DWB Consulting Services Ltd.

Williston Watershed Kokanee Spawner Distribution and Aerial Enumeration Surveys (2018)

FWCP Project No. PEA-F19-F-2895-DC-103364

Prepared for: BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development and The Fish and Wildlife Compensation Program (Peace Region)

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Signature Page

DWB Consulting Services Ltd. is pleased to submit this report for your review. This report has been prepared using sound technical and professional judgement, based on our knowledge and experience, applicable regulatory framework, industry best management practices, and current understanding of project conditions, design, and project setting.

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Executive Summary

Kokanee are the non-anadromous ecotype of sockeye salmon (*Oncorhynchus nerka*) and are widely distributed across Pacific watersheds. Although historically native to some lakes in the Williston Reservoir, Kokanee stocks from Arrow reservoir and Kootenay Lake were introduced from 1991 to 1995 into five Williston Reservoir tributary streams (Langston 2012). The goal of the introductions was to enhance the sport fisheries in the Williston Reservoir (Blackman and Jesson 1990). Kokanee spawner assessments have not occurred since 2010 and little is known about the current distributions and abundances of native and introduced Kokanee in the Williston Reservoir. A better understanding of current Kokanee populations dynamics will inform future management decisions within the Williston watershed.

In September 2018, aerial enumeration surveys were conducted over 28 tributaries across the four main sub-watersheds of the Williston Reservoir (the Finlay, Omineca, Peace and Parsnip). Results of these surveys were compared to spawner surveys conducted in 3 previous years: 2002, 2006, and 2010. The project was designed to meet the following FWCP priority actions in the FWCP Peace Region Reservoirs Action Plan (Action 2a-1) to "Undertake a kokanee assessment study to summarize status, trends, and aquatic and terrestrial ecosystem impacts and potential risks of kokanee introductions. Develop appropriate recommendations for actions, as needed."

At the Reservoir-scale, a modest increase (1.2 fold) in spawner abundance was observed between 2006 and 2010, followed by a substantial (3.2 fold) decrease between 2010 and 2018. Among the four sub-watersheds, the Omineca and Finlay Reaches had the highest proportion of Kokanee spawners enumerated in 2010 and 2018, a finding consistent with results from 2002 and 2006 surveys. Observed changes in spawner abundance at the whole reservoir-scale were not consistently reflected in all four sub-watersheds, with the most notable variation occurring between 2006 and 2010, where abundance increased in the Finlay and Peace but decreased in the Omineca and Parsnip. Spawner abundance decreased in all four sub-watersheds between 2010 and 2018. Kokanee distribution generally decreased in the 2018 survey, which is thought to be a result of an overall reduction in fish abundance. However, although Kokanee abundance within the Mesilinka River remained similar between 2010 and 2018, fish distribution increased significantly in that particular system. Kokanee distribution in Clearwater River slightly increased in 2018, however, overall abundance of fish in the system decreased.

Changes in spawner abundance between years, particularly between 2010 and 2018, may be due to density dependant effects, resulting in lower recruitment into spawning populations. Variation in abundance patterns among the four sub-watersheds, particularly higher spawner abundances in the Finlay and Omineca Reaches, may be due to more favorable spawning and/or rearing habitats in the North and Northwest portions of the Reservoir. Based on abundance data alone, it is unclear if abundance differences represent fluctuations in spawner populations or reflect variation in peak spawner years captured by survey timing. The variation in life history traits of Kokanee means multiple non-overlapping spawning cohorts may exist across the Williston Reservoir and its four sub-watersheds.

We recommend annual Kokanee spawner surveys over the next three years with a focus on aerial enumeration surveys. Increased frequency in spawner surveys will help determine how Kokanee populations are changing in the Williston Reservoir and identify any evidence of multiple non-overlapping Kokanee cohorts across the Reservoir's four primary sub-watersheds and their respective spawning tributaries.

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1.0 INTRODUCTION

1.1 Background and Scope

This report describes the work completed in 2018 by DWB Consulting Services Ltd. (DWB) for the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) in partnership with the Fish and Wildlife Compensation Program (FWCP). The work is part the FWCP project "*Studying Kokanee in our Peace Region*". FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and Public Stakeholders to conserve and enhance fish and wildlife in watersheds impacted by BC Hydro dams. Kokanee spawner abundance and distribution was previously assessed between 2002 to 2006 (Langston 2012) and in 2010 (Langston et al. *unpublished data*). This report compares Kokanee spawner abundance and distribution data from the 2002, 2006, 2010, and 2018 survey years only. Kokanee are known to spawn in 3- to 5-year cycles, so study years were selected to target non-overlapping Kokanee cohorts.

Kokanee Biology and Life History

Kokanee are the nonanadromous ecotype of sockeye salmon (*Oncorhynchus nerka*) and are widely distributed across watersheds of the Pacific region (Taylor et al. 2000). Unlike their anadromous counterpart, Kokanee spawn and rear in freshwater habitats (rivers and lakes). Sockeye, like most pacific salmon species, mature in saltwater before migrating to freshwater streams to spawn (Nelson 1968). Morphologically, Kokanee mature at a much smaller body size than Sockeye salmon, reflecting their exclusive use of freshwater habitats (Wood and Foote 1996; McGurk 2000). Like most pacific salmon species, Kokanee and Sockeye are both semelparous, meaning they spawn only once before they die. Both ecotypes are planktivorous, feeding on zooplankton and other invertebrates. Kokanee are known to exhibit considerable variation in life history traits, particularly with respect to the types of spawning habitat used, and can utilize a variety of lentic (standing water) and lotic (flowing water) habitats for spawning (Taylor et al. 2000; Whitlock et al. 2018). As pelagic planktivores, Kokanee are well-suited to reservoir environments, where periodic water level changes (i.e. drawdowns) result in frequent disturbance to littoral (near-shore) habitats, and have shown to have been successful in other BC reservoirs (Blackman and Jesson 1990).

History of Kokanee in the Williston Reservoir

Prior to construction of the W.A.C. Bennett dam and formation of the Williston reservoir, several lakes were known to contain native Kokanee populations. These lakes included Thutade Lake, located within the Finlay River headwaters, and Arctic and Tacheeda Lakes, both tributaries of the Parsnip River (Figure 1). Aerial spawner surveys were first conducted in 1989 to locate and enumerate native Kokanee in the Finlay River (McLean and Blackman 1991). The survey was expanded in the Finlay River and included 18 other tributaries in 1990, four of which were re-surveyed in 1994 (Langston and Zemlak 1998). The results of these early surveys (5,000 or fewer Kokanee observed) indicated that relatively low numbers of native Kokanee inhabited the Williston Reservoir (Langston 2012). Between 1990 and 1998, Kokanee were stocked in several streams of the Williston Reservoir to create a sport fishery, and to provide a food source for other piscivorous fish species. A total of 5 tributary systems were used for reintroduction: Carbon Creek, Davis Creek, Dunlevy Creek, Manson River, and Nation River (Langston 2012). Individuals used for introduction were sourced from Meadow Creek and Hill Creek in the Columbia River basin and were therefore genetically distinct from the native populations. Although stocked Kokanee populations potentially benefit sport fisheries and local First Nations, there has been ongoing concern that population expansion of stocked Kokanee from the Columbia river may pose a risk to local fish species such as Arctic Grayling (*Thymallus arcticus*), as well as native Kokanee populations in the Williston Reservoir (Langston 2012).

Kokanee spawner surveys were previously conducted between 2002 and 2006 inclusive (Langston 2012), and in 2010 (Langston et al. *unpublished data*). During the 2002 to 2006 surveys, Langston (2012) found that the peak spawning period for Williston Kokanee was mid-September. The 2002 to 2006 data indicated that Kokanee spawner abundance was highest in the Omineca (60-89% of spawners) and Finlay sub-watersheds (2-36%), depending on the study year. In comparison, spawner abundance in the Peace and Parsnip sub-watersheds was considerably lower in the same five year span, containing <1% and <8% of spawners, respectively (Langston 2012). Previous surveys (2002-2006 and 2010) enumerated Kokanee in most of the tributaries within the four main sub-watersheds of the Williston Reservoir: the Finlay, Omineca, Peace and Parsnip River Reaches (Figure 1). A representative sub-sample of 28 streams were surveyed for Kokanee spawners in 2018.

1.2 Goals and Objectives

This project is directed under the **FWCP Reservoir Action Plan (Action 2a-1**) to "Undertake a kokanee assessment study to summarize status, trends, and aquatic and terrestrial ecosystem impacts and potential risks of kokanee introductions. Develop appropriate recommendations for actions, as needed." The ultimate goal is to better understand the abundance and distribution of Kokanee spawning populations across the Williston watershed to inform future management decisions and studies.

1.3 Study Area

The Williston Reservoir (56° N latitude, 124° W longitude) is located approximately 140 km north of Prince George, British Columbia (Figure 1) and represents the largest lentic freshwater system in BC. The reservoir was created in 1968 after construction was completed on the W.A.C. Bennett Dam, located on the upper Peace River near Hudson's Hope, B.C. The Peace River flows east to Lake Athabasca within the Mackenzie River drainage system, which flows north and discharges into the Arctic Ocean (Langston 2012). The reservoir has a mean depth of 44 m and a maximum depth of 166 m (BC Research 1977).

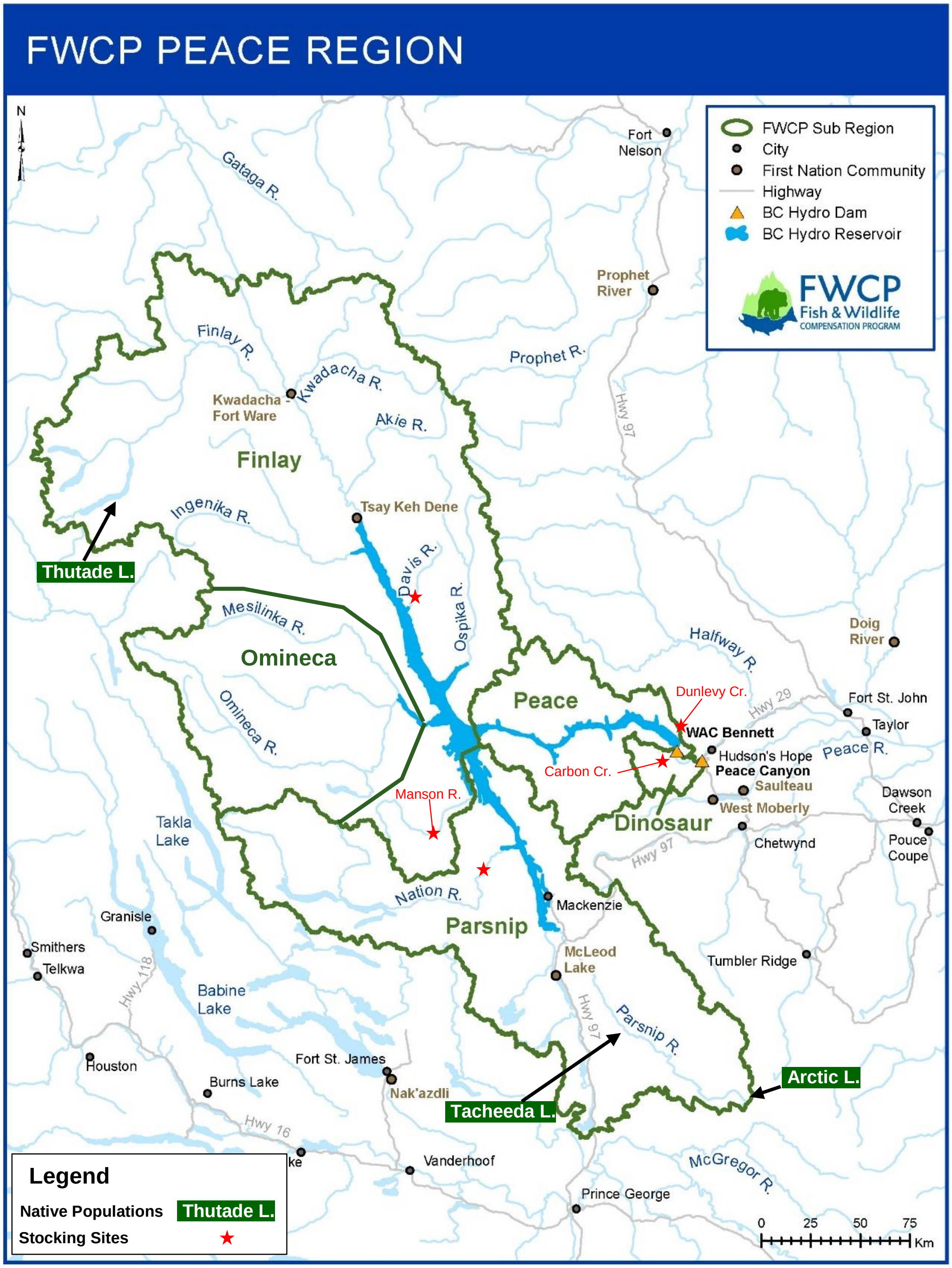


Figure 1. Williston Reservoir watershed showing the four main sub-watersheds relevant to Kokanee enumerations in bold (Parsnip, Peace, Omineca, and Finlay River systems). The Omineca sub-watershed is not an FWCP Sub Region but has always been treated as a distinct reach for the purpose of Kokanee enumerations. Lakes known to have had native Kokanee populations prior to introductions in the 1990's are highlighted in green. The approximate locations of five tributary systems targeted during the stocking programs between 1990-1998 are indicated by red stars.

