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Fish Species Presence and Distribution Surveys at Naval Radio Station (T) Jim Creek

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By Patrick DeHaan
U.S. Fish & Wildlife Service
Western Washington Fish & Wildlife Conservation Office
Lacey, Washington

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Department of the Navy
Commander, Navy Region Northwest
1100 Hunley Rd.
Silverdale, WA 98315
Naval Station Everett

Submitted by:
Patrick DeHaan
US Fish and Wildlife Service
Western Washington Fish and Wildlife Conservation Office
510 Desmond Dr.
Lacey, WA 98503

Summary

Jim Creek, a tributary to the South Fork Stillaguamish River, flows through Naval Radio Station (Transmitter) Jim Creek (NRS(T) Jim Creek) in Snohomish County, WA. NRS(T) Jim Creek is the site of a large radio antenna array and it also serves as a Naval recreation area. The US Navy contracted the US Fish and Wildlife Service, Western WA Fish and Wildlife Conservation Office (WWFWCO) to conduct fish and aquatic habitat surveys within the boundaries of NRS(T) Jim Creek to determine which fish species were present, the quality of available fish habitat, and the overall stream health. This information is important for the Navy's Integrated Natural Resource Management Plan (INRMP) for NSR(T) Jim Creek. During the summers of 2017 and 2018, WWFWCO staff conducted single pass, backpack electrofishing surveys within mainstem Jim Creek and in two smaller tributaries. In total, 10 different fish species were documented; eight native species (Rainbow Trout, Coho Salmon, Torrent Sculpin, Longnose Dace, Coastal Cutthroat Trout, Western Brook Lamprey, Salish Sucker, and Bull Trout) and two non-native species (Brook Trout and Westslope Cutthroat Trout). Rainbow Trout, Coho Salmon, Torrent Sculpin, and Longnose Dace made up over 90% of the total catch each year, and Rainbow Trout were the most abundant species captured both years in terms of numbers and biomass. Stream habitat surveys were also conducted at each electrofishing site. Based on habitat surveys, Jim Creek could be divided into four main sections from downstream to upstream: 1) a downstream reach with relatively in-tact stream habitat; 2) a channelized reach that still contained quality spawning and rearing habitat and healthy riparian vegetation; 3) a highly modified area within the antenna array field where the stream was highly channelized and little to no riparian vegetation existed; and 4) a relatively pristine canyon area upstream of the antenna field. Surveys for benthic macroinvertebrates were also conducted in order to repeat surveys previously done 2008 and to provide a means of assessing stream health. At seven of nine sample sites, Benthic Indices of Biological Integrity (BIBI) were rated as either "Good" or "Excellent". Compared to previous surveys, two sites had the same quality rating, five sites had an increased quality rating (e.g., from "Fair" in 2008 to "Good" in 2017) and two sites had a decrease in quality rating. Overall the fish and aquatic community within the boundaries of NRS(T) Jim Creek was typical of other streams in Puget Sound. This report provides recommendations for habitat restoration actions in areas where the habitat was highly modified.

Introduction

Naval Radio Station (Transmitter) Jim Creek (hereafter NRS(T) Jim Creek) is located in the Stillaguamish River watershed in the foothills of the Cascade Mountains of western Washington (Figure 1). It is in rural Snohomish County, approximately 60 miles (97 km) northeast of Seattle, and 12 miles (19 km) east of the city of Arlington. The installation covers about 4,800 acres (1,943 ha) across a largely undeveloped, forested area, sharing common boundaries with the Mount Baker-Snoqualmie National Forest, state-owned forested lands, and private lands. Approximately one quarter of the installation is a highly modified antenna field, located within the valley bisected by Jim Creek. The installation is in the Jim Creek watershed, which drains to the South Fork Stillaguamish River. There are about seven total miles of streams on the property including 3.75 miles (6 km) of mainstem Jim Creek. Other tributaries of Jim Creek on the installation are Cub Creek and Little Jim Creek as well as several smaller seasonal tributaries (Figure 1).

The Stillaguamish River watershed supports three fish species listed as threatened under the US Endangered Species Act: fall-run Chinook Salmon (*Oncorhynchus tshawytscha*), winter-run steelhead (*O. mykiss*), and Bull Trout (*Salvelinus confluentus).* Steelhead have been documented spawning and rearing within the boundaries of NRS(T) Jim Creek and the other two species are presumed to utilize habitat in NRS(T) Jim Creek in some capacity (WDFW SalmonScape 2019). Coho Salmon (*O. kisutch*) and Chum Salmon (*O. keta*) have also been documented spawning and rearing in streams at NRS(T) Jim Creek, and Pink Salmon (*O. gorbuscha*) are also presumed to occur (WDFW SalmonScape 2019). It is important to note, however, that quantitative surveys for these species, apart from Coho Salmon, have not been conducted and much of this information is based on anecdotal evidence (Linda Wagoner, US Navy, Jim Creek Natural Resource Manager (retired), *personal communication*). Aside from these species, other resident native fishes common in Puget Sound streams may also be present including: Coastal Cutthroat Trout (*O. clarkii clarkii*), Pacific Lamprey (*Entosphenus tridentatus*), Western Brook Lamprey (*Lampetra richardsoni*), sculpin (*Cottus* spp.), Speckled Dace (*Rhinichthys osculus*), Longnose Dace (*R. cataractae)*, and Threespine Stickleback (*Gasterosteus aculeatus*) (Wydoski and Whitney 2003).

Quantitative fish surveys previously conducted within the bounds of NRS(T) Jim Creek were limited to the Twin Lakes and a small reservoir and beaver ponds in Cub Creek. These surveys documented five resident species: Salish Sucker (dwarf form of Longnose Sucker; *Catostomus catostomus*), Redside Shiner (*Richardsonisus balteatus*), Rainbow Trout (*O. mykiss*), Longnose Dace, and Coastal Cutthroat Trout (Garrett and Spinelli 2017). Quantitative fish survey data for the mainstem of Jim Creek is limited prior to the current study. The Navy does have several fisheries management actions in place within the boundaries of NRS(T) Jim Creek. The mainstem of Jim Creek and its tributaries are closed to recreational angling. Recreational angling does occur in the Twin Lakes, and the Navy has stocked trout annually in the Twin Lakes since the late 1950s (US Navy 2001). Rainbow Trout have been the main species stocked, and Coastal Cutthroat Trout and Brook Trout (*Salvelinus fontinalis*) have also been stocked (US Navy 2001). Currently only Rainbow Trout from a local trout farm are stocked. Historically there was a Coho Salmon rearing facility within the boundaries of NRS(T) Jim Creek that operated from 1994 to 1999. Fingerling Coho Salmon from the Stillaguamish Tribe's hatchery near Arlington were brought to the Jim Creek facility for rearing and then juvenile fish were released into NRS(T) Jim Creek streams. This facility has officially been in standby mode since 2000 and no fish are currently reared or released there.

The Navy is responsible for all natural resource management activities within the boundaries of NRS(T) Jim Creek. Given the lack of information on fish species presence and distribution within NRS(T) Jim Creek, the Navy requires further information regarding the species composition in Jim Creek and its tributaries, the general physical characteristics of the streams, and the condition of habitat for fishes. This information will be important for management decisions concerning mission activities, recreational activities, and overall management of the streams. This data is also essential for the Navy's Integrated Natural Resource Management Plan (INRMP) for NRS(T) Jim Creek and will be used for identifying habitat restoration and enhancement opportunities. This information is also important to ensure compliance with natural resource laws, such as the Endangered Species Act (16 USC 1531 et seq), Fish and Wildlife Conservation Act (16 USC 2901 et seq), Fish and Wildlife Coordination Act (16 USC 661 et seq), and Sikes Act Improvement Act (Section 2905 (c). Furthermore, data on fish species distribution within NRS(T) Jim Creek is important to management agencies (e.g., USFWS, WDFW, NOAA) for characterizing the distribution of ESA-listed salmonids and other fishes in Puget Sound and Western Washington.

