Distribution of Juvenile Salmonids and Seasonally Available Aquatic Habitats within the Lower Smith River Basin and Estuary, Del Norte County, California

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FINAL REPORT TO THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
FISHERIES RESTORATION GRANTS PROGRAM
GRANTEE AGREEMENT: P1310518

ON BEHALF OF

THE SMITH RIVER ALLIANCE

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Summary

Understanding the distribution and function of non-natal rearing habitats available to juvenile salmonids has become vital to the management, protection, and restoration of salmonid populations occurring throughout the Pacific Northwest. The Smith River maintains moderately productive salmonid populations due to much of the basin having resilient habitats and exceptional water quality. However, many habitats in the lower river and estuary have been severely modified or lost over the past century through reclamation and flood control measures. Additionally, concern over long-term pesticide use on lily bulb fields occurring throughout the northern portion of the estuary has initiated limited water quality testing with documented toxicity to water flea reproduction varying spatially and temporally. Prior to this study, scant information was available describing the spatial and temporal distribution of juvenile salmonids (especially coho salmon) rearing during the summer and winter months throughout the lower Smith River and its estuary. To better understand the seasonal spatial structure of juvenile salmonids occurring within the study region, we developed a rapid survey approach to efficiently sample a large fraction of habitats to estimate seasonal salmonid occupancy patterns while accounting for individual species detection rates from multiple sampling methodologies.

During the summer of 2014 we surveyed a total of 101 habitats across 17 reaches representing 58% (35 km) of the total estimated summer salmonid rearing habitat in stream kilometers. Estimated summer probability of occupancy (ψ) for coho salmon equaled 0.41 (SE= 0.06), (detection; p=0.76). Other salmonids were also widespread throughout the summer sampling area with site occupancy probabilities equaling 0.44 (SE= 0.06) for Chinook salmon, 0.82 (SE= 0.04) for young-of-year trout spp., 0.71 (SE= 0.07) for 1+ trout spp., and 0.26 (SE= 0.06) for adult coastal cutthroat trout. Model selection provided evidence that summer coho salmon site occupancy was strongly influenced by site cover complexity and the reach-level maximum water temperatures based on the top AIC ranked model. However, the influence of water temperature was likely a result of most fish observations occurring in the mainstem Smith River where water temperatures were much warmer than isolated tributaries having dry channel segments and a general lack of fish passage. Additionally, large wood debris counts and site depth moderately influenced coho salmon occupancy probabilities in close competing models. We measured a total of 3.5 km of dry channel in tributaries representing 10% of the summer sampling frame; these observed conditions were likely exacerbated by the cumulative effects of three continuous years of an exceptional drought. During the winter we surveyed a total of 173 habitats across 17 reaches representing 45% (30.6 km) of the total winter sampling frame using a variety of sampling methods. Estimated winter probability of occupancy for coho salmon was low equaling 0.16 (SE= 0.07) with moderate detection probabilities (p= 0.33 to 0.40). Winter occupancy probabilities for other salmonids were also low equaling 0.15 (SE= 0.04) for 1+ trout spp., and 0.04 (SE= 0.02) for adult coastal cutthroat trout. However, our winter sampling methods were chosen to maximize coho salmon detections and may limit our ability to detect other species (e.g. large adult coastal cutthroat trout cannot fit into minnow traps). Model selection provided evidence that winter coho salmon occupancy probabilities were positively influenced by the amount of cover area, the amount of turbulent water flow, and the sites cover quality rating. Additionally, site maximum depth was negatively associated with coho salmon occupancy.

In addition to sampling various reaches during the summer and winter periods, we also monitored 24 select rearing habitats "apex monitoring stations" during both seasons to better understand temporal occupancy patterns and colonization and extinction processes of salmonids as they relate to measured changes in habitat quality. During the summer a total of 21 of 24 sites were occupied by coho salmon and occupancy probabilities were generally stable across the four sampling periods ranging from 0.80 (SE= 0.08) in June to 0.72 (SE= 0.10) in September. Average water temperatures from thermographs deployed at all sites occupied by coho salmon equaled 21.4 °C, range: 19.3 to 21.9 °C.

These water temperatures are exceptionally high relative to other studies defining the preferred thermal niche for coho salmon. Model selection indicated site water temperature did not influence occupancy probabilities, but aided in explaining site extinction estimates. By using models controlling for site extinction processes, we found the amount cover (meters^3) at each site created by beavers to be the best predictor of site occupancy during the summer period. During the winter we observed coho salmon at eight of 24 apex monitoring stations during at least one of four sampling periods. Coho salmon site occupancy estimates were much lower than observed during the summer but remained stable across the four sampling periods ranging from 0.19 (SE= 0.11) in early January to 0.20 (SE= 0.10) in Mid-March. Model selection indicated the addition of beaver created cover (meters^2) preformed slightly better than the null model having no covariates. Many factors likely influence emigration by juvenile coho salmon from natal to non-natal rearing habitats including, but not limited to: parental run size, natal stream cohort survival and density, and annual hydrologic regime. Understanding these processes requires multiple years of data collection across a range of both environmental conditions and annual cohort abundances. In addition to defining winter coho salmon distribution we marked a total of 77 coho salmon with PIT tags throughout the winter apex monitoring stations to assess site fidelity in non-natal rearing areas. Nine recaptured individuals at one site had minimum residence times averaging of 26 days (22 – 45 days) indicating some juvenile coho salmon maintained residence in the coastal plain throughout the winter.

Although not directly measured, we observed strong anecdotal evidence that North American beavers created or characterized the majority of salmonid rearing habitats occurring throughout the study area during the summer and winter. The Smith River appears to have a very active and widespread beaver population, and we suggest their role in shaping habitats within mainstem coastal rivers is largely underappreciated as most beaver-salmonid interaction studies have focused on the benefits of lentic habitats formed by beaver dams. Future work should focus on the role beavers have on characterizing riparian habitats in coastal rivers. We also found most salmonid rearing areas within the mainstem were either off the main channel in backwaters or were defined by a hydrological control structure such as bedrock or large wood debris. Edge habitats with salmonids typically had dense overhanging vegetation with dead branches submerged in the water column.

In addition to defining fish distribution, we measured the extent of the salt wedge occurring in the Smith River estuary during the summer and winter to better define the distribution of seasonal freshwater rearing habitats. During the summer, we found the Smith River mainstem salt wedge extended 7.65 km upstream from the mouth and into Rowdy Creek 0.37 km above its mouth. These data indicate a much larger upstream saltwater intrusion is occurring in the estuary during the summer low flow period than previously measured by Mizuno (1998). In contrast, we found most of the estuary to be freshwater during the winter with the salt wedge extending up the main Smith River channel approximately 0.9 km from the mouth. The dramatic contrast of the seasonal salt wedge location highlights the importance of defining hospitable rearing habitats for juvenile salmonids based on season. During this investigation we also found multiple patches of native eelgrass (*Zostera marina*) totaling 1.67 acres in area located in sheltered areas of the sublittoral zone of the lower Smith River estuary. To our knowledge this is the first description of this flowering plant occurring in the Smith River despite its role as a keystone species in marine and estuary ecosystems.

We mapped the distribution of reed canary grass (*Phalaris arundinacea*) throughout the study area and found many stream channels completely filled with dense patches including Morrison Slough, Morrison Creek, Yontocket Slough, and Tryon Creek. Reed canary grass can have profound negative effects on stream dissolved oxygen, habitat availability, and fish migration. We found many locations with dense patches of reed canary grass having dissolved oxygen concentrations below the lethal limits for salmonids indicating management prescriptions should be adopted to restore perennial channels important to salmonids by eliminating and reducing the spread of reed canary grass. We also found two small patches of invasive yellowflag iris (*Iris pseudacorus*) occurring in Morrison Creek an important coho salmon stream, and suggest these small populations should be removed before spreading throughout the channel. Last, we detected New Zealand Mud Snails (*Potamopyrgus antipodarum*) at 14 locations in the lower estuary, with the furthest upstream location occurring in Morrison Slough at 7.4 km upstream of the Smith River mouth. These observations represent the most thorough spatial distribution information for this invasive snail in the Smith River to date and suggest the animal is still spreading throughout calm and protected channels within the estuary. Little can be done to stop the spread of this species at this time but we suggest the spread is limited to the coastal plain given the dramatic loss of slow water silt dominated habitats as the stream increases gradient and becomes a cobble and boulder dominated channel just above the estuary.

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Looking south above the estuary and mouth of the Smith River, July 2015. Note: Pacific Ocean is to the right of the picture. Photo: *Justin Garwood*

Introduction

The spatial arrangement of resources across a landscape can have profound effects on species distributions (Dunning et al. 1992, Ricketts 2001). Salmonids have complex life histories within freshwater ecosystems requiring a variety of complementary resources that are spatially and temporally dynamic. The spatial structure of a population refers both to the spatial distributions of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). Spatial structure is important for assessing population viability because understanding extinction risk for population abundance trends occurs at longer timescales than measured changes in the spatial arrangement of the population. Understanding patch use, patch size, patch connectivity, and patch colonization and extinction processes of the population also helps managers define source patches while also protecting or restoring isolated areas that are much more vulnerable to extinction (Adams et al. 2011).

This study was designed to assess current spatial structure of salmonids occurring in unique non-natal rearing habitats that have yet to be studied in detail within in the lower Smith River and estuary. The Smith River coho salmon (*Oncorhynchus kisutch*) population is identified as a core independent population within the Southern Oregon/Northern California Coast Evolutionary Significant Unit (SONCC ESU) and is the main target species for this study. Low abundance and productivity of Smith River coho salmon have put them at risk of extinction (NOAA 2014) and they are listed as threatened under the endangered species act both federally (ESA) and in California (CESA) (Federal Register 1997, CDFG 2002). Recent studies have shown coho salmon exist in streams throughout the lower Smith River basin and in two remote sub-populations occurring in the headwaters of the north fork and south fork drainages (Garwood and Larson 2014, Garwood et al. 2014).

Estuaries, sloughs, backwaters, off channel ponds, and beaver structures occurring in lower rivers and estuaries are productive habitat features for rearing juvenile coho salmon throughout the Pacific Northwest (Wigington et al. 2006, Henning et al. 2006, Wallace and Allen 2009, Koski et al. 2009). Unlike the upper Smith River basin, the lower Smith River and its estuary have been highly modified by anthropogenic activities (Voight and Waldvogal 2002, 2014 NOAA Coho Salmon Recovery Plan). Major factors identified as limiting survival and viability of this population include a lack of floodplain connectivity, lack of channel structure, limited off-channel habitats, migration barriers, and reduced water quality from pesticide use and agricultural runoff (2014 NOAA Coho Salmon Recovery Plan).

Results from this baseline assessment provide detailed information regarding the distribution, seasonal occurrence, and habitat associations of juvenile coho salmon and other salmonid species. Identifying limiting factors and uncertainties associated with juvenile coho salmon rearing habitat in the lower Smith River basin will aid in prioritizing habitat restoration and recovery of the species. For example, California Department of Fish and Wildlife has been monitoring coho salmon use of the stream-estuary ecotone within Humboldt Bay for many years (Wallace and Allen 2009, Wallace et al. *in review*). Information gathered from the Humboldt Bay study has directly informed the planning and design of many successful salmonid habitat restoration projects. We hope the results from this project will benefit planning and restoration goals that are greatly needed throughout the lower Smith River and its estuary.

Materials and Methods

Study Area

Geology and Hydrology

The Smith River basin is the northern most coastal watershed in California meeting the Pacific Ocean six km south of the Oregon border (Figure 1) and is located on the upper plate of the Cascadia subduction zone. The Smith River coastal plain consists of two formations: the Saint George formation (Roberts et al. 1967), which is 350 – 400 ft thick (Monroe 1975) formed during the late Miocene from bioturbated marine sandstone and sandy mudstone mixed with pebbles, carbonized wood, and fragmented molluscan shells (Delattre and Rosinshki 2012); and the Battery formation (Roberts et al. 1967), which is approximately 35ft thick (Monroe 1975 and formed during the late Pleistocene from marine terrace deposits mixed with dune sands and alluvial gravels (Delattre and Rosinshki 2012). These formations were shaped by alluvium deposited over land historically connected to the coast range which separated and sank into the sea (Monroe 1975). The alluvium was further molded and smoothed by wave actions and ocean currents. Since formation of the plain the Smith River channel has eroded creating the current day coastal terrace. Above the coastal plain, approximately where Highway 101 crosses the river, the active channel is surrounded by steeper forested terrain in the Franciscan formation formed during the Jurassic period (Roberts et al. 1967).

The Smith River basin receives an impressive 234.4 cm of rainfall annually at the Gasquet Ranger Station (CDEC 2013). Precipitation is usually delivered during large winter storm events with 84% of annual average rainfall received from October to March (CDEC 2013). The sparsely vegetated and shallow rocky soils throughout most of the interior basin hold little precipitation and streams directly respond with highly variable flows. Average annual peak flow from 1932 to 2013 is 82,363 cubic feet per second (cfs) (USGS 2014) resulting in an estuary largely formed by river dominated hydrological processes, particularly during the winter months. As flow reaches the minimum during the late summer (mean monthly August flow of 338 cfs), ocean tides push saltwater upstream resulting in seasonally varied concentration and extent of mixing ocean-freshwater and salt wedge (Mizuno 1998). These conditions result in the density and diversity of salmonids and other biota to seasonally vary and are correlated with salinity, water quality, nutrient concentration, grass, and algal cover (Parthree 2004, Day et al. 2013).

Lower Estuary

The mouth of the Smith River is narrow and remains open year-round with the north bank abutting an elevated basalt outcrop and terrace. The south bank is a thin strip of shifting sand dunes generated from the ocean wave slope extending south to Point St. George. In portions within 500 meters of the mouth, the channel is deep (>5 meters) and contains an abundance of massive submerged marine rocks and sub-tidal basalt terraces; some elevated at low tide forming patchy isolated tide pools. The low gradient of the mainstem causes deposition of mobilized sediment delivered from the upper basin resulting in a stream channel morphology characterized by an alluvial fan bedform with a large floodplain. The channel in the lower estuary is broad and generally shallow primarily dominated by poorly sorted granule and pebble sized sediments (Mizuno 1998). Fines, silt, and sand are minimal in the lower estuary, except along the west bank which is composed of sand dunes (Mizuno 1998). However, silt deposits in protected areas along the north bank near the old Ship Ashore boat basin and ramp maintain dense patches of native eelgrass (*Zostera marina*) (Appendix A).

Levees and Dikes

Like other coastal basins throughout coastal California and the Pacific Northwest, the northern portion of the Smith River estuary has been highly modified through the construction of levees, dikes, and

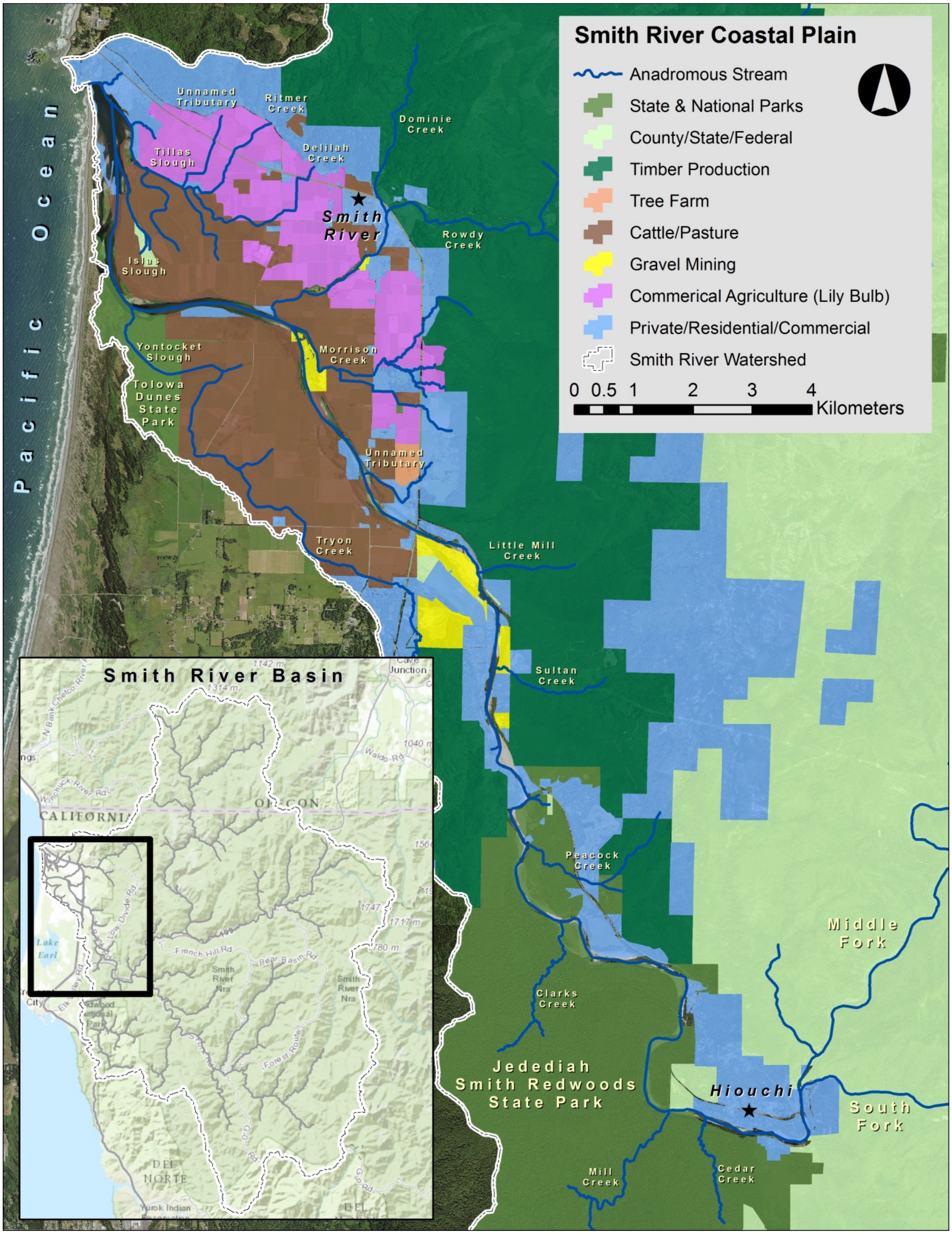

Figure 1. Map of the study area with general land use and ownership throughout the Smith River coastal plain, Del Norte County, California. The general study area extends from below the main river forks in Hiouchi to the mouth and includes major tributaries in the coastal plain: Morrison Creek, Rowdy Creek, Tryon Creek, Yontocket Slough, Tillas Slough, Islas Slough, and various unnamed streams below HWY 101.

drainage ditches throughout the latter half of the 20th century for the purpose of flood control and floodplain reclamation for agricultural uses (Figure 2, Appendix B). As a result, many small drainages and sloughs in the northern portion of the estuary up to the mouth of Rowdy Creek severed from the main estuary channel and filled in based on the loss of riparian vegetation and slough channels between the images in Figure 2 and Appendix B. Tide gates occur at three locations, two along the main levee, and one on an interior dike (Figure 2). The Smith River levees are privately owned and thus not managed by the Army Corps of Engineers.

