Ecological Survey of “Late-Run” Kokanee in Lake Sammamish, 2016

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King County

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Ecological Survey of “Late-Run” Kokanee in Lake Sammamish, 2016

Prepared for:

Lake Sammamish Kokanee Work Group

This Ecological Survey is the product of a Technical Workshop held on November 17, 2016 at Issaquah Salmon Hatchery. Attendees included:

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EXECUTIVE SUMMARY

A technical workshop involving area resource specialists was convened on November 17, 2016 in Issaquah, WA to evaluate the status of Lake Sammamish "late-run" kokanee and consider strategies for conservation. Ongoing efforts to improve population numbers began over 10 years ago, and they appear to have succeeded in preventing the collapse of the population. Nonetheless, the long-term abundance trend appears generally flat and year-to-year returns are extremely variable.

The purposes of the technical workshop – and this report – are to: (1) evaluate the extensive amount of new ecological information that has been developed since the original conservation strategies were initiated, (2) determine the current status of all relevant variables, (3) uncover knowledge gaps, (4) identify adverse effect mechanisms, if possible, and (5) prioritize adaptive management and research needs. In this report, the term "ecological survey" encompasses all of these objectives.

The primary questions guiding these objectives are:

- What are the ecological mechanisms driving both frequent, very low spawner abundances and very high year-to-year variability of spawner abundance?
- What are the most significant ecological risks to the population, and what are the available tools to address these risks?

This Ecological Survey is a data-driven tool and snapshot of professional judgment for recalibrating conservation strategies designed for Lake Sammamish kokanee. The survey presents five high-priority kokanee conservation strategies. Two high-priority strategies involve adaptive management and fundamentally address the value of increased population abundance:

- Continue to expand kokanee access to all high-quality, historic spawning habitats, as this can have a measureable, significant impact on the total abundance of fry annually entering the lake.
- If the supplementation program is continued in the future, modify methods to incorporate approaches that better emulate the condition and fitness of natural fry.

Three high-priority strategies involve filling major knowledge gaps to provide vital information about kokanee lake survival and consequent high variability in spawner abundance:

- Further analyze the potential relationship between the high variability of seasonal phytoplankton and zooplankton biomass and the high variability of kokanee abundance (and other species abundance).

- Further analyze viral and bacterial pathogens and parasites in Lake Sammamish, as this can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance.

- Pursue critically important research opportunities to better understand predator niches in Lake Sammamish to inform the understanding and expectations of the foreseeable ranges of annual spawner abundance. In particular, this should include: a more thorough understanding of coastal cutthroat trout, yellow perch, and walleye status and trends; and an analysis of predator status, predation rates, and bioenergetics.

Going forward, this Ecological Survey provides the scientific basis for approaches to conserving "late-run" kokanee. Lake Sammamish Kokanee Work Group partners and other collaborators are anticipated to use this Ecological Survey to adjust their current programs and future applied natural resource management actions.

1.0 INTRODUCTION

1.1 Lake Sammamish Kokanee History and Project Area Background

Prior to settlement of the Lake Washington Basin and subsequent completion of the Lake Washington Ship Canal in 1916 (Larson 1975), the predominant Pacific salmon inhabiting the watershed appears to have been kokanee, the non-anadromous variant of sockeye salmon (*Oncorhynchus nerka*). [See Appendix A for more information of the status and historic distribution of kokanee runs throughout the Lake Washington Basin.] The first known fisheries surveys of Lake Washington in 1888 and 1889 (Bean 1891) suggest kokanee were more common than anadromous sockeye. Additional surveys of lakes Washington and Sammamish during 1896 also support the earlier findings that kokanee were the most common Pacific salmon in the watershed with few observations of sockeye and no accounts of other salmon species (Evermann and Meek 1898). No records are known to occur describing the common harvest of anadromous salmon in either lake. The lack of a consistent channel, low lake elevations during the non-rainy season, and an extensive wetland complex at the outlet of Lake Washington (pre-Lake Washington Ship Canal) (Chrzastowski 1986) may have been periodic, physical obstacles that precluded the establishment of large runs of other Pacific salmon in the watershed.

Historic narratives indicate indigenous kokanee populations in lakes Washington and Sammamish were important for cultural and personal economic purposes. Tribal accounts describe the harvest of adult kokanee in tributaries to both lakes from August through December (Bean 1891, Pfeifer 1992, Ostergaard et al. 1995, Connor et al. 2000). Today, Lake Sammamish kokanee remain a unique, valuable cultural resource and indicator of environmental cumulative effects for all residents of King County. In many ways the indigenous kokanee population of Lake Sammamish is woven into the fabric of life for many people living in the Lake Sammamish watershed – young and old, new and ancient.

Formed in 2007, the Lake Sammamish Kokanee Work Group (LSKWG) continues to serve as a high-functioning, multi-jurisdictional, private-public organization designed to facilitate conservation measures that integrate the many historic and current resource values of native kokanee. The goal of the LSKWG is: "Prevent the extinction and improve the health of the native kokanee population such that it is viable and self-sustaining, and then supports fishery opportunities."

1.2 Purpose of this Ecological Survey.

A technical workshop involving area resource specialists was convened on November 17, 2016 in Issaquah, WA to evaluate the status of Lake Sammamish "late-run" kokanee and consider strategies for conservation. Ongoing efforts to improve population numbers began over 10 years ago, which appear to have succeeded in preventing the collapse of the population. Nonetheless, the long-term abundance trend appears generally flat and year-to-year returns are extremely variable. (Over the last 20 years, 30% of the annual returns in index streams (Ebright, Laughing Jacobs, and Lewis creeks) have yielded a combined escapement of less than 150 fish; 25% of returns have yielded a combined escapement of over 2,000 fish.)

The purposes of the technical workshop – and this report – are to: (1) evaluate the extensive amount of new ecological information that has been developed since the original conservation strategies were initiated, (2) determine the current status of all relevant variables, (3) uncover knowledge gaps, (4) identify adverse effect mechanisms, if possible, and (5) prioritize adaptive management and research needs. In this report, the term "ecological survey" encompasses all of these objectives.

The primary questions guiding these objectives are:

- What are the ecological mechanisms driving both frequent, very low spawner abundances and very high year-to-year variability of spawner abundance?
- What are the most significant ecological risks to the population, and what are the available tools to address these risks?

All ecological factors affecting "late-run" kokanee are important to understand and address, but these questions are an attempt to frame the conditions that potentially put the population at greatest long-term risk of decline.

This Ecological Survey is designed to be comprehensive, yet user-friendly and succinct. The available data of all relevant variables will be summarized, including an analysis of status. Furthermore, the synthesis of the data provides a rationale for specific adaptive management strategies. This Ecological Survey is expected to serve as a data-driven tool and snapshot of professional judgment for recalibrating conservation strategies designed for Lake Sammamish kokanee.

Three important caveats to the report merit mention. First, several other, recent reports describe the natural history of Lake Sammamish kokanee, assess general population trends, and offer possible rationale for the population trends (Pfeifer 1995, Connor et al. 2000, Berge and Higgins 2003, Jackson 2006, HDR 2009). These resources largely remain relevant today and offer excellent narratives of the local populations' natural history and interpretations of past biological and physical data. Many of the subjects in these reports are beyond the scope of this Ecological Survey. This survey is not designed to supersede these reports, and there is a certain expectation that the reader has a cursory familiarity with Lake Sammamish kokanee natural history and the accounts written in the reports.

Secondly, the information and adaptive management strategies in this Ecological Survey are designed to be utilized concurrently with the Blueprint for the Restoration and Enhancement of Lake Sammamish Kokanee Tributaries (LSKWG 2014) and Conservation Supplementation Plan for Lake Sammamish Late-run (Winter-run) Kokanee (LSKWG 2013a).

Third, this Ecological Survey will not provide detailed narratives explaining the processes and effect mechanisms of resource variables. Since the document will function as a synopsis of data summaries, there is an expectation that the reader has a general understanding of the biological and physical processes affecting kokanee ecology. For detailed information of ongoing or proposed habitat projects the reader is referred to the Blueprint for the Restoration and Enhancement of Lake Sammamish Kokanee Tributaries (LSKWG 2014) and individual actions involving private and public entities, which are commonly coordinated with the LSKWG.

1.3 Organization of this Ecological Survey

The Ecological Survey for Lake Sammamish "late-run" kokanee is organized using the framework of parameters and variables described in Table 1 – Framework of Parameters and Variables. For the purposes of this Ecological Survey, "parameters" are considered major kokanee life history stages, groups of environmental or biological variables, or otherwise, survey processing sections. The three parameters include stream life stage (Section 2.1), lake life stage (Section 2.2), and survey results and targets (Section 3).

Furthermore, the development of benchmarks or other measures of success in Lake Sammamish kokanee conservation have eluded LSKWG partners. An important goal of the Ecological Survey is the proposal and endorsement of one or more meaningful, practical measures of population status. These are discussed as targets in Section 3.

Table 1. Framework of Parameters and Variables.

PARAMETERS	• VARIABLES
STREAM *Life Stage:* EGG-TO-FRY	•Population Genetics •Spawning Habitat Quantity •Stream Hydrology •Stream Water Quality •Stream Productivity
LAKE *Life Stage:* FRY-TO-ADULT	•Lake Water Quality •Lake Primary Productivity and Zooplankton •Lake Pathogens and Other Factors •Lake Species Assemblage •Biosampling and Movement •Escapement, Recruitment, and Lake Productivity •Supplementation Program
Results and Targets	•Summary of Major Knowledge Gaps and Opportunities for Adaptive Management •Practical Indicators of Population Status

2.0 PARAMETERS AND VARIABLES

This section of the report provides information on environmental or biological variables grouped within major life history parameters. Current information for each variable is summarized and followed with an assessment of relative status, priority for kokanee conservation, and a description of knowledge gaps and opportunities for adaptive management. Only "high-priority" issues are labeled as an elevated conservation category.

2.1 Stream Life Stage: Egg-to-Fry

2.1.1 Population Genetics

The first study of genetic status of Lake Sammamish kokanee was performed using DNA microsatellite profiling of samples gathered in 2000 (Young et al. 2001, Young et al. 2004). This first study found that kokanee sampled from Ebright, Laughing Jacobs, and Lewis creeks were genetically distinct from other *O. nerka* samples obtained throughout the Lake Washington watershed.

A second microsatellite analysis using samples obtained in 2001 and 2003 (Warheit and Bowman 2008) validated the results of first study, which indicated kokanee from Ebright, Laughing Jacobs, and Lewis creeks were genetically distinct from other *O. nerka* sampled from the Lake Washington watershed. The 2008 study also suggests that potential inbreeding is mitigated by gene flow among tributaries. Although genetically distinct, the 2008 study indicates some level of introgression may occur between fish from Ebright, Laughing Jacobs, and Lewis creeks and a small number of *O. nerka* from other Lake Sammamish or Lake Washington tributaries.

A third and most recent analysis indicates samples taken from Lake Sammamish tributaries in 2011 are similar to those gathered 2000 and genetically distinct from other *O. nerka* sampled from the Lake Washington watershed (WDFW 2016). However, also comparable to the Warheit and Bowman (2008) analysis, this study indicates a slight drift between 2000 and 2011 non-Lake Sammamish tributary samples that may suggest a demographic or historic linkage to fish from Ebright, Laughing Jacobs, and Lewis creeks.

- **Current ecological assessment:** There are no apparent indications or events that suggest the current genetic status among the lake tributaries may be different than those found in 2001; the results of the three studies are likely relevant today. Native kokanee from Lake Sammamish may be migrating downstream and spawning with *O. nerka* occurring in Lake Washington and Sammamish River tributaries. As part of the supplementation program, 2,176 kokanee tissue samples from the 2009-2010 through 2015-2016 returns have been collected and stored at the US Fish and Wildlife offices in Lacey, WA.

- **<u>Priority:</u>** At this time, the genetic status of "late-run" kokanee is not likely at risk, and the genetic profile is unlikely related to current abundance variability and trend.
- **<u>Major Knowledge Gaps and Opportunities for Adaptive Management:</u>** Newer technology using single nucleotide polymorphisms (SNPs) could enable a significantly higher precision of genetic analysis. The completion of analysis and reporting of recent samples by the US Fish and Wildlife from Lake Sammamish tributaries will provide additional valuable information.

2.1.2 Spawning Habitat Quantity

"Late-run" kokanee spawn primarily in the many tributaries draining small- to medium-sized watersheds surrounding Lake Sammamish. Issaquah Creek provides approximately 70% of the surface flow to Lake Sammamish (Moon 1973), although periodic escapement surveys of tributaries and monitoring at Issaquah Salmon Hatchery suggest very low numbers of "late-run" kokanee spawn within the mainstem creek or its tributaries.

To provide an estimate of spawning habitat quantity, the gross linear feet of various potential spawning habitats are tabulated in Table 2 – Estimated Lengths of Lake Sammamish "Late-run" Kokanee Spawning Habitat. This assessment is considered a coarse-filter approach to quantifying spawning habitat since the actual proportion of stream area providing spawning habitats is not known to have been inventoried in any tributaries, except in Lewis Creek upstream of Interstate 90 (WDFW 2000). The assessment does not consider the historic or current quality of spawning and rearing habitats. A combination of geospatial data, technical stream surveys (where available), rapid assessments during field reviews, the Blueprint for the Restoration and Enhancement of Lake Sammamish Kokanee Tributaries (LSKWG 2014), and professional judgement were used to generate the estimates. Numerous technical stream surveys from private landowners and municipalities helped inform the development of the assessment, including Watershed 1988, Watershed 1992, King County 1994, Watershed 2007, AMEC 2010a, AMEC 2010b, David Evans 2012, R2 Resource 2012, 48 North 2014, Tetra Tech 2014, Herrera 2015, Osborn 2015, Parametrix 2015, R2 Resource 2015a, R2 Resource 2015b. The termini of stream reaches included in the estimates were also delineated at natural barriers, approximate 8% gradients, and estimated low flow transition areas.

The coarse-filter assessment does not consider spawning habitats within the lake. Although lakeshore spawning by kokanee has been observed in other Northwest lakes, the extent to which this potential spawning resource is utilized in Lake Sammamish is not known. Two separate technical surveys to assess this variable did not observe any evidence of lake spawning. A survey in December 1964 by Washington State Department of Fisheries did not locate any redds in near-shore areas of the lake (Buckley 1964). Additional aerial, boat, and scuba surveys performed during the 2011-2012 return did not find evidence of any lake spawning (LSKWG 2013b).

A proposal to re-route the lower reaches of Laughing Jacobs is described in the Blueprint for the Restoration and Enhancement of Lake Sammamish Kokanee Tributaries (LSKWG

2014). The stream lengths associated with this proposal are not included in this assessment. A feasibility analysis of this proposal is required to assess uncertainties associated with the foreseeable net gain of spawning habitats, as well as the cost-benefit to all related resources.

Results of the coarse-filter assessment suggest approximately 60% of all potential spawning habitats in Lake Sammamish tributaries are currently accessible to "late-run" kokanee. Fish passage restoration can provide access to an approximate additional 26% of potential spawning habitats. Approximately 13% of habitats are not likely to be accessed again due to logistical constraints, such as major, permanent land modifications.

- **<u>Current ecological assessment:</u>** Of all likely, accessible, historic spawning habitats, the maximum proportion to ever be utilized again may be approximately 86%. By (1) reconstructing fish passage barriers on Zackuse Creek at East Lake Sammamish Parkway and Trail, and (2) allowing the passage of most or all kokanee arriving at the Issaquah Salmon Hatchery, the amount of historically accessible spawning habitat can be brought up from 60% to 78%. Restoring fish passage on George Davis Creek, while logistically very challenging, could provide "late-run" kokanee access to an additional, approximate 8% of the total potential, historic spawning habitats. Performing these restoration actions would be expected to have a significant positive impact on the abundance and resilience of the "late-run" population.
- **<u>Priority:</u> HIGH**. Expanding access to all historic habitats is vital for diversifying the suite of Lake Sammamish spawning reaches against adverse ecological risks.
- **<u>Major Knowledge Gaps and Opportunities for Adaptive Management:</u>** Continuing to expand access to all high-quality, historic spawning habitats can have a measureable, significant impact on the total abundance of fry. The application of eDNA technology (Barnes and Turner 2015, Wilcox et al. 2016) could help identify or confirm kokanee spawner utilization at unsurveyed sites and help support the rationale to coordinate habitat conservation actions in areas of previous low focus.

Table 2. Estimated Lengths of Lake Sammamish "Late-run" Kokanee Spawning Habitat.

STREAM	Spawning and rearing habitat				
	Current habitat (feet)	Likely historic habitat; current use unknown; accessible (feet)	Likely historic habitat; currently not accessible; potential for restoration (feet)	Likely historic habitat; currently not accessible; no potential for restoration (feet)	Historic use uncertain; accessible (feet)
Alexanders Creek		535			
Carey Creek					19,942
East Fork Issaquah Creek		5,224			13,103
Ebright Creek	4,174				
Fifteenmile Creek					8,382
George Davis Creek	107		10,746		
Holder Creek					9,913
Idylwood Creek	714	3,071		1,173	
Issaquah Creek	16,829		21,051		27,034
Kanim Creek		2,170			
Laughing Jacobs Creek	4,019				
Lewis Creek	3,214			5,150	
Many Springs Creek (Lower)		691			
Many Springs Creek (Upper)			927		
McDonald Creek					7,757
NE-1 unknown		343			
NE-2 unknown		219			
NE-3 unknown		157			
NE-4 unknown		192			
NE-5 unknown		172			
North Fork Issaquah Creek	3,813	6,437			
NW-1 unknown		912		1,170	
Phantom Lake Outlet		296			
Pickering Creek		2,052		2,215	
Pine Lake Creek	2,178	3,792			
Schneider Creek	571			1,437	
SE-1 unknown		223			
SE-2 unknown		548			
SW-1 unknown	477			571	
SW-2 unknown		337		1,698	
Tibbetts Creek	6,608	4,528			8,825
Tosh Creek		3,793			
Vasa Creek	2,412	1,630		4,631	
Zackuse Creek	366		2,549		
TOTAL (feet)	**45,480**	**37,319**	**35,272**	**18,045**	**94,956**
Percentage of all likely historic habitat (136,116 feet)	**33%**	**27%**	**26%**	**13%**	

2.1.3 Stream Hydrology

Stream hydrology is an important ecological variable to understand due to the range of potential adverse impacts on stream features in spawning reaches and, consequently, incubating kokanee embryos. This is a variable particularly sensitive to the range of human development that has occurred in the majority of watersheds supporting kokanee spawning and rearing. Long-term datasets that are available for tributaries in small- to medium-sized watersheds of Lake Sammamish are considered (Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah creeks) (see King County Hydrologic Information Center website: http://green2.kingcounty.gov/hydrology/Default.aspx). The long-term datasets in these streams range from 11 to 28 years and are likely representative of most other, ungauged kokanee spawning streams. A permanent, continuous flow gauge was also deployed on Ebright Creek during 2014; however, at this point in time, the available dataset for Ebright Creek only covers a single water year (2015).

Mainstem Issaquah Creek hosts four separate U.S. Geological Survey (USGS) continuous flow gauges (USGS gauges: 12121600, 12121510, 12121000, and 12120600). Although mainstem Issaquah Creek provides a significant proportion of the surface flow to Lake Sammamish (Moon 1973), the assessment of this data is outside the focus and scope of this Ecological Survey.

The analysis of annual peak and mean flow data (Table 3 – Long-Term Annual Peak and Mean Flow Values) suggests long-term trends of these measures in Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah creeks are generally flat but statistically weak ($p>0.10$). Annual peak flows may be declining in East Fork Issaquah Creek although additional monitoring is needed.

Mean daily flows in Laughing Jacobs and Lewis creeks generally increase during November through mid-January (Figure 1 – Long-term Mean Daily Flow for Laughing Jacobs and Lewis Creeks), which coincides with both the typical spawning period for "late-run" kokanee and the period during which incubating embryos are most sensitive to disturbance (Jensen 2003). Inter-day patterns of mean daily flows are considerably different between Laughing Jacobs and Lewis creeks.

The frequency of high flow events is measured using High Pulse Count, which is equal to the number of times each water year that discrete high pulses occur (daily average flows that are equal or greater than twice the long-term daily average flow). This indicator is expected to increase with urbanization (Cassin et al. 2005, DeGasperi et al. 2009). The High Pulse Count may be increasing in the short-term in Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah creeks; however, additional monitoring is needed to determine long-term trends (Figure 2 – Annual High Pulse Count for Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah Creeks).

The duration of the period between the start of the first high pulse and last high pulse of a water year is the High Pulse Range, which is also expected to increase with urbanization (Cassin et al. 2005, DeGasperi et al. 2009). The High Pulse Range appears stable in

Laughing Jacobs, East Fork Issaquah, and North Fork Issaquah creeks. The duration measure may be increasing in the short-term in Lewis Creek; however, additional monitoring is needed to determine long-term trends. (Figure 3 – Annual Pulse Range for Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah Creeks).

The flashiness of stream flows is measured through the Richards-Baker Flashiness Index (R-B Index). The index is a dimensionless value of flow oscillations relative to total flow based on average daily discharge measured during a water year; the index value is expected to increase with urbanization and has low sensitivity to inter-annual variability in rainfall (Cassin et al. 2005, DeGasperi et al. 2009). There appears to be no general trend in all four streams; however, the degree of flashiness, using this measure, suggests Lewis Creek exhibits intraday differences in low-to-high flows that are nearly twice as great as the other three streams (Figure 4 – Annual R-B Index for Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah Creeks).

T_{Qmean}, the fraction of time during a water year that the daily average flow rate is greater than the annual average flow rate of that year, is another measure of stream flashiness. This measure is expected to decrease with urbanization (Cassin et al. 2005, DeGasperi et al. 2009). There appears to be no general trend in Laughing Jacobs, Lewis, and North Fork Issaquah creek. T_{Qmean} may be increasing in the short-term in East Fork Issaquah Creek, which is contrary to the increase in High Pulse Count noted earlier. Generally, records of ten years or less can result in the identification of spurious upward and downward trends (Konrad and Booth 2002).

- **Current ecological assessment:** If Laughing Jacobs, East Fork Issaquah, and North Fork Issaquah creeks are representative of the majority of tributaries to Lake Sammamish, the hydrologic regimes affecting spawning and rearing habitats may at least be stable. Lewis Creek appears to be an outlier in terms of increasing high flows, "flashiness," and the annual period of duration of high events.
- **Priority:** The restoration and conservation of floodplain processes that mitigate the altered hydrology in "late-run" spawning streams is vital; however, at this time, this parameter is unlikely related to the current variability and trend in kokanee abundance (see additional information in Stream Productivity).
- **Major Knowledge Gaps and Opportunities for Adaptive Management:** The cumulative effect of these factors, especially during the incubation and rearing period, highlight the need to provide well-functioning floodplains on Lewis Creek downstream of the West Lake Sammamish Parkway. A recent stream restoration project (2015) in the lower reaches of Lewis Creek is expected to enhance floodplain processes. Stream restoration and fry abundance monitoring, especially on Lewis Creek, should continue to be performed; monitoring is designed to demonstrate effectiveness of mitigations for altered flow regimes in an urban environment.

Table 3. Long-Term Annual Peak and Mean Flow Values.

Water Year	Annual Peak CFS				Annual Mean CFS			
	Laughing Jacobs	Lewis	East Fork Issaquah	North Fork Issaquah	Laughing Jacobs	Lewis	East Fork Issaquah	North Fork Issaquah
1988				45				3.9
1989				56				6.4
1990				468				9.3
1991				144				8.7
1992	65			97	4.1			6.6
1993	21			35	3.7			5.6
1994	31			37	3.0			4.6
1995	85			112	5.9			5.7
1996	127			143	9.2			9.6
1997	181			125	11.0			9.9
1998	44			38	4.6			6.4
1999	70			114	7.8			9.4
2000	53	101		140	5.4	3.7		6.4
2001	23	27		50	2.1	2.3		3.8
2002	101	183		250	7.6	5.3		8.9
2003	51	85		61	4.0	3.0		4.8
2004	57	271		123	4.8	3.9		4.8
2005	46	92	349	106	3.9	3.1	17.0	3.8
2006	78	141	330	80	6.4	4.6	24.0	6.6
2007	69	110	502	87	8.4	4.0	24.0	7.5
2008	107	400	861	138	5.1	4.0	21.0	5.6
2009	61		650	101	4.3		20.0	5.7
2010	39		172	64	6.6		24.0	8.8
2011	68		466	245	8.5		29.0	9.8
2012	31	125	200	187	5.3	4.9	24.0	8.7
2013	41	190	192	62	6.9	4.7	26.0	8.5
2014	38	160	280	62	5.9	3.8	25.0	7.6
2015	38	148	149	108	5.4	3.8	20.0	7.1
Min.	**21**	**27**	**149**	**35**	**2.1**	**2.3**	**17.0**	**3.8**
Max.	**181**	**400**	**861**	**468**	**11.0**	**5.3**	**29.0**	**9.9**
Mean	**64**	**156**	**377**	**117**	**5.8**	**3.9**	**23.1**	**6.9**

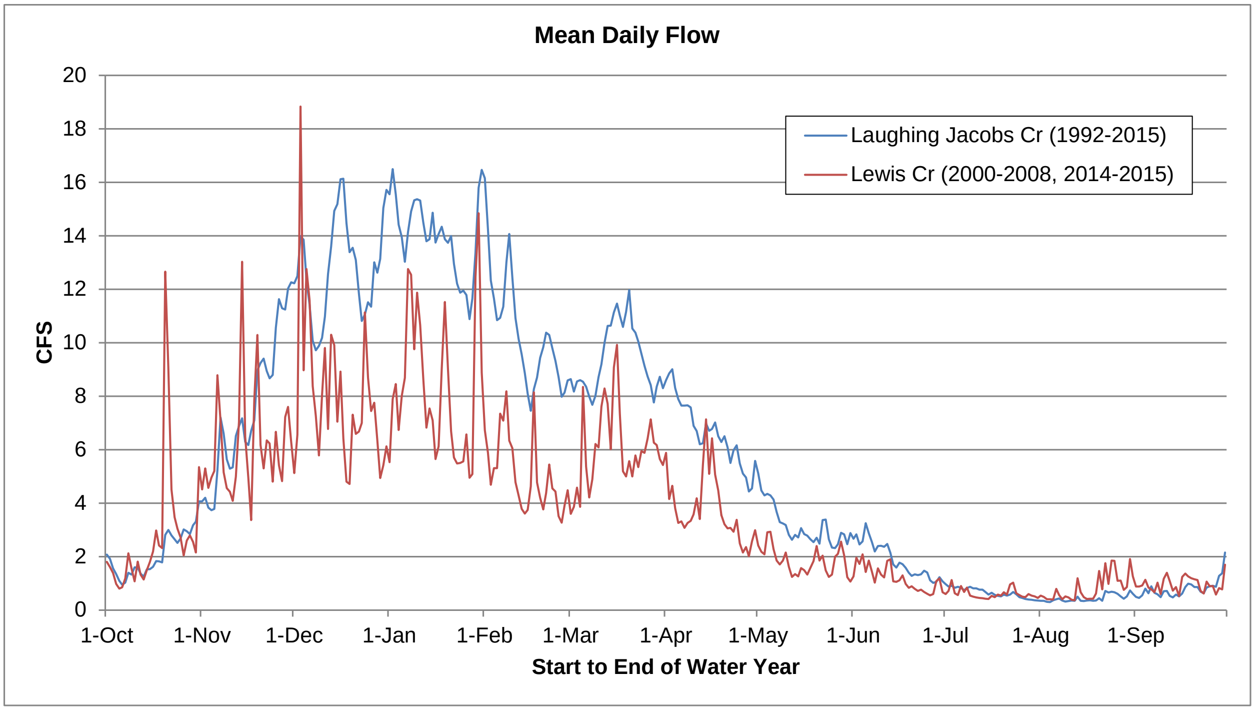

Figure 1. Long-term Mean Daily Flow for Laughing Jacobs and Lewis Creeks.

