

**Lake Sammamish Kokanee
Spawning Ground Survey Summary and Escapement Estimate
for the
2011-12 and 2012-13 Spawning Seasons**



Lake Sammamish late-run kokanee spawners. Photo: R. Tabor, USFWS.

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Introduction

Three separate populations of native kokanee *Oncorhynchus nerka* historically inhabited the Lake Washington-Sammamish Watershed: 1) Early-run kokanee, 2) Middle-run kokanee, and 3) Late-run kokanee (Pfeifer 1995, Berge and Higgins 2003). Early-run kokanee occurred in Lake Sammamish and were only known to spawn in Issaquah Creek. Middle-run kokanee rear in Lake Washington and spawn in tributaries of the Sammamish River, including Swamp, North, Bear, Little Bear, and Cottage Lake Creeks. Late-run kokanee rear in Lake Sammamish and primarily spawn in Ebright, Lewis, and Laughing Jacobs Creeks, which flow into the south end of Lake Sammamish. Late-run kokanee adults have also been reported in other small Lake Sammamish tributaries such as Tibbetts, George Davis, Pine Lake, Vasa, Schneider, Pickering, Idylwood and Zaccuse Creeks (Figure 1).

Native kokanee in the Lake Sammamish watershed were once abundant, and historically supported harvest fisheries with run sizes numbering in the tens of thousands. However, kokanee abundance levels in Lake Sammamish began to decline in the 1980s (Pfeifer 1995). Kokanee fisheries in Lake Sammamish were discontinued during the 1990s, as kokanee abundance continued to decline. Despite reductions in harvest, the early-run kokanee population that used Issaquah Creek for spawning continued to decline, ultimately reaching abundance levels so low that standard stream survey methods were not able to detect any returning fish during the spawning season (Pfeifer 1995). Early-run kokanee spawning escapement is not currently monitored, and this population may have been extirpated. The middle-run kokanee population spawning in tributaries to the Sammamish River was likely affected or replaced by Baker Lake sockeye that were planted throughout the early 1900s (Young et al. 2004). Middle-run kokanee escapement is not currently monitored, and the relative size and health of this population is unknown. Late-run kokanee are currently the only detectable native kokanee population that still spawns and rears within the Lake Sammamish watershed.

Lake Sammamish Watershed kokanee have been petitioned twice for listing under the Endangered Species Act (ESA). The first petition was submitted in 2000 and requested that the early-run kokanee population (only kokanee returning to Issaquah Creek) be listed under the ESA. This petition was later (in 2007) denied by the United States Fish and Wildlife Service (USFWS) under the premise that the Issaquah Creek kokanee population was not sufficiently discreet from other Sammamish Basin kokanee and sockeye populations to represent a distinct population segment (DPS), and was therefore not considered a listable entity under the ESA. Subsequently, a group comprised of local jurisdictions and non-governmental organizations submitted a second petition to list kokanee as either threatened or endangered under the ESA in 2007. The 2007 petition requested that all naturally spawning kokanee in Lake Sammamish (including early, middle, and late returning population segments) be considered for ESA listing. However, the USFWS again determined that Lake Sammamish kokanee were not warranted for listing under the ESA in October 2011. The USFWS justification for not listing kokanee in response to the 2007 petition was that the Lake Sammamish kokanee population was not significant to the remainder of the taxon, and therefore did not qualify as a DPS.



Figure 1. Location of late-run kokanee spawning streams in the Lake Sammamish basin. Red lines indicate upper extent of surveys.

Late-run kokanee abundance has been highly variable in Lake Sammamish, and the efforts of several local natural resource management agencies have focused on monitoring and recovering this population. Recently, the Lake Sammamish Kokanee Technical Workgroup (LSKWG) was formed by Washington Department of Fish and Wildlife (WDFW), King County Department of Natural Resources and Parks (KCDNRP), Save Lake Sammamish, Friends of Pine Lake Creek, Cities of Issaquah, Bellevue, Redmond, and Sammamish, and the USFWS. The goal of the LSKWG is to prevent extinction and improve the health of the native kokanee population such that it is viable and self-sustaining, and can support fishing opportunities. Conservation efforts of the LSKWG include public outreach and education, annual spawning ground surveys, and most recently, development of a supplementation program to increase spawning success of the population.

The KCDNRP, WDFW, and local area volunteers survey selected Lake Sammamish spawning tributaries each year for late-run kokanee between October and March to estimate adult spawning escapement and to monitor adult kokanee biological characteristics. The objective for this report is to summarize spawning ground surveys for late-run kokanee from October 2011 to January 2012 and from October 2012 to March 2013. Broodstock collection numbers for the kokanee supplementation program are also reported and are included in total run size estimates. Results of these monitoring activities will contribute to the index of late-run kokanee abundance in the Lake Sammamish watershed, and help evaluate the long-term success of conservation activities.

Methods

Spawning Ground Surveys

Spawning ground surveys of the three primary kokanee spawning streams (Lewis, Ebright, and Laughing Jacobs Creeks) were conducted during the kokanee spawning period in both 2011-12 and 2012-13. Numbers of live fish, dead fish, and redds were recorded during each survey. Survey coverage during the 2012-13 kokanee spawning season included more small tributaries than in 2011-12, due to an exceptionally large kokanee escapement and broader geographic distribution of spawning activity in 2012-13.

2011-12 Survey Coverage: During the 2011-12 spawning season, regular surveys were conducted three to five days per week in Ebright Creek (from approximately RKM 0.0 – 0.4), Lewis Creek (approximately RKM 0.0 – RKM 1.0), and Laughing Jacobs Creek (approximately RKM 0.0 – RKM 1.0) as conditions allowed and until spawning activity was no longer observed. In 2011-12, kokanee spawning ground surveys began during the week of 10/31/2011 and extended to the week of 1/23/2012. Surveys were also conducted in Lake Sammamish in 2011-12 to detect kokanee spawning activity in shoreline areas. Lake surveys included shallow-water boat surveys, mid-water dive surveys, and two overhead flights conducted during times of peak spawning activity (See summary report in Appendix C). Lake surveys did not cover the entire shoreline area of Lake Sammamish, but concentrated

survey effort near the mouths of known tributary streams and along shallow-water shoals with gravel substrate where sockeye spawning has been documented in the past.

2012-13 Survey Coverage: During the 2012-13 spawning season, regular surveys were conducted one to three times per week in Ebright Creek (from approximately RKM 0.0 – 1.0), Lewis Creek (approximately RKM 0.0 – RKM 1.0), and Laughing Jacobs Creek (approximately RKM 0.0 – RKM 1.0). Survey coverage extended further in Ebright Creek in 2012-13 than in the past because a barrier culvert at approximately RKM 0.4 was removed, and adult kokanee were able to access a greater portion of the stream for spawning. Kokanee spawning ground surveys for the three primary streams began in the week of 10/15/2012 and extended to the week of 3/4/2013.

Surveys were conducted in additional tributaries in 2012-13 in response to the exceptionally large spawning escapement to document the spawning activity and collect biological samples. Additional tributaries surveyed in 2012-13 included Tibbetts Creek (RKM 0.9 to RKM 2.6), Pine Lake Creek, Vasa, Zaccuse, George Davis, Schneider, Idylwood and Pickering Creeks. Surveys in Tibbetts Creek and Pine Lake Creek were conducted weekly, while Vasa, Zaccuse, George Davis, Schneider, Idylwood, and Pickering Creeks were opportunistically spot checked during peak spawning periods. Tibbetts Creek was monitored weekly from 11/9/2012 through 1/14/2013, and Pine Lake Creek was surveyed one or two times per week by a local landowner between 10/14/2012 and 1/27/2013. Surveys were not conducted in shoreline areas of Lake Sammamish in 2012-13.

Carcass Recovery Surveys

Kokanee carcasses that were encountered during spawning ground surveys and spot checks were processed for biological data including length, sex, otoliths, egg retention, and tissue samples for DNA analysis. Biological data and samples were also collected from all fish that were collected for use as broodstock in the supplementation program. During the 2011/2012 survey season, supplemental carcass recovery surveys were conducted in tributaries to the Sammamish River, including Bear Creek, Little Bear Creek, and North Creek, as well as the Sammamish River mainstem. DNA from kokanee carcasses found in the Sammamish River tributaries was analyzed for comparison with kokanee DNA from the Lake Sammamish tributaries. Supplemental carcass surveys were not conducted in the Sammamish River tributaries during the 2012/13 spawning season.

Escapement Estimation

Adult escapement was estimated using the area under the curve index escapement (AUC; Ames 1984; Perrin and Irvine 1990). Live fish counts are combined for a stream system and plotted (y-axis) by date (x-axis). Fish days are calculated (F) as

$$F_{t+1} = \left(\frac{C_t + C_{t+1}}{2} \right) \times (J_{t+1} - J_t), \quad \text{Equation 1}$$

where C_t is the live count for the first survey, C_{t+1} is the live count of the second survey, and J_t and J_{t+1} correspond to the Julian Day of each of the live counts, respectively. AUC is then calculated as

$$AUC = \frac{\sum_t^{t_f} F}{V}, \quad \text{Equation 2}$$

where F represents fish days, V is the average number of days a fish is susceptible to being counted by surveyors (stream life estimate), and t_f represents the last survey date. Stream life for kokanee in Lake Sammamish tributaries is unknown and can vary annually and throughout the spawning run. A 10-day stream life was used as the index of abundance in this report to be consistent with past escapement estimates and to assess long-term trends of abundance. The 10-day stream life value is likely higher than the actual stream life for Lake Sammamish kokanee (i.e. spawning kokanee typically are present in Lake Sammamish spawning streams for less than ten days), and so total AUC spawning escapement was also calculated over a range of stream life values (5, 7, 10, and 12) for the 2011/12 and the 2012/13 spawning seasons. Broodstock removed from streams for use in the supplementation program were not included in the live fish counts because they were not permitted to spawn naturally, but were added into the final escapement estimate (total run size estimate) for each stream.

Broodstock Collection

The kokanee supplementation program, initiated in 2008, is an important strategy in the overall effort to recover late-run kokanee in Lake Sammamish. Adult kokanee are collected for the supplementation program from Lewis, Ebright, and Laughing Jacobs Creeks (and occasionally from other smaller Lake Sammamish spawning tributaries) using a backpack electroshocker or dip nets, and transported to Issaquah Hatchery for use as wild broodstock. Adult kokanee that are actively spawning, or that have initiated redd construction are not collected and efforts are taken to avoid disrupting them. Broodstock collection efforts span the duration of the kokanee spawning season, and the number of wild fish taken for use in the supplementation program varies annually with the strength of the kokanee run (Table 1). Broodstock collection goals and spawning guidelines for the program are described in the Kokanee Supplementation Plan (LSKWG 2012).

Table 1. Broodstock collection goals under different run size scenarios (Source: LSKWG 2012).

Stream	Size of Return/Escapement		
	Low	Medium	Good
Ebright Creek	<50	50-100	>100
Collection goal (% of run)	75%	33%	15%
Laughing Jacobs Creek	<50	50-100	>100
Collection goal (% of run)	75%	50%	25%
Lewis Creek	<50	50-200	>200
Collection goal (% of run)	75%	33%	15%

Results

Spawning Ground Surveys and Adult Escapement

2011/12 Spawning Escapement: Spawning ground surveys were conducted one to three days per week in Lewis, Ebright, and Laughing Jacobs Creeks and began on October 31, 2011 or November 1, 2011 and extended until January 9, 2012 (Lewis Creek) and January 11, 2012 (Ebright and Laughing Jacobs Creeks). Periods of extended rain and high stream flows occasionally prevented effective surveys during portions of the spawning season, but did not prevent at least one survey from being conducted per week. A total of 35 surveys were conducted at Lewis Creek, 41 at Ebright Creek, and 33 at Laughing Jacobs Creek. (Appendix A).