The US Navy established an agreement with the US Fish and Wildlife Service, Western Washington Fish and Wildlife Conservation Office (WWFWCO) to conduct fish and aquatic habitat surveys in Jim Creek in order to fill several data gaps. This project had four primary objectives:

1. Determine the fish species inhabiting streams at NRS(T) Jim Creek
2. Collect data to describe habitat conditions of the streams at NRS(T) Jim Creek
3. Assess the macroinvertebrate community to determine overall stream health
4. Provide recommendations concerning habitat restoration and enhancement

Methods

Fish Surveys

Stream surveys were conducted in August of 2017 and July of 2018. Streams within NRS(T) Jim Creek were partitioned into 100-m sampling reaches using ArcGIS prior to the beginning of stream surveys (Figure 1). This included mainstem Jim Creek as well as several smaller tributaries. A subset of 100-m reaches was selected to sample for fish and aquatic habitat surveys. A greater number of survey sites were selected in 2017 with the assumption that access to some sights may be difficult and there was limited knowledge of whether or not smaller tributaries had year-round surface water flow.

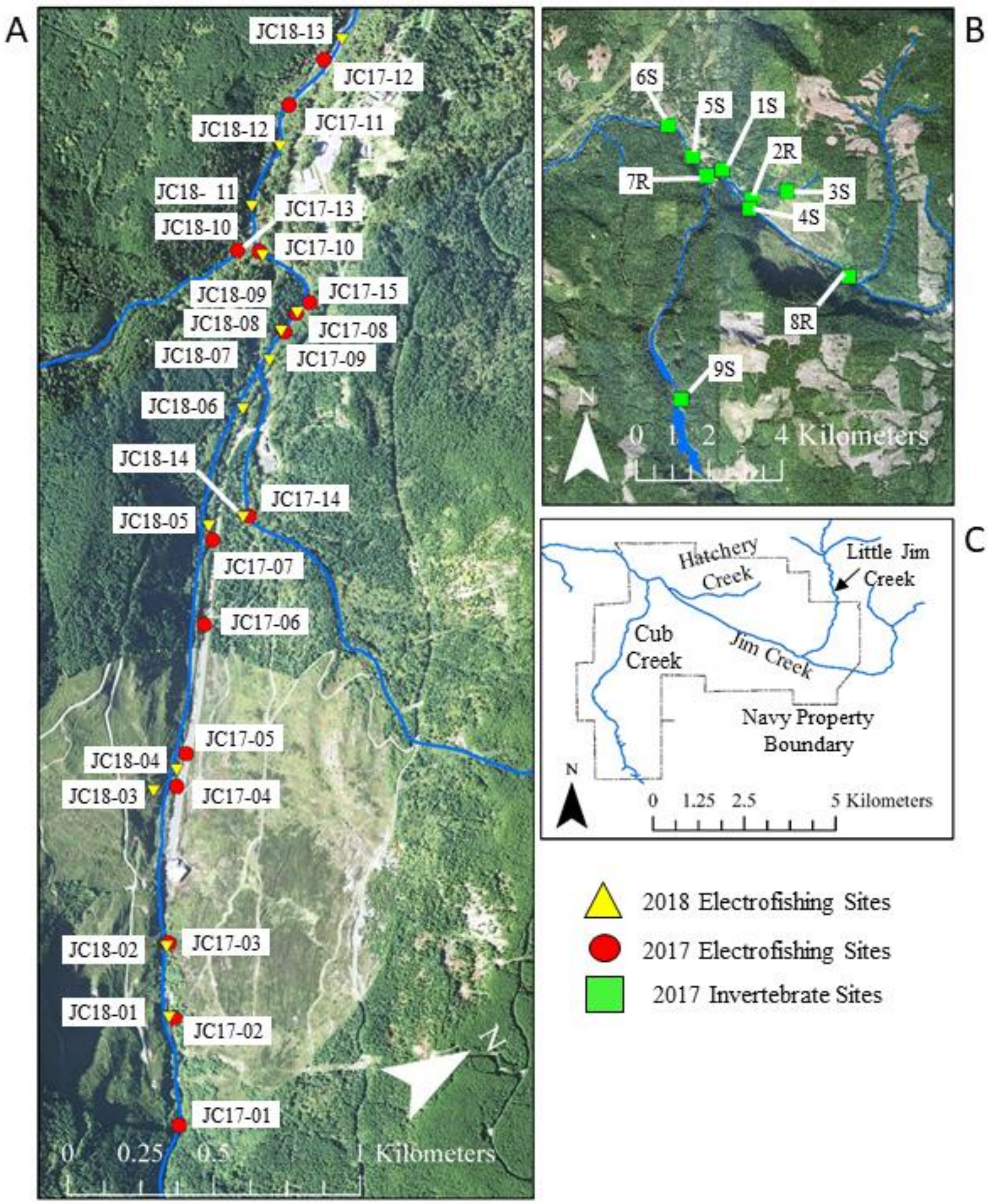

Figure 1. Sample sites within the boundaries of NRS(T) Jim Creek. Figure 1A represents 2017 and 2018 electrofishing sites, Figure 1B represents 2017 aquatic invertebrate sample sites, and Figure 1C shows Jim Creek and the different tributaries described in this report.

The downstream end of each sample reach was located using a GPS and small mesh (1/4 inch) block nets which spanned the entire wetted width of the stream were placed at the upstream and downstream end of each 100-m reach to prevent fish from moving into or out of sampling reaches during electrofishing. In some instances, sample reaches were slightly longer or shorter than 100-m when natural habitat breaks (e.g., cascades, small waterfalls, large boulders) made it difficult to place block nets exactly 100-m upstream of the start. Field crews used standard, single-pass backpack electrofishing techniques (Temple and Pearsons 2007) to target all life stages of all fish species within the creek to get an accurate representation of the species present, their distribution within Jim Creek, and their relative densities. Electrofisher settings followed National Marine Fisheries Service protocols as required in our sampling permit. Initial electrofisher settings for each reach were 300 V of pulsed direct current and 30 Hz, and settings were adjusted as necessary to balance capture efficiency while minimizing the impacts to fish. Backpack electrofishing safety protocols described in Temple and Pearsons (2007) were followed. Electrofishing started at the downstream end of each reach and proceeded upstream to the end of each reach. Stunned fish were collected using dip nets and placed into aerated buckets until processing.

Captured fish were temporarily anesthetized using tricaine methanesulfonate (MS-222) prior to handling. Once anesthetized, fish were identified to species, measured for length to the nearest mm, weighed to the nearest tenth of a gram, and then allowed to recover in aerated buckets. Small fin clips were taken from the caudal fin of all Bull Trout and putative Bull Trout x Brook Trout hybrids and a subset of Rainbow Trout and then preserved in 95% non-denatured ethanol for later genetic analysis. Fin clips from Bull Trout and putative hybrids were taken for species ID. Fin clips were taken from Rainbow Trout for later genetic analysis of hatchery vs. wild origin of the *O. mykiss* population in Jim Creek. Once fish had recovered from processing, they were returned to the creek within the reach they were collected.

Previous studies have demonstrated that sampling efficiency for single-pass electrofishing efforts is often low (Peterson et al. 2004; Temple and Pearsons 2007). One sample site in 2018, JC18-06, was sampled twice to conduct an informal mark-recapture estimate. All fish captured in sample reach JC18-06 were marked with a caudal fin clip prior to returning them to the sample reach. Block nets remained in place in this stream segment and field crews returned 24 hours later to resample this stream segment using the same electrofishing protocol. All fish captured were enumerated as described above and also inspected for fin clips to determine recapture status.

For each sample reach, the total number and biomass (weight in grams) collected for each species and the proportion of the total number and biomass collected for each species was determined. The proportion of the total number and biomass for each species across all sample reaches was also determined. For each species captured, the range, mean, and standard deviation for fork length (FL) and weight across all sample reaches was determined. For Torrent Sculpin (*C. rhotheus*) and Western Brook Lamprey, total length (TL) rather than fork length was calculated. In both sample years, nearly all (approximately 94% and 99% for 2017 and 2018, respectively) of the fish captured were one of four species: Rainbow Trout, Coho Salmon, Torrent Sculpin, and Longnose Dace. For these four species, FLs (TLs for Torrent Sculpin) were binned into 5-mm increments to produce length-frequency histograms to determine the size distribution and make basic inferences regarding the age structure of the population in Jim Creek.

The primary objective of this study was to document the presence and distribution of fish species at NRS(T) Jim Creek; however, this study did not attempt to precisely quantify fish abundance at each sampling site. Catch per unit effort (CPUE) can serve as a reliable metric for relative abundance during electrofishing surveys (Temple and Pearsons 2007). CPUE calculated as the number of fish collected per minute of electrofishing was estimated at each reach for the four most common species: Rainbow Trout, Coho Salmon, Torrent Sculpin, and Longnose Dace. For each of these species, the mean CPUE averaged across sample reaches each year and the associated standard deviation was also calculated.