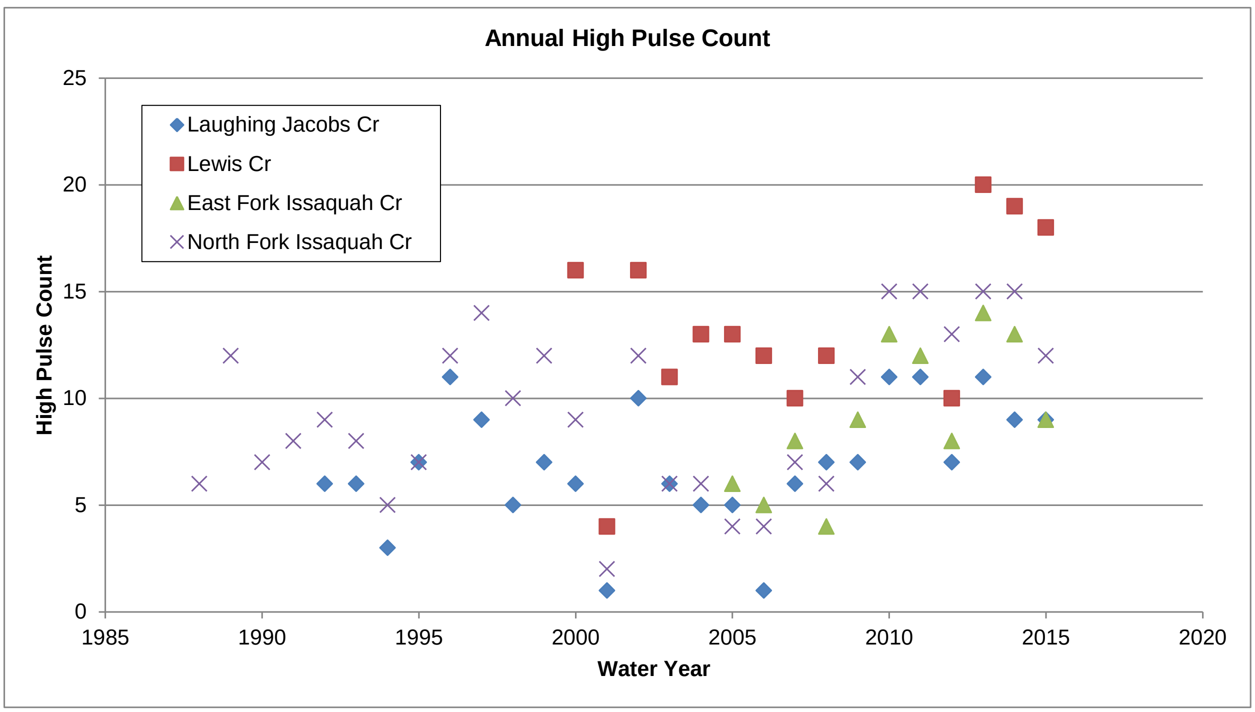

Figure 2. Annual High Pulse Count for Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah Creeks.

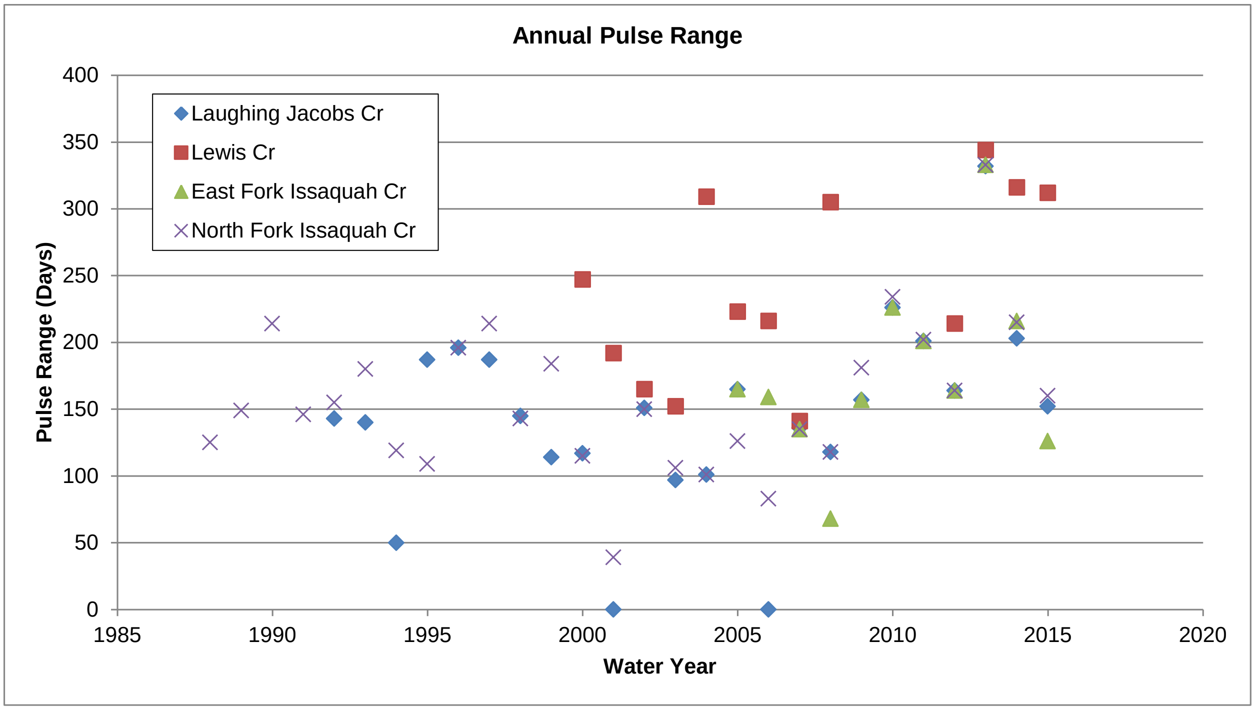

Figure 3. **Annual Pulse Range for Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah Creeks.**

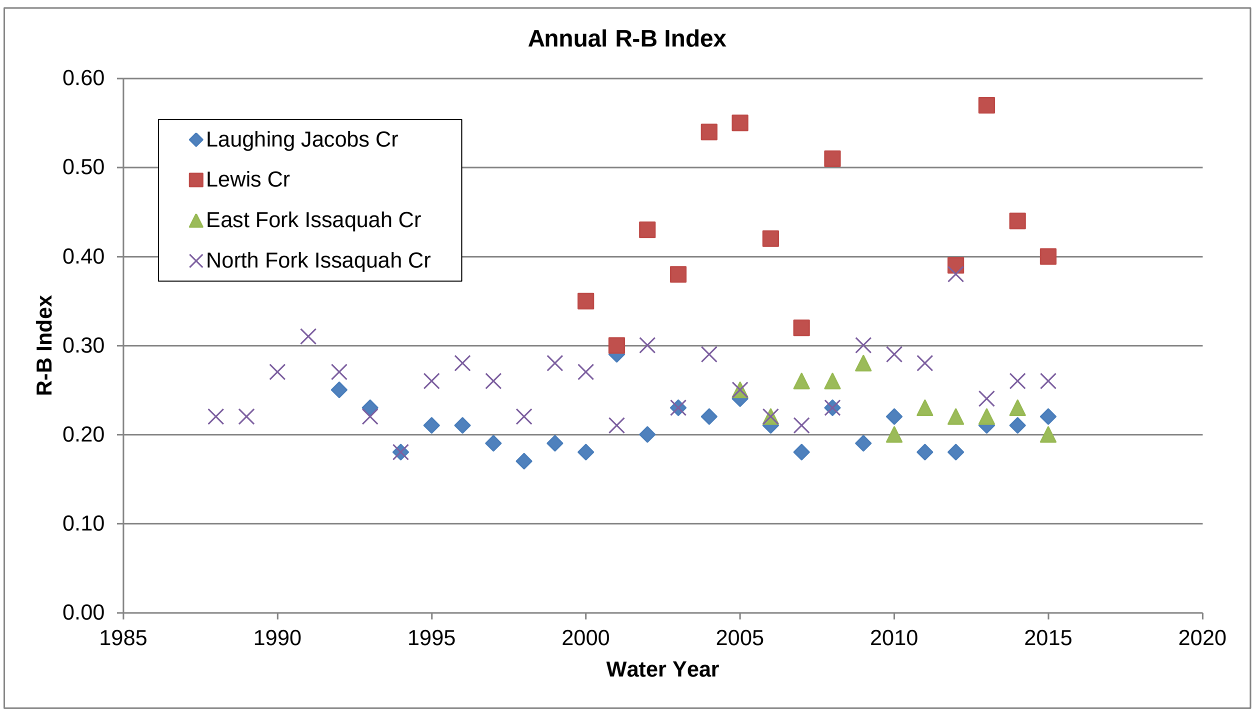

Figure 4. **Annual R-B Index for Laughing Jacobs, Lewis, East Fork Issaquah, and North Fork Issaquah Creeks.**

2.1.4 Stream Water Quality

"Late-run" kokanee are directly affected by stream water quality during November through May, which is the typical spawning, incubation and rearing period. During this period, the water quality variable that can have the most profound effect on kokanee incubation and rearing is fine sediment. Streambed permeability can be significantly impacted by high levels of fine sediment (Wu 2000); incubating eggs require sufficient clean water recharge to both carry away metabolic wastes and provide adequate dissolved oxygen. Fine sediments that embed streambed surface substrates can also entomb kokanee fry as they migrate up from spawning gravels to the water column. A threshold for *O. nerka* of approximately 33% fine sediment (<6.35 mm) in spawning gravels may indicate an increasing risk of embryo mortality (Kondolf 2000 citing others). The monitoring of streambed substrates through bulk coring is not known to have occurred in any "late-run" spawning reaches; however, long-term macroinvertebrate and pebble count data is available that can help indirectly characterize stream substrates critical for spawning kokanee.

The Puget Sound Lowlands Benthic Index of Biotic Integrity (BIBI) is a consistent monitoring tool for evaluating the biological condition of streams throughout the region (King County 2014b). BIBI takes into account numerous macroinvertebrate indicators that are sensitive to changes in stream hydrology, sedimentation, and floodplain function. These are stream variables that tend to be correlated with reduced forest cover, increased road density, and other effects from urbanization. Numerous stakeholders have been collaborating on long-term macroinvertebrate monitoring in the Lake Sammamish watershed for over 18 years, including the cities of Bellevue, Issaquah, and Redmond and King County (see website: http://pugetsoundstreambenthos.org/).

A recent analysis of stream biological condition in the WRIA 8 watershed found that BIBI scores ranged from very low in urban areas to very good in rural areas (King County 2015). The same responses are also found within the Lake Sammamish watershed. Figure 5 – Map of BIBI Monitoring Sites in the Lake Sammamish Watershed shows a gradient of average BIBI scores from sites with 4 or more annual surveys. The lowest scores of biological condition tend to occur in areas with greater levels of urbanization, especially along the west side of Lake Sammamish. The highest scores tend to occur in the undeveloped areas of Issaquah Creek headwaters.

The BIBI analysis includes a metric that is particularly sensitive to fine sediment: "clinger" richness. Macroinvertebrate species characterized as "clingers" forage and seek cover among the interstitial surfaces of streambed substrates. This class of benthic macroinvertebrate depends on stream substrates that are generally free of embedded fine sediments. Figure 6 – Clinger Richness Monitoring shows "clinger" richness scores for a subset of BIBI monitoring sites that overlap current or historic kokanee spawning and rearing reaches. At these sites the percentage of (streambed surface) fine sediment less than 6.35 mm also compliments the assessment of fine sediment (Figure 7 – Pebble Count Monitoring). "Clinger" richness trends are generally stable; however, scores of this metric may be increasing in Laughing Jacobs, Pine Lake, and Vasa creeks. Correspondingly, trends in the proportion of fine sediment less than 6.35 mm may also be declining in these 3 streams. Surface fine sediments may also be declining in George Davis, Idylwood, and Many Springs creeks.

In addition to the macroinvertebrate sampling, Washington Department of Ecology has also performed surveys of stream channel dimension and other physical variables on both Lewis and Idylwood creeks from 2010-2013. Numerous other, discrete surveys in Lake Sammamish tributaries either directly or indirectly describe basic water quality conditions, including: Watershed 1988, Watershed 1992, AMEC 2010a, David Evans 2012, R2 Resource 2012, 48 North 2014, Tetra Tech 2014, Herrera 2015, Osborn 2015, R2 Resource 2015a, R2 Resource 2015b.

Direct and indirect impacts to salmon and salmon habitat from pesticides and other toxins are known to occur. Recent water quality studies conducted in King County streams found that pesticides and metals levels in Lewis Creek may exceed water quality standards (King County 2002, Frans 2004). The analysis of road surface runoff samples taken during July 2015 near Zackuse Creek found elevated levels of copper (25-32 ppb) (Mary Wictor, resident, personal communication). Impacts may occur from both point and non-point sources. The effects from pesticide exposure are known to have adverse impacts to juvenile salmonid behavior and physiology, as well as the macroinvertebrate assemblage they may feed on (Baldwin et al. 2009, Macneale et al. 2010, Macneale et al. 2014). Fish behaviors can be disrupted at concentrations of dissolved copper that are at or slightly above ambient concentrations; dissolved copper is a neurotoxicant that directly damages the sensory capabilities of salmonids at low concentrations (Hecht et al. 2007) although toxicity is also a function of water hardness. Untreated highway runoff is lethal to juvenile and adult coho and their macroinvertebrate prey at very high concentrations (McIntyre et al. 2015, Spromberg et al. 2016). The extent to which these types of impacts affect Lake Sammamish kokanee are not known; impacts may be negligible, para-lethal, or lethal, and chronic or acute to different life stages.

- **Current ecological assessment:** Due to the adverse effects of urbanization and vegetation modification, the concentrations of numerous in-stream water quality parameters are very likely elevated compared to the ranges found at similar reference sites. However, it is unknown if conventional nutrients, pesticides, and related toxins occur in levels that may have measureable effects on salmonid embryo and fry development. Throughout the last 18 years, physical water quality parameters, such as fine sediment, are known to occur at levels sufficient to adversely affect biological condition. Nonetheless, indicators of fine sediment may also suggest an overall stable to improving trend in Lake Sammamish tributaries. As a point of discussion, this long-term monitoring suggests Ebright Creek tends to have elevated concentrations of (streambed surface) fine sediments, but the stream is also a consistent, relatively high producer of juvenile kokanee.
- **Priority:** The mitigation of fine sediment delivery to "late-run" spawning streams due to urban run-off processes is vital; however, at this time, this parameter is

unlikely related to the current variability and trend in kokanee abundance (see additional information in Stream Productivity).

- **Major Knowledge Gaps and Opportunities for Adaptive Management:** Stakeholders should continue to promote conservation actions that restore floodplain processes, reduce delivery of fine sediments and road runoff to spawning streams, and mitigate the effects of altered flow regimes that contribute to in-stream sedimentation.

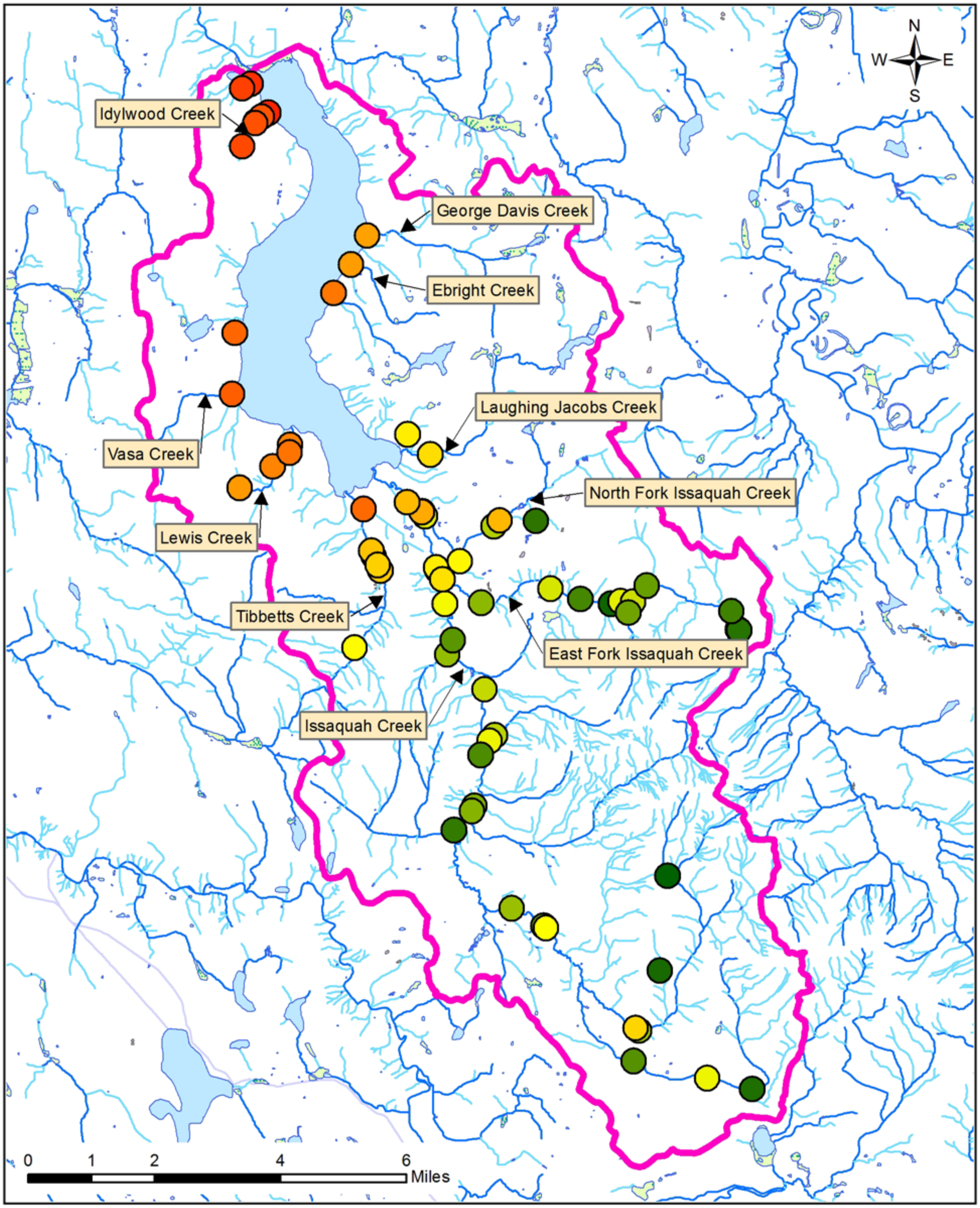

Figure 5. Map of BIBI Monitoring Sites in the Lake Sammamish Watershed. (RED dots indicate sites with lower biological condition; GREEN dots indicate sites with higher biological condition.)

Figure 6. Clinger Richness Monitoring.

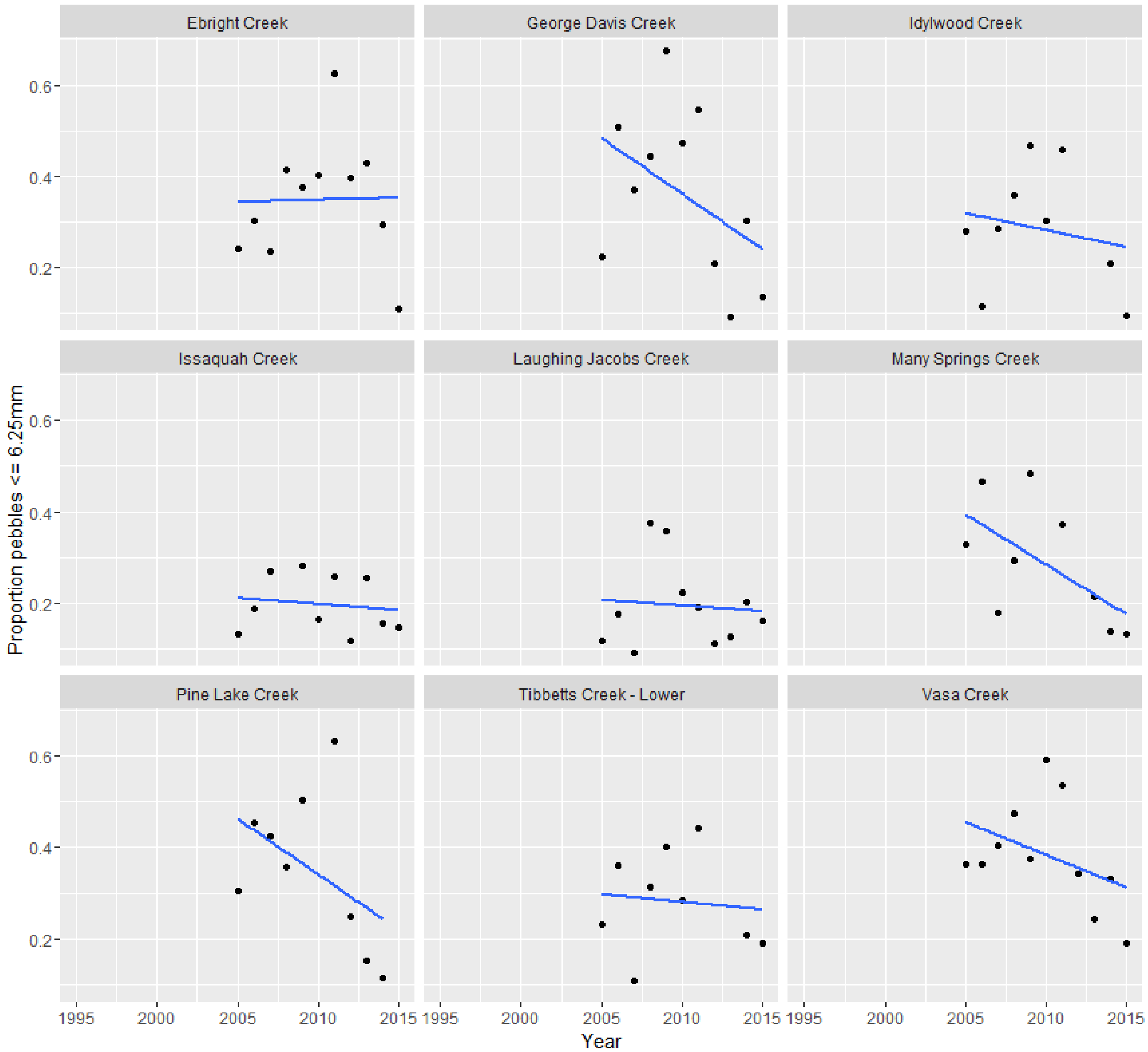

Figure 7. Pebble Count Monitoring.

2.1.5 Stream Productivity

The Bellevue-Issaquah Chapter of Trout Unlimited (BITU) has been performing volunteer monitoring of kokanee fry emigration in the Lake Sammamish basin since 2007. The effort has occurred on Lewis Creek every spring from 2007 to 2016; Ebright Creek from 2010 to 2016; and Laughing Jacobs Creek from 2014-2016. The analysis of this data is described in Lake Sammamish (Late-Run) Kokanee Fry Abundance and Productivity Monitoring (draft, King County unpublished).

Kokanee fry emigration timing and estimated abundance observations are displayed in Figure 8 – Lewis Creek Fry Emigration Observations and Figure 9 – Ebright Creek Fry Emigration Observations. From 2007 to 2010, Lewis Creek appears to have had a peak emigration that generally occurred during early May. Peak emigrations may have shifted earlier toward mid-April after 2010 in both the Lewis and Ebright creek datasets. Long-term records of daily stream temperature profiles in Laughing Jacobs and Lewis creeks (see King County Hydrologic Information Center website: http://green2.kingcounty.gov/hydrology/Default.aspx) are converted to total degree days (Celsius) for the typical spawning, incubation, and emigration period of November through May (Figure 10 – Total Degree Days (Celsius) from November through May in Laughing Jacobs and Lewis creeks). By looking at total degree days across years (with data), the potential rate of incubation may also be compared across years. If the Laughing Jacobs Creek temperature trends during November through May are generally representative of other nearby tributaries, the increasing degree days, especially from 2012 to 2016, may infer a causal relationship with possible earlier peak emigrations.

The extrapolation of fry abundance estimates (Table 4 – Fry Abundance Estimates) from the BITU monitoring is complicated by a high degree of uncertainty due to imprecise measures of trap efficiency. As a result, coefficients of variance of the abundance estimates (for full season trap deployments) range from 38.1% to 92.7%. Fry productivity rates from Lake Sammamish (Late-Run) Kokanee Fry Abundance and Productivity Monitoring (draft, King County unpublished) are shown in Figures 11 - 13. The 95% confidence intervals indicate that actual abundances likely occur within a large range each year, yet the inter-year ranges still provide meaningful information for the project area.

Other factors that may influence stream productivity include spawner density and peak stream flows. A plot of estimated productivity rates and estimated spawner abundance suggests higher productivity in index streams may be more likely when spawner abundance is below 2,000 fish. A density-dependent productivity threshold may occur with 2,000 or more fish, and productivity may decline with high numbers of spawners (Figure 14 – Estimated Productivity Rates and Estimated Spawner Abundance). A theoretical productivity threshold at 2,000 fish is roughly equivalent to 1 spawner per 1.5 linear feet of stream (index streams). High stream flows may also influence productivity. For example, in Lewis Creek, brood years 2006-2007 and 2011-2012 likely exhibited relatively high productivities, and peak flows and high flow pulse counts during those periods were below average. During brood years 2007-2008, 2012-2013, and 2013-2014 productivities appear relatively low, while peak flows and high flow pulse counts were at or above average. This conjecture should be interpreted cautiously due to the uncertainty of the productivity estimates.

- **Current ecological assessment:** Existing stream productivity is likely a function of many of the conditions described in the Stream Hydrology and Stream Water Quality sections. Recent, consistent, relatively low productivity rates in Lewis Creek are notable, but there is an anticipation these rates will rise in response to recent channel and floodplain restoration efforts. Higher productivity rates in all streams are desirable, although the estimated rates and year-to-year fluctuations that have observed through the BITU monitoring are not necessarily unexpected for a salmonid population. The BITU fry abundance monitoring, while lacking in precision, provides valuable insight to egg-to-fry survival in the system. Without the data, the general understanding of stream productivity in the index streams would be a major knowledge gap of the "late-run" population.

- **Priority:** The implementation of conservation strategies to improve egg-to-fry survival rates is vital; however, at this time, this parameter does not appear to be a major component driving the current variability and trend in kokanee abundance.
- **Major Knowledge Gaps and Opportunities for Adaptive Management:** Future fry abundance monitoring by BITU can provide valuable population data, especially in Lewis Creek, where recent channel and floodplain restoration has occurred; monitoring in Lewis Creek also has the potential to provide further understanding of the impacts of altered stream hydrology. Future monitoring by BITU should to be coupled with an improved method for measuring trap efficiency.

