Assessment of Kokanee Spawning in Comox Lake

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Prepared for:
Fish and Wildlife Compensation Program

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On behalf of:
Courtenay and District Fish and Game Protective Association

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EXECUTIVE SUMMARY

A kokanee spawning assessment was conducted on Comox Lake to collect baseline information on the timing, spawning distribution, habitat selection, and spawning behavior of Comox Lake kokanee, as well as to determine potential limiting factors to kokanee production. Kokanee are recognized as being an important fish both in the recreational sport fishery and as a key forage species fish for piscivores such as cutthroat trout, yet little information is available on their life history and spawning habitat preferences in Comox Lake.

Reconnaissance surveys were conducted that identified 16 potential shoreline spawning sites in Comox Lake. Criteria for suitable kokanee nearshore spawning sites included abundant, uniformly small (<30mm), non-compacted, clean gravel substrate, and water depth of less than 3m. Interviews with local cabin owners and fishermen that frequent Comox Lake were conducted that provided additional information that informed spawner survey planning and key areas to focus effort. Weekly spawning assessments were conducted on Comox Lake between October 7 and November 18, 2016 using a combination of boat and foot surveys. Willemar and Forbush Lakes in the Upper Puntledge River were surveyed by boat. Local knowledge was valuable in pinpointing the peak of the kokanee spawning period and specific locations of spawning activity.

Evidence of kokanee spawning in nearshore habitat at the south east end of Comox Lake (Site 10) was recorded on October 31, 2016. Over 50 kokanee were observed spawning and guarding redds at a depth of ~ 2.5 m. Confirmation of spawning activity allowed an opportunity to assess incubation success using eyed coho eggs buried in incubators at the site. Overall, eyed egg-to-fry survival was 85.5%. Average intergravel temperature data collected between December 2016 and March 2017 at the incubation site was 2 degrees warmer than surface water temperature, suggesting possible groundwater sources that may be attracting kokanee spawning to this location.

An analysis of historical reservoir elevations between 1993 and 2015 indicates that in two of every three years, reservoir drawdown may adversely impact kokanee reproductive success in Comox Lake.

Further assessments are recommended to gain more information about kokanee biology, spawn timing, spawning habitat selection and distribution within Comox Lake. This may include a combination of methodologies in addition to boat and foot surveys, such as aerial (UAV), underwater video (ROV), hydroacoustic and gillnetting , as well as an analysis of temperature characteristics at potential spawning sites for groundwater or other hydraulic processes. This information will be essential for understanding the potential effects of reservoir draw down and other limiting factors on kokanee spawning recruitment and incubation survival, and identifying future conservation and enhancement opportunities for kokanee in Comox Lake.

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1 INTRODUCTION

There is limited information on the life history, habitat requirements and abundance of the kokanee (*Oncorhynchus nerka*) population in Comox Lake. Kokanee are recognized as being an important fish both in the recreational sport fishery and as a key forage species fish for piscivores such as cutthroat trout. Understanding the population dynamics of the kokanee in Comox Lake is an important component of future management planning for other fisheries, and will allow for a better understanding of the carrying capacity of Comox Lake. Little information is available on sockeye numbers prior to the Comox Lake dam construction in 1912. Fish passage was not provided in the system until 1922, and a sockeye egg transplanting program took place from 1923 to 1930. It is unclear whether the population of kokanee that resides in Comox Lake is a remnant of this stocking program.

In 2009, the Ministry of Forest, Lands and Natural Resource Operations (FLNRO) assessed the pelagic fish populations in Comox Lake using hydroacoustic trawl surveys (ATS). Based on hydroacoustic data, the estimated kokanee population in the lake was 289,000 (Johner and Sebastian 2009). However, this population estimate was based solely on hydroacoustic transects, and species composition could not be validated because of an equipment issue with the trawl after the first sample was collected.

A more recent study on Comox Lake productivity was completed in 2013 that investigated the status of forage fish, and specifically kokanee in Comox Lake, as available forage for large cutthroat trout (>30cm), as well as the limnological conditions of the lake (Guimond et al. 2014). The study included hydroacoustic-and-trawl surveys (ATS) and water chemistry/zooplankton sampling. The limnological results from the 2013 study indicated that Comox Lake has a similar productive capacity as Great Central, Sproat, and Henderson Lakes, which are three nearby sockeye nursery lakes that have been the subject of long-term monitoring programs. Yet, observed kokanee densities in Comox Lake were an order of magnitude lower than the mean at Henderson Lake, the least productive of the 3 lakes mentioned above. This large discrepancy between kokanee abundance in Comox Lake compared to other Vancouver Island lakes with

similar limnological conditions suggests that there are other factors such as spawning recruitment, habitat, incubation survival, or predation that may contribute to the difference in numbers.

It was unknown prior to this kokanee spawning study whether the Comox Lake kokanee are predominantly near shore spawners, deep water spawners, or tributary spawners. Fish spawning in shallow nearshore habitat are more vulnerable to desiccation/freezing from declining lake levels during the incubations period. Kokanee mature at a small size (180-250 mm) and therefore select smaller substrate size when building redds. Gravel areas at mouths of tributaries can be subject to scouring or deposition during high discharges. Fall-winter flood events and lake level management/fluctuations also are factors that could impact nearshore spawner reproductive success.

Based on gaps in the literature, and an overall lack of knowledge of the life history and spawning habits of the Comox Lake kokanee, a spawning assessment in Comox Lake was recommended to collect baseline information on kokanee spawning distribution, and spawning habitat preferences in order to identify possible limiting factors.

1.1 Goals and Objectives

The goal of this project was to gain a broader understanding of the kokanee spawning population in Comox Lake, including the timing, spawning distribution, habitat selection, and spawning behavior, as well as to determine potential limiting factors to kokanee production. The results from this project will provide a greater understanding of the kokanee population, will build a database on longer term population trends, and will provide direction for future spawning inventories and recommended methodologies.

This project addresses 'Research and Information Acquisition' based priority actions in the Puntledge River Salmonid Action Plan (FWCP 2011) by improving our understanding of the dynamics of and limiting factors to resident fish populations in Comox Lake and its tributaries.

2 STUDY AREA

The Comox Lake watershed encircles an area of approximately 600 km^2 on the northeast side of Vancouver Island, BC, approximately 6 km west of the City of Courtenay. Comox Lake reservoir lies at 135 m above sea level and has a surface area of 2118 ha, an average depth of 61 m and a maximum depth of 109 m (BC Hydro 2003). The upper watershed extends into the Comox Glacier and Forbidden Plateau which provides a continuous flow of freshwater from snow melt during the spring/summer months.