2.0 METHODS

2.1 Aerial Enumeration

The 2018 aerial enumeration surveys were conducted on 28 tributaries within the Williston Reservoir from 17 to 22 September, inclusive. DWB used the aerial enumeration methodology described in Langston (2012) with additional refinements that were implemented in the 2010 surveys (Langston 2010 *unpublished data*). Aerial enumeration surveys were conducted from a Bell 206 Jet Ranger helicopter equipped with a rear bubble-window flying 30-50 m above water level. Spawner enumeration data was collected by two fisheries trained observers and a First Nations observer. The first observer acted as the primary spotter and made estimates on spawner abundance at 1 km intervals along the survey length by grouping fish into schools of 10, 50, 100, 500 and 1,000 individuals. The first observer also recorded GPS tracks of surveys lengths, 1 km intervals, potential fish barriers, and other relevant waypoints with a Garmin handheld GPS unit. The second observer recorded data on standardized field forms (Langston 2012) and acted as the secondary spotter, making independent estimates at each 1 km interval. Observers then conferred with one another until a mutual consensus on each estimate was reached. The First Nations observer provided guidance and assisted with various survey tasks as needed. Modifications to the methodology in 2010 included the addition of an estimate of confidence that was assigned to every group of Kokanee that was counted, based on benchmark criteria (Table 1). The confidence in a count was categorized as very low, low, medium or high and corresponded to a measure of error. After the aerial enumeration was completed, the individual count estimates in each confidence rating category were subtotalled. A minimum and maximum value was calculated for each subtotal by subtracting and adding the error percentage of the count associated with that confidence rating (Table 1). The minimum, maximum and actual count subtotals for each confidence rating were summed to give a grand total of the minimum, maximum and actual count. The minimum and maximum values of the count estimates from 2010 and 2018 could be interpreted as the upper and lower limits of a confidence interval. These confidence intervals could provide insight into whether a difference in the counts from 2010 and 2018 were large enough to be considered truly different or whether they could just as easily be associated with natural variation in Kokanee numbers or observer bias. Fish visibility factors such as turbidity, cloud cover, wind, canopy closure and precipitation during the survey were recorded on data sheets and influenced the choice of confidence rating for each grouping of fish counted. For example, if a group of spawners was observed in a stream with muddy or turbid water, where visibility was reduced or impaired, an observer's confidence in the group size would be expected to be lower than in less turbid waters. In such a case, the observer would assign a lower confidence rating to the observation (e.g. "low" or "very low").

Table 1. Benchmark criteria that defined the level of confidence in a count estimate of Kokanee and associated error for that count in the 2010 and 2018 aerial enumeration surveys (Langston 2010 *unpublished data*).

CONFIDENCE RATING	CRITERIA	ERROR (+ OR -)
Very Low	Counts of tight schools of large numbers of fish >5000.	35%
Low	Counts of tight schools of fish >100.	25%
Moderate	Counts of one or more large, spread out groups of at least 300 fish in each group.	20%
High	Counts of small, spread out groups of fish, cumulatively adding up to as much as 1000.	15%

Potential barriers to fish passage (e.g. waterfalls) were assessed visually from the helicopter during aerial enumeration surveys. Visual assessment of potential barriers was also supplemented by consulting previous years' survey data that detailed Kokanee spawner occurrence records above and below the barrier location. During surveys, observations of other non-Kokanee fish species were made and recorded if possible, but no counts or analyses were completed for this report.

2.2 Kokanee Distribution

2018 was the first year that Kokanee spawner distributions were described as a count of fish per stream kilometer surveyed. Stream kilometers were measured using a handheld GPS unit with a trip odometer that was reset to zero at the survey start location. A waypoint was created at each kilometer that was flown and the count of fish was subtotaled for each kilometer. The trip odometer was not always an accurate estimate of stream distance from the start point as the flight path did not always follow the stream exactly. This was especially true any time that the helicopter had to circle back over a reach or side channel to get a better look at the Kokanee in the stream. The track and waypoints collected in the field were loaded onto Google Earth and verified for accuracy. The distance from each waypoint to the survey start point was measured and the stream kilometer assigned to a given waypoint was changed, where necessary. The kilometer waypoint upstream of the last Kokanee observation identified the upstream distribution limit of spawners observed in the 2018 survey. Fish counts per kilometer of stream surveyed were collected for future work, and therefore no analyses of fish distribution at the 1 km interval-scale were conducted for this report.

2.3 Kokanee Collection

Kokanee were collected from streams in each of the four sub-watersheds of the Williston Reservoir (Finlay, Omineca, Peace, and Parsnip) for aging, fecundity, genetic and fish tissue analysis. Native Kokanee were also collected from the Tacheeda Lakes for comparison with the introduced Kokanee from the reservoir. None of the analyses associated with the Kokanee collections were included in the scope of this project and will be reported separately by another agency. Forty whole Kokanee were collected by helicopter from the Manson and Germansen Rivers, as well as Russel, Aley, Pelly, and Cutoff Creek on the same days they were enumerated (helicopter access). Forty Kokanee were also collected from Dunlevy Creek on 5 October 2018, and 30 were collected from Tacheeda Lake on 10 October 2018 (ground/boat access) which was the alternative site to Arctic Lake. No fish were observed in Arctic lake or its tributaries during the enumeration counts and boat access to the lake was not possible due to low water in the outlet stream resulting in using Tacheeda Lake as the collection site. A collection was also prescribed for Reynolds Creek, with the Mesilinka River as a backup location. However, Kokanee were not observed in either location during the enumeration flights.

Kokanee were captured in the seven streams around the reservoir using a Smith-Root, model 12-B backpack electrofisher to stun fish and either a dip net or a sein net was used to capture them. A seine net was used in smaller streams with large schools of Kokanee, such as Aley and Cutoff Creek. A six meter long and 1.2 meter deep seine net was placed across the wetted width of a stream near the riffle crest below a pool. A crew member with an electrofisher walked downstream with the electricity on to stun the fish in the pool, which were carried into the seine net by the flowing water. This method was efficient for quickly capturing a large number of fish and worked best on narrow streams where fish were concentrated, and flows were strong enough to carry stunned Kokanee downstream. In larger streams with wider channels, such as the Manson and Germansen Rivers and the downstream sections of Dunlevy and Pelly Creeks, a dip net was more efficient than a seine net. Wider and deeper channels provided many more escape routes for Kokanee, and large schools were quickly dispersed when crews got close to them. In these situations, it was more efficient to target smaller groups or individual fish with an electrofisher, which were then captured with a dip net. A dip net also worked better than a seine net in slack water where flows were not strong enough to carry stunned fish downstream.

The Kokanee collected from Tacheeda Lakes were captured with a sinking and floating experimental gill net that met the BC Resources Inventory Committee (RIC) standards for Lake Assessments (FFSCBC and BCMOE 2007). Both nets consisted of six panels, 15.2 m long and of different mesh sizes that were strung together in a "gang" to form a net 91.2 m long and 2.4 m deep. The mesh sizes (in order from panel one to panel six) were 25 mm, 76 mm, 51 mm, 89 mm, 38 mm, and 64 mm. The nets were set in the littoral zones of bays and near islands where Kokanee where observed jumping at the surface. Set times were no longer than two hours and every attempt was made to live release any bi-catch species.

Scientific Fish Collection Permits were obtained through the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) in the Omineca (permit No. PG18-393476) and Peace Regions (permit No. FJ 18-381576) before Kokanee were collected and all appropriate animal care protocols were followed. Kokanee were dispatched immediately after capture by using a hard object to inflict a lethal blow to the top of skull, just behind the eyes. Fish were then weighted using a scale that was accurate to 1 gram. Fork lengths were measured using a tape that was accurate to one millimetre. Fish were individually bagged and labeled with a unique identifier that corresponded to the stream they were captured from and their recorded weight and fork length. The collected Kokanee were frozen and kept frozen within two days of capture. All Kokanee were delivered to Dr. Mark Shrimpton at the University of Northern British Columbia in Prince George within a week from their capture date for further analysis (not addressed in this report).

2.4 Spatial and Temporal Analysis

Kokanee spawner abundance was compared at both the Reservoir-scale, and at the scale of its four main sub-watersheds (the Finlay, Omineca, Peace, and Parsnip Rivers - hereafter also referred to as "Reaches"). Spawner abundance was compared between the four study years by comparing raw spawner abundance estimates (counts) gathered from aerial enumeration surveys. At the Reservoir-scale, abundance estimates were totaled across all tributary streams and rivers surveyed on a given year to gain total annual spawner abundance for the Williston reservoir. Similarly, for the four main sub-watersheds, abundance estimates from aerial surveys were summed to give a total annual abundance for each sub-watershed. The 2018 data for the Finlay River were excluded from analysis since the 2018 survey began upstream of Cutoff Creek (not at the river mouth as in previous years). Any relevant trends within and between individual study tributaries (streams and rivers targeted during aerial enumeration surveys) and how they related to their respective sub-watersheds, are also highlighted. Among study tributaries, a distinction is made between "index" and "non-index" streams. Index streams refer to the nine tributary systems recommended by Langston (2012) for annual Kokanee spawner monitoring, based on findings from initial surveys conducted between 2002 and 2006 (Table 2).

Table 2. Tributaries (streams and rivers) where aerial enumeration surveys were conducted in 2018. Index streams as recommended by Langston (2012) for annual kokanee spawner monitoring in the Williston Reservoir are highlighted in yellow.

Sub-Watershed	Survey Tributary
Finlay Reach	Davis River
	Finlay River
	Bower Creek
	Cutoff Creek
	Russel Creek
	Tsaydiz Creek
	Pelly Creek
	Pelly Lake outlet (Zygadene Creek)
	Swannell River
	Aley Creek
Omineca Reach	Mesilinka River
	Germansen River
	Osilinka River
	Dead Bear Creek
	Silver Creek
Peace Reach	Carbon Creek
	Clearwater River
	Dunlevy C
	Nabesche R
	Gething Creek
Parsnip Reach	Cut Thumb C
	Scott C
	Philip Creek (2010 data)
	Upper Manson R (above lakes)
	Lower Manson River (downstream of lakes)
	Parsnip River
	Misinchinka R
	Reynolds C

2.5 Barriers to Fish Passage

The location and type of any potential barriers to fish passage (e.g. waterfalls) located during 2018 surveys or previous study years within study tributaries, are identified and briefly discussed in relation to the highest upstream locations where Kokanee spawners were detected during aerial surveys. Barrier locations with tributaries are georeferenced in four Supplementary Maps.