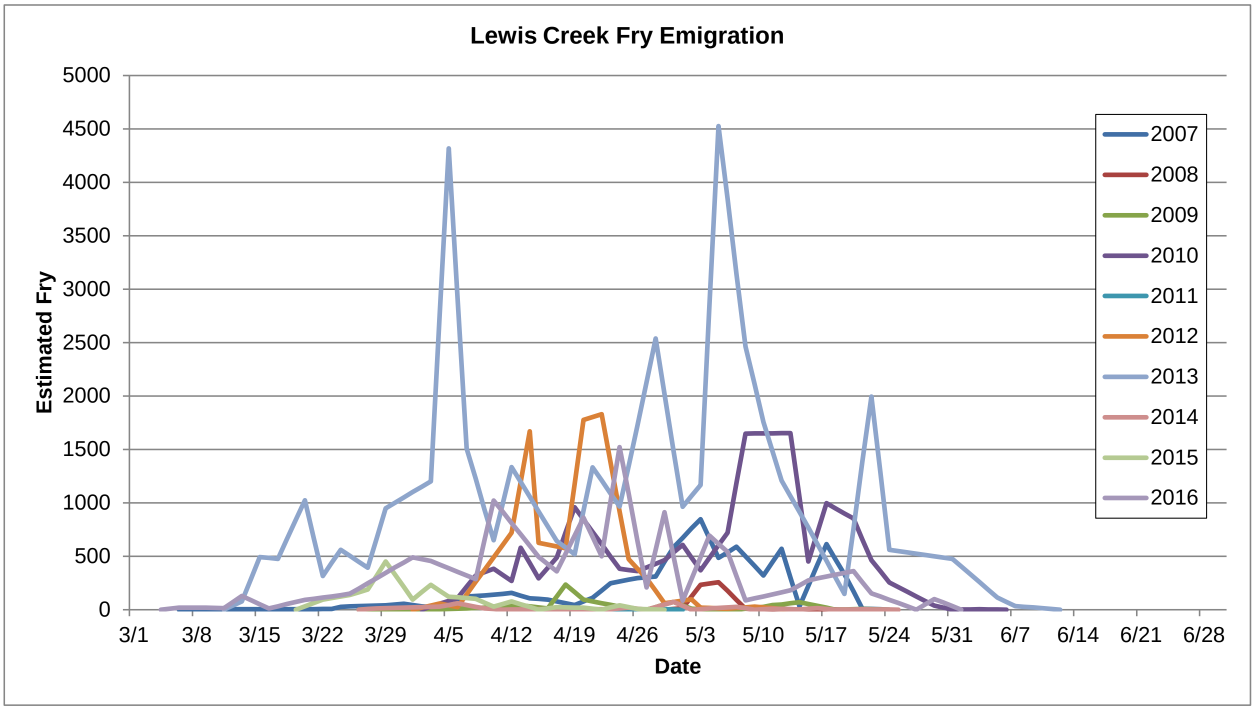

Figure 8. Lewis Creek Fry Emigration Observations.

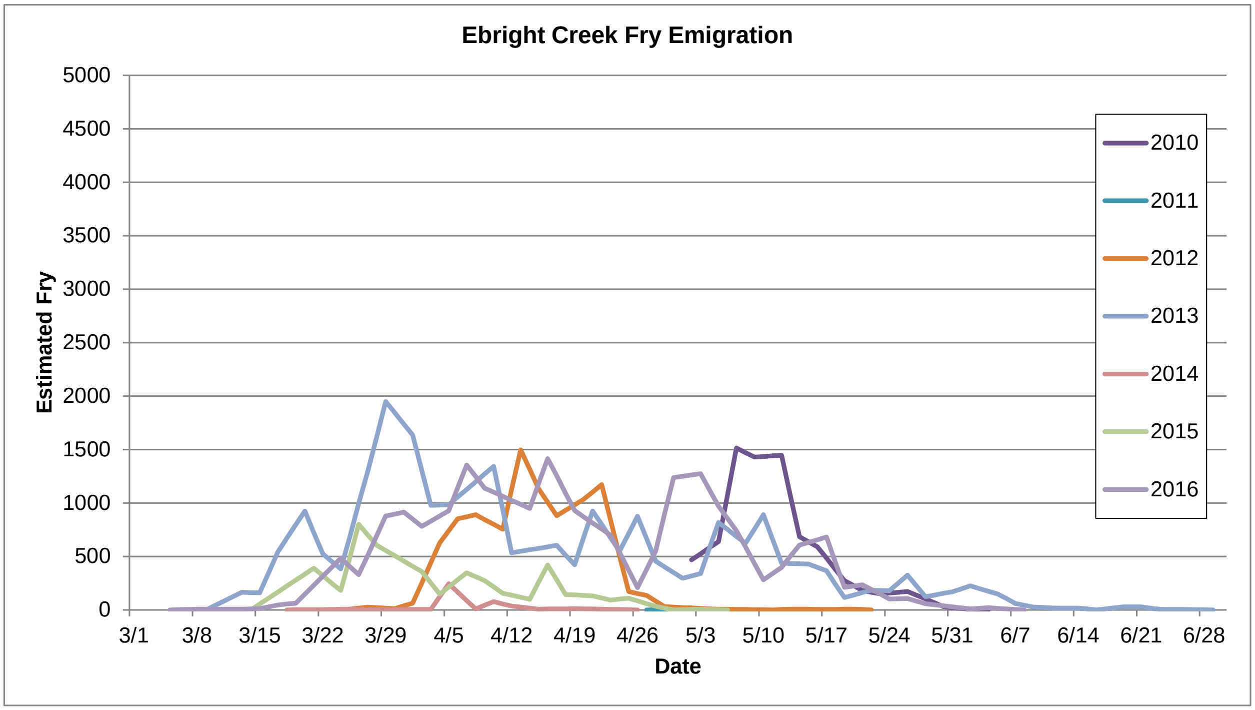

Figure 9. Ebright Creek Fry Emigration Observations.

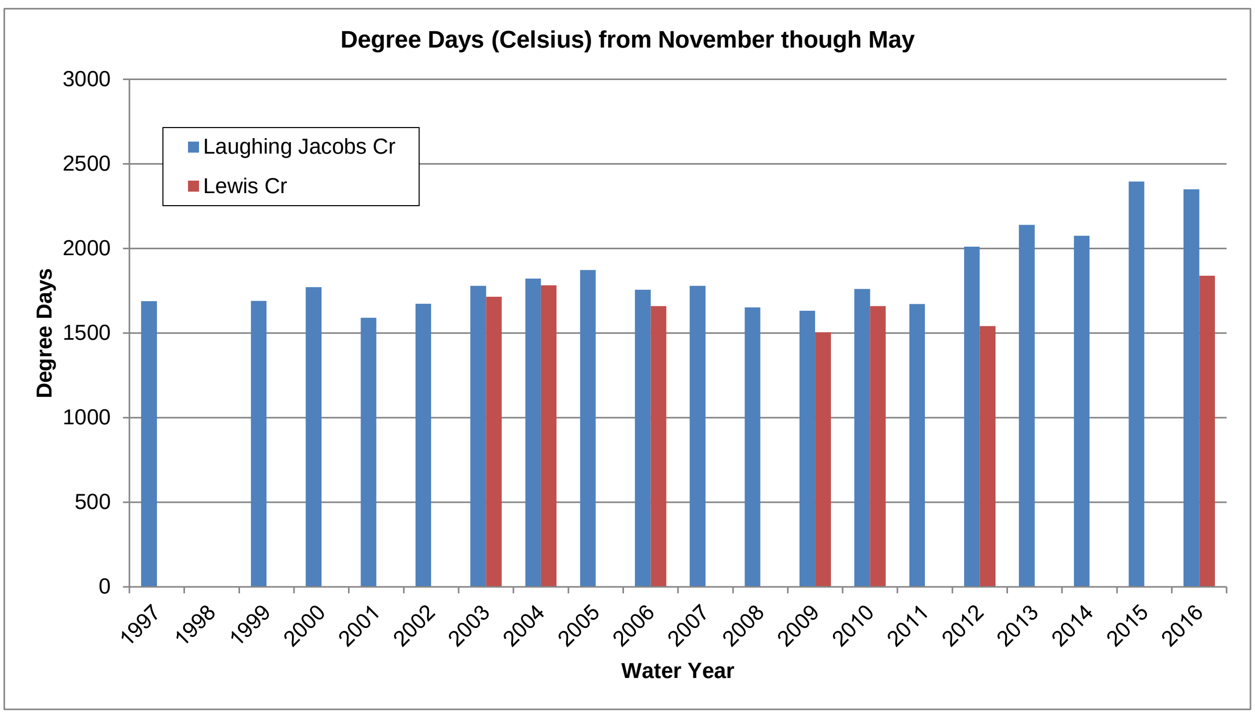

Figure 10. Total Degree Days (Celsius) from November through May in Laughing Jacobs and Lewis creeks.

Table 4. Fry Abundance Estimates.

Stream	Year	Fry Abundance Estimate	95% Confidence Interval, Low	95% Confidence Interval, High	Coefficient of Variance	Note
Lewis Creek	2007	14,478	2,553	26,404	42.0%	
	2008	1,181	195*	2,267	46.9%	* actual count
	2009	1,704	195*	3,298	47.7%	* actual count
	2010	34,273	4,656*	65,988	47.2%	* actual count
	2011	14	2	26	42.3%	
	2012	18,712	1,107*	52,729	92.7%	* actual count
	2013	95,778	5,043*	259,259	87.1%	* actual count
	2014	755	106*	1,539	53.1%	* actual count
	2015	3,820	478*	8,215	58.7%	* actual count
	2016	28,442	2,371*	55,812	49.1%	* actual count
Ebright Creek	2010	35,445	21,316	49,573	20.3%	2x actual estimates
	2011	10	2*	26	79.4%	* actual count
	2012	21,508	3,368*	43,192	51.4%	* actual count
	2013	53,677	7,254*	122,073	65.0%	* actual count
	2014	1,001	156*	2,145	58.3%	* actual count
	2015	11,854	2,832	20,876	38.8%	
	2016	48,568	3,447*	125,137	80.4%	* actual count
Laughing Jacobs Creek	2014	374	81	668	40.0%	2x actual estimates
	2015	6,503	155*	15,764	72.7%	* actual count
	2016	9,195	2,328	16,062	38.1%	

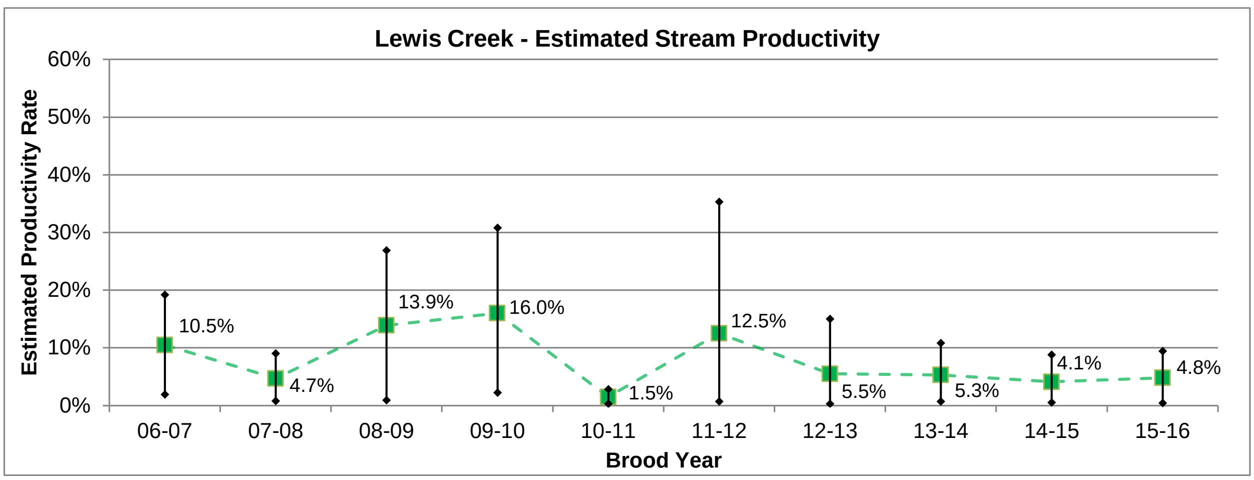

Figure 11. Estimated Stream Productivity in Lewis Creek. (Note: Bars indicate 95% confidence intervals.)

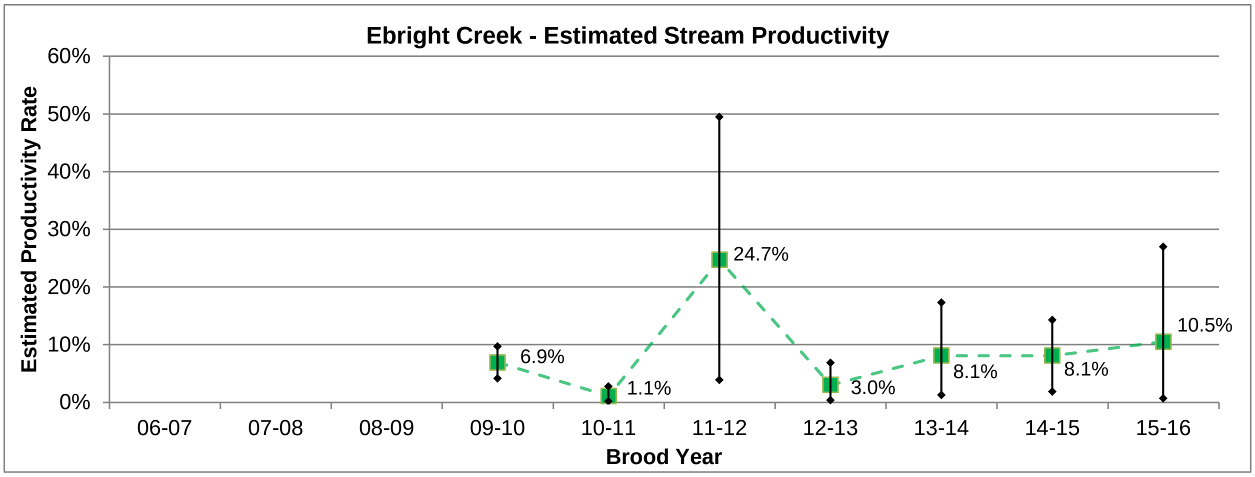

Figure 12. Estimated Stream Productivity in Ebright Creek. (Note: Bars indicate 95% confidence intervals.)

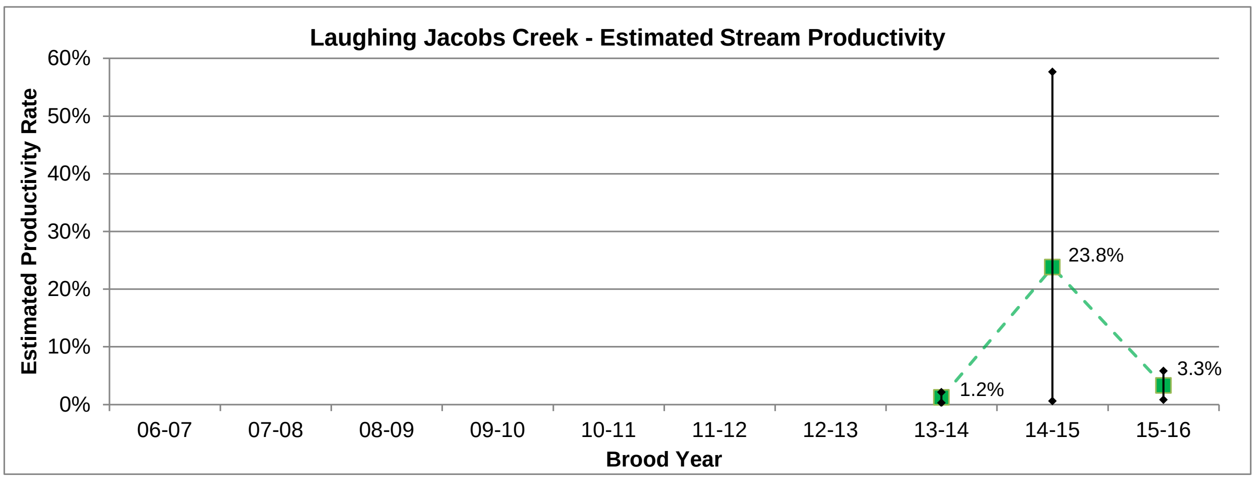

Figure 13. Estimated Stream Productivity in Laughing Jacobs Creek. (Note: Bars indicate 95% confidence intervals.)

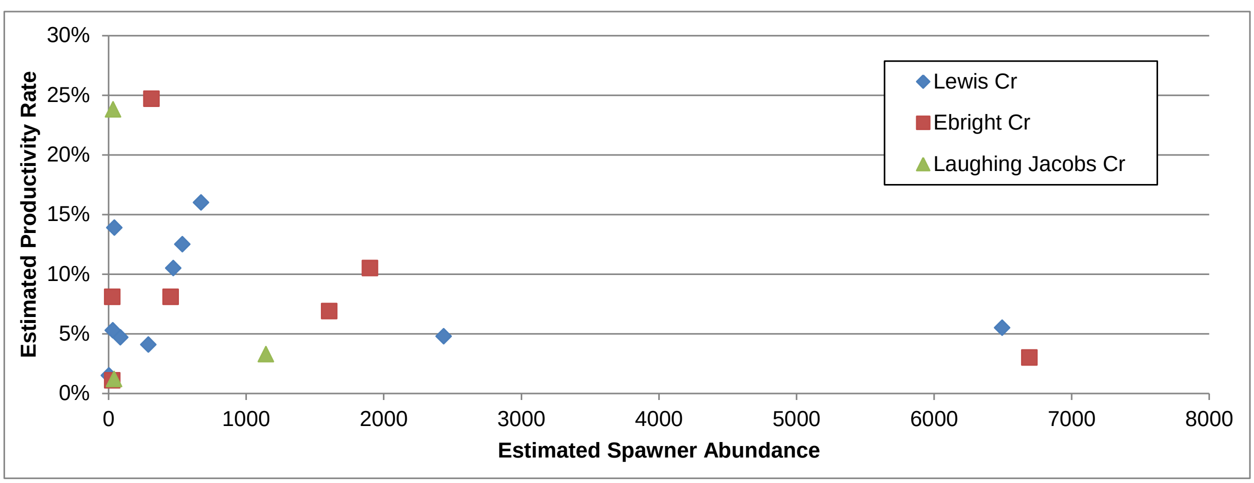

Figure 14. Estimated Productivity Rates and Estimated Spawner Abundance.

2.2 Lake Life Stage: Fry-to-Adult

2.2.1 Lake Water Quality

Monthly, weighted, whole-lake temperatures between 1982 and 2015 (King County 2014a, see King County Lake Sammamish Monitoring Overview website: http://green2.kingcounty.gov/lakes/LakeSammamish.aspx) are shown in Figure 15 – Monthly, Average, Whole-Lake Temperature. The long-term dataset indicates mean, whole-lake temperatures may have increased approximately 0.5 degree Celsius between 1982 and approximately 2005; the overall temperature trend between 2005 and 2015 appears stable.

The actual volume of lake habitat available to kokanee is variable throughout the year due to monomictic stratification and a consequent, so-called temperature-dissolved oxygen (DO) squeeze (Berge 2009, King County 2013). Monomictic stratification is common in lakes within warm temperate zones influenced by oceanic conditions (Wetzel 1983), such as Lake Sammamish. The habitat constriction typically begins in April, peaks in September or October, and dissipates in November. The absolute volume of available habitat during peak stratification may vary according to size class, with fish <100mm being less selective than larger fish (Berge 2009). The volume of available lake habitat for fish >100mm may be reduced by 80-84% during peak stratification (Berge 2009, King County 2013). If local climate warms (compared to an analysis period of 1995-2002), the available habitat for kokanee during peak stratification is also predicted to decline, primarily due to earlier onset of stratification and increased thermal stability (longer stratification) (King County 2013). (See sections Lake Species Assemblage and Biosampling and Movement for more information.)

Two vital elements for lake primary productivity include phosphorous and nitrogen, and the two forms typically measured due their importance in characterizing potential biological metabolism are soluble reactive phosphate (SRP) and nitrate (NO_3). Long-term monitoring (1982-2015) of monthly, weighted SRP (Figure 16 – Monthly, Average, Whole-Lake SRP) and NO_2/NO_3 (Figure 17 – Monthly, Average, Whole-Lake NO_2/NO_3) (King County 2014a, see King County Lake Sammamish Monitoring Overview website: http://green2.kingcounty.gov/lakes/LakeSammamish.aspx) indicate that the concentrations of both nutrients within the lake have declined significantly since the 1980s; observations since 2000 have been relatively stable to slightly declining. Essential micronutrients that are vital for photosynthesis and phytoplankton growth (e.g., iron, sulfur, silica) are not to known to occur in biologically limiting concentrations in Lake Sammamish (King County, unpublished data).

Between 1982 and 2011 the pH in the epilimnion and metalimnion of Lake Sammamish showed no trend; the pH of the hypolimnion decreased slightly over the same period (King County 2014a).

The most current 303(d) list approved by the Environmental Protection Agency suggests that Lake Sammamish is impaired due to DO depletion, elevated levels of polychlorinated biphenyls (PCBs), and elevated bacterial loads (see Washington Department of Ecology website: http://www.ecy.wa.gov/programs/wq/303d/currentassessmt.html). The original listing for DO was a result of low concentrations in the hypolimnetic zone, which also results in the release of sediment phosphorus and may have been exacerbated by human-caused influences. The most recent analysis of total phosphorous in Lake Sammamish indicates that sediment phosphorus release rates have declined significantly since the original listing data was developed in 1981 (King County 2014a).

Determined from a 2006 analysis, mercury concentrations in Lake Sammamish peaked during World War II production efforts but have declined significantly since then. (Lake bed core sampling indicates concentrations during World War II were over 4x levels found in year 1880.) Current levels may be approximately 1.5x 1880 levels and may remain slightly elevated due to the "global reservoir" of atmospheric mercury (Furl 2007).

Direct and indirect impacts to salmon and salmon habitat from pesticides and other toxins are known to occur. Impacts may occur from both point and non-point sources. The effects from pesticide exposure are known to have adverse impacts to juvenile salmonid behavior and physiology, as well as the macroinvertebrate assemblage they may feed on (Baldwin et al. 2009, Macneale et al. 2010, Macneale et al. 2014). Fish behaviors can be disrupted at concentrations of dissolved copper that are at or slightly above ambient concentrations; dissolved copper is a neurotoxicant that directly damages the sensory capabilities of salmonids at low concentrations (Hecht et al. 2007) although toxicity is also a function of water hardness. Untreated highway runoff is lethal to juvenile and adult coho and their macroinvertebrate prey at very high concentrations (McIntyre et al. 2015, Spromberg et al. 2016). The extent to which these types of impacts affect Lake Sammamish kokanee are not known; impacts may be negligible, para-lethal, or lethal, chronic or acute, to different life stages.

- **Current Ecological Assessment:** Relatively small changes in yearly, peak seasonal lake temperatures may compound the adverse biological impact to kokanee by the temperature-DO squeeze. The long-term, foreseeable trend of SRP and NO_3 concentrations is likely stable. The magnitude of any near-term changes may not significantly alter primary productivity, and the current trends in nutrient load would not be expected to support an overall increase in primary productivity in the near-term. If both nutrient load and lake temperature are relatively stable in the near-term, the magnitude and duration of seasonal dissolved oxygen fluctuations would also be expected to be relatively stable in the near-term. At a minimum, a low level of chronic exposure of kokanee to pesticides and other toxins is likely occurring; actual impacts may or may not be measureable or detectable.
- **Priority:** The implementation of conservation strategies to improve lake water quality is vital; however, at this time, the monthly and year-to-year fluctuations of water quality parameters do not appear to be well-correlated to the current variability and trend in kokanee abundance.

- **Major Knowledge Gaps and Opportunities for Adaptive Management:** The King County freshwater toxins monitoring program in Lake Sammamish (also proposed in Pfeifer 1995) could be expanded to include kokanee samples; pre-spawn adult kokanee could be evaluated for chronic exposure during the lake life stage.

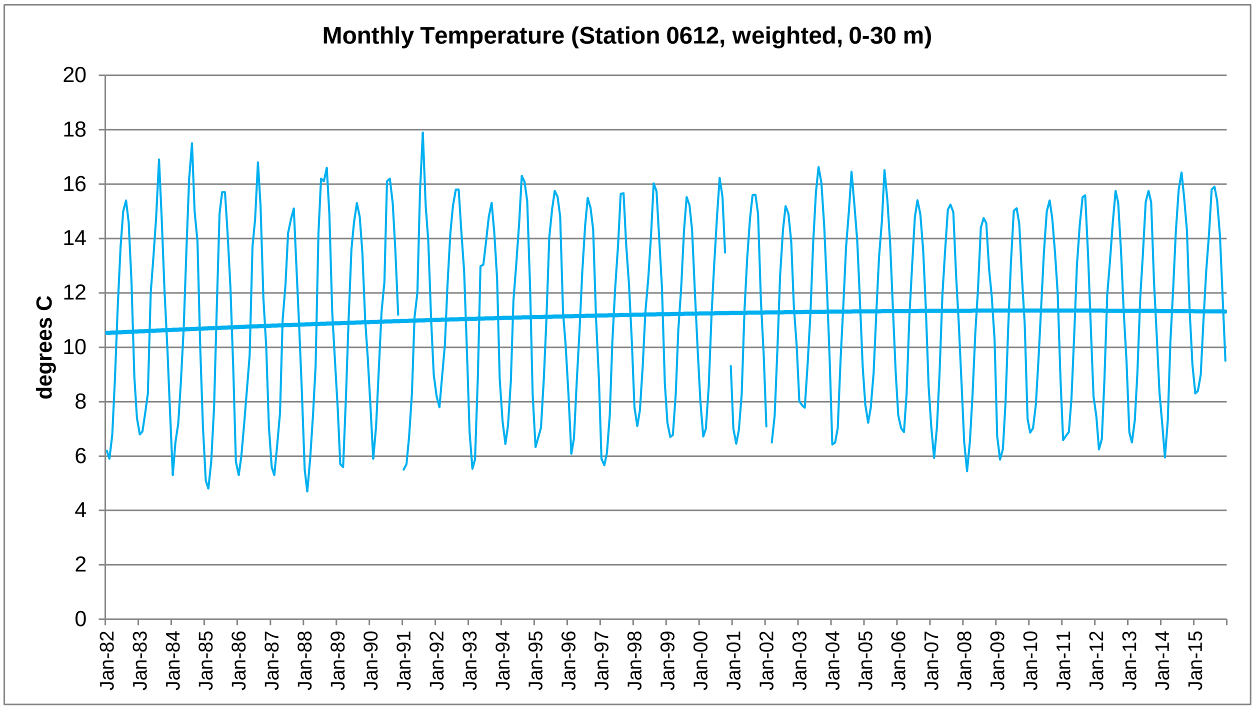

Figure 15. Monthly, Average, Whole-Lake Temperature.

