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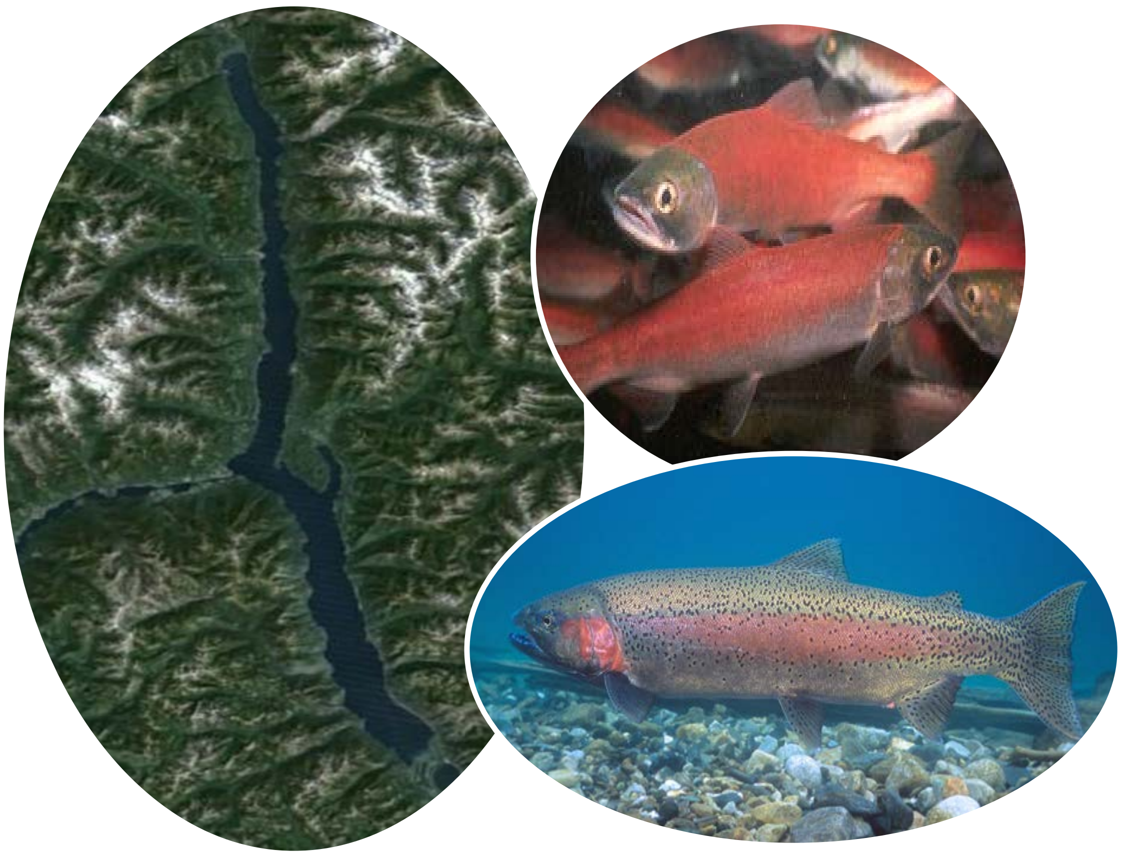
Kootenay Lake Fisheries Meeting Summary, March 12/13, 2015



Final Report

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Acknowledgements

I wish to thank all of the scientists and managers who comprised the Kootenay Lake Fisheries Advisory Team for their valued input. Their general fisheries knowledge and expertise specific to Kootenay Lake were used directly to prepare the issue analysis and recommendations in this report. I would also like to express my appreciation to Matt Neufeld and Jeff Burrows for their initiative in pulling together the Fisheries Advisory Team, providing background documentation, and for their review and technical contributions to this summary.

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 sport fisheries. The trophy sized Gerrard stock rainbow trout (Gerrard trout) are prized by anglers, and are important economically and recreationally. Bull trout, which also grow to a large size are also highly valued. Recently, the Gerrard trout fishery has been evidenced to be in decline, with poor fish condition (skinny), and many smaller sized fish present. Current data indicates that one of the likely leading causes for this is an imbalance between predator (Gerrard trout) and prey (kokanee) abundance. Notably, there are fewer older kokanee (2+ and 3+), and kokanee spawner numbers in 2014 were lowest on record, down from a recent maximum (similar to previous highs) in 2011. Gerrard trout spawner abundance declined from a record high in 2012, with recent high catch rates for smaller fish, and declining catch for fish over 2 kg. These issues are concerning to fisheries scientists and management, the local community, and other stakeholders.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) responded to these concerns by presenting scientific information at a public meeting in Balfour on February 23, 2015. FLNRO also recommended changes to the fishing regulations, allowing four Gerrard trout instead of two (no change to only one daily, five per year, over 50 cm) as a daily quota, and by decreasing the kokanee daily quota from fifteen to zero. FLNRO also committed to having a team of scientists prepare a fishery recovery plan; the results of which would be presented to the public.

On March 12 and 13, 2015 the Kootenay Lake Fisheries Advisory Team (the Team) met in Nelson to develop a Kootenay Lake fisheries recovery plan. Lotic Environmental Ltd (Lotic Environmental) was commissioned by FLNRO to assist with meeting preparations, facilitate the meeting, and document the proceedings. This report summarizes the meeting, which focussed on identifying the issues, reviewing options and identifying viable recommendations that could be implemented in the short-term, towards recovery of the fishery. Next steps towards long-term planning were also identified.

2 Objective

The objective is to restore a productive and sustainable Gerrard trout fishery. This is to be achieved through the development and implementation of a Kootenay Lake fishery recovery plan (the Plan). The Plan is to identify conditions required for a healthy Gerrard trout fishery, the current factors driving the poor quality fishery, and recommendations to attain a productive and sustainable sport fishery. This is to be achieved through both short-term and long-term management recommendations:

The short term recommendations will:

1. Identify how to, as quickly as possible, restore the main lake kokanee population required to support a sustainable trophy Gerrard trout fishery, while also providing ecosystem benefits to the lake; and,
2. Reduce, on a temporary basis, the predator population, to ensure kokanee recovery.

The long-term recommendations will identify how to reduce the likelihood of a kokanee collapse occurring again in the future. This will involve:

1. Analysing historic data to quantitatively identify the array of conditions required for a healthy population (e.g., numbers to achieve a predator/prey balance); and
2. Identifying reference points when the various conditions become limiting or reach levels of management concern; and
3. Identifying specific management actions that would be triggered if/when these reference points were to occur.

3 Kootenay Lake fisheries advisory team

Team members were invited/approved based on their fisheries science and management expertise/responsibility pertinent to benefitting Kootenay Lake fisheries. The March 12/13 participants were comprised of representatives from (Appendix A):

- Province of BC - FLNR stock assessment biologists, and regional fisheries staff;
- Freshwater Fisheries Society of BC (FFSBC) – managers and biologists;
- Ktunaxa Nation government - Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC) biologist; and,
- BC Wildlife Federation – fisheries expert.

4 Timeline

The Plan will be developed following the timeline presented in **Table 1**. Included are tasks associated with preparing short-term recommendations, as well as long-term recommendations (as outlined by the Team at the conclusion of the March 13 meeting). The long-term schedule is considered preliminary, as it is dependent on funding being assured for Team activities after March 31, 2015.

The outcome from the Team meetings will be communicated to other stakeholders by FLNRO. This will include direct communications with and input from the Kootenay Fisheries Regulation Advisory Team (KFRAT) on the Plan's objectives and outcome. The public will be provided information through public meetings, and the Ministry website. Stakeholder input will be considered in finalization of the Plan.

Table 1. Kootenay Lake fishery recovery plan, timeline.

Respons-ibility	Task	Milestone
Regional Fisheries	Gather stakeholder input through public meeting	February, 2015
Short-term recommendations		
Team	Meeting 1 - Evaluate options and provide recommendations to: • Restore the kokanee population to support a sustainable trophy Gerrard trout fishery, while also providing ecosystem benefits. • Reduce, on a temporary basis, the predator population to ensure kokanee recovery. ID the action plan for the team's activities moving forward into 2015/16.	March 12/13, 2015
Facilitator	Summarize meeting discussions, recommendations, and future actions.	March-April, 2015
Regional Fisheries	Stakeholder engagement – public meeting, regional website, Balfour Business Association etc.	Ongoing
FLNRO & FFSBC Management	Decide on kokanee supplementation in time to implement in 2015.	April-May 2015
FLNRO Management	Evaluate and decide on all other short term measures	June 2015
Regional Fisheries	Implement the additional elements of the Plan	June-Ongoing
Regional Fisheries	Gather data on information signals to inform management actions and fill key data gaps	Ongoing
Long-term recommendations		
Team	Conference call: 1. Review status of short-term measure planning and implementation. 2. Prepare to analyse and/or model historic data, identify limiting factors, data gaps and reference points	July 2015-March 2016
Team	Meeting 2 – present analysis results, limiting factors, and develop recommendations for subsequent management actions that would be triggered.	Fall 2015

5 The current situation

At the outset of the meeting, Jeff Burrows, Matt Neufeld, and David Johner provided background information on what is evident through the long-term data set available for Kootenay Lake fish stocks (Appendix B). Additionally nutrient restoration and mysids were discussed. A roundtable discussion followed, allowing team members to contribute other information, summarize their understanding of the driving factors and key concerns, and identify data gaps that required further consideration. Highlights from the presentations and subsequent discussions have been provided.

5.1 *Kokanee*

- Kokanee spawner numbers have fluctuated over the years and have generally seen improvements since nutrient restoration in 1992. Lardeau River and Meadow Creek maintain the vast majority of all main lake kokanee spawners and their combined counts are considered as the total lake escapement (south arm tributaries are excluded given small numbers). Lardeau River spawners have been estimated annually back to 1979 (except 1985) and then intermittently back to 1964, although earlier estimates may be less reliable due to variable methodology. Meadow Creek has been counted annually since 1967. Total lake escapement in 2011 was the second highest since fertilization began, second only to 1998, although 1999 was similarly high. Meadow Creek escapement has been high many times, including several years in the late 1970's, 1999, 2004 and 2011.
- Fry estimates more than doubled with nutrient restoration and have remained high. Fall 2014 fry estimates were equivalent to the long term post nutrient addition average.
- Spawner numbers have been steadily declining from a near record high in 2011. In 2014, full lake spawner numbers were the lowest recorded (approx. 150,000 spawners and 33 million eggs). In 1991, before nutrient restoration, the low for years with data was 277,000 spawners and 41 million eggs. Acoustic surveys and recent fry-to-adult survival predict a lower escapement for 2015.
- Hydroacoustic and trawl data indicate a change in the population structure starting in 2011. Late season fry to 1+ (0-1 age class) survival rate dropped from an all-time high of ~63% in 2008/09, to an above average value in 09/10 (36%), and down to 6% where it has been since 2011/12. It is important to note that survival was 6% or lower in 1992 and 2000, so even the most recent survival rate is not unprecedented. The survival rate drop from an average of ~25% to 6% was not fully explained, as it did not correspond with Gerrard spawner abundance measures (see below); however it appeared to line up with a pulse of smaller rainbow trout starting to enter the fishery. More rigorous analysis was identified as required in the future, to better inform what best correlated with survival changes. Fall 2014 data finalized in January 2015 was most concerning, indicating low numbers of 1+ aged fish, and very few 2+ fish or older fish. This will result in lower kokanee escapement (fish returning to spawn) in the next few years.
- Kokanee biomass, calculated from acoustic and trawl data, indicated that 2014 was the lowest on record. Most years, the majority of biomass is in older fish, but this changed in 2014, where the vast majority of biomass was fry and age 1+.
- Adult spawner length increased in 2013/14. Average annual length prior to 2014 was 224 mm and in 2014 was 323 mm. Fecundity in 2014 was the highest on record at 517 eggs per female.

- Depensation occurs when mortality rates increase at lower densities (instead of compensating by decreasing). As a result, population declines are caused by low densities of fish (e.g. smaller school sizes or impaired school formation leading to higher predation). The mechanism of any depensation in Kootenay Lake kokanee is unknown, but very likely includes predation.
- The goal of the nutrient restoration program is to achieve a pre-dam level of productivity for kokanee. Kokanee exceeded the biomass carrying capacity, which started with declines in fish size as the adult population abundance increased, and then a subsequent shift in age at maturity from 3+ to primarily age 4+ spawners in 2013. Also, in 2012 there was significant overlap in size amongst age classes and fish size failed to respond to substantially lower densities. Overlap occurred for a number of reasons. The 3+ cohort split into two groups with different ages of maturity, so there were 3+ spawners and similar size in-lake 3+ fish. Also, 2+ fish slightly increased in size compared to 2011, while 3+ fish did not. A shift in age at maturity is a good indication of surpassing carrying capacity. Overall, size of kokanee, though a factor, may not be as significant as numbers and density available as forage for predators.
- A strikingly similar scenario occurred in Arrow Reservoir in 2011-12, where survival rapidly decreased and size did not respond until 2013. Regional climatic drivers (cold temperatures and high precipitation) likely contributed to lower kokanee productivity in southern BC large lakes in 2011-12.
- Kokanee are compensating for the recent decline in 0-1 survival and resulting lower densities, through increased growth (especially spawner size) and by increasing fecundity and subsequent fry per spawner. However, the compensation may not be sufficient to recover in a single generation if spawner numbers continue to decline.
- High Gerrard trout counts and record high kokanee 0-1 survival rates were observed in 2009, but age 0-1 kokanee survival declined each year following, until hitting an extreme low in 2012 and remaining there until present (Figure 1), while age 1-2 survival did not drop to an extreme low until 2013. It is important to note that although very low, survival rates this low have been recorded several times in the last 15 years, but did not result in overall escapement declines on the scale observed in 2014. Predator impacts may have been delayed if they consumed older age classes first and then moved down to fall fry/yearlings, but there is not clear data on this because of trawl limitations. This indicates that either: (a) Gerrard escapement is not a good indicator of predation (other ages or other species like bull trout are important), or (b) 0-1 survival is being driven by a factor other than predation (or some combination of factors). Figure 1 also suggests that we may drop into the normal predator density region by next year, if Gerrard trout spawner numbers continue to decline as expected. At that point we will see if Gerrard trout escapement is indicative of predation pressure, and if Gerrard trout predation is driving 0-1 survival rates in kokanee (if this is the case, kokanee survival will go back to average).
    - If the drop in 0-1 kokanee survival is predator driven, stocking kokanee will not lead to a notable increase in kokanee spawner numbers, and almost all remaining kokanee biomass will be transferred directly into predators and thereby likely prolong the problem (if Gerrard trout numbers have not dropped sufficiently already in the last year).
    - If the problem is not driven by predators, and kokanee spawner numbers drop below single generation recovery levels, but 0-1 survival recovers on its own, then stocking could speed up recovery.

- Alternately, predators may be more efficient at low abundance and less efficient at higher abundance of prey (based on the findings of Walters *et al*. 1991[1] and Parkinson and Korman 1994[2], who developed the Kootenay Lake model prior to fertilization). This was termed 'depensatory mortality'. Therefore increases in prey numbers should allow kokanee stock to rebuild. With no stocking, the predators will continue to deplete the remaining numbers of kokanee. With stocking, predators have more prey and a percent of the stocked fish will contribute to spawner numbers.
- Given that the latest acoustic trawl kokanee escapement estimate was below detection levels, collecting eggs to plant in Meadow Creek or elsewhere, may have larger benefits than identified above, as they would form the next generation for recovery.

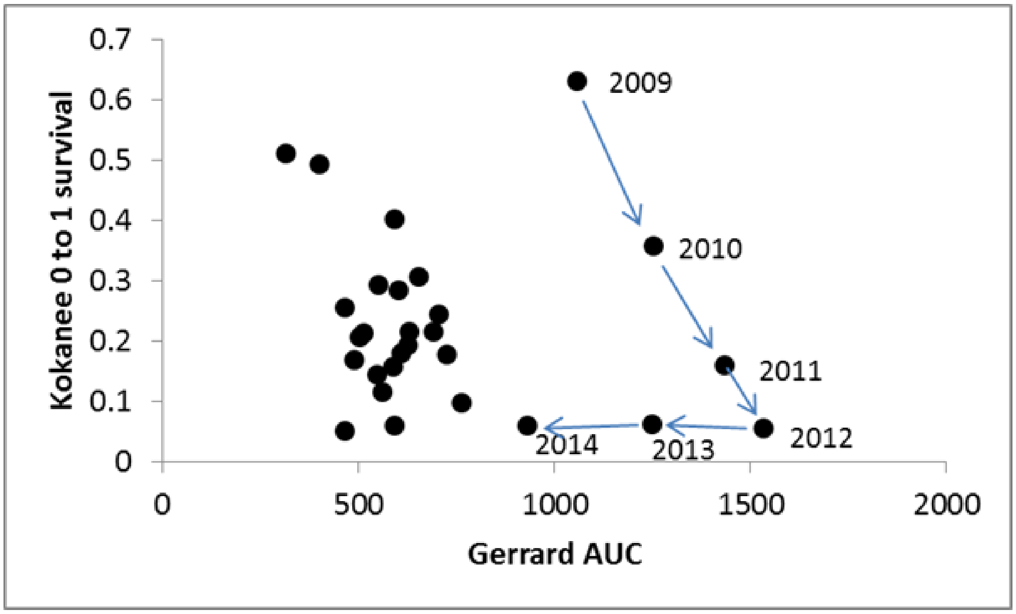

Figure 1. Kokanee age 0 to 1 survival versus Gerrard spawners (P. Askey).

- The potential predation issue could also be viewed as a predator:prey mismatch that is better depicted by the ratio of predators to prey (Figure 2). Summarizing the data in this format leads to a more intuitive pattern where kokanee survival decreases with increasing predator:prey ratio. In this context it appears that the predator:prey ratio is out of balance and kokanee survival is pinned down to a minimal level. This relationship only makes sense if predators somehow become more efficient consumers as the number of prey per predator decreases (in accordance with depensatory mortality described above) and thus would favour stocking. The sequential time series of decreasing survival is somewhat curious, and may hint at other mechanisms, since the ratio of predators to prey has always been very low, and the decline in survival began when the ratio was

[1] Walters, C., J. DiGisi, J Post, and J. Sawada. 1991. Kootenay Lake fertilization response model. Fisheries Centre, University of British Columbia, Fisheries Management Report No. 98. Province of BC.

[2] Parkinson E., and J. Korman. 1994. Application of the large lakes kokanee model to five management problems in British Columbia. University of British Columbia Fisheries Branch, Fisheries Management Report No. 103. Province of BC.

more favourable than now. Taken together, the data indicates that there was a factor other than predators that contributed to decreased kokanee survival, but it could be that predation is preventing recovery now.

- There is no risk seen to stocking other than feeding the predators. However the risk of not stocking is that the predators will further diminish the remaining kokanee.

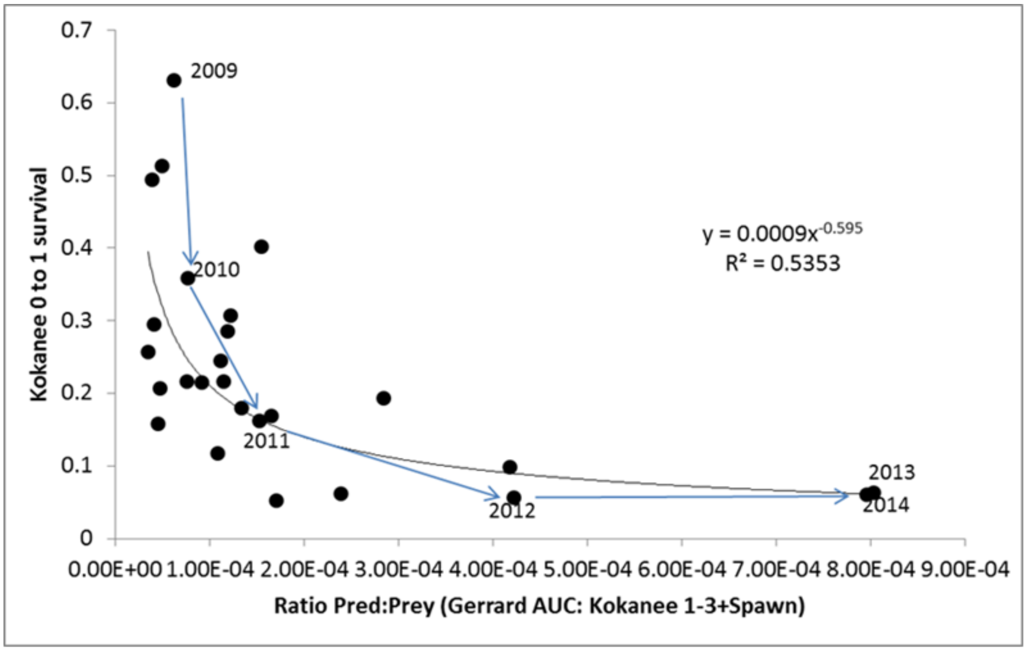

Figure 2. Kokanee 0-1 survival relative to Predator:Prey ratio (provided by P. Askey).

5.2 *Gerrard trout*

- 2009 to 2014 had record high Gerrard trout spawner abundance.
- Kootenay Lake Rainbow Trout Tag (KLRT) mail out creel surveys indicate that catch rates since 2009/10, for almost all size classes were the highest ever observed (peak in 2011/12). However, catch rates have been decreasing over the past two years for all size classes greater than 2 kg, while catch rates for the smallest fish have been increasing (highest observed for the period of record). Catch data from the 2014/15 fishing season is just now being collected, but angler reports suggest a steep decline in all size classes other than the smallest fish (<2kg).
- Degraded individual fish condition has been reported by anglers starting in 2012/13, and recent analysis shows growth in 2014 was very low. However, systematic length and weight data is not available (i.e. through the recent rise and fall in kokanee abundance).
- In the past, the very largest fish (>25 lbs) corresponded with peaks in Gerrard trout abundance. However, the latest peak (2011/12) was 2x higher than the past peaks with no fish recorded over 25 lbs, so competition for food may have been strong enough to limit size. Several other credible hypotheses for the lack of very large rainbow in addition to the competition hypothesis are: annual spawning (foregoing somatic growth in favour of gonad growth), multi-year accumulated harvest rate leaving none or at least very few larger trout, recently increased kelt mortality, inadequate numbers of larger kokanee for maximal trout growth, and genetic selection in the fishery favouring survival of small trout.

- The population of Gerrard trout >50 cm is estimated to be 8,000 to 45,000 fish based on expanding spawner estimates and 2012 creel surveyed harvest, by independently measured probability of spawning and harvest rate, respectively. One Gerrard is estimated to consume ~130 kokanee (50g)/year, resulting in a predation rate of 1 to 5.9 million kokanee/year. There is a caution that bioenergetic estimates of Gerrard consumption rates vary and are uncertain.
- Gerrard trout are believed to be limited by their food source, kokanee. Regulation changes implemented in 2005 favored decreased fishing mortality, and annual angler caused mortality has been low (approx. 13%). Attracting more fishing harvest could benefit the kokanee population, especially in the short term.

Figure 3. Estimate of kokanee (KO) consumption by rainbow trout (RB; as provided by Regional FLNRO staff following the meeting).*

Age	RB length[a]	RB weight[b]	RB annual weight gain [c]	KO consumed (total kg) [d]	# KO consumed per year (if avg. 50g/18cm)	# KO consumed per year (if avg. 100 g/22cm)
1	22.6	0.102	-	0.0	-	-
2	31.5	0.302	-	0.0	-	-
3	45.6	1.005	0.70	3.3	**66**	**33**
4	59.8	2.430	1.42	6.7	**133**	**67**
5	70.1	4.430	2.00	9.3	**187**	**93**
6	74.3	5.040	1.14	5.3	**107**	**53**
7	*78*	*6.160*	1.72	8.1	**161**	**81**
8	*81*	*6.820*	1.40	6.5	**131**	**65**
Lifetime total				39.2	**784**	**392**

Notes:
***This draft table broadly evaluates the potential benefit of actions towards recovery. It was prepared using the best information available at the time. However, there were many assumptions made, and future improvement is likely.

[a] Age and Length from Andrusak and Parkinson 1984[3], except data after age 6 from Andrusak and Andrusak 2014[4] growth and condition report.

[b] Weight estimated from 2011 Kootenay creel data (Fulton's condition factor 1.1 - 1.2 medium) and Andrusak and Andrusak 2014.

[c] For rainbow trout, 12% weight gained lost to gonad weight (Negus et al. 2005[5]).

[d] Assumes conversion efficiency of 21.4% (chinook value from Negus et al. 2005).

[3] Andrusak H., and E. Parkinson. 1984. Food habits of Gerrard stock rainbow trout in Kootenay Lake, British Columbia. Fisheries Technical Circular No. 60. Ministry of Environment, Province of BC.

[4] Andrusak G., and H. Andrusak. 2014. Gerrard rainbow trout growth and condition with kokanee prey at low densities. Prepared by Redfish Consulting Ltd. For the Fish and Wildlife Compensation Program.

[5] Negus, M.T., D.R. Schreiner, T.N. Halpern, S.T. Schram, M.J. Seider and D.M. Pratt. 2005. Bioenergetics Evaluation of the Fish Community in the Western Arm of Lake Superior in 2000 and 2004. Minnesota Department of Natural Resources - Fisheries Investigational Report 542.

5.3 *Bull trout*

- Important to consider bull trout, as they are also a predator species.
- There is no current comprehensive population information for this species in the lake. Bull trout population has been estimated from 2012 creel surveys, exploitation rate estimates, and from 2011 and 2013 spawner counts on index streams. Based on these indicators, 5,000 to 40,000 adults are estimated to be present in the lake. One bull trout may eat 50 kokanee/year, and based on an estimate of 70% diet as kokanee, this equates to a predation rate of 175,000 to 1.4 million kokanee/year. Note, bioenergetic estimates of bull trout consumption vary and are uncertain, (e.g. an initial regional review had suggested bull trout consume 160 kokanee/year).
- Bull trout spawning surveys over the last 2 to 3 years indicate an approximately 50% decline. However, this species was described as being more adaptable than Gerrard trout (e.g., can survive with low food available and switch to other fish species). It is possible that with low food supplies, bull trout may be skipping annual spawning, thus recent spawning counts may be a poor index of population size.
- If bull trout populations are deliberately reduced through temporary actions, the desired level to maintain a sustainable population needs to be identified and other reference points determined in advance, to trigger suspension of such actions.

Figure 4. Estimate of kokanee (KO) consumption by bull trout (BT; as provided by Regional FLNRO staff following the meeting)*.

Age	BT Length[a]	BT Weight[b]	BT Annual weight gain [c]	KO consumed (total kg) [d]	# KO consumed per year (if average 50 g/18cm)	# KO consumed per year (if average 100 g/22cm)
1	22.6	0.087		0		
2	31.5	0.259	0.173	0		
3	45.6	0.877	0.618	1.73	35	17
4	54.6	1.589	0.711	1.99	40	20
5	61.6	2.364	0.966	2.70	54	27
6	66.6	3.057	0.977	2.74	55	27
7	70.6	3.705	1.015	2.84	57	28
8	73.6	4.249	0.989	2.77	55	28
9	75.6	4.642	0.902	2.53	51	25
10	77.6	5.059	0.974	2.73	55	27
Lifetime total				20.0	**400**	**200**

Notes:

*This draft table broadly evaluates the potential benefit of actions towards recovery. It was prepared using the best information available at the time. However, there were many assumptions made, and future improvement is likely.

[a] Based on Arrow 2003 creel sample roughly adjusted to Kootenay length frequency data (no length at age for Kootenay found).

[b] Based on Kootenay Lake creel data 2011-12 (FLNRO data on file).

[c] For rainbow trout, 12% weight gained lost to gonad weight (Negus et. al. 2005).

[d] Based on food conversion rate of 25% (calculation from raw data provided in Mesa et al. 2013[6]) and KO representing 70% of diet.

5.4 *Nutrient Restoration Program*

- The Nutrient Restoration Program replaces nutrients lost behind upstream reservoirs, bringing the lake to its natural productivity. Nutrient additions commenced in the North Arm in 1992, and in the South Arm in 2004.
- The additions are intended to mimic the pre-dam productivity (nutrient levels) and are adjusted to ensure there is a ratio of nitrogen and phosphorus suitable for phytoplankton growth while maintaining water quality guidelines.
- The objective of the program is to add nutrients (phosphorus and nitrogen in the form of liquid agricultural grade fertilizer) to grow phytoplankton which provide a food base for zooplankton.
- The nutrient restoration program continues to produce zooplankton. Zooplankton are tiny aquatic animals, and are the main diet of kokanee. Following fertilization, zooplankton has increased, particularly in the South Arm, where *Daphnia* biomass has become three times higher recently, and average kokanee biomass increased 2.5 times since 1992. Gerrard trout abundance has increased since 2006 (although there are several other confounding influences).
- Kokanee 0-1+ and mysids are at the same trophic level and both eat zooplankton. In the absence of high kokanee biomass, there is a risk that the mysid population will increase; however, there has been no increase evident to date outside past observed ranges. Larger bull trout consume mysids. In Arrow Lakes, mysids have been seen in the stomachs of bull trout up to 60 cm, even during a period of relatively high kokanee abundance. It is not likely that bull trout predation has a measurable impact on mysid abundance.
- What is affecting kokanee survival appears to also be affecting mysid survival in some years. Studies on Lake Pend Oreille, Idaho showed similar survival over time. On Kootenay Lake, high kokanee spawner numbers and high mysid biomass both occurred in 2001 and 2009 (similar factors likely affected both populations). However, there were high kokanee spawner numbers that occurred with lower mysid populations in 2003, 2004 and 2005.
- The goal is to feed *Daphnia* for kokanee grazing. With zooplankton biomass, especially *Daphnia*, increasing the past couple of years, the plan is to continue adding nutrients. The strategy is to keep nitrogen and phosphorus balanced to minimize fluctuation of algae over time and provide a food base for zooplankton (larger celled algae in the microplankton size are not suitable as food for zooplankton).
- How do we define stabilization of nutrients – does it mean adding the same amount of phosphorus every year, or is it based on N:P ratios, etc? Note, all components of the food web that the program monitors are standing crop except for primary production. The program measured primary production in 2000, 2001, and 2004 to present. Continued review of primary productivity data may be useful, to ensure we are not missing productivity measures.

[6] Mesa M.G., L.K. Weiland, H.E. Christiansen, S.T. Sauter, and D.A. Beauchamp. 2013. Development and Evaluation of a Bioenergetics Model for Bull Trout. Transactions of the American Fisheries Society, 142:1, 41-49.

- Some fine tuning was suggested, where there are potential benefits for kokanee. This includes adding nutrients later in the fall, to increase food availability through the winter into the spring. Fall water temperatures would need to be high to support good growing conditions. During the fall, the *Daphnia* population are important (in the spring copepods are important, and *Daphnia* appear late spring to early summer depending on temperature and phytoplankton). Fall temperatures and zooplankton from the long-term data set are currently being reviewed to determine if adjustments would be beneficial.

5.5 *IHN virus*

- IHN (infectious hematopoietic necrosis) virus was found for the first time in adult kokanee spawners at Meadow Creek in 2013 and again in 2014.
- 2014 kokanee fry samples and Gerrard trout spawner testing indicated no viral infection.
- Disease (e.g. IHN virus) and parasites are rarely a major factor that affect wild population status, and this is likely the case for Kootenay Lake:
  - No significant fish kills identified. 2013 had an event, but this likely had a small impact, as large numbers of dead or dying fish were not observed; however, it remains unknown and a potential factor.
  - Adults have spawned successfully despite infection.
  - Egg to fry survival has remained high (IHN typically kills fry).
  - Fry leaving Meadow Creek tested negative for IHN in 2014.
  - Levels of infected kokanee are declining at Meadow Creek.
  - Rainbow trout are not currently infected.

5.6 *Data gaps*

There are complex mechanisms at play, but currently there is not an accurate understanding of many mechanisms and influences of their interactions. Some data gaps identified were:

- How is climate or other factors outside predation influencing kokanee survival?
- Is there a relationship with mysids and kokanee survival? Mysids, which are essentially the same trophic level as fall fry show a similar concurrent rise and fall in recent abundance over time. Is this a false correlation or is there an opportunity to benefit kokanee survival and growth through Mysis removal? Results from the Okanagan Lake mysid fishery may inform how and whether to proceed.
- What is the population structure and abundance of kokanee required to bioenergetically generate the desired body size in Gerrard trout?
- With an increased harvest, what is the target number of Gerrard trout spawners to ensure a sustainable population and catch rates in the fishery that attract anglers? The Lardeau River capacity appears to be about 500 spawners based on Figure 1.
- What is the current bull trout population in the lake, and what is the desired level to maintain a sustainable population?
- What is the causal mechanism that drove Gerrard trout abundance to 2x historic highs in 2012?

- What is the size preference (or preferences as a function of predator size) of Gerrard and bull trout for kokanee, and is this information a relevant or feasible lever to manage for?
- What is the current size structure of Gerrard trout and bull trout caught in the fishery? Has the average size of fish increased since the 2011/12 peak? What is the Gerrard biomass? Data for this is available through catch reports and requires synthesis.
- The extent to which trawl size bias affects kokanee age structure and survival rate estimates is not well understood.
- Is disease influencing kokanee survival?

5.7 *Information signals*

Additional data collection is planned to expand our understanding of the current Kootenay Lake fishery, address some of these data gaps and provide information in the short term to base decisions on short term actions (Table 2). This data will help inform, trigger, and/or suspend actions and was thus called 'Information Signals'. This information will feed into data analysis/modelling components, aimed at identifying reference points and provide long-term recommendations to reduce the likelihood of a collapse in the future.

Table 2. Information signals to inform future actions.

No.	Date	Data
1	May	Gerrard trout spawning numbers.
2	June	Kokanee fry output from Meadow Creek.
3	June	Acoustic data collection for populations of fry and age 1-3 kokanee. Trawling will probably not occur with such low densities, therefore 1-3+ survival will not be available.
4	September/ October	Adult kokanee return in Meadow Creek and the Lardeau River.
5	October	In lake kokanee population, from acoustic trawl, to obtain fry and 1-3 age class survival.
6	April-August	2014-15 rainbow trout and bull trout information on catch (fish kept, fish released, catch per hour etc.) from the Kootenay Lake Rainbow Trout Tag survey.
7	October	Bull trout redd counts (index streams).
8	June-March	Kootenay Lake Rainbow Trout Tag (KLRT) Licence sales for 2015-16 (by June, 50-60% of the year's licences already sold) to gauge potential effort.
9	May – October	Monthly Mysis and *Daphnia* densities from North and South Arm.
10	December	Gerrard trout in lake population estimate report (Fish and Wildlife Compensation Program project).

A creel survey is an additional valuable mechanism to gather data and inform future decisions. This is not currently planned, but was suggested be completed given the circumstances and suggested efforts to increase predator harvest with a variety of unknowns.

5.8 *Consensus moving forward*

Cyclical predator prey dynamics are normal, and in the long-term kokanee stocks would recover on their own and would not go extinct. However, there are opportunities to intervene through short term actions that could be implemented as soon as possible to rebuild the prey population. These actions might **hasten the timescale of recovery**. To improve the condition of Gerrard trout and abundance of trophy Gerrard trout and bull trout, the actions should focus on both increasing the numbers of kokanee prey and temporarily decreasing the number of predators. Planning is to consider cost and benefit of various options, and performance signals.

Long-term fisheries recovery planning will commence following implementation of these short-term interventions. Experimental design should take a precautionary approach and ensure actions do not create other future problems, and consider lag time responses of actions on the target population(s). Recovery planning should also further develop scientifically based performance measures and reference points initiated here, to identify when the various management options incorporate mechanisms to detect which option(s) was effective in driving change. It is uncertain if the scale of intervention will make a difference, as there are many contributing factors, some not under our control.

6 Performance measures and targets

Subsequent to the meeting, Robert Bison analysed the historic dataset to determine preliminary **performance measures and target reference points** (Appendix C). These are intended to identify where the management options have successfully met their objective and should no longer be employed. In order to propose targets, an analysis of kokanee abundance data with stock recruitment models was completed.

Analysis suggests that the fertilization program(s) may be causing rainbow and kokanee populations to couple together and cycle. This should be considered during future modelling exercises. Patterns evident suggesting this relationship are:

- The monitoring of kokanee spawning population abundance from 1985 until present indicates that the spawning stock size is 950,000 if it were allowed to stabilize and come to equilibrium in the absence of fishing or predation. The spawning stock size at maximum sustainable yield (the spawning stock size that on-average will produce the maximum amount of surplus kokanee) is 380,000. However, there appears to be two production patterns for kokanee instead of one. One pattern is that of a higher productivity and recruitment and one is that of lower productivity and recruitment. These periods of higher and lower recruitment alternate over time with a frequency period that is similar in duration to two kokanee generations (6 years). The timing and frequency resemble the pattern in kokanee fecundity and body size. This cyclical pattern begins roughly around 1990, which is close to initial nutrient additions (1992). This coincidence is consistent with results reported by Guill et al. (2014)[7], who reported that the predator prey model for rainbow trout and sockeye salmon became unstable with respect to the prey when the carrying capacity of an oligotrophic lake was increased, in the absence of other constraining factors.

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[7] Guill, C., E. Carmack, and B. Drossel. 2014. Exploring cyclic dominance of sockeye salmon with a predator prey-model. Can. J. Fish. Aquat. Sci. **71**:959-972.

- Piscivore abundance and biomass negatively affects kokanee recruitment. Rainbow trout have a strong effect on kokanee abundance and biomass, while the effect of bull trout is not as strong.
- Variation in piscivore biomass generates a strong response in kokanee biomass 1 and 2 years after. Whereas, the variation in kokanee biomass generates a moderate response in piscivore biomass 1 and 2 years after.
- Given lower kokanee availability, the readjustment of the rainbow population appears to be underway. The bull trout population is responding more slowly, with larger fish showing a declining biomass, and declines just beginning for medium fish, and not yet evident for smaller fish.
- Based on rainbow abundance, the model predicts recruitment of adult kokanee to be 340,000 in 2015 and 430,000 in 2016. Considering both rainbow and bull trout abundance, kokanee recruitment is predicted to be 320,000 in 2015 and 380,000 in 2016. However, predictions of adult kokanee recruitment in 2015, based on analysis of acoustic/trawl data, suggest that kokanee adult recruitment in 2015 will be less than the 2014 estimate of ~150,000 (T. Weir, pers. comm.). A contributing factor to the predicted differences may be related to the cyclical catchability of the trawl, driven by the cyclical pattern of kokanee body size and the ability of larger kokanee to disproportionately avoid the trawl net. In periods when kokanee get large (like at the present time), spawner abundance forecasts based on trawl age structure appear to be biased lower. And if and when kokanee get small again, they will be biased higher. However, analysis of acoustic target size and density data only (independent of the trawl data) suggests that the fall 2014 in-lake population of age 2 or older kokanee (the 2015 age 3+ or older spawners) was very low and supports the estimate of <150,000 spawners in 2015. Significant numbers of age 2+ spawners are not anticipated in 2015 due to small size of age 1+ in the fall of 2014; however, should any 2+ spawners materialize they will be a welcome addition to the low anticipated return of age 3+ or older kokanee. The kokanee/predator stock recruitment model alternative forecast of kokanee spawner abundance in 2015 and 2016 is not nearly as bleak as forecasted by the acoustics and trawl data. Continued monitoring will help to better understand and refine approaches to forecasting kokanee abundance.
- Overall, fertilization may be responsible for coupling and cycling in rainbow/kokanee in Kootenay Lake. The fertilization program is about 23 years old in the North Arm and about 10 years old in the South Arm. At a cycle frequency period of 6 years, only 3.5 cycles would be evident to date since start of North Arm fertilization and only 1.5 cycles would be evident to date since start of South Arm fertilization. If such a cycle exists, then it is important to understand it, so that expectations are accurate (e.g., so that a cyclical downturn is not misunderstood to be a management and conservation crisis). There are many examples of cycles in fish and wildlife populations. In these examples, when predator numbers are high, they reduce prey populations, then the predators numbers go down and the prey increase again. In this way, the system may have the inherent potential to fix the “perceived” problem. Monitoring over the short and medium term will be valuable to confirm if a cycle truly exists and to better understand the effects of the fertilization program.
- If cycling is happening as the data currently suggest, then the question of how to best regulate fishing mortality on the predators to achieve the management objective will require further investigation.

- Adult kokanee spawner numbers (in Meadow Creek and the Lardeau River) may be among the most important data source to obtain, as it is a major variable used to forecast kokanee adult abundance in the following generation via the predictive model. The other data needed to make these forecasts are rainbow catch or piscivore catch from the KLRT. The data indicate the interactive effect between these trophic levels, that being in the direction of predator(s) on kokanee as opposed to kokanee on predator. In the absence of a model that predicts long term cyclical dynamics, this predictive model is a good short term alternative, in addition to the trawl based abundance estimates and forecasts. Such forecasts gives managers a 3-year advanced warning as to what to expect in terms of kokanee abundance.

7 Options to improve native kokanee survival, abundance/ biomass

The Team listed options to restore the main lake kokanee population to improve the trophy Gerrard trout fishery; and reduce, on a temporary basis, the predator population, to ensure kokanee recovery. The options identified were:

1. Fishing regulation changes for Gerrard trout, bull trout and kokanee
2. Other predator control
3. Supplement kokanee from an internal source
4. Supplement kokanee from external sources
5. Nutrient enhancement
6. Fish Health
7. Habitat improvements
8. Mysid harvest

Each of the options were then analysed systematically, identifying benefits, risks, data gaps, target reference points, and information signals. An overview map of Kootenay Lake and locations of relevance is provided as a reference for the options reviewed (Figure 3).

Fisheries benefits were calculated using kokanee survival rate estimates determined from the historic dataset. Survival estimates for relevant age classes under normal and current (limited) conditions were used to provide a range for potential kokanee abundance increases that would occur under various option scenarios (Appendix D). Ongoing **information signal** data being collected (Section 5.7) will be analysed and used to identify when the **preliminary target reference points** have been met (Section 6).

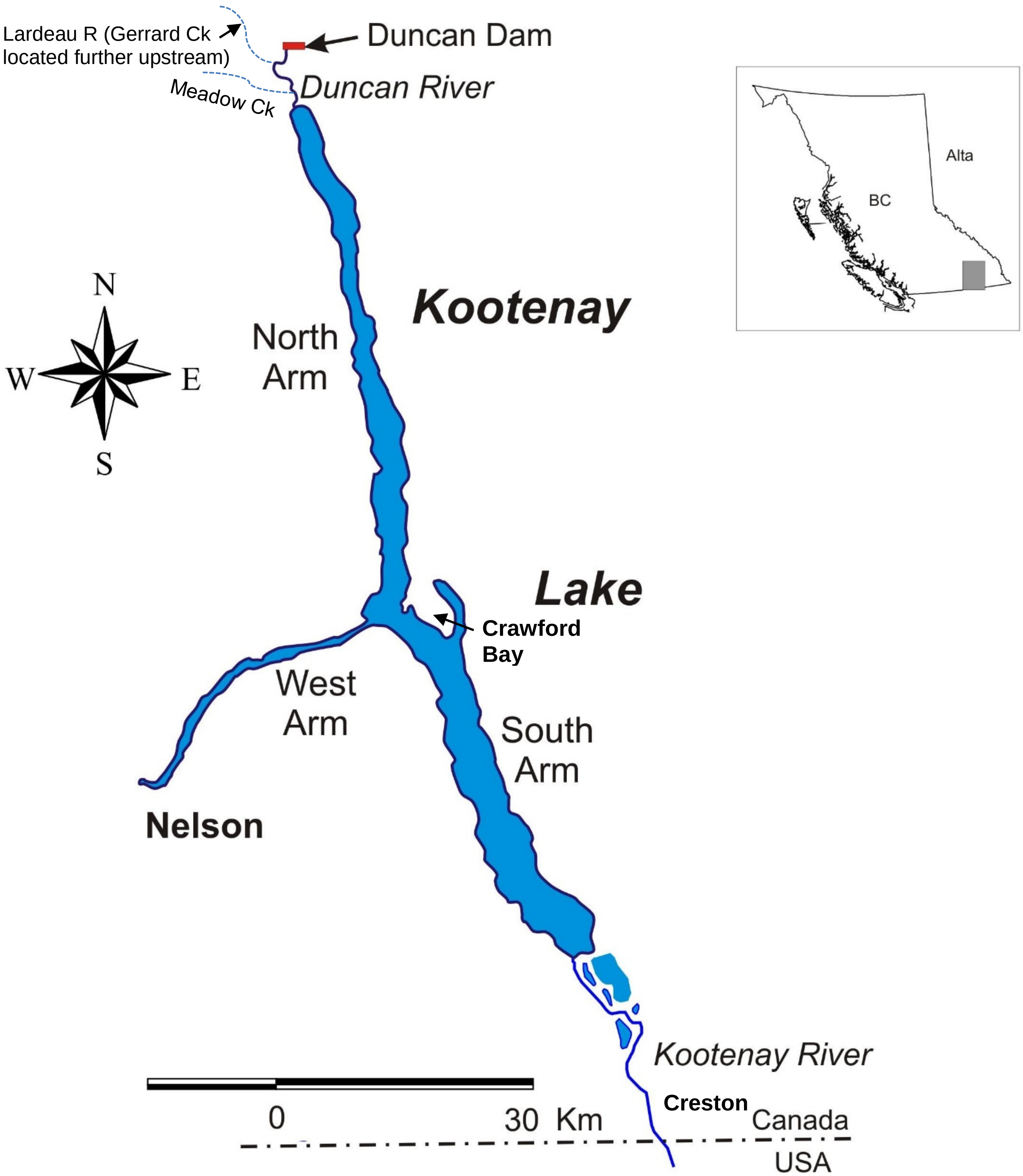


Figure 5. Kootenay Lake and area of relevance to the recovery plan

7.1 *Fishing regulation changes*

Description: Adjust the fishing regulations to reduce prey harvest (kokanee) and increase predator harvest (Gerrard trout, bull trout). The goal of predator reduction is to reduce consumptive pressure on kokanee and increase survival of 0-1 and older kokanee. An overriding caution was to set regulations on predators with a long term perspective, as predators have a slower (longer) life history, while kokanee have a shorter life history. Several options were reviewed.

