RESTORATION MONITORING OF THE SHUFFLETON POWER PLANT FLUME SITE IN SOUTH LAKE WASHINGTON,

2016 PROGRESS REPORT

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Introduction

A key component of habitat restoration projects is biological monitoring to establish the effectiveness of the project to target species. Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*) are currently listed as threatened under the Endangered Species Act and many restoration projects have been designed to improve their habitat conditions in lotic and lentic environments. Recently, the Washington Department of Natural Resources (WDNR) completed a large restoration project in the south end of Lake Washington to benefit Chinook salmon. Both pre- and post-project monitoring of this project are needed to determine if shoreline conditions have been improved for juvenile Chinook salmon. This report presents data from the second year after the project was constructed and also compares that data to the other years of project monitoring (three years of pre-project monitoring and one other year of post-project monitoring).

Puget Sound Chinook salmon are primarily "ocean-type" which typically emigrate to the marine environment as subyearlings and during their juvenile freshwater phase of three to five months can inhabit a wide range of habitat types including large rivers, small streams, lakes, and estuaries (Healey 1991). Ocean-type Chinook salmon commonly have two groups of emigrants; a group that moves downstream as fry and rears in estuaries, coastal ocean habitats, or lakes and another group that rears in the natal river system and emigrates as parr or smolts (Healey 1991).

In the Lake Washington system, the major spawning tributary is the Cedar River and large numbers of fry emigrate from January to April to rear in the south end of Lake Washington. These fish prefer shallow, non-armored shorelines with sand and gravel substrates that have both open beaches and areas with riparian vegetation that provide woody debris and overhanging vegetation (Tabor et al. 2011). However, the Lake Washington shoreline has been extensively developed and resource managers have looked for opportunities to improve shoreline habitat conditions. The abundance of juvenile Chinook salmon is substantially higher at sites close to the mouth of the Cedar River (Tabor et al. 2006). Therefore, restoration projects close to the Cedar River are likely to have a greater benefit to the Chinook salmon population than projects located further away.

One obvious location for restoration was the Shuffleton Power Plant flume structure. The flume was built to help cool water from the adjacent power plant. The power plant has been torn down and replaced with apartments and thus the flume structure was no longer used. The structure was also only about a half of a kilometer from the mouth of the Cedar River. This restoration site is relatively large in comparison to other potential restoration sites; the part of the flume structure removed was about 150-m long and is part of a 360-m long shoreline section owned by WDNR. The flume structure consisted of two parallel, vertical steel walls that resulted in poor habitat conditions (i.e., little shallow water, no sand and gravel substrates, and little structural complexity) for juvenile Chinook salmon. Also, the steep walls were likely habitat for predators of juvenile Chinook salmon such as smallmouth bass (*Micropterus dolomieu*). The area between the two walls was usually extremely turbid and likely had poor water quality for juvenile Chinook salmon. In the summer of 2014, most of the flume structure was removed and replaced with a gentle-sloping sand/gravel beach (see cover photos) and engineered log jams (ELJs).

The overall objective of this study is to monitor the abundance of juvenile Chinook salmon and other fishes at the Shuffleton Power Plant flume structure site before and after the restoration project, which was completed during the summer of 2014. Pre-project monitoring occurred in January-June 2011-2013. This report covers monitoring efforts in 2016 with comparisons to pre-project monitoring from 2011-2013 as well as post-project monitoring in 2015. Additional post-project monitoring will be undertaken in 2017.

Methods

Standard Snorkel Transects

Monitoring of the Shuffleton Power Plant flume structure site and other sites was accomplished through night snorkel transects. Snorkeling allowed us to effectively survey a variety of habitat types and no handling of fish was required. Night surveys were undertaken to minimize the effect the snorkeler had on the behavior of juvenile Chinook salmon. At night, juvenile Chinook salmon typically are inactive, rest near the bottom, can be easily approached by snorkelers and can be accurately counted.

Five transects were established in the south end of Lake Washington (Table 1; Figure 1); one along the outside edge of the flume wall (see cover photos) and four other transects that represented a wide-range of habitat conditions in the south end of Lake Washington. Two of the other transects are also part of the WDNR shoreline and were part of the restoration project (Figure 2). The last two transects are in Gene Coulon Park (City of Renton) and are used as control sites. Length of transects was based on easily recognizable landmarks and obvious changes in habitat type.

Transects were snorkeled twice a month from late January to early June. Snorkelers swam parallel to the shore along the 0.4-m depth contour for shallow, non-armored transects. For deep, armored transects, the snorkeler swam 1 m from the shoreline. Transects widths were standardized at 2.5 m for shallow, non-armored transects (0.4 m) and 2.0 m for armored, deep transects. Snorkelers visually estimated the transect width and calibrated their estimation at the beginning of each survey night by viewing a pre-measured staff underwater.

Snorkeling began shortly after sunset (45 min to 1 h after posted sunset time). Snorkelers used an underwater flashlight to observe the fish. All fish were counted and identified to species or lowest taxonomic category that could be determined accurately through snorkeling (e.g., cutthroat trout [*O. clarkii*] and rainbow trout [*O. mykiss*] were grouped together as trout). We also recorded separate counts for different life stages (juvenile, subadult, adult). Sculpin (*Cottus* spp.) were divided into those less than and greater than 75 mm total length (TL). Sculpin in Lake Washington consist of two species, coastrange sculpin (*C. aleuticus*) and prickly sculpin (*C. asper*) (Tabor et al. 2007); however, we made no attempt to distinguish the two species.

On each survey night, we also took water temperature (^{o}C) and a Secchi depth (m) measurement at the boardwalk between transects #'s 4 and 5. Water temperatures were taken at 0.5 m depth. A dive light was used to observe the Secchi disc (0.2-m diameter disc with alternating black and white quadrants). Preliminary measurements indicated taking Secchi depth measurements at night with a dive light gave similar results as taking them during the day.

Initial habitat information (substrate and slope) was collected in 2011 to help characterize each transect (Table 1). Habitat conditions did not appear to have changed from 2011 to 2013 and no additional information was collected. In 2015, we measured the flume and cove transects again to determine how the habitat had changed as a result of the restoration project. For each transect, we established three to five equal-spaced measurement lines that ran perpendicular from shore. At each measurement line, water depth was measured every 2 m from shore until the water depth was 1 m. Also at 0.5 m depth of each measurement line, we estimated the substrate composition within a 1-m-diameter circle around that point.

To compare among years and take into account differences in juvenile Chinook salmon abundance among years, we calculated the ratio of Chinook salmon abundance between treated and control transects for each sample date as:

Fish density ratio = Fish density in treated transect *i* / Fish density in control transect *i*.

Fish density ratios were expected to increase after construction. Treated transects consisted of the old flume site and the cove-cobble site. Control transects consisted of the two Gene Coulon transects and the cove-sand transect. The cove-sand transect was also altered from pre-project conditions but the habitat type (sandy beach with a gentle slope) was similar before and after construction and we considered this site as another control site.

TABLE 1.— Names and characteristics of five snorkel transects in the south end of Lake Washington, January-June 2011-2013 and 2015-2016. Transect measurements were taken in 2011 and 2015. Highlighted cells in yellow indicate changes in 2015 and 2016 from 2011-2013. GC = Gene Coulon Park (City of Renton). The depth was taken along the midpoint of each transect. The distance offshore is the distance from the shoreline to the midpoint of each transect.

2011-2013

Transect #	Transect name	Armored shore?	Length (m)	Width (m)	Depth (m)	Distance offshore (m)	Substrate
1	Flume	Yes	100	2.0	2.5 - 4.7	1	100% steel wall
2	Cove-sand	No	45	2.5	0.4	2 - 5	100% sand
3	Cove-cobble	No	34	2.5	0.4	4 - 6	88% cobble, 12% gravel
4	GC bulkhead	Yes	57	2.0	0.4 - 0.9	1 - 2	10% sand, 26% gravel, 48% cobble, 16% cement wall
5	GC swim beach	No	140	2.5	0.4	8 - 12	100% sand

2015-2016

Transect #	Transect name	Armored shore?	Length (m)	Width (m)	Depth (m)	Distance offshore (m)	Substrate
1	Old flume site	No	100	2.5	0.4	2 - 3	30% sand, 70% gravel
2	Old cove-sand site	No	45	2.5	0.4	2 - 4	30% sand, 70% gravel
3	Old cove-cobble site	No	34	2.5	0.4	2 - 3	30% sand, 70% gravel
4	GC bulkhead	Yes	57	2.0	0.4 - 0.9	1 - 2	10% sand, 26% gravel, 48% cobble, 16% cement wall
5	GC swim beach	No	140	2.5	0.4	8 - 12	100% sand

Engineered Log Jam Surveys

Snorkel surveys of the new ELJs were also conducted in 2016. The surveys consisted of a single transect around the outside perimeter of three ELJs (labeled as A, B, and C; Figure 1). A fourth ELJ located at the east end of the restoration area was not surveyed because water visibility was constantly poor at this site due to a nearby outflow pipe. ELJ surveys were conducted at night on the same dates as our standard snorkel transects. We observed fish from the shoreline on one side of the ELJ to the outside edge of the ELJ and then back to the shoreline on the opposite side of the ELJ. Maximum depth on the outside edge of the ELJ varied from 0.75 to 0.8 m in February and March to 1.2 to 1.4 m in May and June. For each transect, we were able to effectively observe fish throughout the water column. As the lake level rose, more of the ELJ was submerged and the transect length became longer. Transect length of ELJ-A from 15 m to 26 m, ELJ-B varied from 7 m to 14 m, and ELJ-C varied from 32 m to 40 m. Transect width was 2 m. ELJs A and C were large jams with several large overlapping pieces while ELJ-B was a small jam consisting only of few pieces of wood. Because of the complexity of the ELJs, we were not able to observe the inner parts of each ELJ and we assume our fish counts are an underestimate of the actual number present.

