JUVENILE CHINOOK SALMON REARING IN SMALL NON-NATAL STREAMS DRAINING INTO THE WHIDBEY BASIN

E.M. Beamer[1], W.T. Zackey[2], D. Marks[2], D. Teel[3], D. Kuligowski[3], and R. Henderson[1]

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Strawberry Point N Creek, photo by Rich Henderson

[1] Skagit River System Cooperative, LaConner, WA
[2] Tulalip Tribes, Tulalip, WA
[3] NOAA Fisheries, Seattle, WA

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Abstract

We electrofished 63 small coastal streams draining into the Whidbey basin for juvenile Chinook salmon presence. The small streams sampled ranged in watershed size from 3 to 1,862 hectares and had channel slopes ranging between <1% to 38% for the electrofished reaches. Bankfull channel width of the electrofished stream reaches ranged from 0.8 to 6.9 meters.

In 32 of the 63 streams we found juvenile Chinook salmon present on at least one of the 474 sampling event days over the six year study period (2008 – 2013) in which we caught a total of 1,879 juvenile Chinook salmon. Juvenile Chinook salmon presence rates ranged from 0% to 100%, depending on stream. Most juvenile Chinook salmon were caught in the months of January through May each year. Juvenile Chinook salmon body size found in the small streams was similar to or larger than juvenile Chinook salmon body size found in adjacent nearshore habitat from January through April. After April, juvenile Chinook salmon were larger in nearshore areas than in small streams. While in small streams, individual juvenile Chinook salmon reared an average of 38.5 days and grew 0.23 mm/day.

Statistical analysis suggests that four factors influence whether juvenile Chinook salmon are present within Whidbey Basin small streams: 1) distance to nearest Chinook salmon bearing river, 2) stream channel slope, 3) watershed area, and 4) presence and condition of culverts at the mouth of a stream. Streams further from Chinook salmon bearing rivers and with steeper channel slopes had lower juvenile Chinook salmon presence rates. A minimum watershed size of approximately 45 hectares with channel slopes less than 6.5% may be necessary before juvenile Chinook salmon potential exists. We found culverts at stream mouths likely cause upstream migration problems for small fish such as Chinook salmon fry.

Streams of the size in this study are often not considered salmon habitat because many flow seasonally and do not provide habitat for spawning salmon. However, we found that numerous small streams entering the Whidbey Basin do provide rearing habitat for fry migrant Chinook salmon originating from the three nearby rivers (Skagit, Snohomish, and Stillaguamish). These same small streams are not well mapped and may be subject to inadequate protection as fish habitat. Better mapping of small streams and a predictive model for juvenile Chinook salmon potential would help managers better protect this unique habitat type.

Introduction

Puget Sound Chinook salmon populations were listed as threatened under the Endangered Species Act (ESA) in 1999. This led biologists and natural resource managers to ask questions related to what changes need to occur and to develop plans to recover wild Chinook salmon populations in Puget Sound. By 2005 recovery plans were completed for most ESA-listed Chinook salmon populations in Puget Sound, including all the populations originating from the three rivers entering the Whidbey Basin: Skagit, Stillaguamish, and Snohomish. Our study focusing on independent small streams entering the Whidbey Basin is a result of answering research questions necessary for the development of the Skagit Chinook Recovery Plan (SRSC & WDFW 2005). The paragraphs that follow review how answering these questions led us to further research to determine whether small streams are a critical part of the ecology of fry migrant Chinook salmon.

Fry migrants are present in the populations of Chinook salmon originating from all three rivers in the Whidbey Basin (Kinsel et al. 2008; Griffith et al. 2009; Kubo et al. 2013). They are one of several important juvenile life history types possible for ocean type Chinook salmon. Fry migrants do not rear extensively in their natal river estuary. They enter nearshore areas of the Whidbey Basin in the winter months at an average fork length of 39 mm (Beamer et al. 2005). Some fry migrants take up residence in pocket estuary habitat (Beamer et al. 2003; Beamer et al. 2006). These areas provide fry migrants with a survival and growth advantage over other nearshore habitats early in the year.

Skagit River tidal delta and pocket estuary habitats are much smaller and more fragmented than historically (Beamer et al. 2005), which is a theme for all Whidbey Basin river and pocket estuaries (Collins 2000; Collins & Sheikh 2005). At contemporary Skagit Chinook salmon population levels, current estuary habitat conditions are limiting the number and size of juvenile Chinook salmon rearing in delta habitat, as well as displacing them to Skagit Bay habitat, forcing a change in their life history type from delta rearing to fry migrants (Beamer et al. 2005; Greene & Beamer 2011). Because some fry migrant Chinook salmon rear and take refuge in pocket estuaries, restoration of pocket estuary habitat can be a strategy to partially mitigate delta density dependence and improve survival of naturally occurring fry migrants. Thus, local salmon recovery plans (e.g., Skagit Chinook Recovery Plan, Island County Multi-species Salmon Recovery Plan) included protection and restoration of pocket estuaries within the Whidbey Basin as an important strategy. The regional nearshore chapter of the Puget Sound Chinook Recovery Plan (Redmond et al. 2005) also emphasized the importance of pocket estuaries.

Pocket estuary restoration within the Whidbey Basin began approximately at the time of recovery plan development. One of the first pocket estuaries with restoration activity and fish response monitoring was Lone Tree Pocket Estuary and Creek, located in Skagit Bay. Monitoring results found fry migrant Chinook salmon responded to newly accessible habitat in the creek by moving from the lagoon into the lower creek (Beamer et al. 2009). The surprising results at Lone Tree Creek led us to question whether juvenile Chinook salmon were using other small streams within the Whidbey Basin. Therefore, we began this study.

This small stream study began in 2008 as a pilot project with two objectives: 1) determine whether fry migrant Chinook salmon were present in Whidbey Basin small streams other than Lone Tree Creek, and 2) identify general natural history characteristics of fry migrant Chinook salmon living in small streams. Our study expanded from monitoring just a few small streams to sampling 63 different streams in order to obtain a dataset to identify the landscape, watershed, and stream characteristics associated with streams used by fry migrant Chinook salmon. This document reports on both the pilot and expanded study efforts.

Methods

Site selection

Study streams were selected throughout the Whidbey Basin to represent spatial diversity within the basin (Figure 1) and over a range of watershed sizes and stream characteristics (described below). Actual streams sampled were subject to land owner permission consent.

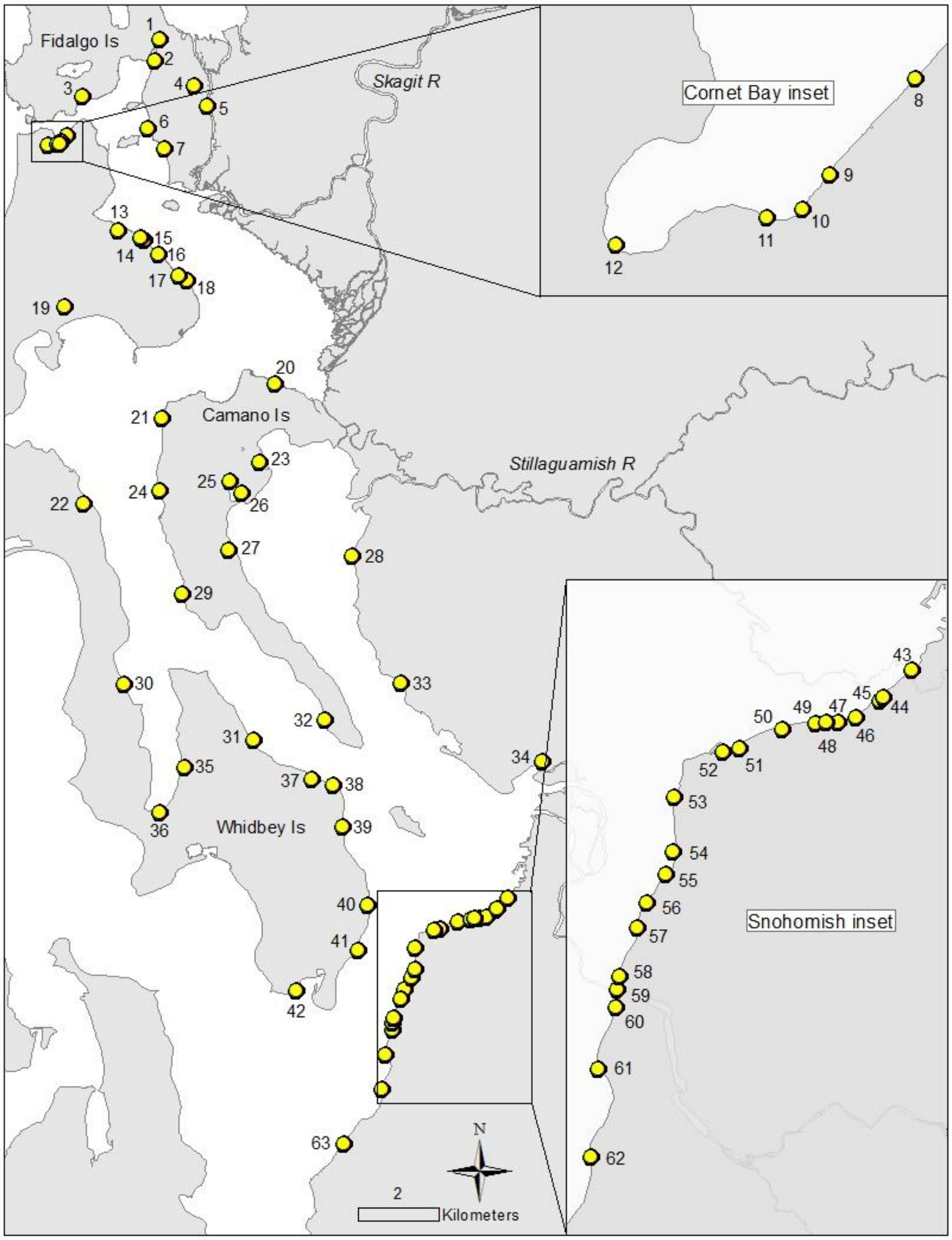


Figure 1. Location of study streams. Numbers shown in the figure correspond to the key shown in Tables 1, 2, 4,and 10.

Habitat measurement

We quantified measurements for each of the sixty-three streams electrofished for juvenile salmon presence to describe each stream in terms of its landscape, channel, and stream mouth characteristics.

Landscape characteristics

Landscape characteristics are: 1) distance to the nearest river, and 2) watershed area.

The distance from the small stream mouth to nearest Whidbey Basin river was measured in GIS (Geographic Information Systems, or computer mapping) based on the shortest distance by water. This measurement is important because the three major rivers entering the Whidbey Basin are the source of juvenile Chinook salmon that may or may not utilize one of our 63 small streams. We hypothesized that streams closer to natal Chinook salmon rivers have more juvenile Chinook salmon and/or higher juvenile Chinook salmon presence rates than streams further away from river mouths.

Watershed area, in hectares, was measured in GIS starting with county watershed polygon data which were edited in-house based on field observations and LiDAR. We hypothesized that: 1) watershed size is positively (bigger is better) correlated with juvenile Chinook salmon use, and 2) a minimum watershed size is required for juvenile Chinook salmon presence.

Channel characteristics

Stream channel surveys were conducted according to methods from the TFW Monitoring Program Methods manuals for the Habitat Unit Survey (Pleus et al. 1999) and Stream Segment Identification (Pleus & Schuett-Hames 1998), and from the WA Department of Ecology field data collection protocols for wadeable streams (Merrit 2009). Reported channel characteristics include: 1) channel slope, 2) bankfull width, 3) wetted width, and 4) depth of pools.

We hypothesized that: 1) channel slope is negatively (lower is better) correlated with juvenile Chinook salmon abundance and/or juvenile Chinook salmon presence rates, and 2) a maximum channel slope is a threshold for juvenile Chinook salmon presence (i.e., slope exceeding the maximum would not have juvenile Chinook salmon present). We calculated average bankfull channel width, wetted channel width, and maximum pool depth to provide the reader with a range of conditions observed in our sampled streams.

Stream mouth characteristics

Stream mouth characteristics include: 1) presence of longshore sediment deposition at stream mouth, 2) whether the stream drains into a pocket estuary or not, and 3) the presence and condition of culvert at mouth. Stream mouth characteristics were documented as present (yes/no) in the field.

<u>Longshore sediment deposition</u> – We hypothesized that longshore sediment deposition at a stream mouth might be a barrier to juvenile Chinook salmon access into the stream, especially if the stream is small and unable to overcome longshore sediment deposition.

Pocket estuaries – We hypothesized that streams entering pocket estuaries have higher use by juvenile Chinook salmon than streams draining directly in marine waters because juvenile Chinook are known to congregate in pocket estuaries.

Culvert at stream mouth – We hypothesized that the presence of a culvert at a stream's mouth would influence the presence rate of juvenile Chinook salmon following the logic stated below:

- Streams without a culvert at the mouth do not have that man-made potential impediment to fish access into the stream.
- Streams with a culvert at the mouth do have the potential barrier to juvenile salmon access, especially for fry-sized salmon.
- Streams with a culvert at the mouth that is backwatered regularly by high tide should have better conditions for upstream salmon fry passage than those with a culvert that is not backwatered by high tide, due to greater water depth and lower water velocity within the culvert, which makes it easier for juvenile salmon to swim upstream.

We grouped our study streams by three categories regarding culverts at the mouth: 1) no culvert present, 2) culvert present, does not backwater at high tide, and 3) culvert present, does backwater at high tide.

A range of conditions exists for each culvert category, including the category of culverts backwatering at high tide. For example, we found streams with culvert outlets located near Mean Higher High Water (MHHW) and some with outlets located much lower in the intertidal zone. Culvert length, cross sectional size and shape, slope, and material was varied. Appendix 1 shows examples of stream mouth conditions.

Fish sampling

We report results on salmonids in this paper with a particular emphasis on juvenile Chinook salmon.

Electrofishing

We used standardized single pass electrofishing methods to capture fish within small streams following methods of NMFS 2000, Johnson et al. 2007, and Nielsen & Johnson 1983. All fish captured were identified to species, counted, and released alive. All juvenile Chinook salmon caught were measured for their fork length. Juvenile Chinook salmon caught in small streams in 2009 were sampled for DNA. Tissue samples from caudal fin clips were taken from fish and preserved in vials filled with 100% ethyl alcohol to be analyzed using DNA analysis to determine the fish's river of origin.

Effort

Over the six-year study period we completed 474 days of electrofishing in 63 different streams (Figure 1, Table 1). The years before 2013 focused on sampling fewer streams with more frequency. These streams were generally sampled twice a month from late winter through early summer. These fewer streams with temporally extensive results were used to establish a standard period when juvenile Chinook salmon are likely to use small streams if habitat and access conditions are adequate. We also used results from these samplings to describe basic juvenile Chinook life information such as timing, relative abundance, and fish size. In 2013 we completed 180 days of electrofishing in 48 different streams, focusing on fishing in many different streams throughout the Whidbey Basin to build a dataset to determine which landscape and stream characteristics are associated with juvenile Chinook salmon utilization.

Table 1. Total number of sampling days electrofishing by stream and year. NS = not sampled.

Stream # (shown in Fig 1)	Stream name	2008	2009	2010	2011	2012	2013
1	Turners Cr	NS	1	7	1	5	NS
2	Turners Spit Cr	NS	NS	NS	NS	5	NS
3	Campbell Cr	NS	NS	NS	NS	NS	1
4	Fornsby Cr	NS	1	3	1	8	NS
5	Monks Cr	NS	1	7	NS	NS	NS
6	Lone Tree Cr	11	7	11	NS	3	4
7	SneeOosh Cr	NS	2	8	1	NS	NS
8	Unnamed stream in Cornet Bay	NS	NS	NS	NS	NS	5
9	Unnamed stream in Cornet Bay	NS	NS	NS	NS	NS	5
10	Unnamed stream in Cornet Bay	NS	NS	NS	NS	NS	5
11	Unnamed stream in Cornet Bay	NS	NS	NS	NS	NS	2
12	Unnamed stream in Cornet Bay	NS	NS	NS	NS	NS	7
13	Dugualla Heights Cr	NS	NS	NS	NS	NS	6
14	Unnamed stream in Skagit Bay	NS	NS	NS	NS	NS	7
15	Unnamed stream in Skagit Bay	NS	NS	NS	NS	NS	7
16	Unnamed stream in Skagit Bay	NS	NS	NS	NS	NS	1
17	Unnamed stream in Skagit Bay	NS	NS	NS	NS	NS	1
18	Strawberry Pt N Cr	NS	3	8	1	NS	NS
19	Crescent Harbor Cr	NS	NS	3	9	8	8
20	English Boom Cr	2	NS	4	2	NS	NS
21	Unnamed stream near Rocky Pt	NS	NS	NS	NS	NS	5
22	Unnamed stream in Race Lagoon	NS	NS	NS	NS	NS	6
23	Unnamed stream near Iverson Spit	NS	NS	NS	NS	NS	4
24	Unnamed stream near Woodland Beach	NS	NS	NS	NS	NS	3
25	Kristoferson Cr	NS	9	11	NS	NS	NS
26	Unnamed stream in Triangle Cove	NS	NS	NS	NS	NS	3
27	Camano Country Club Cr	NS	NS	10	NS	NS	NS
28	Greenwood Cr	NS	1	11	NS	10	6
29	Cama Beach Cr	NS	9	NS	NS	NS	NS
30	Unnamed stream near Greenbank	NS	NS	NS	NS	NS	4
31	Unnamed stream in Saratoga Passage	NS	NS	NS	NS	NS	2
32	Unnamed stream in Saratoga Passage	NS	NS	NS	NS	NS	3
33	Spee-Bi-Dah Cr	NS	NS	NS	NS	NS	3
34	Hibulb Cr	NS	NS	10	NS	NS	NS
35	Unnamed stream in Holmes Harbor	NS	NS	NS	NS	NS	4
36	Freeland Park Cr	NS	NS	NS	NS	NS	3
37	Edgecliff Cr	NS	NS	NS	NS	NS	3
38	Unnamed stream near Sandy Pt	NS	NS	NS	NS	NS	3
39	Unnamed stream in Possession Sound	NS	NS	NS	NS	NS	3
40	Zook Cr	NS	10	11	NS	10	NS
41	Glendale Cr	NS	9	10	NS	NS	NS
42	Unnamed stream in Cultus Bay	NS	NS	NS	NS	NS	3
43	Pigeon Cr #1	NS	10	9	NS	NS	NS
44	Pigeon Cr #2	NS	NS	NS	NS	NS	3

Stream # (shown in Fig 1)	Stream name	2008	2009	2010	2011	2012	2013
45	Unnamed stream near Howarth Park	NS	NS	NS	NS	NS	3
46	Glenwood Cr	NS	NS	NS	NS	NS	6
47	Unnamed stream near Darlington Beach	NS	NS	NS	NS	NS	3
48	Merrill & Ring Cr	NS	11	9	NS	11	NS
49	Narbeck Cr	NS	NS	NS	NS	NS	3
50	Powder Mill Gulch Cr	NS	NS	NS	NS	NS	3
51	Edgewater Cr	NS	NS	NS	NS	NS	5
52	Japanese Gulch Cr	NS	NS	NS	NS	NS	3
53	Unnamed stream near Lighthouse Park	NS	NS	NS	NS	NS	3
54	Unnamed stream in Mukilteo	NS	NS	NS	NS	NS	2
55	Unnamed stream near Naketa Beach	NS	NS	NS	NS	NS	5
56	Unnamed stream in Mukilteo	NS	NS	NS	NS	NS	2
57	Big Gulch Cr	NS	NS	NS	NS	NS	2
58	Unnamed stream in Mukilteo	NS	NS	NS	NS	NS	2
59	Unnamed stream in Mukilteo	NS	NS	NS	NS	NS	3
60	Unnamed stream near Shipwreck Pt	NS	NS	NS	NS	NS	3
61	Picnic Pt Cr	NS	NS	NS	NS	NS	3
62	Lunds Gulch Cr	NS	NS	NS	NS	NS	4
63	Fruitdale Cr	NS	NS	NS	NS	NS	5

Juvenile Chinook salmon

DNA analysis

DNA analysis of juvenile Chinook salmon tissue samples was performed by NOAA Fisheries Manchester Marine Research Station using Genetic Stock Identification (GSI) techniques on standardized microsatellite DNA loci. GSI methods use a "baseline" genetic database to estimate the likely origin of juvenile Chinook salmon collected in our study's small streams. The baseline is the whole set of reference samples representing spawning aggregates in known geographic locations (Appendix 2). We used a Washington and British Columbia baseline dataset extracted from the standardized coast-wide database developed by the multi-agency workgroup Genetic Analysis of Pacific Salmonids (GAPS) collaborators (Moran et al. 2005). Juvenile Chinook salmon tissue samples from our small streams were genotyped at 13 microsatellite loci that were selected for standardization by the GAPS collaborators. Analyses were done using the program Genetic Mixture Analysis (Kalinowski 2003).

