U.S. Fish and Wildlife Service

Restoration Monitoring of Mapes and Taylor Creeks; Two Nonnatal Lake Washington Tributaries for Juvenile Chinook Salmon

Final Report, 2015—2019

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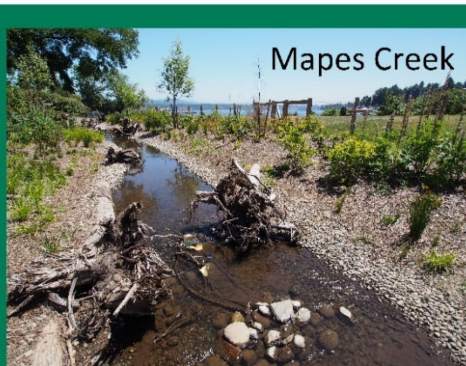

Seattle Public Utilities

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Summary

In 2015 through 2019, the U.S. Fish and Wildlife Service (USFWS) evaluated juvenile Chinook salmon (*Oncorhynchus tshawytscha)* use in two small nonnatal streams (Mapes and Taylor creeks) within the City of Seattle. The lower 130 m (427 ft) of Mapes Creek was daylighted (stream channel was reconfigured from an underground culvert to a more natural stream channel at the surface) in 2014 to provide habitat for juvenile Chinook salmon, and thus the surveys were conducted post-construction. For Taylor Creek, we conducted pre-restoration monitoring of the lower 165 m (541 ft) (downstream of Rainier Ave.). The primary sampling technique for both streams was nighttime visual surveys which included a combination of snorkeling (pools, glides, delta area, and lakeshore reference sites) and surface observations (glides and riffles). In 2015-2017, both streams were sampled twice a month (February to May) with the first survey in late January and the last survey in early June. In 2018 and 2019, surveys were conducted monthly from January to June. Because the riffles in Taylor Creek were mostly too turbulent to observe fish, a subsample of riffles was sampled with electrofishing gear once a month.

On a few occasions, beach seine sampling was conducted to determine if juvenile Chinook salmon move into the stream delta areas following rain events to forage on prey displaced downstream. Each year we also conducted one single-pass electrofishing survey of each study stream section in June to collect some detailed information on the abundance, distribution, and size of other fish species in each stream. To provide further data on pre-project conditions, we also conducted a summer single-pass electrofishing survey of two stream sections in upper Taylor Creek (stream reaches above Rainier Ave) in 2018 and 2019. Previous sampling results of these two stream sections from 2005, 2010, and 2012-2013 were also combined with 2018 and 2019 results to provide a longer-term dataset to be used to compare to post-project monitoring.

Juvenile Chinook salmon were generally common in Mapes Creek from February to April and were found throughout the restored reach. For 2015-2017, peak abundances occurred in early March with an overall peak abundance of 244 fish observed (0.94 fish/m^2) on March 6, 2017. In April and May, the density of juvenile Chinook salmon declined sharply and was

usually lower than a nearby lakeshore reference site. In 2019, juvenile Chinook salmon were not common in Mapes Creek until April and overall numbers were lower than in 2015-2017.

In lower Taylor Creek, juvenile Chinook salmon were predominantly found on the delta or in the L-1 section of our study reach. Only a few were observed in the L-2 and L-3 section. In 2015-2017, a small rock barrier that separated the L-2 and L-3 sections appeared to be a complete barrier to juvenile Chinook salmon as well as a partial barrier to migratory sculpins (*Cottus* spp.). In 2018 and 2019, this rock barrier was no longer present and some juvenile Chinook salmon and large numbers of coastrange sculpin (*C. aleuticus*) were upstream of the barrier location. Most fish collected during June electrofishing surveys were sculpins. Prickly sculpin (*C. asper*) were collected primarily in the slow-water habitats (convergence pool and glides) and coastrange sculpin were collected primarily in riffles. Fish in upper Taylor Creek (stream reaches above Rainier Ave) consisted primarily of cutthroat trout (*O. clarkii*) and in most years they were the only species present. In earlier sampling in 2005 and 2010, juvenile coho salmon (*O. kisutch*) were also present, which were likely from outplanting events because the downstream culvert under Rainier Avenue is an anadromous barrier.

Similar to other nonnatal streams in Lake Washington or Lake Sammamish, the delta area of Taylor Creek appeared to have some valuable habitat for juvenile Chinook salmon. The northwest part of the delta area, where the main streamflow was located, provided preferred habitat conditions (fluvial fan with shallow areas and sand substrates). The northeast and southeast part of the delta area had no streamflow and was primarily composed of coarse gravel and cobbles. The abundance of juvenile Chinook salmon in this part of the delta was generally low and substantially less than along the northwest part where the streamflow was located and sand substrates were present.

Unlike Taylor Creek, few juvenile Chinook salmon were observed on the delta area of Mapes Creek likely because this area did not have preferred habitat conditions. Diet analysis of juvenile Chinook salmon from Taylor Creek delta indicated they preyed primarily on small invertebrates from Lake Washington similar to other lake-dwelling Chinook salmon. Prey from Taylor Creek did not appear to be used extensively except after rain events when Taylor Creek invertebrates were likely displaced downstream.

The number of juvenile Chinook salmon in Mapes Creek from 2015 to 2017 was often greater than that in Taylor Creek even though Taylor Creek is a larger stream and is located over 2 km (1.2 miles) closer to the Cedar River (the natal stream). For example, the total number of juvenile Chinook salmon observed was 1.9 times higher in Mapes Creek than in Taylor Creek in 2015, 2.1 times higher in 2016, and 1.6 times higher in 2017. Additionally, the maximum number observed in Mapes Creek was 244 (0.94 fish/m^2) while it was 157 (0.64 fish/m^2) in the lowest two stream sections (L-1 and L-2) of Taylor Creek. The steeper gradient and possibly the large number of cutthroat trout in Taylor Creek could be limiting the use of Taylor Creek by juvenile Chinook salmon. Based on results from Mapes Creek and other nonnatal streams (Lake Washington basin and other systems), we recommend the gradient in Taylor Creek be less than 2% following restoration construction. Because juvenile Chinook salmon appear to use different habitats as they grow, we recommend the Taylor Creek restoration should aim to create diverse habitat conditions including pools, glides, riffles, overhanging vegetation, and instream woody debris. Additionally, Taylor Creek restoration designs should consider fish passage of small-bodied fishes such as juvenile Chinook salmon and migratory sculpins. In conclusion, results from both streams further support the concept that small nonnatal tributaries play a valuable role in providing nursery habitat for rearing juvenile Chinook salmon, and thus should be a priority to protect and/or restore when possible.

Introduction

Small nonnatal tributaries play a valuable role in providing nursery habitat for rearing juvenile Chinook salmon (*Oncorhynchus tshawytscha*; Murray and Rosenau 1989; Scrivener et al. 1994; Scarnecchia and Roper 2000; Bradford et al. 2001; Daum and Flannery 2011; Tabor et al. 2011b; Gregersen 2019). These small streams provide juvenile Chinook salmon with in-stream habitat as well as shallow, sandy delta areas that offer valuable rearing and refuge habitat. Additionally, nonnatal streams may be a source of prey for lake-dwelling juvenile Chinook salmon, especially during rain events (Tabor et al. 2011b). Nonnatal tributaries used extensively by juvenile Chinook salmon tend to be streams that have a low gradient (i.e., <2%), are small to medium-sized (i.e., < 2 cfs baseline discharge), are close to the natal stream, and have a large delta area (Tabor et al. 2011b).

Identification and restoration of nonnatal streams is particularly important for Puget Sound Chinook salmon because these fish are currently listed as threatened under the Endangered Species Act (ESA; Federal Register 64 FR 14208, March 24, 1999) and often occur in highly altered environments. Land use changes in some areas have significantly reduced access to small, nonnatal streams in the Puget Sound. In prioritizing stream restoration projects, the potential juvenile Chinook salmon use is often an important consideration. Both pre- and post-restoration monitoring are needed to determine project effectiveness.

Puget Sound Chinook salmon are primarily ocean-type Chinook salmon which typically emigrate to the marine environment as subyearlings. During their juvenile freshwater phase of three to five months, juvenile Chinook salmon 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 river and emigrates as parr or smolts (Healey 1991). In some cases, fry may move into a nonnatal system (Murray and Rosenau 1989; Scarnecchia and Roper 2000; Tabor et al. 2011b). Primarily, Chinook salmon from the Lake Washington watershed immigrate to the lake in late January through early June and most migrate through the Lake Washington Ship Canal towards Puget Sound by mid-July (Lisi 2019).

In the Lake Washington system, there are several small, independent tributaries to Lake Washington and Lake Sammamish that do not provide spawning habitat but can be important as juvenile Chinook salmon rearing areas (Tabor et al. 2011b). Two potential south Lake Washington nonnatal tributaries within the City of Seattle are Mapes and Taylor creeks. Both streams are small to medium-sized (< 2 cfs baseline discharge) and are relatively close to the Cedar River (the major Chinook salmon spawning river for this system). In 2014, the lower 130 m (427 ft) of Mapes Creek was daylighted (stream channel was reconfigured from an underground culvert to a more natural stream channel at the surface) to provide stream habitat for juvenile Chinook salmon. The lower reach of Taylor Creek is slated to be restored within the next few years and pre-project evaluation and monitoring has been conducted since 2015.

The objective of this study was to assess the effectiveness of the restoration efforts at Mapes Creek, as well as determine pre-restoration conditions in Taylor Creek to provide both restoration design recommendations and the ability to assess project performance (by comparing pre- to the post-restoration conditions). Our primarily objective was to determine the abundance and distribution of juvenile Chinook salmon in both streams from January to June when they could be present. This was accomplished through nighttime visual surveys (snorkeling and surface observations). Additionally, we collected information on how juvenile Chinook salmon use the delta areas of both creeks. This included beach seining during base flow (no rain) and high (rain) flow conditions to determine if the abundance of juvenile Chinook salmon increases during rain events (Tabor et al. 2011b). We also assessed the diet of juvenile Chinook salmon to determine if lake-dwelling Chinook salmon feed on prey that originated from the two streams, especially during rain events. Lastly, backpack electrofishing surveys of both streams were conducted during the summer low flow period to collect some basic information on the abundance and distribution of other fish species. This included sampling in the upper reaches of Taylor Creek to document pre-project conditions.

Study Site

The two study streams are two small independent tributaries to the southwest part of Lake Washington (Figure 1). This general area is located in the lower Lake Washington watershed which is in the central east part of the Puget Sound region. The watershed has three major Chinook salmon spawning tributaries: Cedar River, Bear Creek, and Issaquah Creek as well as two large lakes, Lake Washington (9,495 ha [23,462 acres]; 33 m [108 ft] mean depth) and Lake Sammamish (1,980 ha [4,893 acres]; 17.7 m [58 ft] mean depth), all of which provide rearing areas for juvenile Chinook salmon. In both lakes, juvenile Chinook salmon commonly inhabit shallow, nearshore areas (i.e., < 1 m [3.3 ft] bottom depth) from January to May (Koehler et al. 2006; Tabor et al. 2011a) and may move into several nonnatal tributaries (Tabor et al. 2011b). Besides naturally-produced fish, juvenile Chinook salmon in this watershed also come from the Issaquah Creek Hatchery, which are typically released in May. In May and June, naturally-produced juvenile Chinook salmon use deeper waters (Tabor et al. 2011a) and together with hatchery-produced juvenile Chinook salmon appear to be widely dispersed throughout Lake Washington before emigrating through the Lake Washington Ship Canal to Puget Sound with a peak emigration in June.

<u>Mapes Creek</u> (mouth, 47.523639°, -122.262678°). -- Mapes Creek is a small tributary (stream length, 2.0 km [1.2 miles]) to Lake Washington and is located in the southeast part of Seattle. The stream's drainage basin is roughly 37 ha (91 acres) and is in a highly urbanized area and the entire lower 900 m (2,952 ft) of the stream was located in a culvert until 2014, when the lower 130 m (427 ft) of the stream was daylighted (Figures 2 and 3). Beside daylighting the stream, the restoration project included substrate and rootwad enhancement, and riparian planting to increase overall habitat productivity for juvenile Chinook salmon. Before 2014, the lower 130 m (426 ft) of stream was located over two meters underground in a culvert. Because of poor light conditions in the deep culvert and the culvert being below their preferred depth, we assumed that juvenile Chinook salmon did not use Mapes Creek. Upstream sections (upstream of the main culvert) of Mapes Creek are generally small with mostly fine, sandy substrates (Tabor et al. 2010). Electrofishing surveys of upper Mapes Creek in 2006, found the only fish species present upstream of the culvert was threespine stickleback (*Gasterosteus aculeatus*) (Tabor et al. 2010).

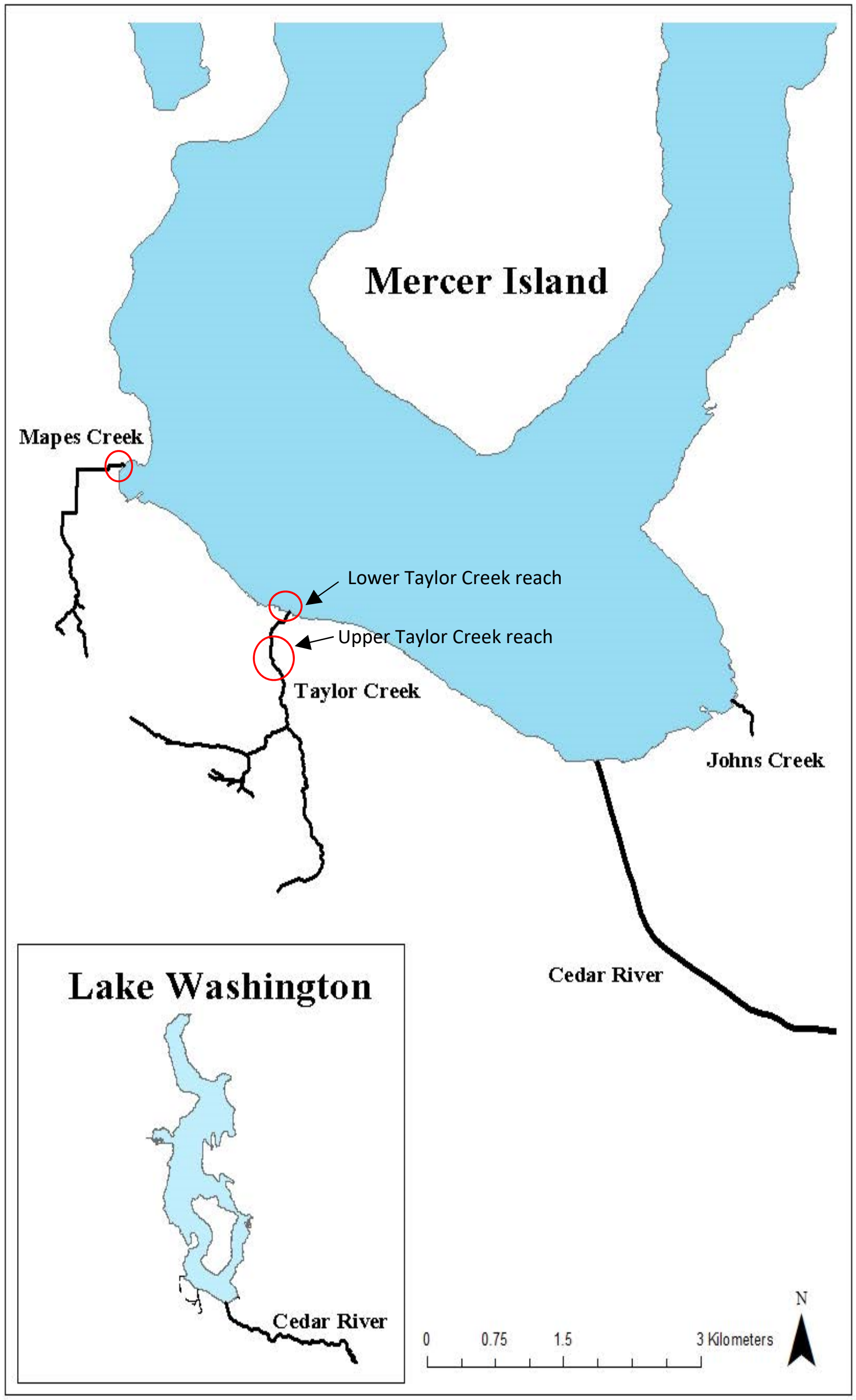

FIGURE 1.- South end of Lake Washington displaying the two study streams (Mapes and Taylor creeks), as well as Johns Creek, another nonnatal stream commonly used by juvenile Chinook salmon. Red ovals indicate the study reaches. The downstream oval on Taylor Creek indicates the primary study reach (lower Taylor Creek) while the upstream oval indicates the additional stream reach (upper Taylor Creek) used only for summer electrofishing surveys. The lower section of the Cedar River (primary Chinook salmon spawning river) is also shown.

FIGURE 2.- Photo of Mapes Creek shortly after the completion of the stream daylighting restoration project. Photo taken 1/21/2015 by Roger Tabor.

FIGURE 3.- Photo of Mapes Creek and established bank vegetation. Photo was taken 5/19/2017 by Roger Tabor. The photo was taken a few meters upstream from where the photo in Figure 2 was taken (note the walking bridge in both photos).

Taylor Creek (mouth, 47.512271°, -122.246217°).-- Taylor Creek is also a small tributary (stream length, 4.3 km [2.7 miles]) to Lake Washington (Figure 4) in the southeast part of the City of Seattle and is located roughly 1.6 km (1 mile) southeast of Mapes Creek (Figure 1). The stream's drainage basin is roughly 250 ha (618 acres). A large restoration project (Taylor Creek Culvert Replacement C399015) is planned for the lower section of the stream. This project will replace a failing culvert under Rainier Avenue S with a fish passable culvert, improve fish passage by removing other barriers, as well as provide improved habitat conditions for juvenile Chinook salmon in the lower channel, mouth, and delta. The Taylor Creek Culvert Replacement project will also maximize floodplain storage in the lower creek and help address storm-related flooding, restore a more balanced sediment transport regime to reduce the rate of coarse sediment deposition at the mouth of the creek, and improve instream and riparian habitat. The culvert under Rainier Avenue is considered an impassable barrier to upstream movement of all fish. Upstream, pools are infrequent and those that are present are usually small and shallow. In the headwaters, the stream splits into two forks (East and West forks). Electrofishing surveys of Taylor Creek in 2006, found a variety of fish species were present downstream of Rainier Ave but only cutthroat trout (*O. clarkii*) and juvenile coho salmon (*O. kisutch*); were present upstream of Rainier Avenue S (Tabor et al. 2010). Because of the impassable barrier under Rainier Avenue, juvenile coho salmon were believed to be from some type of outplanting, such as a school class project.

FIGURE 4.- Photo of the mouth of Taylor Creek and delta habitat with Lake Washington in the background. The concrete slab in the bottom right of the photo is severely undercut and was consistently used by juvenile Chinook salmon. Photo taken 3/23/2017 by Roger Tabor.

Methods

Standard Chinook Salmon Abundance Surveys

From 2015 to 2017, lower Mapes Creek, lower Taylor Creek, and reference sites were surveyed twice per month from late January to early June to determine the abundance of juvenile Chinook salmon. In 2018 and 2019, lower Taylor Creek was surveyed once a month. Lower Mapes Creek was not surveyed in 2018 due to the water quality concerns of snorkeling. However, Mapes Creek was surveyed again in 2019 (once a month) but only consisted of walking surveys with no snorkeling. Visual surveys were conducted at night when juvenile Chinook salmon are relatively inactive and more easily observed and counted. This also allowed us to have minimal impact on juvenile Chinook salmon and limit the need to handle fish. Visual observations in deep water habitats (pools, glides [Taylor Creek only], stream deltas, and lake reference sites) were conducted by a snorkeler who slowly moved upstream and counted fish with the aid of an underwater light. Because shallow areas are difficult to snorkel effectively, we conducted surface observations in these habitats. Observers slowly walked upstream and counted fish with the aid of high-powered lights. The use of surface observations has been shown to be effective for studying juvenile salmonid habitat use in lotic systems where there is little surface turbulence (Heggenes et al. 1990). Fish observed were identified to the lowest possible taxonomic level and counted. Trout were categorized as fry, small, medium, or large based on their size. Based on length frequencies, we thought these four size categories were an approximation of year classes: 0+, 1+, 2+, and 3+. Trout fry were not observed until March and were generally 25 to 40 mm FL in March and April but could be as long as 80 mm FL in June. For small trout, we used the lower size limit of this size class as 60 mm FL in January through April but switched to the lower size limit of 80 mm FL in May and June. We used 130 mm FL as the upper limit of this size class. Medium-sized trout were those 130-200 mm FL and large trout were those > 200 mm FL. We assumed all trout observed during these visual nighttime surveys were cutthroat trout because all trout collected during electrofishing sampling were cutthroat trout. Sculpin (*Cottus* spp.) were split into two categories, small (< 75 mm TL) and large (> 75 mm TL). Other species observed were categorized as juvenile, sub-adult, or adult.

Because riffles in Taylor Creek were steep and difficult to visually count fish, we also sampled three or four short riffle sections (each 2 to 5 m long) once a month (February-May) with electrofishing equipment. Two frame nets were used to allow stunned fish to float downstream into the net with the current. After sampling was completed in each riffle section, captured fish were placed in an anesthetizing bath of MS-222 (tricaine methanesulfonate). Fish collected were identified, counted, and fish lengths were measured (total length for sculpin [TL], fork length for all other fish [FL]).