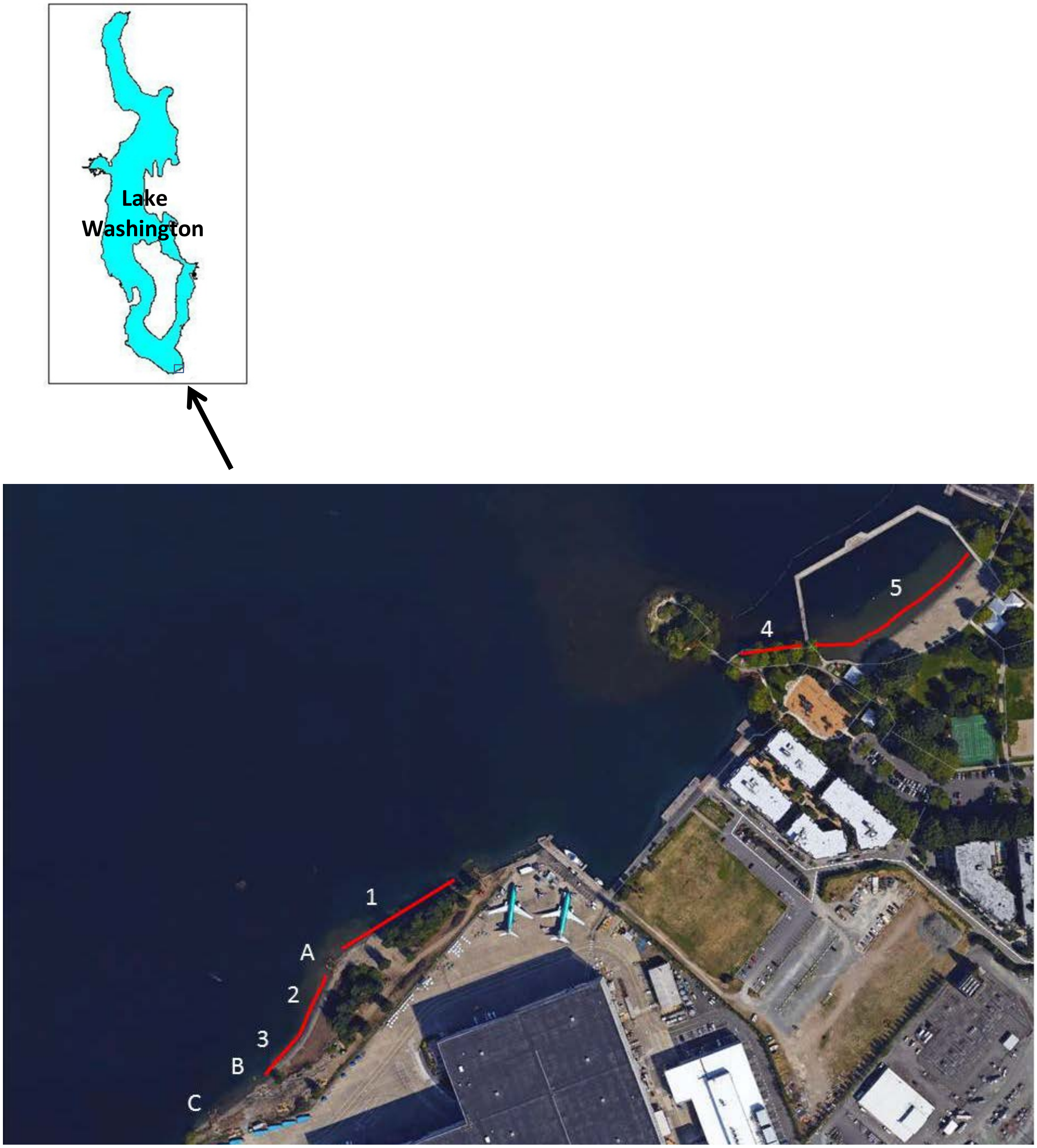

FIGURE 1.— Location of five transects (#'s 1-5) and three engineered log jams (A-C) used to monitor abundance of juvenile Chinook salmon in the south end of Lake Washington, January-June 2015. Transect numbers correspond to numbers in Table 1. The land adjacent to transect #'s 1-3 and engineered log jams A-C is WDNR property. The developed property to the southeast of WDNR property is The Boeing Company property. Transects #'s 4 and 5 are in City of Renton's Gene Coulon Park.

FIGURE 2.— Before and after photos of the cove snorkel transects. In the upper photo, part of the cove-cobble transect is in the foreground and the cove-sand transect is in the upper right and the flume structure can be seen in the background. In the lower photo, part of the old cove-sand transect is in the foreground and engineered log jam A (ELJ-A) can be seen in the background.

Results

Standard Snorkel Transects

A total of ten snorkel surveys were completed in 2016, from January 25 to June 6. (Figure 3). Water visibility and weather conditions were adequate for conducting snorkel surveys on all survey nights; however, we were only able to do partial surveys at the Gene Coulon swim beach on the May 10 and June 6 due to poor visibility conditions (presumably due to human swimming activity during the day). Water visibility (Secchi depth readings) ranged from 5 m on April 4 to 2.4 m on March 7 (Figure 3).

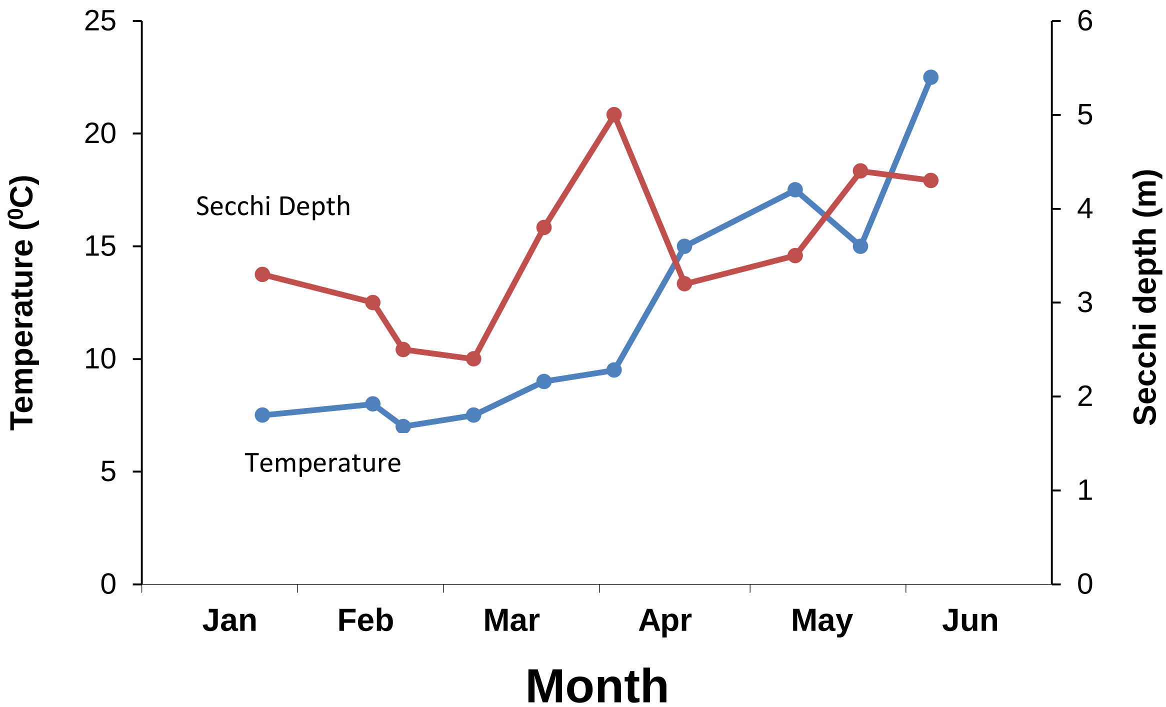

FIGURE 3.— Temperature (ºC) and Secchi depth (m) measurements at Gene Coulon Park, 2016. Measurements were taken on the boardwalk between transects #'s 4 and 5.

Juvenile Chinook salmon.— In comparison to the pre-project years (2011-2013), substantially more juvenile Chinook salmon were observed along the old flume transect in 2015 and 2016 (Figure 4; Wilcoxon paired tests: $P < 0.01$ for each comparison between pre- and post-project). A total of 791 and 1,533 juvenile Chinook salmon were observed along the old flume transect in 2015 and 2016, respectively. In comparison, only 39 were observed in 2011, 98 in 2012, and 227 in 2013. A peak number of 414 juvenile chinook (1.66 fish/m^2) was observed along the old flume transect on February 16, 2016.

