EVALUATING MIGRATION TIMING AND HABITAT FOR JUVENILE CHINOOK SALMON AND WINTER STEELHEAD IN THE MAINSTEM WILLAMETTE RIVER AND MAJOR SPAWNING TRIBUTARIES

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Abstract

The primary goal of this analysis was to describe general rearing and migration timing of juvenile Chinook salmon *Oncorhynchus tshawytscha* relative to river flow in the mainstem Willamette River and the lower reaches of major spawning tributaries. A secondary goal was to describe habitat characteristics where juvenile Chinook salmon were sampled. We also describe the size, timing, and location of juvenile steelhead *O. mykiss*, which were incidentally collected. The analysis is based on data collected during a long-term (2002-2015) beach seine survey on the mainstem Willamette River and lower reaches of the spawning tributaries. Habitat characteristics were measured on a more limited scale than data collected on abundance and distribution of juvenile Chinook salmon. Habitat where large numbers of juvenile salmon were captured generally consisted of shallow gravel bars (mean depth = 0.578 m) with low slope (mean = -0.363 m), high dissolved oxygen (mean = 10.8 mg/l) and low water temperatures (mean = 14.7^{o} C). Catch rates of juvenile Chinook salmon were highest in May, with most fish migrating past Willamette Falls in early summer. Unclipped juvenile *O. mykiss* were visually identified as either rainbow trout or juvenile steelhead smolts. Rainbow trout were common in the major tributaries while steelhead smolts were rare in our seine catch. Steelhead smolts were caught most frequently in May. These results may be used to guide flow and habitat management in the mainstem Willamette River towards the benefit of ESA-listed salmonids and native fish communities.

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Introduction

The Willamette Valley Project (WVP) consists of 13 dams and reservoirs managed jointly by the U.S. Army Corps of Engineers (USACE), Bonneville Power Administration (BPA), and Bureau of Reclamation. The National Marine Fisheries Service concluded in the Willamette Project Biological Opinion (BiOp) that continued operation and maintenance of the WVP will jeopardize the existence of Upper Willamette River (UWR) spring Chinook salmon *Oncorhynchus tshawytscha* and UWR winter steelhead *O. mykiss* (NMFS 2008). Several Reasonable and Prudent Alternative (RPA) measures were identified in the BiOp to address issues relating to river flow; in particular RPA 2.3 (Minimum Mainstem Flow Objectives), RPA 2.4 (Tributary Flow Objectives – Project Release Minimums), RPA 2.7 (Environmental Flow/Pulse Flow Components, RPA 2.10 (Flow Related Research, Monitoring, and Evaluation), and RPA 7.1 (Willamette River Basin Mitigation and Habitat Restoration) (NMFS 2008). Operation of the WVP can affect river levels and flow in the extensive rearing habitat downstream, in the lower portions of spawning tributaries and the mainstem Willamette River. These are important rearing habitats for naturally-produced spring Chinook salmon and winter steelhead, which are listed as threatened under the federal Endangered Species Act.

Juvenile spring Chinook salmon follow a number of different life history pathways as they rear and migrate in the Willamette Basin (Schroeder et al. 2016). These different pathways require certain rearing habitats throughout the Upper Willamette basin (upstream of Willamette Falls) to complete different life histories that support population resilience. Two different phenotypes of Chinook salmon have been identified in Willamette populations based on early migratory behavior; fry that migrate from spawning areas soon after emergence to rear in downstream areas (movers) and fry that rear in spawning areas for 8-16 months after emergence before migrating downstream (stayers) (Schroeder et al. 2016). The primary smolt life histories are those that migrate past Willamette Falls as subyearlings and those that migrate as yearlings (Schroeder et al. 2016). Fry that migrate soon after emergence rely on rearing habitat in the lower tributaries and mainstem Willamette River for much of their growth in freshwater during spring and early summer and migrate as subyearling smolts (Schroeder et al. 2016). Yearling smolts generally rear in the upper reaches of the spawning tributaries during their first summer, with some migrating downstream in fall and winter to rear and others remaining in spawning reaches until their second spring. Yearling smolts typically migrate in fall and early winter or in early spring (Schroeder et al. 2016). The mainstem Willamette River has been shown to be important rearing habitat for juvenile Chinook salmon at various life stages (Friesen et al. 2007; Teel et al. 2009; Schroeder et al. 2016).

Less is known about the life history of winter steelhead in the Willamette basin, although this run has been listed as threatened under the ESA since 1999 (NMFS 1999). Most juvenile winter steelhead presumably rear at various locations in spawning tributaries (large and small) and in mainstem habitats. Trapping at Willamette Falls indicates that juvenile steelhead migrate in the spring (April-June) and scale analyses indicate they migrate primarily as age-2 smolts (Clemens 2015). However, steelhead life-histories are known to be highly variable; both their freshwater and saltwater residence can be 1-4 years (Withler 1966) and they may forgo anadromy entirely (Thorpe 1994). Prior to smolting juvenile steelhead are indistinguishable from resident rainbow trout, which makes it difficult to assess rearing habitat. Although steelhead smolts can be identified by their slender body morphology and silvery scales, actively migrating smolts can be difficult to capture with traditional nearshore sampling gears, such as beach seines.

Although less is known about habitat use by juvenile winter steelhead than for juvenile Chinook salmon, steelhead are known to use a wide variety of habitats above dams (where adult passage is provided), below dams, and in the mainstem Willamette River. Romer et al. (2014) documented the size, number, and timing of juvenile *O. mykiss* (presumably steelhead) entering Foster Reservoir over a number of years; some of these fish were marked with passive integrated transponder (PIT) tags, providing additional data on migration timing to Willamette Falls. Several studies have examined habitat use and migration rate by steelhead in the Willamette River below the falls (e.g., Ward et al. 1994, Friesen et al. 2004). Juvenile steelhead are known to be present in the lower mainstem Willamette River during winter and spring (Friesen 2004) while naturally-produced rainbow trout and steelhead are widespread in the tributaries.

We initiated beach seine sampling in 2002 to identify different life history pathways and rearing habitat for wild juvenile Chinook salmon in the upper Willamette Basin. This sampling is now an annual survey used to monitor the distribution of juvenile Chinook salmon in the basin and to PIT tag these fish for growth, migration timing, and survival estimates. These data were the foundation for a recent paper describing the different life history pathways of juvenile Chinook salmon in the Willamette Basin (Schroeder et al. 2016). Beach seines are particularly effective in the long, shallow gravel bars that characterize the lower reaches of the major spawning tributaries (the McKenzie, North Santiam, and South Santiam rivers) and the mainstem Willamette River. The beach seine survey generally targets juvenile Chinook salmon that migrated as fry soon after emergence to the mainstem Willamette River and subsequently migrate past Willamette Falls as subyearling smolts their first summer.

Information on rearing habitat and timing of use by juvenile Chinook salmon will be an important component of the ongoing Willamette Basin Review and implementation of NMFS' 2008 BiOp, to support recommendations for instream flow management that will benefit UWR Chinook salmon and winter steelhead. Any information on the distribution and habitat preferences of juvenile steelhead will help instream flow management and guide further research. Finally, this work may inform conservation and restoration of riparian habitats that can affect river habitat and native fish communities.

Study Objectives

1. Characterize rearing habitat for juvenile Chinook salmon relative to river flow.

    1.1. Summarize habitat characteristics, including depth, substrate and bank slope, with respect to variation in river flow.

    1.2. Describe a conceptualized model of rearing habitat characteristics for juvenile Chinook salmon.

2. Determine relative timing of juvenile Chinook salmon using rearing habitat.

    2.1. Summarize rearing and migration periods in different areas.

2.2. Compare use of rearing habitat in the mainstem Willamette to that of the major spawning tributaries.

3. Summarize related available data for winter steelhead

3.1. Summarize size, timing, and location of naturally-produced *O. mykiss* (presumptive winter steelhead) captured in the mainstem Willamette River and major tributaries.

3.2. Summarize habitat data associated with winter steelhead capture, where available.

Methods

Catch and habitat data for this report were queried from a database for a long-term beach seine survey conducted by ODFW on the mainstem Willamette River and lower reaches of the major spawning tributaries from 2002 to 2015. Beach seining is a preferred technique for catching juvenile salmon in large rivers, especially for high concentrations of fish rearing in shallow habitats (Hahn et al. 2007), and has been widely used to sample juvenile salmon in rivers and estuaries (Healey 1980; Dawley et al. 1985; Hopkins and Unwin 1987; Dauble et al. 1989; Connor et al. 2001; Seesholtz et al. 2004). In addition, this gear type causes little injury or mortality to juvenile salmonids, making it easier to obtain research permits for listed species. The ODFW survey was implemented in 2002 to collect data on the size and distribution of juvenile Chinook salmon in the Willamette River and spawning tributaries, and to PIT tag these fish for migration studies. Throughout the study, beach and pole seines were used to sample as many habitats as possible, including side channels, runs and glides. Although we caught Chinook salmon in many types of habitat, our catch was consistently highest at shallow gravel bars located on the main channel or around large islands. An average of 60 days of sampling effort was completed annually (2002-2015) for all areas combined, providing a consistent level of effort. Extensive quality assurance and quality control measures were applied to the resulting database.

