Kokanee (*Oncorhynchus nerka*) Spawning Surveys in Webster Creek, Cedar River Municipal Watershed

Summary Report, 1997-2006

Prepared by:
Heidy Barnett, David Chapin, Sally Nickelson, Dwayne Paige, and Bill Richards

Seattle Public Utilities — Watershed Management Division

January 2007

Table of Contents

Executive Summary

In 1997, Seattle Public Utilities (SPU) documented the presence of kokanee salmon in Walsh Lake within the Cedar River Municipal Watershed (CRMW). Spawning surveys for fish in the main tributary of the lake, Webster Creek, were initiated in 1997. These surveys have occurred annually from 1997 through 2006. Data presented in this report were collected by the Fish and Wildlife staff of the Watershed Management Division.

During annual spawning surveys, redd locations were noted and number of fish observed along the stream was recorded. In all years surveys occurred two to three times per week during the peak of the run. Data collected on fish included daily live fish counts through the accessible spawning reach, approximate redd count and locations, and carcass counts and measurements. Prior to 2002, spawning run numbers were extremely low, with fewer that 18 redds documented in years 1997-2001. The largest kokanee run in 2002 had a peak count of 586 fish. The following year, the peak live fish count dropped to 147, and in 2004 the number dropped slightly more to 106 maximum fish counted in Webster Creek.

A bridge replacing a fish-blocking culvert was installed in Webster Creek during 2001, enabling kokanee to access an additional 1,600 feet of habitat. This report documents kokanee use of the additional 1,600 feet of stream habitat following restoration of fish passage in 2001. Another barrier is present at this location and a project is planned to document fish recolonization of this habitat after the barrier is removed during FY 2005.

1.0 Introduction

1.1 Introduction

Seattle Public Utilities (SPU) determined that kokanee salmon were present and spawning in the Cedar River Municipal Watershed (CRMW) during 1997. This discovery prompted SPU to investigate habitat used during spawning by kokanee and count the number of redds and number of fish present in the stream. SPU Fish and Wildlife staff collected these data for years 1997-2006. The purpose of this report is to present information gained through these surveys to better understand the status of kokanee in the CRMW and the Puget Sound region.

1.2 Life History

Kokanee (*Oncorhynchus nerka)* are a resident, freshwater form of sockeye salmon. In the CRMW, fish rear in Walsh Lake and spawn in Webster Creek. Native kokanee were historically widespread in the Lake Washington basin, but are now limited to the Sammamish River and its tributaries, the Lake Sammamish drainage, and the Cedar River drainage (Berge and Higgins 2003). Kokanee are no longer found in several tributaries of both Lake Washington and Lake Sammamish (Berge and Higgins 2003). Whereas sockeye travel to the ocean to mature, kokanee remain within a lake usually near their natal stream. Another form of the sockeye, called residual sockeye, originate from an anadromous lineage but do not migrate to the ocean. Kokanee are distinguished from residual sockeye because the parents were not anadromous. Although kokanee originally were derived from sockeye, isolation from andaromous sockeye for several generations distinguishes them as kokanee. Kokanee average between 7 and 11.7 inches in length (Groot and Margolis 1991). Because of their smaller body size, they require smaller substrate for spawning. The spawning color for both kokanee sexes resembles anadromous sockeye. Males turn a reddish color and develop a kype and hump on the back similar to anadromous sockeye salmon. Females are typically greenish in color with a slight reddish hue on the sides, and both sexes have distinct black spots along the back. In the Lake Washington Basin, kokanee have spots running along their back but not on the head (Bill Priest, King County, pers. com.).

Kokanee eggs hatch in late winter, and fry emergence begins in early spring. The fry migrate from their natal streams to lake habitat to feed and grow when flows increase in the spring. Kokanee spend three to four years feeding in the lake before maturing and returning to their natal stream to spawn. Soon after spawning, kokanee die and their life cycle is complete.

1.3 Current Status in the Lake Washington Watershed

Through the 1990's King County Water and Land Resources Division investigated the status of kokanee in the Lake Washington Basin. The King County surveys documented the timing and distribution of kokanee within tributaries of Lake Sammamish. King County also documented three distinct kokanee stocks present in the basin that are separated spatially and temporally through the spawning season. All three stocks appear to support relatively low populations and are at risk of extinction due to isolation in drainages under heavy development pressure (Berge and Higgins 2003). In fact, one of the three socks, the early-run kokanee, were declared extinct by Ron Simms, King County Executive in 2003 (Seattle Times 2003). King County is

conducting ongoing surveys to assess spawning populations of native kokanee in the Lake Washington basin. Kokanee spawning runs are present in Issaquah Creek, Sammamish River tributaries, and in tributaries of Lake Sammamish. The timing of the middle-run kokanee corresponds to that of Webster Creek in the CRMW (Berge and Higgins 2003). Microsatellite DNA analysis suggests that past introductions of non-native kokanee from Lake Whatcom and Baker Lake have not substantially altered the native gene pool of the Lake Sammamish populations (Young et al. 2003).

1.4 Description of the Cedar River Municipal Watershed (CRMW)

The CRMW provides two-thirds of the City of Seattle's drinking water and is managed under the 50-year Cedar River Watershed Habitat Conservation Plan (CRW-HCP). "The overall goal of the HCP is to implement conservation strategies designed to protect and restore habitats of all species of concern that may be affected by the facilities and operations of the City of Seattle on the Cedar River, while allowing the City to continue to provide high quality drinking water and reasonably priced electricity to the region." Most of the 90,546 acres in the CRMW are forested, with 14,000 acres of unharvested old forest (>190 years old) remaining (Figure 1). Under the CRW-HCP, they City is conducting a variety of habitat restoration projects throughout the CRMW, including forest thinning, riparian thinning and planting, large woody debris augmentation in streams and fish passage restoration. Kokanee are listed as a species of concern in the CRW-HCP. They are protected under a community-based strategy where protection of habitat should lead to protection of individual species that use that habitat.

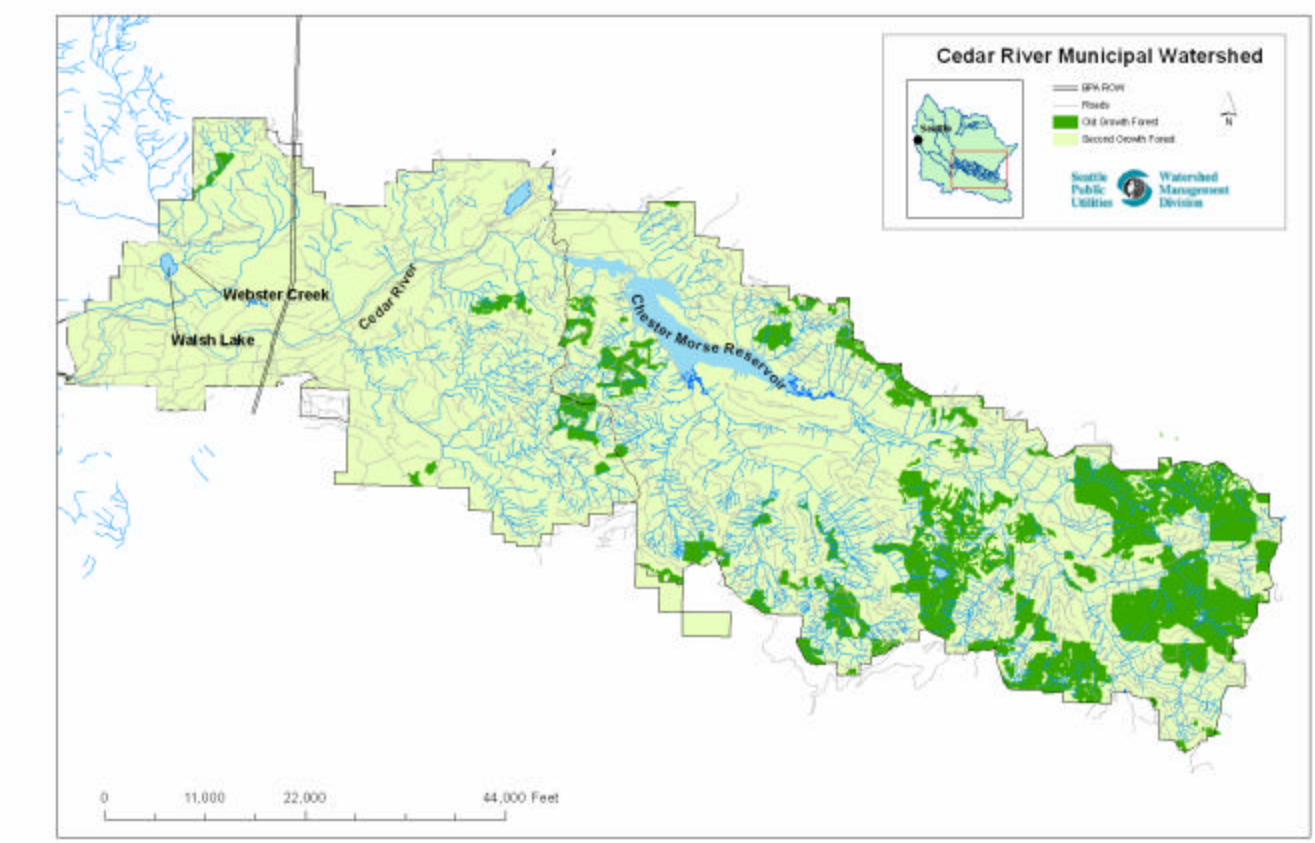


Figure 1. Location of Walsh Lake and Webster Creek within the Cedar River Municipal Watershed.

1.5 Walsh Lake

Walsh Lake, covering 60 acres, is located at the western edge of the CRMW (Figure 1). The water flowing out of Walsh Lake was diverted in the 1930s into the Walsh Lake Diversion Ditch intersecting the Cedar River below Landsburg Diversion Dam (Figure 2). This step was taken to prevent contamination of the water supply by water flowing out of the historic Taylor townsite where mining occurred until 19XX. It is possible that during some flows sockeye from the mainstem Cedar River could have migrated upstream into the Walsh Diversion Ditch and into Webster Creek to spawn. These offspring may have then remained in Walsh Lake and then produced offspring that now comprise the kokanee spawning run. Using microsatellite DNA analysis, Spies (2002) concluded that the Webster Creek kokanee are more closely related to Baker Lake sockeye than they are to any other kokanee in the Lake Washington Basin; however, the sample size of Webster Creek kokanee used in the analysis was small. Further genetic analysis is needed to determine more confidently the relationship of the CRMW kokanee to the rest of the Lake Washington Basin sockeye and kokanee population.

In 1997, SPU conducted a survey in Walsh Lake to determine the number of fish species present. SPU documented the presence of largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavensens*), northern squawfish (a.k.a. bigmouth minnow) (*Ptychochelius oregonesis*), cutthroat trout (*Oncorhynchus clarki*), and kokanee (*O. nerka*) in Walsh Lake. Additionally, rainbow trout (*O. mykiss*), coho (*O. kisutch*), redside shiner (*Richardsonius baleatus*), speckled dace (*Rhinichthys osculus*), and western brook lamprey (*Lampetra richardsoni*) were observed in the Walsh Lake Diversion Ditch (SPU 1997). Western pearlshell mussels (*Margaritifera falcata*) are also known to be present in Walsh Lake as well as the Walsh Lake Diversion Ditch.

Although the CRMW is closed to public access, occasionally fishermen use Walsh Lake due to the close proximity of the lake to a public road. Bait cans provide evidence of fishing presence near the lake. Frequent patrols of the Walsh Lake by watershed security staff minimize any fishing pressure on the fish population in Walsh Lake.

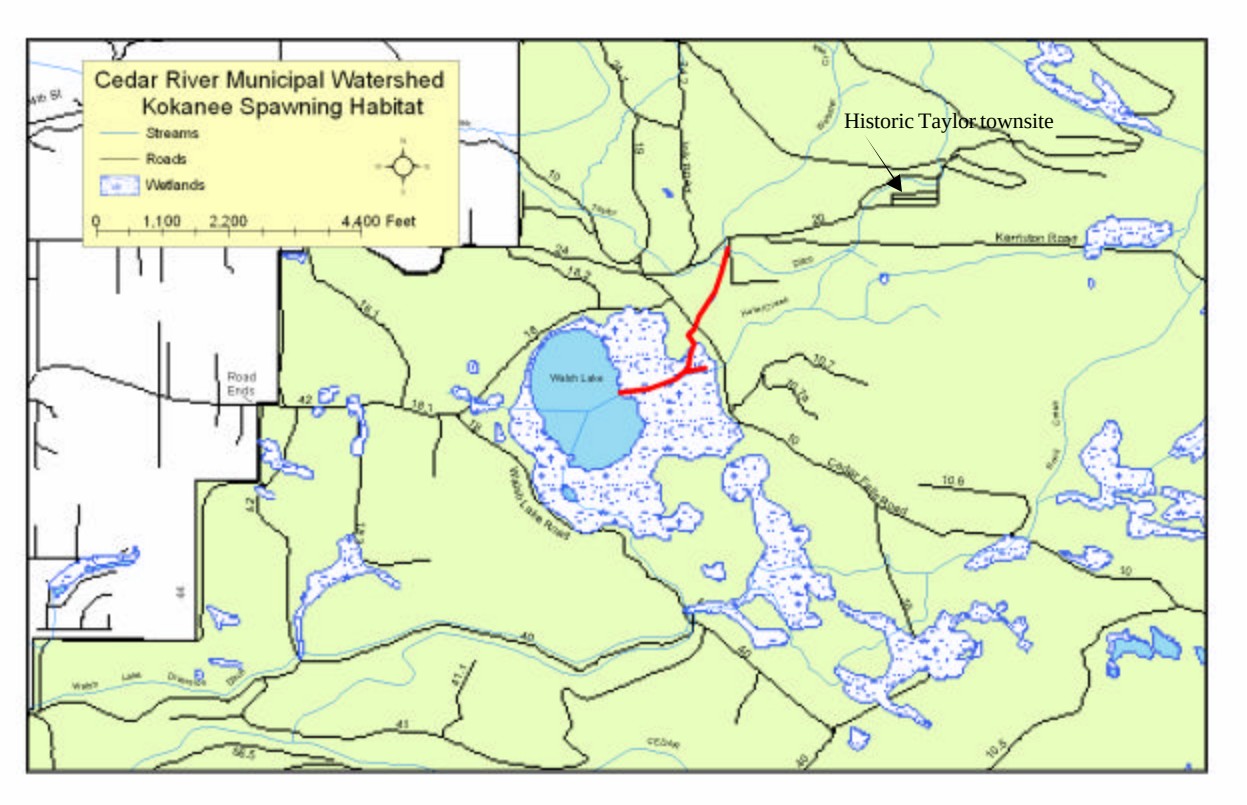


Figure 2. Kokanee Spawning Habitat in Webster Creek (depicted by red line).