Before surveys were conducted each year, we divided each stream reach into habitat units (pools, glides, and riffles) based on physical characteristics (Appendices 1-3). The pool created at the stream mouth, caused by backed up water from the lake level, was classified as a convergence pool. Other pools upstream of the convergence pool had a maximum depth ≥ 0.35 m (1.15 ft). Glides or shallow pools were other slow water habitats that had a maximum depth < 0.35 m (1.15 ft). Riffles were areas that had noticeable surface turbulence with increased water velocities. The length of each site was measured along the thalweg. The wetted width was measured at 25%, 50%, and 75% of the length of the habitat unit to obtain an average wetted width. The maximum depth and tailout depth were measured in each pool and glide. Substrate was categorized by visually identifying substrate types and estimating the percentage of each substrate category within each habitat unit. Substrate categories were sand (< 2 mm [0.1 inches]), fine gravel (2-12 mm [0.1-0.5 inches]), coarse gravel (12-64 mm [0.5-2.5 inches]), cobble (64-256 mm [2.5-10 inches]), and boulder (> 256 mm [> 10 inches]). Additional habitat surveys were conducted as needed to document the habitat changes because the lake level rose approximately 0.6 m (2 ft) each year from January to June and because of two high-flow events in 2017 that altered some habitat units. Stream gradient was measured once on May 18, 2017 (Table 1) using a 7.6-m (25 ft) long plastic tube (10-mm inside diameter) filled with water to serve as a leveling device. Readings (vertical drop and distance between ends of plastic tube) were taken along the entire length of each study reach. The method is similar to that described by Walkotten and Bryant (1980).

TABLE 1. - Stream gradient (%) for lower Mapes Creek and three study sections of lower Taylor Creek, May 18, 2017. An overall gradient value is also given for lower Taylor Creek (all three stream sections combined).

Stream Section	Gradient (%)
Mapes	1.04
Taylor	3.25
L-1	2.60
L-2	2.59
L-3	3.46

The stream habitat in lower Taylor Creek was divided into three stream sections (L-1, L-2, and L-3) to help evaluate juvenile Chinook salmon distribution (Figure 5). The L-1 stream section (≈ 45 m long [148 ft]) included the convergence pool and a series of small pools, glides and riffles. Habitat conditions in this section changed as the lake level rose each year. The L-2 stream section (≈ 52 m long [170 ft]) began at the downstream end of a long riffle (≈ 42 m long [138 ft]) and also included a glide (within a culvert) and a plunge pool at the upstream end. The L-3 stream section was approximately 42 m (138 ft) long for 2015 surveys and for the first few 2016 surveys. After April 21, 2016, this section was expanded about 23 m (75 ft) upstream to include additional habitat units.

A small barrier separated the L-2 and L-3 stream sections. In 2015-2017, the barrier consisted of a ≈ 0.24 m (0.79 ft) hydraulic drop over a large boulder that was presumably placed in the stream for some aesthetic reason (Figure 6). In late 2017 or early 2018, this small barrier was substantially reduced because sediments accumulated behind the passable culvert (Figure 5) located 3 m downstream of this barrier. The sediments caused the water level to rise in the plunge pool below the barrier, effectively allowing complete fish passage (Figure 6).

FIGURE 5.- Overhead photo of the lower reach of Taylor Creek displaying the three stream sections (L-1, L-2, and L-3) used to evaluate juvenile Chinook salmon abundance and distribution. The locations of the two delta snorkel transects are also displayed (Delta A was the main delta transect while Delta B was used a lakeshore reference transect). The location of a rock barrier that was a partial barrier to small-bodied fishes is indicated. The downstream end of the L-1 stream section is an area of the stream where habitat conditions changed with lake level. In January-March, this section was mostly a riffle and as the lake level rose in March to June, it progressively became a large convergence pool.

Figure 6.- Before (left side) and after (right side) views of the rock barrier that was a small partial fish barrier (Figure 5) on lower Taylor Creek. In 2018, sediments accumulated upstream of a culvert located immediately downstream of the plunge pool shown in the photos which caused the water level to rise and eliminate the barrier. The yellow line in the upper left photo represents the approximate change in water level from 2006 to 2019. The location of this site is shown in Figure 5. All photos were taken by Roger Tabor.

Besides stream habitats, we surveyed the delta of each creek to determine how extensively they are used by juvenile Chinook salmon. The delta-transect length at Mapes Creek did not vary and was always 11 m long (36 ft) (Figure 7). The delta-transect (Delta-A) length at Taylor Creek varied from 12 to 18 m (39-59 ft) with lake level. Also, we surveyed an additional lakeshore transect to help compare the abundance of juvenile Chinook salmon along the lakeshore with abundances at the delta and in the nonnatal tributary. At Mapes Creek, we also surveyed two nearby boat ramps (total length, 22.4 m [73.5 ft)) at Be'er Sheva Park to serve as a reference site (Figure 7). We chose this site because of its easy access and in earlier surveys, juvenile Chinook salmon appeared to be more abundant at this site than other nearby locations (Tabor et al. 2004). At Taylor Creek, we surveyed the outside area of the delta (Delta-B; length, 26-39.5 m [85-130 ft]) which was not under the influence of streamflow from Taylor Creek (Figure 5). For all the delta and other lakeshore transects, the snorkeler swam parallel to the shore along the 0.4-m (1.3 ft) depth contour. Transect widths were standardized at 2.5 m (8.2 ft). Snorkelers visually estimated the transect width and calibrated their estimation at the beginning of each survey night by viewing a pre-measured staff underwater. Stream and lakeshore temperature were also recorded on each survey night.

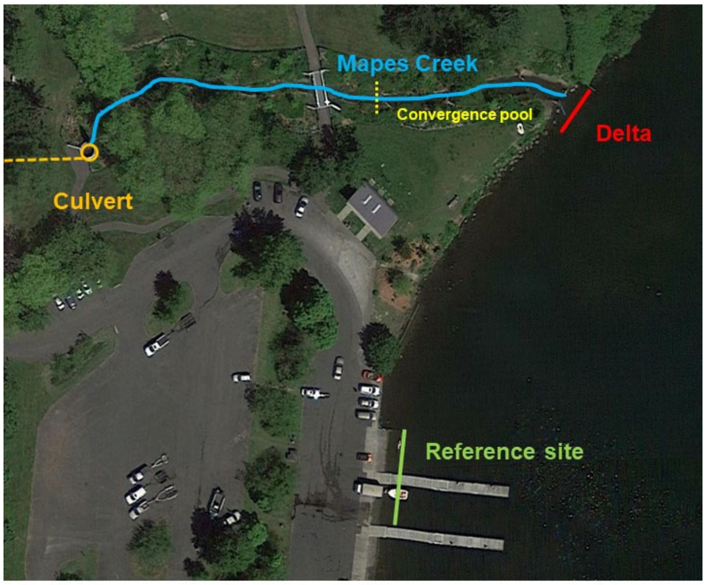

FIGURE 7.- Overhead photo of the lower reach of Mapes Creek in Be'er Sheva Park displaying the stream section used to evaluate juvenile Chinook salmon abundance and distribution. The locations of the delta and reference site transects (Be'er Sheva Park boat ramps) are also displayed. The orange circle is the outlet of the culvert (dotted orange line) that runs under Seward Park Avenue S and S Henderson Street. The approximate upper extent of the convergence pool is shown with a yellow dotted line. The size of the convergence pool varied with lake level; it was not present in January and reached its upper extent in May or June.

Delta Rain Event Surveys

Beach seine sampling was conducted periodically in 2015 through 2017 to determine if juvenile Chinook salmon move (primarily from other lakeshore areas) into the stream delta area following rain events, presumably to forage on prey displaced downstream (Tabor et al. 2011b). Beach seining was conducted shortly after or during a rain event if stream discharge became noticeably higher. We used discharge levels at Kelsey Creek (east Lake Washington tributary; USGS gauge 12120000) and weather forecasts to determine when would be an appropriate time to sample (Table 2). Seining was also repeated several days later, after stream discharge returned to baseline conditions. For each sampling event, 2 to 3 beach seine hauls were conducted at the stream mouth, as well as at a nearby reference site on the lake shore. We used the Be'er Sheva Park boat ramps as the reference site for Mapes Creek and used the outside delta area (Delta B) as the reference site for Taylor Creek. The seine was deployed offshore and set parallel to shore so the stream mouth could be encircled by the seine. The seine was then pulled to shore towards the two corners of the delta habitat unit or lake reference site. We used a small beach seine that was 6-m (20 ft) long and 1.3-m (4.3 ft) deep with a 1.15-m (3.8 ft) deep by 1.3-m (4.3 ft) long bag in the middle (Figure 8). The mesh size in the wings was 8-mm (0.3 inches) stretch mesh while the bag was 4-mm (0.16 inches) stretch mesh. Fish collected in the seine were counted, identified to species, and their length measured.

In 2017, we also collected diet samples to determine if lake-dwelling Chinook salmon use prey that is displaced downstream during rain events. For each date and location, we collected diet samples from a maximum of five Chinook salmon to minimize handling of this ESA-listed fish. These Chinook salmon were anaesthetized with MS-222, the fork length was measured, and their stomach contents were removed through gastric lavage (Figure 8). Stomach contents were put in plastic bags, placed on ice, and froze. In the laboratory, each stomach sample was thawed and examined under a dissecting microscope. Stomach contents were separated into major prey taxa. Aquatic insects and crustaceans were identified to order while other invertebrate prey items were identified to a convenient taxonomic group. Additionally, the order Diptera was divided into Chironomidae and other Diptera because Chironomidae often represents the most important prey group (Koehler et al. 2006; Tabor et al. 2011b). Each prey group was enumerated and then blotted for 10 seconds on a paper towel and weighed to the nearest 0.0001 g. After processing, samples were placed in vials with 70% ethanol and stored for reference.

To describe the diet of juvenile Chinook salmon, we calculated the mean percent by number (MN), mean percent by weight (MW), and frequency of occurrence (%O) for each major prey category (Chipps and Garvey 2007). To help compare the diet of juvenile Chinook salmon between different locations and weather conditions (rain versus no rain), we also calculated Schoener's diet overlap index (Schoener 1971):

$$Cxy = 1 - 0.5\left(\sum \left| p_{xi} - p_{yi} \right|\right)$$

where C_{xy} is the index value, p_{xi} is the proportion of major prey taxa i (MW_i) used by Chinook salmon at site x and p_{yi} is the proportion of major prey taxa i (MW_i) used by Chinook salmon at site y. Diet overlap index values can range from 0 (no overlap) to 1 (complete overlap). Researchers commonly use an overlap index level of 0.6 or less to indicate a significant difference in diet (Zaret and Rand 1971; Johnson 1981). Additionally, a diet breadth index (B; Levins 1968) was calculated to determine if Chinook salmon utilize a wider variety of prey types at the tributary mouths in comparison to the lake shore:

$$B = \frac{1}{\sum p_i^{2}}$$

where p_i is the proportion of the diet represented by food type i. Diet breadth index values can range from 1 (only one prey item in the diet) to infinity.

TABLE 2. Peak discharge levels (cfs) at Kelsey Creek (east Lake Washington tributary; USGS station 12120000, a.k.a. Mercer Creek) that were used to determine when high and low discharge conditions should be present at Taylor and Mapes creeks. Beach seining at the deltas of Taylor and Mapes creeks was conducted on these dates to determine if there was a numerical response by juvenile Chinook salmon to increased discharge levels.

Date	Treatment	Discharge (cfs)
March 15, 2015	Rain (high flow)	313
March 26, 2015	No rain (low flow)	20
March 1, 2016	Rain (high flow)	112
March 4, 2016	No rain (low flow)	22
February 15, 2017	Rain (high flow)	223
February 28, 2017	No rain (low flow)	34
March 7, 2017	Rain (high flow)	81
March 20, 2017	No rain (low flow)	32
March 23, 2017	No rain (low flow)	21
April 5, 2017	Rain (high flow)	69
April 15, 2017	No rain (low flow)	22

FIGURE 8.-- Photographs of the Chinook salmon diet sampling effort. Top photograph: Zachary Moore, Roger Tabor, and Matthew Webster pulling in a seine haul at the mouth of Taylor Creek. Bottom photograph: Zachary Moore lavaging a juvenile Chinook salmon. Both photographs taken on 3/7/2017 by Jennifer Fields, USFWS.

Chinook Salmon Diet - 2018

In 2018, additional diet samples were collected to examine differences in the diet of Chinook salmon between the major areas of Taylor Creek. Of particular interest was whether Chinook salmon at the delta were using prey from Taylor Creek (e.g., mayflies, stoneflies, and caddisflies) or from the lakeshore (e.g., zooplankton). Samples were collected in the stream, delta, and at a lakeshore reference site (Be'er Sheva boat ramp). Diet samples were collected on three occasions: April 5, May 3, and May 14. For each date and at each site, we attempted to collect 10 diet samples. Chinook salmon were collected with either beach seines, electrofishing equipment, or dip netting at night with the aid of hand-held lights. Field and laboratory methods as well as data analyses were the same as for the delta rain event samples (see above).

Summer Electrofishing Surveys

Each year (2015-2109), one complete single-pass electrofishing survey in June was conducted to provide detailed information on fish species presence and distribution in the lower Taylor Creek and lower Mapes Creek study reaches. In 2018 and 2019, additional single-pass electrofishing surveys were conducted in the upper Taylor Creek to provide further data on pre-project conditions (Figures 1 and 9). To increase our sample size for later comparisons, we used two stream sections (U-2 and U-3) in upper Taylor Creek that had been sampled previously as part of other studies (Tabor et al. 2010; King County 2015). The U-2 section is 55-m (180 ft) long and is located between a culvert on 68th Ave S and a culvert on Holyoke Way S. This section was originally sampled in 2005 (Tabor et al. 2010). The U-3 stream section is 150-m (492 ft) long and is located immediately upstream of the culvert on Holyoke Way S. This section was originally sampled once a year during the summer in 2010 and 2012 to 2013 (King County 2015). In 2011, a different stream section (U-1) was sampled as part of the King County surveys (King County 2015). This section is 150-m (492 ft) long and located along the north part or 68th Ave S and included five small bridges (i.e., driveways) over the stream. We also present data from this section to give a more comprehensive review of recent pre-project sampling efforts.

Electrofishing surveys were conducted during the summer low flow period in June or July to minimize the risk of stunning and handling protected Chinook salmon or to coincide with previous sampling efforts. We collected fish with a Smith-Root Model 12® electrofisher system. Electrofishing was conducted with pulsed DC current set at 300 volts. Electrofishing was conducted in an upstream direction with one or more netters following behind or alongside the electrofisher operator to collect stunned fish. In pools and glides, stunned fish were removed from the stream with long handle dip nets. In riffles, one or two frame nets was also used to allow stunned fish to float downstream into the net with the current. Once fish were captured, they were placed in a recovery bucket with an aerator to await processing.

After sampling was completed in each habitat unit, captured fish were placed in an anesthetizing bath of MS-222 (tricaine methanesulfonate). Fish collected were counted, identified, and fish lengths were measured. Fish were identified and measured for fork length (salmonids and threespine stickleback) or total length (TL: nearest mm; sculpin and western brook lamprey [*Lampetra richardsoni*]) and many were weighed (nearest 0.1 g). The percent of fish weighed varied depending on time constraints. Once fish were processed, they were placed in a recovery bucket with an aerator until they were recovered and then they were placed back into the same general area where they were collected. A few unidentifiable small sculpin were retained for identification in the laboratory.

In addition to determining the number of fish caught, we also estimated the total weight of all fish captured. To estimate the weight of fish that were not weighed, we used the following regressions developed from fish from stream monitoring efforts of Taylor Creek and other Puget Sound streams (King County 2015): western brook lamprey, weight (g) = $0.00000342TL^{2.856}$ (r^2 = 0.93; n = 1,282); cutthroat trout, weight (g) = $0.00001601FL^{2.916}$ (r^2 = 0.99; n = 231 [Taylor Creek only]); coho salmon, weight (g) = $0.00001351FL^{2.978}$ (r^2 = 0.96; n = 5,501); threespine stickleback, weight (g) = $0.00000814FL^{3.082}$ (r^2 = 0.96; n = 373); coastrange sculpin *(C. aleuticus)*, weight (g) = $0.00000419TL^{3.241}$ (r^2 = 0.97; n = 6,047); prickly sculpin (*C. asper*), weight (g) = $0.00000632TL^{3.142}$ (r^2 = 0.98; n = 424).

For habitat measurements of lower Mapes Creek, lower Taylor Creek, and the U-2 site in upper Taylor Creek, we used existing habitat data collected from the standard Chinook salmon abundance surveys. Habitat measurements at the U-3 site followed the protocols of WDOE (2009) which were used in 2010 and 2012-2013 surveys (King County 2015).

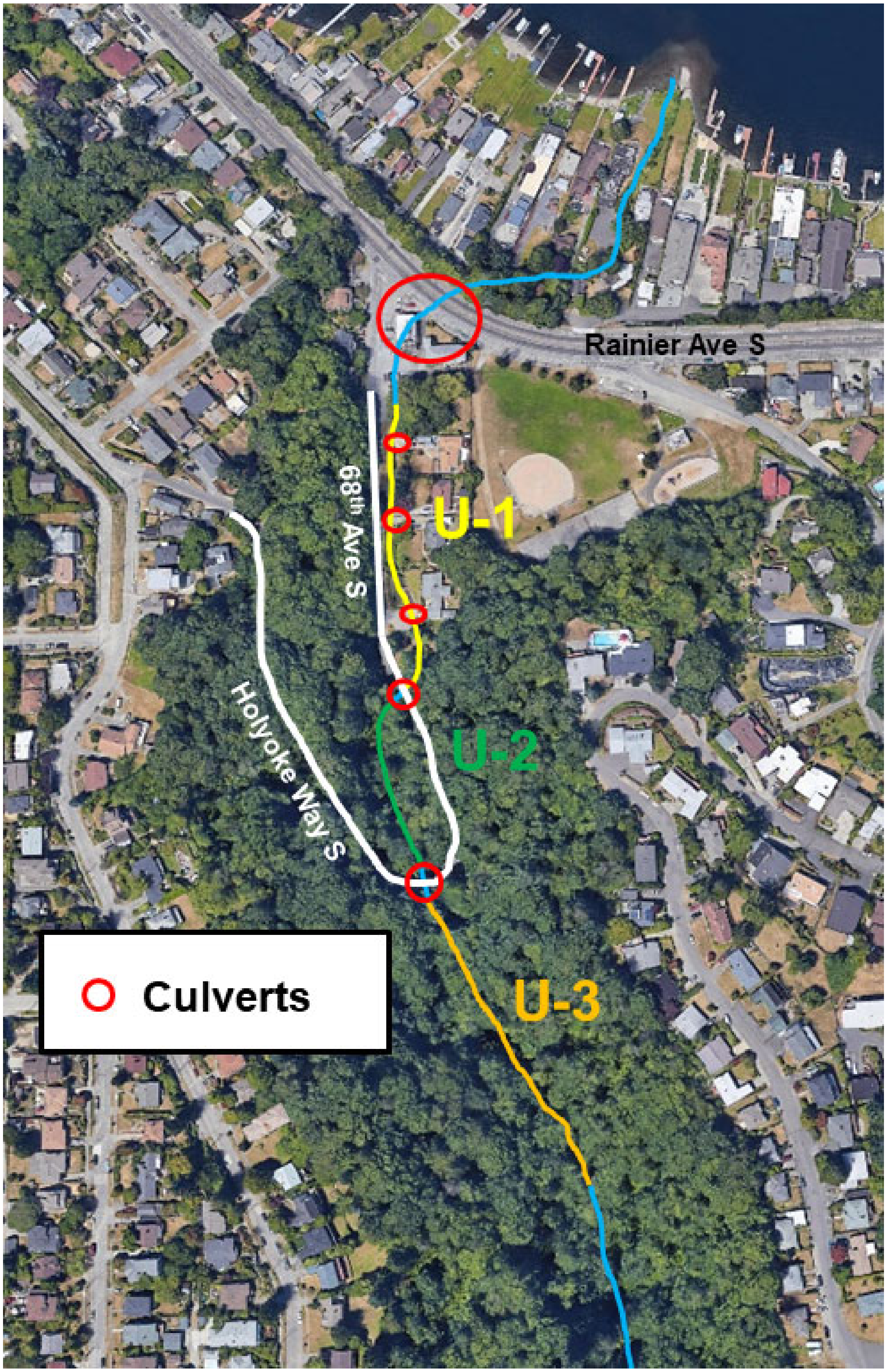

FIGURE 9.- Overhead photo of upper Taylor Creek displaying the three stream sections (U-1, U-2, and U-3) used to evaluate fish distribution.

Results

Standard Chinook Salmon Abundance Surveys

<u>*Mapes Creek.*</u>— For all the Mapes Creek sites from 2015 to 2017 combined, a total of 1,805 juvenile Chinook salmon were observed which included 1,503 in the stream, 46 along the delta transect, and 256 along the Be'er Sheva boat ramp transect (Table 3). In 2019, only the stream was surveyed and a total of 90 juvenile Chinook salmon were observed. The annual pattern of juvenile Chinook salmon use of Mapes Creek was consistent from 2015 to 2017. The abundance increased sharply from January through February with a peak in early March and then declined sharply in April and May (Figure 10; Appendix 4). The peak abundance of 244 fish (0.94 fish/m^2) occurred on March 6, 2017. The peak number of Chinook salmon observed in Mapes Creek increased each year from 70 in 2015 to 244 in 2017 (Table 3). Unlike the 2015-2017 surveys, few Chinook salmon were observed in the February and March 2019 surveys (Figure 10). The 2019 peak count of 57 Chinook salmon occurred on April 24.