For the Chinook salmon origin analysis we used only fish with a "best stock" estimate probability of 0.800 or greater, using tissue samples from only 120 of 197 different juvenile Chinook salmon collected in 2009 (Appendix 3). Fish from Lone Tree (n=57), SneeOosh (n=8), and Strawberry Point N (n=29) Creeks made up the Skagit Bay result. Fish from Kristoferson Creek (n=11) made up the Port Susan result. Fish from Glendale (n=1), Merrill & Ring (n=7), Zook (n=6), and Pigeon #1 (n=1) Creeks made up the Possession Sound result.

Residence, growth, and movement

Juvenile Chinook salmon tissue samples were collected throughout the Whidbey Basin as part of this small stream study and a larger DNA sampling effort including Whidbey Basin pocket estuaries and shoreline habitats (i.e., Salmon Recovery Funding Board project# 07-1589 N titled: *Origins of Juvenile Chinook In WRIA 6 Nearshore*). Thus, we opportunistically recaptured a subset of juvenile Chinook salmon that we had captured beforehand, and analyzed their DNA. When DNA results were identical for more than one sample, we concluded we had data from two different times (i.e., initial capture and recapture) for the same fish. Capture/recapture occurred for 88 different juvenile Chinook salmon from 2008 and 2009 originally captured in small streams, allowing us to calculate residence, growth, and movement results for these fish.

> Residence: *Residence* (R) = C_1-C_2, where C_1 is the initial fish capture date and C_2 is the recapture date. Residence results are reported as days.
>
> Growth: *Growth* (G) = (FL_1-FL_2)/R, where FL_1 is the fork length of the fish at initial capture and FL_2 is the fork length of the fish at recapture. Growth results are reported as mm/day.
>
> Movement: Eleven of the 88 capture/recaptured juvenile Chinook salmon were initially caught in a small stream and then later recaptured in another area outside of the initial capture stream. For these eleven fish we reported *movement locations* (starting and ending locations), *movement distance* (distance between starting and ending location as a fish would swim), and *movement time* (number of days between initial capture and recapture).

We compared residence and growth rates of juvenile Chinook salmon in small streams to residence and growth estimates of juvenile Chinook salmon in pocket estuaries and the Skagit estuary. Residence and growth rates results for juvenile Chinook salmon in pocket estuaries are also from captured and recaptured fish in the same pocket estuary. We used 49 juvenile Chinook salmon pocket estuary samples. For the Skagit estuary juvenile Chinook salmon residence and growth rate samples we used otolith-based results from 136 wild juvenile Chinook salmon collected in the Skagit tidal delta by wetland zone (from Beamer et al. 2000).

Statistical analysis

We calculated juvenile Chinook salmon presence rate and relative abundance for each of the 63 streams electrofished over a standardized period. The standardized period is January through May each year (see results section below on juvenile Chinook timing in small streams). We only included streams where no juvenile Chinook salmon were found if the stream was sampled at least two times (usually many more times) during the standardized period.

- *Juvenile Chinook salmon presence rate* is the number of sampling days juvenile Chinook salmon were present divided by the total number of sampling days for the stream. The result is expressed as a percentage.

- *Juvenile Chinook salmon relative abundance* is calculated as the number of juvenile Chinook salmon caught divided by electrofishing time. The result is expressed as juvenile Chinook per minute.

We used graphs to present natural history results for juvenile Chinook salmon in small streams, such as timing and relative abundance, body size, residence, and growth. We often compared these natural history attributes to the same ones for juvenile Chinook salmon in other nearby habitat types, such as pocket estuaries, natal estuaries, or nearshore habitat. We used ANOVA with pair-wise comparison testing (Tukey's Honestly-Significant-Difference Test) to determine whether mean natural history attributes were different than the same attribute for other habitats.

To accommodate our unbalanced sampling design for categorical variables (Table 1) we used Generalized Linear Models (GLM) to evaluate the effects of habitat variables on juvenile Chinook salmon presence rate and abundance. Juvenile Chinook salmon presence rate and abundance were log (x+1) transformed to reduce the effects of high skew and unequal variance across groups.

Landscape, stream channel, and stream mouth characteristics were evaluated for main effects as fixed factors for their influence on juvenile Chinook salmon. Statistical results from GLM for each effect are reported in tables with graphical presentations. Our hypothesis is that larger and lower gradient streams that are close to the source of Chinook salmon fry (i.e., nearby rivers) should have a higher frequency of juvenile Chinook salmon presence than smaller and steeper streams that are more distant to the source of fish. Threshold relationships for some independent variables might occur. For example, watersheds too small or channels too steep might not have fish. We also factored in whether or not barriers, such as culverts near the mouths of the streams, influence juvenile Chinook salmon presence.

Results

Characteristics of streams

We measured the landscape and stream characteristics for each of the 63 streams electrofished for juvenile salmon presence (Table 2). We summarized results based on landscape, channel, and stream mouth characteristics.

Landscape characteristics: Position within the Whidbey Basin was quantified by distance from nearest river mouth because the three major rivers entering the Whidbey Basin are the source of juvenile Chinook salmon that may or may not utilize one of our 63 small streams. Six of the streams were closest to the Stillaguamish River mouth and 33 streams were closest the Snohomish River. Of the remaining 24 streams, eighteen were closest to the mouth of the north fork Skagit River while six were closest to the south fork Skagit River mouth. The distance from the mouth of the small streams to the nearest river mouth varied from just over three kilometers to nearly 26 kilometers. The streams furthest away from river mouths are located in Saratoga Passage and Holmes Harbor (Figure 1). Watershed area of the 63 streams varied from three hectares (an unnamed stream in Cornet Bay) to 1,862 hectares (Campbell Creek, located in northern Skagit Bay). Average watershed area of all 63 streams was 248 hectares.

Channel characteristics: Overall channel slope for the surveyed stream reaches ranged from <1% to nearly 40%. The average for all sixty-three streams was 7.9%. Average bankfull stream width ranged from less than one meter to nearly seven meters wide. Wetted stream width ranged from 0.5 to 4.7 meters wide. Average maximum pool depth ranged from very shallow (0.03 meters) to over 0.5 meters deep.

Stream mouth characteristics: Of the 63streams, eight had longshore sediment deposits associated with their stream mouths and twelve drained into pocket estuaries. Thirty-four streams had culverts, or culvert-like structures, at their stream mouths. Of the 34 streams that had culverts at their mouth, 22 culverts did not backwater at high tide while 12 culverts did backwater.

Table 2. Summary of watershed and channel characteristics, and survey length, of streams electrofished. The accessible stream length for upstream migrating salmon fry is shown in parentheses if different than survey length. **Estuary* could be one of the 3 large river estuaries or one of the many pocket estuaries in the Whidbey Basin.

		Landscape characteristics		**Channel characteristics**					**Stream mouth characteristics**		
Stream # shown in Fig 1	**Stream name**	**Nearest river mouth & distance (km)**	**Watershed area (ha)**	**Slope %**	**Avg width (m)**	**Avg wetted width (m)**	**Avg max pool depth (m)**	**Survey length (m)**	**Longshore sediment deposition present**	**Enters estuary ***	**Culvert(s) present**
1	Turners Cr	NF Skagit 13.12	47	1.0%	1.6	1.3	0.18	120	no	yes	yes, not tidally backwatered
2	Turners Spit Cr	NF Skagit 12.48	10	2.0%	0.8	0.5	0.04	28	no	yes	no
3	Campbell Cr	NF Skagit 10.29	1,862	1.6%	3.9	2.2	0.27	50	no	no	yes, tidally backwatered
4	Fornsby Cr	NF Skagit 8.97	107	1.0%	3.4	1.1	0.18	185	no	yes	yes, tidally backwatered
5	Monks Cr	NF Skagit 6.22	123	2.5%	3.5	0.7	0.15	60	no	no	no
6	Lone Tree Cr	NF Skagit 6.76	253	2.4%	2.6	1.2	0.26	180 (60)	no	yes	no
7	SneeOosh Cr	NF Skagit 4.62	170	2.2%	3.1	1.7	0.21	175	no	no	yes, tidally backwatered
8	Unnamed stream in Cornet Bay	NF Skagit 10.94	109	7.4%	2.4	0.6	0.04	varies by tide	no	no	yes, not tidally backwatered
9	Unnamed stream in Cornet Bay	NF Skagit 11.49	64	5.7%	1.9	1.6	0.05	varies by tide	no	no	no
10	Unnamed stream in Cornet Bay	NF Skagit 11.66	3	4.1%	1.0	0.5	0.06	26 (11)	no	no	yes, tidally backwatered
11	Unnamed stream in Cornet Bay	NF Skagit 11.69	16	5.2%	0.9	0.7	0.03	varies by tide	no	no	no

Stream # shown in Fig 1	Stream name	Landscape characteristics		Channel characteristics					Stream mouth characteristics		
		Nearest river mouth & distance (km)	**Watershed area (ha)**	**Slope %**	**Avg width (m)**	**Avg wetted width (m)**	**Avg max pool depth (m)**	**Survey length (m)**	**Longshore sediment deposition present**	**Enters estuary ***	**Culvert(s) present**
12	Unnamed stream in Cornet Bay	NF Skagit 12.11	55	3.4%	1.5	1.0	0.14	11	no	no	no
13	Dugualla Heights Cr	NF Skagit 5.49	46	1.3%	1.3	1.0	0.05	144	no	yes	yes, not tidally backwatered
14	Unnamed stream in Skagit Bay	NF Skagit 4.73	17	15.3 %	2.0	1.0	0.04	44	no	no	no
15	Unnamed stream in Skagit Bay	NF Skagit 4.63	31	16.7 %	1.3	0.9	0.05	77	no	no	no
16	Unnamed stream in Skagit Bay	NF Skagit 4.72	127	6.6%	2.5	1.1	0.07	157 (48)	no	no	no
17	Unnamed stream in Skagit Bay	NF Skagit 5.36	154	3.9%	1.8	1.0	0.13	140.8 (86)	no	no	no
18	Strawberry Pt N Cr	NF Skagit 5.58	155	2.8%	1.8	0.7	0.19	150	yes	no	no
19	Crescent Harbor Cr	SF Skagit 18.67	1,382	1.0%	2.2	1.9	0.32	60	no	yes	no
20	English Boom Cr	SF Skagit 5.22	46	2.0%	1.2	0.6	0.15	37	no	yes	no
21	Unnamed stream near Rocky Pt	SF Skagit 12.89	430	27.5 %	4.0	3.4	0.08	92	no	no	no
22	Unnamed stream in Race Lagoon	SF Skagit 19.87	292	1.7%	2.7	0.7	0.11	115	no	yes	yes, not tidally backwatered
23	Unnamed stream near Iverson Spit	Stillaguamish 6.69	68	9.3%	1.2	1.0	0.14	27	no	no	no
24	Unnamed stream near Woodland Beach	SF Skagit 17.63	206	38.2 %	2.7	0.8	0.06	varies by tide	no	no	no

Stream # shown in Fig 1	Stream name	Landscape characteristics		Channel characteristics					Stream mouth characteristics		
		Nearest river mouth & distance (km)	Watershed area (ha)	Slope %	Avg width (m)	Avg wetted width (m)	Avg max pool depth (m)	Survey length (m)	Longshore sediment deposition present	Enters estuary *	Culvert(s) present
25	Kristoferson Cr	Stillaguamish 9.02	866	1.0%	1.8	1.6	0.48	72	no	yes	yes, tidally backwatered
26	Unnamed stream in Triangle Cove	Stillaguamish 7.95	72	3.8%	2.2	1.3	0.19	59	no	yes	yes, not tidally backwatered
27	Camano Country Club Cr	Stillaguamish 8.81	328	5.1%	2.0	1.2	0.18	90 (30)	no	yes	yes, tidally backwatered
28	Greenwood Cr	Stillaguamish 3.45	361	1.2%	1.7	0.7	0.21	100	yes	no	no
29	Cama Beach Cr	SF Skagit 23.16	252	4.0%	1.4	1.0	0.25	107 (5)	yes	no	no
30	Unnamed stream near Greenbank	Snohomish 22.67	71	19.0 %	2.1	0.6	0.05	44	no	no	no
31	Unnamed stream in Saratoga Passage	Snohomish 17.61	95	16.9 %	1.5	1.1	0.06	34 (20)	no	no	no
32	Unnamed stream in Saratoga Passage	Snohomish 14.2	102	14.9 %	1.1	0.9	0.08	11	no	no	no
33	Spee-Bi-Dah Cr	Stillaguamish 7.21	272	5.7%	2.9	1.0	0.07	varies by tide	yes	no	yes, not tidally backwatered
34	Hibulb Cr	Snohomish 3.23	208	1.0%	2.0	1.0	0.36	113	no	yes	no
35	Unnamed stream in Holmes Harbor	Snohomish 24.67	721	17.0 %	1.4	0.8	0.12	84 (40)	no	no	no
36	Freeland Park Cr	Snohomish 25.96	287	1.0%	1.5	0.9	0.11	133	no	no	yes, tidally backwatered
37	Edgecliff Cr	Snohomish 13.53	214	25.1 %	2.8	1.2	0.06	varies by tide	no	no	no

Stream # shown in Fig 1	Stream name	Landscape characteristics		Channel characteristics					Stream mouth characteristics		
		Nearest river mouth & distance (km)	**Watershed area (ha)**	**Slope %**	**Avg width (m)**	**Avg wetted width (m)**	**Avg max pool depth (m)**	**Survey length (m)**	**Longshore sediment deposition present**	**Enters estuary ***	**Culvert(s) present**
38	Unnamed stream near Sandy Pt	Snohomish 11.77	46	37.4 %	2.0	0.7	0.05	varies by tide	no	no	no
39	Unnamed stream in Possession Sound	Snohomish 11.63	166	32.1 %	2.6	1.7	0.07	varies by tide	no	no	no
40	Zook Cr	Snohomish 11.79	133	4.0%	1.5	1.1	0.37	100	yes	no	no
41	Glendale Cr	Snohomish 14.03	548	5.4%	2.7	1.8	0.35	170	no	no	yes, tidally backwatered
42	Unnamed stream in Cultus Bay	Snohomish 20.97	102	6.1%	1.4	0.8	0.35	39	no	no	yes, not tidally backwatered
43	Pigeon Cr #1	Snohomish 6.13	467	2.4%	4.2	3.2	0.52	112	no	no	yes, not tidally backwatered
44	Pigeon Cr #2	Snohomish 6.91	374	2.5%	2.6	1.7	0.42	190	no	no	yes, not tidally backwatered
45	Unnamed stream near Howarth Park	Snohomish 7.03	48	6.6%	2.1	1.0	0.09	204	no	no	yes, not tidally backwatered
46	Glenwood Cr	Snohomish 7.58	159	3.0%	2.5	1.6	0.13	182	no	no	yes, not tidally backwatered
47	Unnamed stream near Darlington Beach	Snohomish 7.86	41	14.5 %	1.8	0.7	0.07	200	no	no	yes, not tidally backwatered
48	Merrill & Ring Cr	Snohomish 7.9	275	3.8%	4.3	2.6	0.39	200	yes	no	no

Stream # shown in Fig 1	Stream name	Landscape characteristics		Channel characteristics					Stream mouth characteristics		
		Nearest river mouth & distance (km)	Watershed area (ha)	Slope %	Avg width (m)	Avg wetted width (m)	Avg max pool depth (m)	Survey length (m)	Longshore sediment deposition present	Enters estuary *	Culvert(s) present
49	Narbeck Cr	Snohomish 8.09	184	1.7%	6.5	2.3	0.16	200	no	no	yes, not tidally backwatered
50	Powder Mill Gulch Cr	Snohomish 8.58	461	11.7 %	6.9	4.7	0.40	208	no	no	yes, not tidally backwatered
51	Edgewater Cr	Snohomish 9.54	91	4.5%	2.6	1.7	0.19	260	no	no	yes, not tidally backwatered
52	Japanese Gulch Cr	Snohomish 9.93	457	3.4%	4.5	3.6	0.30	160	no	no	yes, not tidally backwatered
53	Unnamed stream near Lighthouse Park	Snohomish 11.58	69	10.8 %	3.4	1.2	0.18	200	no	no	yes, not tidally backwatered
54	Unnamed stream in Mukilteo	Snohomish 12.96	98	10.9 %	4.5	2.0	0.17	196	no	no	yes, not tidally backwatered
55	Unnamed stream near Naketa Beach	Snohomish 13.54	76	7.4%	3.9	2.5	0.28	18	no	no	yes, not tidally backwatered
56	Unnamed stream in Mukilteo	Snohomish 14.31	84	8.2%	1.8	1.2	0.11	124	no	no	yes, tidally backwatered
57	Big Gulch Cr	Snohomish 14.87	430	3.3%	2.8	2.5	0.14	209	yes	no	yes, tidally backwatered
58	Unnamed stream in Mukilteo	Snohomish 16.24	146	9.8%	2.4	1.3	0.20	79	no	no	yes, not tidally backwatered

Stream # shown in Fig 1	Stream name	Landscape characteristics: Nearest river mouth & distance (km)	Landscape characteristics: Watershed area (ha)	Channel characteristics: Slope %	Channel characteristics: Avg width (m)	Channel characteristics: Avg wetted width (m)	Channel characteristics: Avg max pool depth (m)	Channel characteristics: Survey length (m)	Stream mouth characteristics: Longshore sediment deposition present	Stream mouth characteristics: Enters estuary *	Stream mouth characteristics: Culvert(s) present
59	Unnamed stream in Mukilteo	Snohomish 16.59	203	8.2%	4.0	2.1	0.21	219	no	no	yes, tidally backwatered
60	Unnamed stream near Shipwreck Pt	Snohomish 17.08	66	6.9%	1.5	1.1	0.11	25	no	no	yes, not tidally backwatered
61	Picnic Pt Cr	Snohomish 18.58	599	3.4%	3.6	2.2	0.56	190	yes	no	no
62	Lunds Gulch Cr	Snohomish 20.85	577	2.2%	5.3	3.7	0.37	206	no	no	yes, tidally backwatered
63	Fruitdale Cr	Snohomish 24.84	105	9.9%	1.4	1.4	0.20	94	no	no	yes, not tidally backwatered

Juvenile salmon presence by stream and species

We caught salmonid fish in 40 of the 63 streams sampled. The majority (31 streams) of the 40 streams with salmonids present had more than one species of salmonid present.