Option 1A - Reduce the Main Lake quota for kokanee from 15 to 0 fish per day

Discussion	Recommended to the FLNRO Director for consideration in March 2015. o Goal is to optimize kokanee abundance for the production of predators. o Some concern over mixing of West Arm and Main Lake kokanee stocks in the West Arm, and potential for harvest during a 4 week proposed kokanee fishery for West Arm stocks. FLNR agreed to evaluate the potential impact to Main Lake kokanee and distribute this to the Team for review. - Analysis as agreed above, subsequent to the meeting, of kokanee catch data suggests a likely maximum harvest of 500 main lake kokanee in West Arm openings at times when Main Lake kokanee abundance is high. Given the low Main Lake kokanee abundance currently, it is likely that this catch will be even lower. - Subsequent to the meeting and analysis above, the Ministry provided recommendations on direction for the West Arm kokanee fishery in 2015. Given the small potential impact and high social cost of closure, West Arm changes are not recommended. Alternate options to closure (i.e. boundary changes) were not pursued because regulation implementation time and complexity would be significant, and historical data on mixing rates by location in the West Arm were not available, so there was no certainty that any action but closure would have a benefit. The Ministry has committed to collecting genetic samples from anglers during this kokanee fishery, to evaluate impact to Main Lake kokanee, and change regulations next year if required. It is important to note that the analysis and subsequent recommendation above were not discussed by the Team at the Kootenay Lake fisheries meeting.
2015/16 priority	High priority – The Team supported the recommendation of reducing the main Lake kokanee quota to 0 per day.
Fisheries benefit	2.5 million eggs from not harvesting up to 10,000 adults potentially caught in the fishery = Additional 8,000 to 9,000 mature kokanee to spawn in the fall.
Reference point	o Age 0 - 1 and 1 - 2 kokanee survival approaching a normal range (~25 and 35% respectively). o 380,000 to 950,000 spawners (total lake). o Revisions to above if new analysis suggests more accurate values.
Information signal	o June and Sept acoustic data (#3, 5); and o Fall kokanee spawning data (#4).

Option 1B - Increase the quota for rainbow trout from 2 to 4 fish per day, while maintaining the regulation to 1 Gerrard trout over 50 cm.

Discussion	Recommended to the FLNRO Director for consideration in March 2015. o Suggested long term quota of 5 rainbow trout to be consistent with regulations throughout the province. o Risk of overharvest. However, as evident through Lake Pend Oreille example and Kootenay Lake exploitation studies, the chance of over-harvest is low. o Annual catch rate estimates for small rainbow are 10,000-20,000/yr in recent years, with only 3,000 to 6,000 harvested. Select an escapement that will reduce predation on kokanee, yet not negatively influence recruitment of young Gerrard (parr production) and provide favourable long term catch rates for anglers. o Angler effort is expected to decline from that which has been historically seen (2012 level) in the lake due to experiences of poor condition and small sized fish and negative publicity.
2015/16 priority	High priority – The Team supported the recommendation.
Fisheries benefit	1 young Gerrard trout eats 130 age 1-2 kokanee/year (50 g Ko). 1,000 Gerrard trout removed = 130,000 kokanee = Additional 5,577 to 22,750 mature kokanee to the system.
Reference point	o Age 0-1 and 1-2 kokanee survival approaching a normal range (~25 and 35% respectively). o KLRT estimated CPUE of <2kg rainbow of <0.9 fish/hour. o Revisions to above if new analysis suggests more accurate values. o Others to be determined, particularly if CPUE proves to be insensitive to abundance.
Information signal	o June and Sept acoustic data (#3, 5); and o Fishing info to ID CPUE and if there was a change of harvest (#6).

Option 1C – Allow guides to collect additional Gerrard trout for biological sampling and kokanee predator reduction (not client consumption)

Discussion	o Provide guides a Scientific Collection Permit to collect more than one daily quota of trout per day. o Annual catch rate estimates for small rainbow are 10,000-20,000/yr in recent years, with only 3,000 to 6,000 harvested. However, there are anglers that do not buy KLRT licences, with catch results thus not reported. o Risk of lag time issue. Do not want to risk overharvest, and have too few adults spawning or too few to support a trophy fishery, as spawning numbers have been declining for two years. o However, in the Lake Pend Oreille example, exploitation never got high enough to have an impact on native predators (rainbow trout), but coupled with low kokanee abundance there is some concern.

Option 1C – Allow guides to collect additional Gerrard trout for biological sampling and kokanee predator reduction (not client consumption)

	o How to best monitor this action to understand population changes? Creel surveys are a possibility, but would be costly. KLRT has bias, but is the only long term trend data.
2015/16 priority	Moderate – Regional staff recommend providing guides who wish to participate, a permit to harvest a limited number of rainbows over and above their own and client's daily quota.
Fisheries benefit	1 young Gerrard trout eats 130 age 1-2 kokanee/year (50 g Ko). 1,000 Gerrard trout removed = 130,000 kokanee = Additional 5,577 to 22,750 mature kokanee to the system.
Reference point	Age 0 - 1 and 1 - 2 kokanee survival approaching a normal range (~25 and 35% respectively).
Information signal	o Gerrard trout escapement/spawning data (#1); o June and Sept acoustic data (#3, 5); and, o Fishing info to identify if there was a change of harvest (#6) or CPUE.

Option 1D - Increase bull trout harvest to 2 fish per day, from current regulation of 1 fish per day, any size.

Discussion	Risks identified: o Telemetry data has shown that bull trout have multiple populations with smaller abundances than Gerrard trout, and they may range as widely through the lake as Gerrard trout do. o Long-term escapement data is only know on one system, Kaslo River. What are reference points to avoid recruitment overharvest? o High harvest rate compared to rainbow. o Analysis of 2012 creel results, subsequent to meeting, suggest 5% of angler days have catch >1/day, so doubling daily quota may not have significant conservation implications (harvest increase of 320 bull trout if effort and catch remained at 2012 levels). o Escapement estimates are low and declining. Some saw a risk to increasing harvest. There could be a time lag in recovery as bull trout have a longer life history.
2015/16 priority	Moderate priority - Regional staff recommend a 1 year temporary change, allowing a harvest of 2 bull trout per day.
Fisheries benefit	One bull trout eats 50 kokanee/year (50 g; 70% Ko diet). 1,000 bull trout removed = 50,000 kokanee = Additional 2,145 to 8,750 mature kokanee to the system
Reference point	o Bull trout escapement target to be determined. o Age 0 - 1 and 1 - 2 kokanee survival approaching a normal range (~25 and 35% respectively).
Information signal	o Fall acoustic data (#5); and o bull trout redd counts (#7).

Option 1E – Tag Gerrard trout and have a lottery or other style reward for fish harvested

Discussion	o Although variable, annual catch for young Gerrard trout has recently been 10,000 to 15,000 fish/yr, with 20-30% harvested. There is an interest for an increase in harvest rates. Tagging fish with the potential for a reward could increase incentive for harvest. o Floy tag was supported because anglers can see it, and it is less labour intensive. However, there is concern that this would only increase harvest of the small number of fish with tags. Uncertain if worth pursuing, as this is a large lake with low catch rates, and there may not be a resulting impact. Discussed scoping it out for cost benefit. o Pit tags are another option (could possibly be inserted by guides) with heads returned to be scanned for a winning tag. Benefits are that there would be a higher harvest, with all fish brought in because the tag is not visibly evident. However, this was seen to be too much like a bounty, with the potential for long term angler behaviour and population impacts, and was not supported. o Significant cost to this program to manage fish returns from anglers. o A bounty program was also discussed ($15/head), similar to the lake Pend Oreille program. The two systems have very different problems - Pend Oreille had introduced kokanee predators (lake trout and ironically Gerrard rainbow) that were to be reduced and kept low; while Kootenay Lake Gerrard trout are a short term problem, but maintaining healthy numbers of Gerrards is a long term objective. Although commercial netting (fishing vessel) and angler rewards have effectively reduced lake trout in Lake Pend Oreille, angler rewards did not increase rainbow exploitation rates high enough to effect the rainbow population (<30% exploitation). o The program has significant costs. Cheaper alternatives for rainbow control are available (i.e., net spawners) and would likely have been pursued on Pend Oreille if spawners were available for easy capture in one location (as they are at Gerrard).
2015/16 priority	The floy tag option was a low priority for implementation, based on effort, cost and potential benefit.

Option 1F – Make all areas fishable by removing sanctuary status

Discussion	Currently the north end of Kootenay Lake is closed to fishing in the spring to protect Gerrard trout staging to spawn, and recovering kelts. Additionally, Kootenay Lake tributaries are closed to bull trout harvest. If the length of the seasonal closure was reduced, it should be accompanied by an effort to monitor and understand effort/harvest, especially for areas where bull trout congregate during discrete times.
2015/16 priority	Moderate priority - this option is to be researched further by regional fisheries management. As a long term approach, there is likely benefit to decreasing the size of the seasonal closure at the north end of Kootenay Lake.

Option 1G – Change regulation on number of rods that people can have in the water at one time – allow 2 rods or more per person

Discussion	• Requires Federal Fisheries Act Order in Council • This regulation change would encourage anglers to return to Kootenay Lake to fish.
2015/16 priority	Moderate - recommend to the Provincial Angling Advisory Team for consideration.

Option 1H – Change fee for Kootenay Lake rainbow trout licence to $0

Discussion	The current cost for a licence for BC residents is $10/year.
2015/16 priority	A change was not recommended

7.2 *Other predator control*

Description: Other ways to further reduce Gerrard trout and bull trout were reviewed, as 8,000 to 45,000 (> 50 cm) are estimated in the lake.

Option 2A - Reduce Gerrard trout in the Lardeau River

Discussion	Options discussed included: o Kelt fence (70% of spawners die; limited impact on recruitment, short term kokanee consumption decrease). However, experience with the resistivity counter on the river suggests it would be difficult to run a kelt fence due to increasing flows. o Remove adults before they spawn (to reduce the number of parr and subsequent juveniles in the lake). o Destroy Gerrard trout redds on the spawning ground (increase egg mortality). Seems risky. If you have good harvest in the lake or increasing mortality rates because of reduced food supply, then do not need to intervene with further Gerrard trout removal. Additionally, given low food supply, escapement is likely a small proportion of population and spawners will be necessary to supply next generation once kokanee is restored.
2015/16 priority	Low priority – May be considered as a future option if 2015 Gerrard escapement is over a threshold to be recommended by the Team.

Option 2B - Remove some bull trout in spawning tributaries

Discussion	o Kaslo River is an important bull trout spawning river. Additionally, they rear in areas where their main food sources kokanee and whitefish are abundant, including the Duncan River, the outlet of the lake at Balfour, Meadow Creek, and elsewhere. Bull trout removal efforts could be focussed in any of these areas. o The Kaslo River provides one of the longer term data sets, thus removing bull trout from other systems may be a better option. For example, they can be caught easier at Meadow Creek (fence), or can be blocked at the Duncan Dam, or a harvest fishery could be opened on the lower Duncan. Kalso River also has an on-going bull trout research project aimed at defining reference points that would be impacted, although a key reference point (stock productivity) can only be determined with lower spawner numbers. As well, asymmetric removal of other bull trout stocks may benefit Kaslo River bull trout and reduce its long term index value for Kootenay Lake. o Bull trout are relatively abundant, not at risk in this system, and they recover quickly. As a result, there is a sense that bull trout will do better than rainbow trout over the next 10 years. However, although relatively abundant, exploitation rates are currently higher than rainbow trout. o Option to hire someone to harvest fish and keep count of what is being removed, rather than putting all the onus on the public. Several risks were identified: - Do not have annual Kootenay Lake data for total bull trout escapement or in lake abundance. - Bull trout spawner abundance is already down in the Kaslo River; what if populations as a whole have declined? - What are the reference points to stop? - Feasible projects would be focussed on small number of populations; impacts may have conservation concern for certain stocks. - Reducing spawner numbers (i.e. stopping passage through Duncan Dam) have limited short term benefits to kokanee and possible long term costs to predator numbers even after kokanee recover. - Do we have information on bull trout condition?
2015/16 priority	Moderate - evaluate kokanee response to the 2015/16 recommendations and re-evaluate these options at a later time, if required.

7.3 *Supplement kokanee from an internal source*

Option 3A -. Transplant fry or egg from Meadow Creek to another location

Discussion	There are 4 to 5 million kokanee fry estimated from Meadow Creek. This option involves capturing fry during their out migration from Meadow Creek. The fry could then be reared through their most sensitive period in a hatchery, and then returned to Kootenay Lake. This would result in larger fry (2 g). o The Kootenay hatchery can raise 500,000 fry, but it would be costly. o There is the risk of fish not returning to Meadow Creek to spawn. o Similarly, the option of transplanting eggs from Meadow Creek to raise in a hatchery to get higher returns, or transplanting to other creeks to establish alternate spawning stocks, was discussed. There are risks of mortality during transfer, and imprinting concerns; is it worth it? o There are risks of stock loss through disease or other catastrophic events at hatchery that could compromise the entire next generation of kokanee.
2015/16 priority	Low Priority - Supplementing kokanee with an external source was considered a better option.

7.4 *Supplement kokanee from external sources*

Description: Estimate for kokanee spawners next year is very low (below detection limits of trawl/acoustic methods). Options were reviewed to supplement the stock from a source outside of Kootenay Lake. Kokanee would be raised in a hatchery environment to the point that they are expected to have good survival (eyed eggs and fry). These kokanee would be outplanted/released to appropriate locations, with the intent that they will imprint, rear in the lake, return to reproduce and contribute to the population over the long-term, providing a food source for Gerrard trout.

Option 4A. Collect and raise kokanee eggs to the eyed stage, and outplant them in a suitable location in Fall 2015

Discussion	It was suggested that 5 million eggs, which is the current capacity for the FFSBC hatchery system, be obtained from a location outside of Kootenay Lake. These will be raised in a hatchery to the eyed stage, and would then be outplanted in a suitable location in the late Fall 2015. o The hatchery has a 97% survival rate to the eyed stage. There is experience with successfully planting eyed eggs (e.g., Meadow Creek). However, there are risks. Challenge is putting 40,000 eggs into one large redd (Hill Creek had a survival of about 50% during plants in 1980's). It is likely that redds constructed by individual kokanee with lower numbers of eggs/redd have higher survival to fry. Because of this, it was suggested that several redds be constructed with less number of eggs per redd. o Meadow Creek provides water and silt control, and would be the optimal location for planting the eggs. Summit and Goat creeks could be other options for egg plants. o Plantings are to minimize negative genetic consequences. If the genetic source is similar to Meadow Creek stock, then outplant the eggs in Meadow

Option 4A. Collect and raise kokanee eggs to the eyed stage, and outplant them in a suitable location in Fall 2015

Creek. If the genetic source is significantly different from Meadow Creek, then outplant the eggs in another location. Will Warnock (CCRIFC) summarized current genetic literature relative to Kootenay Lake (Appendix B). Some considerations:
  - Meadow has historically been stocked with Hill Creek fish (1990, 1992, and 1993).
  - West Arm kokanee founded the stream spawning population in Christina Lake. Given that South Arm populations cluster with West Arm populations (Anders *et al.* 2007[8]), West Arm populations would likely be appropriate for egg sources for fry/egg outplants in South Arm tributaries.
  - Consider how divergent populations have become in terms of their adaptations to their new environment (spawn timing, migration distance etc.).
  - Consider time since the stocking took place which allows greater divergence in heritable traits with increasing generation time.
- If a location other than Meadow Creek is required for the plantings, then interested community groups could potentially help to prepare the creek beds for egg planting (e.g., Goat, Summit, Crawford Creek).
- Logistical question of where the FFSBC will get eggs, as the only proven sources for numbers this high are Hill and Meadow creeks. Other considerations are: Deka Lake, Williston Reservoir, Tyee Lake (Williams Lake), Kinbasket Reservoir, Columbia River at Fairmont, Whatshan Reservoir, Koocanusa Reservoir, or Christina Lake.
- Risk – current in-lake survival rates are low, and this is factored into the feasibility of stocking eggs (see Fisheries Benefit). Estimated cost for hatchery egg take and production is $30,000 (5 million eggs to eyed stage and 500,000 spring fry) plus some additional cost to complete egg plants in streams. There is also a risk that supplementing will simply postpone the collapse if predator numbers have not already declined significantly.
- The risk of hatchery raised fish bringing in a disease is low, as they disinfect the eggs and check for health.
- The question of timing was raised; specifically, should kokanee be supplemented now or later once predators are reduced?
  - Predator control was discussed to outweigh stocking if numbers have not already declined significantly, assuming that there is a kokanee return.
  - Data on predator populations (e.g., Gerrard escapement and angler catch rates) is nearly a year behind, and escapement cannot be predicted well in advance. Although the outcome will still likely result in overall low kokanee abundance, efforts should nonetheless be put into trying to replenish the population.
  - Stocking is considered a short term fallback. For example, stocking would benefit the population by addressing depensation (e.g.

[8] Anders, P., J. Faler, M. Powell, and H. Andrusak. 2007. Initial microsatellite analysis of kokanee (*Oncorhynchus nerka*) population structure in the Kootenai/y River Basin, Idaho, Montana, and British Columbia. Report prepared for the Freshwater Fisheries Society of British Columbia.

Option 4A. Collect and raise kokanee eggs to the eyed stage, and outplant them in a suitable location in Fall 2015

	improving school formation), and kokanee are known to recover quickly under the right conditions. o Opportunities should be sought to understand the benefits of these efforts. This may involve marking stocked fish, outplanting in locations other than Meadow Creek and the Lardeau River, or tracking result to see if there are separate peaks in fry outmigration.
2015/16 priority	High priority - Ask FFSBC to collect 5 million eggs, and raise these to the eyed stage. Outplant eggs with Meadow Creek genetics at Meadow Creek, and eggs that are not genetically similar to Meadow Creek stock in another suitable location.
Fisheries benefit	5,000,000 eyed eggs = additional 4,955 to 84,218 mature kokanee to the system
Reference point	o Age 0 - 1 and 1 - 2 kokanee survival approaching a normal range (~25 and 35% respectively). o KLRT estimated CPUE of <2kg rainbow of <0.9 fish/hour.
Information signal	o Kokanee fry output from Meadow Creek (or other creek stocked; #2); and, o Acoustic population information (#2 and #5).

Option 4B. Raise and release kokanee fry to a suitable location(s)

Discussion	Raise 500,000 kokanee to the fry stage in a FFSBC hatchery, and release these to appropriate Kootenay Lake locations in the spring of 2016. These fish should be diploids, so they are able to reproduce in the future. o There is a risk that these fish will not imprint and therefore not ultimately reproduce, thus only provide food for predators. o Similarly to outplanting eggs, Meadow Creek should only receive fish with genetics that are similar to its current stock. Fry of mixed origin are to be released elsewhere (e.g., Crawford Creek). Caution that there are still predators at Crawford Creek/Bay. o Currently, South Arm stocks are extremely low and have received Meadow Creek egg plants for over 10 years. Thus the risk of restarting another stock (and interfering with genetics etc.) is less concerning in the South Arm, versus West Arm or Lardeau River. o Moyie Lake is slated to receive 80,000 triploid fry in 2015. These fish could be traded all, or in part, for up to 80,000 diploid fry that are currently being raised for other Provincial Lakes. Regionally, fisheries managers do not feel there is a significant loss to Moyie Lake, but trading triploid for diploid fish will require another Region to agree and give up kokanee that provide angling benefit in other lakes.
2015/16 priority	High priority - In 2015, investigate options to trade the 80,000 triploids originally slated for Moyie Lake for diploids slated for release in other Provincial lakes and release these to Crawford Creek. Also, ask FFSBC to raise 500,000 kokanee fry for release in spring 2016. Use genetics to determine the appropriate release location.

Option 4B. Raise and release kokanee fry to a suitable location(s)

Fisheries benefit	Release of 500,000 fry = 991 to 16,843 mature kokanee Release of 80,000 fry to Crawford Creek = 159 to 2,695 mature kokanee
Reference point	o Age 0 - 1 and 1 - 2 kokanee survival approaching a normal range (~25 and 35% respectively). o KLRT estimated CPUE of <2kg rainbow of <0.9 fish/hour.
Information signal	o Kokanee fry output from Meadow Creek (or other creek stocked; #2); and, o Acoustic population information (#2 and #5).

Option 4C. Investigate opportunities to increase the number of kokanee that move downstream past Libby Dam

Discussion	Enquire with the US Army Corp of Engineers, to see if there is flexibility in operations at Libby Dam, to allow kokanee to move downstream safely past the dam. o There is a Libby entrainment report that may provide useful information. o Are the Gerrard trout moving to the south to take advantage of entrained fish? o Another issue is that these fish would not contribute to the population rebuilding, as they would presumably not find and use suitable habitat to spawn. They would thus only provide food for predators.
2015/16 priority	Moderate or low priority, because of the small potential influx of fish

7.5 *Stream habitat improvements*

Option 5A – Conduct stream habitat improvements

Discussion	Conduct stream habitat improvements to improve kokanee habitat. Simple stream habitat improvements exist, where spawning gravels have blown out, and could be replaced annually. Examples include Goat River, Summit Creek, and Crawford Creek. o Community groups have shown interest in helping with this. o Overall, the system is not habitat limited. Egg to fry survival is good now (fry to 1+ is the concern). o Maybe focus on one or a few streams in the South Arm where there is potential for longer term improvement. There are only small numbers of kokanee in the South Arm streams, but they persisted prior to the spawning channel being installed, and prior to Libby Dam construction, and prior to Kimberley fertilizer plant discharge eutrophication. o This was seen as a separate project that would not help in the short term. o Invest in Meadow Creek, because other streams have only small survival
2015/16 priority	Low priority to meet the objectives of this Plan. However, other objectives for the lake (community involvement) may be met through habitat improvements, and the cumulative effect of many small kokanee habitat projects add up to a greater integrated benefit.

7.6 *Nutrient restoration*

Option 6A – Extend the nutrient addition season into the fall, environmental conditions permitting

Discussion	Although the nutrient enhancement program is working well, a suggested consideration was to prolong the nutrient addition season into the fall. This would potentially result in a higher concentration of zooplankton going into the winter, providing an incremental gain in kokanee survival. o The season has already been extended by one week during some years. o The environmental condition data will be reviewed to determine if this is feasible; temperatures need to be warm enough in the fall. o Feasibility and potential effectiveness requires analysis, as there was no evidence presented to suggest that pre-winter zooplankton was/is low, and the data suggests an abundance of Daphniads during the growing season. o Major changes to the program were seen as risky by some, given the current kokanee concerns, and seen by others as having potential to shorten recovery time. o Keep a close eye on mysid data; may capitalize on low kokanee and high zooplankton. o Other ideas for consideration to increase retention time of nutrients, following data analysis, included: - Adding nutrients to Crawford Bay. Background information and further analysis is necessary to confirm the applicability. - Potentially move fertilization zone further south and north. However, two reviewers considered this to be a minimal improvement due to turbidity and temperature factors, and recommended the current zones should remain as they are. o Opportunities for further data collection/ analysis were identified: - Understand climate forcing to optimize growth using fertilization (e.g., look at spring data, growing degree days). - More temperature data needed (e.g. continuous temperature, air temperature etc). - Expand collection time of light data (planned to be implemented in 2015).
2015/16 priority	Moderate priority – small changes (i.e. prolonging nutrient addition into fall to increase over winter food supply and survival) were supported, and larger changes, although worth pursuing as options for improvement, were not supported before kokanee recovery in order not to confound understanding results of other actions.

7.7 *Fish Health*

Option 7A – Test for IHN in fish collected from trawl

Discussion	o IHN disease, although common in wild populations, is typically associated with significant mortality in hatcheries. However, IHN testing is conducted in the Meadow Creek spawning channel because of high fish densities and the use of Meadow Creek as a broodstock for hatchery production in past years. As a precaution to reduce potential mortality, the Meadow Creek spawning channel is now dried annually, has kokanee carcasses removed, and increased flows after spawning to flush virus out the gravel in accordance with DFO protocols. There was agreement that this should be continued. o IHN was not ruled out as a possible kokanee population influence. Fry went out in high densities in 2012, followed by 1-2 + decreases in 2013. Could this be associated with IHN? Could this question be answered by testing fish in the trawl for this disease? The fish are already killed, and there are samples from prior years available. o There was a mortality event in Arrow Lake, which impacted kokanee population in 2012, but no cause of death was determined. o Kokanee kill in Kootenay Lake reported in 2013, but no samples retrieved.
2015/16 priority	Moderate priority – test kokanee from trawl for IHN virus, to see if it possibly is influencing the population. Continue DFO protocols at Meadow Creek Spawning Channel.

7.8 *Mysid harvest*

Option 8A – Harvest mysids to reduce their population

Discussion	Mysids compete with kokanee for food. On systems that are food limited, such as Okanagan Lake, mysids are harvested to reduce populations. o This activity would only be used to control mysids, not eradicate them. o Threshold, what is profitable for harvesters? Densities in Okanagan Lake are two times or more higher than Kootenay Lake (Greg Andrusak and others prepared numerous reports for Okanagan Lake). May not be worth it for fishermen to come here based on a commercial model, but Province could pay for mysid harvest. We could ask the harvesters their opinion. o A lot of work - 10 year time span. o Historic models around the benefit of Kootenay Lake nutrient addition included mysid dynamics. The models showed that there is a potential for mysids to displace kokanee in the planktivore community, but there is no analysis of current evidence of this occurring. o Bull trout may benefit from mysids. o The West Arm also benefits from mysid entrainment. Because of the lake outlet current, mysids get swept from the deep water of the main lake where they can hide at depth, into the West Arm, which is shallow.
2015/16 priority	o Mysid harvest is currently a low priority, conditional on mysid monitoring results and future potential. o Moderate priority to complete a feasibility and benefits analysis of conducting a mysid harvest.
Reference point	o Mysis biomass of 500--1500 mg/m^{2}.

8 Conclusions

In March 2015, the Kootenay Lake Fisheries Advisory Team identified several options towards restoring a productive and sustainable Gerrard trout fishery. Included were requirements for a healthy fishery, the current factors driving the poor quality fishery, and short-term management recommendations. These recommendations identified how to: 1) as quickly as possible, restore the main lake kokanee population to support a sustainable trophy Gerrard trout fishery, while also providing ecosystem benefits to the lake; and, 2) reduce, on a temporary basis, the predator population, to ensure kokanee recovery. A summary of actions and their priority for implementation is as follows:

High priority

- Reduce the quota for kokanee from 15 to 0 fish per day.
- Increase the quota for Gerrard trout from 2 to 4 fish per day, while maintaining the regulation to 1 Gerrard trout over 50 cm.
- Request FFSBC to collect 5 million kokanee eggs, and raise these to the eyed stage. Outplant eggs in a suitable location in Fall 2015 if kokanee escapement is below 2014 levels.
- Release up to 80,000 diploid kokanee fry to Crawford Creek in spring 2015.
- Request FFSBC to raise 500,000 kokanee fry for release in spring 2016.

Moderate priority:

- Increase bull trout daily quota to 2 fish per day, from current regulation of 1 fish per day any size.
- Allow guides by Scientific Collection Permit to collect additional Gerrard trout for biological sampling and kokanee predator reduction (not client consumption).
- Make additional areas of Kootenay Lake fishable by removing angling closures.
- Extend the nutrient addition season into the fall, environmental conditions permitting, to improve kokanee over-winter survival.
- Change regulation on number of rods that anglers can have in the water at one time – allow 2 or more rods per person.
- Remove some bull trout in spawning tributaries.
- Investigate opportunities to increase entrainment of kokanee past Libby Dam.
- Test kokanee from trawl for IHN virus.
- Research feasibility and benefits of Mysid harvest.

Low priority or long term potential but no immediate benefit*

- Tag Gerrard trout with floy tags, and have a lottery style reward for fish harvested.
- Change fee for Kootenay Lake rainbow trout licence to $0.
- Reduce Gerrard trout in Lardeau River habitat.
- Transplant kokanee fry or egg from Meadow Creek to another location.
- Conduct stream habitat improvements to benefit kokanee spawning*.
- Conduct mysid harvest*.

This summary is intended to inform future management action decisions for development and implementation of a Kootenay Lake fishery recovery plan. Long-term recommendations will be developed in 2015/16, and will identify how to reduce the likelihood of a kokanee collapse occurring again in the future.

Appendix A. Kootenay Lake Fisheries Advisory Team, meeting attendance

Name	Title	Affiliation	Day 1	Day 2
Harvey Andrusak	Fisheries Biologist	BC Wildlife Federation	X	X
Steve Arndt	Fisheries Biologist	FLNRO, Nelson	X	X
Paul Askey	Fisheries Scientist	FFSBC	X	X
Marley Bassett	Fish Restoration Biologist	FLNRO	X	X
Robert Bison	Stock Assessment Biologist	FLNRO, Kamloops	X	X
Jeff Burrows	Senior Fish Biologist	FLNRO, Nelson	X	X
Albert Chirico	A/Fish & Wildlife Section Head	FLNRO, Nelson	X	X
Adrian Clarke	Vice President of Science	FFSBC	X	
Joe De Gisi	Stock Assessment Biologist	FLNRO, Smithers	X[1]	X[1]
David Johner	Large Lake Biologist	FLNRO, Victoria	X	X
John Krebs	Director Resource Management	FLNRO, Cranbrook	X	X
Sherri McPherson	Facilitator/Senior Aquatic Biologist	Lotic Environmental, Cranbrook	X	X
Matt Neufeld	Fish Biologist	FLNRO, Nelson	X	X
Lance Page	Kootenay Hatchery Manager	FFSBC	X	
Eva Schindler	Section Head - Fish & Wildlife Compensation Program	FLNRO, Nelson	X	X
Hillary Ward	Stock Assessment Biologist	FLNRO, Penticton	X	X
Will Warnock	Aquatic Biologist	CCRIFC, Cranbrook	X	X[1]
Tyler Weir	Large Lake Ecosystem Specialist	FLNRO, Victoria	X[1]	X[1]

Legend:

1. Participated via conference call.

Appendix B. Background presentations

Appendix B1- J. Burrows and M. Neufeld, FLNRO - Kootenay Lake Background Summary


Kootenay Lake Background
Regional FLNR
Kootenay Lake Fisheries Advisory Team Meeting
March 12-13 2015 - Nelson

Outline

Background - History Leading to 2015

- Kokanee
- Gerrard Rainbow and predation
- Bull trout and predation
- Kootenay Lake Fishery
- IHN Virus
- Nutrient Program

Recap Background, Current Status

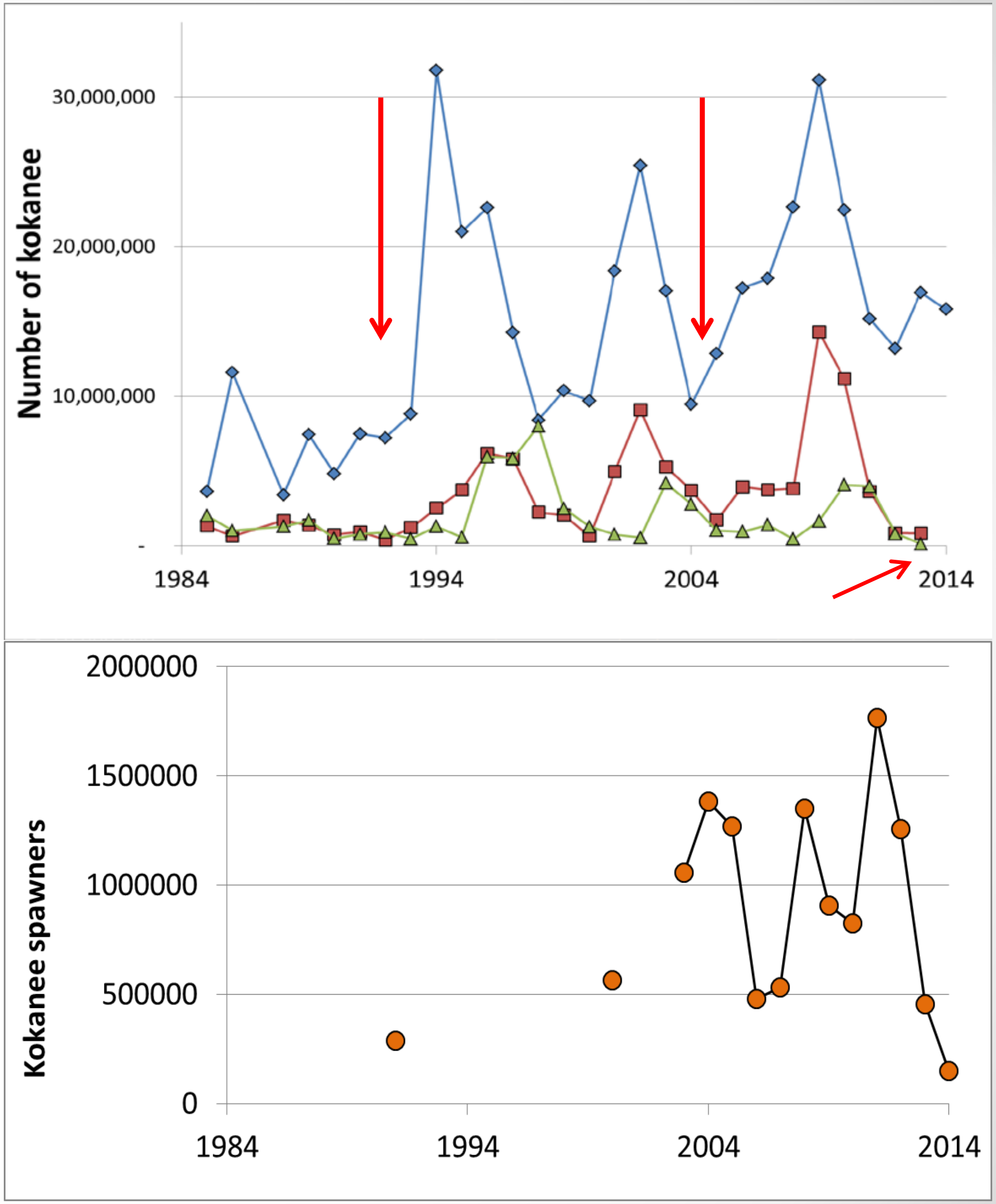
- Kokanee, Gerrards, Bullies, Nutrients and the Fishery

Background - Public meeting - Goals and Actions

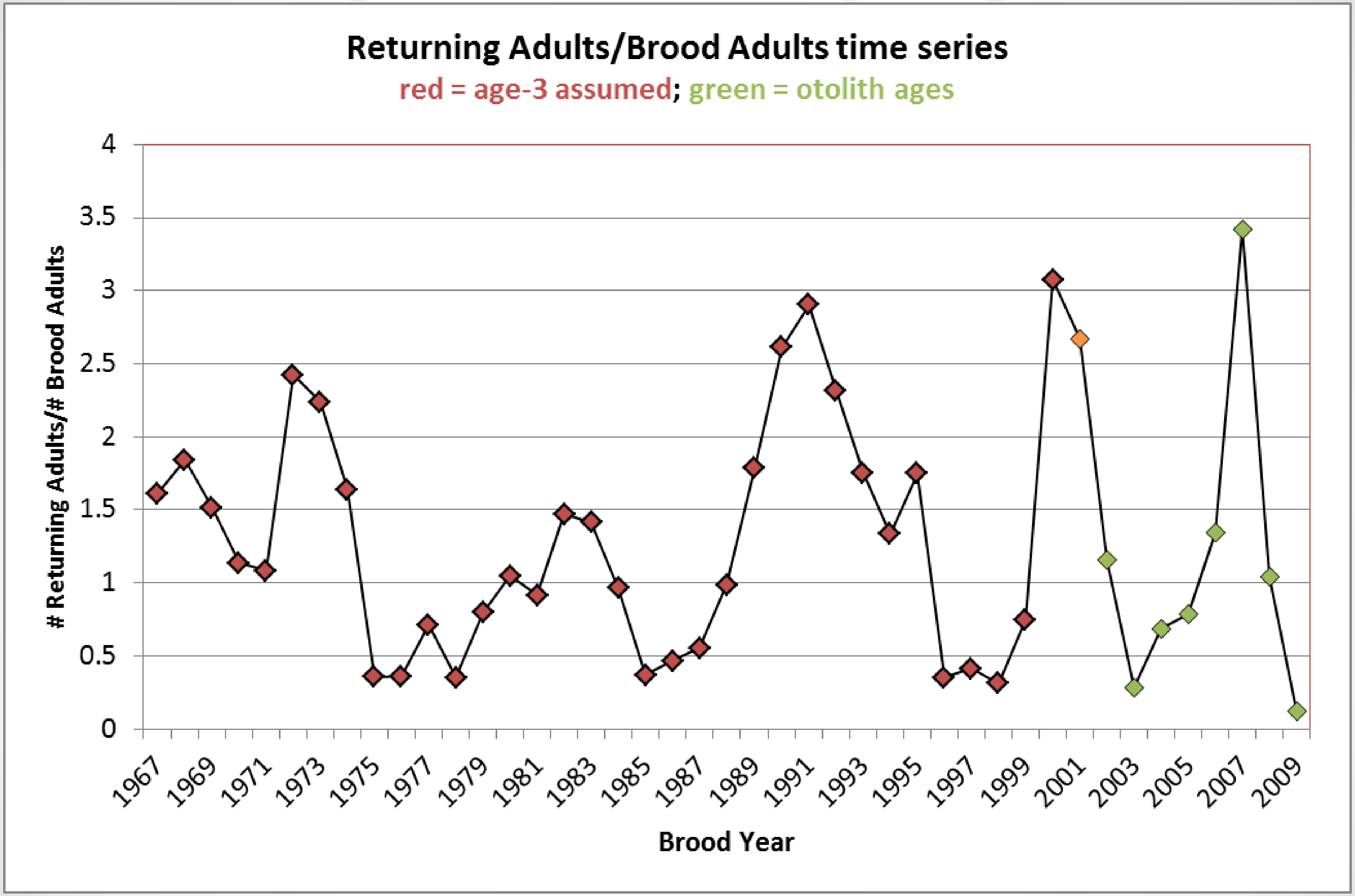
- Kokanee - promote population recovery
- Gerrard Rainbow – population management, trophy fishery
- IHN Virus - mitigation
- Nutrient Program – continued food production for kokanee
- Public invited to ask

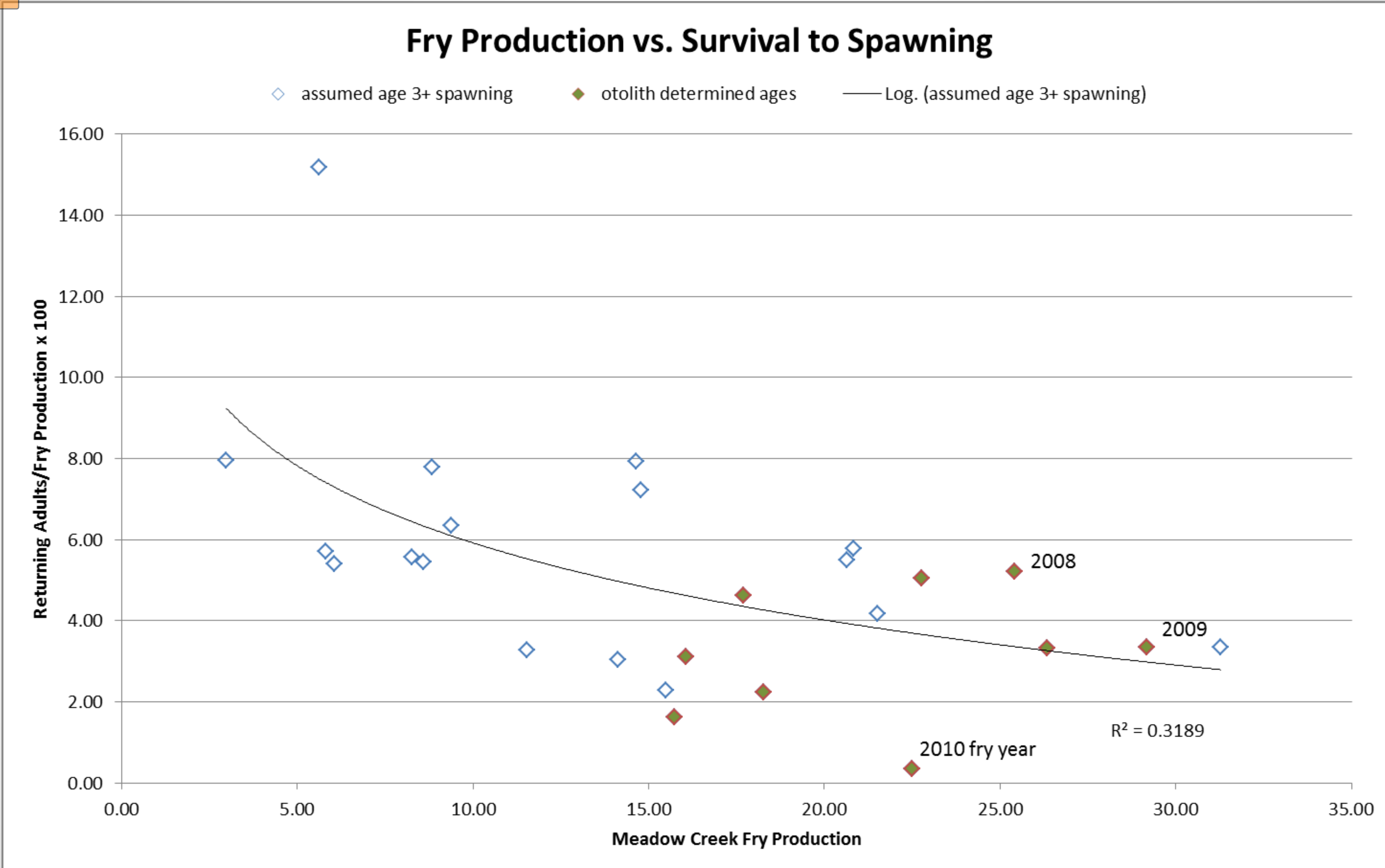
History - Kokanee

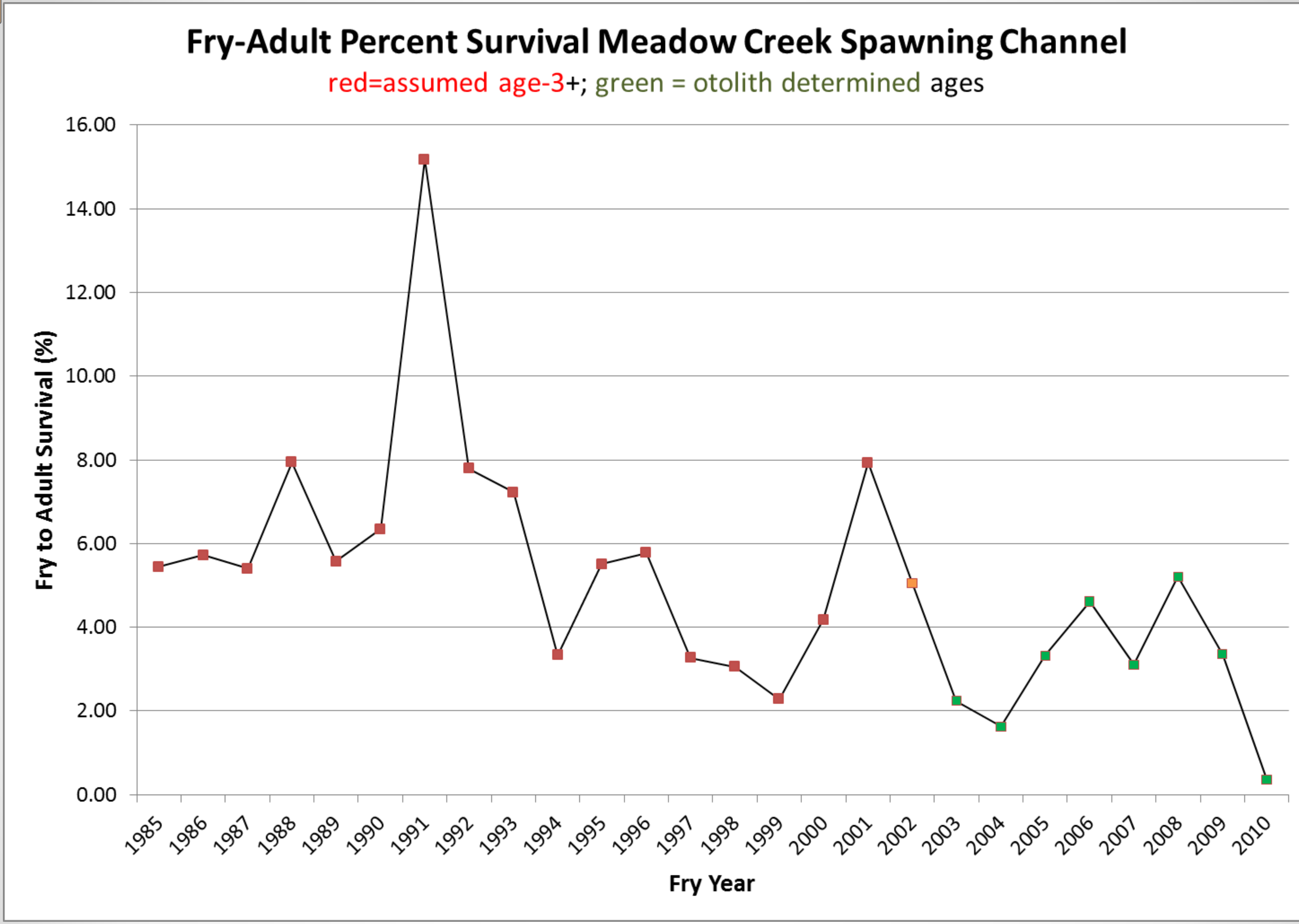
- Kokanee numbers fluctuate
- Improvements since nutrient restoration
- Fry estimates more than doubled with nutrient restoration and have remained high (2014 was post nutrient average)
- Recent very strong reduction in 2 and 3 year old survival
- 2014 ~150,000 spawners and 33 million eggs lowest recorded
- 1991 - low before nutrient restoration 285,000 spawners and 41 million eggs