3.0 RESULTS

3.1 Trends at the Reservoir Level

Across the entire Williston Reservoir, the total number of Kokanee spawners increased dramatically between 2002 and 2006 (Figure 2). A total of 518,117 spawners were enumerated in 2006 compared to only 65,714 spawners in 2002, representing about an 8-fold increase in total spawner abundance across that time span. A much smaller (1.2 fold) increase in spawner abundance was observed between 2006 and 2010, with a total of 598,096 spawners enumerated in 2010. Total spawner abundance decreased between 2010 and 2018, with a total of 184,024 spawners enumerated in 2018, representing a 3.2-fold decrease from 2010.

Spawner abundance varied considerably among the four main sub-watersheds within the Williston Reservoir, both within and between study years. In all four years, the highest number of spawners were observed in the Finlay and Omineca Reaches (Figure 3). The Omineca had the highest number of spawners until 2006. However, total spawner abundance in the Finlay surpassed the Omineca for both the 2010 and 2018 survey years. The difference in total spawner abundance between the 2 sub-watersheds was much greater in 2010 than in 2018. In 2010, approximately 1.7-times as many spawners were observed in the Finlay (353,269) compared to the Omineca (203,473). In 2018, only about 1.2-times as many spawners were observed in the Finlay (97,421) relative to the Omineca (82,036). By comparison, spawner abundance in the Peace and Parsnip Reaches was considerably lower than the Finlay and Omineca, with maximum abundance estimates reaching only 34,823 for the Peace (2010) and 42,400 for the Parsnip (2006). In 2018, the only surveyed stream in the Parsnip Reach where Kokanee were observed was in the Manson River. Fish distribution was found to be reduced in 2018 compared to previous years with Kokanee observed at or further downstream than they were observed in 2010 in all stream with the Mesilinka and Clearwater Rivers, Dead Bear and Bower Creeks being the exceptions (Appendix A Distribution Maps). Eight of the 28 streams assessed had no Kokanee observations.

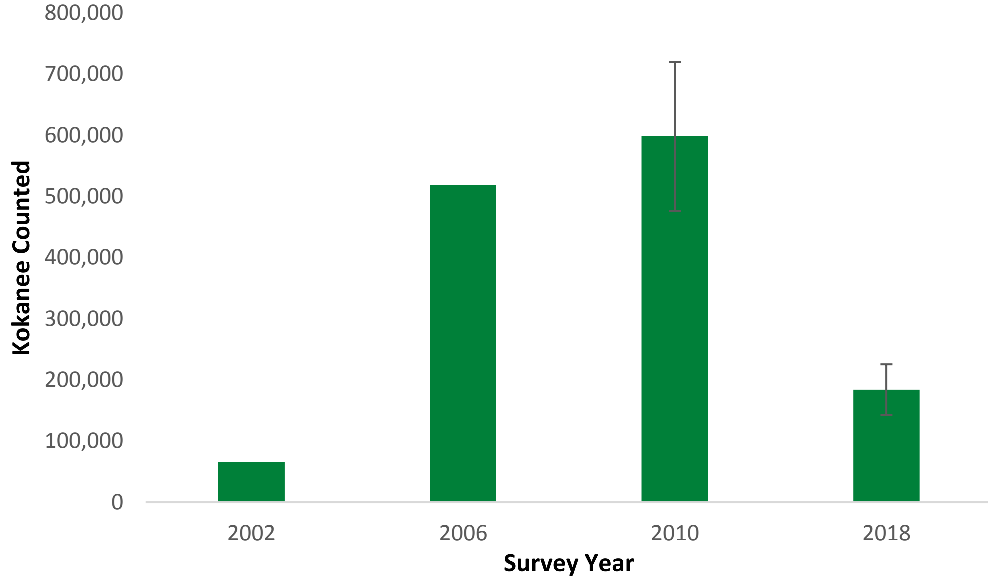


Figure 2. Number of Kokanee spawners counted in tributary streams of the Williston Reservoir from 2002 to 2018. The data included in the totals was limited to those stream counts that were comparable through all four survey years. Although data from Bower and Tsaydiz Creeks was not available for 2002, Kokanee were assumed absent from those streams in that year. The error bars for 2010 and 2018 represent the confidence range for the data in those years.

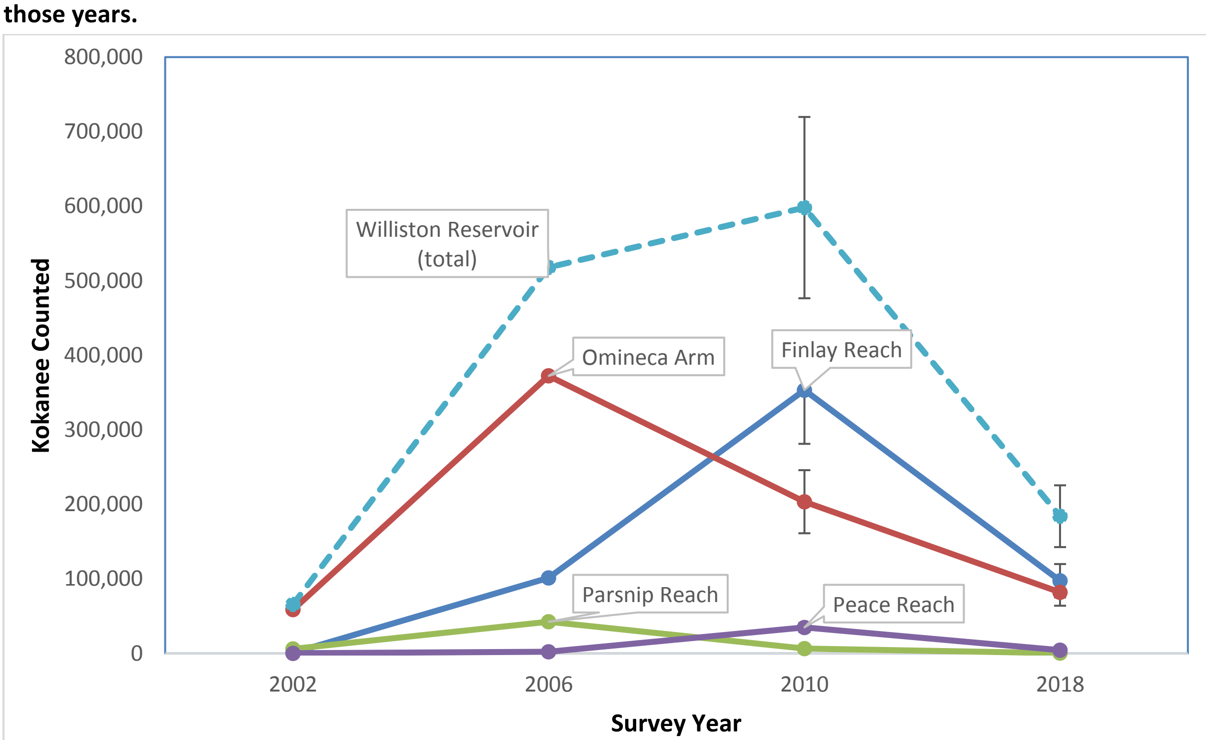


Figure 3. Trends in Kokanee spawner abundance from 2002 to 2018 in each of the four sub-watersheds of the Williston Reservoir compared to the total for the entire watershed.

3.2 Trends at the Sub-Watershed and Stream Level

In 2018, Kokanee spawners were observed in 20 of 28 tributary streams and rivers surveyed. Among the tributaries where no spawners were observed in 2018, 7 of 8 occurred in the Parsnip Reach, with fish only observed at a single tributary, the Lower Manson River (see Tables A2 and A3, *Appendix B*). Gething Creek, a new stream within the Peace Reach not surveyed in any previous years, also had no spawners detected during aerial surveys. The interannual trends in total spawner abundance observed at the Reservoir-scale were not consistently reflected across all 4 sub-watersheds.

Finlay Reach

In the Finlay Reach, Kokanee spawner abundance increased dramatically from 2002 (804) to 2006 (101, 293), and again in 2010 (353,269), representing 126-fold and 3.5-fold increases in spawner abundance in the two 4-year study periods, respectively (Figure 3). A sharp decline in spawner abundance and distribution was observed in 2018, with only 97,421 spawners enumerated, reflecting a 3.6-fold decrease compared to 2010.

The overall trends in the Finlay Reach were consistent across all of its constituent tributaries. Among indexed streams (i.e. those recommended for monitoring by Langston 2012), Russel Creek consistently had the highest number of spawners in all four study years (Figure 5). Spawner abundance varied among the 5 non-indexed streams in the four study years. Spawner abundance was generally comparable among the non-indexed streams in 3 of 4 study years (2002, 2006, and 2018). In 2006 however, the Davis River and Cutoff Creek had considerably higher spawner abundances than Aley Creek (Figure 6). The Pelly Lake Outlet stream (AKA Zygadene Creek) was not surveyed in 2002 or 2010, precluding it from abundance comparisons in those study years.

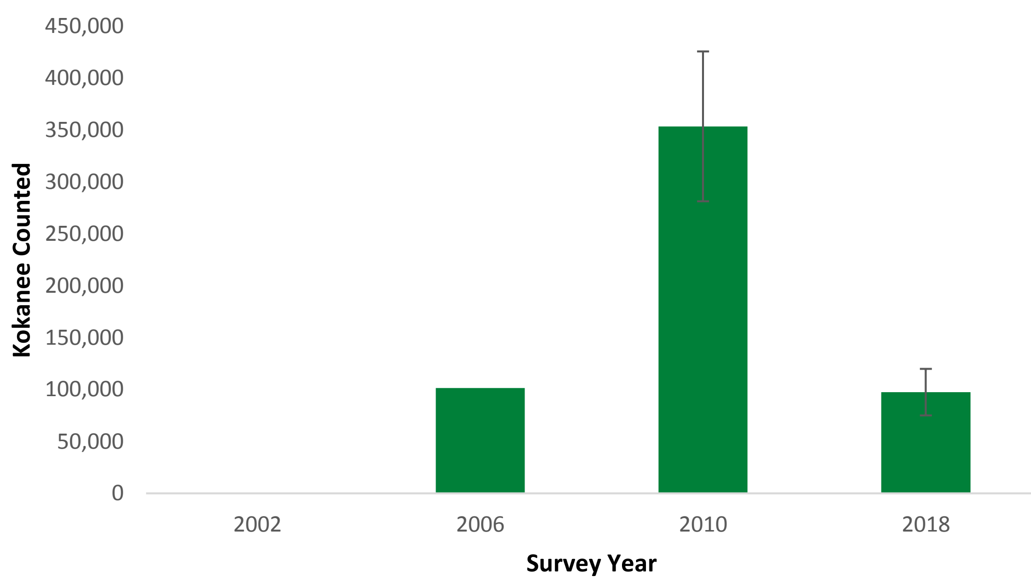


Figure 4. Number of Kokanee spawners counted in 9 tributary streams to the Finlay Reach of the Williston Reservoir from 2002 to 2018. The Finlay River was only enumerated upstream of Cutoff Creek in 2018 and was not comparable to other years. The data shown does not include the Finlay River counts in any of the four survey years. The error bars for 2010 and 2018 represent the confidence range for the data in those years.

