Contributions to Fisheries Management in Eastern Washington State
Number 11, July 27, 2005

Annual Assessment of Hatchery Kokanee in Lake Roosevelt, 2004

By

Holly J. McLellan
Allan T. Scholz
Eastern Washington University

Chuck Lee
Spokane Tribe of Indians

and

Richard LeCaire
Colville Confederated Tribes

Lake Roosevelt Fisheries Evaluation Program
Supplemental Annual Report - 2004
Project Number 1994-043-00
Contract Number 0001480

Submitted to:
United States Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
Portland, Oregon
and
Spokane Tribe of Indians
Lake Roosevelt Fisheries Evaluation Program
Wellpinit, WA 99040

Contributions to Fisheries Management in Eastern Washington State
Number 11, July 27, 2005

Part I.

Temperature influences on precocial maturation of hatchery reared kokanee salmon

Holly J. McLellan[1], Charles Lee[2], and Allan T. Scholz[1]

Part II.

Lake Roosevelt annual hatchery kokanee assessment, 2004

Holly J. McLellan[1] and Allan T. Scholz[1]

Part III.

Big Sheep Creek fry plant evaluation in Lake Roosevelt

Holly J. McLellan[1], Richard LeCaire[3], and Allan T. Scholz[1]

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

BPA Project Number 1994-043-00
BPA Contract Number 00014804

[1] Eastern Washington University, Fisheries Research Center, Department of Biology, 258 Science Building, Cheney, Washington 99004.

[2] Spokane Tribe of Indians, Natural Resource Department, PO Box 480, Wellpinit, Washington, 99040.

[3] Colville Confederated Tribe of Indians, Natural Resource Department, PO Box 150, Nespelem, Washington, 99155.

Part I.

Temperature influences on precocial maturation of hatchery reared kokanee salmon

Prepared by:

Holly J. McLellan[1], Chuck Lee[2], and Allan T. Scholz[1]

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

BPA Project Number 1994-043-00
BPA Contract Number 00014804

[1] Eastern Washington University, Fisheries Research Center, Department of Biology, 258 Science Building, Cheney, Washington 99004.

[2] Spokane Tribe of Indians, Natural Resource Department, PO Box 480, Wellpinit, Washington, 99040.

Abstract

Lake Roosevelt is supplemented annually with hatchery reared post-smolt kokanee salmon. The program has been challenged with an early maturing run of mostly male kokanee. 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 and reared on spring water (cold water during incubation and warmer during summer growing), well water (warmer during incubation and colder during summer rearing), and a combination of well and spring waters. Four hypotheses were tested, with two that encompassed pre-release conditions and two that regarded post-release conditions. Hypotheses 1 and 2 were used to determine if there was a significant difference in the sex ratio and maturation level of kokanee incubated on spring, well, or mixed water treatments at the Spokane Tribal Hatchery before release as sub-yearlings, or as yearlings just prior to release. Hypotheses 3 and 4 were used to determine if there was a significant difference in the sex ratio and maturation rate of adult kokanee on the spawning run that were released from the three test groups.

Prior to release, all test groups did not significantly deviate from a 50:50 sex ratio as sub-yearlings or yearlings and were primarily classified as immature at release. Spring water yearling total length for females and males was significantly greater than well water fish. Spring water gonadosomatic index values for males were significantly greater than the well and mixed water treatments. There was not a significant difference in female gonadosomatic index values prior to release. Significantly more spring water reared adults were collected compared to the well and mixed water treatments. Sex ratios of age-2 adults significantly deviated from a 50:50 for all test groups. Spring water female to male ratios (1:11) and mixed water treatments (1:15) were not as extreme as the well water group (1:115). Conclusions on early maturation will be postponed until age-3 fish return in the fall of 2005.

Table of Contents

List of Tables and Figures

Acknowledgements

We gratefully acknowledge the Lake Roosevelt Fisheries Evaluation Program for advice and coordination in all aspects of this project, including Spokane Tribe of Indians (STI) (Deanne Pavlik and Ben Scofield), the Washington Department of Fish and Wildlife (WDFW; Jason McLellan, Mitch Combs, Chris Donley, Curt Vail, and Heather Woller), and the Colville Confederated Tribe (Richard LeCaire). We thank the Spokane Tribal Hatchery personnel Tim Peone, Darla Ford, Del Brown, James Andrews, and Jayne Abrahamson who assisted with the rearing and tagging of the kokanee. We would also like to thank Eastern Washington University students: Tiffany Hansel, Tami Thueringer, Tamra Knudson, Chris Moan, Derek Radar, and Ali Russell for assisting in field collection. We thank John Hoskins, Tom Steen, Buster Hill, and Chuck Keys for repair and maintenance of the electrofishing boat and truck. This project was funded through the Spokane Tribe of Indians on a contract from the U.S. Department of Energy, Bonneville Power Administration (BPA), Division of Fish and Wildlife, 1995-027-00, BPA Contract Number 00014804.

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) 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 (warmer during incubation and colder during summer growing), 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 supplementation 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 (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 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 adult 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 TL in 4 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 there was a significant difference in the pre-release condition (sex ratios and maturity) of sub-yearling and yearling kokanee incubated and reared on spring, well, and mixed water treatments; and 2) if return rates, age at maturity and sex ratios of adult kokanee were influenced by the three water treatments.

Methods

Description of the 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). The ten year mean drawdown was 15 m and generally occurred in April for flood control.

Hatchery Kokanee Rearing Environment

Lake Whatcom stock kokanee eyed eggs from the 2002 brood years were obtained from the Lake Whatcom Hatchery (WDFW) in Bellingham, Washington. Eggs were received on 11 January 2003 and placed in upwelling units. The water temperature experiment consisted of three groups; well water, spring water, and mixed water. The mixed water group was reared in similar water conditions to previous years, which included initial incubation on well water only through March or the end of fry feed training. In April, water inflow requirements exceed 66 gpm, therefore spring water is supplemented into the well water to meet flow requirements and to keep water temperatures at or below 12.7 ºC (Tim Peone, personal communication, Spokane Tribal Hatchery Manager). The spring water test group was to be reared strictly on spring water to encompass the colder incubation period and warmer rearing period. The well water fish were to be reared strictly on well water to encompass the warmer incubation periods and cooler rearing period.

Fish were fed Skretting (Moore Clark) Nutra Plus Starter feed at 2% body weight from feed training until they were 100/lb, then they were switched to Apollo at 1.5% body weight. Once the fish were approximately 100 mm total length (TL), they were adipose fin clipped according to their specific test group (Table 1).

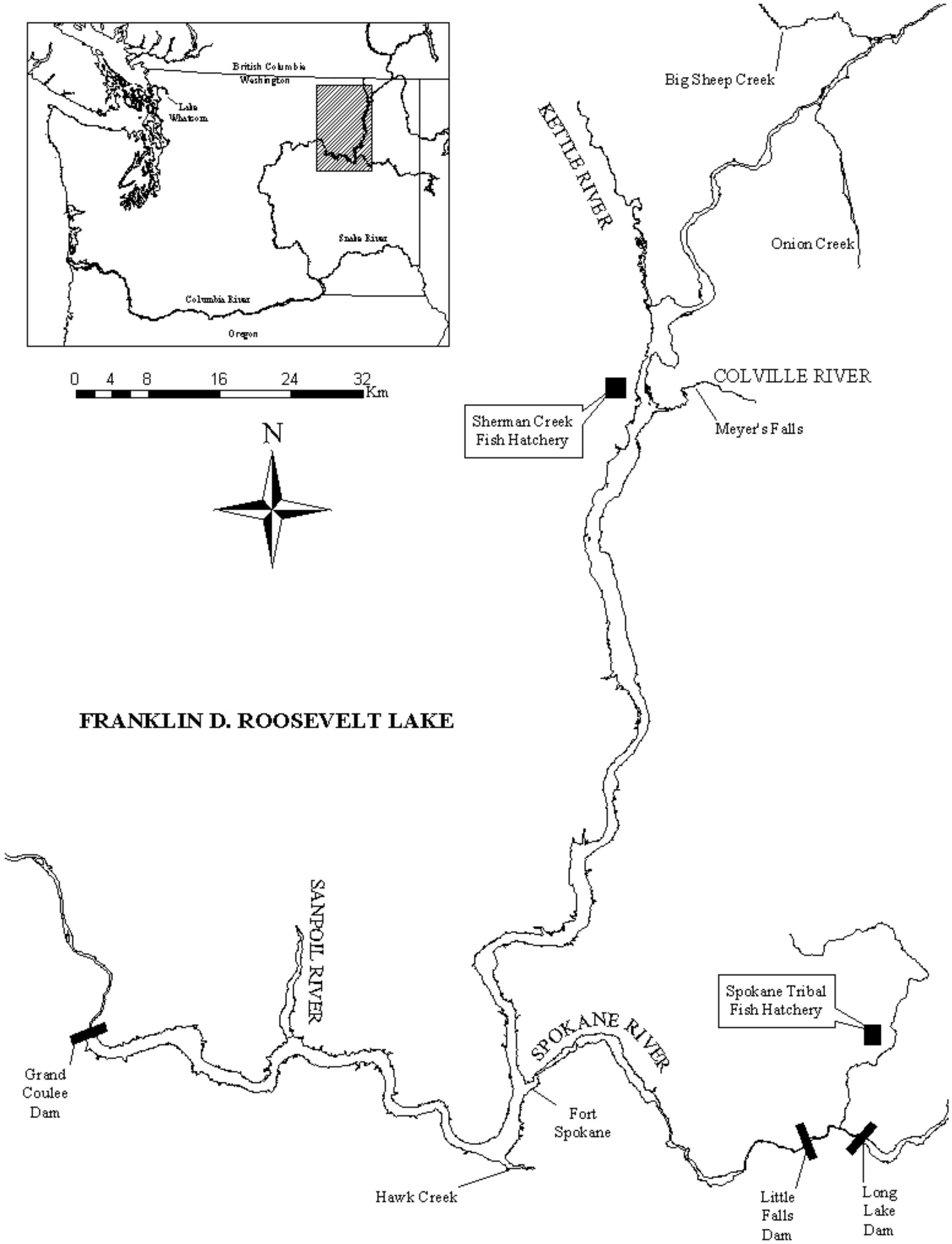

Figure 1. Map of Franklin D. Roosevelt Lake, including kokanee hatcheries and kokanee release sites.

