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Part I.

Hatchery kokanee investigation in Lake Roosevelt, 2005

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Part II.

Temperature influences on precocial maturation of hatchery reared kokanee salmon

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Annual Report Submitted to:
Spokane Tribe of Indians
PO Box 480
Wellpinit, Washington 99040

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Part I

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Abstract

Hatchery kokanee salmon have been released into Lake Roosevelt since 1987 as part of a larger effort to enhance the fishery. Since 1996, post smolt releases have had modest success, with a put-and-take fishery established in the middle reservoir, but the larger goal of a self-sustaining run has not being realized. Various studies have indicated walleye predation, entrainment, and kokanee stock origin as limiting factors. To address these, in 2004, the Lake Roosevelt Fisheries Evaluation program began stocking kokanee fry into Big Sheep Creek, a tributary in the upper reservoir. In 2005, fry were also released in Onion and Hawk creeks as part of a fry to post-smolt comparison study. In addition, adults returning to key locations were collected and spawned in attempts to create a "Lake Roosevelt" stock of kokanee. In the fall of 2005, Big Sheep Creek was monitored daily via a weir trap, and Onion and Hawk creeks were sampled via backpack and boat electrofishing to verify the absence of wild kokanee runs. Otolith samples were taken from smaller sized kokanee collected throughout Lake Roosevelt to monitor distribution. Four wild kokanee and none from the fry plants were collected in the Big Sheep Creek trap. No kokanee were collected in Onion Creek, verifying the absence of a wild run. Similar to previous years, a small run (seven kokanee)of wild kokanee were captured at Hawk Creek. Hatchery kokanee returning to Sherman Creek were spawned and held at the Colville Hatchery for rearing. Trapping of all three creeks is planned for the fall of 2006, when adults from the post-smolt releases are expected to return. Fry plants for Onion and Hawk creeks are planned through 2007 with trapping planned through 2010, at which time managers will decide if fry planting of fry should continue.

Introduction

Kokanee salmon (*Oncorhynchus nerka kennerlyi*), the freshwater form of sockeye salmon, have been stocked into Franklin D. Roosevelt Lake (Lake Roosevelt) since 1987 as partial mitigation for lost anadromous salmon and steelhead runs blocked by the construction of Grand Coulee Dam in 1939 (Northwest Power Planning Council 1987). The Lake Roosevelt Fisheries Evaluation Program (LRFEP) management goals for Lake Roosevelt kokanee include: 1) providing a hatchery kokanee fishery; 2) creating a self-sustaining fishery, where eggs are taken from mature fish collected from Lake Roosevelt and reared in hatcheries; and 3) to provide a subsistence kokanee fishery for Native American Tribes (McLellan 2005).

The Lake Roosevelt hatchery kokanee program was initially designed to produce 10 million fry (T. Peone, Spokane Tribal Hatchery). However, fry plants conducted in the early 1990's were unsuccessful, with less than 0.01% of the fry returning as adults over multiple years (Tilson et al. 1996). The majority (99%) of the adult kokanee collected were from post-smolt plants; therefore in 1996 the program switched to 100% post-smolt releases with a target of 1 million.

The larger size of the post-smolts at release (10/lb) put the Spokane Tribal Hatchery at maximum capacity and required the implementation of net pen rearing as well as other adaptive management techniques to meet release goals. Post-smolt release strategies have had varying success since the program was implemented, with the most successful being a "direct water" release strategy at Fort Spokane (McLellan et al. 2004). This release strategy increased post-stock survival by spatially moving kokanee away from heavy walleye predation areas and by providing a deep limnetic refuge for yearling kokanee. This release strategy was adopted by the management team to create a put-and-take fishery. The success of this plant was indicated by recoveries of marked fish in the Two Rivers Trout Derby where 45.6%, 62.3%, and 93,3% of the kokanee captured were hatchery origin in 2001, 2002, and 2003 respectively (McLellan et al. 2004).

Since 2000, the LRFEP has worked with Canadian agencies to obtain Meadow Creek kokanee eggs. Meadow Creek, a tributary to the north arm of Kootenai Lake, British Columbia, currently supports an abundant native kokanee run. Studies conducted to compare the performance between Meadow Creek stock and the coastal strain currently used in Lake Roosevelt (Lake Whatcom), found that the native kokanee significantly outperformed the Lake Whatcom kokanee, with 2 to 6.5 times more Meadow Creek kokanee retuning than Lake Whatcom kokanee (McLellan and Scholz 2001, 2002b, 2003). Meadow Creek kokanee are now the preferred stock of Lake Roosevelt fisheries managers.

Up river Canadian kokanee are also believed to be the driving force behind the wild kokanee population in Lake Roosevelt. A genetic study of the wild kokanee in Lake Roosevelt, demonstrated that the population is a mixture of SanPoil River and other upper Columbia River sources including Norns Creek and Hill Creek Hatchery (Loxterman and Young 2003). Therefore, the wild kokanee population is driven by immigration of kokanee from Canada. An acoustic estimate of wild kokanee in the limnetic zone was 33,758 in 2003 (Baldwin and Woller 2006). Emulating the wild kokanee immigration with regards to time and size at immigration, could boost the success of the hatchery kokanee program. WDFW in conjunction with the LRFEP are currently developing plans to trap immigrating juveniles in the upper reaches of the Columbia River.

In recent years, the Canadian Ministries have had a surplus of Meadow Creek eggs. Lake Roosevelt fisheries managers wanted to take advantage of the opportunity to utilize fry native to the upper Columbia River drainage. The current post-smolt program maximized the capacity at the Spokane Tribal Hatchery, but space was available in the hatchery to raise more fish if the kokanee are released as fry. Therefore, Lake Roosevelt managers decided to utilize the fry kokanee in tributaries.

Past fry plant release strategies could possibly explain the poor performance of fry observed in the early 1990's. These include (1) stock; Lake Whatcom stock kokanee, the only stock available at the time, were used for initial fry experiments. Recent studies demonstrated Meadow Creek kokanee returned in higher numbers compared to the non-native Lake Whatcom. (2) Kokanee fry were released below Little Falls Dam on the Spokane River and from Sherman Creek located in the upper reservoir. Fry stocked at both areas were immediately exposed to the fast flows during the spring runoff, which increased entrainment potential. The Little Falls Dam area of the Spokane River has also been characterized as the primary walleye spawning area in Lake Roosevelt (McLellan et al. 2002a). The Spokane River is also the largest tributary to Lake Roosevelt, therefore hatchery kokanee released below Little Falls Dam were likely limited by predation and increased entrainment. Likewise, the Sherman Creek area of Lake Roosevelt has been documented as the primary walleye summer home range (McLellan et al. 2002a). Walleye predation on post-smolt kokanee after release from Sherman Creek was documented by Baldwin et al. (2003). Therefore, these two areas with the high walleye densities could have been the major limiting factor for kokanee fry survival in the early 1990's.

The second goal of the kokanee program was to spawn returning adults and rear the fish in hatcheries. In the past, adult returns were relatively low (<5,000), therefore the effort to collect and maintain the eggs was never justified. However, it has been hypothesized that kokanee who survived to return as adults were able to adapt to the environmental conditions in the reservoir possessed certain characteristics that made them more fit than the other fish that did not return. Therefore, in 2002 a pilot study was conducted to determine the feasibility of obtaining eggs from hatchery kokanee that returned to release sites in order to begin the process of field egg collection and hatchery rearing. During the peak kokanee run, fish were collected from Hawk Creek and below Little Falls Dam. These eggs were incubated and reared at the Spokane Tribal Hatchery and released along side the other hatchery kokanee (McLellan et al. 2005). The results were surprising, with a percent return of 4.5%, which was much higher than what was observed for the other hatchery fish (0.13%) (McLellan et al. 2005). Therefore, in 2005 an attempt to collect hatchery kokanee eggs in the field was repeated in hopes of moving towards a "Lake

Roosevelt" stock of kokanee that would enable the second and third goals of the project to be achieved.

The objectives for the 2005 hatchery kokanee plan included: 1) continue stocking and monitoring of Big Sheep Creek; 2) begin fry and post-smolt comparison study at two tributaries (Hawk and Onion creeks); and 3) begin egg collection activities at two primary sites (Hawk and Sherman creeks).

Methods

Study Area

Lake Roosevelt was formed when Grand Coulee Dam impounded the waters of the Columbia River in 1939 (Figure 1). At full pool, the reservoir is 243 km long, inundates 33,490 hectares, and has a maximum depth of 122 m (Stober et al. 1981). At full pool, the lake's surface elevation is 393 m (1290 ft) above mean sea level (MSL).

Kokanee Rearing and Marking

In 2005, two stocks of kokanee were utilized in Lake Roosevelt, Meadow Creek and Lake Whatcom. Meadow Creek stock eyed eggs were obtained from the Clearwater and Kootenai Trout hatcheries in British Columbia, Canada by WDFW personnel (M. Combs, Sherman Creek Hatchery). Lake Whatcom eggs were obtained from the WDFW Lake Whatcom Hatchery in Bellingham, Washington (T. Peone, Spokane Tribal Hatchery).

The management plan requires fry plants to be otolith marked and yearling plants to be fin clipped. Fish destined to be released at Big Sheep Creek were transported to the WDFW Spokane Hatchery for thermal otolith marking. After marking, the eggs were transported to the Spokane Tribal Hatchery for incubation and rearing. Fish destined to be released at Onion and Hawk creeks were thermal otolith marked as fry at the Spokane Tribal Hatchery (T. Peone, personal communication).

Fish were fed Skretting (Moore Clark) Nutra Plus Starter feed at 2% body weight from feed training until the they were 100/lb. Yearlings carried over for post-smolt release were fed Apollo at 1.5% body weight. Yearlings were adipose fin clipped after they reached 100 mm in total length.

Kokanee Stocking

Big Sheep Creek - Big Sheep Creek was selected as the first experimental tributary. This tributary was selected because it once supported a small kokanee run established by the U.S. Fish and Wildlife Service in the early 1980's and because of its location near the Canadian border, potentially giving the fry enough spatial segregation from Grand Coulee Dam to residualize before being entrained. This tributary has 2.6 km of creek before entering Lake Roosevelt which will help lower initial predation and give the fish time to acclimate before they enter the high flows in the mainstem reservoir. Big Sheep

Creek also has a barrier waterfall which enhances our ability to monitor the returning adult population.

On 29 May 2005, 444,800 thermal and OTC otolith marked Meadow Creek fry (640/lb) were trucked from the Spokane Tribal Hatchery and released 2.6 km upstream of the mouth into Big Sheep Creek (48.9480113 ºN, 117.7939330 ºW) below a barrier waterfall (Table 1). A private dam located at the falls diverts a portion of the flow into a holding pond above the falls. In order to release fish below the waterfall, fish were netted out of the stocking trucks, transferred into a 250 gallon transport tank (O_2 @ 1.5 L/min), filled with stream water for acclimation, then lowered on a tram elevator approximately 100 m down a cliff to the plunge pool area (Figure 1). Fish were then piped 24 m from the tank to the plunge pool for release.

Onion Creek – A five year study to evaluate fry and post-smolt kokanee performance of Meadow Creek kokanee began at Onion Creek in 2005. The tributary is smaller than Big Sheep Creek, relatively cold all year long and has a terminal waterfall 1.77 km above the confluence. Fish will be planted for three years, and evaluated for five. Stocking rates are planned to be 10 to 1, with a target goal of 1 million fry to 100,000 post-smolt yearlings. Comparisons will be made of fish from similar cohorts, with fry being planted in the spring and post-smolts from the same cohort released the following spring. Performance will be based on adult returns.

On 30 May 2005, 973,100 Meadow Creek fry were trucked from the Spokane Tribal Hatchery and released 1.1 km (48.8670625 ºN, 177.8477441 ºW) upstream of the mouth (Table 1). Soft ground prevented the fry plant trucks from being able to release the fish any higher. Trucks backed across a field to approximately 20 m from the tributary edge. Fry were then piped from the trucks into the creek for release.

