WHATSHAN RESERVOIR KOKANEE ENHANCEMENT

2012

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Prepared for

Fish and Wildlife Compensation Program – Columbia

Prepared by

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prepared with

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The Fish and Wildlife Compensation Program is a joint initiative between BC Hydro, the BC Ministry of Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) and Fisheries & Oceans Canada (DFO) to conserve and enhance fish and wildlife populations affected by the construction of BC Hydro dams in Canada's portion of the Columbia Basin.

FISH AND WILDLIFE COMPENSATION PROGRAM

Cover Photo: 'Photo of the upper Whatshan River at the confluence with Whatshan Reservoir.' Photograph taken on the 31st of August 2012 by Greg Andrusak.

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EXECUTIVE SUMMARY

The Whatshan Reservoir provides a unique opportunity to restore and enhance fish populations while improving recreational angling within the Columbia Basin. This initial year of survey work was aimed at providing baseline data on the kokanee population for possible future manipulation (reduction) of spawner numbers to increase their size. 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 (MOE on file).

During August-September 2012 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 on August 24th, August 31st, September 12th and September 19th within tributaries of the Whatshan Reservoir. Kokanee spawners were absent from virtually all tributaries except those observed in the upper Whatshan River and less than 15 in Stevens Creek.

A kokanee peak count of 7,584 was obtained on September 12, 2012. The lowest count was observed on August 24 which yielded a total of 2,043 kokanee. Data indicates 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, no kokanee spawners were observed in this system and the gradient and substrate appeared more suitable for bull trout.

A sample of the spawners indicted small size (mean size 229 mm, n=84) with 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.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

INTRODUCTION

Kokanee (*Oncorhynchus nerka*) are considered to be a keystone species (Andrusak and Parkinson 1984) which have colonized lacustrine habitats in many of the large lakes/reservoirs within BC post-glacially (McPhail 2007). Many of these kokanee populations are instrumental in supporting other species of fish such as bull trout (*Salvelinus confluentus*), rainbow trout *(Oncorhynchus mykiss*), sturgeon (*Acipenser transmontanus*) and burbot (*Lota lota*) in these systems. As well, kokanee are considered an important sport species in many recreational fisheries that can generate substantial economic benefits, while sustaining high harvest levels (Askey and Andrusak 2010).

It is well documented that the Columbia Region has endured significant ecological impacts due to the development of hydro-electric throughout the basin (Moody et al. 2007; Utzig and Schmidt 2011). Much of its natural diversity (both aquatic and terrestrial) has been significantly altered leaving a landscape that is generally more homogenous and less productive than prior to the pre-dam state. Despite these alterations, the formation of reservoirs has provided a substantial increase in lentic habitat that does support species that utilize these lacustrine environments, especially kokanee. However, most of these reservoirs are generally nutrient poor (ultra to oligotrophic state) and limit the productive capacity of fish populations (Ney 1996; Stockner et al. 2000). Most often kokanee that reside in reservoirs and unproductive large lakes maintain a relatively small average size that makes them unattractive or unavailable to recreational anglers.

Kokanee populations are often regulated by density dependent factors associated with their rearing environment (Myers et al. 1997, Myers 2001) and this holds true for large lakes and reservoirs of the Upper Columbia Basin (Schindler et al. 2011a; b; Sebastian 2010). In particular, kokanee display compensatory growth responses to variations in stock densities that profoundly influence the size of maturing fish (Hyatt and Stockner 1985, Rieman and Myers. 1992; Andrusak 2012). These underlying mechanisms in conjunction with bio-manipulation (i.e. harvest, stock reduction or control) and nutrient addition can be applied to increase the average size of maturing fish, thus improving the recreational fishing potential for unproductive reservoir systems (Perrin et al. 2006).

The Whatshan Reservoir, considered a small unproductive reservoir (Hirst et al. 1991), provides an opportunity to enhance the existing kokanee stock to create a provincially significant kokanee fishery, similar to that observed on the Alouette Reservoir (Harris et al 2011). Such strategies as bio-manipulation and nutrient addition were initially suggested by Hirst et al. (1991) during their review of 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). It is also notable 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 FWCP Large Lakes Action Plan for the Columbia Basin (FWCP 2012).

This report summarizes baseline information collected in 2012 on the existing kokanee stock in Whatshan Reservoir, including stock size and age structure.

