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# EXECUTIVE SUMMARY

In the early 1990s, King County Surface Water Management Division (now King County Water and Land Resources Division (WLRD)) began to investigate the apparent decline of kokanee in the Lake Sammamish basin. In 1992, WLRD instituted a monitoring program to document the abundance and spatial distribution of spawning kokanee in tributaries of Lake Sammamish, with particular emphasis on the early-run race inhabiting Issaquah Creek. Since that time, data collection has expanded to include spawning abundance and distribution information of all three races of kokanee, genetic tissue collection, and information about the size at maturity and sex ratios of kokanee throughout the basin. These data were collected by WLRD and Washington Department of Fish and Wildlife (WDFW) staff, as well as private citizens interested in the natural resources of the greater Lake Washington Watershed. From these efforts, we have learned a great deal about native kokanee in the basin.

First, we have learned that there are three distinct kokanee stocks in the basin that are spatially and temporally separated from one another during spawning. Early-run kokanee spawn from August to early September in Issaquah Creek and have an average size of 12.9 inches (332 mm). Middle-run kokanee spawn in the larger tributaries to the Sammamish River from late September through November and have the smallest average size at 11.2 inches (287 mm). Late-run kokanee spawn in tributaries to Lake Sammamish from late November to early January and have an average length of 17.7 inches (449 mm).

Early-run kokanee found in Issaquah Creek are known to be of native origin. Until 2000, it was unknown if the other two stocks were native or introduced. In 2001, the WDFW Genetics Laboratory analyzed samples collected in 2000, and determined that late-run kokanee are genetically distinct from other known kokanee and sockeye stocks in the basin and several of the surrounding basins, suggesting they are also of native origin. Not enough samples have been collected of the middle-run race to make the determination of their origin, but preliminary data suggests they are closely related to Bear Creek sockeye, which are of unknown origin.

Spawning abundance of early-run kokanee is dismal. In the last three years of surveys, only two live fish have been observed in Issaquah Creek, suggesting that these fish are likely to be depressed to the point of being functionally extinct. Middle-run kokanee are the least understood and there are many questions that need to be addressed regarding their status, including whether or not they are residualized sockeye salmon and not kokanee at all. The late-run kokanee appear to have consistent population numbers, although little is known about the stability of this population over time, or the risks of extinction due to isolation in increasingly developed drainages.

We recommend the following near-term actions to better understand the health and status of kokanee in the Sammamish River and Lake Sammamish basins:

1. Continue spawner escapement surveys throughout the basin, with more effort placed on capturing the start and end points for each stream
2. Do further genetic analysis of all races of kokanee and compare them to other races in Washington
3. Collect age at maturity and sex ratio data for all three races of kokanee through carcass sampling and live capture
4. Conduct surveys to assess spawning habitat availability in the tributaries of Lake Sammamish and quantify the extent of redd superimposition
5. Conduct surveys of the Lake Sammamish shorelines to quantify extent of lake spawning by kokanee
6. Collect data on the Lake Sammamish food web to understand whether or not predation and food availability are responsible for the decline in early-run kokanee
7. Determine if middle-run kokanee are rearing in Lake Sammamish or in Lake Washington
8. Coordinate data collection efforts with the Sammamish Kokanee Technical Committee

## INTRODUCTION

During the 1980s, the Washington Department of Fish and Wildlife (WDFW) became concerned over a decline of kokanee (*Oncorhynchus nerka*) in the Lake Sammamish Basin, particularly in Issaquah Creek (Pfeifer 1985). The continued decline of Issaquah Creek early-run kokanee throughout the late 1980s and early 1990s prompted the King County Surface Water Management Division (now King County Water and Land Resources Division (WLRD)) to institute a sampling program in 1992 to document the status and abundance of kokanee in Water Resource Inventory Area (WRIA) 8.

Since 1992, WLRD has monitored the status of both early and late-run kokanee in the Sammamish Basin. During this time period, data have been collected by staff representing the WDFW and WLRD, and by citizens who volunteer their time to collect valuable data on streams in their neighborhoods. Data collected in these efforts since 1998 are reported in this document. Additional information and data collected from 1992 through 1997 are available in the 1994, 1995, 1996 and 1997 Kokanee Status Reports (Ostergaard et al. 1995; Ostergaard 1996, 1998a, 1998c).

The purpose of this report is to provide information on WLRD's efforts to better understand the distribution and status of kokanee in the Lake Washington/Sammamish Watershed, and provide information to support near term actions to aid in the recovery of native kokanee.

## BACKGROUND

Two forms of *Oncorhynchus nerka* are native to the Lake Washington/Sammamish watershed: kokanee and sockeye salmon (Hendry 1995). Sockeye salmon generally emerge from gravels in riverine environments, migrate downstream to a lake, rear in the lake for one year, migrate to the Pacific Ocean for another two to three years, and then return to the freshwater systems to spawn. Kokanee originated as sockeye salmon that did not migrate to the ocean, and spend their entire life in freshwater environments (Meehan and Bjornn 1991). Since freshwater lake environments are generally less productive than marine systems, kokanee typically mature at a smaller size than anadromous sockeye, and produce fewer gametes (Foerster 1968).

Kokanee are normally found in land-locked lakes, although Lake Washington and Lake Sammamish are not land-locked (Gustafson et al. 1997). Kokanee are thought to have originated from ancestral sockeye salmon, which were restricted from accessing the marine environment on a regular basis. Because gene flow is restricted, kokanee are often genetically distinct from sympatric (occupying the same geographic areas) sockeye salmon. Kokanee are also distinct from residual (non-anadromous) sockeye salmon since they are derived from non-anadromous parents, while residual sockeye are derived from anadromous parents. Residualized sockeye salmon are more subdued in spawning color than kokanee and sockeye and generally produce larger gametes than kokanee (Ricker 1938; Groot and Margolis 1991; Quinn et al. 1998). For the purposes of this paper the following definitions are used to describe different forms of *Oncorhynchus nerka* in the Lake Washington/Sammamish watershed. See Appendix 1 for photographs of the three forms of *O. nerka* described below.

***Anadromous sockeye**: O. nerka* originating from sea-going parents that spend approximately 1-2 years in freshwater before migrating to the ocean. Sex ratios are typically near 1:1. Spawning coloration of both sexes generally consists of a red body with a green head with few or no spots, although many variations exist. Secondary sexual characteristics of males include a dorsal hump and large kype (hooked jaw). Typical age of maturity is 4 years old, with spawning occurring in both lentic (lake) and lotic (stream) habitats.

***Residual sockeye:*** *O. nerka* originating from at least one sea-going parent that spend their entire life in freshwater. Sex ratios are typically skewed with a strong bias toward males. Spawning coloration is usually a dull olive-gray, with a purple band parallel to the lateral line, with small spots covering the dorsal surface and both lobes of the caudal fin. Secondary sexual characteristics of males are muted, but similar to sockeye and kokanee. Typical age of maturity is 3 years, with known spawning occurring in lotic systems.

***Kokanee:*** *O. nerka* originating from non-anadromous parents. Sex ratios are typically 1:1. Spawning coloration of both sexes is similar to anadromous sockeye, with the addition of small spots across the dorsal surface, although some variation occurs. Secondary sexual characteristics of males include a dorsal hump and large kype. The average age of maturity for kokanee is 4 years, with known spawning occurring in both lentic and lotic environments.

Across their range, kokanee spawn from August through November, although in Lake Sammamish tributaries they often spawn into December and even January. Egg incubation periods depend upon temperature of the water flowing through the egg pocket of the redd, but are generally between 80 and 140 days (Foerster 1968). Newly emerged kokanee fry move to a lake in April and May, and remain in the lake until they reach sexual maturity (Meehan and Bjornn 1991). The age of maturity in kokanee is generally four or even five years (Rieman and Bowler 1980). Size at maturity varies among populations with age, but average from 180 mm to 300 mm (7 inches to 11.7 inches) (Groot and Margolis 1991). Kokanee are planktivorous with most of their diet being made up of small organisms such as copepods and cladocerans (Smith 1921; Foerster 1968). Kokanee normally spawn in small gravels ranging in size from 13 to 19 mm (Averett and Espinosa 1968), and like most anadromous salmonids, kokanee are semelparous, with death occurring after spawning.

### LAKE WASHINGTON/SAMMAMISH WATERSHED

Currently, in the Sammamish River and Lake Sammamish drainage, kokanee can be separated into three races based on spawn timing and location. Early-run kokanee spawn during late summer (August through September) in Issaquah Creek. Middle-run kokanee spawn in late September through November, and are primarily found in the larger Sammamish River tributaries. A third type, late-run kokanee, spawn in the late fall (October through January) in tributaries of Lake Sammamish (King County 2000).

Historically, kokanee were distributed throughout the entire Lake Washington/Sammamish Watershed (Bean 1891; Garlick 1946). Since the early 1900s, kokanee populations have severely declined in abundance and distribution (King County 2000). Once distributed throughout both the Lake Washington and Sammamish drainages (Bean 1891), Gustafson et al. (1997) reported that kokanee are currently limited to the Cedar River (Walsh Lake drainage) and Lake Sammamish drainages, and the Sammamish River and its tributaries (Figure 1). In 2002 and 2003, resident forms of *O. nerka* (up to 250 mm) were found in Lake Washington during trawl surveys conducted by the University of Washington (Michael Mazur, University of Washington, personal communication). Data from these specimens is not available at this time.

Prior to 1915, anadromous salmonids had access to the Lake Washington basin via the basin's outlet at the Black River in South Lake Washington. It is likely that the Black River was not a permanent connection in very low water years and suggesting that kokanee in Lake Washington and Lake Sammamish originated from a population of sockeye that either did not have access to the Puget Sound, or exploited an untapped freshwater strategy. Regardless, a permanent connection was completed between Lake Washington and the Puget Sound in 1917 that allows direct access for anadromous fishes leaving Lake Washington (Chrzastowski 1983). There have been many efforts since that time to transplant exotic sockeye salmon throughout the system (Hendry 1995). Several transplants have been successful, which makes understanding the population structure of native kokanee and sockeye very difficult.

Fletcher (1973) assumed that the kokanee present in Bear Creek in the early 1970s were no longer native due to introgression with transplants of Lake Whatcom kokanee, and the native form of *O. nerka* to be extinct. In the 1980s, the Washington Department of Wildlife (now Washington Department of Fish and Wildlife (WDFW)) surveyed kokanee in the Lake Washington Basin, and found "very low catch rates in Lake Sammamish, and practically no fishery for kokanee in Lake Washington" (Pfeifer 1992). Of particular concern was the severe decline of early-run kokanee in Issaquah Creek (Pfeifer 1995). In the 1970s, it was thought that the annual escapement of early-run kokanee in Issaquah Creek was between one and three thousand fish during the early 1970s (Berggren 1974), and by the 1980s this number would vary from 10 to 1000 (Pfeifer 1992). Within the last five years, only six early-run kokanee have been seen in Issaquah Creek, with no early-run kokanee seen in 2001 and 2002.