Habitat Surveys

Field crews also conducted stream habitat assessments using a modified protocol for Washington streams (WDFW 2009) at each 100-m electrofishing reach. Each reach was divided into pool and riffle habitat. Habitat classifications were based on physical characteristics, with fast-moving, relatively shallow sections with noticeable surface turbulence classified as riffles, and slower-moving, deeper sections with no surface turbulence classified as pools. The length of each habitat type was measured and the following habitat attributes for each habitat type were measured at a representative location within each habitat type: wetted width, scour width, mean depth, maximum depth (pools only), visual estimates of percent canopy cover, instream cover (low, medium, high), and percent of each substrate type: boulder (> 305 mm); rubble/cobble (76 to 305 mm); gravel (5 to 76 mm); sand (< 5 mm). Stream temperature and gradient were also taken for each 100-m sample reach. At the conclusion of habitat surveys, upstream and downstream photographs were taken at the upstream and downstream end of each survey reach (four photographs total for each reach). For each sample reach, the proportion of pool and riffle habitat were calculated. The mean wetted width and scour width as well as the mean depth and maximum pool depth based on measurements at each representative site within each habitat type were also calculated. The mean substrate compositions were similarly estimated based on measurements at each representative habitat site.

Invertebrate Surveys

In 2008, aquatic invertebrate surveys were conducted in Jim Creek as a means of evaluating water quality and stream health (Adopt-a-Stream Foundation [AASF] 2008). These surveys were repeated in 2017 to determine if there had been any changes in the aquatic invertebrate community. Invertebrate surveys were conducted at nine sites previously sampled in 2008 and selected by Navy Natural Resources staff. Each site was located using GPS coordinates. When sites could not be located exactly, a suitable site in close proximity was selected.

The same stream macroinvertebrate sampling protocol used in 2008 (AASF 2008) was used in this study. Briefly, a riffle was selected at each site to conduct stream invertebrate sampling. A 0.092 m^2 (1 ft^2) Surber sampler was placed in the stream with the opening facing upstream and any large rocks within the sampling frame were removed from the streambed and placed into a dish pan. A small garden weeding fork was used to disturb the sediment within the sample frame for 60 seconds. At the end of 60 seconds, the Surber sampler was moved to a nearby spot within the same riffle (within 0.5 m) and the sampling effort was repeated two additional times. Following the third sample, the collection cup was removed from the Surber sampler and the contents were emptied into a plastic dishpan. All visible aquatic invertebrates were removed from the dishpan and preserved in 95% ethanol. The contents of the dishpan were then filtered through a 500 μm sieve and the contents were then sorted and aquatic invertebrates were preserved in 95% ethanol. Concurrently, all of the large rocks removed from the creek were scrubbed with a small brush to remove any aquatic invertebrates that may have been attached. These were preserved in ethanol along with the Surber sampler collections from the same riffle.

Aquatic invertebrate samples were shipped to Aquatic Biology Associates in Corvallis, OR for identification and analysis. Organisms were identified to the lowest taxonomic level possible. Data were then entered in the Puget Sound Stream Benthos online database (https://www.pugetsoundstreambenthos.org/Default.aspx). This website houses data from lowland streams across the Puget Sound including the previous aquatic invertebrate study at Jim Creek. Once uploaded, data were used to calculate a Benthic Index of Biological Integrity (BIBI) for each of the nine sample sites using the 10-metric scoring criteria developed by Karr (1998). Each site was given a numeric BIBI score from 1 to 100 and these scores corresponded to one of five biological condition categories: Very Poor (0-20), Poor (20-40), Fair (40-60), Good (60-80), and Excellent (80-100). The method used to calculate BIBI scores was updated in 2012 and this updated metric was used to calculate BIBI scores for this study. We calculated the mean and standard deviation of the BIBI scores for each year and then conducted a paired t-test to determine if there was a significant difference in the means between the two years.

Results

Fish Surveys

Not all of the sites initially selected for surveys in 2017 had year-round flows and were accessible for sampling. Mainstem Jim Creek and Cub Creek had surface flows during the sample period each year. The rearing facility outlet creek (hereafter referred to as “Hatchery Creek”) had surface flow immediately downstream of the facility outlet and near the confluence with mainstem Jim Creek, but flows were subsurface between these areas. Several other small streams within the boundaries of NRS(T) Jim Creek were represented on maps; however, there was no surface flow in these streams during electrofishing surveys in August of 2017. Access to Cub Creek downstream of the Twin Lakes and Little Jim Creek was difficult due to a lack of roads and trails, and field crews were not able to survey either of these tributaries other than the lower 500 m of Cub Creek. In 2017, a total of 15 randomly selected reaches were surveyed. In 2018, a total of 15 randomly selected reaches were identified to survey; however, one reach on Hatchery Creek had no surface flows, and as a result, only 14 reaches were sampled in 2018. Some of the randomly selected survey reaches were visited in both 2017 and 2018 (e.g., JC17-09 and JC18-08; Figure 1). In both years the majority of the sample reaches were on the mainstem of Jim Creek and were distributed throughout the Creek from the downstream property boundary to the area upstream of the radio transmitter building.

In 2017, the mean electrofishing time per 100-m reach was 1824.7 seconds (sd = 686.5). A total of 10 fish species were documented during 2017 surveys: Western Brook Lamprey, Brook Trout, Bull Trout, Coastal Cutthroat Trout, Coho Salmon, Longnose Dace, Rainbow Trout, Salish Sucker, Torrent Sculpin, and Westslope Cutthroat Trout (*O. clarkii lewisi*) (Table 1). A number of small (typically < 60 mm FL) trout were collected that were difficult to differentiate as Rainbow Trout or Coastal Cutthroat Trout based on physical characteristics; these individuals were simply classified as “Unknown Trout”. Two small (65 and 69 mm FL) fish were identified in the field as possible Bull Trout x Brook Trout hybrids and fin clips were collected from these fish for later genetic analysis. Rainbow Trout (n = 696), Coho Salmon (n = 426), Torrent Sculpin (n = 360), and Longnose Dace (n = 304) were by far the most abundant species encountered and comprised 93.5% of the total catch in 2017 (Table 2). Rainbow trout represented the greatest proportion of the total biomass collected (0.629) followed by Torrent Sculpin, Longnose Dace, and Coho Salmon (0.165, 0.133, and 0.043, respectively; Table 2). Of the remaining species collected, less than 10 individuals of each species were collected in 2017, with the exception of Western Brook Lamprey (n = 12 individuals collected; Table 2).

In 2018, the mean electrofishing time per 100-m reach was 1386.6 seconds (SD = 486.4). Only five species were documented in 2018: Coho Salmon, Rainbow Trout, Torrent Sculpin, Longnose Dace, and Coastal Cutthroat Trout (Table 1). Rainbow trout were the most abundant species collected again in 2018 (n = 630) followed by Coho Salmon (n = 323), Torrent Sculpin (n = 263), Longnose Dace (n = 202), and Coastal Cutthroat Trout (n = 5). Rainbow Trout comprised the greatest proportion of the total biomass collected (0.61) followed by Torrent Sculpin (0.18), Longnose Dace (0.13), and Coho Salmon (0.05) (Table 2). When we re-sampled reach JC18-06, we recaptured a total of seven of the 68 fish collected during our first electrofishing pass; five Rainbow Trout and two Torrent Sculpin.

In both sampling years amphibian species including Tailed Frog (*Ascaphus truei*) tadpoles and Pacific Giant Salamander (*Dicamptodon tenebrosus*) were also encountered, which was consistent with previous amphibian survey data (US Navy 2007).

Table 1. Summary of Jim Creek fish collections in 2017 and 2018. Sample reach locations can be found in Figure 1.

