HILL CREEK SPAWNING CHANNEL
KOKANEE ADULT ESCAPEMENT-2006

Prepared
by

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EXECUTIVE SUMMARY

Hill Creek Spawning Channel (HCSC) was built as partial compensation for fish losses as a result of the construction and development of hydro-electric dams on the upper Columbia River. The HCSC provides enhanced spawning habitat with controlled flow and substrate to increase survival rates for kokanee (*Oncorhynchus nerka*), a keystone species within Arrow Lakes Reservoir (ALR). The channel also provides important spawning and rearing habitat for adfluvial rainbow trout (*Oncorhynchus mykiss*). HCSC is considered a major kokanee producer which supports >30% of all kokanee spawners for Arrow Lakes Reservoir thus contributing to restoring kokanee abundance to pre-impoundment levels.

In total, 112,487 kokanee spawners (natural stream + channel) were estimated to have returned to Hill Creek in 2006. From this total, 92,567 kokanee were passed into the spawning channel while 19,920 kokanee utilized the natural stream below HCSC. Mean size of spawners increased in 2006 (26.0 cm fork length) compared to 2005 (21.3 cm). As well, mean fecundity of 240 eggs per female in 2006 was higher compared to that of 214 eggs per female in 2005. Total egg deposition for the combined spawning channel and the natural stream was estimated to be 14,097,672 eggs in 2006 of which 10,604,700 were deposited in HCSC. The estimate in 2006 was considerably lower than the estimate of 19,970,138 eggs in 2005, but relatively close to the design target of 12,250,000 (Lindsay 1982).

In summary, 2006 kokanee escapement to HCSC was lower than 2004 and 2005. Production difficulties experienced in 2004 and 2005 have been improved in 2006, evidenced by the high egg-to-fry survival rate, due to an increase in monitoring and maintenance. Improvement to the in-lake carrying capacity, due to nutrient addition, may result in increased future kokanee escapements to HCSC and ALR.

Keywords

Hill Creek Spawning Channel, Arrow Lakes Reservoir, kokanee, adult enumeration, escapement, production, cohort.

ACKNOWLEDGEMENTS

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

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INTRODUCTION

Kokanee (*Oncorhynchus nerka*) returning to the Hill Creek Spawning Channel (HCSC) provide an index of abundance and a metric for the overall health and status of kokanee within the Arrow Lakes Reservoir (ALR). Similar to other fish species in British Columbia, kokanee and their habitat have been adversely impacted over the last century by many anthropogenic influences (Northcote 1973; Ashley et al. 1997, Pieters et al. 2003). Specifically within ALR, man made influences as a result of construction and development of hydro-electric dams on the upper Columbia River have had detrimental effects on kokanee. Consequently, to mitigate for damages to fish values on the upper Columbia River, HCSC was built to compensate and restore fish losses incurred from construction of the Revelstoke Dam. Originally intended to produce ~0.5 million adult kokanee and ~500 adult rainbow trout (*Oncorhynchus mykiss*), HCSC to date has yet to mitigate for all of the estimated losses. Overall, the aim of HCSC operations are to increase kokanee abundance in Arrow Lakes Reservoir (ALR), to pre-impoundment levels, through enhanced spawning habitat, controlled flows and increased egg-to-fry survival.

HCSC does provide an important component of total kokanee production in Arrow Lakes Reservoir (Andrusak 2005). Similar to neighboring Kootenay Lake, kokanee are considered a keystone species that are integral prey for piscivorous populations of fish within the Arrow Lakes Reservoir (Andrusak and Parkinson 1984, Arndt 2004b). As well, adult kokanee offer an important recreational fishing opportunity in Arrow Lakes Reservoir while providing an economic benefit to the local communities. Long term trend data suggest that ~6,000 kokanee are caught annually on ALR (Arndt 2002, Arndt 2004a).

The HCSC is operated and funded by the Fish and Wildlife Compensation Program (FWCP) which is a joint initiative between BC Hydro, the Ministry of Environment (MoE), and the Department of Fisheries & Oceans Canada (DFO). The Program’s goal is to conserve and enhance fish and wildlife populations affected by BC Hydro dams in the Canadian portion of the Columbia Basin. This report summarizes the 2006 fall kokanee adult escapement estimate and provides recommendations for further assessment and monitoring at the HCSC.

The objectives are as follows:

- estimate adult kokanee escapement
- estimate potential egg deposition;
- generate fry production approximations for spring 2006;
- generate future adult return projections; and,
- monitor channel performance.

BACKGROUND

Construction of the HCSC commenced in the fall of 1979 and was completed in the late fall of 1980 (Lindsay 1982). The objectives of the channel were to restore and enhance kokanee and rainbow trout production lost as a result of dam construction. The channel was designed to produce an adult return of 0.5 million kokanee and ~500 adult rainbow trout. Additional losses of bull trout and large "trophy" rainbow trout would be compensated through hatchery production (Martin 1976, M.S.) that was ultimately built at the HCSC site.[1]

Historically, Hill Creek supported an annual spawning run of approximately 10,000 kokanee (Lindsay 1982). After construction, kokanee initially used the HCSC starting in 1984. To date, the production target of 0.5 million returning spawning kokanee has never been met. However, from a background level of about 10,000 spawners, escapements expanded to a high of 323,000 in 1989. Unexpectedly, escapements in the 1990's dwindled to less than 50,000 due to in-lake survival problems as a result of declining lake productivity. By the mid 1990's, it was clear the escapement target of 0.5 million adults could not be achieved without improvement to in-lake survival. Proposed lake fertilization in the vicinity of Hill Creek was expected to improve in-lake survival rates similar to what has occurred in the northern portion of Kootenay Lake (Ashley et al. 1997). Additionally, for four years (1991 to 1994) the numbers (75,000) were deliberately held low to reduce fry production in an experiment to increase adult size which was done to elicit a density-dependent response (B. Lindsay, Nelson Fisheries, pers. comm.).

In some instances, loss of spawning habitat due to various impacts have left fisheries managers with little choice but to restore wild kokanee populations by constructing semi-natural spawning channels. In all, there are six spawning channels in BC's southern interior. These include the Meadow, Redfish and Kokanee Creek channels on Kootenay Lake; the Bridge and Hill Creek channels on Arrow Lakes Reservoir; and Mission Creek on Okanagan Lake (Redfish Consulting Ltd. 1999). The HCSC has performed well with escapements averaging more than 160,000 since 1983 and a record escapement of over 300,000 in 1989.

[1] Stocking of bull trout and rainbow trout from Hill Creek Hatchery was discontinued in 2000 due to poor survival of fish after release (Arndt 2002, 2004a), and the conversion of the hatchery to sturgeon production.

SITE DESCRIPTION

The HCSC is located approximately 53 km north of Nakusp and runs adjacent to Hill Creek, a tributary to Galena Bay in the upper basin of Arrow Lakes Reservoir (Figure 1). The Hill Creek watershed is ~14.4 km long and has a drainage area of 26 km^2. The spawning channel is 3.2 km long and 6.1 m wide with an overall grade of 0.15 % (Lindsay 1982). Importantly, a backup water supply is utilized from nearby MacKenzie Creek, via a 2.4 km pipeline with a capacity of 0.28 cubic meters per second, to circumvent concerns of low seasonal water flows in Hill Creek. HCSC contains spawning gravel for kokanee (15,200 m^2) and rainbow trout (750 m^2). The initial 30.5 m section of the channel consists of a settling pond to collect fines. The channel is composed of 54 gravel riffles divided by resting pools. The gravel used in the kokanee spawning section ranges from 6 to 38 mm in diameter with a depth of 0.41 m, whereas in the rainbow trout section gravel ranges in size from 6 to 51 mm in diameter with a depth of 0.6 m (Lindsay 1982).