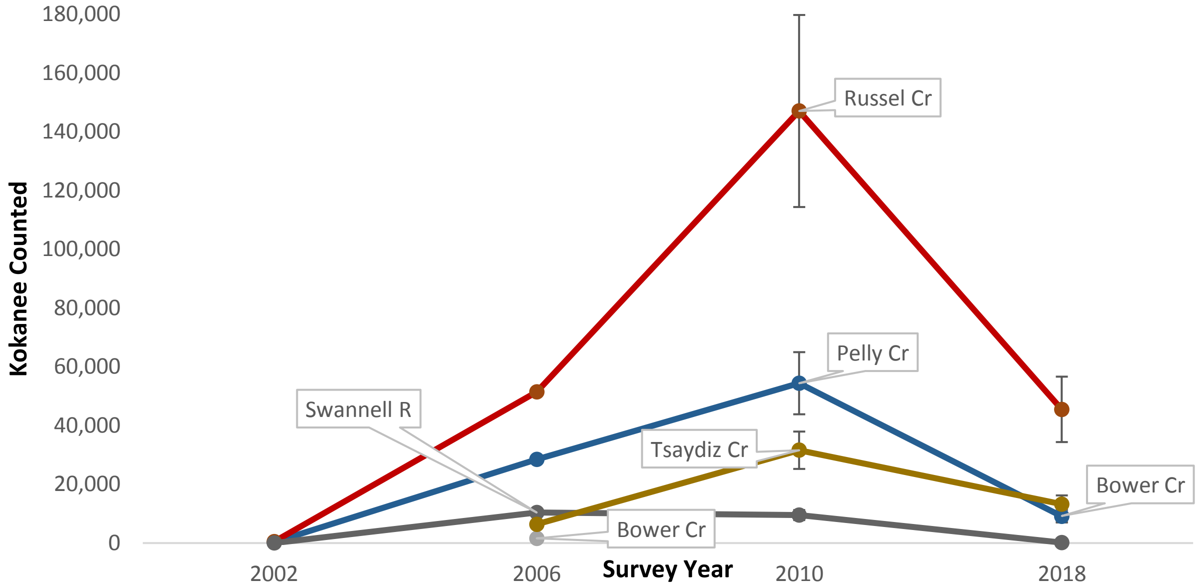


Figure 5. Trends in Kokanee spawner abundance from 2002 to 2018 for indexed streams in the Finlay Reach. Tsaydiz Creek was not enumerated in 2002. Bower Creek was not enumerated in 2002 or 2010. The error bars for 2010 and 2018 represent the confidence range for the data in those years.

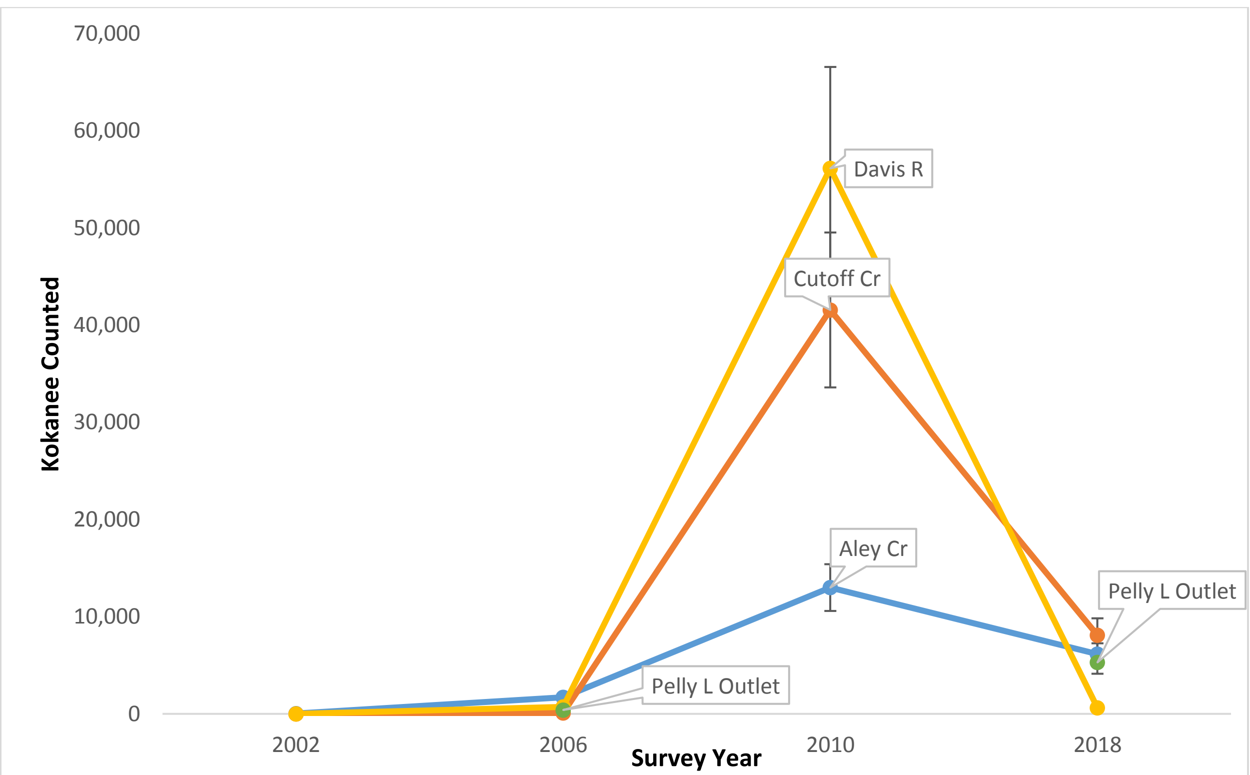


Figure 6. Trends in Kokanee spawner abundance from 2002 to 2018 for non-indexed streams in the Finlay Reach. The Pelly Lake outlet stream (AKA Zygadene Creek) was not enumerated in 2002 or 2010.

Omineca Reach

In the Omineca Reach, Kokanee spawner abundance increased between 2002 (58,600) and 2006 (372,300), representing a 6.4-fold increase in abundance (Figure 7). However, spawner abundance declined in both 2010 (203,473) and 2018 (82,036), representing 1.8-fold and 2.5 decreases in abundance for those two study periods, respectively. Kokanee distribution also generally decreased in 2018 compared to previous survey years, with the exception of the Mesilinka River and Dead Bear Creek.

The overall trends in abundance observed in the Omineca Reach between study years were consistent and most pronounced in both of the index tributary streams, the Osilinka and Germansen Rivers (Figure 8). In the year of highest overall spawner abundance (2006), the Osilinka River had the highest number of spawners (246,800), and the Germansen River the 2nd highest (108,000), relative to all other tributary streams surveyed in the Omineca. Trends between study years varied among the four non-indexed tributary streams. Most notably, the Mesilinka River showed a consistent increase in spawner abundance between 2002 and 2010. There was a slight increase in the actual Kokanee count in 2018 (49,352) compared to 2010 (49,156) but the difference was too small to be significant as the confidence intervals for these two years overlapped. Even though the abundance remained consistent between years fish were observed significantly farther upstream in 2018 than any previous year in the Mesilinka.

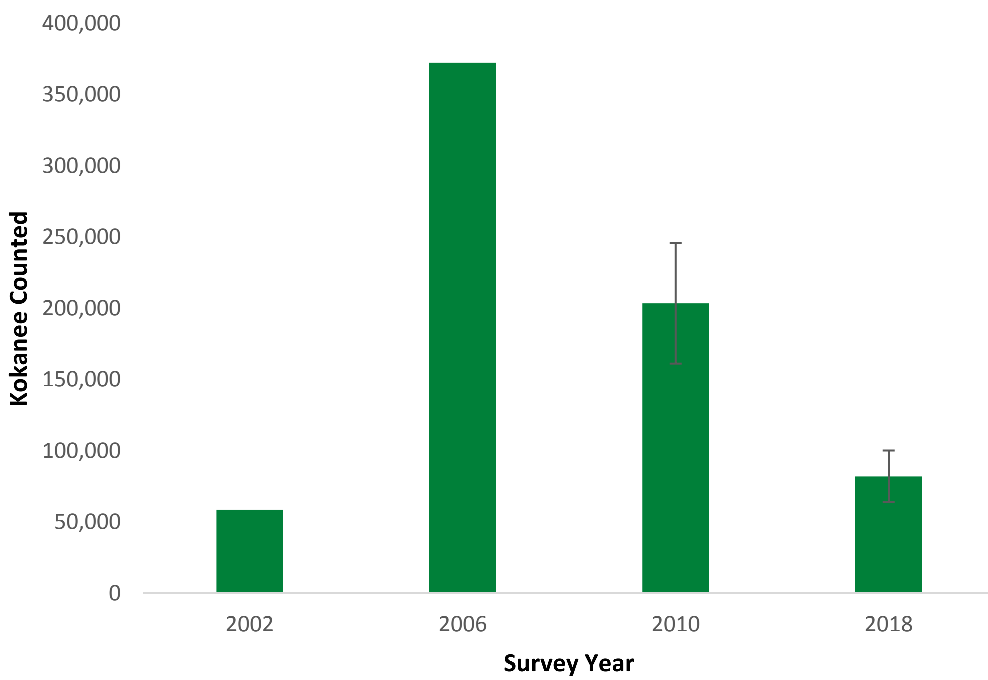


Figure 7. Comparison of the number of Kokanee spawners counted in 5 tributary streams of the Omineca Reach of the Williston Reservoir from 2002 to 2018. The error bars for 2010 and 2018 represent the confidence range for the data in those years.

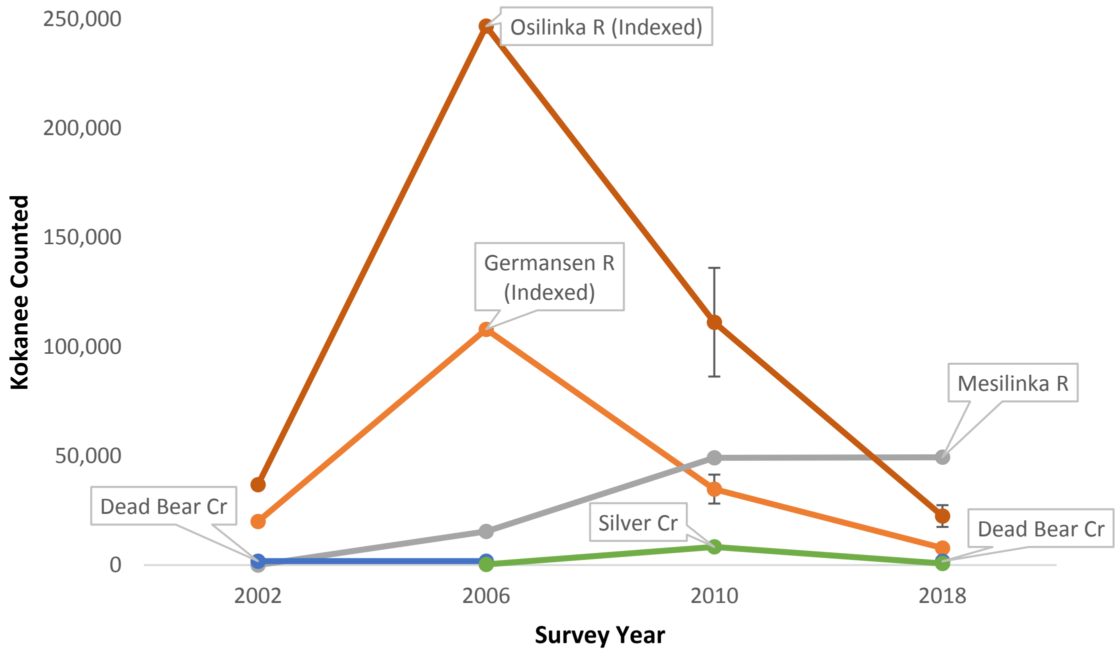


Figure 8. Trends in Kokanee spawner abundance from 2002 to 2018 for 5 streams in the Omineca Reach. Error bars on the two indexed streams (Osilinka and Germansen Rivers) for 2010 and 2018 represent the confidence range for the data in those years.

Peace Reach

In the Peace Reach, Kokanee spawner abundance increased between 2002 (200) and 2006 (2,124), and increased again in 2010 (34,823), representing 10.6-fold, and 16.4-fold increases for these 2 study periods, respectively (Figure 9). A substantial decrease in abundance was observed in 2018 (4,297), representing an 8-fold decrease from the 2010 study year. The overall trends in spawner abundance observed in the Peace Reach were consistent among all of its constituent tributaries, including the single indexed stream, the Clearwater River (Figure 10). Among tributary streams, abundance was generally comparable in 3 of four study years (2002, 2006, and 2018). In the year with the highest overall spawner abundance (2010), Dunlevy Creek and the Nabesche River had the highest and 2nd highest spawner abundance by a considerable margin compared to the other 2 study tributaries (Carbon Creek and the Clearwater River) (Figure 10).

