KOOTENAY LAKE ACTION PLAN

RecoveryPlan *KL AP2016*

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KOOTENAY LAKE ACTION PLAN

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Project No. KL AP2016

Prepared for:

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Summary

This Kootenay Lake Action Plan (KLAP) was prepared for the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). A steep decline in Kootenay Lake Kokanee beginning in 2012 is believed to have been caused primarily by increased predator abundance that ultimately drove the Kokanee to unprecedented low numbers. In turn the older predator numbers and their size have rapidly declined to near record lows.

This five year plan is focused on how to rebuild the Kokanee population and to address the current imbalance between predator and prey on Kootenay Lake. The primary recovery tools available to managers are: 1) supplementation of Kokanee eyed eggs and fry from outside sources in BC into the Meadow Creek spawning channel and the Lardeau River, 2) ensure that lake conditions support Kokanee survival through continued nutrient additions and 3) implementing sport fishing regulations that support recovery objectives.

The main objectives of this recovery plan were to identify key management actions that address:

1. Recovery of the Kokanee population.
2. Recovery of the primary predator populations-Gerrard Rainbow and Bull Trout.
3. Recover the once prominent and provincially significant large lake fishery.

The recovery plan is focused on how to rebuild the Kokanee population using a variety of actions and tools over the next five years (2016-2020). Based on extensive consultation by the KLFAT team during a workshop held on March 7-8 2016, in Kelowna, BC., short term (2015 and 2016) additions of Kokanee eggs and fry were the preferred option(s) to accelerate the Kokanee recovery time on Kootenay Lake. While fisheries managers are fairly confident these measures will contribute to rebuilding of the Kokanee population there is substantial uncertainty that limit the ability to accurately predict the rate of recovery. Key uncertainties include:

1. The number of supplemental Kokanee eggs and fry available and number needed to reduce recovery time.
2. The degree to which predation (i.e. Rainbow Trout and Bull Trout) has declined to permit an increase in Kokanee survival and abundance.

The best science based information indicates the Kokanee population on Kootenay Lake is likely to fully recovery in 6-12 years (annual returns over 500,000). Due to the low Kokanee spawning return in 2015 and predicted low return in 2016 hatchery supplementation is expected to assist in faster recovery of these two cohorts. The hatchery supplementation proposed for 2015 and 2016 brood years is intended to

facilitate a quick recovery despite potential concerns related to Kokanee stock genetics and costs associated with obtaining eggs for out-planting. The recovery plan presents various scenarios with and without hatchery supplementation and evaluates many of the potential benefit/risks associated such management actions. Additionally, the recovery plan assesses various management actions to facilitate and reduce the recovery time of the predator populations in response to predicted increased Kokanee survival and abundance.

Due to the uncertainty associated with the predicted recovery time of Kootenay Lake Kokanee population, this plans' underlying theme encompasses a: ***"Design actions for the best and plan for the worst scenario"*** and will utilize an adaptive management approach for future management actions. Data obtained throughout 2016 will be used to re-evaluate management actions and guide management actions beyond 2016.

Acknowledgements

The Kootenay Lake Fisheries Advisory Team (KLFAT) is acknowledged for their valuable input. Team members consisted of fisheries science and management experts with the specific task of assisting regional MFLNRO fisheries staff. The Team is comprised of representatives from the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), Freshwater Fisheries Society of BC (FFSBC), Ktunaxa Nation government - Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC), and the BC Wildlife Federation (BCWF).

Cover photo ‘Aerial view of Kootenay Lake viewing the North Arm of the lake.’

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Kootenay Lake Action Plan Approval

The undersigned acknowledge they have reviewed the *"Kootenay Lake Action Plan"* and agree with the approach it presents. Changes to this Management Plan will be coordinated with and approved by the undersigned or their designated representatives.

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1 Introduction

The recent collapse of Kootenay Lakes' Kokanee (*Oncorhynchus nerka*) population is unprecedented in British Columbia and has created serious problems for the predator populations that rely on them as their primary prey. Currently the Rainbow Trout (*Oncorhynchus mykiss*) and Bull trout (*Salvelinus confluentus*) populations are in decline due to extremely low Kokanee abundance. As a consequence, sport fishing effort for piscivorous predators has also declined from recent record high levels.

Despite the decline of Kokanee and their predators in Kootenay Lake, it is well known that dramatic cycling in sockeye in the presence of large predator populations can occur (Guill et al. 2014). As well, Kokanee population collapses have been experienced in the nearby States of Idaho, Washington and Montana (Martinez et al. 2009). Although in those cases predation by non-native Lake Trout and Rainbow Trout was found to be the key driver, and recovery depended primarily on large scale predator control efforts (Martinez et al. 2009). Some relevant recovery options contemplated in this plan emanate from studies on Lake Pend Oreille where the Kokanee population collapsed in the early 2000s and more recently have recovered (Hansen et al. 2010, Wahl et al. 2015).

To address the immediate issues on Kootenay Lake a scientific advisory team was formed known as the Kootenay Lake Fisheries Advisory Team (KLFAT). Team members consisted of fisheries science and management experts with the specific task of assisting regional MFLNRO fisheries staff. The Team is comprised of representatives from the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), Freshwater Fisheries Society of BC (FFSBC), Ktunaxa Nation government - Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC), and the BC Wildlife Federation (BCWF). A summary report of scientific advisory teams findings and recommendations are detailed in Lotic Environmental Ltd (2015a, 2015b; draft).

Restoring Kootenay Lakes' Kokanee population requires management actions aimed at a rapid recovery which may in turn minimize further declines to the predator populations. The recovery plan identifies and outlines important management actions based on the KLFAT recommendations. Development and input into this plan came from numerous scientific advisors, detailed in Appendix 1.

2 Rationale for Kootenay Lake Action Plan

The goal of this recovery plan is to restore the lakes' Kokanee and trout populations as quickly as possible. Recovery of Kokanee is considered the top management priority since they are the keystone species in Kootenay Lake important for predators and the maintenance and diversity of other aquatic and terrestrial species. This management plan outlines various actions, benefits/risks and uncertainties associated with recovery of key fish populations. All data sources are identified in Appendix 2. For simplicity various definitions and abbreviations are used throughout, detailed in Appendix 3.

2.1 Objectives

MFLNRO requires management actions that will address three key recovery objectives:

1. Recovery of Kootenay Lake's Kokanee population
2. Recovery of the primary predator populations-Gerrard Rainbow and Bull Trout.
3. Recover the once prominent and provincially significant large lake fishery.

3 Background

3.1 Overview

Kootenay Lake has supported a regionally unique recreational fishery that generates 20,000 to 40,000 angler days per year, estimated to be worth [1]$5-10 million annually to the local economy. The majority of fishing effort (85%) is primarily directed at Rainbow and Bull Trout (Andrusak and Andrusak 2012). The sport fishery has been designated a high priority by the Province as a result of its ability to produce "trophy size" fish. While data from the sport fishery indicate that both species contribute substantively to the overall sport catch on the lake, the majority of anglers seek to catch a large Gerrard Rainbow Trout (Andrusak and Andrusak 2012).

Kootenay Lake has endured significant ecological impacts from cultural eutrophication, introduction of *Mysis diluviana*, hydro-electric impoundments and drastic changes to the hydrograph (Moody et al. 2007) which have had profound negative consequences to fish populations over the last half century (Ashley et al. 1997), summarized in Appendix 4. The cumulative ecological impacts evident by the 1980s required extensive restoration of the lakes' productivity in order to rebuild low Kokanee numbers. Therefore, in 1992, a large lake nutrient restoration program was initiated to restore the Kokanee population with outcomes detailed in Ashley et al. (1997) and Bassett et al. (2016).

[1] *Values are $149.96/angler-day including expenditures, and $228.95/angler-day including wholly or partially attributable major purchases [derived from The Survey of Recreational Fishing in Canada (Fisheries and Oceans Canada 2012; Annexes A.6, 9, 10, 11)].*

3.2 Kokanee

Kokanee are the keystone species in Kootenay Lake. As the most abundant species in the pelagic habitat, they provide the primary food source for large piscivores predators. As the dominant pelagic planktivore, Kokanee rely almost entirely on zooplankton and have benefited substantially from increased productivity through nutrient additions (Ashley et al. 1997, Schindler et al. 2014, Bassett et al. 2016). Kokanee population status is assessed through a number of metrics including their distribution, size, abundance and biomass in the lake and numbers and size of mature fish returning to spawn (Bassett et al. 2016).

Meadow Creek and the Lardeau River are the primary spawning systems for the main lake Kokanee population. Spawner abundance in these systems has been tracked since the early 1960s, making them the most studied Kokanee population in British Columbia. Over the last half century Meadow Creek spawner numbers have provided an index of abundance for main lake Kokanee. Estimates of fry production are used to evaluate egg to fry survival in the spawning channel, as well as fry to adult survival in the lake. This system has also been the primary source for Kokanee egg collection in BC for nearly a century (Northcote 1973). Meadow Creek Kokanee eggs and fry have been planted in many lakes throughout BC, including egg and fry plants in streams tributary to the South Arm of Kootenay Lake (Andrusak and Sebastian 2007).

3.3 Gerrard Rainbow Trout

A considerable amount of research has been dedicated to understanding the biology of Gerrard Rainbow Trout, including a description of their general life history by Cartwright (1961), spawning behavior by Hartman (1969) and juvenile rearing requirements in the Duncan-Lardeau River system by Irvine (1978), Slaney and Andrusak (2003), and Decker and Hagen (2009). These trout represent a rare ecotype (Keeley et al. 2007) that are highly dependent on Kokanee as their primary food source (Andrusak and Parkinson 1984) and grow to large size. This stock is entirely dependent upon the Duncan-Lardeau River system, the only watershed within the basin where they are known to spawn and rear (Irvine 1978).

In recent years, a substantial number of stock assessment studies have been implemented to better understand the stock dynamics of this unique ecotype, especially in relation to the impacts of the recreational fishery and associated fishing mortality. Such studies include: size at age, fecundity and growth detailed in Andrusak and Andrusak (2006, 2015), assessment of natural and fishing mortality rates detailed in Andrusak and Thorley (2012b, 2013b, 2014), stock productivity and capacity detailed in

(Andrusak 2014, 2015a) and in-lake predator population estimates detailed in (Andrusak 2015b).