Only two streams had all six salmonid species present, including pink salmon: Strawberry Point N Creek and Greenwood Creek. Both these streams were sampled on even-numbered years, do not enter pocket estuaries, and are very close to the Skagit or Stillaguamish Rivers, which produce many pink salmon. We did not expect to find pink salmon in the odd-numbered years we sampled, as few even-year spawning pink salmon exist in Whidbey Basin rivers.

A summary of the number of streams with salmonids present by species is in Table 3. For example, 32 of the 63 streams sampled had juvenile Chinook salmon present. A map view of the 32 streams where juvenile Chinook salmon were found is shown in Figure 2. Juvenile Chinook salmon were present only in the intertidal stream reach of 11 of these 32 streams. Table 4 shows the salmonid species found in each stream.

Table 3. Summary of salmonid presence for 63 streams in the Whidbey Basin.

	Number of streams	
Salmonid Species	**Present**	**Not found**
Chinook salmon	32	31
Steelhead trout	9	54
Coho salmon	31	32
Cutthroat trout	23	40
Chum salmon	23	40
Pink salmon	2	61

Table 4. Juvenile salmon presence results by stream. We did not include presence results for juvenile pink salmon in this table because they were found in only two creeks, Strawberry Pt N Creek (stream #18) and Greenwood Creek (stream #28).

Stream # (shown in Fig 1)	**Stream name**	**Chinook**	**Steelhead**	**Coho**	**Cutthroat**	**Chum**
1	Turners Cr	yes	none found	none found	none found	none found
2	Turners Spit Cr	none found	none found	none found	none found	none found
3	Campbell Cr	yes	none found	none found	none found	none found
4	Fornsby Cr	yes	none found	yes	none found	none found
5	Monks Cr	yes	yes	yes	none found	none found
6	Lone Tree Cr	yes	none found	yes	none found	yes
7	SneeOosh Cr	yes	none found	yes	yes	yes
8	Unnamed stream in Cornet Bay	none found	none found	none found	none found	none found
9	Unnamed stream in Cornet Bay	none found	none found	none found	none found	none found
10	Unnamed stream in Cornet Bay	none found	none found	none found	none found	none found
11	Unnamed stream in Cornet Bay	yes, intertidal only	none found	none found	none found	none found
12	Unnamed stream in Cornet Bay	none found	none found	none found	none found	none found
13	Dugualla Heights Cr	none found	none found	none found	none found	none found
14	Unnamed stream in Skagit Bay	none found	none found	none found	none found	none found
15	Unnamed stream in Skagit Bay	none found	none found	none found	none found	none found
16	Unnamed stream in Skagit Bay	yes	none found	none found	none found	none found
17	Unnamed stream in Skagit Bay	yes, intertidal only	none found	none found	none found	none found
18	Strawberry Pt N Cr	yes	yes	yes	yes	yes
19	Crescent Harbor Cr	yes	none found	yes	none found	none found
20	English Boom Cr	yes	none found	yes	none found	none found
21	Unnamed stream near Rocky Pt	none found	none found	none found	none found	none found
22	Unnamed stream in Race Lagoon	none found	none found	none found	none found	none found
23	Unnamed stream near Iverson Spit	none found	none found	yes	yes	yes

Stream # (shown in Fig 1)	Stream name	Chinook	Steelhead	Coho	Cutthroat	Chum
24	Unnamed stream near Woodland Beach	none found	none found	none found	none found	none found
25	Kristoferson Cr	yes	yes	yes	yes	yes
26	Unnamed stream in Triangle Cove	yes, intertidal only	none found	yes	none found	yes
27	Camano Country Club Cr	yes	none found	yes	yes	yes
28	Greenwood Cr	yes	yes	yes	yes	yes
29	Cama Beach Cr	none found	none found	none found	none found	none found
30	Unnamed stream near Greenbank	none found	none found	none found	none found	none found
31	Unnamed stream in Saratoga Passage	none found	none found	none found	none found	none found
32	Unnamed stream in Saratoga Passage	none found	none found	yes	none found	none found
33	Spee-Bi-Dah Cr	none found	none found	none found	none found	none found
34	Hibulb Cr	yes	none found	yes	yes	yes
35	Unnamed stream in Holmes Harbor	yes, intertidal only	none found	yes	yes	yes
36	Freeland Park Cr	none found	none found	none found	none found	none found
37	Edgecliff Cr	none found	none found	none found	yes	none found
38	Unnamed stream near Sandy Pt	yes, intertidal only	none found	none found	none found	none found
39	Unnamed stream in Possession Sound	yes, intertidal only	none found	yes	none found	yes
40	Zook Cr	yes	yes	yes	yes	yes
41	Glendale Cr	yes	none found	yes	yes	yes
42	Unnamed stream in Cultus Bay	none found	none found	none found	none found	none found
43	Pigeon Cr #1	yes	yes	yes	yes	yes
44	Pigeon Cr #2	yes, intertidal only	none found	yes	none found	none found
45	Unnamed stream near Howarth Park	none found	none found	yes	none found	none found
46	Glenwood Cr	yes, intertidal only	yes	yes	yes	yes
47	Unnamed stream near Darlington Beach	none found	none found	none found	none found	none found
48	Merrill & Ring Cr	yes	yes	yes	yes	yes

Stream # (shown in Fig 1)	Stream name	Chinook	Steelhead	Coho	Cutthroat	Chum
49	Narbeck Cr	yes, intertidal only	yes	yes	none found	none found
50	Powder Mill Gulch Cr	none found	none found	yes	yes	yes
51	Edgewater Cr	yes, intertidal only	none found	none found	yes	yes
52	Japanese Gulch Cr	none found	none found	yes	yes	yes
53	Unnamed stream near Lighthouse Park	none found	none found	none found	none found	none found
54	Unnamed stream in Mukilteo	none found	none found	none found	none found	none found
55	Unnamed stream near Naketa Beach	none found	none found	yes	yes	none found
56	Unnamed stream in Mukilteo	none found	none found	none found	none found	none found
57	Big Gulch Cr	yes	none found	yes	yes	yes
58	Unnamed stream in Mukilteo	none found	none found	none found	none found	none found
59	Unnamed stream in Mukilteo	yes, intertidal only	none found	yes	yes	yes
60	Unnamed stream near Shipwreck Pt	none found	none found	none found	none found	none found
61	Picnic Pt Cr	yes	none found	none found	yes	yes
62	Lunds Gulch Cr	yes	none found	yes	yes	yes
63	Fruitdale Cr	none found	none found	yes	yes	none found

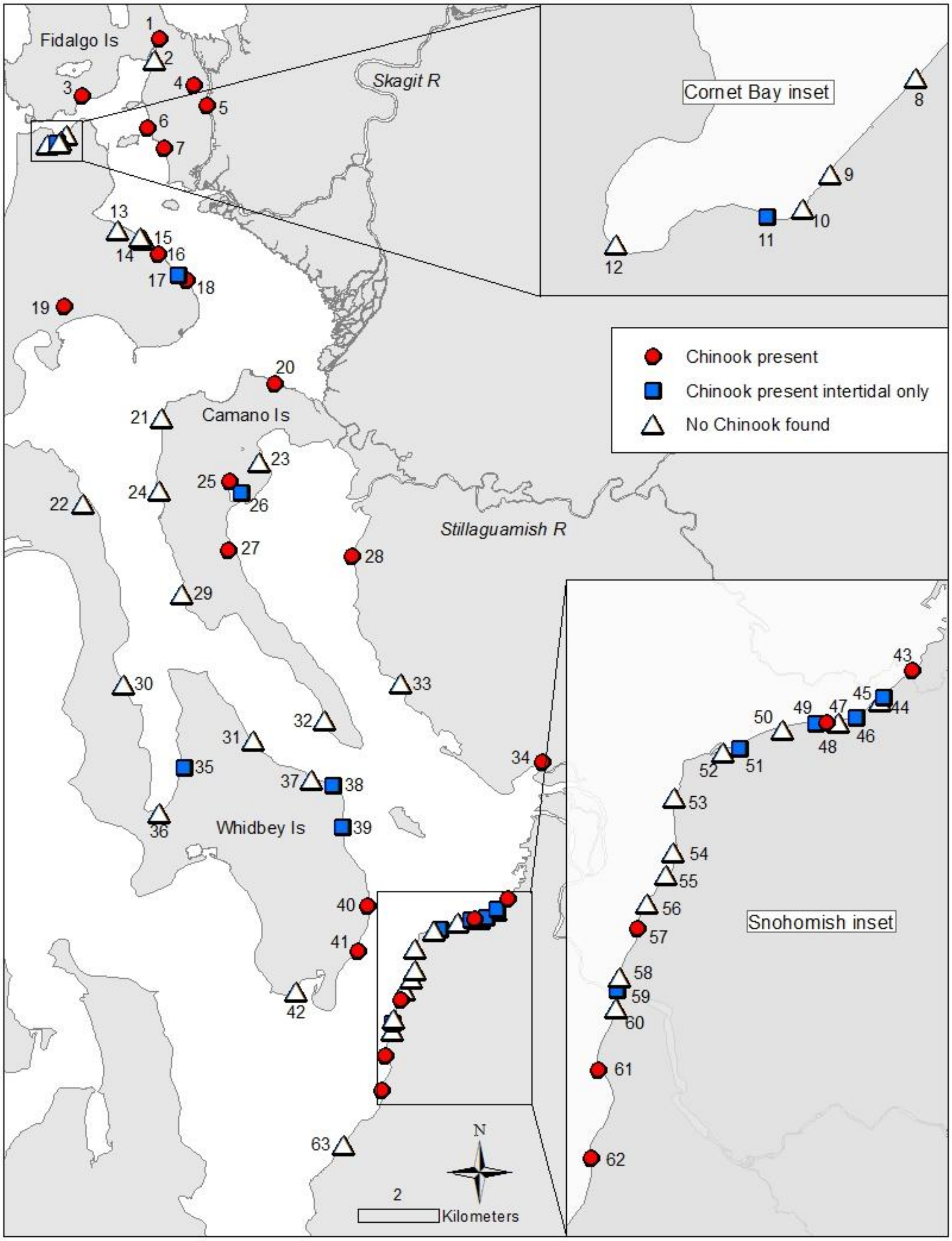


Figure 2. Location and juvenile Chinook salmon presence results for 63 small streams within the Whidbey Basin. Numbers shown in the figure correspond to the key shown in Tables 1,2, 4, and 10.

Juvenile Chinook salmon

Timing and relative abundance

We used electrofishing results from five different streams over four different years to document the period of time when juvenile Chinook salmon utilize small streams (Table 5). Streams were associated with each of the three natal Chinook salmon rivers in the Whidbey Basin (Skagit, Stillaguamish, and Snohomish) to show whether variability in juvenile Chinook timing differed between rivers. The five streams had the most complete temporal data to establish juvenile Chinook timing; electrofishing was done twice a month from January through June or July each year. Three of the five streams were sampled in multiple years to determine whether the beginning and ending months of the juvenile Chinook salmon period for small streams changed.

Table 5. Streams and years used in timing analysis of juvenile Chinook salmon in small streams.

Chinook salmon river	Small stream	Years sampled
Skagit	Lone Tree Cr	2008, 2010
	Strawberry Pt N Cr	2010
Stillaguamish	Greenwood Cr	2010, 2012
	Kristoferson Cr	2010
Snohomish	Merrill & Ring Cr	2009, 2012

There is consistency in the timing of juvenile Chinook in the five small streams (Figure 3, panels A-E). Juvenile Chinook salmon were present in January and peaked in February or March, then started to decline in April or May. Very few juvenile Chinook were present in small streams after May. The timing of juvenile Chinook salmon in small streams is similar to the timing period for juvenile Chinook salmon in pocket estuaries and natal river estuaries (Figure 4).

Because three of these streams had multiple years with complete timing data, we used fish abundance results (fish/min) to investigate whether annual variability in fish abundance exists and whether fish abundance influences the timing of juvenile Chinook salmon presence in small streams. In all three streams with multiple years of data, we saw differences in relative Chinook abundance between years:

- Lone Tree Creek had three times more fish in 2008 than in 2010 (Figure 3, panel A)
- Greenwood Creek had three time more fish in 2012 than in 2010 (Figure 3, panel D)
- Merrill & Ring Creek had twice as many fish in 2012 as in 2009 (Figure 3, panel E)

For every stream the year with the highest relative abundance had later peaks of juvenile Chinook salmon. However, regardless of differences in the relative abundance of juvenile Chinook salmon, the beginning and ending period of juvenile Chinook using small streams stayed similar across streams and years. For statistical analysis of juvenile Chinook salmon presence and relative abundance across creeks we used a standardized small stream rearing period of January through May (depicted by Figure 3, panel F) because during this time period we would expect juvenile Chinook salmon to be present in a Whidbey Basin creek if stream habitat and fish access conditions to the stream were adequate.

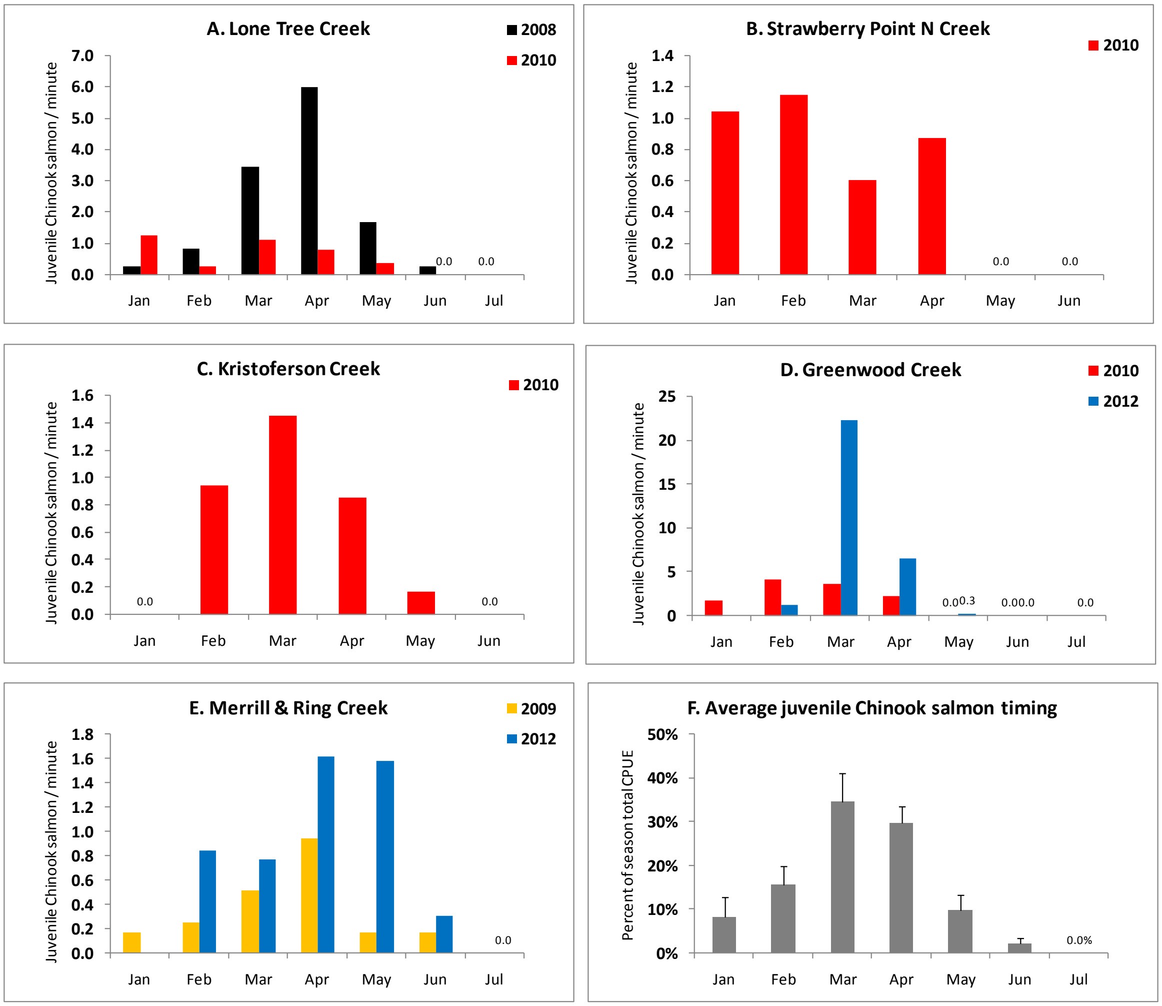


Figure 3. Timing and relative abundance of juvenile Chinook salmon in five small streams. Lone Tree Creek (Panel A) and Strawberry Point N Creek (Panel B) are associated with the Skagit River. Kristoferson Creek (Panel C) and Greenwood Creek (Panel D) are associated with the Stillaguamish River. Merrill & Ring Creek (Panel E) is associated with the Snohomish River. Panel F is average standardized timing of juvenile Chinook salmon in all five streams and years combined. Error bars are standard error.