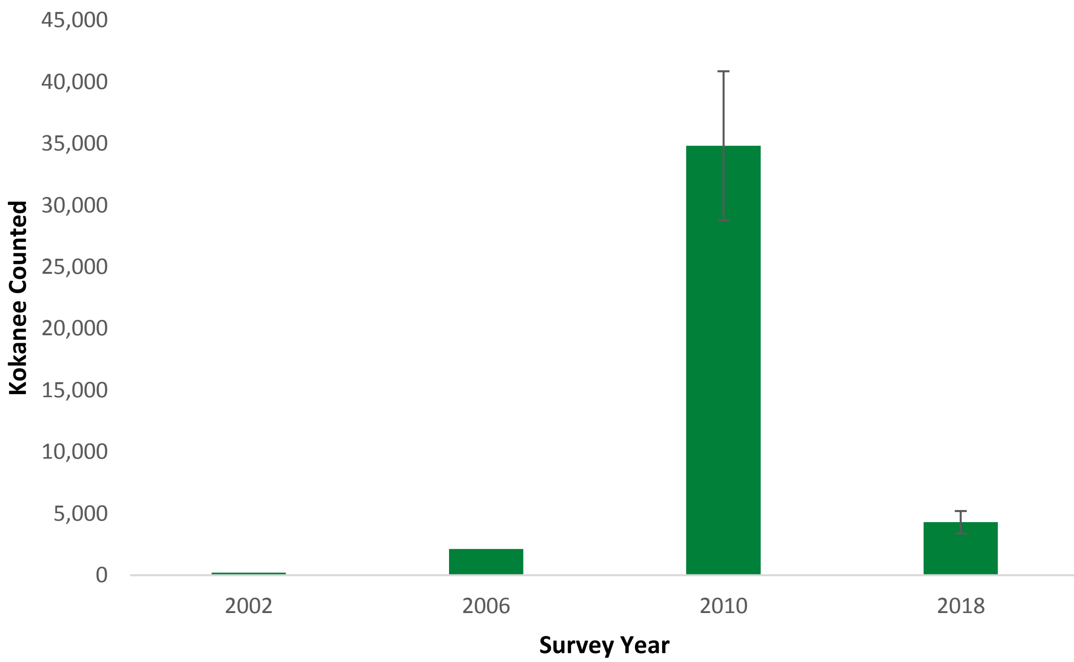


Figure 9. Comparison of the number of Kokanee spawners counted in four tributary streams to the Peace Reach of the Williston Reservoir from 2002 to 2018. The error bars for 2010 and 2018 represent the confidence range for the data in those years.

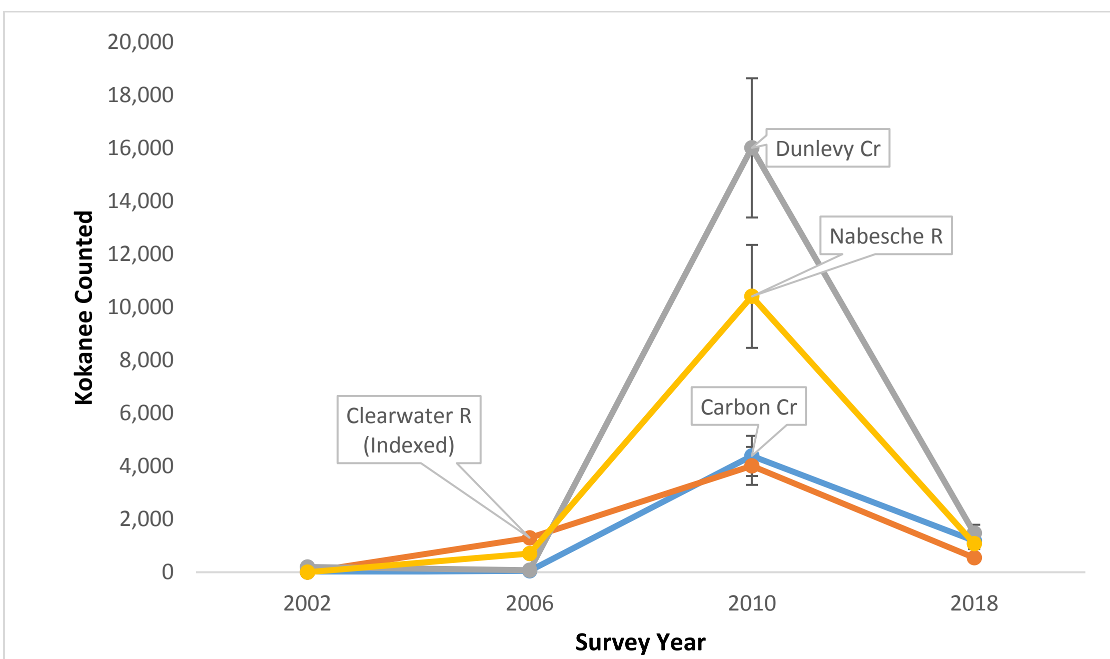


Figure 10. Trends in Kokanee spawner abundance from 2002 to 2018 in 4 streams of the Peace Reach. Error bars on the Clearwater River (indexed stream) for 2010 and 2018 represent the confidence range for the data in those years. Gething Creek not shown as no fish were observed in the only study year (2018).

Parsnip Reach

In the Parsnip Reach, overall Kokanee spawner abundance increased substantially between 2002 (6,120) and 2006 (42,400), representing a 7-fold increase in spawner abundance (Figure 11). In comparison, a large decrease in abundance was noted in 2010 (6,531) and 2018 (270), representing 6.5- and 24-fold decreases from the previous study years (2006 and 2010, respectively). During 2018, Kokanee spawners were only observed in 1 of 8 tributaries surveyed, the Lower Manson River (see Tables A2 and A3, *Appendix B*) where they were observed in areas similar to previous study years.

The overall trend in spawner abundance was consistent among all 7 of its constituent tributaries, with trends being most apparent in the single index stream, the Manson River, which had the highest spawner abundance among all tributaries in 3 of 4 study years (2002, 2006, and 2018) (Figure 12). Most notably, in the year with the highest overall spawner abundance in the Parsnip Reach (2006), the Manson River had 7.4 times as many spawners (31,300) than the Misinchinka River, which had the 2nd highest number of spawners enumerated (4,200).

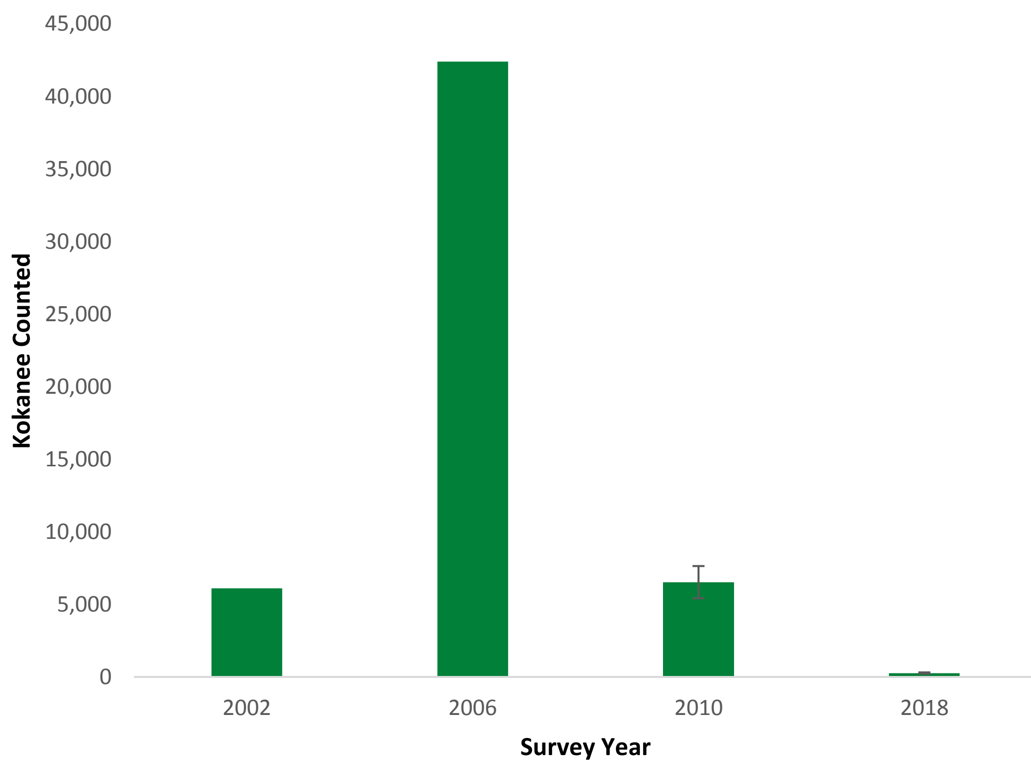
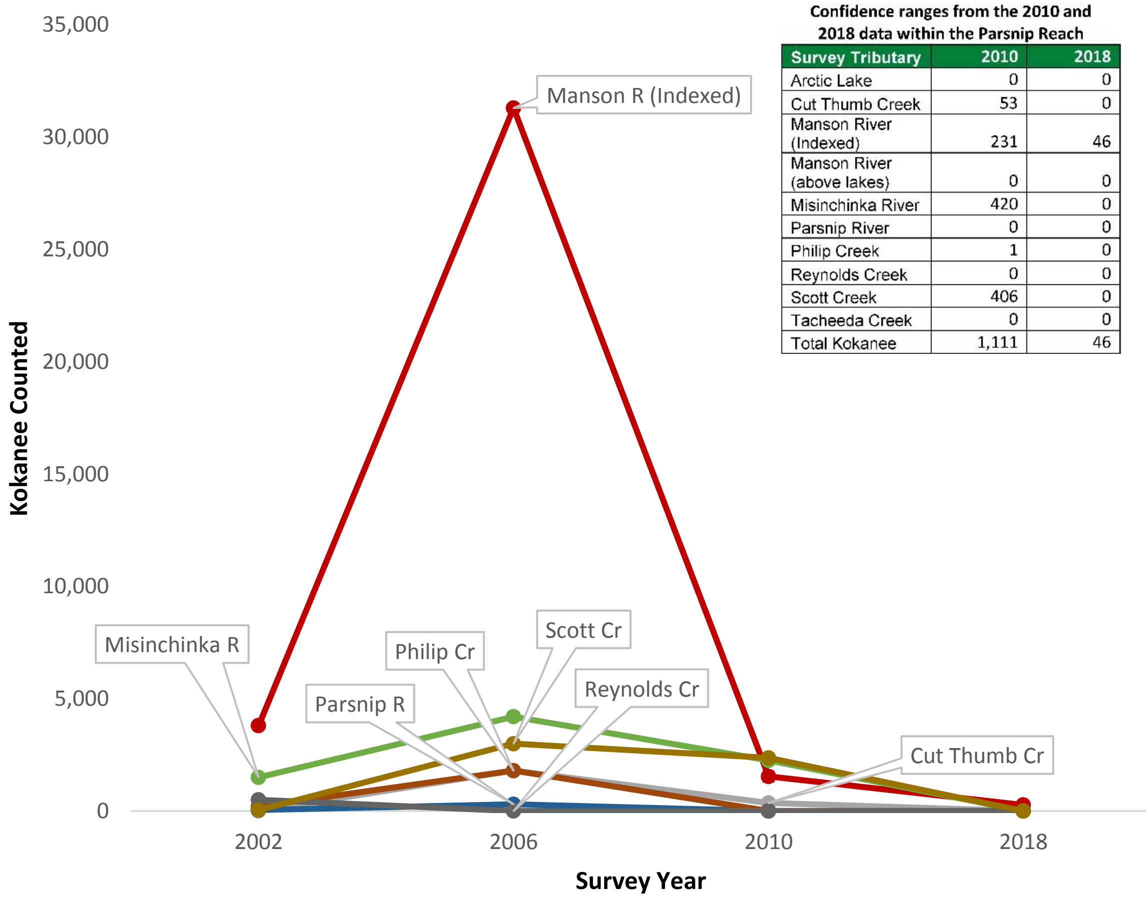


Figure 11. Comparison of the number of Kokanee spawners counted in 10 tributary streams of the Parsnip Reach in the Williston Reservoir from 2002 to 2018. The error bars for 2010 and 2018 represent the confidence range for the data in those years.



