Eastern Washington University
EWU Digital Commons

EWU Masters Thesis Collection

Student Research and Creative Works

2013

Assessment of the hatchery kokanee (Oncorhynchus nerka) release program in Lake Roosevelt 2009 -- 2012

Alix O. Blake
Eastern Washington University

Assessment of the Hatchery Kokanee (*Oncorhynchus nerka*) Release Program in Lake Roosevelt 2009 – 2012

A Thesis

Presented To

Eastern Washington University

Cheney, Washington

In Partial Fulfillment of the Requirements

For the Degree

Biology (Master of Science)

By

Alix O. Blake

Winter 2013

THESIS OF ALIX O. BLAKE APPROVED BY

____ Date____________

Dr. Allan Scholz

____ Date____________

Dr. Ross Black

____ Date____________

Doris Munson

MASTER'S THESIS

In presenting this thesis partial fulfillment of the requirements for a master's degree at Eastern Washington University, I agree that JFK Library shall make copies freely available for inspection. I further agree that copying of this project in whole or in part is allowed only for scholarly purposes. It is understood, however, that any copying or publication of this thesis for commercial purposes, for financial gain, shall not be allowed without my written permission

Signature ________________________

Date_____________________________

Abstract

This study determined which kokanee stock performed best in Lake Roosevelt, WA: Lake Whatcom, Meadow Creek, or F_1 mixed stock. The F_1 mixed stock was created by collecting eggs from Lake Whatcom, Meadow Creek and non-marked kokanee that returned to Hawk Creek and raising them to the residualized smolt stage at the Spokane Tribal hatchery for release back into Lake Roosevelt. Fall spawning run data (2009 – 2012) were analyzed to assess the percentage and sex ratios of each stock returning to spawn in Lake Roosevelt. We had record returns of hatchery kokanee in 2009 (n = 8,895) and 2010 (n = 8,925), but poor returns in 2011 (n = 423) and 2012 (n = 1,893). The F_1 mixed stock significantly outperformed the Lake Whatcom and Meadow Creek stocks for both return percentage ($P < 0.001$) and sex ratios ($P < 0.001$) in each year. The record kokanee returns of 2009 and 2010 coincided with relatively shallow drawdown and longer water retention times, whereas, the poor 2011 and 2012 returns coincided with a deep drawdown and shorter water retention times.

Acknowledgements

I'd like to thank my committee members: Dr. Allan Scholz, Dr.Ross Black and Doris Munson for their time and advice while writing my thesis. I acknowledge the Lake Roosevelt Fisheries Evaluation Program for advice in all aspects of this project: Spokane Tribe of Indians, Washington Department of Fish and Wildlife and Colville Confederated Tribes. I greatly appreciate Tim Peone (Manager Spokane Tribal Hatchery) and Mitch Combs (Manager Sherman Creek Hatchery) for rearing the hatchery kokanee.

I thank EWU students and employees for help with data collection: Mark Paluch, Dana Stroud, Aaron Stroud, Raymond Ostlie, Shawna Warehime, Tyler Parsons, Sarah Stankavich, Kristina Pikalova, Devin Sontag, Gerald Claghorn, Casey Pharr, Elizabeth Lindsey and Taylor McCroskey. I thank Reardan High School students Ruger Lillengreen, Curtis Lee and Bevin Matt who also assisted checking the trap. I thank Tom Steen and Buster Hill, EWU Auto Shop, for their maintenance and repairs to our vehicles and electrofishing boats.

I thank Spokane Tribal field crew members Paul Jurun, Nicklas Eldred, Andy Moss, Michael Andrews, Timothy Hughes, Skyler Peone, Andy Miller, Randy Peone, Donny Carter, Dan Curd, Jackie Johnstone, and Drew Payne, DJ Sebastian, Deanne Pavlik-Kunkel, Tamera Knudsen, Hank Etue, Donny Carter for checking the Hawk Creek trap.

I thank the CCT crew: Holly McLellan, Shay Wolvert, Bill Laramie, Charles Joseph, Todd Nanamkin, and Erick Simonsen, Jory Vallee, Donald Carson, Eric Furguson, Barney Furguson and Shana Furguson for trapping kokanee in the Sanpoil River and providing data.

Table of Contents

List of Tables

List of Figures

Introduction

Kokanee salmon are freshwater resident sockeye salmon, *Oncorhynchus nerka*, which have been stocked into Lake Franklin D. Roosevelt since 1988 under the Northwest Power Planning Council's (NPPC) resident fish substitution policy (NPPC 1987). Grand Coulee Dam permanently blocked the passage of anadromous salmonids (coho salmon *O. kisutch*, steelhead trout *O. mykiss*, sockeye salmon *O. nerka*, and Chinook salmon *O. tschawytscha*) in 1939 due to the lack of a fish ladder (Scholz et al. 1986). In 1987, NPPC adopted the resident fish substitution policy, which allowed resident salmonids to be substituted for lost anadromous fish in cases where dams have permanently blocked anadromous fish. Salmon previously had access to the entire Columbia River. Chinook salmon were previously reported to spawn in the headwater lakes of the Columbia River (Windermere and Columbia lakes) in British Columbia (Bryant and Parkhurst 1950, Fulton 1968).

Kokanee are native to the Pacific Northwest, where they are known by many common names: little redfish, silver trout, kokanee, and Kennerly's salmon (Wallis and Bond 1950). Kokanee are known to recycle nutrients assimilated while growing in the nursery lake (e.g. Lake Tahoe) back to home tributaries during the spawning season (Richey et al. 1975). Historically large runs of salmonids journeyed from the Pacific Ocean to spawn in the Upper Columbia River (now Lake Roosevelt and its tributaries). The returning salmon provided food and energy to both native animal species as well as the local tribes. The Spokane, Colville Confederated, Kalispel, Coeur d'Alene , and Kootenai Tribes all maintained subsistence fisheries in the Upper Columbia prior to the completion of the dams (Scholz et al. 1986). Salmonids were also a keystone species, providing food for species such as river otters (*Lontra canadensis*), bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), great blue heron (*Ardea herodias*), grizzly bear (*Ursus arctos horribilis*), black bear (*Ursus americanus*) and carnivorous fish species. They also provided nutrients from marine environments that fertilized the watershed upon death in their natal tributaries (Hunt et al. 1992, Cedarholm et al. 1999, 2000; Gresh et al. 2000; Scholz and McLellan 2010).

The purpose of stocking kokanee in Lake Roosevelt was to provide substitute sport and Indian subsistence fisheries, as well as ecologically benefit the salmon predators in the system. Throughout Lake Roosevelt, many species have been observed taking advantage of the stocked kokanee as a food source. Bald eagles, river otter, and burbot (*Lota lota*) have been recorded in Hawk Creek consuming kokanee. Black bear, osprey, and coyotes have also been spotted consuming kokanee in recent years. Between 1987 and 2000 bald eagle production in Lake Roosevelt increased from 2 fledged to 24, as hatchery stocking of kokanee increased (Murphy 2000). Approximately 23% of all prey items brought by bald eagles to their nests were kokanee (SAIC 1996).

Before the completion of the third power house on Grand Coulee Dam, naturally reproducing kokanee were still found migrating into what is now Lake Roosevelt (Fulton and Laird 1967; Snyder 1967; Bennett and White 1977; Stober et al. 1977; Scholz et al. 1986). Kokanee are known limnetic planktivores in Lake Roosevelt and consume primarily *Daphnia* zooplankton (Peone et al. 1990; Griffith and Scholz 1991; Griffith et al. 1992; Thatcher et al. 1993, 1994; Underwood and Shields 1996a, 1997b; Underwood et al. 1996; Cichosz et al. 1997, 1998, 1999; McLellan et al. 2003; Lee et al. 2003, 2006; Scofield 2004, 2007; Fields et al. 2004; Pavlik-Kunkel et al. 2005, 2008; Black et al.

2003). An investigation of zooplankton abundance in Lake Roosevelt conducted by Jagielo (1984) found that *Daphnia* production in Lake Roosevelt exceeded that of most kokanee lakes. Jagielo (1984) and Beckman et al. (1985) estimated that *Daphnia* production in Lake Roosevelt could support about 5.9 million adult kokanee. Nigro et al. (1983) estimated that Lake Roosevelt could produce 181,000 kokanee by natural reproduction based on the amount of spawning habitat in the reservoir. Growth of kokanee is known to be dependent on lake productivity and kokanee density (Rieman and Myers 1992, Rieman and Maiolie 1995). These observations led Scholz et al. (1986) to conclude that artificial production of kokanee was needed to make reasonable use of the production potential of the reservoir and recommended that kokanee producing hatcheries be built to replace the lost salmonid runs under the NPPC Columbia Basin Fish and Wildlife Program.

The Lake Roosevelt Fisheries Evaluation Program (LRFEP) was created in 1988 to evaluate the effectiveness of the Grand Coulee hatchery release programs. Kokanee fry were initially planted from 1988 – 1999 and did not contribute to the formation of a fishery because of high predation rates by nonindigenous predators such as walleye (*Sander viterus*) and smallmouth bass (*Micropterus dolieumi*) (Baldwin et al. 2003; McClellan et al. 2004; Stroud at al. 2010a, 2010b). Those that did survive underwent smolt transformation in the reservoir and developed an urge to migrate downstream below Grand Coulee Dam (Scholz et al. 1992; Tilson 1994; Tilson et al. 1994, 1995; McClellan et al. 2004). Smoltifcation is a critical period for olfactory imprinting (formation of a permanent memory of natal water for relocating the home river during the adult migration) (Scholz et al. 1976, 1978a, 1992; Hasler et al. 1978; Hasler and Scholz

1983). Between 1992 and 1999, a total of 789,904 kokanee fry were marked with coded wire tags and only 15 of them were subsequently recovered in the reservoir (< 0.01% recovery), none were recovered by anglers in the reservoir and 58 were recovered below Grand Coulee Dam at Rocky Reach, Rock Island and McNary dams. Consequently, it was decided to release kokanee at age 1.5 after they became residualized smolts. Residualized smolts have already undergone smolt transformation and have lost the urge to migrate downstream.

As the Spokane Tribal Hatchery does not have sufficient space to rear a large number of kokanee to residualized smolt size, the fish managers (Spokane Tribe of Indians, Colville Confederated Tribes, and Washington Department of Fish and Wildlife) decided to to increase the number of residualized smolt stage kokanee released by transfering kokanee fry into net pens at various locations (Kettle Falls, Sherman Creek, Colville River, Seven Bays and Lincoln) in Lake Roosevelt . In the net pens, the fry were raised until residualized smolt stage before release. However, significantly fewer net pen raised kokanee returned to spawn at the Sherman Creek egg collection facility (0.02 – 0.28 % of those released) than kokanee held at Sherman Creek hatchery and released there as residualized smolts (0.63 % of those released) (McLellan et al. 2004). This was likely due to the kokanee held at Sherman Creek becoming imprinted to Sherman Creek water during the smolt stage; whereas those held in net pens did not. Also, significantly fewer kokanee raised in net pens, as compared to kokanee raised at Sherman Creek, were recovered at other locations in Lake Roosevelt that were monitored during the spawning season (McLellan et al. 2004). Total percentage of net pen kokanee collected anywhere in Lake Roosevelt, based on number released, varied from 0.04 – 0.38 %, whereas the percentage of Sherman Creek kokanee was 0.79 % (McLellan et al. 2004). The Sherman Creek net pen site had the highest percentage of net pen raised fish returning to Sherman Creek (0.28 %) and in the reservoir (0.38 %). This result was probably related to net pen kokanee being released before they had residualized due to of the drawdown of the reservoir for flood control. The reservoir was drawn down so far that net pen sites were left dry by mid-May. As a result, the net pen kokanee had to be released before they residualized and probably underwent smolt transformation in the reservoir after being released from the net pens and emigrating downstream below Grand Coulee Dam.

It has been documented that kokanee exhibited two periods when they became sensitive to and imprint on organic odors, at the swimup and smolt stages (Scholz et al. 1992; Tilson et al. 1994, 1995). Both periods correlated with surges of thyroid hormones. McLellan et al. (2004) compared the return rates to Sherman Creek of morpholine and non-morpholine exposed kokanee. The morpholine fish were exposed to morpholine during the swim up and smolt stages prior to their release as residualized smolts into Sherman Creek. The non-morpholine group was held in Sherman creek prior to release during the smolt transformation stage. Sherman Creek was scented with morpholine in 1998 and the returns of both groups to Sherman Creek were compared. The number from each group, morpholine (n = 1,250; 1.8 %) and non-morpholine (n = 1,117; 1.9 %), returning to Sherman Creek or the other tributaries in Lake Roosevelt was not significantly different; indicating the kokanee held at Sherman Creek did imprint to the water during smolt stage and that this was a sufficient stimulus for accurate homing to Sherman Creek.

Poor return rates (historical average < 0.5 %) of residualized smolts released at Sherman Creek were associated with predation by walleye. Walleye spawn in the Spokane River Arm of Lake Roosevelt and migrate north in the Columbia River. They arrive at Sherman Creek at approximately the same time kokanee were released from the Sherman Creek hatchery. Baldwin et al. (2003), found 16,610 walleye consumed approximately 54,073 of 386,622 (15.0 %) of the hatchery kokanee within 41 days of release in 1999. However, the data was collected over a limited area (3-5 RKM), which would not have accurately represented the spatial heterogeneity of walleye, introducing the potential for overestimating reservoir-wide consumption. Baldwin et al. (2003), found 12,233 walleye consumed approximately 34,076 of 493,585 (9.4 %) of the hatchery kokanee within 31 days of release in 2000. In 2000, the data was collected over a broader 55 RKM section of the reservoir, which coincided with the population estimate area. Baldwin's consumption estimates were over 31-41 days post kokanee release; if the walleye had continued to consume kokanee until the temperature dropped below their thermal limit (feeding ceases), the annual mortality due to predation by walleye could have increased substantially. Baldwin also did not factor in walleye under 300 mm, which contributed to kokanee predation in the reservoir. Overall, kokanee mortality due to predation was most likely underestimated by Baldwin et al. (2003) due to the short time frame and exclusion of walleye under 300 mm.

Due to the high predation, the fish managers implemented the strategy of releasing residualized smolt kokanee in areas that spatially isolated them from walleye predators. Kokanee released at Little Falls Dam experienced heavy predation because the Spokane River is a known walleye spawn site and kokanee must migrate through a curtain of walleye in order to reach the reservoir. Instead of releasing the fish at Little Falls Dam (on the Spokane River) and Sherman Creek, the fish managers began releasing them at two boat launches, Fort Spokane at the mouth of the Spokane River about 40 km below Little Falls Dam, and Gifford on the Columbia River, which is 40 km downstream of Sherman Creek. Both sites offered an immediate access to deep water limnetic refuge. In 2003, kokanee were again released at Little Falls (n = 24,900), Fort Spokane (n = 211,461), at Sherman Creek (n = 24,821) and Gifford (n = 203,596). Five (0.02%) from the Little Falls release, 1,163 (0.52%) from the Fort Spokane release, 16 (0.06%) from the Sherman Creek release and 926 (0.45%) from the Gifford release were subsequently caught at tributary mouths throughout the reservoir during their spawning migration (McClellan et al. 2004). The release sites with limnetic refuge had the largest return rates but differed greatly in their contribution to the sports fishery. Anglers caught none of the kokanee released at Little Falls, 352 of those released at Fort Spokane, none of those released at Sherman Creek, and 7 of those released at Gifford (McLellan et al. 2004).

However, precise homing to specific egg collection sites was reduced. Hatchery kokanee released at Fort Spokane are not imprinted to any tributary. If kokanee are released from a hatchery as residualizing smolts, they either return to the hatchery rather than the stocking site (if the hatchery is close to release location) or stray into many streams (if they hatchery is far from the release location) (Ellis 1957, Peck 1970; reviewed by Ricker 1972, Scholz et al. 1976, 1978a; and Hasler and Scholz 1983). Hawk Creek began receiving the highest number of returning kokanee; this is attributable to its proximity to Fort Spokane and its constant year round flow.