The Sloughs

Three major sloughs remain in the Smith River estuary including Tillas, Islas, and Yontocket (Figure 1). Tillas slough is the largest, with its mouth located 1.2 km upstream of the Smith River mouth. The main levee crosses Tillas slough (Figure 2) near its mouth and controls flooding along the northeast floodplain of the lower Smith River. However, the two large pipes (>1 m diameter) under the levee have rusted out and one of the doors has completely fallen off. This has allowed for unregulated daily tidal water exchange above and below the levee likely for decades. Delilah Creek, Ritmer Creek, and unnamed tributary enter Tillas slough 0.43 km upstream of the levee/dike behind a second functioning tide gate largely blocking tidal and saltwater intrusion during summer months (Figure 2). The substrate throughout Tillas slough is primarily silt. Pasture lands and lily bulb fields make up the upland areas that drain into the slough. The levee along the western margins of Islas slough is located 2.1 km upstream from the Smith River mouth (Figure 2). The mouth of Islas slough has mixed cobble gravel substrate with deposited silts dominating the upper slough. Based on the U.S. Forest Service 1942 aerial image, taken on 9/11/1942 with daily average flow of 283cfs, Islas slough historically encompassed approximately 71 acres and was a large side channel feature commonly connecting during winter high flows (Figure 2, Appendix B). Based on the 2012 National Agriculture Imagery Program (NAIP) image, taken on 5/31/2012 with a daily average river flow of 1240cfs, Islas slough is now only approximately 12 acres (Figure 2). This reduction in slough area of approximately 83% is due to the levee preventing the mainstem river from flowing through and scouring this area during winter storm events. Last, Yontocket slough, a remnant river channel, is located on the south bank 4.0 km upstream from the mouth of the Smith River (Figure 1). The downstream half of the slough is part of the Tolowa Dunes State Park and the upstream half is surrounded by pasture lands (Figure 1). Tryon Creek flows into the slough 2.4 km upstream from the sloughs mouth. Culverts across Pala Road, 0.4 km upstream from the mouth, have led to increased sedimentation in the slough, aided in the spread of reed canary grass, (*Phalaris arundinacea*), and hinder fish passage except during high flow events (Love 2006). Pala Road is built on an elevated prism that blocks floodwaters from inundating the upper slough during moderate flooding. However, during large flows, the road, slough, and surrounding low laying fields flood. A barrier remediation project at Pala Road and the slough has been funded and project construction is currently pending.

Middle Estuary

From the mouth of Islas slough to Yontocket slough, the estuary is wide, braided, and shallow with mixed gravel. Primarily along the northeast bank of the estuary are tidal mudflats/backwaters. These features are dominantly composed of silt deposits and large wood debris deposited during winter storm events. Continuing upstream the river turns east as a single deep (>5m) main channel with a sandy bottom near the "sand hole". Entire Shore Pine and Sitka Spruce trees commonly fall into the channel on the south west bank, due to dune erosion, and provide complex instream habitat used by salmonids (*this study*) and by Pacific herring as spawning substrate (Z. Larson, pers. comm.). Upstream from the mouth of Yontocket slough is the cattle crossing riffle where the substrate changes from sand and pebble to predominantly cobble with smaller substrates along the margins. The majority of the floodplain throughout this section is terraced three to five meters above the channel with active erosion (bank calving) more common along the south bank. The tidal influence continues upstream to

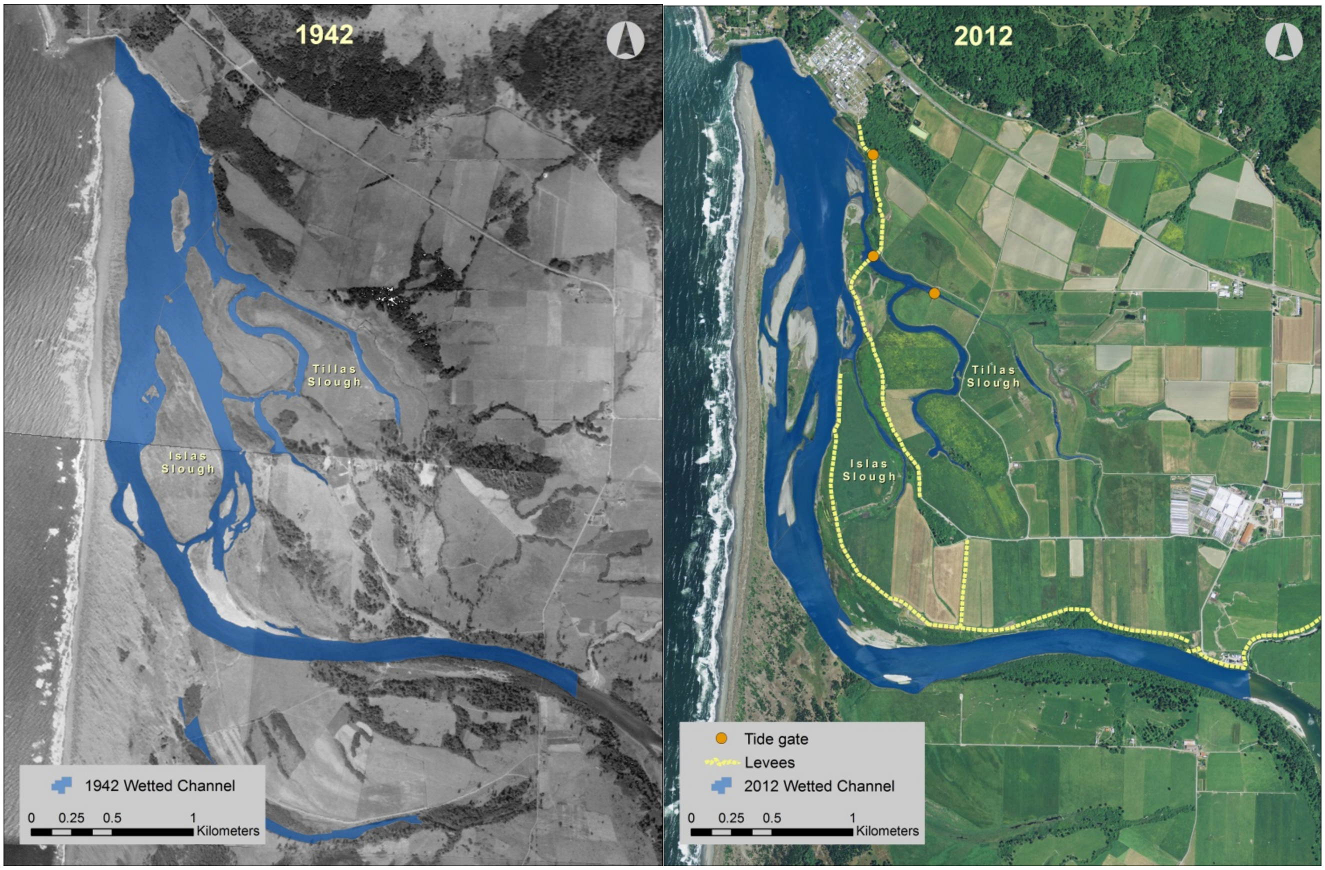

Figure 2. Historic (1942) and current view (2012) of the Smith river plain and estuary, Del Norte County, California. Blue shaded areas in each image depict the estimated active channels at the time the image was collected. Note in 1942 the upper end of Islas Slough was connected to the Smith River and the lower end was connected to Tillas Slough. Also much of the smaller stream and slough channels between Rowdy Creek and Islas slough were still present in 1942 identified by dense strips of riparian vegetation that was later converted to pasture. Construction of private levees began in the 1950s and tide gates were installed after 1965 for the purpose of flood control and land reclamation. Approximate locations of levees were mapped using the 2010 NOAA coastal liDAR dataset.

the Bailey Riffle Crest 8.5 km upstream from the mouth. Overall, the tidal range in the estuary can fluctuate by 9.0 feet (Monroe 1975). Much of the riparian vegetation is composed of willow, alder, and cottonwood adjacent to cattle pastures lining both north and south banks.

Upper Estuary and Tributaries

Besides the sloughs, two major tributaries enter the Smith River estuary including Rowdy Creek and Morrison Creek (Figure 1). Rowdy Creek has a levee on its western bank and the banks have been hardened with rip rap in various locations resulting in a simplified and high-energy channel (James 2015). Early aerial images of the Rowdy Creek channel within the coastal plain show the active channel was braided in many locations with the mouth having a large alluvial fan. Morrison Creek enters the estuary directly above the mouth of Rowdy Creek through a large backwater channel extending ~ 600 meters (Figure 1). Morrison Creek has been channelized and straightened throughout the coastal plain with many tributaries converted to drainage ditches along pasture fields and along Fred Haight Drive. Additionally, a dyke was constructed along Fred Haight drive to build a large private pond capturing multiple springs that originally flowed into Morrison Creek. The combination of undersized culverts, and a constricted channel, coupled with a sharp unnatural channel bend maintained at Fred Haight

Drive, likely contribute to sediment collection and localized flooding. The main Smith River channel from the mouth of Rowdy Creek to the Highway 101 bridge substantially increases in gradient resulting in long riffle and run habitats. The "baily hole" is the only large deep pool in this section and is dominated by bedrock substrate. Much of the riparian vegetation is composed of willow, alder, and cottonwood adjacent to cattle pastures lining both north and south banks.

Lower Mainstem Smith River (Highway 101 to Hiouchi)

Upstream from Highway 101 to the confluence of the South Fork and Middle Fork, the active channel meanders through alluvial point bars and bedrock creating side channels and large bends which form many large backwaters and alcoves. Cobble and gravel dominate the substrate throughout much of the channel with areas of bedrock forming deep pools that collect finer sediments. Tributaries within this section include Little Mill Creek, Sultan Creek, Peacock Creek, Clark's Creek and smaller seeps and streams such as Camp 6 Creek (Figure 1) which provide cold water inputs during the summer and off-channel rearing habitat for juvenile salmonids during the winter. Willow and alder grow within the active channel stabilizing sediments and provide riparian habitat. Groves of black cottonwood are common along the upper portions of the floodplain and redwoods become the dominant riparian vegetation between Peacock Bar and Hiouchi. Many riparian areas below residential structures have been altered to increase views and access to the river.

Land Use

Pasture predominantly used for cattle ranching and dairy production makes up approximately 58% of the land use within the coastal plain below Highway 101, followed by 26% commercial lily bulb production, 8% residential/ commercial, and 8% Tolowa Dunes State Park (Figure 1). Historic gravel extraction has occurred on the majority of the gravel bars in the mainstem extending from Yontocket slough upstream to Sultan Creek as well as in sections of Rowdy Creek (Larue 1998). Currently the main permitted gravel extraction activity within the active channel occurs just upstream of Highway 101 with a smaller operation occurring below the mouth of Sultan Creek (Figure 1). Upstream from Highway 101 to the confluence of the South and Middle forks the banks of the mainstem are lined by residential, State and National Parks Property and National Forest Lands (Figure 1).

Previous Estuarine Studies

Few directed studies have characterized the biodiversity, salmonid life histories, or habitat quality within the Smith River estuary despite this portion of the basin being the most modified through anthropogenic activities. A brief description of fish diversity in the estuary is provided by Monroe (1974) who noted 24 species. However, no actual fish sampling was described or indicated in the document, as such the species list cannot be fully substantiated. A seine study conducted by Mizuno (1998) added six more fish species to Monroe's list resulting in a total of 30. A Fyke net study by Parthree (2004) identified a total of 26 fish species using two major slough habitats (Tillas and Islas sloughs). Overall, a total of 38 fishes have been described in the estuary (Table 1) and many have been confirmed from multiple observations. Parthree (2004) determined life history patterns for a subset of fish species, including recruitment, dispersal, duration of use, and relative abundance. Last, studies by Zajanc (2003), Quinones (2003), and Quinones and Mulligan (2005) determined life history patterns and habitat use of juvenile salmonids rearing along the mainstem Smith River within the estuary. Zajanc (2003) conducted a mark-recapture study on Chinook salmon (*Oncorhynchus tshawytscha*) during the summer (and early fall) months in 1998-2000 to assess the rearing duration and seasonal changes in size. Mean residency time from June to early October was found to be 25 days. The study also concluded that mean residency time was lower in June and July, with a range from 8 -14 days, compared to August with a high of 38 days. Long estuary residency time of released Rowdy Creek

Table 1. Annotated list of 38 documented fish species occurring in the Smith River, Del Norte County, California. All supporting evidence used to compile this list was derived from original data sources.

Common name	Species	Family	Source	This Study (Summer)	This Study (Winter)
Green sturgeon	*Acipenser medirostis*	Acipenseridae	A, B		
Topsmelt	*Atherinops affinis*	Atherinidae	A, C, D		
Jacksmelt	*Atherinops californiensis*	Atherinidae	C, E		
Speckled sanddab	*Citharichthys stigmaeus*	Bothidae	C		Yes
Klamath smallscale sucker	*Catostomus rimiculus*	Catostomidae	C	Yes	Yes
American shad[1]	*Alosa sapidissima*	Clupeidae	A		
Pacific herring	*Clupea harengus*	Clupeidae	A, C, D, E		
Pacific sardine	*Sardinops sagax*	Clupeidae	C		
Sharpnose sculpin	*Clinocottus acuticeps*	Cottidae	C, E		
Coastrange sculpin	*Cottus aleuticus*	Cottidae	D, N	Yes	Yes
Prickly sculpin	*Cottus asper*	Cottidae	A, C, D, E, N	Yes	Yes
Staghorn sculpin	*Leptocottus armatus*	Cottidae	C, E	Yes	Yes
Cabazon	*Scorpaenichthys marmoratus*	Cottidae	C		
Redtail surfperch	*Amphistichus rhodoterus*	Embiotocidae	A		
Shiner surfperch	*Cymatogaster aggregata*	Embiotocidae	A, C, D		Yes
Striped surfperch	*Embiotoca lateralis*	Embiotocidae	C, E		
Northern anchovy	*Engraulis mordax*	Engraulidae	A, C, E		
Threespine stickleback	*Gasterosteus aculeatus*	Gasterosteidae	A, C, E	Yes	Yes
Tidewater goby[2]	*Eucyclogobius newberryi*	Gobiidae	E, F, G		Yes
Whitebait smelt	*Allosmerus elongatus*	Osmeridae	C		
Surf smelt	*Hypomesus prefiosus*	Osmeridae	A, C, D, E		Yes
Night smelt	*Spirinchus starksi*	Osmeridae	C		
Eulachon[2]	*Thaleichthys pacificus*	Osmeridae	A		
Pacific lamprey	*Lampetra tridentata*	Petromyzonidae	A, C	Yes	
Western brook lamprey	*Lampetra richardsonii*	Petromyzonidae	H		
Saddleback gunnel	*Pholis ornata*	Pholidae	A, C, D, E		
English sole	*Parophrys vetulus*	Pleuronectidae	E		
Starry flounder	*Platichtys stellatus*	Pleuronectidae	A, C, D, E	Yes	
Sand sole	*Psettichthys melanostictus*	Pleuronectidae	C		
Coastal cutthroat trout	*Oncorhynchus clarki clarki*	Salmonidae	A, C, D	Yes	Yes
Pink salmon	*Oncorhynchus gorbuscha*	Salmonidae	I		
Chum salmon	*Oncorhynchus keta*	Salmonidae	A, H, J, K		
Coho salmon[2]	*Oncorhynchus kisutch*	Salmonidae	A, C, L	Yes	Yes
Steelhead	*Oncorhynchus mykiss*	Salmonidae	A, C, D, E, M	Yes	Yes
Sockeye salmon	*Oncorhynchus nerka*	Salmonidae	N		
Chinook salmon	*Oncorhynchus tshawytscha*	Salmonidae	A, C, D, E, M	Yes	Yes
Black rockfish	*Sebastes melanops*	Scorpaenidae	A		
Bay pipefish	*Syngnathus leptorhynchus*	Sygnathidae	A, C	Yes	

Annotated list of sources; refer to literature cited section for full document citations:
***A:** Monroe, G. et al. (1975); **B:** Larson, Z. (2014); **C:** Parthree, D. (2004); **D:** Zajanc, D. (2003); **E:** Mizuno, E. (1998); **F:** Dawson, M. et al. (2001); **G:** Chamberlain, C. (2006); **H:** Howard, C. and R. McLeod (2005); **I:** [CDFW files, Arcata, CA] Newspaper story and captured specimen photograph (1964); **J:** Waldvogel, J. (2006); **K:** Garwood, J. et al. (2014); **L:** Garwood, J. (2012); **M:** Quinones, R. (2003); **N:** Garwood, J. and M. Larson (2014); **N:** White, J. and B. Harvey (1999).*

[1]non-native species; [2]Protected under Federal and or State Endangered Species Acts

hatchery fish was also documented with recaptures 86 days and 104 days post hatchery release in 1999 and 2000, respectively. Quinones (2003) and Quinones and Mulligan (2005) focused on habitat use of juvenile Chinook salmon, juvenile trout spp. (coastal cutthroat trout [*Oncorhynchus clarki clarki*] and steelhead [*Oncorhynchus mykiss*]). These studies found salmonids appeared to select for habitats with overhanging vegetation highlighting the importance of maintaining riparian vegetation.