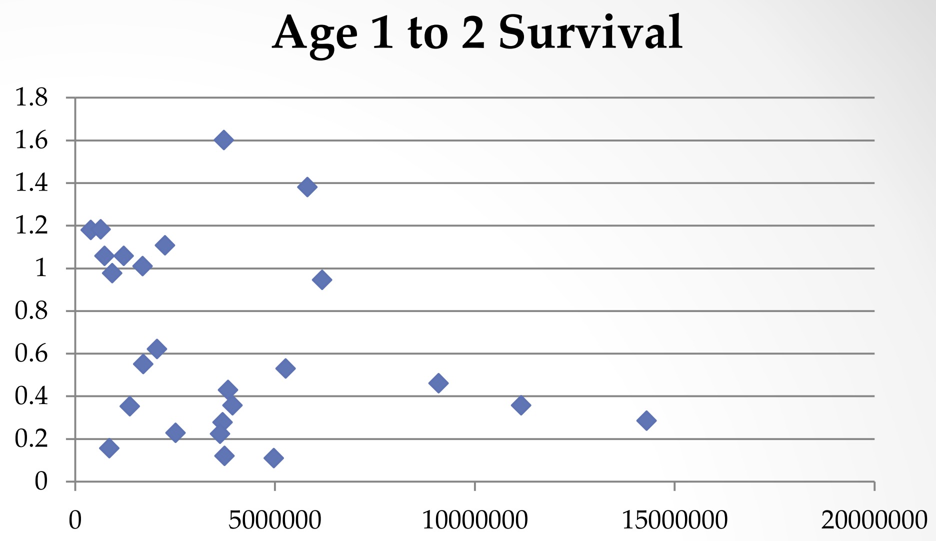
Kokanee spawner recruits per spawner brood




Fry Production vs. Survival to Spawning
assumed age 3+ spawning
otolith determined ages
Log. (assumed age 3+ spawning)
Returning Adults/Fry Production x 100
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Meadow Creek Fry Production
2008
2009
2010 fry year
R² = 0.3189

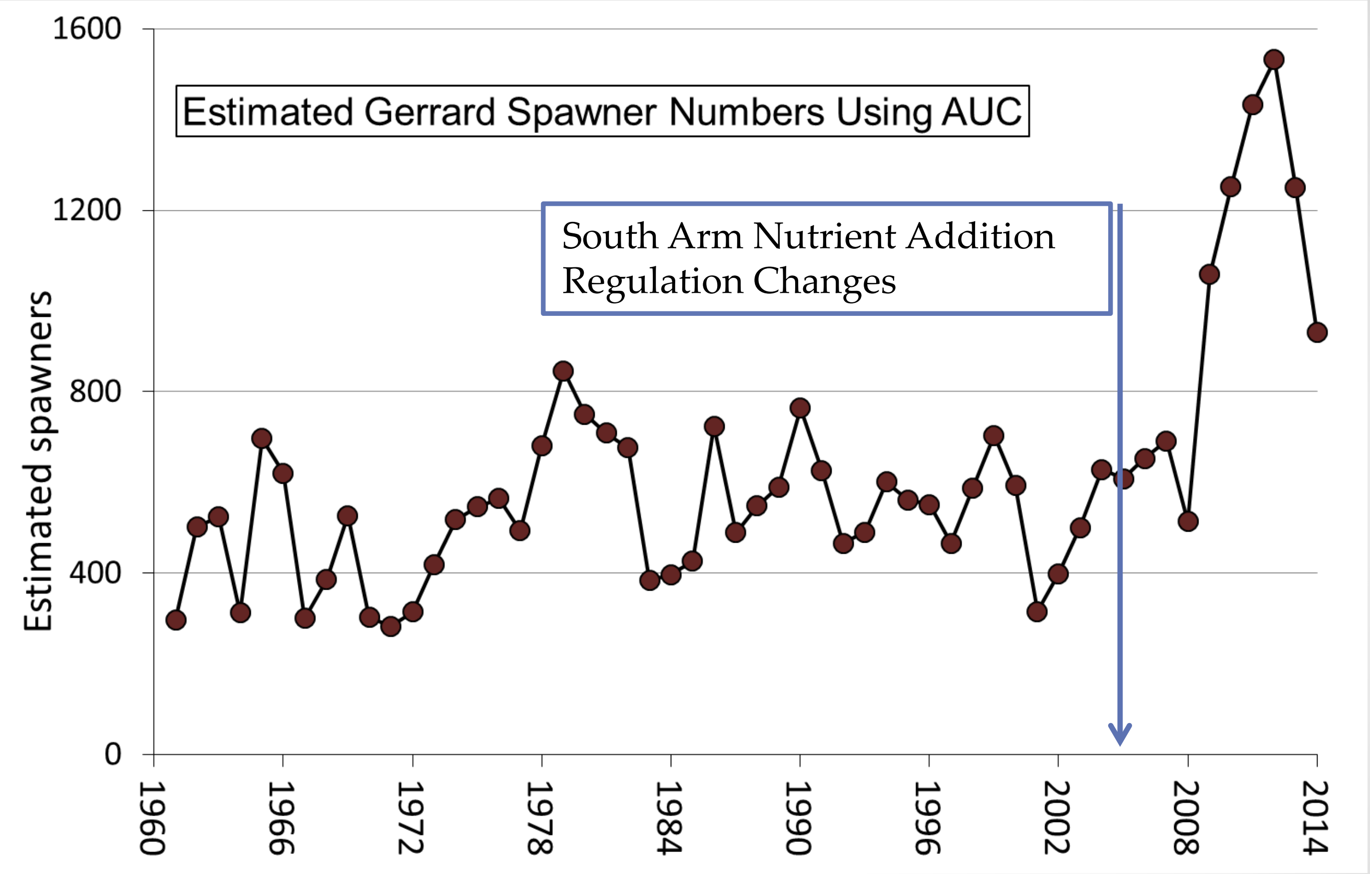

Fry-Adult Percent Survival Meadow Creek Spawning Channel
red=assumed age-3+; green = otolith determined ages
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Fry to Adult Survival (%)
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Fry Year

- Depensation at low densities
- Acoustic fall data
- Fall to fall S vs initial fall cohort size
  - Y dependent on X
  - > 100% survival, Libby entrainment or methods issue?
  - Depensation?



History – Gerrard Rainbow Trout

- Daily bank counts since 1961
- Cyclical
- Long term average ~550
- 2012 peak 300% higher than long term average, and nearly 200% higher than prior record.
- Recent decline



Rainbow predation pressure

How Many Gerrards in Kootenay Lake:

- 2012 Creel Estimate of ~4000 >50cm RB harvested - Separate study suggests ~10% population >50cm at large harvested/year - Potential Gerrard population **45,000**
- Gerrard escapement in 2012 ~1600 - Separate study suggests 20% probability of spawning - Potential Gerrard population **~8,000**

Consumptive Pressure on Kokanee:

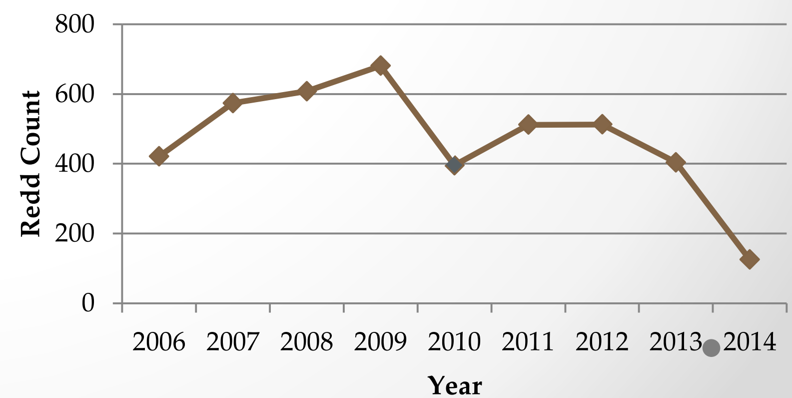
- Individual Gerrard consumes ~80 ko/y (regional bioenergetic calc'ns) and Gerrard population 8 k to 45 k
- Predation rate of 650,000 to 3.6 million ko/y
- Enough to drive observed ko effects ?
- Lake Pend Oreille (*Hydrobiologia*): higher ko consumed/y

Bull Trout spawning population

- 2011 Spawning adult estimate → 3,700-4,500 (including 500 transferred through Duncan Dam)
  - 230 km of 19 tributaries surveyed ≈ 1,700 redds
  - Adult estimate based on redd counts expanded by Kaslo/Crawford electronic count/redds ratio 1.9-2.4
- 2013 spawning adult estimate declined to 2,600-3,100 (assuming 500 Duncan)
  - ≈1,100 redds (141 km of core 2011 streams)
  - + new tributaries Meadow Creek (400 fish in 2013); Sanca, Lockhart and La France (not yet fully surveyed)
- Peak escapement 4,000 – 5,000 (+ Sanca, etc.)
- Kaslo River time series 2006-2014

Kaslo River Redd Counts 2006-2014

(includes Keen Creek; poor visibility in 2010)



Bull trout predation pressure

How Many Bull Trout in Kootenay Lake:

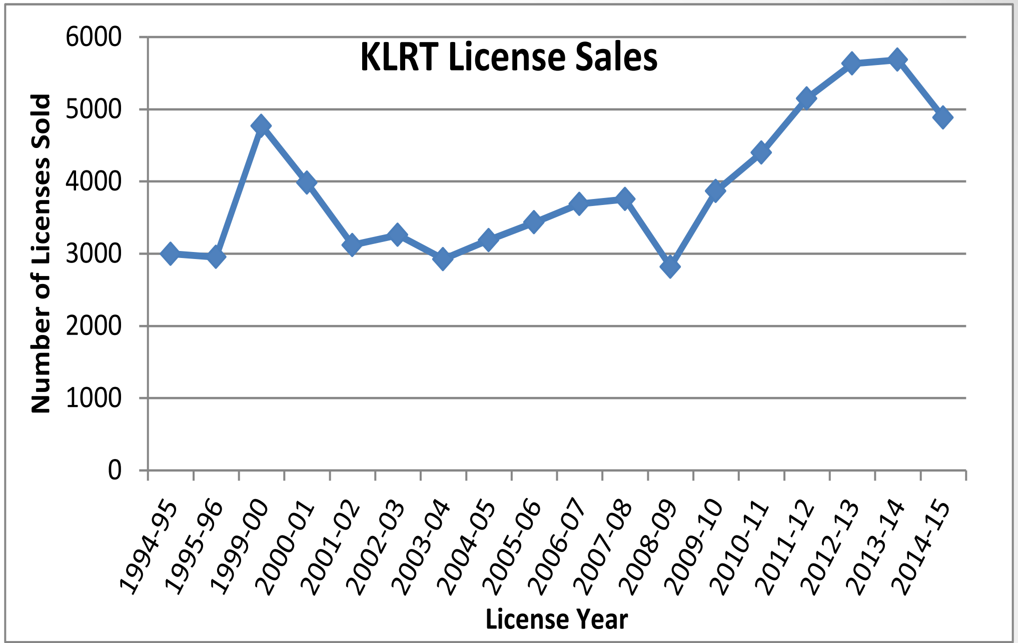
- 2012 Creel Estimate of ~6000 >50cm bt harvested - separate study suggests ~15% population at large harvested/year - Potential >50cm bt population **40,000**
- Bull trout escapement estimate via redd count expansion and Duncan Dam transfers is ~**5,000 spawners**

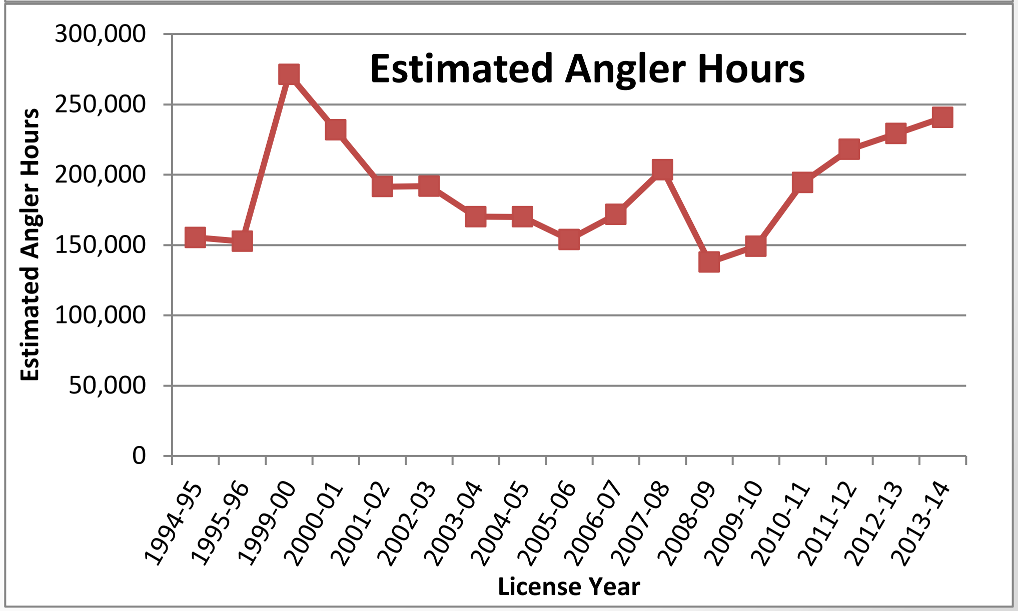
Consumptive Pressure on Kokanee:

- Bull trout consumption ~160 ko/y and bull trout population 5 to 40k
- Predation rate of 800,000 to 6.4 million ko/y
- Enough to drive observed ko effects?
- Ton of assumptions
- Recent redd count declines on index streams (~ 50%)

History - Kootenay Lake Fishery

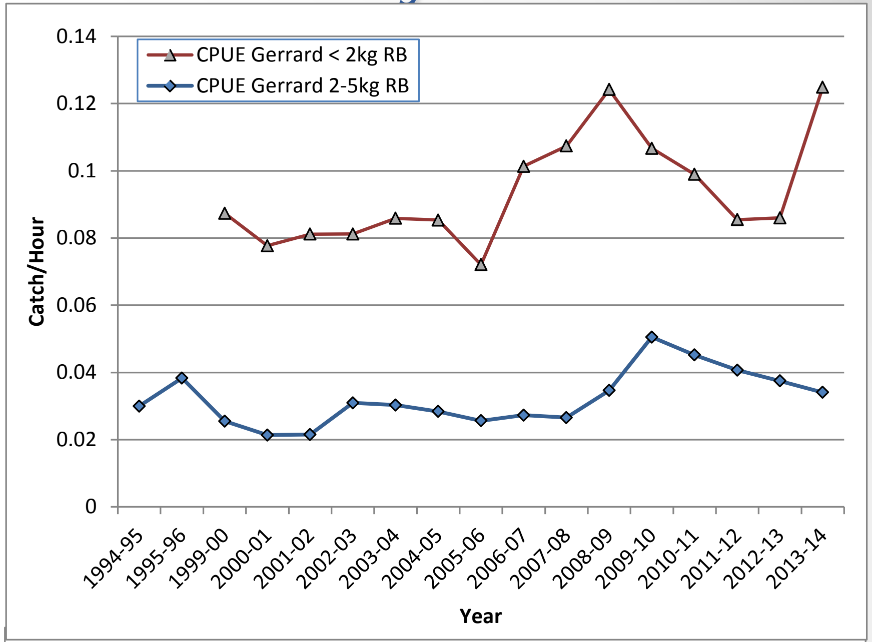
- Estimated direct expenditures between **$3-5 million annually**
- Trout licence sales higher in the last four years than ever (corresponding increases in effort)
- 2014-15 sales high (~5,000), but likely decrease in 2015
- Angler harvest low despite high effort (~13%; harvest likely not driving current change in abundance)

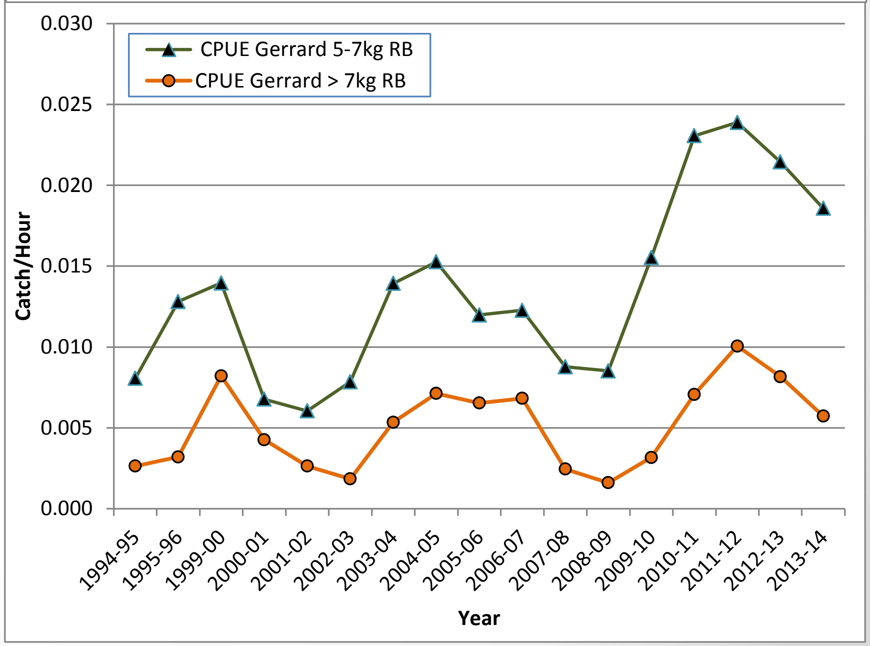




History - Kootenay Lake Fishery

- Catch rate in the past 4 years for almost all size classes were highest ever observed (peak 2011-12)
- Decreasing catch rates in the past two years for all size classes over 2kg
- Likely significant decrease in catch rates currently; not yet reflected in survey results
- Increasing catch rates for the smallest fish (highest ever observed)



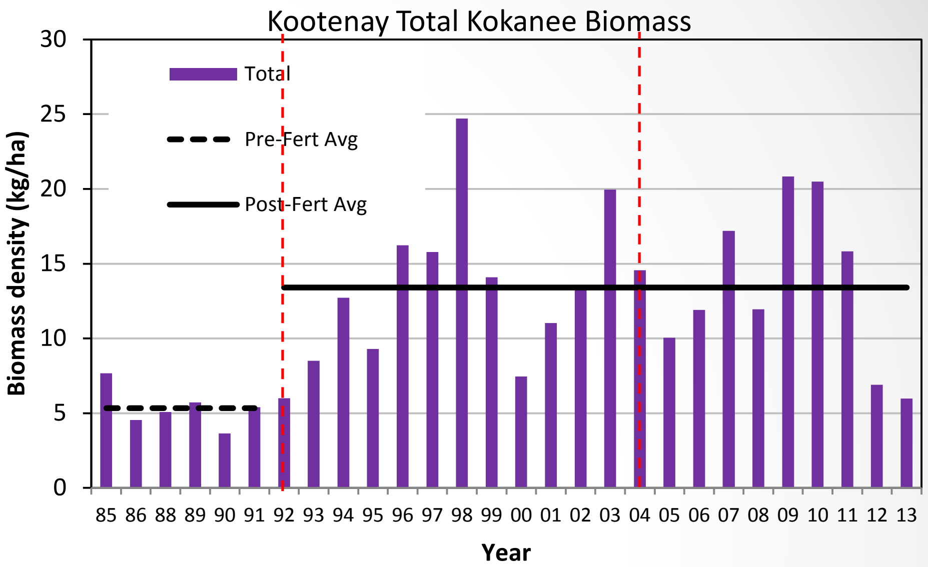


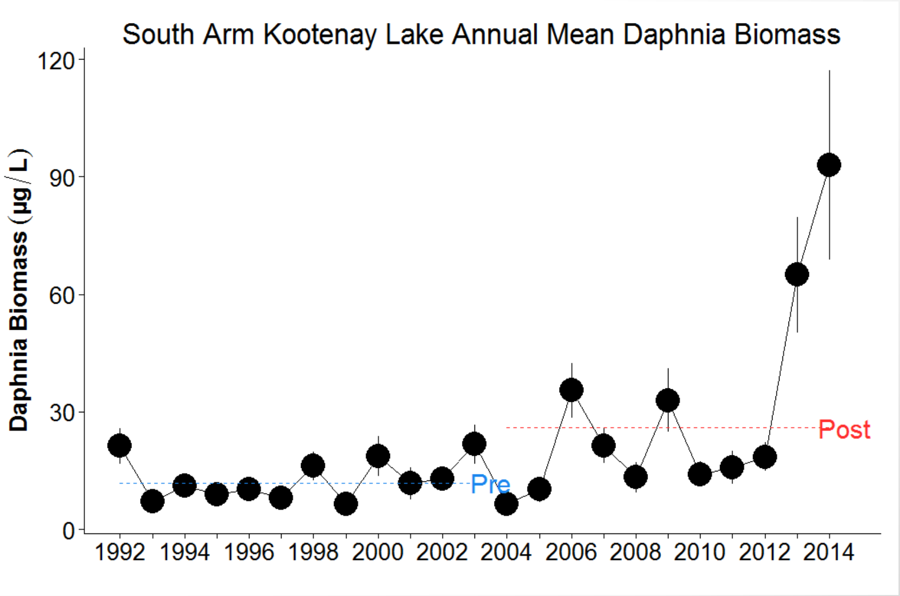
IHN virus

- Infectious hematopoietic necrosis virus (IHN) found for the first time in adult kokanee spawners at Meadow Creek in 2013 and again in 2014;
- Kokanee fry samples 2014 and Gerrard spawners testing indicated no viral infection
- Potential sources; migrating animal (e.g. birds), present in the past but undetected, introduced by a person/boat, or many other possibilities.
- Disease (e.g. IHN virus) and parasites are rarely a major factor that affect wild population status- likely the case for Kootenay Lake:
  - no significant fish kills identified (2013 event, likely small impact -?)
  - adults have spawned successfully despite infection
  - egg to fry survival has remained high (IHN typically kills fry)
  - levels of infected kokanee declining
  - rainbow trout not currently infected
  - Cowichan Lake event?
- **IHN virus is not harmful to people**, and can’t transfer to people by either touching or eating infected fish.

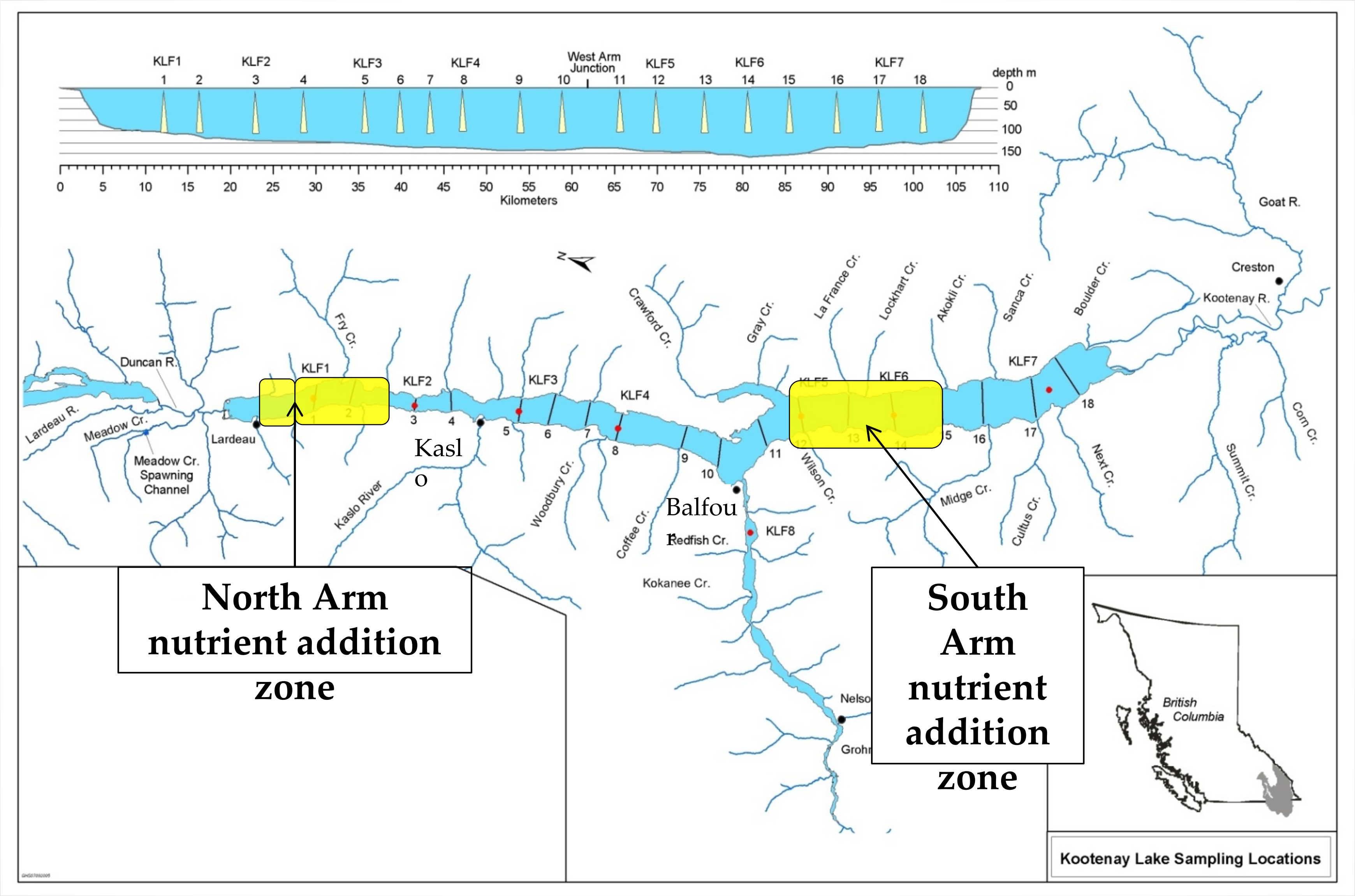
Nutrients

- Productivity in the lake has increased
  - o Gerrard abundance has increased
  - o Kokanee biomass has increased 2.5 times since nutrient additions
  - o Zooplankton has increased, particularly in the South Arm

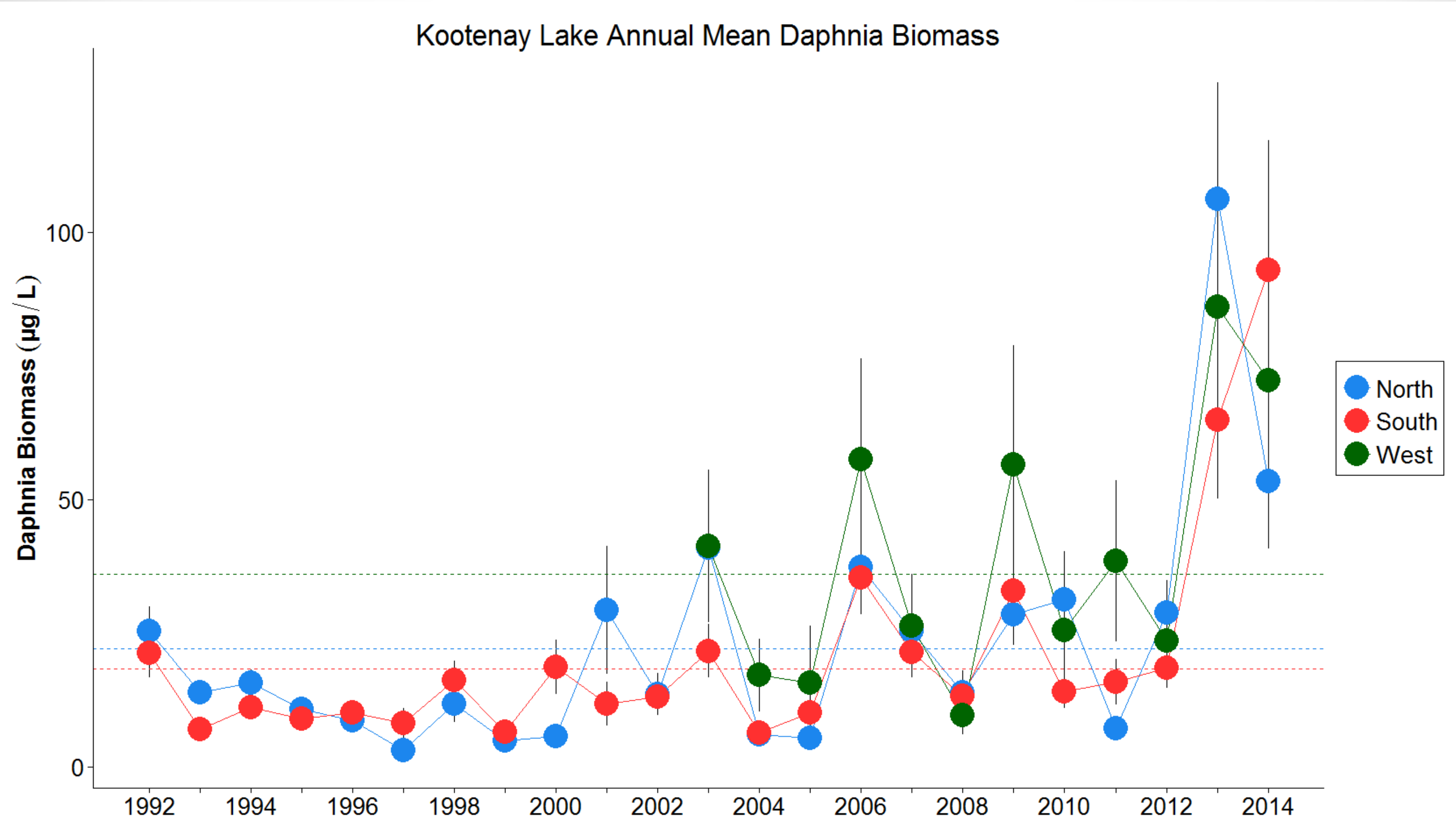




Kootenay Lake Nutrient Addition Zone



Zooplankton



Background Summary

- Recent low older kokanee abundance
- Kokanee fry ~ average abundance
- Kokanee survival concerns
- Recent record high Gerrard trout abundance
- Decreasing Gerrard rainbow trout size and large fish abundance, degrading condition of trout in fishery
- Declining bull trout abundance, or skip spawning
- High abundance of young Gerrard rainbow trout – could increase kokanee recovery time
- Predation pressure: recently immense
- Nutrient program continues to produce fish food
- IHN virus remains present

Kokanee: stock recovery

- Fall fry abundance in 2014 remained high (over 15 million) suggesting recovery could be significant in just two years; *if predator abundance declines rapidly.
- Fry production in 2015 likely to be 7-12 million. Even with low spawner number, recovery building block present.
- The significant uncertainty around recovery time centers on predator response to current low kokanee abundance

Actions

- **Regulation change**
  - In the short term decrease in kokanee quota (0/day) effective April 2015.
  - Could provide 2.5 million extra eggs
- **Expert Review:** Provincial stock assessment team and Freshwater Fisheries Society BC engaged to **review all options, such as stocking,** to speed recovery of kokanee stocks, then maintain abundance

Gerrard rainbows: population management, trophy fishery

- We expect a sharp decline in spawner number and large fish catch rate in 2015
- Small fish catch rates suggest we currently have the raw material to maintain or increase Gerrard numbers as kokanee abundance increases

Actions

- **Regulation Change:** In the short term, daily rainbow quota on the Main Lake to increase to 4/day, 1 over 50cm - decreasing juvenile Gerrard abundance has likely benefits for kokanee recovery (~10,000 caught annually, only 3,000 harvested);
- **Expert Review:** In the short and medium term: Provincial stock assessment team engaged to help better understand predator/prey dynamics in the lake, and inform future management decisions.
- **Future Regulation change:** if and when juvenile cohort abundance has been reduced sufficiently and kokanee abundance increases

Nutrient Restoration: maintain food

- Proven performer
- Quick kokanee recovery depends on continued nutrients (food for fish)
- **Action:** Optimization of timing and inputs
  - Investigate timing with fry outmigration to increase juvenile Kokanee survival
  - Increased monitoring and continued consideration of natural variability and climatic events (flow, temp and natural input) will ensure nutrient additions are optimized to best move up the food chain.

Future –Fish Disease in Kokanee?

- There is no practical way of controlling disease in wild fish populations

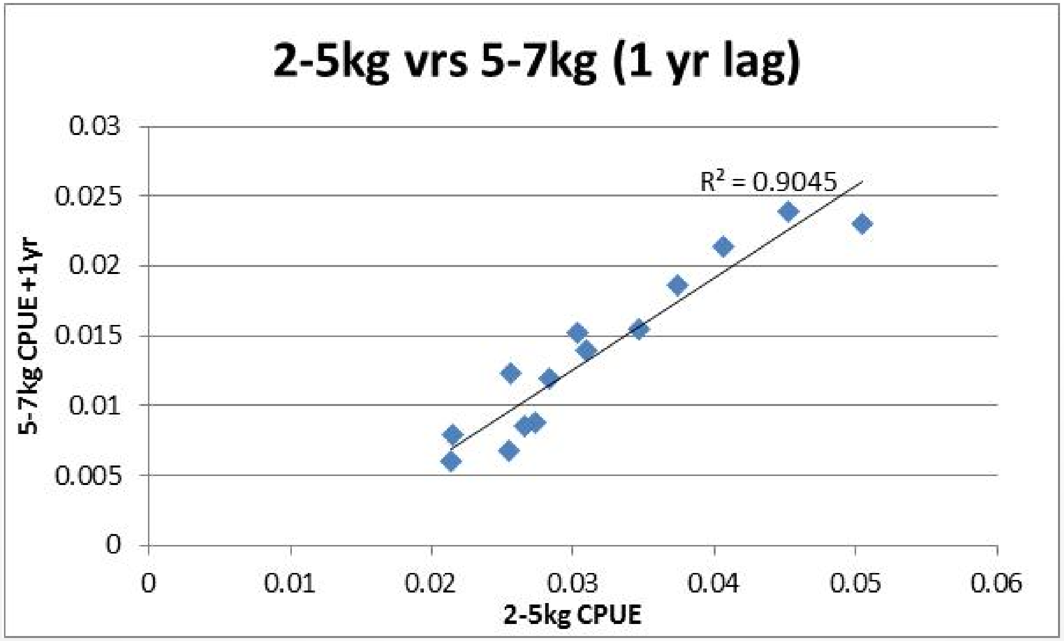
- We can't rule out virus as a factor: continue to limit virus at spawning channels where we have some control
  - carcass removal
  - flushing
  - summer drying
  - kokanee testing will continue annually

Questions and your ideas

- **Looking for your input and to answer any questions as we further develop actions**
  - Input and question form provided tonight can be returned to organizers
  - Questions answered and update on actions provided on Ministry web page:
  - www.env.gov.bc.ca/kootenay/fsh/main/mainfish.htm
  - Google "Kootenay Fisheries"
- **Update bulletin will be available soon**
  - email list (sheet at the door)
  - Regional web page www.env.gov.bc.ca/kootenay/fsh/main/mainfish.htm

KLRT Creel Survey Comparison

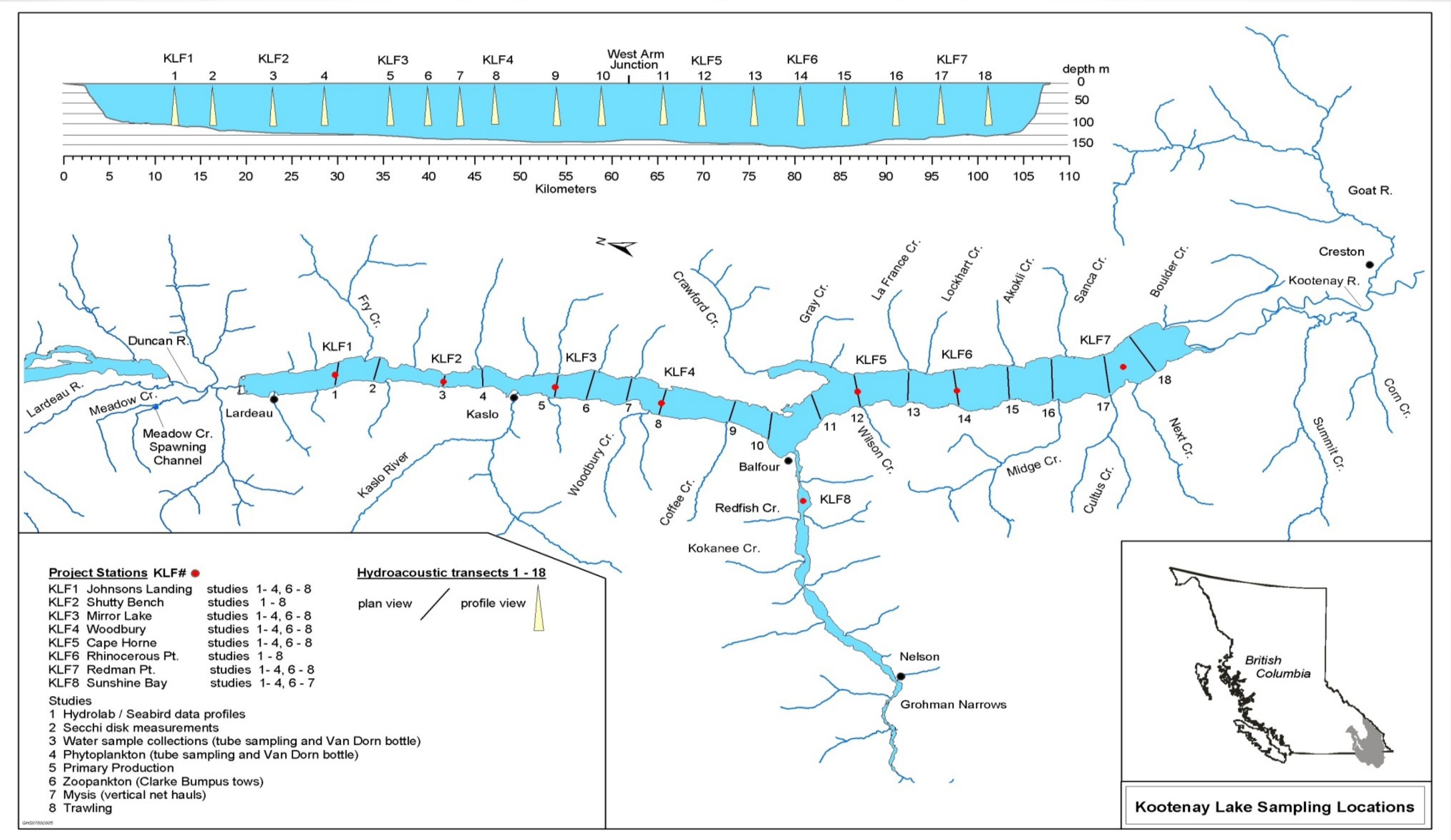
- KLRT vs Creel: effort estimates – **within 0.5% of each other** (Creel 46,053; KLRT 46,311angler days)
- >50cm BT and RB catch and harvest – **1.5 to 2x higher in KLRT** – likely reflects survey bias that is well recognized including anglers that do not report if they did not catch, recollection bias as creel completed on day of catch (with harvest in hand) and survey up to 1.5yrs latter, anglers reporting boat catch not personal catch and other (creel survey a valuable reference point to correct for survey bias)
- Year to year predictive power is internally consistent - KLRT catch rates by size class in one year predict future catch rates of larger fish, so useful index of abundance and fishery performance



Worms in Fish

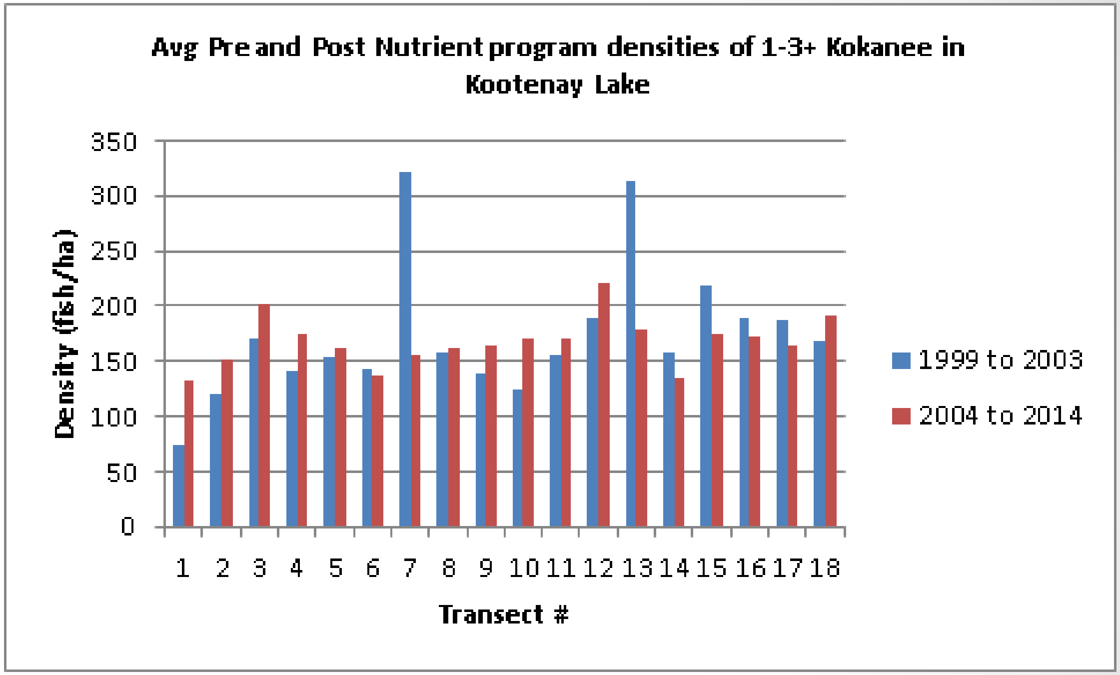
- Worms reported by anglers are "**broad fish tapeworm**", native to Kootenay Lake
- Larvae infect both freshwater and marine fishes, and are **always present** in the Kootenay Lake rainbow population at some level.
- There is **no practical way of controlling parasites** in wild fish populations. For anglers, the key consideration is care in the preparation of your catch prior to consumption.
- Tapeworm eggs are excreted in the feces of **animals hosting the adult tapeworm (fish-eating birds or mammals)**, develop in water into larvae that work their way through the food chain and eventually into fish.
- **Heavy infestations of these larval tapeworms could kill some fish**, especially those an already weakened condition, such as older fish, malnourished fish, or post-spawning migrants that are just returning to the lake.
- **Parasite loads fluctuate**. Although more trout appear to be affected by these parasites now than in the recent past, some anglers and retired fish biologists recall relatively high levels of parasites in past decades.
- We don't know for sure why these parasites are more common at some times, but this cycle is common in other populations