BACKGROUND

Prior to dam construction, rainbow trout, bull trout and kokanee were present in Whatshan Lake (Hirst et al. 1991). Spawning habitats were available in small tributary streams to the lake but migrations from the lower Whatshan River into the lake were blocked by natural obstructions at the lake 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), indicating that natural reproduction in the lake was assumed to be not adequate. Prior to impoundment in 1952 Whatshan Lake was described as providing excellent recreational angling (B.C. Game Branch 1948). Currently, there is no information on the recreational fishery and whether angling quality is considered good or not.

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 2001, 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 the water licence requirements under the Water Act, BC Hydro was required to develop the Whatshan Reservoir Water Use Plan (WUP) that addresses operational impacts as a result of the construction of the Whatshan Dam (BC Hydro 2005). 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 et al. (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. (2011 a, b) and Harris et al. (2011).

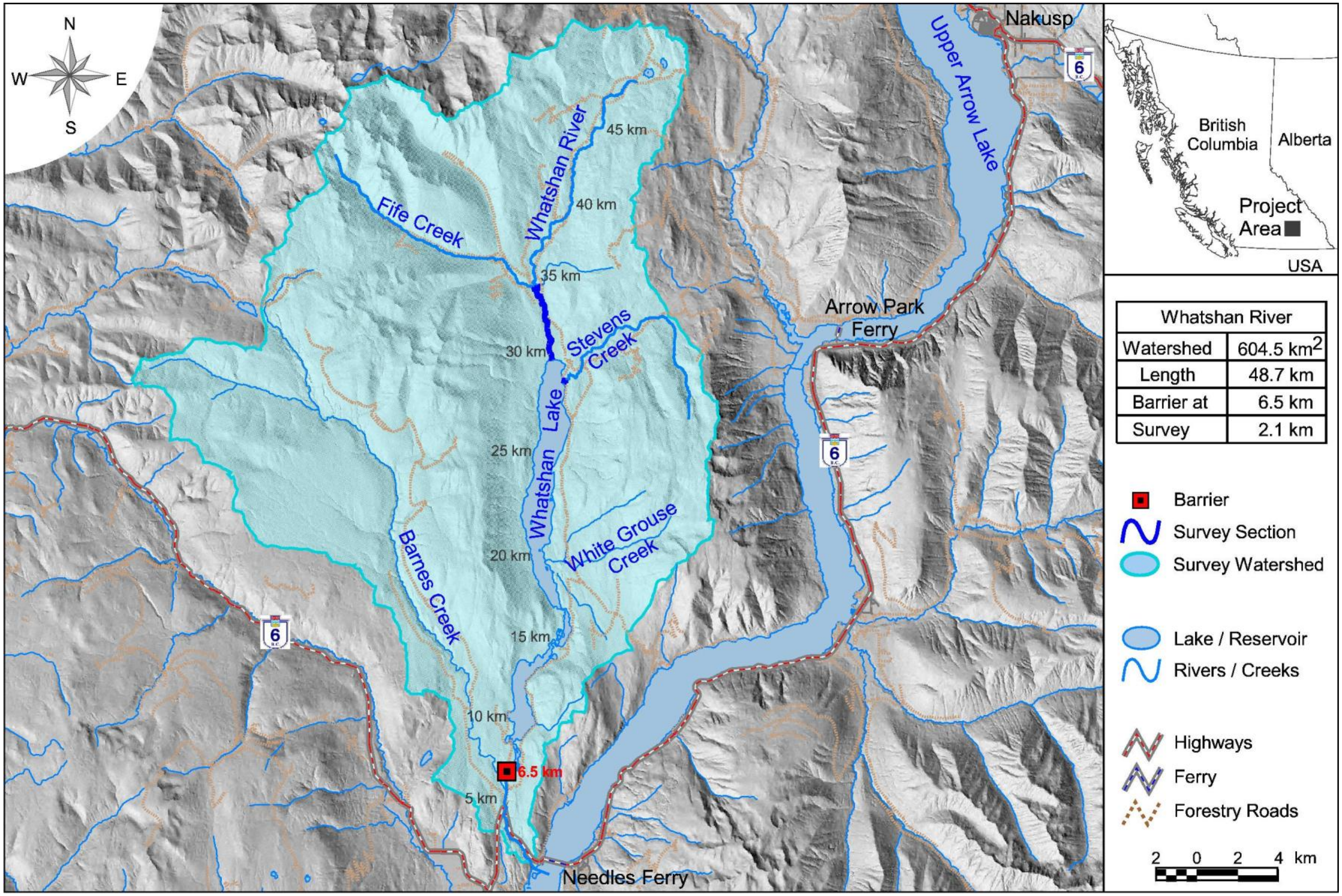
STUDY AREA

Whatshan Lake 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 lake has a mean depth of ~50 m and a maximum depth of 116 m. The lake is roughly divisible into three sections - the original lake (which existed prior to impoundment), a shallow middle section, and a shallow lower portion presently occupied by extensive mats of aquatic vegetation. 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* in Hirst et al. 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 east shore of Lower Arrow Lake. The latter has a nameplate capacity of 50 MW. The reservoir has a storage capacity of 122 million m^3 when it is at maximum operating elevation – enough storage for approximately 30–40 days of continuous operation at full capacity (BC Hydro 2005). 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), phosphorous, 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^2 originating some 15 km from the 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.