Sample Reach	Western Brook Lamprey	Brook Trout	Bull Trout	Coastal Cutthroat Trout	Coho Salmon	Rainbow Trout	Westslope Cutthroat Trout	Unknown Trout	Longnose Dace	Salish Sucker	Torrent Sculpin	Total
2017 Surveys												
JC17-01					8	31	1	58				98
JC17-02				3	12	136	1	31				183
JC17-03					1	51						52
JC17-04						91			2		1	94
JC17-05		1			1	61			1		9	73
JC17-06					2	44			90		27	163
JC17-07					7	43			28		33	111
JC17-08	2	1			15	41			36		37	132
JC17-09	2	1			20	71			52		77	223
JC17-10	2		1	1	33	24			23		75	159
JC17-11					1	11			25		20	57
JC17-12					15	58			46		36	155
JC17-13	7			1	12	11			1	3	36	71
JC17-14				1	50	5		7				63
JC17-15		1			249	17					8	275
2018 Surveys												
JC18-01				2		74						76
JC18-02						41						41
JC18-03				1		104			2		4	111
JC18-04					6	84			13		19	122
JC18-05					18	63			31		10	122
JC18-06					30	15			12		11	68
JC18-07					59	15			9		23	106

Sample Reach	Western Brook Lamprey	Brook Trout	Bull Trout	Coastal Cutthroat Trout	Coho Salmon	Rainbow Trout	Westslope Cutthroat Trout	Unknown Trout	Longnose Dace	Salish Sucker	Torrent Sculpin	Total
JC18-08				1	61	32			26		21	141
JC18-09				1	77	23			30		29	160
JC18-10					26	42			30		66	164
JC18-11					4	45			24		34	107
JC18-12					5	24			7		19	55
JC18-13					4	45			18		27	94
JC18-14					32	23						55

Table 2. Summary statistics (by species) for Jim Creek fish surveys conducted in 2017 and 2018. Length represent fork lengths for all species except Torrent Sculpin and Western Brook Lamprey. Total lengths are given for those two species.

Species	Number Collected	Proportion of Total Catch	Length (mm)				Weight (g)					
			Mean	Min	Max	Std Dev	Mean	Min	Max	Std Dev	Total Biomass	Proportion Biomass
2017 Fish Survey Data												
Western Brook Lamprey	13	0.006	164.0	151.0	185.0	10.8	6.4	4.9	8.5	1.2	77.3	0.004
Bull Trout	1	0.001	174.0*				55.4*				55.4	0.003
Brook Trout	2	0.001	105.0	85.0	125.0	28.3	15.4	5.8	25.0	13.6	30.8	0.002
Bull x Brook Hybrid	2	0.001	67.0	65.0	69.0	2.8	3.4	3.1	3.7	0.4	6.8	0.000
Coho Salmon	426	0.223	62.6	29.0	144.0	14.3	3.3	0.2	27.8	2.6	740.0	0.043
Coastal Cutthroat Trout	6	0.003	147.0	100.0	220.0	44.0	48.6	9.8	111.0	46.8	291.0	0.017
Rainbow Trout	696	0.364	103.0	23.0	251.0	34.4	15.6	0.1	156.0	15.8	10819.0	0.629
Westslope Cutthroat Trout	2	0.001	160.0	151.0	169.0	12.7	42.0	32.8	51.1	12.9	83.9	0.005
Unknown Trout	96	0.050	50.4	37.0	68.0	7.8	1.4	0.3	3.4	0.8	53.1	0.003
Longnose Dace	304	0.159	85.1	62.0	122.0	10.2	7.0	1.7	22.7	2.8	2115.0	0.123
Salish Sucker	3	0.002	138.0	114.0	184.0	40.1	26.9	8.6	55.6	25.2	80.6	0.005
Torrent Sculpin	359	0.188	78.8	20.0	164.0	22.5	7.9	0.1	85.0	7.8	2845.0	0.165
2018 Fish Survey Data												
Coastal Cutthroat Trout	5	0.004	149.0	98.0	235.0	65.3	54.6	9.2	143.0	62.4	273.0	0.022
Coho Salmon	323	0.227	52.5	30.0	147.0	11.4	1.9	0.2	8.8	1.4	611.0	0.050
Rainbow Trout	630	0.443	82.6	21.0	217.0	39.6	12.1	0.1	178.0	17.2	7548.0	0.612
Longnose Dace	202	0.142	88.9	60.0	135.0	13.4	8.3	0.6	25.6	4.2	1634.0	0.133
Torrent Sculpin	263	0.185	80.8	20.0	153.0	17.0	8.7	0.1	87.5	8.9	2265.0	0.184

* Mean length and weight for bull trout represents the actual length and weight for the single fish captured

In both 2017 and 2018, the species composition changed from downstream to upstream reaches. Downstream reaches were a mix of the top four species (Table 1, Figure 2). As surveys progressed further upstream, and stream gradient increased, the composition of species shifted to greater numbers of salmonids, with Rainbow Trout making up the majority of the sample in reaches upstream of the radio transmitter building (Table 1, Figure 2). In 2017, when small numbers of other fish species were observed (e.g., Salish Sucker, Brook Trout, Bull Trout), most of these species were observed in sample reaches near the Jim Creek-Cub Creek confluence (e.g., JC17-10; Table 1). Coho Salmon were most abundant in Hatchery Creek reaches where they comprised nearly 100% of the total catch. Hatchery Creek has a man-made barrier associated with the intake for the old fish rearing facility. Although there were no survey reaches above this barrier, field crews did briefly electrofish above the barrier to determine if any fish were present, but none were detected.

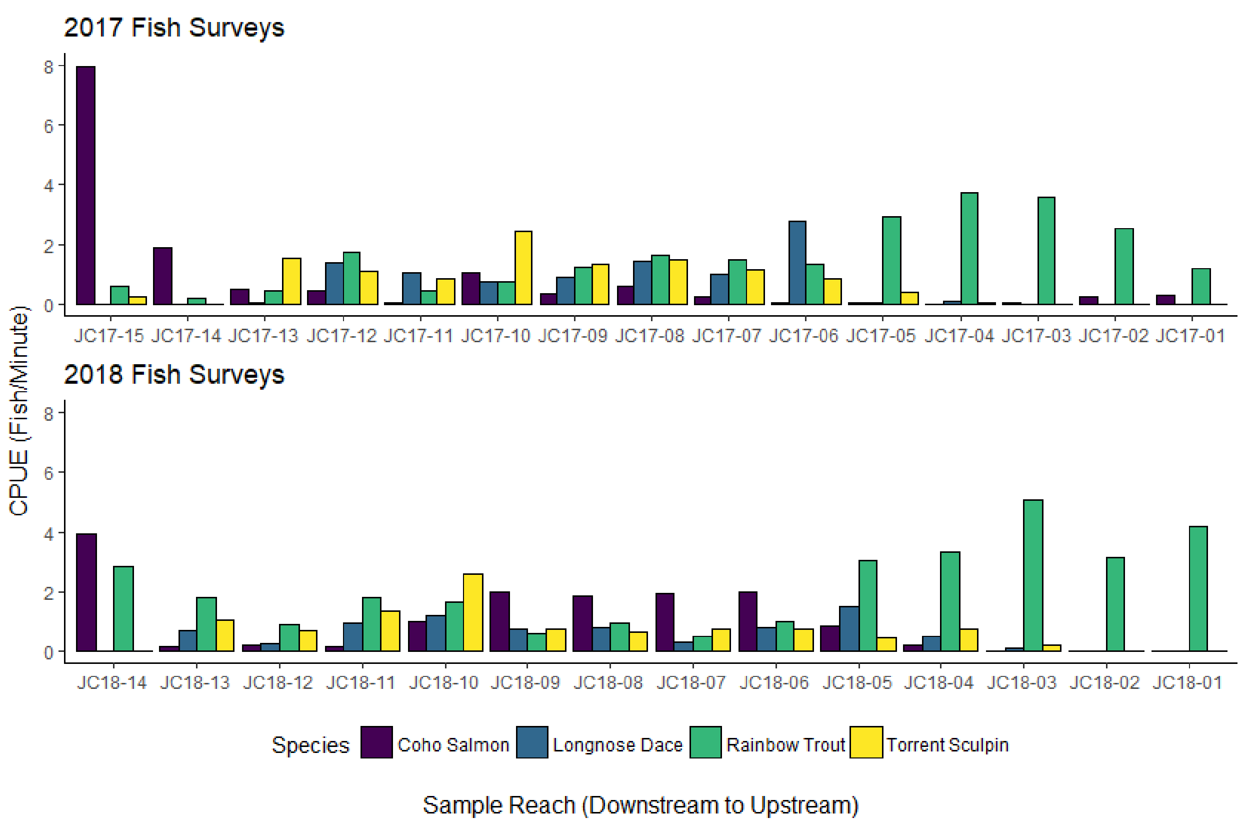

Figure 2. Catch per unit effort (CPUE) for the four most abundant fish species within the boundaries of NRS(T) Jim Creek during surveys in 2017 (top) and 2018 (bottom). CPUE was calculated as the number of each species collected per minute of electrofishing.