Historically there have been two main stocks of kokanee released in Lake Roosevelt: Lake Whatcom and Meadow Creek. Lake Whatcom kokanee salmon is a coastal stock obtained from the Washington Department of Fish and Wildlife (WDFW) Lake Whatcom hatchery located in Bellingham, WA.Lake Whatcom kokanee are the stock of choice used by WDFW for kokanee planting projects and have been stocked into Lake Roosevelt since 1988. Since 2000, the LRFEP (Lake Roosevelt Fisheries Evaluation Program) has worked with Canadian agencies to obtain Meadow Creek kokanee eggs. Meadow Creek, a tributary to the north arm of Kootenay Lake, British Columbia, currently supports an abundant native kokanee run. Meadow Creek kokanee were chosen on the basis of being more locally adapted to the conditions in Lake Roosevelt, since they are an upper Columbia Basin stock.

A study was performed to compare the performance of different genetic strains of kokanee in Lake Roosevelt. Between 1987 and 1999, Lake Whatcom kokanee returned an average rate of 0.05 % with sex ratios averaging 1:30 (female: male). In 2000, matched pairs of kokanee were released at Sherman Creek: Lake Whatcom stock (n = 74,669) and Meadow Creek stock (n = 83,291). Returns of kokanee to Sherman Creek numbered 203 Lake Whatcom fish (0.27% recovery rate) and 1,344 Meadow Creek fish (1.61% recovery rate) (McLellan et al. 2004). From 2000 – 2007, Meadow Creek kokanee significantly outperformed the Lake Whatcom kokanee, with 2 to 6.5 times more Meadow Creek kokanee returning compared to the Lake Whatcom kokanee (McLellan and Scholz 2001, 2002, 2003; McLellan et al. 2004, 2007, 2008). Despite the improved returns using the Meadow Creek stock, they returned at a sex ratio of approximately 10 males: 1 female.

The main issue with skewed sex ratios is that the fish managers were unable to collect enough eggs for hatchery production, in turn, making them dependent on getting eggs from outside sources. Fisheries managers are currently limited by the allotment of eggs from Lake Whatcom and Meadow Creek stocks which can be irregular and even unavailable in some years. In Lake Roosevelt, kokanee maturing at age 2 historically return at sex ratios of approximately 30 males to 1 female; whereas, 3 year old kokanee runs usually return more equal sex ratios. However, a 3 year old run has not materialized, so managers have chosen to focus on improving the 2 year old run sex ratios. A large 2 year old run is usually undesirable to fisheries managers because kokanee have a semelparous life history. Early maturation greatly limits the time kokanee are available for angler harvest; although, 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 3-4 kokanee in other systems (Rieman and Myers 1992, McLellan et al. 2004a, Scholz and McLellan 2010). However, hatchery kokanee are only in the fishery for five months before early maturation sets in, which is a concern to fisheries managers.

Kokanee sex has been found to be temperature dependent at an early developmental stage (Craig et al. 1996, Azuma et al. 2004). Azuma et al. (2004) found all female *O.nerka* exposed to high temperatures became males. The sex change was determined to be immediately after hatching; therefore, managers developed an experiment using two water treatments to determine if the thermal conditions at the Spokane Tribal Hatchery were playing a role in sex determination. Pre-release sex ratios were determined to be approximately 1:1, showing there was no sex change post hatching in the Spokane Tribal Hatchery (McLellan et. al 2004). Sex ratios for age 2 adults returning to spawn significantly deviated from a 1:1 ratio for all test groups. All test groups returned at unequal sex ratios: spring water was 1:11, mixed water was 1:15 and well water was 1:115 (McLellan et al. 2004).

These findings indicated an unknown mechanism within the reservoir (after release) was contributing to skewed sex ratios, not the thermal experience within the hatchery. One theory was the accelerated growth within the reservoir was causing a masculinity of the female population. A second theory was that the skewed ratios were due to release size which may have pushed the males to return as 2 year olds (jack run) but the females didn't mature until three years old. The females remained in the reservoir and were subjected to high mortality (entrainment and predation). The F_1 mixed stock was released at a larger size, and had more females returning; thus, potentially the females needed to be released at the larger size in order to mature at two years old. Predation by walleye on a 3 year old kokanee was unlikely, due to the large size the kokanee and low number of kokanee (2 year old) returning with visible walleye bite scars. Entrainment was a possible cause for the lack of 3 year old run because of the seasonal hormone changes, it was plausible the kokanee developed a 3 year old smolt stage and developed the urge to migrate downstream again.

In an attempt to improve sex ratios of the age 2 run, in 2002, managers began collecting eggs from age 2 – 3 year old Meadow Creek stock, Lake Whatcom stock, and non-marked kokanee that had returned to Hawk Creek (the primary egg collection site) and raising them to the residualized smolt stage at the Spokane Tribal Hatchery, for release back into Lake Roosevelt. By taking eggs from females (parents) that had survived until spawning in Lake Roosevelt we attempted a genetic manipulation to increase the number of females returning to egg collection sites in the F_1 generation. Egg collection from these individuals produced the F_1 mixed stock. This stock has been produced off and on since 2004.

The purpose of this study was to determine which hatchery kokanee stock performed best in Lake Roosevelt: Lake Whatcom, Meadow Creek, or F_1 mixed stock. Fall spawning run data from 2009, 2010, 2011, and 2012 was analyzed to assess the Lake Roosevelt hatchery release program. To determine which stock performed best, the percentage of each stock returning and sex ratios was compared. Secondary goals of the project were to assess the relationship between reservoir conditions and escapement and collect skein data on each stock to determine the potential egg take. A portion of the ripe kokanee returning to Hawk Creek were spawned for hatchery production.

Hypotheses

Hypothesis 1: (H_o) There is no difference in the percentage of each stock returning to spawn in Lake Roosevelt. This hypothesis would be supported if statistical testing indicates that there is no difference in the return rates ($p > 0.05$). (H_{A1}) A higher percentage of F_1 mixed stock will return than Lake Whatcom or Meadow Creek fish. This hypothesis would be supported if statistical test reject the null hypothesis ($p \leq 0.05$) and if a higher percentage of F_1 mixed stock fish are recovered,

Hypothesis 2: (H_o) There is no difference in the sex ratios between each stock. This hypothesis would be supported if statistical testing indicates that there is not a difference in the sex ratios returning between each stock ($p > 0.05$). (H_{A1}) F_1 mixed stock kokanee will return more equal sex ratios than Lake Whatcom or Meadow Creek kokanee. This hypothesis would be supported if statistical tests rejected the null hypothesis ($p \leq 0.05$) and if a more equal sex ratio of F_1 mixed stock fish are recovered.

Hypothesis 3: (H_o) There is no relationship between return percentage (escapement) and reservoir conditions. This hypothesis would be supported if statistical testing showed there was no significant relationship ($p > 0.05$). (H_{A1}) There is a correlation between return percentage (escapement) and reservoir conditions. This hypothesis would be supported if statistical test rejected the null hypothesis ($p \leq 0.05$).

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). The lake elevation fluctuates between a minimum of 1,208 ft above mean sea level and a maximum of 1,290 ft above msl. The dam was primarily designed for electricity generation, irrigation support, flood control and, eventually, water needs of downstream fisheries. The dam is operated for flood control from approximately January through June based on the forecasted runoff for the specific year.

Fish managers attempt to release hatchery kokanee and rainbow trout into Lake Roosevelt when the reservoir is refilling and has reached approximately 1,265 ft elevation (late May – early June). At 1,265 ft and above, entrainment is reduced because water flows are weaker. The reservoir is completely refilled by approximately the beginning of July each year. During the summer months (July and August) lake elevations generally fluctuate between 1,278 and 1,290 ft.

During the fall, the Army Corp of Engineers attempts to keep the reservoir between 1,283 and 1,285 ft to assist the returning kokanee preparing to spawn. The high reservoir elevation is important to aid in kokanee collection, access to tributaries and water retention time for zooplankton production. Lake Roosevelt has also become the supply reservoir for all the lower reservoirs. Grand Coulee Dam is operated to help meet the elevations required below Bonneville Dam to support chum salmon spawning and incubation during the fall and winter, as well as meeting the Priest Rapids weekly flow objectives to support fall Chinook salmon spawning and incubation.

Kokanee Rearing

Feeding rates for all stocks were calculated by the Spokane Tribal Hatchery based on food type, growth rates and temperature. Skretting Nutra starter feed was used for fry and fingerlings, Skretting Apollo diet was used for fingerlings and yearlings (Peone 2009). Each stock of kokanee received a unique combination of fin clips each year.

Stocking Strategies

The co-managers of Lake Roosevelt (WDFW, STOI, CCT) developed the Lake Roosevelt Guiding Document and subsequently the Lake Roosevelt Kokanee Management Plan to assist with guiding stocking strategies for Lake Roosevelt. Due to the unpredictable nature of available kokanee stocks, the specific stocking plan was developed annually during fall and spring coordination meetings. However, in general the following assumptions were made that highlight the reduction in predation and reduce post stocking entrainment: (McLellan et al. 2010; LRMT).

Figure 1. Map of Lake Roosevelt and primary sampling locations.

1) Stock Preference: The mixed kokanee (progeny of hatchery fish that have returned to spawn), then Meadow Creek stock kokanee, followed by Lake Whatcom stock kokanee.

2) Location: Fort Spokane boat launch was the preferred release location, due to increased survival post stocking. Hawk Creek was the primary egg collection site.

3) Release Timing: Kokanee were released after refill began, and after the reservoir elevation reached at least 1,260 msl but preferably <1,280 msl elevation, which is generally near the end of May or in early June, and water retention times were greater than 45 days or more.

4) Size: The hatcheries had a target release size of 5-7 fish/lb. The mixed stock was typically released at a larger size (1.5 – 2.5 fish/lb) because of the reduced densities in the raceways.

Kokanee Plants

Each spring between May and June kokanee residualized smolts were stocked into Lake Roosevelt based on availability of eggs from Lake Whatcom and Meadow Creek and the discretion of Lake Roosevelt fisheries managers. Not all three stocks were released each year due to availability and space within the hatchery. The kokanee were stocked at Fort Spokane to decrease the predation by walleye. The CCT monitored the Sanpoil River for our kokanee and returned the data to us.

In 2009 a total of 510,760 yearling kokanee were stocked into Lake Roosevelt (Table 1). Between 18 May and 8 June 2009, 484,066 Lake Whatcom stock residualized smolts were released at the Fort Spokane boat launch. On 15 June 2009, 23,904 additional Lake Whatcom kokanee were released at Little Falls Dam. These fish ranged

Table 1. Total number of post smolt (yearling) kokanee released into Lake Roosevelt, 2009-2012.Summary included date released, stock and brood year, number released, number of fish per pound, location and mark (AD = adipose; RV = right ventral, LV = left ventral, RP = right pectoral and CWT = coded wire tag).

Date	Stock	# released	Fish/lb	Location	Mark
2009					
5/15	F_1 Mixed	2,790	1.5	F. Spokane	ADRV
5/18 - 6/8	Lake Whatcom	484,066	12.0 - 20.7	F. Spokane	AD
6/15	Lake Whatcom	23,904	13.0	Little Falls	ADLV
	Total	510,760			
2010					
6/1	F_1 Mixed	12,420	3.0	F. Spokane	ADRP
6/2 - 6/8	Meadow Creek	188,805	5.0 - 8.0	F. Spokane	AD
5/10	Meadow Creek	10,080	9.0	Sanpoil River	AD/CWT
	Total	211,305			
2011					
6/7	F_1 Mixed	11,102	2.0	F. Spokane	ADRV
5/31 – 6/11	Lake Whatcom	199,861	8.0 - 11.0	F. Spokane	AD
6/1	Lake Whatcom	20,360	8.0 - 11.0	Sanpoil	AD/CWT
	Total	231,323			
2012					
6/18 - 6/25	F_1 Mixed	39,636	2.0 - 3.3	F. Spokane	ADLV
6/20	F_1 Mixed	4,140	2.0	Little Falls	ADLV
6/6 - 6/18	Lake Whatcom	165,082	6.3 - 13.2	F. Spokane	AD
6/14	Lake Whatcom	22,496	7.4	Sanpoil	AD/CWT
	Total	231,354			
TOTAL		**1,184,742**			

between 12.0 and 20.7 fish per pound. Additionally, on 15 May 2009, 2,790 F_1 mixed stock residualized smolts were released at the Fort Spokane boat launch. These fish were larger, at 1.5 fish per pound, and were right ventral and adipose fin clipped.

In 2010, a total of 211,305 yearling kokanee were stocked into Lake Roosevelt (Table 1). Between 2 June and 8 June 2010, 108,805 Meadow Creek stock residualized smolts were released at the Fort Spokane boat launch. On 10 May 2010, 10,080 Meadow Creek residualized smolts were released in the Sanpoil River at the Brush Creek Campground. These fish ranged between 5.0 and 9.0 fish per pound. Additionally, on 1 June 2010, 12,420 F_1 mixed stock residualized smolts were released at the Fort Spokane boat launch. These fish were larger, at 3.0 fish per pound, and were right pectoral and adipose fin clipped.

In 2011, a total of 231,323 yearling kokanee were stocked into Lake Roosevelt (Table 1). Between 31 May and 11 June 2011, 199,861 Lake Whatcom stock residualized smolts were released at the Fort Spokane boat launch. On 1 June 2011, 20,360 Lake Whatcom residualized smolts were released into the Sanpoil River. These fish ranged between 8.0 and 11.0 fish per pound. Additionally, on 7 June 2011, 11,102 F_1 mixed stock residualized smolts were released at the Fort Spokane boat launch. These fish were larger, at 3.0 fish per pound and were right ventral and adipose fin clipped.

In 2012, a total of 231,354 yearling kokanee were stocked into Lake Roosevelt (Table 1). Between 6 June and 18 June 2012, 165,002 Lake Whatcom stock residualized smolts were released at the Fort Spokane boat launch. On 1 June 2012, 20,360 Lake Whatcom residualized smolts were released in the Sanpoil River. These fish ranged between 6.3 and 13.2 fish per pound. Additionally, between 18 June and 25 June 2012, 39,636 F_1 mixed stock residualized smolts were released at the Fort Spokane boat launch (14 were released at the Keller boat launch). On 20 June 4,140 F_1 mixed stock residualized smolts were released at the Little Falls Dam. These fish were larger, at 2.0 – 3.3 fish per pound, and were right ventral and adipose fin clipped.

Escapement Monitoring

Kokanee weren't released at Hawk Creek, although it continues to be the primary escapement site for egg collection from returning adults. Hawk Creek is a 13 km long embayment located south of the Fort Spokane boat launch release site. It is probably desirable by kokanee due to its constant flows and cool water during the fall spawning run. Unlike most of the creeks flowing into Lake Roosevelt, Hawk Creek never dries upcreek flows year round.