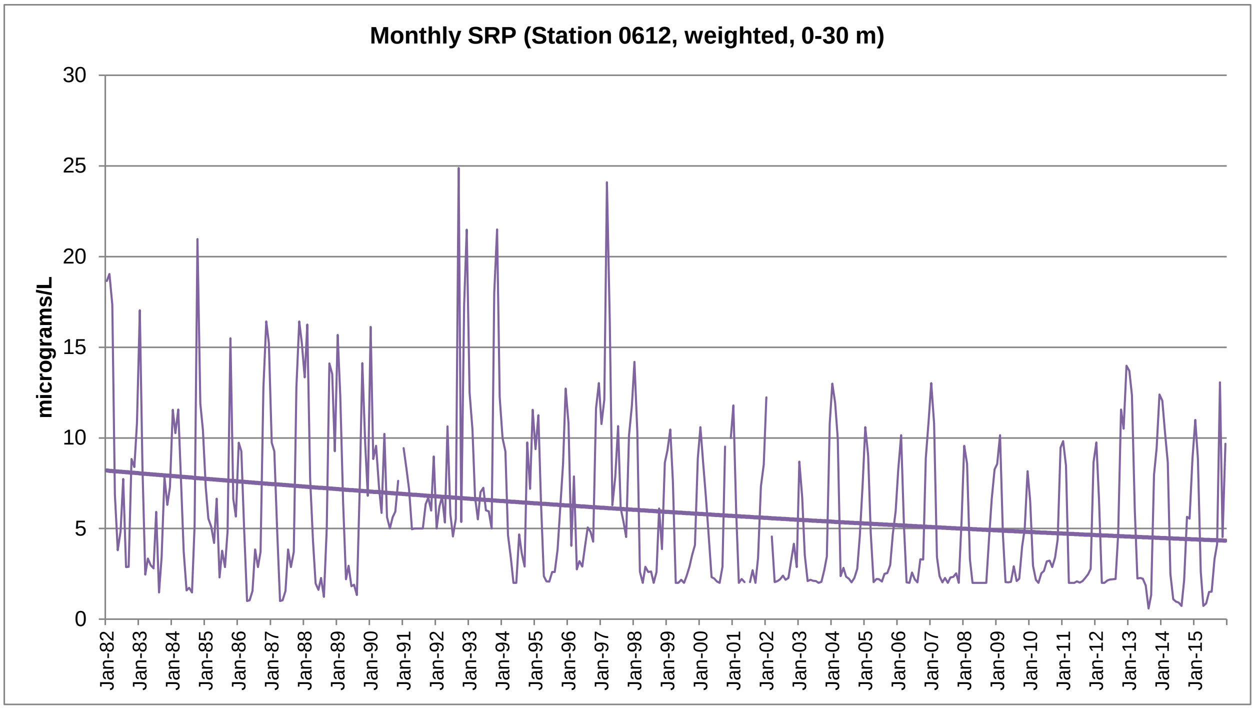

Figure 16. Monthly, Average, Whole-Lake SRP.

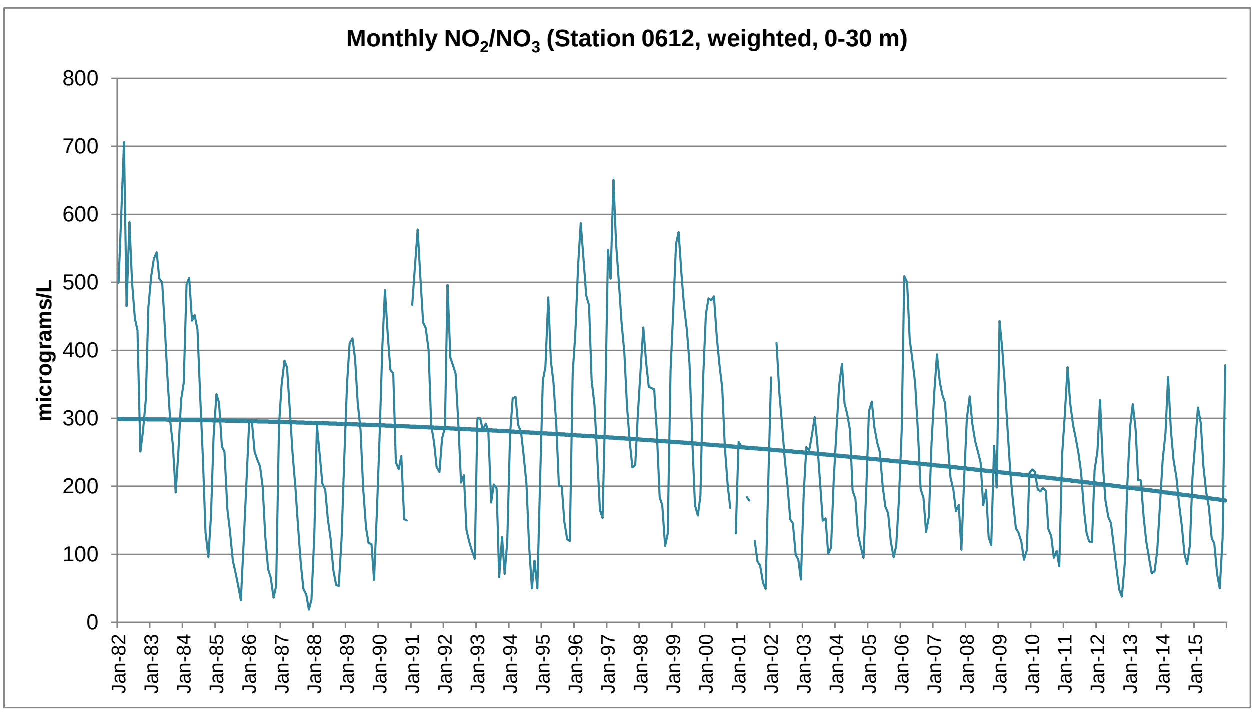

Figure 17. Monthly, Average, Whole-Lake NO_2/NO_3.

2.2.2 Lake Primary Productivity and Zooplankton

Historic trends in Lake Sammamish primary productivity can be estimated through the analysis of lake bed sediment cores. Sediment core analysis indicates a 2- to 3-fold increase in primary productivity in the lake occurred between a period defined as "pre-1905" and the mid-1970s (Birch 1976, Birch et al. 1980). A complimentary analysis found diatom productivity and net deposition of phosphorus in Lake Sammamish approximately doubled between 1860 and 1977; nutrient enrichment peaked between 1940 and 1950 (Lazoff 1980).

Monthly lake sampling of chlorophyll *a* has occurred regularly since 1982 (see King County Lake Sammamish Monitoring Overview website: http://green2.kingcounty.gov/lakes/LakeSammamish.aspx). Total phytoplankton samples were collected and analyzed semi-regularly from 2003 through 2013; zooplankton sampling has occurred semi-regularly since 1997 (King County, unpublished data). The most complete dataset for these measures occurs at Station 0612 near the center of the lake. Zooplankton sampling and analysis (University of Washington) from 1997 to 2002 includes organism count and length only; translating these metrics for comparison with newer data is beyond the scope of this Ecological Survey. Zooplankton sample collection since 2004 has been performed by King County; however, the analysis of samples collected since 2011 has not yet been performed.

The long-term trend in chlorophyll *a* concentration, measured by aggregating samples between depths of 0-10 meters, is likely stable (Figure 18 – Monthly, Average, Composite Chlorophyll *a* [0-10m]). Observations of seasonal chlorophyll *a* concentration do not appear to correlate well with seasonal fluctuations in SRP or NO_3. Inter-year variability in peak concentration is high; concentrations of chlorophyll *a* may or may not be cyclical (e.g., successive years of relatively low or high peak concentrations). Chlorophyll *a* concentration is a practical indicator for phytoplankton biomass (Figure 19 – Monthly, Average, Phytoplankton Biomass [0-10 m]). The biomass of phytoplankton available for zooplankton grazing during peak periods may vary 2- to 3-fold among years.

Observations of peak response of total zooplankton biomass (Figure 20 – Monthly, Average, Total Zooplankton Biomass) and the subset of *Daphnia* biomass (Figure 21 – Monthly, Average, Total *Daphnia* Biomass) tend to lag peak chlorophyll *a* concentration approximately 1 to 3 months. Based on the limited zooplankton dataset (2004-2010), observations of peak total zooplankton biomass generally correlate to peak chlorophyll *a* concentration. Observations of *Daphnia* biomass suggest this metric inconsistently correlates total zooplankton biomass. Two qualifications of these zooplankton samples include: (1) the sampling methodology and equipment likely precludes the capture of very large species, such as *Mysis*, which has been observed to be approximately 20% of kokanee diet (Berge 2009), and (2) all samples are taken from a single point in the lake.

Lake Sammamish kokanee sampled during 2003 suggest *Daphnia* appear to be at least 50% of the annual diet of fish smaller than 300 mm, except during winter; *Daphnia* appear to be at least 50% of the annual diet of kokanee larger than 300 mm, except during both autumn and winter; *Daphnia* appear to be the most important prey item of kokanee in Lake Sammamish across all size classes and seasons (Berge 2009). Based on zooplankton samples from 2002 and 2003 and a modeled population of 8,200 age-1, 3,100 age-2, 1,158 age-3, 434 age-4, and 162 age-5 fish, kokanee consume more than 50% of the estimated monthly standing crop of *Daphnia* during February, March, and through December (Berge 2009).

Although the zooplankton dataset is limited there may be sufficient observations to detect an irregular, bimodal response in both total zooplankton and *Daphnia* biomass. The irregular response may occur at depths between 0-10 m and 10-20 m during the so-called temperature-DO squeeze (Berge 2009, King County 2013). Blue arrows in Figure 20 – Monthly, Average, Total Zooplankton Biomass and Figure 21 – Monthly, Average, Total *Daphnia* Biomass may highlight periods of overlap between a secondary pulse of total zooplankton and *Daphnia* biomass within depths 10-20 m and the period of habitat constriction during the temperature-DO squeeze. Orange arrows may highlight periods when a secondary pulse of total zooplankton and *Daphnia* biomass within depths 10-20 m did not occur during the temperature-DO squeeze. To further explore this irregular bimodal event, monthly average Daphnia densities are shown for depths 0-10 m (Figure 22 – Monthly, Average, *Daphnia* Density [0-10 m]) and 10-20 m (Figure 23 – Monthly, Average, *Daphnia* Density [10-20 m]). Average *Daphnia* density during September, a critical period during the temperature-DO squeeze, is relatively low within the 10-20 m zone; however, observations of infrequent, but high, *Daphnia* densities appear to occur during this period and at this depth.

On Lake Pend Oreille, ID, kokanee fry survival rates appear to be directly related to total zooplankton density and the size of *Daphnia* (Paragamian and Bowles 1995). In a Colorado reservoir, temperature regime, primary productivity, and overstocking were shown to have an interacting regulatory role in kokanee population dynamics, independent from pressures of predatory lake trout (Martinez and Wiltzius 1995).

- **Current Ecological Assessment:** Yearly, seasonal chlorophyll *a* concentrations and related phytoplankton production in Lake Sammamish are highly variable. The zooplankton datasets are insufficient to draw conclusions; however, sufficient information is available to merit further analysis. Consequent total zooplankton and *Daphnia* biomass are also highly variable, but the two measures do not appear to be consistently correlated. Infrequent, but high, *Daphnia* densities within 10-20 m during the temperature-DO squeeze may facilitate significantly reduced mortality to kokanee during this critical period.
- **Priority: HIGH.** The further analysis of phytoplankton and zooplankton variability in Lake Sammamish can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance; i.e., should we expect a high variability in spawner abundance - due to a subsequent high variability of annual lake mortality rates related to variable prey bases at critical periods?
- **Major Knowledge Gaps and Opportunities for Adaptive Management:** This assessment is qualitative; a detailed analysis could be performed to support trend

and correlation assumptions of chlorophyll *a*, phytoplankton, total zooplankton, *Daphnia*, and other measures. The potential relationship between the high variability of seasonal phytoplankton and zooplankton biomass and the high variability of kokanee abundance (and other species abundance) should be further analyzed.

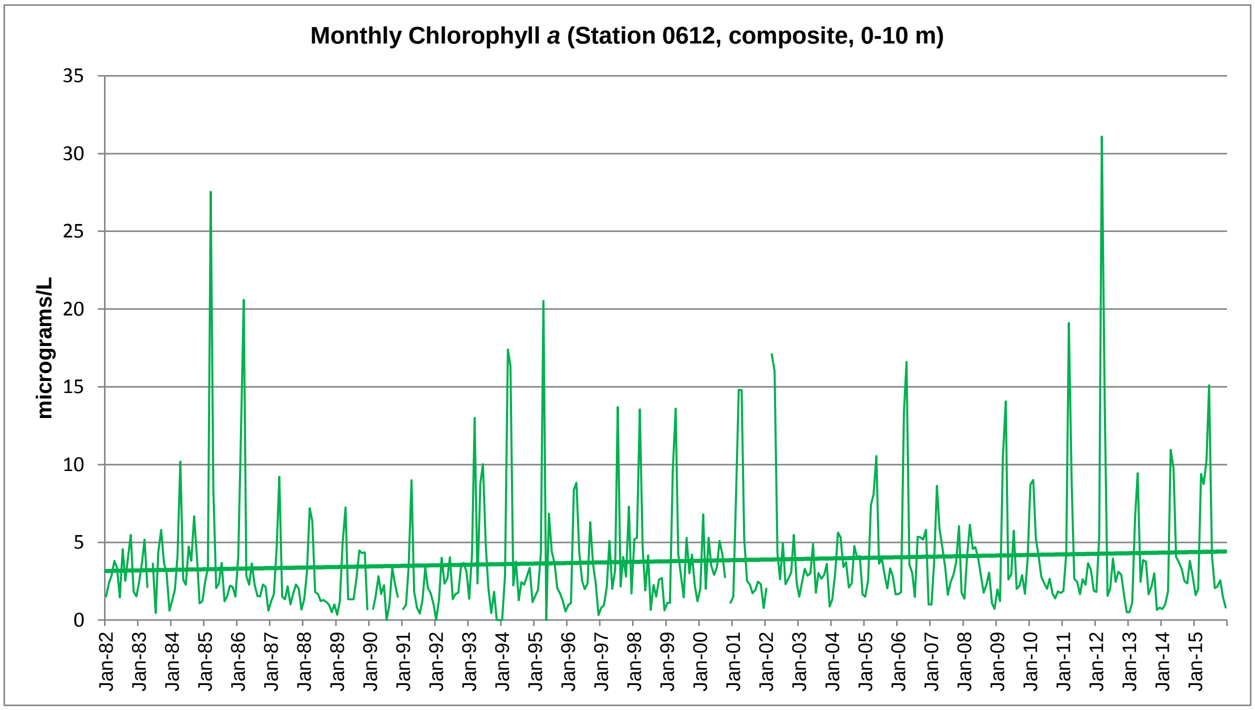

Figure 18. Monthly, Average, Composite Chlorophyll *a* (0-10m).

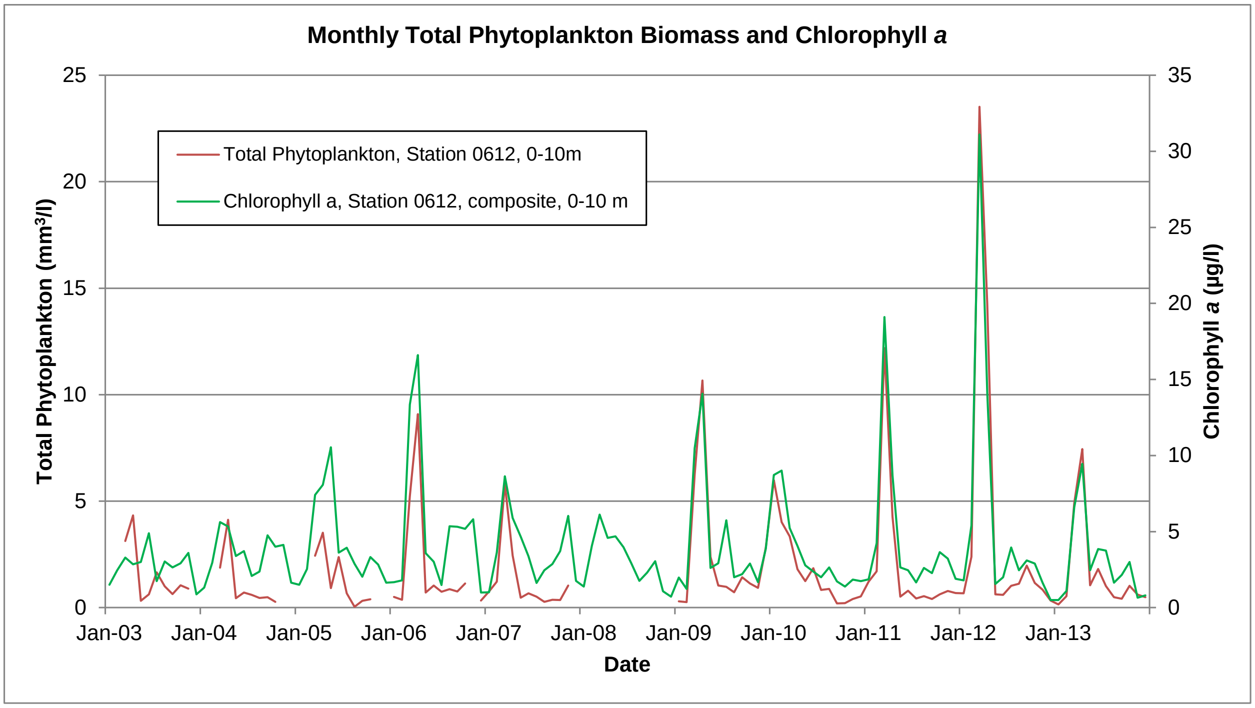

Figure 19. Monthly, Average, Phytoplankton Biomass (0-10 m).

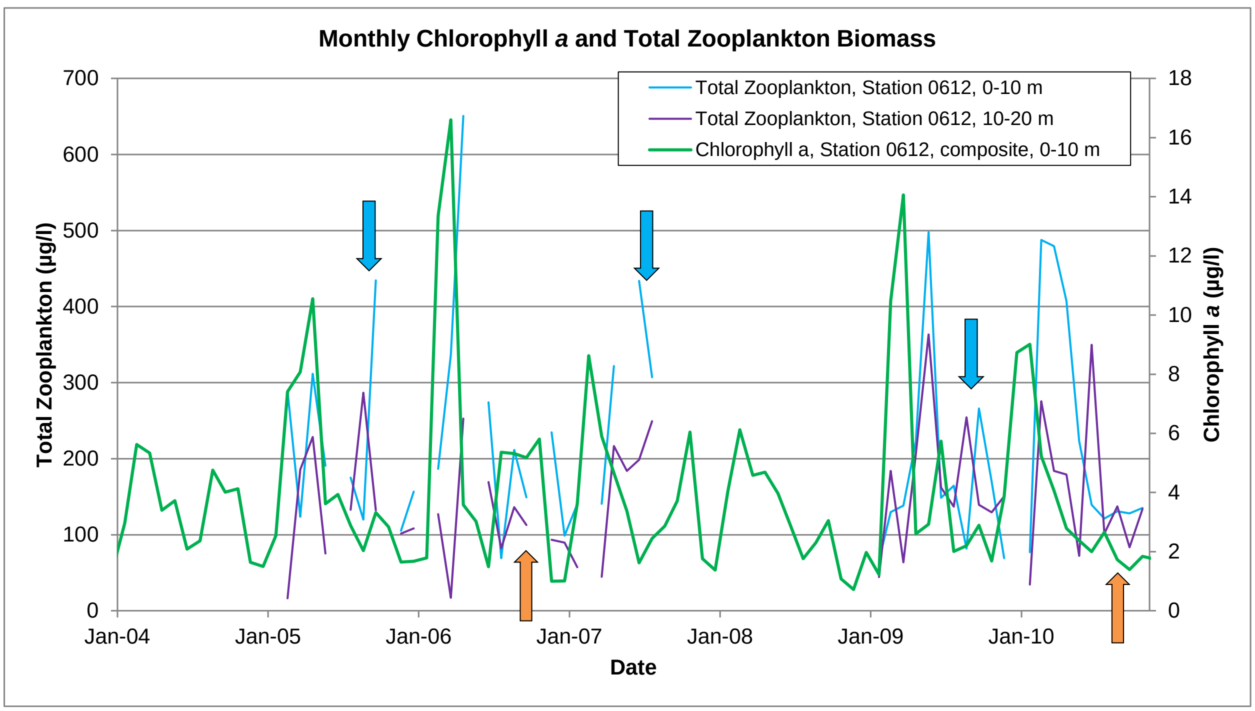

Figure 20. Monthly, Average, Total Zooplankton Biomass. (Note: Regarding arrows, see narrative on page 30.)

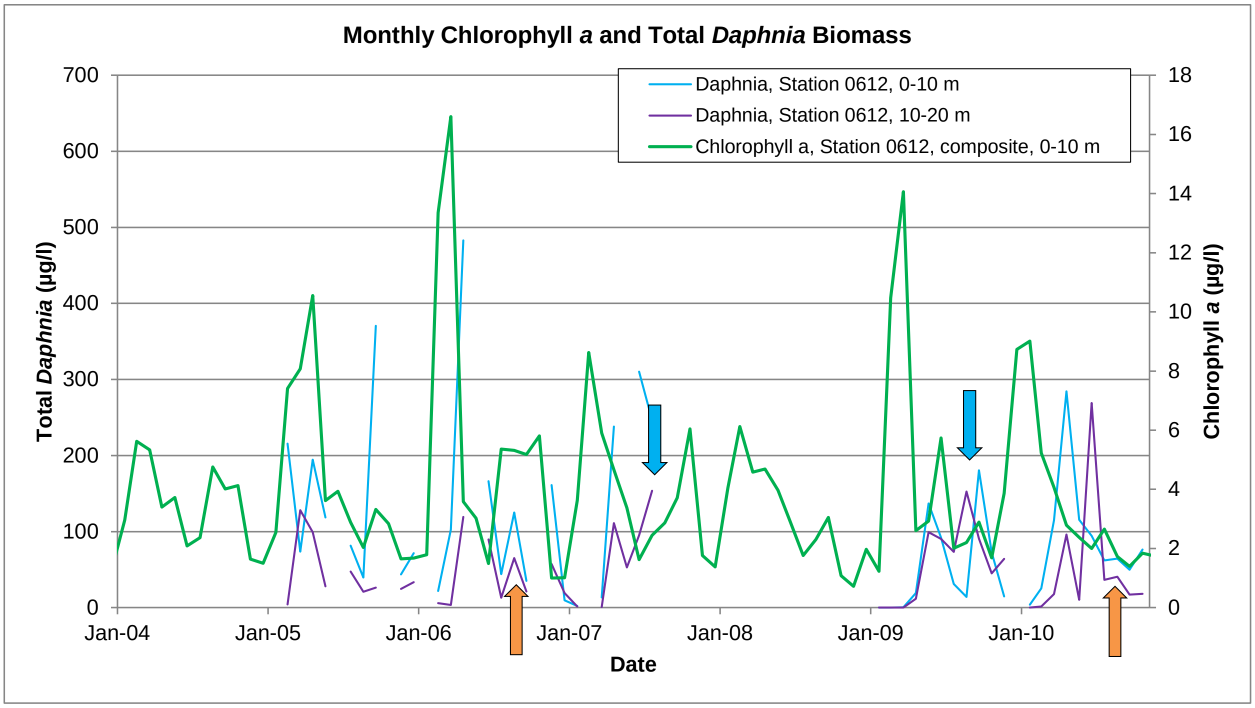

Figure 21. Monthly, Average, Total *Daphnia* Biomass. (Note: Regarding arrows, see narrative on page 30.)

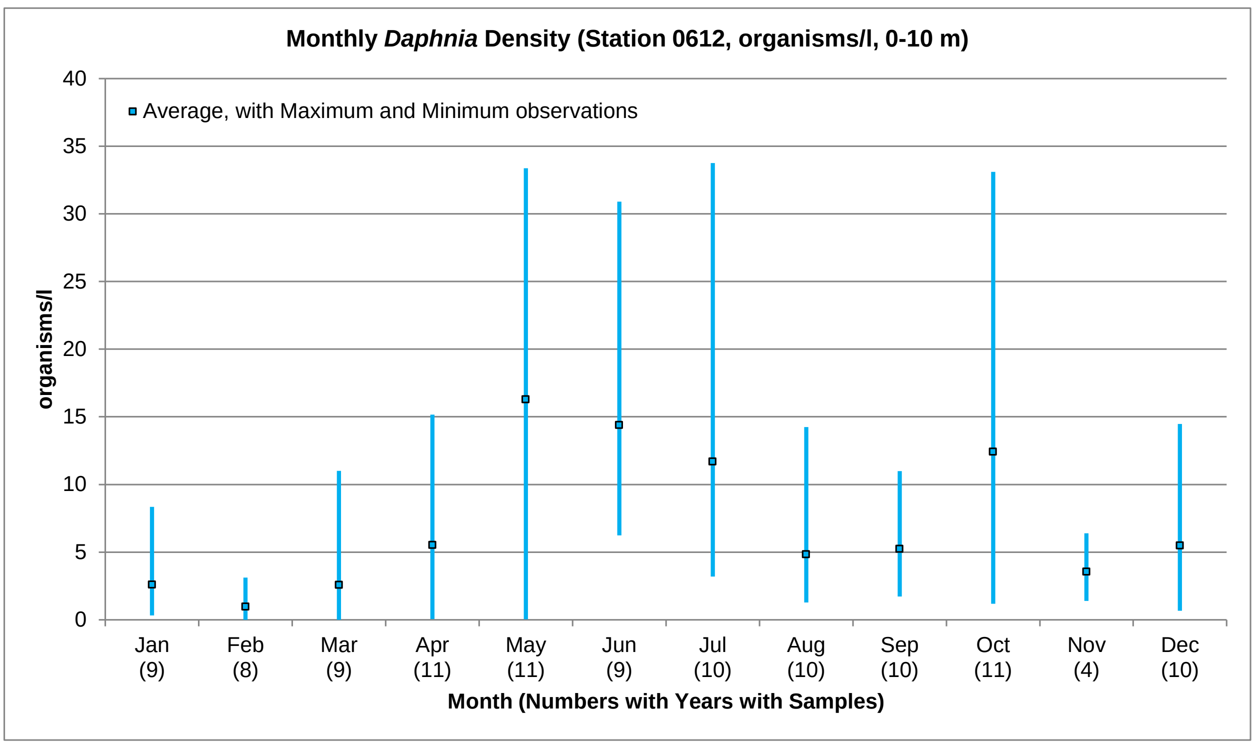

Figure 22. Monthly, Average, *Daphnia* Density (0-10 m).