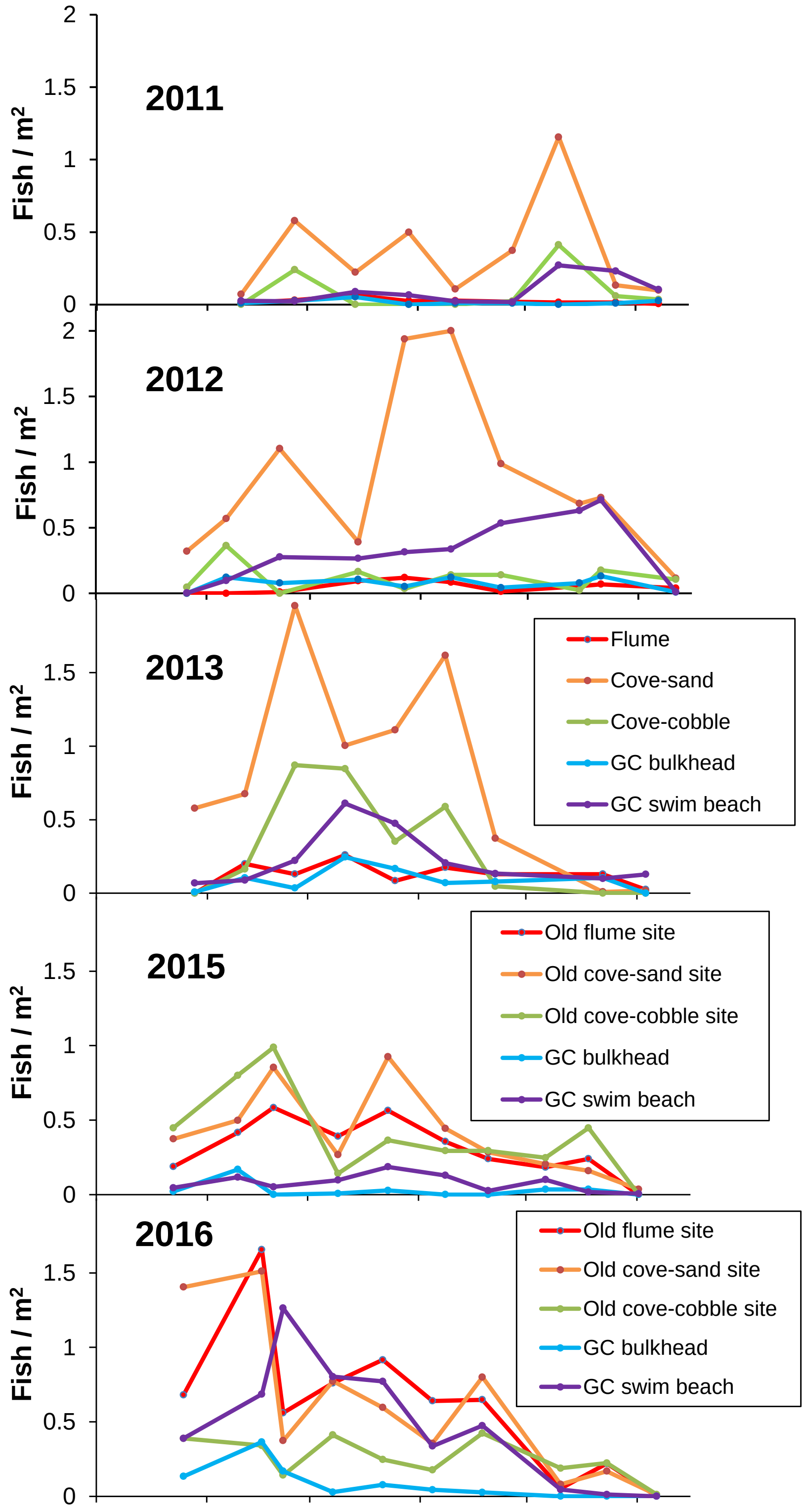

FIGURE 4.— Density (fish/m^2) of juvenile Chinook salmon at five transects in the south end of Lake Washington, January-June 2011-2013 and 2015-2016. Pre-project monitoring was conducted in 2011-2013 and post-project monitoring in 2015-2016. GC = Gene Coulon Park.

From January to April, the fish density ratio of juvenile Chinook salmon for the flume and the three control sites was substantially higher in both 2015 and 2016 than the pre-project survey years (Figure 5). In May and June, the abundance of juvenile Chinook salmon was often low and varied widely among transects and years and subsequently the fish density ratios varied widely. The median fish density ratio of juvenile Chinook salmon for the old flume transect and the old cove-sand transect was 0.84 in 2015 and 1.03 for 2016, whereas it was 0.04 in 2011, 0.04 in 2012, and 0.21 in 2013. For the old flume transect and the Gene Coulon bulkhead, the median fish density ratio was 6.84 in 2015 and 11.86 for 2016, whereas it was 1.14 in 2011, 0.55 in 2012, and 1.19 in 2013. Also, for the old flume transect and the Gene Coulon swim beach transect, the median fish density ratio of juvenile Chinook salmon was 3.55 in 2015 and 1.75 for 2016, whereas it was 0.31 in 2011, 0.07 in 2012, and 0.47 in 2013.

Comparisons among years for the old cove-cobble site and the two control sites with fine substrates also were higher in 2015 and 2016 than most pre-project survey years (Figure 6). The median fish density ratio of juvenile Chinook salmon for the old cove-cobble transect and the cove-sand transect was 1.03 in 2015 and 0.51 for 2016, whereas it was 0.06 in 2011, 0.15 in 2012, and 0.24 in 2013. For the old cove-cobble transect and the Gene Coulon swim beach, the median fish density ratio was 2.47 in 2015 and 0.51 for 2016, whereas it was 0.25 in 2011, 0.34 in 2012, and 0.74 in 2013.

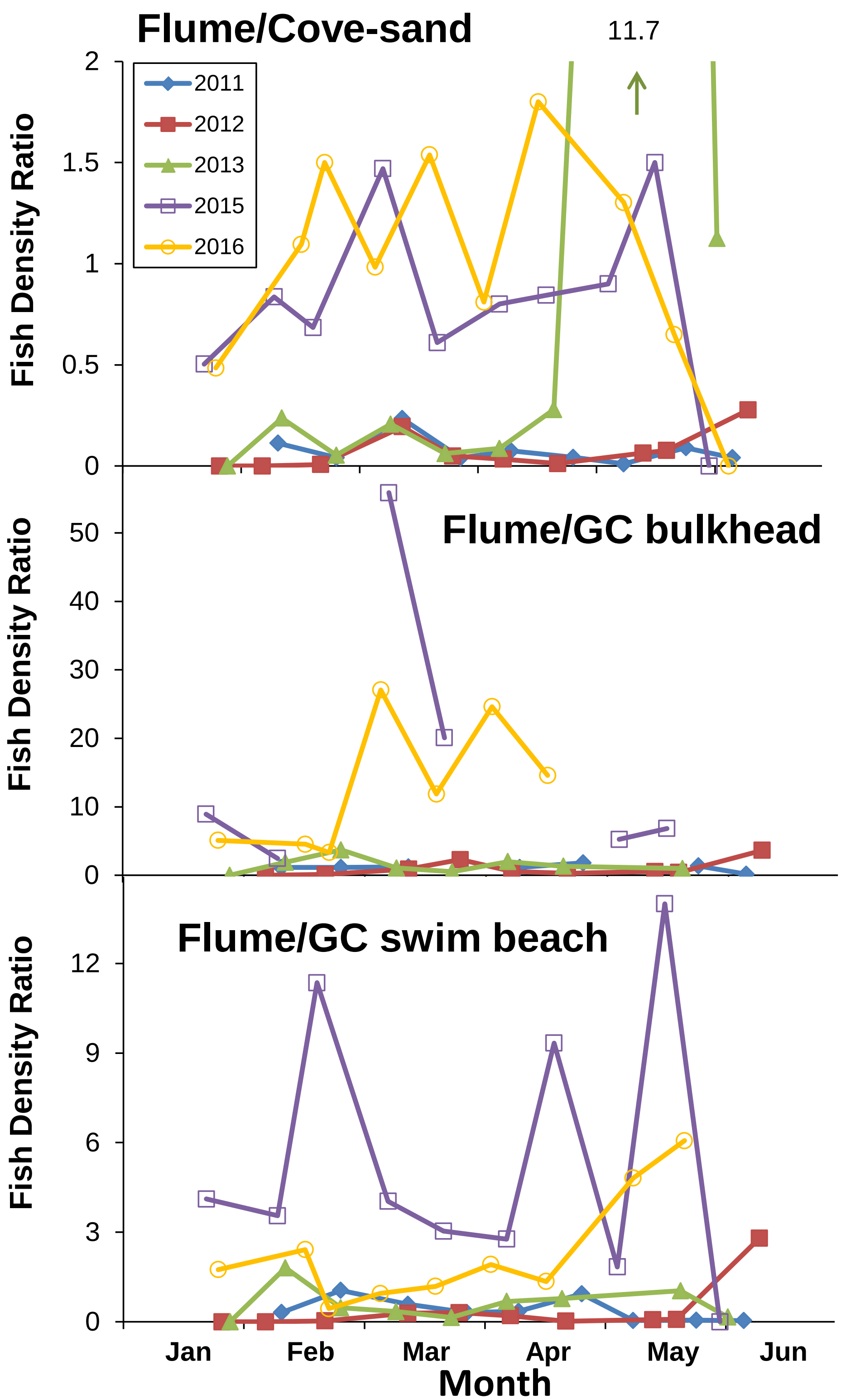

FIGURE 5.— Fish density ratio of juvenile Chinook salmon for the flume site compared to three control sites, January-June 2011-2013 and 2015-2016. Pre-project monitoring was conducted in 2011-2013 and post-project monitoring in 2015-2016. GC = Gene Coulon Park. Missing data points indicate no juvenile Chinook salmon were observed at the control site.

