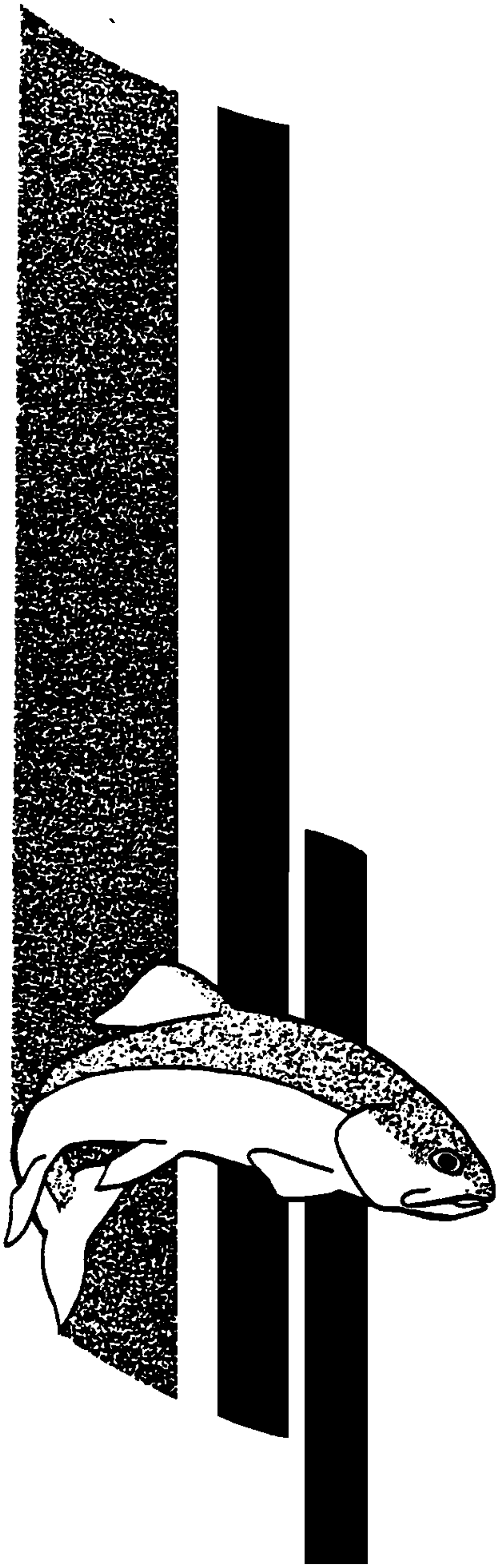


KOOTENAY LAKE
NUTRIENT RESTORATION PROGRAM
NORTH ARM AND SOUTH ARM
2016 REPORT

by

M. C. Bassett, E. U. Schindler, R. Fox, D. Johner,
T. Weir, L. Vidmanic, K. I. Ashley, and K. Peck

Fisheries Project Report No. RD 158
October 2018

Resource Management
Ministry of Forests, Lands and Natural Resource
Operations and Rural Development
Province of British Columbia

Funding by

and

Kootenai Tribe of Idaho

Fisheries Project Reports frequently contain preliminary data, and conclusions based on these may be subject to change. Reports may be cited in publications but their manuscript status (MS) must be noted. Please note that the presentation summaries in the report are as provided by the authors and have received minimal editing. Please obtain the individual author's permission before citing their work.

KOOTENAY LAKE
NUTRIENT RESTORATION PROGRAM
NORTH ARM AND SOUTH ARM
2016 REPORT

by

M. Bassett[1], E. U. Schindler[1], Robert Fox[1],
D. Johner[2], T. Weir[2],
L. Vidmanic[3], K. I. Ashley[4], and K. Peck[1]

[1] Ministry of Forests, Lands and Natural Resource Operations and Rural Development, Resource Management, Province of BC, 401-333 Victoria St., Nelson, BC, V1L 4K3

[2] Ministry of Forests, Lands and Natural Resource Operations and Rural Development, Resource Stewardship Division., Fish, Wildlife and Habitat Management Branch, Province of BC, 4th floor, 2975 Jutland Rd, Victoria, BC V8T 5J9

[3] Limno-Lab Ltd. 506-2260 W. 10th Ave., Vancouver, BC, V6K 2H8

[4] BCIT Rivers Institute, BC Institute of Technology, 3700 Willingdon Ave., Burnaby, BC, V5G 3H2

ACKNOWLEDGEMENTS

Funding for 2016 for the Kootenay Lake North Arm Nutrient Restoration Program was provided by the Fish and Wildlife Compensation Program and the Province of British Columbia. Funding for 2016 for the Kootenay Lake South Arm Restoration Program was provided by the Kootenai Tribe of Idaho and the Province of British Columbia. Thanks to the British Columbia Conservation Foundation and Fish and Wildlife Compensation Program for administering a portion of the funding provided by the Kootenai Tribe of Idaho.

The Fish and Wildlife Compensation Program is a joint initiative of BC Hydro, the Province of British Columbia, First Nations, and the public, who work together to conserve and enhance fish and wildlife in watersheds impacted by the construction of BC Hydro dams.

The contributions from the Province of British Columbia were primarily from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development and the Ministry of Environment and Climate Change Strategy.

The Kootenai Tribe of Idaho receives funding from the Bonneville Power Administration through the Northwest Power and Conservation Council's Columbia Basin Fish and Wildlife Program.

Numerous individuals have worked on Kootenay Lake over several decades. Appendix 1 lists the individuals who participated in the Kootenay Lake Nutrient Restoration Program in 2016.

EXECUTIVE SUMMARY

This report summarizes results from the Nutrient Restoration Program in 2016: the 25th year of nitrogen and phosphorus additions to the North Arm of Kootenay Lake and the 13th year of nitrogen additions to the South Arm. The program was conducted using an adaptive management approach in an effort to restore lake productivity lost as a result of nutrient retention and uptake in upstream reservoirs. The primary objective of this program is to restore kokanee (*Onchorhynchus nerka*) populations, which are the major food source for Gerrard rainbow trout (*Oncorhynchus mykiss*) and bull trout (*Salvelinus confluentus*).

Kootenay Lake is a warm, monomictic lake with a water renewal time of approximately two years. It is 395 km^2 in area with an average depth of 94 metres and a maximum depth of 154 metres. Surface water temperatures are typically warmest in August. The lake is well oxygenated from the surface to bottom depths at all stations throughout the year. It has two main inflows into the South and North Arms and one outflow through the West Arm of the Lake.

The 2016 season was characterized by higher than average spring and fall air temperatures, which were also observed in the surface water temperatures throughout the season. Precipitation during the preceding winter and the fall of 2016 was higher than average, but approximately average for the spring and summer periods. Nutrients were delivered to the lake at loading rates intended to restore pre-dam nutrient loading, and adapted weekly to limnological conditions. A total of 38.6 tonnes of phosphorus and 493 tonnes of nitrogen were added to Kootenay Lake in 2016. Throughout the lake, epilimnetic water samples showed lower than average total dissolved phosphorus (TDP) and higher than average dissolved inorganic nitrogen (DIN). Consequently, the N:P ratio for each Arm was higher than long term averages. Measurements of water transparency were higher than average in late summer and early fall. Phytoplankton showed similar monthly trends in density and biomass as the long-term averages, with the exception of high densities of some low edibility phytoplankton in July. Since the kokanee population collapse in 2015, we have observed a release of grazing pressure on zooplankton and therefore an elevated biomass throughout the lake compared to pre-collapse levels. Zooplankton density has also increased, though not as much as the average biomass, suggesting that individual zooplankton are larger than before the release of grazing pressure. *Mysis diluviana*, conversely, has not shown any measureable change in density or biomass in response to the changes in zooplankton biomass, a pattern that we continued to observe in 2016.

Despite the abundance of available zooplankton food in the main lake, the kokanee population continued to face challenging circumstances through 2016 and failed to recover to average nutrient restoration norms for growth, abundance, and survival. Mature kokanee demonstrated an exceptional positive growth response due to low density and high zooplankton biomass, and spawner size increased to a new historic high. Average age 1 kokanee length increased from a record low in 2013 to just below average. Age 0 abundance declined to well below the nutrient addition era average due to the very low spawner return in 2015, which was exacerbated by bear predation/redd disruption in the spawning channel. The abnormally poor recruitment of fry to the older age classes continued in 2016, resulting in a historic low age 1–3 population in 2016. Despite the large size of the older age classes of kokanee, the low abundance resulted in a decrease in biomass to a record low in 2016. Kokanee spawner abundance increased in 2016 from the lowest on record in 2015 for both Meadow Creek and Lardeau River, although escapement remained among the lowest recorded. Survival trends indicate exceptional survival from egg to fall fry in 2016; however survival from fall fry to age 1 remained very low, similar to 2012–2015.

Piscivore trends were collected outside of this program, but are reported here for context. Gerrard rainbow spawner abundance was exceptionally high from 2009–2013, then began to decline in 2014 and fell to among the lowest on record in 2016. Regardless, piscivore numbers and top-down pressure continues to be the assumed mechanism inhibiting kokanee population recovery.

TABLE OF CONTENTS

INTRODUCTION

Kootenay Lake

Kootenay Lake is world renowned for its sport fishing for an exceptionally large strain of wild rainbow trout, the Gerrard rainbow trout (*Oncorhynchus mykiss*). Fisheries research on Kootenay Lake dates back to the 1950s when considerable effort was directed at understanding the life history of the Gerrard stock of rainbow trout. Over the last four decades, the status of Kootenay Lake's kokanee stocks has been well documented, as has its limnology.

Nutrient losses, resulting from upstream hydro-electric impoundment in the late 1960s and early 1970s, caused Kootenay Lake to shift from oligotrophic to ultra-oligotrophic, which triggered a decline of the keystone species, kokanee (*O. nerka*). There was a concern, based on simulation modelling and population declines, that the dominant North Arm kokanee stock might collapse and sport fish such as Gerrard rainbow trout and bull trout (*Salvelinus confluentus*) would decrease significantly, as kokanee are their main food source.

Therefore, since 1992, carefully monitored additions of limiting nutrients have been used as a restoration technique for reversing oligotrophication (Ney 1996) of the Kootenay Lake ecosystem. Nutrient additions have been used in British Columbia, Alaska, Idaho, and Sweden as a technique for rebuilding depressed stocks of sockeye, kokanee, and other salmonids in lakes and reservoirs (Stockner and MacIssac 1996; Ashley et al. 1999b; Mazumder and Edmundson 2002; Pieters et al. 2003; Perrin et al. 2006; Rydin et al. 2008).

Successful recruitment of fish depends partly on sufficient food supply (Beauchamp 2004) and on food quality (Danielsdottir et al. 2007). Previous research has shown that the preferred food source for kokanee is *Daphnia* spp., a herbivorous zooplankton (Thompson 1999), which in turn mainly ingests nanoplankton (phytoplankton that range in size from 2.0–20.0 µm). Oligotrophic conditions tend to favour the growth of smaller phytoplankton (picoplankton, 0.2–2.0 µm) due to their higher nutrient uptake and growth rates (Stockner 1987). During light applications of nutrients, the picoplankton fraction responds first, but with increased nutrient loads, there is a shift to a greater contribution by the nanoplankton and microplankton (>20.0 µm) fractions (Stockner 1987). Microplankton are considered too large to be edible by most zooplankton.

The central strategy of the nutrient restoration program was to use a "bottom-up" approach to rebuild depressed kokanee and rainbow trout populations (Ashley et al. 1997). Nitrogen and phosphorus, in the form of liquid agricultural grade fertilizer: nitrogen as urea-ammonium nitrate, 28-0-0 (percent by weight N-P_2O_5-K_2O), and phosphorus as ammonium polyphosphate, 10-34-0 (N-P_2O_5-K_2O), have been added annually to the North Arm of Kootenay Lake from late-April through mid-September since 1992. Nutrient additions of nitrogen only as 28-0-0 (N-P_2O_5-K_2O) began in the South Arm in 2004. South Arm nutrient addition focussed on adding only nitrogen as this was the limiting nutrient.

The restoration experiment has been complicated by the presence of *Mysis diluviana (*previously named *M. relicta*; Audzijonyte and Vainola 2005), an exotic crustacean that competes with kokanee for zooplankton, particularly *Daphnia*. *M. diluviana* was intentionally introduced into Kootenay Lake in 1949 by Provincial Fish and Game staff in a misguided attempt to increase growth rates of juvenile Gerard rainbow trout.

Responses to nutrient additions

The experiment's primary objective has been to restore nutrient concentrations in the North Arm to pre-dam conditions, because upstream reservoirs were serving as nutrient sinks (Larkin 1998; Ashley et al. 1999a). The initial response of North Arm kokanee to nutrient additions was very positive. Kokanee escapements to the North Arm's Lardeau River and Meadow Creek systems exceeded 1 million fish in the 1990s.

There was a deliberate reduction in nutrient loading from 1997–2000 to confirm the hypothesis that nutrient additions were responsible for increasing the kokanee numbers through a bottom-up effect. Kokanee numbers and zooplankton biomass declined with the reduced nutrient loading (Schindler et al. 2009). This clear cause-and-effect relationship enabled fisheries managers to secure long-term funding and adjust the annual nutrient loading back to the 1992 nutrient loading inputs starting in 2001. The results of the Kootenay Lake (North Arm) fertilization have been documented in a number of technical reports and other publications (e.g., Ashley et al. 1997; Wright et al. 2002; Schindler et al. 2007a, 2007b, 2009, 2010, 2011, 2013, 2014; Bassett et al. 2016, Bassett et al. 2018).

Since the North Arm nutrient experiment began in 1992, there has been a comprehensive monitoring program aimed at measuring trophic level responses to lake fertilization (see Ashley et al. 1997; Ashley et al. 1999a; Thompson 1999; Wright 2002; Schindler et al. 2007a, 2009, 2010, 2011, 2013, 2014; Bassett et al. 2016, Bassett et al. 2018). Given that phytoplankton community composition and size structure can change quickly with the application of nutrients, the trophic levels need to be closely monitored to ensure efficient transfer of food through the food web to influence the recovery of kokanee.

Kootenay Lake kokanee are an important indicator of the success of the nutrient restoration program and the overall health of the ecosystem. There are various avenues for the uptake of nutrients through the trophic system, not all of which benefit kokanee and piscivorous fish populations to the same degree, and some that may even do harm (e.g., advantage given to inedible plankton). Even when optimal production of large zooplankton, namely *Daphnia*, is achieved, kokanee population responses can be varied, since the temporal scale required for population change is longer and kokanee are influenced by other factors that can collectively affect their recruitment, survival, and growth.

Additional nutrient projects in the Kootenay Lake watershed

Despite the success experienced with the dominant North Arm kokanee stock, there were no obvious benefits to the genetically distinct West Arm stock of kokanee from North Arm fertilization (Redfish Consulting Ltd. 2002). Historically, the South Arm tributaries supported only modest numbers of spawning kokanee (Vernon 1957; Andrusak and Brown 1987) but this stock also began to decline to very low numbers in the late 1970s concurrent with declining lake productivity (Andrusak and Fleck 2007). Kokanee from Kootenay Lake that spawn in northern Idaho streams also underwent a complete stock collapse (Ericksen et al. 2009).

Idaho State Fish and Game (ISFG) and the Kootenai Tribe of Idaho (KTOI) recognized that kokanee spawners observed in northern Idaho streams could only be restored if growth and survival conditions improved in the South Arm of Kootenay Lake. In response, these entities secured funding from the Bonneville Power Administration (BPA), and beginning in August 2004 a nitrogen-only nutrient addition experiment comparable in size to the North Arm project was simultaneously undertaken in the South Arm in an attempt to increase productivity and restore South Arm kokanee. This program is managed by the Ministry of Forests, Lands, and Natural Resource Operations (MoFLNRO) in Nelson, B.C.

A third nutrient addition experiment in the Kootenay watershed began in 2005 in northern Idaho. Low concentrations of ammonium polyphosphate were added to the Kootenai River at Bonners Ferry during the growing season in an effort to restore river nutrients and productivity lost due to impoundment of the Kootenai River by the Libby Dam and Koocanusa Reservoir. A comprehensive monitoring program has been established by the KTOI and ISFG, and to date lower trophic level responses have been positive (Hoyle et al. 2014; Minshall et al. 2014, Ward et al. 2017).

In order to re-establish kokanee to South Arm streams, it was necessary to use eyed-egg plants from North Arm stocks. Egg plants using Meadow Creek stock began in South Arm streams in B.C. during the fall of 2005. The KTOI began kokanee eyed-egg plants (also Meadow Creek stock) in Idaho tributaries as early as 1997, and they intensified their efforts in conjunction with the South Arm fertilization experiment (Sebastian et al. 2010; Ericksen et al. 2009). In 2013, the IHN (Infectious Hematopoietic Necrosis) virus was detected in the spawning adults at the source of eggs, Meadow Creek Spawning Channel (MCSC). Because of disease prevention protocol at the hatchery, eyed eggs were not available for planting. Additionally, MCSC escapement was not high enough to offer surplus eggs from 2014 to 2016.

The KTOI and ISFG recognize that to sustain recovered kokanee in Idaho requires improvement of survival rates for naturally produced eggs. Some stream restoration work has recently been undertaken in Kootenai River tributaries (in Idaho) in an effort to improve spawning and incubation habitat. Habitat restoration activities have been initiated on three streams to date: Trout, Parker, and Long Canyon Creeks (Figure 1). These streams were prioritized for habitat restoration based on potential water and riparian resource problems, as well as KTOI cultural significance and landowner interest. Habitat restoration activities have primarily focused on improving livestock grazing management (i.e., rest, rotation, temporary fencing, off-stream watering options) and re-establishing native plant species within the riparian zone (Ericksen et al. 2009).

Study area

Kootenay Lake lies between the Selkirk and Purcell mountain ranges in the southeast corner of British Columbia (Figure 1). The main lake is 107 km long and approximately 4 km wide with a mean depth of 94 m and a maximum depth of 154 m (Daley et al. 1981). The lake has two major inflowing tributaries: the Lardeau/Duncan system at the north end, and the Kootenay River (spelled Kootenai in the U.S.) at the south end of the lake. The outlet of the main lake is near the midpoint on the west side at Balfour, B.C., where it forms the upper end of the West Arm. At this outlet, a sill lies at a depth of approximately 8 m, producing a distinct boundary between the main lake and the West Arm.

The West Arm is about 40 km long with a mean depth of only 13 m. It is physically and limnologically different from the main lake and consists of a series of rapidly flushed shallow basins interconnected by narrow riverine sections. The West Arm of Kootenay Lake flows in a westerly direction, forming the lower Kootenay River, which flows into the Columbia River at Castlegar, B.C. The entire West Arm has an annual mean retention time of 5–6 days (Martin and Northcote 1991). The main basin of the lake has an average retention time of 1.8 years (Daley et al. 1981). Additional limnological information for Kootenay Lake can be found in Northcote (1973) and Northcote et al. (1999).

Figure 2 shows the location of limnological sampling stations (KLF 1–8), hydroacoustic transects (1–18), and trawl stations (KLF 1–7). The boundary between the North and South Arms can be described as a straight line between Pilot Point on the east side of Kootenay Lake and the lake outlet at Balfour.

In the North Arm, flows are dominated by the Lardeau/Duncan system. Smaller systems also important for spawning are Fry Creek, Campbell Creek, and Powder Creek on the northeast side and Coffee Creek, Woodbury, Cooper Creek, and Kaslo River on the west side.

In addition to Kootenay River, primary streams flowing into the South Arm in B.C. include the Goat River, Boulder Creek, Akokli Creek, Sanca Creek, Lockhart Creek, Grey Creek, and Crawford Creek on the east side and Boundary Creek, Corn Creek, Summit Creek, Next Creek, Cultus Creek, and Midge Creek on the west side (Figure 1). The kokanee work in northern Idaho focuses on tributary streams flowing into Kootenai River, including Boundary Creek, Fisher Creek, Smith Creek, Parker Creek, Long Canyon Creek, Ball Creek, Trout Creek, and Myrtle Creek (Figure 1).

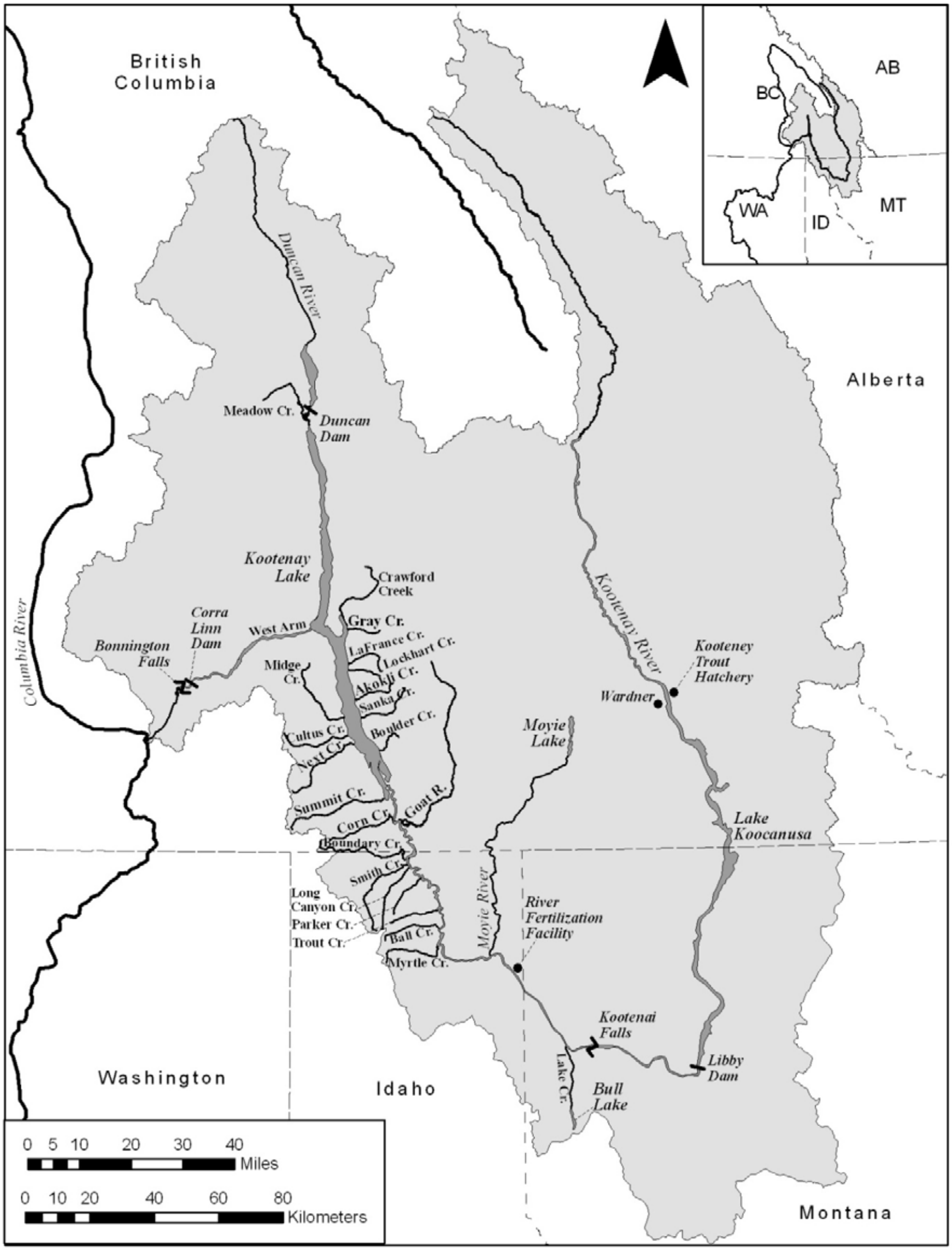
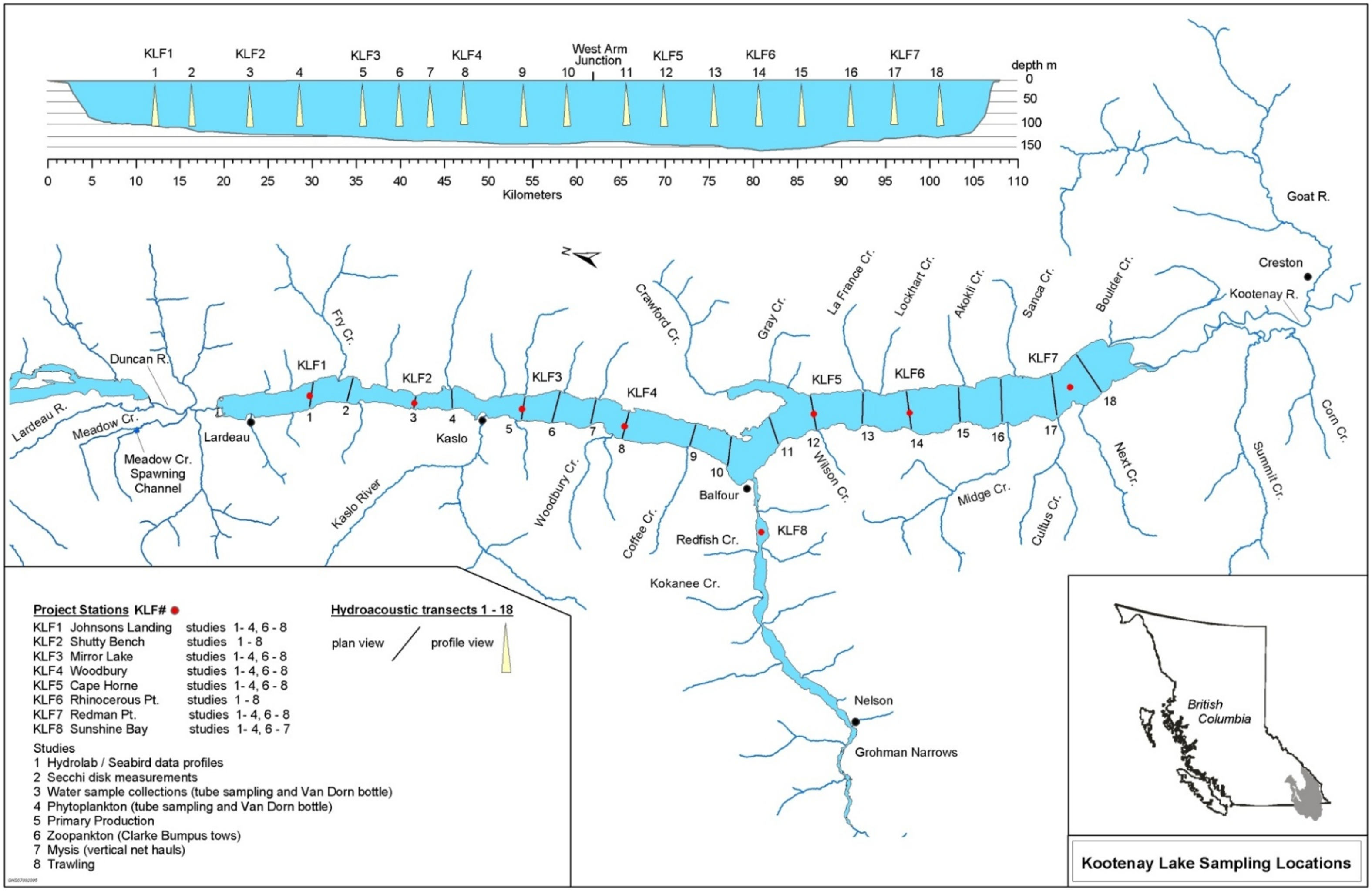


Figure 1. Map of the Kootenay River Basin in British Columbia, Montana, and Idaho showing South Arm tributaries (adapted from Ericksen et al. 2009).

Figure 2. Kootenay Lake, British Columbia, sampling station sites.



Nutrient addition program reporting

This report summarizes the physical, chemical, and biological response data collected from various trophic levels from the North, South, and West Arms of Kootenay Lake in 2016, with comparisons to previous years. Detailed data from previous years are provided in the following reports: Schindler et al. 2006, 2007a, b, 2009, 2010, 2011, 2013, 2014, Bassett et al. 2016 and Basset et al. 2018. Personnel contributing to the program in 2016 are listed in Appendix 1. The sampling activities are listed in Appendix 2.

Objectives

The overall objective of the nutrient restoration program is to promote primary productivity by additions of nutrients. The result of higher productivity is efficient transfer of nutrients up the food web from zooplankton to kokanee. Kokanee are the primary food source for two apex piscivores in Kootenay Lake: Gerrard rainbow trout and bull trout. One of the Kootenay Lake fish priorities as laid out in the FWCP Large Lakes Action plan is: "Province of BC's highest sport fishery priority is the Gerrard rainbow trout, followed by bull trout, and there is a desire to increase the in-lake population of large fish to support a world class recreational fishery." FWCP, 2012). Further objectives of large lakes management as discussed in the FWCP large lakes action plan is to: "1. Conservation – Ensure a productive and diverse aquatic ecosystem, 2. Conservation – Improve the status of species of conservation concern, and 3. Sustainable Use – Maintain or improve opportunities for sustainable use" (FWCP, 2012).

METHODS

Fertilizer additions

North Arm

An agricultural grade liquid fertilizer blend of ammonium polyphosphate (10-34-0, N-P_2O_5-K_2O; % by weight) and urea-ammonium nitrate (28-0-0, N-P_2O_5-K_2O; % by weight) was added to the North Arm of Kootenay Lake. The amounts of phosphorus and nitrogen added per season from 1992 to 2016 are listed in Table 1.

Fertilizer was applied to the North Arm from the Western Pacific Marine/Ministry of Transportation and Infrastructures' MV Balfour ferry. Fertilizer trucks drove onto the ferry and nutrients were applied to the lake via two dispensing diffusers located at the stern of the vessel. The diffusers discharged into the propeller wash to ensure proper mixing and dilution. The area of application was located from two km north of transect 1 to four km south of transect 2, a distance of 10 km (Figure 2). The load was distributed equally with one half of the fertilizer released on the departing trip and one half on the return trip.

The total weight of fertilizer applied in 2016 was 38.6 tonnes of phosphorus and 228 tonnes of nitrogen. Applications started on April 28th, 2016 and continued weekly until September 15th. In July, the planned schedule included three weeks of nitrogen additions only, however due to high observed N:P ratios in water chemistry we altered the blend to a higher phosphorus proportion (Figure 3). One week was cancelled in late July, due to very high inedible phytoplankton results in the July #2 sampling session. The nitrogen to phosphorus (N:P) ratio (weight:weight) of the nutrients added to the lake increased through the season, starting at 0.67:1 for the first four weeks and peaking at 10.9:1 in early August through to mid-September. Phosphorus additions ranged from 0 to 16.3 mg/m^2 and nitrogen additions ranged from 5.1 to 101.6 mg/m^2. Detailed nutrient additions by week are presented in Appendix 3.

South Arm

Nutrients for the South Arm experiment were dispensed from the Western Pacific Marine/Ministry of Transportation and Infrastructures' MV Balfour ferry. One or two fertilizer trucks drove onto the ferry, and nutrients were applied to the lake via two dispensing diffusers located at the stern of the vessel. The weight restriction on the ferry was 70 tonnes of fertilizer. The diffusers discharged into the propeller wash to ensure proper mixing and dilution. The application zone in the South Arm was between transects 12 and 15, a distance of 17.5 km (Figure 2). In previous reports the distance of nutrient addition in the South Arm was reported at 12.5 km, however the zone has been confirmed to be a distance of 17.5km. Half of the nutrient loads were distributed on the departing trip and the other half on the return trip.

In 2016, the previously used strategy of adding only nitrogen to the South Arm was maintained. In total in 2016, 265 tonnes of nitrogen were added in the form of urea-ammonium nitrate (28-

0-0, N-P_2O_5-K_2O; % by weight; Table 1). Additions occurred at weekly intervals from June 3rd to September 9th. On July 8th that week's load was cut back from 70 MT to 43 MT due to high counts of inedible phytoplankton in the June #2 samples. The load the week of July 29th was cancelled due to high amounts of inedible phytoplankton in the July#2 samples. The nutrient loading rate ranged from 43 to 85.9 mg/m^2 (Figure 4). Detailed additions of nutrients in the South Arm by week are in Appendix 4.

Table 1. Total tonnes of phosphorus and nitrogen (from liquid agricultural fertilizer) dispensed into the North Arm of Kootenay Lake, 1992–2016, and tonnes of nitrogen to the South Arm, 2004–2016.

Year	Phosphorus	Nitrogen	Nitrogen
	Tonnes (North Arm)	Tonnes (North Arm)	Tonnes (South Arm)
1992–1996	47.1	207	
1997	29.5	112	
1998	22.9	93	
1999	22.9	93	
2000	29.5	112	
2001	47.1	207	
2002	47.1	207	
2003	47.1	241	
2004	37.6	243	124
2005	44.1	247	234
2006	44.7	248	257
2007	46.2	247	245
2008	45.8	242	265
2009	45.4	241	265
2010	42.5	230	265
2011	34.5	171	256
2012	23.8	140	192
2013	33.0	208	258
2014	26.3	206	247
2015	32.1	213	267
2016	38.6	228	265

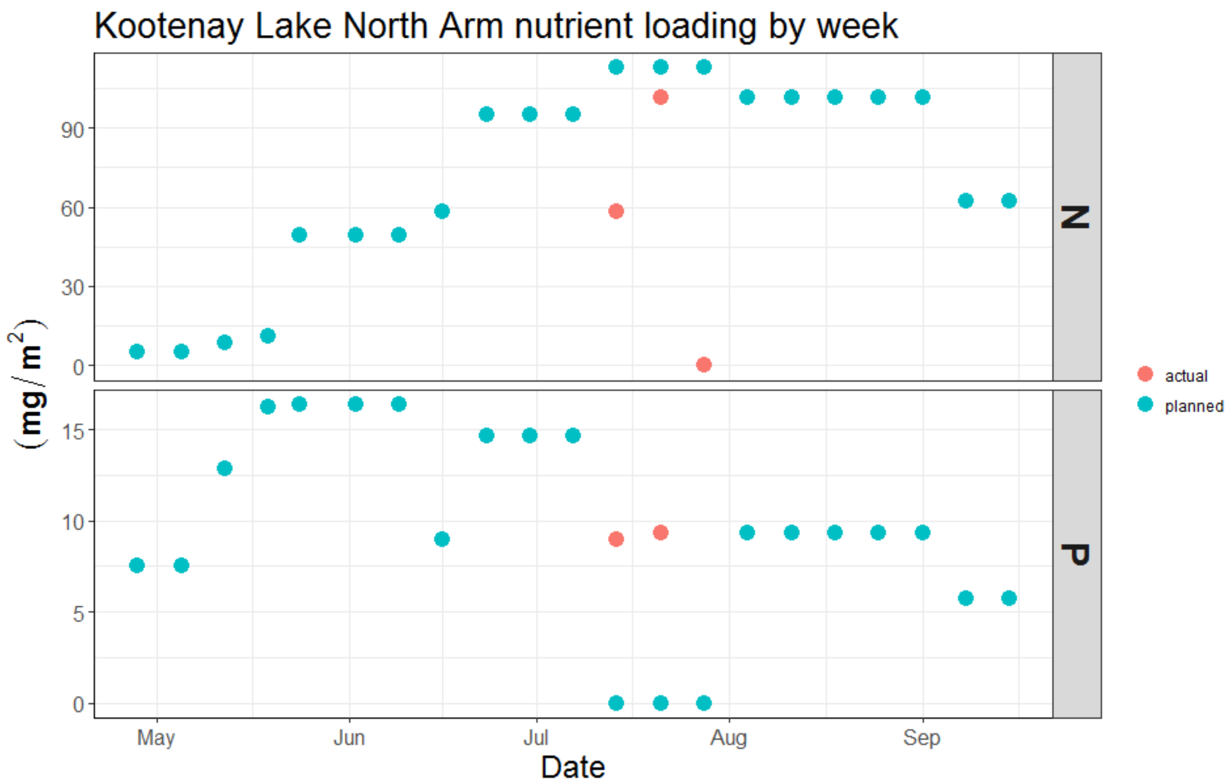


Figure 3. Phosphorus and nitrogen loading to the North Arm of Kootenay Lake (mg/m^2/week) from fertilizer (N:Nitrogen, P:Phosphorus), April–September, 2016. Planned (blue) and actual (red) loads are compared.

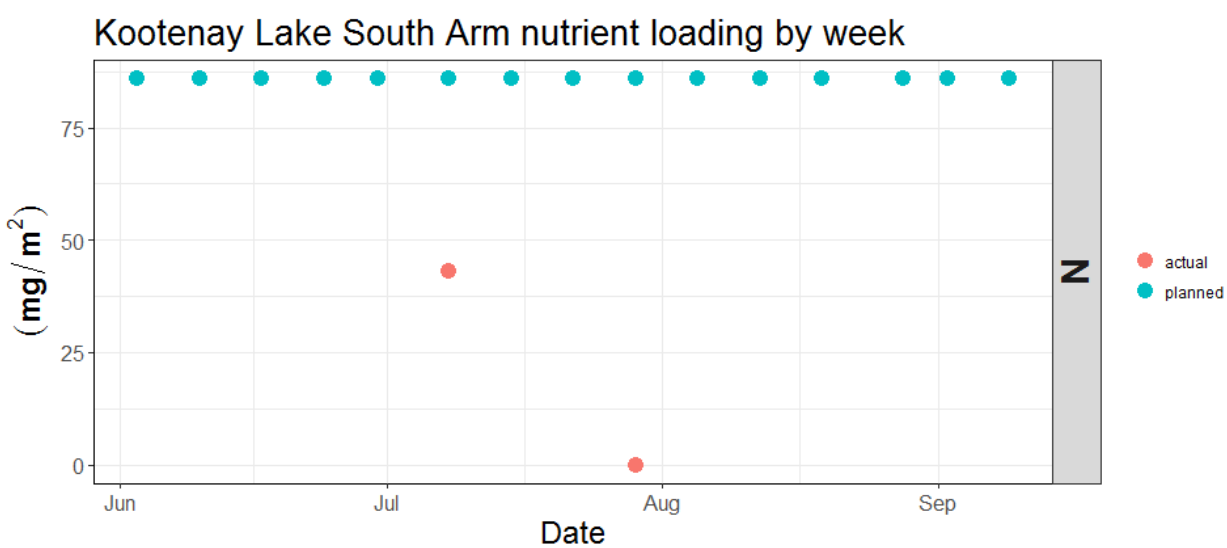


Figure 4. Nitrogen loading to South Arm of Kootenay Lake (mg/m^2/week) from fertilizer (N:Nitrogen), June–September, 2016. Planned (blue) and actual (red) loads are compared.

Physical Limnology and Water Chemistry

Physical and chemical data were collected at pre-established Kootenay Lake Fertilization sampling sites (KLF 1-8; Figure 2) simultaneously with the collection of phytoplankton samples. Monthly sampling was conducted from April to November at eight stations: four in the North Arm, three in the South Arm, and one in the West Arm (Table 2).

Table 2. Kootenay Lake Nutrient Restoration Program limnological sampling sites. EMS site no. refers to the Environmental Monitoring System (Ministry of Environment and Climate Change Strategy 2018) database tracking number where the results of these samples are available. See Figure 2 for a map of the stations.

Site ID	EMS site no.	Site name	Max Depth (m)	UTM NAD 83 Zone 11	
				Easting	Northing
KLF 1	E216949	Kootenay Lake at Johnson's Landing	100	507185	5545282
KLF 2	E216950	Kootenay Lake at Kembell Creek	120	507641	5536157
KLF 3	E216951	Kootenay Lake at Bjerkeness Creek	120	508278	5524429
KLF 4	E216952	Kootenay Lake at Hendricks Creek	135	507820	5512528
KLF 5	E216953	Kootenay Lake at Crawford Bay	140	511773	5492123
KLF 6	E216954	Kootenay Lake at Rhinoceros Point	150	514101	5480843
KLF 7	E218832	Kootenay Lake at Redman Point	125	519001	5464171
KLF 8	E252949	Kootenay Lake – West Arm (Sunshine Bay)	35	499072	5495866

Vertical profiles of temperature, specific conductivity and oxygen were obtained using a SeaBird SBE 19-plus profiler. At all stations, the profiler logged information every 10 cm from the surface to 5 m off the lake bottom. Water transparency was measured at each station using a standard 20-cm Secchi disc (without a viewing chamber). Temperature and dissolved oxygen profiles were used to determine the depth of the thermocline. Conductivity or specific conductance is a measure of the resistance of a solution to electrical flow (Wetzel 2001). In an aqueous solution, the resistance of electrical current declines with increasing ion content (Wetzel 2001), i.e. the lower the salinity content is, the greater the resistance to an electrical current.

Long term temperature and precipitation trends were reported for the time series 1992-2016. Water temperature at 2 m was extracted from the profile data for the years 1992-2016; the 2 m depth was chosen to capture a depth in the epilimnion unaffected by surface noise in the profile data. To establish an index of climate for Kootenay Lake, the Nelson airport weather station (name: Nelson CS, Lat=49.49^o, Long=-117.31^o, elevation=535m) was used for air temperature data, while the Nelson northeast weather station (name: NELSON NE, Lat=49.59^o, Long=-117.21^o, elevation=570m) was used for precipitation data. These two stations are within 13 km of each other and were selected for the completeness of their respective temperature and precipitation datasets. Values are presented by seasons (spring= April–June, summer= July–

Sept., and fall= Oct.–Nov. and winter=Dec.–March). Climate data are available online at http://climate.weather.gc.ca/. Missing data for water temperature, air temperature and precipitation datasets are summarized in Appendix 5.

Water samples were collected at stations KLF 1–8 from April through November using a 2.54-cm (inside diameter) tube sampler to collect an integrated water sample from 0–20 m. A Van Dorn bottle was used to collect hypolimnetic water samples (5 m off the bottom) at stations KLF 1–7 from May to October (Table 2). Water samples were immediately placed on ice and shipped within 24 h of collection to ALS Global in Burnaby, B.C.

Water samples were analyzed for turbidity, pH, total phosphorus, total dissolved phosphorus, orthophosphate, total nitrogen, ammonia, nitrate and nitrite, silica, alkalinity, total organic carbon, total inorganic carbon, and Chlorophyll *a* (Chl *a*). Additional water samples were taken at discrete depths in the epilimnion using a Van Dorn sampling bottle from June to September at stations KLF 2 and KLF 6. Samples were obtained from depths of 2, 5, 10, 15, and 20 m for analysis of total phosphorus, total dissolved phosphorus, orthophosphate, total nitrogen, ammonia, nitrate and nitrite and Chl *a*. Chl *a* samples were prepared by filtering a portion of the integrated water sample through a cellulose acetate filter (AMD Manufacturing Inc.) with 0.45 µm pore diameter. Samples were sent to the Ministry of Environment, University of British Columbia for analysis; however, results are not yet available at the time of this report. Primary productivity sampling and chlorophyll sampling using filters with 2, 0.2 and 0.02 µm pore diameters were also conducted but results will be presented in Harris et al. (*in prep*).

Metals were also analyzed in June and September from the hypolimnion and 0–20 m integrated water samples. Samples were stored in amber glass and preserved with either HNO_3 or H_2SO_4. Metals samples were analyzed by ALS Global. Sampling activities by parameter are listed by frequency, location and technique in Appendix 2.

Phosphorus is commonly used as an indicator of productivity due to the valuable role it plays in biological metabolism. Phosphorus is monitored throughout the season to both evaluate limitations, and to monitor the non-uptake of phosphorus associated with nutrient additions. Results for phosphorus may be slightly inflated as values reported under the Reportable Detection Limit (RDL) were set to the RDL. For total phosphorus and total dissolved phosphorus, this was 2 µg/L.

In fresh water, complex biochemical processes use nitrogen in many forms consisting of dissolved molecular N_2, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, and organic nitrogen. A major source of nitrogen in lakes is the nitrate in watershed precipitation, including snow melt run-off (Horne and Goldman 1994). Nitrate is the most abundant form of inorganic nitrogen in lakes (Horne and Goldman 1994). Total nitrogen (TN) comprises dissolved inorganic forms (i.e., nitrate, nitrite and ammonia) and particulate nitrogen (mainly organic). Dissolved inorganic nitrogen (DIN), consists of nitrite (NO_2-N), nitrate (NO_3-N), and ammonia (NH_3-N). Nitrate and ammonia are the forms of nitrogen most readily available to phytoplankton (Wetzel 2001).

The ratio of dissolved inorganic nitrogen (DIN; NO_2-N+NO_3-N+NH_3-N) to total dissolved phosphorus (TDP) is the N:P ratio, and is a measurement of limitations of productivity in a lake. An N:P ratio < 14 (weight:weight) is indicative of nitrogen limitation, and a ratio >14 is indicative of phosphorus limitation (Koerselman and Meuleman, 1996).

All data were manipulated and graphics produced in R 3.4.3 (R Core Team 2017).

Phytoplankton

Phytoplankton samples were collected from the integrated water column at stations KLF 1–8 from April through November. Additional phytoplankton samples were taken at discrete depths at stations KLF 2 and KLF 6 from June-September. Integrated and discrete sampling methods are described above. Lugol's iodine solution was added immediately after collection and samples were couriered to West Vancouver for processing by Eco-Logic Ltd.

The 2016 integrated and discrete samples were analyzed as follows: phytoplankton enumeration was typically performed within 5 days of receiving the samples. Prior to quantitative enumeration, the samples were gently shaken for 60 seconds and allowed to settle in a 25 mL settling chamber for a minimum of 6–8 hours. Counts were done using a Carl Zeiss inverted phase-contrast plankton microscope.

Initially, several random fields (5–10) were examined at low power (250X magnification) for large microplankton (20–200 µm), including colonial diatoms, dinoflagellates, and filamentous blue-greens. A second step involved counting all cells at high power (1,560X magnification) within a single random transect that was 10–15 mm long. This high magnification permitted quantitative enumeration of minute autotrophic picoplankton cells (0.2–2.0 µm, Cyanophyceae) and small nanoflagellates (2.0–20.0 µm, Chrysophyceae and Cryptophyceae).

In total, about 175–225 cells were enumerated from each sample to ensure statistical accuracy (Lund et al. 1958). Taxonomic identifications were performed using the keys of Prescott (1978) and Canter-Lund and Lund (1995). The phytoplankton species and biomass list used for the computation of population and class biomass estimates for Kootenay Lake appears in Appendix 1 in Schindler et al. (2009).

Zooplankton

From 1997 to 2002, zooplankton samples were collected monthly at four stations (KLF 2, 4, 6 and 7) from April to October. From 2003 onwards, the sampling season was lengthened from April to November and samples were collected from all eight sampling stations.

At each of the stations, three replicate oblique tows were made with a Clarke-Bumpus sampler. The attached net had a mesh size of 153 µm and was sent out at an oblique angle about 40 m out from the boat, which equals about 20 m depth based on the angle of the oblique haul. The net was raised to the surface with a hydraulic winch at a boat speed of ~1 m/s. Tow duration was 3 minutes, with approximately 2,500 L of water filtered per tow. The exact volume sampled was estimated from the revolutions counted by a flow meter on the Clarke-Bumpus sampler. The net and flow meter were calibrated in a flume at the Civil Engineering Department at the University of British Columbia. Note that in previous reports the depth sampled was reported as 40 m, however the methods reported above apply to all previous years of sampling with the Clarke Bumpus sampler.

Zooplankton samples were rinsed from the dolphin bucket through a 100 µm filter to remove excess lake water and were then preserved in 70% ethanol. Zooplankton samples were analyzed for species density and biomass (estimated from empirical length-weight regressions; McCauley 1984). Samples were re-suspended in tap water that had been filtered through a 74 µm mesh and were sub-sampled using a four-chambered Folsom-type plankton splitter. Splits were placed in gridded plastic petri dishes and stained with Rose Bengal to facilitate viewing with a Wild M3B dissecting microscope (at up to 400X magnification). For each replicate, organisms were identified to the species level (where possible) and counted until up to 200 organisms of the predominant species were recorded. If 150 organisms were counted by the end of a split, a new split was not started. Using a mouse cursor on a live television image, the lengths of up to 30 organisms of each species were measured for use in biomass calculations. Lengths were converted to biomass (µg dry weight) using an empirical length-weight regression from McCauley (1984). Zooplankton species were identified with reference to taxonomic keys (Pennak 1989, Brooks 1959, Wilson 1959, Sandercock and Scudder 1996).

Mysis diluviana

Samples of *Mysis diluviana* (hereafter referred to as mysids) from Kootenay Lake were collected at seven stations (KLF 1-7) monthly from January to December from 1999 to 2005, February to November in 2006, and April to November from 2007 to 2016. From 2004 onwards, mysid samples were also collected at station KLF 8 located in the West Arm. Sampling was conducted at night, around the time of the new moon, to decrease the chance of mysids seeing and avoiding the net. With the boat stationary, three vertical hauls were done at each station using a 1 m^2 square-mouthed net with 1,000 µm primary mesh, 210 µm terminal mesh, and 100 µm bucket mesh. Two replicate hauls were made in deep water at the same location, and one haul was made in shallow water (~20 m depth) near either the west or east shore, depending on the station. The net was raised from the lake bottom with a hydraulic winch at 0.3 m/s. The contents of the bucket were rinsed through a filter to remove excess lake water and were then preserved in 100% denatured alcohol (85% ethanol, 15% methanol).

Samples were analyzed for density, biomass (estimated from an empirical length-weight regression; Lasenby 1977), life history stage, and maturity (Reynolds and DeGraeve 1972). The life history stages identified were juvenile, immature male, mature male, breeding male, immature female, mature female, brooding female (brood pouch full of eggs or embryos), disturbed brood female (brood pouch not fully stocked with eggs, but at least one egg or embryo left to show that female had a brood), and spent female (brood pouch empty, no eggs or embryos remaining).

Samples were re-suspended in tap water that had been filtered through a 74 µm mesh filter, placed in a plastic petri dish, and viewed with a Wild M3B dissecting microscope at up to 160X magnification. All mysids in each sample were counted and had their life history stage and maturity identified. Using a mouse cursor on a live television image, the body length (tip of rostrum to base of telson) of up to 30 individuals of each stage and maturity was measured for use in biomass calculations. Lengths were converted to biomass (mg dry weight) using an empirical length-weight regression (Smokorowski 1998).

Kokanee

Kokanee Spawners

Kokanee spawners were enumerated at a number of spawning streams throughout Kootenay Lake using several methods.

Kokanee spawners in Meadow Creek Spawning Channel were enumerated from 1967 to 2016. Enumeration methods are described in detail by Redfish Consulting Ltd. (1999) and have changed very little over this period, thus providing a consistent time-series. Briefly, Meadow Creek Spawning Channel kokanee numbers were determined by manually counting fish moving upstream into the channel using a permanent fish fence located at the lower end of the channel. At the peak of spawner migration, visual ground estimates were also made of kokanee numbers in Meadow Creek downstream of the channel. In years of high spawner numbers, some fish were manually counted and passed upstream of the channel through a permanent fence located at the top end of the channel. Following lower spawner returns and bear predation in 2015, the channel was restricted to the lower portion and surrounded by an electric fence (MFLNRO 2016). Spawning kokanee going into the channel were sampled for length, age, sex ratio, and fecundity. Annual estimates of egg deposition were made, and fry out-migration from the channel was monitored each spring (Redfish Consulting Ltd. 1999). Age at maturity was determined from spawner samples using otolith interpretation methods described by Casselman (1990).