Kokanee spawning escapement (AUC method with 10-day stream life) in 2011/12 was estimated at 912 fish for the three primary spawning streams combined, the fifth highest escapement estimate since monitoring began in 1996/97 (Table 5). Total run size, which includes broodstock collected at the three primary streams, was estimated at 1,163 fish (Table 2). Ebright Creek spawning escapement was estimated at 188 fish with a total run size of 287 and 113 redds. Spawning escapement in Lewis Creek was estimated at 351 fish with a total run size of 411 and 139 redds. Laughing Jacobs Creek spawning escapement was estimated at 377 fish with a total run size of 465 and 171 redds.

Surveys within Lake Sammamish itself failed to find evidence of any lake spawning activity by kokanee in 2011/12. A series of boat surveys in shallow water areas, dive surveys in mid-water areas, and two overhead flights were conducted during periods of peak kokanee spawning (Appendix C). Survey effort was concentrated near the mouths of known spawning streams, along gravel shoals in shallow-water habitats, and in areas thought to have groundwater upwelling. No live kokanee spawners or confirmed kokanee redds were observed during any of the lake survey efforts. Nine potential kokanee redds (redd-shaped substrate disturbances) were identified in mid-water areas (20-40 ft. deep) during the dive surveys, but after excavating six of these areas and failing to find eggs, these areas were determined not to be kokanee redds (Appendix C).

Table 2. Estimated escapement, redd counts, and broodstock collection totals for late-run Lake Sammamish kokanee in the 2011/12 spawning season.

Stream	No. Surveys Conducted	AUC Spawning Escapement			No. Brood Stock Collected	Total Run Size (AUC stream life = 10)	No. Redds	
		12	10	7				
Ebright Creek	41	157	188	269	376	99	287	113
Laughing Jacobs Creek	33	314	377	539	754	88	465	171
Lewis Creek	35	293	351	501	702	60	411	139
TOTAL	109	763	916	1,309	1,832	247	1,163	423

2011/12 Run Timing: The majority of spawning activity in 2011/12 was observed between early- to mid-November and the end of December in Lewis, Ebright and Laughing Jacobs Creeks (Figure 2). Spawning activity peaked in all three creeks in late November. No live fish or new redds were observed after December 23 in Ebright Creek, December 28 in Lewis Creek, or January 6 in Laughing Jacobs Creek.

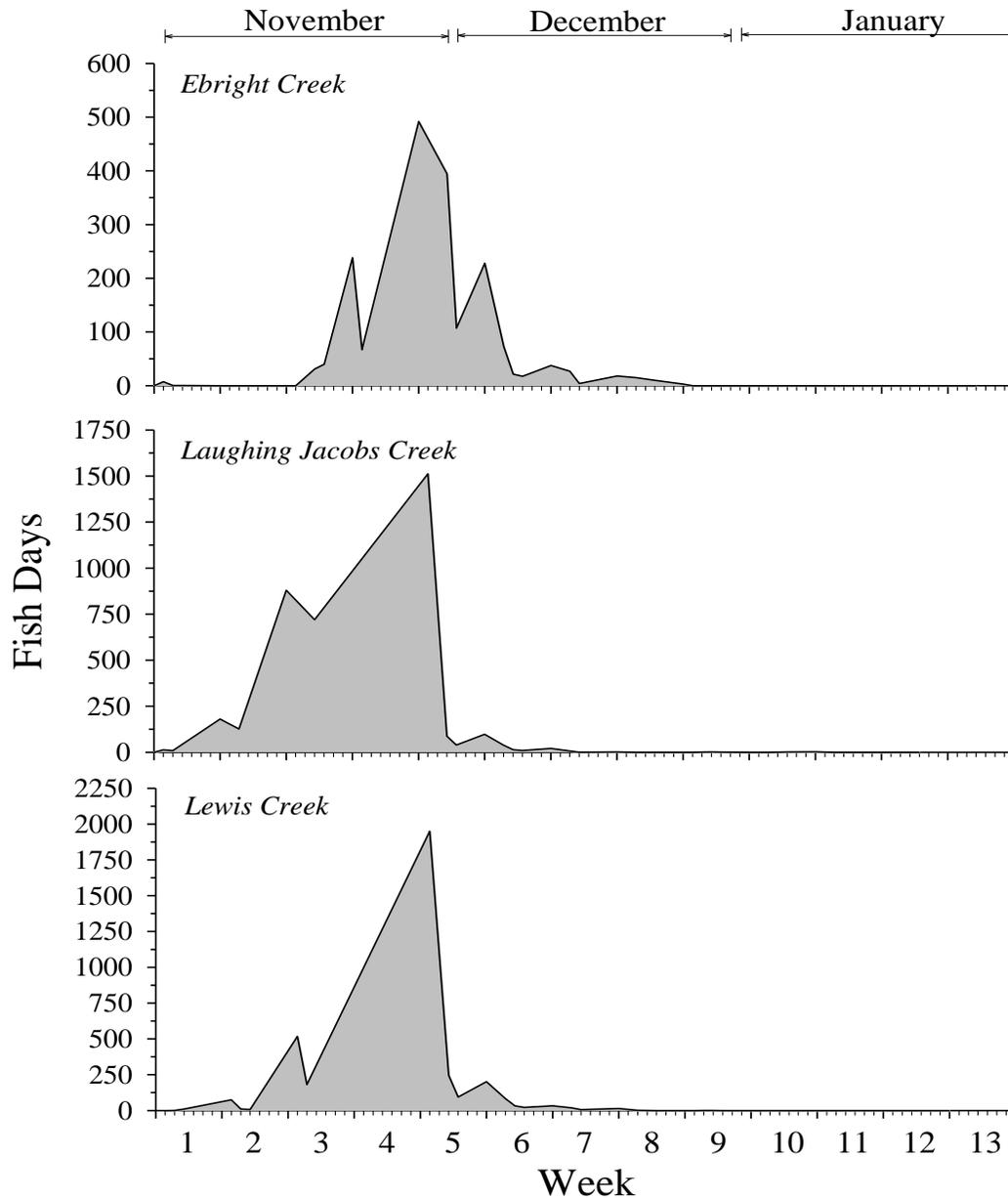


Figure 2. Late-run kokanee run timing (fish days) in Lake Sammamish tributaries during the 2011/12 spawning season. Week 1 began on 10/31/2011, and Week 13 began on 1/23/2012.

2012/13 Spawning Escapement: Spawning ground surveys were conducted one to three days per week in Lewis, Ebright, and Laughing Jacobs Creeks and began on October 15, 2012 and extended until February 26, 2013 (Lewis Creek) and March 5, 2013 (Ebright and Laughing Jacobs Creeks; Appendix B). Surveys were conducted weekly in Tibbetts Creek from November 9, 2012 to January 14, 2013 and at Pine Lake Creek from October 14, 2012 to January 27, 2013. Periods of extended rain and high stream flows occasionally prevented effective surveys during portions of the spawning season, but did not prevent at least one survey from being conducted per week. A total of 35 surveys were conducted at Lewis Creek, 34 at Ebright Creek, 32 at Laughing Jacobs Creek, 10 at Tibbetts Creek, and 19 at Pine Lake Creek.

Kokanee spawning escapement (AUC method with 10-day stream life) in 2012/13 was estimated at 9,939 fish for the three primary spawning streams, the highest estimate on record (Table 5). Total run size, which includes collected broodstock and escapement at two additional tributaries, was estimated at 11,401 fish (Table 3). Ebright Creek spawning escapement was estimated at 4,624 fish with a total run size of 4,906 and 1,801 redds. Spawning escapement in Lewis Creek was estimated at 4,408 fish with a total run size of 4,686 and 1,874 redds. Laughing Jacobs Creek spawning escapement was estimated at 908 fish with a total run size of 1,094 and 410 redds.

Table 3. Estimated escapement, redd counts, and broodstock collection totals for late-run Lake Sammamish kokanee in the 2012/13 spawning season.

Stream	No. Surveys Conducted	AUC Spawning Escapement				No. Brood Stock Collected	Total Run Size (AUC stream life = 10)	No. Redds
		12	10	7	5			
Ebright Creek	34	3,853	4,624	6,605	9,247	282	4,906	1,801
Laughing Jacobs Creek	32	756	908	1,296	1,815	186	1,094	410
Lewis Creek	35	3,673	4,408	6,297	8,815	278	4,686	1,874
Pine Lake Creek	19	283	340	486	680	n/a	340	40*
Tibbetts Creek	10	313	376	537	752	n/a	376	131
TOTAL	130	8,878	10,655	15,222	21,308	746	11,401	4,256

*Underestimate of redds. Redds were only counted on one day.

Escapement to Other Tributaries in 2012/13: Spawning escapement (AUC method with 10-day stream life) in Tibbetts Creek was estimated at 376 fish and 131 redds. Pine Lake Creek spawning escapement was estimated at 340 fish. A peak count of 40 redds was made during a single survey in Pine Lake Creek, but kokanee redds were not monitored on a regular basis in Pine Lake Creek. No broodstock were collected from Tibbetts or Pine Lake Creeks. Although regular surveys were not conducted in other Lake Sammamish tributaries, live fish, carcasses, and redds were observed in all of the known Lake Sammamish tributaries, including George Davis, Idylwood, Issaquah, East Fork Issaquah Pickering, Schneider, Vasa, and Zaccuse creeks (personal communication Dan Lantz, KCDNRP and Roger Tabor,

USFWS). Spawning escapement for these tributaries was not estimated, and the number of fish spawning in these other areas was thought to be small in relation to the numbers estimated in the three primary spawning streams. However, future monitoring efforts may be necessary as introduced supplementation program fish begin to return. Lake surveys for spawning kokanee were not conducted in Lake Sammamish in 2012/13.

Restoration of a barrier culvert at RKM 0.4 in Ebright Creek in 2012 made previously inaccessible habitat available for spawning in 2012/13. Kokanee utilized this new habitat and were observed spawning upstream to about RKM 1.0. Kokanee spawners in Laughing Jacobs Creek were observed spawning up to RKM 1.0, which was about 0.2 RKM further upstream than previously reported in 2011/12.

2012/13 Run Timing: In addition to the largest run since monitoring began in 1996/97, spawning activity in 2012/13 was the most protracted on record. Live fish were consistently observed from October through mid-February and early-March in Laughing Jacobs, Lewis and Ebright Creeks (Figure 3). Fish activity continued in Tibbetts and Pine Lake Creeks until early January. Spawning activity peaked across all creeks in late November, followed by a smaller peak in mid to late December.