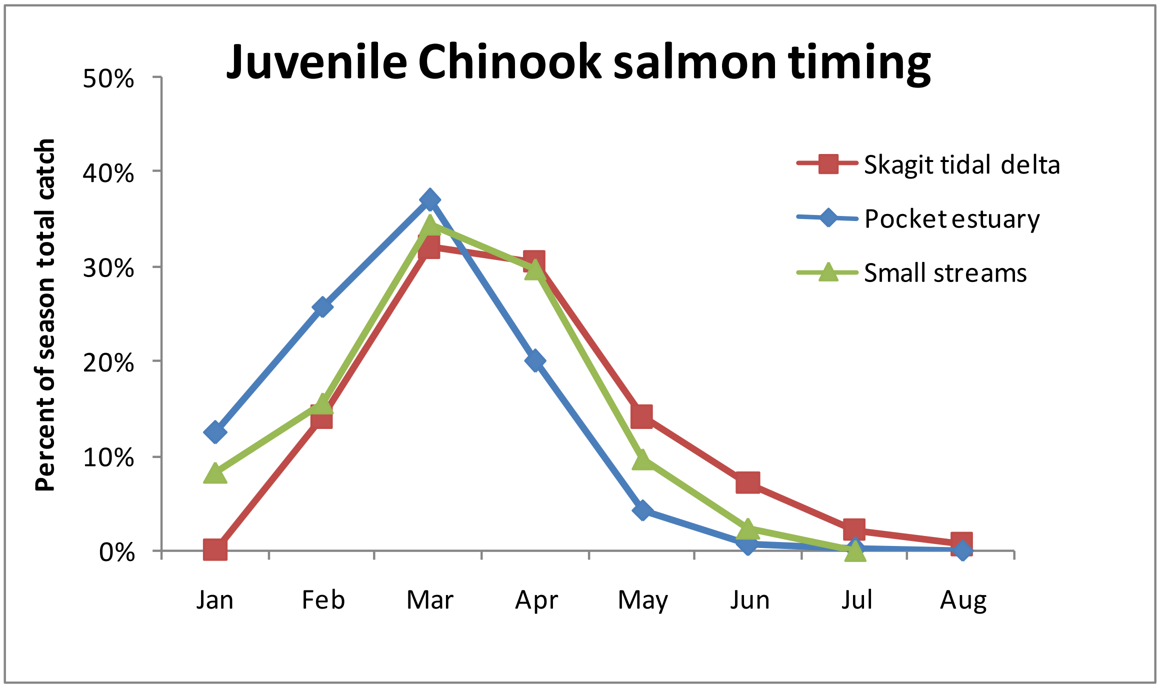


Figure 4. Standardized timing of juvenile Chinook salmon in natal estuary (Skagit tidal delta), pocket estuary and small streams within the Whidbey Basin. Data for the Skagit tidal delta are the ten-year average juvenile wild Chinook salmon timing curve for Skagit delta long-term monitoring sites (from Beamer et al. 2011). Data for pocket estuary habitat are the four year average from Lone Tree Lagoon (from Beamer et al. 2009). Data for small streams are the average of the five streams shown in Figure 3, Panel F.

Body size

Early in the year juvenile Chinook salmon found in small streams were similar in size to, or larger than, juvenile Chinook salmon in adjacent nearshore habitat (Figure 5, Table 6). Juvenile Chinook salmon were not statistically different in their length between groups (i.e., small stream or nearshore) for the months of January, February, and April. In March, juvenile Chinook salmon in small streams were larger than juvenile Chinook salmon in nearshore, possibly reflecting growth of individual fish rearing in the stream compared to the more migratory fish of the nearshore. After April, juvenile Chinook salmon in the nearshore were larger than juvenile Chinook salmon in small streams (Figure 5, Table 6), but the fish in small streams were lower in abundance, likely reflecting movement out of streams and into marine waters of the Whidbey Basin (Figure 4).

Table 6. Pair-wise testing results for juvenile Chinook salmon fork length by strata (nearshore and small stream) and month in 2010 using Tukey's Honestly-Significant-Difference Test. Bold values are significant at the 0.05 level.

MONTH(i) * STRATA(i)	MONTH(j) * STRATA(j)	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
1*nearshore	1*small stream	0.196	1.000	-32.943	33.335
2*nearshore	2*small stream	-0.561	1.000	-19.788	18.666
3*nearshore	3*small stream	-5.730	**0.024**	-11.109	-0.352
4*nearshore	4*small stream	-0.061	1.000	-9.031	8.909
5*nearshore	5*small stream	15.402	**0.000**	8.770	22.034
6*nearshore	6*small stream	21.258	**0.013**	2.180	40.336

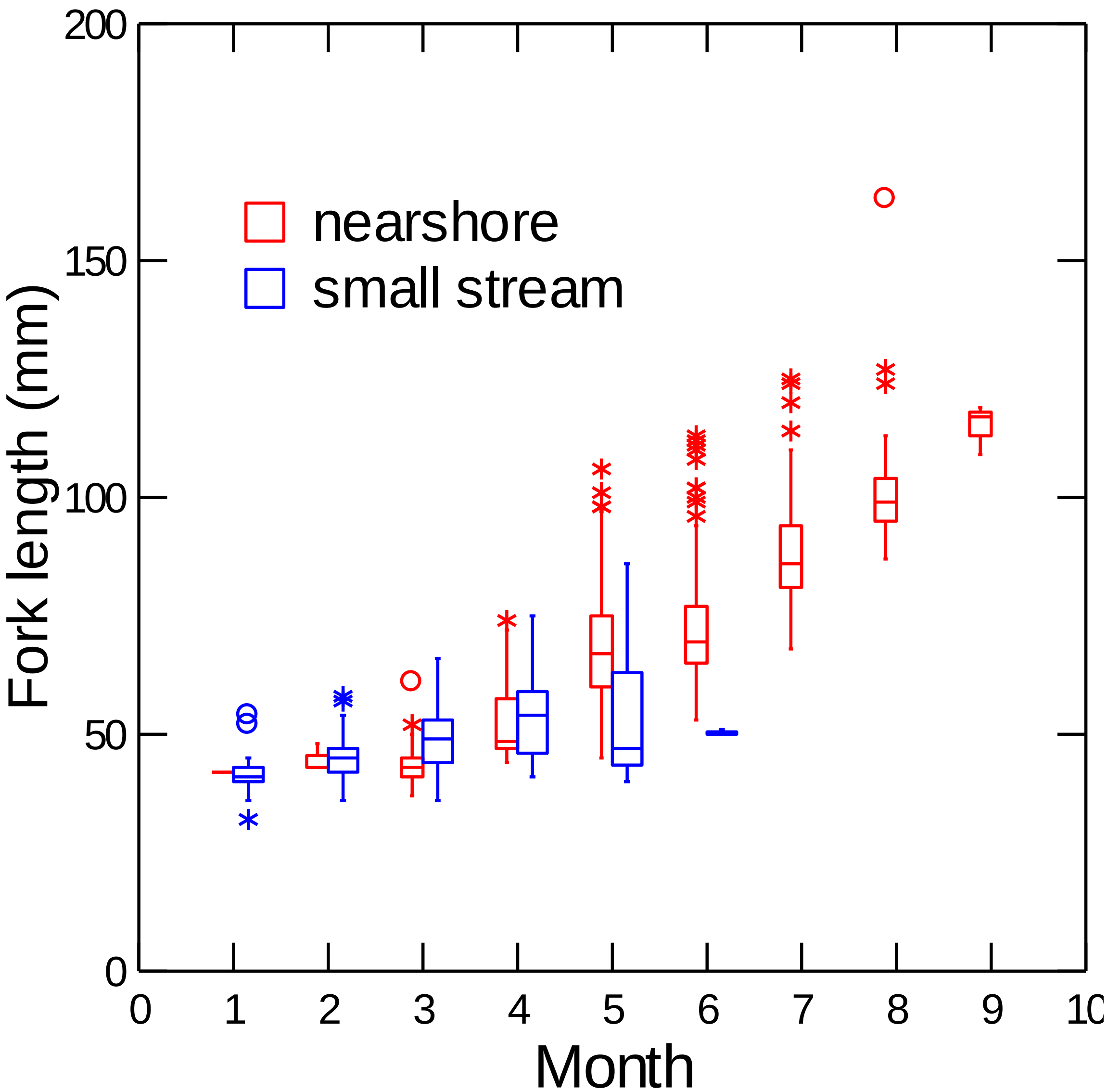


Figure 5. Boxplot of juvenile Chinook salmon size by month for small streams and nearshore habitat in the Whidbey Basin. Data are from 2010 only. Juvenile Chinook salmon length samples for nearshore (n=729) are from Skagit Bay shoreline courtesy of the Skagit Intensively Monitored Watershed Program (Greene and Beamer 2011). Juvenile Chinook salmon length samples for small streams (n=368) are from the 16 streams sampled in 2010 (shown in Table 1).

Residence

We found individual juvenile Chinook salmon reared for a significant period of time in small stream habitat. The overall mean residence period of individual juvenile Chinook salmon in small streams was 38.5 days. The mean monthly residence period was similarly high (33 to 42 days) across late winter and early spring months until May, when mean residence period dropped to 14 days (Figure 6, top panel), possibly reflecting the time when fish were migrating out of small streams and into marine waters of the Whidbey Basin.

The residence period of individual juvenile Chinook salmon in small streams, pocket estuaries, and scrub/shrub habitat of the Skagit River tidal delta (a natal Chinook salmon estuary) are all statistically similar (Table 7), averaging a little over one month for individual fish (Figure 6, bottom panel).

Table 7. Pair-wise testing results for juvenile Chinook salmon residence by strata using Tukey's Honestly-Significant-Difference Test. Strata are: small stream, pocket estuary, and the Skagit River tidal delta broken down by its three wetland zones (EEM = estuarine emergent marsh; SS = estuarine scrub shrub; FRT = forested riverine tidal). Bold values are significant at the 0.05 level.

WETLAND ZONE(i)	WETLAND ZONE(j)	Difference	P Value	95% Confidence Interval	
				Lower	Upper
Pocket estuary	Small stream	-2.543	0.938	-11.488	6.402
Pocket estuary	Tidal Delta EEM	19.374	**0.000**	9.927	28.822
Pocket estuary	Tidal Delta FRT	14.059	**0.014**	1.911	26.207
Pocket estuary	Tidal Delta SS	0.000	1.000	-9.986	9.986
Small stream	Tidal Delta EEM	21.917	**0.000**	13.577	30.257
Small stream	Tidal Delta FRT	16.601	**0.001**	5.293	27.910
Small stream	Tidal Delta SS	2.543	0.938	-6.402	11.488
Tidal Delta EEM	Tidal Delta FRT	-5.315	0.729	-17.025	6.394
Tidal Delta EEM	Tidal Delta SS	-19.374	**0.000**	-28.822	-9.927
Tidal Delta FRT	Tidal Delta SS	-14.059	**0.014**	-26.207	-1.911

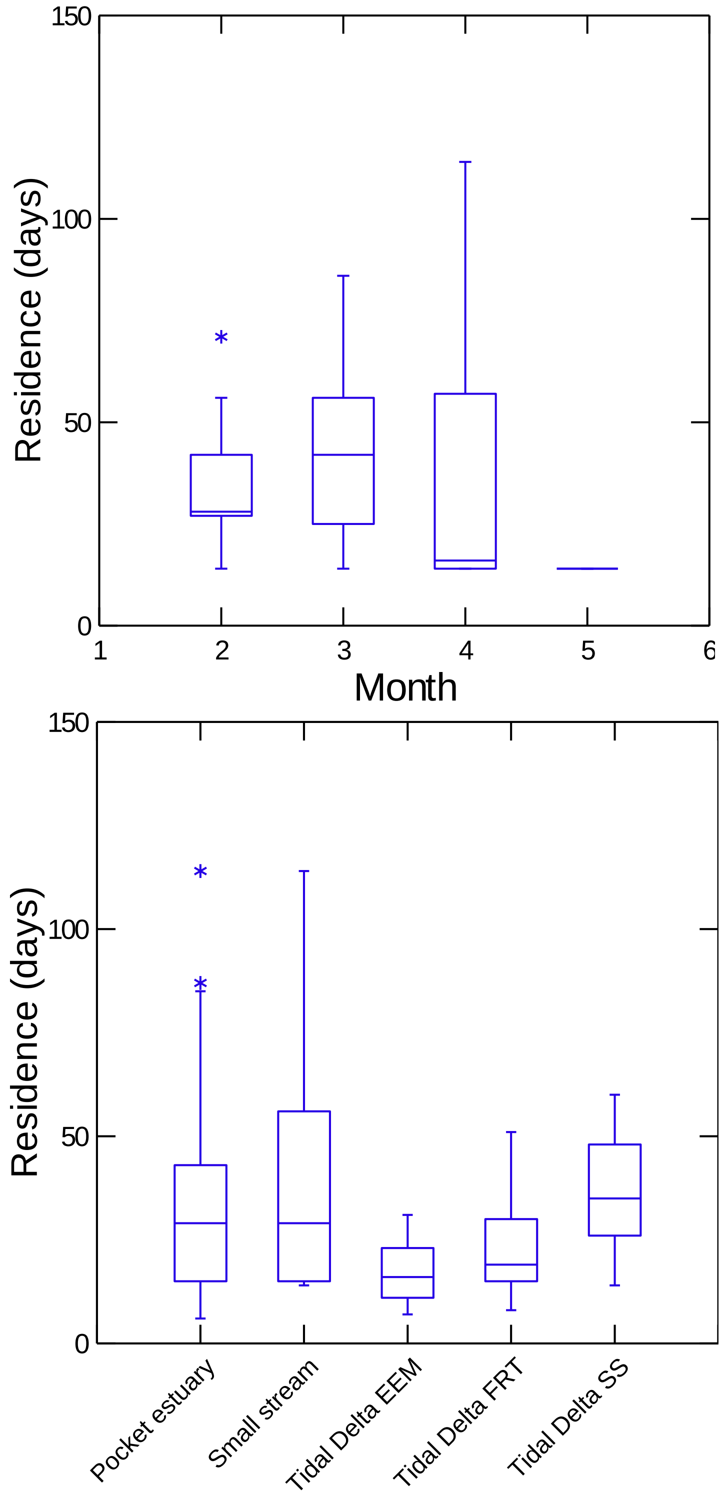


Figure 6. Boxplot of monthly residence of juvenile Chinook salmon in Whidbey Basin small streams (top panel) and residence of juvenile Chinook salmon in Whidbey Basin pocket estuaries and small streams as well as three wetland zones of the Skagit River tidal delta: EEM (estuarine emergent marsh), FRT (forested riverine tidal), and SS (scrub shrub) (bottom panel). Boxes show median, 25th and 75th percentiles. Whiskers show 5th and 95th percentiles. Circles are outliers.

Growth

We found juvenile Chinook salmon grew during the time they spent in small stream habitat. The overall mean growth rate of individual juvenile Chinook salmon in small streams was 0.23 mm/day. Mean monthly growth increased from later winter to May (Figure 7, top panel), possibly reflecting seasonal increases in water temperature and food production.

The growth of individual juvenile Chinook salmon in small streams and pocket estuaries are statistically similar (Table 8), but are less than growth rates of juvenile Chinook salmon in all three wetland zones of the Skagit River tidal delta, a natal Chinook salmon estuary. (Figure 7, bottom panel).

Table 8. Pair-wise testing results for juvenile Chinook salmon growth by strata using Tukey's Honestly-Significant-Difference Test. Strata are: small stream, pocket estuary, and the Skagit River tidal delta broken down by its three wetland zones (EEM = estuarine emergent marsh; SS = estuarine scrub shrub; FRT = forested riverine tidal). Bold values are significant at the 0.05 level.

