Assessment of Kokanee Spawning in Comox Lake

Year 2

COA-F19-F-2720

Prepared for:

Fish and Wildlife Compensation Program

Prepared by:

E. Guimond[1] and C. Heim[2]

On behalf of:

Courtenay and District Fish and Game Protective Association

26 March 2019

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.

---

[1] Esther Guimond, RP Bio., 473 Leighton Ave., Courtenay, BC V9N 2Z5

[2] Caroline Heim, RP.Bio., Carolla Environmental Consulting, 2169 Robb Ave. Comox, B.C. V9M 1M5

EXECUTIVE SUMMARY

Year 2 of a kokanee spawning assessment was conducted on Comox Lake to collect information on the spawning distribution, habitat selection, and spawning behavior of Comox Lake kokanee, and to implement recommendations from Year 1 which took place in 2016 (Guimond and Heim, 2017). Kokanee are an important fish in the recreational sport fishery as a key forage species fish for piscivores such as cutthroat and rainbow trout. Prior to the 2016 study, little information was available on the life history and spawning habitat preferences of kokanee in Comox Lake. Improving our understanding of kokanee and the dynamics of, and limiting factors to resident fish populations in Comox Lake and its tributaries is fundamental to the development of a sustainable fish management strategy for Comox Lake. This project addresses 'Research and Information Acquisition' based priority actions in the Puntledge River Salmonid Action Plan (Priority Action short description PUN.RLR.RI.11.01 ... fish production limitations of habitats in Comox Lake and tributaries-P1; FWCP 2011).

In Year 1, 2016, reconnaissance surveys were conducted that identified 16 potential shoreline spawning sites in Comox Lake based on suitable physical and habitat characteristics. Weekly spawning assessments were conducted on Comox Lake using a combination of boat and foot surveys over the spawning period. Although potential kokanee spawning sites were identified, only one location, Stockand Bay, located at the south end of Comox Lake had a relatively high concentration of shoreline spawning kokanee.

In Year 2, 2018, fish sampling using gill nets combined with underwater video footage was conducted to collect low level spatial distribution of kokanee spawning along the nearshore areas of Comox Lake. In the 15 gill net sets conducted in Comox Lake, a total of 79 fish were captured comprised of 47% Cutthroat Trout, 28% kokanee, 24% Dolly Varden, and 1% Rainbow/Cutthroat Trout hybrid. In one gill net set in Willemar Lake a total of 20 fish were captured, comprised of 90% kokanee (89% were spawned out females), and 5 % each of Cutthroat Trout and Dolly Varden.

Underwater video recordings were made concurrently in areas where gill net sampling was conducted, with a total of 10 transects completed in Comox Lake and 3 transects in Willemar Lake. The videos were reviewed to investigate whether deep water spawning occurs in the study area. Areas with suitable habitat were also noted and geo-referenced. Deep water redds were observed in abundance at the southeast end of the lake in Stockand Bay, with kokanee and redds recorded at 20m depth. SCUBA was used to investigate the extent and frequency of deepwater spawning, and to verify adult kokanee on the redds that had been recorded using the towed underwater video. Redds with kokanee were observed to at least 20m depth. Assessment of deeper water beyond 20m was limited by SCUBA limits and limits of the towed video cable. A nearshore kokanee spawning estimate was made along the 220 m length of Stockand Bay using a GoPro camera during peak spawning on 30 October 2018. Over 500 kokanee adults and over 100 redds were estimated from review of the video file. A significant number of eggs deposited by nearshore spawners may have suffered a high mortality rate due to reservoir draw down because of a winter drought and low inflows in January - March 2019.

A comparison of surface and intergravel temperature data collected in Stockand Bay over the kokanee incubation period suggests possible groundwater influence or other surface-groundwater interactions that may be attracting kokanee to spawn in this location. The extent of these hyporheic processes in Stockand Bay warrants further investigation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1 INTRODUCTION

Kokanee salmon (*Oncorhynchus nerka*) are an important salmonid in Comox Lake both for the recreational sport fishery and as a key forage fish species for piscivores such as Cutthroat Trout (*Oncorhynchus clarkii clarkii*) and Rainbow Trout (*Oncorhynchus mykiss*). There is not much information about the population dynamics or life history requirements of the kokanee in Comox Lake. Although the Comox Lake dam was constructed in 1912, fish passage was not provided in the system until 1922. It is unclear whether the population of kokanee that resides in Comox Lake evolved from a pre-existing anadromous sockeye salmon population following dam construction, or is a remnant of a sockeye egg transplanting program that took place in the Comox Lake watershed from 1923 to 1930 (Bengeyfield and McLaren 1994).

In 2009, the B.C. 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 Comox Lake productivity study 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.

A Year 1 kokanee spawning assessment was conducted on Comox Lake in 2016 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 (Guimond and Heim, 2017). This study assessed nearshore spawning habitat suitability in Comox Lake and identified 16 sites that had physical characteristics suitable for spawning kokanee based on substrate size; 10 of the sites were located in alluvial fans of creeks or large tributaries. Spawner assessments were conducted through October and November 2016, and a significant spawning area was identified at the south end of the lake at Stockand Bay (Site 10).

This study (Year 2) is implementing some of the recommendations from the 2016 Year 1 study including investigation of spawning distribution beyond nearshore areas, assessing kokanee distribution and habitat selection by gillnetting, assessing deep water spawning using underwater video cameras and SCUBA verification, and monitoring of inter-gravel temperature over the incubation period to investigate whether spawning habitat selection is related to temperature and/or groundwater sources.

2 GOALS AND OBJECTIVES

The goal of this project was to build on the results from the 2016 kokanee study and to gain a better understanding of the distribution of spawning kokanee in Comox Lake and Willemar Lake. While the year one study in 2016 focused on an overview of potential spawning sites based on physical characteristics, the goal of the Year 2 study was to conduct a more in-depth examination of previously identified sites, and to include a variety of methodologies to investigate deeper water spawning.

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.

3 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. Field activities during year 2 of the kokanee spawning assessment were concentrated in nearshore areas of the perimeter of Comox Lake, and Willemar Lake (Figure 1).

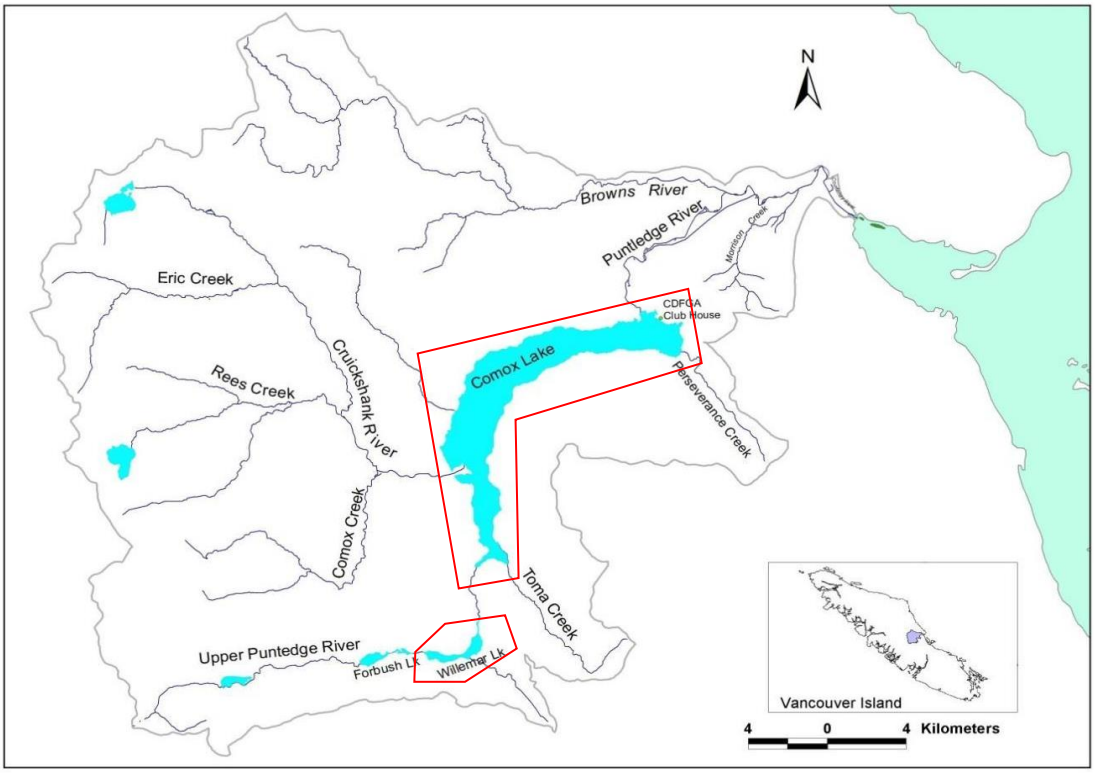


Figure 1. Location map of the Comox Lake watershed and study areas (red polygons).