Comox Lake receives inflows from two large tributaries, the Cruikshank River with a drainage area of 213 km^2, and the upper Puntledge River with a drainage area of 92 km^2, and numerous smaller tributaries. The lake has extensive shoal areas along the northwest shore and south end, and around the mouths of the Cruikshank and upper Puntledge Rivers. The upper Puntledge is of lower gradient than the Cruikshank in its lower reaches. Forbush and Willemar Lakes are located in the lower mainstem of the Upper Puntledge River. These small lakes are 47 and 82 hectares in area, respectively, and are important rearing areas for trout, and juvenile coho.

Downstream of Comox Lake, the lower Puntledge River flows in a north-easterly direction for 14.3 km where it joins with the Tsolum River before discharging into the Strait of Georgia.

The study area where spawner surveys were conducted included the nearshore areas of the perimeter of Comox Lake, as well as nearshore areas around the perimeter of Willemar and Forbush Lakes (Figure 1).

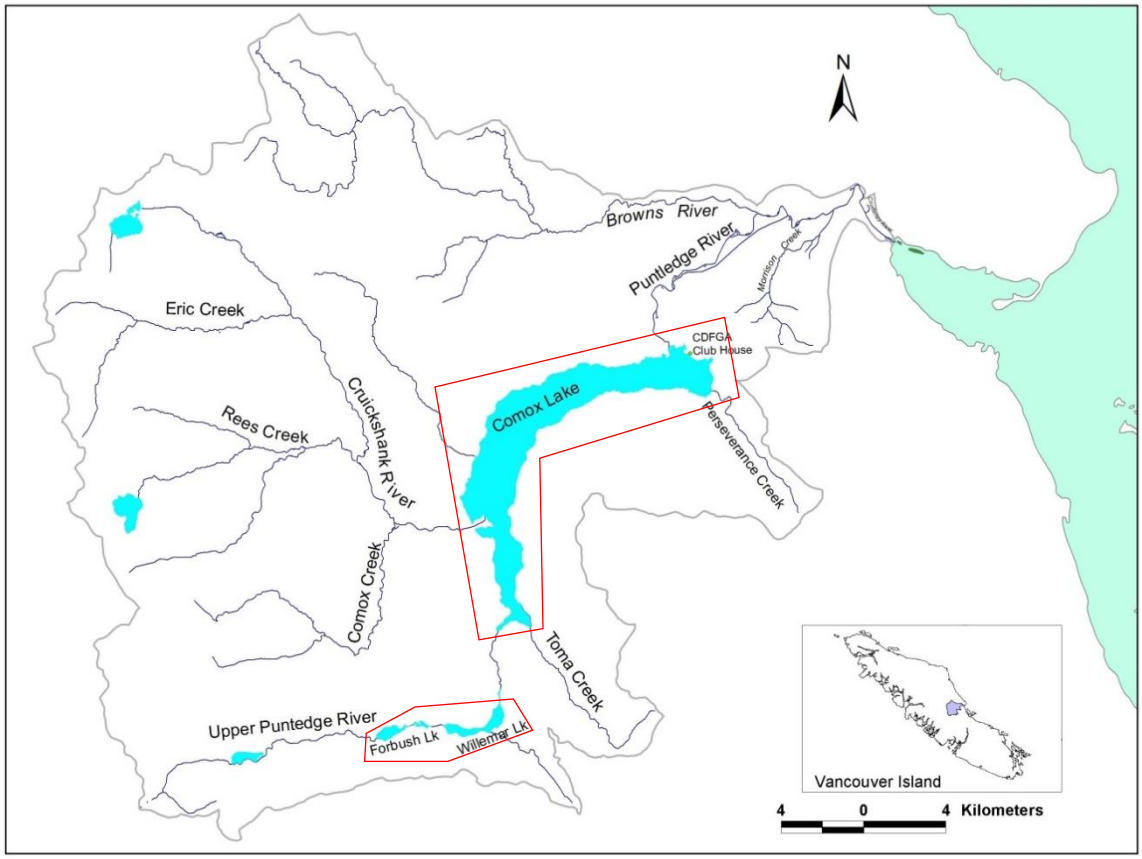

Figure 1. Location map of the Comox Lake watershed and study areas (red polygons).

3 METHODS

3.1 Field Reconnaissance

Two reconnaissance surveys were conducted on September 20th and 21st 2016 to identify potential kokanee spawning locations based on the 3m (10ft) bathymetric contour, and foreshore and littoral habitat features (gravel/cobble beaches, creek inlets, etc.) in Comox Lake. Locations of potential spawning areas were georeferenced using a Garmin Oregon® 450 GPS.

Telephone interviews were conducted with several long-time cabin-owners on Comox Lake, and other residents that have spent many years fishing in the lake. The information helped guide the location and timing of spawning surveys.

3.2 Spawner Surveys

Surveys were conducted weekly between the 7th of October and 18th of November on Comox Lake, and on the 22nd and 30th of October on Willemar and Forbush lakes, respectively. Surveys were either completed by boat or by walking the shoreline on foot. For the latter, only a portion of the sites were surveyed on foot since some of the sites were not easily accessible. Surveys involved traveling the shoreline to visually observe any kokanee activity (schooling, spawning fish, redds, etc.), or any signs of post–spawn mortalities (floaters) on the lake surface or morts along the shoreline. On one occasion, a snorkel survey was completed at one site. Frequent precipitation and strong winds during October and November hampered the survey schedule and visibility during several trips. Similarly, efforts to walk the lower reaches of the Upper Puntledge River (downstream of Willemar Lake and between Willemar and Forbush Lakes) were precluded by high discharges.

3.3 Analysis of Reservoir Fluctuations during Spawning and Incubation

Historical reservoir elevations, between 1993 and 2015, were analyzed to determine the range and frequency of maximum and minimum elevations during the kokanee spawning and incubation periods, respectively (BC Hydro, Power Records, unpubl. data; WSC Historical Hydrometric data 2017). Based on anecdotal information from cabin owners, and 2016 surveys, the kokanee spawning period likely begins in mid-October, peaks at the beginning of November and is completed by late-November. Therefore, the analysis focused on a spawning period from 15 October – 15 November and a conservative estimate of the incubation period from 15 October – 15 April.

3.4 Egg Incubation Assessment

Although not identified as an objective in the proposal, the confirmation of a kokanee shoreline spawning site in Comox Lake allowed an opportunity to assess the incubation success of kokanee eggs. Eyed coho salmon eggs from Puntledge River

hatchery were used as a surrogate. Approximately 50 eyed coho eggs were loaded into 6 cm diam x 11 cm long perforated cylindrical plastic egg tubes (incubators) along with substrate consisting of small gravel (2-16 mm; Photo 1). A total of 9 incubators were planted at 4 locations in Stockand Bay (Site 10) on December 23, 2016, where kokanee were observed spawning. Egg planting locations were carefully selected to avoid known redds. The tubes were buried at a depth of approximately 15 cm (depth of substrate over egg tube) using a garden trowel and each site was marked with a length of rebar painted orange (Photos 2 & 3). This depth was representative of the average depth of kokanee redds observed spawning in the area. A temperature data logger (Onset Hobo) was buried with one of the tubes to collect intergravel temperature. A control group of eggs remained at Puntledge Hatchery to compare survival.