WETLAND ZONE(i)	WETLAND ZONE(j)	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
Pocket estuary	Small stream	0.001	1.000	-0.231	0.232
Pocket estuary	Tidal Delta EEM	-1.450	**0.000**	-1.692	-1.208
Pocket estuary	Tidal Delta FRT	-0.344	**0.022**	-0.656	-0.033
Pocket estuary	Tidal Delta SS	-0.284	**0.021**	-0.540	-0.028
Small stream	Tidal Delta EEM	-1.451	**0.000**	-1.667	-1.235
Small stream	Tidal Delta FRT	-0.345	**0.011**	-0.637	-0.054
Small stream	Tidal Delta SS	-0.285	**0.007**	-0.516	-0.053
Tidal Delta EEM	Tidal Delta FRT	1.106	**0.000**	0.806	1.406
Tidal Delta EEM	Tidal Delta SS	1.166	**0.000**	0.924	1.408
Tidal Delta FRT	Tidal Delta SS	0.060	0.984	-0.251	0.372

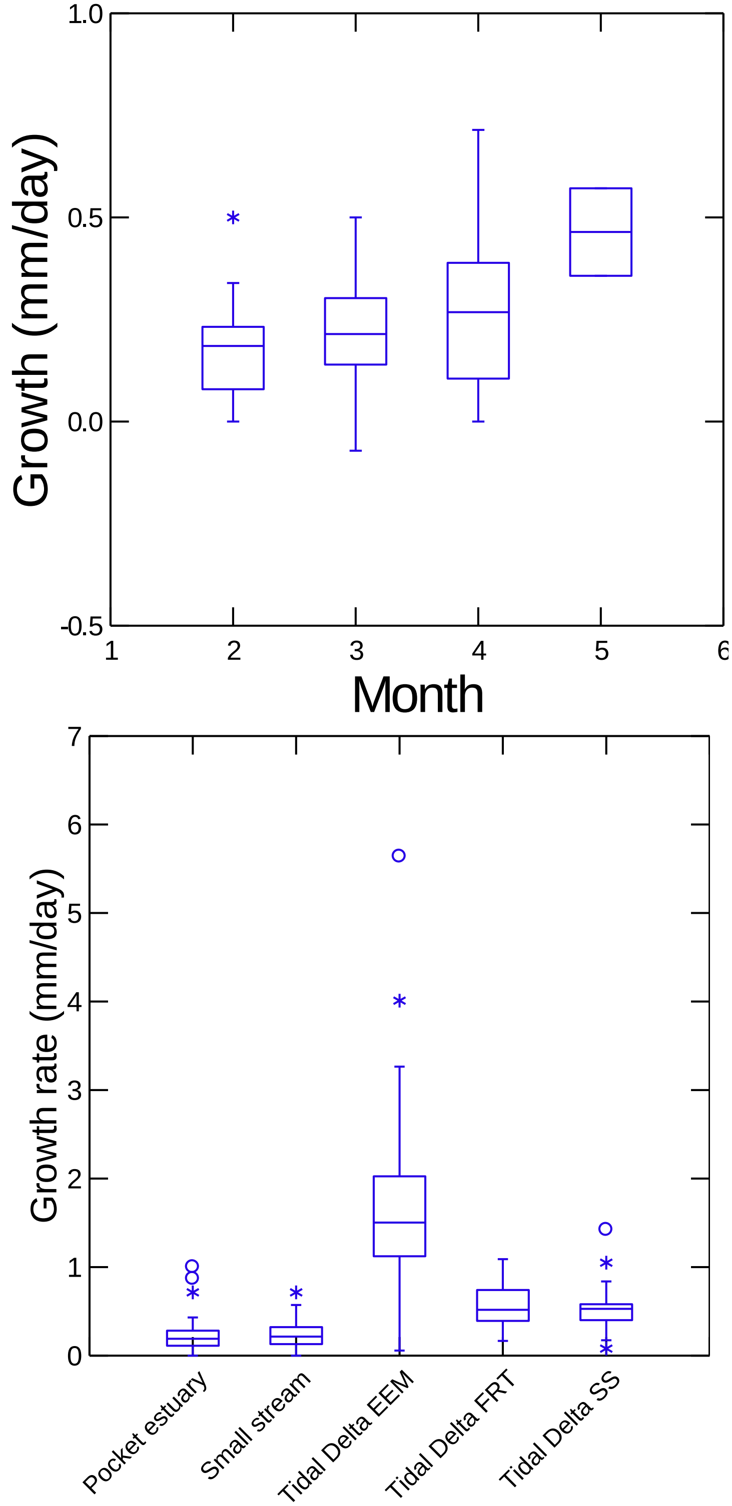


Figure 7. Boxplot of monthly growth rates of juvenile Chinook salmon in Whidbey Basin small streams (top panel) and growth rates of juvenile Chinook salmon in Whidbey Basin pocket estuaries and small streams as well as three wetland zones of the Skagit River tidal delta: EEM (estuarine emergent marsh), FRT (forested riverine tidal), and SS (scrub shrub) (bottom panel). Boxes show median, 25th and 75th percentiles. Whiskers show 5th and 95th percentiles. Circles are outliers.

Movement

We found evidence of juvenile Chinook salmon that lived for months after initial capture in the same small stream, as well as some that traveled up to 19 kilometers away in the nearshore environment of the Whidbey Basin. Eleven juvenile Chinook salmon were initially captured in Lone Tree Creek and then later recaptured at other sites. From these fish we observe three distinct movement patterns (Table 9, Figure 8) demonstrating that juvenile Chinook salmon that reared in small streams did transition to other habitat types, including pocket estuaries and nearshore, later in the year. Movement pattern 2 also demonstrates that juvenile Chinook salmon do move from one pocket estuary system to another as was earlier hypothesized (Beamer et al. 2005, Redman et al. 2005).

Table 9. Summary of juvenile Chinook salmon movement patterns.

Number of observations	Starting location	Ending location	Between starting and ending location	
			Time	**Distance**
Movement pattern 1: stream to lagoon within same pocket estuary system				
Five different fish	Lone Tree Cr	Lone Tree Lagoon	22-64 days	0.2 km
Movement pattern 2: stream to different pocket estuary system				
One fish	Lone Tree Cr	Kiket Lagoon	56 days	5.1 km
Movement pattern 3: stream to nearshore				
Three different fish	Lone Tree Cr	Turners Spit N	50-91 days	8.1 km
One fish	Lone Tree Cr	Hoypus Pt E	168 days	5.9 km
One fish	Lone Tree Cr	Random South 82	100 days	19.4 km

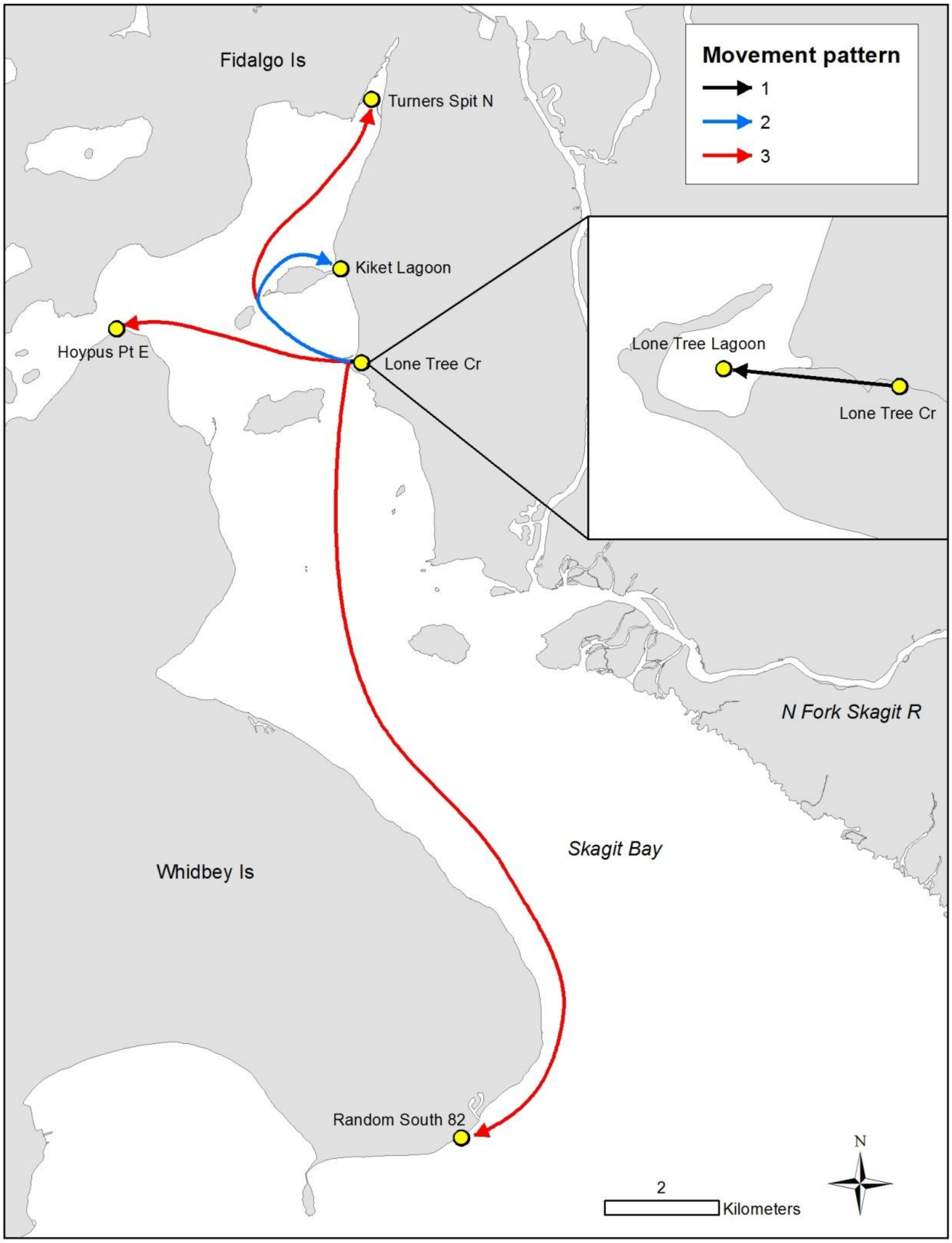


Figure 8. Movement patterns of eleven different juvenile Chinook salmon initially caught in Lone Tree Creek and then recaptured at another location. Movement pattern numbers correspond to descriptions shown in Table 9. The start and end locations are known; the exact pattern of movement between sites is unknown. The arrows are only shown as an illustration of the distance between points.

Origin

Chinook salmon stocks from each of the three (Skagit, Stillaguamish, and Snohomish) source population Chinook salmon rivers were found in small streams throughout the Whidbey Basin (Figure 9). Skagit Chinook salmon were most common in each of the three areas examined within Whidbey Basin, even though other Chinook salmon rivers are in closer proximity to two of the three areas (Port Susan and Possession Sound). This is likely because the total number of outmigrating Chinook salmon is larger in the Skagit than in the other two rivers. We did not find evidence of juvenile Chinook salmon from rivers outside of the Whidbey Basin using small streams within the Whidbey Basin.

There is spatial correspondence between the most common Chinook salmon stock found in a stream and proximity to source population rivers. On the south end of the Whidbey Basin is the Snohomish River. This river is comprised of two main Chinook salmon rivers (Skykomish and Snoqualmie) based on DNA analysis using the GAPS baseline. Snoqualmie River Chinook salmon look genetically like South Sound Falls/Hood Canal (SSF/HC) Chinook salmon in the GAPS baseline. Thus, the black parts of the pie charts in Figure 9 are likely natural origin Chinook salmon originating from the Snoqualmie River. The pie chart for Possession Sound (Figure 9, bottom left panel) has a larger percentage (33%) of fish originating out of rivers from within the Snohomish than the other two pie charts (9% in Port Susan, 3% in Skagit Bay). This is logical because the small streams in Possession Sound are closest to the Snohomish River, of which the Skykomish and Snoqualmie Rivers are both tributaries. This same principle is also true for Skagit origin fish (88% in Skagit Bay, 73% in Port Susan, 47% in Possession Sound); even though Skagit Chinook salmon were the most common ones found throughout the Whidbey Basin. The Port Susan pie chart (Figure 9, top right panel) shows a weaker spatial correspondence with its percentage of Stillaguamish fish being similar to Possession Sound’s (18% and 20% respectively) even though the Stillaguamish River drains into Port Susan and not Possession Sound. Only 8% of the fish in Skagit Bay were identified to be of Stillaguamish origin. These results suggest that most Stillaguamish fish migrate out of the Whidbey Basin to the south rather than to the north.

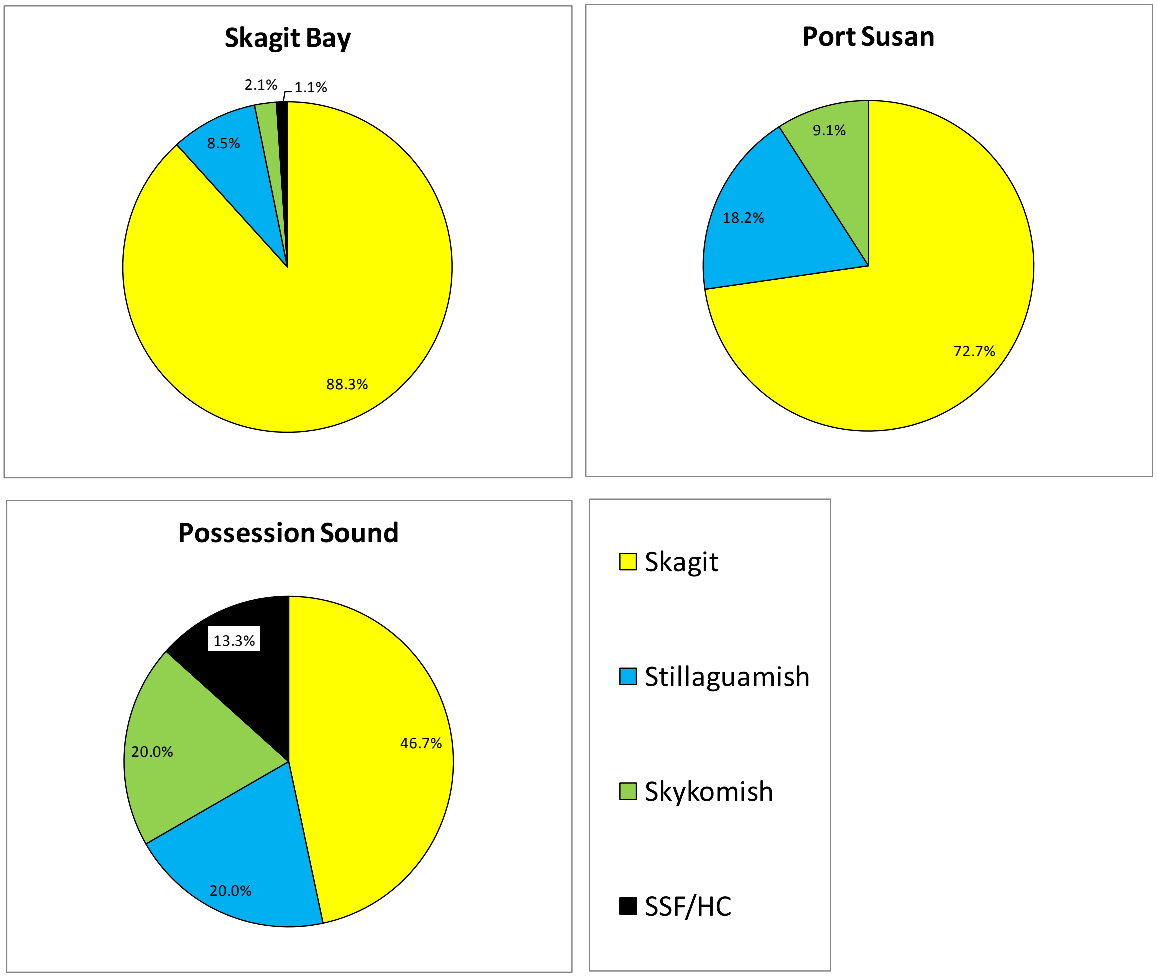


Figure 9. Origin of juvenile Chinook salmon using small streams by regions within the Whidbey Basin based on DNA analysis compared to GAPS baseline. Note: Snoqualmie Chinook salmon look genetically like South Sound Falls/Hood Canal (SSF/HC) Chinook salmon in the GAPS baseline. The black parts of the pie charts are likely natural origin Chinook salmon originating from the Snoqualmie River.

Presence rate and relative abundance

We electrofished 426 days in 63 streams over six years during the period when juvenile Chinook salmon would be expected to use small streams in the Whidbey Basin (January through May). Juvenile Chinook salmon presence rates in our small streams varied from 0% to 100% while average relative abundance varied from 0 to 15.9 juvenile Chinook salmon per minute of electroshocking (Table 10). We used juvenile Chinook salmon presence rate and abundance to statistically test effects of landscape and stream characteristics.

Table 10. Juvenile Chinook salmon presence rate, relative abundance (juvenile Chinook salmon per minute), and years when sampling occurred by stream. NC = not calculated.

Stream # (shown in Fig 1)	Stream name	Chinook presence rate	Average Chinook per minute	Days of electro-fishing	Year
1	Turners Cr	14.3%	0.095	14	2009 - 2012
2	Turners Spit Cr	0.0%	0.000	5	2012
3	Campbell Cr	100.0%	NC	1	2013
4	Fornsby Cr	23.1%	0.038	13	2009 - 2012
5	Monks Cr	62.5%	0.158	8	2009 - 2010
6	Lone Tree Cr	95.7%	1.717	23	2008 - 2010, 2012 - 2013
7	SneeOosh Cr	30.0%	0.162	10	2009 - 2011
8	Unnamed stream in Cornet Bay	0.0%	0.000	5	2013
9	Unnamed stream in Cornet Bay	0.0%	0.000	5	2013
10	Unnamed stream in Cornet Bay	0.0%	0.000	5	2013
11	Unnamed stream in Cornet Bay	50.0%	0.375	2	2013
12	Unnamed stream in Cornet Bay	0.0%	0.000	7	2013
13	Dugualla Heights Cr	0.0%	0.000	6	2013
14	Unnamed stream in Skagit Bay	0.0%	0.000	7	2013
15	Unnamed stream in Skagit Bay	0.0%	0.000	7	2013
16	Unnamed stream in Skagit Bay	100.0%	7.018	1	2013
17	Unnamed stream in Skagit Bay	100.0%	15.862	1	2013
18	Strawberry Pt N Cr	81.8%	1.394	11	2009 - 2011
19	Crescent Harbor Cr	44.4%	0.117	27	2010 - 2013
20	English Boom Cr	33.3%	2.058	6	2008, 2010 - 2011
21	Unnamed stream near Rocky Pt	0.0%	0.000	5	2013

Stream # (shown in Fig 1)	Stream name	Chinook presence rate	Average Chinook per minute	Days of electro-fishing	Year
22	Unnamed stream in Race Lagoon	0.0%	0.000	6	2013
23	Unnamed stream near Iverson Spit	0.0%	0.000	4	2013
24	Unnamed stream near Woodland Beach	0.0%	0.000	3	2013
25	Kristoferson Cr	77.8%	0.829	18	2009 - 2010
26	Unnamed stream in Triangle Cove	33.3%	0.361	3	2013
27	Camano Country Club Cr	25.0%	0.043	8	2010
28	Greenwood Cr	91.3%	3.889	23	2009 - 2010, 2012 - 2013
29	Cama Beach Cr	0.0%	0.000	9	2009
30	Unnamed stream near Greenbank	0.0%	0.000	4	2013
31	Unnamed stream in Saratoga Passage	0.0%	0.000	2	2013
32	Unnamed stream in Saratoga Passage	0.0%	0.000	3	2013
33	Spee-Bi-Dah Cr	0.0%	0.000	3	2013
34	Hibulb Cr	62.5%	0.129	8	2010
35	Unnamed stream in Holmes Harbor	50.0%	0.095	4	2013
36	Freeland Park Cr	0.0%	0.000	3	2013
37	Edgecliff Cr	0.0%	0.000	3	2013
38	Unnamed stream near Sandy Pt	33.3%	0.139	3	2013
39	Unnamed stream in Possession Sound	66.7%	0.109	3	2013
40	Zook Cr	41.7%	0.225	24	2009 - 2010, 2012
41	Glendale Cr	37.5%	0.107	16	2009 - 2010
42	Unnamed stream in Cultus Bay	0.0%	0.000	3	2013
43	Pigeon Cr #1	11.8%	0.020	17	2009 - 2010
44	Pigeon Cr #2	33.3%	0.024	3	2013
45	Unnamed stream near Howarth Park	0.0%	0.000	3	2013
46	Glenwood Cr	16.7%	0.075	6	2013
47	Unnamed stream near Darlington Beach	0.0%	0.000	3	2013
48	Merrill & Ring Cr	66.7%	0.664	24	2009 - 2010, 2012
49	Narbeck Cr	33.3%	0.038	3	2013
50	Powder Mill Gulch Cr	0.0%	0.000	3	2013

Stream # (shown in Fig 1)	Stream name	Chinook presence rate	Average Chinook per minute	Days of electro-fishing	Year
51	Edgewater Cr	20.0%	0.018	5	2013
52	Japanese Gulch Cr	0.0%	0.000	3	2013
53	Unnamed stream near Lighthouse Park	0.0%	0.000	3	2013
54	Unnamed stream in Mukilteo	0.0%	0.000	2	2013
55	Unnamed stream near Naketa Beach	0.0%	0.000	5	2013
56	Unnamed stream in Mukilteo	0.0%	0.000	2	2013
57	Big Gulch Cr	100.0%	0.252	2	2013
58	Unnamed stream in Mukilteo	0.0%	0.000	2	2013
59	Unnamed stream in Mukilteo	66.7%	0.253	3	2013
60	Unnamed stream near Shipwreck Pt	0.0%	0.000	3	2013
61	Picnic Pt Cr	33.3%	0.038	3	2013
62	Lunds Gulch Cr	75.0%	0.079	4	2013
63	Fruitdale Cr	0.0%	0.000	5	2013

Effect of landscape and stream characteristics

We used juvenile Chinook salmon presence rate and abundance to statistically test effects of landscape, stream, and stream mouth characteristics.