Figure 1. Historic and Current Kokanee Distribution in the Lake Washington/Sammamish Watershed

### EARLY-RUN/ISSAQUAH CREEK

The early-run kokanee in the basin are thought to be native, and have been documented by tribal historians since the early 1900s (Hendry 1995; Pfeifer 1995; Ostergaard et al. 1995; King County 2000). Early-run kokanee are consistently found only in Issaquah Creek, although a few individuals have been observed in other tributaries of Lake Sammamish (Ostergaard 1998a). Pfeifer (1980) found that early-run kokanee in Issaquah Creek began spawning during the first week of August, with the peak spawn period during the last week of August, and the end of spawning occurring during the second week of September. Early-run kokanee in Lake Sammamish tributaries have been recognized as genetically distinct based on electrophoretic, allozymes, and microsattelite DNA data (Hendry et al. 1996; Seeb and Wishard 1997; Bentzen and Spies 2000).

### MIDDLE-RUN/SAMMAMISH RIVER TRIBUTARIES AND WALSH LAKE

All of the major tributaries of the Sammamish River contained kokanee as recently as 1946 (Garlick 1946). In Swamp Creek for example, Schultz and Students (1935) observed the habits of adult kokanee from August to December 1933 and found most spawning occurred in October and November, an overlap in run timing that could include both middle and late-run kokanee.

In the 1940s, the kokanee in Bear Creek were so prolific that they were considered to be the most important run of kokanee in the entire Lake Washington Basin, with a run timing from late September through early December (USFWS 1951). As many as 14 million eggs were mined from Bear Creek during the 1940s (USFWS 1951). By the early 1970s, the Bear Creek kokanee population was considered to be extinct (Fletcher 1973). The remaining kokanee were thought to be derived from Lake Whatcom fish, which were extensively planted in this stream beginning in the 1930s (King County 2000).

Middle-run kokanee are also present in Walsh Lake, which flows into the Cedar River via the Walsh Lake Diversion stream in Seattle's Cedar River Watershed (SPU 1998). In Webster Creek, a tributary to Walsh Lake, Seattle Public Utilities (SPU) has captured fish in gillnets, enumerated spawning kokanee in foot surveys, and collected DNA samples since 1997. Fish captured in gillnets have varied in size from 8 to 17 inches (200 to 400 mm). Very little is known about this population; the spawn timing seems to be the first three weeks in October, which corresponds with middle-run kokanee in the larger Lake Washington basin.

Prior to 1977, kokanee from Lake Whatcom were planted in the Lake Washington system (Seeb and Wishard 1977). It is likely that genetic and trophic interactions between Lake Whatcom origin fish and the native kokanee of the Lake Washington Basin have had an effect on native kokanee stocks. These interactions may be responsible for a "middle-run" race of kokanee observed in portions of the basin. Previous reports have assumed that the middle and late-runs of kokanee were of Lake Whatcom origin, but a recent report by WDFW suggests that the middle-run race of kokanee may actually be residualized sockeye salmon (Young et al 2001).

### LATE-RUN/LAKE SAMMAMISH TRIBUTARIES

An indigenous late-run of kokanee spawning in October and November was abundant in most of the tributaries to Lake Washington and Lake Sammamish around 1900 (Evermann and Meek 1898; Gustafson et al. 1997). Approximately 35 million kokanee fry were introduced into Lake Sammamish from Lake Whatcom by WDFW, with almost 3.5 million introduced between 1976 and 1979 alone (Pfeifer 1995). Since the introduced kokanee have a similar run timing to the native late-run kokanee of the basin, it had been presumed that the fitness of the native kokanee has been reduced by intraspecific competition or through genetic saturation. Recent work by the WDFW and WLRD has indicated that late-run kokanee are distinct, and not of Lake Whatcom origin (Young et al. 2001). Current spawning of late-run kokanee begins in October and continues into January, with each tributary stream having a slightly different peak and end date for spawning.

## KING COUNTY SURVEY BACKGROUND

In the early 1990s, WLRD staff and volunteers began to systematically sample the Lake Sammamish Basin for spawning kokanee as part of the East Lake Sammamish Basin and Nonpoint Action Plan (Ostergaard et al. 1995). These surveys provided evidence that the population of Issaquah Creek early-run kokanee was less than 100 individual spawners and that the total number of spawning late-run kokanee in the Lake Sammamish tributaries totaled less than 1,000 fish. WLRD and WDFW staff also undertook surveys in other areas of the Lake Washington basin and concluded that the distribution of kokanee was limited to only twelve streams (Ostergaard et al. 1995; Ostergaard 1996, 1998a, 1998b).

In 1992, WLRD staff initiated the Volunteer Kokanee Spawner Survey Program. The purpose of this program was to document the population size and distribution of kokanee salmon in tributaries to Lake Sammamish, and to provide a supplement to information collected by the WDFW and WLRD. The majority of data from volunteers concerns the late-run kokanee. Data collected by volunteers since 1998 are reported in this document as well as some data previously reported.

In addition to information gathered by volunteer citizens, staff from King County, the City of Issaquah, WDFW, and the National Marine Fisheries Service have been actively involved in enumerating early-run kokanee in Issaquah Creek since 1990.

## METHODS

This section covers methods used to collect data from 1998 through 2001. During this time period our criteria for identifying kokanee changed as a result of observing kokanee outside of the size criteria used in the past. Streams were sampled to document the presence of spawning kokanee, and attempts were made in many instances to obtain genetic tissues and record characteristics such as sex and fork length. In 2001 and 2002, WDFW used a fish weir in an attempt to collect all early-run kokanee in Issaquah Creek as part of a supplementation planning effort.

### IDENTIFICATION OF KOKANEE

Sockeye salmon and kokanee are very similar in coloration and body morphology, although subtle differences can be used to differentiate between them in the field. For field identification purposes, kokanee are identified by their size and spotting pattern. Kokanee are between 8 and 22 inches (200 and 559 mm) in length, and have spots on the dorsal surface, extending to the lateral line in some instances. Residualized sockeye salmon are generally more subdued in color compared to kokanee, with most of the fish being males (Ricker 1938; Quinn et al. 1998). Temporal spawning distribution is also useful to differentiate between populations of a single species within the same geographic range (Groot and Margolis 1991), and may offer insight into the population structure of *O. nerka* in the Lake Washington/Sammamish system. For our purposes, spawn timing was used to further differentiate the early-run, middle-run, and late-run kokanee.

In 1998 and 1999 volunteers were taught to distinguish kokanee from sockeye by size. Fish with red bodies with spots and green heads less than 16 inches (400 mm) in length were identified as kokanee; anything larger was recorded as sockeye. Early in the late-run surveys of the 2000, it became apparent to WLRD and WDFW staff that late-run kokanee present in the Lake Sammamish tributaries were mostly in the range of 16-20 inch (410-510 mm) long. This range is larger than the kokanee found in the Sammamish River Tributaries, and larger than the 16 inch limit put on kokanee identification from previous survey years. Although the fish sampled more nearly resembled sockeye in length, spotting pattern and coloration was similar to kokanee. As a consequence of these observations, the kokanee length guideline was changed to 22 inches (560 mm), with more attention being placed on accurately describing spotting patterns, sex, and spawning behavior.

SPAWNING GROUND ESCAPEMENT SURVEYS

***Survey Reaches***

Survey reaches differed each year due to a variety of factors including changing staff and volunteer levels (Figure 2). Survey reaches were chosen based on previous surveys and on historical kokanee use. Appropriate timing of surveys was determined from historical kokanee data as well as from information on kokanee run timing collected by WLRD staff in 1992 and 1993. Permission to enter private property was secured prior to starting the spawner surveys. Where permission was not obtained, surveys of continuous reaches were not possible and spot checks were undertaken at public right of ways. In 1998 and 1999 stream surveys were conducted in the tributaries of Lake Sammamish, but not in the Sammamish River tributaries.

The Sammamish Kokanee Technical Committee, an interjurisdictional group that was formed in response to the listing petition, created a supplementation plan for early-run kokanee in 2001. At the request of the committee, the 2000 and 2001 early-run surveys were expanded to include as many of the historic early-run streams as possible. This was the first time volunteers were used to survey for early-run kokanee. Only previously trained kokanee volunteers were used in the volunteer surveys for early-run kokanee.

In 2000, WLRD staff surveyed Issaquah Creek from the 56th Street bridge to the Sycamore Street bridge, instead of starting a quarter mile downstream of the 56th Street bridge as was done in 1998 and 1999. This strategy resulted in a more efficient use of time since very little suitable spawning habitat is contained in the quarter mile reach downstream of the 56th Street bridge. Due to a lack of property access, WLRD surveyors performed a combination of spot checks and stream surveys in public rights of way and publicly owned stream reaches on Vasa, Swamp, North, Little Bear, Bear and Cottage

Lake Creeks.  WLRD staff also assisted Seattle Public Utilities staff in surveying Webster Creek in the Cedar River watershed.  Volunteers surveyed the Lake Sammamish tributaries while WDFW surveyed Tibbetts Creek, Issaquah Creek and several of its tributaries.  Volunteers also carried out late-run surveys on Ebright, Pine Lake, Laughing Jacobs, and Lewis Creeks. (Figure 2).

In 2001, early-run kokanee surveys were not as geographically extensive as in 2000. Volunteers surveyed the Lake Sammamish Tributaries (Ebright, Pine Lake, Laughing Jacobs, and Lewis Creeks).  Tributaries to the Sammamish River were not surveyed for early-run kokanee, though WDFW and King County surveyed these streams for spawning chinook while middle-run kokanee were present.  The data collected in those surveys on kokanee are used in this report.

In 2002, early-run kokanee surveys were only done in Issaquah Creek by WDFW as part of their kokanee supplementation program.  Volunteers carried out late-run surveys on Ebright, Pine Lake, Laughing Jacobs, and Lewis Creeks.

Figure 2. Kokanee Survey Reaches - 1998 through 2001

### *WLRD and WDFW Surveys*

Walking surveys were used by WLRD and WDFW to enumerate fish and collect genetic samples. Surveys involved walking through a defined reach in a deliberate manner to count fish and avoid redds. Spot checks were used where property access was not granted and involved watching for fish, typically at road crossings, for 10 to 15 minutes and recording any fish seen. This method is used to determine presence/absence, and it not appropriate for enumeration of spawning ground escapement.

Streams were surveyed once a week, though level of effort occasionally fluctuated between different streams and different years. When actively surveying a stream, WDFW staff walked downstream through survey reaches, while WLRD staff walked upstream. Polarized sunglasses were used to improve visibility of live fish. All species observations and fish counts were recorded in field notebooks. Data on length, sex, type of tissue sample, tissue condition, location in stream, date and photographs were also collected.

### *Early-Run Kokanee Collection Facility on Issaquah Creek*

As a result of low escapement numbers of early-run kokanee in Issaquah Creek and growing concern from the public, the WDFW implemented a supplementation plan for early-run kokanee in Issaquah Creek during 2001. The WDFW (with financial assistance from WLRD) installed a collection weir on Issaquah Creek immediate downstream of the 56$^{th}$ Street bridge. As a result of this effort foot surveys were not used in 2001 to enumerate early-run kokanee in Issaquah Creek. This action was repeated during 2002, with the addition of weekly foot surveys occurring from the collection weir to the mouth of Issaquah Creek. Photographs of the collection weir from 2001 and 2002 are included in Appendix 2.