During 2015-2017 surveys, juvenile Chinook salmon were well distributed throughout the 130 m (427 ft) restored reach (Figure 11). However in 2019, most of the juvenile Chinook salmon were found in the lower part of the stream in the deep, convergence pool. This likely was because few were present until April when they were larger and primarily used the deeper waters of the convergence pool. Overall, juvenile Chinook salmon were found primarily in glides (range of maximum depths, 0.13 to 0.26 m [0.43-0.85 ft]) in January through March and then shifting to deeper water habitats (i.e., convergence pool [range of annual maximum depths, 0.42 to 0.59 m (1.3-1.9 ft)] and a pool at the upstream end [range of annual maximum depths, 0.41 to 0.5 m (1.3-1.6 ft)] in May. In comparison to the lakeshore reference site (nearby boat ramps), the density of juvenile Chinook salmon in Mapes Creek was generally higher in January through March but in April through June the density was usually higher at the lakeshore reference site. Juvenile Chinook salmon were also observed at the delta of Mapes Creek but their density was almost always lower than the lakeshore reference site at the Be'er Sheva Park boat ramps (Figure 10).

In addition to juvenile Chinook salmon, other salmonids also used the restored reach of Mapes Creek, albeit at lower densities than Chinook salmon (Figure 12). Both cutthroat trout (74% of the other salmonids observed) and coho salmon (26% of the other salmonids observed;

subyearlings and yearlings) were observed in Mapes Creek. For all 34 surveys combined (2015-2017, 2019) in Mapes Creek, we observed 368 cutthroat trout, and 124 coho salmon. Overall, 54% of the total other salmonids were observed in the plunge pool at the upper end of the restored reach. Of those, 79% were cutthroat trout and 21% were coho salmon; however, water visibility conditions in that pool often made it difficult to accurately identify the fish and the relative difference in abundance between the two species may not be accurate. We did conduct one electrofishing survey of the plunge pool on February 28, 2016 to check the species composition and 7 cutthroat trout (range, 72-111 mm [2.8-4.4 inches] FL) and 4 coho salmon (range, 79-109 mm [3.1-4.3 inches] FL) were collected. This ratio was similar to what we typically observed when we snorkeled the plunge pool.

TABLE 3. -- Summary of the total number and peak number of juvenile Chinook salmon observed during standard nighttime abundance surveys in Mapes Creek and Taylor Creek. These surveys were a combination of surface (riffles and glides) and snorkeling observation (pools) surveys. The lakeshore reference sites were the Be'er Sheva boat ramps for Mapes Creek and the Delta-B transect for Taylor Creek. The Delta site for Taylor Creek was the Delta A transect. Mapes Creek was not surveyed in 2018.

	Mapes Creek			Taylor Creek		
Location Year	Number of surveys	Number of Chinook observed	Peak Number of Chinook observed	Number of surveys	Number of Chinook observed	Peak Number of Chinook observed
Stream						
2015	9	193	62	8	92	23
2016	10	380	133	10	168	44
2017	10	930	244	10	590	157
2018	0	- -	- -	4	401	123
2019	5	90	57	5	264	145
Total	34	1,593	244	37	1,515	157
Delta						
2015	9	7	5	8	30	12
2016	10	21	8	10	76	16
2017	10	18	6	10	113	46
2018	0	- -	- -	4	142	81
2019	0	- -	- -	5	24	7
Total	29	46	8	37	385	81
Lakeshore reference						
2015	9	43	18	8	11	7
2016	10	76	18	10	27	7
2017	10	137	47	10	82	19
2018	0	- -	- -	4	27	18
2019	0	- -	- -	5	9	7
Total	29	256	47	37	156	19

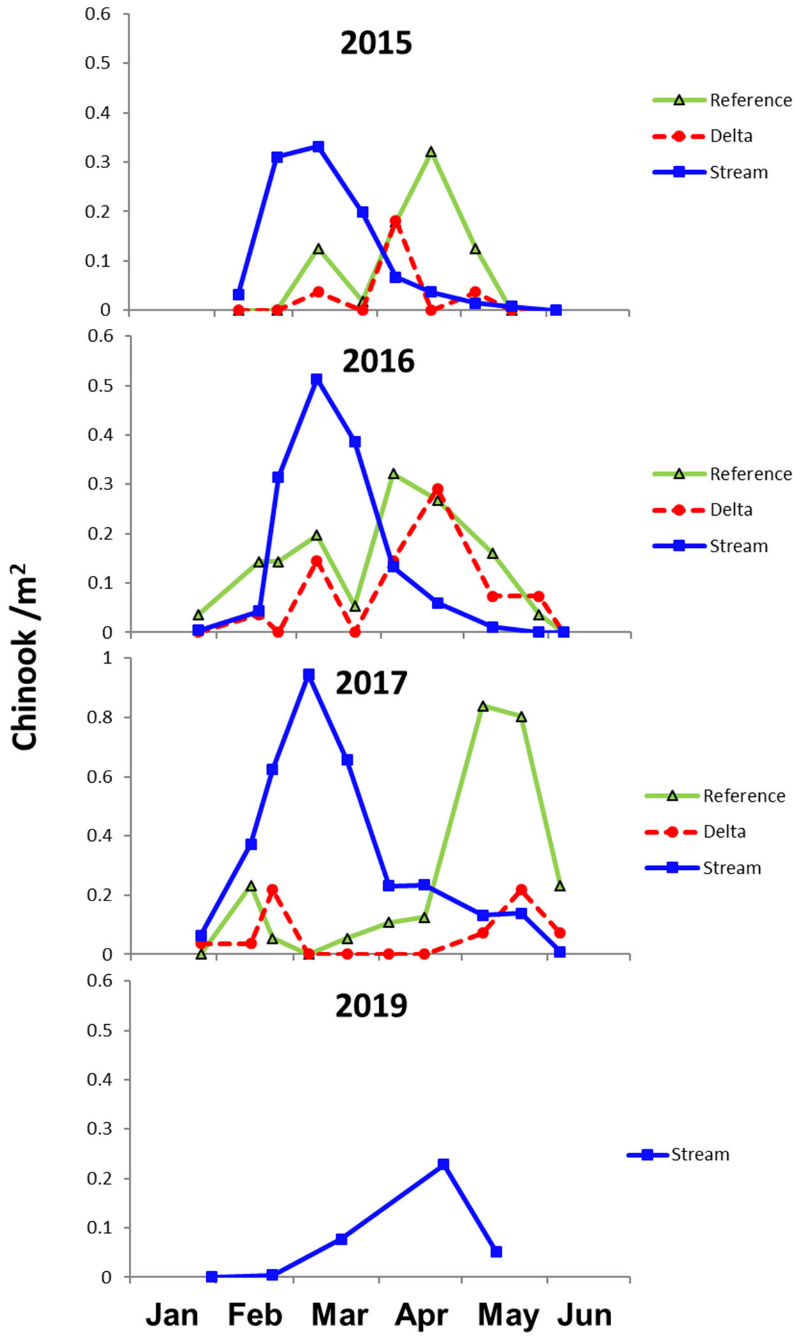

FIGURE 10.-- Juvenile Chinook salmon density (Chinook /m^2) in lower Mapes Creek and along two lake transects: Mapes Creek delta and a lakeshore reference site (Be'er Sheva Park boat ramps), 2015-2017. For the lake transects (reference and delta), surveys were all snorkeling surveys; while for the stream, surveys were a combination of surface (riffles and glides) and snorkeling observations (pools) surveys. Note that the density scale is different for 2017 when fish density was substantially higher.

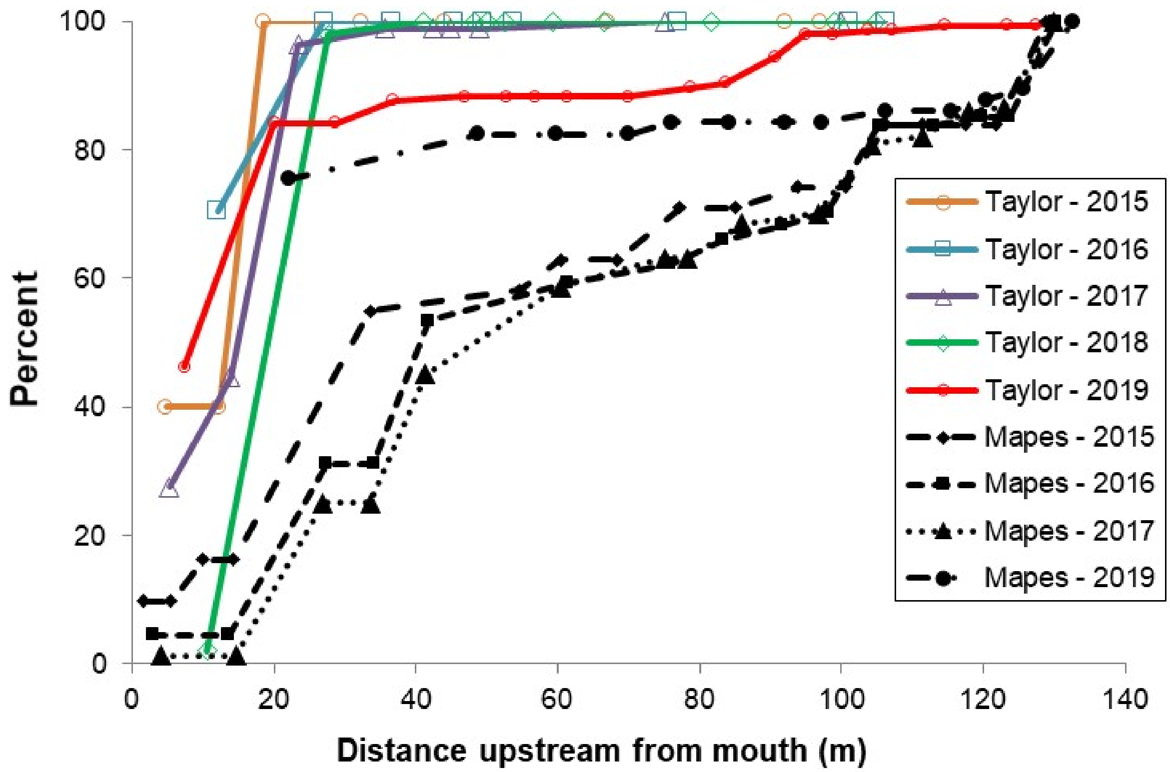

FIGURE 11.—Cumulative percent of the number of juvenile Chinook salmon in lower Mapes Creek (dashed lines and solid symbols) and lower Taylor Creek (colored solid lines and open symbols) from the stream mouth to the upstream end of their distribution. Each data point represents the midpoint of a habitat unit. For each year, data are from the survey date with the highest abundance in the stream (Mapes Creek – 3/10/2015, 3/8/2016, 3/6/2017, and 4/24/2019; Taylor Creek – 3/10/2015, 2/23/2016, 3/20/2017, 2/12/2018, and 4/24/2019).

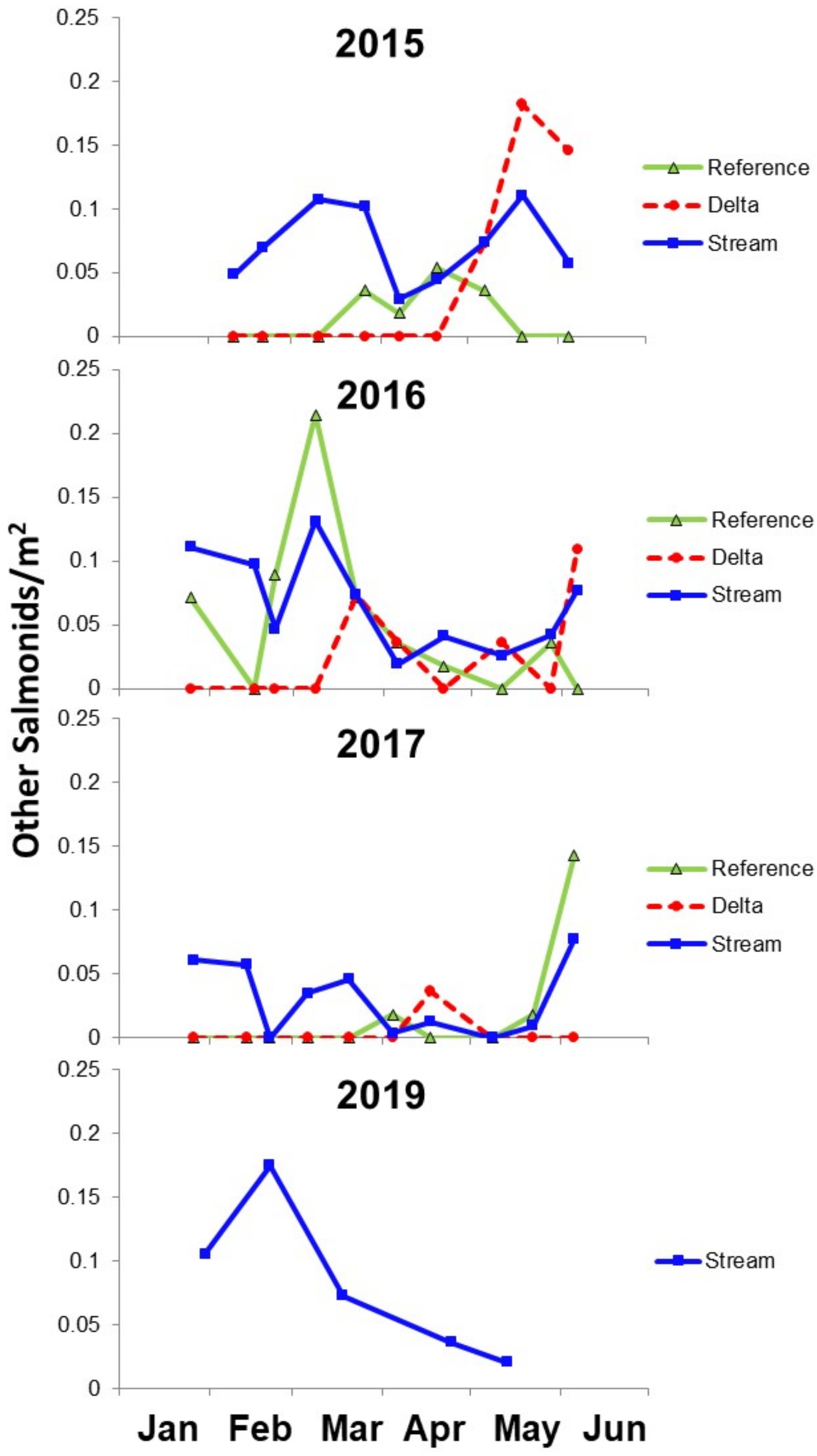

FIGURE 12. -- Density of other salmonids (fish/m^2) observed in lower Mapes Creek and along two lake transects: Mapes Creek delta and a reference site (Be'er Sheva Park boat ramps), 2015-2019. For the lake transects (reference and delta), surveys were all snorkeling surveys; while for the stream, surveys were a combination of surface (riffles and glides) and snorkeling observations (pools) surveys. Other salmonids observed included cutthroat trout and juvenile coho salmon. We assumed all trout observed during these visual nighttime surveys were cutthroat trout because all trout collected during electrofishing sampling were cutthroat trout.

Native, non-salmonids observed in Mapes Creek were primarily sculpins and threespine stickleback although no threespine stickleback were observed in 2017. Additionally, three dace (*Rhinichthys* sp.) were observed in 2015. Nonnative fishes were occasionally observed in Mapes Creek, which included 13 unidentified sunfish (*Lepomis* spp.), 4 juvenile smallmouth bass (*Micropterus dolomieu*), 3 rock bass (*Ambloplites rupestris*), and 1 yellow perch (*Perca flavescens*). Most of these fish were observed in the convergence pool.

Taylor Creek.– For all the Taylor Creek sites, a total of 2,056 juvenile Chinook salmon were observed which included 1,515 in the stream, 385 along the delta (Delta A transect), and 156 along the lakeshore reference site (Delta B transect; Table 3). Similar to Mapes Creek, the annual pattern of juvenile Chinook salmon use of Taylor Creek from 2015 to 2018 was generally consistent from year to year. The abundance increased sharply from January through February, with a peak in February or March, and then declined in April and May (Figure 13 and Appendix 5). In 2019, the annual pattern was different than the previous four years with few juvenile Chinook salmon present until April.

On all survey dates except one, the L-1 section of Taylor Creek had a higher density of juvenile Chinook salmon than in the L-2 section (Figure 13). Unlike Mapes Creek, juvenile Chinook salmon in Taylor Creek were concentrated near the stream mouth (Figures 11 and 14). Similar to Mapes Creek, densities were highest in 2017. Peak densities occurred in either February or March. The overall peak abundance of 157 fish occurred on March 20, 2017. The highest concentration of juvenile Chinook salmon was usually in a pool near the mouth of the stream (Figures 4 and 14). Overall, 51% (38% if the delta is included) of all juvenile Chinook salmon observed in Taylor Creek were observed in this pool. Within this pool, juvenile Chinook salmon were concentrated in the tailout, under a concrete slab on the right bank, or within emergent vegetation on the left bank (Figures 4 and 14).

In 2015-2017 (rock barrier present), no Chinook salmon were found upstream of the barrier between the L-2 and L-3 stream sections. A few juvenile Chinook salmon were observed either immediately downstream of the rock barrier or a few meters farther downstream but never upstream of the rock barrier. In 2018 and 2019 (rock barrier absent), a few Chinook salmon (2 in 2018 and 5 in 2019) were observed in the L-3 stream section. Observations of Chinook salmon in the L-3 stream section were in either late April or May surveys. The farthest upstream a Chinook salmon was observed was 155 m upstream of the confluence with Lake Washington, a few meters downstream from the upper end of the lower Taylor Creek survey reach.

Juvenile Chinook salmon were also commonly observed along the Delta A (main delta area) transect; however, their density at this site varied widely among and within years (Figure 13). Substrate along this transect was a mixture of sand, fine gravel, and coarse gravel. In general, juvenile Chinook salmon appeared to be concentrated in parts of this transect where there was some streamflow and sand was the predominant substrate. Along the Delta B (outside delta area or lakeshore reference) transect, densities were generally low and substantially less than along the Delta A transect. There was little to no streamflow along this transect and the substrate was predominantly coarse gravel and cobbles.

Other salmonids observed in Taylor Creek were primarily cutthroat trout (Figure 15). Coho salmon (Figure 16) were occasionally encountered. On average, 47.8 cutthroat trout were observed on each survey night. For all 37 surveys combined (2015-2019) in Taylor Creek, we observed 1,768 cutthroat trout, and 68 coho salmon. All four size classes of cutthroat trout were commonly observed throughout Taylor Creek. Cutthroat trout fry (0+ fish) were typically observed during the April-June surveys and their abundance varied widely between years. Peak counts ranged from 70 in 2016, 33 in 2019, 10 in 2015, 7 in 2017, and 1 in 2018. Overall, the small size-class (80-130 mm FL [3.1-5.1 inches]) made up 47.8% of the trout observed while the medium and large size-classes made up 27.2% and 8.6%, respectively. In the L-3 stream section, cutthroat trout were by far the most abundant fish, representing 93% of the fish observed. Cutthroat trout densities in the L-3 stream section were consistently higher than in the other two sections (Figure 17). Unlike the L-1 and L-2 stream sections, the L-3 section had several glides and pools and each of these habitats usually had at least one cutthroat trout (mean, 2.95; maximum, 14).

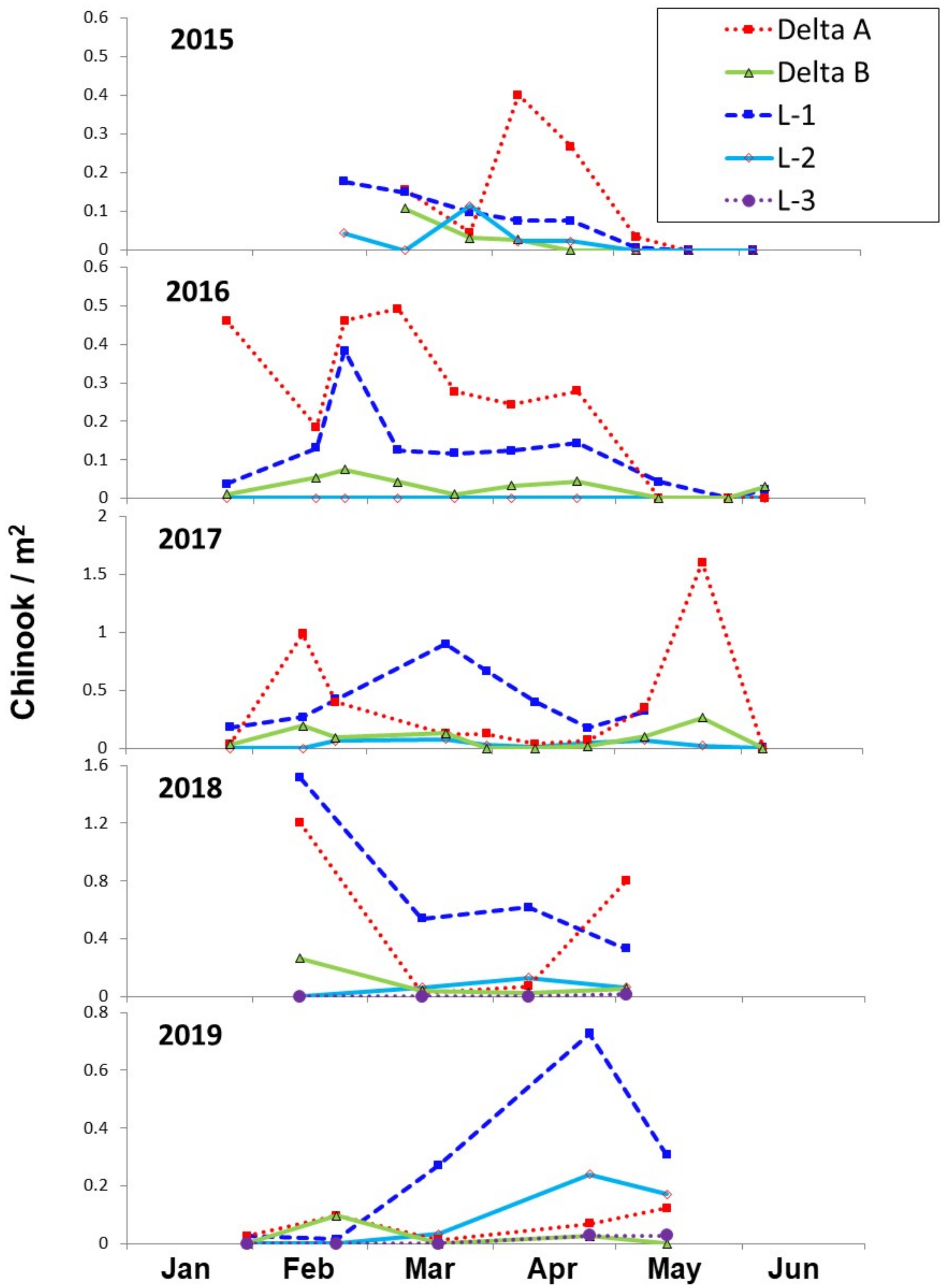

FIGURE 13.-- Juvenile Chinook salmon density (fish /m2) observed in five sections of lower Taylor Creek from 2015-2019. Surveys were a combination of surface (riffles) and snorkeling observations (glides and pools). Juvenile Chinook salmon were only observed in the L-3 stream section in 2018 and 2019. Note that the density scales are different for each year, and fish density was substantially higher in 2017 and 2018. Locations of the different sections are shown in Figure 5.

