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Executive Summary

Habitat, temperature, and fish distributions in the Chehalis River tributaries were identified as data gaps by the Aquatic Species Enhancement Plan Technical Committee of the Chehalis Basin Strategy (Aquatic Species Enhancement Plan Technical Committee, 2014). This information is needed to address questions pertaining to the development of flood reduction strategies, including a proposed dam, and to anticipate fish responses to the combined effects of future restoration actions and climate change, both of which may further influence fish habitat through changes in the hydrological, physical, and thermal environment.

The primary goal of this study was to identify habitat and temperature characteristics associated with summer rearing distribution of juvenile salmon and steelhead in the Chehalis River. Our objectives were to compare and contrast habitat and temperature characteristics associated with fish distributions 1) across six main stem survey areas within four major sub basins of the Chehalis River, and 2) across four years in one sub basin (Upper Chehalis River). While the focus of this study was on juvenile salmon and steelhead, we collected information on all native and non-native fish species observed, providing a broader perspective on fish occupancies and distribution patterns during summer months. Our survey areas were six main stem sections in four major sub basins of the Chehalis River watershed – the Upper Chehalis River main stem, South Fork and North Fork Newaukum River, East Fork and West Fork Satsop River, and West Fork Humptulips River. Spatially continuous "riverscape" surveys conducted in each survey area provided information to describe longitudinal (upstream-downstream) fish and habitat patterns. Surveys were 24 km to 77.3 km in length, began at approximately 250 m above sea level, and were conducted during the summer months (late July – early September) of 2013 – 2016. Snorkelers counted fish by species, age class, and origin (wild or hatchery), and surveyors collected habitat measures for 200 m segments within the study areas. Summer stream temperatures were quantified at fixed monitoring sites spaced an average of 4.3 km apart within each survey area.

Habitat

Pool-riffle was the dominant channel type in the survey areas (>82% in all survey areas). Most survey areas had comparable wetted widths except the South and North Fork Newaukum which were narrower on average than the other survey areas. Large woody debris densities were variable among survey areas and highest in the East Fork Satsop and West Fork Humptulips and lowest in the Upper Chehalis. In general, a longitudinal habitat pattern included upstream segments being characterized by higher pool densities and coarser substrate relative to downstream segments; this longitudinal pattern was observed in all survey areas except the East Fork Satsop. The upstream segments of the East Fork Satsop were characterized as spring-fed headwaters, a habitat type not observed elsewhere in our survey areas.

Temperature

August temperature patterns varied among and within survey areas. Among survey areas, mean daily temperatures during August were on average warmest in the Upper Chehalis and West Fork Satsop (18.9 and 18.5°C, respectively) and coolest in West Fork Humptulips and East Fork Satsop (15.6 and 14.3°C, respectively). The South and North Fork Newaukum were intermediate

in terms of mean daily August temperature compared to all other survey areas at any elevation (17.4 and 16.9℃, respectively). At a given elevation, mean daily August temperatures differed by up to 7.1˚C among survey areas. The East Fork Satsop, with its spring-fed headwaters, was uniquely cool among the survey areas. Temperatures in the East Fork Satsop at elevations less than 100 m were comparable to temperatures in the West Fork Satsop and North Fork Newaukum at elevations above 200 m and colder than temperatures in the Upper Chehalis above 200 m. All survey areas were characterized by a longitudinal pattern of colder temperatures in upstream, higher elevations and warmer temperatures in downstream, lower elevations. The difference in mean daily August temperatures between the upper and lower extent of each survey area ranged between 2.7˚C and 7.6˚C.

Fish

In combining all surveys, we collected roughly 850,000 individual fish observations. Fish observations included 13 species and 27 species-life stage-origin combinations. Juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) were the most commonly observed of all species and life stages among the survey areas. Juvenile Chinook (*O. tshawytscha)* were rarely observed, likely due to the late summer timing of our surveys. Cyprinid species, including redside shiner (*Richardsonius balteatus*), dace (*Rhinichthys cataractae, R. osculus*), and northern pikeminnow (*Ptychocheilus oregonensis*) were commonly observed across all survey areas except the East Fork Satsop and the West Fork Humptulips. Resident trout were observed across survey areas with the most observations in the East Fork Satsop. Wild adult spring Chinook salmon were observed in the Upper Chehalis and the South and North Fork Newaukum survey areas. Wild adult steelhead were rare across survey areas but observed in the Upper Chehalis, East and West Fork Satsop, and West Fork Humptulips. We also observed adult sockeye (*O. nerka*) and adult bull trout (*Salvelinus confluentus*), both in the West Fork Humptulips. Mountain whitefish (*Prosopium williamsoni*) adults were observed in all survey areas, however observations of juveniles were rare. Adult largescale suckers (*Catostomus macrocheilus*) were observed in all survey areas except the West Fork Humptulips and juvenile suckers were observed in all survey areas except the East Fork Satsop. Threespine stickleback (*Gasterosteus aculeatus*) were observed in the South and North Fork Newaukum and East and West Fork Satsop.

Hatchery origin salmonids were observed in the sub basins where hatchery fish are released, including the South Fork Newaukum (juvenile steelhead), East Fork Satsop (juvenile coho and steelhead, resident trout, and adult steelhead), West Fork Satsop (adult steelhead), and West Fork Humptulips (adult steelhead). Non-native fish, including smallmouth and largemouth bass and bluegill were observed in the main stem Chehalis River downstream of Rainbow Falls and in downstream segments of South and North Fork Newaukum survey areas.

Within survey areas, longitudinal patterns were observed in terms of the amount of habitat occupied (e.g. occupancy) and densities of some species and age classes. Occupancies and the densities of juvenile salmon and steelhead, resident trout, and adult mountain whitefish were generally higher in upstream than downstream segments of the survey areas. In contrast, occupancies and densities of cyprinid species and juvenile largescale suckers were generally higher in downstream than upstream segments of the survey areas. Other species and age classes either had low occupancy overall (i.e. unable to examine longitudinal patterns) or no longitudinal pattern was observed.

Among four survey years in the Upper Chehalis survey area, variability in occupancy for juvenile coho salmon and steelhead (age-0 and age-1) was similar to variability observed among survey areas. Occupancy of juvenile coho salmon and steelhead age-1 class varied less than one and a half-fold and juvenile steelhead age-0 age class was consistently >97% among years. In contrast, densities of juvenile coho varied sixteen-fold and juvenile steelhead varied three (age-0) to eight-fold (age-1) among years in the Upper Chehalis. The longitudinal patterns observed for salmonid and cyprinid species were relatively consistent, in that juvenile steelhead occupied more habitat and were observed in greater density upstream compared to downstream and the opposite pattern was observed for cyprinid species.

Synthesis

Juvenile salmonids and cyprinids represented roughly 97.5% of the total fish observed in our surveys. Therefore, for the purpose of analysis, the fish assemblage of each 200m segment was categorized as ‘low’ (0-24.9%), ‘medium’ (25-75%), or ‘high’ (≥75.1%) according to the proportion of juvenile salmon and steelhead in the total counts observed in each segment. Segments classified as ‘high’ salmonid would also reflect ‘low’ cyprinid and vice versa.

Within each of the six survey areas, the fish assemblages were more consistently associated with summer (August) temperature than habitat characteristics. The East Fork Satsop and West Fork Humptulips had the coolest temperatures and very few (<1%) ‘low’ salmonid segments. This contrasted with the Upper Chehalis, South and North Fork Newaukum, and West Fork Satsop survey areas which had warmer temperatures and a higher proportion of ‘low’ salmonid segments (12.1-35.0%). Within each survey area, the summer temperatures associated with ‘high’ salmonid segments were consistently cooler than those associated with ‘low’ salmonid segments. However, the absolute summer temperatures associated with ‘high’ salmonid segments differed among survey areas. Specifically, the mean daily August temperatures associated with ‘high’ salmonid segments in the Upper Chehalis and West Fork Satsop were up to 3.9°C warmer than those observed for ‘high’ salmonid segments in the other survey areas.

Among years in the Upper Chehalis, segments in upstream locations were consistently dominated by juvenile salmonids (‘high’ salmonid) and segments in downstream locations were consistently dominated by cyprinids (‘low’ salmonid). Among years, ‘high’ salmonid segments were consistently cooler than ‘medium’ and ‘low’ salmonid segments. The majority (80-92%) of ‘high’ salmonid segments were observed upstream of the proposed dam site among years. Of the three fish assemblage categories, the ‘medium’ salmonid segments were most variable in terms of location among years; the mean river kilometers of ‘medium’ salmonid segments were 3 to 5 km further upstream in 2014 and 2015 than in 2013 and 2016. However, August temperatures associated with each fish assemblage category did not vary among years therefore, stream temperatures earlier in the summer may be important in shaping the structure of fish distributions observed in August.

Conclusions

Our results demonstrate that despite the extensive amount of aquatic habitat available in the 6,889 km^2 of the Chehalis River watershed, a very limited portion of the watershed has physical characteristics suitable for summer rearing of juvenile salmon and steelhead. A combination of temperature and habitat characteristics are associated with the summer rearing distributions of juvenile salmon and steelhead and their distributions are likely to be further influenced by interactions with the native cyprinid species. Upstream locations within each of the surveyed sub basins are currently valuable summer rearing habitat for juvenile salmon and steelhead and for resident trout. In the Upper Chehalis sub basin, we surveyed summer distribution of fishes over 77 km of the main stem Chehalis River from the confluence of the east and west forks to the confluence with the Newaukum River. Within this survey area, the majority of summer rearing by juvenile salmon and steelhead occurred in close proximity and upstream of the proposed dam location.

A combination of physiological tolerance to stream temperatures and temperature-mediated competition with native cyprinid species likely influences the lower extent of summer rearing for juvenile salmon and steelhead. The composition of fish species observed in our surveys was closely associated with stream temperatures, and river segments with cooler temperatures were associated with juvenile salmon and steelhead rearing. Interestingly, our results support the concept that local adaptation or acclimation to the thermal environments may occur in different sub basins as mean daily August temperatures that supported high proportions of juvenile salmon and steelhead varied by up to 3.9℃ among survey areas.

Increasing stream temperatures from climate change are likely to further limit suitable summer rearing locations for juvenile salmon and steelhead and may facilitate upstream expansion of competing and or predatory native and non-native fish species. Over four years, we have accumulated a comprehensive spatial data set that combines information on fish, habitat, and temperature in the Chehalis River basin. Future work will further examine the relationships of stream temperature and landscape variables with fish occupancy and density, and explore variables associated with the lower spatial extent of juvenile salmon and steelhead summer rearing habitat.

Introduction

The Chehalis River is a large, low gradient coastal watershed in Washington State which supports a diverse assemblage of aquatic species. The basin has undergone over a century of anthropogenic impacts that have degraded habitat used by native fishes and other aquatic species. In recent decades, the basin has experienced major flooding events in relatively rapid succession resulting in significant negative impacts to local residents and the Washington State economy. Thus, both restoration of degraded aquatic habitats and flood reduction strategies have come to the attention of stakeholders. In this context, a thorough understanding of how fish species use the basin is needed to inform decisions and meet concurrent goals of enhancing habitat for aquatic species and reducing the impacts of flooding. Habitat conditions, temperatures, and fish distribution patterns of the Chehalis River tributaries were identified as data gaps by the Aquatic Species Enhancement Plan Technical Committee of the Chehalis Basin Strategy (Aquatic Species Enhancement Plan Technical Committee, 2014). Warm summer stream temperatures were assumed to currently limit juvenile salmon and steelhead rearing potential throughout the basin but minimal information on fish distributions was available from the basin itself. The current study was developed to address questions pertaining to summer distributions of juvenile salmon and steelhead and associated habitat and temperature characteristics in the Chehalis basin.

Distributions of salmonid species in the rivers of the Pacific northwest are influenced by a combination factors operating across temporal and spatial scales. From a geologic perspective, salmonid distributions reflect their evolution with a landscape shaped by processes such as tectonic uplift, glaciation, and megaflood events (Waples et al. 2008). Subsequent landscape features of river basins influence heterogeneity of hydrology, temperature, and habitat characteristics which define finer scale fish distributions longitudinally along a river reach (Baxter 2002; Frissell et al. 1986; Torgersen 1996; Torgersen et al. 2006; Torgersen et al. 1999). Contemporary fish distributions are further influenced by anthropogenic disturbances including dams, floodplain development, deforestation, and systemic temperature shifts as a result of climate change (Bonner and Wilde 2000; Brenkman et al. 2012; Burnett et al. 2007; Lucero et al. 2011; Mantua et al. 2010; Waples et al. 2009). Taken together, a complex suite of variables contribute to patterns in fish distributions within a given river system.

Salmonids are cold water oriented and occupy locations within watersheds characterized by temperatures within suitable ranges (Dunham et al. 2001). Summer conditions in rivers with rain-dominant hydrology are characterized by low stream flows and warm temperatures which effectively limits the overall quantity of suitable rearing habitat for juvenile salmon and steelhead (Bjornn and Reiser 1991). The Chehalis River is comprised of multiple large sub basins that are generally rain-dominant resulting in relatively low stream flows and warm temperatures during summer months (Perry et al. 2016). Additionally, the sub basins of the Chehalis River drain from three mountain ranges (Olympic, Cascade, and Willapa Hills) into the main stem river and flow through diverse landscapes characterized by relatively high vs low elevation areas, timberlands, national forests, and rural residential, agricultural, and urban areas. Such heterogeneity across the landscape of the Chehalis basin necessitates a holistic investigation of fish, habitat, and temperature patterns and associations among and within sub basins in order to describe variables influencing summer rearing distribution of juvenile salmon and steelhead.

The primary goal of this study was to identify habitat and temperature characteristics associated with the summer rearing of juvenile salmon and steelhead in the Chehalis River. Spatially continuous "riverscape" surveys are an effective tool in describing temperature and habitat relationships associated with individual species in addition to describing patterns of species assemblages at a basin wide scale throughout a river system (Brenkman et al. 2012; Fausch et al. 2002; Flitcroft et al. 2014; McMillan et al. 2013). However, independent riverscape surveys represent a "snapshot" of fish distributions and associated habitat and temperature characteristics at a given time of survey and sometimes do not account for temporal variability that occurs on an annual basis. In the Chehalis River, annual variation in fish distributions in the same survey area may provide additional insight into the influence of stream temperatures on fish distributions as stream temperatures are generally more variable than habitat characteristics among years within given areas of the river. In order to identify habitat and temperature associations with juvenile salmon and steelhead summer rearing, our objectives were to compare and contrast the physical characteristics (habitat and temperature) associated with fish distributions 1) across six main stem survey areas within four major sub basins of the Chehalis River, and 2) across four years in one sub basin (Upper Chehalis River).

Methods

Study System

The Chehalis River is a 6,889 km^2 coastal watershed in southwestern Washington comprised of multiple large sub basins draining from the Willapa hills, the foothills of the Cascade Mountains, and Olympic Mountains. Headwaters of the sub basins are relatively low elevation (generally less than 300 m) resulting in a rain dominated river hydrology characterized by high flows during winter months (November to March) and prolonged low flows during summer months (July to September).

Survey Area

Our riverscape survey areas were six spatially continuous main stem sections (24 km – 77.3 km in length) in four major sub basins of the Chehalis River watershed including the Upper Chehalis River main stem, South Fork and North Fork Newaukum rivers, East Fork and West Fork Satsop rivers, and West Fork Humptulips River (Figure 1). The Upper Chehalis River main stem drains from the Willapa hills and is characterized by a relatively confined river valley and commercial timber harvest in the upper extent and less confined valley with rural residential and agricultural land use in the downstream extent. The South and North Fork Newaukum rivers drain from the foothills of the Cascade Mountains and are characterized by relatively confined river valleys and commercial timber harvest in the upper extents and less confined valleys with rural residential and agricultural land use in the downstream extents. The West Fork Satsop River drains from the foothills of the Olympic Mountains and is characterized by a relatively confined river valley and commercial timber harvest in the upper extent and less confined valley with rural residential and agricultural land use in the downstream extent. The East Fork Satsop River drains from the foothills of the Olympic Mountains and is characterized by a relatively unconfined river valley, commercial timber harvest, and low elevation spring-fed headwaters in the upper extent and a relatively unconfined valley with rural residential and agricultural land use in the downstream extent. The West Fork Humptulips River drains from the foothills of the Olympic Mountains and is characterized by a relatively confined river valley and federal lands managed for recreation in the upper extents and less confined valleys with commercial timber harvest in the downstream extents.

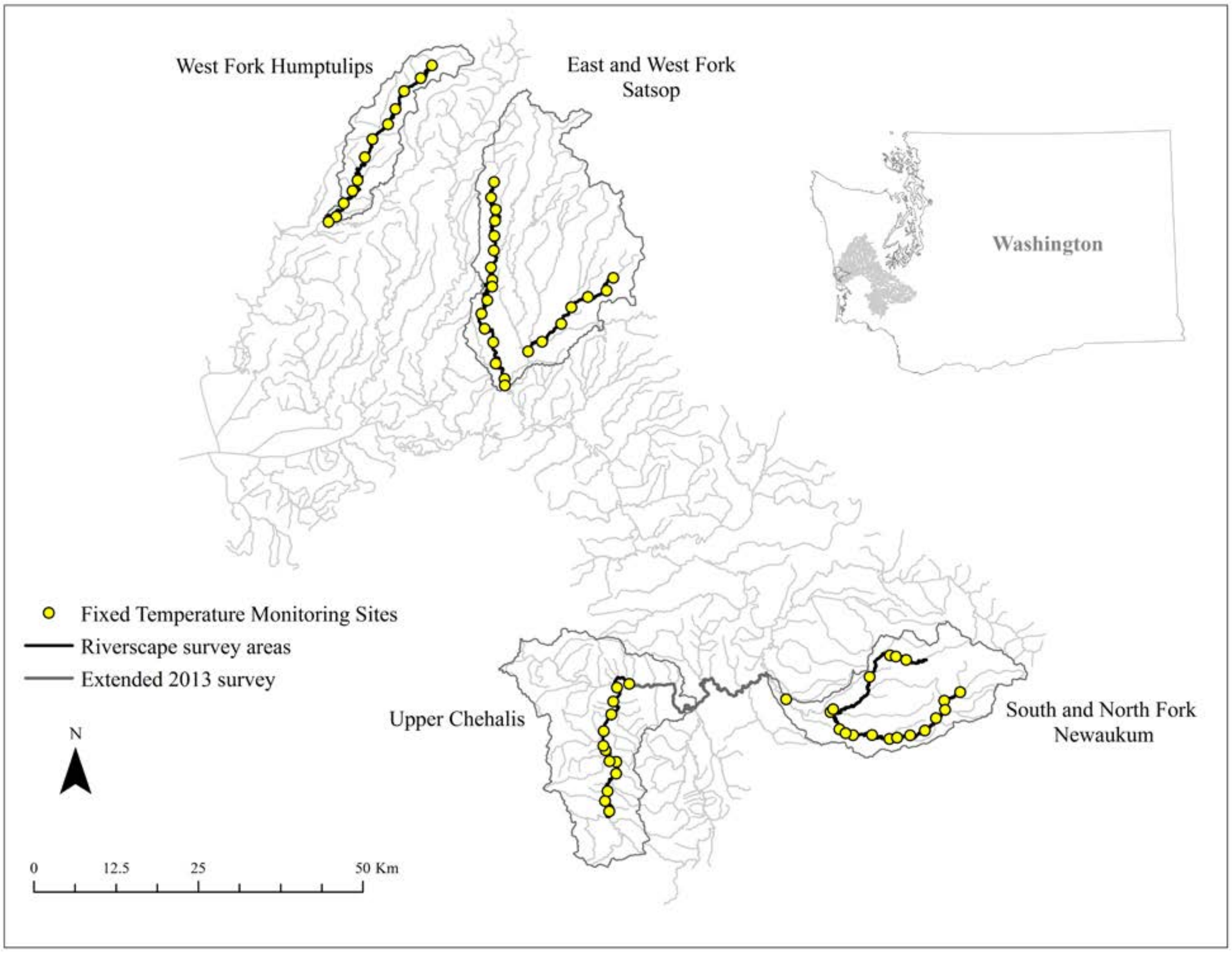

Figure 1. Riverscape survey areas (including the extended survey of the Upper Chehalis in 2013) and fixed temperature monitoring sites in the Chehalis River watershed.

Surveys were conducted during the period of summer base stream flows (late July – early September) in 2013 – 2016. We began surveys at elevations approximately 250 m above sea level in each sub basin except when the upper extent of a river was naturally low elevation (East Fork Satsop headwaters of roughly 100 m elevation) or access was not feasible (West Fork Satsop survey began at roughly 170 m elevation) (Table 1). Downstream extents of survey areas were defined by a major river confluence or by the point at which snorkeling techniques were no longer adequate for sampling due to the river size. The Upper Chehalis survey was conducted for four consecutive years and the length of this survey was shortened from 77.3 km in 2013 to 36.5 km in the 2014-2016 surveys in order to focus data collection on the area with fish distributions of interest for this study. Within each survey area, we collected habitat and fish data in spatially continuous 200-m survey segments. Temperature data were obtained at multiple fixed monitoring sites along the footprint of each survey area. The upstream and downstream extent of survey segment and the location of fixed monitoring sites were georeferenced with a Garmin 60CSx handheld GPS unit. Waypoints were converted to shapefiles in ArcMap 10.4.1 (ESRI 2011) and linear referencing was completed on main stem river polylines drawn with reference to the National Agriculture Imagery Program (NAIP) 2015. Main stem river polylines provided consistent spatial reference among data types and years.

Table 1. Location of riverscape surveys conducted in the Chehalis River, 2013-2016.

Sub basin	**Distance (km)**	**Elevation Range (m)**	**2013**	**2014**	**2015**	**2016**
Upper Chehalis	36.5	85.3 – 262.0		X	X	X
	77.3*	48.2 – 262.0*	X			
South Fork Newaukum	37.5	81.6 – 264.9				X
North Fork Newaukum	27.8	82.1 – 253.5		X		
East Fork Satsop	24.0	30.9 – 96.0			X	
West Fork Satsop	56.4	23.6 – 170.2			X	
West Fork Humptulips	48.7	46.6 – 260.0				X

*Extended survey completed in 2013 only.

Habitat Monitoring

We collected habitat data in accordance with methods described by Zimmerman and Winkowski (in prep.) (Table 2). Data were collected by 1-3 surveyors for each 200-m segment along the survey area. Segment lengths were approximated in the field using a laser range finder (TruPulse 200X Laser Technologies) and were separated by habitat unit breaks (e.g., between a pool and riffle). Data were collected concurrent with the collection of snorkel fish counts. Each segment was assigned a channel type defined for mountain drainage basins (Montgomery and Buffington 1997). Two measures of bankfull width, wetted width, and thalweg depth were obtained for each segment. These were measured at the beginning and 100 m mid-point of each segment during the 2014 survey period and at the 50 m and 150 m interval of the segment during the 2015 and 2016 survey period. Maximum depth was measured in the deepest area of the segment (maximum measure = 4 meters). Widths were measured with a laser range finder. Depths were measured with a stadia rod (maximum measure = 4 meters). Dominant (> 50% of wetted area) substrates were assigned based on visual observation of substrate size (Cummins 1962). Within each segment, surveyors enumerated large woody debris (LWD) and pools, using definitions provided in Table 2.

Table 2. Habitat measures collected in survey areas of the Chehalis River.

Name	Definition	Source
Upper Wetted width	Measured at 50 m downstream from start of reach	
Lower wetted width	Measured at 150 m downstream from start of reach	
Upper bankfull width	Measured at 50 m downstream from start of reach	
Lower bankfull Width	Measured at 150 m downstream from start of reach	
Pool count	Number of depressions at summer low flow, depressions would be expected to retain water in the absence of stream flow (longer than wide, > 0.5m depth)	
Maximum depth	Maximum depth in reach	
Channel Type	Cascade, Step-Pool, Plane Bed, Forced Pool-Riffle, Pool-Riffle, Dune ripple, Canyon, Spring-fed headwaters*	Montgomery and Buffington (1997)
Dominant Substrate	Primary substrate characterizing wetted area in reach (Silt, Sand, Gravel, Cobble, Boulder, Bedrock)	Cummins (1962)
Large woody debris (LWD)	The number of logs greater than 30 cm in diameter and greater than 2 m in length occurring in (or suspended ≤ 0.5 m directly above) the wetted area of the segment	Modified from Garwood and Ricker (2013)

* "Spring-fed headwaters" channel type was added in addition to channel types referenced in Montgomery & Buffington 1997.

Seven habitat metrics were derived from the data to characterize each survey area (Table 3). Within each survey area, we calculated the proportion of segments classified as pool-riffle habitat type. Wetted width and maximum depth were the mean values calculated from all segments. LWD and pools were calculated per 100 linear meters. Dominant substrate was the mean of five ordinal values ranked in order of substrate coarseness (1= silt, 2 = sand, 3 = gravel, 4 = cobble, 5 = boulder). Proportion of bedrock substrate was the proportion of segments characterized as bedrock-dominant to the total number of segments.

Habitat metrics were compared at two scales – among survey areas and among segments within each survey area. Among survey areas, we averaged habitat metrics across the entirety of all segments within each survey area to compare the overall characteristics of these areas. Within survey areas, we performed linear regressions for each habitat metric versus river kilometer (rkm) to evaluate whether individual habitat metrics followed a longitudinal pattern within the survey area. Count data (pool densities, LWD) were log transformed prior to the regression analysis. The regression analysis of ordinal substrate data versus river kilometer was performed with a Kendall's rank correlation. Finally, we calculated the habitat metric values (mean, standard deviation) among segments with low, medium, and high proportions of salmonids. Definitions for the low, medium, and high categories are provided in the "Synthesis of fish, habitat, and temperature" section of this report.

Table 3. Habitat metrics calculated for riverscape survey areas of the Chehalis River.

Metric	**Calculation**
Proportion pool riffle	Ratio of pool-riffle segments to total segments in survey area
Wetted width	Average calculated from all measures in survey area
Maximum depth	Average calculated from all measures in survey area
Large woody debris (LWD) density	LWD frequency per 100 m in each segment; average calculated from all segments in survey area
Pool density	Pool frequency per 100 m in each segment; average calculated from all segments in survey area
Dominant substrate	Average of ordinal substrate ranking from all segments in survey area
Proportion bedrock substrate	Ratio of segments with bedrock as the dominant substrate to total segments in survey area

Temperature Monitoring

We collected stream temperature data at 5-15 fixed monitoring sites throughout each survey area during the time frame that fish and habitat data were collected (Onset Hobo Pendant Logger 64K UA-001-64, Figure 1, Appendix 1). Distances between temperature monitoring sites ranged from 1.3-12.7 river kilometers (mean: 4.3; SD: 2.1) and were evenly spaced within a survey area. Distance between loggers was greatest in the North Fork Newaukum River due to land access issues. Temperature data were collected at 30 minute intervals. At each of the fixed monitoring sites, loggers were positioned based on three criteria: well-mixed water, shade, and adequate depth to remain submerged for the summer low flow period. Loggers were anchored by cable or epoxy (Isaak et al. 2013) and were secured in perforated plastic vinyl chloride (PVC) housing which allowed flowing water to contact the logger but shielded the logger from sunlight. Prior to deployment and upon retrieval, temperature values from the loggers were compared to a NIST reference thermometer at cool and warm temperatures over a 24 h period to ensure measurement deviations did not exceed 0.5^{0}C. We used three levels of screening to remove erroneous temperature data from analyses: 1) loggers were routinely inspected in the field to ensure they were well positioned in the thalweg and submerged, 2) data were plotted by time and visually inspected for outliers or abnormalities compared to neighboring loggers, and 3) data were erroneous if the rate of hourly change exceeded 2.5^{0}C, which likely indicated that the logger was dewatered during that time (Rieman and Chandler 1999).

Temperature metrics were derived from each logger for the month of August, which overlapped with the timing of the fish and habitat surveys. August temperatures also correspond to temperature modelling more broadly available for Pacific northwest rivers (Isaak et al. 2017) and represent the time of maximum summer stream temperatures in the Chehalis River (Chandler et al. 2016; Liedtke et al. 2016). Temperature metrics for each sub basin were derived for the year in which the fish and habitat surveys were conducted. In the Upper Chehalis survey area, temperature metrics were derived for three of the four survey years (2014-2016) from nine locations that collected data across the three years. Four of the nine loggers in the 2016 data set from the Upper Chehalis were missing three to six days of data due to the timing of data download in the field.

Four temperature metrics were derived for analyses: mean daily temperature, mean maximum daily temperature, mean minimum daily temperature, and the proportion of time temperature exceeded or was equal to 18˚C. We selected 18˚C as a threshold to represent unfavorable juvenile salmonid rearing conditions based on previous work with juvenile rainbow trout and coho salmon (Hokanson et al. 1977; Madej et al. 2006). Mean daily temperature (˚C) was calculated as the mean of mean daily temperatures; maximum daily temperature (˚C) was calculated as the mean of maximum daily temperatures; and minimum daily temperature (˚C) was calculated as the mean of minimum daily temperatures. The proportion of time stream temperatures exceeded or equaled 18.0˚C was calculated using all recorded temperature measurements during each day in August.

Similar to the summary of habitat data, temperature metrics were compared at two spatial scales – among survey areas and among segments within each survey area. Among survey areas, we averaged temperature metrics across all temperature loggers. Within survey areas, we plotted temperature metrics of each fixed monitoring site as a longitudinal profile from the high to low elevation. Elevation above sea level was selected rather than river kilometer to more directly compare the temperature data among survey areas. Elevation of temperature logger locations were extracted from 10-m resolution digital elevation models in ArcGIS 10.4.1. No statistical analyses were applied to the longitudinal temperature data.

Finally, we calculated temperature metric values (mean, standard deviation) among segments with low, medium, and high proportions of salmonids. Definitions for the low, medium, and high categories are provided in the "Synthesis of fish, habitat, and temperature" section of this report. In order to make these calculations, a temperature value was interpolated for each survey segment because temperature loggers were not directly located in all segments. We interpolated temperature metrics for each survey segment from linear regressions between the closest upstream and downstream loggers to each segment following the method described in Winkowski and Zimmerman (2017). To validate this approach, we interpolated maximum daily temperature for three logging locations in each survey area (most upstream, most downstream, most central) and calculated the difference between actual and interpolated maximum temperatures for each day of the survey period. The mean difference between actual and interpolated values was 0.9˚C (±0.7 ˚C). While this bias is relatively low, we believe our segment interpolations used for analyses would be even less bias due to the closer proximity of temperature loggers used in the segment interpolation process (mean distance between loggers 4.3 km) compared to those used to validate the interpolation process (mean distance between loggers 9.4 km).

Fish Distribution

Each of the six survey areas was sampled once for fish distribution, except the Upper Chehalis survey area which was sampled four consecutive years (Table 1). For each survey, 2-4 divers collected visual fish counts while snorkeling in a downstream direction in georeferenced 200 m segments that corresponded to the habitat data collection. The number of divers increased with wetted width in order to maintain a distance of roughly five meters or less between divers.

All fish were identified to species, size category, and origin (wild or hatchery). Assignment to size category from underwater observations was based on calibrated lengths on divers hands or arms and was necessarily approximate. Hatchery origin salmonids were determined by the presence (indicating wild origin) or absence (indicating hatchery origin) of an adipose fin.

Juvenile salmon were considered subyearlings based on observed fork lengths (FL) less than 90 mm and were classified as “Coho 0+” and “Chinook 0+.” In 2013, juvenile salmon were combined into one category (“Salmon 0+”). Although snorkel counts did not provide species-level resolution in 2013, supplemental seine and electrofishing efforts in this year indicated that juvenile salmon were primarily coho salmon and that minimal numbers of Chinook salmon were present in the survey area. Thus, 2013 juvenile salmon observations will be referred to as “Coho 0+” hereafter. Juvenile trout were classified as “Trout 0+” (FL < 90 mm), and “Trout 1+” (FL 91-299 mm). Supplemental seine and electrofishing efforts indicated that the majority of juvenile trout were *O. mykiss* and therefore we will refer to these data as “steelhead 0+” and “steelhead 1+” hereafter. Resident trout were classified by relatively large size (FL 300-500 mm) and traits including darker coloration, spotting, and relatively deep ventral-dorsal body shape. During surveys, resident trout were not consistently identified to species due to difficulty distinguishing rainbow and cutthroat (*O. clarkii)* trout underwater and therefore we will refer to these data as “resident trout” hereafter. In survey segments where the presence or absence of the adipose fin could not be determined by snorkelers, we applied the ratio of adipose-clipped to adipose-present fish that were observed within the survey segment to the fish counts of unknown origin to calculate an adjusted fish count value. If all observations within a segment were of unknown adipose status, we averaged the ratio of adipose-clipped to adipose-present fish from the adjacent upstream and downstream segments to apply to unknown counts.

Fish count data were collected for all observed native fish species including redside shiner (*Richardsonius balteatus)*, speckled dace (*Rhininchthys. osculus*), longnose dace (*R. cataractae*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth (*Mylocheilus caurinus*), mountain whitefish (*Prosopium williamsoni*), largescale sucker (*Catostomus platyrhynchus*), and three-spine stickleback (*Gasterosteus aculeatus*). Speckled dace and longnose dace were combined into a single category ("dace spp.") because of challenges distinguishing these species by snorkeling. Juvenile pikeminnow and peamouth were combined into a single category ("juvenile pikeminnow" < 250 mm). Protocols in 2013 and 2014 did not include data collection for juvenile northern pikeminnow. We separated juvenile dace, redside shiner, and suckers from adults based on fork length (< 40 mm for juveniles). Protocols in 2013 did not include data collection for juvenile largescale suckers. We also separated juvenile whitefish from adults based on fork length (< 250 mm). We noted presence of freshwater mussels in each segment but did not collect counts or identify mussels to species. Fish count data were collected for non-native species, including smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*) and bluegill (*Lepomis macrochirus*). Non-native fish not identified to species were reported by general common name (e.g., "Bass" or "Sunfish").