4 METHODS

4.1 Gill net surveys

Gill net sampling was used to collect low level spatial distribution of kokanee spawning along the nearshore areas of Comox and Willemar Lakes. Gill nets consisted of six net panels, each 15.2 m long and of variable mesh sizes, joined together in a "gang" to form a net that was 91.2 m long and 2.4 m deep. The panels are arranged in a standard order and mesh size is selective for a certain size fish (Table 1). Nets were constructed of double knotted, light green monofilament nylon mesh, with braided lead line and cork lines.

Table 1. Order, mesh size and filament size in relation to the mean fork length of fish caught (RISC 1997).

Order	Mesh size (mm)	Filament size (mm)	Fish Fork Length (mm)
1	25	0.2	114
2	76	0.25	345
3	51	0.2	228
4	89	0.3	380
5	38	0.2	178
6	64	0.25	280

On each sampling day, two RISC standard experimental sinking gill nets were deployed by boat in areas identified during the 2016 study as potential shoreline kokanee spawning habitat. These areas were characterized as having suitable substrate, and were often in proximity to small creeks or tributaries. The sites were assessed prior to net deployment using a depth sounder to be free of underwater logs and woody debris that could snag, tear or tangle the net. Nets were anchored on shore and the boat was then reversed in a direction perpendicular from shore while the net was fed out from the bow. The offshore end of the net was anchored with a lead cannonball weight and marked with a floating buoy. Nets were left in place for approximately 90 minutes.

Captured fish were removed carefully from gill nets and placed in a recovery bucket for sampling. All fish were enumerated by species, sex (when possible) and measured for fork length, (and weight for kokanee captures only). Fish that were deemed to be in good condition were released while those in poor condition were euthanized. All Cutthroat Trout captures were retained by request for research by FLNRO lake biologists.

4.2 Underwater video recordings and SCUBA surveys

Underwater video recordings were made using a Splashcam Deep Blue HD camera (Oceans Systems Inc.) connected to a 10” monitor for real time viewing of footage. The camera had a 30m length cable. Transects parallel to shore were recorded by lowering the camera off the side of the boat and slowly passing areas along a consistent depth contour.

The camera recorded GPS coordinates while filming, and water depths were recorded using the boat depth sounder. All video footage was reviewed following collection and areas of gravel, any sightings of kokanee and evidence of redds were noted and cross referenced to GPS coordinates.

SCUBA transects were conducted to investigate and verify deep water spawning in Stockand Bay. Divers conducted depth transects starting from shore and with distances measured using a measuring tape and water depth using the boat depth sounder.

4.3 Nearshore Spawner Survey

A single shore based video transect was conducted on 30 October 2018 by walking along the shoreline at Stockand Bay and filming underwater using a GoPro mounted on a pole. The video footage was reviewed and a tally was made of the kokanee observed as well as the number of redds.

4.4 Reservoir elevation and temperature during spawning and incubation

Comox Lake reservoir elevation data was obtained from the Water Survey Canada real-time hydrometric data search website for the duration of the kokanee spawning and incubation period (https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=08HB082).

Four TidbiT v2 water temperature data loggers (Onset Computer Corp. MA) were buried in the gravel at Stockand Bay, to collect intergravel temperature in areas heavily utilized by spawning kokanee, and adjacent areas with similar habitat attributes where no spawning activity was observed. A fifth data logger was suspended from one of the docks in Stockand Bay to record water column temperature.

5 RESULTS AND OUTCOMES

5.1 Gill net sampling

An initial gill net set conducted on 16 October 2018 captured a high number of 120 mm kokanee juveniles and >300 mm Dolly Varden adults. Since the objective of our survey was to collect information on spawning kokanee distribution, and not an inventory of Comox Lake species composition/age classes, we removed two net panels from the gill nets (25 mm and 76 mm mesh panels) that were selective for these fish sizes to reduce by-catch and more effectively target larger spawning kokanee.

A total of 79 fish were captured in Comox Lake in 15 gill net sets between 16 and 31 October, and 20 fish captured in one survey in Willemar Lake on 4 November 2018 (Figure 2). The overall mean catch-per-unit-effort (CPUE) for all gill netting activities in Comox Lake is estimated at 2.16 fish per 100 m^2 of net area per hour (Table 2). The total catch of 79 fish in Comox Lake was comprised of 37 Cutthroat Trout (47%), 22 kokanee (28%), 19 Dolly Varden (24%) and 1 possible Rainbow/Cutthroat Trout hybrid (1%; Table 3). No mature (spawning) kokanee were caught in gill net surveys in Comox Lake. However, 6 kokanee floaters from Stockand Bay were biosampled on a later date (7 November), 5 of which were males with a mean FL of 212 mm (range 207-215 mm).

The total catch in Willemar Lake consisted of 18 kokanee (90%), 1 Cutthroat Trout (5%) and 1 Dolly Varden (5%). All of the kokanee were caught at a depth of ~9 m (30 ft), and all but 2 were spawned out females with a mean fork length (FL) of 198 mm (range 178-205 mm). As such we were not able to collect information on fecundity. During dissection of a subsample of the females, we were able to collect a small number of eggs, which measured 5 mm in diameter and 0.063 g. Gill net catch data is detailed in Appendix II.

Based on length/age data from previous studies (Johner and Sebastian 2009), the kokanee spawners are estimated to be age 3+ years while the smaller juveniles captured on 16 October are 1+ juveniles. Age analysis from scales collected on mature Willemar Lake kokanee have not yet been completed at the time of reporting. As well, tissue samples

collected from 2016 kokanee samples sent to the DFO Pacific Biological Station Molecular Genetics Lab for genetic analysis are pending and may provide insight on the possible origin of these fish.

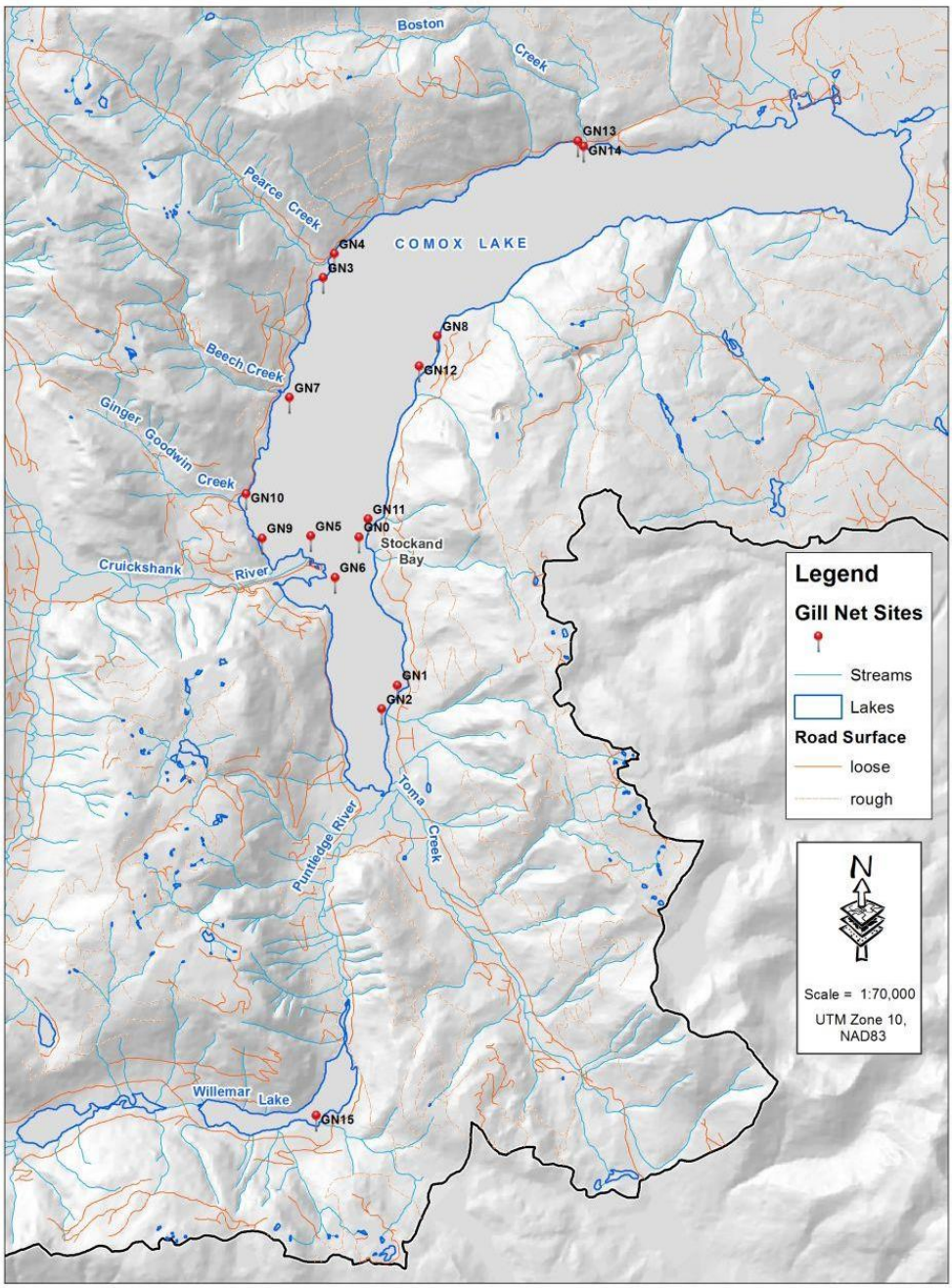


Figure 2. Map of gill net sampling sites in Comox and Willemar Lakes in 2018.