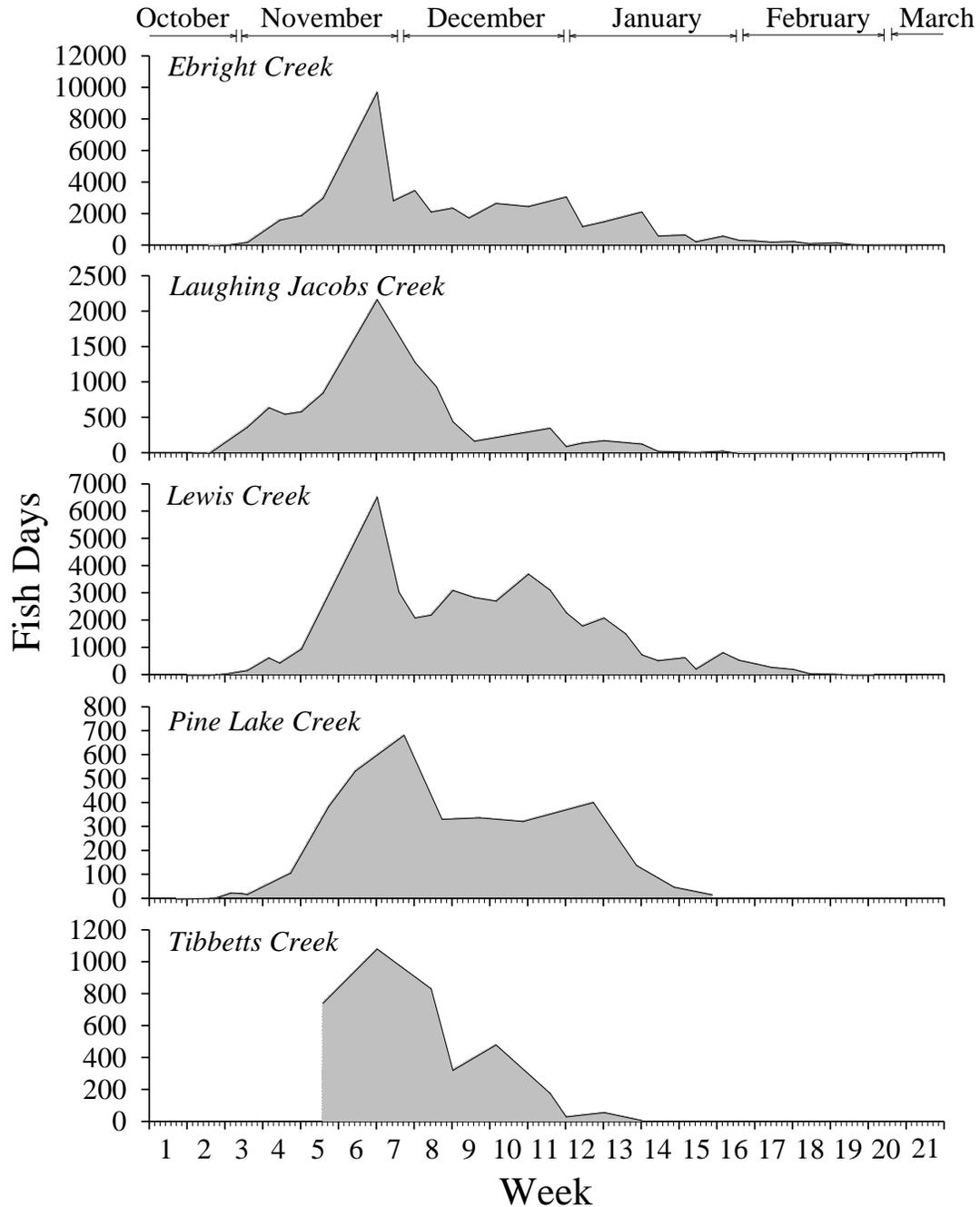


Figure 3. Late-run kokanee run timing (fish days) in Lake Sammamish tributaries during the 2012/13 spawning season. Week 1 began on 10/15/2012, and Week 21 began on 3/4/2013.

Broodstock Collection

Kokanee broodstock were collected from the three primary kokanee spawning tributaries during the 2011/12 and the 2012/13 spawning seasons. During the 2011/12 spawning season, 60 broodstock were collected from Lewis Creek (~15% of the run), 88 brood were collected from Laughing Jacobs Creek (~19% of the run), and 99 broodstock were collected from Ebright Creek

(~35% of the run, Table 2). These broodstock resulted in supplementation program releases of approximately 12,700 fry into Lewis Creek, 19,500 fry into Laughing Jacobs Creek, and 32,500 fry into Ebright Creek in April of 2012 (Table 4).

During the 2012/13 spawning season, 278 broodstock were collected from Lewis Creek (~6% of the run), 186 broodstock were collected from Laughing Jacobs Creek (~17% of the run), and 282 broodstock were collected from Ebright Creek (~6% of the run, Table 3). 24 broodstock were also collected from Zaccuse Creek. These broodstock resulted in supplementation program releases of approximately 45,500 fry into Lewis Creek, 32,400 fry into Laughing Jacobs Creek, and 47,200 fry into Ebright Creek in April and May of 2013 (Table 4). Due to the large number of broodstock collected, approximately 84,700 fry were also released into the Issaquah Creek in April of 2013. The Issaquah Creek fry release was composed of a mixture of offspring from the three primary spawning tributaries and Zaccuse Creek.

Table 4. Late-run kokanee supplementation program fry releases by brood year, 2009/10 to 2012/13.

Stream	Fry Released			
	2009/2010	2010/2011	2011/2012	2012/2013
Ebright Creek	12,031	10,586	32,484	47,238
Issaquah Creek	n/a	n/a	n/a	84,688
Laughing Jacobs Creek	15,740	2,582	19,470	32,430
Lewis Creek	11,771	795	12,725	45,536
TOTAL	39,542	13,963	64,679	125,204

Table 5. Late-run kokanee escapement (stream life = 10) in primary Lake Sammamish spawning tributaries from 1996/97 to 2012/13.

Year	Laughing Jacobs			Combined
	Ebright Creek	Creek	Lewis Creek	
1996/97	70	170	219	459
1997/98	15	29	10	54
1998/99	40	0	43	83
1999/00	134	27	247	408
2000/01	362	92	143	597
2001/02	110	2	722	834
2002/03	319	384	1,002	1,705
2003/04	1,063	232	3,296	4,591
2004/05	134	18	442	594
2005/06	135	44	217	396
2006/07	292	65	330	687
2007/08	17	15	111	143
2008/09	12	1	29	42
2009/10	1,123	61	471	1,655
2010/11	39	13	6	58
2011/12	188	377	351	912
2012/13	4,624	908	4,408	9,940
Average (all years)	510	143	709	1,362
4-Year Average (2009/10-2012/13)	1,493	340	1,309	3,141

Kokanee Genetic Relationships

Tissue samples for genetic analysis were collected from approximately 217 adult kokanee spawners located in the Sammamish River mainstem, Bear Creek, Little Bear Creek, and North Creek during the 2011/12 spawning season. These samples were subsequently compared with kokanee taken from Lake Sammamish spawning tributaries to determine if they were from the same or separate populations. Preliminary results from the genetic analysis indicate that kokanee spawning in the Sammamish River tributaries are from Lake Washington, and are part of a different population than fish taken from the Lake Sammamish spawning tributaries (Ken Warheit, WDFW Genetics Lab, personal communication). A final analysis for this comparison has not yet been completed. Tissue samples were collected from kokanee spawners in Lake Sammamish tributaries during the 2012/13 spawning season (no samples were collected from Sammamish River tributaries in 2012/13), but a genetic analysis has not been conducted on these samples.

Kokanee Age

Kokanee ages were assessed using otoliths collected from carcasses found during spawning ground surveys or from fish that were collected as broodstock for the supplementation program. The true age from hatching to time of sampling of an age-3 fish is approximately 2 years, 9 months, and the true age of an age-4 fish is 3 years, 9 months.

2011/12 Age Distribution: Ages were determined for 321 adult kokanee from the 2011/12 spawning season (Table 6A). Most (74%) kokanee spawners from the 2011/12 season were age-3 (2008/2009 brood year), 26% were age-4 (2007/2008 brood year) and 1% were age-5 (2006/2007 brood year). The majority of male kokanee (80%) and female kokanee (64%) were age-3 (Table 7). Age-4 female kokanee were more abundant (34%) than males (20%), and 1 female kokanee was age-5.

2012/13 Age Distribution: In 2012/13, otoliths were collected from over 1,100 adult kokanee throughout the Lake Sammamish basin and ages were determined for a subsample of 263 individuals from this collection (Table 6B). Nearly all (95%) of the sampled kokanee in 2012/13 were age-3 fish (2009/10 brood year); the remainder (5%) were age-4 fish (2008/09 brood year), and no age-5 fish were encountered. Most male kokanee (92%) and female kokanee (98%) in 2012/13 were age 3 (Table 7), while age-4 male kokanee were slightly more abundant (8%) than age-4 females (2%).

Table 6. Age distribution of late-run kokanee collected from Lake Sammamish tributaries during the 2011/12 (A) and 2012/13 (B) spawning season.

A.

Stream	Sample Size	Age-2	Age-3	Age-4	Age- 5
Ebright Creek	110	0%	55%	43%	3%
Lake Sammamish	5	0%	80%	20%	0%
Laughing Jacobs Creek	108	0%	88%	12%	0%
Lewis Creek	98	0%	79%	21%	0%
TOTAL	321	0%	74%	26%	1%

B.

Stream	Sample				
	Size	Age-2	Age-3	Age-4	Age-5
Ebright Creek	55	0%	96%	4%	0%
George Davis Creek	1	0%	100%	0%	0%
Laughing Jacobs Creek	16	0%	100%	0%	0%
Lewis Creek	57	0%	96%	4%	0%
Pickering Creek	1	0%	100%	0%	0%
Pine Lake Creek	78	0%	97%	3%	0%
Schneider Creek	2	0%	100%	0%	0%
Tibbetts Creek	17	0%	100%	0%	0%
Vasa Creek	3	0%	67%	33%	0%
Zaccuse Creek	33	0%	82%	18%	0%
TOTAL	263*	0%	95%	5%	0%

Table 7. Age distribution of male and female late-run kokanee collected from Lake Sammamish tributaries 2009-2013.

Year	Sex	Sample				
		Size	Age-2	Age-3	Age-4	Age-5
2009/2010	Male	57	0%	2%	98%	0%
	Female	67	0%	7%	93%	0%
2010/2011	Male	24	0%	71%	29%	0%
	Female	22	0%	86%	14%	0%
2011/2012	Male	193	0%	80%	20%	0%
	Female	127	0%	64%	34%	2%
2012/2013	Male	124	0%	92%	8%	0%
	Female	138	0%	98%	2%	0%

Kokanee Otolith Analysis

The 2012/13 spawning season marks the first year that hatchery-origin age-3, otolith-marked kokanee from the supplementation program could be expected on the spawning grounds (Table 9). Otoliths from 326 adult kokanee collected in the three primary spawning streams (Ebright, Lewis, and Laughing Jacobs) and from other, smaller Lake Sammamish spawning tributaries were analyzed to evaluate 1) the contribution of supplementation program fish to the overall kokanee spawning escapement, 2) whether supplementation fish returned to spawn in the streams where they were released, and 3) whether there were differences in survival between release

groups. Two thermally marked female fish, one each from Ebright (358 mm TL; 299 mm POH) and Pine Lake (560 mm TL; 440 mm POH) creeks were identified as stray sockeye from the Cedar River Hatchery, but were included in the analysis as it is unknown if additional sockeye were mistakenly counted as kokanee. Sixteen otoliths were not readable and origin was not able to be determined. Of the remaining 310 otoliths, 92% were determined to be wild and 8% were hatchery origin fish (Table 8).

Hatchery returns were found in all three of the primary streams and made up about 3% of the fish in sample group taken from Ebright Creek, 11% of the sample group from Lewis Creek, and 22% of the Laughing Jacobs Creek group. Based on otolith analysis of the 149 fish sample group collected from the three primary spawning tributaries, hatchery-origin fish collectively made up approximately 9% (13 of 149 fish) of the return to the three primary spawning tributaries. Of the 13 hatchery-origin kokanee that returned to the primary spawning tributaries, 10 returned to the same stream of release, suggesting the many hatchery fish did home to the site where they were released.

Hatchery-origin returns were also found in other smaller tributaries to Lake Sammamish, including Pickering, Pine Lake, Tibbetts, and Zaccuse Creeks. Otolith analysis of 175 fish collected from the non-primary spawning tributaries indicated that hatchery-origin returns collectively made up approximately 7% (13 of 175 fish) of the spawning escapement in these smaller non-primary tributaries. Stray fish in the non-primary spawning tributaries had been released from either Ebright Creek (6 fish) or from Laughing Jacobs Creek (7 fish).

Hatchery kokanee fry released in 2010 were composed of three release groups based on size and release date: A) 13,950 fry at 1,203 fry/lb released on March 25; B) 13,692 fry at 2,500 fry/lb released on April 14; and C) 11,700 fry at 4,000 fry/lb released on April 14. Of the 26 hatchery returns, there was not any apparent difference between release groups: group A had 9 fish, group B had 9 fish, and group C had 8 fish.

On an adult-to-adult basis, supplementation kokanee out-performed natural-produced fish (Chi-square analysis; $\chi^2 = 13.6$; $P < 0.001$). The hatchery fish survived at a rate 2.6 times higher than their wild counterparts. The total escapement of hatchery fish was estimated to be 1,008 fish (2.6% survival rate of fry to adult). If the 86 adults used in the supplementation program were left in the stream to spawn, they would have produced an estimated 530 adult kokanee. Therefore, the supplementation program contributed an additional 478 adult kokanee to the overall escapement.