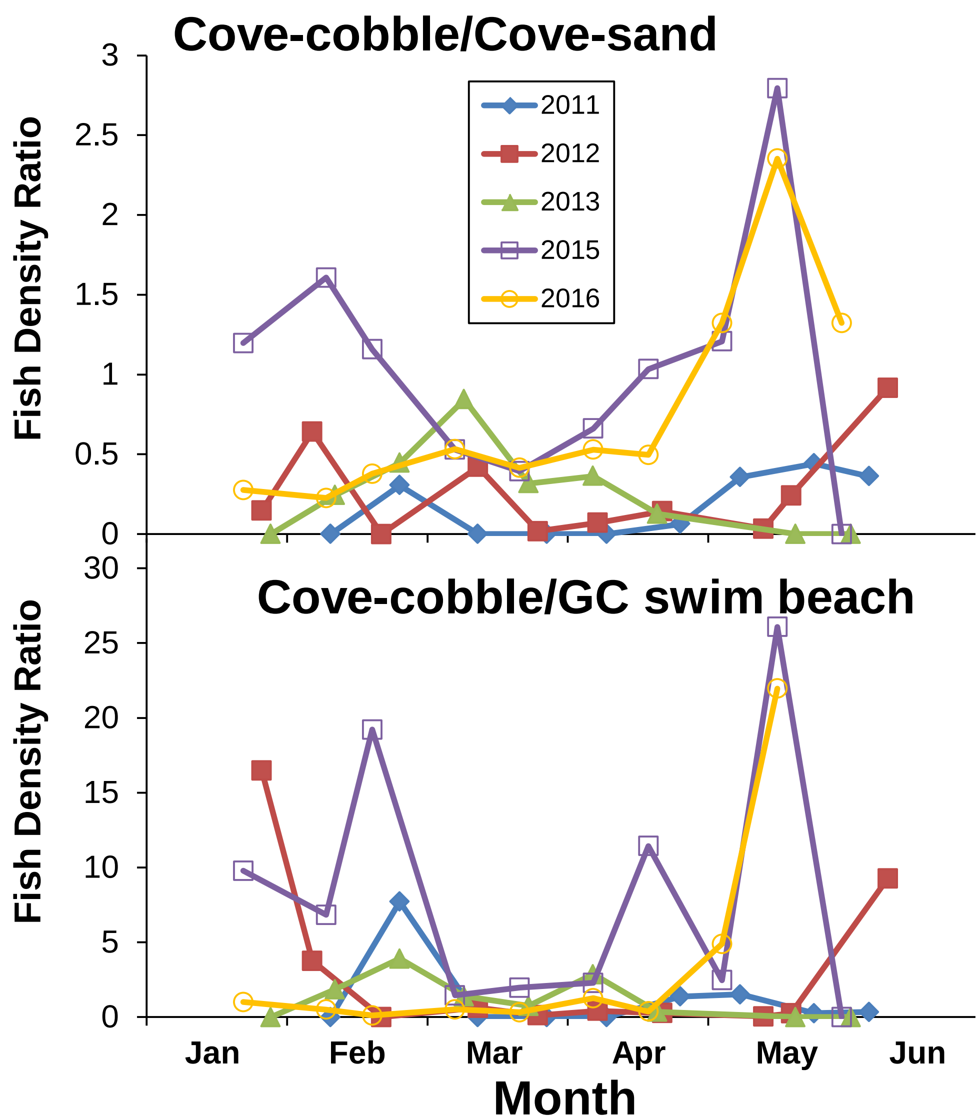

FIGURE 6.— Ratio of fish density of juvenile Chinook salmon for the cove-cobble site compared to two control sites, January-June 2011-2013 and 2015-2016. Pre-project monitoring was conducted in 2011-2013 and post-project monitoring in 2015-2016. GC = Gene Coulon Park.

A total of nine snorkel surveys were conducted around ELJs A-C from February 16 to June 6. The highest densities of juvenile Chinook salmon were observed from February 16 to April 4 (Figure 7) and during this period densities were substantially higher than in the nearby standard transects (Figure 8). Chinook salmon appeared to be concentrated in the shallow waters (typically in water that was less than 0.5 m deep) on the perimeter of each ELJ. The larger ELJs (A and C) constantly had higher densities of juvenile Chinook salmon than the small ELJ-B. After April 4, densities of juvenile Chinook salmon in the ELJs decreased sharply and from April 18 to May 23 they were less than the density in the nearby standard transects (Figure 8).

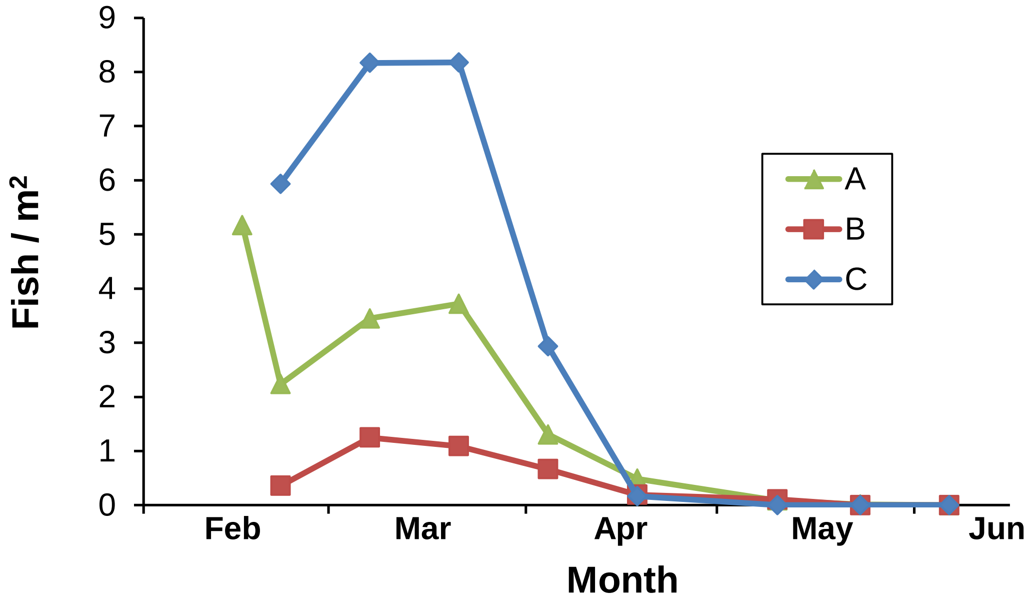

FIGURE 7.— Density (fish/m^2) of juvenile Chinook salmon at three ELJs (A-C), February-June 2016.

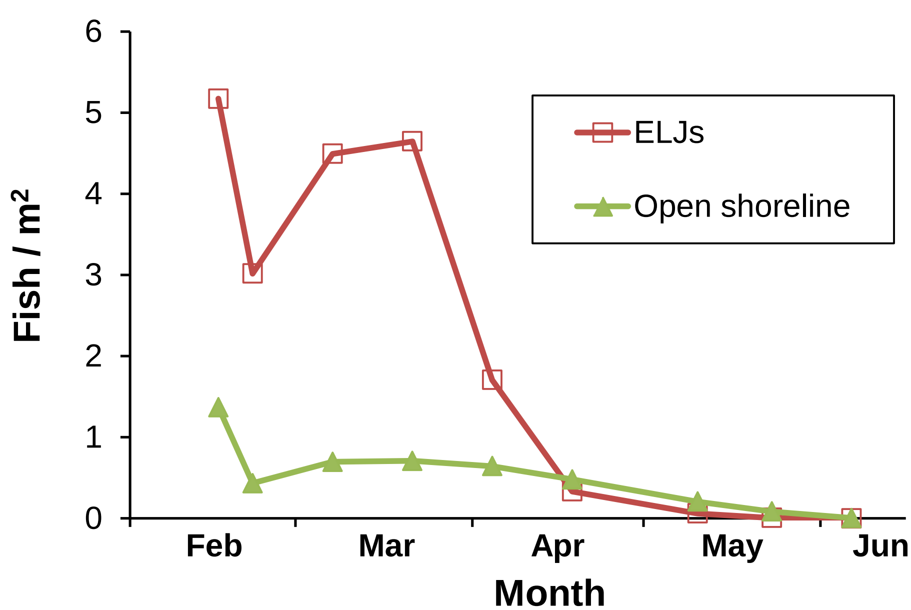

FIGURE 8.— Comparison of the combined density (fish/m^2) of juvenile Chinook salmon along WDNR open beach transects (old cove-cobble, old cove-sand, and old flume transects combined) and the three ELJs (ELJs A-C transects combined), February-June 2016.