4 RESULTS AND OUTCOMES

4.1 Field Reconnaissance

A total of 16 sites were identified around the perimeter of Comox Lake that had suitable nearshore habitat for kokanee spawning (Figure 2). Criteria for suitable kokanee nearshore spawning sites included abundant, uniformly small (<30mm), non-compacted, clean gravel substrate (Photo 4), and water depth at the time of the assessments of less than 3m. GPS coordinates and sites identified are described in Table 1. Of the 16 sites identified, at least 10 were located in the vicinity of alluvial fans associated with creeks or larger tributaries. Subsequent kokanee spawner surveys were focused on the 16 sites identified in the reconnaissance. Telephone interview and on site information from frequent lake users and cabin owners was used to help focus the efforts of subsequent spawner surveys. A summary of the interviews is presented in Appendix 2.

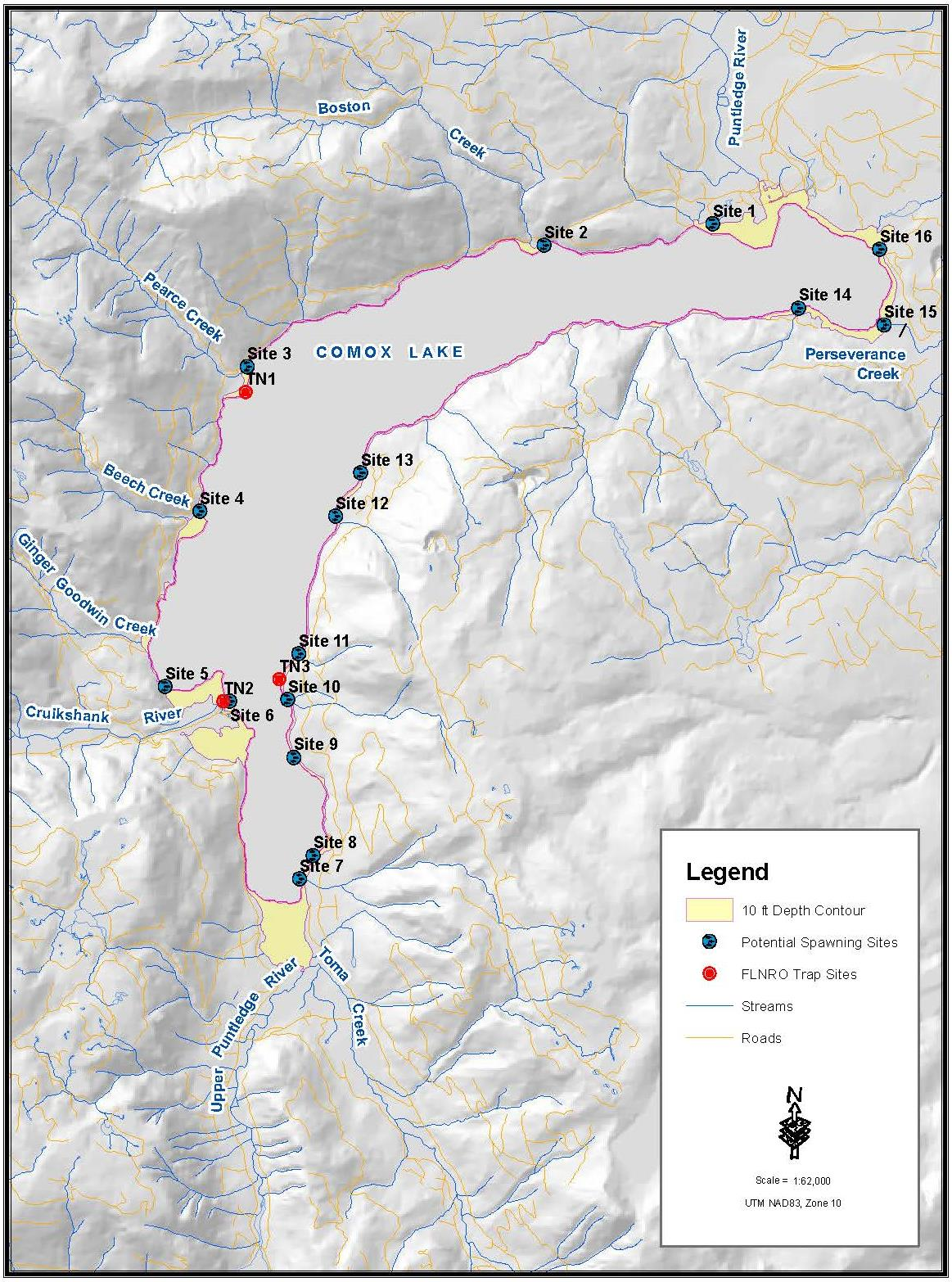

Figure 2. Potential kokanee spawning sites in Comox Lake.

Table 1. Location and description of potential shoreline kokanee spawning sites in Comox Lake.

Coordinates x	y	Site #	Description	Comments
49.6386	-125.104	1	NE end of lake west of lake outlet	Extensive beach, 100s of meters <10 ft contour; small creek appears to enter on western edge
49.6355	-125.1339	2	out-wash at confluence of Boston Creek on point of land	Low gradient beach, finer gravel than previous site; stumps
49.6204	-125.1859	3	Confluence of Pearce Creek	Extensive breach with small gravel; old log dump; east side of beach steeper than west side
49.6036	-125.1936	4	Confluence of Beech Creek	delta bordered by stumps
49.5833	-125.1989	5	Cruickshank spit	north of Cruickshank confluence
49.5822	-125.1896	6	Cruickshank delta	confluence - large area of gravel deposits, varying depths, gradients, gravel size
49.5616	-125.1741	7	East of Upper Puntledge confluence including Toma Ck conf.	Long site
49.5643	-125.1718	8	Beach continues from previous	demarcated by cabins; log boom
49.5756	-125.1756	9	cabin	small steep beach with single cabin; log boom
49.5822	-125.1771	10	Cluster of cabins with log boom locally known as Stockand Bay	Creek conf on north end, clean gravel recently deposited (slide?). Observed KO spawning here.
49.5867	-125.1765	11	Narrow beach just N of Stockand bay	exposed
49.6035	-125.1695	12	Narrow beach just S of Little Italy	exposed
49.6079	-125.1655	13	Cluster of cabins with log boom locally known as Littly Italy	log boomed area with cabins; clean gravel and less angular than areas south
49.629	-125.0884	14	S end of Cumberland Campground	large gravel areas
49.6273	-125.0731	15	Perseverance Creek confluence	homes along south side, coal slag on north side
49.6361	-125.0744	16	White's Bay	extensive beach area to F&G clubhouse

4.2 Spawner Surveys

Spawner surveys were conducted at Comox Lake on October 7, 12, 21, 28, 31, and November 18. Willemar Lake was surveyed on October 22 and Forbush Lake was surveyed on October 30. The first sign of kokanee was on October 12th when several large schools (>100 fish) were observed approximately 100m offshore "porpoising" and heading in a southerly direction. Offshore schools exhibiting this behavior were observed at both Stockand Bay (Site 10) and further south at Site 8. Cabin owners claim that this rippling on the surface is a common behavior when the fish are moving to spawning areas and are forced to the surface by larger trout (Randy Burkley, cabin resident, Linda Tobacca, cabin resident, pers. comm).