Juvenile Chinook salmon presence rate – GLM testing for effects of fixed factors revealed log-transformed Chinook presence rate for small streams in the Whidbey Basin was influenced by all three continuous variables (distance to nearest river, watershed area, and channel slope) and two of three categorical variables (presence of longshore sediment deposition at stream mouth, presence of culvert at stream mouth) (Table 11).

Pair-wise testing results show that streams that have longshore sediment deposition at their mouth have higher juvenile Chinook salmon presence rates than streams without longshore deposition (Table 12). Also, streams that do not have culverts at their mouth have higher juvenile Chinook salmon presence rates than streams with culverts at their mouth that do not backwater at high tide (Table 12). Streams with culverts at their mouth that do not backwater at high tide have lower juvenile Chinook salmon presence rates than streams with culverts that backwater at high tide. Streams without culverts have juvenile Chinook salmon presence rates similar to streams with culverts that backwater at high tide.

Table 11. ANOVA results from Generalized Linear Model effects testing for log-transformed juvenile Chinook salmon presence rate in Whidbey Basin small streams. Bold values are significant at the 0.05 level.

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Distance to nearest river (km)	0.062	1	0.062	12.107	**0.001**
Watershed area (ha)	0.066	1	0.066	13.015	**0.001**
Channel slope (%)	0.028	1	0.028	5.576	**0.022**
Longshore sediment deposition present at stream mouth (yes/no)	0.027	1	0.027	5.355	**0.024**
Stream drains into pocket estuary (yes/no)	0.004	1	0.004	0.800	0.375
Culvert at stream mouth (no/yes and condition if yes)	0.082	2	0.041	8.007	**0.001**
Error	0.281	55	0.005		

Table 12. Pair-wise testing results for juvenile Chinook salmon presence rate by strata using Tukey's Honestly-Significant-Difference Test. Bold values are significant at the 0.05 level.

Strata (i)	Strata (j)	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
Longshore sediment dep at mouth: no	Longshore sediment dep at mouth: yes	-0.071	**0.024**	-0.125	-0.017
Culvert at stream mouth: no	Culvert at stream mouth: yes, not tidally backwatered	0.080	**0.002**	0.031	0.128
Culvert at stream mouth: no	Culvert at stream mouth: yes, tidally backwatered	-0.004	0.987	-0.063	0.055
Culvert at stream mouth: yes, not tidally backwatered	Culvert at stream mouth: yes, tidally backwatered	-0.084	**0.009**	-0.146	-0.022

Predictive model

For the continuous variables identified as statistically significant in GLM testing (Table 11), we developed a multiple regression model to predict log transformed Chinook presence using the streams that grouped the same in the pair-wise analysis for culverts (Table 12). The streams used were: 1) streams without culverts at their mouth, and 2) streams with culverts that backwater at high tide. The regression model was highly significant but explained just slightly over half the variation in our data ($R^2 = 0.56$, $p = 0.0000011$).

The regression model is: Log transformed Chinook presence rate = (-.00865**DIST*) + (.000142**WA*) + (-.4023**SL*) + 0.20033, where

- *DIST* is the distance to nearest river mouth (in kilometers) from the surveyed stream
- *WA* is the watershed area (in hectares) of the surveyed stream
- *SL* is the average channel slope (%) of the surveyed stream reach

The regression coefficients for all three continuous variables are consistent with our hypotheses for these factors. Distance to nearest river is negative, suggesting the closer the stream is to the source of juvenile Chinook salmon the higher the likelihood Chinook will be present. Watershed area is positive, suggesting larger watersheds are more likely to have juvenile Chinook salmon than smaller watersheds. Channel slope is negative, suggesting steeper streams have a poorer chance of having juvenile Chinook salmon than flatter streams. Each of the three regression variables appears to have a threshold relationship with juvenile Chinook salmon presence. Watersheds smaller than 45 hectares (111 acres) did not have juvenile Chinook salmon present (Figure 10, top panel). Very small watersheds, possibly those smaller than 45 hectares, likely do not have enough energy to develop habitat conditions sufficient to support juvenile Chinook salmon or to create suitable fish access conditions. Channels steeper than 6.5% did not have juvenile Chinook salmon present (Figure 10, bottom panel). Streams further away from natal Chinook salmon river mouths generally had lower presence rates, especially streams without culverts at their mouth (Figure 11, top panel). When looking at juvenile Chinook abundance, streams further away than about 7 km from a river mouth had much lower juvenile Chinook abundance than streams closer than 7 km (Figure 11, bottom panel).

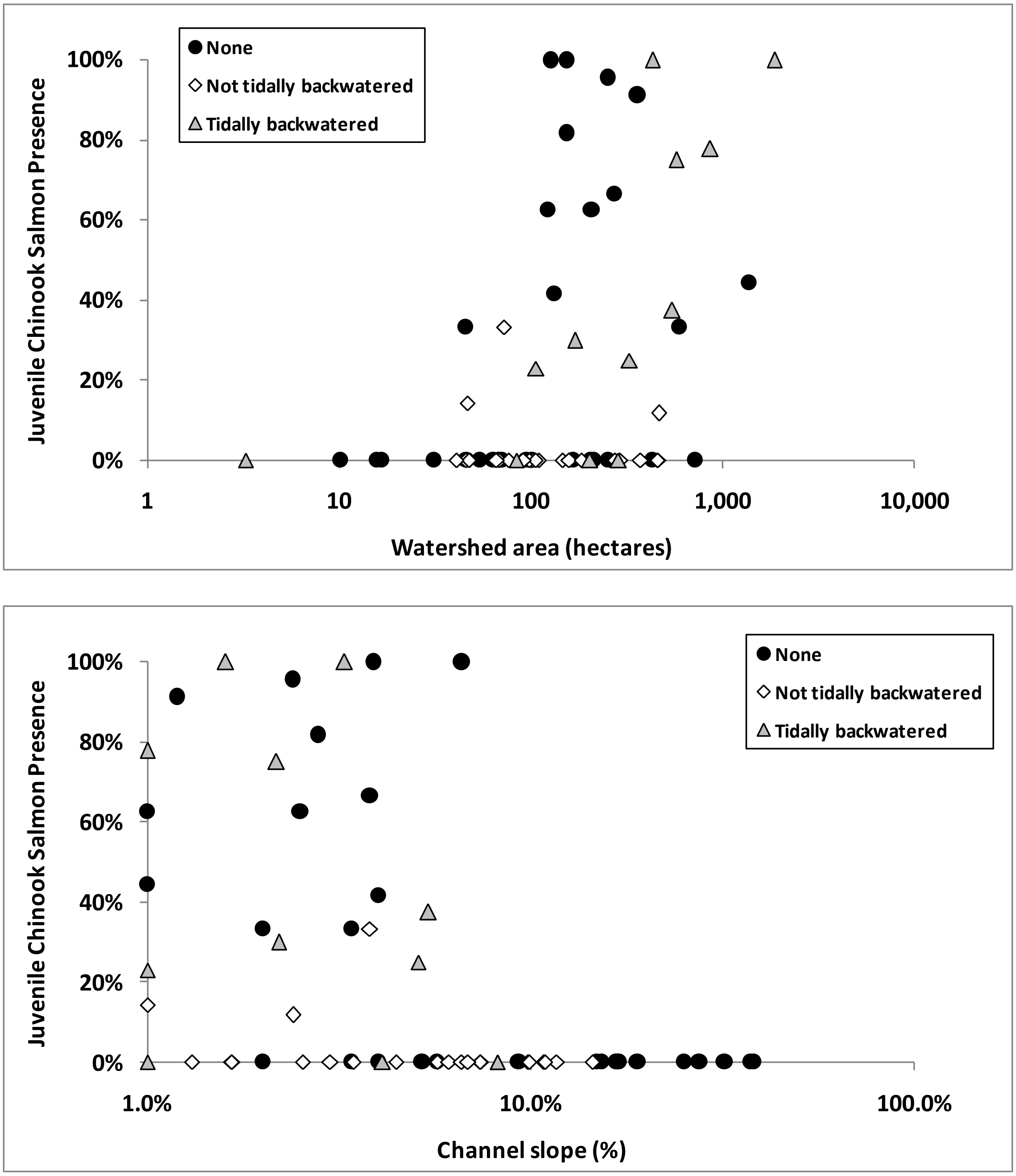


Figure 10. The relationship between watershed area (top panel) or channel slope (bottom panel) and juvenile Chinook salmon presence rate for small streams entering the Whidbey Basin. Solid black circles represent streams with no culverts at their stream mouth. Open diamonds represent streams with culverts at their mouth that do not backwater at high tide. Gray triangles represent streams with culverts at their mouth that backwater at high tide.

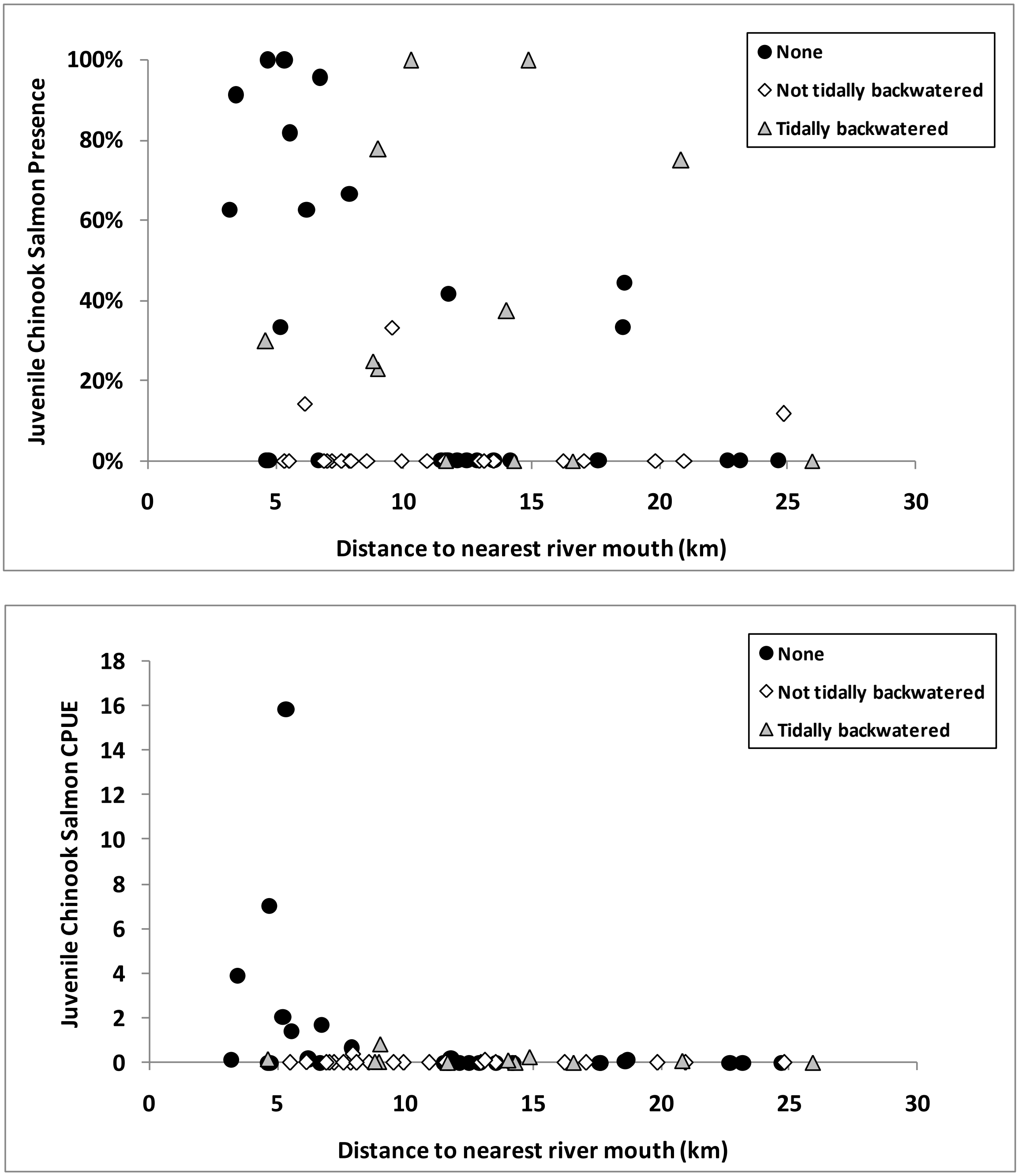


Figure 11. The relationship between distance to nearest river mouth and juvenile Chinook salmon presence rate (top panel) or juvenile Chinook salmon abundance (bottom panel) for small streams entering the Whidbey Basin. Solid black circles represent streams with no culverts at their stream mouth. Open diamonds represent streams with culverts at their mouth that do not backwater at high tide. Gray triangles represent streams with culverts at their mouth that backwater at high tide.

Discussion

Source of salmonids present in small streams

We found at least one of six salmonid species present in 40 of the 63 Whidbey Basin small streams sampled. The biological mechanism resulting in fish presence in a particular stream is by two possible sources: natal or non-natal.

Non-natal origin

Non-natal origin juvenile salmonids are progeny of adult fish that spawned in a different independent stream system than the small stream where the juvenile is found. In this study we are mostly concerned about non-natal origin Chinook salmon.

Since no adult Chinook salmon spawn in the small streams we sampled, juvenile Chinook salmon found using these small streams are of non-natal origin, meaning the juvenile salmon came from a different stream (i.e., one of the three Whidbey Basin rivers) through its estuary and into the marine waters of the Whidbey Basin, and then into the Whidbey Basin small stream.

The same non-natal use of small streams is likely true for the pink salmon we found in Strawberry Pt N Creek and Greenwood Creek. We assume non-natal origin for juvenile Chinook or pink salmon because the Whidbey Basin small streams are too small to support natal populations of Chinook and pink salmon in Puget Sound, and because stream flow is low or completely lacking during the time of year (late summer and early fall) when spawning adults of these species would enter the independent small streams.

The juvenile steelhead found in our study were likely of non-natal origin. Most juvenile steelhead we caught were over 100 mm in fork length, suggesting these fish were more than a year old by the time we caught them. Because steelhead live in fresh water for one to three years before migrating to sea, the general absence of smaller juvenile steelhead in our small streams suggests these 100 mm-sized fish came from areas other than the streams we sampled. In addition, the 100 mm-sized fish found in our study are smaller than the general size range of outmigrating steelhead smolts in the Skagit River (Pflug et al. 2013), which suggests the steelhead we caught were not yet ready to migrate to sea and may be exhibiting the "nomad" life history type identified for coho salmon (Koski 2009).

Natal origin

Natal origin juvenile salmonids are progeny of adult fish that spawned in the same small stream where the juvenile is found.

We assume natal origin for coho salmon, chum salmon, and cutthroat trout in many of the small streams where we documented their presence, based on our knowledge of these species' life history which includes use of small independent streams for spawning throughout in Puget Sound, and on incidental observations during electrofishing surveys. For example, we observed several redds in Zook Creek during our winter sampling in 2009, which were likely coho redds based on the time of year, and later we caught coho salmon fry with prominent egg sacks attached. We also observed a pair of spawning cutthroat in Glendale Creek and a spawned-out chum salmon in Merrill and Ring Creek. These observations are in direct support of natal origin presence for coho, cutthroat and chum salmon, at least for the creeks where the observations were made. We acknowledge that non-natal origin of these species is also possible, especially for coho; non-natal use by coho has been documented in other coastal systems ranging from Oregon to Alaska (Miller & Sadro 2003; Koski 2009).

Limitations

In this report we only analyzed data that we collected. We did not attempt to find and use data from other sources to add to our salmonid presence results. However, we know that others have found juvenile salmonid presence in at least one stream where we did not. A consultant working for WA Department of Transportation captured a juvenile Chinook in Japanese Gulch Creek (McDowell, pers. comm., 2011).

Some of our salmonid presence results may be biased by including fish presence directly caused by humans adding fish to streams. For example, stocked rainbow trout in lakes found in the headwaters of some of our streams may find their way downstream. If we were to have captured any of these fish we would have identified them as juvenile steelhead. Another possible source of direct releases of fish into a stream is from a private hatchery, such as exists on Lunds Gulch Creek.

Juvenile Chinook salmon habitat opportunity in small streams

Fry sized juvenile Chinook salmon exist in the downstream migrating juvenile populations from all three Whidbey Basin rivers (Skagit – Kinsel et al. 2008; Stillaguamish – Griffith et al. 2009; Snohomish – Kubo et al. 2013). A high density of fish occurring in natal estuaries (e.g., Skagit) leads to more fry migrants in nearshore areas through density dependence (Beamer et al 2005; Greene and Beamer 2011). Estuary simplification may also lead to more fry migrants after flood events because fish have few refuge opportunities before they reach nearshore areas. Some fry migrants, once in the nearshore, appear to take up residence not only in pocket estuaries but also in small oft-seasonal streams that drain directly into the Whidbey Basin. Such non-natal stream use has been identified in the much larger but nearby Fraser River (Murray and Rosenau 1989).

