2003-2004 Seton and Anderson Lakes Kokanee Assessment

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March 2004

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EXECUTIVE SUMMARY

The *2003-2004 Seton and Anderson Lakes Kokanee Assessment* study was designed to collect baseline and time series data for kokanee spawners that, over the longer term, would provide insight into biology, habitat selection, year class variability, relative abundance and limiting factors. The primary objectives of the *Seton and Anderson Lakes Kokanee Assessment* as a multi-year project were to:

1. *Assess and document key kokanee spawning sites in Seton and Anderson Lakes.*
2. *Develop a systematic, standard procedure for enumerating kokanee with the intent of establishing key sites for index of abundance estimates.*
3. *Determine kokanee population estimates for both lakes.*
4. *Develop a kokanee conservation plan for both lakes.*

A secondary objective was to obtain basic biological information about the two lake stocks. This report represents Year 1 of the planned multi-year project, and as such, was intentionally exploratory to test sampling techniques and identify potential index methods and sites. The focus of this years work was primarily on Objectives 1 and 2, collecting biological data and setting the ground work for achieving objectives 3 and 4 in subsequent years.

The project provided considerably more insight into the kokanee spawner populations in each lake, however the practice of confirming deep water spawning was challenging. The successful identification of two spawning sites in both Seton and Anderson Lake was the result of a combination of several variations of standard fish assessment methodologies. The use of hydro-acoustics and underwater camera surveys (ROV) in combination with gillnetting validation proved very effective. A combination of hydro-acoustics and gillnetting was most effective for detecting and validating kokanee spawning groups, and the ROV was most effective for describing habitat.

In Seton Lake, two confirmed spawning areas (SE-26 and SE-32) were identified. Gillnet captures at these two sites indicated higher concentrations of mature or spawned out kokanee. The mean fork length for male and female kokanee spawners captured in Anderson Lake in 2004 (gillnetted kokanee and floaters) was 253.95 mm (*n=37, SD=26.39*) and 234.24 mm (*n=21, SD=29.35*), respectively. Otolith analysis indicates that the age-at-maturity for kokanee spawners in Seton Lake is predominately 2+, with a small proportion of fish age 3+.

In Anderson Lake, two confirmed spawning areas (AN-11 and AN-12) were identified. Gillnet sets at AN-11 captured mature kokanee. No kokanee were captured at AN-12, the 2nd suspected spawning site, but both the video and the ROV survey revealed what appeared to be numerous, recently completed small diameter redds starting at a depth of approximately 25 m. Field crews also observed numerous floaters at the site. The mean fork length for male and female kokanee spawners captured in Anderson Lake in 2004 (gillnetted kokanee and floaters) was 253.95 mm (*n=37, SD=26.39*) and 234.24 mm (*n=21, SD=29.35*), respectively. Otolith analysis indicates that the age-at-maturity for kokanee spawners in Anderson Lake in 2004 is predominately age 4+, with a smaller proportion of fish age 3+ and 2 female kokanee aged at 5+.

Morphologically, the Seton and Anderson Lake kokanee appear the same, with the exception of size. Anderson Lake spawners are generally larger. The fish in these two lakes are very different in size and color compared to most stream spawning kokanee with a dark olive-green to almost black coloration.

Spawner surveys in 2003-2004 confirmed that kokanee spawning within the study area lakes are predominately associated with deep water habitat between 20 and 70m. No beach spawning was observed in either Seton or Anderson Lake in 2003-2004. In the absence of site-specific deep-water measurements, temperature at deep water spawning sites is anticipated to be about 4^{o}C. These kokanee are estimated to require 950 ATU's (°C) from fertilization to free swimming fry. Assuming a constant temperature of 4^{o}C for the incubation period it would require 237 days from

egg deposition to fry emergence (mid June to late July). This estimate of emergence timing could be biased late due to the lack of data pertaining to spring water temperature warming, groundwater or geothermal processes. This late fry emergence would place Seton and Anderson Lakes kokanee at a severe feeding disadvantage with sockeye fry that likely emerge much sooner. The eggs possibly receive additional heat units from groundwater or geothermal sources. The spawners may be seeking out deep water sites associated with groundwater upwelling or geothermal plumes that are sufficiently warm and oxygenated. A second possibility is that these kokanee eggs require far fewer heat units through adaptation to local conditions.

We recommend that more focused work be continued in subsequent years to gain additional insight into biology, spawning habitat selection, size class variation, year class variability, spawn timing and distribution of kokanee spawners within each lake. Additional emphasis needs to be placed on evaluating temperature characteristics around spawning sites for groundwater or geothermal processes.

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INTRODUCTION AND BACKGROUD

In 2003, funds were provided by the Bridge Coastal Fish and Wildlife Restoration Program (BCRP) to the British Columbia Conservation Foundation (BCCF) to conduct an assessment of kokanee (*Oncorhynchus nerka*) spawner populations within Seton and Anderson Lakes. In-kind support equipment and personnel were provided by the Ministry of Water, Land and Air Protection (MWLAP), the federal Department of Fisheries and Oceans (DFO) and the Canadian Coast Guard. Interim funding was provided MWLAP. A monetary contribution was made to BCCF by BC Rail to supplement kokanee spawner surveys at specific sites along the rail line on the north shore of Seton Lake, in relation to a proposed BC Rail maintenance project. This 2003 assessment project builds on an initial First Nations, local knowledge and literature survey conducted in 2000 by BCCF and the MWLAP on bull trout (*Salvelinus confluentus*) and kokanee populations within Seton and Anderson Lakes (Morris et al. 2003a). Following the literature survey, a kokanee feasibility study was conducted by BCCF and MWLAP in 2002/2003 (Morris et al. 2003b). This report represents Year 1 of a more comprehensive investigation into kokanee populations within Seton and Anderson Lakes.

Previous work conducted by BCCF and MWLAP in the Seton and Anderson Lakes watershed (Morris et al. 2003) indicates that First Nations, WLAP and BC Hydro have placed a high priority on understanding the status of wild kokanee stocks within the study area. Kokanee were identified by First Nations as a species of concern in the Bridge-Seton Water Use Plan process. There is still very little information on kokanee life history, habitat requirements and population size in either lake. What is known is that the kokanee are culturally significant to First Nations who call them “Gwenis” (First Nation term - pronounced waneesh) and they have been an important supplementary component of their diet. Geen and Andrews (1961) first recorded that First Nations had reported large numbers of kokanee in both lakes. First Nations are now concerned that kokanee populations within both lakes are severely depressed in comparison to their historical abundance. The kokanee populations within Seton and Anderson Lakes have an uncommon olive-green to black spawning coloration, a deep body profile and display unusual spawning site selection in deep water habitats (> 50m). Similar documentation of this life history trait could not be found in journal literature or internet searches.

What is also known about kokanee in these lakes is that very few stream spawners exist (Morris et al. 2003). The few reported have been red in appearance. Further, no shallow water shore spawners had been reported or observed (Morris et al. 2003) leading to the conclusion that deep water spawning must be a primary means of reproduction for the kokanee populations in both lakes. There are few documented cases of deep water spawning by kokanee. Wilson (2000) describes kokanee spawning in Alouette Reservoir at depths as great as 20 m and a few kokanee in the West Arm of Kootenay Lake are known to spawn at depths of 5-10 m but this system is more a river than lake (Andrusak 2004, pers. comm.).

Objectives

The *Seton and Anderson Lakes Kokanee Assessment* study was designed as a multi-year project (4-5 years). The project intent is to collect baseline and time series data for kokanee spawners that, over the longer term, would provide insight into biology, habitat selection, year class variability, relative abundance and limiting factors. The primary objectives of the *Seton and Anderson Lakes Kokanee Assessment* as a multi-year project were to:

1. *Assess and document key kokanee spawning sites in Seton and Anderson Lakes.*
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STUDY AREA

The Seton and Anderson Lakes watershed encompasses an area of approximately 1039 km^2 within the WLAP Southern Interior Region and within the Cascades Forest District of the Southern Interior Forest Region and the Squamish Forest District of the Coastal Forest Region. The Seton River (WSC 100-1235900-000 UTM 10.576204.5613960) is a fifth order tributary to the Fraser River with its confluence with the Fraser located in the village of Lillooet, B.C. The watershed contains two large water bodies, Anderson Lake and Seton Lake Reservoir. Seton Lake Reservoir is within semi-arid climate zone while Anderson Lake is transitional to a coastal climate. The project study area encompasses only that area of the Seton and Anderson Lakes watershed located upstream of Seton Dam (Figure 1). Both lakes lie within the traditional territory of the Stl'atl'mix First Nation.

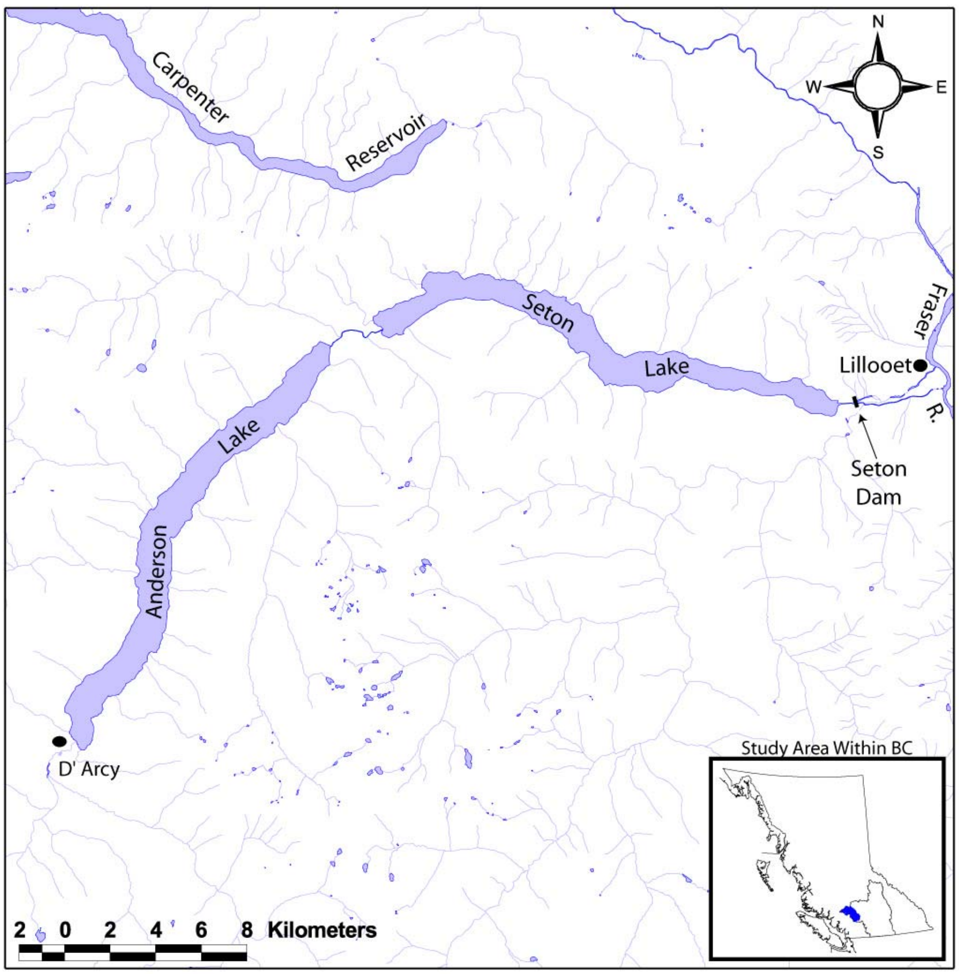

Figure 1. Study area of the 2003-2004 Seton and Anderson Lakes Kokanee Assessment.

The Seton and Anderson Lakes watershed falls within BC Hydro's Bridge River/Coastal Generation Area, where BC Hydro operates two hydro-electric facilities: the Seton River power dam and the Shalath power generation facility. Without understanding biology and life history requirements, it is unclear what effect hydro facilities including diversion of Bridge River water have had on kokanee populations in the watershed. BC Rail tracks run the length of both lakes on the north side and some areas have extensive rock fill. MWLAP and BC Hydro require current fish species data in order to provide information to mitigate adverse impacts or to provide direction on any future fish habitat restoration activities as well as any fish production projects.

METHODS

Pre-Spawn Field Reconnaissance

Field surveys were conducted in June and August of 2003 on both Seton and Anderson Lakes to collect kokanee biological data for age and growth analysis and to identify potential spawning habitat. Samples were also collected by DFO concurrent with summer/fall hydro-acoustic survey.

Biological sampling was conducted in open water, pelagic sites prior to thermal stratification to capture vertically migrating kokanee that utilize surface waters at dusk to feed on epilimnetic zooplankton. All salmonids captured were retained for biological sampling, including; length weight, sex, stomach contents and aging and genetic structures. A representative sample of lengths was taken in the field for non-salmonids captured. Surface temperature was recorded at each gillnet site and an estimate of water clarity was made using a secchi disc.