Whatshan River	
Watershed	604.5 km^2
Length	48.7 km
Barrier at	6.5 km
Survey	2.1 km

Figure 1. Map of the Whatshan Reservoir and associated tributaries where kokanee surveys were conducted in 2012.

METHODS

Kokanee Bank Counts

Bank counts of kokanee spawners in the upper Whatshan River were conducted from August 24th until September 19th, 2012 (Figure 1). These counts were used to assess the run timing and relative abundance of kokanee spawning within the Whatshan Reservoir tributaries. Additional stream surveys were conducted to determine the extent of spawning in other tributaries to the reservoir.

A two person crew was used to conduct the bank count. 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 ±0.5 °C before each survey was conducted. Horizontal visibility during each of the surveys was also recorded underwater using a Secchi disc.

Kokanee Sampling

In order to determine the mean size and age of the spawning population, biological samples were collected on the upper Whatshan River on August 31st, 2012. Kokanee spawners were obtained using a LR-24 Smith-Root electro fish unit set at 400 V and 30 Hz. Fish were stunned and retained for biological information.

All fish were enumerated, length (±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. Otoliths were sent to Birkenhead Laboratory for age estimation.

RESULTS

Temperature data

Temperature data was recorded on each of the surveys dates (August 24 & 31, September 12 &19) using a handheld thermometer on the Whatshan River and Fife Creek. The Whatshan River averaged 9.8 °C, ranging from 9-°C -11.5°C, demonstrating a gradual decline with continuing survey dates (Figure 2). Similarly Fife Creek was a much colder system, averaging 7.3 °C, ranging from 6.5 -9°C.

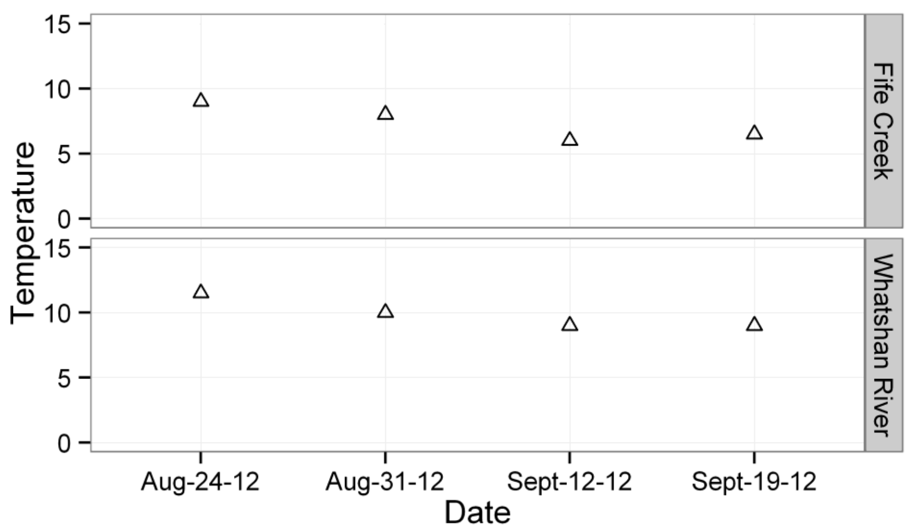


Figure 2. Temperature data from kokanee surveys for Whatshan River and Fife Creek in 2012

Kokanee Biological Data

A total of 84 spawning kokanee (34 females and 50 males) were retained for biological data and age information (Table 1; Appendix 2). Length frequency information indicates a spawner size that ranges from 180 mm-270 mm (SD ± 15.1), with a mean of 229.5 mm (Figure 3).