An adult weir trap was installed just below the plunge pool at the Hawk Creek Falls on 12 August --removed 2 December 2009, 2 August -- removed 6 December 2010, 30 August – removed 22 November 2011 and 9 August – removed 20 November 2012. The trap consisted of an upstream box, and ten panels that were secured in the stream with metal fence posts. The box had a welded aluminum frame that was 1.31 m long and 0.89 m wide and 0.71 m tall. The frame was constructed of 3.81 cm square channel. The top of the box was covered with plywood and it was hinged, so it could be opened to extract fish. The sides, front (entrance), and bottom of the trap were covered with aluminum sheeting that had 2.54 cm tall x 0.95 cm wide holes spaced approximately 2.54 cm apart. The back of the trap was covered with 2.70 cm diameter aluminum bars spaced 1.27 cm apart. The front of the box had a 0.51 m wide and 0.57 m tall rectangular opening, which was the entrance to the throat of the trap. The throat was triangle shaped and it extended 0.55 m into the trap. The sides of the throat consisted of 2.70 cm diameter aluminum bars spaced 1.27cm apart, except the final bar (at the apex of the triangle), which was 7.62 cm from the second to last bars on either side. The trap was designed for kokanee to swim through the throat into the holding box, where they would remain until the trap was checked. The panel frames were 1.22 m tall x 1.52 m wide and constructed with angle iron. A 60 cm long hardware cloth flap extended upstream from the bottom of the panels. Sand bags were placed on the flaps along the bottom of the panels to prevent undercutting. Sand bags were also placed on the shoreline next to the panels to prevent water from cutting around the sides. All panels were secured together with zip ties, cables and padlocks.

The trap was monitored and cleaned daily. Captured kokanee were moved into a holding box for later on-site spawning, or released above the trap. Data taken on kokanee included length, fin clips, sex, origin (non-marked, hatchery, unknown) and reproductive condition (immature, mature, ripe, spawned out); weights were taken on a subsample of the fish. All kokanee were given a dorsal hole punch to ensure recaptures weren't counted twice. Non-kokanee fish species collected in the trap were identified, total length (TL) measured and released upstream or downstream.

Skein Analysis

Adult green females that died during handling were used for skein analysis. Skein sacs were placed in zip lock bags in 95 % ethanol until enumeration was conducted in the laboratory. All eggs were counted for total egg counts per female. A length vs. number of eggs regression was then plotted per stock and the equation used to estimate the potential number of eggs collected by all the females captured during sampling. The equation per each stock was input into an excel file and the total length (mm) of each individual female per stock multiplied by the regression equation to calculate that individual female's potential egg production.

$$Y = mx + b$$

Y=number of eggs

x = total length (mm) of each female

m = slope

b = y intercept

Then we summed the total number of eggs (per stock) that could have potentially been collected if all females homed back to Hawk Creek and if all transported females survived to be spawned in the hatchery.

Additional Reservoir Sampling

Due to significant straying from the release site, we monitored other creek mouths within the reservoir for the presence of returning kokanee (Table 2). The Colville Tribe monitored an adult migration trap in the Sanpoil River year round. EWU conducted boat electrofishing surveys at additional tributary mouths (not including Hawk Creek) located through the middle and upper areas of Lake Roosevelt. Sampling was conducted to monitor presence/absence of non-marked and hatchery kokanee at tributaries that kokanee have historically utilized. Each tributary was sampled one to six times between 11 August - 18 November 2009, 3 August - 11 November 2010, 23 August - 15 November 2011 and 8 August – 14 November 2012. Each tributary mouth was sampled using a standard 10 minute electrofishing method. Fish were identified to species using the taxonomic keys of Wydoski and Whitney (1979, 2003) and Scholz and McLellan

Table 2. Names and latitude and longitude of Lake Roosevelt tributaries sampled for kokanee between 2009 -2012.

Location	Lat.	Long.	Location	Lat.	Long.
Spring Canyon			**Kettle Falls**		
Swawilla Basin	47.94326	118.81600	Colville River	48.57372	118.08770
Neal Canyon	47.92268	118.83092	Sherman Creek	48.58350	118.13749
Wynhoff Cove	47.92452	118.79151	Nancy Creek	48.65510	118.11130
Coffman Canyon	47.90662	118.79102	**China Bend**		
Niles Canyon	47.94978	118.81001	15-mile Creek	48.81945	117.98816
Keller Ferry			Flat Creek	48.82172	117.97852
Hellgate Canyon	47.92684	118.69304	Crown Creek	48.85174	117.91418
Penix Canyon	47.91860	118.58589	Rattlesnake Creek	48.85765	117.90080
Speigal Canyon (E15)	47.91943	118.55770	Onion Creek	48.87402	117.84639
Whitestone Creek	47.93721	118.54380	**Porcupine Bay**		
Burbot Creek	47.93411	118.53145	McCoy Springs	47.94805	118.22772
Seven Bays			A-frame	47.94197	118.19075
Lundstrom Bay	47.89337	118.52546	Porcupine Creek	47.89598	118.17400
Halverson Canyon	47.86834	118.49871	Blue Creek	47.89176	118.14042
Sterling Point	47.87702	118.46935	Pitney Creek	47.87628	118.15206
E21	47.87851	118.45144	Cayuse Cove	47.81840	118.09783
E22	47.86578	118.44792	Harker Canyon	47.79651	118.07663
Lincoln	47.83108	118.42654	Mill Creek	47.79115	118.06206
Hawk Creek	47.81440	118.32616	**Little Falls**		
George Creek	47.86008	118.36996	LF Boat Launch	47.83560	117.98827
Fort Spokane			Spring Creek	47.82430	117.93859
Castle Rock Creek	47.96813	118.34126	Powerhouse	47.82983	117.91718
Nine Mile Creek	48.01868	118.40996	Spillway	47.82836	117.91804
Hunters					
Wilmont Cove	48.05621	118.31425			
Enterprise	48.03699	118.25674			
Alder Creek	48.08162	118.22130			
Managhan Creek	48.09116	118.25421			
Hunters Creek	48.11244	118.22813			
Nez Perce Creek	48.15212	118.23539			
Gifford					
East Strange Creek	48.30733	118.14745			
West Stranger Creek	48.29348	118.18125			
Hall Creek	48.30468	118.20029			

(2009). Total length (mm), sex and fin clips were recorded from all fish collected. Weights were collected from a subsample of kokanee. Genetic samples and otoliths were collected from a subsample of unmarked kokanee. Otoliths were sent to the WDFW lab in Olympia, Washington for analysis.

Reservoir Effects

Lake Roosevelt is a large system with a suite of factors besides stock origin that potentially affecti kokanee returns. Reservoir data was obtained from the DART (data access real time) website, which provided daily values of reservoir elevation, temperature, dissolved gas and various other water quality measures at Grand Coulee Dam. Data spanned from 2009 through 2012. Independent variables tested were year, stock, reservoir elevation (daily elevation, elevation change, lowest elevation, drawdown magnitude, and Julian day of summer refill), water retention time (annual average, lowest monthly average), temperature, dissolved gas (%), location (per site, Hawk Creek vs reservoir wide) and predator presence/absence. Daily, monthly and annual average water retention time was calculated as reservoir storage volume divided by outflow. Reservoir storage volume was determined from USACE (1981). Predator presence was determined by whether or not ≥25 predatory fish species (walleye, smallmouth bass and burbot) were presence per sampling trip and site. My dependent variable was escapement (represented at an arcsine transformed proportion).

Statistical Analysis

The three hypotheses were tested to assist in assessing the status of hatchery kokanee in the reservoir.

The null hypothesis that there was no difference in the return percentage of each stock was tested using chi-square tests for independence. Escapement data was collected in the form of the number of each stock returning reservoir wide divided by the number released, to calculate one percentage return value for each stock per year. To reject the null hypothesis, the chi-squared first determined if the stocks are independent from one another. If independence was significantly proven, we could deduce that the stock with higher returns outperformed the other. The expected return value was calculated the by taking the average return percentage for the year and multiplying it by the number of each stock released to get an expected return number for each stock. The escapement percentages must be used because difference number of each stock are released, using raw return numbers would give false results.

$\chi^2 = \sum$ (observed-expected)^2/expected

Expected = [(escapement % stock A + escapement % stock B)] x release number

The null hypothesis of no difference in sex ratios returns between stocks was tested using chi-square tests for independence. To reject the null hypothesis, the chi-squared first determined if the stocks sex ratios were independent from one another. If independence was significantly proven, we could deduce that the stock with the more equal sex ratio outperformed the other. The expected return value was calculated the by taking the average sex ratio of both stocks combined, then determining how many would have returned to equal the average ratio.

Expected = (# females stock A+ # females stock B) : (# males stock A+ # males stock B)

General linear modeling (GLM) was used to determine if other factors besides stock contribute to higher return rates. A general linear model was created due to the nonparametric dependent variable. The best fit model was selected based on its R^2, P and AIC values. Systat was used to calculate the best fit relationship between these variables. A stepwise regression was performed by removing the variable that contributes the least to the model until all remaining variables are significant. GLM is a statistical linear model written in equation form as:

$$Y = b_0 + b_1X_1 + b_2X_2 + ... + b_zX_z$$

Y= dependent variable

B_0 = intercepts

$B_{1...z}$ = slope

X= independent variables

A model was considered significant if $p < 0,05$ and the strength of the relationship between the variables we determined based on the R^2 value. Systat was used to calculate the best fit relationship between the variables and provided the model of best fit.

Results

Reservoir Wide Escapement

A total of 8,895 kokanee were captured during the fall spawning run in 2009. The stocks included Lake Whatcom (n = 8,667), F_1 mixed (n = 209) and non-marked (n = 19) (Table 3). The Lake Whatcom stock averaged (ranged) 307 (290 – 621) mm TL; F_1 mixed stock averaged (ranged) 390 (225 – 457) mm TL; and non-marked kokanee averaged (ranged) 517 (290 – 621) mm TL (Table 4).

The percentage returning of the number released was 1.7 % (Lake Whatcom) and 7.5 % (F_1 mixed) (Table 3). The stocks significantly deviated from the expected (average) return rate of 4.6 % escapement (independence test, $\chi^2 = 9{,}298$, $p < 0.001$) . Therefore the null hypothesis of no difference was rejected; the stocks were independent of each other. The sex ratio (female: male) of each stock was 1:33 (Lake Whatcom), 1:1.6 (F_1 mixed) and 1:2 (non-marked) (Table 3). The stocks significantly deviated from the expected (average) sex ratio of 1:26 (independence test, $\chi^2 = 638$, $p < 0.001$) (Table 5). Both the F_1 mixed stock and non-marked kokanee returned more equal sex ratios than the Lake Whatcom stock.

A total of 8,925 kokanee were captured during the fall spawning run in 2010. The stocks included Meadow Creek (n = 7,653), F_1 mixed (n = 964), 3-year old Lake Whatcom (n = 257) and non-marked (n = 51) (Table 6). The Meadow Creek stock averaged (ranged) 317 (200 – 486) mm TL; F_1 mixed stock averaged (ranged) 356 (271 – 522) mm TL; 3-year old Lake Whatcom stock averaged (ranged) 424 (270 – 596) mm TL; and, non-marked kokanee averaged (ranged) 374 (260 – 621) mm TL (Table 7).

Table 3. Number, escapement (%) and sex ratios of each stock collected in Lake Roosevelt, 2009.

Stock	n	Escapement (%)	Sex Ratio
F_1 Mixed	209	7.5	1:1.6
Lake Whatcom	8,667	1.7	1:33
Non-Marked	19	-	1:2
Total	**8,895**		

Table 4. Average, minimum and maximum total length (mm) of each kokanee stock collected in Lake Roosevelt, 2009.

		Total Length (mm)		
Stock	**n**	**Average**	**Minimum**	**Maximum**
F_1 Mixed	209	390	225	457
Lake Whatcom	8,667	307	205	453
Non-Marked	19	518	290	621
	8,895	**318**	**205**	**621**

Table 5. Chi squared comparison of stock and sex in 2009. Includes: actual return, expected return, Chi^2 value, P value, actual sex ratios, expected ratio, Chi^2 and p value.

Stock	F_1 Mixed	Lake Whatcom
Actual	209	8,667
Expected	128	23,366
Chi^2	9,298	
P	<0.001	
Actual (F-M)	77 - 125	256 - 8,410
Expected (F-M)	8 - 194	333 - 8,333
Chi^2	638	
P	<0.001	

Table 6. Number, escapement (%) and sex ratios of each stock collected in Lake Roosevelt, 2010.

Stock	n	Escapement (%)	Sex Ratio
F_1 Mixed	964	7.8	1:1.2
Lake Whatcom	257	0.05*	1:2*
Meadow Creek	7,653	6.4	1:5
Non-Marked	51	-	1:3
Total	**8,925**		

* 3 year old (2009 release)

Table 7. Average, minimum and maximum total length (mm) of each kokanee stock collected in Lake Roosevelt, 2010.

		Total Length (mm)		
Stock	**n**	**Average**	**Minimum**	**Maximum**
F_1 Mixed	964	356	271	522
Lake Whatcom	257	424	270	596
Meadow Creek	7,653	318	200	486
Non-Marked	51	375	260	621
	8,925	**325**	**200**	**621**

The percentage of the returning stocknumber released was 6.4 % (Meadow Creek) and 7.8 % (F_1 mixed) (Table 6). The stocks significantly deviated from the expected (average) return rate of 7.1 % escapement (independence test, $\chi^2 = 80$, $p < 0.001$) (Table 8). Therefore the null hypothesis of no difference was rejected; the stocks were independent of each other. The sex ratio (female: male) of each stock was 1:5 (Meadow Creek), 1:1.5 (F_1 mixed) and 1:3 (non-marked) (Table 6). The stocks significantly deviated from the expected (average) sex ratio of 1:5 (independence test, $\chi^2 = 403$, $p < 0.001$) (Table 8). Both the F_1 mixed stock and non-marked kokanee returned more equal sex ratios than Meadow Creek.

A total of 423 kokanee were captured during the fall spawning run in 2011. The stocks included Lake Whatcom (n = 141), F_1 mixed (n = 205) and non-marked (n = 76) (Table 9). The Lake Whatcom stock averaged (ranged) 343 (279 – 542) mm TL, F_1 mixed stock averaged (ranged) 359 (280 – 476) mm TL and non-marked kokanee averaged (ranged) 446 (274 – 544) mm TL (Table 10).

The percentage of the returning stock released was 0.06 % (Lake Whatcom) and 1.86 % (F_1 mixed) (Table 9). The stocks significantly deviated from the expected (average) return rate of 0.96 % escapement (independence test, $\chi^2 = 1{,}928$, $p < 0.001$) (Table 11). Therefore the null hypothesis of no difference was rejected; the stocks were independent of each other. The sex ratio (female: male) of each stock was 1:6 (Lake Whatcom), 1:1.6 (F_1 mixed) and 1:2 (non-marked) (Table 9). The stocks significantly deviated from the expected average sex ratio of 1:2.5 (independence test, $\chi^2 = 24$, $p = 0.001$) (Table 11). Both the F_1 mixed stock and non-marked kokanee returned more equal sex ratios than Lake Whatcom.

Table 8. Chi squared comparison of stock and sex in 2010. Includes: actual return, expected return, Chi^2 value, P value, actual sex ratios, expected ratio, Chi2 and p value.

Stock	**F_1 Mixed**	**Meadow Creek**
Actual	964	7,653
Expected	882	8,437
Chi^2	80	
P	<0.001	
Actual (F-M)	383 - 551	1,181 - 6,271
Expected (F-M)	169 - 747	1,490 - 5,963
Chi^2	402	
P	<0.001	

Table 9. Number, escapement (%) and sex ratios of each stock collected in Lake Roosevelt, 2011.

Stock	**N**	**Escapement (%)**	**Sex Ratio**
F_1 Mixed	205	1.9	1:1.6
Lake Whatcom	141	0.06	1:6
Non-Marked	76	-	1:2
Total	423		

Table 10. Average, minimum and maximum total length (mm) of each kokanee stock collected in Lake Roosevelt, 2011.

		Total Length (mm)		
Stock	**n**	**Average**	**Minimum**	**Maximum**
F_1 Mixed	205	359	280	476
Lake Whatcom	141	343	279	542
Non-Marked	76	447	274	544
	423	**370**	**274**	**544**

Table 11. Chi squared comparison of stock and sex in 2011. Includes: actual return, expected return, Chi^2 value, P value, actual sex ratios, expected ratio, Chi^2 and p value.