Multiple steps were taken to minimize sources of potential error associated with the snorkeling technique. Divers maintained parallel positions to each other when moving through a segment in order to avoid variable detection rates. Upon encountering a large aggregation of fish, divers communicated to avoid duplicate counts. Wetted width of the channel could influence detectability of fish. Therefore, based on visibility estimates, the number of divers was selected to best sample any given segment. Typically, divers could adequately sample 5 m in any given direction. If wetted width exceeded the horizontal visibility limits of the two divers (~20 m), a third diver was introduced to maximize coverage of the wetted channel. In each survey area, a staggered daily rotation from a team of four to five divers was implemented to randomize observer bias in fish counts. The South Fork Newaukum River, where the entire survey area was sampled by the same two divers, was the exception to this protocol but the use of the same divers for the entire survey in this area should also minimize influence of observer bias on the resulting data. To minimize inconsistencies among divers, multiple days of side-by-side snorkel efforts were conducted across different habitat unit types prior to the start of surveys. Pre-survey snorkel efforts helped to maximize the accuracy of species identification, size category, and the precision of fish counts.

Consistent with the summary of habitat and temperature data, fish count data were summarized at two spatial scales – among survey areas and among segments within survey areas. Among survey areas, we present the occupancy and average fish per 100 m for the entire survey area for each species and life stage. Occupancy was the proportion of all segments in survey area that a species/life stage was observed to be present. Average fish per 100 m is a measure of relative density and will be referred to as "density" hereafter. We present fish densities as a mean and standard deviation calculated from all segments within a given survey area, including those where the species count was zero. Data collection in 2014 in the Upper Chehalis included the full combination of habitat, temperature, and fish data, thus we use this dataset for comparison of fish distributions among survey areas. Within survey areas, we examined the relationship between fish distribution and river kilometer by performing binomial regressions of fish occupancy (present, absent) versus river kilometer and linear regressions of fish density versus river kilometer. Count data were log transformed prior to the regression analysis. In order to ensure that adequate data were available for statistical analysis, regression analyses of fish occupancy and density versus river kilometer were conducted when the occupancy of the species was greater than or equal to 25% of the segments within the survey area.

Fish count data were also summarized among survey years in the Upper Chehalis survey area, where four years of distribution data were obtained from the same area. Similar to the comparisons among survey areas, we present the occupancy and densities for each species and life stage among surveys years. We performed binomial regressions of fish occupancy (present, absent) versus river kilometer and linear regressions of fish density versus river kilometer for each of the survey years. Regression analyses were conducted when the occupancy of the species was greater than or equal to 25% of the segments within the survey area. For the purpose of these comparisons, the 2013 survey data were truncated to match the spatial coverage included in the 2014-2016 surveys.

Visibility measurements

We quantified visibility of the water column during the snorkel surveys because visibility had the potential to influence fish counts. Downstream horizontal visibility measurements were obtained by submerging a secchi disk in the river and each diver moved downstream until the black and white markings of the secchi disk were distinguishable. The distance from the secchi disk to each diver was measured and an average daily visibility was calculated. If visibility measurements were greater than 5 meters, which provided sufficient visibility for snorkelers to cover their respective area of the channel, then an exact distance measurement was not obtained except in 2016 when visibility measurements were obtained regardless of distance.

We performed linear regressions between total fish counts (total observations of all species and age classes) and visibility for each survey area to evaluate whether our fish counts were confounded by visibility. Fish counts were log transformed prior to analysis.

Synthesis of Fish, Habitat, and Temperature

Juvenile salmonids (coho 0+, Chinook 0+, trout 0+ and trout 1+) and cyprinids (redside shiner, dace, pikeminnow adults and juveniles) comprised the vast majority of fish observed throughout the survey areas and counts of individuals within each taxonomic group were combined to broadly describe fish assemblage patterns among survey areas and among years. We used a color-coded map to visualize the proportions of salmonids versus cyprinids in each survey segment across all six survey areas and among survey years in the Upper Chehalis survey area.

To synthesize information gathered on fish assemblages, habitat, and temperature, we categorized each survey segment by its fish assemblage. For this synthesis, fish assemblages were categorized according to the numerical dominance of juvenile salmonids (i.e., coho 0+, Chinook 0+, trout 0+ and 1+). Categories corresponded to the proportions of observations in each segment that were juvenile salmonids – low ($\leq$ 24.9% salmonids), medium (25-75% salmonids), and high ($\geq$ 75.1% salmonids). Fish assemblages in each segment will be referred to as ‘low’, ‘medium’, or ‘high’ salmonid reflecting the numerical dominance of salmonids (versus cyprinids).

Among survey areas, we calculated the proportion of survey segments in each fish assemblage category, providing a spatial comparison of salmonid-dominated rearing among different areas of the watershed. We calculated mean values of river kilometer, habitat metrics, and temperature metrics of survey segments assigned to each fish assemblage category in order to describe location and environmental characteristics associated with numerical dominance of the juvenile salmonids.

Among survey years in the Upper Chehalis survey area, we calculated the proportion of survey segments in each fish assemblage category, providing a temporal comparison of salmonid-dominated rearing within the same area of river. We calculated mean values of river kilometer and temperature metrics of survey segments assigned to each fish assemblage category for each of the four years (2014-2016 for which temperature data were available) in order to describe temporal variability in the relative locations of fish assemblage zones and temperature associated with numerical dominance of the juvenile salmonids.

Results

Habitat Among Survey Areas

Physical habitat characteristics varied among survey areas, most notably in terms of wetted width, LWD density, pool density, and the proportion of segments with bedrock as the dominant substrate (Table 4). Wetted widths varied two-fold among survey areas (averages ranged from 9.4-19.8 m). Wetted widths were similar in the Upper Chehalis, East Fork and West Fork Satsop, and West Fork Humptulips (range 19.4-19.8 m) but narrower in the South and North Fork Newaukum (9.4 and 12.3 m, respectively). LWD density varied roughly 4.5-fold among survey areas (1.7 – 8.1 per 100 m). The East Fork Satsop and West Fork Humptulips were characterized by the highest densities of LWD (8.1 and 7.2 per 100 m, respectively) whereas the Upper Chehalis was characterized by the least LWD density (1.7 per 100 m). Within the Newaukum River sub basin, LWD density was similar between the South and North Fork Newaukum (3.7 and 4.4 per 100 m, respectively) whereas within the Satsop sub basin, LWD density in the East

Fork Satsop was nearly double compared to the West Fork Satsop (7.9 and 4.0 per 100 m, respectively). Pool densities varied three-fold among survey areas (0.4 – 1.2 pools per 100 m) and were highest in the South and North Fork Newaukum (1.1 and 1.2 per 100 m, respectively), lowest in the East Fork and West Fork Satsop (0.4 and 0.5 per 100 m, respectively), and intermediate in the Upper Chehalis and West Fork Humptulips (0.8 and 0.8 per 100 m, respectively). The proportion of segments with bedrock-dominant substrate was greatest in the Upper Chehalis (13.9%) and North Fork Newaukum (6.6%) and minimal in the other four survey areas (all ≤ 0.9%).

Other habitat metrics were less variable among survey areas (Table 4). The majority of segments across survey areas were pool-riffle channel type (82.4 – 100%). In survey areas with less than 96% pool-riffle channel types, other channel types included spring-fed headwaters in the East Fork Satsop (16.7%), dune-ripple in the North Fork Newaukum (12.5%), and forced pool riffle in the Upper Chehalis (6.9%). Dominant substrate was comparable among survey areas with a coarseness ranking range of 2.7 – 3.3. Average maximum depths were comparable across survey areas (1.3 – 1.7 m).

Table 4. Habitat metrics summarized for survey areas of the Chehalis River. Numbers are mean (±one standard deviation) of all segments within the survey area except for percentages which represent the proportion of segments in each survey area with the reported categorical value. "Bedrock substrate" represents proportion of segments where bedrock was recorded as the dominant substrate. LWD and pool density were counts per 100m.

Habitat Metric	Upper Chehalis	South Fork Newaukum	North Fork Newaukum	East Fork Satsop	West Fork Satsop	West Fork Humptulips
Wetted width (m)	19.1 (±8.1)	12.3 (±3.4)	9.4 (±3.1)	19.5 (±8.6)	19.4 (±7.4)	19.8 (±8.8)
LWD Density	1.7 (±2.0)	3.7 (±5.1)	4.4 (±5.5)	8.1 (±6.1)	4.0 (±3.8)	7.2 (±11.1)
Pool Density	0.8 (±0.6)	1.1 (±0.6)	1.2 (±0.8)	0.4 (±0.5)	0.5 (±0.4)	0.8 (±0.6)
Bedrock substrate	13.9%	0.0%	6.6%	0.0%	0.8%	0.9%
Pool-riffle channel type	88.4%	99.4%	82.4%	83.3%	100%	96.4%
Dominant substrate	3.1 (±0.6)	3.2 (±0.9)	2.7 (±1.1)	2.9 (±0.9)	3.1 (±0.6)	3.3 (±0.6)
Maximum depth (m)	1.5 (±0.7)	1.5 (±0.5)	1.3 (±0.4)	1.5 (±0.6)	1.7 (±0.7)	1.8 (±0.8)

Habitat Within Survey Areas – Longitudinal Patterns

Longitudinal patterns of habitat characteristics were observed within survey areas, however patterns differed among some survey areas (Table 5, Appendix B). Wetted widths were larger in downstream segments than upstream segments of the Upper Chehalis, West Fork Satsop, and West Fork Humptulips but no longitudinal pattern was observed in the South and North Fork Newaukum or East Fork Satsop. In all survey areas except the East Fork Satsop, upstream segments were characterized by coarser substrate than downstream segments. In the East Fork Satsop, the opposite pattern was observed and substrate was coarser in downstream segments than upstream segments. Pool densities were higher in the upstream segments than downstream segments of the Upper Chehalis, South and North Fork Newaukum, West Fork Satsop and West Fork Humptulips. Maximum depths were higher in downstream segments than upstream segments in the South and North Fork Newaukum and West Fork Humptulips. LWD was higher in upstream segments than downstream segments in the East Fork Satsop and West Fork Humptulips whereas LWD was higher in downstream segments than upstream segments of the West Fork Satsop. No longitudinal pattern of LWD density was observed in the Upper Chehalis or South and North Fork Newaukum.

Table 5. Longitudinal patterns of habitat metrics within survey areas of the Chehalis River. R^2 values are from linear regressions (Kendall's tau for dominant substrate) between individual habitat metrics and river kilometer. Statistically significant regressions are bolded ($\alpha = 0.05$). Positive signs (+) indicate larger values were observed in upstream segments whereas negative signs (-) indicate larger values were observed in downstream segments. LWD and pool density are counts per 100m.

Habitat Metric	Upper Chehalis	South Fork Newaukum	North Fork Newaukum	East Fork Satsop	West Fork Satsop	West Fork Humptulips
Wetted width (m)	(–) 0.48	0.00	0.02	0.01	(–) 0.24	(–) 0.35
Dominant substrate	(+) 0.43	(+) 0.17	(+) 0.53	(–) 0.43	(+) 0.39	(+) 0.40
Pool Density	(+) 0.28	(+) 0.07	(+) 0.12	0.01	(+) 0.12	(+) 0.14
Maximum depth (m)	0.00	(–) 0.06	(–) 0.22	0.00	0.00	(–) 0.02
LWD Density	0.00	0.00	0.01	(+) 0.24	(-) 0.02	(+) 0.15

Temperature Among Survey Areas

August temperatures were variable among survey areas (Table 6). For all metrics, stream temperatures in the Upper Chehalis and West Fork Satsop were the warmest, the West Fork Humptulips and East Fork Satsop were the coolest, and the North and South Fork Newaukum were similar to each other and intermediate relative to other survey areas. Mean August daily temperatures varied up to 4.6°C among survey areas and were warmest in the Upper Chehalis and West Fork Satsop (18.9 and 18.5°C, respectively) and coolest in West Fork Humptulips and East Fork Satsop (15.6 and 14.3°C, respectively). Mean August temperatures in the North and South Fork Newaukum were moderately cool relative to other survey areas (16.9 and 17.4°C, respectively). Mean maximum daily August temperatures varied up to 5.5°C and were warmest in the Upper Chehalis and West Fork Satsop (21.4 and 20.4°C, respectively) and coolest in West Fork Humptulips and East Fork Satsop (17.4 and 15.9°C, respectively). Mean maximum daily August temperatures in the North and South Fork Newaukum were moderately cool relative to other survey areas (18.6 and 19.5°C, respectively). Mean minimum daily August temperatures varied up to 3.9°C and were warmest in the Upper Chehalis and West Fork Satsop (16.9 and 16.8°C, respectively) and coolest in West Fork Humptulips and East Fork Satsop (14.2 and 13.0°C, respectively). Mean minimum daily August temperatures in the North and South Fork Newaukum were moderately cool relative to other survey areas (15.3 and 15.6°C, respectively). The proportion of time August temperatures reached or exceeded 18°C was greatest in the Upper Chehalis and West Fork Satsop (60%) and least in West Fork Humptulips and East Fork Satsop (20% and 0%, respectively). The proportion of time August temperatures reached or exceeded 18°C in the North and South Fork Newaukum were moderate relative to other survey areas (30 and 40%, respectively).

Table 6. August temperature metrics for survey areas of the Chehalis River. Temperature metrics are mean of August daily values (±SD) calculated from all temperature loggers in the survey area.

August Temperature Metric	Upper Chehalis (2014)	South Fork Newaukum (2016)	North Fork Newaukum (2014)	East Fork Satsop (2015)	West Fork Satsop (2015)	West Fork Humptulips (2016)
Mean (˚C)	18.9 (±0.9)	17.4 (±2.1)	16.9 (±1.9)	14.3 (±1.0)	18.5 (±1.5)	15.6 (±2.1)
Maximum (˚C)	21.4 (±1.2)	19.5 (±2.3)	18.6 (±2.0)	15.9 (±1.3)	20.4 (±1.5)	17.4 (±2.4)
Minimum (˚C)	16.9 (±1.0)	15.6 (±2.0)	15.3 (±1.9)	13.0 (±0.8)	16.8 (±1.4)	14.2 (±1.8)
Proportion ≥ 18 ˚C	0.6 (±0.2)	0.4 (±0.3)	0.3 (±0.4)	0.0 (±0.0)	0.6 (±0.3)	0.2 (±0.2)

Temperature Within Survey Areas – Longitudinal Patterns

In general, temperatures warmed as elevation decreased (except in the East Fork Satsop); the difference in mean August daily temperature between the upper and lower elevations of each survey area ranged between 2.7˚C and 7.6˚C (Figure 2, table 7). However, at a given elevation, temperatures ranged up to 7.1˚C among survey areas with the East Fork Satsop being the coldest and the Upper Chehalis being the warmest.

For the purpose comparing survey areas, we describe patterns for three elevation zones (> 200 m, 100 – 200 m, < 100 m above sea level) that had different combinations of overlap in terms of temperature monitoring sites among the six survey areas (Figure 2, Table 7). In the elevation zone greater than 200 m, three of the six survey areas had temperature monitoring sites (Upper Chehalis 243m; South Fork Newaukum 226 and 257m; and West Fork Humptulips 230 and 261m). Due to access issues, we were unable to deploy loggers in the high elevation zone in the North Fork Newaukum or West Fork Satsop and the East Fork Satsop did not reach this elevation. In this higher elevation zone, the West Fork Humptulips and South Fork Newaukum had the coolest temperatures and the Upper Chehalis had the warmest temperatures (Table 7). For example, mean daily August temperatures in the high elevation site of the Upper Chehalis were 4.4-7.1˚C warmer than the high elevation sites of the West Fork Humptulips and 3.7-4.6 ˚C warmer than the high elevation sites of the South Fork Newaukum. Within the higher elevation zone, temperatures increased with decreasing elevation in the West Fork Humptulips and South Fork Newaukum whereas there was minimal change in temperature with decreasing elevation the Upper Chehalis survey area. In the elevation zone between 100 and 200 m, five of the six survey areas had temperature monitoring sites (exception was the East Fork Satsop which did not reach 100 m elevation). In this intermediate elevation zone, the West Fork Humptulips had on average the coolest temperatures, North and South Fork Newaukum and West Fork Satsop had intermediate temperatures, and the Upper Chehalis had the warmest temperatures. Within this intermediate elevation zone, temperature increased with decreasing elevation in all survey areas. At elevations less than 100 m, four of the six survey areas had temperature monitoring sites (Upper Chehalis, West Fork Satsop, West Fork Humptulips, and East Fork Satsop). In this lower elevation zone, mean temperatures in the East Fork Satsop were up to 8.2˚C cooler than the Upper Chehalis, 3.9˚C cooler than the West Fork Humptulips and 4.4˚C cooler than the West and temperatures in the West Fork Humptulips were generally cooler than those in the West Fork Satsop. In addition, temperatures in the East Fork Satsop at elevations less than 100 m were comparable to temperatures in the West Fork Satsop and North Fork Newaukum at elevations above 200 m and colder than temperatures in the Upper Chehalis above 200 m. In the lower elevation zone, temperatures generally increased with decreasing elevation. We observed a deviation from this pattern at the lowest elevation monitoring site in the West Fork Satsop where mean temperature was approximately 3˚C cooler than the closest monitoring site at higher elevation. The lowest elevation monitoring site on the West Fork Satsop was located downstream of a channel connection with the East Fork Satsop and temperatures were therefore influenced by cool water entering the West Fork Satsop from this channel connection.

Table 7. Mean daily August temperatures (°C) in "elevation zones" <100m, 100-200m, and >200m in survey areas of the Chehalis River. The number of sites ("No. sites"), elevation range of sites (meters), and mean daily august temperature or ranges of mean daily august temperature (if multiple sites within elevation zone) ("Mean temp") are displayed. "---" indicates no temperature monitoring sites were located within the elevation zone of a given survey area.

	Elevation < 100m			**Elevation 100 - 200m**			**Elevation > 200m**		
	No. sites	**Elevation range (m)**	**Mean temp (°C)**	**No. sites**	**Elevation range (m)**	**Mean temp (°C)**	**No. sites**	**Elevation range (m)**	**Mean temp (°C)**
Upper Chehalis (2014)	1	98	20.8	7	101-185	18.0-20.1	1	243	17.8
South Fork Newaukum (2016)	2	82-96	19.7-19.9	8	122-193	15.4-19.3	2	226-257	13.2-14.1
North Fork Newaukum (2014)	1	82	20.2	4	117-184	15.2-17.8	---	---	---
East Fork Satsop (2015)	5	31-96	12.6-15.3	---	---	---	---	---	---
West Fork Satsop (2015)	10	24-98	17.0-20.2	4	119-184	14.8-18.3	---	---	---
West Fork Humptulips (2016)	4	49-98	16.5-18.3	5	101-186	14.2-16.4	2	230-261	10.7-13.4

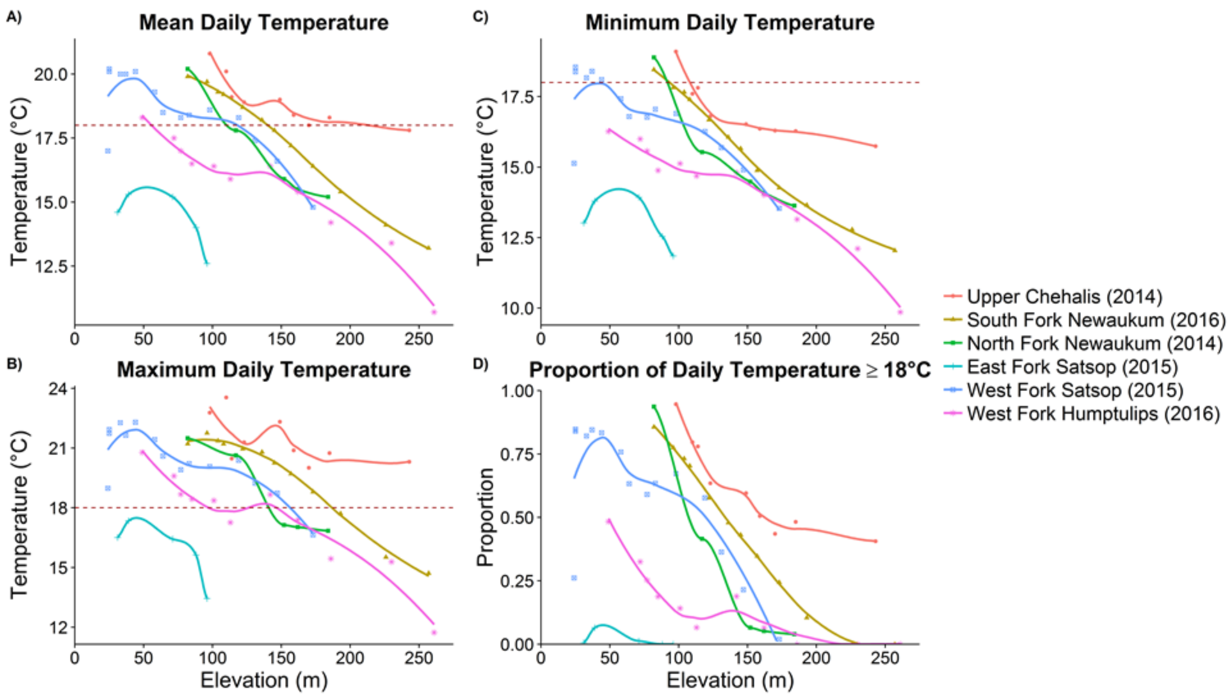

Figure 2. August temperature metrics including A) mean daily, B) mean maximum daily, C) mean minimum daily, and D) proportion of time daily temperatures ≥18°C plotted by elevation (m) for survey areas of the Chehalis River. Lines are lowess smoothed curves fit to the data of each survey area. A horizontal line at 18˚C is added as a reference (panels A-C).

Temperature Among Survey Years (Upper Chehalis)

In contrast to the variation in stream temperatures observed among survey areas, we observed minimal variability in August temperatures among years (2014-2016) in the Upper Chehalis survey area (Table 8, Figure 3). Overall, August temperatures exhibited a similar elevation, or longitudinal, pattern in all three years and were warmer at lower than higher elevations. In all years, mean daily August temperatures were rarely below 18℃ except at elevations above 243 m (rkm 200.7). Among-year variability of mean daily August temperatures at monitoring sites ranged from 0.1 – 0.3℃. Mean maximum daily August temperatures exceeded 18℃ at all sites in all years. Among-year variability of mean maximum daily August temperatures at monitoring sites ranged from 0.2 – 1.1℃. Mean minimum daily August temperatures exceeded 18℃ only in the lowest elevation sites (98 m) in the downstream sections of the survey area (at rkm 170.7) among years. Among-year variability of mean minimum daily August temperatures at monitoring sites ranged from 0.1 – 0.9℃. On average, August temperatures were equal to or greater than 18℃ for 60% of the time among years.

Table 8. August temperature metrics among years (2014-2016) in the Upper Chehalis survey area. Numbers represent mean of daily values for each metric (±SD) calculated from the same nine fixed monitoring sites in the survey area (Rkm 166.4-202.9). Temperature data were not collected in 2013.

Metric	2014	2015	2016
Mean (˚C)	18.9 (±0.9)	18.9 (±0.9)	18.7 (±1.0)
Maximum (˚C)	21.4 (±1.2)	21.3 (±1.2)	21.2 (±1.4)
Minimum (˚C)	16.9 (±1.0)	16.8 (±0.8)	16.6 (±0.9)
Proportion ≥ 18 ˚C	0.6 (±0.2)	0.6 (±0.1)	0.6 (±0.2)

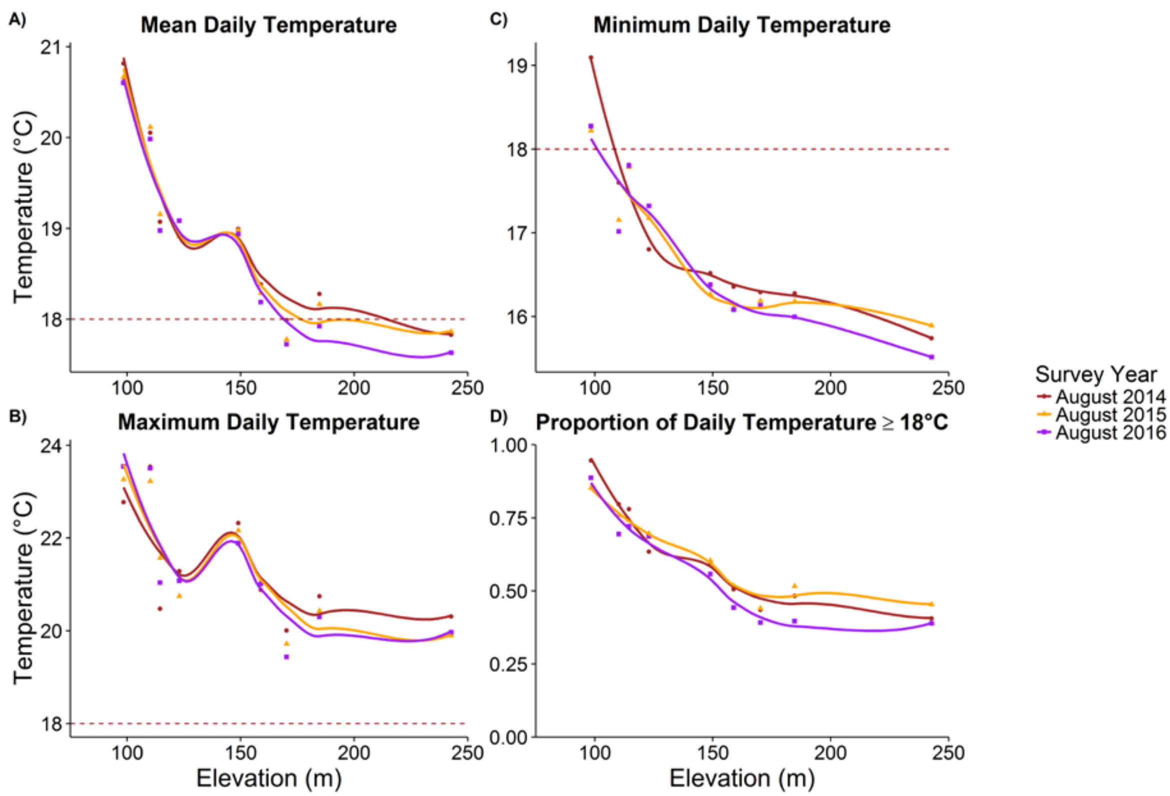

Figure 3. August temperature metrics including A) mean daily, B) mean maximum daily, C) mean minimum daily, and D) proportion of time daily temperatures ≥18℃ by elevation (m) in the Upper Chehalis River survey area from three survey years, 2014-2016. Lines are lowess smoothed curves fit to the data of each survey year. A horizontal line at 18˚C is added as a reference (panels A-C).

Fish Distributions Among Survey Areas

Snorkel Visibility

In 2014, a minimum of one visibility measurement was collected each survey day. In 2015, visibility measurements were collected on at least 80% of survey days in the East and West Fork Satsop and on all surveys days in the Upper Chehalis. In 2016, a minimum of one visibility measurement per day was obtained for 75% of the survey days of the West Fork Humptulips and 100% of the survey days in South Fork Newaukum and Upper Chehalis. No visibility measurements were obtained during the 2013 Upper Chehalis survey. Based on all available data, no relationship was observed between total fish counts and visibility (all p-values > 0.05) for all surveys except the Upper Chehalis 2014 (Table 9).

Table 9. Linear regression results of total fish count and visibility measurements for each riverscape survey conducted in the Chehalis River, 2014-2016.

Survey area	Year	P-value
Upper Chehalis	2014	0.01
Upper Chehalis	2015	0.66
Upper Chehalis	2016	0.78
South Fork Newaukum	2016	0.24
North Fork Newaukum	2014	0.11
West Fork Satsop	2015	0.28
East Fork Satsop	2015	0.52
West Fork Humptulips	2016	0.38

Among Survey Area Observations: Juvenile Salmon and Trout

Coho 0+ occupied 70.5 - 100% of segments among survey areas (Tables 10 and 12). The lowest occupancies of coho 0+ were observed in the Upper Chehalis (70.5% in 2014) and West Fork Satsop (76.4%). Density of coho 0+ varied seven-fold among survey areas and was lowest in the

Upper Chehalis (10.2 fish per 100 m in 2014) and highest in the North Fork Newaukum (74.9 fish per 100 m).

Chinook 0+ observations were relatively rare and occupancy ranged from 0.0 – 25.4% of segments among survey areas (Tables 10 and 12). We did not observe Chinook 0+ in the East Fork Satsop. The lowest occupancy of Chinook 0+ was observed in the West Fork Humptulips, West Fork Satsop, South and North Fork Newaukum (all < 3.2%) and the highest occupancy was observed in the Upper Chehalis (25.4% in 2014). Where observed, density of Chinook 0+ ranged from 0.0 – 1.4 fish per 100 m and was lowest in the West Fork Humptulips, West Fork Satsop, North and South Fork Newaukum (all 0.0 fish per 100 m) and highest in the Upper Chehalis (1.4 fish per 100 m in 2014).

Steelhead 0+ occupied 91.2 – 100% of segments among survey areas (Tables 10 and 12). Density of steelhead 0+ varied 16-fold among survey areas and was lowest in the East Fork Satsop (7.7 fish per 100 m) and highest in the Upper Chehalis (125.9 fish per 100 m in 2014).

Steelhead 1+ occupied 44.4 – 92.9 % of segments among survey areas (Tables 10 and 12). The lowest occupancy of steelhead 1+ was observed in the West Fork Satsop (44.4%) and the highest occupancy was observed in the Upper Chehalis and North and South Fork Newaukum (> 91.0%). Density of steelhead 1+ varied 17-fold among survey areas and was lowest in the West and East Fork Satsop (1.5 and 2.9 fish per 100 m, respectively) and highest in the Upper Chehalis (24.9 fish per 100 m in 2014).

Among Survey Area Observations: Cyprinids

Redside shiner occupied 0.4 – 69.3% of segments among survey areas (Tables 10 and 12). The lowest occupancy of redside shiner was observed in the West Fork Humptulips and East Fork Satsop (0.4 – 6.5 %) and the highest occupancy was observed in the South Fork Newaukum (69.3%). Density of redside shiner ranged from 0.0 – 53.4 fish per 100 m, was lowest in the West Fork Humptulips and East Fork Satsop (0.0 – 1.2 fish per 100 m), and highest in the South Fork Newaukum (53.4 fish per 100 m).

Redside shiner fry occupied 0.0 – 50.0% of segments among survey areas (Tables 10 and 12). We did not observe redside shiner fry in the East Fork Satsop or West Fork Humptulips. The lowest occupancy of redside shiner fry was observed in the South Fork Newaukum (24.6%) and the highest occupancy was observed in the West Fork Satsop (50.0%). Where observed, density of redside shiner fry ranged from 13.9 – 64.4 fish per 100 m, was lowest in the South Fork Newaukum (13.9 fish per 100 m) and highest in the West Fork Satsop (64.4 fish per 100 m).

Dace occupied 22.2 – 79.9% of segments among survey areas (Tables 10 and 12). The lowest occupancy of dace was observed in the East Fork Satsop (22.2%) and the highest occupancy was observed in the Upper Chehalis, South and North Fork Newaukum, and West Fork Satsop (all > 66.0%). Density of dace ranged from 1.9 – 46.4 fish per 100 m and was lowest in the East Fork Satsop (1.9 fish per 100 m) and highest in the North Fork Newaukum (46.4 fish per 100 m).

Dace fry occupied 8.3 – 79.6% of segments among survey areas (Tables 10 and 12). The lowest occupancy of dace fry was observed in the East Fork Satsop (8.3%) and the highest occupancy was observed in the West Fork Satsop (79.9%). Density of dace fry ranged from 0.5 – 28.8 fish per 100 m and was lowest in the East Fork Satsop (0.5 fish per 100 m) and highest in Upper Chehalis (28.8 fish per 100 m in 2014).

Adult northern pikeminnow occupied 0.0 – 43.6% of segments among survey areas (Tables 10 and 12). Adult pikeminnow were not observed in the West Fork Humptulips. The lowest occupancy of adult pikeminnow was observed in the East Fork Satsop (1.9%) and the highest occupancy was observed in the South and Fork Newaukum (43.6 and 42.6%, respectively). Where observed, density of adult pikeminnow ranged from 0.1 – 3.2 fish per 100 m and was lowest in the East Fork Satsop (0.1 fish per 100 m) and highest in the North Fork Newaukum and West Fork Satsop (3.2 and 3.1 fish per 100 m, respectively).

Juvenile northern pikeminnow occupied 0.0 – 68.7% of segments among survey areas (Tables 10 and 12). Juvenile pikeminnow were not observed in the West Fork Humptulips. The lowest occupancy of juvenile pikeminnow was observed in the East Fork Satsop (1.9%) and the highest occupancy was observed in the South Fork Newaukum (68.7%). Where observed, density of juvenile pikeminnow ranged from 0.2 – 11.9 fish per 100 m and was lowest in the East Fork Satsop (0.2 fish per 100m) and highest in the South Fork Newaukum (11.9 fish per 100 m).

Among Survey Area Observations: Adult Salmon, Trout, and Char

Resident trout occupied 18.8 - 69.4% of segments among survey areas (Tables 10 and 12). The lowest occupancy of resident trout was observed in the West Fork Satsop and the highest occupancy was observed in the East Fork Satsop. Density of resident trout ranged from 0.2 – 1.3 fish per 100 m and was lowest in the West Fork Satsop (0.2 fish per 100m) and highest in the East Fork Satsop (1.3 fish per 100 m).