Table 8. Relative percent of hatchery and wild origin of late-run kokanee in the Lake Sammamish basin in 2012/13.

Stream	Sample Size	Hatchery	Wild
Ebright Creek	66	3%	97%
George Davis Creek	1	0%	100%
Laughing Jacobs Creek	18	22%	78%
Lewis Creek	64	11%	89%
Pickering Creek	1	100%	0%

Pine Lake Creek	93	6%	94%
Schneider Creek	4	0%	100%
Tibbetts Creek	21	10%	90%
Vasa Creek	5	0%	100%
Zaccuse Creek	50	8%	92%
TOTAL	323*	8%	92%

*One sample from Zaccuse Creek was unable to be analyzed.

Discussion

The estimated 2011/12 late-run kokanee return was moderately high, and escapement was the fifth highest on record. The majority of spawning activity occurred in a 4-6 week window between mid- November and early-December, peaking in late-November across all surveyed streams.

Estimated kokanee spawning escapement in 2012/13 was the highest on record since monitoring began in 1996/97 and spawning activity was widespread, both temporally and spatially throughout the Lake Sammamish Basin. Adult kokanee were observed spawning further up the primary streams as well as in all the smaller neighboring streams around Lake Sammamish. Age-3 fish from the kokanee supplementation program returned to both supplementation and neighboring streams and contributed to roughly 8% of the return.

Spawning escapement estimates in both 2011/12 and 2012/13 may be lower than the actual spawning escapements. An average stream life of 10 days was used to be consistent with and allow comparison to past escapement estimates, but a shorter stream life value may more accurately reflect the amount of time that adult kokanee are present on spawning grounds. Stream life can vary between and within years. For instance in 2012/13, some kokanee in Laughing Jacobs Creek were observed to be associated with a given redd during only one of multiple surveys in a week whereas other fish were observed consistently until death. No mark-recapture efforts were conducted to estimate actual stream life in 2011/12 or 2012/13, but surveyor observations indicated that a shorter stream life values would have been more representative in these years. Though an index stream life value of 10 days is sufficient for monitoring long-term trends of kokanee abundance in Lake Sammamish a formal estimation of stream life may be appropriate as restoration efforts yield a more viable population of fish in the basin.

It is encouraging to see the contribution of hatchery origin fish to Lake Sammamish kokanee stocks, although the extent of supplementation program contribution is still preliminary, as this was the first year of expected hatchery returns. Supplementation program survival for brood year 2009/10 is preliminarily estimated at 2.6%. As Age-4 fish from brood year 2009/10 and subsequent brood years return, the success of the supplementation program can better be

evaluated. Improvements to rearing conditions, such as RSIs in later brood years, should increase survival in future returns.

The large escapement of kokanee in 2012/2013 may be attributed to favorable lake conditions (mild summers), good stream flow conditions (few flood events) for incubation, and the addition of supplementation fish. Another possible factor for the large escapement is the delay in the release of coho salmon (*O. kisutch*) smolts from Issaquah Creek Hatchery which may have reduced predation pressure on kokanee fry. A revision in the release of coho salmon smolts began in 2010, coinciding with the release of the first supplementation release. In the past, coho salmon smolts were all released in April and appeared to spend a few weeks in Lake Sammamish before emigrating downstream through the Sammamish River. Under the new plan, coho salmon smolts are allowed to emigrate voluntarily starting on May 10. Coho salmon smolts may therefore spend little time in Lake Sammamish and kokanee fry will have increased in size and moved offshore and therefore, the overlap between coho salmon smolts and kokanee fry is greatly reduced.

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Appendix A: 2011/12 Kokanee Spawning Ground Survey Data

Lewis Creek

Date	Live	Dead	Redds	Fish Days	Date	Live	Dead	Redds	Fish Days
11/1	0	0	0		12/15	6	2	0	6
11/2	1	2	1	1	12/19	1	0	0	14
11/3	31	0	1	10	12/21	0	0	0	1
11/8	11	0	2	75	12/23	0	2	0	0
11/9	10	1	2	11	12/26	0	0	0	0
11/10	2	0	2	8	12/27	0	0	0	0
11/15	219	0	65	518	12/28	1	0	0	1
11/16	166	0	14	181	12/29	0	0	0	1
11/29	158	0	13	1,950	12/30	0	0	0	0
12/1	113	5	31	246	1/2	0	0	0	0
12/2	82	1	1	94	1/4	0	0	0	0
12/5	52	5	4	201	1/6	0	0	1	0
12/7	31	4	0	83	1/9	0	0	0	0
12/8	34	4	0	33	1/11	0	0	0	0
12/9	9	4	1	22					
12/12	13	4	1	33	TOTAL	946	36	139	3,508
12/14	6	2	0	19					

Laughing Jacobs Creek

Date	Live	Dead	Redds	Fish Days	Date	Live	Dead	Redds	Fish Days
10/31	26	0	9		12/15	1	0	0	1
11/1	0	0	0	13	12/19	0	0	0	2
11/2	17	0	5	9	12/21	0	0	0	0
11/7	63	0	11	180	12/23	0	0	0	0
11/9	76	6	23	126	12/26	0	0	0	0
11/14	306	2	82	880	12/27	0	0	0	0
11/17	199	0	14	720	12/28	2	0	0	1
11/29	93	1	10	1,512	12/29	2	0	0	2
12/1	35	1	2	88	12/30	0	0	0	1
12/2	43	4	5	39	1/2	0	0	0	0
12/5	22	5	8	98	1/4	0	1	0	0
12/7	16	1	1	38	1/6	2	0	1	2
12/8	12	0	0	14	1/9	0	0	0	3
12/9	7	2	0	10	1/11	0	0	0	0
12/12	7	6	0	21					
12/14	0	1	0	7	TOTAL	929	30	171	3,767

Ebright Creek

Date	Live	Dead	Redds	Fish Days	Date	Live	Dead	Redds	Fish Days
10/31	15	0	1		12/9	4	2	0	18
11/1	0	0	0	8	12/12	21	5	2	38
11/2	1	0	0	1	12/14	6	2	0	27
11/3	0	0	0	1	12/15	4	1	0	4
11/7	0	0	0	0	12/19	7	0	1	18
11/8	0	0	0	0	12/21	14	0	2	15
11/9	0	0	0	0	12/23	2	0	0	10
11/10	0	0	0	0	12/26	0	0	0	3
11/14	0	0	0	0	12/27	0	0	0	0
11/15	0	0	0	0	12/28	0	1	0	0
11/17	31	0	0	31	12/29	0	0	0	0
11/18	59	1	8	40	12/30	0	0	0	0
11/21	110	0	30	239	1/2	0	0	0	0
11/22	72	3	1	67	1/4	0	0	0	0
11/28	160	3	30	492	1/6	0	0	0	0
12/1	135	4	20	395	1/9	0	0	0	0
12/2	91	1	8	107	1/11	0	0	0	0
12/5	61	10	10	228					
12/7	12	1	0	73	TOTAL	836	36	113	1,837
12/8	31	2	0	22					

Appendix B: 2012/13 Kokanee Spawning Ground Survey Data

Lewis Creek

Date	Live	Dead	Redds	Fish Days	Date	Live	Dead	Redds	Fish Days
10/19	0	0	0		01/03	563	165	85	1,811
10/22	1	0	0	2	01/07	488	37	98	2,102
10/25	0	0	0	2	01/11	301	10	52	1,518
10/26	2	0	1	1	01/14	200	6	53	752
10/29	27	0	6	44	01/17	165	52	13	539
11/02	83	0	19	176	01/22	94	21	11	648
11/06	236	5	24	638	01/24	134	28	12	228
11/08	225	13	67	451	01/29	199	7	29	833
11/12	259	4	19	960	02/01	169	8	17	552
11/26	725	9	287	6,545	02/04	113	4	10	423
11/30	837	40	98	3,078	02/07	80	7	17	290
12/03	575	3	38	2,118	02/11	28	13	0	216
12/06	927	30	143	2,208	02/14	13	11	0	62
12/10	632	30	133	3,118	02/19	2	2	0	38
12/14	822	91	104	2,858	02/22	0	0	0	3
12/18	541	14	101	2,726	02/26	1	0	0	2
12/24	721	22	87	3,717					
12/28	867	24	209	3,124	TOTAL	10,696	695	1,874	44,077
12/31	666	39	141	2,300					

Laughing Jacobs Creek

Date	Live	Dead	Redds	Fish Days	Date	Live	Dead	Redds	Fish Days
10/19	6	1	0		01/03	64	2	23	147
10/23	3	0	0	4	01/07	26	0	3	180
10/25	3	0	1	6	01/14	12	0	2	133
10/26	1	0	0	2	01/17	8	4	3	30
11/02	132	0	38	371	01/22	0	0	0	20
11/06	193	0	32	646	01/24	13	2	0	13
11/09	176	5	30	554	01/29	0	0	0	33
11/12	217	4	37	590	02/01	0	0	0	0
11/16	262	9	48	854	02/04	1	0	0	2
11/26	181	1	34	2,175	02/07	1	0	0	3
12/03	215	1	22	1,288	02/11	0	0	0	2
12/07	256	4	85	942	02/14	1	0	0	2
12/10	57	1	19	450	02/19	0	0	0	3
12/14	49	2	14	174	02/22	0	0	0	0
12/28	31	1	8	357	02/26	0	0	0	0
12/31	34	2	11	98	03/05	0	0	0	0
					TOTAL	1,942	39	410	9,075

Ebright Creek

Date	Live	Dead	Redds	Fish Days	Date	Live	Dead	Redds	Fish Days				
10/19	0	0	0		01/03	363	60	99	1,214				
10/23	0	0	0		01/07	400	20	75	1,526				
10/25	0	0	0		01/14	248	4	52	2,146				
10/26	1	0	0	1	01/17	168	23	21	624				
10/29	17	0	5	27	01/22	107	13	9	688				
11/02	122	0	30	220	01/24	156	16	18	263				
11/08	437	6	115	1,629	01/29	91	2	5	618				
11/12	520	12	35	1,914	02/01	140	5	10	347				
11/16	1,036	41	308	3,022	02/04	66	9	10	309				
11/26	914	25	227	9,750	02/07	90	9	25	234				
11/29	1,033	42	103	2,855	02/11	48	5	8	276				
12/03	718	28	67	3,502	02/14	42	8	2	135				
12/06	713	37	96	2,147	02/19	35	2	0	193				
12/10	516	51	116	2,394	02/22	19	3	0	81				
12/13	667	105	139	1,766	02/26	0	0	0	38				
12/18	414	32	59	2,693	03/05	12		5	42				
12/24	444	0	74	2,490	TOTAL					10,002	570	1,801	46,236
12/31	465	12	88	3,098									

Tibbetts Creek

Date	Live	Dead	Redds	Fish Days
11/09	94	3	43	
11/16	119	5	11	746
11/26	98	1	18	1,085
12/06	69	0	12	835
12/10	93	3	34	324
12/18	28	0	6	484
12/28	8	0	2	180
12/31	14	0	5	33
01/07	3	0	0	60
01/14	0	0	0	11
Totals	526	12	131	3,757

Pine Lake Creek

Date	Live	Dead	Redds	Fish Days
10/14	0	0		
10/20	0	0		0
10/21	0	0		0
10/27	1	0		3
10/28	19	2		10
10/30	6	0		25
11/01	17	0		23
11/02	22	17		20
11/10	5	20		108
11/17	105	30		385
11/22	109	2		535
12/01	43	3		684
12/08	52	5		333
12/15	45	11	40	340
12/23	36	3		324
01/05	26	15		403
01/13	9	5		140
01/20	5	1		49
01/27	0	1		18
Totals	500	115	40	3,398

Appendix C. 2011/12 Lake Sammamish Lake Survey Report

Introduction

Historical data suggest that kokanee spawned along the shoreline of Lake Sammamish, near the mouths of Ebright and Laughing Jacobs Creeks, as well as along Sulphur Springs Point (Jackson, 2006). In addition, field surveys conducted during the 1970s indicate widespread distribution of sockeye salmon redds in Lake Sammamish (WDFW, unpublished data). To assess the present-day lake-spawning distribution of kokanee, WDFW staff designed and implemented lake-based kokanee spawning surveys in 2011/12.