Previous Coho Salmon Observations in the Lower River and Estuary

Few anecdotal observations indicate juvenile coho salmon utilize the Smith River coastal plain and estuary. Kimsey (1953) reported rescuing 210 juvenile coho salmon from Morrison Creek during the summer of 1952. A game warden incident report produced by McCormick (1957) estimated approximately 2,000 young-of-year coho salmon were killed in the spring of 1957 from a copper sulfate spill in Morrison Creek. Monroe (1975) mentions coho salmon use the Smith River estuary but does not provide any data or sampling details. A two-year study sampling fishes in Tillas and Islas sloughs (Parthree 2004) captured one juvenile coho in Tillas Slough, and two coho salmon in Islas Slough (Figure 3). Sampling for this study was conducted during times, between mid-March and December, when juvenile coho salmon abundances in the estuary are expected to be at their lowest. Furthermore, the sampled sloughs were near the river mouth, where high salinities are likely intolerable to rearing coho salmon (Mizuno 1998, Wallace and Allen 2009) during these months. Garwood (2012) describes juvenile coho salmon occurring in Dominie Creek in 2001 and 2003, and summarizes coho salmon occurrence in Rowdy Creek for at least 28 individual years from 1938 to 2004. Sampling in a newly constructed backwater on Reservation Ranch bar (Figure 3) yielded 16 juvenile coho salmon over 7 sampling periods between March and May, 2007 (Z. Larson, pers. comm.). Last, studies by Garwood and Larson (2014) and Garwood et al. (2014) describe the extensive use of the lower Smith River from Mill Creek to the estuary by juvenile coho salmon during the summers of 2012 to 2014.

Sampling Approach

We implemented three sampling approaches to assess juvenile salmonid spatial structure and habitat use in the lower Smith River and estuary during the summer and winter periods. These two periods were chosen based on having distinctly contrasting habitat availabilities and unique salmonid life history requirements. Sampling methods varied by season and basin location due to habitat and water quality conditions.

Spatial Structure Sampling Designs

Spatial Structure Sample Frame Development

We developed two reach-based salmonid sampling frames to define the potential spatial extents of all summer and winter juvenile coho salmon rearing habitats specific to the lower Smith River basin. The primary difference between the summer and winter sampling frames was based on seasonal habitat availability, with the winter period having more open water habitats in perennial streams and ephemeral streams or seasonal emergent wetlands having persistent flow. Prior to this project, Garwood and Larson (2014) determined the likely extent of anadromous waters for all anadromous fish species throughout the Smith River basin using a combination of empirical fish and barrier data coupled with a GIS model that incorporated physical stream attributes (Garwood and Ricker 2011). Much of the resulting anadromous distribution has been ground-truthed for accuracy over the previous three years during spawner surveys and summer spatial structure surveys (Garwood and Larson 2014). However, due to limited resources and occurring outside of the range of other study components, a large fraction of the estuary portion was not ground-truthed prior to this study. We largely relied on available information for this portion of the sample frame and ground-truthed areas where we were granted access for both the summer and winter survey periods. Sample frames will

Figure 3. Coho salmon observations from GRTS, apex stations, incidental, spatial structure, and spawner surveys from 2001 to 2015 throughout the lower Smith River and coastal plain, Del Norte County, California. Observations are divided by summer and winter sampling seasons. Note: single locations may represent multiple observations between different dates and years. Reach numbers are labeled in blue.

likely be further refined in this region as we conduct more reconnaissance throughout the area but adjustments are generally expected to be minimal.

Once the spatial extents were defined for each frame we divided the available stream area into reaches. We designed reaches to start or end at tributary junctions or bridge crossings for navigational purposes, with terminal reaches ending at permanent juvenile salmonid migration barriers in non-natal rearing streams. We then divided reaches into two categories depending on the length of channel. Primary reaches were designed to be between 1- 3.5 km in length to assure a survey crew could finish a survey within two days. Reaches less than one kilometer in length were defined as 'sub-reaches' and were connected to the nearest primary reach. Sub-reaches are surveyed by implication if the connected primary reach is selected in the sample draw. This strategy assures sub-reaches are sampled in an economical fashion by grouping survey effort rather than sending a crew out to a remote location to sample a short reach. Some reaches were already defined based on other concurrent monitoring projects in the basin (*see* Garwood and Larson [2014]) allowing us to maintain the same spatial extents for areas having multiple overlapping salmonid monitoring components.

Spatial Structure Sample Frames

Our summer sample frame construction resulted in 31 primary reaches and one sub-reach totaling 60.8 km within the lower Smith River and coastal plain (Table 2, Figure 4). Our winter sample frame construction resulted in 33 primary reaches and 10 sub-reaches totaling 67.6 km within the lower Smith River and coastal plain (Table 2, Figure 5). These sample frames collectively represent 100% of the known available coho salmon habitat within the study area during the summer and winter months highlighting our ability to survey the entire region through the use of various sampling techniques.

Table 2. Various study components used to assess seasonal juvenile coho salmon distribution and habitat throughout the lower Smith River basin, coastal plain, and estuary, Del Norte County, California. Total stream kilometers are included for both the summer and winter spatial structure sample frames based on seasonal differences of available rearing habitats. Stream kilometers were calculated from the National Hydrological Dataset, 24K routed hydrography, and likely underestimate actual stream channel sinuosity.

Study Component	Sample Frame Size	Survey Dates	Metrics
Summer Spatial Structure	60.8 km (32 Reaches)	June – August 2014	Seasonal distribution/ occupancy/ proportion of area occupied
Winter Spatial Structure	67.6 km (43 Reaches)	January – March, 2015	Seasonal distribution/ occupancy/ proportion of area occupied
Summer Apex Monitoring Stations	24 stations	June – August, 2014	Summer occupancy/ immigration/ emigration
Winter Apex Monitoring Stations	24 stations	January – March, 2015	Winter occupancy/ immigration/ emigration
Water Quality	Throughout study area (73.1 km)	2012, 2014 – 2015	Seasonal trends in water temperature, salinity, dissolved oxygen
Incidental Surveys and Literature	Throughout study area (73.1 km)	2001 – 2015	Distribution/ range

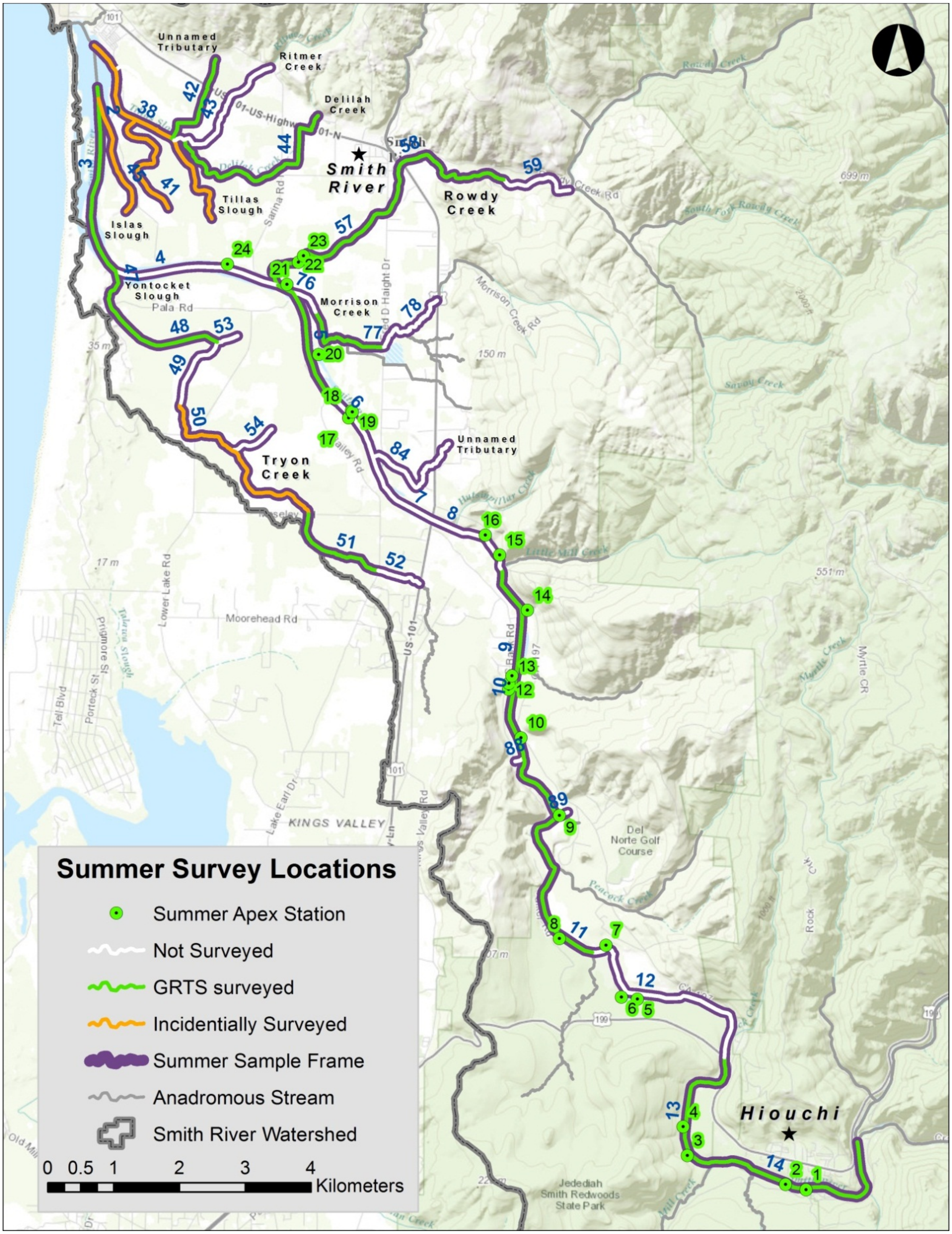

Figure 4. Summer surveys at GRTS, apex stations, and incidental locations across the Smith River coastal plain, Del Norte County, California. Reach location codes are labeled in dark blue and apex station numbers are haloed in green.

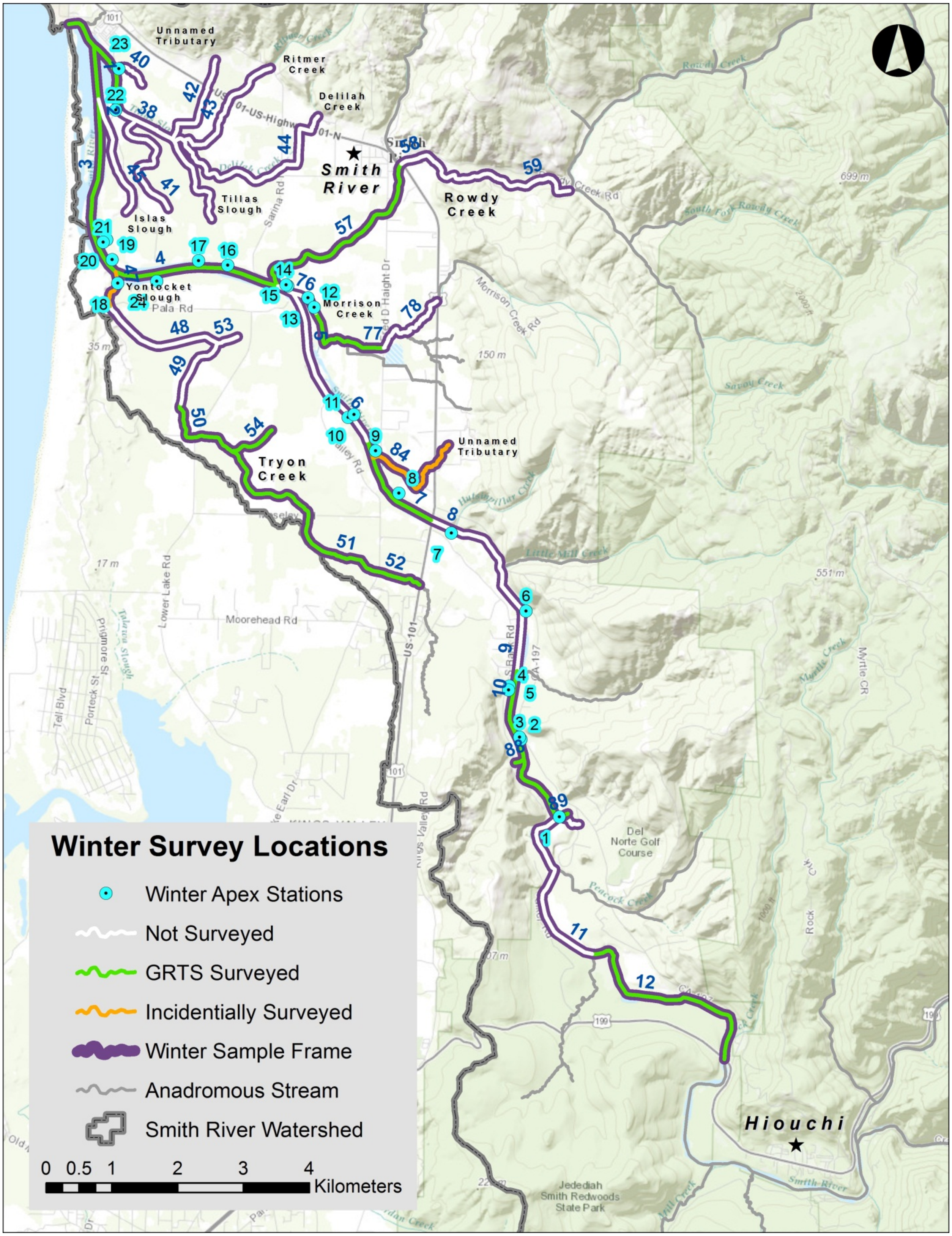

Figure 5. Winter surveys at GRTS, apex stations, and incidental locations across the Smith River coastal plain, Del Norte County, California. Reach location codes are labeled in dark blue and apex station numbers are haloed in bright blue.

Sample Draw Procedures and Sampling Rate

We used the generalized random tessellation stratified (GRTS) algorithm (Stevens and Olson 2004) in Program R (R Core Team 2014) by employing the SDraw package (McDonald, pers. comm.) to select our summer and winter spatial structure reach samples. Our GRTS sample draws included all available primary reaches, with smaller connected sub-reaches surveyed along with a selected reach (Garwood and Ricker 2011). Oversampling ensured our anticipated survey effort could be maintained if landowner permissions could not be secured in individual reaches. Prior to this study, no comprehensive fish distribution surveys have been completed within the study area so we focused on sampling as much area as possible based on available resources. A large sampling rate also ensures the study in capturing environmental and physical variability inherent in estuarine and lower river portions of the Smith River basin. Determining future optimal sampling rates will likely be based on statistical considerations from a refined study focused on temporal trends in annual species distributions.

Apex Monitoring Station Development

We established 24 unique apex monitoring stations for both the summer and winter coho salmon rearing periods based on pre-season surveys and previous data collected throughout study area by Garwood and Larson (2014) and Garwood et al. (2014). Unlike the GRTS spatial structure study component, habitats were not selected at random, but were identified based on their unique properties and having a high likelihood of persisting throughout the summer or winter rearing periods. To ensure salinity at all stations would remain within coho salmon tolerance thresholds throughout the sample season, all sites were located in areas likely to have salinity levels less than 5ppt, as identified by Mizuno (1998). Monitoring stations were distributed throughout the summer sampling frame (Figure 4) and throughout the winter sampling frame (Figure 5) representing a diverse range of potential salmonid non-natal rearing habitats including backwaters, edge waters, beaver lodges, and cold water seeps. Because the summer and winter periods have contrasting available habitats, we selected 24 unique monitoring stations independently for the summer and the winter. However, eight stations were monitored during both the summer and winter seasons.

Field Methods

Summer Spatial Structure Field Surveys

We adapted this survey to incorporate both local (within reach) and landscape (between reach) scales using a coho salmon spatial structure survey protocol developed by Garwood and Ricker (2014). The primary detection method was snorkel surveys explained in the fish sampling procedures section below. Our survey focused on stream pools as the sample unit since pools generally provide slow water habitats and are preferred for rearing by juvenile coho salmon (Bisson et al. 1988, Nickelson et al. 1992). For small and mid-sized streams, we used systematic sampling in every second pool meeting specific depth and area criteria throughout the entire length of each GRTS selected survey reach (*see protocol:* Garwood and Ricker 2014). Sampling in large mainstem Smith River reaches differed from smaller streams by restricting our sample units to slow water portions of edge, side channel, off-channel, and beaver characterized areas. Mainstem pools were effectively difficult to survey based on size and depth (i.e. >5 m deep) and we did not expect juvenile coho salmon to occur in open pelagic waters during daytime hours. Unlike small and mid-sized streams, all available mainstem river habitats in selected reaches were censused because features were typically rare (i.e. usually less than 10 units per reach) and had unique qualities (Garwood and Ricker 2014). Mainstem river units also had specific pool depth and area requirements scaled to the watershed area. Last, all survey units required an underwater visibility threshold (secchi disk transparencies >1.25 meters) and thermal refuge defined as temperatures <22° Celsius at the time of the survey (Garwood and Ricker 2014). Habitat measurements were collected based on Garwood and Ricker (2014), *see* Appendix C for a detailed description.

Summer Apex Station Monitoring Surveys

The primary focus of establishing apex monitoring stations was to understand temporal occupancy patterns (i.e. extinction and colonization processes) of juvenile salmonids as it relates to measured changes in habitat and water quality and availability throughout a specific season by sampling each unique station on multiple occasions. Surveys at apex stations were conducted using Pollock's robust design (Pollock 1982) which has secondary sample occasions within each primary sample occasion. This design assumes closure while sampling within primary sample occasions (i.e., between secondary sampling occasions, dive passes one and two) but allows for colonization (γ) and extinction (emigration in this case) (ε) of a species between primary sampling occasions (i.e, between summer months). All 24 summer apex stations received three primary sampling occasions (once per month) in June, July, and August using the spatial structure snorkel survey protocol from Garwood and Ricker (2014). An opportunistic forth survey was conducted in September by a single surveyor. Most station habitat measurements were based on Garwood and Ricker (2014). However, additional station measurements specific to assessing beaver modifications and water quality parameters were added to explore these influences on station characteristics; *see* Appendix C for detailed descriptions of these covariates. Habitat covariates were measured during each sampling effort as declining water height resulting in changing habitat conditions. Thermographs were deployed at each station and recorded water temperature at 0.5 hour intervals throughout the summer; *see* Water Quality Measurements section for details. Water quality parameters including temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) were measured during each sample period; *see* Water Quality Measurements section for details. No habitat measurements were collected during the fourth survey, with the exception of water quality.