Overnight gillnet sets were conducted on June 3 on Seton Lake and June 4 on Anderson Lake. Two individual floating gillnet gangs were set, consisting of five panels each. Each panel measured 2.4 m deep x 15.2 m long with mesh sizes ranging from 25 mm to 51 mm. Sets were approximately 70 meters in length.

Boat surveys were also conducted on each lake to identify potential spawning areas based on foreshore and littoral habitat features such as gravel/cobble beaches, creek inlets or talus/rubble slopes. Shoreline surveys were conducted on Anderson Lake and Seton Lake on August 18 and 19, respectively. Foreshore and littoral habitat was initially assessed to identify useable substrate for kokanee spawning, based on known habitat preference for other large lake kokanee shore spawning populations in the Southern Interior, such as Okanagan Lake or general habitat characteristics such as stream inlets and clean gravel.

Project personnel also took the opportunity to accompany Department of Fisheries and Oceans (DFO) biologists on their fall hydro-acoustic and trawl surveys of Seton and Anderson Lakes for juvenile sockeye/kokanee abundance estimates and become familiar with the methodologies used. These surveys could be effective to estimate kokanee age class and population abundance in subsequent years (Hume 2004, pers. comm.). Information and data sharing between BCCF, MWLAP and DFO may provide further insight into kokanee abundance for 2003-2004; however, data analysis for the other studies was still preliminary at the writing time of this report.

Spawner Surveys

On Seton Lake, spawner surveys were conducted 12 separate days through mid October to the end of November, 2003, as weather conditions permitted. Anderson Lake was surveyed a total of four days in January and February, 2004. Extreme cold in early November and again in late December and early January delayed the start of both Seton and Anderson Lake field surveys. Periodic strong winds further limited sample efforts. Spawner surveys on Seton and Anderson Lakes were conducted by boat and involved traveling the shoreline to visually observe any spawning activity (spawning fish, redds) or any sign of post–spawn mortalities (floaters) on the lake surface or shoreline. The boat was equipped with a depth sounder (Lowrance ^{LC}X-18c) which was used to detect any fish in deeper water (3 – 70 m). Any predatory bird activity was also noted.

Gillnets were used to attempt validation of any concentrated fish schools detected on the depth sounder at previously identified locations with potential spawning habitat (i.e. creek mouths and low gradient littoral habitat with suitable cobbles or gravels), and, on Anderson Lake, at areas where numerous floaters were observed. Project personnel suspected that small gravel was the preferred spawning substrate based on the severely ragged condition of the lower caudal fin observed on both Seton and Anderson kokanee samples (floaters) collected in preliminary site visits by MWLAP in previous years. Two individual sinking gillnet gangs, each consisting of five panels were used during the surveys. Each panel measured 2.4 m deep x 15.2 m long with mesh sizes ranging from 25 mm to 51 mm. Gillnets were generally set perpendicular to shore and to depths up to approximately 70 m and were numbered from closest to shore (1) to farthest from shore (5). Each gang had a soak time of approximately ½ hour and each gillnet set location was geo-referenced using a hand-held GPS.

Kokanee capture locations were noted for each panel of the gillnet gang and all kokanee and a small sample of bull trout captured were retained from each lake for biological sampling, including length, weight, sex, age structure (otolith) and tissue. Kokanee tissue samples were provided in-kind to the Department of Fisheries and Oceans for a kokanee/sockeye genetic study. Each gillnet site is referenced with an alphanumeric character set with two characters representing the lake name and two numbers representing the site (e.g. SE-01, Seton Lake-Site 1). Only a few non-target species were captured and whenever possible species such as bull trout or rainbow trout were released alive.

Daily water surface temperatures and secchi depth readings were taken at each lake. On Seton Lake, an Eckmann dredge, provided by MWLAP Environmental Protection Section, was used to conduct a benthic grab (to roughly describe substrate type). Substrate was classified as follows: Fines: <2mm, Gravel: 2-64mm, Cobble: 64-256mm, and Rubble/Boulder: >256mm (RIC 2001) A temperature profile using a YSI dissolved oxygen meter was conducted (up to 25 m) at select sample sites (Appendix 1). At confirmed spawning sites on Anderson Lake, a Onset Tidbit temperature logger was lowered by hand to record bottom temperatures for a short duration (several minutes). Water temperature is one possible environmental cue that initiates spawning.

In Seton Lake, a trap net was set along the shoreline on the south side of the lake (UTM: 10.560665.5615797) for four days (November 23 – 26) where floaters have been observed in the past. The trap net consisted of a floating lead set perpendicular to shore and ran to a floating trap box anchored in the lake (~20 m off shore). Fish migrating along the shoreline encounter the lead net and follow it out to the trap box where wing deflectors force them into the trap box. This method is very successful to capture mature fish on littoral habitats and was tested as an alternate method of non-destructive biological sampling and to potentially provide an indication of any nocturnal, spawning movement patterns.

All salmonids captured were retained for biological sampling, including; length weight, sex, stomach contents and aging and genetic structures.

Hydro-acoustics and Video

In Anderson Lake, three additional spawner assessment methods were utilized by Shuksan Fisheries Consulting of Everett, Washington on sub-contract to BCCF: (a) hydro-acoustics transects of potential spawning areas at spawning time; b) an underwater camera video trial with laser measurement of substrate characteristics; and (c) a ROV test, as in-kind support from DFO/Coast Guard and MWLAP, was used to identify and film any redds at depth and general habitat in suspected spawning areas and several other representative deep habitats. Acoustic sampling was conducted from a chartered survey boat using a BioSonics split-beam scientific echo sounder paired with a Garmin differential GPS and linked to a PC with specialized software.

Acoustic transects were run in several areas of the lake where spawning was considered likely, with some unlikely locations also sampled for contrast. Hydro-acoustic and underwater video results appear in a separate report by Shuksan Fisheries Consulting.

Underwater video observations were made by Shuksan Fisheries Consulting at six locations in the northeast half of the lake where spawning was considered probable. To approximate substrate size measurements, two small parallel lasers 10 cm apart within the video camera's field of view provided a continuous size reference during sampling. Still images representing typical substrate types were also captured from video tapes during review.

WLAP, with the assistance of the Canadian Coast Guard, tested the effectiveness of a portable, submersible ROV (Remote Operated Vehicle) set up in a powerboat and equipped with a scale measure and digital videocam to examine eleven potential kokanee spawning sites in Anderson Lake. The ROV trials were run in 1 to 70 meters depth that allowed operators to examine substrate characteristics and suspected redd sites. Kokanee spawning was believed complete in Anderson Lake approximately one week before the trials.

The ROV was a newer unit still under research testing by the Coast Guard, a fact that provided a unique and unexpected opportunity for in-kind support. The unit used in Anderson Lake was a Videoray 2002 with constant depth monitoring. The Videoray has 160° tilt and two 20 watt halogen lights with surface control. The ROV operates from a small, portable Yamaha generator and is equipped with two 76 meter long connectible monitor cables. The Anderson Lake tests utilized only one of the two cables to simplify operation and maximize number the transect sites. Only one cable was used for the Anderson Lake trials. The cable connects to the ROV at one end and the other end connects to a remote control unit and video monitor. The Coast Guard operator has adapted a small metric scale that is visible in front of the camera lens allowing quick evaluation of substrate diameters and was also very helpful to free the cable from snags on debris or rock. The water clarity in Anderson Lake is very good and the ROV was very mobile in any direction, so detailed, repeat observations of significant features were possible. Typically, the boat would pull into a shoreline location and the ROV was deployed towards deep water, perpendicular to the shoreline. When the ROV reached the furthest extent of the cable (about 80 meters), the operator then re-traced an adjacent path back to the shoreline. The viewing field was up to several meters wide, depending on depth. In very calm conditions, it was possible to drift parallel to shore slowly over an area of interest and cover a section of the lake far from shore.

A digital CD is in preparation with a representative section of each transect, important habitat features and any evidence of spawning activity. Transect starting points were recorded on a Garmin 36S hand-held GPS. Accuracy was within 30 meters according to the unit read-out. Site locations are detailed in Appendix 2.

RESULTS

In this Year 1 study, significant progress was made on the first two study objectives and biological data was collected and analyzed for several age classes in both lakes. DFO hydro-acoustic estimates may provide a first attempt at meeting objective 3. Results are presented separately for pre-spawning and spawning/habitat surveys.

Pre-Spawn Field Reconnaissance

Seton Lake

In Seton Lake, overnight floating gillnet sets were conducted on June 3, 2003. Gillnet 1 (SE-SG01) was set at the west end of the lake, near the south shore and gillnet 2 (SE-SG02) was set at the east end of the lake, near the south shore (Figure 2). Water depth at both sites was 70 to 110 m and both nets had a soak time of approximately 18 hrs. Total kokanee catch for gillnets 1 and 2 was one and 26, respectively.

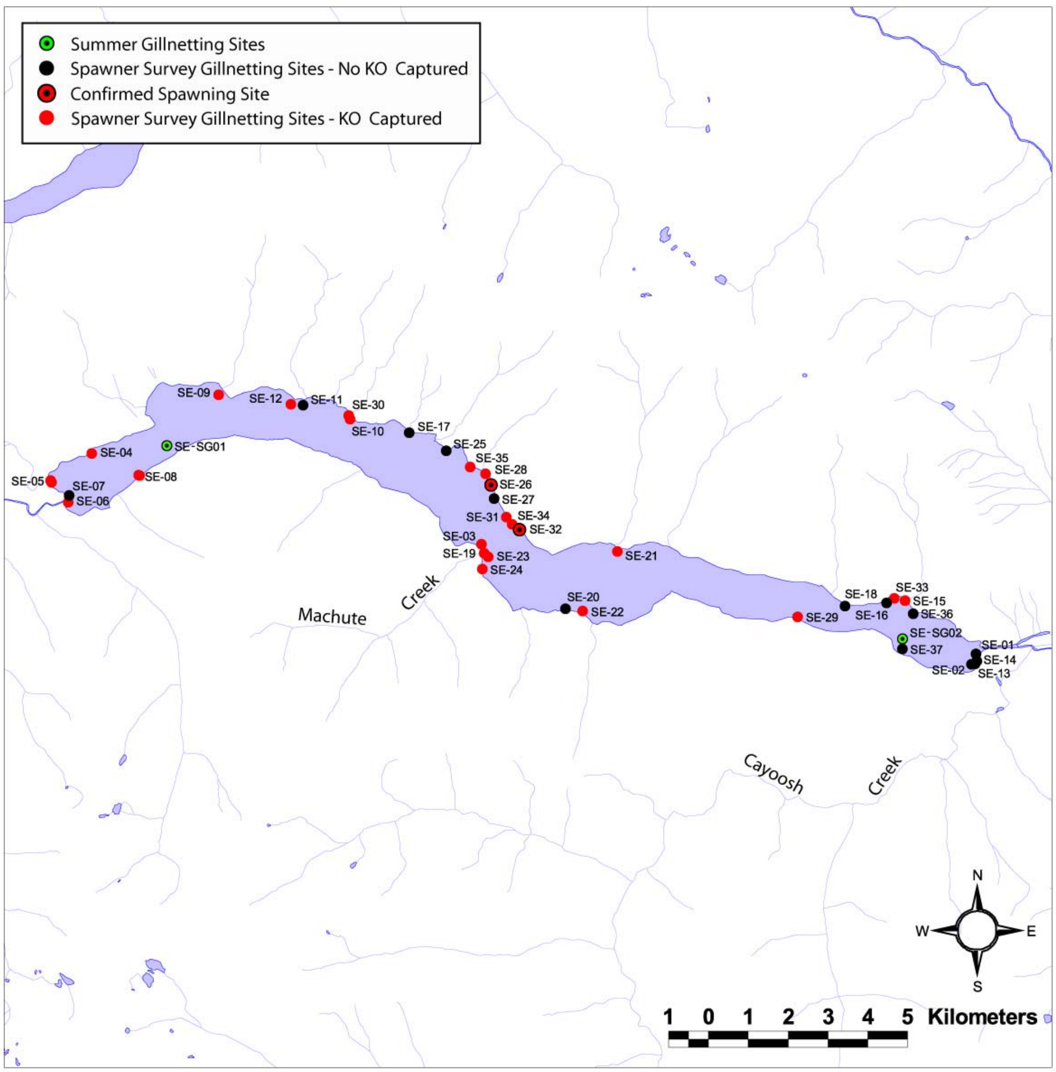

Figure 2. Seton Lake sampling sites, 2003.

Two age classes of kokanee were captured in Seton Lake, age 2+ and age 3+. The mean fork length for age 2+ fish was 130.82 mm (*n=17, SD=8.55*) and for age 3+ fish was 189.00 mm (*n=5, SD=8.03*, Table 1). Sex for most of these samples could not be determined due to minimal gonad and ovary development. A length frequency histogram for captured fish is presented in Figure 3. Biological data for Seton Lake kokanee is in Appendix 3.