Survey Tributary	2010	2018
Arctic Lake	0	0
Cut Thumb Creek	53	0
Manson River (Indexed)	231	46
Manson River (above lakes)	0	0
Misinchinka River	420	0
Parsnip River	0	0
Philip Creek	1	0
Reynolds Creek	0	0
Scott Creek	406	0
Tacheeda Creek	0	0
Total Kokanee	1,111	46

Figure 12. Trends in Kokanee spawner abundance from 2002 to 2018 for 7 streams in the Parsnip Reach.

3.3 Upstream Barriers to fish Passage

In total, potential physical barriers to fish passage have been identified in 6 of 28 tributaries surveyed in 2018, mostly consisting of large waterfalls (Table 3). Among the four main sub-watersheds, the Peace Reach had the most tributaries with potential barriers (4 of 5 tributaries surveyed: Carbon Creek, Dunlevy Creek, Gething Creek, and the Nabesche River). The Finlay and Parsnip Reaches each had one tributary with a potential barrier identified (the Swannell River and Cut Thumb Creek, respectively). No potential barriers were located in any of the tributaries surveyed within the Omineca Reach.

Of the tributaries where potential barriers were identified, the upstream-most location where Kokanee spawners were observed on any of the four survey years was downstream of the potential barrier in all tributaries except Carbon Creek and Gething Creek, both within the Peace Reach (See Supplementary maps, *Appendix A*). For Carbon Creek, Kokanee spawners were located several kilometers upstream of the potential barrier in both 2002 (~ 16 km) and 2010 (~ 4 km), but the upstream limit of spawner detection in 2018 occurred at the barrier itself. No surveys were conducted in Carbon Creek in 2006. For Gething Creek, a tributary only recently included in 2018 surveys, a large waterfall occurred within 1 km of the stream mouth and no spawners were detected downstream of this feature.

Table 3. Location and type of potential barriers to fish passage identified during surveys conducted between 2002-2018 among 28 tributaries in the Williston Reservoir. Only tributaries where barriers were identified are shown. Also indicated is whether upstream-most location of Kokanee spawner observation for any survey year occurred upstream of the potential barrier. No barriers were identified within Omineca Reach tributaries.

Sub-Watershed	Stream	Barrier Location	Barrier type	Kokanee Spawners Upstream of Barrier
Finlay	Swannell River	10U 368290 6278830	Falls	No
Peace	Carbon Creek	10U 521943 6199539	Chute/Cascade	Yes*
	Dunlevy Creek	10U 537127 6228534	Falls	No
	Nabesche River	10U 492813 6228608	Falls	No
	Gething Creek	10U 547192 6206584	Falls	No**
Parsnip	Cut Thumb C	10U 481662 6156594	Falls	No

***Spawners were only detected upstream of the barrier in Carbon Creek in 2002 and 2010 survey years.**
****No Kokanee spawners were not observed in Gething Creek in 2018 (not surveyed in any previous years).**

4.0 DISCUSSION

4.1 Changes in Abundance and Distribution at the Reservoir Level

Among the most notable results at the Reservoir-scale was the lower number of spawners and distribution observed in 2018 compared to the previous survey in 2010, suggesting an overall decline. This apparent trend contrasts sharply with the survey results from 2002 to 2010 in which Kokanee spawner counts in the Williston Reservoir increased from year to year. Based on these data alone, it is uncertain whether Kokanee spawner populations are currently experiencing an overall decline in the Williston Reservoir. The period between 2010 and 2018 represents an 8-year timespan, which potentially encompasses 2 generations or life cycles of one Kokanee cohort (group of individuals hatched during same year). Although Kokanee typically have a 4-year life cycle on average, this period can vary between 3-5 years (Roberge et al. 2002). Based on the 8-year span between surveys, it may be possible that the peak year in spawner abundance was not captured in the 2018 surveys because the introduced Kokanee have deviated from a 4-year life cycle. The Williston Reservoir encompasses a very large and diverse watershed, and salmonids (including Kokanee) are known to exhibit considerable variability in their life history. This is particularly true with respect to generation time and adaptation of populations to local conditions and habitats (Milner et al. 2003; Whitlock et al. 2018). It is therefore conceivable that multiple non-overlapping spawning cohorts exist across the Williston watershed after 20+ years since their introduction.

If the large difference in spawner abundance between 2010 and 2018 does indeed represent a decline in spawning populations, one possible explanation could be related to density-dependant effects. Spawner abundance increased substantially in the early 2000s (2002-2010), approximately 10-15 years following stocking programs, and the declines observed in the last decade (2010-2018) may be the result of negative density-dependent effects. Generally, populations of Kokanee and other salmonid species tend to be controlled by density-dependent effects, primarily at the egg and hatchling stages (Milner et al. 2003). Mechanisms underlying these effects can include increased competition for food, habitat and other resources, or higher predation rates on different life stages. Bull Trout (*Salvelinus confluentus*) and Lake Trout (*Salvelinus namaycush*), for example, are 2 native fish species to the Williston watershed. As large-bodied, piscivorous fish species, Kokanee and other salmonid species constitute an important prey source for Bull Trout (Pate et al. 2014; Beacham and Withler 2017). In these potential scenarios, higher densities within Kokanee populations may have led to reduced survivorship at one or more life stages (eggs, hatchlings) ultimately resulting in lower recruitment into spawner populations (i.e. fewer juveniles and mature spawning adults).

4.2 Changes in Abundance and Distribution at the Sub-Watershed and Stream Level

The overall trends in spawner abundance observed at the Reservoir-scale were not consistent among all four sub-watersheds in all years, with the most notable variation occurring between the 2006 and 2010. Both the Finlay and Peace Reaches saw an increase in spawners between 2006 and 2010, whereas abundance decreased in the Omineca and Parsnip during this period which suggests a distribution shift to the northern reaches of the Reservoir. Kokanee spawner abundance and distribution was reduced in all four sub-watersheds in 2018 compared to 2010.

The Omineca and Finlay Reaches made up the highest proportion of total spawners in both 2010 and 2018. These observations are consistent with the findings from previous surveys conducted between 2002 and 2006 (Langston 2012). This may suggest that Kokanee spawners are preferentially using spawning tributaries in the north and northwest portions of the Williston reservoir, relative to those in south and southeast, represented by the Parsnip and Peace Reaches, respectively. However, given that Kokanee and other salmonids are known to exhibit a high degree of spawning fidelity - where spawners return to the same spawning habitat in which they were reared (Dittman and Quinn 1996) - it seems more plausible that Omineca and Finlay arms simply support larger populations of kokanee spawners than the Peace and Parsnip.

Finlay Reach

Between 2002 and 2010, the Finlay Reach, located in the northern-most portion of the reservoir, showed the largest consistent increase in spawner abundance among the four sub-watersheds. Although the causes behind the increases are currently unclear, they may be due to the presence of more favorable spawning and/or rearing habitat in in the northern-most portion of the Williston Reservoir.

Among the 11 tributaries surveyed within the Finlay Reach, all 6 index streams showed similar interannual trends, with Russel Creek making up the highest proportion of spawners, consistently having the highest spawner abundance from 2006 onward. Given that Russel Creek appears to consistently have the largest Kokanee spawning abundances during surveys, and that its interannual trends mirror those of the entire Finlay Reach, means it makes a good candidate for future spawner surveys. Among the 5 non-index streams, both Davis Creek and Cutoff Creek also appear to support larger Kokanee spawning populations relative to other tributaries surveyed, and therefore may also serve as valuable sites for future survey efforts.

With the exception of Bower Creek, where Kokanee were observed further upstream than in 2006, distribution of fish within the Finlay Reach was generally lower than previous years which is to be expected with a lower overall abundance in the 2018 survey.

Omineca Reach

Contrary to the trend observed at the Reservoir-scale, Kokanee spawner abundance has declined in the Omineca Reach since 2006, with substantial declines observed both in 2010 and 2018. Similar to the Finlay, Kokanee counts in the Omineca Reach have always been a large proportion of total spawners enumerated in the Williston Reservoir. The Omineca Reach had the 2nd highest spawner abundance among the four sub-watersheds in 2010 and 2018, and highest abundance in 2006. Based on these findings, the Omineca, like the Finlay, may support larger Kokanee spawner populations compared to the Peace and Parsnip Reaches (see below). These findings are consistent with those found during initial surveys conducted between 2002 and 2006 (Langston 2012). However, in contrast to abundance trends in the Finlay Reach, and at the Reservoir-scale, spawner abundance declined in the Omineca Reach in 2010. The consistently high spawner counts in the Finlay and Omineca relative to the other reaches may suggest the presence of more favorable spawning or rearing habitats. Because spawner abundances were reduced in both the Finlay and Omineca Reaches over a 4-year (2006-2010) and 8-year (2010-2018) periods suggests they may reflect actual fluctuations in spawner populations rather than being the result of peak spawner returns missed between survey periods. Without performing spawner surveys over shorter time interval (e.g. every 1 or 2 years), the latter possibility cannot be excluded.

Interannual changes in abundance within the Omineca Reach were consistently reflected in its two index streams, the Osilinka and Germansen Rivers. These two tributaries had the highest and 2nd highest spawner abundances in the Omineca from 2006 onward. As such, both streams make suitable candidates for future spawner monitoring efforts.

Similar to the Finlay Reach, Kokanee distribution throughout the Omineca Reach was lower in 2018 as expected with lower overall abundance in each system. However, although Kokanee abundance within the Mesilinka River was similar between 2010 and 2018 Kokanee were observed significantly further upstream in 2018 than 2010. It is uncertain why Kokanee were found further upstream in the Mesilinka despite similar abundance to previous years but could be habitat or flow related both of which were not in the scope of the assessment; however, could be a subject of future discussions if this trend is noted again in future years.

Peace and Parsnip Reaches

Contrasting the Finlay and Omineca, the Peace and Parsnip Reaches both had substantially lower Kokanee spawner abundances during all four study years. Though both sub-watersheds experienced declines in spawner abundance between 2010 and 2018, paralleling observed changes within the Finlay and Omineca, the 2 sub-watershed showed opposing trends between 2006 and 2010. In those years, spawner abundance increased in the Peace and decreased in the Parsnip. Again, although the causes for these fluctuations are unclear, the large changes in spawner abundance over both 4-year and 8-year periods may reflect actual changes in spawner population size rather than missing peak return years.

All survey tributaries in the Peace Reach mirrored interannual abundance fluctuations that were observed at the sub-watershed scale. Dunlevy Creek and the Nabesche River (both non-index sites) showed higher (2010) or comparable spawner abundance to the single indexed stream for the reach, the Clearwater River. Kokanee observations in Carbon Creek were not as high as in Dunlevy Creek or the Nabesche River in 2010, but were always similar to those in the Clearwater River. Dunlevy Creek, Carbon Creek and the Nabesche River are therefore all suitable candidates for future surveys. Gething Creek, however, is not recommended for future surveys. The only year that Gething Creek has been enumerated was in 2018 and no Kokanee were observed there. Very little spawning habitat was observed and a significant barrier (waterfall) was located within 1 km from the stream mouth. 11 Mile Creek was proposed by FWCP as an alternative survey site.