Winter Spatial Structure Field Surveys

The winter spatial structure survey was established with the same design and site selection criteria as those defined for the summer; *see* Summer Spatial Structure Survey section for the specific sampling design. However, the winter months are much more prone to large changes in environmental conditions. We used a combination of beach seines, minnow traps, and snorkel surveys to sample as much of the estuary as possible during the winter. Sampling method was selected to best match the condition of the individual location. Sampling methods are defined in detail in the Fish Sampling Procedures section below. Habitat measurements were collected based on Garwood and Ricker (2014), *see* Appendix C for a detailed description.

Winter Apex Station Monitoring Surveys

We exclusively used baited minnow traps at the 24 winter apex monitoring stations to have more flexibility in sampling across a range of unpredictable environmental and site conditions (e.g. stream flow, turbidity) expected during the winter months. Specific minnow trapping procedure's followed those outlined in the Winter Spatial Structure field survey section below. Water quality readings were taken at all stations during each winter sampling period; see Water Quality Measurements section for details. Habitat parameters were only measured once at apex monitoring stations during the winter. We adjusted monthly sampling to occur during similar river discharges so physical conditions of each station were comparable between primary sampling periods. Last, we did not collect continuous water temperature data or cover volume during the winter (Appendix C).

Incidental Fish Surveys and Literature Review

In addition to the spatial structure and apex station monitoring, we conducted rapid opportunistic sampling in areas that were readily accessible through cooperating landowners or did not fit within the designed protocols in our selected survey reaches (e.g. water visibility too poor for snorkel surveys). This effort was implemented to refine seasonal juvenile salmonid distributions, ground-truth initial summer and winter spatial structure sample frames, and to identify any important findings our established protocols may have overlooked based on sampling limitations. Methods for conducting incidental surveys included mask and snorkel, minnow traps, and beach seining as defined in the various methods sections below. Additionally, we compiled all existing spatial-temporal data on juvenile and adult salmonid presence within the study area including seining, snorkel surveys, minnow trapping, and spawner surveys led by CDFW (J. Garwood) from 2010 to 2015. Last, we incorporated previously documented observations from the literature. We applied an evidence standard to the literature by only including documents having original data. Therefore, documents having second-hand or "best judgment" information were disqualified. This standard allows for the original information to be easily interpreted and reproducible by highlighting specific empirical evidence. All of these date were then combined to map the most thorough and accurate spatial distributions of rearing juvenile coho salmon in the lower Smith River and tributaries throughout the coastal plain.

Fish Sampling Procedures

Snorkel Surveys— We used snorkel surveys to determine coho salmon occupancy throughout the study area during the summer months and to a lesser extent during the winter. Prior to each survey season, we completed intensive underwater training on fish identification, quantitative dive counts, and habitat classification in streams of various sizes hosting different assemblages of fish species. Underwater tests on species identification were given to each crew member to ensure coho salmon and other salmonids were confidently identified. We used waterproof LED flashlights at all times so shadowed and complex habitats could be inspected thoroughly. Each sample unit was surveyed by two independent dive passes occurring on the same day to account for detection rates. Large complex units (>5 meters wide) were surveyed by two divers using lanes (O'Neal 2007). After the first pass, individual divers discussed the dive approach, switched lanes and completed the second pass similar to the first. Each diver identified and counted all fishes observed in each sample unit independently using dive slates and/or hand tally counters. Species and age classes of fish were divided into categories based on size and physical appearance (*see* Garwood and Ricker 2014). For example, juvenile trout were not identified to species, and coastal cutthroat trout were only identified when lacking parr marks indicating a sexually mature adult. All coho salmon observations found in unexpected locations or low numbers were documented using underwater photographs or video and stored in the projects media archive.

Minnow Traps— We used minnow traps to determine coho salmon occupancy throughout the study area during the winter and spring months. Unpredictable stream turbidities made snorkel surveys unreliable whereas minnow traps could be deployed across wide ranges of flow and turbidity. To prevent trapping in areas having poor water quality for salmonids, we measured water quality at each sampling location prior to setting minnow traps. Thresholds for deploying traps were defined as dissolved oxygen >3.5 mg/L, salinity <5 ppt, and temperature <17 ˚C following studies by Ruggerone (2000) and Wallace and Allen (2009). See the water quality methods section below for a detailed description of collection methods. We used Gee ® brand minnow traps (Cuba Specialty Manufacturing Company, Fillmore, NY) composed of two interlocking inverted cone baskets of 6 mm mesh galvanized steel wire measuring 23 cm x 44 cm when assembled. An opening measuring 25 mm diameter located on each side the trap allowed for juvenile fish to enter the trap. We baited minnow traps with ~4 grams (one tablespoon) of sterilized salmon roe procured by CDFW at the Trinity River Hatchery. We deployed minnow traps on the substrate aligned parallel to flow (openings facing upstream and downstream) in areas having flow refuge. We secured the minnow traps to anchors using parachute cord and deployed individual traps for a period between 80 and 120 minutes. Minnow Trapping locations included in the GRTS or Apex station components were sampled twice over two days using the same number of traps and same approximate trap soak times to account for detection rates. We measured and identified all captured salmonids to migrant stage (i.e. young-of year, parr, smolt).

Beach Seines— We used various sizes of beach seines to determine coho salmon occupancy at large sites having broad open water and void of significant underwater obstructions. Seine size was directly related to the depth and size of the habitat. Small habitats less than 1.3 m deep were seined by hand using one of two net sizes (0.9 m x 4.6 m x 7 mm stretched mesh or 1.5 m x 9.1 x 7 mm stretched mesh) attached to 1.5 m long wooden poles on each edge of the net. Larger river and slough channel areas were sampled with a large beach seine (2.4 m x 45.7 m x 9 mm stretched mesh) deployed by a 5.2 m long jet powered boat. Seine locations included in the GRTS component were sampled with a single seine set on day one and then the locations were flagged for a subsequent visit to account for detection rates per sampling period. The same footprint was then sampled the following day with a second seine pass. We measured and identified all captured salmonids to migrant stage (i.e. young-of year, parr, smolt).

Fish Processing and Marking Procedures

Salmonids captured during the winter GRTS, winter apex, and incidental surveys were identified to species (Chinook salmon, coho salmon, trout spp., coastal cutthroat trout), migrant stage (young-of-year, parr, smolt, adult), counted, and measured. All fork lengths of juvenile salmonids were measured to the nearest millimeter. All coho salmon captures were scanned for PIT tags to determine if any of the ~1500 individuals marked during the fall of 2014 in the Mill Creek sub-basin had emigrated to the lower basin and estuary prior to smolting. To explore relative site abundances and possible trap effects on back-to-back capture rates (e.g. trap happy or shy), we marked subsets of coho salmon, steelhead, and juvenile trout (*spp.*) with a batch fin clip. Clips were applied on the first trapping period of every monthly apex station census and during the first of the two trapping periods on GRTS reaches. This clip was made with small sharp scissors removing approximately three square mm of the upper caudal fin. Last, to obtain information on coho salmon site fidelity and tenure, we uniquely tagged a subset of coho salmon >70 mm with 11 mm FDX PIT tags at apex stations during all sampling periods except the final survey. We used sodium bicarbonate at a concentration between 0.14 and 0.69 g/L to anesthetize fish prior to PIT tagging. We inserted PIT tags by hand through a 2mm ventral incision made slightly posterior to the pectoral fins. We disinfected all PIT Tags and scalpel blades in an iodine solution prior to use. We allowed tagged fish to recover from the procedure for 15 minutes before releasing them back into the unit from which they were captured. All other aquatic vertebrates observed during the various sampling events including fishes, amphibians, and mammals, were identified, staged, and counted. Additional observations of invasive vegetation and invasive New Zealand mudsnails were also recorded.

Water Quality Measurements

Fish Sampling Locations– Water quality readings were measured at each fish sampling location and sampling period for all fish monitoring components (summer and winter) (Appendix C) with a Yellow Springs Instrument Professional Plus multi-parameter meter. Parameters measured included water temperature (°C) accuracy of ±0.2°, dissolved oxygen (mg/L) accuracy of ±0.2 mg/L, and salinity (ppt) accuracy of ±0.1 ppt. Three readings were collected at the maximum depth within the unit (i.e. bottom, middle, surface) at units greater than one meter deep, two readings (i.e. bottom and surface) at units less than one meter deep, and one reading (middle) at units less than 31 cm deep. Additionally, we deployed water temperature data loggers at both GRTS reaches and at all apex stations during the summer of 2014 to characterize summer thermal regimes across a variety of habitats. We used HOBO© water temperature pro v2 data loggers- U22-001 (Onset Computer Corporation, USA) with an accuracy rating at ±0.21°C. Data loggers were deployed at all sites from early June to mid-September with logging intervals set at every 30 minutes. To prevent solar radiation from influencing temperature readings care was taken to place loggers under submerged large wood, undercut banks and root wads. Perforated PVC piping was used as a shield where suitable locations presented the possibility of direct sunlight at some time during the survey season.

Estuary Salinity Transects– The Smith River estuary has a dynamic salinity gradient based on location, season, tide, and river discharge (Mizuno 1998). These processes can have a major influence on juvenile salmon rearing potential. Juvenile coho salmon generally rear in habitats <5 parts per thousand (Wallace and Allen 2009) highlighting the need to characterize spatial and temporal salinity gradients throughout the lower Smith River. We collected salinity measurements throughout the estuarine portion of the river during the summer and winter to determine the general location of the salt wedge for each season during high tide and low river flow periods when upstream salt intrusion is expected to be highest. We also compared our summer salt wedge data collected October 15-18, 1993 (Mizuno 1998) during a high tide of 8.0 feet, when daily average flows ranged from 339 – 359 cfs (USGS 2015a). All salinity measurements were collected from a boat or kayak with a Yellow Springs Instrument Professional Plus multi-parameter meter fitted with a 10 meter long probe. Salinity readings were recorded at the maximum channel depth and at every half meter moving up the water column. Additionally a reading was collected at 0.25m at every location (e.g., a site with depth of 1.4m would have a reading at 1.4, 1.0, 0.5, and 0.25m). Water depth for each reading and UTM coordinates were recorded for each sample location. During the summer, we collected salinity measurements on August 10th/11th and September 10th during the highest tides of each month, 8.0 feet at 23:58 and 7.6 feet at 13:09 at the Crescent City harbor, respectively. According to the Smith River USGS stream gauge, average river discharge was 303 cfs and 245 cfs (USGS 2015) during the August and September sampling, respectively. Prior to the current study, we conducted a winter salinity transect on February 22nd 2012 during an outgoing high tide (9.4 feet at 07:54 at the Crescent City harbor) when the average Smith River discharge was 2,760 cfs. Both summer and winter discharges were below the historic daily average values so the salinity transects were not influenced by any unusual runoff events.

Statistical Methods

Summer and Winter Spatial Structure

We determined occupancy for individual salmonid species and age classes during the summer and winter using the estimated probability of site occupancy as our derived spatial structure statistic. Unlike the multi-scale approach used in a complementary spatial structure study implemented throughout the Smith River basin (Garwood and Larson 2014, Garwood et al. 2014), we dissolved the reach-level scale and only used the collection of all sampled units (pools) since this study area is relatively compact and reaches were selected using a spatially balanced design (GRTS). For coho salmon, reach-level occupancy estimates appear to be very sensitive to sample size given the patchy nature of coho salmon distribution. We modeled occupancy (ψ_i) as a function of site characteristics affecting presence-absence while accounting for detection probabilities (MacKenzie et al. 2002) using Program PRESENCE (USGS 2013). We built multiple *a priori* single-season candidate models to determine what habitat variables (Appendix C) influenced coho salmon occupancy rates and used AIC to rank individual model likelihood (Burnham and Anderson 2002). Prior to analysis covariate values were standardized excluding large woody debris (LWD) count and cover rating. To avoid multicollinearity, correlation coefficients were determined using a Pearson correlation matrix in program R (R Core team 2014) for all pairs of predictor variables. We only included uncorrelated variables (R^2 <0.6) in the same candidate models. For the summer, detection probability (p) was modeled based on two individual snorkel passes. For the winter, detection probability (p) was modeled with two survey periods per site, based on survey method used, either beach seines, minnow traps, or snorkel surveys. The primary assumption of this approach is the target animal's occupancy status cannot change between sample periods within a season (MacKenzie et al. 2006) so we completed our primary and secondary sampling occasions within the same day or within two consecutive days to assume site closure and p was considered constant between the two survey periods. Models were ranked based on AIC, calculated Akaike weights (w) and selected the best ranked model from the candidate model set (Burnham and Anderson 2002). Model fit for single-season occupancy models was assessed based on 10,000 bootstrap samples of the most complicated model under consideration using the Pearson chi-square statistic to test whether there was sufficient evidence of poor model fit (Burnham and Anderson 2002, MacKenzie et al. 2006). Overdispersion ($\hat{c} > 1$) was also assessed (Burnham and Anderson 2002) for the most complicated model under consideration. AIC values and model standard errors were adjusted using QAIC when $\hat{c}$ was >1.

Apex Station Occupancy

Summer and winter surveys were conducted at 24 apex monitoring stations using Pollock's robust design (Pollock 1982) which has secondary sample occasions within each primary sample occasion. This design assumes closure while sampling within primary sample occasions (i.e., between secondary sampling occasions, dive passes one and two) but allows for colonization (γ) and extinction (ε) of a species between primary sampling occasions (i.e, between monthly surveys within a season). A multi-season occupancy model developed by MacKenzie et al. (2003) can then be used to evaluate the significance of habitat and water quality covariates on rearing tenure of juvenile coho salmon using the logit link function. Apex monitoring stations were surveyed with four primary sample occasions (t) during both the summer and winter sampling seasons. To account for detection probability two secondary survey occasions were conducted with two independent snorkel surveys on the same day during the summer months. Minnow traps deployed for 80-120 minutes on two back-to-back days were used during the winter months.

Dynamic changes in occupancy were modeled as a first order Markov process to account for the possibility that a site which was previously occupied is more likely to be occupied in subsequent primary sampling occasions. Modeling under the Markov process accounts for temporal autocorrelation where the probability of a site being occupied in a single primary occasion (t) is dependent upon whether or not the site was occupied in the previous primary occasion (t - 1), and:

ψ_1 = probability a station is occupied in season 1

γ_t = probability a station becomes occupied between season t and t+1

ε_t = probability a station becomes unoccupied between season t and t+1

$p_{t,j}$ = probability that coho salmon is detected at a station in a survey j of season t (given presence)

This structure results in a real estimate of occupancy for the first primary occasion (ψ_t) and real estimates of colonization and extinction between each primary occasion. These estimates are then used to derive estimates of ψ for all subsequent primary occasions by incorporating a mechanistic process for how occupancy at each site changes between primary sampling occasions (MacKenzie et al. 2006).

We used an information theoretic approach to model selection (Burnham and Anderson 2002). Site-level habitat and water temperature covariates were selected *a priori* for multi-season occupancy modeling in program PRESENCE (USGS 2013). Similar to the single season models defined above, covariates collected from apex stations were assessed for collinearity. Models were ranked based on AIC, calculated Akaike weights (w) and selected the best ranked model from the candidate model set (Burnham and Anderson 2002). We selected models aimed at answering questions regarding covariates relationship to ψ, ε, γ, and p. Prior to analysis covariates were standardized, excluding LWD count.

Currently no method is widely used to assess model fit for multi-season occupancy models. To explore and evaluate model fit, the variance inflation factor ($\hat{c}$) was calculated using 10,000 bootstrap samples of the global model for each primary sample occasion as a single season occupancy model in program PRESENCE. The $\hat{c}$ of all seasons was then averaged to assess model fit. Increasing $\hat{c}$ >1, models are penalized as the number of parameters (k) increase and thus increasingly favors models with less parameters (Cooch and White 2014). AIC values and model standard errors were adjusted using QAIC when $\hat{c}$ was >1.

During the summer, we examined model sets hierarchically to test multiple hypotheses about the relationship between coho salmon occupancy, habitat, and water quality covariates: 1) We hypothesized coho salmon occupancy was explained by habitat conditions at stations during the first primary sampling occasion (June); 2) Due to high stream temperatures during the summer sampling season, we hypothesized the MWMT (maximum weekly maximum temperature) at a given station explained coho salmon occupancy; 3) We hypothesized extinction at a given station varied and was explained by variations in water temperature across stations; 4) Lastly, we explored the hypothesis that the highest ranked habitat variable would explain occupancy better than stream temperature after accounting for seasonally varied extinction rates explained by MWMT. Due to multicollinearity present between cover area, cover volume and beaver volume (>0.8), the model with no covariates was used to assess model fit. An average $\hat{c}$ of 1.6665 was calculated based on single season occupancy models for the first three primary occasions (i.e. June, July, and August) with $\hat{c}$ values calculated at 0.3504, 1.5465, and 3.1026, respectively. September surveys could not be modeled independently due to the lack of secondary observation data. To account for overdispersion, the candidate model set was evaluated using QAIC and standard errors inflated by a factor of $\sqrt{\hat{c}} = 1.29$ (MacKenzie and Bailey 2004).

Previous to this study, no systematic winter sampling for juvenile coho salmon in the estuary and mainstem had been conducted. Therefore models included in our candidate model set were exploratory aimed at assessing the influence habitat and water quality covariates have on winter occupancy parameters. Equal detection probability was assumed due to consistent trap density, soak time, and amount of bait used per trap occasion. Consequently, no covariates were used to explain detection probability. Models containing cover area, both standardized and non-transformed, were not stable and parameters could not be accurately estimated. Estimates which are close to possible estimate boundaries (close to 0 or 1) fail to find a maximum likelihood estimate resulting in spurious results. Therefore cover area was removed from the candidate model set. Alternatively cover area was converted to percent cover by taking the measured cover area and dividing by the total area of the site. A reduced global model was used to assess model fit due to multicollinearity between percent cover and beaver created cover as well as between depth and dissolved oxygen. We modeled large woody debris, percent cover, site depth, maximum temperature, and maximum salinity on occupancy for each primary sampling season as a single season occupancy model. The four primary occasion $\hat{c}$ values equaled 1.5397, 1.0390, 1.7209, and 1.8493, respectively, resulting in an average $\hat{c}$ of 1.5372. We ranked the candidate model set using QAIC with a $\hat{c}$=1.5372 and with standard errors inflated by a factor of $\sqrt{\hat{c}} = 1.24$ (MacKenzie and Bailey 2004).