During the survey effort, juvenile Chinook salmon were captured by deploying a beach seine that was 150 feet long, 8 feet deep, with ¼" square mesh. A small boat was used to set the net away from shore and the net was retrieved in an arc back to shore where it was bagged in an area with slower current (Hahn et al. 2007; Schroeder et al. 2016). Most sites were located on the inside of a bend of the main river channel along shallow, submerged gravel bars. In addition, side channels and faster riffles were sampled with pole seines. Other sites include shallow runs, point bars at the mouth of sloughs, and around islands. The Willamette River was divided into two sampling reaches; the Upper Willamette from the McKenzie River to the Santiam River and the Mid-Willamette from the Santiam River to Willamette Falls (Figure 1). Most sites in the Mid-Willamette reach were from the mouth of the Santiam River to the San Salvador boat ramp, (83 km). Most sites in the upper Willamette River were from the mouth of the McKenzie River to Corvallis (65 km).The Lower McKenzie reach was defined as the McKenzie River downstream of Leaburg Dam (rkm 55), and much of the sampling was downstream of Hendricks Bridge (rkm 33). The North Santiam and South Santiam rivers were separate reaches downstream of WVP dams (Big Cliff and Foster), although most sampling occurred downstream

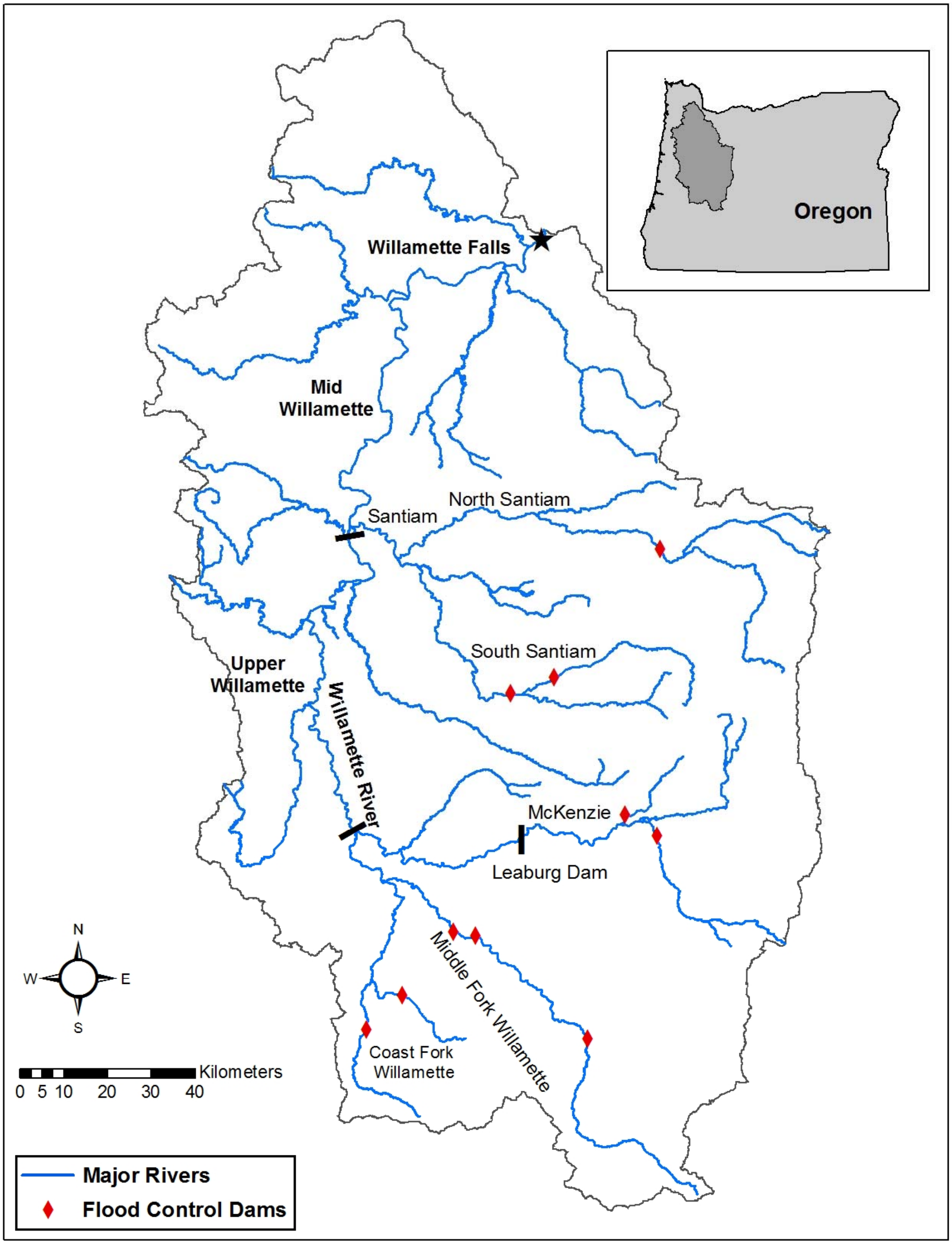

Figure 1. The Willamette Basin, with major spawning tributaries where ODFW beach seining surveys are conducted. Reach breaks (black bars) are indicated for the mainstem Willamette and lower McKenzie rivers.

of Bennett and Lebanon dams, respectively (rkm 25 and 32). The Santiam River (19 km) was sampled from the confluence of the North and South Santiam rivers to the confluence with the Willamette River. Water gauge stations operated by the U.S. Geological Survey (USGS) provided total river flow data for each sampling reach. Daily average river flow (f^3/s) data were queried from the USGS website and recorded for each day of the seining survey. We sampled productive sites from previous seasons and explored new sites during the early part of the season to spread out our effort within each reach. Our schedule was designed to sample each reach on a 7-10 day rotation and we re-sampled two to five sites each sampling cycle. Seining sites were initially selected by identifying potential rearing habitat that could be sampled with seines and included a variety of habitat types. Sites where the catch of juvenile Chinook salmon was consistently high were targeted to increase the number of tagged fish for studying migration and rearing. Some sites were sampled multiple times within and between years, but we were unable to sample some of the exact sites every year because winter floods often resulted in habitat changes. Survey sites were distributed throughout the mainstem Willamette and Santiam rivers and in the lower reaches of the McKenzie, North Santiam, and South Santiam rivers. Due to budget constraints, most seining effort in recent years has been in the mainstem Willamette River and lower McKenzie River.

All unclipped juvenile Chinook salmon we captured were counted and measured for fork length (FL) to the nearest mm. Fish were held in a live well with circulating river water, then anesthetized in a buffered solution of tricaine methanesulfonate (MS222). They were implanted with a 12-mm PIT tag following standard procedures (PTSC 2014). The fish were then allowed to fully recover before being released in the same general area of the site where they were captured. River temperature was measured at each site where fish were tagged.

Passage timing was determined from data collected at the PIT detection system in the Sullivan Hydroelectric Plant at Willamette Falls. The PIT antennae are located in the juvenile bypass routes where fish are guided away from the turbine intakes by screens. The power plant and detection system operate continuously, collecting detection data year round. Tag detections were expanded based on fish entrainment to the plant at different flow levels (Schroeder et al. 2016). Estimates of subyearling smolt detections were affected to a lesser degree by flow than other life histories because flow was relatively stable during late spring and early summer when subyearling smolts were migrating through Willamette Falls. Detections were summarized by day of the year and reach where the fish were tagged and released.