Kokanee were transferred from the Spokane Tribal Hatchery to Sherman Creek Hatchery in March 2004. After transfer, kokanee were held at Sherman Creek Hatchery and released from the raceways directly into the reservoir on 21 May 2004 (Table 1).

Table 1. Fin clip, date of release, number released, and average size at release (total length) of experimental hatchery kokanee released into Lake Roosevelt, 2004.

Location	Fin clip	Date of Release	No. Released	Size at release (mm)
Water Source				
Spring Water	Right pectoral	May 21	62,895	143
Well Water	Left pectoral	May 21	79,803	143
Mixed Water	Left ventral	May 21	74,767	143
Total Sherman Creek			217,465	

Water Temperature Experimental Design

Hatchery kokanee reared at the Spokane Tribal Hatchery mature early and appear to have sex ratios skewed towards males. The Spokane Tribal Hatchery uses two sources of water, spring and well waters. The spring water tends to be slightly colder in the winter months because of its natural exposure to the ambient air temperature. However, the spring water becomes increasingly warmer during the summer months. The well water is slightly warmer during the winter incubation months, but remains cooler and more stable in the summer months.

Kokanee are density dependent (Rieman and Maiolie 1995), thus making age at maturity pliable. Small populations of kokanee tend to grow faster and mature earlier due to an abundance of food and lack of competition. Dense populations of kokanee tend to mature later and mature at smaller sizes due to the increased competition for food. Hatchery kokanee are fed to satiation on a daily basis and reared in warmer temperatures during the summer months. The increased metabolic demand during this growing period combined with the consistent food supply could be contributing to the early maturation rates of hatchery kokanee. To address both sex ratio and early maturation issues, four hypotheses were tested; two to determine pre-release conditions and two to determine post-release conditions.

Null Hypothesis 1 H_o: There is no significant difference in the sex ratio of kokanee incubated on spring, well, or mixed water treatments at the Spokane Tribal Hatchery as sub-yearlings (8 months), or as yearlings (14 months) just prior to release.

Null Hypothesis 2a-c H_o: There is no significant difference in the early maturation of sub-yearling and yearling kokanee reared on spring, well, or mixed water treatments.

a. Determined by visual assessment
b. Determined by mean total length
c. Determined by gonadosomatic index values (GSI)

Null Hypothesis 3a-b H_o: There is no significant difference in the sex ratio of adult kokanee incubated on spring, well, or mixed water treatments.

a. Determined by age-2 adults
b. Determined by age-3 adults

Null Hypothesis 4: H_o: There is no significant difference in the age at maturity for adult kokanee reared on the spring, well, or mixed water treatments.

Pre-Release Methods - Fish were collected from raceways maintained under the specific water treatment (spring, well, and mixed) on 8-11 September 2003 as yearlings (mixed water on 23-24 October, and 12 December 2003), and on 23-26 March 2004 as post-smolts just prior to release. Fish were euthanized with a lethal dose of tricain methanesulfonate (MS-222). Total length (TL) 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 similar methods of 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.

Post Release Methods - 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. 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.

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. 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 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 370-380 mm TL were assigned ages based on a 60/40 age-2/age3 percent, and fish falling within the 390-400 mm length groups were assigned ages based on a 40/60 age2/age3 percent. Chi-square tests for independence were used to test significance between return numbers at each location (Zar 1999; Statview®; $\alpha = 0.05$).

Results

Hatchery Thermal Experience

Initial mean monthly incubation temperatures in January were significantly cooler for the spring water (8.4 ºC) compared to well water (9.6 ºC) ($P < 0.01$, T-test). On 30 January 2003, kokanee held on spring water were at 10% hatch, while the warmer well water kokanee were at 50% hatch. Full hatch for well water occurred on 10 February and full hatch for spring water fish occurred on 6 February 2003. The mixed water group was held on well only water through hatching (T. Peone, Spokane Tribal Hatchery manager).

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. Specific temperature was not monitored for the mixed water treatment, 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 2). The spring water temperature was influenced by the air temperature, therefore spring water had a large amount a variability ranging from a low of 4.4 ºC in the winter to a high of 14.1 ºC in the summer (Figure 3). 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.

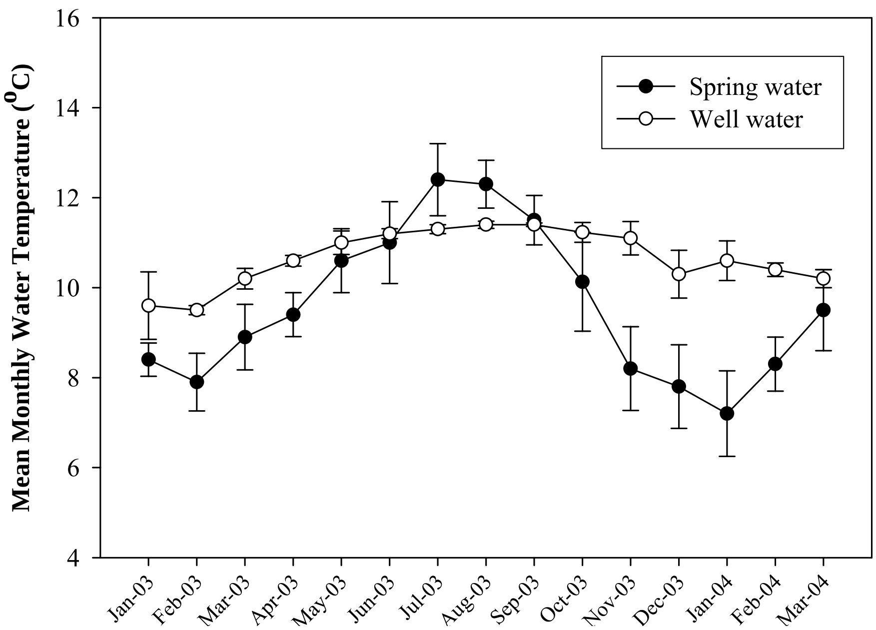

Figure 2. Mean monthly spring and well water temperature (standard errors) at the Spokane Tribal Hatchery January 2003 through March 2004.

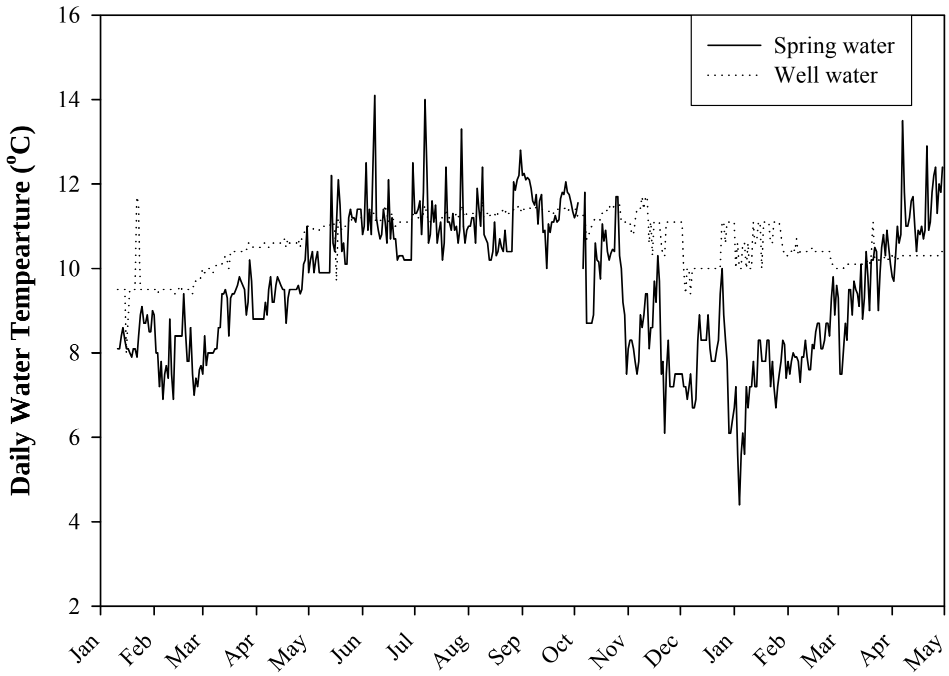

Figure 3. Daily spring and well water temperatures at the Spokane Tribal Hatchery January 2003 through May 2004.

Pre-Release Yearling and Sub-yearling Condition

A total of 619 kokanee were examined in the fall as sub-yearlings (8 months) and 687 yearlings (14 months) the subsequent spring. All sub-yearlings were classified as immature and sex ratios did not deviate from the predicted ratio of 50:50 ($P < 0.01$) (Table 2). 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 2). Sex ratios of yearling fish did not deviate from the predicted ratio of 50:50 (Goodness of Fit Test, $P < 0.01$) (Table 2).

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 3). 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, $P = 0.56$).

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, $P = 0.88$). 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.

The findings **supported** *Hypothesis 1*: There was no significant difference in the sex ratio of kokanee incubated on spring, well, or mixed water treatments at the Spokane Tribal Hatchery before release as sub-yearlings (8 months), or as yearlings (14 months).

The findings **supported** *Hypothesis 2a*: There was no significant difference in visual assessment of early maturation between the three test groups as sub-yearling and yearlings reared on the three water treatments.

The findings **rejected** *Hypothesis 2b*: There was a significant difference in the mean total length of sub-yearlings with the mixed water treatment group being larger. Also, as yearlings, the spring water treatment mean total length for males and females was significantly greater.