3.4 Bull Trout

Adfluvial populations of Bull Trout rely upon the lacustrine habitat within Kootenay Lake and are also dependent on Kokanee as their primary food source (Beauchamp and Van Tassel 2001). Bull Trout, as well as Rainbow Trout, most likely experienced increased in-lake survival and growth conditions as a result of high Kokanee abundance up to 2011, associated with the improved lake productivity from the nutrient restoration program (Schindler et al. 2014, Bassett et al. 2016). This would be similar to improvements in Arrow Reservoir Bull Trout growth and condition factor reported by Arndt (2004) in the early years of the Arrow Reservoir nutrient program.

Recent information on Bull Trout spawning in select tributaries to Kootenay Lake suggests potential spawner numbers may be > 4,500 (Andrusak and Andrusak 2012a) and recent in-lake estimates of >25,000 large (> 50 cm) Bull Trout (Andrusak 2015b) . Bull Trout are well distributed throughout Kootenay Lake tributaries that support their spawning and rearing. However, as with many species of char, Bull Trout are well known to have slow growth rates and mature later than species like Rainbow Trout and Kokanee (McPhail 2007).

4 Kokanee Status and Recovery

The main lake adult Kokanee population appears to have begun a steep decline in 2012 (Figure 1). Population abundance is currently at an unprecedented record low – 98% lower than the long-term average observed since 1964 (Figure 1). An imbalance in the predator-prey relationship is considered to be the key factor for this recent Kokanee collapse. Continued predator pressure could potentially limit Kokanee recovery [depensatory state (Liermann and Hilborn 2001) or predator pit (Bakun and Weeks (2006)], however, this is unlikely due to a near concurrent declines in predator abundance. Indeed, a simple time lag between high predator abundance and Kokanee is a potential mechanism for the rapid decline in Kokanee.

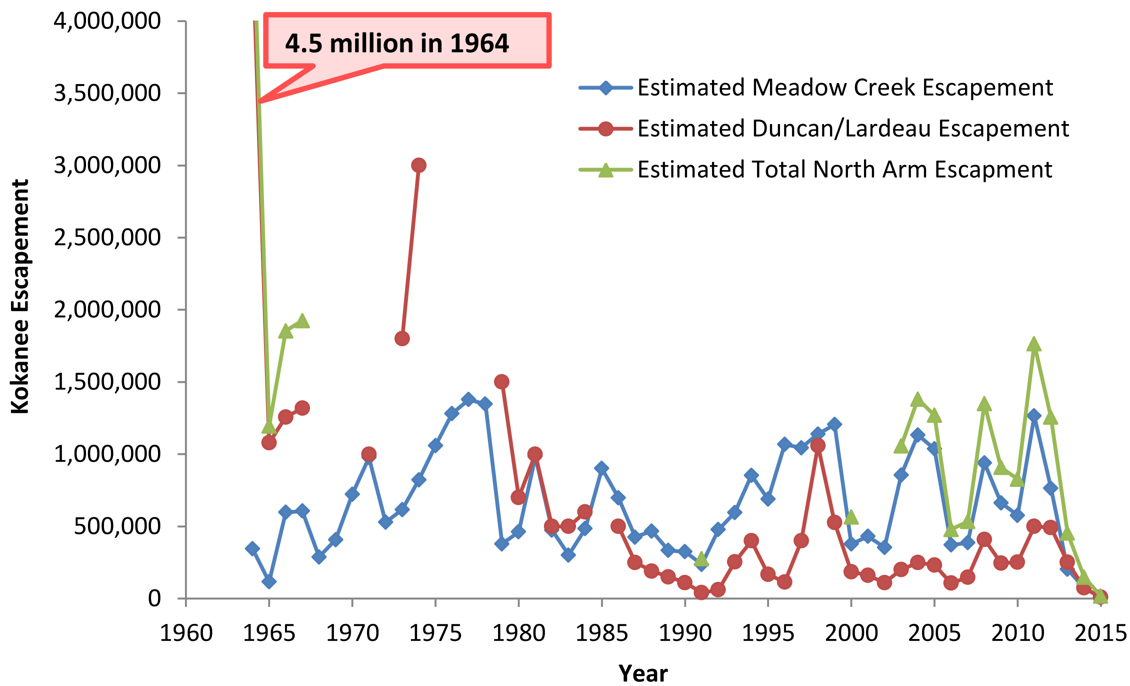

Figure 1. **Kokanee escapements to North Arm of Kootenay Lake estimated from MCSC and Lardeau River from 1964-2015 (MFLNRO data on file).**

4.1 Analysis of Kokanee Population

A number of data analysis tools were used to identify conservation and recovery targets. It is important to note that although these predictive models are the best available tools to estimate future spawner numbers, predicting future population recovery is contingent on increases in Kokanee survival in the lake. As such, population predictions and the associated recovery timeline has high levels of uncertainty and will need to be revised if Kokanee survival does not improve in 2016. The high degree of uncertainty of future predator numbers beyond 2015 also requires caution when interpreting future estimated Kokanee spawner numbers, as they are contingent on Kokanee survival increases. This action plan has incorporated uncertainty in the forecasts, and actions will be evaluated annually through data collection (and adaptive management). In this section, all escapement information is considered to be total North Arm Kokanee spawner numbers.

A time invariant Ricker stock recruitment (SR) model (1991-2008 data) was fit to the available Kokanee abundance data and estimated an optimal spawning stock size at maximum sustainable yield (MSY) of near 500,000 individuals, and a maximum adult recruitment of >1.0 million spawners (Table 1; Appendix 5; Askey and Bison 2016). Analysis indicates the long-term average escapement has been 1.07 million spawners, with a range of 0.277 to 3.8 million from 1964-2012 (MFLNRO on file) and an optimal fall fry production of >17.0 million fry (Appendix 5). This estimate falls within the long-term (1992-2012) average fry production of 17.0 million fry with a range of 7-31 million fry over the same time period.

Table 1. Kokanee escapement targets for Kootenay Lake Kokanee based on a Ricker stock-recruit function. Estimates are based on spawner data for the brood years 1991 to 2008 (Askey and Bison 2016)

Parameter	Ricker-no predator	Ricker-with predator	Description
MSY	0.45	0.65	Spawner density at MSY (millions)
K	1.12	1.71	Carrying capacity of spawners (millions)
Targets	0.5-1.5	0.7-2.0	Escapement target range (millions)

Parameter estimates from the model were projected forward in a deterministic simulation to forecast recovery time and evaluate the potential relative benefit from Kokanee stocking (Askey and Bison 2016). Without hatchery supplementation, this analysis indicates that Kokanee spawner abundance in 2016 will remain near record low abundance, which was also supported by ATS Kokanee data collected in fall 2015. The Kokanee spawner prediction for 2017 and beyond suggests a large increase in Kokanee spawners, however predictions may be optimistic as recovery estimates are dependent on predator abundance that has yet to be indexed.

As mentioned above, there are variable predictions about specific escapement numbers in any given future year depending on modelling assumptions (Askey and Bison 2016) and contingent on increases in Kokanee survival in 2016. However, the predicted magnitude of benefit from supplementation (how much it helps compared to the base case), and overall population trajectory are consistent across all assumptions. A review of the potential benefit of hatchery supplementation indicated that at present, there was only evidence that egg/fry supplementation would reduce recovery time of Kokanee for specific spawning cohorts; which include 2015 and 2016 brood years (Askey and Bison 2016). Table 2 presents scenarios of variable egg-to-adult survival rates to assess the potential benefit/risk associated with hatchery supplementation. For example, when in-lake fall fry to adult survival was considered "normal to good" at approximately 6% (1992-2012) and "poor" at approximately 0.5% (2014-2015), the benefit of stocking 5.0 million eyed eggs would be 112,500 spawners four years later (t+4) at the higher survival rate (6%) compared to 9,375 spawners four years later (t+4) at the lowest survival rate 0.5%. Hatchery augmentation was not recommended in the egg/fry year after 2016/17 based on this modelling, because strong Kokanee spawner numbers were forecast in 2017 and beyond. Again, this is highly dependent on predator numbers remaining low, and will be evaluated annually.

Table 2. The effect of stocking up to 5 million eyed eggs on Kootenay Lake Kokanee in the first fall (when age-0), and the expected number of additional spawners resulting 3 years later from Askey and Bison (2016)

Survival parameter	1992-2012	2014-2015
egg to fry	0.5	0.5
spring fry to fall fry	0.75	0.75
fry to spawn	0.06	0.005
Stock rate (eggs)	**Returns (t+4)**	**Returns (t+4)**
500,000	11,250	938
1,000,000	22,500	1,875
1,500,000	33,750	2,813
2,000,000	45,000	3,750
2,500,000	56,250	4,688
3,000,000	67,500	5,625
3,500,000	78,750	6,563
4,000,000	90,000	7,500
4,500,000	101,250	8,438
5,000,000	112,500	9,375

It is recommended that the "conservation" target for Kokanee recovery be 65,000-140,000 spawners, which would allow an intermediate recovery to the target range of 500,000 within four years (Askey and Bison 2016). In addition, the "recovery" target for Kokanee management should be a minimum of 500,000 spawners which are at the lowest observed range detailed in Table 1.

In summary, based on Kokanee escapement forecasts, hatchery supplementation in the 2015 and 2016 brood years is predicted to result in a benefit to Kokanee spawner abundance and a measurable reduction in the recovery time of the Kokanee population given current predictions of future spawner escapement. In addition, supplementation appears to have limited benefit to the recovery of the Kokanee population when spawner abundance exceeds 65-140,000, assuming in-lake survival rates increase, and future supplementation will be informed by the latest forecast of future spawner abundance.

4.2 Kokanee Genetics

Hatchery supplementation is typically used as a tool in recreational fisheries, however it can also be used to restore or recover fish populations when necessary. Before large-scale supplementation could be contemplated for Kootenay Lake it was necessary to complete an assessment of the genetic relatedness of potential donor stocks in order to help identify the risks associated with stocking. The North Arm populations (Meadow, Lardeau and Duncan) are considered to be genetically related, with much of the parental lineage associated with the Meadow Creek stock that is significantly different from the South and West Arm stocks in the lake (Vernon 1957, Anders et al. 2007, Lemay and Russello 2012).

Potential donor stocks for supplementation would include those stocks that have historical parental lineage (i.e. genetically related) with the Meadow Creek stock. It should be noted that Meadow Creek Kokanee has been used as a donor stock within BC for well over a half century (FFSBC data on file). In order to determine which Kokanee stocks would be the most appropriate for Kootenay Lake supplementation, a recent genetic analysis was conducted using single-nucleotide polymorphisms (SNP) (Russello 2016). This work identified the most appropriate sites for egg collections and supplementation of North Arm Kokanee. This study suggested that there was no statistical difference between North Arm Kokanee and Kinbasket (Mica) Reservoir and Whatshan Reservoir populations (Appendix 6; Appendix 7). However, due to the planned target of up to 5.0 million eyed eggs for supplementation, additional sites may need to be considered if this target is to be reached. The analysis conducted by Russello (2016) suggested that the next closest genetic matches to North Arm Kootenay Lake Kokanee include Kookanusa Reservoir and Slocan Lake (Russello 2016; Appendix 6; Appendix 7).

