U.S. Fish and Wildlife Service
Columbia River Fish and Wildlife Conservation Office

Monitoring of Native Fish in Tryon Creek

City of Portland FY 2012-2019 Final Report

Brook P. Silver, Julianne E. Harris, J. Michael Hudson, and Timothy A. Whitesel

U.S. Fish and Wildlife Service
Columbia River Fish and Wildlife Conservation Office
Vancouver, WA 98683

February 28, 2020

On the cover: *Measuring, weighing and tagging fish below the Highway 43 culvert (l to r Brook Silver, Jeff Everett, and Shauna Everett) photo by Theresa Thom 2019.*

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Abstract

Tryon Creek is a relatively undisturbed urban watershed located in southwest Portland, Oregon. The habitat is well suited for native fish; however, the lower portion of the stream is bisected by a culvert that runs under Oregon State Highway 43. To improve habitat and passage conditions for anadromous fish, a collaborative project retrofitted the culvert with a new baffle system, elevated the pool below the culvert, and enhanced floodplain habitat. From 2005-2019, the U.S. Fish and Wildlife Service worked with the City of Portland to assess the response of multiple species historically present, or believed to be present, in Tryon Creek. Goals were to evaluate fish 1) community, 2) relative abundance, and 3) residence time downstream of the Highway 43 culvert (confluence habitat), 4) estimate the population abundance of trout species upstream of the Highway 43 culvert and 5) investigate larval lamprey occupancy throughout the creek. Between 2012 and 2019, we handled a total 7,425 individual fish among 22 species in the confluence habitat. Native fish were the most abundant comprising 64% (n = 14) of the species captured and 99% (n = 7,351) of the individuals captured. The majority of juvenile anadromous salmonids (Chinook and Coho Salmon) captured in the confluence habitat were of wild origin from elsewhere in the Willamette River Basin (2,170/2,234), all other juvenile anadromous salmonids were hatchery-reared (likely from upstream Willamette River hatcheries). Juvenile Chinook and Coho Salmon were present in the confluence habitat throughout the year and the numbers captured peaked in the winter and spring months. Juvenile anadromous salmonids were detected emigrating from Tryon Creek a median 18 days after their initial capture in the confluence habitat. Salmonids exhibiting both resident and anadromous behaviors (Coastal Cutthroat Trout and hybrid trout) were detected emigrating from Tryon Creek a median 58 days after tagging in the confluence habitat. In 2019, the estimated abundance of trout in 1) Tryon Creek between the Highway 43 and the Boones Ferry Road culverts was 556 (95% CI [474, 660]) individuals, 2) 103 (95% CI [85, 130]) individuals upstream of the Boones Ferry Road culvert and below the SW Maplecrest Drive culvert in Tryon Creek as well as below SW Arnold Street in Arnold Creek, and 3) 63 (95% CI [45, 104]) individuals in Nettle Creek. Since 2005, multiple species of lamprey (primarily larval Pacific Lamprey) have been found in Tryon Creek downstream of the Highway 43 culvert but not upstream of the culvert.

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Table of Contents

List of Tables

List of Figures

Introduction

Tryon Creek is one of the largest (approximately 16.8 km^2), relatively protected, urban watersheds in Oregon (Callison et al. 2002). Native salmonid or anadromous species currently found in this stream include Coastal Cutthroat Trout (*Oncorhynchus clarki*), *O. mykiss* (resident Rainbow Trout and anadromous Steelhead Trout), Coastal Cutthroat Trout x *O. mykiss* hybrids (hybrid trout) (Tinus et al. 2003), Coho Salmon (*O. kisutch*), Chinook Salmon (*O. tshawytscha*) and Pacific Lamprey (*Entosphenus tridentatus*) (Hudson et al. 2008). Historically, Western Brook Lamprey (*Lampetra richardsoni*) may have utilized this stream. Certain species (e.g. Coastal Cutthroat Trout) currently spawn in Tryon Creek (see Hudson et al. 2008) whereas other species (e.g. Coho Salmon) spawned in Tryon Creek historically (see Tinus et al. 2003). In addition, many of these species (e.g. Chinook Salmon) are natal to watersheds further upstream in the Willamette River Subbasin but use Tryon Creek as temporary rearing habitat during their migrations (see Limm and Marchetti 2009). However, a culvert that currently runs under Oregon State Highway 43 and the adjacent railroad potentially inhibits, if not prevents, passage of lamprey and salmonids into upstream areas of Tryon Creek.

A collaborative project was implemented by the Oregon Department of Transportation (ODOT), Oregon Department of Fish and Wildlife (ODFW), Oregon State Parks, National Marine Fisheries Service, Cities of Portland and Lake Oswego, Friends of Tryon Creek, Tryon Creek Watershed Council, National Fish and Wildlife Foundation, and the U.S. Fish and Wildlife Service (USFWS) to improve passage conditions for multiple species historically present, or believed to be present, in Tryon Creek. The initial phase of the Tryon Creek Confluence Habitat Enhancement Project (Enhancement Project), conducted by ODOT in August 2008) retrofitted the existing culvert with a new baffle system to improve fish passage. The effort also provided habitat improvements downstream of the culvert, which included raising the level of the pool below the culvert to create a swim-in, rather than jump-in, situation thought to be more beneficial to lamprey and salmonid passage (Silver et al. 2014). In 2010, the City of Portland completed phase two of the Enhancement Project, which improved floodplain connectivity, removed invasive plant species, and installed root wads and boulders. The project included stream enhancement of approximately 300 m of Tryon Creek from its confluence with the Willamette River to the culvert under Oregon State Highway 43. The third phase of the Enhancement Project, if implemented, is a proposed replacement of the existing culvert.

The USFWS assessment and monitoring program is investigating the effectiveness of the Enhancement Project actions in three stages: 1) prior to the initial phase of culvert improvement; 2) after the first two phases but prior to the third phase; and 3) after the third phase (completed culvert replacement project). Stages 1 and 2 of assessment and monitoring are now complete. When stage 3 of the assessment and monitoring will occur is unclear. The focus of the assessment and monitoring program was originally directed at Pacific Lamprey in Tryon Creek. The first expansion of the program was to include salmonids then, in 2012, the USFWS and City of Portland Bureau of Environmental Services (BES) collaborated to further the program to include all fish species. This partnership supported the following objectives:

1. Assess fish abundance, community, and residence time of fish in the Tryon Creek confluence
    a. Estimate presence/absence and relative abundance of fish species present downstream of the Highway 43 culvert
        i. Conduct monthly sampling (seine/electrofish) from the Tryon Creek confluence to the Highway 43 culvert for City of Portland fiscal years 2013, 2015, 2017, and 2019.
        ii. Conduct weekly sampling (seine/electrofish) from the Tryon Creek confluence to the Highway 43 culvert in the springs of 2013, 2015, 2017, and 2019.
    b. Describe fish community throughout the year
    c. Document salmonid residence time
        i. Maintain a Passive Integrated Transponder (PIT) array at the mouth of Tryon Creek
2. Estimate relative abundance of salmonid species upstream of the Highway 43 culvert
    a. Conduct a two-pass abundance estimate of salmonid species between the Highway 43 culvert and Maplecrest Drive culvert in fall 2015 and 2019 (including parts of Arnold and Nettle creeks); conduct a single pass abundance estimate in fall 2013 and 2017
3. Determine larval lamprey distribution in Tryon Creek

Information collected from this assessment can aid the City of Portland in determining if the project is meeting its goals, evaluating if the site is achieving desired function over time, and improving the design of future projects.

Relationship to the U.S. Fish & Wildlife, Fish & Aquatic Conservation Program's Strategic Plan

Implementation of this project demonstrated the application of the Pacific Region's 2016-2020 Strategic Plan. The following National Goals (NG) and Objectives (O) were addressed by this project:

NG1 Conserve Aquatic Species

- O1.2 Identify population objectives and restoration criteria for declining species
- O1.4 Evaluate effectiveness of our conservation actions and adapt as necessary

NG2 Conserve, Restore, and Enhance Aquatic Habitats

- O2.3 Work with federal, tribal, state and other partners to implement additional actions to achieve landscape-scale habitat conservation objectives

NG5 Enhance Recreational Fishing and Other Public Uses of Aquatic

- O5.3 Increase recreational fishing and other public uses and enjoyment of aquatic resources

NG6 Increase Staffing Levels, Technical Capabilities, and Natural and Physical Assets to Fully Meet Our Mission

- O6.3 Enhance scientific capacity and technological tools necessary for conservation and management

NG7 Educate and Engage the Public and our Partners to Advance our Conservation Mission

- O7.1 Use communication tools to engage and educate the public in the Service's conservation mission
- O7.2 Conduct hands-on community-based recreation and education programs to engage the public in outdoor recreational activities and the Service's conservation mission
- O7.3 In partnership with other federal agencies, states, tribes, and the private sector, develop and implement a comprehensive and unified national public outreach and education strategy

Study Area

Tryon Creek is a 7.8 km, second order tributary to the Willamette River located in southwest Portland, OR (Figure 1). Its watershed includes two major tributaries (Arnold and Nettle creeks); covers 16.8 km^2 in Multnomah and Clackamas counties and its headwaters are located within suburban neighborhoods. The mainstem flows approximately 4 km through privately owned land including culverts at Taylors Ferry Road, SW 18th Place, SW Maplecrest Drive, and a perched pipe culvert at Boones Ferry Road before entering Tryon Creek State Natural Area. Tryon Creek State Natural Area is a 2.59 km^2 area of public land through which the stream flows another 3.5 km. A baffled box culvert bisects the lower portion of Tryon creek at Oregon State Highway 43 and a railroad near the mouth of Tryon Creek. The lowest portion of Tryon Creek flows 0.3 km through public land owned by the City of Lake Oswego and the City of Portland (confluence area) before entering the Willamette River at river kilometer 32.

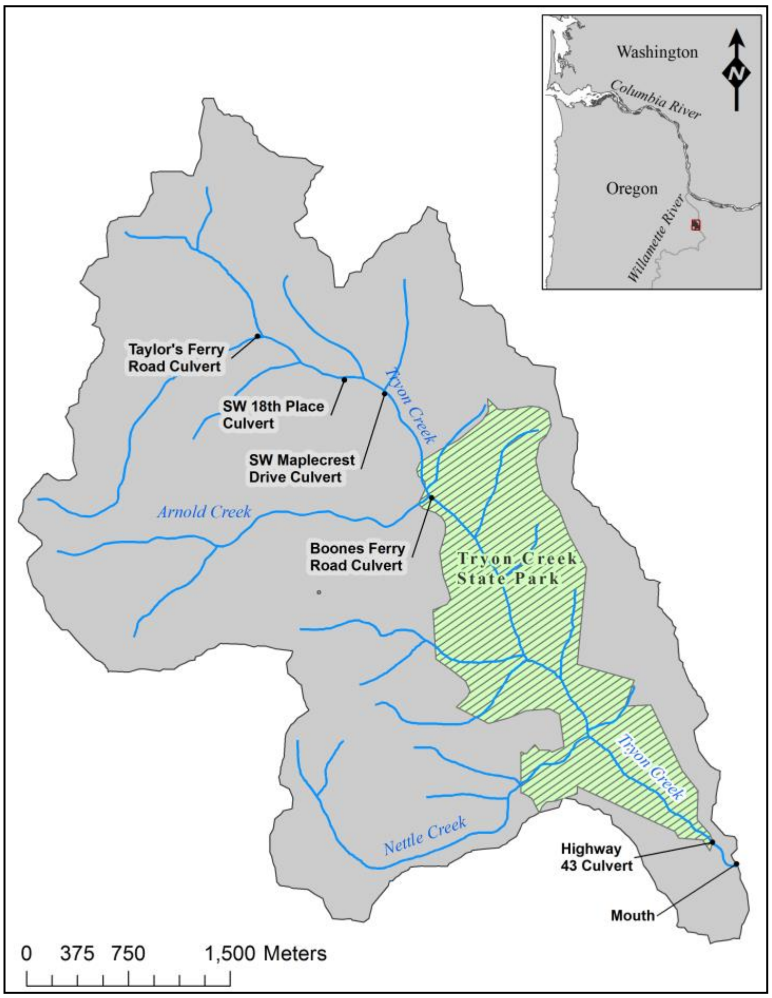

Figure 1. Tryon Creek watershed and major culverts.

The Highway 43 culvert was constructed in the late 1920s. It is approximately 122 m (401 ft.) long with a drop of nearly 6.7 m (22 ft.) from top to bottom, resulting in an average grade of 4.6% (Figure 2). Baffles located within the Highway 43 culvert provide structure, holding water for fish attempting to migrate upstream (Figure 3).

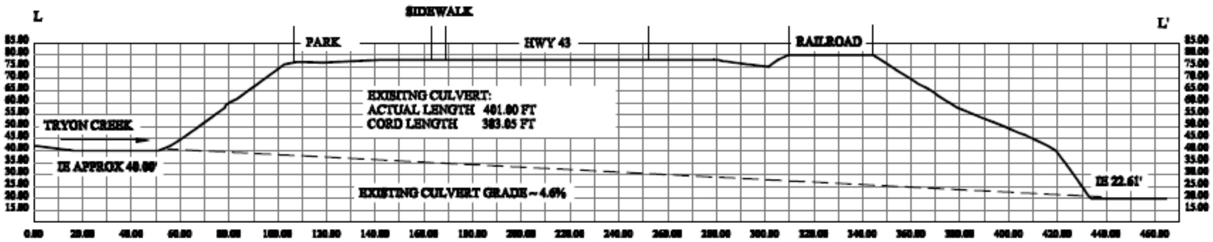

Figure 2. Longitudinal profile of Tryon Creek culvert under Oregon State Highway 43 (Henderson Land Services 2007).

Figure 3. In 2008, modified baffles were installed in the Highway 43 culvert to improve fish passage.

Methods

Downstream of the Highway 43 Culvert - Confluence Sampling

Fish Collection

Sampling in the confluence area occurred monthly July to March, and weekly April to June for the City of Portland's 2012 - 2013, 2014 - 2015, 2016 - 2017, and 2018 - 2019 fiscal years. Backpack electrofishing was conducted as described by Silver et al. (2016) from the mouth of Tryon Creek to the downstream edge of the Highway 43 culvert pool (Figure 4). The pool downstream of the Highway 43 culvert was sampled with a seine in two passes as described by Silver et al. (2016). We suspended electrofishing or seining if environmental conditions posed a safety risk to the field crew or prevented safe handling of fish (i.e. high flow > 20 cfs, temperature > 18 °C, or poor water visibility).

At the completion of each sample method, we anesthetized all captured fish in a bath containing 60 mg/l MS-222 and 60 mg/l sodium bicarbonate until we observed complete loss of equilibrium (3-4 minutes). When possible, each fish was identified to species, checked for any external markings, measured (fork length mm), weighed (g), and scanned for a PIT tag. We PIT-tagged all non-injured salmonids over 70 mm fork length if a PIT tag was not detected. We released all fish back into their capture reach after full recovery within an aerated bucket. Genetic samples were collected from the left pelvic fin of juvenile anadromous salmonids and Coastal Cutthroat Trout upon their initial capture. Tissue samples were less than 25% of the total fin area, measuring approximately two mm^2 and preserved in 99.98% ethyl alcohol. Samples are archived at the USFWS Columbia River Fish and Wildlife Conservation Office.

Oncorhynchus mykiss can have resident (Rainbow Trout) or anadromous (Steelhead Trout) life histories. Because Steelhead Trout have not been observed spawning in Tryon Creek, it is likely juvenile *O. mykiss* were from migrants that spawned elsewhere (hatchery or wild) and swam in to Tryon Creek. Juvenile *O. mykiss* captured in the Tryon Creek confluence habitat were not included in the juvenile anadromous salmonid analysis because we were unable to predict what life history they would assume.