Habitat characteristics

Data on river habitat were recorded during seine surveys in 2011 and 2013. Each seine set was diagramed and measurements were taken where juvenile Chinook salmon were likely holding within the area sampled. Depth and water velocity were measured in a cross-section perpendicular to the shore, spaced out as evenly as possible at three points depending on the seine set (Figure 2). A Flow-Mate flowmeter (model 2000) manufactured by Marsh-McBirney was used to measure water velocity and depth at all three points. A dissolved oxygen and temperature meter (YSI Inc. model Pro20) with a weighted probe was used to measure temperature and dissolved oxygen on the bottom of the river at the middle point (Figure 2). Water velocity data collected at seine sites were only available from 2011 because a flow meter

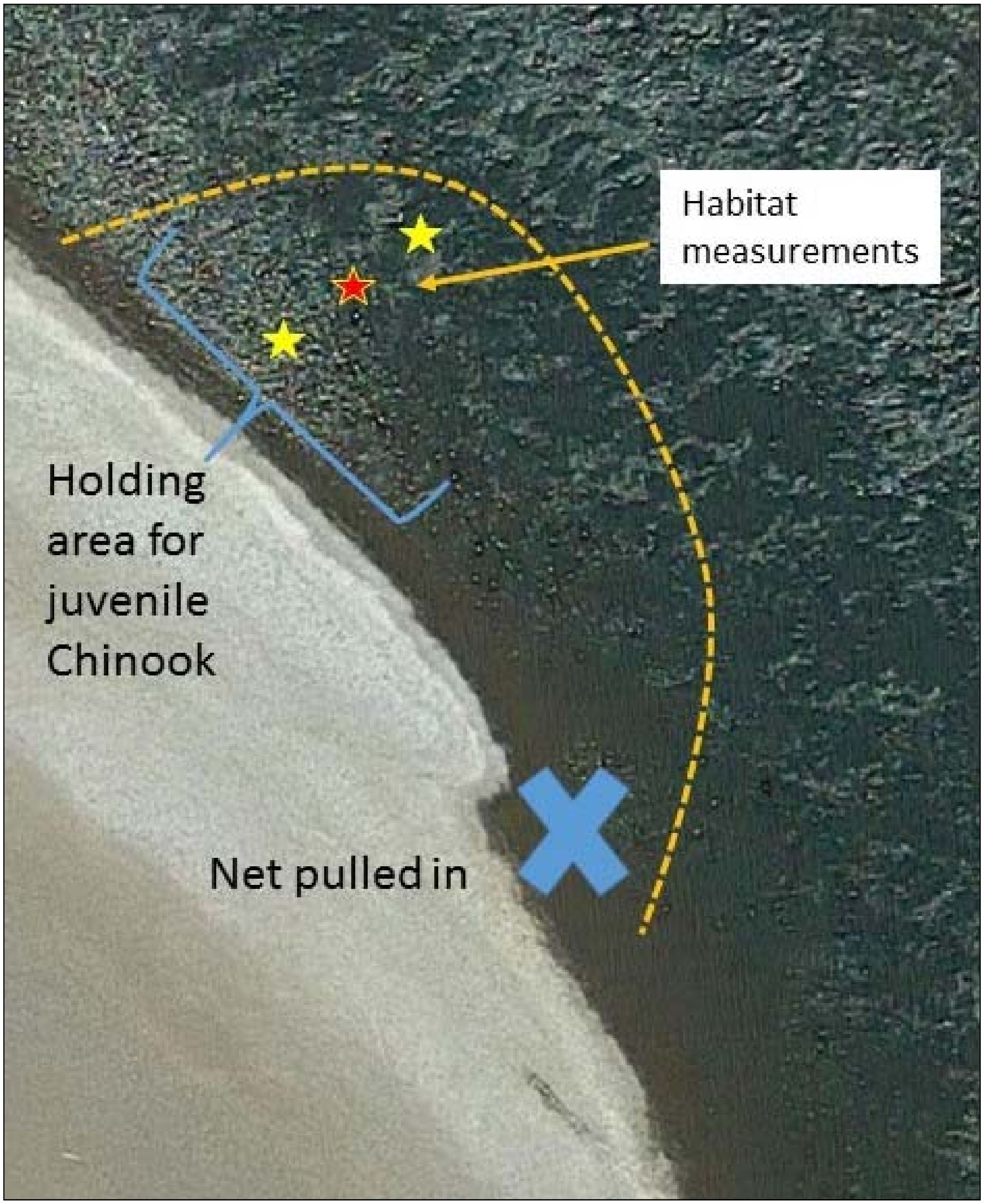

Figure 2. Diagram of a typical beach seine set. Stars mark where depth and water velocity were measured; the red star indicates where temperature and dissolved oxygen were measured.

was not available in 2013. All available data on habitat characteristics were averaged for all sites with a reach and by month.

We analyzed the effect of river flow on mean water velocity, depth, and slope calculated from measurements taken at seining sites in 2011 and 2013. Mean daily flow was calculated by reach from data provided by USGS gauge stations at Harrisburg for the upper Willamette reach, Salem for the mid-Willamette reach, and Coburg for the lower McKenzie reach.

Conceptualized model of rearing habitat

Habitat measurements from the ODFW beach seine sites sampled in 2011 and 2013 were summarized in a diagram. Average water velocity, depth, and slope were calculated from all sites and river reaches, for the entire sampling period. Average temperature in May was calculated for all sites and river reaches for the duration of the ODFW beach seine survey, 2002 – 2015. May was used because densities of juvenile Chinook salmon are highest during this month. This summary represents the habitat preferences at sites where large numbers of subyearling juvenile Chinook salmon reared in the mainstem Willamette River, the Santiam River, and lower reaches of the North Santiam, South Santiam and McKenzie rivers. This model is based on habitat where we captured large numbers of juvenile Chinook salmon using beach seines, which may bias certain parameters. Most of these sites were along the inside bend of the main river channel at the downstream end of large gravel bars in relatively shallow water. Other river habitats where we sampled and did not catch many fish or did not sample are not represented in the model.

Rearing and Migration periods

We used catch of juvenile Chinook salmon per seine set and information from tagged fish to estimate rearing periods and distribution. Our seine survey targeted subyearling juvenile Chinook salmon rearing in shallow river habitats in the mainstem Willamette River and lower reaches of the major spawning tributaries. We sampled along gravel bars with beach seines and other seines in late spring through early summer, which coincides with the primary rearing periods for subyearling juvenile Chinook salmon identified by Schroeder et al. (2016). Although we sometimes sampled in mid- to late summer, effort was often limited because water temperatures reached or exceeded 18 ^{o}C; at this point we stopped sampling due to permit restrictions. We used the mean catch of juvenile Chinook per seine set by month for all reaches combined to assess use of the mainstem Willamette and major spawning tributaries by juvenile Chinook salmon. Rearing times were further summarized in Schroeder et al. (2016). We used catch of fry migrants in late winter and early spring and migration of tagged fish to estimate residence time of juvenile Chinook salmon in the Willamette River and spawning tributaries (*see* Schroeder et al. 2016 for more detail). Migration periods were estimated by summarizing passage data from Willamette Falls for each seining reach. To facilitate comparisons among reaches in analyzing the effect of flow on migration timing, we restricted our analyses to subyearling smolts or fish that migrated in their first summer of life. Detection dates of subyearling migrants were converted to day of the year. The mean and range were calculated for the median day of passage for a given year, and summarized by reach.

We analyzed the effect of river flow and water temperature on the passage timing of subyearling migrants at Willamette Falls for fish tagged in the two Willamette River reaches.

Mean flow and temperature were calculated at the reach level from USGS gauges at Harrisburg for the upper Willamette reach and at Salem/Keizer for the mid-Willamette reach. We analyzed the effect of flow for both the primary migration period and the primary rearing period based on detections at Willamette Falls and capture of juvenile Chinook salmon. The migration period was May-June for the mid-Willamette reach and May-mid July for the upper Willamette reach. Rearing periods were mid-March-May for the mid-Willamette reach and April-mid June for the upper Willamette reach.

Size, timing and location of O. mykiss

When unclipped *O. mykiss* were caught during a survey, they were categorized as either rainbow trout or juvenile steelhead. Because they are unclipped, these fish were considered to be naturally produced. *O. mykiss* were categorized as rainbow trout if they had color and body morphology characteristic of resident fish, which may include winter steelhead before they smolt. They were categorized as juvenile steelhead if they had smolt characteristics, such as silvery scales and more slender body morphology. Both groups have the potential to contribute to the winter steelhead populations in the Willamette basin. The presence of rainbow trout and unclipped juvenile steelhead was summarized by the percentage of all beach seining sites where any of these fish were caught. We then calculated the number caught per seine set. Multiple seine sets were usually performed at each site.

Length data were not collected for rainbow trout or juvenile steelhead, as they were not the primary focus of the survey at the time. However, we summarized length data from wild steelhead smolts caught at Willamette Falls in 2015 and 2016 to characterize the size of these fish as they migrate to the estuary.

Results

We captured and PIT tagged an average of about 6,100 juvenile Chinook salmon in the Willamette and Santiam rivers each year over the course of this study, and 5,800 fish in the lower reaches of the spawning tributaries (North and South Santiam and McKenzie rivers). We also captured an average of about 1,700 fish each year in the Willamette and Santiam rivers, and in spawning tributaries that we released without tags, primarily because they were too small to tag at the time of capture. Within a typical seining site, we generally made two to three sets and estimated that each set covered about 75–100 ft of river length depending on the configuration and velocity of the site, with a mean catch of about 20–25 juvenile salmon per seine set in spring.