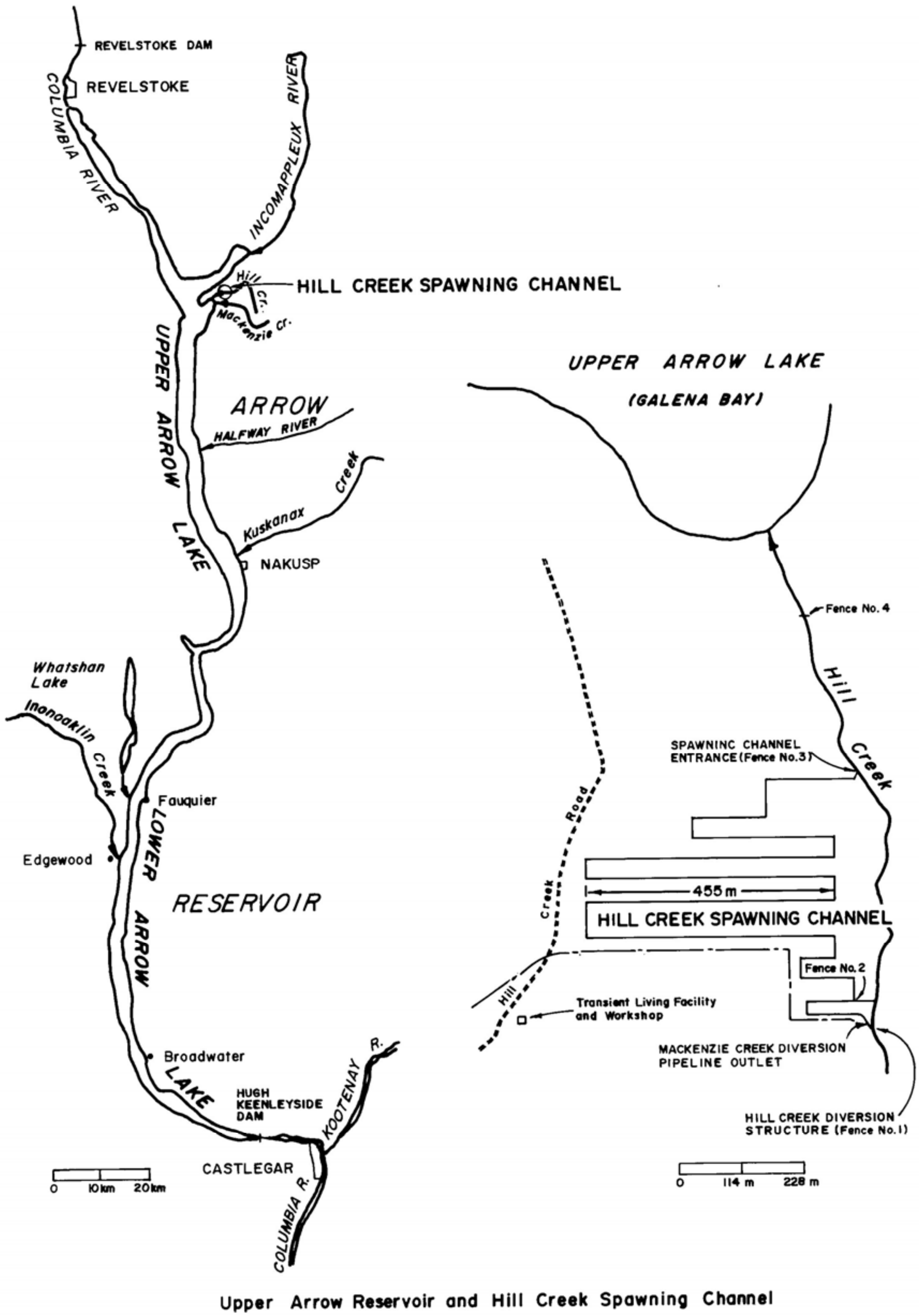

Figure 1. Location of Hill Creek Spawning Channel and stream outlet to upper Arrow Lakes Reservoir.

METHODS

Temperature, Discharge and Turbidity

Temperature (°C), discharge (m^3/s) and turbidity (NTU) were monitored during the fall kokanee spawning event as part of HCSC operations. Daily temperatures were recorded using Onset StowAway™ Tidbit™ and Hobo® data loggers installed at the Hatchery Fence, Fence #1 and Fence # 2 (for locations see Appendix A). Loggers at the Hatchery Fence, Fence # 1 and Fence #2 were set to record temperatures every 0.5 hr or 1 hr from July 13th throughout the adult migration and egg incubation. Additionally, temperature was recorded from a handheld thermometer during adult enumeration at the Hatchery Fence.

Channel flows were monitored by gauge height readings at Fence 2 in HCSC. Water depth data was also recorded from a gauge installed at the Hatchery Fence during fry sampling. Channel discharge at HCSC is calculated from gauge height (cm) at Fence # 2 using the equation:

$$\text{Discharge } (m^3/s) = 0.1545\ e^{9.4169\ (\text{gauge-height (meters)})}$$

Turbidity samples, 2 per site, were periodically taken at the lower (Hatchery Fence) and upper (Fence # 2) locations during the adult migration and measured on site with a LaMotte Model 2020 portable turbidity meter.

Adult Kokanee Enumerations

From August to September, adult kokanee returning to spawn at HCSC are enumerated annually through permanent fish fences (Hatchery Fence) (for location see Appendix A). Specifically, upstream kokanee migrants are manually counted through specially designed aluminium one-way counting boxes located at the Hatchery Fence. Subsequently, kokanee are contained within the HCSC by closure of the upstream Fence # 2. Typically, enumerations cease when the channel is filled to or near capacity.

To determine the total number of fish in the Hill Creek system, enumeration of kokanee spawners downstream of HCSC are also conducted annually. Visual ground counts were conducted by a two person crew walking from the mouth of Hill Creek to the lower Hatchery Fence in HCSC on September 26-27. Counts in the natural stream below HCSC are expanded by a factor of 1.5 to determine the total number of spawners utilizing the lower portion of Hill Creek. The expansion factor was derived from a regression between peak spawner counts and the total number of spawners each year from several kokanee spawning channels within British Columbia (Redfish Consulting Ltd. 1999, Andrusak et al. 2000). The resulting slope of the regression (1.5) explained 94% of the variation (r^2=0.94) between spawner counts and the total number of spawners.

Adult Kokanee Sampling

Spawner Size, Age and Sex Ratio

Collection of key biological data from adult kokanee spawners provides important insight into in-lake life history variables. Samples were obtained from adult kokanee at the Hatchery Fence in HCSC throughout the duration of the migration. These samples were collected with a dip net from fish crowded downstream of the fence immediately prior to each occasion that the fence was opened. Fork-length (mm), weight (g), and sex ratio are collected each day. In addition, annually, ~100 otoliths are obtained each year for determining age at maturity of returning kokanee spawners. Otolith age estimates were not available for this report.

Fecundity

Fecundity samples are collected annually from ~ 50 female adult kokanee for estimating total egg deposition within HCSC. Post-spawner egg retention samples are also collected at random from recently spent females to determine potential egg deposition (PED).

Potential egg deposition was calculated within the HCSC and the natural stream using the following formulas from Manson (2005):

HCSC: Number of female kokanee x (fecundity – egg retention) = PED

while the natural stream assumes a 1:1 sex ratio:

Natural Stream: (estimated # kokanee / 2) x (fecundity – egg retention) = PED

RESULTS

Temperature, Discharge and Turbidity

Temperature data were available for the spawning period from loggers at Fence 1 (near the upstream end of the channel) and the Hatchery Fence (downstream end).The logger at Fence 2 was lost possibly due to vandalism.

