

# Upper Whatshan River Kokanee Assessment

2015



**Final Progress Report**

**Upper Whatshan River Kokanee Assessment (Reference No. F-F16-03)  
Prepared for Fish and Wildlife Compensation Program**

**2015**

Project No.: F-F16-03

Prepared for

Fish and Wildlife Compensation Program – Columbia

Prepared by

Greg Andrusak, RPBio

Redfish Consulting Ltd.  
Nelson, BC

This Project is funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is 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 impacted by the construction of BC Hydro dams.



**Cover Photo:** ‘Photo of the upper Whatshan River at the confluence with Whatshan Reservoir.’  
Photograph taken in August 2015 by Greg Andrusak.

**Suggested Citation:** Andrusak, G.F. 2015. Upper Whatshan River Kokanee Assessment 2015. Prepared for the Fish and Wildlife Compensation Program – Columbia Basin, the Habitat Conservation Trust Foundation and the Ministry of Forests, Lands and Natural Resource Operations, Nelson, BC. October 2015.

## **EXECUTIVE SUMMARY**

Kokanee spawners that utilize the upper Whatshan River were again surveyed in 2015 to determine their numbers and distribution. Four years of surveys of the upper Whatshan River build on the pre-enhancement database required to measure results of future manipulations of spawner numbers and or nutrient additions. Such pre-enhancement data has been a shortcoming of most other nutrient addition projects. The Whatshan Reservoir provides a unique opportunity to restore and enhance fish populations while improving recreational angling within the Columbia Basin. Such a concept aligns with agency mandates (DFO and MFLNRO) and initiatives of restoring and enhancing fish values in the region due to impacts from hydro-electric developments. As well, the proposed enhancement/restoration of the reservoir is supportive of the goal and objectives of the Fish and Wildlife Compensation Program (FWCP) in meeting conditions under various water license requirements.

During August-September 2015 baseline information was collected on the Whatshan Reservoir kokanee spawning population. The focus of the surveys was on the lower ~ 4.5 km of the upper Whatshan River commencing 200 m upstream of the confluence with Fife Creek, a known bull trout spawning and rearing system. Kokanee ground spawner surveys were conducted eight times during August-September on the upper Whatshan River. A kokanee peak count of 13,397 was obtained on September 6th, 2015 with numbers declining thereafter with virtually none evident by late September. Results from four years of surveys indicate that the peak of spawning occurs by mid-September, similar to the other systems on the Arrow Lakes Reservoir. While Fife Creek contributed substantially to the discharge to the upper Whatshan River, virtually no kokanee spawners were observed in this system and the gradient and substrate appeared more suitable for bull trout. However, initial assessment of stream habitat upstream of the small barrier located 4.5 km on the upper Whatshan River suggests high potential for spawning kokanee due to low gradient and small substrate.

The FFSBC conducted an exploratory egg take during the 2015 spawning run. A fish fence was constructed and operated for 10 days before a grizzly bear destroyed it resulting in all trapped fish escaping. A sample of the 2015 spawners indicted small size (mean size 254 mm, n=69) with previous ageing suggesting age at maturity predominately age 3+. Having virtually all kokanee spawning in one system lends itself to easy experimental manipulation of spawning numbers with the aim of increasing size of kokanee more desirable to anglers.

## **ACKNOWLEDGEMENTS**

Funding for this project was provided by the Fish and Wildlife Compensation Program – Columbia Basin (FWCP) and the Habitat Conservation Trust Foundation (HCTF). This report was prepared with financial support of the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders.

Eva Schindler (MFLNRO) and Marley Bassett (MFLNRO) are acknowledged for the in-kind support and continued work on restoration of large lakes in the Columbia-Basin.

Gary Pavan (biologist) is acknowledged for his hard work during the spawner surveys. As well, thanks to Gary for organizing all GIS data and providing GIS maps. Gary Munro (MFLNRO) is also acknowledged for removing otoliths from the kokanee for aging.

## TABLE OF CONTENTS

EXECUTIVE SUMMARY .....	4
ACKNOWLEDGEMENTS.....	5
TABLE OF CONTENTS.....	6
LIST OF FIGURES.....	6
LIST OF TABLES.....	6
INTRODUCTION.....	7
Goal and objectives.....	7
Background .....	8
Study Area.....	9
METHODS.....	11
Kokanee Bank Counts .....	11
Kokanee Sampling.....	11
Results.....	11
<i>Temperature data</i> .....	11
<i>Kokanee Biological Data</i> .....	12
<i>Kokanee Counts</i> .....	12
Kokanee counts 2012-2015 .....	13
DISCUSSION.....	16
RECOMMENDATIONS .....	17
REFERENCES .....	18
Appendix 1.    Lake survey data (MOE on file) .....	20
Appendix 2.    Biological data .....	21
Appendix 3..    Photos.....	23

## LIST OF FIGURES

Figure 1.    Map of the Whatshan Reservoir and location of the Upper Whatshan River where kokanee surveys were conducted in 2015. ....	10
Figure 2.    Model derived AUC estimate for periodic kokanee bank counts on the Upper Whatshan River from 2012-2015.....	15