With the exception of resident trout, adult salmonids observations were rare among survey areas (Tables 10 and 12). Adult Chinook salmon were observed in the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, East Fork Satsop and West Fork Humptulips. The highest counts were in the South Fork Newaukum (n = 28) and North Fork Newaukum (n = 12). Wild adult steelhead were observed in the Upper Chehalis (n = 3 in 2014), East Fork Satsop (n = 9), West Fork Satsop (n = 2), and West Fork Humptulips (n = 3). Adult steelhead with unknown adipose mark status were observed in the Upper Chehalis (n = 3 in 2014), East Fork Satsop (n = 19), West Fork Satsop (n = 1), and West Fork Humptulips (n = 2). Adult sockeye (n = 1) and adult bull trout (n = 2) were observed in the West Fork Humptulips.

Among Survey Area Observations: Native Fish and Mussels

Adult mountain whitefish occupied 9.3 – 54.3% of segments among survey areas (Tables 10 and 12). The lowest occupancy of adult whitefish was observed in the East Fork Satsop (9.3%) and the highest occupancy was observed in the West Fork Humptulips (54.3%). Density of adult whitefish ranged from 0.6 - 2.5 fish per 100 m and was lowest in the Upper Chehalis (in 2014) and South and North Fork Newaukum (all $\leq$ 0.8 fish per 100 m) and highest in the West Fork Humptulips (2.5 fish per 100 m).

Juvenile mountain whitefish occupied 0.0 - 35.2% of segments among survey areas (Tables 10 and 12). Juvenile whitefish were not observed in the Upper Chehalis (all survey years) or the North Fork Newaukum. Where observed, the lowest occupancy of juvenile whitefish was observed in the West Fork Satsop (6.8%) and the highest occupancy was observed in the South Fork Newaukum (35.2%). Where observed, density of juvenile whitefish ranged from 0.0 - 0.5 fish per 100 m and was lowest West Fork Satsop (0.0 fish per 100 m) and highest in the South Fork Newaukum (0.5 fish per 100 m).

Adult largescale suckers occupied 0.0 – 24.0% of segments among survey areas (Tables 10 and 12). We did not observe adult suckers in the West Fork Humptulips. The lowest occupancy of adult suckers was observed in the West and East Fork Satsop (1.9 – 2.8%) and the highest occupancy was observed in the South Fork Newaukum (24.0%). Where observed, density of adult suckers ranged from 0.2 – 2.1 fish per 100 m and was lowest in the North Fork Newaukum and East Fork Satsop (0.2 fish per 100 m, respectively) and highest in the South Fork Newaukum (2.1 fish per 100 m).

Juvenile largescale suckers occupied 0.0 – 52.0% of segments among survey areas (Tables 10 and 12). We did not observe juvenile suckers in the East Fork Satsop. The lowest occupancy of juvenile suckers was observed in the West Fork Humptulips (6.7%) and the highest occupancy was observed in the West Fork Satsop (52.0%). Where observed, density of juvenile suckers ranged from 0.2 – 58.1 fish per 100 m and was lowest West Fork Humptulips (0.2 fish per 100 m) and highest in the Upper Chehalis (58.1 fish per 100 m in 2014).

Threespine stickleback occupied 0.0 - 57.6% of segments among survey areas (Tables 10 and 12). We did not observe threespine stickleback in the Upper Chehalis (all survey years) or West Fork Humptulips. Occupancy and density were highest in the West Fork Satsop (57.6% and 15.1 fish per 100 m) and lowest in the South and North Fork Newaukum (0.7% and 0.1 fish per 100m and 3.4% 0.5 fish per 100 m, respectively).

Freshwater mussels were observed in all survey areas except the West Fork Humptulips (Table 10). Mussel occupancy ranged from 1.2% in the West Fork Satsop to 13.4% in the South Fork Newaukum.

Among Survey Area Observations: Hatchery Salmon and Steelhead

Observations of juvenile and adult hatchery origin salmon and steelhead were variable among survey areas (Tables 10 and 12). We did not observe hatchery juvenile salmon or steelhead in the West Fork Humptulips, West Fork Satsop, North Fork Newaukum, or Upper Chehalis (all survey years). In the East Fork Satsop, hatchery coho 0+ were observed in 8.3% of segments and density was 0.2 fish per 100 m. Hatchery steelhead 0+ were not observed in any survey area during this study (but see Winkowski et al. 2018 where hatchery steelhead 0+ were observed in a

September survey in the South Fork Newaukum). In the East Fork Satsop, hatchery steelhead 1+ occupied 16.7% of segments and density was 0.5 fish per 100 m. In the South Fork Newaukum, hatchery steelhead 1+ occupied 25.1% of segments and density was 0.4 fish per 100 m.

Residualized hatchery trout were observed only in the East Fork Satsop River (n = 5) and occupied 3.7% of segments (Table 10). Hatchery adult steelhead were observed in the West Fork Humptulips (n = 3), West Fork Satsop (n = 1), and East Fork Satsop (n = 15) (Table 10). No hatchery origin adult steelhead were observed in the North Fork or South Fork Newaukum or upper Chehalis (all survey years).

Among Survey Area Observations: Non-Native Fish

Non-native fish species were observed in the Upper Chehalis 2013 extended survey of the main stem river and North Fork and South Fork Newaukum (Figure 4, Table 10, Appendix C). All observations of non-native fish in the Chehalis 2013 survey occurred downstream of the confluence with the South Fork Chehalis River. Smallmouth and largemouth bass (n = 109 and 12, respectively) occupied 7.8 and 0.3% of segments, respectively. General bass not identified to species (n = 692) occupied 19.3% of segments. Bluegill (count of n = 24) occupied 3.7% of segments. (see Appendix C).

In the North Fork Newaukum, bass were observed (n = 1) in the downstream extents of the survey area (e.g. 0.5 river km upstream from the confluence with the South Fork) and occupied 0.7% of segments. In the South Fork Newaukum survey area, sunfish (n = 3) were generally observed in the lower portion of the survey area (e.g. within 1.5 km upstream of the confluence with the North Fork), but one observation occurred roughly 10 km upstream from the downstream most part of the survey area. We did not observe bass in the South Fork Newaukum in this August survey but see Winkowski et al. (2018) for bass observations in the South Fork Newaukum in a September survey.

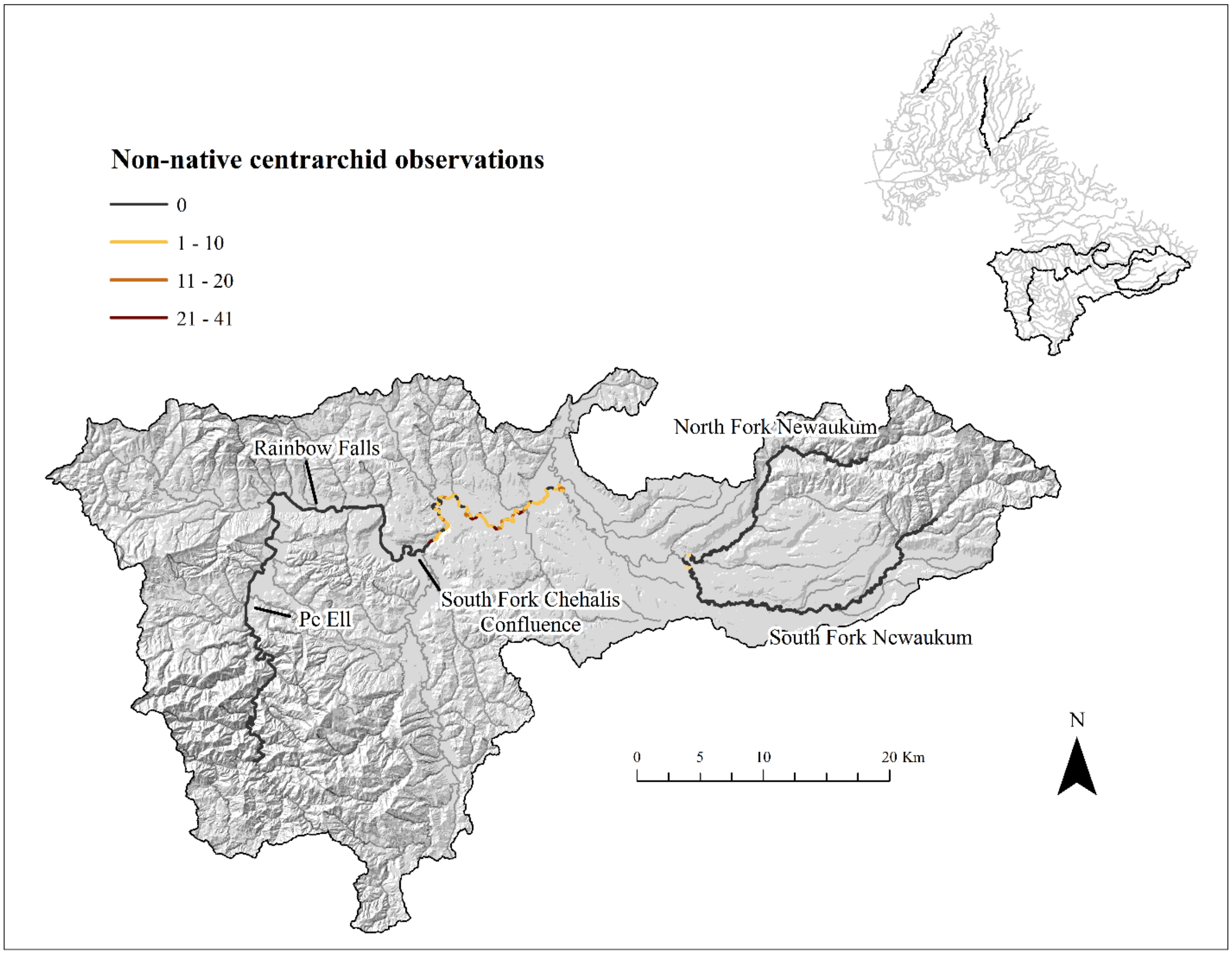

Figure 4. Non-native centrarchid observations in the Upper Chehalis (2013) and Newaukum (North Fork – 2014, South Fork – 2016) survey areas. Legend scale represents total counts in 200-m survey segments. Centrarchid species observed included smallmouth bass, largemouth bass, 'general bass' (no species identification), bluegill sunfish, and 'general sunfish' (no species identification).

Table 10. Fish observations among survey areas of the Chehalis River. Summary includes occupancy (percent of survey segments where species was present), total count (across all survey segments), and density (fish per 100 m, mean ±standard deviation). All fish are wild origin unless indicated with an "H" (hatchery) or "U" (unknown). '---' indicates data were not collected.

	Coho 0+	Chinook 0+	Steelhead 0+	Steelhead 1+
Occupancy				
Upper Chehalis (2014)	70.5%	25.4%	97.7%	91.9%
South Fork Newaukum	88.3%	0.6%	100.0%	91.1%
North Fork Newaukum	100.0%	0.7%	91.2%	91.9%
East Fork Satsop	94.4%	0.0%	95.4%	74.1%
West Fork Satsop	76.4%	3.2%	96.0%	44.4%
West Fork Humptulips	81.2%	0.4%	100.0%	82.5%
Total Count				
Upper Chehalis (2014)	3642	502	45102	8878
South Fork Newaukum	22226	1	14111	3367
North Fork Newaukum	20463	1	6653	1937
East Fork Satsop	8596	0	1842	681
West Fork Satsop	14529	11	8540	820
West Fork Humptulips	13881	1	16283	4731
Density (SD)				
Upper Chehalis (2014)	10.2 (±15.9)	1.4 (±4.4)	125.9 (±114.4)	24.9 (±38.9)
South Fork Newaukum	58.5 (±67.4)	0.0 (±0.0)	37.7 (±28.4)	8.9 (±8.8)
North Fork Newaukum	74.9 (±67.3)	0.0 (±0.0)	23.7 (±29.7)	7.0 (±7.5)
East Fork Satsop	36.8 (±39.5)	0.0 (±0.0)	7.7 (±7.1)	2.9 (±3.6)
West Fork Satsop	26.8 (±49.2)	0.0 (±0.1)	15.8 (±16.7)	1.5 (±3.6)
West Fork Humptulips	28.8 (±37.7)	0.0 (±0.0)	33.8 (±19.6)	9.8 (±13.2)

Table 10. Continued.

	Redside shiner	Redside Shiner (Fry)	Dace	Dace (Fry)	Pikeminnow (Adult)	Pikeminnow (Juv)
Occupancy						
Upper Chehalis (2014)	37.6%	33.5%	66.5%	49.7%	17.3%	---
South Fork Newaukum	69.3%	24.6%	79.9%	26.3%	43.6%	68.7%
North Fork Newaukum	45.6%	29.4%	69.1%	35.3%	42.6%	---
East Fork Satsop	6.5%	0.0%	22.2%	8.3%	1.9%	1.9%
West Fork Satsop	51.6%	50.0%	79.6%	79.6%	18.0%	19.2%
West Fork Humptulips	0.4%	0.0%	45.3%	16.1%	0.0%	0.0%
Total Count						
Upper Chehalis (2014)	4563	16356	10255	14668	312	---
South Fork Newaukum	19535	5191	10948	590	596	4399
North Fork Newaukum	4879	5399	12961	3756	860	---
East Fork Satsop	288	0	444	115	22	38
West Fork Satsop	11887	37313	11007	14786	1761	4910
West Fork Humptulips	2	0	9454	881	0	0
Density (SD)						
Upper Chehalis (2014)	12.5 (±35.5)	44.5 (±96.0)	28.8 (±46.4)	28.8 (±46.4)	0.9 (±4.3)	---
South Fork Newaukum	53.4 (±58.3)	13.9 (±40.7)	29.7 (±40.4)	1.5 (±4.3)	1.6 (±2.8)	11.9 (±16.2)
North Fork Newaukum	18.0 (±29.4)	19.4 (±40.9)	46.4 (±67.4)	13.5 (±23.1)	3.2 (±7.1)	---
East Fork Satsop	1.2 (±7.9)	0.0 (±0.0)	1.9 (±7.5)	0.5 (2.1)	0.1 (±0.9)	0.2 (±1.6)
West Fork Satsop	20.6 (±40.5)	64.4 (±98.0)	19.2 (±24.7)	25.8 (±29.2)	3.1 (±19.8)	8.8 (±43.1)
West Fork Humptulips	0.0 (±0.1)	0.0 (±0.0)	19.2 (±38.7)	1.7 (±6.5)	0.0 (±0.0)	0.0 (±0.0)

Table 10. Continued.

	Steelhead (Adult)	Steelhead (Adult, U)	Chinook (Adult)	Resident trout	Sockeye (Adult)	Bull Trout (Adult)
Occupancy						
Upper Chehalis (2014)	1.7%	1.7%	0.6%	37.6%	0.0%	0.0%
South Fork Newaukum	0.0%	0.0%	8.4%	25.7%	0.0%	0.0%
North Fork Newaukum	0.0%	0.0%	5.1%	26.5%	0.0%	0.0%
East Fork Satsop	7.4%	13.9%	3.7%	69.4%	0.0%	0.0%
West Fork Satsop	0.4%	0.4%	0.0%	18.8%	0.0%	0.0%
West Fork Humptulips	1.3%	0.4%	0.4%	49.8%	0.4%	0.9%
Total Count						
Upper Chehalis (2014)	3	3	1	259	0	0
South Fork Newaukum	0	0	28	73	0	0
North Fork Newaukum	0	0	12	55	0	0
East Fork Satsop	9	19	6	321	0	0
West Fork Satsop	2	1	0	86	0	0
West Fork Humptulips	3	2	1	271	1	2
Density (SD)						
Upper Chehalis (2014)	0.0 (±0.1)	0.0 (±0.1)	0.0 (±0.0)	0.7 (±1.8)	0.0 (±0.0)	0.0 (±0.0)
South Fork Newaukum	0.0 (±0.0)	0.0 (±0.0)	0.1 (±0.3)	0.2 (±0.4)	0.0 (±0.0)	0.0 (±0.0)
North Fork Newaukum	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.3)	0.2 (±0.4)	0.0 (±0.0)	0.0 (±0.0)
East Fork Satsop	0.0 (±0.1)	0.1 (±0.2)	0.0 (±0.2)	1.3 (±2.1)	0.0 (±0.0)	0.0 (±0.0)
West Fork Satsop	0.0 (±0.1)	0.0 (±0.0)	0.0 (±0.0)	0.2 (±0.4)	0.0 (±0.0)	0.0 (±0.0)
West Fork Humptulips	0.0 (±0.1)	0.0 (±0.1)	0.0 (±0.0)	0.6 (±0.9)	0.0 (±0.0)	0.0 (±0.0)

Table 10. Continued.

	Mountain whitefish (Adult)	Mountain whitefish (Juv)	Sucker (Adult)	Sucker (Juv)	Threespine Stickleback	Freshwater Mussels
Occupancy						
Upper Chehalis (2014)	22.5%	0.0%	20.8%	49.1%	0.0%	4.0%
South Fork Newaukum	31.8%	35.2%	24.0%	16.8%	3.4%	13.4%
North Fork Newaukum	26.5%	0.0%	11.0%	41.2%	0.7%	8.1%
East Fork Satsop	9.3%	8.3%	1.9%	0.0%	26.9%	5.6%
West Fork Satsop	29.2%	6.8%	2.8%	52.0%	57.6%	1.2%
West Fork Humptulips	54.3%	11.2%	0.0%	6.7%	0.0%	0.0%
Total Count						
Upper Chehalis (2014)	249	0	635	21321	0	---
South Fork Newaukum	309	178	763	148	167	---
North Fork Newaukum	164	0	52	2188	30	---
East Fork Satsop	552	19	50	0	282	---
West Fork Satsop	985	26	579	3148	8637	---
West Fork Humptulips	1247	39	0	89	0	---
Density (SD)						
Upper Chehalis (2014)	0.7 (±1.7)	0.0 (±0.0)	1.6 (±4.2)	58.1 (±114.5)	0.0 (±0.0)	---
South Fork Newaukum	0.8 (±2.0)	0.5 (±1.1)	2.1 (±7.2)	0.4 (±1.2)	0.5 (±5.5)	---
North Fork Newaukum	0.6 (±1.4)	0.0 (±0.0)	0.2 (±0.9)	7.6 (±15.1)	0.1 (±1.2)	---
East Fork Satsop	1.9 (±13.2)	0.1 (±0.4)	0.2 (±1.2)	0.0 (±0.0)	1.2 (±3.9)	---
West Fork Satsop	1.8 (±4.9)	0.0 (±0.2)	1.1 (±14.9)	5.4 (±10.8)	15.1 (±26.9)	---
West Fork Humptulips	2.5 (±4.1)	0.1 (±0.3)	0.0 (±0.0)	0.2 (±1.0)	0.0 (±0.0)	---

Table 10. Continued.

	Coho 0+ (H)	Steelhead 1+ (H)	Resident trout (H)	Steelhead (Adult, H)	Bass	Sunfish
Occupancy						
Upper Chehalis (2014)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
South Fork Newaukum	0.0%	25.1%	0.0%	0.0%	0.0%	1.7%
North Fork Newaukum	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%
East Fork Satsop	8.3%	16.7%	3.7%	8.3%	0.0%	0.0%
West Fork Satsop	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%
West Fork Humptulips	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
Total Count						
Upper Chehalis (2014)	0	0	0	0	0	0
South Fork Newaukum	0	141	0	0	0	3
North Fork Newaukum	0	0	0	0	1	0
East Fork Satsop	55	100	5	15	0	0
West Fork Satsop	0	0	0	1	0	0
West Fork Humptulips	0	0	0	3	0	0
Density (SD)						
Upper Chehalis (2014)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)
South Fork Newaukum	0.0 (±0.0)	0.4 (±1.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.1)
North Fork Newaukum	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)
East Fork Satsop	0.2 (±1.0)	0.5 (±2.2)	0.0 (±0.1)	0.1 (±0.3)	0.0 (±0.0)	0.0 (±0.0)
West Fork Satsop	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)
West Fork Humptulips	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.1)	0.0 (±0.0)	0.0 (±0.0)

Fish Distributions Within Survey Areas – Longitudinal Patterns

Within Survey Area Observations: Juvenile Salmon and Trout

In general, density of juvenile salmon and steelhead were higher in upstream segments than downstream segments of each survey area whereas occupancy patterns were more variable among survey areas (Table 11). Linear regressions of fish densities and river kilometer are displayed in Appendix D.

Coho 0+ occupancy was greater in upstream segments than downstream segments of the East Fork Satsop and South Fork Newaukum but no association of occupancy and river km was observed in the North Fork Newaukum, West Fork Satsop, or West Fork Humptulips (Table 11). The opposite pattern was observed in the Upper Chehalis (2014) where coho 0+ occupancy was greater in downstream segments than upstream segments. Coho 0+ density was higher in upstream segments than downstream segments of all survey areas except the Upper Chehalis (2014) where density was higher in downstream segments than upstream segments (Table 11). However, longitudinal patterns of coho 0+ occupancy and density in the Upper Chehalis varied among years (See section "Fish Distribution Among Survey Years (Upper Chehalis)," Table 13, Appendix E).

Chinook 0+ occupancy was too low to examine associations of occupancy and density with river kilometer in all survey areas except in the Upper Chehalis (2014) where neither occupancy or density were associated with river km (Table 11, Appendix D).

Steelhead 0+ occupancy was greater in upstream segments than downstream segments of the Upper Chehalis (2014) and North Fork Newaukum (Table 11). No associations of occupancy and river km was observed in the other survey areas. Steelhead 0+ density was higher in upstream segments than downstream segments of all survey areas except the East Fork Satsop, where density was higher in downstream segments than upstream segments, and the West Fork Humptulips where no association was observed (Table 11, Appendix D).

Steelhead 1+ occupancy and density were greater in upstream segments than downstream segments of all survey areas except the West Fork Satsop, where no associations between occupancy or density with river kilometer were observed (Table 11).

Within Survey Area Observations: Cyprinids

In general, cyprinid species occupancy and density were higher in downstream segments than upstream segments of each survey area (Table 11, Appendix D).

Redside shiner occupancy and density were higher in downstream than upstream segments of the Upper Chehalis, South Fork and North Fork Newaukum and West Fork Satsop (Table 11). Occupancy was too low in the West Fork Humptulips and East Fork Satsop to examine associations with river kilometer (Table 11). Redside shiner fry occupancy and density were also higher in downstream segments than upstream of the Upper Chehalis, North Fork Newaukum and West Fork Satsop (Table 11), however occupancy was too low to examine associations with river kilometer in the South Fork Newaukum and fry were not observed in the East Fork Satsop or West Fork Humptulips.

Dace and dace fry occupancy and density were higher in downstream segments than upstream segments of the Upper Chehalis, South Fork and North Fork Newaukum and West Fork Satsop (Table 11), however occupancy was too low in the East Fork Satsop and West Fork Humptulips to examine associations with river kilometer.

Adult northern pikeminnow occupancy and density were higher in downstream segments than upstream segments of the South Fork and North Fork Newaukum Rivers and occupancy was too low to examine associations with river kilometer in all other survey areas (Table 11). Juvenile pikeminnow occupancy and density were higher in downstream segments than upstream segments of the South Fork Newaukum River (Table 11), however occupancy was too low to examine associations with river kilometer in all other survey areas.

Within Survey Area Observations: Adult Salmon, Trout, and Char

Adult Chinook, steelhead, sockeye, and bull trout observations were rare across survey areas and therefore associations of occupancy and density with river kilometer were not examined (Table 10).

Resident trout occupancy was higher in upstream segments than downstream segments of the Upper Chehalis, South Fork Newaukum, East Fork Sastop, and West Fork Humptulips (Table

11). Resident trout occupancy was higher in downstream segments than upstream segments of the North Fork Newaukum and occupancy was too low in the West Fork Satsop to examine association with river kilometer. Resident trout density was higher in upstream segments than downstream segments of the Upper Chehalis, South Fork Newaukum, and East Fork Sastop, and no associations between density and river km were observed in the North Fork Newaukum or the West Fork Humptulips (Table 11).

Within Survey Area Observations: Native Fish

Adult mountain whitefish occupancy was higher in upstream segments than downstream segments of the South Fork Newaukum and West Fork Satsop and higher in downstream segments than upstream segments of the West Fork Humptulips (Table 11). No association between occupancy and river km was observed in the North Fork Newaukum and occupancy was too low to examine associations with river kilometer in the Upper Chehalis and East Fork Satsop. Adult mountain whitefish density was higher in upstream segments than downstream segments of the South Fork Newaukum and West Fork Satsop and higher in downstream segments than upstream segments in the West Fork Humptulips (Table 11). No association was observed between density and river km in the North Fork Newaukum and occupancy was too low in the Upper Chehalis and East Fork Satsop to examine associations with river kilometer.

Juvenile mountain whitefish occupancy was too low to examine associations with river kilometer in all survey areas except in the South Fork Newaukum where no association was observed between occupancy or density with river km (Table 11).

Adult largescale sucker occupancy was too low to examine associations with river kilometer in all survey areas (Table 10).

Juvenile largescale sucker occupancy and density were higher in downstream segments than upstream segments of the Upper Chehalis, North Fork Newaukum, and West Fork Satsop (Table 11). Juvenile largescale sucker occupancy was too low in the South Fork Newaukum and West Fork Humptulips to examine associations with river kilometer. We did not observe juvenile suckers in the East Fork Satsop.

Threespine stickleback occupancy was higher in upstream segments than downstream segments of the East Fork Satsop and higher in downstream segments than upstream segments of the West Fork Satsop (Table 11). Threespine stickleback occupancy was too low to examine associations with river kilometer in the South and North Fork Newaukum. We did not observe threespine stickleback in the Upper Chehalis or West Fork Humptulips. Threespine stickleback density was higher in downstream segments than upstream segments of the West Fork Satsop and no association between density and river km was observed in the East Fork Satsop. Occupancy was too low in the South and North Fork Newaukum to examine associations of density and river kilometer.

Within Survey Area Observations: Hatchery Salmon and Steelhead

Hatchery origin juvenile and adult salmonids were observed in relatively low numbers or not observed in survey areas and therefore associations of occupancy and density with river kilometer were not examined (Table 11).

Within Survey Area Observations: Non-Native Fish

Non-native fish observations were limited across survey areas and therefore associations of occupancy and density with river kilometer were not examined (Table 10).

Table 11. Longitudinal patterns of fish occupancy (O) and density (D) in survey areas of the Chehalis River. Significant associations are displayed as positive signs (+), indicating higher occupancy/density in upstream segments compared to downstream segments, and negative signs (-), indicating higher occupancy/density in downstream segments compared to upstream segments. 'NS' indicates no significant association with river kilometer. 'NA' indicates no regression analysis because occupancy did not exceed 25%. '---' indicates data were not collected. Data are graphically displayed in Appendix D.

	Upper Chehalis (2014) **(O)/(D)**	**South Fork Newaukum (2016)** **(O)/(D)**	**North Fork Newaukum (2014)** **(O)/(D)**	**East Fork Satsop (2015)** **(O)/(D)**	**West Fork Satsop (2015)** **(O)/(D)**	**West Fork Humptulips (2016)** **(O)/(D)**
Juvenile Salmonids						
Coho 0+	**(-)/(-)**	**(+)/(+)**	NS/**(+)**	**(+)/(+)**	NS/**(+)**	NS/**(+)**
Chinook 0+	NS/NS	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Steelhead 0+	**(+)/(+)**	NS/**(+)**	**(+)/(+)**	NS/**(-)**	NS/**(+)**	NS/NS
Steelhead 1+	**(+)/(+)**	**(+)/(+)**	**(+)/(+)**	**(+)/(+)**	NS/NS	**(+)/(+)**
Cyprinids						
Redside shiner	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**	NA/NA	**(-)/(-)**	NA/NA
Redside shiner (Fry)	**(-)/(-)**	NA/NA	**(-)/(-)**	NA/NA	**(-)/(-)**	NA/NA
Dace	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**	NA/NA	**(-)/(-)**	**(-)/(-)**
Dace (Fry)	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**	NA/NA	**(-)/(-)**	NA/NA
Pikeminnow (Adult)	NA/NA	**(-)/(-)**	**(-)/(-)**	NA/NA	NA/NA	NA/NA
Pikeminnow (Juv)	---	**(-)/(-)**	---	NA/NA	NA/NA	NA/NA

Table 11. Continued.

Species -Life Stage	Upper Chehalis (2014)	South Fork Newaukum (2016)	North Fork Newaukum (2014)	East Fork Satsop (2015)	West Fork Satsop (2015)	West Fork Humptulips (2016)
	(O)/(D)	**(O)/(D)**	**(O)/(D)**	**(O)/(D)**	**(O)/(D)**	**(O)/(D)**
Adult salmonids						
Chinook (Adult)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Resident Trout	**(+)/(+)**	**(+)/(+)**	**(+)**/NS	**(-)/(+)**	NA/NA	**(+)**/NS
Steelhead (Adult)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Steelhead (Adult, U)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Sockeye (Adult)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Bull Trout (Adult)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Native fish						
Whitefish (Adult)	NA/NA	**(+)/(+)**	NS/NS	NA/NA	**(+)/(+)**	**(-)/(-)**
Whitefish (Juv)	NA/NA	NS/NS	NA/NA	NA/NA	NA/NA	NA/NA
Sucker (Adult)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Sucker (Juv)	**(-)/(-)**	NA/NA	**(-)/(-)**	NA/NA	**(-)/(-)**	NA/NA
Threespine stickleback	NA	NA	NA	**(+)**/NS	**(-)/(-)**	NA
Hatchery salmonids						
Coho 0+ (H)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Steelhead 1+ (H)	NA/NA	NS/NS	NA/NA	NA/NA	NA/NA	NA/NA
Steelhead (Adult, H)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Resident Trout (H)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Non-native fish						
Bass	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Sunfish	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA

Fish Distribution Among Survey Years (Upper Chehalis)

<u>Among-Year Observations: Juvenile Salmon and Steelhead</u>

Coho 0+ occupancy ranged from 70.5 – 93.4% among years with the lowest occupancy observed in 2014 and the highest in 2013 (Table 12). Coho 0+ occupancy was higher in downstream segments than upstream segments in 2014 and was not associated with river kilometer in 2013, 2015, and 2016 (Table 13). Total counts varied 16-fold among years and were fewest in 2014 (n = 3,642) and greatest in 2013 (n = 58,579). Coho 0+ density varied roughly 16-fold and was lowest in 2014 (10.2 fish per 100 m) and highest in 2013 (161.8 fish per 100 m). Coho 0+ densities were higher in upstream segments than downstream segments in 2013 and 2015, but were higher in downstream segments than upstream segments in 2014. Coho 0+ density was not associated with river kilometer in 2016 (Table 13, Appendix E).

Chinook 0+ occupancy ranged from 0.0 to 25.4% among years (Table 12). We did not observe Chinook 0+ in 2016. Among years where Chinook 0+ were observed, the lowest occupancy was observed in 2015 (11%) and the highest in 2014 (25.4%). Chinook 0+ occupancy was not associated with river kilometer in 2014 and was too low for examining associations with river kilometer in 2015 and 2016 (Table 13). Total count varied roughly 17-fold and was greatest in 2014 (n = 502) and fewest in 2015 (n = 30). Among years where Chinook 0+ were observed, density was lowest in 2015 (0.1 fish per 100m) and highest in 2014 (1.4 fish per 100m). Chinook 0+ density was not associated with river kilometer in 2014 and occupancy was too low to examine associations of density and river kilometer in all other survey years (Table 13, Appendix E).

Steelhead 0+ occupancy was greater than 97% among years (Table 12). Steelhead 0+ occupancy was higher in upstream segments than downstream segments in 2014, 2015, and 2016 and was not associated with river kilometer in 2013 (Table 13). Total count varied three-fold among years and was fewest in 2016 (n = 13,505) and greatest in 2014 (n = 45,102). Steelhead 0+ density varied roughly three-fold and was lowest in 2016 (37.2 fish per 100 m) and highest in 2014 (125.9 fish per 100 m). Steelhead 0+ densities were higher in upstream segments than downstream segments for all survey years (Table 13, Appendix E).

Steelhead 1+ occupancy ranged from 59.5 – 92.9% among years with the lowest occupancy observed in 2015 and highest in 2013 (Table 12). Steelhead 1+ occupancy was higher in upstream segments than downstream in 2014 and was not associated with river kilometer in 2013, 2015, and 2016 (Table 13). Total count varied roughly eight-fold among years and was fewest in 2016 (n = 1,202) and greatest in 2013 (n = 9,347). Steelhead 1+ density varied roughly eight-fold and was lowest in 2016 (3.3 fish per 100 m) and highest in 2013 (26.1 fish per 100 m). Steelhead 1+ densities were higher in upstream segments than downstream segments in 2014, 2015, and 2016 and no association of density and river kilometer was observed in 2013 (Table 13, Appendix E).

Among-Year Observations: Cyprinids

Redside shiner occupancy ranged from 34.6 – 46.2% among years with the lowest occupancy observed in 2013 and the highest in 2015 (Table 12). Redside shiner occupancy was higher in downstream segments than upstream segments all survey years (Table 13). Total count varied three-fold among years and was fewest in 2014 (n = 4,563) and greatest in 2015 (n = 13,602). Redside shiner density varied roughly three-fold and was lowest in 2014 (12.5 fish per 100 m) and highest in 2015 (37.1 fish per 100 m). Reside shiner densities were higher in downstream segments than upstream segments for all survey years (Table 13, Appendix E).

Redside shiner fry occupancy ranged from 9.9 - 35.3% among years with the lowest occupancy observed in 2013 and the highest in 2016 (Table 12). Redside shiner fry occupancy was higher in downstream segments than upstream segments in 2014, 2015, and 2016 and was too low for examining associations with river kilometer in 2013 (Table 13). Total count varied four-fold among years and was fewest in 2013 (n = 5,025) and greatest in 2015 (n = 20,552). Redside shiner fry density varied roughly four-fold and was lowest in 2013 (13.8 fish per 100 m) and highest in 2015 (57.3 fish per 100 m). Reside shiner fry densities were higher in downstream segments than upstream segments in 2014, 2015, and 2016 and occupancy was too low to examine associations of density and river kilometer in 2013 (Table 13, Appendix E).