Habitat characteristics

Juvenile Chinook salmon captured with beach seines occupied habitat with a fairly narrow range of characteristics. The mean depth of all seine sites was 0.578 m, with the deepest sites sampled in the North Santiam River (0.632 m) and the shallowest sites in the upper Willamette reach (0.555 m) (Table 1). The overall range of depth was from 0.223 m to 1.093 m (Table 1). Mean water velocity among all seining reaches combined was 0.464 m/s with a range from 0.067 m/s to 1.037 m/s (Table 2). Mean slope for all reaches combined was -0.363 m across three point measurements with a range from 0.000 m to -1.000 m (Table 3). River flow

Table 1. Mean and range of depth measurements taken at beach seining sites in 2011 and 2013, by river reach.

	Minimum depth (m)	Mean depth (m)	Maximum depth (m)
Mid-Willamette	0.350	0.574	0.867
Upper Willamette	0.233	0.555	1.013
Santiam	0.383	0.576	0.807
North Santiam	0.333	0.632	1.017
South Santiam	0.350	0.613	0.977
Lower McKenzie	0.223	0.574	1.093
	0.223	**0.578**	**1.093**

Table 2. Mean and range of water velocity measurements taken at beach seining sites in 2011, by river reach.

	Minimum water velocity (m/s)	Mean water velocity (m/s)	Maximum water velocity (m/s)
Mid-Willamette	0.197	0.485	0.917
Upper Willamette	0.070	0.480	0.900
Santiam	0.420	0.612	0.807
North Santiam	0.140	0.360	0.637
South Santiam	0.067	0.514	0.810
Lower McKenzie	0.157	0.436	1.037
	0.067	**0.464**	**1.037**

Table 3. Mean and range of slope of the river bottom calculated from three depth measurements taken perpendicular to shore at beach seining sites in 2011 and 2013, by river reach.

	Minimum slope (m)	Mean slope (m)	Maximum slope (m)
Mid-Willamette	-0.150	-0.458	-0.800
Upper Willamette	-0.050	-0.331	-0.850
Santiam	-0.200	-0.292	-0.370
North Santiam	-0.050	-0.387	-0.800
South Santiam	-0.030	-0.296	-0.650
Lower McKenzie	0.000	-0.382	-1.000
	0.000	**-0.363**	**-1.000**

when these measurements were taken varied greatly among seining reaches. For example, the upper Willamette varied from 5,590 f^2/s to 13,200 f^2/s during the period that habitat measurements were taken (Table 4). In contrast to the physical habitat characteristics, seining sites exhibited a wider range of water temperatures. The mean for all months was 14.7° C, with temperatures as low as 9.0° C in May and as high as 19.1° C in July, throughout the different sampling areas (Table 5). The mean dissolved oxygen level among seining sites was 10.8 mg/L, which changed little from May through August (Table 5).

We found few relationships between river flow and water velocity, depth, and slope measured at seining sites. A weak relationship between flow and these variables was found in the mid-Willamette reach, although the sample size was small (Table 6). Little or no relationship was found in the upper Willamette and lower McKenzie reaches; both reaches had large sample size (Table 6).

Conceptualized model of rearing habitat

Based on the data collected at sites where we captured large numbers of juvenile Chinook salmon, preferred rearing habitat in the upper Willamette basin would have the following characteristics:

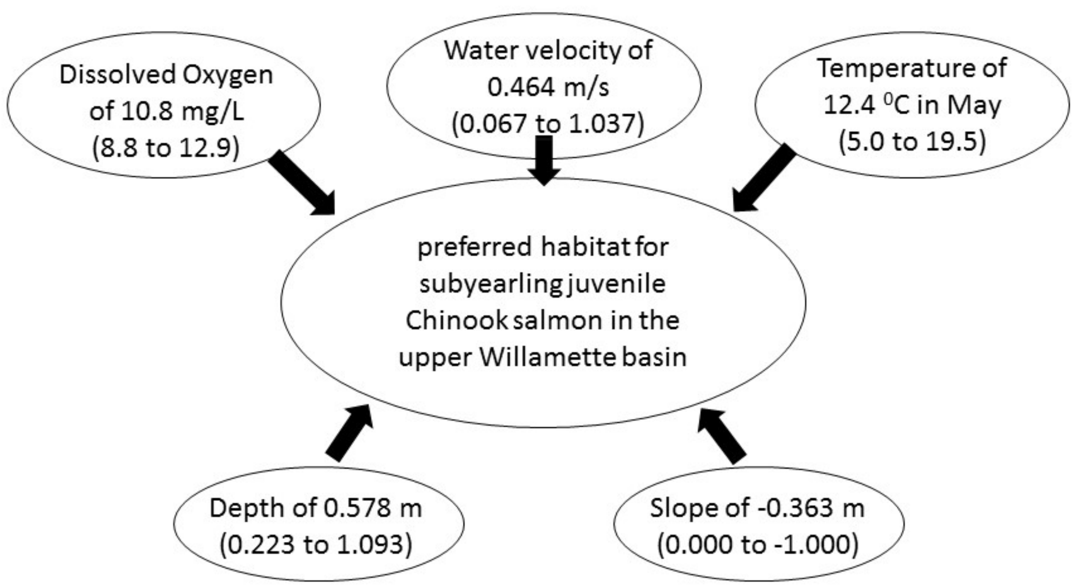

Table 4. Mean and range of total river flow when habitat measurements were taken in 2011 and 2013, by river reach. Flow data were taken from USGS gauge stations in these areas.

	Minimum river flow (f^2/s)	Mean river flow (f^2/s)	Maximum river flow (f^2/s)
Upper Willamette	5,590	7,494	13,200
Mid-Willamette	9,170	13,381	15,600
Santiam	2,360	2,893	4,490
North Santiam	1,300	2,049	3,440
South Santiam	1,470	1,476	1,480
Lower McKenzie	2,380	3,282	5,680

Table 5. Monthly mean water temperatures (° C) and dissolved oxygen (mg/L) with ranges measured at seine sites in 2011 and 2013.

	Mean Water Temperature (° C) with Range	Mean Dissolved Oxygen (mg/L) with Range
May	13.6 (9.0 – 17.0)	10.9 (10.0 – 12.4)
June	14.0 (10.0 – 17.7)	11.1 (9.2 – 12.9)
July	15.6 (11.5 – 19.1)	10.5 (8.8 – 12.6)
August	16.0 (14.3 – 17.4)	10.5 (9.8 – 11.6)
	14.7 (9.0 – 19.1)	**10.8 (8.8 – 12.9)**

Table 6. Correlations between mean flow at the reach level and means of water velocity, depth, and slope measured at seining sites in 2011 and 2013. Sample size is in parentheses.

	Mean Water Velocity (m/s)	Mean Depth (m)	Mean Slope (m)
Mid-Willamette	0.379 (10)	0.482 (23)	0.465 (23)
Upper Willamette	0.126 (43)	0.141 (76)	0.096 (76)
Lower McKenzie	0.122 (30)	0.062 (79)	0.164 (79)

Rearing and Migration periods

For all sampling areas combined, the catch rate of juvenile Chinook salmon was highest in May (Figure 3) when we captured high numbers of fish in all reaches. River flows were relatively high and water temperatures were low in May (Table 7). Catch rates declined in July primarily because many of the juvenile Chinook salmon had migrated to the estuary as smolts, although temperatures did increase later in the summer (Figure 3). Because of low water temperatures we were able to sample in both July and August in 2008, 2010, and 2011 and found that catch rate was higher in July (18.4 fish/set) than in August (11.1 fish/set). We found that catch rate increased in August on two occasions; in the upper Willamette River reach in 2008 and in the lower McKenzie reach in 2011.

Passage timing at Willamette Falls for juvenile Chinook salmon that migrated as subyearling smolts was earliest for fish for fish tagged in the Mid-Willamette (June 3; range May 11-June 27) and upper Willamette reaches (June 11; range May 20-June 30) (Figure 4). Mean passage timing for fish tagged in the Santiam River was June 17 (range May 29-June 28). Among fish tagged in the spawning tributaries, mean passage timing was earlier for fish tagged in the McKenzie River (June 17; range June 2-July 3) than for fish tagged in the North Santiam (July 3; range June 18-July 15) or South Santiam rivers (June 23; range June 11-29) (Figure 4).