Catch per unit effort (CPUE) was calculated as a means to infer the relative abundance of Coho Salmon, Rainbow Trout, Longnose Dace, and Torrent Sculpin at each site in 2017 and 2018. CPUE results were similar to the proportions of fish collected at each site described above (Figure 2). From the Naval property boundary upstream to the sample reaches downstream of the antenna array area, CPUEs were relatively similar between the four species (Figure 2). For sample reaches within the antenna array field and upstream of the Transmitter Building, CPUE was highest for Rainbow Trout (Figure 2). At the sample reaches in Hatchery Creek (JC17-14, JC17-15, and JC18-14), CPUE was highest for Coho Salmon (Figure 2).

Length-frequency data for the top four fish species collected were similar in 2017 and 2018 (Figure 3). The majority of the Coho Salmon observed were a single size class from about 40 to 80 mm FL in 2017 and slightly smaller (~35 to 75 mm) in 2018 when surveys occurred earlier in the summer (Table 2, Figure 3). A few larger (100 mm+) Coho Salmon were also observed each year. Longnose Dace showed a unimodal distribution of sizes each sample year and no fish larger than 135 mm were captured either year (Table 2, Figure 3). In both 2017 and 2018, Rainbow Trout showed a bimodal distribution with one relatively distinct group of smaller fish, presumably representing age 1 individuals, and another group representing a broader distribution of older fish (Figure 3). Torrent Sculpin also showed two distinct size classes, a small group of fish up to about 40 mm TL and then a larger group of fish from about 60 mm TL up to a maximum length of approximately 140 – 160 mm TL (Figure 3).

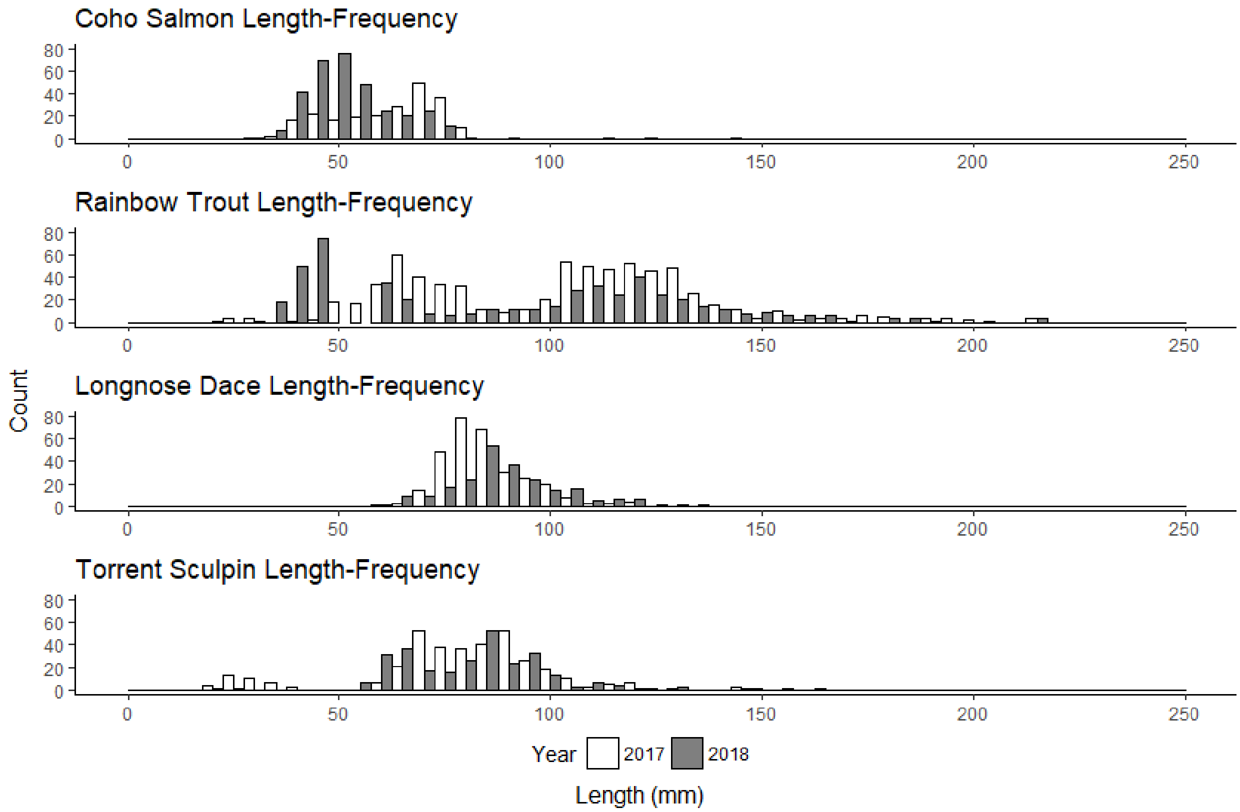

Figure 3. Length-frequency data (5-mm increments) for the four most abundant fish species collected in 2017 and 2018 in Jim Creek. Lengths for Coho Salmon, Longnose Dace, and Rainbow Trout are fork lengths while those for Torrent Sculpin are total length.

Habitat Surveys

Habitat surveys were conducted at each fish sampling reach; 15 sites in 2017 and 14 sites in 2018 (Figure 1). Overall, the majority of the habitat in Jim Creek was classified as riffle, and some reaches (e.g., JC17-12 JC18-04) were entirely riffle habitat (Table 3). Pools that did exist were generally small; however, upstream of the Radio Transmitter Building, there were several large plunge pools that were not possible to survey effectively due to their size and depth. Slope at each of the survey sites ranged from 1% in two of the reaches surveyed in 2018 (JC18-14 and JC18-09) to 16% in one upstream reach sampled in 2017 (JC17-02; Table 3). Field crews did not record the gradient at one site (JC17-03) in 2017. Wetted widths ranged from 1.75 m at site JC17-14 (on Hatchery Creek) to 12.2 m at site JC17-08 and scour widths ranged from 4.01 m also at site JC17-14 to 25.15 m at site JC17-11. The mean wetted width for all sites was 7.23 m and the mean scour width for all sites was 14.24 m. When the sample reaches in Hatchery Creek were omitted (due to the small size of this stream), the mean wetted width was 7.80 m and the mean scour width was 15.38 m. The proportion of each substrate type varied throughout the different sample reaches but there did not seem to be a clear spatial pattern in substrate type (e.g., increasing boulders from downstream to upstream; Table 3). Of all the different substrate types, no one substrate type was predominant over the others; however, sand was generally the least abundant substrate type at nearly all reaches (Table 3).

Table 3. Jim Creek habitat survey data summaries. Wetted width, scour width, mean depth and max depth represent the mean of the values recorded at a representative site at each habitat unit (pool vs. riffle) within each reach. Max depth was only measured in pools. Boulder, rubble, sand, and gravel represent the mean of the values recorded at a representative site at each habitat unit (pool vs. riffle) within each reach. Gradient was measured at one site within each sample reach.