## LIST OF TABLES

Table 1.    Spot temperatures of Fife Creek and upper Whatshan River during August-September 2015 .....	12
Table 2.    Biological data from Kokanee spawners from the upper Whatshan River from 2012-2015 .....	12
Table 3.    Peak counts from kokanee surveys on the upper Whatshan River in 2015. ....	13
Table 4.    Kokanee bank counts on Whatshan River.....	14

## INTRODUCTION

At the onset of this project in 2012 the primary objective has been to determine the size of the kokanee spawning population in the Whatshan Reservoir. The aim of the project is to determine the feasibility of developing a productive sport fishery for large size kokanee. Two methods could achieve the desired results: reduction in numbers of spawners and or lake fertilization. The large fertilization projects on Arrow and Kootenay lakes are aimed at providing ample prey (kokanee) for piscivorous rainbow and bull trout populations that support very popular fisheries (Schindler et al. 2014; Bassett et al. 2015). These projects have been highly successful in increasing lake productivity and has resulted in an abundance of kokanee (prey) that are typically small (< 25 cm). This same strategy is being considered for Whatshan. This brief report summarizes 2015 results of kokanee spawner counts in the primary spawning stream—the Upper Whatshan River that flows into Whatshan Reservoir. This FWCP project is supplemental to a much larger HCTF project that is aimed at providing sport fishery background information that will lead to a proposal to initially reduce spawner numbers to increase kokanee size attractive to anglers. Thus the long term objective is to create large size (> 25 cm) kokanee within the Columbia basin that would be far more attractive to anglers similar to the high use, popular Wood Lake kokanee fishery located south of Vernon BC.

In a review of all BC Hydro's reservoirs, Hirst (1991) considered Whatshan to be a small unproductive reservoir that had the potential to produce a provincially significant kokanee fishery similar to that observed on the Alouette Reservoir (Herbert et al. 2013). Such strategies as bio-manipulation and nutrient addition were initially suggested by Hirst (1991) during his review of the operational impacts of existing hydro-electric developments on fishery resources in BC which was commissioned by the Department of Fisheries and Oceans Canada (DFO). It is also significant that the proposed enhancement/restoration of Whatshan Reservoir meets the goal and objectives of the Fish and Wildlife Compensation Program (FWCP) as outlined in the draft FWCP Large Lakes Action Plan for the Columbia Basin (FWCP 2012).

This report summarizes baseline information collected in 2015 on the existing kokanee spawning population in the Upper Whatshan River and provides comparisons with data collected in 2012-15.

### ***Goal and objectives***

The goal of this project is to determine the number of kokanee spawners that utilize the Upper Whatshan River. The objectives included:

- Conducting 6 surveys during the spawning season to enumerate kokanee in upper Whatshan River and Stevens Creek.
- Determination of upper limit of spawning in the Whatshan River.
- Obtain 100 samples for measurement of length and weights.

## Background

Very little was known about the Whatshan Reservoir fish populations and sport fisheries until this project was launched in 2012. Prior to dam construction, rainbow trout, bull trout and kokanee were known to be present in Whatshan Lake (Hirst 1991). Spawning habitats were available in small tributary streams to the lake, but Arrow Reservoir fish migrations through the lower Whatshan River were blocked by natural obstructions at the Whatshan Reservoir outlet. Stocking of rainbow trout and kokanee into the lake occurred over a period of 22 years prior to 1948 (B.C. Game Branch 1948 cited in Hirst 1991), indicating that natural reproduction in the lake was assumed to be inadequate. Prior to impoundment in 1952 Whatshan Lake was described as providing excellent recreational angling (B.C. Game Branch 1948 cited in Hirst 1991). The on-going HCTF funded project suggests the current sport fishery is very poor.

Despite the natural oligotrophic state of the lake, dam construction likely had a direct effect on nutrients and productivity. Reservoirs often acts as a nutrient sinks, increasing sedimentation rates and reducing productivity of the littoral areas that are subject to large environmental changes with reservoir drawdown (Friedl and Wuest 2002, Stockner and Ashley 2003). The combination of these factors has likely resulted in the Whatshan Reservoir having reduced and unnaturally low productivity with limited ability to support productive fish populations resulting in what Stockner et al. (2000) refer to as “cultural oligotrophication”.

To meet water licence requirements under the Water Act, BC Hydro was required to develop a Whatshan Reservoir Water Use Plan (WUP) that addresses operational impacts as a result of the construction of the Whatshan Dam (BC Hydro 2005a). However, the WUP for this system only relates to operational impacts from the dam and precludes footprint impacts associated with reservoir inundation and impoundment. This means that the enhancement/restoration opportunity identified in Hirst (1991) that is the basis for this project falls under footprint impacts associated with dam construction, which is the purpose and mandate of the FWCP.