Threespine stickleback.— In 2016, a total of 167 threespine stickleback (*Gasterosteus aculeatus*) were observed. Although the number observed was two times larger than in 2015 (total of 83 stickleback observed), the 2016 level was still substantially lower than in 2011-2013 (Figure 9). Overall, we observed a total of 1,232 in 2011, 839 in 2012, and 4,952 in 2013. An additional 61 threespine stickleback were observed while surveying the three ELJs in 2016.

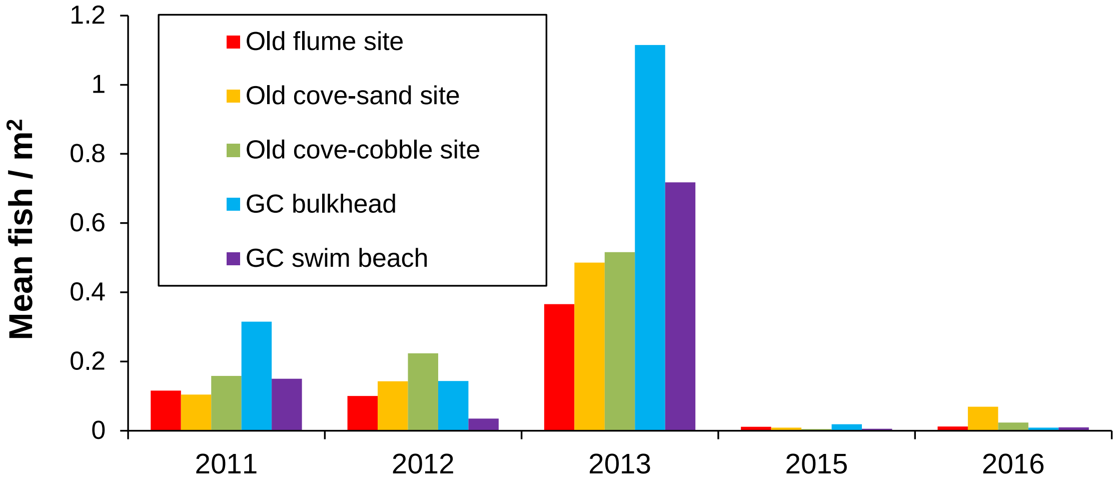

FIGURE 9. — Mean density (fish/m^2) of threespine stickleback at five transects in the south end of Lake Washington, January-June 2011-2016 and 2015-2016. GC = Gene Coulon Park.

Sculpin.- Similar to previous survey years, the density of sculpin was generally low in January and February (Figure 10) and then increased in later months as water temperatures rose. Substantially more sculpin were observed along the old flume transect in 2015 and 2016 than in earlier survey years; however, we likely severely underestimated their abundance in the earlier surveys because the transect water depth was much deeper and we were usually unable to observe the bottom. Additionally, 165 sculpin were observed while surveying the three ELJs.

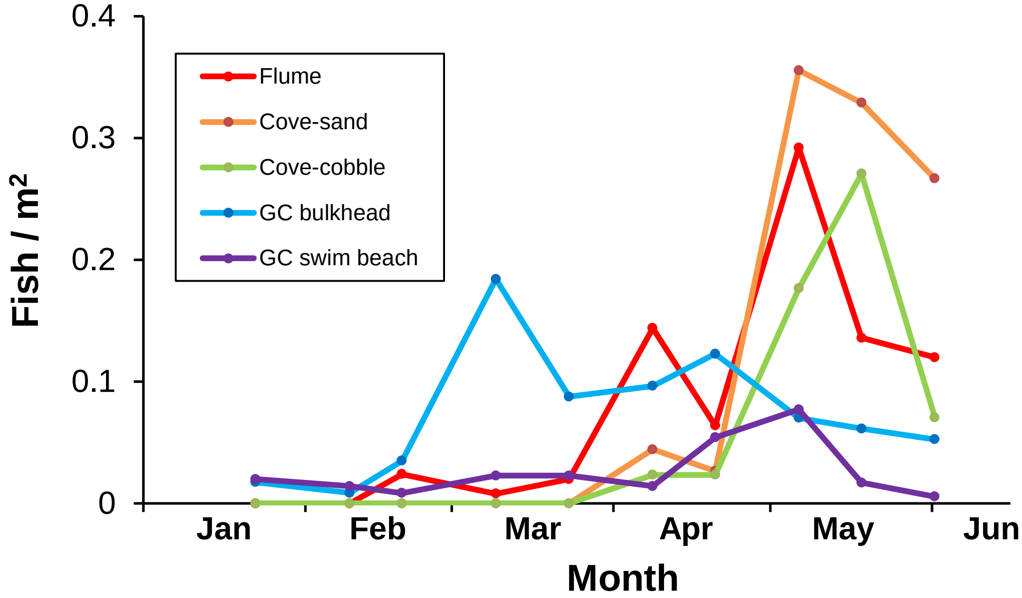

FIGURE 10. — Mean density (fish/m^2) of sculpin (prickly sculpin and coastrange sculpin combined) at five transects in the south end of Lake Washington, 2016. GC = Gene Coulon Park.

Other Fishes.—Similar to 2015, few sockeye salmon fry (*O. nerka*) were observed in 2016. A total of 23 sockeye salmon fry were observed in 2016 and 29 were in 2015, whereas 197 were observed in 2011, 372 in 2012, and 3,475 in 2013. Only 20 trout were observed and were primarily observed along the old flume site and Gene Coulon swim beach transects.

The overall abundance of each species of nonnative centrarchid fishes (pumpkinseed [*Lepomis gibbosus*], bluegill [*L. macrochiris*], rock bass [*Ambloplites rupestris*], smallmouth bass, and largemouth bass [*M. salmoides*]) except crappie (*Pomoxis* spp.) was higher in 2015 and 2016 than in previous survey years (Figure 11). Most of the nonnative centrarchid fishes were juveniles. The other nonnative fish species that was occasionally encountered was yellow perch (*Perca flavescens*; n = 125).

Abundance of nonnative fishes (centrarchids and yellow perch) at the ELJs was generally low in February and March but increased in April through June (Figure 12) as water temperatures increased. The larger, more structurally complex ELJs (A and C) had larger populations of nonnative fish when compared to smaller and shallower ELJ-B. Most of the subadult and adult nonnative fish were often observed where the water column depths were over 0.5 m.

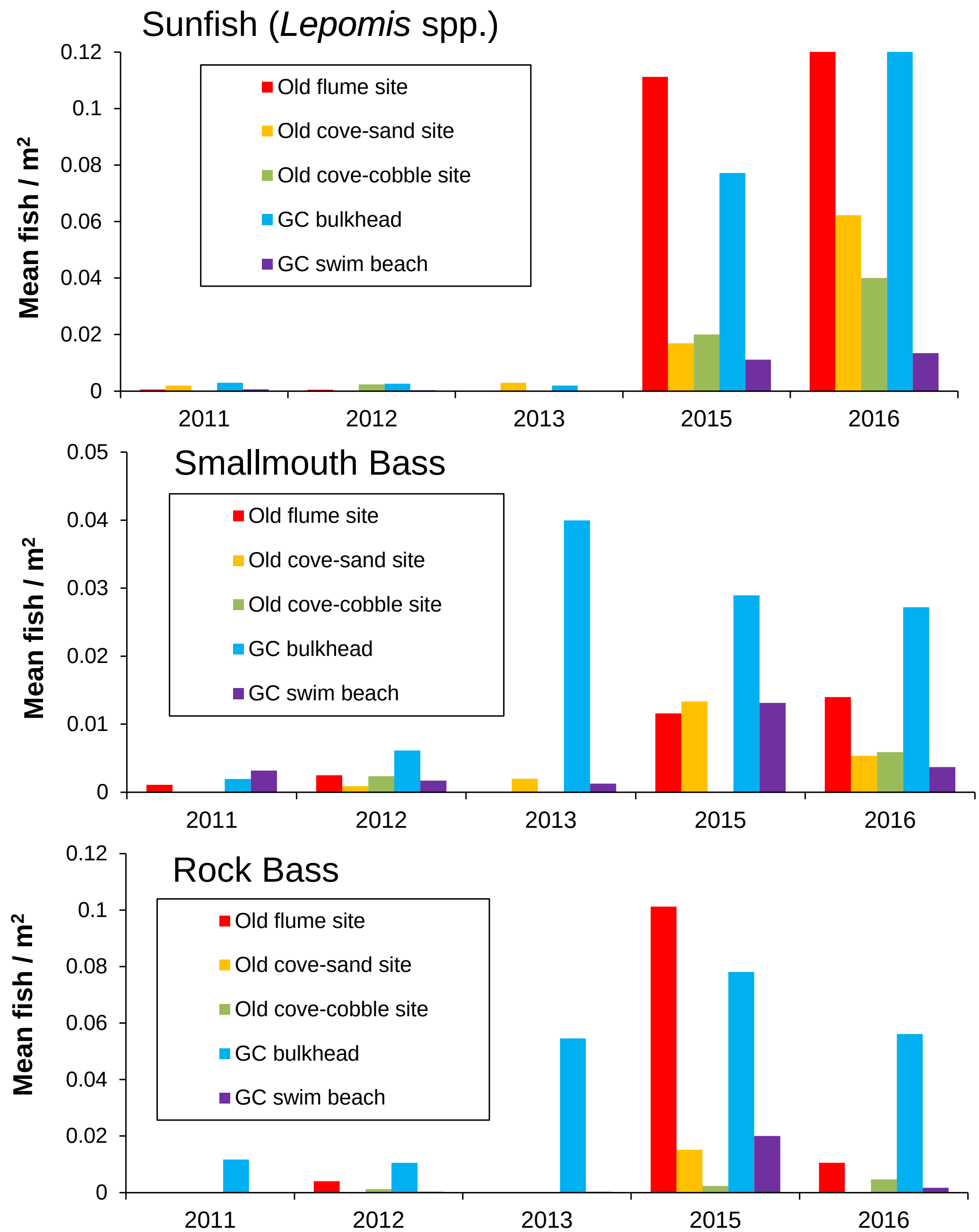

FIGURE 11. — Mean density (fish/m^2) of three types of nonnative centrarchids at five transects in the south end of Lake Washington, January-June 2011-2013 and 2015-2016. Sunfish (*Lepomis* spp.) includes pumpkinseed, bluegill, and unidentified juvenile sunfish. GC = Gene Coulon Park.