Relative Abundance

We used catch per unit effort (CPUE) to determine fish abundance trends in the confluence habitat. Catch per unit effort is an index of relative abundance, which is often related to absolute abundance (Hubert and Fabrizio 2007; Pope et al. 2010). Theoretically, CPUE will increase with an increase in population size or abundance (N), assuming catch (C), effort (E), and catchability (q) remain relatively constant.

$$CPUE = \frac{C}{E} = Nq$$

If catchability varies (i.e. by season, number of crewmembers, temperature, time of day, flow, etc.), observed trends may not accurately indicate true changes in abundance.

Catch per unit effort was calculated differently for electrofishing and seining. For electrofishing, we recorded total sample time (in seconds) at the end of each survey. We then divided the total number of fish collected during the electrofishing survey by the number of seconds the survey lasted. For each seine, we divided the total number of fish collected by sampled pool volume in m^3 (pool width x pool length x seine max depth). Seine CPUE was averaged each sample event.

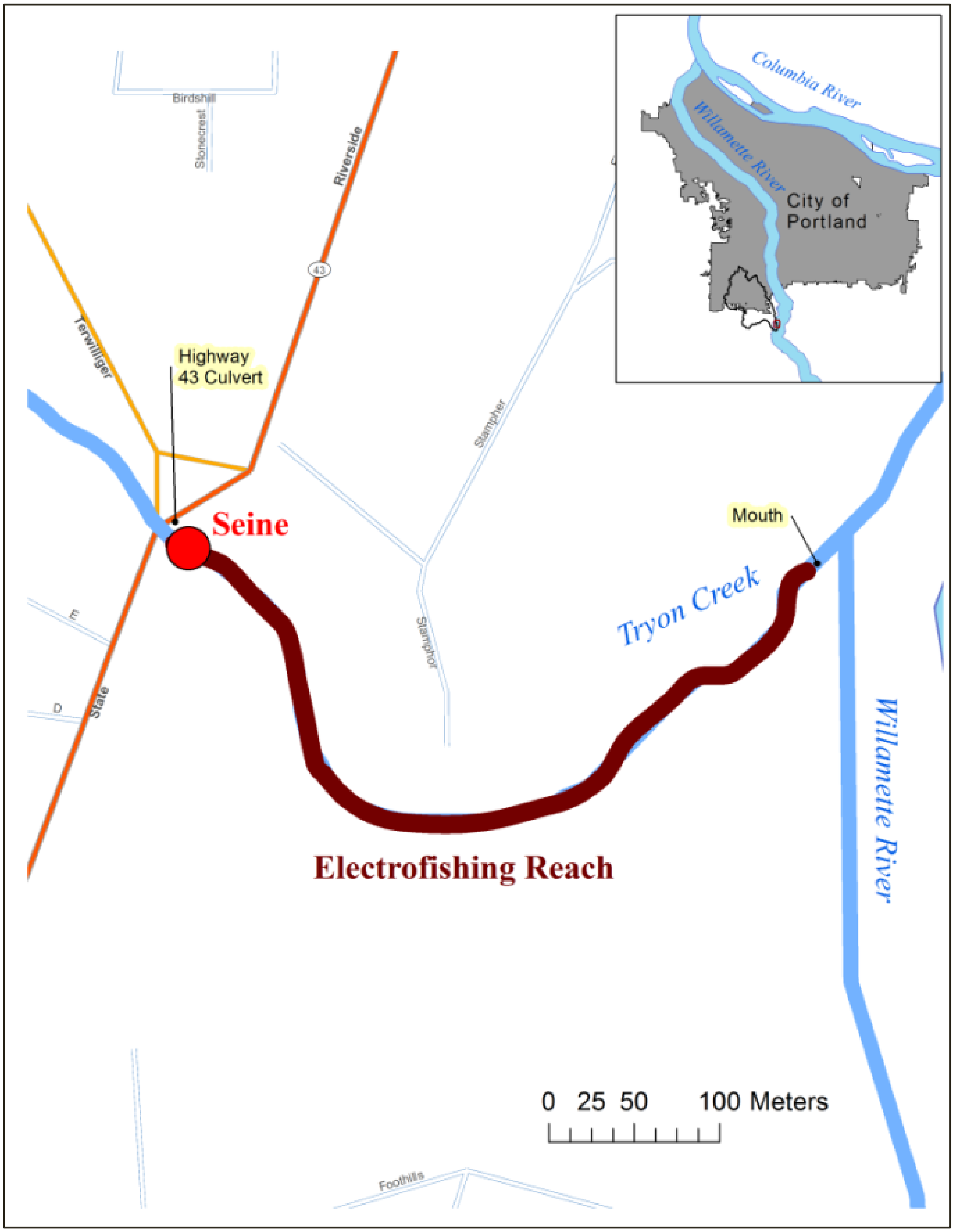

Figure 4. Tryon Creek confluence area monitoring reach

Community

We used the ratio of native to introduced fish, species diversity (Simpson Diversity Index), and relative abundance versus frequency of occurrence (ecological classification) to describe fish community.

Proportion of Native Fish

The total number of unmarked individual fish (recaptured fish excluded) captured by seining and electrofishing combined in the confluence area were categorized as “native” or “introduced” according to the Willamette Basin Atlas (Hulse et al. 2002). We calculated the proportion of native species to introduced species for both richness (number of species present) and abundance (number of fish present).

Species Diversity

The Simpson Index of Diversity (1-D) integrates the number of species within a sample area as well as the number of individuals of each species. This index represents the probability that two individuals randomly selected from a sample will belong to different species.

$$1 - D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right)$$

Where *n* is the total number of individual fish captured for a given species (electrofishing and seining combined) and *N* is the overall total number of individual fish captured for all species (electrofishing and seining combined). The index ranges from 0-1, with greater values representing greater the sample diversity, and it approaches 1.0 when numbers of individuals collected are evenly distributed among the number of species present (Delang and Li, 2013). Species diversity was calculated for each confluence sample event. Because we did not differentiate species of sculpin, we combined all species into one genus.

Ecological Classification

All species encountered in the confluence habitat (electrofishing and seining combined) were ecologically classified according to their abundance (relative to the total number of fish captured) and frequency (number of occurrences divided by number of sample events) for all years (González-Acosta 1998; González-Acosta et al. 2005). This method of classification is based on Olmstead-Tukey’s test (Sokal and Rohlf 1969) and allows an ecological and quantitative classification of the species (González-Acosta et al. 2005). The analysis results in the division of species present into four ecological categories (dominant, common, occasional, and rare) represented by quadrants of a scatter plot that is divided by two axes identifying the mean frequency of occurrence and mean relative abundance for a specific area.

Residence Time

We installed PIT tag antennas at the mouth of Tryon Creek in November 2011 (TCM). Efficiency was calculated in 2014 as described in Silver et al. (2015). Because the average efficiency of the antennas was 80.6% (the proportion of tags detected at both antennas and the number of tags detected at the downstream antenna), it is possible some PIT-tagged fish are not detected entering or leaving Tryon Creek. Therefore, we are unable to determine the direction of fish movements (i.e. entering or leaving) in Tryon Creek. PIT-tagged fish detected moving over or through these antennas could have been tagged after capture in Tryon Creek (as a direct part of this study) or outside of Tryon Creek (as part of other studies). If detected, the PIT tag code and time of detection was logged on a Biomark Multiplexing Transceiver (FS 1001M) from which data was downloaded on a monthly basis and uploaded to the Columbia Basin PIT Tag Information System (PTAGIS) online database. We queried PTAGIS to identify fish detected in Tryon Creek that were tagged and released by other agencies between 2012 and 2019. For all fish tagged or detected in Tryon Creek, we used PTAGIS to query for detections at all interrogation sites in the Columbia River Basin.

Upstream of the Highway 43 Culvert - Abundance Estimate

We estimated abundance and density (individuals/m) of trout (Coastal Cutthroat Trout and hybrid trout) > 100 mm in Tryon Creek using mark-recapture or single-pass electrofishing (as described by Silver et al. 2018). Seven sampling events took place between 2008 and 2019 (2008, 2009, 2011, 2013, 2015, 2017, and 2019) in two locations (l); the Highway 43 culvert to the Boones Ferry Road culvert (reaches 1-16) and the Boones Ferry Road culvert to the SW Maplecrest Drive culvert (in Tryon Creek) or to the SW Arnold Street culvert (in Arnold Creek) (reaches UTC1-UTC3 and AC1; Figure 5). The LR-24 electrofisher used pulsed direct current set at a frequency between 24 and 30 Hz, 12-18% duty cycle, and voltage between 250 and 450 V. All settings were subject to modification depending on conditions (i.e. water depth, conductivity, flow).

In 2008, 2011, 2015, and 2019, 2-pass electrofishing was completed. In these years (i), all cutthroat trout collected during the first pass for each location (l) were marked ($Cap1_{il}$) and released. For the second pass, the total number captured ($Cap2_{il}$) and the number marked during the first pass ($Recap_{il}$) were recorded. We calculated abundance for each of these years by location (N_{il}):

$$N_{il} = Cap2_{il}/2p_{il}$$

In 2009, 2013, and 2017, we completed single-pass electrofishing. Average capture probability ($m.p_l$) for each location (l) was calculated from annual estimates ($2p_{il}$) and abundance was calculated:

$$N_{il} = Cap1_{il}/m.p_l$$

We calculated density for each year and location by dividing each estimated abundance by the length of stream (m) sampled. We also calculated average density both upstream and downstream of the Boones Ferry culvert using all annual estimates.

In 2019, we also estimated abundance and density of trout Nettle Creek using mark-recapture between its confluence with Tryon Creek and the culvert at Atwater Road. The number of untagged fish in the second pass was not known exactly (due to a data recording error), the best estimate was 15 to 20 individuals; thus, the total number of untagged fish was estimated using a categorical model with equal probability assigned to all integer values 15-20. The estimated number untagged was added to the known number of recaptures to estimate the total number captured in the second pass. We estimated capture probability for the second pass ($2p_{il}$) with a binomial distribution:

$$Recap_{il} \sim Binomial(2p_{il}, Cap1_{il})$$

We evaluated model parameters using Bayesian methods with JAGS software (Plummer 2003) called from Program R (R Core Team 2013). We used Package jagsUI with function autojags (Kellner 2017) for 3 chains with 2,000 adaption iterations, 2,000 burn in iterations, and enough saved iterations (increments of 2,000) to reach convergence as assessed by Rhat scores of 1.1 or less for all estimated and calculated parameters (Gelman and Hill 2007; Kéry and Schaub 2012). Priors for capture probability (i.e.,$2p_{il}$) were uniform distributions over the range of 0-1. All posterior distributions are described by the median for central trend (i.e., estimate), and 95% credible intervals for precision.

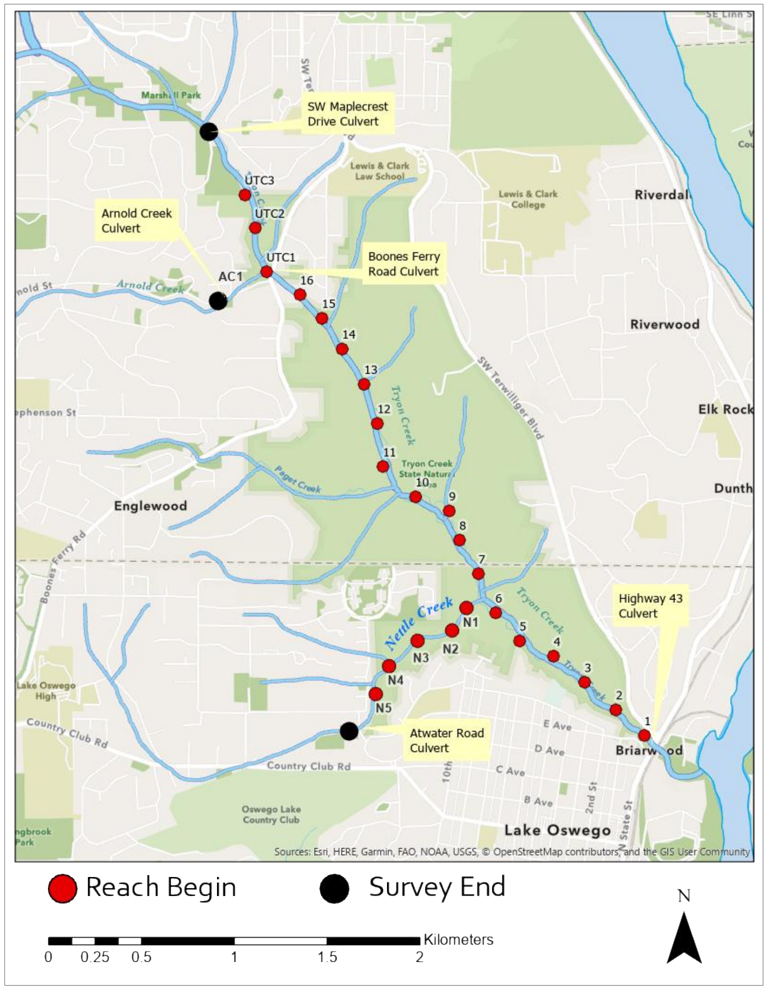

Figure 5. The Tryon Creek abundance estimate study area. Sixteen reaches between the Highway 43 culvert and the Boones Ferry Road culvert, and three reaches in Upper Tryon Creek between the Boones Ferry Road culvert and the SW Maplecrest Drive culvert (UTC3 was not sampled in 2015). One reach is located in Arnold Creek between Boones Ferry culvert and the SW Arnold Street culvert. Five reaches in Nettle Creek from the Tryon Creek confluence to the Atwater Road culvert.

Lamprey Occupancy

We assessed occupancy of larval Pacific and Western Brook Lamprey in Tryon Creek with an annual electrofishing survey. Detailed methods are described in Silver et al. (2013). In brief, we sampled the entire reach from the mouth of Tryon Creek to the Highway 43 culvert each year (except 2008) between 2005 and 2017. Between the Highway 43 culvert and Boones Ferry Road culvert, six 50 m-long, randomly selected, spatially-balanced reaches were sampled in July each year between 2009 - 2016 (Figure 6).

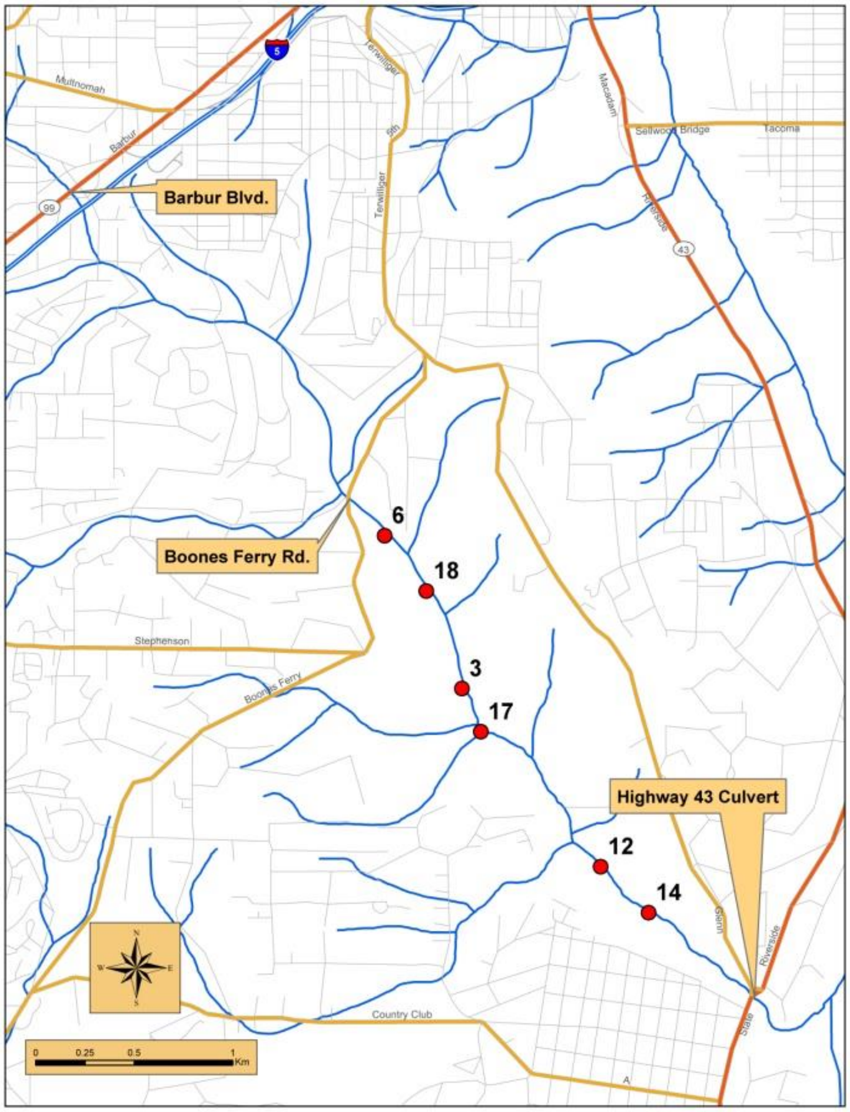

Figure 6. Lamprey survey sites in Tryon Creek between the Highway 43 culvert and Boones Ferry Road culvert (2009-2016).