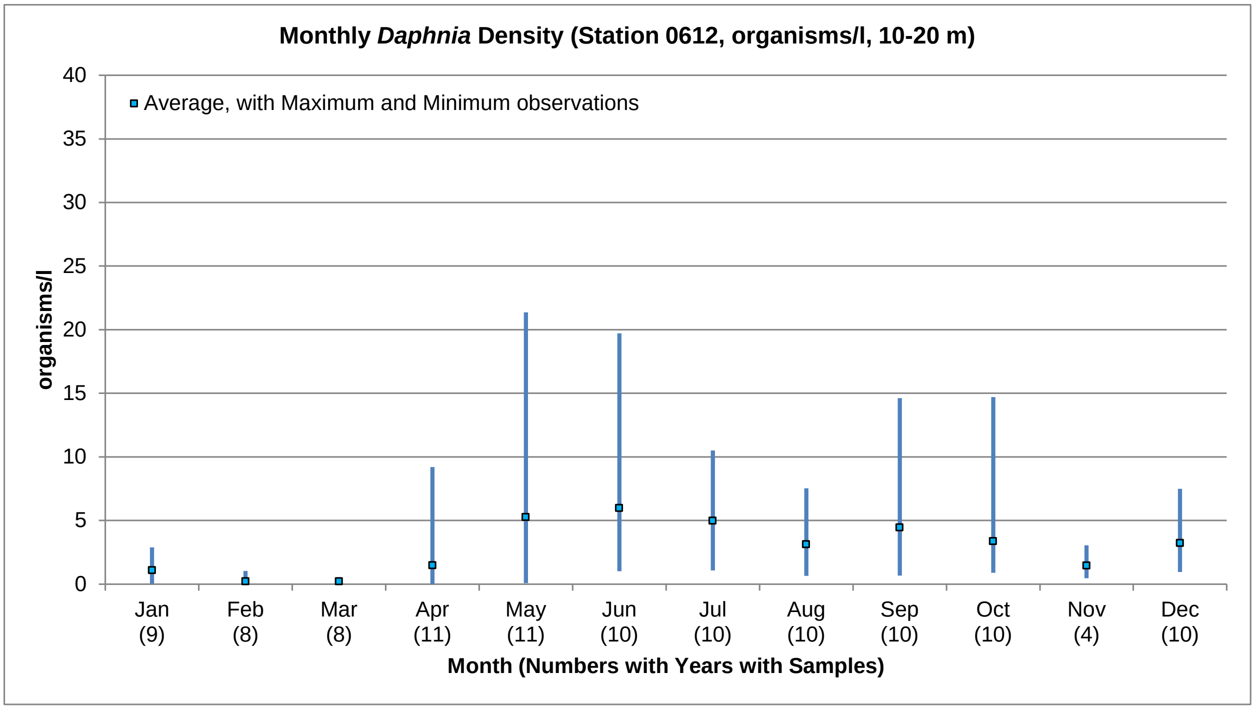

Figure 23. Monthly, Average, *Daphnia* Density (10-20 m).

2.2.3 Lake Pathogens and Other Factors

The incidence and magnitude of viral, bacterial, and parasite pathogens involving Lake Sammamish kokanee are not well understood. The early attention to potential pathogens includes accounts of thousands of "early-run" kokanee reportedly trapped and killed in Issaquah Salmon Hatchery ponds during the 1960s and 1970s due to concerns over potential disease transmission (Pfeifer 1981). These concerns were erroneously thought to be a potential threat to hatchery stocks (HDR 2009 citing Coyle et al. 2011). The extent of current monitoring of viral and bacterial pathogens includes assays of "late-run" spawners utilized in the supplementation program.

Type 4a viral hemorrhagic septicemias (VHSV) is thought to infect *O. nerka* in the Pacific Northwest and appears to have been a concern since the first detections in the region during the early 1980s (Pfiefer 1981, Bartholomew et al. 2011). Live fish with the disease may appear either lethargic or over active; deceased fish may have pale gills, bloated abdomens, fluid-filled body cavities, and external and internal hemorrhaging. Yellow perch may be particularly susceptible to the virus (Bartholomew et al. 2011). It is unknown if outbreaks of this virus have occurred in Lake Sammamish.

Infectious haematopoietic necrosis (IHN) is a viral disease affecting most species of salmonid fish reared in fresh water, including *O. nerka*. Fry are particularly susceptible to the disease and outbreaks of IHN may range from explosive to chronic; losses in acute outbreaks can exceed several per cent of the population per day and cumulative mortality may reach 90–95% or more (OIE 2016). Good fish health seems to decrease susceptibility to IHN, and fish become increasingly resistant to infection with age until spawning, when they once again become highly susceptible and may shed large amounts of the virus in sexual products (OIE 2016). The prevalence of IHN in spawning *O. nerka* in reaches with highly concentrated redds can lead to significant mortality in emerging juveniles (Traxler and Rankin 1989); however, large-scale infections and disease outbreaks under natural conditions appear unlikely when a natural density of eggs and alevins occurs (Mulkahy and Bauersfield 1983). Follett and Burton (1995) found that stressful environmental conditions and high fish density may have precipitated IHN disease outbreaks in *O. nerka* in a lake system with a supplementation program. Similarly, Ogut and Reno (2004) also found that IHN (in *O. mykiss*) may only be a threat to alevins and fry in freshwater when fish are at high densities, such as in a hatchery environment. The capacity of the IHN virus to reside in asymptomatic hosts supports a virus carrier hypothesis and could have significant epidemiological consequences towards maintaining and spreading IHN among susceptible host populations (Müller et al. 2015).

WDFW has been analyzing ovarian fluid and kidney/spleen samples from kokanee brood stock used in the supplementation program since 2010 (Table 5 – Virology Results from Supplementation Program). Positive results for IHN were detected in spawners during all return years 2010-2011 through 2013-2014; results were all negative during 2014-2015 and 2015-2016. During years with IHN detections, all positive results generally occurred during the last two-thirds of the spawner return period. Three of the four return years with positive IHN detections are also years with positive recruitment (see section Escapement, Recruitment, and Lake Productivity); both return years with negative IHN results are also years with negative recruitment.

Bacterial epidemics in wild fish populations are uncommon, although the most well-known epidemics involve furunculosis caused by the bacterium *Aeromonas salmonicida* (Miller et al. 2014). The condition can be acute to chronic and is often fatal. It is unknown if outbreaks of this bacteria have occurred in Lake Sammamish.

Adult kokanee in Lake Sammamish are frequently observed with infections of the ectoparasite *Salmincola californiensis*. Pre-spawn mortality due to extreme gill infection appears uncommon but has been observed during escapement surveys (King County unpublished data). The life history of the copepod includes six stages: the copepodid stage (free-swimming), four chalimus stages (development and molting while attached to a host), and an adult stage (still attached to a host) (Kabata 1973). The copepods tend to be more abundant in the pectoral and pelvic fin region of smaller fish; in larger fish the branchial cavity is the most common attachment site. Macroscopic and microscopic mechanical damage to the fish tissues resulting from the presence and activity of the copepod comprises injuries to gills, skin, muscle, and even bone (Kabata 1977). Importantly, crowding of salmonids in a low DO, relatively warm environment may promote high loads of the parasite (Sutherland and Wittrock 1985, Vigil et al. 2016). Potentially due to habitat preference or gill raker size, juvenile kokanee may not be as vulnerable to infection as other salmonid juveniles (Monzyk et al. 2015).

Secondary bacterial infections from *Flavobacterium columnare* have been observed on *O. nerka* where extensive gill trauma occurred due to *S. californiensis* (Haman 2016). Bacterial gill disease associated with *F. columnare* is often fatal.

Bacterial kidney disease caused by *Renibacterium salmoninarum* may occur in salmonids susceptible to infection. The disease may cause low growth rates in juvenile salmonids (Turgut et al. 2008); chronic infections within populations may cause persistent low-level mortality. However, studies also suggest that recovery from the infection can occur in freshwater (Sandell et al. 2015).

Parvicapsula minibicornis and *Ceratomyxa shasta* are myxozoan parasites that rely on a polychaete, *Manayunkia speciosa*, as an intermediate host (Bartholomew et al. 2007). The lifestage of the parasites that is infectious to salmonids (actinospore) is released from infected polychaetes, which then infect a salmonid. The next stage (myxospore) is then released from the salmonid fish and infects a polychaete worm completing the life cycle (Bartholomew et al. 1997, Haman 2016). The host polychaete, *M. speciose*, may tend to occur in sandy to silty substrates or algae mats associated with eddies, pools, and other low flow areas (Mackie and Qadri 1971, Bartholomew et al. 2006). The actinospores of *C. shasta* enter a fish host's gills and migrate through the circulatory system to the intestine where they develop into myxospores; lethality appears to be associated with water column spore density (Hallet et al. 2012). *P. minibicornis* has recently been found in the Lake Washington drainage, where it was responsible for significant pre-spawn mortality event of *O. nerka* (Haman 2016). It is unknown if *C. shasta* also occurs in the drainage; however, both parasites tend to have overlapping distributions.

The trematode *Nanophyetus salmincola* infects juvenile salmon as a second intermediate host in fresh water. Several studies have demonstrated the ability of *N. salmincola* to increase mortality in infected juvenile salmonids (Jacobson et al. 2008).

Artificial lighting may be another factor affecting both juvenile and adult kokanee. This impact is known to modify the behavior of juvenile salmonids that migrate along shallow, shoreline areas or in zones intersecting well-lit bridges; this effect mechanism may be a catalyst for elevated predation of juvenile fish. Artificial lighting may also impact juvenile and adult kokanee by affecting the movement of zooplankton prey. Spending the bulk of fry-to-adult life stages in the mid-water, pelagic areas of Lake Sammamish, it is unknown if "late-run" kokanee are affected by artificial lighting in many of the same ways as other salmonids in urbanized environments. High predation of emigrating juvenile *O. nerka* in well-lit stream areas has been observed in nearby Cedar River (Tabor et al. 2004).

- **Current ecological assessment:** Very little is known of the numerous pathogens and parasites that affect kokanee in Lake Sammamish. Epidemics that affect kokanee may be chronic or acute; many epidemics are likely cyclical and may further be a function of fish density. It is plausible that the high variability of spawner abundance is at least partially attributable to one more lake pathogens or parasites. Alternatively, the same processes may effect predator populations, which may have positive effects on kokanee abundance. Potential direct or indirect pathways through which artificial lighting may impact kokanee – chronic or acute – are unknown.

- **Priority:** **HIGH.** The further analysis of pathogens and parasites in Lake Sammamish can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance.
- **Major Knowledge Gaps and Opportunities for Adaptive Management:** WDFW is expected to expand their pathology analysis to include bacterial sources of disease. This additional information will greatly expand the understanding of these issues. Stakeholders should also reach out to other area specialists, such as the USGS Fish Health Group. Five considerations for virology and bacteriology analysis involving kokanee include:
    1. Continue with this type of analysis regardless of the long-term status of the supplementation program.
    2. This analysis could potentially be expanded to include in-stream kokanee spawners, in addition to the brood stock collected for the supplementation program.
    3. The virology and bacteriology analysis could also be expanded to in-lake kokanee sampled during the temperature-DO squeeze and other periods of stress or relative high density.
    4. Expand the analysis program to kokanee predator populations, such as coastal cutthroat trout and yellow perch.
    5. Perform presence/absence surveys for the polychaete, *Manayunkia speciosa*, especially in lower Issaquah and Tibbetts creeks, stream deltas at the lake confluence, and other potential preferred habitats.

    If in-stream remote incubators are used in the future as part of the supplementation program, spawned eggs used for this conservation strategy should be disinfected using a standard iodine bath protocol prior to placement in the incubator.

    Furthermore, a research opportunity could be the evaluation of the ecological significance of the very low abundance and recruitment periods; i.e., are the cycles of very low kokanee abundance and recruitment a vital natural regulator of viral and bacterial impacts to the population?

Table 5. Virology Results from Supplementation Program.

SOURCE	DATE	RESULTS	NUMBER OF SAMPLES			
			Ovarian Fluid	OF Pools	Kidney/ Spleen	K/S Pools
Ebright Creek	11/10/10	*negative*	1	1	1	1
Laughing Jacobs/Lewis Creeks	11/17/10	*negative*	7	3	7	2
Ebright Creek	11/30/10	**IHNV**	3	1	3	1
Laughing Jacobs Creek	12/02/10	**IHNV**	3	1	3	1
Lewis Creek	12/10/10	*negative*	1	1	1	1
Laughing Jacobs Creek	11/03/11	*negative*	3	1	5	2
Lewis Creek	11/03/11	*negative*	2	1	4	2
Ebright Creek	11/07/11	*negative*	1	1	3	1
Laughing Jacobs Creek	11/07/11	*negative*	2	1	4	1
Lewis Creek	11/07/11	*negative*	2	1	4	1
Laughing Jacobs Creek	11/16/11	*negative*	6	2	13	4
Lewis Creek	11/16/11	*negative*	7	2	13	4
Ebright Creek	11/21/11	*negative*	5	1	10	2
Ebright Creek	11/28/11	*negative*	14	3	28	6
Laughing Jacobs Creek	11/28/11	**IHNV**	9	2	18	4
Lewis Creek	11/28/11	**IHNV**	7	2	14	4
Ebright Creek	12/05/11	**IHNV**	9	2	18	4
Laughing Jacobs Creek	12/05/11	**IHNV**	1	1	3	1
Lewis Creek	12/05/11	**IHNV**	1	1	3	1
Ebright Creek	12/21/11	**IHNV**	2	1	4	1
unspecified Lake Sammamish tributary	11/05/12	*negative*	18	4	38	10
unspecified Lake Sammamish tributary	11/06/12	*negative*	0	0	4	4
Ebright Creek	11/14/12	*negative*	2	1	4	1
Laughing Jacobs Creek	11/14/12	*negative*	3	1	6	2
Lewis Creek	11/14/12	*negative*	6	2	12	3
Ebright Creek	11/19/12	**IHNV**	16	4	32	7
Laughing Jacobs Creek	11/19/12	**IHNV**	17	4	34	8
Lewis Creek	11/19/12	**IHNV**	5	1	12	3
Ebright Creek	11/26/12	**IHNV**	6	2	12	4
Laughing Jacobs Creek	11/26/12	**IHNV**	2	1	4	2
Lewis Creek	11/26/12	**IHNV**	3	1	7	2
unspecified Lake Sammamish tributary	11/21/13	*negative*	7	2	14	3
Lewis Creek	12/02/13	**IHNV**	2	1	4	1
unspecified Lake Sammamish tributary	11/6/14	*negative*	6	2	15	4
Ebright Creek	11/12/14	*negative*	8	2	16	4
Lewis Creek	11/12/14	*negative*	2	1	6	2
unspecified Lake Sammamish tributary	11/20/14	*negative*	9	2	19	4
unspecified Lake Sammamish tributary	11/25/14	*negative*	7	3	16	4
unspecified Lake Sammamish tributary	12/1/14	*negative*	10	2	20	4
unspecified Lake Sammamish tributary	12/11/14	*negative*	5	2	11	3
unspecified Lake Sammamish tributary	12/29/14	*negative*	6	2	10	2
unspecified Lake Sammamish tributary	11/9/15	*negative*	3	1	6	2
unspecified Lake Sammamish tributary	11/16/15	*negative*	15	4	31	8
unspecified Lake Sammamish tributary	11/24/15	*negative*	20	4	48	9
unspecified Lake Sammamish tributary	12/3/15	*negative*	25	5	30	6
unspecified Lake Sammamish tributary	12/15/15	*negative*	5	1	10	2

2.2.4 Lake Species Assemblage

The estimated native and current assemblages of fish species in Lake Sammamish are described in Table 6 – Fish Assemblage. Prior to European settlement in the region, the native fish predators that likely had regulatory effects on kokanee include coastal cutthroat trout and northern pikeminnow; both species, especially coastal cutthroat trout, continue to be important predators (Berge 2009). Smallmouth bass were introduced to Lake Washington in the 1860s; yellow perch may have been introduced during the 1890s. Today, approximately 12 introduced fish species occur in the Lake Sammamish watershed, all of which are expected to occur predominantly within the lake itself. At least half of the introduced species would be expected to be potential predators of kokanee fry, especially in littoral areas as fry enter the lake. Today, yellow perch is likely the most common, introduced predator of fry to subadult kokanee. The current population status and predatory impact of walleye is unknown.

Very few efforts to describe the fish assemblage of Lake Sammamish have been performed. Creel surveys starting in the 1940s (Pfeifer 1992) had a tendency to only characterize target recreational fisheries. Recent surveys by the Muckleshoot Indian Tribe have targeted walleye presence and abundance. Recent efforts to describe fish assemblage and predation appear to be limited to surveys during 2002 and 2003 and described in Berge (2009). In this analysis, coastal cutthroat trout were observed consuming kokanee at much higher rates during the temperature-DO squeeze than other periods; yellow perch were also found in very high numbers and may also be a significant predator of kokanee. The estimated rate of kokanee fry consumption by coastal cutthroat trout in Lake Sammamish found in Berge (2009) may be lower than that found a similar system (Lake Ozette) (Beauchamp et al. 1995), which could be a result of accompanying coastal cutthroat trout predation on yellow perch.

During 2009, average depth data from tagged kokanee, coastal cutthroat trout, and smallmouth bass suggest the 3 species may respond differently to the temperature-DO squeeze (see section Lake Water Quality). While subadult kokanee tended to stay between 16 and 18 meters from August through September, coastal cutthroat trout appeared to hold in a shallower, warmer zone between 10 and 12 meters. Kokanee overlap with smallmouth bass did not appear to occur until the onset of winter, beginning with the deterioration of the temperature-DO squeeze in October (Berge et al. 2013). The marked diel separation of kokanee and coastal cutthroat trout observed during the 2009 temperature-DO squeeze does not appear to be consistent with inferred species overlap found in the 2002 and 2003 predation study (Berge 2009).

The predation of "late-run" kokanee fry by juvenile coho released from Issaquah Salmon Hatchery has been a concern. Kokanee fry, also produced at Issaquah Salmon Hatchery, (see section Supplementation Program) have been routinely released well before or after coho releases in an attempt to prevent overlap of the species and potential predation. Between 1998 and 2009, an average of 442,257 juvenile coho were released between March 28 and April 21; between 2010 and 2015, an average of 453,653 juvenile coho were released on May 10. During 2016, the release date for 520,502 juvenile coho was moved earlier to April 30 (Darin Combs, Issaquah Salmon Hatchery, personal communication).

- **Current ecological assessment:** The detailed analysis of fish species composition and interactions in Lake Sammamish has essentially occurred only once (Berge 2009), and the state of current populations in the lake may be changing significantly since that study. Both coastal cutthroat trout and yellow perch are likely ongoing, important regulators of kokanee abundance; this could change dramatically depending on whether future walleye abundance remains low or increases. If population trends of kokanee, coastal cutthroat trout, and yellow perch are at least partially responsive to one other, new predation effects from increasing walleye abundance could have a profound impact on predator-prey relationships in the lake. The predation rate of kokanee fry by juvenile coho and Chinook released from Issaquah Salmon Hatchery is unknown.
- **Priority: HIGH.** An updated analysis of predator status, predation rates, and bioenergetics in Lake Sammamish can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance.
- **Major Knowledge Gaps and Opportunities for Adaptive Management:** Vital research opportunities exist to better understand predator niches in the Lake Sammamish, especially a more thorough understanding of coastal cutthroat trout, yellow perch, and walleye status and trends.

Table 6. Fish Assemblage.

Common name	Scientific name	Native to Lake Sammamish (prior to European settlement)	Native to region but not known to have historically occurred in Lake Sammamish	Introduced
Western brook lamprey	*Lampetra planeri*	X		
Coastal cutthroat trout	*Oncorhynchus clarki*	X		
Sockeye salmon (kokanee)	*Oncorhynchus nerka*	X		
Mountain whitefish	*Prosopium williamsoni*	X		
Bull trout	*Salvelinus confluentus*	X		
Peamouth	*Mylocheilus caurinus*	X		
Northern pikeminnow	*Ptychocheilus oregonensis*	X		
Longnose dace	*Rhinichthys cataractae*	X		
Speckled dace	*Rhinichthys osculus*	X		
Largescale sucker	*Catostomus macrocheilus*	X		
Three-spine stickleback	*Gasterosteus aculeatus*	X		
Coastrange sculpin	*Cottus aleuticus*	X		
Prickly sculpin	*Cottus asper*	X		
Shorthead sculpin	*Cottus confusus*	X		
Riffle sculpin	*Cottus gulosus*	X		
Pacific lamprey	*Lampetra tridentata*		X	
River lamprey	*Lampetra fluviatilis*		X	
White sturgeon	*Acipenser transmontanus*		X	
Coho salmon	*Oncorhynchus kisutch*		X	
Rainbow trout	*Oncorhynchus mykiss*		X	
Chinook salmon	*Oncorhynchus tshawytscha*		X	
Common carp	*Cyprinus carpio*			X
Brown bullhead	*Ameiurus nebulosus*			X
Rock bass	*Ambloplites rupestris*			X
Green sunfish	*Lepomis cyanellus*			X
Pumpkinseed sunfish	*Lepomis gibbosus*			X
Warmouth	*Lepomis gulosis*			X
Bluegill sunfish	*Lepomis macrochirus*			X
Smallmouth bass	*Micropterus dolomieu*			X
Largemouth bass	*Micropterus salmoides*			X
Black crappie	*Pomoxis nigromaculatus*			X
Yellow perch	*Perca flavescens*			X
Walleye	*Sander vitreus*			X

2.2.5 Biosampling and Movement

Length frequency histograms for all years of the kokanee supplementation program (return years 2009-2010 to 2015-2016) are shown in Figures 24 – 30. Average fork length, POH length (posterior orbit of the eye to end of hypural plate), and fecundity are shown in Table 7 – Biosampling Results. Yearly average fork lengths of 3-year females range from 326 mm to 395 mm; the grand mean is 364 mm. The yearly average fork length of 3-year males tends to be approximately 3% larger than females. Average annual fork lengths may vary as much as 17%. Return years 2010-2011 and 2013-2014 exhibited 3-year females with relatively high fork lengths; these years also had the 2 lowest spawner abundances (78 and 318 estimated spawners, respectively).

The average annual fecundity of 3-year females from return years 2009-2010 to 2015-2016 ranges from 796 to 1046. This limited information may suggest that relatively small, 3-year females may produce approximately 24% fewer eggs than relatively large, 3-year females. This range in fecundity should be factored in future expectations of spawner abundance. For example, during return years 2014-2015, a disproportionately large percentage of returning females (approximately 34.6%) were relatively small 2-year fish, which may reduce future recruitment compared to other years with very few 2-year old spawners.

For comparison, past data of "early-run" kokanee spawners in Issaquah Creek (Pfeifer 1992) include:

Year	Sex	n	mean fork length (mm)	fork length range (mm)	fecundity
1980	F		367		656
1981	F	132	363	250-449	648
	M	123	376	265-460	
1982	F	375	370	282-428	659
	M	332	386	287-457	

Additional data of "early-run" kokanee spawners in Issaquah Creek (Ostergaard et al. 1995 citing Hendry 1995) include:

Year	Sex	n	mean fork length (mm)	fork length range (mm)	fecundity
1993	F	5	285	240-375	
	M	15	279	240-323	

Female fish from the 1980 to 1982 samples have similar average fork lengths to those sampled in the supplementation program. Pfeifer (1992) developed a length-fecundity model from the 1981 and 1982 samples:

$$\text{Fecundity} = 1.41\ \text{FL}^{1.04}$$

This predictor may suggest "late-run" females recently sampled in the supplementation program may be on average 20-30% more fecund than "early-run" females of similar fork length (sample years 1981 and 1982.)

Age-class distributions for different brood years are reconstructed through a subsample of spawners otoliths (spawner return years: 2011-2012 through 2015-2016) (USFWS, unpublished data) (Table 8 – Otolith Sampling Results). The complete, or nearly complete, reconstruction of 4 consecutive brood years (2008-2009 through 2011-2012) has the following age-class distribution:

	Average	Range
2-Year Spawners:	0.2%	0.0 - 1.0%
3-Year Spawners:	69.1%	53.8 - 99.9%
4-Year Spawners:	30.7%	0.1 - 45.2%
5-Year Spawners:	0.0%	-

The results of this age-class distribution are skewed toward fish from brood years 2008-2009 and 2011-2012. Nonetheless, the results do suggest a high, yearly variability of age-class distribution among 3- and 4-year spawners. Brood year 2012-2103 is not included in this assessment; however, a break down in the very strong 3-year cohort distribution observed with the 2009-2010 brood year (approximately 99.9%) may be occurring. (Otolith subsampling of the 2016-2017 return is expected to reveal the proportion of fish from the 2012-2013 brood year that return as 4-year spawners.)

During 2009, average depth data from tagged kokanee found that subadult fish tended to stay between 16 and 18 meters from August through September. As the temperature-DO squeeze (see section Lake Water Quality) deteriorated in October, subadult fish tended to hold between 9 and 13 meters (Berge et al. 2013).

As noted in section Lake Species Assemblage, reducing the overlap of kokanee fry (produced at Issaquah Salmon Hatchery) and juvenile coho released from Issaquah Salmon Hatchery is an ongoing conservation effort. However, very little is known about kokanee fry movement and behavior upon lake entry. Fry that linger in shallow areas may be more vulnerable to predation by both juvenile coho and Chinook released from Issaquah Salmon Hatchery than fry that immediately move into deeper waters. The rate of movement or conditions that trigger the shift to deeper, mid-lake areas is unknown.

- **Current Ecological Assessment:** Year-to-year spawner size and fecundity may vary as much as 17% and 24%, respectively. Very generally, and based only on the first 4 brood years of the supplementation program, juvenile fish may return (on average) as 3-year spawners approximately 70% of the time and 4-year spawners approximately 30%; 2-year and 5-year spawners occur infrequently and in low numbers. This information, although still limited at this point, is important to begin to understand the propensity for variable age-classes and fecundity that likely supports irregular and cyclical spawner abundances. The incidence of an apparent, recent, strong, 3-year spawner cohort may or may not be coincidence.

- **<u>Priority:</u>** The further analysis of biosampling metrics can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance.
- **<u>Major Knowledge Gaps and Opportunities for Adaptive Management:</u>** Maintain annual monitoring of age-class distribution through otolith subsampling. This effort supports a vital understanding of long-term variability of age-class proportion, fish size, and fecundity. Potentially linking this information with lake phytoplankton, zooplankton, pathogen, predator, and/or other trends could provide valuable insight to overall spawner abundance variation. Studies to evaluate kokanee fry behavior and movement upon lake entry would provide vital information of potential predation rates by juvenile coho and Chinook released from Issaquah Salmon Hatchery.

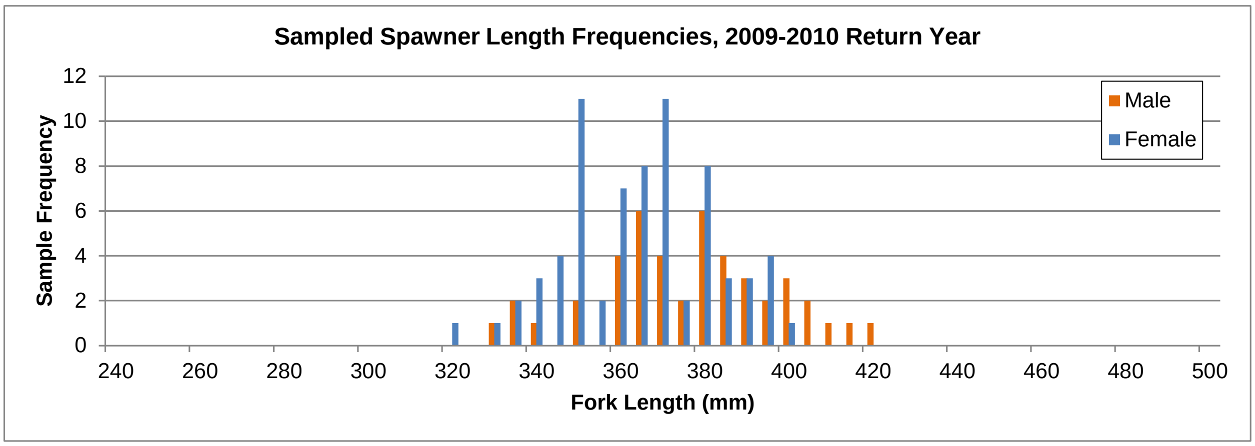

Figure 24. Spawner Length Frequency Histogram (2009-2010).