FIGURE 14. – Juvenile Chinook salmon in the lower section of Taylor Creek. Photo was taken by Roger Tabor during the day (3/23/2017) in the lower stream section near the concrete slab shown in Figure 4.

FIGURE 15. – Photographs of a juvenile (top photo) and an adult (bottom photo) cutthroat trout in lower Taylor Creek. Photos were taken by Roger Tabor during night snorkel surveys (top photo, 5/13/2019; bottom photo, 6/6/2017).

FIGURE 16. - Juvenile **c**oho salmon in the plunge pool at the upstream end of the L-2 section of lower Taylor Creek. Photo taken by Roger Tabor during a night snorkel survey on 6/6/2017.

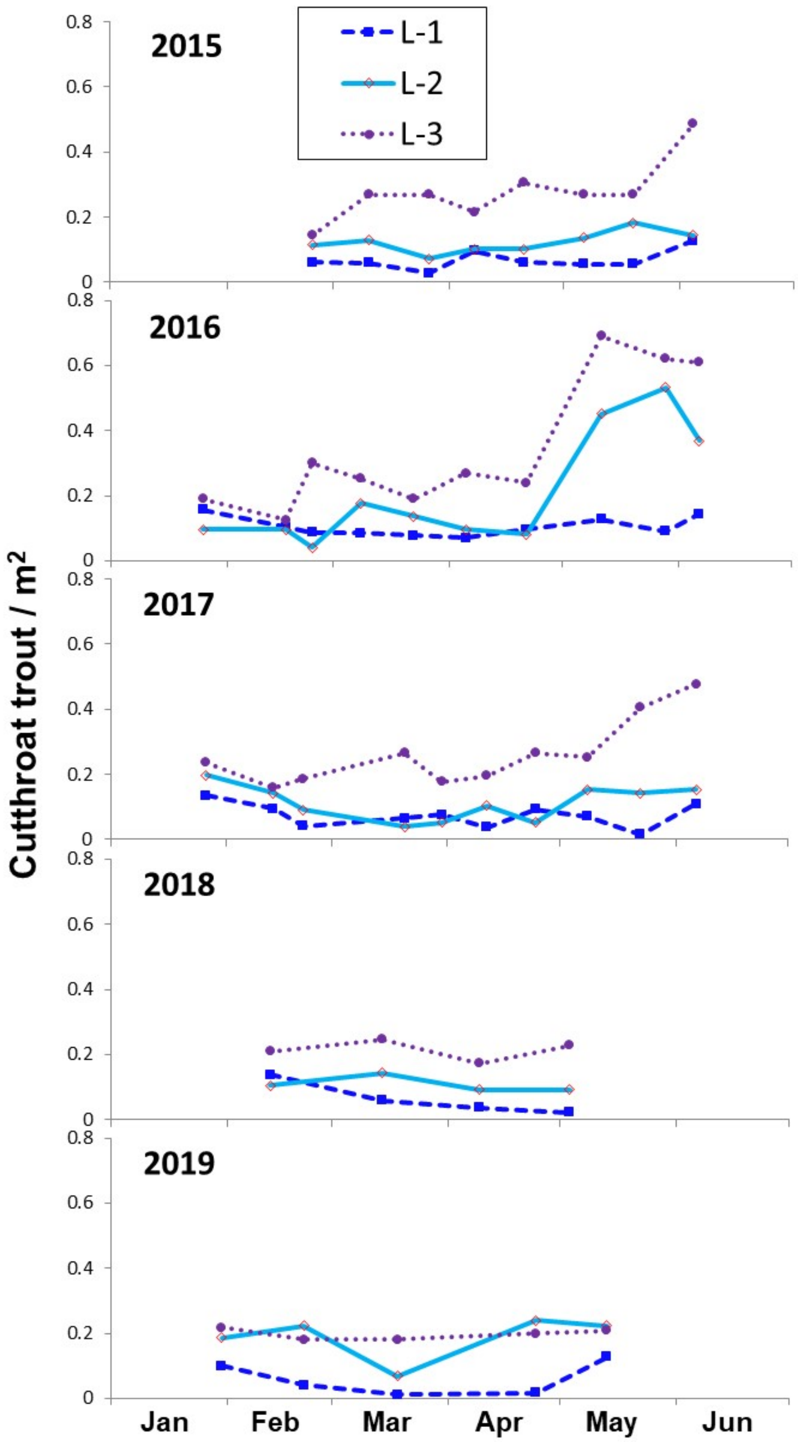

FIGURE 17. -- Cutthroat trout density (fish /m^2) observed in three sections of lower Taylor Creek (2015-2019) during visual nighttime surveys that were a combination of surface (riffles) and snorkeling observations (glides and pools). We assumed all trout observed during these visual nighttime surveys were cutthroat trout because all trout collected during electrofishing sampling were cutthroat trout. Sharp increases in cutthroat trout density in June 2015 and May-June 2016 were due to the increased presence of fry. Few cutthroat trout were observed on the delta transects and those data are not displayed.

Similar to Mapes Creek, native non-salmonid fishes observed in lower Taylor Creek were primarily sculpins (Figure 18) and threespine stickleback (no threespine stickleback were observed in 2017-2019). In 2015-2017 (rock barrier present), only one sculpin was observed upstream of the rock barrier (i.e., in the upper section); whereas in 2018-2019 (rock barrier absent), a total of 26 sculpin were observed upstream of the rock barrier. Adult peamouth (*Mylocheilus caurinus*; $n = 30$) were also observed in lower Taylor Creek (in all three stream sections) and were all observed on May 22, 2017 and presumably were part of a seasonal spawning run from Lake Washington. Nonnative fishes were rarely observed in lower Taylor Creek, which included 1 bluegill (*Lepomis macrochirus*), 1 rock bass, and 4 yellow perch. All of these fish were observed in the L-1 stream section close to the stream mouth.

FIGURE 18. Coastrange sculpin in the plunge pool at the upstream end of the L-2 section of Taylor Creek. Photo taken by Roger Tabor during a night snorkel survey on 6/6/2017.

Riffles in Taylor Creek were sampled with electrofishing equipment on 20 occasions. A total of 19 juvenile Chinook salmon were collected and most were caught in the L-1 stream section (Table 4 and Appendix 6). No Chinook salmon were ever collected upstream of the rock barrier (L-3 stream section). A total of 140 trout were also collected and most were relatively small trout with only 13 fish > 100 mm FL (3.9 inches) (15.5%). Trout ≥ 60 mm FL (2.4 inches) (n = 64) were all identified as cutthroat trout and collected all five months. Trout ≤ 55 mm FL (2.2 inches) (n = 76) were primarily collected in May (75%) and considered 0+ trout fry, which we assumed were all cutthroat trout. The only sculpin species collected in the riffle electrofishing surveys was coastrange sculpin which represented 75% (469 of 628 fish) of all fish collected. In 2015-2017 (rock barrier present), a total of 280 coastrange sculpin were collected downstream of the rock barrier (stream sections L-1 and L-2) and only four (< 2% of total) were collected upstream of the rock barrier (stream section L-3). In 2018 and 2019 combined (rock barrier absent), 138 coastrange sculpin were collected downstream of the old rock barrier location (stream sections L-1 and L-2) and 47 (34% of total) were collected upstream of the old rock barrier location (stream section L-3). Additionally, 2019 was the first year that more coastrange sculpin were collected in stream section L-3 than in either of the other two stream sections (Table 4).

TABLE 4.-- Number of fish collected in three stream sections during riffle electrofishing surveys in lower Taylor Creek, 2015-2019.

		Length	**Number of fish**			
Year	Section	surveyed (m)	Chinook	Cutthroat trout	Trout fry	Coastrange sculpin
2015	L-1	13.5	0	1	4	24
	L-2	15	0	5	1	35
	L-3	24.2	0	4	1	0
2016	L-1	12.4	1	3	14	28
	L-2	25	0	6	2	59
	L-3	37.4	0	6	16	3
2017	L-1	5.7	9	2	0	49
	L-2	30	1	7	2	85
	L-3	36.9	0	10	0	1
2018	L-1	5	5	0	0	16
	L-2	35	0	9	0	82
	L-3	37.7	0	4	0	11
2019	L-1	25	3	1	25	23
	L-2	25	0	4	8	17
	L-3	27.2	0	2	3	36
Totals		**355**	**19**	**64**	**76**	**469**

Delta Rain Event Surveys

Overall, we did not observe a numerical response of juvenile Chinook salmon to increased discharge levels at the deltas of Mapes or Taylor creeks. The number of juvenile Chinook salmon collected in delta beach seine sets following a rain event was higher than during no rain conditions (low flow) in only three of the five sampling periods in Taylor Creek and none in Mapes Creek (Figure 19). Catch rates among all treatments (delta and lakeshore) were highly variable and there was no apparent trend. Other fish species collected at both areas included primarily sockeye salmon (*O. nerka*) fry and sculpin (Table 5).

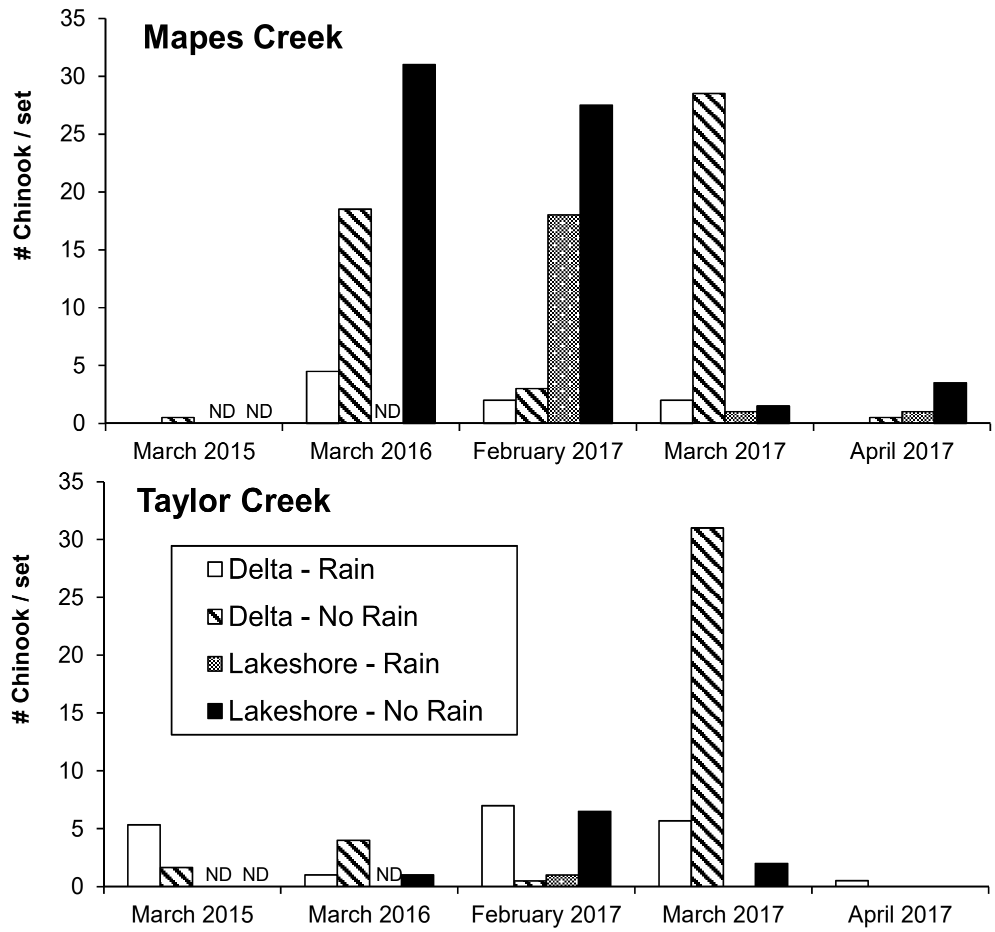

FIGURE 19. -- Number of juvenile Chinook salmon collected per beach seine set during rain event sampling in Mapes and Taylor creeks from 2015-2017. ND = no data. Lakeshore reference sites were the Be'er Sheva boat ramps for Mapes Creek and the Delta B site (southeast part of fluvial fan without any streamflow) for Taylor Creek.

TABLE 5. -- Total number of juvenile Chinook salmon and other fishes captured with beach seine sets in Mapes and Taylor creeks from 2015-2017. Other salmonids include coho salmon and cutthroat trout. Other fish includes brown bullhead (*Ameiurus nebulosus*) and bluegill. Lakeshore reference sites were the Be'er Sheva Park boat ramps for Mapes Creek and the Delta B site (southeast part of fluvial fan without any streamflow) for Taylor Creek.

Stream	Number of fish collected					
Sample type	Chinook	Sockeye fry	Other salmonids	Sculpin	Stickleback	Other fish
Mapes Creek						
Delta - Rain	13	1	1	33	1	1
Delta - No rain	102	5	0	19	4	0
Lakeshore - Rain	48	3	1	0	0	0
Lakeshore - No rain	127	2	0	0	0	0
Total	290	11	2	52	5	1
Taylor Creek						
Delta - Rain	63	3	6	12	0	0
Delta - No rain	101	32	2	7	0	0
Lakeshore - Rain	2	1	0	0	0	0
Lakeshore - No rain	20	32	0	4	0	1
Total	186	68	8	23	0	1

The diet of most juvenile Chinook salmon collected in 2017 consisted largely of chironomids (primarily pupae and emerging adults; Table 6). At Mapes Creek, diet overlap values (*C*) among the delta-rain, lakeshore-rain, and lakeshore-no rain were all > 0.6 thus indicating their diets were relatively similar (Table 7). However, juvenile Chinook salmon from the delta-no rain sample also consumed several amphipods and one relatively large leech in addition to chironomids, which resulted in low diet overlap with other samples ($C < 0.5$) and the diet breadth was higher ($B = 3.6$ while the other samples ranged from 1.1 to 2.4). At Taylor Creek, diet overlap values (*C*) between the delta-rain sample and the no rain samples were 0.18, thus indicating their diets were significantly different (Table 7). Juvenile Chinook salmon had consumed several oligochaetes and ephemeroptera nymphs following the rain event, which represented 64% of the diet by weight and subsequently diet breadth index values (*B*) increased from 1.1 during no rain conditions to 3.4 following the rain event.

TABLE 6.-- Diet composition of juvenile Chinook salmon at the delta of two Lake Washington nonnatal tributaries and two nearby lakeshore reference sites, March-April 2017. Samples were taken shortly after a rain event (high flow conditions in the streams) and when there had not been significant rain in the past 24 h (base flow conditions in the streams). MN = mean percent by number, MW = mean percent by weight, and %O = frequency of occurrence; n = the number of stomach samples that contained prey items.

Stream						
Location	Rain event			No rain event		
Prey category	MN	MW	%O	MN	MW	%O
Mapes Creek						
Delta						
n	4			7		
Insects	78.69	74.20	100.00	30.00	58.47	100.00
Chironomids	67.86	50.15	100.00	25.00	11.25	42.86
Other aquatic insects	8.33	11.21	75.00	5.00	0.05	14.29
Terrestrial insects	2.50	0.47	25.00	0.00	0.00	0.00
Misc. insect parts		12.37	50.00		47.17	71.43
Crustaceans	10.24	3.81	50.00	50.00	15.87	57.14
Annelids	11.07	21.98	75.00	5.00	13.24	14.29
Fish Eggs	0.00	0.00	0.00	15.00	12.42	14.29
Lakeshore						
n	8			7		
Insects	99.25	99.26	100.00	77.84	77.35	100.00
Chironomids	95.78	77.16	87.50	69.57	40.52	100.00
Other aquatic insects	2.54	0.89	25.00	0.65	0.95	14.29
Terrestrial insects	0.93	1.43	25.00	7.62	3.16	42.86
Misc. insect parts		19.78	37.50		32.72	85.71
Crustaceans	0.00	0.00	0.00	22.16	22.65	71.43
Annelids	0.75	0.74	12.50	0.00	0.00	0.00
Taylor Creek						
Delta						
n	7			5		
Insects	49.56	48.28	100.00	98.35	98.12	100.00
Chironomids	27.11	19.28	85.71	93.36	71.87	100.00
Other aquatic insects	20.25	20.75	57.14	0.00	0.00	0.00
Terrestrial insects	2.20	0.28	14.29	4.99	2.90	60.00
Misc. insect parts		7.97	57.14		23.36	80.00
Crustaceans	11.34	5.61	71.43	0.91	0.75	20.00
Annelids	35.74	43.02	71.43	0.00	0.00	0.00
Fish Eggs	2.26	3.09	14.29	0.00	0.00	0.00
Other	1.10	0.01	28.57	0.74	1.13	20.00
Lakeshore						
n	0			5		
Insects				100.00	89.50	100.00
Chironomids				90.00	51.27	80.00
Other aquatic insects				5.00	0.18	20.00
Terrestrial insects				5.00	4.19	40.00
Misc. insect parts					33.86	60.00
Plant Material					10.50	20.00

TABLE 7.-- Diet overlap index values (*C*) of juvenile Chinook salmon between stream deltas and lakeshore sites during different weather conditions, March-April 2017. Samples were taken shortly after a rain event (high flow conditions in the streams) and when there had not been significant rain in the past 24 h (base flow conditions in the streams). Diet overlap index numbers in bold indicate where there was little diet overlap (i.e., significant difference in diet; $C < 0.6$). ND = no data.

1) Mapes Creek

		Delta		Lakeshore	
		No rain	Rain	No rain	Rain
Delta	No rain	------	**0.36**	**0.46**	**0.13**
	Rain		------	0.63	0.62
Lakeshore	No rain			-----	0.60
	Rain				-----

2) Taylor Creek

		Delta		Lakeshore	
		No rain	Rain	No rain	Rain
Delta	No rain	------	**0.18**	0.96	ND
	Rain		------	**0.18**	ND
Lakeshore	No rain			-----	ND
	Rain				-----

Chinook Salmon Diet - 2018

A total of 76 juvenile Chinook salmon were collected in 2018 for diet analysis. We were able to get a good sample ($n \geq 7$) for each location and date except for the May 14 stream sample when we were only able to collect one sample. Similar to the 2017 diet sampling, the overall diet of juvenile Chinook salmon consisted largely of chironomids (primarily pupae and emerging adults; Table 8). The stream samples included more terrestrial insects and other aquatic insects than in the other samples. In contrast, the delta and lakeshore reference sites often included more microcrustaceans (cladocerans and copepods) than the stream site. Overlap index values (C) were all similar for the April 5 sample; however, the stream diet samples had a marginally significant difference (C = 0.5-0.6) from the other two sites for the May 3 and May 14 samples (Table 9). Diet index values (C) between the delta and lakeshore reference index were similar for all three dates. Because the diet consisted largely of chironomids, the diet breadth index values (B) were generally low (Table 10). The stream diet breadth index values (B) for May 3 and May 14 were a somewhat higher due to the variety of terrestrial insects and other aquatic insects in the diet.

TABLE 8.-- Diet composition of juvenile Chinook salmon in the stream area and delta of Taylor Creek and at one lakeshore reference site (Be'er Sheva boat ramps), April-May 2018. MN = mean percent by number, MW = mean percent by weight, and %O = frequency of occurrence; n = the number of stomach samples that contained prey items.