During the spawner survey on October 31, more than 50 kokanee were observed actively spawning nearshore in Stockand Bay, in an area approximately 15m x 20m in size. The fish were spawning in approximately 2.5m deep water, and redds were approximately 0.5m diameter and comprised of small gravel (10mm diameter; Photos 5, 6, and 7). There were no morts or floaters observed, and fish appeared in good

condition, and were guarding redds. Sites 12 (Little Italy), Site 6 (mouth of Cruikshank), Site 4 (mouth of Beech Creek), and Site 3 (Pearce Creek) were inspected on the same day but no fish were observed in these areas.

FLNRO Lake Biologists had set up live trapnets in three areas from October 25 to 28 as part of their on-going cutthroat trout studies in Comox Lake. The nets used were 8ft box trapnets with 100-150 centre leads, and were checked daily after a 24 hour soak period. There were three main trapping sites (Figure 2): One near the mouth of the Cruikshank River (Site 6 - TN2), one off the point near Stockand Bay (Site 10 -TN3), and the third at the mouth of Pearce Creek (Site 3 - TN1). A total of 4 kokanee were captured at the mouth of the Cruikshank, and 17 kokanee from the Stockand Bay trap (Table 2). No kokanee were captured at the Pearce Creek site, which was fished for three of the four days. Almost all kokanee captured in the traps at the Cruikshank and Stockand locations on the four days were mature (ripe and expressing eggs; Photo 8).

On November 18th, a total of 6 morts were collected that had washed up on shore at Stockand Bay, and another two were collected at Little Italy. No other sign of morts were observed at any of the other sites on that day. Local cabin owners claim that any kokanee floaters and visible carcasses on the beach are quickly devoured by the large flock of gulls and eagles that converge at the south end of the lake during the kokanee spawning period.

A spawner survey was conducted at Willemar Lake on October 22nd. The perimeter of the lake was visually assessed, with particular focus on areas with nearshore gravel deposits at mouths of creeks. Intermittent 0.5m square freshly cleaned gravel patches were noted in approximately 2.5 - 3 m depth, but there was no sign of any adult fish, floaters or morts on that day. Forbush Lake was assessed on October 30th with similar observations; there was an area on the north side of Forbush Lake that had several nearshore freshly disturbed gravel patches that looked like redds (Photo 9); however this could not be confirmed, and there were no adult fish observed. The habitat at the confluence of the Upper Puntledge and Forbush Lake had abundant gravel that appeared

to be a similar size as the gravel that the kokanee were observed spawning in at Stockand Bay; however no fish were observed spawning at this location.

Table 2. Kokanee collected in Comox Lake during spawner surveys and trap netting by FLNRO in late October to late November, 2016.

Site	Date	Latitude (deg)	Longitude (deg)	Location	FL (mm)	Sex	AgeID	Comments
TN2	25/10/2016	49.5818	-125.1885	Cruikshank	200	f		expressing
TN3	25/10/2016	49.5846	-125.1787	south shore	210	m		expressing
TN3	25/10/2016	49.5846	-125.1787	south shore	124			
TN2	26/10/2016	49.5818	-125.1885	Cruikshank	200	m		expressing
TN3	26/10/2016	49.5846	-125.1787	south shore	200	m		expressing
TN3	26/10/2016	49.5846	-125.1787	south shore	210	f		expressing
TN3	26/10/2016	49.5846	-125.1787	south shore	208	m		expressing
TN3	26/10/2016	49.5846	-125.1787	south shore	195	f		expressing
TN3	27/10/2016	49.5846	-125.1787	south shore	216	m		expressing
TN3	27/10/2016	49.5846	-125.1787	south shore	210	m	KO1	expressing
TN3	27/10/2016	49.5846	-125.1787	south shore	220	m		expressing
TN3	27/10/2016	49.5846	-125.1787	south shore	205	m	KO2	expressing
TN3	27/10/2016	49.5846	-125.1787	south shore	195	f	KO3	expressing
TN3	27/10/2016	49.5846	-125.1787	south shore	208	f	KO4	expressing
TN3	27/10/2016	49.5846	-125.1787	south shore	215	m		expressing
TN2	28/10/2016	49.5818	-125.1885	Cruikshank	202	f		expressing
TN2	28/10/2016	49.5818	-125.1885	Cruikshank	217	m		expressing
TN3	28/10/2016	49.5846	-125.1787	south shore	207	m		expressing
TN3	28/10/2016	49.5846	-125.1787	south shore	212	m		expressing
TN3	28/10/2016	49.5846	-125.1787	south shore	227	m		expressing
TN3	28/10/2016	49.5846	-125.1787	south shore	205	f	107	expressing
	31/10/2016	49.5822	-125.1771	Stockand Bay	220	m	104	fresh mort
	31/10/2016	49.5822	-125.1771	Stockand Bay	200	m	106	fresh mort
	18/11/2016	49.5822	-125.1771	Stockand Bay	204	m	100	fresh mort
	18/11/2016	49.5822	-125.1771	Stockand Bay	220	m		mort
	18/11/2016	49.5822	-125.1771	Stockand Bay	208	m		mort
	18/11/2016	49.5822	-125.1771	Stockand Bay	200	f		mort
	18/11/2016	49.5822	-125.1771	Stockand Bay	192	f	101	mort
	18/11/2016	49.5822	-125.1771	Stockand Bay	201	m	105	mort
	18/11/2016	49.6079	-125.1655	Little Italy	204	m	102	mort
	18/11/2016	49.6079	-125.1655	Little Italy	208	f	110	mort
				Mean FL Males	***210.2***	***SD***	***7.94***	
				Mean FL Females	***201.5***	***SD***	***6.22***	

The mean fork length for male and female kokanee spawners captured in Comox Lake in 2016 (trap net, floaters and carcasses) was 210.2 mm (n=20, SD=7.94) and 201.5 mm (n=10, SD=6.22), respectively. The majority of kokanee captured during the 2009 hydroacoustic and trawl survey were estimated to be age 3+ (mean fork length 180 mm), suggesting that most Comox Lake kokanee spawn at age 3+ and rarely exceed 225 mm in length (Johner and Sebastian 2009). Otoliths from a sub-sample of captured live kokanee and all post-spawn recoveries in 2016 were extracted for ageing. Results were not

available at the time of reporting. Similarly, tissue samples collected from live and moribund kokanee (removed from the caudal fin) were sent to the DFO Pacific Biological Station Molecular Genetics Lab for genetic analysis. Results of this analysis were not yet available at the time this report, but the information may provide insight on the possible origin of these fish.