Dace occupancy ranged from 61.5 – 70.5% among years with the lowest occupancy observed in 2013 and the highest in 2015 (Table 12). Dace occupancy was higher in downstream segments than upstream segments all survey years (Table 13). Total count varied roughly three-fold among years and was fewest in 2016 (n = 6,204) and greatest in 2013 (n = 17,138). Dace density varied roughly three-fold and was lowest in 2016 (17.0 fish per 100 m) and highest in 2013 (48.1 fish per 100 m). Dace densities were higher in downstream segments than upstream segments for all survey years (Table 13, Appendix E).

Dace fry occupancy ranged from 8.8 - 54.3% among years with the lowest occupancy observed in 2013 and the highest in 2015 (Table 12). Dace fry occupancy was higher in downstream segments than upstream segments in 2014, 2015, and 2016 and was too low for examining associations with river kilometer in 2013 (Table 13). Total count varied three and a half fold among years and was fewest in 2016 (n = 4,175) and greatest in 2014 (n = 14,668). Dace fry density varied three and a half fold and was lowest in 2016 (11.3 fish per 100 m) and highest in 2014 (40.6 fish per 100 m). Dace fry densities were higher in downstream segments than upstream segments in 2014, 2015, and 2016 and occupancy was too low to examine associations of density and river kilometer in 2013 (Table 13, Appendix E).

Adult northern pikeminnow occupancy ranged from 13.7 – 19.1% among years with the lowest occupancy observed in 2013 and highest in 2015 (Table 12). Adult northern pikeminnow occupancy was too low in all survey years to examine associations with river kilometer. Total count varied roughly three-fold among years and was fewest in 2013 (n = 261) and greatest in 2015 (n = 777). Adult pikeminnow density varied roughly three-fold among years and was lowest in 2013 (0.7 fish per 100 m) and highest in 2015 (2.1 fish per 100 m).

Juvenile northern pikeminnow occupied 38.2% and 34.1% of segments in 2015 and 2016, respectively (Table 12). Juvenile northern pikeminnow occupancy was higher in downstream segments than upstream segments in 2015 and 2016 (Table 13). Total count varied roughly four-fold between years and was fewer in 2016 (n = 4,822) than in 2015 (n = 19,511). Juvenile pikeminnow density varied roughly four-fold and was lowest in 2016 (13.3 fish per 100m) and highest in 2015 (54.0 fish per 100m). Juvenile pikeminnow densities were higher in downstream segments than upstream segments in 2015 and 2016 (Table 13, Appendix E).

Among-Year Observations: Adult Salmon, Trout, and Char

Adult Chinook salmon occupancy ranged from 0.0 – 2.7% among years (Table 12). We did not observe adult Chinook in 2015. Total counts were fewest in 2014 and 2016 (n = 1) and greatest in 2013 (n = 14). Adult Chinook occupancy was too low in all survey years to examine associations of occupancy or density with river kilometer.

Resident trout occupancy ranged from 12.7 – 50.5% among years with the lowest occupancy observed in 2016 and highest in 2013 (Table 12). Resident trout occupancy was higher in downstream locations than upstream locations in 2013 and higher in upstream locations than downstream locations in 2014 (Table 13). Resident trout occupancy was too low in 2015 and 2016 to examine associations with river kilometer. Total count varied 10-fold among years and was fewest in 2016 (n = 34) and greatest in 2013 (n = 340). Resident trout density varied roughly nine-fold among years and was lowest in 2015 and 2016 (0.1 fish per 100 m) and highest in 2013 and 2014 (0.9 and 0.7 fish per 100 m, respectively). Resident trout densities were higher in upstream segments than downstream segments in 2013 and 2014 and occupancy was too low to examine associations of density and river kilometer in 2015 and 2016 (Table 13, Appendix E).

Wild adult steelhead occupancy ranged from 0.0 – 2.9% among years (Table 12). We did not observe wild adult steelhead in 2013 or 2016. Adult steelhead occupancy was too low in all survey years to examine associations with river kilometer. Total counts were greater in 2014 (n = 6) than 2015 (n = 4). We observed adult steelhead with unknown adipose mark status in 2015 and 2016 (n = 2 and 1, respectively). Adult steelhead occupancies were too low in all survey years to examine associations between density and river kilometer.

Among-Year Observations: Hatchery Salmon and Steelhead

Hatchery salmon and steelhead were not observed in the Upper Chehalis survey area during any survey year.

Among-Year Observations: Native Fish and Mussels

Adult mountain whitefish occupancy ranged from 9.2 – 22.5% among years with the lowest occupancy observed in 2016 and highest in 2014 (Table 12). Adult mountain whitefish occupancy was too low in all survey years to examine associations with river kilometer. Total count varied roughly 2-fold among years and was fewest in 2016 (n = 111) and greatest in 2014 (n = 249). Density varied roughly 2-fold and was lowest in 2013, 2014, and 2016 (0.3 fish per 100 m) and highest in 2014 (0.7 fish per 100 m). Adult mountain whitefish occupancy was too low in all survey years to examine associations of density and river kilometer.

Juvenile mountain whitefish were not observed in the Upper Chehalis survey area during any survey year.

Adult largescale sucker occupancy ranged from 9.8 – 20.8% among years with the lowest occupancy observed in 2016 and highest in 2014 (Table 12). Adult largescale sucker occupancy was too low in all survey years to examine associations with river kilometer. Total count varied over 3-fold among years and was fewest in 2016 (n = 462) and greatest in 2015 (n = 1,527). Density varied over three-fold among years and was lowest in 2013 (1.2 fish per 100 m) and highest in 2015 (3.9 fish per 100 m). Adult largescale sucker occupancy was too low in all survey years to examine associations of density and river kilometer.

Juvenile sucker occupancy ranged from 41.0-49.1% among years with the lowest occupancy observed in 2015 and highest in 2014 (Table 12). Juvenile sucker occupancy was higher in downstream segments than upstream segments in all survey years (Table 13). Total count varied roughly two-fold among years and was fewest in 2016 (n = 12,143) and greatest in 2014 (n = 21,321). Density varied roughly two-fold among years and was lowest in 2016 (33.0 fish per 100 m) and highest in 2014 (n = 58.1 fish per 100 m). Juvenile sucker densities were higher in downstream segments than upstream segments for all survey years (Table 13, Appendix E).

Freshwater mussels occupied 0.5 – 4.0% of segments among years (Table 12). Freshwater mussels occupied 15.9% of segments in the extended Upper Chehalis survey of 2013 (Appendix C).

<u>Among-Year Observations: Non-Native Fish</u>

Non-native fish were not observed in the 36.5 km extent of the Upper Chehalis surveyed each of the four consecutive years (Rkm 166.4-202.9). Non-native centrarchids including smallmouth and largemouth bass and bluegill were observed in the lower extents of the extended 2013 survey of the Upper Chehalis (see ‘Among Survey Area Observations: Non-Native Fish’ and Appendix C).

Table 12. Fish observations among survey years in the Upper Chehalis survey area (Rkm 166.4-202.9). Summary includes occupancy (percent of survey segments where species was present), total count (across all survey segments), and density (fish per 100 m, mean ±standard deviation). All fish are wild origin unless indicated with an “H” (hatchery) or “U” (unknown). ‘---’ indicates data were not collected.

	Coho 0+	**Chinook 0+**	**Steelhead 0+**	**Steelhead 1+**
Occupancy				
2013*	94.5%	---	97.8%	92.9%
2014	70.5%	25.4%	97.7%	91.9%
2015	72.3%	11.0%	97.1%	59.5%
2016	77.5%	0.0%	97.7%	64.2%
Total Count				
2013*	58690	---	37093	9347
2014	3642	502	45102	8878
2015	12152	30	15574	1626
2016	11121	0	13505	1202
Density (SD)				
2013*	163.8 (±211.4)	---	104.0 (±91.4)	26.1 (±32.5)
2014	10.2 (±15.9)	1.4 (±4.4)	125.9 (±114.4)	24.9 (±38.9)
2015	32.9 (±59.5)	0.1 (±0.3)	43.3 (±42.0)	4.4 (±10.8)
2016	29.8 (±55.2)	0.0 (±0.0)	37.2 (±32.3)	3.3 (±6.7)

*2013 data presented in this table includes the same 36.5 km footprint surveyed in 2014-2016. Data from the entire 2013 survey are provided in Appendix C.

Table 12. Continued.

	Redside shiner	Redside Shiner (Fry)	Dace	Dace (Fry)	Pikeminnow (Adult)	Pikeminnow (Juv)
Occupancy						
2013*	34.6%	9.9%	61.5%	8.8%	13.2%	---
2014	37.6%	33.5%	66.5%	49.7%	17.3%	---
2015	46.2%	34.7%	70.5%	54.3%	19.1%	38.2%
2016	39.9%	35.3%	62.4%	53.8%	13.9%	34.1%
Total Count						
2013*	5879	5025	17138	6786	261	---
2014	4563	16356	10255	14668	312	---
2015	13602	20552	11456	6355	777	19511
2016	7695	16447	6204	4175	352	4822
Density (SD)						
2013*	16.9 (±58.0)	13.8 (±65.4)	48.1 (±122.2)	19.1 (±91.4)	0.7 (±2.9)	---
2014	12.5 (±35.5)	44.5 (±96.0)	28.8 (±46.4)	40.6 (±58.3)	0.9 (±4.3)	---
2015	37.1 (±93.2)	57.3 (±121.9)	31.8 (±47.3)	17.9 (±36.0)	2.1 (±8.1)	54.0 (±150.1)
2016	21.1 (±47.4)	44.5 (±93.5)	17.0 (±40.5)	11.3 (±20.0)	1.0 (±3.7)	13.3 (±35.1)

*2013 data presented in this table includes the same 36.5 km footprint surveyed in 2014-2016. Data from the entire 2013 survey are provided in Appendix C.

Table 12. Continued.

	Steelhead (Adult)	Steelhead (Adult, U)	Chinook (Adult)	Resident trout	Sockeye (Adult)	Bull Trout (Adult)
Occupancy						
2013*	0.0%	0.0%	2.7%	50.5%	0.0%	0.0%
2014	2.9%	0.0%	0.6%	37.6%	0.0%	0.0%
2015	2.3%	0.6%	0.0%	15.0%	0.0%	0.0%
2016	0.0%	0.6%	0.6%	12.7%	0.0%	0.0%
Total Count						
2013*	0	0	14	340	0	0
2014	6	0	1	259	0	0
2015	4	2	0	48	0	0
2016	0	1	1	34	0	0
Density (SD)						
2013*	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.3)	0.9 (±1.7)	0.0 (±0.0)	0.0 (±0.0)
2014	0.0 (±0.1)	0.0 (±0.0)	0.0 (±0.0)	0.7 (±1.8)	0.0 (±0.0)	0.0 (±0.0)
2015	0.0 (±0.1)	0.0 (±0.1)	0.0 (±0.0)	0.1 (±0.4)	0.0 (±0.0)	0.0 (±0.0)
2016	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.1 (±0.3)	0.0 (±0.0)	0.0 (±0.0)

*2013 data presented in this table includes the same 36.5 km footprint surveyed in 2014-2016. Data from the entire 2013 survey are provided in Appendix C.

Table 12. Continued.

	Mountain whitefish (Adult)	Mountain whitefish (Juv)	Sucker (Adult)	Sucker (Juv)	Threespine Stickleback	Freshwater Mussels
Occupancy						
2013*	10.4%	0.0%	13.2%	---	0.0%	0.5%
2014	22.5%	0.0%	20.8%	49.1%	0.0%	4.0%
2015	9.8%	0.0%	20.2%	41.0%	0.0%	3.0%
2016	9.2%	0.0%	9.8%	46.2%	0.0%	3.0%
Total Count						
2013*	127	0	729	---	0	---
2014	249	0	635	21321	0	---
2015	128	0	1527	14209	0	---
2016	111	0	462	12143	0	---
Density (SD)						
2013*	0.3 (±1.5)	0.0 (±0.0)	2.1 (±11.4)	---	0.0 (±0.0)	---
2014	0.7 (±1.7)	0.0 (±0.0)	1.6 (±4.2)	58.1 (±114.5)	0.0 (±0.0)	---
2015	0.3 (±1.9)	0.0 (±0.0)	3.9 (±13.0)	39.0 (±96.0)	0.0 (±0.0)	---
2016	0.3 (±1.5)	0.0 (±0.0)	1.2 (±5.2)	33.0 (±83.3)	0.0 (±0.0)	---

*2013 data presented in this table includes the same 36.5 km footprint surveyed in 2014-2016. Data from the entire 2013 survey are provided in Appendix C.

Table 12. Continued.

	Coho 0+ (H)	Steelhead 1+ (H)	Resident trout (H)	Steelhead (Adult, H)	Bass	Sunfish
Occupancy						
2013*	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2014	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2015	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2016	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total Count						
2013*	0	0	0	0	0	0
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	0	0	0	0	0	0
Density (SD)						
2013 *	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)
2014	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)
2015	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)
2016	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)

*2013 data presented in this table includes the same 36.5 km footprint surveyed in 2014-2016. Data from the entire 2013 survey are provided in Appendix C.

Table 13. Longitudinal patterns of fish occupancy (O) and density (D) among survey years of the Upper Chehalis survey area (Rkm 166.4-202.9). Significant associations are displayed as positive signs (+), indicating higher occupancy/density in upstream segments compared to downstream segments, and negative signs (-), indicating higher occupancy/density in downstream segments compared to upstream segments. 'NS' indicates no significant association with river kilometer. 'NA' indicates no regression analysis because occupancy did not exceed 25%. '---' indicates data were not collected. Data are graphically displayed in Appendix E.

Species -Life Stage	**2013*** (O)/(D)	**2014** (O)/(D)	**2015** (O)/(D)	**2016** (O)/(D)
Juvenile Salmonids				
Coho 0+	NS/(+)	(-)/(-)	NS/(+)	NS/NS
Chinook 0+	---	NS/NS	NA/NA	NA/NA
Steelhead 0+	NS/(+)	(+)/(+)	(+) /(+)	(+)/(+)
Steelhead 1+	NS/NS	(+)/(+)	NS/(+)	NS/(+)
Cyprinids				
Redside shiner	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**
Redside shiner (Fry)	NA/NA	**(-) /(-)**	**(-)/(-)**	**(-)/(-)**
Dace	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**
Dace (Fry)	NA/NA	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**
Pikeminnow (Adult)	NA/NA	NA/NA	NA/NA	NA/NA
Pikeminnow (Juv)	**---**	**---**	**(-)/(-)**	**(-)/(-)**

*2013 data presented in this table represent the same 36.5 km footprint surveyed in 2014-2016.

Table 13. Continued.

Species -Life Stage	2013*	2014	2015	2016
	(O)/(D)	**(O)/(D)**	**(O)/(D)**	**(O)/(D)**
Adult salmonids				
Chinook (Adult)	NA/NA	NA/NA	NA/NA	NA/NA
Resident Trout	**(-)/(+)**	**(+)/(+)**	NA/NA	NA/NA
Steelhead (Adult)	NA/NA	NA/NA	NA/NA	NA/NA
Steelhead (Adult, U)	NA/NA	NA/NA	NA/NA	NA/NA
Sockeye (Adult)	NA/NA	NA/NA	NA/NA	NA/NA
Bull Trout (Adult)	NA/NA	NA/NA	NA/NA	NA/NA
Native fish				
Whitefish (Adult)	NA/NA	NA/NA	NA/NA	NA/NA
Whitefish (Juv)	NA/NA	NA/NA	NA/NA	NA/NA
Sucker (Adult)	NA/NA	NA/NA	NA/NA	NA/NA
Sucker (Juv)	---	**(-)/(-)**	**(-)/(-)**	**(-)/(-)**
Threespine stickleback	NA/NA	NA/NA	NA/NA	NA/NA
Hatchery salmonids				
Coho 0+ (H)	NA/NA	NA/NA	NA/NA	NA/NA
Steelhead 1+ (H)	NA/NA	NA/NA	NA/NA	NA/NA
Steelhead (Adult, H)	NA/NA	NA/NA	NA/NA	NA/NA
Resident Trout (H)	NA/NA	NA/NA	NA/NA	NA/NA
Non-native fish				
Bass	NA/NA	NA/NA	NA/NA	NA/NA
Sunfish	NA/NA	NA/NA	NA/NA	NA/NA

*2013 data presented in this table represent the same 36.5 km footprint surveyed in 2014-2016.

Synthesis of Fish, Habitat, and Temperature

Salmonid versus Cyprinid Distribution: Among Survey Areas

Fish assemblages were consistently organized in a longitudinal pattern in all survey areas. Survey segments in the upstream extents of survey areas were characterized by high salmonid proportions (75.1-100%), segments more centrally located in survey areas were characterized by medium salmonid proportions (25-75%), and segments in downstream extents of survey areas were characterized by low salmonid proportions (0 – 24.9%) (Figure 5). Cyprinids were observed in the opposite pattern with low proportions in upstream segments and high proportions in downstream segments of each survey area (Figure 6).

The prevalence of each fish assemblage category (e.g., high, medium, and low proportion salmonid) varied among survey areas. Specifically, the proportions of fish assemblage categories observed in the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, and West Fork Satsop contrasted with those observed in the East Fork Satsop and West Fork Humptulips (Figure 7, Appendix F-1). In the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, and West Fork Satsop, 36 – 60% of the segments were categorized as ‘high’ salmonid segments and 12 – 35% of the segments were categorized as ‘low’ salmonid segments. In comparison, 75 – 93% of the segments in the East Fork Satsop and West Fork Humptulips were categorized as ‘high’ salmonid and just 1% (West Fork Humptulips) and 0% (East Fork Satsop) of the segments were categorized as ‘low’ salmonid.

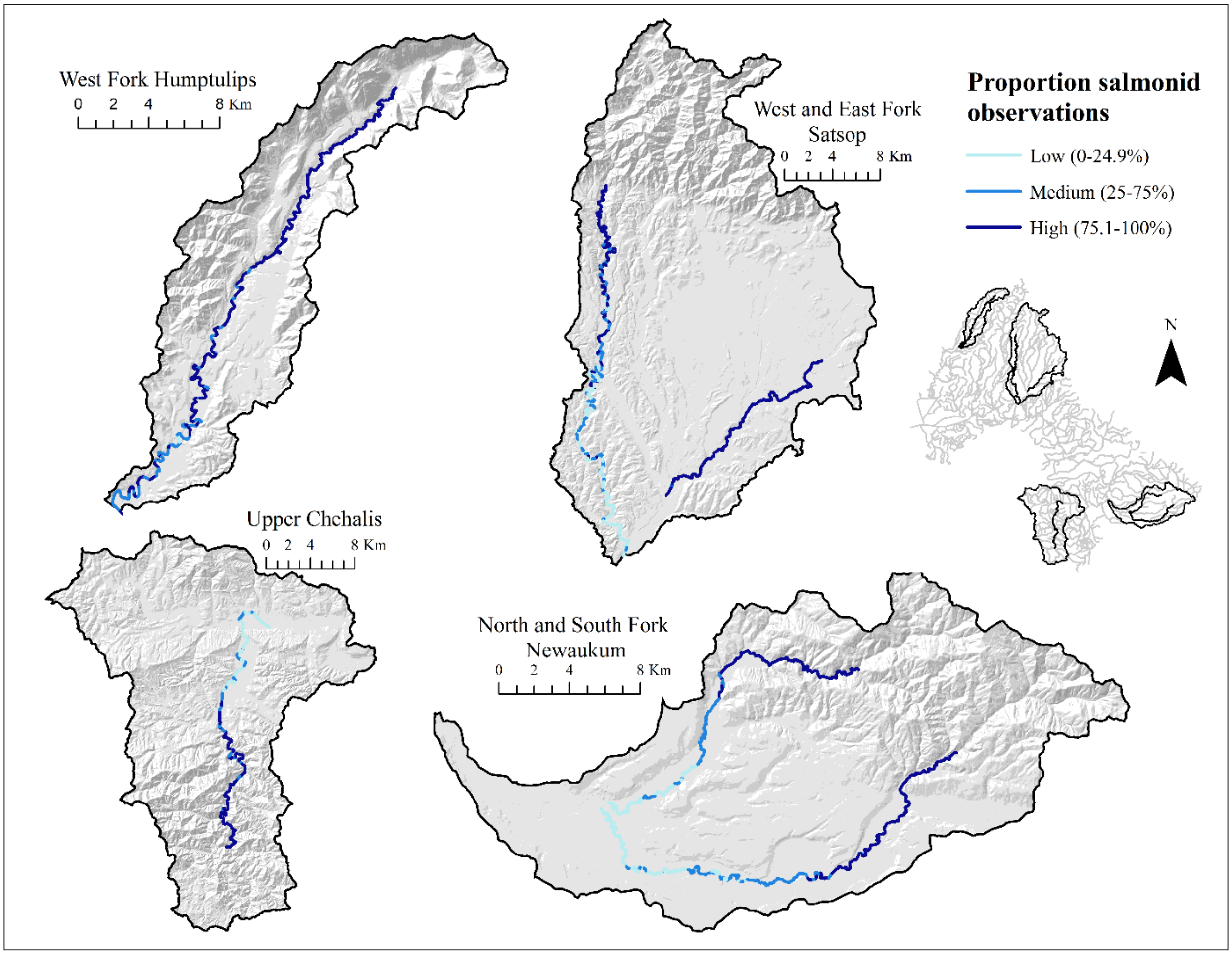

Figure 5. Proportion of juvenile salmonid observations in fish count data shown by survey segment in survey areas of the Chehalis River over three years (2014-2016). Darker blue areas represent segments with high proportions of salmonids whereas lighter blue areas represent segments with low proportions. Upper Chehalis data shown are from 2014 survey, East and West Fork Satsop data shown are from 2015, and South Fork Newaukum and West Fork Humptulips data shown are from 2016.

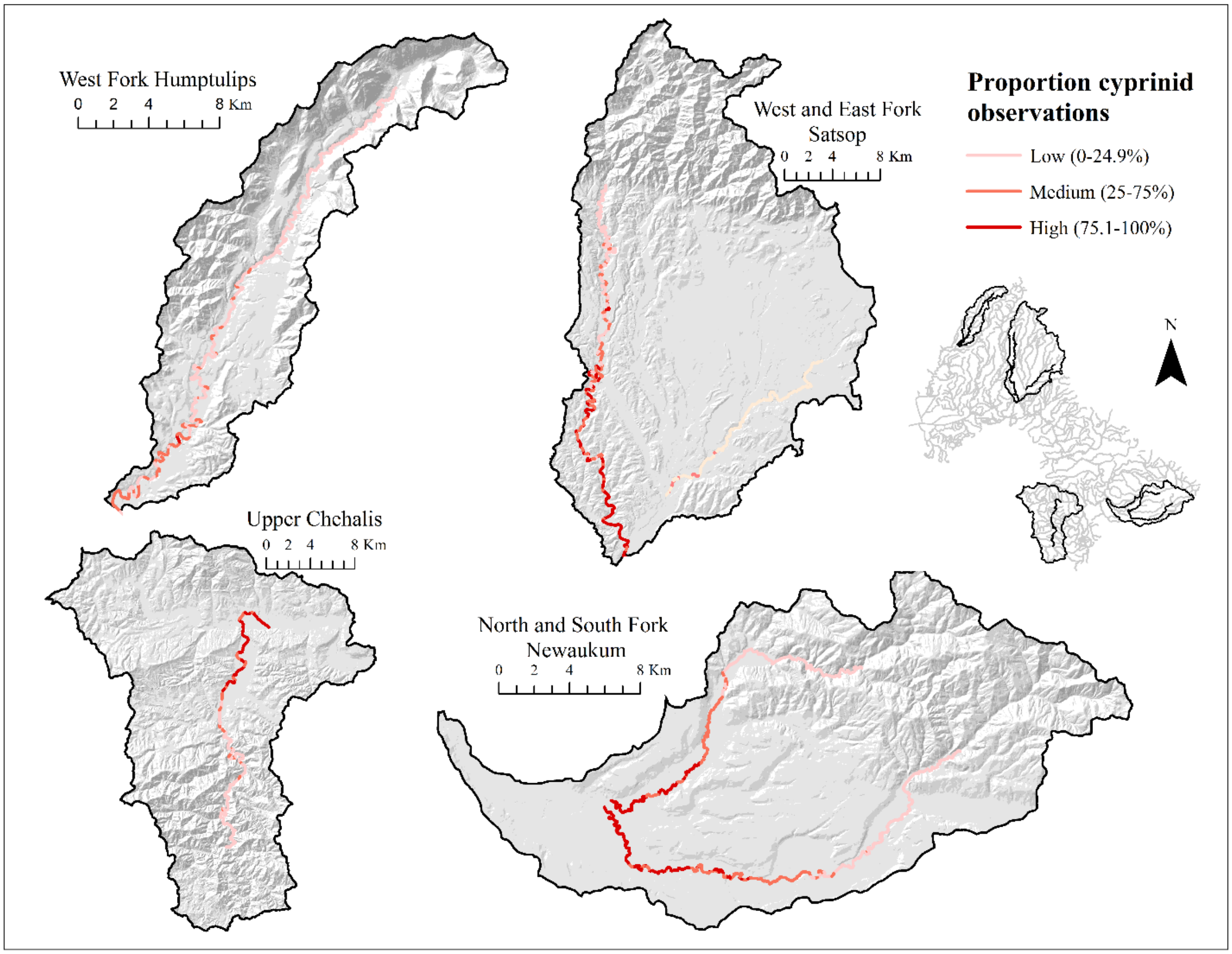

Figure 6. Proportion of cyprinid observations in fish count data shown by survey segment in survey areas of the Chehalis River over three years (2014-2016). Darker red areas represent segments with high proportions of cyprinids whereas lighter red areas represent segments with low proportions. Upper Chehalis data are from the 2014 survey, East and West Fork Satsop data shown are from 2015, and South Fork Newaukum and West Fork Humptulips data shown are from 2016.

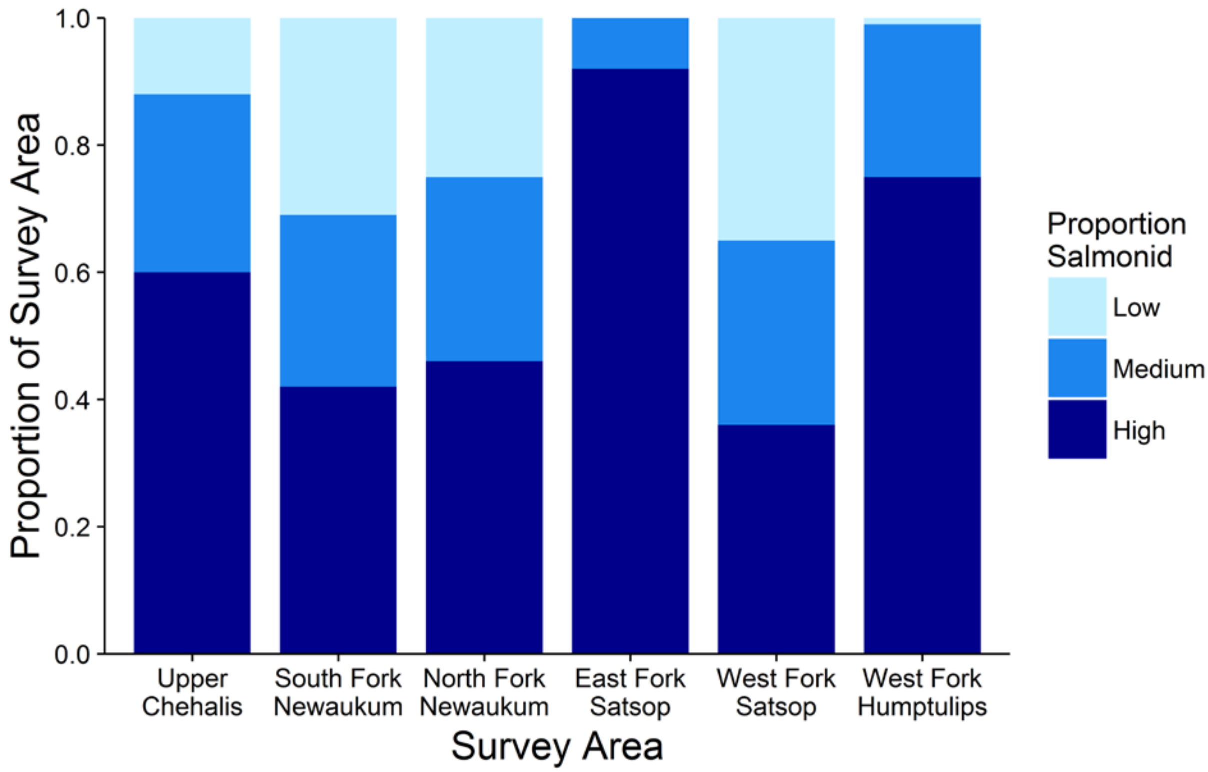

Figure 7. Proportion of survey segments associated with fish assemblages in riverscape surveys of the Chehalis basin, 2014-2016. Fish assemblages are categorized as low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions salmonids. Upper Chehalis data shown are from the 2014 survey. Data are provided in Appendix F-1.

Within each survey area, temperature metrics associated with ‘high’ salmonid (low cyprinid) segments were consistently cooler than those associated with ‘medium’ and ‘low’ salmonid segments (Figure 8, Appendix F-2). Temperature metrics associated with ‘medium’ salmonid segments were intermediate in temperature compared to ‘high’ and ‘low’ salmonid segments, except the West Fork Humptulips survey area where there was minimal difference between the temperature of ‘low’ and ‘medium’ salmonid segments. Our ability to describe temperature associated with ‘low’ salmonid segments in the West Fork Humptulips was limited to the 1% of survey segments which were classified as ‘low’ salmonid. The contrast in temperature between ‘medium’ and ‘low’ salmonid segments could not be made in the East Fork Satsop because no ‘low’ salmonid segments were present in this survey area.

The absolute temperature values associated with each fish assemblage category differed among survey areas (Figure 8, Appendix F-2). August temperatures associated with ‘high’ salmonid segments were warmer in the Upper Chehalis and West Fork Satsop relative to the other four survey areas. This difference was observed for each temperature metric, including mean temperatures (Upper Chehalis 3.0 – 3.9℃ warmer, West Fork Satsop 2.0 – 2.9℃ warmer), maximum temperatures (Upper Chehalis 3.4 – 4.8℃ warmer, West Fork Satsop 1.9 – 3.3℃ warmer), minimum temperatures (Upper Chehalis 2.5 – 3.3℃ warmer, West Fork Satsop 1.8 – 2.6℃ warmer), and the proportion of time temperature was equal to or exceeded 18℃ (40 – 50% in the Upper Chehalis and West Fork Satsop versus 0 – 10% in other survey areas). August temperatures contrasted among survey areas in a similar manner for ‘medium’ salmonid segments. Our ability to describe the full temperature profile of the ‘medium’ salmonid segments in the East Fork Satsop and West Fork Humptulips is limited because we did not fully observe a transition to ‘low’ salmonid segments within the survey area. However, differences in temperature associated with ‘medium’ segments was observed for each temperature metric, including mean (Upper Chehalis 1.7 – 4.8℃ warmer, West Fork Satsop 0.9 – 4.0℃ warmer), maximum (Upper Chehalis 1.6 – 5.2℃ warmer, West Fork Satsop 0.4 – 4.0℃ warmer), minimum (Upper Chehalis 1.8 – 4.3℃ warmer, West Fork Satsop 1.2 – 4.3℃ warmer), and the proportion of time temperature was equal to or exceeded 18℃ (80 and 70% in the Upper Chehalis and West Fork Satsop versus 0 – 50% in other survey areas). Temperatures associated with ‘low’ salmonid segments were less variable among survey areas (Appendix F-2). Our ability to describe the temperature profile of the ‘low’ salmonid segments in the West Fork Humptulips was limited to the 1% of survey segments which were classified as ‘low’ salmonid.