1.6 Webster Creek

Webster Creek is a perennial stream flowing into Walsh Lake (Figure 2). The stream is a low gradient, glaciofluvial terrace tributary (Cupp and Metzler 1995). Much of Webster Creek where kokanee spawn exhibits plane bed morphology. Substrate is comprised mainly of gravel and small cobble, with areas of smaller substrate (Photo 1). The riparian forest on Webster Creek consists mainly of alder trees with a few conifers. Some wood is present in the stream, mainly consisting of relatively smaller alder boles and branches. A few large pieces of wood are found downstream of the 10 Road crossing (Figure 2).

Photo 1. Typical habitat chosen as kokanee spawning sites on Webster Creek (Fall 2002).

Prior to the fall of 2001, a culvert crossing the 10 Road created a migration barrier to spawning kokanee. The culvert was replaced with a cement box bridge, and SPU staff observed kokanee passing beneath the bridge immediately upon its opening on October 11, 2001. The installation of this structure opened approximately 1,600 additional feet of spawning habitat for kokanee upstream of the 10 Road (Figure 3).

A small amount of habitat in Hotel Creek is available and used by kokanee during the spawning season (Figure 2). Hotel Creek has very low flow and in most reaches does not provide appropriate gravel size and habitat structure needed for spawning. Kokanee have been observed in Hotel Creek just upstream of the confluence with Webster Creek, but do not appear to extensively use the stream.

2.0 Objectives and Methods

2.1 Project Objectives

Objectives for kokanee spawning surveys (1997-2006) were to:

- Determine the timing of the kokanee spawning run in Webster Creek.
- Estimate the number of fish in the kokanee spawning run.
- Determine the distribution of spawning habitat used by kokanee and locate any barriers to passage.
- Collect DNA samples from spawning kokanee for analysis of genetic relationship to the rest of the Lake Washington Basin.

2.2 Spawning Survey Methods

Spawning surveys were initiated during 1997, 1998, 1999, and 2002, in early October. During 2000, 2001, 2003, 2004, 2005, and 2006 surveys began in the middle of September. For spawning survey years 1997-2000, the stream reach between Walsh Lake and the 10 Road was surveyed weekly with a few exceptions due to high flows. During spawning survey years 2001-2006, the survey reach was extended to include habitat upstream to the Kerriston Road (Road 24) due to the installation of the new bridge opening passage for kokanee. Spawning reaches were surveyed weekly beginning in late September until fish were observed. Once fish were documented, surveys intensified to identify the peak of the spawning run. Redds were measured, marked with flagging, and located using station locations previously established by Fish and Wildlife staff. The stationing started at 0 feet at the lake outlet and continued upstream to the Kerriston Road with a flag marking each 50 foot station (Figure 3). Any observations made during spawning surveys could then be referenced to this stationing.

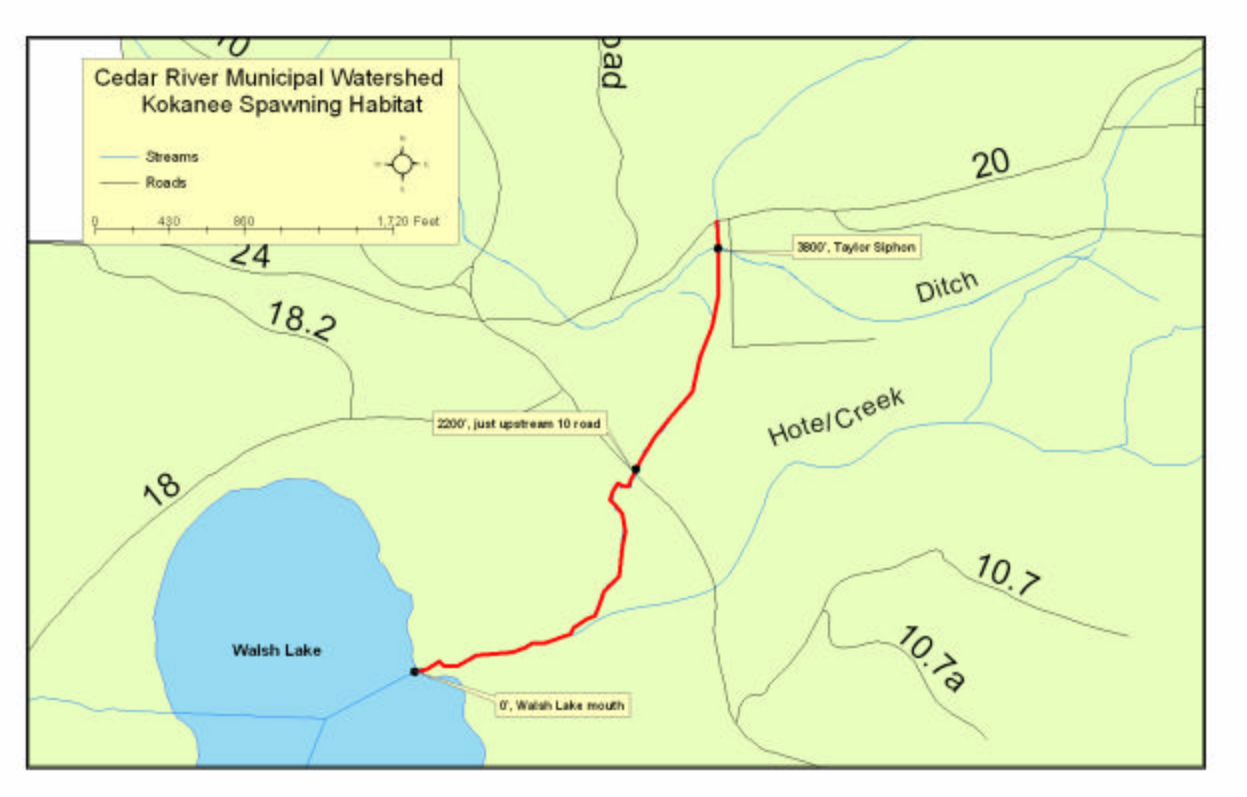


Figure 3. Kokanee stationing along Webster Creek. The reach was stationed with flagging every 50 feet beginning at Walsh Lake confluence and continuing upstream to the Kerriston Road at approximately 4,000 feet.

Redd superimposition, limited habitat availability in the stream, and overhanging banks created difficult survey conditions to accurately determine all redd sites. The total number of redds each year is a conservative count but should provide an index between years. Additionally, the relative abundance of redds spatially are captured through these data. The number of fish in the stream throughout the season was also tracked by counting the number of fish and noting their approximate location in the stream. As surveyors were not at the site daily, fish counts provide only approximations of the total and peak spawning run. When carcasses were encountered, surveyors made measurements of the carcasses and noted their condition. Finally, during 2002 DNA samples from the dorsal fin were collected on both live fish and fresh carcasses throughout the spawning run for genetic analysis.

3.0 Results

Spawning surveys were conducted for ten spawning seasons between the years of 1997 and 2006 (Table 1). Prior to 2001, few kokanee were observed spawning in Webster Creek. Because very little data are available regarding location of redds between 1997 and 2001, only spawning years 2002-2006 are discussed in detail. We attempted to count kokanee redds in Webster Creek, although typically kokanee spawning surveys do not enumerate redds due to high density spawning and high frequency of superimposition rates. Additionally, a single female (Groot and Margolis 1991) produces multiple egg pockets.

The greatest number of redds documented in the stream during the 1997-2001 period was in 1999, when 18 redds were located through the spawning season. The spawning run during 2002, with 371 documented redds, was much larger than any in the previous five years. During 2003 and 2004, relatively large runs of kokanee were observed in Webster Creek, with a total of 152 and 116 redds documented for the two years, respectively.

Table 1. Total number of kokanee redds documented in Webster Creek, 1997-2006.

	1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
Downstream of 10 Road	14	4	18	7	0	296	84	65	4	0
Upstream of 10 Road	0	0	0	0	1	75	68	51	1	0
Total	14	4	18	7	1	371	152	116	5	0

The temporal distribution of kokanee redds in Webster Creek between 1997 and 2006 was variable (Table 2). The earliest redd for each year was located during the first week of October except in 2002, when redds were not documented until the second week of October. In all years, except 2001, most redds were documented during October. A few kokanee spawned into November, but most activity slowed by the first week in November. In 1998 and 2002, one redd was documented after November 16. In 2002, 2004 and 2005, spawning activity was limited to a concentrated period of time where most redds were documented within a week. Timing for CRMW kokanee spawning coincides with middle-run kokanee in the Lake Washington Basin (Berge and Higgins 2003). The early-run kokanee in Issaquah Creek spawn much earlier, with peak spawning at the end of August (Berge and Higgins 2003). Late-run kokanee spawn much later than CRMW kokanee, with a peak spawning time at the end of November and beginning of December.

Table 2. Temporal distribution of kokanee redd counts, 1997-2006. (Dashed line (--) indicates no survey was performed during that time period.)

	1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
9/13-9/20	--	--	--	0	0	--	0	0	0	--
9/21-9/27	0	--	--	0	0	--	0	0	0	0
9/28-10/4	--	--		2	0	0	0	2	0	0
10/5-10/11	8	0	11	0	0	0	47	3	0	0
10/12-10/18	5	1	0	5	0	7	8	101	3	0
10/19-10/25	1	2	0	0	0	113	19	8	2	0
10/26-11/1	0	0	8	0	0	241	71	2	0	0
11/2-11/8	0	0	0	--	1	9	7	--	0	--
11/9-11/15	--	--	0	--	0	0	--	--	0	--
11/16-11/22	--	1	--	--	0	1	--	--	--	--
11/23-11/29	--	0	--	--	0	--	--	--	--	--

3.1 Kokanee Live Fish Counts 2001-2006

In 2001, 76 fish were observed on October 11, 2001 when the bridge at the 10 Road was opened. Despite the large live fish count only one redd was documented all season. Nineteen fish were present in Webster Creek one week later. The last two kokanee of 2001 were observed on October 29.

As previously described, Webster Creek had an unusually large run of kokanee salmon in the fall of 2002. Surveys were initiated on October 1, 2002 and were conducted weekly until the first 23 kokanee were observed in the stream on October 15. Very little activity was observed until the 24th of October, when 446 fish were counted (Table 3). With the documentation of such a large number of kokanee in the stream, surveys were conducted more frequently. The spawning run peaked on October 27, 2002 when 586 fish were counted in the stream segment between Walsh Lake and the Kerriston Road (Figure 4, Appendix 1). Four days later, 360 fish were counted in the same reach of stream indicating that many of the fish had completed spawning and were expiring.

Table 3. Live fish counts by date in Webster Creek during 2002.

Date	*Male*	*Female*	*Unknown sex*	*Total live fish*	*Total Carcasses*
10-1-02	-	-	-	0	0
10-7-02	-	-	-	0	0
10-15-02	-	-	23	23	0
10-18-02	-	-	16	16	21
10-21-02	-	-	0	0	1
10-24-02	-	-	446	446	-
10-26-02	131	97	338	566	11
10-27-02	105	101	380	586	5
10-28-02	-	-	-	-	66
10-29-02	-	-	-	-	49
10-31-02	49	100	211	360	-
11-1-02	-	-	-	-	21
11-4-02	50	181	63	294	-
11-8-02	18	89	70	177	0
11-12-02	2	17	68	87	1
11-15-02	17	24	5	46	3
11-21-02	0	0	0	0	0

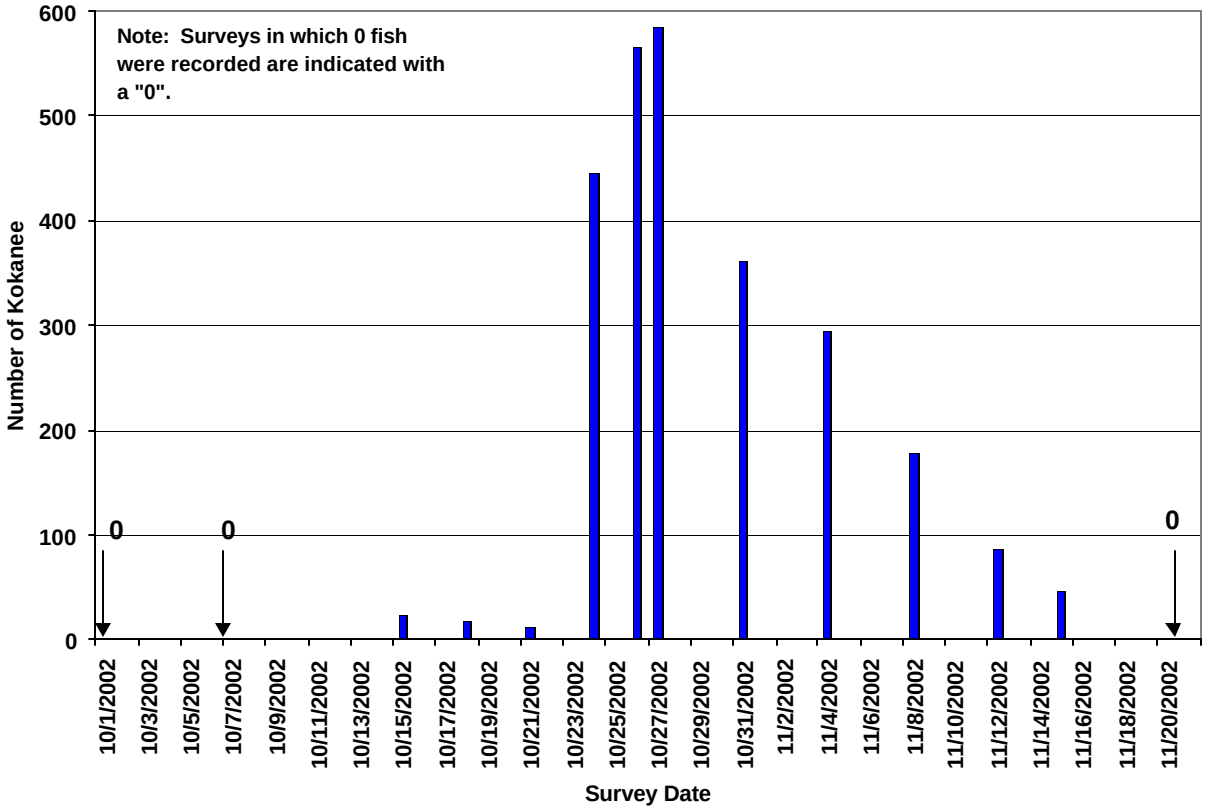


Figure 4. Temporal distribution of kokanee in Webster Creek during 2002.