4.3 Analysis of Reservoir Fluctuations during Spawning and Incubation

Comox Lake reservoir elevation over the spawning and incubation period (to early March) is illustrated in Figure 3. Following the date that shoreline spawning kokanee was observed at Site 10 (Stockand Bay), during what may be considered peak spawning, the lake elevation increased significantly, exceeding the maximum operating range of the Comox impoundment dam (135.3 m) when water spills freely over the dam (Figure 3). The volume of water inflow into the Comox lake reservoir between October and 24 November was the highest on record, or 266% of normal (S. Watson personal communication Nov 24, 2016). After about a week at >135 m, the lake then declined gradually over the incubation period, reaching a low of 132.0 m on 16 January 2017 before increasing again.

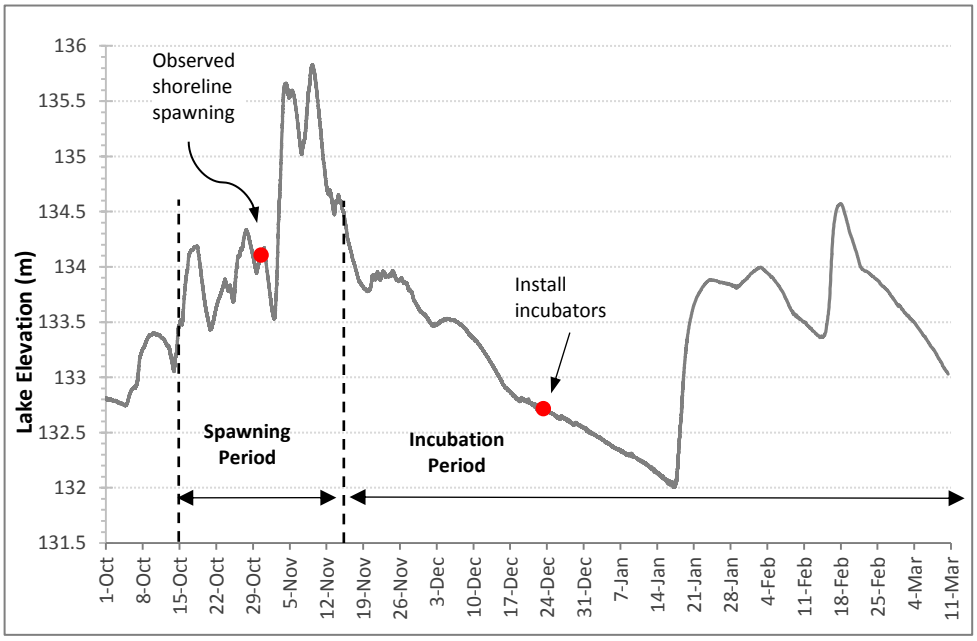

Figure 3. Comox lake reservoir elevation (WSC Real Time hydrometric data) during the 2016 kokanee spawning and incubation period.

Water depth of the observed kokanee redds at Site 10 was approximately 2.1 m, at a reservoir elevation of 134.05 m. By 23 December when eyed coho eggs were planted at the site, water depth was ~1 m (reservoir 132.71 m), and declined a further 0.71 m to a critical level, potentially increasing the likelihood of redd dewatering and exposure to wave action.

An analysis of past reservoir fluctuations over the kokanee spawning and incubation period and the depth of the observed kokanee shoreline spawning in Stockand Bay, may lend insight into the potential effects of reservoir draw down on shoreline spawning and incubation success. Minimum, maximum and mean reservoir draw down during spawning and incubation over the past 24 years was 0.3 m, 4.25 m and 2.36 m respectively (Table 3).

Table 3. Comox Lake reservoir elevation during estimated kokanee spawning and incubation /emergence periods 1993-2016.

Year	Max Elevation during spawning period (m)[1]	Min Elevation during incubation & emergence period (m)[2]	Reservoir Draw Down (m)
1993	130.82	130.52	0.30
1994	132.36	131.18	1.18
1995	134.15	132.89	1.26
1996	132.92	131.64	1.28
1997	135.14	133.62	1.52
1998	132.64	131.38	1.26
1999	134.79	130.75	4.04
2000	132.90	131.46	1.44
2001	134.63	130.92	3.71
2002	133.62	130.49	3.13
2003	136.18	131.93	4.25
2004	134.72	131.39	3.33
2005	134.56	132.06	2.50
2006	134.30	131.21	3.09
2007	135.29	131.14	4.15
2008	134.76	131.74	3.02
2009	134.73	131.95	2.78
2010	134.36	132.44	1.92
2011	134.38	132.26	2.12
2012	132.95	131.81	1.15
2013	133.23	131.85	1.38
2014	135.05	132.22	2.83
2015	134.09	132.93	1.16
2016	135.83	132.00[3]	3.83

[1] From 15 October to 15 November
[2] From 15 October to 15 April
[3] to March 2017

Assuming that kokanee spawn at an elevation of ~132 m, the reservoir dropped below this level during the incubation and emergence period in 67% of years (16 of 24 years). However, if we use reservoir draw down as a prediction of redd dewatering, with a draw down in excess of 3 m considered to pose the highest risk, then only 9 of the 16 years were high risk. Thus speculating that years with large reservoir fluctuations may be potentially detrimental, it is largely dependent on the preferred depth contour of egg deposition. Based on this crude analysis and one year of observations, reservoir drawdown may adversely impact kokanee reproductive success in two of every three years. A better understanding of kokanee habitat selection and spawning depth preferences is required to determine the potential effects of reservoir draw down on kokanee spawning recruitment and incubation survival.

4.4 Egg Incubation Assessment

From our field observations of shoreline spawning, mean water column temperature at time of peak spawning was 10.5^{o} C and declined to a low of 4^{o} C in February during incubation (Figure 4). Conversely, intergravel temperature at Site 10 was relatively constant over the monitored portion of the incubation period fluctuating by only 0.6 ^{o}C, and averaging 6.72 ^{o}C. The development rate of Comox Lake shore spawning kokanee eggs is unknown, however we used an average of ~950 ATUs from fertilization to emergence based on the literature (Groot and Margolis 1991, Quinn 2005; Morris and Caverly 2004). Using the more variable surface water temperature (lake outlet) to predict the period of development and emergence timing from peak spawning (Oct 31st) would place fry emergence by mid-April. However, at Site 10, under the more constant intergravel temperature regime recorded during the latter part of the incubation period may advance egg development and result in earlier emergence, possibly by mid-March.