Lardeau River kokanee spawners were enumerated irregularly beginning in 1964 then annually since 1979 (with the exception of 1985). Due to the high cost of enumerating the Lardeau River via helicopter, only a single peak count estimate was conducted historically to provide an index for understanding population trends. The timing of the count was based on the timing of the peak count from nearby Meadow Creek. Multiple flights on the lower Duncan River occurred under a separate project which also informed the timing of Lardeau counts (Zimmer et al. 2016). In 2015 three flights of the entire Lardeau occurred and in 2016 two flights occurred to determine a peak count estimate. These data are not considered valid to provide a statistical estimate of absolute abundance of kokanee spawners in the Lardeau River, but are rather an index of abundance to help inform total North Arm escapement trends.

South Arm spawning streams in B.C. were assessed by experienced fisheries personnel on foot. Bank counts of areas accessible to spawning kokanee or spot counts at pre-determined sites along the stream were conducted on index streams. The spot check sites and reaches are presented in Appendix 6. These index sites have changed minimally since the beginning of the index counts in 1992 over the course of the time series. The surveys occurred approximately every week from late August to the end of September to ensure coverage of the peak spawning time. Index streams included Crawford, Gray, Lockhart, La France, Akokli, Sanca, Boulder, and Summit Creeks and Goat River (Figure 1). In 2016, each of the nine streams was counted on September 2, 13, and 19. At the same time, Kootenai Tribe of Idaho (KTOI) staff conducted kokanee spawner surveys on seven northern Idaho tributaries to the Kootenai River (Table 6). The Idaho surveys were also generally conducted from mid-August to early October, but the frequency of surveys varied owing to few, if any, fish being observed.

More extensive spawner surveys on Kootenay Lake tributaries occurred in 2016 concurrent with the South Arm long-term index counts. Complete methods and results can be found in Redfish Consulting Ltd. (2017). In summary, throughout September 2016 the entire lengths of 29 Kootenay Lake tributaries were counted twice throughout the spawning run (Appendix 22; Redfish Consulting 2017). A third survey was completed on three of those tributaries: Crawford Creek, Summit Creek, and Goat River. Time between surveys was approximately 10 days. Efforts were made to record the location of possible migration barriers and collect biological samples of spawning kokanee for future DNA analysis.

South Arm Tributaries Eyed-Egg Plants

The term “eyed-egg plants” refers to eggs that were developed at a hatchery to the eyed life stage then planted in tributary gravel. Eyed-eggs were planted in South Arm tributaries in B.C. from 2005–2012 and in Idaho from 1997–2012. All of the streams selected for eyed-egg plants were known to have historically supported spawning populations (see Ericksen et al. 2009). The number of eggs placed within a redd varied from 20,000 to 48,000 per redd depending on the tributary or method used. Sites within streams were chosen primarily based on accessibility and habitat suitability. For detailed egg plant methods, see Bassett et al. (2018). Assuming an age at maturity of 3 years, the eggs planted in fall 2012 returned to spawn in 2016. No collection of kokanee eggs for stocking South Arm tributaries took place in 2013 due to the detection of infectious hematopoietic necrosis virus (IHN) in Meadow Creek spawning stock. Eggs were not collected 2014–2016 due to the low escapement to Meadow Creek.

Meadow Creek Spawning Channel Eyed-Egg Plants

Starting in the fall of 2015 and continued in 2016, eyed-eggs (sourced from various stocks, see Appendix 7) were planted into Meadow Creek spawning channel in an attempt to bolster low kokanee abundance in Kootenay Lake. These efforts were undertaken to assist with Kootenay Lake kokanee recovery following the recommendations of the Kootenay Lake recovery team (Redfish Consulting Ltd. 2016), and were funded primarily through the Freshwater Fisheries Society of BC (FFSBC) and the Province of B.C. Methods and survival results are detailed in Neufeld and Arndt (2016). A total of 477,418 eyed-eggs were planted in the MCSC in fall of 2015 and 6.8 million eyed-eggs were planted in 2016. The eyed-eggs planted into Meadow

Creek in the fall of 2015 were thermally marked in the hatchery by systematically varying the water temperature to imprint patterned growth checks on the otoliths for evaluation of survival to later life stages. The eyed-eggs planted in the fall of 2016 were not marked in any way due to logistical challenges.

Hatchery Fry Releases

Hatchery raised kokanee fry were released into tributaries to Kootenay Lake beginning in the spring of 2015 and continued in 2016 under the same rationale, direction and funding as described above for the egg plants into Meadow Creek. The Freshwater Fisheries Society of BC (FFSBC) raised kokanee eggs to the fry stage in their Kootenay hatchery which were released into Crawford Creek and Meadow Creek in the spring of 2016. These fry were heat marked in the hatchery in the same fashion as the eyed-eggs planted into Meadow Creek as described above. See Appendix 7 for details on brood source, release locations and numbers by year.

Trawl and Hydroacoustic Sampling

Two night time hydroacoustic surveys were conducted on Kootenay Lake in 2016 during the nights of June 28–30 and September 27–29. A trawl survey also occurred during the fall sampling period. Since 1985, both hydroacoustic and trawl surveys have been carried out concurrently each fall during the new moon period using consistent methods (Schindler et al. 2010). When the South Arm fertilization began in 2004, additional acoustic and trawl monitoring was added during the early summer period. The intent of early sampling was to get a snapshot of fish distribution and abundance early in the growing season while the North and South Arm fry populations were still segregated. Early sampling provides an index of South Arm fry abundance as well as some size information for all ages, which can be compared with the North Arm population. However, due to low densities and a poorly-defined fish layer as seen in the acoustics, no trawl survey was conducted in early summer in 2016.

Trawl Surveys

Mid-water trawl samples provide species verification for the acoustic survey, age structure, size-at-age, and the proportion of mature fish in the catch. Fall trawl surveys typically consist of three stepped-oblique trawls (located west, center, and east) at each of six stations: KLF 1, 2, and 4–7 (Figure 2). Each trawl was towed through five depth layers for eight minutes each, ranging from 20–45 m depth to capture a representative sample of fish from each depth stratum. If >100 kokanee of any age class (typically fry) were captured in the first trawl at any station the center trawl was omitted and the remaining east or west trawl conducted. All three trawls at each of the six sites were conducted in 2016 in the fall. Trawl gear consisted of an opening and closing 5 m by 5 m beam trawl net which was 20 m long with graduated mesh size (92 mm down to 6 mm, stretched), towed at 0.80-0.95 m/s. The trawl net depth was initially calibrated against boat speed and cable length with a Notus net depth sensor system, after which depths were estimated by cable length. A Global Positioning System (GPS) was used to estimate distances travelled for calculating sampled volumes.

An exception to the standard oblique trawl methodology and equipment occurred in 2013, 2015 and again in 2016 to increase sample size to assist with determination of size at age and to better inform future thermal mark and genetic investigations. A 7 m by 3 m beam trawl net (depth by width) that was 21 m long with graduated mesh size (92 mm down to 6 mm, stretched) was towed directly through the fish layer, targeting the densest portion (hereafter referred to as “directed trawling”). A total of two trawls, each an hour in duration, were conducted in this manner at station KLF 1 on September 30, 2016. The age 1–3 data from directed trawling and standardized oblique trawl data were pooled for estimating size at age as well as age structure specific to the age 1–3 component. Comparisons of the trawl type and resulting catch are found in Appendix 8.

Captured fish were kept on ice until they were processed the following morning. Species, fork length, weight, scale code, and stage of maturity were recorded. Scales were taken from fish >75 mm for aging. Fish lengths from fall sampling were adjusted to an October 1 standard using empirical growth data from Rieman and Myers (1992) in Appendix 9.

Hydroacoustics

Acoustic data for each survey were collected at 18 standard transect locations evenly spaced along the North and South Arms of the main lake (Figure 2). Survey data were obtained using a Simrad model EK60 120 KHz split beam system (specification and field settings are shown in Appendix 10). The echosounder system was calibrated in the field at the beginning of the survey following the procedure described by Kongsberg Maritime AS (2008). The transducer was towed on a planer alongside the boat at a depth of 1 m, and data were collected continuously along survey lines at 2–5 pings/s while cruising at approximately 2 m/s. Navigation was by radar, GPS, and a 1:75,000 Canadian Hydrographics bathymetric chart.

Echo counting in Sonar 5Pro software was used to generate target densities for unit area by depth stratum. See Appendix 10 for data processing specifications. Echo counting is considered suitable based on low fish densities, high single echo detection (SED) probability, and a low amount of false SED detections (Balk and Lindem, 2011). Target sizes assumed to encompass the entire fish population and the upper cut-off of fry were estimated using the split beam method, as described by Simmonds and MacLennan (2005). The fish densities in number/ha for each transect and depth stratum were output in 1-decibel (dB) size groups and compiled on an MS Excel spreadsheet. The resulting layered fish densities were used to stratify transects of each survey into homogenous zones. A stochastic simulation (a Monte Carlo method) estimated confidence intervals. For each depth stratum, 30,000 random realizations of normal distribution were calculated using the stratum mean and the standard error of the population mean as mean and standard deviation, respectively. The 0.05 and 0.95 quantiles were used as the 95% confidence intervals. Simulations were done in the statistical programming environment R 3.4.0 (R Core Team, 2016). Bounds were produced for the entire fish population, fry sized fish population (age 0 kokanee), and for fish larger than fry size (age 1-3 kokanee).

Kokanee Biomass

Spawner biomass was estimated by applying the average weight of spawners measured at Meadow Creek spawning channel to the total estimated number of spawners from Lardeau River and Meadow Creek. For years when only spawner lengths were available, individual weights were estimated from a length-weight relation derived from previous Meadow Creek data on file (MFLNRO, Nelson). This number was then divided by the surface area of pelagic habitat to determine a biomass density (kg/ha). See Appendix 11 for biomass calculations. In-lake biomass estimates for pelagic habitat were determined from acoustic abundance portioned into age groups based on both trawl and acoustic surveys. Fish abundance by age group was then expanded to biomass using mean weight of fish by age group determined from the trawl samples.

Kokanee Survival

Meadow Creek Spring Fry to Adult Survival

Kokanee fry to adult (spawner) survival rates were estimated using the Meadow Creek long-term dataset for total fry production and escapement. Fry production data includes channel fry estimates plus an estimate of natural production from above and below the channel assuming 5% egg to fry survival (Redfish Consulting Ltd. 1999). Escapement data were adjusted based on age proportions obtained from otolith age data to represent proper cohort returns with varying age at maturity.

North Arm Egg to Fall Fry Survival

Spring fry enumeration was limited to Meadow Creek Spawning Channel; therefore, survival to fall fry was estimated from the egg stage for all Meadow Creek and Lardeau River spawners (the vast majority of all Kootenay Lake production). Egg deposition estimates used to generate an index of survival included the estimate for Meadow Creek (eggs from channel and non-channel spawners including egg plants) and the calculated value for Lardeau spawners (peak count*annual net fecundity and sex ratio from Meadow Creek). Survival to fall fry was generated by dividing the acoustic age 0 estimates collected in the fall by the annual egg deposition estimates the previous year. Data were then standardized by subtracting the series mean from the individual raw score and then dividing the difference by the series standard deviation.

Fall Fry to Age 1 Survival

Fall fry to age 1 survival estimates were determined using the acoustic age 0 abundance estimates and the following year age 1 abundance estimate. The age 1 estimates were generated by proportioning the annual age 1–3 acoustic estimate by the trawl age structure for ages 1–3 in each year’s fall trawl. Note that the age 1 estimates may be less robust than the age 0 estimates as they are susceptible to an undetermined degree of trawl catchability bias. These estimates were not considered robust statistical estimates of age 1 abundance; however we believe they adequately represent the trend in age 1 abundance allowing for evaluation of survival trends.

Piscivores

Enumeration of Gerrard rainbow trout and bull trout is of relevance to this program, particularly given the recent kokanee population collapse, however collection of these data occurs outside of this program. Only information regarding the Gerrard rainbow trout spawner index is referenced in this report. Methods for collection of this long-term data series are described in Neufeld (2014) and Neufeld (2015), and recent results are reported in Andrusak (2017).

RESULTS

Physical Limnology

Temperature

West Arm

The shallow, riverine West Arm of Kootenay Lake is different from the main basin of the lake, with physical and chemical limnology similar to that of the epilimnion of the main lake (Daley et al. 1981). Temperatures were fairly uniform from surface to bottom, although more stratification was observed in summer months. Peak temperature was observed on July 27th, 2016 (Table 4).

Table 4. Seasonal mean and standard deviation (SD) of water temperatures (^{o}C) in the West Arm (KLF 8) taken at 0–35 m depths, 2016.

Month	**2016**		
Category	**Date**	**Mean**	**SD**
Apr	2016-04-07	5.5	0.3
May	2016-05-04	8.2	0.4
Jun	2016-06-01	11.9	0.3
Jun#2	*2016-06-15*	*14.7*	*0.4*
Jul	2016-06-29	17.4	0.3
Aug	2016-07-27	18.4	0.5
Sep	2016-08-28	18.0	0.1
Oct	2016-09-28	14.8	0.3
Nov	2016-10-26	13.0	0.04

Main Lake

In 2016, the main body of Kootenay Lake (stations KLF 1–7) began warming in April, with a strong thermocline developing by mid-June and a maximum surface temperature occurring in late July. Representative temperature, oxygen and specific conductivity profiles for reference stations in the North Arm (KLF 2) and the South Arm (KLF 6) are presented in Figure 5. Technical issues resulted in a lack of oxygen data for most of the season and occasional incomplete data in late June and early July.

In the North Arm, a maximum surface temperature was recorded on August 30, 2016 at station KLF 4 (19.3^{o}C). In the South Arm, the maximum surface temperature was 20.7^{o}C on August 1, 2016 at station KLF 7. Hypolimnetic temperatures remained at 4–6^{o}C throughout the year.

Spatial and temporal differences in stratification exist between the North and the South Arms (Figure 5a) due to variation in temperature and discharge regimes from the Duncan/Lardeau rivers in the North and Kootenay River in the South, which are partially or entirely regulated by upstream hydroelectric dams and reservoirs. Surface inflows are probably the most important sources affecting water quality conditions of this large lake system (Northcote et al. 1999). The Kootenay and Duncan rivers comprise 56% and 21% of the total inflow to Kootenay Lake, respectively (Binsted and Ashley 2006). Other differences in the thermal structure of the North and South Arms are also caused by many complex interactions of surface-driven processes (wind and heat exchange) and internal wave dynamics within Kootenay Lake (Northcote et al. 1999).

Dissolved Oxygen

Kootenay Lake is well oxygenated from the surface to the bottom depths at each station (data on file, MFLNRO, Nelson). The 2016 data is incomplete due to a dissolved oxygen sensor failure mid-April. In previous years, oxygen has been consistent through the water column and typical of an orthograde profile. Nutrient enrichment has had no detectable effect on hypolimnetic oxygen concentrations in previous years.

Specific Conductance

Seasonally, conductivity was highest in April for both North and South Arms and lowest in August in the South Arm and August to September in the North Arm (Figure 5b). Conductivity in the North Arm was also low during mid-June sampling where readings around 135 µS/cm were recorded to depths of 25 m. Epilimnion conductivity was generally lower and more variable in the North Arm (range 125 to 161 µS/cm) than the South Arm (range 147 to 178 µS/cm). Hypolimnion conductivity had smaller ranges, but was also lower and more variable in the North Arm (range 154 to 180 µS/cm) than the South Arm (range 173 to 192 µS/cm).

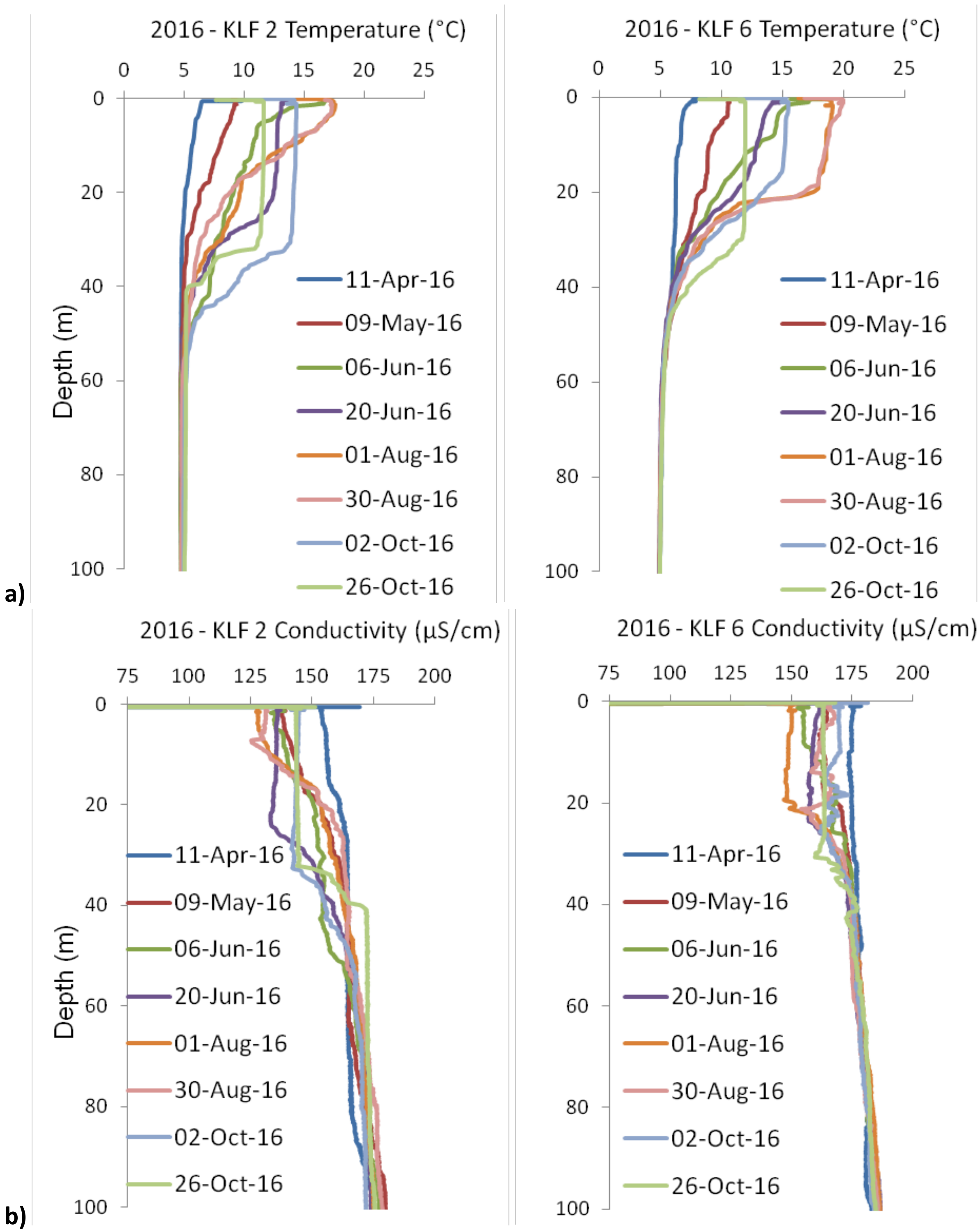


Figure 5. a)Temperature and b) specific conductance profiles at a representative North Arm station (KLF 2) and a representative South Arm station (KLF 6), April to November, 2016. Data are not shown for July 5, 2016 due to an equipment malfunction.

Long term temperature and precipitation trends (1992–2016)

The seasonal 2 m water temperatures for both the North and South arms were above the mean for all seasons (Figure 6). In 2016, springtime water temperatures were higher than the previous year (2015), and were at or near all-time recorded highs for both arms since the beginning of the Nutrient Restoration Program in 1992. Summer and fall water temperatures dropped slightly from 2015 in the North Arm, but increased moderately in the South Arm. The 2016 summer 2 m water temperature in the South Arm was also the second highest recorded since 1992.

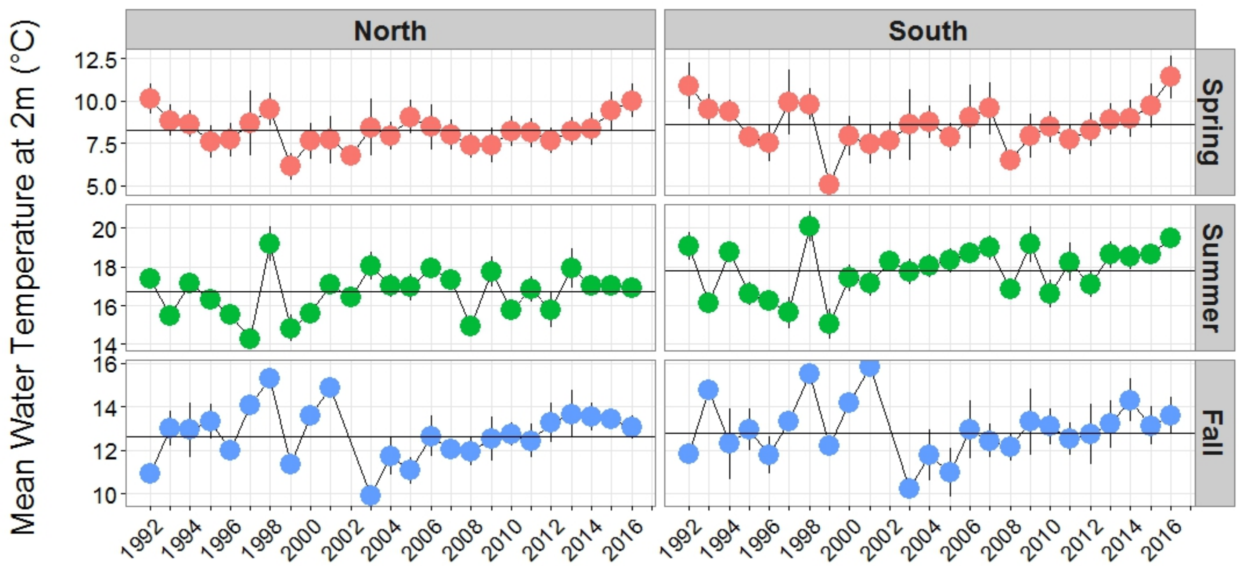


Figure 6. Annual mean water temperatures (°C) at 2 m depth by Arm (North: KLF1–4 and South: KLF 5–7) and by season 1992–2016. Means ±SE. Solid lines indicate the long-term mean.

The mean annual daily temperature for Nelson, B.C. in 2016 was 10.22°C, second only to 2015 (10.52°C) in the 1992–2016 dataset and well above the 1992–2016 average. Both 2015 and 2016 were substantially hotter than the previous eight years; the last time mean annual daily temperatures for Nelson were so warm was in 2006. Seasonal air temperatures for 2016 were well above average for winter, spring, and fall, increasing slightly over similarly hot seasons in 2015 (Figure 7). In fact, 2016 was either the hottest or second-hottest year on record since 1992 for these three seasons, primarily driven by substantially hotter temperatures in February, March, April, and November. By contrast, summer air temperatures have declined slightly over the past three seasons and summer 2016 was not significantly different from the long term average.

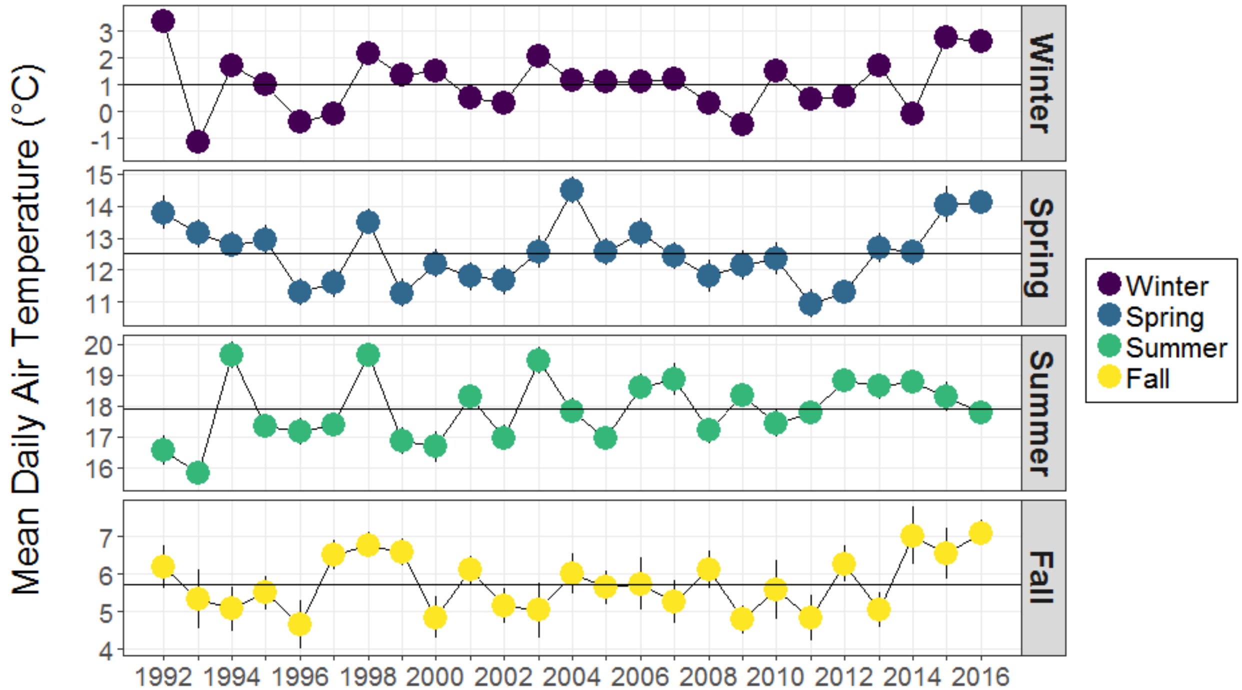


Figure 7. Annual daily mean air temperatures (°C) recorded at the Nelson airport weather station 1992-2016 by season. Note winter data is from respective year (January to March) and December data of previous year. Means ±SE. Solid lines indicate the long-term mean.

Precipitation in 2016 was similar to the long term 1992–2016 mean for spring, but was slightly below average for summer, slightly above average for winter, and well above average for fall (Figure 8). In fact, fall 2016 was the wettest recorded fall season in the 1992–2016 dataset; 2016 had markedly more precipitation than 2015.

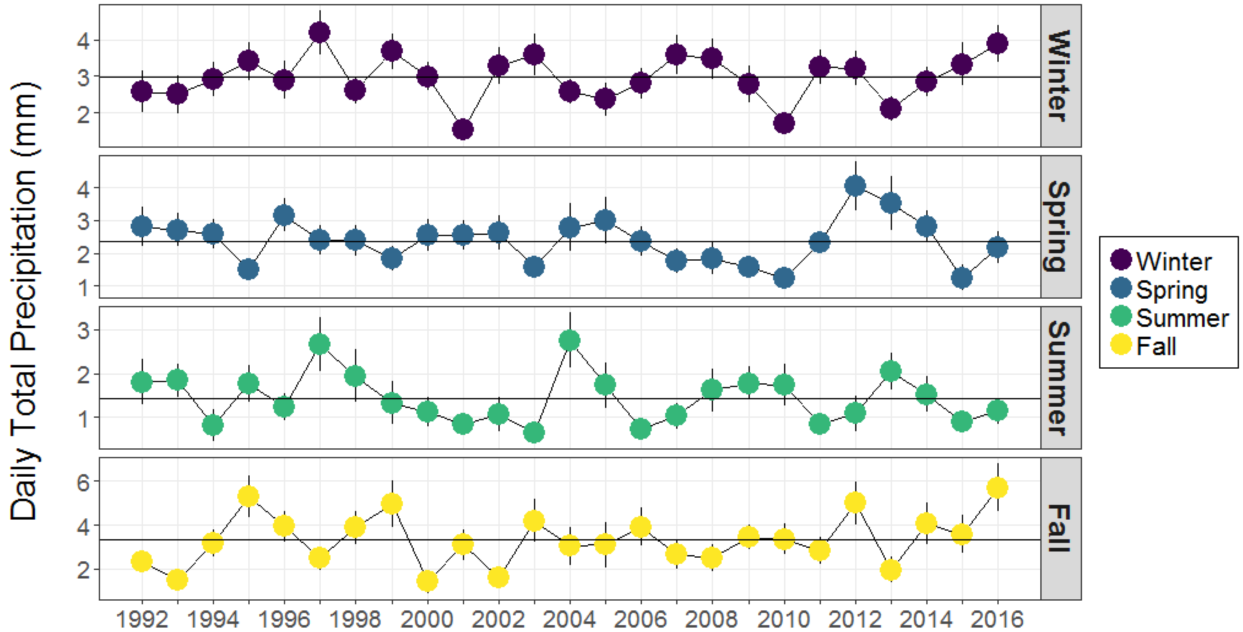


Figure 8. Average annual total daily precipitation (mm) recorded at the Nelson NE weather station 1992–2016 by season. Note winter data is from respective year (January to March) and December data of previous year. Means ±SE. Solid lines indicate the long-term mean.

In summary, the climatic conditions in 2016 were above average, often marking highs in the 1992–2016 dataset. Kootenay Lake water temperatures were warmer, particularly in the South Arm; daily mean air temperature was the second-hottest since 1992 (only slightly cooler than 2015) and well above average for most seasons except summer; and while daily total precipitation was near average for most seasons, fall 2016 was the wettest fall season since nutrient additions began in 1992.

Secchi depth

Secchi disk measurements on Kootenay Lake in 2016 indicated a typical seasonal pattern of decreasing transparency associated with the spring phytoplankton bloom, followed by an increase in transparency as the bloom gradually abated by the late summer and fall (Appendix 12). Secchi disk values were high in late summer and fall likely due to the increased grazing of zooplankton. This led to a deeper than average Secchi depth mean in 2016 relative to the long term mean in all Arms (Figure 9). The mean depths in 2016 for the North, South and West Arms were 7.69 m, 8.00 m, and 8.38 m, respectively.

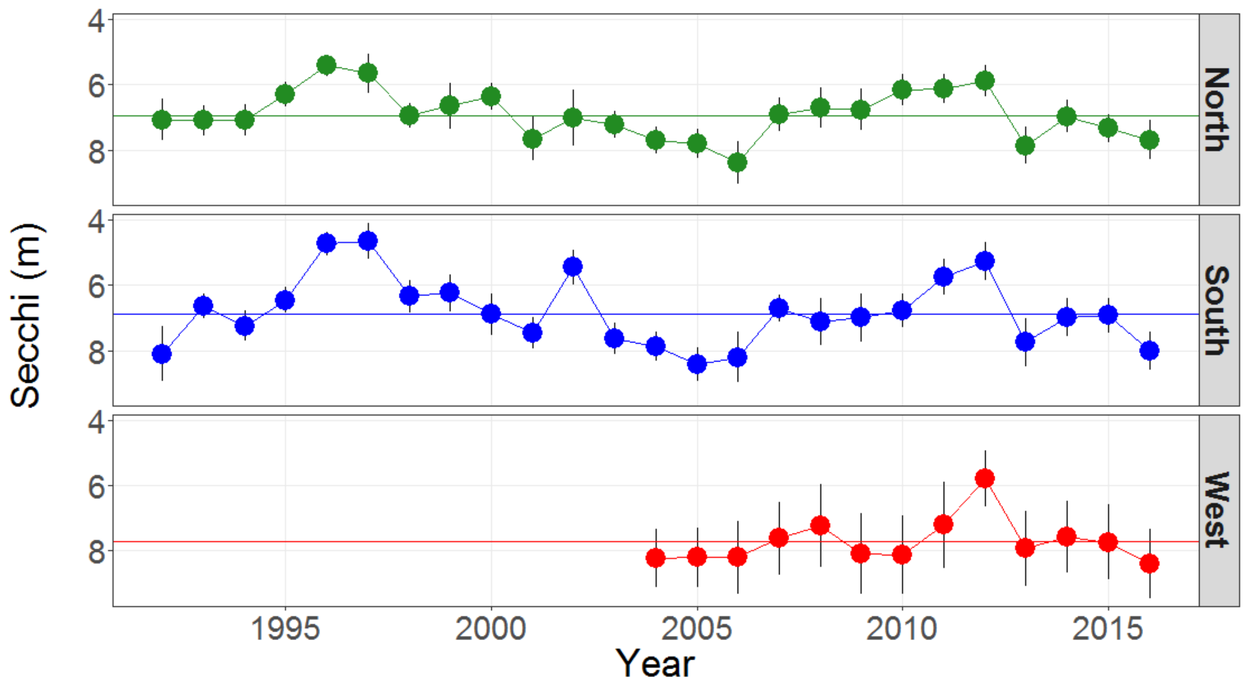


Figure 9. Kootenay Secchi (m) annual mean by arm (North, South and West) 1992–2016 (complete season sampling began in West Arm in 2004). Means ±SE. Solid lines indicate long term means by Arm. Secchi depth on the y-axis is represented as the most shallow at the top and deepest at the bottom.

Water Chemistry

Integrated Epilimnion

Water chemistry results are reported in for the North Arm in Appendices 13 and 15, and the South and West Arms in Appendices 14 and 16. Phosphorus and nitrogen parameters are presented in the section below. Other parameters (pH, Turbidity, Alkalinity, Silica, Total Inorganic Carbon and Total Organic Carbon) are reported in Appendix 15 and 16, for the North Arm and the South/West Arms, respectively). Results from the discrete samples are reported in Appendix 17.

Phosphorus

In 2016, samples from the integrated 0–20 m water layer showed 38.2% of total phosphorus (TP) values and 84.2% of total dissolved phosphorus (TDP) values were measured at less than the reportable detection limits (RDL; set at 2 µg/L). The annual mean for monthly TP values in 2016 for the North Arm was 3.3 µg/L (range: <RDL to 5.9 µg/L), which was lower than the 1992–2016 mean of 4.5 µg/L. The max TP in the North Arm was observed at KLF 1 in August (Appendix 13). South Arm mean TP was 2.9 µg/L (range: <RDL to 9.7 µg/L), which was lower than the South Arm 1992–2016 mean of 4.6 µg/L. The max TP in the South Arm was observed at KLF 5 in August. The West Arm 2016 mean was 2.7 µg/L (range: <RDL to 4.6 µg/L), which was

also lower than the long term mean of 3.7 µg/L. The max TP in the West Arm was observed in August (Appendix 14; Figure 10).

The 2016 mean for monthly total dissolved phosphorus (TDP) values for the North Arm was 2.3 µg/L (range: <RDL to 7.5 µg/L), which was lower than the 1992–2016 mean of 3.0 µg/L. The max TDP was measured at KLF 3 in late June (Appendix 13). The South Arm mean TDP was 2.4 µg/L (range: <RDL to 9.1 µg/L), which was lower than the South Arm 1992–2016 mean of 3.2 µg/L. The max TDP was measured at KLF 6 in late June. The West Arm 2016 mean TDP was 2.3 µg/L (range: <RDL to 4.4 µg/L), which was also lower than the long term mean of 2.8 µg/L. The max TDP was measured in late June (Appendix 14; Figure 11).

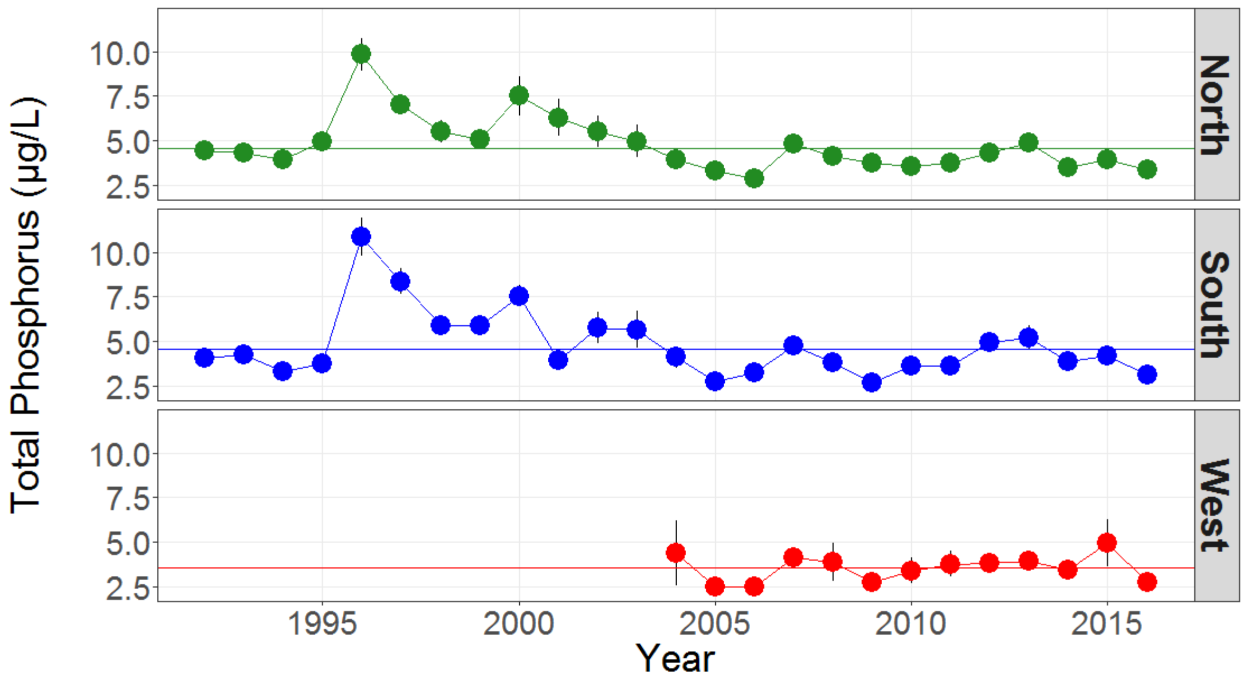


Figure 10. Kootenay total phosphorus (TP) annual monthly mean by Arm (North, South and West) 1992-2016 (complete season sampling began in West Arm in 2004). Means ±SE. Solid lines indicate long term means by arm.

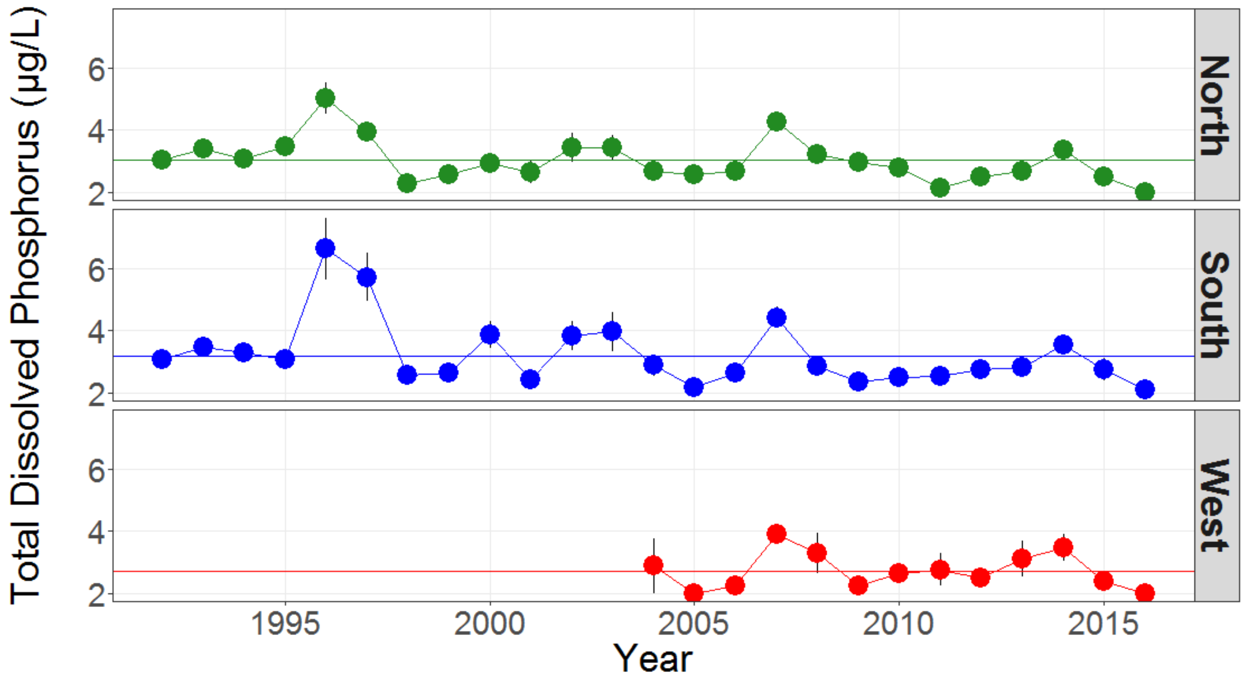


Figure 11. Kootenay total dissolved phosphorus (TDP) annual monthly mean by Arm (North, South and West) 1992-2016 (complete season sampling began in West Arm in 2004). Means ±SE. Solid lines indicate long term means by arm.

Nitrogen

The 2016 mean for total nitrogen (TN) measured in the North Arm was 191.8 µg/L (range: 132 to 310 µg/L), which was higher than the 1992–2016 mean of 182.4 µg/L. The lowest TN observed were at KLF 2 in late August and the highest observed were at KLF 1 in November (Appendix 13). In the South Arm, the mean TN was 195.5 µg/L (range: 140 to 292 µg/L), which was higher than the 1992–2016 mean of 182 µg/L. The lowest TN observed was at KLF 5 in August and the highest was at KLF 5 in May. In the West Arm, the mean TN was 185.6 µg/L (range: 124 to 230 µg/L), which was similar to the long term mean of 179 µg/L. The lowest TN was observed in August and the highest in late June (Appendix 14; Figure 13).

In all Arms, the within season trends showed high values of dissolved inorganic nitrogen (DIN) in the spring and fall, and seasonal lows in the summer sampling sessions. DIN values in 2016 were generally higher than the long term averages, particularly in the South Arm. The annual mean for monthly DIN measured in 2016 for the North Arm was 112.4 µg/L (range: 52 to 188 µg/L), which was higher than the 1992–2016 mean of 95.9 µg/L. The lowest observed DIN was at KLF 1 in August and the highest at KLF 1 in May (Appendix 13). In the South Arm the mean DIN was 111.3 µg/L (range: 42 to 189 µg/L), which was higher than the South Arm 1992–2016 mean of 94.5 µg/L. The lowest observed DIN was observed at KLF 6 in August and the highest at KLF 6 in April. In the West Arm, the mean DIN was 102.6 µg/L (range: 26 to 178 µg/L), which was higher than the long term mean of 88.6 µg/L. The lowest DIN was observed in August and the highest in April (Appendix 14; Figure 13).

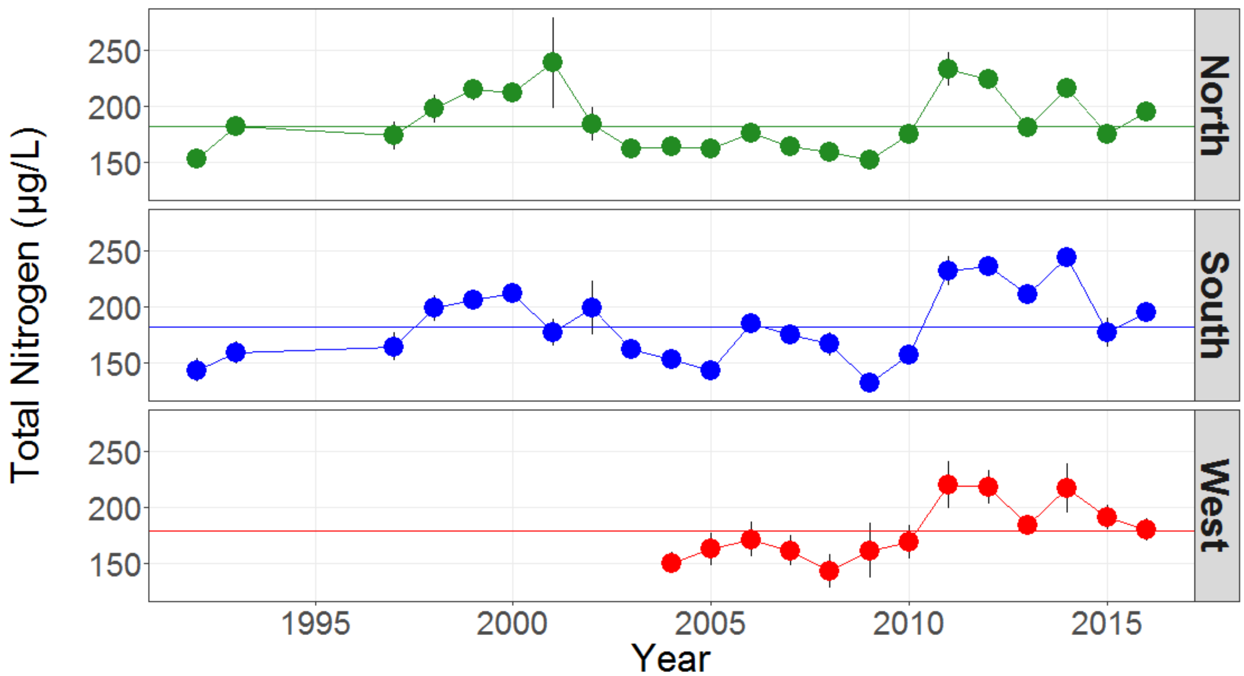


Figure 12. Kootenay total nitrogen (TN) annual monthly mean by Arm (North, South and West) 1992-2016 (complete season sampling began in West Arm in 2004). Means ±SE. Solid lines indicate long term means by arm.

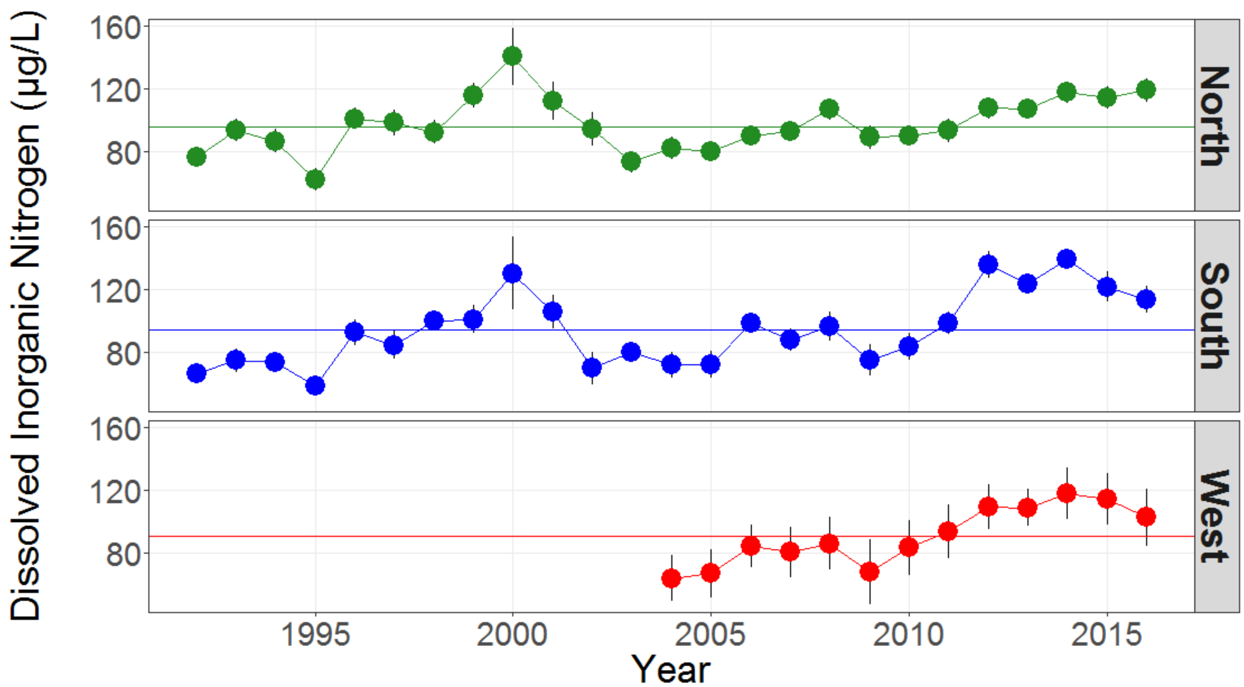


Figure 13. Kootenay dissolved inorganic nitrogen (DIN) annual monthly mean by Arm (North, South and West) 1992-2016 (complete season sampling began in West Arm in 2004). Means ±SE. Solid lines indicate long term means by arm.

Nitrogen:Phosphorus Ratio

Similar to the DIN results, higher nitrogen (DIN) to phosphorus (TDP), or N:P, ratios have been observed particularly in the South Arm since 2011 (Figure 14). The 2016 mean N:P ratio for the North Arm was 53.9 (range: 10 to 94), which was higher than the 1992–2016 mean of 36.3 (Figure 14). The South Arm mean N:P ratio was 51.6 (range: 13 to 95), which was higher than the long term mean of 35.2. The West Arm mean N:P ratio was 45.8 (range: 13 to 89), which was higher than the long term West Arm mean of 36.1 (Figure 14).