### *Volunteer Surveys*

The volunteer sampling effort from 1998 to 2001 utilized only volunteers from previous years. No new volunteer recruitment efforts were undertaken. Refresher training was provided at the beginning of each field season by WLRD staff. Training included instruction in adult salmon and redd identification, photography of carcasses, demonstrations of walking surveys in a creek, safety procedures, genetic sampling protocols (for allozyme and later DNA analysis) and proper data recording protocols.

### TISSUE COLLECTION

The dearth of genetic samples from kokanee in the Sammamish basin has prevented researchers and fisheries managers from concretely establishing the genetic origin of kokanee. Based on historical run timings, it was widely assumed that kokanee spawning later in the year (September-January) were of non-native origin, most likely Lake Whatcom stock, while the earlier run of fish in August were probably native (Pfeifer 1992; Ostergaard 1995; King County 2000). The assumptions on late-run origin remained unchallenged by rigorous genetic analyses due to the difficulty of finding fresh carcasses for an allozyme analysis.

In 1998 and 1999, WLRD worked with NMFS to collect allozyme samples of kokanee in Lake Sammamish tributaries for genetic analysis. Nineteen tissue samples were collected from late-run kokanee during 1998 and 1999 late-run kokanee surveys. The sampling experiences of 1998 and 1999 showed that finding viable allozyme samples from kokanee carcasses can be difficult.

In 2000, the sampling regime shifted from collecting genetic samples for an allozyme analysis to tissue samples for mitrochondrial DNA analysis. This was done for several reasons. First, it would take many years to get enough samples to do an allozyme study. Second, allozyme sampling requires collecting internal tissue from various areas of a carcass that has not decayed appreciably. Third, ultra-cold storage presents a logistical problem not associated with preserving tissues in ethanol (ETOH). Fourth, a DNA analysis only requires a small amount of tissue (0.5 $cm^2$) from almost any surface of the fish, allowing tissues to be sampled from both carcasses and live fish. In combination, these four criteria made DNA sampling a logical alternative. Although carcasses can be used in DNA tissue collection, attempts were made to sample live fish.

***Capture Techniques***

WLRD and WDFW biologists attempted several methods to collect genetic samples from live kokanee. Due to there being so few early-run kokanee, no attempt was made to collect samples from any of the live early-run fish. Every effort was taken to minimize the amount of redd disturbance caused by genetic sampling. The following methods of collecting live fish apply only to the middle and late-run kokanee and were only performed by WLRD and WDFW staff.

*Fyke net*

After finding a high-density spawning area with downstream flow and depth suitable for a fyke net, WLRD biologists installed a fyke net downstream of the observed kokanee. A block net was then dragged from an upstream location downstream toward the fyke net in an attempt to herd the spawning fish into the fyke net. In general, the block net was not sufficiently heavy to prevent fish from swimming beneath it. Also, fish would often dart into areas where they could get around the block net, such as areas with wood jams and overhanging vegetation. This technique is not suitable for efficient capture of spawning kokanee in streams, due to the numerous small twigs that catch the block net and the number of places small fish can hide. For this technique to be effective one must find a reach devoid of refuge areas and with water deep enough for a fyke net to be set effectively.

Original attempts in North Creek and Little Bear Creek proved difficult, with only one specimen captured (under 228$^{th}$ Bridge at Little Bear Creek) in the net after several field trials. Even though this technique was unsuccessful, its description may be useful for future reference.

*Dip Net/Hand Grab*

These two techniques were very effective at capturing kokanee in the smaller tributaries of the Lake Sammamish basin. These methods were borne from observations during stream walking surveys on Lewis Creek. While walking in Lewis Creek, many of the kokanee would swim under overhanging vegetation, rocks, or woody debris when encountering a foot surveyor. Often these fish would not even move when touched. WLRD staff found that it was possible to capture them by slowly grabbing the fish around their caudal peduncle and head.

Some kokanee would not seek cover and merely swam back and forth through a small length of stream. A dip net was used to catch kokanee as they swam back and forth. This technique involved positioning a net person downstream of a fish concentration while an upstream wader herded the fish towards the dipnetter. This method accounted for many live samples, but similar problems occurred here as with the fyke net method.

***Genetic Sampling***

Once captured, fork lengths were recorded to the nearest millimeter from both live and dead specimens, and their adipose fins were clipped with surgical scissors in an effort to collect an adequate sample for DNA analysis. Adipose fins are less likely to be contaminated by fungal infestation, and provide a marking procedure to avoid sampling fish more than once. Once removed, fin clips were stored in 95% ETOH at room temperature in individually marked microcentrifuge tubes for subsequent analysis by the WDFW genetics lab in Olympia (see Young et al. 2001). Live kokanee were returned to the stream following the sampling. In the case of volunteer collected specimens, only carcasses were used, and preservation methods were the same.

Many of the carcasses that were collected by WLRD and WDFW staff had the otoliths removed, so that further analysis could be performed to investigate whether these fish were actually residualized sockeye, their age structure, and individual growth rates.

## RESULTS

It is necessary to discuss some of the limitations of the data and collection methods. First, the data are presented in numbers of fish seen per survey, not an estimate of escapement. Second, while survey reaches are mostly standardized, they have not been sampled consistently from year to year, since effort by volunteers varied from one year to the next (e.g. there are sometimes gaps of 2 weeks between surveys versus a typical one week gap). Also, many of the fish recorded as sockeye before 2000 are highly likely to be kokanee as a result of incorrect assumptions regarding the size of kokanee versus sockeye. A 16-inch (400 mm) size limit was put on kokanee to ease in identification for the 1998-2000 kokanee spawning surveys. After observing several kokanee over 21 inches (533 mm) in length during the 2000 season, WDFW and WLRD realized that the 16 inch size limit was inadequate. Therefore, the size criterion of 16 inches (400 mm) was removed from identification criteria early in the 2000 and subsequent sampling seasons.

Early-run, middle-run, and late-run kokanee are separated by spawn timing and geographic location (Figure 3). In 2000, early-run kokanee spawned in Issaquah Creek, and had a peak spawn date of late August. Early-run kokanee were not observed in 2001. In 2000 and 2001 Little Bear, Cottage Lake, North, and Bear Creeks had peak spawn times between mid October and early November. The late-run kokanee streams surveyed in 2000 and 2001 had peak spawning dates from mid-November through mid-December.

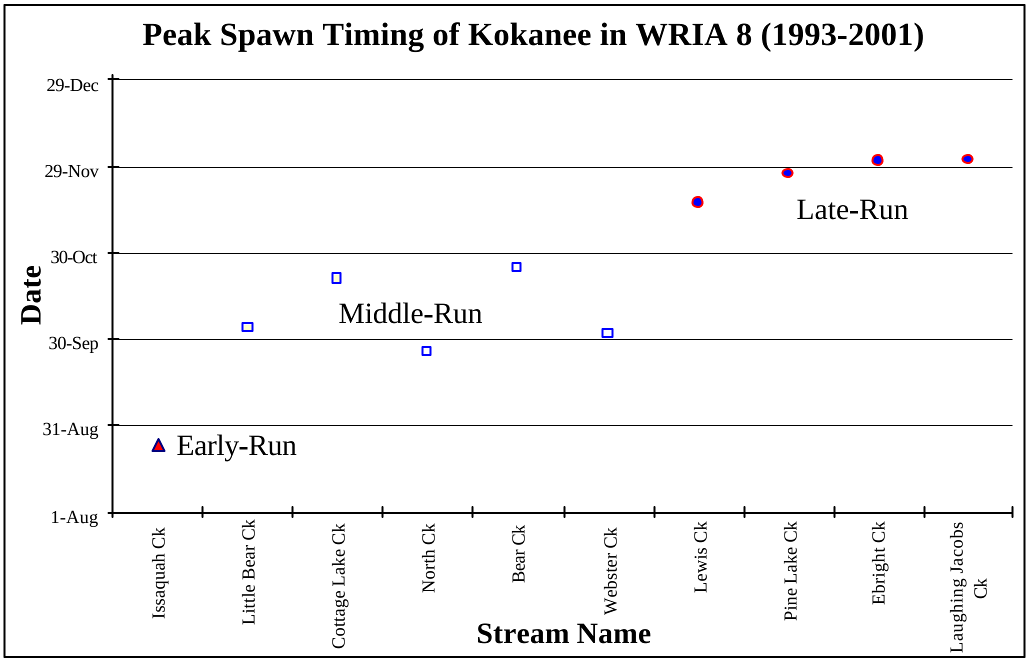


**Figure 3**: Peak spawn timing of kokanee in streams sampled during 1993-2001 surveys.

### EARLY-RUN

Early-run kokanee in Issaquah Creek spawn much earlier than other kokanee in the Lake Sammamish tributaries (Figure 4). To date, the only stream with known populations of early-run kokanee is Issaquah Creek, with peak spawning occurring during the last week of August.

Berggren (1974) and Pfeifer (1995) report escapements of early-run kokanee in Issaquah Creek numbering in the thousands during the 1970s. Since 1980, the escapement of early-run kokanee in Issaquah Creek has plummeted dramatically. Between 1998 and 2001, only 3 early-run kokanee redds were observed in Issaquah Creek (Figure 5), suggesting that barring aggressive conservation measures including supplementation, this population is not likely to persist even over the next generation.

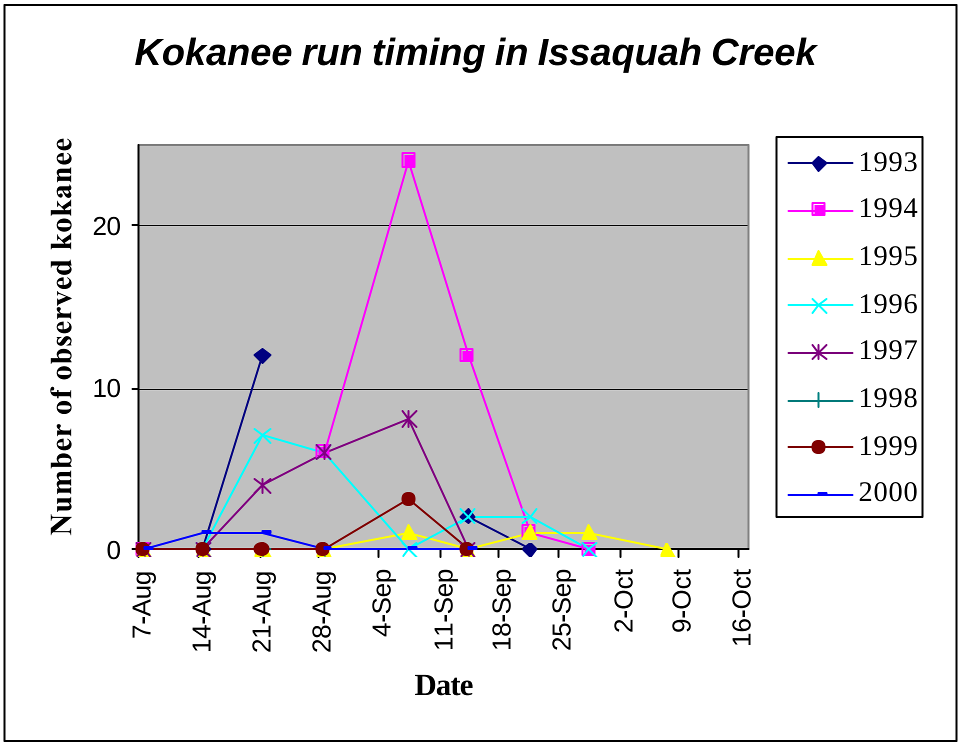


**Figure 4**: Spawn timing of kokanee in Issaquah Creek (1993-2002). Note that no kokanee were seen in Issaquah Creek in 2001 and 2002.