The 24 apex stations were not randomly selected and therefore estimates of occupancy parameters only apply to these sites and cannot be expanded to the landscape level. All stations selected were presumed to be suitable for juvenile coho salmon rearing by having habitat features such as LWD, overhanging vegetation, etc. Therefore analyses of apex stations were used to assess the importance of habitat covariates and water quality on overall site occupancy within a given season (i.e. winter, summer) by estimating occupancy on multiple occasions. Individual detection histories of each apex station were assumed to be independent of detection history at all other stations (i.e. any one station being occupied does not influence the occupancy of any other station). Due to time constraints and low dissolved oxygen, some stations had missing observation data for both seasons (Table 3, Table 4). The flexible unconditional model developed by MacKenzie et al. (2003) allows for these stations to remain in the analysis under the assumption that the probability of occupancy is equal between surveyed and unsurveyed stations.

Results

Coho Salmon Distribution

Prior to this study, very limited information existed on coho salmon distribution in the lower Smith River and coastal plain. By making use of multiple recent datasets from 2001 to 2015, we compiled the most comprehensive coho salmon distribution to date for the lower Smith River and estuary (Figure 3). We found juvenile coho salmon were widely distributed during the summer, especially throughout the mainstem Smith River from the mouth of Mill Creek to the sand hole, just below the mouth of Yontocket Slough. In contrast, we commonly found juvenile coho salmon rearing during the winter in streams and sloughs that either dry or have poor water quality during the summer (Figure 3). For example, we found coho salmon rearing during the winter throughout Yontocket Slough and Tryon Creek up to Highway 101 for four consecutive years (2012 to 2015) with most of the channel drying up during the summer months (Figure 6). However, we are certain some data gaps still exist in defining all seasonally available habitat given the relatively short length of this investigation. For example, reach 78 in Morrison Creek was not assessed due to lack of access. We found coho salmon occurring above and below this reach (Figure 3) and suspect the channel contains major adult spawning and juvenile rearing area since we found juvenile coho salmon using a portion of Morrison creek across four consecutive years. We also did not have sampling access to Tillas and Islas sloughs or their associated tributaries during the winter which is likely the only period juvenile salmonids use these unique drainages based on the summer 2014 water quality data collected in these areas. Additionally, the exceptional drought conditions observed during this study may have limited the amount of measurable habitat available for rearing throughout the area than in contrasting years with higher precipitation (Figure 6).

Summer Spatial Structure

Summer GRTS Species Occupancy

We surveyed a total of 101 units across 17 GRTS drawn reaches (Table 5, Figure 4) during the summer period representing 58 percent (35 km) of the total summer sampling frame. The survey period extended 71 days from June 4th to August 11th. Six of the 17 survey reaches did not have any survey units that met our protocol standards (Table 6). Reach 84 was entirely dry during inspection and five other reaches had substantial dry portions representing 3.5 km (10%) of the surveyed area (Figure 6). The amount of observed dry channel was likely exacerbated by the cumulative effects caused from having three continuous years of exceptional drought conditions.

We documented juvenile coho salmon in all 11 surveyed reaches and within 35 of 101 sampled units (Table 6, Figure 7). When coho salmon were found, the mean number counted per sample unit equaled 9.5; range: 1-73. Most of these detections were within mainstem Smith River reaches (63%) but juvenile coho salmon were also observed in Rowdy Creek, Morrison Creek, and Yontocket Slough (Table 6). Estimated summer probability of occupancy (ψ) for coho salmon equaled 0.41 (SE= 0.06) (Table 7). The overall detection probability (p) equaled 0.76 (SE= 0.07) (Table 7).

Table 3. Combined two pass detection history of juvenile coho salmon and water quality conditions including maximum weekly average temperature (MWAT), maximum weekly maximum temperature (MWMT), dissolved oxygen (DO), and salinity at apex monitoring stations during the summer 2014. A (-) denotes that the site was not surveyed during that specific occasion.

Site	Coho Salmon Occupancy Jun	Jul	Aug	Sep	MWAT (°C)	MWAT Date	MWMT (°C)	MWMT Date	Max Daily Range (°C)	Max Daily Range Date	Mean DO (mg/L)	Min DO (mg/L)	Max DO (mg/L)	Mean Salinity (ppt)	Min Salinity (ppt)	Max Salinity (ppt)
1	Y	Y	Y	Y	21.21	8/3/2014	22.22	8/3/2014	2.03	7/28/2014	6.77	5.36	8.36	0.075	0.07	0.08
2	Y	Y	Y	N	21.76	8/3/2014	22.79	8/3/2014	2.00	7/14/2014	8.88	7.51	9.9	0.073	0.06	0.08
3	Y	Y	Y	Y	21.61	8/3/2014	22.79	8/2/2014	2.60	7/26/2014	8.54	7.52	9.45	0.070	0.06	0.08
4	Y	Y	Y	Y	19.29	8/4/2014	19.44	8/3/2014	1.86	7/9/2014	8.06	6.03	10.93	0.063	0.03	0.08
5	Y	Y	Y	Y	20.47	8/3/2014	22.07	7/10/2014	4.05	6/30/2014	7.01	5.34	8.66	0.063	0.04	0.08
6	Y	Y	Y	Y	20.16	8/2/2014	21.21	8/2/2014	2.93	6/18/2014	6.61	5.06	7.91	0.076	0.07	0.08
7	Y	Y	Y	–	21.96	8/3/2014	22.95	8/2/2014	7.08	10/10/2014	7.73	6.54	9.42	0.070	0.06	0.08
8	Y	Y	Y	Y	21.30	8/3/2014	21.98	8/2/2014	3.62	6/30/2014	6.84	4.17	8.89	0.073	0.06	0.08
9	Y	Y	Y	Y	22.02	8/3/2014	22.80	8/3/2014	3.52	6/30/2014	8.51	6.56	9.91	0.072	0.06	0.08
10	Y	Y	Y	Y	21.92	8/3/2014	22.70	8/3/2014	3.43	6/30/2014	8.41	6.50	9.8	0.070	0.06	0.08
11	Y	Y	Y	Y	19.72	8/3/2014	20.14	8/3/2014	3.45	7/24/2014	6.29	4.81	7.89	0.074	0.06	0.08
12	Y	Y	Y	N	21.98	8/3/2014	23.41	8/3/2014	3.31	6/5/2014	7.08	5.87	8.35	0.071	0.06	0.08
13	Y	Y	Y	Y	22.00	8/3/2014	22.94	8/2/2014	2.74	6/29/2014	8.24	6.52	9.73	0.070	0.06	0.08
14	Y	Y	Y	–	22.04	8/3/2014	23.89	8/2/2014	5.40	6/11/2014	8.08	6.24	9.39	0.069	0.06	0.08
15	Y	N	N	–	–	–	–	–	–	–	8.73	7.21	9.64	0.067	0.06	0.07
16	Y	Y	Y	–	21.86	8/3/2014	23.37	8/2/2014	8.35	6/11/2014	8.91	7.34	9.72	0.067	0.06	0.07
17	Y	Y	Y	N	22.08	8/2/2014	23.59	8/2/2014	4.17	7/24/2014	7.36	5.28	9.63	0.071	0.06	0.08
18	Y	Y	Y	N	21.89	8/2/2014	23.30	7/31/2014	3.94	7/25/2014	7.01	5.41	8.95	0.073	0.06	0.08
19	N	N	Y	Y	21.74	8/3/2014	22.95	8/1/2014	3.57	7/24/2014	7.55	6.11	9.11	0.073	0.06	0.08
20	N	N	N	N	21.96	8/2/2014	23.28	7/31/2014	3.90	7/25/2014	8.61	7.73	9.52	0.073	0.06	0.08
21	N	N	N	N	21.84	8/2/2014	22.68	7/31/2014	3.50	6/30/2014	6.91	0.59	9.75	1.804	0.06	9.70
22	N	Y	Y	Y	17.73	8/26/2014	20.80	8/25/2014	7.16	7/24/2014	7.87	4.29	10.87	0.048	0.04	0.06
23	N	N	N	N	18.81	9/4/2014	21.00	9/15/2014	6.96	9/10/2014	8.79	4.69	12.49	0.046	0.04	0.07
24	Y	Y	N	N	21.72	8/26/2014	23.36	8/26/2014	3.75	9/5/2014	8.00	6.38	9.17	3.880	0.06	17.21
	Overall Average:				21.18	–	22.42	–	4.06	–	7.78	5.79	9.48	0.299	0.06	1.19

Table 4. Quantity of Coho salmon trapped at each apex monitoring station during each winter sampling occasion. Number of traps was consistent at each site for each effort. A (-) denotes that the site was not surveyed during that specific occasion.

Location Code	Site	# of Traps/ Effort	Average Soak Time (min)	Range of Soak Times	Occasion 1 1/3/15 - 1/7/15		Occasion 2 1/28/15 - 1/31/15		Occasion 3 2/19/15 - 2/22/15		Occasion 4 3/17/15 - 3/20/15	
					1	2	1	2	1	2	1	2
10	1	2	128	87 - 188	0	0	0	0	0	0	0	0
10	2	2	122	85 - 165	0	0	0	0	0	0	0	0
10	3	2	120	80 - 153	0	0	0	0	0	0	0	0
10	4	2	114	80 - 144	0	0	0	0	0	0	0	0
10	5	3	111	70 - 146	0	0	0	0	2	0	0	0
9	6	4	124	85 - 163	0	0	0	0	1	2	0	0
8	7	10	115	68 - 213	0	0	0	0	0	0	0	0
7	8	2	133	90 - 240	0	11	39	2	8	5	1	0
7	9	16	138	106 - 228	1	0	0	0	1	0	0	0
6	10	4	131	82 - 242	0	0	0	0	0	0	0	0
6	11	2	133	82 - 244	0	0	2	0	1	0	0	0
76	12	2	118	92 - 196	1	0	0	0	0	0	0	0
76	13	2	119	89 - 200	0	0	0	0	0	0	0	0
5	14	2	123	91 - 192	-	0	0	0	0	0	0	0
5	15	2	118	89 - 193	0	0	0	0	0	0	0	0
4	16	2	122	90 - 220	0	0	0	0	0	0	0	0
4	17	2	115	87 - 191	0	0	0	0	0	0	1	0
47	18	5	117	84 - 170	0	0	14	1	0	0	0	0
3	19	5	116	79 - 209	0	0	0	0	0	0	0	0
3	20	2	125	81 - 185	0	0	0	0	0	0	0	0
3	21	2	114	100 - 128	-	-	0	0	0	0	0	0
38	22	4	127	91 - 188	0	0	0	0	0	0	0	0
40	23	2	127	90 - 205	0	0	0	0	0	0	0	0
4	24	2	133	101 - 193	-	0	-	0	0	0	-	-
Totals:		83	124	68 - 244	2	11	55	3	13	7	2	0

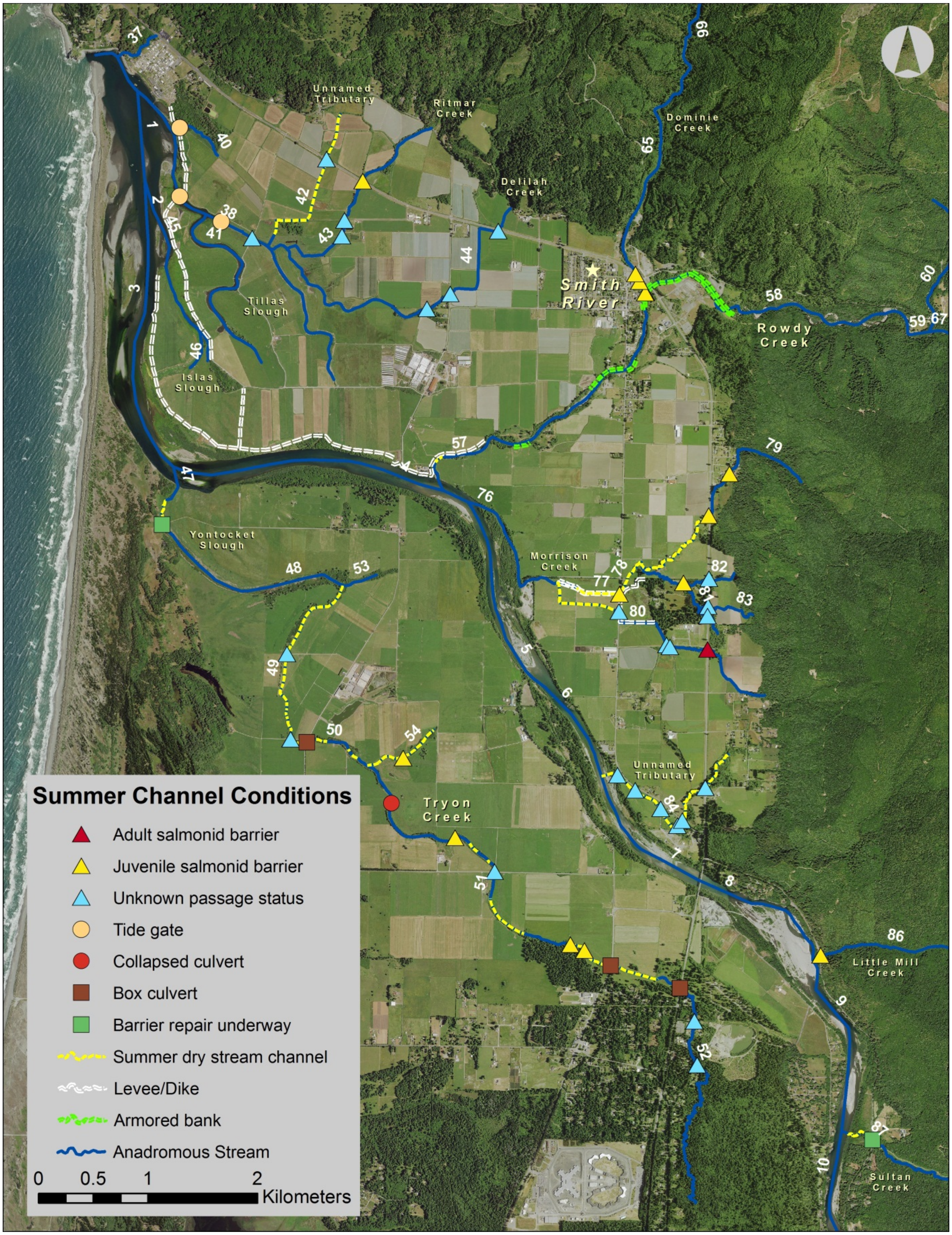

Figure 6. Channel features limiting juvenile and adult salmonid passage throughout the Smith River coastal plain, Del Norte County, California. Dry channel was assessed during the summer of 2014 during an exceptional drought. Reach location codes are labeled in white.

Table 5. Characteristics of eleven out of 17 GRTS drawn summer coho salmon spatial structure study reaches in the lower Smith River basin, Del Norte, California. Six of the 17 reaches did not have any units that met protocol standards, or were completely dry upon inspection.

Location Code	Number of Units	Mean Unit Depth (cm)	Mean Unit Surface Area (m^2)	Reach MWAT (c)[1]	Reach MWMT (c)[2]	Mean Unit Temperature (c)[3]
3	4	327 (252 – 460)	147 (48 – 412)	21.6	22.8	18.6 (18.0 – 19.0)
5	8	172 (62 – 257)	89 (30 – 142)	21.8	23.1	19.7 (12.0 – 21.5)
9	4	131 (53 – 218)	190 (33 – 490)	22.0	22.8	20.0 (16.0 – 22.0)
10	9	129 (29 – 232)	119 (21 – 220)	21.9	22.7	20.2 (12.9 – 23.0)
11	2	154 (97 – 210)	125 (102 – 149)	19.7	20.1	19.1 (18.8 – 19.5)
13	5	121 (55 – 237)	52 (15 – 88)	22.0	22.9	19.8 16.0 – 22.0)
14	8	157 (92 – 280)	294 (11 – 1483)	21.8	22.8	19.8 (18.0 – 21.0)
47	1	100	411	18.8	21.9	12.0
57	17	73 (32 – 137)	760 (22 – 2142)	17.5	19.4	14.0 (one location)
58	24	66 (21 – 171)	202 (5 – 630)	15.6	17.3	14.0 (one location)
77	19	37 (21 – 84)	17 (4 – 107)	16.1	18.3	13.0 (one location)
Totals:	101	133 (21 – 460)	219 (4 – 2142)	19.9	21.3	18.9 (12.0 – 23.0)

[1]*Maximum weekly average temperature of the reach based on thermograph data*
[2]*Maximum weekly maximum temperature of the reach based on thermograph data*
[3]*Mean survey unit temperature; recorded at most survey units with a handheld thermometer during fish sampling*

Testing of the most global model for describing summer coho salmon occupancy did not indicate evidence of lack of fit (X^2 = 2.97, *P*-value = 0.14), however the estimated ĉ = 1.93 indicating the model was overdispersed so we corrected AIC rankings using QAIC. Model selection statistics (Table 8) provided evidence that summer coho salmon occupancy probabilities were strongly influenced by site cover complexity rating and the reach-level maximum water temperature (MWMT) based on the top QAIC ranked model. Additionally, site large wood counts (LWD), hydrology (mainstem vs. tributary), and site depth moderately influenced coho salmon occupancy probabilities with these parameters being in the third through fifth ranked models having ΔQAIC <2 (Table 8). Hydrology (mainstem vs. tributary) was highly correlated with MWMT (R^2= 0.93) but did not predict coho salmon occupancy probability as well as MWMT in model selection (Table 8). The strong correlation between the two covariates likely was a result of mainstem river reaches having consistently higher water temperatures than tributaries (Table 5). Effect plots of habitat covariates (Figure 8) indicate sites with high cover ratings and increasing peak water temperatures best explained coho salmon distribution. Based on odds ratios, sites were 2.5 times more likely to have coho salmon for every one increase in cover rating and 2.4 times more likely to have coho salmon for every one increase in standard deviation of (maximum weekly average temperature (MWAT). Furthermore, sites having more LWD with increased maximum site depths appeared to influence coho salmon occupancy (Figure 8).

We detected juvenile Chinook salmon in 40 units across 9 reaches (Table 6, Figure 9) with an estimated summer occupancy rate of 0.44 (SE= 0.06) (Table 7). We detected young-of-the-year unidentified trout (steelhead [*O. mykiss*] or coastal cutthroat trout [*O. clarki clarki*]) in 81 units across 10 reaches (Table 6, Figure 9) with an estimated summer occupancy rate of 0.82 (SE= 0.04) (Table 7). Additionally, we detected yearling (1+) unidentified trout in 60 units across 10 reaches (Table 6, Figure 9) with an estimated summer occupancy rate of 0.71 (SE= 0.07) (Table 7). Last, we detected resident adult coastal cutthroat trout in 21 units across 7 reaches (Table 6, Figure 9) with an estimated the summer occupancy rate of 0.26 (SE= 0.06) (Table 7).