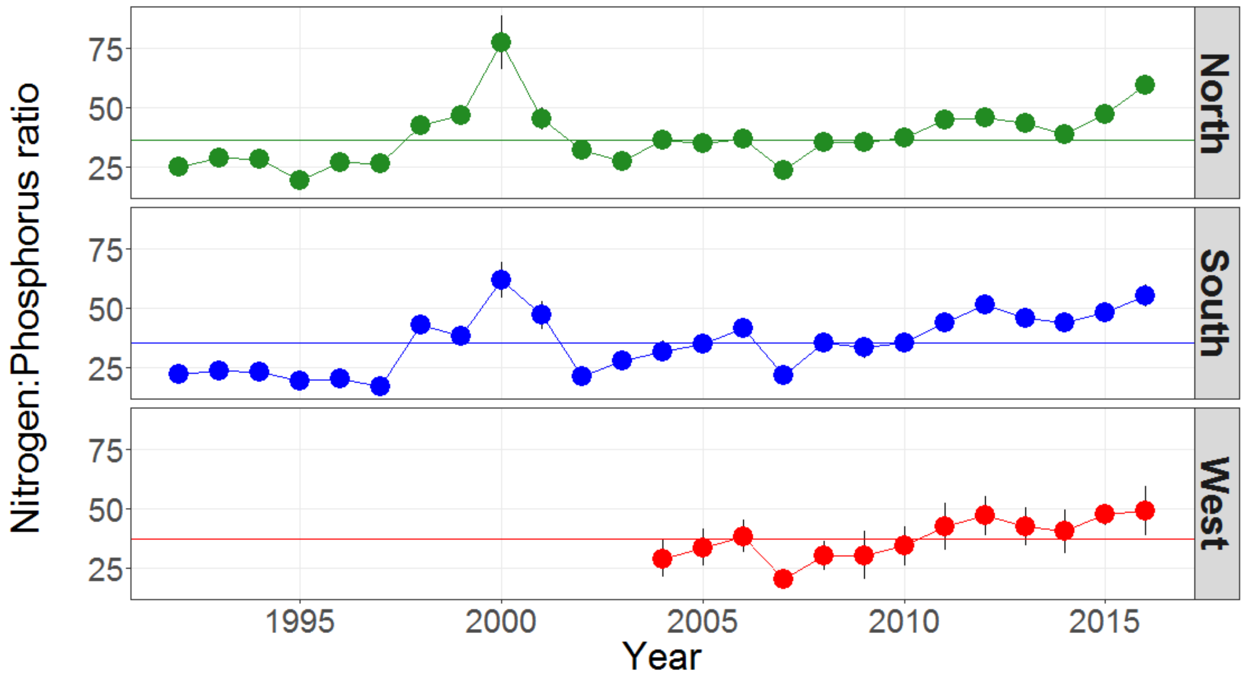


Figure 14. Kootenay nitrogen (DIN) to phosphorus (TDP) ratio annual means by Arm (North, South and West) 1992–2016 (complete season sampling began in West Arm in 2004). Means ±SE. Solid lines indicate long term means by arm.

Phytoplankton

Class

Phytoplankton data by station and month is reported as raw data in Appendix 18. Total phytoplankton monthly arm mean abundance ranged from 1066 cells/mL in September in the South Arm to 14,688 cells/mL in the North Arm in late July (Figure 15). As with other summer and early fall samples, this was predominantly the class Bacillariophyceae. Biovolume was lowest in the North Arm in April at 0.135 mm^3/L, which was largely species from the Chrysophyceae and Cryptophyceae classes. Peak biovolume was noted in the North and South Arms in the late July samples (1.979 and 1.550 mm^3/L; respectively), with the highest contributions from Bacillariophyceae (Figure 16).

Figure 15. Kootenay Lake phytoplankton mean density (cells/mL) by month and Arm in 2016. Results are separated by taxonomic group.

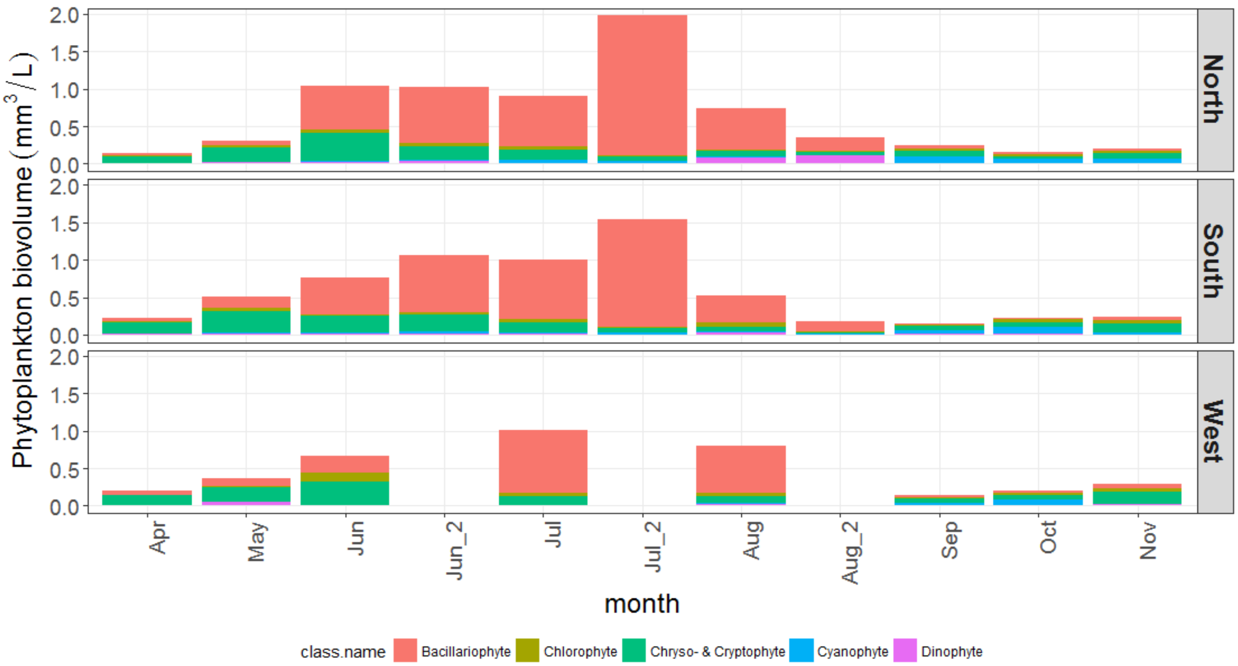


Figure 16. Kootenay Lake phytoplankton mean biovolume (mm^3/L) by month and Arm in 2016. Results are separated by taxonomic group.

Edible and Inedible Biovolume

In 2016, the biovolume of phytoplankton fluctuated over the course of the sampling period from April to November (Figure 17). The phytoplankton community generally builds over the course of the growing season and then tapers off as fall conditions predominate, defined by lower nutrients, colder temperatures and shorter photoperiods. This pattern is more notable in the inedible phytoplankton community, which are less affected by zooplankton grazing pressure. In 2016, the inedible community was generally within previous year's results for each monthly sampling session, with the exception of higher results of inedibles in 2016 in the late July sampling session. It is worth noting that the late July (July_2) and late August (Aug_2) sampling means are only from 2012–2016, so less variability is captured for those sampling sessions. The group that contributed largely to that high result were the Bacillariophyceae (diatoms); in particular, the species *Fragilaria crotonensis*. Less seasonal variation occurred in the edible community: as a standing crop metric it is influenced by top-down pressure from zooplankton and is quickly grazed down (Figure 18). Aside from the June samples, the edible community in 2016 was at, or slightly lower than previous years monthly observations. For all Arms, the 2016 edible mean increased from the previous year, and was higher than the long term mean. The annual biovolume of inedible phytoplankton was also slightly below the long term means for all arms. Also, 2016 inedible phytoplankton showed an increase from 2015 in all arms.

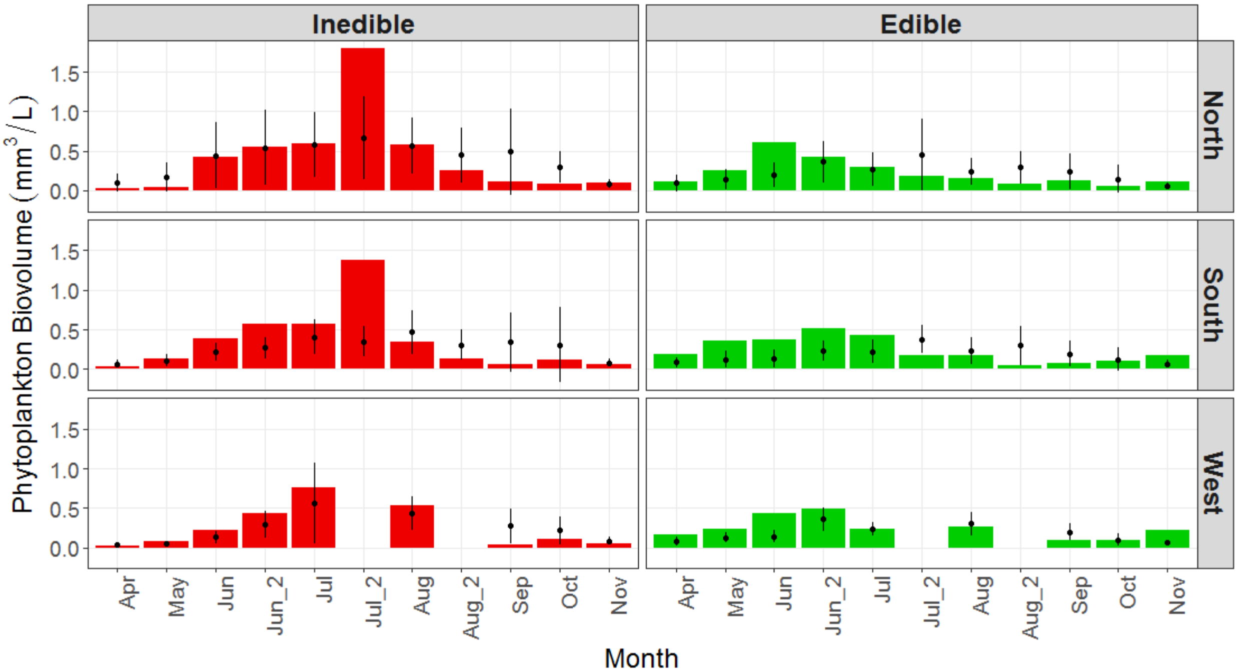


Figure 17. Kootenay phytoplankton mean biovolume (mm^3/L) month and Arm in 2016 (bars). Inedible (red) and edible (green) phytoplankton to zooplankton. 1992–2016 monthy means by arm are denoted as black points (Means ± Standard Deviation). West Arm sampling started in 2003, therefore, West Arm means and standard deviations are from 2003–2016. Jul_2 and Aug_2 sampling started in 2012, therefore, Jul_2 and Aug_2 means and standard deviations are from 2012 to 2016.

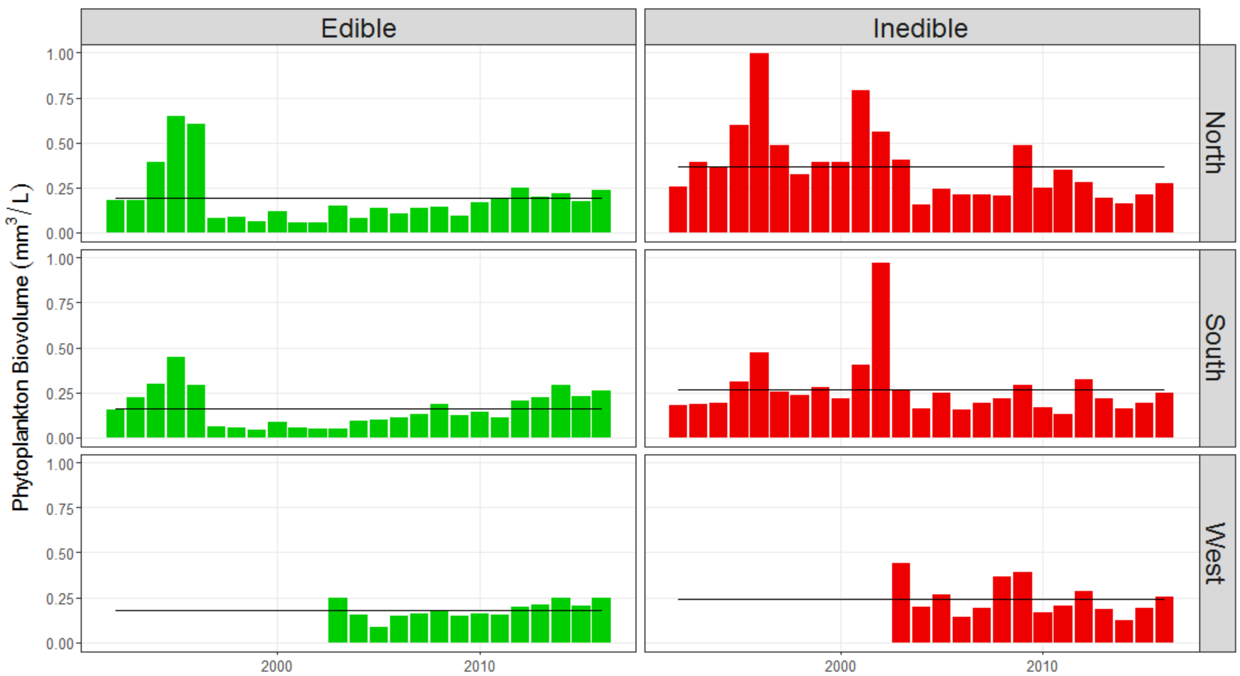


Figure 18. Kootenay phytoplankton biovolume (mm^3/L) mean by year (1992–2016). Sampled Apr-Nov. Inedible (red) and edible (green) phytoplankton to zooplankton. 1992–2016 arm means are denoted as black horizontal lines. For annual comparisons, Jul_2 and Aug_2 are omitted from these data.

Zooplankton

Density

Twenty two species of macrozooplankton were identified in the samples over the course of the study, with copepods such as *Leptodiaptomus ashlandi, Epishura nevadensis* and *Diacyclops bicuspidatus thomasi*, and the cladocerans *Daphnia galeata mendotae* and *Bosmina longirostris* being the most numerous. Four calanoid copepod species, *Epischura nevadensis* (Lillj.), *Leptodiaptomus ashlandi* (Marsh), *Leptodiaptomus pribilofensis* (Juday and Muttkowski) and *Leptodiaptomus sicilis* (Forbes), were identified in samples from Kootenay Lake. Only one cyclopoid copepod species, *Diacyclops bicuspidatus thomasi* (Forbes), was identified during the same time period.

In 2016, the following species were present: *Leptodiaptomus ashlandi* (Marsh), *Epishura nevadensis* (Lillj.), *Diacyclops bicuspidatus thomasi* (Forbes), *Daphnia galeata mendotae* (Birge), *Daphnia pulex* (Leydig), *Daphnia longispina* (O.F.M.), *Bosmina longirostris* (O.F.M.), *Leptodora kindtii* (Focke), and *Diaphanosoma brachyurum* (Liéven). Three rare cladoceran species: *Ceriodaphnia reticulata* (Jurine), *Chydorus sphaericus* (Baird), and *Syda cristallina* (O.F.M.) were seen in July and August at station KLF 7, and one rare copepod species *Macrocyclops albidus* (Jurine) was seen at station KLF 8 in July.

In 2016, the average zooplankton density in the North Arm was dominated by copepods (83% total zooplankton density), followed by *Daphnia* sp. (11%), and cladocerans other than *Daphnia* sp. (6%; Figure 19). The annual average density of copepods was 26.47 individuals/L, *Daphnia* sp. 3.48 individuals/L, and cladocerans other than *Daphnia* sp. 2.09 individuals/L (Figure 20). In the South Arm, the composition was similar, with 79% copepods (23.02 individuals/L), 15% *Daphnia* sp. (4.29 individuals/L) and 6% cladocerans other than *Daphnia* sp. (1.84 individuals/L). The West Arm station comprised 70% copepods (22.57 individuals/L), 24% *Daphnia* sp. (7.58 individuals/L) and 6% cladocerans other than *Daphnia* sp. (2.02 individuals/L).

The average zooplankton density amongst North and South Arm stations (West Arm results not included in the calculation) decreased in 2016 to 30.81 individuals/L from 33.37 individuals/L in 2015 (Figure 21).

Figure 19. Seasonal composition of zooplankton as a percentage of average density in the North, South and West Arms of Kootenay Lake, 1997 to 2016.

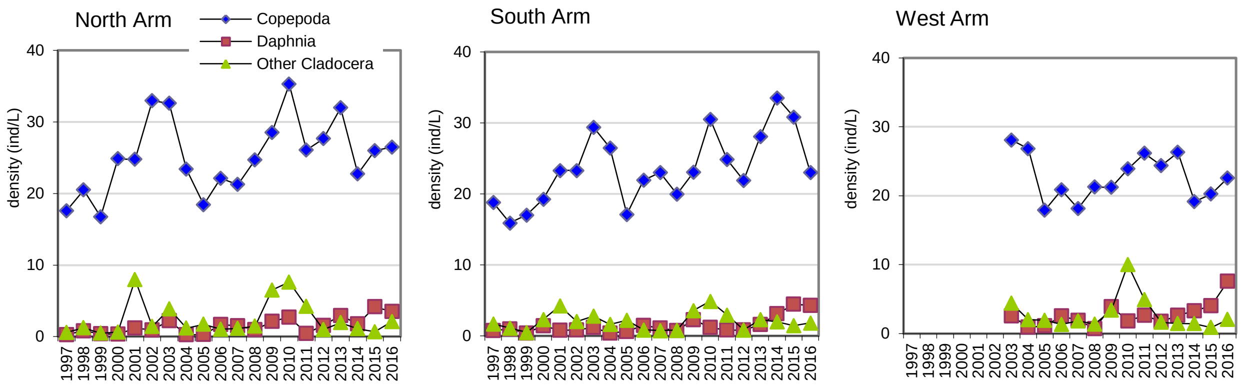


Figure 20. Seasonal average density of zooplankton in Kootenay Lake North, South and West Arms, 1997 to 2016

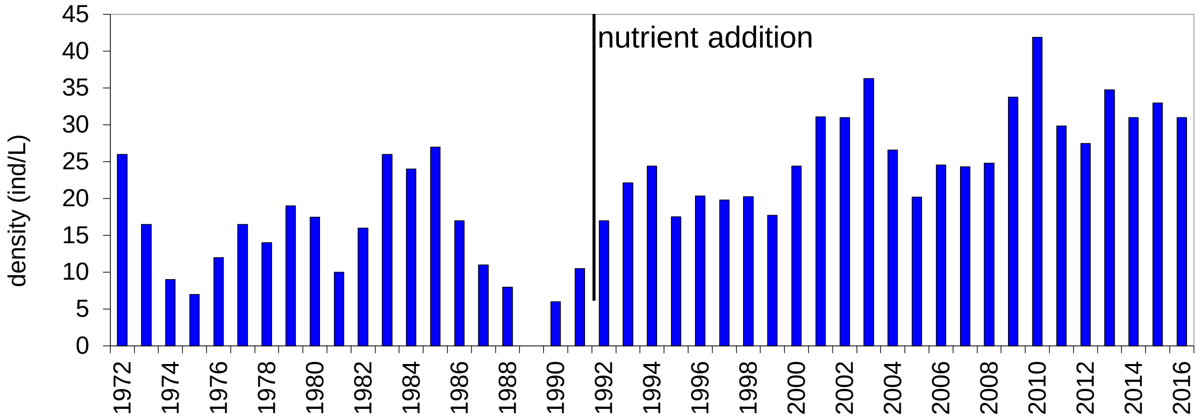


Figure 21. Average whole lake zooplankton density, 1972 to 2016. Note: 1972 to 1991 data collected from a station near to the current KLF 5 station and 1992 to 2016 data calculated as whole-lake average (West Arm data not included).

Biomass

The average zooplankton biomass in 2016 in the North Arm was comprised of 27% copepods, 70% *Daphnia* sp., and 3% cladocerans other than *Daphnia* sp. with 45.82 µg/L, 116.69 µg/L and 4.87 µg/L respectively. In the South Arm, the composition was similar with 22% copepods (39.48 µg/L), 74% *Daphnia* sp. (134.35 µg/L) and 4% cladocerans other than *Daphnia* sp. (6.97 µg/L). At the West Arm station copepods comprised 17% (39.86 µg/L), *Daphnia* sp. 81% (188.48 µg/L) and cladocerans other than *Daphnia* sp. 2% (3.44 µg/L; Figures 22 and 23).

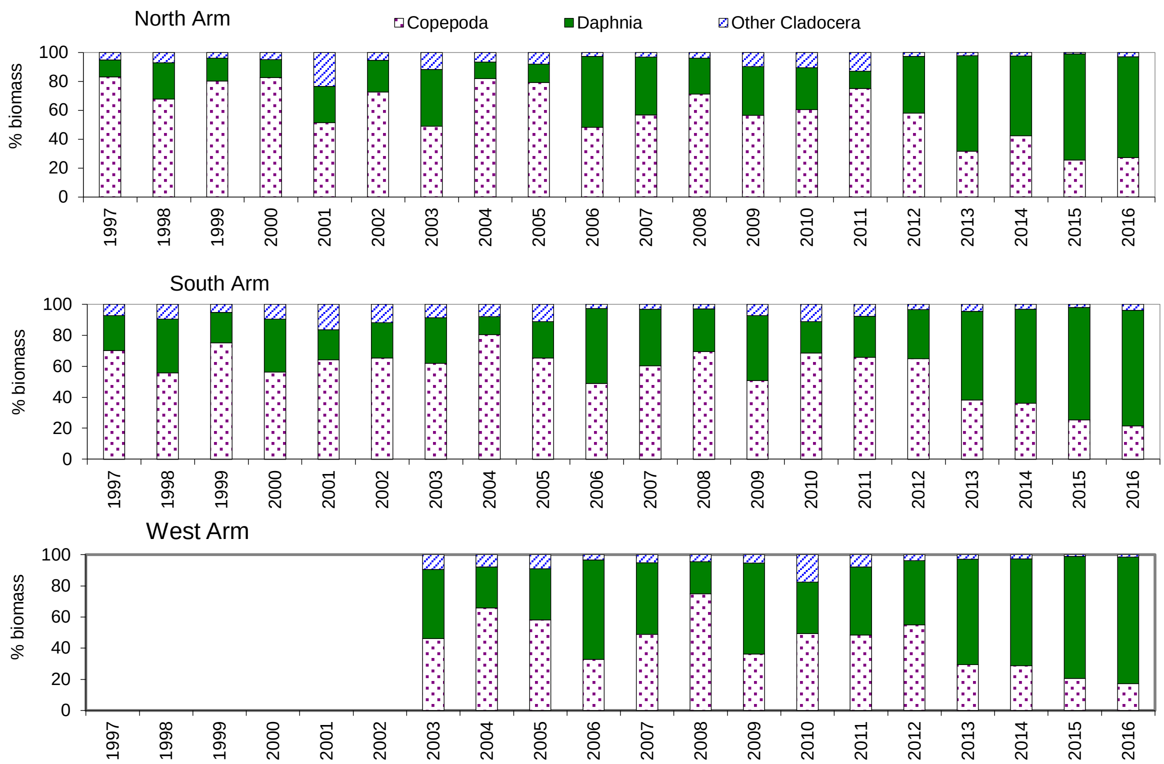


Figure 22. Seasonal composition of zooplankton as a percentage of average biomass in the North, South and West Arms of Kootenay Lake, 1997 to 2016.

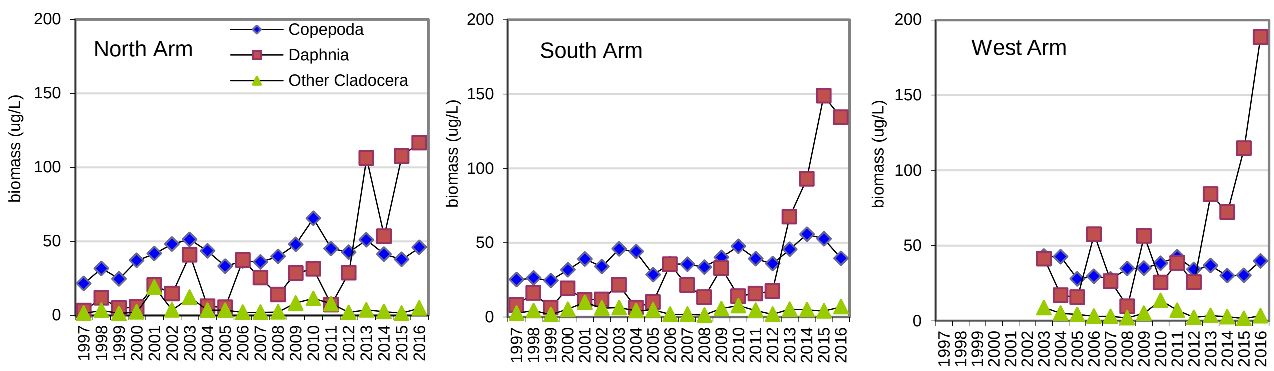


Figure 23. Seasonal average biomass of zooplankton in Kootenay Lake North, South and West Arms, 1997 to 2016.

Seasonal and lake patterns

Copepods were the main contributor to the overall zooplankton population in the spring with *Daphnia* sp. appearing in late spring, peaking in summer and maintaining a population through November. This pattern occurred in the North, South, and West Arms. 2016 was an "early" year, with *Daphnia* first appearing in May during the same sampling session in all three arms of

Kootenay Lake, whereas in previous years *Daphnia* has usually appeared in June or July (Figure 24). The long-term pattern shows either the appearance of *Daphnia* first in the South Arm and a month later in the North Arm, or simultaneous appearance in both Arms. Only in 2001 and 2009 did *Daphnia* appear first in the North Arm. 2009 and 2014 were also unique “early years” when *Daphnia* appeared in April, but only in the West Arm.

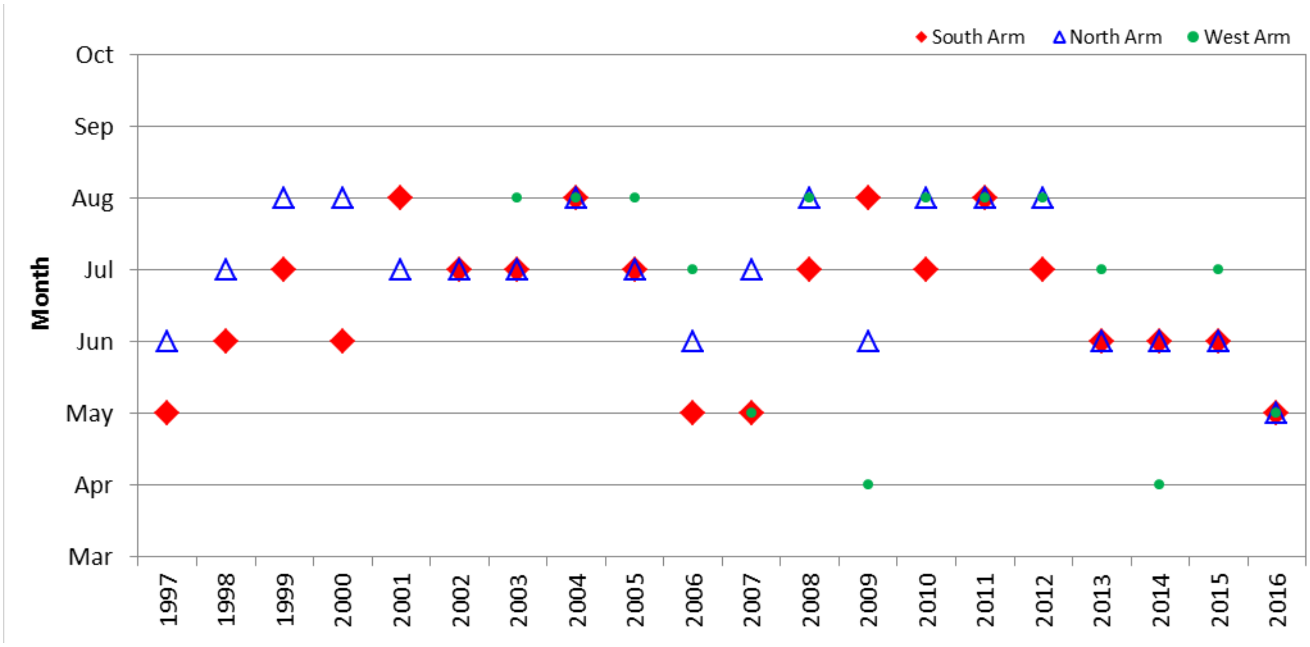
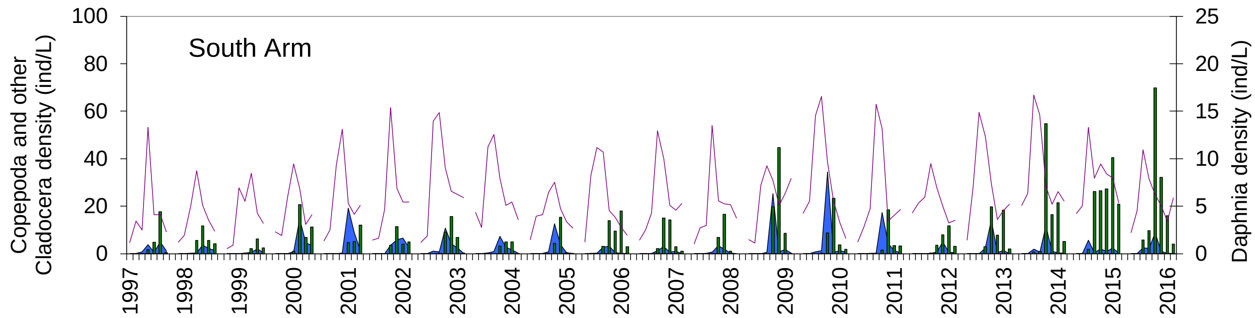
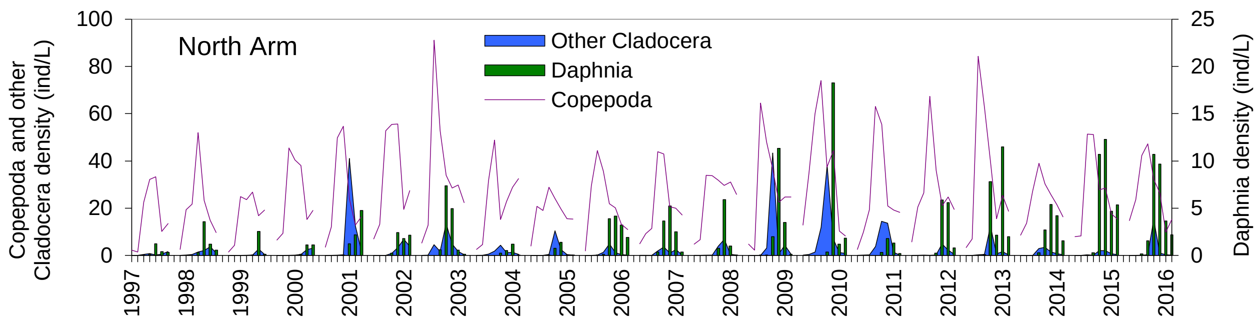


Figure 24. First appearance of *Daphnia* sp. in the season in North, South and West Arm of Kootenay Lake, 1997 to 2016 .

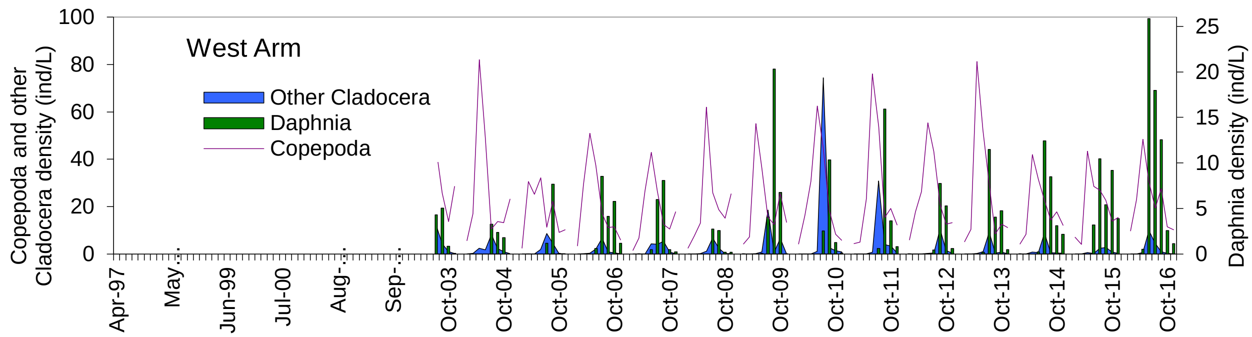
In the 2016 season, *Daphnia* sp. reached its maximum density in July in the West Arm and August in the North and South Arms (Figure 25 for abundance and Figure 26 for biomass). Copepod abundance was the main contributor throughout the sampling season while the trend in biomass was dominated by *Daphnia* from July through November. This is the typical trend observed throughout studied years.



a. Seasonal density of zooplankton in the North Arm of Kootenay Lake, 1997 to 2016.

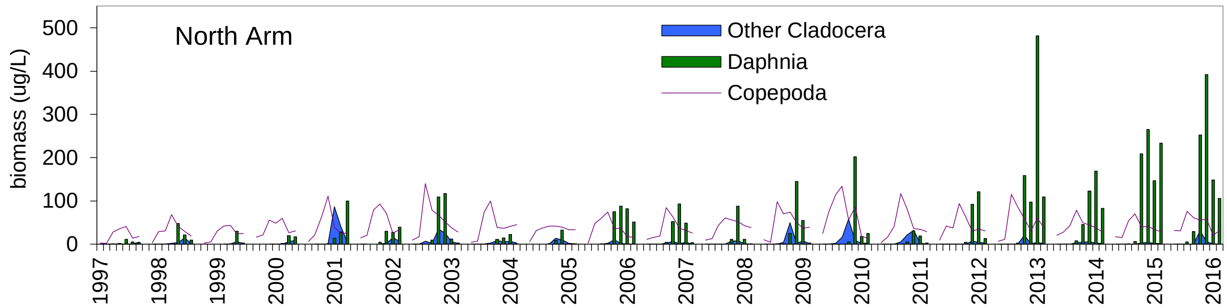


b. Seasonal density of zooplankton in the South Arm of Kootenay Lake, 1997 to 2016.

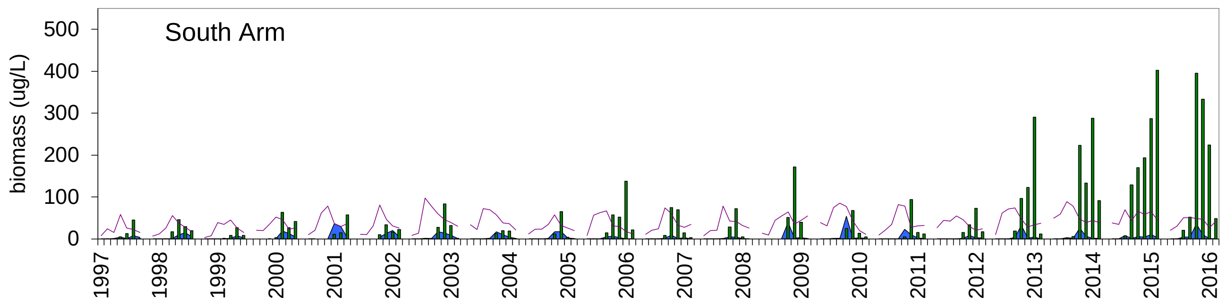


c. Seasonal density of zooplankton in the West Arm of Kootenay Lake, 1997 to 2016. The *Daphnia* density exceeding the Y axis limit in July 2016 is 25.9 ind/L.

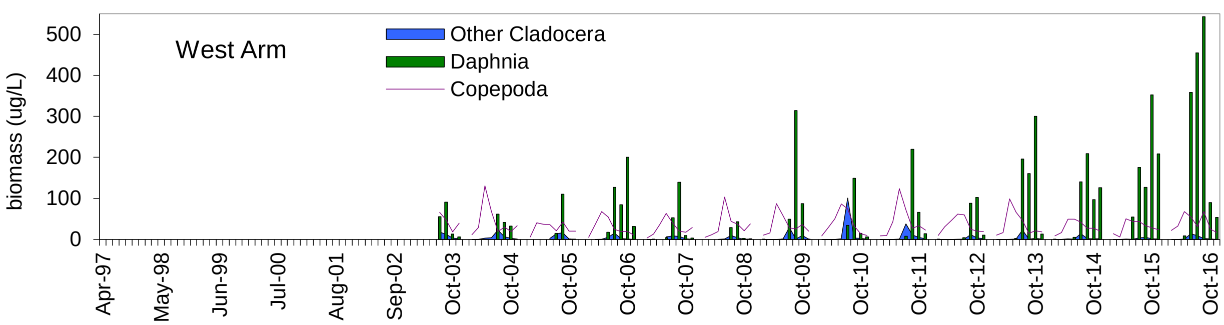
Figure 25. Zooplankton density in Kootenay Lake, 1997 to 2016.



a. Seasonal biomass of zooplankton in the North Arm of Kootenay Lake, 1997 to 2016.



b. Seasonal biomass of zooplankton in the South Arm of Kootenay Lake, 1997 to 2016.



c. Seasonal biomass of zooplankton in the West Arm of Kootenay Lake, 1997 to 2016.

Figure 26. Zooplankton biomass in Kootenay Lake, 1997 to 2016.

In 2016, total zooplankton density in the North Arm was higher than in the South Arm for the first time since 2013. Since 1997, zooplankton density in the North Arm has been consistently higher than in the South in each year except in 2004, 2007, 2014 and 2015 (Figure 27). Average zooplankton biomass of all three Arms of Kootenay Lake was the highest amongst all studied years in 2016, continuing a trend of increasing biomass seen since 2013 (Figure 28). At 180.46 µg/L, biomass increased again in comparison to 2015 (168.72 µg/L), likely due to appearance of very large *Daphnia* individuals (unpublished data). Among the three Arms of the lake, total biomass was the highest in the West Arm.

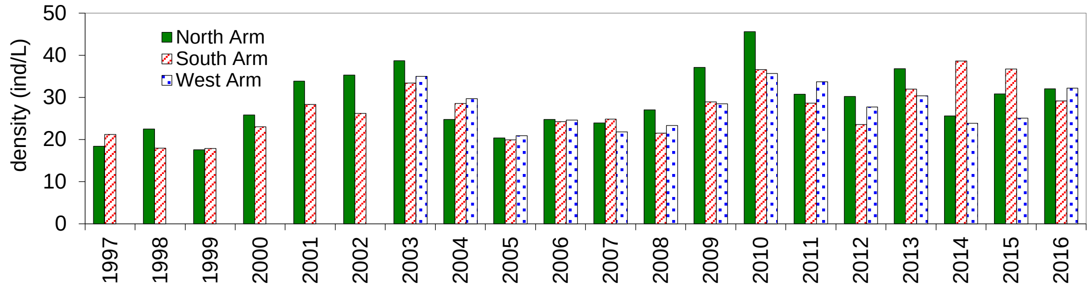


Figure 27. Seasonal average density of total zooplankton in North, South and West Arms, 1997 to 2016.

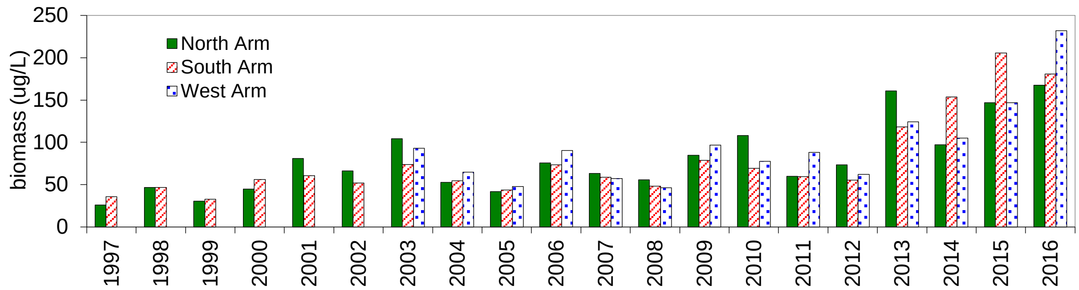


Figure 28. Seasonal average biomass of total zooplankton in North, South and West Arms, 1997 to 2016.

Monthly results of density and biomass by station for North, South and West Arm are shown in Figure 29. When comparing densities amongst stations in the North Arm by months in 2016, results differ at station KLF 4 for April, May, June, and August, and at station KLF 2 for July (Figure 29). By comparison, South Arm densities fluctuated at the same seasonal pattern at all three sampling stations. Biomass results were similar among stations in the North Arm and slightly different among the three stations in the South Arm in August and September.

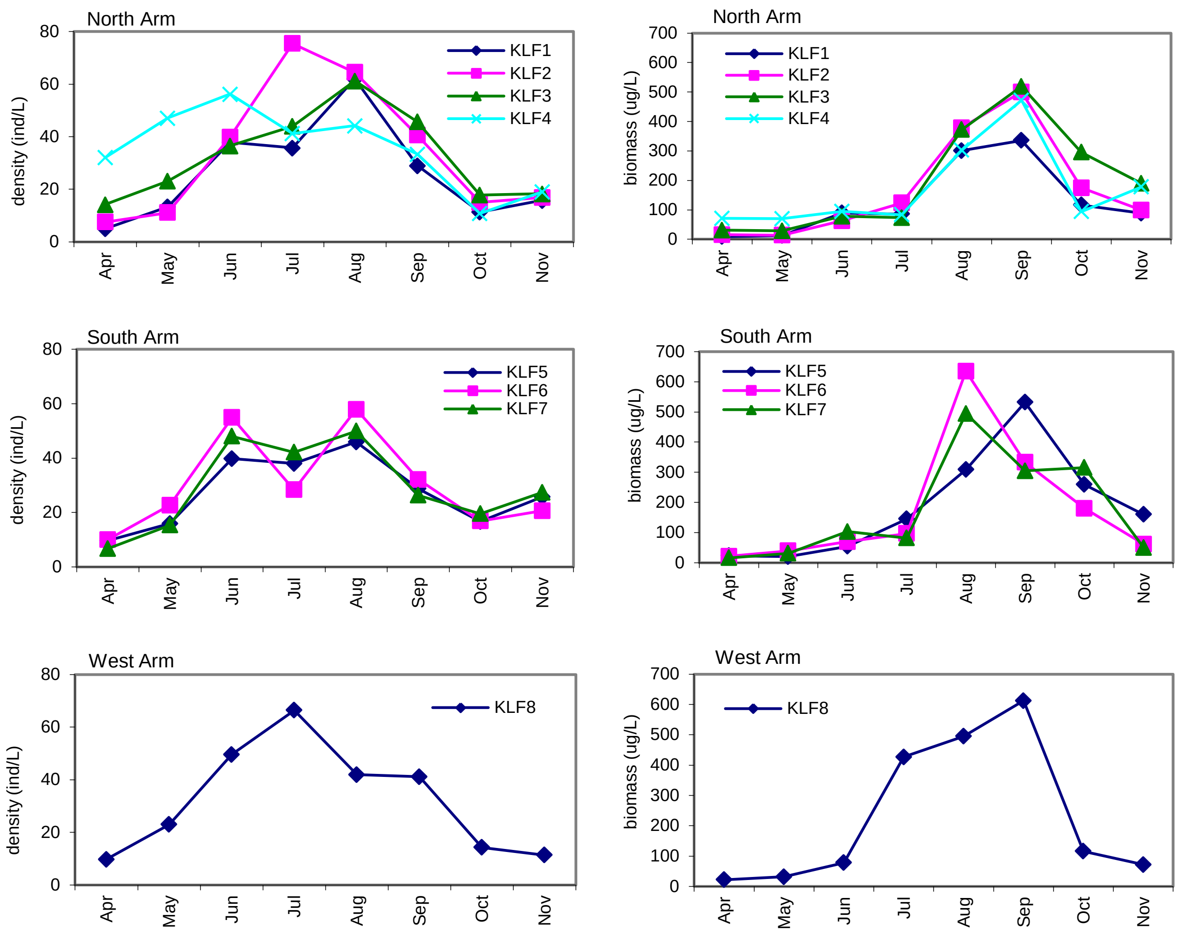


Figure 29. Total zooplankton density and biomass at each station, Kootenay Lake, April to November 2016.

Mysis diluviana

Density

In the main lake, seasonal average mysid densities during the nutrient addition period (1992–2016) were lower than results from the late 1970s and the mid-1980s (Figure 30). However, samples collected in the late 1970s and mid-1980s were less frequently sampled than during the current study, and the plankton net used to collect samples had a finer mesh (Crozier and Duncan 1984). From 1992 to 2004, sampling of mysids began in January and continued until December. In 2006 samples were collected for ten months, between February and November, and from 2007 to 2016 for eight months from April to November. For annual comparisons, all annual average data are calculated for the period from April to November in each studied year. During the nutrient addition period, the highest density was observed in 1992, the first year of nutrient additions. The second highest density occurred in 2001, when after a four-year period of decreased phosphorous and nitrogen additions nutrients were increased again to match the additions from the first five years of the program (1992–1996; Table 1).

In 2016, densities of mysids decreased slightly in comparison to 2015 (Figure 30). Average densities were higher in the North Arm than the South Arm in deep sites, a trend that was also seen from 1995-2000, 2003-2006, 2011-2012 and 2014 (Figure 31). Conversely, at shallow sites there was a trend of higher mysid densities in South Arm than in the North and West Arm from 2008 to 2016.

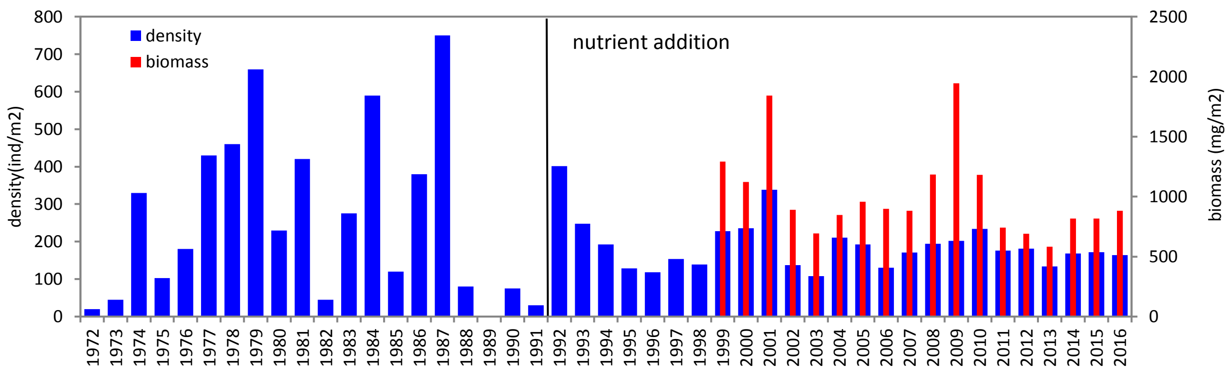


Figure 30. Annual average density and biomass (1999–2016) of *Mysis diluviana* in Kootenay Lake, 1972 to 2016.

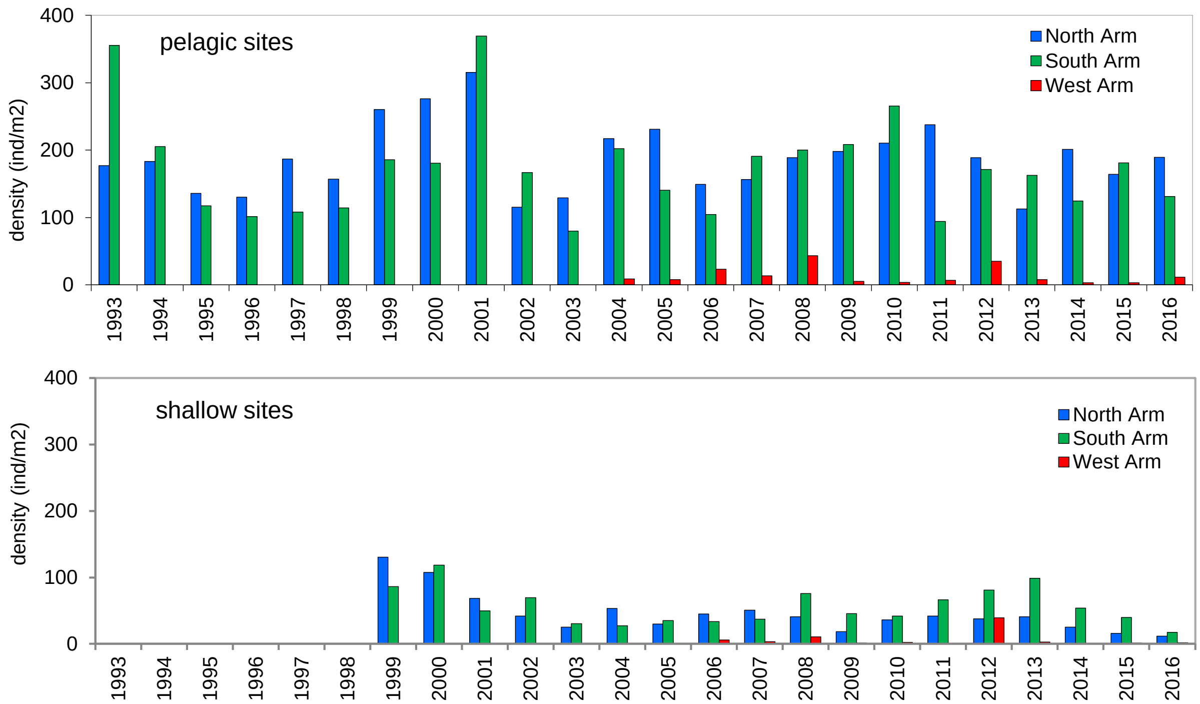


Figure 31. Annual average density of *Mysis diluviana* in pelagic and shallow sites in the North, South and West Arms of Kootenay Lake, 1993 to 2016. Averages calculated from April to November.

The peak density in 2016 occurred in August at station KLF 1 with 778 ind/m^2, mainly because of an increased number of immature males and females (Figures 32 and 33). In the West Arm, peak density occurred in May at 54 ind/m^2; this is a month earlier than in all previously studied years (Figure 33). The main contributors to the total densities at most stations were the immature male and female developmental stages, except in the West Arm where juveniles were predominant.