Hawk Creek – Hawk Creek was selected as the middle reservoir site to conduct the fry and post-smolt comparison study. A five-year study to evaluate fry and post-smolt kokanee performance of Lake Whatcom kokanee began at Hawk Creek in 2005. Hawk Creek has a terminal waterfall near the mouth of the creek. The plunge pool becomes inundated when the reservoir elevation exceeds approximately 388.6 m (1275 ft) above mean sea level. There is a small run of wild kokanee that utilize Hawk Creek during the spawning season (McLellan et al. 2005). Successful reproduction is unlikely due the extreme draw downs the reservoir experiences every winter and spring. The fish are thought to be strays that are attracted to the flow coming from Hawk Creek.

Lake Whatcom stock fry were released at the Hawk Creek boat launch (47.8143789 ºN, 118.3230143 ºW) between 7 April and 9 June 2005, for a total of 1,313,828 fry (Table 1).

Post-smolt releases - Post-smolt kokanee were also released into Lake Roosevelt as part of an ongoing water temperature study (see Part 2 of this report), and as continued efforts to create a put-and-take fishery. A total of 515,996 post-smolts were released from Sherman Creek, Little Falls Dam, and Fort Spokane (Table 1; details in Appendix A).

Table 1. Stocking summary of fry released into Lake Roosevelt during 2005. Summary included date released, stock and brood year, number released, number of fish per pound, location, and otolith mark (OTC: oxytetracycline).

Date	Stock:Brood Yr	Number released	Fish/lb	Location	Mark
Fry Plants					
3/29/05	Meadow Ck:04	444,800	640	Sheep Creek	Thermal & OTC
3/30/05	Meadow Ck:04	973,100	740	Onion Creek	Thermal & OTC
4/7/05	Lake Whatcom:04	216,000	1080	Hawk Creek	Thermal Otolith
4/8/05	Lake Whatcom:04	216,000	1080	Hawk Creek	Thermal Otolith
5/24/05	Lake Whatcom:04	94,560	544-656	Hawk Creek	Thermal Otolith
5/25/25	Lake Whatcom:04	197,120	544-656	Hawk Creek	Thermal Otolith
6/7-9/05	Lake Whatcom:04	590,148	388	Hawk Creek	Thermal Otolith
Post smolt Plants					
5/19-25/05	Meadow Ck:03	219,928	10	Sherman Ck	Adipose+
3/17/05	Meadow Ck:03	24,750	25	Little Falls	Adipose
3/22-5/20/05	Meadow Ck:03	221,768	16	Fort Spokane	Adipose

+ See section two for other fin clips.

Kokanee Collections

Big Sheep Creek - A weir style trap was installed on 15 August 2005 and monitored through 8 November 2005 near the mouth of Big Sheep Creek (48.9409533 ºN, 117.7685006 ºW). The trap included a large holding box (1 m wide x 1 m deep x 2.7 m long), two side panels were placed into the down stream end of the holding box in the form of a V. Two additional panels were placed across the inside of the holding box to help prevent escapement. Following installation of the live well, tripods constructed out of heavy gauge (10.2 cm.) angle iron were placed diagonally downstream from the live well. The tripods were 1.5 m long and functioned as fence posts when installed between the shorelines. Once the tripods were placed in a suitable anchored position, the cross bars were attached horizontally to the tripods using chain and wire. Each 1.5 m cross bar had a series of holes (22) drilled in them. Following the attachment of the crossbars, 1.5 m aluminum pickets were placed down through each pair of cross pieces.

The trap was checked almost every day between 15 August and 8 November. The Spokane Tribe, Colville Tribe and Eastern Washington University employees shared in the daily maintenance of the trap. On their assigned days, each agency was responsible for checking the trap for fish, noting data (species, length, weight, sex, origin (wild or hatchery) marks, and release location), cleaning debris buildup on the trap, taking water temperature, and noting the water height on a staff gauge.

Water quality data was collected by the Spokane Tribe on 4 April 2005 and weekly from 15 August through 8 November near the trap. Water quality parameters were measured using a Hydolab Surveyor 4a and included: temperature, pH, turbidity, conductivity, dissolved oxygen, total dissolved gas, and total dissolved solids. Each parameter was measured twice, and the average was used in the analysis. A Marsh-McBirney (model 201D) velocity meter was used to measure flow, and then discharge was calculated. A Tidbit temperature data logger was deployed on 15 August for daily water temperatures.

Onion Creek - A trap was not installed because no fish were expected to return. On 9 September 2005 EWU backpacked shocked the creek to verify the absence of a wild kokanee run. A Tidbit temperature logger was installed on 15 August 2005. Water quality data was collected by the Spokane Tribe on 4 April and 15 August 2005. Parameters measured were the same as mentioned above.

Hawk Creek - Five boat electrofishing surveys were conducted on 30 August, 9 and 27 September and 5 and 8 October 2005. Water temperature was taken on the sampling dates. No other water quality parameters were measured.

All other sites sampled – Boat electrofishing surveys were conducted at 30 sites in Lake Roosevelt from Whitestone Creek north to Onion Creek. Egg collections were focused on two primary tributaries, Hawk and Sherman creeks. During field days at Hawk Creek, Spokane Tribal Hatchery personnel were available to spawn on-site any mature kokanee captured. Eggs were then transferred to the Spokane Tribal Hatchery for incubation and rearing. During field days to Sherman Creek, kokanee collected in the tributary were placed in a holding box set in a deep pool in the creek. Fish captured in the cove were placed in an empty net pen at the mouth of Sherman Creek cove. Hatchery personnel collected the fish weekly from the trap and net pen at Lake Roosevelt and transferred the fish to the WDFW Colville Hatchery. Hatchery personnel monitored the fish daily, then once a group of fish were ripe, they were spawned. Eggs were incubated and fry reared at the WDFW Colville Hatchery until the planting date.

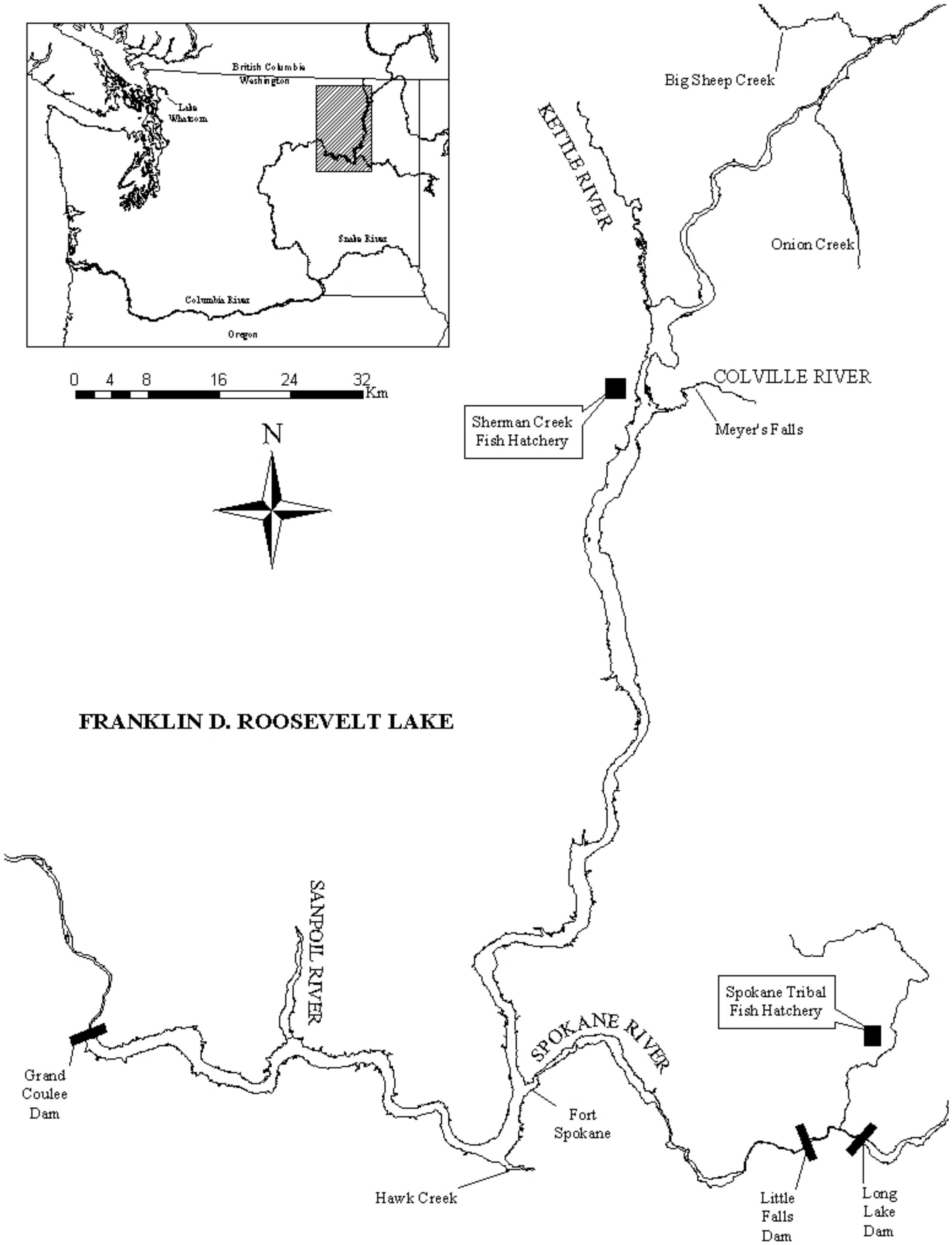

Figure 1. Map of Lake Roosevelt showing location of 2005 fry plant locations, which included Big Sheep, Onion, and Hawk creeks.

Results

Big Sheep Creek - Water quality at Big Sheep Creek appeared stable with water temperature and dissolved oxygen levels well within the optimal levels for kokanee (Table 2). Daily temperatures recorded from the Tidbit thermograph showed a range of 14.3 ºC in August to 4.0 ºC in November (Figure 2). Staff gauge results were inconclusive. Varying results were due to timing when the gauge was read (pre or post trap cleaning). The trap was operational for 85 days, in which no major problems occurred. Two rainbow trout, four kokanee, and one mountain whitefish were collected (Table 3). All fish were released up stream of the trap. Three of the kokanee were wild origin and too large to be part of the initial fry release. No data was collected on the fourth kokanee, which escaped before personnel could gather it.

Onion Creek – Water quality data collected at Onion Creek indicated temperature and dissolved oxygen levels were within optimal levels for kokanee (Table 4). The Tidbit thermal graph indicated optimal water temperatures throughout the fall spawning period (Figure 2). The lower sections were backpack electrofished on 9 September when the water temperature was 12 °C. During 12.86 min. of effort 127 fish were collected; 8 torrent sculpins that averaged 82 mm total length (ranged: 35-103), and 119 rainbow trout that averaged 84 mm total length (range: 45-184). No kokanee were collected and it is presumed that there are no kokanee presently utilizing the creek.

Hawk Creek – Water quality at Hawk Creek was minimal. Temperature data was only taken on sampling dates, which indicated water temperatures were much warmer than the upper tributaries (Figure 2). A total of 83 kokanee were collected, with 7 wild origin fish that averaged 415 mm total length (range: 271-514) and 76 hatchery origin fish that averaged 334 mm total length (range: 282-454). All kokanee were larger than expected for a fry release, therefore they were not taken for otolith screening.

Egg Collections - A total of 815 hatchery kokanee (584 males and 225 females) and 17 wild kokanee were captured in the fall of 2005 (see Appendix B for other fish captured). The majority of fish were collected at Sherman Creek (n = 677) (Table 5). Age-2 hatchery kokanee averaged 313 (25.2) mm total lengths, and age-3 kokanee averaged 408 (32.1) mm total length (Table 6). Age-3 wild kokanee averaged 340 (49.3) mm total length and age-4 kokanee averaged 513 (62.5) mm total length. Wild kokanee lengths were highly variable due to the small sample size (Table 6).

Kokanee that returned to Sherman Creek were sorted by sex, and the healthiest females and males were selected to be transported to the Colville Hatchery for spawning. This was considered a pilot study, therefore the transfer numbers were kept small. Fish were held at the hatchery until they were ripe, then spawned. Spawning occurred on three days in which 51 females were spawned with 45 males to produce 14,225 eggs (Table 7). Fish are planned to be reared through the spring of 2006 and released 2.4 km up Sherman Creek to increase homing fidelity. Hawk Creek egg collections were unsuccessful due to limited numbers of kokanee females during the sampling days. Anecdotal data suggested there was illegal poaching occurring at Hawk Creek. Enforcement officials have been notified and plans for signing the area are underway.