Kokanee Distribution

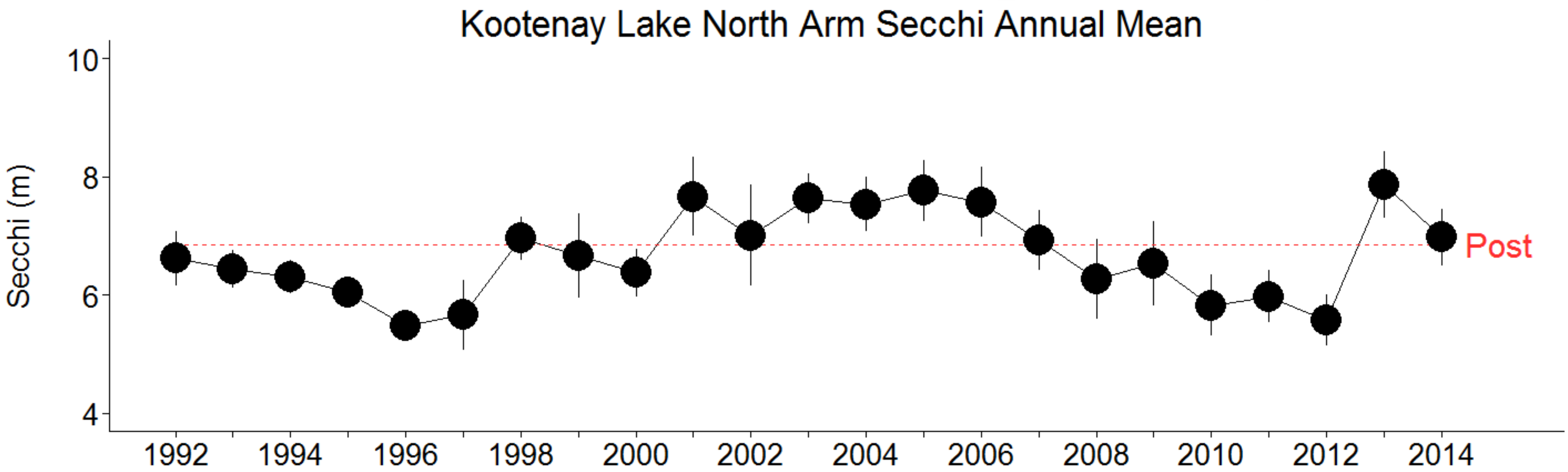


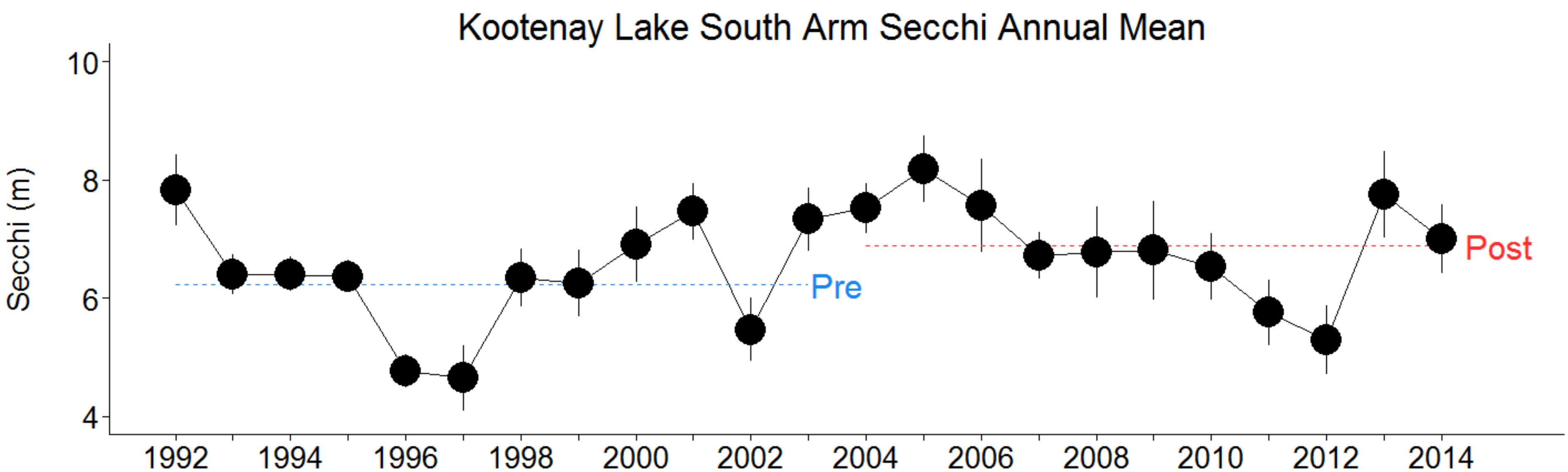
Kokanee Distribution

- Density of kokanee higher after south arm nutrients
- No significant change in distribution, with high densities at all transects in both the north and south arms

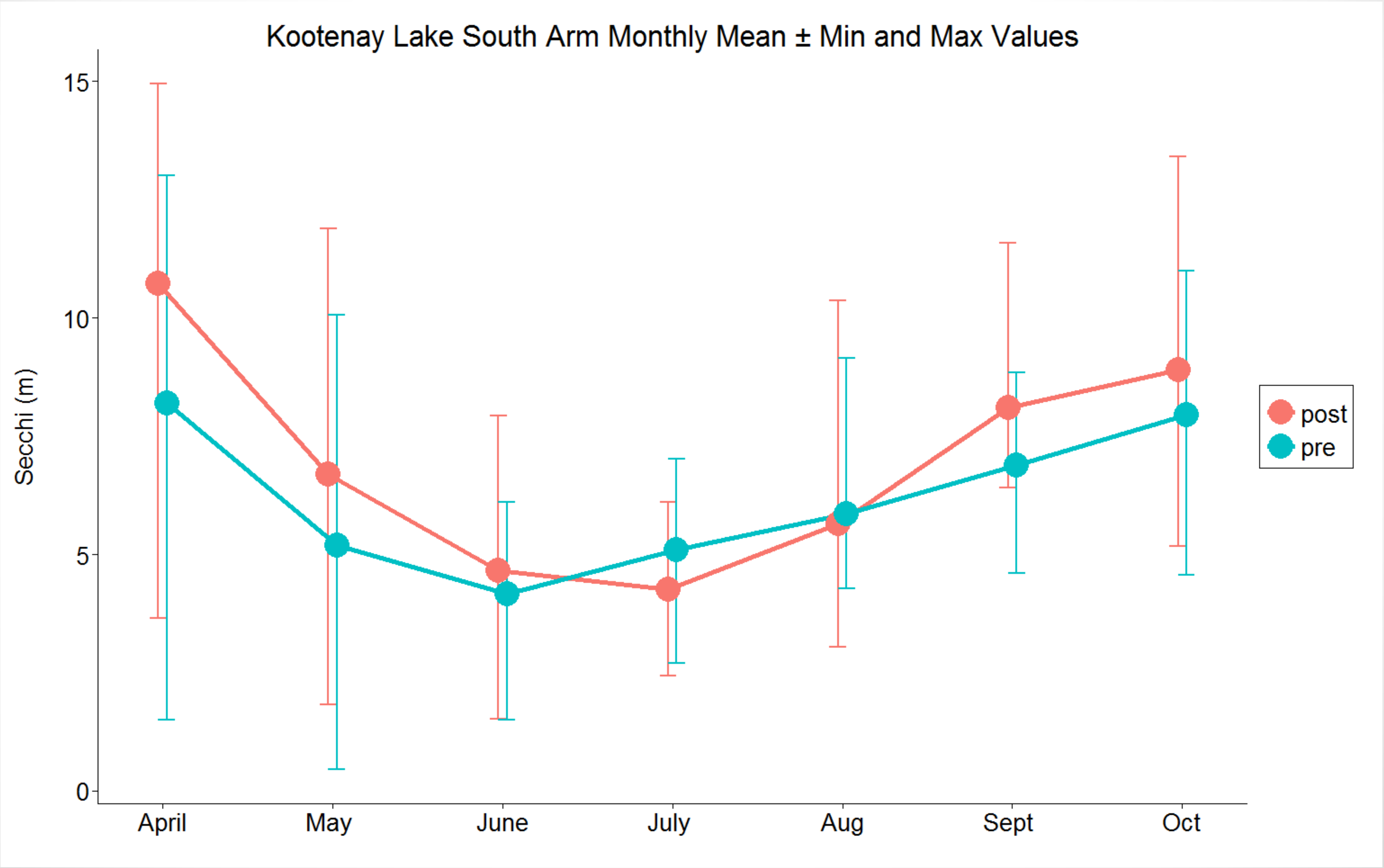


Secchi – measure of transparency

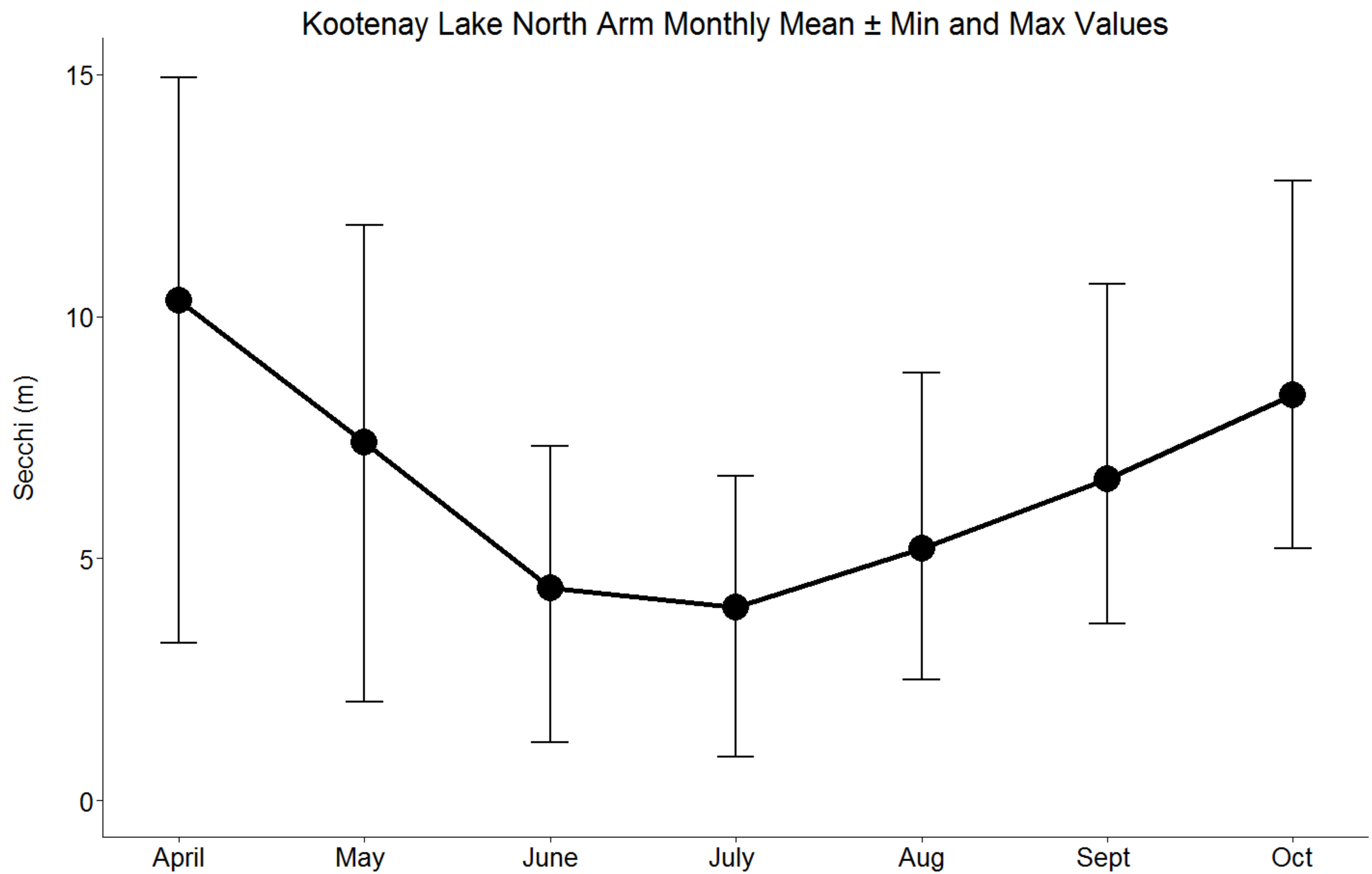




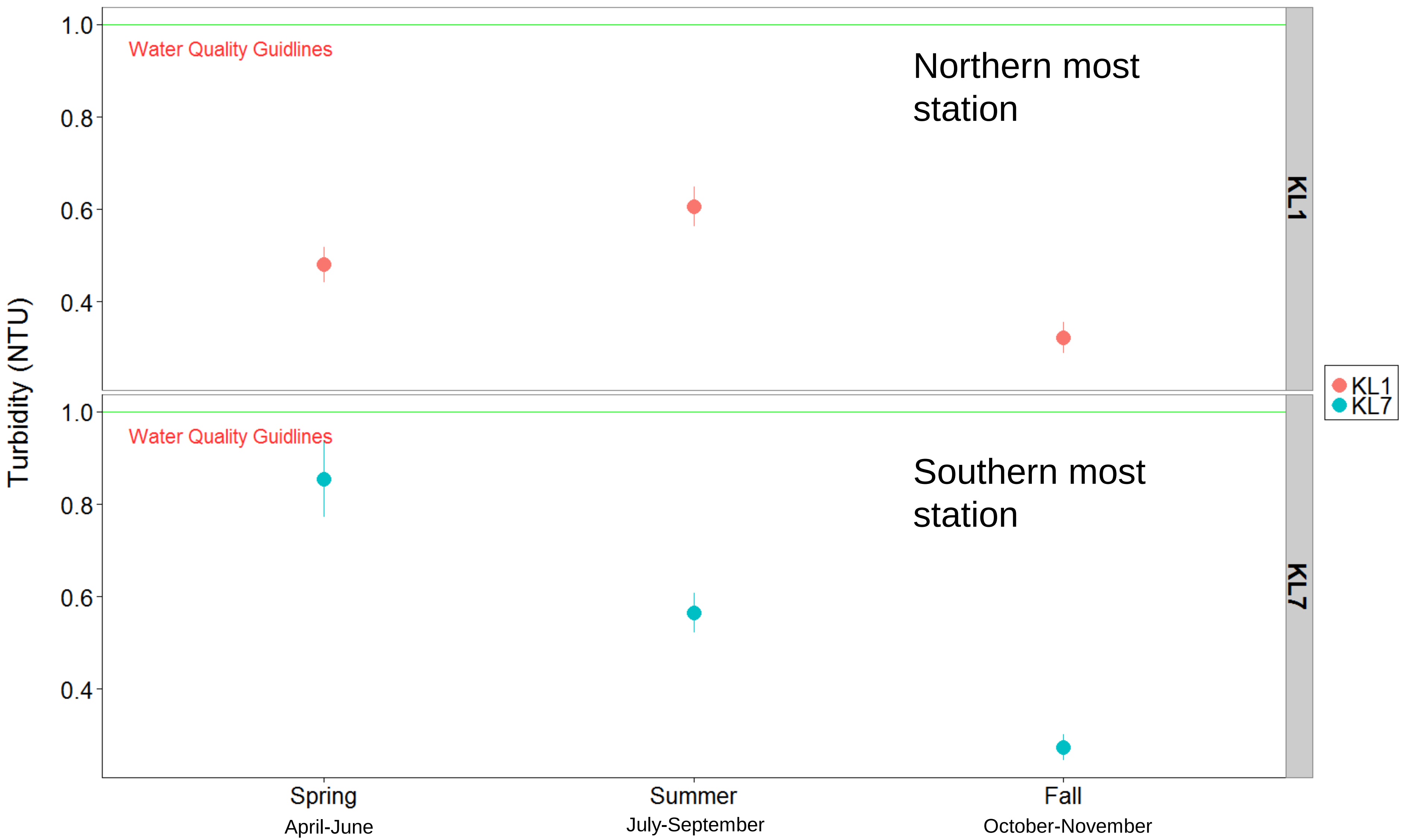
South Arm Secchi



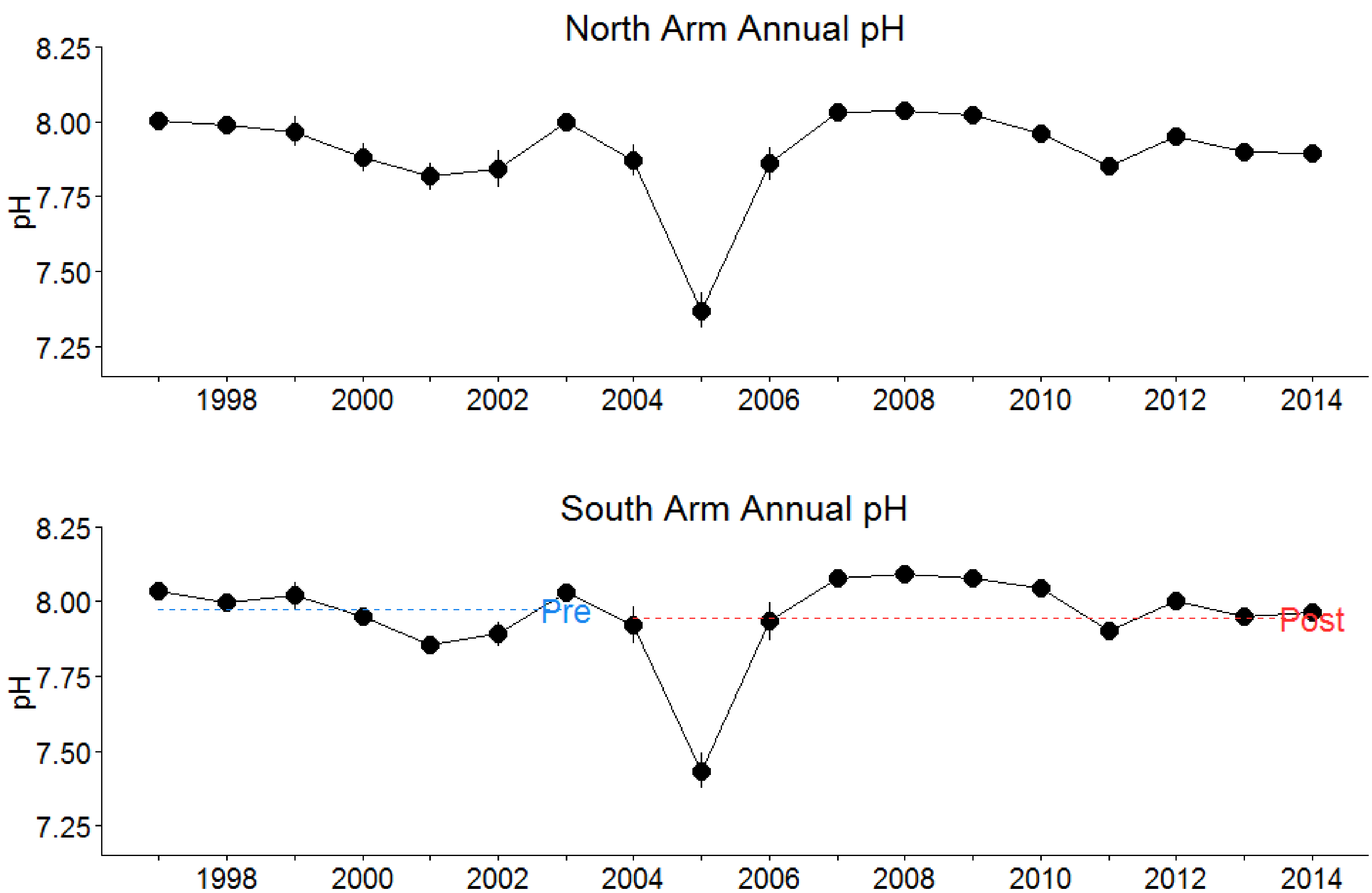
North Arm Secchi



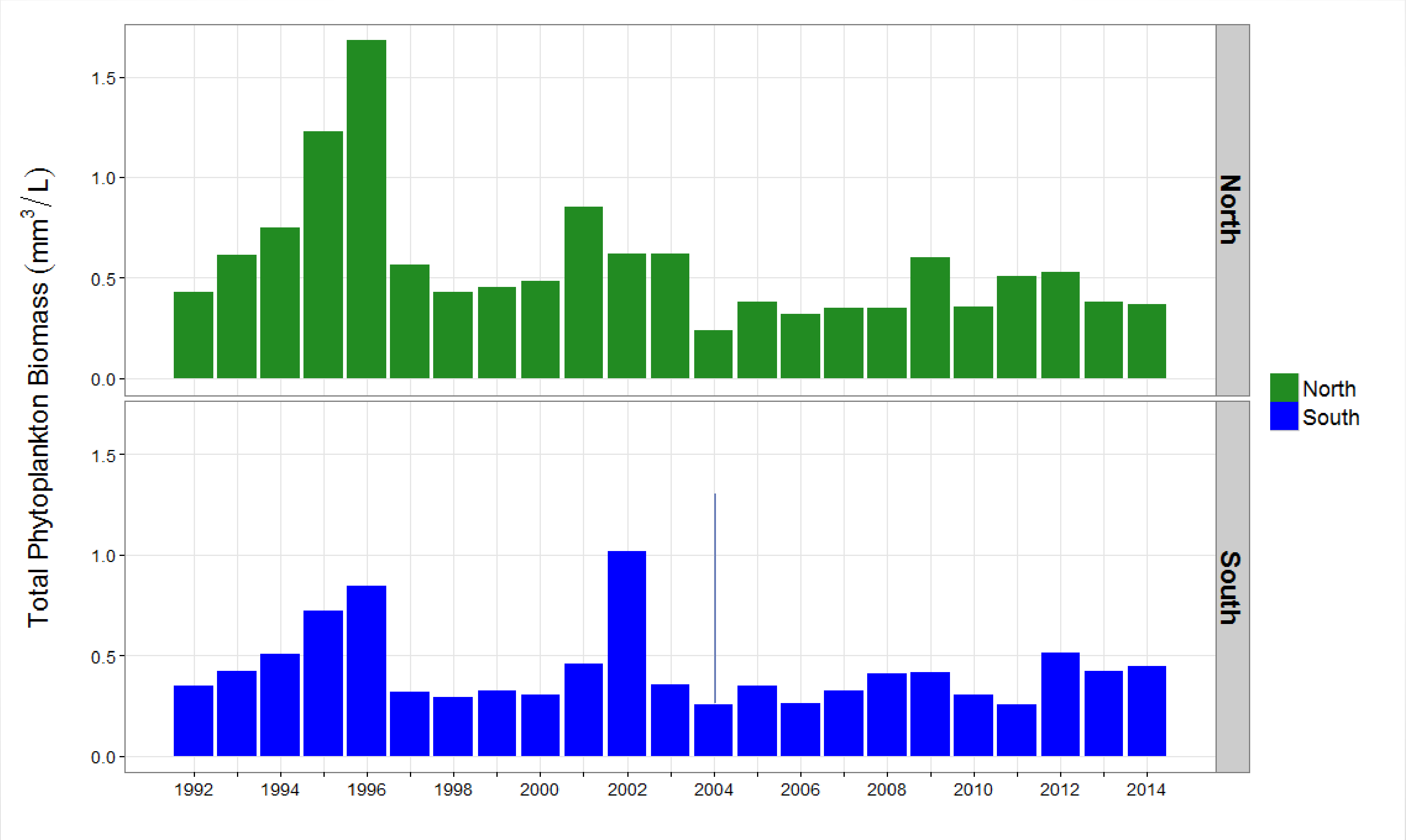
Turbidity


Turbidity (NTU)
1.0
0.8
0.6
0.4
Water Quality Guidlines
Northern most station
KL1
Water Quality Guidlines
Southern most station
KL7
KL1
KL7
Spring
April-June
Summer
July-September
Fall
October-November

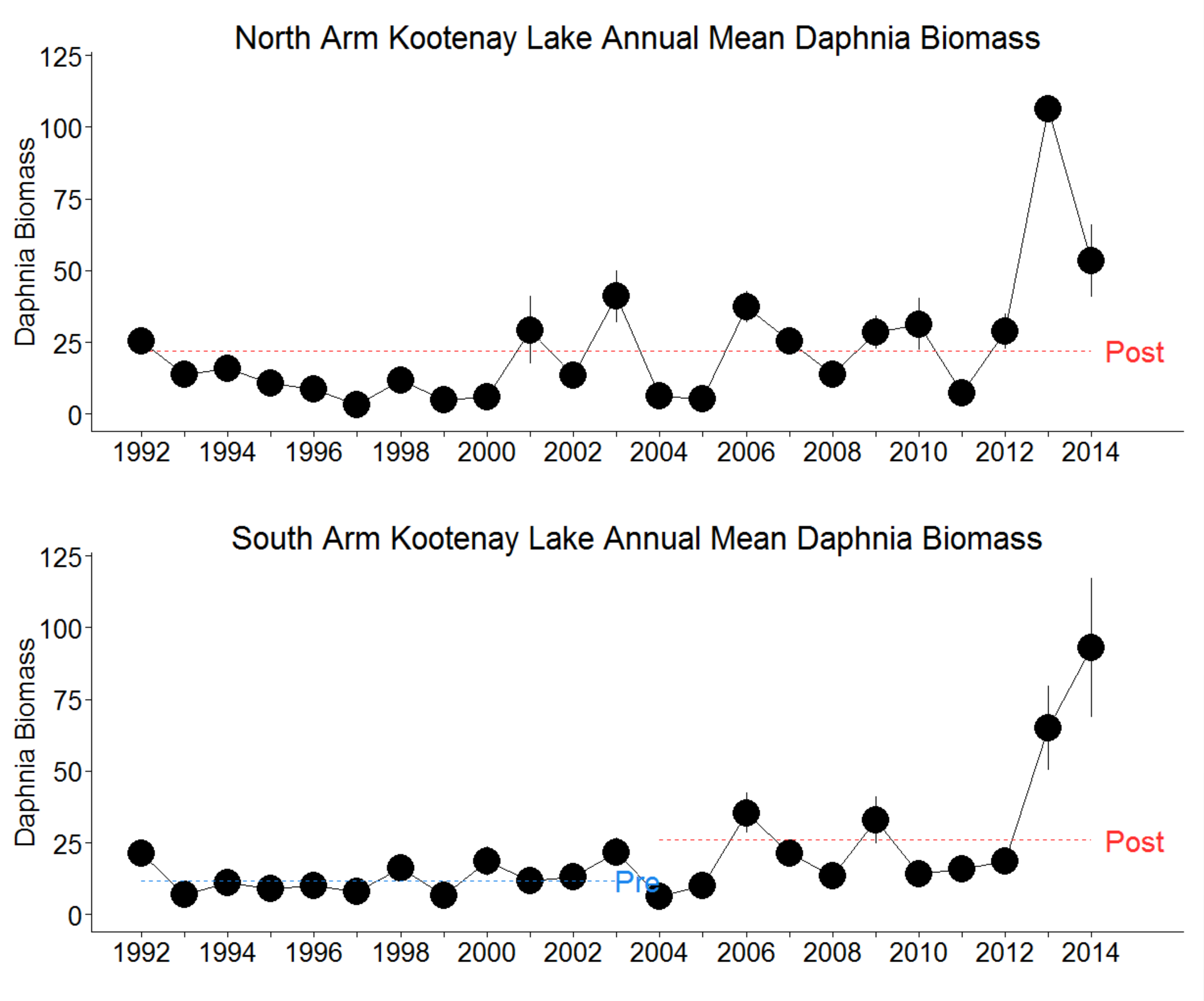
pH


North Arm Annual pH
8.25
8.00
7.75
7.50
7.25
pH
1998
2000
2002
2004
2006
2008
2010
2012
2014
South Arm Annual pH
8.25
8.00
7.75
7.50
7.25
pH
Pre
Post
1998
2000
2002
2004
2006
2008
2010
2012
2014

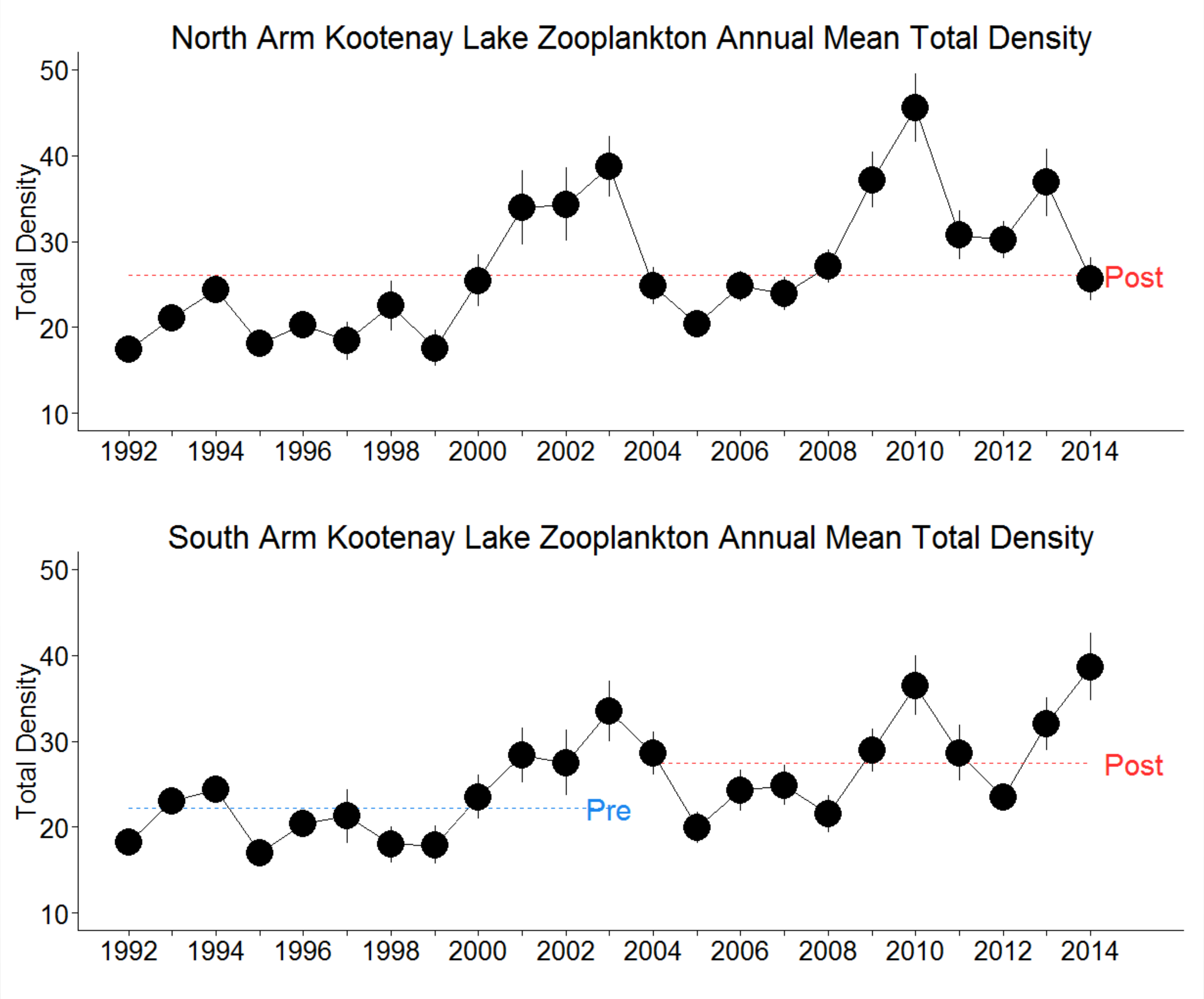
Phytoplankton



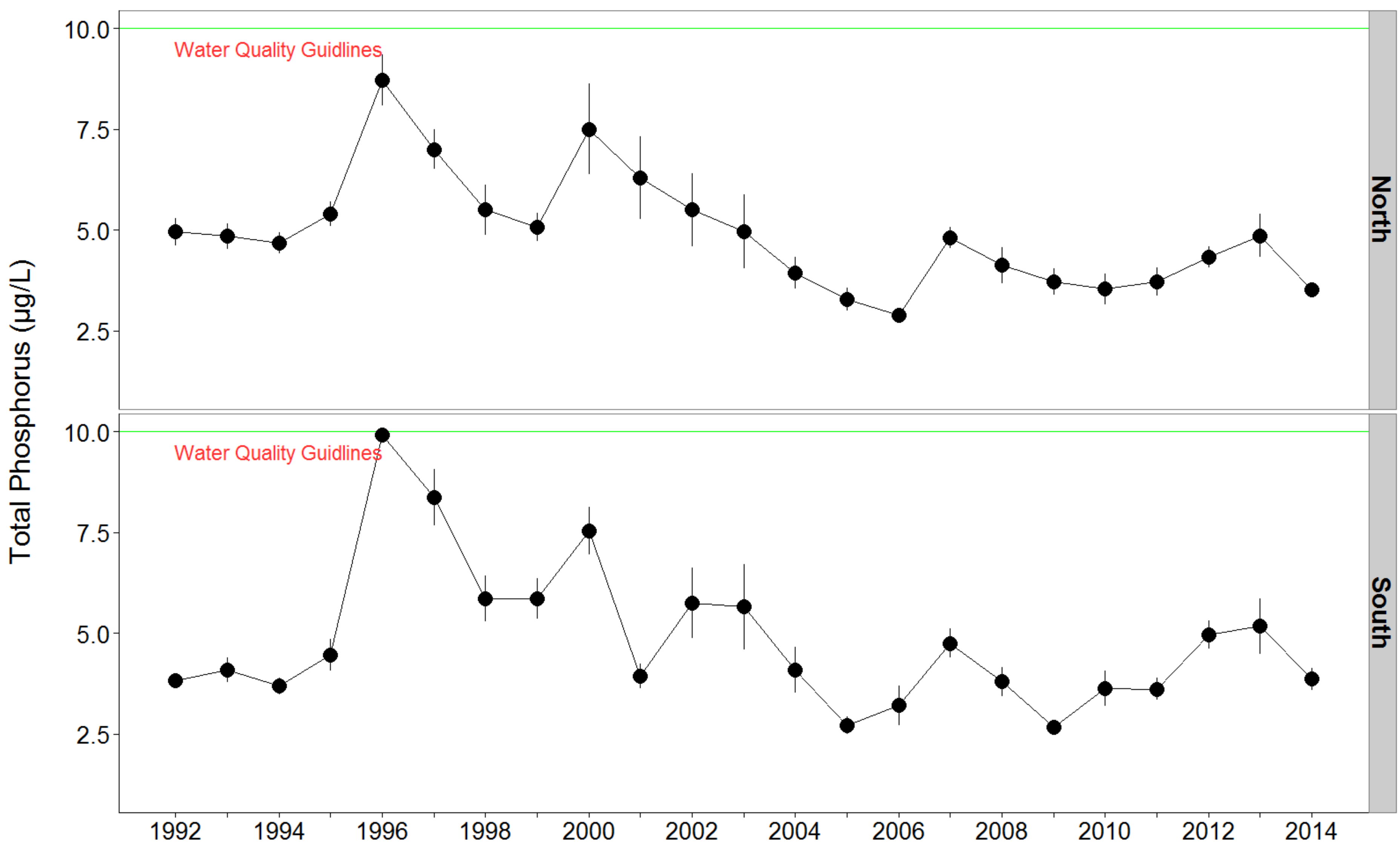
Zooplankton – Adult Kokanee Food
Daphnia



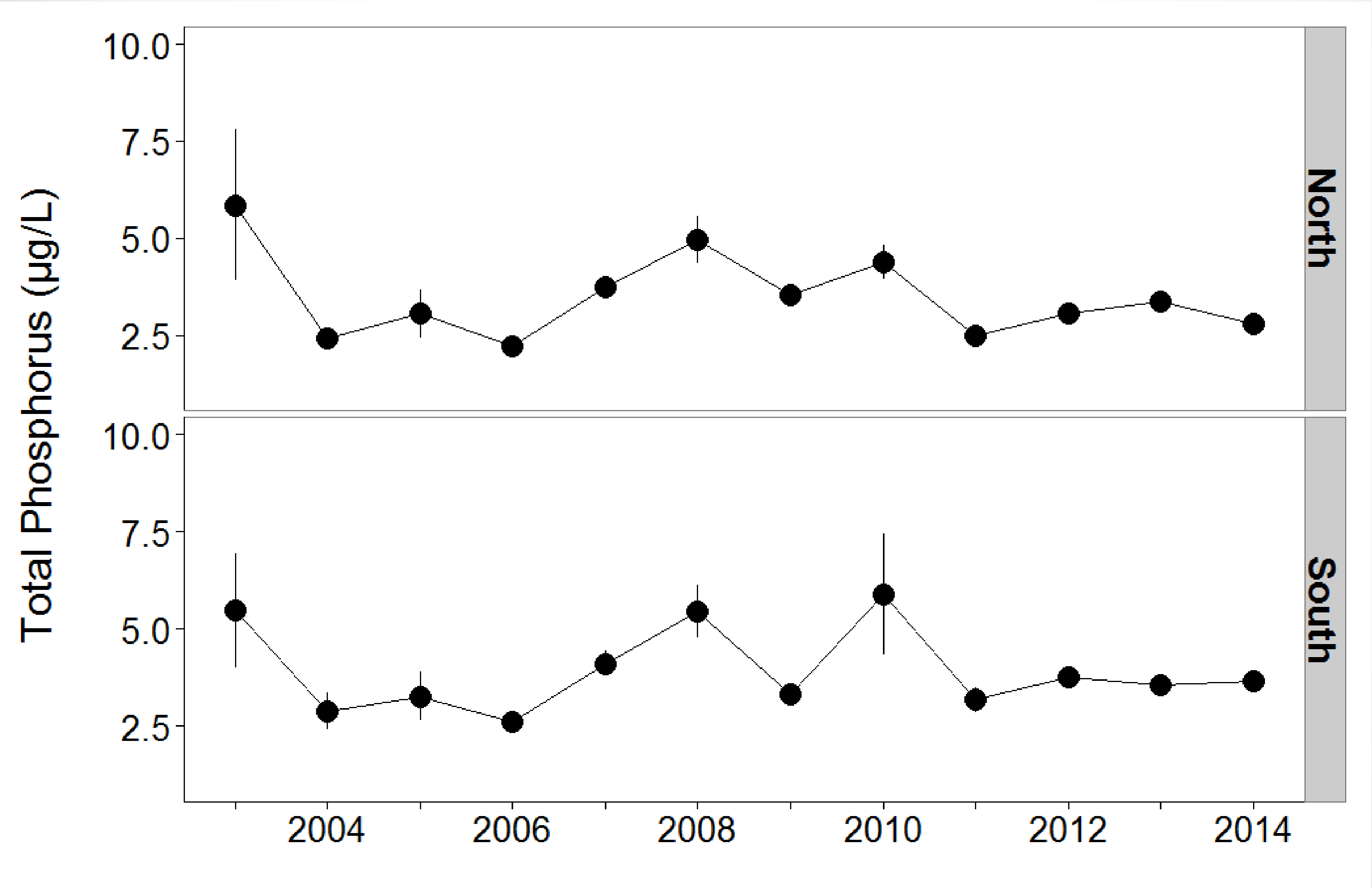
Zooplankton – Kokanee Food
Total Density