	Length (m)						Substrate (proportion)				
Reach	**Riffle**	**Pool**	**Wetted Width (m)**	**Scour Width (m)**	**Mean Depth (m)**	**Max Depth (Pools) (m)**	**Boulder**	**Rubble**	**Gravel**	**Sand**	**Gradient**
						2017 Surveys					
JC17-01	79.1	20.9	7.03	13.80	0.52	0.99	0.29	0.14	0.30	0.28	10.0%
JC17-02	198.4	14.7	7.28	14.21	0.36	0.75	0.38	0.18	0.25	0.19	16.0%
JC17-03	77.0	23.0	6.94	13.95	0.40	0.87	0.38	0.19	0.25	0.18	N/A
JC17-04	88.0	12.0	7.55	11.35	0.31	0.43	0.39	0.29	0.14	0.19	6.5%
JC17-05	67.8	34.3	5.96	9.74	0.34	0.47	0.22	0.25	0.30	0.23	3.0%
JC17-06	73.7	26.3	6.55	11.58	0.29	0.55	0.33	0.20	0.31	0.16	5.0%
JC17-07	100.0	0.0	6.80	9.50	0.20		0.30	0.30	0.25	0.15	5.0%
JC17-08	100.0	0.0	12.20	17.40	0.30		0.30	0.25	0.30	0.15	6.0%
JC17-09	81.0	29.0	11.27	21.00	0.27	0.61	0.18	0.20	0.38	0.23	5.5%
JC17-10	27.7	72.3	6.88	13.63	0.24	0.47	0.40	0.33	0.14	0.14	12.0%
JC17-11	22.3	77.7	6.43	25.15	0.38	0.90	0.30	0.26	0.28	0.17	6.0%
JC17-12	100.0	0.0	7.20	21.80	0.21		0.35	0.35	0.20	0.10	3.5%
JC17-13	54.8	44.2	4.78	9.84	0.23	0.65	0.23	0.49	0.21	0.07	7.0%
JC17-14	73.5	15.9	1.75	4.01	0.13	0.29	0.21	0.20	0.46	0.12	9.0%
JC17-15	61.4	34.9	2.85	4.92	0.18	0.18	0.12	0.25	0.35	0.29	2.5%
						2018 Surveys					
JC18-01	60.8	37.2	6.67	10.27	0.35	0.75	0.25	0.35	0.30	0.10	14.0%
JC18-02	79.9	31.1	4.25	10.38	0.68	1.80	0.28	0.31	0.28	0.14	11.0%
JC18-03	89.0	9.0	6.07	10.83	0.40	0.85	0.10	0.25	0.38	0.28	6.0%
JC18-04	100.0	0.0	8.50	12.05	0.33		0.50	0.25	0.20	0.10	2.0%
JC18-05	62.4	35.70	6.54	14.92	0.34	0.51	0.07	0.49	0.29	0.15	5.0%
JC18-06	100.0	0.0	10.00	14.20	0.30		0.25	0.50	0.20	0.05	5.0%
JC18-07	75.4	22.4	10.63	16.63	0.24	0.30	0.17	0.43	0.33	0.07	2.5%
JC18-08	84.3	9.8	7.87	18.00	0.28	0.54	0.15	0.50	0.27	0.08	3.5%
JC18-09	51.0	42.3	9.80	18.54	0.29	0.61	0.19	0.38	0.30	0.13	1.0%
JC18-10	100.0	0.0	7.80	17.85	0.28		0.50	0.35	0.12	0.04	4.0%
JC18-11	80.0	20.0	8.90	16.10	0.22	0.40	0.10	0.65	0.18	0.08	3.0%
JC18-12	100.0	0.0	10.40	23.50	0.24		0.10	0.60	0.20	0.10	3.0%
JC18-13	37.0	56.7	8.60	23.75	0.25	0.51	0.22	0.49	0.20	0.09	6.0%
JC18-14	94.4	6.0	2.24	4.12	0.15	0.30	0.03	0.68	0.16	0.13	1.0%

Invertebrate Surveys

Field crews conducted stream invertebrate surveys at nine sites within the boundaries of NRS(T) Jim Creek. All of the previous sample sites were re-located; however, site 9S did not have any surface flow. Another small tributary to Upper Twin Lake a few hundred meters due north was selected as an alternative site 9S. BIBI scores ranged from 35.1 (rating of 'Poor') at site 5S to 97.5 (rating of 'Excellent') at site 3S (Table 4). Seven of nine BIBI scores from 2017 were classified as either 'Good' or 'Excellent' quality. The other two were classified as "Poor" (site 5S) and "Fair" (site 8R). Comparisons between current BIBI scores to previous scores from 2008 showed that three sites (2R, 4S, 6S) had no change in quality score, four sites had an increased quality score in 2017 (e.g., site 3S from "Fair" to "Excellent"), and two sites had a decreased quality score (e.g., site 8R from "Fair" to "Poor"; Table 4). The mean BIBI score for the 2017 surveys was 69.4 (SD = 18.5) and the mean BIBI score for 2008 was 59.8 (SD = 11.9). A paired t-test showed that there was no significant difference between the two means (t = -1.59, p = 0.15).

Table 4. Stream invertebrate sample summary. The first four columns contain data related to the sample sites. Subsequent columns contain the scores for each of the 10 metrics used to calculate BIBI and the final column gives the overall BIBI score. Scores from the previous surveys in 2008 are shown alongside data from the current study. BIBI ratings are as follows: 0-20 = "Very Poor"; 20-40 = "Poor"; 40-60 = "Fair"; 60 to 80 = "Good"; 80-100 = "Excellent".

Site Code	Latitude	Longitude	Sample Year	Taxa Richness Score	Ephemeroptera Richness Score	Plecoptera Richness Score	Trichoptera Richness Score	Clinger Richness Score	Long-Lived Richness Score	Intolerant Richness Score	Percent Dominant Score	Predator Percent Score	Tolerant Percent Score	Overall BIBI Score
1S	48.215636	-121.935804	2017	5.5	10.0	4.3	6.2	8.8	2.5	8.6	7.8	1.4	9.6	64.8
1S	48.215636	-121.935804	2008	1.4	4.3	5.7	6.2	4.1	3.8	4.3	9.1	10.0	9.8	58.7
2R	48.210934	-121.928415	2017	7.6	10.0	10.0	7.5	6.5	8.8	10.0	4.9	4.8	9.9	79.9
2R	48.210934	-121.928415	2008	3.1	5.7	10.0	6.2	5.3	10.0	10.0	8.6	10.0	9.9	78.9
3S	48.212066	-121.919816	2017	10.0	10.0	10.0	10.0	7.6	10.0	10.0	10.0	10.0	9.8	97.5
3S	48.212066	-121.919816	2008	2.1	7.1	2.9	7.5	4.7	3.8	4.3	8.7	2.4	9.7	53.1
4S	48.209200	-121.929100	2017	5.5	10.0	8.6	6.2	7.6	5.0	8.6	5.4	1.9	10.0	68.8
4S	48.209200	-121.929100	2008	1.4	10.0	7.1	7.5	7.1	5.0	8.6	8.1	5.8	9.9	70.4
5S	48.217800	-121.943063	2017	2.8	2.9	2.9	6.2	4.1	1.2	2.9	1.1	1.0	10.0	35.1
5S	48.217800	-121.943063	2008	2.1	10.0	4.3	6.2	7.6	3.8	7.1	0.6	3.4	9.9	55.0
6S	48.222907	-121.949140	2017	7.2	10.0	5.7	7.5	10.0	2.5	8.6	7.0	2.6	9.9	71.1
6S	48.222907	-121.949140	2008	1.0	10.0	4.3	5.0	7.1	3.8	8.6	5.7	5.3	9.6	60.3
7R	48.214606	-121.939649	2017	10.0	7.1	4.3	3.8	9.4	10.0	4.3	7.8	2.4	7.6	66.6
7R	48.214606	-121.939649	2008	1.7	8.6	4.3	5.0	5.9	3.8	7.1	5.8	4.5	4.1	50.7
8R	48.198100	-121.904514	2017	3.4	10.0	1.4	7.5	8.8	3.8	7.1	0.0	0.4	10.0	52.5
8R	48.198100	-121.904514	2008	3.1	7.1	8.6	8.8	7.6	8.8	10.0	1.6	4.7	10.0	70.2
9S	48.177851	-121.945954	2017	10.0	2.9	10.0	10.0	5.3	10.0	10.0	10.0	10.0	9.9	88.1
9S	48.177851	-121.945954	2008	0.0	2.9	5.7	3.8	0.0	2.5	2.9	2.3	9.8	10.0	39.7

Discussion

Fish Surveys

The fish species composition observed in Jim Creek was typical of Puget Sound tributaries (McPhail 1967; Wydoski and Whitney 2003). Previous fish surveys within the boundaries of NRS(T) Jim Creek focused on the Twin Lakes and lotic sections of Cub Creek

(Garrett and Spinelli 2017). These surveys documented a subset of the species observed in the present study (Salish Sucker, Coastal Cutthroat Trout, Rainbow Trout, Longnose Dace), plus one additional species; Redside Shiner. This difference was presumably due to sampling the lakes in the previous surveys vs. the streams in this study. The additional species documented here (Coho Salmon, Brook Trout, Bull Trout, Torrent Sculpin, Western Brook Lamprey, and Westslope Cutthroat Trout) are typically stream residents. A large (~10 m high) natural barrier exists approximately 500 m upstream of the mouth of Cub Creek which prevents these additional species from accessing habitat in the lakes.