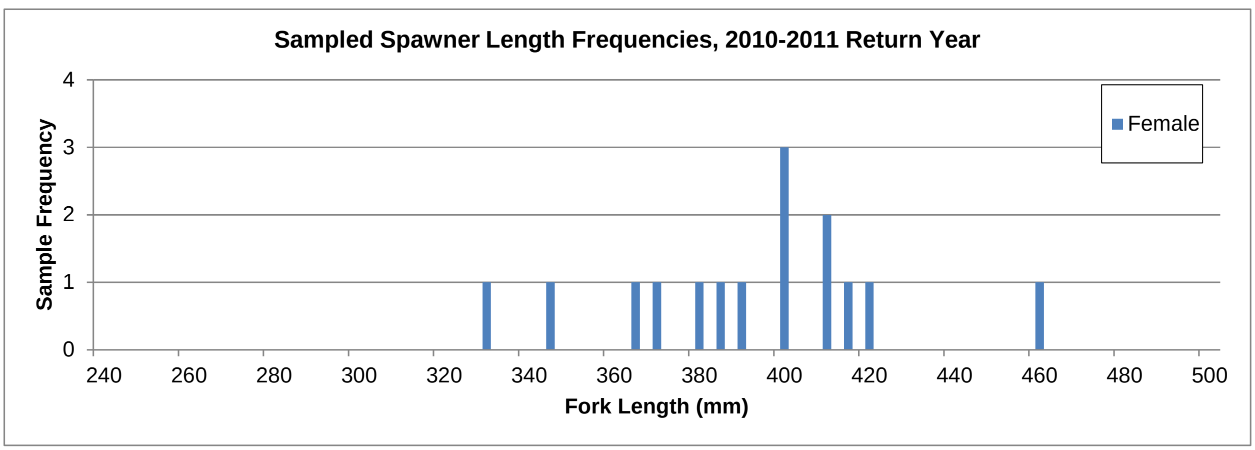

Figure 25. Spawner Length Frequency Histogram (2010-2011).

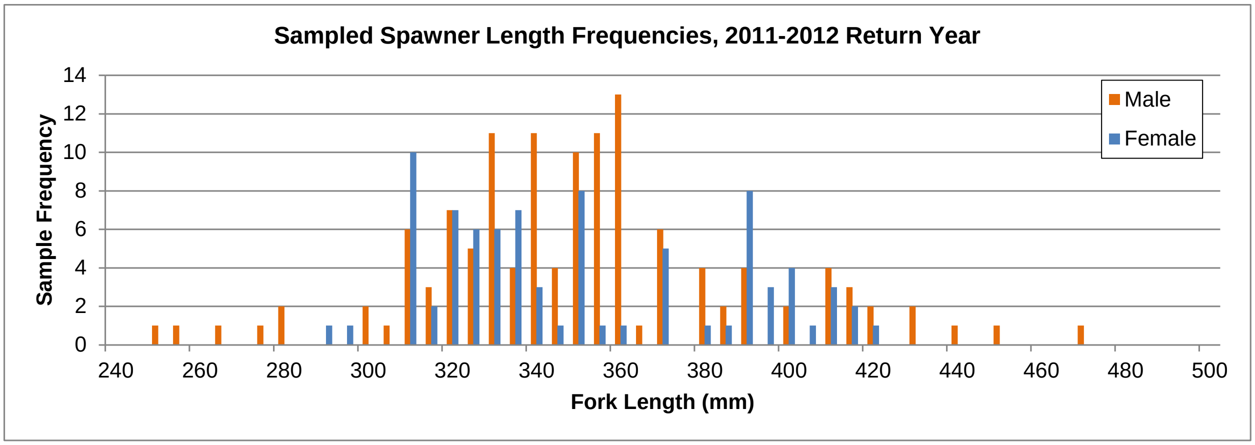

Figure 26. Spawner Length Frequency Histogram (2011-2012).

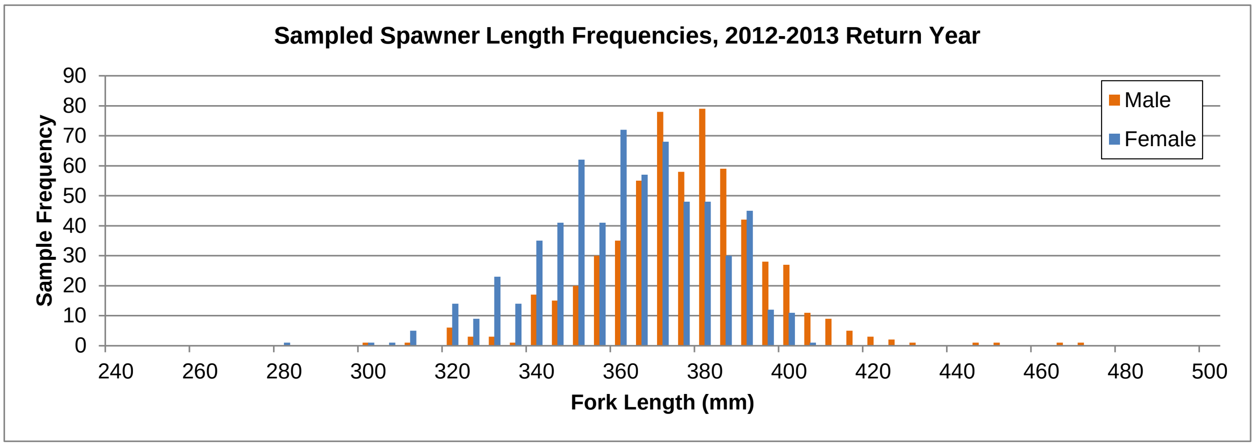

Figure 27. Spawner Length Frequency Histogram (2012-2013).

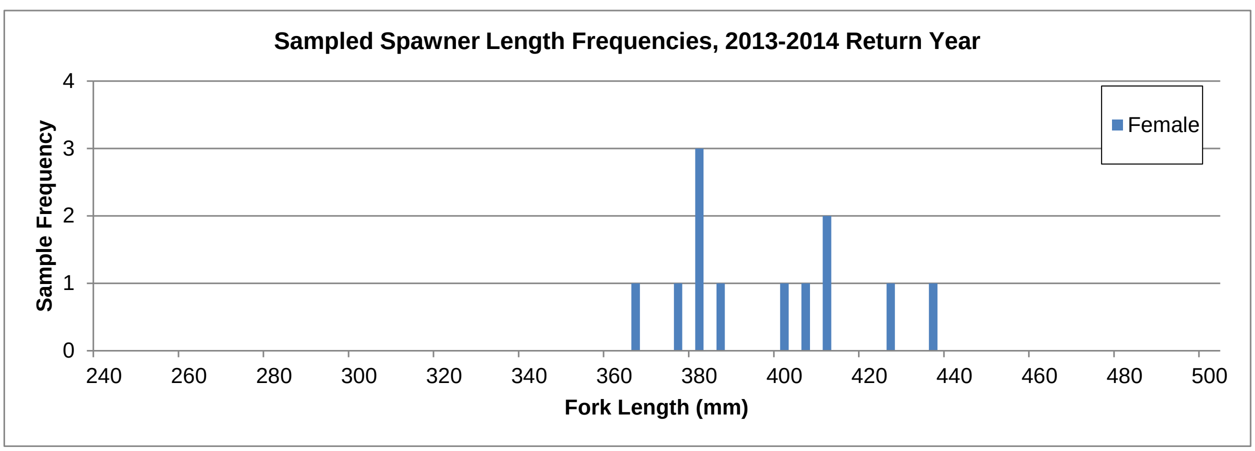

Figure 28. Spawner Length Frequency Histogram (2013-2014).

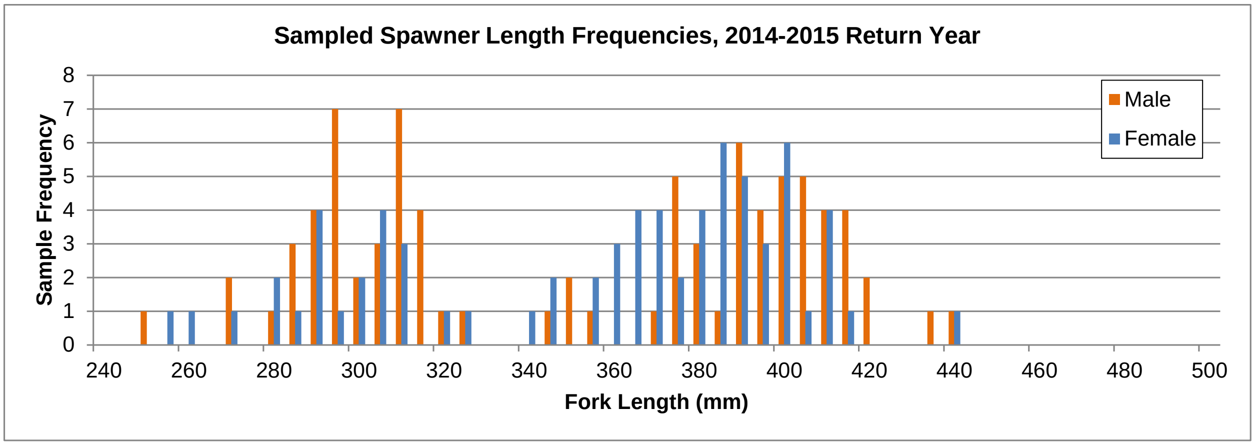

Figure 29. Spawner Length Frequency Histogram (2014-2015).

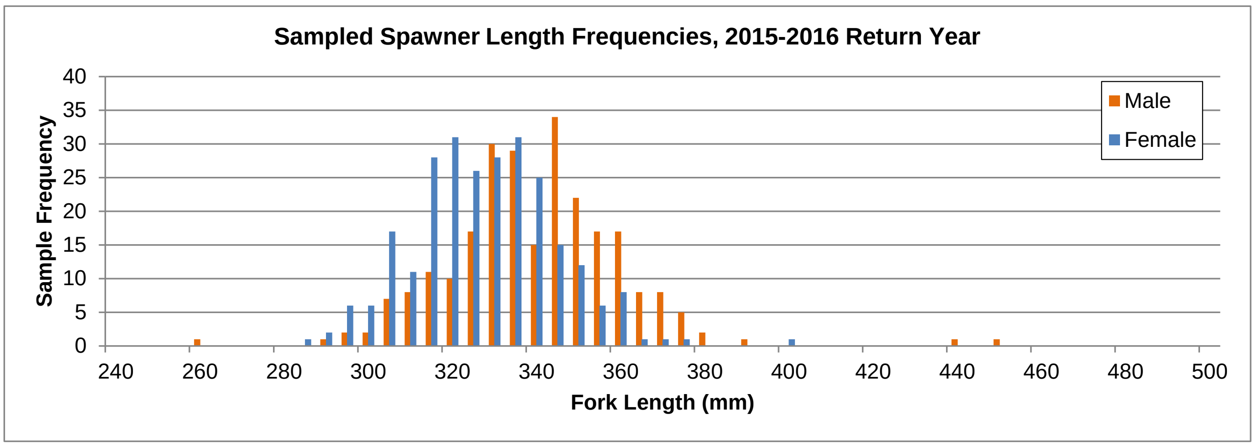

Figure 30. Spawner Length Frequency Histogram (2015-2016).

Table 7. Biosampling Results.

Return Year	Age Class	Sample Source	Female Average Fork Length (mm) [Sample Size]	Female Average POH* Length (mm) [Sample Size]	Female Average Weight (g) [Sample Size]	Female Average Fecundity [Sample Size]	Male Average Fork Length (mm) [Sample Size]	Male Average POH* Length (mm) [Sample Size]	Male Average Weight (g) [Sample Size]
"09-10"	**3-Year**	All Carcasses	**364** [71]	**291** [9]			**375** [45]	**303** [9]	
"10-11"	**3-Year**	Supplementation/ Hatchery Only	**386** [14]	**314** [14]	**693** [14]	**856** [14]			
	4-Year	Supplementation/ Hatchery Only	**460** [1]	**375** [1]	**1066** [1]	**1688** [1]			
"11-12"	**3-Year**	All Carcasses	**331** [59]	**273** [59]			**335** [100]	**268** [100]	
	4-Year	All Carcasses	**398** [24]	**323** [24]			**407** [26]	**320** [26]	
"12-13"	**3-Year**	All Carcasses	**360** [640]	**299** [699]	**505** [287]		**373** [589]	**300** [583]	**529** [261]
	4-Year	All Carcasses					**457** [4]	**343** [4]	**799** [3]
"13-14"	**3-Year**	Supplementation/ Hatchery Only	**395** [12]	**328** [12]	**688** [12]	**1046** [12]			
"14-15"	2-Year	All Carcasses	**294** [22]	**240** [22]	**275** [18]		**297** [36]	**240** [36]	**294** [24]
	3-Year	All Carcasses	**381** [48]	**316** [48]	**554** [40]		**391** [44]	**315** [44]	**591** [36]
	4-Year	All Carcasses	**435** [1]	**356** [1]	**725** [1]		**437** [2]	**356** [2]	**849** [2]
"15-16"	2-Year	Stream					**260** [1]		
	3-Year	All Carcasses	**326** [255]	**266** [255]	**375** [182]	**796** [181]	**338** [245]	**269** [245]	**407** [193]
	4-Year	All Carcasses	**396** [1]	**340** [1]			**445** [2]		**519** [2]

Table 8. Otolith Sampling Results.

Brood Year(s)		2-year spawners	3-year spawners	4-year spawners	5-year spawners
2006-2007	Percentage of future otolith age-class.				0.9%
	Estimated number of brood that later returned as spawners.				19
	Estimated percentage of brood that later returned as spawners.				
2007-2008	Percentage of future otolith age-class.			25.7%	0.0%
	Estimated number of brood that later returned as spawners.			511	0
	Estimated percentage of brood that later returned as spawners.				
2008-2009	Percentage of future otolith age-class.		73.4%	6.2%	0.0%
	Estimated number of brood that later returned as spawners.	*est.*	1459	1133	0
	Estimated percentage of brood that later returned as spawners.	***0.0%***	**56.3%**	**43.7%**	**0.0%**
2009-2010	Percentage of future otolith age-class.	0.0%	93.8%	4.6%	0.6%
	Estimated number of brood that later returned as spawners.	0	17120	16	6
	Estimated percentage of brood that later returned as spawners.	**0.0%**	**99.9%**	**0.1%**	**0.0%**
2010-2011	Percentage of future otolith age-class.	0.0%	92.7%	15.4%	0.0%
	Estimated number of brood that later returned as spawners.	0	324	164	0
	Estimated percentage of brood that later returned as spawners.	**0.0%**	**66.4%**	**33.6%**	**0.0%**
2011-2012	Percentage of future otolith age-class.	2.8%	49.5%	6.4%	
	Estimated number of brood that later returned as spawners.	10	527	443	*est.*
	Estimated percentage of brood that later returned as spawners.	**1.0%**	**53.8%**	**45.2%**	***0.0%***
2012-2013	Percentage of future otolith age-class.	34.6%	93.4%		
	Estimated number of brood that later returned as spawners.	369	6503		
	Estimated percentage of brood that later returned as spawners.	**</=5.4%**	**</=94.6%**		
2013-2014	Percentage of future otolith age-class.	0.3%			
	Estimated number of brood that later returned as spawners.	17			
	Estimated percentage of brood that later returned as spawners.				
2014-2015					
2015-2016					

2.2.6 Escapement, Recruitment, and Lake Productivity

"Late-run" estimates of spawner abundance have been calculated for the 3 index streams (Lewis, Ebright and Laughing Jacobs creeks) since 1996 (Figure 31 – Estimated Spawner Abundance). The estimates are calculated using area-under-curve (AUC) and an average stream-life of 7 days. Surveys are typically performed 3 days per week during the entire season; the entire length of all index stream spawning reaches is surveyed. Index streams are used since they represent the majority of utilized spawning reaches in the system, and the survey extents are replicated each year to give an indication of trend. Abundance is also estimated for all tributaries to Lake Sammamish; a coefficient of 0.2 is typically used to increase the index stream abundance to reflect an estimate of the entire run. The coefficient is based on the comprehensive survey of both index and non-index streams (Tibbetts, mainstem Issaquah, North Fork Issaquah, Vasa, Idylwood, Pine Lake, and Zackuse creeks) in 2015-2016 that found approximately 20% of the total abundance occurred in non-index streams.

No known spawner abundance surveys of the "late-run" in all 3 index streams were performed prior to 1996. Lake Sammamish creel surveys from 1942-1990 (Pfeifer 1992) indicate historic year-to-year catch rates of kokanee were variable; catch rates were generally higher during the 1940s and 1950s than during the 1960s and 1980s. Over the past 20 years spawner abundance estimates have been highly variable. Twenty-five percent of the estimated spawner returns in all streams during the last 20 years have been below 200 fish; 25% of the returns have been over 2,500 fish. The estimated median spawner abundance in all streams is 1,121; the estimated average spawner abundance is 2,557, which is skewed to a small number of years with relatively high abundances. The long-term spawner abundance trend may appear flat; however, there is no statistical support for this description.

Spawner recruitment over the last 16 years has also been highly variable (Figure 32 – Estimated Spawner Recruitment [1]). (A recruitment rate of 1 indicates the population is replacing itself at a no-growth rate.) The recruitment curve from 2011-2012 through 2015-2016 is based on estimated year-class return rates from supplementation otolith monitoring (Table 8 – Otolith Sampling Results); the recruitment rate for all other prior years is based on the average year-class return rates derived from all supplementation program otolith monitoring (2-year returns = 9.0%, 3-yr = 79.2%, 4-yr = 11.5%, 5-year 0.3%). Recruitment over the past 16 years may support the concept that the long-term population trend appears flat, yet highly variable year-to-year; half of years (8) are positive recruitment years (rate > 1; average 7.0); half of years (8) are negative recruitment (rate < 1; average of -6.3). The best spawner recruitment class was in 2011-2012 with an escapement of approximately 1,990 (not in 2012-2013 when total estimated spawner abundance was 18,266 fish). The high recruitment during 2011-2012 was due to an exceptional return rate from very low spawner abundance years in 2006-2007 and 2007-2008. Recruitment trends may also appear cyclical.

The fry-to-adult survival rate ("lake productivity" in this Ecological Survey) can be estimated for the complete, or nearly complete, 3 consecutive brood years reconstructed from 2008-2009 through 2011-2012 (see Biosampling and Movement section). The total estimated fry abundances for these brood years can be found in the following section (see Supplementation Program). The estimated lake productivity includes:

Brood year	Estimated lake productivity
2009-2010	13.5%
2010-2011	3.5%
2011-2012	0.7%
2012-2013	>1.7% (does not include 4- or 5-year old adult spawners)

Although limited in number, the estimates of lake productivity that are able to be calculated suggest fry-to-adult survival appears highly variable. The very high estimated lake productivity of the 2009-2010 brood class (13.5%) contributed to the highest estimated spawner abundance (18,266 fish) reported for the "late-run." The estimated lake productivities of the following brood years were at least 3x lower.

- **Current ecological assessment:** Measures of spawner escapement, spawner recruitment, and lake productivity suggest lake mortality and consequent year-to-year adult abundance is highly variable. The variability could be a result of one or more parameters, which may be related, coincident, and perhaps cyclical, that affects the population. Variables within the lake may have much more of a profound effect overall on adult numbers than stream variables. For instance, fry abundances from brood year 2009-2010 (Table 4 - Fry Abundance Estimates) coupled with very high lake productivity generated an exceptional return in 2012-2013, but brood years 2011-2012 and 2012-2013 - also with relatively high fry abundances - experienced high lake mortality (lake productivity <2%) and depressed returns. The manifestation of depensation or Allee effects appears unlikely since a set of conditions that foster consecutive years of apparent low numbers seem equally likely to facilitate continued relatively low abundances or a rapid population expansion.
- **Priority:** The further analysis of escapement and recruitment metrics can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance.
- **Major Knowledge Gaps and Opportunities for Adaptive Management:** Continue monitoring spawner abundance and recruitment to inform population status and trend. The current extent of kokanee bycatch during recreational fishing and the impact to abundance is unknown; creel surveys could provide valuable information on this potential impact.

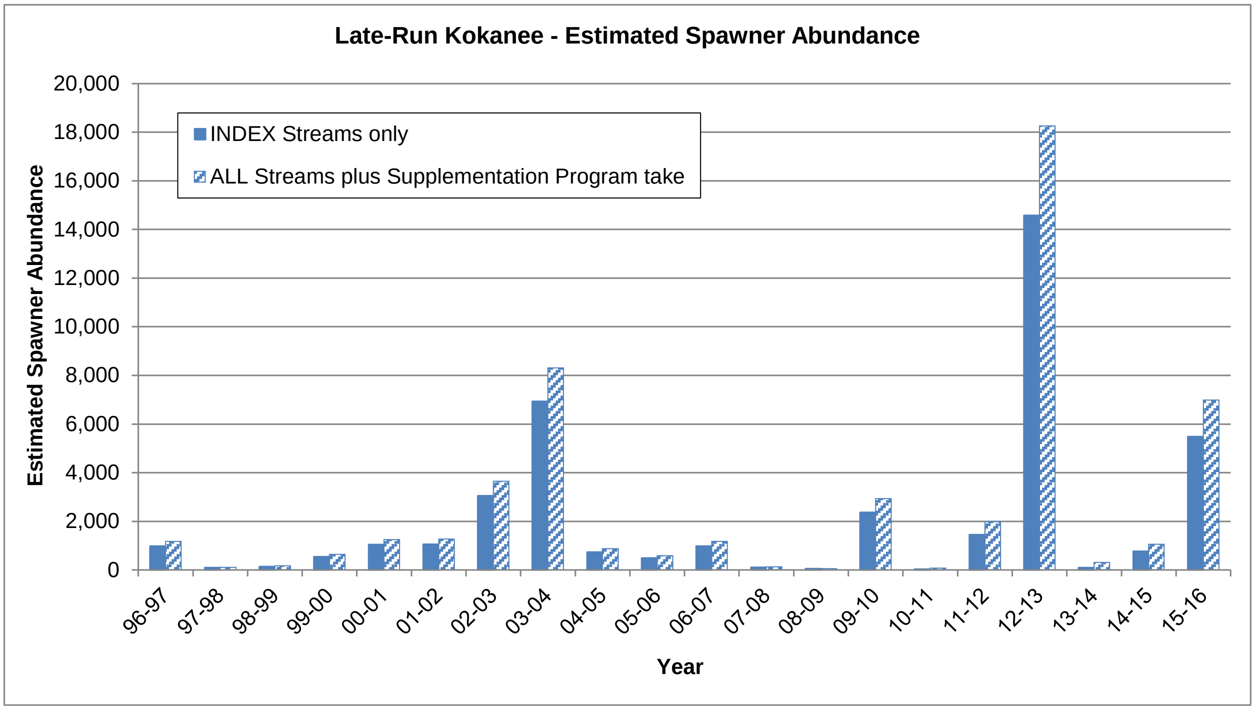

Figure 31. Estimated Spawner Abundance.

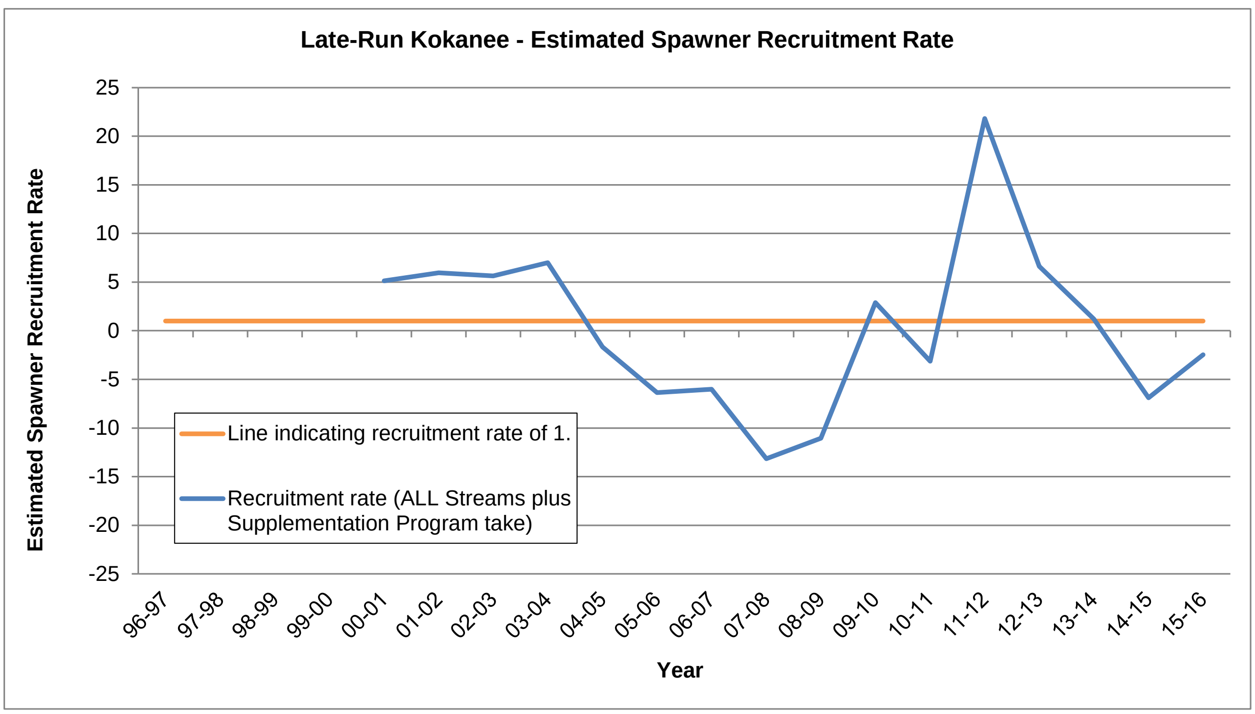

Figure 32. Estimated Spawner Recruitment (1).

2.2.7 Supplementation Program

A supplementation program was initiated in 2007 to mitigate the risk of potential catastrophic events to the population during periods of low abundance (Jackson 2006, LSKWG 2013a). Due to very low spawner abundances in 2007-2008 and 2008-2009, the first implementation of program did not occur until 2009-2010. The use of multiple hatcheries were used in 2009-2010; approximately half of the fry were released after yolk absorption and the other half were fed to an approximate density of 1,500 fish/lb. before release in their natal stream. A recirculating, natal-water incubation system was used from 2010-2011 through 2014-2015; fry were fed to an approximate density of 1,500 fish/lb. before release back to their natal stream. Shallow troughs and water from both Issaquah Creek and nearby Darigold Dairy were used in 2015-2016; the majority of fry were also fed to an approximate density of 1,500 fish/lb. before release back to their natal stream. Fry releases through this program usually occur in bulk and shortly after dusk; it is not known if this concentrated release of fry increases near-term predation risk. The estimated number of fry produced and released by the supplementation program is described in Table 9 – Estimated Total Abundances of Natural and Supplementation Fry.