Table 1. Length-at-age of Seton and Anderson Lake kokanee – summer gillnetting, 2003.

	Kokanee Age		
	2+	3+	4+
Seton Lake			
mean fork length (mm)	130.82	189.00	
n	17	5	
Anderson Lake			
mean fork length (mm)		143.25	216.67
n		8	3

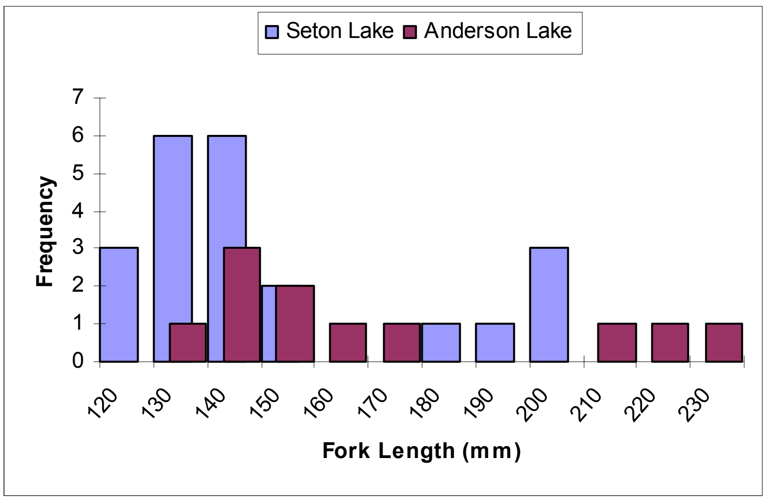

Figure 3. Length-frequency histogram for June gillnet kokanee captures in Seton and Anderson Lakes, 2003-2004.

Additional by-catch species included small numbers of rainbow trout, bull trout, numerous peamouth chub and several northern pikeminnows . The stomach contents of two of the bull trout retained for samples (both 610 mm in fork length) were kokanee, with one containing a total of six whole kokanee.

Boat surveys conducted to identify potential spawning areas based on foreshore and littoral habitat features was limited to the identification of several sloping gravel and talus beaches of moderate to steep gradient. In retrospect, these surveys were not successful in delineating spawning areas as near shore habitat varied from observed offshore habitat utilized by kokanee spawners (see below).

Project personnel accompanied DFO on a single, fall night survey of Seton Lake. Results will appear in a separate report by DFO. One interesting observation should be mentioned in this report - on Seton Lake, very little nocturnal, vertical migration of sockeye/kokanee juveniles occurred in comparison to Anderson Lake.

Anderson Lake

In Anderson Lake, overnight floating gillnet sets were conducted on June 4, 2003. Gillnet 1 (AN-SG01) was set at the north-east of the lake, near the east shore and gillnet 2 (AN-SG02) was set midway along the length of the lake, near the east shore (Figure 4). Water depth at both sites was 80 – 140 m and both nets had a soak time of approximately 19 hrs. Total kokanee catch for Gillnet 1 and 2 was eight and four, respectively.

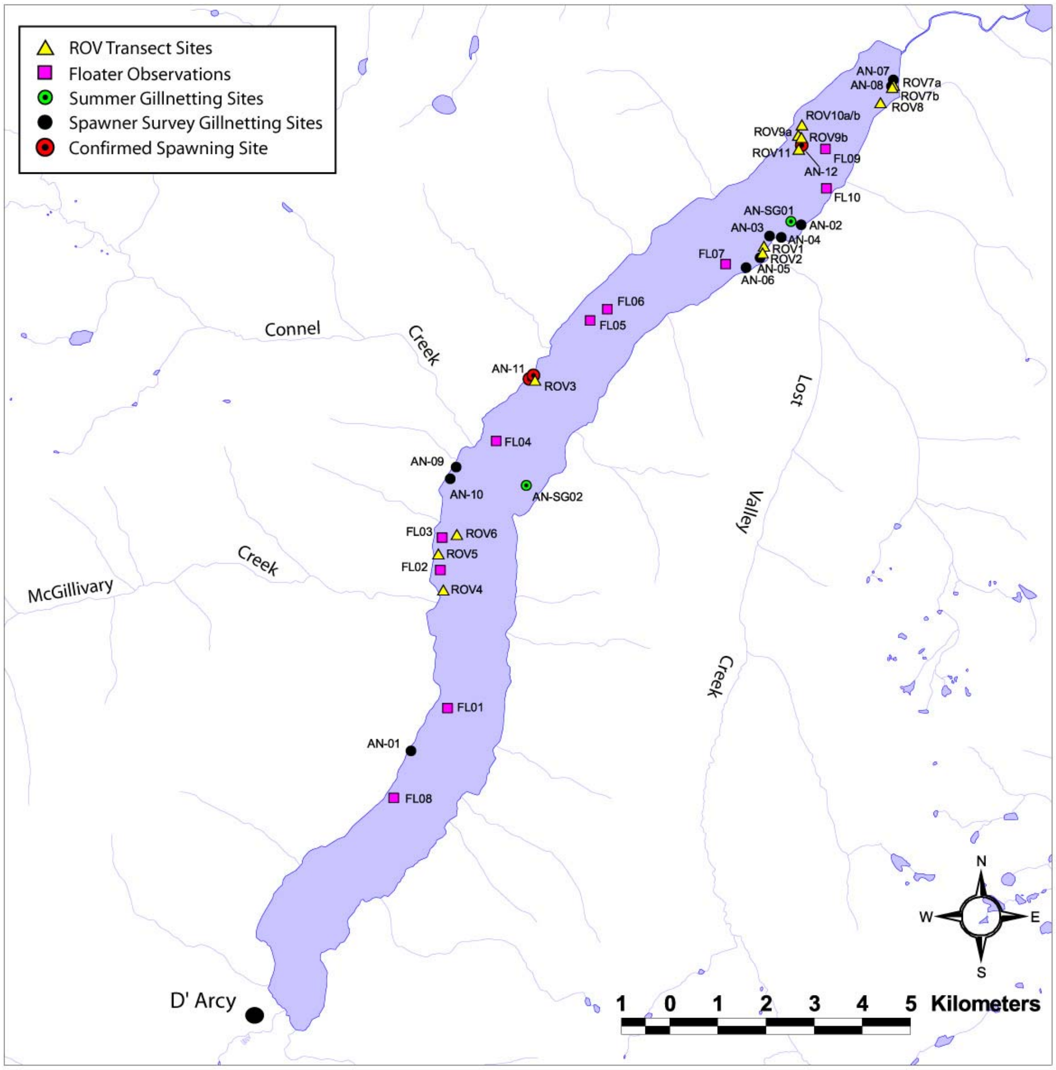

Figure 4. **Anderson Lake sampling sites, 2004.**

Two age classes of kokanee were captured in Anderson Lake, age 3+ and age 4+. Age 3+ fish had a mean fork length of 143.25 mm (*n=8, SD=11.73*) and age 4+ having a mean fork length of 216.67 mm (*n=3, SD=3.00*). Sex for most of these samples could not be determined due to the minimal gonad and ovary development. A length frequency histogram for Anderson Lake kokanee is presented in Figure 3. Kokanee biological data for Anderson Lake can be found in

Appendix 4. Additional by-catch species in Anderson Lake included rainbow trout, bull trout, peamouth chub and northern pikeminnow.

Unlike Seton Lake, the late October hydro-acoustic surveys conducted by DFO on Anderson Lake revealed a strong diurnal migration for sockeye/kokanee juveniles from up to 40 to 70m depth during the day to <20m at dusk. A second observation on Anderson Lake just before dark was extensive surface activity (jumping, rising) by juvenile sockeye/kokanee schools throughout the mid-lake areas. This dusk surface activity was later observed in the February spawner survey.

Spawner Surveys

Seton Lake

The initial spawner surveys by boat on Seton Lake focused on attempting to visually observe kokanee spawning along the shoreline, a proven technique in Okanagan Lake (Andrusak et al. 2004). Due to the turbidity of Seton Lake, visibility was limited to littoral areas less than 3 m in depth. No spawning kokanee were visually observed in the littoral zone in 2003, in spite of good visibility in several, shallow areas believed to be good kokanee spawning habitat. No kokanee were captured in the shoreline trap net over a four-day period. However, the trap was known to be functioning properly as 3 peamouth chub and six juvenile salmonids were captured.

Due to the poor visibility at depths > 3 m, gillnet sets were used to validate any fish detections observed on the depth sounder and at various locations that had good potential spawning habitat (i.e. creek mouths and low gradient littoral habitat with suitable cobbles and gravels). This methodology proved very effective and resulted in the identification of two suspected spawning areas.

A total of 48 gillnet sets were conducted on Seton Lake from November 5 - 26, and of these, 34 (71%) resulted in the capture of mature kokanee (Figure 2, Appendix 5). The majority of the 34 gillnet sets yielded few kokanee (*mean kokanee capture/gillnet set=2, min.=1, max.=7, n=31*), but those fish captured provided an initial indication of spawning locations, confirmed spawn timing and depth of spawning based on which panel of the 5-panel gillnet gang they were captured in. Most captured fish were observed in the 3rd, 4th or 5th panel at depths ranging from approximately 30 to 50 m and many kokanee were captured close to the lead line. The remaining three (6%) gillnet sets (of the 34 which captured kokanee) captured a much greater number of kokanee (ranging from 20 to 77 mature kokanee/set) and resulted in the identification of two suspected spawning areas.

The two suspected spawning areas (SE-26 and SE-32) were located midway down the length of Seton Lake on the north shore (Figure 2). Gillnet captures at these two sites indicated higher concentrations of mature or spawned out kokanee. A 32 minute set at SE-26 captured 77 kokanee on November 20 and a follow-up gillnet set on November 26 captured an additional 20 kokanee. At SE-32, 42 kokanee were captured during a 57 minute gillnet set on November 25. The majority of fish captured at these two sites were in the 3rd and 4th panels at a depth of approximately 30m. Almost all fish captured were orientated on the lead line of the gillnet (Figure 5), suggesting that they were grouped near the lake bottom. Shore spawning kokanee were captured with the same technique at Adams Lake in late fall (Andrusak and Morris 2004).

Figure 5. **Gillnet capture of concentrated mature kokanee on gillnet lead line at SE-26 on Seton Lake, 2003.**

The mean fork length for mature male and female kokanee captured in Seton Lake was 161.49 mm (*n=168, SD=12.00*) and 169.68 mm (*n=38, SD=24.25*), respectively. A length-frequency histogram for Seton Lake kokanee is presented in Figure 6. Biological data for Seton Lake kokanee is in Appendix 3. Otolith analysis indicates that the age-at-maturity for kokanee spawners in Seton Lake is predominately 2+, with a small proportion of fish age 3+ (Figure 7, Table 2). The proportion of male and female kokanee aged at 2+ was 87% and 3+ was 73%, respectively. All female fish captured were at least partially spawned and no fecundity counts were possible. Fecundity samples are typically obtained when the egg skein is still intact to insure that all eggs are accounted for. In contrast, the fish captured in early November (Figure 8) appeared to be in good condition with no indication of frayed caudal fins (indicative of digging redds). These fish had a light gray-green or gray coloration and examination of gonad and egg skein condition indicated that fish were just starting to spawn (i.e. large gonads and large number of loose eggs). As surveys continued through November, captured kokanee appeared much darker (darker olive-green with mottled black, Figure 9) and most fish had frayed caudal fins. A few fish captured in late November had signs of decomposition with small areas of fungus forming on various parts of the body. No post-spawn kokanee (floaters) were observed on the lake surface throughout the survey period. In the first week of December, twenty-seven carcasses were recovered at the east end of Seton Lake, along the shoreline near the lake outlet. These fish had accumulated on the shoreline due to prevailing west to east winds. The condition of the fish throughout the survey period and the recovery of post-spawn carcasses provide a good indication of the spawn timing for 2003 (Figure 10).

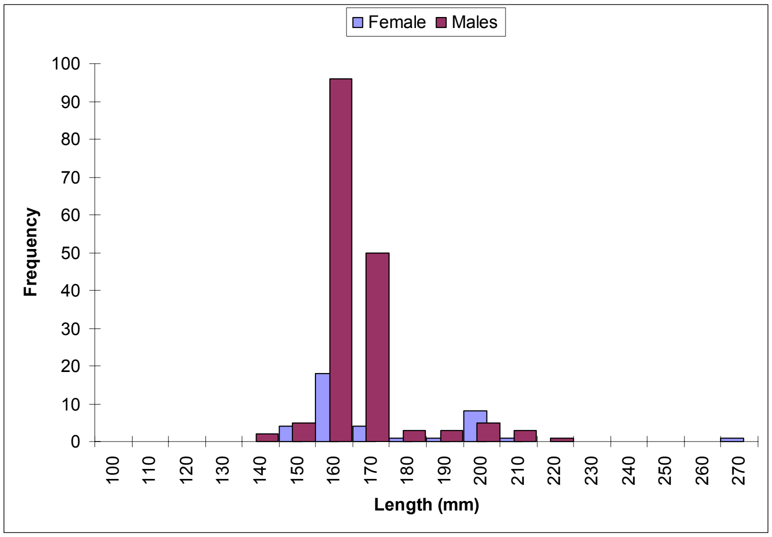

Figure 6. Length frequency histogram for captured Seton Lake kokanee spawners, 2003.

