predator problem. Diminishing gains.
2. The predators also appear to be putting more energy into fecundity, thus being more efficient with the limited food available.
3. Two-step process suggested: a) first get the predators down this summer, and see outcome of predator reduction, then b) place eggs. Probably will not remove Bull Trout in time for fall stocking.
4. Diet and consumption data suggests there is significant Kokanee consumption by Rainbow Trout.
5. How much can we reduce predation on subsequent age classes (age 1)? Lake Pend Oreille provides case history with three predators including non-native Lake Trout (as opposed to two at Kootenay Lake). A commercial fishery for Lake Trout on the spawning beds is what worked for them. All three predators were suppressed in the lake. Recovery didn't occur until they got rid of predators. All the Kootenay Lake predators spawn in streams, which should simplify suppression.

In support of low stocking number approaches (using Whatshan and Fairmont brood):

1. Look at risk versus reward. Kootenay Lake has had good survival of egg-fry and spring fry-fall fry, but after that survival is low (5-7% survival for age 0-1, and continued similarly low survival for age 1-2). Have not seen a difference overall since stocking began in 2016. There appears to be a low reward, thus perhaps we shouldn't take on high risk brood. Brood eggs from Cariboo (Deka Lake) have low survival of eggs, due to temperature. Right now, doubled number of interior brood lake spawners, but still do not have a lot of fish. Would feel more comfortable going to sources that are genetically more suitable for Meadow Creek. There are both genetic and environmental aspects to the decision.
2. Support to minimize the potential to dilute the local genetics. We know survival is low because of predators, and also maybe because of lost local adaptation. Was there introgression of alleles into the local population?
3. In 2017, 60% of eggs were from fish that came from outside Kootenay Lake, meaning the chance of diluting out local stock is significant. Should thus deal with mortality risk before putting non-native genetics into Meadow Creek.
4. Concern that taking eggs from non-desirable places will not lead to a long term, self-sustaining population of these individuals.
5. Considered low risk if using closely related Kokanee - if it is not successful, then the stocked fish will simply become fish food.
6. More likely to have Kokanee respond earlier with augmentation.
7. Stocking gives another option. Potential win-win, can shorten recovery if both egg stocking and predator control work concurrent.
8. Unquantified risk and irreversible genetic changes if high risk genetics methods are chosen. Risk reward – are we willing to take on risk to be a year ahead?
9. Conserve the stock and conserve the genetics.

In support of higher risk genetic stocking approaches:

1. A certain percentage of Kokanee are also coming from Koocanusa Reservoir (they return to Kootenai R. in Idaho and Montana to spawn).
2. Introgression is naturally occurring. Hasn't this already occurred with the last 3 years of work?
3. It is unknown if they will home back to spawning stream.
4. Considered an insurance measure.
5. Need to increase prey, because Parkinson study found with fewer prey, predators become more efficient.

5.2.3 Stocking options poll

Hillary W. set up an online poll (using menti.com) for the three options, with the KLAT casting their votes from their phones or computers at the workshop. The outcome was split nearly equally amongst the options with 6 votes to not stock, 6 votes to stock only the best genetic sources, and 5 votes to stock as many eggs as possible (Figure 19). It is important to note that at least some votes for the option to 'stock only the best genetic sources (1.5 million)' were cast with the intent that either that option or 'no stocking' were acceptable options (i.e. if stocking is to occur it should only include the best genetic sources). In that light, the results from the poll can be interpreted as 35% choosing not to stock any, while another 35% of the KLAT felt some stocking was preferable or acceptable if limited to only the preferred sources. Combined, 70% were not in favour of stocking as many as possible from higher risk genetic sources.

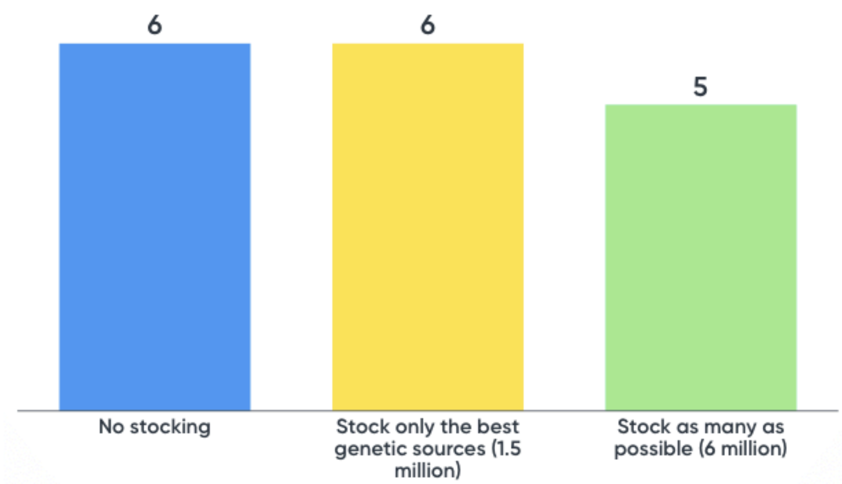


Figure 19. Poll results for stocking options

5.3 *Would a more assertive piscivore reduction accelerate Kokanee recovery?*

5.3.1 Piscivore background

Matt presented summary overheads for both Bull Trout (Figure 20) and Rainbow Trout (Figure 21). Information provided included current actions being implemented, additional removal options, and pros and cons for the options.

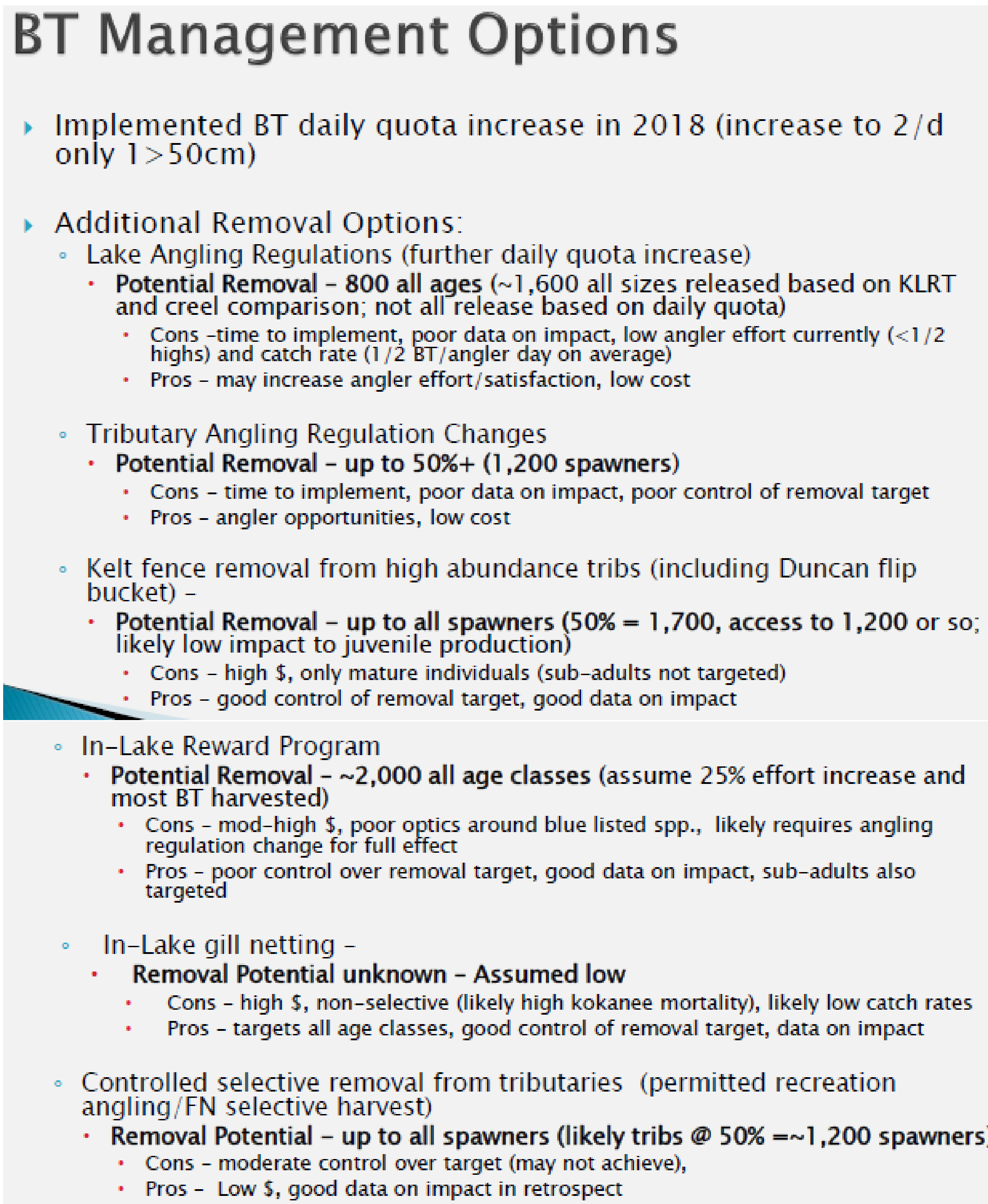


Figure 20. Bull Trout management options.

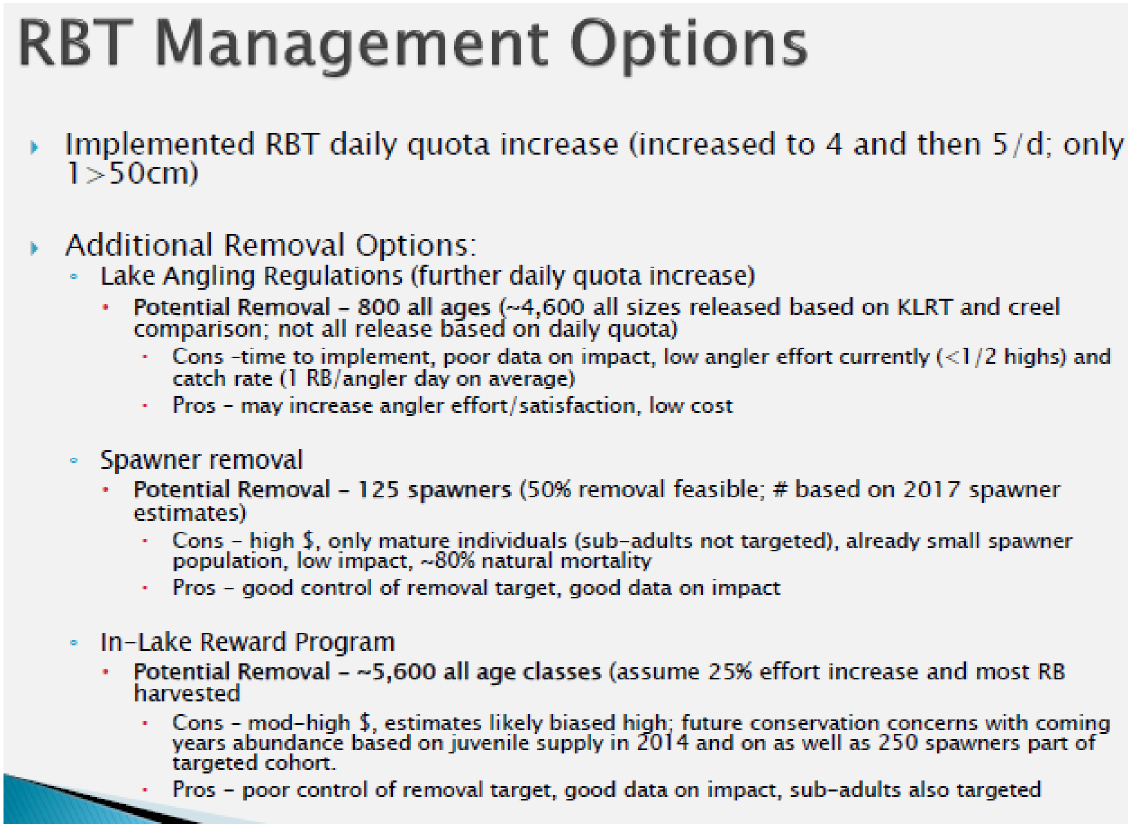


Figure 21. Rainbow Trout management options.

5.3.2 How many Kokanee do Bull Trout and Rainbow Trout eat and what are the predicted impacts of these management actions?

1. Steve A. presented the results of two methods used to estimate biomass of Kokanee consumed, using 2015-17 diet data collected in spring and fall. Overall the results were similar with larger Bull Trout consuming over 10 kg of Kokanee annually and larger Rainbows up to 5 kg (Table 6).

Table 6. Estimated annual consumption of Kootenay Lake Kokanee (kg of Kokanee consumed per predator), using two methods. The first (H. Ward, pers. comm.) assumes stomach contents represent 24-h of consumption and expands consumption data by predator size category. The second uses a temperature range to estimate min/max evacuation rate and consumption over 24 h with all predator sizes pooled[4].

Predator species	% Kokanee in diet	Average predator size (kg; range)	Kokanee consumption (kg/year)	
			Method 1	Method 2
Bull Trout	0.343	1 (0-2)	2.98	1.7-2.6
		3.5 (2-5)	8.29	6.0-9.0
		6 (5-7)	10.57	10.3-15.4
		8 (>7)	11.79	13.8-20.6
Rainbow Trout	0.118	1 (0-2)	1.03	0.5-0.7
		3.5 (2-5)	2.85	1.7-2.4
		6 (5-7)	3.64	2.9-4.1
		8 (>7)	4.05	2.9-5.4

2. Hillary Ward's analysis revealed that based on 2016-2017 estimated predator abundance and diet data (see Section 4), Kokanee consumption in 2016-17 was estimated to be ~56,000 kg/year by Rainbow Trout and 35,000 kg/year by Bull Trout (Figure 22). It was noted that values for prior years, outside of the diet study, were likely underestimates.

[4] He and Wurtsbaugh (1993) Trans. Am. Fish. Soc. 122: 717-730; Diana (1979) Can. J. Zoology 57:2121-2127.

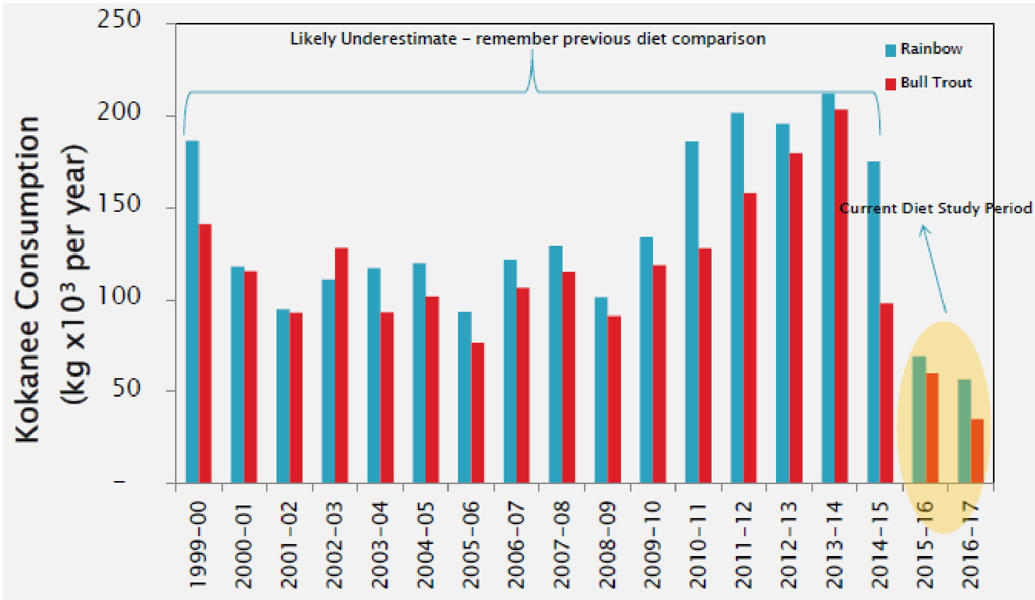


Figure 22. Kokanee consumption estimates, based on predator/prey weight relationship, and % occurrence in diet data.

3. Diet data now – does predation change when there is higher Kokanee abundance? Rainbow Trout are eating less than they used to. Thus, even at static Rainbow Trout abundance, increases in Kokanee populations from supplementation will be taken up to some degree by diet shifts back to consuming more Kokanee. Thus, there may be more benefit to remove predators than to stock eggs.
4. Steve provided a comparison of Kokanee consumption to elimination (mortality) estimates, which considered: fall biomass, elimination (tons lost between yearly estimates), predator biomass (all ages, tons), consumption (tons), consumption (both methods):
   a) Data shows that predator consumption is a major factor limiting Kokanee age 0-1 survival.
   b) Age 1-2 elimination estimates may be biased high (methodological limits) and consumption estimates low (if smaller prey are digested prior to sampling); if either of these is true the impact of predators is higher than estimated.
   c) Strengthens fact that lake needs management of predators to help Kokanee survival.
5. Consumption estimates show higher Kokanee consumption by estimated total Rainbow Trout population, but this is because there are more of them.
6. Suggestion to not remove Rainbow Trout. Numbers are going to go down sooner or later given the low amount of Kokanee as food.
7. Bull Trout have multiple age classes (stream rearing, lake sub-adults and adults, stream spawners), not going to hit all age classes unless there are both in-lake and stream reductions.
8. Once things turn around then do not need to stock Kokanee anymore, because in-lake survival is expected to increase.
9. Based on 2016 to 2017 KLRT creel and previous exploitation rate study, there are ~49,000 Rainbow Trout, and ~9,000 Bull Trout (Figure 15).
   a. Disagreement identified for Bull Trout numbers, but Rainbow Trout numbers seem accurate.

   b. Rainbow Trout spawning population indicates a small run with small fish, which is worrisome. Why aren't the 4 and 5 year olds maturing? Is it because they cannot get past and put enough energy into the gonads? Are we impacting big spawners, as there are very few large fish? Suggest shifting fishery to the 45,000 Rainbow Trout cohort (<2 kg); proportion under 50 cm.

10. Some advice on targets: above Gerrard targets are correct; pulled levers with Rainbow Trout already with catch limits, do not think it would benefit to reduce Gerrard spawners further. Maintain the KLRT (maybe make it free).
11. Matt provided predator management options and associated stocking equivalencies (Figure 23), as well as Kokanee consumption reductions information (Figure 24).
    a. Harvest of 13,000 Rainbow Trout and Bull Trout is equivalent to 13 million eggs, and we've been stocking 6 million. Incentive program for anglers would be beneficial. Lake Pend Oreille paid per fish head.

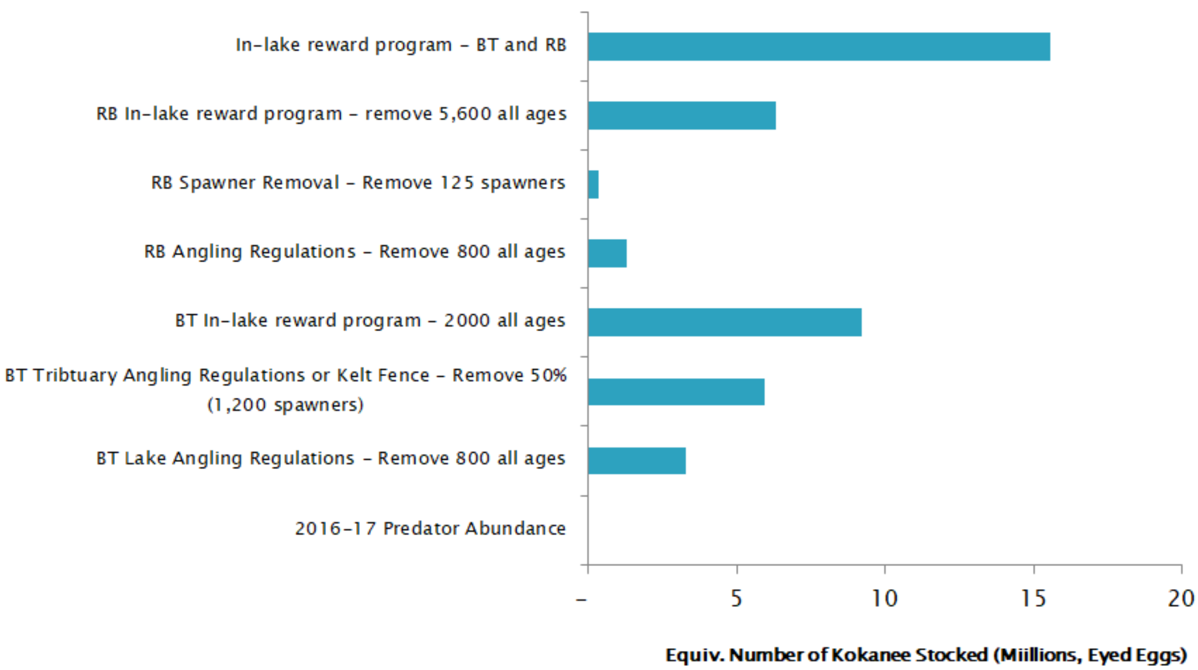


Figure 23. Predator management options compared to stocking benefits (assumes 35% eyed egg to fall fry survival and assumptions in Figure 22; might be an underestimate).

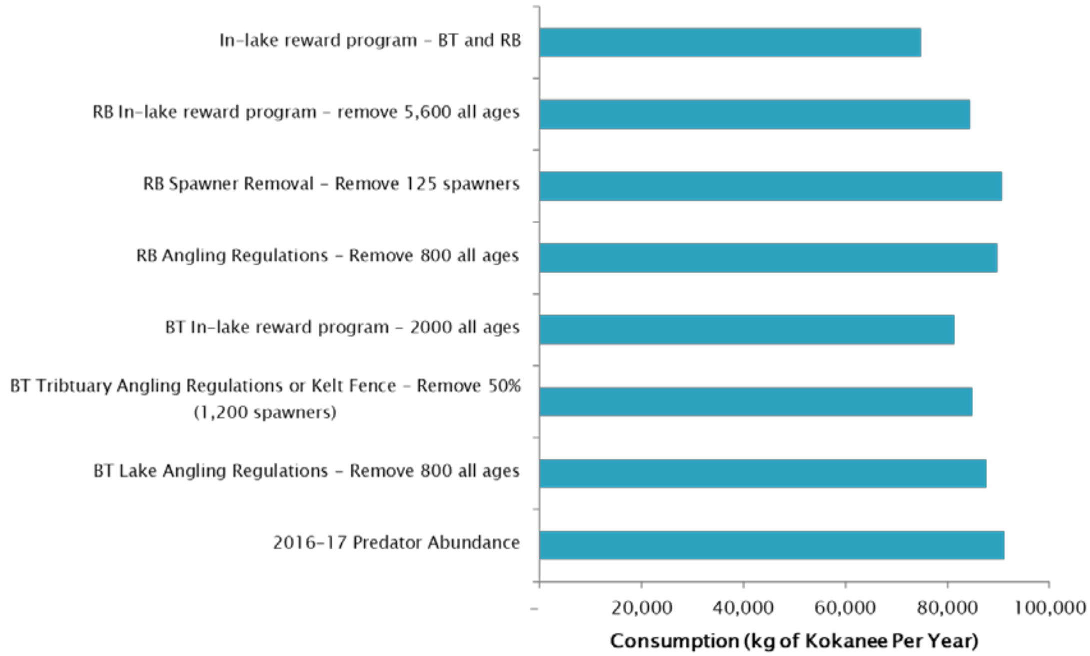


Figure 24. Predator management options and associated Kokanee consumption reductions.

Rainbow Trout spawner harvest

1. Total 250 spawners based on 2017 estimates, therefore, feasible to remove 50% or 125 spawners. This option was not discussed in any detail and did not have any apparent support.

Bull Trout spawner harvest

1. Bull Trout are considered resilient, as long as the habitat is there.
2. If you open up the streams to general fishing, there are some risks (build permanent expectations when temporary reductions are the action, for one example).
3. There is room to reduce spawners without impacting recruitment. For example, there is a surplus of 2,159 Bull Trout spawners (Table 7).

Table 7. Bull Trout spawners and potential surplus

	Kaslo and Keen			All Kootenay Lake Tribs		
2017 redds	477					
2017 spawners	1049	Surplus (n)	Surplus (%)	3421	Surplus (n)	Surplus (%)
Spawners required for 5 redd/km	387	662	63%	1262	2159	63%
Spawners required for 7.5 redd/km	581	469	45%	1893	1528	45%
Spawners required for 10 redd/km	774	275	26%	2525	896	26%

4. Would not impact Bull Trout viability, if only adults were targeted after they have spawned.
5. Also, Bull Trout do not prey on Kokanee until age 3-4. Thus, there would be a reserve of future supply.
6. How much rearing capacity is in the stream? Relationship for the Kaslo River, might not transfer over to other tributaries; risk to applying Kaslo data more broadly.

7. Kaslo River and Keen Creek combined make up 30% of the spawning population. Hamill Creek contributes to another 20%+ of the spawning population.
8. Combined with Duncan, these three systems make up >70% of measured escapement.
9. Hamill might be too big for a kelt fence at the bottom end. Could still put anglers in that stream:
   a) Unrealistic to get a regulation change to allow anglers to catch Bull Trout on tributaries in short time frame.
   b) Could harvest with a scientific collection permit. This would allow for better data collection, and help ensure stock structure is not damaged by overharvest. But could be seen as favoritism (who gets the permits).
10. Bull Trout spawner removal target:
   a) Decide on a percentage, like 75% of fish. When conditions were good, they were spawning every year.
   b) Via a kelt fence, can tag other 25%. This will put a large number of marks in the lake, to help estimate the Bull Trout population.
11. Acoustic tags may be a monitoring option. Could selectively pass females so you have less impact on future populations. Already have a Bull Trout redd counting crew on the Kaslo River.
12. Consider hiring contract anglers, to harvest Bull Trout in Duncan River and other streams in a prescribed way. Do in-lake harvest to help, although not as efficient.

In-lake predator control options

1. Free Gerrard surcharge stamps from Province.
2. Gill netting – no sense of where the fish would be concentrated. Could put in front of spawning tributaries for a few weeks. Could attract fish into net using flashers and vibration. However, gill nets are not selective (kill kokanee too), and are thus not a good idea, as we cannot control the catch. Likely significant risk, cost and uncertainty around this method.
3. Changing fishing regulations can take a long time, to both implement and then reverse. Also, the changes do not show up for many anglers who don't check for in-season changes on-line, until the regulations are printed. Also, such an angler might not notice when a temporary change goes back to more restrictive regulations.
4. General fishery promotion to the public may only have ancillary benefits, not huge gains.
5. Lottery or bounty does not provide the same opportunity to gather information and control the outcome. However:
   a. Can request that people prove that they caught a fish, by returning heads.
   b. Could have a bunch of high reward tags.
   c. Could have a bounty, which is what they did on Lake Pend Oreille.
   d. Could have a lottery style reward system
6. Reward tag/lottery program as an incentive to harvest fish, as currently 75% of fish are being released.
   a) To encourage increased public fishing.
   b) Put enough tags that people would be interested to participate (to kill all fish captured, and reduce the release rate).
   c) If anglers do the work, it would result in a bigger impact than hiring guides.
   d) Strategy to recapture the tags?
      - With lottery, every fish head could be an entry for a lottery.

- There are some sensitive Bull Trout and Rainbow Trout in the area that are not in Kootenay Lake, and people could cheat. Want to ensure some level of control. Could thus subsample for genetics for Kootenay stock, or the winner's head could be genetically tested (to ensure it is from Kootenay Lake).
- $10,000 prize, or more.

e) Could see people going fishing more if there were 10 prizes for $10,000 available. It is recognized that it would be a conflict of interest for provincial government employees).

f) Can choose to target Bull Trout and or Rainbow Trout. Seems to be a bit more risk averse for Rainbow Trout than Bull Trout.

g) Although increasing interest in the sport is a good thing, the potential liability of a bounty is high. Could set a maximum per person for the lottery (10 heads a person)?

h) Potentially remove ~ 2000 Bull Trout all age classes (assume 25% effort increase and most Bull Trout harvested), and 5,600 Rainbow Trout all age classes.

7. Hire a contract angler to harvest fish is a low impact option already used:
   a) Pay $500 per day, or ~$80k for the 2.5 year program.
   b) Previous contractor, harvested with a collection permit for diet study etc. He caught ~800 fish over 3 years, and on average caught 10-15 fish/d.
   c) Can also pay per head?
   d) This contractor can also tag fish, to help with monitoring.
   e) Can hire 2 or 3 contractors, depending on budget and target.
   f) Will – Directed removal by guides is socially undesirable, if culled and thrown out. Would suggest fish to go to a soup kitchen.
8. Fishing derby is another option. Do we get information from the derbies?
9. Could hire someone to conduct creel checks at boat launch (e.g., on Saturdays). They would pay out $80 a head. Probably do not want public bringing fish to the office. This person can also be at the derbies.
10. Bull Trout total catch rates in 2016 ~3000/yr based on adjusted KLRT estimate, ~1500 released.
11. Consider asking guide to kill every fish when out with clients; maybe they need to be paid as well for this.
12. As per Quesnel Lake program, tag as many as you can catch. Then start to collect Rainbow Trout size, age, and maturity data.
13. Good to get both anglers and guides involved. There may be poor optics to giving guides all the opportunities. Yet, can lose control by giving to the recreational fishery.
14. Consider option to open Bull Trout fishery on Duncan River (1,500 to 2,000 fish). Would allow opportunity for the anglers. The local club would like that idea.
15. Be careful about devaluing what you value. Encourage fishing. Communication is key.
16. Overall, select in-lake fishing incentive options that are actually legal, since many of the above free-form brainstorm ideas are not legal (such as paying a licenced angler $ per head).

How to best synchronize stocking Kokanee with predator management?

Overall goal is to recover Kokanee as rapidly as possibly, and ensure long term sustainability of Rainbow Trout and Bull Trout. Do not want further erosion of Gerrards. A variety of options were presented:

1. Harvest Bull Trout since they currently have a healthy population. Need to determine to what degree Bull Trout can be reduced without impacting their long-term sustainability.
2. Start by not putting eggs in (so as to not feed the predators) and deal with predators first. Synchronization required, if resources are limited.
   a) If group suggests no stocking the funding could go towards something else (cost of 10 million eggs, or 500,000 fry = $240k).
   b) Start reducing predators in lake.
   c) Then plant eggs that are most genetically similar,
   d) Then in fall conduct predator removal (bottleneck is 0-1 yrs olds).
   e) Then monitor.
3. Both supress predators and plant eggs, since there are hints from data that focus on egg planting is not working. Feedback takes a long time, but there is a risk in having this issue continuing. Thus, it was suggested to be heavy handed for the shortest amount of time.
   a) Stock as many eggs as you can.
   b) Implement predator control of Bull Trout only at this time. The bar isn't even moving much based on predator management options (e.g., total Kokanee consumption change), thus hit predators as hard, for as short of a period as possible. Rationale for not targeting Rainbow Trout:
      - There is a contingent of young Gerrards not available to the fishery (in river up to 3 years). Those populations are decent coming out of Lardeau River (40,000 1 yr old Gerrards). Would have to take a lot out of the lake from angling compared to Bull Trout. There is a disconnect with this and the low amount of spawners.
      - Expecting a natural precipitous decline of Rainbow Trout, as there is currently a lot of standing crop from the previous years when populations of kokanee were healthy, but supply has declined recently.
      - We know there are 250 Rainbow Trout and 3,500 Bull Trout spawners.
      - There are currently liberal Rainbow Trout regulations now (5 fish/day under 50 cm).

5.3.3 Predator control options poll

Overall, there appeared to be consensus to reduce predators especially Bull Trout regardless of the method details. Online polls were set-up to evaluate the options for Bull Trout spawner removal, Bull Trout in-lake removal, and Rainbow Trout in-lake removal (Figure 24 - Figure 26). The following options were most highly favoured by the voters:

- **Bull Trout spawners** - removal at a kelt fence, and removal under a special collection permit/First Nations harvest. Note, 3 participants did not vote, it was not determined if this indicated that doing nothing was the option they favoured.
- **Bull Trout in-lake removal** - Angler reward (lottery – head return), and fishery promotion (derby).
- **Rainbow Trout in-lake removal** – both contract angling and fishery promotion were equally high. Note, 4 participants did not vote, it was not determined if this indicated that doing nothing was the option they favoured.

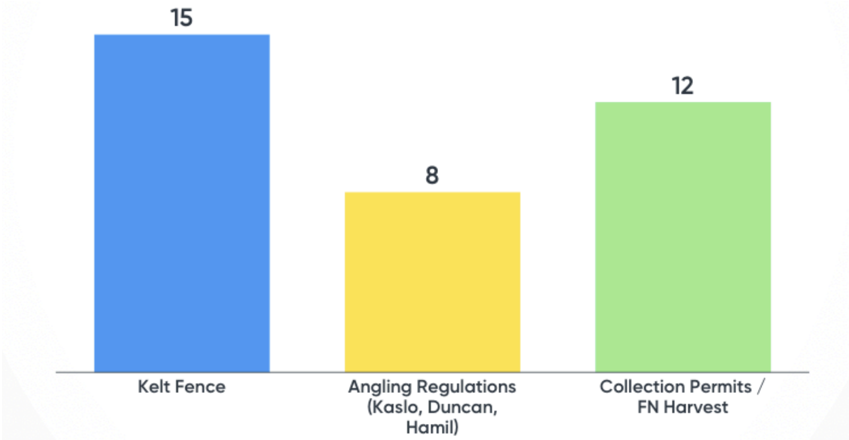


Figure 25. Bull Trout spawner removal options and poll outcome (15 participants voted).

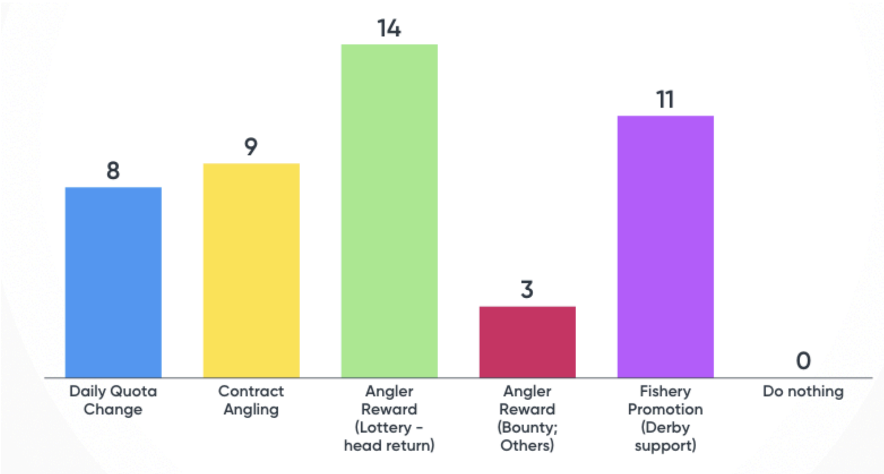


Figure 26. Bull Trout in-lake removal options and poll outcome (18 participants voted).

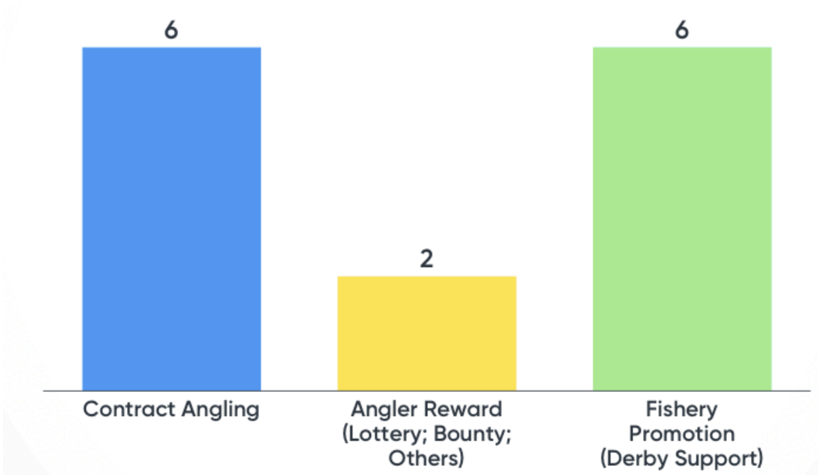


Figure 27. Rainbow Trout in-lake removal options and poll outcome (14 participants voted).

5.4 *There is partial 2018 -19 funding for modelling support through Freshwater Fisheries Society. Is this required, and what direction should this take?*

5.4.1 Model discussion:

1. Brett provided an overview of the Kurota Model:
   a. Model is quite complicated.
   b. Does not have Bull Trout in it, but otherwise it fits all data available for Kootenay Lake.
   c. It can project scenarios forward in time, like adding eggs and removing predators.
   d. The model fits the time series and is a tool to help explore options. It allows for exploration of stability questions, and what policies to implement to avoid future collapse.
   e. Want to use this model to support decisions, but in current state is not easily useable.
   f. The group could apply for post doc support to work on the model and other issues. This would provide directed manpower from someone who is not in government.
   g. There is no current tool to trust.
   h. Can put a user friendly front end on the Kurota model, as it should be able to be used by more than just one person.
2. The modeller should be someone who is a long-term employee who will see it through into the future. The capacity should be available in house.
3. Although not an employee, Joe Thorley works locally in the Kootenays.
4. The bigger picture for the model is seen as: a place for structured thoughts, a tool that provides options for management decisions, and a tool that identifies what additional information is needed. We need to be able to correct or adapt the model so the predicted outcome comes closer to the observed outcome. We should be able to improve it over time.
5. The model should include Bull Trout.
6. The ability to incorporate field component outcomes into the model is also required (e.g., to understand outbreak of Gerrards). It is an ultra-complex model; it may be better to have a simple model. Brett's model example at the meeting might be almost what is required.
7. Obtain data on Lake Pend Oreille bio energetics, or other data to possibly help the model.