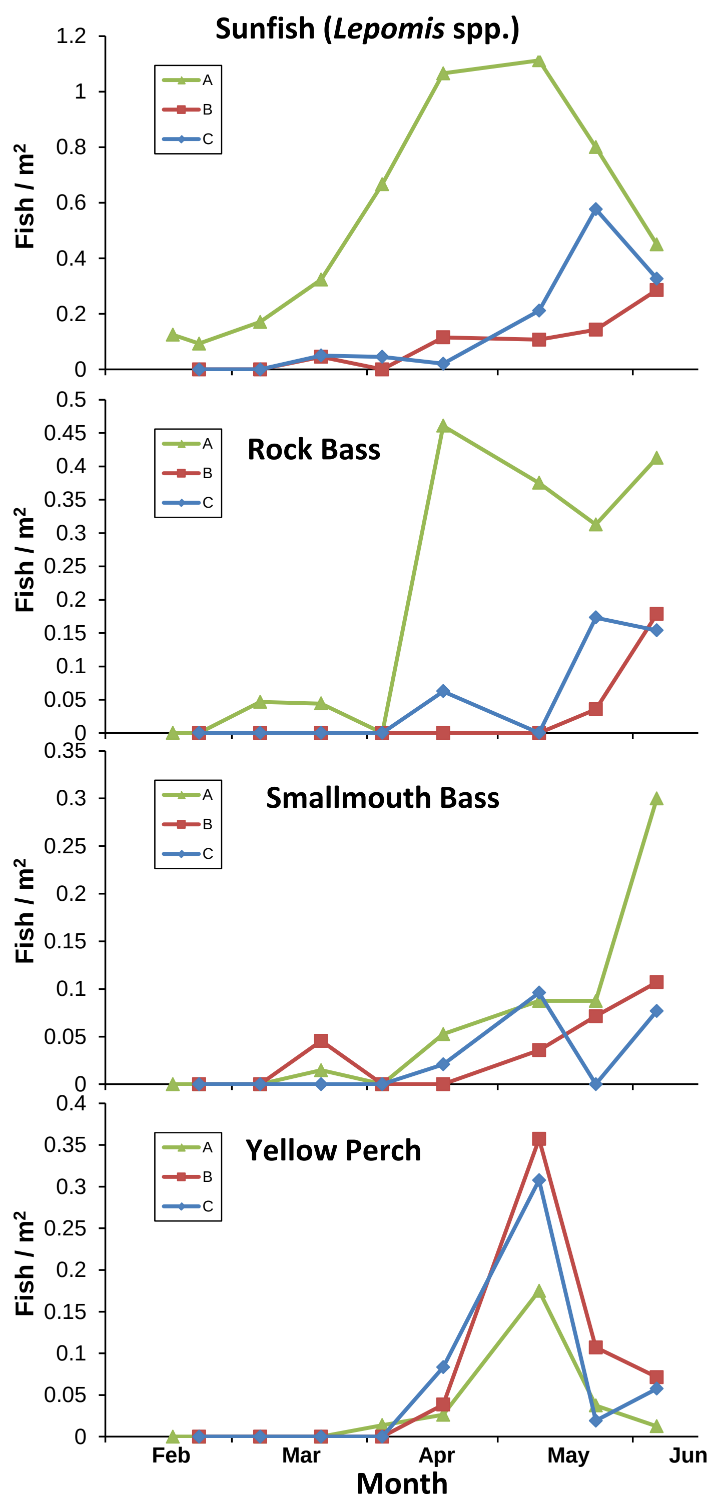

FIGURE 12.— Density (fish/m^2) of three types of nonnative centrarchids and yellow perch along three transects for ELJs (A-C), February-June 2016. Sunfish (*Lepomis* spp.) includes pumpkinseed, bluegill, and unidentified juvenile sunfish.

Discussion

Because good numbers of juvenile Chinook salmon (i.e., > 40 fish on each survey night from January to mid-May in both 2015 and 2016) were observed along the flume transect and their density was similar or higher than control sites, removal of the flume structure and replacing it with a sandy beach appeared to create valuable habitat for juvenile Chinook salmon. This site should be particularly valuable for juvenile Chinook salmon because it is close to the mouth of the Cedar River, the source from which large numbers of Chinook salmon fry emigrate in the winter and early spring. The old flume wall structure is a good example of a suboptimal habitat: little shallow water, no sand and gravel substrates, steep slope, and little structural complexity (Tabor et al. 2011). The restored nearshore habitat now has a large area of shallow water < 1 m deep, primarily sand and gravel substrate, a gentle slope, and some nearby ELJs for refuge. These habitat types can provide daytime feeding areas and nighttime resting locations while minimizing predation risk (Tabor et al. 2011). Additionally, as juvenile Chinook salmon grow their habitat use changes and shoreline diversity will be beneficial to a wide range of fish sizes.

The first adequate assessment of the ELJs was completed in 2016. In 2015, we attempted to assess ELJs through daytime snorkeling observations but juvenile Chinook salmon were often difficult to observe because of poor visibility and it was difficult to see fish inside of the ELJ. In 2016, we switched to nighttime snorkeling observations. Based on previous snorkeling efforts (Tabor et al. 2011), we expected juvenile Chinook salmon would move away from the ELJs at night and it would be difficult to determine Chinook salmon use of these structures. However, it appeared they only moved a short distance away (< 2 m) from the structure and were concentrated on the outside perimeter. In 2017, we plan to continue our assessment of the ELJs through nighttime snorkeling observations.

Nighttime surveys of ELJs indicated large numbers of Chinook salmon are often closely associated with these structures. Based on nighttime surveys in 2016, a few daytime surveys in 2015, and other observations (Tabor et al. 2011), it appears juvenile Chinook salmon are primarily in small schools in the middle of the ELJ during the day and then move to the outside perimeter of the ELJ at night to rest on the bottom. The degree that juvenile Chinook salmon forage in the ELJ is unknown. Koehler (2002) found that, among various Lake Washington shoreline types, natural forested shorelines with overhanging vegetation had the lowest densities of chironomids (the main forage item of juvenile Chinook salmon); therefore, ELJs may not have higher levels of prey abundance than other sites. There are likely times (e.g., dawn and dusk) when some juvenile Chinook salmon move away from the ELJ to forage. Likely, the most important function of the ELJs is to provide juvenile Chinook salmon refuge from their predators.

The ELJs appeared to provide valuable habitat for juvenile Chinook salmon but may also provide habitat for nonnative centrarchids including smallmouth bass. However, centrarchids we observed were mostly juveniles and too small to predate on juvenile Chinook salmon. The ELJs do not extend out into deep water (i.e., > 1.5 m depth) which probably minimizes the use by subadult and adult smallmouth bass. Also, the abundance of juvenile Chinook salmon is low in May and June when smallmouth bass are common in the ELJs. Therefore, the new ELJs likely do not directly affect juvenile Chinook salmon through predation but could indirectly affect them by enhancing centrarchid populations.

The observed number of introduced centrarchid fishes (pumpkinseed, bluegill, rock bass, smallmouth bass, and largemouth bass) appeared to be higher in 2015 and 2016 than in the previous survey years. Several factors could account for this change. First, the flume structure was removed and shallow water habitat is now available for juvenile centrarchids; however, this would only account for an increase in abundance in one of the five transects. Secondly, water temperatures were higher in 2015 and 2016 than in 2011-2013 survey years and our observed centrarchid abundance in May and June may be typical of their abundance in July or August in other years. Many of the centrarchids observed in 2015 were observed on our last survey of June 1. Lastly, observed increases in their abundance may be an indication of an increase in their population size in south Lake Washington. This may be particularly true for rock bass and bluegill which were not observed during snorkel and electrofishing surveys of south Lake Washington in the late 1990's (R. Tabor, USFWS, unpublished data) and may have recently colonized south Lake Washington. There has also been some evidence of an increase of overall lake temperatures (Arhonditsis et al. 2004), which may favor warm-water fishes such as centrarchids over cool-water fishes.