Date	Stream			Delta			Lakeshore		
Prey category	MN	MW	%O	MN	MW	%O	MN	MW	%O
April 5									
n	8			10			10		
Insects	88.80	95.03	100.00	99.25	97.90	100.00	60.83	85.24	100.00
Chironomids	79.84	88.45	100.00	97.21	95.51	100.00	51.16	76.44	100.00
Other aquatic insects	5.50	4.31	37.50	1.63	0.50	40.00	5.75	2.82	40.00
Terrestrial insects	3.46	2.16	25.00	0.40	0.37	10.00	3.92	4.79	30.00
Misc. insect parts		0.11	25.00		1.52	30.00		1.20	10.00
Microcrustaceans	11.00	2.16	25.00	0.00	0.00	0.00	39.17	5.91	80.00
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish Eggs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.20	2.81	50.00	0.75	2.10	60.00	0.00	8.84	60.00
May 3									
n	7			10			10		
Insects	83.62	77.34	100.00	63.30	90.11	100.00	60.71	85.19	100.00
Chironomids	16.30	36.73	100.00	62.80	88.31	100.00	57.03	75.34	100.00
Other aquatic insects	2.08	1.33	71.43	0.10	0.00	10.00	0.46	0.57	40.00
Terrestrial insects	65.24	21.96	85.71	0.41	1.26	50.00	3.22	3.88	80.00
Misc. insect parts		17.32	85.71		0.54	50.00		5.40	90.00
Microcrustaceans	14.47	1.54	71.43	36.21	9.85	100.00	38.06	10.37	90.00
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.69	10.00
Fish Eggs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	1.91	21.11	85.71	0.48	0.05	30.00	0.92	3.75	70.00
May 14									
n	1			10			10		
Insects	100.00	76.55	100.00	64.40	89.50	100.00	55.88	77.11	100.00
Chironomids	61.54	43.72	100.00	59.78	83.75	100.00	50.13	62.62	100.00
Other aquatic insects	23.08	29.01	100.00	0.13	0.01	10.00	0.95	1.99	40.00
Terrestrial insects	15.38	1.63	100.00	4.48	5.48	60.00	4.79	8.72	100.00
Misc. insect parts		2.19	100.00		0.25	40.00		3.78	70.00
Microcrustaceans	0.00	0.00	0.00	33.68	8.47	100.00	42.70	17.29	100.00
Fish	0.00	0.00	0.00	0.14	0.24	10.00	0.25	1.32	10.00
Fish Eggs	0.00	13.31	100.00	0.00	0.00	0.00	0.00	0.02	20.00
Other	0.00	10.14	100.00	1.78	1.80	100.00	1.17	4.26	80.00

TABLE 9.-- Diet overlap index values (*C*) of juvenile Chinook salmon among stream area and delta of Taylor Creek and one lakeshore reference site (Be'er Sheva boat ramps), April-May 2018. All samples were taken under base flow conditions. Diet overlap index numbers in bold indicate where there was little diet overlap (i.e., significant difference in diet; $C < 0.6$).

1) April 5

	Stream	Delta	Lakeshore
Stream	-----	0.91	0.86
Delta		-----	0.86
Lakeshore			-----

2) May 3

	Stream	Delta	Lakeshore
Stream	-----	**0.54**	**0.57**
Delta		-----	0.88
Lakeshore			-----

3) May 14

	Stream	Delta	Lakeshore
Stream	-----	**0.51**	**0.52**
Delta		-----	0.78
Lakeshore			-----

TABLE 10.-- Diet breadth index values (*B*) of juvenile Chinook salmon among stream area and delta of Taylor Creek and one lakeshore reference site (Be'er Sheva boat ramps), April-May 2018. All samples were taken under base flow conditions. Diet breadth index values can range from 1 (only one prey item in the diet) to infinity.

	Date		
Location	April 5	May 3	May 14
Stream	1.23	3.11	2.62
Delta	1.03	1.25	1.36
Lakeshore	1.37	1.50	2.00

Summer Electrofishing Surveys

Mapes Creek.– Salmonids (cutthroat trout, coho salmon, and Chinook salmon) only comprised 5.7% of the catch (Table 11). Cutthroat trout ranged in size from 104 mm to 194 mm FL. Coho salmon consisted of both juveniles (range, 65 mm to 92 mm FL [2.6-3.6 inches]) and smolts (range, 120 mm to 162 mm FL [4.7-6.4 inches]). Juvenile coho salmon were collected primarily in the pool at the upstream end of the study reach while smolts were primarily collected in the convergence pool. Only one juvenile Chinook salmon (120 mm FL [4.7 inches]) was collected during the four surveys.

Of the 618 fish collected in Mapes Creek (all years combined), sculpins made up 82.8% of the fish collected and were present throughout the stream reach (Table 11). Sculpins consisted of coastrange sculpin and prickly sculpin. Overall, coastrange sculpin made up 77.6% of the total number of sculpin collected and prickly sculpin made up 22.4%. Prickly sculpin represented 37.7% of the sculpins in slow-water habitats (convergence pool, other pools, and glides), while they only made up 3.8% of sculpins in riffles. In the convergence pool, prickly sculpin made up 45% of the sculpin but only 9% farther upstream. Although the total number of sculpin collected did not vary considerably from year to year, there was a noticeable reduction of 1+ and older sculpin in 2019 (Figure 20). Additionally, the overall weight of all fish collected per area of 0.49 g/m^2 in 2019 was the lowest level of the four survey years and was substantially lower than the weight collected per area in both study reaches of Taylor Creek (Table 12).

Besides salmonids and sculpins, the only other fish species collected in Mapes Creek during electrofishing surveys was threespine stickleback, which included 57 fry (range, 14-29 mm FL) and 14 adults (range, 57-79 mm FL). The number of threespine stickleback fry collected is likely a large underestimate of the total because the fry were small and thus difficult to see and some may have slipped through the dip net mesh. Also, they may have been less affected by the electrofishing than larger fish.

TABLE 11.-- Number of fish collected in lower Mapes Creek and lower Taylor Creek (L-1, L-2, and L-3 combined) from June single-pass electrofishing surveys, 2015-2019.

Stream Fish group Species	Number collected					
	2015	2016	2017	2018	2019	Total
Mapes						
Salmonids						
Chinook salmon	1	0	0	ND	0	1
Coho salmon - juveniles	6	1	5	ND	6	18
Coho salmon - smolts	1	2	1	ND	0	4
Cutthroat trout - 1+ and older	3	2	6	ND	1	12
Sculpins						
Coastrange sculpin	91	82	102	ND	82	357
Prickly sculpin	44	24	21	ND	14	103
Unidentified sculpin fry (< 30 mm TL)	1	0	48	ND	3	52
Other native species						
Threespine stickleback - fry	12	43	0	ND	3	57
Threespine stickleback - adults	6	7	0	ND	1	14
Taylor						
Salmonids						
Chinook salmon	0	0	0	1	0	1
Coho salmon - juveniles	2	1	7	4	15	29
Coho salmon - smolts	3	2	2	0	7	14
Cutthroat trout - juveniles (0+)	47	159	25	2	77	310
Cutthroat trout - 1+ and older	30	26	40	19	14	129
Sculpins						
Coastrange sculpin	78	38	124	166	82	488
Prickly sculpin	9	9	4	9	0	31
Unidentified sculpin fry (< 30 mm TL)	18	0	41	9	0	68
Other native species						
Threespine stickleback - adults	1	3	0	0	0	4
Western brook lamprey - adults	0	0	0	2	3	5
Nonnative						
Rock bass	1	0	0	0	0	1

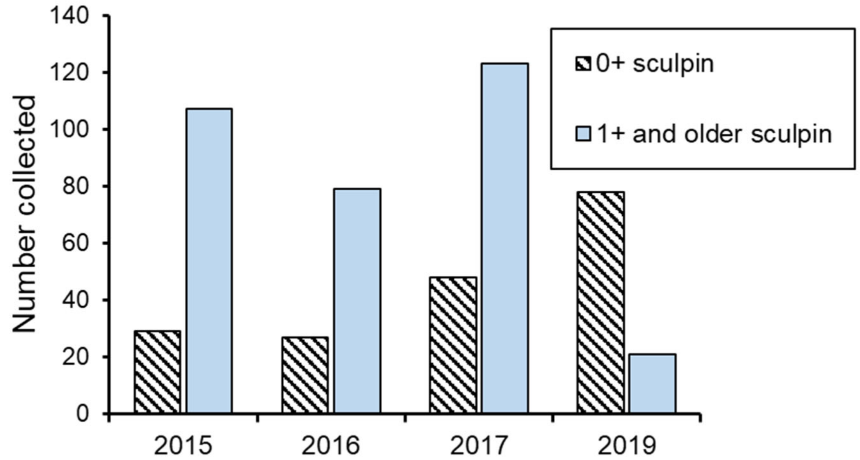

FIGURE 20. – Number of sculpin fry (0+) and larger sculpins collected in lower Mapes Creek during June single-pass electrofishing surveys, 2015-2017, 2019. Based on length frequencies, sculpin species that were < 38 mm TL were considered sculpin fry (0+).

TABLE 12.-- Number and total weight estimates of fish in lower Mapes Creek and Taylor Creek sites from summer single-pass electrofishing surveys. Fish caught in lower Mapes Creek and lower Taylor Creek consisted primarily of salmonids, sculpins, and threespine stickleback; whereas most fish caught in upper Taylor Creek sites were cutthroat trout.

Site	Year	Date	Area (m^2)	Number of fish	Number/m^2	Weight (g)	g/m^2
Lower Mapes Creek							
	2015	June 9	245.6	165	0.67	448	1.82
	2016	June 8	285.3	161	0.56	411	1.44
	2017	June 6	323.5	183	0.57	643	1.99
	2019	June 20	289.8	109	0.38	141	0.49
Lower Taylor Creek (L-1, L-2, and L-3 combined)							
	2015	June 8	159.1	189	1.19	1,564	9.83
	2016	June 8	178.3	238	1.33	1,720	9.65
	2017	June 7	206.2	243	1.18	2,054	9.96
	2018	June 20	203.6	212	1.04	1,358	6.67
	2019	June 18	191.2	198	1.04	1,157	6.05
Upper Taylor Creek - U-1							
	2011	September 1	239.6	105	0.44	1,334	5.57
Upper Taylor Creek - U-2							
	2005	June 30	87.5	60	0.69	391	4.47
	2018	July 18	102.9	24	0.23	434	4.22
	2019	July 18	98.3	14	0.14	224	2.28
Upper Taylor Creek - U-3							
	2010	August 10	496.7	54	0.11	1,136	2.29
	2012	August 23	475.4	121	0.25	2,175	4.57
	2013	July 10	397.8	77	0.19	1,738	4.37
	2018	July 18	388.5	51	0.13	1,210	3.11
	2019	July 18	388.5	109	0.28	1,165	3.00

Lower Taylor Creek.– In lower Taylor Creek, 44.7% of the fish collected were salmonids (439 cutthroat trout, 43 coho salmon, and 1 Chinook salmon). Of the cutthroat trout, 70.6% were ≤ 80 mm FL (3.1 inches) and based on length frequencies, all these fish were likely age 0+ (Figure 21). This size class was particularly abundant in 2016 and 2019 (2016, *n* = 159; range 27-70 mm FL [1.1-2.8 inches]; 2019, *n* = 77; range 26-80 mm FL [1.0-3.1 inches]) and made up 85.9% and 84.6%, respectively of the cutthroat trout caught in those two years. Older cutthroat trout ranged in size from 90 mm to 262 mm FL (3.5-10.3 inches). Seventy-one percent of age 0+ cutthroat trout were collected in riffles while only 11.6% of the older cutthroat trout were collected in riffles. Cutthroat trout lengths were significantly different among habitat types (Kruskal-Wallis test; $P < 0.001$ and Conover-Inman pairwise comparisons) but were not significantly different among stream sections (Kruskal-Wallis test; $P = 0.11$) (Figure 22).

Coho salmon were primarily associated with pools and consisted of both juveniles (range, 60 mm to 97 mm FL [2.4-3.8 inches]) and smolts (range, 111 mm to 224 mm FL [4.4-8.8 inches]). Only one juvenile Chinook salmon (110 mm FL [4.3 inches]) was collected during the five surveys. Overall, salmonids made up 12% (2018) to 79% (2016) of the total number of fish collected; however, they comprised 74% (2018) to 89% (2016) of the fish by weight.

Similar to Mapes Creek, sculpins in Taylor Creek consisted of coastrange sculpin and prickly sculpin. Overall, they made up 54.4% of all fish collected (Table 11). Prickly sculpin only represented 5.9% of all sculpin collected and were only found in the L-1 and L-2 stream sections. They made up 12% of the sculpins in slow-water habitats but none were collected in riffles. In 2015-2017 when the rock barrier was a partial fish barrier, only a few coastrange sculpin (n = 11; 6.8% of total upper section fish catch) were collected upstream of the rock barrier; however, after the rock barrier was absent in 2018 and 2019, large numbers of coastrange sculpin (n = 141; 75.8% of total upper section fish catch) were collected and were present throughout the upper section (Figure 23). In 2015-2017, coastrange sculpin in the L-3 section were longer than those in the other two stream sections while in 2018-2019, there was little difference among three stream sections (Figure 24).

Besides salmonids and sculpins, other fish species collected in Taylor Creek were adult western brook lamprey (*Lampetra richardsoni*) (*n* = 5; range, 140-160 mm TL [5.5-6.2 inches]), adult threespine stickleback (n = 4; range, 73-77 mm FL [2.9-3.0 inches]), and juvenile rock bass (n = 1; 45 mm FL [1.8 inches]).

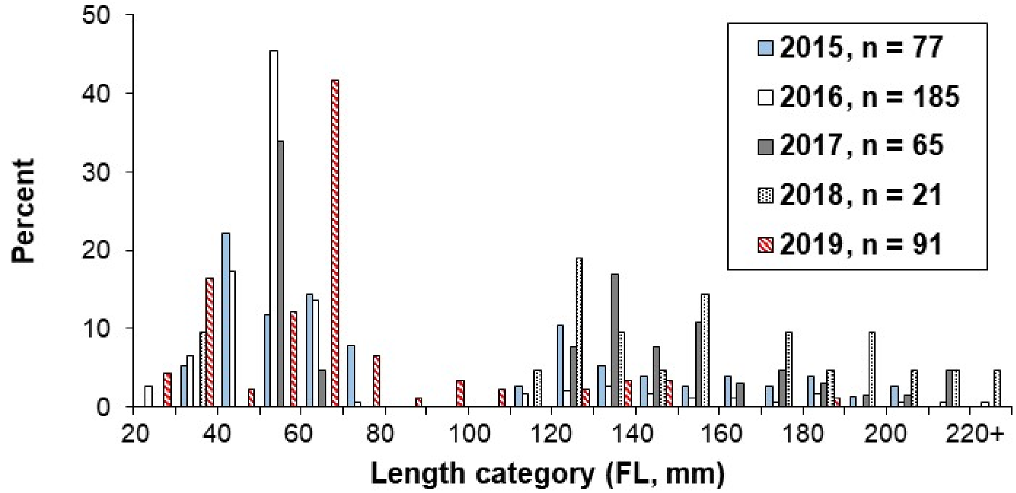

FIGURE 21.-- Yearly length frequencies (10-mm increments) of cutthroat trout in lower Taylor Creek from June single-pass electrofishing surveys, 2015-2019.

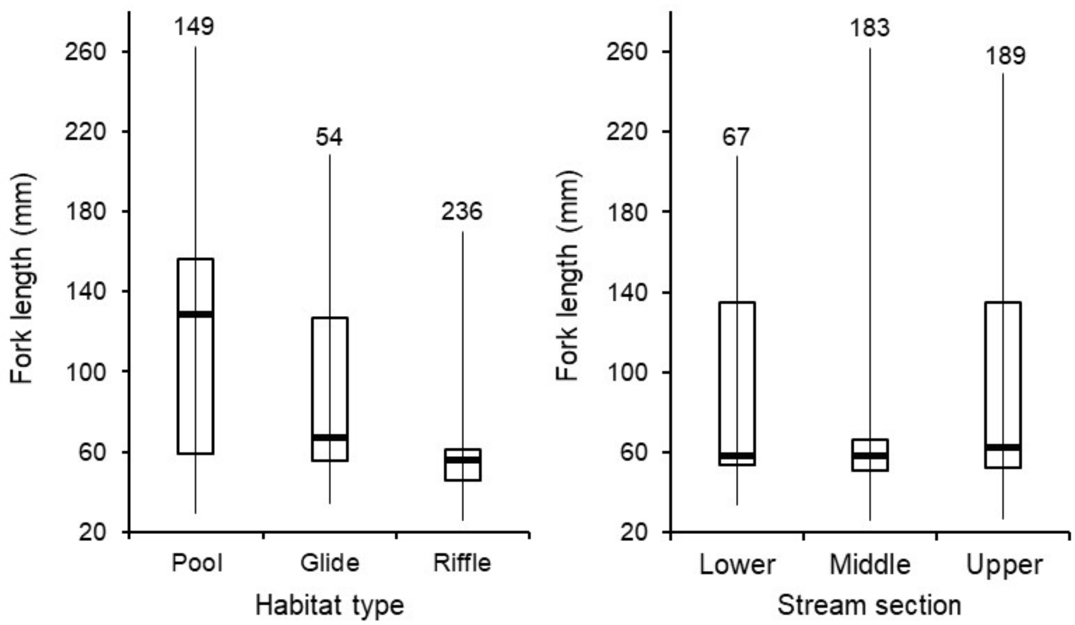

FIGURE 22.-- Fork length box plots (range, 25 and 75% quartiles, and median) of cutthroat trout by habitat type (left panel) and by stream section (right panel) in lower Taylor Creek from June single-pass electrofishing surveys, 2015-2019 combined. The number of fish collected and measured is given above each box plot. Cutthroat trout lengths were significantly different among each habitat type (left panel, Kruskal-Wallis test; $P < 0.001$ and Conover-Inman pairwise comparisons) but were not significantly different among stream sections (right panel, Kruskal-Wallis test; $P = 0.11$).

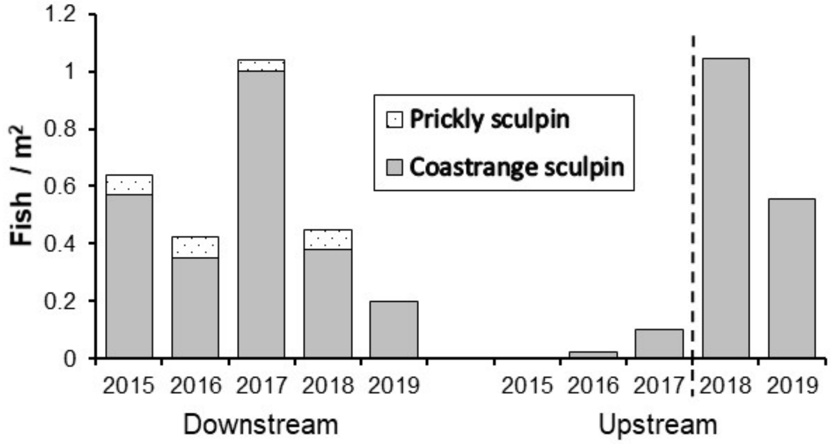

FIGURE 23 -- Abundance (number/m²) of migratory adult sculpin species (coastrange sculpin and prickly sculpin) in lower Taylor Creek in relation to the rock barrier, 2015-2019. Data are from a single-pass electrofishing survey in June. Downstream (L-1 and L-2 stream sections combined) and upstream (L-3) represent study stream sections downstream and upstream of the rock barrier. The dashed vertical lines separates before and after the rock barrier was eliminated.

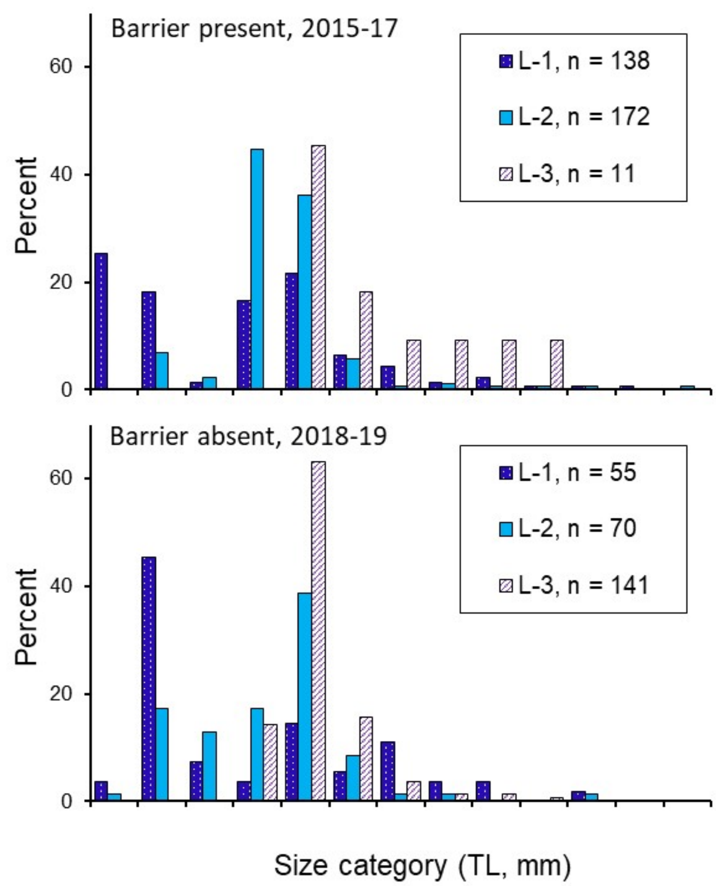

FIGURE 24. -- Length frequencies (10-mm increments) of sculpins collected in three sections of lower Taylor Creek during June single-pass electrofishing surveys, 2015-2017.

<u>Upper Taylor Creek</u>.– Of the 60 fish collected in 2005 at the U-2 stream section, 51 were juvenile coho salmon and 9 were cutthroat trout (Figure 25). In 2018 and 2019, all fish collected at this site were cutthroat trout. There was only one pool in this stream section in 2018 and 2019 and many of the fish were collected in this pool.

For the five years combined, a total of 408 cutthroat trout were collected in the 150-m long U-3 stream section. Of those, 35.3% (144 of 408) appeared to be 0+ trout (< 80 mm FL [3.1 inches]; Figure 26). For three of the five years, the number of 0+ trout collected was less than or equal to 12; however, the number caught was considerably higher in the other two years: 2012 (*n* = 40) and 2019 (*n* = 72). The number of 1+ and older cutthroat trout varied from 39 in 2010 to 82 in 2014.