Table 2. Location and description of gill net sampling sites in Comox and Willemar lakes.

Crew Initials	Set #	Location	Latitude (deg)	Longitude (deg)	Depth Covered From - To (m)	Date	Time In	Time Out	Time Fished (min)	Total Catch	Total KO	CPUE Total[1]
EG, DC, CH	GN0	Point N Stockand Bay	49.5833	-125.1793	0 - 34.1	16-Oct-18	11:15	12:50	95	29	22	8.36
EG, DC, CH, JA	GN1	South end Site 8	49.5646	-125.1710	0 - 18.7	29-Oct-18	10:20	11:45	85	7	0	3.38
EG, DC, CH, JA	GN2	South end Site 7 @ creek outlet	49.5615	-125.1739	0 - 22.6	29-Oct-18	10:45	12:11	86	3	0	1.43
EG, DC, CH, JA	GN3	Pearce Ck S (Site 3)	49.6169	-125.1880	0 - 7.0	29-Oct-18	12:56	14:15	79	3	0	1.56
EG, DC, CH, JA	GN4	Pearce Ck N (Site 3)	49.6200	-125.1860	0 - 29.6	29-Oct-18	13:05	14:29	84	3	0	1.47
TB, DC, CH, JA	GN5	Cruickshank west	49.5835	-125.1890	0 - 13.0	30-Oct-18	9:25	10:45	80	2	0	1.03
TB, DC, CH, JA	GN6	Mosquito Bay	49.5783	-125.1840	0 - 2.0	30-Oct-18	9:40	11:00	80	4	0	2.05
TB, DC, CH, JA	GN7	Beach Ck	49.6013	-125.1940	0 - 23.2	30-Oct-18	11:45	13:30	105	4	0	1.57
TB, DC, CH, JA	GN8	Little Italy N	49.6098	-125.1650	0 - 17.0	30-Oct-18	11:55	13:20	85	3	0	1.45
EG, DC, TB	GN9	Cruickshank N	49.5830	-125.1987	0 - 24.0	31-Oct-18	9:25	10:51	86	5	0	2.39
EG, DC, TB	GN10	Ginger Goodwin Ck	49.5887	-125.2021	0.2 - 3.0	31-Oct-18	9:47	11:17	90	3	0	1.37
EG, DC, TB	GN11	Point N Stockand	49.5859	-125.1778	0 - 18.0	31-Oct-18	11:40	13:08	88	3	0	1.40
EG, DC, TB	GN12	Little Italy S	49.6058	-125.1684	0 - 31.4	31-Oct-18	11:58	13:48	110	4	0	1.49
EG, DC, TB	GN13	Boston Bar S	49.6355	-125.1382	0 - 18.3	31-Oct-18	14:09	15:18	69	4	0	2.38
EG, DC, TB	GN14	Boston Bar N	49.6349	-125.1370	0 - 15.0	31-Oct-18	14:17	15:33	76	2	0	1.08
Total Comox Lake									**1298**	**79**	**22**	
EG, DC, CH	GN15	Willemar @ NimNim Ck outlet	49.5088	-125.1846	0.5 - 10.7	4-Nov-18	12:50	14:17	87	20	18	9.45

[1]Gill netting CPUE was expressed in terms of the number of fish per 100 m^2 of net area per hour

Table 3. Summary of biosampling data from gillnet catches in Comox and Willemar lakes, October – November 2018.

		Fork Length (mm)		
Species		**Comox Lake**	**Willemar Lake**	**Total**
Kokanee		120 *(119-122)*	198 *(178-220)*	
	n	22	18	40
Cutthroat Trout		293 *(160-455)*	210	
	n	37	1	38
Dolly Varden		338 *(220-460)*	305	
	n	19	1	20
CT/RB Hybrid		227	0	
	n	1	0	1

5.2 Underwater video surveys and SCUBA survey

Underwater video transects were conducted in areas that had been previously identified in Year 1 as being suitable for kokanee spawning based on substrate size and/or proximity to alluvial fans of creeks or larger tributaries. Video transects were located in depths ranging from approximately 4 m to 20 m in order to photo document deeper water spawning beyond areas that could be visually assessed during shore based visual surveys. Main tributaries that were video recorded included Boston and Pearce Creeks, Cruikshank River, and the small unnamed tributary that flows into the point just north of Stockand Bay. Three videos were recorded in Willemar Lake; one at the inflow of the upper Puntledge River, one near the inflow of Nim Nim Creek, and the third at the east end of the lake along the foreshore near the boat launch. Locations of video transects collected in Comox Lake and Willemar Lakes are shown in Figures 3 and 4, respectively.

A total of 13 video transects were recorded between 29 October and 7 November 2018, with a total recording time of 141 minutes. Each video was reviewed and substrate characteristics and areas of suitable substrate, observations of redds, and signs of kokanee were georeferenced and described. Results of the video observations with descriptions are in Appendix III.

Of the 13 video transects recorded, only two areas had obvious redds; Stockand Bay on Comox Lake, and the outlet of Nim Nim Creek on the south shore of Willemar Lake.

These were also the only two areas where kokanee were either captured during the gillnetting sets, or visually observed. There was a small patch of gravel at Pearce Creek that looked like redds, but it could have been gravel disturbed by wave action, creek inflow, or other fish species such as Dolly Varden. No kokanee were observed or caught at the Pearce Creek site. Site 11, which is located on the shoreline north of Stockand Bay also had one small patch of gravel that looked like a redd, but again, no kokanee were observed or captured near this site. The small sizes of these two patches of gravel is relatively insignificant, and the fact that no fish were observed or gillnetted near the disturbed gravel is further evidence that they were not likely to be kokanee redds.

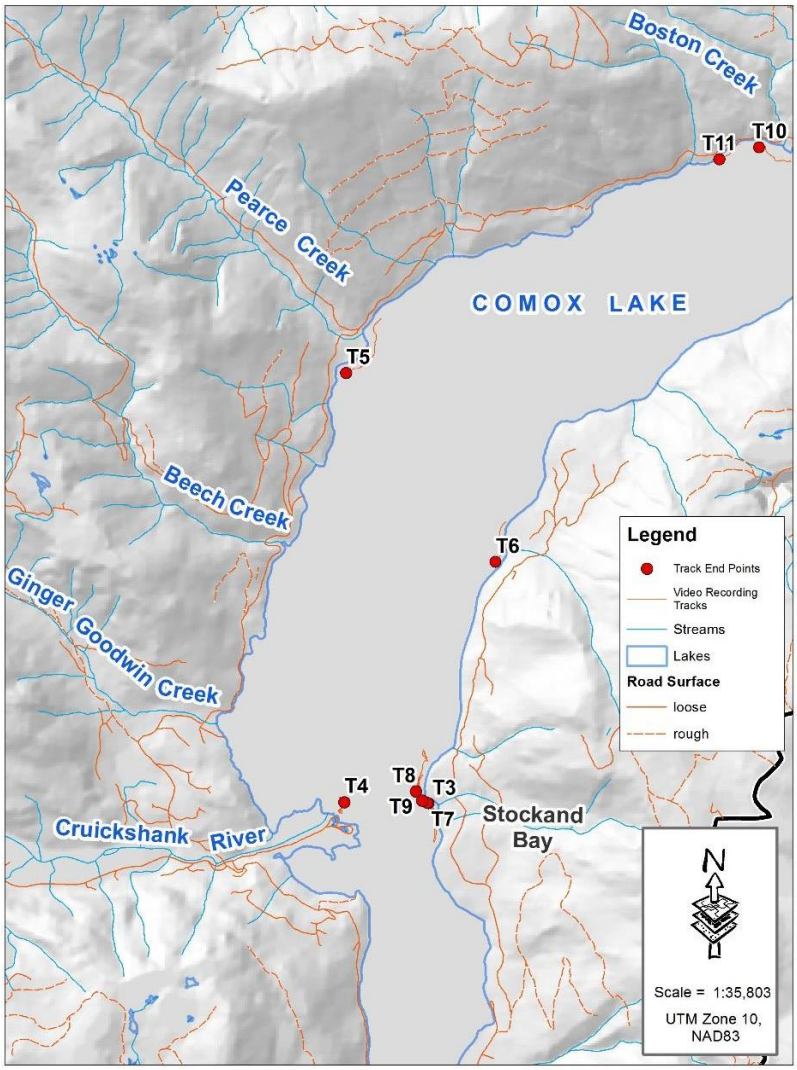


Figure 3. Map showing underwater video tracks in Comox Lake.