Among all sampling reaches, the overall catch rate of juvenile Chinook salmon was highest in the mid-Willamette and lowest in the North Santiam River (Table 7). For the mid-Willamette, catch rates were highest in April. For all other areas, the catch rates were highest in May (Table 7). The high catch rates in May often coincided with relatively high mean river flows in the different reaches (Table 7). Mean river temperature in May was lowest in the lower McKenzie at 10.9^{o} C (range 7.0 – 15.0^{o} C) (Table 7). The mid-Willamette generally had the highest temperatures as this area is farthest downstream, with a mean temperature in May of 13.5^{o} C (range 5.0 – 19.5^{o} C) (Table 7). A very wide range of river flows were observed during this period (Table 7). Juvenile Chinook salmon spent an average of 125 days rearing in these areas before migrating as subyearling smolts (Schroeder et al. 2016).

The estimated mean number of days juvenile Chinook salmon reared in the Willamette and Santiam rivers was 120-126 (Table 8). Among the spawning tributaries, rearing time in the lower McKenzie River (124 d) was similar to that in the Willamette River (126 d) and was shorter than that in the North and South Santiam rivers (145 and 151 d, respectively, Table 8).

We found a strong, positive relationship between reach flow during the primary migration period and the median day of migration past Willamette Falls for subyearling migrants tagged in the Willamette River ($r = 0.80$ and 0.77 for mid- and upper Willamette reaches, respectively). We also found a strong, positive relationship between reach flow during the primary rearing period and migration timing at Willamette Falls for subyearling migrants ($r = 0.78$ and 0.73 for mid- and upper Willamette reaches, respectively). Migration timing for subyearling migrants was negatively correlated with water temperature during rearing (migration was earlier at higher water temperatures) and was more strongly correlated with for fish tagged in the upper Willamette River ($r = -0.94$) than for those tagged in the mid-Willamette River ($r = -0.58$). Water temperature was more highly correlated with flow in the upper Willamette reach ($r = -0.88$) than in the mid-Willamette reach ($r = -0.49$).

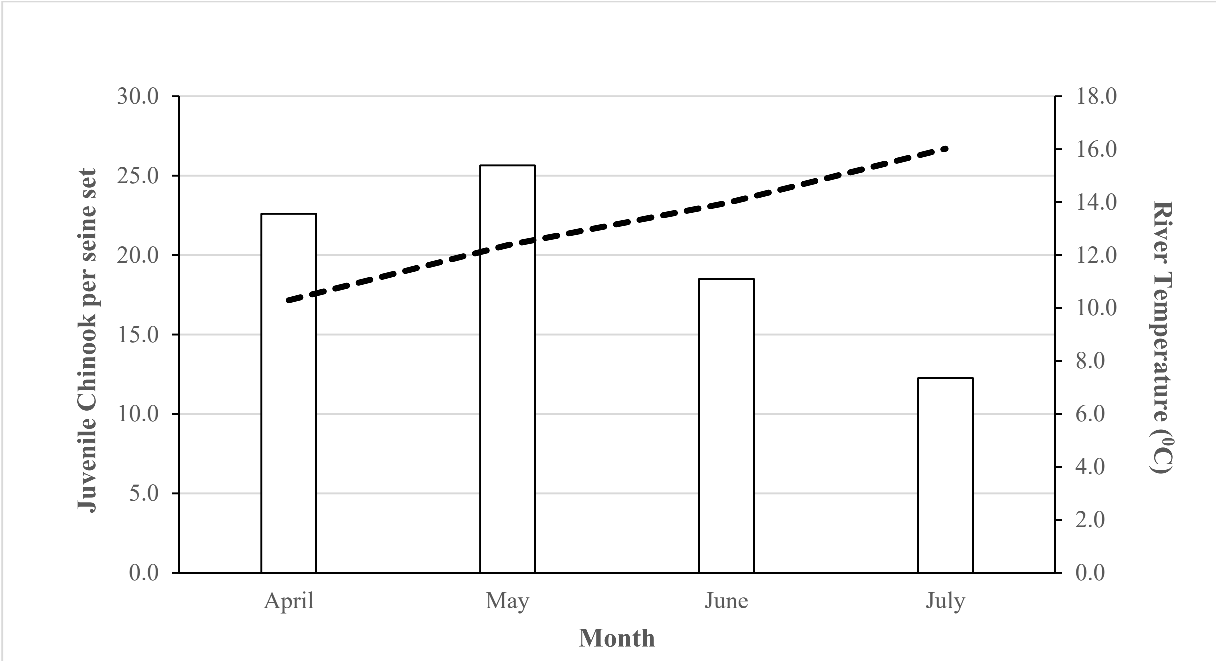

Figure 3. Mean number of juvenile Chinook salmon caught per seine set for all areas by month. Mean river temperatures are on the secondary axis.

Table 7. Mean catch rates of juvenile Chinook salmon, mean river flow, and mean water temperature with ranges, summarized for each sampling reach by month, 2002 - 2015. The number of sampling sites is indicated in parentheses in the left column.

	Mean (range) of juvenile Chinook caught per seine set	Mean (range) river flow (f^3/s)	Mean (range) river temperature (°C)
Mid-Willamette	**23 (0 – 558)**	**18,678 (6590 – 48200)**	**14.1 (5.0 – 21.0)**
April (23)	45 (0 – 268)	12705 (2500 – 7290)	11.2 (9.0 – 13.0)
May (129)	23 (0 - 450)	17270 (2260 – 6870)	13.5 (5.0 – 19.5)
June (140)	21 (0 - 558)	20845 (1980 – 7040)	14.8 (10.5 – 21.0)
July (24)	10 (0 - 48)	22536 (2130 – 3850)	17.7 (16.0 – 18.5)
Upper Willamette	**18.5 (0 – 564)**	**9609 (3960 – 33300)**	**13.9 (9.0 – 19.5)**
April (48)	12.8 (0 – 120)	13626 (4980 – 26600)	10.4 (9.0 – 12.5)
May (177)	24.5 (0 – 349)	11908 (4300 – 22000)	12.1 (9.0 – 19.0)
June (340)	19.3 (0 – 564)	9951 (4310 – 33300)	14.3 (10.0 – 18.0)
July (129)	10.1 (0 – 91)	5418 (3960 – 8420)	16.4 (13.0 – 19.5)
August (53)	16.0 (0 – 117)	5243 (4920 – 5610)	16.1 (15.0 – 17.5)
Santiam	**19.9 (0 – 256)**	**4335 (2360 – 10700)**	**14.5 (9.0 – 18.5)**
April (4)	41.4 (0 – 74)	4234 (3971 – 4497)	10.4 (10.0 – 11.0)
May (24)	39.0 (0 – 256)	5833 (3170 – 8820)	11.9 (9.0 – 14.5)
June (84)	16.8 (0 – 146)	4361 (2530 – 10700)	14.7 (11.0 – 18.5)
July (37)	11.2 (0 – 115)	3212 (2360 – 5500)	16.8 (15.0 – 18.0)
North Santiam	**11.9 (0 – 155)**	**2018 (1210 – 5370)**	**14.7 (8.0 – 19.0)**
May (16)	10.5 (0 – 56)	3734 (1810 – 4680)	8.3 (8.0 – 9.0)
June (200)	16.3 (0 – 124)	2205 (1300 – 5240)	13.7 (10.0 – 17.5)
July (233)	8.9 (0 – 155)	1746 (1300 – 5370)	15.8 (12.0 – 19.0)
August (32)	5.1 (0 – 34)	1889 (1210 – 3580)	16.6 (13.0 – 19.0)
South Santiam	**16.1 (0 – 240)**	**1810 (731 – 9610)**	**13.6 (8.0 – 18.5)**
April (7)	3.2 (0 – 13)	1606 (1550 – 1700)	8.5
May (26)	41.6 (0 – 129)	1827 (1130 – 3810)	11.6 (9.5 – 13.5)
June (252)	19.8 (0 – 240)	1902 (850 – 4490)	13.1 (8.0 – 18.5)
July (162)	7.8 (0 – 125)	1752 (731 – 9610)	15.7 (12.5 – 18.5)
August (15)	1.5 (0 – 18)	884 (874 – 893)	17.0
Lower McKenzie	**18 (0 – 426)**	**3088 (1980 – 7290)**	**14.4 (7.0 – 20.0)**
April (15)	11 (0 – 37)	5092 (2500 – 7290)	8.1 (7.0 – 11.0)
May (49)	28 (0 – 241)	3944 (2260 – 6870)	10.9 (7.0 – 15.0)
June (300)	17 (0 – 266)	3371 (1980 – 7040)	13.7 (9.5 – 18.5)
July (342)	17 (0 – 426)	2740 (2130 – 3850)	15.9 (12.0 – 20.0)
August (110)	19 (0 – 228)	2699 (2380 – 3110)	15.3 (11.0 – 17.7)