5.4.2 Model recommendation

1. There was general support for the development of a model. A subcommittee will be formed to decide how to best apply the money to this task. The committee will be Brett, Trevor, Hillary, Paul, Rob, Jeff and Matt. Inform Kristen/Eva if any of the nutrient restoration program data is used, and how it will be utilized in the model.

5.5 *Do we continue with the nutrient program? Are any changes required?*

5.5.1 Nutrient program discussion

The nutrient restoration program replaces nutrients lost behind upstream reservoirs. Nutrient additions commenced in the North Arm in 1992. Fertilization was initiated in the South Arm in 2004, and was fully implemented in 2005. The fertilization program objective is to replace nutrients lost from upstream impoundments to provide algal populations that support zooplankton as a food source for kokanee.

1. There was a period of really good fishing following South Arm fertilization, and an outburst of Rainbow Trout abundance over a period of years (indexed by escapement time series and KLRT, figures elsewhere in this summary). However, the fishing regulations changed at the same time. There might have been other things that lined up perfectly that were not measured, that resulted in the good supply of Kokanee and more Rainbow Trout.
2. Has fertilization been a destabilizing factor (e.g., for Kokanee/ Rainbow Trout cycles in time series change in age 1-3 Rainbow Trout survival)?
3. What are the trends evident in other interior lakes? Are there larger climatic influences at play?
   a. **POST WORKSHOP INFO:** Trends in other interior lakes are being evaluated, and in general most years during the mid-late 2000's were above average to excellent for Kokanee productivity. There is some evidence pointing to larger climatic influences at play on Kokanee and lower trophic levels.
4. Since the implementation of the South Arm nutrient additions*,* *Daphnia* production increased in both the North and South arm in 2006 and 2007, decreased in 2008 in both arms, increased in both arms in 2009, was average in the South Arm and increased in the North Arm in 2010, was average in both arms in 2011, increased in the North Arm in 2012 (Figure 28). Production was high during 2013 to 2017 due to lack of kokanee grazing pressure.

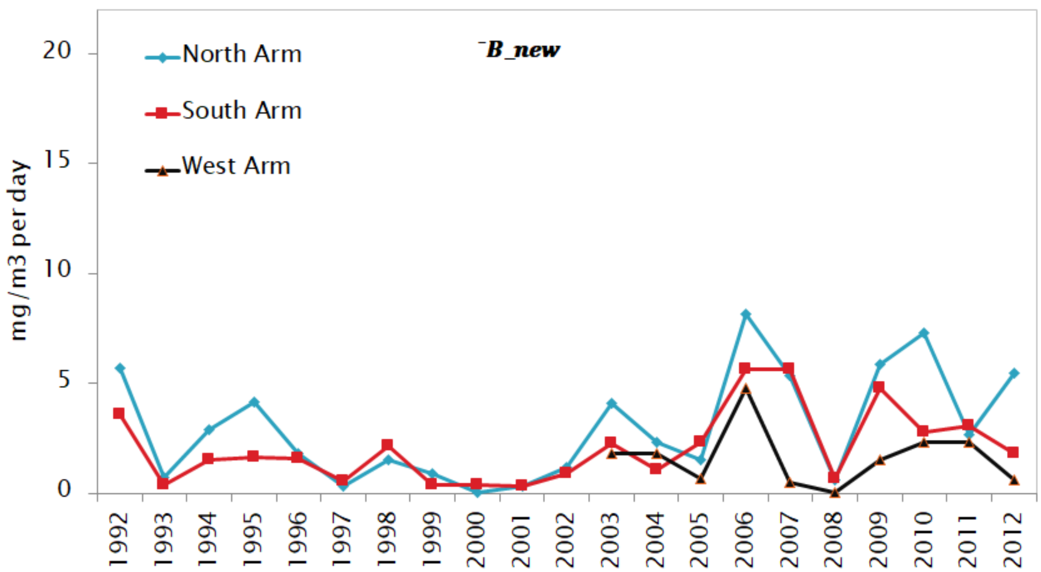


Figure 28. Zooplankton production - Daphnia

5. Since South Arm nutrient additions, age 0 to 1 kokanee survival ranged from 18% to 31% from 2004 to 2011, with the exception of 63% in 2009. Juvenile Rainbow Trout survival or

supply increased during this period, but it is not clearly linked to a period of excellent kokanee survival. However, Kokanee did go through a three year period of exceptionally high standing crop biomass from 2009-11 (also preceded by the highest spawner biomass on record in 2008).

6. Effect of nutrients on invertebrate production - Kootenay Lake does not have any significant diet component from benthic invertebrate production. Terrestrial insects are seen in the predator diet. This is during the period of lake entry, and also period of high mortality. However, nutrient restoration is not likely affecting terrestrial insects. Bigger climate patterns are more likely at play.

5.5.2 Nutrient program recommendation

1. No specific changes to the nutrient program were identified.
2. Future options to evaluate nutrient program impacts on Rainbow Trout dynamics was seen as useful.
3. Eva and Kristen may have some data that could benefit the modelling program. This perhaps, could inform future potential fertilization or other improvements.

5.6 *What is the required monitoring program over the next 3 years to track response?*

The monitoring plan as presented in the 2016 Action Plan was reviewed in brief at the end of the meeting. The discussion focussed on the Enhanced Monitoring Plan, not the Routine Monitoring Plan.

1. **Kokanee**
   a. Use thermal marks to identify wild from hatchery fish (on spawners and in-lake fish).
      i. Also look at otoliths.
   b. Increased trawl surveys to capture juvenile Kokanee
      i. To get an adequate sample of the population. Since all are one age class, can reduce to 3 layers from 5.
      ii. Harder in spring, because the layer is spread out. Requires more effort.
2. **Gerrard Rainbow Trout**
   a. Juvenile abundance (S-R and annual production). HCTF and FWCP funded.
   b. There is a shift in size at each age due to reduced growth. An independent monitoring program, should be undertaken to look at size and age.'
   c. Measure survival rate of Rainbow Trout by age now, versus past (2008-2014 acoustics), to estimate current age 1-4 in lake survival.
   d. Conduct Rainbow Trout stock assessment.
   e. Genetic analysis of Rainbow Trout stock composition (fishery admixture)
   f. Diet – should we continue collect fish from the lake and get samples or not?
      i. Derbies are one venue to get samples.
      ii. Do we want to know exploitation rates? What is important to measure? Are we happy with a snapshot in time? It was pretty stable.

iii. Might be good to have a signal, test if Rainbow Trout are refocussing on Kokanee following Bull Trout reductions. Could be used to indicate if predator reduction is working. Nice to have.
iv. Is opportunistic with derby enough? Is it misleading to take a few samples? Right now not enough effort outside of derby. Best design is to control location (spread over the lake) and timing through contract angling.
v. Regarding sample size, we already have a baseline. Just need a subsample of the population (e.g., 30-50 fish). Do not need to analyze each fish. Maybe also do not need to do every year. Will be interesting when the Kokanee comes back.

g. In lake age structure – have data from guides, continue to do this.

3. Bull trout

a. Redd counts (full lake survey required; frequency?)
   i. Eva has some funding for this year for some tributaries.
   ii. Same index streams?
   iii. Only measure of whether any success in temporarily reducing Bull Trout abundance.
   iv. Would do in 2019 to measure changes from the new actions.
   v. Should monitor all streams as much as possible, as it is most reliable data.
   vi. Unlikely to see a change, maybe not needed every year.
   vii. Some is funded already, more data is better.
   viii. Maximize data coming out of kelt fence
   ix. High priority on streams where reduction efforts occur, as well on controls.

4. *Mysis*

a. Research on diel vertical migration (for both Kokanee and *Mysis*)– suggested in the Action Plan for 2016-17, required?
   i. Didn't do partly because it would be very intensive. Lot of work and time.
   ii. They migrate up through the water column at night. 20% of Rainbow Trout diet.
   iii. Has their behavior, numbers, or productivity changed? Biomass is the same. Could get that information (Kirsten).
   iv. Overall, nice to know, but not necessary. Some do not see it forming a management decision.

b. Should there be further development on a *Mysis* removal project (pilot)?
   i. Jeff provided background information (Figure 29).

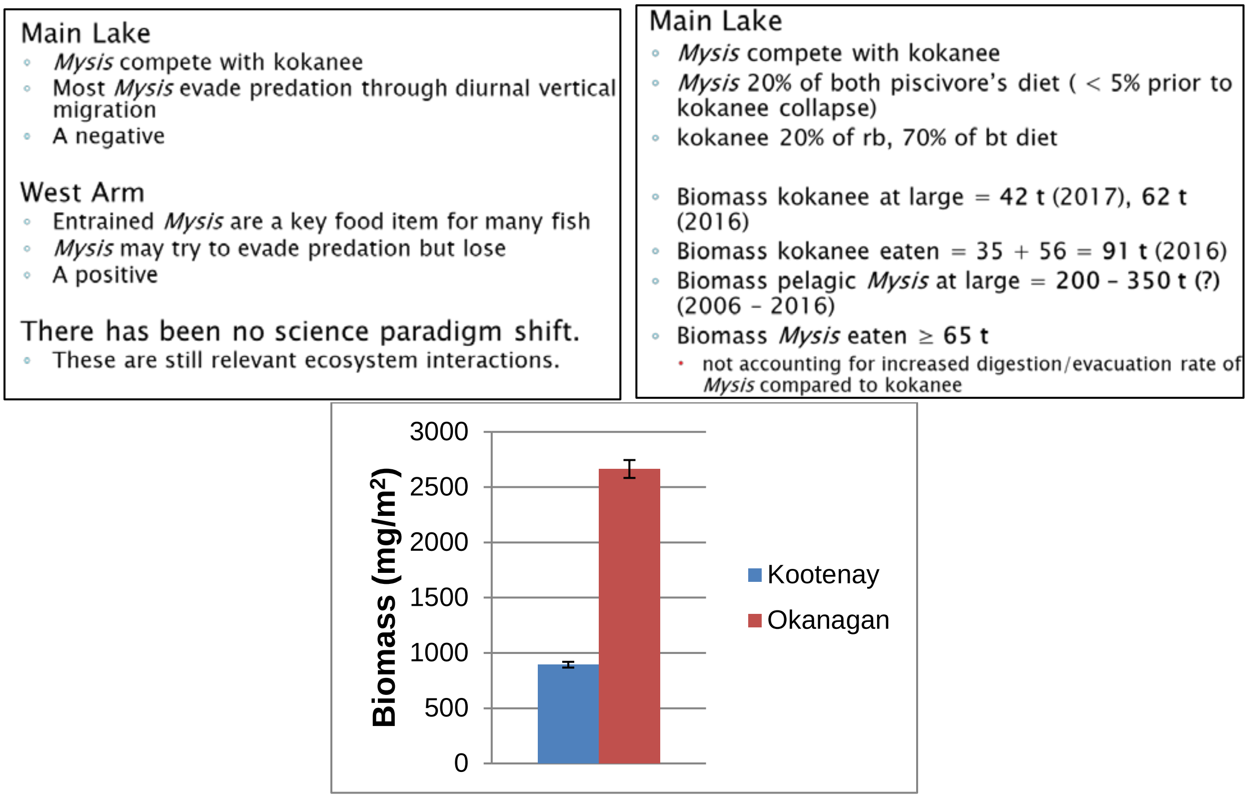


Figure 29. Mysis and Kokanee (top slides), *Mysis* biomass in Kootenay and Okanagan lakes (bottom; J. Burrows).

- The hope is to gain better conditions for Kokanee. Main Lake *Mysis* compete with Kokanee, a negative.
- West Arm, isn't deep enough for mysids to avoid predation, a positive.
- Overall, need to remove 30% of Mysis biomass, to get to a tipping point for Kokanee.
- Ktunaxa is developing a feasibility report. Almost completed.

ii. *Mysis* are cannibalistic. Do not want to upset an equilibrium that is stable.

iii. Rationale for not removing Mysids:

- Mysids may not be a problem, as there is no evidence of a major impact on Kokanee. However:
- Based on removal efforts on Okanagan Lake, there is no evidence that removal will have an improvement.
- Concern that we would never get Mysid production down enough. Limited market; have been trying for 20 years. Hard to finding permittees to do it on Okanagan Lake.
- Predator removal should be the focus, do not want to pull too many levers at once.

iv. Rationale for considering mysid removal:

- Additional *Mysis* abundance (in piscivore diet) has appeared. Since there is competition between Kokanee and *Mysis*, it would be a concern if the *Mysis* population has increased or become more productive.

- Diet has changed – mysids are supporting Rainbow Trout and Bull Trout; maybe the productivity would change if they were removed/reduced.
- Okanagan Lake only removed one third of the full amount recommended. Modelling guidance was to remove 30% of Mysis biomass not 10%. So it hasn't even been tested in Okanagan Lake, yet. Also, the business model is not the right approach. Mysids could be treat as invasive species. If you pay people to do this, then they would, versus relying on a weak and unreliable business. Maybe the Columbia Basin Trust (CBT) could provide funding.
- Do pilot studies – astronomical cost, not much more to invest at this point. Half of nutrient investment goes into mysis.
- Predators are going to go after Kokanee first over mysids. Do we need the feasibility study in place if mysids increase? Is a feasibility study applicable to investment and resources to do pilots?

v. Overall thought was to finish the existing feasibility study. This would be useful to help make an informed decision moving forward.

5. Fishery

a. Creel census (KLRT mail-out and/or full lake)

i. KLRT is currently the only metric for in-lake abundance. Are we collecting the correct data, how do we best use it?

ii. Get an age sample from angler caught fish

iii. A creel census is used to measure annual effort, catch, and harvest estimates.

iv. Is it worth it now, or in the next few years to implement a full lake on the ground creel survey?

- Would be useful to hire someone to conduct a creel survey some days at boat launches. It would also be a promotion tool. This person could also attend the derby.
- From an education and public communication perspective, a creel survey would be very valuable.

v. Overall thought was to proceed as above with both a KLRT mail out, and a creel census as described above.

b. Exploitation rates

i. We know this will be low.

ii. Trying to drive change in exploitation rates through lottery; one way to measure success.

iii. Al - If sufficient samples, it is important to gather data on size at age, age composition, mortality rates. This should be an integrated program, with control of the collection of samples, reach sample size both spatially and temporally (contract angling).

5.6.1 Monitoring program recommendations

Overall, there was consensus for a continued Enhanced Monitoring Program. Since many suggestions were not well fleshed out, and there was not time to address this in detail, recommendations and design review will be further evaluated. A decision to proceed will be made if resourced and a high priority.

6 Conclusions

This section is a post workshop summary, and was prepared by Matt Neufeld

Overall, the Kootenay Lake Fisheries Advisory Team remains very committed to understanding the processes and implementing actions to recover the Kootenay Lake Gerrard fishery. This meeting allowed members to review data and analysis completed since 2016, as well as review Action Plan actions and triggers. The objective of the meeting was to develop recommendations to Regional Management, on required changes to the Action Plan actions to increase the chance of short term Kokanee recovery. In general, no significant changes to actions or triggers were identified. However, predator management and Kokanee stocking actions were discussed in detail (two most significant recovery levers), and refined actions and/or advice provided.

In relation to Kokanee stocking, the Action Plan identified stocking of 5 million eggs as the action, triggered by low kokanee abundance/survival. However, after meeting discussions, members were polled in relation to support of three levels of suggested stocking effort. In this poll, there was a lack of consensus support for action plan targets, with the majority (70%) supporting either no stocking or reduced stocking (1-2 million using best genetic sources). There were a number of reasons for support by the majority to stock fewer than 5 million eggs, including the risk of feeding predators, genetic risk to future kokanee populations (non-Meadow genetic impacts), low cost benefit given current survival rates (don't know what survival rates will be one year after stocking), and others.

The 2016 Action Plan, had identified predator conservation and management actions (to increase or reduce predator numbers), but because of the concern over low future predator abundance at the time, detail was only identified for conservation actions. However, Diet Data collected after Action Plan development identified significant Kokanee consumption by Bull Trout (70% of current diet), while Rainbow Trout diet was only comprised of ~20% kokanee. Analysis to reconstruct in-lake population size over time, and then use diet data to index Kokanee consumption by both species, suggested that Rainbow Trout and Bull Trout are consuming almost equal amounts of Kokanee currently, when scaled to estimated abundance by species. Therefore, reducing either population would have benefits for Kokanee survival. However, the prevailing opinion of advisory team members was that there was risk to further Rainbow Trout reduction actions (beyond the current angling regulation changes in effect for daily quota), because although estimated in-lake abundance in reasonably high, spawner escapement for the entire Gerrard population is currently only ~200 adults. Additionally, recent low spawner abundance and juvenile supply may soon be apparent in the lake in the form of in-lake population reductions. Bull Trout on the other hand are less abundant in the lake (rear to age 2-4 in tributaries), however their spawning populations are currently very strong (~3500 in 2017) and geographically diverse. Stock recruit data collected on the Kaslo River (Andrusak 2018[5]) suggests that given 2017 Bull Trout spawner return estimates on that system, that ~50% of the spawners were surplus to production needs, and therefore short term Bull Trout reductions likely come at little risk to future Bull Trout supply. As a result of this data, advisory team members had the consensus opinion that reductions in Bull Trout populations would benefit Kokanee recovery, and come at no significant risk to these populations in the short term. When members were polled with options for reductions, there was no consensus on the approach.

[5] Andrusak, G.F. 2018. Kootenay Lake Bull Trout Productivity and Capacity for Defining Management Reference Points-CAT # 17-4-465-2017. Prepared for the Habitat Conservation Trust Foundation and the Ministry of Forests, Lands and Natural Resource Operations, Victoria, BC. January 2018. 32 pp+

In general, the prevailing opinion of advisory team members was that reducing Bull Trout populations in the short term, in addition to some level of Kokanee stocking was the most likely approach to recover Kokanee populations quickly. It was clear that the opinion of many was that Kokanee stocking without predator reductions had a low chance of success given recent data, and potential risk of prolonging recovery (by feeding predators).

The original Kootenay Lake Action Plan provided status and recovery tables outlining recovery tools, triggers/measures, rationale, benefits/risk, and priorities (Redfish Consulting Ltd 2016). In addition to that above, a summary of actions implemented since 2016 and recommendations from this workshop has been provided in updated recovery tables for Kokanee, Gerrard Rainbow Trout, and Bull Trout (Table 8 a-c). The original routine and enhanced monitoring table is also provided, with updates pending further internal management review and decision (Table 8 d).

Table 8. Kootenay Lake Action Plan Summary, 2016-2018.

Table 8a. Kokanee Action Plan Summary, 2016-2020

Objective	Action	Tools	Trigger	Measure	Rationale	2016 Benefit/Risk	2016 Rank	2016-2018 Implementation	2018 Benefit/Risk/Comment	2018 Rank
Recovery of Kokanee	**Maintain main lake fishery closure for Kokanee**	Recreational Fishery Regulations	KO escapement < 140,000, age 0 to age 1 survival < 11%, KLRT > 2 kg RBT CPUE mod-high	KO escapement >65- 140K	This action will ensure no mortality from angling occurs on the main lake Kokanee population during the recovery	High benefit to increase probability of Kokanee recovery. Main lake Kokanee fishery is not considered to be highly valued	High	In 2015 - 2017, maintained Kokanee daily quota=0.	-	-
	No Supplementation	Natural resiliency and recovery	NA	NA	Allow ecosystem to recover naturally	Reduced cost, no genetic concern, prolong recovery, prolong recovery of fishery	Low	-	Stocking could simply feed the predators, prolonging their survival and the problem. Thus, follow multi-step process to reduce predators first, then stock.	Moderate (35%)
	Supplementation - general	Egg plant and/or fry release - general	KO escapement < 140,000, age 0 to age 1 survival < 11%, < 17.0 million fry, KLRT > 2 kg RBT CPUE mod-high	KO escapement > 65-140K	Reduce recovery time for low abundance KO cohorts (brood 2015 and 2016)	Increase probability of survival of the Kokanee, with an estimated egg to fry survival of near 70%. FFSBC has a limited capacity to incubate eggs at their facilities.	High	> 5 million eyed eggs were stocked annually in Meadow Creek in 2016 and 2017. However, more than half of the eggs departed from the low risk genetic recommended sources.	Eyed eggs to emergent fry are surviving well (40% in 2017). Therefore continue to stock eggs.	High (70%)
	Supplementation (option a)	Stock eggs from meadow genetic sources (1.5 million)				-	-	-	Past stocking results indicate the reward of stocking is low; thus, avoid risk of diluting genetics, to ensure long term self-sustaining KO population.	Moderate (35%)
	Supplementation (option b)	Stock the greatest number of eggs, including from non-Meadow genetic sources (6 million)				-	-	-	Plant as many eggs as possible as an insurance measure to increase KO population.	Low (30%)

Table 8a. Kokanee Action Plan Summary, 2016-2020

Objective	Action	Tools	Trigger	Measure	Rationale	2016 Benefit/Risk	2016 Rank	2016-2018 Implementation	2018 Benefit/Risk/Comment	2018 Rank
Recovery of Kokanee	**MCSC hatchery to support supplementation**	MCSC facility	Increase capacity beyond 5.0 million eggs, ability to use "green eggs" for out-planting and imprinting at MCSC	> 2.0 million eggs	Increase FFSBC hatchery capacity > 5.0 million by incubating at MCSC	Increased capacity egg incubation capacity of >5 million eggs available	Low	~1 million eggs were incubated in 2017; FFSBC has also increased capacity to ~8 million through upgrades/staff and facility planning.	-	-
	Kootenay Lake Nutrient Restoration Program	Continue to modify seasonal and weekly nutrient addition amounts and fine-tune timing of nutrient additions in spring and fall	Analysis of annual monitoring data; Stratification (spring) of lake, de-stratification (fall) of lake, temperature and light	Variable annual phosphorus (25-47 tonnes) and nitrogen (140-250 tonnes in North Arm and 190-270 tonnes in the South Arm)	Replace Nutrients Lost through the creation of upstream impoundments to Improve efficiency and biological uptake of nutrients for phytoplankton to zooplankton to ensure Kokanee food supply	Take advantage of seasonal changes in climate to facilitate better growing conditions for phytoplankton	High	Continued implementation of current program (late April through early to mid-September).	-	-
	Mysis removal	Test fishery to remove Mysis similar to Okanagan Lake	Increase in biomass and density 2 SD over long term average (168 ind/m^2) would be 463 ind/m^2	KO escapement > 65-140K	Remove >30% of the total Mysis biomass to reduce Kokanee competition and increase Kokanee survival	Mysis of requires over 30% of the total biomass to be removed before a benefit to Kokanee can be realized. Substantial costs would be associated with the development of the Mysis suppression.	Low	A Mysis removal feasibility review is in development.	Support to finish feasibility	-
	Predator Management - see Gerrard and Bull trout tables	Recreational Fishery Regulations	KO escapement < 140,000, age 0 to age 1 survival < 11%, KLRT > 2 kg RBT CPUE high	KO escapement > 140,000	Further removal of predators may provide additional benefits to the recovery of Kokanee through increased survival.	Increase impact to predator population. May have limited improvement for Kokanee.	Low	In 2018, BT quota was increased to 2/day. In 2015, RBT daily harvest quota increased to 4 fish/day, and then 5 fish/day in 2018. Only 1 >50 cm for both species.	Low survival (5%) for age 0-1, continued for age 1-2 KO.	High

Table 8b. Gerrard Rainbow Trout Action Plan Summary, 2016-2020

Objective	Action	Tools	Triggers, Measure and Target	Rationale	2016 Benefit/Risk	2016 Rank	2016-2018 Implementation	2018 Benefit/Risk/Comment	2018 Rank
Recovery of Gerrard Rainbow Trout	**Recreational Angling Regulations**	Recreational fishery regulations to zero retention of Rainbow Trout > 50 cm	Gerrard escapement LRP <50-100 AUC	Implement a precautionary approach that ensures conservation levels, reduce all mortality from fishery	Reduce the recovery time of predators, reduce mortality when population is critically low	High	RBT daily harvest quota increased to 4 fish/day in 2015 and then 5 fish/d in 2018; only 1>50 cm.	-	-
Recovery of Gerrard Rainbow Trout	**Gerrard Rainbow Trout population Viability**	Collect individuals for hatchery rearing	Gerrard escapement LRP <50-100 AUC	Secure future viability and persistence of Gerrard Rainbow Trout population by obtaining individuals from current population for hatchery rearing	Hatchery risk of relatively new stock. Genetic insurance policy if population decreases further	Mod	-	-	-
Recovery of Gerrard Rainbow Trout	**Hatchery Augmentation**	Use hatchery augmentation to recover population	Gerrard escapement LRP <50-100 AUC	Facilitate recovery of population	Hatchery augmentation may have negative effects to remaining wild stock, reduced fitness and productivity. May increase predation on recovering Kokanee.	Low	-	-	-
Predator Mgmt for kokanee	**Spawner harvest**	Remove spawners from tributary streams.	KO: <140,000 spawners; age 0-1 survival <11%. Gerrard conservation: escapement <50-100 AUC in 2 consecutive years.	166 spawners estimated in 2017. Potentially 66, or ~30%, could be removed and still meet conservation trigger.	-	-	-	Option not discussed in detail, as no apparent support.	Low

Table 8b. Gerrard Rainbow Trout Action Plan Summary, 2016-2020

Objective	Action	Tools	Triggers, Measure and Target	Rationale	2016 Benefit/Risk	2016 Rank	2016-2018 Implementation	2018 Benefit/Risk/Comment	2018 Rank
Predator Mgmt for kokanee	**In-lake removal**	Removal through contract angling	KO: <140,000 KO spawners; age 0-1 survival <11%. Gerrard conservation: escapement 50-100 spawners, and/or <50-100 AUC in 2 consecutive years.	KO consumption by RBT in 2016-17 ~56,000 kg/yr. Goal is to reduce predator numbers in the lake. Currently 75% of fish are being released. General caution for all options since: few spawners, expecting natural decline, and catch regs are liberal.	-	-		Low impact option. Previously completed successfully. Contractor can also tag fish, to help with monitoring. On its own, does not adress the value of promoting fishing to the public. Costly per fish	Moderate (42%)
		Removal through fishery promotion (derby)			-	-	-	May not have huge gains, but many anglers could result in a bigger impact than hiring guides. Reward/tag program identified as an incentive (e.g., 10 prizes for $10k). Prizes require gaming licence	Moderate (42%)
		Removal through angler reward (lottery, bounty etc).			-	-	-	Bounty/paying a licenced angler $ per head is not legal. With lottery, every fish head could be entry, with genetic testing to confirm from lake if needed. Could hire someone to collect heads at boat launch and conduct creel survey. Risk to small spawner population from added removal.	Low (14%)

Table 8c. Bull Trout Action Plan Summary, 2016 - 2020

Objective	Action	Tools	Trigger, Measure or Target	Rationale	2016 Benefit/Risk	2016 Rank	2016-2018 Implementation	2018 Benefit/Risk/Comment	2018 Rank
Recovery of Bull Trout	Mortality Reduction on Bull Trout	Recreational fishery regulations to zero retention of Bull Trout > 50 cm	LRP 50/500	Implement a precautionary approach that ensures conservation levels are being met by reducing all mortality from recreational fishery on Kootenay Lake.	Reduce the recovery time of predators, reduce mortality when population is critically low	Moderate	-	-	-
Bull trout mgmt for kokanee	Spawner harvest in tributary streams	Remove spawners using kelt fence.	KO: <140,000 spawners; age 0-1 survival <11%. BT conservation: escapement <50 spawners in Kaslo R., <500 spawners in lake wide index.	In 2017, 1049 spawners in Kaslo and Keen creeks, and 3421 spawners lake wide, thus surplus. BT are considered resilient, as long as habitat is available. Would not impact viability if only adults were targetted after spawning. BT do not prey on KO until age 3-4, so gives a few years of reprieve for KO. Need to determine target (75% of fish?).	-	-	-	Can harvest target amount of fish and then tag remaining, to help with in-lake monitoring.	High (100%)
		Remove spawners using angling regulation changes.			-	-	-	Risk of building a permanent expectations, when temporary reductions are the action. Unrealistic to get a regulation change in short time frame.	High (67%)
		Remove spawners using scientific collection permits/First Nations harvest.			-	-	-	Alternative to angling regulation change. Would allow for better data collection, provide control to ensure no overharvest. Could be seen as favouritism.	Moderate (53%)

Table 8c. Bull Trout Action Plan Summary, 2016 - 2020

Objective	Action	Tools	Trigger, Measure or Target	Rationale	2016 Benefit/Risk	2016 Rank	2016-2018 Implementation	2018 Benefit/Risk/Comment	2018 Rank
Bull trout mgmt for kokanee	**In-lake removal**	Do nothing	KO: <140,000 spawners; age 0-1 survival <11%. BT conservation: escapement <50 spawners in Kaslo R. and <500 spawners in lake wide index.	KO consumption by BT in 2016-17 estimated to be ~ 35,000 kg/yr. Goal is to reduce predator numbers in the lake. Currently 75% of fish are being released.	-	-	-	-	Low (0%)
		Angler reward (lottery - head return)			-	-	-	Every fish head could be an entry, with genetic testing of the winner to confirm its from lake. Could hire someone to collect heads at boat launch and conduct creel survey. Entries and prizes require gaming licence.	High (78%)
		Fishery promotion (derby).			-	-	-	Many anglers could result in a bigger impact than hiring guides. Reward/tag program identified as an incentive (e.g., 10 prizes for $10k).	Moderate (61%)
		Contract angling.			-	-	-	Low impact option. Previously completed successfully. Contractor can also tag fish, to aid in monitoring. On its own, does not address the value of promoting fishing to the public.	Moderate (50%)
		Regulation daily quota increase)			-	-	In 2015, recommended increase opposed by stakeholders. In 2018, the daily catch quota increased to 2 Bull Trout / day (only 1 >50 cm).	'Risk of building a permanent expectation, when temporary reductions are the action. Unrealistic to get a reg change in short time frame.	Moderate (44%)
		Angler reward (bounty, other).			-	-	-	Does not provide opportunity to gather as much information and control catch outcome. Paying a licenced angler $ per head is not legal.	Low (16%)

Table 8d. Routine and enhanced monitoring 2016-2020

Action	Routine Monitoring (annual)	Timing	Measures
Kokanee	Estimation of spawner abundance in Meadow Creek	Fall	Determine total run size & obtain biological data
	Estimation of spawner abundance in Duncan & Lardeau rivers	Fall	Estimate spawner abundance
	Calculate egg deposition for MC & L&D rivers	Fall	Estimation of total egg deposition
	Conduct counts on SA streams	Fall	Spawner counts on selected index streams
	Acoustic surveys	Spring/Fall	Annual estimates of in-lake Kokanee abundance
	Trawl surveys	Fall	estimates of size, growth and condition of juvenile Kokanee
	Fry enumeration at MCSC	Spring	Annual estimates of fry production
Gerrard Rainbow Trout	Gerrard rainbow trout daily counts at Gerrard	Spring	Annual AUC estimate of number of spawners
	Conduct annual KLRT survey	Annual	Catch and effort statistics
Bull Trout	Redd surveys on Kaslo River and lake-wide	Fall	Estimate spawner numbers, trend data
KL Nutrient Program	Annual monitoring program of primary & secondary trophic levels and kokanee acoustics and trawl and spawner enumeration on the Duncan/Lardeau and South Arm tributaries	Annual	Water quality, phytoplankton taxonomy, primary production, zooplankton and mysid abundance, biomass, kokanee acoustic and trawl surveys and spawner surveys on Duncan/Lardeau and South Arm tributaries (listed above in the kokanee section)
KL Fishery	Main lake currently closed to Kokanee harvest	Annual	conserve as many potential Kokanee spawners as possible
	Annual regulations	Annual	Manage predator populations
Action	**Enhanced Monitoring (2016-2017)**	**Timing**	**Measures**
Kokanee	Release ~0.5 million fry in spring 2016	Spring	Increased numbers of spawners in 2019
	Estimate planted eyed egg survival rates	Spring	Determination of survival rate
	Increase # of flights for Lardeau counts to 3 per spawning season	Fall	Improved accuracy of spawner estimates
	Increase trawl surveys to capture juvenile Kokanee	Spring/Fall	Increase sample size for growth and condition determinations
	Conduct bank counts on Lardeau River	Fall	Improved accuracy of spawner estimates
	Collect 5.0 million eggs	Fall	Produce 5.0 million eyed eggs for implanting into Meadow Creek
	Evaluate survival rate of egg plants	Fall	Egg-to-fry survival rate and estimation of fry numbers produced
	Track thermal marks in hatchery fry vs wild fry	Fall	% of fry with thermal marks
Predator Food Habits	Food habits of smaller predators	Summer	Determine extent of Kokanee predation
Rainbow Trout	Genetic analysis of rainbow trout stock composition	Annual	Identification of Gerrards vs non-Gerrards
	Lardeau river snorkel survey of juvenile RB during low abundance	Spring	Determination of stock productivity at low abundance
Bull Trout	Redd surveys of Index streams	Fall	Estimate spawner numbers, trend data
	Kaslo River snorkel survey of juvenile BT	Fall	Determination of stock productivity at low abundance
Mysis	Monitor abundance and biomass of Mysis shrimp	Summer	Estimate of mysid abundance and biomass
	Mysis and Kokanee research on diel vertical migration and develop a Mysis suppression plan (feasibility etc).	Summer	Determine if migration has changed under low Kokanee abundance. Prepare suppression action plan if suppression triggered.
KL Fishery	Creel census/KLRT questionnaire	Annual	Annual effort, catch and harvest estimates for Rainbow and Bull Trout

Appendix A. Kootenay Lake Fisheries Advisory Team meeting attendance.

Name	Title	Affiliation	May 15	May 16
Committee				
Harvey Andrusak	President	BC Wildlife Federation	x	x
Steve Arndt	Fisheries Biologist	FLNRORD, Nelson	x	x
Dr. Paul Askey	Fisheries Scientist	FFSBC, Penticton	x	x
Robert Bison	Fisheries Stock Assessment Biologist	FLNRORD, Kamloops	x	x
Holger Bohm	Section Head, Fish and Wildlife	FLNRORD, Cranbrook	x	x
Jeff Burrows	Senior Fish Biologist	FLNRORD, Nelson	x	x
Adrian Clarke	Vice President of Science	FFSBC, Victoria	x	x
Dr. Trevor Davies	Stock Assessment Specialist	FLNRORD, Victoria	x	x
David Johner	Large Lake Technician	FLNRORD, Victoria	x	x
Alan Martin	Director of Strategic Initiatives	BC Wildlife Federation	x	x
Matt Neufeld	Fish Biologist	FLNRORD, Nelson	x	x
Kristen Peck	Fish Restoration Biologist	FLNRORD, Nelson	x	x
Mike Ramsay	Associate Director, Fisheries	FLNRORD, Williams Lake	x	x
Eva Schindler	Section Head - Fish & Wildlife Compensation Program	FLNRORD, Nelson	x	x
Dr. Brett van Poorten	Unit Head, Applied Freshwater Ecology Research	MoE, Vancouver	x	x
Dr. Hillary Ward	Fisheries Stock Assessment Biologist	FLNRORD, Penticton	x	x
Dr. Will Warnock	Senior Aquatic Biologist	Ktunaxa Nation Council, Cranbrook	x	x
Tyler Weir	Large Lake Ecosystem Specialist	FLNRORD, Victoria	x	x
Observer				
Michael Zimmer	Biologist	Okanagan Nation Alliance Fisheries Department, Castlegar	x[1]	x[1]
Tia Scott	Administration	FLNRORD, Nelson	x	x

1: Participated via conference call

Affiliation:
BC MoE – BC Ministry of Environment
FFSBC - Freshwater Fisheries Society of BC
FLNRORD - BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development

Appendix B. Kootenay Lake advisory team presentation (prepared by Matt Neufeld, Tyler Weir, David Johner, Jeff Burrows, Eva Schindler, Hillary Ward, Kristen Peck, Steve Arndt and Robert Bison).

