

Lake Washington Sockeye Smolt Collection: 2017 and 2018 Report

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This report describes the 2017 and 2018 collection of sockeye (*Oncorhynchus nerka*) smolt in lakes Union and Washington as they began their migration to the sea. Since 2004, the goal of this collection is to assess the relative survival of hatchery and natural origin sockeye salmon after one to two years of rearing in Lake Washington as fry to smolt. Sockeye smolt are sampled with a purse seine once per week in late April through May. Hatchery origin sockeye have been marked with unique otolith thermal bands so they can be differentiated from natural origin fish. Other information collected as part of the sampling effort includes smolt length, pathology evaluations, catch rate, and species composition. These data offer insight into annual rearing conditions for sockeye in Lake Washington.

Background

Sockeye salmon were introduced into the Cedar River basin from the Baker River (Skagit basin) and Cultus Lakes (BC) between 1917 and 1945 and naturalized by the 1960s (Kolb 1971). The Baker Lake transplants eventually provided self-sustaining populations in Cedar River and Issaquah Creek (Hendry et al. 1996). Four populations of anadromous sockeye salmon are recognized in the Lake Washington basin. These include a small population of beach spawners near Mercer Island, the tributaries of the Sammamish River (primarily Bear and Cottage Creeks), Issaquah Creek, and the Cedar River (Hendry and Quinn 1997). Small tributaries feeding into Lake Washington and Sammamish also have genetically distinct native population of kokanee, a non-migratory variant of *Oncorhynchus nerka* (Spies et al. 2007).

Today, the Cedar River produces the majority of Lake Washington sockeye salmon relative to other Lake Washington populations. Sockeye production from the Cedar River includes natural and hatchery-origin fish. The purpose of the hatchery program is to mitigate for loss of sockeye salmon spawning habitat above Landsburg Diversion Dam. A fish passage facility at the dam allows most salmonids to access spawning and rearing habitat upstream. However, sockeye are not allowed to pass upstream in order to protect the quality of Seattle's water supply. The Washington Department of Fish and Wildlife (WDFW) and Seattle Public Utilities co-operate the hatchery. WDFW collects brood stock from sockeye returns at a weir at river mile 1.7 of the Cedar River. Seattle Public Utilities' Cedar River hatchery rears the eggs to fry. State and local tribal entities monitor fall spawning adults to estimate escapement. WDFW enumerates spring emergent sockeye fry in the Cedar River using an inclined plane trap or rotary screw trap positioned near the river mouth (Seiler and Kishimoto 1996; Kiyohara 2016).

Beginning in 1992, hatchery sockeye fry were released into the Cedar River. Hatchery releases are categorized according to three temporal groups (early, middle, late). Natural and hatchery-origin sockeye in Lake Washington have no external marks that identify their origin. Hatchery sockeye fry receive a thermally-induced otolith mark (Volk et al 1990) that is retained to adulthood. Thermal marking is applied in different patterns in order to specify spatial and temporal release information. Relative abundance of natural and hatchery-origin sockeye fry is studied at two subsequent points of their life history: smolts leaving the lake and adult spawners returning to the river. The proportions of natural and hatchery-origin sockeye at the fry, smolt, and adult life stages provide a measure of relative survival through the lake and marine environment.

In 2004, WDFW began collection of sockeye smolts from Lake Union and Lake Washington for otolith analyses to identify hatchery or natural spawner origin. A subset of fish were also examined for pathogens at the WDFW Pathology Lab. Annual collections target 1,000 sockeye

smolts during the sockeye smolt outmigration period in April and May. This report describes the 2017-2018 collection of sockeye smolts in lakes Union and Washington as they began their migration to the sea. In addition to sockeye salmon catch, we describe the relative catch of native and non-native fishes in Lake Washington and Lake Union (Eggers et al. 1978).