Stock	F_1 Mixed	Lake Whatcom
Actual	206	141
Expected	106	2,107
Chi^2	1,929	
P	<0.001	
Actual (F-M)	79 - 127	20 - 121
Expected (F-M)	58 - 145	40 - 100
Chi^2	24	
P	0.001	

A total of 1,893 kokanee were captured during the fall spawning run in 2012. The stocks included Lake Whatcom (n = 853), F_1 mixed (n = 1,027) and non-marked (n = 13) (Table 12). The Lake Whatcom stock averaged (ranged) 340 (200 – 490) mm TL; F_1 mixed stock averaged (ranged) 332 (200 – 460) mm TL; and non-marked kokanee averaged (ranged) 318 (111 – 526) mm TL (Table 13).

The percentage returning of the number released was 0.5 % (Lake Whatcom) and 2.35 % (F_1 mixed) (Table 12). The stocks significantly deviated from the expected (average) return rate of 1.4 % escapement (independence test, $\chi^2 = 1,477$, $p < 0.001$) (Table 14). Therefore the null hypothesis of no difference was rejected; the stocks were independent of each other. The sex ratio's (female: male) of each stock was 1:21 (Lake Whatcom), 1:1.2 (F_1mixed) and 2:1(non-marked) (Table 12). The stocks significantly deviated from the expected (average) sex ratio of 1:2.7 (independence test, $\chi^2 = 404$, $p < 0.001$) (Table 14). Both the F_1 mixed stock and non-marked kokanee returned more equal sex ratios than Lake Whatcom.

Hawk Creek Escapement

A total of 8,413 kokanee were captured at Hawk Creek during the fall spawning run in 2009 (Table 15). The stocks included Lake Whatcom (n = 8,193), F_1 mixed (n = 201), and non-marked (n = 19). The sex ratio (female: male) of each stock was1:34 (Lake Whatcom), 1:1.6 (F_1 mixed) and 1:2 (non-marked). The percentage returning of the number released was 1.6 % (Lake Whatcom) and 7.2 % (F_1 mixed).

A total of 5,638 kokanee were captured at Hawk Creek during the fall spawning run in 2010 (Table 16). The stocks included Meadow Creek (n = 4,888), F_1 mixed (n = 637), Lake Whatcom (n = 87) and non-marked (n = 26). The sex ratio (female: male) of

Table 12. Number, escapement (%) and sex ratios of each stock collected in Lake Roosevelt, 2012.

Stock	n	Escapement (%)	Sex ratio
F_1 Mixed	1,027	2.35	1:1.2
Lake Whatcom	853	0.45	1:21
Non-marked	13	-	2:1
Total	**1,893**		

Table 13. Average, minimum and maximum total length (mm) of each kokanee stock collected in Lake Roosevelt, 2012.

		Total Length (mm)		
Stock	**n**	**Average**	**Minimum**	**Maximum**
F_1 Mixed	1,027	332	200	460
Lake Whatcom	835	340	200	490
Non-Marked	13	318	111	526
	1,875	**335**	**111**	**526**

Table 14. Chi squared comparison of stock and sex in 2012. Includes: actual return, expected return, Chi^2 value, P value, actual sex ratios, expected ratio, Chi^2 and p value.

Stock	**F_1 Mixed**	**Lake Whatcom**
Actual	1,027	853
Expected	2,626	613
Chi^2	1,477	
P	<0.001	
Actual (F-M)	463 - 564	39 - 810
Expected (F-M)	375 - 652	311 - 541
Chi^2	404	
P	<0.001	

Table 15. Number, escapement (%) and sex ratio of each stock returning to Hawk Creek, 2009.

Stock	**n**	**Escapement (%)**	**Sex Ratio**
F_1 Mixed	201	7.2	1:1.6
Lake Whatcom	8,193	1.6	1:34
Non-Marked	19	-	1:2
Total	**8,413**		

Table 16. Number, escapement (%) and sex ratio of each stock returning to Hawk Creek, 2010.

Stock	**n**	**Escapement (%)**	**Sex Ratio**
F_1 Mixed	637	5.1	1:1.3
Lake Whatcom	87	-	1:2
Meadow Creek	4,888	4.1	1:5
Non-Marked	26	-	1:3
Total	**5,638**		

each stock was 1:5 (Meadow Creek), 1:1.3 (F_1 mixed), 1:-1.8 (Lake Whatcom) and 1:3 (nonNon-marked). The percentage returning of the number released was 4.1 % (Meadow Creek) and 5.1% (F_1 mixed).

A total of 200 kokanee were captured at Hawk Creek during the fall spawning run in 2011 (Table 17). The stocks included Lake Whatcom (n = 99), F_1 mixed (n = 93), and non-marked (n = 8). The sex ratio (female: male) of each stock was 1:7 (Lake Whatcom), 1:1.6 (F_1 mixed) and 1.6:1 (nonNon-marked). The percentage returning of the number released was 0.04 % (Lake Whatcom) and 0.84 % (F_1 mixed).

A total of 1,591 kokanee were captured at Hawk Creek during the fall spawning run in 2012 (Table 18). The stocks included Lake Whatcom (n = 648), F_1 mixed (n = 905), and non- marked (n = 2). The sex ratio (female: male) of each stock was 1:23 (Lake Whatcom), 1:1.1 (F_1 mixed) and 2:0 (nonNon-marked). The percentage returning of the number released was 0.36 % (Lake Whatcom) and 2.07 % (F_1 mixed).

Additional Reservoir Sampling

In 2009, an additional 482 kokanee were collected at 14 sites (Table 19). Large proportions of these fish were collected at Sherman Creek (n = 189), Hunters Creek (n = 115) and Nez Perce Creek (n = 67). The only stock collected in Sherman Creek was Lake Whatcom (n = 189) and the sex ratio (female: male) waswere 1:20 The stocks collected at Hunters Creek included Lake Whatcom (n = 114) and F_1 mixed stock (n = 1). The sex ratio (female: male) of each stock was 1:113 (Lake Whatcom) and 1:0 (F_1 mixed). The stocks collected at Nez Perce Creek included Lake Whatcom (n = 65) and F_1 mixed stock (n = 2). The sex ratio (female: male) of each stock was 1:15 (Lake Whatcom) and 1:2 (F_1 mixed).

Table 17. Number, escapement (%) and sex ratio of each stock returning to Hawk Creek, 2011.

Stock	n	Escapement (%)	Sex Ratio
F_1 Mixed	93	0.8	1:1.6
Lake Whatcom	99	0.04	1:7
Non-Marked	8	-	1.6:1
Total	**200**		

Table 18. Number, escapement (%) and sex ratio of each stock returning to Hawk Creek, 2012.

Stock	N	Escapement (%)	Sex Ratio
F_1 Mixed	905	2.07	1:1.6
Lake Whatcom	684	0.35	1:23
Non-Marked	2	-	2:0
Total	**1,591**		

Table 19. Number of each stock of kokanee captured via electrofishing in Lake Roosevelt (excluding Hawk Creek), 2009.

Location	**F_1Mixed**	**Lake Whatcom**	**Nonmarked**	**Total**
A-Frame	1	10	0	11
Alder Creek	0	24	0	24
Burbot Creek	0	8	0	8
Enterprise	1	10	0	11
Hall Creek	0	5	0	5
Hunters Creek	1	114	0	115
McCoys	2	19	0	21
Nez Perce Creek	3	65	0	68
Nine Mile Creek	0	11	0	11
Pitney Creek	0	5	0	5
Sanpoil	0	8	0	8
Sherman Creek	0	189	0	189
Wilmont Cove	0	6	0	6
Total	**8**	**474**	**0**	**482**

In 2010, an additional 3,292 kokanee were collected at 14 sites (Table 20). Large proportions of these fish were collected at Enterprise (Orapaken Creek) (n = 539), McCoy Springs (Ente Creek) (n = 532) and the Sanpoil River (n = 685). The stocks collected in the Enterprise included Meadow Creek (n = 457), F_1 mixed (n = 66) and Lake Whatcom (n = 16). The sex ratio (female: male) of each stock was 1:6 (Meadow Creek), 1:1.4 (F_1 mixed) and 1:3 (Lake Whatcom). The stocks collected at McCoy Springs included Meadow Creek (n = 420), F_1 mixed stock (n = 55) and Lake Whatcom (n = 47). The sex ratio (female: male) of each stock was 1:3 (Meadow Creek), 1.5:1 (F_1 mixed) and 1:2 (Lake Whatcom). The stocks collected at the Sanpoil River included Meadow Creek (n = 638), F_1 mixed stock (n = 39) and non-marked (n = 8). The sex ratio (female: male) of each stock was 1:4 (Meadow Creek), 1:2 (F_1 mixed) and 0:8 (Lake Whatcom).

In 2011, an additional 223 kokanee were collected at 13 sites (Table 21). Large proportions of these fish, were collected in the Sanpoil weir (n = 112), at the Little Falls powerhouse (n = 46) and in Spring Creek (n = 21).The stocks collected in the Sanpoil weir included Lake Whatcom (n = 15), F_1 mixed (n = 91), non-marked (n = 5) and 3 year old F_1 mixed stock (n = 1).). The sex ratio's (female: male) of each stock were 1:2 (Lake Whatcom), 1:1.8 (F_1 mixed) and 0:5 (non-marked). The stocks collected at the Little Falls powerhouse included Lake Whatcom (n = 5) and non-marked (n = 41). The sex ratio (female: male) of each stock was 1:4 (Lake Whatcom) and 2.4:1 (non-marked). The stocks collected at Spring Creek included Lake Whatcom (n = 12) and non-marked (n =

Table 20. Number of each stock of kokanee captured via electrofishing in Lake Roosevelt (excluding Hawk Creek), 2010.

Location	**F_1 Mixed**	**Lake Whatcom**	**Meadow Creek**	**Non marked**	**Total**
A-Frame	35	7	224	0	266
Alder Creek	18	35	100	1	154
Blue Creek	21	5	144	1	171
Burbot Creek	3	1	15	0	19
Cayuse Cove	1	1	10	0	12
Cove Across From Bouy	1	1	11	0	13
Enterprise	66	16	457	0	539
Hall Creek	0	0	6	1	7
Halverson Canyon	1	0	4	0	5
Harker Canyon	0	0	4	0	4
Hunters Creek	30	32	108	0	170
Little Falls Powerhouse	1	2	3	1	7
Little Falls Spillway	1	0	3	2	6
McCoys	55	47	421	0	523
Mill Creek	11	2	94	0	107
Nez Perce Creek	4	0	38	0	42
Nine Mile Creek	4	0	19	0	23
Pitney Creek	19	2	141	1	163
Porcupine Creek	1	1	11	0	13
Sanpoil	39	0	638	8	685
Sherman Creek	0	1	65	6	72
Spring Creek	0	13	0	3	16
Wilmont Cove	16	4	249	1	270
Total	**327**	**170**	**2,765**	**25**	**3,287**

Table 21. Number of each stock of kokanee captured via electrofishing in Lake Roosevelt (excluding Hawk Creek), 2011.

Location	**F_1 Mixed**	**Lake Whatcom**	**Non marked**	**Total**
Alder Creek	6	5	0	11
Burbot Creek	0	0	1	1
Enterprise	5	1	2	8
Hall Creek	0	0	1	1
Hunters Creek	8	3	0	11
Little Falls Powerhouse	0	0	7	7
Little Falls Spillway	0	5	41	46
Nine Mile Creek	1	0	0	1
Pitney Creek	1	0	0	1
Sanpoil	92	15	5	112
Spring Creek	0	12	9	21
Wilmont Cove	0	1	2	3
Total	**113**	**42**	**68**	**223**

9). The sex ratio (female: male) of each stock waswere 1:5 (Lake Whatcom) and 3.5:1 (non-marked).

In 2012, 302 kokanee were collected at 15 sites (Table 22). Large proportions of these fish were collected in the Sanpoil weir (n = 113), at Hunters creek (n = 58) and at McCoys Marina (n = 48). The stocks included in the Sanpoil weir included Lake Whatcom (n = 63), F_1 mixed (n = 46) and non-marked (n = 4). The sex ratio (female: male) of each stock waswere 1:10 (Lake Whatcom), 1:2 (F_1 mixed) and 1:1 (non-marked). The stocks collected at Hunters Creek included Lake Whatcom (n = 38) and F_1 mixed (n = 20). The sex ratio (female: male) of each stock waswere 1:37 (Lake Whatcom) and 1:4 (F_1 mixed). The stocks collected at McCoys Marina included Lake Whatcom (n = 40) and F_1mixed (n = 8). The sex ratio's (female: male) of each stock were 0:40 (Lake Whatcom) and 1:1.6 (F_1 mixed).

Reservoir Effects

Data from 2009-2012 was used to run a general linear model (GLM) to determine the best fit model (Table 23). There was a significant relationship (R^2 = 0.76; AIC = 199.6) between escapement, stock ($p < 0.001$), return site ($p = 0.01$) and mean total length ($p = .52$). Mean total length is necessary in the model to remove some of the error potentially caused by the fact that each stock is released at different sizes. Although, there was no significance found for the model including return location ($p = 0.35$) and mean total length ($p = 0.2$). The lowest drawdown elevation down was determined for each year: 1,257.3; 1,259.4; 1,217.6 and 1,227.2 ft msl, respectively (Figure 2). There was also a significant relationship ($P = 0.01$, $R^2 = 0.024$) between escapement and lowest drawdown elevation. Lastly, there was a significant relationship ($P = .007$, $R^2 = .02$)

Table 22. Number of each stock of kokanee captured via electrofishing in Lake Roosevelt (excluding Hawk Creek), 2012.

Location	**F_1 Mixed**	**Lake Whatcom**	**Non marked**	**Total**
A-Frame	6	1	0	7
Alder Creek	9	2	0	11
Blue Creek	6	3	0	9
Crown Creek	0	0	1	1
Enterprise	6	1	1	8
Flat Creek	0	0	3	3
Hunters Creek	20	38	0	58
Little Falls Powerhouse	1	1	0	2
McCoys	8	40	0	48
Nine Mile Creek	2	0	0	2
Sanpoil	46	63	4	113
Spring Creek	7	19	1	27
West Stranger Creek	5	0	0	5
Wilmont Cove	7	0	0	7
15 Mile Creek	0	0	1	1
Total	**123**	**168**	**11**	**302**

Table 23. General linear models of interests with the dependent (y) variable, independent ($x^1 \ldots x^n$) variable(s), P value, R^2 and AIC value for each model.