Therefore, potential donor stocks may include Whatshan Reservoir, Kinbasket Lake and Kookanusa Reservoir (Lussier River) Kokanee. Eggs will likely be collected from Kokanee at these locations in order to attempt to meet the 5.0 million target of green eggs needed to supplement to Kootenay Lake.

4.3 Recovery Objectives and Rationale

The goal of this Kokanee recovery plan is to identify management actions required to facilitate a short-term recovery and long-term maintenance and persistence of Kootenay Lakes' Kokanee population (Table 3). Recovery of Kokanee is critical in meeting conservation and recovery of the lakes' predator populations, primarily Gerrard Rainbow Trout and Bull Trout.

4.3.1 Objective#1- Kokanee Status and Recovery

Table 3. Kokanee Status and Recovery

Goal	Estimated Target and Timeframe
Recovery	*Estimated target of >65,000-140,000 spawners, 6-12 years*

4.3.1.1 Option 1-Enhanced Monitoring

Rationale-Debate amongst the KLFAT team as to the necessity of planting Kokanee eggs or fry to facilitate a quick recovery led to an agreement to outline options for no supplementation (no stocking) compared to supplementation.

Under this option no hatchery supplementation of Kokanee (egg-plants or fry release) would occur. This option would rely on the natural resiliency of the Kootenay Lake ecosystem to recover the Kokanee population over time. There were varying opinions on the benefit and absolute need for supplementation, however the majority of KLFAT members considered this to be the least preferable in the short term, especially since Kokanee spawner numbers for 2016 are projected to be less than the threshold of 65,000-140,000 spawners beyond which point stocking Kokanee has little benefit, as described by Askey and Bison (2016). After 2016 this option will be reconsidered depending on updated forecasts of in-lake abundance and spawner numbers determined in the fall, 2016.

Enhanced monitoring (Table 4) would be implemented under this option in addition to current monitoring conducted on Kootenay Lake. The additional monitoring would involve collecting key pieces of information associated with current uncertainties that would assist in making future management decisions. This option assumes that Kokanee will naturally compensate through increased survival as predator abundance and predation rates decline over time that may well be the case after 2016. While current indicators suggest predator abundance and predation has been substantially reduced, there is still considerable uncertainty whether predators have declined to a level that is low enough to not limit the Kokanee population at the current extremely low abundance level. If predation has not been reduced enough, there is potential that this option of no supplementation could potentially delay the Kokanee recovery time.

Finally, fisheries management must assess the benefit/risk to implementing this option (Table 5). Certainly there is a substantial cost savings and reduced risk associated with genetic concerns for Kokanee under this option. Additionally, future recovery scenarios using a reasonably simple modeling approach (Askey and Bison 2016) suggest that stocking ~5 million Kokanee eggs annually would likely have little benefit to recovery time, so the benefit suggested through this forecast is small, especially after 2016. However the recovery time for Kokanee could potentially be prolonged if predation rates are sufficiently high and continue to suppress Kokanee abundance. In addition, with the potential to prolong the recovery time, there is a substantial concern regarding the recovery of the recreational fishery and its estimated value $5-10 million to the local economy.

4.3.1.1.1 Actions, Tools and Targets

Various management actions under this option, detailed in Table 5 include:

Table 4. Routine Annual and Enhanced Monitoring 2016-2020

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

Table 5. Kokanee Status and Recovery 2016-2020

Objective	Action	Tools	Trigger	Measure	Rationale	Benefit/Risk	Rank
Recovery of Kokanee	**No Supplementation**	Natural resiliency and recovery	NA	NA	Allow ecosystem to recover naturally	Reduced cost, no genetic concern, prolong recovery, prolong recovery of fishery	low
	Main lake fishery closure for Kokanee	Recreational Fishery Regulations	ATS age 0 to age 1 survival > 11%, KLRT > 2 kg RBT CPUE low	KO escapement > 140,000	Reduce mortality on population during the recovery.	High benefit to increase probability of Kokanee recovery. Main lake Kokanee fishery is not considered to be highly valued	high
	Supplementation	Egg plant and/or fry release	KO escapement < 140,000, age 0 to age 1 survival < 11%, < 17.0 million fry, KLRT > 2 kg RBT CPUE mod-high	KO escapement > 65-140K	Reduce recovery time for low abundance KO cohorts (brood 2015 and 2016)	Increase probability of survival of the Kokanee, with an estimated egg to fry survival of near 70%. FFSBC has a limited capacity to incubate eggs at their facilities.	high
	MCSC hatchery to support supplementation	MCSC facility	Increase capacity beyond 5.0 million eggs, ability to use "green eggs" for out-planting and imprinting at MCSC	> 2.0 million eggs	Increase FFSBC hatchery capacity > 5.0 million by incubating at MCSC	Increased capacity egg incubation capacity of >5 million eggs available	low
	Maintain main lake fishery closure for Kokanee	Recreational Fishery Regulations	KO escapement < 140,000, age 0 to age 1 survival < 11%, KLRT > 2 kg RBT CPUE mod-high	KO escapement >65-140K	This action will ensure no mortality from angling occurs on the main lake Kokanee population during the recovery	High benefit to increase probability of Kokanee recovery. Main lake Kokanee fishery is not considered to be highly valued	high
	Kootenay Lake Nutrient Restoration Program	Continue to modify seasonal and weekly nutrient addition amounts and fine-tune timing of nutrient additions in spring and fall	Analysis of annual monitoring data; Stratification (spring) of lake, de-stratification (fall) of lake, temperature and light	Variable annual phosphorus (25-47 tonnes) and nitrogen (140-250 tonnes in North Arm and 190-270 tonnes in the South Arm)	Replace Nutrients Lost through the creation of upstream impoundments to Improve efficiency and biological uptake of nutrients for phytoplankton to zooplankton to ensure Kokanee food supply	Take advantage of seasonal changes in climate to facilitate better growing conditions for phytoplankton	high
	Mysis removal	Test fishery to remove Mysis similar to Okanagan Lake	Increase in biomass and density 2 SD over long term average (168 ind/m^2) would be 463 ind/m^2	KO escapement > 65-140K	Remove >30% of the total Mysis biomass to reduce Kokanee competition and increase Kokanee survival	Mysis of requires over 30% of the total biomass to be removed before a benefit to Kokanee can be realized. Substantial costs would be associated with the development of the Mysis fishery..	low
	Predator Management	Recreational Fishery Regulations	KO escapement < 140,000, age 0 to age 1 survival < 11%, KLRT > 2 kg RBT CPUE high	KO escapement > 140,000	Further removal of predators may provide additional benefits to the recovery of Kokanee through increased survival.	Increase impact to predator population. May have limited improvement for Kokanee.	low

1. No supplementation

This action would rely on the natural resiliency of the ecosystem to recover Kokanee naturally over time. Enhanced monitoring (Table 4) would be implemented to assess performance measures around this management action and key thresholds/triggers would be used to ensure the actions are meeting the intended objectives. It should be noted that the 2015 cohort has already been supplemented with eyed egg plants (0.5 million) and a scheduled release of 0.5 million fry in the spring 2016.

Key triggers for this option would include an age 0 to 1 survival rate of > 11.5 % from acoustic and trawl surveys (ATS) surveys and an inferred reduction in predation based on KLRT >2 kg RBT CPUE (Table 5). Key targets or thresholds that ensure the action is meeting its intended objective include a combined escapement of 65,000-140,000 spawners in the MCSC and Lardeau and Duncan rivers (Table 5).

Reduced cost compared to hatchery supplementation may warrant this action after 2016. There is some uncertainty that hatchery supplementation will be successful in recovering Kokanee if predation levels are still moderate to high.

1. Maintain main lake Kokanee closure

The tool for this action utilizes existing regulations to maintain the fishing closure for Kokanee on the main lake (Table 5). The main objective of this action is to reduce and minimize all harvest induced mortality from angling. Due to their increased average size in recent years, Kokanee would be more susceptible to harvest from the fishery which could potentially prolong recover time.

The primary tool would be to maintain the zero retention of Kokanee on the main lake through regulations. Key triggers to lift this closure include an age 0 to 1 survival of > 11.5 % from ATS surveys and an inferred reduction in predation based on KLRT >2 kg RBT CPUE (Table 5). Key targets or thresholds that ensure the action is meeting its intended objective include an escapement of 65-140,000 spawners within MCSC and Lardeau and Duncan rivers combined (Table 5).

4.3.1.1.2 Measures or Targets

Under option 1 recovery of the lakes' Kokanee population to a target of 65,000-140,000 cannot be achieved in 2016 based on current spawner projections. The ATS and enhanced monitoring will assist in determining the strength of the 2017 cohort and whether or not supplementation is required in the future. Monitoring tools will determine if age 0 to age 1 Kokanee survival has improved to long-term average of

11.5%, indicating a recovery may be imminent. Improved condition of age 1 Kokanee from the 2016 trawl surveys will also be a key factor.

4.3.1.1.3 Benefit/Risk

Benefit	Risk
• No supplementation option will have reduced cost	• Slower recovery time for Kokanee
• No genetic concern on wild stock Kokanee	• Prolong recovery of predator populations that rely on Kokanee
• Natural resilience of KL ecosystem to recovery (without confounding supplementation)	• Prolong recreational fishery recovery
• Forecasts suggest limited benefit to stocking (especially after 2016)	• Lost revenues ($5-10 million) to local economy

4.3.1.2 Option 2-Enhanced Monitoring with Supplementation and other Management Actions

Rationale-The option of enhanced monitoring with supplementation is aimed at facilitating a rapid recovery of known low abundant Kokanee cohorts (2015 and 2016) through large scale egg supplementation and hatchery released fry (Table 5). There is some uncertainty around the Kokanee response to supplementation given the inability to predict the level of predator abundance and predation. In the short term, data analysis indicates supplementation could potentially reduce recovery time for the 2015 and 2016 brood years if sufficient numbers of eggs or fry are available. The recommendation of KLFAT members was to supplement the 2015 and 2016 brood years with planting of eyed eggs and fry. i.e. recommend Option 2.

Enhanced monitoring (Table 4) was suggested to be implemented over and above annual monitoring conducted on Kootenay Lake to assist in assessment of recovery efforts. Option 2 would be re-evaluated in the fall of 2016 to assess whether further supplementation of future cohorts of Kokanee would be necessary. This adaptive management approach requires a number of triggers or thresholds to be developed to guide whether further management actions are required.