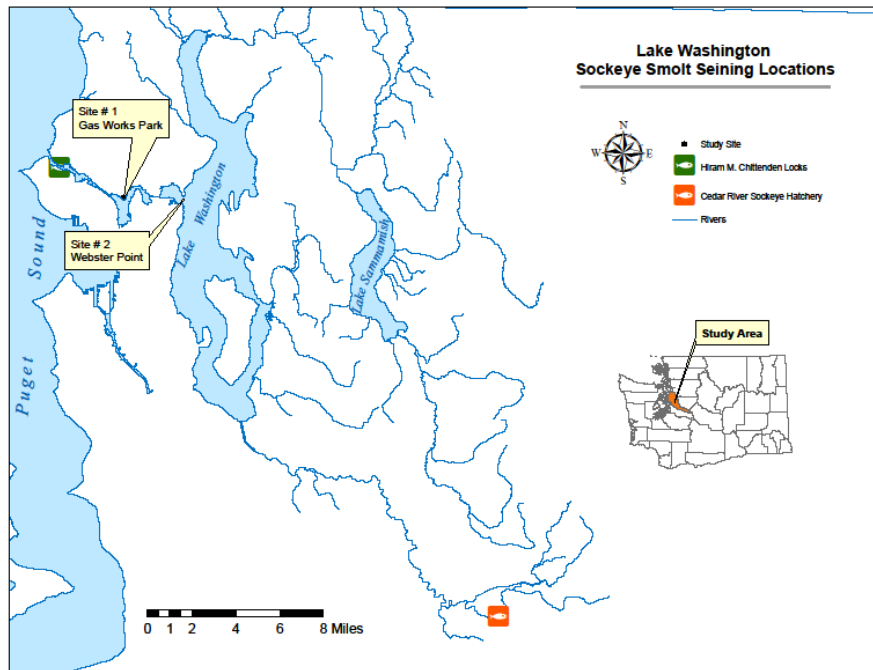


Figure 1. Locations of the sockeye smolt collection sites in the Lake Washington basin.

Methods

Collection

Weekly catches targeted 250 sockeye smolt per week (4-6 weeks) to spread the samples throughout the migration period between late April and May. Fish in excess of the weekly target are released. Sampling from multiple sets and sites is usually needed to reach the target number of sockeye salmon. A seine net was deployed from a 10-m pontoon barge powered by an outboard motor. The skiff pulled the net off the barge in a manner similar to that of commercial purse seine operations for herring. The net is 2 cm mesh diameter, 206 m in length, and 11 m in depth at the center. The net is deployed off the barge with another small skiff, towed for a length of time (~15-60 minutes), and round hauled back to the barge. The bottom of the net is “pursed” and then catches were examined by hand. If initial visual observations indicated a large catch of Chinook salmon, the end of the net was let go and all fish were released. This approach was adopted in order to minimize stress on juvenile Chinook salmon which are listed as threatened under the Endangered Species Act. At the end of each set, fish were removed from the seine net with a large dip nets fitted with bags to retain water for processing fish. Sockeye were euthanized using MS-222 and held in a cooler with ice for transport to the Cedar River Sockeye Hatchery for biological sampling. A subsample of these fish were sent to the WDFW Virology Lab in Olympia for pathology prior to otolith extraction. All fish were sent to Sagilith for otolith extraction and analysis.

Results

Sockeye smolt catch in 2018 was the lowest in the history of the project. Despite a relatively large seining effort of nineteen sets spread across 6 weeks, only 156 sockeye smolts were caught (Table 1). Effort was focused at Webster Point (site 2), except for two sets at Lake Union (site 1). All sockeye were kept for ageing and 94 were held for pathology. Twelve of nineteen sets produced no sockeye. The first two weeks of seining produced only two sockeye and both were two year old fish. No sockeye were found on the last sampling week on May 30th. The majority of sockeye were captured on May 9th and May 23rd (94 and 58 sockeye respectively).

The low sample size precludes statistical power to estimate the proportion hatchery origin sockeye by release site. Nonetheless, the otolith results indicate that only 19.2% (30 of 156), sockeye smolt originated from hatchery production. Of the 30 hatchery-origin fish, one originated from the early release period, 19 were from the middle period, and 10 were late release period.

Table 1. Catch of sockeye and origin by hatchery (HOR) or natural (NOR) in 2018. Site 1 is Gas Works Park and site 2 is Webster Point. Environmental conditions during the set include air and water temperature (aTemp, wTemp, °F), wind speed (mph), atmospheric pressure (ATM, in mm Hg).