Model #	y	x^1 (p value)	x^2 (p value)	x^3 (p value)	R^2	AIC
1	return rates	drawdown elevation (0.01)			0.024	1118.3
2	return rates	lowest WRT (0.007)			0.02	1118.8
3	return rates	stock (<0.0001)	location (<0.0001)		0.69	392.1
4	return rates	mean TL (0.2)	location (0.35)		0.59	176.9
5	return rates	stock (<0.0001)	location (0.011)	mean TL (0.52)	0.76	199.6

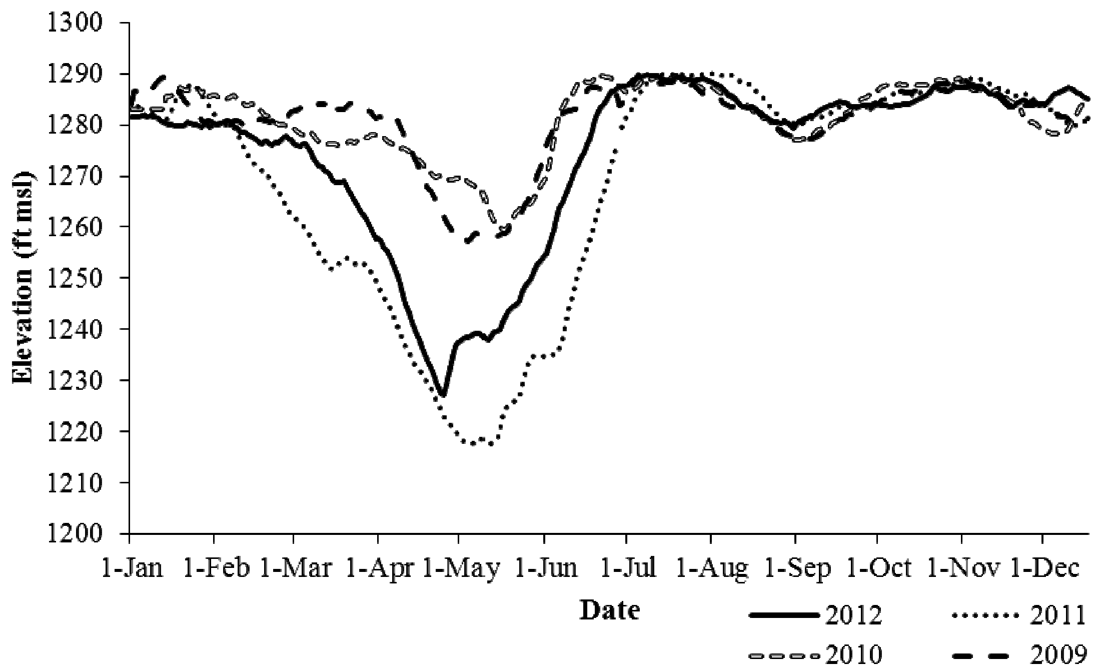

Figure 2. Daily reservoir elevation (feet above mean sea level) of Lake Roosevelt, annually between 2009 -2012.

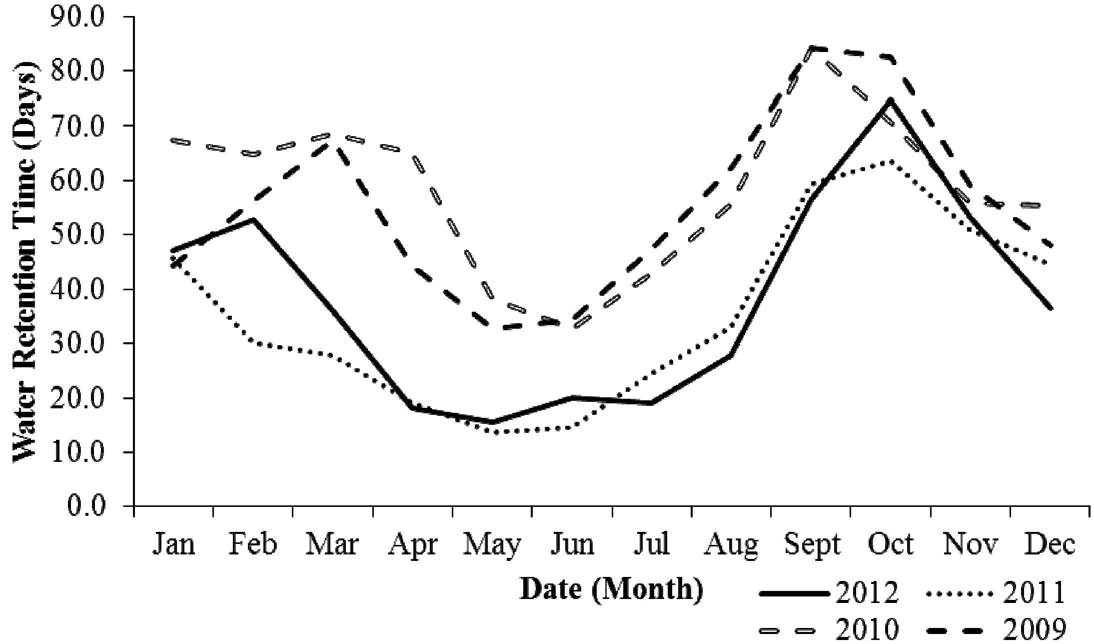

Figure 3. Mean monthly water retention time (days) of Lake Roosevelt annually from 2009 – 2012.

between escapement and lowest monthly water retention time (May) for each year: 32.6, 38.1, 13.7 and 15.6 days (Figure 3). No other significant relationships were found.

Skein Analysis

For the period of 2009-2012, 111 females were sacrificed for skein counts: 26 Lake Whatcom stock, 51 F_1 mixed stock, 20 Meadow Creek stock and 14 non-marked kokanee. A length (mm TL) versus number of eggs regression was plotted for each stock. The equation used for Lake Whatcom stock was $y = 2.68x + 21.23$ (Figure 4). The equation used for the F_1 mixed stock was $y = 6.7x – 1603$ (Figure 5). The equation used for Meadow Creek kokanee was $y = 7.10x – 1809$ (Figure 6). The equation used for non-marked kokanee was $y = 9.24x – 2726$ (Figure 7).

In the fall of 2009, 59 females were spawned at Hawk Creek for a total of 29,892 eggs. We multiplied the length of each fish by thelength specific fecundity to determine potential egg counts. We determined the females captured during the 2009 fall kokanee sampling potentiallypotential contained 167,090 eggs (Lake Whatcom 70,684 [42 %]; F_1 mixed 80,154 [48 %]; non-marked 16,252 [10 %]) (Table 24). A total of 152,760 of the 167,090 (91 %) eggs were from kokanee that returned to Hawk Creek. Overall, 29,892 of 167,090 potential eggs (18 %) were spawned.

In the fall of 2010, 250 females were spawned at Hawk Creek for a total of 75,691 eggs. We determined the females captured during the 2010 fall kokanee sampling potentiallypotential contained 873,592 eggs (Meadow Creek 490,154 [56 %]; F_1 mixed 274,323 [31 %]; Lake Whatcom 102,228 [14 %] and non-marked 6,887 [1 %]) (Table 24). A total of 536,349 of the 873,592 (61 %) eggs were from kokanee that returned to Hawk Creek. Overall, 75,691 of 873,592 potential eggs (8.7 %) were spawned.We

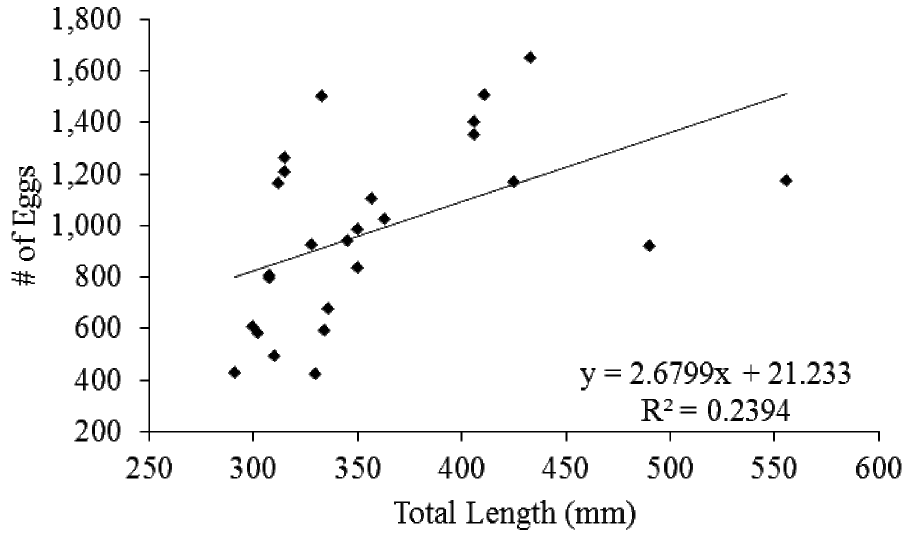

Figure 4. Lake Whatcom stock kokanee regression of female total length (mm) vs. number of eggs.

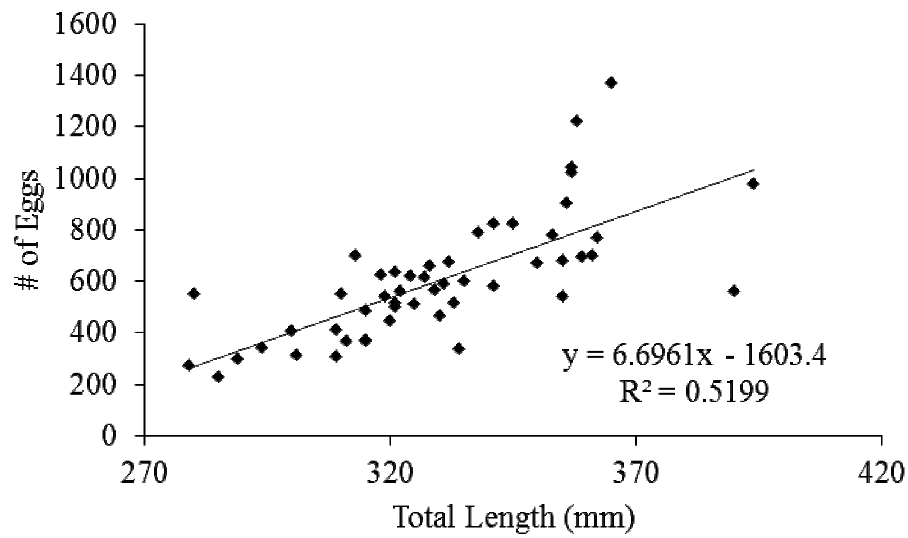

Figure 5. F_1 mixed stock kokanee regression of female total length (mm) vs. number of eggs.

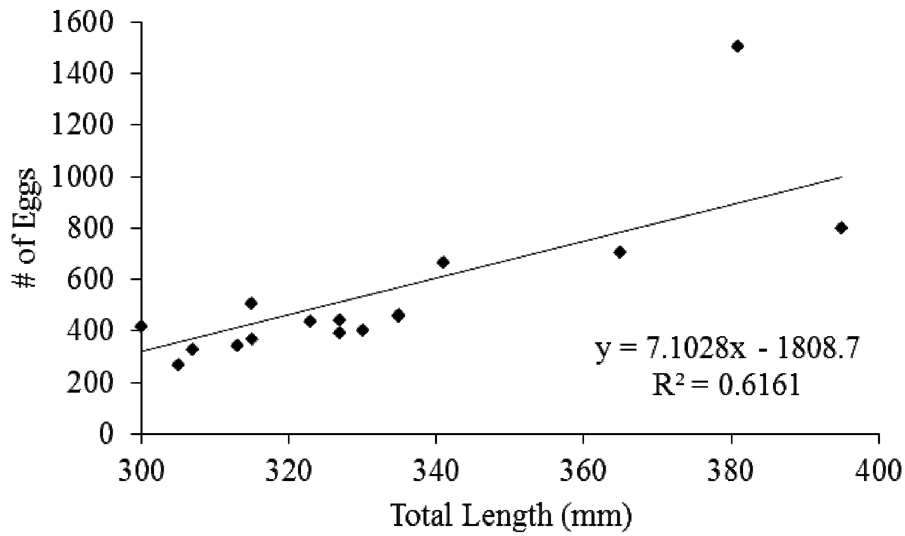

Figure 6. Meadow Creek stock kokanee regression of female total length (mm) vs. number of eggs.

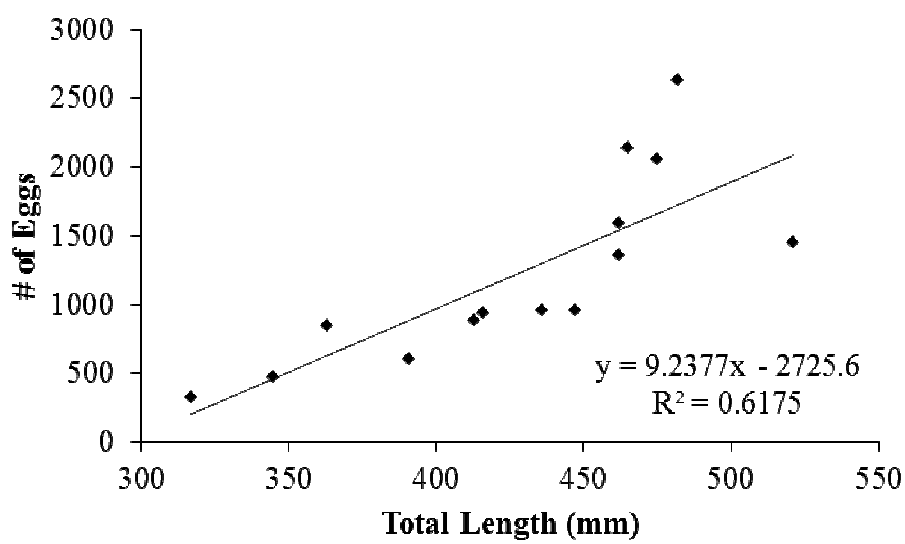

Figure 7. Non-marked kokanee regression of female total length (mm) vs. number of eggs.

Table 24. Number of eggs potentially collected per stock from females that returned to Hawk Creek, other reservoir tributaries and reservoir wide, annually between 2009 – 2012.

Year/Stock	Eggs Hawk Creek	Eggs Other Sites	Total
2009			
F_1 Mixed	67,814	2,870	70,684
Lake Whatcom	68,694	11,460	80,154
Non-Marked	16,252	0	16,252
	152,760	14,330	167,090
2010			
F_1 Mixed	185,434	88,889	274,323
Lake Whatcom	33,960	68,268	102,228
Meadow Creek	315,886	174,268	490,154
Non-Marked	1,069	5,818	6,887
	536,349	337,243	873,592
2011			
F_1 Mixed	25,105	29,872	54,977
Lake Whatcom	9,735	8,423	18,158
Non-Marked	7,628	56,745	64,373
	44,683	92,825	137,508
2012			
F_1 Mixed	238,218	22,308	260,526
Lake Whatcom	25,799	7,685	33,484
Non-Marked	2,918	4,027	6,945
	266,935	34,020	300,955
Total	**1,000,727**	**478,419**	**1,479,145**

determined the females captured during the fall kokanee sampling potentially

In the fall of 2011, 13 females were spawned at Hawk Creek for a total of 11,716 eggs. contained 137,508 eggs (Lake Whatcom 18,158 [12 %]; F_1 mixed 54,977 [40 %]; non-marked 64,373 [47 %]) (Table 24). A total of 44,683 of the 137,508 (30.4 %) eggs were from kokanee that returned to Hawk Creek. Overall, 11,716 of 137,508 potential eggs (8.5 %) were spawned.

In the fall of 2012, 71 females were spawned at Hawk Creek for a total of 32,975 eggs. We multiplied the length of each fish by the length specific fecundity to determine potential egg counts. We determined the females captured during the 2012 fall kokanee sampling potentially contained 300,955 eggs (Lake Whatcom 33,484 [11 %]; F_1 mixed 260,526 [87 %]; non-marked 6,945 [2 %]) (Table 24). A total of 266,935 of the 300,995 eggs (88.7 %) potentially collected were from females that returned to Hawk Creek. Overall 32,975 of 300,955 potential eggs (11 %) were spawned.

Discussion

This study was conducted from 2009 – 2012. The focus of this study was to assess differences between strains of kokanee stocked into Lake Roosevelt (Lake Whatcom, Meadow Creek and F_1 mixed stocks). The mixed stock statistically outperformed the other stocks in each year based on sex ratios and escapement.