Because fry migrant juvenile Chinook salmon are leaving the saline waters of the Whidbey Basin and entering these small streams, it may be true that the freshwater input serves to attract fish into the stream. It is likely that the fresh water in the stream serves an important function – osmoregulation – and that these independent small coastal streams could be considered a physiological refuge for juvenile Chinook salmon (as suggested by Redmond et al. 2005). Regardless, juvenile Chinook salmon are staying in the small streams long enough, and for other activities such as foraging, for the streams to be considered important. We did indeed find growth rates of individual juvenile Chinook salmon in small streams to be similar to the growth rates of juvenile Chinook salmon in pocket estuaries and tidal delta scrub shrub habitat. Based on these results, we suggest that independent small coastal streams have the ability to provide fry migrant Chinook salmon with suitable rearing habitat during the same period when many juvenile Chinook salmon are rearing in natal or pocket estuaries, thus providing habitat diversity opportunity for Chinook salmon populations with fry migrants.

Landscape and habitat factors influencing Chinook salmon presence

Our statistical analysis results support some of our original landscape and stream characteristic hypotheses for juvenile Chinook salmon use of small streams in the Whidbey Basin. We discuss each hypothesis below because they relate to identifying: 1) streams that could have juvenile Chinook salmon, and 2) potential actions to protect and restore these streams within the Whidbey Basin.

Presence of longshore sediment deposition at stream mouth

We hypothesized that longshore sediment deposition at a stream mouth might be a barrier to juvenile Chinook salmon access into the stream, especially if the stream is small and unable to overcome sediment deposition. However, we found juvenile Chinook salmon used small streams whether or not longshore sediment deposition was present and that juvenile Chinook salmon presence rates were actually higher in streams with longshore sediment deposition at their mouth. In some cases, we observed sediment deposition created a small impoundment, almost a lagoon, which the fish utilized. In other cases we found a lack of longshore sediment deposition at a stream mouth coinciding with a bulkhead with a culvert through it. In these instances the culvert, rather than a lack of sediment deposition, was likely the cause of low juvenile Chinook salmon presence rates. Thus, we conclude that juvenile salmon access conditions into small streams are a function of inter-relationships between fluvial and longshore processes, presence and condition of bulkheads, and presence and condition of culverts at stream mouths. Our study was not designed to unravel this level of covariation between the three factors.

It is likely true that longshore sediment deposition can act as a barrier to juvenile Chinook access into a stream, especially if the stream is small and unable to erode through or flow over deposited sediment. However, streams without human modification (e.g., bulkheads, culverts) at the mouth may benefit from habitat formed by the dynamic between healthy fluvial and longshore processes occurring at the stream's mouth.

Whether stream drains into a pocket estuary

We hypothesized that streams entering pocket estuaries have higher use by juvenile Chinook salmon than streams draining directly into marine waters because juvenile Chinook are known to congregate in pocket estuaries. We found juvenile Chinook salmon used small streams whether or not the stream entered a pocket estuary.

Presence and condition of culvert at stream mouth

We hypothesized that the presence and condition of a culvert at a stream's mouth would influence the presence rate of juvenile Chinook salmon. Our analyses support our culvert-at-stream-mouth hypothesis at all levels. We found that streams that do not have culverts have higher juvenile Chinook salmon presence rates than streams with culverts that do not backwater at high tide. Streams with culverts that do not backwater at high tide have lower juvenile Chinook salmon presence rates than streams with culverts that backwater at high tide. Streams without culverts have juvenile Chinook salmon presence rates similar to streams with culverts that backwater at high tide. These results infer that tidally-backwatering culverts allow juvenile Chinook salmon fry access to streams similar to streams with no culvert at their stream mouth. They also infer that culverts that do not backwater are barriers to upstream migration of juvenile Chinook salmon.

We recognize that a range of conditions exists for culverts. We found streams with culvert outlets located near MHHW and others much lower in the intertidal zone. Culvert length, cross sectional size and shape, slope, and material varies (see Appendix 1). This range of culvert conditions likely influences upstream juvenile salmon passage. For example, an undersized culvert with an outlet low in the intertidal may not work well for upstream fish passage even though the outlet is backwatered frequently. We did not analyze the range of culvert conditions in our study but recommend it for future work as culverts at stream mouths are common.

A small stream protection strategy should consider preventing new culverts from being added to stream mouths. A small streams restoration strategy should include removing culverts or retrofitting streams with culverts at their mouth to a design that allows upstream juvenile salmon passage.

Stream channel slope

We hypothesized that: 1) channel slope is negatively (lower is better) correlated with juvenile Chinook salmon abundance and/or juvenile Chinook salmon presence rates, and 2) a maximum channel slope is a threshold for juvenile Chinook salmon presence (i.e., slope exceeding the maximum would not have juvenile Chinook salmon present). We found channels steeper than 6.5% to not have juvenile Chinook salmon present. Limits of channel slope are constrained by the geomorphology of the watershed; some streams are naturally steep and these will not likely be used by juvenile Chinook salmon if they are steeper than 6.5%. However, channel straightening and rerouting can dramatically change channel slope so these types of actions in streams could be a positive (remeandering) or negative (straightening) influence on juvenile Chinook salmon. Restoration and protection actions should consider the effects of actions that influence channel slope in small streams near nearshore areas of the Whidbey Basin.

Watershed size

We hypothesized that: 1) watershed size is positively (bigger is better) correlated with juvenile Chinook salmon use, and 2) a minimum watershed size is required for juvenile Chinook salmon presence. We found watersheds smaller than 45 hectares (111 acres) did not have juvenile Chinook salmon present. Very small watersheds, possibly those smaller than 45 hectares, likely do not have enough energy to develop habitat conditions sufficient to support juvenile Chinook salmon or create suitable access conditions for upstream migrating juvenile salmon. Stream channel relocation due to development (e.g., drainage, road construction, etc.) can alter the effective watershed size and the hydrograph in small watersheds. These types of changes in small watersheds may flip a stream from being capable of supporting juvenile Chinook salmon to a watershed that cannot.

Distance to nearest river mouth

We hypothesized that streams closer to natal Chinook salmon rivers have more juvenile Chinook salmon and/or higher juvenile Chinook salmon presence rates than streams further away from river mouths. We found streams further away from natal Chinook salmon river mouths had lower presence rates, suggesting the closer the stream is to the source of juvenile Chinook salmon the higher the likelihood Chinook salmon will be present. Streams further than about 20 km away had no juvenile Chinook present in them. However, when looking at juvenile Chinook abundance, streams further away than about 7 km from a river mouth had much lower juvenile Chinook abundance than streams closer than 7 km. Distance to nearest river mouth could be a useful variable to prioritize small streams for restoration activities such as retrofitting or removing culverts. All small streams should be protected that have the potential to be used by juvenile Chinook salmon.

Conclusions

Our study focused on the potential for small coastal streams in the Whidbey Basin to be important rearing habitat for juvenile Chinook salmon. While we observed other species of salmon present in small streams, our conclusions and recommendations focus on Chinook salmon.

The juvenile Chinook salmon found in the small coastal streams of the Whidbey Basin are a result of non-natal processes. The fish originate from the three Whidbey Basin Chinook salmon bearing rivers: Skagit, Snohomish, and Stillaguamish. We show that juvenile Chinook salmon are not just present in these small streams, but are actively rearing and growing. They appear to be using the streams as a nursery, much like natal and pocket estuaries are used by juvenile Chinook salmon.

These small streams appear to be one of the habitats used by fry migrant Chinook salmon after they have left their natal river. Protecting and restoring these streams would benefit the recovery of Whidbey Basin Chinook salmon populations because all rivers demonstrate existence – if not an abundance – of fry migrants in their populations. Providing habitat opportunity for fry migrants should improve survival of this life history type and improve overall viability of the populations through improved life history diversity.

The small coastal streams of the Whidbey Basin are often spatially and/or temporally intermittent. They could easily be overlooked as potential salmon habitat, especially for Chinook salmon, since no Chinook spawning occurs in these streams. The streams are small enough that instream habitat can easily be degraded through direct actions such as channel straightening, armoring, removal of riparian vegetation, and culverting. Some examples of this are shown in photographs in Appendices 1 and 4.

The watershed areas of these streams are generally quite small and therefore more susceptible to development actions that change the hydrologic character of streams, such as rerouting flow when roads are developed in the watershed (e.g., not enough culverts, not the right location of culverts) or extending channels through ditching, resulting in a flashier hydrograph.

These streams may also be overlooked as salmon habitat from a regulatory and restoration standpoint because of their lack of accurate mapping and stream typing. Better mapping of small streams and use of our predictive model for juvenile Chinook salmon presence would help managers better protect small stream habitat. In the discussion section of this report we identified specific characteristics of streams and recommended actions that would better identify, protect and restore these small streams.

References

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K. Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. Skagit River System Cooperative, Appendix D to the Skagit Chinook Recovery Plan, LaConner, WA. www.skagitcoop.org.

Beamer, E., A. McBride, R. Henderson, J. Griffith, K. Fresh, T. Zackey, R. Barsh, T. Wyllie-Echeverria, and K Wolf. 2006. Habitat and fish use of pocket estuaries in the Whidbey Basin and north Skagit County bays, 2004 and 2005. Skagit River System Cooperative, LaConner, WA. www.skagitcoop.org.

Beamer, E., R. Henderson, and K. Wolf. 2009. Lone Tree Creek and pocket estuary restoration: Progress report for 2004-2008 fish monitoring. Skagit River System Cooperative, LaConner, WA. www.skagitcoop.org.

Beamer, E, R Henderson, and K Wolf. 2011. Juvenile salmon, estuarine, and freshwater fish utilization of habitat associated with the Fisher Slough Restoration Project in 2010. Report prepared for The Nature Conservancy, Washington. www.skagitcoop.org.

Beamer, EM, A McBride, R Henderson, K Wolf. 2003. The importance of non-natal pocket estuaries in Skagit Bay to wild Chinook salmon: An emerging priority for restoration. Skagit River System Cooperative, LaConner, WA. www.skagitcoop.org.

Beamer, E., J. Sartori, and K. Larsen. 2000. Skagit Chinook Life History Study Skagit System Cooperative, Progress Report Number 3, LaConner, WA. www.skagitcoop.org.

Collins, B. 2000. Mid-19th Century Stream Channels and Wetlands Interpreted from Archival Sources for Three North Puget Sound Estuaries. University of Washington, Seattle.

Collins, B., and A. Sheikh. 2005. Historical reconstruction, classification, and change analysis of Puget Sound tidal marshes. University of Washington, Department of Earth and Space Sciences, Seattle.

Greene, C., and E. Beamer. 2011. Monitoring population responses to estuary restoration by Skagit River Chinook salmon. Fish Ecology Division, Northwest Fisheries Science Center, Seattle. www.skagitcoop.org.

Griffith, J., R. Van Arman, and J. Drotts. 2009. Annual Report- 2008 Stillaguamish River smolt trapping project. Stillaguamish Tribe of Indians, Natural Resource Department, Arlington, WA.

Johnson, D.H., and coauthors. 2007. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, MD.

Kalinowski, S.T. 2003. Genetic Mixture Analysis 1.0. Montana State University, Bozeman.

Kinsel, C., M. Zimmerman, L. Kishimoto, and P. Topping. 2008. 2007 Skagit River salmon production evaluation. WA State Department of Fish & Wildlife, Olympia.

Koski, K. 2009. The fate of coho salmon nomads: The story of an estuarine-rearing strategy promoting resilience. Ecology and Society 14:1:4.

Kubo, J., K. Finley, and K. Nelson. 2013. Draft 2000-2012 Skykomish and Snoqualmie Rivers Chinook and coho salmon out-migration study. Tulalip Tribes Natural Resources Department, Tulalip, WA.

McDowell, M. 2011. Personal communication *in* Mukilteo Multimodal project Draft EIS, January 2012.

Merrit, G. 2009. Status and Trends Monitoring for Watershed Health & Salmon Recovery, Field Data Collection Protocol: Wadeable Streams. Publication no. 09-03-xxx, Environmental Assessment Program, Washington State Department of Ecology, Olympia. www.ecy.wa.gov/programs/eap/stsmf/docs/01SnTWadeableManA-Vv3bhfl.pdf

Miller, B., and S. Sadro. 2003. Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. Trans. Amer. Fish. Society 132:546-559.

Moran, P., and 11 co-authors. 2005. Interlaboratory standardization of coast-wide Chinook salmon genetic data for international harvest management. Unpublished report to Pacific Salmon Commission, U.S. Chinook Technical Committee.

Murray, C., and M. Rosenau. 1989. Rearing of juvenile Chinook salmon in nonnatal tributaries of the Lower Fraser River, British Columbia. Trans. Amer. Fish. Society 118:284-289.

Nielsen, L.A., and D. L. Johnson. 1983. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

National Marine Fisheries Service. 2000. Guidelines for Electrofishing Waters Containing Salmonids Listed under the Endangered Species Act. www.westcoast.fisheries.noaa.gov/publications/reference_documents/esa_refs/section4d/electro2000.pdf

Pflug, D., and coauthors.. 2013. Ecological, Genetic and Productivity Consequences of Interactions between Hatchery and Natural-Origin Steelhead of the Skagit Watershed. Final Technical Report to Saltonstall-Kennedy Project # NA08NMF4270424.

Pleus, A.E., and D. Schuett-Hames. 1998. TFW Monitoring Program methods manual for stream segment identification. Prepared for the WA Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-98-001. DNR #103.

Pleus, A.E., D. Schuett-Hames, and L. Bullchild. 1999. TFW Monitoring Program methods manual for the habitat survey. Prepared for the WA State Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-003. DNR #105.

Redman, S., D. Myers, D. Averill, K. Fresh, and B. Graeber. 2005. Regional nearshore and marine aspects of salmon recovery in Puget Sound. Puget Sound Action Team, NOAA Fisheries, Seattle.

Skagit River System Cooperative & Washington Department of Fish and Wildlife. 2005. Skagit Chinook Recovery Plan. Available at www.sharedsalmonstrategy.org/ or www.skagitcoop.org/.

Appendix 1. Photographs of stream mouths

Figure 1. Example of culvert that backwaters by tide with outlet in the lower intertidal (Freeland Park Cr, stream # 36).


Figure 2. Example of culvert that backwaters by tide with outlet in the upper intertidal (Big Gulch Creek, stream #57).

Figure 3. Example of culvert that backwaters by tide with outlet in the upper intertidal (Lunds Gulch Creek, stream #62).

Figure 4. Example of culvert that backwaters by tide with outlet in the upper intertidal (Glenwood Creek, stream #46).


Figure 5. Example of culvert that does not backwater by tide with outlet higher than MHHW (Unnamed stream in Mukilteo, stream #54).


Figure 6. Example of stream mouth with no culvert. The creek has a steep debris-filled channel immediately upstream of intertidal zone (Edgecliff Cr, stream #37).

Figure 7. Example of stream mouth with no culvert. The creek is low gradient across the intertidal and immediately upstream of intertidal zone (Unnamed stream in Skagit Bay, stream #16).

Appendix 2. GAPS Baseline for Chinook salmon

Table 1. GAPS Baseline for Chinook salmon used in this study.

Region	Drainage / Area	River	Source	Run	Origin
Puget Sound	S Puget Sound	Soos Creek	Soos Creek	Fall	H
Puget Sound	S Puget Sound	White River	White River	Spring	H
Puget Sound	S Puget Sound	Nisqually	Clear Creek	Fall	H
Puget Sound	S Puget Sound	Puyallup	South Prairie Creek	Fall	H
Puget Sound	S Puget Sound	Puyallup	Voights Creek	Fall	H
Puget Sound	Hood Canal	Skokomish	George Adams	Fall	H
Puget Sound	Hood Canal	Hamma Hamma	Hamma Hamma	Fall	W
Puget Sound	Whidbey Basin	Snohomish	Skykomish	Summer	W
Puget Sound	Whidbey Basin	Snohomish	Snoqualmie	Fall	W
Puget Sound	Whidbey Basin	Snohomish	Wallace	Summer	H
Puget Sound	Whidbey Basin	Stillaguamish	NF Stillaguamish	Summer	H/W
Puget Sound	Whidbey Basin	Skagit	Lower Sauk	Summer	W
Puget Sound	Whidbey Basin	Skagit	Upper Sauk	Spring	W
Puget Sound	Whidbey Basin	Skagit	Marblemount	Spring	H
Puget Sound	Whidbey Basin	Skagit	Marblemount	Spring	H
Puget Sound	Whidbey Basin	Skagit	Cascade	Spring	W
Puget Sound	Whidbey Basin	Skagit	Skagit	Summer	W
Puget Sound	Whidbey Basin	Skagit	Suiattle	Spring	W
Puget Sound	Whidbey Basin	Samish	Samish	Fall	H
Puget Sound	N Puget Sound	Nooksack	NF Nooksack	Spring	H/W
Puget Sound	Juan de Fuca	Dungeness	Dungeness	Spring	W
Puget Sound	Juan de Fuca	Elwha	Elwha	Summer	W
Puget Sound	Juan de Fuca	Elwha	Elwha	Summer	H
Washington Coast	Washington Coast	Queets	Queets	Fall	W
Washington Coast	Washington Coast	Quillayute	Quillayute/ Bogachiel	Fall	W
Washington Coast	Washington Coast	Quillayute	Sol Duc	Spring	H
Washington Coast	Washington Coast	Hoh	Hoh	Fall	W
Washington Coast	Washington Coast	Sooes	Makah NFH	Fall	H
Strait of Georgia	South BC Mainland	Porteau Cove	Porteau Cove	Fall	H
Strait of Georgia	South BC Mainland	Klinaklini	Klinaklini	Fall	W
Strait of Georgia	E Vancouver Is.	Big Qualicum	Big Qualicum	Fall	H
Strait of Georgia	E Vancouver Is.	Quinsam	Quinsam	Fall	H
Strait of Georgia	E Vancouver Is.	Cowichan	Cowichan	Fall	H
Strait of Georgia	E Vancouver Is.	Nanaimo	Nanaimo	Fall	H
Strait of Georgia	E Vancouver Is.	Puntledge	Puntledge	Fall	H
West Vancouver Is.	W Vancouver Is.	Nitinat	Nitinat	Fall	H
West Vancouver Is.	W Vancouver Is.	Robertson	Robertson	Fall	H
West Vancouver Is.	W Vancouver Is.	Sarita	Sarita	Fall	H
West Vancouver Is.	W Vancouver Is.	Marble	Marble	Fall	H
West Vancouver Is.	W Vancouver Is.	Conuma	Conuma	Fall	H
West Vancouver Is.	W Vancouver Is.	Tahsis	Tahsis	Fall	W
West Vancouver Is.	W Vancouver Is.	Tofino Inlet	Tranquil Creek	Fall	W
Fraser	Lower Fraser	Chilliwack	Chilliwack	Fall	H
Fraser	Lower Fraser	Birkenhead	Birkenhead	Spring	H
Fraser	Lower Fraser	Maria Slough	Maria Slough	Summer	W

Region	Drainage / Area	River	Source	Run	Origin
Fraser	Thompson	L Thompson	Nicola	Spring	H
Fraser	Thompson	L Thompson	Spius	Spring	H
Fraser	Thompson	S Thompson	Adams	Fall	H
Fraser	Thompson	S Thompson	Lower Thompson	Fall	W
Fraser	Thompson	S Thompson	Mid Shuswap	Fall	H
Fraser	Thompson	N Thompson	Clearwater	Spring	W
Fraser	Thompson	N Thompson	Louis	Spring	W
Fraser	Thompson	N Thompson	Deadman	Spring	H
Fraser	Thompson	N Thompson	Raft	Summer	W
Fraser	Mid Fraser	Chilko	Chilko	Spring	W
Fraser	Mid Fraser	Chilko	Upper Chilcotin	Spring	W
Fraser	Mid Fraser	Nechako	Nechako	Spring	W
Fraser	Mid Fraser	Quesnel	Quesnel	Spring	W
Fraser	Mid Fraser	Stuart	Stuart	Spring	W
Fraser	Upper Fraser	Morkill	Morkill	Spring	W
Fraser	Upper Fraser	Salmon	Salmon	Spring	W
Fraser	Upper Fraser	Swift	Swift	Spring	W
Fraser	Upper Fraser	Torpy	Torpy	Spring	W

Appendix 3. River of origin analysis

Table 1. List of juvenile Chinook salmon from small streams surveyed in 2009, used for river-of-origin analysis, with their origin assignments. All fish were unmarked and age 0+.