The basic design of this monitoring project is a before-after-control-impact (BACI) model (Smith et al. 1993). A major drawback of this study design is that it may take several years of sampling to detect a statistically significant change in fish abundance (Roni et al. 2003). For example, 10 years of sampling is required to statistically detect a two-fold increase in juvenile coho salmon (*O. kisutch*) abundance in restoration projects in Oregon coastal streams (Roni et al. 2003). The flume structure site went from poor habitat conditions for juvenile Chinook salmon to ideal habitat conditions (i.e., available shallow water, gentle sloping shoreline with small substrate, and nearby woody debris), and the change in abundance might be much higher than two-fold and thus fewer years of monitoring would be needed. Thus far, there appears to be a four to twenty-fold increase and sampling for three years after construction might be sufficient to detect a statistically significant change.

In conclusion, removal of the flume structure and replacing it with a more natural shoreline (open beach with areas of large woody debris) appeared to have improved juvenile Chinook salmon habitat in Lake Washington. Secondly, the change of the old cove-cobble site from cobble to sand/gravel substrate demonstrated the importance of small substrates for juvenile Chinook salmon. Lastly, earlier surveys indicate there can be large variability between years and underscores the need to survey over multiple years.

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Appendix A-1. Number of fish observed in 2011 along five shoreline transects in the south end of Lake Washington. GC = Gene Coulon (City of Renton park). Length and area surveyed for each transect is given in Table 1.

			Date									
Transect	**Fish group**	**Species**	10-Feb	25-Feb	14-Mar	29-Mar	11-Apr	27-Apr	10-May	26-May	7-Jun	**Total**
Flume	Salmonids	Chinook salmon	2	6	13	5	2	4	3	3	1	39
		Sockeye salmon (fry)		42	1	3						46
		Trout							1			1
	Other native	Sucker (juveniles)							1			1
		Threespine stickleback		2		9		104	53	7	33	208
		Sculpin	3		2			1				6
	Nonnative	Smallmouth bass						1		1		2
		Black crappie							1	2	4	7
		Sunfish (juveniles)								1		1
Cove - sand	Salmonids	Chinook salmon	8	65	25	56	12	42	130	15	11	364
		Sockeye salmon (fry)		42	4	23	7			1		77
		Trout						1				1
	Other native	Longfin smelt				4						4
		Peamouth									1	1
		Sucker (juveniles)							1		5	6
		Threespine stickleback					8	2	42	22	32	106
		Sculpin	14	4	31	37	4	3	30	21	34	178
	Nonnative	Sunfish (juveniles)							1			1
		Pumpkinseed								1		1
		Yellow perch							5	10	6	21
Cove - cobble	Salmonids	Chinook salmon	0	15	0	0	0	2	35	5	3	60
		Sockeye salmon (fry)	1	21								22
		Trout									1	1
	Other native	Threespine stickleback					2	4	40	15	60	121
		Sculpin	10	2	37	44	1	2	25	15	4	140
	Nonnative	Yellow perch							5	6	5	16
GC bulkhead	Salmonids	Chinook salmon	1	3	6	0	1	1	0	1	3	16
		Trout					1					1
	Other native	Threespine stickleback					23	52	65	88	95	323
		Sculpin	8	2	5	24	17	27	38	42	44	207
	Nonnative	Smallmouth bass				1	1					2
		Sunfish (juveniles)								1	2	3
		Rock bass				1		4	2	2	3	12
		Yellow perch							1	1	3	5
GC swim beach	Salmonids	Chinook salmon	9	8	31	23	8	6	95	81	36	297
		Sockeye salmon (fry)	11	9	9	19	4	1	3	35	1	92
		Trout		2		1	1				2	6
	Other native	Longfin smelt	2		8		1					11
		Peamouth									4	4
		Sucker (juveniles)							2			2
		Threespine stickleback			2	2	41	134	90	125	80	474
		Sculpin	25		24	19	15	14	124	111	24	356
	Nonnative	Smallmouth bass								9	1	10
		Sunfish (juveniles)							1			1
		Pumpkinseed							1			1
		Yellow perch							2	21	3	26

Appendix A-2. Number of fish observed in 2012 along five shoreline transects in the south end of Lake Washington. GC = Gene Coulon (City of Renton park). Length and area surveyed for each transect is given in Table 1.

			Date										
Transect	**Fish group**	**Species**	26-Jan	6-Feb	21-Feb	14-Mar	27-Mar	9-Apr	23-Apr	15-May	21-May	11-Jun	**Total**
Flume	Salmonids	Chinook salmon			2	19	24	17	3	11	14	8	98
		Sockeye salmon (fry)					2	1					3
	Other native	Longfin smelt			1								1
		Peamouth									1	5	6
		Threespine stickleback			1			1	180	11	4	4	201
		Sculpin	1	6	3		6	1	1				18
	Nonnative	Smallmouth bass								2	1	2	5
		Black crappie										2	2
		Sunfish (juveniles)										1	1
		Rock bass										8	8
		Yellow perch									1		1
Cove - sand	Salmonids	Chinook salmon	36	64	124	44	218	225	111	77	82	13	994
		Coho salmon (presmolt)							2			1	3
		Sockeye salmon (fry)	10	10	143	4	19	20		4			210
		Trout								2	1	1	4
	Other native	Sucker (juveniles)										3	3
		Threespine stickleback							3	3	115	40	161
		Sculpin	6	3	6	32	3	17	12	30	53	105	267
	Nonnative	Smallmouth bass										1	1
		Yellow perch										11	11
Cove - cobble	Salmonids	Chinook salmon	4	31		14	3	12	12	2	15	9	102
		Sockeye salmon (fry)	1	5			1	2					9
		Trout									3		3
	Other native	Threespine stickleback								23	92	75	190
		Sculpin	2	11		7	3	10		1	25	9	68
	Nonnative	Smallmouth bass					1					1	2
		Sunfish (juveniles)										2	2
		Rock bass									1		1
		Yellow perch										3	3
GC bulkhead	Salmonids	Chinook salmon		14	9	12	6	14	5	9	15	1	85
		Sockeye salmon (fry)					4						4
		Trout					1						1
	Other native	Peamouth									3		3
		Threespine stickleback					1	9	31	25	48	50	164
		Sculpin	9	4	9	6	22	12	17	1	32	52	164
	Nonnative	Largemouth bass			1					1			2
		Smallmouth bass	1	1			1	1	1		1	1	7
		Sunfish (juveniles)										2	2
		Pumpkinseed										1	1
		Rock bass							2	1	5	4	12
GC swim beach	Salmonids	Chinook salmon	1	34	97	93	110	118	187	221	249	4	1,114
		Coho salmon (presmolt)							1				1
		Sockeye salmon (fry)	4	9	50	34	22	4	27		1		151
		Trout							6	1	2		9
	Other native	Threespine stickleback		1		1		2	72	5	29	13	123
		Sculpin	16	41	40	28	36	17	44	4	96	24	346
	Nonnative	Smallmouth bass	1	1					2		1	1	6
		Sunfish (juveniles)										1	1
		Rock bass										1	1
		Yellow perch										2	2

Appendix A-3. Number of fish observed in 2013 along five shoreline transects in the south end of Lake Washington. GC = Gene Coulon (City of Renton park). Length and area surveyed for each transect is given in Table 1.

			Date									
Transect	**Fish group**	**Species**	28-Jan	11-Feb	25-Feb	11-Mar	25-Mar	8-Apr	22-Apr	22-May	3-Jun	**Total**
Flume	Salmonids	Chinook salmon	0	40	26	52	17	35	26	26	5	227
		Coho salmon (presmolt)							9			9
		Sockeye salmon (fry)		50	20	270	47	6	2			395
	Other native	Threespine stickleback	48	120	15	35	52	16	36	187	150	659
		Sculpin	3						1			4
Cove - sand	Salmonids	Chinook salmon	65	76	220	113	125	182	42	1	2	826
		Coho salmon (fry)							102			102
		Coho salmon (presmolt)							4			4
		Sockeye salmon (fry)	38	3	76	160	800	30	24			1,131
	Other native	Longfin smelt			1							1
		Peamouth								30	6	36
		Threespine stickleback	2	29	25	52	42	72	10	110	150	492
		Sculpin	4	8	17	4	6	44		12	19	114
		sucker								6	4	10
	Nonnative	Smallmouth bass								1	1	2
		Sunfish (juveniles)								3		3
		Yellow perch			1	2		1	2	10	15	31
Cove - cobble	Salmonids	Chinook salmon	0	14	74	72	30	50	4			244
		Sockeye salmon (fry)			28	57	15	15	2			117
	Other native	Threespine stickleback	2	27	33	59	67	39	20	73	75	395
		Sculpin			10	8	5	18	3	2		46
	Nonnative	Black crappie								1		1
		Yellow perch				4						4
GC bulkhead	Salmonids	Chinook salmon	1	12	4	28	19	8	9	12		93
		Sockeye salmon (fry)	1	12	3	20	27	3	1			67
	Other native	Threespine stickleback	80	108	42	55	157	107	57	238	300	1,144
		Sculpin	2	11	3	4	1	11	7	11	15	65
		signal crayfish							1	3		4
	Nonnative	Smallmouth bass	7	4	2	8	9	4	5	2		41
		Sunfish (juveniles)								2		2
		Rock bass	2	5	4	3	11	9	8	8	6	56
		Yellow perch						3				3
GC swim beach	Salmonids	Chinook salmon	24	31	78	214	166	72	47	35	45	712
		Coho salmon (presmolt)		1					4			5
		Sockeye salmon (fry)	6	73	25	741	870	27	13	10	12	1,777
		Trout	1						4			5
	Other native	Longfin smelt						1	3			4
		Peamouth					1					1
		Threespine stickleback	215	172		602	740	167	56	235	75	2,262
		Sculpin	35	5	27	40	40	55	32	16	17	267
		signal crayfish								1		1
		sucker									2	2
	Nonnative	Smallmouth bass								2	2	4
		Rock bass									1	1
		Yellow perch				3		5	2	8	9	27

Appendix A-4. Number of fish observed in 2015 along five shoreline transects in the south end of Lake Washington. Length and area surveyed for each transect is given in Table 1.