For the Parsnip Reach, Kokanee spawners were only observed at a single tributary in 2018, the Lower Manson River. In contrast, no Kokanee spawners have ever been observed in the Upper Manson River during any previous years' surveys. Habitat observations from 2010 (Langston *unpublished data*) and 2018 noted an abundance of fines and mud in the substrate and poor overall spawning potential upstream of the Manson Lakes. It is very unlikely that Kokanee will ever be observed spawning in the Upper Manson River and it is recommended that it be removed from future surveys. The upper Parsnip River above the Hominika River mouth is also a poor candidate for future survey efforts. Previous surveys of the Parsnip River have never counted more than a total of 300 Kokanee and its glacial influenced tributaries contribute to high seasonal turbidity levels and poor visibility. In 2018, gravel substrates that had potential to support Kokanee spawning were only observed from the mouth of the Parsnip River upstream to the mouth of the Hominika River. The substrate is dominated by silt upstream of that point, and spawning potential is poor to non-existent upstream of the Hominika River and all the way to Arctic Lake. The lack of Kokanee observations in 2018 at other survey tributaries in the Parsnip Reach may again be due to the presence of several non-overlapping Kokanee spawning cohorts across the different tributaries of the Williston Reservoir. Future spawner surveys on an annual basis would determine if the absence of Kokanee from these sites in 2018 was due to multiple cohorts.

Fish distribution in both the Peace and Parsnip Reaches decreased in 2018 with many systems having no Kokanee observations in 2018. Kokanee were observed as far as 7 km upstream within the Clearwater River, which was slightly more than any of the previous survey years. However, Kokanee abundance within the Clearwater River decreased from previous years. In general it is thought that fish distribution decreased as a result of lower Kokanee abundance in the 2018 survey.

4.3 Uncertainty Analysis

The low numbers of Kokanee observed in 2018 relative to the 2010 and 2006 surveys initially raised concerns about the timing of the enumeration flights relative to peak Kokanee returns. The 2018 survey occurred in the window recommended by Langston (2012) and overlapped the dates flown in 2010 (12 to 18 September - Langston 2010 *unpublished data*). However, the lower than expected counts gave the initial impression that the 2018 survey may have been scheduled too early or too late in the run of Kokanee spawners to capture the peak return. No Kokanee carcasses were observed in any of the streams during the 2018 survey which does not suggest that the timing was too late. The condition of the Kokanee spawners that were collected from Alley Creek, Russel Creek, Cutoff Creek, Pelly Creek, Germanson River and the Manson River during the enumeration flights provided assurances that the timing was appropriate. The Kokanee collected were in relatively good condition with few signs of fin or tissue damage associated with redd construction or rapid senecence. Females were observed that appeared to still have most or all of their eggs intact (pre-spawn or actively spawning) while others were observed that appeared to have spent their eggs (post-spawn). Males were also observed producing varying amounts of milt upon collection, suggesting that they were yet to spawn or were in the process of fertilizing eggs. Kokanee redds were observed on many streams in 2018 and further suggested spawning was actively occurring during the flights. Kokanee were collected from Dunlevy Creek two weeks after the enumeration flights on 5 October, 2018 and the condition of those fish suggested that spawning in that location was nearing completion. No dead Kokanee carcasses were observed at that time but many of the females had little of their tail and anal fins left and although some still had eggs, many appeared to have completed spawning and were showing signs of rapid, post-spawn senescence. The conditions observed during the 2018 spawner survey provides compelling evidence that it was well timed and that the counts accurately estimated the peak in Kokanee returns to spawning grounds.

Count accuracy and confidence is influenced by the skill and experience of the observers during enumeration flights and there was significant difference in the level of crew experience in 2018 compared to earlier surveys. Arne Langston and Randy Zemlak from the FWCP enumerated Kokanee in the Williston Reservoir in 2002, 2006 and 2010. Arne and Randy were also able to conduct an enumeration flight with an experienced Kokanee enumerator at some point during the 2002 to 2006 surveys. The crew from DWB that counted Kokanee in 2018 were significantly less skilled and experienced in areal enumerations than the FWCP staff and this was evident when comparing the data sheets from 2010 and 2018. The confidence ratings assigned to individual Kokanee counts in 2010 appeared to be higher, in general, than those assigned to Kokanee counts in 2018. This was especially evident when the confidence rating by grouping size was compared. However, the error associated with the counts from both years appears to be proportional to the total count (Figure 2). Although it is reasonable to assume that Arne and Randy were more skilled and experienced in 2010 than DWB was in 2018, DWB didn’t have to count as many fish, or as many very large groups. This may have mitigated differences in the accuracy of the two enumeration years despite the lack of consistency between survey crews.

Interpretations of the enumeration data from 2002, 2006, 2010 and 2018 are based on a number of critical assumptions. Key assumptions include the 4-year life cycle of Kokanee and that the observed changes in the selected cohort are representative of all Kokanee in the reservoir. Aging the Kokanee spawners collected in the 2018 survey will provide useful information that will support or discredit the assumption of a 4-year life cycle. Considerable variation in population size appears to have occurred in the study cohort since 2002 but little is known about the variation in the other cohorts that were enumerated from 2003 to 2005. Enumerating Kokanee returns in 2019, 2020, and 2021, would provide a more complete and accurate interpretation of Kokanee population dynamics in the reservoir.

5.0 RECOMMENDATIONS

Based on the findings from this study, we recommend continued annual Kokanee spawner surveys over the next 3 years. Enumerating spawners annually over a 4-year period (including 2018) will help achieve the following objectives: (i) determine if Kokanee spawning abundances increase or continue to decline, and (ii) identify any evidence of multiple overlapping Kokanee cohorts across the Williston watershed, sub-watersheds, and spawning tributaries. This will help to determine if stocks are declining or if the peak spawning year for Williston Kokanee populations did not occur in 2018. Spawner surveys should focus on the same tributaries surveyed in 2018, with the exception of Gething Creek in the Peace Reach, and the Upper Manson River in the Parsnip Reach. Based on communications with FWCP, 11 Mile Creek is recommended as a replacement stream for Gething Creek as it is also located in the Peace Reach. Despite lack of observations in the Parsnip River over the years, there is still interest in surveying the river due to conservation concerns with the native Kokanee population in Arctic Lake; however, FWCP has suggested a modified survey approach. The modified approach would see the assessment split into two reaches with the first reach being the confluence with the reservoir to the confluence with Reynolds Creek and another section from the outlet of Arctic Lake downstream for 10 km (approximately Lat: 54.52296 N, Lon: 121.92229 W).

Survey methods should continue to follow those used during previous study years, with a primary focus on aerial enumeration surveys. Aerial surveys should continue to include confidence estimates on spawner counts to allow robust comparisons in future years. In addition, given that the 9 index streams recommended by Langston (2012) showed interannual trends in spawner abundance that consistently reflected those seen at the reservoir-scale, and at each sub-watershed, these sites should continue to be included in future surveys.

FWCP and MFLNRORD with collaboration from UNBC have indicated there is interest in continuing with field collection of Kokanee within the watershed. The recommendation includes a total of 5 sites: Russel Creek, Germansen River, Aley Creek, Finlay River side channels, and Arctic Lake. This list includes 1 new site (Finlay River side channels) as well as a summer sample of Arctic Lake when boat access is more likely possible. Fish collection from the Finlay River side channels is being considered for sampling since native Kokanee have been historically documented in these locations. The Kokanee have been observed in these locations later than the typical aerial surveys would be completed, and therefore the recommended timing is mid to late October.

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7.0 REFERENCES

BC Research. 1977. Limnology of Arrow, McNaughton, Upper Campbell, and Williston Lakes. Project No. 1-05-807. Prepared for BC Hydro Power and Authority, Vancouver, BC.

Beacham TD, Withler RE. 2017. Population structure of sea-type and lake-type sockeye salmon and kokanee in the Fraser River and Columbia River drainages. PLoS One 12:e0183713.

Blackman BG, Jesson D. 1990. Williston Lake fisheries compensation program management plan. Peace Williston Compensation Program. Prince George, BC.

Dittman A, Quinn T. 1996. Homing in Pacific salmon: mechanisms and ecological basis. J. Exp. Biol. 199:83–91.

Langston AR, Zemlak RJ. 1998. Williston Reservoir Stocked Kokanee Spawning Assessment, 1994. Fish and Wildlife Compensation Program. Prince George, BC.

Langston AR, Murphy EB. 2008. The history of fish introductions (to 2005) in the Peace/Williston Fish and Wildlife Compensation Program Area. Fish and Wildlife Compensation Program. Prince George, BC.

Langston AR. 2012. Williston Watershed Kokanee Spawner Distribution and Enumeration Surveys (2002 – 2006). Fish and Wildlife Compensation Program. Prince George, BC.

McLean AR, Blackman BG. 1991. Williston watershed aerial Kokanee (Oncorhynchus nerka) spawning survey 1990. Peace/Williston Fish and Wildlife Compensation Program. Prince George, BC.

McGurk MD. 2000. Comparison of fecundity-length-latitude relationships between nonanadromous (kokanee) and anadromous sockeye salmon (Oncorhynchus nerka) . Can. J. Zool. 78:1791–1805.

Milner NJ, Elliott JM, Armstrong JD, Gardiner R, Welton JS, Ladle M. 2003. The natural control of salmon and trout populations in streams. Fisheries Research 62:111–125.

Nelson JS. 1968. Distribution and Nomenclature of North American Kokanee, *Oncorhynchus nerka*. J. Fish. Res. Bd. Can. 25:409–414.

Pate WM, Johnson BM, Lepak JM, Brauch D. 2014. Managing for coexistence of kokanee and trophy lake trout in a montane reservoir. North American Journal of Fisheries Management 34:908–922.

Roberge MH, Hume JM, Minns CK, Slaney T. 2002. Life history characteristics of freshwater fishes occurring in British Columbia and the Yukon, with major emphasis on stream habitat characteristics. Can. Manuscr. Rep. Fish. Aquat. Sci.:xiv–248.

Taylor EB, Kuiper A, Troffe PM, Hoysak DJ, Pollard S. 2000. Variation in developmental biology and microsatellite DNA in reproductive ecotypes of kokanee, Oncorhynchus nerka: Implications for declining populations in a large British Columbia lake. Conservation Genetics 1:231–249.

Whitlock SL, Campbell MR, Quist MC, Dux AM. 2018. Using Genetic and Phenotypic Comparisons to Evaluate Apparent Segregation among Kokanee Spawning Groups. Trans Am Fish Soc 147:43–60.

Wood CC, Foote CJ. 1996. Evidence for Sympatric Genetic Divergence of Anadromous and Nonanadromous Morphs of Sockeye Salmon (Oncorhynchus nerka). Evolution 50:1265.

Appendix A

Maps

Appendix B

Data Tables

Table A1. UTM coordinates for start and end points of aerial enumeration surveys conducted in 2002, 2006, 2010, and 2018 in 28 spawning tributaries of the Williston Reservoir. All surveys started at the stream or river mouth. Not all streams were surveyed every year.