The findings both **rejected and supported** *Hypothesis 2c*: The GSI values were significantly greater for males reared on the spring water treatment. However, the hypothesis is accepted for female yearlings which did not show a significant difference in mean GSI.

Table 2. 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	**F**	**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 3. 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								
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
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								
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
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
Mature Yearlings								
Well	1	F	M	165.0 ± 0.0	41.6 ± 0.0	0.93± 0.00	0.119 ± 0.000	0.286 ± 0.000
Spring	2	M	M	139.0 ± 19.8	25.0 ± 13.0	0.88 ± 0.10	0.045 ± 0.011	0.224 ± 0.162

Post Release Adult Kokanee Condition

A total of 747 kokanee were collected from the water temperature experiment with 91% being collected at Sherman Creek (Table 4). The majority of the fish collected were from the spring water test group, followed by the well water, then the mixed water group. 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 5).

Chi-square analysis indicated a significant difference between the three test groups, with significantly more spring water fish returning to Sherman Creek and reservoir wide (Table 6). Testing each group independently identified a significant difference between each group with the degree of significance decreasing to reflect the percents recovered (Table 6).

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 7).

The findings **rejected** *Hypothesis 3a*: There was a significant difference in the sex ratios of age 2 adults, with significantly more males being captured in all test groups.

We **postponed** the assessment of *Hypothesis 3b*: Sex ratio differences for age-3 adult returns will be assessed in the fall of 2005.

We **postponed** the assessment of *Hypothesis 4* H_o: There is no significant difference in the percent of early maturing fish as adult returns of kokanee reared on the spring water, well water, and the mixed water mixed group, until age-3 fish return.

Table 4. Number of kokanee collected (percent of release) at Sherman Creek and reservoir wide from the water temperature experiment in Lake Roosevelt, 2004.

Sherman Creek Release Experiment	# Released	# Collected at Sherman Creek (% recovered)	# Collected in Reservoir (% recovered)
Spring Water	62,895	317 (0.50)	366 (0.58)
Well Water	79,803	225 (0.28)	230 (0.29)
Control	74,767	141 (0.19)	151 (0.20)

Table 5. Summary of mean total length and total length range of age-2 females and males collected from each of the three test groups.

	Females			Males		
Treatment	n	Mean TL mm (SD)	Range (mm)	n	Mean TL mm (SD)	Range (mm)
Spring Water	33	318 (29.5)	261-398	329	333 (26.2)	255-418
Well Water	2	333 (9.9)	326-340	28	327 (25.4)	221-418
Mixed Water	10	332 (62.5)	271-460	140	329 (29.4)	262-438

Table 6. Chi-square analysis per test for kokanee collected at Sherman Creek and reservoir wide from the water temperature experiment, 2004.

Sherman Creek Release Experiment	Sherman Creek Chi-square (p-value)	Reservoir Chi-square (p-value)
Spring water Well water Mixed water	122.711 ($p < 0.001$) d.f. = 2	155.323 ($p < 0.001$) d.f. = 2
Spring water Mixed water	102.497 ($p < 0.001$) d.f. = 1	131.810 ($p < 0.001$) d.f. = 1
Spring water Well water	45.843 ($p < 0.001$) d.f. = 1	72.954 ($p < 0.001$) d.f. = 1
Well water Mixed water	14.24 ($p < 0.0002$) d.f. = 1	11.678 ($p < 0.0006$) d.f. = 1

Table 7. Sex ratio results for age-2 adult kokanee released from Sherman Creek (water temperature experiment), Meyers Falls, non-experimental kokanee, and the Lake Roosevelt stock kokanee collected in Lake Roosevelt, 2004.

Release group	Fin Clip	Number of Females	Number of Males	Total Fish Examined	Ratio (Female:Male)	Significance From 50:50
Spring water	Right pectoral	33	330	363	1:11	$P < 0.01$
Well water	Left pectoral	2	228	230	1:115	$P < 0.01$
Mixed water	Left ventral	10	140	150	1:15	$P < 0.01$

Discussion

This experiment was initially designed to begin addressing two primary issues that limit the success of the hatchery kokanee program on Lake Roosevelt; skewed sex ratios and early maturation. Skewed sex ratios limit egg takes from adult kokanee and early maturing fish are not in the fishery long enough to make the post-smolt program cost-effective. It was hypothesized that the water sources at the Spokane Tribal Hatchery were playing a role in both the sex ratio problems and the early maturation issue. If sex in kokanee salmon can be manipulated during the incubation stage, as suggested by Craig et al. (1996), then the water sources selected to incubate the kokanee could be the culprit. Advanced growth due to warmer water temperatures coupled with unlimited food availably might be the trigger for early maturation of kokanee pre-release, thereby pre-determining their maturation age.

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 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 sets in; which is a concern to fisheries managers.

During this study, the majority of the hatchery post-smolt kokanee were classified as immature pre-release in 2004. These results were not expected and deviate from what has been documented in previous years, where 70% maturity rate pre-release was typical. The discrepancy in the data needs further investigation. Additional data collected in 2005-06 should clarify some of the confusion.

Pre-release sex ratios were determined to be 1:1 with the majority of the fish being immature. The precocity data collected in 2004 was the first time the majority of the fish were identified as immature since 2001, when maturation stage pre-release began being documented. Field data collected on returning adults were similar to previous adult collections, showing skewed sex ratios. 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 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). Data collected on adult kokanee in the field were similar to results collected in all previous years regarding early maturing kokanee in Lake Roosevelt. The discrepancy in sex ratios of pre-released kokanee compared to the adult return ratios is currently unclear. Additional information collected in the fall of 2005 on the age-3 run, coupled with the first year of the repeat pre-release study should shed some light on the situation. Conclusions will be drawn after this data is collected and analyzed.

Literature Cited

Baldwin, C.M., J.G. McLellan, M.C. Polacek, and K. Underwood. 2003. Walleye predation on hatchery releases of kokanees and rainbow trout in Lake Roosevelt, Washington. North American Journal of Fisheries Management 23:660-676.

Beauchamp, D.A., M.G. LaRiviere, and G.L. Thomas. 1995. Evaluation of competition and predation as limits to juvenile kokanee and sockeye salmon production in Lake Ozette, Washington. North American Journal of Fisheries Management 15:193-207.

Berglund, I. 1995. Effects of size and spring growth on sexual maturation in 1+ Atlantic salmon (*Salmo salar*) male parr: interactions with smoltification. Canadian Journal of Fisheries and Aquatic Sciences 52: 2682-2694.

Craig, J.K., C.J. Foote, and C.C. Wood. 1996. Evidence of temperature-dependent sex determination in sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 53: 141-147.

Foote, C.J., W.C. Clarke, and J. Blackburn. 1991. Inhibition of smolting in precocious male Chinook salmon *Oncorhynchus tshawytscha*. Canadian Journal of Zoology 69:1848-1852.

Gipson, R.D. and W.A. Hubert. 1993. Spawning-site selection by kokanee along the shoreline of Flaming Gorge Reservoir, Wyoming-Utah. North American Journal of Fisheries Management 13:475-482.

Health, D.D., R.H. Devlin, J.W. Heath, and G.K. Iwanma. 1994. Genetic, environmental and interaction effects on the incidence of jacking in *Oncorhynchus tshawytscha* (Chinook salmon) Heredity. 72:146-154.

Hopkins, D.L. and M.J.Unwin. 1997. The effect of restricted springtime feeding regime on growth and maturation of freshwater-reared Chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Aquaculture Research 28:545-549.

Iwanmoto, R.N., B.A. Alexander, and W.K. Hershberger. 1984. Genotypic and environmental effects on the incidence of sexual precocity in coho salmon (*Oncorhynchus kisutch*). Aquaculture 43: 105-121.

Kato, F. 1991. Life histories of masu and amago salmon (*Oncorhynchus masou* and *Oncorhynchus rhodurus*). Pages 447-520 in. C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Larsen, D.A., B.R. Beckman, K.A. Cooper, D. Barrett, M. Johnston, P. Swanson, W.W. Dickhoff. 2004. Assessment of high rates of precocious male maturation in a spring Chinook salmon supplementation hatchery program. Transactions of the American Fisheries Society 133: 98-120.

Lewis, S. L. 1971. An evaluation of 3 kokanee races in Oregon Lakes (1967-69). Research Division. Oregon State Game Commission. Federal Aid Completion Report 36-724.

McLellan, H.J., J.G. McLellan, A.T. Scholz, and M.B. Tilson. 2001. Lake Whatcom kokanee salmon (*Oncorhynchus nerka kennerlyi*) investigations in Lake Roosevelt, 1998-2000. 1999 Annual Report. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number BP96, Contract No. 96BP192246.

McLellan, H.J., J.G. McLellan, and A.T. Scholz. 2004a. Evaluation of release strategies for hatchery kokanee in Lake Roosevelt. Northwest Science, 78 (2): 158-167.

McLellan, H.J., A.T. Scholz, and J.G. McLellan. 2004b. Open water release strategies for kokanee in Lake Roosevelt, 2003. Annual Report 2003. Prepared by Eastern Washington University Fisheries Center and Washington Department of Fish and Wildlife for Bonneville Power Administration, Portland Oregon.

McLellan, H.J. and A.T. Scholz. 2001. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt, 2000. Annual Report 2000. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number 00000118-00001, Contract No. 96BP192246.

McLellan, H.J. and A.T. Scholz. 2002. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt, 2001. Annual Report 2001. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number 1997-043-00, Contract Number 00005756.

McLellan, H.J. and A.T. Scholz. 2003. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt. Final Report 2002. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number 1997-043-00, Contract Number 00005756.

Northwest Power Planning Council. 1987. Columbia River Basin Fish and Wildlife Program. Section 900 Resident Fish, unpublished. Northwest Power Planning Council, Portland, Oregon.