Methods

Historical sockeye/kokanee spawning distribution data for Lake Sammamish were digitized using ArcGIS software (Figure 1). Eight shoreline areas, each approximately 1600 m in length, were selected for boat-based visual and Scuba surveys based on historic spawning activity. Direct observation surveys were conducted at depths shallower than 20 ft., and Scuba surveys were conducted at depths from 20 ft. to 45 ft. A 20 ft. minimum depth for Scuba surveys was selected due to hazards, such as docks and dense aquatic vegetation at shallower depths. A 45 ft. maximum depth was selected to maximize available survey time using agency Scuba dive tables.

Direct Observation Surveys

For depths ranging from 1 to 20 ft. deep, WDFW staff used direct observation from a 16 ft. outboard boat to survey for kokanee and redds (Figures 4v-4y). An observer equipped with polarized sunglasses searched for kokanee redds as evidenced by clean, bright patches of gravel, while the boat operator negotiated the vessel along near shore waters. The boat operator recorded the locations of live kokanee, dead kokanee, and potential kokanee redds using a handheld GPS. Substrate classification and the presence of Eurasian milfoil were recorded along shorelines with GPS waypoints to delineate habitat conditions and substrate types.

Aerial Surveys

Aerial surveys were conducted during peak spawn times to determine if live kokanee or kokanee redds in shallow-water areas (<20 ft. deep) would be visible from the air (Figures 4a-4u). Aerial surveys have historically been used by WDFW staff to estimate sockeye spawner abundance in shoreline areas of Lake Sammamish. During flights, a Robinson R-22 Helicopter would fly slowly along the entire shoreline of Lake Sammamish at elevations ranging between 300 and 400 feet. Flights also encompassed the Sammamish River, where kokanee also spawned in 2011/12. Flight times typically lasted about 1.5 hours.

Scuba Surveys

At depths from 20 ft. to 45 ft., Scuba divers performed strip-transect surveys by swimming alongside each other from a designated starting point. Divers began each survey transect at approximately 20 ft. depth, swam diagonally offshore to the 45 ft. depth contour, then diagonally onshore to the 20 ft. depth contour, repeating this procedure for a total of 25 minutes. For each transect vector, the lead diver recorded the predominant and secondary substrate type (Greene et. al., 1999, Table 3), and the presence/absence of kokanee or redds. The lead diver also estimated

the average horizontal visibility as well as other notable features, such as the presence and distribution of debris and aquatic vegetation. Potential kokanee redds were revisited and excavated using a hand trowel and mesh bag to verify if kokanee eggs were present, and to collect eggs if possible.

Dive boat operators collected location and water depth information at each major course change using GPS waypoints and a fathometer. Position and depth data were also recorded where divers' bubbles separated by several feet, as a pre-arranged signal to surface staff that a feature of interest had been located. Waypoint data for each vector start/stops and point of interest were reconciled with divers upon completion of each dive.

Results

Direct Observation Surveys

Three days of direct observation surveys were conducted along the near shore waters of Lake Sammamish (Table 2). On November 17, 2011, no redds or dead kokanee were seen. Forty live kokanee were observed, oriented upstream at the mouth of Ebright Creek (in low flow conditions), and appeared to be staged for upstream migration. On December 5, 2011, one dead kokanee was observed in water approximately 3 feet deep near the mouth of Ebright Creek, and no live salmon or redds were seen. On December 22, 2011, no redds or dead kokanee were observed.

Aerial Surveys

Two aerial surveys were completed during peak kokanee spawning periods. One flight was conducted on 12/1/2011 and a second flight was conducted on 12/16/2011. No live kokanee or kokanee redds were observed during either flight. One flight over the Sammamish River was conducted when kokanee spawners were known to be present in the stream (just downstream from the Little Bear Creek confluence), yet these fish were not visible from the air (Figure 4t). Flights may not be an optimal technique for enumerating or detecting live kokanee or their redds.

Scuba Surveys

Seven dive surveys were conducted in November 2011, ten in December 2011, and eight in January, 2012. The total linear distance of surveyed transects was approximately 11.4 km with an area swept of approximately 18.1 hectares (Table 1). Suitable spawning substrate (gravel) was observed as the predominant substrate type on some transect vectors near stations 1, 3, 7, 8, 9, and 16 (Figure 2a-2i, Figure 3). One dead kokanee was observed near station 4 and no live kokanee were observed during any of the dive surveys. Nine potential redds were observed- four near station 1, four near station 3, and one near station 8. Potential redds were characterized as small, round (about 15-20 inches in diameter) depressions/disturbance areas where the substrate appeared to have been disturbed. At the request of USFWS staff, three dives were conducted to evacuate potential redds and collect eggs. Divers excavated six potential kokanee redds, but found no eggs in the substrate. Divers did, however, find a clear, gelatinous substance in or near some of the potential redds. A sample of this substance was collected and preserved on alcohol for later examination.

Discussion

We did not document any kokanee redds in Lake Sammamish, and the few live kokanee that were observed appeared to be waiting for higher water to enter Ebright Creek. Historical distribution data for sockeye salmon redds in Lake Sammamish suggests that suitable spawning substrate was broadly distributed throughout the lake. The 2011/12 lake survey data, however, suggests that the distribution and quality of suitable spawning substrate (clean gravel) has changed considerably. Sedimentation and the spread of aquatic invasive vegetation, specifically Eurasian milfoil (*Myriophyllum spicatum*), appear to have embedded and inundated most areas where spawning activity has been historically observed. Of all stations surveyed, only three areas had gravel that was not heavily embedded with sediment (Stations 1, 3, and 8). Remaining areas consisted of fine substrate (sand or mud) or gravel that was completely embedded and covered with mud.

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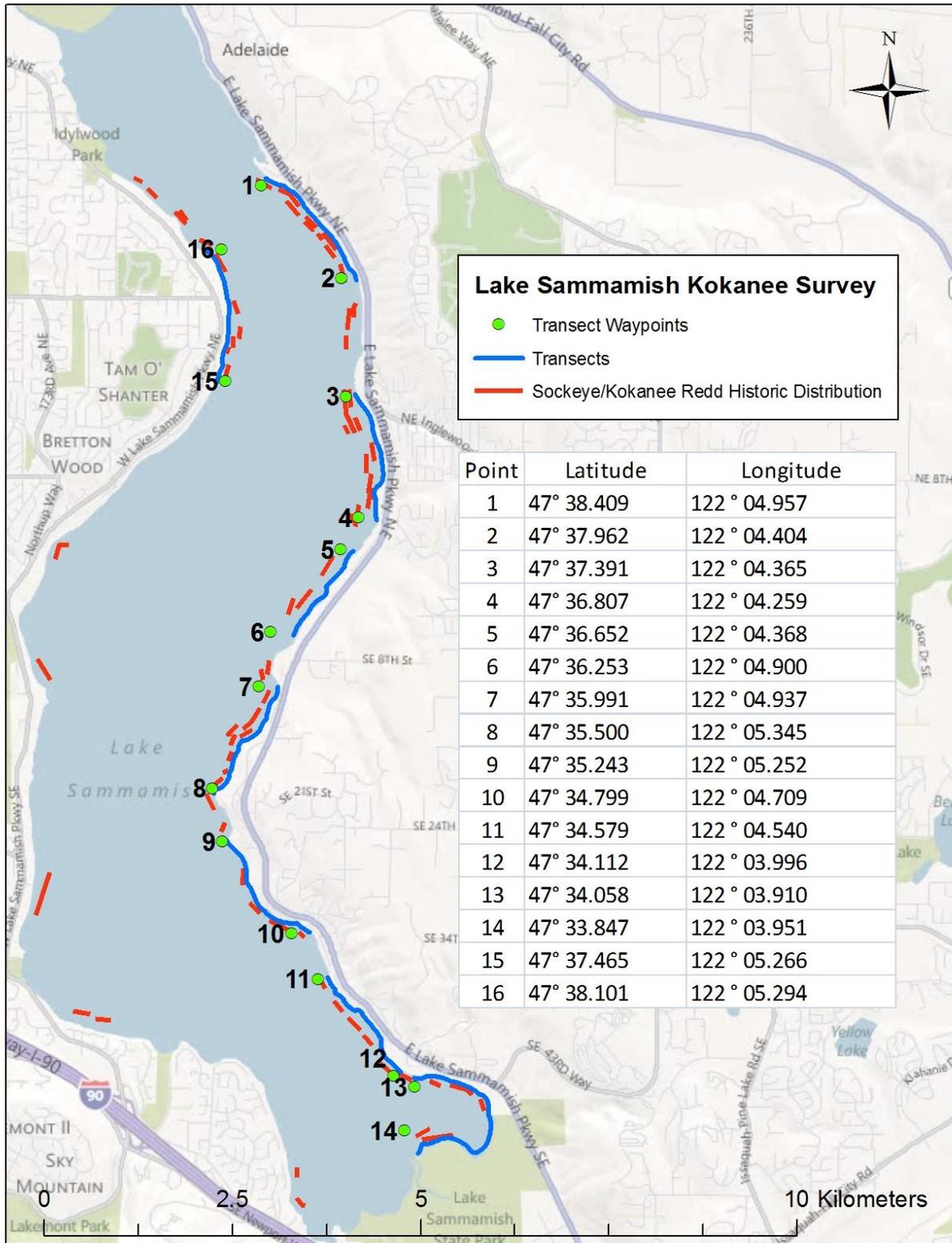


Figure 1. Historical distribution of *O. nerka* spawning activity and planned kokanee salmon spawning survey areas in Lake Sammamish.