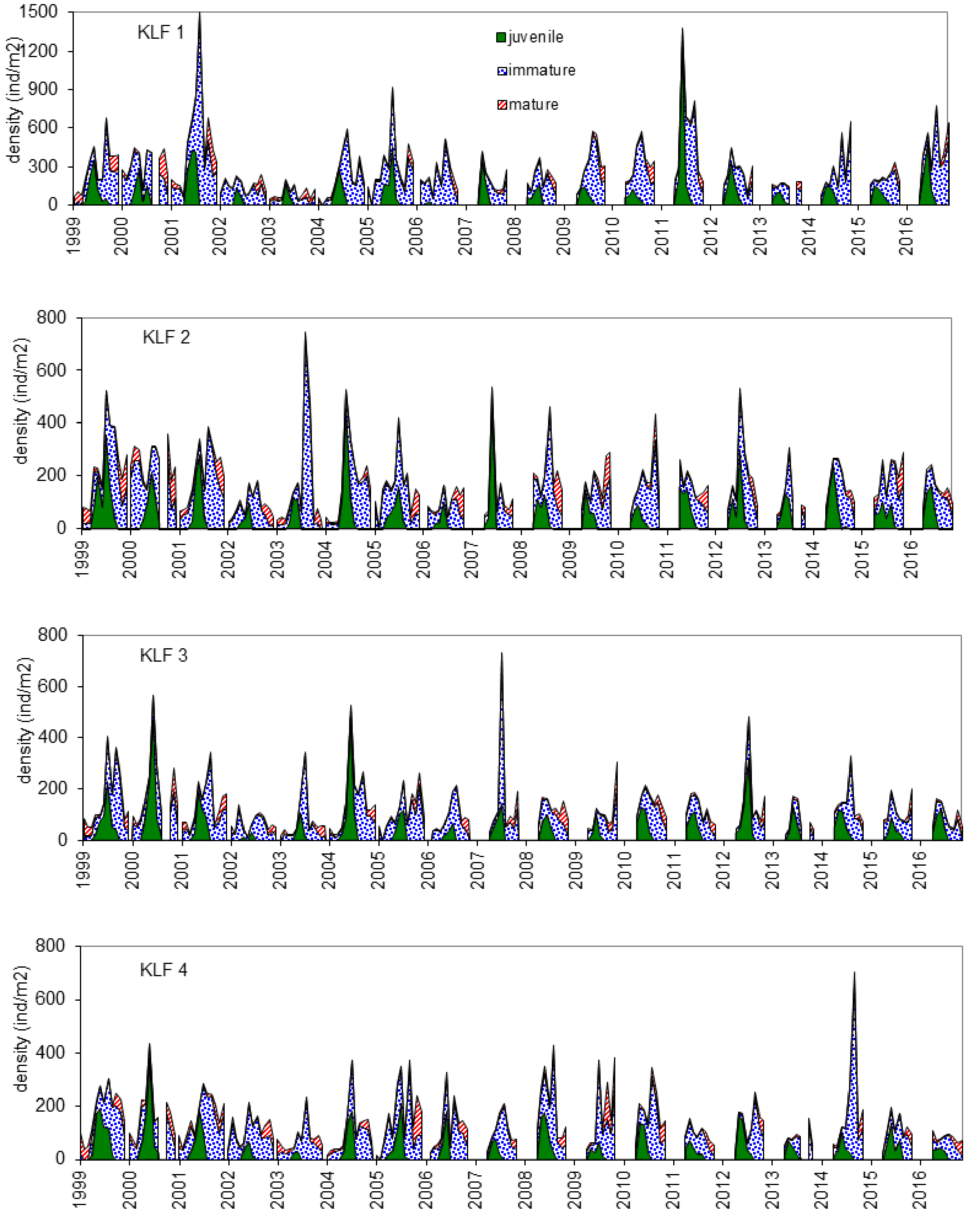


Figure 32. Densities of developmental stages of *Mysis diluviana* at deep sites, North Arm stations, Kootenay Lake, 1999 to 2016. Note: The graph for station 1 has different scale

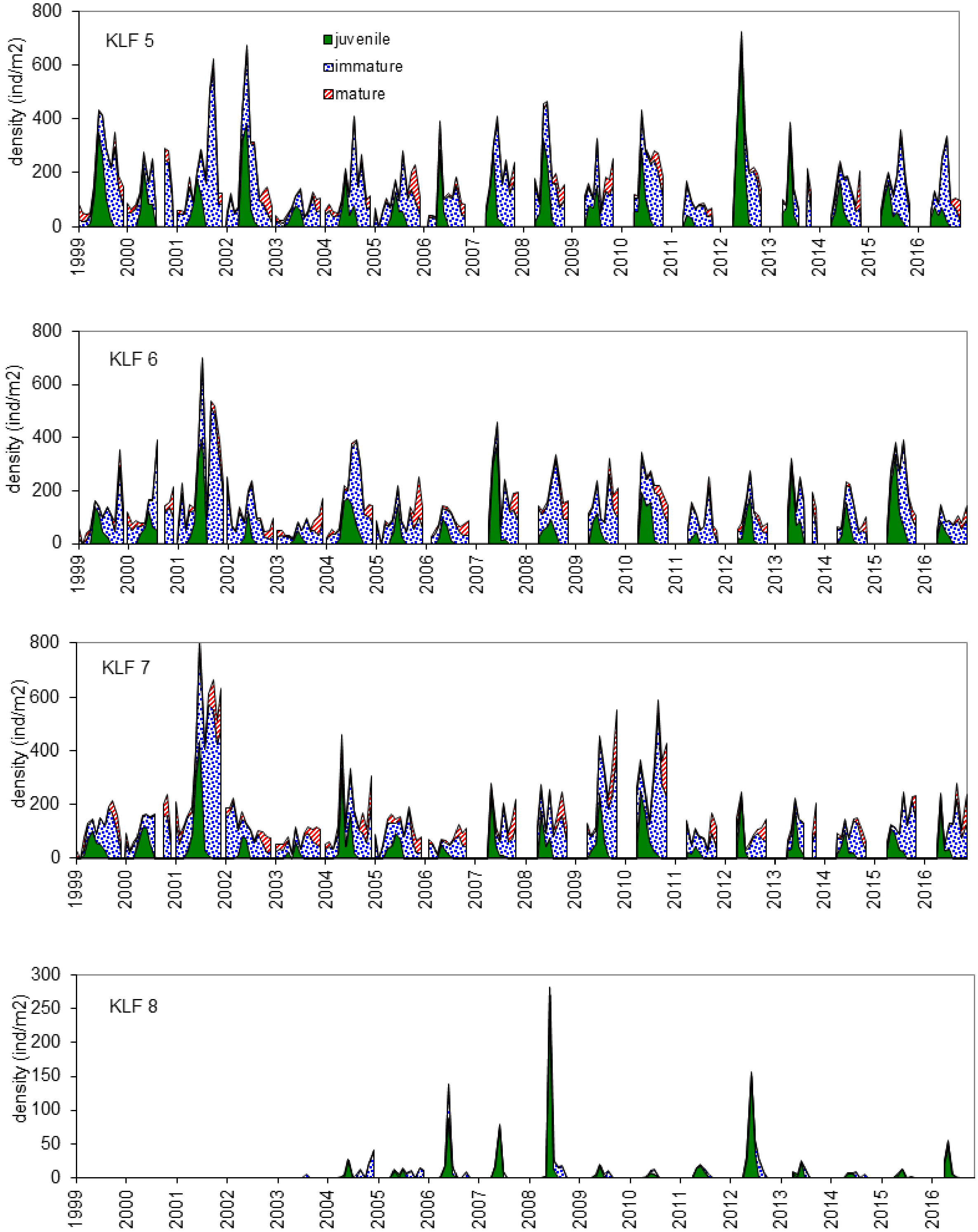


Figure 33. Densities of developmental stages of *Mysis diluviana* at deep sites, South Arm (KLF 5–7) and West Arm stations (KLF 8), Kootenay Lake, 1999 to 2016. Note: The graph for station 8 has different scale.

Biomass

Biomass at deep sites in all three Arms increased in 2016 compared to the previous year, while biomass at shallow sites decreased (Figure 34). Average biomass in deep sites was higher in the North Arm than the South Arm, while at shallow sites biomass was higher in the South than in the North Arm. Immature and mature developmental stages contributed the most to overall biomass. The release of juveniles from female brood pouches occurs in early spring and is reflected by a density increase in April of each year (Figure 35). By July, the juveniles have grown into the immature stage, therefore during the summer and fall immature males and females dominate the mysid population. Brooding females and breeding males increase in density in the late fall as they reach maturity (Schindler et al. 2011). Biomass in the West Arm increased more than six times in 2016 in comparison to the previous year (Figure 37). The majority of total lake biomass was comprised of the immature developmental life stage. Peak biomass occurred in November 2016 at station KLF1 with 4,172.28 mg/m^2.

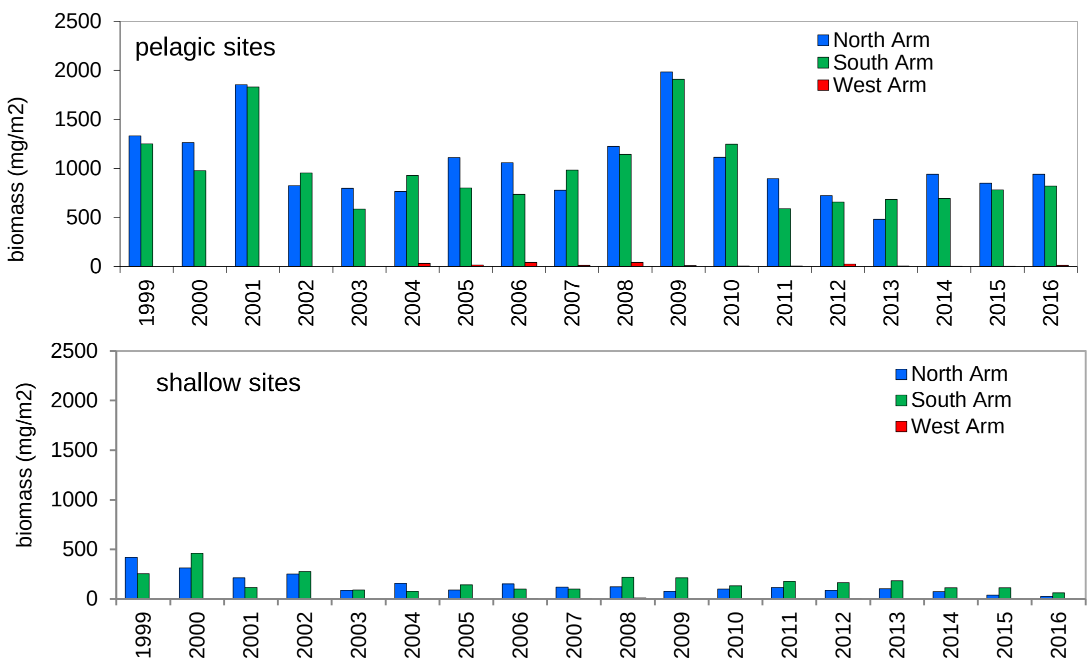


Figure 34. Annual average biomass of *Mysis diluviana* at deep and shallow sites in the North, South and West Arms of Kootenay Lake, 1999 to 2016. Averages calculated from April to November.

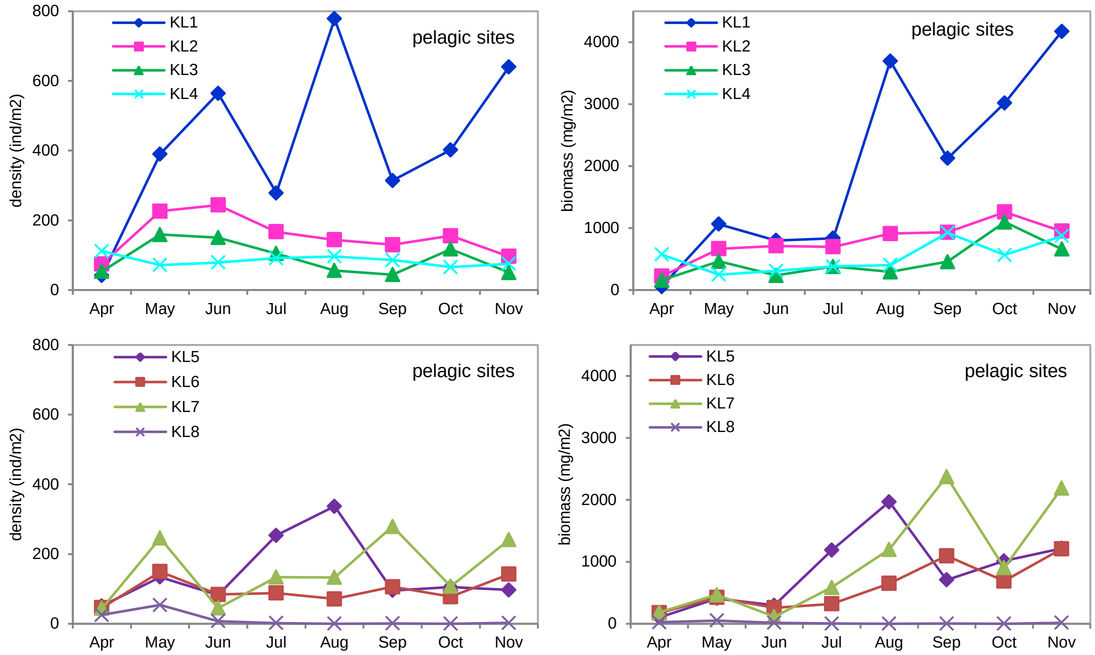


Figure 35. Mysid density and biomass at deep sites in Kootenay Lake, April to November 2016

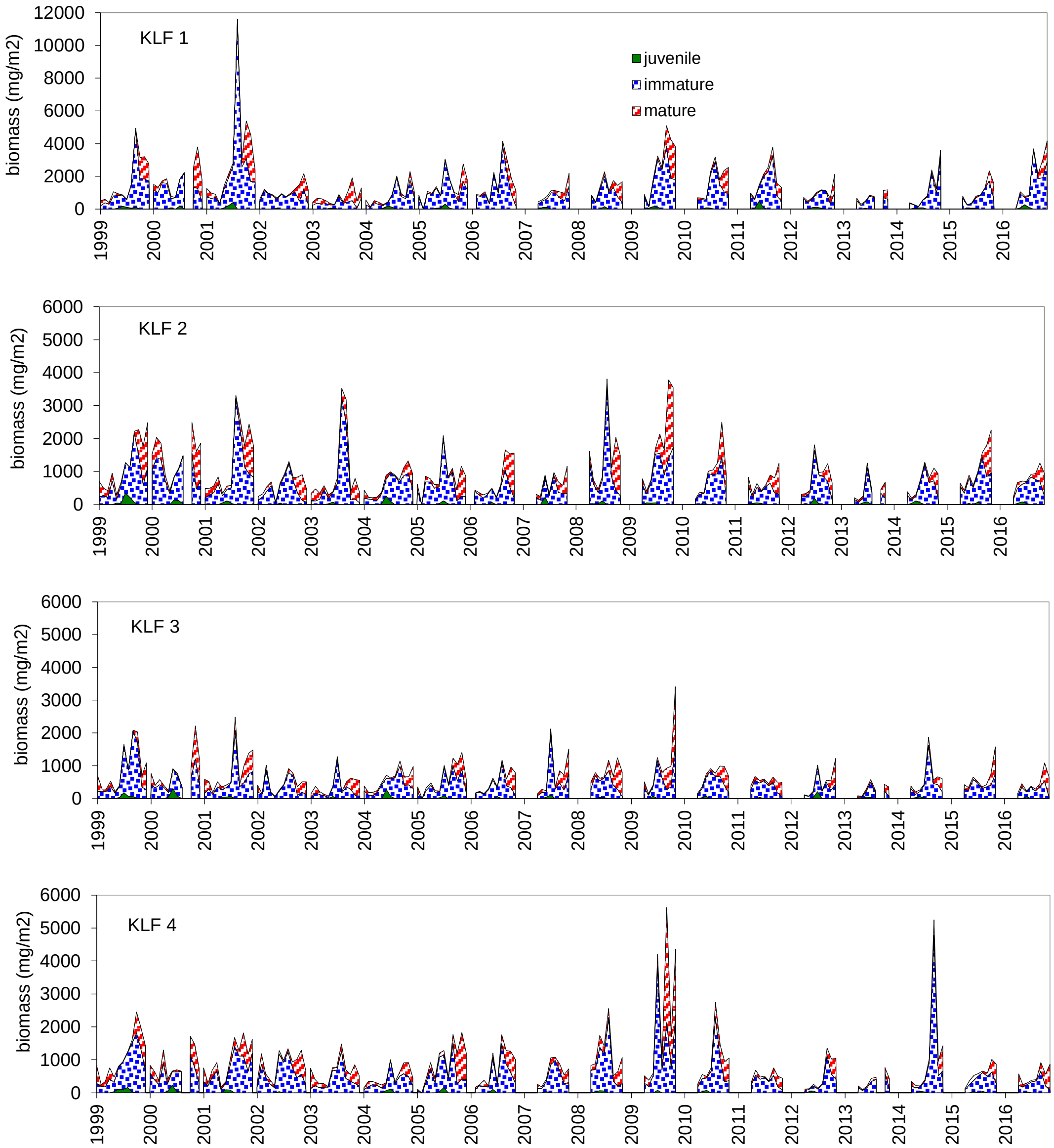


Figure 36. Biomass of developmental stages of *Mysis diluviana* at deep sites, North Arm stations, 1999 to 2016. Note: The graph for station 1 has different scale

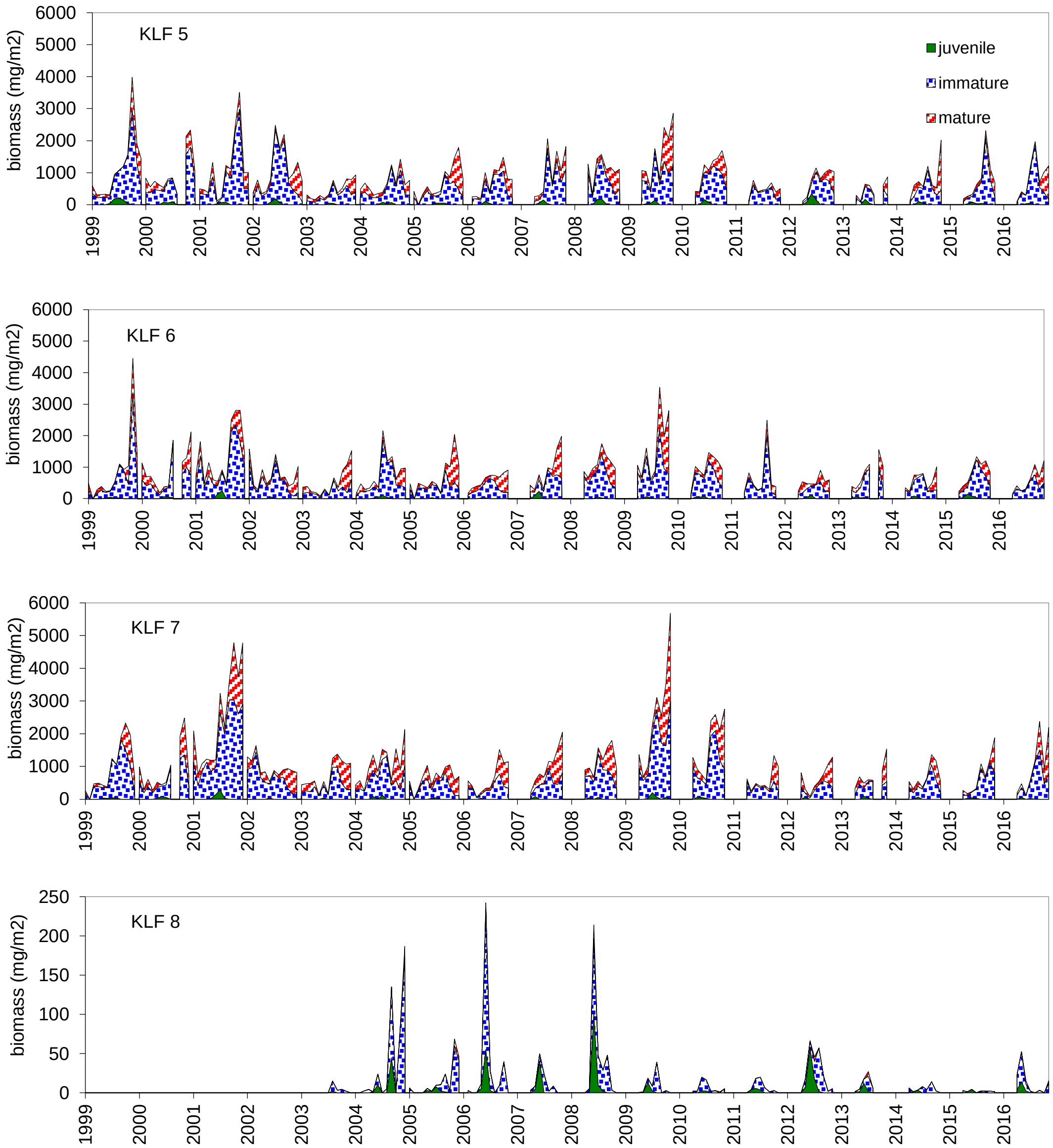


Figure 37. Biomass of developmental stages of *Mysis diluviana* at deep sites, South Arm (KLF 5–7) and West Arm stations (KLF 8), Kootenay Lake, 1999 to 2016. Note: The graph for station 8 has different scale

When comparing densities and biomasses amongst stations at deep sites in the North Arm by months in 2016, results are higher at station KLF 1 than at other stations in all months except April (Figure 35). By comparison, South Arm densities and biomasses fluctuated at the same seasonal pattern except in July and August at station KL 5 and in September and November at station KL 7 when both density and biomass were higher than at other stations. At shallow sites mysid densities and biomasses fluctuated during the whole sampling season 2016 among stations in North, South and West Arm (Figure 38).

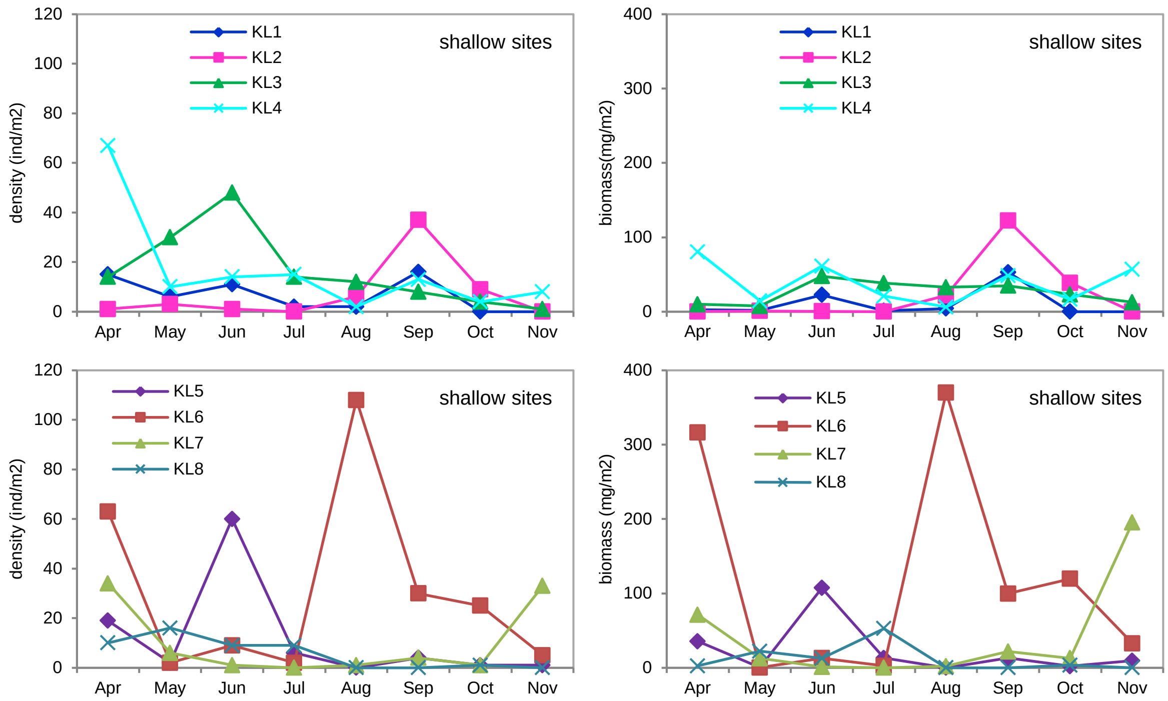


Figure 38. Mysid density and biomass at shallow sites in Kootenay Lake, April to November 2016

Kokanee

Trends in Kokanee Escapement

Spawner escapement to both Meadow Creek and the Lardeau River increased slightly from the historical low in 2015 but remained well below the long term average. Meadow Creek (channel and non-channel) received only 15,614 kokanee in 2016 (Figure 39) while Lardeau River received only 24,986 (Figure 40). To demonstrate “normal” conditions we have used 1 standard deviation from the pre- and post-nutrient addition averages in Figures 39 and 40. Note that a review of the Lardeau escapement time series resulted in minor changes from what has been reported previously; see Appendix 21 for the complete revised dataset and source list.

In the Meadow Creek Spawning Channel, the number of spawners in the channel has ranged from a maximum of 519,557 in 2012 to a minimum of 5,679 in 2015 since nutrient additions began in 1992 (Appendix 23, Figure 39). Escapement to the channel in 2016 was 11,087 (MFLNRO 2017).

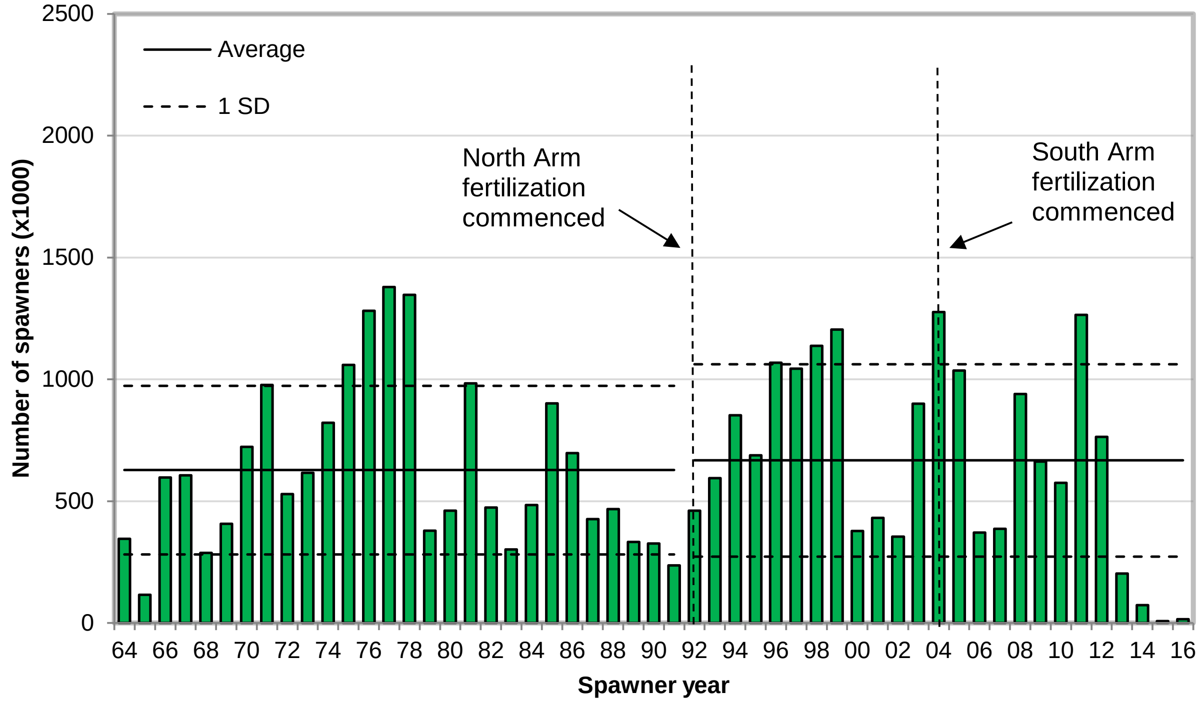


Figure 39. Kokanee escapements to Meadow Creek, North Arm of Kootenay Lake, 1964–2016. (1964–1968 data from Acara 1970 unpublished MS). Note that the pre-nutrient addition period also had unnatural levels of nutrient addition from an industrial operation in Kimberley, B.C. until the 1970s.

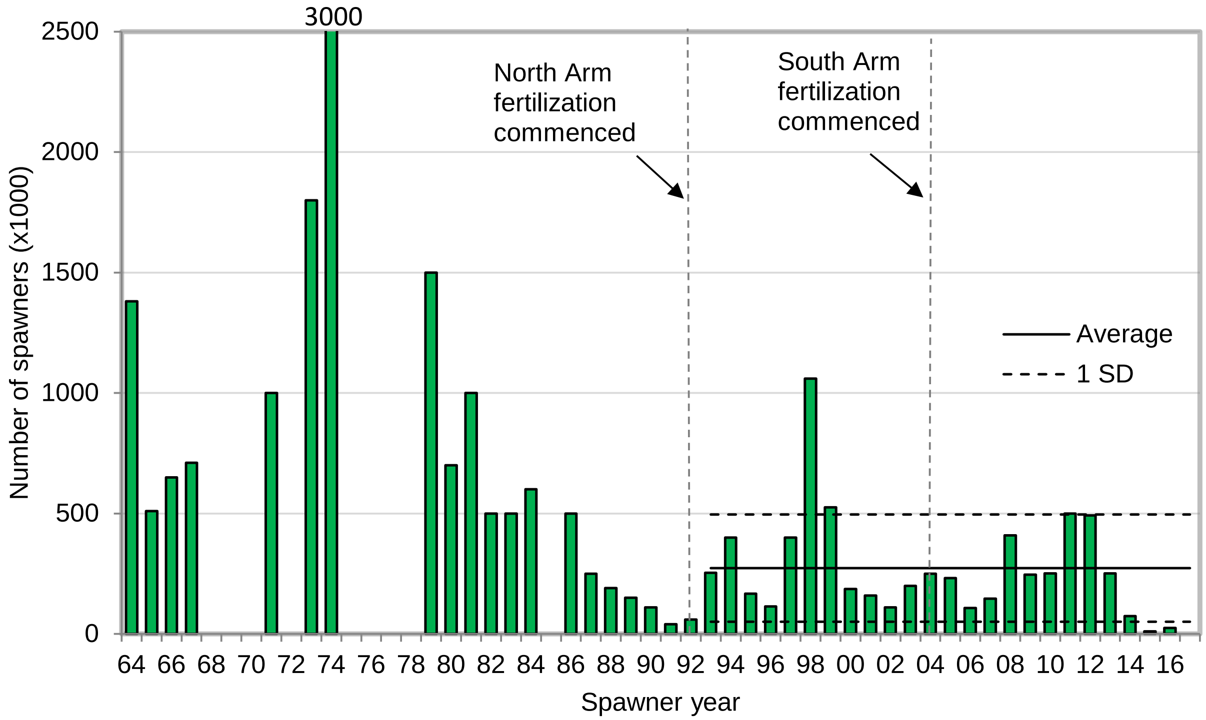


Figure 40. Kokanee escapements to the Lardeau River, North Arm of Kootenay Lake, 1964–2016. No data exist for years without bars; pre-nutrient addition average omitted due to missing data. Note that the pre-nutrient addition period also had unnatural levels of nutrient addition from an industrial operation in Kimberley, B.C. until the 1970s.

Kokanee egg plants and escapements – South Arm

Egg plants in select South Arm tributaries began in northern Idaho in 1997 and in British Columbia in 2005 with varying levels of effort and success. Egg plants in BC South Arm tributaries are detailed in Table 4, and index site and full count (2016) kokanee spawner counts for the B.C. South Arm tributaries are presented in Appendix 22. While the B.C. tributaries that have not received egg plants (right side of Table 5) continued to have zero or very few spawners counted, the four tributaries which received egg plants from 2005 to 2012 (Table 4 and left side of Table 5) have had modest numbers of spawners recorded since 2009. Blue shading in Table 5 highlights the returns expected to have resulted from egg plants. In 2016, Goat River and Summit Creek index sites were expected to benefit from eggplants in 2012 and had 64 and 14 kokanee present, respectively. Additionally, 61 kokanee spawners were counted in Crawford Creek despite no eggs being planted since 2008, an increase from 36 spawners counted in 2015. While index counts have been highest most years in Goat River, it has also had larger numbers of eggs planted (Table 4). Assuming age 3 kokanee spawners, and until new egg plants take place, 2016 marks the last year that fish from egg plants are expected as escapement to South Arm tributaries.

Results from the complete bank counts of spawners in B.C. South Arm tributaries were completed in the fall of 2016 and results are presented in full by Redfish Consulting (2017), while summary results are provided in Appendix 22. An increasing number of spawners were counted from the first to second survey, indicating the possibility that surveys were conducted earlier than peak run timing, particularly in Crawford Creek and Goat River where a third survey was conducted with similar results. Therefore, the counts may have been underestimated.

Table 4. Number of kokanee eyed egg plants in B.C. and Idaho South Arm tributaries, 1997–2016. See Figure 1 for map of tributary locations.

Year	**British Columbia Tributaries**					**Idaho Tributaries**								
	Boulder	**Crawford**	**Goat River**	**Summit**	**Total B.C.**	**Boundary**	**Long Canyon**	**Parker**	**Trout (S. fork)**	**Trout (N. fork)**	**Ball**	**Myrtle**	**Fisher**	**Total Idaho**
1997							100,000							**100,000**
1998							100,000	100,000	100,000					**300,000**
1999							200,000	150,000	150,000					**500,000**
2000							no egg plants							
2001							no egg plants							
2002							no egg plants							
2003							417,000	417,000	417,000	50,000		200,000		**1,501,000**
2004							500,000	500,000	587,500	325,000		587,500	500,000	**3,000,000**
2005	200,000	300,000	1,000,000	500,000	**2,000,000**		420,000	420,000	420,000	200,000		420,000	420,000	**2,300,000**
2006	175,000			210,000	**385,000**		100,000			25,000			25,000	**150,000**
2007	150,000	300,000	1,100,000		**1,550,000**		625,000	300,000	425,000	93,000		150,000	150,000	**1,743,000**
2008a	90,000	120,000	828,000	80,000	**1,118,000**	1,000,000	500,000	50,000	325,000	200,000	325,000		100,000	**2,500,000**
2008b	240,000	180,000	700,000	240,000	**1,360,000**									
2009a				236,000	**236,000**	300,000								**300,000**
2009b				264,000	**264,000**									
2010a	370,000				**370,000**	700,000			300,000					**1,000,000**
2010b	780,800				**780,800**									
2011a			2,300,000	940,000	**3,240,000**	1,000,000			500,000					**1,500,000**
2012a			1,500,000	700,000	**2,200,000**	400,000			300,000		300,000			**1,000,000**
2013*														
2014**														
2015**														
2016**														

[a] Eggs planted in the gravel using a flexible PVC pipe
[b] Eggs placed in tubes and then buried in the gravel

*No eggs planted due to IHN at Meadow Creek (source of eggs)
**No egg take due to low kokanee escapement

Table 5. Kokanee spawner counts from index sites in B.C. South Arm tributaries, 1992–2016. Data up to 2008 is from Ericksen et al. (2009). NS = not sampled. Blue shading indicates years and streams where returns of age 3 spawners were anticipated from egg plants four years earlier (see Table 4). Peak counts of full counts are reported for Goat River in 2012 and all tribs in 2016 in parentheses (Redfish Consulting Ltd. 2017 and Appendix 22). See Figure 1 for tributary locations.

	Egg Plant Tributaries				**No Egg Plants**							
Year	**Boulde**	**Crawford**	**Goat River**	**Summit**	**Gray**	**La France**	**Lockhart**	**Akokli**	**Sanca**	**Midge**	**Cultus**	**Combined**
1992	3	NS	20	30	NS	NS	NS	NS	6	NS	NS	**59**
1993	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**
1994	0	2	0	0	0	0	0	100	4	0	0	**106**
1995	0	0	0	0	0	0	0	0	0	0	0	**0**
1996	0	40	4	0	30	20	20	200	0	50	50	**414**
1997	0	0	0	0	100	3	1	150	7	0	NS	**261**
1998	0	0	2	0	5	0	0	50	2	5	NS	**64**
1999	0	0	0	0	20	2	0	20	2	0	NS	**44**
2000	1	0	0	0	2	0	0	20	0	NS	NS	**23**
2001	0	0	0	0	8	0	0	6	0	33	NS	**47**
2002	0	0	0	0	10	0	0	5	0	NS	NS	**15**
2003	0	5	2	1	35	0	0	151	8	0	NS	**202**
2004	0	0	0	0	8	0	0	8	0	0	0	**16**
2005	0	0	0	0	0	0	0	1	0	NS	NS	**1**
2006	0	0	0	1	9	0	0	2	0	NS	NS	**12**
2007	0	8	0	0	40	0	3	4	0	NS	100	**155**
2008	0	0	0	0	6	2	0	0	0	NS	NS	**8**
2009	0	22	187	114	4	0	0	2	0	NS	NS	**329**
2010	0	0	0	0	19	2	0	NS	0	NS	NS	**21**
2011	0	575	274	203	10	0	0	10	0	NS	NS	**1,072**
2012	3	57	568	315	1	0	0	0	0	0	0	**1,817**
2013	0	2	100	1	0	0	0	0	0	NS	NS	**103**
2014	0	0	34	3	0	0	0	0	0	NS	NS	**37**
2015	0	36	235	10	0	0	0	13	0	NS	NS	**294**
2016	0 (0)	61 (260)	64 (2386)	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	NS (158)	NS (0)	**139 (2815)**

*A complete aerial count was conducted in addition to the index site count for the Goat River in 2012.

**Full ground counts conducted in addition to the index site counts in 2016. For full tributary counts, see Redfish Consulting Ltd. (2017)

In 2012, one million eggs were planted in Idaho South Arm tributaries (Table 4), with 400,000 in Boundary Creek and 300,000 each in Trout and Ball creeks. Index counts in 2016 (Table 6) resulted in 5, 5 and 41 spawners, respectively. The Long Canyon index count in 2016 found 120 fish despite no egg plants since 2008.

Table 6. Kokanee spawner index site counts in Northern Idaho streams. Data provided by Kootenai Tribe of Idaho. NS = not sampled. Blue shading indicates years and streams where returns of age 3 adults were anticipated from egg plants four years earlier (see Table 4). See Figure 1 for tributary locations.

Year	Boundary	Long Canyon	Parker	Trout	Ball	Myrtle	Smith	Combined
1980	2,000	2,000	500	100	0	0	2,000	6,600
1981	1,100	1,600	350	50	50	50	600	3,800
1982-92	No records							
1993	0	17	47	0	NS	0	NS	64
1994-95	No records							
1996	0	0	0	0	NS	0	0	0
1997	0	3	0	0	NS	NS	0	3
1998	8	0	0	0	NS	NS	0	8
1999	38	0	0	0	NS	NS	0	38
2000	17	30	7	0	NS	NS	NS	54
2001	31	25	0	7	NS	NS	NS	63
2002	0	NS	30	0	NS	NS	30	60
2003	0	40	55	0	NS	0	NS	95
2004	9	11	1	5	NS	0	NS	26
2005	0	0	3	0	NS	0	NS	3
2006	0	6	5	0	NS	0	NS	11
2007	NS	150	10	325	100	2	200	787
2008	0	0	62	535	455	9	215	1,276
2009	NS	130	70	100	NS	0	NS	375
2010	NS	125	3	6	NS	0	NS	134
2011	0	1000	6	2	100	6	NS	1,114
2012	300	350	NS	650	275	NS	0	1,575
2013	0	0	NS	25	0	NS	NS	25
2014	40	7	NS	133	0	NS	NS	180
2015	50	50	NS	20	20	NS	NS	140
2016	5	120	NS	5	41	NS	NS	171

Spawner size and fecundity

Very few morphological data are collected on Kootenay Lake spawners, with the exception of those returning to Meadow Creek spawning channel. Meadow Creek kokanee spawners are generally small, similar to most kokanee found in large oligotrophic lakes in B.C. The mean length of Meadow Creek kokanee was remarkably consistent prior to the nutrient addition period but has since increased in variability. Since 1969, Kokanee spawner fork lengths have ranged from 195–385 mm with the time series mean length of females (231 mm) slightly smaller than that of males (234 mm). In 2016, the average fork length increased to 380 mm for females and 385 mm for males. Annual average size increased from the second smallest on record in 2012 to the largest on record in 2016 (Figure 41). For complete results of the 2016 North Arm escapement, see MFLNRO (2017).

Fecundity increased with spawner size in 2016 reaching an average of 779 eggs per female (Figure 42). This is a historical high and well above the time series average (1967–2016) of 284 eggs per female. The relative fecundity was near the predicted value as demonstrated in Figure 42.

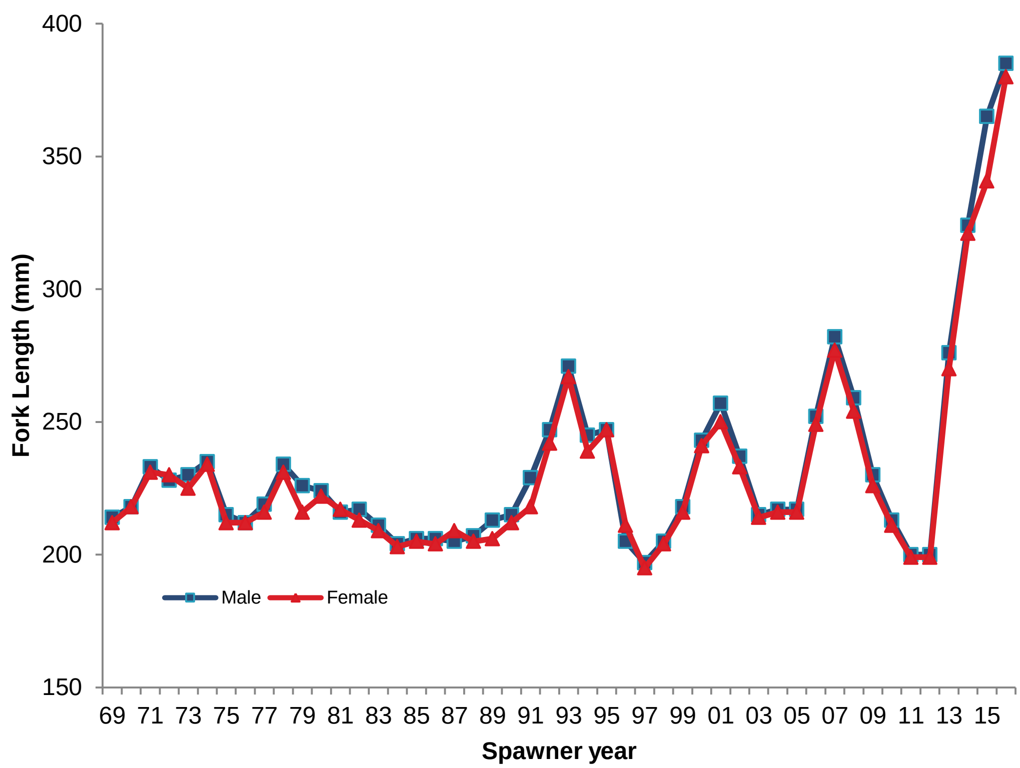


Figure 41. Mean fork length (mm) of Meadow Creek female and male kokanee, 1969–2016.

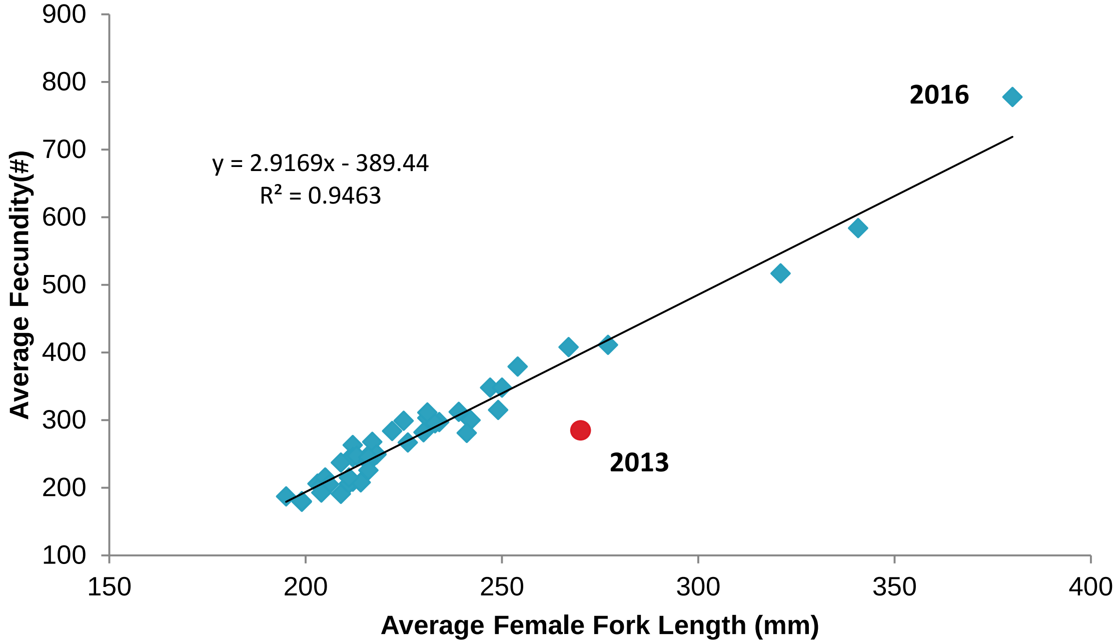


Figure 42. The relationship between annual average female fork length (mm) of kokanee spawners and average fecundity (# of eggs/female) for years 1969–2016. 2013 is considered an outlier and not included in the regression (Bassett et al. 2016).

Meadow Creek kokanee fry production

Meadow Creek spawning channel has been the largest contributor of kokanee fry to Kootenay Lake most years, and the management of this channel has had a significant influence on the kokanee population. Fry production from Meadow Creek channel in the spring of 2016 was estimated at 80,467 for naturally-spawned eggs, the lowest recorded and far below the post-fertilization average of 15.97 million (1992–2016; Figure 43; MFLNRO 2017), reflecting the low number of spawner returns and bear predation in 2015. Channel egg to fry survival could not be properly estimated due to unknown amount of predation in 2015 by bears after spawning kokanee had been counted above the Meadow Creek spawning fence. Total Meadow Creek fry production was estimated at 1,186,316 and included 605,500 hatchery raised fry released and 477,418 fry resulting from eggs planted in autumn of 2015, plus 22,931 fry attributed to natural spawning in Meadow Creek below the channel. Figure 44 illustrates the relationship between channel egg deposition and spring fry estimates for all years on record.

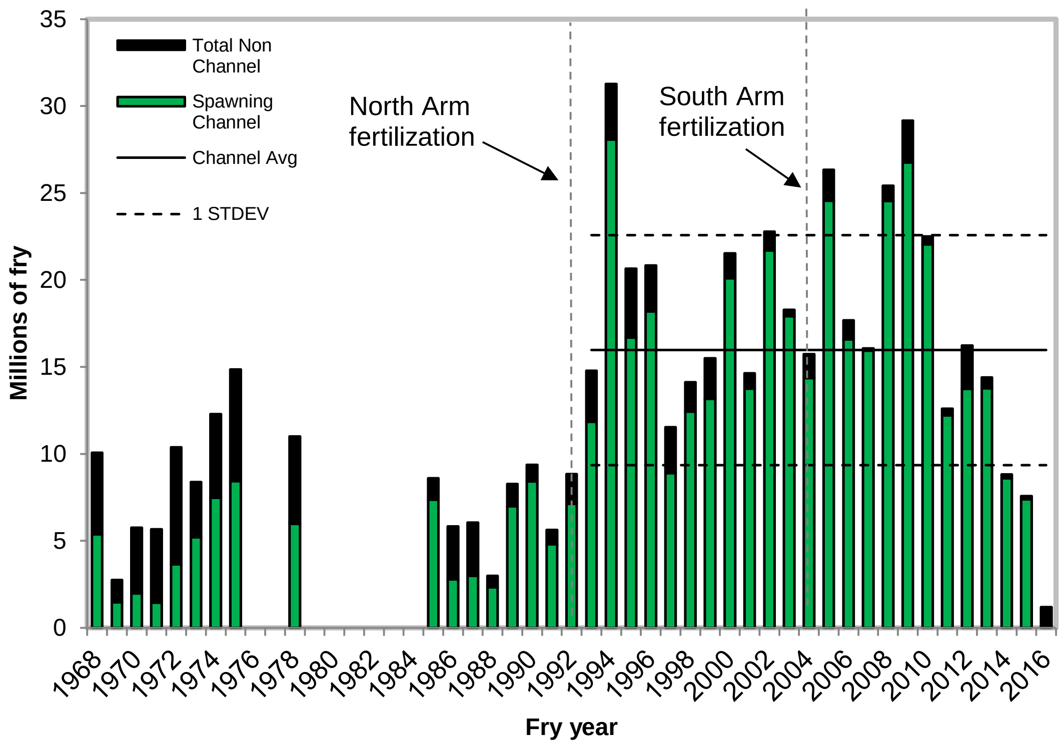


Figure 43. Meadow Creek kokanee fry production from the spawning channel and areas upstream and downstream of the channel, fry year 1968–2016. Low returns and predation by bears in the channel in 2015 resulted in lower than expected 2016 fry production. No data for years without bars.

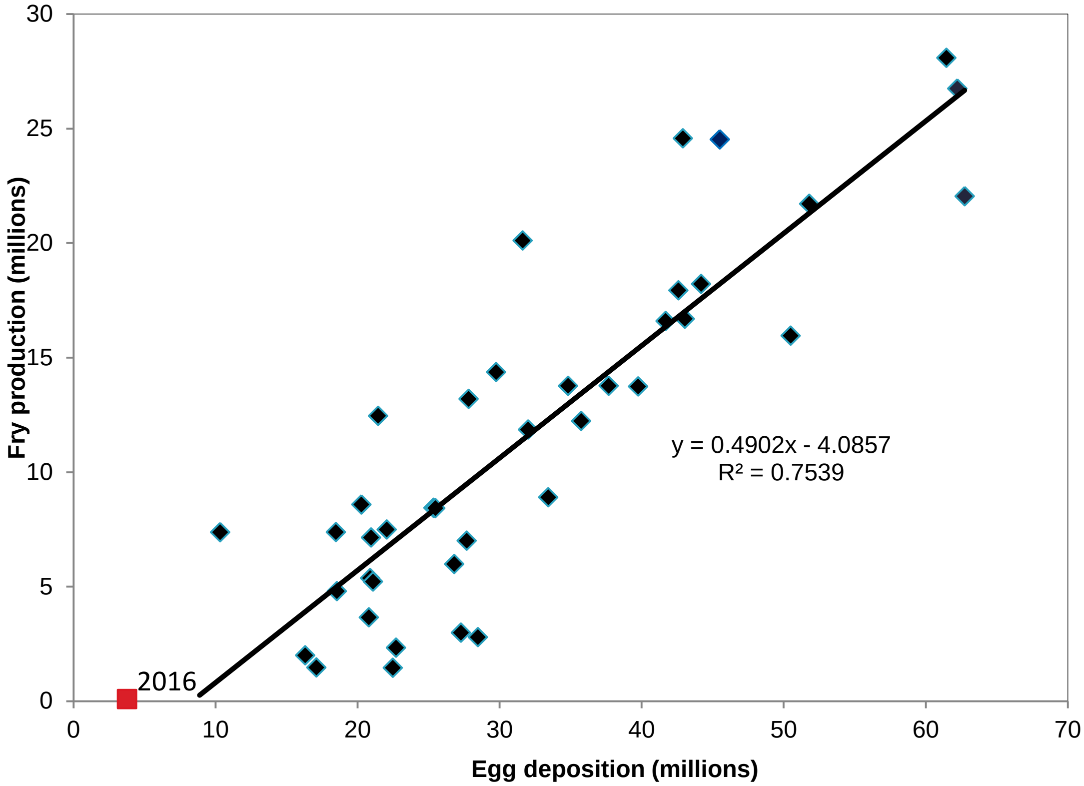


Figure 44. Meadow Creek spawning channel egg deposition versus fry production for years with available data, 1968–2015. Note: 2016 (red square) omitted from the regression due to bear predation in 2015 affecting egg deposition an unknown amount.