In July 2001 and 2002, attempts were made to collect broodstock for an early-run kokanee supplementation program. The WDFW installed a fish weir across Issaquah Creek downstream of the 56th Street Bridge, in an attempt to capture all migrating kokanee, and spawn them in a hatchery. Unfortunately, no kokanee were captured in these attempts (WDFW 2002).

Figure 5. Issaquah Creek early-run kokanee spawning locations (1992-2001)

### *MIDDLE-RUN*

Very little is known about the life history and ecology of middle-run kokanee in the Lake Washington Basin. In the late 1800s, Bean (1891) and Evermann and Meek (1898) observed kokanee spawning in September through November in tributaries of Lake Washington and the Sammamish River. Bean (1891) went on to describe kokanee as being common in the Lake Washington Watershed, while sockeye were generally rare, south of the Nooksack River. Jordan and Evermann (1902) described kokanee in 1902 as occurring in Lake Sammamish. More recently Fletcher (1973) considered the run of native kokanee in Bear Creek to be virtually extinct due to hypothesized introgression with introduced Lake Whatcom kokanee. As noted earlier, a lack of historical data makes it difficult to ascertain if the current run timing of Sammamish River Tributary kokanee is the same as it was around the turn of the 20$^{th}$ century, or if we are now looking at a run of residualized sockeye. In 2000, otoliths were collected from 53 middle-run kokanee spawners with 48 of those showing high levels of strontium, indicating that the maternal parent was anadromous. Furthermore, the fish were predominately 2 years old, which is consistent with residual sockeye and not kokanee (Ricker 1938).

Young et al (2001) analyzed kokanee DNA samples collected in 2000 on Bear, Little Bear, and North Creeks. Since there were not enough samples to analyze each creek system separately they pooled all three streams together for the analysis. Their analysis revealed that there was not a significant genetic divergence between Bear Creek Sockeye and Sammamish River Tributary kokanee. The otolith and genetic data combined suggests that these "kokanee" are actually residualized sockeye.

#### *Swamp Creek and North Creek*

Little attention has been focused upon kokanee spawning in Swamp and North Creeks in recent years. In 1935, Schultz reported over 100 spawning kokanee on one riffle of Swamp Creek. When Ostergaard (1998a) surveyed the same area in 1996, only 7 kokanee were observed. Little is known about the population structure, spawning location, and annual escapement of kokanee in Swamp Creek. Historically, spawning of kokanee was highest in October and November (Delacy 1931; Schultz 1935), while the majority of kokanee in North Creek spawn from September through November. The lower portion of Swamp Creek was considered the "usual" spawning habitat by Donaldson (1939). In 1946, Swamp Creek was found to have a "good" population of kokanee (Garlick 1946). He also indicated that North Creek had a "very excellent" run size with relation to streams in the Lake Washington Basin. These historic accounts help provide insight to the remnant kokanee population in these streams. In 2000, WLRD staff were unable to collect any DNA samples from Swamp Creek and only in 7 samples from North Creek. There was insufficient data on Swamp and North Creeks to establish run timing graphs.

*Little Bear Creek*

In contrast with North and Swamp Creeks, Garlick (1946) identified Little Bear Creek as having a "fair" number of kokanee. Today, Little Bear Creek contains more kokanee than North and Swamp Creeks, combined. Kokanee in Little Bear Creek can be observed from mid-September through mid-November (Figure 6).

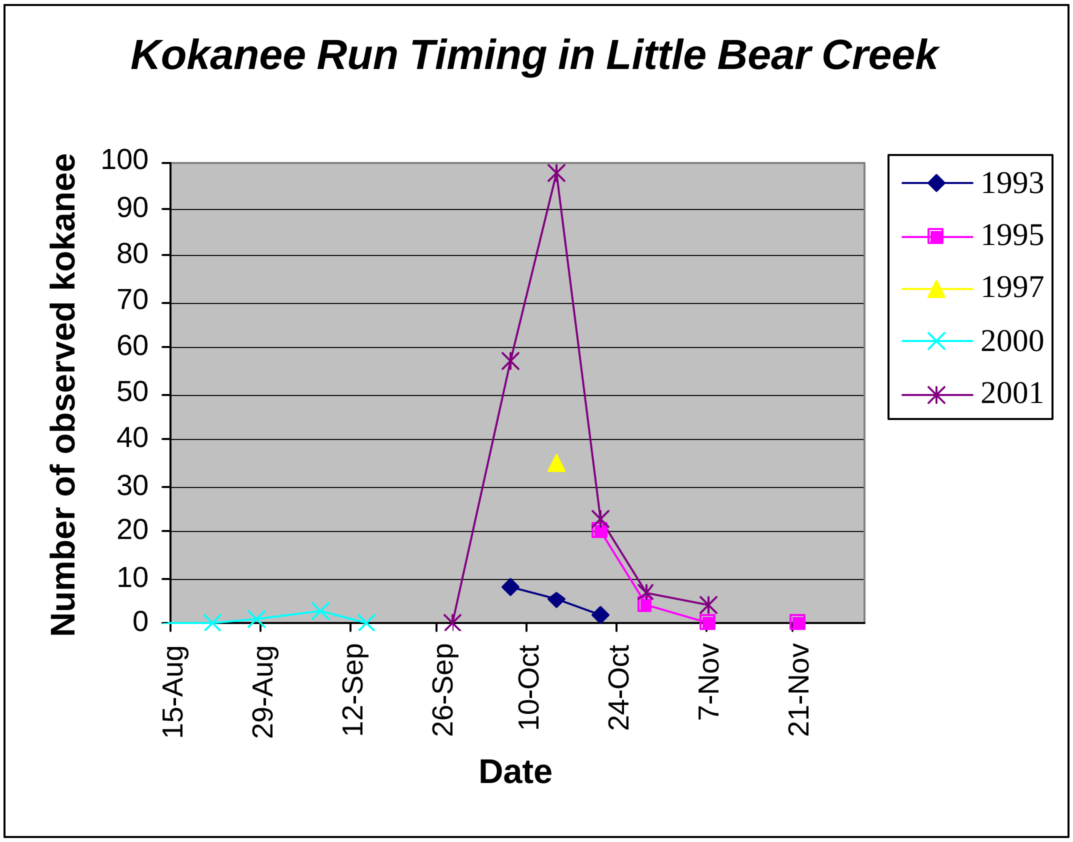


**Figure 6**: Spawn timing of kokanee in Little Bear Creek (1993-2001).

*Cottage Lake Creek*

Kokanee can be seen in Cottage Lake Creek, a tributary of Bear Creek, from mid-September through early November (Figure 7). No historic information is available on the use of Cottage Lake Creek by kokanee. However, it is likely that kokanee used the creek historically since Bear Creek had such a large run of kokanee. Kokanee in Cottage Lake Creek are generally found in close proximity to spawning sockeye salmon, particularly during the month of October.

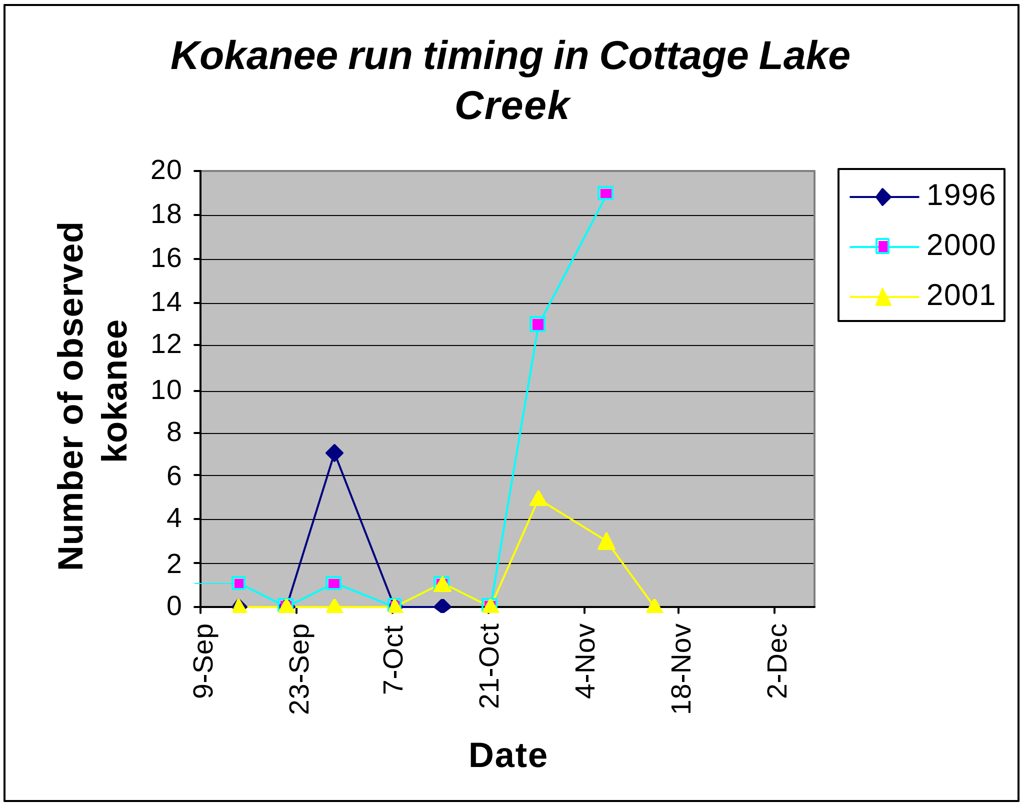


**Figure 7**: Spawn timing of kokanee in Cottage Lake Creek (1996, 2000, and 2001).

*Bear Creek*

Kokanee have been observed in Bear Creek during September and October since the 1880s (Bean 1891). From the observations made during chinook spawning ground surveys in recent years, peak kokanee spawning occurred around the third week in October (Figure 8). However, spawning surveys ended before kokanee spawning ceased and recent observations indicate that kokanee spawn well into November. Washington Department of Game (now WDFW) had a fish weir on Bear Creek and collected 1.6 million eggs in 1941 and 5.5 million eggs in 1945 (USFWS 1951). Assuming 480 eggs (Delacy 1931) per female, that means that approximately 3,300 female kokanee returned to the weir in 1941 and approximately 11,458 in 1945. This does not take into account any natural escapement or contribution to the population by males. Kokanee numbers in Bear Creek were found to be significantly lower in recent years. Kokanee observed in Bear Creek during September and early October are generally seen in close proximity to spawning sockeye salmon, and are mostly males. They also have a coloration that is consistent with residual sockeye. Coincidentally, the peak spawning date for sockeye in Bear Creek is approximately October 10th (Steve Foley, WDFW, personal communication). In November, kokanee in Bear Creek are often observed on redds, and with an approximate equal mixture of males and females. In addition, during 2001 and 2002 a large number of kokanee were observed in the Sammamish River below the mouth of Bear Creek and in Bear Creek during November, with sex ratios close to 50:50 for males and females (Steve Foley, WDFW, personal communication). The November spawning kokanee appear to have coloration more consistent with kokanee than residual sockeye, suggesting a closer relationship to kokanee.