Thirty-five otoliths were sent to the WDFW Otolith Lab for analysis. Of those, 23 were hatchery kokanee, which were sent to verify ages. The other 12 were wild origin fish ranging in size from 191 – 520 mm total length. One otolith marked fish was captured, which is presumed from the Big Sheep Creek 2004 release (184 mm total length).

Table 2. Summary of water quality parameters; temperature (T), dissolved oxygen (D.O.), conductivity, turbidity, total dissolved gas (TDG), pH, total dissolved solids (TDS) and total gas saturation (Tot Sat), measured at Big Sheep Creek in 2005.

Date	Temp. (°C)	D.O. (mg/l)	Conductivity (µS/cm)	Turbidity (NTU)	TDG (mmHg)	pH	TDS (mg/l)	Tot Sat %
4/4/2005	5.10	13.38	133.30	0.00	743.00	8.40	85.30	102.58
8/15/2005	15.05	13.45	163.90	13.05	726.00	8.89	104.85	100.05
8/30/2005	13.55	10.43	173.60	9.95	723.00	8.77	111.10	99.03
9/8/2005	12.48	10.37	179.00	X	717.00	8.69	114.60	99.23
9/15/2005	12.80	11.07	186.90	X	719.50	8.74	119.60	99.13
9/20/2005	11.90	11.21	193.65	X	715.50	8.61	123.85	98.18
9/27/2005	9.98	13.12	194.30	4.80	710.50	8.65	124.30	97.43
10/4/2005	8.98	11.67	192.40	8.65	718.00	8.60	123.15	98.05
10/11/2005	8.75	11.15	193.20	0.00	701.00	8.69	123.65	96.15
10/20/2005	9.05	12.33	185.68	4.13	799.00	8.81	118.83	109.43
10/25/2005	7.90	12.59	189.73	2.27	705.33	8.90	121.47	97.62
11/8/2005	3.29	13.58	182.25	0.00	707.50	8.61	116.65	96.24

Table 3. Summary of fish collected in the Big Sheep Creek trap, 2005. Total length (TL), weight (wt), sex, reproduction condition (Rep. Con), origin (wild or hatchery), and release location.

Date	Species	TL (mm)	Wt (g)	Sex	Rep Con	Origin	Release
8/26/2005	Rainbow trout	62				W	Above trap
8/30/2005	Kokanee	--	--	--	--	--	--
9/2/2005	Rainbow trout	62				W	Above trap
9/27/2005	Kokanee	560	1200	F	M	W	Above trap
10/7/2005	Kokanee	385		F	R	W	Above trap
10/11/2005	Kokanee	413	680	M	R	W	Above trap
10/10/2005	Mountain whitefish	279					Above trap

Table 4. Summary of water quality parameters; temperature (T), dissolved oxygen (D.O.), conductivity, turbidity, total dissolved gas (TDG), pH, total dissolved solids (TDS) and total gas saturation (Tot Sat), measured at Onion Creek in 2005.

Date	Temp. (°C)	D.O. (mg/l)	Conductivity (µS/cm)	Turbidity (NTU)	TDG (mmHg)	pH	TDS (mg/l)	Tot Sat %
4/4/2005	5.7	11.4	316.9	4.2	732	8.6	202.7	101.3
8/15/2005	14.0	12.4	446.9	0	732	8.8	286.0	101.0

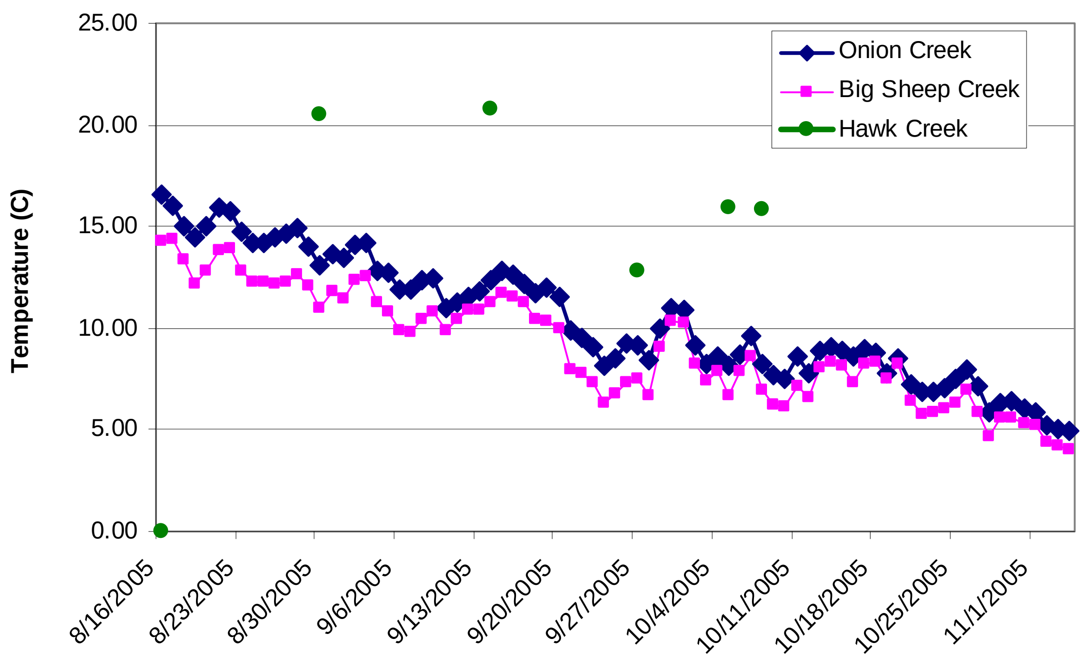

Figure 2. Thermograph of Big Sheep and Onion creeks from 16 August through 4 November, 2005. Hawk Creek temperature data was only taken on sampling days.

Table 5. Summary of hatchery and wild kokanee collected in Lake Roosevelt, fall 2005.

Species	Location	# Females	# Males	Unknown	# Immature	Total
Kokanee (Hatchery)	Sherman Ck	206	471	1		678
	Nez Perce Ck		1			1
	Hunters Ck		4			4
	Alder Ck		3	3	1	7
	Enterprise Ck		4	4		8
	Hawk Ck	4	71	1		76
	Harker Canyon			4		4
	Little Falls	2	2	4		8
	McCoys Marina	2	16	1		19
	Orazada Ck		7		1	8
	Blue Ck			1		1
Total		214	579	20	2	815
Kokanee (Wild)	Fifteen Mile Ck	1				1
	Sherman Ck	2				2
	Enterprise Ck	1				1
	Hunters				1	1
	Hawk Ck	6	1			7
	Harker Canyon		1			1
	McCoys Marina	1				1
	Orazada Ck		1			1
	Blue Ck		2			2
Total		11	5			16
Grand Total		**225**	**584**			**809**

Table 6. Average length of mature male and female hatchery and wild kokanee captured in Lake Roosevelt, 2005. BY = brood year age based on otoliths.

Species	Age 1 (BY 0)	Age 2 (BY 1)	Age 3 (BY 2)	Age 4 (BY 3)
Kokanee (Hatchery)				
Females		300 (23.2) n=211	435 (49.4) n=3	
Males		318 (24.3) n=566	401 (25.3) n=13	
Total		**313 (25.2) n=777**	**408 (32.1) n=16**	
Kokanee (Wild)				
Females			337 (56.4) n=4	523 (65.4) n=7
Males	121 n=1		352 n=1	490 (59.9) n=3
Total	**121 (0) n=1**		**340 (49.3) n=5**	**513 (62.5) n=10**

Table 7. Summary of egg collections from adult returns to Sherman Creek, 2005.

Date	Eggs/oz	Ounces of eggs	N females	N Males	N Eggs
22 Sept 2005	351	3.5	7	8	1,229
1 October 2005	351	24	24	22	8,424
11 October 2005	381	12	20	15	4,572
Total			**51**	**45**	**14,225**

.

Discussion

The fall of 2005 was the first year early maturing age-2 kokanee would have returned to Big Sheep Creek. The first adult run is not expected until the fall of 2006. Trap data collected in 2005 indicated no precocial hatchery kokanee, and a few wild kokanee were present. These data are consistent with the hypothesis that only a few stray wild kokanee return to Big Sheep Creek to spawn. Trapping is currently planned for the fall of 2006-08 to determine if fry plants will produce adult runs.

Trapping will begin at Onion Creek in the fall of 2006 to capture age-2 jack returns and to collect the first lot of post-smolt kokanee plants that will be released in the spring of 2006. Based on previous post-smolt work, the majority of the post-smolts will return the same year they were planted. Boat electrofishing will be utilized at Hawk Creek to capture returning age-2 fish. Adult collections in both of these creeks are planned for the fall of 2006-10 to determine the differential performance of fry and post-smolt kokanee at these two release locations.

Egg collections were successful at Sherman Creek. Continued monitoring and spawning are planned for Sherman Creek in the fall of 2006 with the intent of continually stocking fry back into the creek. Egg collections were less successful at Hawk Creek, but actions are being taken to post signs around the area in hopes of deterring the public from taking spawning kokanee.

Appendix A

Summary of kokanee stocked into Lake Roosevelt, 2001-04.

Date	Sp:Stock:BY:BO	Location	# Release	Fish/lb	TL(mm)	Mark
04/25/2001	KO:WHAL:99:H	Spokane River	46,560	16	143	AD CLIPPED
05/14/2001	KO:MEAD:99:W	Meyers Falls	21,648	7	188	AD RIGHT PEC
06/01/2001	KO:MEAD:99:W	Spokane River	24,533	7	188	62-03-67
06/06/2001	KO:MEAD:99:W	Spokane River	27,875	7	188	62-03-67
6/11-12/2001	KO:WHAL:99:H	Ft. Spokane	57,477	8	180	62-03-65
06/04/2001	KO:MEAD:99:W	Seven Bays NP	98,217	11.5	159	AD CLIPPED
05/27/2001	KO:MEAD:99:W	Kettle Falls NP	334,324	18	137	AD CLIPPED
06/25/2001	KO:MEAD:99:W	Kettle Falls NP	49,699	18	137	AD CLIPPED
06/25/2001	KO:MEAD:99:W	Sherman Creek	62,928	7.6	184	62-02-98
06/25/2001	KO:MEAD:99:W	Sherman Creek	39,065	10	167	62-02-99
06/25/2001	KO:WHAL:99:H	Sherman Creek	35,251	7.6	184	62-03-64
06/25/2001	KO:WHAL:99:H	Sherman Creek	26,037	10	167	62-03-64
06/25/2001	KO:WHAL:99:H	Sherman Creek	52,062	10	167	62-03-62
06/25/2001	KO:WHAL:99:H	Sherman Creek	92,558	7	188	AD LEFT PEC
Total			**968,234**			
05/15/2002	KO:WHAL:00:H	Fort Spokane	12,448	8	180	AD RIGHT PEC
05/15/2002	KO:WHAL:00:H	Fort Spokane	12,280	8	180	AD RIGHT PEC
05/16/2002	KO:WHAL:00:H	Little Falls	12,456	8	180	AD LEFT PEC
05/16/2002	KO:WHAL:00:H	Little Falls	12,656	8	180	AD LEFT PEC
05/29/2002	KO:WHAL:00:H	Meyers Falls	17,000	8	180	AD RL VENT PEC
05/26/2002	KO:WHAL:00:H	Colville River NP	247,484	18	137	AD CLIPPED
05/18/2002	KO:WHAL:00:H	Seven Bays NP	109584	16	143	AD CLIPPED
06/26/2002	KO:WHAL:00:H	Sherman Creek	231,038	10	167	AD CLIPPED
Total			**653,946**			
5/14-21/2003	KO:WHAL:01:H	Fort Spokane	211,461	10.9	162	AD RIGHT PEC
5/5/2003	KO:WHAL:01:H	Little Falls Dam	24,900	12.0	157	AD LEFT PEC
5/6/2003	KO:WHAL:01:H	Meyers Falls	24,960	12.0	157	AD RIGHT VENT
6/9/2003	KO:WHAL:01:H	Gifford	203,596	11.0	162	AD LEFT VENT
6/9/2003	KO:WHAL:01:H	Sherman Creek	24,821	10.8	163	AD RL VENT
6/2/2003	KO:WHAL:01:H	Colville River NP	232,106	20.6	132	AD CLIPPED
5/21/2003	KO:WHAL:01:H	Seven Bays NP	34,792	16.6	141	AD CLIPPED
5/5/2003	KO:WHAL:01:H	Lincoln NP	104,472	19.1	134	AD CLIPPED
6/6/2003	KO:WHAL:01:H	Grand Coulee	198	18.0	137	AD Sonic tag (CCT)
6/6/2003	KO:WHAL:01:H	Grand Coulee	19,862	18.0	137	AD CLIPPED
Total			**871,168**			
5/11/2004	KO:WHAL:02:H	Colville R./Seven Bays NP	238,871	34.6	110	AD CLIPPED
5/21/2004	KO:WHAL:02:H	Sherman Ck-well	79,803	15.9	143	AD Left Pectoral
5/21/2004	KO:WHAL:02:H	Sherman Ck-spring	62,895	15.9	143	AD Right Pectoral
5/21/2004	KO:WHAL:02:H	Sherman Ck-control	74,767	15.9	143	AD Left Ventral
5/17/04	KO:WHAL:02:H	Meyers Falls	24,832	16	143	AD Right Ventral
5/6/24	KO:ROOS/MEAD:02:W	Ft. Spokane	4,550	2.5	254	AD RL Vent
5/6-14/04	KO:WHAL:02:H	Ft. Spokane	201,405	17	140	Adipose
5/10/04	KO:WHAL:02:H	A-Frame	25,568	16	143	Adipose
3/24/04	KO:WHAL:02:H	Little Falls	33,600	50	98	Adipose
5/12/04	KO:WHAL:02:H	Little Falls	24,880	16	143	Adipose
3/30/04	KO:MEAD:03:W	Big Sheep Ck	322,200	600	43	Thermal Otolith
10/25-28/04	KO:MEAD:03:W	Little Falls	505,875	31		Adipose clip
Total			**1,599,246**			
3/29/05	KO:MEAD:04:W	Sheep Creek	444,800	640		Thermal & OTC