Average male kokanee length was 230 mm (SD ± 14.1) compared with the average female length of 227 mm (SD ± 16.5). However, the largest fish recorded was a female of 270 mm slightly larger than the largest male kokanee recorded of 265 mm (Figure 4).

Table 1. Biological data from kokanee (spawners) obtained from the Whatshan River in 2012

Sex	#	Mean Length	SD	Minimum	Maximum
F	34	228.	16.6	185	270
M	50	231	14.1	180	265
Grand Total	84	229	15.1	180	270

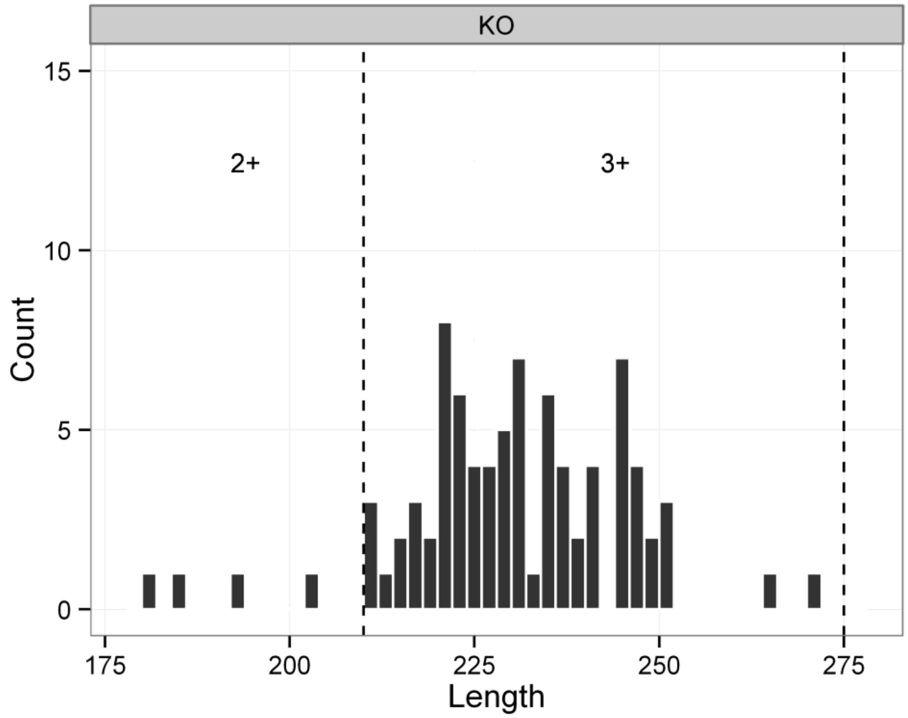


Figure 3. Length frequency (n=84) from kokanee spawners in the Whatshan River in 2012. Age data is also displayed from a sub-sample (n=32) from the total collected.