Flows in Webster Creek were low all year and fish could be seen and heard splashing through shallow riffles while moving upstream. The few large pools were consistently filled with fish during the major portion of the spawning period. The run began to diminish around November 4, 2002, and steadily tailed off until the end of November (Figure 4, Appendix 2). Sex ratios were fairly even in the run, although counts toward the end of the season suggested that higher numbers of females were present in the stream (Table 3). Many of these females were observed defending a redd site which is common for *Oncorhynchus nerka* (Groot and Margolis 1991).

Fish were distributed throughout Webster Creek to 3,000 feet upstream of the 10 Road in 2002. An alder log created a temporary barrier across the stream, creating a small plunge pool with insufficient depth for jumping. One male carcass was found beached on a wedge of leaves just upstream of this barrier, indicating very few fish were able to navigate the barrier; and those that did likely could not make it over the piled leaves into the stream. As graphs in Appendix 1 show, several pools repeatedly held high numbers of kokanee (e.g. pool at 1,700 feet). These

fish were congregated in pools, possibly resting before moving upstream through the shallow waters (Photo 2).

During 2003, the first kokanee was observed in Webster Creek on October 13, 2003, only two days later than in 2002, and the entire stream was surveyed the following day. A heavy rainstorm caused an increase in flows in Webster Creek and made viewing conditions difficult on October 16th and 23rd. Even during this high flow event, fish were observed moving upstream in Webster Creek and actively spawning. The male:female ratio was skewed toward males early in the run and changed to favor females later in the run, much like 2002 (Table 4). The peak date for fish presence in Webster Creek fell on October 28, when 147 fish were observed in the stream. By October 31, over one-third of these fish were no longer present in the stream and by November 4th, only seven live fish were found in Webster Creek (Figure 5,). The temporal pattern of kokanee spawning closely mirrored that observed during 2002 (Appendix 2).

Table 4. Live fish counts by date in Webster Creek 2003.

Date	*Male*	*Female*	*Unknown sex*	*Total live fish*
9/29/2003	0	0	0	0
10/1/2003	0	0	0	0
10/10/2003	0	0	0	0
10/14/2003	61	36	10	107
10/16/2003	31	13	7	51
10/23/2003	44	33	47	124
10/28/2003	58	57	32	147
10/31/2003	21	55	14	90
11/4/2003	2	3	2	7
11/6/2003	0	0	0	0

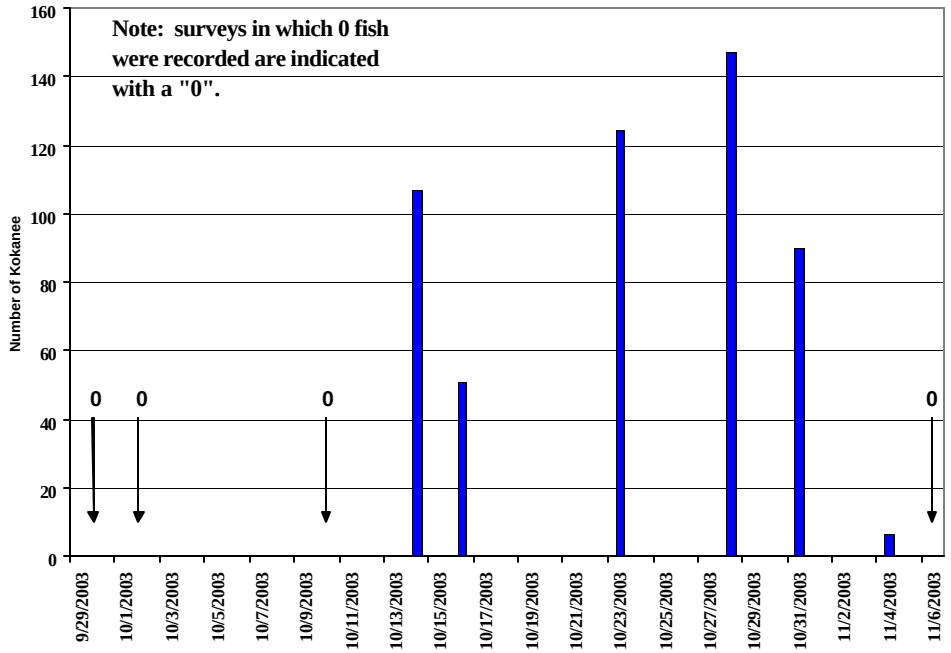


Figure 5. Temporal distribution of kokanee in Webster Creek during 2003.

Photo 2. Many kokanee holding in a pool in Webster Creek on October 25, 2002.

The 2004 kokanee spawning run contained slightly fewer individuals than the spawning run of 2003. Additionally, the run was compacted temporally and lasted only two weeks (Table 5, Figure 6, and Appendix 3). A peak fish count of 106 individuals was recorded on October 15th, then quickly fell to half that number by October 18th (Table 5). Very few carcasses were observed during the 2004 spawning surveys, likely indicating that scavengers (e.g. raccoons, bear) in the area were quickly removing carcasses from the stream. Our general impression was that fish in the 2004 spawning run were larger than those of previous years, although insufficient carcasses were collected to document this. The few carcass measurements collected supported this observation, with the smallest measurement being 355 millimeters fork length (average fork length in 2002 was 367 millimeters).

Table 5. Live fish counts by date in Webster Creek 2004.

Date	*Male*	*Female*	*Unknown sex*	*Total live fish*
9/23/04	0	0	0	0
10/1/04	0	0	0	0
10/6/04	0	0	0	0
10/11/04	47	44	10	101
10/15/04	41	55	10	106
10/18/04	17	18	15	50
10/22/04	0	0	0	0
10/27/04	0	0	0	0

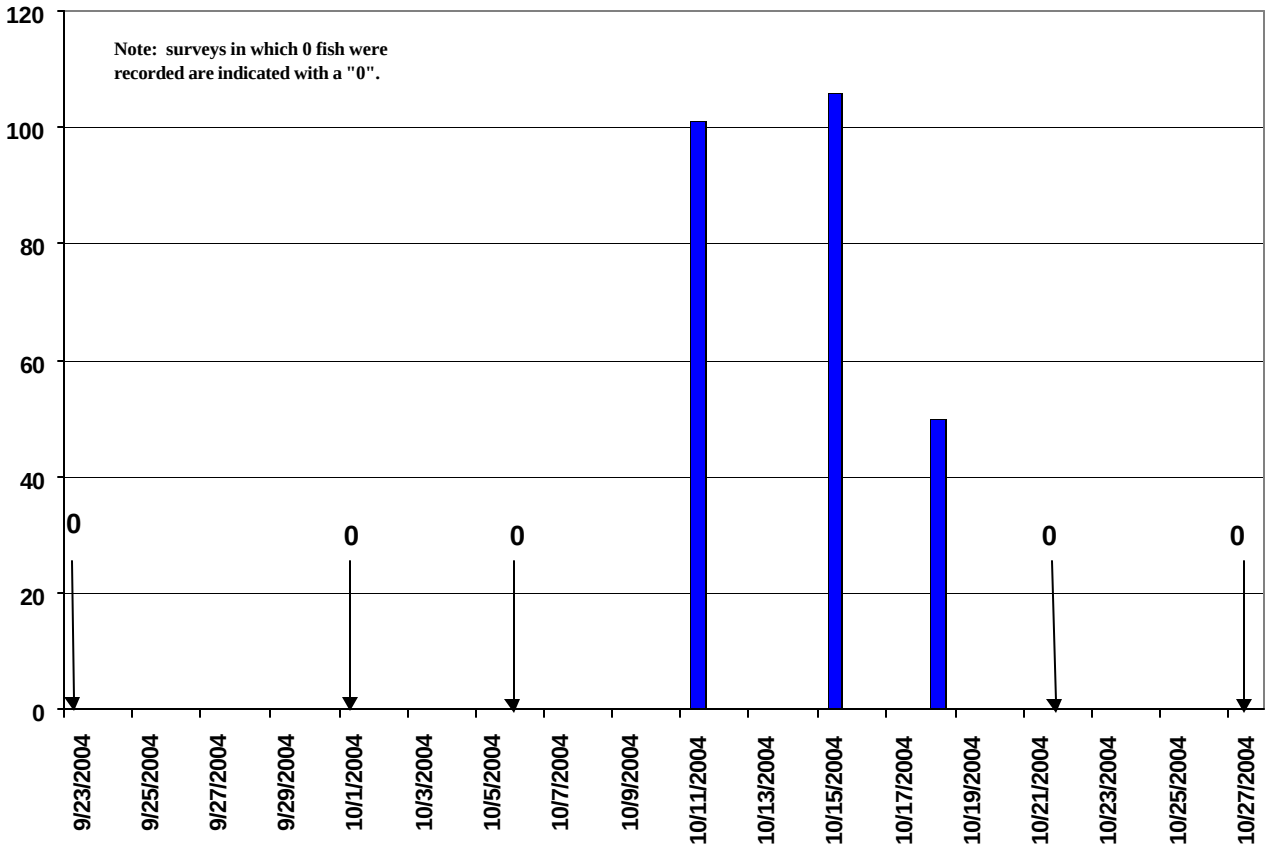


Figure 6. Temporal distribution of kokanee in Webster Creek during 2004.

3.2 Kokanee Redd Surveys

Although we made an effort to count all of the kokanee redds, distinguishing them from one another is difficult and in many cases impossible. The fish used small substrates, occasionally even sand, that did not hold an easily recognizable redd shape. Therefore, our redd counts are likely to be conservative. Virtually all potential spawning sized gravel in the stream was used, and some locations were repeatedly used during the spawning run, suggesting that a high number of eggs in early redds were disturbed and possibly harmed by later spawning fish.

Only twenty percent of the kokanee redds were placed upstream of the 10 Road during 2002 (13.8 and 8.8 redds per 100 feet of stream downstream and upstream of the 10 Road bridge, respectively) (Figure 7). The gravel in this section of stream is larger than downstream of the 10 Road, and may not have provided as much preferred spawning gravels for fish compared to downstream of the 10 Road. Redds distributed downstream of the 10 Road were scattered throughout the stream reach with a few hotspot localities (Figure 7). There were very few 50-foot sections with fewer than 5 redds, especially downstream of the 10 Road (Figure 7).

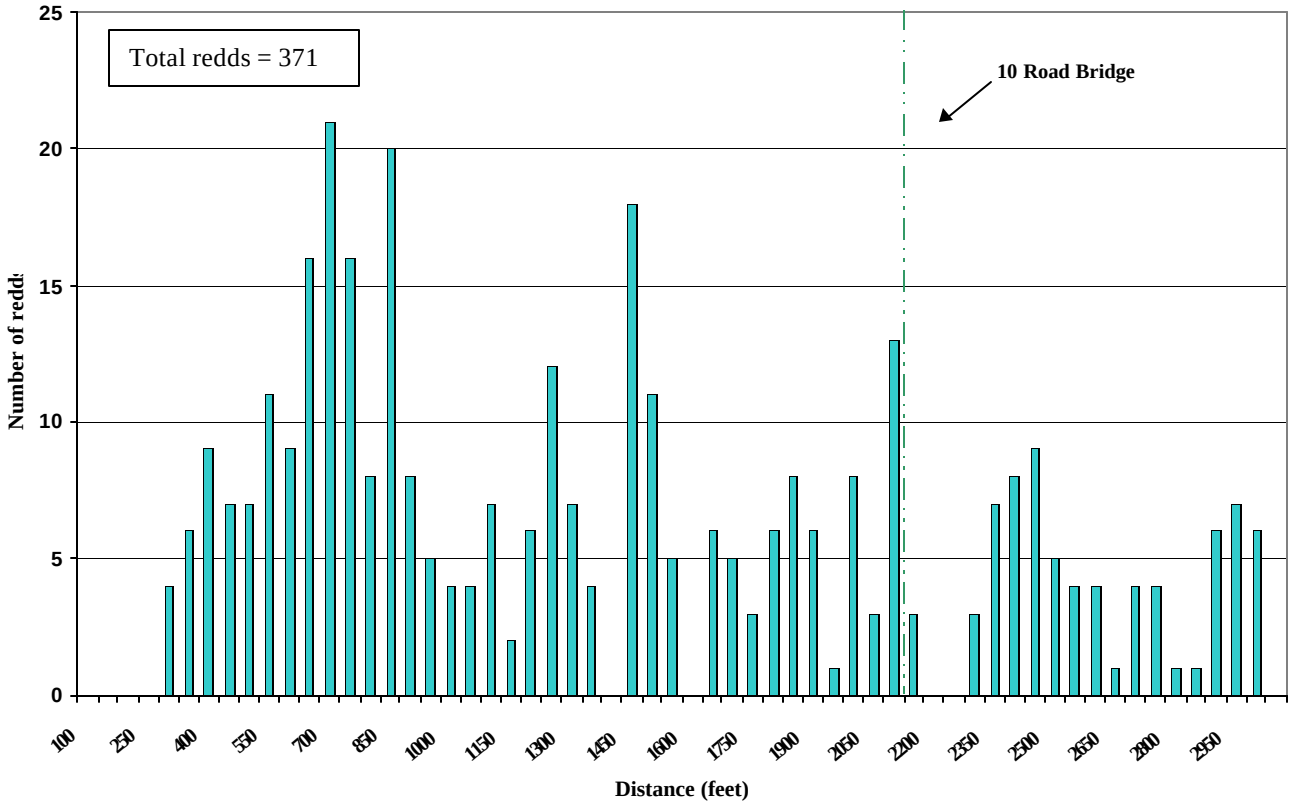


Figure 7. Distribution of kokanee redds in Webster Creek during 2002.

Total redd counts during 2003 were 41 percent lower than during 2002 (153 and 371, respectively). In contrast to 2002, fish in 2003 were evenly spread throughout the stream, so that just over half of all redds located during spawning surveys were documented upstream of the 10 Road bridge (3.4 and 4.8 redds per 100 feet of stream downstream and upstream of the 10 Road bridge, respectively) (Figure 8). A temporary log barrier located at approximately 3,000 feet was removed by high flows the second week of October 2003. This alder log had been present through the entire 2002 spawning season, preventing further upstream movement of kokanee. During 2003, fish moved upstream to the next barrier at the Taylor Siphon (3,800 feet upstream of Walsh Lake). Redds were found distributed throughout the stream to this point. The uppermost redd was located at the 3,750 foot station just downstream of the Taylor Siphon pool.