4.3.1.2.1 Actions, Tools and Targets

Various management actions under this option, detailed in Table 5 include:

1. Supplementation.

Tools for this action will rely on hatchery raised fry releases (500,000) and large scale egg plants (5.0 million) to recover the 2015 and 2016 brood years, respectively.

Implementation of this option has to be based on individual cohort strength since natural numbers in the lake are highly variable and there is uncertainty for each cohort in-lake survival. i.e. the extent of supplementation depends on estimations of fry production and in-lake survival estimates from fry to age 1. Enhanced monitoring would be initiated to assess performance measures around this management action and key thresholds/triggers would be used to ensure the actions are meeting the intended objectives related to the recovery of Kokanee (Table 5).

Key triggers include an age 0 to 1 survival of < 11.5 % from ATS surveys and an inferred reduction in predation based on KLRT >2 kg RBT CPUE (Table 5). Key targets or thresholds that ensure the action is meeting its intended objective include reaching a combined escapement threshold of 65-140,000 spawners within MCSC and Lardeau and Duncan rivers (Table 5). Reaching this target threshold would invoke management actions to reduce or eliminate further supplementation since it is expected this level could potentially return 500,000 four years later (t+4).

1. Maintain main lake Kokanee closure (zero retention)

The tools for this action utilize existing regulations for maintaining the closure for Kokanee on the main lake (Table 5). The main goal of this action is to reduce and minimize all harvest induced mortality from angling. Due to increased average Kokanee size in recent years, they would be more susceptible to harvest which could potentially prolong recover time.

Key triggers that would re-evaluate this management action include an improved age 0 to 1 survival of > 11.5 % from ATS surveys and an inferred reduction in predation based on KLRT >2 kg RBT CPUE (Table 5). Key targets or thresholds that ensure the action is meeting its intended objective include reaching an escapement threshold of 65-140,000 spawners within MCSC and Lardeau and Duncan rivers combined (Table 5).

2. Kootenay Lake Nutrient Addition Program

The current Kootenay Lake nutrient addition program adaptively manages nutrient loading to optimize efficiency of nutrient uptake for phytoplankton. Ensuring balanced N:P ratios and areal nutrient loading are key to ensuring the most efficient transfer of nutrient generated carbon to zooplankton and the remainder of the food chain. The annual target (budget) and weekly dosing forecast for nutrient input is set at the beginning of the year, and then weekly optimization requires variable inputs of phosphorus and/or nitrogen between April and September to adapt to changing lake conditions.

The annual nutrient budget and dosing schedule is determined based on performance the year before by reviewing phytoplankton biomass, zooplankton biomass and Kokanee abundance. In addition, the long-term data is also reviewed. During the nutrient addition season, key triggers for adaptively managing weekly nutrient inputs in-season include thermal stratification (note: weak in the spring; stronger in the fall) of the lake and associated environmental influences that change by season (e.g., light). Stratification of the lake, which relies on water temperatures, is a key trigger for varying the timing of nutrient loading in the spring. Similarly, stratification or de-stratification, based on water temperatures, is a key trigger for adjusting the timing of nutrient loading in the fall. Based on these variables, weekly inputs of phosphorus and/or nitrogen are carefully matched to seasonal lake conditions of water chemistry and phytoplankton. Consensus input from KLFAT limnology experts indicates macro-zooplankton food limitation is not a concern for Kokanee in Kootenay Lake at this time, nor for the past several years (Dr. Ken Ashley pers. comm.). However, as the Kokanee population recovers, it will be important to quantify the increased requirement for additional zooplankton and when Kokanee food limitation could potentially occur in future. As the Kokanee population recovers, nutrient additions will be adaptively managed to match lake conditions (within recommended P input of >25T and < 47T), and could include increases to the annual nutrient addition target and associated budget to support increasing Kokanee biomass.

Key recommendations from KLFAT limnology experts:

a) Continue to ensure N:P ratios are optimized for nutrient balance and carbon transfer to zooplankton

b) Increase or decrease P and N loading to adapt to changing lake conditions, with the goal of always ensuring sufficient zooplankton are available to meet Kokanee demands

c) Continue to collaborate with colleagues to adaptively manage the nutrient addition program to changing lake conditions, and report annually on the nutrient addition program.

3. Mysis removal

Removal of *Mysis diluviana*, a co-competitor with Kokanee for zooplankton, may provide an additional benefit to Kokanee, especially if mysids respond to lack of Kokanee biomass with population level increase (not yet observed). Such work has been conducted on Okanagan Lake since 2000 (Andrusak and Andrusak 2016).

A tool for this action is the removal of mysids from Kootenay Lake that could potentially improve survival of Kokanee and reduce recovery time (Table 5). However, despite the fact that mysids are a direct competitor with Kokanee for macro-zooplankters, there is no scientific evidence that Mysis are currently having any direct impact on Kokanee survival or recovery. There is evidence that mysids may have an indirect effect on Kokanee because some recent analyses of predator food habits indicate mysids in their diet (MFLNRO on file). While considerably more complex than the situation on Kootenay Lake, mysids facilitated an indirect increase in predation that was implicated in the collapse of Kokanee on Flathead Lake in Montana (Ellis et al. 2011).

As a precautionary approach, a key trigger that would invoke management actions for the removal of mysids is an increase in biomass and density above the long-term average of ±2 standard deviations (SD) (Table 5). The long term average is 168 ind/m^2, and therefore the threshold to consider implementing this action would be 463 ind/m^2 (MFLNRO data on file). In 2015, monitoring data indicated the mean was 150 ind/m^2 (MFLNRO data on file). Options for mysid removal will be researched by MFLNRO staff.

Based on the decision making process by KLFAT team, mysids removal was not considered to be an immediate priority for the recovery of Kokanee. Mysis harvest requires over 30% of the total biomass to be removed before a benefit to Kokanee can be realized (Kay 2002). Substantial costs are associated with the development of a Mysis fishery which relies on supply and demand economics as well as considerable infrastructure costs. However, the recommendation was to proceed with an evaluation of the options for a removal program, so that there was a more defined action to trigger if Mysid abundance increases in the future.

4. Predator management

High predator abundance and predation are considered to be the likely causal factor for the collapse of Kokanee in Kootenay Lake. Further removal of predators may provide additional benefits to the recovery of Kokanee (also discussed in Gerrard Rainbow Trout *Section 5.0* and Bull Trout *Section 6.0*). Elsewhere, simulations of predator reduction indicated that predator reduction could be an effective strategy to facilitate the recovery of Kokanee populations in Montana, Colorado, Washington and Idaho (Hansen et al. 2010, Dux et al. 2011, Schoen et al. 2012, Pate et al. 2014).

Tools for this action would primarily utilize recreational angling regulations to conduct a predator reduction program on Kootenay Lake- if needed (Table 5). The program would target Rainbow Trout and Bull Trout and possible other species. Elsewhere in the US North-West, removal methods such as gillnetting and incentive or reward programs have also been utilized to reduce Kokanee predators (Martinez et al. 2009). However, because predator populations are currently in significant decline, and that there are some challenges with incentive and gill net removal implementation on Kootenay Lake, the KLFAT considered these measures to be unnecessary at this time on Kootenay Lake.

Key triggers that may invoke management actions to further reduce predators include, continued low age 0 to 1 survival of < 11.5 % in 2016 based on ATS data and an inferred increase in predation based on 2015 KLRT CPUE data for both Rainbow Trout and Bull Trout (Table 5). Additionally, the inability of the Kokanee cohorts to reach the threshold of 65-140,000 spawners would also be a trigger for further predator reduction (Table 5).

Further predator removal was not given a high priority by KLFAT members since recent predator indices have declined substantially indicating a significant correction in predator abundance (Table 5). However, despite the apparent reduction in the large predator indices (> 2kg RBT CPUE) which infers reduced predation, there was concern that predation may still be underestimated since model analysis did not account for small predators (< 2kg RBT CPUE) or Bull Trout consumption. Smaller predators have been identified as a major source of consumptive pressure on Kokanee (Pate et al. 2014) which could decrease the Kootenay lake Kokanee recovery time. As well, non-consumptive pressure can also potentially reduce Kokanee productivity through behavioral changes (Schoen et al. 2012). The status of the predators requires close monitoring since this is the greatest uncertainty for predicting Kokanee recovery.

Potential costs of predator reduction should be weighed by the benefits to Kokanee. Further removal of predators may delay their recovery as Kokanee recover. Bull trout is a species of special concern in BC already and the Gerrard Rainbow Trout ecotype is provincially significant and population abundance of both species has declined substantially already. However, it is unclear if this decline is significant enough to allow Kokanee survival rates to increase given their current low abundance.

5. Egg incubation at MCSC hatchery

This action requires the modification of the existing structure at MCSC that was historically used for incubating and rearing Gerrard Rainbow Trout. Modifying this structure could provide additional hatchery capacity above existing FFSBC hatchery production capability to incubate eggs for eyed egg plants. This option would require updating at the existing MCSC hatchery facility partly decommissioned in the late 1980s.

There would be an additional cost for installation of incubation infrastructure and costs associated with monitoring.

4.3.1.2.2 Measures or Targets

Recover the lakes' Kokanee population to a target of 65,000-140,000 spawners in 6-12 years. Meeting this target would initiate the reduction or elimination of hatchery supplementation. Monitoring tools will determine if age 0 to age 1 Kokanee survival has improved above 11%, indicating a recovery may be imminent. Improved condition of age 1 Kokanee from ATS surveys will also be a key factor.

4.3.1.2.3 Benefit/Risk

Benefit	Risk
• Potential faster recovery of Kokanee population • Potential faster recovery of predators • Predator conservation levels retained • Potential quick recovery of fishery • Increased egg plant capacity beyond FFSBC capability	• High cost associated with management actions • Potential for loss of genetic variation from hatchery supplementation • Greater risks associated with fry releases • Short term fishing closures

5 Gerrard Rainbow Trout Status and Recovery

The recent collapse of Kootenay Lakes' Kokanee population has created concern for the Gerrard Rainbow Trout population since they are highly dependent upon them as their primary food source (Andrusak and Parkinson 1984, Andrusak and Andrusak 2015). The current escapement index at the Gerard spawning grounds suggests the population has experienced a severe decline in abundance since its record high in 2012 to a level that is near the low end of the historic range (Figure 2) and indications from the in-lake fishery suggest that the 2016 spawner numbers may be even lower with smaller size and lower fecundity.