Kootenay Lake Advisory Team

May 15-16, 2018

Contributions by: Matt Neufeld, Hillary Ward, Steve Arndt, Tyler Weir, Kristin Peck, Jeff Burrows, Rob Bison

Thanks to funders and contributors

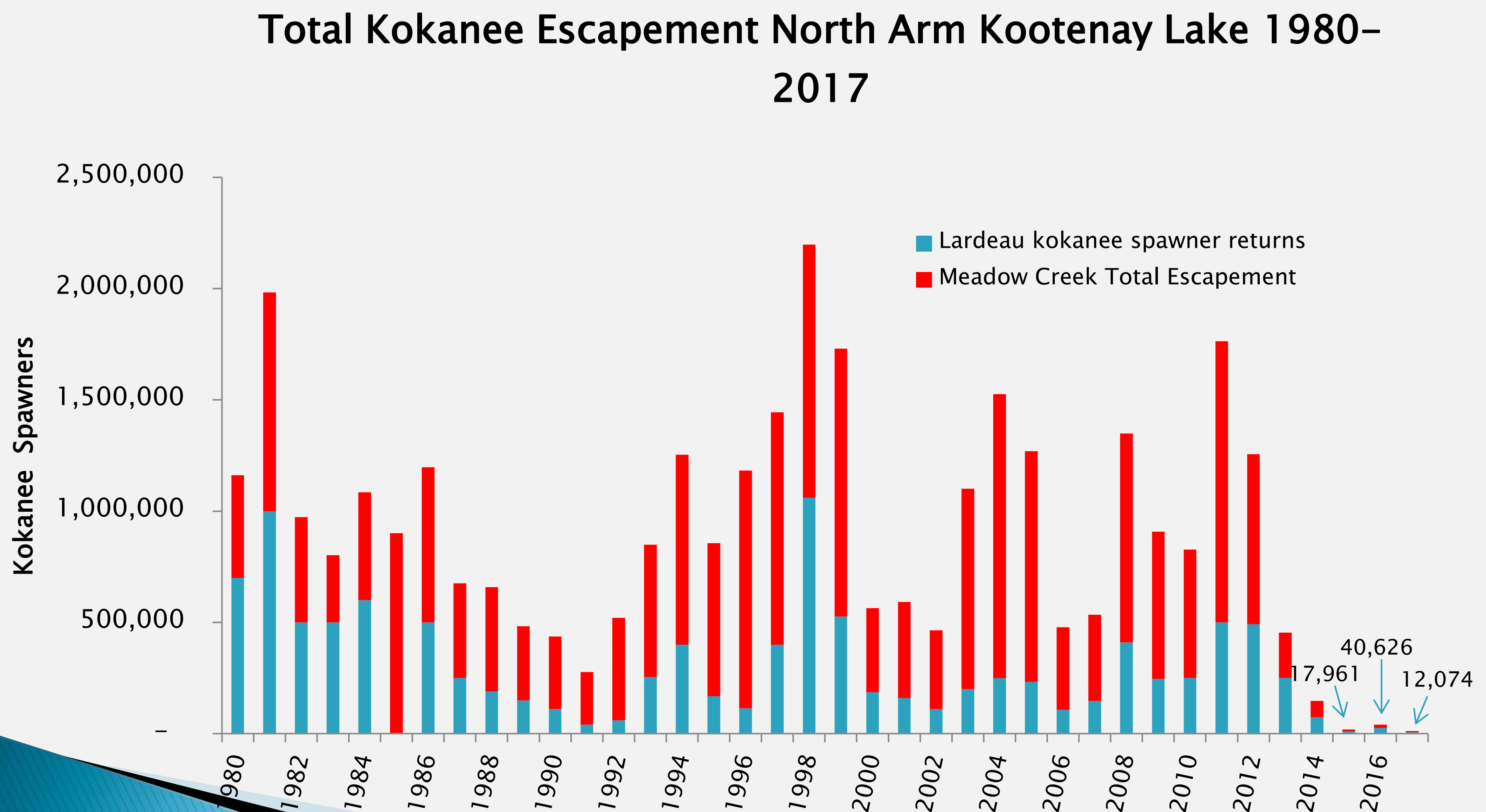
- Acknowledgments for funding – Nutrient program funding (FWCP, KTOI, BC Hydro, MoE, FLNRORD) Action plan implementation and enhance monitoring (FFSBC, FLNRORD, FWCP, and HCTF)

- Acknowledgments for contributors – too many to list…truly a collaborative, multi-faceted effort to recovery Kootenay Lake. We thank all Advisory Team members, research technicians, FFSBC staff, FWCP nutrient program delivery team, external contractors delivering monitoring components…..

Outline

- Background/Biological Response Update
- Review Actions, Triggers, and Implementation update from 2016-18 (what did we do?)
- Provide some analysis/ideas to help inform discussions around Key Questions.

Kootenay Kokanee Escapement Spawner Trends



Slide from Basset - 2017

Kootenay Kokanee In-Lake Abundance

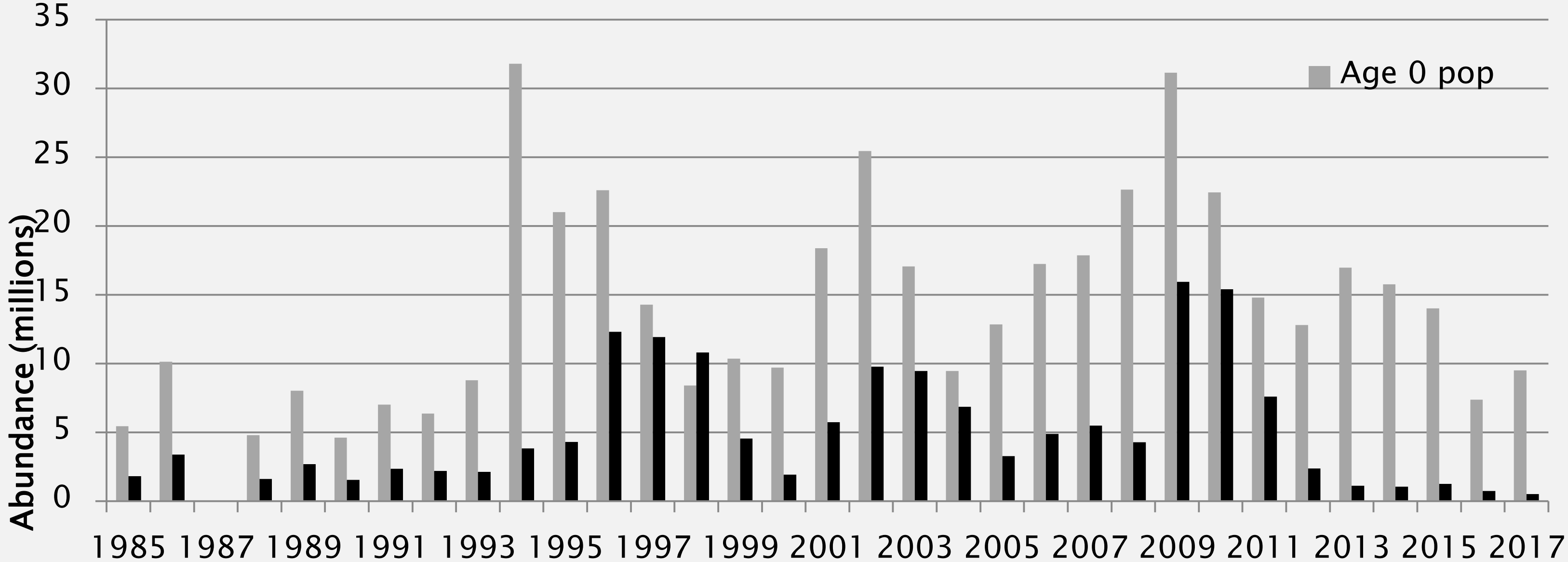


Figure 5. Acoustic abundance trends for age 0 and age 1-3+ kokanee from fall surveys of Kootenay Lake. 2017 data are preliminary.

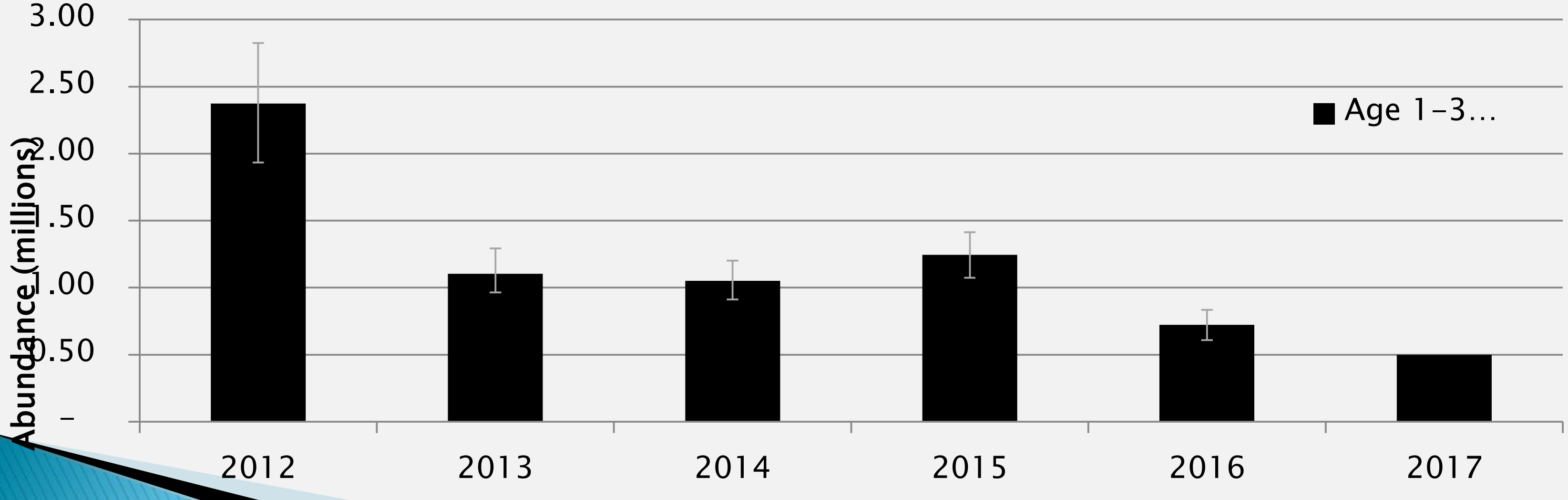


Figure 6. Acoustic abundance trends for age 1-3+ kokanee from fall surveys of Kootenay Lake from 2012 to 2017. 2017 data are preliminary.

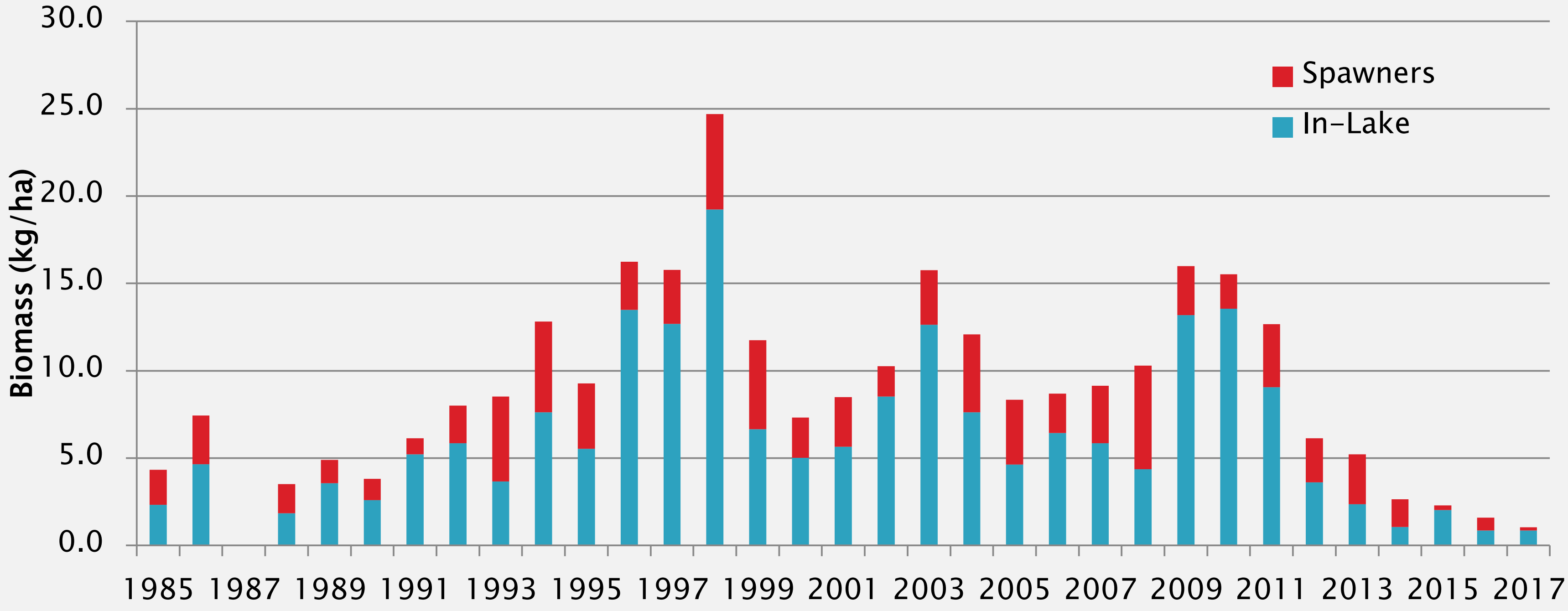


Figure 6. Kokanee biomass density estimates for Kootenay lake.

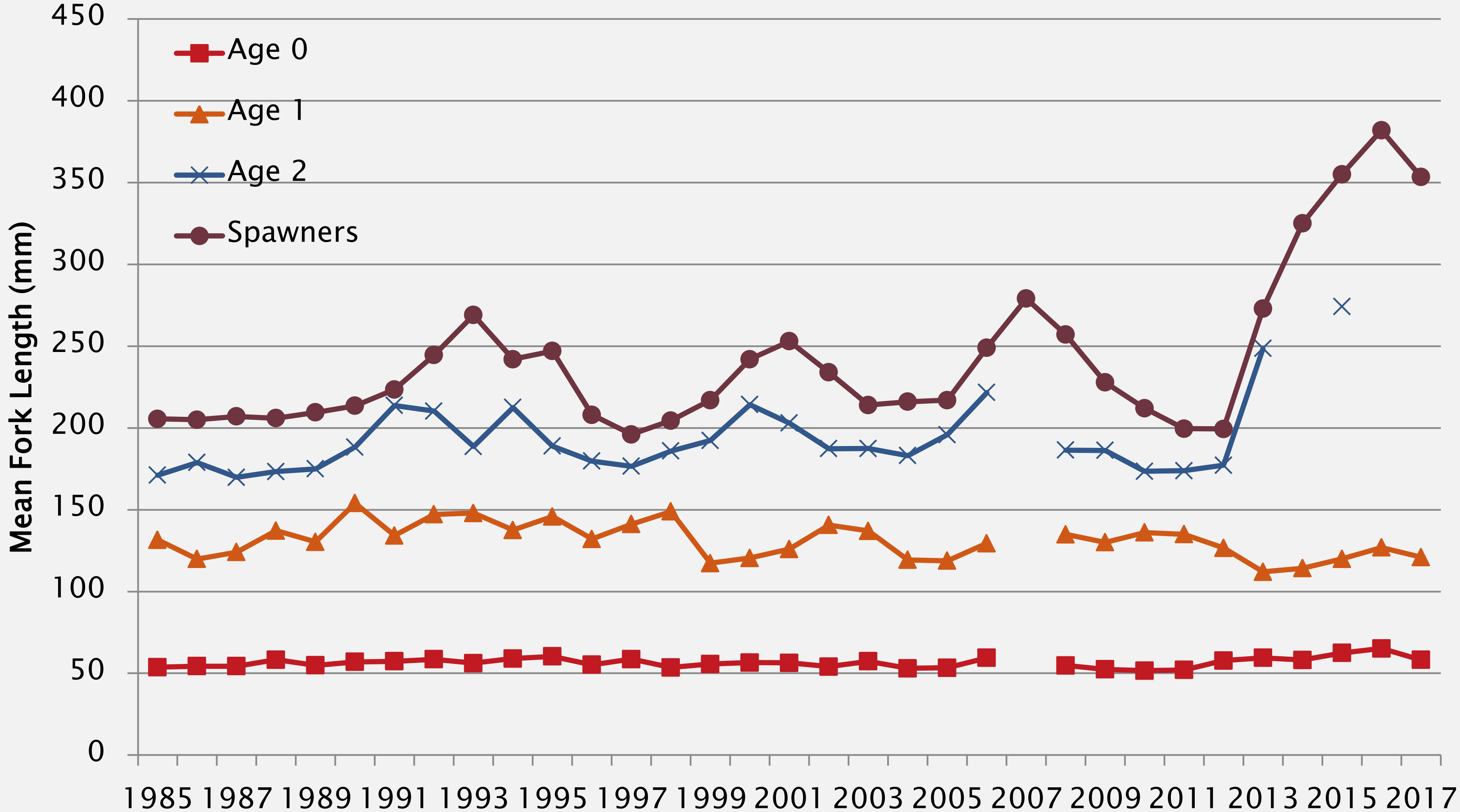


Figure 1. Mean fork length of trawl caught age 0-2 kokanee from fall trawl sampling in Kootenay Lake, and mean spawner fork length from Meadow Creek spawning channel. Fork lengths from trawl captured fish are corrected to an October 1st standard.

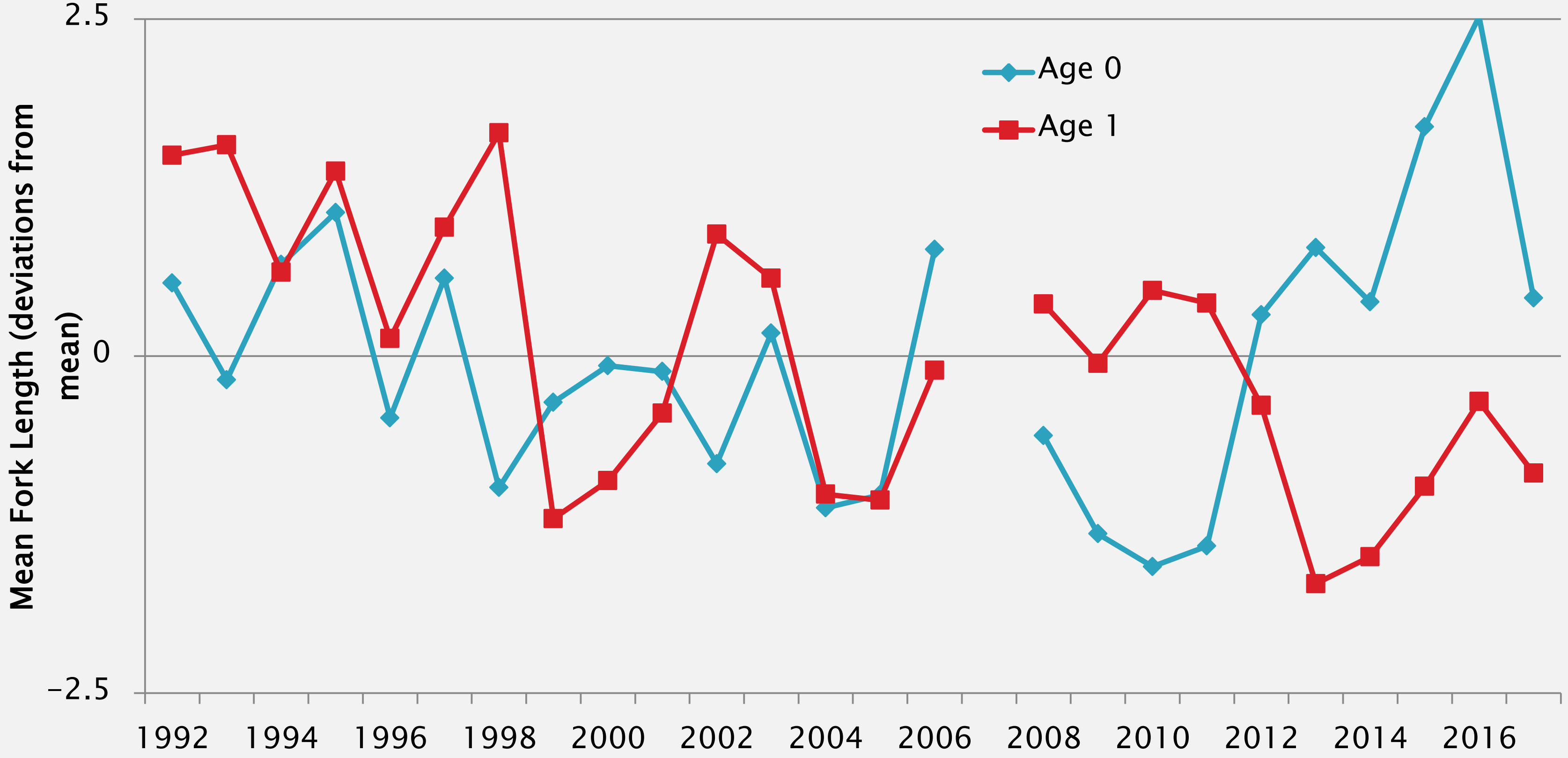


Figure 2. Trends in standardized mean lengths for age 0 and age 1 kokanee from fall trawling in Kootenay lake.

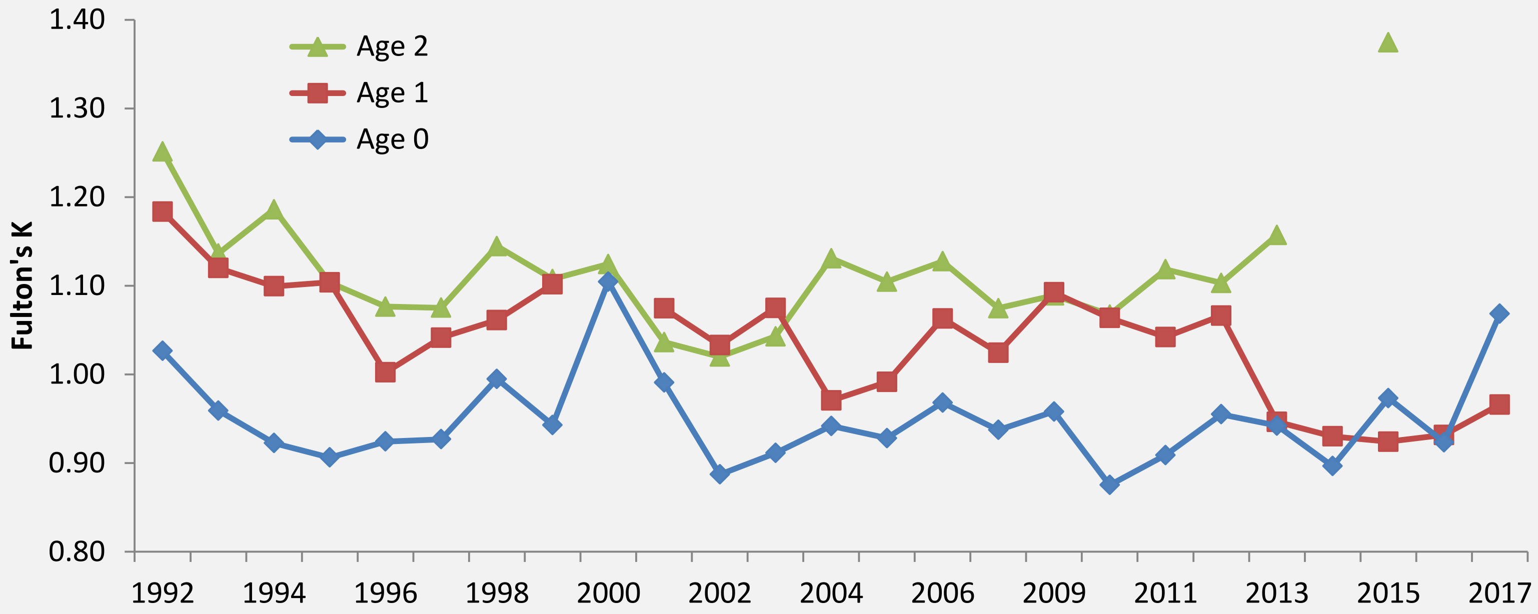


Figure 3. Fulton’s condition factor trends for fall trawl caught kokanee in Kootenay Lake during post fertilization years.

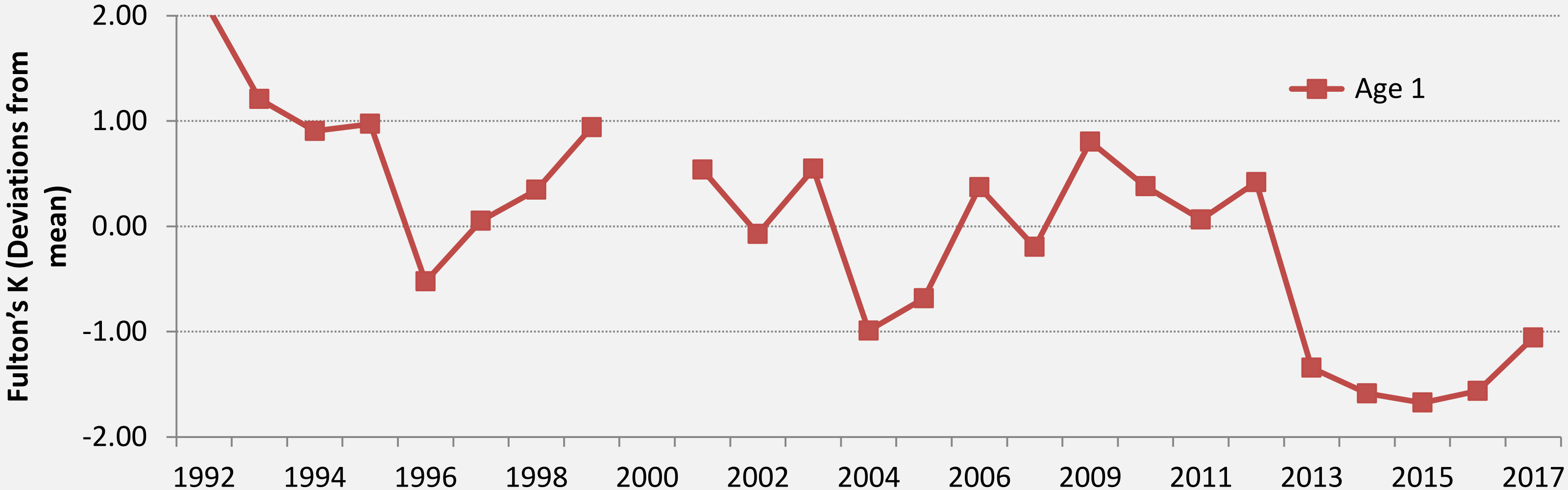
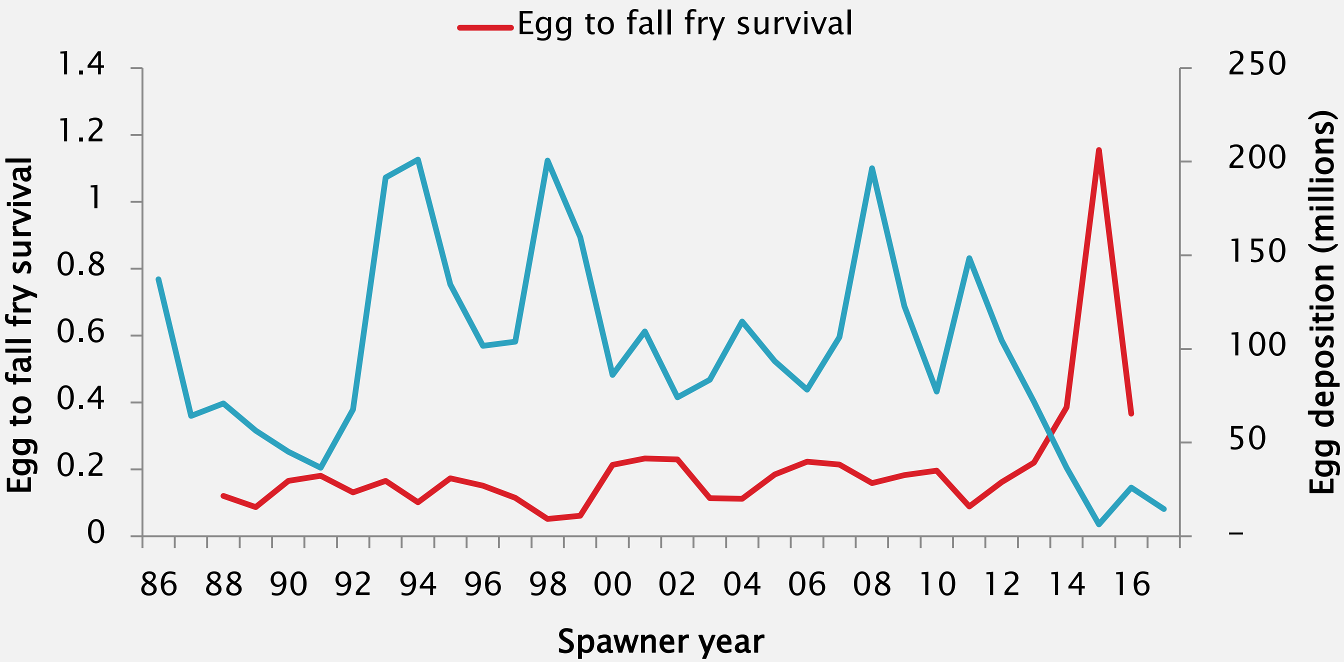
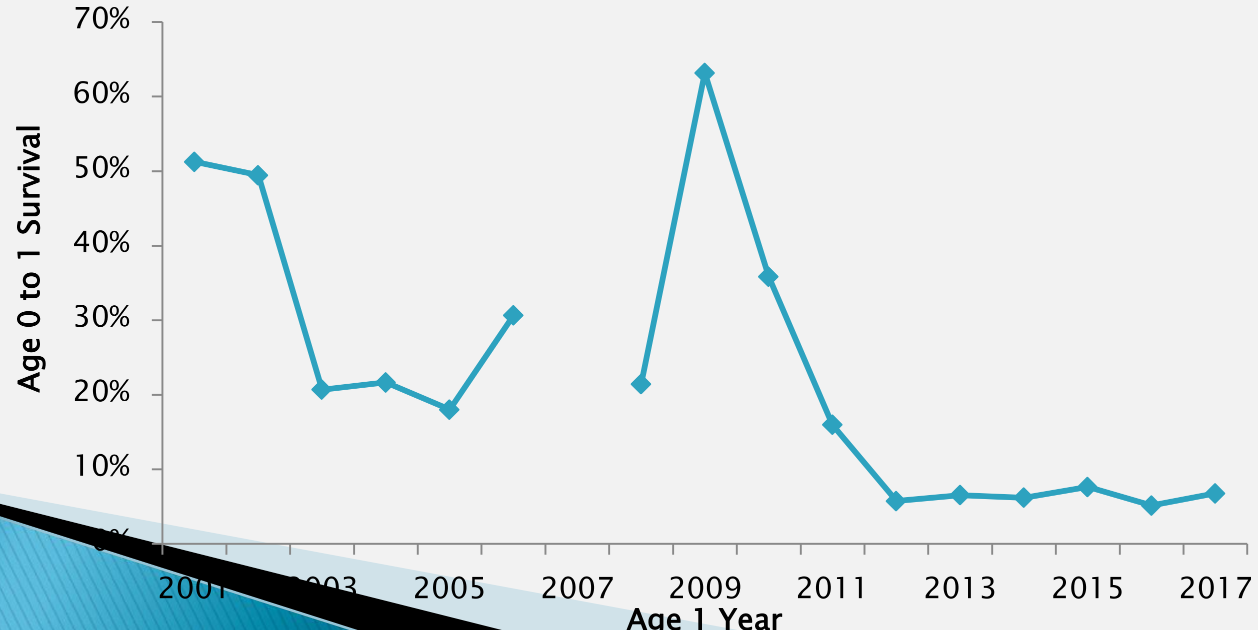


Figure 4. Trend in standardized condition (Fulton’s K) for fall trawl caught age 1 kokanee in Kootenay Lake during post fertilization years.

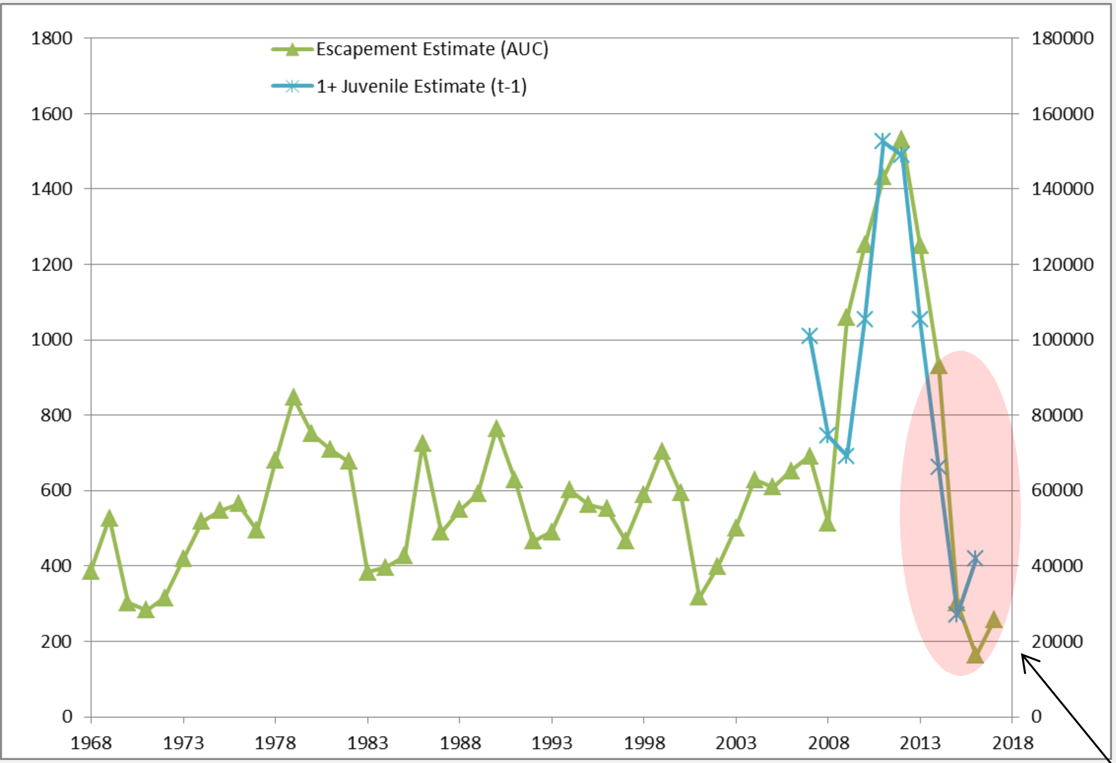
Table 1. Spawner counts and number of predicted spawners based on acoustic targets >-37 dB from year prior. Observed spawner number is meadow creek escapement + peak Lardeau count.

Spawner year	Observed spawners	Predicted spawners	pred/obs
2010	826,788	872,360	106%
2011	1,764,100	1,962,835	111%
2012	1,255,843	1,190,265	95%
2013	453,592	222,626	49%
2014	147,418	175,993	119%
2015	17,961	27,831	155%
2016	40,626	40,423	100%
2017	12,137	22,874	188%
2018		30-40 k	


Egg to fall fry survival
Egg to fall fry survival
Egg deposition (millions)
Spawner year
1.4
1.2
1
0.8
0.6
0.4
0.2
0
250
200
150
100
50
–
86 88 90 92 94 96 98 00 02 04 06 08 10 12 14 16


Age 0 to 1 Survival
Age 1 Year
70%
60%
50%
40%
30%
20%
10%
2005 2007 2009 2011 2013 2015 2017

Gerrard Escapement and Juvenile Production Estimates



Juvenile Estimates – Andrusak, FLNRORD data on file
Adult Escspament – Nelson FLNRORD data on file

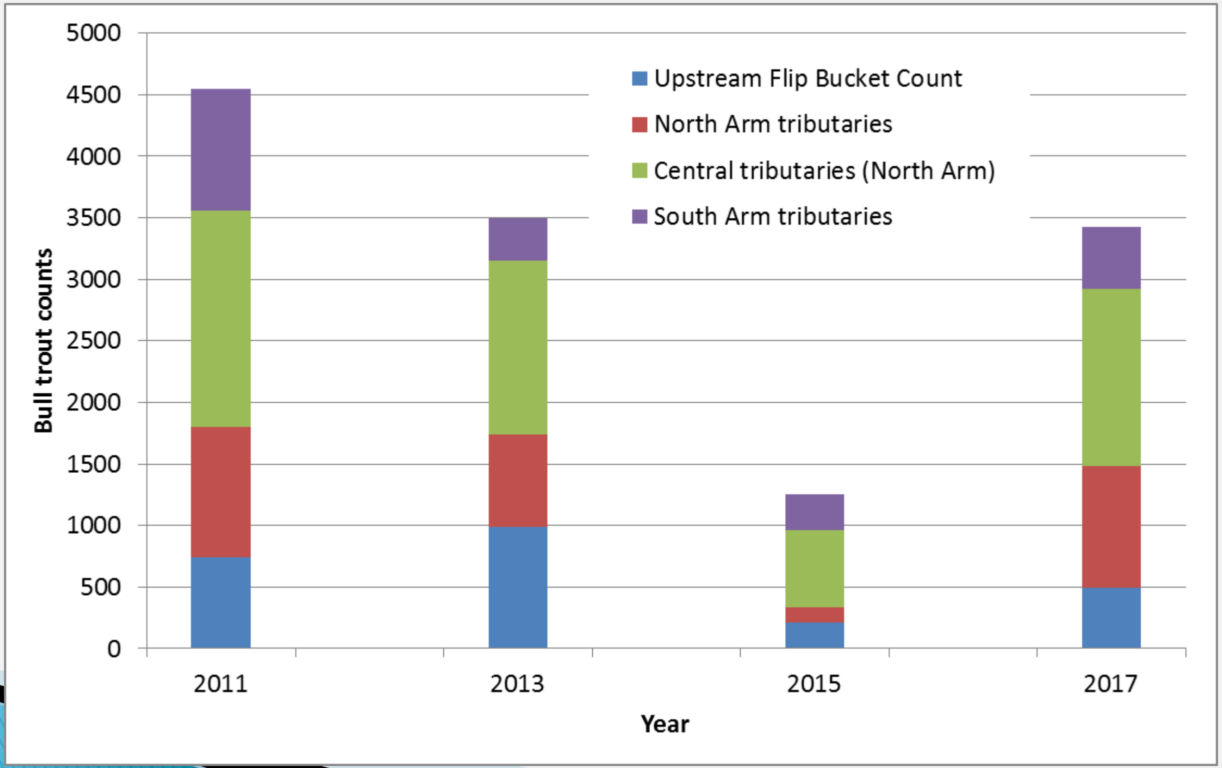
- Future in-lake abundance reductions likely as a result of declining juvenile supply
- Unknown what the current in-lake (age 1-4) survival looks like

- Declining Gerrard spawner size and abundance
- Spawner age relatively stable
- Juvenile supply also down;
- Future in-lake abundance impacts; need for RB reduction?