Date	Site	Set	Start	End	Time	aTemp.	wTemp.	Wind	Weather	ATM	Sockeye	HOR	NOR
4/25/2018	2	1	10:00	10:40	0:40	53	64	5	Clear	30.13	0		
4/25/2018	2	2	12:10	12:40	0:30	53	68	4	Clear	30.12	2	1	1
5/2/2018	2	1	9:07	9:45	0:38	54	54	5	Clear	30.15	0		
5/2/2018	2	2	10:30	11:05	0:35	54	63	4	Clear	30.15	0		
5/9/2018	2	1	9:05	9:35	0:30	58	58	10	Cloudy	30.05	92	22	70
5/9/2018	2	2	10:07	10:30	0:23	58	58	10	Overcast	30.05	0		
5/9/2018	2	3	11:08	11:30	0:22	57	60	14	Overcast	30.09	0		
5/9/2018	2	4	12:05	12:30	0:25	58	61	12	Overcast	30.05	0		
5/9/2018	1	5	13:15	13:30	0:15	60	66	11	Clear	30.05	2	0	2
5/16/2018	2	1	8:57	9:15	0:18	61	62	5	Cloudy	30.04	0		
5/16/2018	2	2	10:05	10:30	0:25	61	63	2	Cloudy	30.04	2	1	1
5/16/2018	2	3	11:20	12:10	0:50	61	64	8	Cloudy	30.05	0		
5/16/2018	2	4	12:50	13:15	0:25	70	63	5	Clear	30.04	0		
5/23/2018	2	1	9:40	10:10	0:30	67	66	4	Clear	29.82	16	0	
5/23/2018	2	2	11:07	12:00	0:53	67	73	5	Clear	29.80	41	6	35
5/23/2018	2	3	12:37	13:40	1:03	67	77	4	Clear	29.76	1	0	1
5/23/2018	1	4	14:45	15:00	0:15	68	77	2	Clear	29.76	0		
5/30/2018	2	1	9:00	9:50	0:50	64	53	2	Cloudy	30.01	0		
5/30/2018	2	2	10:15	11:20	1:05	65	59	1	Cloudy	30.01	0		
Totals:		19			10:52						156	30	126

In addition to sockeye smolts, a number of other salmonids were captured in 2018: 13 natural-origin Chinook (*Onchorhynchus tshawytscha*), 296 hatchery origin-Chinook, 98 natural-origin coho (*Onchorhynchus kitsutch*), and 150 hatchery-origin coho salmon. One steelhead trout (*Onchorhynchus mykiss*), 11 juvenile cutthroat trout (*Onchorhynchus clarkii clarkii*), and 5 planted

rainbow trout (*Onchorhynchus mykiss*) were caught. All five rainbow trout coincided Bear Creek smolt trap catches of similar sized escapees from the Cottage Lake trout stocking program (Lisi 2019). Of non-salmonids, only 1 perch (*Perca flavescens*) and 2 stickleback (3-spine, *Gasterosteus aculeatus*) were caught (Table 2).

Table 2. Catches of sockeye smolt and incidental species natural (NOR) and hatchery (HOR) origin juvenile Chinook (Chin.), coho, steelhead, cutthroat trout (Juv. Cutt), three spine stickleback (3-spine), yellow perch, and rainbow trout encountered from Lakes Union and Washington in 2018.

Date	Site	Set	Time h:mm	Sockeye	NOR Chin.	HOR Chin.	NOR Coho	HOR Coho	Steel head	Juv. Cutt	3- Spine	Yellow Perch	Rainbow Trout
4/25/2018	2	1	0:40								2		
4/25/2018	2	2	0:30	2		2							
5/2/2018	2	1	0:38										
5/2/2018	2	2	0:35										
5/9/2018	2	1	0:30	92			11	3		2		2	
5/9/2018	2	2	0:23										3
5/9/2018	2	3	0:22										
5/9/2018	2	4	0:25						1				
5/9/2018	1	5	0:15	2			5	1					1
5/16/2018	2	1	0:18			3							1
5/16/2018	2	2	0:25	2						1			
5/16/2018	2	3	0:50		1								
5/16/2018	2	4	0:25										
5/23/2018	2	1	0:30	16	6	232	21	29		2			
5/23/2018	2	2	0:53	41	1	15	43	59		2			
5/23/2018	2	3	1:03	1	5	40	8	3		3			
5/23/2018	1	4	0:15							1			
5/30/2018	2	1	0:50			4	10	55					
5/30/2018	2	2	1:05										
Total		19	10:52	156	13	296	98	150	1	11	2	2	5