Hatchery Fry Releases and Eyed Egg Plants

Starting in the fall of 2015 and continued in 2016, eyed eggs were planted into Meadow Creek spawning channel in an attempt to bolster low kokanee abundance in Kootenay Lake. These efforts were undertaken to assist with Kootenay Lake kokanee recovery following the recommendations of the Kootenay Lake recovery team (Redfish Consulting Ltd. 2016), and were funded primarily through the Freshwater Fisheries Society of BC (FFSBC) and the Province of B.C. Results of Meadow Creek eyed egg plants are presented in Neufeld and Arndt (2016) and Campbell and Neufeld (2017).

In the spring of 2015, ~93,000 fry were released into Crawford Creek, while another 5,000 were released into Hendryx Creek: both tributaries to the South Arm. In the fall of 2015, 477,418 eyed-eggs were planted into the Meadow Creek spawning channel. In the spring of 2016, ~605,500 hatchery raised fry were released into Meadow Creek and ~30,000 fry were released into Crawford Creek. In the fall of 2016, 6,800,000 eyed-eggs were planted into the Meadow Creek spawning channel. Complete details on brood sources, numbers by life stage and release location are provided in Appendix 24.

Trawl Catch Data

Fall trawl survey sampling in 2016 included nine oblique trawls in the North Arm and nine trawls in the South Arm, catching a total of 173 kokanee. The South Arm catch included 29 age 0 and three age 1 kokanee. The North Arm catch included 135 age 0 and six age 1 kokanee. Two directed trawls occurred in the North Arm catching 142 age 0 and 27 age 1 (Table 6).

Table 6. Kokanee catch statistics from fall trawl surveys in 2016 (oblique and directed).

Survey time 2016	**Arm**	**Station**	**Hauls**	**Age 0**	**Age 1**	**Age 2**	**Age 3**	**Total**
Spring	*No Trawling Conducted*							
Fall	North Arm	KLF 1	3	66	2	0	0	**68**
Fall (Directed)	North Arm	KLF 1	2	142	27	0	0	**169**
Fall	North Arm	KLF 2	3	47	4	0	0	**51**
Fall	North Arm	KLF 4	3	22	0	0	0	**22**
Fall	South Arm	KLF 5	3	8	0	0	0	**8**
Fall	South Arm	KLF 6	3	14	1	0	0	**15**
Fall	South Arm	KLF 7	3	7	2	0	0	**9**
Fall	**North Arm**	**total**	**9**	**277**	**33**	**0**	**0**	**310**
Fall	**South Arm**	**total**	**9**	**29**	**3**	**0**	**0**	**32**
Fall 2016 TOTALS			***18***	***306***	***36***	***0***	***0***	***342***
				90%	*10%*	*0%*	*0%*	***100%***

Length-at-age

The trawl sampling in the fall of 2016 captured only age 0 and age 1 kokanee, with each age class falling under single modes peaking at 70 and 130 mm bins, respectively (Figure 45). The fork lengths of kokanee caught in the directed trawling were pooled with the standard oblique trawl data to increase sample sizes; when compared separately the average lengths do not significantly differ (data not shown). One notable difference between the oblique and directed trawl catch is the range in age 1 fish fork lengths, mainly driven by a single large kokanee at 188 mm that was captured in the directed trawling. As reported earlier, spawners measured at Meadow Creek spawning channel were exceptionally large and fell under a single mode ranging from the 310 mm bin to the 420 mm bin.

The long term time-series for mean length at age from trawl-caught kokanee (both oblique and direct trawling) and spawners measured at the spawning grounds is illustrated in Figure 46 and age class specific length statistics from the 2016 trawl are presented in Table 7. Age 0 mean length was near the nutrient addition program average of 57 mm from 2012 to 2014 before increasing to the largest on record at 62 mm in 2015 and then to a new record again at 65 mm in 2016. Age 1 mean length was among the smallest on record in 2013 and 2014 before increasing to 120 mm in 2015 and again to 127 mm in 2016, which was near the nutrient addition program average of 131 mm. Age 1 mean length at age may be an unreliable metric of in-lake conditions, as there are often two size modes of age 1 fish and trawl bias may result in variable representation of either mode on any given year. No age 2 kokanee were captured in 2016 in either the oblique or directed trawl sampling.

Table 7. Size statistics (fork length corrected to Oct 1 standard, see Appendix 9) from trawl-captured kokanee during September survey in 2016 (no trawling occurred in early season 2016).

Basin	Station	age 0	age 1	age 2	age 3
North Arm	Avg. length (mm)	65	128	-	-
	Length range (mm)	43-94	98-188	-	-
	Standard deviation (mm)	7.1	15.4	-	-
	Sample size (n)	277	33	-	-
South Arm	Avg. length (mm)	67	118	-	-
	Length range (mm)	60-77	113-123	-	-
	Standard deviation (mm)	4.1	5.3	-	-
	Sample size (n)	29	3	-	-
Both Arms - pooled avg. length (mm)		***65***	***127***		

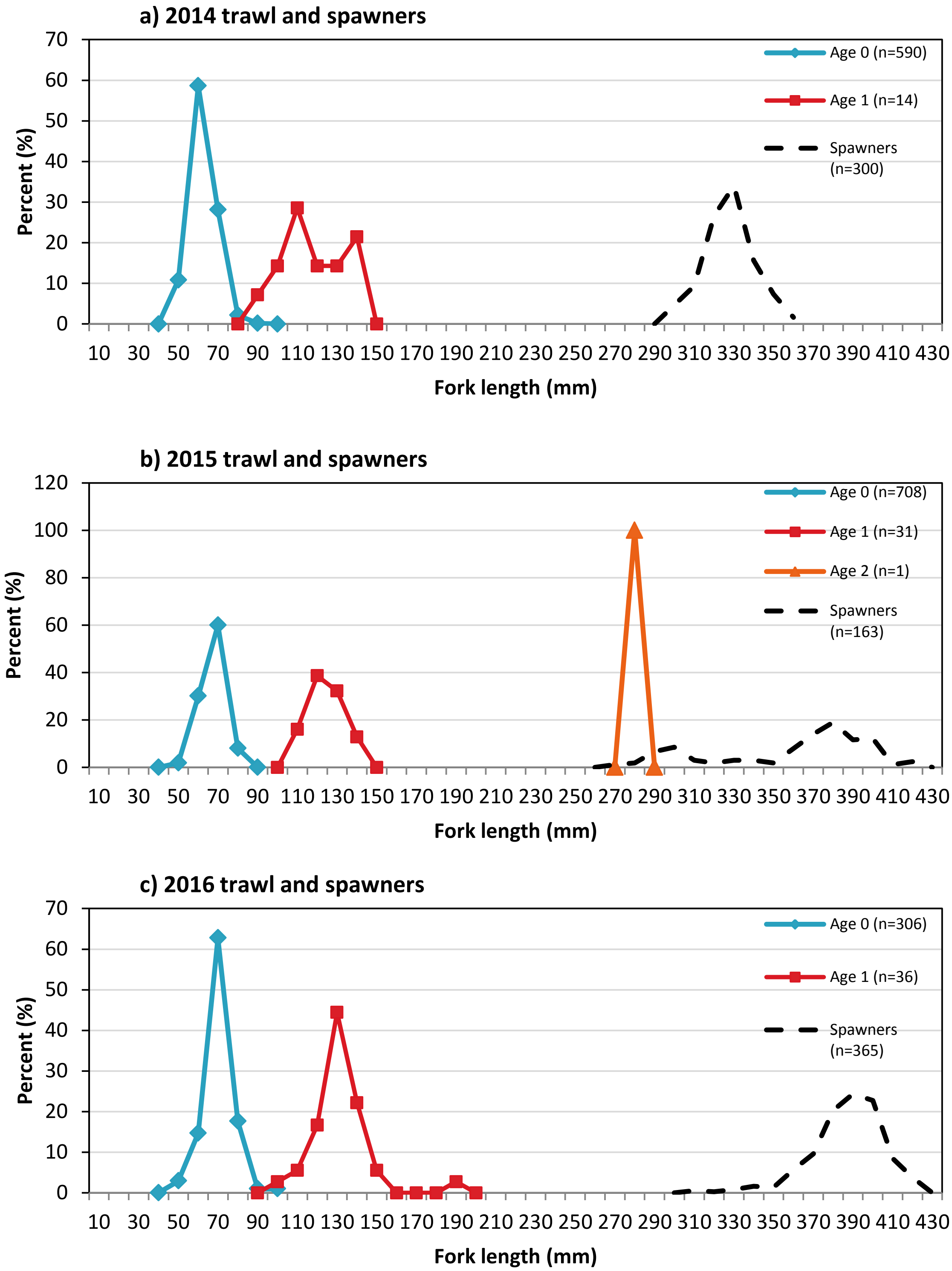


Figure 45. Kokanee length-frequency distribution by age from fall trawling in a) 2014 b) 2015 and c) 2016 and including spawner data from Meadow Creek.

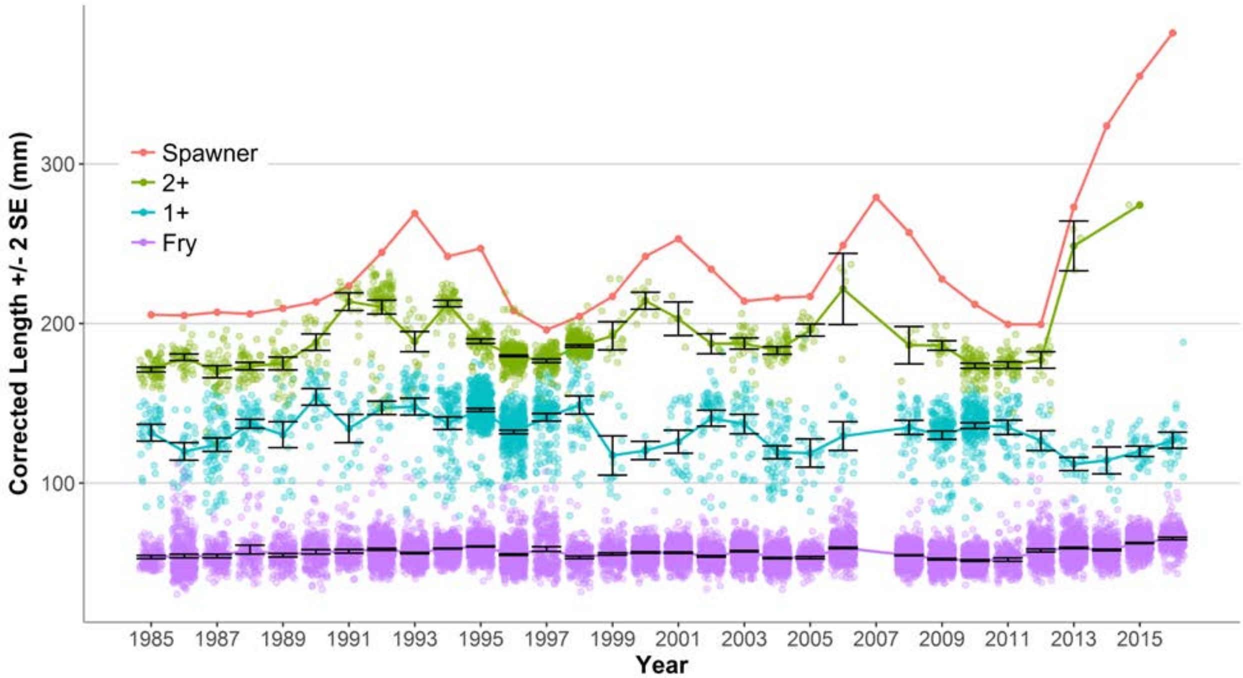


Figure 46. Trends in mean length-at-age for trawl-captured kokanee in Kootenay Lake, 1985–2016. Age 0 (fry), 1 and 2 kokanee lengths are corrected to Oct 1st growth date (Appendix 9). Length data for spawners were obtained from Meadow Creek kokanee. No trawling occurred in 2007. Error bars indicate 2 standard errors. Note that confidence intervals for spawners were not available at the time of writing, however sample sizes were large for all years (e.g. >100/yr).

Age-at-maturity

Kootenay Lake kokanee have undergone a dramatic increase in growth from 2013 to 2016 while age at maturity has ranged from age 2 to age 5 (Figure 47). In 2016, 86% of spawning kokanee were age 3, 12% were age 4, and 2% returned at age 2.

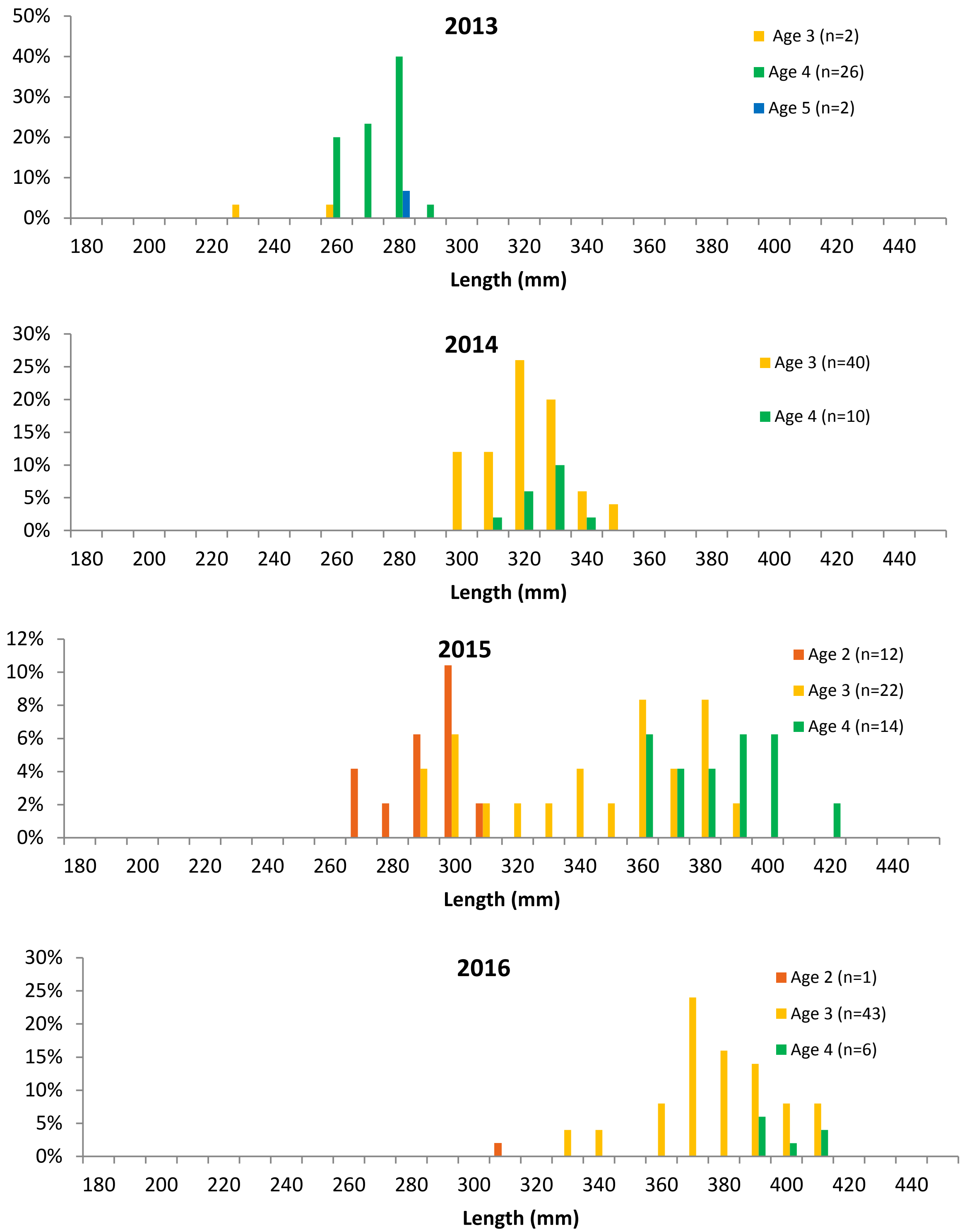


Figure 47. Percent length frequency of kokanee spawners by age returning to Meadow Creek from 2013–2016. Note: y-axis is different for each year.

Hydroacoustic abundance estimates and trends

Hydroacoustic and trawl surveys of the limnetic zone have been conducted using standard methods since 1991, and comparable manual echo counts date back to 1985. These hydroacoustic and trawl survey data provide evidence of the positive impact of nutrient addition on the kokanee population in Kootenay Lake. In the late 1980s and early 1990s, prior to lake fertilization, fall surveys indicated 6–13 million kokanee in the lake (Figure 48). By 1994, two years after the start of lake fertilization, the population reached 35 million kokanee. This increase was mainly due to the rapid growth response to more favourable in-lake conditions at the onset of fertilization, which resulted in a peak of both fecundity and total egg deposition at Meadow Creek in 1993 (Appendix 23). The total population fluctuated below that peak until 2009 but remained larger than in the pre-fertilization period. In 2009 and 2010, the population was the largest since fertilization began (2009= 47.1 million, 2010= 37.8 million) as a result of strong escapements from 2007 to 2009. Hydroacoustic abundance estimates of kokanee decreased substantially after 2010 then stabilized and have been statistically unchanged during the 2012–2015 period, ranging between ~15–18 million. The total kokanee abundance in 2016 declined to the lowest level since nutrient additions began, and was estimated at only 8.1 (95% confidence intervals: 7.0–9.2) million.

The Kootenay Lake fry population fluctuated between ~13 to 17 million from 2011 to 2015, near the post fertilization average of approximately 16.3 million. In 2016, the fry population dropped to the lowest abundance during post fertilization at 7.37 million (6.25–8.48 million).

Prior to 2009, the post fertilization average fall abundance of ages 1–3 was 6.2 million, with a peak of 11.6 million in 1996 (Figure 49). The 2009 estimate of 15.9 million age 1–3 population was 37% higher than the 1996 peak abundance. Remarkably, the 2010 age 1–3 population estimate was similarly high at 15.4 million. The dramatic increase in age 1–3 abundance in 2009 and 2010 suggests excellent survival among all ages during this period, but in particular from 2008 fry to 2009 age 1. From 2011-2013 the age 1–3 population decreased from 7.6 million to 1.1 million, the latter being the lowest age 1–3 population on record. This rapid decline signaled a sharp reversal in survival; in particular for fry to age 1, given that the age 0 populations remained relatively high. The age 1–3 population estimates for 2014 and 2015 remained stable at 1.1 and 1.2 million, respectively. In 2016 the age 1–3 abundance estimate dropped further to 0.74 million (0.61–0.83 million). Complete fall kokanee density, abundance and biomass statistics for 2016 are provided in Appendices 25, 26a, and 26b, and 27.

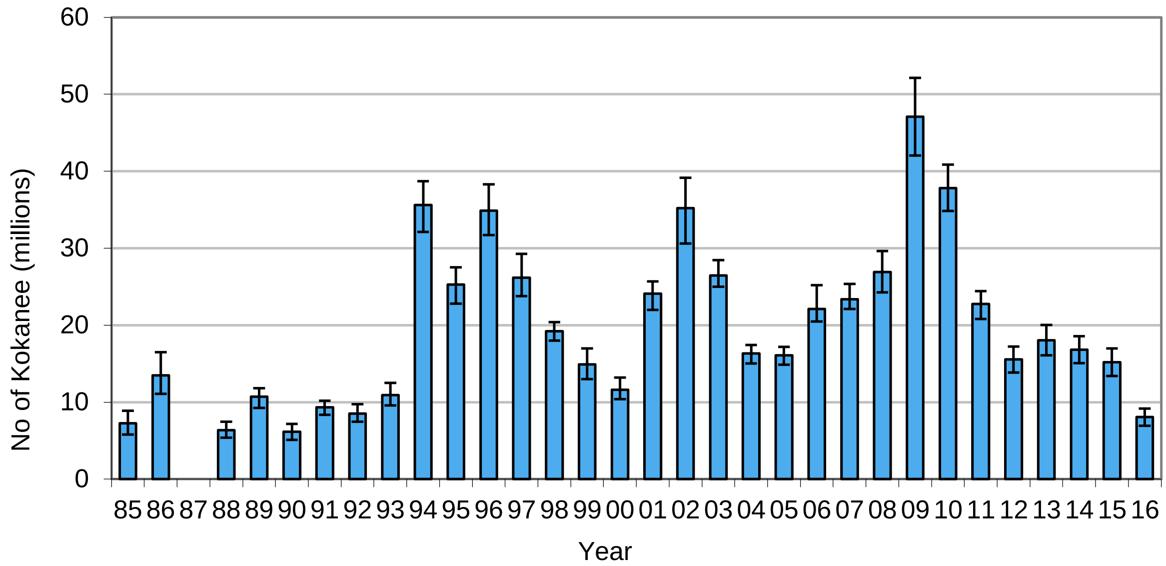


Figure 48. Kootenay Lake kokanee abundance (all ages) based on fall hydroacoustic surveys with 95% confidence intervals.

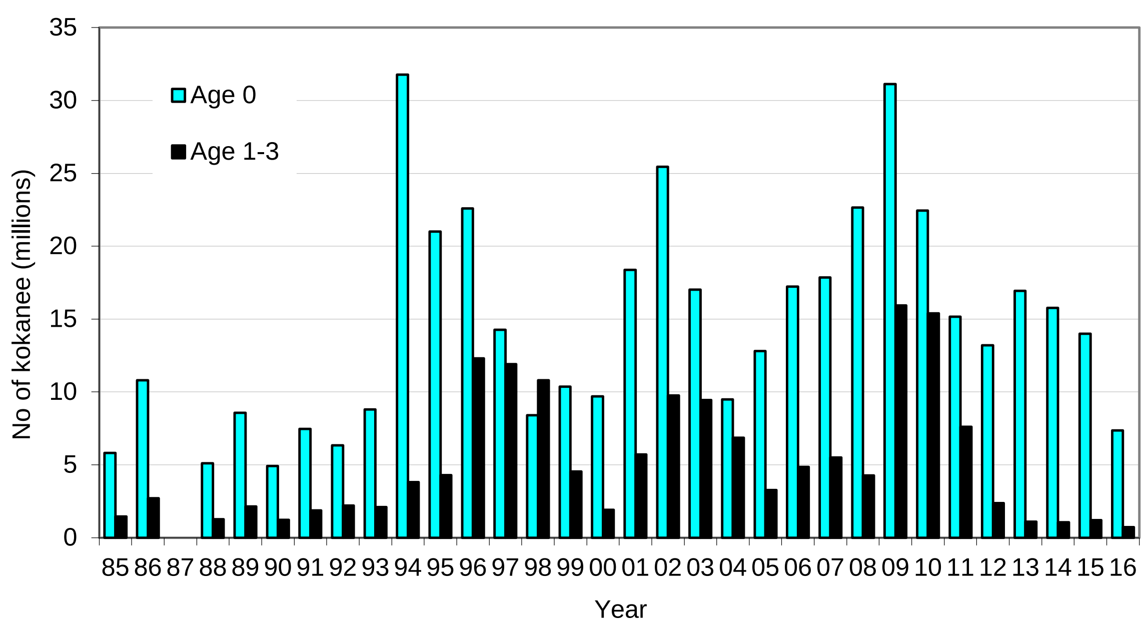


Figure 49. Kootenay Lake age 0 and ages 1–3 kokanee abundances based on fall hydroacoustic surveys.

South Arm fry population

The late spring/early summer hydroacoustic surveys were initiated primarily to estimate fry abundance originating from South Arm spawning streams prior to the fry mixing with North Arm fish. Over the last thirteen years, early season South Arm fry estimates have ranged from 1.3 million in 2014 to 6.5 million in 2011 (Table 8) with 2009–2011 being far higher than previous years, similar to the trend of increased lake-wide abundance during those years. Abundance of South Arm fry in 2016 was low at 1.63 million. Confidence intervals on the South Arm estimates are relatively large some years, particularly in 2004, due to low densities, patchy distribution, and few acoustic survey transects (n=8) in the South Arm.

Table 8. Early summer acoustic fry estimates for the South Arm of Kootenay Lake during the South Arm nutrient addition period, 2004–2016.

Year	Survey dates	Fry MLE[1] (95% CI) (millions)
2004	June 13–16	3.85 (0.76–6.75)
2005	July 8–10	1.41 (0.90–1.95)
2006	June 26–28	2.39 (0.67–3.98)
2007	July 4–7	3.12 (1.61–4.49)
2008	July 5–6	2.37 (0.84–3.92)
2009	June 26–28	6.4 (4.89–8.08)
2010	July 12–15	5.42 (4.45–6.74)
2011	July 5–8	6.49 (5.48–7.49)
2012	July 17–20	3.11 (2.53–3.68)
2013	July 6–8	2.58 (1.99–3.19)
2014	June 24–26	1.26 (1.00–1.52)
2015	June 18–22	3.87 (2.58–5.18)
2016	June 28–30	1.63 (1.06–2.20)

[1]MLE = maximum likelihood estimate

In-lake distribution

Comparisons of the two hydroacoustic surveys conducted each year illustrate the seasonal distribution of kokanee fry across the lake. In early summer, fry have typically been highly skewed to the north end of the lake, since most kokanee production is from Meadow Creek and the Lardeau River. By the end of summer, the fry tend to disperse more evenly throughout the lake, as illustrated by comparing July and September fry distributions for all years except 2005 (Schindler et al. 2013). The 2013, 2014 and 2015 fry distributions followed the familiar pattern of southward movement over the summer, although September fry densities remained higher overall in the North Arm in comparison to the South Arm in 2013 and 2014. In 2016 the June and September fry density distributions looked relatively similar, and the early season densities were less skewed towards the north end than in other years (Figure 50).

Unlike fry, age 1–3 distributions are not expected to be affected by proximity to spawning areas in early season sampling, nor in late season sampling which occurs after mature fish have left the lake to spawn. In June of 2016 there were relatively higher densities of adult kokanee mid-lake and, to a lesser extent, in the North Arm. The September 2016 age 1–3 densities were slightly higher at the north end of the lake (~ transects 1-5) then relatively even throughout the rest of the lake.

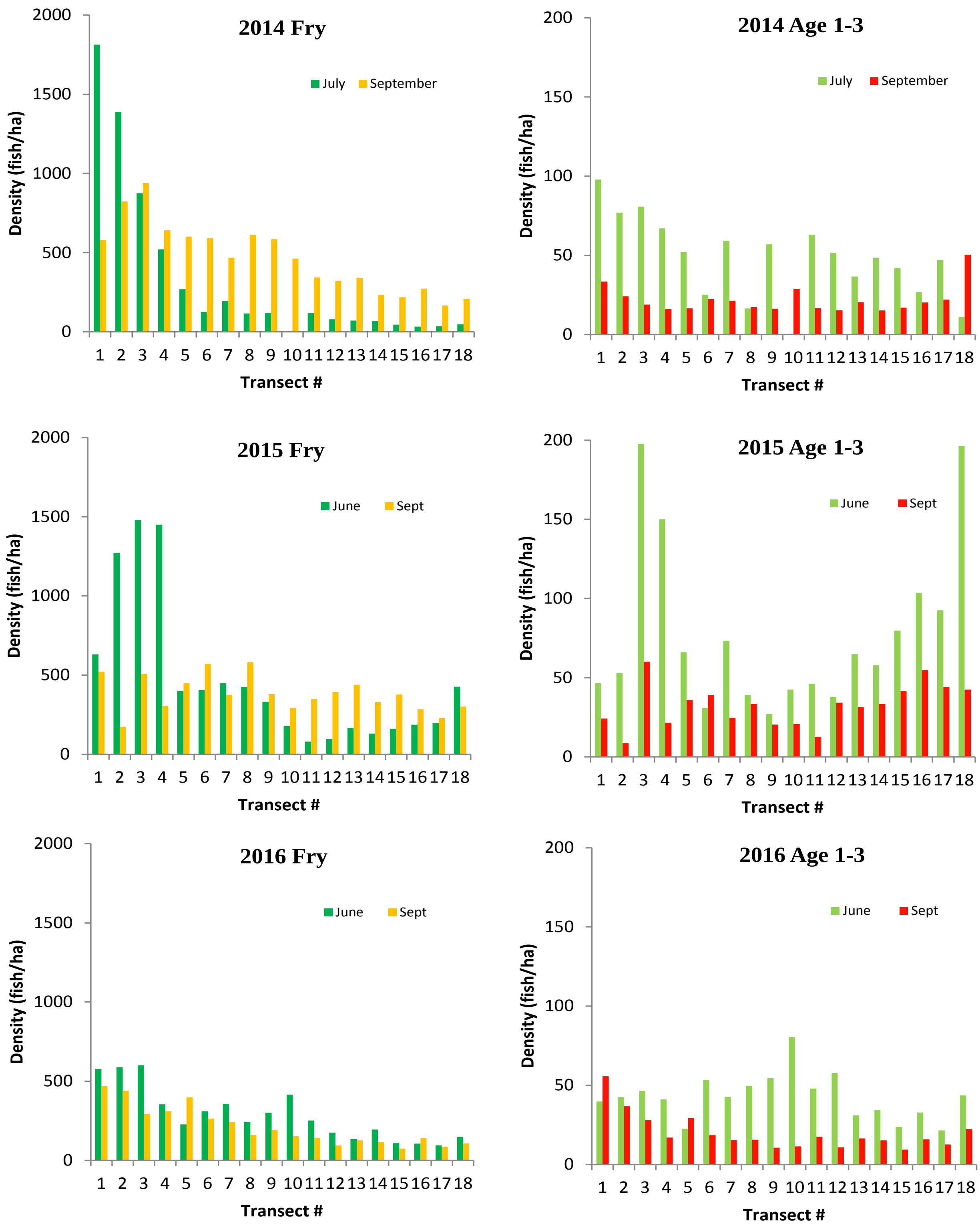


Figure 50. Density distributions for age 0 and ages 1–3 kokanee in Kootenay Lake during early season and late season 2014–2016. Note: Transects are in order from North to South with #1–10 representing the North Arm and #11–18 representing the South Arm. See Figure 2 for a map of transect locations.

Kokanee biomass estimates

The in-lake kokanee biomass in Kootenay Lake was estimated using mean weights and abundances of all age groups determined from trawl and hydroacoustic surveys (see Appendix 27a and b for details). Prior to nutrient additions to the North Arm (1985–1991), the average kokanee biomass in Kootenay Lake was 3.4 kg/ha (not including spawners). With nutrient additions (1992–2016), the biomass of in-lake kokanee has more than doubled from the pre-addition to an average of 7.2 kg/ha (Figure. 51; Appendix 27b). The in-lake biomass estimated for 2016 was the lowest on record at 0.9 kg/ha.

Spawner biomass was calculated by applying average weights from fish in Meadow Creek spawning channel to the combined escapement estimate from Meadow Creek and Lardeau River. While spawner size increased from 2013–2015, abundance generally decreased, driving biomass lower. A slight increase in spawner abundance in 2016, concurrent with an increase in size, resulted in an increase of biomass from a historical low of 0.3 kg/ha in 2015 to the second lowest post-nutrient addition at 0.7 kg/ha in 2016 (Appendix 27c).

As fall acoustic surveys occur when spawners have left the lake, the in-lake and spawner biomass estimates were summed to estimate the total kokanee biomass in Kootenay Lake. The total biomass was 1.8 kg/ha in 2015, only 17% of the post-fertilization average of 10.4 kg/ha. Total biomass decreased further to a historical low of 1.6 kg/ha in 2016. Although spawner biomass increased slightly from 2015 to 2016, the decrease in in-lake biomass resulted in a decrease in total biomass in 2016 (Figure 51).

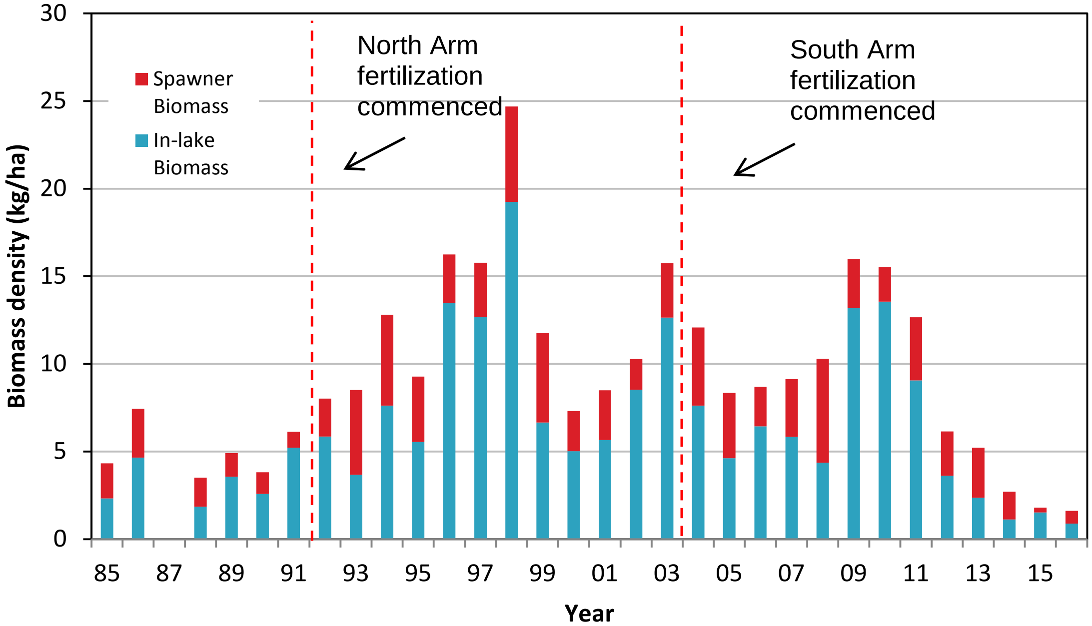


Figure 51. Trends in biomass density (kg/ha) for Kootenay Lake based on acoustic, trawl and spawner surveys, 1985–2016. The dotted lines indicate the start of nutrient additions to the North Arm in 1992 and South Arm in 2004. Note: No trawling occurred in 2007 and in-lake biomass is estimated based on the average of 2006 and 2008 weights and age structure.

Meadow Creek Spring Fry to Adult Survival

Survival from emigrant fry to spawner in Meadow Creek has been estimated by fry cohort and is presented in Figure 52. The fry to spawner survival rate has been historically low since the 2010 cohort survived to spawn at a rate below 1%. This trend continued with another year of spawner data in 2016 informing the survival rate of the majority of the 2013 fry cohort; only $1/10^{th}$ of a percent of the 2013 fry cohort survived to spawn as age 2 in 2015 or age 3 in 2016. The post fertilization average of fry to adult survival is 3.4%.

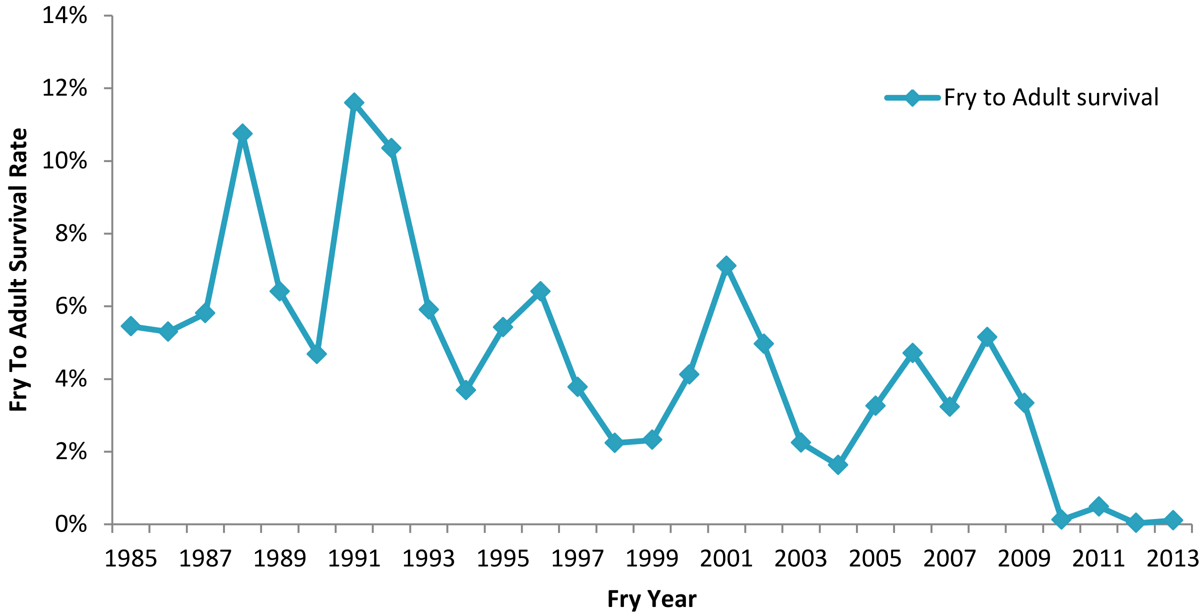


Figure 52. Meadow Creek Kokanee fry to adult survival rate (fry year on x-axis). Age of maturity derived from otolith age proportions. The 2013 fry year estimate only includes age 2 (2015) and 3 (2016) spawner returns for that cohort and may increase marginally if any age 4 spawners return in 2017.

North Arm Egg to Fall Fry Survival

The Meadow Creek spawning channel (MCSC) provides spring (emigrant) fry estimates which allow for survival estimates to be determined for egg-to-spring fry, detailed above under the Meadow Creek fry production section. Previously, Bassett *et al.* (2016) also reported on the relationship between MCSC fry production and acoustic fall fry estimates. This relationship demonstrated the importance of the MCSC for total fry production in Kootenay Lake, and provided insight into survival to fall fry (represented by the fall acoustic age 0 estimates). However, in recent years the decline in kokanee abundance has placed increased importance on Lardeau spawners to overall kokanee production. Lardeau spawner numbers (reflected by the peak count trend, not expanded by residence time) surpassed Meadow Creek escapement annually beginning in 2013 (Figures 39 and 40), which has not occurred since the early 1980s. As such, evaluating survival to fall fry is not possible without including Lardeau River, which appears to have been as, or more important, to overall kokanee production than Meadow Creek. Although the Lardeau data are typically single peak count estimates, these data have been collected in a relatively consistent manner since the mid-1960s, and as an index of abundance still allows for further insight into survival trends.

Figure 53 illustrates the egg to fall fry survival index trend for Kootenay Lake, converted to standard scores in order to illustrate deviation from the time-series mean. After the recent low point in 2012 at 0.5 standard deviations below the series mean (zero), survival to fall fry increased to new record highs each successive year in 2014, 2015, and 2016. The 2016 value is 4.6 standard deviations from the series mean, and the degree to which it deviates from the remainder of the time series suggests that one or more of the estimates used to generate the index value are questionable. Regardless, the primary intent of presenting these data was to illustrate that survival to fall fry has been good or excellent since 2013 in Kootenay Lake.

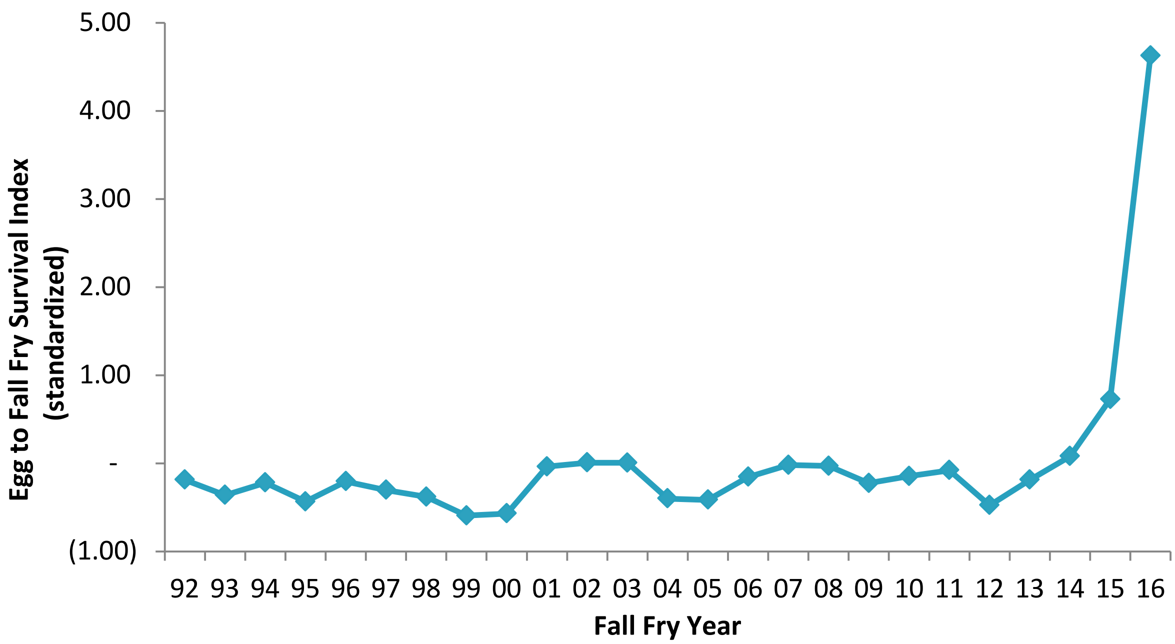


Figure 53. Standardized egg-to-fall fry survival index trend for Kootenay Lake kokanee during the post-fertilization era. Each data point represents deviation from the long-term mean, which is set to zero.

Fall Fry to age 1 survival

Figure 54 illustrates the survival trend from fall age 0 to the following fall at age 1 since 2000; data prior to 2001 were collected using a slightly different trawl net so may not be directly comparable and have been omitted. In contrast to the egg to fall fry survival illustrated in Figure 53, age 0–1 survival has declined dramatically in recent years, remaining between 5 and 8% from 2012 to 2016. This sharp decline follows variable but relatively higher survival from 2001–2011 with estimates ranging from 18–63%. Five consecutive years of very low survival clearly indicates a significant bottleneck occurring between fall age 0 and fall age 1.

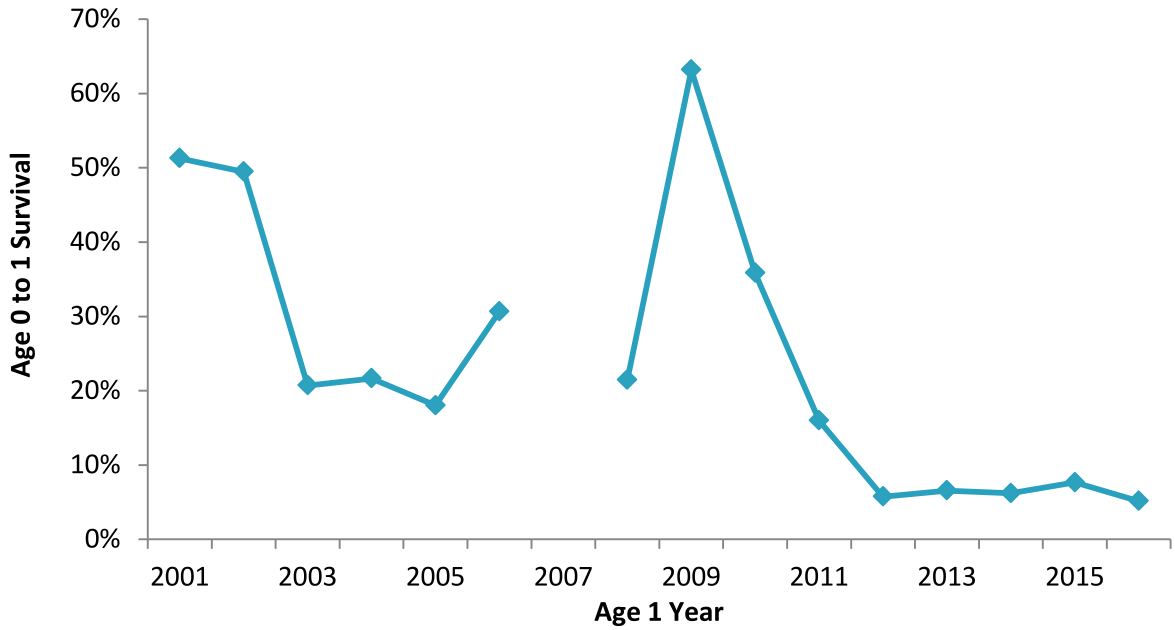


Figure 54. Trends in fall fry to following fall age 1 relative survival rates for Kootenay Lake from 2001 to 2016 derived from acoustic and trawl based age 0 and age 1 estimates. No trawling occurred in 2007.

Piscivores

Gerrard Rainbow Trout

The Gerrard rainbow trout spawner AUC abundance time series, a key index of predator abundance, was relatively stable from the 1960s until 2008, ranging between ~300 and 800 spawners (Figure 55). Beginning in 2009, Gerrard spawners increased dramatically to a peak of 1532 in 2012. Spawner numbers then plunged steeply, declining to 932 spawners in 2014 and to 301 spawners in 2015. The trend continued in 2016 with just 163 spawners returning to the Lardeau River, the lowest on record since 1961 (Gerrard spawner counts reported in Andrusak 2017).

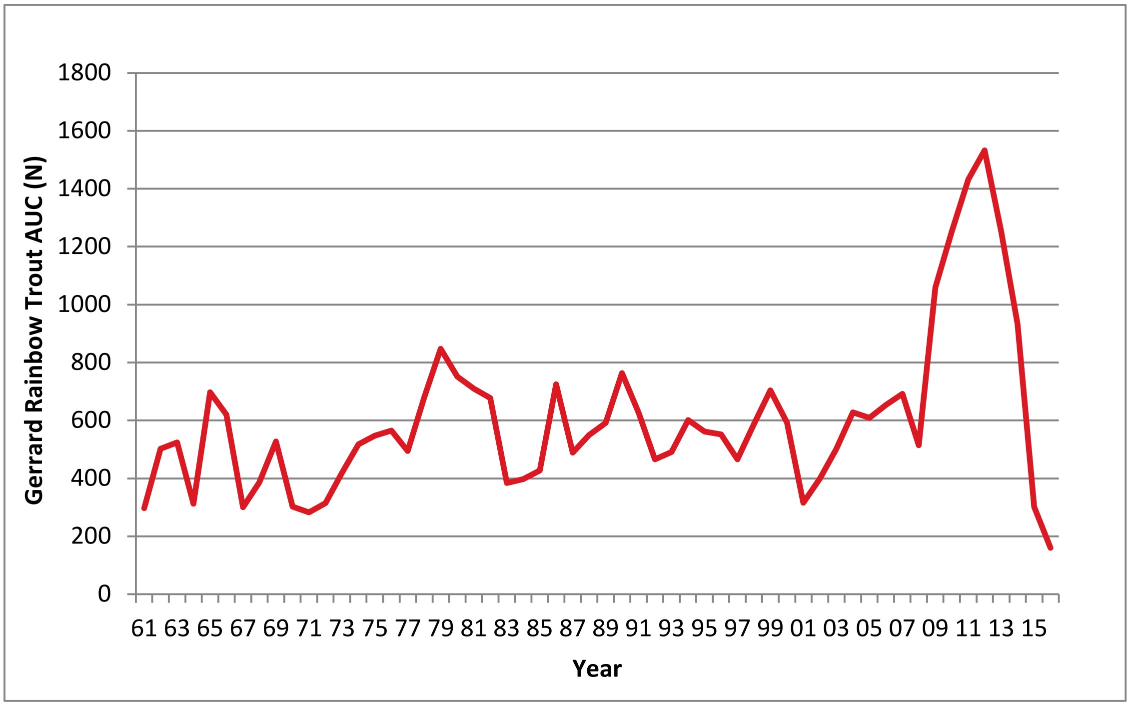


Figure 55. Trends in Gerrard rainbow trout peak spawner estimate during 1961–2016. Data courtesy of MFLNRO (Nelson).

DISCUSSION

Trends in lake conditions

The 2016 climate showed overall higher air and surface water temperatures, and elevated early and late season precipitation. Nutrients were delivered with the intent of restoring pre-dam nutrient concentrations in the lake, with the exception of one week in the North Arm and two weeks in the South Arm which were reduced or canceled due to a high number of low edibility phytoplankton observed in the epilimnion. Nutrient loads are reduced when the effectiveness of the additions would appear to be low, or if there is a risk of an algal bloom that would impact other users of the lake. For the past five years we have seen increased levels of dissolved inorganic nitrogen (DIN), resulting in a higher dissolved nitrogen to phosphorus ratio in the North and South Arms of the lake in 2016. This elevated level of DIN has also been observed by a neighbouring program in the Kootenai River (Ward et al. 2017, IKERT 2018). Dissolved phosphorus, or the type of phosphorus that is most biologically available, averaged at or just above detection level (RDL=2 µg/L) in all Arms of the lake, indicating that this was a limiting nutrient for biological growth in 2016 (Ashley and Stockner 2003). These N:P ratios indicate that nitrogen was not limiting in the North, South or West Arms in 2016 (Ashley and Stockner 2003).

Zooplankton and *Mysis diluviana*

Large individuals of *Daphnia* have dominated the zooplankton biomass in Kootenay Lake during the last few years (2013-2016), most likely as a consequence of a drastic fish stock reduction and decreased grazing pressure. In water bodies with a high number of planktivorous fish, predation pressure is high and large zooplankton – especially *Daphnia* as a favourite fish food – are consumed and removed from the zooplankton community, leaving a higher remaining proportion of smaller zooplankton. Reduction of planktivorous fish stocks may cause a shift from high density of small zooplankton species to the domination of large *Daphnia* individuals that would otherwise be eaten. The larger individual sizes may also be due to individuals growing larger as they survive longer into the season. This would reflect the significant biomass increase, given the less dramatic increase in zooplankton density. Despite this increase in zooplankton biomass over the last several years, the density and biomass of *Mysis diluviana* have not shown any concurrent changes.

Kokanee

In the late 2000s, peaks in both spawner size (2006–2008) and abundance of kokanee (2008–2010) occurred due to a combination of favourable survival and growth conditions, likely enhanced by the onset of South Arm fertilization at a time when abundance of kokanee was low in 2004. This peak in kokanee abundance coincided with three years of Meadow Creek channel fry production in excess of 20 million, which sustained exceptional survival rates to older age classes in the 2008 and 2009 fry years. Coinciding with this period, the Gerrard rainbow trout numbers were building, yet kokanee survival was excellent from fry to older age classes. This led to two consecutive years (2009 and 2010) of the highest age 1–3 population sizes ever recorded (>15 million vs. previous peaks of 10–12 million). Through this period, a density dependent growth response resulted in kokanee size declining rapidly; age 2 and spawner size declined to among the smallest on record during 2010–2012. The extent to which size declined, and the shift in age at maturity to predominantly age 4 in 2013, is unprecedented in the time series and is a sign that in-lake carrying capacity may have been exceeded at some point in the life cycle of the 2009 cohort.