3/30/05	KO:MEAD:04:W	Onion Creek	973,100	740	Thermal & OTC
11/8-9/05	KO:MEAD:04:W	Gold Ck-SanPoil	67,520		Adipose clip
4/7/05	KO:WHAL:04:H	Hawk Creek	216,000	1080	Thermal Otolith
			1,485,420		
4/8/05	KO:WHAL:04:H	Hawk Creek	216,000	1080	Thermal Otolith
5/24/05	KO:WHAL:04:H	Hawk Creek	94,560	544-656	Thermal Otolith
5/25/25	KO:WHAL:04:H	Hawk Creek	197,120	544-656	Thermal Otolith
6/7-9/05	KO:WHAL:04:H	Hawk Creek	590,148	388	Thermal Otolith
			2,731,728		
3/17/05	KO:MEAD:03:W	Little Falls Dam	24,750	25	Adipose clip
3/22/05	KO:MEAD:03:W	Ft. Spokane	24,125	25	Adipose clip
4/7-8/05	KO:MEAD:03:W	Ft. Spokane	46,515	15	Adipose clip
4/14-15/05	KO:MEAD:03:W	Ft. Spokane	99,976	10-14	Adipose clip
5/19-20/05	KO:MEAD:03:W	Ft. Spokane	51,360	12	Adipose clip
5/25/05	KO:MEAD:03:W	Sherman Ck	49,305	10	AD Left Vent
5/25/05	KO:MEAD:03:W	Sherman Ck	52,453	10	AD Left Pec
5/19/05	KO:MEAD:03:W	Sherman Ck	24,811	10	AD Left Pec
5/19/05	KO:MEAD:03:W	Sherman Ck	22,115	10	AD Left Vent
5/21/05	KO:MEAD:03:W	Sherman Ck	71,294	10	AD Right Pec
			515,996		
Grand Total					

Appendix B.

Summary of all fish collected in Lake Roosevelt during EWU fall sampling. Boat electrofishing effort = 5.85 hrs.

Spp	Count	Mean TL (SD)	TL range
Black crappie	7	85 (24.6)	51-130
Bull trout	1	478	478.0
Brown trout	14	346 (173.3)	114-672
Bridgelip sucker	5	115 (38.6)	77-170
Burbot	9	500 (61.7)	449-619
Chinook	3	227 (184.5)	115-440
Cottidae	12	81 (34.2)	35-155
Carp	8	190 (162.4)	59-580
Brook trout	10	219 (64.8)	163-362
Kokanee (H)	815	315 (28.7)	226-475
Kokanee (W)	17	419 (141.3)	121-609
Largemouth bass	4	95 (7.3)	84-101
Longnose dace	1	42	42.0
Longnose sucker	13	151 (118.2)	62-448
Largescale sucker	113	386 (204.7)	54-600
Lake whitefish	2	531 (147.1)	427-635
Northern pikeminnow	6	120 (81.2)	32-246
Pumpkinseed	1	95	95.0
Rainbow trout	187	162 (146.8)	45-756
Smallmouth bass	102	143 (63.7)	49-415
Walleye	21	257 (185.9)	126-657
Yellow perch	116	80 (35.3)	45-245
Mountain whitefish	11	281 (100.6)	143-416
Grand Total	1478		

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Part II.

Temperature influences on early maturation of hatchery kokanee salmon

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Abstract

As partial mitigation for lost salmon, Lake Roosevelt is supplemented annually with hatchery reared kokanee salmon. One of the primary goals, to create a self-sustaining population, has not been achieved due to highly skewed sex ratios. To determine if the water source at the Spokane Tribal Hatchery was playing a role in sex determination and early maturation, experimental groups of fish were incubated on spring water (cold water during incubation and warmer during summer growing)and well water (warmer during incubation and colder during summer rearing) test groups. Then a mixed water treatment was added during the rearing phase. Fish were analyzed as sub-yearlings, yearlings, and adults to determine maturation level and sex ratios for each test group in the 2002 (Lake Whatcom stock) and 2003 (Meadow Creek stock) cohorts. For Lake Whatcom kokanee, prior to release, all three test groups were primarily classified as immature with near normal sex ratios (1:1). However, the adult run did not reflect pre-release conditions. Kokanee from the spring water treatment comprised the majority of the run, and all three test groups sex ratios were skewed towards males. Pre-release results were opposite for Meadow Creek kokanee. As yearlings, 64-97% of the females were classified as mature, but only 1% of the males were classified as mature. Sex ratios prior to release for Meadow Creek kokanee were skewed for the well and mixed groups (1:4), but closer to normal for the spring water treatment (1:2). Adult returns were similar to previous years, when the run was comprised mostly of age-2 males. Significantly more kokanee from the spring water treatment returned compared to the other two test groups. The sex ratio observed in the hatchery was consistent sex ratios for age-2 adults collected in the reservoir four months after release. Spring water treated fish returned in significantly higher numbers for both stocks of kokanee. The Meadow Creek spring water treated fish had sex ratios that would enable egg collections to proceed. Due to the variation in some of the results between stocks, we recommend repeating the study to verify our results that spring water treatment fish outperform (in numbers and sex ratios) well water and mixed water treated fish.

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Introduction

Kokanee salmon (*Oncorhynchus nerka kennerlyi*), the freshwater form of sockeye salmon, have been stocked into Franklin D. Roosevelt Lake (Lake Roosevelt) since 1987 as partial mitigation for lost anadromous salmon and steelhead runs blocked by the construction of Grand Coulee Dam in 1939 (Northwest Power Planning Council 1987). The Lake Roosevelt Fisheries Evaluation Program (LRFEP) management goals for Lake Roosevelt kokanee include: 1) providing a hatchery kokanee fishery; 2) creating a self-sustaining fishery, where eggs are taken from mature fish collected from Lake Roosevelt and reared in hatcheries; and 3) to provide a subsistence kokanee fishery for Native American Tribes (McLellan 2005).

The LRFEP has been challenged with an early maturing run of mostly male kokanee. An experiment using three water treatments was designed to determine if the thermal conditions at the Spokane Tribal Hatchery were playing a role in sex determination and early maturation of hatchery post-smolts. Experimental groups of fish were incubated and reared on spring water (cold water during incubation and warmer during summer growing), well water (consistent water temperature), and a combination of well and spring water.

Kokanee growth and maturity are density dependent and driven by the productivity of the rearing environment (Rieman and Meyers 1992, Rieman and Maiolie 1995). Lewis (1971) found a positive relationship between the size of kokanee at maturity and lake productivity. Kokanee life cycles are extended under conditions of low lake productivity and slow growth (mature at 4-5 years) and shortened where lake productivity and growth rates were higher (mature at 2-3 years) (Lewis 1971). In general, kokanee exhibit a 1:1 sex ratio and mature between ages 3 and 4 (Gipson and Hubert 1993, Beauchamp et al. 1995).

The Lake Roosevelt hatchery kokanee artificial production program annually releases approximately 1 million post-smolts (16 months) in late May (Peone 2004). Results from annual adult collections in Lake Roosevelt from 1997-2003 continuously reveal a small run (< 1 % of the release) of age-2 kokanee comprised primarily of males and an even smaller number of age-3 kokanee (McLellan et al. 2001, McLellan and Scholz 2001, 2002, 2003, McLellan et al. 2004a, 2004b). The runs have been typical of precocial runs, where a proportion of the males became sexually mature at a smaller size a year before the large run returns composed of relatively equal numbers of larger males and females (Foote et al 1991). However, the larger run of age-3 kokanee has never materialized in Lake Roosevelt (McLellan and Scholz 2004).

Precocious male maturation has been extensively studied on numerous salmon including masu salmon (Kato 1991) *O.masou*, coho salmon (Iwanmoto et al. 1984), *O. kisutch*, Atlantic salmon *Salmo salar*, sockeye salmon (Ricker 1959), chinook salmon *O. tshawytscha*, (Larsen et al. 2004) and steelhead *O. mykiss* (Schmidt and House 1979, Tipping et al. 2003). Early maturation of males has been associated with genetics (Heath et al. 1994), biotic and abiotic factors, including energy stores (fat and whole-body lipid content) (Rowe et al. 1991, Shearer and Swanson 2000), growth rates at specific times of the year (Berglund 1995), and feeding (Rowe and Thorpe 1990, Hopkins and Unwin 1997).

In wild Chinook salmon populations, precocious fish typically comprise 1-5% of the total population (Tipping et al. 2003, Larsen et al. 2004). However, the incidence of precocious maturation in hatchery reared Chinook salmon has been reported between 11% and 80% (Foote et al. 1991, Larsen et al. 2004), and 1-64% in hatchery reared steelhead (Schmidt and House 1979). Saunders et al. (1982) and Sutterlin and Maclean (1984) showed that accelerated incubation and early rearing of Atlantic salmon by increased water temperatures resulted in high proportions (30-60%) of mature males at age 0, whereas under normal hatchery practices and in nature, they rarely mature before age 1 (Rowe and Thorpe 1990).

Visual assessment of the gonads of 799 kokanee sampled at the Spokane Tribal Hatchery in 2001, found that 63% of the fish showed signs of maturity, with most of the mature fish (87%) being males (Spokane Tribe of Indians (STI), unpublished data). Of the remaining immature fish (37%), the sex ratios reflected a typical adult run sex ratio of 50:50 (STI unpublished data). These data indicated that the majority of the fish would mature at age-2, and the run would have a sex ratio of 1:7 (females to males). Adult data collected in the fall on this test group verified a skewed sex ratio of 1:10 females to males, and the age-3 run did not materialize (McLellan and Scholz 2002).

Lake Roosevelt age-2 kokanee differ from precocious kokanee (age-2) in other systems in that they are much larger. Age-2 mature males average 341 mm total length (TL), which is much larger than age-3 adults from surrounding lakes in Idaho; Coeur d' Alene Lake (225 mm), Spirit Lake (270 mm), Pend Oreille Lake (242 mm), or Priest Lake (290 mm) (Rieman and Myers 1992). Post-smolt hatchery kokanee are fed to satiation in the Spokane Tribal Hatchery on a daily basis, and then released in the spring at an approximate size of 203 mm TL. Excessive growth is continued in the reservoir with hatchery kokanee growing 138 mm in four months (McLellan and Scholz. 2004). The fast growth rates experienced in the hatchery coupled with optimal growth rates experienced in Lake Roosevelt could be forcing the majority of the hatchery kokanee released into early maturation.