In 2017, only 300 sockeye smolt were captured and aged (Table 3). Otoliths were extracted and saved, but not analyzed for origin by the date of this report. Thirteen seine sets were completed over the 4 weeks in 2017 (Table 3). No fish were seen surfacing at the Gas Works locations (site 1), so efforts focused on the Webster Point location (site 2). The second sampling effort on May 10, 2017 produced half of the season's catch. A number of other salmonids were captured: 7 natural-origin Chinook, 4 hatchery origin-Chinook, 446 natural-origin coho, and 451 hatchery-origin coho. On May 17, we captured one adult hatchery chinook and five adult hatchery origin Coho that seem to be residing in Lake Washington. Numerous trout were captured: 4 steelhead trout, 23 juvenile cutthroat, and 1 adult cutthroat trout. One yellow perch and one crappie (*Pomoxis spp.*) were captured, but notably, 3-spine stickleback were absent in the catch (Table 4).

Table 3. Catches of purse seine collections of sockeye smolts from Lakes Washington 2017. Site 2 is Webster Point. Data also include environmental conditions associated with each collection event include air and water temperature (aTemp, wTemp, °F), wind speed (mph) and atmospheric pressure (ATM, in mm Hg).

Date	Site	Set	Start	End	Time	wTemp.	aTemp.	Wind	Weather	ATM	Sockeye
5/3/17	2	1	10:40	11:15	0:35	52.1	57.8	2.9	Overcast	30.2	0
5/3/17	2	2	11:57	12:30	0:33	52.2	61.7	1.2	Overcast	30.1	0
5/10/17	2	1	9:30	10:15	0:45	57.8	58.0	6	Overcast	29.9	0
5/10/17	2	2	10:35	11:15	0:40	58.2	61.0	2	Overcast	29.9	0
5/10/17	2	3	11:45	12:30	0:45	58.3	61.0	2	Overcast	30.0	150
5/17/17	2	1	9:40	10:20	0:40	55.5	53.0	5	Overcast	30.1	0
5/17/17	2	2	10:25	10:45	0:20	55.4	51.0	7	Overcast	30.1	0
5/17/17	2	3	11:17	12:15	0:58	55.2	53.0	5	Overcast	30.2	0
5/24/17	2	1	8:45	9:30	0:45	60.9	51.8	8	Overcast	30.1	92
5/24/17	2	2	10:10	10:55	0:45	62.2	56.0	7	Overcast	30.1	0
5/24/17	2	3	11:30	12:30	1:00	63.1	55.6	6	Overcast	30.1	0
5/24/17	2	4	12:30	13:00	0:30	66.9	62.0	5	Overcast	30.1	23
5/24/17	2	5	13:15	13:45	0:30	63.1	64.0	2	Overcast	30.1	35
Totals:		13			8:46						300

Table 4. Catches of sockeye smolt and incidental species natural (NOR) and hatchery (HOR) origin juvenile Chinook (Chin.), coho, steelhead, cutthroat trout (Juv. Cutt), three spine stickleback (3-spine), yellow perch, and rainbow trout encountered from Lake Washington in 2017. Site 2 location is Webster Point.

Date	Site	Set	Start	End	Time	Sockeye	NOR Chin	HOR Chin	NOR Coho	HOR Coho	Steel head	Juv. Cutt	Adult Cutt	3- Spine	Yellow Perch	Crappie
					h:mm											
05/03/17	2	1	10:40	11:15	0:35											
05/03/17	2	2	11:57	12:30	0:33											1
05/10/17	2	1	9:30	10:15	0:45							2	1			
05/10/17	2	2	10:35	11:15	0:40											
05/10/17	2	3	11:45	12:30	0:45	150										
05/17/17	2	1	9:40	10:20	0:40											
05/17/17	2	2	10:25	10:45	0:20											
05/17/17	2	3	11:17	12:15	0:58			1		5						
05/24/17	2	1	8:45	9:30	0:45	92	2		204	203	4	15				
05/24/17	2	2	10:10	10:55	0:45		1			3		2				
05/24/17	2	3	11:30	12:30	1:00				1						1	
05/24/17	2	4	12:30	13:00	0:30	23			55	55		1				
05/24/17	2	5	13:15	13:45	0:30	35	4	3	186	185		3				
Total		13			8:46	300	7	4	446	451	4	23	1	0	1	1