			Date										
Transect	**Fish group**	**Species**	22-Jan	9-Feb	19-Feb	9-Mar	23-Mar	8-Apr	20-Apr	6-May	18-May	1-Jun	**Total**
Old flume site	Salmonids	Chinook salmon	47	104	146	98	141	89	60	46	60	0	791
		Coho salmon							3	4	2		9
		Sockeye salmon				1				2			3
		Trout								2	2		4
	Other native	Peamouth (juveniles)	1										1
		Threespine stickleback				1	1	7	11	2	2	4	28
		Sculpin	3	6	8	1	24	44	39	38	40	66	269
	Nonnative	Largemouth bass	3		1								4
		Smallmouth bass					1	2	1	3	1	21	29
		Sunfish (juveniles)	54	7	16	2	5	1	5	6	59	120	275
		Pumpkinseed										3	3
		Rock bass	1	1				2	21	25	83	120	253
		Yellow perch				1			1	2	4	4	12
Old cove-sand transect	Salmonids	Chinook salmon	42	56	96	30	104	50	32	23	18	4	455
		Coho salmon							6	1			7
		Sockeye salmon				2	1	2		1			6
		Trout		1					2				3
	Other native	Threespine stickleback				2			6		2		10
		Sculpin	2		5		5	3	6	33	42	26	122
	Nonnative	Largemouth bass									2		2
		Smallmouth bass					1	1	2	2		9	15
		Sunfish (juveniles)	1						1			14	16
		Bluegill									1	1	2
		Pumpkinseed										1	1
		Rock bass								1		16	17
		Yellow perch		1						2	2		5
Old cove-cobble transect	Salmonids	Chinook salmon	38	68	84	12	31	25	25	21	38	0	342
		Coho salmon							5				5
		Sockeye salmon	1				1			2			4
		Trout										1	1
	Other native	Threespine stickleback						1		2	1		4
		Sculpin			4			2	9	10	30	10	65
	Nonnative	Sunfish (juveniles)										13	13
		Pumpkinseed										4	4
		Rock bass								1	1		2
		Yellow perch								1	1	4	6
		Crappie										3	3
Gene Coulon bulkhead	Salmonids	Chinook salmon	3	24	0	1	4	0	0	4	4	0	40
		Trout								3	2	1	6
	Other native	Threespine stickleback				4	1	9	6			1	21
		Sculpin	1	3	5	14	29	30	17	9	7	20	135
		Sucker						1					1
	Nonnative	Largemouth bass					2	2			2	1	7
		Smallmouth bass	8	4	3	7	3			1	1	6	33
		Sunfish (juveniles)		1		1	4	5			1	40	52
		Bluegill							4	3	12		19
		Pumpkinseed								1	6	10	17
		Rock bass	3	3	13	1	9	12	9	8	6	25	89
		Yellow perch			1					2	3	1	7
Gene Coulon swim beach	Salmonids	Chinook salmon	16	41	18	34	65	45	9	35	6	2	271
		Coho salmon							2				2
		Sockeye salmon	3	2		2	7	6	3	11	1		35
		Trout				6	1	1		4	1	1	14
	Other native	Peamouth								2	2		4
		Threespine stickleback				2	2	12	1	2		1	20
		Sculpin	16	7	26	13	25	25	22	32	38	31	235
	Nonnative	Largemouth bass				1				2			3
		Smallmouth bass	2		1	4		2	2	11	8	16	46
		Sunfish (juveniles)			1							26	27
		Bluegill									1		1
		Pumpkinseed									5	6	11
		Rock bass						1	3	12	9	45	70
		Yellow perch				1			2	2	10	9	24
		Bullhead									1		1

Appendix A-5. Number of fish observed in 2016 along five shoreline transects in the south end of Lake Washington. Length and area surveyed for each transect is given in Table 1.

			Date										
Transect	**Fish group**	**Species**	25-Jan	16-Feb	22-Feb	7-Mar	21-Mar	4-Apr	18-Apr	10-May	23-May	6-Jun	**Total**
Flume	Salmonids	Chinook salmon	170	414	140	190	229	162	160	55	13		1,533
		Trout							1	2	5	2	10
	Other native	Threespine stickleback						5	12	4	2	2	25
		Sculpin			6	2	5	16	36	34	73	30	202
	Nonnative	Largemouth bass					1		2				3
		Smallmouth bass		1	1		4	1	3	4	5	9	28
		Rock bass							1	6	4	10	21
		Sunfish	75	12	11	1	19	48	61	82	86	113	508
		Yellow perch				1		1	4	14	4		24
Cove-sand	Salmonids	Chinook salmon	158	170	42	87	67	90	40	19	9	1	683
		Sockeye salmon	2										2
	Other native	Threespine stickleback						55	22	1			78
		Sculpin						3	5	37	40	30	115
	Nonnative	Smallmouth bass							3	2		1	6
		Sunfish	1				2	1	29	6	20	11	70
		Yellow perch						1	1	10	2	9	23
Cove-cobble	Salmonids	Chinook salmon	33	29	12	35	21	36	15	19	16	1	217
		Coho salmon								1			1
		Trout									1		1
	Other native	Threespine stickleback							10	8	2		20
		Sculpin						2	2	23	15	6	48
	Nonnative	Largemouth bass							1				1
		Smallmouth bass					2					3	5
		Rock bass								3		1	4
		Sunfish							10	8	13	3	34
		Yellow perch				2	2	1	1	5	8	39	58
GC bulkhead	Salmonids	Chinook salmon	19	52	24	4	11	3	5				118
		Trout								1			1
	Other native	Threespine stickleback						4	5		1		10
		Sculpin	2	1	4	21	10	14	11	7	8	6	84
	Nonnative	Bullhead				1	1						2
		Largemouth bass		1		1	2		3				7
		Smallmouth bass	8	4	6	1	7	2	1	1	1		31
		Rock bass						2	19	22	6	15	64
		Sunfish	2	8	2	1	7	26	76	34	51	43	250
		Yellow perch							2	2	5	2	11
GC swim beach	Salmonids	Chinook salmon	136	240	442	281	270	118	166	16	3		1,672
		Trout						7	2	3	2		14
		Sockeye salmon	3	3	2		3	9			1		21
	Other native	Peamouth								1			1
		Threespine stickleback		1			3	28	1		1		34
		Sculpin	7	5	3	8	8	19	5	6	27	2	90
		Yellow perch				1							1
	Nonnative	Largemouth bass							1				1
		Smallmouth bass						4	3	3	3		13
		Rock bass						1	1	2	2		6
		Sunfish		3				4	6	3	21	9	46
		Pumpkinseed					1						1
		Yellow perch					2	1	3	1		2	9

Appendix B-1. Number of fish observed in 2016 along three ELJ transects in the south end of Lake Washington. Transects were conducted along the outside perimeter of each ELJ. ND = no data.

			Date									
Transect	**Fish group**	**Species**	16-Feb	22-Feb	7-Mar	21-Mar	4-Apr	18-Apr	10-May	23-May	6-Jun	**Total**
Woody debris pile A	Salmonids	Chinook salmon	331	144	222	253	94	37	7	1		1,089
		Trout								1		1
	Other native	Threespine stickleback					4	7	5	5	1	22
		Sculpin	1	1	2	7	17	5	12	41	11	97
	Nonnative	Largemouth bass							1		1	2
		Smallmouth bass				1		4	7	7	24	43
		Rock bass			3	3		35	30	25	33	129
		Sunfish	8	6	10	22	48	81	89	64	36	364
		Pumpkinseed			1							1
		Crappie						1				1
		Yellow perch					1	2	14	3	1	21
Woody debris pile B	Salmonids	Chinook salmon	ND	5	25	24	16	5	3			78
		Trout	ND						1	2		3
	Other native	Threespine stickleback	ND			9	1	5		4	1	20
		Sculpin	ND	1		1		4	3	8	4	21
	Nonnative	Largemouth bass	ND								1	1
		Smallmouth bass	ND			1			1	2	3	7
		Rock bass	ND							1	5	6
		Sunfish	ND					3	3	4	8	18
		Bluegill	ND			1						1
		Yellow perch	ND					1	10	3	2	16
Woody debris pile C	Salmonids	Chinook salmon	ND	178	294	327	129	8				936
	Other native	Threespine stickleback	ND				4	5	6	4		19
		Sculpin	ND			2	5	2	10	17	11	47
	Nonnative	Smallmouth bass	ND					1	5		4	10
		Rock bass	ND					3		9	8	20
		Sunfish	ND			2	2	1	11	30	17	63
		Yellow perch	ND					4	16	1	3	24