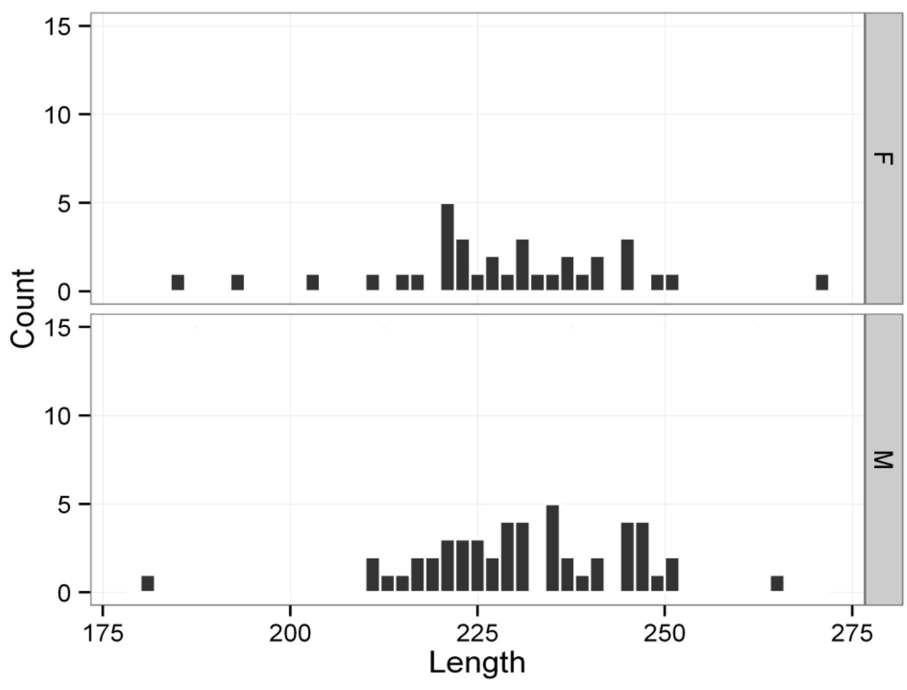


Figure 4. Length frequency of male (n=50) and female (n=34) from kokanee spawners in the Whatshan River in 2012.

Age data and analysis of kokanee otoliths (n=32) indicate the spawning population was predominantly 3+, with a small contingent of 2+ present (Figure 3; Appendix 2). Age analysis also suggests that the otoliths exhibited very little plus growth in the current year since the last annulus formed in the spring of 2012, common for kokanee that are preparing to spawn. Using the age data, the majority of the 2012 kokanee spawners originated from brood year 2008.

Table 2. Age data (otoliths) from kokanee (spawners) obtained from the Whatshan River in 2012

Age	#	Mean Length	SD	Minimum	Maximum
2+	2	210	1.1	202	217
3+	30	232	1.17	213	265

Kokanee Counts

Kokanee spawner surveys were conducted on August 24th, August 31st, September 12th and September 19th within tributaries of the Whatshan Reservoir (Figure 1). However, due to the limited presence of kokanee spawning in other tributary systems that all had very low flows, the surveys focused on the upper Whatshan River and Stevens Creek. All surveys commenced ~ 4.5 km upstream of the Whatshan Reservoir, 200 m upstream of the confluence with Fife Creek (Figure 5). Access to the survey start point was via the upper Whatshan and Fife Creek Forest Service Road (FSR).

A kokanee peak count of 7,584 was obtained on September 12, 2012 (Table 3). The lowest count was experienced on August 24 which yielded a total of 2,043 kokanee. Data indicates that the peak of spawning occurs by mid-September, similar to the other systems on the Arrow Lakes Reservoir (Eva Schindler pers. comm. MFLNRO biologist). The only other tributary that kokanee were observed in was Stevens Creek which had a total peak count of 12 fish recorded on September 19th. While Fife Creek contributed substantially to the discharge to the upper Whatshan River, no spawning was observed in this system during the surveys.

Table 3. Peak counts from kokanee surveys on the upper Whatshan River in 2012.

Survey Date	Peak Count
24-Aug-12	2,043
31-Aug-12	7,375
12-Sep-12	7,584
19-Sep-12	4,273

With the exception a section near the confluence with the reservoir, where the majority of spawning occurred (Figure 5), the Whatshan River provides limited spawning habitat for kokanee. Sections of the river further upstream from the reservoir increased in gradient (>1.5%) and were dominated by boulder/cobble substrate, less suitable for spawning kokanee (Photo 1 and Photo 2). This distribution is quite obvious and detailed in Figure 5, where most of the spawning occurred in the low gradient (< 1%) sections near the reservoir (Photo 3 and Photo 4). This lower portion of the river was dominated by clean gravel areas scoured by large woody debris (LWD) accumulations.

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 (Photo 4-8).

Stevens Creek was surveyed on the same days as the Upper Whatshan River with no spawners observed except for 12 on September 19th. It is possible a few spawners were present on previous survey days given numerous sections of dense over hanging brush and deep cut banks that were difficult to survey. Having said this, it was quite evident that this stream for at least 700 m provides good spawning habitat for kokanee (Photos 5-8). It is speculated that the reason for so few spawners is due to a large culvert located near the stream entering the reservoir. There were signs that this culvert had been recently modified to permit fish passage with the downstream end back flooded for ease of fish passage and baffles located in the culvert for ease of fish moving through the culvert. It is speculated that this culvert was until very recently a barrier to fish passage and the reason why so few kokanee were observed during 2012.