All kokanee fry released by the supplementation program have been thermally marked during incubation. A sample of otoliths from the annual return of spawners is later analyzed for the presence of thermal marks to evaluate the estimated proportion of fish produced by the supplementation program (USFWS, unpublished data) (Table 10 – Estimated Percentage and Abundance of Thermally-Marked Spawners). The proportions of fish produced by the supplementation program were calculated by dividing the estimated number of marked fish by the estimated total number of brood that later returned as spawners (Table 8 – Otolith Sampling Results).

There is a program expectation that the proportion of spawners produced through the supplementation program would be representative, and even exceed in number, the proportion of fry produced through the supplementation program. For example, if the supplementation program produces approximately 31% of all the fry in the system during brood year 2009-2010, then approximately 31% of the spawners that return (across all age classes) from that brood year should also be from the supplementation program (thermally marked). In this example, the assumption that the proportion of subsequent spawners may be higher than 31% is due to the large size of (fed) fry at release. The typical weight of (fed) fry at release is 0.27 to 0.33 g., which is roughly 3-4 times larger than fry naturally emigrating from streams (0.05-0.08 g). The program assumption is that the larger fry have higher fitness and are therefore less prone to predation and disease (Jackson 2006, LSKWG 2013a).

Figure 33 – Estimated Return Rate of Fry from Supplementation Program (Estimate 1) shows the estimated percent of all the fry produced in the system that come from the supplementation program. The analysis of thermal marks from the first 4 years of the supplementation program is largely complete; the analysis of brood year 2012-2013 does not yet include an abundance estimate of 4-year-old spawners. The diagram also shows the estimated proportion of fry from the supplementation program that return as spawners.

Fry from the supplementation program appear to return as spawners at a consistently lower rate than naturally spawned fry; an estimate of only 26-48% of the fry from the supplementation program appear to be returning as spawners. Due to the high degree of uncertainty with the BITU fry trapping results, the estimated percent of all the fry produced in the system that come from the supplementation program was recalculated using the high limit of the 95% confidence intervals from the in-stream fry abundance estimates. The recalculation reduces the estimated percent of fry coming from the supplementation program (Figure 34 – Estimated Return Rate of Fry from Supplementation Program [Estimate 2]); however, even under this scenario, fry from the supplementation program continue to return as spawners at a consistently lower rate than naturally spawned fry.

The overall impact of the supplementation program on the "late-run" kokanee population may depend on implementation timing (Figure 35 – Estimated Spawner Abundance from Natural and Supplementation Production). During years with relatively low spawner abundance, such as return years 2013-2014 (approximately 350 total fish) and 2014-2015 (approximately 1,065 total fish), the proportion of the spawners produced by the supplementation program was approximately 41% and 28%, respectively. During both return years 2012-2013 and 2015-2016, when spawner abundance was relatively high, the proportion of the spawners produced by the supplementation program was approximately 7%.

- **Current ecological assessment:** The supplementation program may help mitigate risks to the population during years with very low spawner abundance (e.g., return year 2013-2014 when approximately 41% of returning spawners were produced in the supplementation program). However, during the first four years of program implementation, fry from the program returned as spawners at a consistently lower rate than naturally spawned fry. The reasons for this trend are unknown, and potential effects from domestication may be a contributor. If predation is a driver of kokanee abundance in the lake, the size and condition of the supplementation program fry may make these subcohorts disproportionally greater prey targets.
- **Priority: HIGH.** The supplementation program should be modified; the goal of this conservation strategy is not being realized as intended, and implementation is both costly and time intensive. More specific to the goal of this Ecological Survey, however, this parameter and strategy may or may not be related to the current variability and trend in kokanee abundance.
- **Major Knowledge Gaps and Opportunities for Adaptive Management:** While the strategies of the current supplementation program plan (LSKWG 2013a) have been methodically implemented, the supplementation program goal of increasing the population size to reduce extinction risk and support a harvestable fishery may not be achievable with the current strategies. The existing plan (LSKWG 2013a) provides sufficient flexibility to implement sound adaptive management. Naturally produced fry likely have a consistently higher lake survival rate. If the supplementation program is continued in the future, strategy modifications should

incorporate approaches that better emulate the condition and fitness of natural fry. Specific adaptive management strategies include:

1. Organize upcoming supplementation fry production (from return years 2017-2018 and 2018-2019) into two groups: one fed and one not fed. These two groups should have unique thermal marks, and future returns should be analyzed to compare the potential impact of feeding.

Additional adaptive management could include:

2. Utilize colder water at the hatchery to extend the incubation period, significantly reduce or eliminate feeding, and release fry in comparable condition to natural fry during otherwise normal emigration timeframes.
3. Reduce crowding, flow velocities, and other potential sources of stress in shallow-water troughs at Issaquah Salmon Hatchery; juveniles exhibiting stress may be more susceptible to IHN or other naturally occurring pathogens upon release.
4. Continue annual program reviews, analysis, and adaptive management strategies by the Supplementation Technical Working Group.
5. Fully test, deploy and monitor [streamside] remote site incubators to fully incorporate natural stream conditions, increase the spatial extent of the population, and diversify the suite of available supplementation techniques.

Table 9. Estimated Total Abundances of Natural and Supplementation Fry. (* Indicates years without actual fry abundance estimates in Laughing Jacobs Creek; estimated values are the average of Ebright and Lewis creeks monitoring results.)

Brood Year	Stream	Estimated Number Spawners in Index Streams	Estimated Fry Abundance in Index Streams	Estimated Fry Abundance, Coefficient of Variance	Estimated Subtotal Fry Abundance, Natural Spawners in *ALL* Streams (Index Stream Abundance * 1.2)	Estimated Fry Abundance from Supplementation Program	Estimated Subtotal Fry Abundance, Supplementation Program
2009-2010	Ebright	1604	35445	20.3%	87506	12031	39542
	Laughing Jacobs	88*	3203*	33.8%*		15740	
	Lewis	673	34273	47.2%		11771	
	Other						
2010-2011	Ebright	3	10	79.4%	38	10579	14051
	Laughing Jacobs	2*	8*	60.9%*		2677	
	Lewis	3	14	42.3%		795	
	Other						
2011-2012	Ebright	313	21508	51.4%	85792	31298	62473
	Laughing Jacobs	603*	31273*	72.1%*		18882	
	Lewis	536	18712	92.7%		12293	
	Other						
2012-2013	Ebright	6694	53677	65.0%	198981	44305	197938
	Laughing Jacobs	1384*	16362*	76.1%*		32430	
	Lewis	6495	95778	87.1%		43009	
	Other					78194	
2013-2014	Ebright	41	1001	58.3%	2556	2417	9928
	Laughing Jacobs	52	374	40.0%		2137	
	Lewis	47	755	53.1%		5374	
	Other						
2014-2015	Ebright	451	11854	38.8%	26612	23181	46109
	Laughing Jacobs	33	6503	72.7%		7476	
	Lewis	290	3820	58.7%		15452	
	Other						
2015-2016	Ebright	1900	48568	80.4%	103446	15423	120178
	Laughing Jacobs	1144	9195	38.1%		16167	
	Lewis	2436	28442	49.1%		15421	
	Other					73167	

Table 10. Estimated Percentage and Abundance of Thermally-Marked Spawners.

Brood Year(s)		2-year spawners	3-year spawners	4-year spawners	5-year spawners
2009-2010	Percentage of future otoliths with thermal marks.	0.0%	7.4%	0.0%	0.0%
	Estimated number marked fish that returned as spawners.	0	1358	0	0
	Estimated percentage marked fish that returned as spawners.	**0.0%**	**7.9%**	**0.0%**	**0.0%**
2010-2011	Percentage of future otoliths with thermal marks.	0.0%	38.5%	0.6%	0.0%
	Estimated number marked fish that returned as spawners.	0	135	6	0
	Estimated percentage marked fish that returned as spawners.	**0.0%**	**27.7%**	**1.2%**	**0.0%**
2011-2012	Percentage of future otoliths with thermal marks.	2.8%	14.2%	0.5%	
	Estimated number marked fish that returned as spawners.	10	151	36	*est.*
	Estimated percentage marked fish that returned as spawners.	**1.0%**	**15.4%**	**3.7%**	***0.0%***
2012-2013	Percentage of future otoliths with thermal marks.	13.7%	6.9%		
	Estimated number marked fish that returned as spawners.	145	478		
	Estimated percentage marked fish that returned as spawners.	**</=2.1%**	**</=7.0%**		
2013-2014	Percentage of future otoliths with thermal marks.	0.0%			
	Estimated number marked fish that returned as spawners.	0			
	Estimated percentage marked fish that returned as spawners.				
2014-2015					
2015-2016					

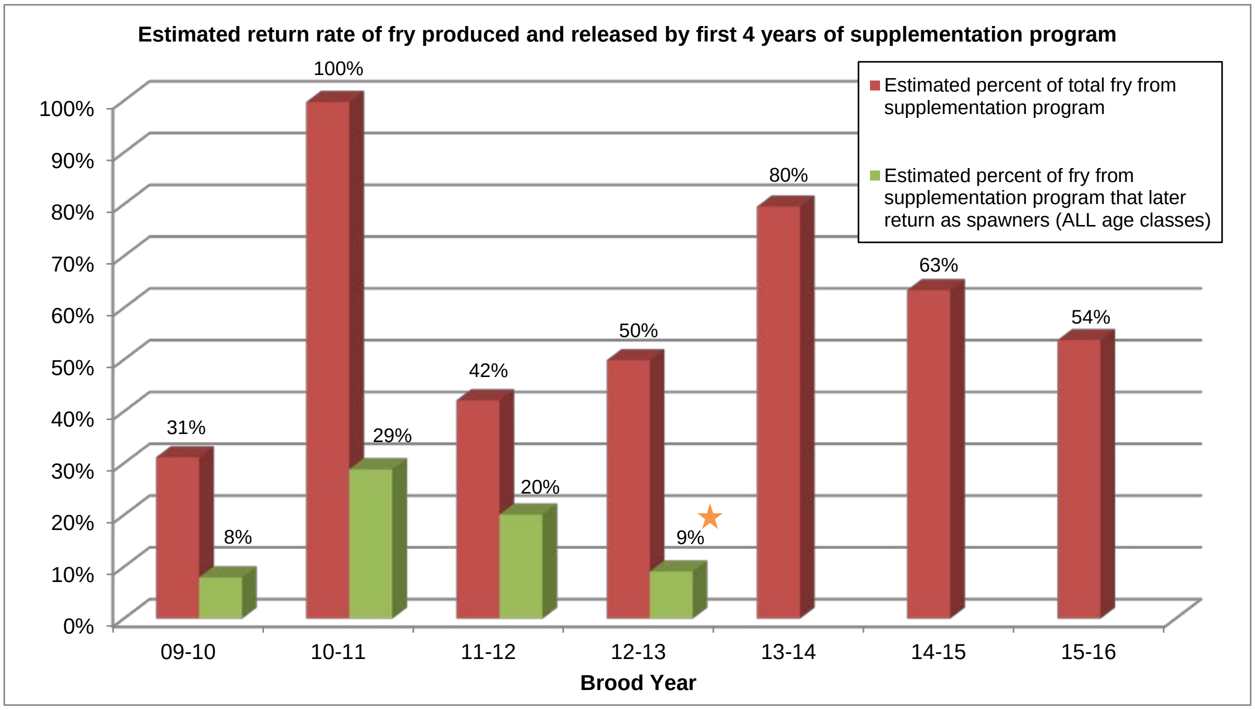

Figure 33. Estimated Return Rate of Fry from Supplementation Program (Estimate 1). (Note: Brood year 2012-2013 does not yet include an abundance estimate of 4-year-old spawners.)

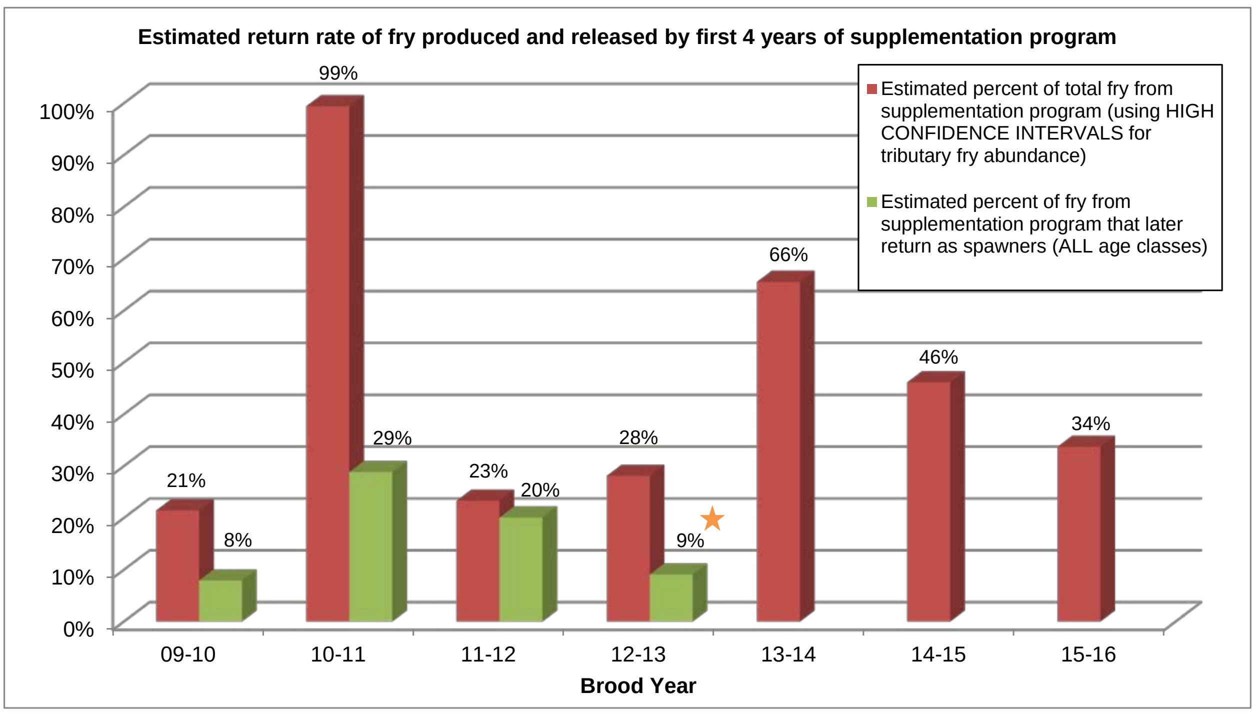

Figure 34. Estimated Return Rate of Fry from Supplementation Program (Estimate 2). (Note: Brood year 2012-2013 does not yet include an abundance estimate of 4-year-old spawners.)

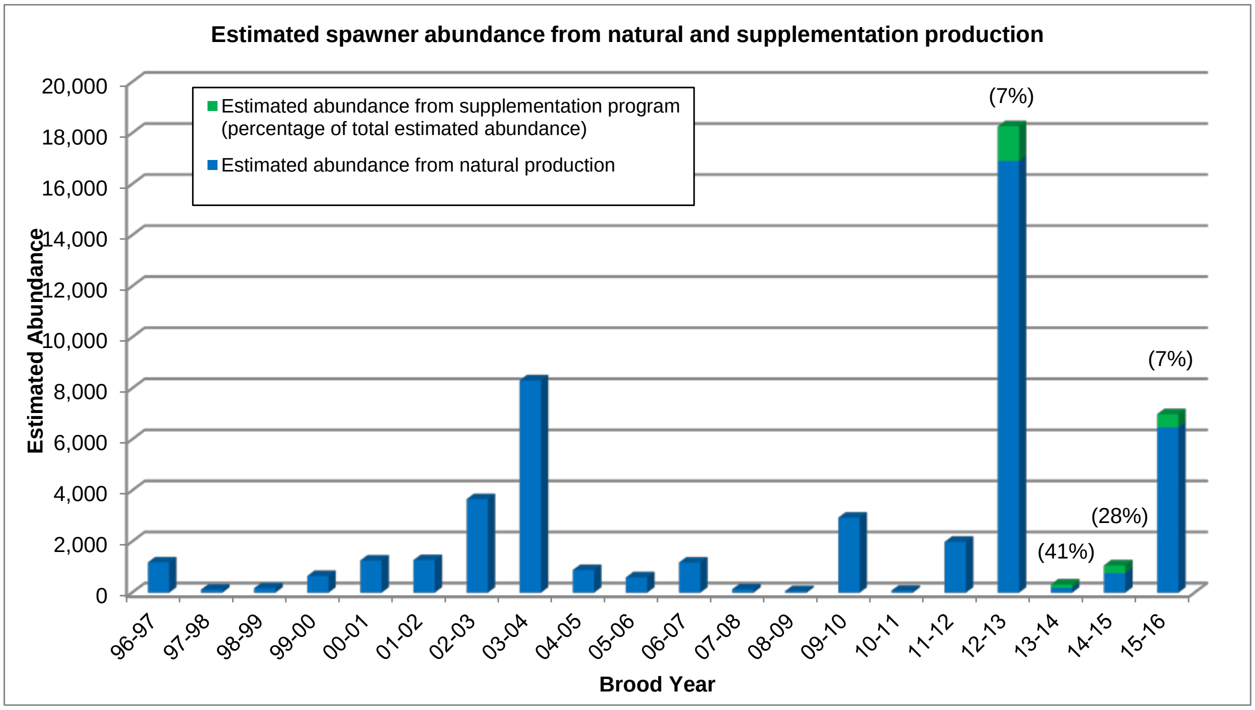

Figure 35. Estimated Spawner Abundance from Natural and Supplementation Production.

3.0 RESULTS AND TARGETS

3.1 Summary of Major Knowledge Gaps and Opportunities for Adaptive Management

The objectives of the Ecological Survey include uncovering and summarizing knowledge gaps, prioritizing adverse effect mechanisms, and discussing opportunities for adaptive management and research. This effort has given rise to the conservation strategies below. Long-term survival of Lake Sammamish kokanee will depend on implementation of all of these conservation strategies. Considering the essential questions guiding the objectives (What are the ecological mechanisms driving frequent, very low spawner abundance and very high year-to-year variability of spawner abundance? What are the most significant ecological risks to the population?), a subset of 5 High-Priority strategies are proposed for focused, near-term conservation efforts.

Two High-Priority strategies involve adaptive management and fundamentally address the value of increased population abundance. Although the "normal" range of cohort abundances is unknown, higher abundances are expected to mitigate potential near- to mid-term risks of catastrophic adverse effects to the population. Three High-Priority strategies involve major knowledge gaps and could provide vital information about lake survival and consequent high variability in spawner abundance. A deeper understanding of the prey, predation, pathogen, and parasite dynamics in the lake will greatly inform our expectations of future abundances. For instance, should a range of spawner abundances between 200 and 20,000 otherwise be considered "normal"? Are years with extremely low returns essential for mitigating viral, bacterial, or parasitic epidemics and overall long-term survival? Are the recent observations of "high" spawner abundance (e.g., return years 2003-2004 and 2012-2013) a function of existing, "normal" predator population cycles in the lake?

3.1.1 Population Genetics

Analysis using newer technology (e.g., single nucleotide polymorphisms [SNPs]) can enable a more precise understanding of population history and genetic risks. The completion of analysis and reporting of recent samples by the US Fish and Wildlife from Lake Sammamish tributaries will provide additional valuable information.

3.1.2 Spawning Habitat Quantity

[**HIGH PRIORITY – *Adaptive Management***] Continuing to expand access to all high-quality, historic spawning habitats can have a measureable, significant impact on the total abundance of fry annually entering the lake.

The application of eDNA technology could help identify or confirm kokanee spawner utilization at unsurveyed sites; the technology could help support the rationale to coordinate habitat conservation actions in areas of previous low focus.

3.1.3 Stream Hydrology

Continue to restore and protect floodplain processes that mitigate the altered hydrology of most "late-run" spawning streams.

Fry abundance monitoring, especially on Lewis Creek, should continue to be performed; monitoring is designed to demonstrate effectiveness of stream restoration and other mitigations that address altered flow regimes in the urban environment.

3.1.4 Stream Water Quality

Stakeholders should continue to promote conservation actions that restore floodplain processes, reduce delivery of fine sediments to spawning streams, and mitigate the effects of altered flow regimes that contribute to in-stream sedimentation.

3.1.5 Stream Productivity

Future fry abundance monitoring by BITU can provide valuable population data, especially in Lewis Creek, where recent channel and floodplain restoration has occurred; monitoring in Lewis Creek also has the potential to provide further understanding of the effects of altered stream hydrology.

Future monitoring by BITU should to be coupled with an improved method for measuring trap efficiency.

3.1.6 Lake Water Quality

Expand the King County freshwater toxins monitoring program to Lake Sammamish; adult kokanee could be evaluated for chronic exposure during the lake life stage.

3.1.7 Lake Primary Productivity and Zooplankton

[**HIGH PRIORITY – *Knowledge Gap***] The potential relationship between the high variability of seasonal phytoplankton and zooplankton biomass and the high variability of kokanee abundance (and other species abundance) should be further analyzed; analysis of phytoplankton and zooplankton variability in Lake Sammamish can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance.

3.1.8 Lake Pathogens and Other Factors

[**HIGH PRIORITY – *Knowledge Gap***] The further analysis of viral and bacterial pathogens and parasites in Lake Sammamish can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance. Specific considerations include:

1. Continue with this type of analysis regardless of the long-term status of the supplementation program.

2. This analysis could potentially be expanded to include in-stream kokanee spawners, in addition to the brood stock collected for the supplementation program.
3. The virology and bacteriology analysis could also be expanded to kokanee sampled during the temperature-DO squeeze and other periods of stress or relative high density.
4. Expand this type of analysis to kokanee predator populations, such as coastal cutthroat trout and yellow perch.
5. Perform presence/absence surveys for the polychaete, Manayunkia speciosa, especially in lower Issaquah and Tibbetts creeks, stream deltas at the lake confluence, and other potential preferred habitats.

If in-stream remote incubators are used in the future as part of the supplementation program, spawned eggs used for this conservation strategy should be disinfected using a standard iodine bath protocol prior to deposit in the incubator.

A research opportunity could be the evaluation of the ecological significance of very low abundance and recruitment periods; i.e., are the cycles of very low kokanee abundance and recruitment a vital natural regulator of viral and bacterial impacts to the population?

3.1.9 Lake Species Assemblage

[**HIGH PRIORITY – *Knowledge Gap***] Vital research opportunities exist to better understand predator niches in the Lake Sammamish, especially a more thorough understanding of coastal cutthroat trout, yellow perch, and walleye status and trends; an analysis of predator status, predation rates, and bioenergetics in Lake Sammamish can potentially inform the understanding and expectations of the foreseeable ranges of annual spawner abundance.

3.1.10 Biosampling and Movement

Maintain annual monitoring of age-class distribution through otolith subsampling; this effort supports the understanding of long-term variability of age-class proportion, fish size, and fecundity. Potentially linking this information with lake phytoplankton, zooplankton, pathogen, predator, and/or other trends could provide valuable insight to overall spawner abundance variation. Studies to evaluate kokanee fry behavior and movement upon lake entry would provide vital information of potential predation rates by juvenile coho and Chinook released from Issaquah Salmon Hatchery.

3.1.11 Escapement, Recruitment, and Lake Productivity

Continue monitoring spawner abundance and recruitment to inform population status and trend. The current extent of kokanee bycatch during recreational fishing and the impact to abundance is unknown; creel surveys could provide valuable information on this potential impact.

3.1.12 Supplementation Program

[**HIGH PRIORITY – *Adaptive Management***] The supplementation program goal of increasing the population size to reduce extinction risk and support a harvestable fishery may not be achievable with the current strategies. Naturally produced fry likely have a consistently higher lake survival rate. If the supplementation program is continued in the future, strategy modifications should incorporate approaches that better emulate the condition and fitness of natural fry. Specific adaptive management strategies include:

1. Organize upcoming supplementation fry production (from return years 2017-2018 and 2018-2019) into two groups: one fed and one not fed. These two groups should have unique thermal marks, and future returns should be analyzed to compare the potential impact of feeding.

Additional adaptive management could include:

2. Utilize colder water at the hatchery to extend the incubation period, significantly reduce or eliminate feeding, and release fry in comparable condition to natural fry during otherwise normal emigration timeframes.
3. Reduce crowding, flow velocities, and other potential sources of stress in shallow-water troughs at Issaquah Salmon Hatchery; juveniles exhibiting stress may be more susceptible to IHN or other naturally occurring pathogens upon release.
4. Continue annual program reviews, analysis, and adaptive management strategies by the Supplementation Technical Working Group.
5. Fully test, deploy and monitor [streamside] remote site incubators to fully incorporate natural stream conditions, increase the spatial extent of the population, and diversify the suite of available supplementation techniques.

3.2 Practical Indicators of Population Status

As mentioned at the beginning of the Ecological Survey, the development of benchmarks or other measures of conservation success has eluded LSKWG partners. An important goal of the technical workshop and Ecological Survey is the proposal and endorsement of one or more meaningful, practical measures of population status and trend.

The ecological processes driving year-to-year abundance are not well understood, but at this point in time, ongoing, high variability in spawner abundance is a reasonable expectation. In the near- to mid-term, presuming the population should (or could) maintain an absolute annual abundance at or above a determined number is likely not practical. The two proposed indicators below attempt to incorporate population abundance, trend, and variability.

3.2.1 (Proposed) Indicator of Conservation Success #1

- The moving, 10-year median spawner abundance for the 3 index streams is (1) greater than 800, and (2) exhibits an increasing (10-year) trend.

  Rationale: This measure incorporates approximately 3 generations of fish. The moving median accounts for abundance variability and does not skew results toward unusual returns. The timeframe is within the anticipated near-term response period of the population to implementation of high priority conservation strategies; the measure should be sensitive to those high priority strategies involving habitat access and supplementation program adaptive management. The current trend is decreasing slightly (Figure 36 – Moving, 10-Year, Median Spawner Abundance in the Index Streams); however, the population (measured through index streams) has experienced 4 of the last 10 years with returns of 109 or lower.