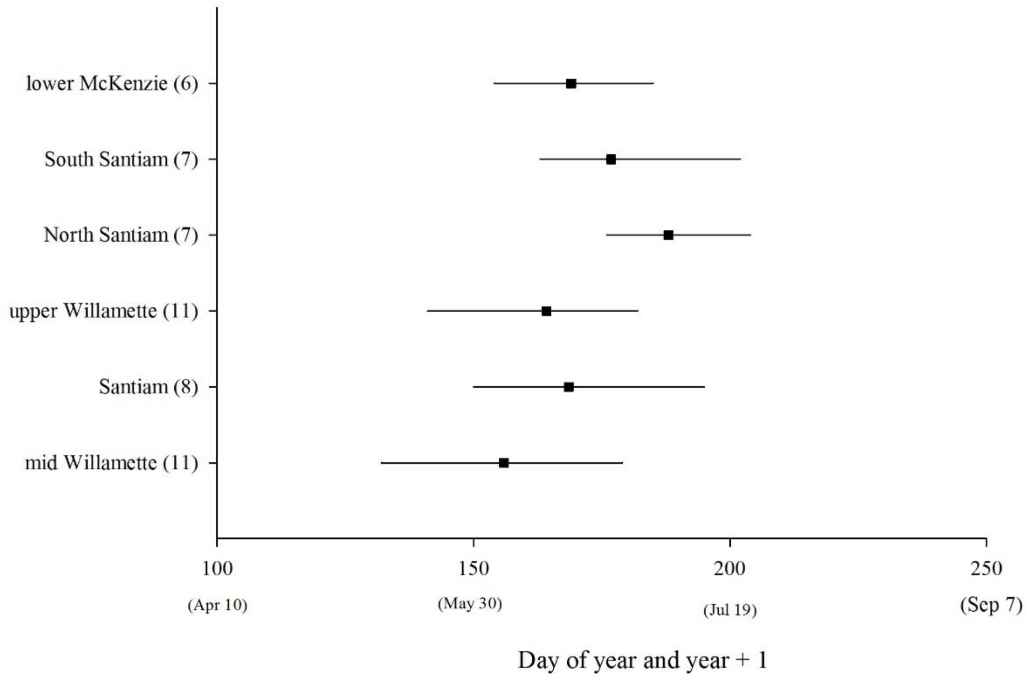

Figure 4. Mean (and range) of the median day of passage timing at Willamette Falls of PIT tagged juvenile Chinook salmon that migrated as subyearlings for six reaches in the upper Willamette River basin. Number of brood years for each reach is in parentheses.

Table 8. Mean time (days) and standard deviation (SD) juvenile Chinook salmon reared downstream of spawning areas in the Willamette River basin for fish that migrated as subyearling smolts. Rearing time was estimated from the number of days between release of tagged fish and detection at Willamette Falls and included estimated number of days between fry migration and tagging based on fry sampling (Schroeder et al. 2016).

Reach	Mean (SD)	n
Mid-Willamette	125.5 (16.8)	2,317
Upper Willamette	125.9 (15.1)	1,923
Santiam	120.2 (16.3)	737
North Santiam	145.2 (13.1)	689
South Santiam	150.8 (12.3)	765
Lower McKenzie	123.5 (15.8)	314

Size, timing and location of O. mykiss

Unclipped *O. mykiss* we identified as rainbow trout were caught in 34% of all seine sites in the upper Willamette basin (Table 9). They were caught most frequently in the North Santiam basin, at 62% of seine sites, and least frequently in the mid-Willamette, at 9.9% of seine sites (Table 9). The mean of rainbow trout caught per set was 2.6 for all areas (Table 9). The South Santiam river had the highest mean of rainbow trout per set at 6.7 (Table 9).

Unclipped *O. mykiss* identified as juvenile steelhead were much less common, caught in only 3.2% of all seine sites (Table 10). The Santiam River had the greatest percentage of sites where steelhead were caught, 7.4% (Table 10). At sites where they were caught, the mean number of unclipped juvenile steelhead caught per seine set was 0.5 (Table 10). Unclipped juvenile steelhead were caught most frequently in May (Figure 5).

Mean lengths for steelhead smolts at Willamette Falls were similar in both years, 197 mm FL in 2015 and 195 mm FL in 2016.

Habitat characteristics for winter steelhead

Habitat data associated with juvenile steelhead were limited. Juvenile steelhead were caught at only three sites in 2011 and 2013 where habitat characteristics were measured, one site each in the North Santiam, South Santiam, and upper Willamette. These sites had a mean depth of 0.760 m and slope of -0.453 m. The mean water velocity was 0.215 m/s. The mean temperature was 13.2^{o} C and the dissolved oxygen was 11.9 mg/L.

Discussion

Spring Chinook salmon within the Willamette River basin smolt and go to the ocean as subyearlings in their first summer of life and as yearlings in spring of their second year of life (Schroeder et al. 2016). Within these two life history types, juvenile spring Chinook salmon follow several different migratory pathways including early fry migrants and fall migrants (Schroeder et al. 2016). Fish rearing in the mainstem Willamette and lower reaches of the spawning tributaries in the spring and summer that migrate as subyearling smolts were the focus of this study. These generally migrate out of the spawning areas as fry, soon after emergence. The two primary life histories of subyearling smolts and yearling smolts and general migration periods in the Willamette River basin are similar to that described by Taylor (1990) and Healey (1991). Murphy et al. (1997) also observed similar migration periods for Chinook salmon in the Taku River, a large river system in British Columbia. Most juvenile Chinook in this system were observed migrating from April - June as yearlings. Copeland and Venditti (2009) report similar migration periods for juvenile Chinook salmon in the Pahsimeroi River from monitoring passage at Lower Granite Dam on the Snake River. Yearling smolts migrated past this dam during in April, while subyearling smolts migrated in June and July. Daum and Flannery (2011) studied juvenile Chinook salmon rearing in non-natal streams in the Yukon River system. Juvenile Chinook salmon in this system were found to move long distances to habitat downstream of the spawning areas for rearing through the summer, similar to observed patterns in the Willamette Basin. Additional life history types have been documented in the Willamette Basin by Schroeder et al. (2016).

Table 9. Presence and catch of *O. mykiss* (rainbow trout) in all seine sites by reach.

Subbasin	**% seine sites with rainbow trout**	**rainbow trout/seine set**
McKenzie	44.4%	3.7
Mid-Willamette	50.0%	1.8
North Santiam	9.9%	0.5
South Santiam	60.8%	6.7
Santiam	28.0%	2.7
Upper Willamette	48.5%	2.7
All	**34.0%**	**2.6**

Table 10. Presence and catch of unclipped *O. mykiss* (steelhead smolts) in all seine sites by reach.

Subbasin	**% sites with unclipped steelhead**	**unclipped steelhead/seine set**
McKenzie	0.4%	0.5
Mid-Willamette	5.0%	0.5
North Santiam	0.9%	1.2
South Santiam	2.0%	0.8
Santiam	7.4%	0.6
Upper Willamette	3.7%	0.4
All	**3.2%**	**0.5**

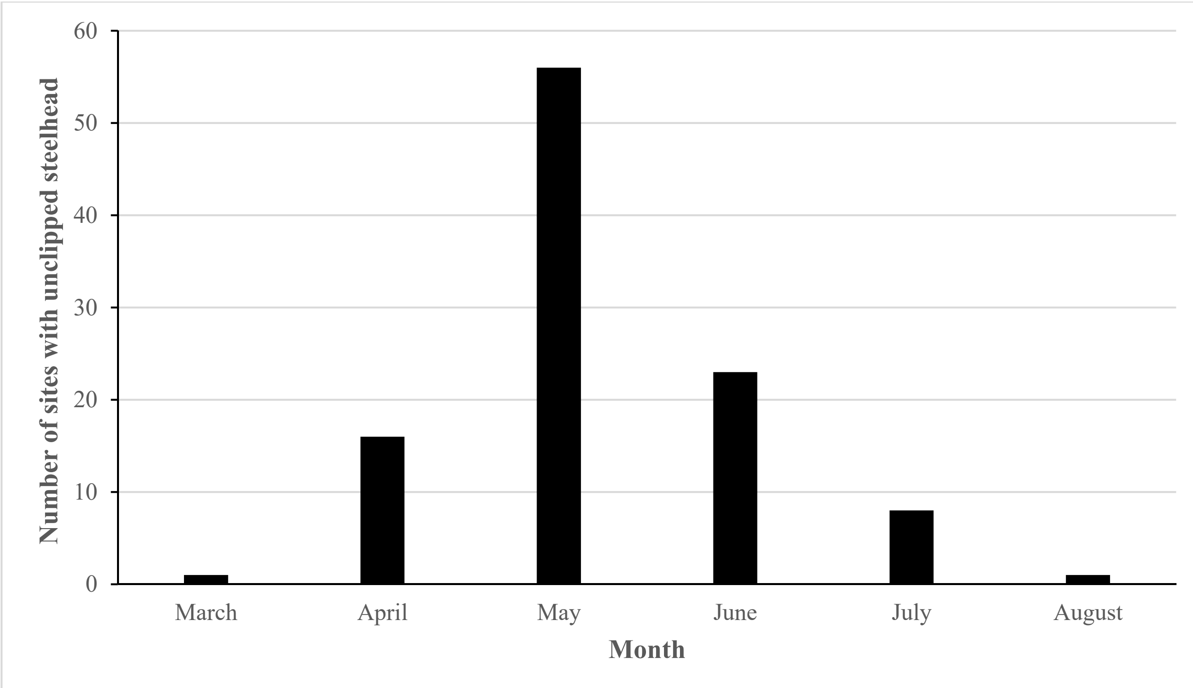

Figure 5. The number of all seine sites where unclipped juvenile steelhead were present, by month.