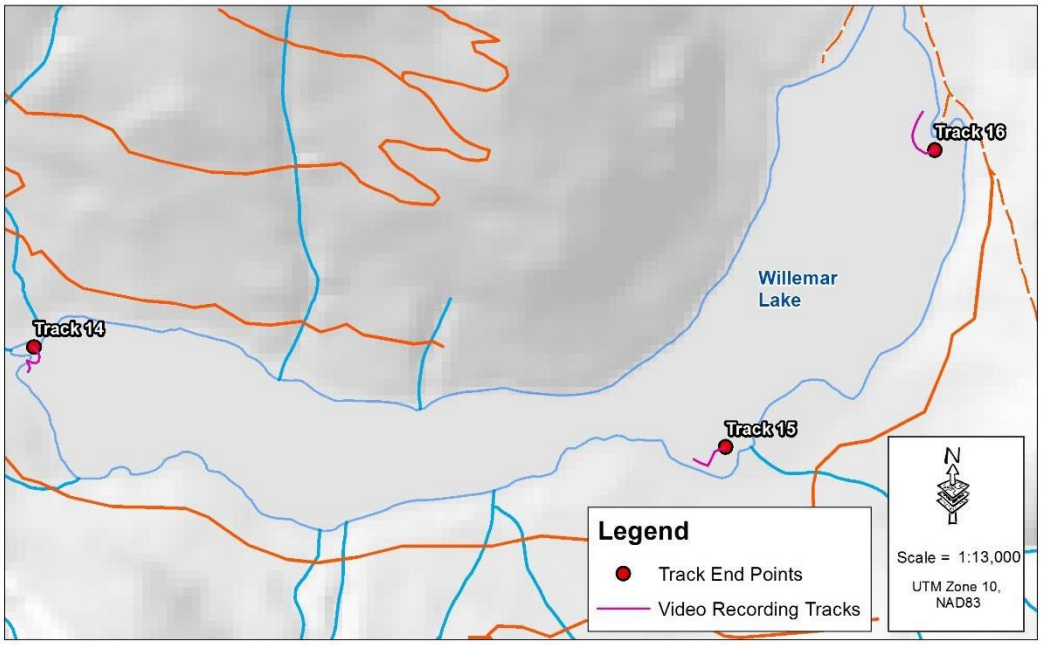


Figure 4. Map showing underwater video tracks in Willemar Lake.

Two SCUBA transects were conducted in Stockand Bay on 7 of November. The transects were perpendicular to shore and approximately 30 m in length to an approximate depth of 20 m. Kokanee and redds were observed along the length of each of the transects, in slopes ranging from approximately 12-20%. The limit of the transects was at the log boom indicated in Figure 5.

5.3 Comox Lake kokanee spawning observations

As in 2016, active spawning of kokanee along the shoreline in Comox Lake was only observed at Stockand Bay (Site 10) during surveys from 29 October to 7 November 2018, and in Willemar Lake on 4 November. No spawning was observed on the first survey (16 October) but cabin owners noted schools of kokanee "porpoising" offshore, a behavior frequently observed when the fish are moving to spawning areas and may be forced to the surface by larger trout.

Site 10, locally known as Stockand Bay, is a small beach on the southeast shore of Comox Lake directly across from the Cruickshank River confluence. It is one of three beach areas in the south end of the lake protected by log booms, with a cluster of cabins and boat docks (Figure 5). The log boom encloses an area 6100 m^2 in size with a shoreline length of 225 m, the majority of which provides suitable spawning habitat. The beach has an average gradient of 12% with a predominantly gravel substrate (Table 4).

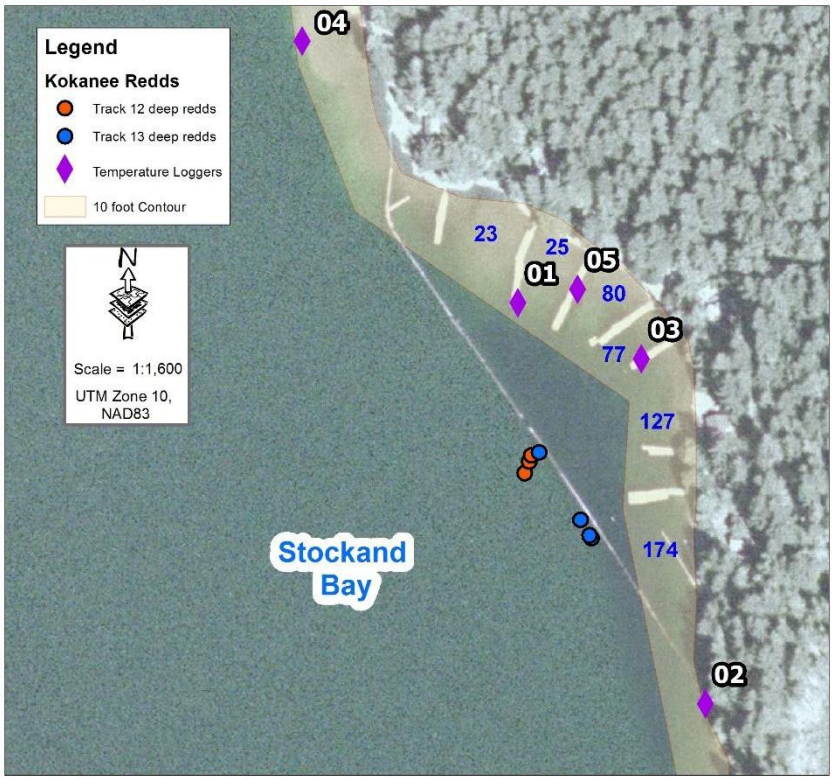


Figure 5. Enlarged view of Stockand Bay showing temperature data logger locations, counts of kokanee spawners in nearshore habitat within the 10 ft bathymetry contour (blue font), and deeper water redds identified during underwater video surveys.

Table 4. Substrate sizes at kokanee spawning habitat in Stockand Bay from visual estimates.

Substrate category	Size Class	Estimate (%)
Fines	≤2 mm	20
Small Gravel	>2 - 16 mm	50
Large Gravel	>16 - 64 mm	25
Small Cobble	>64 - 128 mm	5

5.4 Nearshore Spawner Survey

Over 500 kokanee adults and over 100 redds were estimated from counts on the GoPro video file. In many areas, redd digging was extensive reflecting multiple spawners, and individual redds could not be differentiated. In these situations, a count was estimated based on the average size of an individual redd (approximately 0.5 m diameter). The southern end of the bay had the highest concentration of spawners and redds possibly due to the higher content of small gravel compared to the north end of the beach.

Local cabin owner, Billie Roses, who has resided near Comox Lake for over 50 years, spoke of kokanee spawning in Perseverance Creek at the north end of Comox Lake. On the 8th of November a spawner survey was conducted on Perseverance Creek with crew walking the lower 400 m of the creek. Although there was excellent spawning gravel observed in the stream length assessed, there were no kokanee observed, and no evidence of redds.

Shoreline visual surveys were also conducted on 30 October 2018 at the two other occupied beaches which are also protected by log booms. One of these beaches, locally known as “Little Italy”, or Site 13, is located north of Stockand Bay, and has very similar habitat characteristics, to Stockand Bay. The other is located at the lower end of the lake adjacent gill net sites (GN1 & GN2). Additional shoreline surveys conducted near the Fish and Game beach at the north end of the lake between the boat launch and the clubhouse, and at Beech Creek (tributary between the Cruikshank River and Pearce Creek) did not show any evidence of fish or disturbed gravel.

5.5 Reservoir elevation and temperature during spawning and incubation

Comox Lake reservoir elevation over the kokanee spawning and incubation period (to early March) is illustrated in Figure 6 for the current year’s study (2018/2019) and Year 1 (2016/2017) for comparison. Observed kokanee spawning activity at Site 10 (Stockand Bay) on 29-31 October 2018 corresponded to the minimum reservoir elevation (132.4 m)

recorded during the spawning period defined as 15 October to 15 November. The reservoir elevation over the spawning period varied by 0.8 m (range 132.4 - 133.2 m) in 2018 compared to 2.26 m (range 133.5 - 135.8 m) in 2016.