Nutrient addition in concert with reduction in spawner numbers is expected to result in an increase in kokanee size. The success of nutrient addition to Kootenay Lake, Arrow Lakes Reservoir (ALR) and Alouette Reservoir have been well documented and the details are described in (Schindler et al. 2013, 2014) , Bassett, M., 2015 and Herbert et al. (2013).

## Study Area

Whatshan Reservoir is approximately 22 km long and 2.5 km wide at the broadest point, with a maximum surface area is about 1691 ha (Figure 1; Appendix 1). The reservoir has a mean depth of ~50 m and a maximum depth of 116 m. It is roughly divisible into three sections - the original lake (which existed prior to impoundment), a shallow middle section, and a shallow lower portion that has some mats of aquatic vegetation and more complex shoreline. The upper basin contains around 74% of the total reservoir area (1255 hectares (ha)) and has a maximum depth of 116 m. The middle basin, containing “the narrows” accounts for about 6% of the reservoir by area (99 ha) and has a maximum depth of 15.2 m. The lower basin accounts for about 20% of the total reservoir area (338 ha) and has a maximum depth of 33 m (BC Hydro 2005). Prior to dam construction there were natural rock barriers at the lake outlet which prevented fish access to and from the Whatshan River and this remains a barrier to upstream fish migration (*Fleming and Smith 1988b* cited in Hirst 1991).

Whatshan Dam was built in 1952 by the B.C. Power Commission and is presently owned and operated by B.C Hydro. The dam is a 12 m high, 104 m long, earth - and rock fill dam located at the outflow of Whatshan Lake into the Whatshan River, which is a tributary of Lower Arrow Lake (Figure 1). A 2 km power tunnel leads to the powerhouse on the west shore of Lower Arrow Lake. The latter has a nameplate capacity of 50 MW. The reservoir has a storage capacity of 122 million m<sup>3</sup> when it is at maximum operating elevation – enough storage for approximately 30–40 days of continuous operation at full capacity. The normal maximum operating elevation is 641.3 m while the normal minimum elevation is 634.0 m – a range of about 7.3 vertical metres.

Water quality samples taken in Whatshan Lake in 1959 recorded total dissolved solids content of 58 ppm (MOE on file; Appendix 1), indicating that the lake at that time was oligotrophic. Thermal stratification is apparent in the upper lake in late summer, the thermocline commencing some 6 m below the surface. Dissolved oxygen concentrations decline sharply below 20 m depth, presumably due to high macrophyte densities and possibly decomposition. The lake has remained oligotrophic with low concentrations of dissolved solids (total residue 41-48 mg/l), phosphorus, nitrogen and other nutrients.

The upper Whatshan River flows in at the north end of the reservoir. The watershed covers an area of 604 km<sup>2</sup> originating some 15 km from its head waters at Caribou Lake. Fife Creek is a major tributary to the river, emanating from the Monashee Mountain range, contributing the majority of discharge within the river before it flows into Whatshan Reservoir.