Besides cutthroat trout, the only other fish species collected was juvenile coho salmon which were only collected in 2010 (*n* = 4; range, 63-91 mm FL [2.5-3.6 inches]). In addition to the fish collected, 2 northwestern salamanders (*Ambystoma gracile*) and 1 Pacific giant salamander (*Dicamptodon tenebrosus*) were collected in the 2019 survey.

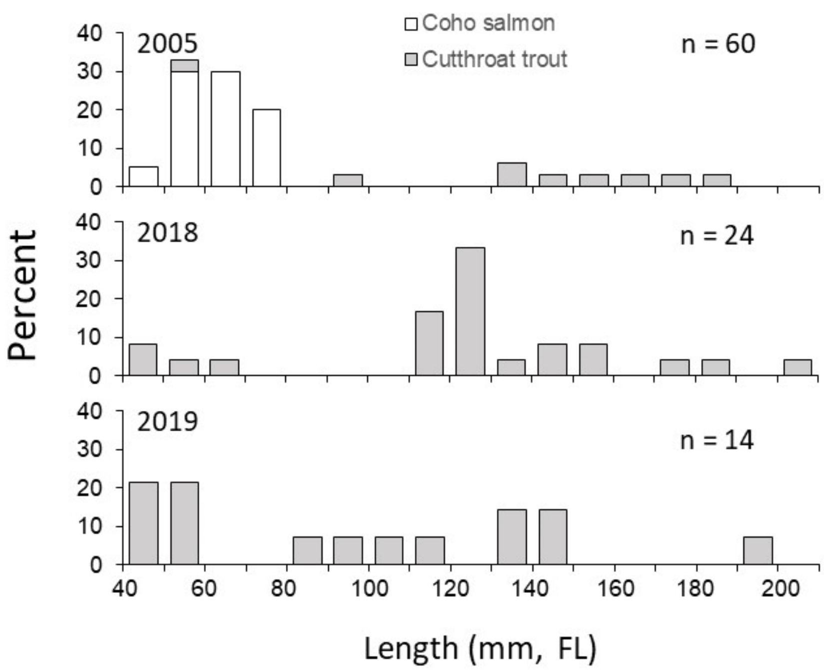

FIGURE 25.-- Yearly length frequencies (10-mm increments) of fish collected in the U-2 stream section in upper Taylor Creek from summer single-pass electrofishing surveys, 2005 and 2018-2019. The total number of fish collected is given for each year.

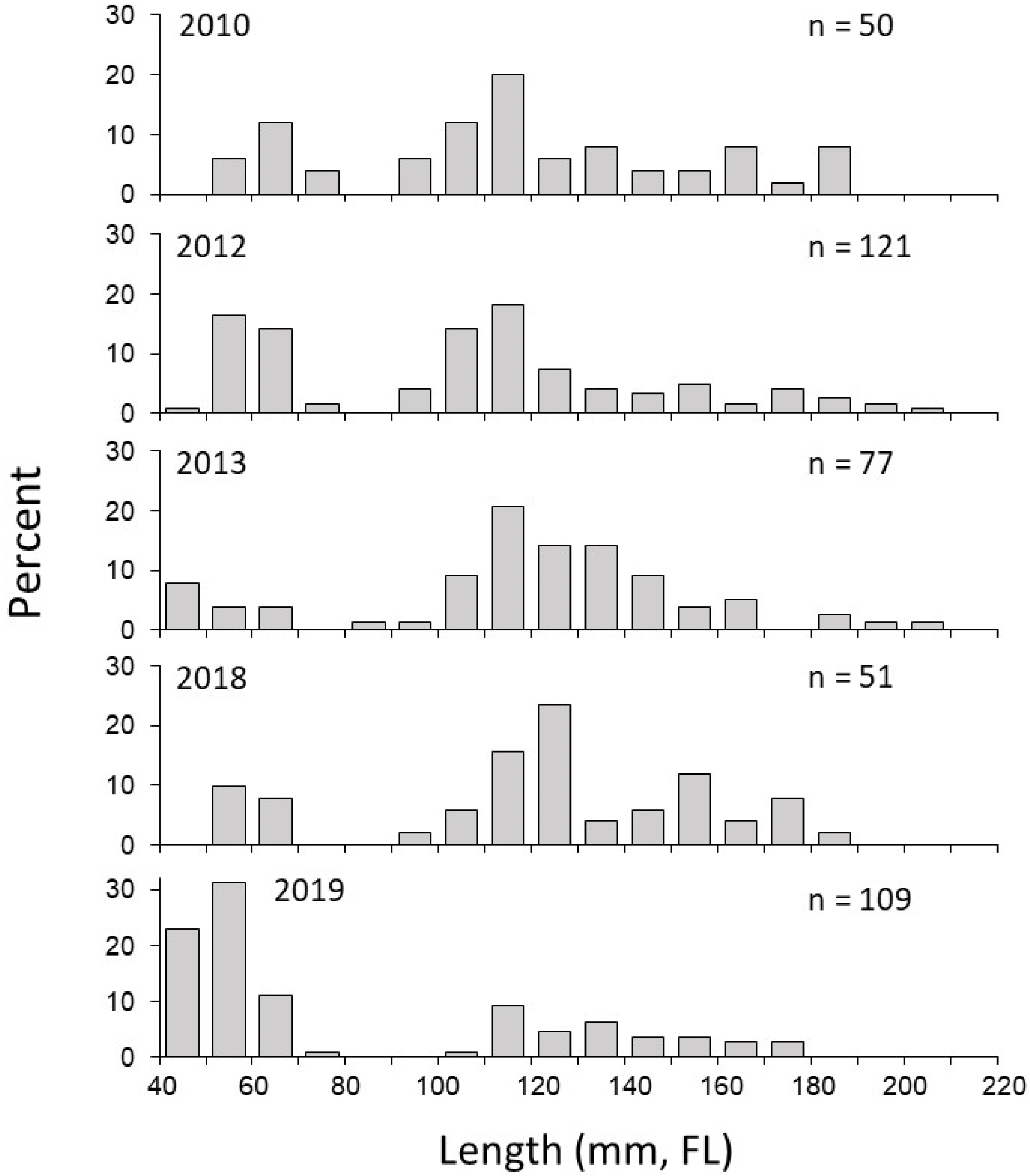

FIGURE 26.-- Yearly length frequencies (10-mm increments) of cutthroat trout in the U-3 stream section in upper Taylor Creek from summer single-pass electrofishing surveys, 2010, 2012-2013 and 2018-2019. The total number of cutthroat trout collected is given for each year.

Discussion

Standard Chinook Salmon Abundance Surveys

Surveys of lower Mapes Creek demonstrated that juvenile Chinook salmon were commonly using the recently-restored stream channel. Results were consistent with surveys of other nonnatal tributaries of Lake Washington and Lake Sammamish (Tabor et al. 2011b). Also, densities of juvenile Chinook salmon in Mapes and Taylor creeks compare favorably with densities observed in nonnatal tributaries from other systems (Table 13). Small, low-gradient streams that are close to the mouth of a natal stream (e.g., Cedar River) appear to be particularly valuable habitat for rearing juvenile Chinook salmon. Restoring Mapes Creek appears to have successfully added this valuable rearing habitat. Taylor Creek is substantially closer to the mouth of the Cedar River than Mapes Creek, and thus improving habitat conditions on the delta and in the lower channel is expected to have a strong positive effect on rearing conditions for juvenile Chinook salmon and should result in higher densities than those observed in Mapes Creek.

TABLE 13.-- Maximum densities (fish/m²) of juvenile Chinook salmon observed in this study (bolded) compared to other nonnatal tributaries. The method used to assess fish density is also displayed. For all sites, the exact distance from the natal site to the nonnatal stream is not known. However for the Cedar River (Lake Washington) nonnatal streams, the distance is at least the distance from the mouth of the Cedar River to the nonnatal stream (1.2 to 4.5 km [0.7-2.8 miles]). Two values are given for Johns Creek, one for the entire stream and the other (in parentheses) excludes the convergence pool, which was a large deep slough that was not used extensively by juvenile Chinook salmon. The Taylor Creek value does not include the upper section because a rock barrier prevented juvenile Chinook salmon from moving farther upstream.

Natal system	Stream name	Maximum density (fish/m^2)	Method	Reference
Lower Fraser River	Brunette	0.22	Multiple-pass electrofishing	Murray and Rosenau 1989
	Nathan	0.68	"	"
	Scott	0.33	"	"
	Squakum	0.14	"	"
	Wade	0.06	"	"
	West	0.13	"	"
	Whonnock	0.06	"	"
Upper Fraser River	Hawks	0.76	Mark-recapture with seining	Scrivener et al. 1994
South Umpqua River	Buckeye	0.01	Day snorkeling	Scarnecchia and Roper 2000
	Boulder	0.02	"	"
	Deadman	0.01	"	"
	Dumont	0.01	"	"
	Francis	0.01	"	"
	Stouts	0.01	"	"
Yukon River	Croucher	0.49	Mark-recapture with electrofishing	Bradford et al. 2001
Cedar River (Lake Washington)	Johns	0.54 (1.18)	Day snorkel/surface observations	Tabor et al. 2011b
	Mapes	**0.94**	Night snorkel/surface observations	this study
	Taylor	**0.64**	"	this study (lower and middle sections)

In lower Mapes Creek, juvenile Chinook salmon were distributed throughout the restored reach while in lower Taylor Creek they were concentrated in the lower section of our study reach and rare farther upstream (Figure 11). A major difference between the two streams is the gradient. We estimated the overall gradient to be about 1% in Mapes Creek and 3% in Taylor Creek for our study reaches (Table 1). Tabor et al. (2011b) also found that the nonnatal tributaries used extensively by juvenile Chinook salmon in the Lake Washington system had a gradient less than 1%. Studies from other systems have also found the nonnatal tributaries used extensively by juvenile Chinook salmon have a low gradient; ranging from <0.25% to 2% (Murray and Rosenau 1989; Scrivener et al. 1994; Bradford et al. 2001). The proposed restoration project for Taylor Creek should attempt to reduce the gradient to < 2%, ideally by adding more sinuosity to the stream. Unfortunately, the City of Seattle property is relatively narrow (approximately 34 m at the widest portion), which does not provide much room to meander the stream. Under current conditions the middle section of the study reach primarily consists of a long riffle (≈ 50 m [164 ft] long) within a single thread channel. Ideally the newly constructed channel will provide some slow-water habitats to the channel downstream of Rainier Avenue, not only to benefit upstream movements of juvenile Chinook salmon, but also to maximize rearing and refuge habitat. Suggested approaches include: adding hydraulic complexity, providing off-channel habitat, and/or splitting the single thread channel into multiple channels.

Another major difference between the two streams was the abundance of cutthroat trout which appeared to be abundant in Taylor Creek, and relatively infrequent in Mapes Creek. Taylor Creek is a larger stream than Mapes Creek and even in its currently degraded condition, the lower reach of Taylor Creek has more pool habitat than lower Mapes Creek (Appendix 3) and thus is able to support several medium-sized and large cutthroat trout (e.g., > 150 mm FL [5.9 inches]). These larger cutthroat trout may affect the distribution of juvenile Chinook salmon through predation risk. In some situations, cutthroat trout can be a predator of juvenile Chinook salmon (Nowak et al. 2004). Additionally, cutthroat trout are often larger than juvenile Chinook salmon and may be dominant over them for space and food. Fish size has been shown to be an important variable affecting foraging and agonistic behavior in salmonids (Abbott et al. 1985; Sabo and Pauley 1997). However, snorkel observations from Taylor Creek and Johns Creek indicate cutthroat trout and juvenile Chinook salmon often occupy different habitats or different areas within the same habitat which may reduce their interactions (R. Tabor, personal observations). The relatively more diverse habitat conditions (pools, glides, riffles, woody debris, overhanging vegetation, etc.) in Taylor Creek likely allowed cutthroat trout and juvenile Chinook salmon to coexist.

Over the first three years of surveys (2015-2017), the Chinook salmon abundance in Mapes Creek increased each year; however in 2019, the abundance was substantially lower than the first three years. It is unclear if this variability was due to differences in the annual abundance of juvenile Chinook salmon in Lake Washington, differences in our sampling protocol, or changes in habitat conditions. The relative annual differences among years in Mapes Creek was generally similar as that observed in Taylor Creek. For example, the abundance of juvenile Chinook salmon in Taylor Creek was highest in 2017 similar to Mapes Creek and in 2019, they were rare in both creeks until April. Thus it is likely that much of the differences among years was due to annual differences in Chinook salmon abundance along the southwest shorelines of Lake Washington. During the first three years, we surveyed twice a month, whereas in 2019 we only surveyed once a month and perhaps we could have more easily missed periods when juvenile Chinook salmon abundance was high. Alternatively, habitat conditions (increased riparian vegetation and prey availability) in Mapes Creek may have progressively improved over the first three survey years and it is possible the stream could have supported larger numbers of juvenile Chinook salmon. Also, the quality of habitat conditions in Mapes Creek may have been reduced in 2019 because large amounts of emergent vegetation (Figure 27) may have reduced the amount of available habitat and increased embeddedness (Figure 28) may have reduced prey availability.

For both streams, the abundance of juvenile Chinook salmon did not appear to be related to the annual number of fry entering the lake from the Cedar River (2015 – 326,901 fry; 2016 – 941,443 fry; 2017 – 151,262; 2018 – 492,574; 2019 – 186,407 (Lisi 2019; P. Lisi, WDFW, unpublished data) (Figure 29). In particular, the lowest abundance of fry entering the lake among our five survey years was in 2017 yet it had one of the highest numbers of Chinook salmon observed in both Mapes and Taylor creeks. In addition to the number of fry entering the lake, there are likely a number of other factors (e.g., lake entry date, direction of stream flow on the Cedar River delta, water temperature and clarity, weather patterns including strong rain events, prey availability, Chinook salmon size, predator abundance) that influence the annual number of Chinook salmon at a particular site in south Lake Washington during their rearing period (January to May). Other than they appear to be more concentrated in areas close to the mouth of the Cedar River (Tabor et al. 2004), little is known on the movement patterns of juvenile Chinook salmon once they enter the lake and the various factors that influence their movement and relative abundance in the lake nearshore area and in nonnatal tributaries.

FIGURE 27. Photos of Mapes Creek (looking upstream) and the pedestrian bridge to show the changes in riparian vegetation from 2015 to 2019.

FIGURE 28. Photos of the substrate in Mapes Creek including inserts to show close-ups of cobbles. Both photos were taken in approximately the same location (note the rootwad in the top center part of the photos). Red arrows highlight the change in embeddedness. Conditions during October 2019 appeared to be similar to June 2019 (no photo available) when we our fish collections were undertaken.

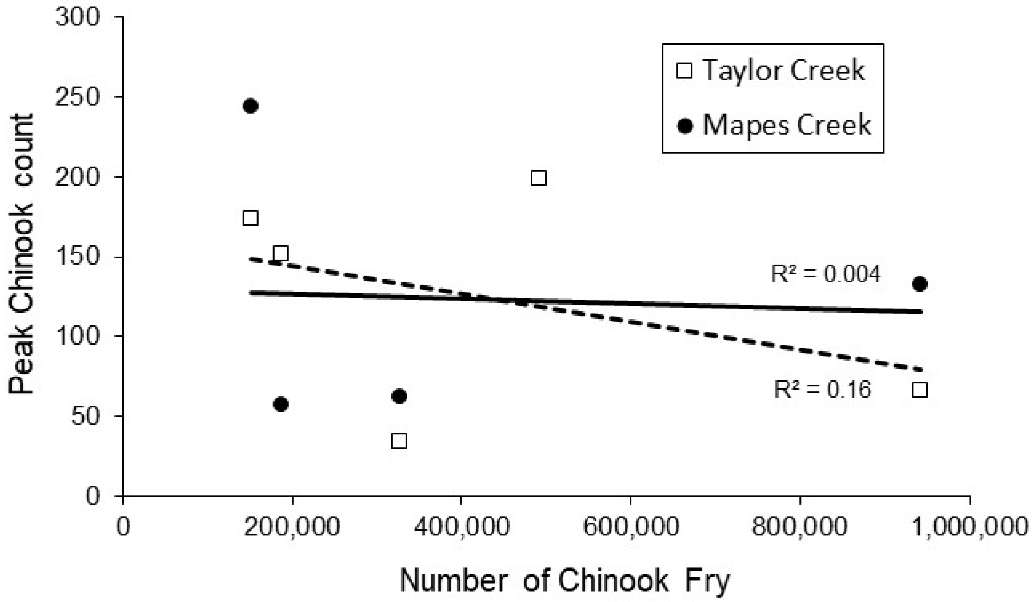

FIGURE 29.—Relationship between the annual number of Chinook salmon fry entering Lake Washington from the Cedar River and the annual peak snorkel count of juvenile Chinook salmon in two nonnatal streams (Mapes and Taylor creeks), 2015-2019. The dashed regression line is for Taylor Creek and the solid regression line is for Mapes Creek.

For 2015-2017, the numbers of juvenile Chinook salmon in Mapes Creek declined sharply in April while the numbers concurrently increased at the nearby lakeshore reference site (Be'er Sheva Park boat ramps). In Mapes Creek, some of this is likely because the requirements of juvenile Chinook salmon for space and food increase as they grow (Chapman 1966) and there should be some level of self-thinning due to intense competition (Elliot 1993; Dunham and Vinyard 1997). Additionally, habitat conditions in Mapes Creek may not support larger juvenile Chinook salmon because there are few pools (Appendix 3). In Johns Creek (another nonnatal tributary in Lake Washington) in late March and April, juvenile Chinook salmon shifted from inhabiting shallow-water habitat (glides) to using deeper-water habitats (pools) (Tabor et al. 2011b). In contrast to Mapes Creek, juvenile Chinook salmon at the lakeshore reference site were able to progressively move to deeper waters as they grow (Tabor et al. 2011a). The restoration project in Mapes Creek included the placement of several rootwads to provide cover and create scour pools. Over time, habitat conditions for larger Chinook salmon may improve if scour pools are created. If not, resource managers should consider exploring options for increasing the number of pools.

In contrast to Taylor Creek, few juvenile Chinook salmon were observed on the delta area of Mapes Creek in comparison to a nearby shoreline transect or in the stream. Delta habitat conditions are markedly different between the two streams. At Taylor Creek, part of the delta area (roughly 25%) has gentle slopes with fine, clean sand substrates that are preferred by juvenile Chinook salmon (Tabor et al. 2011a, b). In contrast, there is no delta fan at Mapes Creek and the habitat at the mouth of the stream does not appear to be different than adjacent shoreline areas. There is also some rip rap along the shore at the Mapes Creek delta area and thus the amount of preferred shallow beach habitat is reduced. Lastly from our limited observations, wave action from prevailing winds seemed to be stronger at the Mapes Creek delta than at Taylor Creek and perhaps the Mapes Creek delta is not a preferred location for juvenile Chinook salmon. The stream channel at Mapes Creek was just constructed in 2014 and it may take several years for a fluvial delta fan to develop. However, because the stream is relatively small and perhaps because wave action from prevailing winds may continually move deposited sand from Mapes Creek; it is possible that a fluvial delta fan will not develop to any degree at this site.

The Taylor Creek delta area (also called fluvial fan) covers a relatively large area; however, juvenile Chinook salmon appeared to only extensively use part of this area where there was a combination of streamflow and sand substrate. In January and February when the lake level was low, this preferred area was roughly 25% of the 41 to 58 m long outside edge of the delta area (Delta-A and Delta-B combined). Much of the remaining delta (primarily Delta-B) available to Chinook salmon was composed of coarse gravel and cobble with no streamflow and few juvenile Chinook salmon were present. As lake levels rose starting in March, the delta area was composed of the outside edge (Delta-A and Delta-B combined) as well as a convergence pool. Juvenile Chinook salmon commonly used both the outside edge (Delta A) and the convergence pool where there was streamflow and sand substrate. The percent of the total delta area that provided preferred habitat conditions varied widely with lake level. A rough estimate would be that, at highest lake level, half of the delta area (west side of delta area; see Figure 5) provided preferred habitat conditions. Observations of juvenile Chinook salmon in other areas of south Lake Washington indicated juvenile Chinook salmon prefer sand and gravel substrates (Tabor et al. 2011a) and thus replacing coarse gravel and cobble in areas where there is no streamflow with finer substrates would improve habitat conditions. However, restoration efforts also need to consider substrate preferences of sockeye salmon that spawn annually in either the delta area and/or lower channel areas of Taylor Creek (Wild Fish Conservancy 2008). Some combination of fine and coarse gravels will likely provide adequate habitat conditions for both species. The east side of the delta contains a high percent of cobbles and removal of substrates in that area would seem to be beneficial to both species. However, the west side of the delta has predominantly sand and gravel and likely does not warrant major changes.

The small rock barrier (approximately 100 m [328 ft] upstream from the mouth) in Taylor Creek appeared to have a strong effect on the distribution of small-bodied fishes in 2015-2017. After the rock barrier was eliminated prior to 2018 sampling effort, small-bodied fishes were able to inhabit the entire study stream section up to Rainier Avenue. In 2015-2017, juvenile Chinook salmon were occasionally observed just downstream of the rock barrier but never upstream of it. Sculpin were abundant downstream of the rock barrier but rare upstream of the rock barrier and the sculpin found upstream of the rock barrier tended to be larger individuals. Recent studies of several other streams in the Puget Sound region have also found the distribution of migratory sculpins can be impacted by small barriers (i.e., > 15 cm perch height) and generally only large individuals are found upstream of these barriers (LeMoine and Bodensteiner 2014; Tabor et al. 2017). The proposed restoration project will reconstruct the channel and remove any potential barriers. Full-spanning log weirs and other drop structures are often used to improve fish habitat conditions (e.g., increase pool depth and frequency), but can have the unintended consequence of reducing the upstream movements of small-bodied fishes, including juvenile Chinook salmon (Tabor et al. 2017). In our upper Taylor Creek monitoring sites at the lower end of the U-2 stream section there is a channel-spanning log weir (0.3 m [1 ft] perch height) that will likely limit upstream movements of small-bodied fishes. If upstream movements of small-bodied fishes is a part of the overall fish restoration objective then this structure and perhaps other similar structures will need to be modified. Other types of instream restoration features have been recommended such as roughened channels/constructed riffles and porous weirs instead of log weirs and other drop structures (Cramer 2012).