The fall temperature data recorded from loggers indicated a significant (t-Test, $p<0.05$) thermal regime difference between the upper (Fence #1) and lower (Hatchery Fence) portion of HCSC for the comparable time period of July 13 to October 29 (Fig. 2), with the downstream Hatchery Fence recorder consistently demonstrating higher mean daily temperatures compared to Fence # 1 (Table 1).

Table 1. Temperature profiles (^{o}C) at HCSC July 13 to October 29, 2006.

Location	Mean	StdDev	Max	Min
Fence # 1	9.7	2.4	14.3	4.2
Hatchery Fence	10.3	2.9	19.0	4.1

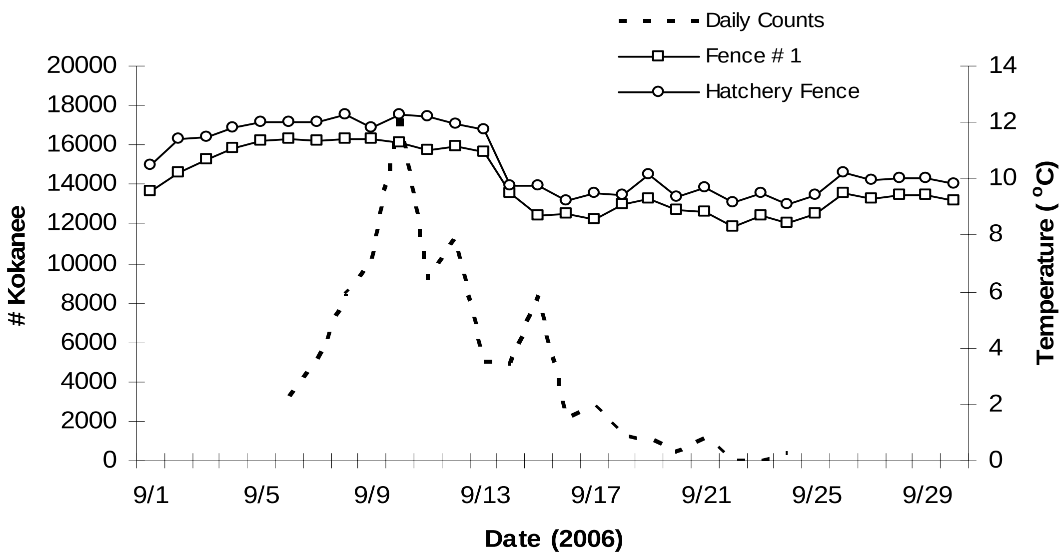

Figure 2. Daily kokanee numbers entering HCSC and temperature profiles measured at Hatchery Fence and Fence # 1 from September 1 to September 30, 2006. Kokanee were allowed into the channel starting September 6.

Daytime heating of water through the length of the channel most likely accounts for the difference in temperature since most of the channel has little instream cover. Similarly, diurnal variation between maximum and minimum temperatures was larger at the Hatchery Fence (Table 1).

HCSC flows averaged 0.32 m^3/s during most of the adult migration in 2006 (Fig 3). Maximum discharge of 0.36 m^3/s was recorded on September 1 with additional peaks occurring on September 15 and 16. Shortly after September 1, flows decreased to 0.30 m^3/s for the remainder of the adult migration except for the aforementioned peaks occurring on September 15 and 16.

Turbidity samples were periodically taken from September 3 to September 30, 2006. Mean turbidity, a measurement of suspended particles, was higher at the upper end (Fence # 2) at 0.125 NTU compared to the lower end (Hatchery Fence) at 0.11 NTU in HCSC. Turbidity was observed to have spiked on September 14, after a day of heavy rains (Fig. 3).

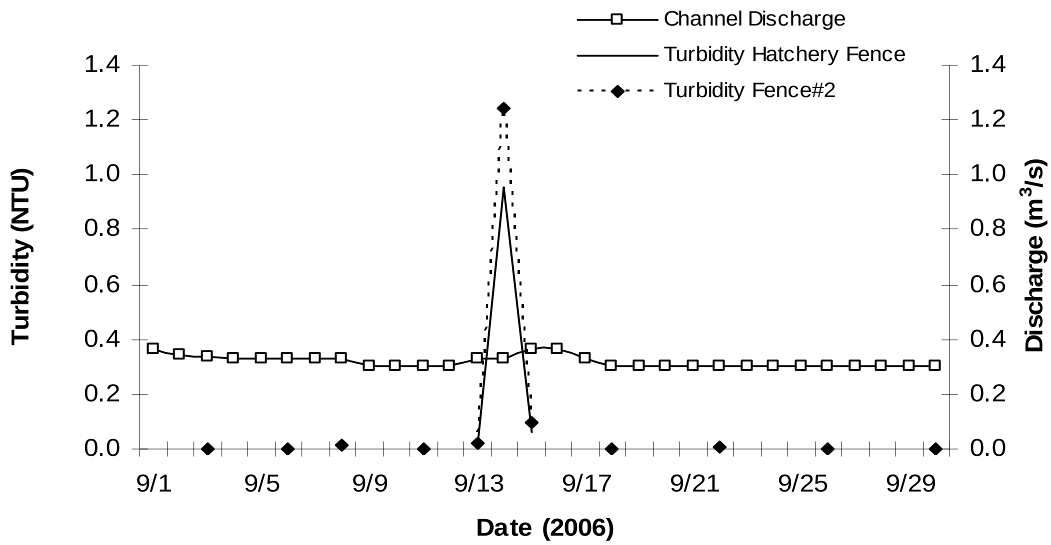

Figure 3. Daily discharge (m^3/s) and daily turbidity measured at Hatchery Fence and Fence # 2 from September 1 to September 30, 2006.

Adult Kokanee Enumerations

The 2006 adult kokanee migration commenced on August 24 when adult kokanee were first observed at the Hatchery Fence and was complete by September 24. However, appreciable numbers were delayed and most did not arrive until September 6 when enumeration into HCSC began (Fig. 2). Stream counts below HCSC were conducted on September 26 and 27. As in past years, beaver activity was problematic throughout the run in 2006 (Barney 2006b).

In total, 122,447 kokanee spawners (natural stream + channel) were estimated to have returned to Hill Creek in 2006. Of this, 92,567 kokanee were manually enumerated into the spawning channel while 19,920 kokanee (expanded by 1.5 = 29,880) were counted in the natural stream below HCSC. The peak count occurred on September 10 when 17,678 fish were enumerated into the channel. The 2006 escapement was appreciably smaller than the 2005 escapement for both the natural stream and spawning channel (Table 2).

Table 2. Hill Creek kokanee escapements to HCSC and natural stream (x1.5) since channel commencement in 1984.

Year	Spawning Channel	Stream Peak Count x 1.5	Spawning Channel + Stream
1984	36,162	33,774	69,936
1985	40,183	19,993	60,176
1986	35,199	40,690	75,889
1987	73,437	34,091	107,528
1988	150,000	148,112	298,112
1989	150,000	173,437	323,437
1990	185,750	91,489	277,239
1991	130,973	104,470	235,443
1992	75,000	166,871	241,871
1993	218,968	54,711	273,679
1994	76,059	98,165	174,224
1995	26,368	47,086	73,454
1996	17,468	11,604	29,072
1997	37,633	21,344	58,977
1998	28,396	14,144	42,540
1999	78,024	22,915	100,939
2000	102,597	39,506	142,103
2001	122,400	14,696	137,096
2002	151,826	43,236	195,062
2003	133,951	21,875	155,826
2004	199,820	86,370	286,190
2005	142,755	67,050	209,805
2006	92,567	29,880	122,447
Average	100,241	60,240	160,480

Adult Kokanee Sampling

Spawner Size and Sex Ratio

Size at maturity indicated that male kokanee spawners were larger at 262 mm (n=104) compared to female kokanee spawners at 256 mm (n=102, Table 3, Appendix B). Similarly, mean weight of males was slightly heavier at 212 g compared to females at 193 g. From a total of 206 samples obtained throughout the run, mean size of spawners (male + female) increased in 2006 compared to 2005 (Fig. 4).