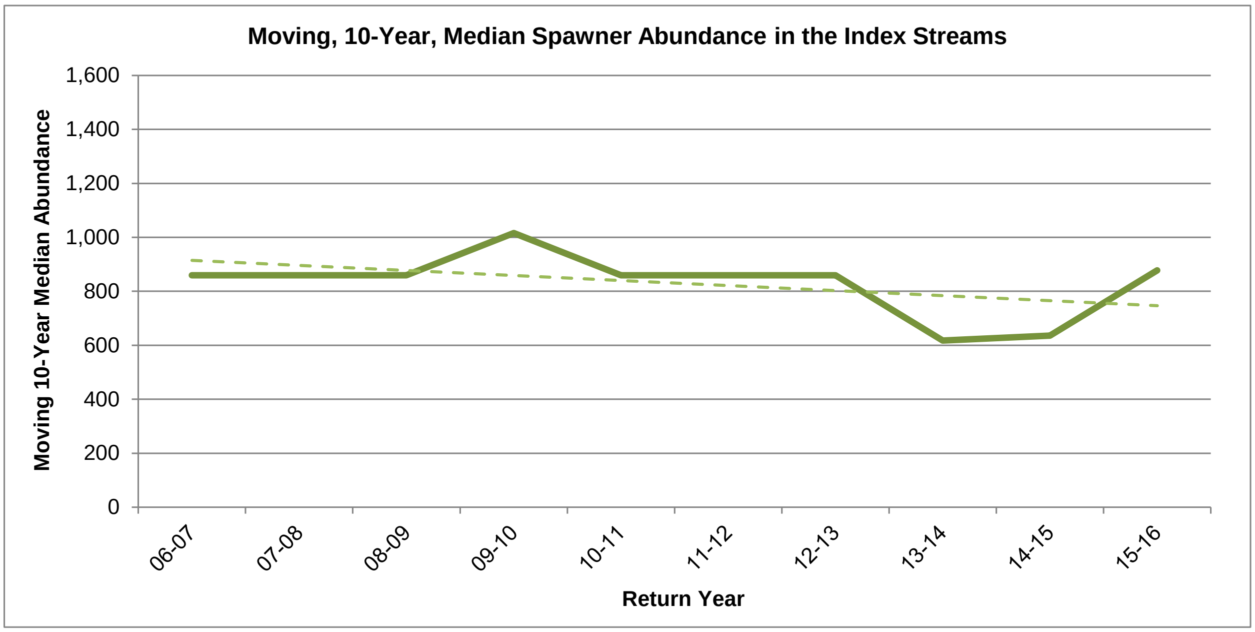

Figure 36. Moving, 10-Year, Median Spawner Abundance in the Index Streams.

3.2.2 (Proposed) Indicator of Conservation Success #2

- The 10-year average spawner recruitment for the 3 index streams is greater than 1 after return year 2025-2026.

  Rationale: This measure incorporates approximately 3 generations of fish. The 10-year average accounts for natural cycles in recruitment. The timeframe is within the anticipated near-term response period of the population to implementation of high priority conservation strategies; the measure should be sensitive to those high priority strategies involving habitat access and supplementation program adaptive management. The current recruitment rate in index streams (Figure 37 – Estimated

Spawner Recruitment [2]) is approximately -0.1 over that last 16 years; approximately -1.7 over the last 10 years.

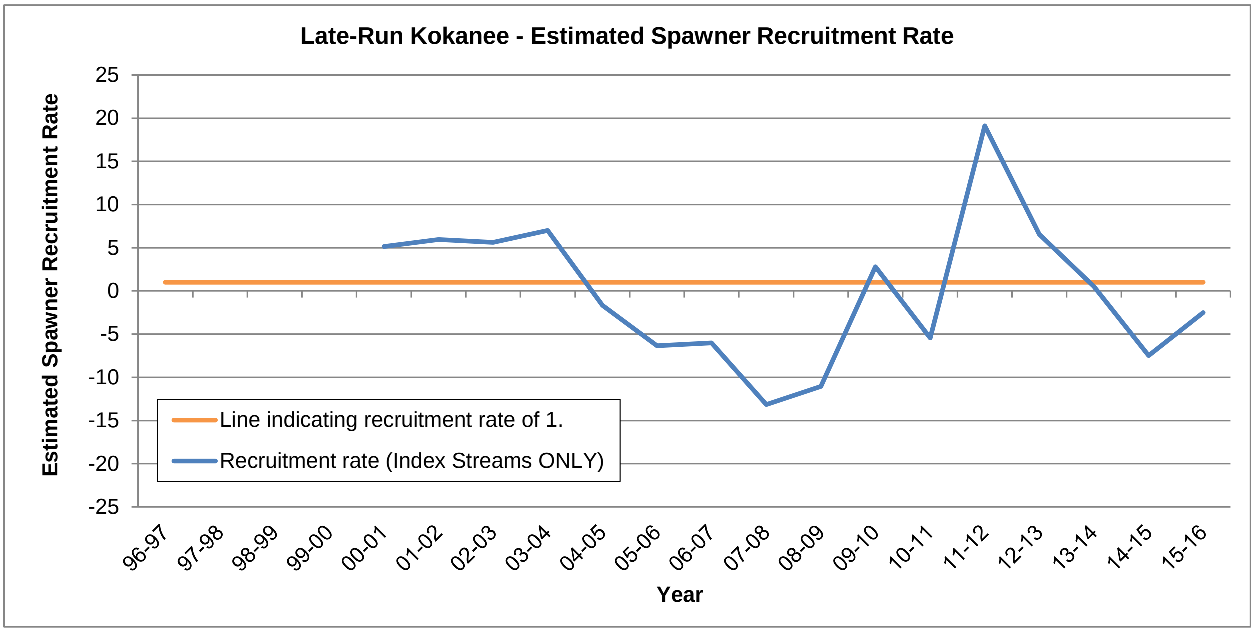

Figure 37. Estimated Spawner Recruitment (2).

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Appendix A: Map of Historic Kokanee Distribution in the Lake Washington Basin

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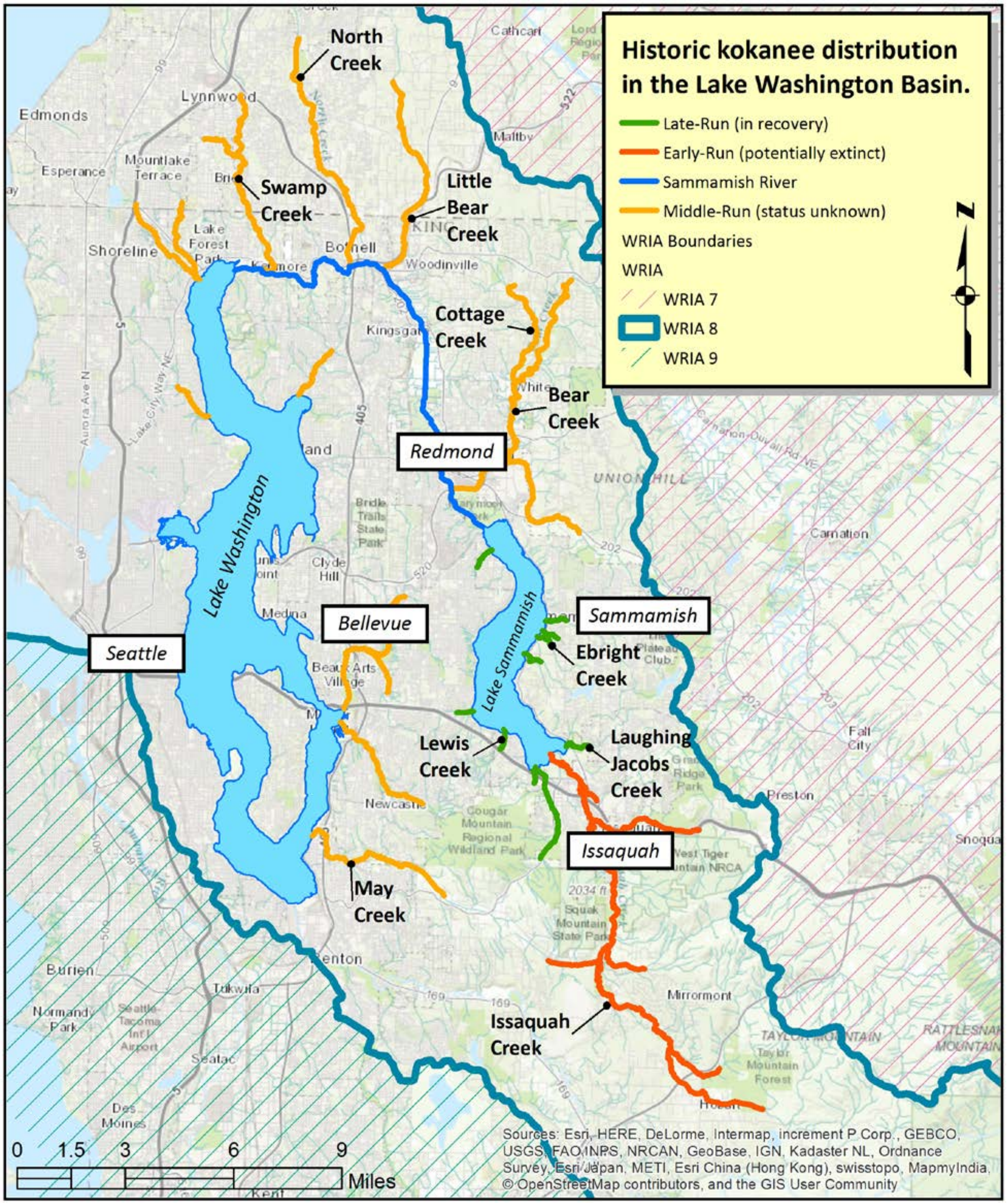
MAP – The distribution (and status) of Lake Sammamish "late-run" kokanee relative to the historic distribution of kokanee throughout the Lake Washington Basin.



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Appendix B: Lake Sammamish Kokanee Technical Workshop – Agenda

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Lake Sammamish Kokanee Technical Workshop – Agenda

Issaquah Salmon Hatchery – ***Watershed Science Center***

17 November, 2016

8:45 – 9:00 Arrive

9:00 – 9:25 Introduction, purpose and objectives, logistics, agenda items, pace (J Bower)

9:25 – 9:50 Personal perspective on history, current effort, and future of kokanee conservation (R Tabor)

9:50 – 10:40 MORNING TOPIC SET [Informational]: Population Genetics, Spawning Habitat Quantity, Stream Hydrology, Stream Water Quality, Stream Productivity, Lake Water Quality, Biosampling, Escapement/Recruitment/Lake Productivity (J Bower)

10:40 – 10:50 Short Break

10:50 – 11:45 MORNING TOPIC SET [Problem-solving]: Discussion of Conservation Strategies

11:45 – 12:15 Lunch – *Sponsored by the Bellevue-Issaquah Chapter of Trout Unlimited*

12:15 – 12:40 (Working Lunch) TOPIC: Lake Species Assemblage

12:40 – 1:10 TOPIC: Lake Primary Productivity and Zooplankton

1:10 – 1:30 TOPIC: Lake Pathogens and Other Factors

1:30 – 1:45 Short Break

1:45 – 2:30 TOPIC: Supplementation Program

2:30 – 2:45 Summary of Major Knowledge Gaps and Opportunities for Adaptive Management

2:45 – 3:15 TOPIC: Practical Indicators of Population Status

3:15 – 3:30 Wrap-up; Close

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Appendix C: Technical Workshop Meeting Notes and Summaries from Enviroissues

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WORKSHOP SUMMARY

Lake Sammamish Kokanee Technical Workshop
November 17, 2016
Issaquah Salmon Hatchery, Watershed Science Center
Issaquah, WA

Contents

This is a summary report from the Lake Sammamish Kokanee Technical Workshop. It may not fully represent the breadth or depth of ideas or opinions expressed.

Introduction, Purpose and Objectives

Jim Bower, King County, welcomed the group and thanked everyone for taking the time to attend the Lake Sammamish Kokanee Technical Workshop. Jim highlighted the importance of the workshop given the wealth of new information that has been made available since the last formal gathering of key stakeholders. Jim identified two key documents that have guided the group's work to-date: *Blueprint for Restoration and Enhancement of Lake Sammamish Kokanee Tributaries* and *Conservation Supplementation Plan for Lake Sammamish Late-run Kokanee.* David St. John, King County, provided an overview of the kokanee workgroup and noted the urgent need for action.

Following introductions, Jim noted that the purposes of the workshop were to:

- Identify opportunities for new and improved adaptive management strategies
- Highlight research needs and knowledge gaps, and
- Better define the questions that need to be answered.

He added that the points brought up during the workshop would support conservation work in years to come.

History, Current Efforts and Future of Conservation

Roger Tabor, US Fish and Wildlife Service – Presentation

Roger Tabor provided a presentation on the evolutionary history and ecological context of kokanee salmon and their habitat. Key points in Roger's presentation included the evolutionary history of kokanee salmon in relation to sockeye, historic local and regional habitat distribution, past efforts to list kokanee salmon in Lake Sammamish under the Endangered Species Act (ESA) and potential areas of focus for future species and habitat conservation efforts. In addition, Roger noted the following key points:

- Historically, kokanee salmon in Lake Sammamish have been concentrated in three stocks: fall run, winter run and summer run. Currently, save for a small number of observed fish in fall run tributaries, kokanee are concentrated in the winter run.
- Kokanee in Lake Sammamish experience a dramatic change in total population numbers year to year. The reasons for these dramatic variations are unclear.
- Conservation strategies have been focused on supplementation and habitat restoration, with an emphasis on the former. More research is needed to determine how well supplementation strategies support long-term restoration efforts.

Topic: Information

Jim Bower, King County – Presentation

The goal of Jim's presentation was to provide an overview of factors that contribute to kokanee health and habitat function. An overview of key topic areas and questions raised during the presentation are covered below.

Population genetics

Following an overview of population genetics of kokanee salmon in Lake Sammamish, Jim asked the group whether more research was needed to determine if the Lake Sammamish kokanee population was genetically distinct. The group consensus was that this was a low priority.

Spawning habitat quantity

Jim provided an overview of an analysis he performed on the spawning habitat available to kokanee salmon surrounding Lake Sammamish. The analysis assessed gross linear feet of viable spawning habitat. Jim highlighted the fact that current accessible habitat is estimated to be 60 percent of the historic total and estimated that an additional 27 percent of historic habitat could be opened up if several key barriers are eliminated.

- David St. John asked what the threshold was that eliminated 13 percent of habitat in the analysis. Jim explained that it was mostly a judgement call based on local conditions (i.e., creeks blocked by East Lake Sammamish Parkway).

Stream hydrology

Jim presented an analysis of adverse impacts on spawning habitat due to development, barriers and climate change. He highlighted the extreme sensitivity of kokanee salmon to unpredictable and variable stream flow rates, especially on the ascending limb of the hydrograph. Key points included:

- The number and frequency of high-flow events has been trending upward, especially in Lewis Creek. Actions to mitigate high-flow events could reduce adverse impacts on spawning kokanee salmon.
- Dave Beauchamp, University of Washington, pointed out that kokanee salmon using the early run rely on base flows. Therefore, it is important to create conditions that allow for productive spawning at base flow rates.
- Kit Paulsen, City of Bellevue, called the group's attention to the impact of upland conditions as a key contributing factor to stream health and flow rate. A reduction in material flowing downstream would improve the habitat and water quality downstream.

Stream water quality

Jim noted the susceptibility of spawning kokanee salmon to fine sediment levels due to reduced permeability and reduced dissolved oxygen levels. He noted a poor level of understanding about various creeks and pointed out that recent efforts to reduce fine sediment levels in streams may be relatively effective.

Stream productivity

Jim highlighted the extensive work Trout Unlimited has done to trap, mark, test and track kokanee salmon in the streams that feed into Lake Sammamish. He summarized their findings and noted that trapping methods are imprecise and have led to a large degree of uncertainty in fry abundance estimates. Key findings included:

- Productivity levels between 5 and 20 percent are similar to findings from other streams in the region.
- Lewis Creek's productivity has been low for the past four years. This could be due to the number of construction projects along the creek, which have increased materials in the system.
- Ebright Creek's productivity may be trending upwards.
  - Brad Throssell, Trout Unlimited, pointed out that there have been several culverts removed along Ebright Creek in the past several years.

Pat DeHaan, US Fish and Wildlife Service, asked if sampling could be controlled to limit the variability in the data. Jim clarified that the population size numbers varied in part due to efficiency samples being taken throughout the season and suggested increasing the sampling frequency and improving sampling methodology. Jim noted that current findings may indicate a carrying capacity of about 2,000 fish per stream, and posited that in order to increase total population, more streams would need to be restored and reconnected within the watershed.

The group discussed rapidly changing conditions in the streams and lake. Key points included:

- The impacts of rising water temperatures – due to climate change, run off and other factors – are unknown. Given kokanee's sensitivity to temperature changes, variations in temperature could explain a portion of the extreme variation in population year to year.
- Nutrient loads have been declining since the 1960s due to a reduction in agricultural run-off. These changes could have a small or large impact on lake productivity.
- Higher than average dissolved oxygen (DO) levels may be correlated with lower than average annual population numbers. DO levels for 2016 are especially low and raise concerns over population viability looking ahead to 2017.
- Having a consistent and thorough sampling method is important in comparing populations year to year; 2015 was one of the most rigorous sampling years.
- More research is needed to determine how well the supplementation program is aiding long-term restoration efforts. The goal should be to raise spawner recruitment to above one.

Topic: Problem-Solving

Jeff Chan, US Fish and Wildlife Service, opened the discussion by asking for the group's thoughts on focusing restoration efforts on the early run and asked if that would change conservation strategies moving forward. David St. John stated that the focus in the past has been on actions that improve conditions in all runs and noted specific actions like paving in watersheds and groundwater diversion as potential future areas of focus. Jim reiterated that the highest priority actions should address pressures in all three runs and noted that kokanee using the summer run have the advantage of avoiding the DO squeeze.

David St. John highlighted the following physical and biological constraints that limit recolonization:

- Base flow rates
- Thermal squeeze and availability of cold water
- Rising stream temperatures (especially for early run fish)
- Combined impacts of changing flow rates, temperature and water quality on fry and adult health
- Water quality in Lake Sammamish

Jim brought the group's attention back to population genetics. Roger Tabor noted that there is a draft report on population genetics that has yet to be finalized. The final report would include information on Lake Sammamish and its tributaries. The group agreed that finalizing the report would provide valuable information for future conservation efforts.

Mark Taylor, Trout Unlimited, asked if it would be possible to determine the most important factors for kokanee health in Lake Sammamish. While the group agreed that this information would help inform future conservation strategies, the technology and labor necessary to perform such an analysis would need to be developed.

Jim asked the group for feedback on strategically opening up smaller streams to increase the amount of viable spawning ground. He noted that proving these efforts were successful could increase support and funding opportunities. Roger asked whether successful restoration would require registered sightings of kokanee fry in newly opened streams and highlighted the difficulties in reliable sampling – especially in smaller streams. Jim explained eDNA sampling method, which could lessen some of the current uncertainty surrounding viable spawning grounds. Kit Paulsen noted that eDNA is a useful tool but is limited to detecting presence and cannot determine total population numbers. On the subject of technology, Pat DeHaan noted that any new technology would need to go through thorough testing before it could be used to support or modify any conservation strategies.

Moving onto stream hydrology and water quality, Jim summarized the need to keep fry trapping and monitoring and Dave Beauchamp reiterated that monitoring is a necessary first step to determine the success of any conservation effort.

Kit Paulsen touched on a point she had brought up earlier in the workshop regarding the importance of upland hydrology and landscape conservation for stream and lake hydrology. She noted that upland circumstances (run off, erosion, pollution, etc.) have a tremendous impact on stream and lake health and can compromise any effort that is taken to improve habitat function.

In addition to the topics above, the following items were discussed:

- Expanding trapping locations: group consensus was that funding and labor limit how much trapping and analysis can be done.
- Dave Beauchamp noted that analyzing various important data is probably more costly and time-intensive process than collecting samples. He suggested backlogging samples so that they could be analyzed to confirm hypotheses and trends as they arise.
- Improving water quality in Lake Sammamish: Jim proposed using King County's toxics analysis program to perform a similar study to what is currently being done in Lake Union. It was determined that pollution had the largest impact on higher trophic level fish than kokanee and that the costs could outweigh the direct benefits for kokanee.

Topic: Lake Primary Productivity and Zooplankton

Jim highlighted the need to answer the following questions in order to efficiently conserve habitat and promote kokanee health in Lake Sammamish:

- What are the key factors driving population variability?
- What are the specific species dynamics and knowledge gaps that would reveal what drives population variability?

Mark Taylor noted that the release window for coho salmon could increase predation on kokanee and called for more predator surveys. Mark went on to suggest attempting to lessen overlap between coho and kokanee to limit the time kokanee would be exposed to predators.

Roger pointed out that prior to modifying the times that fish are released, it would be necessary to determine what kokanee fry do when they enter Lake Sammamish (i.e., do they linger in shallow areas along the shore or do they migrate to the deeper waters in the middle of the lake?). The group discussed how a more refined picture of kokanee fry habits would supplement predator studies but highlighted the fact that kokanee salmon are very difficult to track given their size and abundance.

Regarding predator studies, the group brought up the following key points:

- It would be difficult to look back at past release dates to analyze the effect of predation on kokanee salmon because there are so many contributing and conflicting factors.
- There was a group consensus that more data and analysis is needed on the movement of kokanee once they enter Lake Sammamish.

The group discussed how primary productivity and phytoplankton impact kokanee health and viability. Jim described potential relationships between chlorophyll and zooplankton and surface spikes in Daphnia blooms, noting how these factors could increase food abundance for kokanee and survival rates. Dave Beauchamp highlighted the timing of nutrient releases as playing a key role in the amount of food available to kokanee. The group agreed that to better understand how much of an impact the above factors have on kokanee, more data analysis and information is needed.

Topic: Lake Pathogens and Other Factors

The group discussed the topics below related to pathogens and their impact on kokanee health.

- Type four viral septicemia: It is unknown whether there has even been a widespread outbreak of type four viral septicemia in Lake Sammamish kokanee.
- IHN virus: Under high-stress conditions (i.e., high temperatures, low DO levels, low availability of food), kokanee could be at risk to IHN, which is already spread throughout the watershed. If positive cases are widespread, IHN could have a large impact on kokanee population.
    - There have been multiple cases of IHN positives in kokanee in the past six years.
- Bacterial epidemics: Bacterial epidemics are known to occur but have yet to be documented in Lake Sammamish kokanee.
- Parasites: Impacts due to parasites are difficult to measure because the infected fish sink.
    - As conditions change, newly introduced parasites could have a large impact on kokanee health and susceptibility to parasites.
    - Dave Beauchamp suggested connecting with Jim Winton, USGS Fish Health Group, to discuss future study of parasites.

Brad Throssell suggested focusing on conservation strategies that are manageable (i.e., increasing viable spawning ground, improving water quality, etc.). He highlighted that improving these circumstances would mitigate unmanageable pressures.

<u>Topic: Supplementation Program</u>

The most challenging topic discussed during the workshop was the lower than expected survival rates of fry released as part of the supplementation program. In 2009-2010, it was estimated that of the 31 percent of kokanee fry released as part of the supplementation program, only eight percent returned. The cause of the high fatality rates is unknown. Jim asked the group if there were any ideas or proposals that could shed light on the low survival rates. David St. John noted that the total number of kokanee salmon was higher during from supplementation years but conceded that the percentage of returns could be higher.

The group discussed what conditions could have enabled high survival rates during some years and low survival rates in others. The topics below arose out of these discussions.

- Roger Tabor noted that natural fish exit tributaries and streams over a wider range of time (from dusk to dawn) than supplemental fish – which go out in one large batch. This concentration could lead to higher predation rates.
- David St. John highlighted the differences between wild fish and supplemental fish, especially during very early life stages. He noted that the fry released in the supplementation program are fed before they are released. As a result, they are much larger than wild fry, which could lead to increased predation rates.
    - Roger noted that the State recommends feeding because it makes transporting fish easier.
    - Darin Combs, Issaquah Salmon Hatchery, recalled that early on in the supplementation program one batch of fry were not fed. The group was too small to have yielded any conclusive data on return rates but he said not feeding would be an option if the group wanted to try it.
    - Dave Beauchamp voiced his reluctance to halt feeding completely because the implications would be unknown. He noted that, while return rates may not be as high as the group hoped, the goal of the supplementation program is to ensure returns and that current practices are achieving that goal. In response, Jim suggested organizing next year's supplemental group into two batches: one fed and one not fed. These two groups would be marked and returns would be analyzed to determine the impact of not feeding.
    - With buyoff from Jim, David St. John and Darin Combs, the group decided to modify feeding through 2019. Future supplemental fry will be split into two groups: one will be fed and one will not. Percentage of returns from each group will inform future supplementation program practices.
- Darin noted that a difference in water temperature between natural streams and the incubating tanks could play a role in the size of fry released in the supplementation program.
    - There was a group consensus that cooling the water in the tanks to better replicate natural conditions could be a strategy to improve fry survival rates.

    - Several members in the group were concerned that emulating natural conditions would put supplemental fry at a disadvantage to predators. With handling, there is a certain amount of domestication, which could play into the low survival rates.
- Kit Paulsen called for additional research into the impacts of incidental harvest in Lake Sammamish, citing a lack of data and understanding. She noted that the impacts from incidental harvest could decimate the kokanee population, especially during high-take years.

In addition to the topics above, the group brought up the following key points:

- Kokanee survival rates could rely on cycles that are yet to be fully understood. There is some evidence for a three-year cycle but it lacks supporting data.
- More research is needed on the impacts of natural events (i.e., landslides, high precipitation, high flow rates, etc.).
- Warming trends should increase the abundance of three-year kokanee in Lake Sammamish.
- Predation seems to have a high impact on kokanee survival rates and should be a major focus of future research. Jim noted that there is a need to fine-tune stream and lake productivity estimates to try to account for predation during key life stages. Dave highlighted the funding issues around predator analysis studies and noted that while the information would be valuable, funding may have to come from other sources. These studies would be mechanistic and would therefore reveal a lot of information in one year, reducing the need for comprehensive analysis year after year.

<u>Topic: Practical Indicators of Population Status</u>

In an effort to better define the success of restoration efforts in Lake Sammamish, Jim and the group proposed several indicators.

- Measure ten-year median abundance in three index streams.
    - The group agreed that since the data is available, it would make sense to make that adjustment. Jim also proposed aiming to keep spawner recruitment above one. This would ensure population growth and minimize the chance of a catastrophic collapse.
- Jeff Chan proposed aiming to have above 500 kokanee return annually and the group agreed that was a reasonable number.
- Dave suggested using indicators that measure progress at various life stages in an effort to determine how well current strategies are working and better inform future conservation efforts.
- Bill Gerdts, Trout Unlimited, proposed organizing additional angler surveys. These would (1) reveal any malpractice by anglers and (2) support data collection efforts.
- Dave suggested establishing a goal for increasing viable spawning area above baseline.

Action Items

Action items included the following:

- Brad Throssell: look into feasibility of expanding trapping and testing into Tibbetts Creek and other smaller tributaries. Trout Unlimited will follow up on proposed expansions during their January 4, 2017, meeting.
- Darin Combs: follow up with the group with additional information about the timing of the releases in 2010.

Attendees (in random order)

Jim Bower, King County	Dave Beauchamp, University of Washington	Josh Kubo, King County
Jeff Jensen, University of Washington Bothell	Brad Throssell, Trout Unlimited	Kit Paulsen, City of Bellevue
Bill Mavros, Consultant	Dave Steiner, Snoqualmie Tribe	Pat DeHaan, US Fish and Wildlife Service
Casey Costello, WA Department of Fish and Wildlife	Mary Wictor, Resident	Peter Holte, City of Redmond
Tawni Dalziel, City of Sammamish	Mark Taylor, Trout Unlimited	Darin Combs, WA Department of Fish and Wildlife
Jeff Chan, US Fish and Wildlife Service	Roger Tabor, US Fish and Wildlife Service	Bill Gerdts, Trout Unlimited
Dave Kyle, Trout Unlimited	Kate O'Laughlin, King County	Dan Lantz, King County
David St. John, King County	Darin Combs, WDFW, Issaquah Salmon Hatchery	Harrison Price, EnviroIssues