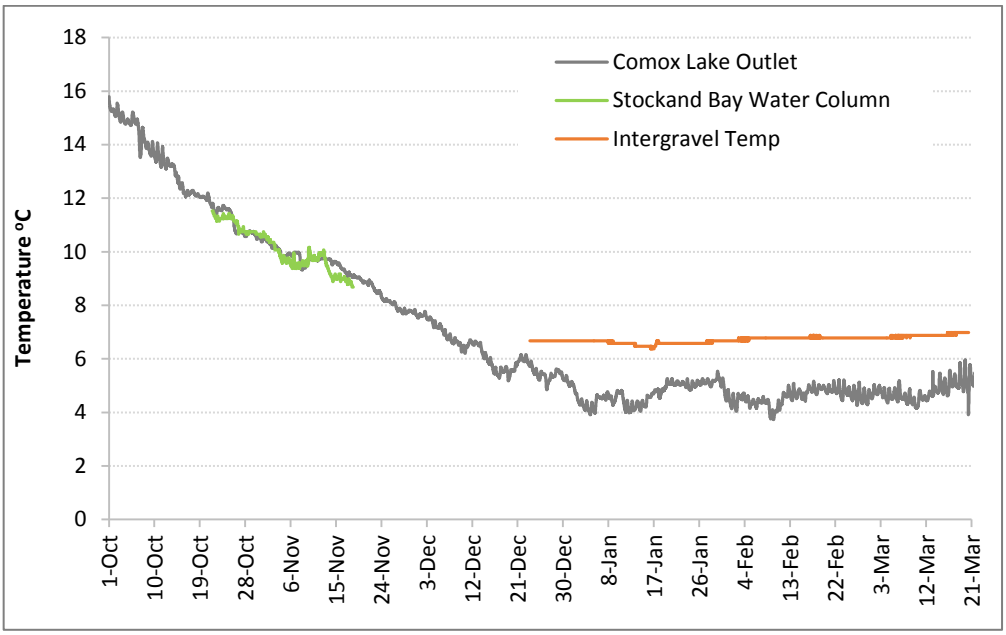

Figure 4. Water column and intergravel temperature recorded at Site 10 (Stockand Bay) and at the Comox Lake outlet over the period of kokanee spawning and incubation (Oct 2016 - Mar 2017).

Incubation survival results (eyed egg-to-fry) for the coho at the 4 locations at Site 10 are summarized in Table 4. An analysis of survival between the 4 locations was not conducted. The objective was to provide a qualitative assessment of potential survival at this location, and potential effects of reservoir draw down and wave action on incubation success. Overall eyed egg-to-fry survival was 85.5%. Eight of the 9 incubators had survival rates ≥88% and one incubator experienced very poor survival (<9%). This estimate was based on the number of live fry recovered from the incubator and not a count of dead eggs/alevins. We assumed that most of the dead material decomposed. However, an alternative explanation is that the alevins escaped through the perforations. Since we did not observe this in the other 8 incubators, we discounted this hypothesis.

Table 4. Summary of eyed egg-to-fry survival for coho planted at Site 10 (Stockand Bay) in Comox Lake, December 2016 - March 2017.

Site #	Inc #	No. Eggs Planted	Site Description	Live Fry	Dead Fry	Dead Alevins	Dead Eggs	% Survival	Comments
1	3	58	B. Roses dock - west side; approx. 1 m depth	51	1	6	0	87.9	
1	7	56		51	0	3	0	91.1	Tidbit data logger buried with incubator
2	6	55	BR dock - west side; approx. 1.1 m depth	52	2	1	0	94.5	
2	8	55		53	1	1	0	96.4	
3	1	55	BR dock - east side near observed spawning area; approx. 0.9 m depth	54	0	0	0	98.2	
3	2	60		60	0	0	0	100.0	
4	4	55	BR dock - east side near spawning area; approx. 1 m depth	51	1	3	0	92.7	
4	5	56		5	0	51	0	8.9	Minimal dead material.
4	9	48		48	0	0	0	100	
Overall Survival eyed egg to fry								**85.5**	
Control Group		500	Puntledge Hatchery					98.7	Eggs loaded into egg tube, transported to lake and back to hatchery

5 DISCUSSION

The focus of the effort in the 2016 spawner survey, was to first identify nearshore suitable spawning areas, then to monitor these sites over the locally reported spawning period. Kokanee spawning timing and habits varies from system to system; local knowledge combined with periodic visits to known spawning areas such as Stockand Bay helped to pinpoint the peak of the spawning period. Overall, total numbers of observed spawning kokanee in nearshore habitat (<3m depth water) was much lower than would be expected, based on estimates of the kokanee population in the 2014 and 2009 hydroacoustic studies previously cited.

Willemar and Forbush Lakes were inspected for sign of spawning fish very close to the time when ripe expressing fish were captured at both the mouth of the Cruikshank and at the point near Stockand Bay. No fish, floaters or morts, were observed at either of the lakes. However, excellent spawning habitat was identified at tributary inflow

locations at both Willemar and Forbush Lakes, and there were signs of areas of recently disturbed gravel in nearshore areas some distance from tributaries. Spawning habitat quality in the stream reach between Willemar Lake and Forbush Lake is described as excellent, as is the habitat in the 600m section of the upper Puntledge River upstream of Forbush Lake (Griffith, 1994). These sections could not be accessed by boat or on foot to look for kokanee spawning due to the excessively high flows during October and November.

Local cabin owners indicated that kokanee have been spawning in the same nearshore area in Stockand Bay for at least 50 years (Billy Roses, pers.comm). There may be upwelling of groundwater in this location that attracts the kokanee to this precise location; other studies have hypothesized that deep water spawning kokanee are attracted to upwelling groundwater locations (Morris and Caverly, 2004). Monitoring of the temperature at known reoccurring spawning locations compared to control non-spawning areas may give insight into whether sites are being selected based on groundwater sources.

Low numbers of spawning kokanee observed over the spawning period in nearshore habitat may indicate that the Comox Lake kokanee are spawning in deeper portions of the lake. Kokanee populations in Anderson and Seton Lakes are almost exclusively deep water spawners. A study in 2003/04 combined hydroacoustics, ROV underwater camera surveying, and gillnetting validation , found that most of the kokanee were spawning in water ranging in depth from 20 to 70m (Morris and Caverly, 2004). In the study, the ROV sites were selected based on hydroacoustic detection of fish at depth, presence of floaters, shoreline eagles, and mature kokanee captured in gillnets. The ROV footage detected numerous small recently completed redds, and ROV was recommended as a good methodology to document spawning habitat. Gaining a spawner population estimate combining these techniques is not straightforward, but the study objective was also to develop a systematic standard procedure for enumerating kokanee and determining preferred spawning locations.