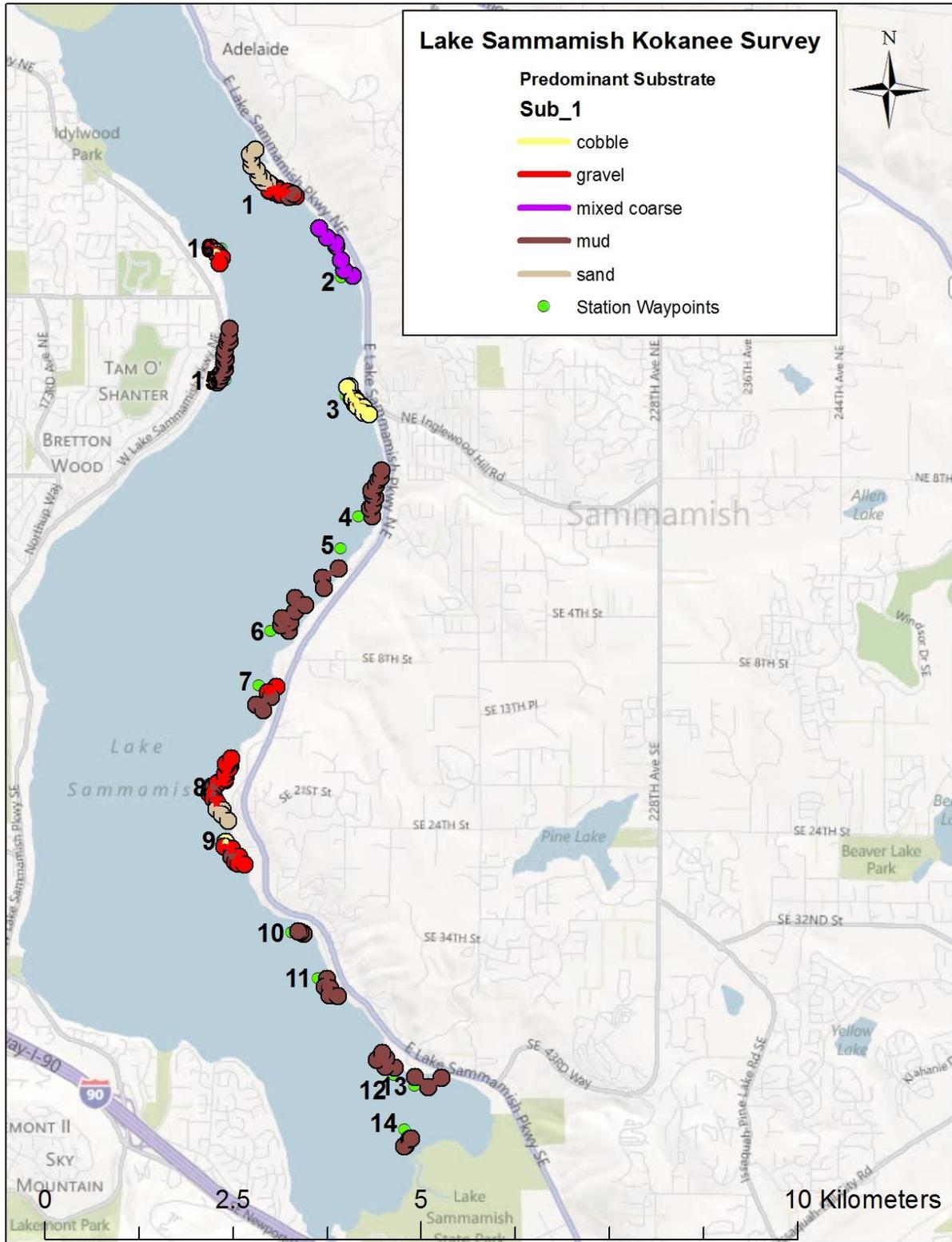


Figure 2a. Predominant substrates observed during Scuba surveys in Lake Sammamish.

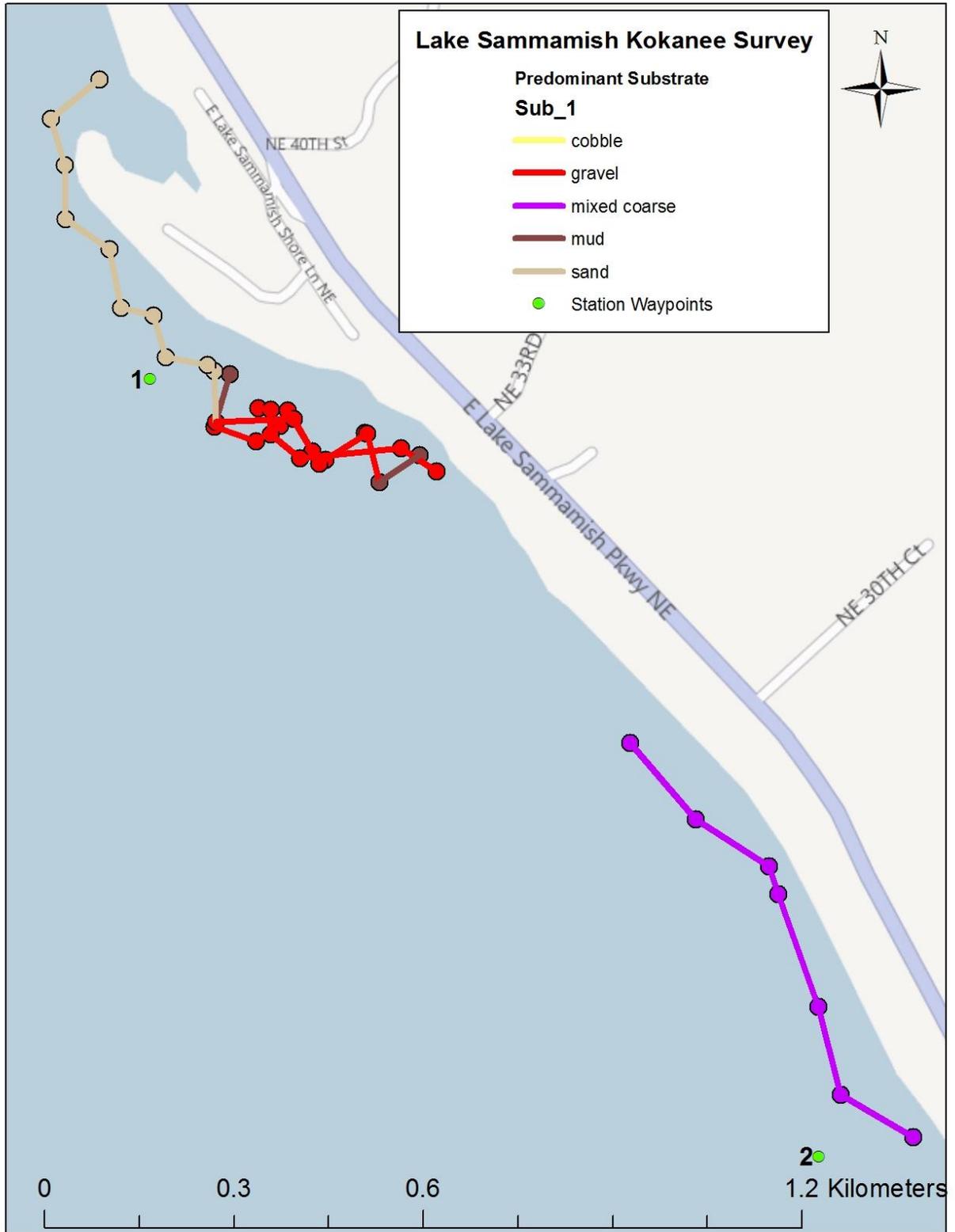


Figure 2b. Predominant substrates observed during Scuba surveys at area 1-2 in Lake Sammamish.

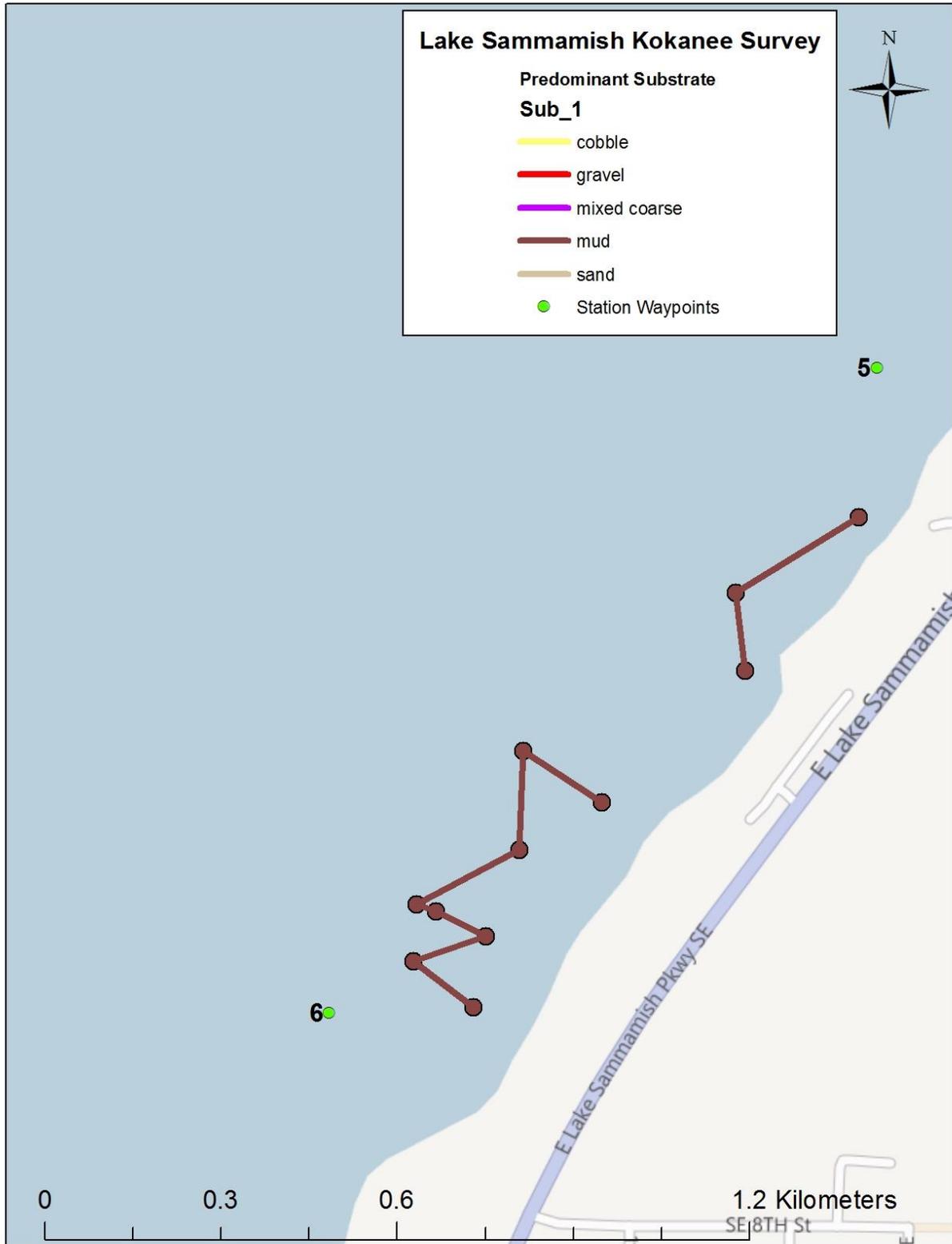


Figure 2d. Predominant substrates observed during Scuba surveys at area 5-6 in Lake Sammamish.

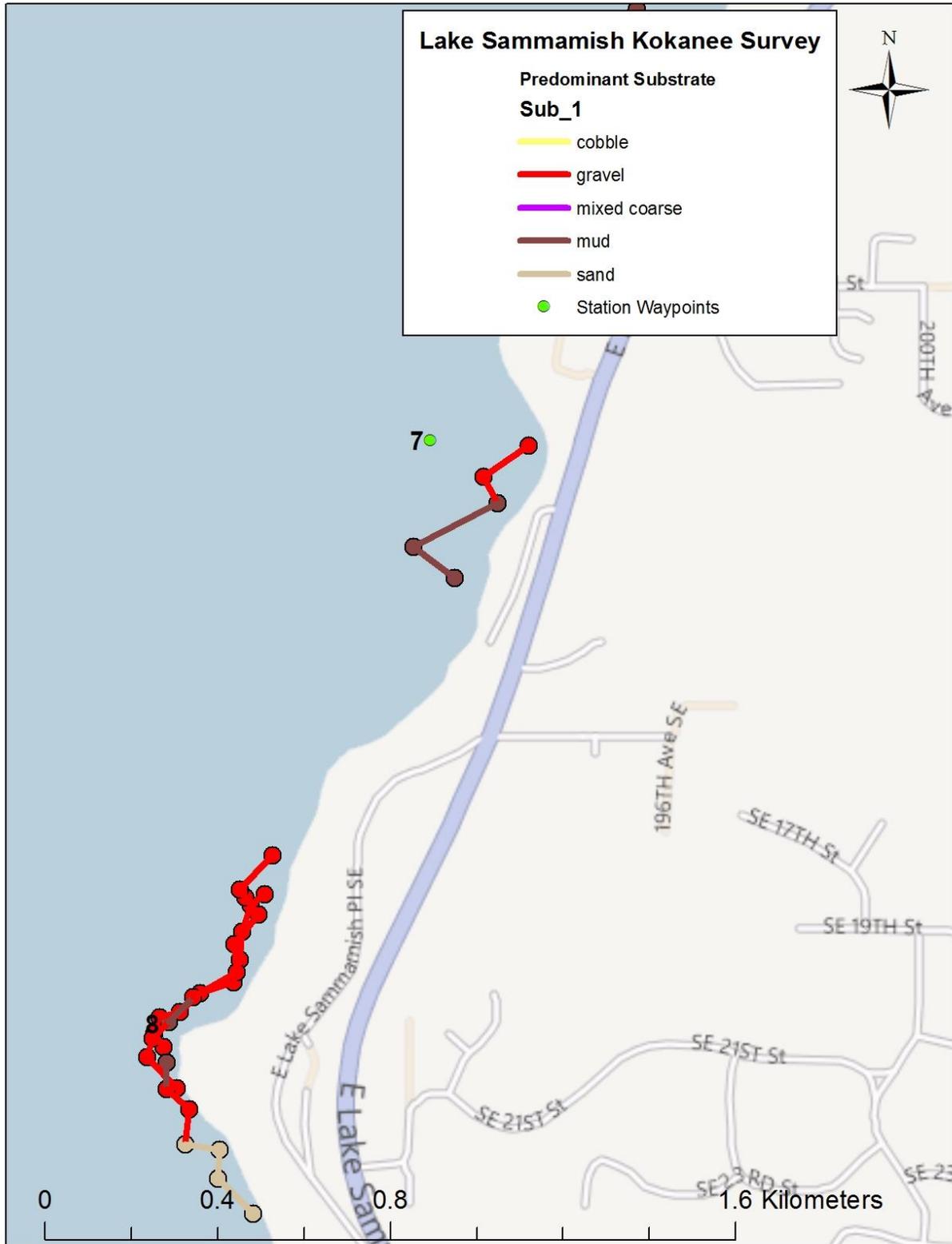


Figure 2e. Predominant substrates observed during Scuba surveys at area 7-8 in Lake Sammamish.