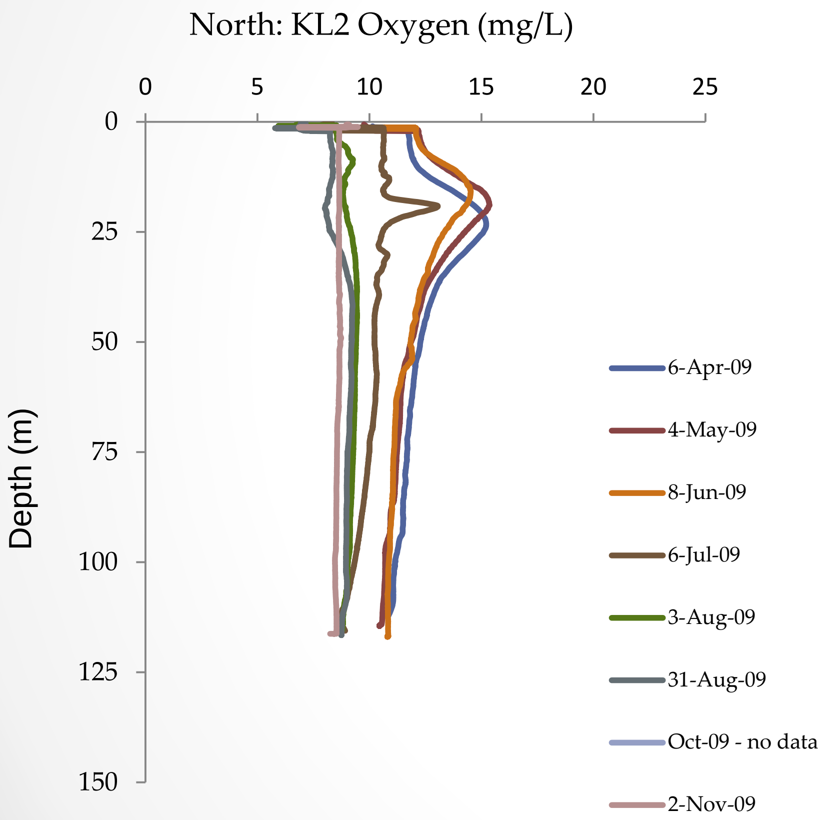
Phosphorus – Top 20 meters

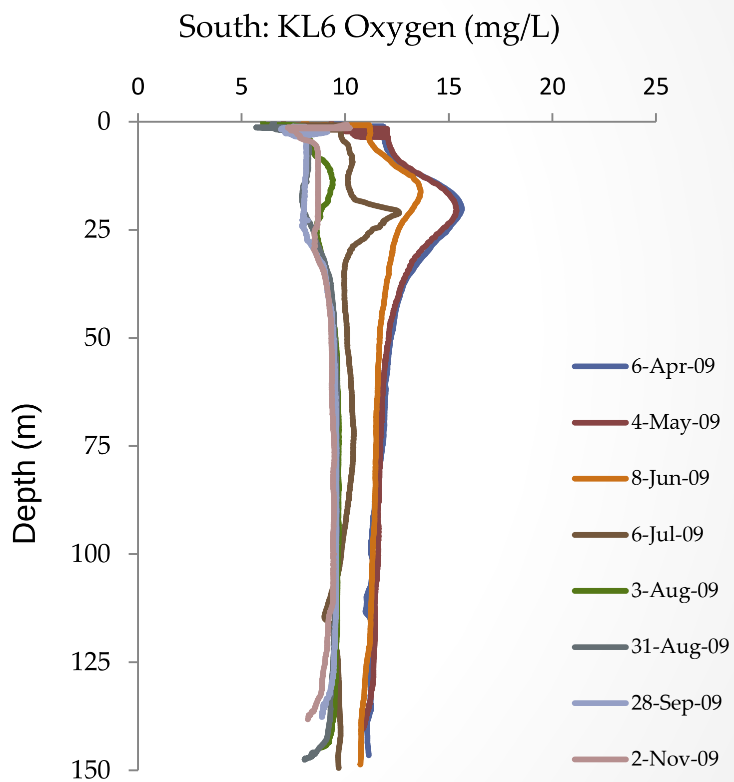


Phosphorus - Bottom

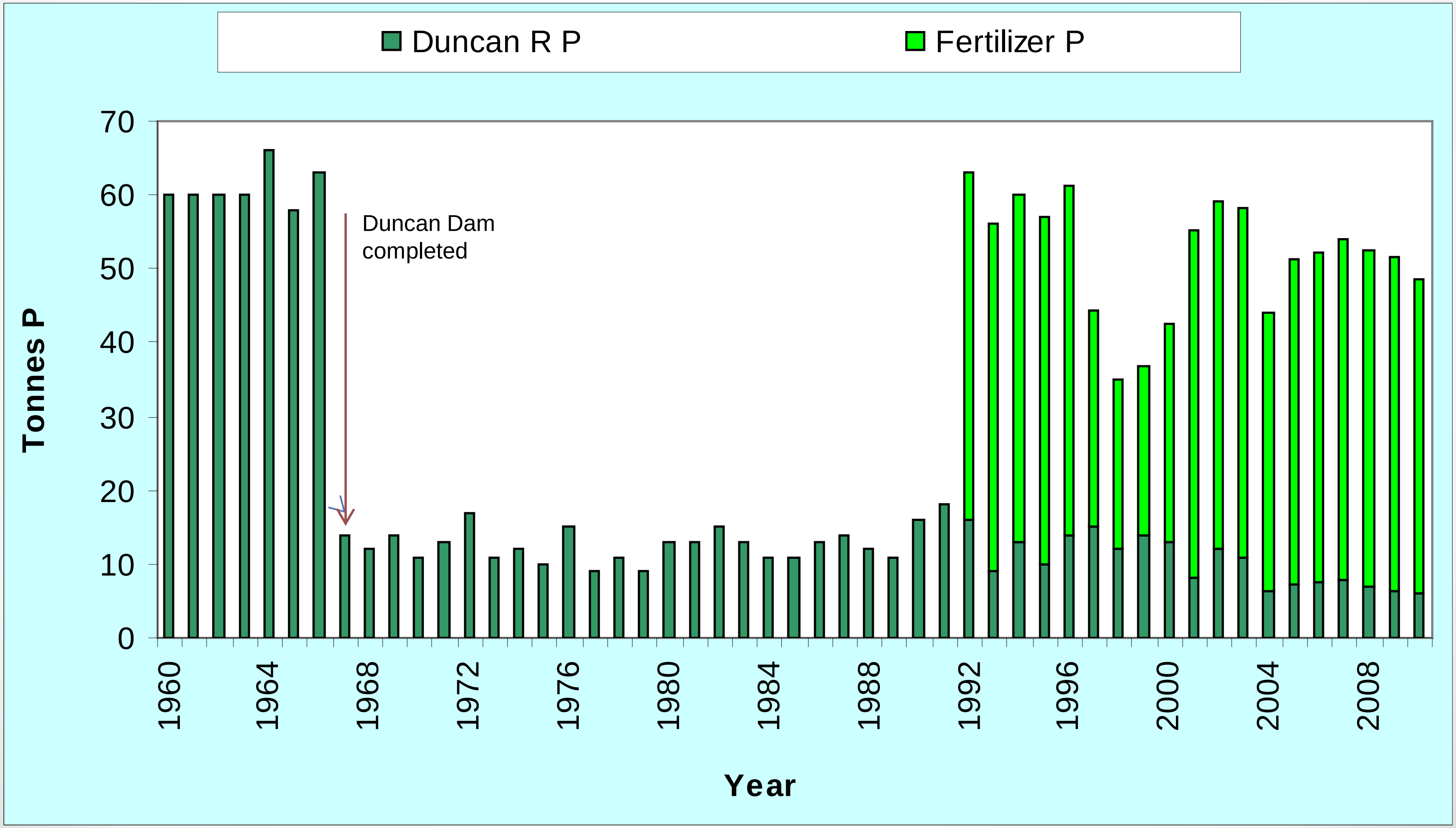


Oxygen Profile in a higher phytoplankton year

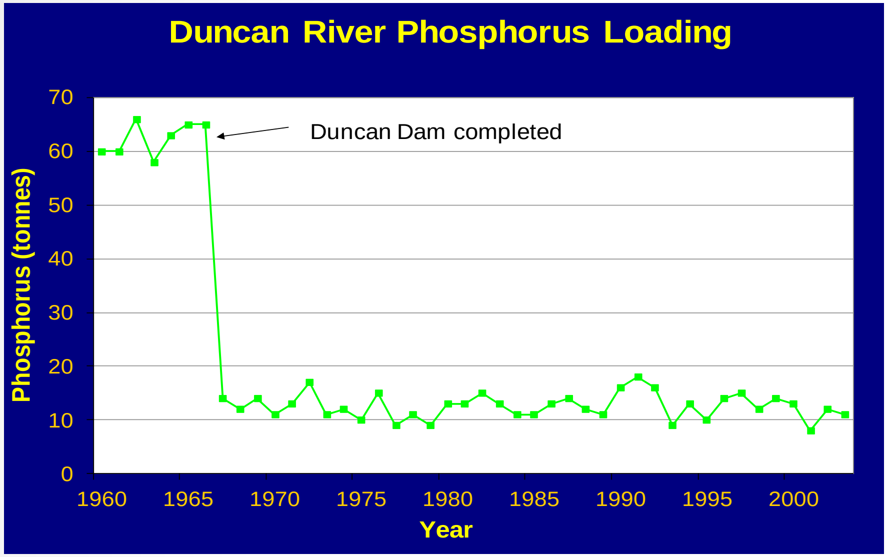


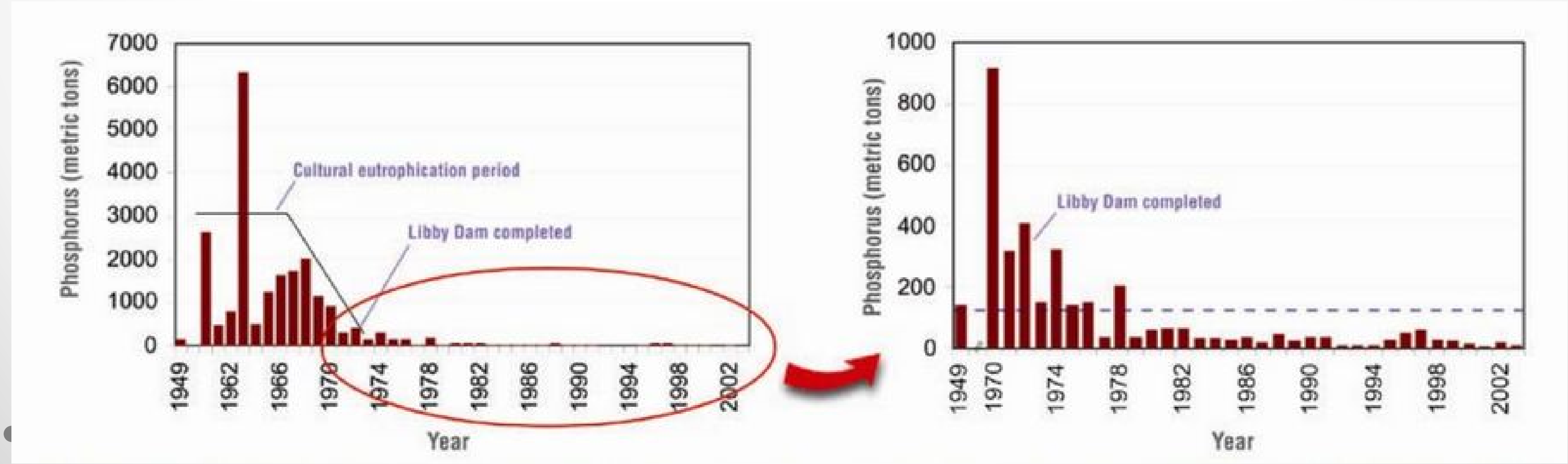


Phosphorus loading

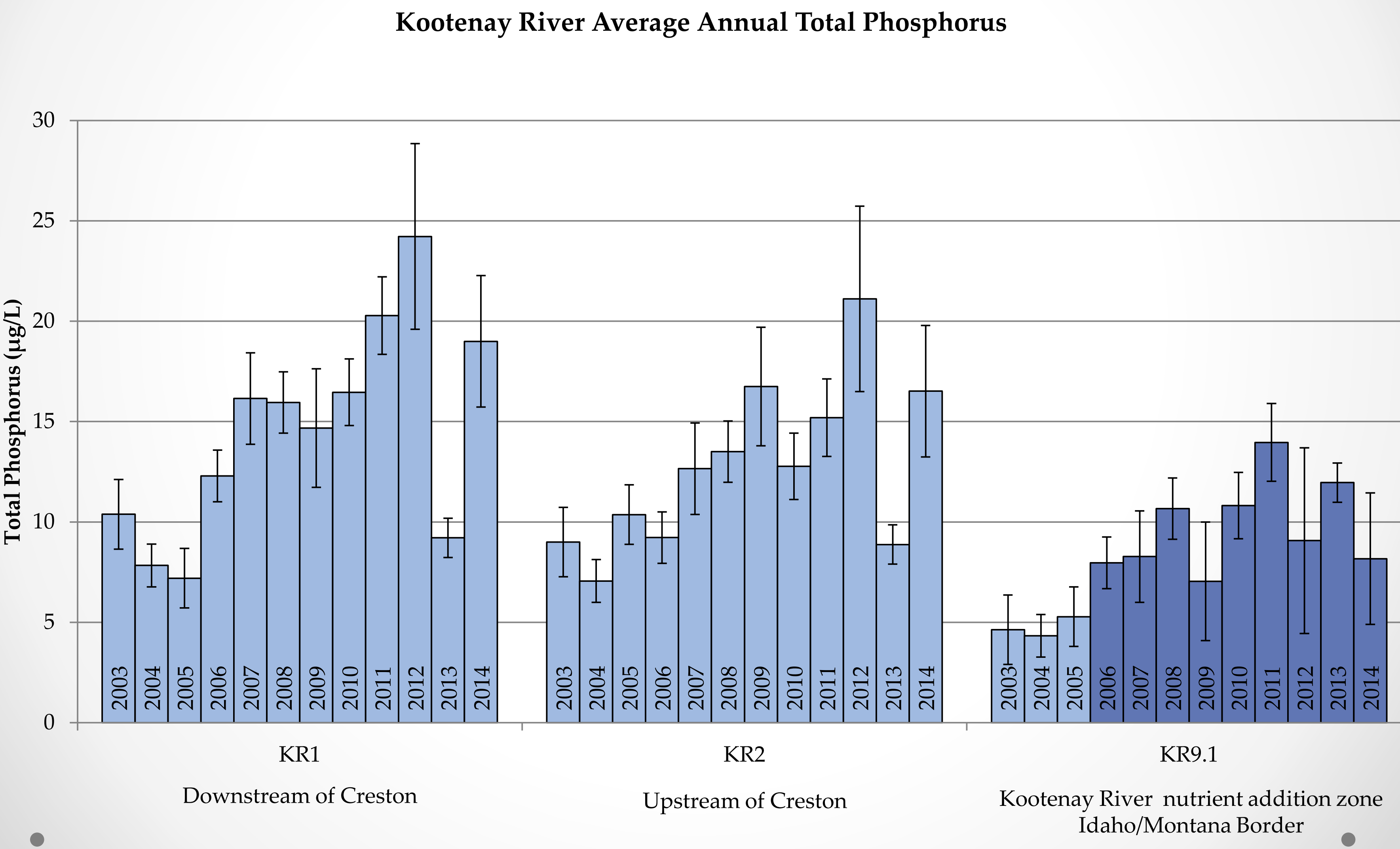


Phosphorus loading

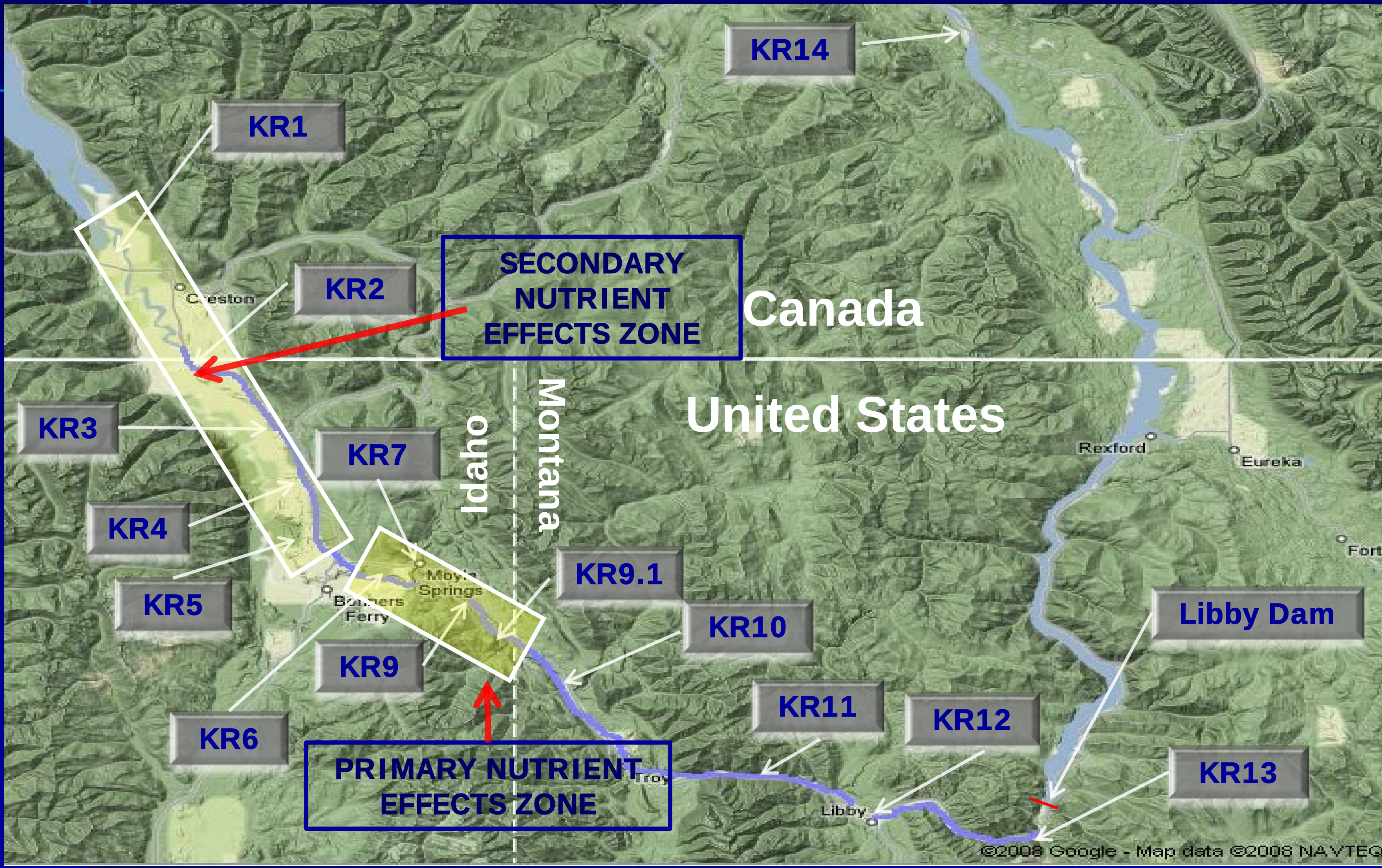




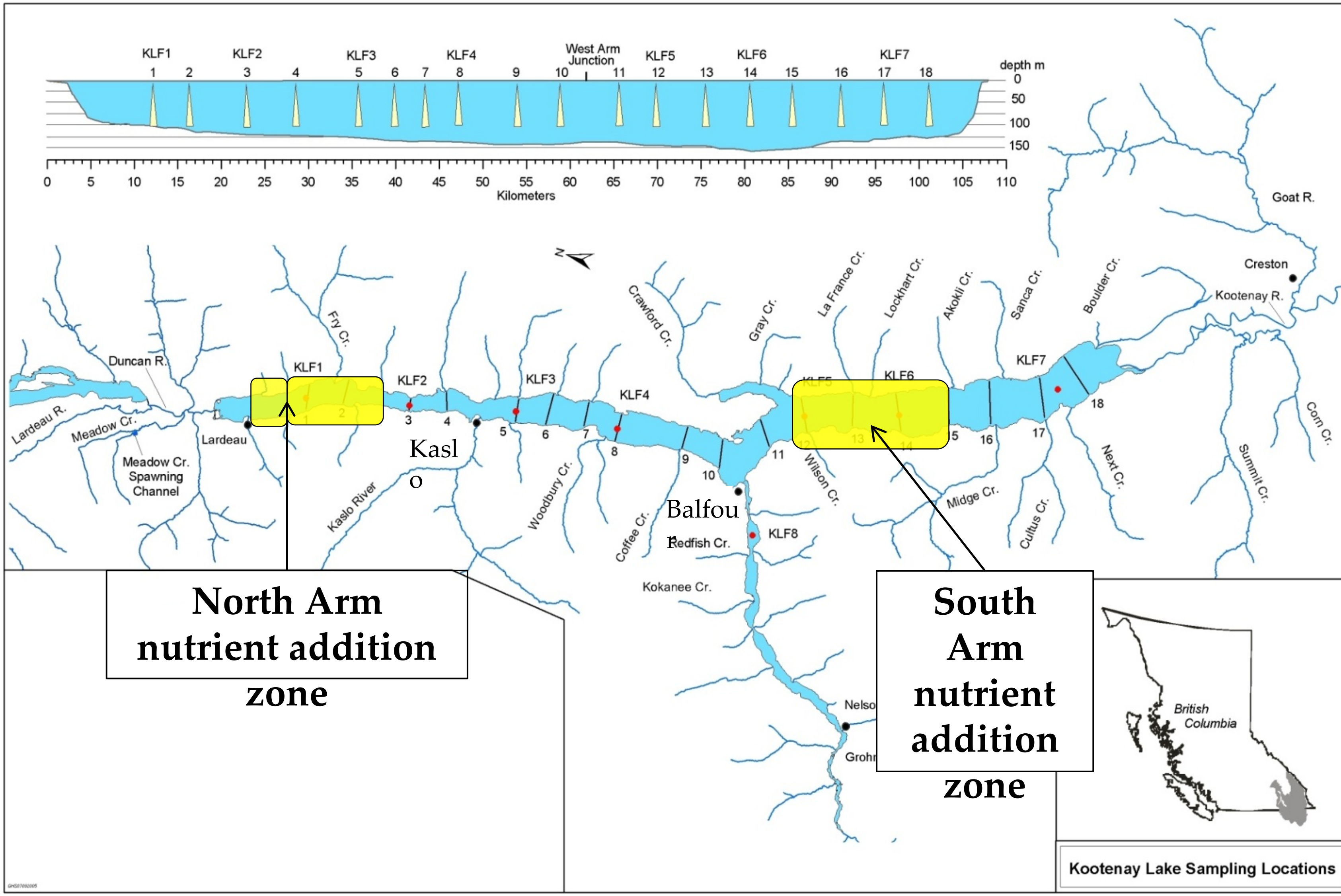
Phosphorus loading in Kootenay River



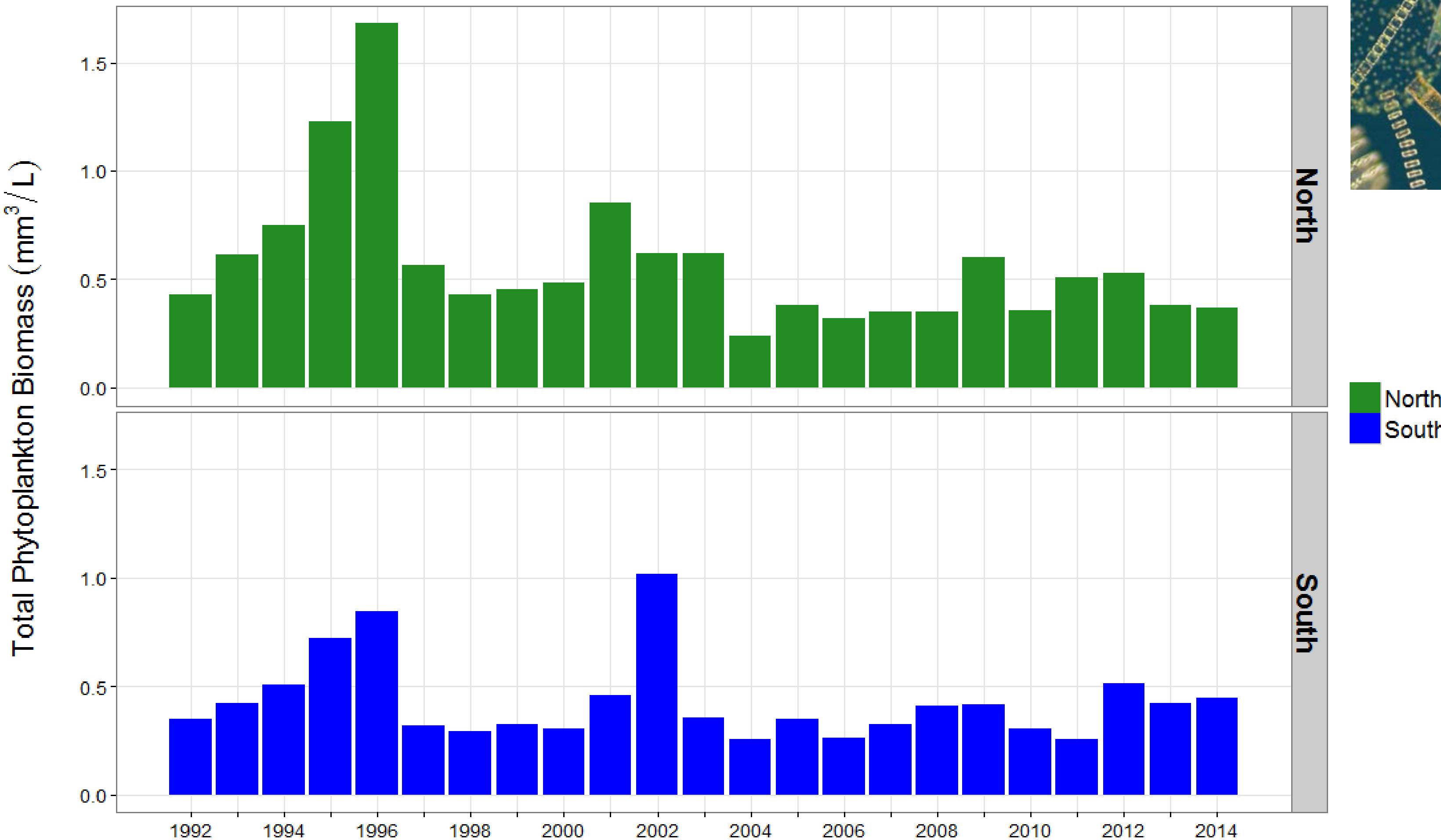
Kootenai(y) River Nutrient Addition Bio-Monitoring Sites

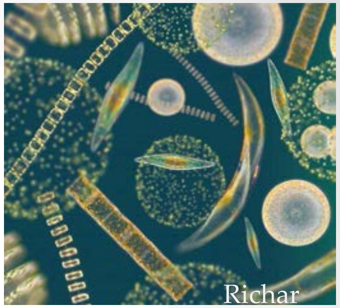


Nutrient addition Zones

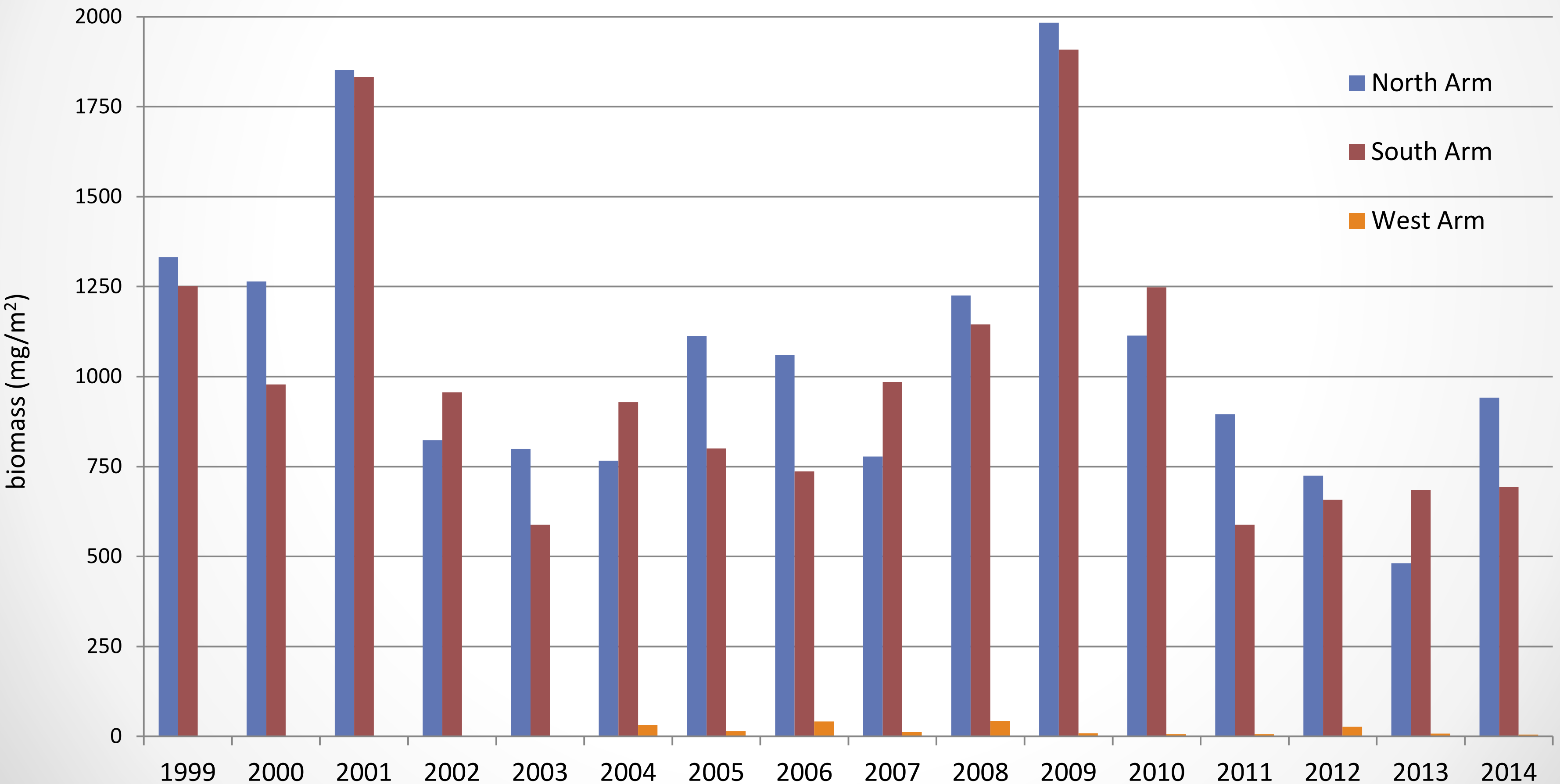


Annual Phytoplankton Biomass





Mysids

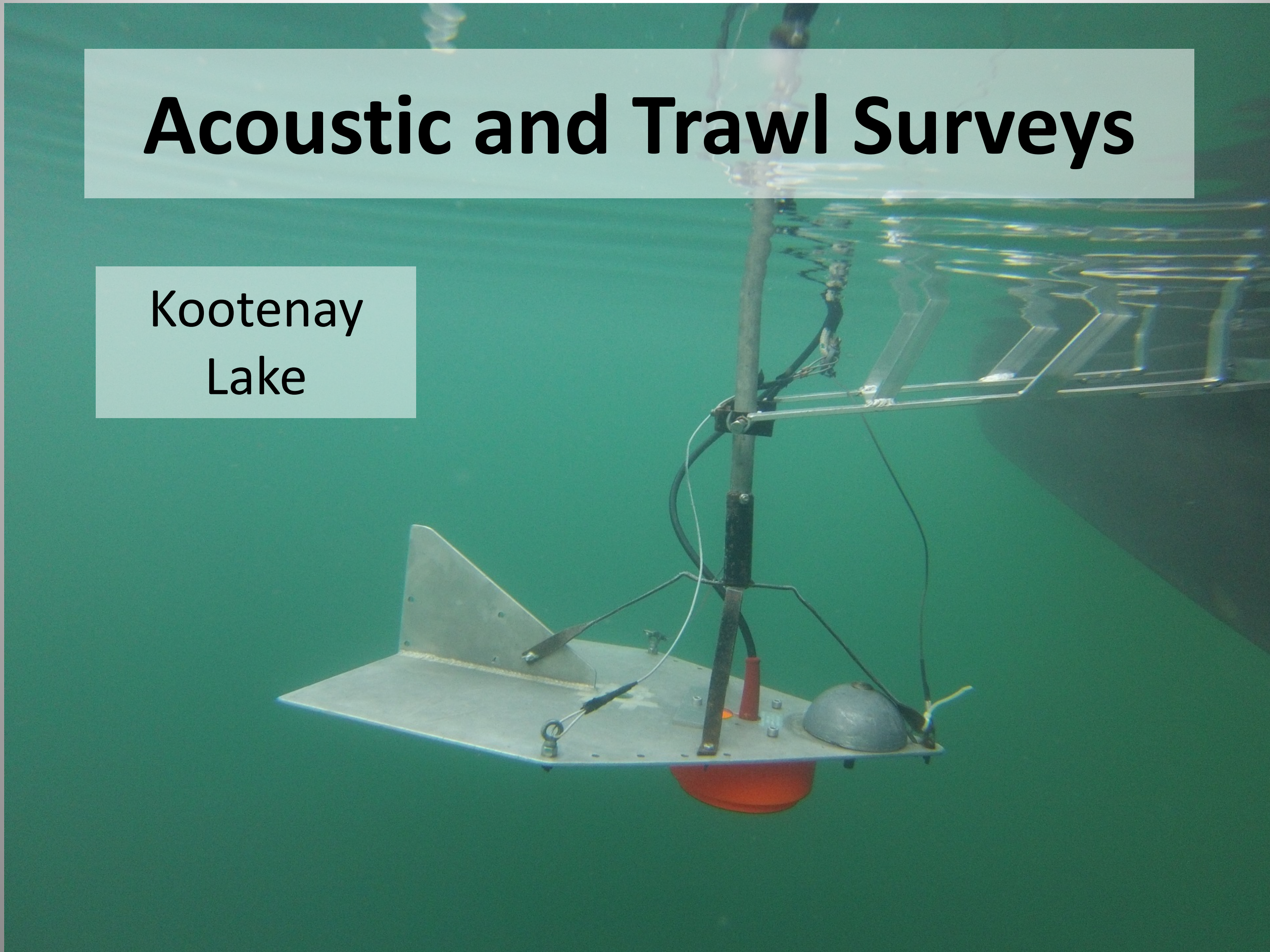


biomass (mg/m²)
2000
1750
1500
1250
1000
750
500
250
0
North Arm
South Arm
West Arm
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

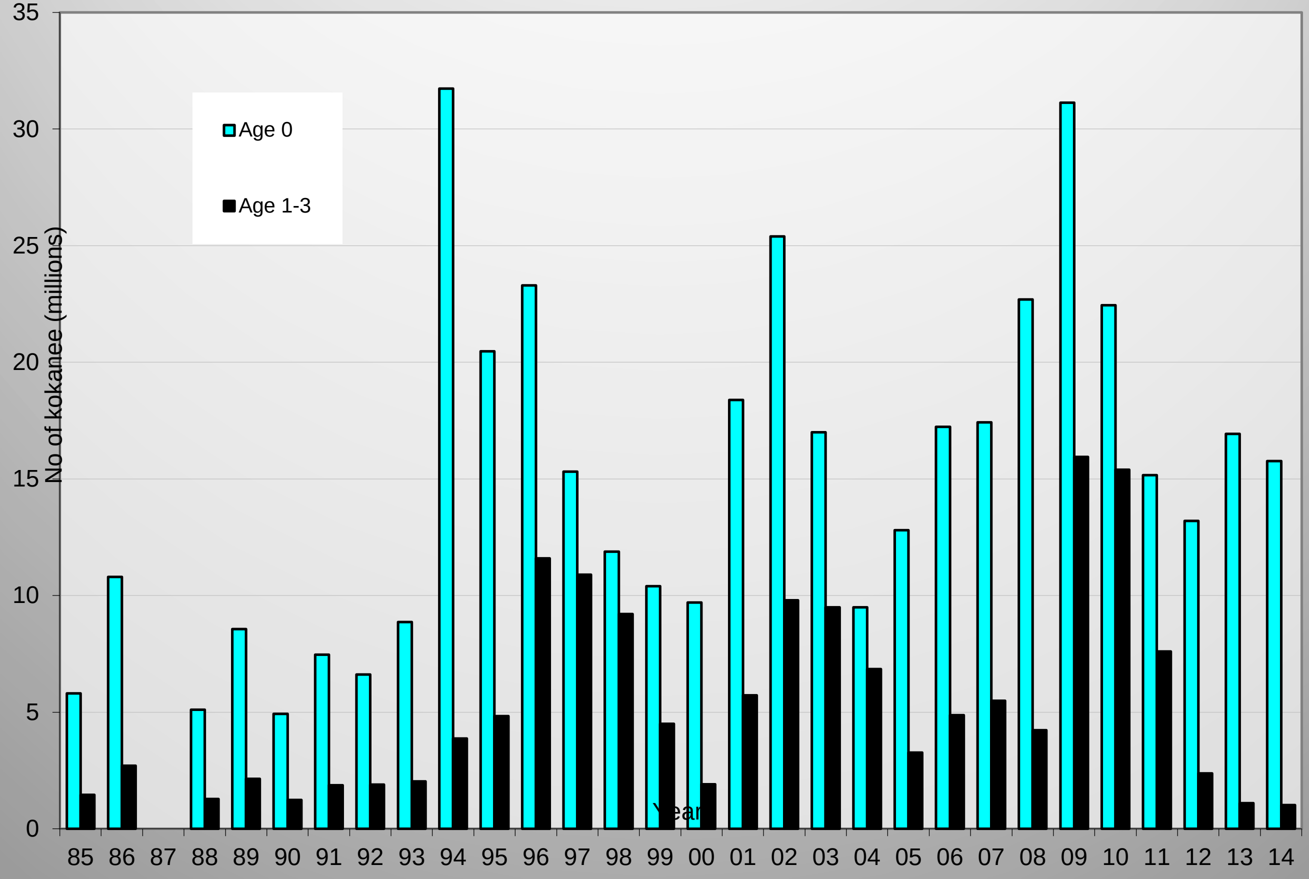
Appendix B2 - D. Johner, FLNRO – Kootenay Lake Acoustic and Trawl Surveys

Acoustic and Trawl Surveys

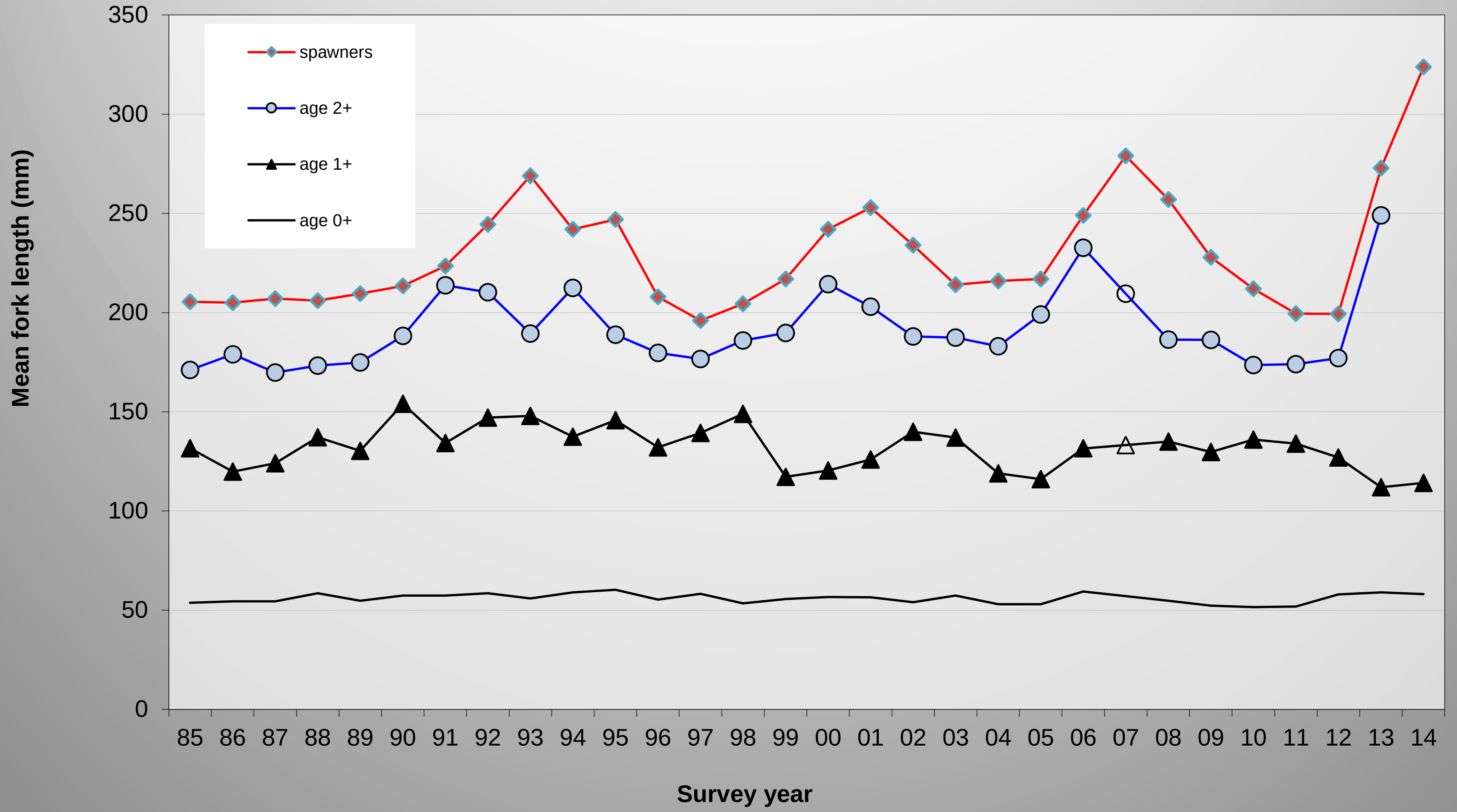
Kootenay Lake

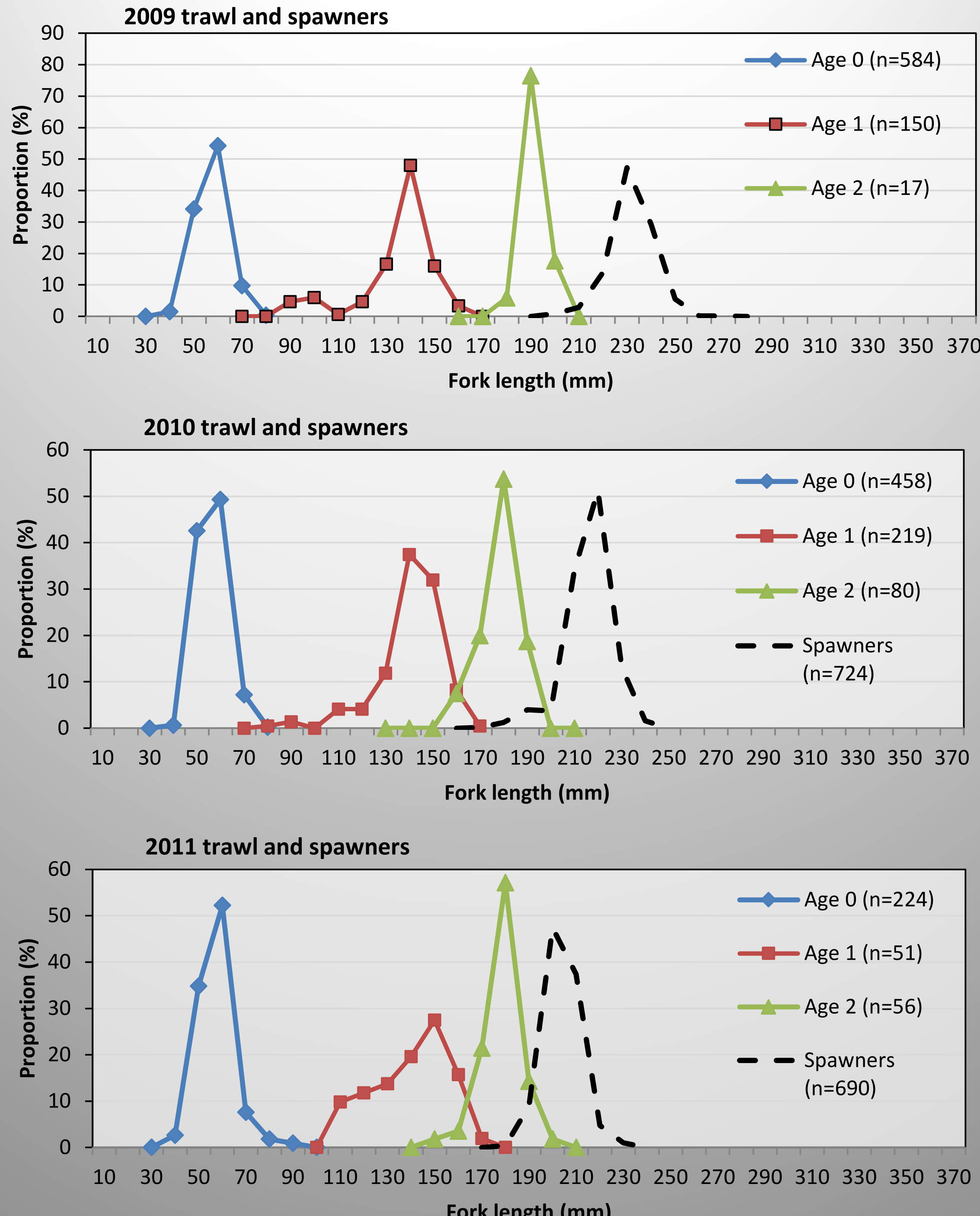


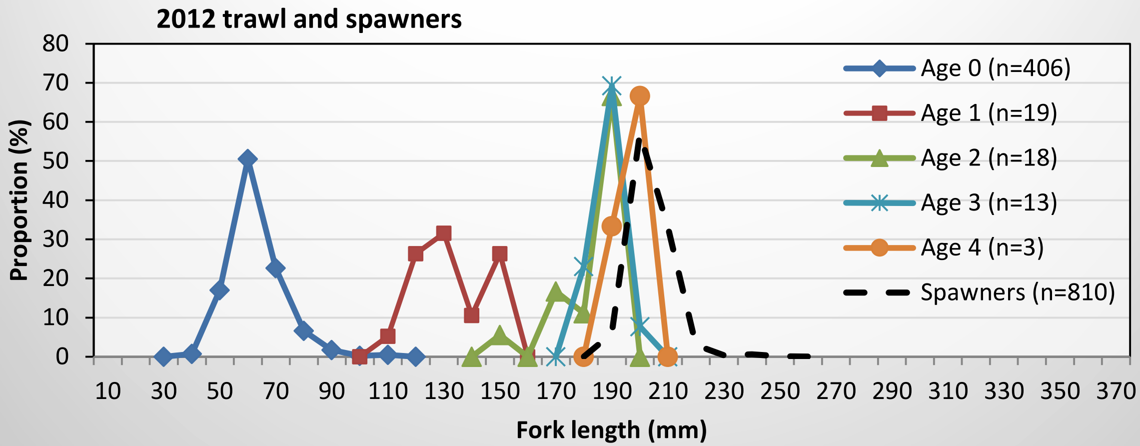
Kokanee Abundance

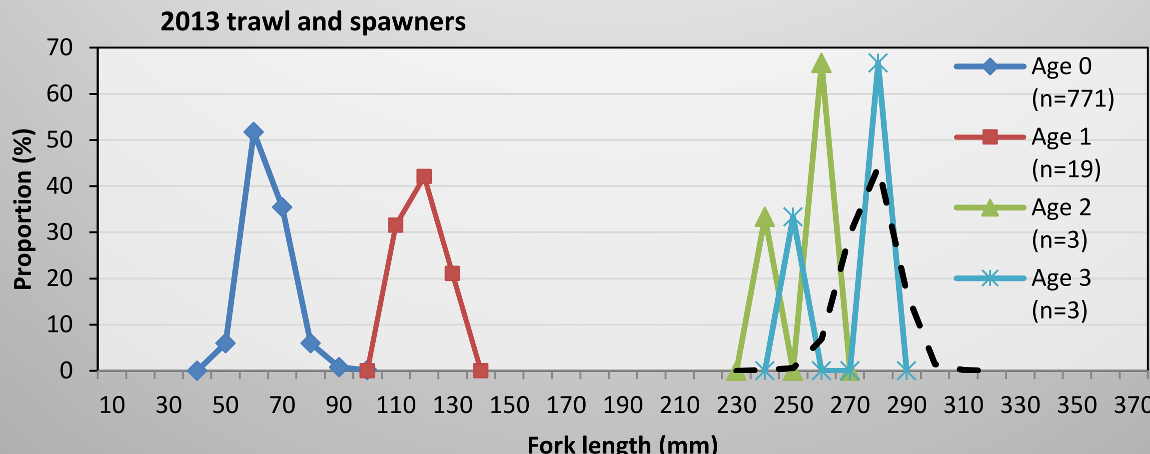


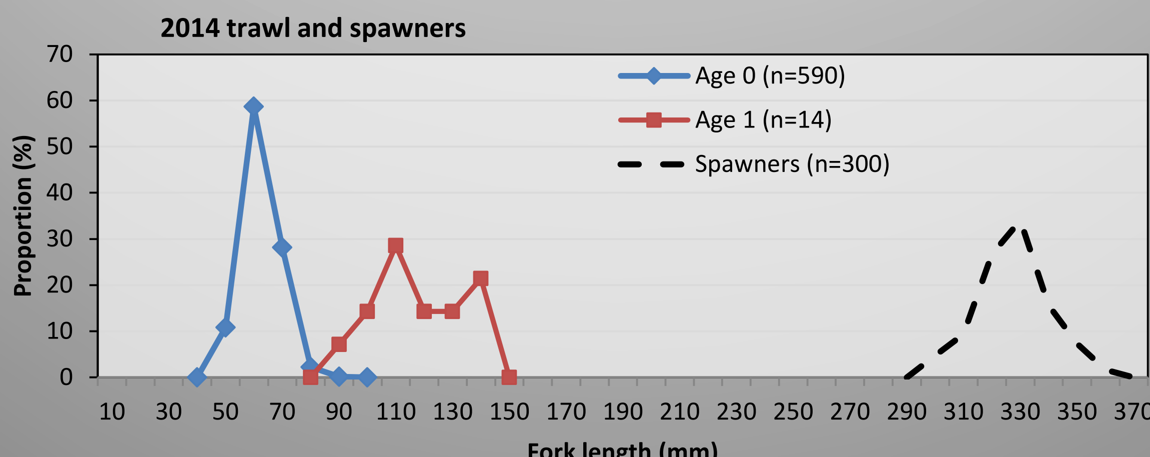
Kokanee Size at Age



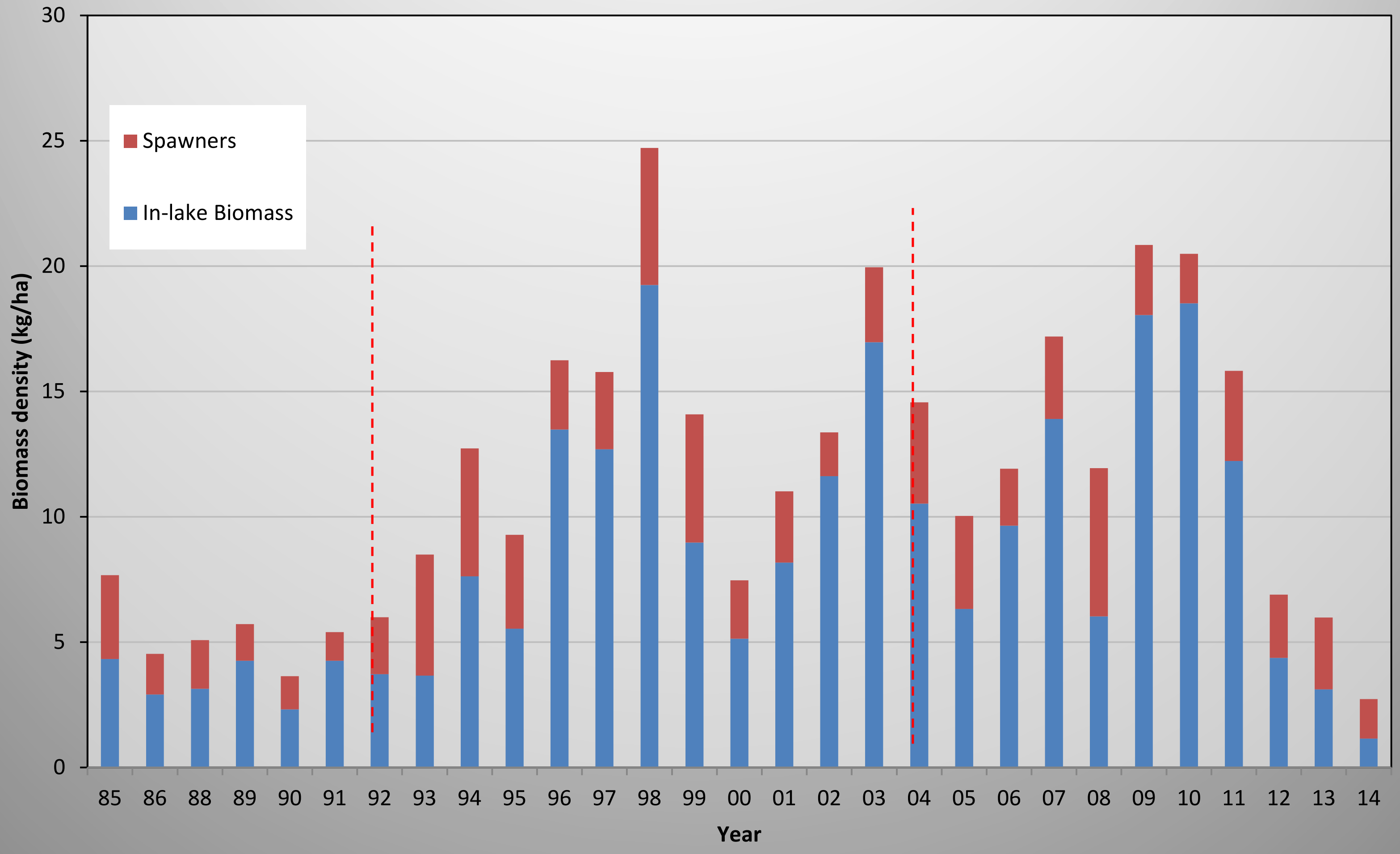

2009 trawl and spawners
Proportion (%)
Fork length (mm)
Age 0 (n=584)
Age 1 (n=150)
Age 2 (n=17)
2010 trawl and spawners
Proportion (%)
Fork length (mm)
Age 0 (n=458)
Age 1 (n=219)
Age 2 (n=80)
Spawners (n=724)
2011 trawl and spawners
Proportion (%)
Fork length (mm)
Age 0 (n=224)
Age 1 (n=51)
Age 2 (n=56)
Spawners (n=690)