Results

Downstream of the Highway 43 Culvert - Confluence Sampling

We sampled the confluence habitat on 81 occasions from 7/3/2012 to 6/13/2019. The habitat showed seasonal variation of water temperature and flow. In the spring and summer (March - August) it was relatively warm (mean = 12.6 °C) and flowing relatively slowly (mean = 4.3 cfs). In the fall and winter (September - February) it was relatively cold (mean 7.8 °C) with relatively high flows (mean = 5.5 cfs) (USGS 2019; Appendix A). Beaver dams constructed in the summers of 2014, 2016, and 2018 washed away during October storm events of the same years. These beaver dams did not appear to prohibit fish passage, as untagged, anadromous fish were present upstream in the pool downstream of the Highway 43 culvert.

Relative Abundance

Electrofishing effort ranged from 369 seconds to 1,547 seconds, seine effort was two hauls of the pool (volume = 225 m^3) for all 81 events except 4/4/2017 and 3/7/2019, when only one seine haul was completed (Appendix A). Electrofishing CPUE ranged from 0.01 to 0.28 individuals/second with a mean 0.09 (± 0.007 CE) individuals/second. Seine CPUE ranged from 0.0 to 0.39 individuals/m^3 with a mean 0.09 (± 0.008 SE) individuals/m^3 (Figure 7).

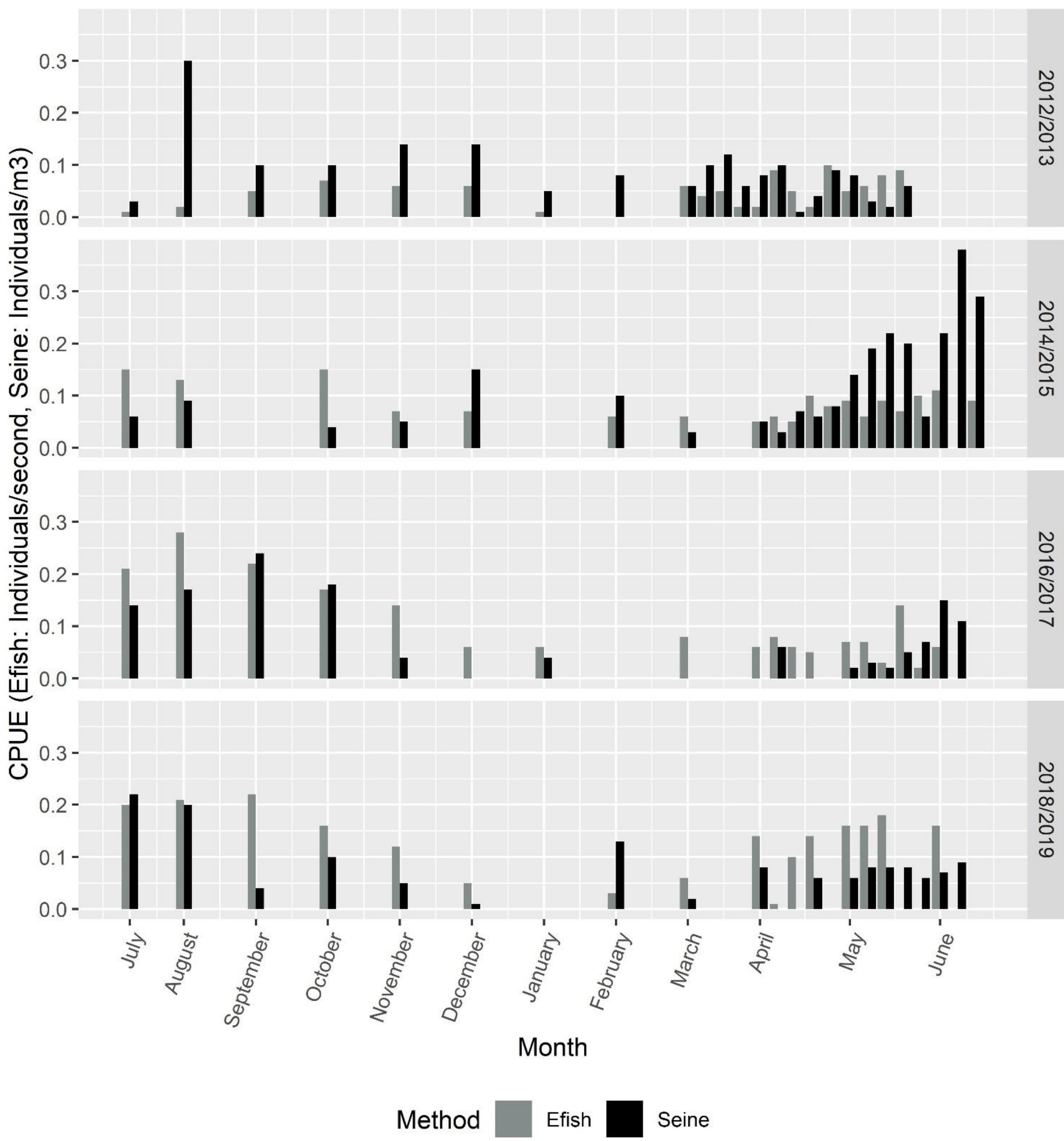

Figure 7. Catch per unit effort (electrofish: individuals/second, seine: individuals/m^3) for all sample events in the Tryon Creek confluence habitat 2012 - 2019.

Sculpin (*Cottus spp.*) were the most abundant genera followed by salmon and trout (*Oncorhynchus spp.)*: Coho Salmon, Chinook Salmon, Coastal Cutthroat Trout, hybrid trout, and *O. mykiss* (Figure 8). Genetic samples collected from salmonids were either archived at the CRFWCO or sent to Abernathy Fish Technology Center for analysis (n = 1,104) (Table 1).

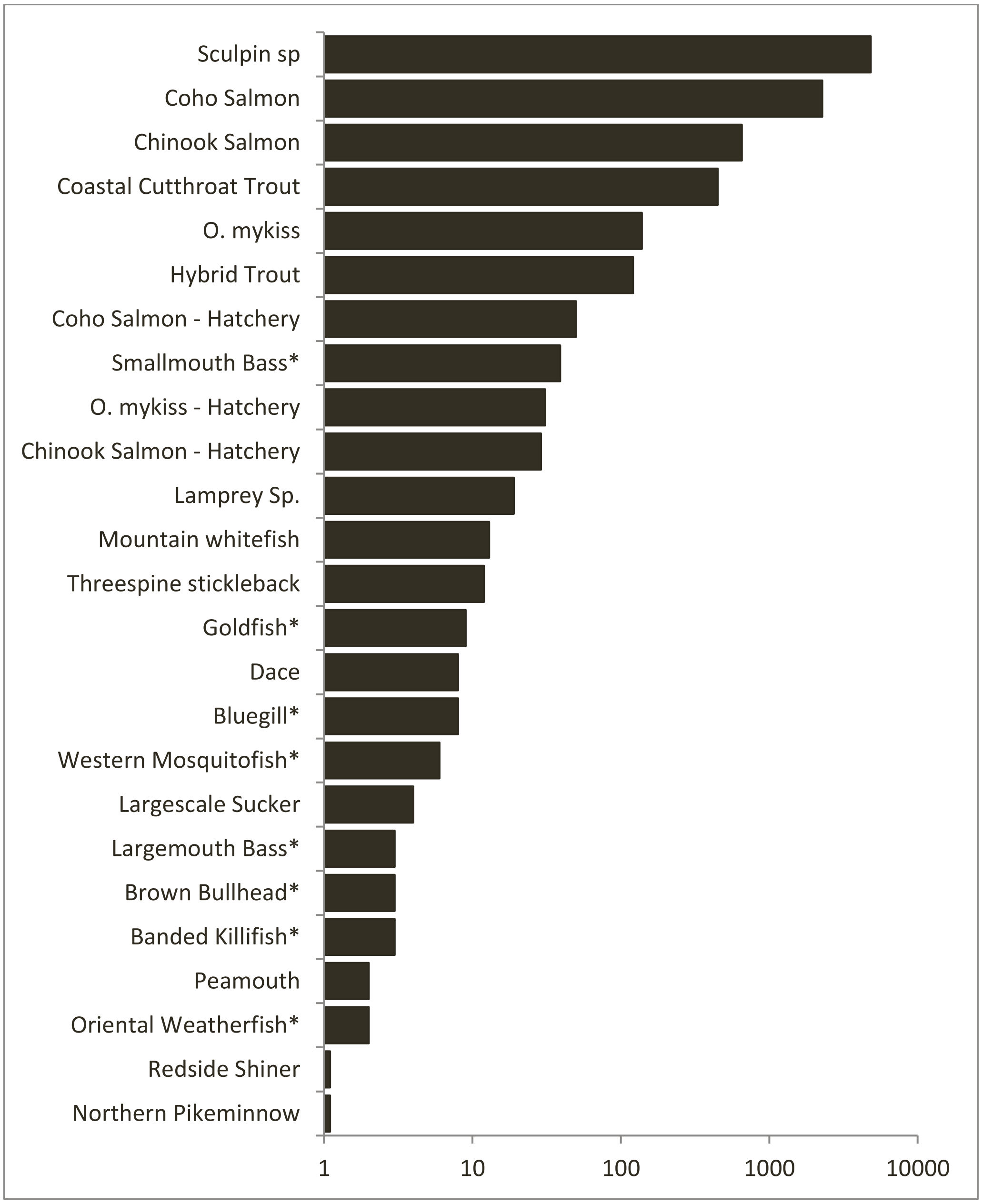

Figure 8. Total fish captured in the Tryon Creek Confluence habitat 2012 - 2019. *Introduced species

Table 1. Genetic Samples collected in the Tryon Creek confluence habitat 2013 – 2019

Species	2013	2014	2015	2016	2017	2018	2019	Total
Coastal Cutthroat Trout	5	1	6	--	1	--	--	**13**
Chinook Salmon	56	54	31	21	33	26	9	**230**
Chinook Salmon-Hatchery	4	1	--	--	2	--	--	**7**
Coho Salmon	103	68	334	65	40	76	100	**786**
Coho Salmon - Hatchery	2	1	--	--	--	--	3	**6**
Hybrid Trout	12	--	--	--	--	--	1	**13**
Pacific Lamprey	--	1	10	2	--	--	--	**13**
O. mykiss	14	1	4	--	10	--	3	**32**
Trout Fry	4	--	--	--	--	--	--	**4**
Total	**200**	**127**	**385**	**88**	**86**	**102**	**116**	**1,104**

Overall, we recaptured 36% (581/1,636) of PIT-tagged fish at least once. Coastal Cutthroat Trout and hybrid trout were recaptured at a relatively high and similar recapture rate (overlapping confidence intervals). Chinook Salmon and *O. mykiss* tended to be recaptured at a relatively low and similar recapture rates (overlapping confidence intervals). Mountain Whitefish and Trout Fry recapture rates were too few to warrant analysis (Table 2).

Table 2. Number of PIT-Tagged and recaptured salmonids in the Tryon Creek confluence habitat from 2012 - 2019

Species	# PIT Tagged	# Recap	Recapture Rate (95% CI range)	Size Class	Life History
Coastal Cutthroat Trout	162	87	0.54 (0.46-0.62)	Adult/Juvenile	Resident/Migrant
Chinook Salmon	327	69	0.21 (0.17-0.26)	Juvenile	Migrant
Coho Salmon	987	366	0.37 (0.34-0.40)	Juvenile	Migrant
Hybrid Trout	39	29	0.74 (0.58-0.87)	Adult/Juvenile	Resident
Mountain Whitefish	6	0	0.00	Juvenile	Migrant
O. mykiss	97	29	0.30 (0.21-0.40)	Adult/Juvenile	Resident/Migrant
Trout Fry < 100 mm	18	1	0.06	Juvenile	Resident/Migrant

Hatcheries in the Willamette River subbasin primarily use adipose fin clips to distinguish hatchery origin from natural origin fish. The majority (2,170/2,234 or 97%) of juvenile anadromous salmonids (Chinook and Coho Salmon) captured in the confluence habitat were unmarked and presumably of natural origin. At the mouth of Tryon Creek, juvenile Chinook Salmon and juvenile Coho Salmon were present throughout the year with CPUE peaking in the spring months (Figure 9).