Delta Rain Event Surveys

We did not observe any numerical response of juvenile Chinook salmon to increased storm-related increases in discharge levels at the deltas of Mapes or Taylor creeks. Based on earlier sampling in Lake Washington tributaries, we had expected to see an increase in catch rates (Tabor et al. 2011b). Catch rates in this study were quite variable and may have been related to several factors, thus requiring a larger sample size to fully explore the role of nonnatal streams as feeding areas for juvenile Chinook salmon following storm events. Similar to earlier sampling, it's possible the small beach seine could easily have missed fish that are in deeper waters. In addition, high turbidity levels following rain events may allow juvenile Chinook salmon to move into deeper waters when predation risk is lower. For example, Tabor and Wurtsbaugh (1991) found juvenile rainbow trout (*O. mykiss*) moved offshore during periods of high turbidity to feed on large zooplankton presumably because risk from visual predators was lower. Juvenile Chinook salmon are often in schools during the day and beach seine catches may be extremely variable depending if a school is encountered or not. Most of our sampling was done during the day and because juvenile Chinook salmon appear to have a crepuscular feeding pattern (Tabor et al. 2011a), we may have missed the time of the day when there is a numerical response to the high discharge event. The duration and magnitude of the high discharge event further complicates sampling because it may also influence the numerical response by juvenile Chinook salmon.

Similar to previous sampling on Lake Washington tributaries (Tabor et al. 2011b), we observed a shift in the diet of juvenile Chinook salmon with increased discharge levels at the delta of Taylor Creek. Instead of Chinook salmon diet being almost entirely composed of prey that likely originated from the lake shoreline (e.g., chironomids), they switched to prey from Taylor Creek (e.g., oligochaetes and mayflies). The high discharge event likely displaced a large number of invertebrates downstream (referred to as invertebrate drift) that they were able to consume. Invertebrate drift typically increases during high discharge events (Anderson and Lehmkuhl 1968), and it is this phenomenon that is expected to draw juvenile Chinook salmon to nonnatal streams following peak discharge events. Salmonid foraging success in the main channel of Taylor Creek may be reduced due to increased turbidity levels (Sweka and Hartman 2001) and water velocities (Piccolo et al. 2008). However, once the stream enters the lake following a rain event, there will be a wide range of water velocities and turbidity levels from turbid, high velocity conditions near the stream mouth to clear, low velocity conditions in the lake and juvenile Chinook salmon may be able to find the ideal location that provides good foraging conditions and still minimizes risk to visual predators.

Unlike Taylor Creek, we did not observe any major shift in the diet of juvenile Chinook salmon at the Mapes Creek delta following a rain event. Mapes Creek is a smaller and lower gradient stream than Taylor Creek and there may not be as many displaced invertebrates moving downstream. Also, there may be differences in the abundance of macroinvertebrates between the two streams because Mapes Creek watershed is located in a heavily-urbanized area and may have poor habitat conditions (e.g., long culverted stream sections, predominately sand substrates; Tabor et al. 2010).

Chinook Salmon Diet - 2018

Diet sampling in 2018 indicated juvenile Chinook salmon at the Taylor Creek delta fed more similarly to lakeshore-dwelling Chinook salmon than to stream-dwelling Chinook salmon. Bioenergetics analysis of juvenile Chinook salmon collected from the nearshore areas of Lake Washington indicated they grow well and prey appears to be abundant (Koehler et al. 2006); therefore, feeding on prey that originated in the lake may be preferred. It is unclear if prey availability is better in the stream or the lake. Perhaps the stream has lower prey availability but is attractive to juvenile Chinook salmon because of reduced predation risk. The high density of juvenile Chinook salmon on the delta may be due to the presence of ideal habitat conditions (sand substrates and shallow waters) and proximity to good foraging conditions along the lakeshore.

Summer Electrofishing Surveys

The numbers of cutthroat trout caught during summer electrofishing surveys in lower and upper Taylor Creek varied widely among years. Much of the variability was due to the large differences in the numbers of 0+ age cutthroat trout caught. For example, in lower Taylor Creek in 2018 only two were caught yet 159 were caught in 2016 and 77 were caught in 2019. Egg survival rates likely varied widely among years due in large part to differences in physical factors such as the amount of fine sediments and physical displacement from scour caused by high flow events (Quinn 2018). In the lower reach in 2016 and 2019 when 0+ cutthroat trout were abundant, peak streamflows appeared to have been much lower (based on USGS Kelsey Creek February-April stream gage measurements) than in 2015, 2017, and 2018 when numbers were substantially lower (Figure 30). In the upper reach, the highest number of 0+ cutthroat trout collected was also the year when peak streamflows in Kelsey Creek were the lowest among the five survey years; however, the relationship between peak streamflow and the number of 0+ cutthroat trout was not as strong as for the lower reach.

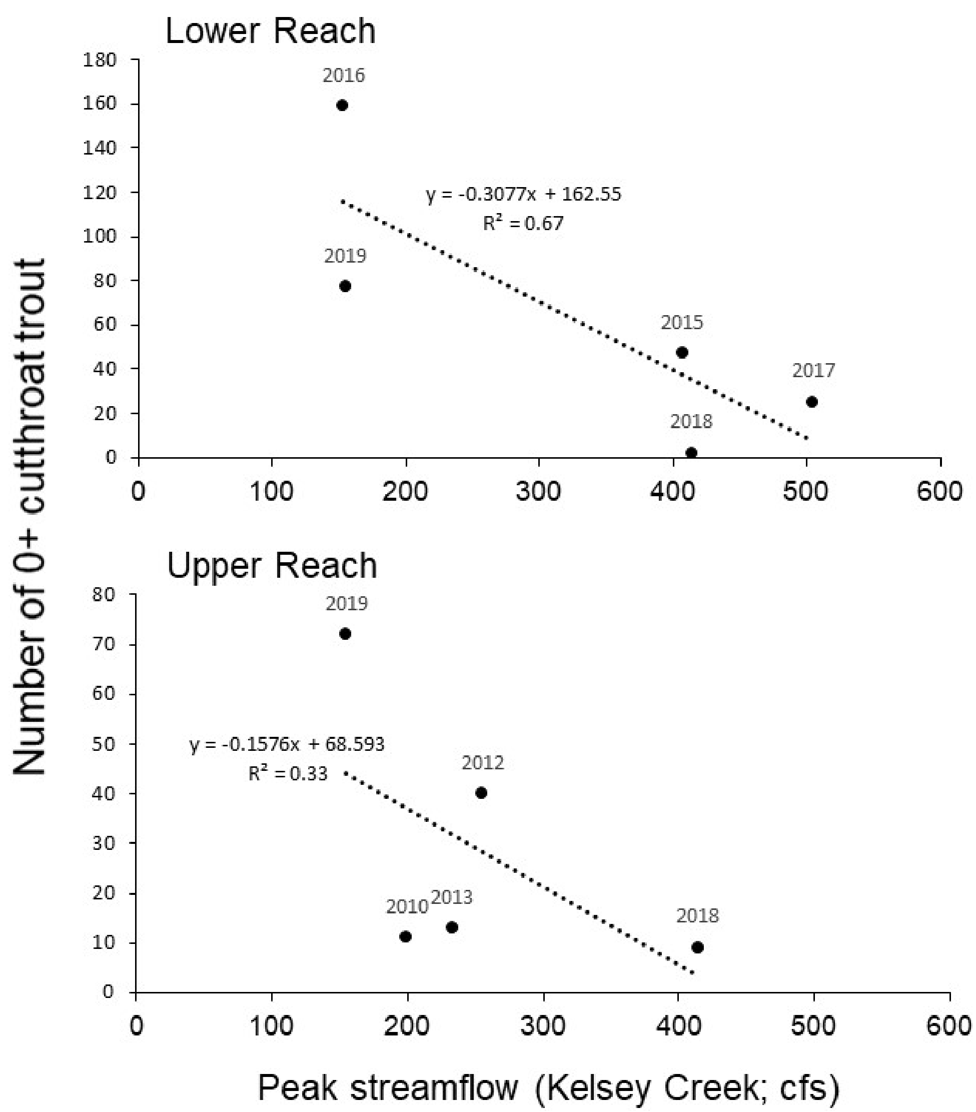

FIGURE 30.—Relationship between peak streamflow (February-April, Kelsey Creek USGS stream gauge) and the number of 0+ cutthroat trout collected during an annual single-pass electrofishing survey in two reaches of Taylor Creek. The lower reach (L-1, L-2, and L-3 combined) surveys were conducted in June while the upper reach (U-3) surveys were conducted in July or August.

Cutthroat trout appear to successfully spawn in the lower and upper study reaches of Taylor Creek; however, there was no evidence of successful spawning of cutthroat trout in Mapes Creek. During June electrofishing surveys, only a total of five cutthroat trout > 150 mm (5.9 inches) FL were collected in Mapes Creek; whereas in lower Taylor Creek, 55 cutthroat trout > 150 mm (5.9 inches) FL were collected. Mapes Creek is a smaller and shallower stream than Taylor Creek (Appendix 3) and may not have adequate habitat conditions for spawning adults. Additionally, Mapes Creek has a lower gradient and appears to have a higher level of embeddedness than Taylor Creek which may result in poor egg survival rates if spawning did occur.

The two sculpin species present in both Mapes Creek and Taylor Creek were both migratory sculpin. Both species are generally widespread in lowland lakes, estuaries, and the lower reaches of streams and rivers and have small planktonic larvae that drift downstream to slow-water environments after hatching. After larvae grow for a few weeks, they assume a benthic existence and then migrate upstream to inhabit lower reaches of rivers or streams. Because of their planktonic larval stage, they can quickly invade new habitats such as coastal streams opened from glacier retreat (Milner et al. 2008). Similarly, migratory sculpins appeared to have colonized Mapes Creek soon after the restoration project was completed. Electrofishing of upstream sections of Mapes Creek in May 2017 (part of this study) and July 2005 (Tabor et al. 2010) indicated that sculpin were not present. Thus migratory sculpin likely had to colonize Mapes Creek from Lake Washington. The restoration project was completed in September 2014 and we observed sculpin in the new stream channel during our first surveys in February 2015 and they appeared to be abundant when we did our electrofishing survey in June 2015.

The relative distribution between the two species of migratory sculpins in Taylor Creek and Mapes Creek was consistent with results from other studies. Coastrange sculpin were substantially more common in riffles (faster-water habitats) than prickly sculpin in both study streams. Several other studies have found that prickly sculpin and coastrange sculpin are spatially segregated with prickly sculpin primarily inhabiting pools and coastrange sculpin inhabiting riffles (Taylor 1966; Mason and Machidori 1976; White and Harvey 1999; Tabor et al. 2007). Because coastrange sculpin inhabit faster waters than prickly sculpin, they are likely better adapted for moving upstream through riffles and thus are typically found farther upstream (Mason and Machidori 1976; Tabor et al. 2017). Only one prickly sculpin was ever collected in the middle section of Taylor Creek whereas some coastrange sculpin were collected in the upper section. In Mapes Creek, coastrange sculpin were well distributed throughout the study reach while prickly sculpin were primarily found in the lower part of the study reach in the convergence pool.

In 2019, the catch of 1+ and older sculpin in Mapes Creek was considerably lower than during 2015-2017 surveys. Reduction of the catch of these sculpin was likely due to major changes in habitat conditions including 1) increased embeddedness (Figure 28), and 2) increased levels of riparian vegetation (Figure 27). In general, large substrates that have abundant interstitial spaces with little embeddedness appear to support larger sculpin populations than areas with small substrates or high embeddedness (Hawkins et al. 1983; Brown 1991; Haro and Brusven 1994; Knaepkens et al. 2002; Davey et al. 2005). During the 2015-2017 surveys, many of the 1+ and older larger sculpin were caught in areas near the rootwads where cobbles were positioned (Figure 28). In 2019, few sculpin were collected around these cobbles presumably because of the high level of embeddedness. Habitat conditions have also changed dramatically because of the increase in riparian vegetation (Figure 27); however, it is unclear exactly how this affects sculpin catch rates. Increased levels of riparian vegetation may reduce capture efficiency because some areas are difficult to shock and/or see the stunned fish. Additionally, increased levels of riparian vegetation might reduce the amount suitable habitat for sculpins or perhaps reduce the availability of macroinvertebrates, their primary prey base. Results from Mapes Creek highlight the need to monitor habitat conditions as well as fish populations for several years to determine the long-term effectiveness of each restoration project; a critical process that is not universally conducted.

During the five years of June electrofishing surveys, the only nonnative fish collected was one rock bass in lower Taylor Creek. Additionally, nonnative fish were occasionally observed during our standard juvenile Chinook salmon in both streams and represented a small fraction of the total number of fish observed. Most nonnative species found in the Lake Washington basin primarily inhabit lentic systems and slow-moving streams and rivers and Mapes and Taylor creeks may not have preferred habitat conditions. Additionally, nonnative fish may not compete well with native salmonids and sculpin that are better adapted for the stream habitat conditions found in Mapes and Taylor creeks.

The only fish species collected in the upper reaches of Taylor Creek (above Rainier Ave) were cutthroat trout and coho salmon. Because there is an anadromous barrier at Rainier Avenue, cutthroat trout appear to have a self-sustaining fluvial population in upper Taylor Creek. Fluvial populations of coastal cutthroat trout have also been documented upstream of anadromous barriers in other small coastal streams (Northcote and Hartman 1988; Heggenes et al. 1991b). At both upper Taylor Creek sites, 1+ and older cutthroat trout appeared to occur primarily where there were deeper pools and glides. Coastal cutthroat trout that are 1+ and older generally show a strong preference for deeper pools (> 25 cm) and areas with some type of cover and lower water velocities (Heggenes at al. 1991a).

Juvenile coho salmon were only collected in upper Taylor Creek in 2005 and 2011. Because of the anadromous barrier, these fish are considered from some type of an outplanting, likely from a local school education project. This highlights the difficulty of long term monitoring and evaluating barrier removal projects if additional variables such as outplantings are included in the overall project. Additionally, outplanting of juvenile coho salmon had recently been planned for Mapes Creek, which would have made it difficult to assess the use of the stream by juvenile Chinook salmon which could be displaced by juvenile coho salmon.

We recommend continuing the summer surveys in upper Taylor Creek, especially the upstream reach, to document if other species such as coho salmon and sculpins have colonized the upper stream reaches and how the fish community has changed once the restoration project is completed. In comparing the two upper Taylor Creek stream sections, the U-3 stream section sppeared to be the best site to continue sampling if only one site was able to be surveyed. Unlike the U-2 stream section, the U-3 stream section had three years of prior sampling efforts, was conducted over a 150-m stream reach, and included several pools. The downside of this site is that it is farther upstream from the U-2 stream section and some fishes, especially small-bodied fishes, may not move that far upstream and could be missed in post-project monitoring. Therefore, some combination of sampling just upstream of Rainier Avenue and continuing to sample the U-3 stream section as well as lower Taylor Creek would be preferable to document changes in fish distribution once fish passage is improved.

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Appendix 1. Number (#), length (m), and area (m^2) of different habitat types in the Mapes Creek study reach during fish surveys. The start and end survey dates is the period of fish survey dates that corresponds to each row of habitat values.

Year		Habitat type										
		Convergence Pool		Other pools			Glides			Riffles		
Survey dates		Length	Area		Length	Area		Length	Area		Length	Area
start	end	(m)	(m^2)	#	(m)	(m^2)	#	(m)	(m^2)	#	(m)	(m^2)
2015												
9-Feb	Mar-15	3.0	10.1	1	11.5	30.7	7	62.2	91.0	8	48.4	54.9
7-Apr	7-Apr	30.0	68.0	1	11.5	30.7	6	41.5	62.0	7	42.2	47.6
20-Apr	20-Apr	57.5	168.7	1	11.5	30.7	4	23.3	36.5	5	32.8	34.4
6-May	19-May	54.3	164.7	1	11.5	30.7	5	26.5	42.0	5	32.8	34.4
4-Jun	4-Jun	38.9	83.0	1	11.4	35.7	5	27.1	52.5	5	48.9	74.4
2016												
25-Jan	25-Jan	0.0	0.0	1	10.8	30.7	6	48.9	102.1	7	75.9	120.0
16-Feb	23-Feb	0.0	0.0	1	10.8	30.7	6	48.9	98.8	7	75.9	127.9
8-Mar	22-Mar	5.8	10.6	1	10.8	30.7	6	48.9	98.8	7	70.1	118.7
5-Apr	5-Apr	28.5	61.8	1	10.8	30.7	5	37.1	76.5	6	54.4	94.0
21-Apr	11-May	44.0	95.3	1	10.8	30.7	4	23.1	51.3	5	52.9	91.1
28-May	8-Jun	46.0	112.1	1	10.8	30.7	4	23.1	51.3	5	52.9	91.1
2017												
26-Jan	26-Jan	0.0	0.0	1	8.0	29.4	7	59.8	119.0	7	68.7	116.0
13-Feb	21-Feb	0.0	0.0	2	12.0	34.5	6	55.8	108.1	8	70.1	121.1
6-Mar	6-Mar	8.0	17.6	1	9.4	27.6	6	55.8	108.1	7	61.5	105.2
20-Mar	20-Mar	12.0	27.7	1	9.4	27.6	6	55.8	108.1	7	55.9	100.6
4-Apr	4-Apr	33.5	83.8	1	9.4	27.6	5	44.5	87.1	6	48.2	87.4
17-Apr	5-Jun	49.0	151.6	1	9.4	27.6	4	31.0	61.6	5	46.2	82.8
2019												
30-Jan	21-Feb	0.0	0.0	1	7.5	19.5	6	49.2	82.1	8	79.7	116.2
18-Mar	18-Mar	9.5	16.5	1	7.5	19.5	6	49.2	82.1	8	70.2	101.6
24-Apr	24-Apr	44.0	96.8	1	7.5	19.5	5	34.2	60.1	6	50.7	73.3
13-May	13-May	57.7	159.6	1	7.5	19.5	4	24.7	43.7	6	46.5	67.0

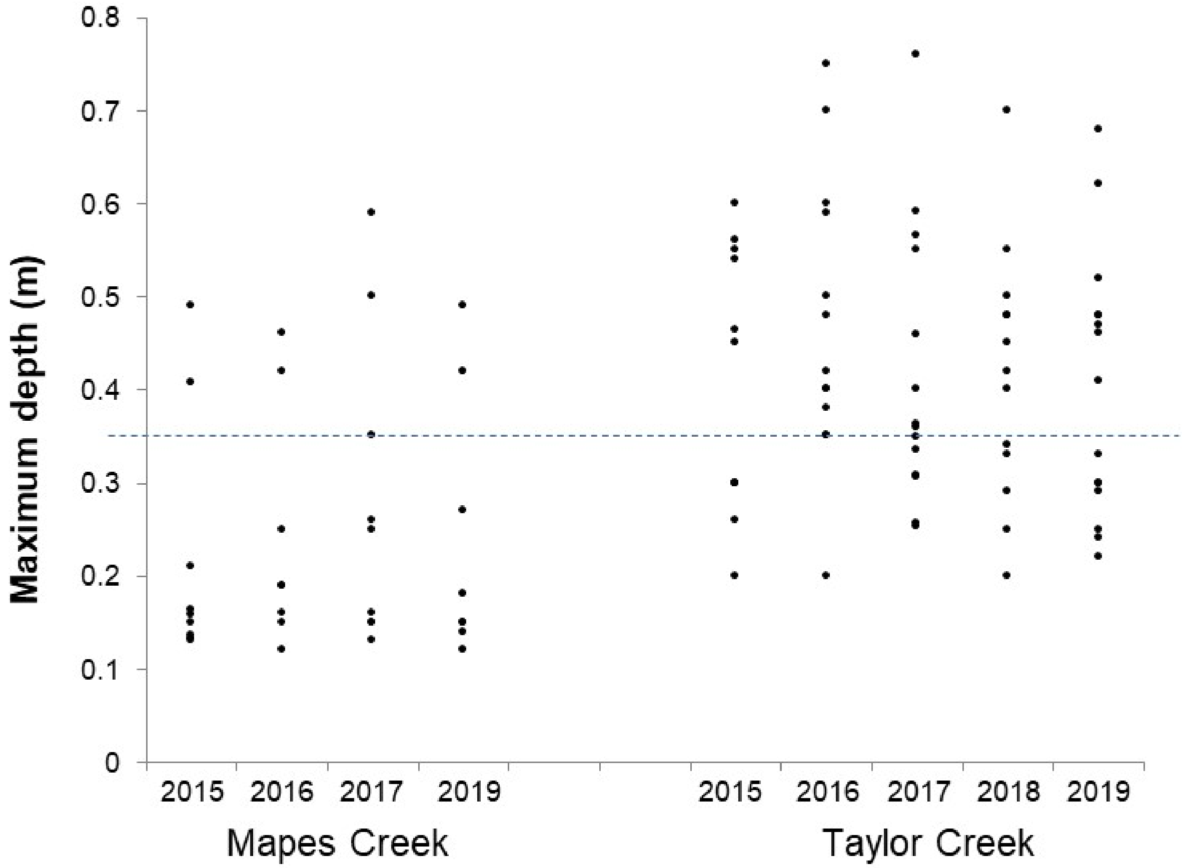
Appendix 2. Number (#), length (m), and area (m^2) of different habitat types in three sections of the lower Taylor Creek study reach during bimonthly fish surveys (late Jan- early June, 2015-2019. The start and end survey dates is the period of fish survey dates that corresponds to each row of habitat values. The L-1 stream section occasionally included some secondary habitat units and thus the sum of the length of habitat types is longer than the total stream length.