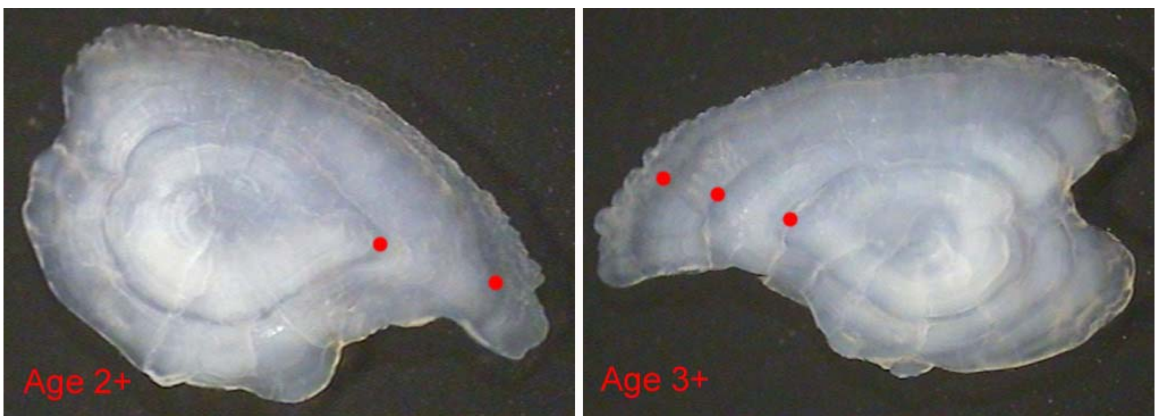

Figure 7. Sample of Age 2+ and 3+ otoliths from Seton Lake, 2003.

Table 2. Length-at-maturity and age of Seton and Anderson Lake kokanee spawners, 2002/2003 and 2003/2004.

	Male Kokanee Age			Female Kokanee Age			
	2+	3+	4+	2+	3+	4+	5+
Seton Lake (2003/2004)							
mean fork length (mm)	156.06	200.50		156.64	196.20		
n	54	8		28	10		
Anderson Lake(2003/2004)							
mean fork length (mm)			253.95		212.50	249.11	276.00
n			37		10	9	2
Anderson Lake(2002/2003)							
mean fork length (mm)		226.50	276.86		217.22	258.17	
n		8	7		9	6	

Figure 8. **Seton Lake kokanee at the start of spawning period - captured in early November, 2003. Note light gray-green coloration.**

Figure 9. **Seton Lake kokanee near end of spawning period - captured in late November, 2003. Note darker green-black coloration.**

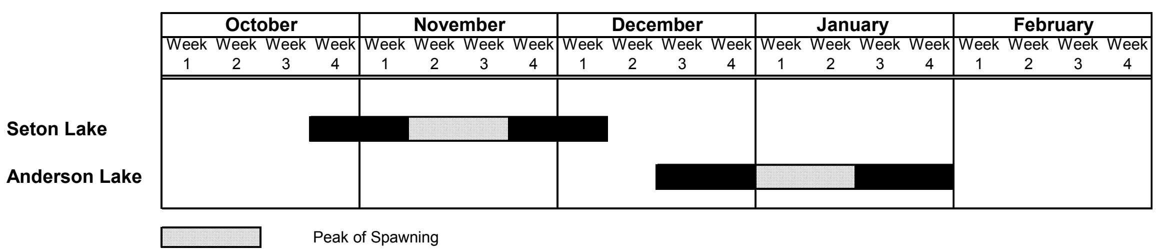

Figure 10. **Suspected spawn timing of Seton and Anderson Lakes kokanee, 2003**

An Eckmann dredge bottom sampler was used to sample substrate at a total of 11 sites, including the two suspected spawning sites: SE-26 and SE-32 (Table 3). At SE-26, substrate was sampled at 27m and 50 m. At 27 m the substrate was 100% clean large gravels and at 50 m consisted of 40% small gravel and 60% fines. The substrate at SE-32 was 100% clean, small angular gravels (Figure 11). Of the remaining nine sites, three were 100% fines (sand and mud), and the remaining six were mostly small and large gravel with some fines.

Table 3. Summary of Eckman dredge substrate sampling in Seton Lake, 2003.

Site No.	KO captured	Eckman dredge Substrate Sampling (% compostion)		Sample Depth (m)
		fines	gravels	
SE-17	no	100	0	18
SE-19	yes	35	65	20
SE-20	no	100	0	17
SE-21	yes	0	100	14
SE-22	yes	0	100	24
SE-24	yes	70	30	15
SE-25	no	30	70	18
SE-26	yes	0	100	21
SE-26	yes	60	40	50
SE-26	yes	0	100	27
SE-32	yes	0	100	50

Figure 11. Small angular gravels sampled at 27m depth using an Eckman dredge at SE-01 on Seton Lake, 2003.

Lake surface temperatures at Seton Lake ranged from 8.6^{o}C in early November to 6.6^{o}C in early December. In the absence of site-specific deep-water measurements, temperature at deep water spawning sites is anticipated to be about 4^{o}C. Water is most dense at this temperature. Temperature profiles to 25 meters suggest almost isothermic conditions at spawning time. However, given the depth of spawning and winter months it is a certainty that the deeper temperature was very near 4^{o}C (i.e. typical temperature of hypolimnetic water). Okanagan Lake shore spawning kokanee eggs require about 950 ATU's (°C) from fertilization to free swimming fry (Wilson and Andrusak 2003). Assuming a constant temperature of 4^{o}C for the incubation period at both confirmed spawning sites on Seton Lake, it would require 237 days from egg deposition to fry emergence. Based on a spawning period from October 21 to December 7, the estimated emergence time of Seton Lake kokanee fry would be between June 14 and July 31 Table 4). If peak spawning occurred in Seton Lake in mid November, then at 4 °C the eggs would only accumulate about 600 ATUs by mid April (5x 120 days). This estimate of emergence timing could be biased late due to the lack of data pertaining to spring water temperature warming or geothermal processes. Assuming that the hypolimnial water temperature somehow increases by 2°C in mid April, the developing eggs would still only accumulate another 300-360 ATUs by mid June for a total of about 950 ATUs (i.e. free swimming fry stage). This is very late for kokanee fry emergence and would place them at a severe feeding disadvantage with sockeye fry that likely emerge much sooner.

Table 4. Summary of spawning and estimated emergence timing for Seton and Anderson Lake kokanee, 2003/2003.

	Seton Lake		Anderson Lake	
	spawning	emergence	spawning	emergence
start	21-Oct	14-Jun	15-Dec	12-Jun
peak	15-Nov	7-Jul	7-Jan	7-Jul
end	7-Dec	31-Jul	31-Jan	28-Jul

Anderson Lake

On the first day of spawner surveys on Anderson Lake (January 13 2004), live, post-spawned near moribund kokanee (floaters) were readily observed on the calm lake surface, approximately one third of the distance moving east along the lake from the west end at D'Arcy, BC. Floater observations were made at numerous locations and the locations, combined with hydro-acoustic readings and eagle observations, provided guidance for the setting of gill nets.

Floaters were observed at a total of 10 sites on Anderson Lake throughout the survey period (January 13 – January 22, Figure 3, Appendix 6). All of these sites were within the deeper areas of the lake, however at two locations floaters were recovered close to steep bedrock shorelines. Most floaters were live at the time of observation and appeared to have distended swim bladders, causing the fish to float on their sides (many were still attempting to swim). The number of floaters observed at each site ranged from one or two fish to >100. A representative sample of 13 floaters was recovered for biological analysis. Movement of floaters on the lake surface, as well as, observations of eagles diving and picking up live or dead kokanee or perched on trees along the shoreline often directed field crews to floater sites. These fish were very similar in appearance to the spawners observed in Seton Lake (although no occurrences of floaters were observed on Seton Lake in 2003). The Anderson lake fish had a dark grey-green to black coloration and most fish captured (particularly females) had frayed caudal fins (Figure 12).

Figure 12. Anderson Lake kokanee (floaters) captured on January 13, 2003.

A total of 16 gillnet sets were conducted on Anderson Lake from January 13 – January 22, 2004 (Figure 3, Appendix 7). Of these, only two gillnet sets yielded mature kokanee. Both sets were at site AN-11, which is one (of two) confirmed spawning areas identified in 2004.

The remaining 14 gillnet sets were conducted at sites where suspected kokanee targets were observed on the depth sounder (Lowrance ^{LC}X-18c) and on the BioSonics split-beam scientific echo sounder operated in the 2nd boat and where eagle and floater observations were made. Although the net sets did not confirm kokanee spawning, many sites warrant further investigation and are still considered potential spawning areas.

The two suspected spawning areas (AN-11 and AN-12) were located midway down the length of the lake on the north shore (Figure 3). Two separate gillnet sets at AN-11 on January 14, each with an approximate 40 minute soak time, captured a total of 45 kokanee. The majority of fish captured at these two sites were in the 4th and 5th panels at depths ranging from 52 to 66 m depth. Almost all fish captured were orientated on the gillnet lead line, similar to the kokanee captures on Seton Lake. This suggests these normally open water fish that were in spawning condition were searching the lake bottom for suitable spawning sites. Milling and searching behavior is commonly observed amongst shore spawning kokanee in Okanagan Lake (Andrusak et al. 2003). Even though no kokanee were captured at AN-12, the 2nd suspected spawning site, both the video and the ROV survey revealed what appeared to be numerous, recently completed small diameter redds starting at a depth of approximately 25 m. Field crews also observed numerous floaters at the site and a local First Nation resident reported that he had observed numerous floaters in the area over the last few days.

The mean fork length for male and female kokanee spawners captured in Anderson Lake in 2004 (gillnetted kokanee and floaters) was 253.95 mm (*n=37, SD=26.39*) and 234.24 mm (*n=21, SD=29.35*), respectively. In January 2003, 30 post-spawn kokanee mortalities were recovered from the beaches of Anderson Lake and were sampled this year to compare with the 2004 samples. The mean fork length for male and female kokanee captured in Anderson Lake in 2003 were similar at 250.0 mm (*n=15, SD=25.18*) and 233.60 mm (*n=15, SD=27.47*), respectively. Length-frequency histograms for Anderson Lake kokanee are presented in Figures 13 and 14. All female fish captured were partially spawned and no fecundity counts were possible. Otolith analysis indicates that the age-at-maturity for kokanee spawners in Anderson Lake in 2004 is predominately age 4+, with a smaller proportion of fish age 3+ and 2 female kokanee aged at 5+ (Figure 15, Table 2). Male and female kokanee aged at 4+ were 100% and 53%, respectively. Kokanee otolith samples collected the previous winter (2003) were also aged at 3+ and 4+. In 2003, however, a slightly higher proportion of both male and female kokanee were age 3+ rather than 4+ (Table 2). 53% and 60% of male and female kokanee were age 3+ in 2003, respectively. Biological data for Anderson Lake kokanee is in Appendix 4.

Bull trout were the only additional by-catch species (Appendix 1). At suspected spawning sites where no kokanee were captured, bull trout were apparently feeding on kokanee spawners. The stomachs of two of the bull trout retained in one set contained whole mature kokanee.

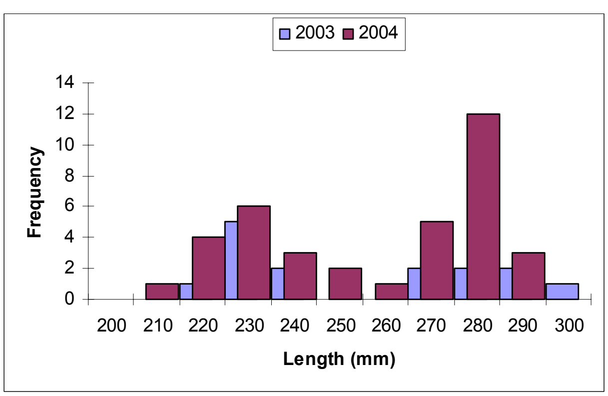

Figure 13. Length frequency histogram for Anderson Lake male kokanee captured in 2003 and 2004.