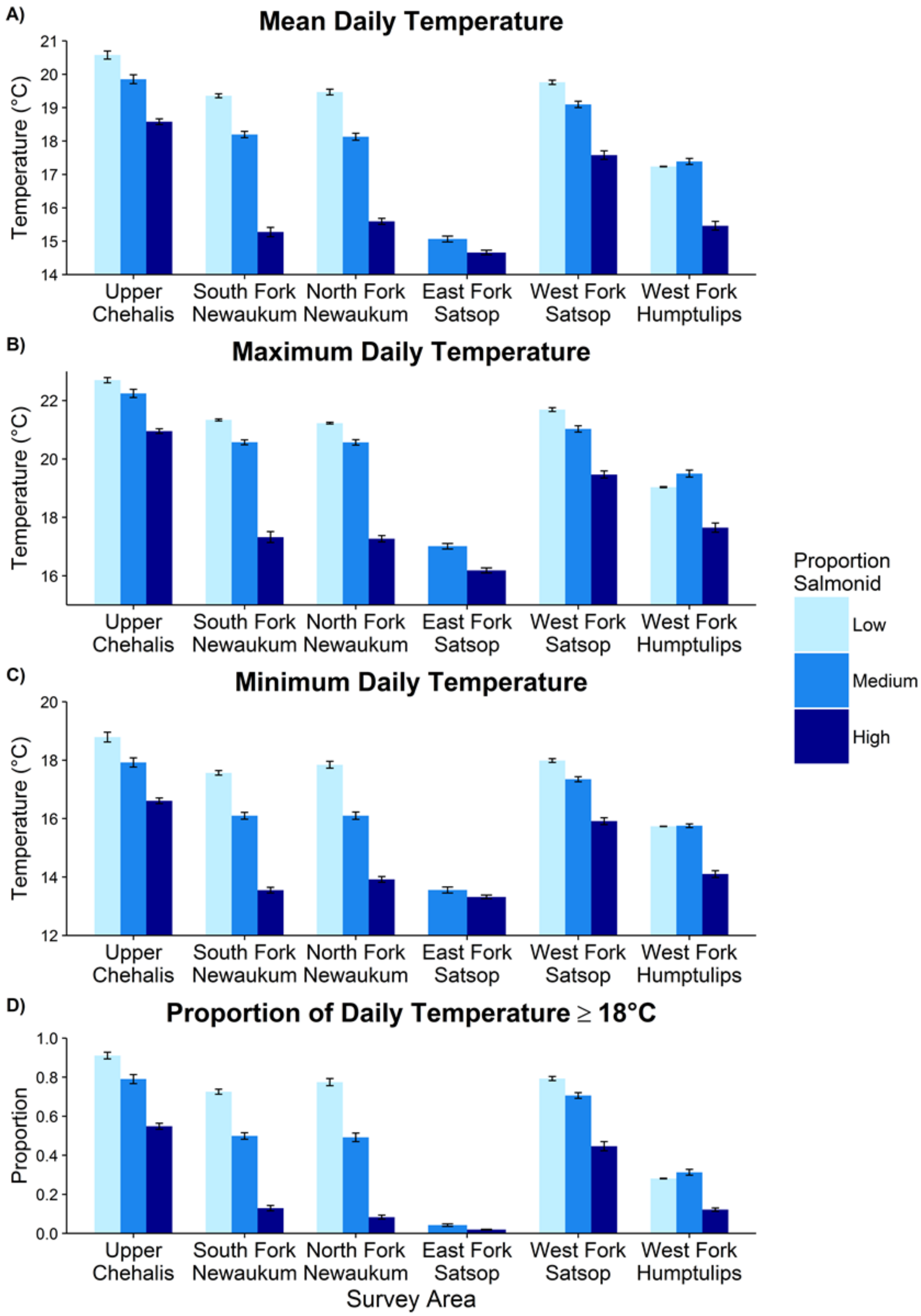

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Figure 8. August temperatures associated with fish assemblages in riverscape surveys of the Chehalis River, 2014-2016. Fish assemblages are categorized as low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids. Data shown are mean (±one standard deviation) of segment values in each fish assemblage category. Upper Chehalis data plotted are from the 2014 survey. Data are provided in Appendix F-2.

Wetted width, substrate coarseness, pool density, and LWD density were associated with fish assemblage categories, but the patterns were not as consistent among survey areas as observed for temperature (Figure 9, Appendix F-3). Mean wetted widths of ‘high’ salmonid segments were narrower than ‘medium’ and ‘low’ salmonid segments across all survey areas. This contrast was most evident in the Upper Chehalis, West Fork Satsop, and West Fork Humptulips where ‘high’ salmonid segments were 1.3 – 1.5 times narrower than ‘low’ salmonid segments. Dominant substrate coarseness was greater in ‘high’ salmonid segments than ‘medium’ and ‘low’ salmonid segments across all survey areas except the East Fork Satsop. Pool densities were higher in ‘high’ salmonid segments than ‘medium’ and ‘low’ salmonid segments across all survey areas except the East Fork Satsop and the West Fork Humptulips. This contrast was most evident in the Upper Chehalis, North Fork Newaukum, and West Fork Satsop where ‘high’ salmonid segments had 1.5-2 times higher pool density compared ‘low’ salmonid segments. LWD densities were 1.2-1.4 times higher in ‘high’ salmonid segments than ‘medium’ and ‘low’ salmonid segments in the North Fork Newaukum, East Fork Satsop, and West Fork Humptulips.

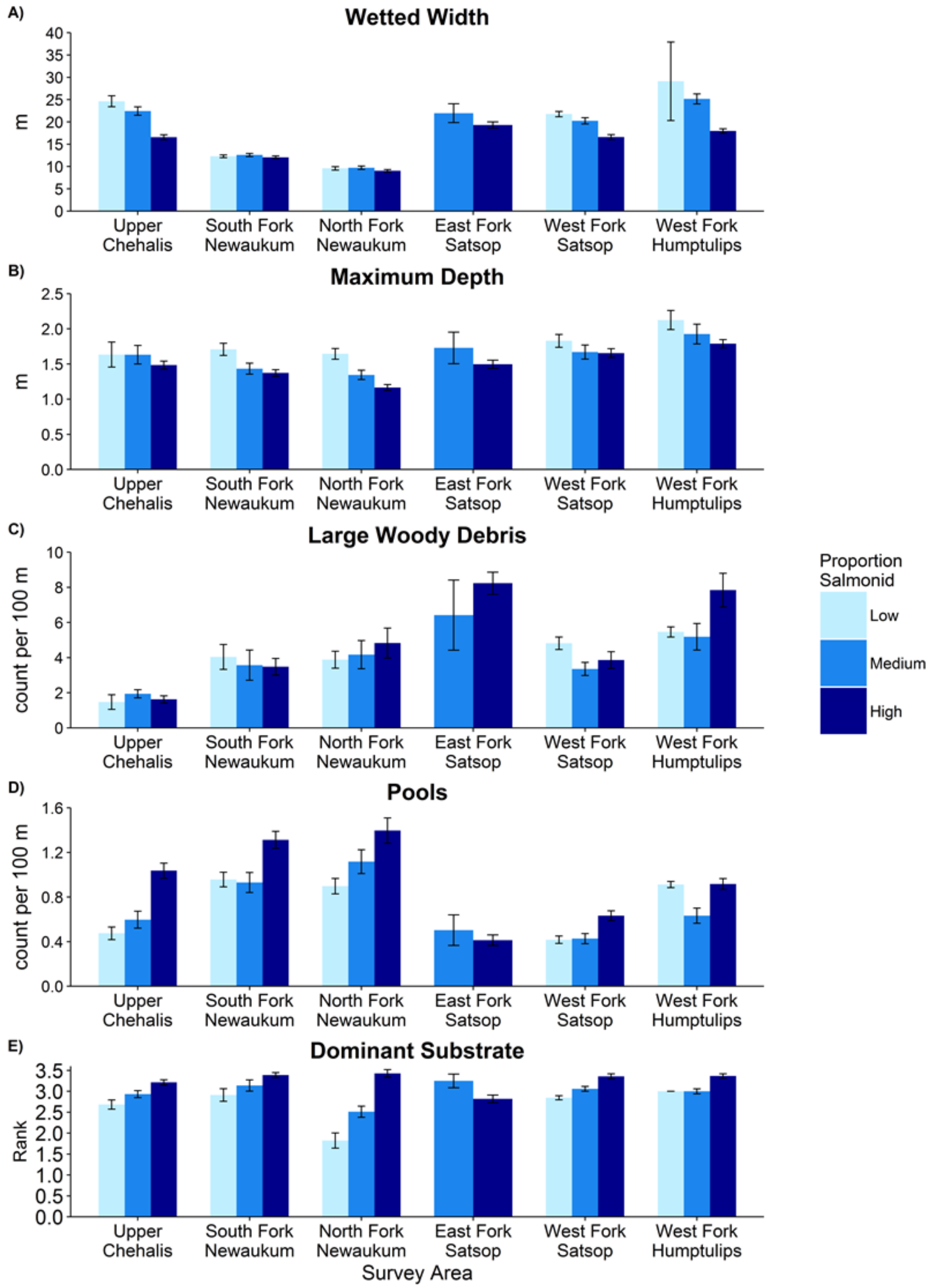

Figure 9. Habitat metrics associated with fish assemblages in riverscape surveys of the Chehalis River 2014-2016. Fish assemblages are categorized as low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids. Data shown are mean (± one standard deviation) of segment values in each fish assemblage category. Upper Chehalis data shown are from the 2014 survey. Data are provided in Appendix F-3.

Salmonid Versus Cyprinid Distribution: Among Survey Years (Upper Chehalis)

Fish assemblages were consistently organized in a longitudinal pattern in all four survey years of the Upper Chehalis survey area. Survey segments in upstream locations were dominated by salmonids ('high' salmonid segments) and survey segments in downstream locations were dominated by cyprinids ('low' salmonid segments) (Figure 10 and Figure 11). The fish assemblage was co-dominated by salmonids and cyprinids ('medium' salmonid segments) generally in the central portion of the survey area between rkm 170.4 and rkm 179.0. This transition occurred near the town of Pe Ell, roughly three river kilometers downstream of the proposed dam site (Figure 10 and 11).

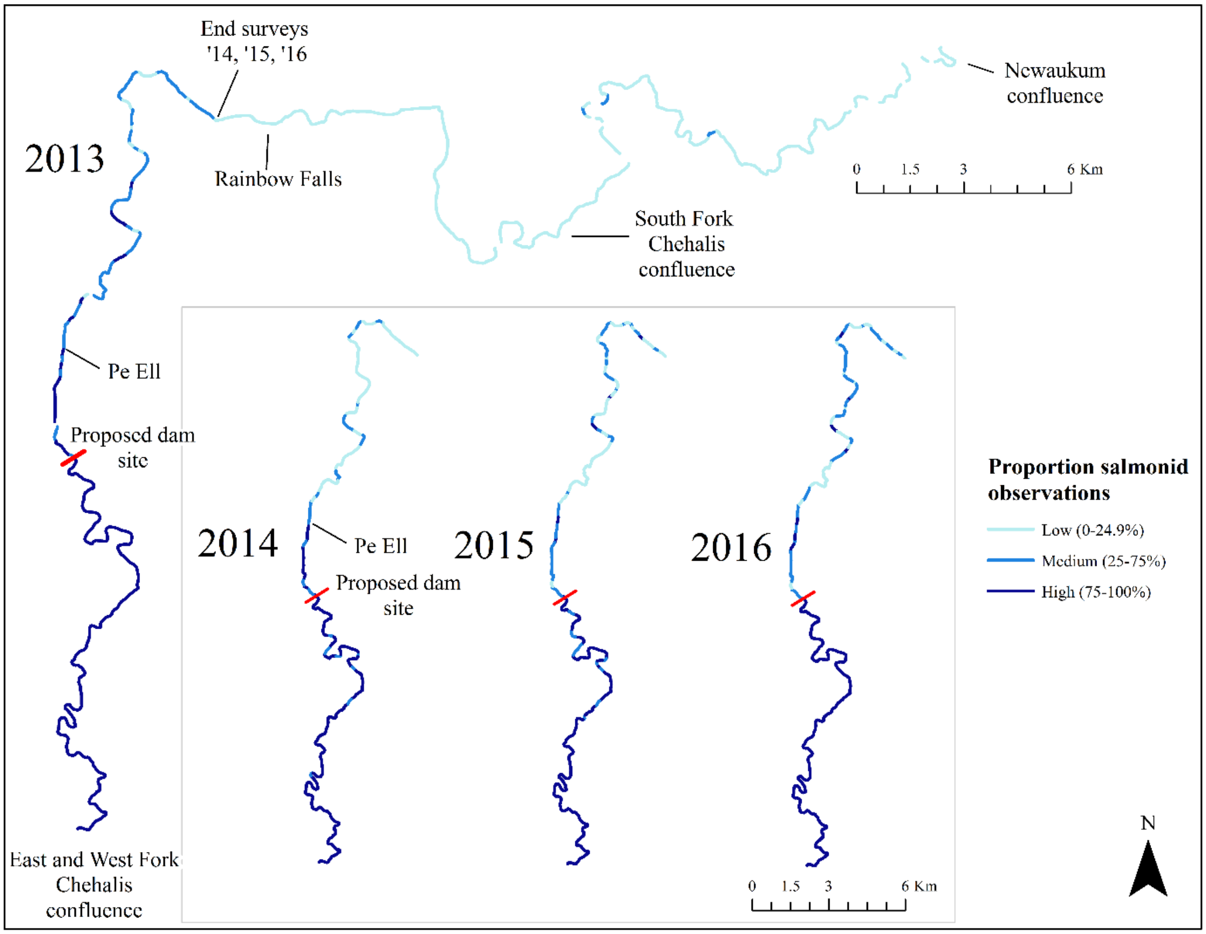

Figure 10. Proportion of juvenile salmonid observations in fish count data in survey segments of the Upper Chehalis River over four years (2013-2016). Darker blue represents segments with high proportions of salmonids whereas lighter blue represents segments with low proportions. The 2013 survey was 77.3 km whereas surveys in 2014-2016 were 36.5 km. Surveys for all years began at the confluence of the East and West Fork Chehalis River in the upper watershed.

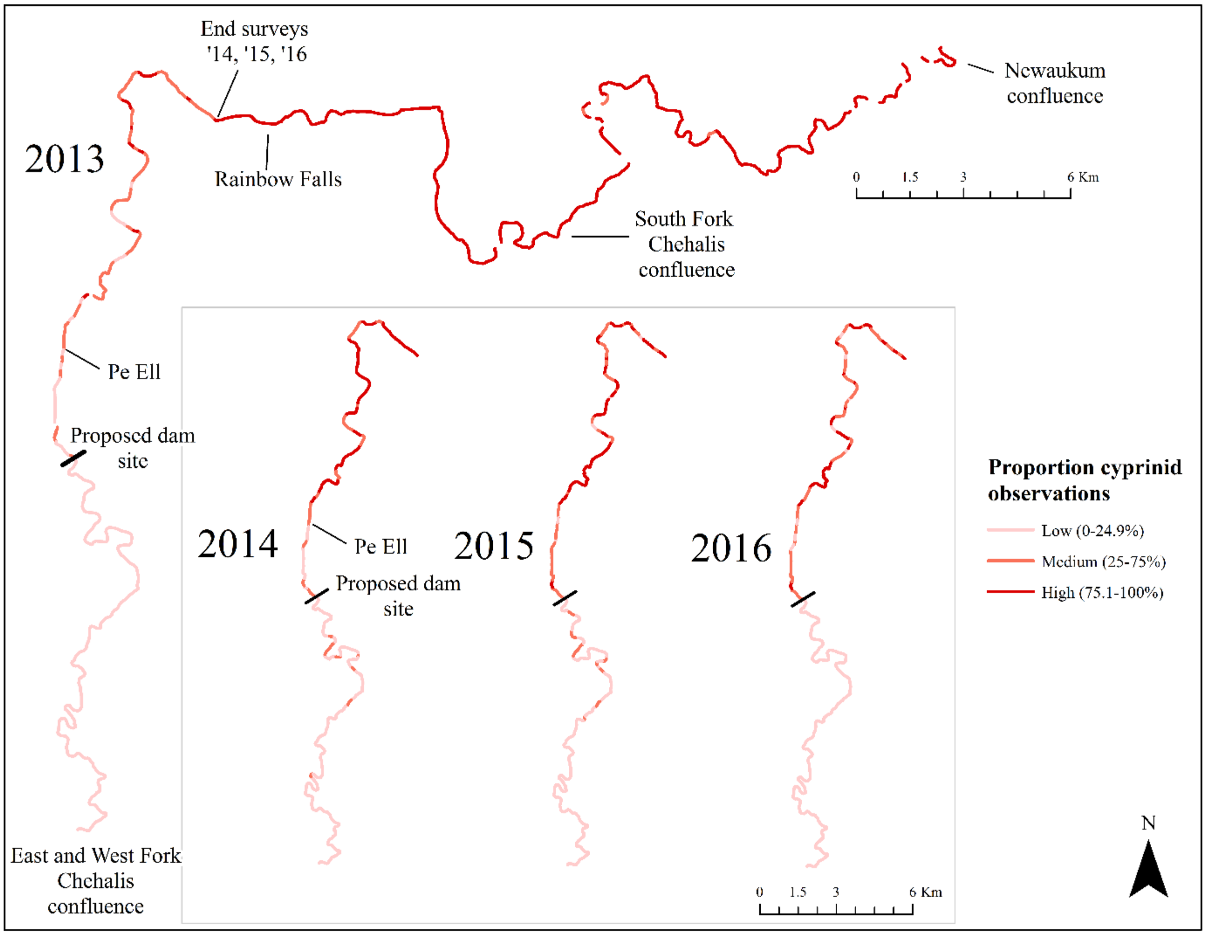

Figure 11. Proportion of cyprinid observations in fish count data is survey segments of the Upper Chehalis River over four years (2013-2016). Darker red represents segments with high proportions of cyprinids whereas lighter red represents segments with low proportions. The 2013 survey was 77.3 km whereas surveys in 2014-2016 were 36.5 km. Surveys for all years began at the confluence of the East and West Fork Chehalis River in the upper watershed.

The proportion of ‘low’ salmonid segments varied roughly four-fold among years and was greatest in 2015 (24%) and least in 2013 (6%) (Figure 12, Appendix G-1). Total proportions of ‘medium’ and ‘high’ salmonid segments were minimally variable among years (25-29% and 51-63%, respectively). Across all four years, 80-92% of the ‘high’ salmonid segments within the survey area occurred upstream of the proposed dam site (river kilometer 183.7) and 88-100% of segments upstream of the proposed dam site were categorized as ‘high’ salmonid. No ‘low’ salmonid segments were observed above the proposed dam site during any survey year.

Although the ‘high’, ‘medium’, and ‘low’ salmonid segments were organized in a consistent longitudinal pattern along the survey area, the mean river kilometer of each segment category varied among years (Appendix G-1). The locations of the ‘medium’ salmonid segments were the most variable with a major contrast observed between 2014 and 2015 compared to 2013 and 2016. In 2014 and 2015, the mean river km of ‘medium’ salmonid segments was shifted upstream by 3 to 5 km and the upstream extent of segments in this category were shifted upstream by 10 to 13 km compared to 2013 and 2016 (Appendix G-1). In comparison, the mean river km of ‘high’ and ‘low’ salmonid segments was minimally variable across years; mean locations of both categories varied less than 3 km among years, the lowest extent of the ‘high salmonid segments varied less than 6 km among years, and the upper extent of the ‘low’ salmonid segments varied by 3 km among years.

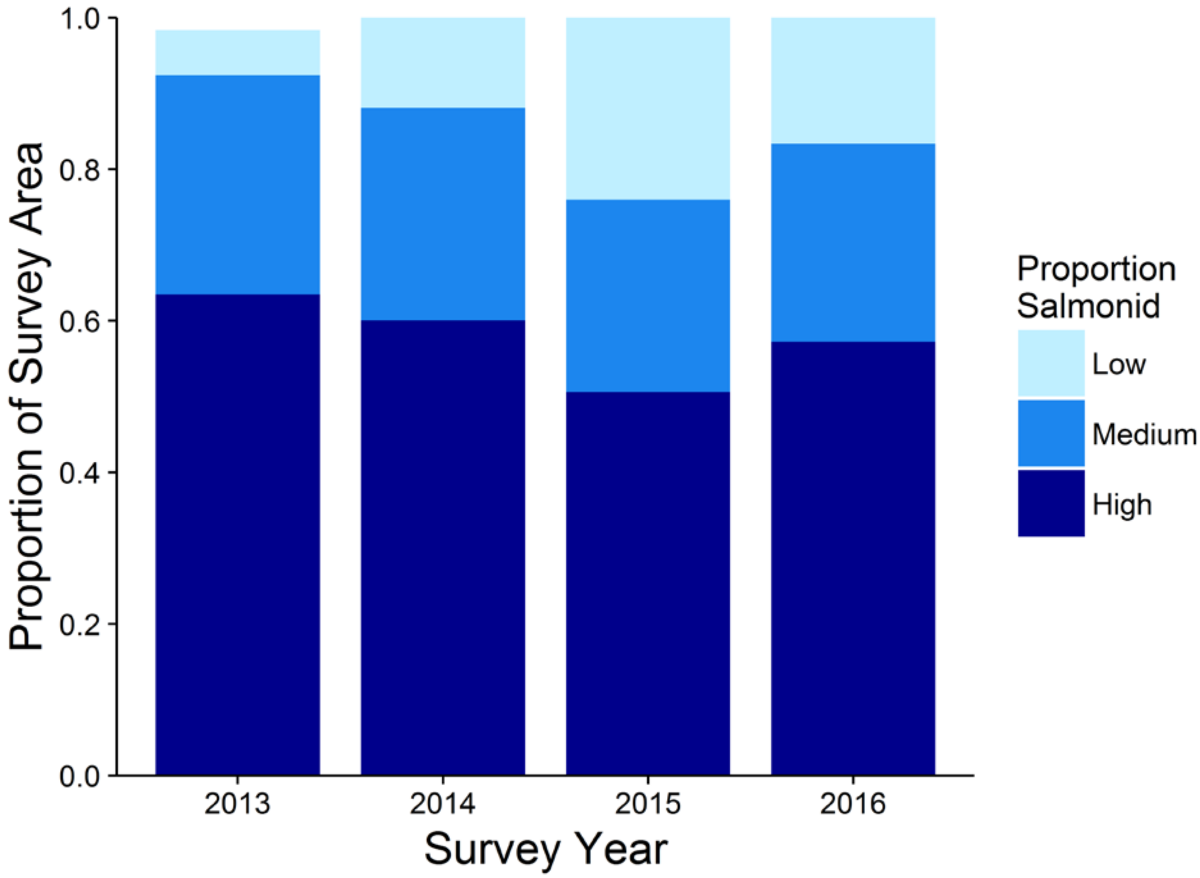

Figure 12. Proportion of survey segments associated with fish assemblages over four years (2013-2016) in the Upper Chehalis survey area (Rkm 166.4-202.9). Fish assemblages are categorized as low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions salmonids. Data from the 2013 survey presented includes the same 36.5 km surveyed in 2014-2016. Data are provided in Appendix G-1.

Among years, 'high' salmonid segments were consistently cooler compared to 'medium' and 'low' salmonid segments in terms of mean daily, mean daily maximum, mean daily minimum, and the proportion of time temperatures were equal to or greater than 18 ˚C (Figure 13, Appendix G-2). The absolute values of August temperature metrics associated with 'high', 'medium', and 'low' salmonid segments were minimally variable among years (Figure 13, Appendix G-2).

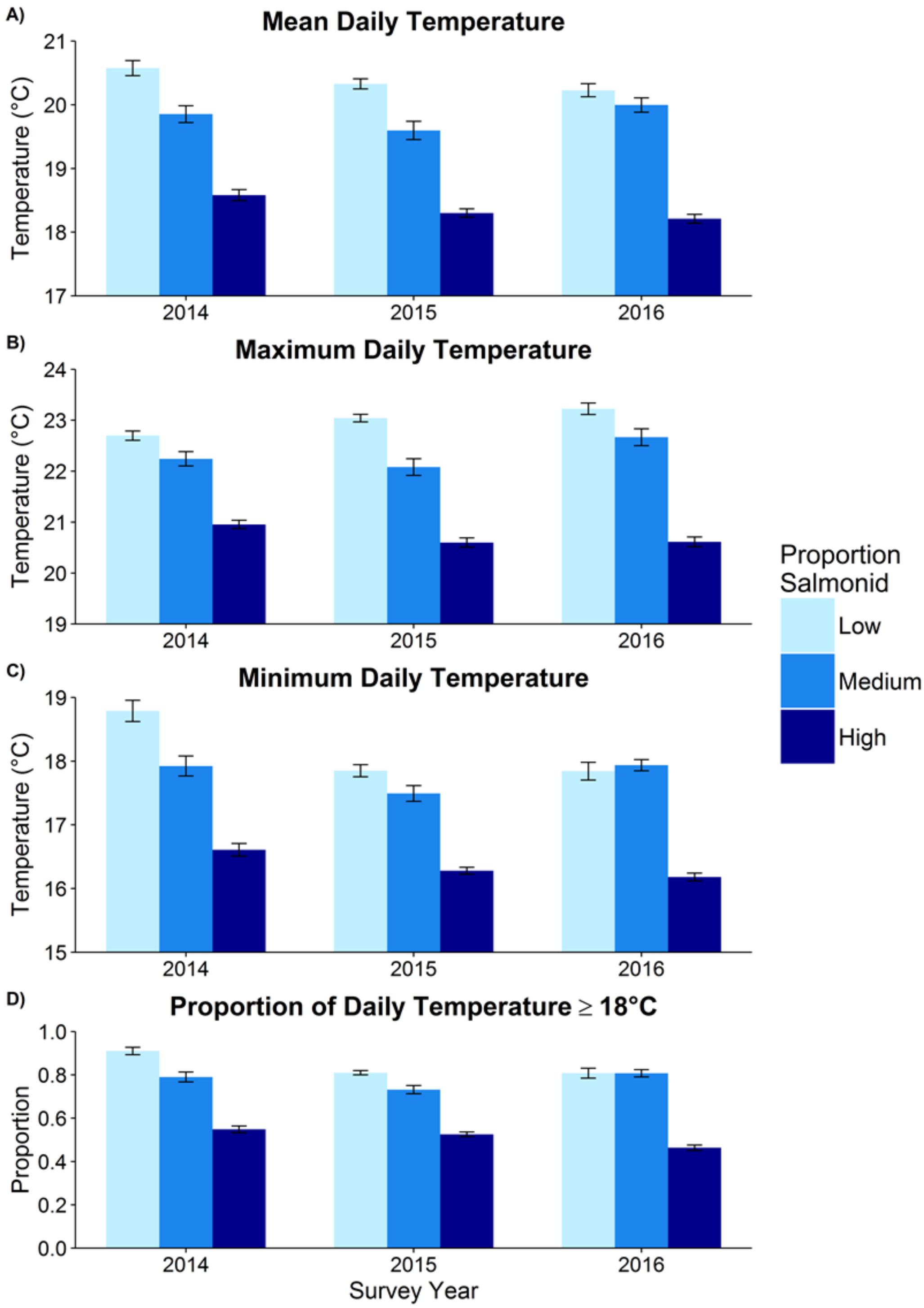

Figure 13. August temperature metrics associated with fish assemblages over three years (2014-2016) in the Upper Chehalis survey area (Rkm 166.4-202.9). Fish assemblages are categorized as low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids. Data shown are mean (±one standard deviation) of segment values in each fish assemblage category. Data are provided in Appendix G-2.

Discussion

Our study describes summer fish, habitat, and temperature patterns and associations in sub basins of the Chehalis River for which previous information has been limited. In total, we surveyed 271.7 km of main stem habitat in four major sub basins of the Chehalis River. The spatial extent of this work spanned from the Humptulips River in Grays Harbor to the main stem Chehalis River upstream of Rainbow Falls near Doty, Washington. Surveys of the Chehalis River upstream of Rainbow Falls were repeated for four consecutive years. Thus, with the inclusion of annual surveys repeated upstream of Rainbow Falls, we surveyed a cumulative distance of 381.2 km (or 236.9 miles) for this study.

Our primary goal was to identify habitat and temperature characteristics associated with summer rearing of juvenile salmon and steelhead. Surveys in the Upper Chehalis, specifically, were completed to provide information relevant for evaluating impacts of a potential dam on juvenile salmon and steelhead summer rearing habitat. Surveys in other sub basins were conducted to more broadly understand fish, habitat, and temperature diversity throughout the Chehalis basin and inform questions related to the planning and design of restoration projects. We collected information on all fish species and age classes which were adequately sampled by the method (snorkel) and season (summer) of our surveys. Although the study was designed with a primary focus on juvenile salmon and steelhead, the resulting data provide a much broader perspective on the diversity of fish species that use riverine habitat of the Chehalis River during the summer months. Further, the resulting data describe a portion of the diversity in summer habitat and stream temperatures within the basin. We planned to start each survey at similar elevations to allow for a common baseline for comparisons of fish, habitat, and temperature observations among survey areas. Limitations in the starting location occurred when upper extents of some survey areas were low elevation by nature (East Fork Satsop) or not safely accessible (West Fork Satsop). Taken together, our study provides insight into spatial and temporal variation in fish, habitat, and temperature as well as some specific associations of juvenile salmon and steelhead rearing with habitat and temperature characteristics during the summer base flows in the Chehalis River.

Our results demonstrate a broad consistency in fish, habitat, and temperature patterns associated with summer base flows among the four sub basins (six survey areas). Juvenile salmon and steelhead were fairly ubiquitous in terms of the amount of habitat occupied within each survey area. We generally observed higher density of juvenile salmonids in upstream cooler locations compared to downstream warmer locations - this pattern was consistently observed among survey areas and among years within the same survey area. The opposite pattern was observed for cyprinid species, where we observed higher density in downstream locations, relative to upstream. Consequently, summer fish assemblages were dominated by salmonids (upstream) and cyprinids (downstream). This longitudinal pattern in fish assemblage was associated with a longitudinal pattern in temperature, although the longitudinal pattern in temperature and fish was less prevalent in the West Fork Humptulips and nearly non-existent in the East Fork Satsop, where salmonids dominated the entirety of the survey area. Taken together, our results demonstrated that despite the extensive amount of aquatic habitat available in the 6,889 km^2 of the Chehalis River watershed, a very limited portion of the watershed has physical characteristics suitable for summer rearing of salmonids. Below we elaborate on key findings and caveats of this study.

Habitat and Temperature in the Six Survey Areas

Channel morphology of the Chehalis River reflects a combination of processes which have acted over geologic and historical time scales including erosion of the landscape, changes in discharge and sediment supply resulting from floods and droughts, and anthropogenic impacts including timber harvest, splash dams, and alteration of the floodplain for agriculture or urban development (Montgomery and Buffington 1998). Pool-riffle was the dominant channel type among the survey areas. Pool-riffle channel type is expected in relatively low gradient river reaches in mountain drainages, where gravel dominated substrates, bars, pools, and riffles are commonly observed (Montgomery and Buffington 1997). Other channel types of mountain drainages such as plane bed, step pool, forced pool riffle, and dune ripple were rare or absent in our survey areas. Of note, these results are not comprehensive of riverine habitat in the Chehalis basin as our surveys were conducted in main stem habitat, began at chosen elevations, and ended at major river confluences or in areas where the river channel precluded high quality data collection via snorkeling.

Our surveys revealed unique habitat and temperature features among survey areas that reflect the diversity of the Chehalis River watershed. Specifically, upstream segments of the East Fork Satsop River were particularly low elevation, low gradient, and cool compared to other survey areas. The river in these upstream extents was characterized by wide, meandering channels, submerged aquatic vegetation, beaver activity, and high density of submerged LWD with abundant groundwater inputs. We classified the upstream portions of the East Fork Satsop River survey area as “spring-fed headwaters” which contrasted with pool-riffle upstream extents of all other survey areas (Figure 14). August temperatures in the East Fork Satsop River were on average 3-5°C colder than comparable elevations in other survey areas. Additionally, temperatures near 75 m elevation in the East Fork Satsop were comparable to temperatures near 150 m elevation in other survey areas, and were colder than temperatures near 250 m elevation in the Upper Chehalis (the upper most extent of that survey area). In addition to its cool temperatures, the East Fork Satsop had some of the highest LWD densities observed among survey areas. Despite this distinction, LWD densities may have been underestimated in the East Fork Satsop as a majority of LWD observations consisted of submerged wood.

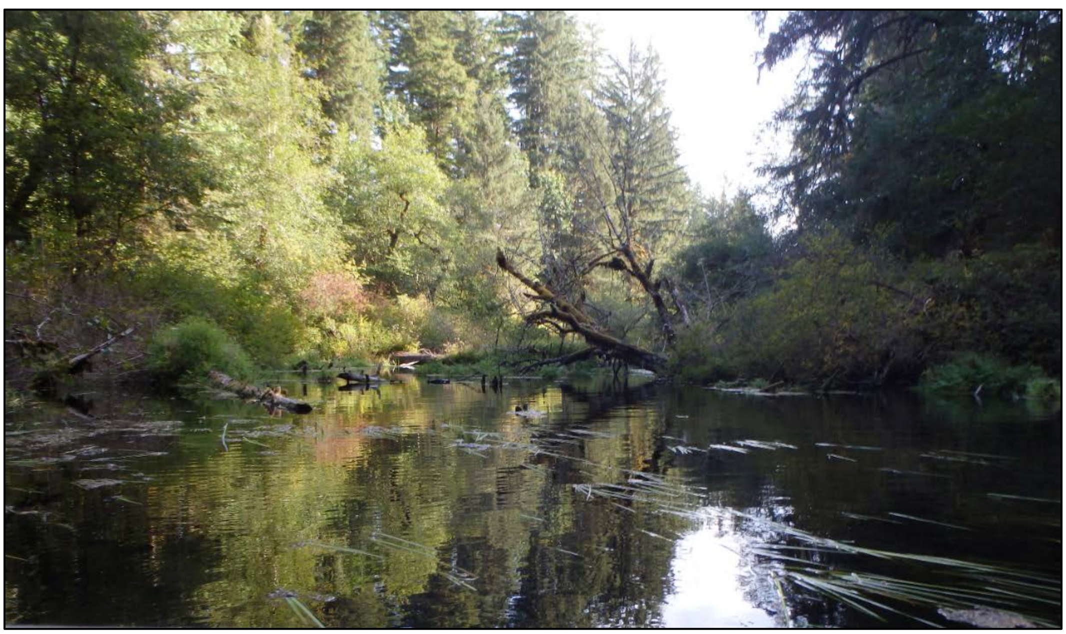

Figure 14. Upstream segments of the East Fork Satsop River survey area were classified as “spring-fed headwaters.”

A unique feature qualitatively observed of the West Fork Humptulips survey area was the size of some of the woody debris, which was notably large relative to those of other survey areas.

Woody debris in the West Fork Humptulips included old growth logs which were commonly observed within and outside the wetted channel and in riparian and valley forests (Figure 15). Additionally, large aggregates of wood were observed in relatively high frequencies in the river channel and were often located in close proximity to complex, braided sections of the river, which were less common in other survey areas (Figure 15). The landscape surrounding the upstream portions of the West Fork Humptulips River is part of the Olympic National Forest where stands of old growth forest have been preserved; this contrasts with other survey areas where the riparian vegetation was primarily secondary growth forest re-grown after timber harvest.

Figure 15. Large woody debris common to the upper extents of the West Fork Humptulips survey area (upper panel) and a braided channel surrounded by aggregations of LWD (lower panel).