The STI data indicated that 75% of all the fish sampled (mature and immature) were males, which indicated that regardless of maturity at release, hatchery kokanee released into Lake Roosevelt were primarily males. Craig et al. (1996) observed distorted sex ratios, skewed towards females, in kokanee and sockeye salmon that were subjected to temperature manipulations during embryonic development. The Spokane Tribal Hatchery must mix spring and well water for their water supply. Initially the spring water is colder in the winter months, but becomes increasingly warmer during the summer months. Mixing of water is necessary to maintain adequate water flows and to keep water temperatures below lethal levels. Initial incubation temperatures for kokanee held at the Spokane Tribal Hatchery averaged 9.0 ºC in January (STI, unpublished data). These initial incubation temperatures were higher than January incubation temperatures at another hatchery nearby which averaged 6.5 ºC (WDFW Ford Hatchery, unpublished data). Precocity data from the Ford Hatchery indicated near 1:1 sex ratios and 2% precocity (WDFW, unpublished data). These data indicated that the water regime at the Spokane Tribal Hatchery could explain the large male aspect of the hatchery kokanee population, through altered sex ratios due to raised incubation temperatures and excessive growth rates.

This study was conducted to determine: 1) if the pre-release condition (maturity and sex ratios) of the kokanee incubated and reared on the three water treatments was significantly different from the standard; with the standard being immature and 50:50 sex ratios; and 2) if return rates, age at maturity, and sex ratios of adult kokanee from the three water treatments were significantly different from each other. The experiment was conducted on two cohorts of kokanee, first on Lake Whatcom stock kokanee (2002 cohort), and secondly on the Meadow Creek stock kokanee (2003 cohort).

Methods

Description of the Study Area

Lake Roosevelt was formed when Grand Coulee Dam impounded the waters of the Columbia River in 1939 (Figure 3). At full pool, the reservoir is 243 km long, inundates 33,490 hectares, and has a maximum depth of 122 m (Stober et al. 1981). At full pool, the lake's surface elevation is 393 m (1290 ft) above mean sea level (MSL). The ten-year mean drawdown was 15 m and generally occurred in April for flood control.

Water Temperature Experiment

The water temperature experiment was conducted for two years. The first experiment was conducted on the 2002 brood year Lake Whatcom stock kokanee, and the second year the 2003 brood year Meadow Creek stock kokanee. Lake Whatcom eyed eggs were obtained from the Lake Whatcom Hatchery (WDFW) in Bellingham, Washington on 11 January 2003. The Meadow Creek eyed eggs were obtained from the Clearwater Trout Hatchery in British Columbia on 27 October 2003 (1.6 million) by WDFW personnel (Lovrak 2004). Eggs were transported to the Spokane Tribal Hatchery.

Incubation – Historically, the Spokane Tribal Hatchery strictly used upweller units on well water to incubate kokanee eggs. For this experiment, upwellers were used for the well water only eggs, but Heath trays had to be used for spring water only egg incubation. Water temperatures were taken daily from both incubation types.

Rearing – Two weeks after 100% hatch, fish were transferred to raceways. Water sources for the spring and well water treatments were kept consistent. Historically, the Spokane Tribal Hatchery mixed spring water with the well water in April when water inflow requirements exceed 66 gpm to keep water temperatures at or below 12.7 ºC for fish health concerns (T. Peone, personal communication, Spokane Tribal Hatchery Manager). Therefore, after being transferred to the raceways a third water treatment was used, that mixed the two water sources. Water temperatures were taken daily from the spring and well water test groups. No water temperatures were taken from the mixed water treatment.

Fish were fed Skretting (Moore Clark) Nutra Plus Starter feed at 2% body weight from feed training until they were 100/lb, then switched to Apollo at 1.5% body weight. Once the fish were approximately 100 mm total length (TL), fish were fin clipped according to their test group (adipose plus another fin) (Table 8).

Sub-yearling and yearling sampling - Hatchery kokanee reared at the Spokane Tribal Hatchery mature early and appear to have sex ratios skewed towards males. To address both sex ratio and early maturation issues, maturation and sex ratios were determined as sub-yearlings (8 months) and yearlings (14 months) prior to being released.

Fish were collected from raceways maintained under the specific water treatment (spring, well, and mixed). Fish were euthanized with a lethal dose of tricain methanesulfonate (MS-222). Total length was measured to the nearest mm and weight recorded to the nearest 0.1 g. An incision was made from the vent towards the anterior section to the base of the pectoral fin. An additional incision from the base of the pectoral fin approximately ¾ the depth of the fish perpendicular to the first incision was made to facilitate internal observations. The intestine was severed at the most posterior location to allow the internal organs to be easily moved. Sex and maturity of the fish were identified using methods similar to Larsen et al. (2004). Immature female gonads appeared clear in color, granular, and occupied <15% of the body cavity. Immature male gonads appeared clear to red in color, were thin and treadlike, and occupied <15% of the body cavity. Mature female gonads were full of developing or well-developed eggs that appeared yellow to orange in color and occupied >15% of the body cavity. Mature male gonads appeared gray to white in color and occupy >15% of the body cavity. Gonads were then removed, blotted with a dry paper towel to remove any excess fluid and weighed to the nearest 0.0001 g with an Ainsworth (Model 100A) analytical scale. Small sub-samples of fish were observed until a minimum of 200 of each sex were recorded.

The Lake Whatcom stock sub-yearlings were tested between 8 and 11 September 2003 (mixed water on 23-24 October, and 12 December 2003), and yearlings were tested between 23 and 26 March 2004 as yearlings. The Meadow Creek sub-yearlings were tested between 24 September and 7 October 2004, and the yearlings were tested between 15 and 24 March 2005.

Release into Reservoir - Kokanee were transferred from the Spokane Tribal Hatchery to Sherman Creek Hatchery between 2 and 6 April 2004 (Lake Whatcom) and between the 5 and 15 April 2005 (Meadow Creek). After transfer, kokanee were held at Sherman Creek Hatchery and released from the raceways directly into the reservoir on 21 May 2004 and 19-25 May 2005 (Table 8).

Table 8. Fin clip[1], release date, number released, and average size at release (fish per pound) of experimental hatchery kokanee released into Lake Roosevelt, 2004 and 2005.

Location	**Fin clip**	**Date of Release**	**No. Released**	**Size at release**
Water Source				
2002 Brood Year (Lake Whatcom)				
Spring Water	Right pectoral	21 May 2004	62,895	16 fish/lb
Well Water	Left pectoral	21 May 2004	79,803	16 fish/lb
Mixed Water	Left ventral	21 May 2004	74,767	16 fish/lb
Total			217,465	
2003 Brood Year (Meadow Creek)				
Spring Water	Right pectoral	21 May 2005	71,294	10 fish/lb
Well Water	Left pectoral	19,25 May 2005	77,264	10 fish/lb
Mixed Water	Left ventral	19,25 May 2005	71,420	10 fish/lb
Total			219,978	

[1] All fish adipose fin clipped.

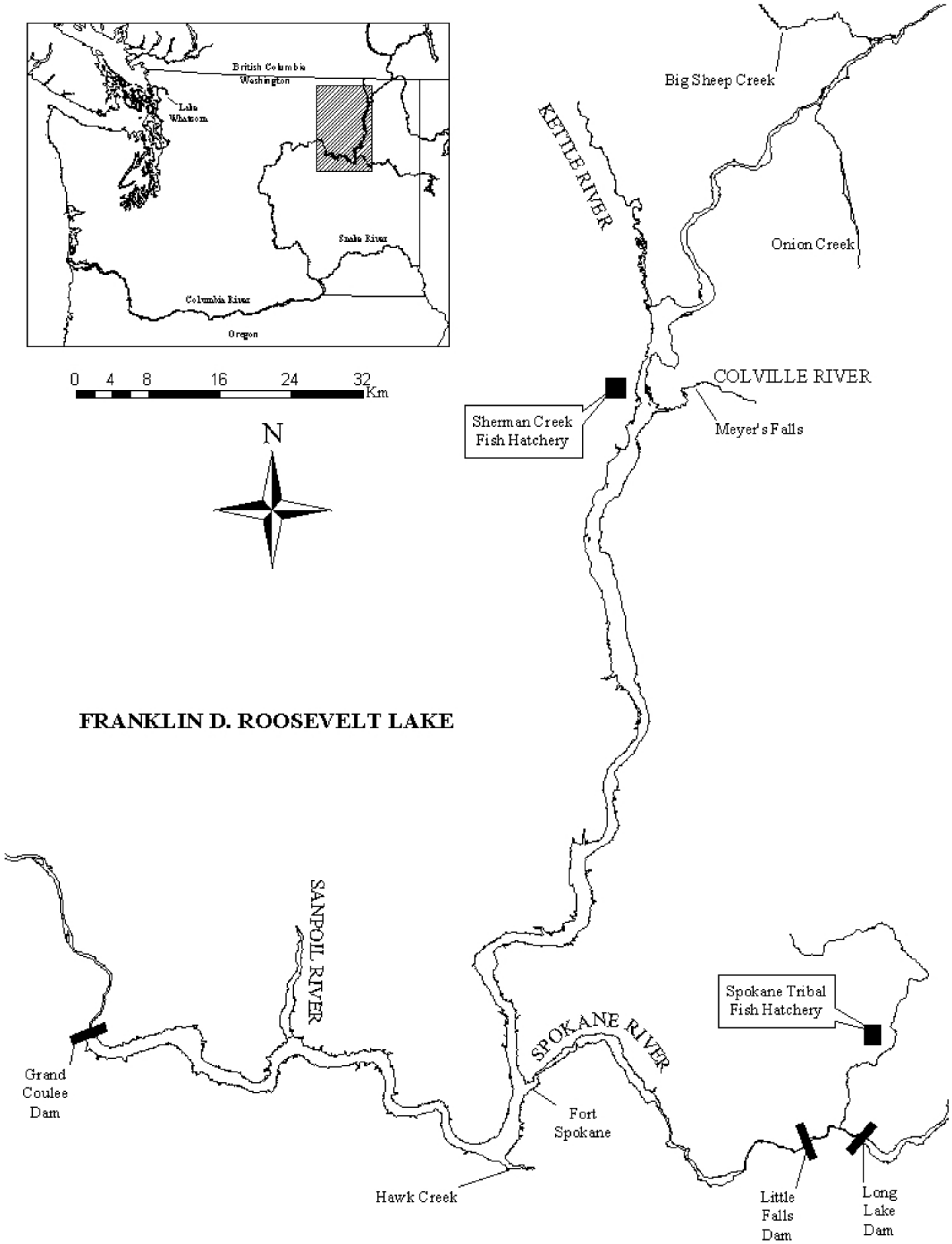

Figure 3. Map of Franklin D. Roosevelt Lake, including kokanee hatcheries and kokanee release sites.

Adult Analysis - Sherman Creek was selected as the release and primary adult return location because kokanee can be transferred to the hatchery before the second imprinting phase, and thus partially imprint to the Sherman Creek water. This partial imprinting has been shown to increase homing abilities (Tilson and Scholz 1996). Sherman Creek is also the historical release location in the upper reservoir, and it is easily accessible by boat or back-pack shocking for adult collections.

Adult collections consisted of boat electrofishing (Smith-Root electrofishing boat 3-5 amps, voltage low (50-500) with 50%, 120 pps DC current) at 25 sites in the upper and middle reservoir from 8 September through 2 November, 2004 and 24 August through 25 October 2005. Upper reservoir sites included Sherman Creek and the Colville River. Middle reservoir sites included creeks from Whitestone Creek (rkm 40.2 from Grand Coulee Dam) north to Hunters Creek (rkm 104.6), as well as the Spokane River to Little Falls Dam. Each site was sampled two to five times for five to ten minutes depending on the size of the site and number of kokanee present. Back-pack electrofishing was utilized when kokanee moved into Sherman Creek.