In 2009, there was a record kokanee return of 8,895 kokanee reservoir wide (8,413 Hawk Creek). In 2007, 144 Meadow Creek fish, and 2 Lake Whatcom fish were spawned to create the 2009 F_1 mixed stock. This produced 2,790 F_1 mixed stock kokanee that were planted at the Fort Spokane boat launch at Lake Roosevelt in 2009. A total of 199 (7.13 %) of these fish were subsequently recovered in Lake Roosevelt as 2-year old spawners at the mouths of tributary streams, most of them in Hawk Creek. A total of 73 females, 122 males and 4 unidentified sex individuals were collected among these fish with a female:male sex ratio of 1:1.7. In comparison, in 2009, 507,970 Lake Whatcom residualized smolts were released and 8,141 (1.68 %) were recovered in the fall with a sex ratio of 1:33. In the fall of 2009, 59 females were spawned at Hawk Creek for a total of 29,892 eggs. We determined that the females captured during the 2009 fall kokanee sampling potentially contained 167,090 eggs. Overall 29,892 of 167,090 potential eggs (17.9 %) were spawned. The limited number of eggs successful spawned was due to transporting live kokanee back to the Spokane Tribal Hatchery for spawning. The transported kokanee had to survive the approximately 50 miles from Hawk Creek to the Spokane Tribal Hatchery. By the time kokanee were ready to spawn, they had extremely high levels of corticosteroids to stimulate the conversion of the gastro-intestinal tract into energy for gamete production and were under extreme stress (Scholz and McLellan 2010).

In 2010, there was a record kokanee return of 8,925 kokanee reservoir wide (5,638 at Hawk Creek). In 2008, 169 Lake Whatcom fish and 4 non-marked kokanee were spawned to create the 2010 F_1 mixed stock. This produced 12,420 F_1 mixed stock kokanee that were planted at the Fort Spokane boat launch in Lake Roosevelt in 2010. A total of 965 (7.8 %) of these fish were subsequently recovered in Lake Roosevelt as 2-year old spawners at the mouths of tributary streams, most of them in Hawk Creek. A total of 383 females, 551 males and 31 unidentified sex individuals were collected among these fish with a sex ratio of 1:1.5. In comparison in 2010, 118,805 Meadow Creek residualized smolts were released 7,656 (6.4 %) were recovered in the fall with a sex ratio of 1:5. There was also a large 3-year old run of Lake Whatcom kokanee (n = 253) in 2010, with a return of 0.05 % and sex ratio of 1:2 (Blake et al. 2011). In the fall of 2010, 250 females were spawned at Hawk Creek for a total of 75,691 eggs. We determined the females captured during the 2010 fall kokanee sampling potentially contained 873,592 eggs. Overall 75,691 of 873,592 potential eggs (8.7 %) were spawned. In 2010, adult kokanee were again transported to the hatchery for spawning. Upon spawning at the Spokane Tribal Hatchery, 75.7% of the eggs transported to the hatchery in ripe females were not successfully spawned, mainly due to heavy mortality during transportation and mortality at the hatchery while maturing. Overall in 2010, 91.2 % of the eggs potentially collected in the kokanee returns were missed due to lack of returns to the primary collection site, inadequate egg collection at Hawk Creek and high mortality due to transportation from Hawk Creek to the hatchery. Also, a large number of kokanee were missed when the reservoir levels quickly increased and overflowed the trap, approximately 300 kokanee went over the trap and resided in the plunge pool below Hawk Creek.

In 2011, the kokanee run was very poor with only 423 kokanee reservoir wide (200 to Hawk Creek). In 2009, 59 female kokanee were spawned to create the 2011 F_1 mixed stock. This produced 11,102 F_1 mixed stock kokanee that were planted at the Fort Spokane boat launch in Lake Roosevelt in 2011. A total of 206 (1.9 %) of these fish were subsequently recovered in Lake Roosevelt as 2-year old spawners at the mouths of tributary streams, most of them in Hawk Creek. A total of 79 females and 127 males were collected among these fish, giving a female:male sex ratio of 1:1.6. In comparison in 2011, 220,221 Lake Whatcom residualized smolts were released, 141 (0.06 %) were recovered in the fall with a sex ratio of 1:7. In the fall of 2011, 13 females were spawned at Hawk Creek for a total of 11,716 eggs. We determined that the females captured during the 2011 fall kokanee sampling potentially contained 137,508 eggs. Overall, 11,716 of 137,508 potential eggs (8.5 %) were spawned. In 2011, a secondary holding box was installed to hold kokanee until enough were collected to be successfully spawned on site in an attempt to decrease mortality during transport to the hatchery. However, the poor return to Hawk Creek over the sampling period didn't allow for accumulation of enough kokanee in the secondary holding box to warrant spawning. Kokanee transferred to the holding box were held for up to three weeks and experienced high mortality; the hold kokanee most likely spawned in the box before dying.

In 2012, the kokanee run was poor and had only 1,893 kokanee reservoir wide (1,591 to Hawk Creek). In 2010, 250 female kokanee were spawned to create the 2012 F_1 mixed stock. This produced 43,578 F_1 mixed stock kokanee that were planted at the Fort Spokane boat launch at Lake Roosevelt in 2012. A total of 1,027 (2.35 %) of these fish were subsequently recovered in Lake Roosevelt as 2-year old spawners at the mouths of tributary streams, most of them in Hawk Creek. A total of 463 females and 564 males were collected among these fish, giving a sex ratio of 1:1.2. In comparison, in 2012, 187,578 Lake Whatcom residualized smolts were released; 853 (0.5 %) were recovered in the fall with a sex ratio of 1:21. In 2012 a record number of mixed stock kokanee were released due to a very high Hawk Creek return in 2010. Also, the 2012 release was postponed approximately 2 weeks in an attempt to decrease entrainment over Grand Coulee Dam in another deep drawdown year. The postponed release did not appear to have an effect on the number of returning fish. Also, a breakout of bacterial kidney disease occurred in the Spokane Tribal Hatchery prior to release, potentially causing the mortality of an unknown number of the kokanee after they were released into the reservoir. In the fall of 2012, 71 females were spawned at Hawk Creek for a total of 32,975 eggs. Overall 32,975 of 300,955 potential eggs (10.9 %) were spawned. The Spokane Tribal Hatchery also kept F_1 mixed stock in the hatchery and spawned approximately 40,000 eggs. Despite the generally poor return in 2012, the combination of onsite (Hawk Creek) spawning and in-hatchery spawning produced a good number of fertilized eggs for a 2014 F_1 mixed stock release. Although the egg collection was much improved from 2011, the late implementation of the weir trap caused a larger number of females to be missed. The reservoir did not come down to a low enough elevation to put the trap in until mid-August. Kokanee that arrived before the trap was placed travelled up Hawk Creek and stayed in the plunge pool until spawning. Those fish we not spawned, 165 females were found dead above the trap and did not contributed their eggs to the production of the F_1 mixed stock.

The 2009 and 2010 escapements were record runs for kokanee in Lake Roosevelt with escapement of 7.5 % for the F_1 mixed stock and 1.7 % for the Lake Whatcom stock in 2009. The escapement was 7.8 % for the F_1 mixed stock and 6.4 % for the Meadow Creek stock in 2010. In contrast, the 2011 and 2012 escapement was generally poor in comparison at 1.9 % for the F_1 mixed stock and 0.06 % for the Lake Whatcom stock in 2011, and 2.35 % for the F_1 mixed stock and 0.05 % for the Lake Whatcom stock in 2012. A major factor contributing to the low returns in 2011 and 2012 of both the F_1 mixed and Lake Whatcom stocks was the combination of deep drawdown and short water retention times. The record kokanee returns of 2009 and 2010 coincided with relatively shallow drawdowns (1,257.3 and 1,259.4 ft msl, respectively) and longer water retention times (32.6 and 38.1 days respectively), whereas the poor 2011 and 2012 returns coincided with a deep drawdown (1,217.6 and 1,227.2 ft msl, respectively) and short water retention times (13.7 and 15.6 days respectively). The GLM confirmed that return rates were correlated with both reservoir drawdown elevation ($P = 0.01$) and water retention time ($P = 0.007$) at the time of release. This provides evidence that the extent of the spring drawdown and its coinciding water retention time had an effect on the spawning run kokanee in the fall. McLellan et al. (2008) constructed a model of the relationship between various reservoir operations in Lake Roosevelt and coastal hatchery rainbow trout success. They verified that deep drawdown events, low water retention time and low reservoir elevation resulted in fewer rainbow trout tag recoveries in Lake Roosevelt and more tag recoveries downstream from Grand Coulee Dam (McLellan et al. 2008). Hatchery kokanee in Lake Roosevelt are subjected to the same operation conditions and therefore most likely have the same negative responses to deep drawdown and low reservoir elevation at release.

In 2010, a multi-year ultrasonic tracking study of hatchery kokanee was initiated on the F_1 mixed stock due to its larger release size and consistently large return runs. An array of 87 receivers was located in Lake Roosevelt and the Columbia River in British Columbia between Grand Coulee Dam and Keenlyside Dam and one receiver was located in Rufus Woods Reservoir about 12 km downstream from Grand Coulee Dam. During 2010, 36 kokanee were released at Fort Spokane. Of the 36 tagged kokanee, only one was detected at the receiver located in Rufus Woods reservoir below Grand Coulee Dam (2.8 %) and no additional kokanee were probably entrained (Korst et al. 2011).

During 2011, 19 of the kokanee were released at Fort Spokane and 16 at Keller Ferry. Of those, 6 (17 %) were detected on the Rufus Woods receiver and 7 additional fish probably entrained bringing the total entrainment to 14 fish (37 %) Fish classified as definitely entrained were detected on the Rufus Woods receiver. Fish classified as probably entrained were last detected at one of the two receivers closest to the dam at or near the time of maximum drawdown and then disappeared. We classified them as probably entrained because testing of the Rufus Woods receiver indicated that a sonic tag floated past the receiver only 33 % of the time (Stroud and Scholz 2012).

During 2012, 18 kokanee were released at Fort Spokane and 17 at Keller Ferry. Of these, 2 (6%) were detected on the Rufus Woods receiver and 5 more probably entrained bringing total entrainment to 7 fish (20 %) (Stroud and Scholz 2013). This gave direct proof that lower drawdowns and shorter water retention times is associated with greater entrainment of kokanee at Grand Coulee Dam, so it would be logical to anticipate that escapement of kokanee to spawning tributaries would be reduced in years with lower drawdown and shorter retention times.

Annual fluctuations in drawdown also affected kokanee distribution in the reservoir prior to spawning. Kokanee in Lake Roosevelt usually experienced two distribution patterns. In years with shallow drawdown and longer water retention times, kokanee generally stay in the middle section of the reservoir close to the Fort Spokane release site. Deep drawdown and short water retention times caused kokanee to disperse into the lower section of the reservoir. This variation in distribution between years can be explained by food availability and water retention times. Shorter water retention times are associated with a decrease in phytoplankton standing crop (primary production).

Phytoplankton are unable to assimilate necessary nutrients when discharge is high which, in turn, decreases the food available for zooplankton (primary consumers), in particular *Daphnia* (kokanee's main food source). Between 1999-2008 June (time of kokanee release), water retention times in Lake Roosevelt ranged from 24 to 56.9 days (Table 25) (McLellan et al. 2003; Lee et al. 2003, 2006, 2010; Scofield et al. 2004, 2007; Fields et al. 2004; Pavlik-Kunkel et al. 2005, 2008; Miller et al. 2011). From 1999 – 2008, there was a significant regression between water retention time and *Daphnia* biomass in June, just after the kokanee were released annually ($R^2 = .79$, $P = 0.003$) (Figure 8). In Lake Roosevelt from 1988 to 2006, stomach contents of 15 to 111 kokanee per year (n = 758 total) were examined (Peone et al. 1990; Griffith and Scholz 1991; Thatcher et al. 1993, 1994; Griffith et al. 1995; Underwood et al. 1996; Underwood and Shields 1996; Cichosz et al. 1997, 1999; Spotts et al. 2002; McLellan et al. 2003; Lee et al. 2003; Scofield et al. 2004, 2007; Fields et al. 2004; Pavlik-Kunkel et al. 2005). *Daphnia* occurred in 593 (78.7 %) of the stomach and averaged 90.4 % by number and 84.7 % by weight of the stomach contents (Scholz and McLellan 2010). A stable isotope analysis indicated that kokanee in Lake Roosevelt derived 89 (77 – 100) % of their carbon from limnetic sources (phytoplankton → *Daphnia* → kokanee) (Black et al. 2003).

Daphnia are abundant in the lower and middle sections of the reservoir and scarce in the upper sections of the reservoir. Between 1996 and 2008, *Daphnia* biomass was highest at Spring Canyon and in the Sanpoil and Spokane Arms, averaging 3,014 mg/m^3; 26,268 mg/m^3 and 9,146 mg/m^3 respectively and low in the upper sections of the reservoir averaging 1,095 mg/m^3 at Gifford and 251 mg/m^3 at Kettle Falls. In 2010, only

Table 25. Lowest elevation ft above mean sea level (ft msl), water retention time (WRT) in days and *Daphnia* biomass (µg/m^3) in Lake Roosevelt from 1999 – 2008.

Year	**Lowest Elevation (ft msl)**	**WRT (days)**	***Daphnia* Biomass (µg/m^3)**
1999	1,220.9	26	1,185
2000	1,239.8	36.2	1,068
2001	1,219.4	56.9	7,316
2002	1,244.7	24	190
2003	1,271.6	37.7	--
2004	1,259.8	37.6	1,236
2005	1,253.9	37	2,107
2006	1,243.4	25.1	221
2007	1,256.5	32.6	--
2008	1,238.8	22.8	1,345

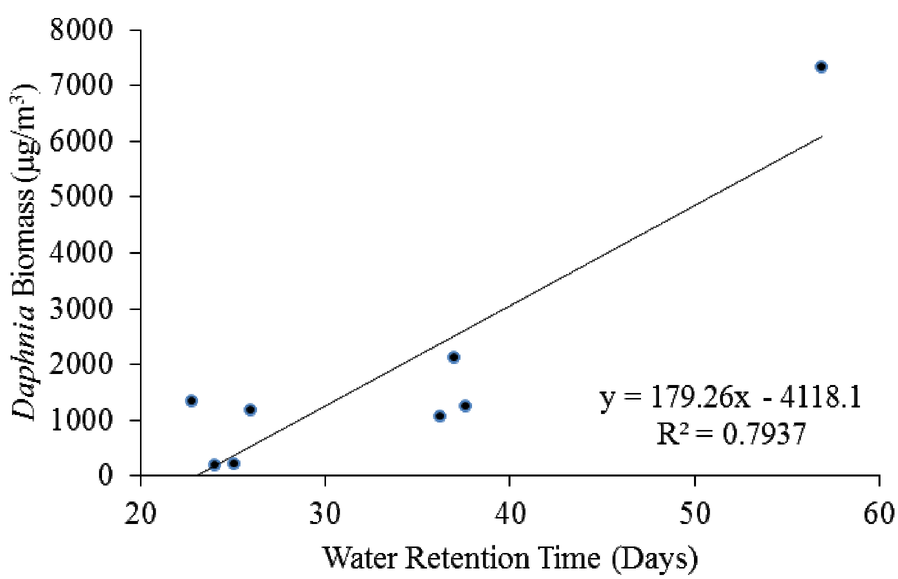

Figure 8. Regression (P = 0.03) of water retention time (days) and Daphnia biomass (µg/m^3) in Lake Roosevelt from 1999 – 2008.

In 2010, only 1 (3 %) of 36 tagged kokanee released at Fort Spokane entrained over Grand Coulee dam. In 2010, 20 (56 %) of the tagged kokanee consistently stayed in the Spokane River, located near their Fort Spokane release location (Korst et al. 2011). Their prolonged presence within the Spokane River most likely due to high *Daphnia* abundance in proximity to the release site (Korst et al. 2011). More fish were detected in the middle section of the reservoir, which coincided with the shallow drawdown and longer water retention times of 2010. In contrast, transmitter implanted kokanee released at Fort Spokane in 2011 and 2012 remained in the Spokane River. Instead many of them traveled downstream and utilized the lower reservoir or Sanpoil River (Stroud and Scholz 2012, 2013). Significantly more of the tagged kokanee were found in the lower third of the reservoir from release until mid-August (Stroud and Scholz 2012). The kokanee most likely utilized the Sanpoil River more in 2011 due to lack of food available near their release site; they had to stray to other sections of the reservoir in search of *Daphnia*. The shift from the middle to lower reservoir supports our hypothesis. In years with short water retention times, *Daphnia* biomass decreases, which forces the kokanee to search for food and utilize the relatively high zooplankton abundance in the Sanpoil River and lower reservoir.