Habitat preference can vary widely among different runs of Chinook salmon and rearing pathways, with different life history types using many different areas in a river basin (Murphy et al. 1997; Copeland and Venditti 2009; Daum and Flannery 2011; Schroeder et al. 2016). Our surveys targeted the life history that migrated soon after emergence to rear in large river habitats downstream of spawning areas. Large rivers have been demonstrated to be important rearing habitat for juvenile Chinook salmon (Levings and Lauzier 1991; Copeland et al. 2014). We captured large numbers of juvenile Chinook salmon in the Willamette River and lower spawning tributaries in shallow, nearshore habitats, similar to rearing habitats reported in other studies. Friesen et al. (2004, 2007) found that subyearling juvenile Chinook salmon were strongly associated with nearshore habitats in the lower Willamette River. Juvenile Chinook salmon were found to use shoreline habitats in the upper and lower Columbia River in area with low lateral slope and generally low water velocity (Garland 2004; Tiffan et al. 2006), and used shallow shoreline areas in Lake Washington that included open beaches and areas associated with riparian vegetation that provided woody debris and overhanging vegetation Tabor et al. (2011).

We used catch of juvenile Chinook salmon in beach seines and habitat measurements at sampling sites to assess rearing habitat characteristics, migration and rearing periods, and relative use of spawning tributaries and the Willamette River for rearing. The primary objective of the ODFW beach seine survey was to capture juvenile Chinook salmon rearing in different habitats of the mainstem Willamette River during spring and early summer to determine rearing and migration periods. Although we sampled different types of habitats, we targeted sites where we consistently captured large numbers of juvenile Chinook salmon, maximizing the release of PIT-tagged fish to estimate relative abundance and migration timing from different areas of the basin.

Beach seines and pole seines were used during the ODFW survey to sample fish in a variety of habitats, but highest catches of fish were on inside bends of the river (including those associated with islands) just downstream of submerged gravel bars.

Our objective in measuring habitat variables was to generally describe conditions at sites where we captured large numbers of juvenile Chinook salmon. The use of any sampling gear to capture fish is inherently selective and the selectivity depends on factors such as species and size of fish, fish behavior, site selection, and environmental conditions (Hahn et al. 2007; O'Neal 2007; Temple and Pearsons 2007; Volkhardt et al. 2007). We sampled many types of habitat with beach and pole seines, but consistently caught large numbers of juvenile Chinook salmon over many years and across a range of environmental conditions in areas associated with shallow gravel bars along the inside bend of the main river channel or around islands. Researchers at Oregon State University have done extensive boat electrofishing throughout the mainstem Willamette River from Newberg upstream to the confluence of the McKenzie River. Over many years of sampling, the highest concentrations of juvenile Chinook salmon were found in shallow habitats along mainstem gravel bars (Dr. Stanley Gregory and Randall Wildman, Oregon State University, *personal communication*). Other sampling with boat electrofishing has found some juvenile Chinook salmon along riprap banks in the lower McKenzie River and the upper Willamette River, although densities were very low with between 0.1 - 0.6 juvenile Chinook salmon caught per 100 feet of riprap bank (Andrus and Walsh 2002). By comparison, we estimated that our mean catch in spring was about 20–33 juvenile Chinook salmon per 100 ft. based on the length of river cover by a typical seine set. The low catch of juvenile Chinook in habitats other than those associated with gravel bars by our sampling efforts or by other researchers using different sampling gear suggests that the ODFW beach seine survey targeted the primary habitat of juvenile Chinook rearing in the Willamette River during spring and early summer.

Other evidence that our sampling was representative of primary rearing habitat for juvenile Chinook in the Willamette River and lower spawning tributaries include the schooling behavior of juvenile Chinook salmon and our observation of site fidelity based on recaptures of PIT-tagged fish. Schooling behavior has been observed in juvenile Chinook salmon (Taylor 1990; Kelsey et al. 2002; Tiffan et al. 2010; Neuswanger et al. 2014). Taylor (1990) found a lower level of aggression among juvenile fish from populations of Chinook salmon that migrated to the ocean at an earlier age (subyearlings) than those migrating at an older age (yearlings), suggesting schooling would be stronger in fish following a subyearling life history, which was the primary life history we sampled. However, we also observed schooling behavior of juvenile Chinook salmon in the upper McKenzie River and Horse Creek during snorkel surveys, and these fish migrated as yearling smolts. Because of their schooling behavior, we believe the preferred habitat of juvenile Chinook salmon in the Willamette River and spawning tributaries can be more accurately identified (at least at the scale of sampling sites) than if they exhibited a high level of territorial behavior. For example, although we were able to effectively seine other habitats such as runs, we consistently caught fewer fish in these areas than in habitat associated with inside bends and submerged gravel bars.

We also observed site fidelity within the areas where we caught and tagged large numbers of juvenile Chinook salmon, which indicated a preference for certain habitats. For example, we recaptured 1,443 fish that had been tagged in the McKenzie and Willamette rivers during the seining seasons of 2009-2014 (when we increased efforts to re-visit sites) and 87% of these were recaptured at the same site where they had been originally tagged. Although we sampled other sites downstream of where we released fish (including preferred habitat sites and other sites where we could effectively sample with our gear), we recaptured few fish in locations other than in sites with preferred habitat. These data do not include the migrating smolts that were detected at Willamette Falls.

Characteristics of habitat used by juvenile Chinook salmon were consistent among ODFW seine sites where we captured large numbers of fish. Of the habitat characteristics we measured, water temperature varied more among the sampling sites than other variables including depth, water velocity, slope, and dissolved oxygen. Although the range of habitat characteristics we report for juvenile Chinook salmon may be constrained by limitations of our sampling gear, we believe our measurements provide a general description of habitats used by large numbers of fish during spring and early summer. Juvenile Chinook salmon were captured in large numbers in areas with similar habitat characteristics across a range of river flows likely because fish could find preferred rearing habitat (e.g., depth and velocity) by moving laterally within a site as river flow increased or decreased. The habitat characteristics at seining sites (Table 1 – 3) were fairly consistent over a range of river flow levels (Table 4). Moreover, the regression analysis found no relationship between river flow and water velocity, depth or slope found no relationship, indicating that juvenile Chinook salmon find their preferred habitat as river flow changes. Other sites where some juvenile Chinook salmon were sampled, such as runs, smaller side channels, and habitat with submerged vegetation were underrepresented in our habitat measurements because we caught few fish or beach seines were not effective in these habitats, although we did sample some of these habitats with pole seines. Inclusion of all sites where juvenile salmon were captured would likely increase the range of habitat characteristics in a model of rearing habitat, but we believe that our measurements encompass a reasonable range for preferred habitat of juvenile spring Chinook salmon in the Willamette River in spring and early summer.