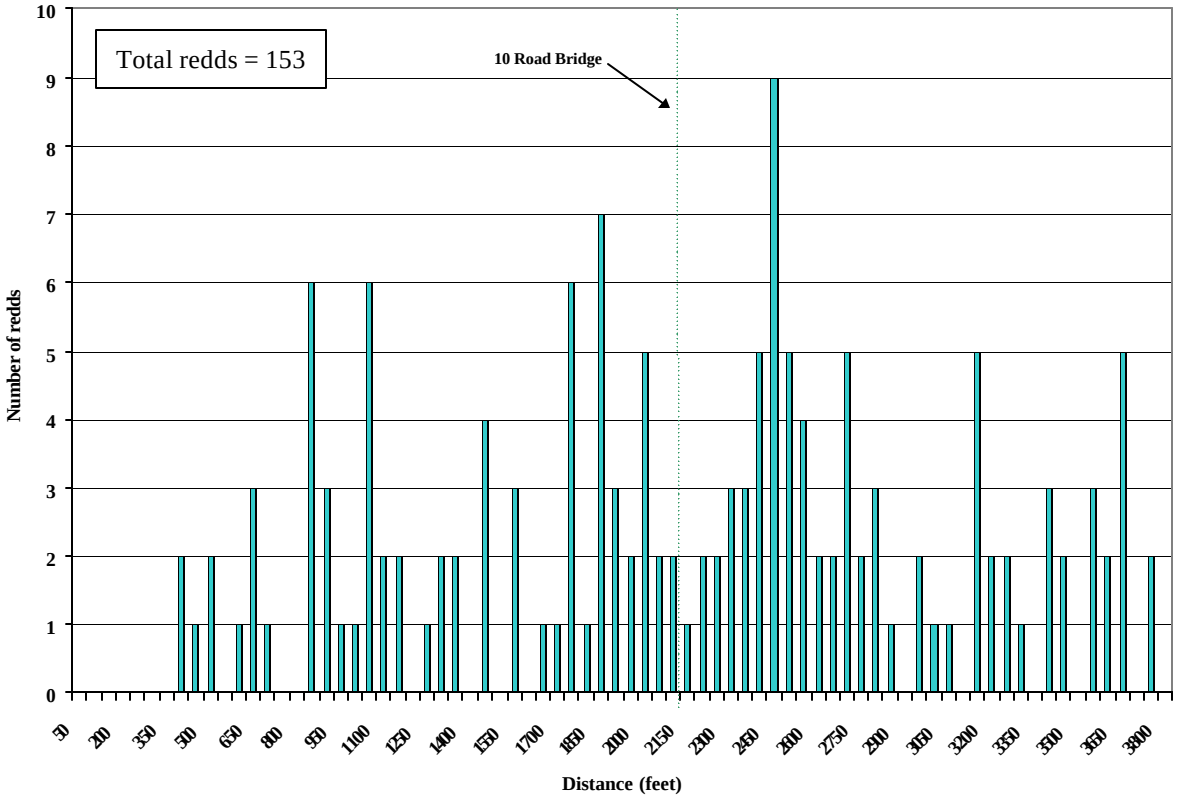


Figure 8. Distribution of kokanee redds in Webster Creek during 2003.

Similar to 2002, kokanee were observed spawning in many different types of substrate from nearly three-inch gravel to fine sandy substrate in 2003. Many redds were tucked against the bank and in some cases were under overhanging banks or vegetation. The high flows during the third week of October moved much of the wood within the stream and changed the habitat in many areas. It appeared that many of the existing redds were scoured during this high flow event.

During 2004 kokanee redds were distributed evenly upstream and downstream of the 10 Road bridge from Walsh Lake to the barrier at the Taylor Siphon (2.9 and 3.3 redds per 100 feet of stream downstream and upstream of the 10 Road bridge, respectively). A total of 116 redds were documented in Webster Creek in 2004, with 43 percent upstream of the 10 Road (Figure 9). (SPU hopes to remove the barrier at the Taylor Siphon before the 2005 kokanee spawning season.) Redd counts in 2004 were only slightly lower than in 2003, but well below the number observed during 2002.

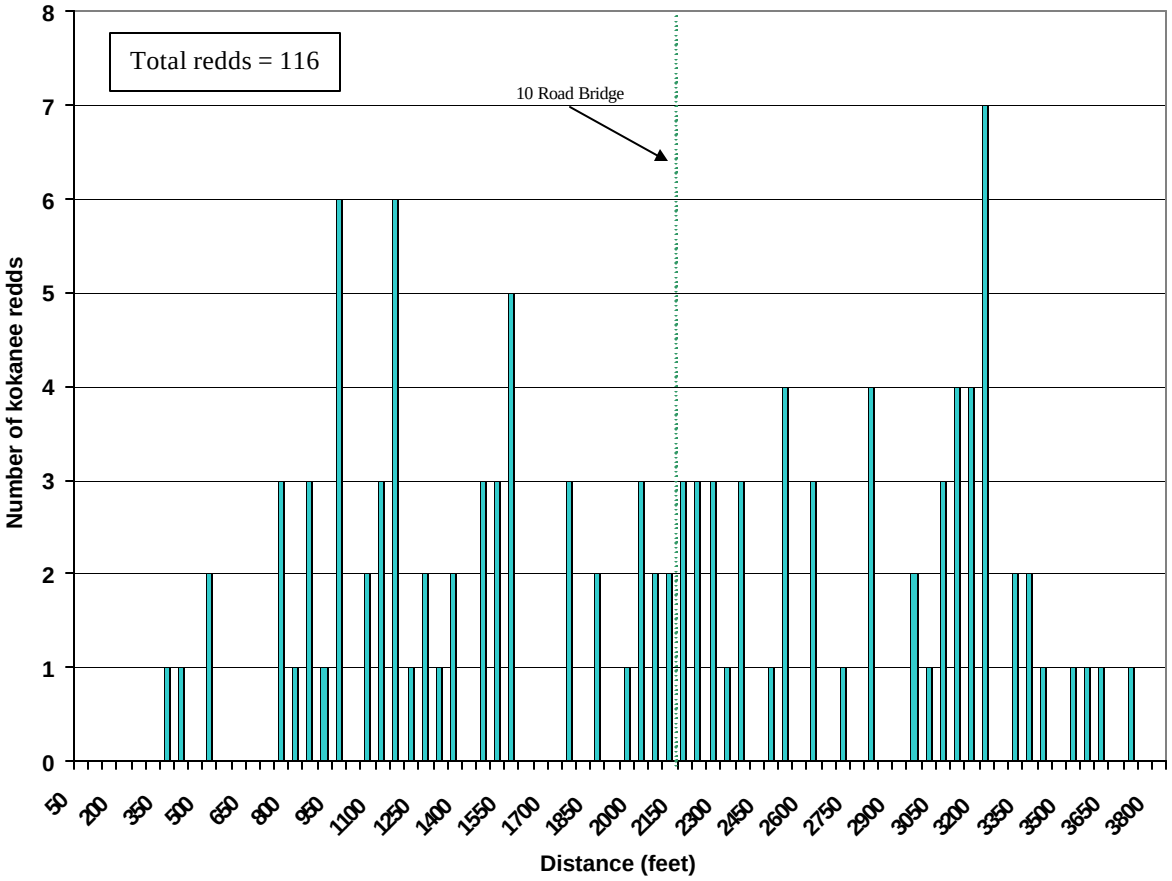


Figure 9. Distribution of kokanee redds in Webster Creek during 2004.

Kokanee redd distribution following the installation of the 10 Road bridge shifted so that higher densities of redds were located upstream of the 10 Road (Figure 10). Prior to 2001, the culverts at the 10 Road delineated the upstream extent of kokanee distribution in Webster Creek. Because habitat upstream of the 10 Road is slightly shorter in length than habitat downstream of the 10 Road, the density of spawning fish is greater.

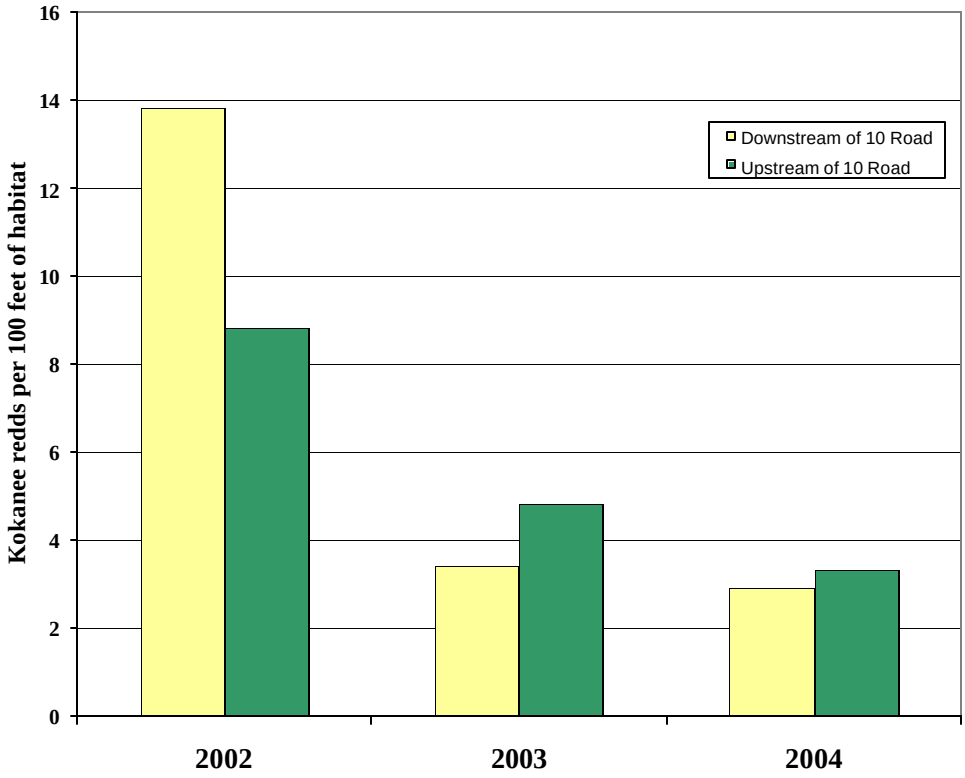


Figure 10. Kokanee redds per 100 feet of stream length in Webster Creek following installation of a bridge at the 10 Road.

3.3 Genetic Samples

Based on a small number of samples (n = XX), Spies (2002) found that the genetic identity of Webster Creek kokanee was more closely related to Baker Lake sockeye than any native sockeye stocks in the Lake Washington Basin. However, because the sample size analyzed by Spies was small, the results of her analysis should be considered preliminary and in need of confirmation using a higher number of samples. Genetic samples were collected from fish in Webster Creek to be analyzed at a later date (Table 7).

Table 7. Kokanee genetic samples collected in 2002.

Date	*No. DNA Samples*	*No. upstream of 10 Road*	*No. downstream of 10 Road*
10-17-02	1	0	1
10-18-02	16	0	16
10-21-02	1	0	1
10-24-02	5	0	5
10-25-02	49	0	49
10-26-02	13	13	0
Total	85	13	72

3.4 Kokanee Carcass Counts

The first carcasses of 2002 were found at the mouth of Webster Creek on October 18, 2002. Of the eleven carcasses found at the mouth, only one had spawned. Additional carcasses, including both spawned and unspawned individuals, were observed upstream had obvious predator and scavenger damage on their bodies, and raccoon and bear tracks were found near the stream. We suspect that most carcasses were removed quickly from the stream, because our carcass surveys did not account for the large numbers of fish observed using Webster Creek during the spawning run. The greatest number of carcasses located on the stream totaled 50 on the 28th of October during the peak of the spawning run in 2002. When a carcass was measured, a clip was taken off of the fin in order to distinguish it as already counted during subsequent surveys. By November 4th, all these carcasses had been removed from the stream (Table 8), and surveyors no longer observed the clipped fin carcasses. Sex ratios of carcasses were fairly even through the year. At the highest density of carcasses, slightly more males than females were observed (Table 8), although in some cases it was impossible to distinguish sex on carcasses. The majority of fork lengths measured on kokanee carcasses ranged between 290 and 300 mm during 2002 (Figure 11).

Table 8. Number of kokanee carcasses by date during 2002.

Date	*No. carcasses*	*No. males*	*No. females*	*Carcasses already included in previous counts*
10/01/02	0	0	0	0
10/07/02	0	0	0	0
10/15/02	0	0	0	0
10/18/02	22	9	5	8
10/21/02	1	1	0	0
10/26/02	11	5	5	1
10/27/02	5	0	0	5
10/28/02	50	24	11	15
10/29/02	46	2	0	44
11/01/02	23	2	9	12
11/04/02	0	0	0	0
11/08/02	0	0	0	0
11/12/02	1	0	0	1
11/15/02	3	0	2	1
11/21/02	0	0	0	0
Totals	156	43	32	87

In 2003, only 12 carcasses were found during the spawning season. Of these carcasses, five were males, three were females, and four were of unknown sex. Fork length for intact carcasses ranged from 250 millimeters to 420 millimeters with an average of 329 millimeters. Even fewer carcasses were located in 2004, when four were found during the spawning season. Fork length during 2004 ranged from 356 millimeters to 375 millimeters, with an average of 368 millimeters.