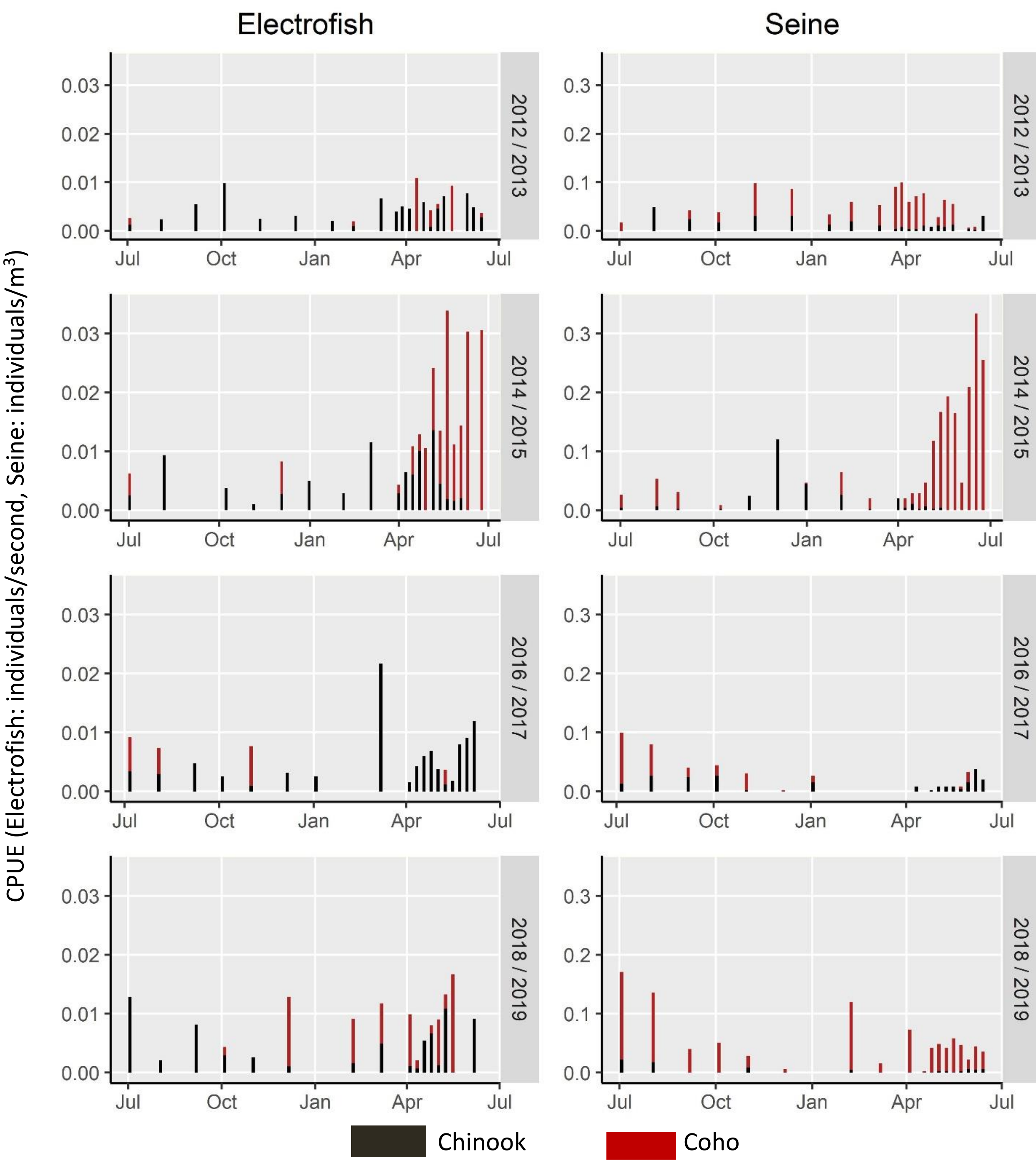

Figure 9. Total catch per unit effort (CPUE) (electrofish: individuals/second, seine: individuals/m^3) of wild anadromous salmonids sampled in the Tryon Creek confluence habitat in 2012 -2019

Community

Proportion of Native Fish

The fish community in the Tryon Creek confluence habitat included 22 species from which 7,425 individual fish were captured between 2012 and 2019 (unmarked fish, i.e. non-salmonids may have been captured more than once) (Table 3, Appendix B). Native fish comprised 64% (14/22) of the species captured and 99% (7,351/7,425) of the individuals captured.

Table 3. All species captured in the Tryon Creek Confluence Habitat 2012 - 2019. N = Native, I = Introduced

Family	Genus species	Common Name	Species Abbreviation	Origin (Native/ Introduced) (Hulse 2002)
Catostomidae	*Catostomus sp.*	Sucker	SUK	N
Centrarchidae	*Lepomis macrochirus*	Bluegill	BG	I
	Micropterus dolomieu	Smallmouth Bass	SMB	I
	Micropterus salmoides	Largemouth Bass	LMB	I
Cobitidae	*Misgurnus anguillicaudatus*	Oriental Weatherfish	OW	I
Cottidae	*Cottus sp.*	Sculpin	SCP	N
Cyprinidae	*Carassius auratus*	Goldfish	GF	I
	Mylocheilus caurinus	Peamouth	PEA	N
	Ptychocheilus oregonensis	Northern Pikeminnow	NPM	N
	Rhinichthys sp.	Longnose Dace	DCE	N
	Richardsonius balteatus	Redside Shiner	RSN	N
Cyprinodontidae	*Fundulus diaphanus*	Banded Killifish	BKF	I
Gasterosteidae	*Gasterosteus aculeatus*	Threespine Stickleback	SKB	N
Ictaluridae	*Ameiurus nebulosus*	Brown Bullhead	BBH	I
Petromyzontidae	*Entosphenus tridentatus*	Pacific Lamprey	PCL	N
Poeciliidae	*Gambusia affinis*	Western Mosquitofish	MQF	I
Salmonidae	*Oncorhynchus clarki*	Coastal Cutthroat Trout	CCT	N
	Oncorhynchus clarki/mykiss	Cutthroat/*O. mykiss* hybrid	HYB	-
	Oncorhynchus kisutch	Chinook Salmon	CHN	N
	Oncorhynchus mykiss	Steelhead/Rainbow Trout	OMY	N
	Oncorhynchus tshawytscha	Coho Salmon	COHO	N
	Prosopium williamsoni	Mountain Whitefish	WHF	N

Species Diversity

The mean (± SE) Simpson Index of Diversity (1-D) was 0.54 ± 0.02 and ranged from 0.16 to 0.78 (Figure 10, Appendix C). Across years, diversity was generally stable although showing seasonal patterns where it dropped slightly in fall (September – November) and was variable in spring (March – July).

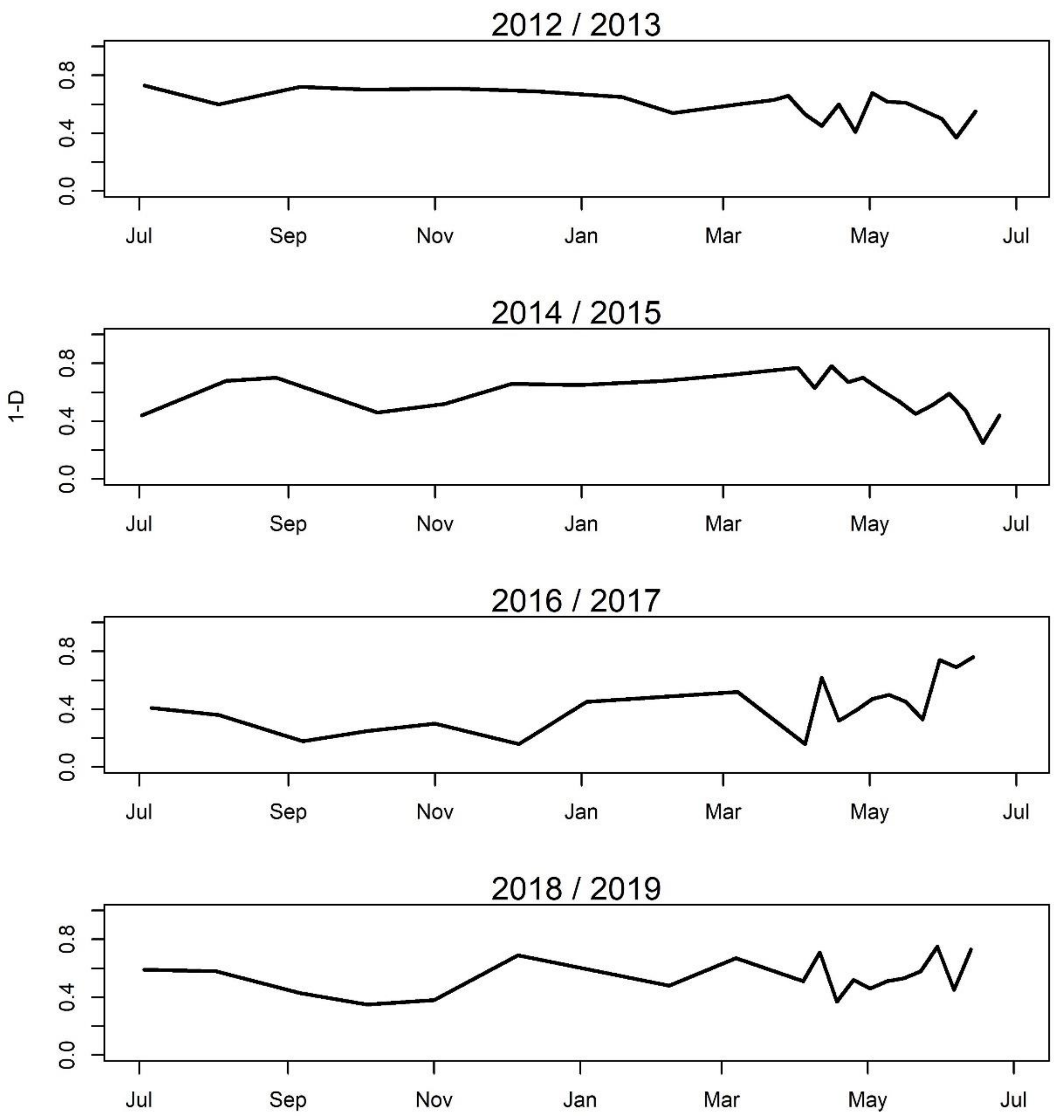

Figure 10. Simpson Index of Diversity (1-D) in the Tryon Creek confluence habitat

Ecological Classification

Ecological classification indicated Coho Salmon, Chinook Salmon, Coastal Cutthroat Trout and species of sculpin were dominant species for all years combined; their capture was frequent and in relatively high numbers (Figure 11). We captured common species, *O. mykiss* and hybrid trout, less frequently and in smaller numbers. All other species were classified rare because we captured them infrequently and in small numbers. The ecological classification of each species remained the same each year.

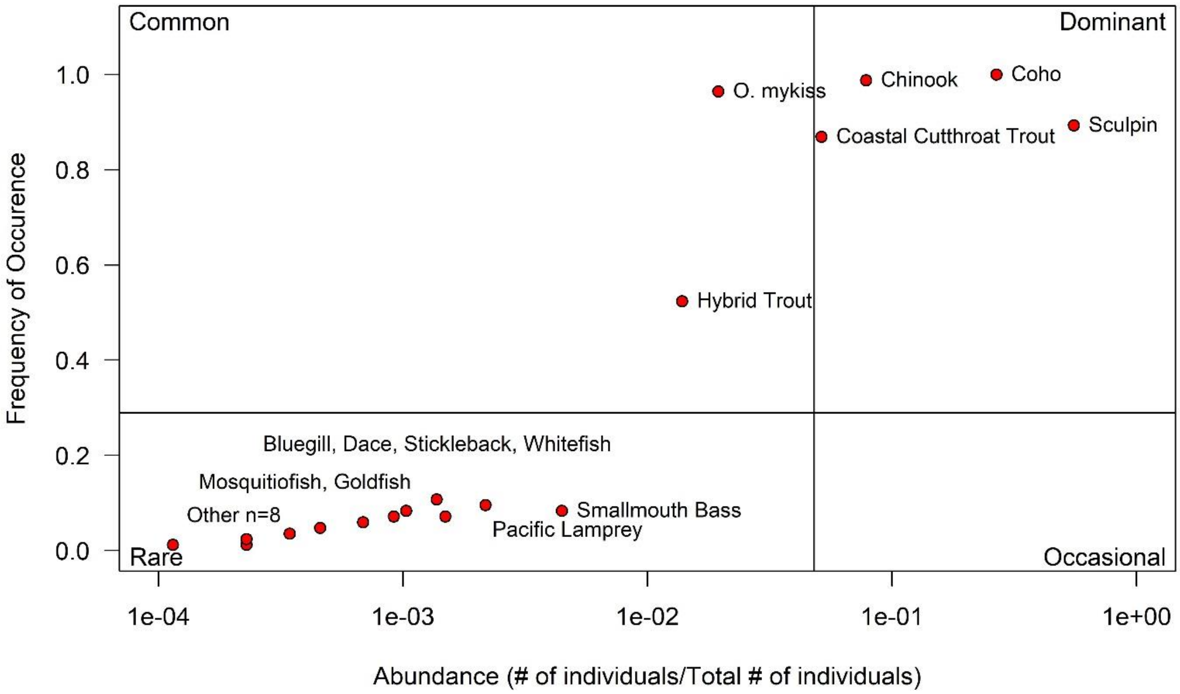

Figure 11. Ecological Classification of species captured in the Tryon Creek confluence habitat from 2012 - 2019. Abundance is the total number of individual fish of each species relative to the total number of fish captured for all species. Frequency of occurrence is the number of times a species occurred divided by the number of sample events for all years.

Residence Time

We installed the Tryon Creek Mouth (TCM) antenna site in November 2011, which monitored for PIT tags until July 2013. In February 2014, we reinstalled antennas and they were operational until a high water event (>600 cfs) washed out all but one antenna in December 2015. We installed replacements for two antennas in February 2016. A high flow event (>200 cfs) in October 2016 severed the cable for one antenna and was repaired that same month. We removed the antenna site in November 2019.

Between 2012 and 2019, 1,636 fish were PIT tagged in the confluence habitat (Table 4). The TCM antenna site had 31,409 detections of 801 unique PIT tags, 95% of all tags were detected less than 26 times. While the median number of detections for all PITs tag was two, the number of detections ranged from one to 15,201 (one Coastal Cutthroat Trout tagged in 2015 was detected at an antenna 15,201 times until December of 2015). Of the unique detections, 81% (650/801) were PIT tags implanted in juvenile anadromous salmonids (Chinook and Coho Salmon). The majority (772/801, 96%) of all PIT tags detected were from fish tagged in Tryon Creek in the confluence habitat. The peak of unique detections occurred in June for Coho Salmon, December for Chinook Salmon and April for Coastal Cutthroat Trout, *O. mykiss* and hybrid trout (Figure 12).

Table 4. Total number of individuals tagged by species and month in the confluence habitat 2012 – 2019.

	Coastal Cutthroat Trout	**Chinook Salmon**	**Coho Salmon**	**Hybrid Trout**	***O. mykiss***	**Trout Fry < 100 mm**	**Mountain Whitefish**	**Total**
January	3	14	21	1	2	--	--	**41**
February	7	17	104	2	1	1	1	**133**
March	7	13	38	2	10	1	--	**71**
April	43	18	71	10	39	1	--	**182**
May	21	29	110	9	16	2	--	**187**
June	7	27	251	1	7	--	--	**293**
July	31	24	161	4	4	--	--	**224**
August	32	29	53	4	2	1	3	**124**
September	5	8	1	1	2	--	--	**17**
October	3	22	19	4	1	1	2	**52**
November	--	35	74	1	2	5	--	**117**
December	3	91	84	--	11	6	--	**195**
Total	**162**	**327**	**987**	**39**	**97**	**18**	**6**	**1,636**

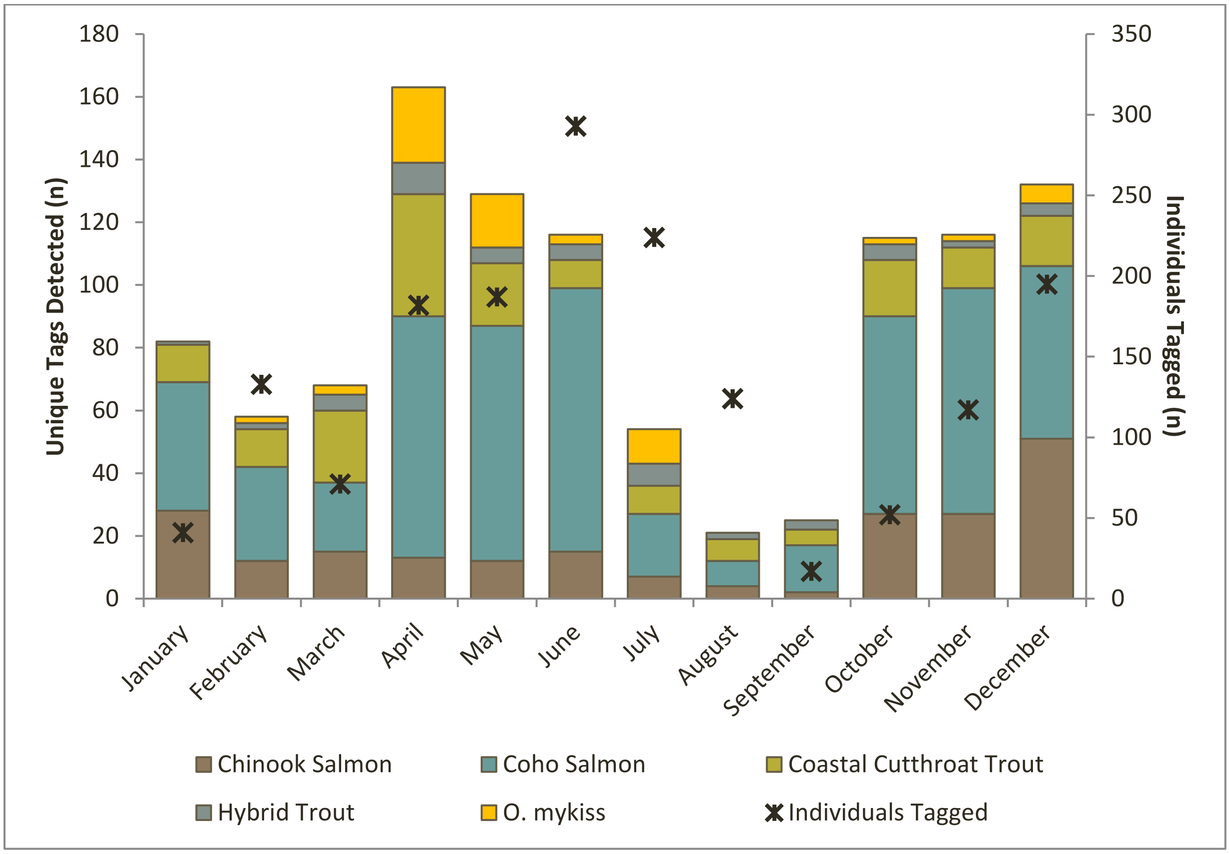

Figure 12. Number of unique PIT tag detections by month and species 2012 – 2019. Asterisks indicate total number of fish tagged by month for all years combined.