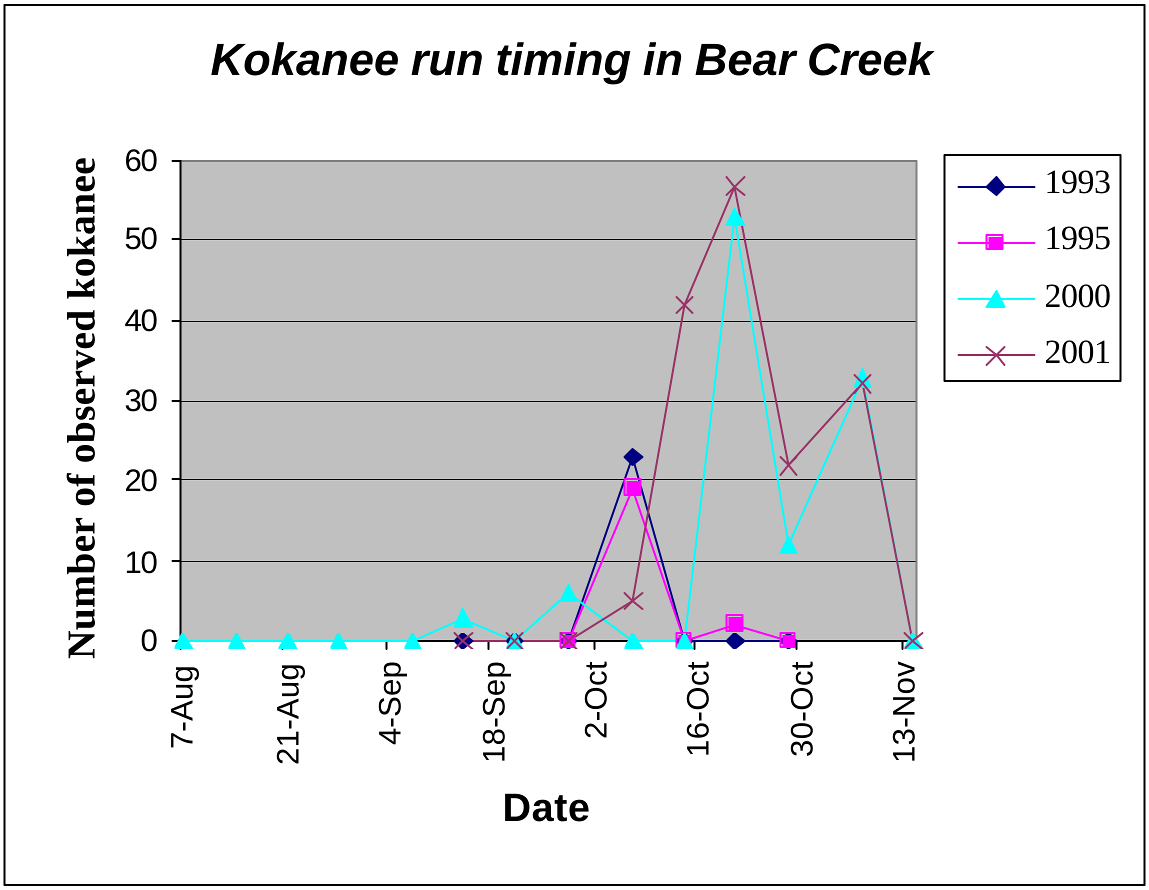


**Figure 8**: Spawn timing of kokanee in Bear Creek (1993-2001).

Webster Creek

In 2000, WLRD assisted the City of Seattle and surveyed portions of Webster Creek for kokanee, and observed spawning in early October. Webster Creek is a tributary to Walsh Lake in the City of Seattle's municipal watershed. Spawning coloration and size appears to be consistent with that of kokanee. While WLRD does not have more than several surveys from one year to analyze, the average run size appears to be small (less than 150 adults a year). However, the City of Seattle surveys in 2002 show a minimum of 586 kokanee in Webster Creek, a much larger run size than previously seen, although the size of this population appears to be highly variable (Dwayne Paige, Seattle Public Utilities, personal communication). More recently, Spies (2002) concluded that the Webster Creek kokanee were more closely related to Baker Lake sockeye than any of the *O. nerka* stocks in the basin, though this was based on a limited number of samples.

***LATE-RUN***

The late-run kokanee in Lake Sammamish tributaries have been described since the 1880s (Bean 1891). Throughout the 1970's WDG planted Lake Whatcom Kokanee throughout the basin (Pfeifer 1995). Microsattelite DNA characterization by WDFW in 2000 on samples collected by volunteers and various agency staff, determined that late-run kokanee from Lewis, Ebright, and Laughing Jacobs Creeks were distinct from other populations of *Oncorhynchus nerka* in the Lake Washington Watershed (Young et al. 2001). There were not enough samples collected on Pine Lake Creek in order to analyze the samples at that time. However, Pine Lake Creek is located between Ebright Creek and Laughing Jacobs Creek and the kokanee spawn at the same time as the other late-run kokanee. Pine Lake Creek kokanee are likely very closely related to the other late-run kokanee. Until this study, it was assumed that the late-run kokanee population in Lake Sammamish tributaries was largely made up of Lake Whatcom kokanee.

*Ebright Creek and Pine Lake Creek*

Late-run kokanee in Ebright Creek have been observed since the late 1880s (Personal communication cited in King County 2000). Peak spawning in Ebright Creek occurs during the first week of December and stretches into January (Figure 9). It is unknown how long kokanee have been spawning in Pine Lake Creek, but they have been found since surveys started in 1996. The majority of these fish spawn in November and December (Figure 10).

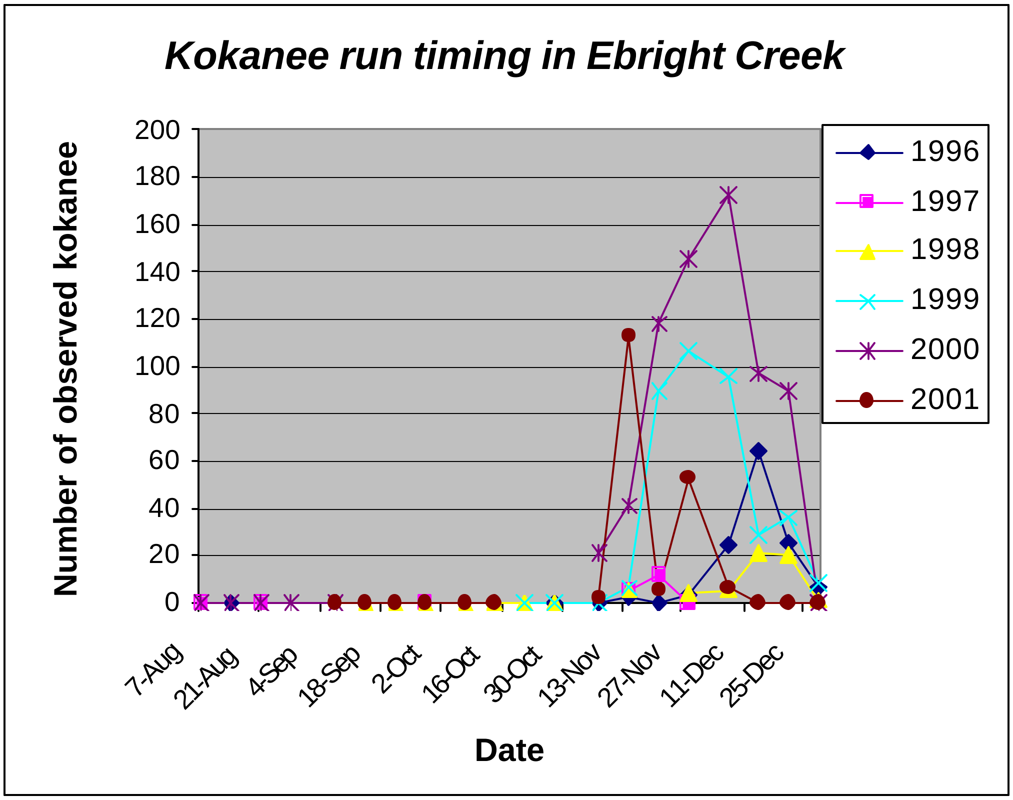


**Figure 9**: Spawn timing of kokanee in Ebright Creek (1996-2001).

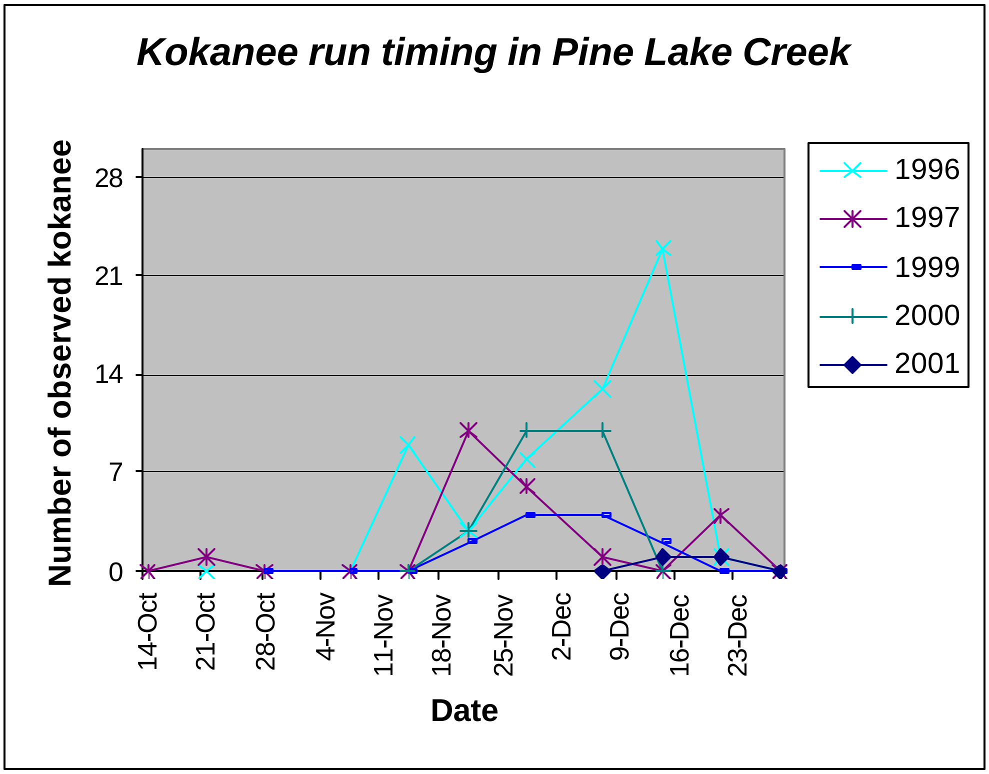


**Figure 10**: Spawn timing of kokanee in Pine Lake Creek (1996-2001). *Note that the scale for the run size is smaller than the other graphs.*

*Laughing Jacobs and Lewis Creeks*

Late-run kokanee in Laughing Jacobs Creek spawn throughout the fall months, with a peak in spawn timing around the second week in December (Figure 11). A large number of late-run kokanee spawn in Lewis Creek, with the peak in spawning occurring during the third week in November in most years (Figure 12).