One potential cause of the large return of two year old kokanee in Lake Roosevelt is that they grow rapidly after their release into the lake. Growth of kokanee is known to be dependent on lake productivity and kokanee density (Rieman and Myers 1992, Rieman and Maiolie 1995). Growth of kokanee is greater in Lake Roosevelt when compared to the majority of other kokanee producing lakes in Eastern Washington (Lake Chelan, Bumping Lake, Bead Lake, Horseshoe Lake, Sullivan Lake, Deer Lake, Loon lake) and North Idaho (Coeur d'Alene Lake, Dworshak Reservoir, Pend Oreille Lake, Priest Lake, Upper Priest Lake, Spirit Lake) because there is an abundant supply of *Daphnia* in Lake Roosevelt and the density of kokanee in Lake Roosevelt is low (4.5 kokanee/hectare) (Baldwin et al. 2005, Scholz and McLellan 2010). Baldwin estimated the majority of those kokanee were of wild origin based on a combination of hydro acoustic tracking and gill netting surveys. Between 2009-2012 hatchery kokanee contributed approximately 15.2, 3.9, 6.3 and 6.9 kokanee/hectare annually. When the density of wild and hatchery kokanee are combined they range from 8.4 – 19.7 kokanee/hectare, far less than in other kokanee lakes. For example, Baldwin and McLellan (2008) used hydroacoustic and gillnet surveys to determine the density of kokanee in Sullivan Lake in 2003 (117 kokanee/hectare). Polacek et al. (2003) used the same methods to estimate the average density of kokanee in Bead lake (292 hectares), the average density was 332 (± 129) kokanee/hectare. Rieman and Myers (1992) estimated the kokanee density in Coeur d'Alene Lake between 1978 – 1987 (173 kokanee/hectare), Dworshak Reservoir in 1988 (20 kokanee/hectare), Pend Oreille Lake between 1977 – 1988 (43 kokanee/hectare), Priest Lake between 1978 – 1986 (21 kokanee/hectare) and Upper Priest Lake between 1978 – 1987 (15 kokanee/hectare). The average back calculated total lengths of spawning kokanee in all of these lakes (including Lake Roosevelt) was 201 mm at age 2, 259 mm at age 3 and 305 mm at age 4 (Scholz and McLellan 2010). Lake Roosevelt kokanee had the largest length and averaged 279 mm at age 2, 406 mm at age 3 and 428 mm at age 4 (Scholz and McLellan 2010).

Despite the poor return in 2011 and 2012, F_1 mixed stock greatly exceeded the returns of Lake Whatcom kokanee, returning 22 times more fish in 2011 and 52 times more fish in 2012. In an attempt to curb the effect of a shallow drawdown, kokanee were released 2-3 weeks later in 2012 than in 2011. We hypothesized holding the fish longer would allow the reservoir to begin to refill and less kokanee would entrain over Grand Coulee Dam. The kokanee did return higher rates in 2012 (2.35 %, 0.45 %) in comparison to 2011 (1.9 %, 0.06 %), even though no statistical difference was found between years ($P = 0.06$). The F_1 mixed stock outperformed the Lake Whatcom and Meadow Creek stocks with respect to percentage returning and sex ratios in all four years of the study (2009-2012). The F_1 mixed stock provided better escapement and sex ratio, even under poor reservoir conditions. This further suggests that fish that were able to survive and adapt to the environmental conditions in the reservoir and return to the appropriate creek possess certain characteristics that made them more fit than the other fish that did not return (McLellan and Scholz 2003; McLellan et al. 2005, 2010).

However, skepticism remains as to whether the success of the F_1 mixed stock is due to genetics or release size. Due to differences in rearing conditions and densities, the F_1 mixed stock is able to grow to larger sizes than the Lake Whatcom or Meadow Creek stocks at the Spokane Tribal Hatchery. Lake Whatcom fish released in 2009, 2011 and 2012 ranged between 8 - 20.7 fish/lb at release. The Meadow Creek kokanee released in 2010 were reared to 5 – 8 fish/lb at release and the F_1 mixed stock were reared to 1.5-3.3 fish/lb at release. Was the better performance of the F_1 mixed stock related to a difference among the stocks or a difference in the size of each stock at release? The Meadow Creek performed much better than the Lake Whatcom ever has, potentially owing to their larger release size. The stock released at a larger size may be able to evade walleye predation, due to the fact that walleye are gap limited (Baldwin et al. 2003) and have better stamina when fighting the higher flow rates in the reservoir.

For coho salmon (*O. kisutch*), Chinook salmon (*O. tshawytscha*) and steelhead (*O. mykiss*), smolt size has been found to affect the structure of returning fish (Hager and Noble 1979, Martin and Wertheimer 1989, Ward and Slaney 1988). Hager and Noble (1979) found that in coho salmon, a higher proportion of the larger, faster growing males within a population tend to mature as 2 year olds. Also, the male to female ratio increased with mean size of release from 52.9 % males in the smallest release group to 90.9 % males in the largest size release group (Hager and Noble 1979).

The return of kokanee in our experiment paralleled their size at release. Lake Whatcom kokanee released at 8 - 20.7 fish/lb returned an average (range) of 0.05 (0.04 - 0.06) % of the number released. Meadow Creek kokanee released at 5.0 – 8.0 fish/lb returned 6.4 % of the fish released. F_1 mixed stock kokanee released at 1.5 - 3.3 fish/lb returned 4.9 (1.9 - 7.8) % of the fish released. Although the F_1 mixed stock returned significantly more fish than the Meadow Creek stock in 2010 (7.8 % vs. 6.4 %), the return ratio was only 1.2 F_1 mixed fish per Meadow Creek fish compared to an average (range) of 29.5 (4.4 - 32.0) F_1 mixed stock fish to Lake Whatcom stock fish in 2009, 2011, and 2012. Sex ratios (F:M) averaged (ranged) 1:19 (1:6 - 1:33) for Lake Whatcom stock 1:5, for Meadow Creek stock and 1:1.5 (1:1.2 - 1:1.6) for F_1 mixed stock. Thus, an alternative to genetic stock difference being responsible for the results is the difference in size at release. The results with the Meadow Creek stock, which were released at an intermediate size, support the interpretation of a release size affect. However, the fact that Meadow Creek kokanee returned 5 males per female and that the F_1 mixed stock returned about 1.5 males per female is suggestive of a real difference in stock. The general linear model is also suggestive of a real stock effect. Stock remained a significant contributor to the model even when error was reduced by adding mean total length. Whereas, when return location and mean total length were modeled without stock significance was reduced from $p = .01$ to $p = .35$, providing evidence that stock might contributes the most to the difference in return rates.

Consequently, we propose conducting one more experiment. Two groups of each stock (Lake Whatcom, Meadow Creek and F_1 mixed stock) should be reared at the Spokane Tribal Hatchery. One group of about 10,000 fish of each stock would be reared to about 3.0 fish/lb in three separate raceways. One group of about 40,000 fish of each stock would be reared to about 10.0 – 20.0 fish/lb in three separate raceways. Fish from each group would be marked with unique marks that identify it as a member of that group. Equal numbers of fish from the first groups and second groups would be released at Fort Spokane and the returns to Hawk Creek and other tributaries would be monitored. This experiment would test the null hypothesis that equal numbers returning for each group would be expected. Depending on the deviation from the expected values by each group, this experiment should allow us to statistically determine if the F_1 mixed stock is truly superior or if size at release determines return success of kokanee populations in Lake Roosevelt.

Literature Cited

Azuma T., K. Takeda, T. Doi, K. Muto and M. Akutsu. 2004. The influence of temperature on sex determination in sockeye salmon *Oncorhynchus nerka*. Aquaculture 234: 461–473.

Baldwin C. and J. McLellan. 2008. Use of gill nets for target verification of a hydroacoustic fisheries survey and comparison with kokanee spawner escapement estimates from a tributary trap. North American Journal of Fisheries Management 28: 1,744 – 1,757.

Baldwin, C., H.Woller and M.Polacek. 2005. Limnetic fish surveys in Lake Roosevelt Washington: 2000 Annual Report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. DOE/BP-00000118-2: 60 pp.

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

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

Bennett, D.H. and R.G. White. 1977. A survey of existing literature on Franklin D. Roosevelt Lake. Forestry Wildlife and Range Experiment Station, University of Idaho. Moscow, Idaho. Contribution No. 61: 94pp.

Black, A.R., G.W. Barlow and A.T. Scholz. 2003. Carbon and nitrogen stable isotope assessment of Lake Roosevelt aquatic food web. Northwest Science 77: 1 – 11.

Bryant, F.G. and Parkhurst, Z.E. 1950. Survey of the Columbia River and its tributaries, Area III. Washington streams from the Klickitat and Snake rivers to Grand Coulee dam; with notes on the Columbia and its tributaries above Grand Coulee dam. Unites States Fish and wildlife Serces Special Scientific Report. Fisheries No. 37-4: 108 pp.

Cedarholm, C.J., H.D. Johnson, R.E. Bilby, L.R. Dominguez, A.M. Garrett, W.H. Graeber, E.L. Greda, M.D. Kunza, B.G. Marcot, J.F. Palmisano, R.W. Plotnikoff, W.G. Percy, C.A. Simenstad and P.C. Trotter. 2000. Pacific salmon and wildlife ecological contexts, relationships and implications for management. Washington Department of Fish and Wildlife, Olympia, Washington. Special Edition Technical Report: 145 pp.

Cederholm, C. J., M. D. Kunze, T. Murota, and A. Sibatani. 1999. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24(10):6-15.

Cichosz, T., J. Shields, and K. Underwood. 1999. Lake Roosevelt monitoring/data collection program. Annual report 1997. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No.32148–3: 182 pp.

Cichosz, T., J. Shields, and K. Underwood. 1998. Lake Roosevelt monitoring/data collection program. Annual report 1996. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 32148–2.

Cichosz, T., J. Shields, K. Underwood, A. Scholz, and M.B. Tilson. 1997. Lake Roosevelt fisheries and limnological research. Annual report 1996. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 32148–2: 325 pp.

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.

Ellis, C.H. 1957. Homing of chinook salmon transported downstream after smolt transformation. Progressive Fish-Culturist 19: 205-207.

Fields, K., B. Scotfield, C. Lee, and S. Pavlik–Kunkel. 2004. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 2002. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No.00005756–5: 196 pp.

Fulton, L.A. and M.C. Laird. 1967. A cursory survey of tributaries to Roosevelt Lake with reference to spawning potential for salmon. United States Fish and Wildlife Service, Seattle, Washington. Internal report.

Gresh T., J. Lichatowich, and P. Schoonmaker. 2000. An estimation of historical and current levels of salmon production in the northeast Pacific ecosystem: evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. Fisheries 25(1): 15 – 21.

Griffith, J.R., A.C. McDowel and A.T. Scholz. 1995. Measurement of Lake Roosevelt biota in relation to reservoir operations. Annual Report 1991. Bonneville Power Administration. Portland, OR. Project No. 88-63.

Griffith, J.R., A.C. McDowell and A.T. Scholz. 1992. Lake Roosevelt fisheries monitoring program: measurements of Lake Roosevelt biota in relation to reservoir operations. Annual Report 1991. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 91819-8: 144 pp.

Griffith, J.R., and A.T. Scholz. 1991. Lake Roosevelt fisheries monitoring program. United States Department of Energy, Bonneville Power Administration, Portland, Oregon Annual report 1990. United States. Report No. 91819-3: 232 pp.

Hager, R., and R. Noble. 1976. Relation of size at release of hatchery coho to age, size and sex composition of returning adults. Progressive Fish-Culturist 38: 144–147.

Hasler, A.D., A. T. Scholz and R. M. Horrall. 1978. Olfactory Imprinting and Homing in Salmon: Recent experiments in which salmon have been artificially imprinted to a synthetic chemical verify the olfactory hypothesis for salmon homing American Scientist 66: 347-355.

Hasler, A. D.. and A. T. Scholz. 1983. Olfactory imprinting and homing in salmon. Springer-Verlag. Berlin, 134 pp.

Hunt, G. V., B. S. Johnson, and R. E. Jackman. 1992. Carrying capacity for bald eagles wintering along a northwestern river. Journal of Raptor Restoration 26:49-60.

Jagielo, T. 1984. A comparison of nutrient loading, phytoplankton standing crop, and trophic state in two morphologically and hydraulically different reservoirs. MS thesis. University of Washington. Seattle, WA: 99 pp.

Korst, M.N., M.C. Paluch, A.T. Scholz, H.J. McLellan 2011 (in manuscript). Acoustic Tracking of Hatchery Kokanee Salmon in Lake Roosevelt: Annual Report 2010. Pages 147 -205 (Chapter 4) *in* Scholz, A. T., A. O. Blake, M. N. Korst, D. Stroud,

T. Parsons, M. Paluch, H. J. McLellan, and A. Miller. Hatchery investigations and sonic tracking of wild and hatchery kokanee in Lake Roosevelt, 2010 Annual report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. 224 pp.

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.

Lee, C., S. Pavlik–Kunkel, K. Fields, and B. Scofield. 2006. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 2004. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 00014804–1: 202 pp.

Lee, C., B. Scofield, S. Pavlik, and K. Fields. 2003. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 2000. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 00000118–1: 271 pp.

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

LRMT (Lake Roosevelt Management Team). 2009. Lake Roosevelt Fisheries Guiding Document. Spokane Tribe of Indians, Wellpinit, Washington, Colville Confederated Tribes, Nespelem, Washington and Washington Department of Fish and Wildlife, Spokane Washington.

Martin R.M. and A. Wetheimer. 1989. Adult production of Chinook salmon reared at different densities and released as two smolt sizes. Progressive Fish Culturist 51: 194-200.

McLellan, H.J. and A.T. Scholz. 2003. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt. Final Report 2002. United States Department of Energy, Bonneville Power Administration Portland, Oregon Report No. DOE/BP 00005756-4. 48 pp.

McLellan, H.J. and A.T. Scholz. 2002. Meadow Creek vs. Lake Whatcom kokanee salmon investigations in Lake Roosevelt, 2001. Annual Report 2001. United States Department of Energy, Bonneville Power Administration, Portland Oregon. Report No. DOE/BP 00005756-3. 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. United States Department of Energy, Bonneville Power Administration, Portland Oregon. DOE/BP 00000118-4. 36 pp.

McLellan, H J., A.T. Scholz, and A. Miller. 2010. Annual Assessment of Hatchery kokanee in Lake Roosevelt, 2009. United States Department of Energy, Bonneville Power Administration Portland, Oregon Report No. Project 1994-043-00, Doc ID na. 45 pp.

McLellan, H. J., A. T. Scholz, C. D. Hultberg, and B. Nine. 2008. Annual Assessment of Hatchery kokanee in Lake Roosevelt, 2007. United States Department of Energy, Bonneville Power Administration Portland, Oregon Document ID P110094. 43 pp.

McLellan, H.J., S.G. Hayes and A.T. Scholz. 2008. Effect of reservoir operation on hatchery coastal rainbow trout in Lake Roosevelt, Washington. North American Journal of Fisheries Management 28: 1210 – 1213.

McLellan H.J., A. T. Scholz, and B. Nine. 2007. Annual Assessment of Hatchery kokanee in Lake Roosevelt, 2006. United States Department of Energy, Bonneville Power Administration, Portland Oregon. Document ID P107018. 19 pp.

McLellan, H.J., A.T. Scholz, C. Lee, and R. LeCaire. 2005. Annual Assessment of Hatchery kokanee in Lake Roosevelt. Annual Report 2004. United States Department of Energy, Bonneville Power Administration Portland, Oregon Report No. DOE/BP 00014804-2. 64 pp.