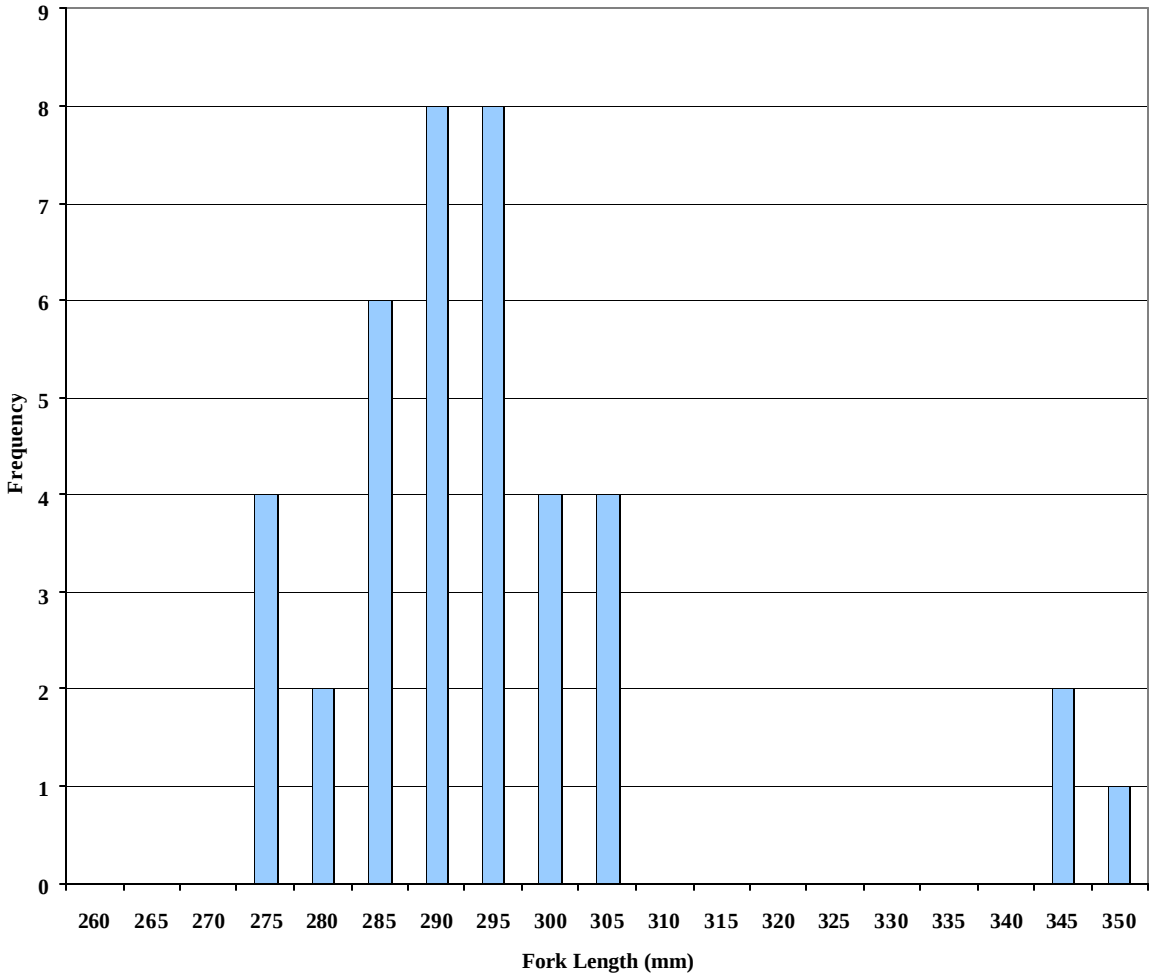


Figure 11. Length-frequency distribution of kokanee in Webster Creek during 2002.

4.0 Discussion and Recommendations

SPU has been monitoring the Webster Creek-Walsh Lake population of kokanee salmon for eight years. From spawning surveys, morphological measurements, and preliminary genetic analysis, we are gaining a better understanding of this population. In this discussion we address how this information helps to answer two primary, interrelated questions concerning the Webster Creek-Walsh Lake kokanee population: (1) What is the origin of this population? And (2), what accounts for the dramatic variation in spawning numbers from year-to-year?

4.1 Origin of the Webster Creek-Walsh Lake Kokanee Population

4.2 Year-to-Year Variation in Spawning Numbers

Spawning surveys show that the population numbers increased dramatically in 2002 from any previously surveyed year, then decreased to intermediate levels in 2003 and 2004. The reason for the sudden increase during 2002 in kokanee salmon observed in Webster Creek is unknown.

An unlikely explanation is that kokanee spawned either before mid September or after late November, and were missed by the SPU surveys. The early-run of kokanee salmon in Issaquah Creek spawn mid to late August (Berge and Higgins 2003), and if Webster Creek kokanee express this life history our surveys would miss them. Kokanee were not sighted in Webster Creek prior to late September in any year from 1997-2006. In September 2001, when a bridge was installed at the 10 Road, SPU staff were present at the site frequently through late August and early September preparing for bridge installation. Kokanee were not observed in Webster Creek until October 11, 2001 when the bridge was opened. On this date, 76 kokanee were observed at the bridge. Shortly after this date, a fuel spill from a large tank in the area may have contaminated Webster Creek. Because only one redd was documented in the stream during all of 2001, it is possible the fish left Webster Creek without spawning. Surveys from 2002-2004, when large numbers of kokanee were observed in Webster Creek, indicate that Walsh Lake kokanee are similar in timing to the middle-run Lake Washington kokanee in time of spawning (late October), which falls well within our survey period. Thus, it is doubtful that survey timing explains the low counts of kokanee prior to 2002.

Our surveys were not designed to document lake spawning that some portion of the population in Walsh Lake could express. Lake spawning is known in several kokanee populations (Taylor et al. 2000) and is an important life history alternative influencing overall population dynamics within a watershed. Although snorkeling surveys by SPU staff indicate that the substrate in Walsh Lake is primarily fines and not gravels preferred by kokanee, areas of groundwater upwelling could be present in the lake. Upwelling sites are chosen in some kokanee populations resulting in enhanced incubation success (Garrett et al. 1998). Because of the lack of gravel shoreline in Walsh Lake, it is doubtful that large numbers of kokanee spawn on the lake shore.

Alternatively, conditions in Walsh Lake were not monitored and a change in the fish community after 2001 may favor the survival of kokanee in the lake environment. A variety of community interactions could explain an increase in total fish numbers including reduced predation (e.g. of predator is rainbow trout), reduced competition for space or resources (e.g. of competitor is yellow perch), or other trophic interactions. Kokanee feed on zooplankton (Rieman and Bower 1981), and this food source could become more plentiful with a shift in fish species composition. In Lake Pend Oreille, Idaho, hatchery releases of age-0 kokanee correlated with yearly mean total zooplankton density as well as total mean zooplankton density during the time of release (Paragamian and Bowles 1995). As determined by Paragamian and Bowles, the timing of migration to lake rearing habitat influences survival of a cohort. Fish returning in the 2002 run likely were age-0 during 1998, and flow conditions and zooplankton densities in Walsh Lake might have been ideal in 1998, increasing survival of the cohort. Although this explanation is possible, only 4 redds were documented in Webster Creek during 1998, bringing into question the origin of the 2002 kokanee run.

Finally, some proportion of kokanee juveniles could rear in Walsh Lake and then undergo a migration to sea before returning to spawn. Sockeye salmon exhibit a wide variety of life history patterns and these could change within a population through time. If fewer juveniles migrated downstream, but instead remained in Walsh Lake to rear, we might expect to see larger spawning counts like in 2002-2004, than if a greater proportion of the population outmigrated. As discussed above, food resources may provide one mechanism to explain this life history choice. A substantial constriction point in Walsh Diversion Ditch downstream of the CRMW administrative boundary limits passage of sockeye that might be navigating back to Webster Creek (Bill Priest, King County, personal communication). The low numbers of spawning kokanee observed in 1997-2001 might reflect cohorts where a greater proportion of individuals migrated to sea and thus did not return to spawn in Webster Creek.

Even though Webster Creek kokanee share run timing with middle-run kokanee in the Lake Washington Basin, they express slightly different morphological characteristics. A sample of 65 middle-run kokanee showed that mean fork length was 287 millimeters. Webster Creek kokanee with an average fork length of 329 millimeters, were closer in size to early-run Lake Washington kokanee that had a mean fork length of 332 millimeters. Webster Creek kokanee were much different than late-run kokanee that had a mean fork length of 453 millimeters (Berge and Higgins 2003). Other morphological traits like color vary greatly between kokanee populations.

By replacing a fish blocking culvert at the 10 Road an additional 1,650 feet of habitat opened to spawning kokanee salmon (photos in Appendix 4). This improvement almost doubled the linear stream length fish accessed and used for spawning, and in 2002, 20 percent of kokanee redds were located upstream of the new bridge. In 2003 this number increased to 45 percent of all redd and in 2004, 43 percent of all redds were located upstream of the bridge. These data demonstrate the important and immediate effect that fixing fish blockages has on a population. Kokanee now spawn over a greater linear distance and have increased redd sites to select from. By spreading redds over a greater area, the risk of scour may be reduced. The Taylor Siphon currently blocks fish at 3,800 feet upstream of Walsh Lake (Appendix 4). When this barrier is corrected, fish will likely move upstream to spawn in additional stream habitat until a gradient break upstream of the Kerriston Road.

Further genetic analysis should be conducted on the DNA samples collected in 2002 to determine the relationship of Webster Creek kokanee to the rest of the Lake Washington Basin. The population should be followed for several more years in order to document fish passage over the Taylor Siphon barrier just downstream of the Kerriston Road. Understanding how the opening of new habitat affects the kokanee population when the generation from 2002 returns will be informative. It is unknown if providing additional spawning habitat will correlate to increases in population numbers, or if food resources in Walsh Lake may limit the population. Finally, these data should be coordinated with King County's ongoing effort to better understand and conserve kokanee populations throughout the Lake Washington Basin.

5.0 References

Berge, Hans B. and Kollin Higgins. 2003. The current status of kokanee in the greater Lake Washington Watershed. King County Report.

Cupp, C. Edward and JoAnn Metzler. 1995. Cedar River Watershed Assessment—stream channel and fish habitat assessment. Prepared by Foster Wheeler Environmental Corporation for Seattle Public Utilities.

Connor, Edward, and Bruce Kvam. 2000. Historic and current status of kokanee in the Lake Washington Basin (Draft). Prepared by R2 Resource Consultants, Inc., for King County Department of Natural Resources.

Garrett, James W., David H. Bennett, Frank O. Frost, and Russell Thurow. 1998. Enhanced incubation success for kokanee spawning in groundwater upwelling sites in a small Idaho stream. North American Journal of Fisheries Management 18(4): 925-930.

Groot, C. and L. Margolis. 1991. Pacific Salmon Life Histories. UBC Press. Vancouver, B.C.

Paragamian, Vaughn L. and Edward C. Bowles. 1995. Factors affecting survival of kokanees stocked in Lake Pend Oreille, Idaho. North American Journal of Fisheries Management 15: 208-219.

Priest, Bill and Hans S. Berge. 2002. 2001 Spawning Surveys in selected tributaries of the Cedar River, Washington. King County Report.

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

Seattle Public Utilities. 1997. Walsh Lake Report.

Seattle Times. November 18, 2003. "Sims Says kokanee run extinct." By Keith Ervin and Craig Welch.

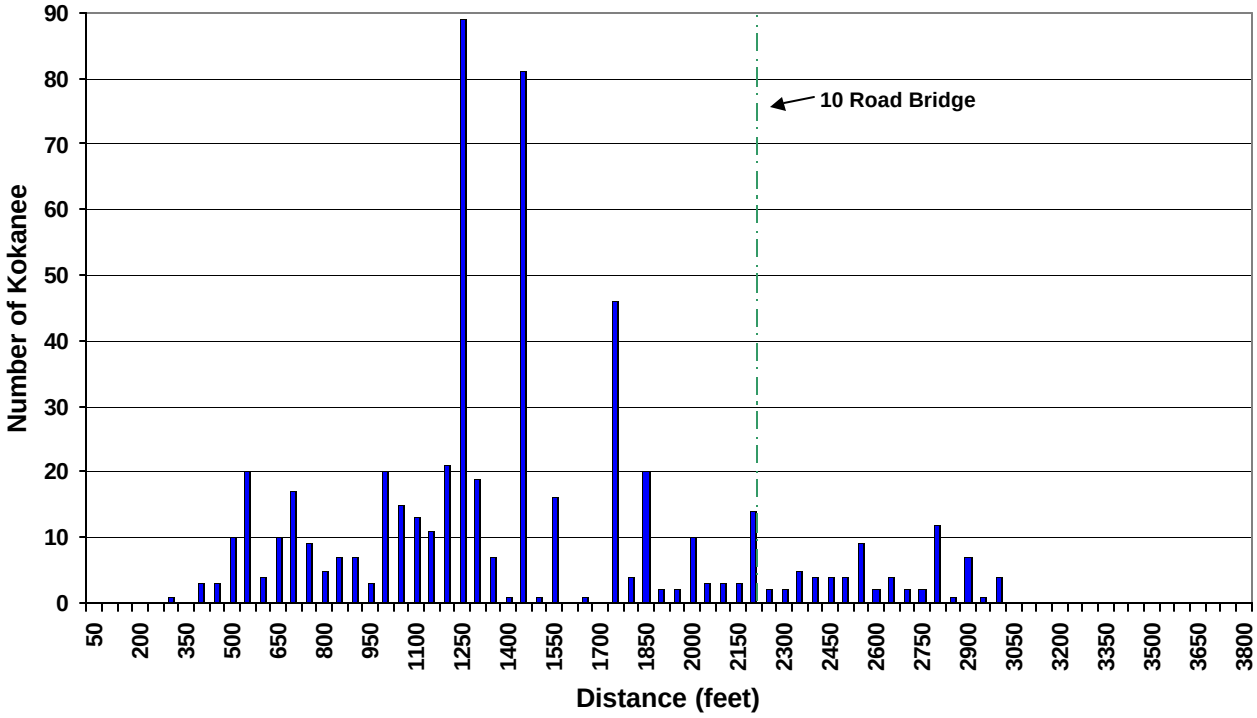
Spies, I. B. 2002. The origin of sockeye salmon (Oncorhynchus nerka) in the Kake Washington Watershed, Washington State: a reappraisal based on microsatellite data. Master's Thesis, School of Fisheries and Aquatic Sciences, University of Washington, Seattle.

Taylor, Eric B., A. Kuiper, P.M. Troffe, D.J. Hoysak, and S. Pollard. Variation in developmental biology and microsatellite DNA in reproductive ecotypes of kokanee, *Oncorhynchus nerka*: Implications for declining populations in a large British Columbia lake. Conservation Genetics 1(3): 231-249.