Gerrard Spawner Bio Data				
Year	**Mean FL (cm)**	**mean Wt (Kg)**	**Mean Age**	**Sample Size**
1949-59	67		5.3	54
1979	83			11
1980	83			8
1981	79	5.8		10
1982	83	7.2		21
1991	83	7.4		15
1992	78	7.1		23
1994	75	6.8	6.0	17
1998	81	7.3	6.4	18
2004	72	7.1		25
2005	77	4.4		25
2006	83	6.9		37
2010	73	4.5		59
2014	78			20
2016	58	1.9	5.8	24
2017	53	1.4	5.9	20

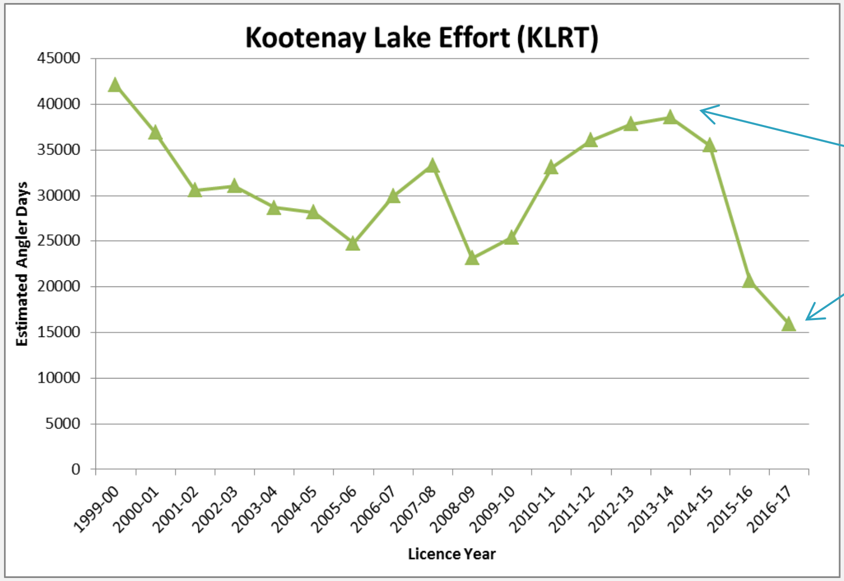
Kootenay Lake Bull Trout Escapement Estimates

- Bull trout spawner abundance similar to 2013; large increase
- South arm tribs remain a small contributor
- Central and North tributaries strong (Hamill Creek and Kaslo River half of all spawners)



FLNRORD Nelson data on file – various sources

Fishery Trends – KLRT Creel

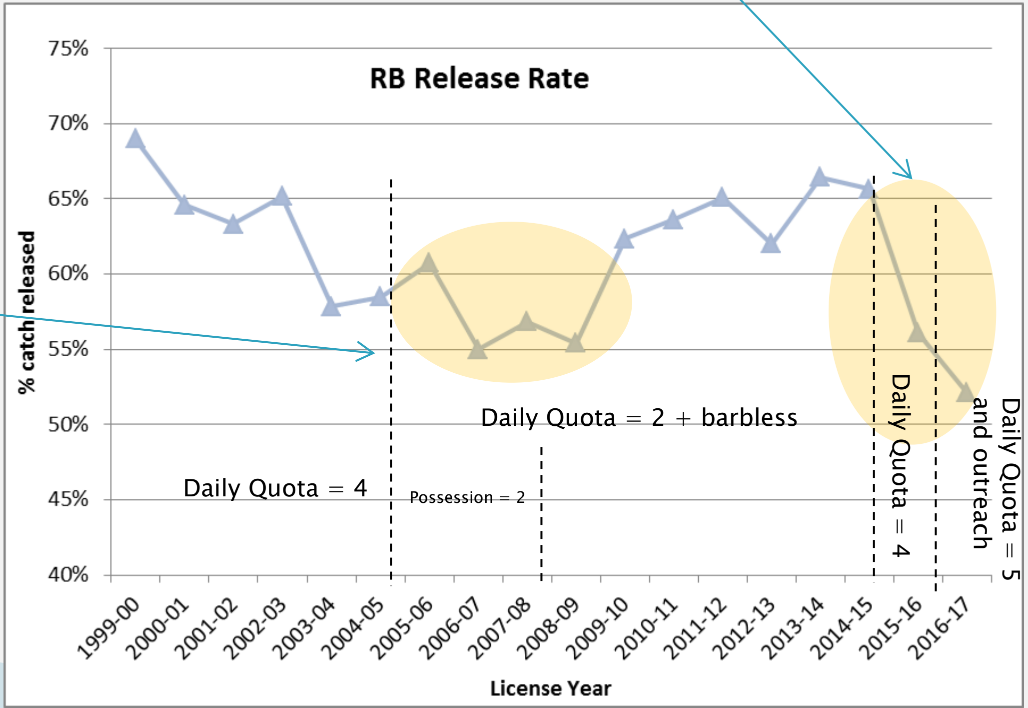


Effort Declines – 40,000 to 15,000 angler days

Recent outreach/daily quota increase = more harvest

No strong evidence for daily quota changes affecting exploitation

Fits with CPUE data: ~1 RB per rod day average



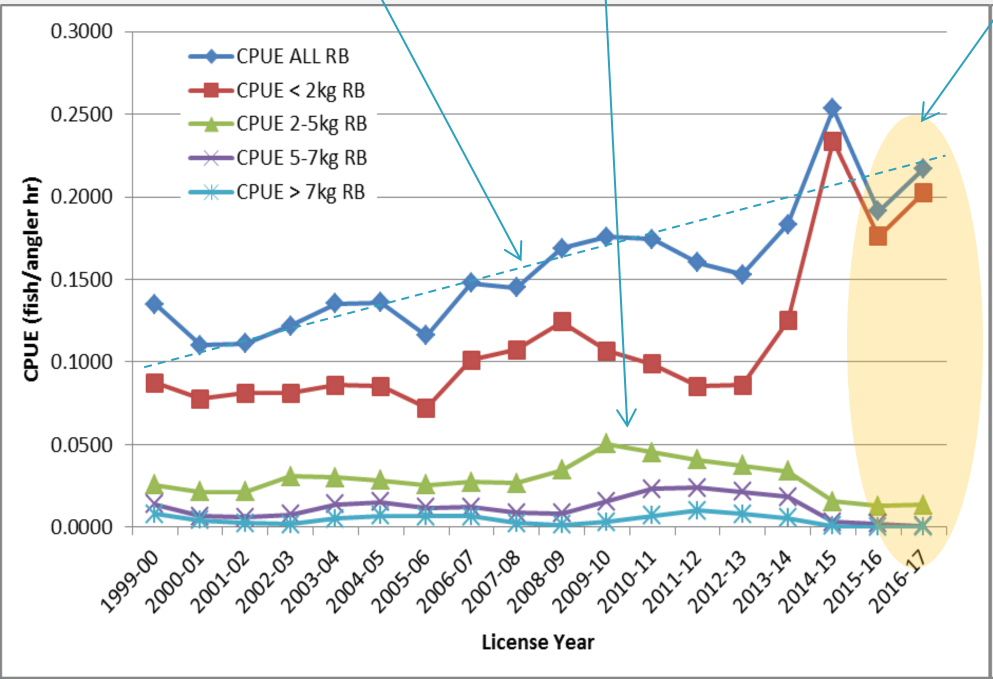
Rainbow Trout Catch Trends (KLRT)

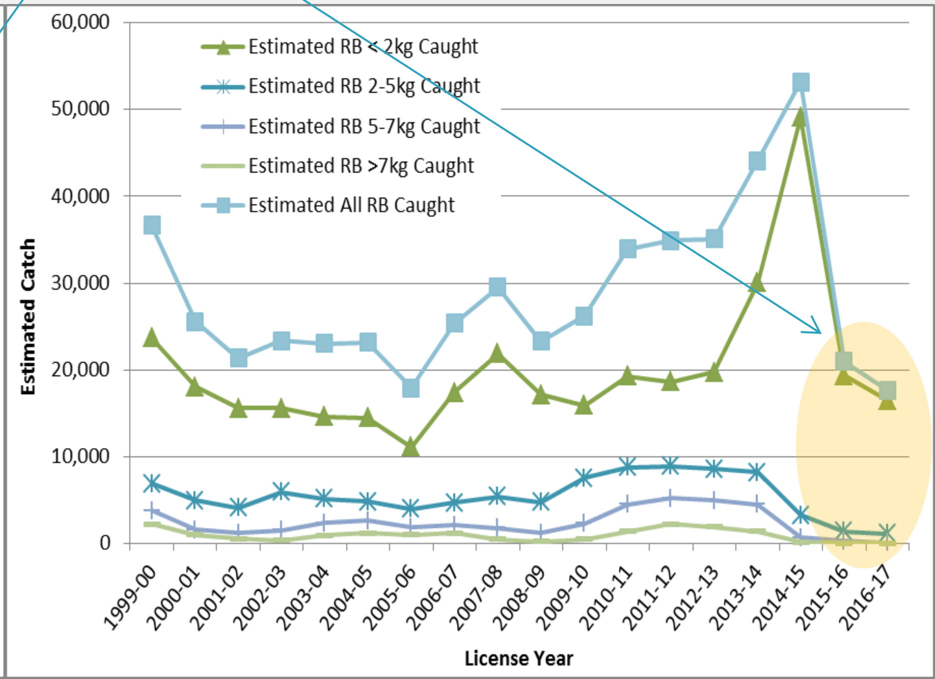
Large size classes
now gone

general RB CPUE
increase over
time?

Recent departure between
CPUE and catch trends

Catch now all small





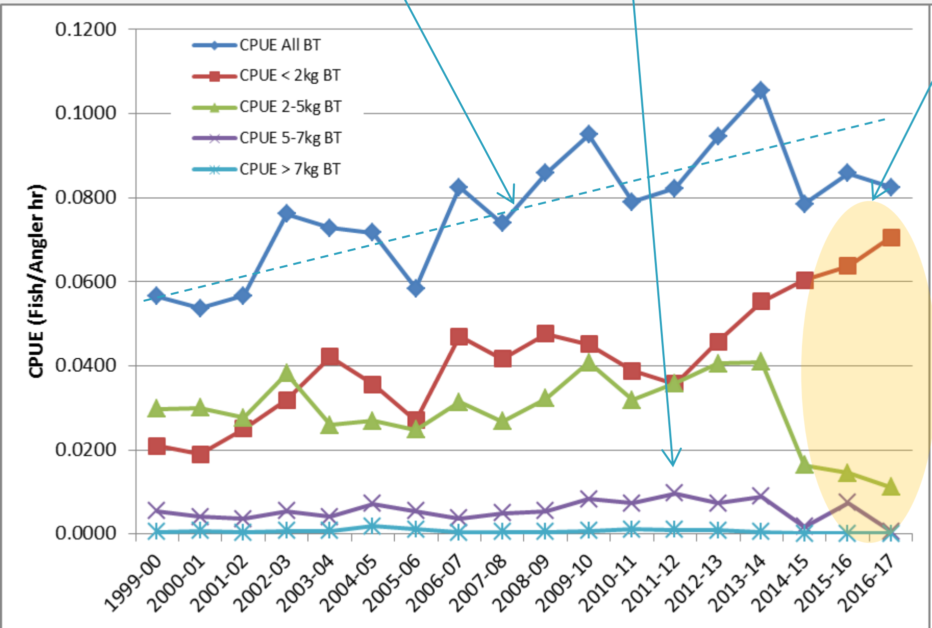
Bull Trout Catch Trends (KLRT)

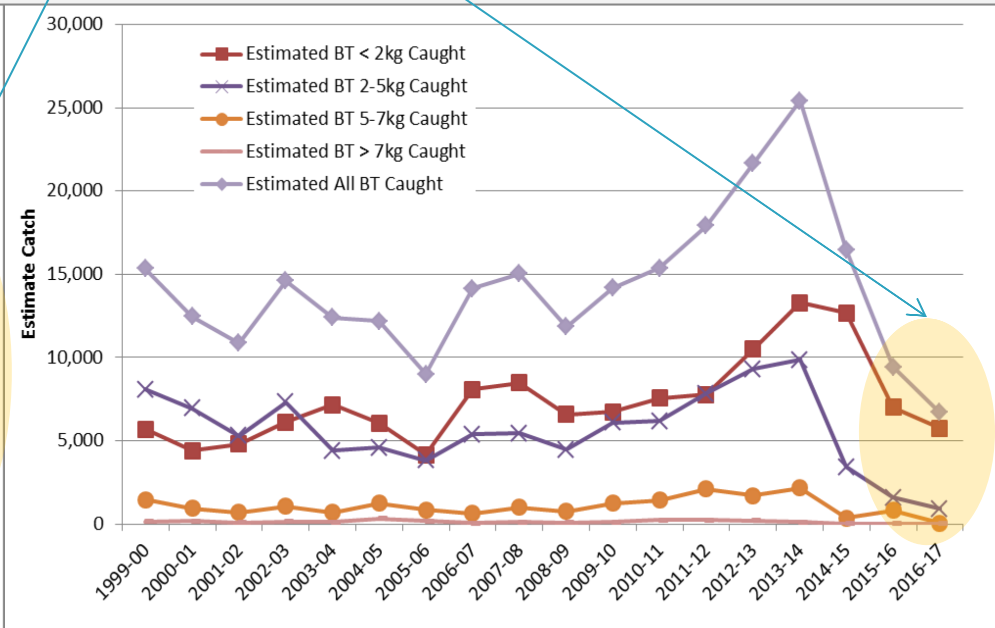
general BT CPUE increase over time?

Largest size classes now gone

Recent departure between CPUE and catch trends

Catch now all small





Piscivore Monitoring (2015-17)

- Objectives were to better inform recovery actions, included identifying; Genetic structure of mixed stock RB fishery (% Gerrard vrs. Insectivores in catch) age structure, current diet, maturation rate (% ripe) by ecotype, fecundity, and age at entry to lake.

- Fish samples collected by an angling guide, using standard large lake fishing methods

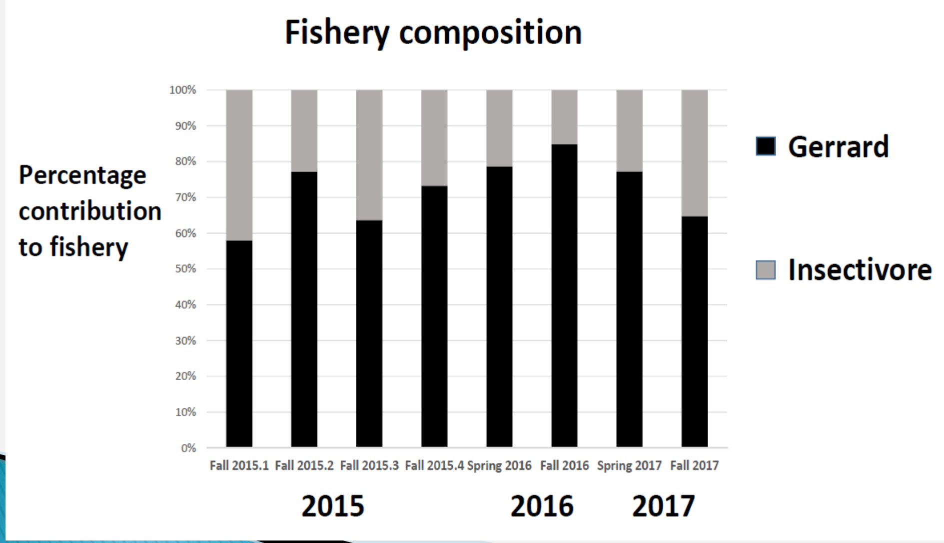
- Total of 580 angler days effort expended between Fall of 2015 and 2017

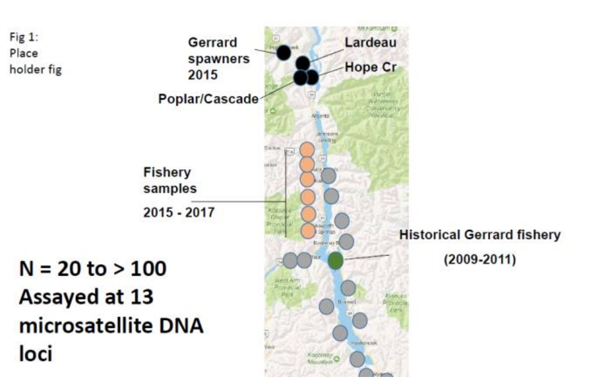
- Total of 641 RB and 181 BT captured

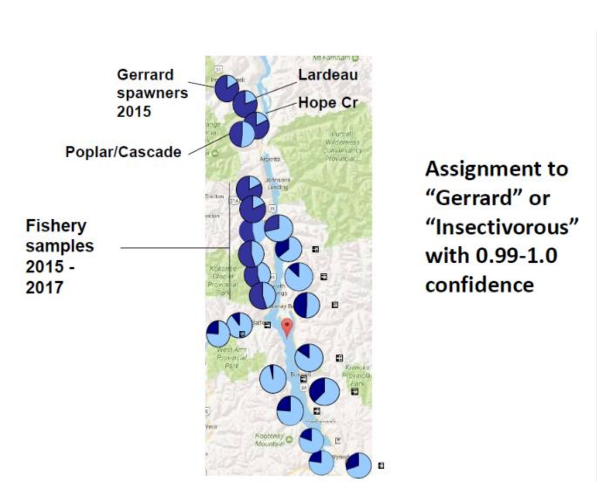
- Subsequent analysis in-progress or complete

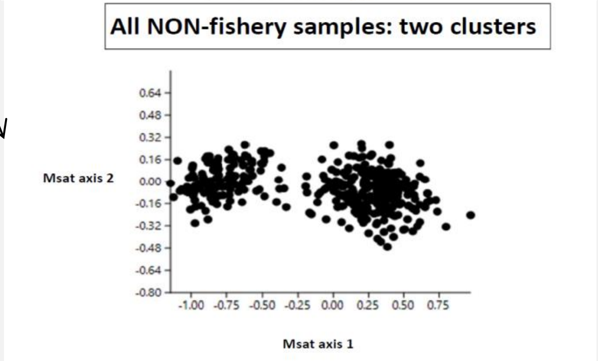
Piscivore Monitoring (2015-17) Mixed stock fishery genetics

- Key data to help interpret in-lake abundance trends (KLRT)
- A total of 921 fish across 25 distinct samples (18 reference site samples; 6 mixed stock fishery)
- Genetics – methods successful differentiating fishery samples (2 distinct groups; Gerrards and other RB)
- ~99% assignment rate
- ~75% of catch are Gerrards; relatively stable between 2015-2017



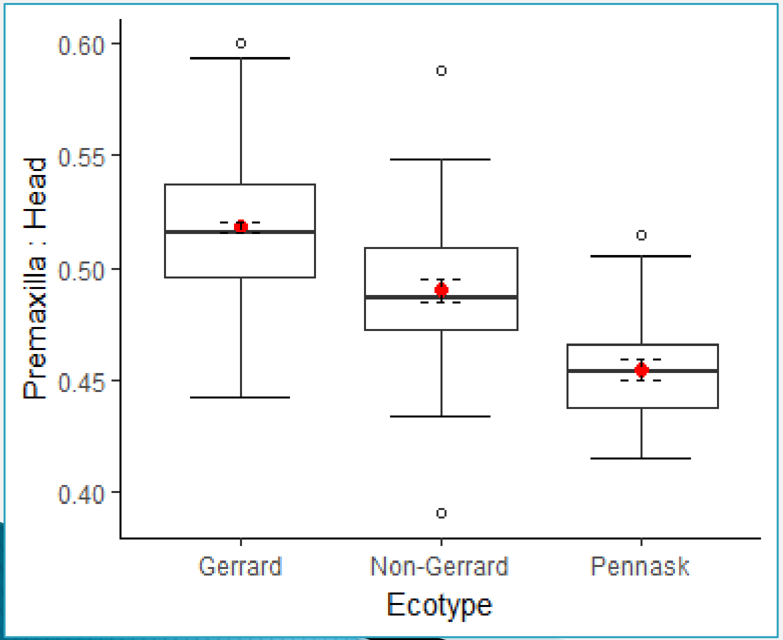


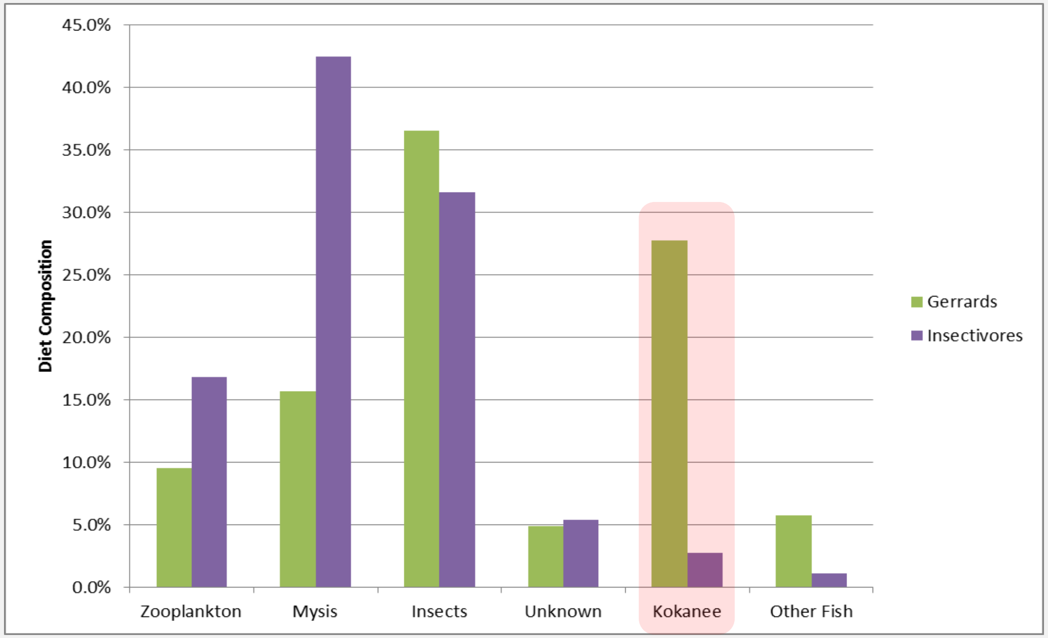




Piscivore Monitoring (2015-17) Mixed stock fishery genetics

- Morphometric measures and diet, partitioned by genetic results, showed expected contrast (confirmed genetics)
  - Kokanee represent a significant portion of diet only for piscivores
  - Mysis and Zooplankton more important for insectivores
  - Piscivores have larger mouth/head ratio; larger mouth to capitalize on kokanee
  - Morphometric difference significant (large sample size), but high assignment error used as a tool to differentiate groups

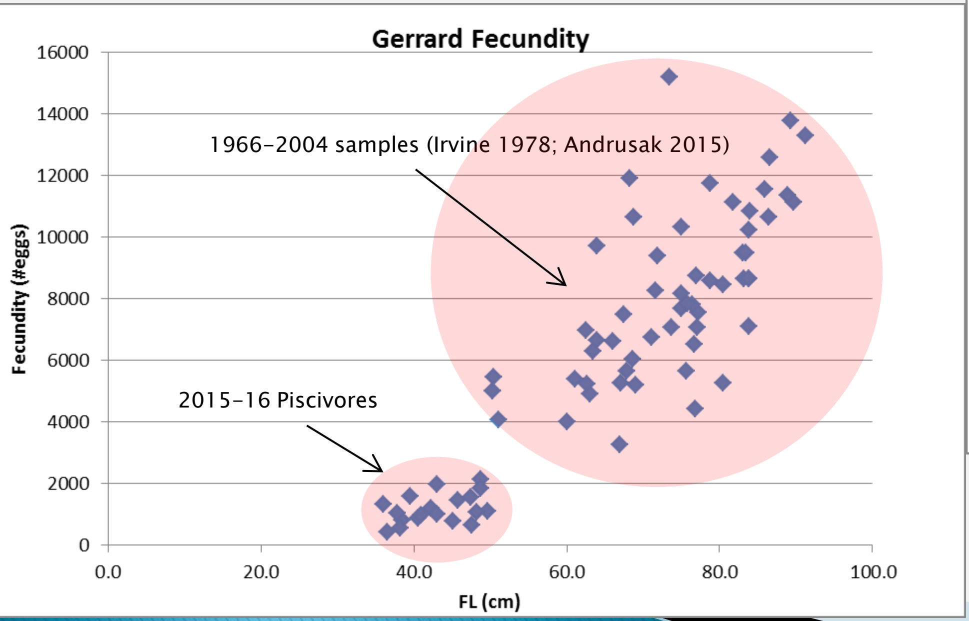


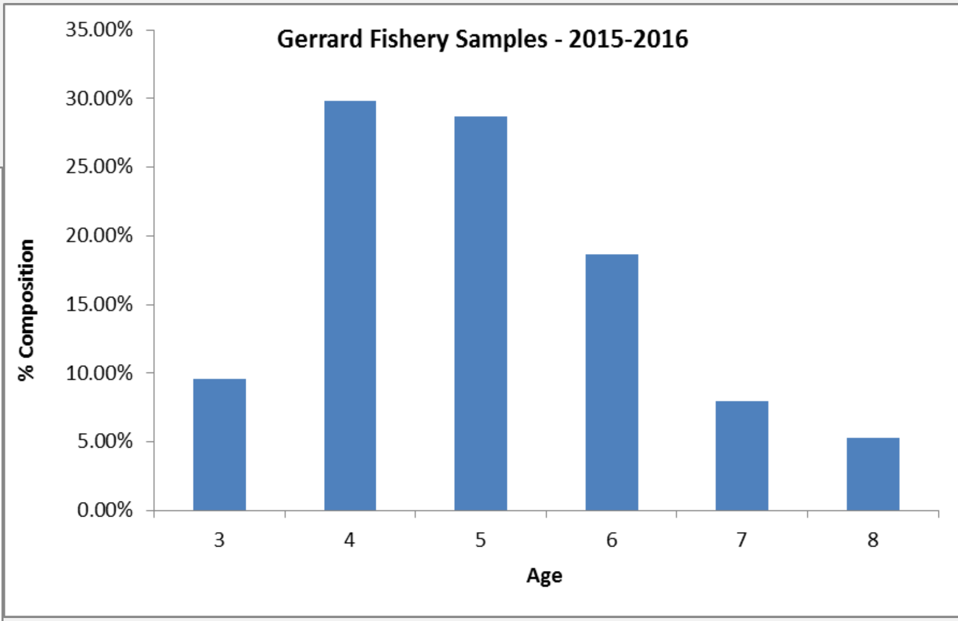


Piscivore Monitoring (2015-17)
Fecundity and Age

- Age structure – 2015-16 data only, suggests expected in-lake age structure. No truncated age structure as a result of kokanee declines and historic large fish.

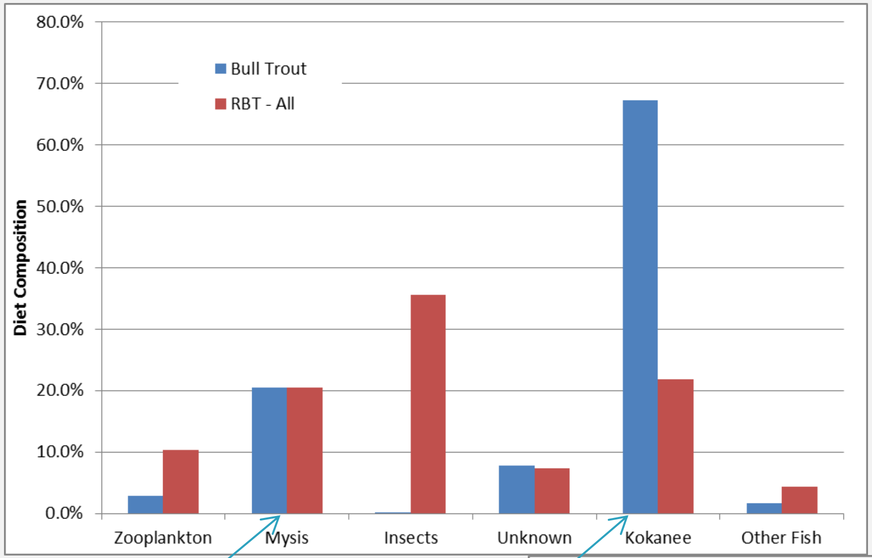
- Fecundities – Significant decrease from historic samples, concurrent with fish size





Piscivore Monitoring (2015-17)

Diet Composition – % composition by mass



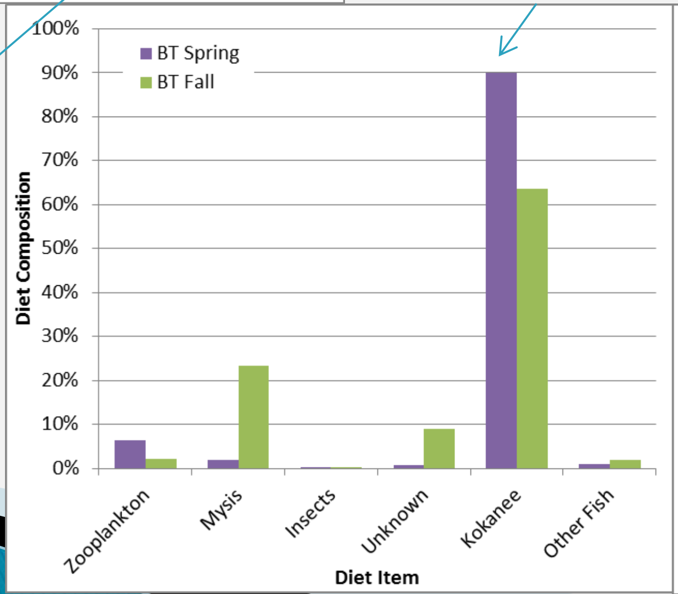
Seasonal shifts in diet apparent

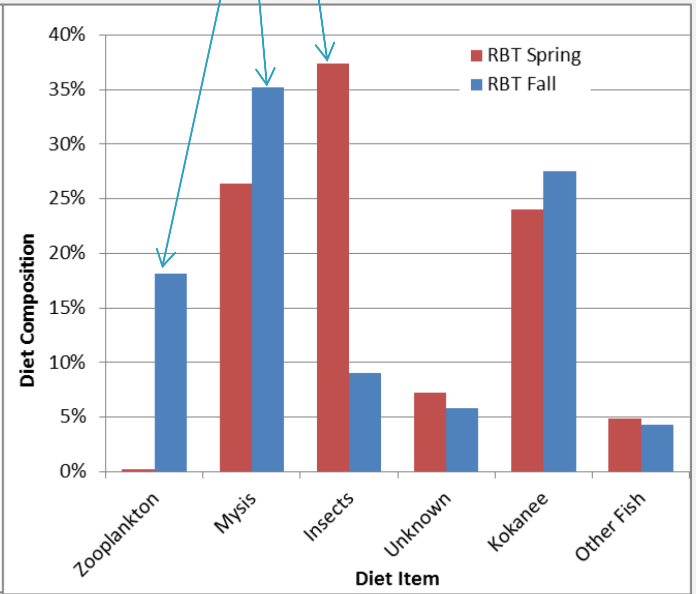
Kokanee – BT in spring: May 2018 (13 in one 2Kg fish, 92 in 11 fish)

Insects for RB in spring, mysis/zooplankton in Fall

Mysis consumption

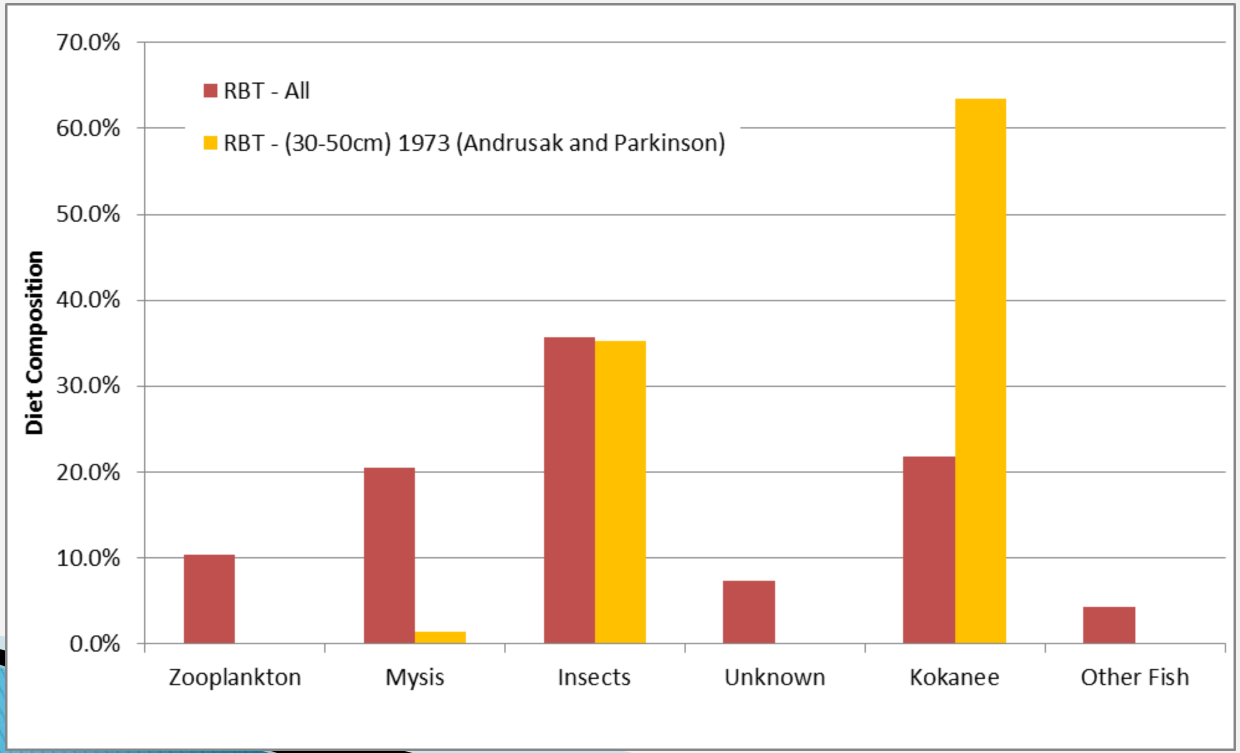
Kokanee most significant portion of BT diet; Insects most significant portion of RB diet





Piscivore Monitoring (2015-17)
Diet Composition

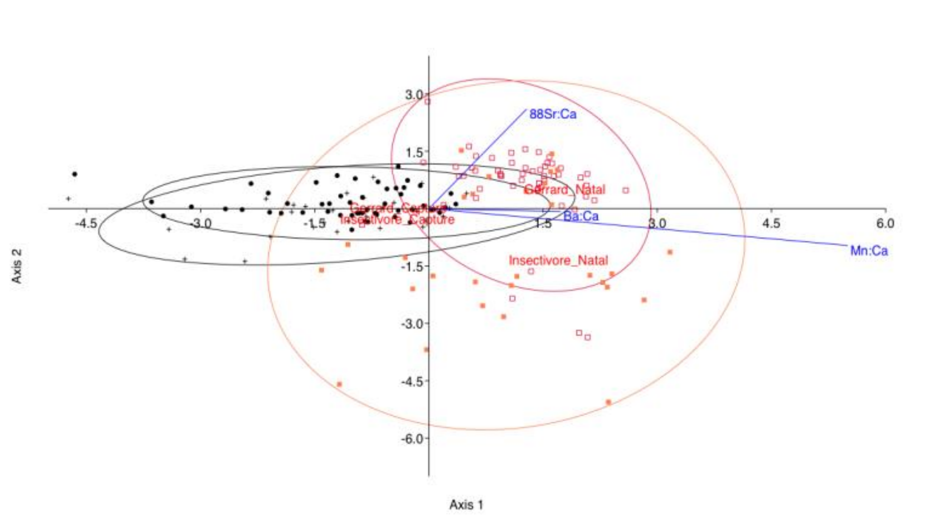
- RB diet at low kokanee abundance different that historic sample at higher kokanee supply
- Current shift to mysis and zooplankton to offset kokanee in diet
- Implications for kokanee recovery: even at static predator density in the future, RB kokanee consumption will likely increase concurrent with KO abundance increases -do we account for this in predictions; does this argue for predator reductions along with KO stocking?