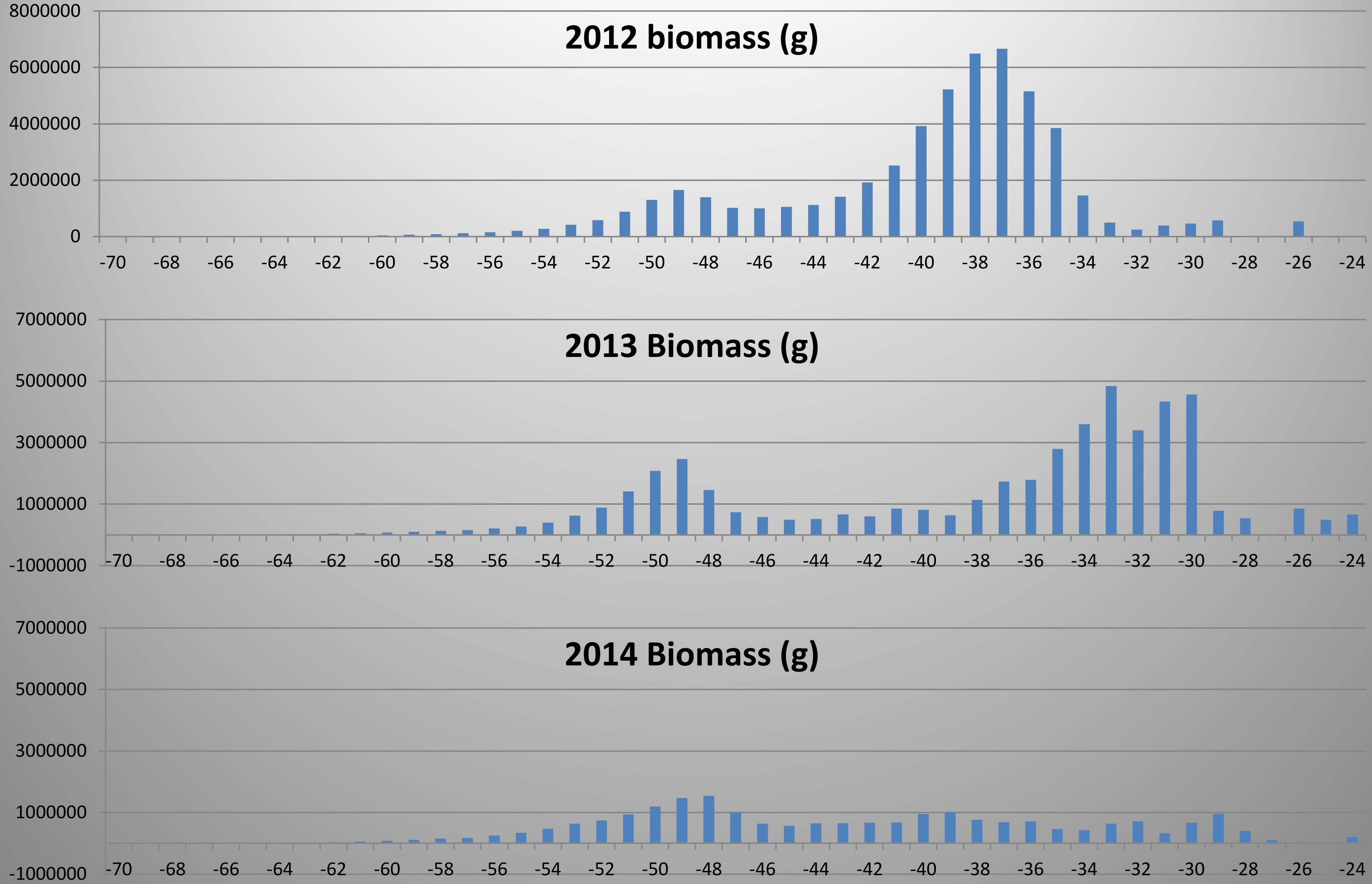

2012 trawl and spawners
Proportion (%)
Fork length (mm)
Age 0 (n=406)
Age 1 (n=19)
Age 2 (n=18)
Age 3 (n=13)
Age 4 (n=3)
Spawners (n=810)


2013 trawl and spawners
Proportion (%)
Fork length (mm)
Age 0 (n=771)
Age 1 (n=19)
Age 2 (n=3)
Age 3 (n=3)


2014 trawl and spawners
Proportion (%)
Fork length (mm)
Age 0 (n=590)
Age 1 (n=14)
Spawners (n=300)

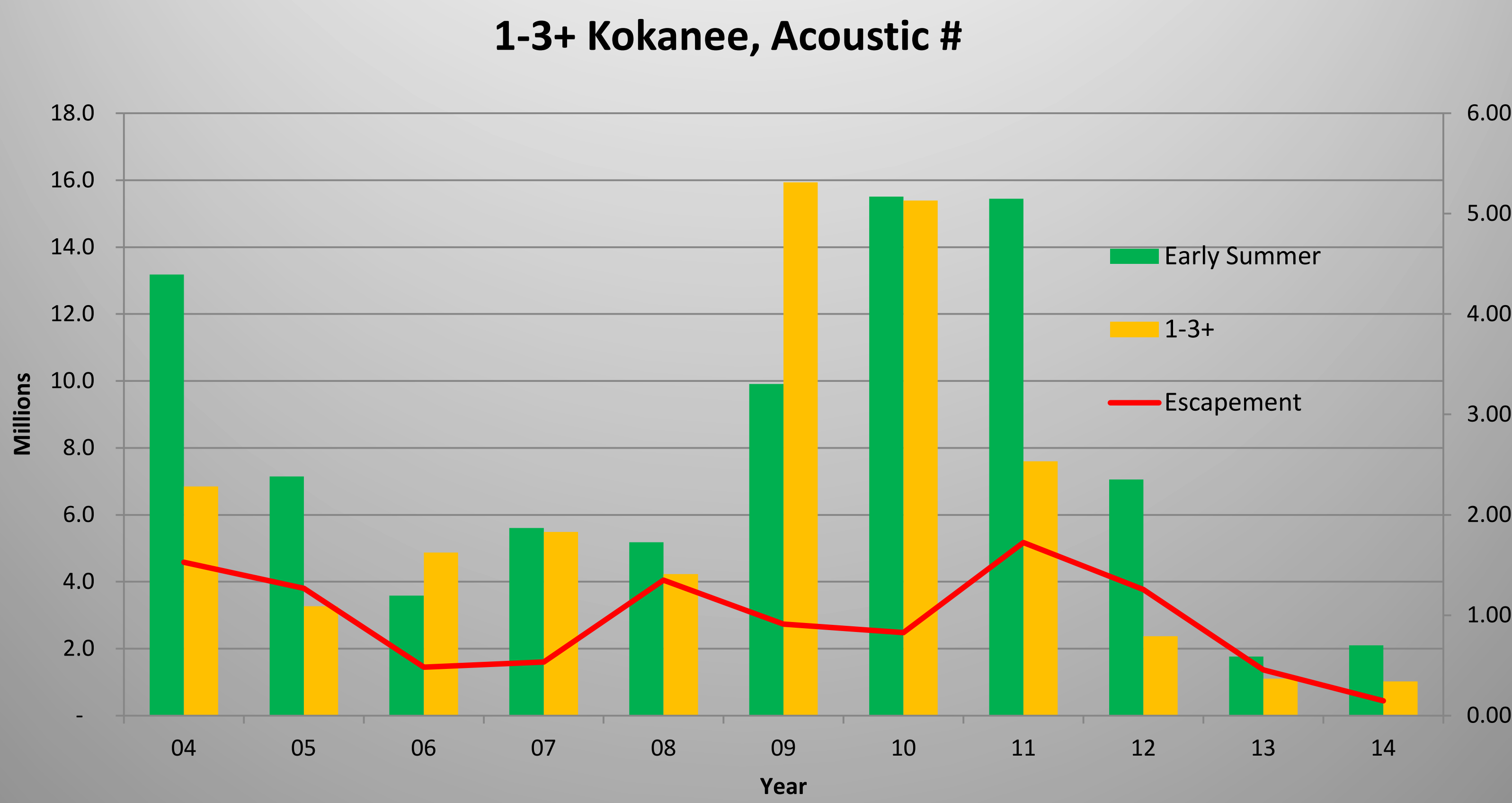
Kokanee Biomass



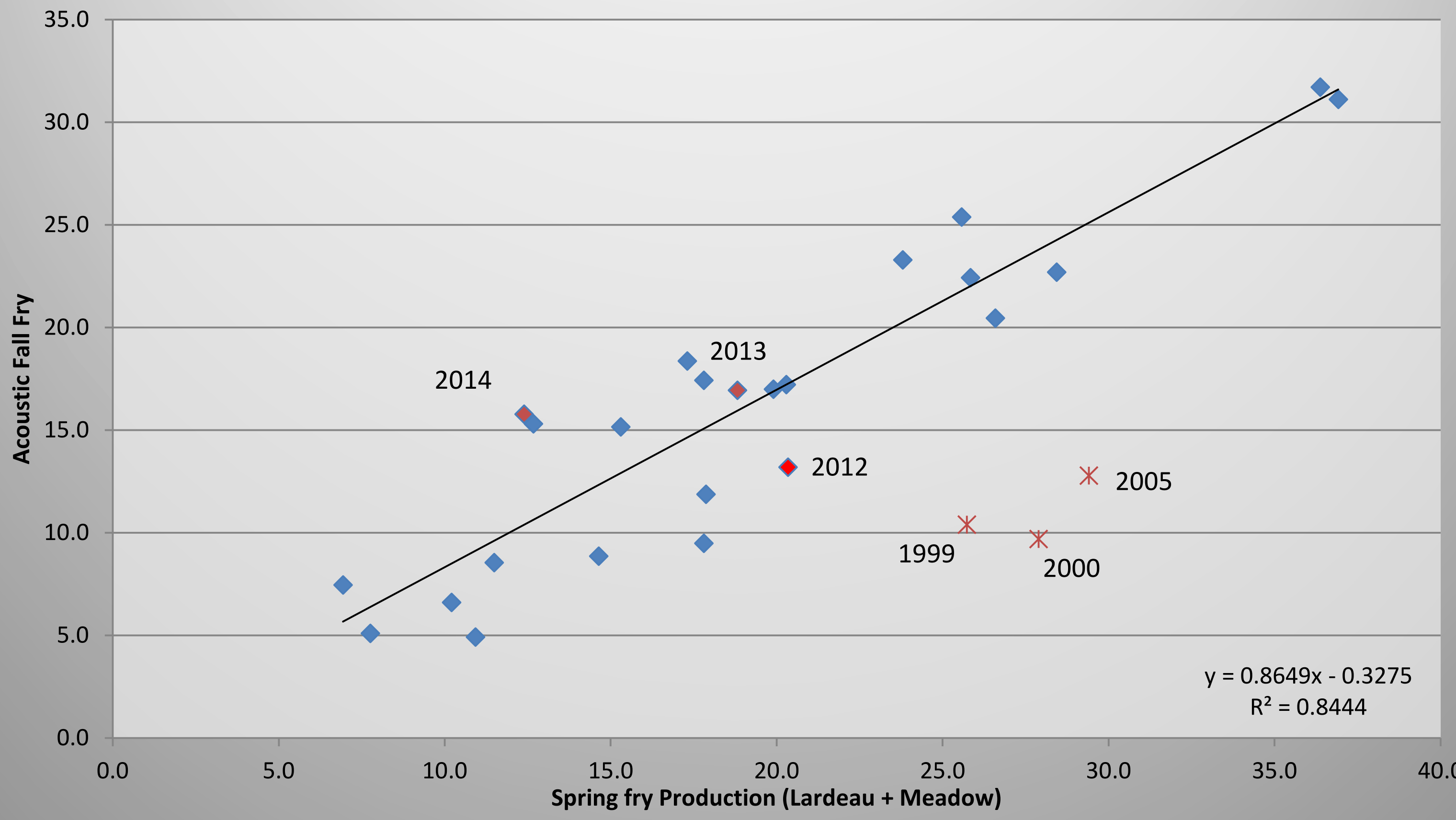


2012 biomass (g)
8000000
6000000
4000000
2000000
0
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24
2013 Biomass (g)
7000000
5000000
3000000
1000000
-1000000
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24
2014 Biomass (g)
7000000
5000000
3000000
1000000
-1000000
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24

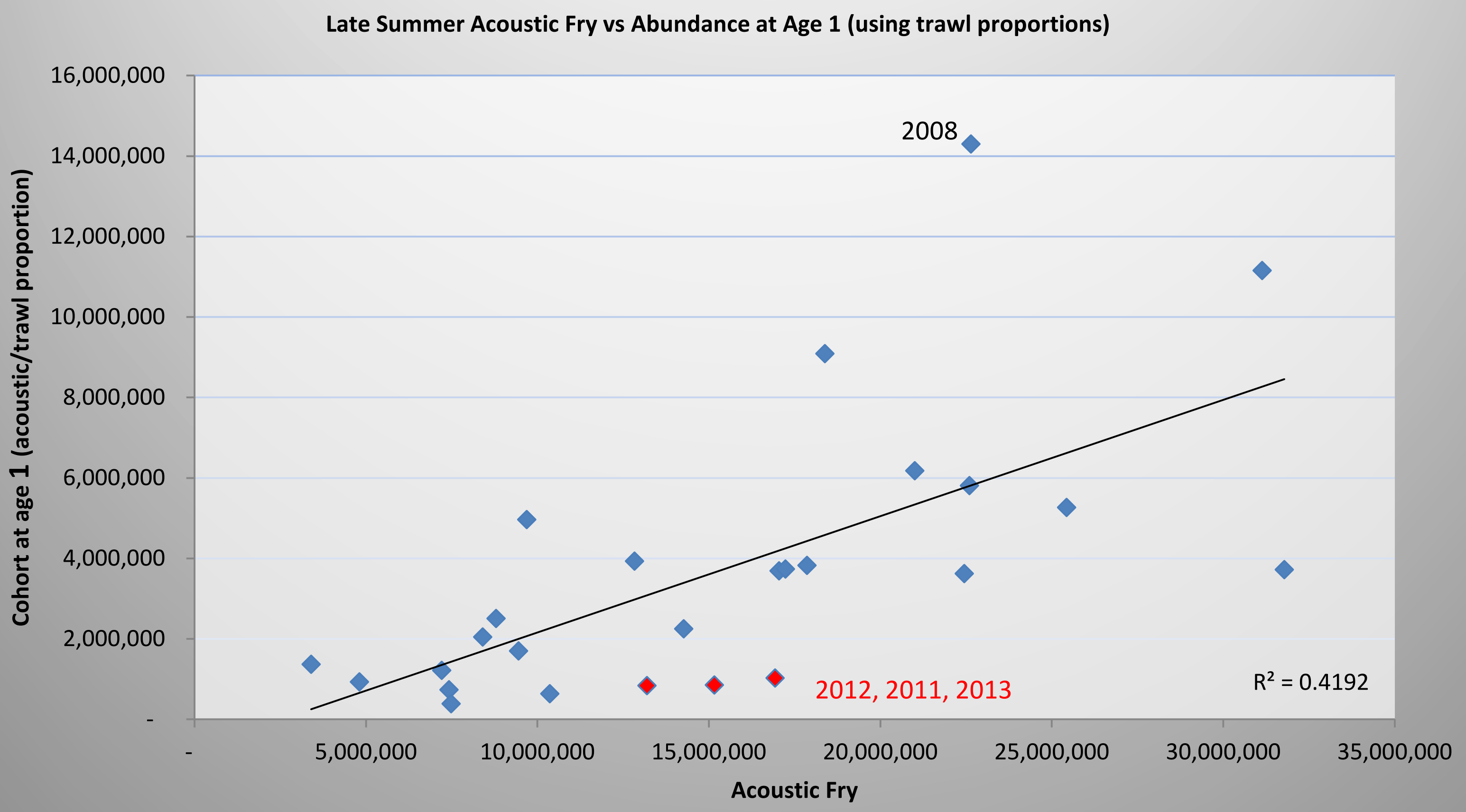
Early Season to Late Season Adult Kokanee Abundance

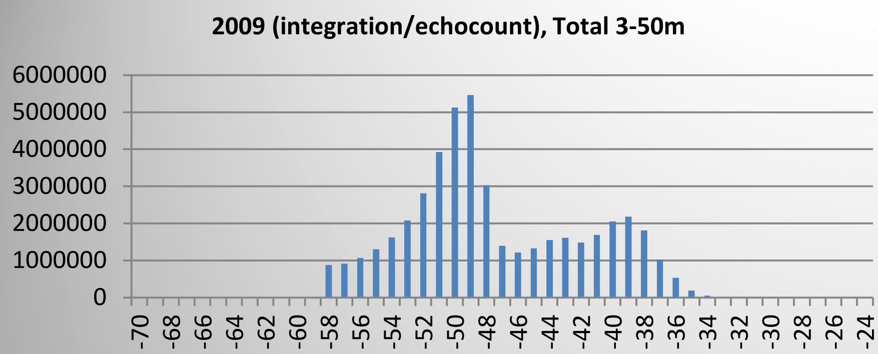


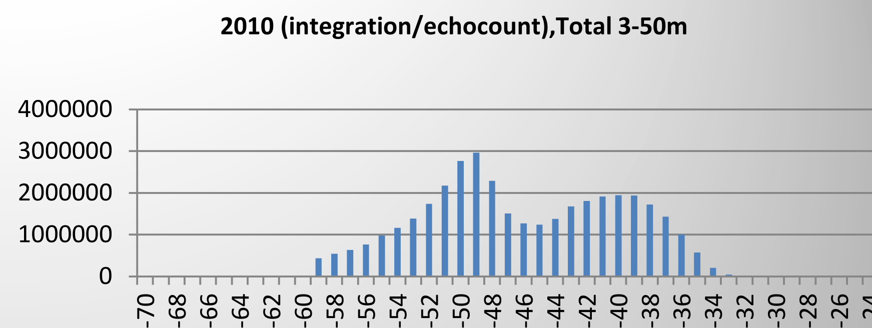
Meadow & Lardeaux Fry to Late Season Acoustic Fry Survival

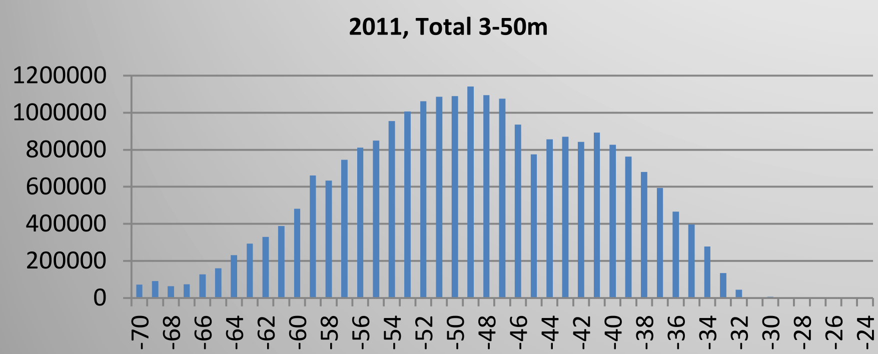


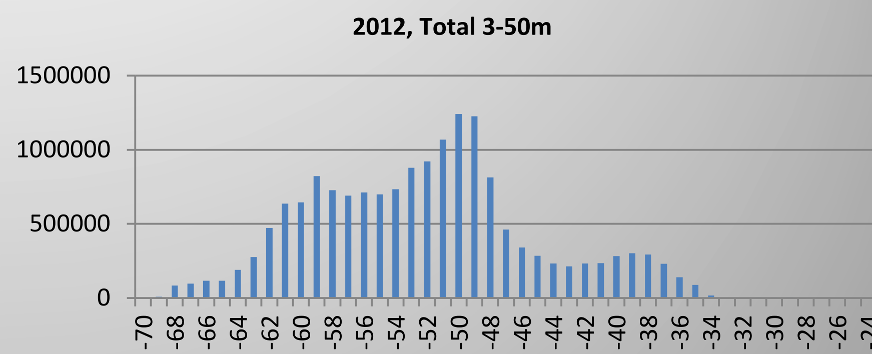
Late Season Fry to 1+ Survival

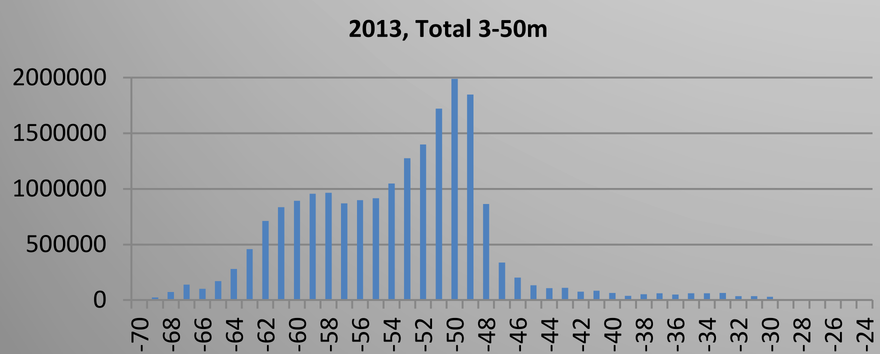


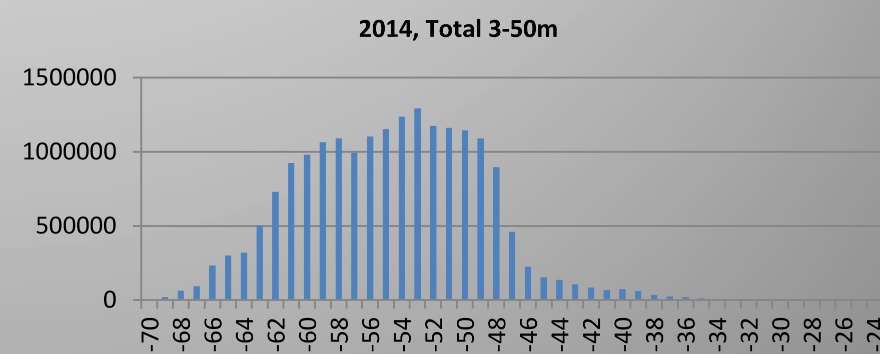

2009 (integration/echocount), Total 3-50m
6000000
5000000
4000000
3000000
2000000
1000000
0
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24


2010 (integration/echocount),Total 3-50m
4000000
3000000
2000000
1000000
0
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24

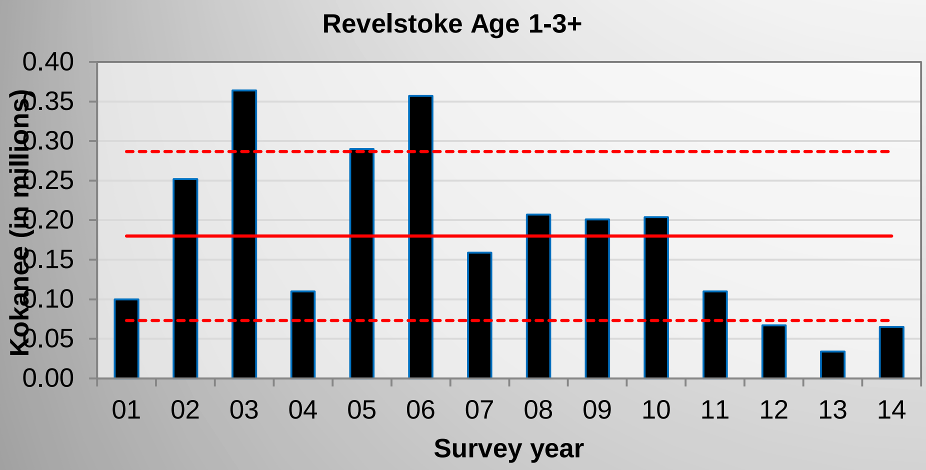

2011, Total 3-50m
1200000
1000000
800000
600000
400000
200000
0
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24

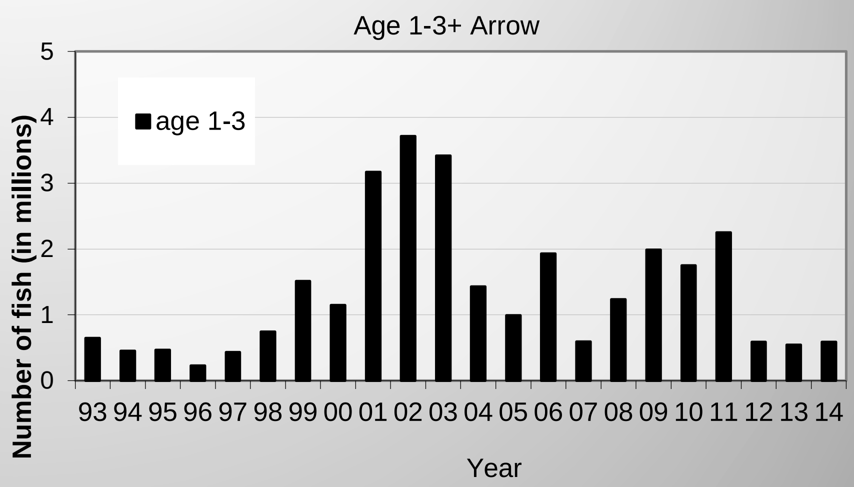

2012, Total 3-50m
1500000
1000000
500000
0
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24

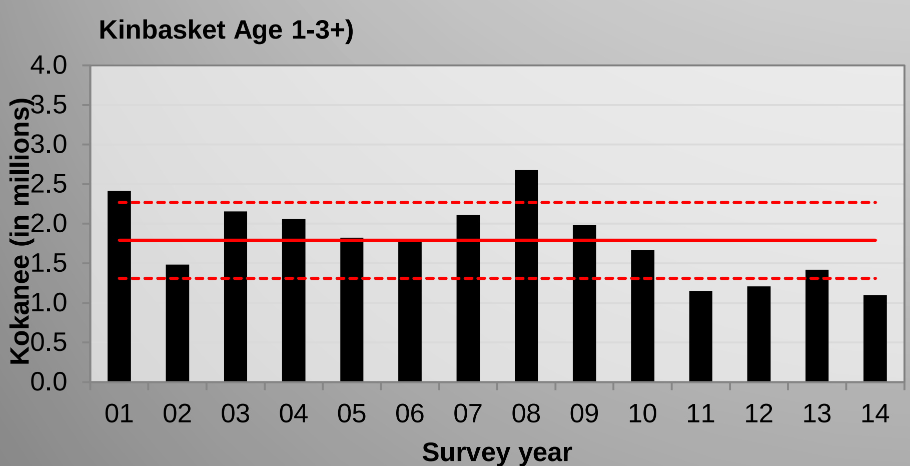

2013, Total 3-50m
2000000
1500000
1000000
500000
0
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24

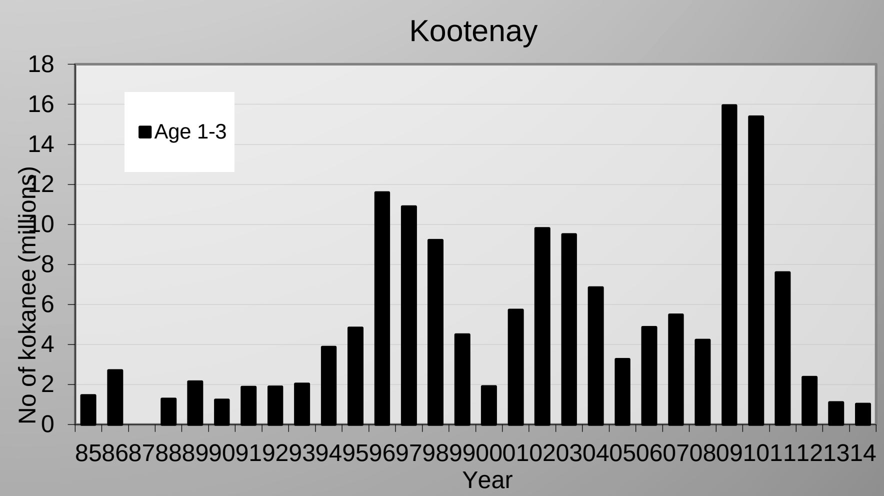

2014, Total 3-50m
1500000
1000000
500000
0
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24

Adult Kokanee Abundance, Multi-Lake







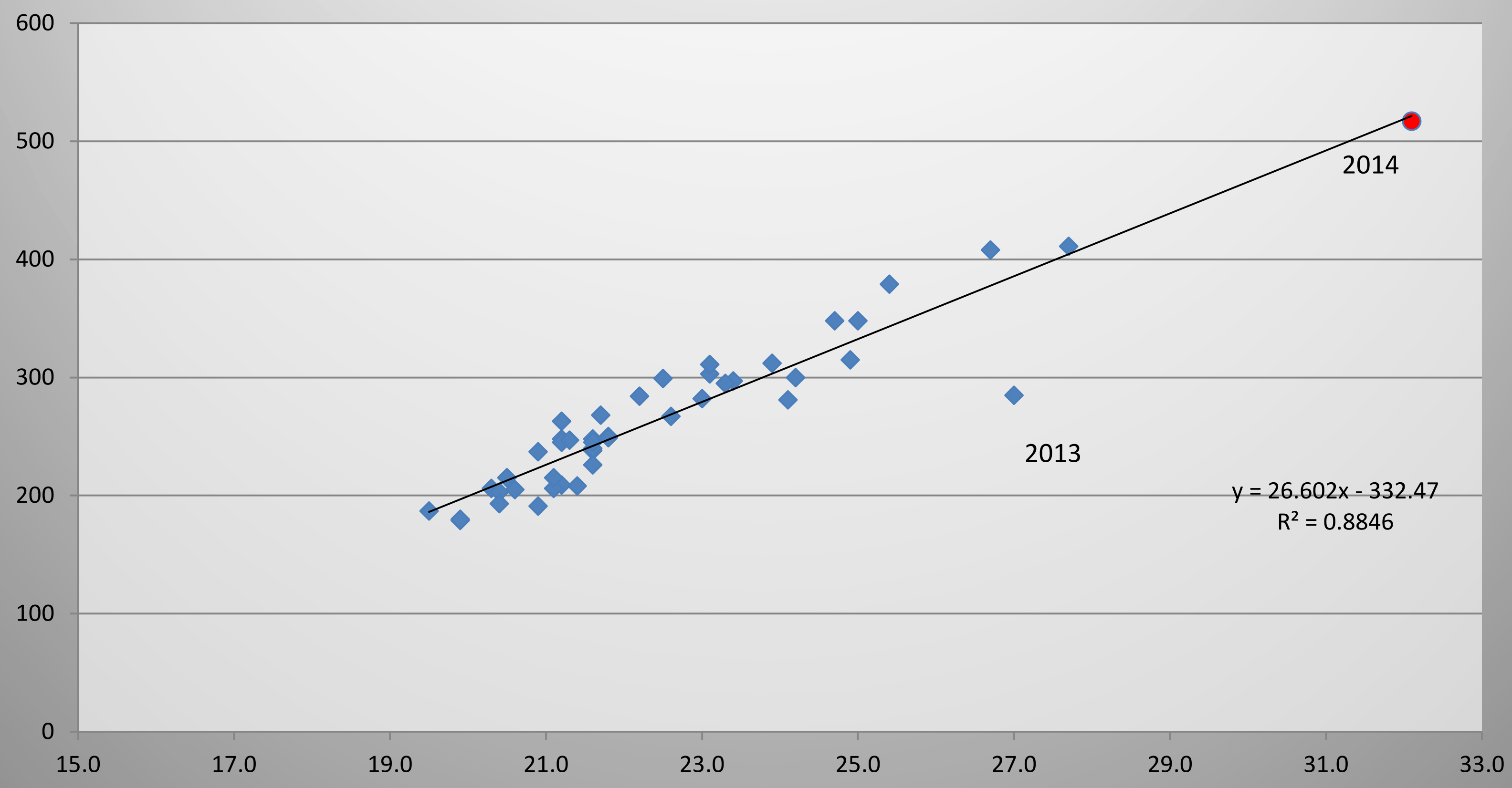


Summary

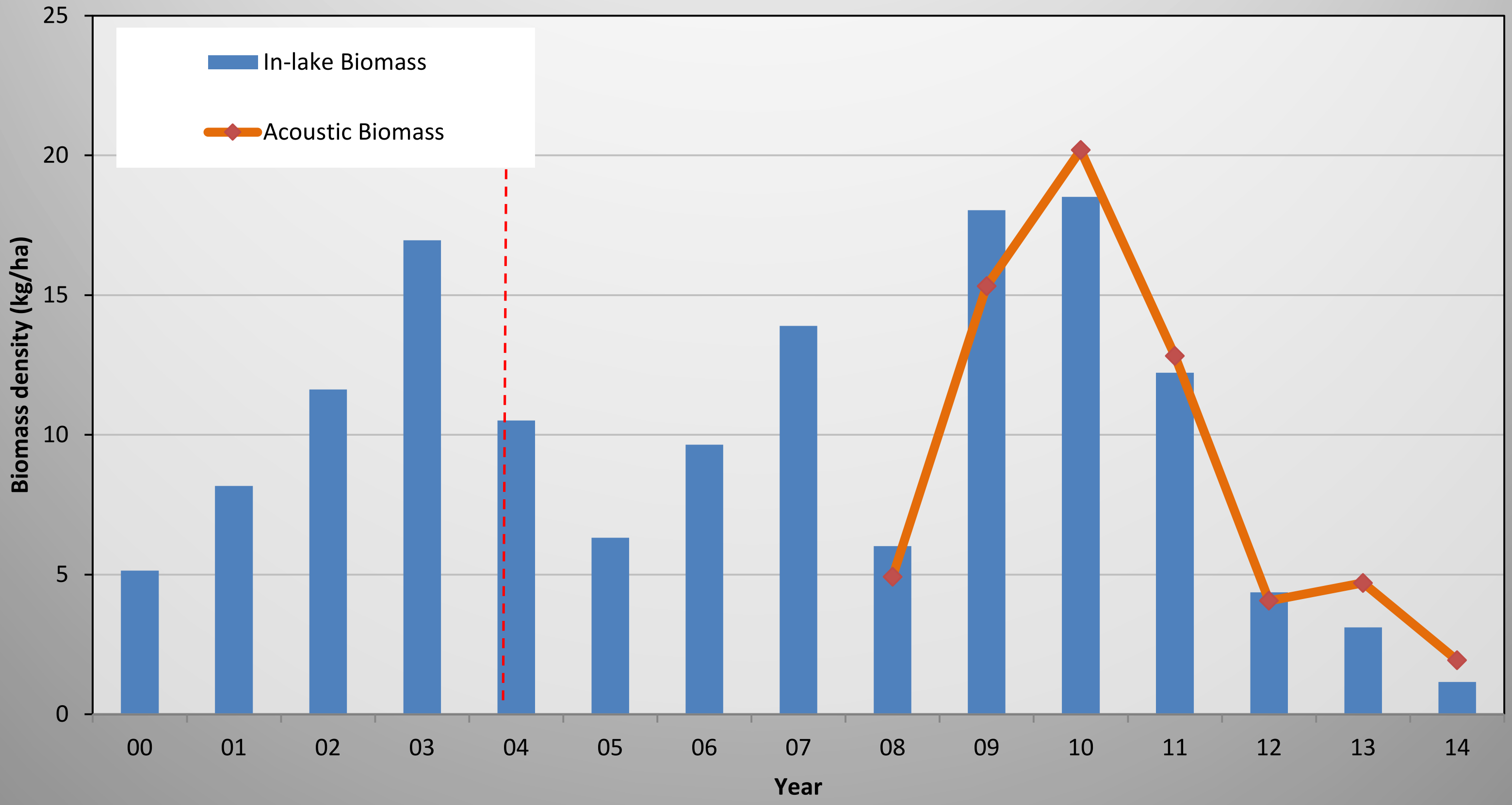
- Abundance down, Size up
- Biomass down
- Will last years fry survive to 1+?
- Indications are lower escapement for 2015


End

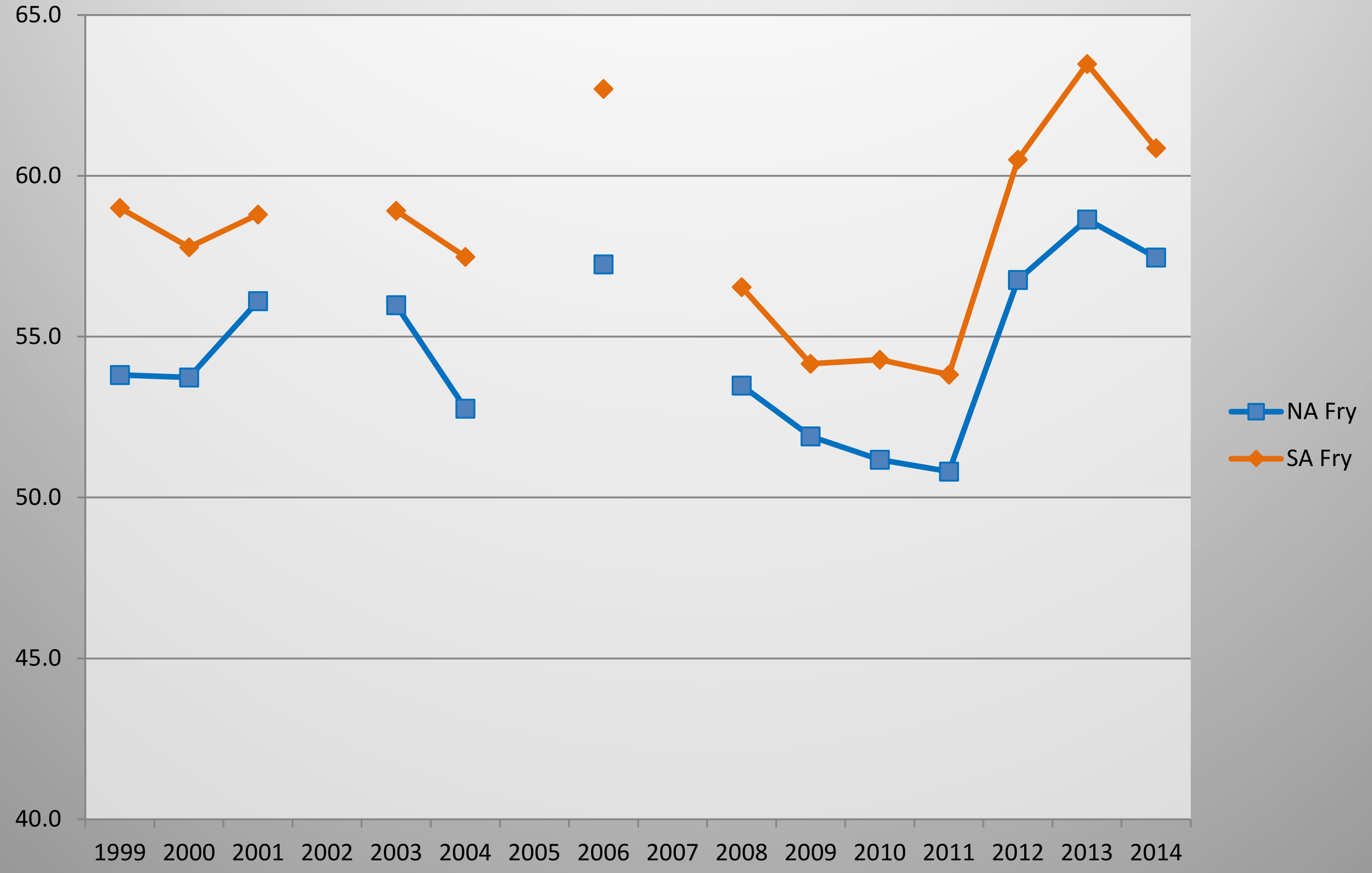
Meadow Creek Fecundity

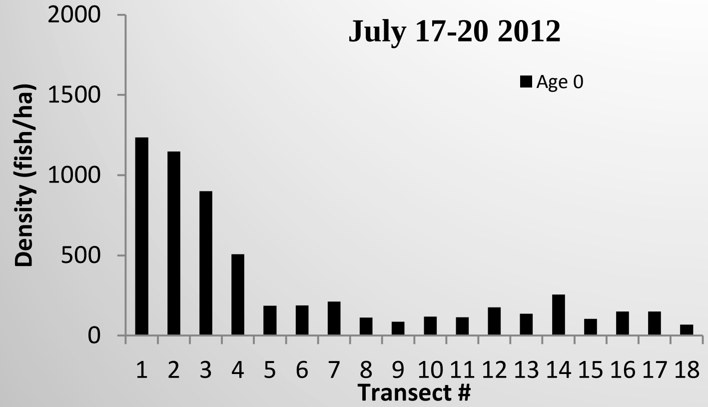


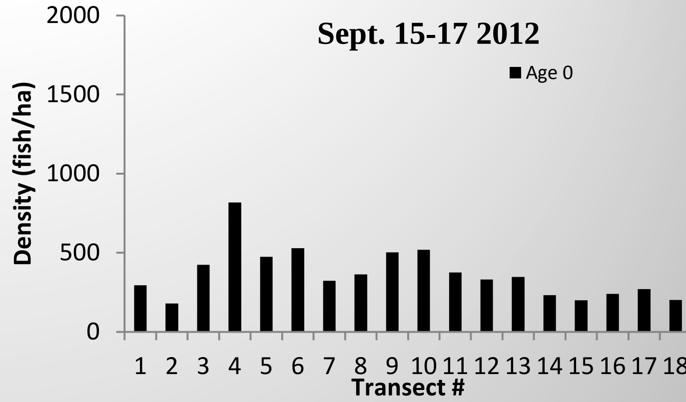
Kokanee Biomass

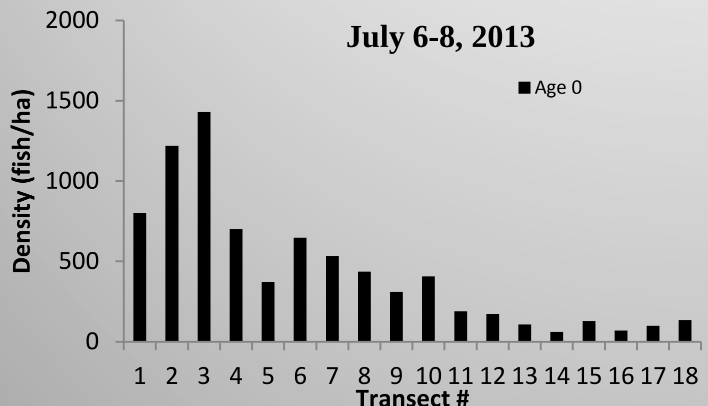


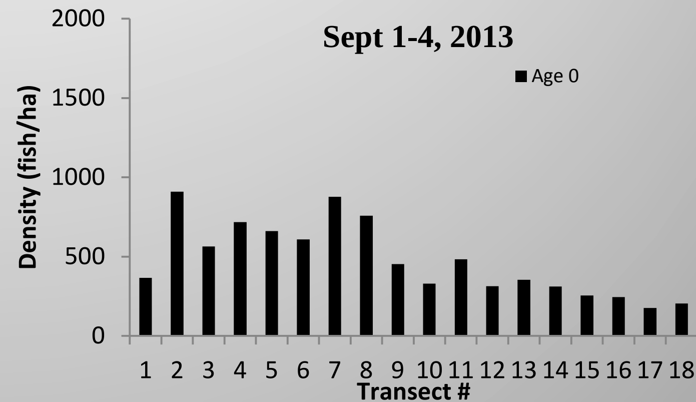
NA and SA Kokanee Fry Average Size

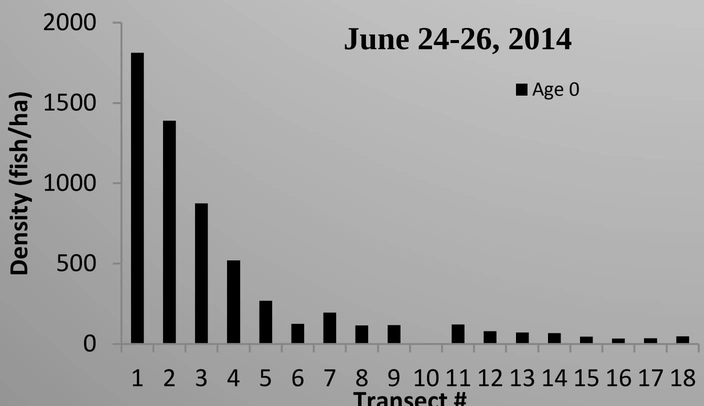


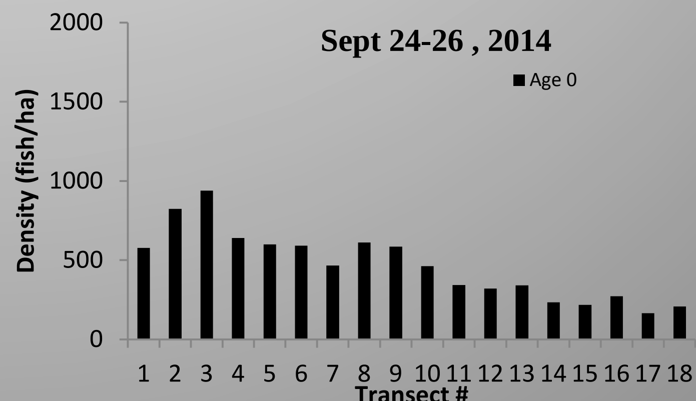

July 17-20 2012
Age 0
Density (fish/ha)
0
500
1000
1500
2000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