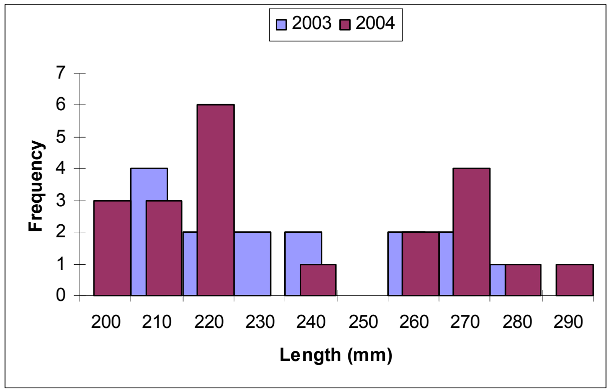

Figure 14. Length frequency histogram for Anderson Lake female kokanee captured in 2003 and 2004.

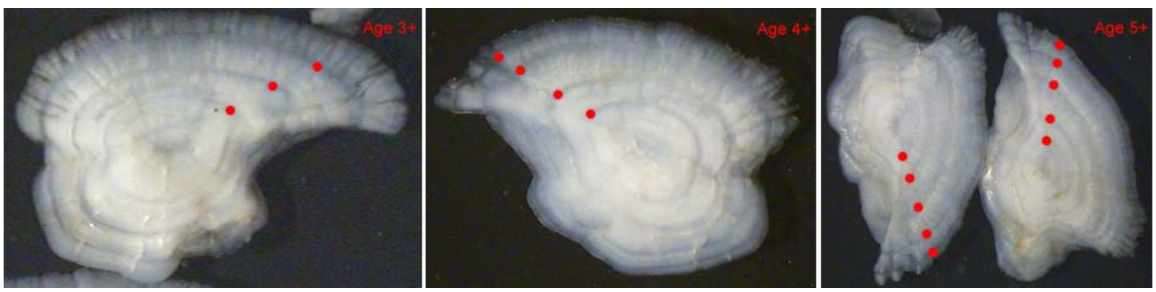

Figure 15. Sample of Age 3+, 4+ and 5+ otoliths from Anderson Lake, 2004.

The condition of captured fish, numerous eagles perching and actively feeding and the presence of floaters during surveys conducted between January 13 and January 22 suggest that the peak of spawning in some parts of Anderson Lake occurred prior to the field surveys, likely during the first two weeks of January. Based on the duration of spawning observed for Seton Lake kokanee, it is likely that spawning started mid to late December in Anderson Lake and continued to approximately the end of January (Table 4).

Lake surface temperatures ranged from 4.4°C to 5.3°C in during the survey period. Temperature loggers were lowered to the substrate at 66m and 27m at the two suspected spawning sites (AN-11 and AN-12), respectively. The mean temperature at spawning depth for both AN-11 and AN-12 was 5.3°C. Secchi depth readings were consistent for the individual survey days at approximately 15m.

As mentioned earlier, kokanee eggs require about 950 ATU's (°C) from fertilization to free swimming fry. Assuming a constant temperature of 5.3°C for the incubation period at both confirmed spawning sites on Anderson Lake, it would require 180 days from egg deposition to fry emergence. Based on a spawning period from December 15 to January 31, the estimated emergence time of Anderson Lake kokanee fry would be between June 12 and July 28. Even if temperature at lake depths suddenly increased to 10 °C through all of April and May (another 60 days x 10) at depths >20m fry emergence would not begin until the end of May (about 960 ATUs). This scenario is most unlikely given the water depth of spawning (>20 m) that is well below the typical thermocline (Shortread et al. 2001). A more likely explanation is that the eggs are developing at 5.3°C but receive additional heat units from groundwater or even geothermal sources. The spawners may be seeking out deep water sites associated with groundwater upwelling or geothermal plumes that are sufficiently warm and oxygenated. A second possibility is that these kokanee eggs require far fewer heat units through adaptation to local conditions.

Hydro-acoustics and Video

The results of hydro-acoustic and underwater video camera trials are documented in a separate report still in preparation by Shuksan Fisheries Consulting. Target strengths of fish indicated that a large proportion of the fish detected throughout the lake by Shuksan were the size of kokanee spawners (Staples 2004, in prep.) These targets are unlikely to be that of any other fish species although peamouth chub and whitefish are abundant and of similar size and the gill net data supports the hypothesis that the targets are kokanee. Although few fish were observed in direct contact with the bottom, spawning kokanee sized fish occurred in dense schools, the lower portion very close to bottom. Schools were near shore at some locations, and in dense offshore layers in others. Mean density of possible spawners was highest in the northeast half of the lake. Highest densities of possible spawners occurred between 30 and 60 meters depths in most areas. Potentially spawning habitat in bottom substrate tended to occur in patches that varied considerably in spatial extent. For example, only small, scattered pockets of gravel were observed among dominant talus and boulders at location AN-11, whereas beds of gravel at least tens of meters in size were present at AN-12.

ROV trials took place on February 9 and 10, 2004 in either overcast or clear; generally calm conditions with air temperatures ranging from one to six degrees C. Eleven sites were chosen for ROV trials (Figure 3). Most locations were previously noted in January for presence of kokanee floaters, hydro-acoustic detection of kokanee schools, shoreline eagle concentrations or mature kokanee gillnet captures. UTMs were recorded at each transect start point. General transect results are described in Table 5. ROV trials took place in an open boat; however, the operator recommends covered craft to protect electronic instruments.

Table 5. Summary of Anderson Lake ROV transect results, 2004.

Transect No.	Results
ROV1	Located just west of the Lost Valley Creek inlet, on the south shoreline; a location where eagles were concentrated on shoreline trees in both January 2003 and January 2004. Hydroacoustics identified at least two dense schools of kokanee size fish in the general vicinity of ROV1 in February 2004 (Staples 2004, in prep.). Near shore, the substrate is predominantly is rubble with pockets of small to large gravels for a short distance out, then fines dominate the bottom out to 80 meters from shore. A few gravel pockets were present, one near a distinct rubble mound. One section of fine gravel appeared to contain small, fresh, shallow excavations.
ROV2	ROV2 is just west of ROV1 and has a similar shoreline. Fines dominated the entire transect length and no significant features or potential spawning habitat were located along the transect. Maximum survey depth was 30 meters along a gradually sloping bottom profile.
ROV3	ROV3 corresponds to gillnet site AN-11 and is adjacent to a bedrock wall on the north side of Anderson Lake. Numerous mature kokanee and dying floaters were captured at this site in January and the site is considered a confirmed spawning site. An underwater shelf is present adjacent to steep inlet stream. The shelf is dominated by coarse rubble, however, patches of small gravel up to several square meters in diameter exist and what appeared to be small excavations were noted with one concentrated area of depressions. The excavations were close together and no larger than 25 cm. in diameter. Redds were visible as clean gravel depressions.
ROV4	ROV4 is about 100 meters east of McGillivary Creek inlet on the north side of the lake. The only indication of kokanee spawning activity in January was one or two perched eagles. The inlet of McGillvary Creek is a significant gravel source and creekmouths are still considered good potential spawning. However, this transect was dominated by fine sediment out to a maximum depth of 39 meters.
ROV5	ROV5 is on the north side of the lake adjacent to a steep, vegetated side-hill. The transect video displayed angular rubble (10 to 15 cm diameter) dominating the substrate out to 42 meters depth, but a few small gravel patches exist along the way. No evidence of spawning was
ROV6	ROV6 is just east of ROV5. The dominant habitat type on the transect of this gently sloping shoal is large gravel changing to a continuous layer of fine sediment to a depth of 26 meters.
ROV7a/b	ROV7 a/b are located at the far, east end of Anderson Lake directly off-shore from a gravel beach in front of several cabins at Seton Portage and is just south of the Portage River outlet. Eagle congregations, a dense school of kokanee on one of the hydro-acoustic echograms and bull trout with mature kokanee in their stomachs in January were earlier indicators of spawning. The ROV was deployed in two parallel transects about 80 meters apart to a maximum depth of 40 meters. The substrate consisted of large gravel and cobbles with some silt overlain out to 20 meters depth, then changed to silt until 35 meters depth where a section of clean large gravel appeared. No evidence of spawning was evident on the 7a and 7b transects.
ROV8	ROV8 was located along a steep, talus section of the south shoreline, near the beach at Seton Portage. A few eagles were still present in shoreline trees. The substrate alternated between angular cobble/boulder and silts however a strip of gravel was present from about 1 meter to 3 meters depth. Portions of the shallow gravel strip had the appearance of recent disturbance, however further analysis of the videotape is needed. Maximum transect depth 35 meters.
ROV9a/b	ROV9a/b were located in the eastern third of Anderson Lake extending along and out from the North Shore. ROV9a/b is a long, gently sloping shoal that extends out from a beach known for collecting gwenis. First Nations were observed looking for or collecting gwenis along the beach and from a small boat on three occasions. Floaters were captured just to the east by the BCCF sample crew and were reported in abundance by First Nations in late-January. Hydro-acoustic echo-grams noted dense kokanee sized fish schools and the underwater video trial spotted possible redd excavations. ROV9a extended to 34 meters depth and was dominated by silt substrate. A couple of small to large gravel pockets were noted. ROV9b started at an off-shore location from the drifting boat close to the end of transect ROV9a approx. 80 meters off the beach). Although fines dominated, several distinct, large patches of gravel (2 – 3 meter diameter) appeared as distinct features in the silt at depths of 40 to 43 meters. Numerous, small excavations/depressions were photographed. Several excavations were closely examined with the ROV and appeared as clean gravel circles of 20 to 25 cm. diameter.
ROV10a/b	ROV10a/b is a section of rip-rap angular rock fill just east of ROV9a. A dense school of kokanee size fish was located by hydro-acoustics in January and floaters were found at the surface. No gravel habitat for spawning kokanee was present down to 20 meters depth. ROV10b was a deepwater site starting offshore from ROV10a. A thin silt layer over small gravel started at 24 meters depth extending to 30 meters. This habitat type extended to 54 meters depth. No potential spawning activity was noted (silt free areas or gravel excavations). A large salmonid was observed hovering several meters above the bottom.
ROV11	Rov11 corresponds closely to AN-12 and is a short distance west of ROV9a/b. The transect started in 60 meters depth about 120 meters off the beach. At 60 meters the shoal drops off steeply and fine sediment (sand and silt) dominated. The transect took the boat on a gradual, shoreward drift. At 40 meters and continuing to 30 meters depth, the substrate abruptly changed to small and large gravels with thin fines overlain. Several distinct excavations were found, exposing clean gravel underneath. Once again, the excavations looked like typical kokanee redds observed in other, river-type spawning habitat for kokanee averaging 25 cm. in size. One small sculpin was observed near one excavation, perhaps there to feed on loose eggs.

It is noteworthy that at some of the sites clean gravel and circular depressions 20-25 cm in diameter were observed. It is possible that these sites are groundwater or upwelling sources that the spawners are attracted to. Otherwise even from one spawning event to the next you would expect be some accumulation of fines, based on the dominant fines at most locations.

DISCUSSION

The 2003-2004 Seton and Anderson Lake kokanee assessments provide considerably more insight into the kokanee spawner populations in each lake, however the practice of confirming deep water spawning in the winter months was challenging. The project provided further insight into biology, spawning habitat selection, lake to lake variations, year class variability and confirmed location, spawn timing and distribution of kokanee spawners at a minimum of two sites within each lake.

Previous stream surveys and near shore observations were unable to detect any spawning kokanee, leading to the conclusion that deep water spawning must occur. Spawner surveys in 2003-2004 confirmed that kokanee spawning within the study area lakes are predominately associated with deep water habitat between 20 and 70m. No beach spawning was observed in either Seton or Anderson Lake in 2003-2004. Gradual sloping shoals, steep shorelines with gravel depositions and bedrock shelf/outcrops with gravel accumulations all were areas where spawning was identified or strongly suggested. There is no clear correlation with suitable foreshore spawning substrates and littoral habitat features (i.e. creek mouths) to observed offshore habitat utilized by kokanee spawners. Deepwater spawning is not currently documented for any other kokanee stocks in the Southern Interior or the Okanagan. There is no obvious reason the Seton and Anderson Lake kokanee are selecting these sites over available beach spawning habitat. However, spawning at depth (30 – 55m) was documented for sockeye in Alaska (Bocking and Gaboury 2003). Several hypotheses for Seton and Anderson Lake kokanee spawning depth include;

- Predator and light avoidance by deep water spawning at similar depths to rearing.
- Favorable thermal regime via south facing slope warming in late winter and spring
- Reduced risk of off-shore alevins/fry transport in spring winds from shallow spawning
- Groundwater sources, thermal advantage and oxygenation
- Avoidance of direct competition for spawning sites with sockeye spawners.