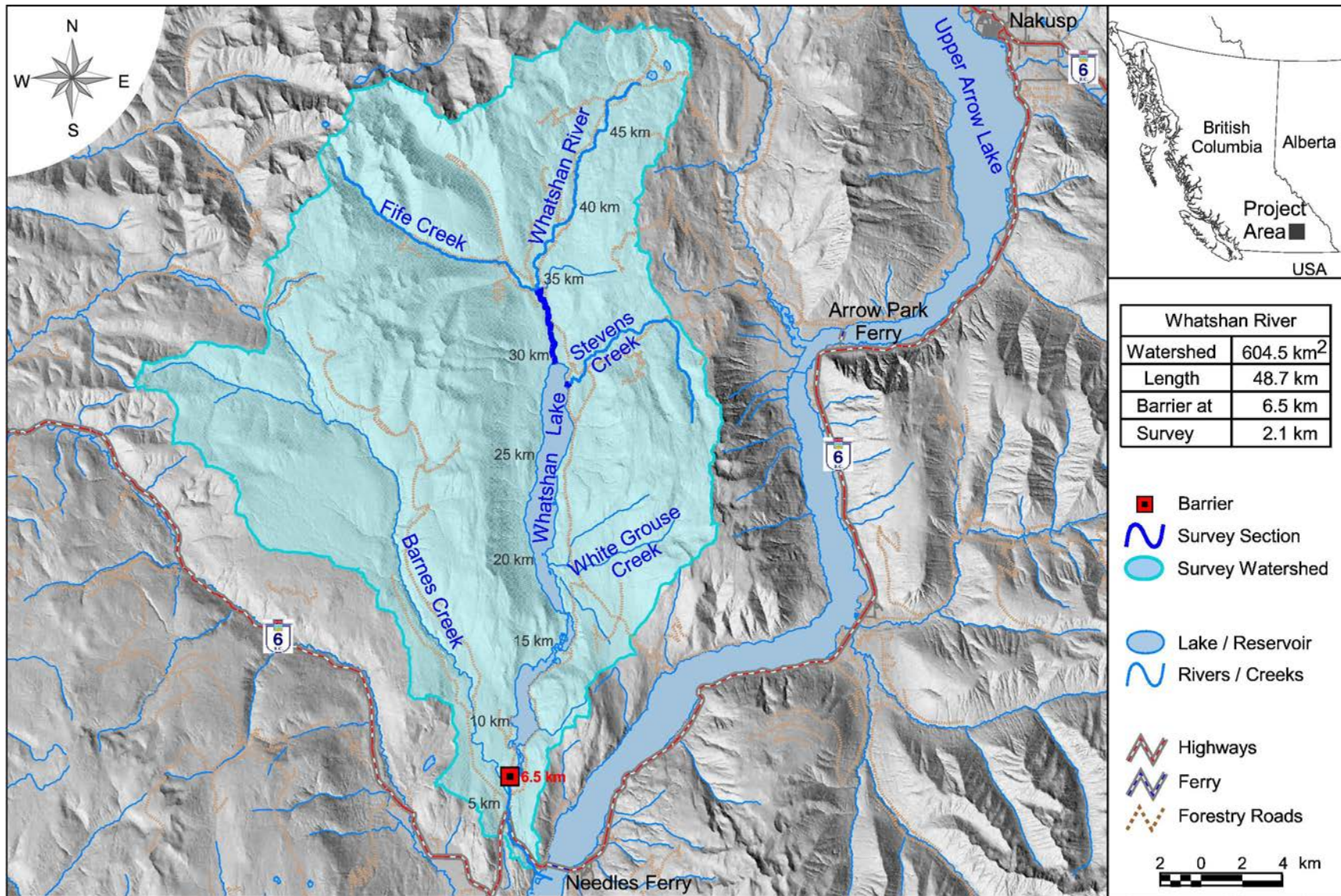


Figure 1. Map of the Whatshan Reservoir and location of the Upper Whatshan River where kokanee surveys were conducted in 2015.

## **METHODS**

### ***Kokanee Bank Counts***

Kokanee spawners were counted from the river banks in the upper Whatshan River during August and September, 2015 (Figure 1). These counts were used to assess the run timing and relative abundance of kokanee spawning within the upper Whatshan River. Previous years' surveys had confirmed this system supported the majority of kokanee spawners. A two person crew was used to conduct the bank counts. Crews walked slowly in a downstream direction on separate banks (i.e. left and right bank); with each crew member counting kokanee separately. Where the creek or river wetted widths were < 3m, counts were conducted by one observer while the other crew member recorded the information.

Fish observations were recorded by time, geo-referenced by GPS location and recorded into a waterproof Duksbak notebook. GPS 62s were utilized and configured to have active track logs set to record the surveys. In addition to fish observations, locations of important spawning areas were also recorded. Observations of redds were also recorded, but were not considered an objective of the study.

Temperature data was recorded using a handheld thermometer to the nearest  $\pm 0.5$  °C before each survey was conducted.

### ***Kokanee Sampling***

In order to determine the mean size and age of the spawning population, biological samples were collected during September 2015 from the upper Whatshan River. Kokanee spawners were obtained during the 2015 spawning run from a fish fence set up by the Freshwater Fisheries Society (FFSBC). All fish were enumerated, length ( $\pm 1$  mm), sex (M=male and F=female), and maturity (SP=spawning and ST=spent) were recorded. Samples were stored on ice and later used to obtain otoliths for aging purposes.

## **Results**

### ***Temperature data***

Temperature data was recorded on each of the surveys dates using a handheld thermometer on the upper Whatshan River and Fife Creek. Fife Creek averaged 9.9 °C, ranging from 9.0°C to 11.0°C, demonstrating a gradual decline with continuing survey dates (Table 1). The upper Whatshan was consistently warmer with an average of 11.1°C, ranging from 10 °C to 12.0°C. Previous year's data also confirms the upper Whatshan is warmer than Fife Creek. Similar results were reported in 2014.

Table 1. Spot temperatures (°C) of Fife Creek and upper Whatshan River during August-September 2015.

Date	Whatshan	Fife Creek
11-Aug	12	11
21-Aug	12	11
29-Aug	11	10
06-Sep	11	10
10-Sep	11	9.5
16-Sep	11	9
25-Sep	10	9

### ***Kokanee Biological Data***

During 2015 a total of 69 spawning kokanee (41 females and 28 males) were retained for biological data (Table 2) and age information (Appendix 2). The females ranged from 225-279 mm with average size 253 mm). The males were slightly larger ranging in size from 231-275 mm averaging 255 mm (Twenty-nine otolith samples were obtained for future ageing if required. The three previous year’s data indicated >90% were age 3+.

Table 2. Biological data from Kokanee spawners from the upper Whatshan River from 2012-2015.