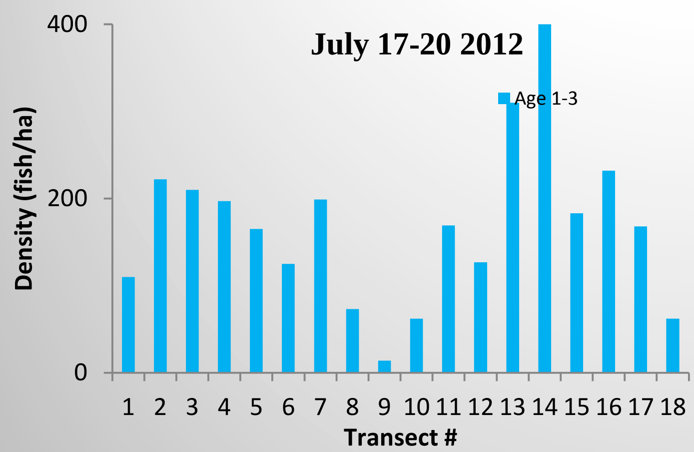

Sept. 15-17 2012
Age 0
Density (fish/ha)
0
500
1000
1500
2000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

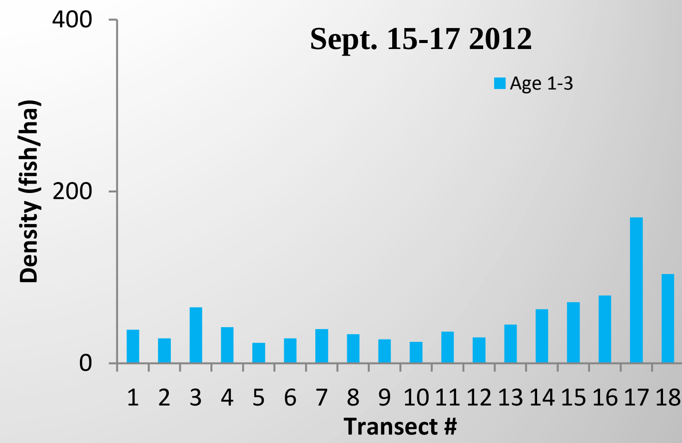

July 6-8, 2013
Age 0
Density (fish/ha)
0
500
1000
1500
2000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

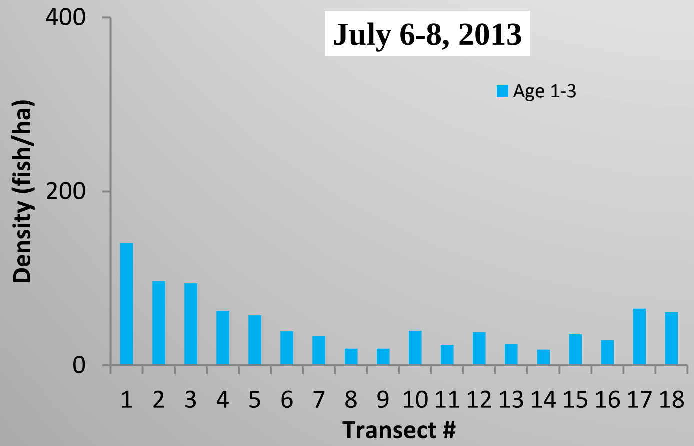

Sept 1-4, 2013
Age 0
Density (fish/ha)
0
500
1000
1500
2000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

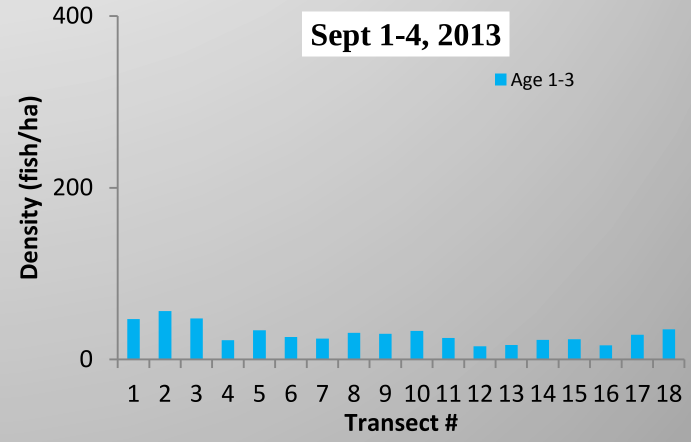

June 24-26, 2014
Age 0
Density (fish/ha)
0
500
1000
1500
2000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

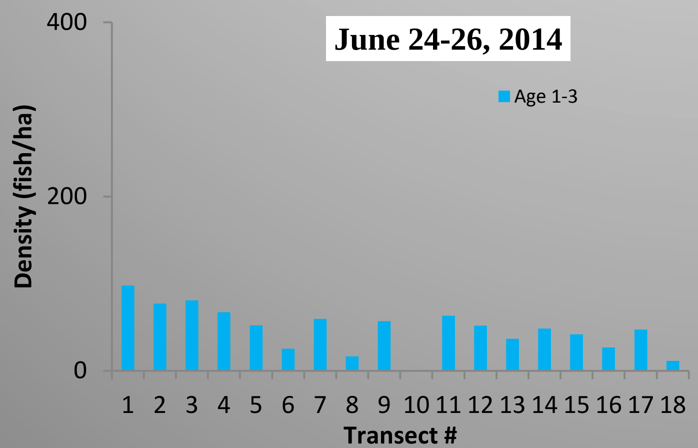

Sept 24-26 , 2014
Age 0
Density (fish/ha)
0
500
1000
1500
2000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

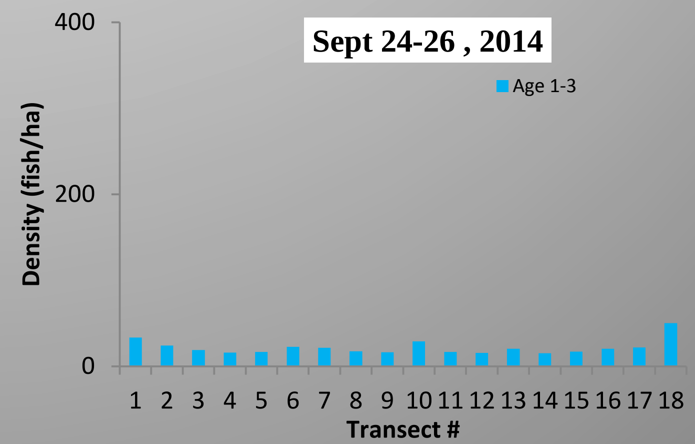

July 17-20 2012
Age 1-3
Density (fish/ha)
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #


Sept. 15-17 2012
Age 1-3
Density (fish/ha)
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

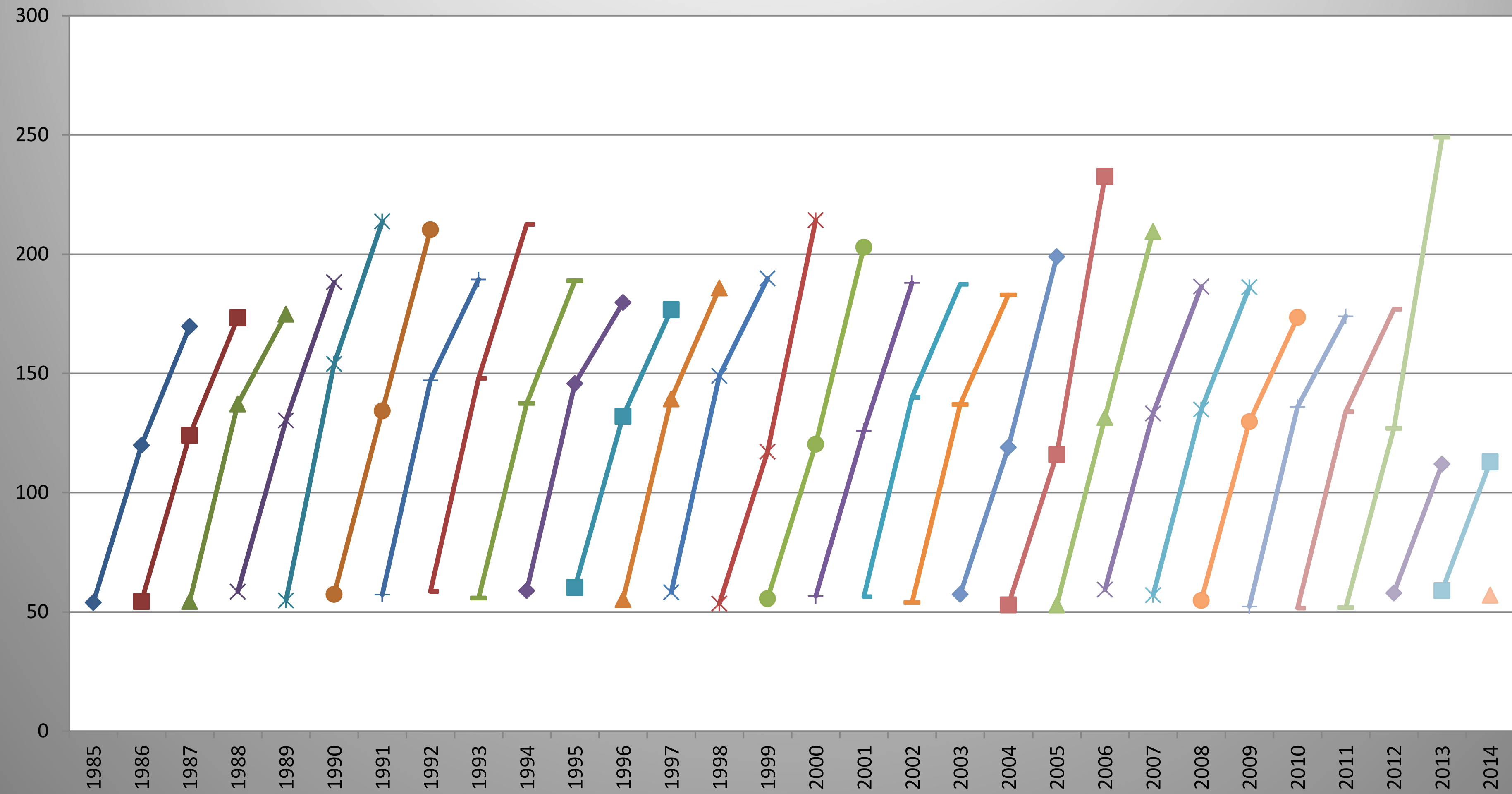

July 6-8, 2013
Age 1-3
Density (fish/ha)
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #


Sept 1-4, 2013
Age 1-3
Density (fish/ha)
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

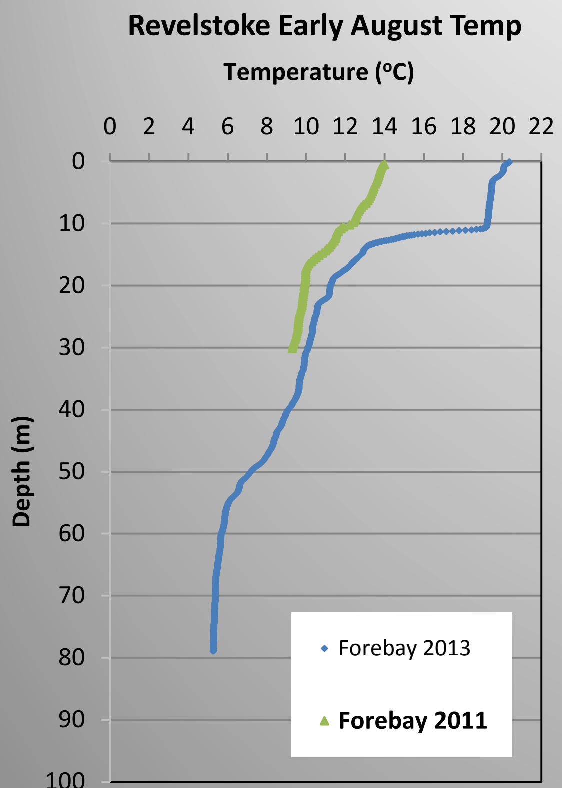

June 24-26, 2014
Age 1-3
Density (fish/ha)
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

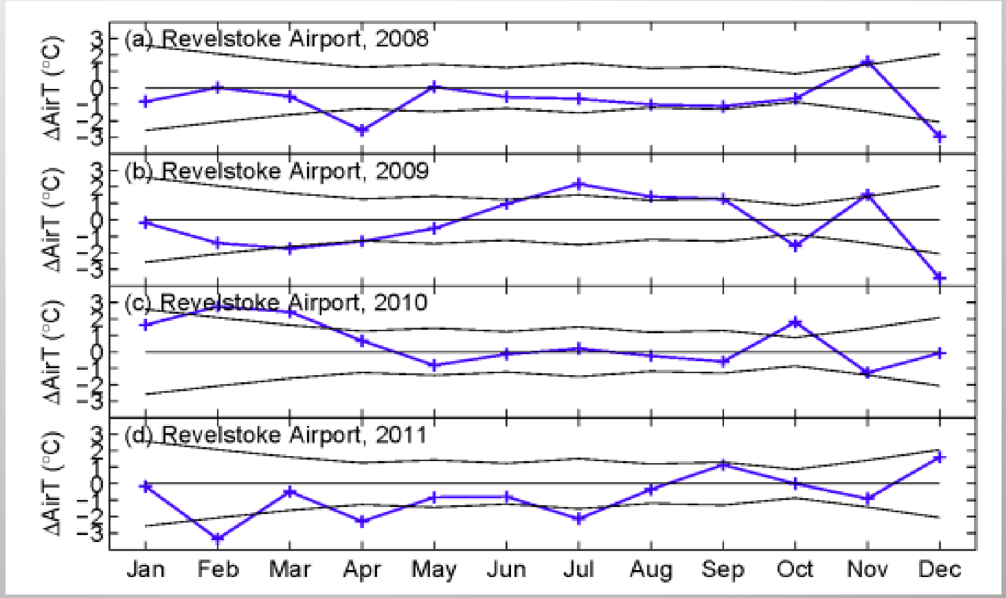

Sept 24-26 , 2014
Age 1-3
Density (fish/ha)
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Transect #

Cohort, Size and Growth In-lake



2011 lowlights





Okanagan

2011 - #'s stable but size down

2012 - #'s down no size increase – biomass way down

2012 – spawners way down

Kin/Rev

2011 - #'s down and small (minimal data)

2012 - #'s down further in rev and remain low in Kin

Appendix B-3 W. Warnock, CCRIFC – Summary of results of genetic studies pertaining to Kootenay Lake.

Summary of results, Vernon 1957

- Phenotypic characteristics identify three races of kokanee in Kootenay Lake, from the North, West and South arms.
- Stray rate is low between tributaries of the three arms (~2.8%), but stray rate is variable between years. There appeared to be the highest exchange between west arm and south arm tributaries, but it is hardly a strong trend.

TABLE XVIII. The number and origin of spawning kokanee identified as strays from their home area.

Area and year	Stream	Total No. in sample	Strays No.	Strays %	Origin of strays
1951					
West Arm	Kokanee Cr.	74	3	4.0	South End
	Redfish Cr.	97	8	8.2	South End
North End	Lardeau R.	102	0	0	
	Meadow Cr.	120	0	0	
South End	Cultus Cr.	114	0	0	
	Sanka Cr.	78	1	1.3	West Arm
	Goat Cr.	177	16	9.0	North End
1952					
West Arm	Kokanee Cr.	49	2	4.1	South End
North End	Meadow Cr.	73	0	0	
South End	Goat Cr.	86	0	0	
1953					
West Arm	Kokanee Cr.	65	2	3.1	South End
North End	Meadow Cr.	96	0	0	
	Totals	1131	32	2.83	

Summary of results, Anders et al 2007

- Kookanusa populations are divergent from Kootenay lake west arm and south arm populations. North arm populations and south arm tributaries within Idaho are intermediate to these two.
- STRUCTURE results and pairwise FST provide evidence that South Arm Kootenay Lake tributary (Goat) is more closely related to west arm tributaries than to Meadow Creek.

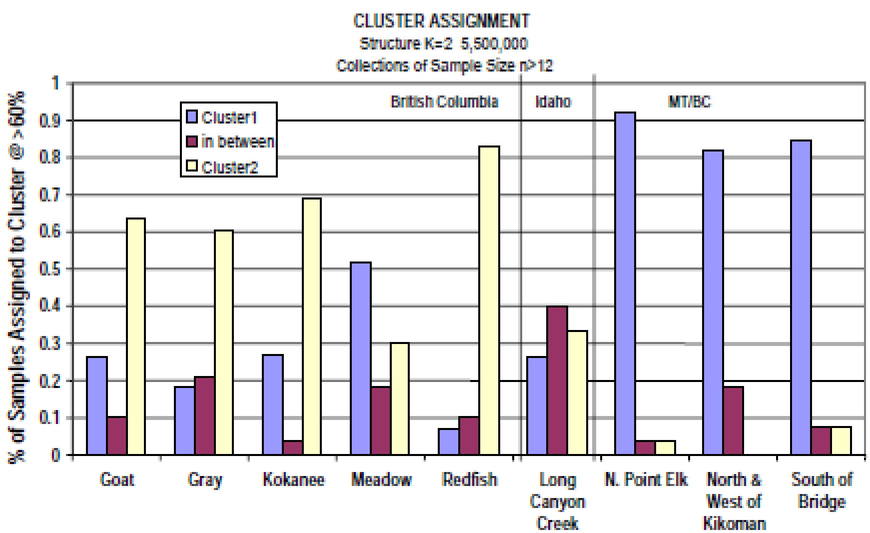


Figure 4. Percent of individuals in a collection (sample size n > 12) assigned to a cluster from a STRUCTURE run for two populations (k) using burn-in of 500,000 repetitions followed by 5,000,000 repetitions.

Table 11. Sample size (n) and pairwise genetic differentiation index (F_{ST}) of 14 collections of kokanee from the Kootenai/y Basin. Values in bold italics on the diagonal are the average of 13 pairwise FST values for each collection.

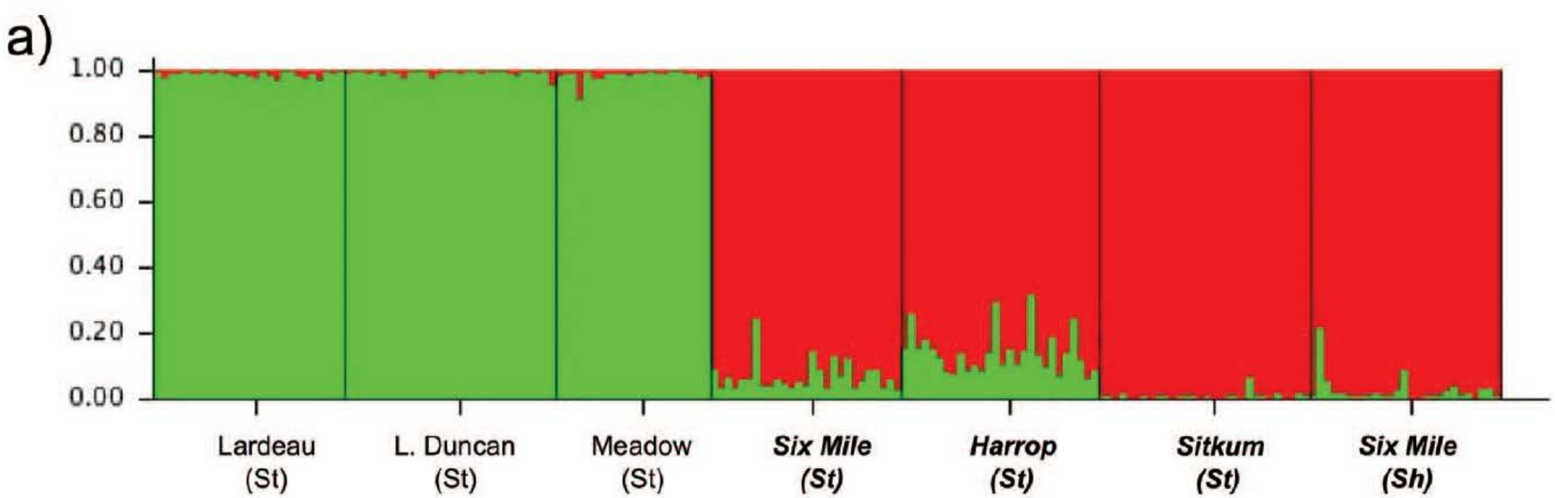
		Kootenay Lake Collections					Kootenai River Collections						Koocanusa Reservoir		
Collection	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Goat	30	***0.013***													
2 Gray	35	0.000	***0.016***												
3 Kokanee	32	0.010	0.017 [1]	***0.026***											
4 Meadow	60	0.008 [1]	0.013 [1]	0.025 [1]	***0.013***										
5 Redfish	30	0.005	0.018 [1]	0.006	0.024 [1]	***0.036***									
6 Cow Creek	6	0.013	0.018 [2]	0.015 [2]	0.008	0.027 [1]	***0.013***								
7 Hemlock Bar	1	0.046	0.032	0.065 [2]	0.031	0.093 [1]	0.023	***0.046***							
8 Long Canyon Creek	15	0.001	0.003	0.023 [1]	0.003	0.029 [1]	0.005	0.028	***0.010***						
9 N. Fork Trout	2	0.017	0.031	0.068 [2]	0.030	0.069 [1]	0.045	0.127	0.013	***0.041***					
10 S. Fork Trout	2	-0.020	-0.024	-0.010	-0.035	0.023 [1]	-0.019	-0.038	-0.052	0.000	***-0.019***				
11 Shorty's Island	4	0.021	0.011	0.020	0.016	0.048 [1]	0.004	0.091	0.003	0.068	-0.041	***0.023***			
12 N. Point Elk	25	0.025 [1]	0.034 [1]	0.043 [1]	0.022 [1]	0.046 [1]	0.008	0.028	0.026 [1]	0.017	-0.008	0.019	***0.020***		
13 North & West of Kikoman	22	0.013 [1]	0.023 [1]	0.029 [1]	0.012 [1]	0.033 [1]	0.003	0.015	0.014 [1]	0.018	-0.018	0.015	0.001	***0.013***	
14 South of Bridge	13	0.027 [1]	0.029 [1]	0.031 [2]	0.020 [1]	0.044 [1]	0.020	0.057	0.028 [2]	0.029	-0.001	0.022	0.000	0.009	***0.024***

[1]Significant after sequential Bonferroni correction for 91 tests (0.00055).
[2]Significant after less stringent B-Y correction for 91 tests (0.00938).

- Possible sources of kookanusa fish include fish flushed from kooenay hatchery from 1969-1978. The stocks used were Okanagan, Chilliwack Lk, Moyie Lake (until 1974) and Meadow Creek (1976-1979).

Summary of results, Lemay and Russello 2012

- Study designed to determine genetic differences between shore spawning and stream spawning kokanee in Kootenay Lake.
- Did not examine south arm tributaries.
- Results support those of Vernon (1957) and Anders (2007) in that West Arm and North Arm tributaries are genetically divergent



Summary of results, Kassler et al 2010

Figure 2. Relationship of kokanee collections from Lake Roosevelt, Arrow Lakes, B.C., L. Whatcom, and surrounding rivers using Cavalli-Sforza and Edwards (1967) chord distance.

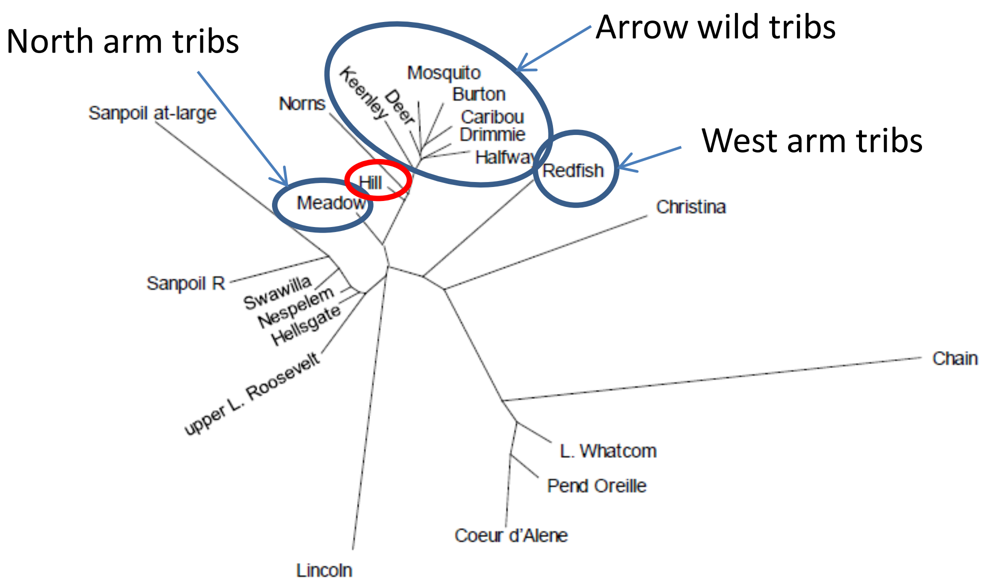
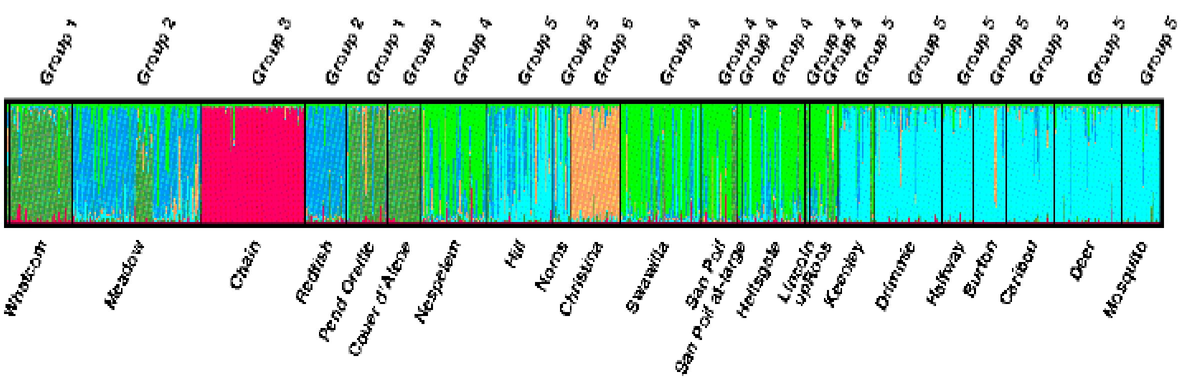


Figure 3. Structure plot showing percent membership of each individual kokanee into the six groups that STRUCTURE found in the dataset. Individuals with more than one color in the bar likely have mixed ancestry. The group number identifies the collections with similar ancestry.



- Study designed to test relationships between Lake Roosevelt Kokanee and various sources, including upstream in BC
- Dendrogram of genetic distance suggest North Arm and West Arm tributaries are divergent, but Hill Creek is intermediate to North arm and wild Arrow Lakes stock.
- STRUCTURE results cluster Hill Creek more with wild Arrow Lakes stock (group 5) than with Kootenay Lake stock (group 2) , but there is a significant amount of assignment uncertainty between either cluster in Hill Creek.
- The upshot: Hill Creek is probably somewhat intermediate genetically to Kootenay Lake and Arrow Lakes

Summary of results, Iwamoto et al 2012

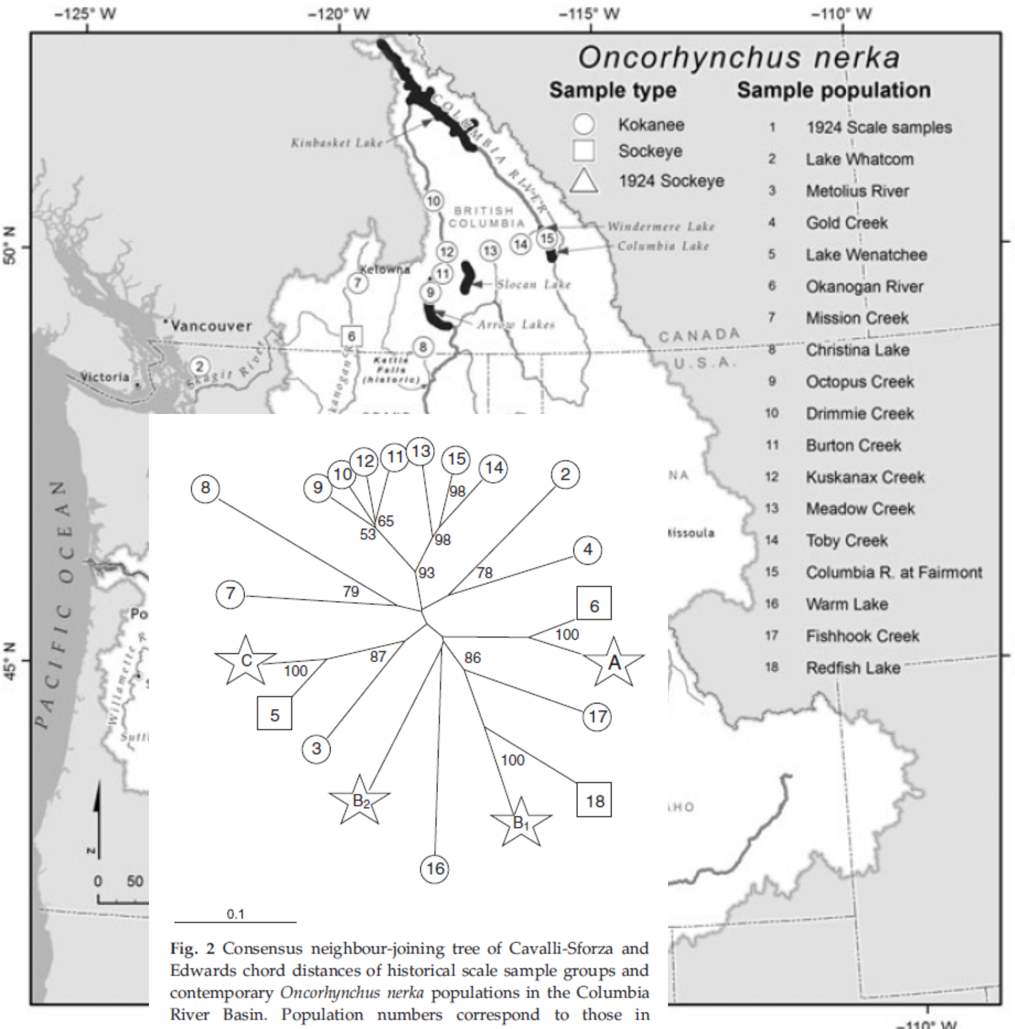


Fig. 2 Consensus neighbour-joining tree of Cavalli-Sforza and Edwards chord distances of historical scale sample groups and contemporary *Oncorhynchus nerka* populations in the Columbia River Basin. Population numbers correspond to those in Table 1. Population 1 (1924 sockeye salmon scales) has been divided into genetic groupings: A, B_1, B_2 and C based on results from STRUCTURE analysis. Stars (☆) indicate samples from the 1924 Columbia River fishery, squares (□) from contemporary sockeye salmon populations and circles (○) from contemporary kokanee populations. Numbers at the nodes (only values >50% are shown) indicate the percentage of 10 000 bootstrap trees where collections beyond the nodes grouped together.

- Study designed to examine contemporary and historic population structure of sockeye and kokanee in the entire columbia basin.
- For Canada, examined wild Arrow Lakes stocks, Meadow Creek and upper Columbia stocks (Kinbasket or Lake Windermere)
- Dendrogram of genetic distance suggest that wild Arrow Lakes stock are more divergent from Meadow Creek (north arm) than upper columbia stocks.
- Supplementary Table S3 from study reports significant FST between Meadow Creek and Arrow tributaries, but not between Meadow Creek and Toby/Fairmont
- This makes sense given recent stocking of Kinbasket Reservoir with Meadow Creek origin fish.

Weight-of-evidence from 5 studies and stocking records

- Within Kootenay Lake, the West and North Arms are genetically divergent (4 studies)
- Within Kootenay Lake, South Arm and West Arm tributaries are more closely related to one another than they are to the North Arm (1 study)
- Arrow Lake wild populations and Kootenay lakes are genetically divergent, but Hill Creek is somewhat intermediate to the two lakes, with the most closely related Kootenay Lake population being from the North Arm (1 study)
- The recently founded Kookanusa population is genetically divergent from Kootenay Lake, but more closely related to the North Arm than the West/South Arms (1 study)
- The recently founded Kinbasket population is not differentiated from North Arm Kootenay Lake (1 study)
- Stocking records indicate Kookanusa stock may be a mix of populations (lower mainland, okanagan and kootenay lake), and Kinbasket is a mix of established Kookanusa stock (1980s) and meadow creek

Appendix C. Kootenay Lake Advisory Team follow-up regarding performance measures and targets (R. Bison).

Memorandum

April 2, 2015

To: Jeff Burrows, BC Ministry of Forests, Lands and Natural Resource Operations, Nelson
Matt Neufeld, BC Ministry of Forests, Lands and Natural Resource Operations, Nelson
Sherri McPherson, Lotic Environmental, Cranbrook
Paul Askey, FFFSBC, Summerland.

From: Robert Bison, BC Ministry of Forest, Lands and Natural Resource Operations, Kamloops

Re: Kootenay Lake Advisory Team follow-up regarding performance measures and targets.

Summary:

I expected that a summary of performance measures and targets based on the material presented at the meeting would have been a relatively straight forward exercise. However part away through the exercise, I analyzed the kokanee abundance data with stock recruitment models in order to propose some time-invariant abundance based targets. The patterns in the recruitment data complicated the idea of setting time invariant targets. This in turn lead to further exploratory analyses some of which is summarized in the material below.

In summary, the data suggests to me that the fertilization program(s) may be causing rainbow and kokanee populations to couple together and cycle. Guill et al. (2014) and Guill et al. (2011) describe such processes for sockeye and their predators (mainly rainbow) and much of what they report has interesting relevance to Kootenay Lake. I am not sure whether previous population dynamics models for Kootenay predict the sort of cyclical patterns that now seem to be evident in the data. Others that are more familiar with these models should be consulted for confirmation.

Regarding performance measures and “targets”, the data suggest that the population dynamics of kokanee and rainbow may be coupled and therefore, targets may be difficult to achieve if they are time invariant. The accompanying xl spreadsheet contains a preliminary list of suggested measures and time invariant targets that may be informative to guide short term management action. But I suggest that any longer term management consider the potential that fertilization may be causing cyclical population dynamics in kokanee and at least the rainbow predators if not the bull trout as well.

Kokanee Recruitment Patterns:

The recruitment of kokanee shows a pattern that suggests some form of recruitment non-stationarity (Figures 1 and 2). About half (15/29) of the recruitment observations are loosely clustered above the replacement line while the remaining half are loosely clustered below the replacement line (Figure 1). The overall pattern suggests the following population attributes according to the Ricker model: maximum-recruitment of 990,000, unfished equilibrium spawning stock size of 950,000 and spawning stock size at MSY of 380,000. However, patterns illustrated in both figures 1 and 2 suggest that there are two patterns, one associated with a higher level of recruitment and one associated with a lower level of recruitment.

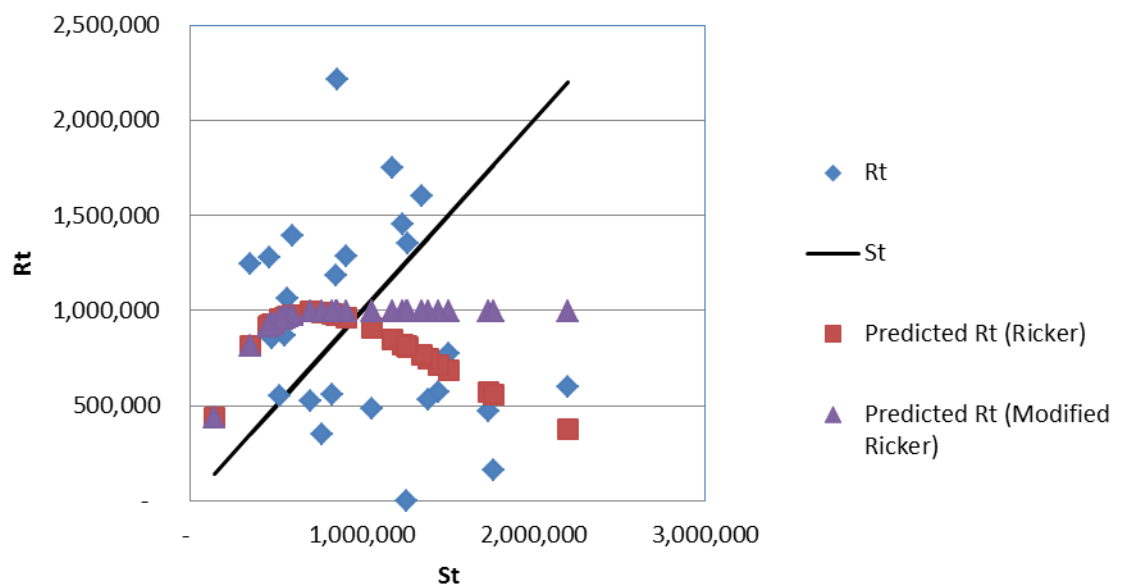


Figure 1. Observed recruitment (R_t) in relation to spawning stock size (S_t), illustrated by the diamond points, predicted recruitment according to the Ricker model $R_t=S_t*\exp(a-b*S_t+w_t)$, illustrated by the square points, and predicted recruitment according to a modified Ricker in which predicted $R_t=R_{max}$ at spawning stock sizes greater than those that predict R_{max}. The black line illustrates replacement. Recruitment (R_t) is defined as the pre-fishery adult recruits in their final year of life. The stochastic definition of parameter 'a' is the mean productivity at low spawner abundance in units of ln(R/S). Parameter 'b' is the effect of spawner abundance on this mean productivity. The residual errors (w_t) are also referred to as recruitment anomalies. The time series of w_t are estimates of changes in productivity over time that are not attributable to the size of the spawning stock (S_t).

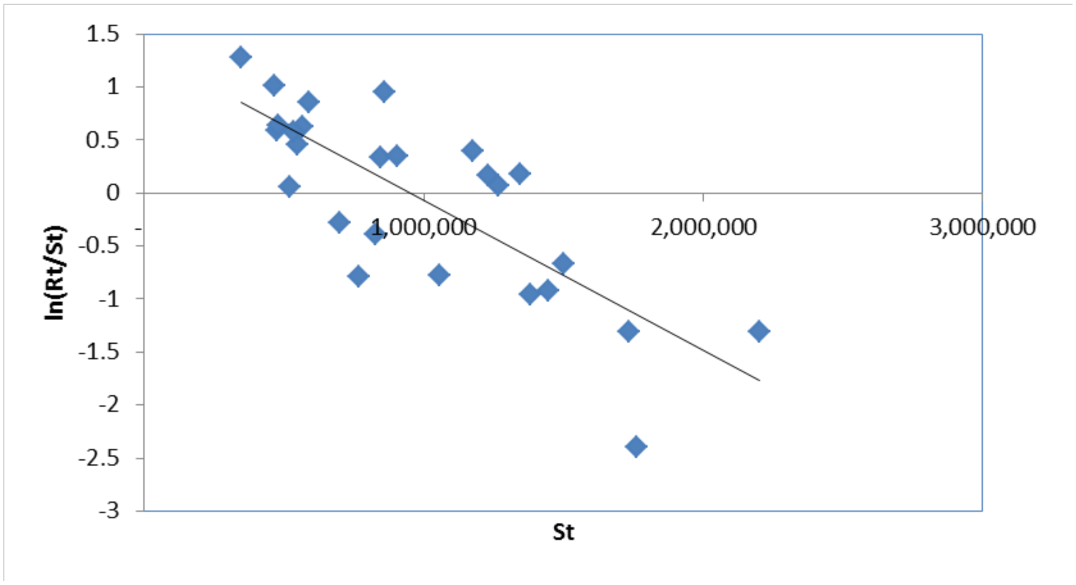


Figure 2. Observed recruitment rates (points) and predicted recruitment rates according to a single Ricker model (line), however the pattern suggests that there may be at least two recruitment patterns, one associated with an unfished equilibrium spawning stock size of about 1.5 million and one associated with an unfished equilibrium spawning stock size of about 500,000.

The time series of estimated recruitment anomalies suggests alternating periods of high and low recruitment rates varying in duration from 2 to 7 years (Figure 3). The timing and frequency of this pattern resembles the pattern observed in kokanee fecundity and body size (Figure 4). For the few oscillations observed to date, the frequency period of the fecundity temporal pattern varies from 6-8 years which is about equal to 2 kokanee generations. The time series of kokanee fecundity and body length dating to the late 1960's suggests that this cyclical pattern begins around 1990 which is about the time that nutrient addition began (1992). Guill et al. 2014 show that a predator-prey model for rainbow-sockeye becomes unstable with respect to sockeye abundance when the sockeye carrying capacity of an oligotrophic lake is increased, provided there is no other factor constraining the predator dynamic other than prey abundance (for example a limitation like predator spawning habitat limitation).