Table 3. Sample size (n), mean length (mm) and weight (g) of male and female kokanee from HCSC in 2006.

	Sample Size	Length (mm)		Weight (g)	
	n	Mean	Range	Mean	Range
Female	102	256	225-280	193	140-260
Male	104	262	235-288	212	160-270

The male to female sex ratio was 1:0.96 (51% male and 49% female). This translates into an estimated total of 45,358 viable females within the spawning channel. Applying a 1:1

sex ratio, a total of 14,940 gravid females utilized the natural stream below HCSC in 2006.

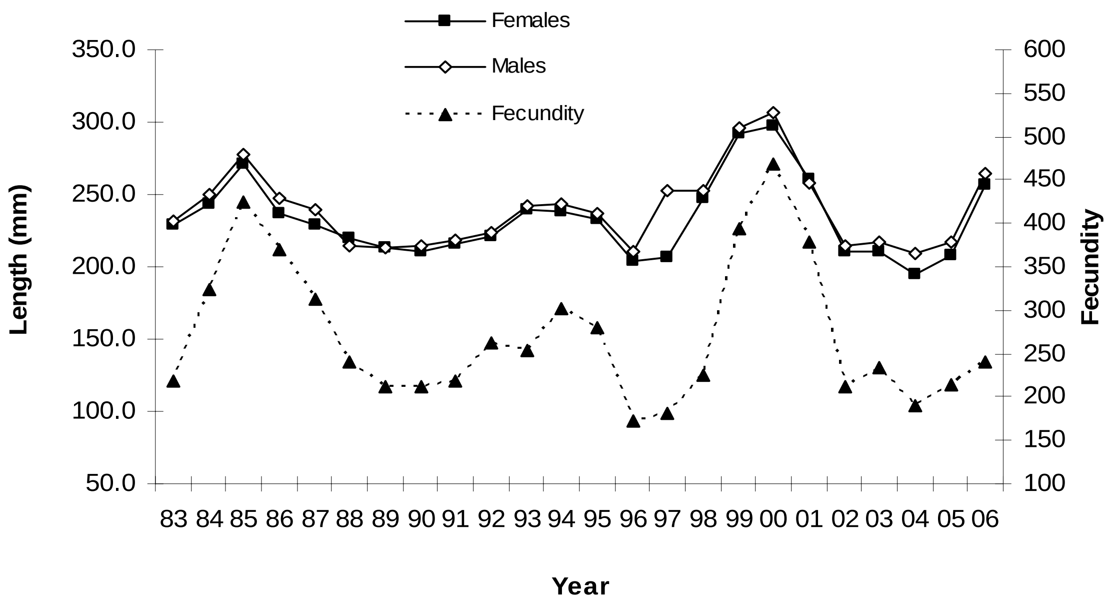

Figure 4. Mean length (mm) of male and female Hill Creek kokanee spawners and mean fecundity from 1983 to 2006.

Fecundity

In 2006, a mean fecundity of 240 eggs per female was derived from 53 female kokanee (Table 4). In addition, 112 post-spawner samples were randomly taken to determine a mean retention of 6.2 eggs per female. Fecundity in 2006 of 240 eggs per female was appreciably higher compared to 2005 of 214 eggs per female. Average egg-retention estimates in 2006 (6.2 eggs per female) was slightly higher compared to 2005 (5.8 eggs per female) reported in Porto (2006b).

Table 4. Fecundity (n=53) and egg retention (n=112) samples taken at HCSC in 2006

	n	Mean	Range
Fecundity	53	240	200-275
Egg-retention	112	6.2	0-33

Potential egg deposition for the channel was estimated to be ~10,604,700. Calculations for channel PED are as follows:

$$45{,}358 \times (240 - 6.2) = 10{,}604{,}700.$$

Potential egg deposition for Hill Creek (natural stream) was estimated to be 3,492,972 based on an assumed 1:1 ratio over a 23 year period. Calculations for stream PED are as follows:

$$(29{,}880 / 2) \times (240 - 6.2) = 3{,}492{,}972$$

Total egg deposition for the combined spawning channel and the natural stream was estimated to be 14,097,672 eggs. The estimate in 2006 was considerably lower when compared to 19,970,138 eggs in 2005.

Projected Fry Emergence and Subsequent Adult Returns

Projected 2007 spring fry emergence for HCSC, based on a conservative egg-to-fry survival of 30%, would be ~3,181,410 fry. Use of this conservative egg-to-fry survival estimate is well below the 22 year average survivals of 42% in HCSC between 1984 and 2006, excluding production problems in 2004 and 2005 (Andrusak 2006). In addition, projected spring fry emergence from the natural stream, based on a 5 % egg-to-fry survival, would be 174,649 fry. Natural stream survival estimates for kokanee of 5% have been reported by Redfish Consulting Ltd. (1999). Total projected 2007 fry production from Hill Creek is estimated to be ~3.4 million fry.

Based on a fry-to-adult survival rate of 5%, the projected adult return in 2010 from the 2007 cohort is estimated to be ~167,803. The fry-to-adult survival rates are based on historical survival rates in previous kokanee reports (e.g., Thorp et al. 2003, Manson 2005). Projections are provided as a rough approximation and should be used as a guide only since fry to adult survival rates have varied from 1% to 9% (FWCP file data).

DISCUSSION

HCSC kokanee escapements represent an index of abundance which is integral to fisheries management on Arrow Lakes Reservoir (Andrusak et al 2004). Kokanee are considered a keystone species which provide an important forage base for many other species of fish within ALR. Concern over the rapid decline in kokanee numbers to precariously low levels in the late 1990’s, as a result of impoundment and subsequent nutrient abatement, prompted the initiation of a whole lake fertilization experiment on ALR in 1997. The data obtained to date indicates HCSC operations combined with nutrient addition (whole lake fertilization) to the reservoir has restored kokanee abundance to levels similar to the late 1980’s to near pre-impoundment levels in some years (Schindler et al. 2006).

The 2006 escapement, for both the HCSC and natural stream combined, was well below the average escapement of ~160,000 recorded since 1983 (Appendix C). Total escapement to the Hill Creek system was highest in 1989 (323,437) and lowest in 1996 (29,072).In addition, slightly over 82% of the total escapement was enumerated into the HCSC in 2006 which is well above the 64% average since 1984.

An increase in kokanee average size was observed in 2006 (260 mm) so that it was similar to the size observed in 2001 (259 mm, Appendix D). As a result, not surprisingly, mean fecundity (240 eggs per female) also increased compared to the estimate for 2005 (214 eggs per female) but slightly below the 23 year average since 1983 (272 eggs per female). The sex ratio in 2006 of 1:0.96 (male:female) has remained fairly consistent since 1983, females have constituted on average 47% of the runs over the 23 year period. Egg retention in 2006 (6.2 eggs per female) are similar to those recorded 1998 to 2000 and from 2003 to 2005 (5.8 eggs per female) reported in Porto (2006b).Although no age data was available from samples taken at HCSC in 2006, age 3+ has been the dominant age at maturity in ALR in past years (Schindler et al. 2006).