While the decline in the population is associated with the collapse of the Kokanee population, a number of potential factors led to rather large and significant increases in the escapement index beginning in 2009 (Figure 2). These potential factors include: a possible reduction in fishing mortality associated with regulation changes that were implemented in 2005 (Appendix 8) and increased lake productivity with the onset of South Arm nutrient addition in 2004 (Bassett et al. 2016), the latter of which may have improved in-lake survival, growth and fecundity of predators during the last decade.

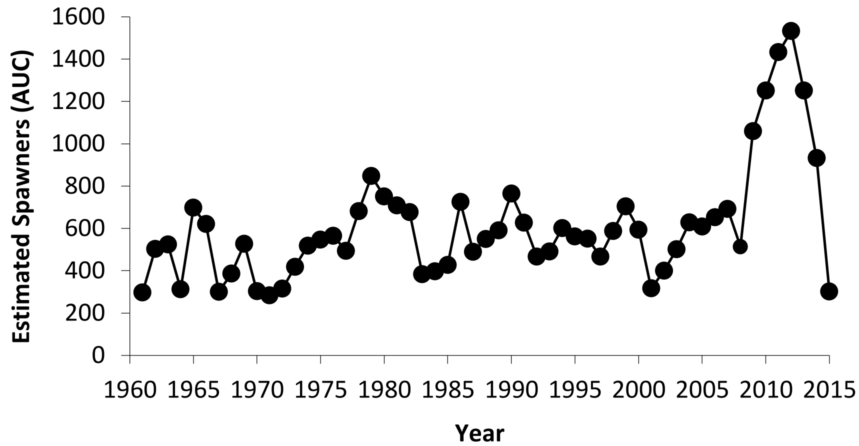

Figure 2. Gerrard Rainbow Trout spawner area under curve (AUC) estimates 1961-2015 (data from MNFLRO file data). Dashed red line indicates conservation concern thresholds.

An abundance based management framework is recommended for defining recovery and management actions for the Gerrard Rainbow Trout population (Figure 3). Such framework utilizes biological reference points to guide management actions to maximize social and economic benefits while ensuring the population meets conservation thresholds, similar to the management of steelhead in BC (MFLNRO 2015). Similar objectives and guiding principle are also outlined in the Provincial Freshwater Management Plan (Ministry of Environment 2007) and Fish and Wildlife Compensation (FWCP) Large Lake Plan (FWCP 2012).

It may be suitable to refine management reference points for the Gerrard population similar to that derived for steelhead (Johnston et al. 2000, 2002, Johnston 2013). In lieu of a formal analysis, an escapement limit reference point (LRP) of <50-100 AUC, a conservation concern threshold (CCT) of 100-350 AUC, and a target reference point (TRP) of 350-750 AUC are currently recommended for this population.

- LRP of <50-100 AUC would define an extreme conservation concern threshold (ECC) which would require management to reduce all associated mortality on population.
- CCT of 100-350 AUC would define a conservation concern or precautionary threshold where management may need to implement management actions (moderate harvest opportunity)
- TRP of 350-750 AUC would define a routine management zone where social and economic benefits are maximized.
- Escapements above the TRP would also necessitate management actions (i.e. increase harvest) to avoid collapsing the Kokanee population due to increased predation, similar to the current situation.

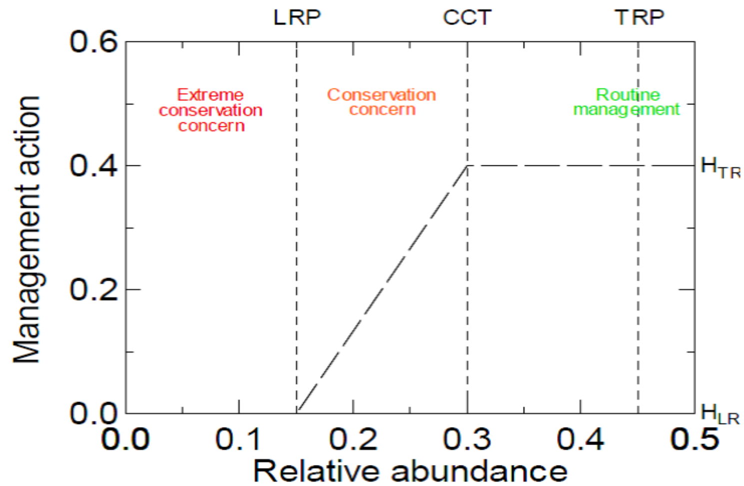

Figure 3. Conceptual abundance based management framework using biological reference points that guide future management actions from Johnston (2013).

Recent KLFAT assessment (Lotic Environmental Ltd 2015a, 2015b) and preliminary stock recruitment (SR) information for this population also provide support for the recommended abundance reference points described above (Andrusak 2015a). The KLFAT analysis indicates a relatively stable equilibrium target of near 500 AUC for this population over a 22 year period (Figure 4). Similarly, SR information indicates that the rivers (Lardeau and Duncan) are near carrying capacity for spring age 1 trout (Appendix 9), suggesting that most of the density dependent mortality occurs prior to this stage and where the population is likely regulated similar to many other salmonids (Stringer et al. 1980, Post et al. 1999, Post and Parkinson 2001, Biro et al. 2004, Imre et al. 2005, Kurota et al. 2011, Vincenzi et al. 2011, Ratliff et al. 2015). The carrying capacity appears to be reached at an escapement level of just over 500 spawners (Appendix 9) although data collected currently may better define this. As well, no appreciable increase in juvenile abundance was evident with increases in escapements above 750 AUC, although increases in catch rate in the recreational fishery were apparent above this level (KLRT Data on file).

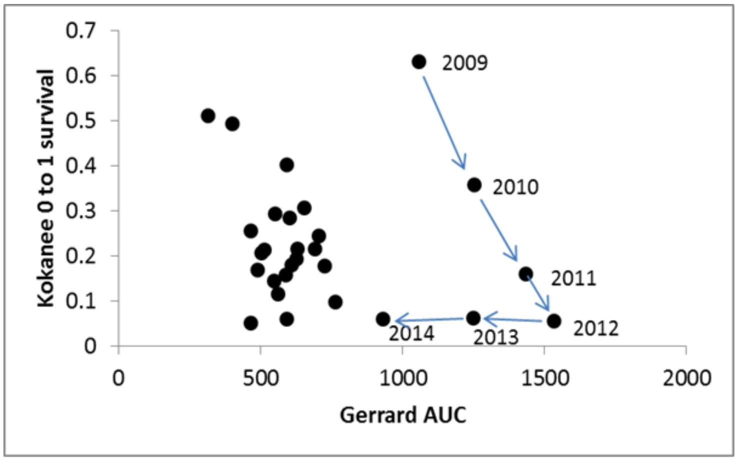

Figure 4. Escapement of Gerrard Rainbow Trout (AUC) in relation to Kokanee survival (age0 to age 1) from 1985 to 2014, analysis provided by P. Askey member of the Kootenay Lake Fisheries Advisory Team (KLFAT).

5.1 Recovery Objectives and Rationale

The secondary goal of the recovery plan is to identify management actions required to facilitate a short-term recovery and long-term maintenance and persistence (Table 6) of Kootenay Lakes' Gerrard Rainbow Trout population. Unlike Kokanee, basic life history and generation time for the Gerrard Rainbow Trout make recovery of this population back to equilibrium conditions (1992-2008) much more difficult, especially if there are further reductions in population abundance. Given this uncertainty, it is therefore difficult to anticipate the recovery time, especially for large size (trophy-sized) Gerrards. Potential Gerrard recovery could range from 1 to 2 generations or approximately 8 to 16 years after the Kokanee population has recovered. Therefore, the recovery plan presents management actions only for conservation of the Gerrard Rainbow Trout population.

5.1.1 Objective # 2-Gerrard Rainbow Trout Status and Recovery

Table 6. Conservation of Gerrard Rainbow Trout

Goal	Estimated Target and Timeframe
Conservation	*Ensure population exceeds conservation threshold of 50-100 AUC*

Rationale-The precipitous downward trend in number of Gerrard spawners requires close monitoring during the next five years (2016-2020). If spawner numbers decline below 50-100 AUC and juvenile parr densities decline below critically low densities, immediate actions may be required. Based on the uncertainty in the Gerrard population response to low Kokanee abundance, it would be prudent to invoke a precautionary approach that ensures conservation levels of 50-100 AUC (genetics and population persistence) are being met and implement recovery options to meet imminent population threats. Such an escapement level is considered to be below conservation levels (ECC) which put the population at further risk. At such levels, the probability of inbreeding depression and loss of genetic variability may increase. Management actions should be implemented that eliminate all sources of mortality on the population to facilitate a recovery above this threshold (50-100 AUC).

5.1.1.1.1 Actions, Tools and Targets

Various management actions under this objective, also detailed in Table 7, would include:

1. Gerrard Rainbow Trout Population Status

Determine the health and status of the Gerrard Rainbow Trout population over the next 5 years (2016-2020) would be considered a very high management priority. Management needs to determine if abundance is below the conservation threshold which would invoke further management actions.

Tools for this action will rely on enumeration of spawner numbers at Gerrard. During the spawning run, daily bank counts are used to provide information for a final escapement estimate using the area under the curve (AUC) and peak count (MFLNRO on file). Additionally collection of juvenile abundance and development of a stock recruitment (SR) relationship for this stock would provide information necessary in developing abundance based reference points that may direct future management actions.

The key trigger that would invoke further management actions would be an escapement that is <50-100 AUC over the next five years (2016-2020). Such information can be provided on a real time basis, allowing managers to implement future management actions if necessary. An additional trigger would be if the future recruitment information, collected by juvenile assessment surveys indicates age-1 recruitment below critical levels. Juvenile assessment information will be collected over the next three years (2016-2018).

Based on the KLFAT team, the future uncertainty associated with the Gerrard Rainbow Trout population remains high but there was consensus that the collection of information from the fishery ,from the spawning grounds and rearing portion of their life cycle will provide the necessary information to make appropriate future management actions.

2. Mortality Reduction on Gerrard Rainbow Trout

The tool for this action utilizes recreational angling regulations on Kootenay Lake. The main goal of this action is to minimize all harvest induced mortality from angling on Rainbow Trout (Table 7).

The key trigger that would invoke further management actions would be an escapement that is < 50-100 AUC in any of the future spawning returns over the next five years.

If conservation concern thresholds are below 50-100 AUC, implementing a precautionary approach that ensures conservation levels are being met by reducing all fishing mortality from recreational fishery would be required. Depending on various fishery metrics (KLRT CPUE), zero retention of > 50 cm Rainbow Trout may be necessary. This action is intended to reduce the recovery time of predators through reduced mortality if the population is critically low.