Detections of PIT tags (n = 624) from juvenile anadromous salmonids (Chinook and Coho Salmon) tagged in the Tryon Creek confluence habitat were detected by a TCM antenna a median 18 days after the date of tagging. PIT tags from salmonids exhibiting both resident and anadromous behaviors (i.e., Coastal Cutthroat Trout, *O. mykiss*, and hybrid trout) (n = 138) were detected by a TCM antenna a median 58 days after date of tagging. Median residence time of Coastal Cutthroat Trout and hybrid trout were significantly longer than Chinook Salmon, Coho Salmon and *O. mykiss*. Residence times of *O. mykiss* were not significantly different from Chinook or Coho Salmon; however, Coho Salmon residence times were significantly longer than Chinook Salmon (Table 5, Figure 13).

In the course of sampling the confluence habitat, we recaptured 35% (575/1,636) of tagged fish at least once. Eighty-seven Coastal Cutthroat Trout were recaptured after a median 42 days (range 6 – 1,044), 66 Chinook Salmon were recaptured after a median 34 days (range 6 – 219), and 364 Coho Salmon were recaptured after a median 28 days (range 6 – 303).

Table 5. Median number of days (and sample size) between date of tagging and last detection each year and median for all years in the Tryon Creek confluence habitat 2012 – 2019.

Tag Year	Coastal Cutthroat Trout	Chinook Salmon	Coho Salmon	Hybrid Trout	*O. mykiss*
2012	612 (4)	9 (22)	5 (42)	358 (2)	117 (3)
2013	591 (3)	510 (9)	554 (8)	278 (6)	199 (4)
2014	260 (25)	8 (53)	19 (50)	115 (2)	174 (2)
2015	26 (12)	15 (27)	11 (173)	27 (3)	16 (13)
2016	--	45 (14)	23 (46)	323 (1)	--
2017	41 (25)	10 (20)	17 (21)	--	9 (11)
2018	117 (3)	31 (13)	145 (49)	215 (1)	52 (3)
2019	23 (8)	24 (7)	40 (70)	75 (2)	15 (5)
Median	102[a]	15[b]	20[c]	174[a]	16[bc]

* Median values sharing the same letter are not significantly different (alpha = 0.05)

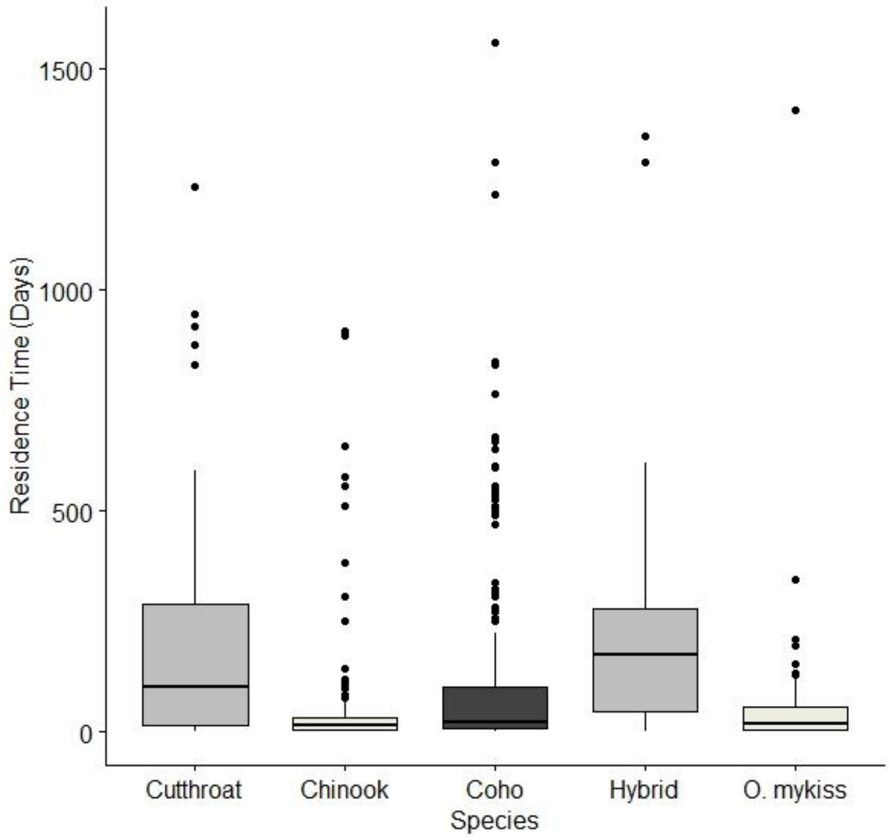

Figure 13. Median number of days between date of tagging and last detection by species for all years in the Tryon Creek confluence habitat 2012 – 2019. Boxplot box = interquartile range, horizontal line = 50th percentile (median), vertical lines = largest value within 1.5 times the interquartile range above 75th percentile and the smallest value within 1.5 times the interquartile range below the 25th percentile, dots = outside values >1.5 times interquartile range.

Movement

Between 2012 and 2019, the TCM antenna site detected 30 salmonids PIT-tagged and released upstream in tributaries to the Willamette River (Table 6). None of these fish were detected again after exiting Tryon Creek. Interrogation sites in the Columbia River detected 21 salmonids after they were PIT-tagged in the Tryon Creek confluence habitat (1.2% of fish tagged). Eight of these fish were detected in the Lower Columbia River, two were detected at Eagle Creek National Fish Hatchery, two were detected at the Clackamas River Mill Dam, and nine were mortalities on the East Sand Island Avian Colony (Table 7, Figure 14).

Travel time from last observation (PIT antenna, electrofishing or seining) in the Tryon Creek confluence habitat downstream to the Lower Columbia River PIT array was an average 12 days and ranged from 3 to 27 days. All last observations were in the spring between March 28 and May 4. Two adult Coho Salmon were detected in the fall (October and November) at Eagle Creek National Fish Hatchery between 10 and 20 months after they were tagged as juveniles in the Tryon Creek confluence habitat. Two adult Chinook were detected upstream in the Clackamas River Mill Dam adult ladder 2.5 and 3.25 years in August and May, respectively, after being tagged as out-migrating juveniles in Tryon Creek.

Table 6. Fish tagged in the Willamette River and detected entering Tryon Creek. No fish were detected at more than one observation site.

Release Year	Observation Year	Species Name	Release Site Name	Number of Fish
2012	2012	Chinook-Hatchery	Middle Fork Willamette	4
2013	2013	Chinook	Willamette River	1
	2014	Chinook-Hatchery	North Santiam River	1
2014	2014	Chinook-Hatchery	North Santiam River	8
	2015	Chinook-Hatchery	North Santiam River	3
2015	2015	Steelhead-Hatchery	South Santiam River	2
	2016	Chinook	McKenzie River	1
	2016	Chinook-Hatchery	North Santiam River	2
2016	2016	Chinook-Hatchery	Detroit Dam Forebay	1
	2016	Chinook	Leaburg Dam Bypass	1
	2016	Chinook-Hatchery	North Santiam River	1
	2016	Coho	Sullivan Dam Bypass	3
	2016	Steelhead	Sullivan Dam Bypass	1
	2017	Chinook-Hatchery	North Santiam River	1

Table 7. Fish tagged in the Tryon Creek confluence habitat and detected after leaving. Travel time days are from the last observation in Tryon Creek (PIT antenna, electrofishing or seining) to the first observation outside of Tryon Creek. No fish were detected at more than one observation site after leaving Tryon Creek.

Tag Year	Observation Year	Species Name	Observation Site	Number of Fish	Travel Time (days)
2012	2013	Coho	Eagle Creek NFH	1	321
	2014	Steelhead	East Sand Island [a]	1 (Mortality)	--
2013	2013	Coho	Estuary Towed Array	1	8
	2013	Coho	Estuary Towed Array	1	21
	2013	Hybrid Trout	East Sand Island	1 (Mortality)	--
	2013	Steelhead	Estuary Towed Array	1	5
	2014	Coho	Eagle Creek NFH	1	598
	2014	Steelhead	East Sand Island [a]	1 (Mortality)	--
2015	2015	Chinook	East Sand Island [a]	1 (Mortality)	--
	2015	Coho	East Sand Island [a]	2 (Mortality)	--
	2015	Cutthroat Trout	Estuary Towed Array	1	6
	2015	Steelhead-Hatchery	East Sand Island [a]	1 (Mortality)	--
	2015	Steelhead	Estuary Towed Array	1	3
	2017	Coho	East Sand Island [a]	1 (Mortality)	--
	2018	Chinook	Clackamas River Mill Dam	1	1,187
2017	2018	Coastal Cutthroat	East Sand Island [a]	1 (Mortality)	--
	2019	Chinook	Clackamas River Mill Dam	1	936
2019	2019	Coho	Estuary Towed Array	1	8
	2019	Coho	Estuary Towed Array	1	18
	2019	Coho	Estuary Towed Array	1	27

[a] Tags detected on East Sand Island do not necessarily reflect the year they were deposited; tags can be recovered several years after they were dropped.

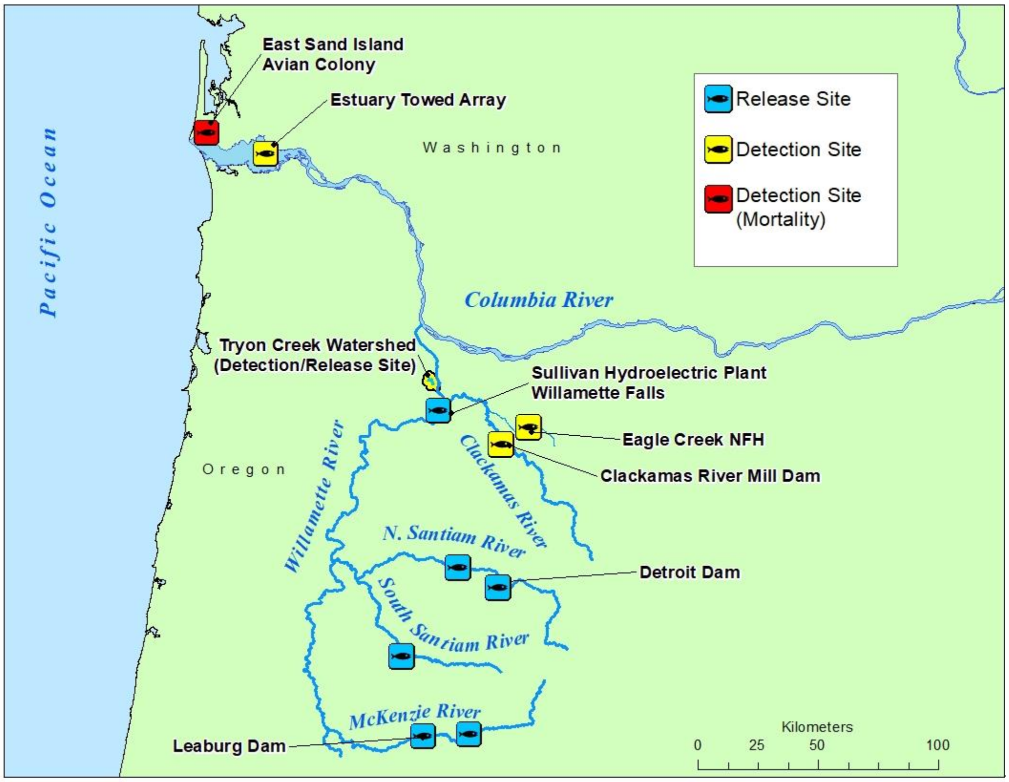

Figure 14. Detections of PIT-tagged salmonids associated with Tryon Creek from 2012 – 2019.

Upstream of the Highway 43 Culvert - Abundance Estimate

The most recent two-pass abundance survey occurred in 2019. The estimated abundance of trout (Coastal Cutthroat Trout and hybrid trout) > 100 mm between the Highway 43 culvert and the Boones Ferry Road culvert was 541 (95% CI [403, 779]) individuals and the estimated density was 0.033 (95% CI [0.025, 0.048]) individuals/m (Table 8, Figure 15). The estimated abundance of trout between the Boones Ferry Road culvert and the SW Maplecrest Drive culvert (Tryon Creek) and the SW Arnold Street culvert (Arnold Creek) was 66 (95% CI [50, 102]) individuals and the estimated density was 0.014 (95% CI [0.010, 0.021]) individuals/m (Table 9, Figure 15). From 2012 to 2018, mean density of trout downstream of Boones Ferry Road was 0.031 individuals/m, the 2019 estimate was 6% greater but not significantly different (overlapping confidence intervals) than the 2012-2018 mean. From 2012 to 2018, mean density of trout upstream of Boones Ferry Road was 0.020 individuals/m, the 2019 estimate was 30% less but not significantly different (overlapping confidence intervals) than the 2012-2018 mean. Capture probabilities between the Highway 43 culvert and Boones Ferry Road culvert were not significantly different in any year (range 0.21-0.28). Capture probabilities between the Boones Ferry Road culvert and SW Maplecrest Drive and SW Arnold Street culverts were not significantly different in any year (range 0.32-0.59). Capture probabilities between the Highway 43 culvert and Boones Ferry Road culvert were estimated to be significantly lower (95% confidence intervals do not overlap) than upstream of the Boones Ferry Road culvert in 2019

(0.26 versus 0.59). The length of trout in Tryon Creek ranged from 100 mm to 292 mm for all abundance estimates conducted from 2008 – 2019 (Figure 16).

As part of the mark recapture abundance estimate, Coastal Cutthroat Trout PIT tagged upstream of the Highway 43 culvert could be detected by antenna arrays downstream in the confluence habitat. Between 2008 and 2019, we PIT tagged 1,197 fish, of these, 7.4% (88/1,197) were detected in the confluence habitat a median 190 days (range 4 – 2,273) later. Of the 88 PIT tags detected by our antennas, one fish was observed returning after it was tagged upstream of the Highway 43 culvert 9/16/2009, detected in the confluence habitat 4/13/2010, and recaptured 10/6/2011 upstream of the Highway 43 culvert.