Rainbow Trout were the most abundant species observed both in terms of total number of individuals collected and biomass. Length frequency histograms for this species were bimodal, suggesting the presence of two distinct age classes, and a few larger fish (200-250 mm FL) were also observed. Steelhead, the marine migratory life history form of *O. mykiss* are designated as threatened in Puget Sound whereas the freshwater life history form, Rainbow Trout, is not. The relationship between these two life history forms can be complex (Kendall et al. 2015) with both types often occurring sympatrically and no way to differentiate life history forms in pre-migratory juvenile fish. Washington Department of Fish and Wildlife conducts annual steelhead spawner surveys in Jim Creek downstream of NRS(T) Jim Creek and has documented spawning redds right up to the Navy property boundary (Peter Verhey, WDFW area fish biologist, *personal communication*). Puget Sound steelhead typically rear in freshwater for one to two years before emigrating to the marine environment as two- or three–year-olds (Kinsel et al. 2013; Klungle et al. 2018). Length-frequency data presented here suggest that most fish are either one or two years old and that most *O. mykiss* in Jim Creek are steelhead that migrate to Puget Sound as three-year-olds; consistent with steelhead life history in the nearby Skagit River (Kinsel et al. 2013).

Larger (200 mm FL or greater) Rainbow Trout were also collected suggesting that there is a resident component to the population as well. The two Twin Lakes have been stocked with Rainbow Trout since the late 1950s for recreational fishing. Some portion of these fish likely migrate downstream of the lakes and may reside in mainstem Jim Creek. This creates the potential for introgression between native steelhead and introduced Rainbow Trout. Genetic analyses have previously been used to detect introgression between native and introduced *O. mykiss* (Matala et al. 2008; Larson et al. 2018) and may be useful in Jim Creek to determine if the population represents native Puget Sound steelhead or if some level of introgression has occurred. Genetic samples were taken from a subset of the Rainbow Trout collected in 2017 for potential analysis in the future. These data will be useful for determining if past or current stocking practices at NRS(T) Jim Creek represent a threat to a native steelhead population.

Bull Trout are another ESA-listed fish species that have been documented in the Stillaguamish River; however, their status in Jim Creek was somewhat unclear. Jim Creek is exempted from Bull Trout critical habitat designation (due to an existing INRMP) and no information on spawning adults exists. We documented a single 174 mm FL Bull Trout in our study. This suggests that Bull Trout do utilize habitat in Jim Creek, but it does not clarify if a spawning population is present. Bull Trout are typically found in higher elevation headwater streams (Rieman and McIntyre 1993) and spawning likely occurs at higher elevation tributaries further upstream in the South Fork Stillaguamish Basin. The size of this fish suggests it is a migratory subadult (Fraley and Shepard 1989) and it may have originated from a different Stillaguamish tributary. Stream surveys did not include Little Jim Creek and the headwaters of Jim Creek due to time and access constraints. In the future, it may be worthwhile to conduct surveys in these areas to further clarify the status of Bull Trout in the system.

Another unique species documented in 2017 was Salish Sucker, which were abundant in previous surveys of the Twin Lakes in the Cub Creek headwaters (Garrett and Spinelli 2017). Only three Salish Suckers were captured, all near the confluence of Cub Creek and Jim Creek. These data suggest that Salish Suckers periodically move downstream into Jim Creek. These fish would not be able to return to the Twin Lakes due to the falls near the mouth of Cub Creek and a small dam upstream of that barrier. Salish Suckers are presently considered a unique form of Longnose Sucker (Wydoski and Whitney 2013) and its taxonomic status is unclear. Populations in Washington such as in Twin Lakes and the Jim Creek watershed represent an important component of the species evolutionary legacy (McPhail and Taylor 1999; Pearson and Healy 2003; Garrett and Spinelli 2017).

Coho Salmon were the second most abundant species captured. The majority of Coho Salmon were collected in Hatchery Creek (2017 and 2018) or in pools in mainstem Jim Creek downstream of the campgrounds (JC18-09 to JC18-06) in 2018. Coho Salmon typically spend one full year in freshwater and then migrate downstream to the ocean the following spring (Sandercock 1991). Length frequency data were consistent with this life history. Juvenile Coho

Salmon prefer pools and low velocity habitat, often associated with large woody debris in streams (Bisson et al. 1988; Sandercock 1991). As noted above, the majority of the habitat surveyed was classified as ‘riffle’ and there was not an abundance of woody debris in Jim Creek. Habitat actions aimed at benefitting Coho Salmon could focus on increasing habitat complexity and creating pools within Jim Creek (see below).

One ESA-listed species that was not observed during stream surveys was fall-run Chinook Salmon. Fall-run Chinook Salmon are presumed to use habitat in Jim Creek, but there have been no recent surveys to document their presence within the boundaries of NRS(T) Jim Creek. Typically ocean-type (‘Fall Run’) Chinook Salmon emigrate from natal tributaries as subyearlings (age 0) by late June (Healy 1991; Waples et al. 2004). We chose late July and August for our surveys because this time period coincides with summer base flows and was a safer period for our stream surveys; however, this was after the typical outmigration period for Puget Sound fall-run Chinook Salmon. Adult fall-run Chinook Salmon may return to natal tributaries to spawn late in the summer (Healy 1991), but no adult Chinook Salmon were observed during these surveys in either year, and 2017 surveys occurred in late August. Future surveys to document threatened fall-run Chinook Salmon in Jim Creek could consist of fall spawner surveys to document adult presence and/or snorkel surveys for juvenile Chinook Salmon during spring months prior to downstream emigration.

Although they are not ESA-listed, Chum Salmon and Pink Salmon may also utilize habitat in Jim Creek for spawning and rearing according to WDFW records (WDFW 2019). Both of these species have a relatively short freshwater residence time and migrate downstream during spring flows shortly after emerging from redds (Heard 1991; Salo 1991); thus we would not have detected them in our surveys. Fall spawner surveys would be the best way to detect these two species in the future if that information was determined to be necessary.

Two non-native fish species were detected in Jim Creek: Westslope Cutthroat Trout and Brook Trout. Two Westslope Cutthroat Trout were collected in 2017 in mainstem Jim Creek upstream of the radio transmitter building. Although Westslope Cutthroat Trout are native to Washington State in the Lake Chelan and Methow River basins, they are not native to Puget Sound watersheds (Wydoski and Whitney 2003). Hatchery propagation and subsequent stocking for this species began in the early 1900s and several watersheds west of the Cascade Mountains have been stocked, and now contain naturally reproducing populations (Wydoski and Whitney

2003; Thompson et al. 2011). Westslope cutthroat trout are a species of conservation concern in many areas they are native (Shepard et al. 2005); however, there is little information available on the impacts of Westslope Cutthroat trout to native fish and aquatic organisms in areas they have been introduced. One Brook Trout and two smaller fish which were identified in the field as possible Bull Trout x Brook Trout hybrids were also collected in 2017. Genetic analysis confirmed field species ID for all of these (Jennifer Von Bargen, USFWS Conservation Geneticist, *personal communication*). Brook Trout have been introduced extensively outside of their native range including stocking events in the Twin Lakes in the 1950s. In areas where Brook Trout co-occur with Bull Trout, hybridization has been identified as a major threat to the persistence Bull Trout populations (Rieman et al. 1997). Although only one sub-adult sized Bull Trout was captured in Jim Creek and there was no evidence of a Bull Trout spawning population within the boundaries of NRS(T) Jim Creek (i.e., no juvenile fish observed), the two hybrids captured were relatively small, suggesting that they were not likely migrants from another nearby tributary. These data indicate that hybridization with Brook Trout may be a concern for any adult Bull Trout in Jim Creek.

The primary objective in this study was to document the presence and distribution of fish species within Jim Creek. Electrofishing provided an ideal sampling means to accomplish this because it allowed field crews to collect and handle a large number of fish. Several studies have noted that single pass electrofishing surveys may suffer from low capture efficiency (Rodgers et al. 1992; Peterson et al. 2004; Temple and Pearsons 2007) and that was demonstrated in this study by the low number of recaptures we had at site JC18-06. Furthermore, electrofishing capture efficiencies vary among species; species such as salmonids may have higher capture efficiencies whereas benthic oriented species such as Torrent Sculpin may have lower efficiencies (Hense et al. 2010). As such, abundance data presented in this study should be interpreted with caution as there were likely many more fish in each reach that we did not collect. Interestingly, twice as many fish species were captured in 2017 (n = 10) compared to 2018 (n = 5) despite similar levels of effort and several of the same survey reaches. This highlights the value of repeated sampling efforts to fully characterize the fish community.