Peone, T. 2004. Spokane Tribal Hatchery, 2004 Annual Report. Submitted to Bonneville Power Administration, Portland Oregon. Project No. 91-046-00.

Ricker, W.E. 1959. Additional observations concerning residual sockeye and kokanee (*Oncorhynchus nerka*). Journal of the Fisheries Research Board of Canada 16: 897-902.

Rieman, B.E., and D.L. Myers. 1992. Influence of fish density and relative productivity on growth of kokanee in ten oligotrophic lakes and reservoirs in Idaho. Transactions of the American Fisheries Society 121:178-191.

Rieman, B.E., and M.A. Maiolie. 1995. Kokanee population density and resulting fisheries. North American Journal of Fisheries Management 15:229-237.

Rowe, D.K. and J.E. Thorpe. 1990. Suppression of maturation in male Atlantic salmon (*Salmo sala*r L.) parr by reduction in feeding and growth during spring months. Aquaculture 86: 291-313.

Rowe, D.K., J.E. Thorpe, and A.M. Shanks. 1991. The role of fat stores in the maturation in male Atlantic salmon (*Salmo salar*) parr. Canadian Journal of Fisheries and Aquatic Sciences 48:405-413.

Saunders, R.L., Henderson, E.B., and Glebe, B.D. 1982. Precocious sexual maturation and smoltification of male Atlantic salmon (*Salmo salar*). Aquaculture, 28:211-229.

Schmidt S.P. and E.W. House. 1979. Precocious sexual development in hatchery-reared and laboratory-maintained male steelhead trout (*Salmo gairdneri*). Journal of Fisheries Research Board of Canada 36: 90-93.

Shearer, K.D. and P. Swanson. 2000. The effect of whole body lipid on early sexual maturation of 1+ age male Chinook salmon (*Oncorhynchus tshawytscha*). Aquaculture 190: 343-367.

Sutterlin, A.M. and D. Maclean. 1984. Age at first maturity and the early expression of oocyte recruitment process in two forms of Atlantic salmon (*Salmo salar*) and their hybrids. Canadian Journal of Fisheries and Aquatic Sciences 41:1139-1149.

Stober, Q.J., M.E. Kopache, and T.H. Jagielo. 1981. The limnology of Lake Roosevelt. Final Report Contract No. 14-16-0009-80-0004, to the U.S. Fish and Wildlife Service. National Fisheries Research Center, Seattle WA. Fisheries Research Institute, University of Washington, Seattle, WA. FRI-VW-8 106:116 pp.

Tilson, M.B., A.T. Scholz, and J.L. Miller. 1996. Artificial imprinting of juvenile kokanee salmon (*Oncorhynchus nerka*): Implications for operating Lake Roosevelt kokanee salmon hatcheries. Pages 281-340 *in* K.D. Underwood and J.P. Shields. 1996. Lake Roosevelt Fisheries and Limnological Research: 1995 Annual Report. United Stated Department of Energy, Bonneville Power Administration, Portland, Oregon. Report number DOE/BP-91819-16. 340 pp.

Tipping, J.M., A.L. Gannam, T.D. Hillson, and J.B. Poole. 2003. Use of size for early detection of juvenile hatchery steelhead destined to be precocious males. North American Journal of Aquaculture 65: 318-323.

Zar, J.H. 1999. Biostatistical Analysis 4th edition. Prentice-Hall Inc. Simon and Schuster/ A Viacom Company, Upper Saddle River, NJ 07458. 663 pp.

Part II.

Lake Roosevelt Annual Hatchery Kokanee Assessment, 2004

Prepared by:

Holly J. McLellan[1] and Allan T. Scholz[1]

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

BPA Project Number 1994-043-00
BPA Contract Number 00014804

[1] Eastern Washington University, Fisheries Research Center, Department of Biology, 258 Science Building, Cheney, Washington 99004.

Abstract

Lake Roosevelt is stocked annually with hatchery reared kokanee. In an effort to increase post stock survival and adult returns, kokanee were released eight km up the Colville River below a terminal waterfall. Wild and Meadow Creek stock kokanee were also collected and spawned in 2002 to produce a "Lake Roosevelt" stock. Adult returns to Meyer's Falls on the Colville River were lower than 2003. Evaluation of this site has been postponed until additional fish can be allocated for a more adequate assessment. The Lake Roosevelt stock of kokanee had the highest return rate of age-2 kokanee on record (4.51 %). The very large size of the Lake Roosevelt stock probably played a role in their high return rates. Future assessment of Lake Roosevelt stock kokanee should be considered.

Acknowledgements

We gratefully acknowledge the Lake Roosevelt Fisheries Evaluation Program for advice and coordination in all aspects of this project, including Spokane Tribe of Indians (STI) (Deanne Pavlik, Chuck Lee, Kim Fields, and Ben Scofield), the Washington Department of Fish and Wildlife (WDFW; Jason McLellan, Mitch Combs, Heather Woller), and the Colville Confederated Tribe (Richard LeCaire). We thank the Spokane Tribal Hatchery personnel Tim Peone, Darla Ford, Del Brown, James Andrews, and Jayne Abrahamson who assisted with the rearing and tagging of the kokanee. We would also like to thank Eastern Washington University students: Tiffany Hansel, Tami Thueringer, Tamra Knudson, Chris Moan, Derek Radar, and Ali Russell for assisting in field collection. We thank John Hoskins, Tom Steen, Buster Hill, and Chuck Keys for repair and maintenance of the electrofishing boat and truck. We also thank Meyer's Falls Hydroelectric project (Mike Johnson, dam owner) for providing access and assisting with the collections at Meyers Falls. This project was funded through the Spokane Tribe of Indians on a contract from the U.S. Department of Energy, Bonneville Power Administration (BPA), Division of Fish and Wildlife, 1995-027-00, BPA Contract Number 00014804.

Table of Contents

List of Tables

List of Figures

Introduction

Annual hatchery kokanee adult collections have been conducted on Lake Roosevelt since 1990. Predation studies on hatchery kokanee found that walleye reduced the post-stock survival of hatchery fish (Baldwin et al. 2003). Additional walleye behavior studies indicated historical kokanee release sites were in the primary walleye spawning location and the primary summer home range for walleye (McLellan et al. 2002, McLellan and Scholz 2002). Heavy walleye predation prompted managers to experiment with releasing kokanee in areas that are less dense with walleye and offered kokanee a deep, large pelagic area for immediate escapement from predation. These spatial isolation studies significantly increased post-stock survival when compared to historical release locations (McLellan et al. Scholz 2004).

In 2003, post-smolt kokanee were also released 8 km up the Colville River below a terminal waterfall as another measure to move hatchery kokanee away from immediate walleye predation at release. First year age-2 returns were promising with 0.40% of the fish returning (McLellan and Scholz 2003). These positive results prompted managers to continue monitoring Meyers Falls.

In 2002, age-2 Meadow Creek stock kokanee and wild kokanee collected at Hawk Creek and Little Falls were spawned, and termed the "Lake Roosevelt hatchery stock". Eggs were taken to the Spokane Tribal Hatchery for rearing and incubation. Selecting hatchery and wild fish that survived in Lake Roosevelt could possibly benefit the hatchery kokanee program by creating a strain of fish that appeared to have adapted to the dynamic conditions found in Lake Roosevelt.

Objectives for the 2004 annual hatchery kokanee assessment included 1) summarizing continued efforts to evaluate Meyers Falls as a potential release site, 2) summarizing hatchery kokanee adult returns including age-2 and age-3 returns to tributaries throughout Lake Roosevelt, and 3) summarizing returns of age-2 adults from the Lake Roosevelt stock.

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). The Colville River is regulated by a small dam 8.3 km upstream of the confluence at the base of Meyers Falls (48.5945358 ºN, 118.0601287 ºW). Meyers Falls is a complete fish barrier, with a large plunge pool which makes fish collections conducive with a boat electrofisher.

Lake Whatcom stock kokanee eyed eggs from the 2002 brood years were obtained from the Lake Whatcom Hatchery (WDFW) in Bellingham, Washington. Kokanee eggs were also collected from wild and Meadow Creek stock adults collected in the field during the fall sampling in 2002. These fish were collected at Hawk Creek and below Little Falls Dam and referred to as the Lake Roosevelt stock from this point forward. All fish were reared at the Spokane Tribal Hatchery in Wellpinit, Washington. Fish were fed Skretting (Moore Clark) Nutra Plus Starter feed at 2% body weight from feed training until the they were 100/lb, and then switched to Apollo at 1.5% body weight. Once the fish were approximately 100 mm total length (TL), they were adipose fin clipped according to their specific test group (Table 1).

Fish destined for Sherman Creek Hatchery were transferred from the Spokane Tribal Hatchery in March. After transfer, the kokanee were held at Sherman Creek Hatchery and released from the raceways directly into the cove on 21 May. Kokanee were trucked from the Spokane Tribal Hatchery and released into the plunge pool below Meyers Falls on 17 May. Lake Roosevelt stock kokanee were reared at the Spokane Tribal Hatchery until release at the Fort Spokane boat launch (11 May). Additional non-experimental kokanee were released from Little Falls, Fort Spokane, A-Frame, Colville River net pens, and the Seven Bays net pens (Table 1, Appendix A).

Table 1. Summary of hatchery kokanee released into Lake Roosevelt, 2004. Totals do not include a fall yearling plant at Little Falls.