Once it was apparent that kokanee were not beach spawning on Seton Lake and that the near shore habitat varied from observed offshore habitat, the identification of spawning sites on Seton Lake followed an intuitive “hit or miss” approach. Gillnet sets were focused on sites where fish were detected on the depth sounder and where suitable foreshore spawning substrates and littoral habitat features (i.e. creek mouths) were observed. Although many of the gillnet sets yielded mature kokanee, the low numbers of fish captured did not confirm that the locations were all key spawning areas. Still, these sites warrant future surveys in order to conclusively determine or deny spawning. No occurrences of floaters (or feeding eagles) were observed on Seton Lake, in contrast to Anderson Lake where eagles are abundant. This difference made the detection of spawning areas in Seton even more difficult. Local First Nations report that historically Seton Lake floaters have been observed and often washed up in large numbers on the beaches; but no floaters have been documented in the BCCF/WLAP work conducted during the past few years and only sporadic fish show up on the beaches. The two spawning areas identified in Seton Lake were largely a result of the request and financial contribution by BC Rail to conduct site-specific surveys in front of their rail line. The sites are proposed for rail line maintenance work. BC Rail had biological surveys conducted by G3 Consulting Ltd. (G3 Consulting Ltd. 2003) in 2003 to document aquatic habitat values in front of the BC Rail sites; however the work was conducted prior to the kokanee spawning window and lacked data specific for kokanee spawning habitat. In the BCCF survey, spawning sites were identified and kokanee biological and habitat data was collected.

The combination of habitat attributes that make these sites attractive to spawning kokanee is still uncertain without more confirmed spawning sites. There are numerous areas of clean, small gravels that appear well-suited for spawning at the appropriate depths of 25 to 70 meters. The damaged condition of the caudal fin on captured mature kokanee at this and other sites is definitely caused by fish physically digging (or attempting to dig) redds. It is suspected that this occurs in small gravel substrates, rather than through broadcast spawning in larger substrates. This behavior has been observed for gravel beach spawning kokanee in Adams Lake (Andrusak and Morris 2004). However, shore spawning kokanee have been observed exhibiting digging behavior over angular rocks and cobble substrates in Okanagan Lake, indicative of broadcast spawning (Andrusak et al. 2003).

In Anderson Lake, the spawner surveys were more selective than at Seton Lake, based on the 2004 observations of floaters and feeding eagles made on the first survey day and continuing throughout the survey period. These observations, combined with 2003 observations, gillnetting, hydro-acoustic surveys and ROV surveys were key in the identification of two spawning areas. In many cases floaters were actually observed rising to the lake surface. The first floater observations in the west third of the lake were scattered above very deep water and their origin is unknown. Floaters occurred later the same day at the first identified spawning site on Anderson (AN-11), and resulted in the capture by gillnet of 45 mature kokanee clearly in spawning condition. At the second spawning site (AN-12), a large group of live floaters was observed (>100), but no kokanee could be captured in gillnets. However, bull trout were captured at this site and mature kokanee were observed in the stomach of one of these fish. The ROV survey conducted at this site two weeks later confirmed spawning with the identification of numerous excavated redds. It may be that the spawning at AN-12 site was almost over, an explanation for a large number of kokanee floaters observed, but none captured in gillnets. In comparison, only a few floaters were observed at AN-11 and mature kokanee were captured on the gillnet lead-line, suggesting that spawning was still underway at this site and post-spawn mortalities were just beginning. Exactly why these kokanee exhibit floating behavior after spawning is unclear. It may be the result of swim bladder distention as the kokanee weaken and move up from great depth and pressure to the surface of the lake. Kokanee likely lose the ability to regulate their swim bladder as they slowly die after spawning. It's possible the production of gas in the body cavity increases as the internal organs break down, or a combination of all these effects. The swim bladder expansion contributes to the "deep bodied" appearance of these stocks.

Small gravel substrate was utilized by both Seton and Anderson kokanee for spawning. In Seton Lake, Eckman dredges at the two spawning sites contained high proportions of clean small gravels and in Anderson Lake, both the video and the ROV surveys identified redd excavation in small gravels at AN-12. However, the underwater camera survey at site AN-11 on Anderson Lake revealed large cobble and boulder substrate with very little gravel, suggesting that some of the Anderson Lake fish may be broadcast spawning. Further work with the ROV confirmed that some gravel substrate was in fact present in the vicinity of this site, but was limited in comparison to the quantity of larger rubble. Broadcast spawning is well documented for Okanagan Lake spawners, and Christina Lake kokanee also appear to utilize a variety of spawning substrates, including digging redds in small gravels and broadcast spawning on cobble substrates (Wilson 2004, pers. comm.). Broadcast spawning into spaces between large substrates should also be considered as potential spawning behavior for some of the Seton and Anderson Lake kokanee. G3 Consulting Ltd. (2003) completed an assessment of littoral and aphotic habitat values in Seton Lake for BC Rail. Of specific interest is survey data for BC Rail Mile 147.5, which was confirmed as a spawning site (SE-32) during this project. At depths 15 – 40 m G3 Consulting Ltd. reported a mixed gravel/cobble substrate which they attributed to slope instability in the littoral zone transporting smaller substrate to deeper areas. They also noted that sediment covered areas not recently disturbed. The substrate composition described by G3 Consulting Ltd. is consistent with the habitat values identified during the kokanee assessment at SE-32. Bathymetry was also conducted by G3 Consulting Ltd. on Seton and Anderson Lake and further analysis of both transect and bathymetric data may provide additional insight into available spawning habitat.

The successful identification of spawning sites in both Seton and Anderson Lake was the result of a combination of several variations of standard fish assessment methodologies not generally associated with enumeration of beach spawning kokanee populations. Results of the Seton Lake surveys demonstrated the need for innovative methods for identifying fish and habitat characteristics at depth. For example, the use of hydro-acoustics and underwater camera surveys in combination with gillnetting validation proved very effective on Anderson Lake. A combination of hydro-acoustics and gillnetting is most effective for detecting and validating kokanee spawning groups, and the ROV is most effective for describing habitat. The ROV may not be effective for enumeration or validation of kokanee targets by hydro-acoustics however as kokanee may avoid the ROV unit as a potential predator. Certainly further testing at spawning time is recommended in both lakes. The ability to use an underwater camera on Seton Lake is also questionable due to the turbidity of the water, but it still may be useful to describe substrate and detect redds if positioned very close to the lake bottom. The determination of additional spawning site selection by kokanee, the development of a systematic, standard procedure for enumerating kokanee with the intent of establishing key sites for index of abundance estimates and ultimately determining population estimates for kokanee in Seton and Anderson Lakes will require continued surveys and experimentation with hydro-acoustics, gillnetting and underwater camera surveys. Hydro-acoustic surveys as practiced by DFO and Shuksan Fisheries Consulting are the most promising methods to enumerate kokanee. The ROV trial in Anderson Lake demonstrated that this technology is well suited to confirming spawning site location, depth and habitat attributes. The ROV is a safe alternative to other techniques such as divers and is non-intrusive and non-destructive. In areas where net sets did not confirm kokanee spawning, the sites considered to have potential for spawning warrant further surveys before they can be included or excluded as spawning habitat.

All occurrences of spawning identified in Seton and Anderson Lakes to date were situated closest to the northern or south facing shoreline. This may be due to the additional thermal units available at these locations with south exposure, yet at depths chosen, this seems unlikely. The floater activity between January 13 and January 22 suggests that there is spatial and temporal variation in spawning activities throughout Anderson Lake with a gradient of activity from west to east over three to four weeks. The water depths where spawning appears to occur is clearly in the hypolimnion where water temperatures are not likely to exceed 6 °C and most of the time are closer to 4 °C. Theoretical fry emergence time at these temperatures would be well into the summer, an unlikely scenario. It is possible that groundwater upwelling or geothermal vents are selected by the spawners thus providing the required heat units for spring (May) fry emergence. Note that the temperature profiles in Seton Lake reached a maximum depth of 30m at which the temperature was 8^{o}C on November 12, 2003.

Morphologically, the Seton and Anderson Lake kokanee appear the same, with the exception of size. Anderson Lake spawners are generally larger. These fish are very different in size and color compared to most stream spawning kokanee and even compared to Okanagan Lake shore spawners they have very little coloration. Residual sockeye are known to have similar coloration (Bocking and Gaboury 2003), however the Seton and Anderson Lake fish appear to be kokanee based on life history an Sr/Ca analysis by DFO. Age analysis for fish captured shows that Seton Lake kokanee spawn up to one or two years earlier than Anderson Lake kokanee. This suggests that their size is proportionate for their age. The only comparable age class between the two lakes was 3+. Anderson Lake fish were larger (*mean fork length= 218.22 mm, n=27*) than those in Seton Lake (*mean fork length=198.11 mm, n=18*). This may be partially explained by the higher levels of phytoplankton and zooplankton biomass in Anderson Lake (*2622 mg dry wt/m*^{2}) than Seton Lake (*422 mg dry wt/m*^{2}, Shortreed et al. 2001) thus reducing competition for food. It is also been suggested that most Gates Creek sockeye fry move out of Anderson Lake and rear in Seton Lake (Geen and Andrew 1961, Shortreed et al. 2001). This is further supported by Sr/Ca ratio analysis of otoliths for trawled *O. nerka* which indicated that >95% of the fall density of *O. nerka* was kokanee (Shortreed et al. 2001). Increased competition from sockeye fry in Seton Lake from both Gates and Portage Creeks combined with the lower plankton biomass may explain the smaller size of Seton Lake kokanee.

In 2000, DFO estimated *O. nerka* populations for Seton and Anderson Lakes based on hydro-acoustic and trawl analysis. Using a combined total for age-0 and age-1 kokanee, Seton Lake had an estimated abundance of 67,739 kokanee while Anderson Lake had an estimated abundance of 3,000,074 kokanee in all age classes. Applying a kokanee biostandard of 5 kg/ha for mature kokanee (see Andrusak and Morris 2004) would place the annual escapement for both lakes at about 60,000. These estimates conflict with the acoustics estimates. However, using a biostandard of 5% (Sebastian 2004, pers. comm.) of the total lake population (e.g. about 100,000 for Seton and 4 million for Anderson Lake) results in adult estimates of 5,000 and 150,000 respectively). These estimates appear more realistic than those using the 5 kg/ha biostandard. More detailed analysis of specific age class numbers by target strength evaluation of hydro-acoustic data and application of fry to adult biostandards could provide a population estimate for adult kokanee and all age classes.

One interesting observation was that Seton Lake male kokanee were smaller than the females (*fork length: M=161.49, F=169.68 mm*), while Anderson Lake male kokanee were larger than the females (*fork length: M=253.95, F=234.24 mm*). For spawner surveys conducted in 2003 in the Southern Interior Region around Kamloops, mean fork lengths for male kokanee were consistently larger than those of female kokanee and, across stocks, as female fork length increased so did fecundity.

Finalized DFO hydro-acoustics and abundance estimates for 2003 were not available at the time of this report; however, some preliminary hydro-acoustic results were available from DFO staff. Fish densities were moderate to high in both lakes in spite of only 1,100 effective female sockeye spawners in Gates Creek and Channel and 8,000 in Portage Creek. This seems to indicate a large kokanee population in Anderson Lake. Analysis of the length frequency from the trawl catch and acoustic target strength analysis will provide a clearer picture of age/taxa breakdown and analysis of Sr/Ca content of the otolith cores will provide determination of the sockeye/kokanee breakdown in the age-0 fish this fall/winter. Diel acoustic transects in both lakes were conducted for the first time in 2003 and provided some surprising results. Anderson Lake juvenile *O. nerka* showed a typical daytime distribution for clear-water lakes in B.C. Kokanee/sockeye were down deep (Anderson kokanee/sockeye below 40 meters) within the water column in daylight with a few schools detected nearer the surface which are likely older kokanee or other, larger fish. Target strength analysis may help here. In Seton Lake, the daytime fish layer was centered on about 20m, with very few targets recorded below 30m. Fish may move even shallower than this, as the acoustic beam is quite narrow nearer the surface and there may be increased boat avoidance in the near surface waters during the day. Note the reported observations of surface activity at dusk in Anderson. This daytime distribution is found in many glacially turbid lakes. This may have implications on the higher growth rate of sockeye observed in Seton Lake, as the fish remaining in warmer temperatures and there is the possibility of daytime feeding as well (Hume 2003, pers. comm.).

It is of some interest to note that there appears to be more sockeye rearing in Seton Lake where there are fewer rearing kokanee. Conversely, there appears to be more kokanee in Anderson Lake than sockeye. Although entirely speculative one possible explanation is that Anderson Lake kokanee fry emerge earlier than sockeye fry thus gaining a competitive advantage. This could be one explanation for why a large component of the Anderson Lake sockeye fry move into Seton Lake where there are far fewer kokanee despite the fact that Anderson Lake is far more productive (Shortreed et al. 2001). Such speculation implies that the deep water kokanee spawners in Anderson Lake gain the advantage through relatively rapid egg development that could only occur through geothermal heated water. Obviously this possibility warrants further investigation.