Year/Sex	Count	Length (mm)	Min	Max
<b>2012</b>	<b>119</b>	<b>230</b>	<b>180</b>	<b>270</b>
Female	51	229	185	270
Male	68	231	180	265
<b>2013</b>	<b>128</b>	<b>219</b>	<b>196</b>	<b>250</b>
Female	61	218	198	239
Male	67	221	196	250
<b>2014</b>	<b>91</b>	<b>230</b>	<b>201</b>	<b>269</b>
Female	39	231	204	269
Male	52	230	201	266
<b>2015</b>	<b>69</b>	<b>253</b>	<b>225</b>	<b>279</b>
Female	41	253	225	279
Male	28	255	231	275
<b>Grand Total</b>	<b>407</b>	<b>231</b>	<b>180</b>	<b>279</b>

### ***Kokanee Counts***

On August 30, 2015 a fish fence was set up near the river outlet by the FFSBC and therefore the kokanee upstream migration was disrupted for ten days before the fence was removed (Photo 1, Photo 2, Photo 3 and Photo 4). The spawner counts were conducted upstream of the fence and a total of eight surveys were conducted (Table 3). As in previous years the 2015 surveys commenced ~ 4.5 km upstream of the Whatshan Reservoir, 200 m upstream of the confluence with Fife Creek. Access to the survey start point was via the upper Whatshan and Fife Creek Forest Service Road (FSR).

A kokanee peak count of 13,397 was obtained on September 6th (Table 3). Three surveys were conducted in late August with no counts for the first two and 2,261 on the third count. Spawning was not observed in any other tributary. While Fife Creek contributed substantially to the discharge to the upper Whatshan River, minimal spawning was observed in this system during the surveys.

Table 3. Peak counts from kokanee surveys on the upper Whatshan River in 2015.

Year	Date	Month	Count
2015	11-Aug	August	0
2015	21-Aug	August	0
2015	29-Aug	September	2,261
2015	03-Sep	September	7,716
2015	06-Sep	September	13,397
2015	12-Sep	September	8,901
2015	16-Sep	September	12,608
2015	25-Sep	September	4,308

The majority of 2015 spawning occurred in upper Whatshan River immediately upstream of the reservoir (where the fish fence was positioned) within the first 1.0 km comprised of small substrate and low gradient. This lower portion of the river was dominated by clean gravel areas scoured by large woody debris (LWD) accumulations. The remainder of the river provides limited spawning habitat with increased gradient (>1.5%) dominated by boulder/cobble substrate, far less suitable for spawning kokanee. A small barrier located 4.5 km prevents kokanee movement to ideally suitable spawning habitat for an undetermined length of stream certainly worthy of further assessment. In contrast, Fife Creek was dominated by boulder/cobble substrate and gradients of >2% in the initial 500 m before steeping to gradients exceeding 5%, demonstrating low suitability for kokanee spawning. Only minimal numbers of spawning kokanee (n< 200) have been observed in Fife Creek.

### ***Kokanee counts 2012-2015***

There has been four years of kokanee surveys conducted on the upper Whatshan River (Table 4). In 2012 the peak count of 7,584 was on September 12<sup>th</sup>; peak count in 2013 was 10,696 on September 9<sup>th</sup> while in 2014 the peak count was 12,000 on September 17<sup>th</sup>. The 2015 spawning run was earlier with a peak count of 13,397 on September 6<sup>th</sup>.

Based on bank counts, using area under the curve (AUC) model escapements were 20,540 (95% CRI 12,518-34,926), 24,267 (95% CRI 15,257-40,388), 27,205 (95% CRI 17,774-45,091) and 26,820 (95% CRI 17,650-44,220) in 2012, 2013, 2014, and 2015, respectively (Figure). AUC estimates are based on the model derived residence time of

10.9 days (95% CRI 6.3-14.8). The peak spawn timing was significantly different in 2012 compared to 2013-2015.

Table 4. Kokanee bank counts on Whatshan River

Year	Date	Count
2012	Aug. 12	2,043
2012	Aug. 31	7,375
2012	Sept. 12	<b>7,584</b>
2012	Sept. 19	4,273
2013	Aug. 24	156
2013	Sept. 3	6,776
2013	Sept. 9	<b>10,696</b>
2013	Sept. 13	8,996
2013	Sept. 19	8,616
2014	Aug. 15	0
2014	Aug. 23	0
2014	Sept. 2	4,400
2014	Sept. 7	10,400
2014	Sept. 12	10,084
2014	Sept. 17	<b>12,000</b>
2014	Sept. 24	8,194
2015	Aug. 11	0
2015	Aug. 21	0
2015	Aug. 29	2,261
2015	Sept. 3	7,716
2015	Sept. 6	<b>13,397</b>
2015	Sept. 12	8,901
2015	Sept. 16	12,608
2015	Sept. 23	4,308