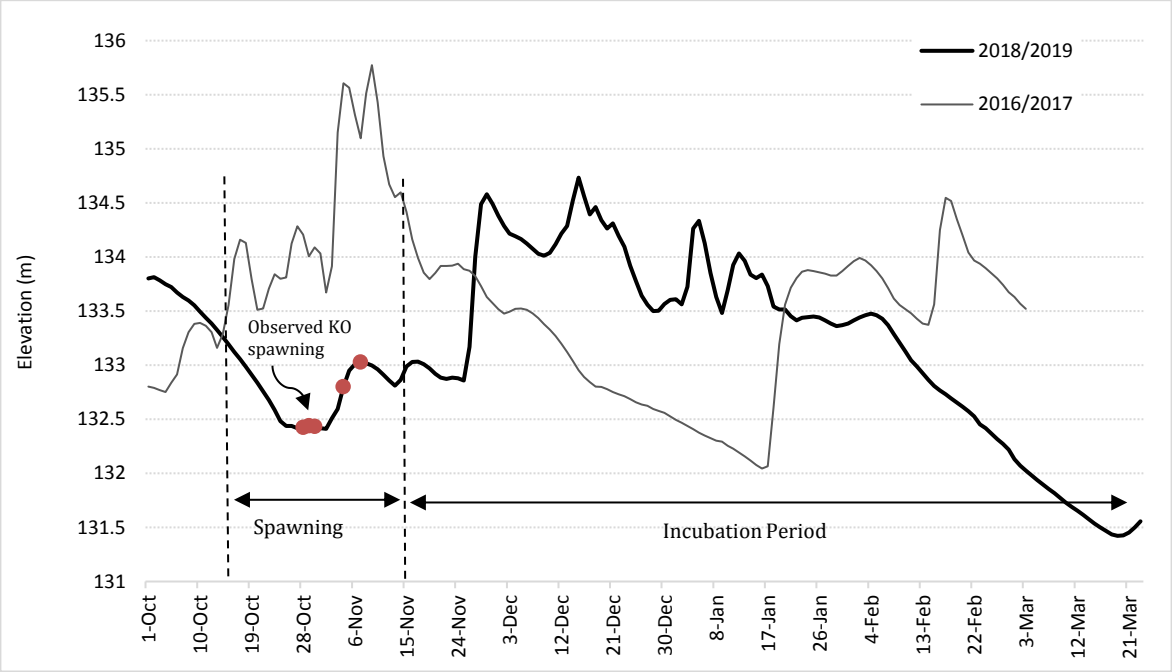


Figure 6. Comox Lake reservoir elevation (WSC Real Time hydrometric data) during the 2018 kokanee spawning and incubation period, and in 2016 for comparison. Observed spawning during surveys denoted by orange symbols.

During the period of observed spawning activity, water depth over the kokanee redds ranged from a minimum of 0.25 m, which corresponds to an elevation of 132.15 m, to 20m as evidenced from underwater video surveys. A significant number of kokanee spawners were located nearshore, within a depth of 0.5 – 1.5 m. On March 19, 2019, the minimum reservoir elevation was recorded at 131.4 m, approximately 1.0 m lower than the level during observed spawning, and below average for this time of year (S. Watson, pers. comm. 3/8/2019). Dewatering of kokanee redds was observed on 2 March 2019, and the current low water levels are estimated to have impacted over 45% of the nearshore kokanee redds in Stockand Bay. The months of January through March 2019 had very

little rainfall which influenced the level to which the reservoir dropped over this time period.

Mean water column temperature (Temp #1) at time of peak spawning was 11.5^{o} C and declined to a low of 4.4^{o} C in February during incubation (Figure 7). Three of the four temperature loggers buried in the gravel within and adjacent Stockand Bay were recovered on 3 of March (the fourth could not be located and may have been stolen). Two of the data loggers (Temp #2 and #3) measured slightly elevated temperatures, by as much as 2.2 degrees above surface temperatures at the site within Stockand Bay where spawning was observed, and at the south end of the bay (Figures 5 & 7).

Hyporheic exchange processes affecting surface - groundwater interactions along the Comox Lake shoreline may account for the differences in temperature recorded by the temperature loggers. We did not investigate these hydrologic processes to any extent however they may affect localized environmental conditions such as groundwater seepage rates that kokanee are targeting.

Using an average of ~950 ATUs for predicting kokanee development from fertilization to emergence (Billard and Jensen 1996, Groot and Margolis 1991, Quinn 2005), Comox Lake shore spawning kokanee emergence timing is estimated around the third week of March. This estimate is calculated from peak spawning (31 October) and based on water column temperature data. Under the warmer intergravel temperature recorded by two of the data loggers, emergence may occur up to 3 weeks earlier. However, an examination of kokanee embryo development in a dewatered redd on 3 March 2019 found alevins with large yolk sacs, suggestive of either a slower rate of development and yolk absorption, and possible later emergence than our prediction, or they may be progeny from later spawners.

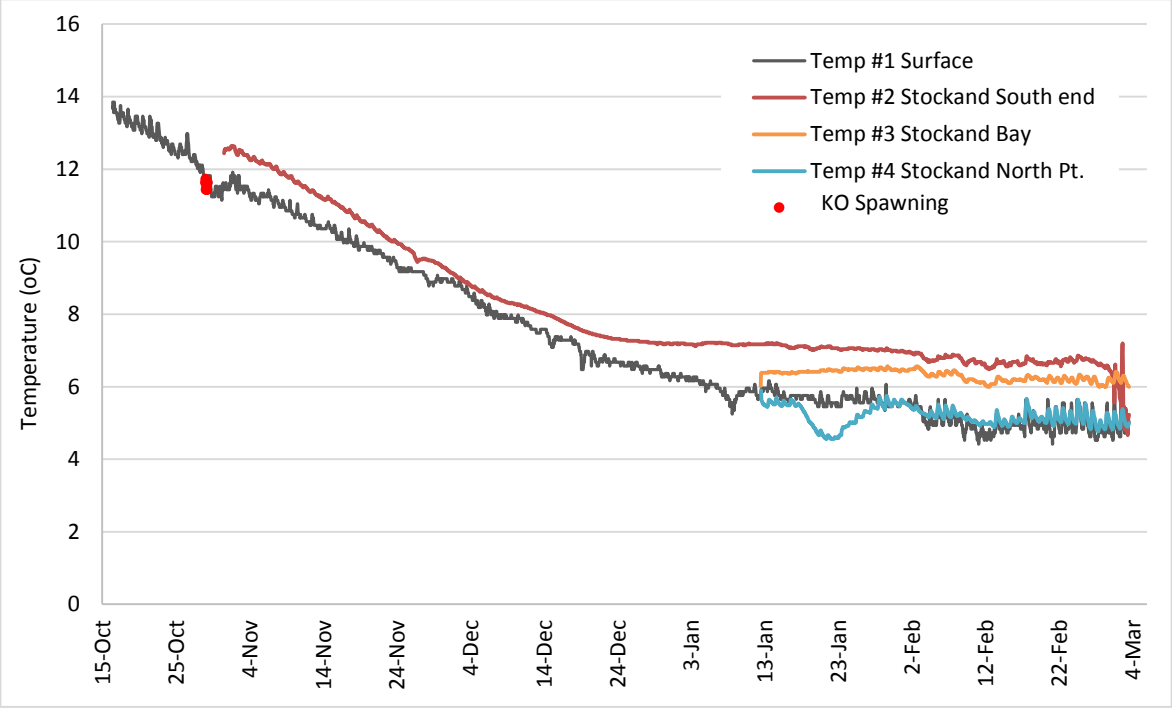


Figure 7. Water column and intergravel temperature recorded at Site 10 (Stockand Bay) over the period of kokanee spawning and incubation (Oct 2018 - Mar 2019).

6 DISCUSSION

The second year of the kokanee spawning assessment in Comox Lake built on the results from the 2016 Year 1 study, incorporating a variety of sampling methods to investigate where kokanee are spawning in the study area as well as to what extent Comox Lake kokanee are spawning in deeper water.

Failure to catch any mature kokanee in gill net sets in Comox Lake, even in survey locations just north of Stockand Bay adjacent to an active spawning area suggests that spawning may be occurring at depths not targeted by the gill nets or that spawning is limited to Stockand Bay. However, gill net surveys did not cover the entire shoreline of Comox Lake, nor all areas previously identified as 'potential' spawning areas in 2016, since much of the shoreline, and many of the sites with suitable substrates and/or slopes

were excluded due to underwater debris and risk of snagging the nets. We deliberately selected sites that contained similar physical attributes (substrate, slope) to Stockand Bay, or were near the mouths of small drainages or creeks. However, kokanee utilizing deeper habitat may be broadcast spawning in larger substrate as observed in other lakes, rather than the types of substrate selected for our gill net surveys (Hassemer and Rieman 1981; Gaboury and Murray 2006; Morris and Caverly 2004). A more extensive systematic survey would have required significantly more field days, not included in the scope of our study.