			Survey End			
Sub-Watershed	**Stream**	**Survey Start**	**2002**	**2006**	**2010**	**2018**
Finlay	Davis River	10 409740 6268587	10 411406 6283144	10 411406 6283144	10 412132 6283820	10 412894 6277655
	Finlay River	10 376713 6316052	9 626764 6330417	9 626764 6330417	9 673145 6383941	9 670453 6388539
	Bower Creek	10 324801 6370015	9 678082 6369629	9 678082 6369629	**Not Surveyed**	9 675804 6366585
	Cutoff Creek	9 675443 6380017	10 674285 6380630	10 674285 6380630	9 666083 6383151	9 667901 6382583
	Russel Creek	10 357499 6342941	10 357535 6342937	10 357535 6342937	10 345987 6345394	10 346851 6345706
	Tsaydiz Creek	10 370755 6322856	**Not Surveyed**	10 367046 6321753	10 366022 6321472	10 366274 6321570
	Pelly Creek	10 350034 6293856	10 348670 6301820	10 348670 6301820	10 344183 6305421	10 345097 6305106
	Pelly Lake outlet (Zygadene Creek)	10 349285 6300589	**Not Surveyed**	10 351135 6302672	**Not Surveyed**	10 349292 6300602
	Swannell River	10 371674 6289552	10 366767 6278529	10 366767 6278529	10 367355 6278698	10 369115 6279864
	Aley Creek	10 442799 6258212	10 445206 6259428	10 445206 6259428	10 448850 6262505	10 447183 6261644
Omineca	Mesilinka River	10 408033 6222765	10 332074 6255964	10 332074 6255964	10 378361 6256207	10 365621 6246227
	Germansen River	10 394482 6183985	10 395835 6177595	10 395835 6177595	10 397114 6177120	10 397217 6176601
	Osilinka River	10 404251 6216805	10 360488 6215118	10 360488 6215118	10 371300 6223295	10 371378 6223445
	Dead Bear Creek	10 387972 6221477	10 387604 6221759	10 387604 6221759	**Not Surveyed**	10 385456 6224435
	Silver Creek	10 348097 6181799	**Not Surveyed**	10 346180 6181292	10 346395 6181334	10 344988 6181108
Peace	Carbon Creek	10 519586 6205293	10 512075 6181409	10 512075 6181409	10 522905 6194816	10 522765 6195091
	Clearwater River	10 489828 6194512	10 506904 6163649	10 506904 6163649	10 490002 6195158	10 492325 6186844
	Dunlevy Creek	10 538523 6224798	10 537127 6228534	10 537127 6228534	10 537172 6228582	10 537266 6229632
	Nabesche River	10 488869 6220139	10 490878 6223936	10 490878 6223936	10 492882 6228679	10 493141 6229476

	Gething Creek	10 538385 6224897	**Not Surveyed**	**Not surveyed**	**Not Surveyed**	10 547001 6206369
Parsnip	Cut Thumb Creek	10 479367 6154909	10 481643 6129946	10 481643 6129946	10 481314 6156524	10 481662 6156594
	Scott Creek	10 464419 6175528	10 465275 6176956	10 465275 6176956	10 466235 6178557	10 466150 6178896
	Philip Creek (2010 data)	10 458282 6128886	No Data	No Data	10 461217 6127620	10 461344 6127679
	Upper Manson River (above lakes)	10 412305 6168756	**Not Surveyed**	10 410017 6170926	10 411365 6169391	10 409128 6170039
	Lower Manson River (downstream of lakes)	10 448217 6177096	10 416773 6160421	10 416773 6160421	10 416817 6160433	10 417414 6159716
	Parsnip River	10 495440 6114475	10 584155 6032398	10 584155 6032398	10 581935 6033178	10 581928 6033185
	Misinchinka River	10 502588 6106299	10 508856 6109016	10 508856 6109016	10 509494 6032319	10 508805 6109564
	Reynolds Creek	10 519907 6085825	10 525021 6088910	10 525021 6088910	10 522003 6088566	10 522197 6088861

Table A2. UTM coordinates for the uppermost extent of Kokanee spawner observations during aerial enumeration surveys conducted in 2002, 2006, 2010, and 2018 in 28 spawning tributaries of the Williston Reservoir.
***Bold depicts streams where fish distribution was greater than previous survey.**

		Uppermost location Kokanee observed					
Sub-Watershed	Stream	2002	2006	2010	2018	Barrier Location	Barrier type
Finlay	Davis R	No Fish	10U 409456 6268631	No Data	10U 412017 6273944	-	-
	Finlay R	No Fish	10U 320519 6378020	9U 673145 6383941	9U 673027 6384331	9U 673027 6384331	Chute/Falls
	Bower C	No Fish	9U 678417 6370402	Not Surveyed	9U 676274 6367730	-	-
	Cutoff C	No Fish	9U 674474 6380592	9 668002 6382562	9U 669577 6381585	-	-
	Russel C	No Data	No data	10U 347697 6345684	10U 347575 6345757	-	-
	Tsaydiz C	Not Surveyed	10U 367761 6322172	10U 367023 6321735	10U 367741 6322157	-	-
	Pelly C	No Data	10U 348670 6301820	10 345523 6304169	10U 347517 6302859	-	-
	Pelly Lake outlet (Zygadene Creek)	Not Surveyed	No data	Not Surveyed	10U 350060 6302190	-	-
	Swannell R	No Fish	10U 369154 6279820	10U 369186 6279670	10U 370951 6287752	10U 368290 6278830	Falls
	Aley C	No Data	No data	10U 448321 6262260	10U 444319 6259449	-	-
Omineca	**Mesilinka R**	No Fish	10U 379102 625551	10U 380855 6254783	10V 368755 6247991	-	-
	Germansen R	No Data	10U 395242 6179108	10U 396341 6177637	10U 395257 6179308	-	-
	Osilinka R	No Data	10U 374534 6223328	10U 373826 6223322	10U 388061 6221646	-	-
	Dead Bear C	No Data	10U 387604 6221759	Not Surveyed	10U 386595 6222859	-	-
	Silver C	Not Surveyed	10U 346180 6181292	10U 346666 6181233	10U 346680 6181213	-	-
Peace	Carbon C	10U 521090 6184950	No Fish	10U 522594 6196123	10U 521943 6199539	10U 521943 6199539	Chute/Cascade

	Clearwater R	No Fish	10U 490095 6191235	10U 490766 6189219	10U 490900 6188861	-	-
	Dunlevy C	No Data	10U 537699 6225870	10U 537127 6228534	10U 537153 6228541	10U 537127 6228534	-
	Nabesche R	No Fish	10U 490878 6223936	10U 492813 6228608	10U 492050 6227637	10U 492813 6228608	-
	Gething Creek	Not Surveyed	Not Surveyed	Not Surveyed	No Fish	10U 547192 6206584	-
Parsnip	Cut Thumb C	No Data	10U 481643 6156589	10U 480984 6155972	No Fish	10U 481662 6156594	-
	Scott C	No Data	No data	10U 466342 6177932	No Fish	-	-
	Philip Creek	No Data	10U 462037 6176802	10U 460479 6128299	No Fish	-	-
	Upper Manson R (above lakes)	Not Surveyed	No Fish	No Fish	No Fish	-	-
	Lower Manson R (below lakes)	No Data	10U 410076 6170891	No data	10U 459094 6129079	-	-
	Parsnip River	No Data	10U 504225 6104817	No Fish	No Fish	-	-
	Misinchinka R	No Data	10U 508856 6109016	10U 507844 6108148	No Fish	-	-
	Reynolds C	No Data	10U 521308 6087799	No Fish	No Fish	-	-
	Gething C	Not Surveyed	Not Surveyed	Not Surveyed	No Fish	-	-

Table A3. Kokanee spawner abundance for each of the 28 tributaries surveyed in 2002, 2006, 2010, and 2018 in the Williston Reservoir. Index streams recommended for annual spawner monitoring by Langston (2012) are highlighted in yellow. Note - not all streams were surveyed every year (NS = Not surveyed). *2018 data for the Finlay River were excluded from analysis since 2018 survey began upstream of Cutoff Creek (not at river mouth as in previous years). **No data for 2002 so 2003 data used to allow comparisons.

Sub-Watershed	Stream	2002	2006	2010	2018
		Total	Total	Total	Total
Finlay	Aley Creek	36	1700	12992	6145
	Cutoff Creek	0	93	41555	8090
	Bower Creek**	**0**	**16000**	**NS**	**9230**
	Davis River	0	700	56120	631
	Finlay River*	0	33200	268756	2250
	Pelly Lake Outlet (Zygadene)	NS	400	NS	5295
	Pelly Creek	**300**	**28500**	**54406**	**9040**
	Russel Creek	**468**	**51500**	**147080**	**45510**
	Swannell River	**0**	**10400**	**9526**	**210**
	Tsaydiz**	**0**	**6400**	**31590**	**13270**
Omineca	**Germansen River**	**20000**	**108000**	**34789**	**7825**
	Mesilinka River	0	15400	49156	49352
	Osilinka River	**36800**	**246800**	**111236**	**22450**
	Dead Bear	1800	1800	NS	1704
	Silver Creek	NS	300	8292	705
Parsnip	Cut Thumb	10	1800	356	0
	Manson River (below lakes)	**3800**	**31300**	**1538**	**270**
	Manson River (above lakes)		0	0	0
	Misinchinka River	1500	4200	2257	0
	Parsnip River	50	300	0	0
	Philip Creek	200	1800	5	0
	Reynolds Creek	500	0	0	0
	Scott Creek	50	3000	2375	0
Peace	Carbon Creek	0	49	4388	1186
	Clearwater River	**0**	**1300**	**4012**	**550**
	Dunlevy Creek	200	75	16014	1481
	Nabesche River	0	700	10409	1080
	Gething Creek	NS	NS	NS	0
	Total Kokanee	**65714**	**518117**	**598096**	**184024**

Table A4. Kokanee spawner abundance for each of the 28 tributaries surveyed in 2010 and 2018 with minimum and maximum values calculated based on confidence ratings (see Table 1). Index streams recommended for annual spawner monitoring by Langston (2012) are highlighted in yellow. Note - not all streams were surveyed every year (NS = Not surveyed). *2018 data for the Finlay River were excluded from analysis since 2018 survey began upstream of Cutoff Creek (not at river mouth as in previous years).

Sub-Watershed	Stream	2010			2018		
		Total	Min	Max	Total	Min	Max
Finlay	Aley Creek	12992	10587	15397	6145	5030	7261
	Cutoff Creek	41555	33587	49523	8090	6350	9830
	Bower Creek**	**NS**			**9230**	**7100**	**11360**
	Davis River	56120	45685	66556	631	534	728
	Finlay River*	268756	211893	325619	2250	1733	2768
	Pelly Lake Outlet (Zygadene)	NS			5295	4126	6464
	Pelly Creek	**54406**	**43830**	**64982**	**9040**	**7014**	**11066**
	Russel Creek	**147080**	**114386**	**179775**	**45510**	**34379**	**56642**
	Swannell River	**9526**	**7822**	**11230**	**210**	**166**	**254**
	Tsaydiz**	**31590**	**25232**	**37949**	**13270**	**10323**	**16217**
Omineca	**Germansen River**	**34789**	**28156**	**41422**	**7825**	**6285**	**9365**
	Mesilinka River	49156	39959	58353	49352	38235	60469
	Osilinka River	**111236**	**86338**	**136134**	**22450**	**17468**	**27433**
	Dead Bear	NS			1704	1361	2047
	Silver Creek	8292	6693	9891	705	569	841
Parsnip	Cut Thumb	356	303	409	0	0	0
	Manson River (below lakes)	**1538**	**1307**	**1769**	**270**	**225**	**316**
	Manson River (above lakes)	0	0	0	0	0	0
	Misinchinka River	2257	1837	2677	0	0	0
	Parsnip River	0	0	0	0	0	0
	Philip Creek	5	4	6	0	0	0
	Reynolds Creek	0	0	0	0	0	0
	Scott Creek	2375	1969	2781	0	0	0
Peace	Carbon Creek	4388	3630	5146	1186	904	1468
	Clearwater River	**4012**	**3295**	**4729**	**550**	**441**	**659**
	Dunlevy Creek	16014	13387	18641	1481	1171	1791
	Nabesche River	10409	8466	12352	1080	872	1288
	Gething Creek	NS			0	0	0
	Total Kokanee	**598096**	**476472**	**719720**	**184024**	**142553**	**225495**

Table A5. Number of fish sampled, average length (fork length), and average weight of Kokanee in 7 streams and 1 lake where Kokanee were collected in 2018. Average values represent the mean ± standard deviation. All Kokanee were transferred to project collaborators at UNBC for detailed analysis as directed by MFLNRORD.

STREAM	SUB-WATERSHED	NUMBER OF FISH SAMPLED	AVERAGE LENGTH (CM)	AVERAGE WEIGHT (G)
Russel Creek	Finlay	40	21.7 ± 1.4	105.7 ± 23.1
Cutoff Creek	Omineca	40	21.5 ± 1.2	102.9 ± 22.5
Germansen River	Omineca	40	22.1 ± 1.0	119.4 ± 22.5
Manson River	Parsnip	41	22.7 ± 1.3	125.0 ± 24.5
Pelly Creek	Peace	41	21.8 ± 1.0	106.2 ± 14.8
Dunlevy Creek	Peace	41	21.7 ± 1.1	106.1 ± 22.6
Aley Creek	Parsnip	42	22.8 ± 1.0	131.2 ± 18.2
Tacheeda Lake	Parsnip	30	20.9 ± 2.6	103.8 ± 34.8