3. Gerrard Rainbow Trout Population Viability /gene banking

The aim of this action would be to obtain genetic information from a portion of the population needed to maintain population viability and persistence in case of further population decline below 50-100 AUC (Table 7). This would entail collection of brood or juveniles to be raised as captive brood stock in an FFSBC hatchery. The intention of such actions would be to utilize hatchery rearing as a living gene bank, and then future hatchery supplementation could be used from them as an insurance policy in the unlikelihood of extirpation. Note: Having a gene bank of Gerrard Rainbow Trout does not mean actually planting them back in the system.

The key trigger that would invoke consideration of further management actions would be an escapement that is < 50-100 AUC in any two consecutive spawning returns over the next five years. It is well understood that hatchery supplementation may have negative effects as a result of reduced fitness and productivity, similar to that identified for steelhead (Pollard 2013). As well, hatchery supplementation may increase predation on recovering Kokanee which was implicated as a causal factor in the collapse of Kokanee.

Based on the KLFAT team, this was considered the least preferable option and was ranked low accordingly.

5.1.1.1.2 Measures or Targets

Implementation of conservation measures when Gerrard Rainbow Trout escapement conservation threshold target is below 50-100 AUC.

Table 7. Objective 2 Gerrard Rainbow Trout Status and Recovery 2016-2020

Objective	Action	Tools	Triggers, Measure and Target	Rationale	Benefit/Risk	Rank
Status and Recovery of Gerrard Rainbow Trout	**Gerrard Rainbow Population Status**	Gerrard escapements, AUC bank counts and peak counts	Gerrard escapement LRP <50-100 AUC	Determine if abundance is below conservation threshold which would invoke further management actions	Determine if abundance is below conservation threshold which would invoke further management actions	high
	Recreational Angling Regulations	Recreational fishery regulations to zero retention of Rainbow Trout <> 50 cm	Gerrard escapement LRP <50-100 AUC	Implement a precautionary approach that ensures conservation levels, reduce all mortality from fishery	Reduce the recovery time of predators, reduce mortality when population is critically low	high
	Gerrard Juvenile Status	Development of stock recruitment information	Determine abundance and densities and juvenile % capacity	Obtain juvenile abundance information at low abundance	Critical piece of information, concern on precision and accuracy of information to be informative for management purposes	
	Gerrard Rainbow Trout population Viability	Collect individuals for hatchery rearing	Gerrard escapement LRP <50-100 AUC	Secure future viability and persistence of Gerrard Rainbow Trout population by obtaining individuals from current population for hatchery rearing	Hatchery risk of relatively new stock. Genetic insurance policy if population decreases further	mod
	Hatchery Augmentation	Use hatchery augmentation to recover population	Gerrard escapement LRP <50-100 AUC	Facilitate recovery of population	Hatchery augmentation may have negative effects to remaining wild stock, reduced fitness and productivity. May increase predation on recovering Kokanee.	low

6 Bull Trout Status and Recovery

The recent collapse of Kootenay Lakes' Kokanee population has created immediate concern for Bull Trout which are already considered a species of special concern in BC, and listed as a threatened in many other areas of their geographic distribution (Hagen and Decker 2011). The current long-term escapement trend on the Kaslo River suggests the population has experienced an extensive decline in abundance starting in 2009 (Figure 5). In addition, periodic redd counts from the lake-wide index streams also suggest a significant downward trend (Figure 5). In their favor, Kootenay Lake Bull Trout spawn in numerous tributaries to the lake (i.e. numerous sub-populations) and are likely less reliant on Kokanee than Gerrard Rainbow Trout.

Similar to most char species, Bull Trout are considered slow growing and long lived, often exceeding 10 years of age (Johnston et al. 2007, McPhail 2007). Adfluvial Bull Trout rear in natal tributaries for 1-4 years before undergoing migrations downstream to larger lakes with migration at age-2+ being the most common (Fraley and Shepard 1989, Downs et al. 2006). As a result, their life history characteristics make them susceptible to growth overfishing (Post et al. 2003, Johnston et al. 2007). In some cases, populations of Bull Trout are being fished at exploitation rates that may be above sustainable levels (Post et al. 2003, Post 2013). Relatively high exploitation rates were observed on Kootenay Lake up to 2011 (Andrusak and Thorley 2014) which may disproportionally impact weaker stocks as suggested in a mixed stock fishery (Hilborn 1985).

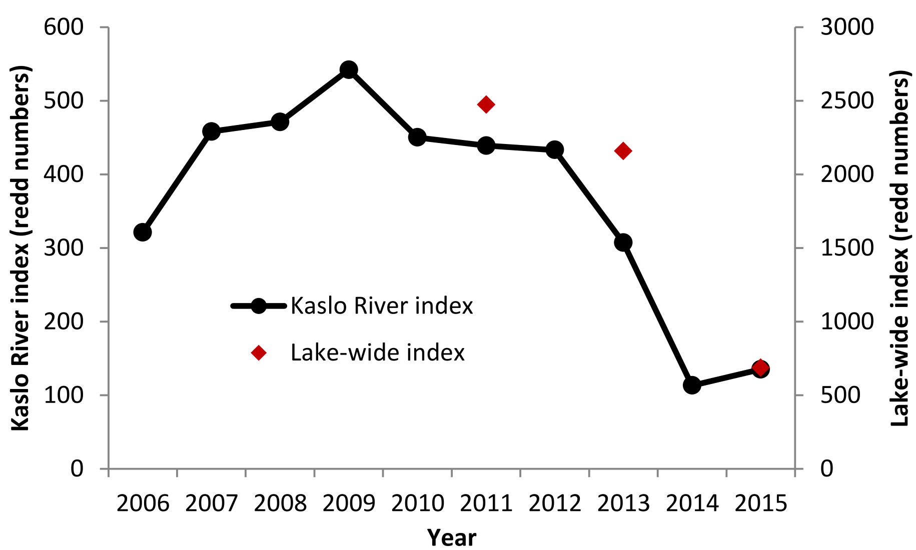

Figure 5. Bull Trout trends from redd count index on Kaslo River (primary y axis) from 2006-2015 and lake-wide index (secondary y axis) from 2011, 2013 and 2015.

Unlike Gerrard Rainbow Trout, Bull Trout are likely better adapted to lower Kokanee abundance and slow growing environment currently experienced on Kootenay Lake (Johnston and Post 2009). Evidence of Bull Trout resilience is indicated their ability to prey-switch, with recent observations of them utilizing *Mysis diluviana* in their diets (Kerry Reed pers. comm., Kootenay Lake Angling Guide). As well, it has been demonstrated that Bull Trout populations will delay maturation and forgo spawning events in slower growing environments, since a substantial allocation of energy and resources is required for reproduction (Johnston and Post 2009).

Due to their the phenotypic plasticity, Bull Trout may continue to persist at lower abundance and continue to hamper the recovery of effort of Kokanee on Kootenay Lake in the short-term. If low Kokanee abundance persists for an extended period of time (> 10 years), Bull Trout populations may be severely impacted over the long-term extending their recovery time due to their low intrinsic rate of increase (r=0.056; Post et al. 2003, Johnston et al. 2007, Hansen et al. 2010). Therefore, it could potentially take between 10-20 years (1 to 2 generations) before population abundance returns to levels observed in the early 2000s (Andrusak 2015b).

6.1 Recovery Objectives and Rationale

Another goal of the recovery plan is to identify management actions required to facilitate a short-term recovery of Kootenay Lakes' Bull Trout population (Table 8). Basic life history suggests recovery of Bull Trout will take substantially longer compared to Gerrard Rainbow Trout making recovery predictions very difficult and well beyond the scope of this plan. For example a review of information on Kananaskis Lake in Alberta revealed that a depressed Bull Trout population only recovered after a decade of reduction in total mortality (Johnston et al. 2007). Based on recommendation from KLFAT, 50/500 was adopted as the most appropriate abundance based metrics for Bull Trout on Kootenay Lake.

6.1.1 Objective#3- Bull Trout Status and Recovery

Table 8. Bull Trout Status and Recovery

Goal	Estimated Target and Timeframe
Conservation	*Conservation threshold of 50/500*

Rationale- Utilize a precautionary approach that ensures conservation levels (genetics and population persistence) of 50/500 redds are being met and implement recovery options to meet imminent population threats.

To ensure conservation target of 50/500 redds are being met, a reduction in all mortality associated with recreational fishing is recommended below the conservation threshold. Lower survival due to current limited food resources compounded by continual harvest could potentially cause population abundance to decline to extremely low levels, extending the recovery time. Current population status should be monitored by means of the KLRT data, Kaslo River redd counts and redd counts from the key index streams.

6.1.1.1.1 Actions, Tools and Targets

Various management actions under this objective are outlined in Table 9 and would include:

1. Monitor Bull Trout Population Status

Determine the health and status of the Bull Trout population over the next 5 years (2016-2020) would be considered a high management priority. If abundance is below the conservation threshold further management actions would be required.

Tools for this action will rely on redd surveys on the Kaslo River and the periodic lake-wide survey index. These surveys will provide information on escapements to determine if abundance is below the conservation threshold. Similar to Gerrard Rainbow Trout, juvenile assessment information on the Kaslo River would also provide an independent measure of future recruitment for this population. Juvenile information at low abundance and development of a stock recruitment (SR) relationship for this stock would also provide information necessary to develop reference points that may direct future management actions.

The key trigger that would invoke further management actions would be an escapement that is < 50 and < 500 redds, respectively, in any of the future spawning returns to the Kaslo River and lake wide index over the next five years (2016-2020) , respectively. Such information can be provided on a real time basis, allowing managers determine to future management actions if necessary.

Based on the KLFAT team, the future uncertainty associated with the Bull Trout population remains high but that there was consensus that the collection of information from the fishery and from the spawning portion of their life cycle will provide the necessary information to make appropriate future management actions.

2. Mortality Reduction on Bull Trout

Tool for this action utilizes recreational angling regulations on Kootenay Lake. The main goal of this action is to reduce and minimize all harvest induced mortality from angling on Bull Trout on the lake.

The key trigger that would invoke further management actions would be an escapement (redds) that is < 50 and <500 in any of the future spawning returns to the Kaslo River and lake wide index over the next five years (2016-2020) , respectively.

If the population is below these conservation thresholds, implementing a precautionary approach would be required to ensure conservation levels are being met by reducing fishing mortality from the recreational fishery. Depending on various fishery metrics (KLRT CPUE), zero retention of Bull Trout may be necessary. This action is intended to reduce the recovery time of predators, reduce mortality when population is critically low.