Piscivore Monitoring (2015-17) Rearing Origin and Age at Lake Entry

- Otolith Microchemistry (along with genetic assignment) used to identify Gerrard age at entry to Kootenay Lake
- Includes Gerrards and insectivores to allow validation of approach and provide contrast; do signatures differ between genetic groups?
- If fry, in excess to Lardeau River capacity do not contribute to Gerrards caught in the lake fishery, then S-R data suggests that high Gerrard abundance and kokanee collapse driven by a change to in-lake survival (between age 1+ and 3)
- Validation of age at lake entry via microchem (provide support for scale age estimates)

- Analysis in progress; Capture signal for all RB similar (all captured in Kootenay Lake); rearing signals differ.
  - Gerrards group (one watershed of production)
  - Insectivore group (many watersheds, many signatures)
  - Still need to finish interpretation/ages

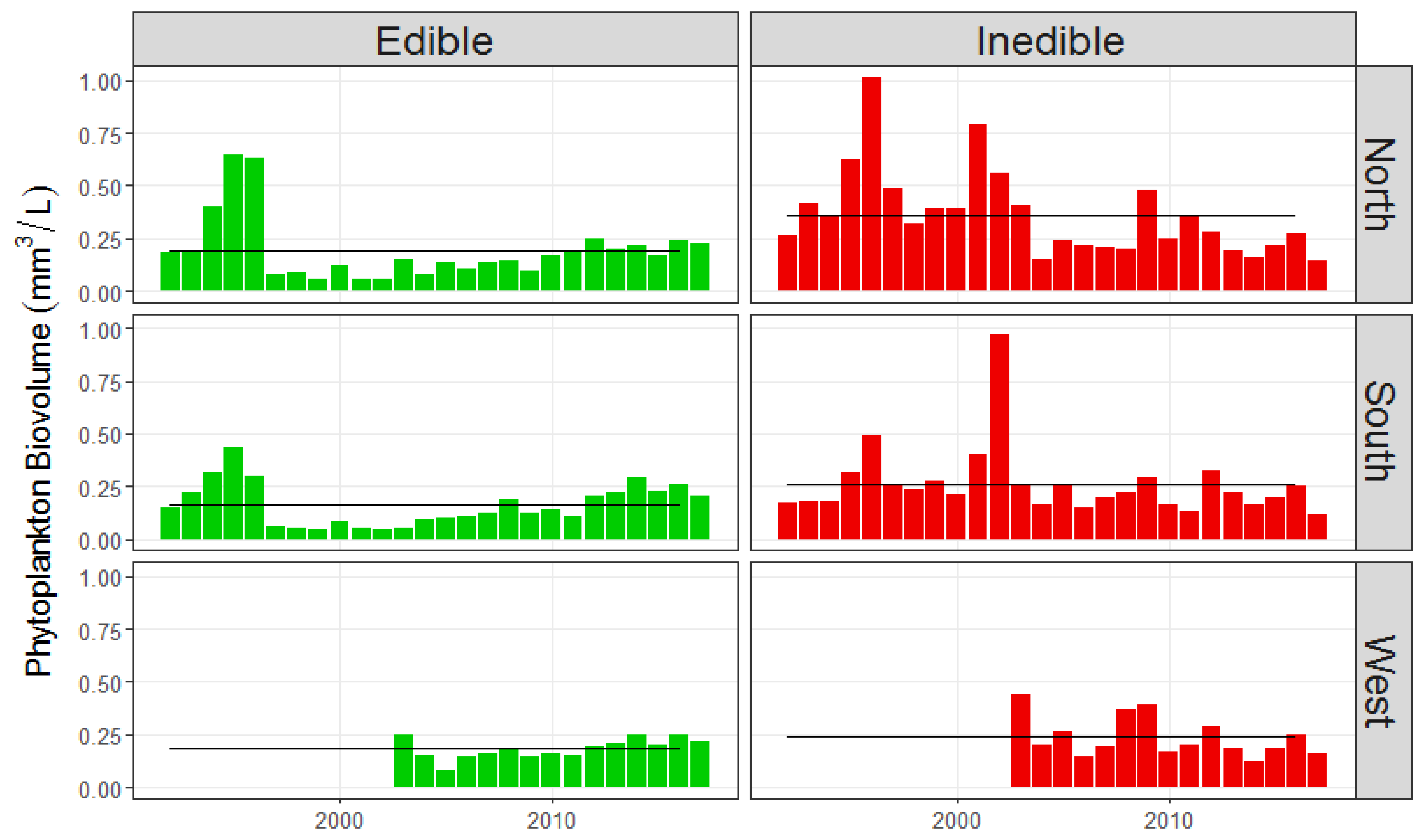


Nutrient Restoration Program monitoring

- Water temperature, Secchi
- Water quality
- Phytoplankton, primary production
- Zooplankton
- Mysids
- Kokanee hydroacoustic (two surveys per year) and trawl (fall survey)
- Spawner escapement – Duncan/Lardeau and South Arm tributaries
- 2017 – Bull trout redd surveys (additional tributaries to Kaslo/Keen surveys (funded by HCTF)

Annual Phytoplankton Biomass

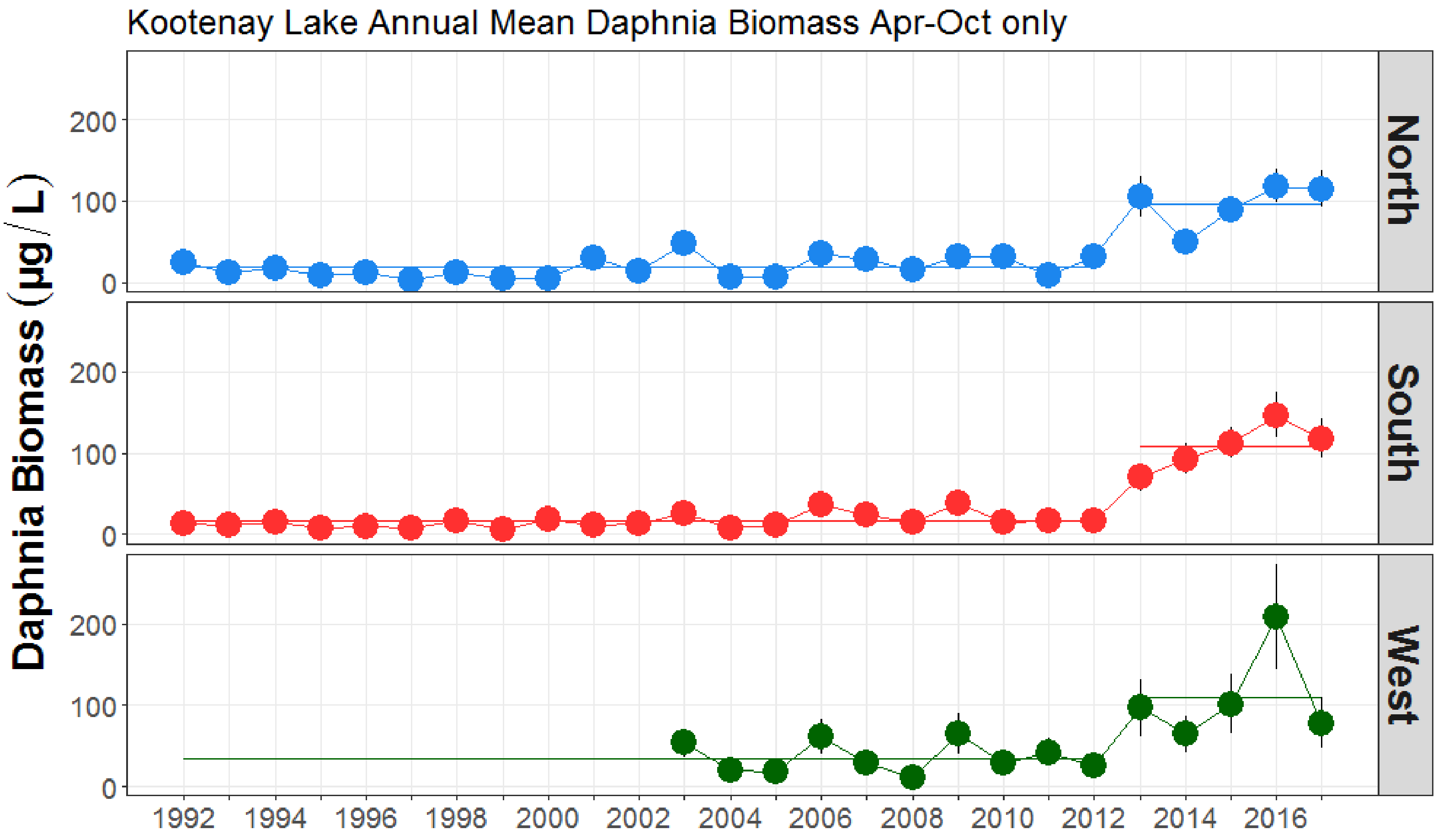
Integrated 0–20m 1992–2017, Apr– Nov



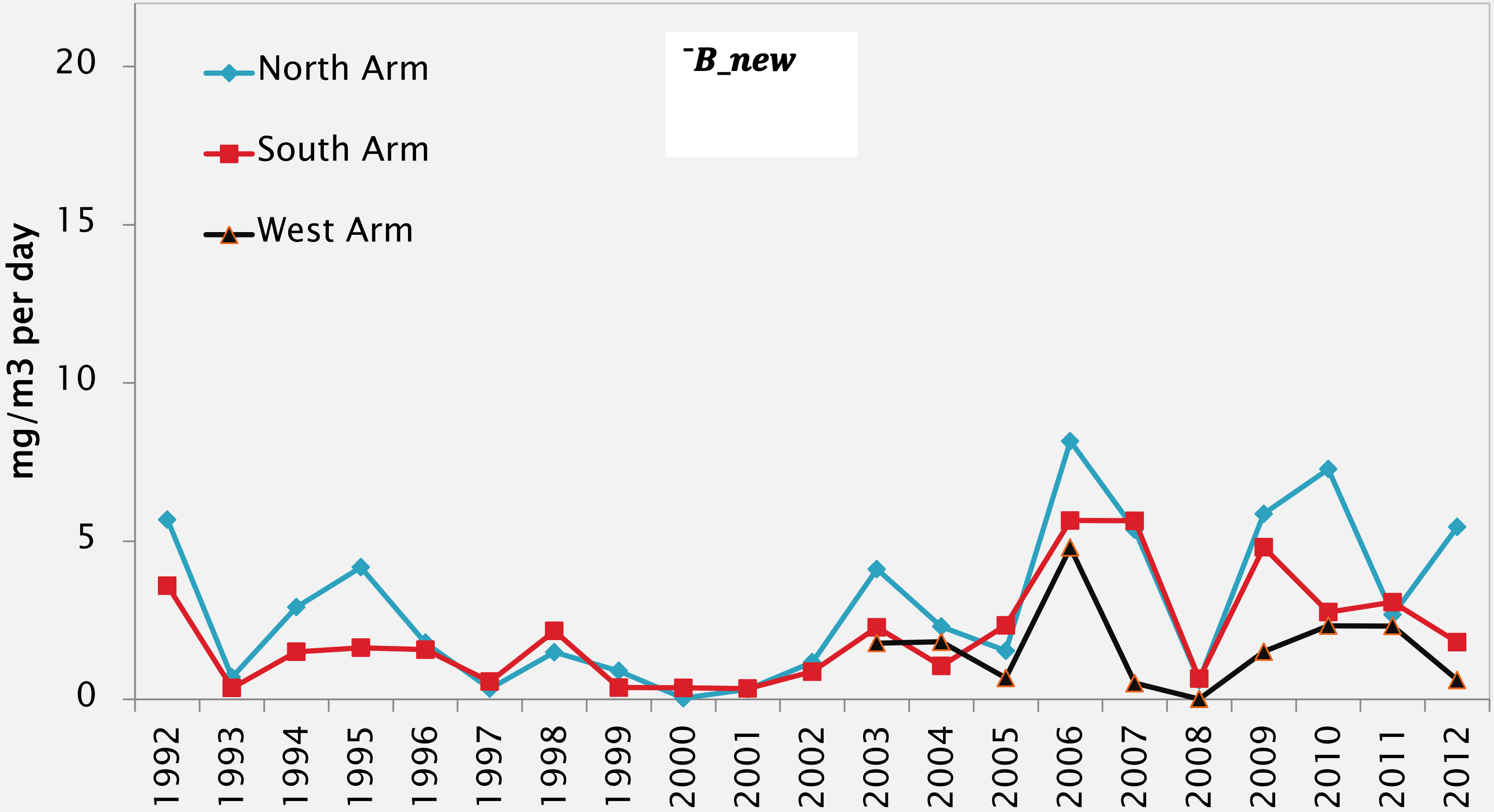
FWCP/KTOI

Eco-Logic

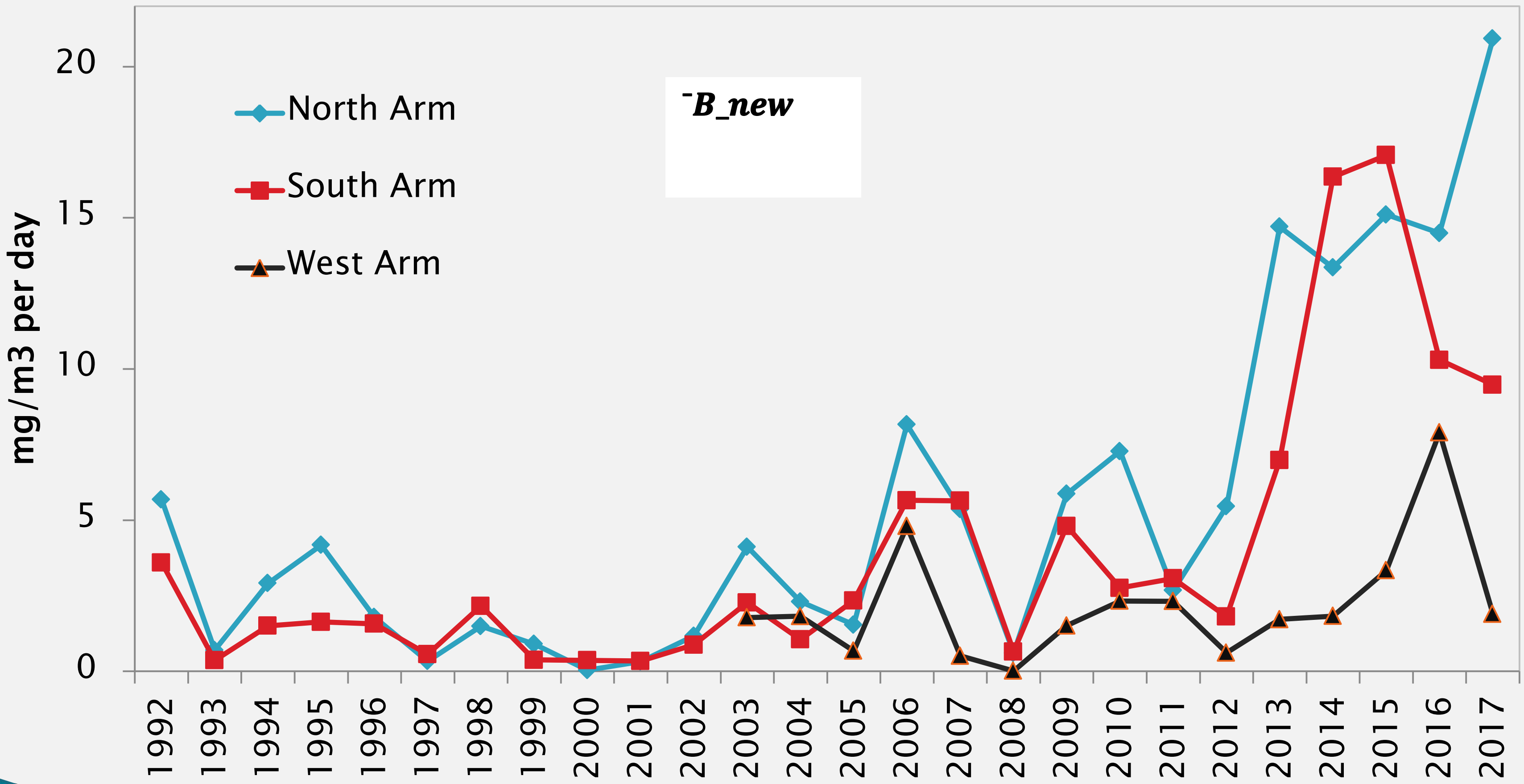
Kootenay Lake Results
Zooplankton 1992-2017



Zooplankton production - *Daphnia*

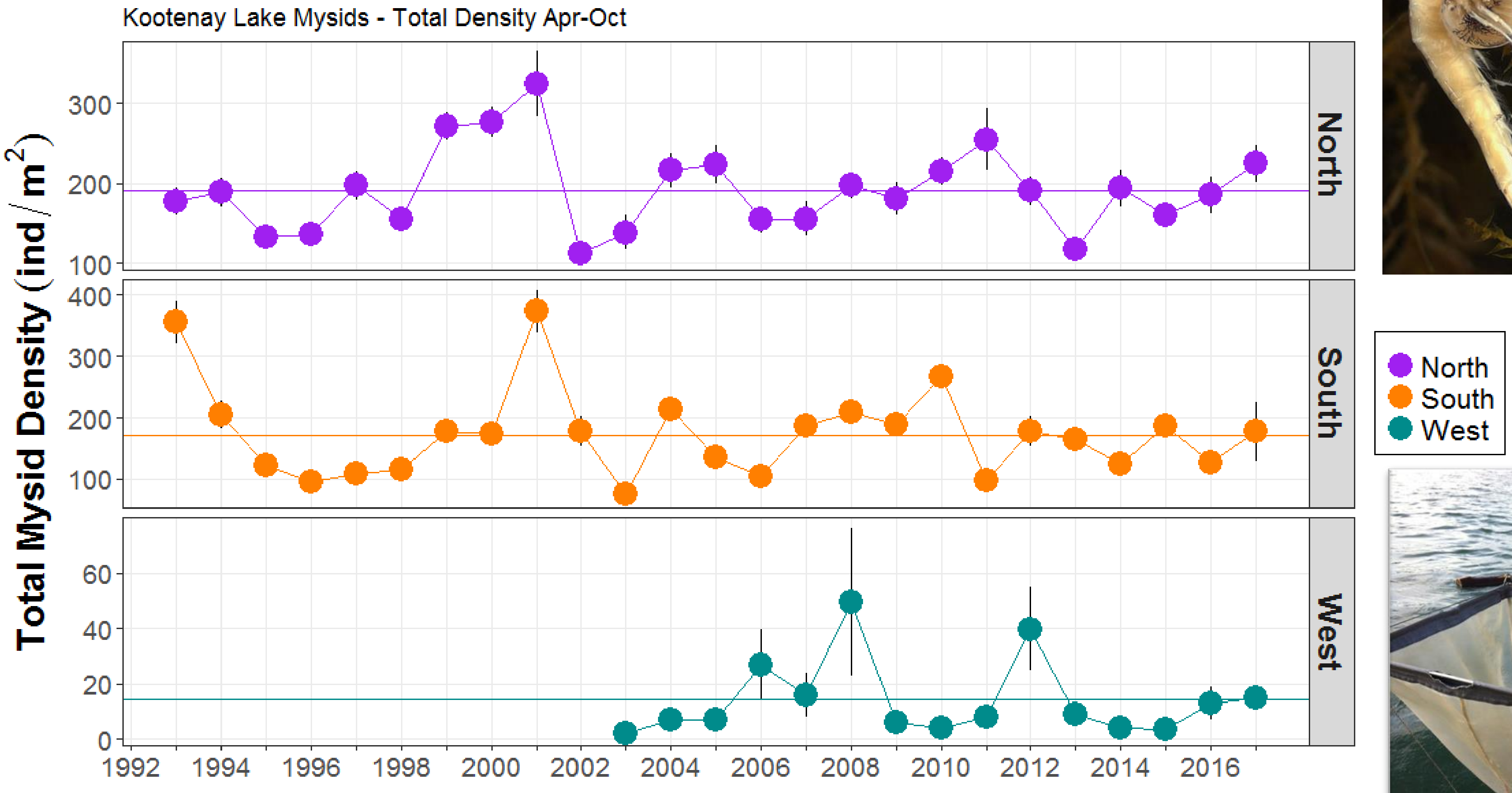


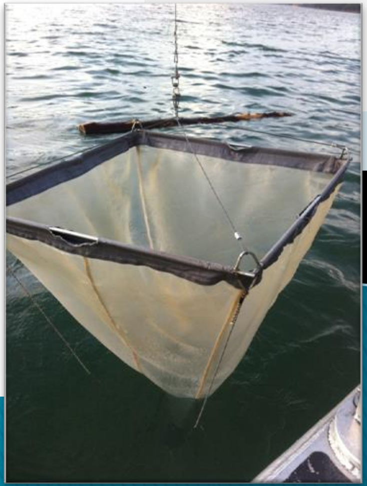
Zooplankton production - *Daphnia*



Kootenay Lake Results

Mysids 1992-2017





South Arm Kokanee Spawners

Year	Crawford	Boulder	Goat	Summit	Midge**
2006	0	0	0	1	
2007	8	0	0	0	
2008	0	0	0	0	
2009	22	0	187	114	
2010	0	0	0	0	
2011	575	0	274	203	
2012	57	3	1441*	315	
2013	2	0	100	1	
2014	0	0	34	3	
2015	36	0	235	10	
2016	260*	0*	2386*	14*	158*
2017	504*	0	59*	0	378*

* entire tributary counted to barrier; other counts are index locations
** Midge is genetically different from other tributaries (MC stock)

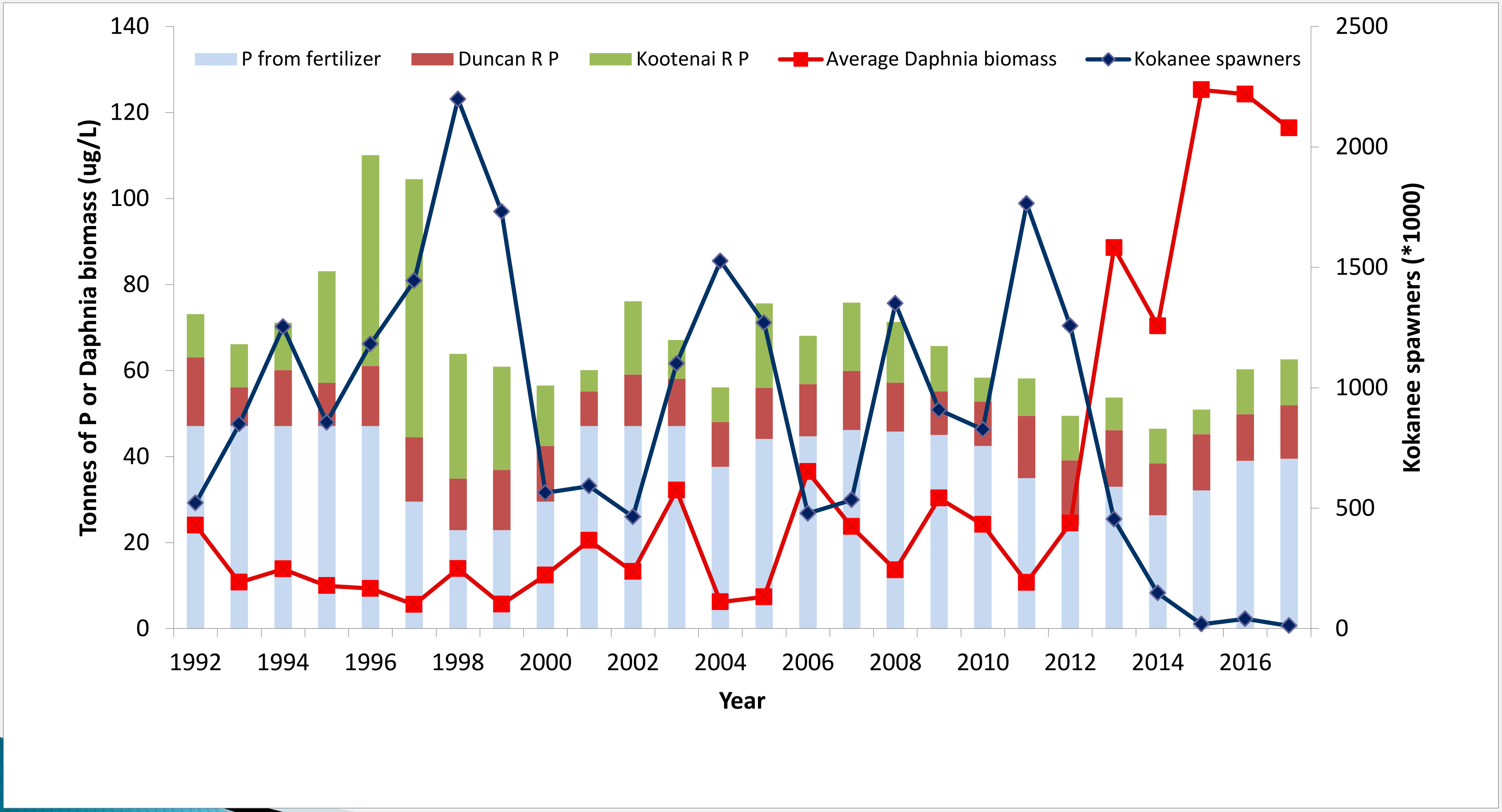
Photo credit: CCRFIC

Photo credit: CCRFIC

FLNRORD, Crystal Springs Consulting, Redfish Consulting, CCRIFC

KTOI

Kootenay Lake Phosphorus Loading, *Daphnia* and Kokanee



Action Plan – Review

Action Update

Kokanee Supplementation

- Action – stock 5 million eyed eggs in Meadow Creek
- Trigger – <140,000 spawners; age 0-1 <11%
    - Stocking delivered in 2016+2017




Action Update

Kokanee Supplementation

- 2016 Identified genetic sources suitable (Action Plan) – Whatshan, Kinbasket Reservoirs and Lussier River
- 2015 locations –

Source Location	Egg/Fry Number	% Contr.
Hill Creek	477,398	43%
Koocanusa (Lussier and Norbury)	493,371	44%
Interior Brood Lakes	142,237	13%
Total	**1,113,006**	

- 2016 locations –

Source Location	Eyed Egg Number	% Contr.
Whatshan	603,164	9%
Fairmont (Columbia)	1,569,888	23%
Hill Creek	1,381,059	20%
Koocanusa (Lussier, Norbury and Bull	1,203,857	18%
Interior Brood Lakes	2,001,606	30%
Total	**6,759,574**	

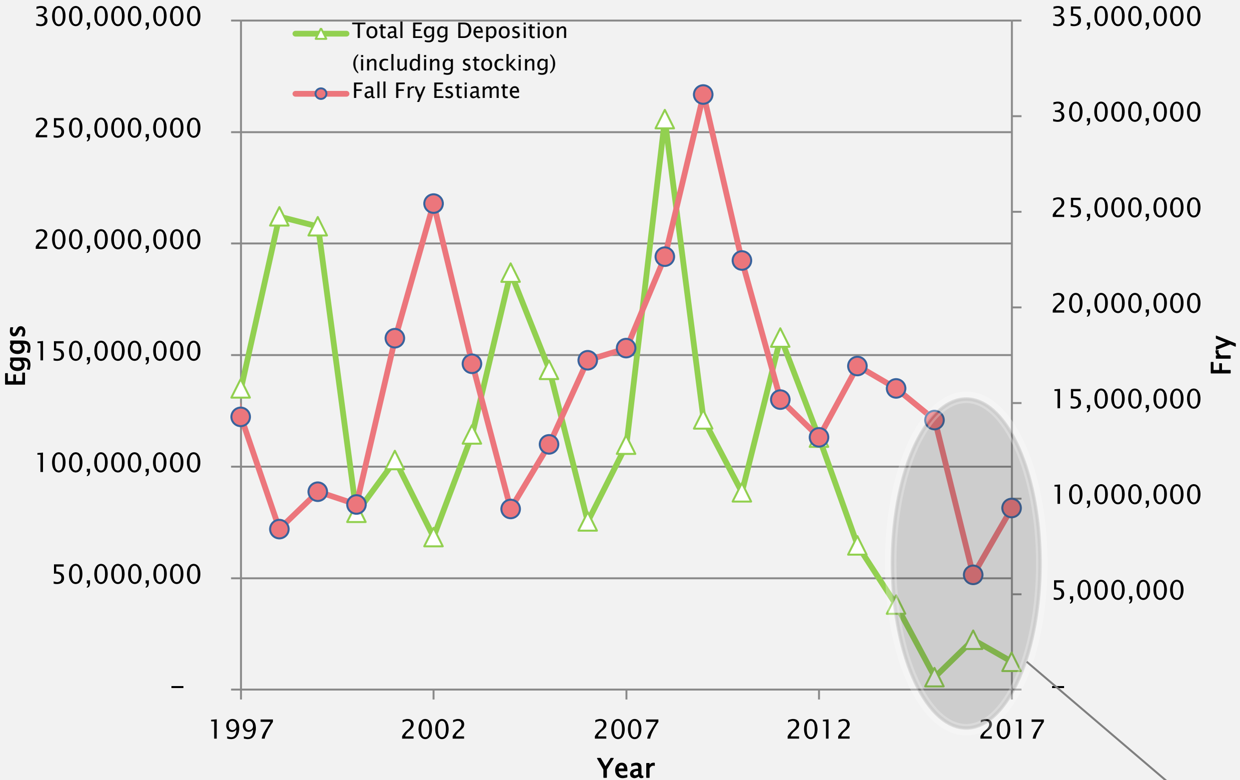
50%

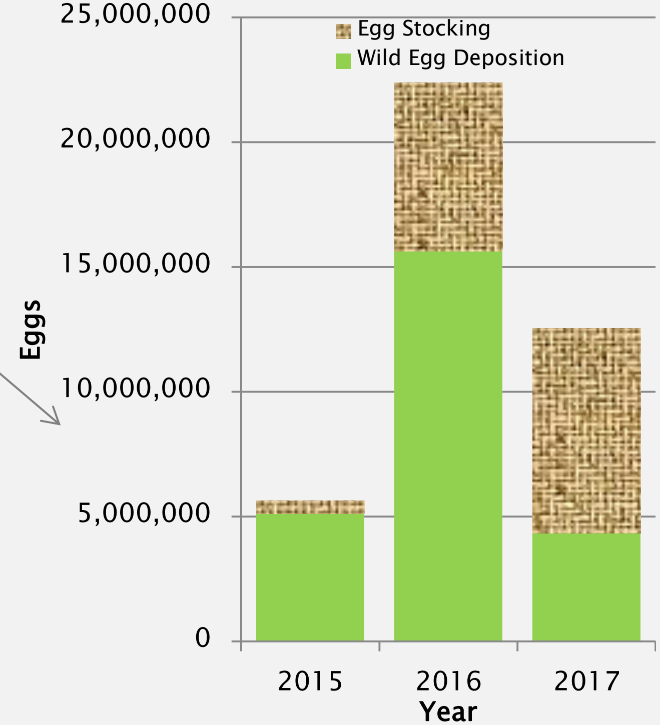
- 2017 locations –

Source Location	Eyed Egg Number	% Contr.
Whatshan	240,270	3%
Fairmont (Columbia)	1,238,740	14%
Hill Creek	6,496,339	75%
Interior Brood Lakes	726,544	8%
Total	**8,701,893**	

83%

Action Update – Kokanee Supplementation





- Egg deposition crash (roughly tracks escapement) – Fry supply decreases, but not well outside historic lows (supply is OK?).

- Supplementation (egg stocking) significant contributor to overall egg supply (30-60% of all eggs) in the past two years

Action Update – Kokanee Supplementation

Are stocking efforts meeting with success?
What is success?

- Success survival similar to wild kokanee? Increase in overall kokanee survival?
- Eyed Egg to fry measured in Meadow Creek– 60-90% survival; as good or better than wild survival to out-migrating fry
- In-Lake Stocked Cohort Survival
  - 2015 cohort – heat marks; too small to detect? (1 million combined fry/egg stocking) – spawners in 2018+19
  - 2016 cohort – Genetics required (6.8 million egg stocking), 2018 feasibility analysis..
  - 2017 cohort – Heat marks, 2019 trawl first data available (8.7 million egg stocking)
- In-Lake kokanee 0-1 survival remains ~5%

Egg plant/fry stocking – sampling matrix

stocking type	Metric	2016 fall	2017 fall	2018 fall	2019 fall	2020 fall	2021 fall
ee	survival/abundance as age 1+ (trawl sample analysis)		n=0	DNA	TM		
ee	survival/abundance as age 2+ spawner			TM	DNA	TM	
ee	survival/abundance as age 3+ spawner				TM	DNA	TM
ee	survival to spawn (using cumulative age 2-4 spawner abundance)					TM	DNA
fry	Fall age 0 abundance	n=2	n/a				
fry	survival/abundance as age 1+ (trawl sample analysis)	ns	n=0	n/a			
fry	survival/abundance as age 2+ spawner		ns	TM	n/a		
fry	survival/abundance as age 3+ spawner			DNA	TM	n/a	
fry	survival to spawn (using cumulative age 2-4 spawner abundance)				DNA	TM	n/a

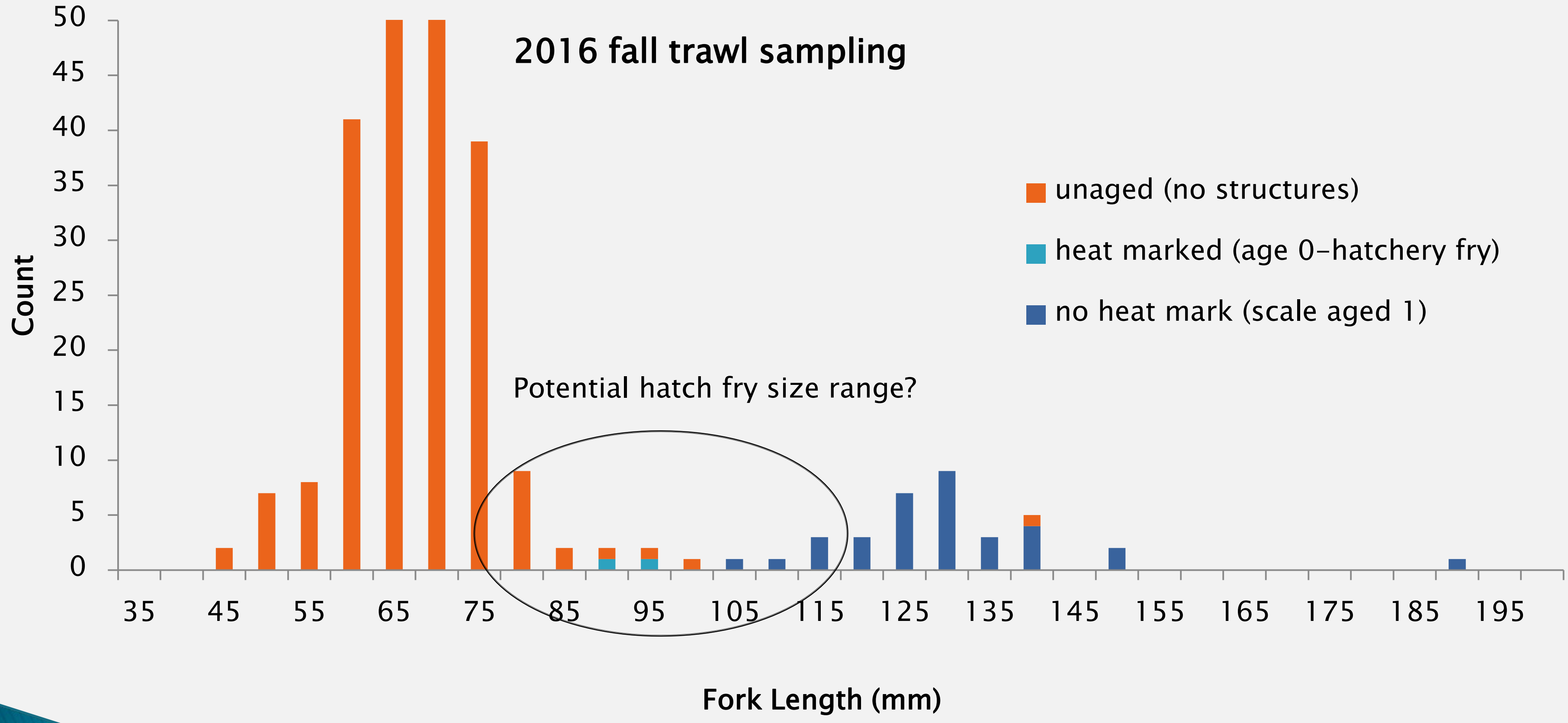
Stocking Type	Brood year	fry year	Heat Marked	Number	comment
ee	2015	2016	Y	477,000	TM Band - III_III
ee	2016	2017	N	6,800,000	
ee	2017	2018	Y (89%)	8,700,000	TM Band - IIII
ee	2018	2019		tbd	
fry	2014	2015	N	92,541	All -> Crawford, DNA from spawners
fry	2015	2016	Y	635,000	TM Band - III_III (30,000 -> Crawford
fry	2016	2017	N	80,000	All -> Crawford

* Hatchery fry are closer in size to the smallest wild age 1 at time of stocking in spring

DNA = no heat mark, would require DNA analysis (if a viable method)

n/a = no TM, DNA not likely possible

ns = not sampled


2016 fall trawl sampling
Count
50
45
40
35
30
25
20
15
10
5
0
35
45
55
65
75
85
95
105
115
125
135
145
155
165
175
185
195
Fork Length (mm)
unaged (no structures)
heat marked (age 0-hatchery fry)
no heat mark (scale aged 1)
Potential hatch fry size range?

Action Update

Meadow Creek KO Incubation

- Action – upgrade of MC Hatchery to increase incubation capacity above 5 million
- Tigger – none
  - Complete – ~1 million eggs incubated in 2017; FFSBC capacity ~8 million through upgrades/staff and facility planning (maybe not sustainable into the future?)
  - Meadow Creek poor/last option for incubation (no alarms, egg quality issues, cold water pushes plants late)
  - Egg supply is more limiting that incubation space (only so many wild eggs available by source; collection/egg management also big time sink)

Action Update

Kokanee Angling Closure

- Action – maintain kokanee daily quota=0
- Trigger – <140,000 spawners; age 0–1 <11%

  - Implemented in 2015, continued

Nutrient Restoration Program

- Action – Continue current implementation program (plus fall application?)
- Trigger – none

  - Program delivered – fall program?......