Table 6. Summary statistics for all salmonids observed in 17 GRTS drawn reaches during the summer of 2014 in the Smith River Coastal plain, Del Norte County, CA.

Stream name	Location Code	Reach length (m)	Number of units surveyed	Coho Salmon		Chinook Salmon		0+ Unidentified Trout		1+ Unidentified Trout		Coastal Cutthroat Trout	
				Units Occupied	Mean count	Units Occupied	Mean count	Units Occupied	Mean count	Units Occupied	Mean count	Units Occupied	Mean count
Mainstem Smith River	2	956	0[a]	–	–	–	–	–	–	–	–	–	–
Mainstem Smith River	3	1,961	4	3	1.8	4	18.8	4	9.5	4	4.3	0	–
Mainstem Smith River	5	2,044	8	1	6.0	2	7.5	6	6.2	5	1.8	0	–
Mainstem Smith River	9	1,654	4	4	20.8	2	130.5	2	4.5	2	9.0	2	1.0
Mainstem Smith River	10	2,520	9	8	18.1	7	16.9	7	8.9	7	6.4	2	1.0
Mainstem Smith River	11	2,765	2	1	15.0	2	11.0	2	7.0	2	2.5	1	1.0
Mainstem Smith River	13	2,968	5	3	10.3	3	50.3	4	6.3	3	1.7	1	1.0
Mainstem Smith River	14	2,618	8	2	3.0	7	10.3	8	7.3	7	4.6	3	1.0
Tillas Slough Tributary	42	1,559	0[a]	–	–	–	–	–	–	–	–	–	–
Delilah Creek	44	3,516	0[a]	–	–	–	–	–	–	–	–	–	–
Yontocket Slough	47	597	1	1	15.0	0	–	0	–	0	–	0	–
Yontocket Slough	48	1,924	0[a]	–	–	–	–	–	–	–	–	–	–
Tryon Creek	51	1,,612	0[a]	–	–	–	–	–	–	–	–	–	–
Rowdy Creek	57	3,216	17	6	2.7	8	6.5	17	82.3	16	6.4	8	3.9
Rowdy Creek	58	1,860	24	1	2.0	5	2.8	24	41.6	12	5.0	4	1.5
Morrison Creek	77	1,485	19	5	1.4	0	–	7	1.0	2	5.5	0	–
Unnamed Tributary	84	1,867	0[a]	–	–	–	–	–	–	–	–	–	–
Total		35,122	101	35	9.5	40	19.5[b]	81	32.7[b]	60	5.1[b]	21	2.2[b]

[a]*Entire reach was dry during sampling period,* [b]*Mean value*

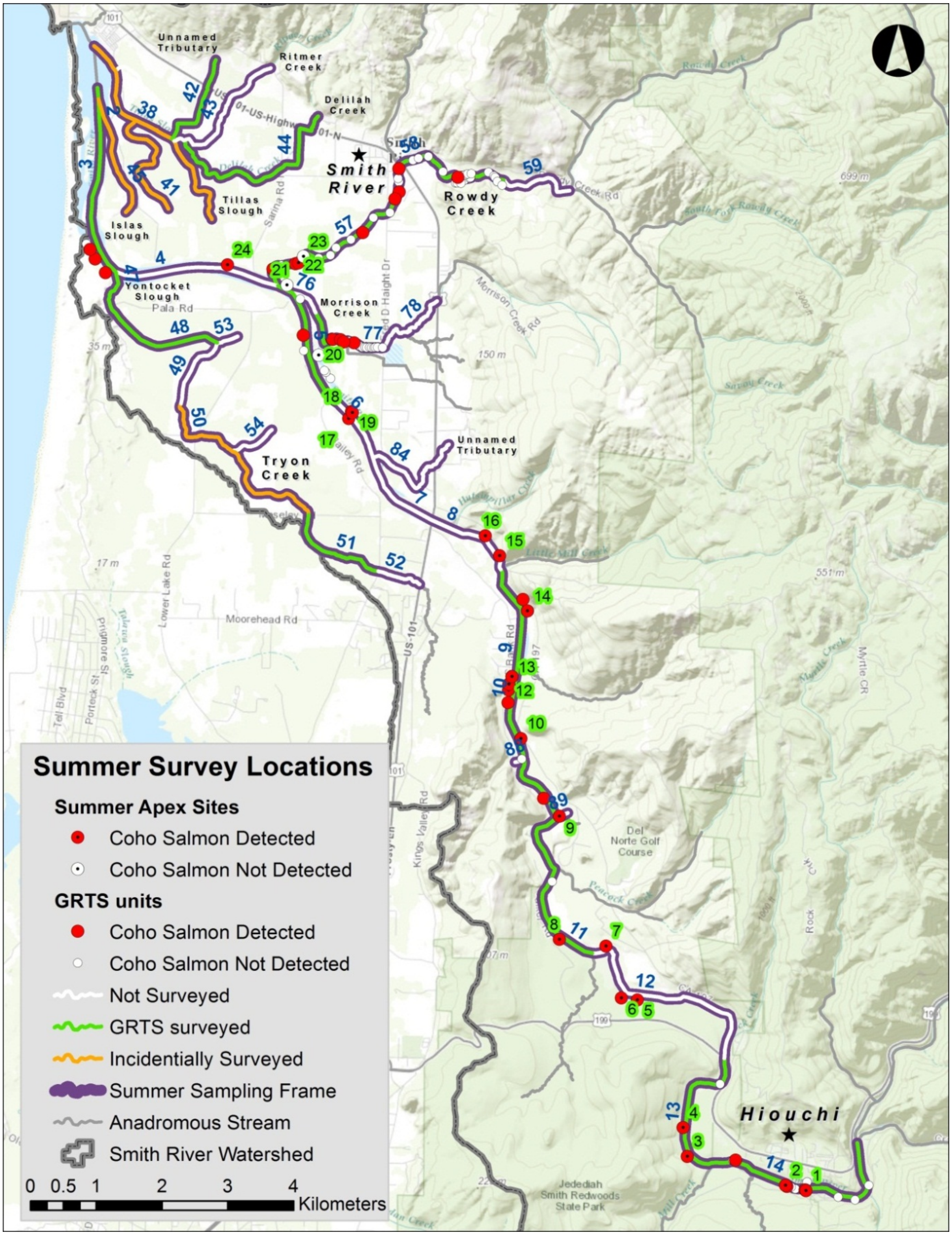

Figure 7. Map showing the spatial distribution of pools containing juvenile coho salmon during the summer 2014 GRTS and apex station surveys, Smith River Basin, California. Numbers with green halos indicate apex stations; dark blue numbers indicate reach location codes. GRTS surveyed sampling reaches with no sampling locations indicate the entire reach was dry during the summer sampling period (*see* Figure 6).

Table 7. Occupancy estimates and relative count densities of salmonids in the lower Smith River and estuary observed during the summer of 2014 Smith River basin.

Species	ψ	SE	95% CI	*p*	SE	95% CI	# of units present	Mean pool count
Coho Salmon	0.41	0.06	0.30 - 0.54	0.76	0.07	0.59 - 0.87	35 of 101	9.5
Chinook Salmon	0.44	0.06	0.33 - 0.55	0.84	0.06	0.69 - 0.92	40 of 101	19.5
Trout spp. (YOY)	0.82	0.04	0.72 - 0.89	0.95	0.02	0.89 - 0.98	81 of 101	32.7
Trout spp. (1 +)	0.71	0.07	0.56 - 0.82	0.74	0.06	0.60 - 0.84	60 of 101	5.1
Coastal Cutthroat Trout	0.26	0.06	0.16 - 0.39	0.68	0.12	0.41 - 0.86	21 of 101	2.2

ψ: Occupancy rate. The probability a species is detected in a given sample unit for the survey year.
p- Individual species detection probability if present in a given sample pool.

Table 8. Summary of model selection procedure for juvenile coho salmon occupying habitats in the lower Smith River and estuary during the summer of 2014.

Model		QAIC	ΔQAIC	AIC wt.	Model Likelihood	K
1)	ψ(COVRATE + MWMT), *p*(.)	86.56	0	0.2587	1	4
2)	ψ(COVRATE), *p*(.)	88.31	1.75	0.1078	0.4169	3
3)	ψ(COVRATE + MWMT + LWD), *p*(.)	88.37	1.81	0.1047	0.4045	5
4)	ψ(COVRATE + HYDROLOGY), *p*(.)	88.38	1.82	0.1041	0.4025	4
5)	ψ(COVRATE + MWMT + DEPTH), *p*(.)	88.39	1.83	0.1036	0.4005	5
6)	ψ(MWMT), *p*(.)	88.43	1.87	0.1016	0.3926	3
7)	ψ(COVRATE + LWD), *p*(.)	90.04	3.48	0.0454	0.1755	4
8)	ψ(COVRATE + COVAREA), *p*(.)	90.16	3.60	0.0428	0.1653	4
9)	ψ(COVRATE + MWMT + LWD + DEPTH), *p*(.)	90.19	3.63	0.0421	0.1628	6
10)	ψ(HYDROLOGY), *p*(.)	90.78	4.22	0.0314	0.1212	3
11)	ψ(DEPTH), *p*(.)	91.75	5.19	0.0193	0.0746	3
12)	ψ(LWD), *p*(.)	91.76	5.20	0.0192	0.0743	3
13)	ψ(COVAREA), *p*(.)	93.06	6.50	0.0100	0.0388	3
14)	ψ(.), *p*(.)	93.23	6.67	0.0092	0.0356	2

Ψ: Occupancy, *p*: Detection probability, COVAREA: Estimated area in a sample unit with fish cover, COVRATE: Rank (1-5) of cover availability and complexity, DEPTH: Maximum depth of a sample unit, LWD: total number of large wood pieces in a sample unit, HYDROLOGY: Categorical variable identifying mainstem vs. tributary sample units, MWMT: Reach-level maximum weekly maximum water temperature derived from thermographs.

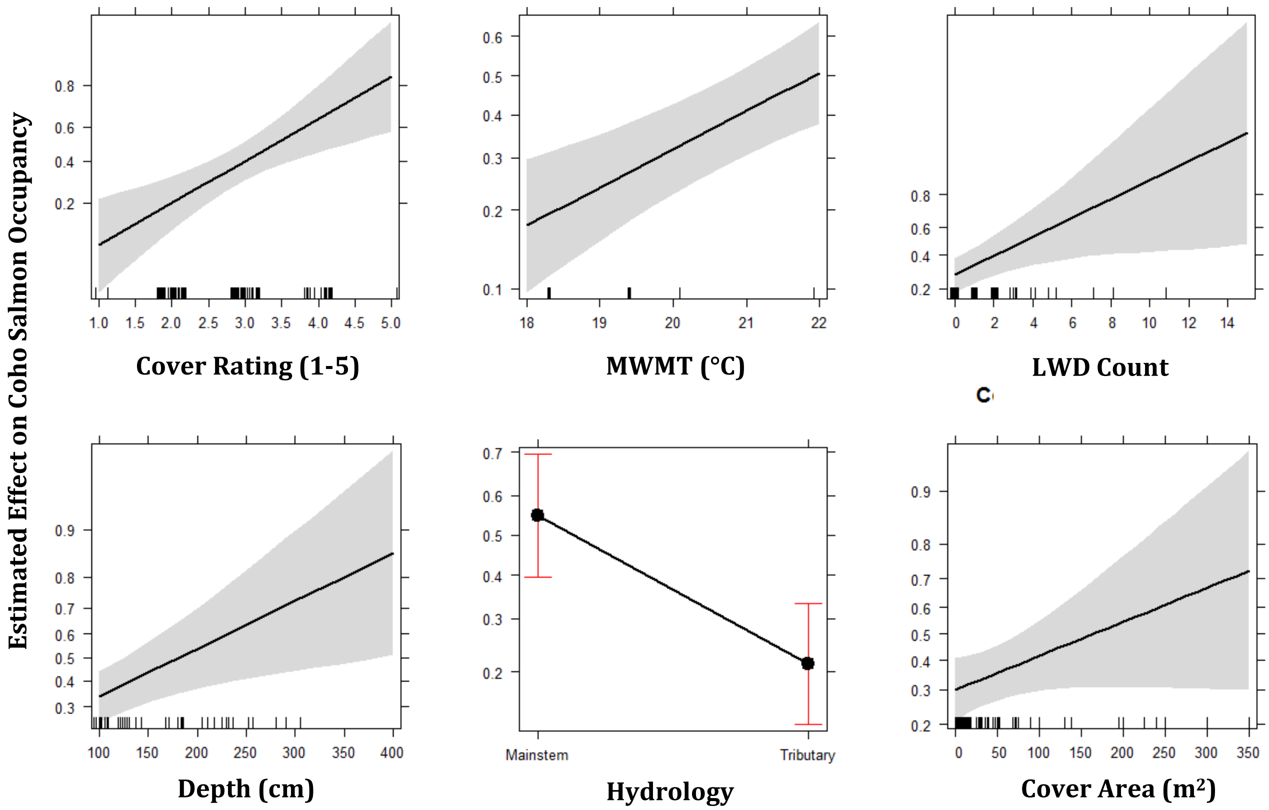

Figure 8. Effect plots showing the influence of individual habitat covariates on the probability of juvenile coho salmon presence at a given site from the summer 2014 spatial structure survey, Smith River, Del Norte County, California. 95% confidence intervals are displayed in grey shading and red bars for the two hydrology groups. Plots are arranged in descending order based on AIC-based variable importance.

Summer Apex Stations

Summer apex monitoring stations were distributed across 22.5 km, beginning 5.8 km upstream from the mouth (Figure 4). We surveyed each station on three occasions in 2014 from June 23 to August 21, with 18-27 days separating each sampling occasion. On average, each census (i.e. primary sampling occasion) required four days to survey all 24 stations. An opportunistic forth census was conducted from September 15th to 20th by a single surveyor while retrieving deployed temperature loggers; thus missing a secondary survey. Flows ranged from 230 – 783 cubic feet/sec (cfs) during the sampling season reaching the minimum on September 14.

Snorkel surveys were found to be an effective and efficient sampling method at detecting coho salmon during the summer with a detection probability of 0.93 (SE=0.03) (Table 9). Coho salmon were consistently detected at 17 of the 24 stations (Figure 7) during the summer sampling season with eight stations having a change in occupancy status; six with extinction and two with colonization. Four of these changes in occupancy status occurred between the last two sampling periods (Table 3). These low observed site transition rates produced low estimates of overall colonization at 0.14 (SE=0.1) and extinction at 0.08 (SE=0.04) (Table 9). Additionally, estimated coho salmon occupancy remained

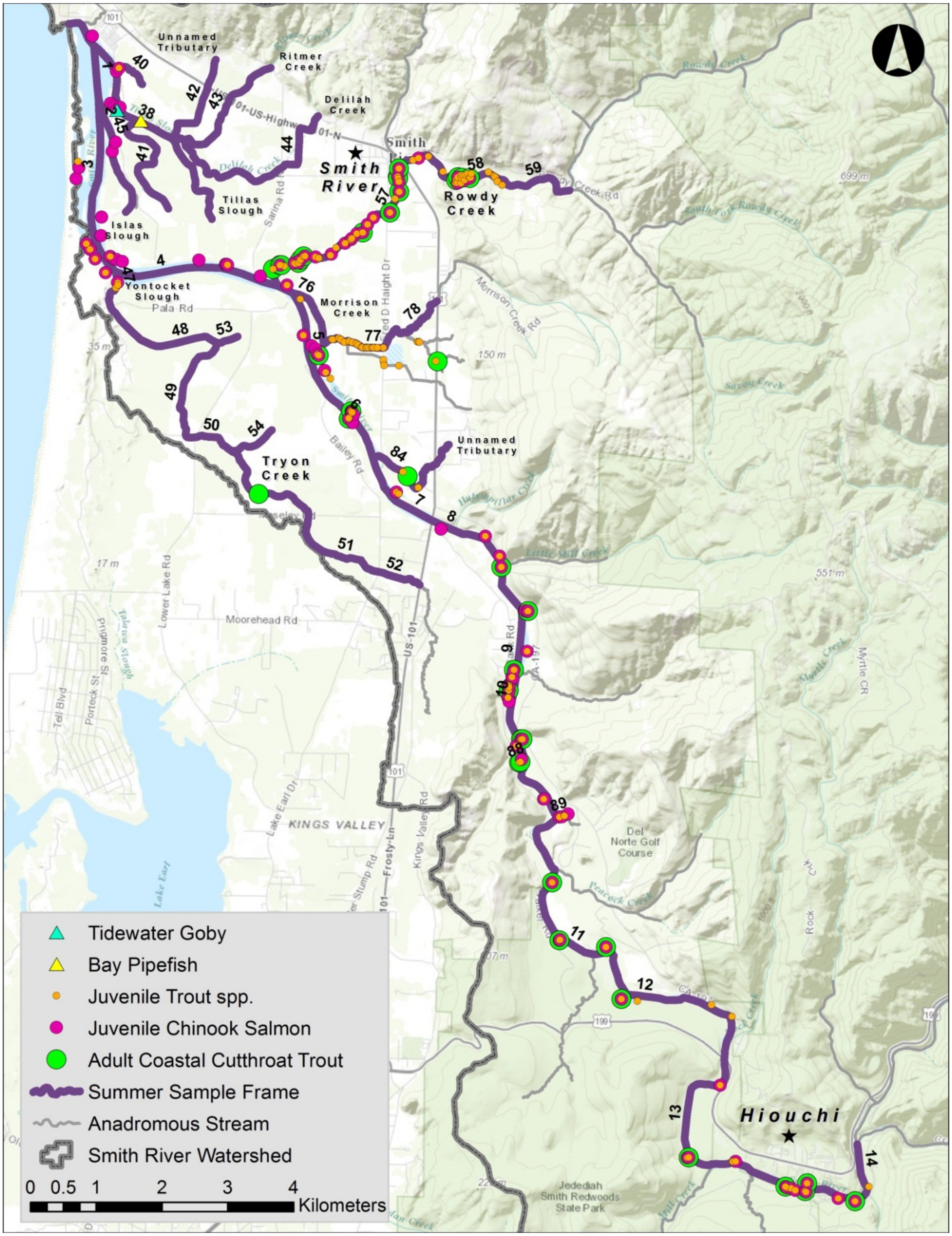

Figure 9. Distribution of various fish species captured during GRTS and apex surveys during the summer of 2014 and the winter of 2015, Lower Smith River and coastal plain, Del Norte County, California. Reach location codes are labeled in black.