Location	**Fin clip**	**Date of Release**	**No. Released**	**Avg. sze at release (mm)**
Sherman Creek Experiment				
Spring Water	Right pectoral	May 21	62,895	143
Well Water	Left pectoral	May 21	79,803	143
Control	Left ventral	May 21	74,767	143
Total Sherman Creek			217,465	
Meyers Falls	Right ventral	May 17	24,832	143
Fort Spokane (FDR stock)	Right/Left ventral	May 17	4,550	254
Big Sheep Creek[1]	Otolith mark	May 30	322,200	43
Non experimental				
Fort Spokane	Adipose	May 6-14	201,405	140
Colville River & Seven Bays NP	Adipose	May 11	238,871	110
Little Falls	Adipose	March 24	33,600	98
Little Falls	Adipose	May 12	24,880	143
A-Frame	Adipose	May 10	25,568	143
Grand Total			**1,093,371**	

[1] Fry plant evaluated by Colville Confederated Tribe

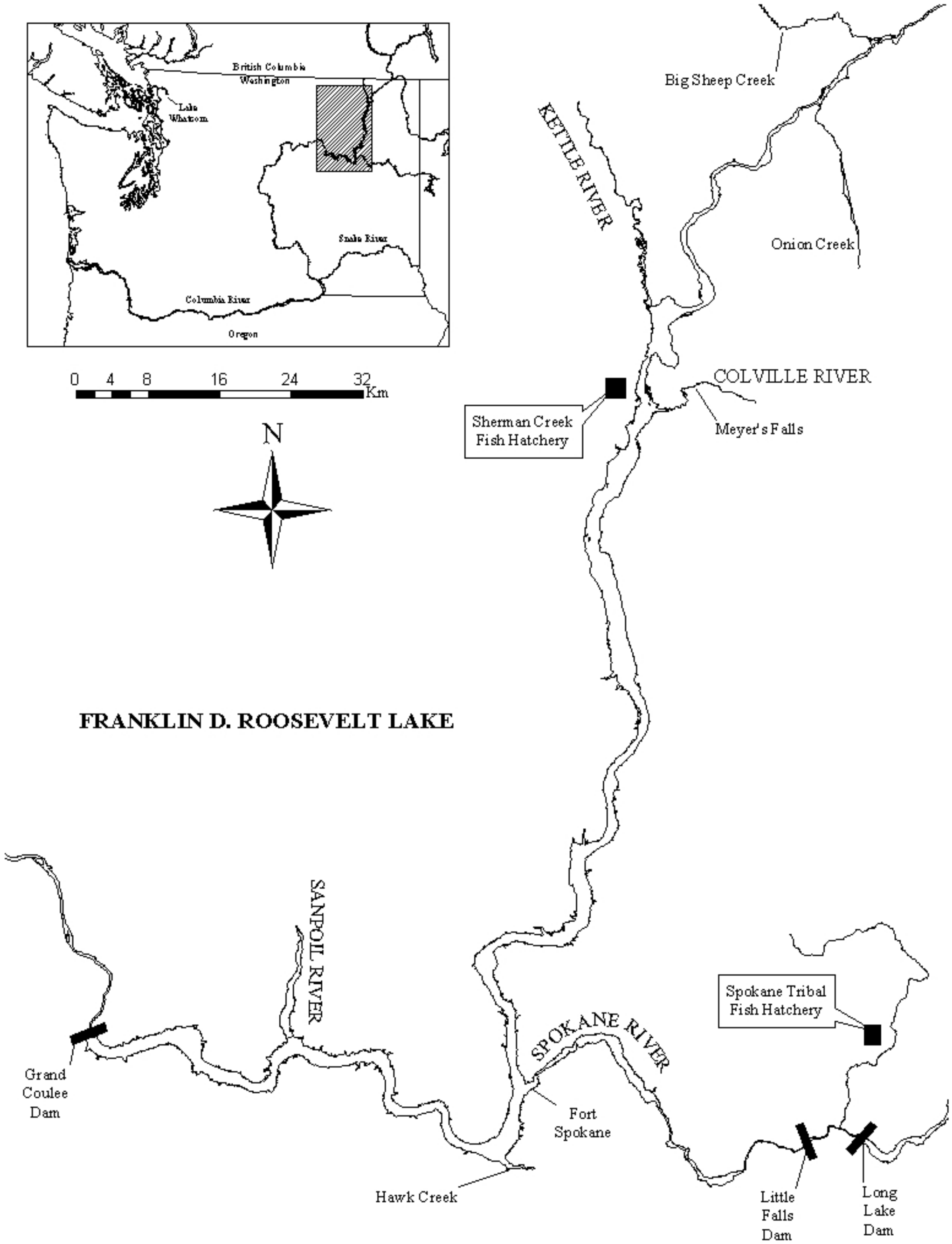

Figure 4. Map of Franklin D. Roosevelt reservoir including kokanee hatcheries and kokanee release locations.

Adult Kokanee Collections - Adult collections consisted of boat electrofishing [Smith-Root electrofishing boat (3-5 amps, voltage low (50-500) with 50%, 120 pps DC current; (60 pps in drift boat]. at 25 sites in the upper and middle reservoir from 8 September through 2 November 2004. 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 5 to 10 minutes depending on size of the site and number of kokanee present. Backpack 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.

Length frequency distributions for each test group were created (Lake Whatcom and Lake Roosevelt stock). Age structure of the returning run was determined by fin clips. 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 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 370-380 mm TL were assigned ages based on a 60/40% age-2/age3 percent, and fish falling the 390-400 mm length groups were assigned ages based on a 40/60% age2/age3 percent. Chi-square tests for independence were used to test for significance between return numbers at each location (Zar 1999; Statview®; $\alpha = 0.05$).

Meyers Fall's Evaluation - The terminal waterfall 8.3 km up the Colville River was found to have slightly higher returns compared to historical release locations (McLellan et al. 2004). Additional monitoring of adult returns in 2004 included working in coordination with WDFW to drift boat sample below the falls in the plunge pool once a week for six weeks between 22 September and 26 October, 2004. A drift boat mounted with a Smith

Root 2.5 GPP electrofishing unit, 1.5-2.0 amps, voltage low (50-500 with 40%), 30 pps DC current was used. The plunge pool was sampled two to three times for five minutes per sample, until all of the observed kokanee were collected each of the trips made. Fish collected were analyzed using the methods described above.

Results

Lake Whatcom Stock - The majority of adult kokanee (94%) collected were age-2 (n = 998), with few (n = 64) age-3 kokanee collected. Sizes of adult age-2 kokanee ranged from 261-478 mm TL for females and 221-484 mm TL for males. Females were slightly larger on average (349 mm TL; SD 53) compared to males (335 mm TL; SD 35) (Figure 2). Overall hatchery kokanee averaged 337 mm TL (SD 37). A list of all fish collected in Lake Roosevelt was summarized in Appendix B.

Lake Roosevelt Stock - The Lake Roosevelt stock age-2 kokanee were released at a much larger size compared to the other hatchery fish, therefore their sizes were kept separate and ranged from 320-475 mm TL for females and 312-495 mm TL for males. The females averaged 372 mm TL (26 SD; n = 102), and the males averaged 392 mm TL (30 SD; n = 100). Overall this group averaged 382 mm TL (30 SD) (Figure 3).

The Lake Roosevelt stock kokanee had the highest percentage returns on record with 4.51 % (Table 1). These kokanee were released from the Fort Spokane boat launch and dispersed throughout the reservoir. The majority (49 %) of these kokanee were collected at Hawk Creek (n=101). A large number (n=64) migrated to tributaries along the Spokane River [McCoys Springs (n=19), Orazada Creek (n=9), Blue Creek (n=5), Pitney Creek (n= 17), Mill Canyon (n=5), and Little Falls (n=9)]. These kokanee were also collected at tributaries south of the release site near Whitestone Rock [Burbot Creek (n=1)], as well as north to the Hunters area, [Gerome Creek (n=10), Alder Creek (n=16), Hunters Creek (n=1), Nez Perce Creek (n=6)], and further north to Sherman Creek (n=2) and Meyers Falls (n=4).

Meyer's Falls - Returns to Meyers Falls were low, with 20 hatchery kokanee being collected during the survey, of which four of those were originally released from Meyers Falls (Table 1). The majority of kokanee collected (n=13) were released from Sherman Creek (spring water group). The remaining kokanee included: one Sherman Creek well water group, one Sherman Creek mixed water group, and one adipose only kokanee. Meyers Falls released kokanee were also collected at Sherman Creek (n=1), Alder Creek (n=1), and Hawk Creek (n=2).

Wild Kokanee - The majority of the 38 wild kokanee collected via boat electrofishing in Lake Roosevelt were collected at Hawk Creek (n= 6), and 5 sites on the Spokane River (n = 16); specifically McCoys Springs (n=7), Mill Creek (n=5), A-Frame (n=2), Blue Creek (n=1), and Little Falls (n=1). Other sites where wild fish were collected included: Gerome Creek (n=1), Alder Creek (n=1), Sherman Creek (n=2), and Meyers Falls (n=1). The mean length of wild kokanee was 483 (68.9 SD) (size range 183 - 561 mm TL) (Figure 4).

An additional wild female kokanee was collected at Meyers Falls (515 mm TL) during a drift boat survey. Another wild female was also collected in Sherman Creek (490 mm TL) during a back pack electrofishing survey. Both fish were immediately returned to the water after lengths and weights were taken.

Sex Ratio Analysis - Sex ratios of age-2 adult kokanee were skewed towards males, and ranged between 1:4 and 1:8 females to males (Table 2). Sex ratios for age-3 adult kokanee were also skewed towards males, but were not as pronounced (Table 10). Wild fish were opposite results four times as many females being collected (Table 10).