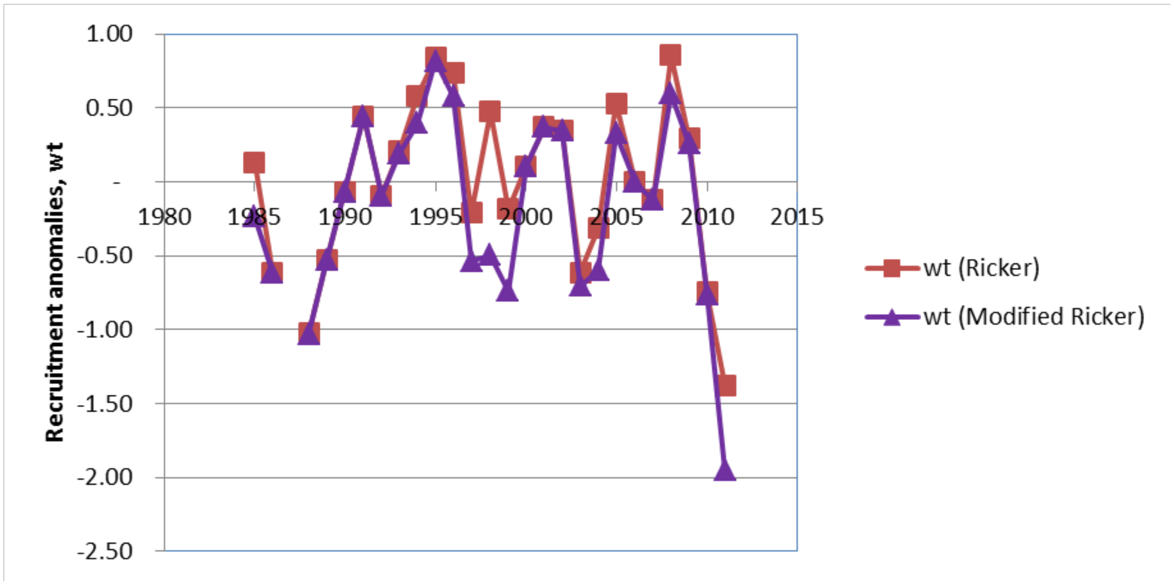


Figure 3. Time varying pattern in estimated recruitment anomalies.

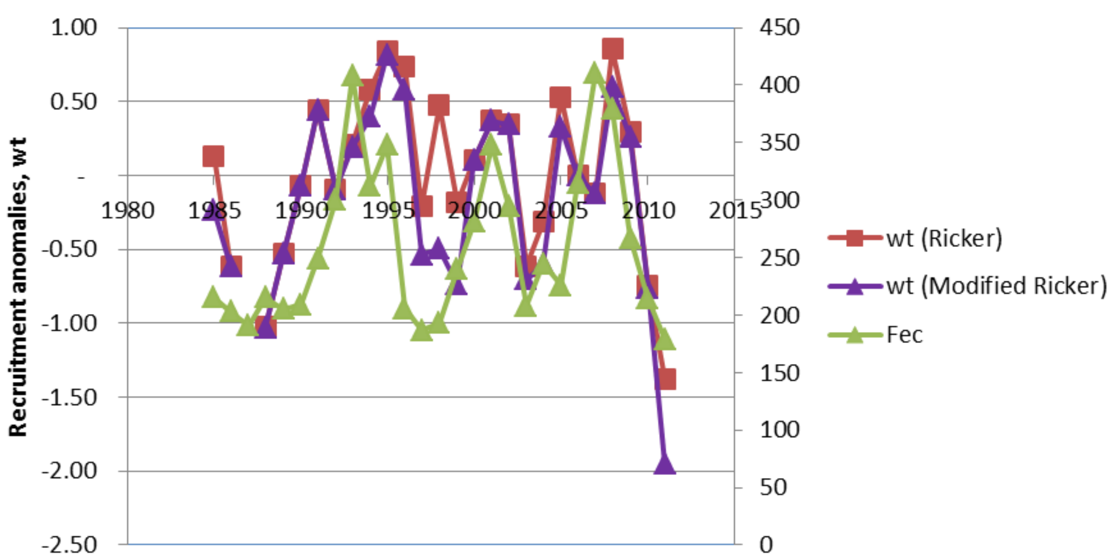


Figure 4. Kokanee recruitment anomalies vary with kokanee fecundity (and kokanee body size).

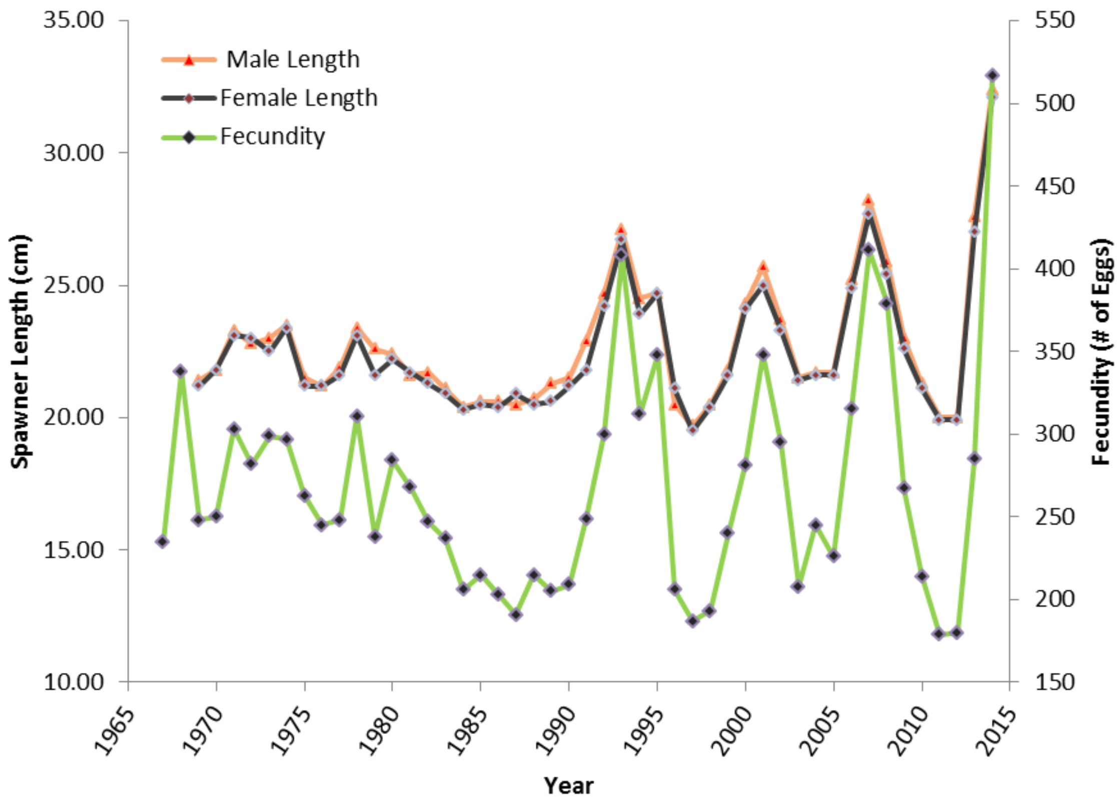


Figure 5. Cyclical pattern in fecundity and body length appears to have started around 1990.

Given the apparent body size and fecundity dynamics exhibited by kokanee, kokanee stock size is best measured in terms of eggs (Figure 6).

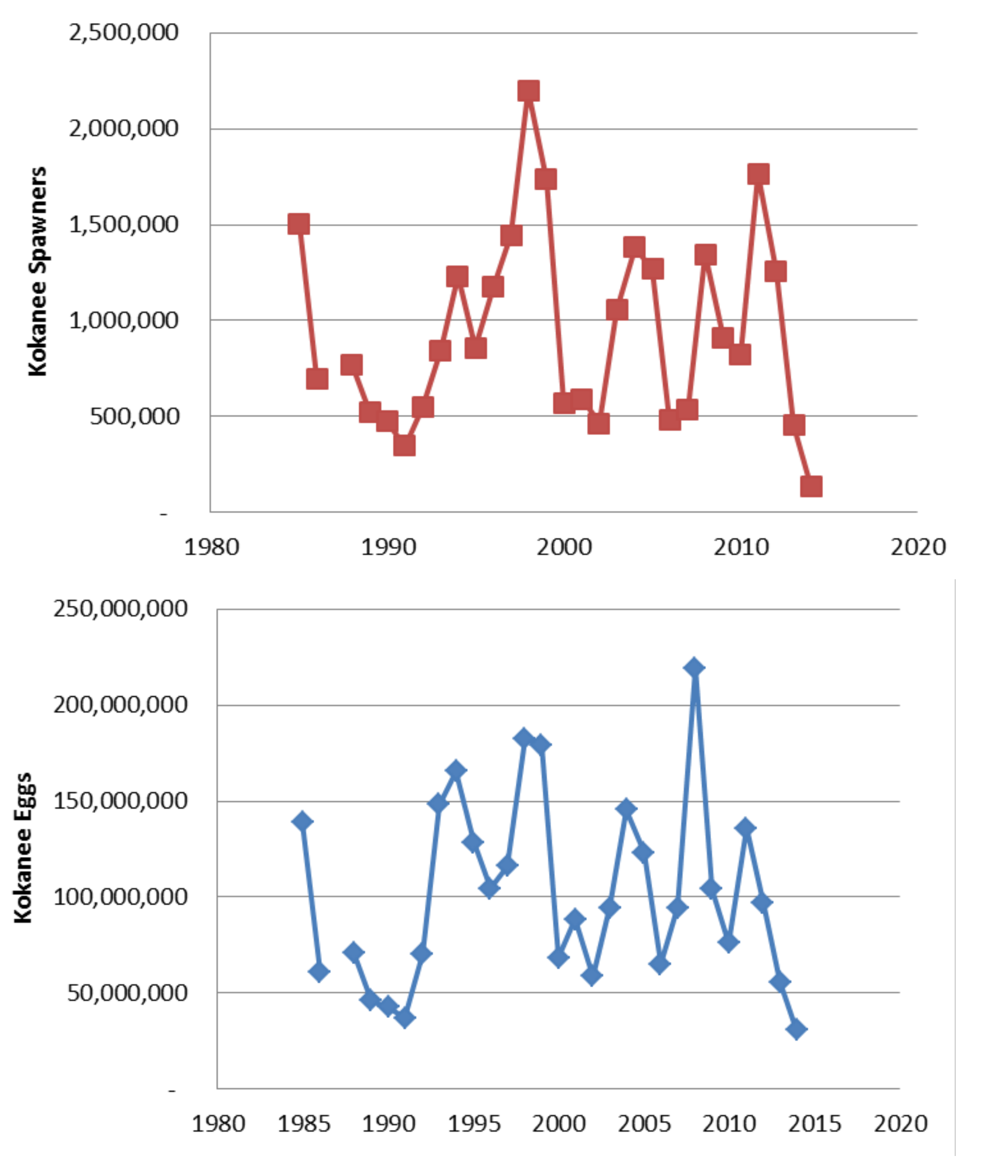


Figure 6. Kokanee stock size measured in eggs shows a less dramatic recent decline than stock size measured in spawner abundance.

Some Observed Patterns of Population Interaction between Kokanee and their Predators:

Kokanee recruitment is negatively correlated with predator abundance as indicated by various measures of predator abundance including the measures that are specific to rainbow or bull trout and measures expressed both as abundance or biomass. It is most strongly correlated with various measures of rainbow abundance and less so with bull trout abundance. The correlation is particularly strong and significant with the biomass of the rainbow catch in the sport fishery (i.e. rainbow > 2 Kg; r=-0.71, p=0.001; Figure 6a). The correlation with the biomass of the bull trout catch (bull trout > 2 kg) was moderate (r=-0.45) and less significant (p=0.09; Figure 6b).

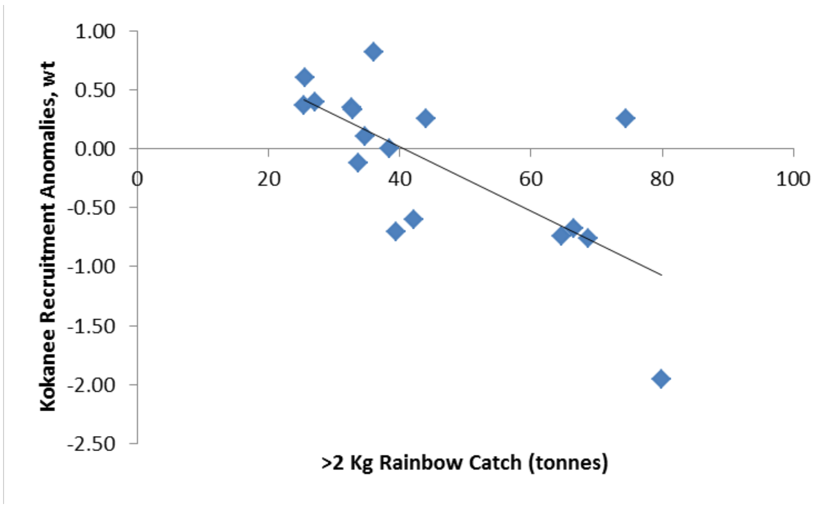


Figure 6a. Kokanee recruitment anomalies in relation to rainbow abundance, as measured by the biomass of the rainbow catch in the sport fishery (i.e. rainbow > 2 Kg).

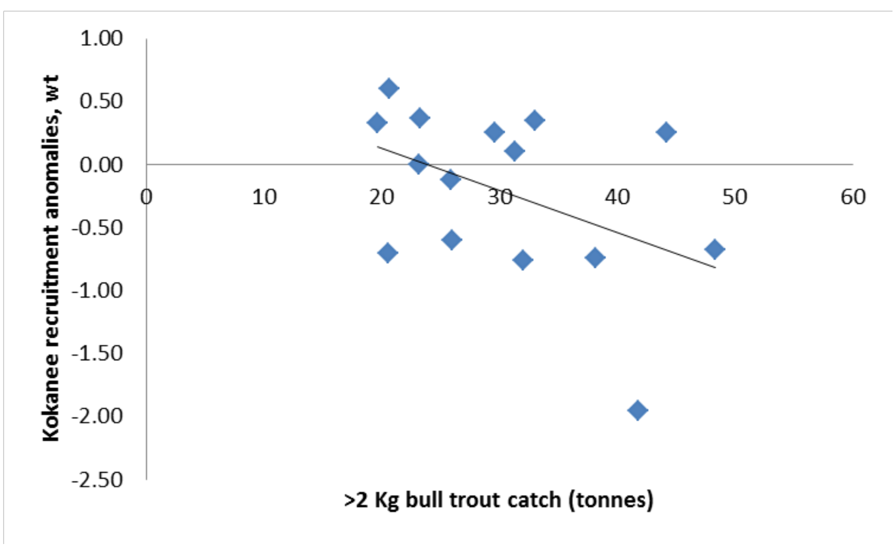


Figure 6b. Kokanee recruitment anomalies in relation to bull trout abundance, as measured by the biomass of the bull catch in the sport fishery (i.e. bull trout > 2 Kg).

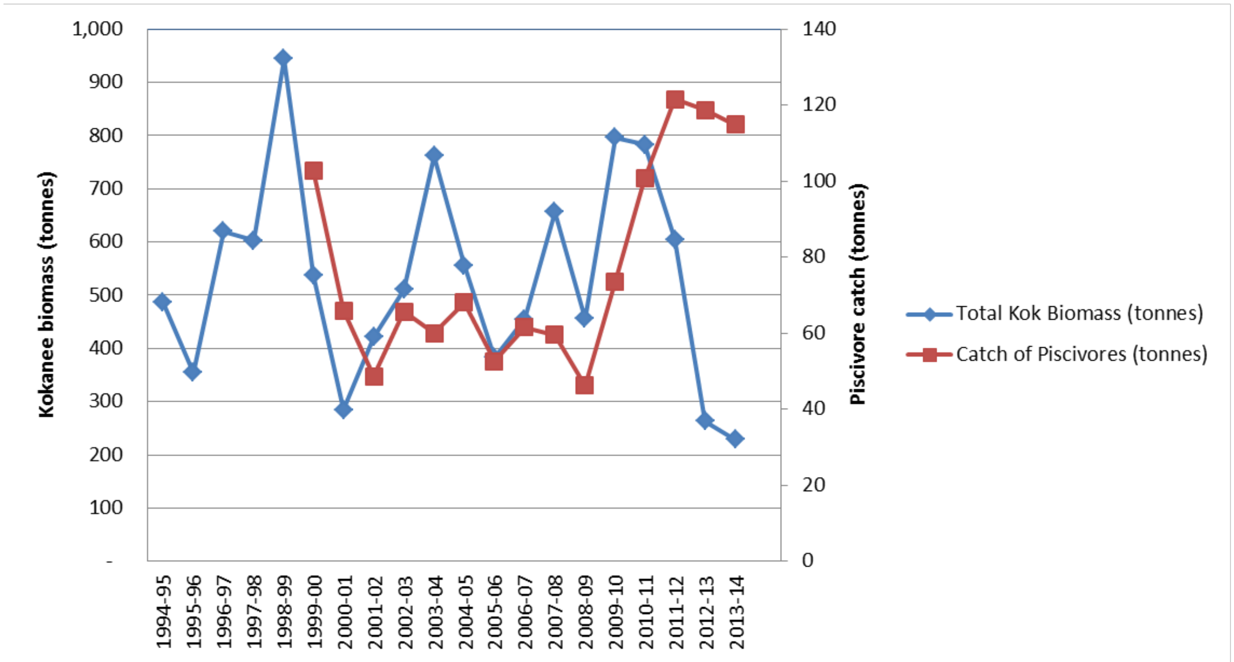


Figure 7a. Temporal patterns of kokanee biomass and piscivore catch, as measured as the biomass of the catch_of rainbow trout and bull trout > 2 Kg.

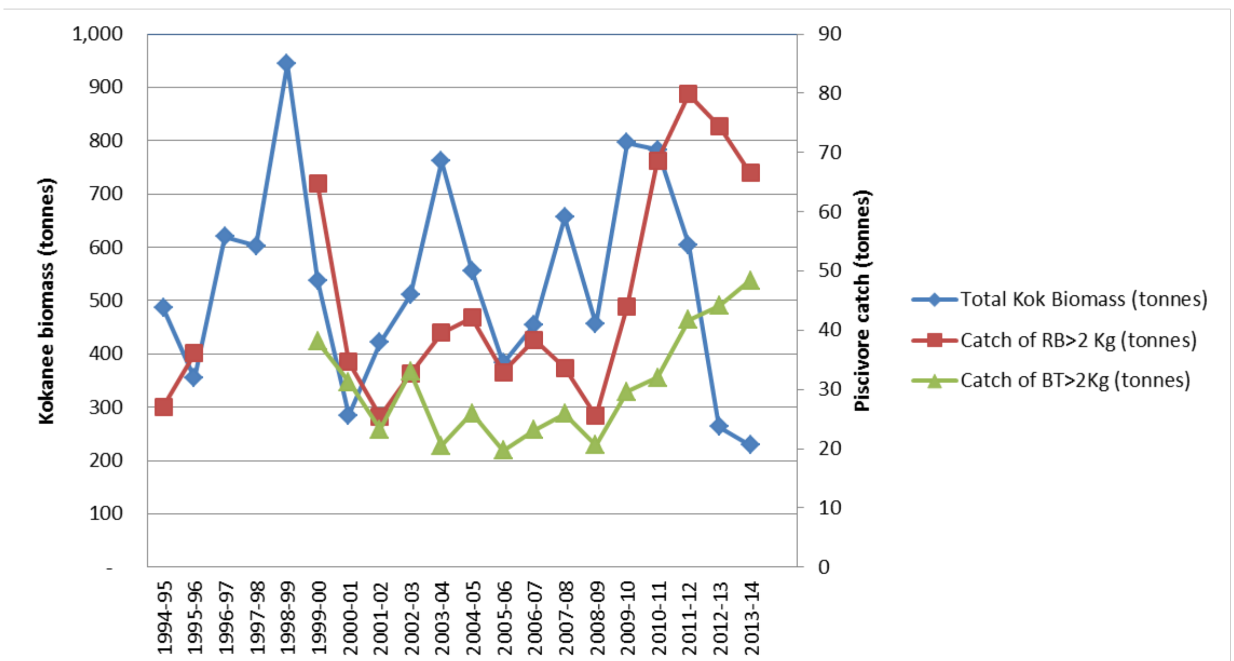


Figure 7b. Temporal patterns of kokanee biomass and piscivore catch by species, measured separately as the biomass of the catch of rainbow trout > 2 Kg and biomass of the catch of all bull trout > 2 Kg.

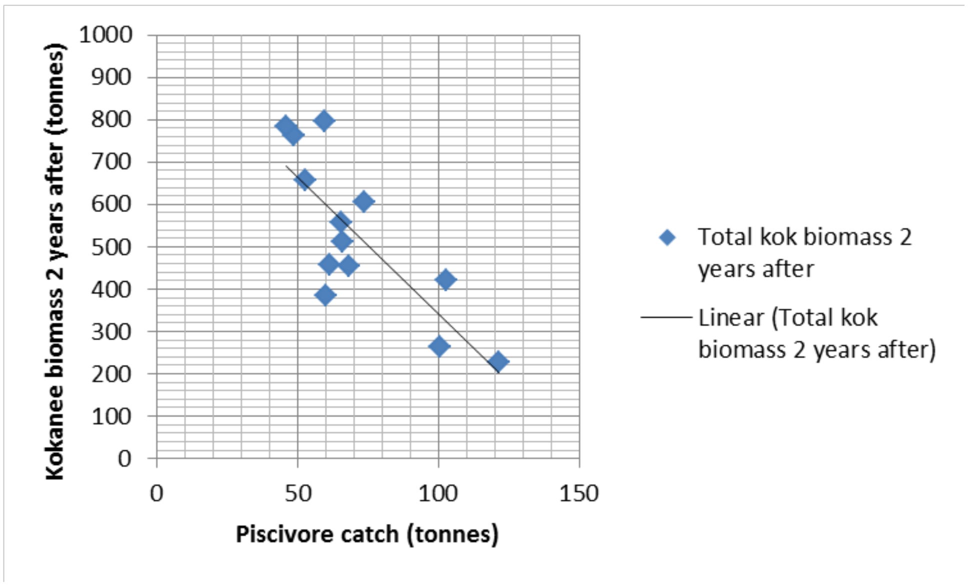


Figure 8a. Variation in total piscivore biomass (measured as the total biomass of the catch of bull trout and rainbow > 2 Kg) generates a strong response in kokanee biomass 1 and 2 years after. The correlations are strong, negative (r=-0.60 and -0.79, respectively), and significant (p=0.02 and p=0.0008, respectively). Response 3 years after is also negative, but moderate (r=0.43) and less significant (p=0.15).

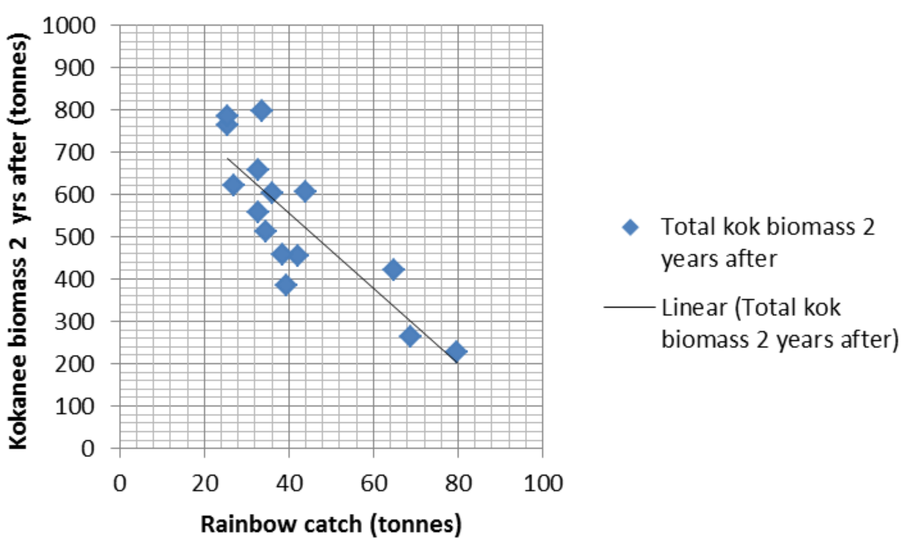


Figure 8b. Similarly, variation in rainbow biomass (absent bull trout and measured as the biomass of the rainbow catch > 2 Kg) generates a strong response in kokanee biomass 1 and 2 years after. The correlations are strong, negative (r=--0.51 and -0.74, respectively) and significant (p=0.026 and 0.00001, respectively). Response 3 years after is also negative, but moderate (r=-0.43) and less significant (p=0.09).

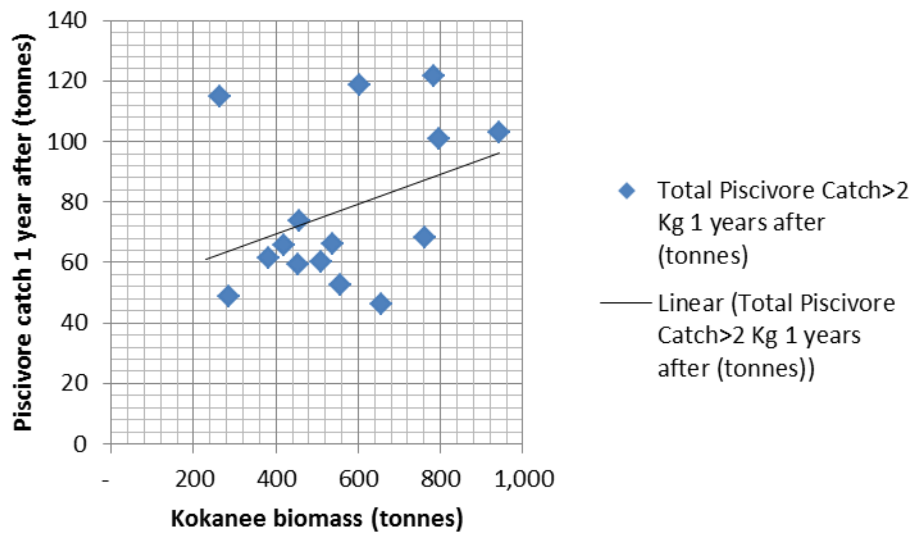


Figure 8c. From the kokanee perspective, variation in kokanee biomass generates moderate responses in piscivore biomass 1 and 2 years after. These correlations are moderate, positive (r=0.36 and 0.35, respectively) and less significant than the lagged piscivore effect on kokanee (p=0.18 and 0.20, respectively).

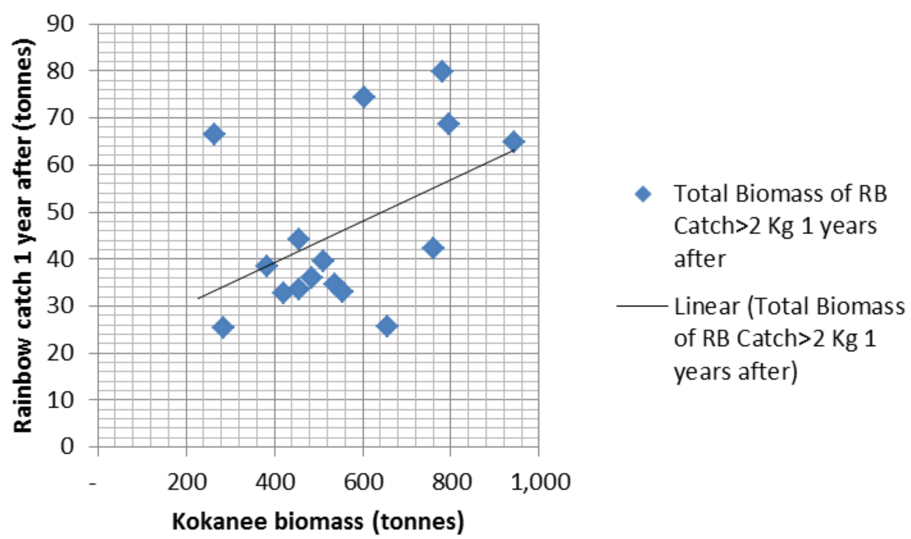


Figure 8d. From the kokanee perspective, variation in kokanee biomass generates moderate responses in rainbow biomass 1 and 2 years after. These correlations are moderate, positive (r=0.47 and 0.34, respectively) and less significant than the lagged rainbow effect on kokanee (p=0.07 and 0.21, respectively).

The lag effect of kokanee biomass on piscivore and rainbow biomass is not as strong as the lag effect of piscivore and rainbow biomass on kokanee biomass. This seems reasonable given that the shorter term piscivore response is mainly in the form of size and condition whereas the kokanee response would be mainly in the form of abundance and age class structure. Response in the form of size and condition of piscivores should translate into fecundity responses, which have the potential to influence piscivore recruitment later-on. It is known anecdotally that the condition of piscivorous rainbow trout has declined following the recent decline in kokanee biomass beginning in about 2009-2011.

Predicting Future Kokanee Recruitment

It is noteworthy that the readjustment of the piscivorous rainbow population is already underway (Figure 9a) whereas the readjustment of the bull trout population may be underway for the larger bull trout, just beginning for the medium sized (5-7 Kg) bull trout, but not yet underway for the smaller (2-5 Kg) class of bull trout. The biomass of all size classes of rainbows > 2 Kg in currently declining. Larger bull trout (> 7 Kg) are also declining. Smaller bull trout (2-5 Kg) are increasing. Medium sized bull trout (5-7 Kg) are wavering. These trends indicate that bull trout population is responding more slowly than the rainbow population.

Smaller (2-5 Kg) and medium sized rainbows (5-7 Kg) as well as smaller bull trout (2-5 Kg) should account for the largest consumption of kokanee at the present time. Of these three size and species classes, only the smaller bull trout (2-5 Kg) are still increasing.

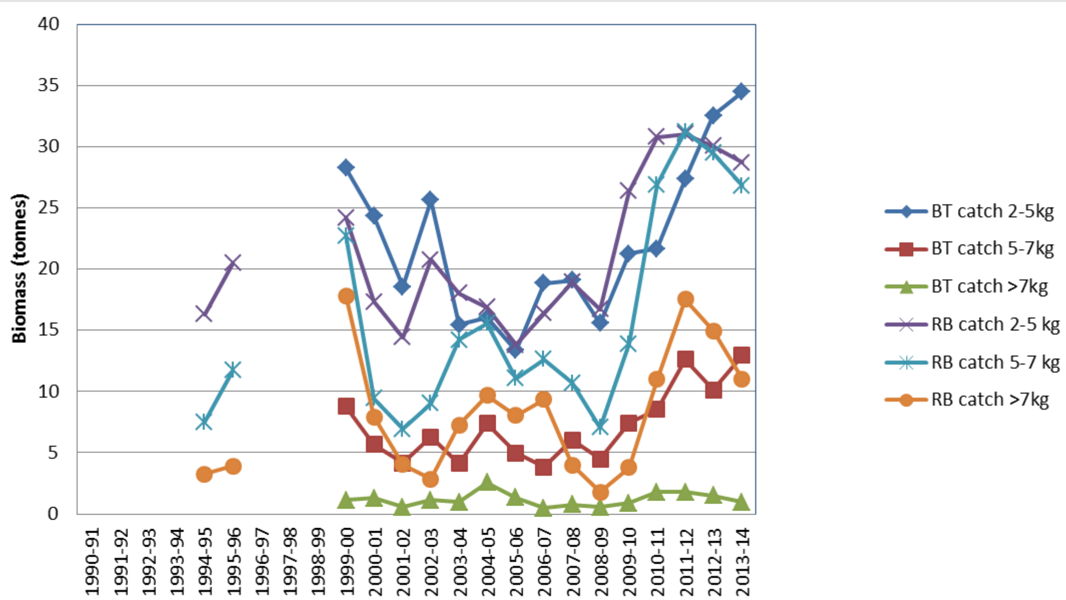


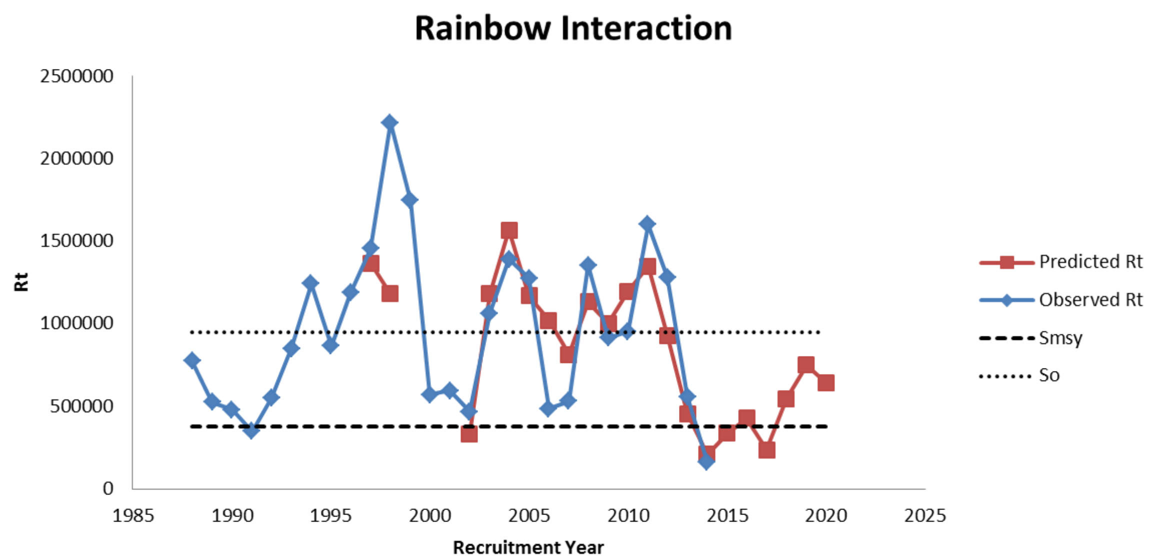
Figure 9. Biomass trends in terms of species and size class at indicated by the sport catch. The biomass of all size classes of rainbows > 2 Kg is currently declining. Larger bull trout are also declining. Smaller bull trout are increasing. Medium sized bull trout may be wavering.

To predict short term future responses in kokanee abundance, I use a stock recruitment model as described in Figure 1, except I add a species interaction term. Specifically, $R_t=S_t*exp(a-bS_t-cC_t+w_t)$ where C_t is a time series of piscivore abundance and c is a parameter estimated from the data that represents the piscivore effect on kokanee recruitment. Because the latest trends in rainbow and bull trout abundance are mixed (Figure 9), I use two variations of this model. One variation uses the time series of rainbow catch (rainbow>2Kg in biomass terms) and the other uses the time series of total piscivore catch (rainbow and bull trout > 2 Kg, again in biomass terms). Using two such versions helps to predict what the consequences might be if potential effects from bull trout are also considered.

It is interesting to note, that both models estimate that, on average and over time, the mortality effect of predation on kokanee adult recruitment is about equal to the mortality effect of kokanee density.

Using the recruitment model with the rainbow interaction term, the predicted recruitment of adult kokanee in 2015 is 340,000 (Figure 10). In 2016, it is 430,000. Similarly, the model with the piscivore interaction term predicts that the recruitment of adult kokanee in 2015 is 320,000 and in 2016, 380,000. Prediction beyond 2016 is conditional on how future piscivore abundance responds. At current rates of rainbow or total piscivore decline (Figures 7a and 7b), model predictions diverge somewhat. At the current rate of rainbow decline, the rainbow interaction model predicts an increasing kokanee abundance trend. At the current rate of total piscivore decline, which is a lesser rate of decline in comparison to just rainbow, the piscivore interaction model predicts a flat trend in future kokanee recruitment abundance.

As a point for future reference, should rainbow decline faster than the latest trend suggests, for example if rainbow catch>2kg suddenly declines to 30 tonnes in 2014 (about the minimum observed from 1994 to 2013) and stays level for just a couple of years, kokanee recruitment should exceed the upper reference point (So) illustrated in Figure 10 by 2018 at which point it may be advisable to keep kokanee abundance from going too high. Similarly, should total piscivore catch decline to 50 tonnes by 2014 (about the minimum observed from 1994 to 2013) and stay level, the model predicts a similar result in that kokanee recruitment should exceed the upper reference point by 2018.



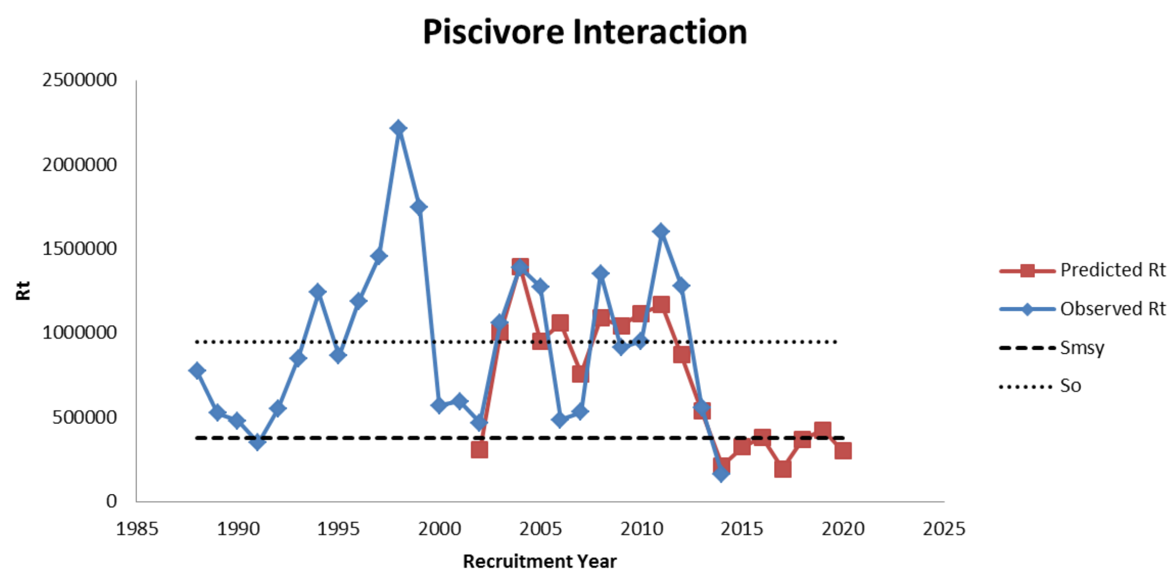


Figure 10. Observed and predicted kokanee recruitment using a Ricker model with a rainbow interaction term (upper chart) and with a piscivore interaction term (lower chart). Predicted kokanee responses in recruitment years 2015 and 2016 are based on kokanee spawner abundance estimates in 2012 and 2013 as well as rainbow and piscivore catch estimates in 2012 and 2013. Kokanee spawner abundance is known for 2014 but rainbow and piscivore catch is not known yet. Prediction of kokanee recruitment in 2017 is therefore based on an extrapolation of the lasted trend in rainbow and piscivore biomass as indicated by the sport catch. Predictions of kokanee recruitment for years beyond 2017 are based predicted forecasts of kokanee recruitment and extrapolation of the latest trends in rainbow and piscivore biomass in the sport catch. Note that S_{msy} and S_o are estimates based on the standard Ricker model as described in Figure 1.

Kootenay Lake Plan, March 2015 - A Preliminary List of Candidate Performance Measures and Targets for Short Term Management (R. Bison)

Management Objective	Variable	Target	Lever	Notes
Stabilize primary production at some level within range observed during the fertilization program time period.	Total phytoplankton biomass	0.3-0.6 mm^3/L	Manage fertilizer	Note that this level of fertilization may be responsible for the cyclical coupling of kokanee and rainbow population dynamics.
Optimize kokanee abundance for the production of predators (see notes)	Total north arm kokanee spawner abundance including Meadow Creek as well as Duncan/Lardeau	380,000-950,000 spawners; conditional on fertilization regime from year 2000 to present. Note Smsy=380,000 and So=950,000	Manage Meadow Creek Channel	This is a time invariant perscription that may be hard to meet if the population is cycling. Therefore consider using forecasts of kokanee adult recruitment abundance as described in Appendix D to guide and prepare for managment of the spawning channel in the short term. Note that management of the sport fishery is inconsequential to kokanee spawner abundance at this level of kokanee abundance, growth and at the current fertilization rate. Finally, these interim targets may not optimize kokanee abundance for the production of predators if the population dynamics of kokanne and predators are indeed cyclical. Further analyses and possible experimentation may be required to estimate targets that achieve this managment objective.
Optimize kokanee abundance for the production of predators	Kokanee 2+ body length	>180 mm	Requires a balance of Meadow Creek Channel operation and sport fish harvesting of predators.	Note that kokanee body length also shows a cycling pattern that is strongly associated with the abundance of large rainbow (>7 Kg) in the sport catch.

Kootenay Lake Plan, March 2015 - A Preliminary List of Candidate Performance Measures and Targets for Short Term Management (R. Bison)

Management Objective	Variable	Target	Lever	Notes
Optimize kokanee abundance for the production of predators by maintaining kokanee abundances and growth rates	Kokanee spawner body length	> 210 mm	Requires a balance of Meadow Creek Channel operation and sport fish harvesting of predators.	Note that kokanee body length also shows a cycling pattern that is strongly associated with the abundance of large rainbow (>7 Kg) in the sport catch.
Correct and stabilize rainbow predator abundance	Gerrard spawners	Restore to abundance ~ 500 Gerrard spawners	Manage rainbow fishing mortality	
Correct and stabilize rainbow predator abundance	KLRT catch of 2-5 kg rainbow	Restore to catch of 4000-6000	Manage rainbow fishing mortality	
Correct and stabilize rainbow predator abundance	KLRT catch of 5-7 kg rainbow	Restore to catch of 1500-2500	Manage rainbow fishing mortality	
Correct and stabilize bull trout predator abundance; alternatively set bull trout abundance target lower if management objective is to cultivate the production of rainbows.	KLRT catch of all bull trout	Restore to catch of 9000-15000	Manage bull trout fishing mortality	Note that the most effective and perhaps one of the most urgent management actions may be in regard to the reversing the latest bull trout trend and restoring bull trout abundance to a lower level.
Monitor for any population growth or crash outside of historic range.	Mysis biomass	500-1500 mg/m^2	none	

Appendix D. Fisheries benefit analysis of various regulation change and stocking options.

Appendix D1. Fisheries benefit analysis of regulation change options.

Action	Close kokanee fishery
Benefit	Expect 2.5 million eggs from not harvesting 10,000 adults caught in the fishery*

Normal Conditions

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.25
1 to 2	0.35
2 to 3	0.5
Number	10,000
Stage	2 to 3
Number of Age 3	9,000.00

Current Conditions

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.06
1 to 2	0.13
2 to 3	0.33
Number	10,000
Stage	2 to 3
Number of Age 3	8,000.00

Action	Increase Gerrard Retention
Benefit	1 RB eats 130 age 1-2 kokanee / year (50g KO) 1,000 RB removed = 130,000 kokanee

Normal Conditions

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.25
1 to 2	0.35
2 to 3	0.5
Number	130,000
Stage	Age 2
Number of Age 3	22,750

Current Conditions

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.06
1 to 2	0.13
2 to 3	0.33
Number	130,000
Stage	Age 2
Number of Age 3	5,577

Action	Increase Bull Trout Retention
Benefit	1 BT eats 50 ko/ year (50g KO; 70% KO Diet) 1,000 BT removed = 50,000 kokanee

Normal Conditions

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.25
1 to 2	0.35
2 to 3	0.5
Number	50,000
Stage	Age 2
Number of Age 3	8,750

Current Conditions

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.06
1 to 2	0.13
2 to 3	0.33
Number	50,000
Stage	Age 2
Number of Age 3	2,145

Total Benefit:

All regulation actions, normal survival	40,500
All regulation action,s current survival	15,722

Notes:
*Close kokanee fishery: No historic survival estimates were available for the few months between fishery mortality and spawning, so an arbitrary number of 10% and 20% was applied for “normal” and “current” conditions.

Appendix D2. Fisheries benefit analysis of various stocking options.

Action: 5,000,000 Eyed Eggs

Normal

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.25
1 to 2	0.35
2 to 3	0.5
Number Stocked	5,000,000
Stage Stocked	Eyed Eggs
Number of Age 3	84,218.75

Current

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.06
1 to 2	0.13
2 to 3	0.33
Number Stocked	5,000,000
Stage Stocked	Eyed Eggs
Number of Age 3	4,955

Action: 500,000 Fry

Normal

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.25
1 to 2	0.35
2 to 3	0.5
Number Stocked	500,000
Stage Stocked	Fry
Number of Age 3	16,843.75

Current

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.06
1 to 2	0.13
2 to 3	0.33
Number Stocked	500,000
Stage Stocked	Fry
Number of Age 3	991

Action: 80,000 Fry into Crawford Creek

Normal

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.25
1 to 2	0.35
2 to 3	0.5
Number Stocked	80,000
Stage Stocked	Fry
Number of Age 3	2,695.00

Current

Life Stage	Survival
Egg to Fry	0.5
Fry to 0	0.77
0 to 1	0.06
1 to 2	0.13
2 to 3	0.33
Number Stocked	80,000
Stage Stocked	Fry
Number of Age 3	159

Total Benefit:

All stocking actions, normal survival	103,758
All stocking actions, current survival	6,104