Other kokanee populations, such as in Okanagan Lake, spawn extensively in shallow nearshore water (<0.75m deep); redds in water this shallow are vulnerable to drying out during the fall drawdown of the lake, and the shallow water preference combined with lower fall lake levels is linked to significant declines in kokanee abundance since the 1970's (Andrusak and Matthews, 2002). A fish/water management tools project was undertaken in Okanagan Lake to incorporate kokanee life histories and spawning timing when managing reservoir levels. Efforts have been made to make the timing of reservoir fluctuations more favourable for kokanee spawning and incubation survival in Okanagan Lake, when possible. Although Comox Lake kokanee were not observed spawning in water as shallow as in Okanagan Lake, timing and extent of fall and winter drawdown would ideally consider kokanee habitat requirements and reproductive success.

Kokanee in the Coquitlam Reservoir are reported to broadcast spawn. A spawner survey in 2005 that involved gillnetting, captured high concentrations of spawning and spent kokanee at depths of approximately 15m, that had no caudal fin fraying or abrasion marks on their bellies, which led the authors to surmise that the fish were broadcast spawning (Gaboury and Murray, 2006).

6 SUMMARY AND RECOMMENDATIONS

- Further assessments are recommended in Comox Lake to gain more information about the combination of habitat attributes that attract spawning kokanee. There are numerous beach areas around Comox Lake that appear to be well suited for spawning with clean small gravel and similar depth profiles as observed at Site 10. Although physical nearshore redd excavations were observed, other spawning behaviours such as broadcast spawning may also occur in Comox Lake; broadcast spawning would allow kokanee to spawn in areas with larger substrates.
- The attraction of kokanee spawning to Site 10 may be influenced by a groundwater source that provides improved survival through oxygen delivery, a shorter rate of

development, or some protection from desiccation during low reservoir levels. Continuous monitoring of intergravel temperature over a longer duration at this and other shoreline sites may provide more insight into the temperature characteristics at confirmed and potential spawning sites for groundwater or other hydraulic processes that may influence habitat selection.

- Visual observations of shoreline spawning activity by boat may be supported by use of a drone or UAV (weather permitting in consideration of wind and sun exposure for optimal visibility). This would allow a greater coverage of potential shorelines with little disturbance. Also shoreline surveys by boat could be accompanied by a portable, submersible ROV (Remote Operated Vehicle) to observe signs of redds at depth, and to confirm whether or not spawning occurs at greater depths than observed in 2016. This would also eliminate sources of error relating to visibility limitations associated with light, wave action, precipitation and turbidity.
- Gillnetting, and hydroacoustic validation, in combination with ROV surveying and/or SCUBA should be utilized to investigate whether kokanee are spawning in deeper water habitat.
- Collect information on fecundity from pre-spawn kokanee females.
- Collaboration with FLNRO activities during their multiyear cutthroat trout study on Comox Lake would facilitate future kokanee assessment work, and provide cost efficiencies.
- Currently, Comox Lake water levels are not managed or operated for kokanee salmon. During the Puntledge Water Use Planning process in 2003, potential impacts on shoreline spawning from fluctuating reservoir levels or other issues were not identified. No information on shoreline spawning of kokanee in the reservoir was provided, and it was assumed that dewatering of kokanee redds, if they did exist, would be unlikely (BC Hydro 2003). Kokanee habitat requirements should be considered in future discussions and water use planning/review on Comox Lake reservoir operations.

7 ACKNOWLEDGEMENTS

We are grateful for the financial support for this study from Fisheries and Oceans Canada (DFO) Ecosystem Management and the Fish and Wildlife Compensation Program (FWCP), on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders. This project was made possible by the commitment and contributions of DFO Puntledge River Hatchery, and volunteers with the Courtenay and District Fish and Game Protective Association (CFGA). In particular, we wish to acknowledge M. Sheng and D. Miller, W. White, F. Clifford, P. Bolton, and G. Gallagher. Also, B. Anderson (FLNRO Lake Biologist) provided observations and live kokanee samples during a concurrent lake study on cutthroat trout. We would like to thank the K'omoks First Nation Guardians for their contribution to field work and transport. Thanks to Timberwest for cooperating when access to the forestry roads around Comox Lake was required. And finally, thanks to the cabin owners at Stockand Bay and others that spend time on Comox Lake for providing invaluable local knowledge on the elusive kokanee.

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Personal Communication

Stephen Watson — Stakeholder Engagement Advisor, BC Hydro; email November 24, 2016.

Appendix 1. Photos

Photo 1. Eyed coho eggs loaded with substrate in egg tube incubator.

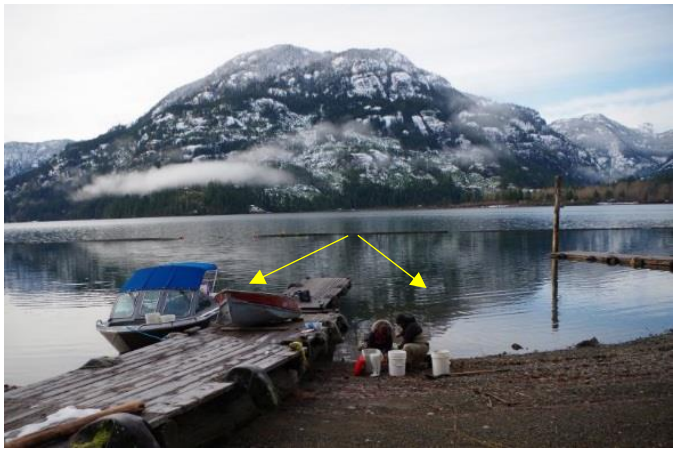

Photo 2. Location of incubation study. Coho eggs planted in incubators on left and right of dock.

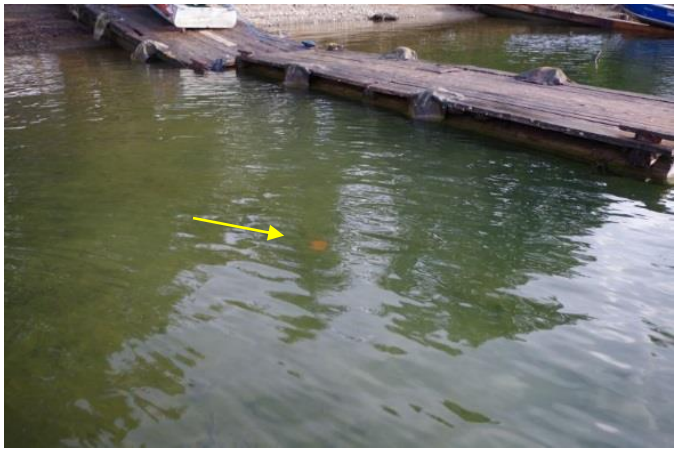

Photo 3. Location of buried incubators denoted by orange rebar marker.

Photo 4. Gravel size on exposed beach at Site 10 (Stockand Bay) at southeast end of Comox Lake.