Egg deposition, for the combined spawning channel and the natural stream, was estimated to be 14,097,672 eggs in 2006. This estimate was lower when compared to 19,970,138 eggs in 2005 (Porto 2006b). Importantly the egg deposition of 10,604,700 is above the average egg deposition of 8,000,000 for HCSC since 1984 (Appendix C). Spring fry emergence for HCSC in 2007, based on a conservative egg-to-fry survival of 30%, is projected to be ~3,181,410 fry. Note that using this rate is conservative since it is well below the 20 year average survival of 42% between 1984-2003 and 2006 (Andrusak 2006). Although fry to adult survival is highly variable, subsequent recruitment based on a fry-to-adult survival rate of 5% project ~167,803 adult kokanee could return from the 2007 cohort. The projected return from the 2007 cohort is critically important since HCSC is expected to experience low returns from 2007 to 2009 due to lower fry production from the channel in 2003 and virtually no fry in 2004 and 2005. As well, it is highly likely that the 2007-escapements may see a significant shift to an earlier age at maturity (e.g. age 2+) as a result of in-lake compensatory mechanisms. Moreover, this effect may also increase the 2009 escapement that might otherwise be lower.

Kokanee and their anadromous form, sockeye salmon (*Oncorhynchus nerka*), often display compensatory growth responses to variations in stock densities (Hyatt and Stockner 1985, Myers et al. 1997, Myers 2001). The increase in spawner size in 2006 at Hill Creek most likely reflects a density related growth response to in-lake dynamics. Increased fecundity and spawner length observed in 2006 at HCSC coincided with the decrease in total spawner abundance in 2006 (Fig. 5). The increase in fecundity is related to an increase in the average size at maturity of female spawners in 2006 as shown by a regression between the average length of female spawners and the average fecundity (Fig. 6). Similar to many interior large lakes/reservoirs, prevailing limnological conditions, inter-cohort density (Levy and Wood 1992), and predator-prey dynamics within ALR all contribute to growth, fecundity and age responses observed in spawning kokanee at HCSC (Pieters et al. 2003, Andrusak et al. 2006).

HCSC has been the largest single kokanee producer in the ALR since the late 1980’s, supporting >30% of all kokanee spawners since 1988 (Fig. 5). Thus it appears that kokanee production from HCSC is integral to sustaining many piscivorous populations of fish within the ALR. Studies from ALR and neighboring Kootenay Lake have indicated the importance of kokanee prey in diets of many piscivorous species (Andrusak and Parkinson 1984, Arndt 2004b). As well, rainbow trout and other large piscivorous species, along with kokanee, support an important recreational fishery on Arrow Lakes Reservoir while providing local economic benefits (Arndt 2004a).

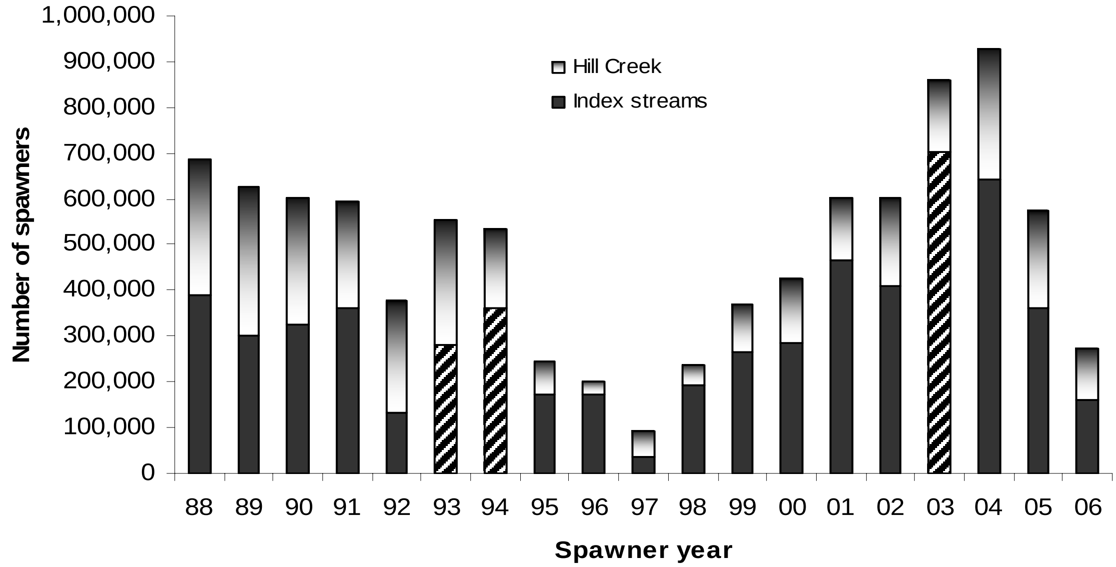

Figure 5. Relative contribution of Hill Creek spawners vs. those estimated in the major index streams throughout the basin. Note: Major index streams were not enumerated in 1993, 1994 and 2003 and therefore indicate predicted escapements. Data for index streams are from expanded air or ground counts (MoE data on file).

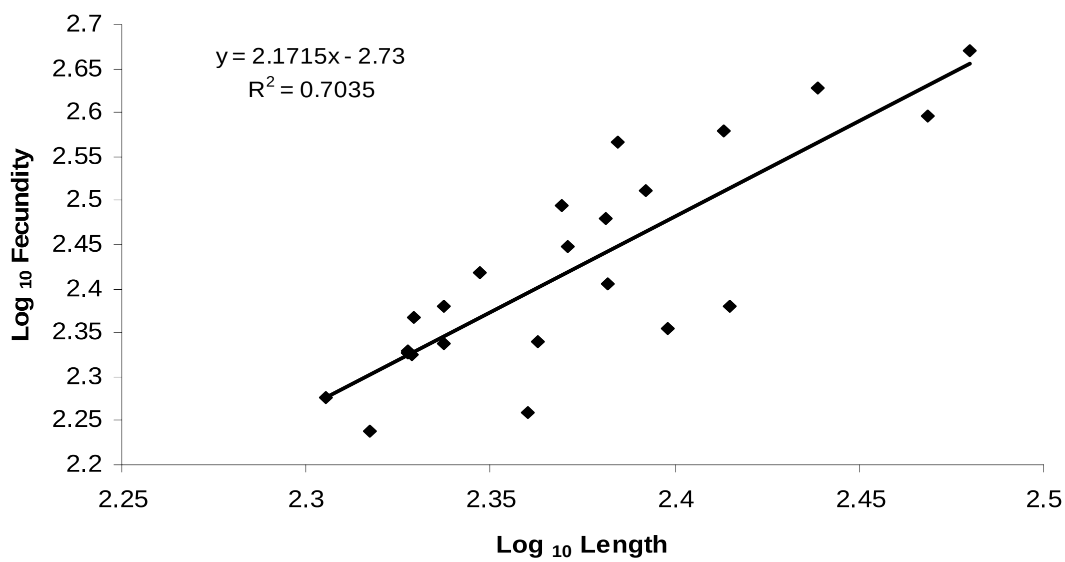

Figure 6. Linear relationship between transformed mean length and mean fecundity for HCSC from 1983 to 2006.

In summary, HCSC was originally intended to restore an estimated 0.5 million adult kokanee and ~500 adult rainbow trout (Lindsay 1982) to a system that, historically, may have had kokanee escapements exceeding 1.0 million (Sebastian et al. 2000). Returns to the channel have yet to reach 0.5 million kokanee spawners, even under the increased reservoir productivity afforded by fertilization. However, the channel does produce a significant proportion of all kokanee in the ALR and data from the HCSC provide important information for analysis of trends in the health and status of the kokanee population. Improvement to the in-lake carrying capacity, due to nutrient addition, may result in increased future kokanee escapements to HCSC and ALR.