Aside from the East Fork Satsop River, the West Fork Humptulips River had the coolest August temperatures across elevations. The extreme headwaters of the West Fork Humptulips River in the Olympic Mountains (upstream of our survey area) were some of the highest elevation among our study sub basins. Furthermore, this sub basin was the closest in proximity to the Pacific Ocean, exposing the sub basin to year round cool maritime climate. A combination of snowmelt and maritime climate may be contributing to summer stream flows and temperatures of this sub basin. In addition, the relatively intact riparian environments in the West Fork Humptulips likely buffer stream temperatures from solar influence reducing the rate at which stream temperature warms as distance from the headwater sources increase (Poole and Berman 2001). Overall, a combination of factors driving stream temperatures including topography, shade (riparian), hyporheic flow, phreatic groundwater, tributaries, and anthropogenic induced factors likely play a role in shaping temperature patterns of our survey areas (Caissie 2006; Poole and Berman 2001). A comprehensive understanding of such mechanisms in the Chehalis basin would shed light on variability in summer temperatures across survey areas and provide important perspective in further understanding factors influencing fish diversity.

The Upper Chehalis survey area contained the least LWD and most bedrock relative to all other survey areas (Figure 16). Additionally, the Upper Chehalis survey area was warmer at any given elevation compared to all other survey areas. The most upstream, highest elevation segments (e.g., 150-250 m) of the Upper Chehalis survey area were notably warmer compared to all other survey areas at similar elevations. These temperature observation in the Upper Chehalis suggest that substantial warming of the river occurred upstream of our survey footprint and at higher elevations than observed in other survey areas (e.g., the East Fork and/or West Fork Chehalis River).

Figure 16. Riverscape surveyors in bedrock dominated segment of the Upper Chehalis survey area.

Longitudinal patterns in habitat and temperature were observed within each survey area. Wetted widths increased as valleys widened in a downstream direction in the Upper Chehalis, West Fork Satsop, and West Fork Humptulips rivers. However, we did not observe this pattern in either fork of the Newaukum River or the East Fork Satsop River. Among all survey areas, except the East Fork Satsop, pools were observed in higher frequencies and substrate was coarser in upstream areas. However, the upstream areas of the East Fork Satsop were not lacking pools, rather the existing pools were longer and less numerous for a given length of river (i.e., number of pools per 100 m was lower) in comparison to other survey areas. Qualitatively, upstream segments of all survey areas except the East Fork Satsop River appeared to be slightly higher in gradient relative to downstream segments, which may explain the coarser substrate observed in upstream segments (Montgomery and Buffington 1997). In the East Fork Satsop River, finer substrate was observed in the low gradient "spring fed headwaters" of the upstream segments and substrate became coarser (more gravel and cobble observations) as the prevalence of pool-riffle habitat increased in a downstream direction, suggesting gradient was slightly higher in downstream segments compared to the upstream most segments. Longitudinal patterns in LWD density were observed in the two survey areas with the highest LWD densities overall, e.g. LWD density was higher in upstream than downstream segments of the West Fork Humptulips and East Fork Satsop rivers.

Longitudinal temperature patterns were consistent among survey areas in that August temperatures were cooler in upstream extents and warmer in downstream extents. However, we observed notable variability in the absolute August temperature among survey areas. At any given elevation, the Upper Chehalis and West Fork Satsop were generally the warmest survey areas, the South and North Fork Newaukum were moderate, and the West Fork Humptulips and the East Fork Satsop were the coldest. In contrast, we observed minimal variability in August temperatures among three years in the Upper Chehalis. At any given elevation in the Upper Chehalis survey area, mean daily August temperatures varied by less than 1˚C for the three years for which temperature data were available. This result was surprising given that summer air temperatures varied among years – specifically, the summers of 2014 and 2015 were distinguished by warmer temperatures than 2016. Additional data exploration revealed that stream temperatures in the Upper Chehalis survey area (this study) as well as the Chehalis River main stem (Liedtke et al. 2017; Liedtke et al. 2016) were more variable among years in the month of July than the month of August. We selected August stream temperatures for analysis because they overlapped with the timing of the snorkel and habitat surveys and have been selected elsewhere for analysis of spatial and temporal trends in the Pacific Northwest (Isaak et al. 2017). However, in retrospect, our data suggest that some of the greatest inter-annual variability in fish exposure to summer stream temperatures may occur earlier in the summer season.

Fish Observations in the Six Survey Areas

Our riverscape surveys provided information on diversity of fish species, age classes, and origins (wild and hatchery) across survey areas of the Chehalis basin. In total, we observed 13 fish species and 27 combinations of species, age class, and origin (i.e., ‘count group’). Some of the species and age classes were ubiquitous while other observations were unique to specific survey areas. Juvenile coho and steelhead, all cyprinid species, adult suckers, and adult whitefish were the most consistently observed among survey areas. Other count groups, such as adult and juvenile Chinook salmon and bull trout as well as hatchery salmon and trout were observed in just a few of the survey areas.

Riverscape surveys are excellent tools for describing fish distributions across relatively large spatially continuous sections of river at a given time but, like any survey method, there are caveats to the interpretation of resulting data. Interpretation of the fish data should account for the type and timing of survey efforts as well as the life history of fish species observed. Snorkel counts are an index and not an absolute count of fish numbers and can be influenced by factors such as visibility and fish behavior. Visibility within our survey areas was generally good during summer months. Our analysis indicated that visibility was unlikely to have had a large influence on the results as we did not detect a relationship between fish counts and visibility except for one year in the Upper Chehalis (2014). In this year, visibility never fell below 3.1m which we believe to be adequate for accurate fish counts given the wetted widths and number of divers used for survey. In addition to visibility, variability in fish behavior limits interpretations from snorkel counts that are a one-time ‘snapshot’ of the river. A one-time snorkel effort does not account for the seasonality of fish movements or diel activity. Seasonality of our surveys (mid to late summer months) limited the information gathered to particular species or age classes with life histories that overlapped the location and timing of the surveys. For example, our surveys coincided with summer rearing of juvenile coho and steelhead and these species and life stages made up a vast majority of our observations, but our surveys did not overlap in time with the known presence of other species in some survey areas such as chum salmon (*O. keta*). Additionally, juvenile Chinook were rarely observed, a result that likely reflects an “ocean-type” life history strategy of which fry and subyearlings migrate downstream from upper river rearing areas from March – July, generally preceding our surveys (Winkowski and Zimmerman 2017; Wydoski and Whitney 2003). Finally, snorkel techniques do not collect reliable information on species with benthic or sub-benthic orientation, such as species of sculpin and lamprey ammocoetes.

Juvenile salmon and steelhead were commonly observed among survey areas but densities were variable among and within survey areas and among years. Given the efforts to standardize our data collection (see Methods section) and the consistency of the survey crews among years, we do not attribute the variability to observation error but rather to true spatial and temporal differences. However, the fish densities observed among survey areas are confounded with survey year. Temporal variability of fish densities in the same survey area can be influenced by a combination of factors including, but not limited to, parental spawner abundance and distribution and environmental conditions such as flow and temperature (Flitcroft et al. 2014). Repeated annual surveys in the Upper Chehalis survey area highlight the importance of considering the magnitude of temporal variability in fish densities. The most dramatic example of this was evident with juvenile coho density. Juvenile coho densities ranged 16-fold among four years (2013-2016) in the Upper Chehalis survey area. Depending on the year, coho densities in the Upper Chehalis were both higher and lower than densities in the North Fork Newaukum survey area which was surveyed in 2014 and had the next highest observed densities in this study. The highest juvenile coho density in the Upper Chehalis survey area occurred in 2013 and was two times the juvenile coho density observed in the North Fork Newaukum survey area. In contrast, the lowest juvenile coho density in the Upper Chehalis survey area occurred in 2014 and was just fourteen percent that observed in the North Fork Newaukum. As a result, depending on the year the survey was conducted, a single year of information may lead to misinformed conclusions regarding the relative importance of habitat for juvenile salmonids in a given area. Therefore, our results are best interpreted based on patterns of relative fish occupancy and densities within survey areas and how those patterns are repeated (or unique) among survey areas. Because survey area and survey year are confounded, we strongly caution against drawing conclusions based on direct contrasts of fish densities among survey areas.

Juvenile steelhead (0+) and juvenile coho were the most ubiquitous salmonids observed among study areas and years (minimum of 70.5% occupancy) and were generally found in higher densities in cooler upstream locations relative to warmer downstream locations (See Appendix 9-11). This pattern was repeated in the Upper Chehalis survey area among all years for juvenile steelhead (0+), 3 of the 4 years for juvenile steelhead (1+), and 2 of the 4 years for juvenile coho. These observations highlight the importance of juvenile salmon and steelhead summer rearing areas in upstream extents of the Upper Chehalis survey area, which would be impacted by the construction of a dam. We also observed this longitudinal density pattern for juvenile coho across all other survey areas, juvenile steelhead (0+) across survey areas (except the East Fork Satsop and West Fork Humptulips), and juvenile steelhead (1+) across survey areas (except the

West Fork Satsop). The lack of a longitudinal pattern in juvenile steelhead (0+ and 1+) densities in the East Fork and West Fork Satsop may reflect a lack of contrast due to low overall densities observed in this sub basin. Nonetheless, these observations highlight the importance of juvenile salmon and steelhead summer rearing areas in upstream extents of survey areas.

Native cyprinid species were commonly observed but occupancy and density were variable within survey areas and among years in the Upper Chehalis. Cyprinid observations were especially limited in the East Fork Satsop and West Fork Humptulips, which were the coolest of the survey areas. Specifically, redside shiner and northern pikeminnow were rarely observed in both the East Fork Satsop and West Fork Humptulips, whereas dace were rarely observed in the East Fork Satsop but were relatively common in the West Fork Humptulips. These observations suggest cooler temperatures may have excluded the distribution of some cyprinid species within these specific survey areas. In both the Satsop and Humptulips sub basins, our surveys concluded at the confluence of the east and west forks and distribution downstream of the survey area is unknown. In the Satsop sub basin, all cyprinid species found in this study (northern pikeminnow, redside shiner, and dace) were observed in the West Fork Satsop. In the Humptulips sub basin, we did not survey the East Fork Humptulips or the Humptulips main stem, thus occupancies and densities of northern pikeminnow and redside shiner are unknown in these portions of the basin. The remaining survey areas (i.e., Upper Chehalis, South and North Fork Newaukum, and West Fork Satsop) were characterized by redside shiner and dace densities which were generally comparable or slightly lower than juvenile coho and juvenile steelhead (0+) densities. As noted above, cyprinid density was higher in downstream warmer segments relative to upstream cooler segments within survey areas. The longitudinal pattern for cyprinid species was repeated among years in the Upper Chehalis.

Interactions with cyprinids may be an important factor defining lower extents of juvenile salmon and steelhead distributions in sub basins of the Chehalis River. Laboratory studies have suggested competition between these two taxonomic groups to be temperature-mediated, i.e., cyprinids outcompete juvenile salmonids in warm water and the opposite occurs in colder water (Reese and Harvey 2002; Reeves et al. 1987). Thus, the lower extent of salmonids and upper extent of cyprinids may be sensitive to temperature characteristics which change throughout the summer, e.g., distributions of cyprinids may expand upstream and salmonids constrict upstream as summer temperatures increase (Winkowski et al. 2018). This concept is further discussed relative to our findings in sections to follow.

Adult salmonid observations were rare among survey areas. The most observations of adult Chinook salmon were in the Upper Chehalis 2013 survey (n = 14) and South Fork Newaukum (n = 28) and North Fork Newaukum (n = 12) survey areas. Given the timing of the surveys (mainly July and August), these observations were likely spring Chinook salmon, consistent with knowledge of spring Chinook distribution in the Chehalis basin (C. Holt, WDFW Region 6, personal communication). We observed very few adult Chinook in the East Fork Satsop (n = 6) or West Fork Humptulips (n = 1) and no observations occurred in the West Fork Satsop. We also observed few adult steelhead across survey areas. Adult steelhead present in the river during summer months could be winter steelhead kelts, strays from outside the basin, or hatchery summer steelhead. There is no known naturally reproducing population of summer steelhead in the Chehalis River. In our survey of the West Fork Humptulips River, we observed two adult bull trout roughly 32 km upstream from the confluence with the East Fork Humptulips and 73 km upstream from Grays Harbor. Bull trout were listed as *threatened* under the Endangered Species Act in 1999 and historical observations of this species have rarely been documented in the Chehalis basin (Smith and Wenger 2001). Our observation of the adult life stage may reflect mobile foraging patterns among coastal watersheds (Brenkman and Corbett 2005) and does not necessarily indicate an established (i.e., reproductive) population within the Humptulips River.

Resident trout occupancy and density were greatest in the East Fork Satsop River and least in the West Fork Satsop. In the East Fork Satsop, many of the observations occurred in upstream "spring-fed headwaters" segments of the survey area where individuals tended to occupy deep sections of river with relatively high quantities of LWD. Where the occupancy rates of resident trout were frequent enough for analyses of longitudinal relationships, the highest density was observed in upstream locations of most survey areas, except the North Fork Newaukum. Thus, upstream locations within sub basins, including above the proposed dam site in the Upper Chehalis, appear to be important habitat for resident trout.

We observed hatchery origin salmonids (anadromous adult, residualized smolts, and subyearling parr) mainly within survey areas where hatchery programs exist. Hatchery origin fish, including residualized steelhead smolts and coho parr were observed to be rearing in the East Fork Satsop where hatchery programs exist for both species. Our observations of hatchery-origin *O. mykiss* the size of resident rainbow trout in the East Fork Satsop River demonstrate that a portion of hatchery steelhead smolts released into this sub basin are not emigrating to the ocean and survive to residualize in freshwater. We also observed hatchery-origin juvenile steelhead (1+) in the South Fork Newaukum River where releases occur into Carlisle Lake. In addition, Winkowski et al (2018). observed hatchery origin steelhead (0+) in the South Fork Newaukum River during a September riverscape survey in 2016. We observed hatchery-origin adult steelhead in the East Fork and West Fork Satsop and West Fork Humptulips which were the survey areas closest in proximity to existing summer steelhead hatchery programs in the Wynoochee River basin (Lake Aberdeen hatchery) and the Humptulips River basin (Humptulips hatchery). We did not observe hatchery origin salmonids in the North Fork Newaukum or Upper Chehalis during any survey year. These observations indicate that a portion of the fish assemblage during the summer rearing period in some sub basins is comprised of residualized hatchery coho and steelhead and that interactions between hatchery and wild fish are generally occurring within the sub basins where the hatchery fish are released.

Adult mountain whitefish were observed in all survey areas. In the East Fork Satsop River, two survey segments accounted for 95% of observations, whereas occupancy in other survey areas were more broad (22.5-54.3% occupancy). Within survey areas, longitudinal patterns were observed in the South Fork Newaukum and West Fork Satsop, where higher density was observed in upstream locations than downstream locations and a weak but opposite pattern was observed in the West Fork Humptulips (higher density in downstream locations than upstream locations). Adult whitefish were observed in small groups more often than solitary and generally occupied pool habitat. In other river systems, adult mountain whitefish undertake extensive movements and use different portions of watersheds throughout their life cycle (Boyer 2016). Therefore, the information gathered in our study should not be considered comprehensive of whitefish distribution patterns in the Chehalis River and only reflects a snapshot of summer locations occupied by whitefish. Additional information on distribution and seasonal movements of mountain whitefish in the Chehalis River is currently being investigated by E.M. Winkowski (WDFW).

Juvenile mountain whitefish were rarely observed in our survey areas and were not observed in the Upper Chehalis during any survey year. We did not observe juvenile whitefish in the North Fork Newaukum River and only rare observations occurred in the East and West Fork Satsop and the West Fork Humptulips rivers. The most observations of juvenile whitefish occurred in the South Fork Newaukum. Whitefish fry are thought to passively drift downstream after emergence and settle in shallow backwater areas (Wydoski and Whitney 2003), thus depending on spawning location and timing of adults, our surveys may have been outside summer rearing distributions or juveniles were not occupying thalweg habitat where our snorkel data were collected. The latter hypothesis may be partially supported by our extensive summer riverscape surveys in the South Fork Newaukum River where density and upstream distribution of juvenile whitefish increased from May – September, i.e., a potential hypothesis may be that fish growth and redistribution into thalweg habitat may occur over summer months as temperatures increase (Winkowski et al. 2018). However, we rarely detected juvenile whitefish in August surveys in other systems where adults were relatively abundant like the West Fork Humptulips and West Fork Satsop. An additional hypothesis is that juvenile whitefish may exhibit more nocturnal behavior, which would not be detected by our daytime data collection protocols. Taken together, while we were able to document presence in some survey areas, our study design was not adequate to understand juvenile whitefish summer rearing habitat or distribution and a more focused investigation would be required.

Adult largescale suckers were relatively abundant in the Upper Chehalis and South Fork Newaukum River. We also observed a large aggregation of adult suckers in the most downstream segment of the West Fork Satsop River (n = 503) which accounted for 87% of our total observations in this survey area. However, during reconnaissance of the West Fork Satsop River prior to the riverscape survey (i.e., late June 2015), a large aggregation (n = 100+) of adult suckers were observed roughly 30 km upstream from the confluence with the East Fork. This aggregation was not detected at this location during the riverscape survey two months later in August. This observation highlights the importance of considering fish movement and life history information (e.g., spawning migrations) when interpreting some of our distribution data. Adult sucker observations were fewer in the North Fork Newaukum and East Fork Satsop rivers and we did not observe any individuals in the West Fork Humptulips River. However, at the culmination of our survey, opportunistic snorkelers continued 100 m downstream into the main stem Humptulips where a large aggregation (n = 100+) of adult suckers was observed (E. Walther, WDFW Fish Science, personal communication). Suckers undertake spawning migrations in spring months and based on timing of our surveys and life history information, our data should not be interpreted as comprehensive distribution information for the species (Wydoski and Whitney 2003).

Juvenile suckers were observed in all survey areas except the East Fork Satsop River. The vast majority of juvenile suckers observed in our study were fry (< 40mm). Although adult sucker observations were rare in the West Fork Satsop and North Fork Newaukum rivers and undetected in the West Fork Humptulips River, the presence of sucker fry in these sub basins suggests adult suckers may use locations in these survey areas for spawning.

Threespine stickleback were relatively rare in our survey areas. Minimal observations of threespine stickleback occurred in the North and South Fork Newaukum and West and East Fork Satsop survey areas and no observations occurred in the Upper Chehalis or West Fork Humptulips survey areas. Most observations of threespine stickleback occurred in the West Fork and East Fork Satsop. Stickleback were observed in the coolest sections of the “spring fed headwaters” of the East Fork Satsop in addition to warmer sections of other survey areas such as the West Fork Satsop suggesting a wide range of temperature tolerance in the sub basins where they occur. Threespine stickleback are commonly observed in off channel floodplain habitat in the Chehalis River (Henning et al. 2007; Kuehne and Olden 2016).

In addition to fish species, we collected presence information on freshwater mussels in our survey areas. We collected presence information and did not distinguish species; however at least four species of freshwater mussel are documented in the Chehalis River basin (Blevins et al. 2017). Freshwater mussels were observed in highest proportions of the South and North Fork Newaukum River compared to other survey areas. Although relatively rare, we observed freshwater mussels in the East and West Fork Satsop and Upper Chehalis above Rainbow Falls. In the main stem Chehalis (extended 2013 survey), we found that freshwater mussels occupied more segments between Rainbow Falls and the Newaukum River confluence (31%, or 60 segments) compared to segments upstream of Rainbow Falls (0.5%, or 1 segment). In several survey segments downstream of Rainbow Falls, mussel densities were so high that they were the dominant substrate for that 200-m survey segment. We did not observe freshwater mussels in the West Fork Humptulips survey area.

Non-native Fishes

Non-native fishes were observed in downstream segments of survey areas in the Chehalis main stem and North and South Fork Newaukum rivers. In these downstream areas, observations of non-native fish were often in segments with aquatic vegetation, which sometimes reduced the field of vision of snorkelers. Thus, we believe the relative densities of the non-native species may be biased low compared to other fish species in our surveys. Nevertheless, in the Chehalis main stem between Rainbow Falls and the confluence with the Newaukum River (extended 2013 survey), we observed multiple species of non-native fish including smallmouth and largemouth bass and bluegill. We did not observe non-native fish upstream of Rainbow Falls in any survey. Observations of non-native bass in the North Fork Newaukum River were limited to the downstream most survey segment, roughly 500 m upstream of the confluence with the South Fork Newaukum River. Observations of non-native sunfish in the South Fork Newaukum River were generally within 1.5 km upstream of the confluence with the North Fork Newaukum, but one observation occurred roughly 10 km upstream from the confluence. In a September survey of the South Fork Newaukum River, sunfish and bass were limited to the lower 4 km of the survey area (Winkowski et al. 2018). Taken together, these downstream observations of non-native fish across survey areas suggests warmer stream temperatures associated with these locations are suitable for these species and colder temperatures likely limits their distributions into upstream areas (Carey et al. 2011). In the case of smallmouth bass, cool stream temperatures are thought to limit juvenile growth thereby increasing mortality during the first winter (Rubenson and Olden 2017; S. Rubenson and Olden 2016). However, climate change projections of increasing stream temperatures could facilitate upstream expansion into locations currently dominated by native fish including juvenile salmonids (Lawrence et al. 2014). We recommend an assessment on the current spatial distribution and temperature associations of non-native fishes in the Chehalis basin, which would aid in predicting potential upstream expansion under climate change scenarios.

Temporal Variability

Results from our repeat annual surveys in the Upper Chehalis revealed variability among years in terms of juvenile salmon and steelhead occupancies and densities. These results may be expected as both biotic and abiotic variables influencing the abundance and distribution of juvenile salmon and steelhead vary annually. For example, parental spawner abundance was closely tied to annual variability in juvenile salmon summer occupancy patterns in coastal rivers of Oregon, e.g. juvenile coho distribution expanded and contracted with the size of the spawning run (Flitcroft et al. 2014). Patterns of juvenile salmonid occupancy and density observed in our study are likely reflective of parental spawner abundance coupled with legacy effects from large flood events in the last decade. For example, occupancy and density of juvenile coho observed in 2014 were the lowest among years, with densities roughly sixteen fold fewer than in 2013 and three fold fewer than 2015 and 2016. Juvenile coho observed in the summer of 2014 were spawned from adults in brood year 2013, which were two generations removed from the 2007 flood event. These results highlight the importance of incorporating historical context into interpreting fish occupancy and density information from these surveys.

Temporal variation in temperature may also explain patterns in juvenile salmon and steelhead summer distributions. The mean river kilometer location of ‘medium’ salmonid segments in 2014 and 2015 was 3 to 5 kilometers upstream compared to 2013 and 2016. Winkowski et al (2018) observed an upstream constriction of ‘medium’ salmonid segments associated with increasing stream temperatures from May through August in the South Fork Newaukum River. While, August stream temperatures measured in this study were consistent among years, however additional data exploration revealed that stream temperatures in the Upper Chehalis survey area in addition to other locations in the Chehalis River main stem (Liedtke et al. 2017; Liedtke et al. 2016) were more variable among years in the month of July compared to August.. Taken together, temperatures earlier in the summer months may be important in shaping the structure of fish distributions observed in August.

Salmonid versus Cyprinid Fish Assemblages

The longitudinal and inverse pattern between numbers of salmonids (juveniles) versus cyprinids was consistent among our survey areas. This result provided an organizing construct for synthesizing the fish, habitat, and temperature data in the Chehalis River watershed. In all survey areas, upstream segments were proportionally dominated by juvenile salmonids and the fish assemblage transitioned to cyprinid dominated in a downstream direction. This pattern was most distinct in the Upper Chehalis (all years), South and North Fork Newaukum, and West Fork Satsop rivers. In the cooler rivers such as the East Fork Satsop, salmonids were the dominant taxa observed throughout the majority of the survey area and in the West Fork Humptulips, salmonids dominated upstream reaches and co-dominated downstream reaches but few segments were dominated by cyprinid species. While previous work in a single sub basin had concluded that the contribution of habitat and temperature on fish assemblage could not be disentangled in a single survey area (Zimmerman and Winkowski in prep), a broader spatial examination among survey areas supported temperature as a general organizing factor for fish distributions and indicated that connections between fish distributions and habitat characteristics were more localized to each sub basin. For example, the lowest occupancy and densities of cyprinids were observed in the coolest survey areas of the West Fork Humptulips and East Fork Satsop and subsequently, salmonids dominated a larger proportion of those survey areas.

We simplified fish assemblage patterns into ‘high’, ‘medium’ and ‘low’ salmonid categories to further examine salmonid distributions. These categories were assigned to relatively short (~200 m) segments of river where rearing salmonids were numerically dominant (high), co-dominant (medium) or inferior to (low) cyprinids. We developed fish assemblage categories by numerical dominance in the 200-m segments but acknowledge that the segments were not independent from their position in the river (i.e., species present in neighboring segments) and that juvenile salmon and trout have been shown to migrate distances exceeding 200m during the summer base flow period (Winkowski and Zimmerman 2017, Winkowski et al 2018). Nevertheless, the fish assemblage categories were used to compare habitat and temperature characteristics associated with dominance of the salmonid versus cyprinid taxa.

In our categorical approach, we are assuming that numerical dominance of fish species reflects their ecological dominance. This approach is based on the assumption that each segment has a capacity with respect to food and shelter and that the ecologically dominant taxa will occupy more of that capacity than the ecologically inferior taxa. The observed spatial organization for each taxonomic group may relate to temperature-mediated outcomes of competitive interactions between salmonids and cyprinids. In laboratory experiments, juvenile pikeminnow and redside shiner have been observed to outcompete juvenile steelhead for space and food in stream temperatures from 19-23℃, resulting in reductions in growth and altered habitat use of juvenile steelhead (Reeves et al. 1987; Reese and Harvey 2002). Such temperatures are comparable to August temperatures observed in the cyprinid dominated downstream extents of the Upper Chehalis, South and North Fork Newaukum, and West Fork Satsop. However, in cooler waters below 18℃, comparable to August temperatures in salmonid dominated upstream extents of these survey areas, juvenile steelhead growth and habitat use were less effected in the presence of competing cyprinid species (Reeves et al. 1987; Reese and Harvey 2002). Temperature mediated competition contributing to the organization of species which replace each other along stream gradients has been observed in other systems in both cold and warm water fishes (Taniguchi et al. 1998; Troia et al. 2015). Thus, each taxonomic groups' competitive ability appears sensitive to temperature and is reflected in the spatial organization observed in our surveys.

Each survey area had discrete shifts between 'high' versus 'medium' and 'low' salmonid segments that were associated with temperature and, to some extent, habitat characteristics. Within each survey area, 'high' salmonid segments were consistently cooler than 'medium' and 'low' salmonid segments, demonstrating the importance of temperature in structuring ecological dominance within the stream segments. In comparison, the temperatures of 'medium' and 'low' segments did not always differ. Therefore, local habitat characteristics, as opposed to temperature, may be important in determining a segment's suitability for each taxonomic group in terms of competitive outcomes and subsequently numerical proportions.

Temperature differences between 'high' salmonid versus 'medium' and 'low' salmonid segments were up to 3.9℃ (August mean daily temperature) within each survey area. However, the absolute temperatures associated with 'high' salmonid segments in the Upper Chehalis and West Fork Satsop were roughly 3-4℃ warmer (August mean daily temperature) than 'high' salmonid segments of other survey areas. The warmest temperatures associated with 'high' salmonid segments were observed in the Upper Chehalis survey area, where we observed minimal variation in August temperatures associated with the 'high' salmonid segments among four years (< 0.5℃ for mean daily temperature). The repeated results suggest ecological dominance of juvenile salmon and steelhead in the Upper Chehalis consistently occurs in warmer stream segments relative to other survey areas. This observation suggests a role for local adaptation or acclimation specific to each survey area which may affect the physiology and or competitive ability of rearing salmonids and potentially challenges the concept that a single temperature threshold should define quality salmonid rearing habitat. Thus, acclimation or local adaptation combined with other factors such as food supply, tributary habitat, and thermal refugia may provide additional insight into the rearing abundance of juvenile salmonids across the Chehalis River watershed.

The comparison of temperatures associated with fish assemblage categories relies on the accuracy of the temperature data used for each survey segment. We believe our interpolation technique for assigning temperatures to stream segments was relatively representative of stream temperatures available to fish, however the technique is insensitive to local temperature features important to fish especially in locations with relatively warm temperatures. Thermal refugia within segments, such as groundwater seeps and tributary junctions (Dugdale et al. 2013) have less likelihood of being detected at a 4 km resolution. Thus, a finer scale or more rigorous approach to understanding stream temperatures within our survey areas, such as thermal infrared imagery or stream network modelling (Isaak et al. 2014), may reveal temperature features which further explain fish diversity among and within survey areas, such as differences between ‘medium’ and ‘low’ salmonid rearing segments.

Temperature associations with ‘high’ salmonid segments were more consistent among surveys compared to habitat characteristics. However, some of our findings are in agreement with fish-habitat associations commonly observed in the literature, such as juvenile coho associations with pool habitat and juvenile steelhead associations with coarse substrate (Bisson et al. 1988; Winkowski and Zimmerman 2017). For example, coarser substrate was associated with ‘high’ salmonid segments in the Upper Chehalis, South and North Fork Newaukum, West Fork Satsop, and West Fork Humptulips but not the East Fork Satsop. Pool density was positively associated with ‘high’ salmonid segments in the Upper Chehalis, South and North Fork Newaukum, and West Fork Satsop, but not the East Fork Satsop or West Fork Humptulips. Our approach of combining all species and age classes of juvenile salmon and steelhead into a broad “salmonid” category may undermine associations specific to individual species or age classes therefore a finer scale approach may be more revealing of fish-habitat associations in our study areas.

In summary, our results suggest that a combination of temperature and habitat characteristics are associated with the summer rearing distributions of juvenile salmon and steelhead and that these distributions are likely to be further influenced by interactions with the native cyprinid species (also see Winkowski et al 2018). Occupancy (or ‘presence’) of juvenile salmonids in a given river reach may not translate to numerical or ecological dominance. Thus, a distinction between occupancy and density (or ‘numerical dominance’) of salmonids should be considered when modelling the salmonid rearing habitat in the Chehalis River watershed. Such resolution would likely better focus our understanding on the temperature and habitat features which characterize locations where juvenile salmon and steelhead are ecologically dominant under current conditions and where they may be ecologically dominant under future modeled scenarios.

Implications for Future Change

Our surveys revealed fish, habitat, and temperature patterns and variability among sub basins of the Chehalis River. Results presented here provide context for ongoing discussions regarding impacts of a flood retention dam, restoration or protection actions, and climate change. With respect to habitat protection, our surveys revealed upstream areas within each sub basin are currently valuable summer rearing habitat for juvenile salmon and steelhead as well as resident trout. Although the watershed area above the proposed dam site is roughly only 3% of the entire Chehalis basin, our results suggest that the relative importance of this portion of the watershed for summer rearing of juvenile salmon and steelhead may be much higher. Thus, valuable juvenile salmon and steelhead habitat, which is already limited in the Chehalis River, is likely to be negatively impacted by the construction of a dam and result in negative ramifications on the freshwater rearing portion of salmon and steelhead life cycles in this part of the river.

Restoration efforts often focus on enhancing habitat that is currently used by species of interest with the goal of increasing localized survival, growth, and ultimately densities or expanding spatial distributions. While our study may provide some context for understanding localized survival and growth, study designs outside of the scope of this study would best inform such questions. Thus, we focused on what we have learned about connections between habitat and temperature conditions and spatial distribution of fish species. Our discussion has highlighted the downstream extent of salmonid rearing and the potential influence of temperature-mediated interactions with cyprinid species, which are native to the basin and thus a natural component of the river ecosystem. As summer temperatures increase and competitive interactions presumably shift in favor of cyprinids in some locations, summer rearing of juvenile salmon and steelhead may constrict in an upstream direction (Winkowski et al 2018). Additionally, downstream 'low' salmonid segments observed in our survey may have historically provided more suitable juvenile salmon and steelhead summer rearing temperatures but anthropogenic effects such as reductions of riparian corridors, which help to buffer stream temperatures from solar radiation, may have reduced suitability in these locations. Thus, we suggest developing a comprehensive understanding of mechanisms driving temperature patterns in the Chehalis River to predict suitable summer rearing locations for juvenile salmon and steelhead and inform questions related to restoration planning and vulnerability to climate change.

Climate change will likely exasperate temperature related issues for juvenile salmon and steelhead summer rearing in the Chehalis River. We have found a limited portion of the Chehalis basin is currently suitable for juvenile salmon and steelhead summer rearing based on broad scale temperature patterns. We speculate that limited summer rearing habitat is likely naturally occurring to an extent but that anthropogenic factors have impacted natural temperature patterns through channelization, riparian loss, water withdrawals, and other factors that further limit suitable rearing areas. Warming stream temperatures through climate change would likely limit salmonid rearing zones to even more restricted spatial extents throughout the basin. Unsuitable habitat will likely increase and moderately suitable, e.g. "low" or "medium" salmonid rearing zones, could expand due to more favorable conditions for native cyprinids which outcompete salmonids in warm water. Additionally, non-native fish observations in our study should raise alarm when considering increasing stream temperatures may facilitate upstream expansion of non-natives into native fish habitat (Carey et al. 2011; Lawrence et al. 2014).