Table 9. Estimates of multi-season occupancy parameters for all salmonids detected with minnow traps at apex monitoring stations during the summer, 2014, and winter, 2014-15, based on the dot model.

		Apex Station Occupancy (ψ)				Colonization (γ)			Extinction (ε)			Detection (*p*)		
	species	June	July	August	September	estimate	SE	95% CI	estimate	SE	95% CI	estimate	SE	95% CI
Summer	coho salmon	0.80 ± 0.08 (0.59 - 0.92)	0.76 ± 0.08 (0.62 - 0.91)	0.74 ± 0.09 (0.57 - 0.91)	0.72 ± 0.10 (0.52 - 0.92)	0.14	0.1	0.03 - 0.44	0.08	0.04	0.02 - 0.21	0.93	0.03	0.86 - 0.96
Summer	Chinook salmon	0.88 ± 0.07 (0.68 - 0.96)	0.69 ± 0.08 (0.54 - 0.84)	0.55 ± 0.10 (0.36 - 0.74)	0.44 ± 0.11 (0.23 - 0.65)	0.03	0.06	<0.01 - 0.83	0.22	0.07	0.11 - 0.38	0.89	0.04	0.80 - 0.94
Summer	Unidentified Trout Spp.	0.88 ± 0.07 (0.67 - 0.97)	0.83 ± 0.06 (0.72 - 0.93)	0.80 ± 0.7 (0.67 - 0.94)	0.80 ± 0.08 (0.64 - 0.95)	0.51	0.18	0.20 - 0.81	0.13	0.05	0.06 - 0.27	0.90	0.03	0.83 - 0.95
Summer	Coastal Cutthroat Trout	0.15 ± 0.08 (0.05 - 0.38)	0.28 ± 0.08 (0.12 - 0.44)	0.38 ± 0.11 (0.17 - 0.59)	0.45 ± 0.14 (0.17 - 0.73)	0.17	0.06	0.08 - 0.32	0.09	0.14	<0.01 - 0.73	0.60	0.11	0.38 - 0.79
	species	Early Jan	Late Jan	Mid-Feb	Mid-March	estimate	SE	95% CI	estimate	SE	95% CI	estimate	SE	95% CI
winter	coho Salmon	0.19 ± 0.11 (0.05 - 0.50)	0.20 ± 0.08 (0.04 - 036)	0.20 ± 0.09 (0.03 - 0.38)	0.20 ± 0.10 (0.01 - 0.40)	0.11	0.06	0.04 - 0.28	0.42	0.25	0.09 - 0.84	0.44	0.15	0.19 - 0.72
winter	Unidentified Trout Spp.	0.13[a]	0.21[a]	0.08[a]	0.08[a]	-	-	-	-	-	-	-	-	-

[a] Naïve estimates due to small sample size producing unstable estimate in multi-season occupancy models.

relatively consistent throughout the summer ranging from 0.80 in June to 0.72 in September (Table 9) based on the model with no covariates. Low extinction and colonization coupled with high and stable occupancy rates indicates most apex stations provided rearing habitats throughout most of the summer period.

Maximum weekly maximum temperature (MWMT) at stations occupied by coho salmon averaged of 22.5 °C (19.4 – 23.9 °C) and an average maximum weekly average temperature (MWAT) averaged 21.4 °C (19.3 – 21.9 °C) (Table 3) indicating coho salmon were rearing in locations exceeding acceptable thermal limits well defined in the literature. Average salinity equaled 0.07 ppt (0.03 – 0.08 ppt) and average dissolved oxygen equaled 7.66 mg/L (4.17 – 10.93 mg/L) (Table 3) both within acceptable thresholds previously defined for coho salmon. Based on model rankings (Table 10) we concluded that physical habitat measurements better explained coho salmon occupancy than station MWMT. This result was expected given most stations occurred in the mainstem river where water temperatures were relatively similar across sites (Table 3).

Model ranking found that stations having beaver created cover had the highest influence on summer coho salmon occupancy probabilities (Table 10). However, modeling June peak water temperature and total volume cover on occupancy resulted in competing models with ΔQAIC <2. Large standard errors relative to the covariate estimates modeled on occupancy was common for all covariates in the candidate models (Table 11). In general, apex stations were selected based on their high habitat quality and likelihood to be used by coho salmon for non-natal rearing. Habitat quality did not widely vary and we had very few apex stations lacking coho salmon detections. The large standard errors are likely a function of a lack of variation in covariates and coho occupancy throughout the summer data set. Notwithstanding, beaver activity was prevalent throughout the majority of the apex stations with 20 of the 24 stations having signs of feeding, food caching, or lodge/ burrow excavation activity.

Table 10. Occupancy models evaluating habitat and temperature covariates ability to explain coho salmon occupancy at apex monitoring stations during the summer 2014. Models are ranked by QAIC values to account for overdispersion using a ĉ = 1.6665.

Model		QAIC	ΔQAIC	QAIC wt	Model Likelihood	k
1)	ψ(BEAVVOL), γ(.), ε(MWMT + season), p(.)	81.38	0	0.2065	1	8
2)	ψ(BEAVVOL), γ(.), ε(.), p(.)	82.22	0.84	0.1357	0.6570	5
3)	ψ(.), γ(.), ε(.), p(.)	82.26	0.88	0.1330	0.6440	4
4)	ψ(MWMT-June), γ(.), ε(MWMT + season), p(.)	82.78	1.40	0.1026	0.4966	8
5)	ψ(VOLCOV), γ(.), ε(.), p(.)	82.84	1.46	0.0995	0.4819	5
6)	ψ(MWMT-June), γ(.), ε(.), p(.)	83.62	2.24	0.0674	0.3263	5
7)	ψ(CC), γ(.), ε(.),p(.)	83.79	2.41	0.0619	0.2997	5
8)	ψ(.), γ(.), ε(MWMT + season), p(.)	83.98	2.60	0.0563	0.2725	7
9)	ψ(LWD), γ(.), ε(.), p(.)	84.04	2.66	0.0546	0.2645	5
10)	ψ(CA), γ(.), ε(.), p(.)	84.14	2.76	0.0520	0.2516	5
11)	ψ(.), γ(.), ε(season), p(.)	85.20	3.82	0.0306	0.1481	6

Occupancy (ψ) was modeled to be constant (.) or to vary on covariates including volume cover created by beaver (m^3, BEAVVOL), maximum weekly maximum temperature measured in June (MWMT- June), total volume cover (m^3, VOLCOV), canopy cover (CC), cover rating (CR), large woody debris count (LWD), and cover area (m^2, CA). Extinction (ε) is either constant, constant with regard to monthly MWMT, or to vary by season based on monthly MWMT. Colonization (γ) and detection (p), are held constant in all models. k: number of parameters in the model, AIC w: probability the current model is the best approximate model in the candidate set.

Table 11. Covariate estimates and standard errors individually modeled on occupancy of coho salmon at apex monitoring sites during the summer 2014.

Covariate	Estimate	SE with $\sqrt{\hat{c}}$ =1.29	95% Confidence Interval with $\sqrt{\hat{c}}$ =1.29	
			lower limit	upper limit
Volume Beaver cover	8.199	11.221	-13.794	30.192
Total volume cover	1.232	1.485	-1.678	4.142
June - MWMT	0.389	0.478	-0.547	1.325
Canopy cover	-0.528	0.882	-2.256	1.200
Large woody debris	0.124	0.288	-0.440	0.688
Cover area	0.176	0.560	-0.922	1.274

Seasonally varying extinction was the lowest ranking model (*see* Model 11 *in* Table 10). However, the model with an additive effect of MWMT and season on extinction and occupancy performed substantially better in explaining extinction (*see* Model 4 *in* Table 10) despite the parameter estimate being low overall (ε= 0.08, SE 0.04) (Table 9). This model had low extinction probabilities between the first three primary sampling occasions (i.e., between June-July and between July-August) and increased extinction probability between the third and fourth primary occasions (Figure 10). Biologically speaking, as stream temperature increased in the mainstem, there is a low probability of coho salmon emigrating or going extinct from their current rearing location. However, once the stream temperature peaked and began to decrease, the probability of coho salmon emigrating or going extinct from their current rearing location increased.

Juvenile Chinook salmon occupancy rates declined consistently throughout the summer which is expected given their fixed life history of migrating to the ocean during their first fall (Table 9). However, their occupancy rate still equaled 0.44 (SE 0.11) in September indicating the Smith River has a strong stream-type Chinook salmon life history. Similar to coho salmon, occupancy rates of juvenile trout were generally high (0.80 – 0.88) and remained stable throughout the summer (Table 9). Last, coastal cutthroat trout occupancy rates generally increased through time equaling 0.15 in June and 0.45 in September (Table 9). Overall, we found a diverse community of salmonids and other fish species using most apex monitoring stations highlighting the importance of summer habitats characterized with underwater cover features.

Winter Spatial Structure

Winter GRTS Reaches

We surveyed a total of 173 units across 17 GRTS drawn reaches (Table 12, Figure 5) during the winter period representing 45 percent (30.6 km) of the total winter sampling frame. The survey period extended 61 days from January 12 to March 13, 2015. All sites visited were within water quality thresholds outlined in the sampling protocol. Unlike the summer period, multiple sampling methods were employed during the winter. Twenty one percent of the sites were sampled with beach seines, 66 percent with minnow traps, and 22 percent with snorkel surveys.

We documented juvenile coho salmon occurring in six of the 17 surveyed reaches and in only 14 of the 173 sampled units (Table 12, Figure 11). In the mainstem Smith River, we detected coho salmon in only four of the 52 units (8 %). In tributaries we detected coho salmon in only 10 of 121 units (8 %) within Tryon Creek, Morrison Creek, and an unnamed tributary (Reach 89) to the mainstem Smith River

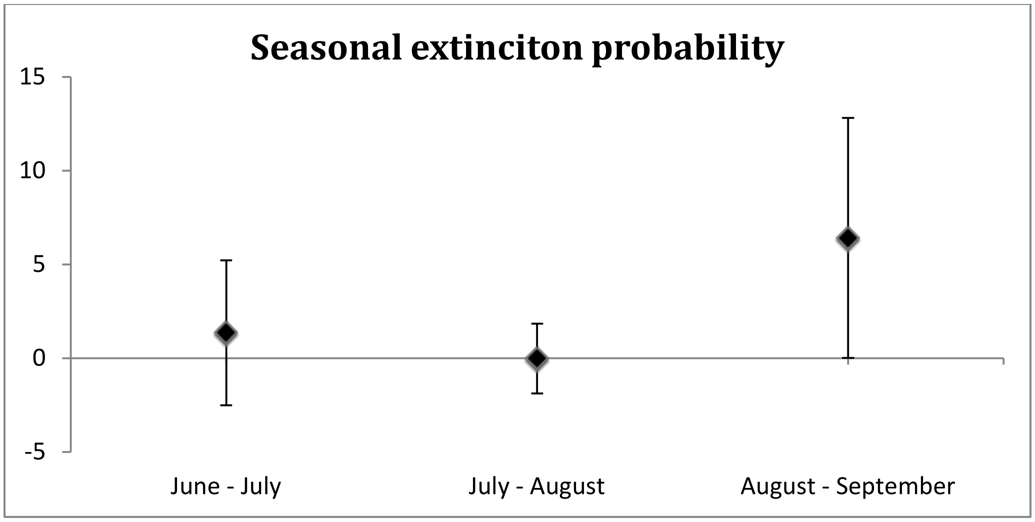

Figure 10. Estimates of station extinction probability of coho salmon between four primary sampling occasions conducted at apex monitoring stations during the summer of 2014. The black marker represents the extinction probability estimate calculated in the top model (ψ(B BEAVVOL), γ(.), ε(MWMT + season), p(.)) using multi-season occupancy and the error bars represent the confidence interval.

(Figure 11). In contrast to the summer, our coho salmon detection rates were substantially less during the winter. For example, detection equaled only 0.33 (SE= 0.15) for minnow traps and 0.40 (SE=0.22) for snorkel surveys (Table 13) compared to 0.76 for the summer (Table 7). We did not capture any coho salmon with beach seines so detection estimates could not be determined for this method. Estimated winter probability of occupancy (ψ) for coho salmon equaled 0.16 (SE= 0.07) (Table 13).

Testing of the top model for describing winter coho salmon occupancy did not indicate evidence of lack of fit using 10,000 bootstrap samples (X^2 = 0.40, *P*-value = 0.77, ĉ = 0.22). Model selection statistics (Table 14) provided evidence that winter coho salmon occupancy probabilities were positively influenced by the amount of cover area, the amount of turbulent flow, and the site cover rating (Figure 12). Additionally site maximum depth was negatively associated with coho salmon occupancy based on the top AIC ranked model and effect plots (Table 13, Figure 12). Beaver created cover was highly correlated with cover area (R^2= 0.79) but did not predict coho salmon occupancy probability as well as cover area (Table 14).

We detected juvenile Chinook salmon in 39 units across 8 reaches (Table 12, Figure 9). Given their reproduction and development timing, the season closure assumption could not be met for winter occupancy modeling. However, we started observing alevin stages in the estuary having conspicuous yolk sacs as early as February 13, 2015. From this point on in the sampling season we regularly found juvenile Chinook salmon in reaches throughout the sample frame. Young-of-the-year unidentified trout (steelhead or coastal cutthroat trout) were found in only six sampled units in one reach 57 (Figure 4) of Rowdy Creek on 13 March, 2015 (Table 12). Similar to Chinook salmon, age zero trout could not meet our site closure assumption for occupancy modeling given their reproductive and development timing. We detected yearling (1+) unidentified trout in 23 units across 7 reaches (Table 12) with an estimated winter occupancy rate of 0.15 (SE= 0.04) (Table 13). Detection rates varied by method ranging from 0.56 to 0.62; confidence intervals were generally wide for all detection methods indicating we had poor

Table 12. Summary of sampling location characteristics and salmonid detections within 173 sample units across 17 GRTS drawn reaches surveyed during the winter of 2015 in the Smith River Coastal plain, Del Norte County, California.

Stream Name	Location Code	Reach Length (m)	Number of Units Surveyed	Mean Unit Depth (cm)	Mean Unit Surface Area (m^2)	Survey Methods[1]	Number of sample units with detections: Coho Salmon	Chinook Salmon	0+ Trout spp.	1+ Trout spp.	Coastal Cutthroat Trout
Mainstem Smith River	1	1210	3	183 (70 – 240)	270 (163 – 324)	BS	0	2	0	0	0
Mainstem Smith River	2	956	1	130	38	MT	0	0	0	0	0
Mainstem Smith River	3	1961	10	90 (30 – 270)	231 (33 – 810)	MT, BS	0	7	0	0	0
Mainstem Smith River	4	2541	8	211 (125 – 280)	100 (29 – 209)	SS	1	4	0	0	0
Mainstem Smith River	6	798	5	212 (110 – 370)	190 (64 – 543)	SS	1	4	0	1	1
Mainstem Smith River	7	1639	5	139 (41 – 258)	669 (29 – 1813)	SS	2	0	0	1	0
Mainstem Smith River	9	1654	1	240	358	SS	0	1	0	0	0
Mainstem Smith River	10	2520	12	159 (80 – 320)	104 (26 – 222)	SS	0	10	0	0	0
Mainstem Smith River	12	3335	7	210 (153 – 280)	197 (22 – 544)	SS	0	0	0	2	0
Tryon Creek	50	3139	39	133 (44 – 223)	29 (20 – 36)	MT	0	0	0	0	0
Tryon Creek	51	1612	26	47 (22 – 86)	21 (5 – 36)	MT	3	0	0	0	0
Tryon Creek	52	3505	17	47 (22 – 110)	17 (4 – 36)	MT, BS	0	0	0	0	0
Tryon Creek Tributary	54	736	4	69 (32 – 100)	23 (15 – 30)	MT, BS	0	0	0	0	0
Rowdy Creek	57	3216	9	87 (45 – 140)	209 (64 – 539)	SS	0	9	6	8	1
Morrison Creek	77	1485	17	39 (22 – 72)	13 (3 – 24)	MT	6	0	0	9	0
Unnamed Tributary	88	142	4	96 (44 – 234)	10 (8 – 14)	MT	0	0	0	1	2
Unnamed Tributary	89	184	5	29 (18 – 47)	4 (3- 5)	MT	1	2	0	1	0
Totals:		30633	173	103 (18 – 370)	89 (3 – 1813)		14	39	6	23	4

[1]*Fish sampling method: BS= Beach Seine; MT= Minnow Trap; SS= Snorkel Survey*

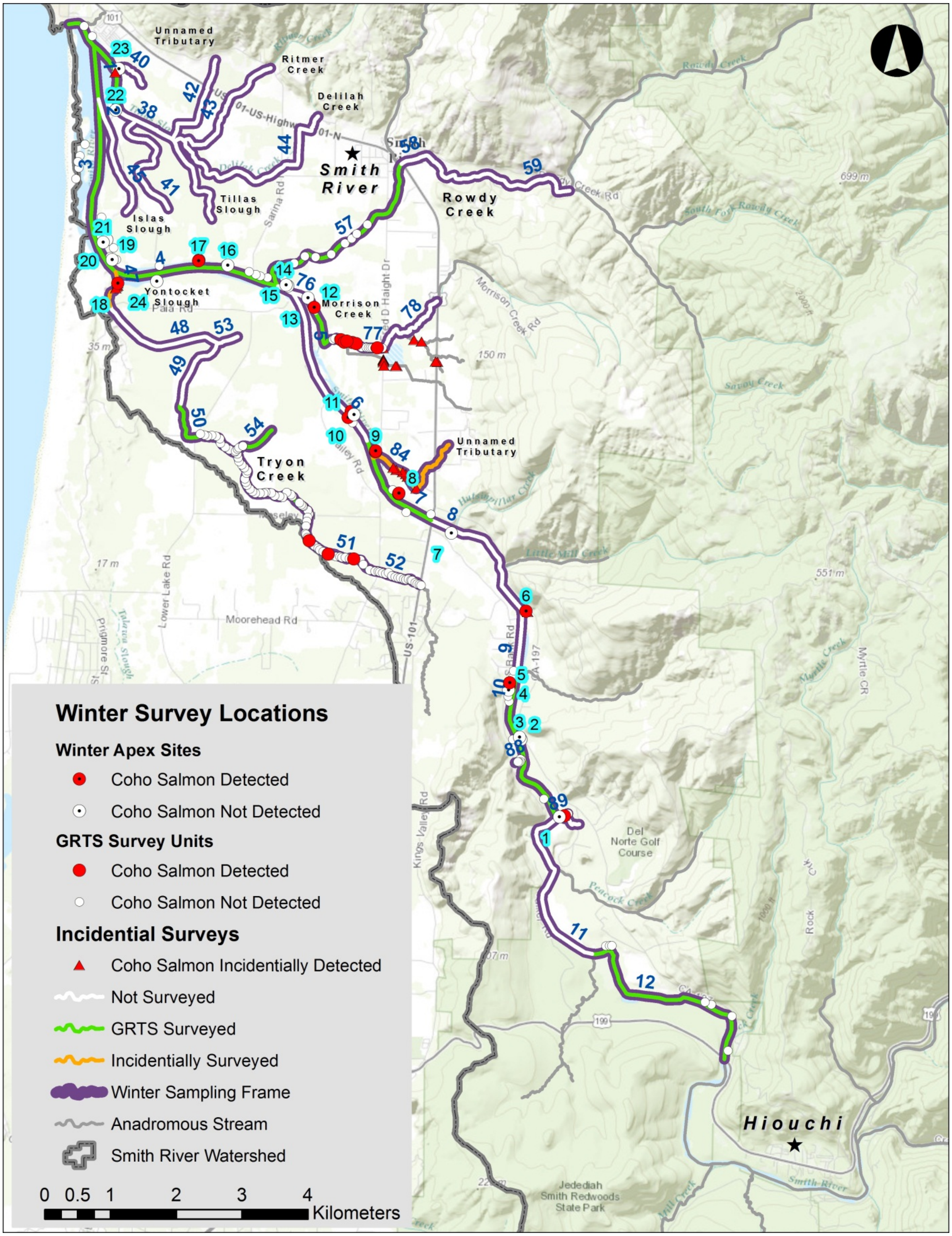

Figure 11. Map showing the spatial distribution of pools containing juvenile coho salmon during the winter 2015 GRTS and apex station surveys, Smith River Basin, California. Numbers with blue halos indicate apex stations, dark blue numbers indicate reach location codes. Note: some incidental observations are included in areas outside of the GRTS sampled portion.