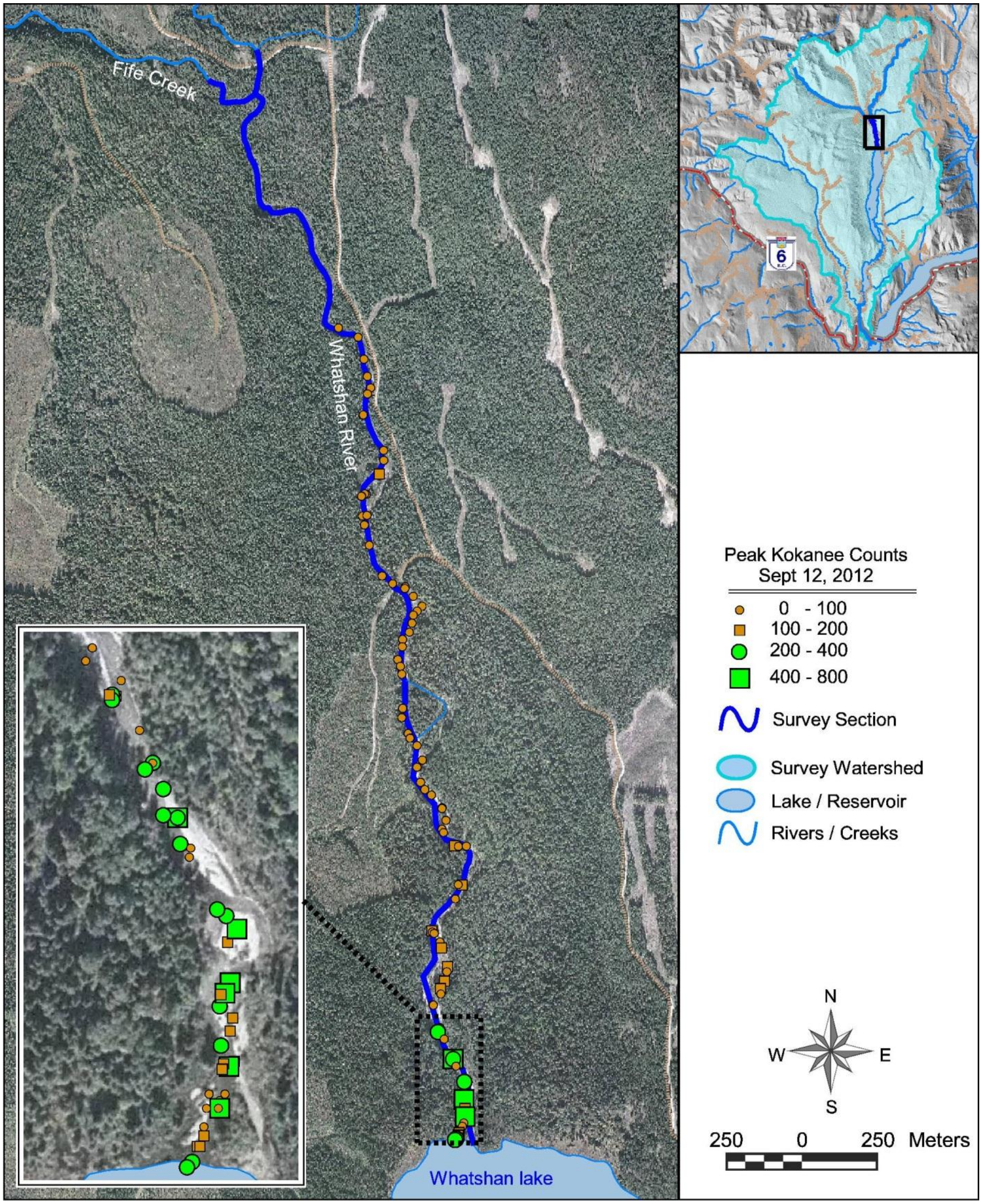


Figure 5. Peak count and distribution of kokanee spawning in the Whatshan River from surveys conducted in August- September 2012**.**

DISCUSSION

The Whatshan Reservoir provides a unique opportunity to restore and enhance fish populations while improving the recreational angling opportunities within the Columbia Basin. These opportunities align with agency mandates (DFO and MFLNRO) and initiatives of restoring and enhancing fish values in the region, resulting from hydro-electric impacts. As well, the proposed 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 2005).