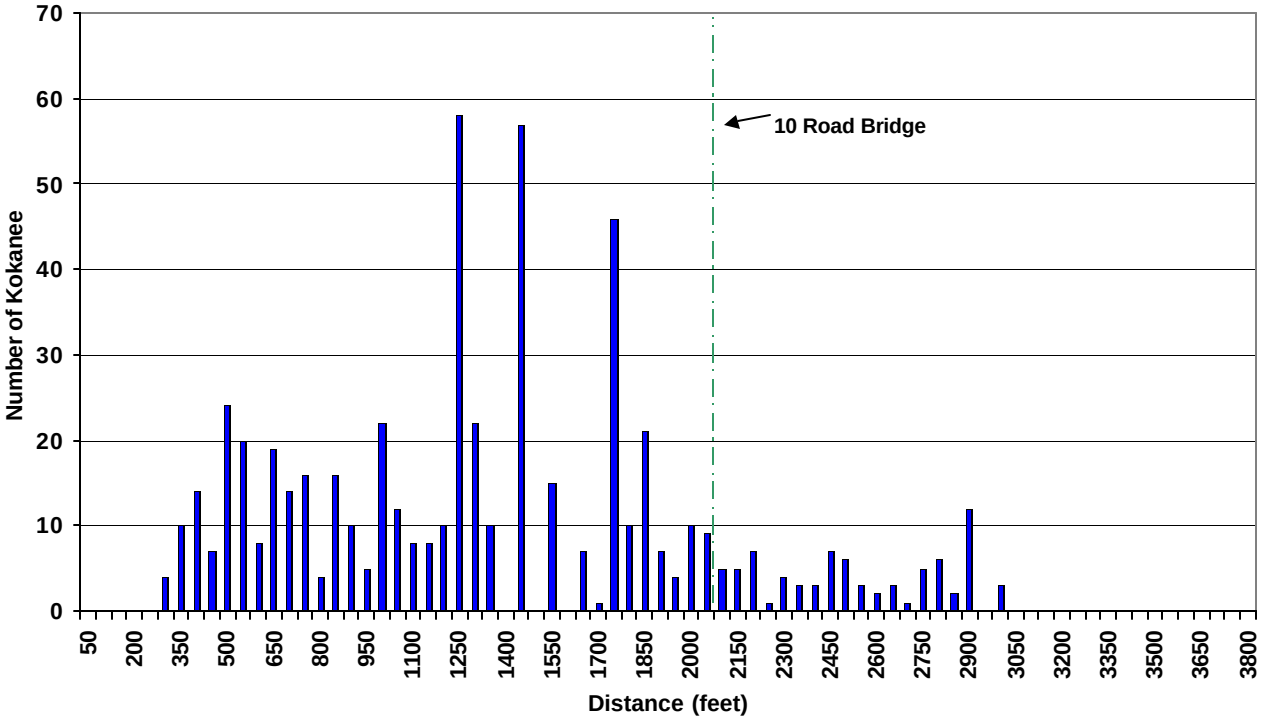
Young, Sewall F., Mark R. Downen, and James B. Shaklee. Microsatellite DNA data indicate distinct native populations of kokanee, *Oncorhynchus nerka,* persist in the Lake Sammamish Basin, Washington. Environmental Biology of Fishes 69: 63-79.

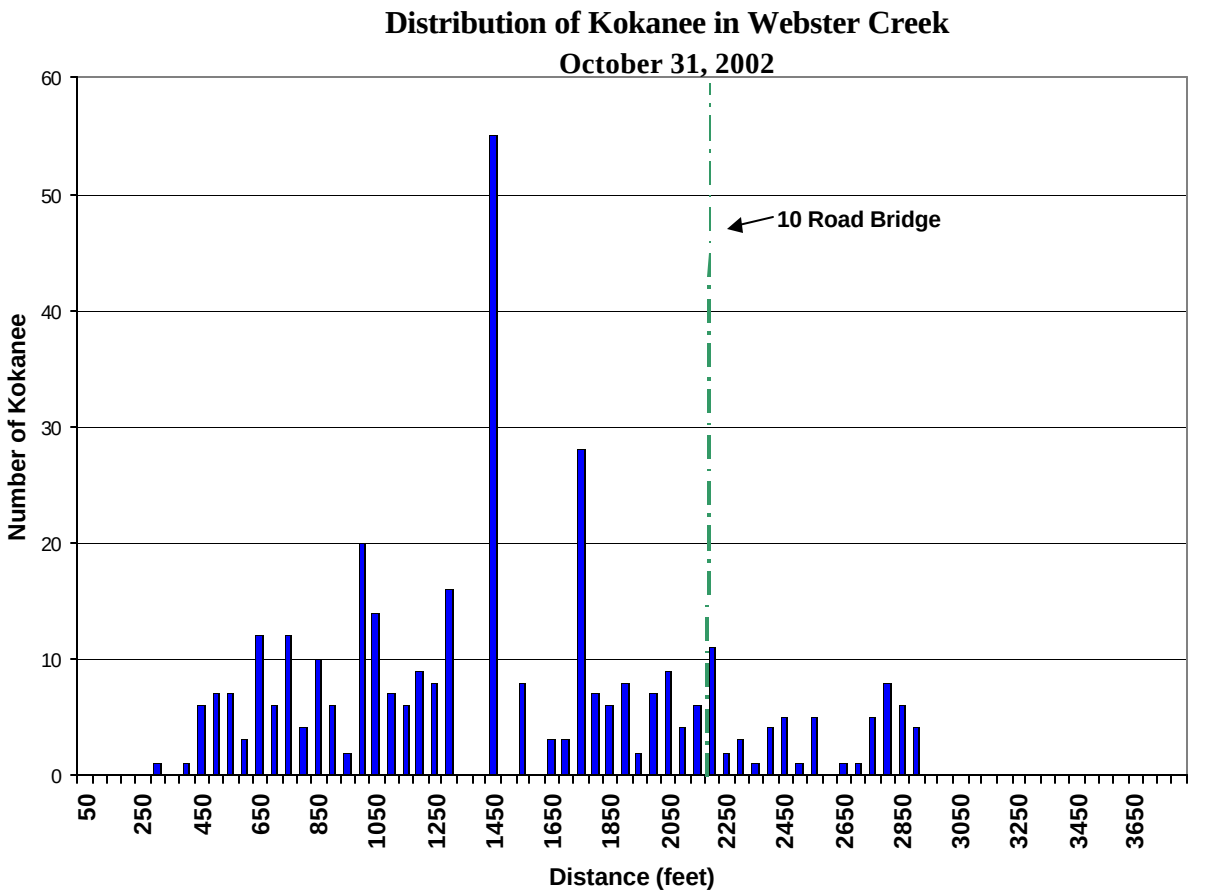
Appendix 1. Distribution of Kokanee in Webster Creek during spawning season 2002.

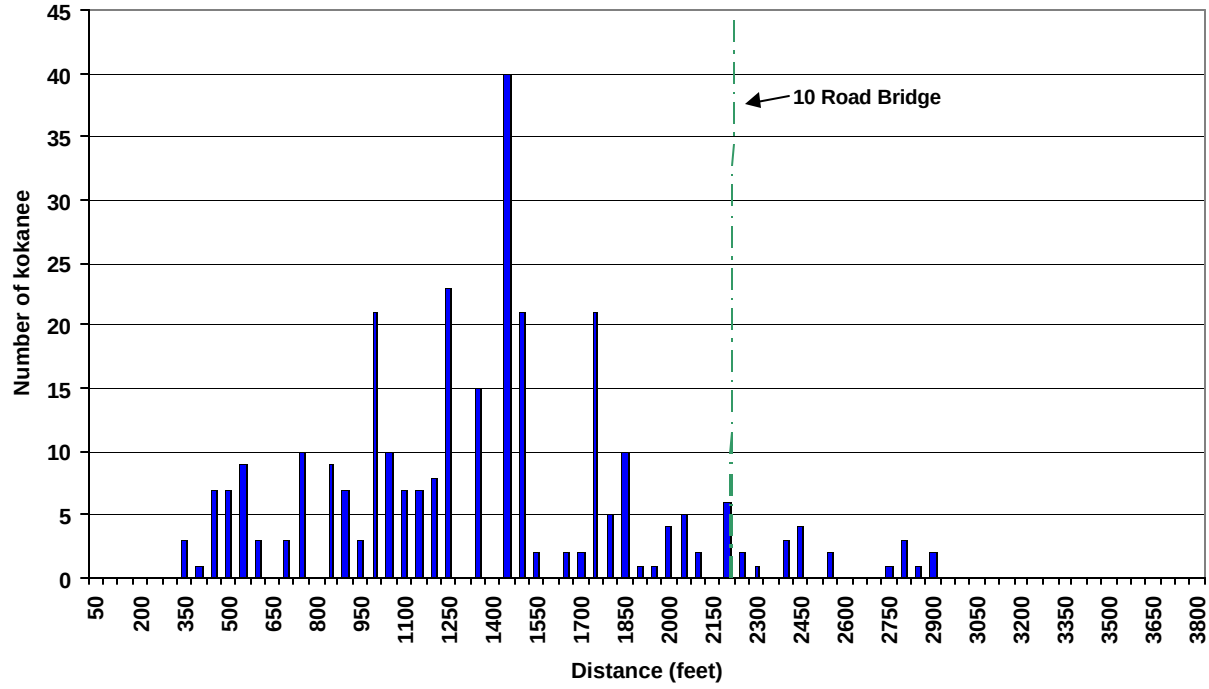
Distribution of Kokanee in Webster Creek
October 26, 2002



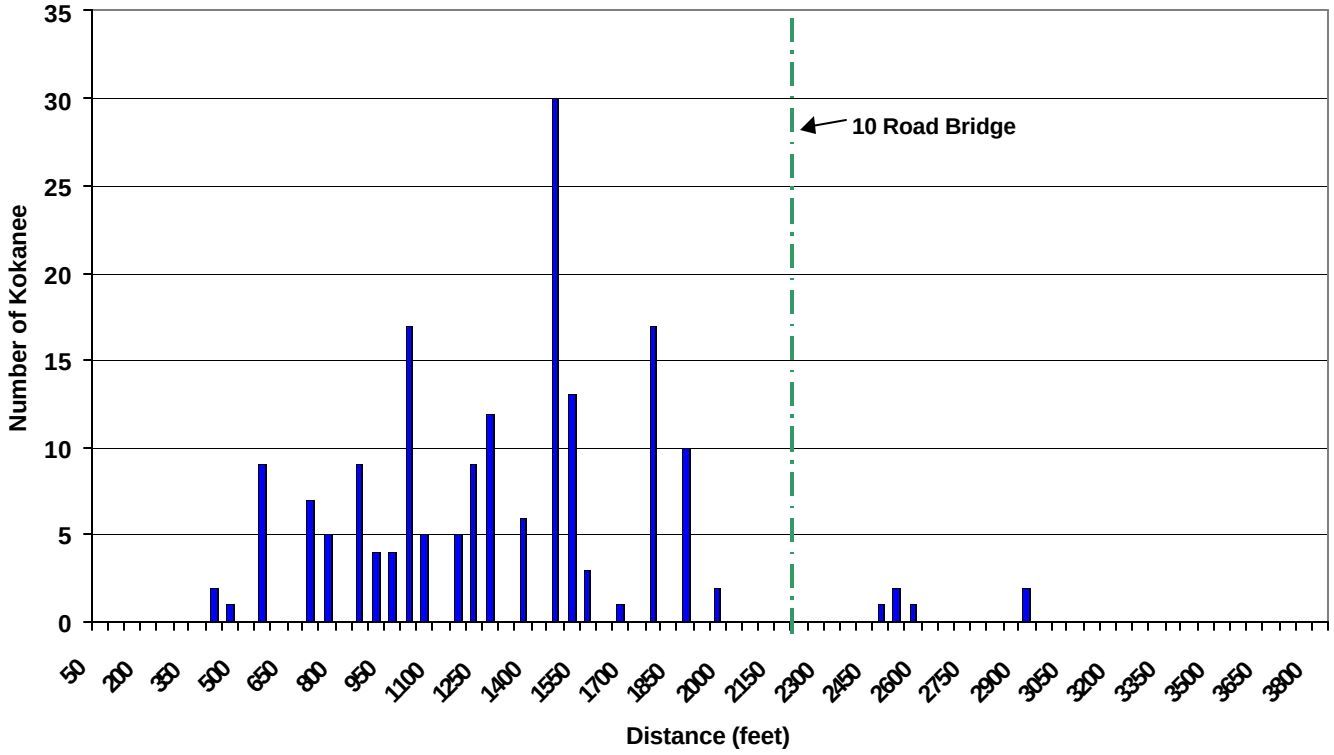
Distribution of Kokanee in Webster Creek
October 27, 2002



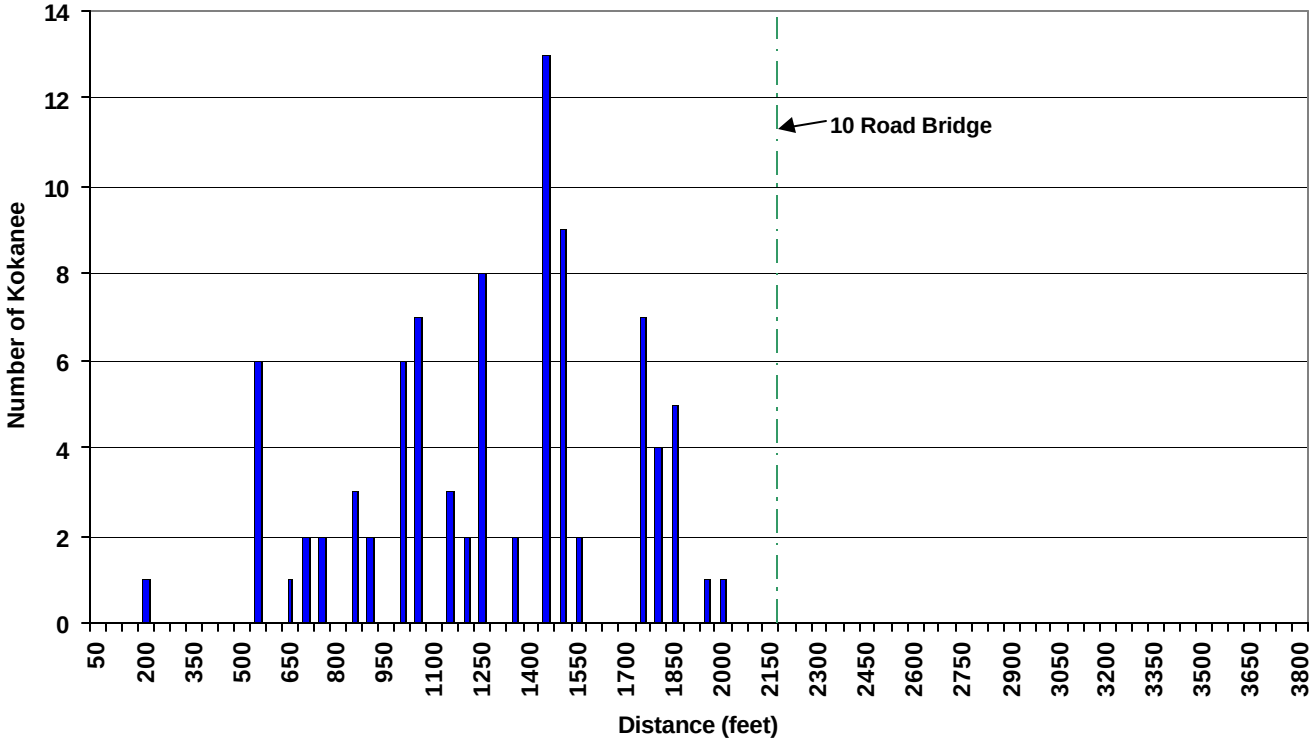

Distribution of Kokanee in Webster Creek
October 31, 2002
Number of Kokanee
Distance (feet)
10 Road Bridge
0
10
20
30
40
50
60
50
250
450
650
850
1050
1250
1450
1650
1850
2050
2250
2450
2650
2850
3050
3250
3450
3650