Region within Whidbey Basin	Creek	Date	Fork length (mm)	Genetic ID	Best Estimate	Probability of best estimate
Skagit Bay	Lone Tree Cr	4/27/09	39	90314-1323	SSF/HC	0.803
Possession Sound	Glendale Cr	2/20/09	44	90313-138	Skykomish	0.807
Possession Sound	Zook Cr	5/29/09	76	90334-77	Skagit	0.807
Possession Sound	Merrill & Ring Cr	4/9/09	43	90313-054	Stillaguamish	0.809
Skagit Bay	Strawberry Cr	3/11/09	42	90314-0260	Skagit	0.812
Skagit Bay	Lone Tree Cr	3/27/09	41	90314-0296	Skagit	0.813
Skagit Bay	Lone Tree Cr	1/15/09	41	90314-0201	Skagit	0.820
Skagit Bay	SneeOosh Cr	4/6/09	42	90314-1110	Skagit	0.821
Port Susan	Kristoferson Cr	3/17/09	48	90313-072	Skagit	0.823
Skagit Bay	Strawberry Cr	4/7/09	50	90314-1121	Skagit	0.823
Possession Sound	Merrill & Ring Cr	5/15/09	53	90313-069	Stillaguamish	0.826
Possession Sound	Zook Cr	3/20/09	42	90313-029	Skagit	0.828
Skagit Bay	Lone Tree Cr	4/27/09	54	90314-1321	Stillaguamish	0.835
Skagit Bay	Lone Tree Cr	3/2/09	38	90314-0247	Skagit	0.842
Skagit Bay	Lone Tree Cr	1/15/09	38	90314-0204	Skagit	0.843
Skagit Bay	Lone Tree Cr	2/12/09	43	90314-0231	Skagit	0.849
Skagit Bay	SneeOosh Cr	4/6/09	48	90314-1109	Skagit	0.855
Possession Sound	Merrill & Ring Cr	3/20/09	48	90313-016	SSF/HC	0.857
Skagit Bay	Lone Tree Cr	2/12/09	42	90314-0235	Skagit	0.857
Skagit Bay	Lone Tree Cr	3/27/09	43	90314-0153	Skagit	0.859
Skagit Bay	Lone Tree Cr	4/2/09	42	90314-1154	Skykomish	0.862
Skagit Bay	Lone Tree Cr	2/12/09	41	90314-0240	Skagit	0.867
Skagit Bay	Lone Tree Cr	1/15/09	41	90314-0206	Skagit	0.872
Skagit Bay	Strawberry Cr	3/11/09	42	90314-0252	Skagit	0.874
Skagit Bay	Lone Tree Cr	2/12/09	41	90314-0232	Stillaguamish	0.877
Skagit Bay	Strawberry Cr	4/7/09	39	90314-1142	Skagit	0.878
Skagit Bay	Strawberry Cr	4/7/09	44	90314-1124	Skagit	0.879
Skagit Bay	Strawberry Cr	4/7/09	43	90314-1127	Stillaguamish	0.884
Skagit Bay	Lone Tree Cr	1/15/09	37	90314-0217	Skagit	0.889
Skagit Bay	Lone Tree Cr	1/15/09	38	90314-0213	Skagit	0.889
Skagit Bay	Lone Tree Cr	4/27/09	50	90314-1338	Skagit	0.892
Skagit Bay	Strawberry Cr	3/11/09	41	90314-0265	Stillaguamish	0.894
Possession Sound	Zook Cr	4/9/09	51	90313-042	Skagit	0.898
Possession Sound	Zook Cr	3/20/09	52	90313-030	Skagit	0.899
Skagit Bay	Strawberry Cr	4/7/09	44	90314-1123	Skagit	0.903
Skagit Bay	Strawberry Cr	4/7/09	42	90314-1129	Skagit	0.905
Skagit Bay	Lone Tree Cr	2/12/09	39	90314-0237	Skagit	0.907
Port Susan	Kristoferson Cr	4/1/09	48	90313-032	Stillaguamish	0.907
Skagit Bay	SneeOosh Cr	4/6/09	44	90314-1114	Skagit	0.908
Skagit Bay	Lone Tree Cr	3/27/09	42	90314-0295	Skagit	0.910
Skagit Bay	Lone Tree Cr	2/12/09	42	90314-0238	Stillaguamish	0.912
Skagit Bay	Strawberry Cr	4/7/09	41	90314-1140	Skagit	0.916

Region within Whidbey Basin	Creek	Date	Fork length (mm)	Genetic ID	Best Estimate	Probability of best estimate
Skagit Bay	Lone Tree Cr	3/2/09	41	90314-0272	Stillaguamish	0.917
Skagit Bay	Lone Tree Cr	2/12/09	43	90314-0228	Skagit	0.922
Skagit Bay	Lone Tree Cr	1/15/09	37	90314-0207	Skagit	0.923
Skagit Bay	Strawberry Cr	3/11/09	41	90314-0255	Skagit	0.927
Possession Sound	Merrill & Ring Cr	6/12/09	59	90334-76	Skagit	0.929
Skagit Bay	Lone Tree Cr	4/27/09	46	90314-1337	Skagit	0.931
Skagit Bay	Lone Tree Cr	3/27/09	43	90314-0294	Skagit	0.932
Skagit Bay	Lone Tree Cr	4/2/09	42	90314-1157	Skagit	0.932
Skagit Bay	Lone Tree Cr	4/27/09	43	90314-1320	Skagit	0.934
Skagit Bay	Lone Tree Cr	3/27/09	37	90314-0152	Skagit	0.939
Skagit Bay	Strawberry Cr	4/7/09	42	90314-1134	Skagit	0.939
Skagit Bay	Strawberry Cr	3/11/09	40	90314-0263	Skagit	0.943
Skagit Bay	Strawberry Cr	4/7/09	42	90314-1137	Skagit	0.943
Skagit Bay	Lone Tree Cr	1/15/09	37	90314-0216	Skagit	0.944
Skagit Bay	Lone Tree Cr	4/27/09	50	90314-1317	Skagit	0.945
Skagit Bay	Lone Tree Cr	3/2/09	46	90314-0248	Skagit	0.945
Port Susan	Kristoferson Cr	2/18/09	43	90313-123	Skagit	0.947
Port Susan	Kristoferson Cr	3/4/09	39	90313-141	Skagit	0.950
Skagit Bay	Strawberry Cr	4/7/09	41	90314-1135	Skagit	0.952
Skagit Bay	Lone Tree Cr	3/2/09	43	90314-0271	Skagit	0.953
Skagit Bay	Lone Tree Cr	3/27/09	43	90314-0154	Skagit	0.953
Port Susan	Kristoferson Cr	3/17/09	44	90313-007	Skagit	0.954
Possession Sound	Merrill & Ring Cr	4/9/09	59	90313-058	Stillaguamish	0.956
Possession Sound	Merrill & Ring Cr	2/6/09	38	90313-117	Skagit	0.957
Skagit Bay	Strawberry Cr	3/11/09	47	90314-0253	Skykomish	0.960
Skagit Bay	Lone Tree Cr	1/15/09	43	90314-0220	Skagit	0.962
Skagit Bay	Lone Tree Cr	1/15/09	36	90314-0215	Skagit	0.964
Skagit Bay	Lone Tree Cr	1/15/09	38	90314-0210	Skagit	0.965
Skagit Bay	Lone Tree Cr	1/15/09	38	90314-0218	Skagit	0.965
Skagit Bay	Strawberry Cr	4/7/09	40	90314-1138	Skagit	0.968
Skagit Bay	Strawberry Cr	3/11/09	36	90314-0266	Stillaguamish	0.969
Skagit Bay	Strawberry Cr	4/7/09	48	90314-1125	Skagit	0.969
Skagit Bay	Lone Tree Cr	1/15/09	40	90314-0203	Skagit	0.969
Skagit Bay	Lone Tree Cr	2/12/09	44	90314-0230	Skagit	0.970
Possession Sound	Pigeon #1 Cr	4/15/09	42	90313-066	Skagit	0.978
Port Susan	Kristoferson Cr	2/18/09	41	90313-124	Skagit	0.979
Skagit Bay	Lone Tree Cr	1/15/09	40	90314-0211	Stillaguamish	0.980
Skagit Bay	Strawberry Cr	5/6/09	42	90314-1253	Skagit	0.981
Skagit Bay	Lone Tree Cr	4/27/09	51	90314-1339	Skagit	0.983
Skagit Bay	SneeOosh Cr	4/6/09	51	90314-1117	Skagit	0.983
Skagit Bay	SneeOosh Cr	4/6/09	39	90314-1112	Skagit	0.986
Skagit Bay	Strawberry Cr	4/7/09	44	90314-1211	Skagit	0.986
Skagit Bay	Strawberry Cr	3/11/09	48	90314-0267	Skagit	0.987
Skagit Bay	Strawberry Cr	3/11/09	44	90314-0256	Skagit	0.988
Skagit Bay	Lone Tree Cr	4/27/09	39	90314-1330	Skagit	0.988
Skagit Bay	Strawberry Cr	3/11/09	40	90314-0258	Skagit	0.989

Region within Whidbey Basin	Creek	Date	Fork length (mm)	Genetic ID	Best Estimate	Probability of best estimate
Skagit Bay	Lone Tree Cr	3/27/09	40	90314-0291	Skagit	0.989
Skagit Bay	Lone Tree Cr	3/2/09	40	90314-0244	Skagit	0.989
Possession Sound	Zook Cr	4/9/09	55	90313-045	SSF/HC	0.991
Port Susan	Kristoferson Cr	3/17/09	46	90313-004	Skagit	0.992
Skagit Bay	Lone Tree Cr	1/15/09	38	90314-0208	Skagit	0.992
Skagit Bay	Lone Tree Cr	1/15/09	41	90314-0205	Skagit	0.993
Skagit Bay	SneeOosh Cr	4/6/09	50	90314-1118	Skagit	0.993
Skagit Bay	Lone Tree Cr	2/12/09	45	90314-0229	Skagit	0.994
Skagit Bay	SneeOosh Cr	4/6/09	41	90314-1116	Skagit	0.994
Skagit Bay	Strawberry Cr	4/7/09	42	90314-1143	Skagit	0.995
Skagit Bay	Strawberry Cr	4/7/09	41	90314-1141	Skagit	0.995
Skagit Bay	Lone Tree Cr	4/27/09	43	90314-1318	Skagit	0.995
Possession Sound	Zook Cr	2/6/09	37	90313-112	Skykomish	0.995
Skagit Bay	Lone Tree Cr	2/12/09	41	90314-0234	Skagit	0.996
Skagit Bay	Lone Tree Cr	3/27/09	41	90314-0156	Skagit	0.996
Skagit Bay	Lone Tree Cr	4/27/09	53	90314-1334	Skagit	0.997
Port Susan	Kristoferson Cr	2/18/09	42	90313-121	Skagit	0.998
Skagit Bay	Strawberry Cr	4/7/09	49	90314-1122	Skagit	0.998
Possession Sound	Merrill & Ring Cr	3/20/09	41	90313-015	Skykomish	0.998
Port Susan	Kristoferson Cr	5/13/09	62	90313-067	Stillaguamish	0.998
Skagit Bay	Lone Tree Cr	2/12/09	43	90314-0236	Skagit	0.999
Port Susan	Kristoferson Cr	3/17/09	46	90313-009	Skykomish	0.999
Skagit Bay	SneeOosh Cr	4/6/09	38	90314-1115	Skagit	0.999
Skagit Bay	Lone Tree Cr	2/12/09	41	90314-0233	Skagit	1.000
Skagit Bay	Lone Tree Cr	4/27/09	43	90314-1329	Skagit	1.000
Skagit Bay	Strawberry Cr	3/11/09	42	90314-0259	Skagit	1.000
Skagit Bay	Lone Tree Cr	4/27/09	43	90314-1328	Skagit	1.000
Skagit Bay	Lone Tree Cr	4/2/09	46	90314-1158	Skagit	1.000
Port Susan	Kristoferson Cr	3/17/09	48	90313-005	Skagit	1.000
Skagit Bay	Lone Tree Cr	4/2/09	43	90314-1155	Skagit	1.000
Skagit Bay	Lone Tree Cr	4/27/09	49	90314-1331	Skagit	1.000
Skagit Bay	Strawberry Cr	3/11/09	38	90314-0257	Skagit	1.000

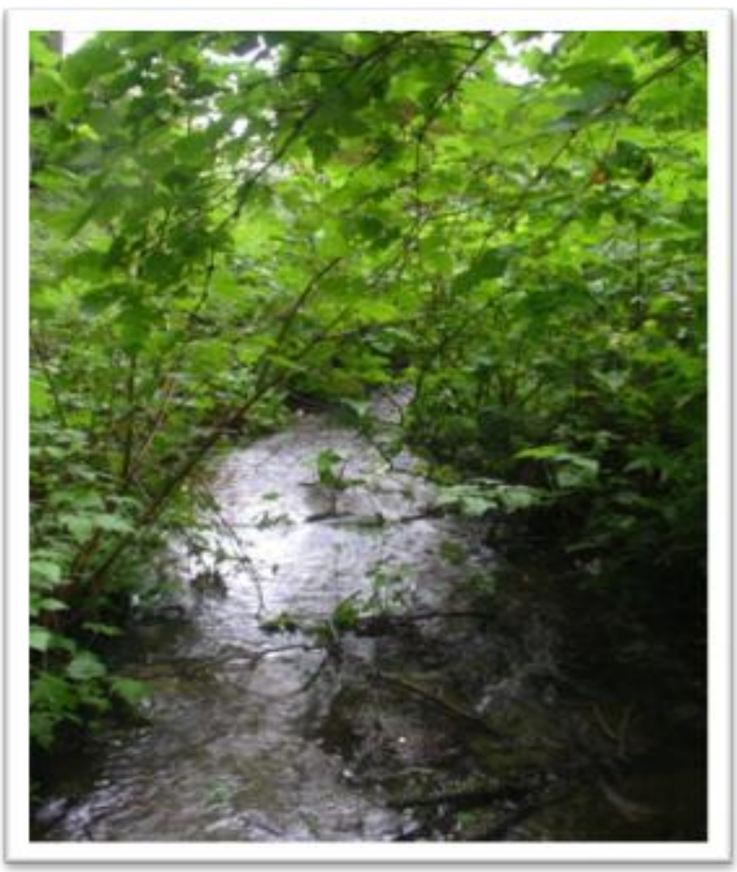
Appendix 4. Photographs of selected streams

Photos of a subset of the 63 streams sampled in our study.

Cama Beach Creek (#29)

Camano Country Club Creek (#27)

Kristoferson Creek (#25)



Greenwood Creek (#28)


Hibulb Creek (#34)


Pigeon Creek #1 (#43)

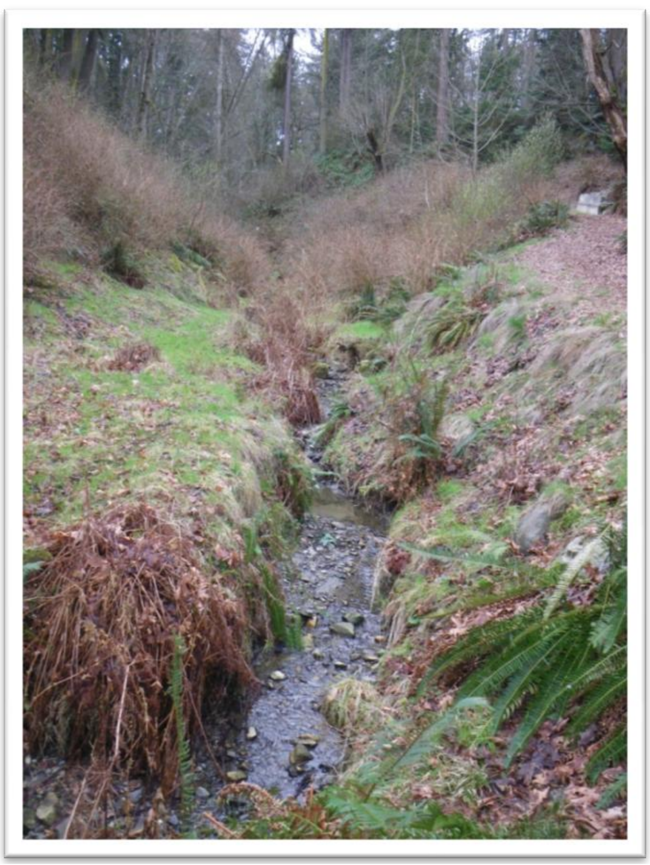
Merrill & Ring Creek (#48)

Zook Creek (#40)

Glendale Creek (#41)

Turners Creek (#1)

Strawberry Point N Creek, mouth (#18)



Strawberry Point N Creek, channel (#18)