Following the peak in lake biomass and abundance in 2009/2010, kokanee survival decreased and the population began to decline sharply, as has been the case after each previous peak in abundance in the time-series. This decline coincided with back to back years with abnormally cold spring seasons in 2011 and 2012 (Figure 7). In 2011, seasonal spring air temperature was the lowest since the onset of fertilization in 1992. The cold spring may have contributed to the low *Daphnia* biomass in 2011, as there is compelling evidence that bottom-up processes driven by regional weather patterns limited *Daphnia* production that year based on the same trends occurring at nearby Arrow Lakes and Kinbasket and Revelstoke Reservoirs (Bassett et. al, 2015; Bray, 2017)

In 2012, spring air temperatures were again well below average and among the coldest since nutrient additions began (Figure 7). The spring of 2012 was also exceptionally wet (Figure 8):

June precipitation was the highest over the 1992–2016 time period (Figure 8). Zooplankton biomass, as well as kokanee biomass and survival, declined severely in nearby Arrow Lakes Reservoir during this time also (Bassett et al. 2018). Dramatic declines in kokanee abundance were observed in Kinbasket and Revelstoke reservoirs in 2011 and 2012 (Sebastian and Weir 2013) and Okanagan Lake spawner returns and in-lake abundance/biomass declined in 2012 (MFLNRO data on file). These systems are all different from each other and from Kootenay Lake in many ways (e.g. predator community, mysid presence, hydrology, etc.), which suggests that perhaps regional climatic drivers were unfavourable to kokanee production/survival in 2011 and 2012.

From 2013 to 2015 the kokanee fry abundance remained near average at around 15 million but decreased to 7 million in 2016. Although part of this decrease can be attributed to bear predation in Meadow Creek spawning channel in 2015, decreasing spawner numbers are the primary factor despite increased fecundity and contributions by egg plants and fry releases.

Survival to fall fry has been excellent since 2013, although the 2016 data point in Figure 53 suggests a potential issue with one or more data components that year. It is possible that the 2015 count of Lardeau spawners may have missed the peak, or that the peak count estimates may be disproportionately underestimated at very low spawner densities. As there were three flights conducted to enumerate kokanee spawners in Lardeau River in 2015, and no indication of poor viewing conditions, it is unlikely the peak was missed or poor conditions affected the estimate. If the spawner estimates were not dramatically underestimated in 2015, the issue could be related to the fall fry estimate for 2016. Entrainment from Libby dam during 2016 could have contributed significant numbers of fry to the fall acoustic estimate, or the acoustic fry estimate could be biased disproportionally high at the relatively low densities encountered in the fall of 2016. Regardless of potential sources of error in spawner or fall fry estimates, the survival trend presented in Figure 53 illustrates that poor kokanee survival was not apparent prior to the fall fry stage.

The age 1–3 population remained very low in 2016, indicating the bottleneck in survival beyond the fall fry stage that has been evident since 2012 persisted in 2016. Spawner numbers increased slightly over 2015 as did the size of age 2 and older kokanee, including spawners; however these gains were not enough to offset the decreased abundance and therefore overall kokanee biomass declined even further. The failure of kokanee survival to improve beyond the fall fry stage regardless of low densities and abundant zooplankton resources is unprecedented.

The increased escapement and fecundity of spawners in 2016 (compared to 2015) resulted in increased egg deposition in Meadow Creek and presumably also in Lardeau River relative to 2015, although relative to the long-term dataset egg deposition was still minimal. Combined with a large contribution of eyed eggs planted in Meadow Creek in the fall of 2016, the 2017 fry abundance is expected to increase over 2016.

In recent years the Lardeau River has become just as or more important to overall kokanee production as Meadow Creek. This shows a shift from approximately three decades of significantly higher escapements to the Meadow Creek system. Assuming the Lardeau index of abundance is precise enough to allow for this type of trend comparison, this transition suggests that differential survival at one or more life stages must have occurred for Lardeau spawner abundance to consistently surpass Meadow Creek escapement in recent years. Given that the spawning channel habitat is enhanced to maximize survival from egg to emergent fry, it is assumed that the un-enhanced wild habitat in Lardeau River would result in much lower survival at this key survival stage. Remarkably, this assumption may be incorrect, or alternatively the Lardeau kokanee may be experiencing higher survival after the emergent fry stage than the Meadow Creek kokanee. This notable development should be further investigated going forward, as these data may provide important insight into the implications of long term spawning channel production.

Early season kokanee abundance estimates in the South Arm are higher than would be expected (or possible) based on production solely from the egg plants. Assuming the index counts reflect abundance to some degree for South Arm tributary counts, the acoustic estimates are not biased high, and the North Arm fry have not yet dispersed into the South Arm, there must be another significant source of fry production in the South Arm. Full length surveys of South Arm tributaries in 2016 indicated that index counts highly underestimate escapement, and it is possible that these streams are a source of substantial numbers of fry in the South Arm population. Regardless, it remains unlikely that production from these tributaries fully accounts for the relatively high South Arm fry estimates unless egg to fry survival is extremely high or the actual numbers of spawners are higher than observed in 2016. As there is no evidence of shoal spawners in the main body of Kootenay Lake, one potentially large source of fry in the South Arm is entrained fry through Libby Dam. Investigations by Skaar *et al.* (1996) into entrainment rates at Libby Dam in the early 1990s found 97.5% of entrained fish were kokanee, with age 0 being the large majority of these. The estimate of entrained fish from January 1992 to January 1993 was ~4.5 million fish. Spring season estimates were also produced for the May–June periods in 1993 and 1994, which are perhaps more relevant to understanding the early season fry population in the South Arm of Kootenay Lake. These spring entrainment estimates were ~1.1 million and ~0.5 million in 1993 and 1994, respectively. Although the numbers that were entrained and survived to rear in Kootenay Lake each year since 2004 are unknown, it is apparent that entrained fish from Libby Dam could be a significant component of the South Arm population estimate.

While kokanee in Meadow Creek typically mature at age 3, as is common in many large-lake kokanee populations in B.C., there have been shifts in age at maturity over the years. These shifts in kokanee age at maturity generally corresponded with changes in size at age, which is consistent with the hypothesis that changes in growth rates can induce a shift in age at maturity (Grover 2005, Leifasbjorn et al. 2004). Patterson et al. (2008) suggest sexual maturation in kokanee begins from 10–16 months prior to spawning and that attaining a size threshold of 180–190 mm during fall was a good predictor of maturation the following year. Given the conditions for excellent growth in Kootenay Lake in recent years (low densities of older age class kokanee and the exceptional zooplankton resources), rapid growth should have occurred resulting in kokanee reaching a large enough size by the fall at age 1 to trigger maturation and spawn at age 2. As such, it is remarkable that only 2% of spawners returned at age 2 in 2016, while 86% returned at age 3, and a component (4%) even remained in lake to spawn at age 4. The lack of age 2 spawners in 2016 and the small size at age 1 observed in the trawl in recent years indicates that the kokanee are not capitalizing on the abundant food resources until after the fall of age 1. This unusual outcome may be a symptom of abnormally high top-down pressure forcing the age 1 kokanee to take fewer risks to feed and to spend more time avoiding predation in deeper, darker water; and/or only the component of each cohort that exhibit this cautious behaviour survives to spawn.

Top-down pressure is thought to be the key driver of the continued suppression of kokanee numbers, given the dramatic spike in abundance evident in the Gerrard rainbow trout spawner data. Piscivory is known to have top-down effects on prey fish populations, including fish communities where kokanee act as the main prey source of larger predators (Baldwin and Polacek 2002, Beauchamp et al. 1995). Accordingly, it is likely that the Gerrard rainbow trout, bull trout, and other piscivores have a pronounced effect on the kokanee population in Kootenay Lake. While Gerrard spawner numbers have recently declined to below average, Kootenay Lake recreational fishery data (MFLNRO data on file) indicate that high catch rates of small rainbow and bull trout continue in the fishery. Assuming catch rate is proportional to abundance, the high numbers of younger age classes of predators should continue to exert significant pressure on the kokanee population, resulting in the extremely poor survival evident between fall fry and older age classes.

The Ministry of Forests, Lands and Natural Resource Operations formed an advisory team of Provincial Government biologists, First Nations and other stakeholders in 2014. The intent of this team is to consider and make recommendations on management actions over the next few years that will contribute to recovery of the Kokanee population, and ensure predator populations remain viable. Kokanee recovery is also dependent on nutrient additions which support food web function (i.e., zooplankton biomass). The Kootenay Lake Action Plan (Redfish Consulting Ltd., 2016), provides further information and summarizes the recommendations of the advisory team.

REFERENCES

Acara, A.H. 1970. The Meadow Creek Spawning Channel. Unpublished MS. Department of Recreation and Conservation, Fish and Wildlife Br., Victoria, BC.

Andrusak, H., and C. Brown. 1987. Kootenay Lake Fisheries Management Plan 1987-89. B.C. Ministry of Environment, 56 pp.

Andrusak, H. and L. Fleck. 2007. Status of Kokanee in the South Arm of Kootenay Lake Prior to Experimental Fertilization. Pages 251 – 272 in Schindler et al. Kootenay Lake Fertilization Experiment, Year 13 (north Arm) and Year 1 (South Arm) (2004) Report, Fisheries Project Report No. RD 117, Ministry of Environment, Province of British Columbia.

Andrusak, G. 2017. Determination of Gerrard Rainbow Trout Stock Productivity at Low Abundance. Prepared for Fish and Wildlife Compensation – Columbia. Ministry of Forests, Land and Natural Resource Operations and Rural Development, Victoria, B.C. https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=53132

Ashley, K.I., and Stockner, J.G. 2003. Protocol for applying nutrients to inland waters. American Fisheries Society Symposium 24: 245–258.

Ashley, Ken, L.C. Thompson, D. C. Lasenby, L. McEachern, K. E. Smokorowski and D. Sebastian. 1997. Restoration of an Interior Lake Ecosystem: the Kootenay Lake Fertilization Experiment. Water Qual. Res. J. Canada 32: 295-323.

Ashley, K.I., L.C. Thompson, D. Lombard, J.R. Yang, F.R. Pick, P.B. Hamilton, G. Larkin, D.C. Lasenby, K.E. Smokorowski, D. Sebastian, and G. Scholten. 1999a. Kootenay Lake Fertilization Experiment–Year 6 (1997/98) Report. Fisheries Project Report No. RD 65. Ministry of Fisheries, Province of British Columbia.

Ashley, K.I, L.C. Thompson, D. Sebastian, D.C. Lasenby, K.E. Smokorowski, and H. Andrusak. 1999b. Restoration of Kokanee Salmon in Kootenay Lake, a Large Intermontane Lake, by Controlled Seasonal Application of Limiting Nutrients in Murphy, T.P. and M. Munawar 1999b. Aquatic Restoration in Canada Backhuys Publishers, Leiden, 1999.

Audzijonyte, A. and R. Vainola. 2005. Diversity and distributions of circumpolar fresh- and brackish Mysis (Crustacea:Mysida): descriptions of M. relicta Loven, 1862, M. salemaai n. sp., M. segerstralei n. Sp. and M. diluviana n. sp. based on molecular and morphological characters. Hydrobiologia 544:89 – 141.

Baldwin, C. and Polacek, M. 2002. Evaluation of Limiting Factors for Stocked Kokanee and Rainbow Trout in Lake Roosevelt, Washington, 1999. Washington Department of Fish and Wildlife Fish program, Inland Fish Investigations.

Balk and Lindem, 2011. Sonar4 and Sonar5-Pro post processing systems, Operator manual version 6.0.1, 464p. Lindem Data Acquisition Humleveien 4b. 0870 Oslo Norway.

Bassett, M.C., Schindler, E.U., T. Weir, D. Sebastian and K. I. Ashley. 2015. Arrow Lakes Reservoir Nutrient Restoration Program Year 15 (2013) Report. Fisheries Project Report No. 148, Ministry of Forests, Lands and Natural Resource Operations, Province of British Columbia

Bassett, M.C., Schindler, E.U., D. Johner, T. Weir, D. Sebastian, L. Vidmanic, and K.I. Ashley. 2016. Kootenay Lake Nutrient Restoration Program, Years 22 (North Arm) and Years 10 (South Arm) (2013) Report.

Bassett, M.C., Schindler, E.U., Johner, D., Weir, T., Vidmanic, L., and Ashley, K.I. 2018. Kootenay Lake Nutrient Restoration Program North Arm and South Arm 2014 and 2015 Report.

Beauchamp, D.A., Lariviere, M.G., Thomas, G.L. 1995. Evaluation of Competition and Predation as Limits to Juvenile Kokanee and Sockeye Salmon Production in lake Ozette, Washington. *North American Journal of Fisheries Management*. Vol. 15, Issue 1. Pp.193-207.

Beauchamp, D.A., C.J. Sergeant, M.M. Mazur, J.M. Scheuerell, D.E. Schindler, M.D. Scheuerell, K.L. Fresh, D.E. Seiler, and T.P. Quinn. 2004. Temporal-spatial dynamics of early feeding demand and food supply of sockeye salmon fry in Lake Washington. *Transactions of the American Fisheries Society*. 133:1014-1032.

Binsted, G.A., and K.I. Ashley. 2006. Phosphorus Loading to Kootenay Lake from the Kootenay and Duncan rivers and Experimental Fertilization Program. Prepared for the British Columbia Conservation Foundation.

Bray, K 2017. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 8 (2015). BC Hydro, Environment. Study no. CLBMON-3 and CLBMON-56.Brooks, J.L. 1959. Cladocera. Pp. 586-656 In Edmondson, W.T. (Ed.), Fresh-Water Biology, 2nd Ed. John Wiley and Sons, New York.

Campbell, T. and M. Neufeld. 2018. Meadow Creek Spawning Channel – 2016/17 Kokanee Egg to Fry. Unpublished report. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Nelson, B.C.

Canter-Lund, H. and J.W.G. Lund. 1995. Freshwater Algae – Their Microscopic World Explored. BioPress Ltd., Bristol, UK, 360pp.

Casselman, J.M.. 1990. Growth and relative size of calcified structures of fish. Transactions of the American Fisheries Society 119:673-688.

Crozier, R.J., and W.F.A. Duncan. 1984. Kootenay Lake: 1984. British Columbia Ministry of Environment. 187 pp.

Daley, R.J., E.C. Carmack, C.B.J. Gray, C.H. Pharo, S. Jasper, and R.C. Wiegand. 1981. The effects of upstream impoundments on Kootenay Lake, B.C. Canada Inland Waters Directorate, Research Institute, Scientific Series, West Vancouver, British Columbia.

Danielsdottir, M. G., M. T. Brett and G.B. Arhonditsis. 2007. Phytoplankton food quality control of planktonic food web processes. Hydrobiologia 589: 29-41.

Ericksen, R., P. Anders, C. Lewandowski and J. Siple. 2009. Status of Kokanee Populations in the Kootenai River in Idaho and Montana and South Arm Kootenay Lake, British Columbia. Contract report prepared for the Kootenai Tribe of Idaho 30p.

FWCP. 2012. Fish and Wildlife Compensation Program Columbia Basin Large Lakes Action Plan Draft. Fish and Wildlife Compensation Program (FWCP). 33pp. + appendices. **http://fwcp.ca/app/uploads/2015/07/columbia_LargeLakes_ActionPlan_2012_jun.pdf**

Grover, M.C. 2005. Changes in size and age at maturity in a population of kokanee *Oncorhynchus nerka* during a period of declining growth conditions. Journal of Fish Biology 66: 122-134.

Horne, A.J. and C.R. Goldman. 1994. Limnology 2nd edition. McGraw-Hill Inc.

Hoyle G.M., Holderman, C., Anders, P.A., Shafii, B. and K.I. Ashley. 2014. Water quality, chlorophyll, and periphyton responses to nutrient addition in the Kootenai River, Idaho. *Freshwater Science*. 33(4). 1024-1029.

IKERT 2018. Results presented at the International Kootenai/y River Ecosystem Restoration Team meeting in Nelson, May 2018.

Koerselman, W and A.F.M. Meuleman. 1996. The Vegetation N:P Ratio: a New Tool to Detect the Nature of Nutrient Limitation. Journal of Applied Ecology. 33(6). 1441-1450.

Kongsberg Maritime AS. 2008. Simrad ER60 scientific echosounder reference manual for software version 2.2.0. Kongsberg Maritime, Horten, Norway. 221p. Lakes Fisheries Commission Tech. Rep. 25

Larkin, G.A. 1998. Kootenay Lake phosphorus loading from the Kootenay and Duncan Rivers. Report prepared for the Columbia Basin Fish and Wildlife Compensation Program, 26 p.

Lasenby, D.C. 1977. The ecology of *Mysis relicta* in Kootenay Lake, British Columbia: final report 1976-1977. Manuscript.

Leifasbjorn, V., Peterson, J., and Quinn, TP. 2004. Effects of Freshwater and Marine Growth Rates on Early Maturity in Male Coho and Chinook Salmon. *Transactions of the American Fisheries Society* 133:495-503

Lund, J.G., C. Kipling, and E.D. LeCren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. Hydrobiol. 11: 143-170.

Martin, A.D., and T.G. Northcote. 1991. Kootenay Lake: An inappropriate model for Mysis relicta introduction in north temperate lakes. American Fisheries Society Symposium 9:23-29.

Mazumder, A., and J.A. Edmundson. 2002. Impact of fertilization and stocking on trophic interactions and growth of juvenile sockeye salmon (Oncorhynchus nerka). Can. J. Fish. Aquat. Sci 59:1361-1373.

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. Pp. 228-265 *In* Downing, J.A. and F.H. Rigler (Eds.), A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters. Blackwell Scientific Publications, Boston.

Ministry of Environment and Climate Change Strategy 2018. BC Environmental Monitoring System Results. DataBC Data Catalogue. **https://catalogue.data.gov.bc.ca/dataset/bc-environmental-monitoring-system-results**

Minshall, W., Shafii, B., Price, W.J., Holderman, C., Anders, P.A., Lester, G. and P. Barrett. 2014. Effects of nutrient replacement on benthic macroinvertebrates in an ultraoligotrophic reach of the Kootenai River, 2003–2010. *Freshwater Science.* 33(4). 1009-1023.

MFLNRO 2016. 2015 North Arm Kokanee Escapement/Fry Production Summary Report (unpublished). Nelson, B.C.

MFLNRO. 2017. 2016 North Arm Kokanee Escapement/Fry Production Summary Report (unpublished). Nelson, B.C.

Neufeld, M. 2014. Kootenay Fisheries Field Report Gerrard (Lardeau River) 2013. Ministry of Forests, Lands and Natural Resource Operations, Nelson, B.C. **https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=41588**

Neufeld, M. 2015. Kootenay Fisheries Field Report Gerrard (Lardeau River) 2015. Ministry of Forests, Lands and Natural Resource Operations, Nelson, B.C.

Neufeld, M., and Arndt, S. 2016. Kootenay Fisheries Field Report Meadow Creek Spawning Channel - 2016 Fry Survival Estimate of October 2015 Egg Plants. **https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=51486**

Ney, J.J. 1996. Oligotrophication and its discontents: effects of reduced nutrient loading on reservoir fisheries. Pages 285-295 in L.E. Miranda and D.R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Symposium 16, Bethesda, Maryland.

Northcote, T.G. 1973. Some Impacts of Man on Kootenay Lake and Its Salmonids. Great Lakes Fisheries Commission, Technical Report No. 25. **http://www.glfc.org/pubs/TechReports/Tr25.pdf**

Northcote, T.G., D.B. Fillion, S.P. Salter, and G.L. Ennis. 1999. Interactions of Nutrients and Turbidity in the Control of Phytoplankton in Kootenay Lake British Columbia, Canada, 1964 to 1966. Misc. Fisheries Project Report No. 1, Province of British Columbia.

Patterson, S.D., D.L. Scarnecchia and J.L Congleton. 2008. Sexual Maturation in Kokanee *Oncorhynchus nerka*. Northwest Science Vol. 82, No. 1. p 30-47.

Pennak, R.W. 1989. Fresh-Water Invertebrates of the United States: Protozoa to Mollusca, 3rd Ed. John Wiley and Sons, New York. 628 pp.

Perrin, C.J., M. L. Rosenau, T. B. Stables, and K. I. Ashley. 2006. Restoration of a Montane Reservoir Fishery via Biomanipulation and Nutrient Addition. North Am. J. Fish. Manag. 26:391-407.

Pieters, R., S. Harris, L.C. Thompson, L. Vidmanic, M. Roushorne, G. Lawrence, J.G. Stockner, H. Andrusak, K.I. Ashley, B. Lindsay, K. Hall and D. Lombard. 2003. Restoration of kokanee salmon in the Arrow Lakes Reservoir, British Columbia: Preliminary results of a fertilization experiment. Pages 177-196 *in* J.G. Stockner, editor. Nutrients in salmonid ecosystems: sustaining production and biodiversity. American Fisheries Society, Symposium 34, Bethesda, Maryland.

Prescott, GW. 1978. Freshwater Algae, 3rd Edition, W.C. Brown Co., Dubuque, Iowa.

R Core Team, 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL **https://www.R-project.org/**.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL **https://www.R-project.org/**.

Redfish Consulting Ltd. 1999. Performance Evaluation of Six Kokanee Spawning Channels in British Columbia. Ministry of Fisheries, Province of British Columbia, Victoria, BC.

Redfish Consulting Ltd. 2002. West Arm of Kootenay Lake Kokanee Sport Fishery and Kokanee Food Habits 2002. Contract report for the Nelson Fisheries Branch of the BC Ministry of Water, Land and Air Protection, Nelson, BC.

Redfish Consulting Ltd. 2016. Kootenay Lake Action Plan. Contract report for BC Ministry of Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), Nelson, BC. http://www.env.gov.bc.ca/kootenay/fsh/main/pdf/KLAP%20Kootenay%20Lake%20Action%20PLan%20final%209_May_2016.pdf

Redfish Consulting Ltd. 2017. Kootenay Lake Tributaries Kokanee Counts 2016. Contract report for BC Ministry of Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), Nelson, BC. https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=54392

Reynolds, J.B. and G.M. DeGraeve. 1972. Seasonal population characteristics of the opossum shrimp, *Mysis relicta,* in southeastern Lake Michigan, 1970-71. Proc. 15th Conf. Great Lakes Res. 1972: 117-131.

Rieman, B.E. and D.L. Myers. 1992. Influence of Fish Density and Relative Productivity on Growth of Kokanee in Ten Oligotrophic Lakes and Reservoirs in Idaho. Trans. Am. Fish. Soc. 121:178–191.

Rydin, E., T. Vrede, J. Persson, S. Holmgren, M. Jansson, L. Tranvik and G. Milbrink. 2008. Compensatory nutrient enrichment in an oligotrophicated mountain reservoir – effects and fate of added nutrients. Aquat. Sci. 70:323-336.Sandercock, G.A. and Scudder, G.G.E. 1996. Key to the Species of Freshwater Calanoid Copepods of British Columbia. Department of Zoology, UBC Vancouver, BC.

Sandercock, G.A. and Scudder, G.G.E. 1996. Key to the Species of Freshwater Calanoid Copepods of British Columbia. Department of Zoology, UBC Vancouver, BC.

Schindler, E.U., K.I. Ashley, R. Rae, L. Vidmanic, H. Andrusak, D. Sebastian, G. Scholten, P. Woodruff, F. Pick, L.M. Ley and P.B. Hamilton. 2006. Kootenay Lake Fertilization Experiment, Years 11 and 12 (2002 and 2003). Fisheries Report No. 114, Ministry of Environment, Province of British Columbia.

Schindler, E.U., R. Rae, K.I. Ashley, L. Vidmanic, D. Sebastian, H. Andrusak, G. Scholten, P. Woodruff, J. Stockner, F. Pick, L.M. Ley, P.B. Hamilton, G.F. Andrusak and L. Fleck. 2007a. Kootenay Lake Fertilization Experiment, Year 13 (North Arm) and Year 1 (South Arm) (2004) Report. Fisheries Project Report No. RD 117, Ministry of Environment, Province of British Columbia.

Schindler, E.U., H. Andrusak, K.I. Ashley, G.F. Andrusak, L. Vidmanic, D. Sebastian, G. Scholten, P. Woodruff, J. Stockner, F. Pick, L.M. Ley and P.B. Hamilton. 2007b. Kootenay Lake Fertilization Experiment, Year 14 (North Arm) and Year 2 (South Arm) (2005) Report. Fisheries Project Report No. RD 122, Ministry of Environment, Province of British Columbia.

Schindler, E.U., D. Sebastian, G.F. Andrusak, H. Andrusak, L. Vidmanic, J. Stockner, F. Pick, L.M. Ley, P.B. Hamilton, M. Bassett and K.I. Ashley. 2009. Kootenay Lake Fertilization Experiment, Year 15 (North Arm) and Year 3 (South Arm) (2006) Report. Fisheries Project Report No. RD 126, Ministry of Environment, Province of British Columbia.

Schindler, E.U., D. Sebastian, H. Andrusak L. Vidmanic, S. Harris, G.F. Andrusak, F. Pick, L.M. Ley, P.B. Hamilton, D. Johner, P. Woodruff, M. Bassett and K.I. Ashley. 2010. Kootenay Lake Nutrient Restoration Program, Year 16 (North Arm) and Year 4 (South Arm) (2007) Report. Fisheries Project Report No. RD 127, Ministry of Environment, Province of British Columbia.

Schindler, E.U., D. Sebastian, H. Andrusak, L. Vidmanic, G. F. Andrusak, M. Bassett, T. Weir and K. I. Ashley. 2011. Kootenay Lake Nutrient Restoration Program, Year 17 (North Arm) and Year 5 (South Arm) (2008) Report. Fisheries Project Report No. RD 131. Ministry of Forests, Lands and Natural Resource Operations, Province of British Columbia.

Schindler, E.U., D. Sebastian , T. Weir, H. Andrusak, G.F. Andrusak, M. Bassett, L. Vidmanic, and K.I. Ashley. 2013. Kootenay Lake Nutrient Restoration Program, Years 18 and 19 (North Arm) and Years 6 and 7 (South Arm) (2009 and 2010) Report. Fisheries Project Report No. RD 136, Ministry of Forests, Lands, and Natural Resource Operations, Province of British Columbia.

Schindler, E.U., D. Johner, T. Weir, D. Sebastian , M. Bassett, L. Vidmanic, and K.I. Ashley. 2014. Kootenay Lake Nutrient Restoration Program, Years 20 and 21 (North Arm) and Years 8 and 9 (South Arm) (2011 and 2012) Report. Fisheries Project Report No. RD 147, Ministry of Forests, Lands, and Natural Resource Operations, Province of British Columbia

Sebastian, D., H. Andrusak, G. F. Andrusak, and P. Woodruff. 2010. South Arm of Kootenay Lake Response to Nutrient Additions 2004 – 2007. Pages 231 – 268 *in* Schindler, E.U.et al. 2010. Kootenay Lake Nutrient Restoration Program, Year 16 (North Arm) and Year 4 (South Arm) (2007) Report. Fisheries Project Report No. RD 127, Ministry of Environment, Province of British Columbia.

Sebastian, D. and T. Weir. 2013. Kinbasket and Revelstoke Reservoirs Kokanee Population Monitoring - Year 5 (2012). Prepared for BC Hydro under the Columbia River Water Use Plan, Water Licence Requirements Study No. CLBMON-2. 42p

Simmonds, J., and D. MacLennan. 2005. Fisheries acoustics: Theory and practice. Blackwell, Oxford, UK.

Skaar, D., J. DeShazer, L. Garrow, T. Ostrowski, and B. Thornburg. 1996. Investigations of fish entrainment through Libby Dam, 1990-1994. Montana Dept. of Fish, Wildlife, and Parks, Prepared for Bonneville Power Administration, Project Number 83-467, Portland, Oregon.

Smokorowski, K.E. 1998. The response of the freshwater shrimp, Mysis relicta, to the partial fertilization of Kootenay Lake, British Columbia. Ph.D. thesis, Trent University, Peterboriugh, Ontario, Canada, 227 p.

Stockner, J.G. 1987. Lake fertilization: The enrichment cycle and lake sockeye salmon (Onchorhynchus nerka) production. Pages 198-215 in H.D. Smith, L. Margolis and C.C. Woods, editors. Sockeye salmon (Onchorhynchus nerka) populations biology and future management. Canadian Special Publication of Fisheries and Aquatic Sciences 96.

Stockner, J. G., and E.A. MacIsaac. 1996. British Columbia lake enrichment program: two decades of habitat enhancement for sockeye salmon. Regul. Rivers Res. Manag. 12:547-561.

Thompson, L.C. 1999. Abundance and production of zooplankton and kokanee salmon.(Oncorhynchus nerka) in Kootenay Lake, British Columbia during artificial fertilization. Ph.D. thesis, Department of Zoology, University of British Columbia, Vancouver, British Columbia, 252 p.

Vernon, E. H. 1957. Morphometric Comparison of Three Races of Kokanee (Oncorhynchus nerka) Within a Large British Columbia Lake. Journal of the Fisheries Research Board of Canada 27:1239–1250.

Ward, P.R.B, Anders, P.J., Minshall, G.W., Holderman, C., Hoyle, G.M., and Yassien, H. 2018. Nutrient uptake during low-level fertilization of a large, seventh-order oligotrophic river. Canadian Journal of Fisheries and Aquatic Sciences 75(4): 569–579, https://doi.org/10.1139/cjfas-2017-0062.

Wetzel, R.G. 2001. Limnology. 3rd Ed, Academic Press, San Diego.

Wilson, M.S. 1959. Free-living copepoda: Calanoida. Pp. 738-794 In Edmondson, W.T. (ed.) Fresh-Water Biology, 2nd Ed., John Wiley and Sons, New York.

Wright, M.E., K.I. Ashley, H. Andrusak, H. Manson, R. Lindsay, R.J. Hammond, F.R. Pick, L.M. Ley, P.B. Hamilton, S.L. Harris, L.C. Thompson, , L. Vidmanic, D. Sebastian, G. Scholten, M. Young, and D. Miller. 2002. Kootenay Lake Fertilization Year 9 (2000/2001) Report. Fisheries Project Report No. RD 105. Ministry of Water, Land and Air Protection, Province of British Columbia.

Zimmer, M., Whitney, C.K., Thorley, J., and Plate, E. 2016. Duncan Dam Project Water Use Plan, 2013 Lower Duncan River Kokanee Spawning Monitoring. Implementation Year: Year 6 Data Report. Reference: DDMMON-4. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/ddmmon-4-yr6-2016-02-01.pdf

APPENDICES

Appendix 1. Kootenay Lake participants, activities, and affiliation for 2016 studies.

Contribution	Personnel	Affiliation
Project co-ordination, management and scientific liaison	Marley Bassett	Resource Management, MoFLNRO[1], Nelson
Report compilation	Marley Bassett Rob Fox Kristen Peck	Resource Management, MoFLNRO, Nelson
Report editing and review	Marley Bassett Eva Schindler Rob Fox Kristen Peck Steve Arndt Tyler Weir David Johner Ken Ashley	Resource Management, MoFLNRO, Nelson Resource Management, MoFLNRO, Victoria BC Institute of Technology Rivers Institute
Fertilizer schedule, loading	Marley Bassett Ken Ashley Al Jelfs	Resource Management, MoFLNRO, Nelson BC Institute of Technology Rivers Institute Agrium, Kamloops
Fertilizer application	Western Pacific Marine Marley Bassett Rob Fox	Western Pacific Marine, Balfour Resource Management, MoFLNRO, Nelson
Physical limnology, water chemistry, phytoplankton, zooplankton, mysid sampling	Don Miller and staff Marley Bassett Eva Schindler Rob Fox Les Fleck Dave Gottdenker	Kootenay Wildlife Services Ltd. Resource Management, MoFLNRO, Nelson Crystal Springs Consulting BC Parks, MoE
Physical limnology, water sampling data analysis and reporting	Marley Bassett Rob Fox	Resource Management, MoFLNRO, Nelson
Primary production sampling	Shannon Harris Allison Hebert Jennifer Sarchuk Les Fleck Eugene Volokhov	Environmental Sustainability Division, MoE, Vancouver Crystal Springs Consulting British Columbia Conservation Foundation
Primary productivity analysis and reporting (not included in this report)	Shannon Harris	Environmental Sustainability Division, MoE, Vancouver
Phytoplankton sample analysis	Dr. John Stockner	Eco-Logic Ltd.
Zooplankton and mysid sample analysis and reporting	Dr. Lidija Vidmanic	Limno-Lab Ltd.
Kokanee acoustic sampling	Tyler Weir David Johner Sam Albers	Fish, Wildlife and Habitat Management, MoFLNRO, Victoria British Columbia Conservation Foundation

(cont'd)		
Contribution	**Personnel**	**Affiliation**
Kokanee trawling	Don Miller and staff Tyler Weir David Johner	Kootenay Wildlife Services Ltd. Fish, Wildlife and Habitat Management, MoFLNRO, Victoria
Kokanee analysis and reporting	Tyler Weir David Johner Sam Albers Morgan Davies	Fish, Wildlife and Habitat Management, MoFLNRO, Victoria MoE, Vancouver
South Arm tributary adult kokanee enumeration	Stefan Himmer Kerry Reed Marley Bassett Rob Fox Katherine McGlynn	Subcontracted by Redfish Consulting Ltd. Resource Management, MoFLNRO, Nelson
Regional support	Jeff Burrows Matt Neufeld	Resource Management, MoFLNRO, Nelson
FWCP Technical Committee	Jeff Burrows Tyler Weir Guy Martel Karen Bray	Resource Management, MoFLNRO, Nelson MoFLNRO, Victoria BC Hydro, Vancouver BC Hydro, Revelstoke
FWCP Board	John Krebs David Tesch Patrice Rother Doug Johnson Rick Morley Grant Trower Dave White Joe Nicholas Adam Neil Howie Wright	Resource Management, MoFLNRO, Nelson Environmental Sustainability Division, MoE, Victoria BC Hydro, Vancouver BC Hydro, Castlegar Public Representative Public Representative Public Representative First Nations Representative First Nations Representative First Nations Representative
FWCP Policy Committee	Marc Zacharias Rebecca Reid Edi Thome	MoE, Victoria Fisheries and Oceans Canada BC Hydro, Burnaby
Administration	Trevor Ousorren Crystal Klym Lorraine Ens Sue Ireland Charlie Holderman Barb Waters Anne Reichert Elaine Perepolkin Disa Westerhaug	FWCP[3] FWCP FWCP Kootenai Tribe of Idaho Kootenai Tribe of Idaho British Columbia Conservation Foundation Resource Management, MoFLNRO Corporate Services Branch, MoFLNRO, Nelson

1-MoFLNRO = Ministry of Forests, Lands and Natural Resource Operations
2-MoE = Ministry of Environment
3-FWCP=Fish and Wildlife Compensation Program

Appendix 2. Sampling activities on Kootenay Lake in 2016.

Parameter sampled	***Sampling frequency***	***Locations***	***Sampling technique***
Temperature, dissolved oxygen, conductivity	Monthly: April to November	KLF 1-8	SeaBird profile from surface to 5 m above bottom. NOTE: some missing data due to battery failure (Appendix 5)
Transparency	Monthly: April to November; Twice monthly: June, July and August	KLF 1-8 KLF 2 & KLF 6	Secchi disk (without viewing chamber)
Epilimnion Water chemistry Turbidity, pH, TP, TN, NO_3, NO_2, TIC, TDP, OP, TOC, alkalinity, silica TP, TN, NO_3, NO_2,TDP, OP, silica TP, TN, NO_3, NO_2, TDP, OP	Monthly, April to November Mid June Twice monthly, July and August	KLF 1-8 KLF 1-8 KLF 2 & KLF 6	Integrated sampling tube at 0 – 20m
Total metals	June and September (or October)	KLF 1-8 KLF 8 omitted from bottom sampling	Integrated sampling tube at 0 – 20m. Van Dorn sampler 5 m off the bottom
Discrete Epilimnion Water Chemistry TP, NO_3, NO_2, TDP, OP	Monthly, June to September	KLF 2 & KLF 6	Discrete samples at 2 m, 5 m, 10 m, 15 m and 20 m (Van Dorn sampler)
Hypolimnion Water chemistry Turbidity, pH, TP, TN, NO_3, NO_2, TIC, TDP, OP, TOC, alkalinity, silica	Monthly, May to October	KLF 1-7	Samples 5 m off the bottom (Van Dorn sampler)
Epilimnion Chlorophyll *a*	Monthly, April to November Mid June Twice monthly, July and August	KLF 1-8 KLF 1-8 KLF 2 & KLF 6	Integrated sampling tube at 0 – 20m
Discrete Epilimnion Chlorophyll *a*	Monthly, June to September	KLF 2 & KLF 6	Discrete samples at 2 m, 5 m, 10 m, 15 m and 20 m
Epilimnion Phytoplankton	Monthly, April to November Mid June Twice monthly, July and August	KLF 1-8 KLF 1-8 KLF 2 & KLF 6	Integrated sampling tube at 0 – 20m
Discrete Epilimnion phytoplankton	Monthly, June to September	KLF 2 & KLF 6	Discrete samples at 2 m, 5 m, 10 m, 15 m and 20 m

(cont'd)

Parameter sampled	***Sampling frequency***	***Locations***	***Sampling technique***
Primary Production	Monthly, June to September	KLF 2 & KLF 6	Discrete samples at regular depths within the PAR zone (Van Dorn sampler) Light meter (Li-Cor) at Balfour set up from May to September
Macrozooplankton	Monthly, April to November	KLF 1-8	3 oblique Clarke-Bumpus net hauls (3 minutes each) from ~20–0 m with 150 μm net mesh
Mysids	Monthly, April to November	KLF 1-8	3 replicate hauls with mysid net, two deep (1 m off the bottom) and one shallow (25 m)
Kokanee acoustic sampling	2 surveys, June and September	18 transects	Standard MoFLNRO Simrad and Biosonics hydroacoustic procedures
Kokanee trawling	September trawl	KLF 1-7 KLF 3 omitted	Standard MoFLNRO trawl series using oblique hauls at specified transects Additional directed trawls to increase catch in 2016
Adult kokanee enumeration	Fall spawning period	Meadow Creek, Lardeau River, and selected South Arm tributaries to Kootenay Lake	Standard Meadow Creek spawner renumeration, Lardeau River aerial peak counts, ground point (index) counts on South Arm tributaries, and additional full ground counts on South Arm tributaries in 2016

Appendix 3. Kootenay Lake North Arm nutrient loading from fertilizer during 2016 - liquid ammonium polyphosphate (phosphorus: 10-34-0, N-P_2O_5-K_2O) and liquid urea-ammonium nitrate (nitrogen: 28-0-0, N-P_2O_5-K_2O).

Week #	Week	P Load (mg/m^2)	P Amount (kg)	10-34-0 Amount (tonnes)	N Load (mg/m^2)	N Amount (kg)	28-0-0 Amount (tonnes)	Total Amount (tonnes)	N:P ratio wt:wt
1	28-Apr	7.5	1,307	8.8	5.1	880	0.00	8.8	0.67
2	05-May	7.5	1,307	8.8	5.1	880	0.00	8.8	0.67
3	12-May	12.8	2,227	15.0	8.6	1,500	0.00	15.0	0.67
4	19-May	16.2	2,821	19.0	10.9	1,900	0.00	19.0	0.67
5	24-May	16.3	2,836	19.1	49.5	8,602	23.90	43.0	3.0
6	02-Jun	16.3	2,836	19.1	49.5	8,602	23.90	43.0	3.0
7	09-Jun	16.3	2,836	19.1	49.5	8,602	23.90	43.0	3.0
8	16-Jun	9.0	1,559	10.5	58.5	10,150	32.50	43.0	6.5
9	23-Jun	14.6	2,538	17.1	95.2	16,524	52.91	70.0	6.5
10	29-Jun	14.6	2,538	17.1	95.2	16,524	52.91	70.0	6.5
11	07-Jul	14.6	2,538	17.1	95.2	16,524	52.91	70.0	6.5
12	14-Jul	9.0	1,559	10.5	58.5	10,150	32.50	43.0	6.5
13	21-Jul	9.3	1,618	10.9	101.6	17,635	59.09	70.0	10.9
14	28-Jul	0.0	0	0.0	0.0	0	0.00	0.0	0.0
15	04-Aug	9.3	1,618	10.9	101.6	17,635	59.09	70.0	10.9
16	11-Aug	9.3	1,618	10.9	101.6	17,635	59.09	70.0	10.9
17	18-Aug	9.3	1,618	10.9	101.6	17,635	59.09	70.0	10.9
18	26-Aug	9.3	1,618	10.9	101.6	17,635	59.09	70.0	10.9
19	01-Sep	9.3	1,618	10.9	101.6	17,635	59.09	70.0	10.9
20	08-Sep	5.7	995	6.7	62.4	10,834	36.30	43.0	10.9
21	15-Sep	5.7	995	6.7	62.4	10,834	36.30	43.0	10.9

Appendix 4. Kootenay Lake South Arm nutrient loading from fertilizer during 2016: liquid urea-ammonium nitrate (nitrogen: 28-0-0, N-P_2O_5-K_2O).

Week #	Week	N Load (mg/m^2)	N Amount (kg)	28-0-0 Amount (Tonnes)
1	03-Jun	85.9	19,600	70.00
2	10-Jun	85.9	19,600	70.00
3	17-Jun	85.9	19,600	70.00
4	24-Jun	85.9	19,600	70.00
5	30-Jun	85.9	19,600	70.00
6	08-Jul	43.0	9,800	35.00
7	15-Jul	85.9	19,600	70.00
8	22-Jul	85.9	19,600	70.00
9	29-Jul	0.0	0	0.00
10	05-Aug	85.9	19,600	70.00
11	12-Aug	85.9	19,600	70.00
12	19-Aug	85.9	19,600	70.00
13	28-Aug	85.9	19,600	70.00
14	02-Sep	85.9	19,600	70.00
15	09-Sep	85.9	19,600	70.00

Appendix 5. Missing data from Kootenay Lake water temperature (CTD) and climatic (weather station) datasets.

Missing monthly water temperature data - Seabird 19+ profiler					
Year	***# readings total***	***Missing N.Arm months***	***Missing S.Arm months***	***Missing W.Arm months***	***Description***
1992	66	Jul	Jul	No KL8 sampling	Missing: Jun - KL6, Jul - all stations, KL7 - all months
1993	57	Sep	Nov	No KL8 sampling	Missing: various data points across months and stations
1994	105	-	-	No KL8 sampling	Extended sampling: 15 readings each for KL1-KL7
1995	101	-	-	No KL8 sampling	Extended sampling: 15 readings each for KL1-KL7; Missing one of two May readings for KL5-KL7; Missing one Apr reading for KL5
1996	105	-	-	No KL8 sampling	Extended sampling: 15 readings each for KL1-KL7
1997	28	Nov	Nov	No KL8 sampling	Limited sampling: Apr-Oct for KL2, KL4, KL6, KL7
1998	28	Nov	Nov	No KL8 sampling	Limited sampling: Apr-Oct for KL2, KL4, KL6, KL7
1999	29	Nov	Jun, Nov	No KL8 sampling	Limited sampling: Apr-Oct for KL2, KL4, KL6, KL7; Also Apr for KL1, KL3, KL5. Missing May for KL6, KL7
2000	28	Nov	Nov	No KL8 sampling	Limited sampling: Apr-Oct for KL2, KL4, KL6, KL7
2001	28	Nov	Nov	No KL8 sampling	Limited sampling: Apr-Oct for KL2, KL4, KL6, KL7
2002	42	Oct, Nov	Oct, Nov	No KL8 sampling	Oct-Nov - all stations; KL8 - all months
2003	40	Oct	Oct	Limited KL8 sampling	Apr-Jul - KL1, KL3, KL5, KL8; Oct - all stations
2004	64	-	-	-	No data missing
2005	63	-	-	-	Missing: Aug - KL6 **change from Hydrolab to Seabird profiler in 2005**
2006	56	May	May	May	May - all stations missing
2007	55	Apr	Apr	Apr	Missing: Apr - all stations; Jun - KL1
2008	59	-	-	Jul, Aug	Missing: Jul - KL1, KL2, KL8; Aug - KL1, KL8
2009	63	-	-	-	Missing: Oct - KL2
2010	64	-	-	-	No data missing
2011	61	-	-	-	Missing: Oct - KL4, KL6, KL8
2012	63	-	-	-	Missing: Oct - KL7
2013	56	Sep	Sep	Sep	No Semptember sampling for all stations
2014	24	July to Nov	July to Nov	July to Nov	Instrument failure Jul-Oct 2014
2015	54	May	-	-	Top 2-4m not recorded in ten readings
2016	57	-	Jul	Jul	Missing: Jul - all stations except KL3

Missing daily air temperature data - NELSON CS weather station			**Missing daily precipitation data - NELSON NE weather station**		
Year	***#Temp days missing***	***Description***	***Year***	***#Precip days missing***	***Description***
1992	303	Jan-Oct	1992	0	No data missing.
1993	2	Sep 2-3	1993	0	No data missing.
1994	0	No data missing.	1994	0	No data missing.
1995	2	Sep 9,18	1995	0	No data missing.
1996	1	Jul 10	1996	0	No data missing.
1997	2	Jul 23-24	1997	0	No data missing.
1998	0	No data missing.	1998	0	No data missing.
1999	0	No data missing.	1999	6	Aug 11-16
2000	1	Apr 13	2000	0	No data missing.
2001	3	Mar 28-30	2001	0	No data missing.
2002	0	No data missing.	2002	0	No data missing.
2003	3	Nov 20-21, 23	2003	0	No data missing.
2004	2	Jan 3-4	2004	30	Apr 1-30
2005	0	No data missing.	2005	0	No data missing.
2006	33	Jul 4, 10, 31; Aug 1-4; Oct 25-Nov 6; Nov 19-28; Dec 15-17	2006	2	Mar 8-9
2007	20	Apr 29-May3; May 17; Jun 16-19; Sep 1-4; Nov 10-15	2007	18	Mar 7; Jun 28-30; Jul 1-5, 30, 31; Aug 9, 10, 23, 26, 27; Nov 19; Dec 22
2008	7	May 5-7, 29; Jun 1-2; Dec 31	2008	15	Jul 4-5; Sep 16-19; Oct 8-14, 22, 23
2009	5	Jan 1-5	2009	8	Jul 24; Aug 16-21, 26
2010	1	Dec 15	2010	40	Jan 13; Apr 6-9,14-18, 26; May 2, 18-20; Jun 2, 16-19; Jul 26-27; Aug 20, 22-24, 31; Sep 1-9; Oct 24; Dec 6-8
2011	0	No data missing.	2011	20	Jan 30-31; Feb 1-5; Mar 8-13; May 3; Jun 3; Jul 4-5, 18; Oct 30; Dec 15
2012	3	Jul 18-20	2012	13	Feb 25; Mar 27; Jun 19, 23; Sep 5-13
2013	4	Jul 3, 16-17, 22	2013	24	Feb 15-20; Mar 25; Apr 16, 29; May 6-8; Jun 2; Aug 14-21; Sep 11; Oct 25-26
2014	2	May 14-15	2014	18	Apr 6, 26-30; Jul 12-13; Nov 7-10, 27-30; Dec 1,
2015	4	Jun 11-13; Dec 18	2015	18	Jan 9, 22; Jun 1, 22-25; Jul 21,22; Aug 27-31; Sep 20, 21; Oct 14, 15
2016	4	Feb 10-11; Jun 21-22	2016	23	Jan 7-8, 29; Feb 22; Mar 18; Jul 22-23; Aug 9-10; Oct 21, 25-26; Nov 11; Dec 9, 12-13,16-18, 21-22, 26-27

Appendix 6. The spot check sites and reaches for select tributaries for the annual index counts adult of kokanee in the South Arm of Kootenay Lake.

Creek	Details	UTM Easting	UTM Northing	Survey type	Source
Crawford	Upper end of survey, Bailey bridge survey point	514143	5505042	Point	GPS
Crawford	Mid-survey, golf course bridge survey point	513447	5504219	Point	GPS
Crawford	Lower end bottom survey, outlet to Crawford Bay	513473	5501419	Start	GPS
Crawford	Upper end of bottom survey	513389	5501830	End	GPS
Gray	Lower end of survey	515243	5496751	Start	GPS
Gray	Upper end of survey	515509	5496734	End	GPS
LaFrance	Highway bridge survey point	515712	5485937	Point	GPS
Lockhart	Highway bridge survey point	515515	5484145	Point	GPS
Akokli	Highway bridge survey point	517901	5474707	Point	GPS
Akokli	Lower pool survey point	517858	5474769	Point	Google Earth
Sanca	Highway bridge survey point	519850	5469336	Point	GPS
Sanca	Lower pool survey point	519614	5469189	Point	Google Earth
Boulder	Highway bridge survey point	525195	5458978	Start	GPS
Boulder	Outlet to the East Branch of Kootenay River	524797	5458905	End	GPS
Goat River	Highway bridge survey point	534893	5436696	Start	GPS
Goat River	Lower end of survey	534538	5436812	End	GPS
Goat River	Upper end of survey below Canyon Lister Rd. bridge	539958	5438171	Point	GPS
Summit	Upper end of survey at Bailey bridge	526397	5443254	Start	GPS
Summit	Lower end of survey	526622	5443295	End	GPS

Appendix 7. Eyed-egg plants and hatchery-raised fry releases into Kootenay Lake tributaries in 2015 and 2016 as part of the Kootenay Lake Recovery initiative. Eyed-eggs were planted into the gravel in the fall of the release year to incubate until emergence the following spring. Hatchery fry releases occurred in the spring of the release year indicated. MCSC refers to the Meadow Creek Spawning Channel.

Brood Source	Brood Yr	Release Yr	Release Site	Stage	Number	Otolith Heat Mark
Hill Cr	2014	2015	Crawford Creek	fry	92,541	no mark
Hill Cr	2014	2015	Hendryx Creek	fry	5,000	no mark
Hill Cr	2015	2015	MCSC	eyed-egg	477,398	III_III
Norbury Cr	2015	2016	MCSC	fry	104,006	III_III
Lussier R	2015	2016	MCSC	fry	359,335	III_III
Lussier R	2015	2016	Crawford Creek	fry	30,030	III_III
Deka Lk	2015	2016	MCSC	fry	142,237	III_III
Columbia R	2016	2016	MCSC	eyed-egg	1,569,888	no mark
Hill Cr	2016	2016	MCSC	eyed-egg	1,381,059	no mark
Bull R	2016	2016	MCSC	eyed-egg	47,247	no mark
Whatshan R	2016	2016	MCSC	eyed-egg	603,164	no mark
Norbury Cr	2016	2016	MCSC	eyed-egg	329,371	no mark
Lussier R	2016	2016	MCSC	eyed-egg	827,239	no mark
Bridge Lk	2016	2016	MCSC	eyed-egg	675,294	no mark
Deka Lk	2016	2016	MCSC	eyed-egg	915,097	no mark
Sulphurous Lk	2016	2016	MCSC	eyed-egg	411,215	no mark

Appendix 8. Comparison of trawl catch and age structure between standard oblique trawl sampling and non-standard directed trawl sampling from 2013-2016. Only the standard oblique sampling was conducted in 2014.