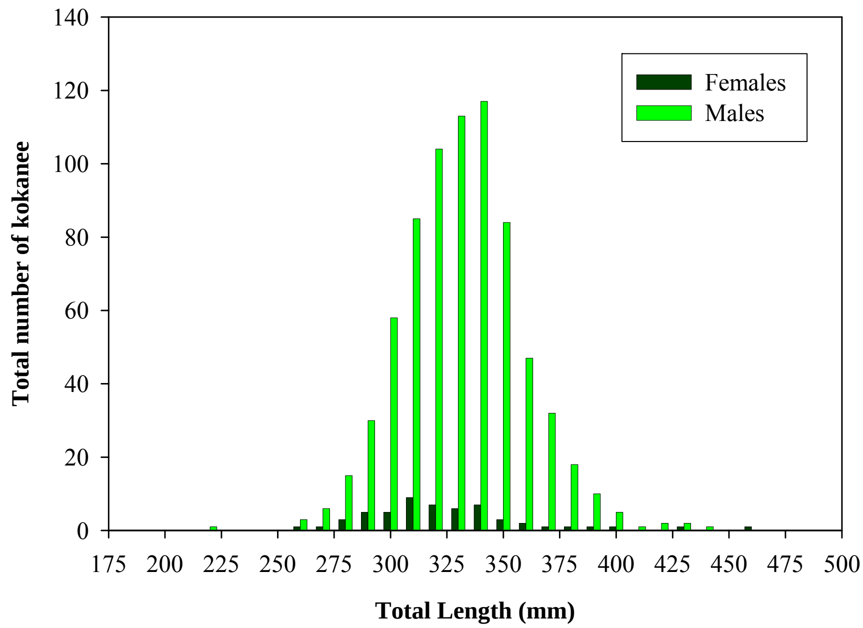

Figure 5. Length frequency distribution of Lake Whatcom stock female (n = 77) and male (n = 773) hatchery age-2 kokanee collected in Lake Roosevelt, 2004.

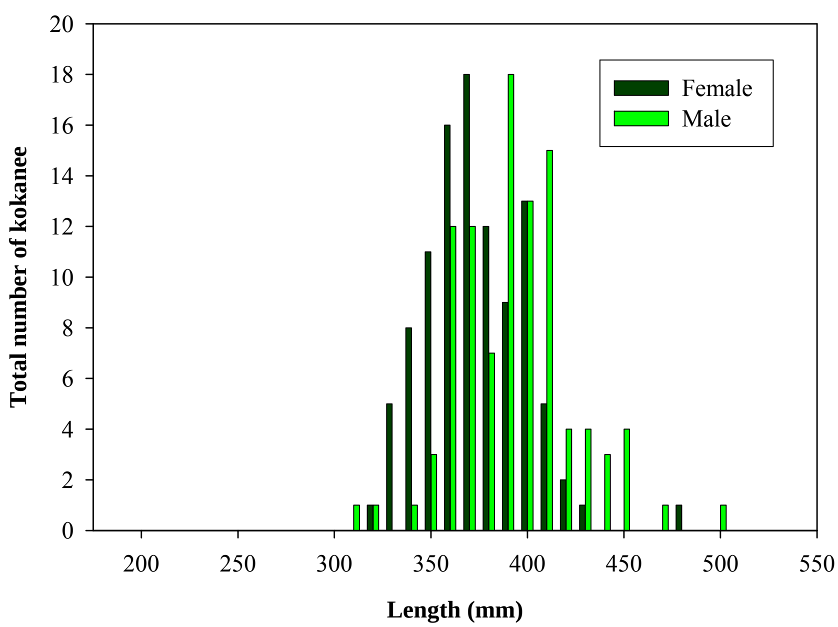

Figure 6. Length frequency distribution of Lake Roosevelt stock female (n=102) and male (n=100) kokanee collected in Lake Roosevelt, 2004.

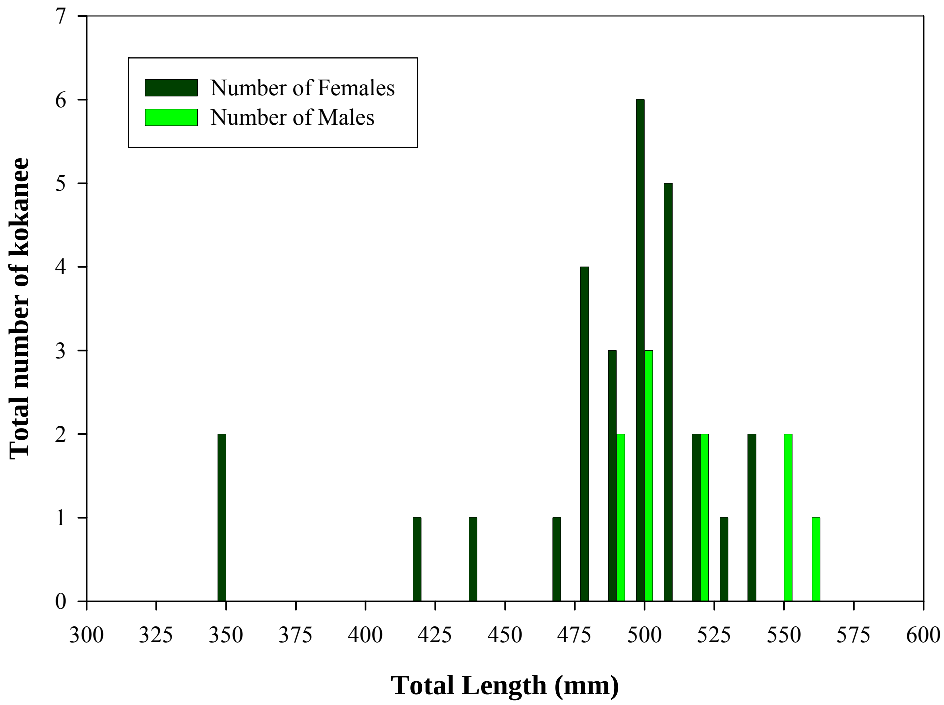

Figure 7. Length frequency distribution of wild kokanee females (n=29) and male (n=10) collected in Lake Roosevelt, 2004.

Table 8. Number of kokanee collected from both the Meyers Falls and Lake Roosevelt stock released then collected during fall sampling, 2004.

Location	# Released	# Collected at Meyers Falls (% recovered)	# Collected in Reservoir (% recovered)
Meyers Falls	24,832	4 (0.02)	8 (0.03)
Adipose Only1	524,324	--	41 (0.01)
Total 2004	771,171		1,001 (0.13)
Lake Roosevelt Stock	4,550	--	205 (4.51)

[1]Adipose only include fish released from Fort Spokane, Little Falls, Seven Bays net pens, Colville River net pens, and A-Frame

Table 9. Sex ratio results for age-2 adult kokanee released from Sherman Creek (water temperature experiment), Meyers Falls, non-experimental kokanee, and the Lake Roosevelt stock kokanee collected in Lake Roosevelt, 2004.

Release Group	Fin Clip	Number of Females	Number of Males	Total Fish Examined	Ratio (Female:Male)	Significance From 50:50
Meyers Falls	Right ventral	1	7	8	1:8	P < 0.01
Non-experimental	Adipose only	9	30	39	1:4	P < 0.01
Lake Roosevelt Stock	Right/Left ventral	102	100	202	1:1	P = 0.92

Table 10. Sex ratio results of age-3 adult kokanee and wild kokanee collected in Lake Roosevelt, 2004.

Release Group	Fin Clip	Number of Females	Number of Males	Total Fish Examined	Ratio (Female:Male)
Miscellaneous	Adipose only	2	12	14	1:7
Gifford	Left ventral	3	6	9	1:3
Fort Spokane	Right pectoral	17	21	38	1:2
Total		22	39	61	1:3
Wild	None	29	10	39	4:1

Discussion

The overall return of hatchery kokanee resembled previous years with the majority of the fish being age-2 males. Returns to Meyers Falls were not as high as anticipated and lower than the previous year. An increase in release numbers from the current 25,000 post-smolts would increase the precision for a proper evaluation of return performance. Meyers Falls releases and evaluation has been postponed by the Lake Roosevelt Fisheries Evaluation Program until a larger number fish can be allocated for this site.

The Lake Roosevelt stock (mixed Meadow Creek and wild Lake Roosevelt kokanee), were collected in the highest percent on record (4.51% of the release). These fish were raised separate of the other fish, thus release sizes were much larger than typical post-smolts sizes. Growing these fish in the hatchery to a larger size pushed the fish into early maturation, yet when compared to other stocks, this particular stock of fish had a normal sex ratio. Historically, the hatchery kokanee appear to always have more males in the total population, therefore if all the fish were to mature at the same time, there would always be more males. The quandary as to why this particular stock maintained a normal sex ratio and was recovered in such large numbers deserves more attention.

Literature Cited

Baldwin, C.M., J.G. McLellan, M.C. Polacek, and K. Underwood. 2003. Walleye predation on hatchery releases of kokanees and rainbow trout in Lake Roosevelt, Washington. North American Journal of Fisheries Management 23:660-676.

McLellan, J.G., H.J. McLellan, and A.T. Scholz. 2002. Assessment of the Lake Roosevelt Walleye Population: A compilation of data 1997-1999. Annual Report. Prepared by Eastern Washington University Fisheries Center Spokane Tribe to be delivered to Bonneville Power Administration, Portland Oregon. Project Number 88-63, Contract No. 94BI321486.

McLellan, H.J., J.G. McLellan, A.T. Scholz, and M.B. Tilson. 2001. Lake Whatcom kokanee salmon (*Oncorhynchus nerka kennerlyi*) investigations in Lake Roosevelt, 1998-2000. 1999 Annual Report. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number BP96, Contract No. 96BP192246.

McLellan, H.J. and A.T. Scholz. 2002. Movements and growth of marked walleye recaptured in Lake Roosevelt, 2000-01. Annual Report 2001. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number 00000118-00001, Contract No. 96BP192246. 41 pp.

McLellan, H.J. and A.T. Scholz. 2003. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt. Final Report 2002. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number 1997-043-00, Contract Number 00005756.

McLellan, H.J., A.T. Scholz, and J.G. McLellan. 2004. Open water release strategies for kokanee in Lake Roosevelt, 2003. Annual Report 2003. Prepared by Eastern Washington University Fisheries Center and Washington Department of Fish and Wildlife for Bonneville Power Administration, Portland Oregon.