Photo 5. Kokanee spawning in Stockand Bay on October 31, 2016.

Photo 6. Kokanee spawning in Stockand Bay with redds in foreground.

Photo 7. Kokanee on redds at Stockand Bay, October 31, 2016.

Photo 8. Mature male (bottom) and female (top) kokanee captured in Comox Lake, October 2016.

Photo 9. Possible kokanee redd at Forbush Lake, October 30, 2016.

Appendix 2. Comox Lake cabin owner contact survey, 2017

Comox Lake cabin owner/fisherman survey	Gary Smith (Contacted July 11, 2016)	Joe Franceschini (Contacted July 21, 2016)	Doug Stockand (Contacted July 26, 2016)	Otto Winnig (Contacted Aug 2, 2016)	Billy Roses (contacted August 15, 2016
1. Where do you live on the lake, and how long have you had a cabin there?	Little Italy	Little Italy, just south of Stockand Bay (SB). Father built cabin in 1946. Has been fishing since he was 15, but not as much recently.	Stockand Bay (SB). Father built cabin in 1946.	Don't own a cabin but fished in the lake since 1949, mainly trolling from boat.	Stockand Bay, near Doug Stockand, has had a cabin for 50 years.
2. Have you ever seen Kokanee spawning, and where and between what years?	Last 2 years, KO observed bubbling, circling between log boom and shoreline in Stockand Bay (in front of Pug Miller's cottage); directly across from Cruickshank River.	No, but have lots of friends/cabin neighbors that have. Heard they are seen 'boiling' near surface at SB during late fall. Someone said they spawn on a full moon. Has never seen KO spawning in Little Italy. Have seen large schools of KO and fished lots of KO between May and October. Logging Camp at mouth of Cruickshank – discard food scraps off dock – lots of jigging 1930's-40's.	Yes, usually every year in Stockand Bay. Also in Bay nearer cabins at outlet of Upper Puntledge River, and along point between Stockand Bay and Little Italy, and to a lesser degree, at bottom of lake (Cumberland end) but not as many as top.	Not spawning but schooling along shore.	Yes, every year, at the end of his wharf in 5ft of water. Also sees them passing by in schools. From 8-15 inches in size
3. Have you seen lake spawners, and how deep have you seen spawners in the lake?	Yes, see #2 above.	Heard they are seen 'boiling' near surface at SB during late fall. Someone said they spawn on a full moon.	See the KO schooling just off-shore prior to spawning, then they move closer to shore. Usually spawn in 5-10 feet of water. May not spawn if the lake is too low because they don't have the same quality gravel (muddier). See carcasses by late November.	Have not witnessed spawning activity, mainly schools of KO swimming at mouth of Cruickshank R. No carcasses observed, but have seen KO schools and carcasses in other lakes – (Wolf and Horne)	Yes, sees them spawn in 5ft of water. Has seen redds exposed when fall drawdown occurs, which dries eggs.

Appendix 2. Cont'd

Comox Lake cabin owner/fisherman survey	Gary Smith(Contacted July 11, 2016)	Joe Franceschini (Contacted July 21, 2016)	Doug Stockand (Contacted July 26, 2016)	Otto Winnig (Contacted Aug 2, 2016)	Billy Roses (contacted August 15, 2016
4. Have you observed Kokanee in any of the tributaries draining into the lake? If yes, which tribs?	No	No. Neighbor saw spawning on shore south of Perseverance Creek. Another cabin owner (Karen) in bay north of SB saw KO but not sure whether they were spawning.	No. But used to see schools of KO in Willemar and Forbush Lakes during hunting trips, before road network (15-20 years ago).	No	Not recently, because he doesn't go up the tributaries any more, but suspects that they spawn up to third lake in upper Puntledge and possibly further up in Cruikshank
5. When do you think the peak spawning period is?	Late October	Late October/early Nov? Not very long.	Always, first week of November (~7th) to 3rd week always. Usually 2 - 2.5 weeks. Small spawners (5-6").	Fall, not sure of exact 'spawning' period	They spawn over a three week period; peak in the middle of October, and are finished by middle of November.
6. How have the numbers changed in the time that you have been visiting/using the lake?	Not sure	Seems to have declined in last 10 years. 3-4 yrs ago, lake dropped (3 ft) quickly in late fall.	Definitely declined in last 7 years. November typically when BCH releases large amounts of water during floods. Still KO but not as many as there were 15-20 years ago.	Have not seen large schools of KO compared to the past. Significant declines in both KO and trout.	Fewer KO than there used to be. Doesn't see the numbers that there were historically. Thinks that dropping lake levels in the lake have impacted lake spawner numbers.
7. Can we quote your information in a written report?	Yes	Yes	Yes	Yes	Yes
8. Do you know of any other knowledgeable locals, or other cabin owners that we should get in touch with?	**Billy Roses – 336-2423** (wife is Roberta)	Doug Stockand		Terry Curtain (spelling?) – cabin owner.	No one other than the names we contacted already. A lot of the old timers are gone.

Appendix 3. Confirmation of FWCP Recognition (article in the Comox Valley Echo, September 29, 2016).

COMOX VALLEY ECHO

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NEWS

Kokanee salmon study in Comox Lake seeks local knowledge

Seen any kokanee lately in Comox Lake? New study on the species wants to hear from you. — *Image Credit: Submitted*

Like 2

Comox Valley *posted* Sep 29, 2016 *at* 11:00 AM

Did you know that there are Kokanee Salmon in Comox Lake?

Kokanee are a small salmon that are closely related to Sockeye Salmon, except for the fact that they spend their entire lives in freshwater. They are sometimes referred to as "landlocked Sockeye."

While it is unclear whether Kokanee were present in the lake prior to Sockeye egg transplanting in the 1920s, Kokanee are now considered an important species in Comox Lake, both in the recreational sport fishery and as a key forage fish for cutthroat trout.

Not much is known about the Comox Lake watershed Kokanee life history, and overall population. A local study is underway to try and better understand the timing, spawning preferences and habitat selection of Kokanee Salmon.

This multi-year project, made possible with funding from the Fish and Wildlife Compensation Program (FWCP) started in early September, 2016. The 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 impacted by the construction of BC Hydro dams.

Local fisheries biologists Esther Guimond and Caroline Heim are heading up the study in partnership with the Courtenay and District Fish and Game Protective Association, and with support from the K'omoks First Nation Fisheries Guardians.

Some of the objectives of the study are to map key spawning areas, and to monitor the incubation period (while eggs are in the gravel) to get a better understanding of survival.

Tapping into local knowledge is important for this project. We are asking for anyone with information about current and historical sightings of Kokanee to contact Esther or Caroline with your information at our "Kokanee Hotline".

Call Caroline at 250.890.1786 if you have ever noticed Kokanee, or if you see them this fall. If you frequent the lake, or have a cabin up there and have any information tips, we want to hear from you!