6.1.1.1.2 Measures or Targets

Recovery and/or conservation target minimum of 50 redds (25 spawners) for the Kaslo River should be considered a conservation threshold at local level for Bull Trout on Kootenay Lake. Recovery and/or conservation target minimum of 500 redds (250 spawners) for lake-wide index should be considered a conservation threshold within the Lower Kootenay Ecological Drainage Units (EDU).

7 Next Steps

Initial recovery of Kokanee will be dependent on natural fry production and supplementing the 2015 and 2016 cohorts with fry releases and planting of eyed eggs into the Meadow Creek spawning channel. The acoustic and trawl surveys scheduled for the spring 2016 and fall 2016 will be critically important as the data collected will give insight into how well juvenile Kokanee are growing and surviving compared to previous years. The current status of the predators-Gerrard Rainbow Trout and Bull Trout- will be measured through 2016 spawner and redd surveys in the spring and fall, respectively. The juveniles produced from the spawners will also be determined and this information will inform fisheries management of whether further reduction of predators needs to be considered. The KLFAT will reconvene in late fall 2016 to consider the new information and provide recommendations for the 2017 Kokanee cohort that appears to be fairly strong.

Table 9. Objective 3 Bull Trout Status and Recovery 2016-2020.

Objective	Action	Tools	Trigger, Measure or Target	Rationale	Benefit/Risk	Rank
Status and Recovery of Bull Trout	**Monitor Bull Trout Population Status**	Lake-wide Redd Survey Index and Kaslo River Redd Survey Index	Kaslo River BT redd abundance, LRP <50 spawners (25 redds)	Determine if abundance is below conservation threshold which would invoke further management actions	Determine if abundance is below conservation threshold which would invoke further management actions	high
	Mortality Reduction on Bull Trout	Recreational fishery regulations to zero retention of Bull Trout <> 50 cm	LRP 50/500	Implement a precautionary approach that ensures conservation levels are being met by reducing all mortality from recreational fishery on Kootenay Lake.	Reduce the recovery time of predators, reduce mortality when population is critically low	mod

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ONA-Okanagan Nation Alliance
FFSBC - Freshwater Fisheries Society of BC
FLNRO - BC Ministry of Forests, Lands and Natural Resource Operations
MOE-BC Ministry of Environment

Appendix 2. Data Sources

Species/Data	Data	Period	Details	Reference
Kokanee	MCSC	1967-2015	Escapement, egg deposition and fry recruitment time series	MFLNRO
Kokanee	Lardeau/Duncan	1964-2015	Abundance time series	MFLNRO
Kokanee	Duncan	2008-2013	Mortality from dam operations, abundance time series	BC Hydro
Kokanee	Acoustic and Trawl Survey	1985-2015	In-lake abundance estimates of Kokanee by age class	MFLNRO
Rainbow Trout	Gerrard Critical Monitoring	1957-2015	Gerrard escapement time series	MFLNRO, Hagen et al. 2007
Rainbow Trout	Gerrard Juvenile Recruitment	2006-2015	Gerrard juvenile recruitment time series	Andrusak 2015, Hagen et al 2010
Rainbow Trout	Gerrard Life History	1961	Investigations of the Rainbow Trout of Kootenay Lake	Cartwright 1961
Rainbow Trout	Gerrard Life History	1978	Gerrard basic life history	Irvine 1978
Rainbow Trout	Gerrard Life History	1969	Reproductive biology of the Gerrard Rainbow Trout	Hartman 1969
Rainbow Trout	Gerrard Life History	1970	Reproductive environment of the Gerrard Rainbow Trout	Hartman and Galbraith 1970
Rainbow Trout	Gerrard Diet	1984	Food habits of Gerrard Rainbow Trout in Kootenay Lake	Andrusak and Parkinson 1984
Rainbow Trout	Gerrard Fecundity	2006	Gerrard growth, condition, size at age and fecundity	Andrusak and Andrusak 2006
Rainbow Trout	Gerrard Growth	2015	Gerrard growth and condition	Andrusak and Andrusak 2015
Rainbow Trout	Gerrard In-lake Abundance	2015	Gerrard in-lake abundance estimates	Andrusak 2015
Rainbow Trout	Gerrard Exploitation Study	2008-2014	Determination of natural and fishing mortality	Andrusak and Thorley 2014
Bull Trout	Bull Trout Redd Survey	2006-2015	Kaslo River redd survey index	Andrusak 2015
Bull Trout	Bull Trout Redd Survey	2011	Kootenay Lake wide redd survey index	Andrusak and Andrusak 2012
Bull Trout	Bull Trout Redd Survey	2013	Kootenay Lake wide redd survey index	Andrusak and Andrusak 2013
Bull Trout	Bull Trout Redd Survey	2015	Kootenay Lake wide redd survey index	MEC 2016
Bull Trout	Bull Trout Exploitation Study	2008-2014	Determination of natural and fishing mortality	Andrusak and Thorley 2014
Bull Trout	Bull Trout In-lake Abundance	2015	Bull Trout in-lake abundance estimates	Andrusak 2015
Bull Trout	Bull Trout Juvenile Recruitment	2010-2016	Bull Trout juvenile recruitment time series	Andrusak 2016
Fishery	Creel Census	1963-1986	Kootenay Lake fishery information (effort, catch and CPUE)	MFLNRO
Fishery	Creel Census	1987-2015	Kootenay Lake mail-out survey (effort, catch and CPUE)	MFLNRO
Fishery	Creel Census	2011	Kootenay Lake, intensive survey (effort, catch and CPUE)	Andrusak and Andrusak 2012

Appendix 3 Definitions and Abbreviations

Term	Definition	Abbreviation
NA	not applicable	NA
Objective	primary management goal	NA
Sub-objective	secondary goal to objective	NA
Action	management action to meet objective	NA
Tool	actual metric method used to implement action	NA
Measure or Target	defined goal or target of management objective	NA
Stock	fish stock usually refers to a particular fish population that is more or less isolated from other stocks of the same species	NA
Population	Summation of all the organisms of the same group or species, which live in a particular geographical area, interchangeable with stock	NA
Compensation	survival increases at low abundance	NA
Depensation	survival decreases at low abundance	NA
Kokanee	land lock sockeye salmon, primary prey source for predators	Kokanee
Gerrard Rainbow Trout	Piscivorous stock of Rainbow Trout in lake	Gerrard Rainbow Trout
Bull Trout	defined as one population for Kootenay Lake	Bull Trout
Meadow Creek spawning channel	primary Kokanee spawning area at Meadow Creek using spawning channel	MCSC
Redd	a spawning nest that is built by fish in the gravel of streams or the shoreline of lakes, enumeration provides index of abundance	NA
Eyed egg	a fish egg containing an embryo with visible black spot of the eyes. Stage that has relatively high survival to fry	NA
Green egg	a fish egg fertilized but no developed embryo. Stage that has lower survival to fry	NA
Fry	free swimming development stage after egg and alevin, 5-30 mm in length	NA
Parr	older juvenile stage of development, > age 0 (fry)	NA
Biological reference point	biological reference point for abundance based management	BRP
Limit reference point	limit reference point for abundance based management, where stock is at < 10% carrying capacity	LRP
Extreme conservation concern	synonymous with LRP	ECC
Conservation concern threshold	conservation reference point for abundance based management, where stock is at 10-30 % carrying capacity, rebuild stock to RMZ or TRP	CCT
Target reference point	target reference point for abundance based management, where stock is at >30 % carrying capacity, also known as RMZ	TRP
Routine management zone	synonymous with TRP	RMZ
Hydroacoustic and trawl survey	Method used to assess fish population density and abundance in open water (limnetic) areas of lake	ATS

Appendix 4. Historic and Ecological Impacts to KL

Year	History and Ecological Impact
1949	Mysis introduced
1953	Cominco fertilizer plant and eutrophication of KL
1967	Duncan Dam completion
1966-1967	MCSC spawning channel
1972	Libby Dam built
1973	Cominco fertilizer plant closes cessation of nutrients
1974	Altered hydrograph
1980-1990	Decline in lake productivity due upstream impoundment
1992	KL Nutrient Addition Program-North Arm as compensation
2004-2005	KL Nutrient Addition Program-South Arm as compensation
2005	Kootenai River Nutrient Addition Program

Appendix 5 Kokanee Stock Recruitment

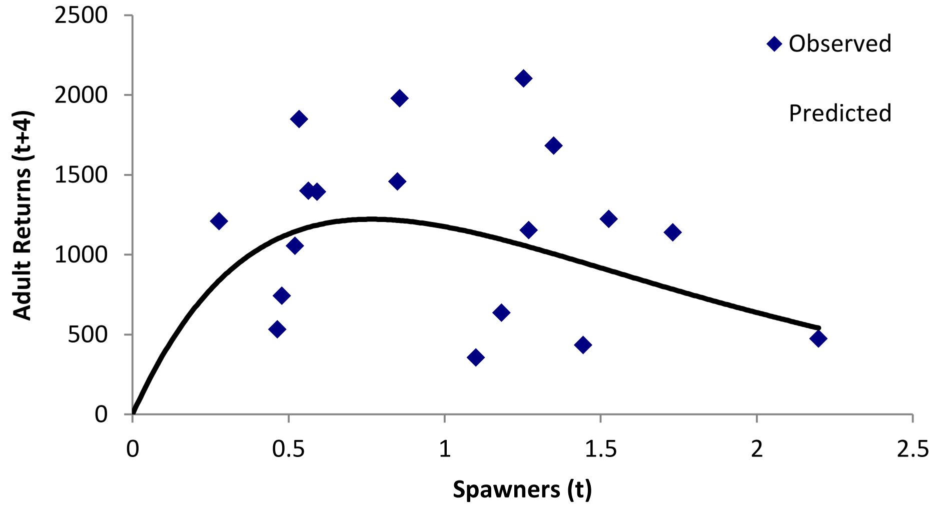

Figure 6. Predicted adult recruits (t+4) in relation to spawning stock (MCSC and Lardeau). Assumed all spawners were age 3+ and used data from 1991-2008.