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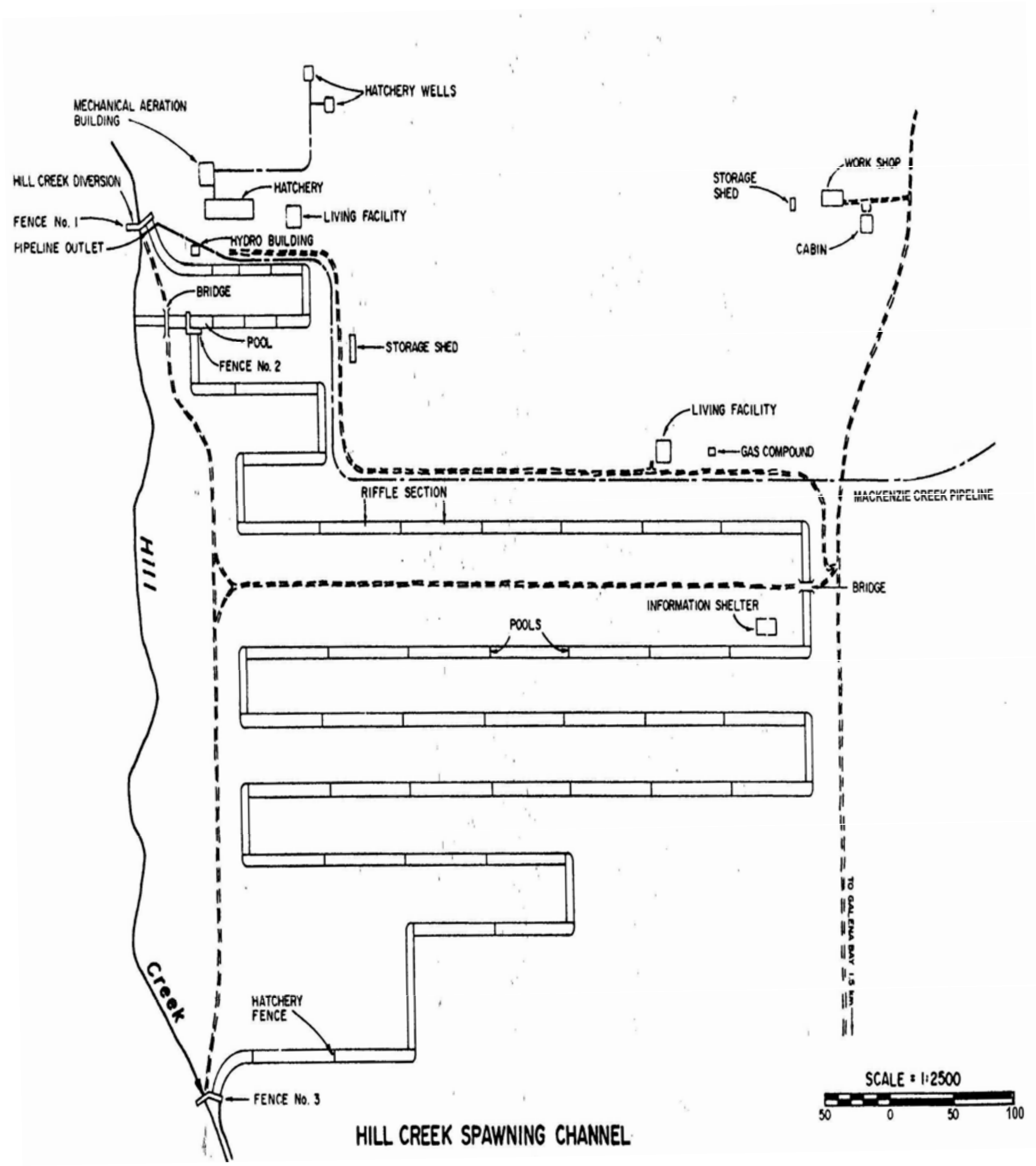
APPENDIX A: SCHEMATIC OF HILL CREEK SPAWNING CHANNEL



Schematic of Hill Creek Spawning Channel, completed in 1980 and operational by 1984

APPENDIX-B. 2006 HCSC KOKANEE SAMPLING DATA

Date	Sample #	Species	Fork Length	Weight	Sex	Fecundity	Age	Otolith Sample
9/6/2006	1	Kokanee	256	185	M			
9/6/2006	2	Kokanee	250	180	M			
9/6/2006	3	Kokanee	239	180	M			
9/6/2006	4	Kokanee	262	210	M			
9/6/2006	5	Kokanee	241	180	F	217		
9/6/2006	6	Kokanee	250	190	F	228		
9/6/2006	7	Kokanee	258	200	F	251		
9/6/2006	8	Kokanee	255	190	M			
9/7/2006	9	Kokanee	244	175	M			
9/7/2006	10	Kokanee	260	210	M			
9/7/2006	11	Kokanee	257	210	M			
9/7/2006	12	Kokanee	239	165	M			
9/7/2006	13	Kokanee	253	185	F	230		
9/7/2006	14	Kokanee	240	170	F	229		
9/7/2006	15	Kokanee	250	220	M			
9/7/2006	16	Kokanee	250	180	F	232		
9/7/2006	17	Kokanee	260	220	F	260		
9/8/2006	18	Kokanee	255	190	F	233		
9/8/2006	19	Kokanee	262	220	M			
9/8/2006	20	Kokanee	258	210	M			
9/8/2006	21	Kokanee	255	200	M			
9/8/2006	22	Kokanee	262	200	F	240		
9/8/2006	23	Kokanee	264	205	F	238		
9/8/2006	24	Kokanee	258	200	M			
9/8/2006	25	Kokanee	258	200	F	230		
9/8/2006	26	Kokanee	248	180	F	228		
9/8/2006	27	Kokanee	260	220	F	260		
9/8/2006	28	Kokanee	263	220	M			
9/8/2006	29	Kokanee	257	190	M			
9/8/2006	30	Kokanee	263	225	M			
9/8/2006	31	Kokanee	271	235	M			
9/8/2006	32	Kokanee	245	175	M			
9/8/2006	33	Kokanee	256	205	M			
9/8/2006	34	Kokanee	263	215	F	257		
9/8/2006	35	Kokanee	225	170	F	201		
9/9/2006	36	Kokanee	264	210	F	268		
9/9/2006	37	Kokanee	254	185	M			
9/9/2006	38	Kokanee	263	215	M			
9/9/2006	39	Kokanee	272	240	M			
9/9/2006	40	Kokanee	279	260	F	257		
9/9/2006	41	Kokanee	257	185	F	232		
9/9/2006	42	Kokanee	250	175	M			
9/9/2006	43	Kokanee	264	220	F	240		
9/9/2006	44	Kokanee	260	210	F	246		
9/9/2006	45	Kokanee	266	200	M			
9/9/2006	46	Kokanee	265	245	M			
9/9/2006	47	Kokanee	255	185	F	232		
9/10/2006	48	Kokanee	256	185	M			
9/10/2006	49	Kokanee	270	230	M			
9/10/2006	50	Kokanee	265	245	M			
9/10/2006	51	Kokanee	260	200	M	246		
9/10/2006	52	Kokanee	255	185	F	236		
9/10/2006	53	Kokanee	264	225	F			
9/10/2006	54	Kokanee	245	175	M	201		
9/10/2006	55	Kokanee	260	200	F	269		
9/10/2006	56	Kokanee	266	225	F			
9/10/2006	57	Kokanee	260	210	M			
9/10/2006	58	Kokanee	273	230	M	270		
9/10/2006	59	Kokanee	249	175	F	230		
9/10/2006	60	Kokanee	250	180	F			
9/10/2006	61	Kokanee	260	190	M	237		
9/11/2006	62	Kokanee	275	245	F	263		
9/11/2006	63	Kokanee	278	250	F	275		
9/11/2006	64	Kokanee	249	175	F	224		
9/11/2006	65	Kokanee	255	185	F	233		
9/11/2006	66	Kokanee	260	240	M			1
9/11/2006	67	Kokanee	275	260	F	240		2
9/11/2006	68	Kokanee	276	240	F	262		3
9/11/2006	69	Kokanee	266	230	F	266		4
9/11/2006	70	Kokanee	262	220	F	270		5
9/11/2006	71	Kokanee	270	230	M			6
9/11/2006	72	Kokanee	280	265	M			7
9/11/2006	73	Kokanee	252	175	F	244		8
9/11/2006	74	Kokanee	270	230	M			9
9/11/2006	75	Kokanee	268	220	M			10
9/11/2006	76	Kokanee	265	200	F	267		
9/12/2006	77	Kokanee	274	240	M			
9/12/2006	78	Kokanee	258	185	M			
9/12/2006	79	Kokanee	263	215	M			
9/12/2006	80	Kokanee	262	200	F	254		
9/12/2006	81	Kokanee	264	205	F	257		11
9/12/2006	82	Kokanee	260	200	F	228		12
9/12/2006	83	Kokanee	260	145	F	230		13
9/12/2006	84	Kokanee	240	170	F	200		14
9/12/2006	85	Kokanee	245	175	M			15
9/12/2006	86	Kokanee	269	230	M			16
9/12/2006	87	Kokanee	265	250	M			17
9/12/2006	88	Kokanee	268	190	M			18
9/12/2006	89	Kokanee	273	240	M			19
9/12/2006	90	Kokanee	285	255	M			20
9/12/2006	91	Kokanee	260	185	F	234		21
9/13/2006	92	Kokanee	250	175	F	213		
9/13/2006	93	Kokanee	268	220	M			
9/13/2006	94	Kokanee	264	215	M			
9/13/2006	95	Kokanee	262	230	M			
9/13/2006	96	Kokanee	266	225	M			
9/13/2006	97	Kokanee	259	190	M			
9/13/2006	98	Kokanee	257	190	F	221		
9/13/2006	99	Kokanee	267	210	M			22
9/13/2006	100	Kokanee	273	225	M			23
9/13/2006	101	Kokanee	268	200	F	247		24