Habitat Surveys

Based on habitat survey data and visual observations, Jim Creek can be divided into four sections based on differences in habitat (Figure 4). From the downstream property boundary to the area downstream of the campgrounds, Jim Creek has relatively natural conditions. There are several natural meanders in the channel, good riparian vegetation, woody debris and other instream cover, and a relatively low gradient (roughly 1-4%; e.g., sites JC18-13 to JC18-10 in 2018). There were also multiple off-channel habitats in this area that were seasonally connected to mainstem Jim Creek, some of which contained fish during summer base flows. This section of the stream supported the greatest diversity of fish species. The next section of the creek from the area downstream of the campgrounds to the bridge crossing Jim Creek (e.g. sites JC18-09 to JC18-06), was similar in slope, riparian vegetation, and substrate type, but it was highly channelized. This section had much less off-channel habitat, and instream cover consisted mostly of large boulders but little woody debris. Fish species collected this section were mostly Rainbow Trout, Coho Salmon, Torrent Sculpin, and Longnose Dace. The third section was the area within the antenna field which was highly altered due to the construction and on-going maintenance and operation associated with the radio antenna array. This section had a noticeable lack of riparian vegetation (other than small alders growing down in the creek channel), no natural bends or meanders, and very little instream cover other than large boulders. There was no off-channel habitat in this section as the stream was highly channelized and the banks were lined with rip-rap. The slope in this section was slightly greater than the downstream sections (roughly 5-6%). In this section of Jim Creek, Torrent Sculpin and Longnose Dace, which presumably cannot navigate steeper gradients, were rare. Upstream of the radio transmitter building (e.g. sites JC17-01 to JC17-03) where the creek flows through a steep canyon section, conditions are much more natural. Slope in this section was much greater (>10%), riparian vegetation was abundant, and there were several large boulders, woody debris, and plunge pools in the creek. There were some natural meanders and bends in the creek in this section, but little off-channel habitat was observed. Fish species observed were exclusively salmonids.

Figure 4. General habitat photos from four distinct sections of Jim Creek. Figure 8A shows typical habitat in the area near the downstream property boundary. Figure 8B shows typical habitat in the area downstream of and though the campgrounds. Figure 8C shows typical habitat in the area within the antenna field from the bridge crossing Jim Creek to the radio transmitter building. Figure 8D shows typical habitat in the canyon upstream of the radio transmitter building.

A diversity of habitat types is important for maintaining a diverse fish assemblage and for species of fishes such as ESA-listed salmonids that have complex life history patterns (Gorman and Karr 1978). Species such as Torrent Sculpin prefer low gradient riffles that facilitate foraging and do not contain small barriers or gradients that might impede upstream movements. Other species, such as Coho Salmon, may utilize pools and areas with low flows early in their life history, slightly faster moving waters with plenty of instream cover during juvenile phases, and fast moving waters with suitable spawning gravels when they are reproducing adults (Sandercock 1991; Quinn 2005). Jim Creek did have a variety of aquatic habitats within the Navy property boundary, and habitats ranged from relatively pristine in the furthest downstream and upstream sections to highly altered in the middle sections of the creek. Similar to other studies, the greatest diversity and highest relative abundances of fish were observed in areas with complex, relatively natural habitats. Several studies have demonstrated the benefits of localized stream restoration projects such as the addition of woody debris and renewed connections to floodplains and off-channel areas (Schmetterling and Pierce 1999; Roni et al. 2002; Roni 2019). The areas of Jim Creek near and downstream of the campgrounds may benefit from stream restoration work including the addition of woody debris that could facilitate the creation of pool habitat and reconnection to some off-channel areas. Stream habitat in the antenna array field was also highly altered, but it may be difficult to balance stream restoration activities in this section with the operation of the radio antenna array. Smaller-scale restoration practices, such as the placement of stumps and root wads as opposed to entire trees, may be more feasible in this area.

Invertebrate Surveys

BIBI scores, which are based on aquatic macroinvertebrate presence and abundance, provide a good means to assess the health of streams in the Pacific Northwest where fish assemblages are often somewhat limited (Karr 1998; Morley and Karr 2002; Larson et al. 2019). BIBI results suggest that Jim Creek within the boundaries of NRS(T) Jim Creek represents a relatively healthy aquatic ecosystem; nearly all sites had a BIBI score of 60 or above. These data seem to corroborate fish survey data that showed a relatively high diversity of species and an abundance of juvenile salmonids. The BIBI is largely influenced by the percent of sand and fine substrate in the stream (increased sand results in lower BIBI scores; Larson et al. 2019) and very little sandy substrate was documented in this study. Canopy cover is also an important variable influencing BIBI scores (Larson et al. 2019). Although there is very little canopy cover in the antenna field, there were no invertebrate collection sites directly in this area. The site nearest the antenna field (4S) was slightly downstream of the area where vegetation is managed and there was still healthy canopy cover at that site.

When BIBI scores from 2017 surveys were compared to the previous surveys conducted in 2008, seven showed a change in score and quality rating. Of those quality rating scores that did change, five were an increase in BIBI scores and two were a decrease. It is difficult to say what may have caused these changes. Previous surveys were conducted in October as opposed to August in this study, and seasonal changes in flows may have affected the presence of aquatic invertebrates. As noted above, site 9S in the current study was a different site than in 2008 because the original site was dry. Flow at the original site 9S may be highly dependent on seasonal precipitation and it’s feasible that the invertebrate community at this site changes annually as a result. Site 3S also showed a large increase in BIBI score and was similar to site 9S in that it was a small, higher elevation stream with very low flows where the invertebrate community could change from year to year based on seasonal precipitation.

The use of a standard scoring system for BIBI facilitated comparisons to other sites within the Stillaguamish River Watershed as well. A comparison between scores for NRS(T) Jim Creek and those reported to the Puget Sound Stream Benthos Website for the Stillaguamish Watershed (WRIA-5) from 2010 to the present (n = 76) showed that all but one of the Jim Creek sites had BIBI scores in top 50% of the scores reported. Across Puget Sound and Washington State, BIBI has been used to monitor the health of numerous watersheds. Morley and Karr (2002) reported BIBI results for 45 urban streams in Puget Sound and found that only 10% of sites were rated as good or excellent. Larson et al. (2019) reported BIBI scores for over 400 sites across Washington State and found that the highest proportion of streams in poor condition was in Puget Sound. The authors of both studies noted that many streams in this region are highly urbanized and habitat has been severely degraded due to development and other anthropogenic activities (Morley and Karr 2002; Larson et al. 2019). Jim Creek is within the Puget Sound Lowlands geologic province as defined by the Washington Department of Natural Resources, but it’s near the upper elevations (elevations in mainstem Jim Creek are approximately 150 - 200 m) near the transition zone to the Cascade Mountains region. As noted above, stream habitat in Jim Creek, and at invertebrate sample sites in particular, remains relatively natural. Comparisons to other studies in lower elevation, urbanized watersheds should be interpreted with these factors in mind.

Conclusions

Jim Creek supports a typical Puget Sound stream fish assemblage. Although it was not unexpected to find the four most common species there during our surveys (Rainbow Trout, Coho Salmon, Torrent Sculpin, Longnose Dace), the total number of fish species observed over the two sample years was somewhat higher than expected. There are likely additional fish species that utilize habitat in Jim Creek during some part of their life cycle (e.g., Chum Salmon) and future surveys may benefit from monitoring efforts across a greater period of the year compared to the summertime surveys presented here. This study also demonstrate the importance of sampling across multiple years as there were several species that were documented in 2017 but not 2018. Data on fish distribution and relative abundance in Jim Creek will be useful for state and federal natural resource agencies tasked with managing ESA-listed and recreationally important species within the Stillaguamish Basin and Puget Sound. Data on habitat and aquatic ecosystem health suggest that overall, Jim Creek contains a diversity of stream habitats and represents a relatively healthy stream. There were areas within NRS(T) Jim Creek where habitat conditions had been altered that may benefit from localized stream restoration projects. The data presented here provide a good baseline dataset for comparing the aquatic community in Jim Creek before and after any stream restoration that may occur.

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Appendices

Appendix I – See attached excel file for raw data from fish surveys (“Appendix I Fish Data 10-11-19.xlsx”)

Appendix II – See attached excel file for data from stream habitat surveys (“Appendix II Habitat data 10-11-19.xlsx”)

Appendix III – see attached excel file for raw data and summary statistics from aquatic invertebrate surveys (“2017 USFWS Jim Creek Invert Analysis.xlsx”)