Discussion

Low sockeye catches in 2018 and 2017 preclude accurate assessment of relative smolt-to-fry survival of hatchery and natural origin stocks, especially by hatchery release time. Fewer sockeye were likely the result of a lower number of fry migrants from hatchery and natural stocks. While purse seining sets were never designed to estimate fish abundance, the seine log can provide an index of relative change in catch. To illustrate, historical catch per unit effort from smolt seining sets were summarized at the annual scale and compared to the natural or hatchery production of fry entering Lake Washington at Cedar River and Bear Creek from the previous year (Table 5, Kiyohara 2016, Lisi 2018). The number of fry entering Lake Washington can explain about 40% of the variation in smolt catch per purse seine set (smolt CPUE = $5 \times 10^{-6} \times \text{Fry} - 24.9$, $R^2 = 0.40$). For smolt years 2017 and 2018, a relatively low number of fry entered Lake Washington a year prior (5.5 and 7.3 million fry, respectively) and likely resulted in a smaller smolt catch.

Sockeye smolt body size can also be an indicator of lake conditions and survival. Age 1 smolt were relatively large in 2017 and 2018, averaging 153 mm (SD = 11 mm) and 149 mm (SD = 10 mm) fork length, respectively (Figure 1). Recent analysis of data 2003-2014 smolt body length suggests that regardless of origin (hatchery or natural) or hatchery release time (early, middle, or late), smolt length is largely determined by an annual rearing conditions in the lake (Hovel et al. 2018). Since 2014, smolt body size was on the larger side of the size distribution (147-170 mm, Figure 2). Current body size is much larger than the early 2000s-2009 (109-134 mm) or historical body length estimates from the late 1960s (127 mm, brood years 1965-69, Eggers 1978). Larger smolt body size suggests that prey of sockeye fry and smolt in Lake Washington were abundant during key periods of juvenile sockeye rearing. Recent analysis shows that during the spring of the smolt year, earlier onset of spring *Daphnia* blooms and higher *Daphnia* density during the year of smolt migration has a positive effect on smolt size (Hovel et al. 2018).

Annual effects on growth could result of several interacting factors such as reduced competition with longfin smelt, other salmonids, or stickleback. The diversity and quantity of non-salmonid species has indeed changed over time. As recently as 2016, three-spine sticklebacks (*Gasterosteus aculeatus*) were the most abundant species in the catch, but their numbers have declined to near zero (Table 6). It's plausible that fewer competitors and fewer sockeye fry entering the lake allow sockeye smolts to reach a larger size.

Table 5. Recent annual effort by total sets, hours and catch per unit effort catch of sockeye smolt from 2010-2018. Catch rates may vary with the number of fry entering Lake Washington.

Smolt year	Fry year	total sets	total hours	Smolt catch	Smolt per set	NOR Cedar fry	NOR Bear fry migrants	HOR Cedar fry	Total Fry
2010	2009	12	8.3	1001	83	1,630,081	327,225	2,783,000	4,740,306
2011	2010	17	14.5	1912	112	12,519,260	129,903	4,543,000	17,192,163
2012	2011	16	13.0	1093	68	4,517,705	8,160,976	8,770,000	21,448,681
2013	2012	8	6.1	1165	146	14,763,509	266,899	4,914,235	19,944,643
2014	2013	13	5.5	2495	192	55,793,120	1,553,602	9,906,509	67,253,231
2015	2014	10	4.2	5618	562	37,975,769	438,534	7,426,928	45,841,231
2016	2015	12	8.0	1093	91	13,878,932	1,590,812	5,027,803	20,497,547
2017	2016	13	8.8	300	27	2,163,843	81,125	3,286,509	5,531,477
2018	2017	19	10.9	156	14	2,530,668	512,651	4,315,000	7,358,319