Stober, Q.J., M.E. Kopache, and T.H. Jagielo. 1981. The limnology of Lake Roosevelt. Final Report Contract No. 14-16-0009-80-0004, to the U.S. Fish and Wildlife Service. National Fisheries Research Center, Seattle WA. Fisheries Research Institute, University of Washington, Seattle, WA. FRI-VW-8 106:116 pp.

Appendix A- Kokanee Stocking Records, 2001-2004

Table 11. Summary of kokanee stocked into Lake Roosevelt, 2001-04.

Date	Sp:Stock:BY:BO	Location	# Release	Fish/lb	TL(mm)	Fin Clip
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
Total			**1,093,371**			

Appendix B – Summary of all species of fish collected in 2004

Table 12. Summary of fish collected via back-pack electrofishing in tributaries of the Spokane River and Sherman Creek, 2004.

Location	Species	Number	Mean total length (mm)	Size Range (mm)
Spring Ck	Rainbow trout	33	122	90-183
A-Frame	Kokanee	4	379	353-400
A-Frame	Yellow perch	2	81	77-85
McCoys Spring	Kokanee	1	330	330
Sherman Ck	Kokanee	345	328	134-490
Total		**385**		

Table 13. Summary of fish collected via boat electrofishing in Lake Roosevelt, 2004.

Species	Number	Mean total length (mm)	Size Range (mm)
Cyprinidae			
Carp	4	547	435-693
Peamouth	2	101	100-101
Northern pikeminnow	5	285	64-583
Tench	2	213	193-233
Catostomidae			
Longnose sucker	1	110	110
Bridgelip sucker	5	341	251-488
Largescale sucker	72	468	93-680
Salmonidae			
Lake whitefish	3	427	417-441
Rainbow trout	93	322	94-590
Kokanee	741	360	170-561
Chinook	18	526	379-678
Mountain whitefish	6	231	147-380
Brown trout	3	437	277-606
Bull trout	1	621	621
Brook trout	9	242	151-304
Gadidae			
Burbot	6	550	515-628
Cottidae	4	81	60-127
Centrarchidae			
Pumpkinseed	2	103	86-120
Bluegill	5	50	35-65
Smallmouth bass	52	153	64-340
Largemouth bass	5	175	66-276
Black crappie	7	73	50-98
Percidae			
Yellow perch	201	76	44-189
Walleye	16	411	140-722
Total	**1,263**		

Table 14. Summary of fish collected via drift boat electrofishing at Meyer's Falls, 2004

Species	Number	Mean total length (mm)	Size Range
Brown bullhead	8	143	100-220
Bridgelip sucker	10	248	135-302
Brown trout	167	416	225-571
Cottidae	3	83	58-117
Kokanee	29	356	293-515
Largescale sucker	197	270	103-525
Northern pikeminnow	1	96	96
Pumpkinseed	11	101	81-130
Rainbow trout	61	276	171-489
Redside shiner	8	85	60-101
Tench	45	272	172-446
Mountain whitefish	5	298	150-431
Yellow perch	2	217	213-220
	547		

Part III.

Big Sheep Creek fry plant evaluation in Lake Roosevelt, 2004

Prepared by:

Holly J. McLellan[1], Richard LeCaire[2], and Allan T. Scholz[1]

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

BPA Project Number 1994-043-00
BPA Contract Number 00014804

[1] Eastern Washington University, Fisheries Research Center, Department of Biology, 258 Science Building, Cheney, Washington 99004.

[2] Colville Confederated Tribe of Indians, Natural Resource Department, PO Box 150, Nespelem, Washington, 99155.

Table of Contents

List of Figures

List of Tables

Acknowledgments

We gratefully acknowledge the Lake Roosevelt Fisheries Evaluation Program for advice and coordination in all aspects of this project. Special thanks to the Phillips Family Hydropower, who allowed the use of their property facilities to release fish below the Big Sheep Creek waterfall. We also gratefully appreciate Tim Peone (Spokane Tribal Hatchery) and Mitch Combs (Washington Department of Fish and Wildlife Hatchery) for their dedication to the project. Special thanks to Colville Confederated technician Steve Francis and Charlie Joseph for checking the trap daily. We also thank Ben Scofield (STI) for water quality samples and Chuck Lee (STI) for assistance with checking the trap.

Abstract

Hatchery kokanee salmon have been released into Lake Roosevelt since 1987 as part of a larger effort to enhance the fishery. Since 1996, it has been the goal of the Lake Roosevelt Fisheries Evaluation Program to release approximately 1 million post-smolt kokanee. These releases have had modest success, but fall short of the programs harvest and adult collection goals. Previous hatchery kokanee studies on post-smolt kokanee indicated walleye predation, entrainment, and kokanee stock limit their success. Release strategies that increased post stocking survival included spatially moving the release location to less dense walleye areas, releasing fish away from high flow areas, and using a kokanee stock native to the upper Columbia River drainage. In 2004, LRFEP took these successful tactics and applied them to an experimental fry release and coupled it with a saturation tactic. Big Sheep Creek, located in the upper reservoir near the Canadian border, was selected as the first fry release site. Meadow Creek stock kokanee (322,200 fry) were released 2.6 km up Big Sheep Creek below a terminal waterfall on 30 May 2004. A weir style adult kokanee trap was installed near the mouth of the creek on 1 September 2004. Kokanee were not expected back this year, but the trap was installed to verify the absence of a kokanee run and to determine any improvements needed for the future. Three stay kokanee were collected in the trap, which verified the absence of a natural spawning population. Improvements have been noted for the following year. Possible jack returns are expected in the fall of 2006, with the adult run expected in the fall of 2007. Additional fry plantings are planned for the spring of 2005 and 2006, with additional experiments planned for adjacent tributaries. Annual evaluation of these releases will give the managers of the Lake Roosevelt fishery the tools to determine if fry plantings should be continued.

Introduction

The Lake Roosevelt Fisheries Evaluation Program (LRFEP) embarked on a new strategy to increase hatchery kokanee performance in Lake Roosevelt. In most recent years, 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 in two post-smolt experiments (McLellan and Scholz 2001, 2002b, 2003). The significant increase in performance has made Meadow Creek kokanee the preferred stock by Lake Roosevelt fisheries managers, as well as ecologically more responsible.

The Lake Roosevelt hatchery kokanee program was initially set up to produce 10 million fry (T. Peone, Spokane Tribal Hatchery Manager). 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 all 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 programs implementation, with the most successful being an "open water" release strategy occurring 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 pelagic refuge for yearling kokanee. This release strategy was adopted by the management team to create a put-and-take fishery.

In recent years, there have been surpluses of eggs from the Meadow Creek stock in Canada. 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 has maximized the capacity at the Spokane Tribal Hatchery because of the larger sized kokanee, but space is available in the hatchery if the fish are released as fry. With the recent opportunities with the Meadow Creek stock, the LRFEP decided to take a new look at fry plants in Lake Roosevelt.

Past fry plant release strategies could possibly explain the overall poor performance of fry observed in the early 1990's. Lake Whatcom stock kokanee, the only stock available at the time, was used for initial fry experiments. Recent studies demonstrated Meadow Creek kokanee perform better in Lake Roosevelt could be one of the factors that limited initial fry attempts. Second, 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 found in Lake Roosevelt during the spring runoff, which increased entrainment potential. The Little Falls Dam area of the Spokane River has 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 be the major limiting factor for kokanee fry survival.

The new fry release strategies addressed the past fry planting limitations (entrainment and predation) and took advantage of techniques that have improved the post-smolt portion of the hatchery kokanee program (use of an upper Columbia River native stock and spatial removal from predators). It was hoped that saturation planting of fry at a site removed from walleye predators and was far enough from Grand Coulee Dam to reduce entrainment would increase the success of fry plants in Lake Roosevelt.

Methods

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. 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 30 May 2004, approximately 322,200 thermal otolith marked Meadow Creek fry (537/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 (Figure 1). A private dam located at the falls diverts a portion of the flow into a holding pond above the falls. The powerhouse is located on the south side of 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 lt/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 2). Fish were then piped 24 m from the tank to the plunge pool for release.

Water quality data were collected on 17 March 2004 (1 week prior release) 13 m below the plunge pool and near the mouth of the creek. During the spawning season, water quality were collected at the trap site on 23 August, 3 September, and 26 October by the Spokane Tribe of Indians (STI). Water quality parameters were measured using a Hydolab Surveyor 4a and included: temperature, pH, turbidity, conductivity, dissolved oxygen, total dissolved gas, total dissolved solids, and percent nitrogen. A Marsh-McBirney (model 201D) velocity meter was used to measure flow, and then discharge was calculated.

A weir style trap was installed on 1 September 2004 and monitored through 24 October 2004. The trap included a large holding box (1 m wide x 1 m deep x 2.7 m long) and that was constructed out of 1 ½ in. heavy wall aluminum tubing. The tubing was welded into place on 2.54 cm (1 in.) centers using a mig welder. The spacing prevented upstream migration while allowing juveniles to pass downstream. The live well was assembled on site before being placed in the stream, and was anchored to the substrate on each corner using 5/8 inch iron re-enforcing bar driven into the substrate. 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 live well to help prevent escapement. In areas of heavy flow, a small piece of plywood was placed on the outside of the upper end of the live well to provide some slack water so that fish may rest.