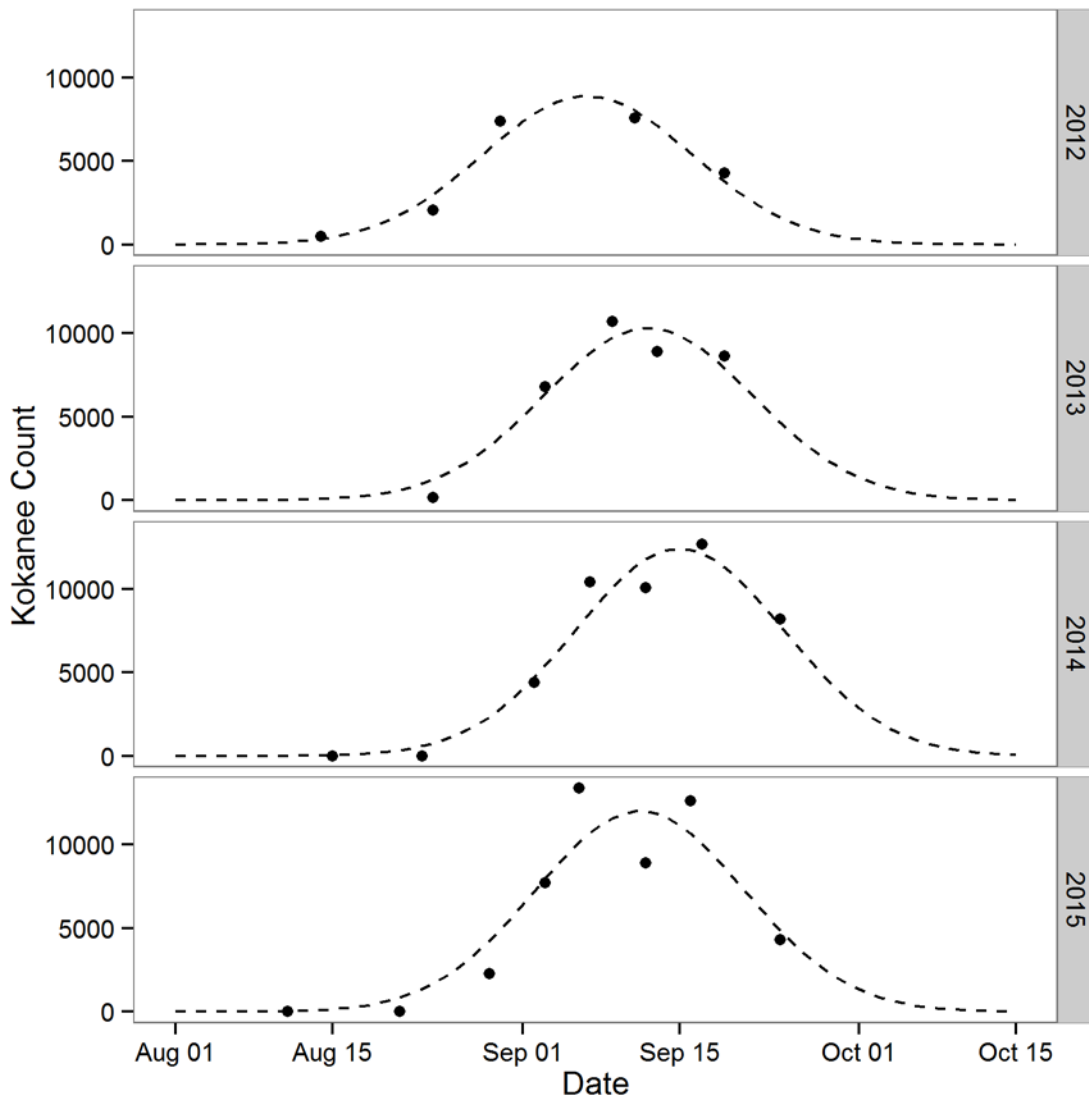


Figure 2. Model derived AUC estimate for periodic kokanee bank counts on the Upper Whatshan River from 2012-2015.

## DISCUSSION

This four year project provides a good understanding of run timing and total numbers of Whatshan kokanee spawners that are highly informative for future restoration or enhancement activities. This reservoir appears to have high potential for restoring and enhancing sport fish populations that could improve recreational angling opportunities within the Columbia Basin. These opportunities align with agency mandates (FWCP, DFO and MFLNRO) and initiatives of restoring and enhancing fish values in the region, resulting from hydro-electric impacts. As well, enhancement/restoration of the reservoir meets the objectives and mandates of the BC Hydro in meeting their conditions under the water license requirements (BC Hydro 2005a) and there has the potential to provide off-site compensation for the FWCP.

Data collected over the last four years suggests the reservoir is quite unproductive, supporting a small population (15,000-40,000 spawners) with a small average size (~23 cm) consisting of a stable, predominant age structure (3+), comparable to Kootenay Lake and ALR (Schindler et al. 2014). Nerkid abundance is often regulated by density dependent factors (Rieman and Myers 1992) related to "bottom up" processes associated with lake/reservoir productivity, defining the carrying capacity of these systems.