All fish species were collected and measured to the nearest mm TL to standardize catch data with previous surveys. All kokanee collected were checked for fin clips, a sub-sample were weighed (g), and sex and maturity were noted. See Section 1 of this report for further activities with hatchery kokanee not related to this experiment.

Statistical Analysis - Mean monthly water temperatures at the Spokane Tribal Hatchery for the experimental period were analyzed using a paired t-test (Sigma Plot). Sex ratios and percent maturity were determined for fish in each test group for each sampling event. Condition factor (K_{TL}) (weight/length^3 x 100,000) and gonadosomatic index (GSI) [(wet weight of gonads/total weight of wet fish) x 100] were calculated for each water treatment, maturity level, and sex.

Length frequency distributions of adults from each test group were created. Age structure of the returning run was determined by fin clips and an age length frequency distribution of adults from each test group. The majority of kokanee were easily assigned ages according to fin clips and size. Kokanee that had fin clips similar to the previous year were assigned ages using an age-length key developed from previous coded wire tag data (McLellan et al. 2001). Kokanee less than 360 mm TL were classified as age-2 fish, greater than 410 were classified as age-3. Kokanee falling between these sizes were divided into 10 mm increment groups. Kokanee within the length groups 370-389 mm TL were assigned ages based on a 60/40 age 2/age 3 percent, and fish falling within the 390-400 mm length groups were assigned ages based on a 40/60 age 2/age 3 percent. Chi-square tests for independence were used to test significance between return rates for each test group (Zar 1999; Statview®; $\alpha = 0.05$).

Results

Hatchery Analysis

Lake Whatcom (Cohort 2002)

Incubation - Lake Whatcom kokanee eggs were received and incubated on 11 January 2002. Lake Whatcom kokanee were incubated for 27 (spring water) and 23 (well water) days until full hatch occurred. Full hatch for spring water fish occurred on 6 February and full hatch for well water fish occurred on 2 February 2003 (Spokane Tribal Hatchery, unpublished data). Mean incubation temperatures were significantly cooler for the spring water treatment (8.3ºC SD 0.52) compared to the well water treatment (9.6ºC 0.72) (T-test, $P < 0.01$). (Figure 4).

Rearing - The mixed water treatment began in March, at which time spring water was added to a well only water group to maintain a 12.7 ºC rearing environment. Temperature data for the mixed water treatment group was not consistently recorded, therefore it was not included in the thermal analysis. Mean monthly water temperatures for spring and well water were significantly different every month ($P < 0.01$, ANOVA) except during the months of June, July, and September 2003 (Figure 5). The spring water temperature was influenced by the air temperature, therefore spring water had a large amount of variability ranging from a low of 4.4 ºC in the winter to a high of 14.1 ºC in the summer (Figure 5). Colder well water had to be mixed with the rising spring water to maintain the acceptable standard 12.7 ºC for fish health (T. Peone, Spokane Tribal Hatchery manager). Well water temperatures were slightly warmer during the incubation period (8.0 ºC), but remained stable during the rearing period and did not exceed 11.7 ºC.

Sub-yearling and Yearling Condition

Sex Ratio - A total of 619 Lake Whatcom kokanee were examined in the fall as sub-yearlings (8 months) and 687 yearlings (14 months) the subsequent spring. Sex ratios of sub-yearlings and yearlings did not deviate from the predicted ratio of 50:50 (Goodness of Fit Test, $P < 0.01$) (Table 9).

Reproductive Condition - All sub-yearlings were classified as immature. The majority of yearlings (14 months) were classified as immature, the mixed water had no mature fish, the spring water group had two mature males, and the well water had one mature female (Table 9).

Length Analysis - As sub-yearlings, immature female and male kokanee total lengths from each test group were significantly different (ANOVA females ($P < 0.01$, ANOVA males $P < 0.01$). Fish in the mixed water group were the largest followed by the spring and well water treatments for both females and males (Table 10).

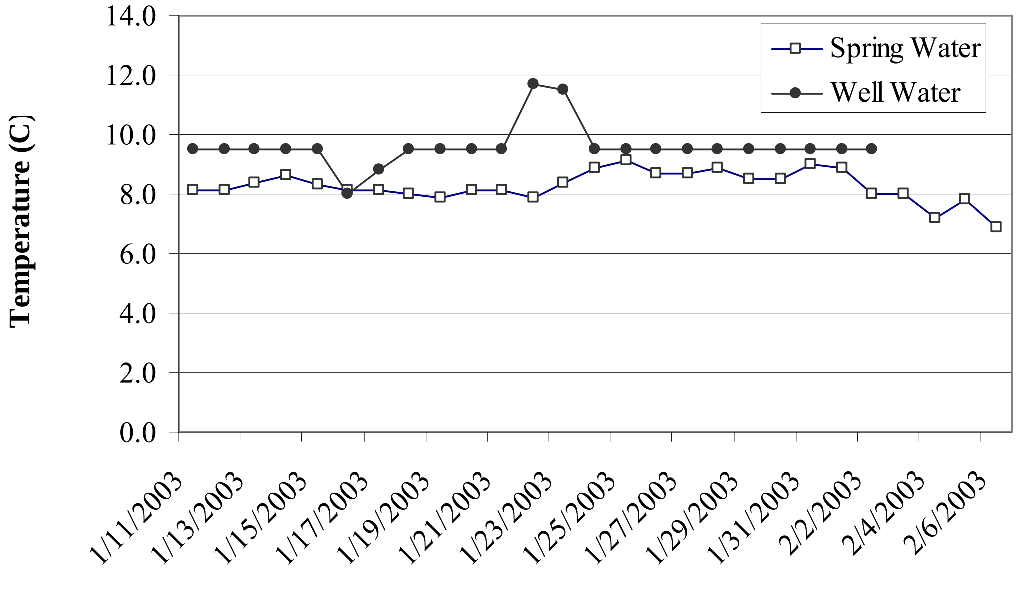

Figure 4. Daily incubation temperatures for Lake Whatcom kokanee reared on spring and well water treatments.

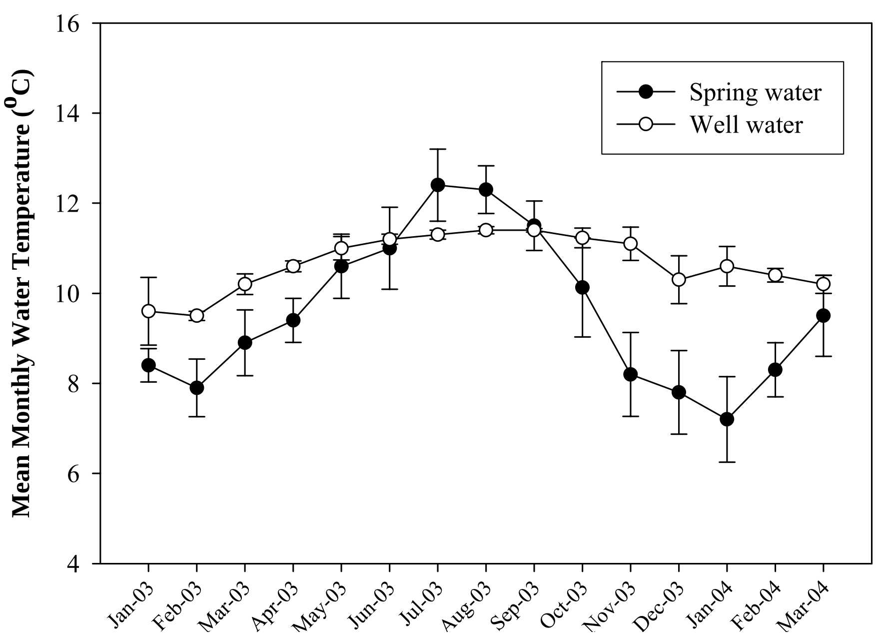

Figure 5. Mean monthly spring and well water temperature (standard errors) at the Spokane Tribal Hatchery January 2003 through March 2004 (Lake Whatcom kokanee).

As yearlings, mean immature female total length from the spring water treatment was significantly greater than the well treatment (T-test, $P < 0.01$), but not the mixed water treatment. The females from the mixed and well water treatments were not significantly different (T-test, $P = 0.07$). Mean immature male total length from the spring water treatment was significantly greater than both the well and mixed treatments. The mean male total length between the well and mixed treatments were not significantly different (T-test, $P = 0.88$) (Table 10).

GSI Analysis - Female GSI values from the well water treatment were significantly greater than the GSI of the spring and mixed water treatments (T-test, $P < 0.01$), but there was no significant difference between the mixed and spring water treatments (T-test, $P = 0.32$). Male GSI values from the well treatment were significantly greater than the spring and mixed water treatment (T-test, $P < 0.01$), but the spring and mixed water treatments were not significantly different from each other (T-test, $P = 0.56$) (Table 10).

Yearling female GSI values were not significantly different from each other (ANOVA, $P = 0.02$). Yearling male GSI values were significantly different from each other (ANOVA, $P < 0.01$), with spring water GSI values being greater than both the well (T-test, $P < 0.01$) and mixed (T-test, $P < 0.01$) water treatments. There was no significant difference between male GSI values from the mixed and well treatments (T-test, $P = 0.39$).

Therefore, the mixed water treatment fish had larger total lengths as sub-yearlings for both males and females, but the well water GSI values were the largest for both male and female sub-yearlings. As yearlings, just prior to release, both the spring water females and males had the greatest total length. The GSI values for the females were not significant from each other at release, but the males GSI values were the largest for the spring water treatment.

Table 9. Number of males and females (N), male to female sex ratio (M:F), percent mature, and life stage of Lake Whatcom stock kokanee salmon examined as sub-yearlings (8 months) and yearlings (14 months) at the Spokane Tribal Hatchery (2003-2004).

Month	**Life Stage**	**Treatment**	**N Males**	**N Females**	**N Total**	**M:F**	**% Mature M**	**% Mature F**	**% Mature Total**
September	Sub-yearling	Mixed[1]	109	102	211	1.1 : 1.0	0	0	0
	Sub-yearling	Spring	114	100	214	1.1 : 1.0	0	0	0
	Sub-yearling	Well	100	100	200	1.0 : 1.0	0	0	0
March	Yearling	Mixed	135	101	236	1.3 : 1.0	0	0	0
	Yearling	Spring	127	101	228	1.3 : 1.0	1.5	0	0.9
	Yearling	Well	102	115	217	1.0 : 1.1	0	0.9	0.5

[1] Samples taken on 23 and 24 Oct and 12 December 2003.

Table 10.The number (n), sex (male or female), maturity (immature or mature), mean total length (TL), mean weight (Wt), mean condition factor (K_{TL}), mean gonad weight (G_{wt}), gonadosomatic index (GSI), and standard deviations for Lake Whatcom stock kokanee salmon observed during precocity investigations at the Spokane Tribal Hatchery (2003-2004).