Year / Stream section / Survey dates start	end	Convergence Pool Length (m)	Convergence Pool Area (m^2)	Other pools #	Other pools Length (m)	Other pools Area (m^2)	Glides #	Glides Length (m)	Glides Area (m^2)	Riffles #	Riffles Length (m)	Riffles Area (m^2)
2015												
L-1												
23-Feb	23-Feb	11.0	58.7	1	7.2	15.4	1	3.5	3.0	2	25.5	36.0
10-Mar	10-Mar	19.0	79.7	1	7.2	15.4	1	3.5	3.0	2	25.5	36.0
26-Mar	26-Mar	19.0	79.7	1	7.2	15.4	2	12.2	29.4	1	20.0	19.3
7-Apr	19-May	16.0	96.7	2	21.8	38.9	1	3.5	3.0	1	4.0	5.6
19-May	19-May	16.0	96.7	2	22.6	41.8	1	3.5	3.0	1	5.0	7.0
L-2												
23-Feb	4-Jun	0.0	0.0	1	2.8	6.7	1	7.5	9.0	1	42.5	53.8
L-3												
23-Feb	4-Jun	0.0	0.0	3	7.8	10.8	3	8.2	12.1	5	25.9	32.7
2016												
L-1												
25-Jan	23-Feb	0.0	0.0	2	18.1	12.5	1	4.5	5.3	3	41.0	84.1
8-Mar	8-Mar	32.1	120.3	2	18.1	12.5	1	4.5	5.3	3	21.6	32.3
22-Mar	22-Mar	36.7	141.7	2	18.1	12.5	1	4.5	5.3	2	17.0	16.0
5-Apr	5-Apr	16.5	151.3	2	15.6	10.1	1	4.5	5.3	2	14.0	13.4
21-Apr	21-Apr	16.5	151.3	2	21.2	15.6	1	9.5	11.2	1	4.0	4.6
11-May	6-Jun	16.5	151.3	2	31.8	26.2	0	0.0	0.0	1	4.0	4.6
L-2												
25-Jan	6-Jun	0.0	0.0	1	3.3	10.1	1	7.0	8.4	1	41.5	54.6
L-3												
23-Feb	5-Apr	0.0	0.0	5	14.2	22.1	1	7.5	10.7	4	21.3	30.5
21-Apr	6-Jun	0.0	0.0	7	18.7	31.9	1	7.5	10.7	5	36.2	57.3
2017												
L-1												
26-Jan	26-Jan	7.5	16.9	2	15.4	16.4	1	2.8	2.5	4	40.4	112.7
13-Feb	20-Mar	5.0	31.8	2	17.5	27.1	1	1.4	1.9	4	33.5	107.1
30-Mar	30-Mar	10.5	73.5	2	17.5	27.1	1	1.4	1.9	4	30.4	56.2
11-Apr	24-Apr	18.7	137.1	2	17.5	27.1	1	1.4	1.9	2	15.5	17.2
8-May	8-May	16.5	151.3	1	18.2	24.0	1	5.0	6.1	2	9.0	9.2
22-May	6-Jun	16.5	151.3	1	24.3	32.1	0	0.0	0.0	0	8.0	8.0
L-2												
26-Jan	26-Jan	0.0	0.0	1	2.6	7.2	1	7.3	8.8	1	39.0	54.9
13-Feb	24-Apr	0.0	0.0	1	2.6	6.9	0	0.0	0.0	1	49.0	70.0
8-May	6-Jun	0.0	0.0	1	2.0	6.4	1	7.4	8.9	1	43.0	65.6
L-3												
26-Jan	26-Jan	0.0	0.0	6	18.9	33.0	2	5.6	7.1	6	41.3	65.3
13-Feb	24-Apr	0.0	0.0	5	14.9	28.4	3	8.1	14.1	6	42.1	70.2
8-May	5-Jun	0.0	0.0	6	16.3	30.0	2	3.6	5.5	6	44.4	75.2

Appendix 2, continued. Number (#), length (m), and area (m^2) of different habitat types in three sections of the lower Taylor Creek study reach during monthly fish surveys (late January-May, 2018-2019. The start and end survey dates is the period of fish survey dates that corresponds to each row of habitat values. The L-1 stream section occasionally included some secondary habitat units and thus the sum of the length of habitat types is longer than the total stream length.

Year		**Habitat type**											
Stream section		Convergence Pool		Other pools			Glides			Riffles			
Survey dates		Length	Area		Length	Area		Length	Area		Length	Area	
start	end	(m)	(m^2)	#	(m)	(m^2)	#	(m)	(m^2)	#	(m)	(m^2)	
2018													
L-1													
22-Feb	22-Feb	0.0	0.0	1	13.4	18.8	2	3.8	3.9	3	36.5	64.8	
13-Mar	13-Mar	14.8	133.2	1	13.4	18.8	2	3.8	3.9	3	30.6	62.5	
9-Apr	9-Apr	17.0	171.7	1	13.4	18.8	2	3.8	3.9	2	15.5	11.9	
3-May	3-May	17.0	177.4	1	32.7	43.2	0	0.0	0.0	0	0.0	0.0	
L-2													
22-Feb	3-May	0.0	0.0	1	3.2	8.5	2	11.8	16.5	2	37.7	51.6	
L-3													
22-Feb	3-May	0.0	0.0	5	15.0	26.3	3	8.6	13.6	6	45.0	69.6	
2019													
L-1													
30-Jan	21-Feb	0.0	0.0	2	14.2	23.0	4	5.8	22.2	6	35.3	77.7	
18-Mar	18-Mar	8.5	105.5	2	14.2	23.0	3	5.8	3.3	5	22.9	26.5	
24-Apr	24-Apr	14.7	148.5	1	10.7	19.6	1	9.4	7.7	2	17.4	14.0	
13-May	13-May	13.0	164.7	1	18.8	37.6	1	7.4	5.9	2	12.9	9.9	
L-2													
30-Jan	30-Jan	0.0	0.0	1	1.9	4.5	4	14.6	19.4	3	27.2	35.0	
21-Feb	13-May	0.0	0.0	1	1.9	4.5	4	12.6	16.2	3	29.2	37.6	
L-3													
30-Jan	13-May	0.0	0.0	5	16.0	28.3	2	6.8	8.8	6	45.6	68.0	

Appendix 3. Maximum depth of slow-water habitats (glides and pools) in lower Mapes Creek and lower Taylor creeks (2015-2019). The dashed horizontal line at 0.35 m maximum depth is the level we used to classify each slow-water habitat unit as either a pool or a glide.



Appendix 4. Number of fish observed during visual nighttime surveys in lower Mapes Creek, 2015-2017, and 2019. Only the six primary species (sculpin is a combination of two species) observed are included. Coho salmon were categorized as either subyearlings (0+; < 100 mm FL) or yearlings (1+; > 120 mm FL). Trout were categorized as either small (65-130 mm FL), medium (130-200 mm FL), or large (> 200 mm FL). All trout collected during electrofishing sampling were cutthroat trout, thus we assumed all trout observed during visual nighttime surveys were cutthroat trout.

Year			Coho salmon		Trout				
Date	Location	Chinook salmon	0+	1+	small	medium	large	Sculpin	Stickleback
2015									
9-Feb	Mapes Creek	6		9	0			1	
19-Feb	Mapes Creek	58		4	9			3	
10-Mar	Mapes Creek	62		6	14			7	9
	Delta	1						2	
	Reference site	7		1				26	
26-Mar	Mapes Creek	37		7	12				13
	Delta							1	1
	Reference site	1			2			43	1
7-Apr	Mapes Creek	14		1	2			1	22
	Delta	5						4	1
	Reference site	10						34	
20-Apr	Mapes Creek	10		11	1			8	11
	Delta							7	3
	Reference site	18		3				28	
5-May	Mapes Creek	4	19			1		27	8
	Delta	1				1		5	
	Reference site	7		2				13	
19-May	Mapes Creek	2	14	15	1			7	8
	Delta			5				2	2
	Reference site							6	
4-Jun	Mapes Creek		8		1	5		51	15
	Delta			1	1	2		17	2
	Reference site							53	
2016									
25-Jan	Mapes Creek	1			13	13	2	2	1
	Delta								
	Reference site	2				4		12	
16-Feb	Mapes Creek	11			22	3		1	
	Delta	1						2	
	Reference site	8						16	
23-Feb	Mapes Creek	81			12			2	
	Delta								
	Reference site	8			5			3	
8-Mar	Mapes Creek	133		1	31	2		2	
	Delta	4							
	Reference site	11		12				1	
22-Mar	Mapes Creek	100		6	10	3		10	4
	Delta					2		1	
	Reference site	3			4			4	
5-Apr	Mapes Creek	35			5			11	7
	Delta	4				1			
	Reference site	18				2		41	
21-Apr	Mapes Creek	16			11			17	10
	Delta	8						6	4
	Reference site	15			1			9	7
11-May	Mapes Creek	3			7			38	16
	Delta	2				1		1	2
	Reference site	9						5	
24-May	Mapes Creek				9	3		38	15
	Delta	2						15	1
	Reference site	2				2		13	
6-Jun	Mapes Creek			12	10			37	8
	Delta						3	6	
	Reference site							25	

Appendix 4, continued. Number of fish collected during riffle electrofishing surveys in lower Taylor Creek, 2015-2017 and 2019. Only the six primary species (sculpin is a combination of two species) observed are included. Coho salmon were categorized as either subyearlings (0+; < 100 mm FL) or yearlings (1+; > 120 mm FL). Trout were categorized as either small (65-130 mm FL), medium (130-200 mm FL), or large (> 200 mm FL). All trout collected during electrofishing sampling were cutthroat trout, thus we assumed all trout observed during visual nighttime surveys were cutthroat trout.

Year			Coho salmon		Trout				
Date	Location	Chinook salmon	0+	1+	small	medium	large	Sculpin	Stickleback
2017									
26-Jan	Mapes Creek	17			12	4			
	Delta	1						2	
	Reference site							20	
13-Feb	Mapes Creek	98			15			7	
	Delta	1							
	Reference site	13						24	
21-Feb	Mapes Creek	165						3	
	Delta	6							
	Reference site	3							
6-Mar	Mapes Creek	244			9			4	
	Delta							2	
20-Mar	Mapes Creek	173			11	1		2	
	Delta							1	
	Reference site	3						12	
4-Apr	Mapes Creek	71			1			6	
	Reference site	6				1		7	
17-Apr	Mapes Creek	76			4			20	
	Delta				1			3	
	Reference site	7						13	
8-May	Mapes Creek	43						29	
	Delta	2						1	
	Reference site	47						5	
22-May	Mapes Creek	45		1	2			76	
	Delta	6						2	
	Reference site	45				1		9	
5-Jun	Mapes Creek	3		10	8	7		60	
	Delta	2						1	
	Reference site	13		8				3	
2019									
30-Jan	Mapes Creek				23			2	2
21-Feb	Mapes Creek	1			38			1	
18-Mar	Mapes Creek	17			16			1	1
24-Apr	Mapes Creek	57			9			4	
13-May	Mapes Creek	15			6			13	

Appendix 5. Number of fish observed during visual nighttime surveys in four sections of lower Taylor Creek, 2015-2019. Only the six primary species (sculpin is a combination of two species) observed are included. Coho salmon were categorized as either subyearlings (0+; < 100 mm FL) or yearlings (1+; > 120 mm FL). Trout were categorized as either fry (< 65 mm FL), small (65-130 mm FL), medium (130-200 mm FL), or large (> 200 mm FL). All trout collected during electrofishing sampling were cutthroat trout, thus we assumed all trout observed during visual nighttime surveys were cutthroat trout.

Year			Coho salmon		Trout					
Date	Section	Chinook salmon	0+	1+	fry	small	medium	large	Sculpin	Stickleback
2015										
23-Feb	L-1	20				6	1			
	L-2	3				6	1	1	1	
	L-3					7	1			
10-Mar	Delta	14								
	L-1	20			1	7			4	
	L-2			1	2	4	1	2	7	
	L-3					5	10			
26-Mar	Delta	4							4	2
	L-1	14				2	2			1
	L-2	8				5				
	L-3					12	3			
7-Apr	Delta	14							2	7
	L-1	11				12	2		1	
	L-2	2			4	3	2			
	L-3					5	5	2		
20-Apr	Delta	8				1			19	3
	L-1	11	1		1	7	1		8	3
	L-2	2	1		1	6	1	1	1	
	L-3					12	4	1		
6-May	Delta	1							13	
	L-1	1	1			3	4	1	4	
	L-2		10			3	7	2	4	
	L-3			1		3	9	3		
19-May	Delta								17	
	L-1		3		1	7			16	1
	L-2		3		4	8	3	1		
	L-3				2	4	6	3		
4-Jun	Delta								14	
	L-1			1		12	7		9	1
	L-2		2	1			7	3	1	1
	L-3		1		10	1	9	7		

Appendix 5, continued. Number of fish observed during visual nighttime surveys in four sections of lower Taylor Creek, 2015-2019. Only the six primary species (sculpin is a combination of two species) observed are included. Coho salmon were categorized as either subyearlings (0+; < 100 mm FL) or yearlings (1+; > 120 mm FL). Trout were categorized as either fry (< 65 mm FL), small (65-130 mm FL), medium (130-200 mm FL), or large (> 200 mm FL). All trout collected during electrofishing sampling were cutthroat trout, thus we assumed all trout observed during visual nighttime surveys were cutthroat trout.

Year			Coho salmon		Trout					
Date	Section	Chinook salmon	0+	1+	fry	small	medium	large	Sculpin	Stickleback
2016										
25-Jan	Delta	16					2	2		
	L-1	4				1	13	3		
	L-2						4	3	1	
	L-3					3	6	3		
16-Feb	Delta	11							1	
	L-1	15				9	3			
	L-2					3	4		2	
	L-3					2	5	1		
23-Feb	Delta	22					2	1		
	L-1	44				5	4	1	2	
	L-2					3				
	L-3					9	8	2		
8-Mar	Delta	20					1		5	
	L-1	22				12	3			1
	L-2					10	3		2	
	L-3					11	5			
22-Mar	Delta	10				1	1	1	2	1
	L-1	21				10	3	1	3	
	L-2					4	4	2	3	
	L-3					4	7	1		
5-Apr	Delta	10								
	L-1	23				6	6	1	1	2
	L-2					1	4	2	1	
	L-3					8	6	3		
21-Apr	Delta	12						1	1	1
	L-1	27		4	7	10		1	7	6
	L-2					2	3	1	2	
	L-3				2	12	6	4		
11-May	Delta					2	1		4	
	L-1	8		1		4	17	3	16	5
	L-2				22	3	7	1	3	
	L-3				45	9	12	3		
24-May	Delta						1	15	22	1
	L-1				1		8	8	22	
	L-2				30		7	2	2	
	L-3				36	11	11	4	1	
6-Jun	Delta	2					2	2	15	1
	L-1	4			9		8	10	15	1
	L-2				22		3	2	6	
	L-3				39	9	9	4		

Appendix 5, continued. Number of fish observed during visual nighttime surveys in lower Taylor Creek, 2015-2019. Only the six primary species (sculpin is a combination of two species) observed are included. Coho salmon were categorized as either subyearlings (0+; < 100 mm FL) or yearlings (1+; > 120 mm FL). Trout were categorized as either fry (< 65 mm FL), small (65-130 mm FL), medium (130-200 mm FL), or large (> 200 mm FL). All trout collected during electrofishing sampling were cutthroat trout, thus we assumed all trout observed during visual nighttime surveys were cutthroat trout.

Year			Coho salmon		Trout					
Date	Section	Chinook salmon	0+	1+	fry	small	medium	large	Sculpin	Stickleback
2017										
26-Jan	Delta	4					5		2	
	L-1	27				14	5	1		
	L-2					9	5		4	
	L-3					16	7	2		
13-Feb	Delta	51					1			
	L-1	68				13	2	1		
	L-2					8	2	1	6	
	L-3					13	1	4		
28-Feb	Delta	22							1	
	L-1	71				7				
	L-2	5				4	2	1	1	
	L-3					8	11	2		
20-Mar	Delta	17							1	
	L-1	172				9	2		3	
	L-2	2				2	1		2	
	L-3					21	7	2		
30-Mar	Delta	4				1			1	
	L-1	106				9	3		2	
	L-2	2				3	1		2	
	L-3					15	3	2		
11-Apr	Delta	1								
	L-1	73				6	1			
	L-2	1				5	3			
	L-3					15	7			
24-Apr	Delta	4		1		2				
	L-1	32				12	5		3	
	L-2	4				4			1	
	L-3				1	23	5	1		
8-May	Delta	20					3	1	6	
	L-1	58	1			6	7		6	
	L-2	6			4	4	5		1	
	L-3				3	15	8	2		
22-May	Delta	72							8	
	L-1		3			3			6	
	L-2	2	3		4	6	1	1	8	
	L-3		1		2	29	10	4		
6-Jun	Delta						1		14	
	L-1	1				8	12		33	
	L-2		5	1		8	5		9	
	L-3		3			46	6	1		

Appendix 5, continued. Number of fish observed during visual nighttime surveys in lower Taylor Creek, 2015-2019. Only the six primary species (sculpin is a combination of two species) observed are included. Coho salmon were categorized as either subyearlings (0+; < 100 mm FL) or yearlings (1+; > 120 mm FL). Trout were categorized as either fry (< 65 mm FL), small (65-130 mm FL), medium (130-200 mm FL), or large (> 200 mm FL). All trout collected during electrofishing sampling were cutthroat trout, thus we assumed all trout observed during visual nighttime surveys were cutthroat trout.

Year			Coho salmon		Trout					
Date	Section	Chinook salmon	0+	1+	fry	small	medium	large	Sculpin	Stickleback
2018										
12-Feb	Delta	99					2			
	L-1	100				10	1	1	2	
	L-2					6	2			
	L-3					16	7			
14-Mar	Delta	5		3		1	1			
	L-1	118				8	5			
	L-2	5				10	1		2	
	L-3					23	3	1		
9-Apr	Delta	7								
	L-1	103				3	2	1		
	L-2	10				6	1			
	L-3		1			1	14	4		
3-May	Delta	58				1			1	
	L-1	58				3	1		11	
	L-2	5				4	3		4	
	L-3	2		1	1	14	10		4	
2019										
30-Jan	Delta	2							2	
	L-1	3		3		10	1		2	
	L-2					4	6	1	1	
	L-3			2		12	9	2		
21-Feb	Delta	14								1
	L-1	2				4		1		
	L-2					10	2	1		
	L-3					10	6	3		
18-Mar	Delta	1								
	L-1	43				2			1	
	L-2	2		1		4			6	
	L-3					16	2	1	2	
24-Apr	Delta	7								
	L-1	128			1	2				
	L-2	14			9	5				
	L-3	3		1	2	17	2		9	
13-May	Delta	17							1	
	L-1	57	8		16	5			2	
	L-2	10	1		8	5				
	L-3	2	2		9	10	3		11	

Appendix 6. Number of fish collected during riffle electrofishing surveys in lower Taylor Creek, 2015-2019.

Year	Date	Section	Length surveyed (m)	Number of fish: Chinook	Cutthroat trout	Trout fry	Coastrange sculpin
2015	March 26	L-1	5	0	1	0	12
		L-2	5	0	1	0	8
		L-3	10	0	1	0	0
	April 7	L-1	5	0	0	2	5
		L-2	5	0	2	0	6
		L-3	5.7	0	2	0	0
	May 5	L-1	3.5	0	0	2	7
		L-2	5	0	2	1	21
		L-3	8.5	0	1	1	0
2016	February 16	L-1	5	1	0	0	10
		L-2	5	0	2	0	15
		L-3	10.2	0	0	0	1
	March 8	L-1	4.4	0	1	0	17
		L-2	5	0	2	0	23
		L-3	7	0	2	0	2
	April 5	L-2	10	0	2	0	15
		L-3	10.2	0	3	0	0
	May 11	L-1	3	0	2	14	1
		L-2	5	0	0	2	6
		L-3	10	0	1	16	0
2017	February 14	L-1	2.3	6	0	0	30
		L-2	5	0	2	0	6
		L-3	10	0	4	0	0
	March 20	L-1	3.4	3	2	0	19
		L-2	5	1	2	0	20
		L-3	10	0	2	0	0
	April 11	L-2	10	0	0	0	33
		L-3	6.9	0	4	0	1
	May 9	L-2	10	0	3	2	26
		L-3	10	0	0	0	0
2018	February 2	L-1	5	5	0	0	16
		L-2	5	0	3	0	5
		L-3	10	0	2	0	3
	March 18	L-2	10	0	2	0	4
		L-3	10	0	0	0	5
	April 13	L-2	10	0	3	0	42
		L-3	7.7	0	0	0	0
	May 3	L-2	10	0	1	0	31
		L-3	10	0	2	0	3
2019	January 30	L-1	5	0	0	0	1
		L-2	5	0	2	0	5
		L-3	7.2	0	0	0	2
	February 19	L-1	5	0	1	0	13
		L-2	5	0	0	0	1
		L-3	5	0	1	0	8
	March 18	L-1	5	0	0	0	2
		L-2	5	0	0	0	6
		L-3	5	0	1	0	8
	April 24	L-1	5	3	0	13	7
		L-2	5	0	2	3	3
		L-3	5	0	0	1	5
	May 13	L-1	5	0	0	12	0
		L-2	5	0	0	5	2
		L-3	5	0	0	2	13
Totals			**355**	**19**	**64**	**76**	**469**