The SCUBA and video transects however, did confirm that kokanee are spawning not only in the nearshore areas of Stockand Bay, but as deep as 20 m. It is possible that kokanee are spawning in even deeper water, but the depth range that could be examined in this study was limited to 20m due to equipment constraints. Evidence of kokanee deep water spawning is documented in other coastal systems including Anderton and Seton Lakes at depths between 20 m and 70 m depths (Morris and Caverly 2004). Alouette Lake tracking studies have been conducted to gather information about probable spawning locations in that reservoir. Tagged sockeye were spawning at depths between 20–60 m, in substrate ranging from sand to cobble, and in areas with possible groundwater inflow into spawning beds (Plate and Bocking 2013). A more recent study in Alouette Lake identifying spawning habitat using ROV found kokanee redds and kokanee on redds in depths up to 50m (Hebert, 2017). This study also noted after analysis of deepwater ROV quadrates that substrate size is not the only habitat attribute that attracts kokanee and that other parameters should be investigated including temperature, dissolved oxygen and groundwater influence (Hebert, 2017). As in Comox Lake, the Alouette Lake deepwater spawning kokanee seem to concentrate in certain key areas, even though there is similar substrate in other areas of the lake (Shannon Harris, pers. comm. 3/22/19).

The relatively high number of kokanee that were captured by gill netting in Willemar Lake compared to the small areas of redds observed both through visual inspection and in the adjacent video transect may suggest that kokanee are spawning in deeper water in Willemar Lake beyond the depth limit of the underwater camera. The majority (89%) of

kokanee captured in Willemar lake were spawned out females, that may have been spawners spooked from nearby redds during our sampling; we did not see kokanee actively spawning or guarding redds that were visible along the shoreline at the outlet of Nim Nim Creek. On October 10, 2017, FLNRO Biologists captured and sampled over 50 kokanee in a trap net in Willemar Lake. The kokanee ranged in size from 136 mm to 225 mm, and over 50% were mature. Based on these results, the kokanee population in Willemar Lake may be more significant than we initially suspected and warrants further assessment.

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). Further monitoring of temperature and dissolved oxygen concentrations at known reoccurring spawning locations compared to adjacent non-spawning and pelagic areas may give insight into whether sites are being selected based on groundwater sources.

For the nearshore kokanee spawning population in Stockand Bay, it is likely that the eggs they deposited may have suffered a high mortality rate due to reservoir drawdown in 2019. While current reservoir conditions are influenced by the extended period of dry weather that occurred in winter 2018/19, consideration of kokanee habitat requirements should be included in future discussions and water use planning/review on Comox Lake reservoir operations among government, First Nations and community stakeholders and BC Hydro.

Due to the lack of historical data on the kokanee population in Comox Lake, we are unable to provide any insight into the current status or trends in the population. Anecdotal information from local fishers and cabin owners have noted significant declines in the population over the past 10 - 20 years. A longer term study to collect relative abundance estimates over a 3 to 4 year time series would provide a more quantitative assessment of kokanee abundance, potential mechanisms underlying population trends, and may provide further insight into spawning habitat selection. Any enhancement of the Comox Lake

kokanee population at this stage is pre-mature as current status of the existing population as well as their life history requirements is still in preliminary stages.

Comox Lake is one of 11 lakes on Vancouver Island where cutthroat trout co-exists with kokanee and/or sockeye populations (Anderson and Atkinson 2018). Comox Lake kokanee, along with threespine stickleback (*Gasterosteus aculeatus*) are important forage species of cutthroat trout, allowing them to grow to large sizes. However, our understanding on the significance of kokanee in the diet of cutthroat trout or the effects of predation on kokanee from piscivores is not well understood. The stomach contents of one 430 mm cutthroat trout captured in Comox Lake in March 2017 contained 10 kokanee (Anderson and Atkinson 2018), providing some evidence of piscivory of large cutthroat on kokanee. Further monitoring of the kokanee and cutthroat trout population dynamics in Comox Lake would enhance our understanding of the relationship between these populations and their vulnerability to annual fluctuations in abundance.

7 RECOMMENDATIONS

- Further fall spawning assessments are recommended with a focus on Willemar and Forbush Lakes as well as the upper Puntledge in order to assess the significance of the areas upstream of Comox Lake as spawning and/or rearing habitat for kokanee. Commencement of these assessments should occur by mid-October to capture the full spawn timing, in the event the timing of spawning is earlier in these systems.
- Future studies could investigate in more detail what characteristics of Stockand Bay are attracting kokanee to spawn there in such comparatively high concentrations. More rigorous monitoring of temperature, dissolved oxygen, and groundwater seepage rates could help provide a better understanding about the habitat factors influencing kokanee spawning selection.
- Documentation of the maximum depth of spawning kokanee was limited by length of video cable (30 m), and maximum diver depth (approximately 20m). Kokanee may

be spawning in deeper water than documented in this study. It is recommended that a remotely operated underwater video (ROV) camera with longer cables and lights should be used to investigate deeper water in Stockand Bay, and other potential sites that were excluded from gill net surveys.

- Replace RISC experimental gill nets with nets of a uniform mesh size (38 - 51 mm) that will specifically target KO spawners (178 - 228 mm) to minimize by-catch and expand the sampling area and effort.
- Conduct a long term (3-4 years) hydroacoustic and midwater trawl survey (ATS) to more accurately assess the status and trends in the population of kokanee in Comox Lake and compare abundance estimates to previous ATS studies in 2009 and 2014.
- Further monitoring of the kokanee and cutthroat trout population dynamics in Comox Lake to enhance our understanding of the relationship between these populations and their vulnerability to annual fluctuations in abundance.

8 ACKNOWLEDGEMENTS

We are grateful for the financial support for this study from 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. We would like to thank the Courtenay and District Fish and Game Association for supporting this project and reviewing this report. We also thank Brendan Anderson and Scott Sylvestri (FLNRO Lake Biologists) for their ongoing support, valuable advice, and use of two RISC experimental gill nets; and Jamieson Atkinson (BCCF) for assistance with gill net sampling on Comox Lake. We also appreciate the efforts from Nick Leone (DFO RRD) for arranging video equipment in-kind to test suitability for our needs, D. Miller for safely transporting us in the field, and the K'omoks First Nation members for their support and assistance in data collection. Finally, we acknowledge Timberwest for cooperating when access to the forestry roads around Comox Lake was required, and to the cabin

owners at Stockand Bay and others that spend time on Comox Lake for providing up to date information on the 2018 spawning season.

9 REFERENCES

Anderson, B. and J Atkinson. 2018. An evaluation of exploitation rate on cutthroat trout in Comox Lake. West Coast Region Fisheries. [online] URL: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=54960

Bengeyfield, W. and W. A. McLaren. 1994. Puntledge River gravel placement feasibility study. Global Fisheries Consultants Ltd. White Rock, B.C. and McLaren Hydrotechnical Engineering, Coquitlam, B.C. for: Environmental Resources, B.C. Hydro, Burnaby.

Billard, R., and Jensen, J.O.T. 1996. Gamete removal, fertilization and incubation. Pages 291-363 In: W. Pennell and B.A. Barton, Editors. Developments in Aquaculture and Fisheries Science V. 29: Principles of Salmonid Culture. Elsevier, Amsterdam.

BC Hydro. 2003. Consultative committee report: Puntledge River water use plan. Prepared by the Puntledge River water use plan consultative committee.

FWCP. 2011. Fish and Wildlife Compensation Program – Puntledge River Watershed Salmonid Action Plan. Final Draft. [online] URL: http://fwcp.ca/app/uploads/2015/07/puntledge_salmonid_plan.pdf

Groot C. and Margolis L. 1991. Pacific salmon life histories. Vancouver, Canada: UBC Press.

Guimond, E., C. Heim. 2017. Assessment of kokanee spawning in Comox Lake. Prepared for the Fish and Wildlife Compensation Program, Burnaby, BC.

Guimond, E., R. Ferguson, K. Hyatt, G. Graf, M. Lough, and M. Sheng. 2014. Assessment of Comox Lake carrying capacity and coho-cutthroat interactions in the Cruickshank and Upper Puntledge River systems. Project No. 13.Pun.05. Prepared for the Fish and Wildlife Compensation Program, Burnaby, BC.

Hassemer P.F. and B.E. Rieman. 1981. Observations of deep-spawning kokanee on artificially created spawning habitat. North American Journal of Fisheries Management. 1: 173- 176.

Hebert, Allison. 2017. Alouette Watershed Sockeye-Fish Passage Feasibility Project Year 1- Task 2- Alouette Reservoir Oncorhynchus nerka spawning behaviour and habitat study. Prepared for the Fish and Wildlife Compensation Program. Prepared by: Pacific Salmon Ecology and Conservation Laboratory, UBC.

Johner, D. and D. Sebastian. 2011. Comox Lake hydroacoustic and trawl survey July 2009. Ministry of Forests, Lands and Natural Resource Operations, Fish, Wildlife and Habitat Management Branch. Stock Management Report No. 33.

Morris A.R. and A. Caverly. 2004. 2003-2004 Seton and Anderson lakes kokanee assessment. Prepared for: BC Conservation Foundation, Kamloops, BC, and Ministry of Water, Land and Air Protection, Kamloops, B.C.

Plate, E.M. and R.C. Bocking. 2013. Alouette Lake Sockeye tracking study, 2011–2012. Prepared for BC Hydro Bridge Coastal Restoration Program, Burnaby, B.C., by LGL Limited, Sidney, B.C.

Quinn, T.P. 2005. The behavior and ecology of Pacific salmon and trout. Vancouver Canada: UBC press.