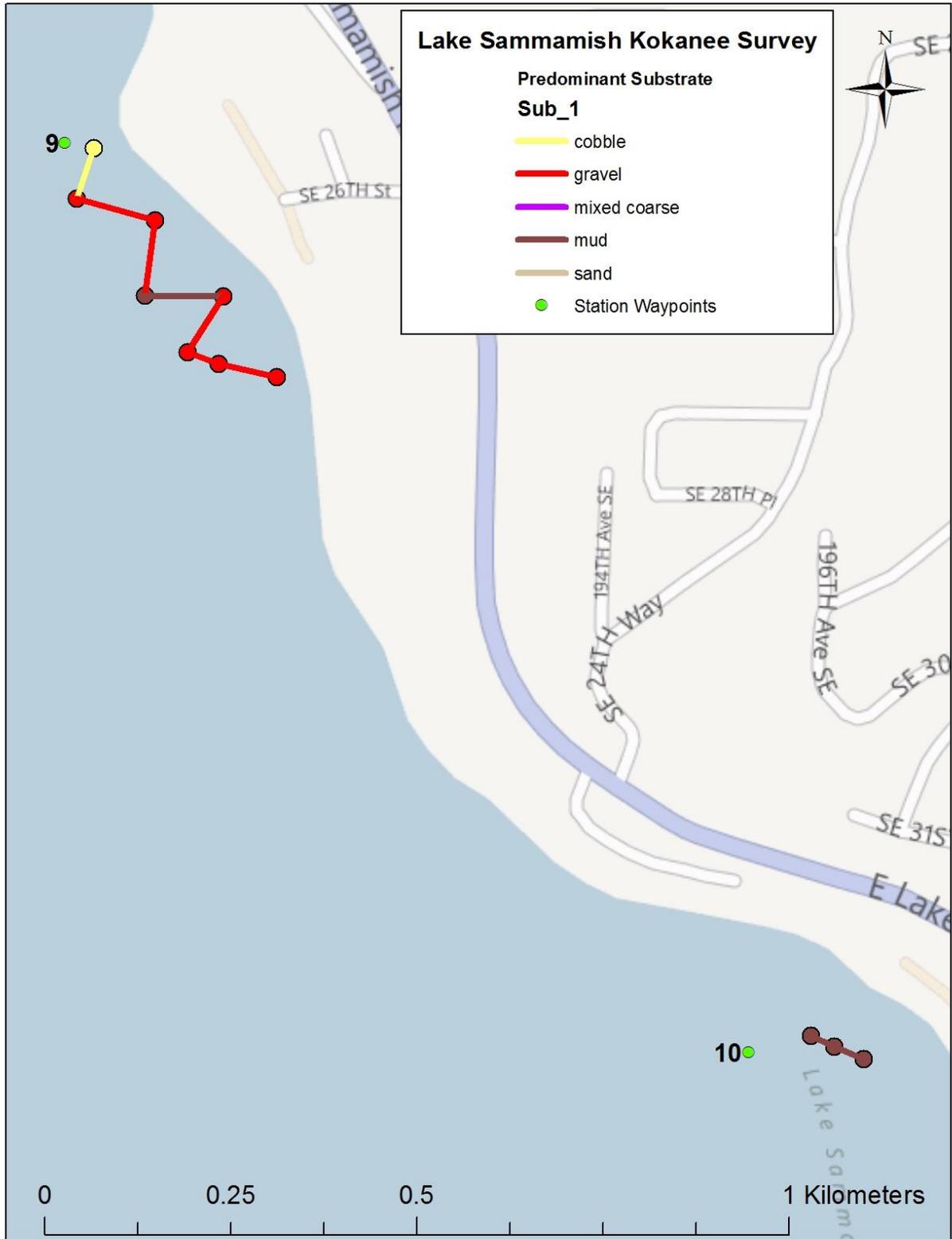


Figure 2f. Predominant substrates observed during Scuba surveys at area 9-10 in Lake Sammamish.

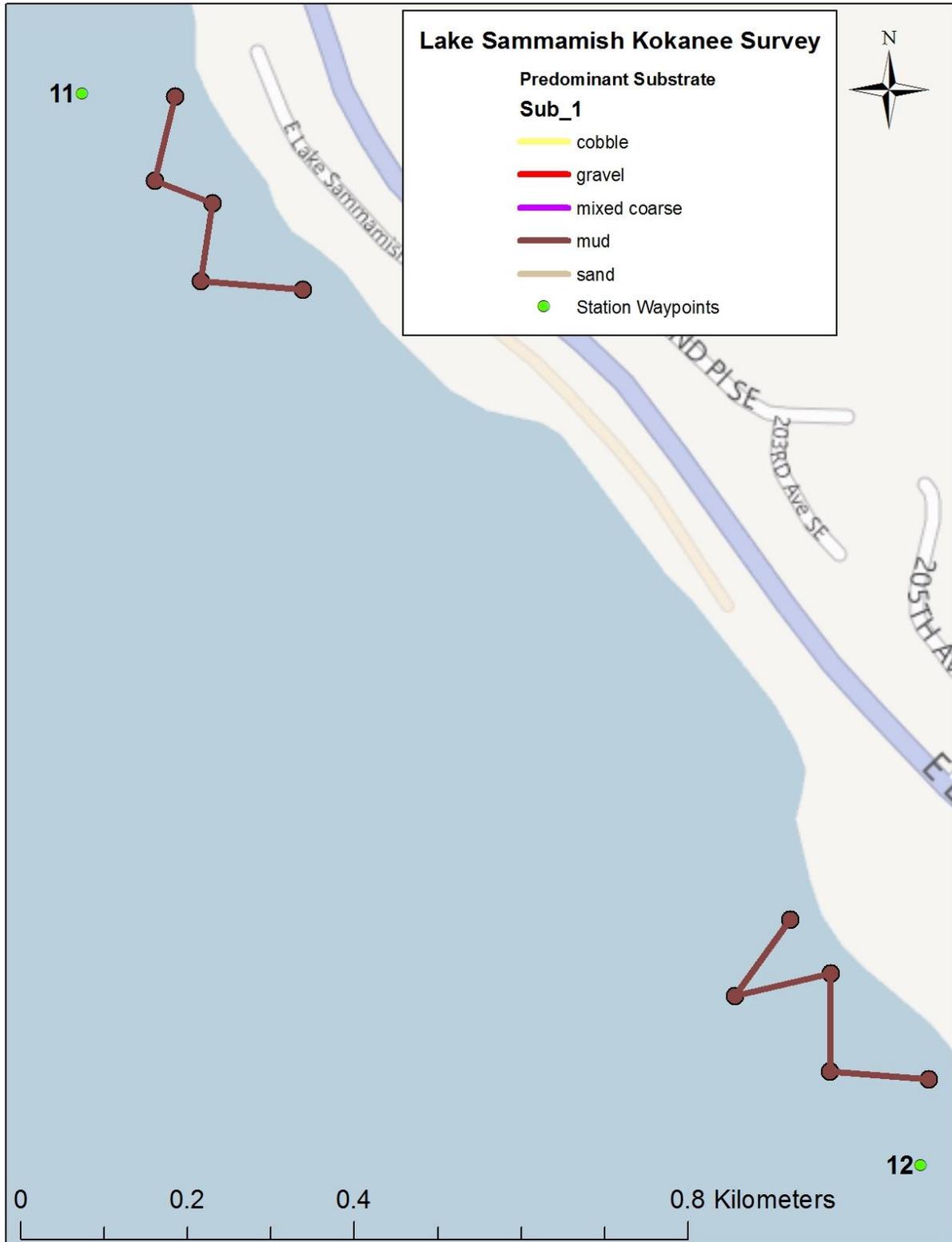


Figure 2g. Predominant substrates observed during Scuba surveys at area 11-12 in Lake Sammamish.

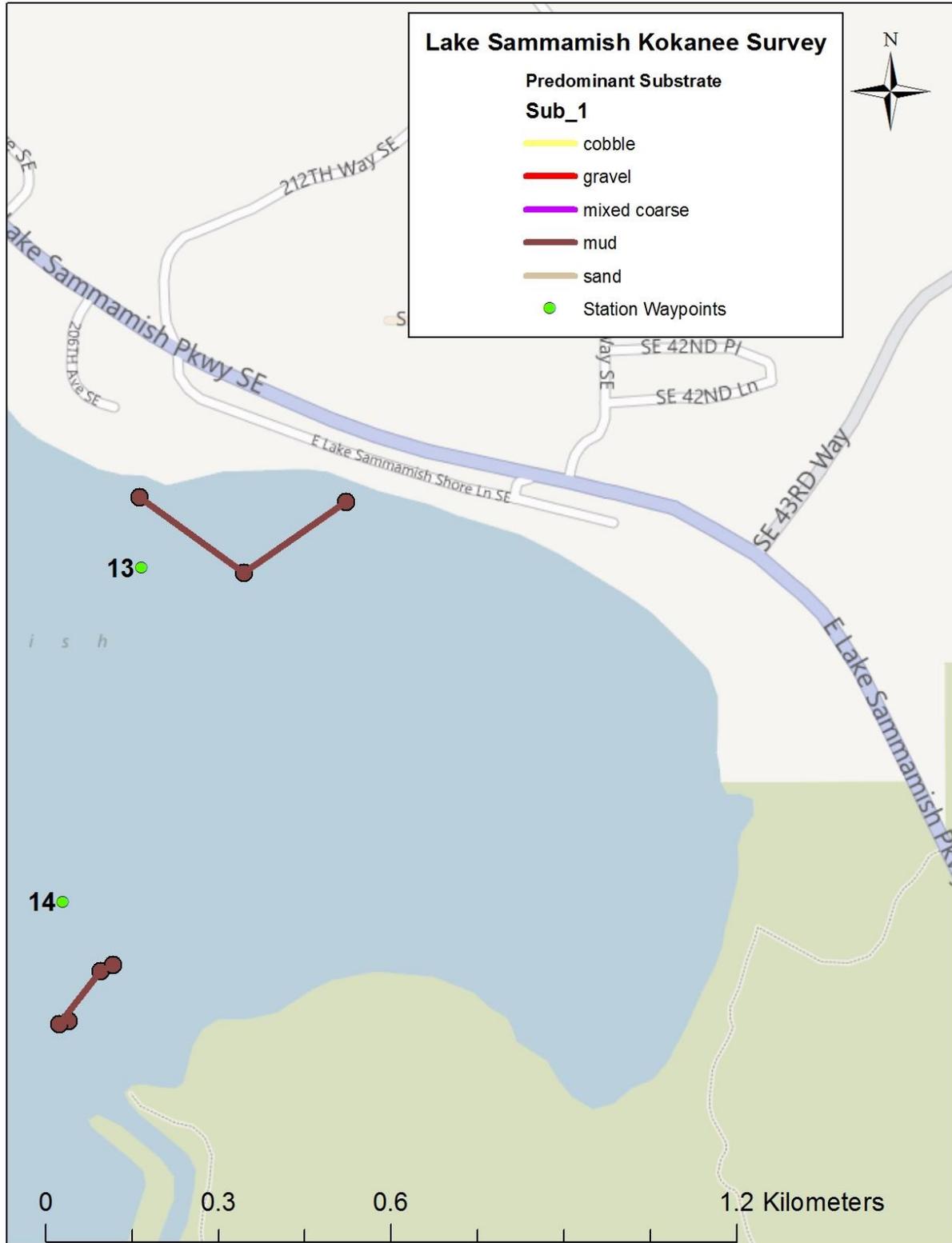


Figure 2h. Predominant substrates observed during Scuba surveys at area 13-14 in Lake Sammamish.