Kokanee tissue samples were provided in-kind to the DFO Pacific Biological Station for a kokanee/sockeye genetic study. Results of this study were not yet available at the time this report was prepared but that information should lend further insight on the biology of these fish. The kokanee populations in Seton and Anderson Lakes are an important food source for the bull trout populations in both lakes. Observations of bull trout predation on juvenile and mature kokanee were made in both lakes during the duration of the project. Bull trout are a key fish of interest for anglers and are important to First Nations. Angling for kokanee is popular with some fisherman in Anderson Lake but is unknown in Seton Lake. Bald eagles definitely rely on kokanee as a winter food source in Anderson Lake. Kokanee in Seton Lake, at least at current low population levels, do not attract foraging eagles.

RECOMMENDATIONS

- Additional summer netting would provide more information on size class variation and growth between the two lakes and kokanee stocks.

- Comparison of sample data for fish size with DFO trawl data would help confirm suspected emergence timing and identify differences between the two lakes.
- Future surveys for Seton Lake kokanee should focus on combined hydro-acoustics and gillnetting in deepwater areas of the lake to identify more spawning areas and meet objective 1 and 2. The turbidity of Seton Lake may make underwater camera work difficult, but a trial survey, such as was conducted on Anderson lake this year, is recommended to attempt to locate kokanee spawners or identify redds.
- Subsequent surveys and gillnet captures at SE-01 and SE-02 on Seton Lake and AN-01 and AN-02 on Anderson Lake in the future would further confirm these as key spawning areas and as potential index sites.
- Spawner surveys should start earlier in both lakes to further define spawn timing and to collect fecundity data from pre-spawn female kokanee.
- In areas where net sets did not confirm kokanee spawning, the sites considered to have good potential for spawning warrant further net surveys before they can be eliminated as important habitats.
- Hydro-acoustic surveys are considered the most viable technique to meet the third objective of the study: obtain kokanee population estimates.
- ROV trials should be expanded to a systematic survey of all potential spawning areas and delineation of index sites.
- A larger, covered boat would extend winter sampling ability by protecting electronic equipment and boat/equipment operators.
- Kokanee are an important summer/winter forage species for bull trout in Seton and Anderson Lakes and are important to winter bald eagle feeding in Anderson Lake. The importance to First Nations is already well documented.
- Future surveys should evaluate temperature characteristics around spawning sites for groundwater or geothermal processes.

ACKNOWLEDGEMENTS

We would like to thank the following groups, agencies and personnel for work and assistance in the field and for sharing their knowledge of Seton and Anderson Lake kokanee. The Stl'atl'mix First Nations have supported this project throughout. Rod Louie and William Alexander from Seton Band and Perry Rudan and Bonnie Adolph from Cayoosh Band are individually thanked for their support and involvement. Brian Frank and Alan Alexander worked with Eric Braumandl in difficult field survey conditions. Eric assisted lab sampling and data entry. Brock Staples of Shuksan Fisheries Consulting provided draft information to describe hydro-acoustics and video survey techniques and results. Dave Lee skillfully operated his boat for long hours of winter hydro-acoustic surveys and the D' Arcy residents were provided advice, information and hospitality. Cathy Bliault from BCCF aptly handled the administration of this project. Harvey Andrusak assisted with the initial study design and was most helpful in reviewing the final report. Jeremy Hume and Steve McClellan welcomed staff on their fall surveys for DFO and BC Hydro and generously shared scientific knowledge and data. Dale Sebastian with Victoria WLAP offered critique and advice based on his extensive experience with kokanee and hydro-acoustic surveys around the province. Colin Parkinson and the Canadian Coast Guard provided two days of ROV operational testing on Anderson Lake in the middle of winter. WLAP fisheries staff supplied boats, equipment, manpower assistance and science/technical advice throughout the project.

This project was funded by:

The BC Hydro Bridge Coastal Fish and Wildlife Restoration Program

BC HYDRO FISH & WILDLIFE BRIDGE COASTAL RESTORATION PROGRAM

BC Rail

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APPENDICES

Appendix 1: Seton Lake Temperature Profiles

Date: November 12, 2003
UTM: 10 E556602 N5619508

Depth (m)	Temperature (°C)
0	8.3
1	8.3
2	8.3
3	8.3
4	8.2
5	8.2
6	8.2
7	8.3
8	8.2
9	8.2
10	8.2
11	8.2
12	8.2
13	8.2
14	8.2
15	8.2
16	8.2
17	8.2
18	8.2
19	8.2
20	8.2
21	8.2
22	8.2
23	8.2

Date: November 12, 2003
UTM: 10 E563067 N5614631

Depth (m)	Temperature (°C)
0	7.7
1	7.8
2	7.8
3	7.8
4	7.8
5	7.9
6	7.9
7	7.9
8	7.9
9	7.9
10	7.9
11	7.9
12	7.9
13	7.9
14	7.9
15	7.9
16	7.9
17	7.9
18	7.9
19	7.9
20	7.9
21	7.9
22	7.9
23	7.9
24	7.9
25	7.9
26	7.9
27	7.9
28	7.9
29	7.9
30	7.9

Appendix 2: Anderson Lake R.O.V. Transects

Date	Site No.	Zone	Easting	Northing	Max Depth (m)
9-Feb-04	ROV1	10	546617	5613593	N/A
9-Feb-04	ROV2	10	546590	5613467	30
9-Feb-04	ROV3	10	542367	5611341	32
9-Feb-04	ROV4	10	540547	5607610	39
9-Feb-04	ROV5	10	540475	5608273	42
9-Feb-04	ROV6	10	540828	5608610	26
9-Feb-04	ROV7a	10	549089	5616407	40
9-Feb-04	ROV7b	10	549067	5616366	40
9-Feb-04	ROV8	10	548844	5616100	35
9-Feb-04	ROV9a	10	547324	5615572	34
9-Feb-04	ROV9b	10	547386	5615529	56
9-Feb-04	ROV10a/b	10	547406	5615762	54
10-Feb-04	ROV11	10	547325	5615318	60

Appendix 3: Seton Lake Kokanee Biological Data

Year Captured	Lake Name	Sex	Length (mm)	Weight (g)	Age	Spawn Cond.	Comments
2003	Seton	F	153	25	2+	spent	frayed tail
2003	Seton	F	143	18	2+	spent	frayed tail
2003	Seton	F	157	29	2+	spent	frayed tail
2003	Seton	F	150	23	2+	spent	frayed tail
2003	Seton	F	160	29	2+	spent	frayed tail
2003	Seton	F	166	44	2+	spawned	
2003	Seton	F	162	38	2+	spawned	
2003	Seton	F	159	30	2+	few eggs	frayed tail
2003	Seton	F	156	32	2+	spawned	frayed tail
2003	Seton	F	156	42	2+	spawned	frayed tail
2003	Seton	F	175	38	2+	spawned	frayed tail
2003	Seton	F	160	36	2+	spawned	frayed tail
2003	Seton	F	161	36	2+	spawned	frayed tail
2003	Seton	F	158	36	2+	spawned	frayed tail
2003	Seton	F	157	32	2+	spawned	slight frayed tail
2003	Seton	F	155	30	2+	spawned	slight frayed tail
2003	Seton	F	155	28	2+	spawned	tail frayed off
2003	Seton	F	143	30	2+	immature	bright fish
2003	Seton	F	153	28	2+		frayed tail
2003	Seton	F	157	26	2+		frayed tail
2003	Seton	F	158	30	2+		frayed tail
2003	Seton	F	156	36	2+	spawned	frayed tail
2003	Seton	F	162	28	2+	spawned	frayed tail
2003	Seton	F	162	34	2+	spent	frayed tail
2003	Seton	F	156	23	2+	spent	frayed tail
2003	Seton	F	152	26	2+	spent	frayed tail
2003	Seton	F	157	27	2+	spent	frayed tail
2003	Seton	F	147	19	2+	spent	frayed tail
2003	Seton	F	192	58	3+	spawned	
2003	Seton	F	192	54	3+	spent	frayed tail
2003	Seton	F	200	59	3+	spent	frayed tail
2003	Seton	F	194	50	3+	spent	frayed tail
2003	Seton	F	200	74	3+	spawned	
2003	Seton	F	197	70	3+	Partial Spawn	no frayed tail
2003	Seton	F	200	70	3+	partially spawned; some eggs left	no frayed tail
2003	Seton	F	182	54	3+	partially spawned; some eggs left	frayed tail
2003	Seton	F	205	77	3+	spent	frayed tail
2003	Seton	F	200	64	3+		
2003	Seton	M	159	42	2+		
2003	Seton	M	151	26	2+		
2003	Seton	M	157	34	2+		
2003	Seton	M	163	40	2+		
2003	Seton	M	160	38	2+		
2003	Seton	M	156	42	2+		
2003	Seton	M	153	36	2+		
2003	Seton	M	157	48	2+		
2003	Seton	M	150	36	2+		tape worm

Year Captured	Lake Name	Sex	Length (mm)	Weight (g)	Age	Spawn Cond.	Comments
2003	Seton	M	152	44	2+		
2003	Seton	M	156	42	2+		
2003	Seton	M	157	40	2+		
2003	Seton	M	170	54	2+		
2003	Seton	M	145	36	2+		
2003	Seton	M	153	38	2+		
2003	Seton	M	158	44	2+		
2003	Seton	M	160	48	2+		
2003	Seton	M	153	38	2+		
2003	Seton	M	156	46	2+		
2003	Seton	M	165	52	2+		
2003	Seton	M	172	50	2+		
2003	Seton	M	155	36	2+		
2003	Seton	M	156	36	2+		
2003	Seton	M	152	34	2+		
2003	Seton	M	155	42	2+		
2003	Seton	M	154	42	2+		
2003	Seton	M	158	46	2+		
2003	Seton	M	157	44	2+		
2003	Seton	M	140	32	2+		
2003	Seton	M	157	42	2+		
2003	Seton	M	161	41	2+		
2003	Seton	M	151	36	2+		
2003	Seton	M	155	40	2+		
2003	Seton	M	158	38	2+		
2003	Seton	M	158	42	2+		
2003	Seton	M	166	44	2+		
2003	Seton	M	152	32	2+		
2003	Seton	M	153	42	2+		
2003	Seton	M	157	42	2+		
2003	Seton	M	155	38	2+		
2003	Seton	M	147	40	2+		
2003	Seton	M	148	38	2+		
2003	Seton	M	158	40	2+		
2003	Seton	M	136	38	2+		
2003	Seton	M	157	40	2+		
2003	Seton	M	160	40	2+		
2003	Seton	M	155	44	2+		
2003	Seton	M	161	40	2+		
2003	Seton	M	165	40	2+		
2003	Seton	M	160	40	2+		
2003	Seton	M	154	36	2+		
2003	Seton	M	156	34	2+		tail frayed off
2003	Seton	M	157	30	2+		
2003	Seton	M	160	48	2+		
2003	Seton	M	200	74	3+		
2003	Seton	M	200	74	3+		

Year Captured	Lake Name	Sex	Length (mm)	Weight (g)	Age	Spawn Cond.	Comments
2003	Seton	M	195	64	3+	Ripe fish unspawned	
2003	Seton	M	186	68	3+	mature, bright	
2003	Seton	M	212	124	3+		
2003	Seton	M	157	44			
2003	Seton	M	167	50			
2003	Seton	M	155	32			
2003	Seton	M	161	40			
2003	Seton	M	160	44			
2003	Seton	M	160	42			
2003	Seton	M	159	40			
2003	Seton	M	163	52			
2003	Seton	M	155	48			
2003	Seton	M	166	54			
2003	Seton	M	156	52			
2003	Seton	M	152	42			
2003	Seton	M	155	44			
2003	Seton	M	166	54			
2003	Seton	M	156	46			
2003	Seton	M	155	44			
2003	Seton	M	152	36			
2003	Seton	M	171	54			
2003	Seton	M	153	46			
2003	Seton	M	166	50			
2003	Seton	M	163	48			
2003	Seton	M	160	54			
2003	Seton	M	157	46			
2003	Seton	M	155	50			
2003	Seton	M	157	44			
2003	Seton	M	157	56			
2003	Seton	M	162	50			
2003	Seton	M	160	44			
2003	Seton	M	153	46			
2003	Seton	M	160	44			
2003	Seton	M	155	50			
2003	Seton	M	167	50			
2003	Seton	M	148	36			
2003	Seton	M	190	76			
2003	Seton	M	161	48			
2003	Seton	M	161	52			
2003	Seton	M	163	50			
2003	Seton	M	157	52			
2003	Seton	M	160	44			
2003	Seton	M	160	50			
2003	Seton	M	156	45			
2003	Seton	M	153	42			
2003	Seton	M	157	48			
2003	Seton	M	160	48			
2003	Seton	M	162	44			
2003	Seton	M	164	48			