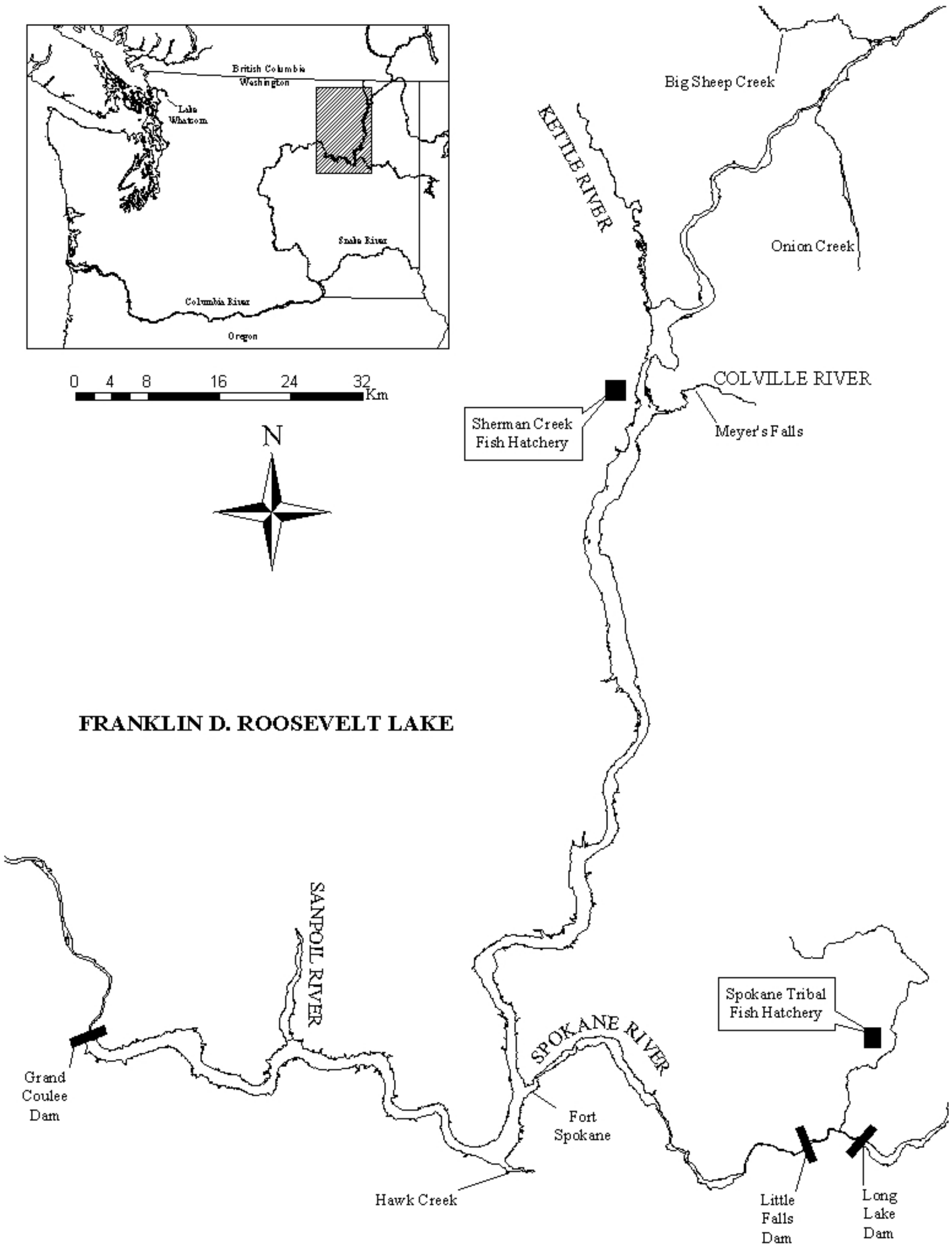

Figure 8. Map of Lake Roosevelt showing location of Big Sheep Creek, a tributary of Lake Roosevelt, Washington, where 322,200 Meadow Creek kokanee fry were released.

Figure 9. Big Sheep Creek waterfall, powerhouse, and tram located 2.6 km from the creek mouth.

Figure 10. Tram used to haul kokanee fry from the top platform to the base of the water fall.

Following installation of the live well, tripods constructed out of heavy gauge (4 in.) angle iron were placed diagonally downstream from the live well. The tripods were 1.5 m (5 ft) long and functioned as fence posts when installed along an imaginary line from bank to bank. 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. When assembled, the weir resembled a picket fence that fish followed up into the live well where they remained until personnel examined them.

Data collected on fish captured in the trap included: species, total length, sex, origin (hatchery or wild), released up or downstream. Stream temperature was taken when fish were observed in the trap. The Colville Confederated Tribe (CCT) was primarily responsible for the daily collection and maintenance of the trap.

Results

Water quality at the release site and trap site appeared stable with cool temperatures, no turbidity, and percent nitrogen saturation below lethal levels for fish (Table 1). The trap was operational 54 days, until 24 October, when a heavy rain event disengaged the trap. The trap was not set back-up due to the lack of fish being captured, and because of forecasted heavy rain events. Six fish were collected in the trap including 3 kokanee, 1 bull trout, 1 mountain whitefish, and 1 rainbow trout (Table 2). The kokanee collected on 1 November was in the live box, despite the trap panels being down.

Discussion

Adult returns to Big Sheep Creek were not expected during this sampling period. Kokanee are expected the fall of 2005 (as age-2 precocial fish), and 2006 (as age-3 adults). Trapping in the fall of 2004 was primarily used to verify that a run of kokanee does not currently exist in Big Sheep Creek. Despite the trap failure after the extremely high flow, the lack of a significant number of kokanee (n=3) collected in the fall of 2004 verified the assumption that a kokanee run does not currently exist in Big Sheep Creek with the exception of the occasional straying fish. Additionally, wild kokanee tend to be early running fish (September); supporting the notion that a run does not exist.

Additional fry stocking of Big Sheep Creek is planned for 2005, with an increased release target of 500,000 kokanee. The five year plan put together by the Lake Roosevelt Fisheries Management Team indicated annual stocking through 2006 with an annual evaluation to determine the success of fry plants. Additional fry vs. post-smolt experiments are planned for Lake Roosevelt to determine the variation in success between the new fry planting methodology and the current program of post-smolts. These data collected over the next five years will assist managers in determining if the program should maintain a post-smolt release strategy or move towards fry plants.

Table 15. Summary of water quality data taken 15 m below the water fall and near the creek mouth where the trap was set on Big Sheep Creek, 2004.

Parameter	17 Mar Release Site	17 Mar Trap Site	23 Aug Trap Site	3 Sept Trap Site	23 Sept Trap Site	26 Oct Trap Site
Depth (m)	0.5	0.5	0.3	0.4	0.5	0.4
Mean temp (°C)	5.8	5.8	16.2	12.2	12.0	4.4
pH	8.1	8.2	8.7	8.6	8.5	7.3
Turbidity. (NTU)	0	0	0	0	0	0
Conductivity (µS/cm)	178.6	178.6	176.4	181.4	159.8	137.5
Mean dissolved oxygen (mg/l)	11.7	11.0	10.7	10.6	10.2	15.0
Total dissolved gas (mmHg)	742	731	740	771	740	737
Mean total dissolved gas (%)	102.7	101.0	103.1	106.0	101.3	101.9
Total dissolved solids (mg/l)	0.1143	0.1143	0.1129	0.1161	0.1023	0.088
% Nitrogen saturation	105.0	104.2	102.8	108.8	104.1	102.7
Discharge (ft^3/s)	65.3	--	51.1	--	64.7	77.1
Mean velocity (ft/s)	1.5	--	1.5		1.7	2.0

Table 16. Data on fish collected in the trap at Big Sheep Creek, including date, species, sex, total length (TL), origin, release location (upstream or downstream of the trap), and water temperature. Dashes indicate no data taken.

Date	Species	Sex	TL (mm)	Origin	Release Location	Water Temp (ºC)
8/25/04	Kokanee	Male	378	Hatchery	Mortality	15
8/25/04	Kokanee	Female	497	Wild	Up	15
8/26/04	Rainbow trout	--	476	--	Down	13
9/15/04	Mountain whitefish	--	360	Wild	Down	11
9/01/04	Bull trout	Male	410	Wild	Upstream	
11/1/04	Kokanee	--	--	--	--	4

Literature Cited

Baldwin, C.M., J.G. McLellan, M.C. Polacek, and K. Underwood. 2003. Walleye predation on hatchery releases of kokanees and rainbow trout in Lake Roosevelt, Washington. North American Journal of Fisheries Management 23:660-676.

Beckman, L. G., J. F. Novotny, W. R. Parsons, and T. T. Tarrell. 1985. Assessment of the fisheries and limnology in Lake F.D. Roosevelt 1980-1983. U.S. Fish and Wildlife Service (USFWS), Final Report to U.S. Bureau of Reclamation (USBR). Contract No. WPRS-0-07-10-X0216; FWS-14-06-009-904, Boise, Idaho.

McLellan, H.J. and A.T. Scholz. 2002a. Movements and growth of marked walleye recaptured in Lake Roosevelt, 2000-01. Annual Report 2001. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number 00000118-00001, Contract No. 96BP192246. 41 pp.

McLellan, H.J. and A.T. Scholz. 2001. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt, 2000. Annual Report 2000. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon. Project Number 00000118-00001, Contract No. 96BP192246.

McLellan, H.J. and A.T. Scholz. 2002b. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt, 2001. Annual Report 2001. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon.

McLellan, H.J. and A.T. Scholz. 2003. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt. Final Report 2002. Prepared by Eastern Washington University Fisheries Center for Bonneville Power Administration, Portland Oregon.

McLellan, H.J., A.T. Scholz, and J.G. McLellan. 2004. Open water release strategies for kokanee in Lake Roosevelt, 2003. Annual Report 2003. Prepared by Eastern Washington University Fisheries Center and Washington Department of Fish and Wildlife for Bonneville Power Administration, Portland Oregon.

Tilson, M.B., A.T. Scholz, and J.L. Miller. 1996. Artificial imprinting of juvenile kokanee salmon (Oncorhynchus nerka): Implications for operating Lake Roosevelt kokanee salmon hatcheries. Pages 281-340 *in* K.D. Underwood and J.P. Shields. 1996. Lake Roosevelt Fisheries and Limnological Research: 1995.