Distribution of Kokanee in Webster Creek
November 4, 2002
Number of kokanee
Distance (feet)
10 Road Bridge
0
5
10
15
20
25
30
35
40
45
50
200
350
500
650
800
950
1100
1250
1400
1550
1700
1850
2000
2150
2300
2450
2600
2750
2900
3050
3200
3350
3500
3650
3800

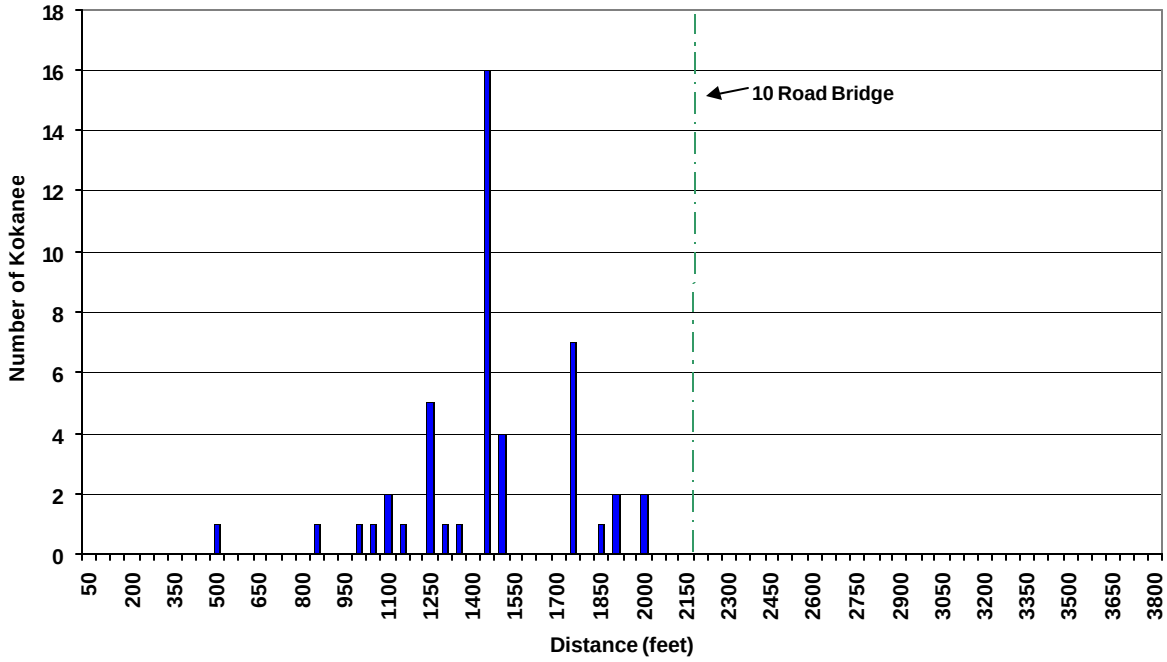
Distribution of Kokanee in Webster Creek
November 8, 2002



Distribution of Kokanee in Webster Creek
November 12, 2002

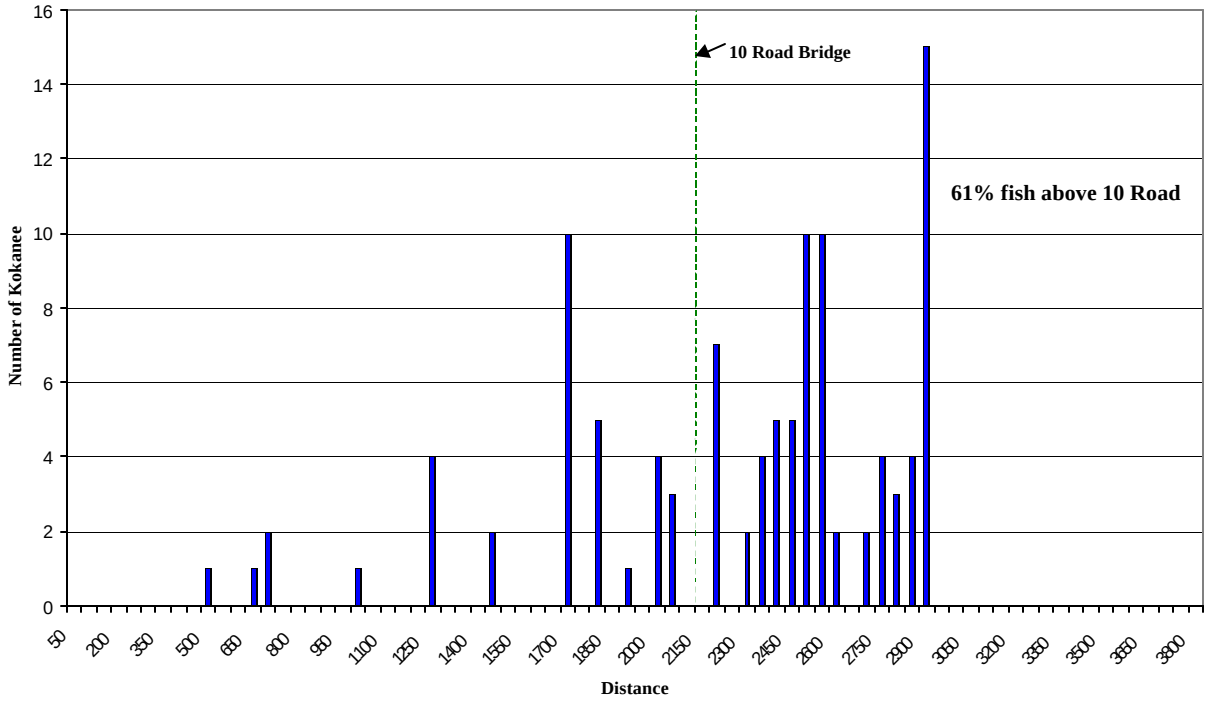


Distribution of Kokanee in Webster Creek
November 15, 2002

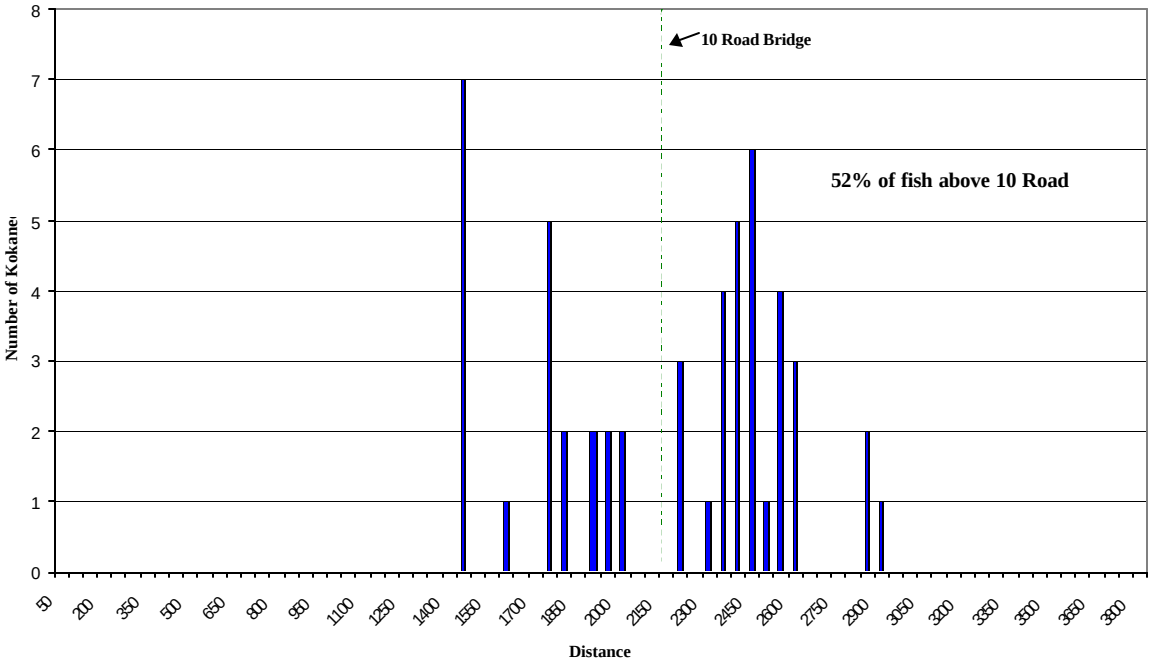


Appendix 2. Kokanee Distribution in Webster Creek during 2003 Spawning Surveys.

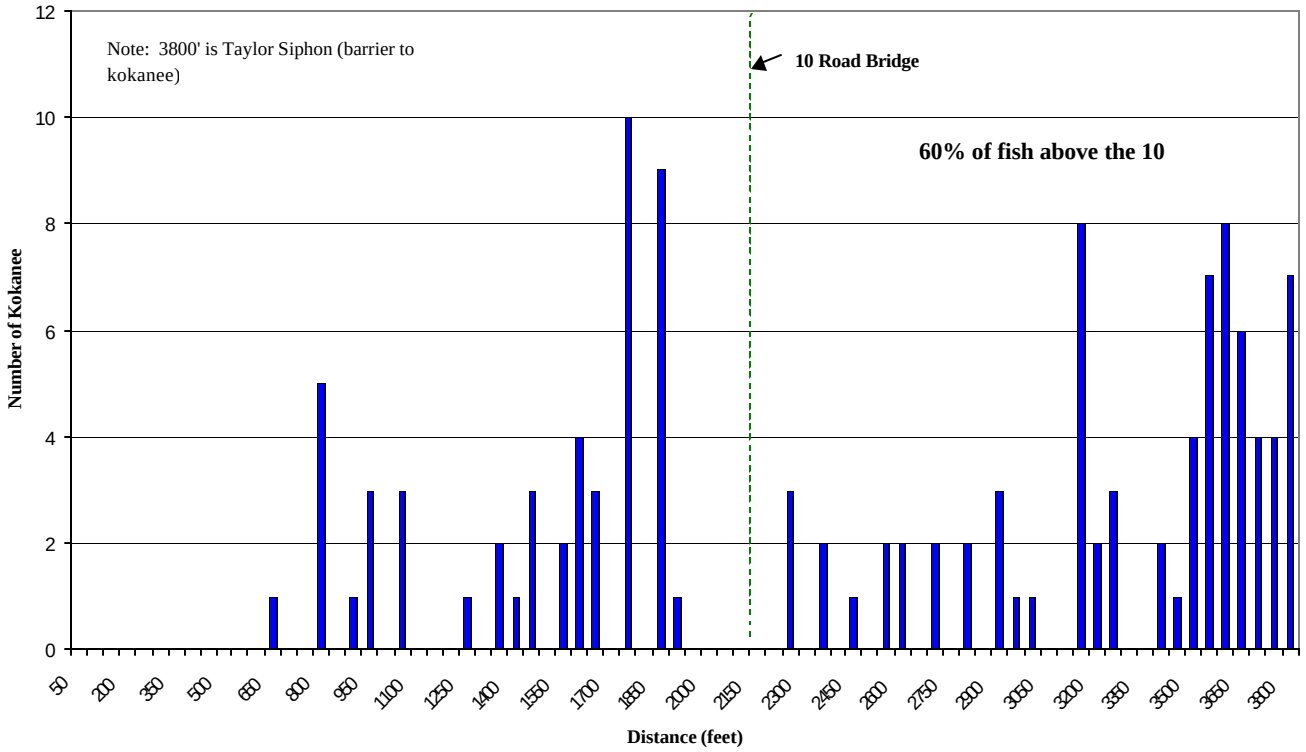
Distribution of Kokanee in Webster Creek
October 14, 2003



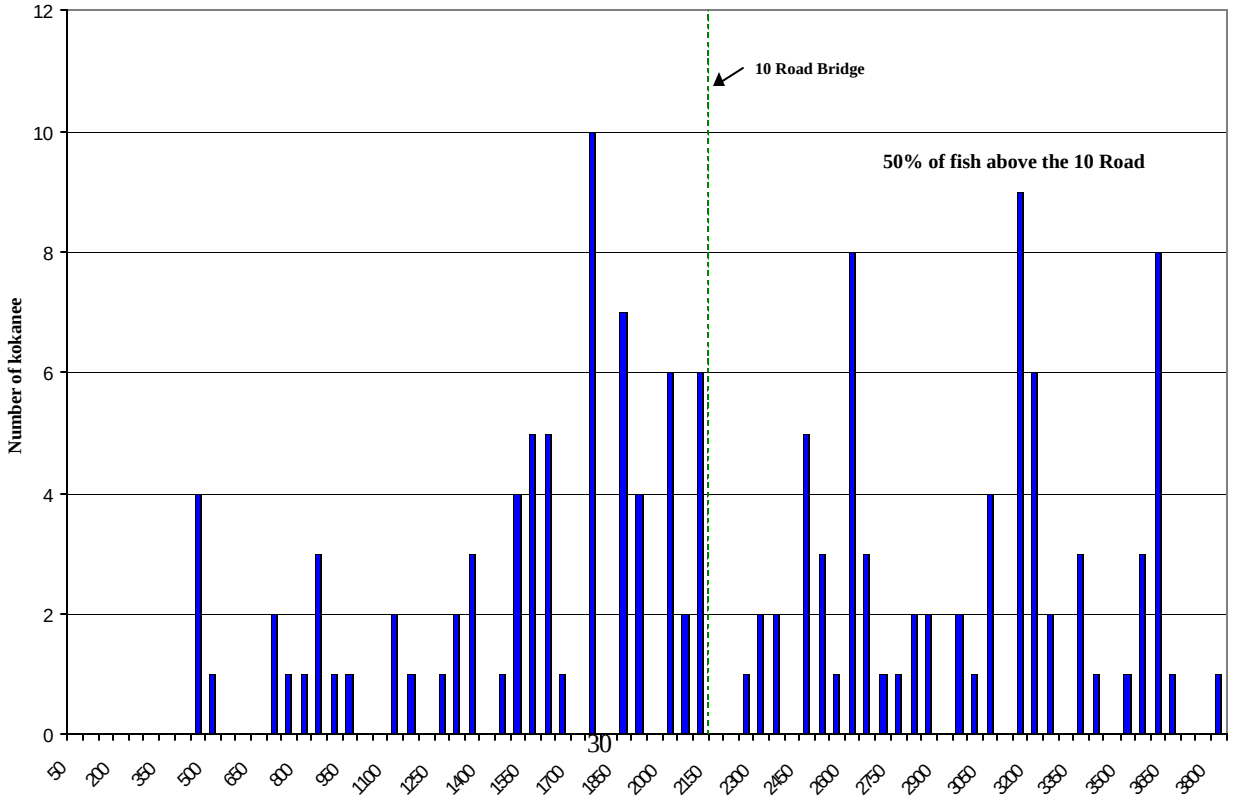
Distribution of Kokanee in Webster Creek
October 16, 2003