Action Update

Mysis Removal

- Actions – evaluate feasibility, mysis removal
- Trigger – explore feasibility, removal if density/biomass > 463 ind/m2 (2 SD > mean).
  - Feasibility study in development

Action Update

Predator Management – Rainbow Trout

- Action – Recreational Fishery Regulations
- Trigger – <140,000 spawners; age 0-1 <11%

  - Implemented RBT daily quota increase (increased to 4/day in 2015 and then 5/d in 2018; still only 1>50cm)

  - KLRT RB harvest rate increased ~14% between 2015 and 2017 (regulations and outreach combined)

  - Effort declines resulted in a decrease in overall RB harvest (~9,000 to 4,000 in the same period)

Action Update

Predator Management – Bull Trout

- Action – Recreational Fishery Regulations
- Trigger – Trigger – <140,000 spawners; age 0-1 <11%
  - Regional biologists recommended an increase to 2/d (only 1>50cm) in 2015, management decision not to proceed (stakeholder opposition)
  - In 2018 daily catch quota increase met with approval, 2/d (only 1>50cm) implemented
  - Too soon to index changes in release rate that would indicate success

Action Update

Predator Conservation

Gerrards

- Action – reduce exploitation though regulations;
- Trigger<50-100 spawners; ***action not triggered***

- Hatchery Supplementation “Gene Banking”
- Trigger – <50-100 spawners in two consecutive years; ***action not triggered***

Bull Trout

- Action – reduce exploitation though regulations;
- Trigger – escapement < 50/500 spawners in Kaslo River and lake-wide index respectively; ***action not triggered***

Key Questions

Kokanee Sources Suitable?

- What kokanee sources are suitable to stock and where are they suitable to stock?
  - Brood source options initially screened for undesirable phenotypic expression; clearly divergent from Meadow Creek
    - Anadromy
    - Shoal spawners
    - Spawner age differences (i.e. 1+ or 5+ spawners etc.)
  - Genetic analysis completed (some components after Action Plan developed)
    - Action Plan identified Whatshan, Kinbasket Reservoirs and Lussier River as sources
    - 2016+2017 stocking departed from Action Plan recommendations; new genetic results suggested Hill Creek more appropriate than Koocanusa (Okanagan genetic component)
  - Discussion required to:
    - Confirm/modify Action Plan recommendations on brood sources
    - Identify preferred options to combine stocking location and brood sources to manage risk

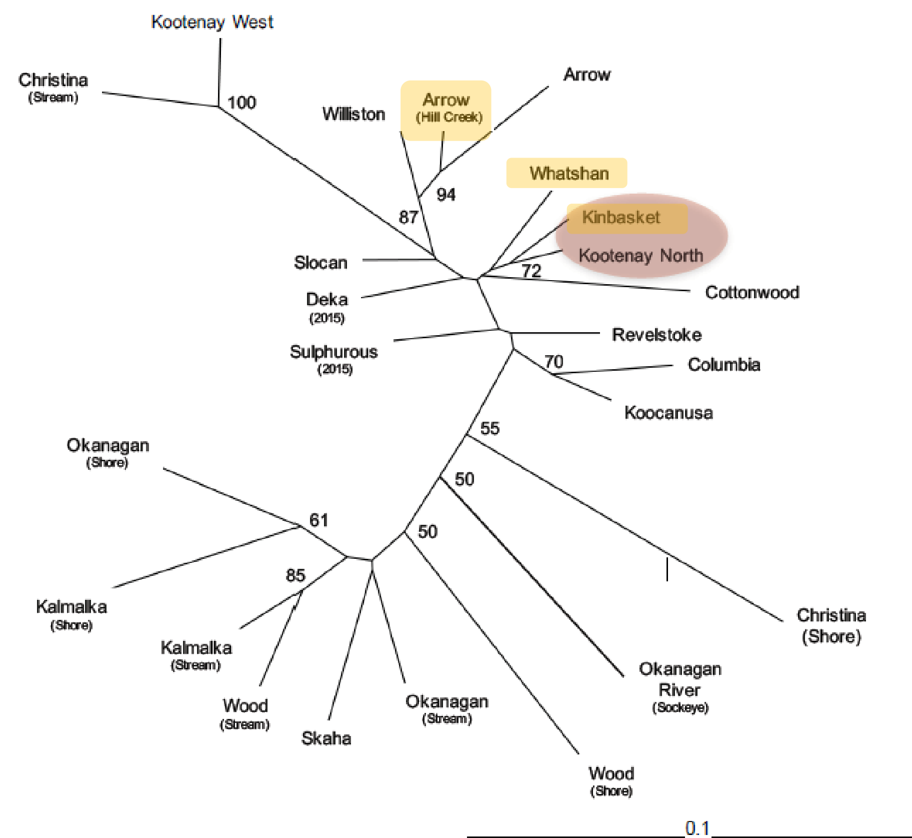


Figure 1. Unrooted neighbor-joining tree based on pairwise Cavalli-Sforza & Edwards (1967) chord distance. Nodes supported by >50 bootstrap values are indicated.

Table 3. Among-site differentiation between Kootenay Lake Meadow Creek and all other sites samples. Samples added this year indicated in *italics*.

Lake/River	Sampling Location	Kootenay Lake - Meadow Creek		
		F_{ST}[a]	*p*-value	significance[b]
Arrow Reservoir	*Burton Creek*	*0.1335*	*0.0006*	*
Arrow Reservoir	*Deer Creek*	*0.1382*	*0.0006*	*
Arrow Reservoir	*Drimmie Creek*	*0.1163*	*0.0006*	*
Arrow Reservoir	Hill Creek	0.0570	0.0002	*
Arrow Reservoir	*Mosquito Creek*	*0.1296*	*0.0006*	*
Arrow Reservoir	*Taite Creek*	*0.1126*	*0.0006*	*
Christina Lake	Sanders Creek	0.1280	0.0002	*
Christina Lake	Shore	0.2097	0.0002	*
Columbia River	Norns Creek	0.0732	0.0002	*
Cottonwood Lake	-	0.0653	0.0002	*
Deka Lake (2015)	Interior Plateau	0.0080	0.0044	NS
Kinbasket Reservoir	All[c]	0.0016	0.4211	NS
Kinbasket Reservoir	Bush Trawl	-0.0070	0.6605	NS
Kinbasket Reservoir	Columbia River	0.0065	0.2022	NS
Kinbasket Reservoir	Main Trawl	0.0053	0.4136	NS
Kinbasket Reservoir	Wood Trawl	0.0124	0.0437	NS
Koocanusa Reservoir	Lussier River	0.0481	0.0002	*
Koocanusa Reservoir	Norbury Creek	0.0428	0.0002	*
Kootenay Lake	*Crawford Creek*	*0.0104*	*0.6057*	NS
Kootenay Lake	*Goat River*	*0.0000*	*0.6640*	NS
Kootenay Lake	Lardeau River	0.0041	0.3111	NS
Kootenay Lake	Lower Duncan River	0.0009	0.7820	NS
Kootenay Lake	*Midge Creek*	*0.0920*	*0.0006*	*
Kootenay Lake	West Arm - Fisheries	0.1118	0.0002	*
Kootenay Lake	West Arm - Kokanee Creek	0.1503	0.0002	*
Kootenay	West Arm - Shore	0.1493	0.0002	*
Revelstoke Reservoir	*In Lake*	*0.0283*	*0.0006*	*
Revelstoke Reservoir	*Standard Creek*	*0.0201*	*0.0006*	*
Slocan Lake	Bonanza Creek	0.0352	0.0002	*
Slocan Lake	Wilson Creek	0.0270	0.0002	*
Sulphurous Lake (2015)	Interior Plateau	0.0252	0.0002	*
Whatshan Reservoir	Arrow Watershed	0.0097	0.0103	NS
Willistin Reservoir	Osolinka River	0.0544	0.0002	*

[a] Weir and Cockerham (1984) unbiased estimator of F_{ST} (θ)
[b] Indicative adjusted nominal level (5%) for multiple comparisons is : 0.000198
[c] Given small sample sizes of trawls, Kinbasket reservoir analyzed with all samples pooled and unpooled

Kokanee Egg Stocking Options – 2018 Genetic Risk Structure

Risk to Genetic Structure in Meadow Creek	Option	Description	Sources	Forecast Egg Supply
None	1	No Kokanee stocking	Only natural production	None
Low	2	Use only sources that are not significantly different	Whatshan, Kinbasket,	1,500,000
	3	Incorporate statistically significant different sources, but limit relative proportion of those stocks to be a maximum of 49% (i.e. 51% from mostly pure Kootenay Lake strains)	Above plus Hill Creek and Brood Lakes	3,000,000
	4	Incorporate statistically significant different sources, but limit relative proportion of those stocks to be a maximum of 49% (i.e. 51% from mostly pure Kootenay Lake strains) to Meadow Creek, remainder to Sout Arm Tribs	Above plus Hill Creek and Brood Lakes	3 million for Meadow; additional 6 million for South Arm
	5	Incorporate significantly different sources; no limit of relative proportion	Same as above	~ 9 million
High	6	Incorporate anywhere you can get eggs efficiently (notable include Koocanusa Tribs) no limits on relative contribution (potentially above FFSBC capacity to collect)	Above plus Lussier, Norbury	> 9 million

2018 Brood Collection fo KL - Order of Preference

Suitability	Collection Location	Potential Egg Supply
Most Suitable	Whatshan/Kinbasket (Fairmont); same as MC	1,500,000
	Bridge Lake (100% MC; F2 generation from ~150 F)	1,000,000
	Deka Lake (85% MC and 15% Hill; F2 generation from ~150 F)	400,000
	Hill Creek	6,000,000
	Sulphurous Lake (100% Hill; F2 Generation from ~150 F)	250,000
Least Suitable	Koocanusa (Lussier/Norbury/Bull)	1,500,000
		10,650,000
		Likely above FFSBC capacity to collect

- Robs modeling and trend data ……..

Examining Kootenay Lake Kokanee Dynamics with a Stock Recruitment Approach

Kootenay Lake Advisory Team Meeting

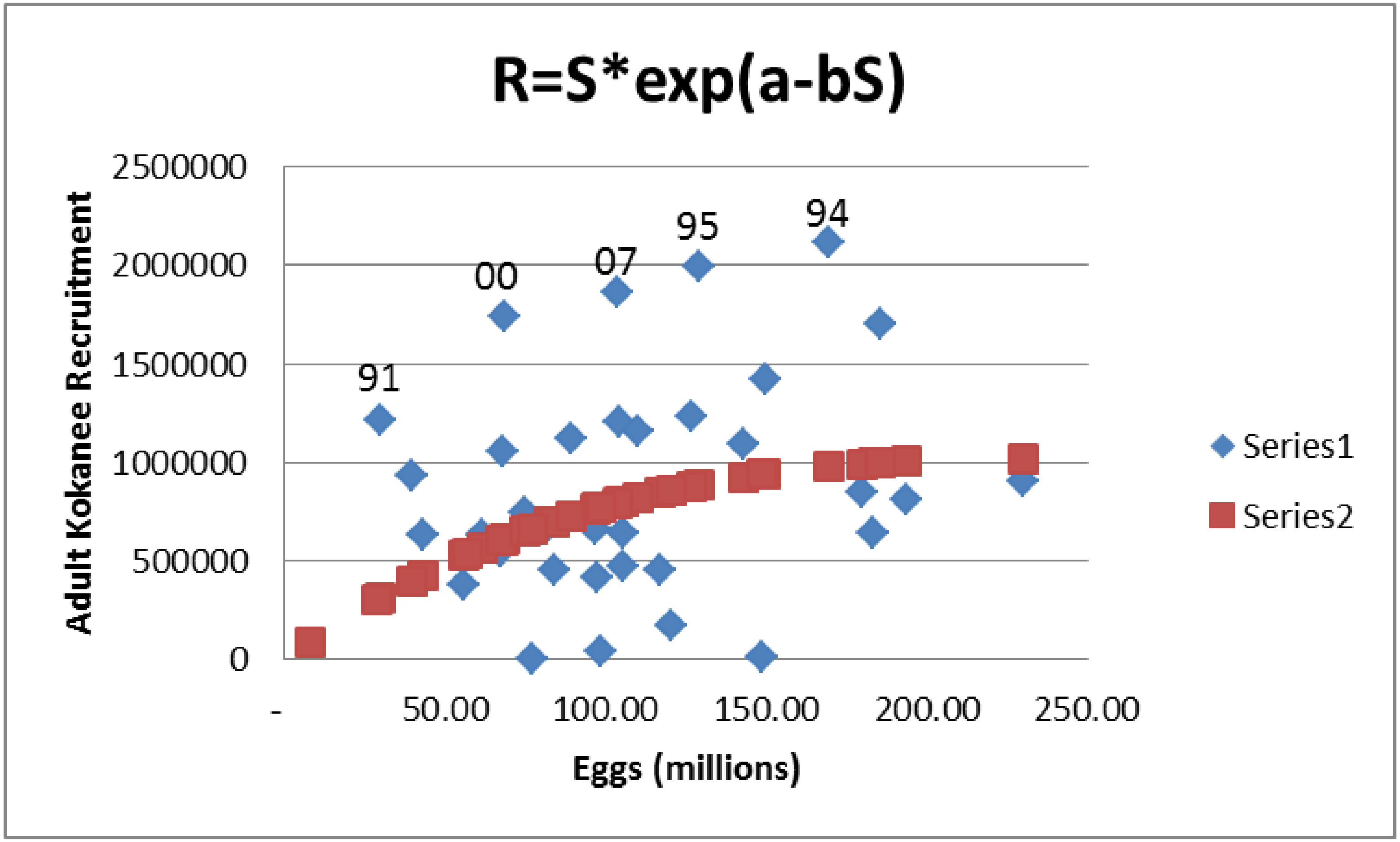
May 15-16, 2018

Nelson, BC

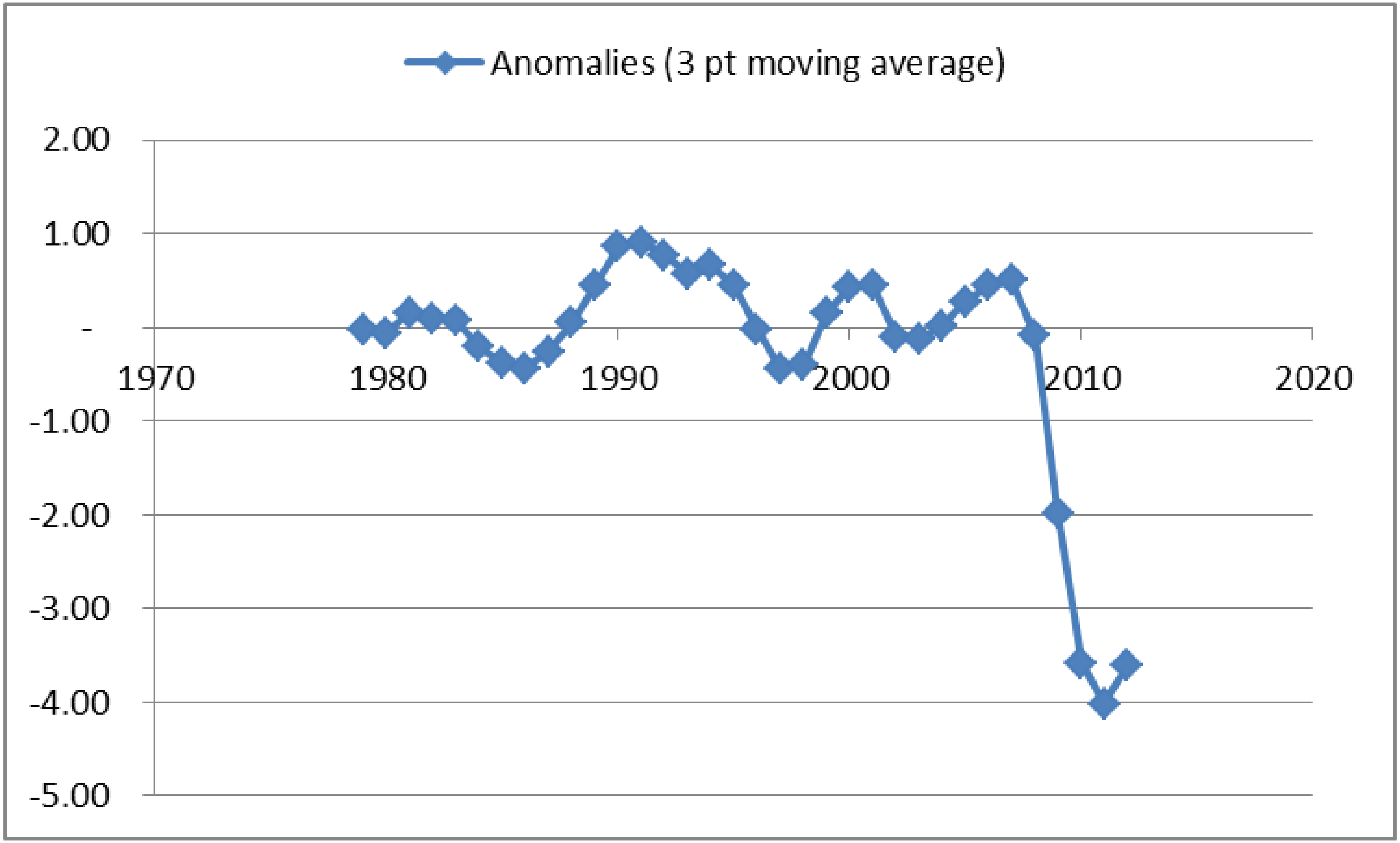
Outline

- Kokanee Recruitment Anomalies
- Cycles
- Predator Covariates. Why catch?
- Kokanee Recruitment Predictions

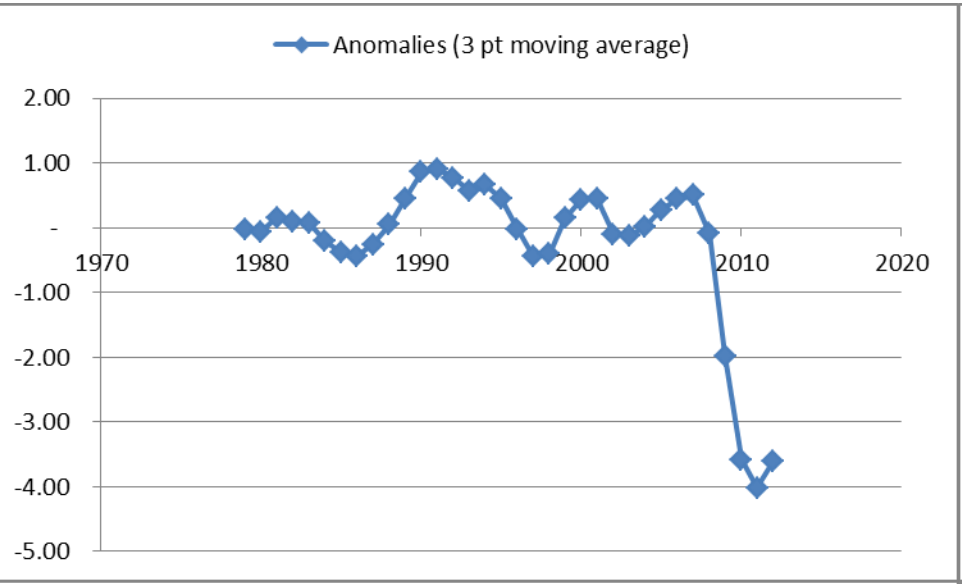
Kokanee Stock Recruitment

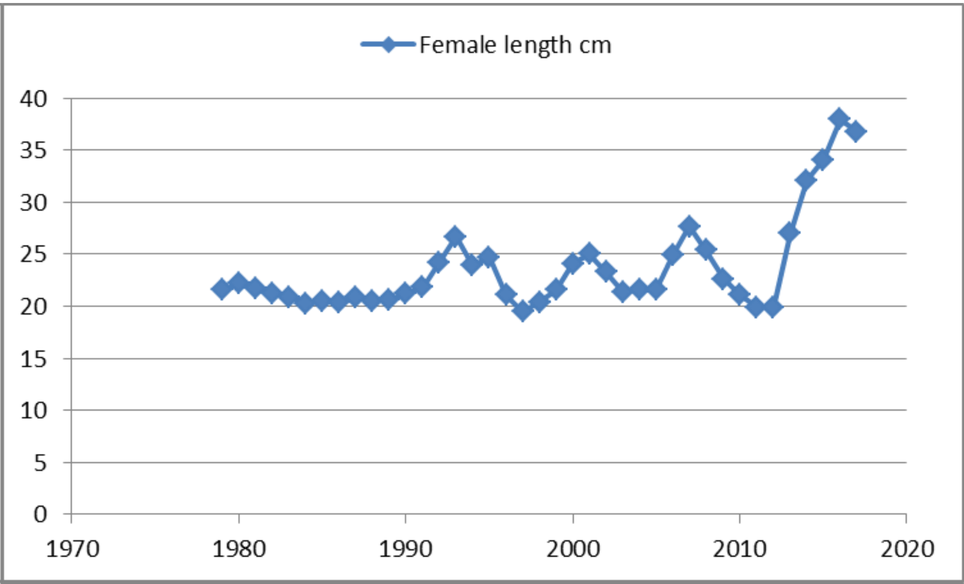


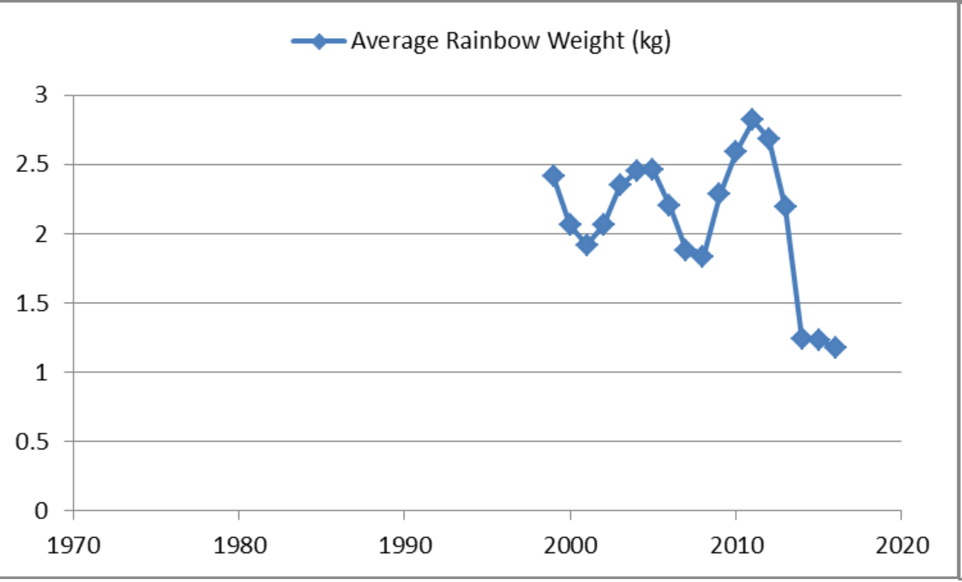
Recruitment Anomalies

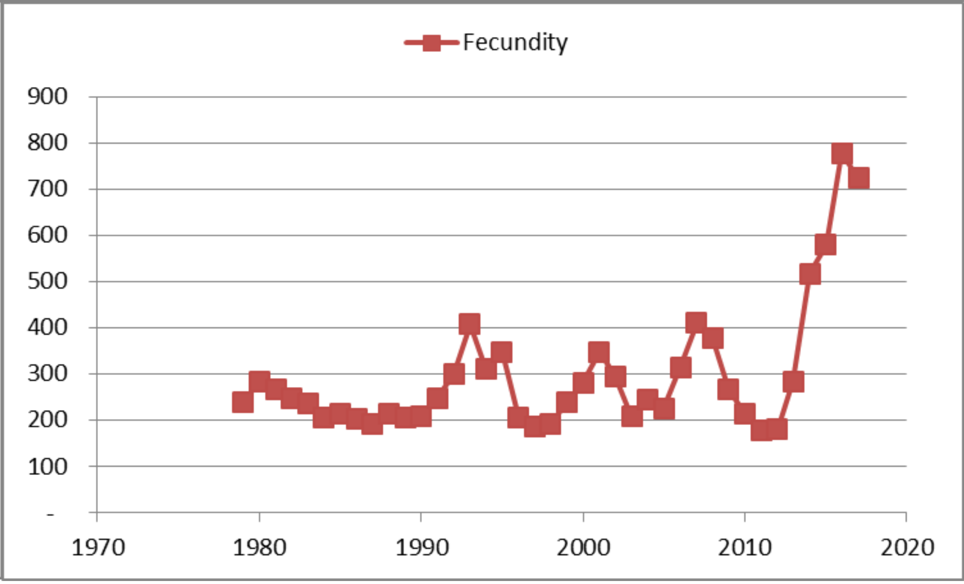


Cycles in Kokanee

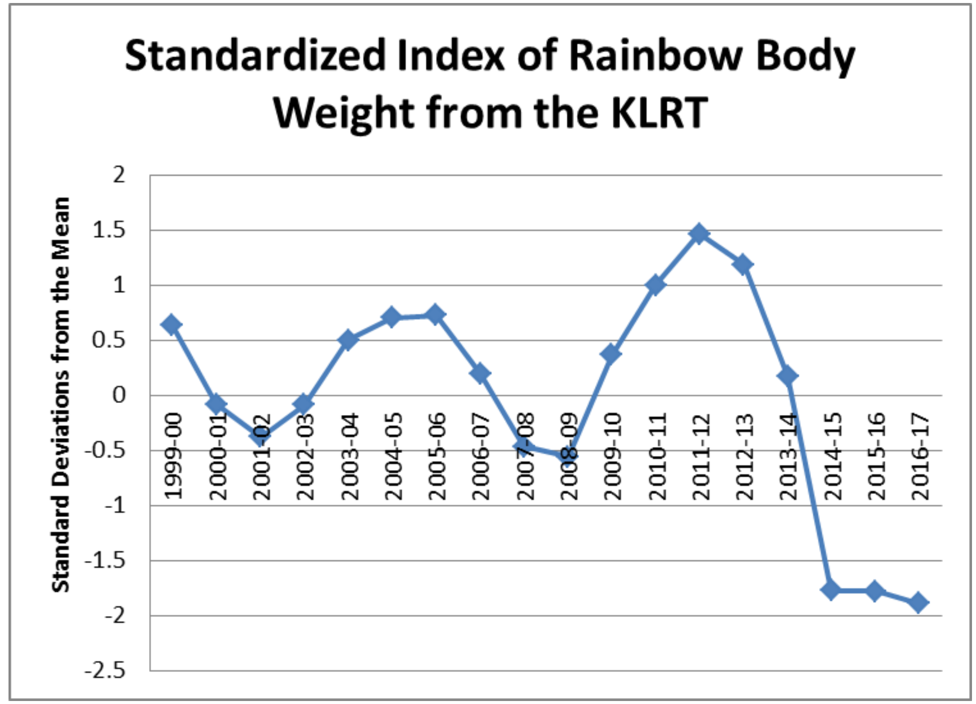


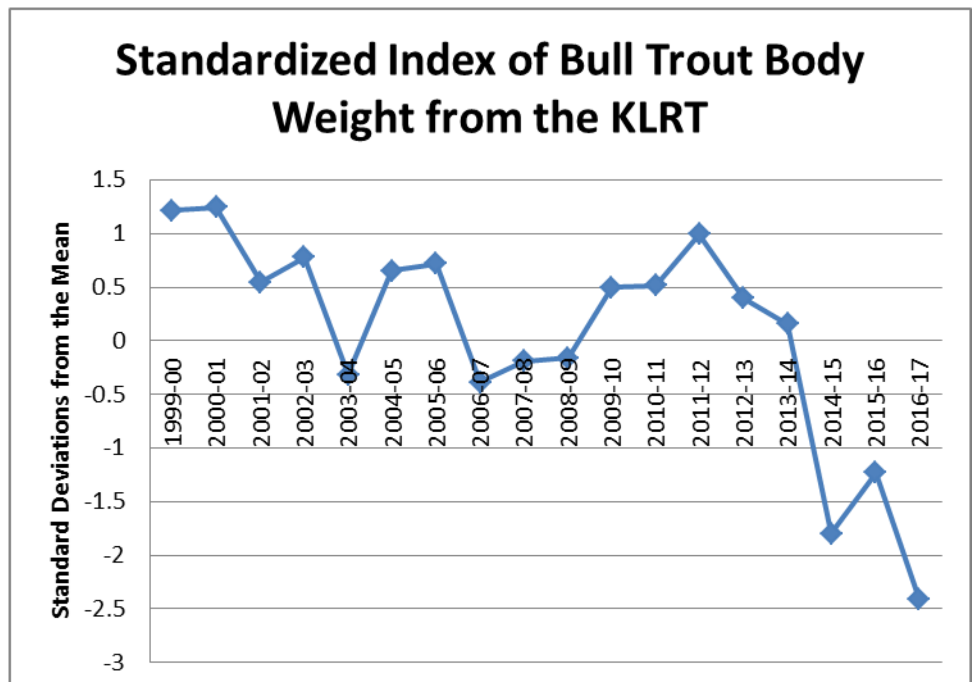






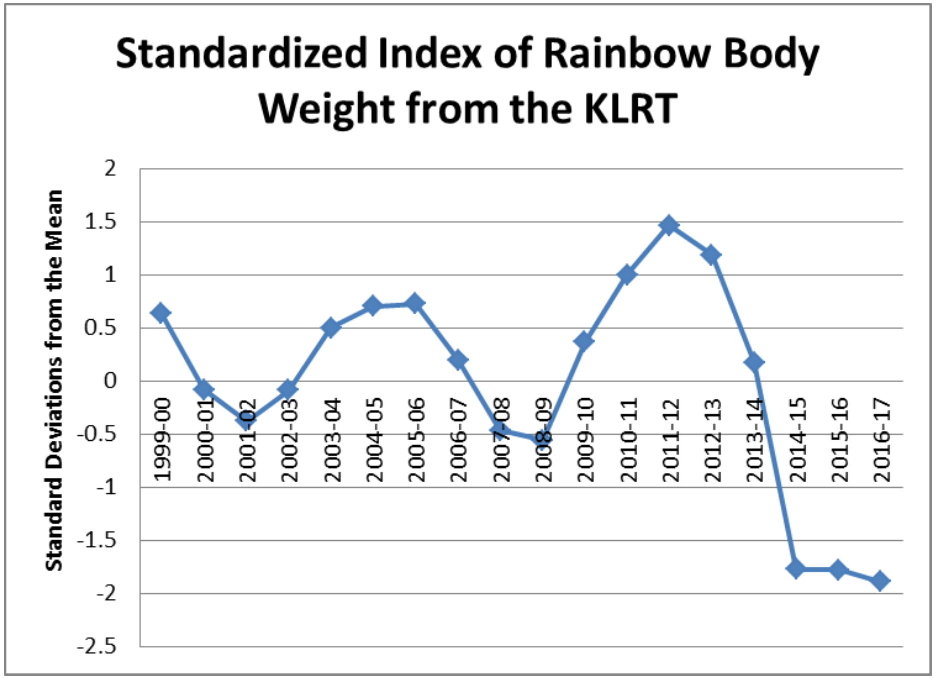
Cycling in body weight is apparent in rainbow trout, but not so much in bull trout.

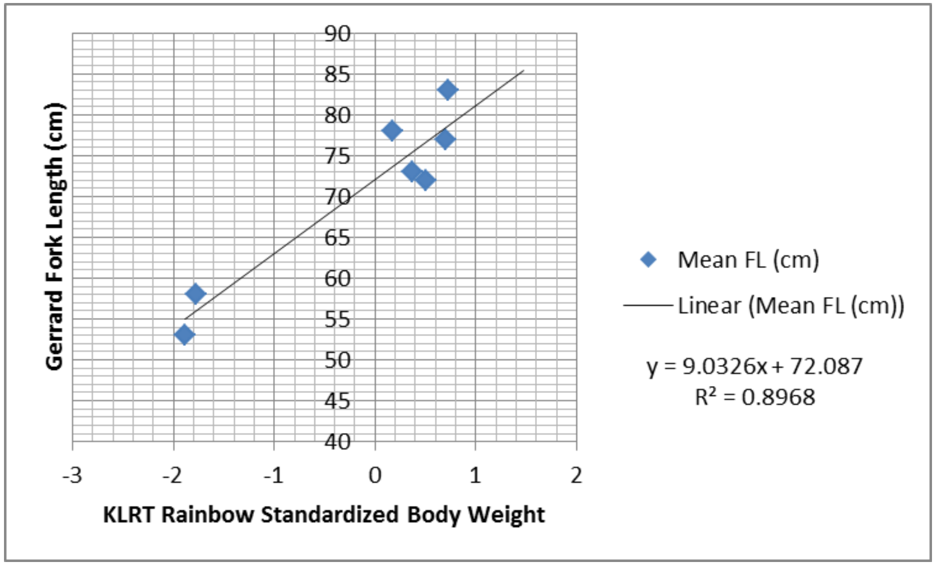




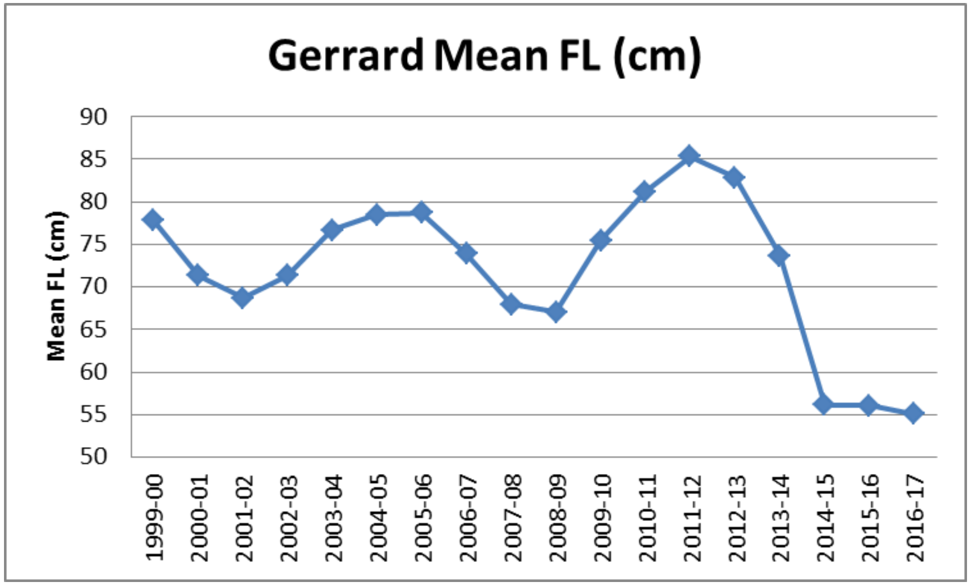
Might bull trout impart some stabilizing effect under more “normal” conditions?

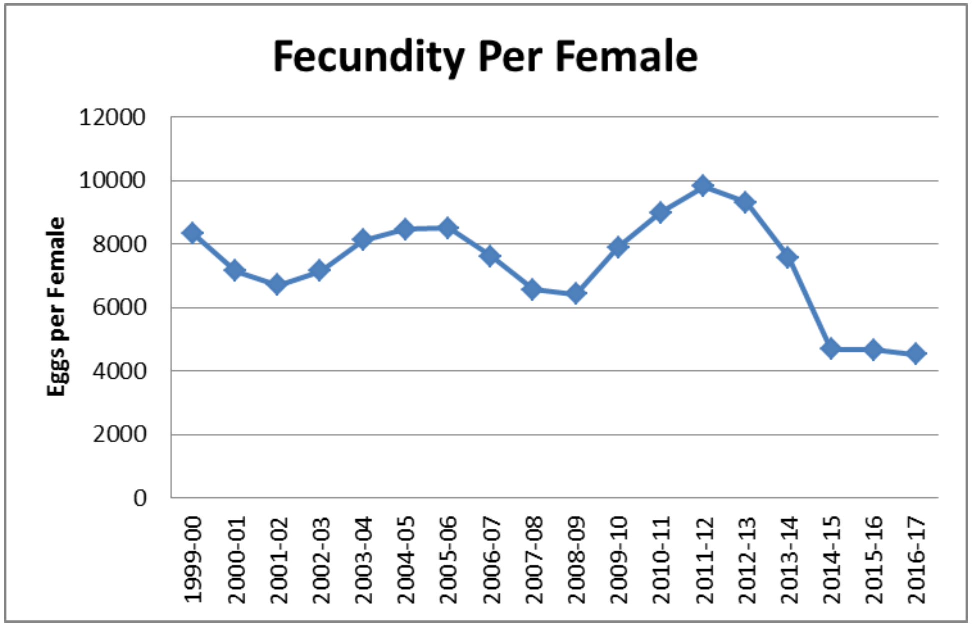
Cycles in Gerrard Rainbow





Cycles in Gerrard Rainbow



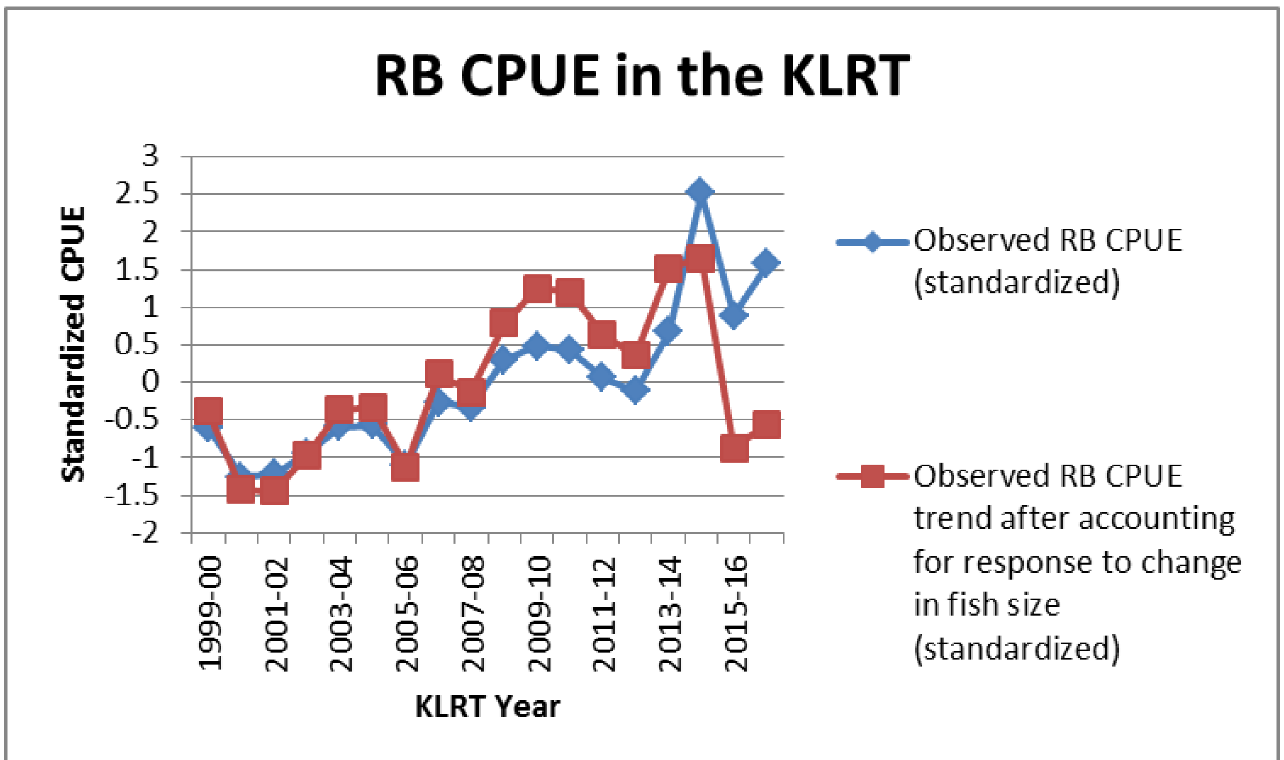


Predator Covariates,
Why Catch and Not CPUE?