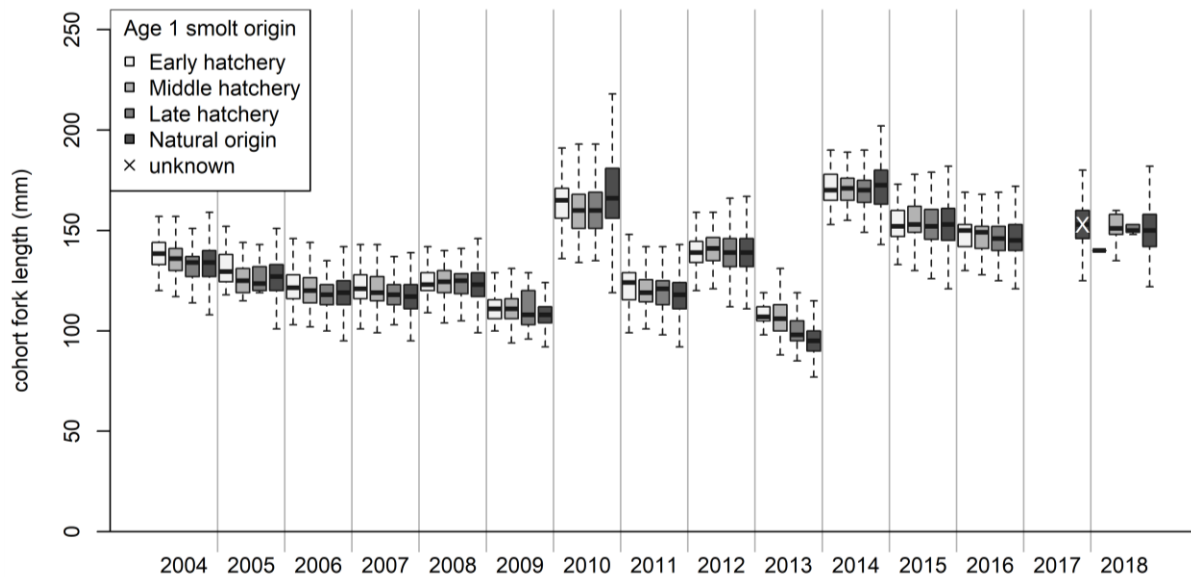


Figure 2: Mean size of sockeye age 1+ salmon smolts during year of seaward migration of wild and hatchery origin for early, middle, and late hatchery release times for years 2004-2016 and 2018. Smolt length and ages are available for 2017, but origin is unknown. Figure updated from Hovel et al. 2018 with permission.

Table 6. Annual effort and catch of salmonids and other fishes from 2010-2018.

Year	First set	Last set	Total sets	Hours	sockeye smolt	NOR Chinook	HOR Chinook	NOR coho	HOR coho	steelhead smolt	juv. cutthroat	adult cutthroat	3-spine stickleback	yellow perch	rainbow trout	pink salmon	chum salmon	peamouth chub	sculpin	pike minnow	smelt	carp	crappie
2010	5/6	5/25	12	8.3	1001	8	496	281	157	0	44	1	157	0	0	2	4	0	0	0	0	0	0
2011	5/10	6/2	17	14.5	1912	18	321	202	771	0	7	7	6125	0	0	0	0	0	0	0	0	0	0
2012	5/8	5/24	16	13.0	1093	76	107	395	249	1	17	1	1199	15	0	0	2	0	8	1	2	0	0
2013	5/1	5/22	8	6.1	1165	16	382	245	42	0	10	4	4140	6	0	0	0	0	13	0	0	0	0
2014	5/1	5/29	13	5.5	2495	77	291	1106	214	0	53	1	25	0	0	4	0	0	0	0	0	0	0
2015	4/22	5/20	10	4.2	5618	20	213	113	97	0	7	1	1265	2	0	0	0	1	0	0	0	1	0
2016	4/20	5/18	12	8.0	1093	38	239	191	349	12	28	5	1198	132	0	0	0	20	0	0	0	0	0
2017	5/10	5/24	13	8.8	300	7	7	446	448	4	23	1	0	1	0	0	0	0	0	0	0	0	1
2018	4/25	5/30	19	10.9	156	13	296	99	150	1	11	0	2	2	5	0	0	0	0	0	0	0	0

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