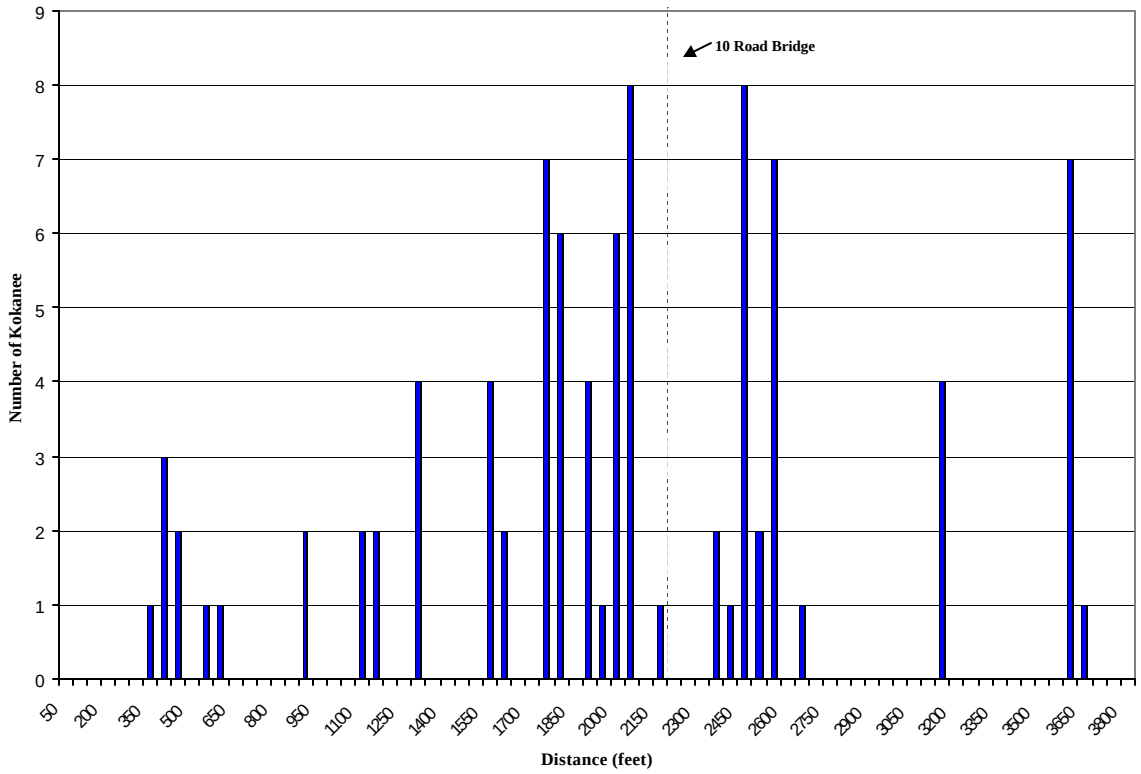
Distribution of Kokanee in Webster Creek
October 23, 2003



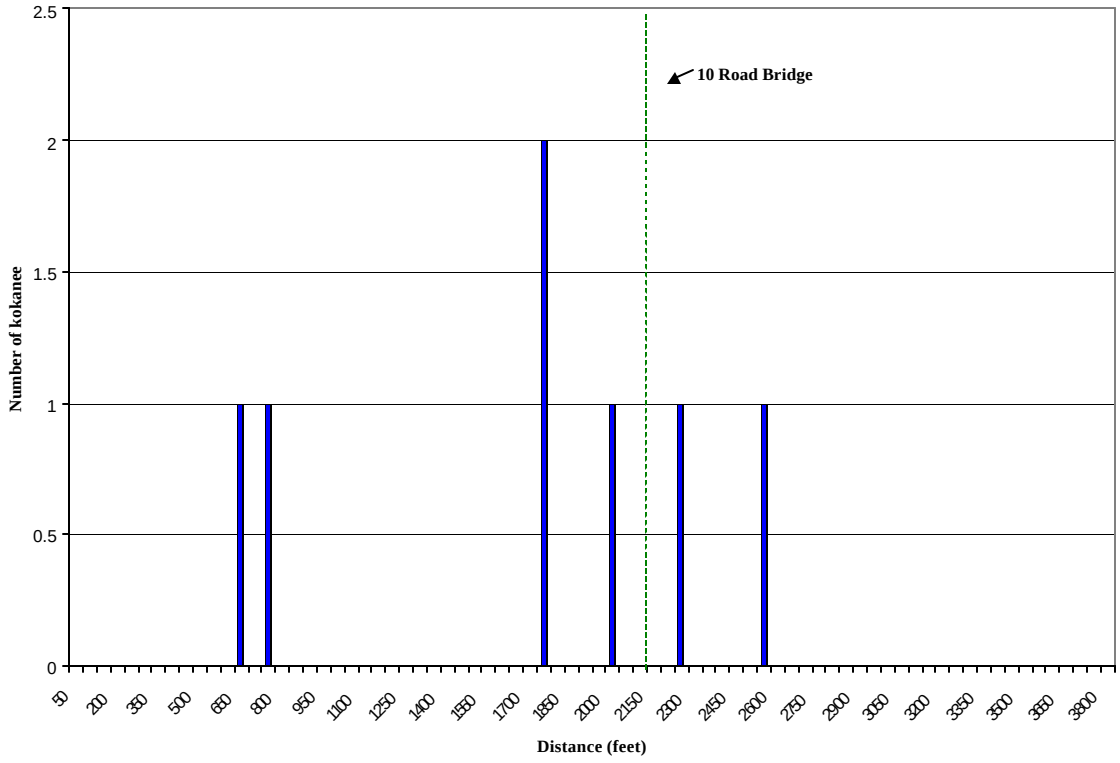
Kokanee Distribution in Webster Creek
October 28, 2003



Distribution of Kokanee in Webster Creek
October 31, 2003

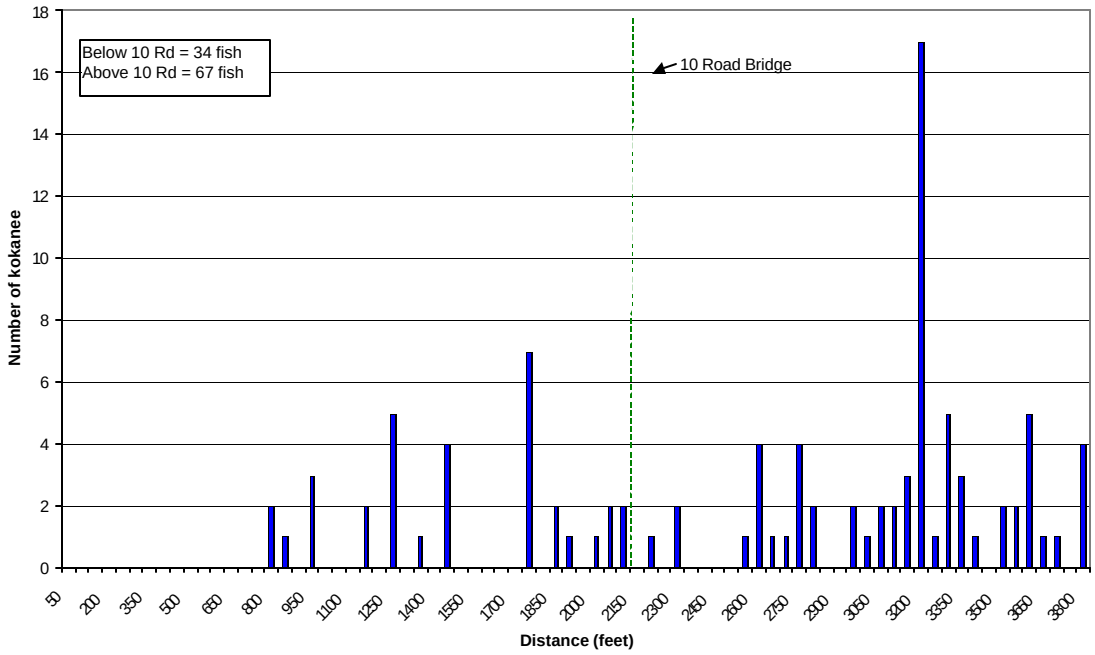


Distribution of Kokanee in Webster Creek
November 4, 2003

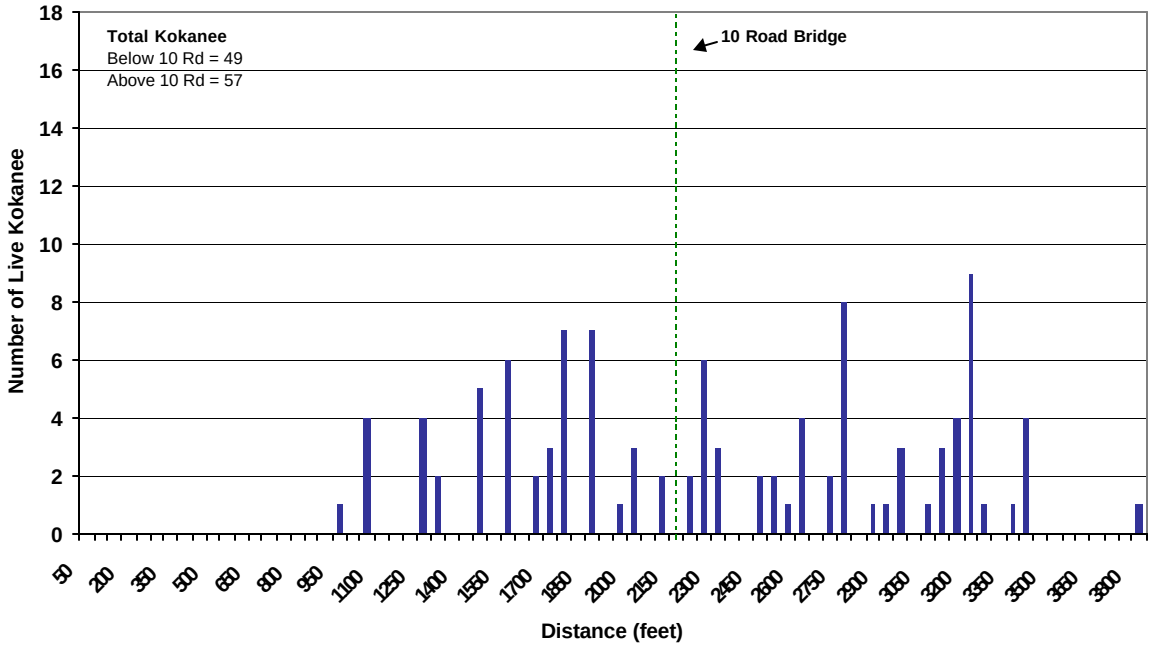


Appendix 3. Distribution of Kokanee in Webster Creek during 2004 Spawning Season.

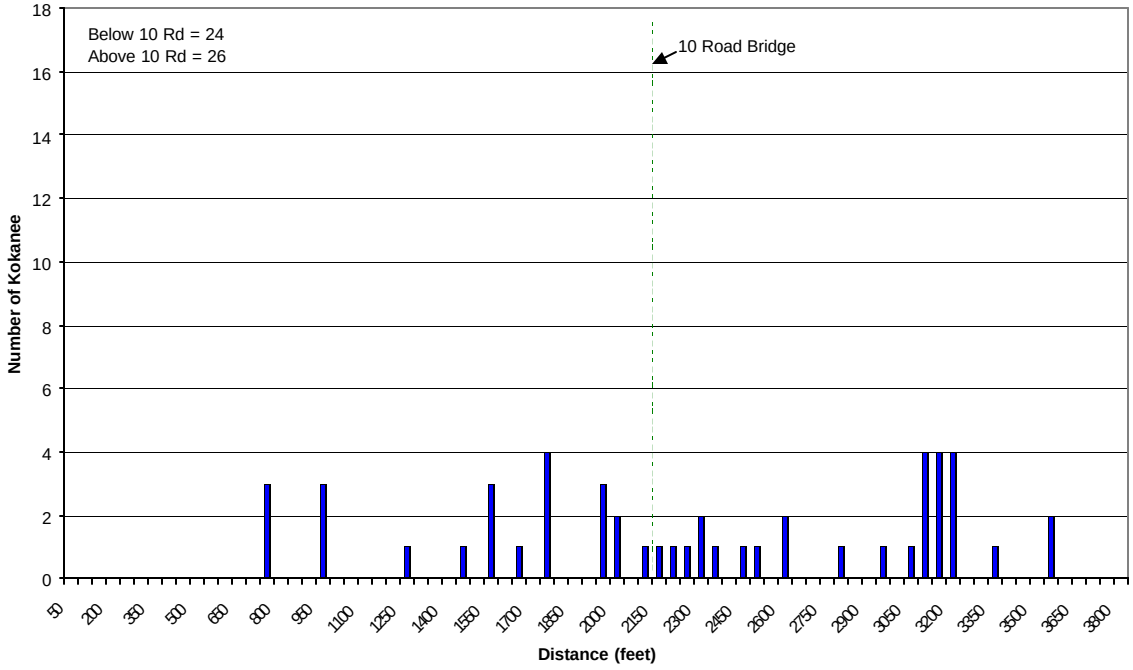
Kokanee Distribution in Webster Creek (10-11-04)



Kokanee Distribution in Webster Creek
October 15, 2004



Kokanee Distribution in Webster Creek (10-18-04)



Appendix 4. Photos

Webster Creek at 10 Road prior to bridge installation.

Webster Creek at 10 Road after bridge installation.

Habitat used by kokanee for spawning in Webster Creek.

Habitat used by kokanee for spawning in Webster Creek.

Female kokanee defending redd site in Webster Creek, 2003.

Pair of kokanee at redd site in Webster Creek.

Taylor Sipon located 3,800 feet upstream of Walsh Lake is a barrier to kokanee. SPU is planning a project to eliminate this fish barrier (FY 2005).