Generally, sites where we captured large numbers of juvenile spring Chinook in the Willamette River and lower spawning tributaries were similar to habitat characteristics of juvenile Chinook salmon in other rivers in use of natural shoreline areas, near-shore habitat, and low bank slopes relatively low water velocities (Everest and Chapman 1972; Johnson et al. 1992; Garland et al. 2002; Tiffan et al. 2006; Tiffan et al. 2010). Studies on juvenile Chinook salmon in other areas and from fish rearing in different areas of a river basin report a similar range of habitat preferences. Dauble et al. (1989) found wild juvenile Chinook salmon in the Hanford Reach of the Columbia River rearing close to shore during the spring and early summer. The size of these fish were similar to those caught by the ODFW seine survey and water velocities were between 0.24 m/s and 0.98 m/s at the sampling station that caught the most subyearling Chinook. This range is similar to those measured during the ODFW survey. Liepitz (1994) found similar rearing patterns for subyearling (age-0) juvenile Chinook salmon in the Kenai River. Most rearing habitat was within six feet of the bank and the optimum water velocity was between 3 and 18 cm/s (0.03 and 0.18 m/s). These rearing habitats are closer to shore than many of the areas sampled by the ODFW beach seine survey and water velocity is lower. This may be because of slower growth in a colder system or because the mainstem Kenai River is higher gradient than the Willamette River. USFWS (2008) modelled optimum habitat for juvenile Chinook salmon in the Sacramento River based on field observations. Juvenile Chinook salmon were defined as those greater than 60 mm FL and sampling occurred from March to September. Optimum depth was estimated to be between 0.37 and 1.16 m with optimum water velocities between 0.05 and 0.23 m/s. Depth preferences were similar to those found by the ODFW beach seine survey, although water velocities were lower. This study included a somewhat longer period (May – September) and the authors acknowledge that they captured fewer juvenile Chinook over 60 mm than expected.

Water temperature was more variable among the sites than other characteristics we measured to describe habitats where large numbers of juvenile Chinook salmon were captured. As noted previously, juvenile salmon could move laterally in the habitats to find preferred depths and velocities for rearing. Because we did not sample when water temperatures were ≥ 18° C, temperatures at the sites where we captured large numbers of salmon remained within the tolerance limits for juvenile salmon. At the upper range of temperatures we sampled, juvenile salmon may have found micro habitats with lower water temperatures than we were able to discern at the scale we measured temperatures. In addition, when water temperatures reached 16–18° C many of the juvenile salmon rearing in the Willamette River and lower reaches of spawning tributaries had begun to migrate as subyearling smolts. Other studies have reported optimum temperatures for growth of juvenile Chinook salmon similar to those observed on the ODFW beach seine survey. McCullough et al (2001) synthesized a number of different data sets, finding the preferred temperature range for juvenile Chinook salmon was between 10.0° C and 15.6° C. Banks et al. (1971) found 15° C to be the optimum temperature for growth in juvenile Chinook salmon. Brett et al. (1982) found the temperature for optimum growth in juvenile Chinook salmon was 14.8° C. Wilson et al. (1987) recommended 10.5° C for optimum growth based on data collected from juvenile Chinook salmon sampled in Alaska. Armour (1990) considered 19.1° C the upper limit for positive growth in juvenile Chinook salmon. Marine and Cech (2004) found that juvenile Chinook salmon could survive and grow at temperatures between 17° C and 24° C, although growth and appetite were greatly decreased and fish were more vulnerable to predators. Our passage data from PIT tag detections indicates that some juvenile Chinook salmon are still using the mainstem Willamette River after the river exceeds 18° C. However, because we rarely sample at these higher temperatures we cannot quantify the distribution or habitats juvenile salmon are using, including use of thermal refugia.

The highest densities of juvenile Chinook salmon in habitat along the mainstem Willamette River and lower reaches of the major spawning tributaries were consistently observed in May. The only exception was the mid-Willamette reach, where fish were generally larger than in other reaches and migrated from the reach earlier. Our catch rates were high in early spring despite generally higher flows, which theoretically would reduce the effectiveness of capturing fish with a beach seine. These data confirm that the highest use of the mainstem Willamette River and lower reaches of the spawning tributaries is in spring and early summer prior to migration as subyearling smolts. Our catch rates declined once the river reached 16° C. Although these data suggest that juvenile Chinook salmon may have moved into different habitats that we were unable to effectively sample, our migration timing data indicated that most of the juvenile salmon had migrated as subyearling smolts by the time water temperatures increased to 16–18° C. Our highest catch rates were in the mid-Willamette reach and we found a number of sites that were consistently productive over the years of our survey. We were able to sample in April only in years when flow was low enough to effectively seine; therefore the mean monthly flow in the mid-Willamette reach was lower in April than in May. As expected, mean monthly water temperatures steadily increased through the course of the summer. We sampled in late July and August only during especially cool years when water temperatures remained below 18^{o} C, and we continued to catch some juvenile Chinook salmon, but at lower densities. These fish were likely growing on a slower trajectory and continued rearing later in the summer before migrating as smolts.

Juvenile Chinook salmon tagged in the Santiam and Willamette rivers that migrated as subyearling smolts tended to migrate past Willamette Falls earlier than those tagged in the lower reaches of spawning tributaries, but with a wider range of median detection dates. In all reaches, most of the tagged fish migrated past Willamette Falls by the middle of July. Rearing conditions among reaches can vary greatly from year to year, depending on snowmelt, summer temperatures, and precipitation, which can affect growth and smolt development. Schroeder et al. (2016) found that many fish rearing in spawning tributaries migrated past Willamette Falls after their first summer, resulting in an increased range of variation in the migration timing for all life histories combined. The McKenzie River in particular has extensive rearing habitat in the upper reach of the subbasin that juvenile Chinook salmon use for rearing through their first summer (Schroeder et al. 2016). Late migration timing generally occurred in years with lower water temperature and higher flow, which affects emergence timing and growth, and results in an extended period when habitat conditions remain favorable for rearing.

We demonstrated extensive rearing of 120–150 days in the Willamette River and the lower reaches of spawning tributaries for juvenile Chinook salmon that migrated as subyearling smolts. In addition, Schroeder et al. (2016) documented rearing of other life history types such as fall migrants and yearling smolts in the Willamette River and lower reaches of the spawning tributaries. Our data demonstrate the importance of the Willamette River and lower reaches of spawning tributaries as rearing habitat for juvenile Chinook salmon.

Although we found positive relationships between flow and migration timing of juvenile Chinook salmon in the Willamette River, water temperature had more influence on migration timing than flow for fish tagged in the upper Willamette River reach. Water temperature and flow were also correlated, therefore making it difficult to separate distinct effects of each factor. Water temperature and flow are important environmental factors that along with photoperiod influence the physiological development and migration timing of juvenile salmon (McCormick et al. 1998; Sykes et al. 2009; Spence and Dick 2014). Water temperature is an important factor affecting incubation and emergence timing of salmonid eggs (Alderdice and Velsen 1978; Beacham and Murray 1990; Quinn 2005), and growth and migration timing of juvenile salmon (Beckman et al. 1998; Roper and Scarnecchia 1999; McCormick et al., 1998, Sykes et al. 2009). Juvenile Chinook salmon in the Willamette River basin migrate as fry to lower reaches of spawning tributaries and the Willamette River to rear (Schroeder et al. 2016). Those migrating as subyearling smolts are likely fish that attain a size (in conjunction with other environmental cues such as photoperiod, flow, and water temperature) for entering the ocean at a critical size and time (Beamish and Mahnken 2001; Duffy and Beauchamp 2011; Woodson et al. 2013).

Steelhead smolts caught at Willamette Falls were large, after likely rearing in freshwater for two years. These fish were usually much larger than juvenile Chinook salmon caught at Willamette Falls. The density of wild steelhead smolts was much lower than for Chinook salmon in sites from our beach seine survey and the larger steelhead may be traveling in the thalweg as they migrate as smolts, making it more difficult for us to catch them with beach seines. The distribution of wild juvenile winter steelhead is equivocal because of the presence of resident rainbow trout and summer steelhead (Van Doornik et al. 2015) and the limitations of beach seining. The Santiam River had a relatively high proportion of steelhead smolts, although few were caught in the North and South Santiam rivers. The North and South Santiam rivers are an important component of the historical range of winter steelhead in the Willamette Basin. If juvenile steelhead are using deeper habitat, they would be more difficult to catch consistently with our beach seines.

Sites where juvenile steelhead were caught were somewhat deeper and had more slope than other seining sites. Also, water temperatures were lower with higher dissolved oxygen. Juvenile steelhead are larger than subyearling juvenile Chinook salmon and may be using deeper habitat or traveling further offshore. However, these data are extremely limited and further study is needed to understand habitat preferences of juvenile steelhead in the upper Willamette Basin.

Habitat management in large rivers should focus on processes that result in a variety of habitats for juvenile salmon and steelhead to follow life history pathways, rather than attempting to “create” specific habitats. Diverse habitats along with spatial and temporal connectivity provides the ecological template that allows for local adaptation and the development and sustainability of diverse life histories (Rogers and Schindler 2008; Waples et al. 2009; Fraser et al. 2011). An important consideration in river management is to integrate habitat conservation and restoration with the spatial and temporal scales at which life histories are expressed (Kocik and Ferrei 1998; Baguette et al. 2013). Conservation and recovery actions should include measures to restore a suite of variable and connected habitats to provide benefits for all life histories not just the most common ones observed under current conditions (Watters et al. 2003; Bisson et al. 2009; Jorgensen et al. 2013; Copeland et al. 2014).

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