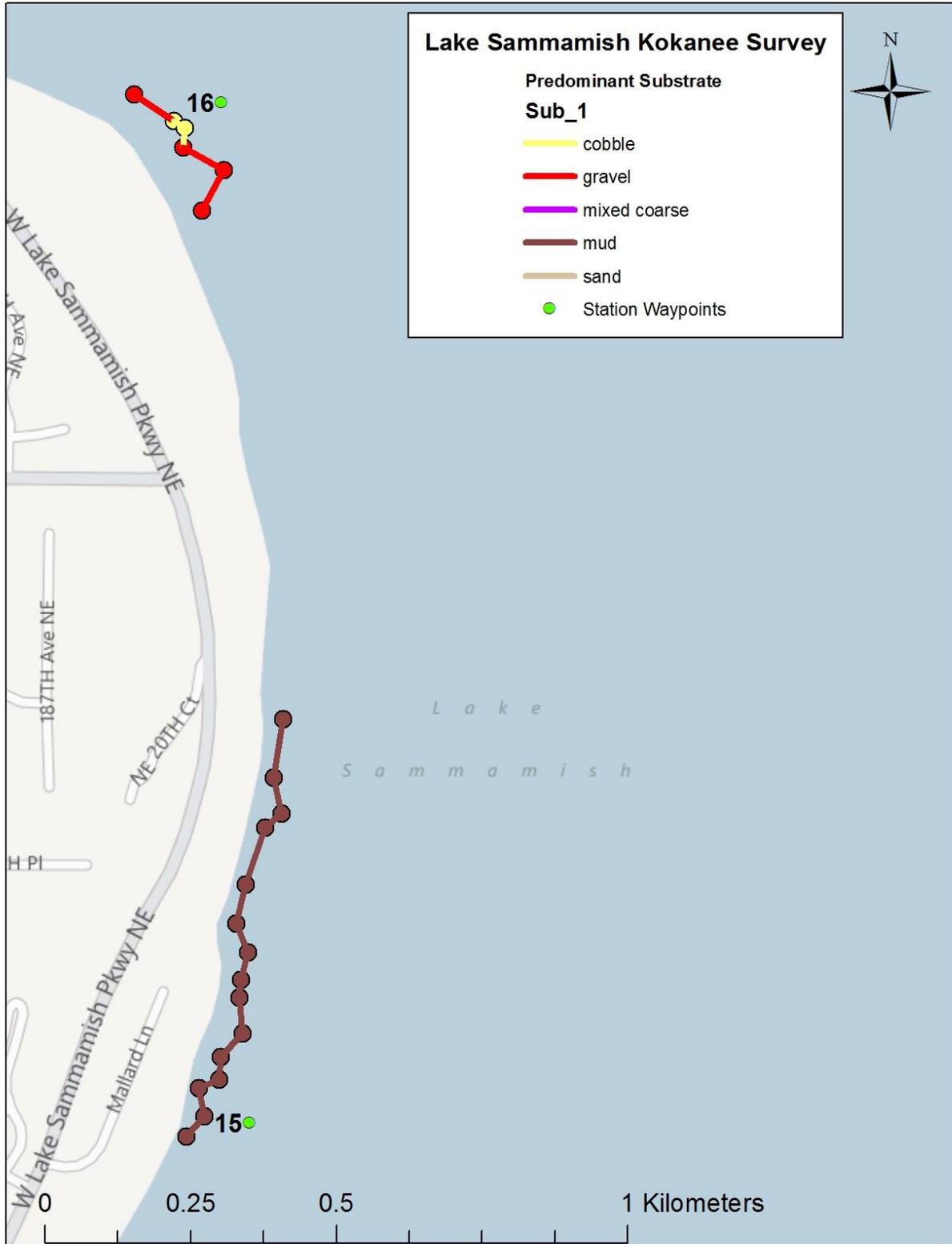


Figure 2i. Predominant substrates observed during Scuba surveys at area 15-16 in Lake Sammamish.

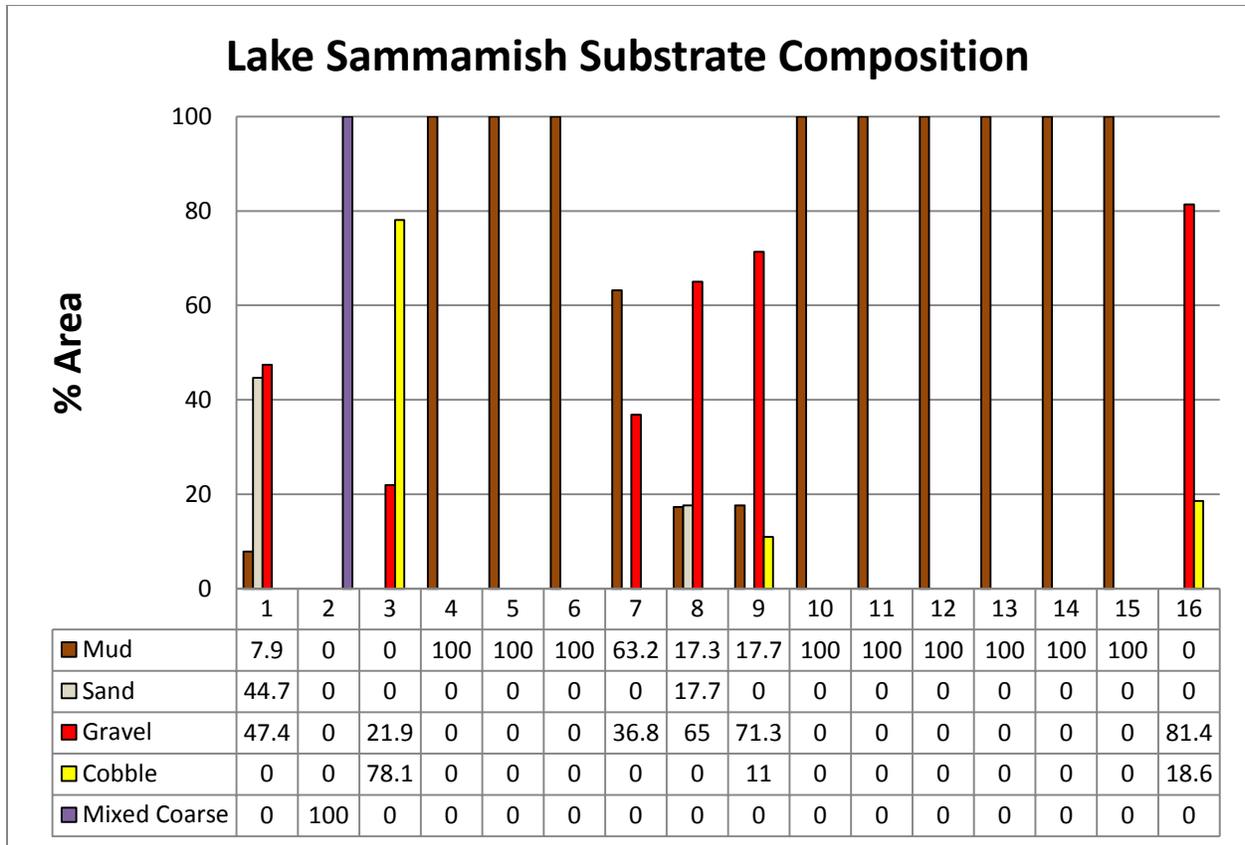


Figure 3. Substrate composition observed during Scuba surveys at Lake Sammamish (Percent area).

Table 1. Lake Sammamish kokanee survey Scuba dives.

Date	Station	Strip Width (m)	Area Swept (m ²)	Comments
11/29/2011	1	15	12136	
11/29/2011	4	15	7043	Dead Kokanee near mouth of Ebright Creek.
11/29/2011	15	15	7937	
11/30/2011	6	6	5485	
11/30/2011	14	<1	158	Aborted due to low visibility
11/30/2011	10	<1	156	Aborted due to low visibility
11/30/2011	8	15	7450	
12/12/2011	1	15	6071	
12/12/2011	2	15	4435	
12/12/2011	13	15	6613	
12/12/2011	12	6	7023	
12/13/2011	1	15	5179	
12/13/2011	3	15	4198	
12/13/2011	5	15	5707	
12/13/2011	7	15	8026	
12/14/2011	9	15	9759	
12/14/2011	11	15	6462	
01/10/2012	1	24	13947	
01/10/2012	1	NA	NA	Redd Excavation Dive
01/10/2012	8	24	19162	
01/10/2012	8	24	12512	
01/11/2012	1	24	16502	
01/11/2012	3	24	14929	
01/11/2012	1	NA	NA	Redd Excavation Dive
01/12/1012	1	NA	NA	Redd Excavation Dive

Table 2. Lake Sammamish kokanee salmon direct observation nearshore surveys.

Date				
10/14/2011				Reconnaissance Survey
11/17/2011				40 live kokanee school at mouth of Ebright Creek
12/05/2011				One dead kokanee at WPT 243

Table 3. Substrate classifications used during Scuba surveys (Greene et. al., 1999).

Substrate	Particle Size
Mud	<0.06mm
Sand	0.06-2mm
Gravel	2-64mm
Cobble	64-256mm
Boulder	0.25-3m
Mixed Coarse	Sand, gravel, cobble
Hardpan	Compressed mud, sand, gravel



Figure 4a. Aerial flight photo.



Figure 4b. Aerial flight photo.



Figure 4c. Aerial flight photo. Pine Lake Creek mouth.



Figure 4d. Aerial flight photo. Alexander's Creek mouth.



Figure 4e. Aerial flight photo. Laughing Jacobs Creek mouth.



Figure 4f. Aerial flight photo. Issaquah Creek mouth.



Figure 4g. Aerial flight photo.



Figure 4h. Aerial flight photo. Tibbetts Creek mouth.



Figure 4i. Aerial flight photo. Unnamed tributary mouth.



Figure 4j. Aerial flight photo. Lewis Creek mouth.



Figure 4k. Aerial flight photo. Lewis Creek mouth.



Figure 4l. Aerial flight photo. Vasa Creek mouth.



Figure 4m. Aerial flight photo.



Figure 4n. Aerial flight photo.



Figure 4o. Aerial flight photo. Idylwood Creek mouth.



Figure 4p. Aerial flight photo of Sammamish River. Bear Creek confluence.



Figure 4q. Aerial flight photo of Sammamish River.



Figure 4r. Aerial flight photo of Sammamish River.



Figure 4s. Aerial flight photo of Sammamish River.



Figure 4t. Aerial flight photo of Sammamish River. Little Bear LSKWG confluence.



Figure 4u. Aerial flight photo of Sammamish River. North Creek confluence.



Figure 4v. Shoreline survey photo.



Figure 4w. Shoreline survey photo.



Figure 4x. Shoreline survey photo.



Figure 4y. Shoreline survey photo.