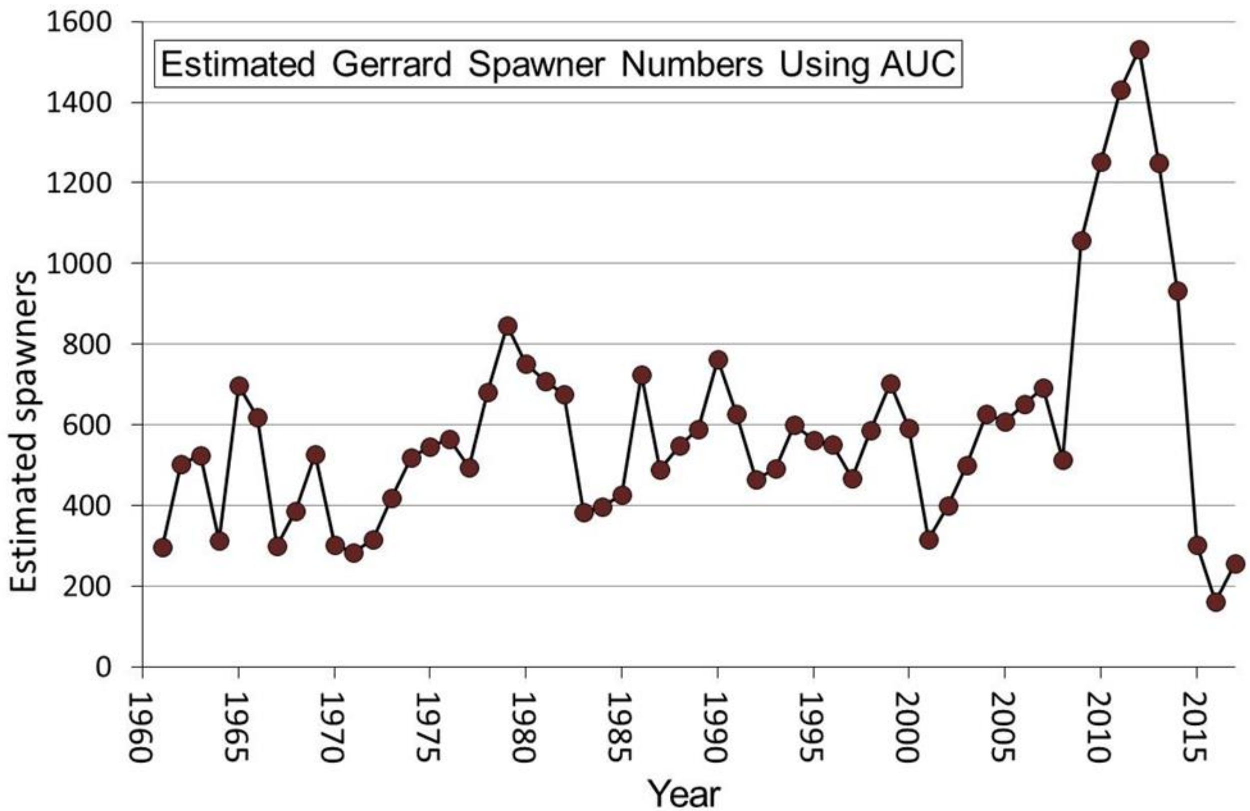
- Normally we would expect hyperstable CPUE in open access fisheries if the effort has the potential to be responsive to catch rates.
- But we also expect angler response to fish size to have an effect on CPUE.

Predator Covariates, Why Catch and Not CPUE?

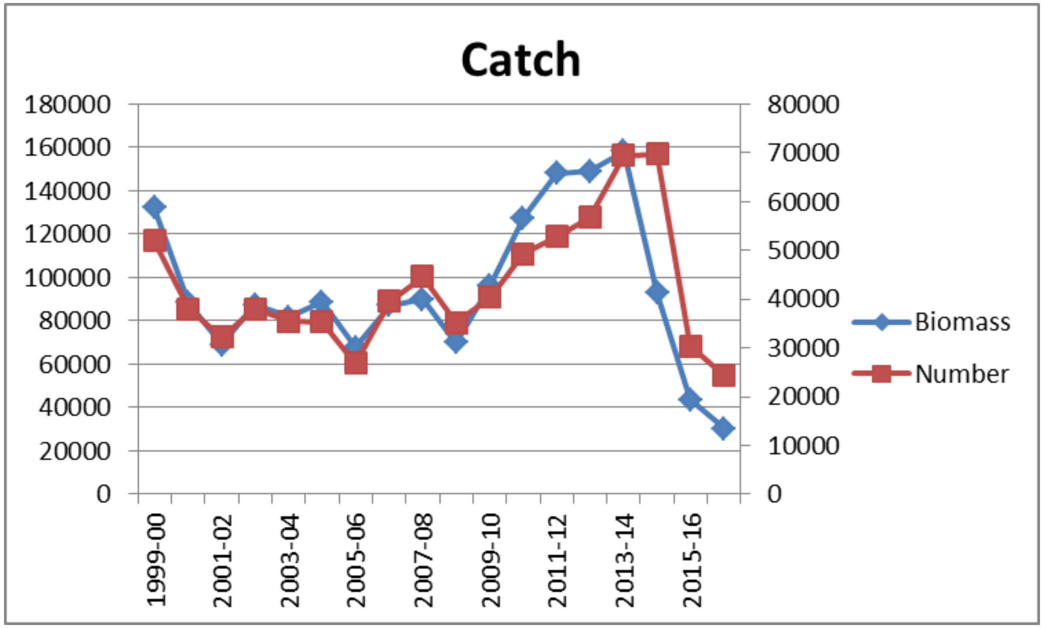
- Effort response to CPUE does not appear strong
- If we correct for fish size, CPUE resembles Catch which is more consistent with Gerrard Abundance.

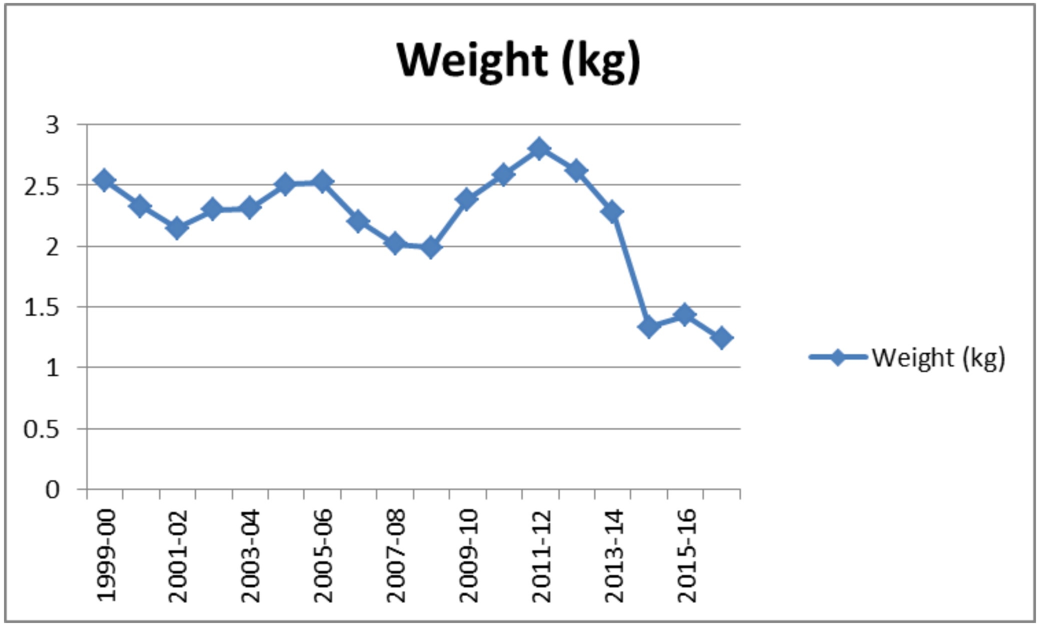


Gerrard spawner abundance is not that low

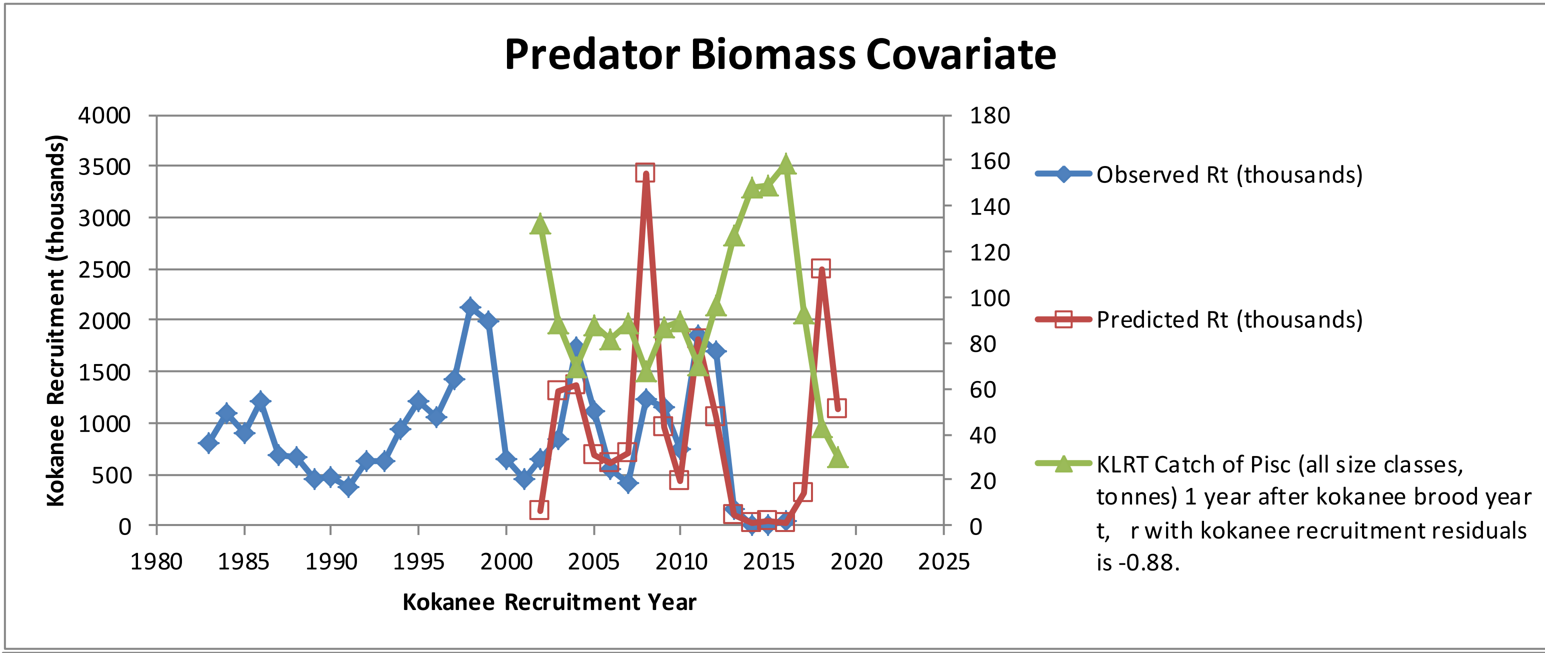


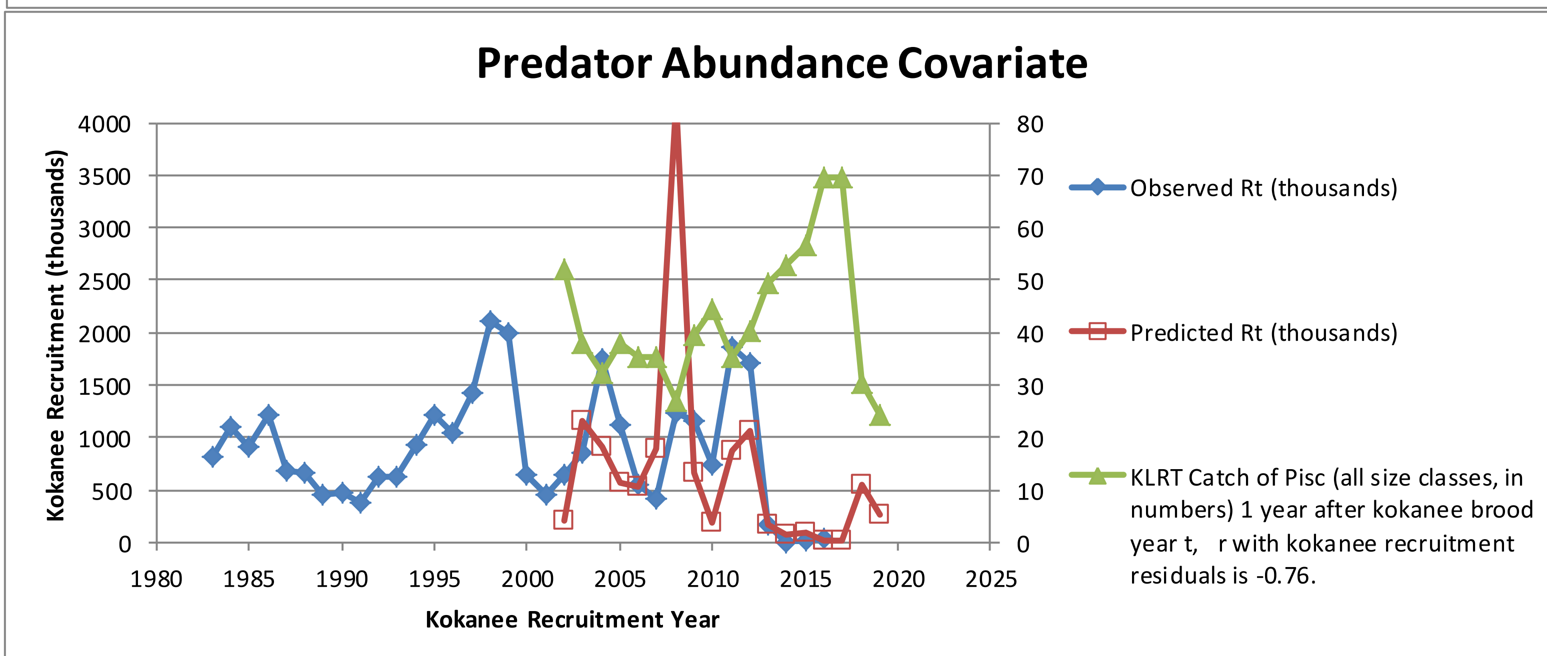
Predator numbers seem only slightly lower than they were before, except their condition is much lower.





Future Kokanee Recruitment Predictions


Predator Biomass Covariate
Kokanee Recruitment (thousands)
4000
3500
3000
2500
2000
1500
1000
500
0
180
160
140
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Kokanee Recruitment Year
Observed Rt (thousands)
Predicted Rt (thousands)
KLRT Catch of Pisc (all size classes, tonnes) 1 year after kokanee brood year t, r with kokanee recruitment residuals is -0.88.

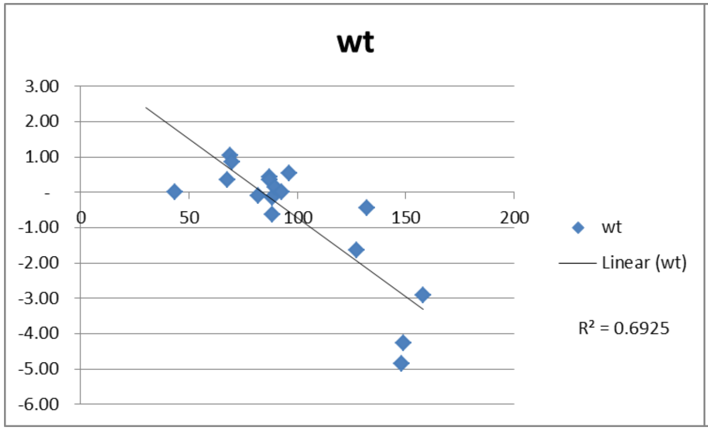

Predator Abundance Covariate
Kokanee Recruitment (thousands)
4000
3500
3000
2500
2000
1500
1000
500
0
80
70
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Kokanee Recruitment Year
Observed Rt (thousands)
Predicted Rt (thousands)
KLRT Catch of Pisc (all size classes, in numbers) 1 year after kokanee brood year t, r with kokanee recruitment residuals is -0.76.

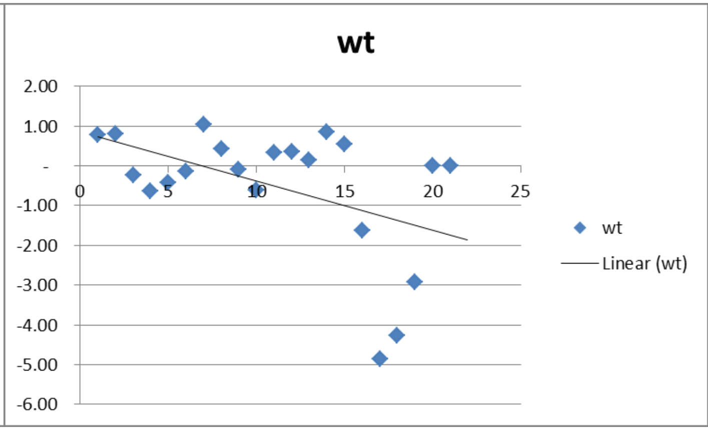
Is predator number rather than biomass a better covariate?

Biomass

Number

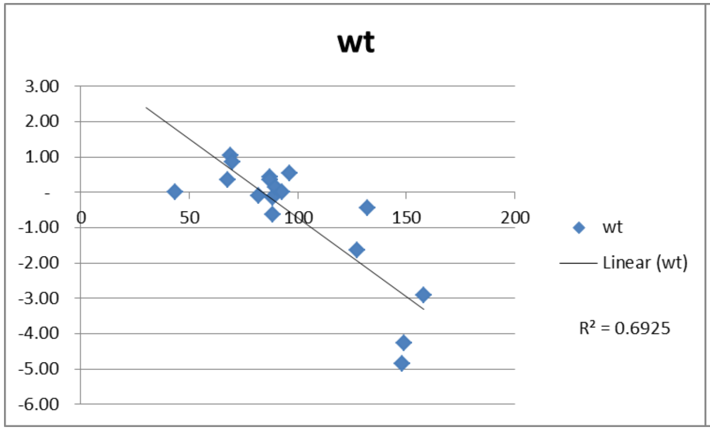
All anomalies included



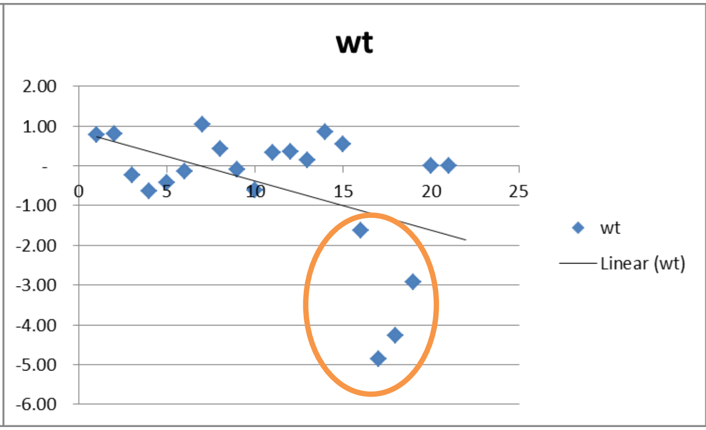


Is predator number rather than biomass a better covariate?

Biomass



Number



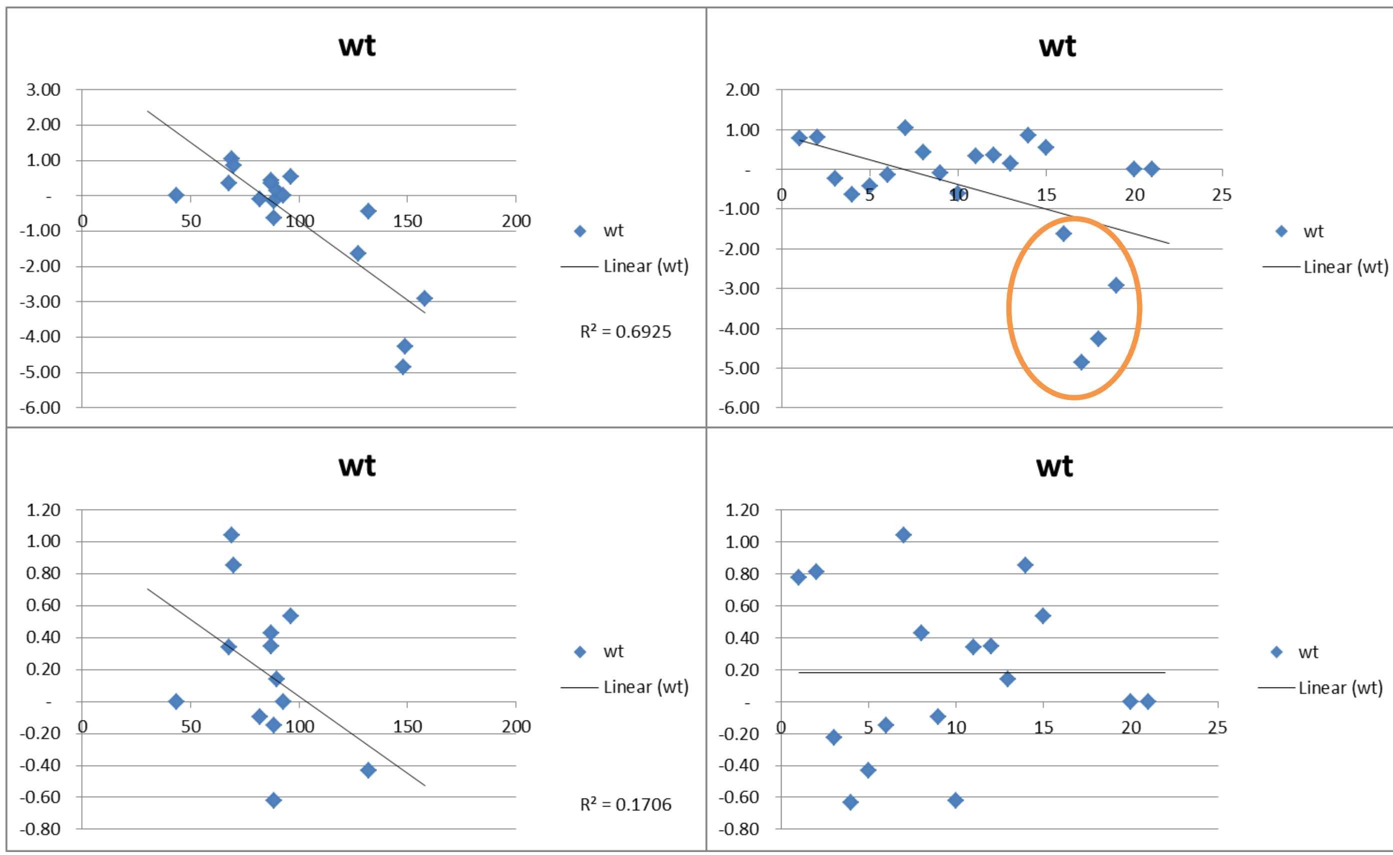
All anomalies included

Is predator number rather than biomass a better covariate?

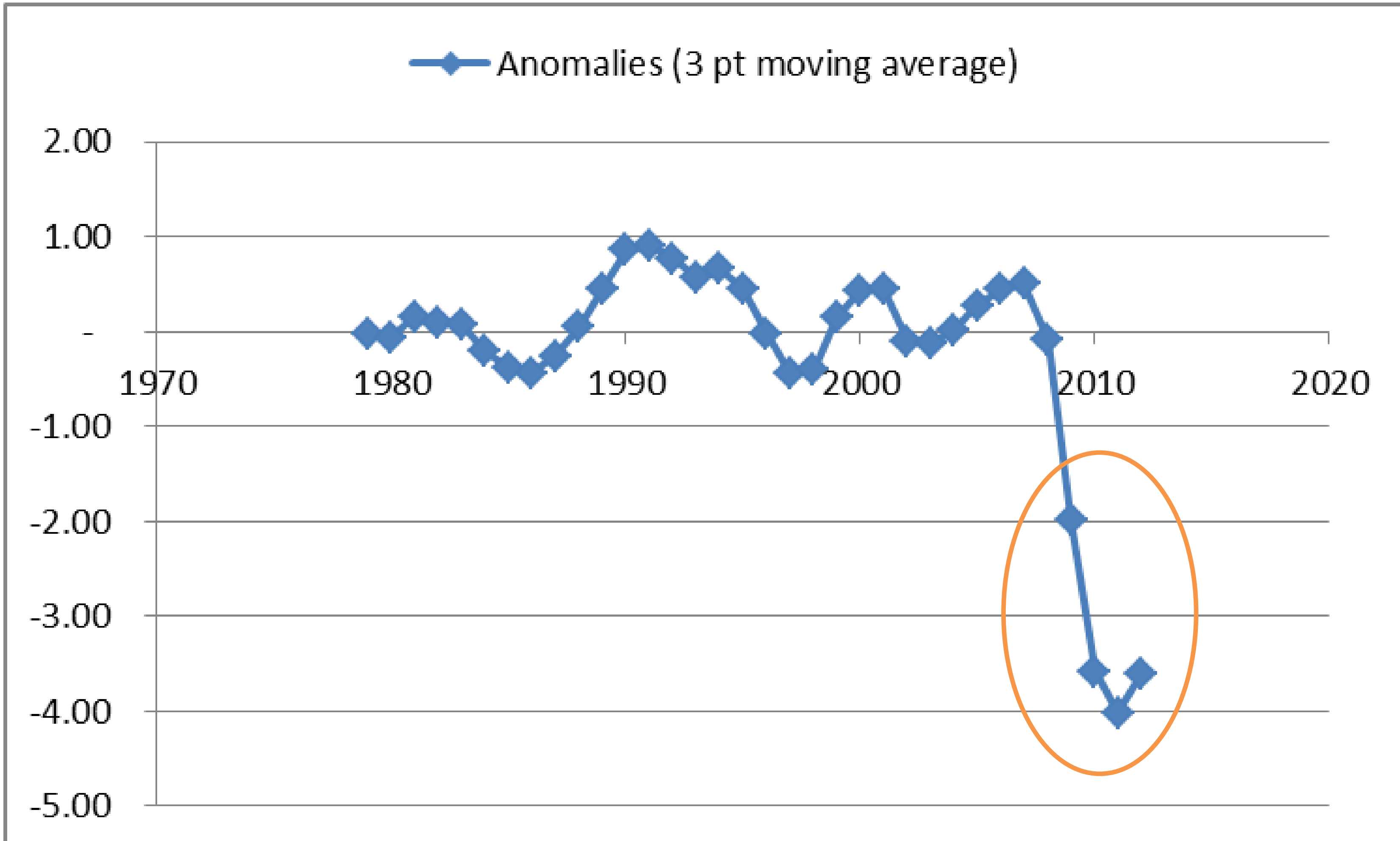
Biomass | Number

All anomalies included

Recent outliers excluded



Recruitment Anomalies



End

- Would a more assertive piscivore reduction accelerate kokanee recovery;
  - Rainbow Trout
  - Bull Trout
  - If yes, what number and which method/size/age/stage?
  - Slides to follow –
    - management action options (what feasible options available and what removal potential),
    - kokanee consumption by predators (diet and predator trend data)
    - combination of diet and potential removal to look at scale of benefit of management actions
    - Benefit scaled to current kokanee mortality

BT Management Options

- Implemented BT daily quota increase in 2018 (increase to 2/d only 1>50cm)

- Additional Removal Options:
  - Lake Angling Regulations (further daily quota increase)
    - **Potential Removal – 800 all ages** (~1,600 all sizes released based on KLRT and creel comparison; not all release based on daily quota)
      - Cons –time to implement, poor data on impact, low angler effort currently (<1/2 highs) and catch rate (1/2 BT/angler day on average)
      - Pros – may increase angler effort/satisfaction, low cost

  - Tributary Angling Regulation Changes
    - **Potential Removal – up to 50%+ (1,200 spawners**)
      - Cons – time to implement, poor data on impact, poor control of removal target
      - Pros – angler opportunities, low cost

  - Kelt fence removal from high abundance tribs (including Duncan flip bucket) –
    - **Potential Removal – up to all spawners (50% = 1,700, access to 1,200** or so; likely low impact to juvenile production)
      - Cons – high $, only mature individuals (sub-adults not targeted)
      - Pros – good control of removal target, good data on impact

BT Management Options

- Additional Removal Options:
  - In-Lake Reward Program
    - **Potential Removal – ~2,000 all age classes** (assume 25% effort increase and most BT harvested)
      - Cons – mod-high $, poor optics around blue listed spp., likely requires angling regulation change for full effect
      - Pros – poor control over removal target, good data on impact, sub-adults also targeted
  - In-Lake gill netting –
    - **Removal Potential unknown – Assumed low**
      - Cons – high $, non-selective (likely high kokanee mortality), likely low catch rates
      - Pros – targets all age classes, good control of removal target, data on impact
  - Controlled selective removal from tributaries (permitted recreation angling/FN selective harvest)
    - **Removal Potential – up to all spawners (likely tribs @ 50% =~1,200 spawners)**
      - Cons – moderate control over target (may not achieve),
      - Pros – Low $, good data on impact in retrospect

Bull Trout Spawners – Potential Surplus/Production Needs

Kaslo and Keen				All Kootenay Lake Tribs		
2017 redds	477					
2017 spawners	1049	Surplus (n)	Surplus (%)	3421	Surplus (n)	Surplus (%)
Spawners required for 5 redd/km	387	662	63%	1262	2159	63%
Spawners required for 7.5 redd/km	581	469	45%	1893	1528	45%
Spawners required for 10 redd/km	774	275	26%	2525	896	26%

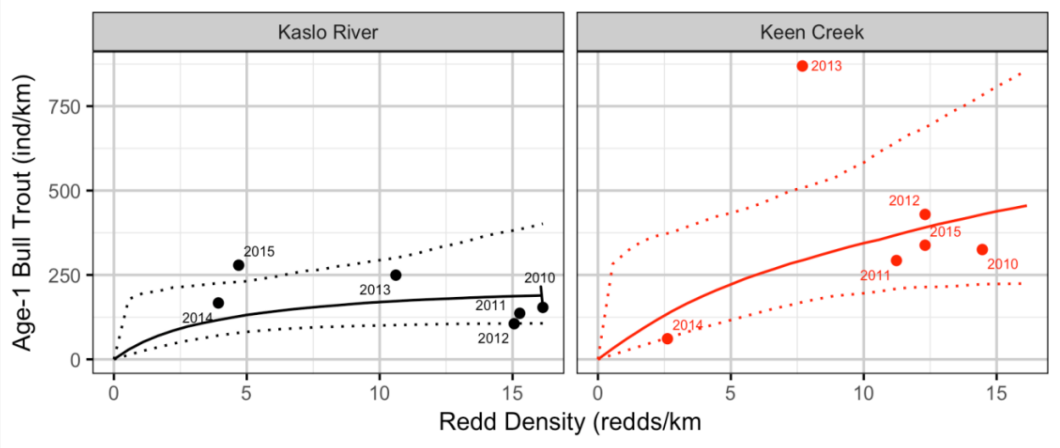


Figure from – Andrusak, G.F. 2018. Draft Kootenay Lake Bull Trout Productivity and Capacity for Defining Management Reference Points-CAT # 17-4-465-2017. Prepared for the Habitat Conservation Trust Foundation and the Ministry of Forests, Lands and Natural Resource Operations, Nelson, BC. January 2018. 32 pp+

RBT Management Options

- Implemented RBT daily quota increase (increased to 4 and then 5/d; only 1>50cm)

- Additional Removal Options:
  - Lake Angling Regulations (further daily quota increase)
    - **Potential Removal – 800 all ages** (~4,600 all sizes released based on KLRT and creel comparison; not all release based on daily quota)
      - Cons –time to implement, poor data on impact, low angler effort currently (<1/2 highs) and catch rate (1 RB/angler day on average)
      - Pros – may increase angler effort/satisfaction, low cost

  - Spawner removal
    - **Potential Removal – 125 spawners** (50% removal feasible; # based on 2017 spawner estimates)
      - Cons – high $, only mature individuals (sub-adults not targeted), already small spawner population, low impact, ~80% natural mortality
      - Pros – good control of removal target, good data on impact

  - In-Lake Reward Program
    - **Potential Removal – ~5,600 all age classes** (assume 25% effort increase and most RB harvested
      - Cons – mod-high $, estimates likely biased high; future conservation concerns with coming years abundance based on juvenile supply in 2014 and on as well as 250 spawners part of targeted cohort.
      - Pros – poor control of removal target, good data on impact, sub-adults also targeted

Predator Consumption

- How many kokanee do Bull Trout and Rainbow eat?
- What are the predicted impacts of these management actions?

Reconstructing Predator Abundance

Numbers at Age in 2011
(Andrusak et al.)