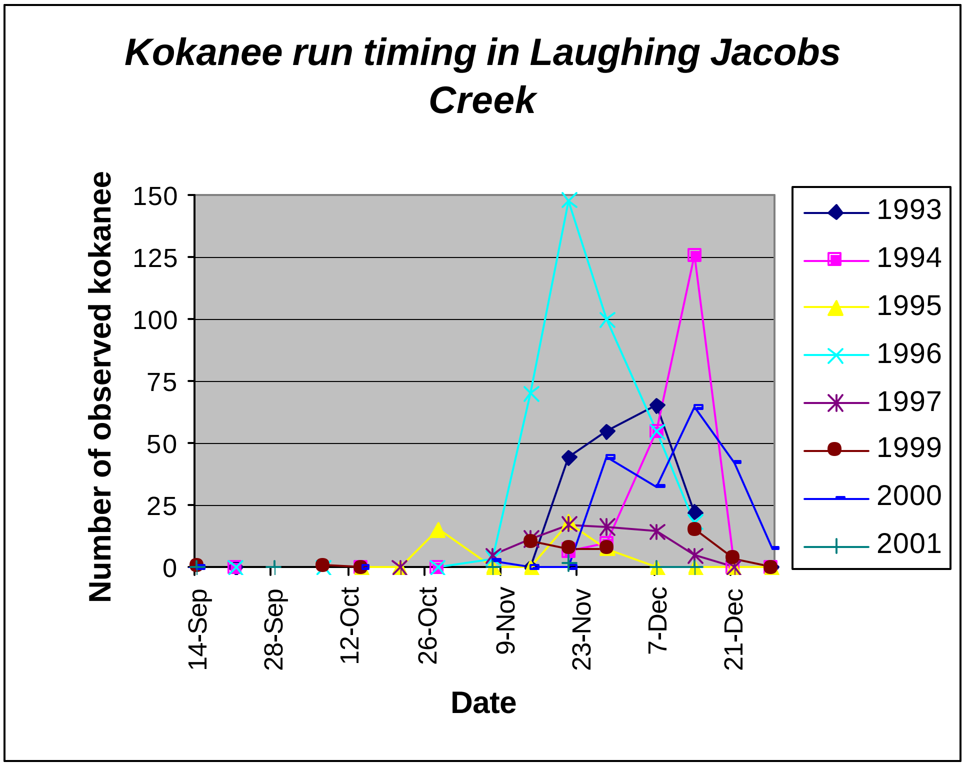


**Figure 11**: Spawn timing of kokanee in Laughing Jacobs Creek (1993-2001).

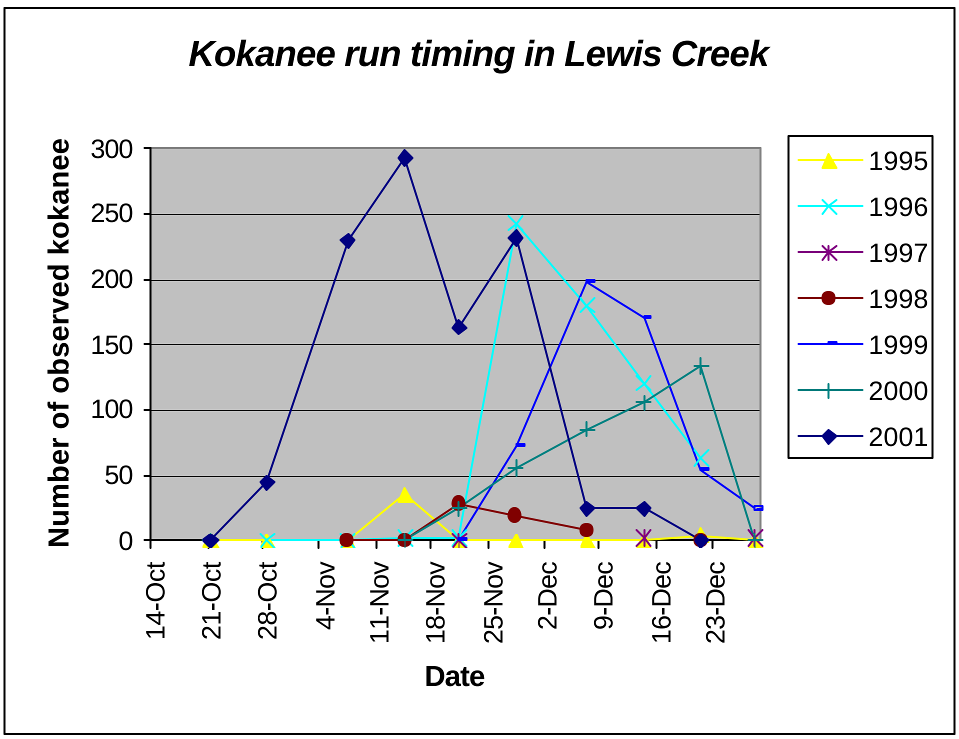


**Figure 12**: Spawn timing of kokanee in Lewis Creek (1995-2001).

*Vasa and Tibbetts Creeks, and the East Fork of Issaquah Creek*

Vasa Creek is another tributary of Lake Sammamish that may support a small population of kokanee. In 1998, nine live kokanee were observed in Vasa Creek. In 2000, no kokanee were seen during spot checks. Two surveys in 1997 showed no kokanee in Tibbetts Creek, though one spot check in 2000 found kokanee present. Surveys of the East Fork of Issaquah Creek in 1998 by WDFW showed substantial numbers of kokanee, but WLRD has not followed up with further surveys. Little is known about the spawning distribution and relative abundance of spawning kokanee in any of these creeks as few surveys have been done.

***LENGTHS OF KOKANEE***

Data on local kokanee lengths from the literature vary considerably. Some of the earliest data on lengths comes from Smith (1921), where he found mature kokanee to be 8.3 inches (213 mm). It is not known which race of kokanee he sampled, though it is likely that it was one of the middle-run races as there is a reference to collecting mature kokanee from the Sammamish River. Delacy (1931) found the middle-run race in Swamp Creek to be between 6.5 inches (167 mm) and 10 inches (256.4 mm), which would fit with Smith's length data. Scattergood (1949) reported average lengths (from the posterior edge of the hypural plate to the tip of the snout) for kokanee collected on October 2, 1938 on North Bear Creek as 9.62 inches (248 mm) for males and 10.02 inches (257 mm) for females. It is hard to know which creek was sampled since there are four different creeks that could have been sampled based on the name he used (North Creek, Little Bear Creek, Bear Creek, Cottage Lake Creek). The run timing corresponds to the middle-run race and the average lengths (converted to fork lengths) fit with what Smith and Delacy found for middle-run kokanee. These data are consistent with length information collected in 2000 from middle-run kokanee (Figure 13).

Early-run kokanee found in Issaquah Creek by Fletcher (1973) had an average fork length of 13.57 inches (345 mm). This is consistent with data collected by Pfeifer (1992), with average kokanee lengths in Issaquah Creek in 1981 and 1982 of 14.4 inches (369 mm) and 14.7 inches (377 mm) respectively. Lengths collected by Hendry (1995) in

1993 showed mean early-run kokanee lengths of 10.92 inches (280 mm), somewhat smaller than Pfeifer's account (Pfeifer 1992), but Hendry's (1995) sample size was relatively small (n=20).

Unfortunately, there does not appear to be any historic length frequency data on late-run kokanee, as no one specifically sampled them until the 1990s. Average lengths of kokanee throughout the basin from the most recent data available are included in Figure 13. The average length of early-run kokanee sampled from 1981, 1982 and 1993 is 12.9 inches (332 mm) (Pfeifer 1992, Hendry 1995). The average length from the 2000 kokanee samples for the combined middle-run kokanee and the combined late-run kokanee are 11.2 inches (288 mm) and 17.67 inches (453 mm) respectively (Figure 13). Note the sample sizes for middle and early-run kokanee are far fewer than the sample size for the late-run kokanee.

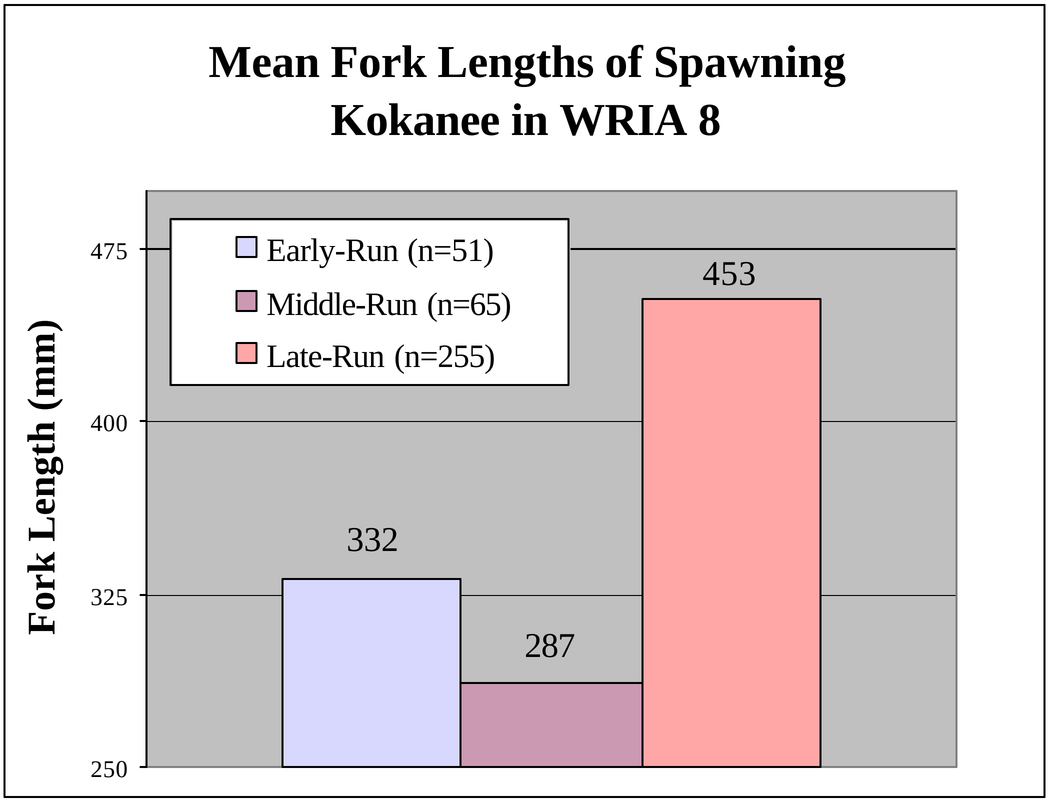


**Figure 13**: Mean fork lengths of early-run, middle-run and late-run kokanee. Middle and late-run averages are composed of several streams from 2000 surveys, while the early-run average is from Pfeifer 1992 and Hendry 1995.