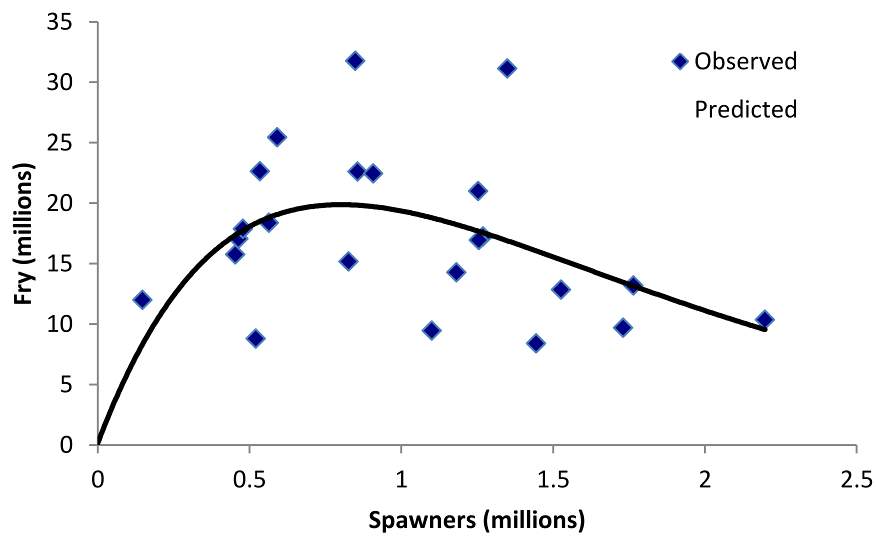

Figure 7. Predicted fall fry recruitment in relation to spawning stock (MCSC and Lardeau). Assumed all spawners were age 3+ and used data from 1991-2014

Appendix 6 Donor Stocks Genetic Analysis

Table 10. Kokanee donor stock analysis from Russello (2016)

Lake/River	Sampling Location	Kootenay Lake - Meadow Creek		
		q [a]	*p*-value	significance
Arrow Reservoir	Hill Creek	0.057	0.0002	*
Christina Lake	Sanders Creek	0.128	0.0002	*
Christina Lake	Shore	0.2097	0.0002	*
Columbia River	Norns Creek	0.0732	0.0002	*
Cottonwood Lake	-	0.0653	0.0002	*
Deka Lake	Interior Plateau	0.008	0.0044	NS
Kinbasket Reservoir	All[c]	0.0016	0.4211	NS
Kinbasket Reservoir	Bush Trawl	-0.007	0.6605	NS
Kinbasket Reservoir	Columbia River	0.0065	0.2022	NS
Kinbasket Reservoir	Main Trawl	0.0053	0.4136	NS
Kinbasket Reservoir	Wood Trawl	0.0124	0.0437	NS
Kookanusa Reservoir	Lussier River	0.0481	0.0002	*
Kookanusa Reservoir	Norbury Creek	0.0428	0.0002	*
Kootenay Lake	Lardeau River	0.0041	0.3111	NS
Kootenay Lake	Lower Duncan River	0.0009	0.782	NS
Kootenay Lake	West Arm - Fisheries	0.1118	0.0002	*
Kootenay Lake	West Arm - Kokanee Creek	0.1503	0.0002	*
Kootenay	West Arm - Shore	0.1493	0.0002	*
Slocan Lake	Bonanza Creek	0.0352	0.0002	*
Slocan Lake	Wilson Creek	0.027	0.0002	*
Sulphorous Lake	Interior Plateau	0.0252	0.0002	*
Whatshan Reservoir	Arrow Watershed	0.0097	0.0103	NS
Williston Reservoir	Osolinka River	0.0544	0.0002	*

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

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

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

Appendix 7 Dendrogram of Donor Stocks

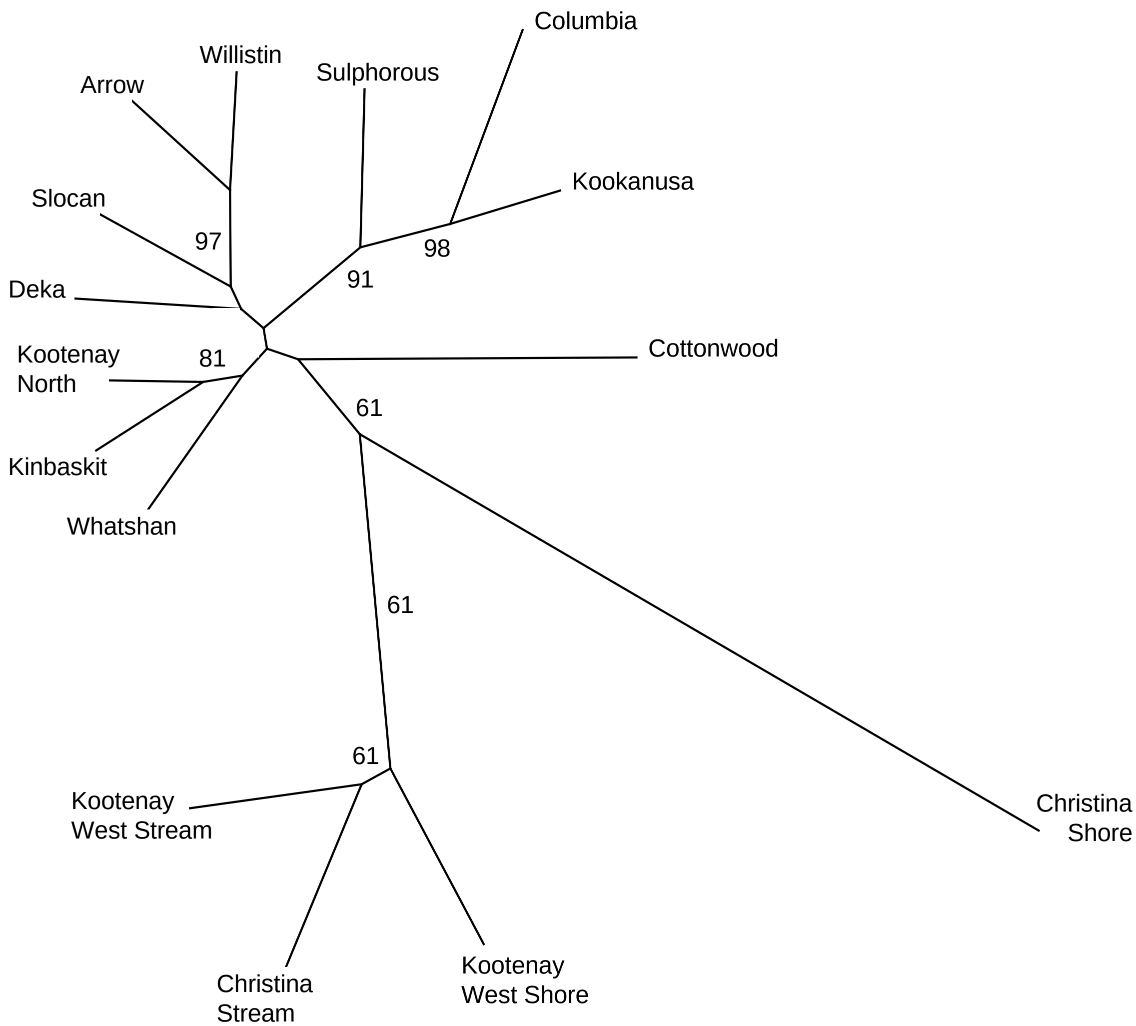

Figure 8. Dendrogram of donor stocks detailed and taken in Russello (2016)

Appendix 8. MFLNRO Regulation Changes on KL

Year	Regulation Change	Location
2005	Changed from daily quota of 4 trout/char to daily quota of 2 trout/char (1 over 50 cm did not change)	All Parts (main lake, upper west arm, lower west arm)
2005	Possession quota changed from 2 daily quotas to 1 daily quota	All Parts (main lake, upper west arm, lower west arm)
2005	Gear restriction: changed from barbs allowed, to barbless required	Main lake only
2008	Possession quota changed from 1 daily quota back to 2 daily quotas	Main lake only
present	Bull trout 1 per day any size, but must be included in trout/char daily quota	All Parts (main lake, upper west arm, lower west arm)
present	1 rainbow per day over 50 cm (all parts); 1 rainbow per day over 50 cm with KLRT licence, and 5 over 50 cm annual quota (main lake)	Main lake only

Appendix 9 Gerrard Rainbow Trout Stock Recruitment

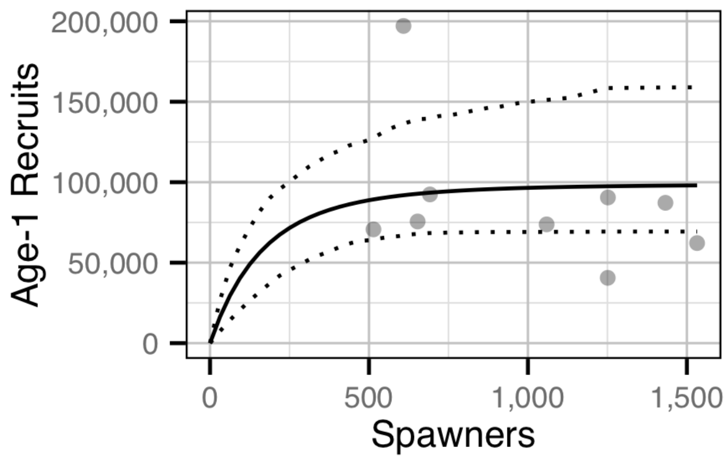

Figure 9. Predicted Gerrard Rainbow Trout stock-recruitment relationship (with 95% CRIs). Recruitment of spring age 1 observed in the Lardeau and Duncan rivers and spawners based on AUC from Gerrard.

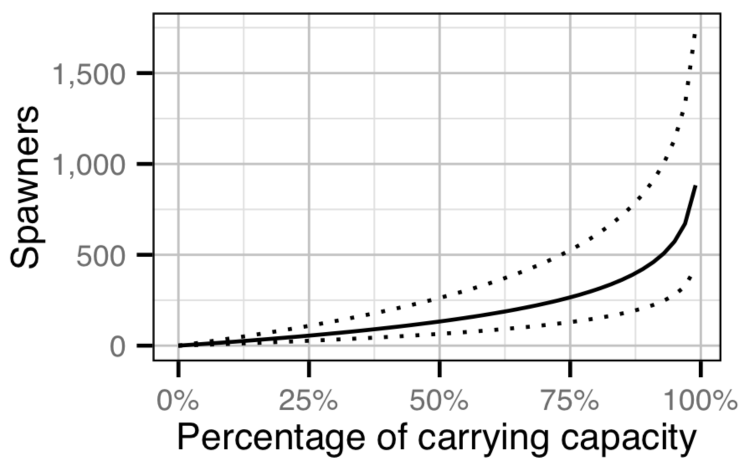

Figure 10. Predicted number of spawners (AUC) required to reach a given percentage carrying capacity of age-1 recruits (with 95% CRIs)