RISC 1997. Resources Inventory Standards Committee. Fish collection methods and standards, Version 4.0. Prepared by the B.C. Ministry of Environment, Lands and Parks, Fish Inventory Unit for the Aquatic Ecosystems Task Force, Resources Inventory Committee.

Personal Communication

Shannon Harris	MoE Limnologist, phone conversation; 22-Mar-2019.
Billie Roses	Comox Lake cabin owner.
Stephen Watson	Stakeholder Engagement Advisor, BC Hydro; email 8-Mar-2019.

Appendix I. Photos

Photo 1. Image from video footage of kokanee spawning in Stockand Bay. Note extensive redd clearing in foreground and numerous kokanee adults visible to the edge of the 10 ft contour where the lakeshore becomes steeper.

Photo 2. Kokanee captures in one gill net set in Willemar Lake, 4 November 2018.

Photo 3. Kokanee and redds observed in approximately 20m of water at Stockand Bay, 7 of November. Kokanee indicated by yellow arrows.

Photo 4. Adult kokanee captured by gillnetting in Willemar Lake that were 89% spawned out females.

Photo 5. Video camera monitor for real time viewing of underwater transects.

Photo 6. Reservoir level on March 2, 2019. Line indicates approximate water level during 2018 kokanee spawning period.

Appendix II. Fish captures from gill net sampling in Comox and Willemar lakes, 2018.

Site #	Date	Latitude (deg)	Longitude (deg)	Location	Species	FL	Wt (g)	Sex	Comments/ Actions
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	DV	350		F	mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	DV	360		M	released
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	DV	370	642.0	F	mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	DV	310	311.8	F	mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	CT	320			released
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	CT	160			released
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	CT	260	184.9		mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	KO	120			mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	KO	122			mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	KO	119			mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	KO	120			mort
GN0	10/16/2018	49.5833	-125.1793	Point N Stockand Bay	KO	-		-	18 KO released not measured
GN1	10/29/2018	49.5646	-125.1710	South end Site 8	DV	460		F	mature; released
GN1	10/29/2018	49.5646	-125.1710	South end Site 8	DV	330		F	mature; released
GN1	10/29/2018	49.5646	-125.1710	South end Site 8	DV	270		UNK	released
GN1	10/29/2018	49.5646	-125.1710	South end Site 8	DV	220		UNK	cull
GN1	10/29/2018	49.5646	-125.1710	South end Site 8	DV	260		UNK	cull
GN1	10/29/2018	49.5646	-125.1710	South end Site 8	CT	290		UNK	cull
GN1	10/29/2018	49.5646	-125.1710	South end Site 8	CT	375		UNK	cull
GN2	10/29/2018	49.5615	-125.1739	South end Site 7 @ ck outlet	DV	390		F	cull
GN2	10/29/2018	49.5615	-125.1739	South end Site 7 @ ck outlet	CT	435		M	cull
GN2	10/29/2018	49.5615	-125.1739	South end Site 7 @ ck outlet	DV	365		M	cull
GN3	10/29/2018	49.6169	-125.1880	Pearce Ck S (Site 3)	DV	390		M	cull
GN3	10/29/2018	49.6169	-125.1880	Pearce Ck S (Site 3)	CT	222		UNK	cull
GN3	10/29/2018	49.6169	-125.1880	Pearce Ck S (Site 3)	CT	285		UNK	cull
GN4	10/29/2018	49.6200	-125.1860	Pearce Ck N (Site 3)	CT	184		UNK	cull
GN4	10/29/2018	49.6200	-125.1860	Pearce Ck N (Site 3)	CT	213		UNK	cull
GN4	10/29/2018	49.6200	-125.1860	Pearce Ck N (Site 3)	CT	186		UNK	cull
GN5	10/30/2018	49.5835	-125.1890	Cruickshank west	CT	274		UNK	cull
GN5	10/30/2018	49.5835	-125.1890	Cruickshank west	DV	300		F	cull
GN6	10/30/2018	49.5783	-125.1840	Mosquito Bay	CT/RB	277		HYB	cull
GN6	10/30/2018	49.5783	-125.1840	Mosquito Bay	CT	274		M	cull
GN6	10/30/2018	49.5783	-125.1840	Mosquito Bay	CT	325		M	cull
GN6	10/30/2018	49.5783	-125.1840	Mosquito Bay	CT	330		M	cull
GN7	10/30/2018	49.6013	-125.1940	Beach Ck	DV	351		UNK	released
GN7	10/30/2018	49.6013	-125.1940	Beach Ck	DV	365		F?	released
GN7	10/30/2018	49.6013	-125.1940	Beach Ck	CT	283		UNK	cull
GN7	10/30/2018	49.6013	-125.1940	Beach Ck	CT	320		UNK	cull
GN8	10/30/2018	49.6098	-125.1650	Little Italy N	CT	315		F?	cull
GN8	10/30/2018	49.6098	-125.1650	Little Italy N	CT	360		M	cull
GN8	10/30/2018	49.6098	-125.1650	Little Italy N	CT	363		UNK	cull

Appendix II. Cont'd

Site #	Date	Latitude (deg)	Longitude (deg)	Location	Species	FL	Wt (g)	Sex	Comments/Actions
GN9	10/31/2018	49.5830	-125.1987	Cruickshank N	CT	208		UNK	cull
GN9	10/31/2018	49.5830	-125.1987	Cruickshank N	CT	208		UNK	cull
GN9	10/31/2018	49.5830	-125.1987	Cruickshank N	CT	216		UNK	cull
GN9	10/31/2018	49.5830	-125.1987	Cruickshank N	CT	320		UNK	cull
GN9	10/31/2018	49.5830	-125.1987	Cruickshank N	CT	435		M	cull
GN10	10/31/2018	49.5887	-125.2021	Ginger Goodwin Ck	CT	300		UNK	cull
GN10	10/31/2018	49.5887	-125.2021	Ginger Goodwin Ck	CT	372		UNK	cull
GN10	10/31/2018	49.5887	-125.2021	Ginger Goodwin Ck	CT	354		UNK	cull
GN11	10/31/2018	49.5859	-125.1778	Point N Stockand	CT	385		F	cull
GN11	10/31/2018	49.5859	-125.1778	Point N Stockand	DV	373		UNK	released
GN11	10/31/2018	49.5859	-125.1778	Point N Stockand	DV	240		UNK	cull
GN12	10/31/2018	49.6058	-125.1684	Little Italy S	CT	260		UNK	cull
GN12	10/31/2018	49.6058	-125.1684	Little Italy S	CT	190		UNK	cull
GN12	10/31/2018	49.6058	-125.1684	Little Italy S	CT	190		UNK	cull
GN12	10/31/2018	49.6058	-125.1684	Little Italy S	CT	325		UNK	cull
GN13	10/31/2018	49.6355	-125.1382	Boston Bar S	CT	455		F	cull
GN13	10/31/2018	49.6355	-125.1382	Boston Bar S	CT	187		UNK	cull
GN13	10/31/2018	49.6355	-125.1382	Boston Bar S	CT	330		UNK	cull
GN13	10/31/2018	49.6355	-125.1382	Boston Bar S	CT	321		UNK	cull
GN14	10/31/2018	49.6349	-125.1370	Boston Bar N	DV	415		F	released
GN14	10/31/2018	49.6349	-125.1370	Boston Bar N	DV	305		UNK	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	-		F	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	-		F	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	200		F	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	205		F	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	200		F	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	202		F	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	DV	305		F	released
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	198	71.5	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	198	68.8	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	184	52.3	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	205	68.9	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	203	81.8	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	196	72.3	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	188	63.9	M	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	202	68.3	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	178	46.6	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	203	77.8	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	195	64.4	F	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	KO	220	96.1	M	cull
GN15	11/4/2018	49.5088	-125.1846	Willemar @ NimNim Ck outlet	CT	210	82.8	UNK	cull

Appendix III. Underwater video transects with descriptions and GPS coordinates.