We chose survey areas that spanned the Chehalis River watershed from the Humptulips River to the Upper Chehalis sub basin in order to capture diversity of fish, habitat, and temperature patterns across the spatial extent of the Chehalis basin. We acknowledge that a relatively large proportion of habitat in the Chehalis basin was not surveyed in our study however, in our conclusions and future plans, we assume that sampling of instream habitat that was completed here help to inform expectations on fish, habitat, and temperature patterns, relationships, and diversity across the Chehalis basin. Data collected in our study provide opportunity to explore analyses with respect to relationships of fish, habitat, temperature, and landscape variables. In the future, we plan to develop species-specific models of occupancy and density as predicted by temperature and landscape variables that can be extrapolated to areas of which data is lacking. These species-habitat functional relationships are currently assumed within habitat-based models of capacity for the Chehalis River watershed (i.e., Ecosystem Diagnostic Treatment model, Watershed Assessment model) and we will use the empirical information gathered through these riverscape surveys to develop species-habitat functional relationships that should improve the information used to predict the impacts of dam construction and restoration actions. Additionally, we plan to explore the influences of potential climate change scenarios (e.g., variable stream warming scenarios) on the downstream spatial extents of juvenile salmon and steelhead summer rearing distributions using fish, habitat, and temperature data collected in this study.

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Appendices

Appendix A. Locations, elevations, and data collection periods (installation and removal dates) for temperature loggers used for analyses in the six survey areas of the Chehalis River.

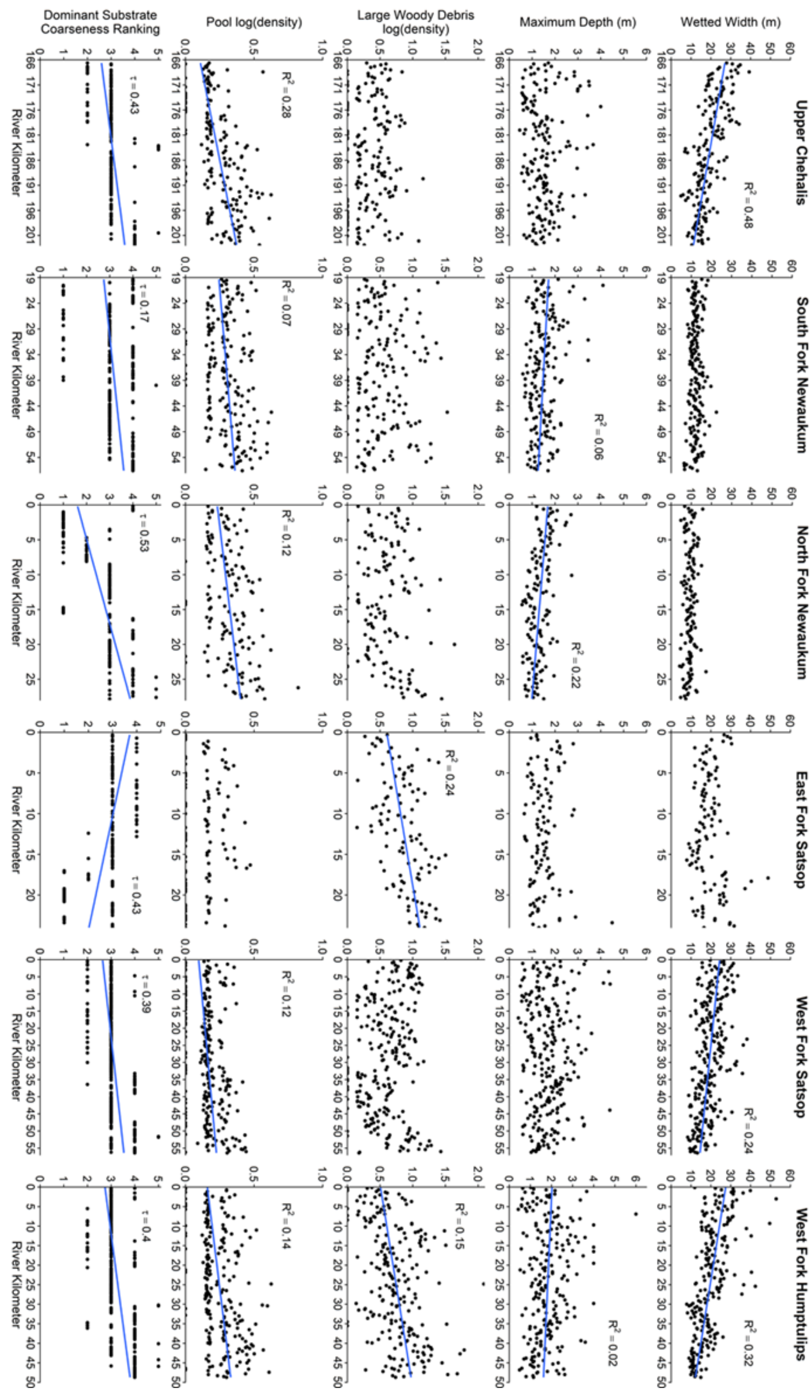
Survey Area	Site ID	Latitude	Longitude	Elevation (m)	Installation Date	Removal Date
Upper Chehalis	4-UCH	46.628080	-123.281020	98	5/15/2014	ongoing
	13-CH	46.591240	-123.290310	110	6/10/2014	ongoing
	3-UCH	46.569350	-123.304550	114	5/15/2014	ongoing
	11-UCH	46.548020	-123.303990	123	6/9/2014	ongoing
	2-UCH	46.527070	-123.290760	149	5/15/2014	ongoing
	9-UCH	46.526590	-123.277190	159	6/5/2014	ongoing
	8-UCH	46.510310	-123.276800	170	6/5/2014	ongoing
	7-UCH	46.486040	-123.292590	185	6/5/2014	ongoing
	5-UCH	46.458520	-123.287810	243	6/2/2014	ongoing
South Fork Newaukum	New-10	46.604260	-122.855850	82	4/19/2016	10/6/2016
	New-11	46.581020	-122.837090	96	4/19/2016	10/6/2016
	NEW-7	46.575880	-122.824530	104	4/30/2015	10/6/2016
	New-12	46.573570	-122.809710	108	4/21/2016	10/6/2016
	New-13	46.574440	-122.772390	122	4/19/2016	10/6/2016
	New-14	46.569840	-122.737570	136	4/19/2016	10/6/2016
	New-20	46.571920	-122.722290	145	7/8/2016	10/6/2016
	New-15	46.575600	-122.696610	157	4/21/2016	10/6/2016
	New-16	46.582760	-122.667720	173	4/20/2016	10/6/2016
	New-17	46.599920	-122.646380	193	4/20/2016	10/6/2016
	New-18	46.624360	-122.630900	226	4/21/2016	10/6/2016
	New-19	46.636640	-122.599530	257	4/21/2016	ongoing
North Fork Newaukum	NFNEW-2	46.608340	-122.850830	82	7/15/2014	ongoing
	NFNEW-3	46.654080	-122.780360	117	7/14/2014	ongoing
	NFNEW-4	46.684200	-122.740910	152	7/14/2014	ongoing
	NFNEW-5	46.682890	-122.729300	162	7/14/2014	ongoing
	NFNEW-6	46.678710	-122.708600	184	7/14/2014	ongoing
East Fork Satsop	EFSAT-6	47.084160	-123.482670	31	7/8/2015	9/16/2015
	EFSAT-5	47.097980	-123.455360	39	7/7/2015	9/16/2015
	EFSAT-3	47.146640	-123.399300	71	7/8/2015	9/16/2015
	EFSAT-1	47.171190	-123.330000	88	7/7/2015	9/16/2015
	EFSAT-START	47.189000	-123.317540	96	7/7/2015	9/16/2015

Appendix A. Continued.

Survey Area	Site ID	Latitude	Longitude	Elevation (m)	Installation Date	Removal Date
West Fork Satsop	WFSAT-15	47.036350	-123.526650	24	7/8/2015	9/3/2015
	WFSAT-14	47.045060	-123.527470	25	7/7/2015	9/3/2015
	WFSAT-13	47.065650	-123.546520	25	7/7/2015	9/3/2015
	WFSAT-12	47.094910	-123.553250	33	7/7/2015	9/3/2015
	WFSAT-11	47.112790	-123.571410	37	7/8/2015	9/3/2015
	WFSAT-10	47.133130	-123.578930	44	7/8/2015	9/3/2015
	WFSAT-8	47.170800	-123.559680	58	7/13/2015	9/3/2015
	WFSAT-7	47.179840	-123.559890	64	7/7/2015	9/1/2015
	WFSAT-6	47.197040	-123.563530	77	7/8/2015	9/2/2015
	WFSAT-5	47.220320	-123.559270	83	6/29/2015	9/2/2015
	WFSAT-4	47.240230	-123.559070	98	6/29/2015	9/2/2015
	WFSAT-3	47.260950	-123.558810	119	6/24/2015	9/2/2015
	WFSAT-2	47.276330	-123.558470	131	6/24/2015	9/2/2015
	WFSAT-1	47.292530	-123.568530	147	7/2/2015	9/1/2015
	WFSAT-START	47.314000	-123.564000	173	7/2/2015	9/1/2015
West Fork Humptulips	WFHUMP-13	47.250100	-123.893120	49	7/25/2016	9/8/2016
	WFHUMP-11	47.276540	-123.864360	72	7/21/2016	9/8/2016
	WFHUMP-10	47.294110	-123.847640	77	7/27/2016	9/12/2016
	WFHUMP-09	47.308680	-123.838360	85	7/21/2016	9/12/2016
	WFHUMP-07	47.340890	-123.825480	101	7/19/2016	9/12/2016
	WFHUMP-06	47.365970	-123.811800	113	7/20/2016	9/12/2016
	WFHUMP-05	47.387230	-123.781740	142	7/19/2016	9/8/2016
	WFHump-04	47.408440	-123.768030	162	7/18/2016	9/8/2016
	WFHUMP-03	47.433560	-123.752240	186	7/18/2016	9/8/2016
	WFHUMP-02	47.452270	-123.719860	230	7/14/2016	9/8/2016
	WFHUMP-01	47.470420	-123.698390	261	7/14/2016	9/8/2016

Appendix B. Longitudinal patterns in habitat metrics for six survey areas of the Chehalis River basin

Appendix B. Longitudinal patterns in habitat metrics for six survey areas of the Chehalis River. Graph shows wetted width, maximum depth, log transformed large woody debris density and pool density, and dominant substrate coarseness ranking. R^2 values and regression line added for statistical significant relationships (α=0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream.



Appendix C. Fish observations among survey years in the extended Upper Chehalis survey area.

Appendix C. Fish occupancy (proportion of segments occupied), total counts, and density (fish per 100m) of the extended Chehalis River survey area (Rkm 125.7-202.8) conducted August 13 to September 12, 2013. '---' indicates species-age class data were not collected.

	Occupancy	Total Count	Density (±SD)
Juvenile salmonids			
Coho 0+*	52.7%	58931	78.1 (±167.0)
Chinook 0+	---	---	---
Trout 0+	57.4%	37276	49.7 (±81.5)
Trout 1+	66.3%	9724	12.9 (±25.7)
Cyprinids			
Redside shiner	63.2%	28157	36.8 (±76.0)
Redside Shiner (fry)	30.8%	27212	34.5 (±82.9)
Dace	64.8%	31266	41.0 (±96.0)
Dace (fry)	4.4%	7070	9.4 (±64.0)
Northern Pikeminnow (adult)	13.2%	261	0.7 (±2.9)
Northern Pikeminnow (juvenile)	---	---	---
Adult salmonids			
Steelhead (Adult)	0.0%	0	0.0 (±0.0)
Steelhead (Adult, U)	0.0%	0	0.0 (±0.0)
Chinook (Adult)	1.3%	14	0.0 (±0.2)
Resident Trout	50.5%	340	0.9 (±1.7)
Sockeye (Adult)	0.0%	0	0.0 (±0.0)
Bull Trout (Adult)	0.0%	0	0.0 (±0.0)
Native Fish and Mussels			
Mountain Whitefish (Adult)	7.3%	149	0.2 (±1.1)
Mountain Whitefish (juvenile)	0.0%	0	0.0 (±0.0)
Largescale Sucker (Adult)	15.7%	889	1.2 (±8.0)
Largescale Sucker (juvenile)	11.7%	2078	2.5 (±16.2)
Threespine Stickleback	0.3%	1	0.0 (±0.0)
Freshwater Mussels	15.9%	---	---

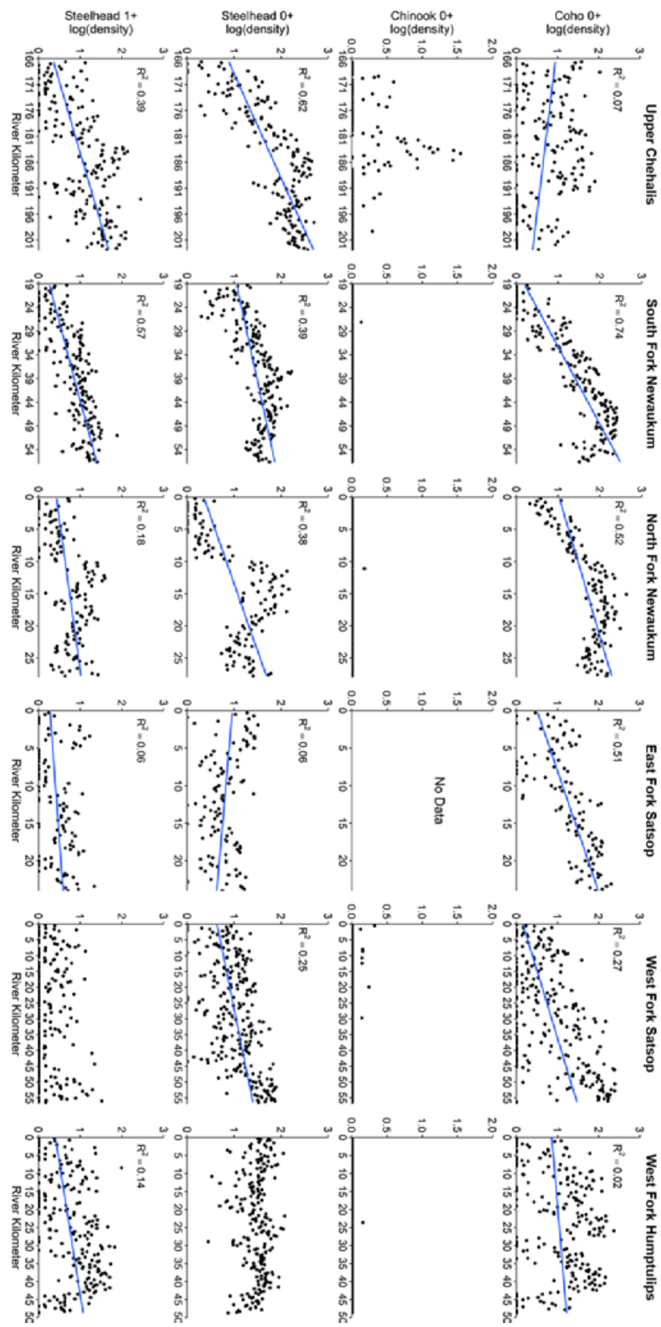
Appendix C. Continued.

	Occupancy	Total Count	Density (±SD)
Hatchery & Non-native fish			
Coho 0+	0.0%	0	0.0 (±0.0)
Steelhead 1+	0.0%	0	0.0 (±0.0)
Resident Trout	0.0%	0	0.0 (±0.0)
Bass	19.3%	692	0.9 (±2.7)
Smallmouth Bass	7.8%	109	0.1 (±0.8)
Largemouth Bass	0.3%	12	0.0 (±0.3)
Bluegill	3.7%	24	0.0 (±0.2)

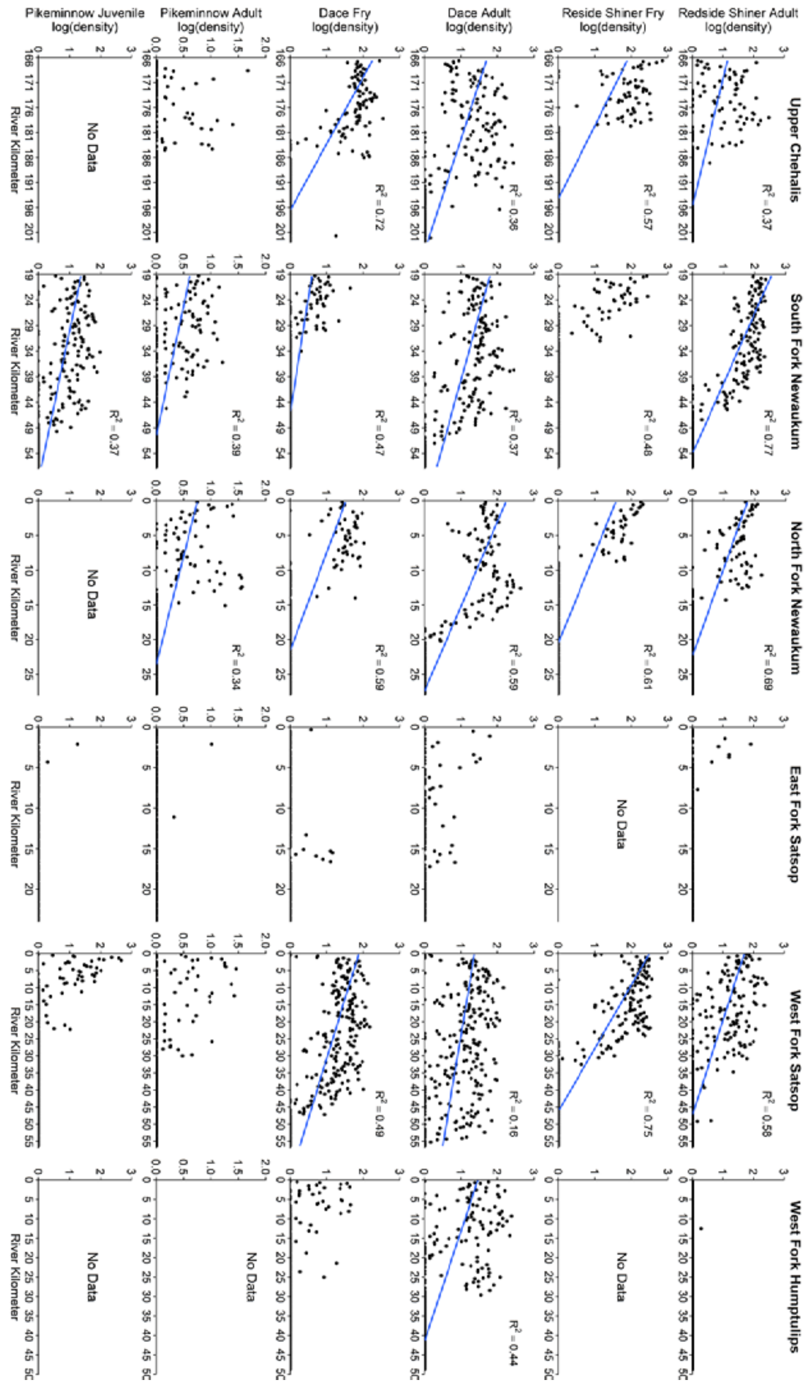
*Juvenile salmon were noted as "salmon 0+" however supplemental seine and electrofishing surveys suggested the majority of juvenile salmon observed were coho 0+.

Appendix D. Longitudinal patterns in fish observations for six survey areas of the Chehalis River basin.

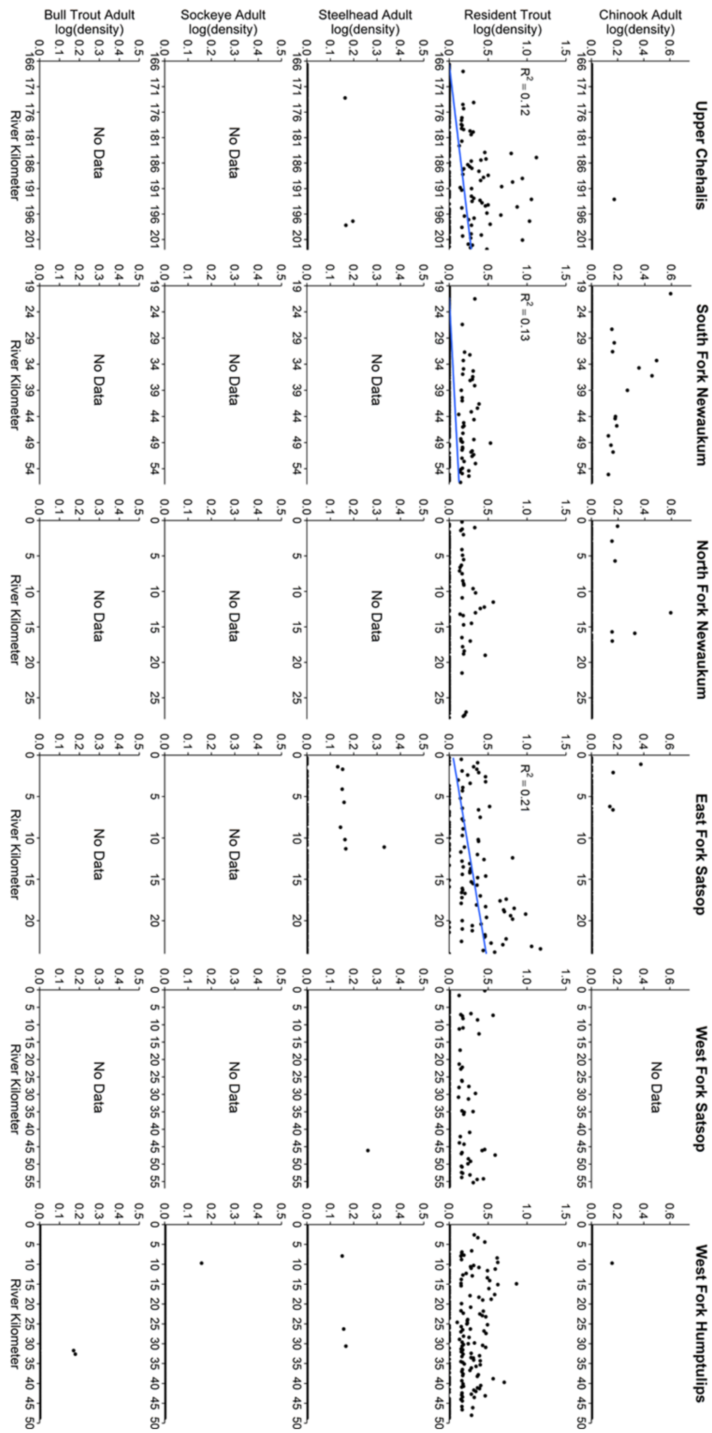
Appendix D-1. Longitudinal patterns of juvenile salmonids in six survey areas of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys of the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, East Fork Satsop, West Fork Satsop, and West Fork Humptulips survey areas. R^2 values and regression line added for statistical significant relationships ($\alpha = 0.05$). Larger river kilometer values are upstream and smaller river kilometer values are downstream. “No Data” indicates no observations occurred.



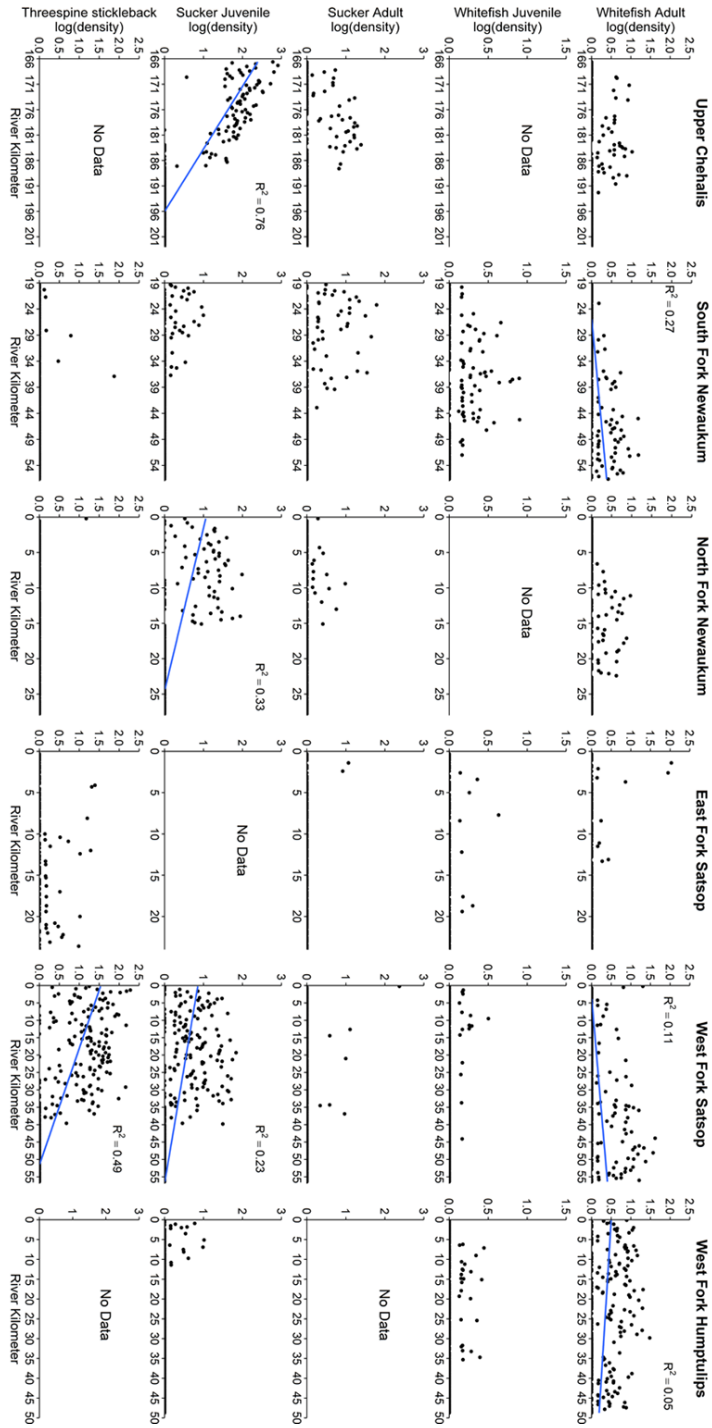
Appendix D-2. Longitudinal patterns of cyprinid species in six survey areas of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys of the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, East Fork Satsop, West Fork Satsop, and West Fork Humptulips survey areas. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. "No Data" indicates no observations occurred. In 2014, no juvenile pikeminnow data were collected in the Upper Chehalis or North Fork Newaukum.



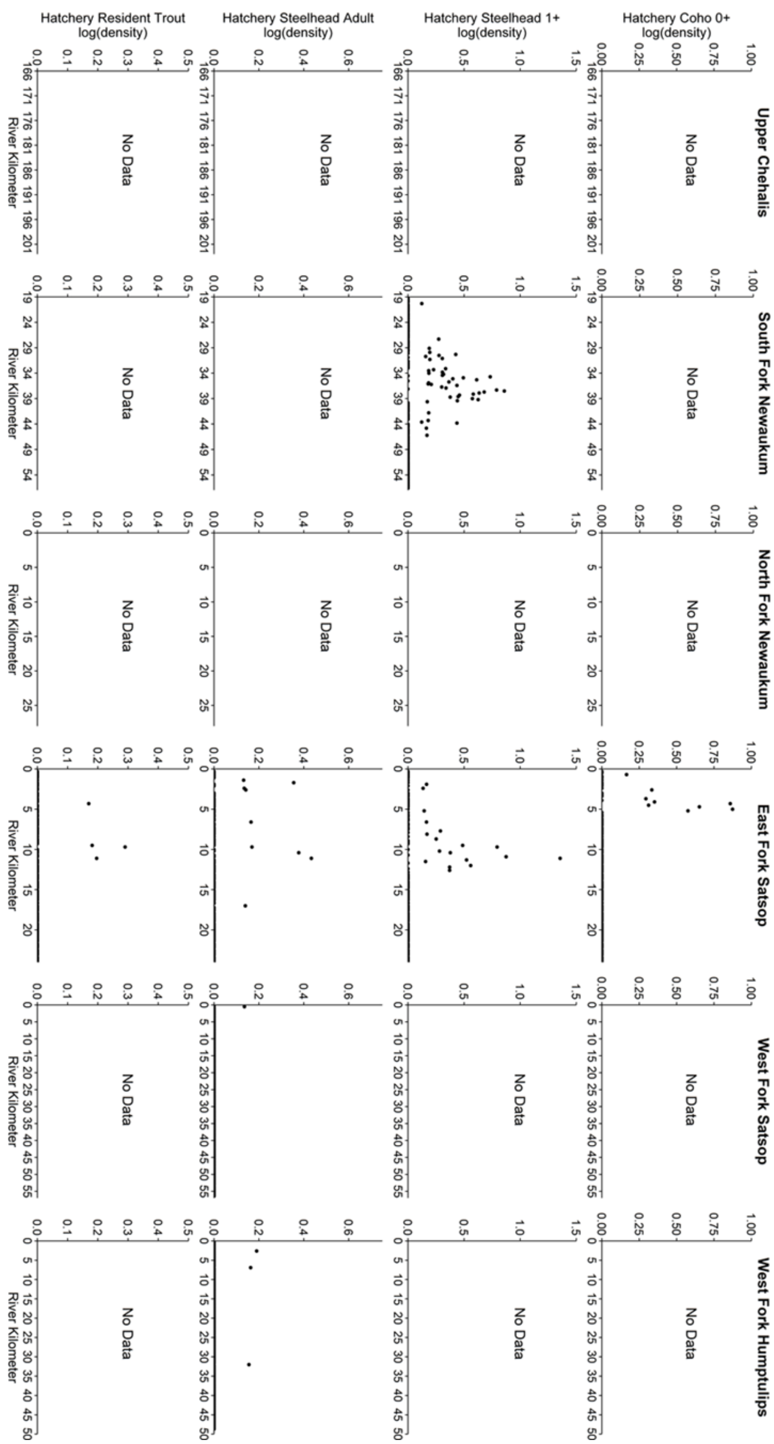
Appendix D-3. Longitudinal patterns of adult salmonids in six survey areas of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys of the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, East Fork Satsop, West Fork Satsop, and West Fork Humptulips survey areas. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. “No Data” indicates no observations occurred.



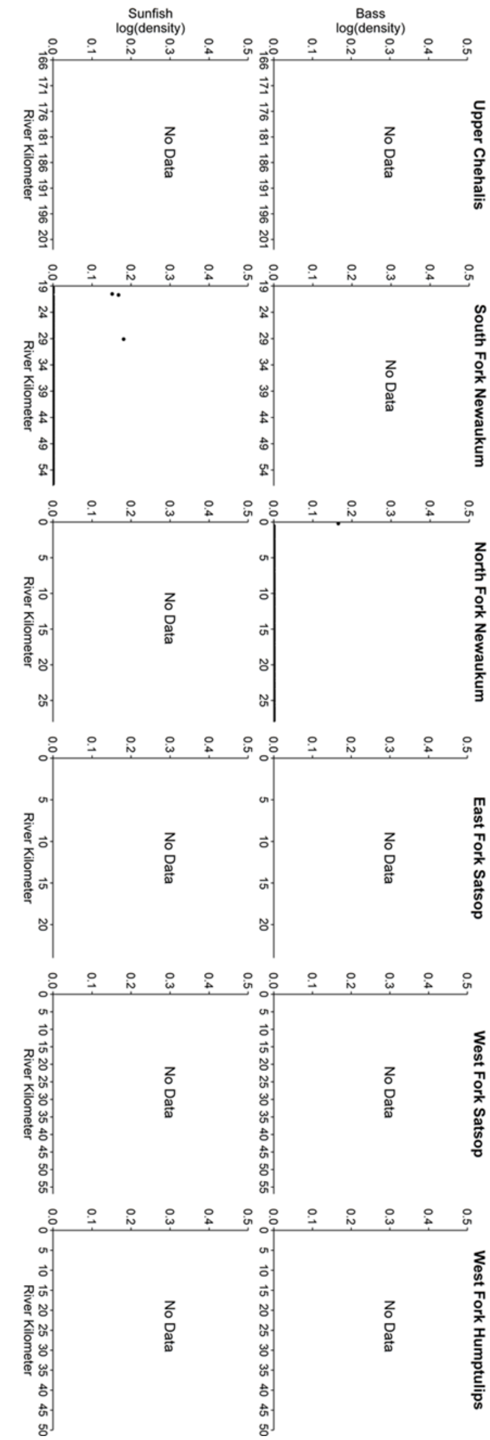
Appendix D-4. Longitudinal patterns of native fish species in six survey areas of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys of the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, East Fork Satsop, West Fork Satsop, and West Fork Humptulips survey areas. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. “No Data” indicates no observations occurred.



Appendix D-5. Longitudinal patterns of hatchery salmonids in six survey areas of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys of the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, East Fork Satsop, West Fork Satsop, and West Fork Humptulips survey areas. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. “No Data” indicates no observations occurred.