APPENDIX-B. CONTINUED

Date	Sample #	Species	Fork Length	Weight	Sex	Fecundity	Age	Otolith Sample
9/13/2006	102	Kokanee	245	170	F	208		25
9/13/2006	103	Kokanee	276	250	M			26
9/13/2006	104	Kokanee	262	235	M			27
9/13/2006	105	Kokanee	255	180	F	232		28
9/13/2006	106	Kokanee	262	220	M			29
9/13/2006	107	Kokanee	250	160	M			30
9/13/2006	108	Kokanee	267	220	M			31
9/14/2006	109	Kokanee	268	220	F	242		
9/14/2006	110	Kokanee	255	180	F	220		
9/14/2006	111	Kokanee	262	220	M			
9/14/2006	112	Kokanee	254	185	M			
9/14/2006	113	Kokanee	260	205	M			
9/14/2006	114	Kokanee	271	225	F	243		
9/14/2006	115	Kokanee	260	210	M			
9/14/2006	116	Kokanee	249	170	F			
9/14/2006	117	Kokanee	254	180	F			
9/14/2006	118	Kokanee	266	225	M			32
9/14/2006	119	Kokanee	265	190	F	253		33
9/14/2006	120	Kokanee	257	180	F			34
9/14/2006	121	Kokanee	277	260	M			35
9/14/2006	122	Kokanee	254	180	F			36
9/14/2006	123	Kokanee	250	175	F			37
9/14/2006	124	Kokanee	256	180	F			38
9/14/2006	125	Kokanee	260	190	F			39
9/14/2006	126	Kokanee	264	215	M			40
9/15/2006	127	Kokanee	262	230	M			41
9/15/2006	128	Kokanee	250	170	F			
9/15/2006	129	Kokanee	258	185	F			
9/15/2006	130	Kokanee	256	185	M			
9/15/2006	131	Kokanee	260	205	F			
9/15/2006	132	Kokanee	263	200	M			
9/15/2006	133	Kokanee	272	235	M			
9/15/2006	134	Kokanee	267	200	F			
9/15/2006	135	Kokanee	245	170	F			
9/15/2006	136	Kokanee	264	210	F			
9/15/2006	137	Kokanee	269	230	M			
9/15/2006	138	Kokanee	266	210	M			
9/15/2006	139	Kokanee	227	140	F			42
9/15/2006	140	Kokanee	250	175	M			43
9/15/2006	141	Kokanee	249	175	M			44
9/15/2006	142	Kokanee	262	235	F			45
9/15/2006	143	Kokanee	254	180	F			46
9/15/2006	144	Kokanee	250	175	F			47
9/15/2006	145	Kokanee	260	220	M			48
9/15/2006	146	Kokanee	262	225	M			49
9/15/2006	147	Kokanee	275	255	M			50
9/15/2006	148	Kokanee	248	180	F			51
9/16/2006	149	Kokanee	258	185	F			
9/16/2006	150	Kokanee	257	185	M			
9/16/2006	151	Kokanee	256	195	M			
9/16/2006	152	Kokanee	271	220	F			
9/16/2006	153	Kokanee	264	200	F			
9/16/2006	154	Kokanee	258	195	F			
9/16/2006	155	Kokanee	243	175	F			
9/16/2006	156	Kokanee	268	235	M			
9/16/2006	157	Kokanee	254	180	F			
9/16/2006	158	Kokanee	252	185	F			52
9/16/2006	159	Kokanee	235	165	M			53
9/16/2006	160	Kokanee	258	210	M			54
9/16/2006	161	Kokanee	250	180	F			55
9/16/2006	162	Kokanee	247	175	F			56
9/16/2006	163	Kokanee	263	220	M			57
9/16/2006	164	Kokanee	250	190	F			58
9/16/2006	165	Kokanee	260	210	M			59
9/16/2006	166	Kokanee	255	195	F			60
9/16/2006	167	Kokanee	260	220	M			61
9/19/2006	168	Kokanee	247	170	F			62
9/19/2006	169	Kokanee	256	190	F			63
9/19/2006	170	Kokanee	256	200	M			64
9/19/2006	171	Kokanee	280	230	F			65
9/19/2006	172	Kokanee	255	190	M			66
9/19/2006	173	Kokanee	262	210	M			67
9/19/2006	174	Kokanee	259	210	M			68
9/19/2006	175	Kokanee	258	195	F			69
9/19/2006	176	Kokanee	254	180	F			70
9/22/2006	177	Kokanee	262	200	M			71
9/22/2006	178	Kokanee	253	180	F			72
9/22/2006	179	Kokanee	242	170	F			73
9/22/2006	180	Kokanee	250	165	M			74
9/22/2006	181	Kokanee	265	250	M			75
9/22/2006	182	Kokanee	255	185	F			76
9/22/2006	183	Kokanee	256	175	F			77
9/22/2006	184	Kokanee	260	200	M			78
9/22/2006	185	Kokanee	256	185	F			79
9/23/2006	186	Kokanee	274	230	M			80
9/23/2006	187	Kokanee	245	175	M			81
9/23/2006	188	Kokanee	254	180	F			82
9/23/2006	189	Kokanee	271	230	M			83
9/23/2006	190	Kokanee	260	215	M			84
9/23/2006	191	Kokanee	264	195	F			85
9/23/2006	192	Kokanee	267	220	M			86
9/23/2006	193	Kokanee	249	170	F			87
9/23/2006	194	Kokanee	252	175	F			88
9/23/2006	195	Kokanee	263	230	M			89
9/23/2006	196	Kokanee	254	180	F			90
9/24/2006	197	Kokanee	275	250	M			91
9/24/2006	198	Kokanee	254	190	F			92
9/24/2006	199	Kokanee	288	270	M			93
9/24/2006	200	Kokanee	255	185	F			94
9/24/2006	201	Kokanee	256	185	M			95
9/24/2006	202	Kokanee	265	210	M			96
9/24/2006	203	Kokanee	257	190	F			97
9/24/2006	204	Kokanee	265	220	M			98
9/24/2006	205	Kokanee	255	185	F			99
9/24/2006	206	Kokanee	253	185	F			100