		Catch				Age Structure*		
Year	**Trawl Type**	**Age 0**	**Age 1**	**Age 2**	**Age 3**	**Age 1**	**Age 2**	**Age 3**
	Directed	241	8	3	3	57%	21%	21%
	Oblique	530	11			100%	0%	0%
2013	***Total***	***771***	***19***	***3***	***3***	***76%***	***12%***	***12%***
	Oblique	590	14			100%	0%	0%
2014	***Total***	***590***	***14***	***0***	***0***	***100%***	***0%***	***0%***
	Directed	741	21	1		95%	5%	0%
	Oblique	373	10			100%	0%	0%
2015	***Total***	***1114***	***31***	***1***		***97%***	***3%***	***0%***
	Directed	142	27			100%	0%	0%
	Oblique	164	9			100%	0%	0%
2016	***Total***	***306***	***36***			***100%***	***0%***	***0%***

**Trawl derived age structure is only applicable to the age 1-3 component of the population.*

Appendix 9. Kokanee length correction factors for Kootenay Lake**.** Correction factors for >180 mm fish and for 100–180 mm fish are from Rieman and Myers (1992). Correction factors for <100 mm fish were derived from Okanagan Lake trawl samples collected during 1988–1993.

Date	>180 mm	100–180 mm	<100 mm	Date	>180 mm	100–180 mm	<100 mm
1-Sep	1.025	1.064	1.090	7-Oct	1.000	1.000	0.982
2-Sep	1.023	1.061	1.087	8-Oct	1.000	1.000	0.979
3-Sep	1.021	1.058	1.084	9-Oct	1.000	1.000	0.976
4-Sep	1.020	1.056	1.081	10-Oct	1.000	1.000	0.973
5-Sep	1.018	1.053	1.078	11-Oct	1.000	1.000	0.970
6-Sep	1.016	1.050	1.075	12-Oct	1.000	1.000	0.967
7-Sep	1.014	1.047	1.072	13-Oct	1.000	1.000	0.964
8-Sep	1.012	1.044	1.069	14-Oct	1.000	1.000	0.961
9-Sep	1.011	1.042	1.066	15-Oct	1.000	1.000	0.958
10-Sep	1.009	1.039	1.063	16-Oct	1.000	1.000	0.955
11-Sep	1.007	1.036	1.060	17-Oct	1.000	1.000	0.952
12-Sep	1.005	1.033	1.057	18-Oct	1.000	1.000	0.949
13-Sep	1.003	1.030	1.054	19-Oct	1.000	1.000	0.946
14-Sep	1.002	1.028	1.051	20-Oct	1.000	1.000	0.943
15-Sep	1.000	1.025	1.048	21-Oct	1.000	1.000	0.940
16-Sep	1.000	1.023	1.045	22-Oct	1.000	1.000	0.936
17-Sep	1.000	1.022	1.042	23-Oct	1.000	1.000	0.933
18-Sep	1.000	1.020	1.039	24-Oct	1.000	1.000	0.930
19-Sep	1.000	1.018	1.036	25-Oct	1.000	1.000	0.927
20-Sep	1.000	1.017	1.033	26-Oct	1.000	1.000	0.924
21-Sep	1.000	1.015	1.030	27-Oct	1.000	1.000	0.921
22-Sep	1.000	1.013	1.027	28-Oct	1.000	1.000	0.918
23-Sep	1.000	1.011	1.024	29-Oct	1.000	1.000	0.915
24-Sep	1.000	1.010	1.021	30-Oct	1.000	1.000	0.912
25-Sep	1.000	1.008	1.018	31-Oct	1.000	1.000	0.909
26-Sep	1.000	1.006	1.015	1-Nov	1.000	1.000	0.906
27-Sep	1.000	1.005	1.012	2-Nov	1.000	1.000	0.903
28-Sep	1.000	1.003	1.009	3-Nov	1.000	1.000	0.900
29-Sep	1.000	1.001	1.006	4-Nov	1.000	1.000	0.897
30-Sep	1.000	1.000	1.003	5-Nov	1.000	1.000	0.894
1-Oct	1.000	1.000	1.000	6-Nov	1.000	1.000	0.891
2-Oct	1.000	1.000	0.997	7-Nov	1.000	1.000	0.888
3-Oct	1.000	1.000	0.994	8-Nov	1.000	1.000	0.885
4-Oct	1.000	1.000	0.991	9-Nov	1.000	1.000	0.882
5-Oct	1.000	1.000	0.988	10-Nov	1.000	1.000	0.879
6-Oct	1.000	1.000	0.985	11-Nov	1.000	1.000	0.876

Appendix 10. Equipment and data processing specifications. Echosounder specifications and field settings.

Category	Parameter	Value
Echosounder	Manufacturer	Simrad EK60
Transceiver	Frequency	120 kHz
	Max power	100 W
	Pulse duration	0.256 ms
	Band width	8.71 kHz
	Absorption coefficient	4.11 dBKm
Transducer	Type	split-beam
	Depth of face	0.75 m
	Orientation, survey method	vertical, mobile, tow foil
	Sv, TS transducer gain	27.0 dB
	Angle sensitivity	23.0
	nominal beam angle	7.0 deg
	Data collection threshold	-70 dB
	Ping rate	2 – 5 pps

Data Processing Specifications:	SONAR 5 software version 6.0.1	
Data conversion	Amplitude/ SED thresholds	-70 dB (40 Log R TVG)
	Sv, TS gain (correction)	-26.76 dB (June 2016 field calibration) -27.00 dB (Sep 2016 field calibration)
Single target filter	analysis threshold[1]	-70 to -24 dB (47 1dB bins)
	Min echo length	0.7 – 1.3
	Max phase deviation	0.30
Fish tracking	Minimum no. echoes	2
	Max range change	0.20 m
	Max ping gap	1
Density determination	Integration method	20 log r density (total) from Sv/Ts
	Echo counting method[2]	40 log r density based on SED
	Fish size distributions	From in situ single echo detections

[1] Lower Threshold varied with survey from -62 to -58dB depending on interference from mysids.

[2] Note: echo counting was the main method used for determining fish densities in 2016

Appendix 11. Estimates of kokanee biomass for Kootenay Lake. Note: a comprehensive review of historic data in 2016 resulted in minor changes to estimates presented here from those previously reported.

a) Estimated number of fish at each age based on fall acoustic abundance, trawl proportions (age 1-3 only), and mean weights by year and age from trawl samples.

	Estimated number of fish				**Mean weight (g)**			
Year	**Age 0**	**Age 1**	**Age 2**	**Age 3**	**Age 0**	**Age 1**	**Age 2**	**Age 3**
1985	5,445,000	667,051	1,008,333	139,615	1.6	24.9	54	66
1986	10,125,000	1,154,605	1,820,724	399,671	1.9	17.9	60	69
1987	No Survey				2.0	21.9	55	66
1988	4,785,000	902,222	692,778	-	2.2	26.6	52	
1989	8,025,000	1,117,405	1,388,291	169,304	1.6	25.5	60	68
1990	4,620,000	835,254	548,136	156,610	2.2	39.9	75	89
1991	7,005,000	1,167,500	972,917	194,583	2.1	29.7	128	131
1992	6,350,000	646,483	1,503,448	30,069	2.1	36.3	121	181
1993	8,790,000	1,218,451	460,634	430,915	1.5	36.5	76	109
1994	31,780,000	2,510,286	1,287,886	21,829	2.0	31.0	114	134
1995	21,000,000	3,721,029	572,466	6,505	2.0	34.2	74	138
1996	22,600,000	6,181,282	5,956,053	162,665	1.4	21.4	57	63
1997	14,270,000	5,824,120.88	5,824,121	261,758	1.7	25.0	50	77
1998	8,400,000	2,248,680	8,012,903	538,416	1.4	36.8	73	97
1999	10,360,000	2,050,323	2,489,677	-	1.4	24.4	76	
2000	9,690,000	636,667	1,273,333	-	2.0	24.4	123	
2001	18,380,000	4,967,368.42	752,632	-	1.6	24.5	85	
2002	25,430,000	9,091,528	542,778	135,694	1.2	27.7	57	84
2003	17,049,000	5,263,848	4,187,152	-	2.2	29.6	69	
2004	9,450,000	3,692,578	2,782,813	374,609	1.3	16.7	68	76
2005	12,830,000	1,703,125	1,021,875	545,000	1.1	15.8	77	104
2006	17,230,000	3,933,462	936,538	-	1.9	24.4	124	
2007[1]	17,859,000	*4,748,108*	*741,892*	-	*1.8*	*25.2*	*97.1*	
2008	22,644,000	3,827,896	445,104	-	1.6	26.0	70	
2009	31,130,000	14,305,795	1,632,205	-	1.4	24.3	70	
2010	22,443,755	11,157,199	4,075,689	152,838	1.0	24.8	50.7	72.4
2011	14,799,515	3,585,444	4,015,697	-	1.3	26.3	57.9	
2012[2]	12,792,831	851,196.42	806,397	716,797	1.9	21.0	59.3	67.2
2013	16,962,755	838,940	132,464	132,464	1.9	12.6	174.5	176.6
2014	15,751,710	1,051,135	-	-	1.8	14.3		
2015	14,004,614	1,205,290	38,880	-	2.1	15.0	283.4	
2016	7,368,613	721,989	-	-	2.6	20.1		

[1] no trawling in 2007; applied average weight and age structure by averaging 2006 and 2008 values for ages 1-3. Estimates are italicized.

[2] *Three age 4 kokanee were included in the age 3 sample.*

b) Calculation of in-lake biomass (metric tons) and biomass density ($kg^{\cdot}ha^{-1}$) of kokanee in Kootenay Lake.

	Biomass (metric tonnes)					**Biomass Density ($kg^{\cdot}ha^{-1}$)**				
Year	**Age 0**	**Age 1**	**Age 2**	**Age 3**	**Total**	**Age 0**	**Age 1**	**Age 2**	**Age 3**	**Total**
1985	8.9	16.6	53.9	9.2	89	0.23	0.43	1.41	0.24	2.3
1986	19.3	20.7	110.0	27.7	178	0.50	0.54	2.88	0.73	4.7
1987										
1988	10.4	24.0	36.2	-	71	0.27	0.63	0.95	-	1.8
1989	12.7	28.5	83.2	11.6	136	0.33	0.75	2.18	0.30	3.6
1990	10.3	33.3	41.3	14.0	99	0.27	0.87	1.08	0.37	2.6
1991	14.8	34.7	124.4	25.4	199	0.39	0.91	3.26	0.67	5.2
1992	13.3	23.5	181.4	5.4	224	0.35	0.61	4.75	0.14	5.9
1993	13.6	44.5	35.2	46.9	140	0.36	1.16	0.92	1.23	3.7
1994	63.7	77.7	147.0	2.9	291	1.67	2.04	3.85	0.08	7.6
1995	41.0	127.3	42.6	0.9	212	1.07	3.33	1.12	0.02	5.5
1996	31.8	132.3	340.8	10.2	515	0.83	3.46	8.92	0.27	13.5
1997	24.3	145.7	294.0	20.3	484	0.64	3.81	7.70	0.53	12.7
1998	11.9	82.7	588.0	52.4	735	0.31	2.16	15.39	1.37	19.2
1999	15.0	49.9	189.1	-	254	0.39	1.31	4.95	-	6.6
2000	19.3	15.5	156.7	-	191	0.50	0.41	4.10	-	5.0
2001	30.2	121.6	64.1	-	216	0.79	3.18	1.68	-	5.7
2002	31.6	251.7	31.0	11.3	326	0.83	6.59	0.81	0.30	8.5
2003	37.6	155.9	289.2	-	483	0.98	4.08	7.57	-	12.6
2004	12.2	61.7	188.9	28.4	291	0.32	1.62	4.94	0.74	7.6
2005	14.5	27.0	78.6	56.6	177	0.38	0.71	2.06	1.48	4.6
2006	33.6	96.1	116.4	-	246	0.88	2.52	3.05	-	6.4
2007[1]	31.6	119.7	72.1	-	223	0.83	3.13	1.89	-	5.8
2008	35.9	99.5	31.2	-	167	0.94	2.61	0.82	-	4.4
2009	42.0	347.0	114.6	-	504	1.10	9.08	3.00	-	13.2
2010	23.3	276.8	206.5	11.1	518	0.61	7.25	5.41	0.29	13.6
2011	19.3	94.4	232.7	-	346	0.50	2.47	6.09	-	9.1
2012[2]	24.0	17.9	47.8	48.2	138	0.63	0.47	1.25	1.26	3.6
2013	32.9	10.6	23.1	23.4	90	0.86	0.28	0.60	0.61	2.4
2014	28.1	15.0	-	-	43	0.74	0.39	-	-	1.1
2015	29.2	18.1	11.0	-	58	0.76	0.47	0.29	-	1.5
2016	19.3	14.5	-	-	34	0.50	0.38	-	-	0.9
Pre-nutrient addition mean	12.7	26.3	74.8	14.6	129	0.33	0.69	1.96	0.38	3.4
Nutrient addition mean	27.2	97.1	139.3	12.7	276	0.71	2.54	3.65	0.33	7.2

[1] *Note: 2007 biomass estimates are based on assumptions from table above*

[2] Note: Three age 4 kokanee were included in the age 3 sample

c) Calculation of kokanee spawner biomass (metric tons) and biomass density ($kg \cdot ha^{-1}$) in Kootenay Lake. Note: bottom rows compare average biomass during pre-fertilization (1985-1991) and fertilization years (1992-2016).

Year	Total Spawners (no)	Mean Weight (g)	Spawner Biomass (tonnes)	Spawners ($kg \cdot ha^{-1}$)	In-lake ($kg \cdot ha^{-1}$)	Total ($kg \cdot ha^{-1}$)
1985	901,100[1]	85	76.6[1]	2.0[1]	2.3	4.3[1]
1986	1,197,600	89	106.6	2.8	4.7	7.4
1987						
1988	657,900	97	63.5	1.7	1.8	3.5
1989	483,000	107	51.5	1.3	3.6	4.9
1990	436,607	107	46.8	1.2	2.6	3.8
1991	277,088	126	34.8	0.9	5.2	6.1
1992	520,903	159	82.6	2.2	5.9	8.0
1993	848,959	218	185.2	4.8	3.7	8.5
1994	1,253,000	158	198.2	5.2	7.6	12.8
1995	855,745	167	142.6	3.7	5.5	9.3
1996	1,181,718	89	105.7	2.8	13.5	16.3
1997	1,444,227	82	118.1	3.1	12.7	15.8
1998	2,198,000	95	208.5	5.5	19.2	24.7
1999	1,730,720	113	194.9	5.1	6.6	11.8
2000	563,956	156	88.1	2.3	5.0	7.3
2001	591,308	184	108.8	2.8	5.7	8.5
2002	464,000	144	66.6	1.7	8.5	10.3
2003	1,100,501	108	119.1	3.1	12.6	15.8
2004	1,526,125	112	170.4	4.5	7.6	12.1
2005	1,269,028	112	142.1	3.7	4.6	8.3
2006	478,307	180	86.1	2.3	6.4	8.7
2007[2]	534,073	236	125.8	3.3	5.8	9.1
2008	1,349,325	168	226.7	5.9	4.4	10.3
2009	907,839	118	107	2.8	13.2	16.0
2010	826,788	91	75.5	2.0	13.6	15.5
2011	1,764,100	78	137.4	3.6	9.1	12.7
2012	1,255,843	77	96.6	2.5	3.6	6.1
2013	453,592	241	109.5	2.9	2.4	5.2
2014	147,418	410	60.5	1.6	1.1	2.7
2015	17,961	576	10.3	0.3	1.5	1.8
2016	40,626	692	28.1	0.7	0.9	1.6
Pre	**661,314**	**102**	**63.3**	**1.7**	**3.4**	**5.0**
Fert	**932,962**	**191**	**119.8**	**3.1**	**7.2**	**10.4**

[1]1985 is an underestimate as Lardeau spawners were not counted and may have accounted for ~500,000 or more additional spawners

[2]*In-lake biomass assumptions for 2007 outlined in tables above.*

Appendix 12. Kootenay Lake Secchi (m) depth results in 2016.

Station	Arm	Month	Date	Secchi (m)
KLF1	North	Apr	2016-04-11	10.7
KLF1	North	May	2016-05-09	3.7
KLF1	North	Jun	2016-06-06	4.0
KLF1	North	Jun_2	2016-06-20	5.2
KLF1	North	Jul	2016-07-05	5.2
KLF1	North	Aug	2016-08-01	5.8
KLF1	North	Sep	2016-08-30	9.5
KLF1	North	Oct	2016-10-02	11.0
KLF1	North	Nov	2016-10-26	12.2
KLF2	North	Apr	2016-04-11	11.3
KLF2	North	May	2016-05-09	5.8
KLF2	North	Jun	2016-06-06	4.6
KLF2	North	Jun_2	2016-06-20	4.9
KLF2	North	Jul	2016-07-05	4.3
KLF2	North	Jul_2	2016-07-18	3.4
KLF2	North	Aug	2016-08-01	5.5
KLF2	North	Aug_2	2016-08-15	8.5
KLF2	North	Sep	2016-08-30	8.8
KLF2	North	Oct	2016-10-02	11.6
KLF2	North	Nov	2016-10-26	12.2
KLF3	North	Apr	2016-04-11	8.5
KLF3	North	May	2016-05-09	5.5
KLF3	North	Jun	2016-06-06	4.0
KLF3	North	Jun_2	2016-06-20	4.6
KLF3	North	Jul	2016-07-05	4.3
KLF3	North	Aug	2016-08-01	5.5
KLF3	North	Sep	2016-08-30	8.5
KLF3	North	Oct	2016-10-02	10.4
KLF3	North	Nov	2016-10-26	12.2
KLF4	North	Apr	2016-04-11	12.5
KLF4	North	May	2016-05-09	5.8
KLF4	North	Jun	2016-06-06	3.7
KLF4	North	Jun_2	2016-06-20	5.5
KLF4	North	Jul	2016-07-05	3.7
KLF4	North	Aug	2016-08-01	3.4
KLF4	North	Sep	2016-08-30	9.2
KLF4	North	Oct	2016-10-02	12.2
KLF4	North	Nov	2016-10-26	11.0

Station	Arm	Month	Date	Secchi (m)
KL 5	South	Apr	2016-04-11	10.1
KL 5	South	May	2016-05-09	7.3
KL 5	South	Jun	2016-06-06	6.1
KL 5	South	Jun_2	2016-06-20	4.6
KL 5	South	Jul	2016-07-05	5.5
KL 5	South	Aug	2016-08-01	5.5
KL 5	South	Sep	2016-08-30	11.0
KLF5	South	Oct	2016-10-02	12.2
KLF5	South	Nov	2016-10-26	11.6
KLF6	South	Apr	2016-04-11	8.5
KLF6	South	May	2016-05-09	5.5
KLF6	South	Jun	2016-06-06	5.5
KLF6	South	Jun_2	2016-06-20	4.9
KLF6	South	Jul	2016-07-05	5.5
KLF6	South	Jul_2	2016-07-18	5.2
KLF6	South	Aug	2016-08-01	5.8
KLF6	South	Aug_2	2016-08-15	11.0
KLF6	South	Sep	2016-08-30	10.1
KLF6	South	Oct	2016-10-02	12.2
KLF6	South	Nov	2016-10-26	11.3
KLF7	South	Apr	2016-04-11	5.2
KLF7	South	May	2016-05-09	3.4
KLF7	South	Jun	2016-06-06	6.1
KLF7	South	Jun_2	2016-06-20	4.0
KLF7	South	Jul	2016-07-05	4.6
KLF7	South	Aug	2016-08-01	7.6
KLF7	South	Sep	2016-08-30	10.7
KLF7	South	Oct	2016-10-02	11.9
KLF7	South	Nov	2016-10-26	9.2
KLF8	West	Apr	2016-04-11	11.9
KLF8	West	May	2016-05-09	8.5
KLF8	West	Jun	2016-06-06	4.3
KLF8	West	Jun_2	2016-06-20	5.5
KLF8	West	Jul	2016-07-05	5.5
KLF8	West	Aug	2016-08-01	5.5
KLF8	West	Sep	2016-08-30	10.1
KLF8	West	Oct	2016-10-02	9.5
KLF8	West	Nov	2016-10-26	11.9

Appendix 13. Kootenay Lake North (N) Arm water chemistry results in 2016; nitrogen and phosphorus parameters. Depth Category: Int=Integrated (0-20 m), Hypo=Hypolimnion (5m off the bottom). Data not available is noted as: no data. Reportable detection limit (RDL) is 2.0 µg/L for phosphorus measures.

Depth Category	Station	Date sampled	Nitrogen Total (µg/L)	Dissolved Inorganic Nitrogen (µg/L)	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)
Int	KL1	11-Apr-16	215	178	RDL	RDL
Int	KL2	11-Apr-16	220	183	RDL	RDL
Int	KL3	11-Apr-16	213	185	RDL	RDL
Int	KL4	11-Apr-16	219	180	RDL	RDL
Hypo	KL1	9-May-16	259	233	RDL	RDL
Int	KL1	9-May-16	217	188	RDL	RDL
Hypo	KL2	9-May-16	258	240	RDL	RDL
Int	KL2	9-May-16	228	180	RDL	RDL
Hypo	KL3	9-May-16	259	243	2.9	RDL
Int	KL3	9-May-16	204	177	RDL	RDL
Hypo	KL4	9-May-16	267	239	2.8	RDL
Int	KL4	9-May-16	205	161	2.8	RDL
Int	KL1	6-Jun-16	179	120.5	5.0	RDL
Hypo	KL1	6-Jun-16	252	237.9	RDL	RDL
Int	KL2	6-Jun-16	192	128.5	5.0	RDL
Hypo	KL2	6-Jun-16	267	245	RDL	2.5
Int	KL3	6-Jun-16	182	105.5	4.7	RDL
Hypo	KL3	6-Jun-16	259	235	RDL	RDL
Hypo	KL4	6-Jun-16	270	246.9	2.8	3.5
Int	KL4	6-Jun-16	206	106.1	3.4	RDL
Int	KL1	20-Jun-16	166	76.6	2.7	5.4
Int	KL2	20-Jun-16	218	75.9	no data	3.9
Int	KL3	20-Jun-16	175	77.8	3.7	7.5
Int	KL4	20-Jun-16	183	86.2	RDL	3.0
Int	KL1	5-Jul-16	152	69.7	4.2	RDL
Hypo	KL1	5-Jul-16	276	247	2.3	RDL
Int	KL2	5-Jul-16	181	63.3	4.2	RDL
Hypo	KL2	5-Jul-16	260	245.8	3.1	RDL
Int	KL3	5-Jul-16	186	73.7	4.6	RDL
Hypo	KL3	5-Jul-16	275	246	2.6	2.1
Int	KL4	5-Jul-16	167	66.7	4.4	RDL
Hypo	KL4	5-Jul-16	267	248	3.6	RDL
Int	KL2	18-Jul-16	185	95.6	3.3	RDL
Int	KL1	1-Aug-16	140	51.9	5.9	RDL
Hypo	KL1	1-Aug-16	251	232	2.6	RDL
Int	KL2	1-Aug-16	154	64	4.7	RDL
Hypo	KL2	1-Aug-16	276	239	2.2	RDL
Int	KL3	1-Aug-16	190	93.4	5.0	RDL
Hypo	KL3	1-Aug-16	297	248	2.7	RDL

(cont'd)						
Depth Category	**Station**	**Date sampled**	**Nitrogen Total (µg/L)**	**Dissolved Inorganic Nitrogen (µg/L)**	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**
Int	KL4	1-Aug-16	180	56.1	4.3	RDL
Hypo	KL4	1-Aug-16	309	249	3.3	2.6
Int	KL2	15-Aug-16	132	58.5	2.7	RDL
Hypo	KL1	30-Aug-16	268	247	3.5	2.2
Int	KL1	30-Aug-16	239	115.8	4.2	RDL
Hypo	KL2	30-Aug-16	378	248	3.8	RDL
Int	KL2	30-Aug-16	173	126.2	3.5	RDL
Int	KL3	30-Aug-16	162	87.4	4.7	RDL
Hypo	KL3	30-Aug-16	264	246	3.2	2.7
Hypo	KL4	30-Aug-16	291	263	5.3	2.8
Int	KL4	30-Aug-16	291	68.8	3.9	RDL
Hypo	KL1	2-Oct-16	279	252	RDL	2.7
Int	KL1	2-Oct-16	171	114.5	RDL	RDL
Int	KL2	2-Oct-16	179	113.3	RDL	RDL
Hypo	KL2	2-Oct-16	265	245.9	no data	RDL
Hypo	KL3	2-Oct-16	264	243	RDL	2.2
Int	KL3	2-Oct-16	171	109	RDL	RDL
Int	KL4	2-Oct-16	168	111	RDL	2.1
Hypo	KL4	2-Oct-16	261	241	RDL	RDL
Int	KL1	26-Oct-16	310	129.3	no data	RDL
Int	KL2	26-Oct-16	174	130.5	2.2	RDL
Int	KL3	26-Oct-16	183	131.7	2.6	RDL
Int	KL4	26-Oct-16	180	131	RDL	RDL

Appendix 14. Kootenay Lake South (KLF 1–7) and West (KLF 8) Arm water chemistry results in 2016; nitrogen and phosphorus parameters. Depth Category: Int = Integrated (0–20 m), Hypo = Hypolimnion (5 m off the bottom). Data not available is noted as: no data. Reportable detection limit (RDL) is 2.

Depth Category	Station	Date sampled	Nitrogen Total (µg/L)	Dissolved Inorganic Nitrogen (µg/L)	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)
Int	KL7	11-Apr-16	237	178	2.9	2.0
Int	KL5	11-Apr-16	224	187	2.0	2.0
Int	KL6	11-Apr-16	227	189	2.0	2.0
Int	KL8	11-Apr-16	215	178	2.0	2.0
Hypo	KL6	9-May-16	271	239	2.6	2.0
Hypo	KL7	9-May-16	252	235	2.2	2.0
Hypo	KL5	9-May-16	248	234	2.0	2.0
Int	KL5	9-May-16	292	155	2.0	2.0
Int	KL6	9-May-16	197	148	2.0	2.0
Int	KL7	9-May-16	194	125	2.0	2.0
Int	KL8	9-May-16	203	156	2.0	2.0
Hypo	KL6	6-Jun-16	254	244.4	3.5	3.5
Int	KL6	6-Jun-16	194	113.7	3.4	2.0
Hypo	KL5	6-Jun-16	265	227	2.5	3.1
Hypo	KL7	6-Jun-16	268	232	2.4	2.0
Int	KL7	6-Jun-16	189	122.4	3.0	2.0
Int	KL8	6-Jun-16	179	96	3.2	2.0
Int	KL5	6-Jun-16	171	108.9	2.1	2.0
Int	KL6	20-Jun-16	195	115.1	2.0	9.1
Int	KL5	20-Jun-16	205	104.2	2.0	3.7
Int	KL7	20-Jun-16	243	120.8	2.0	3.4
Int	KL8	20-Jun-16	230	103.5	2.0	4.4
Hypo	KL5	5-Jul-16	280	254	5.0	3.9
Hypo	KL7	5-Jul-16	276	247	4.8	2.4
Hypo	KL6	5-Jul-16	285	257	4.0	4.3
Int	KL5	5-Jul-16	181	83.3	3.9	2.0
Int	KL6	5-Jul-16	183	87.5	3.7	2.0
Int	KL7	5-Jul-16	182	70.8	3.5	2.0
Int	KL8	5-Jul-16	164	56	2.2	2.0
Int	KL6	18-Jul-16	173	75.9	3.1	2.0
Hypo	KL6	1-Aug-16	283	256	4.2	3.3
Int	KL5	1-Aug-16	140	52.5	9.7	2.0
Hypo	KL5	1-Aug-16	312	246	3.4	2.5
Int	KL8	1-Aug-16	124	26.4	4.6	2.0
Int	KL7	1-Aug-16	141	58.2	3.5	2.0
Int	KL6	1-Aug-16	145	42	3.3	2.0
Hypo	KL7	1-Aug-16	247	237	2.3	2.2
Int	KL6	15-Aug-16	166	82.5	2.0	2.0
Hypo	KL6	30-Aug-16	300	267	5.3	4.7

(cont'd)

Depth Category	Station	Date sampled	Nitrogen Total (µg/L)	Dissolved Inorganic Nitrogen (µg/L)	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)
Hypo	KL5	30-Aug-16	271	255	4.6	3.6
Int	KL6	30-Aug-16	172	79.9	2.6	2.2
Hypo	KL7	30-Aug-16	260	243	3.6	3.7
Int	KL7	30-Aug-16	254	85.7	3.9	2.0
Int	KL8	30-Aug-16	184	65.4	3.5	2.0
Int	KL5	30-Aug-16	160	77.6	2.7	2.0
Int	KL5	2-Oct-16	183	118.5	5.0	2.0
Hypo	KL6	2-Oct-16	304	262	2.1	5.0
Int	KL7	2-Oct-16	209	118.7	2.3	2.0
Int	KL8	2-Oct-16	178	107.8	2.5	2.0
Hypo	KL5	2-Oct-16	270	247	2.0	3.1
Hypo	KL7	2-Oct-16	264	242	2.0	2.8
Int	KL6	2-Oct-16	198	116.5	2.0	2.0
Int	KL7	26-Oct-16	230	140	2.0	no data
Int	KL8	26-Oct-16	193	134.4	2.0	no data
Int	KL5	26-Oct-16	193	135.1	2.3	2.0
Int	KL6	26-Oct-16	192	135	2.0	2.0

Appendix 15. Other parameters (excluding nitrogen and phosphorus) from Kootenay Lake North Arm water chemistry results from 2016. Depth Category: Int = Integrated (0-20m), Hypo = Hypolimnion (5m off the bottom).

Depth Category	Station	Date sampled	Alkalinity (mg/L)	Total Inorganic Carbon (mg/L)	Total Organic Carbon (mg/L)	Silica (mg/L)	Turbidity (NTU)	pH
Int	KL1	11-Apr-16	64	15.7	1.3	4.6	0.3	8.0
Int	KL2	11-Apr-16	65	16.4	0.8	4.4	0.3	8.0
Int	KL3	11-Apr-16	66	16.6	1.2	4.5	0.2	8.0
Int	KL4	11-Apr-16	69	17.0	1.4	4.7	0.2	8.0
Hypo	KL1	9-May-16	71	19.3	1.3	5.3	0.3	7.9
Int	KL1	9-May-16	58	15.1	1.2	4.4	0.7	8.0
Hypo	KL2	9-May-16	74	19.4	1.3	5.6	0.3	8.0
Int	KL2	9-May-16	59	15.8	1.2	4.5	0.4	8.0
Hypo	KL3	9-May-16	75	20.1	1.5	5.7	0.2	8.0
Int	KL3	9-May-16	62	16.4	1.5	4.5	0.4	8.0
Hypo	KL4	9-May-16	77	20.1	1.6	5.4	0.3	8.1
Int	KL4	9-May-16	61	16.1	1.2	4.5	0.6	8.0
Int	KL1	6-Jun-16	60	13.3	1.3	3.9	0.5	8.0
Hypo	KL1	6-Jun-16	76	17.3	1.2	5.3	0.2	7.9
Int	KL2	6-Jun-16	63	14.2	1.4	4.3	0.5	8.0
Hypo	KL2	6-Jun-16	79	17.9	1.2	5.7	0.2	7.9
Int	KL3	6-Jun-16	61	13.7	1.4	3.9	0.6	8.1
Hypo	KL3	6-Jun-16	79	17.9	1.4	5.5	0.2	8.0
Hypo	KL4	6-Jun-16	81	18.2	1.3	5.7	0.3	8.0
Int	KL4	6-Jun-16	63	14.3	1.6	4.2	0.6	8.0
Int	KL1	20-Jun-16						
Int	KL2	20-Jun-16						
Int	KL3	20-Jun-16						
Int	KL4	20-Jun-16						
Int	KL1	5-Jul-16	53	12.3	1.5	3.0	0.6	8.1
Hypo	KL1	5-Jul-16	72	17.4	1.3	5.4	0.2	7.9
Int	KL2	5-Jul-16	56	13.2	1.4	2.9	0.7	8.1
Hypo	KL2	5-Jul-16	73	18.0	1.6	5.5	0.2	8.0
Int	KL3	5-Jul-16	58	13.5	1.4	3.1	0.7	8.1
Hypo	KL3	5-Jul-16	75	18.1	1.4	5.6	0.2	8.0
Int	KL4	5-Jul-16	60	14.1	1.6	3.2	0.7	8.1
Hypo	KL4	5-Jul-16	75	18.1	1.4	5.4	0.2	8.1
Int	KL2	18-Jul-16						
Int	KL1	1-Aug-16	54	13.3	1.6	2.3	0.8	7.9
Hypo	KL1	1-Aug-16	70	17.2	1.4	5.1	0.3	7.6
Int	KL2	1-Aug-16	55	13.3	1.6	2.3	0.9	7.8
Hypo	KL2	1-Aug-16	73	18.3	1.4	5.3	0.1	7.7
Int	KL3	1-Aug-16	57	14.2	1.6	2.9	0.7	7.8
Hypo	KL3	1-Aug-16	74	18.7	1.4	5.8	0.2	7.8
Int	KL4	1-Aug-16	57	13.8	1.6	2.4	0.7	7.9

(cont'd)

Depth Category	Station	Date sampled	Alkalinity (mg/L)	Total Inorganic Carbon (mg/L)	Total Organic Carbon (mg/L)	Silica (mg/L)	Turbidity (NTU)	pH
Hypo	KL4	1-Aug-16	75	18.6	1.3	6.0	0.2	7.8
Int	KL2	15-Aug-16						
Hypo	KL1	30-Aug-16	76	17.0	1.0	5.4	0.2	7.9
Int	KL1	30-Aug-16	56	12.6	1.1	2.9	0.3	7.8
Hypo	KL2	30-Aug-16	79	17.7	1.4	5.5	0.2	8.0
Int	KL2	30-Aug-16	61	13.6	1.3	2.7	0.3	7.9
Int	KL3	30-Aug-16	59	13.1	1.1	2.2	0.3	7.9
Hypo	KL3	30-Aug-16	80	17.4	1.2	5.5	0.2	8.0
Hypo	KL4	30-Aug-16	81	17.8	1.3	6.2	0.2	8.0
Int	KL4	30-Aug-16	62	13.6	1.3	2.1	0.3	8.0
Hypo	KL1	2-Oct-16	73	16.6	1.3	5.5	0.2	7.8
Int	KL1	2-Oct-16	59	13.1	1.2	2.9	0.3	7.9
Int	KL2	2-Oct-16	64	14.0	1.5	3.0	0.3	7.9
Hypo	KL2	2-Oct-16	75	16.3	1.3	5.2	0.2	7.9
Hypo	KL3	2-Oct-16	75	16.6	1.4	5.2	0.2	7.9
Int	KL3	2-Oct-16	66	14.8	1.3	2.9	0.3	7.9
Int	KL4	2-Oct-16	67	15.0	1.6	3.0	0.2	8.0
Hypo	KL4	2-Oct-16	77	17.4	1.5	5.3	0.2	7.9
Int	KL1	26-Oct-16	60	14.2	1.3	3.3	0.2	8.0
Int	KL2	26-Oct-16	62	14.8	1.4	3.2	0.2	8.0
Int	KL3	26-Oct-16	63	15.1	1.4	3.2	0.2	8.0
Int	KL4	26-Oct-16	65	15.6	1.8	3.4	0.2	8.0

Appendix 16. Other water chemistry parameters (excluding mitrogen and phosphorus) from Kootenay Lake South (KLF 1–7) and West (KLF 8) Arms in 2016. Depth Category: Int = Integrated (0-20m), Hypo = Hypolimnion (5m off the bottom).

Depth Category	Station	Date sampled	Alkalinity (mg/L)	Total Inorganic Carbon (mg/L)	Total Organic Carbon (mg/L)	Silica (mg/L)	Turbi dity (NTU)	pH
Int	KL5	11-Apr-16	72	17.9	1.3	4.7	0.2	8.1
Int	KL6	11-Apr-16	73	17.7	1.2	5.0	0.3	8.1
Int	KL7	11-Apr-16	73	18.2	1.5	5.6	0.6	8.1
Int	KL8	11-Apr-16	71	17.4	1.0	4.8	0.2	8.1
Hypo	KL5	9-May-16	77	20.6	1.4	5.2	0.2	8.1
Int	KL5	9-May-16	67	17.7	1.4	4.8	0.3	8.1
Hypo	KL6	9-May-16	78	19.3	1.5	5.5	0.3	8.1
Int	KL6	9-May-16	67	17.8	1.4	5.0	0.5	8.1
Hypo	KL7	9-May-16	78	20.5	1.3	5.5	0.3	8.1
Int	KL7	9-May-16	65	17.3	1.9	5.4	0.7	8.1
Int	KL8	9-May-16	68	18.0	1.4	5.0	0.3	8.1
Hypo	KL5	6-Jun-16	81	18.2	1.3	5.4	0.2	8.1
Int	KL5	6-Jun-16	69	15.2	1.7	4.7	0.5	8.1
Hypo	KL6	6-Jun-16	79	18.4	1.4	5.5	0.2	7.9
Int	KL6	6-Jun-16	70	15.4	1.6	4.9	0.5	8.1
Hypo	KL7	6-Jun-16	78	18.1	1.3	5.3	0.2	7.9
Int	KL7	6-Jun-16	70	16.0	1.7	5.0	0.6	8.1
Int	KL8	6-Jun-16	64	14.5	1.3	4.1	0.6	8.2
Int	KL5	20-Jun-16						
Int	KL6	20-Jun-16						
Int	KL7	20-Jun-16						
Int	KL8	20-Jun-16						
Hypo	KL5	5-Jul-16	79	18.6	1.4	6.0	0.2	8.1
Int	KL5	5-Jul-16	64	15.1	1.8	3.7	0.5	8.1
Hypo	KL6	5-Jul-16	79	18.7	1.3	6.2	0.2	8.1
Int	KL6	5-Jul-16	66	15.5	2.0	3.6	0.6	8.2
Hypo	KL7	5-Jul-16	78	18.4	1.4	5.8	0.2	8.1
Int	KL7	5-Jul-16	69	15.9	2.1	3.6	0.7	8.2
Int	KL8	5-Jul-16	60	14.4	1.6	2.9	0.6	8.2
Int	KL6	18-Jul-16						
Int	KL5	1-Aug-16	61	14.8	1.8	2.3	0.7	8.0
Hypo	KL5	1-Aug-16	77	18.8	1.3	5.7	0.2	7.9
Hypo	KL6	1-Aug-16	78	19.1	1.4	6.3	0.2	7.8
Int	KL6	1-Aug-16	63	15.1	1.7	2.3	0.6	8.0
Int	KL7	1-Aug-16	71	17.3	1.8	2.7	0.5	8.0
Hypo	KL7	1-Aug-16	77	18.4	1.4	5.4	0.2	7.9
Int	KL8	1-Aug-16	62	14.5	1.8	2.0	0.6	8.1
Int	KL6	15-Aug-16						
Hypo	KL5	30-Aug-16	83	18.0	1.2	5.9	0.2	8.0

(cont'd)

Depth Category	Station	Date sampled	Alkalinity (mg/L)	Total Inorganic Carbon (mg/L)	Total Organic Carbon (mg/L)	Silica (mg/L)	Turbi dity (NTU)	pH
Int	KL5	30-Aug-16	72	15.2	2.0	2.4	0.3	8.1
Hypo	KL6	30-Aug-16	83	18.2	1.3	6.4	0.2	7.9
Int	KL6	30-Aug-16	73	15.8	1.3	2.5	0.3	7.9
Hypo	KL7	30-Aug-16	82	18.2	1.5	5.5	0.2	7.9
Int	KL7	30-Aug-16	76	16.9	1.7	2.8	0.2	8.0
Int	KL8	30-Aug-16	68	14.9	1.5	2.4	0.3	8.0
Int	KL5	2-Oct-16	71	15.9	1.8	3.1	0.3	8.0
Hypo	KL5	2-Oct-16	81	18.2	1.6	5.7	0.2	8.0
Hypo	KL6	2-Oct-16	82	18.6	1.4	6.2	0.3	8.0
Int	KL6	2-Oct-16	74	16.7	1.8	3.2	0.2	8.0
Int	KL7	2-Oct-16	76	17.2	1.5	3.2	0.3	8.1
Hypo	KL7	2-Oct-16	81	18.1	1.5	5.5	0.2	8.0
Int	KL8	2-Oct-16	68	15.4	1.6	3.0	0.3	8.0
Int	KL5	26-Oct-16	70	16.5	1.5	3.4	0.2	8.0
Int	KL6	26-Oct-16	71	17.0	1.4	3.6	0.2	8.0
Int	KL7	26-Oct-16	73	17.2	1.6	3.8	0.2	8.1
Int	KL8	26-Oct-16	68	16.3	1.5	3.6	0.2	8.0

Appendix 17. Kootenay Lake North (N) and South (S) Arm discrete water chemistry results - 2016.

DepthCat	Station	Arm	Depth	Month	Date Sampled	Ammonia, Total (as N)	Nitrate (as N)	Nitrite (as N)	Nitrate and Nitrite (as N)	Total Nitrogen	Orthophosphate-Dissolved (as P)	Phosphorus (P)-Total Dissolved	Phosphorus (P)-Total	Dissolved Inorganic Nitrogen	Nitrogen/Phosphorus	Ammonia, Total (as N)	Nitrite (as N)	Orthophosphate-Dissolved (as P)	Phosphorus (P)-Total Dissolved	Phosphorus (P)-Total
					RDL:	**5**	**3**	**1**	**4**	**30**	**1**	**2**	**2**			**<RDL?**	**<RDL?**	**<RDL?**	**<RDL?**	**<RDL?**
					Units:	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**DIN/TDP**	**Y/N**	**Y/N**	**Y/N**	**Y/N**	**Y/N**
D	KLF2	N	2	Jun	6-Jun-2016	16.1	80	3.3	83.2	172	1.0	2.0	7.1	99	50	N	N	Y	Y	N
D	KLF2	N	5	Jun	6-Jun-2016	5.0	112	1.0	113.0	190	1.0	2.0	5.7	118	59	Y	Y	Y	Y	N
D	KLF2	N	10	Jun	6-Jun-2016	7.1	133	3.0	136.0	194	1.0	2.0	4.6	143	72	N	N	Y	Y	N
D	KLF2	N	15	Jun	6-Jun-2016	7.1	140	1.0	141.0	201	1.0	2.0	2.0	148	74	N	N	Y	Y	Y
D	KLF2	N	20	Jun	6-Jun-2016	9.7	151	1.0	152.0	226	1.0	2.0	2.0	162	81	N	Y	Y	Y	Y
D	KLF6	S	2	Jun	6-Jun-2016	5.0	96	1.0	97.1	188	1.0	2.0	2.0	102	51	Y	Y	Y	Y	Y
D	KLF6	S	5	Jun	6-Jun-2016	5.0	93	1.7	94.6	198	1.0	2.0	4.9	100	50	Y	N	Y	Y	N
D	KLF6	S	10	Jun	6-Jun-2016	5.0	91	1.0	91.7	181	1.0	2.0	2.0	97	48	Y	Y	Y	Y	Y
D	KLF6	S	15	Jun	6-Jun-2016	5.0	120	1.0	121.0	197	1.0	2.0	2.0	126	63	Y	Y	Y	Y	Y
D	KLF6	S	20	Jun	6-Jun-2016	5.0	141	1.5	142.5	209	1.0	2.0	2.0	148	74	Y	N	Y	Y	Y
D	KLF2	N	2	Jul	5-Jul-2016	5.0	31	1.3	31.8	131	1.0	2.0	4.6	37	18	Y	N	Y	Y	N
D	KLF2	N	5	Jul	5-Jul-2016	5.0	34	1.3	35.2	143	1.0	2.0	4.7	40	20	Y	N	Y	Y	N
D	KLF2	N	10	Jul	5-Jul-2016	5.0	55	1.4	56.6	179	1.0	2.0	4.6	62	31	Y	N	Y	Y	N
D	KLF2	N	15	Jul	5-Jul-2016	5.7	76	2.0	77.8	347	1.0	2.0	3.3	84	42	N	N	Y	Y	N
D	KLF2	N	20	Jul	5-Jul-2016	9.6	87	2.5	89.4	186	1.0	2.0	3.4	99	50	N	N	Y	Y	N
D	KLF6	S	2	Jul	5-Jul-2016	5.2	60	1.0	60.5	176	1.0	2.0	2.0	66	33	N	Y	Y	Y	Y
D	KLF6	S	5	Jul	5-Jul-2016	5.0	59	1.0	60.4	187	1.0	2.0	2.4	65	33	Y	Y	Y	Y	N
D	KLF6	S	10	Jul	5-Jul-2016	5.0	60	1.1	61.1	178	1.0	2.0	2.1	66	33	Y	N	Y	Y	N
D	KLF6	S	15	Jul	5-Jul-2016	12.9	99	2.3	100.8	205	1.0	2.0	3.5	114	57	N	N	Y	Y	N
D	KLF6	S	20	Jul	5-Jul-2016	15.7	118	7.0	125.0	209	1.0	2.0	3.5	141	70	N	N	Y	Y	N
D	KLF2	N	2	Aug	1-Aug-2016	5.0	9	1.0	10.1	112	1.0	2.0	3.6	15	8	Y	Y	Y	Y	N
D	KLF2	N	5	Aug	1-Aug-2016	5.0	11	1.0	12.2	121	1.0	2.0	3.9	17	9	Y	Y	Y	Y	N
D	KLF2	N	10	Aug	1-Aug-2016	5.8	65	1.5	66.5	150	1.0	2.0	3.5	72	36	N	N	Y	Y	N

(cont'd)

DepthCat	Station	Arm	Depth	Month	Date Sampled	Ammonia, Total (as N)	Nitrate (as N)	Nitrite (as N)	Nitrate and Nitrite (as N)	Total Nitrogen	Orthophosphate-Dissolved (as P)	Phosphorus (P)-Total Dissolved	Phosphorus (P)-Total	Dissolved Inorganic Nitrogen	Nitrogen/ Phosphorus	Ammonia, Total (as N)	Nitrite (as N)	Orthophosphate-Dissolved (as P)	Phosphorus (P)-Total Dissolved	Phosphorus (P)-Total
D	KLF2	N	15	Aug	1-Aug-2016	5.0	120	1.0	121.0	192	1.0	2.0	3.8	126	63	Y	Y	Y	Y	N
D	KLF2	N	20	Aug	1-Aug-2016	5.0	161	1.0	162.0	229	1.0	2.0	3.6	167	84	Y	Y	Y	Y	N
D	KLF6	S	2	Aug	1-Aug-2016	7.2	28	1.1	29.1	128	1.0	2.0	3.2	36	18	N	N	Y	Y	N
D	KLF6	S	5	Aug	1-Aug-2016	7.0	29	1.1	29.6	140	1.0	2.0	3.5	37	18	N	N	Y	Y	N
D	KLF6	S	10	Aug	1-Aug-2016	6.6	29	1.0	30.1	147	1.0	2.0	2.9	37	18	N	Y	Y	Y	N
D	KLF6	S	15	Aug	1-Aug-2016	6.7	30	1.1	30.9	161	1.0	2.0	2.7	38	19	N	N	Y	Y	N
D	KLF6	S	20	Aug	1-Aug-2016	7.6	85	1.5	86.9	182	1.0	2.0	3.0	95	47	N	N	Y	Y	N
D	KLF2	N	2	Sep	30-Aug-2016	11.5	62	1.0	62.6	183	1.0	2.0	4.9	74	37	N	Y	Y	Y	N
D	KLF2	N	5	Sep	30-Aug-2016	11.0	70	1.0	71.1	356	1.0	2.0	4.9	82	41	N	Y	Y	Y	N
D	KLF2	N	10	Sep	30-Aug-2016	7.5	99	1.0	100.2	164	1.0	2.0	4.4	108	54	N	Y	Y	Y	N
D	KLF2	N	15	Sep	30-Aug-2016	5.0	160	1.0	161.0	208	1.0	2.0	3.9	166	83	Y	Y	Y	Y	N
D	KLF2	N	20	Sep	30-Aug-2016	5.0	195	1.0	196.0	238	1.0	2.0	3.5	201	101	Y	Y	Y	Y	N
D	KLF6	S	2	Sep	30-Aug-2016	12.4	62	1.1	62.7	170	1.0	2.0	4.5	75	38	N	N	Y	Y	N
D	KLF6	S	5	Sep	30-Aug-2016	12.1	62	1.0	63.0	149	1.0	2.0	2.8	75	38	N	N	Y	Y	N
D	KLF6	S	10	Sep	30-Aug-2016	12.6	64	1.1	65.4	158	1.0	2.0	2.6	78	39	N	N	Y	Y	N
D	KLF6	S	15	Sep	30-Aug-2016	12.0	69	1.3	70.2	152	1.0	2.0	3.6	82	41	N	N	Y	Y	N
D	KLF6	S	20	Sep	30-Aug-2016	8.5	97	1.6	98.5	173	1.0	2.0	2.6	107	54	N	N	Y	Y	N

Appendix 18. Kootenay phytoplankton Integrated (0-20 m) results - 2016; Abundance (cells/mL) and biovolume (mm^3/L). Arm N=North, S=South, W=West. Class: Bac= Bacillariophyte (Diatoms), ChrCry= Chryso- & Cryptophyte (Flagellates), Din= Dinophyte (Dinoflagellates), Chl= Chlorophyte (Coccoid Greens, Desmids, etc.) and Cya= Cyanophyte (Blue-greens). Edible or inedible to zooplankton (see appendix 12).