Treatment	**n**	**Sex**	**Mat.**	**TL (mm)**	**Wt (g)**	**K_{TL}**	**G_{wt}**	**GSI**
Sub-yearling Females								
Mixed	99	F	I	94.1(10.2)	7.2 (2.8)	0.83 (0.07)	0.010 (0.003)	0.149 (0.039)
Spring	99	F	I	85.7 (11.7)	5.6 (2.9)	0.82 (0.08)	0.008 (0.002)	0.154 (0.044)
Well	99	F	I	81.5 (7.4)	4.4 (1.4)	0.79 (0.06)	0.007 (0.002)	0.174 (0.059)
Sub-yearling Males								
Mixed	100	M	I	90.8(10.1)	6.4 (2.3)	0.83 (0.08)	0.002 (0.004)	0.038 (0.031)
Spring	92	M	I	86.3 (12.8)	5.8 (3.0)	0.84 (0.07)	0.003 (0.001)	0.049 (0.032)
Well	84	M	I	80.6 (6.5)	4.3 (1.3)	0.80 (0.06)	0.002 (0.001)	0.053 (0.035)
Yearling Females								
Mixed	101	F	I	126.6 (14.3)	18.9 (8.0)	0.89 (0.06)	0.023 (0.012)	0.125 (0.033)
Spring	100	F	I	129.5 (17.1)	20.0 (10.1)	0.86 (0.07)	0.029 (0.027)	0.147 (0.072)
Well	99	F	I	122.6 (13.6)	17.4 (6.5)	0.90 (0.07)	0.023 (0.008)	0.139 (0.053)
Well	1	F	M	165.0 (0.0)	41.6 (0.0)	0.93 (0.00)	0.119 (0.000)	0.286 (0.000)
Yearling Males								
Mixed	100	M	I	125.6 (12.9)	19.4 (13.0)	0.96 (0.79)	0.006 (0.006)	0.029 (0.019)
Spring	98	M	I	132.5 (18.2)	21.6 (11.5)	0.86 (0.06)	0.008 (0.006)	0.040 (0.018)
Well	100	M	I	126.6 (14.8)	19.5 (8.4)	0.91 (0.06)	0.006 (0.006)	0.027 (0.017)
Spring	2	M	M	139.0 (19.8)	25.0 (13.0)	0.88 (0.10)	0.045 (0.011)	0.224 (0.162)

Meadow Creek (Cohort 2003)

Incubation - Meadow Creek kokanee eggs were received and incubated on 28 October 2003. Meadow Creek kokanee were incubated for 25 days, until full hatch occurred on 22 November 2003. Mean incubation temperatures were significantly cooler for the spring water treatment (8.5ºC SD 0.95) compared to the well water treatment (11.1 ºC SD 0.40) (T-test, P < 0.01). (Figure 6)

Rearing – Mean monthly temperatures between well and spring water were significantly different during each month (T-test, unequal variances, P<0.01). Spring water temperatures approached well water temperatures around 20 March, then were consistently higher between 5 April 2004 and 3 January 2005 (Figure 7). The spring water treatment group water temperatures exceeded the fish health standard of 12.7º C between June and September. The warmer water temperatures exacerbated a bacterial kidney disease (BKD) the kokanee were experiencing. There were significant losses due to the BKD in both test groups.

Sub-yearling and Yearling Condition

Sex Ratio – A total of 1,265 sub-yearling and 1,357 yearling kokanee were examined for sex and reproductive condition (Table 11). The well water and mixed water treatments significantly deviated from the expected 50:50 ratio in both the sub-yearling and yearling tests (P < 0.01), but the spring water treatment group did not deviate from the 50:50 ratio (P = 0.26 sub-yearlings and 0.30 for yearlings) (Goodness of Fit Test) (Table 11).

Reproductive Condition – As sub-yearlings, few fish were identified as mature, with the percent mature ranging between 0.7 and 1.2% (Table 11). Five months later during the yearling testing, the males were still primarily immature (0.4 – 2.6 % mature), but the majority of the females were classified as mature (63.6 to 97.0 % mature).

Length Analysis – All sub-yearling females were immature and averaged 113 mm (SD 14) total length. The majority of sub-yearling males were also immature and averaged 113 mm (SD 15) total length. Only 11 sub-yearling males were mature, and averaged 140 mm (SD 21) total length (Table 12).

As yearlings, the immature females averaged 124 mm (SD 18), and the mature females averaged 148 mm (SD 18) total length. The mature mixed water treatment group were significantly larger than the spring (P<0.01) and the well treatments (P <0.01) (ANOVA test). The spring and well water treatments were not significantly different from each other (P = 0.29, T-test). With the immature females, the mixed water treatment fish were larger than the other two groups, but only significantly with the well water group (P<0.01) (Table 12).

As yearlings, the majority of the male fish were classified as immature, and the immature males averaged 145 mm (SD 24) total length and the mature males averaged 160 mm (SD 18) total length (Table 12).

GSI Analysis – The majority of all sub-yearlings were classified as immature, with the few mature GSI index values being obviously much larger than the immature fish (Table 12). As yearlings, the female GSI values were significantly greater for mature fish compared to immature fish (*P*<0.01) as expected. There was no significant difference between GSI values between any of the treatments for mature females (ANOVA *P* = 0.72). The majority of yearling males were immature, therefore sample sizes were to small to conduct comparative analysis.

In summary, similar to the Lake Whatcom stock, sub-yearling fish were classified as immature. However, sex ratios were skewed in the mixed and well water treatments, but not in the spring water treatment. It appeared that the male yearlings were not maturing, and the female fish made up the majority of the mature fish despite the fact there were 4 times as many males as females.

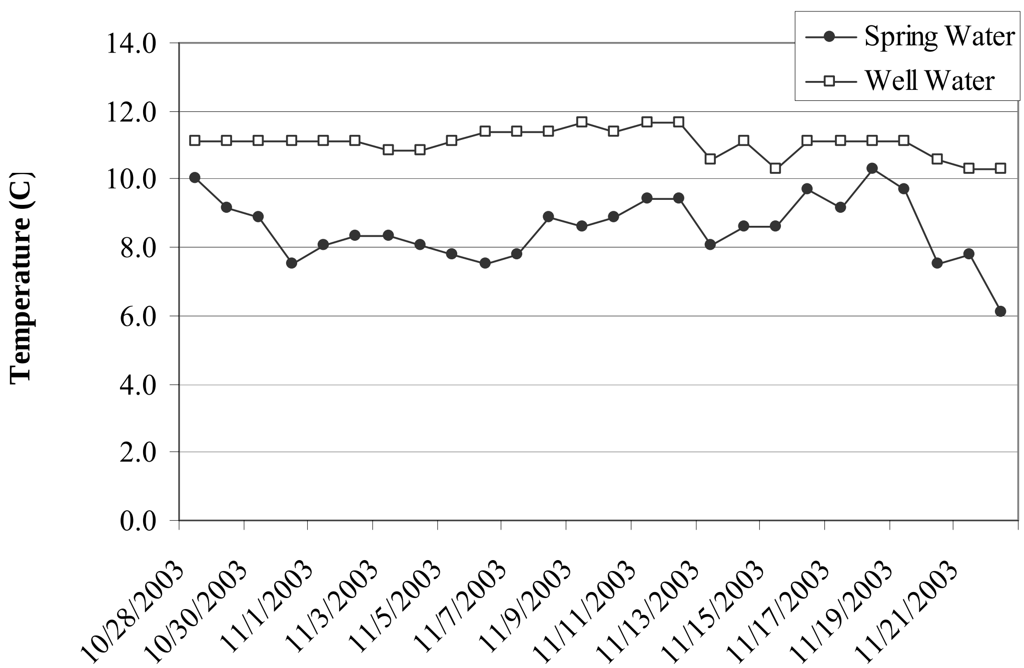

Figure 6. Daily incubation temperatures for Meadow Creek eggs held on spring and well water treatments.

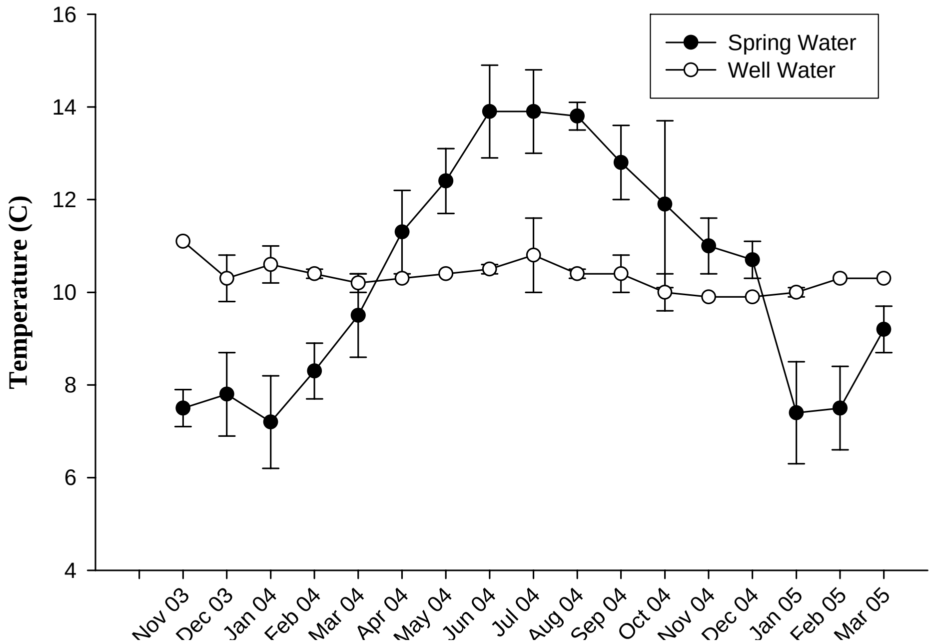

Figure 7. Mean monthly rearing temperatures for spring and well water Meadow Creek kokanee treatments.

Table 11 . Number of males and females (N), male to female sex ratio (M:F), percent mature, and life stage of Meadow Creek stock kokanee salmon examined as sub-yearlings (8 months) and yearlings (14 months) at the Spokane Tribal Hatchery (2004-2005).

Month	Life Stage	Treatment	N Males	N Females	N Total	M:F	% Mature M	% Mature F	% Mature Total
September	Sub-yearling	Mixed	402	100	502	4.0:1.0	1.5	0	1.2
	Sub-yearling	Spring	126	102	228	1.2:1.0	1.6	0	0.9
	Sub-yearling	Well	435	100	535	4.4:1.0	0.7	0	0.6
March	Yearling	Mixed	453	100	553	4.5:1.0	2.6	70.0	14.8
	Yearling	Spring	123	101	224	1.2:1.0	2.4	97.0	45.1
	Yearling	Well	481	99	581	4.8:1.0	0.4	63.6	11.2

Sub-yearling data taken on 29 Sept – 7 Oct. 2004
Yearling data taken on 15 March – 24 March 2005

Table 12. The number (n), sex (male or female), maturity (immature or mature), mean total length (TL), mean weight (Wt), mean condition factor (K_{TL}), mean gonad weight (G_{wt}), gonadosomatic index (GSI), and standard deviations for Meadow Creek stock kokanee salmon observed during precocity investigations at the Spokane Tribal Hatchery (2004-2005).

Treatment	n	Mat.	TL (mm)	Wt (g)	K_{TL}	G_{wt}	GSI
Sub-yearling Females							
Mixed	100	I	109 (15.0)	12.3 (6.3)	0.85 (0.09)	0.021 (0.010)	0.179 (0.050)
Spring	102	I	121 (11.7)	16.0 (5.7)	0.87 (0.06)	0.072 (0.378)	0.283 (1.005)
Well	100	I	110 (13.0)	11.7 (4.7)	0.84 (0.06)	0.021 (0.009)	0.186 (0.052)
Sub-yearling Males							
Mixed	396	I	110 (16.0)	12.3 (6.3)	0.85 (0.11)	0.005 (0.003)	0.050 (0.026)
Spring	124	I	123 (13.2)	17.2 (7.6)	0.87 (0.06)	0.012 (0.035)	0.069 (0.133)
Well	432	I	112 (14.3)	12.5 (5.6)	0.86 (0.34)	0.016 (0.057)	0.123 (0.390)
Mixed	6	M	149 (20.1)	35.2 (16.6)	1.01 (0.13)	2.055 (0.999)	5.887 (1.531)
Spring	2	M	144 (17.7)	31.8 (12.1)	1.03 (0.02)	0.885 (0.543)	2.655 (0.698)
Well	3	M	119 (11.6)	16.1 (4.0)	0.93 (0.04)	1.112 (0.427)	6.798 (1.155)
Yearling Females							
Mixed	30	I	130 (19.9)	20.9 (13.3)	0.84 (0.07)	0.094 (0.069)	0.460 (0.238)
Spring	3	I	125 (11.5)	17 (7.0)	0.84 (0.10)	0.044 (0.007)	0.276 (0.067)
Well	36	I	119 (14.0)	14.4 (6.5)	0.81 (0.06)	0.066 (0.038)	0.477 (0.233)
Mixed	70	M	155 (20.4)	35.7 (16.3)	0.90 (0.08)	0.211 (0.093)	0.604 (0.103)
Spring	98	M	144 (16.9)	28 (10.8)	0.89 (0.10)	0.167 (0.070)	0.600 (0.163)
Well	63	M	147 (18.2)	30.0(13.4)	0.88 (0.07)	0.173 (0.069)	0.594 (0.106)
Yearling Males							
Mixed	441	I	147.7 (23.7)	31.3 (18.9)	0.88 (0.11)	0.043 (0.032)	0.129 (0.064)
Spring	120	I	151.5 (17.4)	32.8 (12.5)	0.90 (0.06)	0.042 (0.070)	0.121 (0.175)
Well	479	I	141.3 (25.1)	27.3 (16.9)	0.86 (0.08)	0.032 (0.026)	0.123 (0.127)
Mixed	12	M	162.3 (19.4)	41.1 (17.1)	0.93 (0.11)	0.213 (0.149)	0.531 (0.240)
Spring	3	M	154.7 (4.2)	33.7 (6.7)	0.90 (0.12)	0.317 (0.192)	0.950 (0.505)
Well	2	M	157 (29.7)	38.5 (20.5)	0.95 (0.01)	--	--

Adult Kokanee Condition

Lake Whatcom adult collections - A total of 747 experimental kokanee were collected in the fall of 2004 (see McLellan et al. 2005 for other kokanee collected during 2004). The majority of the fish were collected at Sherman Creek (91%) (Table 6). Sizes of adult age-2 kokanee ranged from 221-438 mm TL for all test groups combined. Males from the spring water treatment were slightly larger than spring water females. This trend was opposite in the well and mixed water treatments (Table 13).