McLellan, H.J., J.G. McLellan, and A.T. Scholz. 2004. 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. United States Department of Energy, Bonneville Power Administration, Portland Oregon. 30 pp.

McLellan, H., C. Lee, B. Scotfield, and S. Pavlik. 2003. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 1999. United States Department of Energy, Bonneville Power Administration Portland, Oregon. Report No. 32148–8: 226 pp.

Murphy, M. 2000. Bald eagle nest production, Lake Roosevelt, Washington, 1987 – 2000. Colville Confederated Tribes, Inchelium, Washington. Final report to

United States Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. Grant No. 1425-7FG-10-0300: 27 pp.

Nigro, A. A., T. T. Terrell, and L. G. Beckman. 1982. Assessment of the limnology and fisheries in Lake F. D. Roosevelt. Annual Report to United States Bureau of Reclamation. United States Fish and Wildlife Service National Fishery Research Center. FWS-14-06-0009-80-904. 97 pp.

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

Pavlik–Kunkel, D., B. Scofield, and C, Lee. 2008. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 2006. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Document ID P107017. Project No. 1994–043–000. Contract No. 00024144.1: 155 pp.

Pavlik–Kunkel, S., K. Fields, B. Scofield, and C. Lee. 2005. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 2003. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 00005756–6: 206 pp.

Peck, J.W. 1970. Straying and reproduction of coho salmon, Oncorhynchus kisutch, planted in a Lake Superior tributary. Transactions of the American Fisheries Society 99: 591-595.

Peone, T.L., A.T. Scholz, J.R. Griffith, S. Graves, and M.G. Thatcher. 1990. Lake Roosevelt fisheries monitoring program. Annual report 1989 and 1988. United

States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 91819–1: 250 pp.

Peone, T. 2009. Spokane Tribal Hatchery Operations and Maintenance, 2009 Annual Report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Document ID # P111981: 13 pp.

Polacek, M., C. Baldwin and A. Smith.2003. An offshore fisheries survey of Bead Lake, Washington using hydroacoustics and gill nets, September 1999. Washington Department of Fish and Wildlife, Olympia, Washington: 11 pp.

Rieman, B.E. and B. Bowler. 1980. Kokanee trophic ecology and limnology in Pend Orielle Lake. Idaho Department of Fish and Game, Boise, Idaho. Fisheries Bulletin 1: 1 – 27.

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

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.

Richey, J.E., M.A. Perkins and C.R. Goldman. 1975. Effects of kokanee salmon (Oncorhynchus nerka) decomposition on the ecology of a subal-pine stream. Journal of the Fisheries Research Board of Canada 32:817-820.

Ricker, W.E. 1972. Hereditary and environmental factors effecting certain salmonid populations. pp. 27-160 in: R.C. Simon and P.A. Larkin (editors) The stock concept in pacific salmon. In H.R. MacMillian. Lectures in Fisheries. University of British Columbia, Vancouver, British Columbia.

SAIC. 1996. Lake Roosevelt bald eagle study. Final report prepared by Science Applications International Corporation, San Diego, California. Prepared for United States Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. Contract No. 125-3-CS-10-12990. 75 pp.

Scholz, A.T. and H.J. McLellan. 2010. Fishes of the Columbia and Snake River Basins in Eastern Washington. Eagle Printing. Cheney, Washington. 771 pp.

Scholz, A.T. and H.J. McLellan. 2009. Field Guild to the Fishes of Eastern Washington. Eagle Printing. Cheney, Washington. 310 pp.

Scholz, A.T., R.J. White, V.A. Koehler, and S.A. Horton. 1992. Measurement of thyroxine concentration as an indicator of imprinting in kokanee salmon (Oncorhynchus nerka): Implications for operating Lake Roosevelt kokanee hatcheries. Annual report 1991. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. DOE/BP-91819-5: 96 pp.

Scholz, A.T., J.K. Uehara, J. Marco and J. Hisata. 1986. Feasibility report on restoration of Lake Roosevelt Fisheries. In: Northwest Power Planning Council. Applications for Amendments:Columbia River Basin Fish and Wildlife Program. Vol. 4. pp 1215-1374.

Scholz, A.T., C.K. Gosse, J.C. Cooper, R.M. Horrall, A.D. Hasler, R.J. Poff and R.I. Daly. 1978a. Homing of rainbow trout transplanted in Lake Michigan: A comparison of three procedures used for imprinting and stocking. Transactions of the American Fisheries Society 107: 439-444.

Scholz, A.T., R.M. Horrall, J.C. Cooper and A.D. Hasler. 1976. Imprinting to chemical cues: the basis for home stream selection in salmon. Science 192: 1,247 – 1,249.

Scofield, B., C. Lee, S. Pavlik–Kunkel, and K. Fields. 2007. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 2005. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 00014804–5: 197 pp.

Scofield, B., C. Lee, S. Pavlik, and K. Fields. 2004. Lake Roosevelt fisheries evaluation program: limnological and fisheries monitoring. Annual report 2001. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 00005756–1: 201 pp.

Snyder, G.R. 1967. Unpublished data of fish samplings in Lake Roosevelt. NOAA, National Marine Fisheries Service. Seattle, Washington.

Stober, Q.J., M.E. Kopache, and T.H. Jagielo. 1981. The limnology of Lake Roosevelt Final Report. Prepared by the University of Washington, Fisheries Research Institute, Seattle, Washington. Prepared for the United States Fish and Wildlife Service, National Fisheries Research Center, Seattle, Washington. Contract number 14-16-0009-80-0004. FRI-VW-8106: 126 pp.

Stober, Q.J., R.W. Tyler, C.E. Petrosky, T.J. Carlson, C. Gaudet, and R.E. Nakatani. 1977. Survey of fisheries resources in the forebay of FDR Reservoir, 1967-1977. Fisheries Research Institute, University of Washington. Final Report to United States Bureau of Reclamation. Contract 14-06-100-9001. 108 pp.

Stroud, D.H.P., G. C. Claghorn, K.A. Wagner, B. Nine, S. Wolvert, and A.T. Scholz. 2010a. Bioenergetic models for walleye and smallmouth bass to determine the number of rainbow trout and kokanee salmon they consume in the Sanpoil River

Arm of Lake Roosevelt. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Document ID # P115131: 107 pp.

Stroud, D.H.P., A.O. Blake, G. C. Claghorn, B. Nine, S. Wolvert, and A.T. Scholz. 2010b. Salmonid consumption in the Sanpoil River Arm of Lake Roosevelt by smallmouth bass and walleye using bioenergetic modeling. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Project No. 1995–011–00. Contract No. 45289: 185 pp.

Stroud, D.H.P. and A.T. Scholz. 2012 (in manuscript). Hatchery kokanee tracking and movement study in Lake Roosevelt. 2011 Annual report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon.

Stroud, D.H.P. and A.T. Scholz. 2013 (in manuscript). Hatchery kokanee tracking and movement study in Lake Roosevelt. 2012 Annual report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon.

Thatcher, M.C., J.R. Griffith, A.C. McDowell, and A.T. Scholz. 1994. Lake Roosevelt fisheries monitoring program. Annual report 1992. Prepared by: Spokane Tribe of Indians, Wellpinit, Washington and Eastern Washington University, Cheney, Washington. Submitted to: United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Project No. 88–63. Contract No. DE–8179–88 BP91819: 304 pp.

Thatcher, M.C., J.R. Griffith, A.C. McDowell, and A.T. Scholz. 1993. Lake Roosevelt fisheries monitoring program. Annual report 1993. Prepared by: Spokane Tribe of Indians, Wellpinit, Washington and Eastern Washington University, Cheney, Washington. Submitted to: United States Department of Energy, Bonneville

Power Administration, Portland, Oregon. Project No. 88–63. Contract No. DE–8179–88 BP91819: 326 pp.

Tilson, M.B. 1994. Smolt transformation in kokanee salmon, Onchorhynchus nerka kennerlyi Suckley. MS thesis. Eastern Washington University, Cheney, Washington. 150 pp.

Tilson, M.B., A.T. Scholz, J.R. White and H. Galloway. 1995. Thyroid-induced chemical imprinting in early life stages and assessment of smoltification in juvenile kokanee salmon. Implications for operation Lake Roosevelt kokanee salmon hatcheries: Annual report 1994. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. DOE/BP-91819-10: 140 pp.

Tilson, M.B., A.T. Scholz, J.R. White and H. Galloway. 1994. Thyroid-induced chemical imprinting in early life stages and assessment of smoltification in kokanee salmon. Implications for operation Lake Roosevelt kokanee salmon hatcheries: Annual report 1993. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. DOE/BP-91819-7:168 pp.

Underwood, K., and J. Shields. 1996a. Lake Roosevelt fisheries monitoring program. Annual report 1993. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 91819–13: 100 pp.

Underwood, K., J. Shields, and M.B. Tilson. 1996. Lake Roosevelt fisheries and limnological research. Annual report 1994. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 91819–14: 362 pp.

Underwood, K., and J. Shields. 1996b. Lake Roosevelt fisheries and limnological research. Annual report 1995. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Report No. 91819–15: 337 pp.

Wallis, O.L. and C.E. Bond. 1950. Establishment of kokanee in Crater Lake, Oregon. Journal of Wildlife Management 14: 190-193.

Ward, B.R. and P.A. Slaney. 1988. Life history and smolt-to-adult survival of Koegh River steelhead trout (*Salmo gardneri*) and the relationship to smolt size. Canadian Journal of Fisheries and Aquatic Science 45: 1110-1122.

Wydoski, R.S. and R.R. Whitney. 1979. Inland Fishes of Washington. University of Washington Press, Seattle, Washington. 220 pp.

Wydoski, R.S. and R.R. Whitney. 2003. Inland Fishes of Washington, Second Edition Revised and Expanded. University of Washington Press, Seattle, Washington. 322 pp.

VITA

AUTHOR

Alix O. Blake

EDUCATION

2011-2013	Master of Science (March 22, 2013). Department of Biology, Eastern Washington University
2008-2011	Bachelor of Science (August 2011). Department of Biology, Eastern Washington University

RESEARCH EXPERIENCE

2010-2013	Kokanee assessment in Lake Roosevelt
2011-2013	Movements of Bull Trout Above and Below Albeni Falls Dam
2011-2012	Diet Analysis of predators in Lake Pend Oreille
2011-2012	Wild kokanee acoustic tracking in Lake Roosevelt
2011-2012	Hatchery kokanee acoustic tracking in Lake Roosevelt
2009-2011	Northern pikeminnow, Walleye, and Smallmouth Bass bioenergetic modeling to determine the number of rainbow trout and kokanee salmon they consume in the Sanpoil River Arm of Lake Roosevelt
2009	Assisted in the radio tracking of elk to determine the movements and aspen regeneration on Turnbull National Wildlife Refuge.
2008-2009	Aided field research; "Coyote abundance across an urban-wildland gradient in northeastern Washington."

REPORTS

Blake, A.O., A.T. Scholz, H.J. McLellan and A. Miller. 2013. Hatchery Kokanee investigation in Lake Roosevelt, 2012 Annual report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon.

Blake, A.O., A.T. Scholz, H.J. McLellan and A. Miller. 2012. Hatchery Kokanee investigation in Lake Roosevelt, 2011 Annual report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon.

Blake, A.O., A.T. Scholz, H.J. McLellan and A. Miller. 2011. Hatchery Kokanee investigation in Lake Roosevelt, 2010 Annual report. Pages 42 – 82 (Chapter 2) in Scholz, A.T., A.O. Blake, T. Parsons, M. Korst, D. Stroud, M. Paluch, H.J. McLellan and A. Miller. Hatchery investigations and sonic tracking of wild and hatchery kokanee in Lake Roosevelt, 2010 annual report. United States Department of Energy, Bonneville Power Administration, Portland, Oregon.

Stroud, D.H.P, A.O. Blake, G.C. Claghorn, B. Nine, S. Wolvert and A.T. Scholz. 2010. Salmonid consumption in the Sanpoil River Arm of Lake Roosevelt by smallmouth bass and walleye using bioenergetic modeling. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Project No. 1995-011-00. Contract No. 45289, 185 pp.

Blake, A.O., D.H.P. Stroud, G.C. Claghorn, B. Nine, S. Wolvert and A.T. Scholz. 2010. Assessment of northern pikeminnow age/growth, populations, and diet in the Sanpoil River and Lake Roosevelt. Pages 101-152 in Stroud, D.H.P, A.O. Blake, G.C. Claghorn, B. Nine, S. Wolvert and A.T. Scholz. 2010. Salmonid consumption in the Sanpoil River Arm of Lake Roosevelt by smallmouth bass and walleye using bioenergetic modeling. United States Department of Energy, Bonneville Power Administration, Portland, Oregon. Project No. 1995-011-00. Contract No. 45289, 185 pp.

PUBLICATIONS

Blake A.O., A.T. Scholz, H.J. McLellan and A. Miller. In preparation. Evaluation of Three Stocks of Hatchery Kokanee in Lake Franklin D. Roosevelt, Washington. Northwest Science

Stroud, D.H.P, A.O. Blake, G.C. Claghorn, B. Nine, S. Wolvert and A.T. Scholz. In review. Salmonid consumption in the Sanpoil River Arm of Lake Franklin D. Roosevelt by introduced walleye and smallmouth bass using bioenergetic modeling. Transactions of the American Fisheries Society.

PRESENTATIONS

Assessment of three kokanee salmon stocks released in Lake Roosevelt, WA. Oral Presentation. Washington British Columbia American Fisheries Society Chapter Conference, Victoria, BC. May 15 – 18, 2012.

Lake Roosevelt, Lake Whatcom and Wild Stock Fecundity-Length-Weight Comparison in *Oncorhynchus nerka.* Poster Presentation. 15th Annual Student Research & Creative Works Symposium. Cheney, WA. May 15 – 16, 2012.

Assessment of Hatchery Kokanee (*Oncorhynchus nerka*) Release Program in Lake Roosevelt 2009-2011. Oral Presentation. Lake Roosevelt Forum Conference, Spokane WA. April 16 – 17, 2012.

Salmonid Consumption by Nonindigenous Smallmouth Bass Determined by Bioenergetics Modeling. Oral Presentation. American Fisheries Society National Conference. Seattle, WA. September 4 – 8, 2011.

Assessment of Northern Pikeminnow Age/Growth, Population and Diet in the Sanpoil Arm of Lake Roosevelt. Oral Presentation. 14th Annual Student Research & Creative Works Symposium. Cheney, WA. May 17 - 18, 2011.

Noise Induced Stress Response in Walleye (*Sander vitreus*). Poster Presentation. 14th Annual Student Research & Creative Works Symposium. Cheney, WA. May 17 - 18, 2011.

Salmonid consumption by walleye using bioenergetics modeling. Oral presentation. NCUR (National Conference of Undergraduate Research), Ithaca, NY. 31 March – 2 April 2011.

<u>SCHOLARSHIPS/AWARDS</u>

2012	Eastern Washington University High Demand Major Tuition Reduction Award
2012	WA/BC 2012 Chapter Meeting Best Student Presentation Honorable Mention
2012	Eastern Washington University Teaching Assistant Fellowship
2011	J. Herman & Jean Swartz and Frances & William P. Werschler Graduate Fellowship
2011	Eastern Washington University Research Assistant Fellowship
2011	Outstanding Senior in Biology
2011	EWU NCUR Library Award
2009, 2010	Safari Club Scholarship
2010	EWU Alumni Scholarship
2008	Dale Wilson Scholarship
2008	Dale Wilson Mondovi Grange Scholarship
2008	PEO Sisterhood Scholarship
2008	Washington Grange Association Scholarship
2008	Reardan Lions Club Scholarship
2008, 2009	EWU Honors (Program) Academic Scholarship
2008, 2010	WSP Troopers Association Scholarship