Trk #	Location	Date	Time (min)	Depth Range (m)	Video Time (minutes)	Lat	Long	Comments
3	Stockand Bay	29-Oct	15:20	3.5 - 9	5:39	49.58234	125.17717	KO/redds
					6:04	49.58229	125.17711	redds
					6:11	49.58226	125.17707	redds
					7:53	49.5819	125.17665	KO/redds
					9:04	49.58174	125.17651	redds
					9:29	49.58191	125.17662	KO/redds
					9:42	49.58202	125.1767	redds
					10:03	49.58222	125.17683	KO/redds
					12:45	49.58201	125.17671	redds
					13:48	49.58194	125.17667	redds
					14:52	49.58239	125.17716	redds
					15:01	49.58244	125.17726	redds
					15:20	49.58255	125.17749	redds
4	Cruikshank River mouth	29-Oct	12:30	3 - 10.7		49.58163	125.188105	silt/wood debris
						49.58167	125.1882	coarse gravel/cobble
						49.58178	125.18831	silt and less coarse gravel
						49.58223	125.18800	leaf litter
						49.58270	125.18801	good gravel in river- no redds
						49.58278	125.18803	leaf litter
						49.58281	125.18824	silt/gravel
						49.58278	125.18820	leaf litter
5	Pearce Creek	29-Oct	12:13	3 - 9.8		49.61789	125.18615	coarse gravel
						49.61766	125.18635	silt/wood debris
						49.61764	125.18664	good gravel patch
7	Stockand Bay	30-Oct	17:38	3 - 10.5	0:58	49.58232	125.17742	redds
					3:09	49.58175	125.17669	redds
					3:43	49.58148	125.1765	redds
					3:52*	49.58141	125.17646	KO/redds
					4:25	49.58114	125.17646	KO/redds
					4:26	49.58113	125.17645	KO/redds
					4:50	49.58091	125.17646	redds
					5:29	49.58065	125.1765	redds
					6:18	49.58799	125.17651	redds
					8:19	49.51988	125.17665	redds
					8:52	49.58023	125.17858	redds
					9:26	49.58063	125.17666	redds
					9:46	49.58081	125.17671	redds
					11:08	49.58173	125.17662	redds
					11:50	49.58203	125.1769	redds
					12:58	49.58254	125.1776	redds
					17:30	49.58231	125.17728	camera snagged from 12:58
6	Site 12 - Beach S of Little Italy	31-Oct	13:09		0:22	49.60567	125.16911	start- silty/no gravel
					5:41	Not available	Not available	some gravel
					6:21	Not available	Not available	some gravel
					9:20	Not available	Not available	gravel
			Silty bottom throughout transect, areas with some gravel noted above. Coordinates at start only					
8	Site 11 - Beach N of Stockand Bay	31-Oct	13:19		0:37	49.58364	125.17901	siver fish mid column
					1:57	49.5835	125.17851	
					2:56	49.58393	125.17855	gravel - possible redd
9	Point north of Stockand Bay	31-Oct	10:04		7:00	49.58343	125.17867	good gravel
					9:41	49.58284	125.17824	end
10	Boston Bar	31-Oct	11:32		0:00	49.6336	125.13372	silt/aquatic plants
					0:57	49.63535	125.1339	gravel/cobble
					4:45	49.63453	125.13689	poor visibility
					5:50	49.63476	125.13761	wood debris
					8:18	49.63534	125.13862	possible redd
					11:23	49.63566	125.13922	end

Appendix III. Cont'd

Trk #	Location	Date	Total Time (min)	Depth Range (m)	Video Time (minutes)	Lat	Long	Comments
11	South of Boston Bar					49.63578	125.14201	start
						49.63442	125.14435	end
12	Stockand Bay	7-Nov	7:58	6 - 17	2:25	Not available	Not available	
					3:39	Not available	Not available	KO/redds
					6:58	Not available	Not available	KO/redds
					7:00	Not available	Not available	KO/redds
					7:21	49.58201	125.17712	KO/redds
					7:58	49.58205	125.1771	KO/redds
						49.58207	125.17709	KO/redds
13	Stockand Bay	7-Nov	7:30	5 - 15	0:10	49.58208	125.17705	KO/redds
					3:46	49.58186	125.17683	KO/redds
					4:25	49.58181	125.17678	KO/redds
					*4:32	49.5818	125.17677	redds from 4:32 to 5:20
					7:30	49.58158	125.17653	end
14	Upper Puntledge inflow into Willemar Lake	3-Nov	5:27	2 - 4.5	5:27	Not available	Not available	coarse gravel cobble
15	Nim Nim Creek inflow into Willemar Lake	3-Nov	6:43	3 - 8	0:06	49.50894	125.18487	freshwater mussels
					5:42	49.50855	125.18424	possible redds on slope
					6:34	49.50853	125.18434	end
16	Willemar Lake at east end beach	3-Nov	8:02		3:18			thick leaf litter
					8:02			end

Appendix IV. Outreach and Confirmation of FWCP Recognition

1. Three panels that were on display at Puntledge Hatchery Open House, Oct. 21, 2018

Kokanee Study at Comox Lake

Local biologists in partnership with the Courtenay and District Fish and Game Protective Association are conducting Year 2 of a Kokanee spawning study in Comox Lake in 2018. If you have ever observed or captured kokanee in Comox Lake, we would love to hear your story.
Contact: Esther at guimonde@telus.net or
Caroline at clheim10@gmail.com

Mature female kokanee from Comox Lake

Did you know?
Kokanee 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".

We are grateful to FWCP for funding this study

FWCP Fish & Wildlife COMPENSATION PROGRAM

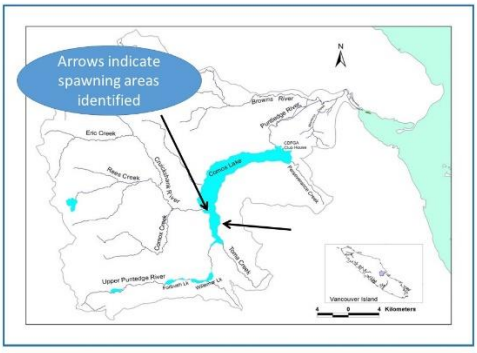
The kokanee study will use:

- Shore and boat surveys to identify shore spawning
- Gill netting to assess migration patterns and deep water spawning locations
- Underwater remotely operated video cameras to document spawning sites
- SCUBA divers or snorkel surveys to locate and map underwater nests ("redds")

Kokanee near redd, 2016

Kokanee spawn in late October, and have been observed spawning in shallow water. In many other lakes in B.C., Kokanee spawn in deep water.

One of the objectives of the study is to identify where Comox Lake kokanee prefer to spawn. They may be attracted to upwelling groundwater sources.

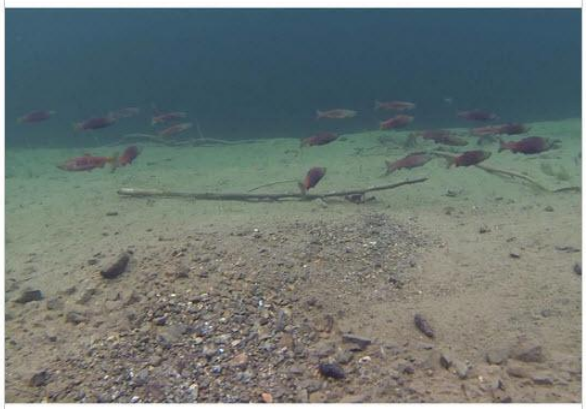


Did you know? Kokanee are an important food item for Cutthroat Trout and Dolly Varden. They are an important part of the food chain, yet we know little about the population in the lake. Kokanee are zooplankton eaters, and are much smaller than other salmonids.

2. Press Release Comox Valley Record Newspaper, Jan. 12, 2019.

NEWS CALENDAR VIDEO CLASSIFIEDS OBITUARIES E-EDITIONS JOBS CONTACT MARKETPLACE CONTESTS

COMOX VALLEY RECORD 5°



Kokanee salmon spawning study continues in Comox Lake

Jan. 12, 2019 4:30 p.m. / COMMUNITY

Local fisheries biologists are in the second year of a study investigating the kokanee salmon population in Comox Lake. Kokanee Salmon form an important part of the Comox Lake ecosystem, providing food for cutthroat trout and dolly varden. Kokanee are zooplankton feeders, and are approximately 20-25 centimetres when mature. They are sometimes called "landlocked sockeye" as they spend their entire lives in fresh water.

In the first year of the study in 2016, biologists Esther Guimond and Caroline Heim identified key spawning habitat areas, based on suitable gravel sizes and habitat characteristics such as inputs from smaller streams and rivers. Specific spawning sites were monitored through the incubation period, and key spawning areas around Comox Lake and smaller upstream lakes were identified. Local knowledge was invaluable in the first year of the study, as many resident cabin owners on Comox Lake have watched and fished the lake for decades.

In the fall of 2018, the study ramped up with intensified sampling using a combination of gill net setting, remotely-operated towed video cameras, and scuba divers to verify camera footage. Preliminary results show that kokanee not only spawn in nearshore beach areas, but also at depths up to 17 metres (56 feet). While kokanee and sockeye are known to spawn in deep water in mainland lakes, Guimond and Heim were pleased to find the same may be true in Comox Lake.

"Eggs incubating in shallow locations are more vulnerable to changes in water levels," said Heim. "Verifying that kokanee are using deeper water gravels to spawn in is exciting information."

The biologists are currently assessing why a particular region of the lake at the south end is so attractive to the kokanee spawners. An estimated 500 kokanee were observed spawning in one specific beach area. Upwelling of groundwater may be one factor, and inter-gravel temperature monitoring is taking place over the winter months.

Guimond and Heim have partnered with the Courtenay and District Fish and Game Club for the study, and are grateful for the support from the Fish &Wildlife Compensation Program (FWCP). 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 in watersheds impacted by BC Hydro dams.