Significantly more spring water treatment fish were collected compared to the well (χ^2 45.8, $P < 0.01$, df =1) and mixed water treatments (χ^2 131.8, $P < 0.01$, df = 1). Significantly more well water treatment fish were recaptured compared to mixed water treatment (χ^2 11.7, $P < 0.01$, df =1)

Sex ratios for age-2 adults significantly deviated from a 50:50 ratio (χ^2 Goodness of Fit Test) for all test groups. The spring water test group had the lowest female to male ratio (1:11), which was similar to the mixed water treatment (1:15). The well water group was comprised primarily of males (1:115) (Table 14). All three test groups had unacceptable sex ratios to proceed with egg collections.

Meadow Creek adult collections – A total of 665 experimental kokanee were collected during the fall 2005 sampling (see Section 1 for additional kokanee collected in 2005). Two fish were collected at Hawk Creek, and the rest were recaptured at Sherman Creek (Table 13). Sizes of adult age 2 kokanee ranged from 226 to 392 mm total length. Sizes between the spring and well water were similar. Two age 3 fish were captured, one female and one male.

Similar to the previous year, the majority of the kokanee collected were from the spring water treatment group. Significantly more spring water kokanee were collected compared to the well (χ^2 551.8, $P < 0.01$, df =1), and mixed (χ^2 511.0, $P < 0.01$, df =1) water treatments. There was no difference between the well and mixed water treatments.

Similar to the previous year, sex ratios deviated from a 50:50 ratio for all test groups. However, the spring water treatment had the best female to male ratio with a 1:2 ratio (χ^2 36.7, $P < 0.01$, df =1), which was acceptable for egg collections. The well water group had a 1:7 ratio (χ^2 10.5, $P < 0.01$, df =1) and the mixed treatment group had a 1:16 ratio (χ^2 16.4, $P < 0.01$, df =1) (Table 14), which did not provide adequate egg numbers for egg collections.

Table 13. Number of kokanee collected (percent of release) at Sherman Creek and reservoir wide from the water temperature experiment in Lake Roosevelt, 2004 and 2005.

Sherman Creek Release Experiment	# Released	# Collected at Sherman Creek (% recovered)	Total # Collected (% recovered)
2004 Collections			
Spring Water	62,895	317 (0.50)	366 (0.58)
Well Water	79,803	225 (0.28)	230 (0.29)
Mixed Water	74,767	141 (0.19)	151 (0.20)
2005 Collections			
Spring Water	71,294	597 (0.84)	599 (0.84)
Well Water	77,264	34 (0.05)	34 (0.05)
Mixed Water	71,420	32 (0.04)	32 (0.04)

Table 14. Mean total length (standard deviation), total length range (mm)of age 2 and age 3 females and males, and sex ratio of kokanee collected from each of the three test groups in 2004 and 2005.

	Females			Males			Sex Ratio
Treatment	n	Mean TL mm	Range	n	Mean TL mm	Range	F:M
Lake Whatcom 2004 Collections (Age 2)							
Spring Water	33	318 (29.5)	261-398	329	333 (26.2)	255-418	1:11
Well Water	2	333 (9.9)	326-340	228	327 (25.4)	221-418	1:115
Mixed Water	10	332 (62.5)	271-460	140	329 (29.4)	262-438	1:15
Meadow Creek 2005 Collections (age 2)							
Spring Water	195	299 (22.9)	236-380	401	315 (23.6)	226-392	1:2
Well Water	4	290 (18.3)	268-312	28	310 (20.7)	270-352	1:7
Mixed Water	2	319 (19.1)	305-332	32	309 (23.0)	266-350	1:16
Lake Whatcom 2005 Collections (age 3)							
Spring Water	1	451	451	1	395	395	1:1

Discussion

This experiment was initially designed to begin addressing two primary issues that limit the hatchery kokanee program from reaching the goal of a self-sustaining run, which are; skewed sex ratios and early maturation. Skewed sex ratios limit the number of eggs a run of kokanee should produce. Historically, the average ratio was 1 female for every 10 males collected. This hampered the egg collection activities because the run size was less than expected (5,000 returns).

Precociously maturing males are generally the youngest and smallest of the returning adults, and thus considered undesirable by sportsman (Health et al. 1994). Precocious maturation is also undesirable to fisheries managers because kokanee have a semelparous life history, therefore early maturation greatly limits the time they are available for angler harvest. This ultimately impairs the cost-effectiveness of hatchery programs (Tipping et al. 2003). The quality of the fish, as indicated by the total length, is not an issue in Lake Roosevelt because age-2 hatchery kokanee in Lake Roosevelt tend to be larger than age-3 kokanee in other systems (Rieman and Myers 1992, McLellan et al. 2004a). However, hatchery kokanee are only in the fishery for five months before early maturation removes them from the fishery. This limited time in the fishery would only be acceptable by managers if an adequate number were being harvested during the five months, as seen with the hatchery rainbow trout.

It was hypothesized the water sources at the Spokane Tribal Hatchery were playing a role in both the sex ratio problem and the early maturation issue. If gender in kokanee salmon can be manipulated during the incubation stage, as suggested by Craig et al. (1996), then the water sources selected at the hatchery to incubate the kokanee eggs could be the culprit for the skewed sex ratios. Advanced growth due to warmer water temperatures coupled with unlimited food availably might be the trigger for early maturation.

During this study, the Lake Whatcom sub-yearlings and yearlings were primary classified as immature with near 50:50 sex ratios pre-release in 2004. These results deviated from what had been documented in two previous years. Lake Whatcom kokanee observed at the Spokane Tribal Hatchery as yearlings in June 2000 were 81% mature and yearlings in May 2001 were 58% mature before release (STI, unpublished data). The current study was conducted in March, two months prior to the previous studies. Perhaps early maturation is not fully detectable in March. Regardless, the results indicated the adult run should be comprised of equal numbers of males and females.

However, field data collected on returning Lake Whatcom adults were similar to previous years. There was a significant difference in sex ratios between all three groups, with kokanee incubated and reared on well water having the highest skewed ratio. Spring water and mixed water treatments maintained skewed ratios similar to previous years, which were typically 1:8 (females to males) (McLellan et al. 2004b). Catch data collected during the Two Rivers Trout Derby in August 2004 supported the adult skewed sex ratio with 70% of the catch being mature males (n = 36) (STI unpublished data). A run of age 3 fish never materialized for the Lake Whatcom kokanee.

The second study using Meadow Creek kokanee revealed a different story. Kokanee tested as sub-yearlings and as yearlings from the spring water treatment group did not significantly deviate from a normal 50:50 sex ratio. However, the well and mixed water treatments were skewed towards males prior to release (4:1). All test groups had a high percentage of mature females prior to release (64-97%), with the spring water treatment fish experiencing the highest maturity rate. Very few males from any of the test groups were classified as mature prior to release.

The sex ratio trend observed in the hatchery was also observed in the adult run of Meadow Creek kokanee (age-2 adults). The spring water treatment fish had a very close to normal ratio (1 female to 2 males), but the other two groups were highly skewed toward males (1:7 well water and 1:16 mixed water treatments).

Our results indicated that fall testing of the pre-yearlings was too early to detect early maturation for either stock. For the Meadow Creek stock, early maturation was not detected in the pre-yearlings (September), but fully detectable in the yearling samples (March). This trend was not realized with the Lake Whatcom kokanee, with those fish primarily being classified as immature during the spring sample (March). The difference between the two stocks could be explained by the difference in age. Meadow Creek fish are considered "early" run kokanee, and the Lake Whatcom fish are considered "late" run kokanee. Meadow Creek fish hatch out approximately two months before the Lake Whatcom eggs hatch. The two-month difference in age could be the reason for the difference in results. Additionally, as mentioned before, it is suspected that March might be too early to detect maturity levels in Lake Whatcom kokanee.

Our data supported the idea that kokanee incubated on spring water resulted in sex ratios much closer to normal with the Meadow Creek stock, but not for the Lake Whatcom stock. However, the adult returns from the Lake Whatcom stock were skewed towards males, with the best ratios coming from the spring water treatment group. We feel the data supported incubating eggs on cooler spring water to help lower skewed sex ratios. Understanding exactly how the temperature manipulated the sex ratios is beyond the scope of this study. Additional studies would be required to determine the mechanisms controlling sex ratios.

Additionally, our data clearly indicated that fish in the spring water treatment group returned as adults in significantly higher numbers compared to the other test groups, regardless of stock. The reasoning behind this is somewhat unclear. Some hypotheses include: 1). Spring water fish were larger at release, therefore had a higher chance of escaping predation, or 2) Spring water fish were forced into maturity because of the warmer water temperatures in the summer months, therefore they did not distribute down stream, but stayed near Sherman Creek in order to return for the spawning event.

Our results were inclusive with regards to length. The spring water treatment for Lake Whatcom stock yearling males showed a significant increase in length compared to the other test groups, but this did not completely hold true for the Lake Whatcom females in which the spring water group was longer than the well treatment, but not the mixed treatment. For the Meadow Creek kokanee, the mature females in the mixed water treatment group were significantly longer than the other two test groups. Sample sizes for the mature males in the Meadow Creek group were too small for analysis. This suggestion was not substantiated with our data.

Our data supported the idea that spring water fish were more advanced sexually at release for the Meadow Creek stock. For both sexes, at the yearling stage, 45% of the spring water fish were classified as mature, and 11% of the well water and 15% of the mixed water treatments. Our data supported the hypothesis that hatchery rearing kokanee to advanced sizes promotes early maturation. As long as hatchery kokanee are fed to satiation in the hatchery and have an abundant zooplankton food supply in the reservoir, they will mature at age-2. Another way to change the age kokanee mature would be to reduce growth either at the hatchery or in the reservoir. Reducing growth at the hatchery could be achieved if the water temperatures remained cool enough to lower metabolism rates. Crowding kokanee is not an option because increased stress which would exacerbate disease. Reduced food rations could possibly be used to reduce growth at the hatchery. Reducing food availably in the reservoir could be achieved if more fish were planted thereby decreasing the amount of food. Other options including swap fish with other hatcheries (Ford Hatchery for example) that could rear fish on cold water throughout the year. Currently, the LRFEP requests the maximize amount of eggs available through the allotment from Lake Whatcom and from our Canadian counterparts. Additional eggs collected from the returning Meadow Creek run will supplement the number of eggs purchased with hopes of moving towards a self-sustaining run.

In conclusion, our results clearly indicated the spring water treatment groups had different sex ratios and return rates compared to the well and mixed water treatments. We recommend continuing to incubated kokanee eggs on the cooler spring water source, then keeping the water as cool as possible to reduce excessive growth in the hatchery. Kokanee released and returning to Sherman Creek should be spawned, reared and released again at Sherman Creek to facilitate a self-sustaining run. We recommend repeating this study with both stocks of kokanee. Repeating the Lake Whatcom study, but changing the analysis date of the yearlings to May would possibly clear up confusion with maturity levels prior to release. Repeating the Meadow Creek study would confirm our suspicions about the role spring water is having on the sex and maturity levels of kokanee.

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