				Abundance (cells/mL)								Biovolume (mm^3/L)							
Station	Arm	Month	Date	Bac	ChrCry	Din	Chl	Cya	Total	Edible	Inedible	Bac	ChrCry	Din	Chl	Cya	Total	Edible	Inedible
KLF 1	N	Apr	2016-04-11	334.5	740.0	10.1	81.1	182.5	1348.2	1267.1	81.1	0.022	0.084	0.005	0.009	0.003	0.123	0.115	0.008
KLF 2	N	Apr	2016-04-11	273.7	577.8	20.3	141.9	223.0	1236.7	1145.5	91.2	0.025	0.067	0.010	0.017	0.003	0.121	0.108	0.014
KLF 3	N	Apr	2016-04-11	141.9	689.3	10.1	111.5	182.5	1135.3	1064.4	71.0	0.015	0.071	0.005	0.009	0.003	0.103	0.092	0.011
KLF 4	N	Apr	2016-04-11	364.9	689.3	20.3	152.1	202.7	1429.3	1145.5	283.8	0.058	0.100	0.010	0.020	0.003	0.191	0.138	0.054
KLF 5	S	Apr	2016-04-11	435.9	1104.9	20.3	253.4	233.2	2047.7	1946.3	101.4	0.033	0.127	0.010	0.017	0.002	0.190	0.176	0.014
KLF 6	S	Apr	2016-04-11	223.0	1246.8	20.3	182.5	182.5	1855.0	1692.9	162.2	0.027	0.138	0.010	0.026	0.012	0.213	0.181	0.032
KLF 7	S	Apr	2016-04-11	476.4	1297.5	10.1	111.5	202.7	2098.3	1824.6	273.7	0.073	0.174	0.005	0.015	0.008	0.274	0.213	0.062
KLF 8	W	Apr	2016-04-11	294.0	1054.2	20.3	71.0	141.9	1581.4	1459.7	121.7	0.046	0.127	0.010	0.010	0.002	0.195	0.165	0.031
KLF 1	N	May	2016-05-09	212.9	1398.9	10.1	182.5	364.9	2169.3	2067.9	101.4	0.034	0.130	0.005	0.025	0.006	0.200	0.174	0.026
KLF 2	N	May	2016-05-09	395.4	1236.7	20.3	192.6	395.3	2240.3	1966.6	273.7	0.046	0.143	0.010	0.030	0.007	0.236	0.197	0.039
KLF 3	N	May	2016-05-09	699.4	2290.9	20.3	324.4	304.1	3639.1	3294.5	334.5	0.074	0.301	0.020	0.039	0.005	0.439	0.374	0.049
KLF 4	N	May	2016-05-09	537.2	1703.0	20.3	243.3	283.8	2787.6	2432.9	334.5	0.067	0.223	0.020	0.029	0.004	0.344	0.275	0.048
KLF 5	S	May	2016-05-09	729.9	2949.8	10.1	395.3	243.3	4328.5	3791.2	517.0	0.095	0.294	0.005	0.042	0.004	0.440	0.350	0.080
KLF 6	S	May	2016-05-09	952.9	2199.7	30.4	304.1	243.3	3730.4	3000.5	699.5	0.122	0.284	0.025	0.042	0.009	0.481	0.357	0.099
KLF 7	S	May	2016-05-09	1338.1	2169.3	20.3	375.1	344.7	4247.4	3183.0	1044.1	0.230	0.296	0.020	0.044	0.010	0.601	0.371	0.209
KLF 8	W	May	2016-05-09	496.7	1571.2	50.7	192.6	182.5	2493.7	2149.0	314.2	0.095	0.197	0.046	0.020	0.003	0.360	0.242	0.082
KLF 1	N	Jun	2016-06-06	6730.9	3274.2	20.3	202.7	172.3	10400.4	5433.4	4967.1	0.866	0.655	0.009	0.032	0.003	1.565	0.915	0.649
KLF 2	N	Jun	2016-06-06	2949.8	2098.3	30.4	121.6	182.5	5382.7	3183.0	2189.6	0.378	0.360	0.024	0.012	0.007	0.782	0.479	0.288
KLF 3	N	Jun	2016-06-06	4267.6	2422.7	30.4	263.6	162.2	7146.5	4450.1	2686.3	0.588	0.294	0.025	0.087	0.007	1.001	0.580	0.406
KLF 4	N	Jun	2016-06-06	3426.3	1540.8	50.7	172.3	202.8	5392.8	3112.0	2260.5	0.458	0.236	0.034	0.055	0.008	0.791	0.441	0.330
KLF 5	S	Jun	2016-06-06	4348.7	1530.7	20.3	172.3	131.8	6203.8	3071.5	3112.0	0.649	0.302	0.020	0.038	0.007	1.016	0.505	0.490
KLF 6	S	Jun	2016-06-06	3649.3	1520.5	20.3	141.9	202.7	5534.7	2899.1	2625.5	0.566	0.177	0.020	0.012	0.013	0.788	0.321	0.453
KLF 7	S	Jun	2016-06-06	1885.5	1074.5	10.1	91.2	172.3	3233.7	1926.0	1297.5	0.282	0.182	0.015	0.017	0.008	0.503	0.280	0.208
KLF 8	W	Jun	2016-06-06	1439.5	1682.7	20.3	314.2	141.9	3598.6	2858.6	719.7	0.230	0.307	0.009	0.120	0.002	0.668	0.441	0.216
KLF 1	N	Jun_2	2016-06-20	5200.2	1348.2	60.8	263.6	212.9	7085.7	4075.0	2970.1	0.726	0.102	0.069	0.034	0.003	0.934	0.404	0.469

(cont'd)

Station	Arm	Month	Date	Bac	ChrCry	Din	Chl	Cya	Total	Edible	Inedible	Bac	ChrCry	Din	Chl	Cya	Total	Edible	Inedible
KLF2	N	Jun_2	2016-06-20	5159.7	1216.4	30.4	202.7	253.4	6862.7	3679.7	3162.7	0.831	0.127	0.025	0.028	0.009	1.019	0.414	0.588
KLF3	N	Jun_2	2016-06-20	6031.5	1804.4	30.4	273.7	294.0	8433.9	3852.0	4531.2	0.858	0.203	0.025	0.079	0.034	1.199	0.431	0.698
KLF4	N	Jun_2	2016-06-20	4571.7	1936.2	40.6	375.1	283.8	7207.4	3882.5	3264.1	0.593	0.256	0.029	0.087	0.014	0.979	0.460	0.445
KLF5	S	Jun_2	2016-06-20	5230.6	1814.5	30.4	233.2	212.9	7521.5	3831.8	3679.7	0.764	0.170	0.025	0.024	0.008	0.990	0.417	0.558
KLF6	S	Jun_2	2016-06-20	6436.9	2463.3	20.3	415.6	334.5	9670.6	5666.5	3993.9	0.961	0.355	0.009	0.047	0.009	1.381	0.735	0.640
KLF7	S	Jun_2	2016-06-20	5210.4	1277.3	20.3	223.0	364.9	7095.8	3091.8	3963.5	0.666	0.160	0.020	0.073	0.039	0.958	0.379	0.509
KLF8	S	Jun_2	2016-06-20	4592.0	1703.0	20.3	212.9	294.0	6822.2	3943.3	2868.8	0.668	0.211	0.020	0.018	0.024	0.941	0.485	0.441
KLF1	N	Jul	2016-07-05	4095.3	892.0	20.3	202.7	182.5	5392.8	1814.5	3547.9	0.537	0.087	0.020	0.075	0.022	0.740	0.207	0.508
KLF2	N	Jul	2016-07-05	4896.1	1338.1	20.3	202.7	202.7	6659.9	2270.7	4358.9	0.683	0.167	0.020	0.070	0.028	0.968	0.279	0.663
KLF3	N	Jul	2016-07-05	6122.7	1713.1	10.1	192.6	263.6	8302.2	2848.5	5433.4	0.808	0.157	0.005	0.051	0.043	1.065	0.293	0.742
KLF4	N	Jul	2016-07-05	4855.6	1368.5	10.1	91.2	212.9	6538.3	1956.4	4571.7	0.643	0.144	0.005	0.010	0.037	0.840	0.203	0.632
KLF5	S	Jul	2016-07-05	5372.6	1287.4	20.3	152.1	131.8	6964.1	2351.8	4571.7	0.918	0.159	0.020	0.066	0.017	1.179	0.294	0.834
KLF6	S	Jul	2016-07-05	5980.8	1540.8	10.1	172.3	202.7	7906.8	3750.6	4146.0	0.953	0.133	0.005	0.037	0.018	1.146	0.415	0.726
KLF7	S	Jul	2016-07-05	3912.8	983.3	20.3	212.9	192.6	5321.9	2078.1	3223.5	0.524	0.099	0.020	0.037	0.017	0.697	0.223	0.454
KLF8	W	Jul	2016-07-05	5027.9	810.9	10.1	294.0	202.7	6345.7	1794.2	4541.3	0.834	0.114	0.005	0.054	0.003	1.010	0.232	0.773
KLF2	N	Jul_2	2016-07-18	13887.6	527.1	10.1	121.6	121.6	14668.1	1490.1	13178.0	1.868	0.051	0.005	0.019	0.036	1.979	0.185	1.793
KLF6	S	Jul_2	2016-07-18	9964.6	506.8	10.1	101.4	141.9	10724.8	1419.2	9305.7	1.448	0.047	0.005	0.019	0.031	1.550	0.175	1.375
KLF1	N	Aug	2016-08-01	1104.9	567.7	30.4	91.2	162.2	1956.4	1064.4	881.9	0.143	0.054	0.071	0.015	0.027	0.310	0.109	0.185
KLF2	N	Aug	2016-08-01	5129.3	679.2	30.4	202.7	131.8	6173.4	1530.7	4632.6	0.703	0.070	0.071	0.024	0.022	0.891	0.164	0.711
KLF3	N	Aug	2016-08-01	4875.9	547.4	30.4	172.3	182.5	5808.5	1449.6	4358.9	0.688	0.067	0.107	0.017	0.028	0.906	0.162	0.744
KLF4	N	Aug	2016-08-01	4987.4	800.8	20.3	162.2	162.2	6132.9	1753.7	4379.2	0.685	0.059	0.056	0.023	0.027	0.850	0.169	0.681
KLF5	S	Aug	2016-08-01	4217.0	851.5	20.3	263.6	182.5	5534.8	1966.6	3558.1	0.598	0.073	0.066	0.049	0.018	0.803	0.193	0.595
KLF6	S	Aug	2016-08-01	1966.6	689.3	20.3	172.3	152.1	3000.5	1358.4	1632.0	0.263	0.048	0.020	0.019	0.012	0.363	0.118	0.230
KLF7	S	Aug	2016-08-01	1844.9	699.5	20.3	405.5	162.2	3132.3	1561.1	1550.9	0.232	0.062	0.020	0.096	0.013	0.423	0.201	0.202
KLF8	W	Aug	2016-08-01	3852.0	760.3	30.4	233.2	162.2	5038.0	1986.8	3041.1	0.628	0.092	0.024	0.050	0.007	0.802	0.259	0.528
KLF2	N	Aug_2	2016-08-15	1287.4	354.8	40.5	91.2	101.4	1875.3	800.8	1044.1	0.183	0.034	0.112	0.019	0.006	0.354	0.086	0.253
KLF6	S	Aug_2	2016-08-15	983.3	223.0	10.1	71.0	101.4	1388.8	557.5	821.1	0.138	0.018	0.005	0.014	0.011	0.186	0.050	0.130
KLF1	N	Sep	2016-08-30	598.1	547.4	0.0	283.8	354.8	1784.1	1003.5	729.9	0.069	0.056	0.000	0.056	0.093	0.274	0.117	0.151
KLF2	N	Sep	2016-08-30	253.4	740.0	20.3	131.8	334.5	1480.0	1104.9	324.4	0.045	0.074	0.020	0.015	0.092	0.246	0.109	0.118

(cont'd)

Station	Arm	Month	Date	Bac	ChrCry	Din	Chl	Cya	Total	Edible	Inedible	Bac	ChrCry	Din	Chl	Cya	Total	Edible	Inedible
KLF 3	N	Sep	2016-08-30	304.1	486.6	0.0	152.1	294.0	1236.7	800.8	395.3	0.046	0.076	0.000	0.031	0.062	0.215	0.111	0.100
KLF 4	N	Sep	2016-08-30	91.2	628.5	10.1	243.3	324.4	1297.5	1094.8	162.2	0.026	0.093	0.005	0.044	0.067	0.235	0.149	0.082
KLF 5	S	Sep	2016-08-30	50.7	283.8	10.1	81.1	192.6	618.4	476.4	101.4	0.006	0.027	0.005	0.006	0.045	0.089	0.043	0.043
KLF 6	S	Sep	2016-08-30	223.0	871.8	0.0	111.5	354.8	1561.1	1186.0	294.0	0.024	0.077	0.000	0.018	0.089	0.209	0.107	0.093
KLF 7	S	Sep	2016-08-30	101.4	577.8	20.3	121.7	182.5	1003.6	871.8	91.2	0.016	0.062	0.010	0.023	0.016	0.127	0.090	0.033
KLF 8	W	Sep	2016-08-30	111.5	892.1	10.1	152.1	223.0	1388.7	1206.3	131.8	0.023	0.063	0.005	0.018	0.032	0.140	0.091	0.044
KLF 1	N	Oct	2016-10-02	243.3	486.6	10.1	152.1	263.6	1155.6	811.0	334.5	0.034	0.022	0.005	0.029	0.066	0.156	0.057	0.094
KLF 2	N	Oct	2016-10-02	253.4	415.6	10.1	121.7	314.2	1115.1	760.3	334.5	0.029	0.025	0.005	0.016	0.065	0.140	0.052	0.086
KLF 3	N	Oct	2016-10-02	304.1	294.0	20.3	81.1	172.3	871.8	557.5	304.1	0.030	0.020	0.010	0.009	0.028	0.096	0.045	0.051
KLF 4	N	Oct	2016-10-02	212.9	405.5	10.1	212.9	304.1	1145.5	770.4	334.5	0.029	0.032	0.005	0.052	0.086	0.204	0.089	0.106
KLF 5	S	Oct	2016-10-02	131.8	517.0	10.1	304.1	233.1	1196.2	963.0	182.5	0.013	0.033	0.015	0.071	0.054	0.186	0.099	0.059
KLF 6	S	Oct	2016-10-02	263.6	811.0	10.1	162.2	466.3	1713.1	1145.5	537.3	0.035	0.060	0.005	0.031	0.157	0.288	0.100	0.185
KLF 7	S	Oct	2016-10-02	141.9	476.4	10.1	162.2	375.1	1165.8	892.1	233.2	0.018	0.050	0.005	0.029	0.097	0.199	0.093	0.102
KLF 8	W	Oct	2016-10-02	233.2	628.5	10.1	141.9	263.6	1277.2	942.7	334.5	0.033	0.064	0.005	0.027	0.078	0.206	0.102	0.104
KLF 1	N	Nov	2016-10-26	415.6	831.2	0.0	192.6	334.5	1774.0	1338.1	435.9	0.045	0.072	0.000	0.049	0.079	0.245	0.132	0.114
KLF 2	N	Nov	2016-10-26	253.4	567.7	0.0	141.9	233.2	1196.2	932.6	263.6	0.030	0.042	0.000	0.024	0.033	0.129	0.072	0.057
KLF 3	N	Nov	2016-10-26	172.3	547.4	0.0	91.2	192.6	1003.6	831.2	172.3	0.020	0.066	0.000	0.012	0.030	0.128	0.083	0.045
KLF 4	N	Nov	2016-10-26	314.3	1104.9	0.0	111.5	334.5	1865.2	1409.0	456.2	0.036	0.118	0.000	0.019	0.116	0.289	0.140	0.150
KLF 5	S	Nov	2016-10-26	162.2	1175.9	0.0	172.3	233.1	1743.5	1520.5	212.9	0.020	0.105	0.000	0.039	0.041	0.206	0.147	0.058
KLF 6	S	Nov	2016-10-26	364.9	1621.9	0.0	263.6	131.8	2382.2	1997.0	375.1	0.036	0.153	0.000	0.061	0.017	0.268	0.212	0.051
KLF 7	S	Nov	2016-10-26	486.6	1257.0	10.1	192.6	172.3	2118.6	1713.1	385.2	0.066	0.108	0.005	0.029	0.009	0.217	0.157	0.058
KLF 8	W	Nov	2016-10-26	263.6	1327.9	20.3	243.3	172.3	2027.4	1804.4	202.7	0.057	0.164	0.020	0.041	0.003	0.286	0.219	0.051

Appendix 19. Kootenay phytoplankton discrete (2, 5, 10, 15, 20 m) results from 2016; abundance (cells/mL) and biovolume (mm^3/L) by Arm: N=North, S=South. Taxonomic group: Bac= Bacillariophyceae (Diatoms), ChrCry= Chryso- & Cryptophyceae (Flagellates), Din= Dinophyceae (Dinoflagellates), Chl= Chlorophyceae (Coccoid Greens, Desmids, etc.) and Cya= Cyanophyceae (Blue-greens).

				Abundance (cells/mL)						Biovolume (mm^3/L)					
Station	Arm	Depth (m)	Date	Bac	ChrCry	Din	Chl	Cya	Total	Bac	ChrCry	Din	Chl	Cya	Total
KLF2	N	2	06/06/2016	3578	2524	10	182	243	6538	0.437	0.415	0.005	0.051	0.004	0.912
KLF2	N	5	06/06/2016	4095	2159	20	203	233	6711	0.521	0.260	0.020	0.037	0.004	0.842
KLF2	N	10	06/06/2016	2970	1389	10	162	243	4774	0.394	0.228	0.005	0.023	0.009	0.659
KLF2	N	15	06/06/2016	1855	1024	10	132	142	3163	0.224	0.197	0.005	0.015	0.007	0.447
KLF2	N	20	06/06/2016	1602	598	20	71	152	2443	0.215	0.109	0.020	0.016	0.002	0.362
KLF2	N	2	05/07/2016	5606	1044	10	132	345	7136	0.711	0.105	0.005	0.015	0.108	0.945
KLF2	N	5	05/07/2016	6234	1095	10	284	304	7927	0.865	0.147	0.005	0.050	0.068	1.134
KLF2	N	10	05/07/2016	4957	1379	20	243	304	6903	0.673	0.167	0.020	0.054	0.054	0.968
KLF2	N	15	05/07/2016	5058	1419	10	253	264	7005	0.671	0.240	0.005	0.089	0.038	1.043
KLF2	N	20	05/07/2016	2565	730	10	193	274	3771	0.405	0.104	0.005	0.023	0.019	0.556
KLF2	N	2	01/08/2016	4957	1064	51	112	172	6356	0.666	0.113	0.115	0.007	0.012	0.913
KLF2	N	5	01/08/2016	7268	1125	41	172	132	8738	1.194	0.198	0.019	0.016	0.012	1.438
KLF2	N	10	01/08/2016	6062	699	30	172	172	7136	0.872	0.101	0.025	0.016	0.027	1.041
KLF2	N	15	01/08/2016	5798	537	20	112	91	6559	0.764	0.037	0.020	0.010	0.026	0.857
KLF2	N	20	01/08/2016	3467	497	10	203	91	4268	0.430	0.067	0.005	0.031	0.011	0.544
KLF2	N	2	30/08/2016	669	933	10	91	172	1875	0.082	0.084	0.005	0.003	0.013	0.187
KLF2	N	5	30/08/2016	831	740	10	203	142	1926	0.119	0.076	0.005	0.028	0.018	0.246
KLF2	N	10	30/08/2016	629	497	10	142	142	1419	0.095	0.068	0.005	0.021	0.012	0.201
KLF2	N	15	30/08/2016	395	294	0	71	112	872	0.052	0.039	0.000	0.006	0.001	0.098
KLF2	N	20	30/08/2016	689	203	0	51	122	1064	0.084	0.018	0.000	0.007	0.001	0.110
KLF6	S	2	06/06/2016	2311	882	10	81	112	3396	0.302	0.110	0.005	0.003	0.002	0.421
KLF6	S	5	06/06/2016	3457	1794	10	112	182	5555	0.646	0.436	0.005	0.041	0.003	1.131
KLF6	S	10	06/06/2016	3507	1541	10	142	203	5403	0.524	0.279	0.005	0.023	0.008	0.838
KLF6	S	15	06/06/2016	3994	1500	10	182	274	5961	0.493	0.235	0.005	0.030	0.004	0.767
KLF6	S	20	06/06/2016	2392	1642	30	71	213	4349	0.285	0.294	0.036	0.004	0.003	0.622
KLF6	S	2	05/07/2016	5018	953	20	142	152	6285	0.721	0.155	0.056	0.023	0.002	0.957
KLF6	S	5	05/07/2016	5626	1024	10	223	132	7015	0.850	0.170	0.005	0.020	0.002	1.047
KLF6	S	10	05/07/2016	5900	649	10	172	233	6964	0.824	0.068	0.005	0.023	0.023	0.943
KLF6	S	15	05/07/2016	3031	466	10	152	193	3852	0.385	0.040	0.005	0.016	0.008	0.453
KLF6	S	20	05/07/2016	2301	507	10	152	172	3142	0.286	0.033	0.005	0.014	0.002	0.340
KLF6	S	2	01/08/2016	2331	902	10	152	81	3477	0.466	0.079	0.005	0.020	0.006	0.576
KLF6	S	5	01/08/2016	2534	608	10	162	162	3477	0.383	0.059	0.005	0.012	0.008	0.467

(Cont'd)

Station	Arm	Depth (m)	Date	Bac	ChrCry	Din	Chl	Cya	Total	Bac	ChrCry	Din	Chl	Cya	Total
KLF6	S	10	01/08/2016	3609	497	10	172	81	4369	0.527	0.043	0.005	0.038	0.011	0.624
KLF6	S	15	01/08/2016	3507	588	41	132	71	4339	0.498	0.078	0.029	0.014	0.006	0.625
KLF6	S	20	01/08/2016	2382	446	10	122	81	3041	0.399	0.061	0.015	0.004	0.021	0.500
KLF6	S	2	30/08/2016	61	568	10	162	172	973	0.010	0.061	0.005	0.028	0.030	0.134
KLF6	S	5	30/08/2016	61	487	10	132	264	953	0.010	0.046	0.005	0.010	0.072	0.145
KLF6	S	10	30/08/2016	142	598	10	162	365	1277	0.025	0.049	0.005	0.020	0.074	0.172
KLF6	S	15	30/08/2016	456	426	10	101	304	1298	0.060	0.047	0.005	0.018	0.059	0.188
KLF6	S	20	30/08/2016	253	365	0	91	193	902	0.036	0.063	0.000	0.013	0.039	0.151

Appendix 20. Kootenay Lake species phytoplankton results from 2016; Edibility to zooplankton by class, class alias and species. I= inedible, E= edible, and E/I= either edible or inedible. Assignment made by John Stockner at Eco-Logic Ltd (analyst in 2016).

Taxon name	Taxon alias	Species	Edibility
Bacillariophyte	Diatoms	Achnanthidium sp.	E
Bacillariophyte	Diatoms	Asterionella formosa var1	I
Bacillariophyte	Diatoms	Cyclotella glomerata	E
Bacillariophyte	Diatoms	Cyclotella stelligera	E
Bacillariophyte	Diatoms	Fragilaria capucina	I
Bacillariophyte	Diatoms	Fragilaria construens	I
Bacillariophyte	Diatoms	Navicula sp.	I
Bacillariophyte	Diatoms	Synedra acus	I
Bacillariophyte	Diatoms	Synedra nana	I
Bacillariophyte	Diatoms	Aulacoseira italica	I
Bacillariophyte	Diatoms	Eunotia sp.	I
Bacillariophyte	Diatoms	Diatoma elongatum	I
Bacillariophyte	Diatoms	Fragilaria crotonensis	I
Bacillariophyte	Diatoms	Synedra ulna	I
Bacillariophyte	Diatoms	Hannea Arcus	I
Bacillariophyte	Diatoms	Rhizosolenia sp.	I
Bacillariophyte	Diatoms	Tabellaria fenestrata	I
Bacillariophyte	Diatoms	Tabellaria flocculosa	I
Bacillariophyte	Diatoms	Cymbella sp.	E
Bacillariophyte	Diatoms	Aulicoseira distans	I
Bacillariophyte	Diatoms	Cymbella sp. (large)	I
Bacillariophyte	Diatoms	Synedra acus var. angustissima	I
Bacillariophyte	Diatoms	Diatoma sp.	I
Bacillariophyte	Diatoms	Cyclotella comta	I
Bacillariophyte	Diatoms	Stephanodiscus sp.	I
Chlorophyte	Coccoid greens, desmids, etc.	Chlorella	E
Chlorophyte	Coccoid greens, desmids, etc.	Scourfieldia	E
Chlorophyte	Coccoid greens, desmids, etc.	Stichococcus minutissimus	E

Taxon name	Taxon alias	Species	Edibility
Chryso- & Cryptophyte	Flagellates	Chroomonas acuta	E
Chryso- & Cryptophyte	Flagellates	Chrysochromulina sp.	E
Chryso- & Cryptophyte	Flagellates	Cryptomonas sp.	E
Chryso- & Cryptophyte	Flagellates	Kephyrion sp.	E
Chryso- & Cryptophyte	Flagellates	Komma sp.	E
Chryso- & Cryptophyte	Flagellates	Ochromonas sp.	E
Chryso- & Cryptophyte	Flagellates	Small microflagellates	E
Chryso- & Cryptophyte	Flagellates	Pseudokephrion sp.	E
Chryso- & Cryptophyte	Flagellates	Bitrichia sp.	E
Chryso- & Cryptophyte	Flagellates	Chromulina sp1	E
Chryso- & Cryptophyte	Flagellates	Chrysococcus	E
Chryso- & Cryptophyte	Flagellates	Dinobryon sp	E
Chryso- & Cryptophyte	Flagellates	Mallomonas sp2	E
Chryso- & Cryptophyte	Flagellates	Isthmochloron	E
Cyanophyte	Blue-greens	Synechococcus sp. (rod)	E
Cyanophyte	Blue-greens	Synechocystis	E
Cyanophyte	Blue-greens	Synechococcus sp. (coccoid)	E
Cyanophyte	Blue-greens	Lyngbya sp.	I
Cyanophyte	Blue-greens	Microcystis sp.	I
Cyanophyte	Blue-greens	Merismopedia sp.	E
Cyanophyte	Blue-greens	Chroococcus sp.	I
Cyanophyte	Blue-greens	Aphanothecae sp.	I/E
Cyanophyte	Blue-greens	Anabaena sp	I
Cyanophyte	Blue-greens	Coelosphaeria sp.	I
Cyanophyte	Blue-greens	Gomphosphaeria sp.	I
Dinophyte	Dinoflagellates	Gymnodinium sp1	E
Dinophyte	Dinoflagellates	Gymnodinium sp2	I/E
Dinophyte	Dinoflagellates	Peridinium spp.	E

(cont'd)

Taxon name	Taxon alias	Species	Edibility
Chlorophyte	Coccoid greens, desmids, etc.	Cosmarium sp.	E
Chlorophyte	Coccoid greens, desmids, etc.	Monoraphidium	E
Chlorophyte	Coccoid greens, desmids, etc.	Gyromitus sp.	E
Chlorophyte	Coccoid greens, desmids, etc.	Cateria sp.	E
Chlorophyte	Coccoid greens, desmids, etc.	Monomastix sp	E
Chlorophyte	Coccoid greens, desmids, etc.	Chodatella spp.	I/E
Chlorophyte	Coccoid greens, desmids, etc.	Sphaerocystis sp.	E
Chlorophyte	Coccoid greens, desmids, etc.	Closterium	E
Chlorophyte	Coccoid greens, desmids, etc.	Clamydocapsa sp.	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Ankistrodesmus sp.	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Phacus	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Elakatothrix sp3	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Tetraedron	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Coelastrum sp.	I/E
Chlorophyte	Coccoid Greens, Desmids, etc.	Nephroselmis	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Pyramimonas	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Actinastrum hantschii	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Euglena	I/E
Chlorophyte	Coccoid Greens, Desmids, etc.	Oocystis sp.	E
Chlorophyte	Coccoid Greens, Desmids, etc.	Planctosphaeria	I
Chlorophyte	Coccoid Greens, Desmids, etc.	Staurastrum sp.	I
Chlorophyte	Coccoid Greens, Desmids, etc.	Planctonema sp.	E

Taxon name	Taxon alias	Species	Edibility
Dinophyte	Dinoflagellates	Ceratium	I

Appendix 21. Lardeau Kokanee spawner peak counts. Note that previous data has been updated with corrections.

Year	Spawner Counts (No.)
1964	1,380,000
1965	510,000
1966	650,000
1967	710,000
1968	-
1969	-
1970	-
1971	1,000,000
1972	-
1973	1,800,000
1974	3,000,000
1975	-
1976	-
1977	-
1978	-
1979	1,500,000
1980	700,000
1981	1,000,000
1982	500,000
1983	500,000
1984	600,000
1985	-
1986	500,000
1987	250,000
1988	190,000
1989	150,000
1990	110,000
1991	40,000

Year	Spawner Counts (No.)
1992	60,000
1993	254,000
1994	400,000
1995	167,650
1996	113,718
1997	400,000
1998	1,060,000
1999	526,000
2000	186,240
2001	160,000
2002	110,000
2003	199,969
2004	249,400
2005	232,390
2006	107,113
2007	146,821
2008	409,731
2009	245,555
2010	250,958
2011	499,572
2012	491,560
2013	250,844
2014	73,950
2015	10,308
2016	24,986

Appendix 22. Full length survey results of Kootenay Lake South Arm tributary (B.C. only) spawner counts, throughout September 2016, from Redfish Consulting (2017). NS = Not surveyed.

Tributary Name	Survey #1	Survey #2	Survey #3
Coffee Cr.	16	8	NS
Woodbury Cr.	9	9	NS
Fletcher Cr.	0	0	NS
Bjerkness Cr.	0	1	NS
Kaslo R.	18	26	NS
Schroeder Cr.	0	0	NS
Lost Ledge Cr.	0	0	NS
Davis Cr.	3	8	NS
Fry Cr.	0	143	NS
Campbell Cr.	0	1	NS
Powder Cr.	0	0	NS
Bernard Cr.	2	19	NS
Loki Cr.	0	0	NS
Tam O'Shanter Cr.	0	0	NS
Hendryx Cr.	0	0	NS
Crawford Cr.	0	110	260
Gray Cr.	0	0	NS
La France Cr.	0	0	NS
Lockhart Cr.	0	0	NS
Akokli Cr.	0	0	NS
Sanca Cr.	0	0	NS
Boulder Cr.	0	0	NS
Goat R.	1	800	2386
Summit Cr.	0	0	10
Corn Cr.	0	0	NS
Next Cr.	0	0	NS
Cultus Cr.	1	1	NS
Midge Cr.	158	85	NS
Wilson Cr.	0	0	NS

Appendix 23. Summary of production statistics for Meadow Creek spawning channel, 1985–2016.

Spawning year	Spawner counts[1] (no.)	Mean Fecundity (egg no.)	Egg Retention[2] (egg no.)	Females[2] (%)	Egg Deposition[3] (millions)	Fry emigration[4] (millions)	Egg-to-fry survival (%)
1985	287,252	215			28.47	7.37	39.8
1986	256,410	203			27.29	2.78	9.8
1987	236,062	191			22.72	2.98	10.9
1988	291,895	215			27.69	2.32	10.2
1989	230,000	205			25.48	6.99	25.2
1990	203,197	209			18.56	8.41	33.0
1991	168,775	249			20.95	4.79	25.8
1992	253,545	300			32.01	7.13	34.0
1993	291,368	408			61.46	11.85	37.0
1994	300,000	312			43.05	28.07	45.7
1995	302,063	348			44.20	16.69	38.8
1996	371,000	206			33.43	18.20	41.2
1997	352,093	187			21.46	8.89	26.9
1998	336,636	193			27.82	12.44	59.3
1999	353,674	240			31.62	13.17	47.4
2000	250,056	281			34.82	20.10	62.5
2001	303,808	348			51.80	13.75	39.4
2002	302,500	295	7	49	42.59	21.69	41.9
2003	358,782	208	10	43	29.76	17.92	42.1
2004	514,791	245	16	34	42.91	14.35	48.2
2005	463,614	226	11	38	41.70	24.56	57.2
2006	331,194	315	11	50	50.50	16.58	39.7
2007	245,991	411	11	47	45.50	15.94	31.6
2008	437,236	379	17	36	62.22	24.53	53.9
2009	506,035	267	19	50	62.74	26.75	43.0
2010	452,530	214	14	44	35.74	22.05	35.2
2011	485,128	179	15	47	39.76	12.22	34.2
2012	519,557	180	13	43	37.68	13.73	34.5
2013	165,748	285	8	44	20.27	13.77	36.6
2014	53,468	517	5	38	10.32	8.59	42.4
2015	5,679[5]	584	12	41[5]	1.32[5]	7.38	71.5
2016	11,087	778	9	44	3.78	0.08[5]	6.1[5]

[1] Refers only to fish in the spawning channel and does not include fish above and below channel or fish removed by FFSBC during egg takes.

[2] Derived by sampling at spawning channel

[3] Potential egg deposition based on number of adults in channel x (fecundity – retention) x % females. Note, there were green females returned to channel some years so these are deducted from channel before applying % females and then added to determine total females (Calculations are more complex than suggested by this table).

[4] Fry emigration from spring time sampling does not include non-channel production which is estimated separately based on a 5% egg-to-fry survival rate. Note that percent survival is based on fry from the previous year.

[5] Bear predation in 2015 on spawners (after being passed upstream of numeration fence) affected egg deposition by an unknown, but likely substantial, amount.

Appendix 24. Eyed-egg plants and hatchery raised fry releases into Kootenay Lake tributaries in 2015 and 2016 as part of the Kootenay Lake Recovery initiative. Eyed-eggs were planted into the gravel in the fall of the release year to incubate until emergence the following spring. Hatchery fry releases occurred in the spring of the release year indicated.

Brood Source	Brood Yr	Release Yr	Release Site	Stage	Number	Otolith Heat Mark
Hill Cr	2014	2015	Crawford Cr	fry	92,541	no mark
Hill Cr	2014	2015	Hendryx Cr	fry	5,000	no mark
Hill Cr	2015	2015	Meadow Cr sp ch	eyed egg	477,398	III_III
Norbury Cr	2015	2016	Meadow Cr sp ch	fry	104,006	III_III
Lussier R	2015	2016	Meadow Cr sp ch	fry	359,335	III_III
Lussier R	2015	2016	Crawford Cr	fry	30,030	III_III
Deka Lk	2015	2016	Meadow Cr sp ch	fry	142,237	III_III
Columbia R	2016	2016	Meadow Cr sp ch	eyed egg	1,569,888	no mark
Hill Cr	2016	2016	Meadow Cr sp ch	eyed egg	1,381,059	no mark
Bull R	2016	2016	Meadow Cr sp ch	eyed egg	47,247	no mark
Whatshan R	2016	2016	Meadow Cr sp ch	eyed egg	603,164	no mark
Norbury Cr	2016	2016	Meadow Cr sp ch	eyed egg	329,371	no mark
Lussier R	2016	2016	Meadow Cr sp ch	eyed egg	827,239	no mark
Bridge Lk	2016	2016	Meadow Cr sp ch	eyed egg	675,294	no mark
Deka Lk	2016	2016	Meadow Cr sp ch	eyed egg	915,097	no mark
Sulphurous Lk	2016	2016	Meadow Cr sp ch	eyed egg	411,215	no mark

Appendix 25. Transect fish densities (number ha^{-1}) in Kootenay Lake in 2016. Refer to Figure 2 for transect locations.

	June 2016			Sept. 2016		
Transect Number	All Ages	Age 0	Age 1-3	All Ages	Age 0	Age 1-3
1	618	579	40	525	469.002	55.7
2	631	588	42	477	440.457	36.868
3	648	602	46	321	292.985	27.858
4	395	354	41	328	311.156	17.006
5	250	228	23	427	397.927	29.339
6	364	311	53	283	264.794	18.451
7	399	357	43	258	242.946	15.353
8	293	244	50	178	162.516	15.62
9	356	301	55	201	190.472	10.66
10	496	416	80	165	153.043	11.458
11	301	253	48	160	142.676	17.585
12	234	176	58	105	94.162	10.878
13	166	135	31	143	126.384	16.45
14	230	196	34	131	115.472	15.268
15	133	109	24	84	74.442	9.423
16	140	107	33	157	141.503	15.937
17	117	95	21	100	86.854	12.683
18	192	148	44	130	107.262	22.347

Appendix 26a-b. Maximum likelihood population estimates for (a) all ages of kokanee and (b) ages 1–3 kokanee in Kootenay Lake in June 2016. See figure 2 for locations of transects. MLE = maximum likelihood estimate, LB = lower bound, and UB = upper bound.

a) Statistics for kokanee of all ages (>-63 dB) two zones (Zone 1=TR 01–10; Zone 2=TR 11–18).

Zone	Depth (m)	N	Density	Std. Error	Area	Statistic	Abundance
1	3-5	10	6.820	2.904	16740		
1	5-10	10	147.524	30.697	16740		
1	10-15	10	125.215	17.642	16740		
1	15-20	10	78.775	13.220	16740		
1	20-25	10	21.519	5.895	16575		
1	25-30	10	8.523	2.292	16421	LB=	8,569,859
1	30-35	10	4.846	1.426	16225	MLE=	9,912,891
1	35-40	10	2.437	0.423	16015	UB=	11,244,863
1	40-45	10	1.001	0.274	15824		
1	45-50	10	1.209	0.296	15629		
2	3-5	8	2.500	1.637	21460		
2	5-10	8	8.166	2.132	21460		
2	10-15	8	36.584	8.059	21460		
2	15-20	8	60.268	4.293	21460		
2	20-25	8	28.779	4.860	21341		
2	25-30	8	6.857	1.150	21221		
2	30-35	8	3.270	1.475	21046		
2	35-40	8	2.632	0.557	20888		
2	40-45	8	2.247	0.492	20773		
2	45-50	8	1.203	0.177	20655		

b) Statistics for age 1–3 kokanee (>-48 dB); two zone (Zone 1=TR 1–3; Zone 2 = 04–18).

Zone	Depth	N	Density	Std. Error	Area	Statistic	Abundance
1	5-10	3	3.4	2	38200		
1	10-15	3	14.0	5	38200		
1	15-20	3	18.2	5	38200		
1	20-25	3	2.0	1	37916	LB=	1,064,561
1	25-30	3	1.8	1	37642	MLE=	1,632,567
1	30-35	3	1.9	1	37271	UB=	2,198,796
1	35-40	3	1.0	0	36903		
1	40-45	3	0.3	0	36596		
1	45-50	3	0.4	0	36284		

Appendix 26c-d. Maximum likelihood population estimates for (c) all ages of kokanee and (d) ages 1–3 kokanee in Kootenay Lake in Sept 2016. MLE = maximum likelihood estimate, LB = lower bound, and UB = upper bound.

c) Statistics for kokanee of all ages (>-61 dB); two zones (Zone 1=TR 1–05; Zone 2=TR 06–18)

Zone	Depth	N	Density	Std. Error	Area	Statistic	Abundance
1	3-5	5	0.000	0.000	8030		
1	5-10	5	11.924	5.641	8030		
1	10-15	5	52.725	25.095	8030		
1	15-20	5	116.773	30.010	8030		
1	20-25	5	98.944	8.879	7944		
1	25-30	5	69.998	23.701	7863	LB=	6,874,434
1	30-35	5	31.449	11.476	7759	MLE=	8,061,301
1	35-40	5	19.348	6.302	7645	UB=	9,267,226
1	40-45	5	9.703	3.682	7528		
1	45-50	5	4.795	1.973	7412		
2	5-10	13	4.449	1.343	30170		
2	10-15	13	5.323	1.399	30170		
2	15-20	13	4.461	0.864	30170		
2	20-25	13	24.676	9.734	29973		
2	25-30	13	50.584	10.270	29779		
2	30-35	13	38.466	5.524	29512		
2	35-40	13	17.557	2.627	29259		
2	40-45	13	9.610	1.347	29068		
2	45-50	13	5.999	0.814	28872		

d) Statistics for age 1–3 kokanee (>-44 dB); two zones (Zone 1=TR 01–03; Zone 2=TR 04–18)

Zone	Depth	N	Density	Std. Error	Area	Statistic	Abundance
1	5-10	3	0.886	0.886	5320		
1	10-15	3	3.482	0.615	5320		
1	15-20	3	8.687	3.073	5320	LB=	609,093
1	20-25	3	11.099	1.741	5267	MLE=	721,989
1	25-30	3	8.328	1.036	5211	UB=	834,431
1	30-35	3	3.528	1.015	5138		
1	35-40	3	2.561	1.039	5052		
1	40-45	3	1.165	0.622	4965		
1	45-50	3	0.406	0.406	4878		
2	5-10	15	0.096	0.096	32880		
2	10-15	15	0.393	0.325	32880		
2	15-20	15	0.139	0.062	32880		
2	20-25	15	0.918	0.309	32649		
2	25-30	15	6.231	1.262	32431		
2	30-35	15	4.953	0.840	32132		
2	35-40	15	1.397	0.362	31852		
2	40-45	15	0.869	0.220	31632		
2	45-50	15	0.902	0.250	31406		

Appendix 27. Estimates of kokanee biomass for Kootenay Lake. Note: a comprehensive review of historic data in 2016 resulted in minor changes to estimates presented here from those previously reported.

a) Estimated number of fish at each age based on fall acoustic abundance, trawl proportions (age 1–3 only), and mean weights by year and age from trawl samples.

	Estimated number of fish				Mean weight (g)			
Year	**Age 0**	**Age 1**	**Age 2**	**Age 3**	**Age 0**	**Age 1**	**Age 2**	**Age 3**
1985	5,445,000	667,051	1,008,333	139,615	1.6	24.9	54	66
1986	10,125,000	1,154,605	1,820,724	399,671	1.9	17.9	60	69
1987	No Survey				2.0	21.9	55	66
1988	4,785,000	902,222	692,778	-	2.2	26.6	52	
1989	8,025,000	1,117,405	1,388,291	169,304	1.6	25.5	60	68
1990	4,620,000	835,254	548,136	156,610	2.2	39.9	75	89
1991	7,005,000	1,167,500	972,917	194,583	2.1	29.7	128	131
1992	6,350,000	646,483	1,503,448	30,069	2.1	36.3	121	181
1993	8,790,000	1,218,451	460,634	430,915	1.5	36.5	76	109
1994	31,780,000	2,510,286	1,287,886	21,829	2.0	31.0	114	134
1995	21,000,000	3,721,029	572,466	6,505	2.0	34.2	74	138
1996	22,600,000	6,181,282	5,956,053	162,665	1.4	21.4	57	63
1997	14,270,000	5,824,120.88	5,824,121	261,758	1.7	25.0	50	77
1998	8,400,000	2,248,680	8,012,903	538,416	1.4	36.8	73	97
1999	10,360,000	2,050,323	2,489,677	-	1.4	24.4	76	
2000	9,690,000	636,667	1,273,333	-	2.0	24.4	123	
2001	18,380,000	4,967,368.42	752,632	-	1.6	24.5	85	
2002	25,430,000	9,091,528	542,778	135,694	1.2	27.7	57	84
2003	17,049,000	5,263,848	4,187,152	-	2.2	29.6	69	
2004	9,450,000	3,692,578	2,782,813	374,609	1.3	16.7	68	76
2005	12,830,000	1,703,125	1,021,875	545,000	1.1	15.8	77	104
2006	17,230,000	3,933,462	936,538	-	1.9	24.4	124	
2007[1]	17,859,000	*4,748,108*	*741,892*	-	*1.8*	*25.2*	*97.1*	
2008	22,644,000	3,827,896	445,104	-	1.6	26.0	70	
2009	31,130,000	14,305,795	1,632,205	-	1.4	24.3	70	
2010	22,443,755	11,157,199	4,075,689	152,838	1.0	24.8	50.7	72.4
2011	14,799,515	3,585,444	4,015,697	-	1.3	26.3	57.9	
2012[2]	12,792,831	851,196.42	806,397	716,797	1.9	21.0	59.3	67.2
2013	16,962,755	838,940	132,464	132,464	1.9	12.6	174.5	176.6
2014	15,751,710	1,051,135	-	-	1.8	14.3		
2015	14,004,614	1,205,290	38,880	-	2.1	15.0	283.4	
2016	7,368,613	721,989	-	-	2.6	20.1		

[1] *no trawling in 2007; applied average weight and age structure by averaging 2006 and 2008 values for ages 1-3. Estimates are italicized.*

[2] Three age 4 kokanee were included in the age 3 sample.

b) Calculation of in-lake biomass (metric tons) and biomass density ($kg \cdot ha^{-1}$) of kokanee in Kootenay Lake.

	Biomass (metric tonnes)					Biomass Density ($kg \cdot ha^{-1}$)				
Year	**Age 0**	**Age 1**	**Age 2**	**Age 3**	**Total**	**Age 0**	**Age1**	**Age2**	**Age 3**	**Total**
1985	8.9	16.6	53.9	9.2	**89**	0.23	0.43	1.41	0.24	**2.3**
1986	19.3	20.7	110.0	27.7	**178**	0.50	0.54	2.88	0.73	**4.7**
1987										
1988	10.4	24.0	36.2	-	**71**	0.27	0.63	0.95	-	**1.8**
1989	12.7	28.5	83.2	11.6	**136**	0.33	0.75	2.18	0.30	**3.6**
1990	10.3	33.3	41.3	14.0	**99**	0.27	0.87	1.08	0.37	**2.6**
1991	14.8	34.7	124.4	25.4	**199**	0.39	0.91	3.26	0.67	**5.2**
1992	13.3	23.5	181.4	5.4	**224**	0.35	0.61	4.75	0.14	**5.9**
1993	13.6	44.5	35.2	46.9	**140**	0.36	1.16	0.92	1.23	**3.7**
1994	63.7	77.7	147.0	2.9	**291**	1.67	2.04	3.85	0.08	**7.6**
1995	41.0	127.3	42.6	0.9	**212**	1.07	3.33	1.12	0.02	**5.5**
1996	31.8	132.3	340.8	10.2	**515**	0.83	3.46	8.92	0.27	**13.5**
1997	24.3	145.7	294.0	20.3	**484**	0.64	3.81	7.70	0.53	**12.7**
1998	11.9	82.7	588.0	52.4	**735**	0.31	2.16	15.39	1.37	**19.2**
1999	15.0	49.9	189.1	-	**254**	0.39	1.31	4.95	-	**6.6**
2000	19.3	15.5	156.7	-	**191**	0.50	0.41	4.10	-	**5.0**
2001	30.2	121.6	64.1	-	**216**	0.79	3.18	1.68	-	**5.7**
2002	31.6	251.7	31.0	11.3	**326**	0.83	6.59	0.81	0.30	**8.5**
2003	37.6	155.9	289.2	-	**483**	0.98	4.08	7.57	-	**12.6**
2004	12.2	61.7	188.9	28.4	**291**	0.32	1.62	4.94	0.74	**7.6**
2005	14.5	27.0	78.6	56.6	**177**	0.38	0.71	2.06	1.48	**4.6**
2006	33.6	96.1	116.4	-	**246**	0.88	2.52	3.05	-	**6.4**
2007[1]	31.6	119.7	72.1	-	**223**	0.83	3.13	1.89	-	**5.8**
2008	35.9	99.5	31.2	-	**167**	0.94	2.61	0.82	-	**4.4**
2009	42.0	347.0	114.6	-	**504**	1.10	9.08	3.00	-	**13.2**
2010	23.3	276.8	206.5	11.1	**518**	0.61	7.25	5.41	0.29	**13.6**
2011	19.3	94.4	232.7	-	**346**	0.50	2.47	6.09	-	**9.1**
2012[2]	24.0	17.9	47.8	48.2	**138**	0.63	0.47	1.25	1.26	**3.6**
2013	32.9	10.6	23.1	23.4	**90**	0.86	0.28	0.60	0.61	**2.4**
2014	28.1	15.0	-	-	**43**	0.74	0.39	-	-	**1.1**
2015	29.2	18.1	11.0	-	**58**	0.76	0.47	0.29	-	**1.5**
2016	19.3	14.5	-	-	**34**	0.50	0.38	-	-	**0.9**
Pre-nutrient addition average	**12.7**	**26.3**	**74.8**	**14.6**	**129**	**0.33**	**0.69**	**1.96**	**0.38**	**3.4**
Nutrient addition average	**27.2**	**97.1**	**139.3**	**12.7**	**276**	**0.71**	**2.54**	**3.65**	**0.33**	**7.2**

[1] *Note: 2007 biomass estimates are based on assumptions from table above*

[2] Note: Three age 4 kokanee were included in the age 3 sample

c) Calculation of kokanee spawner biomass (metric tons) and biomass density ($kg \cdot ha^{-1}$) in Kootenay Lake. Note: bottom rows compare average biomass during pre-fertilization (1985–1991) and fertilization years (1992–2016).

Year	Total Spawners (no)	Mean Weight (g)	Spawner Biomass (tonnes)	Spawner biomass density ($kg \cdot ha^{-1}$)	In-lake biomass density ($kg \cdot ha^{-1}$)	Total biomass density ($kg \cdot ha^{-1}$)
1985	901,100[1]	85	76.6[1]	2.0[1]	2.3	4.3[1]
1986	1,197,600	89	106.6	2.8	4.7	7.4
1987						
1988	657,900	97	63.5	1.7	1.8	3.5
1989	483,000	107	51.5	1.3	3.6	4.9
1990	436,607	107	46.8	1.2	2.6	3.8
1991	277,088	126	34.8	0.9	5.2	6.1
1992	520,903	159	82.6	2.2	5.9	8.0
1993	848,959	218	185.2	4.8	3.7	8.5
1994	1,253,000	158	198.2	5.2	7.6	12.8
1995	855,745	167	142.6	3.7	5.5	9.3
1996	1,181,718	89	105.7	2.8	13.5	16.3
1997	1,444,227	82	118.1	3.1	12.7	15.8
1998	2,198,000	95	208.5	5.5	19.2	24.7
1999	1,730,720	113	194.9	5.1	6.6	11.8
2000	563,956	156	88.1	2.3	5.0	7.3
2001	591,308	184	108.8	2.8	5.7	8.5
2002	464,000	144	66.6	1.7	8.5	10.3
2003	1,100,501	108	119.1	3.1	12.6	15.8
2004	1,526,125	112	170.4	4.5	7.6	12.1
2005	1,269,028	112	142.1	3.7	4.6	8.3
2006	478,307	180	86.1	2.3	6.4	8.7
2007[2]	534,073	236	125.8	3.3	5.8	9.1
2008	1,349,325	168	226.7	5.9	4.4	10.3
2009	907,839	118	107	2.8	13.2	16.0
2010	826,788	91	75.5	2.0	13.6	15.5
2011	1,764,100	78	137.4	3.6	9.1	12.7
2012	1,255,843	77	96.6	2.5	3.6	6.1
2013	453,592	241	109.5	2.9	2.4	5.2
2014	147,418	410	60.5	1.6	1.1	2.7
2015	17,961	576	10.3	0.3	1.5	1.8
2016	40,626	692	28.1	0.7	0.9	1.6
Pre-nutrient addition mean	**661,314**	**102**	**63.3**	**1.7**	**3.4**	**5.0**
Nutrient addition mean	**932,962**	**191**	**119.8**	**3.1**	**7.2**	**10.4**

[1]1985 is an underestimate as Lardeau spawners were not counted and may have accounted for ~500,000 or more additional spawners

[2]*In-lake biomass assumptions for 2007 outlined in tables above.*