APPENDIX-C. HCSC ESCAPEMENT AND PRODUCTION 1979-2006

Brood Year	Adult Return	Adult # Channel	Channel Production Source(s)			Fry Output[4]
			EE[1]	FF[2]	Wild[3]	
1979	10,899	n/a	-	-	-	-
1980	11,147	n/a	-	-	-	-
1981	n/a	n/a	2,000,000	-	-	1,284,026
1982	5,175	n/a	1,800,000	-	-	1,147,503
1983	15,277	n/a	-	-	-	-
1984	69,936	36,162	-	175,000	4,374,155	3,025,387
1985	60,176	40,183	-	-	8,994,964	4,287,495
1986	75,889	35,199	174,000	-	5,883,261	3,972,643
1987	107,528	73,437	-	-	9,916,980	4,356,112
1988	298,112	150,000	-	-	13,780,785	7,920,814
1989	323,437	150,000	-	-	15,706,062	5,755,875
1990	277,239	180,000	-	-	12,364,895	5,486,264
1991	235,443	75,000	-	-	7,583,615	2,866,345
1992	241,871	75,000	-	-	8,628,124	3,003,165
1993	273,679	75,000	500,000	123,695	8,540,704	3,432,935
1994	174,224	75,000	-	59,077	9,415,760	2,218,154
1995	73,840	16,328	108,000	125,582	2,240,450	675,000
1996	29,072	25,030	310,000	129,514	2,154,140	687,730
1997	58,977	22,566	115,500	172,745	1,985,808	934,076
1998	42,540	19,087	-	357,784	1,805,630	857,810
1999	100,939	78,024	-	347,462	12,381,394	3,721,752
2000	142,103	102,597	-	-	22,359,457	8,458,266
2001	137,096	122,400	-	-	18,815,207	8,320,343
2002	195,062	151,826	-	-	12,264,578	3,925,414
2003	155,279	133,951	-	-	14,432,796	57,165
2004	286,190	199,820	-	-	9,526,608	135,670
2005	209,805	142,755	-	-	12,986,880	4,660,360
2006	122,447	92,567	-	-	10,604,700	-

1 **EE** = Denotes eyed-egg plant (fry production assumed to be 50% of eyed egg #).

2 **FF** = Denotes fed-fry release.

3 **Wild** = Wild egg deposition estimate.

4 **Sampled Fry** = Fry enumeration data from spawning channel production only;
note that these numbers are for the brood year noted to the left;
actual sampling was spring of subsequent year.

APPENDIX-D. HCSC SUMMARY OF KOKANEE ATTRIBUTES 1983-2006.

Year	Sample Size	Sample Size M	Sample Size F	% female	M : F	Male Size Range (cm)	Male Size Mean (cm)	Female Size Range (cm)	Female Size Mean (cm)	Male Size Mean (cm)	Mean Length	Fecundity Range	Mean Fecundity
1983	67	32	35	52%	1:1.09	21.0 - 26.4	23.2	21.1 - 25.5	22.9	23.2	23.05	112 - 327	219
1984	119	69	50	42%	1:0.72	23.3 - 26.5	25	22.2 - 26.7	24.3	25	24.65	158 - 425	324
1985	100	45	55	55%	1:1.22	24.0 - 33.0	27.8	23.8 - 32.1	27.1	27.8	27.45	233 - 677	425
1986	98	53	45	46%	1:0.85	22.0 - 28.9	24.8	21.1 - 29.4	23.7	24.8	24.25	215 - 604	369
1987	123	68	55	45%	1:0.81	17.5 - 32.6	23.9	19.2 - 26.3	22.9	23.9	23.4	163 - 579	313
1988	142	86	56	39%	1:0.65	19.2 - 26.4	21.5	19.8 - 27.8	22	21.5	21.75	131 - 398	240
1989	113	55	58	51%	1:1.05	19.0 - 25.6	21.3	19.2 - 25.6	21.3	21.3	21.3	131 - 323	211
1990	147	96	51	35%	1:0.53	19.4 - 26.1	21.5	19.6 - 24.9	21	21.5	21.25	131 - 328	212
1991	148	75	73	49%	1:0.97	19.7 - 24.2	21.9	19.8 - 23.8	21.6	21.9	21.75	119 - 347	218
1992	175	55	120	69%	1:2.18	20.4 - 26.1	22.4	19.0 - 26.1	22.1	22.4	22.25	57 - 450	262
1993	301	143	158	52%	1:1.05	20.7 - 27.9	24.2	21.8 - 26.4	24	24.2	24.1	153 - 352	254
1994	298	146	152	51%	1:1.04	21.3 - 27.0	24.3	21.0 - 27.0	23.8	24.3	24.05	149 - 498	302
1995	158	78	80	51%	1:1.03	21.0 - 26.1	23.7	20.7 - 25.4	23.3	23.7	23.5	145 - 470	280
1996	101	48	53	52%	1:1.04	18.1 - 24.3	21.1	18.2 - 22.7	20.4	21.1	20.75	106 - 239	173
1997	128	64	64	50%	1:1.00	18.1 - 24.8	25.2	18.1 - 23.1	20.6	25.2	22.9	97 - 268	182
1998	104	58	46	44%	1:0.79	23.0 - 27.0	25.2	23.0 - 27.5	24.8	25.2	25	123 - 346	226
1999	115	68	47	41%	1:0.69	26.6 - 32.0	29.6	25.8 - 32.2	29.2	29.6	29.4	272 - 628	394
2000	225	120	105	47%	1:0.88	26.6 - 35.6	30.6	26.0 - 35.0	29.8	30.6	30.2	228 - 862	469
2001	242	142	100	41%	1:0.70	11.0 - 42.6	25.8	14.0 - 39.3	26	25.8	25.9	183 - 904	379
2002	287	175	112	39%	1:0.64	18.5 - 26.2	21.5	18.4 - 24.7	21	21.5	21.25	106 - 538	212
2003	237	123	114	48%	1:0.93	17.3 - 35.8	21.7	17.7 - 38.4	21	21.7	21.35	129 - 1272	233
2004	116	75	41	35%	1:0.38	18.5 - 31.8	20.9	18.0 - 24.5	19.5	20.9	20.2	105 - 340	189
2005	205	106	99	48%	1:0.93	19.5 - 28.0	21.7	19.0 - 20.8	20.8	21.7	21.25	163 - 272	214
2006	206	104	102	50%	1:0.96	23.5-28.8	26.4	22.7-27.8	25.6	26.4	26.0	200-275	240