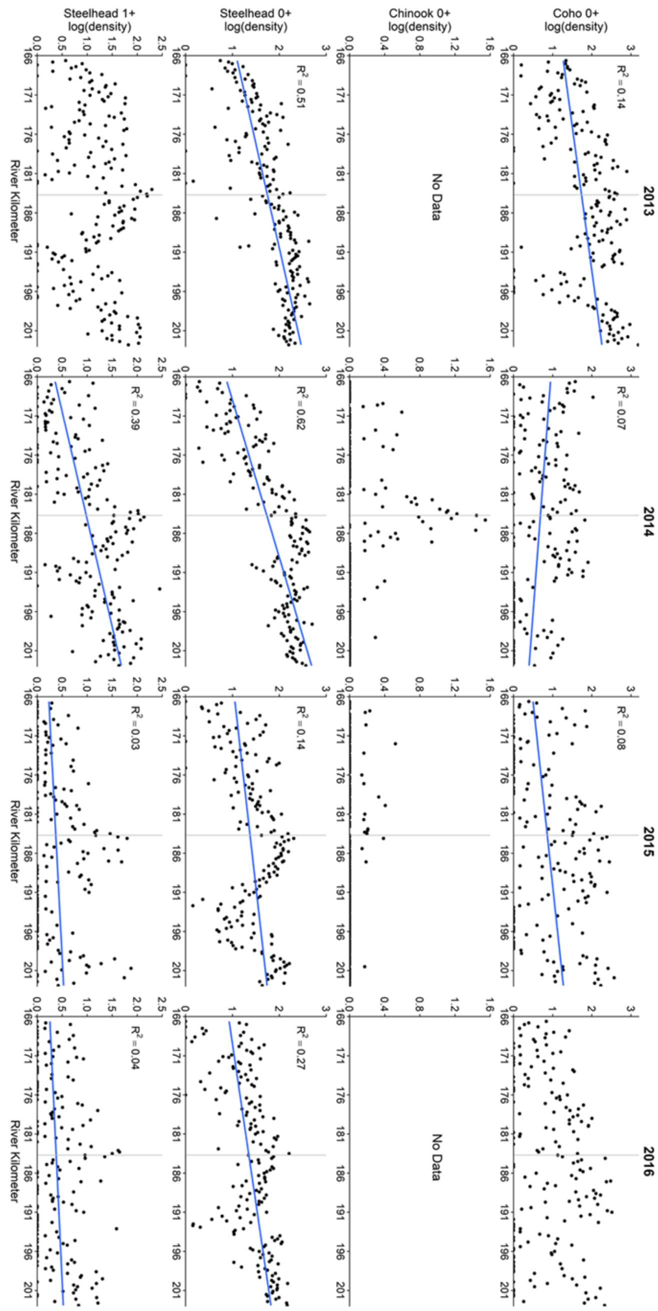


Appendix D-6. Longitudinal patterns of non-native fish species in six survey areas of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys of the Upper Chehalis, South Fork Newaukum, North Fork Newaukum, East Fork Satsop, West Fork Satsop, and West Fork Humptulips survey areas. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. "No Data" indicates no observations occurred.

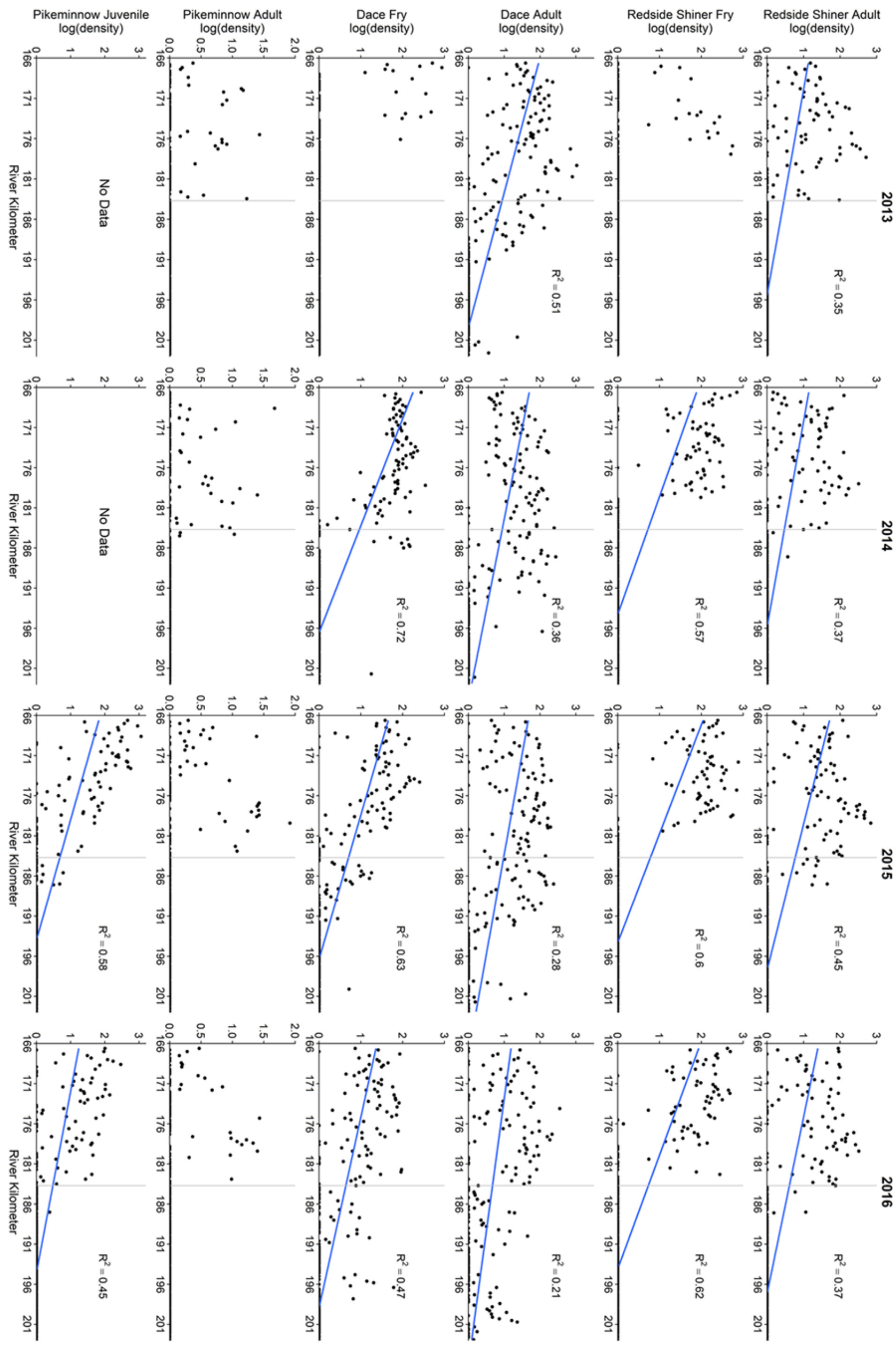


Appendix E. Longitudinal patterns in fish observations for four survey years of the Upper Chehalis survey area. Data for 2013 includes same survey footprint as data collected in 2014-2016.

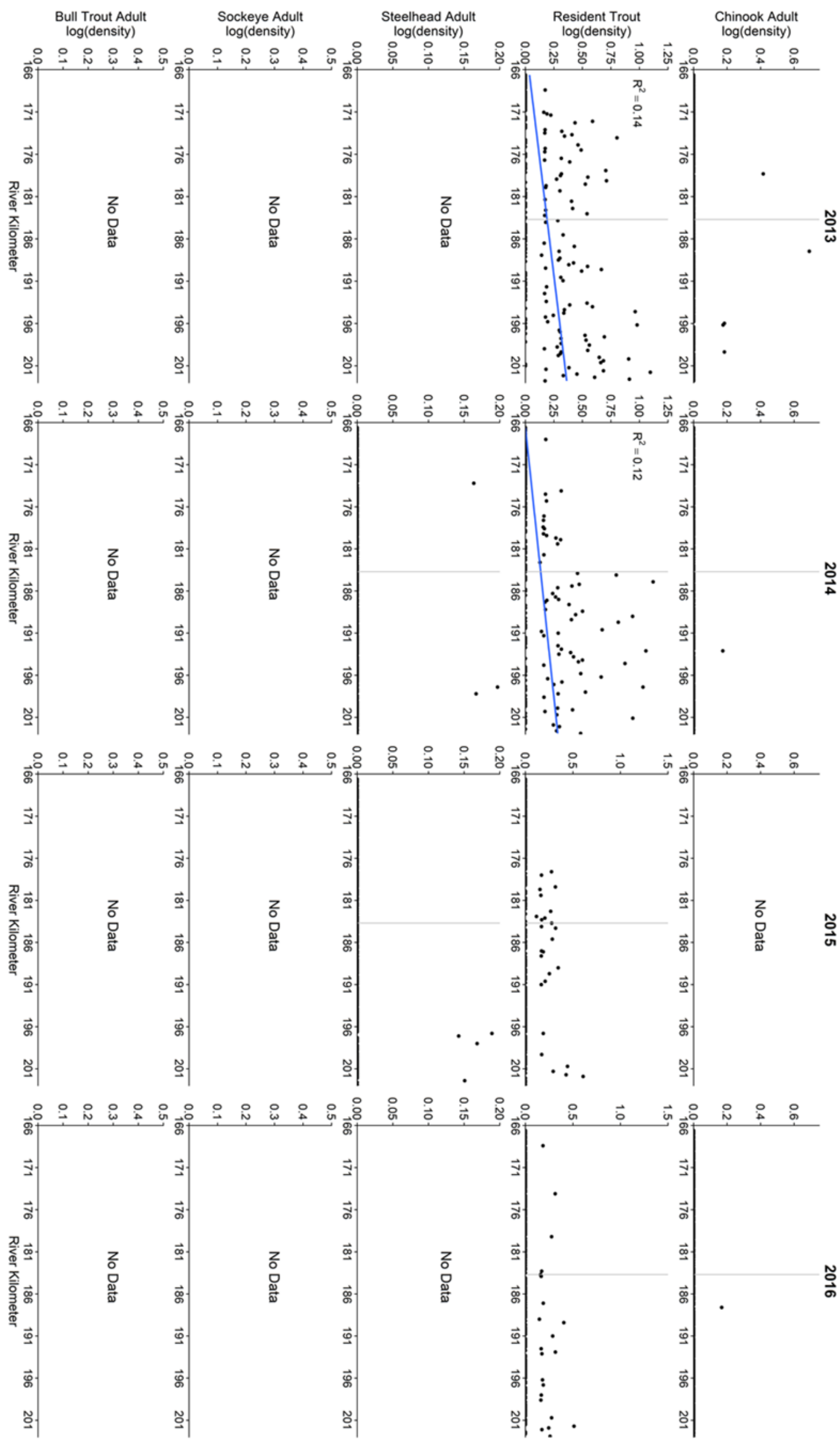
Appendix E-1. Longitudinal patterns of juvenile salmonids over four survey years of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys conducted 2013-2016. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. Vertical gray line represents approximate location of proposed dam site at river kilometer 183.7. "No Data" indicates no observations occurred. In 2013, no Chinook 0+ data were collected.



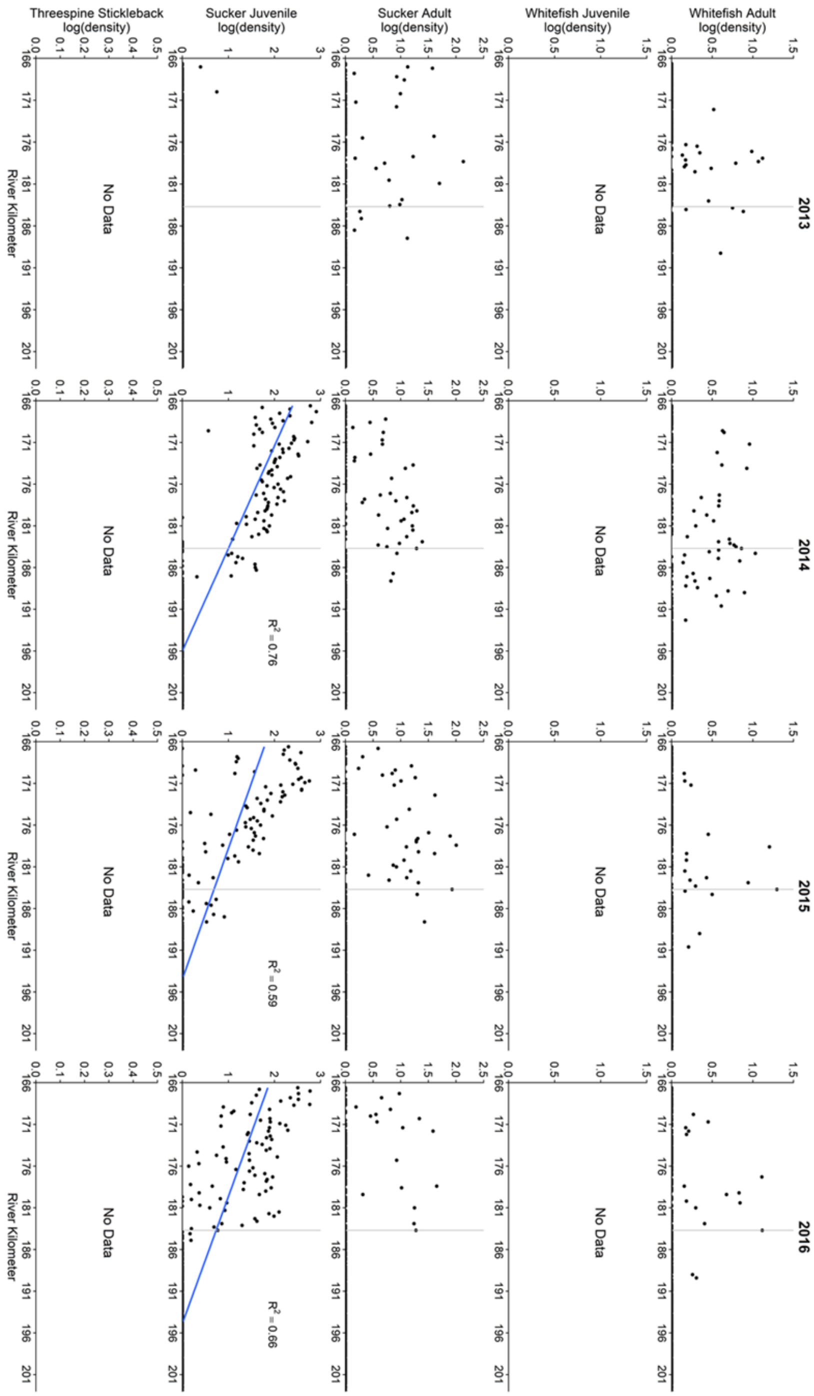
Appendix E-2. Longitudinal patterns of cyprinid species over four survey years of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys conducted 2013-2016. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. Vertical gray line represents approximate location of proposed dam site at river kilometer 183.7. “No Data” indicates no observations occurred. In 2013 and 2014, no juvenile pikeminnow data were collected.



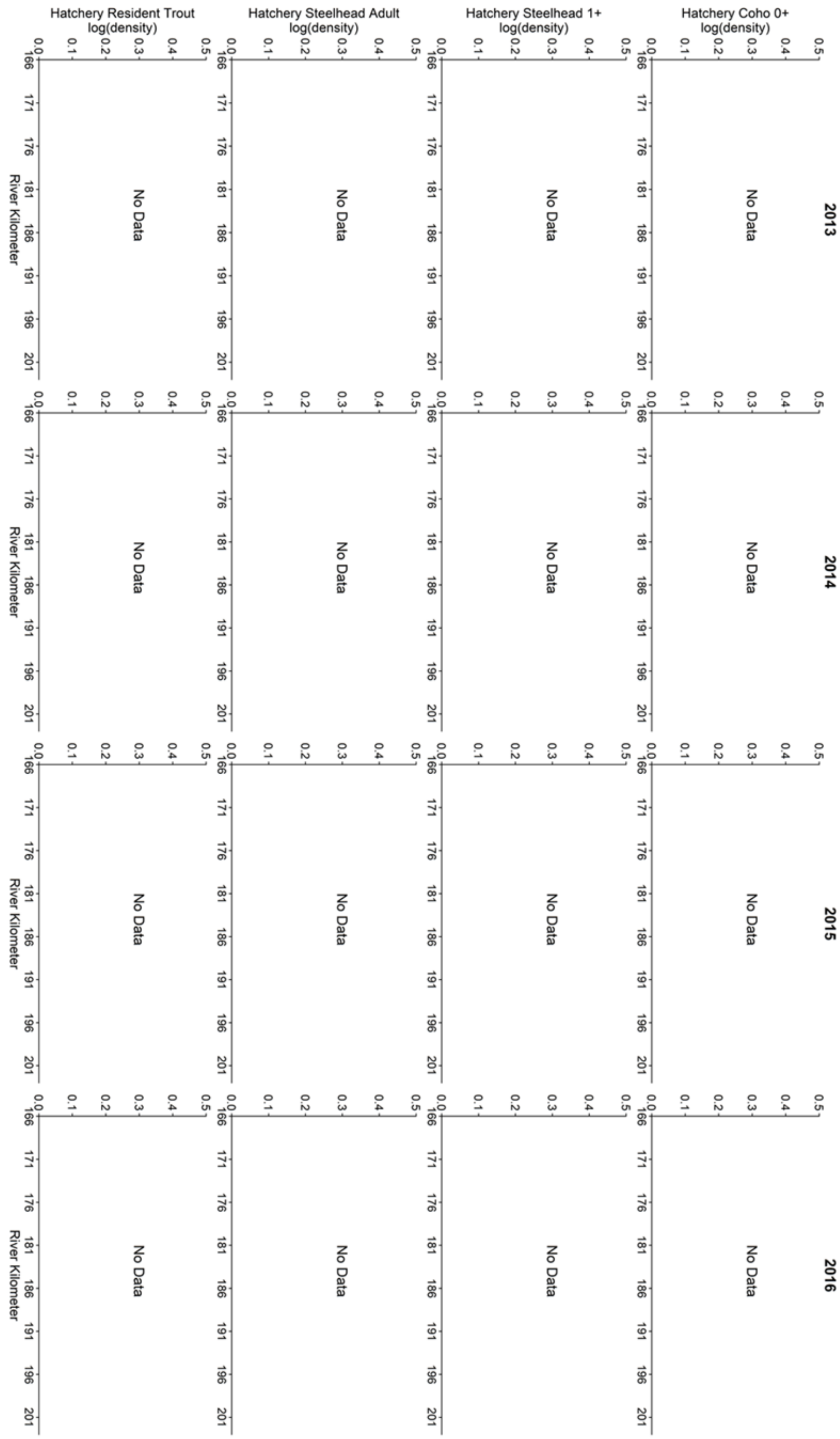
Appendix E-3. Longitudinal patterns of adult salmonids over four survey years of the Chehalis River Graph shows fish densities (counts per 100 m) by river kilometer for surveys conducted 2013-2016. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. Vertical gray line represents approximate location of proposed dam site at river kilometer 183.7. “No Data” indicates no observations occurred.



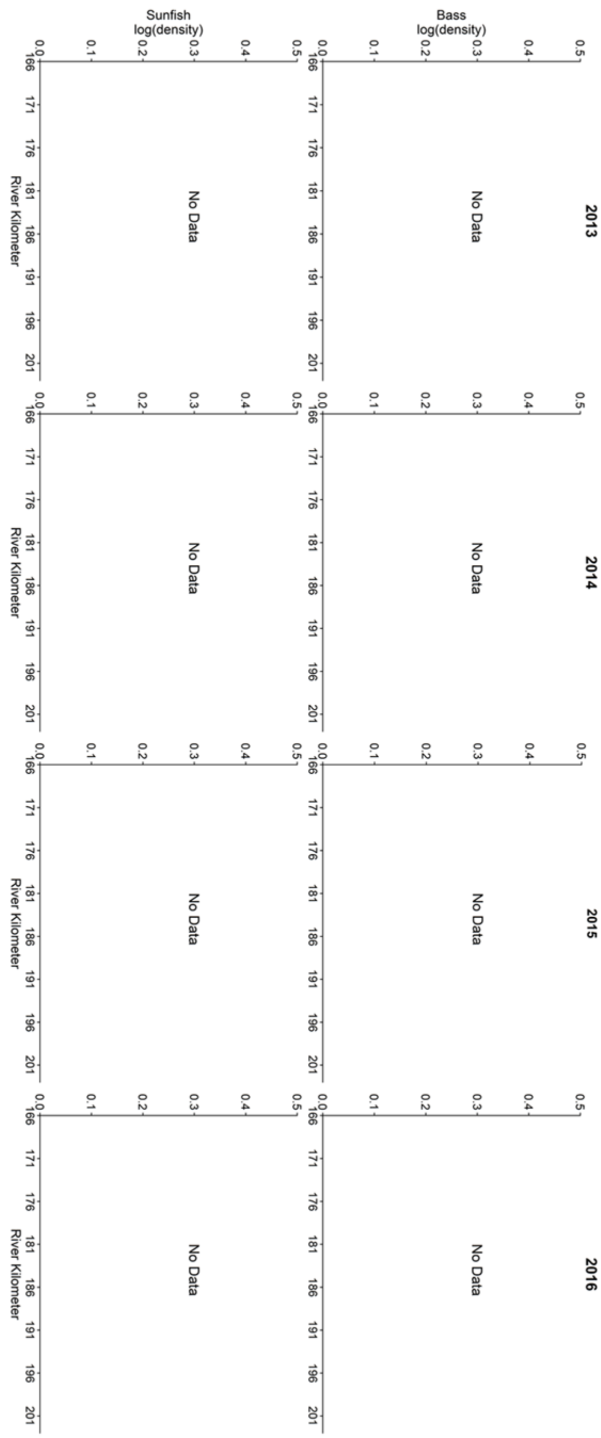
Appendix E-4. Longitudinal patterns of native fish species over four survey years of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys conducted 2013-2016. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. Vertical gray line represents approximate location of proposed dam site at river kilometer 183.7. “No Data” indicates no observations occurred.



Appendix E-5. Longitudinal patterns of hatchery salmonids over four survey years of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys conducted 2013-2016. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. "No Data" indicates no observations occurred.



Appendix E-6. Longitudinal patterns of non-native fish species over four survey years of the Chehalis River. Graph shows fish densities (counts per 100 m) by river kilometer for surveys conducted 2013-2016. R^2 values and regression line added for statistical significant relationships (α= 0.05). Larger river kilometer values are upstream and smaller river kilometer values are downstream. "No Data" indicates no observations occurred.



Appendix F. Habitat and summer temperatures associated with fish assemblage categories among survey areas of the Chehalis River basin.

Appendix F-1. Proportion of 200-m survey segments categorized as low, medium, and high salmonid in survey areas of the Chehalis basin, 2014-2016. Fish assemblage categories assigned to each 200-m survey segments are low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids.

Year	Survey Area	Low salmonid	Medium salmonid	High salmonid
2014	Upper Chehalis	0.12	0.28	0.60
2016	South Fork Newaukum	0.31	0.27	0.42
2014	North Fork Newaukum	0.25	0.29	0.46
2015	East Fork Satsop	0.00	0.07	0.93
2015	West Fork Satsop	0.35	0.29	0.36
2016	West Fork Humptulips	0.01	0.24	0.75

Appendix F-2. August temperatures associated with low, medium, and high proportions salmonid segments among survey areas of the Chehalis River basin, 2014-2016. Data shown are mean (±one standard deviation) of temperature values for 200-m survey segments in each fish assemblage category. No 'low' salmonid segments were observed in the East Fork Satsop. Fish assemblage categories assigned to 200-m survey segments are low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids.

Survey Area	Low	Medium	High
Upper Chehalis (2014)			
Mean Daily Temperature (˚C)	20.6 (±0.5)	19.9 (±0.9)	18.6 (±0.9)
Maximum Daily Temperature (˚C)	22.7 (±0.4)	22.2 (±1.0)	21.0 (±0.8)
Minimum Daily Temperature (˚C)	18.8 (±0.8)	17.9 (±1.1)	16.6 (±1.0)
Proportion ≥ 18 ˚C	0.9 (±0.1)	0.8 (±0.2)	0.5 (±0.2)
South Fork Newaukum			
Mean Daily Temperature (˚C)	19.4 (±0.4)	18.2 (±0.7)	15.3 (±1.2)
Maximum Daily Temperature (˚C)	21.3 (±0.3)	20.6 (±0.6)	17.3 (±1.6)
Minimum Daily Temperature (˚C)	17.6 (±0.6)	16.1 (±0.8)	13.6 (±0.8)
Proportion ≥ 18 ˚C	0.7 (±0.1)	0.5 (±0.1)	0.1 (±0.1)
North Fork Newaukum			
Mean Daily Temperature (˚C)	19.5 (±0.5)	18.1 (±0.7)	15.6 (±0.7)
Maximum Daily Temperature (˚C)	21.2 (±0.2)	20.6 (±0.6)	17.3 (±0.9)
Minimum Daily Temperature (˚C)	17.8 (±0.7)	16.1 (±0.8)	13.9 (±0.8)
Proportion ≥ 18 ˚C	0.8 (±0.1)	0.5 (±0.1)	0.1 (±0.1)
East Fork Satsop			
Mean Daily Temperature (˚C)	NA	15.1 (±0.2)	14.7 (±0.7)
Maximum Daily Temperature (˚C)	NA	17.0 (±0.3)	16.2 (±0.9)
Minimum Daily Temperature (˚C)	NA	13.6 (±0.3)	13.3 (±0.6)
Proportion ≥ 18 ˚C	NA	0.0 (±0.0)	0.0 (±0.0)
West Fork Satsop			
Mean Daily Temperature (˚C)	19.8 (±0.6)	19.1 (±0.8)	17.6 (±1.2)
Maximum Daily Temperature (˚C)	21.7 (±0.6)	21.0 (±0.9)	19.5 (±1.2)
Minimum Daily Temperature (˚C)	18.0 (±0.6)	17.3 (±0.7)	15.9 (±1.1)
Proportion ≥ 18 ˚C	0.8 (±0.1)	0.7 (±0.1)	0.4 (±0.2)
West Fork Humptulips			
Mean Daily Temperature (˚C)	17.2 (±0.0)	17.4 (±0.7)	15.5 (±1.7)
Maximum Daily Temperature (˚C)	19.0 (±0.0)	19.5 (±0.9)	17.6 (±2.0)
Minimum Daily Temperature (˚C)	15.7 (±0.0)	15.8 (±0.5)	14.1 (±1.5)
Proportion ≥ 18 ˚C	0.4 (±0.2)	0.3 (±0.1)	0.1 (±0.1)

Appendix F-3. Habitat metrics summarized for low, medium, and high proportion salmonid segments among survey areas of the Chehalis River basin, 2014-2016. Data shown are mean (±one standard deviation) and range of habitat values for 200-m survey segments in each fish assemblage category. Fish assemblage categories assigned to 200-m survey segments are low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids.

Survey Area	Low	Medium	High
Upper Chehalis			
Wetted width (m)	24.6 (±5.5), 17.3-34.8	22.4 (±6.4), 11.5-39.3	16.6 (±5.7), 5.0-32.5
Maximum depth (m)	1.6 (±0.8), 0.6-3.5	1.6 (±0.9), 0.5-4.0	1.5 (±0.6), 0.6-3.3
LWD/100m	1.5 (±1.9), 0.0-6.6	1.9 (±1.6), 0.0-5.9	1.6 (±2.1), 0.0-13.4
Pool Count/100m	0.5 (±0.3), 0.0-1.1	0.6 (±0.5), 0.0-2.7	1.0 (±0.7), 0.0-3.2
Dominant substrate coarseness	2.7 (±0.5), 2.0-3.0	2.9 (±0.6), 2.0-5.0	3.2 (±0.6), 2.0-5.0
South Fork Newaukum			
Wetted width (m)	12.3 (±2.3), 8.3-18.2	12.6 (±2.5), 9.1-22.5	12.1 (±2.7), 6.5-19.8
Maximum depth (m)	1.7 (±0.6), 0.8-4.1	1.4 (±0.5), 0.6-3.5	1.4 (±0.4), 0.7-2.3
LWD/100m	4.0 (±5.3), 0.0-23.1	3.6 (±6.0), 0.0-32.8	3.5 (±4.0), 0.0-18.0
Pool Count/100m	1.0 (±0.5), 0.0-2.3	0.9 (±0.6), 0.0-3.2	1.3 (±0.6), 0.4-3.0
Dominant substrate coarseness	2.9 (±1.1), 1.0-4.0	3.1 (±0.9), 1.0-5.0	3.4 (±0.5), 3.0-4.0

Appendix F-3. Continued.

Survey Area	Low	Medium	High
North Fork Newaukum			
Wetted width (m)	9.6 (±2.3), 4.9-15.7	9.7 (±2.3), 5.2-15.1	9.0 (±2.3), 4.3-17.3
Maximum depth (m)	1.6 (±0.4), 0.8-2.7	1.3 (±0.4), 0.6-2.7	1.2 (±0.3), 0.6-2.1
LWD/100m	3.9 (±2.8), 0.0-11.7	4.2 (±4.9), 0.0-25.4	4.8 (±6.7), 0.0-42.6
Pool Count/100m	0.9 (±0.4), 0.4-1.8	1.1 (±0.7), 0.0-2.6	1.4 (±0.9), 0.0-5.6
Dominant substrate coarseness	1.8 (±1.0), 1.0-4.0	2.5 (±0.8), 1.0-3.0	3.4 (±0.7), 1.0-5.0
East Fork Satsop			
Wetted width (m)	NA	22.0 (±5.6), 14.6-30.4	19.3 (±6.9), 8.0-48.8
Maximum depth (m)	NA	1.7 (±0.6), 0.8-2.8	1.5 (±0.6), 0.7-4.5
LWD/100m	NA	6.4 (±5.3), 0.9-16.8	8.2 (±6.2), 0.4-30.8
Pool Count/100m	NA	0.5 (±0.4), 0.0-1.0	0.4 (±0.5), 0.0-2.0
Dominant substrate coarseness	NA	3.3 (±0.4), 3.0-4.0	2.8 (±0.9), 1.0-4.0

Appendix F-3. Continued.

Survey Area	Low	Medium	High
West Fork Satsop			
Wetted width (m)	21.8 (±5.4), 9.9-33.6	20.2 (±5.7), 10.6-38.2	16.6 (±5.4), 8.3-36.4
Maximum depth (m)	1.8 (±0.8), 0.5-4.4	1.7 (±0.8), 0.4-4.4	1.7 (±0.6), 0.5-3.3
LWD/100m	4.8 (±3.3), 0.0-12.9	3.4 (±3.0), 0.0-13.7	3.9 (±4.6), 0.0-26.0
Pool Count/100m	0.4 (±0.3), 0.0-1.3	0.4 (±0.4), 0.0-1.6	0.6 (±0.4), 0.0-1.8
Dominant substrate coarseness	2.8 (±0.4), 2.0-4.0	3.1 (±0.5), 2.0-4.0	3.4 (±0.6), 2.0-5.0
West Fork Humptulips			
Wetted width (m)	29.1 (±8.8), 20.3-37.9	25.2 (±8.2), 15.3-52.9	18.0 (±6.2), 7.9-42.4
Maximum depth (m)	2.1 (±0.1), 2.0-2.3	1.9 (±1.0), 0.4-6.0	1.8 (±0.7), 0.5-4.0
LWD/100m	5.5 (±0.3), 5.2-5.7	5.2 (±5.5), 0.0-29.7	7.8 (±12.3), 0.0-121.6
Pool Count/100m	0.9 (±0.0), 0.9-0.9	0.6 (±0.5), 0.0-2.3	0.9 (±0.6), 0.0-3.2
Dominant substrate coarseness	3.0 (±0.0), 3.0-3.0	3.0 (±0.4), 2.0-4.0	3.4 (±0.7), 2.0-5.0

Appendix G. Spatial distribution and summer temperatures associated with fish assemblages among survey years in the Upper Chehalis survey area.

Appendix G-1. Location of low, medium, and high proportion salmonid segments among years in the Upper Chehalis survey area, 2013-2016. Data are mean river kilometer (+ SD), river kilometer range, and proportion of 200-m survey segments each fish assemblage category. Fish assemblage categories assigned to 200-m survey segments are low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids.

Survey Year	Low	Medium	High
2013			
Mean (rkm)	171.1 (±3.0)	174.0 (±4.6)	190.9 (±7.4)
Range (rkm)	167.2-178.3	166.6-183.5	173.1-202.8
Proportion*	0.06	0.29	0.63
2014			
Mean (rkm)	172.8 (±3.5)	178.1 (±6.9)	190.3 (±9.0)
Range (rkm)	167.0-179.4	167.3-196.4	166.6-202.9
Proportion	0.12	0.28	0.6
2015			
Mean (rkm)	174.0 (±4.1)	179.0 (±7.2)	192.7 (±7.2)
Range (rkm)	166.6-182.9	167.0-192.7	167.8-202.9
Proportion	0.24	0.25	0.51
2016			
Mean (rkm)	174.1 (±4.3)	175.4 (±5.3)	192.0 (±7.1)
Range (rkm)	166.6-182.9	166.8-183.7	169.8-202.9
Proportion	0.17	0.26	0.57

*Does not sum to 1.0 because two segments were not surveyed due to access issues.

Appendix G-2. August temperatures associated with low, medium, and high proportions of salmonids among years (2014-16) in the Upper Chehalis survey area. Data shown are mean (±one standard deviation) values from 200-m survey segments in each fish assemblage category. No temperature data were available for 2013. Fish assemblage categories assigned to 200-m survey segments are low (0.0-24.9%), medium (25.0-75.0%), and high (75.1-100.0%) proportions of salmonids.

Survey Year	**Low**	**Medium**	**High**
2014			
Mean Daily Temperature (˚C)	20.6 (±0.5)	19.9 (±0.9)	18.6 (±0.9)
Maximum Daily Temperature (˚C)	22.7 (±0.4)	22.2 (±1.0)	21.0 (±0.8)
Minimum Daily Temperature (˚C)	18.8 (±0.8)	17.9 (±1.1)	16.6 (±1.0)
Proportion ≥ 18 ˚C	0.9 (±0.1)	0.8 (±0.2)	0.5 (±0.2)
2015			
Mean Daily Temperature (˚C)	20.3 (±0.5)	19.6 (±0.9)	18.3 (±0.6)
Maximum Daily Temperature (˚C)	23.0 (±0.5)	22.1 (±1.1)	20.6 (±0.9)
Minimum Daily Temperature (˚C)	17.9 (±0.6)	17.5 (±0.8)	16.3 (±0.5)
Proportion ≥ 18 ˚C	0.8 (±0.1)	0.7 (±0.1)	0.5 (±0.1)
2016			
Mean Daily Temperature (˚C)	20.2 (±0.5)	20.0 (±0.7)	18.2 (±0.7)
Maximum Daily Temperature (˚C)	23.2 (±0.6)	22.7 (±1.1)	20.6 (±1.0)
Minimum Daily Temperature (˚C)	17.8 (±0.7)	17.9 (±0.6)	16.2 (±0.6)
Proportion ≥ 18 ˚C	0.8 (±0.1)	0.8 (±0.1)	0.5 (±0.1)