## DISCUSSION

The primary purpose of the King County Kokanee Program is to document the distribution and abundance of native kokanee. The program was initiated in 1992 to assist WDFW in tracking the size of the kokanee runs in Lake Sammamish. While the data collection described here has improved our overall understanding of distribution and abundance of kokanee, it has also raised additional questions.

The early-run kokanee population has declined precipitously over the past 28 years. This negative trend in escapement has decreased to the point that only six early-run spawning kokanee have been observed in Issaquah Creek since 1998, and none have been observed in the past two years (figure 14). The last year of stream surveys for early-run kokanee was in 2000, with only 2 kokanee observed in that year. Currently, WDFW is undertaking an early-run kokanee supplementation program in cooperation with various government agencies, including WLRD. In 2001 and 2002, WDFW placed a weir across Issaquah Creek near the 56th Street Bridge in an attempt to capture any early-run kokanee and propagate them artificially. While weirs are an effective way to capture migratory salmonids, they are not completely effective. High flow events can have a profound effect on weir operation, and completely eliminate their use in some instances. In 2001, such an event rendered the weir inoperable for approximately 36 hours. Since no foot surveys were undertaken for three weeks following this event, it is likely that any kokanee that got past the weir would have spawned without detection. A similar event occurred in 2002, but WDFW conducted foot surveys within five days of the event, reducing the potential of spawning kokanee going unnoticed. No early-run kokanee have been captured or seen in Issaquah Creek during 2001 or 2002, which may mean that we are too late to prevent extinction.

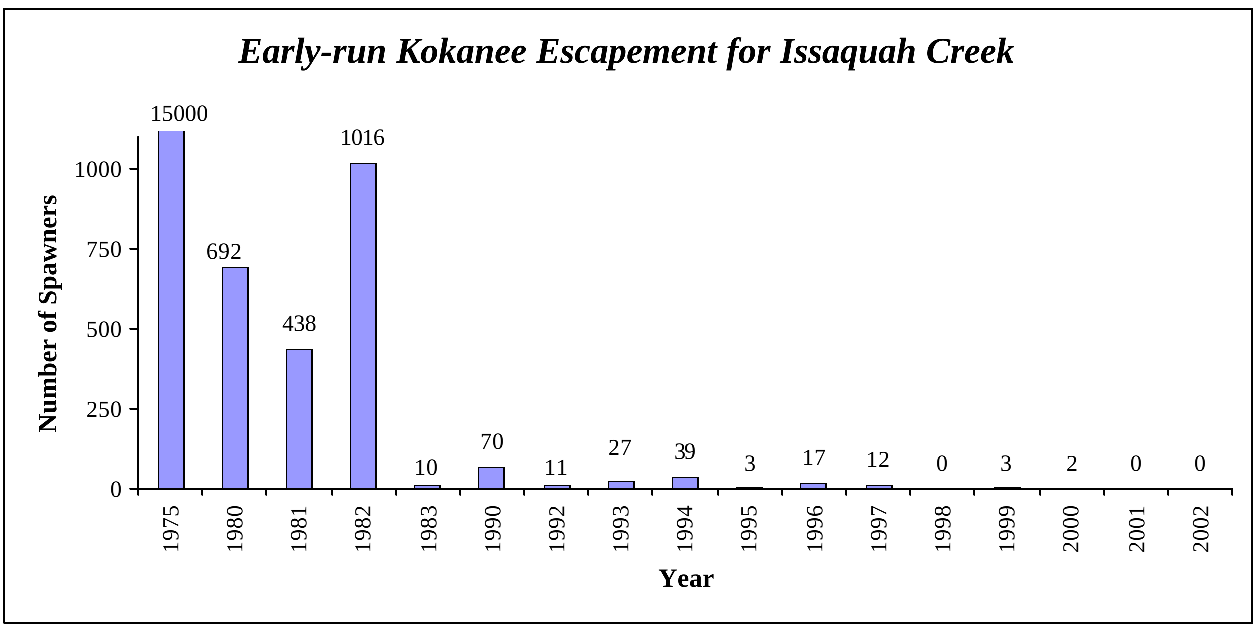


**Figure 14**: Early-run kokanee escapement for Issaquah Creek (1975-2002).

In November of 2002, kokanee were observed spawning in Lake Sammamish at depths between 33 ft and 40 ft (10-12 meters), near the mouth of Ebright Creek. Another study by Hassemer and Rieman (1981), noted deep beach spawning by kokanee, as deep as 65 feet (20 meters), in an area with abundant springs in Lake Coeur d'Alene, Idaho. The observation of deep spawning during the late-run spawn timing raises the question of whether or not it is possible that early-run kokanee may be spawning in the lake, as well as Issaquah Creek. Continuing the supplementation effort and investigating the potential that early-run kokanee may also spawn in Lake Sammamish may represent the last chance to recover native early-run kokanee.

Middle-run kokanee originating from the Sammamish River tributaries likely rear in Lake Washington, since the majority of *O. nerka* migrate downstream as emergent fry to rear in the lake environment, particularly in a situation where the outlet of the spawning stream is between two lakes (Groot and Margolis 1991). It is believed that early-run and late-run kokanee rear in Lake Sammamish. As shown in Figure 13, middle-run kokanee appear to have the shortest average length of the three races, though this average length fits with historic size data. There are several possibilities to explain the smaller size in middle-run kokanee, including biological and physical differences in nursery lakes. Trophic interactions have a very pronounced effect on the biological community in a lake. For instance, non-native mysid shrimp (*Mysis relicta*) have been known to cause declines of kokanee throughout the western United States through exploitative competition (Lasenby et al. 1986; Rieman and Falter 1981). In these instances, mysids directly compete with kokanee for zooplankton, which can limit the growth of kokanee during critical times of the year. During the summer of 2002, native mysids (*Neomysis mercedis*) were observed in Lake Sammamish, and in kokanee stomachs (H. B. Berge, unpublished data). Native mysids are also known to occur in Lake Washington, and appear to be an important component in the food web (Chigbu and Sibley 1996). To date, it is unknown what effect, if any, these species may have on *O. nerka* in the basin, or if their abundance in Lake Sammamish has fluctuated in recent years.

Another direct competitor with native kokanee are sockeye salmon. Present in large numbers in the Cedar River and Bear Creek basins, sockeye smolts directly compete with kokanee for preferred prey items, including copepods and cladocerans, particularly consuming (“high-grading”) larger zooplankton (Ricker 1938; Groot and Margolis 1991).

It is also possible that some of the races of middle-run fish are now residualized sockeye. Recent genetic testing by WDFW suggests that these populations are indistinguishable from Bear Creek sockeye (Young et al 2001), which in turn are distinct from introduced Baker Lake Sockeye and Cultus Lake Sockeye (Hendry 1995). However, the sample size for middle-run kokanee was too small to analyze each middle-run creek separately, which resulted in a pooled analysis and is not as definitive as if they could have been analyzed separately. Furthermore, samples were only collected during the early half of the run and don't include the entire run. Combining a low sample size with a bias toward early arriving fish results in a less than complete view of the middle-run *O. nerka.* The belief that North Creek and Little Bear Creek kokanee are actually residual sockeye is further corroborated by the observed muted coloration, skewed sex ratio (female to male) data and high levels of strontium in their otoliths from samples collected in 2000, suggesting a freshwater life history strategy similar to that of kokanee. These sex ratios (represented in Figure 15) are consistent with what one would expect from residual sockeye, with the ratio being heavily skewed towards males (Ricker 1938; Groot and Marglois 1991). However, data from Bear Creek is less clear. The sex ratio data from Bear Creek in 2000 is more consistent with late-run kokanee with an equal ratio of males to females. Combining sex ratio data with observations of spawning behavior and coloration of the two populations represented by the peaks of kokanee seen in 2000 and 2001 seems to indicate that there may be both residual sockeye and kokanee in Bear Creek. This information leads one to believe that the smaller form of *O. nerka* found in Bear Creek are likely residualized sockeye originating from the anadromous form of Bear Creek sockeye ancestry.

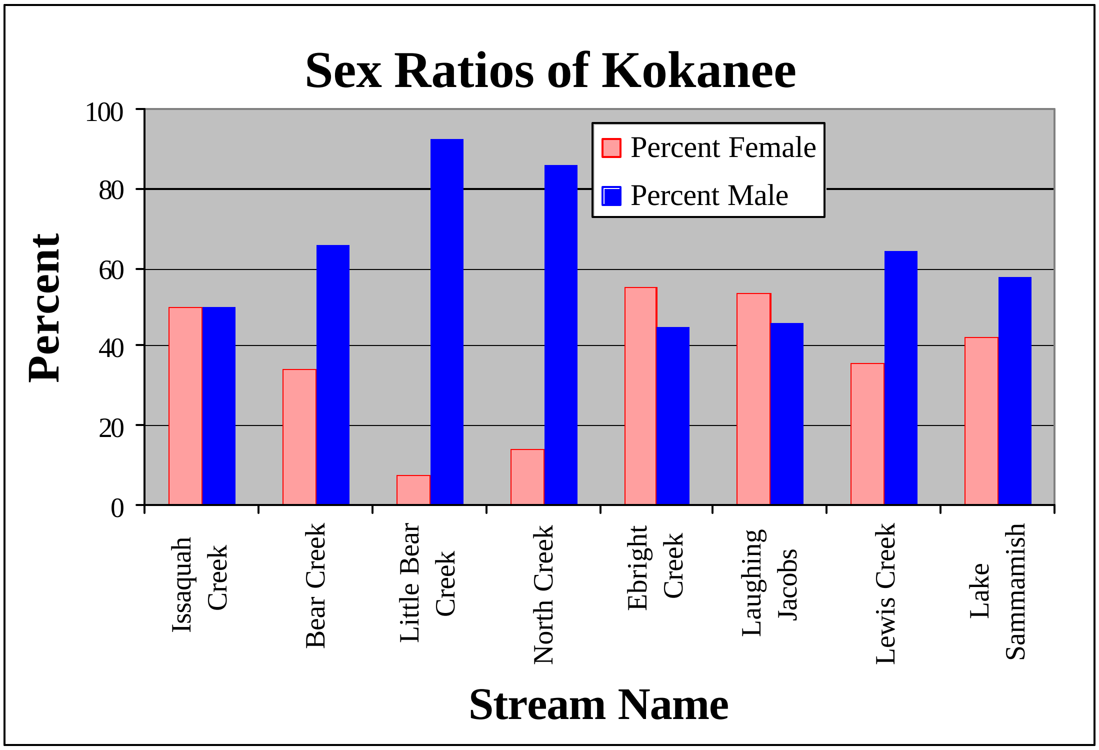


**FIGURE 15**: Early, middle and late-run sex ratios. Late-run and middle-run data are from 2000, early-run data come from samples taken in 1981, 1982, and 1993 (Pfeifer 1995; Hendry 1995), Lake Sammamish data was collected in 2002 on a population of beach spawners near Sulphur Springs Point (H. B. Berge, unpublished data).