This preliminary survey of Whatshan Reservoir kokanee proved highly successful with magnitude of spawner numbers and their size determined. Data collected in 2012 on the spawning population of kokanee suggests the reservoir is likely quite unproductive, supporting a small population (< 15,000 spawners) with a small average size (~23 cm) consisting of a stable age structure (3+), comparable to Kootenay Lake and ALR (Schindler et al. 2010 a, b). Nerkid abundance is often regulated by density dependent factors (Hyatt and Stockner 1985, Myers et al. 1997, Myers 2001) 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 would be highly feasible since the majority of the stock utilizes a small portion of the upper Whatshan River for spawning and it is possible that quality spawning habitat may be a limitation.

Increased reservoir capacity through increased productivity via nutrient addition may provide substantial benefits to enhancing the average kokanee size and 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 Reservoir (Schindler et al. 2011 a, b; Harris et al. 2011) where average size of spawners increased dramatically following nutrient inputs when kokanee densities were low. Perrin et al. (2006) demonstrated the benefits of revitalizing a recreational fishery through nutrient addition and bio-manipulation strategies on Wahleach Reservoir.

Similar to Kootenay Lake and ALR, kokanee are considered a keystone species within the Whatshan Reservoir and the species of interest for an enhancement program. It is anticipated that the bottom-up and top-down control mechanisms will be prominent regulating and restoring the kokanee population in this oligotrophic reservoir. Kokanee enhancement on Whatshan Reservoir follows 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 et al. (1991).

RECOMMENDATIONS

- Obtain baseline physical and chemical limnological data on reservoir
- Obtain trophic status of reservoir
- Establish index of kokanee abundance utilizing spawner surveys in upper Whatshan Reservoir and Stevens Creek
- Establish an index of abundance for bull trout utilizing redd surveys on Fife Creek
- Obtain biological information on kokanee spawner size and age structure
- Establish a minimum of two sampling stations on reservoir
- Assess annual reservoir operations
- Assess reservoir flow related input, output, elevation, and flow through (water residency)
- Assess current fishery (catch, effort and harvest)

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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

ID	Year	Species	Length	Sex
1	2012	KO	202	F
2	2012	KO	225	F
3	2012	KO	222	F
4	2012	KO	249	M
5	2012	KO	225	M
6	2012	KO	222	M
7	2012	KO	234	M
8	2012	KO	228	M
9	2012	KO	245	M
10	2012	KO	220	F
11	2012	KO	250	F
12	2012	KO	224	M
13	2012	KO	213	M
14	2012	KO	236	F
15	2012	KO	216	F
16	2012	KO	245	F
17	2012	KO	244	M
18	2012	KO	235	M
19	2012	KO	217	M
20	2012	KO	239	F
21	2012	KO	265	M
22	2012	KO	227	M
23	2012	KO	235	M
24	2012	KO	220	F
25	2012	KO	244	F
26	2012	KO	245	F
27	2012	KO	231	M
28	2012	KO	241	M
29	2012	KO	241	F
30	2012	KO	220	F
31	2012	KO	231	F
32	2012	KO	223	M
33	2012	KO	219	M
34	2012	KO	223	F
35	2012	KO	235	F
36	2012	KO	217	M
37	2012	KO	237	M
38	2012	KO	245	M
39	2012	KO	249	F
40	2012	KO	246	M
41	2012	KO	180	M

42	2012	KO	222	M
43	2012	KO	230	M
44	2012	KO	230	M
45	2012	KO	232	F
46	2012	KO	237	F
47	2012	KO	226	M
48	2012	KO	247	M
49	2012	KO	229	M
50	2012	KO	225	M
51	2012	KO	228	M
52	2012	KO	221	M
53	2012	KO	185	F
54	2012	KO	250	M
55	2012	KO	227	F
56	2012	KO	227	F
57	2012	KO	246	M
58	2012	KO	222	F
59	2012	KO	192	F
60	2012	KO	239	M
61	2012	KO	218	M
62	2012	KO	228	M
63	2012	KO	270	F
64	2012	KO	237	M
65	2012	KO	228	F
66	2012	KO	220	F
67	2012	KO	234	M
68	2012	KO	221	F
69	2012	KO	210	M
70	2012	KO	246	M
71	2012	KO	230	M
72	2012	KO	220	M
73	2012	KO	250	M
74	2012	KO	244	M
75	2012	KO	210	F
76	2012	KO	210	M
77	2012	KO	230	F
78	2012	KO	215	M
79	2012	KO	215	F
80	2012	KO	235	M
81	2012	KO	240	F
82	2012	KO	240	M
83	2012	KO	221	M
84	2012	KO	230	F