Parameter	Estimate
Total > age 4	67,590
Age 1	126,600
Age 2	82,310
Age 3	53,920
Age 4	35,590
Age 5	16,920
Age 6	8,151
Age 7	3,979
Age 8	1,968
Age 9	985

KLRT Catch Time Series 2010-2011

	< 2kg RB	2-5kg RB	5-7kg RB	> 7kg RB	Sum
RB Catch	19,249	8,793	4,487	1,375	33,904

- Assumptions about vulnerability to angling at age:
  RB – 50% Age 3, 100% Age 4+
  → Total Vulnerable Population = 93,568

  BT – 50% Age 4, 100% Age 5+

- Catch is an index of abundance → $C = qN$

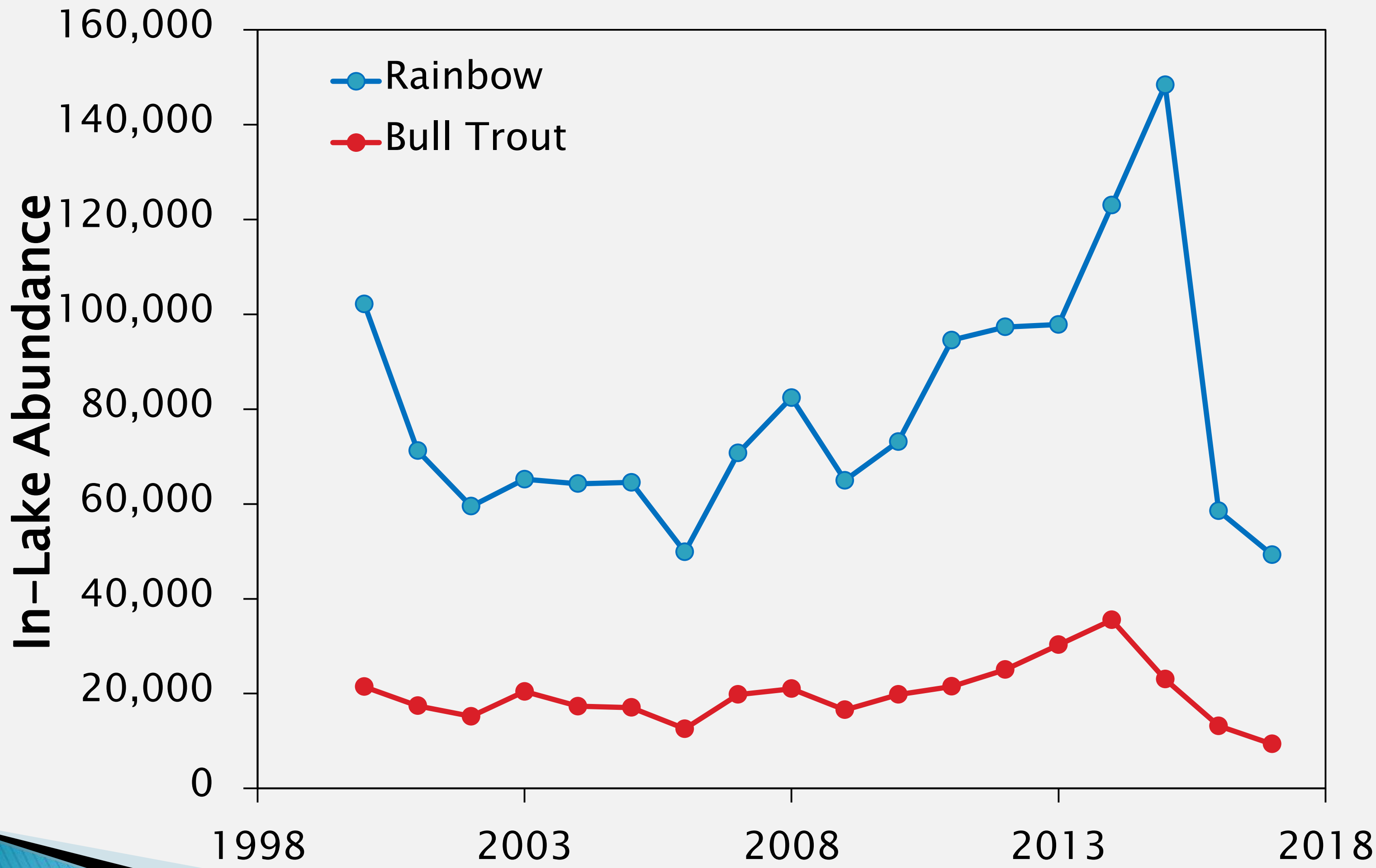
Reconstructing Predator Abundance

Year	KLRT Catch				Abundance			
	< 2kg RB	2-5kg RB	5-7kg RB	> 7kg RB	< 2kg RB	2-5kg RB	5-7kg RB	> 7kg RB
1999-00	23,703	6,914	3,785	2,229	66,106	19,282	10,557	6,216
2000-01	18,020	4,952	1,570	989	50,256	13,811	4,380	2,758
2001-02	15,549	4,123	1,158	505	43,365	11,500	3,231	1,409
2002-03	15,582	5,938	1,506	354	43,456	16,559	4,200	988
2003-04	14,609	5,157	[illegible]	[illegible]	[illegible]	[illegible]	6,609	2,538
2004-05	14,508	4,825	[illegible]	[illegible]	[illegible]	[illegible]	7,236	3,379
2005-06	11,092	3,944	[illegible]	[illegible]	[illegible]	[illegible]	5,142	2,804
2006-07	17,401	4,688	[illegible]	[illegible]	[illegible]	[illegible]	5,874	3,266
2007-08	21,856	5,406	[illegible]	[illegible]	[illegible]	[illegible]	4,982	1,392
2008-09	17,122	4,778	1,175	222	47,752	13,324	3,276	618
2009-10	15,913	7,530	2,314	473	44,379	21,000	6,454	1,319
2010-11	19,249	8,793	4,487	1,375	53,684	24,523	12,512	3,833
2011-12	18,631	8,867	5,207	2,193	51,958	24,729	14,521	6,117
2012-13	19,714	8,586	4,915	1,871	54,979	23,946	13,707	5,217
2013-14	30,059	8,200	4,470	1,379	83,830	22,867	12,467	3,845
2014-15	49,086	3,288	691	145	136,895	9,170	1,928	404
2015-16	19,316	1,398	246	27	53,871	3,899	686	76
2016-17	16,482	1,115	57	16	45,967	3,111	159	45

Catch → Abundance

$$N = C/q$$

Reconstructing Predator Abundance

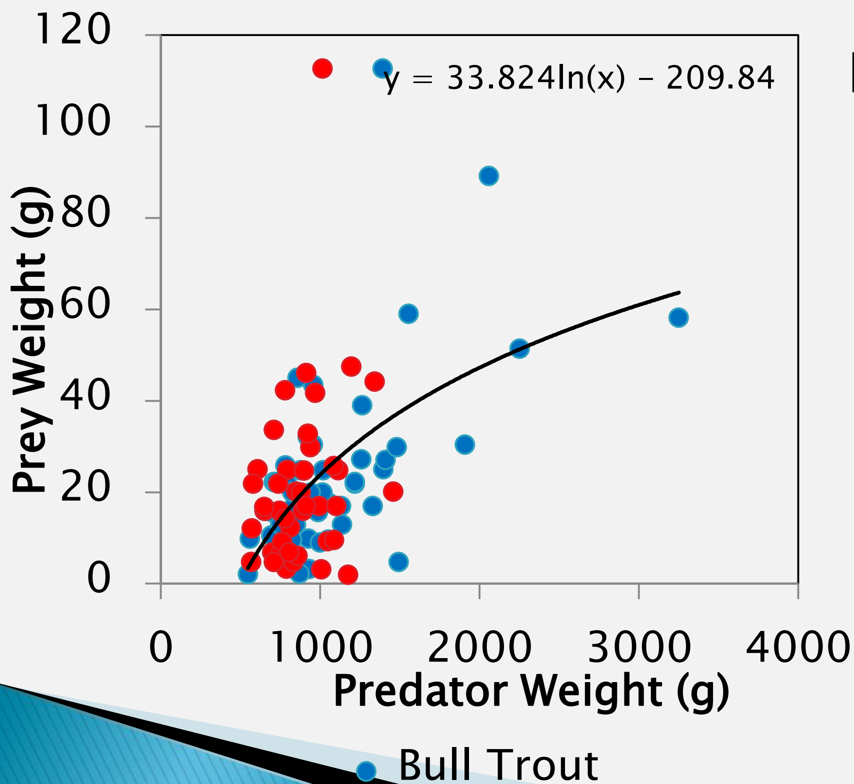


Kokanee Consumption

- How many kokanee do Bull Trout and Rainbow eat?

  Two methods explored:

  1) Predator/prey wt relationship, and % occurrence in diet data



Individual Consumption (kg per year)

Size Bin	% of Diet Fish	<2kg	2-5 kg	5-7 kg	>7 kg
		1	3.5	6	8
BT	0.343	2.98	8.29	10.57	11.79
RB	0.118	1.03	2.85	3.64	4.05

Observed in diet data

Kokanee consumption by Rainbow and Bull Trout

2) Temperature, evacuation rate method

1. Determine Kokanee FL → pre-digested weight
2. Estimate rate of evacuation (He and Wurtsbaugh 1993)
   - 2 temperature assumptions (surface, Kinbasket Bull T. study)
   - Pre-digested prey weight
3. Estimate daily and annual KO consumption (Diana 1979)
   - Min/max depending on assumed temperature

Results:

Annual consumption **0.48 – 0.68 kg KO/kg Rainbow**
1.72 – 2.57 kg KO/kg Bull
(sizes pooled; average of 5 sampled periods)

Caveats:

- temperature assumptions
- Spring and Fall sampling only
- may underestimate consumption of smaller prey (<10 g) especially at higher temperatures (detection reduced if <<24 hours to evacuate)

Kokanee Consumption

Individual Consumption

Pred/prey and % diet occurrence

Size Bin	% of Diet Fish	<2kg	2–5 kg	5–7 kg	>7 kg
		1	3.5	6	8
BT	0.343	2.98	8.29	10.57	11.79
RB	0.118	1.03	2.85	3.64	4.05

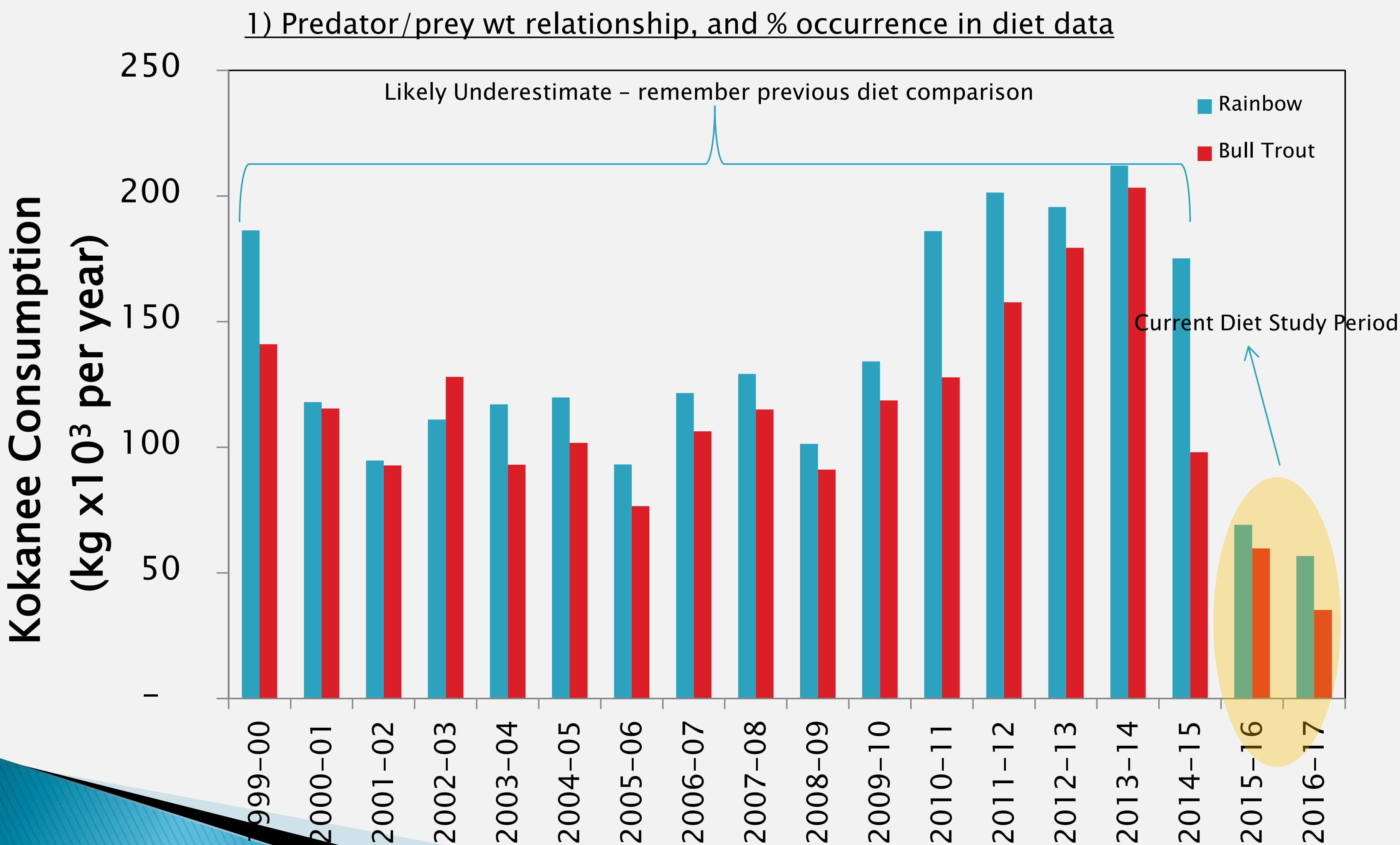
Based on evacuation rate, temperature, etc

Size Bin	<2kg	2–5 kg	5–7 kg	>7 kg
	1	3.5	6	8
BT	1.7–2.6	6.0–9.0	10.3–15.4	13.8–20.6
RB	0.5–0.7	1.7–2.4	2.9–4.1	2.9–5.4

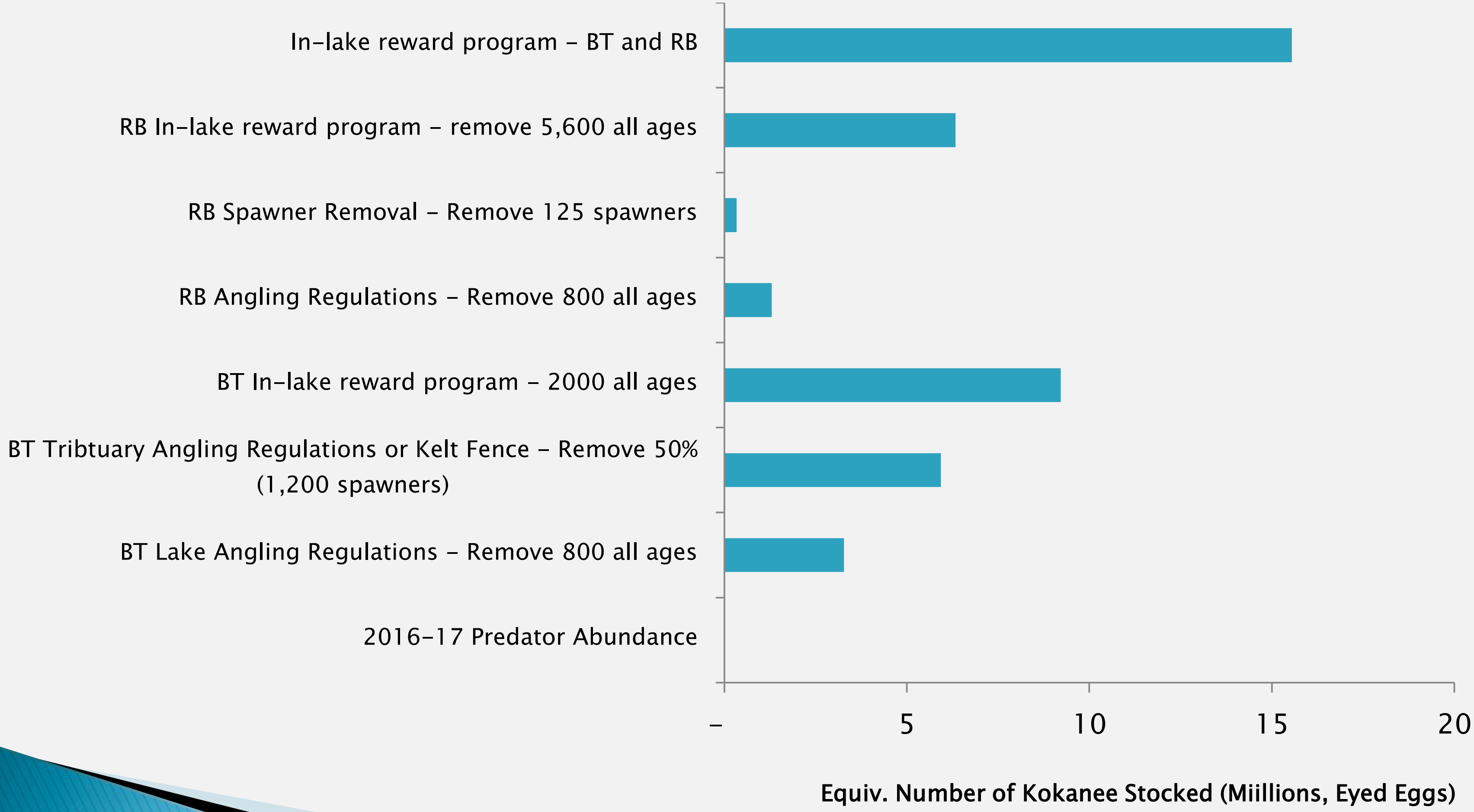
X

Year	Abundance			
	< 2kg RB	2–5kg RB	5–7kg RB	> 7kg RB
1999–00	66,106	19,282	10,557	6,216
2000–01	50,256	13,811	4,380	2,758
2001–02	43,365	11,500	3,231	1,409
2002–03	43,456	16,559	4,200	988
2003–04	40,742	14,366	6,609	2,538
2004–05	40,461	13,456	7,236	3,379
2005–06	30,934	10,999	5,142	2,804
2006–07	48,529	13,074	5,874	3,266
2007–08	60,954	15,077	4,982	1,392
2008–09	47,752	13,324	3,276	618
2009–10	44,379	21,000	6,454	1,319
2010–11	53,684	24,523	12,512	3,833
2011–12	51,958	24,729	14,521	6,117
2012–13	54,979	23,946	13,707	5,217
2013–14	83,830	22,867	12,467	3,845
2014–15	136,895	9,170	1,928	404
2015–16	53,871	3,899	686	76
2016–17	45,967	3,111	159	45

Kokanee Consumption

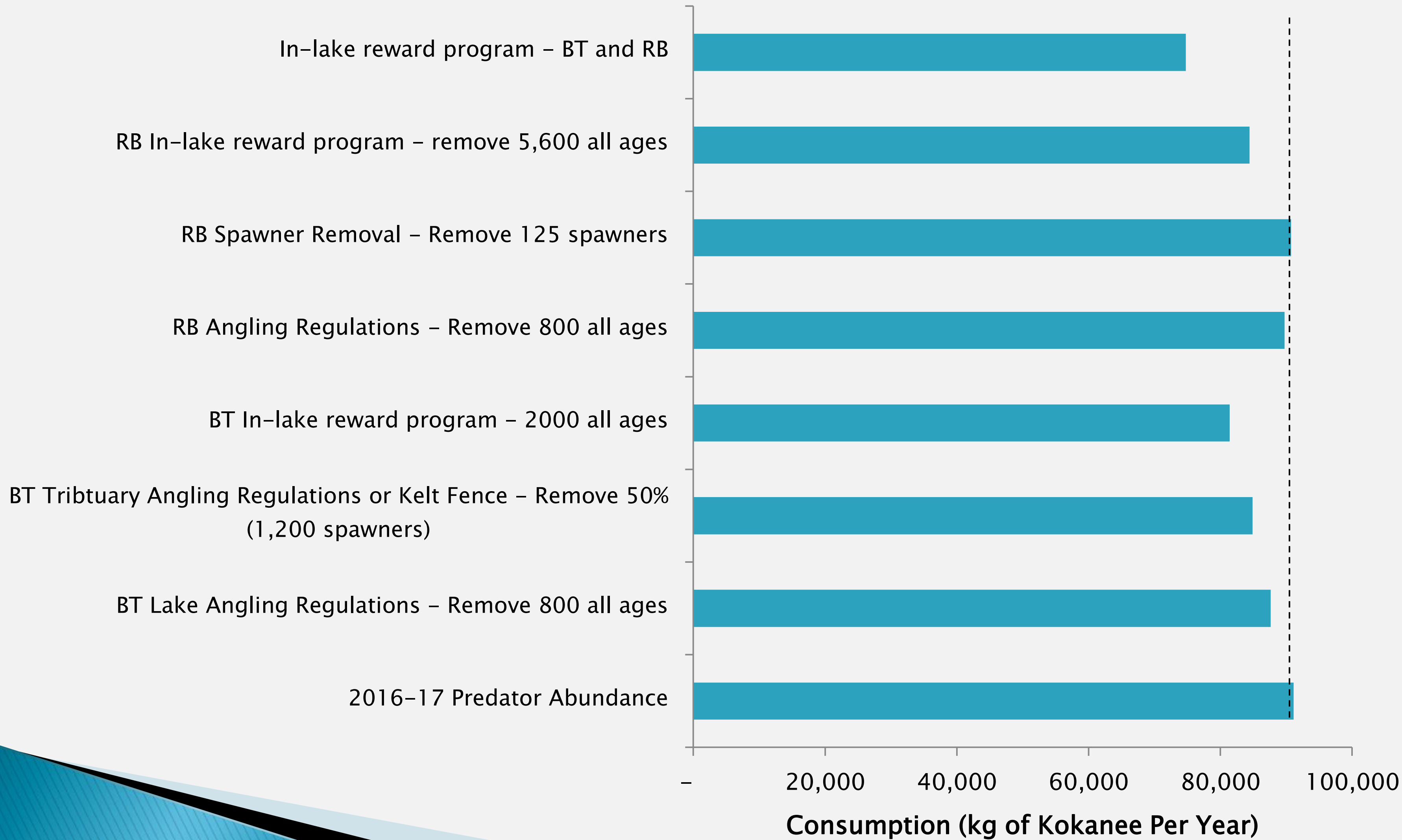


Predator Management Options– Potential Kokanee Benefit



Assumes 35% EE to Fall Fry Survival: might be an underestimate

Predator Management Options – Total KO consumption change



Comparing Kokanee Consumption to Kokanee Elimination (mortality) Estimates

Estimated Fall Biomass, Elimination (mortality) and Consumption for Kootenay Lake Kokanee

Year	Fall Biomass (tons)		Kokanee Elimination (tons)			Predator Biomass (all ages; tons)		Consumption (tons; Diana method)			Consumption (predator size method)		
	Age 0	Age 1	Age 0-1	Age 1-2	Age 0-2	Rainbow	Bull	Rainbow	Bull	Total	Rainbow	Bull	Total
2015	29.2	18.1	**122**	149	**271**	**93**	**16**	45 - 63	28 - 42	**72 - 105**	89	39	**128**
2016	19.3	14.5	**147**	182	**329**	**75**	**9**	36 - 51	15 - 22	**51 - 73**	73	23	**96**
2017	24.9	9.0	71	112	182								
			mean weight x number lost										

Results:

1. Consumption estimates can explain the age 0-1 elimination for 2015, but not 2016.
2. Consumption is half or less of elimination if you include age 1-2 in elimination.

Considerations:

1. Age 1-2 elimination is probably overestimated because it uses the mean weight between fall age 1 and fall age 2, and most are likely consumed prior to reaching the midway point.
2. Consumption estimates may be biased low due to underestimation of small prey, and no summer data (higher temperature = higher consumption?)

Reconstructed KO Population Mortality and PredationRemoval

- Full time series of consumption/biomass removed not yet completed (must scale diet to historic KO consumption/interpret KO biomass estimates). Useful?
  - Confirm collapse mechanism (i.e. consumption on a scale that matches reductions during colapse)
  - Eliminate some collapse hypotheses (i.e. pike minnow mortality, IHN, others?)

Do we require additional tools for evaluating egg supply and predator abundance levels required for recovery? There is partial 2018-19 funding for modelling support, is this required, and what direction should this take?

- Kurota Model Update and front end?
- PDA Bio Energetics?
- Others?

- Would Mysis suppression per Aran Kay 2002 thesis accelerate recovery? Should we seek to implement?

Kootenay Lake *Mysis* – Paradigm

- Main Lake
  - *Mysis* compete with kokanee
  - Most *Mysis* evade predation through diurnal vertical migration
  - A negative
- West Arm
  - Entrained *Mysis* are a key food item for many fish
  - *Mysis* may try to evade predation but lose
  - A positive
- There has been no science paradigm shift.
  - These are still relevant ecosystem interactions.
- Kootenay Lake Action Plan
  - Suppress *Mysis* if triggered
  - Develop a suppression plan

B. Briscoe, JB – photos

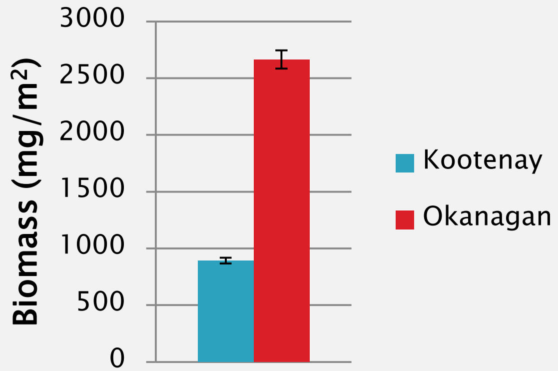
Kootenay Lake – Main Body – *Mysis* and kokanee

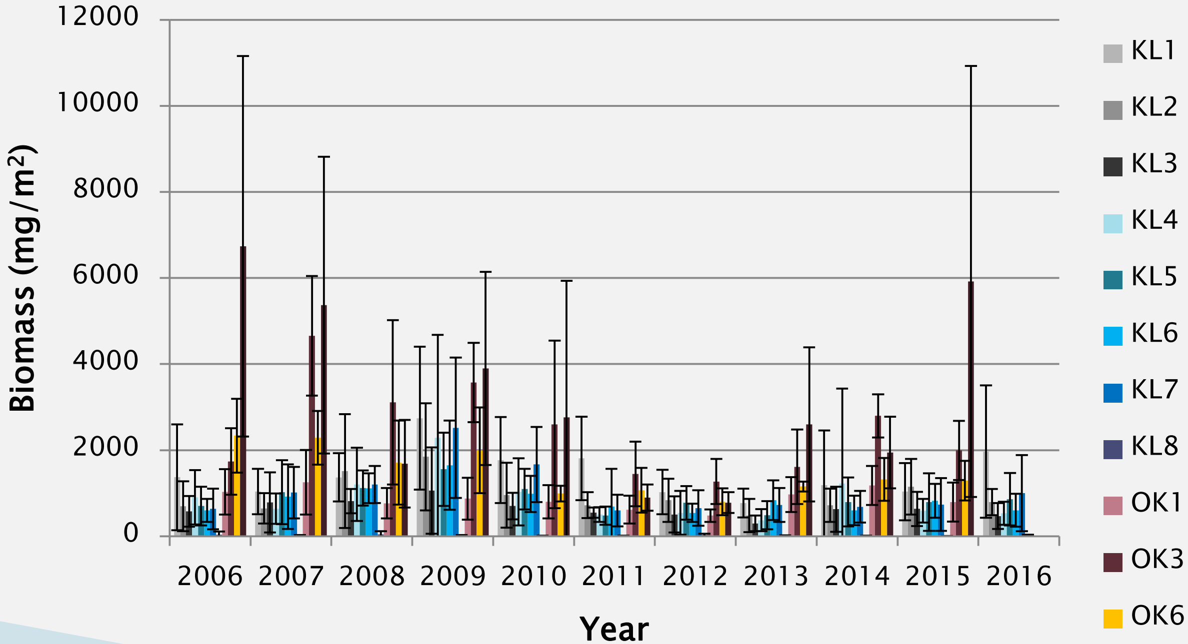
- Main Lake
  - *Mysis* compete with kokanee
  - *Mysis* 20% of both piscivore's diet ($<$ 5% prior to kokanee collapse)
  - kokanee 20% of rb, 70% of bt diet

  - Biomass kokanee at large = **42 t** (2017), **62 t** (2016)
  - Biomass kokanee eaten = 35 + 56 = **91 t** (2016)
  - Biomass pelagic *Mysis* at large = **200 – 350 t (?)** (2006 – 2016)
  - Biomass *Mysis* eaten ≥ **65 t**
    - not accounting for increased digestion/evacuation rate of *Mysis* compared to kokanee

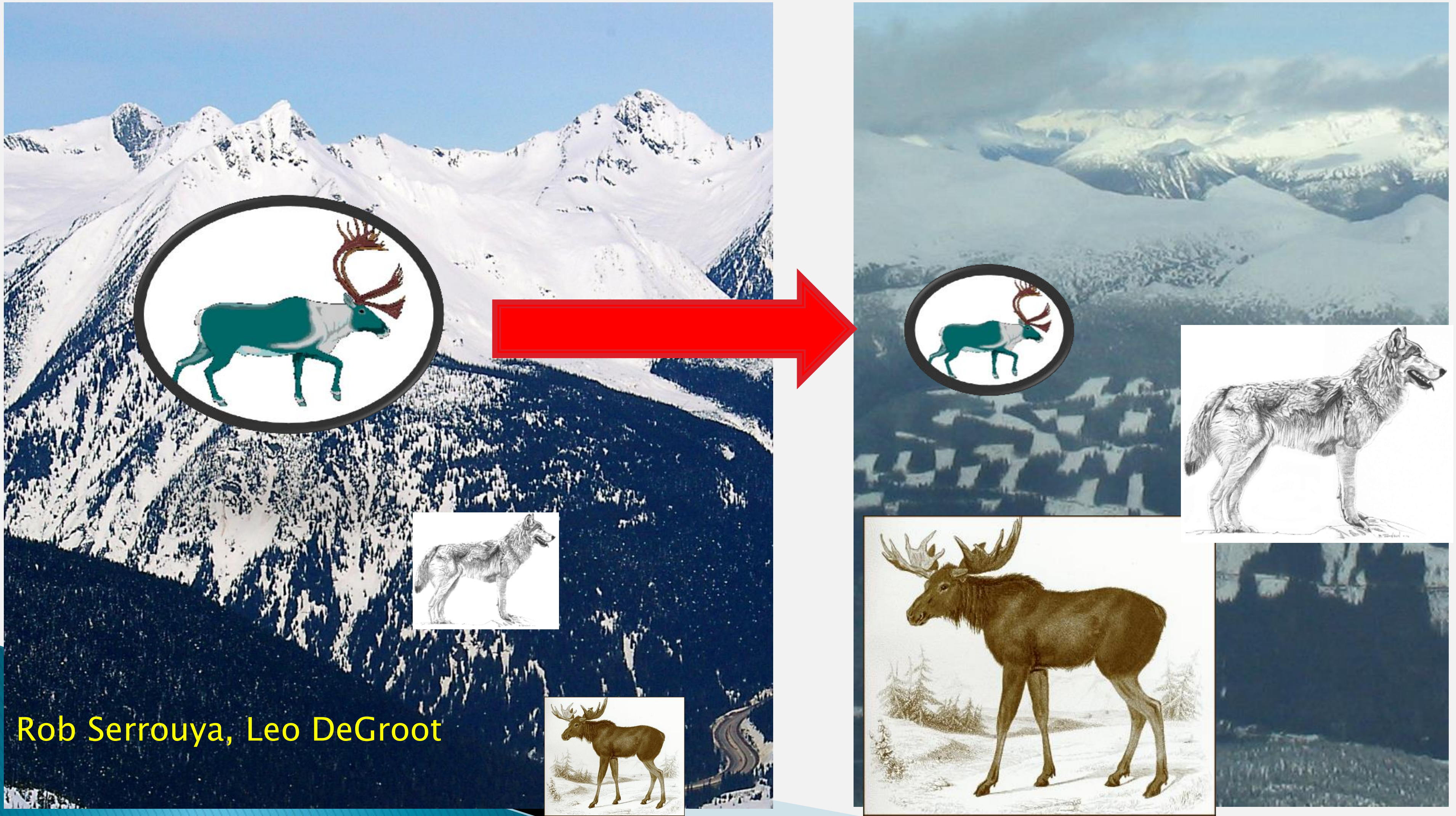
B. Briscoe

Pelagic Mysis – from suppression draft

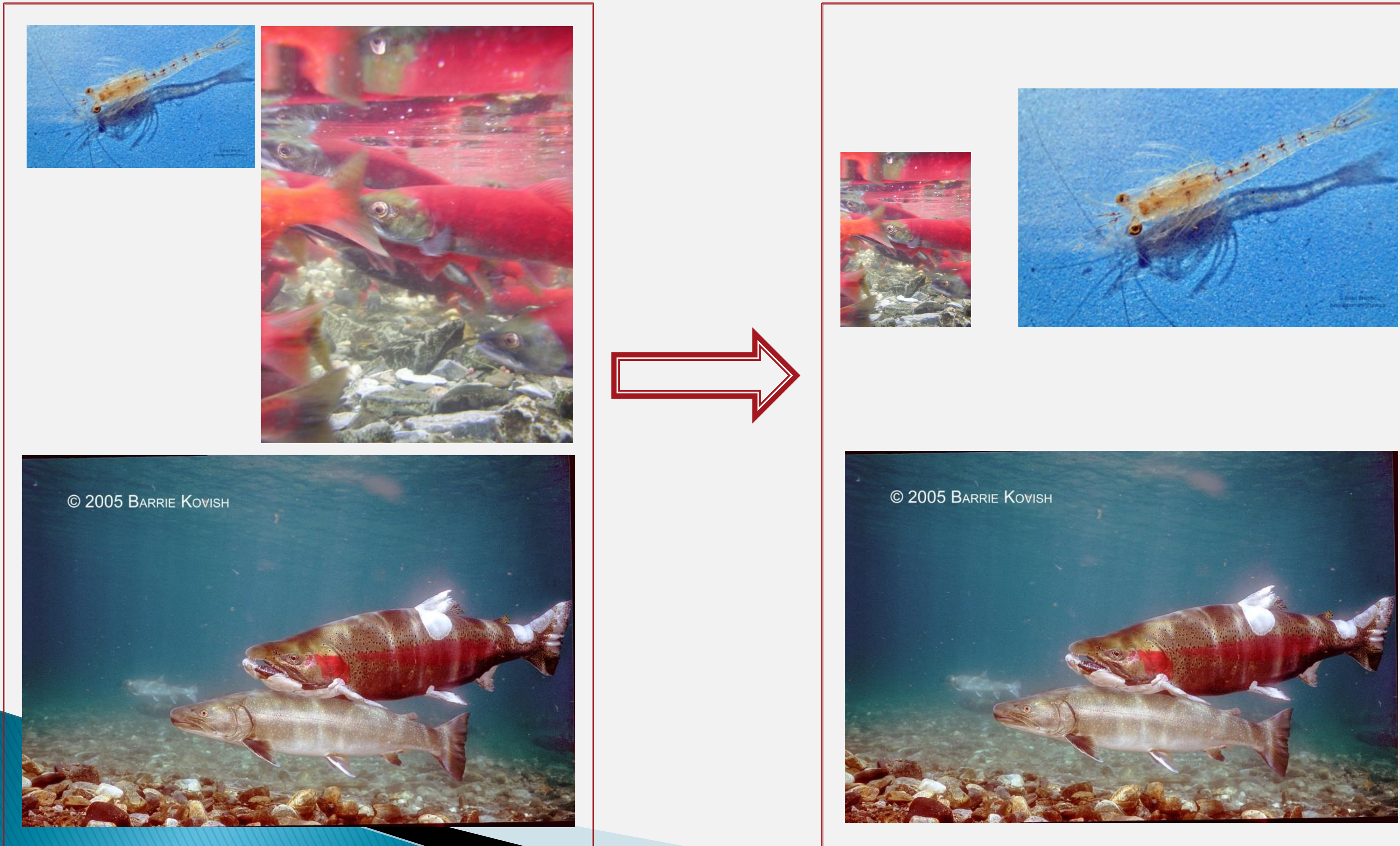




moose, wolf, and caribou – a problem



Mysis, piscivores, and main lake kokanee – a problem ?



- Do we continue the Nutrient Program? Are changes required?

  - Proven benefit to KO carrying capacity, replacing nutrients lost from upstream impoundments (used to be present in similar amount)
  - Destabilizing factor? – Kokanee/RB cycles in time series, change in age 1-3 RB survival?

  - What are the next steps if any to start working on this question?

Enhanced Monitoring – beyond 2016-17 Action Plan tables?

- Kokanee
  - Thermal Marks(spawners/in-lake)
  - Increased trawl surveys
- Gerrard
  - Juvenile RB abundance (S-R and annual production)
  - Genetic Analysis (fishery admixture)
  - Diet
- Bull Trout
  - Redd counts (full lake survey required, frequency)
  - Kaslo juvenile BT abundance (S-R and annual production)
- Mysis
  - Research on diel vertical migration – suggested for 2016-17, required?
  - More developed removal development (pilot?)
- Fishery
  - Creel census (KLRT mail-out and/or full lake)
  - Exploitation rates

New or modified Actions/Triggers

- What to add/change in Action Plan tables
- What monitoring is required? (updates to 2016-17 enhanced monitoring table)

Number of trout at large =

$$N_{\text{spawners at gerrard}} \times (N_{\text{lake sampled}} / N_{\text{lake maturing}})$$

- A rough **Petersen mark-recapture** using maturing gonads as a "mark."
- Method estimates the number of trout by expanding the number of spawners by the ratio of trout sampled the previous year to the number ripe in that sample.
- "Marking session" (spawning) occurs after "recapture session" (previous year of observations) reverse order compared to typical mark-recap estimation projects.

- Described:

Mottley, C.M. 1949. The statistical analysis of creel-census data. **Trans. Am. Fish. Soc.** 76: 290-300. (table 3 and text, for Paul Lake in 1933)

Haig-Brown, R.L. 1947. **The western angler**. William Morrow and Co., New York. 356 p. (Paul Lake chapter)

Mottley 1949 – Table 3

TABLE 3.—*Proportion of maturing male and female rainbow trout in several year classes at Paul Lake, the number estimated in the spawning component of the population in 1933, and the estimate of the uumber of legal-sized fish in the population as derived from the data*

Year classes[1]	Males				Females				Total population
	Proportion maturing	Estimated number spawning	Estimated number of immature fish	Total number of males	Proportion maturing	Estimated number spawning	Estimated number of immature fish	Total number of females	
1931	0.25	500	1,500	2,000	0.01	10	[2]1,990	2,000	4,000
1930	0.60	100	70	170	0.50	150	150	300	470
1929	0.75	30	10	40	0.80	100	20	120	160
Older	1.00	20	–	20	1.00	90	–	90	110
Totals	...	650	1,580	2,230	...	350	2,160	2,510	4,740

[1] Members of year-class 1932 below legal size and not available to the fishery
[2] This estimate is based on a 50-50 sex ratio in the year-class

Piscivore sampling 2015 and 2016

1. Trout at large estimates

Spawner year	Spawners (AUC)	Gerrards sampled (SY-1)	Gerrards maturing (SY-1)	Peterson estimate
2016	162	123	15	**1328**
2017	256	64	3	**5461**
SY combined	418	187	18	4343

2. Probability of spawning estimates

age (SY-1)	spawner age	n	maturing	p(spawning)
2	3	18	1	6%
3	4	56	3	5%
4	5	52	8	15%
5	6	35	2	6%
6	7	15	2	13%
7	8	10	2	20%

Exploitation study
For rb > 50 mm =
22%

Table 2 p. 12
Andrusak and Thorley. **2014.** [tag-telemetry to estimate fishing and natural mortality of large Bull Trout and Rainbow Trout on Kootenay Lake. Poisson Consulting Ltd. Redfish Consulting Ltd.]