Another potential question centers around the possibility that Bear Creek sockeye identified by Hendry (1995) are in fact derived from native kokanee, corroborated by the findings of Young et al. (2001) on the relatedness of Bear Creek sockeye and kokanee. Kaeriyama et al. (1992) found that sockeye introduced into a landlocked lake persisted as kokanee, but after more than 15 generations, the "kokanee" were moved to a lake with access to the marine environment where they reverted to anadromous sockeye. Given the tremendous changes in Lakes Washington and Sammamish immediately following the replumbing of Lake Washington and the permanent outlet established at the Chittenden Locks in the early 1900s (Chrzastowski 1983), it would not be surprising for kokanee to adapt to these changes by selecting an anadromous life history. The sex ratio, size of maturity, and spawn timing reiterates the need to do further genetic testing and an analysis of the age structure of middle-runs of *O. nerka* in order to determine if they are kokanee or sockeye.

Potential limits of freshwater spawning habitat may pose a more severe threat to the long-term survival of native kokanee in the basin. It has been shown that spawning habitat can be one of the main limiting factors of kokanee (Groot and Margolis 1991), and given the amount of human influence in the basin, it is no surprise that spawning habitat has been degraded over the past century. Past spawning surveys have not assessed the adequacy and quantity of available spawning habitat, but rather presence/absence and numbers of fish. Early-run kokanee appear to have a substantial amount of spawning habitat in Issaquah Creek, although the quality of much of this habitat has been rated as low (King County 1991; City of Issaquah, 2002). Low stream flows in Issaquah Creek may also have an effect on the success of early-run kokanee, although very little attention has been placed on this potential impact. Previous hatchery practices of restricting kokanee from going above the hatchery due to concerns about the possible transmission of the Infectious Hematopoietic Necrosis Virus (IHNV) also restricted access to available habitat in previous years. The middle-run race of kokanee does not appear to be limited by the amount of available spawning habitat, but the quality of the available habitat may not be adequate. Late-run kokanee spawning appears to be restricted to the lower reaches of Lake Sammamish tributaries, which can limit production of kokanee in these streams. For example, the longest accessible reach for late-run kokanee utilized in recent years is in Lewis Creek, with approximately 0.75 miles (1.2 km) of spawning habitat from the mouth to a fish blocking culvert at the I-90 corridor. Furthermore, late-run kokanee are found in developed or developing sub basins. The development is likely changing the hydrology of these streams to the detriment of late-run kokanee. More frequent and higher magnitude “high” flow events (due to increased impervious surface area) scour redds and force adult kokanee out of the streams. This occurs frequently in urban streams and is known to have a negative impact on spawning salmonids (Booth 1990; King County 1991). As an example, in Lewis Creek during mid-November of 2001, a high flow event had a dramatic effect on the number of spawning kokanee in the stream (Figure 16). This flow does not represent any of the likely damage to incubating embryos in redds that were previously constructed, but demonstrates the effects on spawning salmonids. A comprehensive survey of the quality and availability of spawning habitat in kokanee spawning streams is warranted, and may help in our understanding of the ability of many of these streams to produce naturally spawning kokanee.

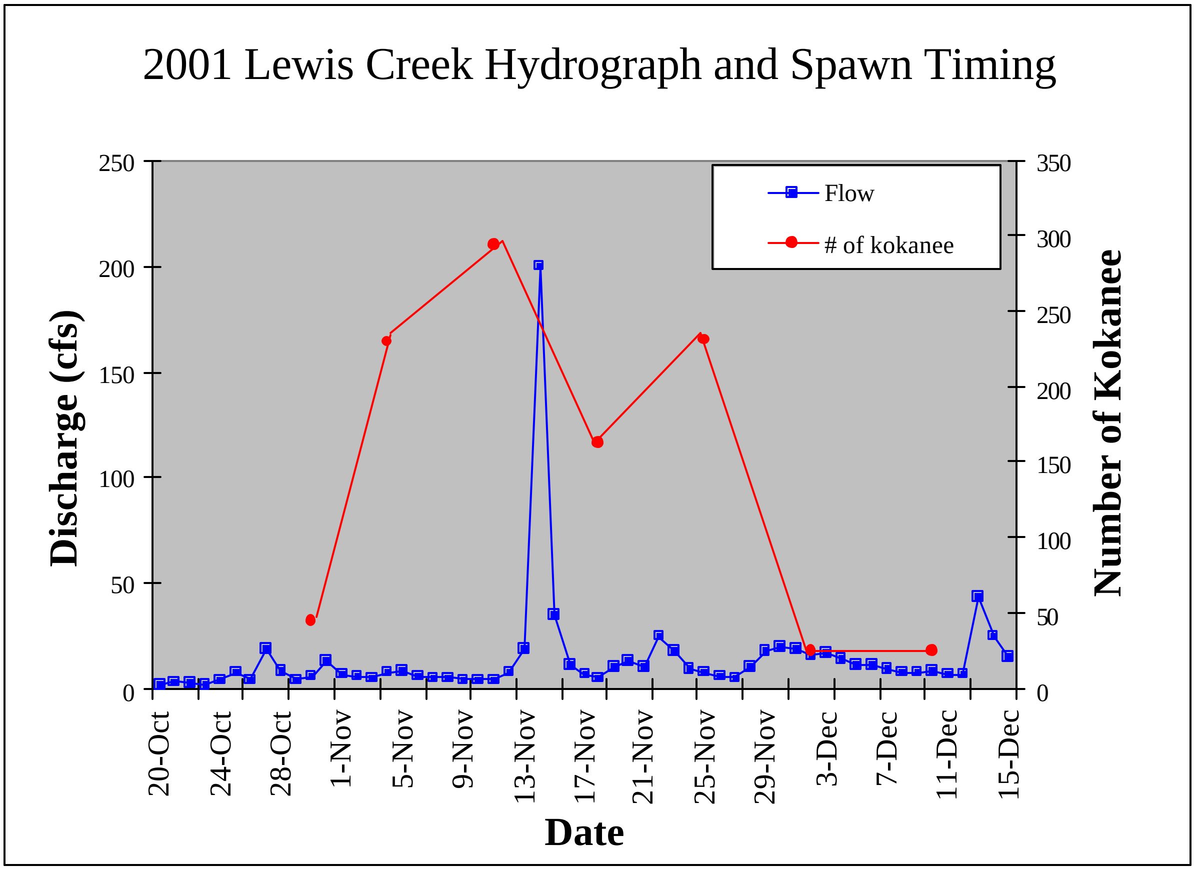


**Figure 16**. 2001: Lewis Creek hydrograph and spawn timing.

Competition for spawning sites is an additional pressure on kokanee. Early-run kokanee are the first salmonid to spawn in Issaquah Creek during the autumn. Due to their small size, compared to other fall spawning salmonids, kokanee redds are not as deep as other salmonids, making them especially vulnerable to superimposition (DeVries 1997; Wood and Foote 1996). Chinook have been seen spawning on top of kokanee redds in Issaquah Creek (Pfeifer 1995) and presumably sockeye and coho would superimpose their redds on top of kokanee redds as well, further compromising the successful incubation of kokanee embryos. Middle-run kokanee spawn at the same time as sockeye and chinook, which creates competition for initial spawning site selection, and while superimposition has not been observed, it is likely to occur. Competition for spawning sites does not appear to be critical for late-run kokanee. Although, coho and sockeye spawn during the same time period as late-run kokanee, they do not appear to use the same streams as late-run kokanee to any significant extent, or similar spawning sites within these drainages. Due to an overlap in spawn timing, there is the potential for redd superimposition of late-run kokanee by cutthroat or rainbow trout, although it is probably not significant since the overlap in spawn timing is slight.

Conditions in lacustrine habitats can have a dramatic effect on fish communities. Lake Sammamish is highly stratified by temperature and dissolved oxygen concentrations during the summer months, which may have an effect on the distribution and abundance of kokanee. Recent work conducted by the University of Washington supports this hypothesis and may help in understanding the effects of hypoxia and thermal stratification on the potential growth of salmonids in Lake Sammamish (H. B. Berge, unpublished data).

An interesting side note is that in 1973, Fletcher was searching for the parent stock of Lake Stevens kokanee in order to help supplement kokanee in Lake Stevens. He surmised that Lake Stevens kokanee were originally transplanted in 1912 or 1913, and from a nearby source due to the primitive fish handling/hauling abilities of the time. Fletcher assumed that the early-run kokanee and the historic Bear Creek race of kokanee were two of the likely candidates. Fletcher's analysis showed the early-run race not a good fit, based upon spawn timing, size at maturity, fecundity, etc. Since he believed the Bear Creek race to be extinct by the 1970s due to introgression with introduced Lake Whatcom kokanee he did not include Bear Creek kokanee in his comparison. In addition, Fletcher did not include late-run kokanee in his analysis. Consequently, Fletcher was not able to identify the parent stock for Lake Stevens kokanee. Interestingly, the Lake Stevens fish had an average size of 18 inches (457 mm) and run timing of October 23 to January 15 in 1972, which closely matches that of the Lake Sammamish late-run kokanee (average length of 17.8 inches (453 mm), overall run timing of late October to early January). While this might indicate late-run kokanee as the parent stock due to timing and size, Wood and Foote (1990), showed that the size of *O. nerka* is an environmental effect and that when grown under controlled conditions, kokanee and sockeye show little difference in size. Furthermore, while Bear Creek kokanee are smaller, their spawn timing overlaps part of Lake Stevens kokanee. In all the various genetic analyses that have been done on *O. nerka* in the Greater Lake Washington Watershed, no one has compared these three stocks. It would be of great value to collect genetic samples of the Lake Stevens kokanee and compare them to the Lake Sammamish late-run and Bear Creek kokanee.

## RECOMMENDED IMMEDIATE ACTIONS

In summary, the following actions should be taken immediately to aid in our understanding of kokanee in the Lake Washington/Sammamish Watershed. First, it is important to continue to document the spawn timing and distribution of *O. nerka* throughout the watershed to understand whether or not the early-run are extinct and to get a better idea regarding the distribution and escapement of late-run kokanee. Second, further genetic analysis of early, middle, and late-run kokanee is needed to gain a better understanding into the subtleties and differences between these races. Third, there is a need for more age data and sex ratio data to see if these parameters are changing over time. Fourth, better information on spawning habitat availability and redd superimposition is needed to understand potential limits to the recruitment of naturally spawning kokanee. Fifth, the presence and extent of lake spawning early-run and late-run kokanee should be quantified. If early-run kokanee are spawning in Lake Sammamish they could serve as a potential source of fish for the supplementation program and further our recovery efforts. Sixth, better data on the competition/predation problems in Lake Sammamish and Lake Washington are needed to understand potential limits on sub-adult kokanee. Seventh, it may be important to determine whether Sammamish River tributary fish are migrating and rearing upstream in Lake Sammamish or downstream in Lake Washington. Finally, this data collection and analysis effort should be coordinated with the Sammamish Kokanee Technical Committee to ensure new technical information is guiding conservation activities across jurisdictions.

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