APPENDIX 3. Birkenhead Scale Analysis

Whatshan Reservoir=Kokanee Lengths and Otoliths - Sept. 1/12					
#ID	Length cm.	Sex	Otoliths	Age	Comments
1	20.2	F	1 only	2+	tip broken; age estimate
2	22.5	F		n/a	envelope empty
3	22.2	F		3+	1 broken
4	24.9	M		3+	
5	22.5	M		3+	1 tip broken
6	22.2	M		3+	
7	23.4	M		3+	
8	22.8	M		3+	broken/tip broken
9	24.5	M		3+	1 tip broken
10	22	F		3+	1 broken
11	25	F	1 only	n/a	broken; unreadable
12	22.4	M		3+	
13	21.3	M		3+	1 broken
14	23.6	F	1 only	3+	poor condition; age estimate
15	21.6	F		3+	1 broken
16	24.5	F		3+	
17	24.4	M		3+	1 broken
18	23.5	M		3+	
19	21.7	M		2+	broken; age estimate
20	23.9	F		3+	1 tip broken
21	26.5	M		3+	
22	22.7	M		3+	
23	23.5	M		3+	
24	22	F		3+	1 otolith
25	24.4	F	1 only	3+	
26	24.5	F		3+	
27	23.1	M		3+	1 tip broken
28	24.1	M		3+	
29	24.1	F		3+	
30	22	F	1 only	n/a	envelope empty
31	23.1	F		3+	poor condition; age estimate
32	22.3	M		3+	
33	21.9	M	1 only	3+	tip broken
34	22.3	F		3+	1 broken
35	23.5	F		3+	

APPENDIX 4. Photos

Photo 1. Upper section of the Whatshan River dominated by boulder/cobble substrate

Photo 2. First observation of spawning observed ~ 4.0 km upstream of reservoir on the Whatshan River

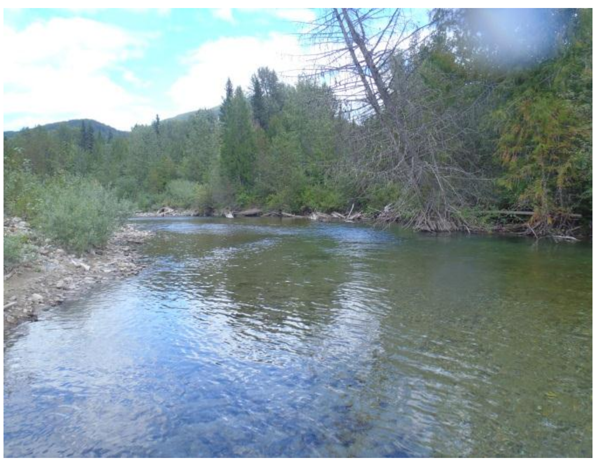

Photo 3. Upstream view of low gradient habitat near confluence with Whatshan Reservoir

Photo 4. Downstream view of low gradient habitat near confluence with Whatshan Reservoir

Photo 5. Stevens Creek above FSR culvert

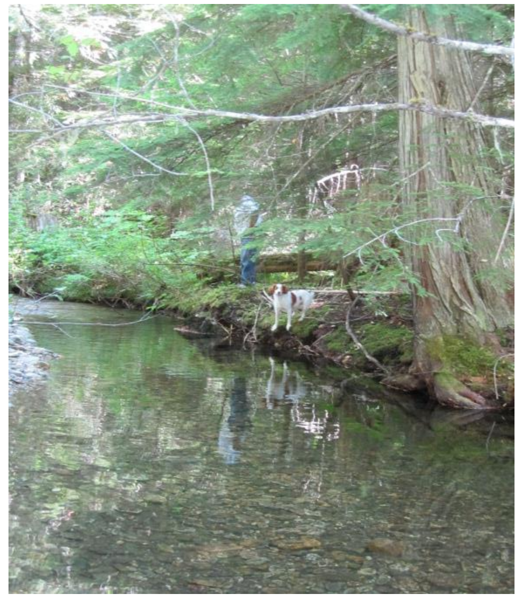

Photo 6. Upstream habitat above (~300 m) FSR culvert on Steven Creek

Photo 7. Upstream habitat above (~500 m) FSR culvert on Steven Creek

Photo 8. Upstream habitat above (~600 m) FSR culvert on Steven Creek where first kokanee observations were made.