Year Captured	Lake Name	Sex	Length (mm)	Weight (g)	Age	Spawn Cond.	Comments
2003	Seton	M	165	56			
2003	Seton	M	165	48			
2003	Seton	M	162	44			
2003	Seton	M	153	42			
2003	Seton	M	168	46			
2003	Seton	M	164	46			
2003	Seton	M	160	46			
2003	Seton	M	160	46			
2003	Seton	M	157	52			
2003	Seton	M	165	54			
2003	Seton	M	157	52			
2003	Seton	M	157	52			
2003	Seton	M	154	40			
2003	Seton	M	153	48			
2003	Seton	M	173	54			
2003	Seton	M	170	48			
2003	Seton	M	153	40			
2003	Seton	M	162	46			
2003	Seton	M	163	44			
2003	Seton	M	163	44			
2003	Seton	M	155	40			
2003	Seton	M	153	40			
2003	Seton	M	160	44			
2003	Seton	M	165	40			
2003	Seton	M	162	48			
2003	Seton	M	165	42			
2003	Seton	M	154	44			
2003	Seton	M	163	38			
2003	Seton	M	159	40			
2003	Seton	M	162	46			
2003	Seton	M	162	46			
2003	Seton	M	165	50			
2003	Seton	M	160	52			
2003	Seton	M	155	48			
2003	Seton	M	162	44			
2003	Seton	M	165	48			
2003	Seton	M	167	46			
2003	Seton	M	162	46			
2003	Seton	M	160	54			
2003	Seton	M	160	46			
2003	Seton	M	155	44			
2003	Seton	M	152	38			
2003	Seton	M	157	44			
2003	Seton	M	160	46			
2003	Seton	M	163	42			
2003	Seton	M	153	44			
2003	Seton	M	160	42			
2003	Seton	M	168	58			
2003	Seton	M	170	48			

Year Captured	Lake Name	Sex	Length (mm)	Weight (g)	Age	Spawn Cond.	Comments
2003	Seton	M	155	35			
2003	Seton	M	206	73			
2003	Seton	M	163	38			
2003	Seton	M	160	31			frayed tail
2003	Seton	M	162	31			
2003	Seton	M	165	39			
2003	Seton	M	163	41			
2003	Seton	M	190	68			
2003	Seton	M	200	69			
2003	Seton	M	153	29			
2003	Seton	M	162	33			
2003	Seton	U	182	52	2+		
2003	Seton	U	110	12	2+	immature	
2003	Seton	U	113	16	2+	immature	

Appendix 4: Anderson Lake Biological Data

Year Captured	Lake Name	Sex	Length (mm)	Weight (g)	Age
2004	Anderson	F	207	83	3+
2004	Anderson	F	210	72	3+
2004	Anderson	F	215	80	3+
2004	Anderson	F	224	92	3+
2004	Anderson	F	209	55	3+
2004	Anderson	F	232	91	3+
2004	Anderson	F	233	98	3+
2004	Anderson	F	215	79	3+
2004	Anderson	F	210	89	3+
2004	Anderson	F	221	102	4+
2004	Anderson	F	264	147	4+
2004	Anderson	F	255	138	4+
2004	Anderson	F	270	167	4+
2004	Anderson	F	280	164	4+
2004	Anderson	F	259	151	4+
2004	Anderson	M	226	101	3+
2004	Anderson	M	220	108	3+
2004	Anderson	M	223	106	3+
2004	Anderson	M	233	116	3+
2004	Anderson	M	224	91	3+
2004	Anderson	M	238	107	3+
2004	Anderson	M	222	99	3+
2004	Anderson	M	226	95	3+
2004	Anderson	M	299	285	4+
2004	Anderson	M	275	180	4+
2004	Anderson	M	272	230	4+
2004	Anderson	M	263	192	4+
2004	Anderson	M	281	275	4+
2004	Anderson	M	281	203	4+
2004	Anderson	M	267	248	4+
2004	Anderson	F	240	146	3+
2004	Anderson	F	220	83	3+
2004	Anderson	F	215	70	3+
2004	Anderson	F	215	78	3+
2004	Anderson	F	200	61	3+
2004	Anderson	F	210	62	3+
2004	Anderson	F	200	66	3+
2004	Anderson	F	215	81	3+
2004	Anderson	F	210	74	3+
2004	Anderson	F	200	74	3+
2004	Anderson	F	275	155	4+
2004	Anderson	F	220	68	4+
2004	Anderson	F	260	131	4+
2004	Anderson	F	265	137	4+
2004	Anderson	F	260	154	4+

Year Captured	Lake Name	Sex	Length (mm)	Weight (g)	Age
2004	Anderson	F	270	162	4+
2004	Anderson	F	265	151	4+
2004	Anderson	F	207	83	4+
2004	Anderson	F	220	75	4+
2004	Anderson	F	262	148	5+
2004	Anderson	F	290	174	5+
2004	Anderson	M	250	133	4+
2004	Anderson	M	275	198	4+
2004	Anderson	M	285	207	4+
2004	Anderson	M	280	221	4+
2004	Anderson	M	280	214	4+
2004	Anderson	M	280	209	4+
2004	Anderson	M	275	203	4+
2004	Anderson	M	265	176	4+
2004	Anderson	M	275	175	4+
2004	Anderson	M	280	244	4+
2004	Anderson	M	272	177	4+
2004	Anderson	M	280	210	4+
2004	Anderson	M	265	193	4+
2004	Anderson	M	265	189	4+
2004	Anderson	M	285	197	4+
2004	Anderson	M	270	230	4+
2004	Anderson	M	290	230	4+
2004	Anderson	M	270	188	4+
2004	Anderson	M	280	213	4+
2004	Anderson	M	278	202	4+
2004	Anderson	M	260	226	4+
2004	Anderson	M	220	85	4+
2004	Anderson	M	227	108	4+
2004	Anderson	M	215	93	4+
2004	Anderson	M	232	121	4+
2004	Anderson	M	241	120	4+
2004	Anderson	M	220	94	4+
2004	Anderson	M	274	171	4+
2004	Anderson	M	209	75	4+
2004	Anderson	M	222	89	4+
2004	Anderson	M	221	103	4+
2004	Anderson	M	232	109	4+
2004	Anderson	M	223	102	4+
2004	Anderson	M	220	108	4+
2004	Anderson	M	225	102	4+
2004	Anderson	M	223	107	4+
2004	Anderson	M	232	111	4+

Appendix 5: Seton Lake Gillnet Data

Site No.	Date	Zone	Easting	Northing	Gillnet Type	Gillnet Soak Time (minutes)	Max Depth (m)	Total Kokanee Captured
SE-01	5-Nov-03	10	571361	5613400	Sinking	90	30	0
SE-02	5-Nov-03	10	571236	5613174	Sinking	100	30	0
SE-03	5-Nov-03	10	560629	5616260	Sinking	45	53	2
SE-03	5-Nov-03	10	564821	5616130	Sinking	38	25	11
SE-04	6-Nov-03	10	552135	5618647	Sinking	40	43	1
SE-04	6-Nov-03	10	565044	5616094	Sinking	38	24	11
SE-05	6-Nov-03	10	551187	5618036	Sinking	43	50	1
SE-05	24-Nov-03	10	551243	5618063	Sinking	46	47	1
SE-05	6-Nov-03	10	565268	5616058	Sinking	37	24	11
SE-06	6-Nov-03	10	551615	5617566	Sinking	48	37	2
SE-07	6-Nov-03	10	551630	5617713	Sinking	59	34	0
SE-08	7-Nov-03	10	553174	5618094	Sinking	42	46	1
SE-08	20-Nov-03	10	553187	5618082	Sinking	38	42	1
SE-09	7-Nov-03	10	554993	5619785	Sinking	47	74	2
SE-10	7-Nov-03	10	557866	5619122	Sinking	77	52	2
SE-11	7-Nov-03	10	556572	5619506	Sinking	47	80	3
SE-12	7-Nov-03	10	556834	5619470	Sinking	38	49	0
SE-13	25-Nov-03	10	571362	5613148	Sinking	40	29	1
SE-13	14-Nov-03	10	571362	5613148	Sinking	39	45	0
SE-14	14-Nov-03	10	571389	5613226	Sinking	74	27	1
SE-15	14-Nov-03	10	570238	5615466	Sinking	40	40	1
SE-16	24-Nov-03	10	569546	5614406	Sinking	31	34	1
SE-16	14-Nov-03	10	569546	5614406	Sinking	38	54	0
SE-17	20-Nov-03	10	559173	5618549	Sinking	42	54	1
SE-17	14-Nov-03	10	559173	5618549	Sinking	43	37	0
SE-18	24-Nov-03	10	568465	5614401	Sinking	38	45	3
SE-18	15-Nov-03	10	568465	5614401	Sinking	45	38	0
SE-19	15-Nov-03	10	560671	5616065	Sinking	34	40	1
SE-20	15-Nov-03	10	562420	5614529	Sinking	47	45	0
SE-21	17-Nov-03	10	563597	5615979	Sinking	36	49	1
SE-21	24-Nov-03	10	563597	5615979	Sinking	57	49	3
SE-22	17-Nov-03	10	562756	5614689	Sinking	50	50	3
SE-22	24-Nov-03	10	562756	5614689	Sinking	42	50	4
SE-23	18-Nov-03	10	560749	5615977	Sinking	49	51	3
SE-24	18-Nov-03	10	560611	5615719	Sinking	58	45	1
SE-25	24-Nov-03	10	559937	5618342	Sinking	49	29	5
SE-25	18-Nov-03	10	559937	5618342	Sinking	41	48	0
SE-26	20-Nov-03	10	560888	5617549	Sinking	35	53	77
SE-26	26-Nov-03	10	560881	5617546	Sinking	33	53	20
SE-28	20-Nov-03	10	561315	5617940	Sinking	37	28	3
SE-29	24-Nov-03	10	567476	5614377	Sinking	44	40	1
SE-30	24-Nov-03	10	557823	5619204	Sinking	37	32	3
SE-31	25-Nov-03	10	561187	5616829	Sinking	34	50	6
SE-32	25-Nov-03	10	561465	5616545	Sinking	57	47	42
SE-33	25-Nov-03	10	569622	5614691	Sinking	25	43	1
SE-34	26-Nov-03	10	561314	5616665	Sinking	34	55	1
SE-35	26-Nov-03	10	561414	5618582	Sinking	44	40	7
SE-SG01	3-Jun-03	10	553818	5618714	Floating	18 (hrs)		15
SE-SG02	3-Jun-03	10	569754	5613794	Floating	18 (hrs)		11

Appendix 6: Anderson Lake Kokanee Post Spawn Floaters

Survey Date	Site No.	Zone	UTM Easting	Northing	No. of KO Observed	Activity	Comments
13-Jan-04	FL01	10	540541	5605466	3 KO - 1M, 2F	post-spawn live floaters	4 eagles observed along shoreline;
13-Jan-04	FL02	10	540510	5607975	2 KO - 2F	post-spawn live floaters	1 fish completely spawned out, the other still had lots of eggs
13-Jan-04	FL03	10	540574	5608561	~40	post-spawn live floaters	mostly female KO
13-Jan-04	FL04	10	541618	5610267	~20	post-spawn live floaters	mostly female KO; 15 eagles observed on shoreline at UTM: 10.542670.5611881
13-Jan-04	FL05	10	543419	5612381	~20	post-spawn live floaters	mostly female KO; water depth at fish recovery site 670 ft
13-Jan-04	FL06	10	543734	5612567	~100	post-spawn live floaters	mostly male KO; all out in middle of lake; 600-700 ft water depth
13-Jan-04	FL07	10	545913	5613297	2	rising	KO observed jumping on lake surface; not post-spawn floaters
21-Jan-04	FL08	10	539496	5603884	1	post-spawn live floaters	3 eagles
21-Jan-04	FL09	10	547812	5615302	100+	post-spawn live floaters	
22-Jan-04	FL10	10	547802	5614591	6	post-spawn live floaters	

Appendix 7: Anderson Lake Gillnet Data

Date	Site No.	Zone	Easting	Northing	Gillnet Soak Time (minutes)	Water Depth (m)
13-Jan-04	AN-01	10	539842	5604734	30.0	61
14-Jan-04	AN-02	10	547317	5613954	30.0	61
14-Jan-04	AN-03	10	546739	5613778	40.0	46
14-Jan-04	AN-04	10	546952	5613744	36.0	46
14-Jan-04	AN-05	10	546536	5613391	52.0	80
14-Jan-04	AN-06	10	546280	5613224	25.0	60
14-Jan-04	AN-07	10	549092	5616508	45.0	65
14-Jan-04	AN-08	10	549066	5616390	70.0	30
14-Jan-04	AN-09	10	540879	5609834	30.0	50
14-Jan-04	AN-10	10	540762	5609630	22.0	55
15-Jan-04	AN-11	10	542275	5611368	40.0	66
15-Jan-04	AN-11	10	542340	5611433	43.0	70
21-Jan-04	AN-12	10	547385	5615392	51.0	45
21-Jan-04	AN-12	10	547385	5615392	35.0	60
21-Jan-04	AN-13	10	547428	5615393	60.0	55
22-Jan-04	AN-14	10	547445	5615324	31.0	40