The ability to assess and regulate the Whatshan Reservoir kokanee population via bio-manipulation appears highly feasible since the majority of the stock utilizes a small portion of the upper Whatshan River for spawning. A major finding during this project was the identification of quality kokanee spawning habitat on the upper Whatshan River above a small barrier located 4.5km upstream of the reservoir. Previous surveys have observed most kokanee spawn in the lower 1 km of the river primarily due to gradient and suitable spawning substrate. The remainder of the river appears to represent poor kokanee spawning habitat. A few spawners have ascended to the barrier therefore bypassing the barrier could substantially change the spawning capacity for kokanee hence the capacity of the reservoir if nutrients were added. Increased reservoir capacity through increased productivity via nutrient addition may provide substantial benefits to enhancing the average kokanee size and numbers thus improving the recreational angling opportunities within the reservoir. Such benefits have been evident within early years of nutrient programs on ALR, Kootenay Lake and Alouette where average size of spawners increased dramatically following nutrient inputs when kokanee densities were low (Herbert et al. 2013, Schindler et al. 2014). Perrin et al. (2006) has demonstrated the benefits of revitalizing a recreational fishery through nutrient addition and bio-manipulation strategies on Wahleach Reservoir.

During 2014 and 2015 a summer time creel census has been conducted on the reservoir through a HCTF funded project. While the results will be reported separately it can be

stated that fishing was very poor with little effort (< 3,000 rod hours May-Sept.). Virtually no kokanee were caught with few rainbow or bull trout. Reduction in kokanee spawners combined with nutrient addition would certainly have similar positive affects similar to ALR and Alouette reservoirs (Herbert et al. 2013, Schindler et al. 2013).

Kokanee enhancement on Whatshan Reservoir would meet the stated objectives of MFLNRO and BC Hydro detailed in the Large Lake Plan (FWCP 2012) which include; Objective 1-ensure a productive and diverse ecosystem; Objective 2- improve the status of species of conservation concern and Objective 3; optimize recreational angling opportunities, participation and local benefits. In addition, enhancement/restoration opportunity follow recommendations on the impacts of the operation of existing hydro-electric developments on fishery resources in BC, commissioned by the Department of Fisheries and Oceans Canada (DFO) detailed in Hirst (1991).

Finally there may be an additional benefit to increasing the capacity of Whatshan Reservoir through nutrient addition and reduction of spawning. The Freshwater Fisheries of BC (FFSBC) conducted an exploratory kokanee egg collection in 2015 owing to their need to expand their collection opportunities. Samples provided to the FFSBC in 2014 proved to be negative for IHN disease and this is another reason for their interest in Whatshan River kokanee. Samples were taken by FFSBC again in 2015 but results were unavailable at time of writing.

### ***RECOMMENDATIONS***

- © Continue index of kokanee abundance utilizing spawner surveys in upper Whatshan Reservoir.
- © Assess upper Whatshan River upstream of the barrier.
- © Implement an experimental nutrient addition program

## REFERENCES

- B.C. Game Branch. 1948. B.C. Game Branch. 1948. Game fish culture obstructions. Memo report, B.C. Game Department.
- BC Hydro. 2005a. Consultative Committee Report: Columbia River Water Use Plan. BC Hydro, Vancouver, B.C.
- BC Hydro. 2005b. Consultative Committee Report: Whatshan Project Water Use Plan. BC Hydro, Vancouver, B.C.
- Bassett, M., E. U. Schindler, D. Sebastian, T. Weir and L. Vidmanic. 2015. Arrow Lakes Reservoir Nutrient Restoration Program. Year 15 (2013) Report Fisheries Project Report No. RD 148. Ministry of Forests, Lands and Natural Resource Operations, Province of British Columbia.
- Friedl, G., and Wuest, A. 2002. Disrupting biogeochemical cycles – Consequences of damming. *Aquat. Sci.* **64**(64): 55–65.
- FWCP. 2012. Columbia Basin: Large Lake Action Plan-DRAFT. Fish and Wildlife Compensation Program –BC Hydro.
- Herbert, A.S., Harris, S.L., Weir, T., Sebastian, D., Andrusak, G.F., Andrusak, H., and Down, N.E. 2013. Alouette Reservoir Nutrient Restoration Project 2011-2012. Ministry of Environment, Ecosystems Protection & Sustainability Branch, Aquatic Conservation Science Section, Vancouver, B.C.
- Hirst, S.M. 1991. Impacts of the Operation of Existing Hydroelectric Developments on Fishery Resources in British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences, Habitat Management Division Pacific Region Department of Fisheries and Oceans, Vancouver, B.C.
- Perrin, C.J., Rosenau, M.L., Stables, T.B., and Ashley, K.I. 2006. Restoration of a Montane Reservoir Fishery via Biomanipulation and Nutrient Addition. *North Am. J. Fish. Manag.* **26**(2): 391–407. doi: 10.1577/M04-186.1.
- Rieman, B.E., and Myers, D.L. 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**(2): 178–191.
- Schindler, E.U., Sebastian, D., Weir, T., Andrusak, G.F., Andrusak, H., Bassett, M., and Ashley, K.I. 2013. Arrow Lakes Reservoir Nutrient Restoration Program, Years 11 and 12 (2009 and 2010) Report. Fisheries Project Report, Ministry of Forests, Lands and Natural Resource Operations, Nelson, BC.
- Schindler, E.U., Weir, T., Bassett, M., Vidmanic, L., Ashley, K.I., and Johner, D. 2014. Kootenay Lake Nutrient Restoration Program, Years 18 and 19 (north Arm) and Years 6 and 7 (south Arm) (2009 and 2010). Fisheries Project Report, Ministry of Forests, Lands and Natural Resource Operations.