Table 8. Abundance (95% CI) and density (95% CI) estimates for Coastal Cutthroat Trout and hybrid trout) upstream of the Highway 43 culvert and downstream of the Boones Ferry Road culvert. Area = the estimated length of stream sampled by backpack electrofishing, $1p_i$ = capture probability in the first pass (95% CI), p_i was only calculated in years when two pass surveys were conducted.

Year	Length (m)	$1p_i$	Abundance	Density (fish/m)
2008	16,314	0.28 (0.22 – 0.36)	580 (459 – 758)	0.036 (0.028 – 0.046)
2009	16,314		413 (351 – 493)	0.025 (0.022 – 0.030)
2011	16,314	0.21 (0.15 – 0.28)	623 (467 – 890)	0.038 (0.029 – 0.055)
2013	16,314		728 (619 – 869)	0.045 (0.038 – 0.053)
2015	10,981*	0.23 (0.13 – 0.34)	163 (108 – 277)	0.015 (0.010 – 0.025)
2017	16,314		417 (355 – 498)	0.026 (0.022 – 0.031)
2019	16,314	0.26 (0.18 – 0.35)	541 (403 – 779)	0.033 (0.025 – 0.048)
Mean		0.25 (0.18 – 0.33)	556 (474 – 660)	0.034 (0.027 – 0.037)

* Beaver dams or low water prevented sampling entire length of habitat in 2015 and is excluded from the mean abundance estimate

Table 9. Abundance (95% CI) and density estimates (95% CI) for Coastal Cutthroat Trout and hybrid trout upstream of the Boones Ferry Road culvert and downstream of the SW Maplecrest Drive culvert (Tryon Creek) and SW Arnold Street culvert (Arnold Creek). Area = the estimated length of stream sampled by backpack electrofishing, $1p_i$ = capture probability in the first pass (95% CI), p_i was only calculated in years when two pass surveys were conducted.

Year	Length (m)	$1p_i$	Abundance	Density (Fish/m)
2008	4,866	0.39 (0.28 – 0.51)	160 (121 – 226)	0.033 (0.025 – 0.046)
2009	4,866		95 (78 – 122)	0.020 (0.016 – 0.025)
2011	4,866	0.32 (0.18 – 0.49)	100 (65 – 179)	0.021 (0.013 – 0.037)
2013	4,866		89 (72 – 114)	0.018 (0.015 – 0.023)
2015	1,312*	0.45 (0.18 – 0.74)	15 (9 – 36)	0.012 (0.007 – 0.028)
2017	4,866		100 (81 – 128)	0.021 (0.017 – 0.026)
2019	4,866	0.59 (0.38 – 0.78)	66 (50 – 101)	0.014 (0.010 – 0.021)
Mean		0.43 (0.28 – 0.59)	103 (85 – 130)	0.021 (0.016 – 0.030)

* UTC03 not sampled in 2015 due to construction on private property and is excluded from the mean abundance estimate

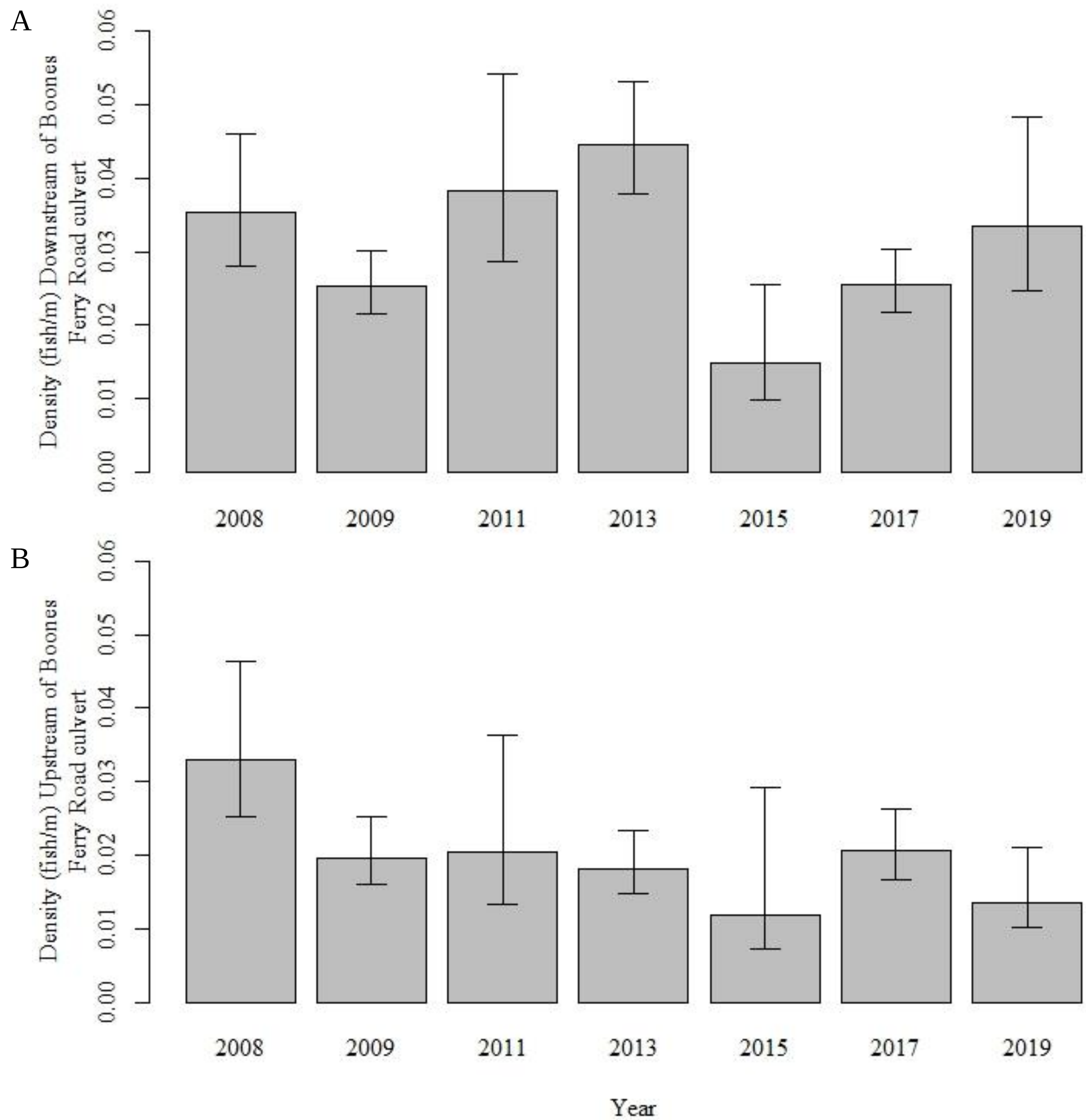

Figure 15. Estimated density (with 95% credible intervals) of Coastal Cutthroat Trout and hybrid trout upstream of the Highway 43 culvert. Estimates are for (A) between the Highway 43 culvert and Boones Ferry Road culvert and (B) between the Boones Ferry Road culvert and the SW Maplecrest Drive culvert and SW Arnold Street culverts 2008 – 2019

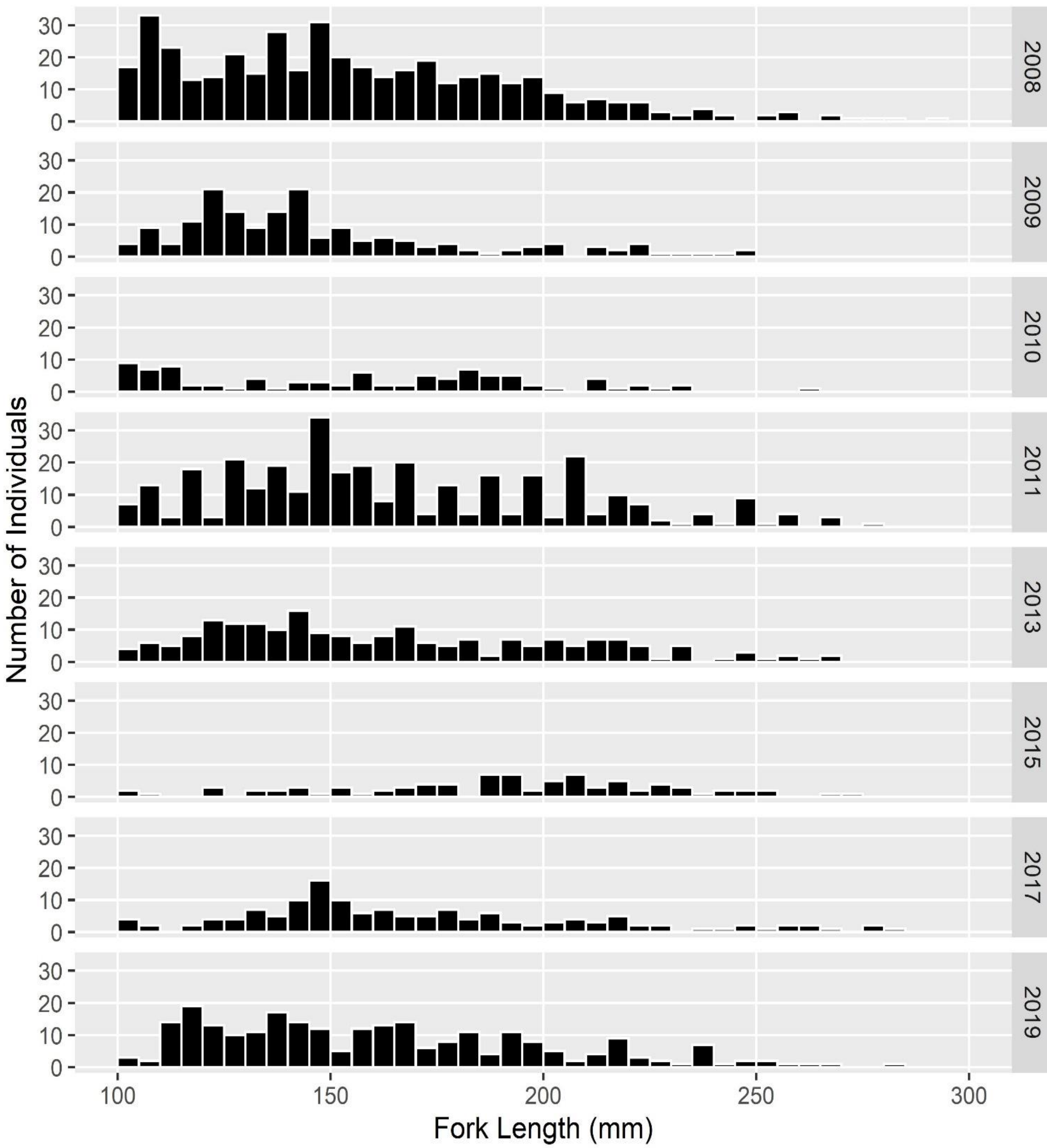

Figure 16. Length-frequency histogram of trout captured in Tryon Creek between the Highway 43 culvert and the SW Maplecrest Drive and SW Arnold Creek culverts 2008 – 2019.

Nettle Creek - Abundance Estimate

In 2019, we conducted a two-pass abundance survey of Nettle Creek. The estimated abundance of trout (Coastal Cutthroat Trout and hybrid trout) > 100 mm between the Tryon Creek confluence and Atwater Road culvert was 63 (95% CI [45, 104]) individuals, the estimated density was 0.062 (95% CI [0.044, 0.102]) individuals/m with a capture probability of 0.47 (95% CI [0.28, 0.64], Figure 17, Table 10). A length/frequency histogram of trout in Nettle Creek shows a range of sizes from 108 mm to 205 mm (Figure 18).

Figure 17. Nettle Creek survey end at Atwater Road Culvert

Table 10. Abundance (95% CI) and density (95% CI) estimates for trout (Coastal Cutthroat Trout and hybrid trout) in Nettle Creek between its confluence at Tryon Creek and Atwater Road culvert. Area = the estimated area length of stream sampled by backpack electrofishing, 1*pi* = capture probability in the first pass (95% CI).

Year	Length (m)	$1p_i$	Abundance	Density (Fish/m)
2019	1,019	0.47 (0.28 – 0.64)	63 (45 – 104)	0.062 (0.044 – 0.102)

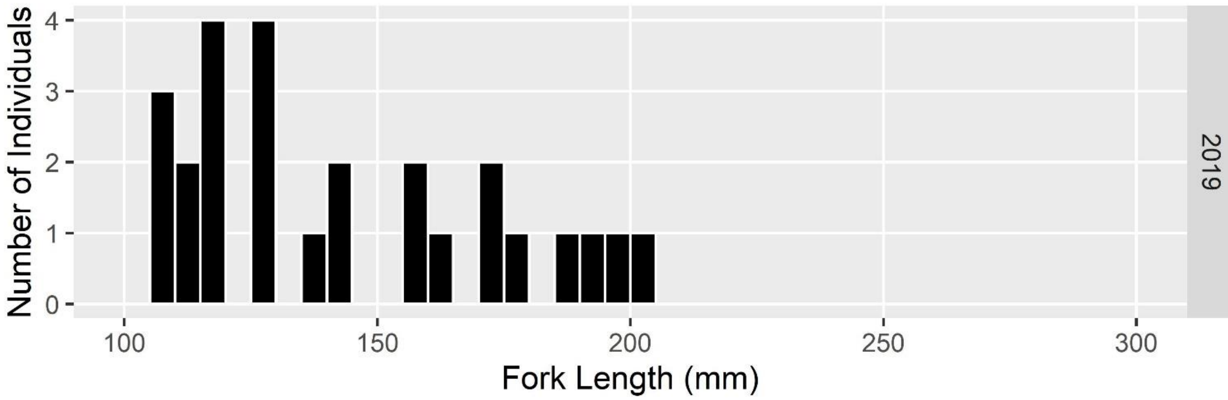

Figure 18. Length-frequency histogram of trout captured in Nettle Creek between its confluence at Tryon Creek and below the Atwater Road culvert in 2019

Lamprey Occupancy

Between 2005 and 2017, 29 larval Pacific Lamprey, one western brook lamprey and six larval lamprey of unknown species were caught in targeted lamprey surveys in the Tryon Creek confluence habitat and zero were caught upstream of the Highway 43 culvert (Table 11). In 2013, we tagged and released 1,046 larval Pacific Lamprey into Tryon Creek upstream of the Highway 43 culvert as part of an experimental translocation of (Silver, 2014). That same year, six lamprey were collected upstream of the Highway 43 culvert and had visible tags. Three lamprey were also collected upstream of the Highway 43 culvert in 2014 and 2015 but did not have visible tags. During the 2016 larval lamprey occupancy survey one larval Pacific Lamprey was caught in the Tryon Creek confluence habitat and zero lamprey were captured upstream of the Highway 43 culvert. In 2017, one larval Pacific Lamprey was caught in the Tryon Creek confluence habitat; occupancy sampling upstream of the culvert did not occur. No lamprey sampling occurred in 2018 or 2019. Overall, larval Pacific Lamprey have been detected eight out of the 12 (75% of the) years of lamprey electrofishing in the Tryon Creek confluence habitat.

Table 11. Number of larval Pacific Lamprey collected downstream or upstream of the Highway 43 culvert from 2005 - 2017.

Sample Year	Downstream of the Highway 43 Culvert	Upstream of the Highway 43 Culvert
2005	1 (+ 6 unidentified larvae)	N/A
2006	26	N/A
2007	0 (+1 Western Brook Lamprey)	N/A
2009	0	0
2010	0	0
2011	2	0
2012	0	0
2013	4	6
2014	1	1
2015	10	2
2016	1	0
2017	1	N/A

Discussion

The Tryon Creek confluence habitat appears to play a substantial role supporting native fish. Native fish species, including salmonids, were present throughout the year and were far more abundant than non-native fish species. In the Tryon Creek confluence habitat, we identified 14 native species and 8 introduced species (2012 - 2019); the Willamette Basin contains 31 native species and 29 introduced species (Hulse et al. 2002). Our ecological classification in the confluence habitat indicated all native species are dominant or common, which suggests conditions are suitable for native species below the Highway 43 culvert. Currently, all fish species upstream the Highway 43 culvert are native. Planned improvements to passage conditions under the Highway 43 culvert may permit the possible movement of introduced species upstream into the Tryon watershed. It will be valuable to sample upstream the Highway 43 culvert to document potential changes in species distribution, including non-native (invasive) species after passage improvements are completed. The relatively extensive use of the confluence habitat by salmonids and other native fish demonstrates the potential value of off-channel habitat in urban areas, and can help us understand habitat enhancement actions that promote recovery and conservation.

The confluence habitat in Tryon Creek is important to both migratory and resident species throughout the year. In winter, flooding of the Willamette River creates strong currents and migrating juvenile salmonids need access to floodplains that contain slower moving water (Schroeder et al. 2014). In February 2017, the USGS reported the highest flows (837 cfs) in the Willamette River since our confluence sampling began in 2012 (USGS 2017). That same spring, we observed Chinook Salmon fry (age-0, < 40 mm) which may have been displaced from their natal streams by high water (Hartman et al. 1982). However, we did not capture as many juvenile Coho overwintering in the pool below the Highway 43 culvert as previous years; this could be due to abundant backwater pools throughout the inundated Willamette River floodplain. Although likely good for fish, deep water created by beaver dams in 2015 and flooding in 2017 prevented us from effectively backpack electrofishing and sampling the confluence habitat where we typically capture multiple species of fish. Because we were not able to sample the habitat entirely, it is likely we underestimated the number of fish present, which could explain the lower CPUE we observed. In summer, Tryon Creek provides cold-water refuge for salmon (for example, in June 2015, mean water temperature in the Willamette River was 22 °C, Tryon Creek mean water temperature was 15 °C [Silver et al. 2016; USGS 2017]). Beaver dams, when present, are known to create habitat suitable for juvenile salmon by raising the water level, creating large pools where sediment is deposited, and lowering the water temperature (Bouwes et al. 2016).

Non-natal Chinook and Coho Salmon utilize the Tryon Creek confluence during their migrations. Adult salmonids may use Tryon Creek as refuge during their upstream migration and their offspring may use Tryon Creek as refuge during their downstream migration. With the exception of Coastal Cutthroat Trout, there has been little to no evidence of native salmonids spawning in Tryon Creek. Thus, juvenile Chinook and Coho Salmon using the confluence habitat did not originate in Tryon Creek. In other words, run-of-the-river fish from the Willamette River subbasin appeared to use the Tryon Creek confluence habitat as temporary rearing or holding habitat. This finding is similar to previous reports of juvenile salmonids using non-natal tributaries as refuge habitat during their migration to the Pacific Ocean (Limm and Marchetti 2009). In addition, this helps to emphasize the potential importance of non-natal habitat to native fish.

In spring, we observed a pattern of lowered diversity when non-natal juvenile salmonids arrived in abundance and dominated the community. The connection to confluence habitat may provide these juvenile salmonids growth benefits (Sommer et al. 2001; Jeffres et al. 2008) and maximize their life history diversity thus increasing their potential for survival (Greene et al. 2010; Takata et al. 2017). Juvenile anadromous salmonids also had the shortest median residence times (15 – 20 days) compared to Coastal Cutthroat Trout (102 days), which do not typically migrate far from their home river. While the majority of Coastal Cutthroat Trout in Tryon Creek appear to express a resident life history, seven percent of PIT tags from fish tagged upstream of the Highway 43 culvert were detected in the confluence habitat. One of these fish was then recaptured back upstream of the Highway 43 culvert 541 days later potentially exhibiting fluvial or anadromous migratory behavior. The Tryon Creek confluence habitat and its connectivity to the Willamette River plays an important role allowing Coastal Cutthroat Trout to migrate between local populations (see Bohling et al. 2018) and may allow them to successfully respond to environmental changes over long-time periods (Griswold 2009).

Salmonids from urban streams, including Tryon Creek, likely move throughout the Columbia and Willamette River Basins. This migration can be rapid as evidenced by juvenile salmonids can migrating from Tryon Creek to the Lower Columbia River in as few as three days. A towed PIT antenna array in the Lower Columbia River detected eight fish (five Coho Salmon, two *O. mykiss*, and one Coastal Cutthroat Trout) between 3 and 27 days after their last observation in the confluence habitat. In addition to PIT tags observed by the towed array, nine PIT tags were recovered from East Sand Island, an avian colony where ocean birds nest at the mouth of the Columbia River. It is likely birds deposited these tags on the island after consuming juvenile fish as the fish migrated toward the Pacific Ocean. Three fish tagged as juveniles in the confluence habitat were detected as adults at Eagle Creek National Fish Hatchery and at the Clackamas River Mill Dam between one and three years later. Detections of tagged fish may continue for several years as fish mature, potentially migrate, or as tags are recovered. It is important to note that shed PIT tags (i.e. not in a fish) can move downstream during high flow events in later years. These shed tags may account for false positives when detected by our antennas and would lengthen the time between PIT tag date and last detection. In 2013, our antennas detected 30 fish, of which, 16 (53%) were detected during high flow events 100 - 600 cfs more than a year later; these unusually long residence times are anomalies and may not be reflective of fish.

Tryon Creek provides habitat that can support lamprey species. In the Tryon Creek confluence, we found evidence of lamprey (primarily larval Pacific Lamprey) eight out of 12 consecutive years of sampling (2005-2017). Surveys upstream of the Highway 43 culvert had negative results for the presence of lamprey for seven consecutive years (2010 – 2016). Although lamprey do not appear to pass upstream of the Highway 43 culvert, the habitat appears viable. After experimentally outplanting larval lamprey upstream of the Highway 43 culvert in 2013, we proceeded to observe these fish for multiple years. Based on the size and location of the larvae as well as the challenges adults would encounter to migrate upstream through the Highway 43 culvert, it is most likely that they were larvae from the outplanting. This suggests if adults did access and spawn upstream of the Highway 43 culvert successfully, the habitat may be able to support larval rearing. However, evidence continues to suggest that lamprey cannot pass the Highway 43 culvert, or, are not attracted to the upstream area (i.e. zero observations of age-0 lamprey and no evidence of nests, carcasses, or live adults during spawning during spawning season). Consequently, until passage or attraction conditions change, additional monitoring for naturally-produced lamprey upstream of the Highway 43 culvert is not warranted.

Upstream of the confluence habitat, the Coastal Cutthroat Trout in Tryon Creek exhibits characteristics of an established population. While there is natural variation between years, the population appears relatively stable (estimated abundance ranged 413-728 individuals between the Highway 43 culvert and Boones Ferry Road culvert, 66-160 individuals upstream of the Boones Ferry Road to the SW Maplecrest Drive culvert, and 63 individuals in Nettle Creek). Density variations are not uncommon; Duffy and Bjorkstedt (2008) observed average population density varied seasonally with habitat type and stream location. The density of the Tryon Creek population was within the range of population densities observed in non-urban areas, albeit at the low end (Silver et al. 2017). Density of fish is likely a function of environmental conditions, movement, interannual survival variability, or limits to carrying capacity (Duffy and Bjorkstedt 2008; Minto et al. 2008). Tryon Creek's relatively stable Coastal Cutthroat Trout density and full use of its habitat suggests the population is abundant enough to persist through ecological time and maintain its abundance near capacity (Connolly et al. 2008).

Nettle Creek, a tributary to Tryon Creek, may be high quality habitat for Coastal Cutthroat Trout. In 2019, we estimated the abundance of Coastal Cutthroat Trout in Nettle Creek and found it had a higher density of Coastal Cutthroat Trout (0.062 individuals/m) than Tryon Creek (range 0.012 - 0.045 individual/m). Coastal Cutthroat Trout were found both upstream and downstream of the former site of the Stone Bridge culvert. A bridge replaced the undersized culvert in 2014 and boulder grade-control structures created pools and suitable for fish habitat and passage. Our survey ended downstream of a perched culvert at Atwater Road that may limit upstream movement. Restricted passage at this culvert could result in loss of spawning and rearing habitat upstream and overall reduced productivity (Burford et al. 2009). Expanding the monitoring to areas upstream of the Atwater Road culvert would allow an evaluation of Coastal Cutthroat Trout characteristics (i.e. length frequency, density, and presence/absence) and assessment of the extent of passage impairment.

This report summarizes work characterizing the fish in Tryon Creek, an urban stream, and serves to provide a baseline for future assessments. While monitoring of Tryon Creek has concluded for the first two phases of the Highway 43 culvert replacement project, a post-assessment of the completed culvert replacement will be valuable. If passage conditions change, the fish community in Tryon Creek may also change. Access to upstream habitat could shift the proportion of native and introduced fish, increase the presence and abundance of migratory and resident salmonids, and could result in the presence of lamprey. Future monitoring will be useful to document changes over time, determine if the project has met its goals, and improve the design of future projects.

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Appendix A: Sample conditions and catch per unit effort (CPUE) for all sample events in the Tryon Creek confluence habitat (2012 - 2019)

Sample Date	Water Temp (C°)	Flow (cfs)*	Sample Method	Seine Effort (pool volume m^3, hauls)	EFish Effort (sec)	Fish Captured (n)	EFish individuals/second	Seine individuals/m^3
07/03/2012	14.3	2.5	Electrofish		758	8	0.01	
07/03/2012	14.3	2.5	Seine	225, 2		14		0.03
08/03/2012	14	1.5	Electrofish		1238	28	0.02	
08/03/2012	14	1.5	Seine	225, 2		138		0.31
09/06/2012	14.8	1	Electrofish		1106	58	0.05	
09/06/2012	14.8	1	Seine	225, 2		45		0.10
10/04/2012		0.5	Electrofish		1217	84	0.07	
10/04/2012		0.5	Seine	225, 2		48		0.11
11/08/2012		3	Electrofish		806	45	0.06	
11/08/2012		3	Seine	225, 2		64		0.14
12/13/2012		15	Electrofish		965	54	0.06	
12/13/2012		15	Seine	225, 2		65		0.14
01/18/2013		5	Electrofish		1428	10	0.01	
01/18/2013		5	Seine	225, 2		24		0.05
02/08/2013		6	Electrofish		1018	5	< 0.00	
02/08/2013		6	Seine	225, 2		40		0.09
03/07/2013		8.5	Electrofish		1193	67	0.06	
03/07/2013		8.5	Seine	225, 2		31		0.07
03/22/2013		7	Electrofish		1265	51	0.04	
03/22/2013		7	Seine	225, 2		48		0.11
03/28/2013		4	Electrofish		1195	61	0.05	
03/28/2013		4	Seine	225, 2		56		0.12
04/04/2013		3	Electrofish		1089	17	0.02	
04/04/2013		3	Seine	225, 2		30		0.07
04/11/2013		5	Electrofish		1099	20	0.02	
04/11/2013		5	Seine	225, 2		40		0.09
04/18/2013		3.5	Electrofish		1022	90	0.09	
04/18/2013		3.5	Seine	225, 2		46		0.10
04/25/2013		3	Electrofish		1184	62	0.05	
04/25/2013		3	Seine	225, 2		5		0.01
05/02/2013		2.5	Electrofish		1076	20	0.02	
05/02/2013		2.5	Seine	225, 2		18		0.04
05/08/2013		2	Electrofish		701	70	0.10	
05/08/2013		2	Seine	225, 2		43		0.10
05/16/2013		2	Electrofish		1076	57	0.05	
05/16/2013		2	Seine	225, 2		39		0.09
05/31/2013		5	Electrofish		1547	94	0.06	
05/31/2013		5	Seine	225, 2		16		0.04
06/06/2013		2.6	Electrofish		1241	95	0.08	
06/06/2013		2.6	Seine	225, 2		13		0.03
06/14/2013		2.5	Electrofish		1089	93	0.09	
06/14/2013		2.5	Seine	225, 2		31		0.07
07/02/2014	17.5	1.7	Electrofish		796	118	0.15	
07/02/2014		1.7	Seine	225, 2		29		0.06
08/06/2014	16.6	0.7	Electrofish		427	54	0.13	
08/06/2014	16.6	0.7	Seine	225, 2		43		0.10
08/27/2014	17	0.5	Seine	225, 2		40		0.09
10/08/2014	13.9	0.9	Electrofish		800	118	0.15	
10/08/2014		0.9	Seine	225, 2		18		0.04
11/05/2014	13.3	7.5	Electrofish		952	65	0.07	
11/05/2014	13.3	7.5	Seine	225, 2		23		0.05

Sample Date	Water Temp (C°)	Flow (cfs)*	Sample Method	Seine Effort (pool volume m^3, hauls)	EFish Effort (sec)	Fish Captured (n)	EFish individuals/second	Seine individuals/m^3
12/03/2014	4.4	4.7	Electrofish		724	48	0.07	
12/03/2014	4.4	4.7	Seine	225, 2		68		0.15
12/31/2014	1.7	4.5	Electrofish		597	14	0.02	
12/31/2014	1.7	4.5	Seine	225, 2		41		0.09
02/04/2015	8.9	10	Electrofish		681	42	0.06	
02/04/2015	8.9	10	Seine	225, 2		48		0.11
03/04/2015	4.9	3.9	Electrofish		522	30	0.06	
03/04/2015	4.9	3.9	Seine	225, 2		14		0.03
04/01/2015	8.9	5.5	Electrofish		691	35	0.05	
04/01/2015	8.9	5.5	Seine	225, 2		25		0.06
04/08/2015	10.4	4	Electrofish		932	58	0.06	
04/08/2015	10.4	4	Seine	225, 2		14		0.03
04/15/2015	6.7	5.7	Electrofish		829	45	0.05	
04/15/2015	6.7	5.7	Seine	225, 2		33		0.07
04/22/2015	9.7	3.9	Electrofish		698	67	0.10	
04/22/2015	9.7	3.9	Seine	225, 2		27		0.06
04/28/2015	13.4	3.6	Electrofish		665	50	0.08	
04/28/2015	13.4	3.6	Seine	225, 2		38		0.08
05/06/2015	11	3.1	Electrofish		663	59	0.09	
05/06/2015	11	3.1	Seine	225, 2		66		0.15
05/13/2015	11.6	3.4	Electrofish		889	53	0.06	
05/13/2015	11.6	3.4	Seine	225, 2		86		0.19
05/20/2015	13.4	2.4	Electrofish		532	49	0.09	
05/20/2015	13.4	2.4	Seine	225, 2		99		0.22
05/27/2015	12.7	2	Electrofish		628	41	0.07	
05/27/2015	12.7	2	Seine	225, 2		90		0.20
06/03/2015	14.4	3	Electrofish		488	50	0.10	
06/03/2015	14.4	3	Seine	225, 2		27		0.06
06/10/2015	15.2	1.7	Electrofish		593	67	0.11	
06/10/2015	15.2	1.7	Seine	225, 2		103		0.23
06/17/2015	14.5	1.4	Seine	225, 2		175		0.39
06/24/2015	15.8	1.1	Electrofish		720	67	0.09	
06/24/2015	15.8	1.1	Seine	225, 2		131		0.29
07/06/2016	14.6	0.9	Electrofish		871	186	0.21	
07/06/2016	14.9	0.9	Seine	225, 2		66		0.15
08/03/2016	14.9	0.6	Electrofish		680	188	0.28	
08/03/2016	14.9	0.6	Seine	225, 2		79		0.18
09/07/2016	15.2	1.5	Electrofish		1250	275	0.22	
09/07/2016	15.2	1.5	Seine	225, 2		110		0.24
10/04/2016	12.4	1.1	Electrofish		1169	195	0.17	
10/04/2016	12.4	1.1	Seine	225, 2		82		0.18
11/01/2016	12	5	Electrofish		1041	145	0.14	
11/01/2016	12	5	Seine	225, 2		20		0.04
12/06/2016	7.2	18	Electrofish		947	57	0.06	
12/06/2016	7.2	18	Seine	225, 2		1		0.00
01/03/2017	1.6	6.83	Electrofish		1148	68	0.06	
01/03/2017	1.6	6.83	Seine	225, 2		21		0.05
03/07/2017	7.3	21	Electrofish		600	46	0.08	
04/04/2017	9	10	Electrofish		649	42	0.06	
04/04/2017	9	10	Seine	225, 1		3		0.01
04/11/2017	8.7	7.76	Electrofish		692	53	0.08	
04/11/2017	8.7	7.76	Seine	225, 2		28		0.06
04/18/2017	11.4	10.9	Electrofish		495	31	0.06	
04/18/2017	11.4	10.9	Seine	225, 2		2		0.00
04/25/2017	10.8	16.1	Electrofish		730	40	0.05	