Stockner, J.G., and Ashley, K.I. 2003. Salmon nutrients: closing the circle. *In* American Fisheries Society Symposium. pp. 3–15.

Stockner, J.G., Rydin, E., and Hyenstrand, P. 2000. Cultural oligotrophication: causes and consequences for fisheries resources. *Fisheries* **25**(5): 7–14.

## Appendix 1. Lake survey data (MOE on file)

SURVEY DATE:		AGENCY: BC Hydro (C005)			
Surface Area(ha)		Littoral Area (ha)		Perimeter (km)	
Inlets (Permanent)		Inlets (Intermittent)		Outlets:	
Maximum Depth (m)		Mean Depth (m)		Volume (m3)	
Secchi Depth (m)		PH		TDS	
Specific Conductance					
SURVEY DATE: 01/03/1985		AGENCY: BC Hydro (C005)			
Surface Area(ha)		Littoral Area (ha)		Perimeter (km)	
Inlets (Permanent)		Inlets (Intermittent)		Outlets:	
Maximum Depth (m)		Mean Depth (m)		Volume (m3)	
Secchi Depth (m)	7.7	PH		TDS	
Specific Conductance	70				
SURVEY DATE: 23/06/1959		AGENCY: MOE - Fisheries Inventory (C027)			
Surface Area(ha)	1691.65	Littoral Area (ha)		Perimeter (km)	51206
Inlets (Permanent)		Inlets (Intermittent)		Outlets:	1
Maximum Depth (m)	116.1	Mean Depth (m)	48.2	Volume (m3)	815498776
Secchi Depth (m)		PH		TDS	58
Specific Conductance					
SURVEY DATE: 14/01/1948		AGENCY: MOE - Nelson (C162)			
Surface Area(ha)		Littoral Area (ha)		Perimeter (km)	
Inlets (Permanent)		Inlets (Intermittent)		Outlets:	
Maximum Depth (m)		Mean Depth (m)		Volume (m3)	
Secchi Depth (m)		PH		TDS	
Specific Conductance					
SURVEY DATE: 01/01/1901		AGENCY: BC Hydro (C005)			
Surface Area(ha)		Littoral Area (ha)		Perimeter (km)	51206
Inlets (Permanent)		Inlets (Intermittent)		Outlets:	
Maximum Depth (m)		Mean Depth (m)		Volume (m3)	
Secchi Depth (m)		PH		TDS	58
Specific Conductance					

## Appendix 2. Biological data

Year	Species	Length (mm)	Sex
2015	KO	242	Female
2015	KO	250	Female
2015	KO	253	Female
2015	KO	261	Female
2015	KO	259	Female
2015	KO	257	Female
2015	KO	275	Female
2015	KO	261	Female
2015	KO	253	Female
2015	KO	243	Female
2015	KO	259	Female
2015	KO	244	Female
2015	KO	254	Female
2015	KO	263	Female
2015	KO	246	Female
2015	KO	236	Female
2015	KO	260	Female
2015	KO	260	Female
2015	KO	247	Female
2015	KO	258	Female
2015	KO	250	Female
2015	KO	275	Female
2015	KO	270	Female
2015	KO	257	Female
2015	KO	279	Female
2015	KO	251	Female
2015	KO	240	Female
2015	KO	261	Female
2015	KO	240	Female
2015	KO	259	Female
2015	KO	241	Female
2015	KO	249	Female
2015	KO	247	Female
2015	KO	226	Female
2015	KO	246	Female
2015	KO	255	Female
2015	KO	249	Female
2015	KO	225	Female
2015	KO	248	Female
2015	KO	264	Female
2015	KO	244	Female

2015	KO	258	Male
2015	KO	256	Male
2015	KO	259	Male
2015	KO	247	Male
2015	KO	260	Male
2015	KO	261	Male
2015	KO	254	Male
2015	KO	238	Male
2015	KO	259	Male
2015	KO	266	Male
2015	KO	242	Male
2015	KO	270	Male
2015	KO	254	Male
2015	KO	242	Male
2015	KO	252	Male
2015	KO	255	Male
2015	KO	257	Male
2015	KO	247	Male
2015	KO	264	Male
2015	KO	244	Male
2015	KO	249	Male
2015	KO	261	Male
2015	KO	255	Male
2015	KO	255	Male
2015	KO	270	Male
2015	KO	231	Male
2015	KO	275	Male
2015	KO	251	Male

## Appendix 3. Photos



**Photo 1.** Upper Whatshan River Kokanee FFSBC fish fence in 2015



**Photo 2.** Holding pens and trap box for FFSBC fish fence in 2015



**Photo 3.** Grizzly bear capturing Kokanee between upstream and downstream FFSBC fish fence in 2015



**Photo 4.** Grizzly bear capturing Kokanee between upstream and downstream FFSBC fish fence in 2015