Sample Date	**Water Temp (C°)**	**Flow (cfs)***	**Sample Method**	**Seine Effort (pool volume m³, hauls)**	**EFish Effort (sec)**	**Fish Captured (n)**	**EFish individuals/second**	**Seine individuals/m³**
04/25/2017	10.8	16.1	Seine	225, 2		3		0.01
05/02/2017	11.2	8.02	Electrofish		795	57	0.07	
05/02/2017	11.2	8.02	Seine	225, 2		10		0.02
05/09/2017	12.8	6.03	Electrofish		818	54	0.07	
05/09/2017	12.8	6.03	Seine	225, 2		15		0.03
05/16/2017	11.3	13.6	Electrofish		1127	35	0.03	
05/16/2017	11.3	13.6	Seine	225, 2		9		0.02
05/23/2017	14.6	5	Electrofish		997	137	0.14	
05/23/2017	14.6	5	Seine	225, 2		23		0.05
05/30/2017	14.1	3.63	Electrofish		661	12	0.02	
05/30/2017	14.1	3.63	Seine	225, 2		34		0.08
06/06/2017	14.2	2.84	Electrofish		588	37	0.06	
06/06/2017	14.2	2.84	Seine	225, 2		70		0.16
06/13/2017	12.7	5.18	Seine	225, 2		53		0.12
07/03/2018	13.4	0.9	Electrofish		781	154	0.20	
07/03/2018	13.4	0.9	Seine	225, 2		100		0.22
08/02/2018	17.5	0.62	Electrofish		490	101	0.21	
08/02/2018	17.5	0.62	Seine	225, 2		88		0.20
09/06/2018	15	1.57	Electrofish		369	83	0.22	
09/06/2018	15	1.57	Seine	225, 2		19		0.04
10/04/2018	12.1	1.53	Electrofish		686	111	0.16	
10/04/2018	12.1	1.53	Seine	225, 2		44		0.10
11/01/2018	12.8	1.7	Electrofish		1147	134	0.12	
11/01/2018	12.8	1.7	Seine	225, 2		24		0.05
12/06/2018	3.8	1.67	Electrofish		934	46	0.05	
12/06/2018	3.8	1.67	Seine	225, 2		5		0.01
02/07/2019	0.8	7.16	Seine	225, 2		57		0.13
02/07/2019	0.8	7.16	Electrofish		1212	39	0.03	
03/07/2019	4.6	2.99	Seine	225, 1		7		0.03
03/07/2019	4.6	2.99	Electrofish		1020	58	0.06	
04/04/2019	10.8	3.31	Seine	225, 2		38		0.08
04/04/2019	10.8	3.31	Electrofish		906	126	0.14	
04/11/2019	9.8	17	Electrofish		1456	10	0.01	
04/18/2019	10.3	7	Seine	225, 2		2		0.00
04/18/2019	10.3	7	Electrofish		733	70	0.10	
04/25/2019	10.3	4.38	Seine	225, 2		29		0.06
04/25/2019	10.3	4.38	Electrofish		751	104	0.14	
05/02/2019	10.9	2.54	Seine	225, 2		29		0.06
05/02/2019	10.9	2.54	Electrofish		774	120	0.16	
05/09/2019	14.4	2.13	Seine	225, 2		35		0.08
05/09/2019	14.4	2.13	Electrofish		830	130	0.16	
05/16/2019	13.5	2.69	Seine	225, 2		35		0.08
05/16/2019	13.5	2.69	Electrofish		479	86	0.18	
05/23/2019	13.5	3.15	Seine	225, 2		34		0.08
05/30/2019	14.5	1.64	Seine	225, 2		25		0.06
06/06/2019	14.5	1.22	Seine	225, 2		32		0.07
06/06/2019	14.5	1.22	Electrofish		764	122	0.16	
06/13/2019	18	1.04	Seine	225, 2		41		0.09

* Data retrieved from U.S. Geological Survey WaterWatch (USGS 2019). Gauging station moved downstream in February 2017.

Appendix B: Fish Captured in the Tryon Creek confluence habitat (recaptured fish) (2012 - 2019)

Date	Banded Killifish*	Bluegill*	Brown Bullhead*	Chinook Salmon	Coastal Cutthroat Trout	Coho Salmon	Dace	Goldfish*	Hybrid Trout	Largemouth Bass*	Largescale Sucker	Mountain whitefish	Northern Pikeminnow	O. mykiss	Oriental Weatherfish*	Lamprey sp.	Peamouth	Redside Shiner	Sculpin sp.	Smallmouth Bass*	Threespine stickleback	Western Mosquitofish*
7/3/2012				1	4	10			4 (1)					2								
8/3/2012			1	25	7 (1)	21			3			4		4					99		1	
9/6/2012				13 (4)	8 (3)	15 (5)				1		4		2					46		2	
10/4/2012				17 (3)	(6)	14 (4)	3		2 (3)		1	2		(1)					66	10		
11/8/2012				15 (1)	(1)	45 (1)			(1)	1				(1)					30	13		
12/13/2012				15 (2)	2	39 (1)			(2)					7 (1)					46			
1/18/2013				7 (2)	2	16 (2)			1 (2)					2								
2/8/2013				4 (6)	(1)	22 (7)			1 (2)					(2)								
3/7/2013				8 (5)	1 (1)	9 (16)			1 (1)					(1)					55			
3/22/2013				4 (3)	1	11 (32)			(3)					2 (1)					42			
3/28/2013				6 (4)	1	2 (44)			(2)					4 (5)					48		1	
4/4/2013				3 (4)	1	3 (28)			1 (4)					(3)								
4/11/2013				0 (2)	1 (1)	12 (32)			2 (4)					3 (1)							2	
4/18/2013				5 (6)	1	3 (36)			(3)					1 (4)					76		1	
4/25/2013				2 (3)	(1)	5			(1)					2 (1)					51		1	
5/2/2013		1		7 (3)	(1)	12 (7)	1		1					(3)							2	
5/8/2013				5 (4)	1	8 (21)			1 (6)					4 (1)					62			
5/16/2013				5 (1)		18 (17)			2 (4)					1					48			
5/31/2013				13 (1)	1 (1)	9			4 (5)					(1)					75			
6/6/2013				6 (1)	1 (1)	5 (1)			1 (6)										79			
6/14/2013				16 (1)	(3)	7 (6)			(7)					3 (1)					80			
7/3/2013																4						
7/2/2014				4	18	17								1					106			
8/6/2014				7	16 (4)	22 (2)			(1)							1			45			
8/27/2014				1	3 (11)	4 (10)			(1)										10			
10/8/2014				3 (1)	3 (9)	3 (1)	1		2 (1)	1				1					98	12		
11/5/2014				12	(7)	6	1		(1)					(1)					59	1		
12/3/2014				54 (2)	1 (6)	16			(1)					2			1		33			
12/31/2014				20 (3)		21													11			
2/4/2015				13 (1)	3 (1)	29 (2)			(1)			1							38	1		
3/4/2015				7	1 (2)	9 (1)	1		(1)					2					20			
4/1/2015				10 (1)	2 (4)	7 (5)		1	1					3 (2)					23		1	
4/8/2015				7 (1)	3 (4)	6 (6)								3 (1)					41			
4/15/2015				5 (5)	3 (9)	10 (12)			2 (1)					4 (3)					24			
4/22/2015				6 (2)	3 (9)	12 (10)			(3)					(2)					47			

Date	Banded Killifish*	Bluegill*	Brown Bullhead*	Chinook Salmon	Coastal Cutthroat Trout	Coho Salmon	Dace	Goldfish*	Hybrid Trout	Largemouth Bass*	Largescale Sucker	Mountain whitefish	Northern Pikeminnow	O. mykiss	Oriental Weatherfish*	Lamprey sp.	Peamouth	Redside Shiner	Sculpin sp.	Smallmouth Bass*	Threespine stickleback	Western Mosquitofish*
4/28/2015				1 (2)	4	19 (9)		3	(1)					1 (1)					37			
5/6/2015				6 (4)	7 (1)	63 (6)													34			
5/13/2015				4 (2)	8 (3)	85 (2)								2					35			
5/20/2015				1	(6)	98 (7)		1						(2)					30			
5/27/2015				1	(1)	74 (7)													41			
6/3/2015				1	6	24 (4)													40			
6/10/2015					2	99 (13)													52			
6/17/2015					(1)	91 (59)													19			
6/24/2015					1 (1)	86 (51)													55			
7/13/2015					1											10						
7/6/2016		3		9	1	53													186			
7/19/2016					1										2	1						
8/3/2016		1		5 (9)	1 (1)	12 (29)			1										209			
9/7/2016		1		5 (12)	1	(18)			(1)					1					346			
10/4/2016		1		2 (13)	(1)	(20)			(1)							1			238			
11/1/2016	1			2	(1)	22		1					1						135	1		1
12/6/2016				2 (1)	1	2													52			
1/3/2017				7 (3)		13 (1)													64			
3/7/2017				13	1 (1)	3								1					29			
4/4/2017				1	7 (2)									3					41			
4/11/2017				7	(3)	1								11					45			
4/18/2017				3							1			1					27			
4/25/2017				6	19									3 (1)					33			
5/2/2017				7	16 (4)	5								(2)					48			1
5/9/2017				2 (3)	3 (11)	6								4 (1)					47			
5/16/2017				3 (3)	3 (9)	1					1								32			
5/23/2017				10	(7)	5													129			2
5/30/2017	1			12 (1)	1 (6)	14 (1)													5			
6/6/2017				22 (2)		8 (5)			(1)					1					49			
6/13/2017				9	3 (1)	6 (3)								1					18			
6/27/2017					1 (2)											1						
7/3/2018			1	20	2 (4)	86								1					136			
8/2/2018				4 (5)	3 (4)	10 (52)						1							105			
9/6/2018			1	3	3 (9)	1 (18)			1			1							75			
10/4/2018				2	3 (9)	2 (24)													124	1		
11/1/2018				6 (1)	2 (12)	6 (10)			1					2				1	123			
12/6/2018				1	(12)	9 (6)			(1)					2 (2)			1		1 (24)			
2/7/2019				2 (2)	(9)	56 (9)			1					1 (2)					16			

Date	Banded Killifish*	Bluegill*	Brown Bullhead*	Chinook Salmon	Coastal Cutthroat Trout	Coho Salmon	Dace	Goldfish*	Hybrid Trout	Largemouth Bass*	Largescale Sucker	Mountain whitefish	Northern Pikeminnow	O. mykiss	Oriental Weatherfish*	Lamprey sp.	Peamouth	Redside Shiner	Sculpin sp.	Smallmouth Bass*	Threespine stickleback	Western Mosquitofish*
3/7/2019				4 (1)	(9)	8 (11)			1 (1)					1 (1)					31			
4/4/2019				1	(8)	28 (14)			2 (3)					2					106			
4/11/2019				1	(8)	2 (1)					1								5			
4/18/2019		1		4	1 (5)	2 (1)		1	1 (1)					1 (2)					57			
4/25/2019	1			5	(6)	17 (8)			1 (3)					2 (1)					88			
5/2/2019				2	(6)	9 (20)		1	(2)					3 (1)					105	1		
5/9/2019				10		16 (14)		1	(1)					3 (2)		1			111			1
5/16/2019					1	26 (8)	1							1 (2)					76			1
5/23/2019				1		20 (1)								(2)					3			
5/30/2019				3	1	10			1					(2)					1			
6/6/2019				9	(1)	22			(1)					2 (2)					112			

*Introduced species

Appendix C: Simpson (1-D) Diversity Index for each sample event in the Tryon Creek confluence habitat (2012 - 2019)

Sample Event	Season	Simpson (1-D) Diversity Index
7/3/12	Summer	0.73
8/3/12	Summer	0.62
9/6/12	Summer	0.73
10/4/12	Fall	0.73
11/8/12	Fall	0.70
12/13/12	Fall	0.72
1/18/13	Winter	0.65
2/8/13	Winter	0.54
3/7/13	Winter	0.61
3/22/13	Spring	0.63
3/28/13	Spring	0.67
4/4/13	Spring	0.54
4/11/13	Spring	0.43
4/18/13	Spring	0.60
4/25/13	Spring	0.41
5/2/13	Spring	0.69
5/8/13	Spring	0.63
5/16/13	Spring	0.62
5/31/13	Spring	0.51
6/6/13	Spring	0.45
6/14/13	Spring	0.55
7/2/2014	Summer	0.45
8/6/2014	Summer	0.69
8/27/2014	Summer	0.71
10/8/2014	Fall	0.45
11/5/2014	Fall	0.53
12/3/2014	Fall	0.67
12/31/2014	Winter	0.65
2/4/2015	Winter	0.68
3/4/2015	Winter	0.73
4/1/2015	Spring	0.77
4/8/2015	Spring	0.63
4/15/2015	Spring	0.79
4/22/2015	Spring	0.68
4/28/2015	Spring	0.70
5/6/2015	Spring	0.62
5/13/2015	Spring	0.56
5/20/2015	Spring	0.47
5/27/2015	Spring	0.52
6/3/2015	Spring	0.59
6/10/2015	Spring	0.47
6/17/2015	Spring	0.25
6/24/2015	Summer	0.45
7/6/2016	Summer	0.41
8/3/2016	Summer	0.36
9/7/2016	Summer	0.19
10/4/2016	Fall	0.25
11/1/2016	Fall	0.31
12/6/2016	Fall	0.22
1/3/2017	Winter	0.45
3/7/2017	Winter	0.53

Sample Event	Season	Simpson (1-D) Diversity Index
4/4/2017	Spring	0.17
4/11/2017	Spring	0.63
4/18/2017	Spring	0.33
4/25/2017	Spring	0.39
5/2/2017	Spring	0.47
5/9/2017	Spring	0.51
5/16/2017	Spring	0.45
5/23/2017	Spring	0.34
5/30/2017	Spring	0.75
6/6/2017	Spring	0.70
6/13/2017	Spring	0.76
7/3/2018	Summer	0.59
8/2/2018	Summer	0.58
9/6/2018	Summer	0.43
10/4/2018	Fall	0.35
11/1/2018	Fall	0.38
12/6/2018	Fall	0.69
2/7/2019	Winter	0.48
3/7/2019	Winter	0.67
4/4/2019	Spring	0.51
4/11/2019	Spring	0.71
4/18/2019	Spring	0.37
4/25/2019	Spring	0.52
5/2/2019	Spring	0.46
5/9/2019	Spring	0.51
5/16/2019	Spring	0.53
5/23/2019	Spring	0.58
5/30/2019	Spring	0.75
6/6/2019	Spring	0.45
6/13/2019	Spring	0.73

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