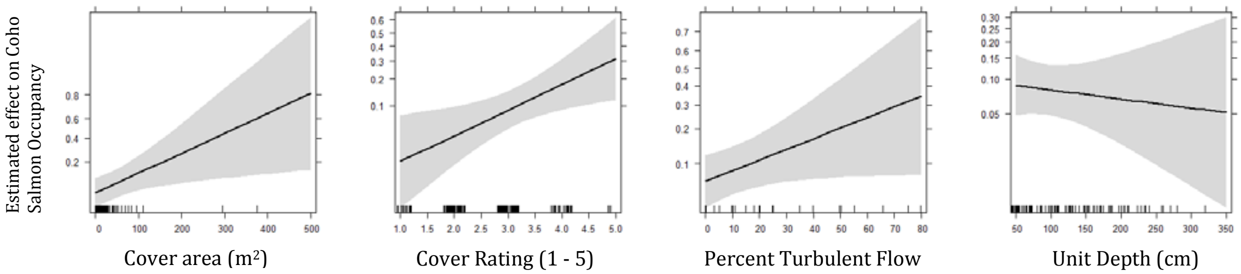

Figure 12. Effect plots showing the influence of individual habitat covariates on the probability of juvenile coho salmon presence at a given site from the winter of 2015 spatial structure survey, Smith River, Del Norte County, California. 95% confidence intervals are displayed in grey shading. Plots are arranged in descending order based on AIC-based variable importance.

Table 13. Occupancy estimates and relative count densities of salmonids in the lower Smith River and estuary during the winter of 2015, Smith River basin, Del Norte County, California.

Species	ψ	SE	95% CI	*p*	SE	95% CI	# of units present
Coho Salmon				BS: 0.00	–	–	
	0.16	0.07	0.07 – 0.33	MT: 0.33	0.15	0.11 – 0.66	14 of 173
				SS: 0.40	0.22	0.10 – 0.80	
Chinook Salmon[1]	–	–	–	–	–	–	39 of 173
Trout spp. (YOY)[1]	–	–	–	–	–	–	6 of 173
Trout spp. (1 +)				BS: 0.63	0.15	0.32 – 0.86	
	0.15	0.04	0.09 – 0.23	MT: 0.56	0.16	0.25 – 0.82	23 of 173
				SS: 0.62	0.25	0.17 – 0.92	
Coastal Cutthroat Trout				BS: 0.00	–	–	
	0.04	0.02	0.01 - 0.12	MT: 0.21	0.20	0.02 – 0.75	4 of 173
				SS: 0.21	0.20	0.02 – 0.75	

ψ: Occupancy rate. The probability a species is present in a given sample unit for the survey year.
p- Individual species detection probability if present in a given sample pool; BS= Beach Seine, MT= Minnow Trap, SS= Snorkel Survey.
[1]season closure assumption could not be met given redd emergence timing occurring mid to late winter.

Table 14. Summary of model selection procedure for juvenile coho salmon occupying habitats in the lower Smith River and estuary during the winter of 2015.

Model		AIC	ΔAIC	AIC wt.	Model Likelihood	k
1)	ψ(COVAREA + DEPTH + TURBULENT + COVRATE), *p*(METHOD)	115.72	0	0.5457	1	8
2)	ψ(COVAREA + DEPTH + TURBULENT), *p*(METHOD)	116.70	0.98	0.3343	0.6126	7
3)	ψ(COVAREA + DEPTH), *p*(METHOD)	119.80	4.08	0.0710	0.1300	6
4)	ψ(COVAREA + DEPTH + LWD), *p*(METHOD)	121.63	5.91	0.0284	0.0521	7
5)	ψ(BEAVER + DEPTH), *p*(METHOD)	123.67	7.95	0.0102	0.0188	6
6)	ψ(COVAREA), *p*(METHOD)	127.29	11.57	0.0017	0.0031	5
7)	ψ(BEAVER), *p*(METHOD)	127.48	11.76	0.0015	0.0028	5
8)	ψ(COVRATE + DEPTH), *p*(METHOD)	127.71	11.99	0.0014	0.0025	6
9)	ψ(BEAVER + COVRATE), *p*(METHOD)	127.75	12.03	0.0013	0.0024	6
10)	ψ(COVAREA + HYDROLOGY), *p*(METHOD)	128.00	12.28	0.0012	0.0022	6
11)	ψ(COVRATE), *p*(METHOD)	128.10	12.38	0.0011	0.0020	5
12)	ψ(BEAVER + HYDROLOGY), *p*(METHOD)	128.30	12.58	0.0010	0.0019	6
13)	ψ(TURBULENT), *p*(METHOD)	129.26	13.54	0.0006	0.0011	5
14)	ψ(.), *p*(METHOD)	131.13	15.41	0.0002	0.0005	4
15)	ψ(LWD), *p*(METHOD)	132.73	17.01	0.0001	0.0002	5
16)	ψ(DEPTH), *p*(METHOD)	132.77	17.05	0.0001	0.0002	5
17)	ψ(HYDROLOGY), *p*(METHOD)	133.13	17.41	0.0001	0.0002	5

Ψ: Occupancy, *p*: Detection probability, COVAREA: Estimated area in a sample unit with fish cover, COVRATE: Rank (1-5) of cover availability and complexity, DEPTH: Maximum depth of a sample unit, LWD: total number of large wood pieces in a sample unit, HYDROLOGY: Categorical variable identifying mainstem vs. tributary sample units, TURBULENT: Estimated percent of the unit having turbulent flow, BEAVER: Estimated area in the sample unit with fish cover created by beaver activity, METHOD: Method of fish sampling used on a given survey (i.e. snorkel, minnow trap, beach seine).

to moderate success in detecting yearling and older trout in the estuary during the winter. Last, we detected resident adult coastal cutthroat trout in only four units across three reaches (Table 12) with an estimated winter occupancy rate of 0.04 (SE= 0.02) (Table 13). The detection rate for minnow trapping and snorkel surveys equaled 0.21 (SE= 0.20) (Table 13). The lack of observations coupled with excessively wide confidence intervals around detection indicate our occupancy estimate has little value describing winter estuary use by this species and likely reflects the size limitations of the minnow trap openings preventing larger individuals from entering the traps.

Winter Apex Stations

All 24 winter apex monitoring stations were distributed across 15.8 km, beginning 0.97 km upstream from the mouth (Figure 5). Eight of these locations were also surveyed as summer apex stations. We surveyed each station on four occasions in 2015 ranging from January 3 to March 30, with 18-23 days separating each primary sampling occasion. On average, each census (i.e. primary sampling occasion) required four days to survey all 24 stations. Flows of the Smith River ranged from 1,130 – 38,400 cfs during the sampling season with a storm event producing a rise in flows between each primary sampling occasion (Figure 13). The peak flow for the winter was 59,100 cfs on December 21, 2014.

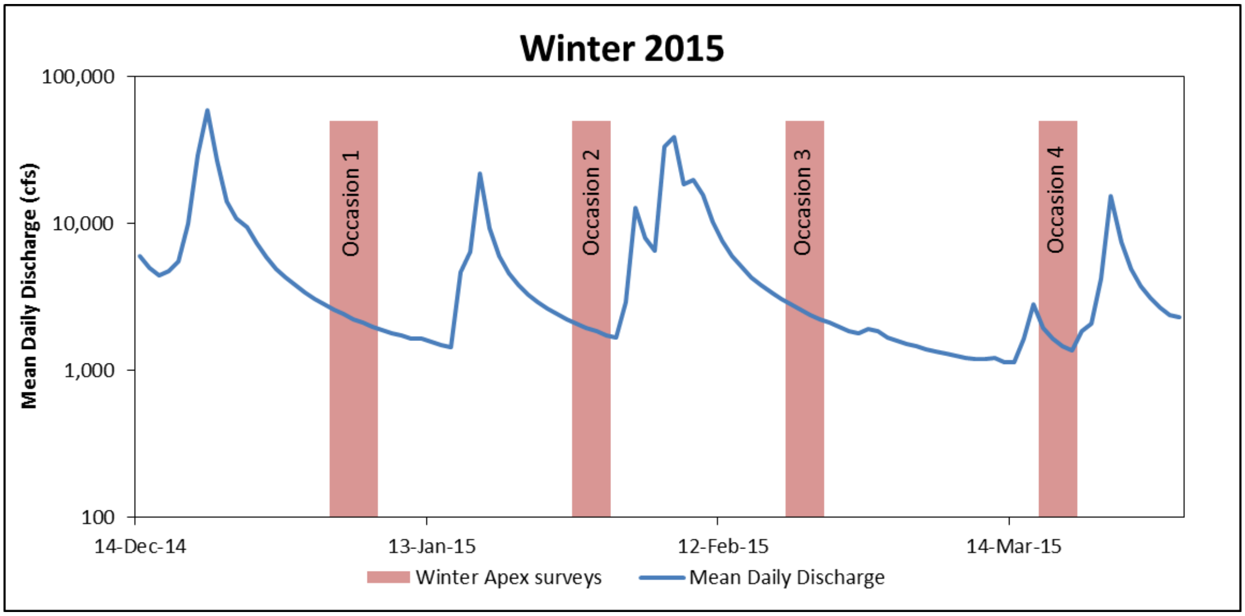

Figure 13. Daily average winter discharge and timing of winter sample surveys conducted at winter apex sites. Flow measured and recorded by the USGS Jed Smith stream gauge (11532500) located on the Smith River 25.97km upstream from the mouth near Hiouchi, California.

Based on the model with no covariates, estimated coho salmon occupancy was low (0.20, SE= 0.09) and remained consistent (0.19 – 0.20) throughout the winter sampling season (Table 9). Extinction was estimate to be 0.42 and colonization was estimated to be 0.11 (Table 9). However, based on the small number of occupied stations coupled with a moderate detection rate for minnow traps (p= 0.44, SE=0.15), estimated standard errors were large around colonization and extinction estimates (Table 9). For example, coho salmon were detected at eight of the 24 apex stations (Figure 11) but were present at only one location (station #8) consistently throughout the winter (Table 15). This location is a large alcove formed from a remnant gravel harvest pit that is connected intermittently to the mainstem river during high winter flows. This location also had the highest number of individual coho salmon detections during any single trapping occasion (Table 4). The water quality at this station did not vary greatly from the others, however, it did maintain the highest mean water temperature of all locations (Table 15).

Based on QAIC rankings we conclude no single covariate stands out as explaining occupancy of coho salmon given the data. The model with no covariates is the highest ranking model however an additional 6 models have a ΔQAIC <2 (Table 16). When evaluating the ranks of individual habitat covariates, area of cover created by beaver was found to rank highest. Furthermore water quality out ranked all habitat variables except for area of beaver cover. We found consistent extinction and colonization rates (*see* Model 1 *in* Table 16) to better explain the data than allowing for extinction (*see* Model 10 *in*) or colonization (*see* Model 11 *in* Table 14) to vary by season. Combining the top ranked covariate on occupancy and allowing for extinction to seasonally vary (*see* Model 9 *in* Table 16) was out performed by the simpler model without varying extinction (*see* Model 2 *in* Table 16). Overall the low detection probability and low occupancy throughout the apex monitoring stations reduces our ability to evaluate the influence of habitat and water quality conditions on coho salmon occupancy.

Table 15. Water quality and juvenile Coho salmon detections at 24 winter apex sites. All water quality measurements were recorded at the substrate, mid-water column and the water surface at the max depth of the site during each of the four survey occasions with a YSI professional plus. Temperature (temp) in degrees Celsius (°C). Dissolved oxygen (DO) in milligrams/liter (mg/L). Salinity in parts per thousand (ppt).

Site	Coho Salmon Occupancy 1	2	3	4	Mean Temp (°C)	Min Temp (°C)	Max Temp (°C)	Mean DO (mg/L)	Min DO (mg/L)	Max DO (mg/L)	Mean Salinity (ppt)	Min Salinity (ppt)	Max Salinity (ppt)
1	N	N	N	N	9.07	6.6	11.6	12.38	11.15	13.16	0.05	0.05	0.05
2	N	N	N	N	9.09	6.6	11.7	12.07	10.55	13.09	0.05	0.05	0.05
3	N	N	N	N	9.15	6.9	11.6	10.77	6.35	12.50	0.05	0.05	0.06
4	N	N	N	N	9.42	6.9	11.8	10.11	6.21	11.78	0.05	0.05	0.06
5	N	N	Y	N	9.78	6.9	11.9	11.22	10.11	12.98	0.05	0.05	0.05
6	N	N	Y	N	9.92	7.5	12.0	10.66	8.95	11.76	0.05	0.02	0.05
7	N	N	N	N	10.99	8.8	12.6	8.72	6.65	10.08	0.09	0.07	0.13
8	Y	Y	Y	Y	12.98	12.6	13.8	8.37	7.16	10.48	0.08	0.06	0.09
9	Y	N	Y	N	12.70	12.2	13.3	6.78	5.95	7.32	0.07	0.06	0.10
10	N	N	N	N	10.41	8.4	12.5	10.97	9.97	12.18	0.05	0.05	0.05
11	N	Y	Y	N	10.88	9.0	13	11.22	10.38	11.94	0.05	0.05	0.05
12	Y	N	N	N	11.33	10.5	13.2	9.89	8.74	10.38	0.04	0.04	0.06
13	N	N	N	N	11.18	9.7	12.4	10.26	9.51	11.08	0.05	0.03	0.06
14	N	N	N	N	10.41	9.3	11.7	11.63	10.89	12.12	0.05	0.05	0.05
15	N	N	N	N	10.28	9.3	11.7	11.54	11.10	12.13	0.05	0.05	0.05
16	N	N	N	N	10.25	9.3	11.4	11.54	10.96	12.19	0.05	0.05	0.05
17	N	N	N	Y	10.42	9.9	11.4	11.15	10.18	11.85	0.05	0.05	0.05
18	N	Y	N	N	9.52	8	11.6	6.72	3.74	10.75	0.10	0.06	0.14
19	N	N	N	N	10.72	9.6	11.6	8.78	5.94	10.80	0.24	0.09	0.37
20	N	N	N	N	10.26	8.9	11.9	11.78	10.29	14.16	0.14	0.06	0.53
21	N	N	N	N	11.08	9.3	14.7	10.17	8.29	11.39	0.19	0.06	0.41
22	N	N	N	N	10.60	8.6	12.0	9.07	5.86	10.99	1.48	0.42	2.43
23	N	N	N	N	9.71	8.1	12.5	9.46	8.17	10.82	1.48	0.07	5.31
24	N	N	N	N	8.27	6.8	9.6	3.34	1.09	5.24	0.18	0.11	0.33
Overall Average:					10.35	8.74	12.15	9.94	8.26	11.30	0.20	0.07	0.44

Lastly, our standard errors were large for all covariate estimates (Table 17) which is likely due to a lack of variation and minimal detection data at apex stations throughout the winter sampling season.

One Chinook salmon was detected during the first January sampling occasion in station 8 but was not detected again. Due to the rare and limited data no occupancy parameters were assessed for Chinook salmon. Detections of unidentified trout and steelhead were also rare with only 15 individuals at 7 stations across all four primary sampling occasions. Due to this sparse data occupancy parameters were not stable in occupancy models and could not be accurately estimated. Therefore only naïve estimates are reported and found to vary between 0.08 and 0.21 (Table 9). No Coastal cutthroat trout were detected with minnow traps at winter apex sites. However, we surmise our winter sampling methods were chosen to maximize coho salmon detections and may limit our ability to detect other larger-bodied species (e.g. large adult coastal cutthroat trout cannot fit into minnow traps).

Table 16. Summary of multi-season occupancy models evaluating habitat and temperature covariates ability to explain coho salmon occupancy at apex monitoring stations during the winter of 2014 - 2015.

Model		QAIC	ΔQAIC	AIC w	Model Likelihood	k
1)	ψ(.), γ(.), ε(.), p(.)	72.37	0.00	0.1809	1	4
2)	ψ(BEAVCOV), γ(.), ε(.), p(.)	72.58	0.21	0.1628	0.9003	5
3)	ψ(maxSALINITY), γ(.), ε(.), p(.)	73.57	1.20	0.0993	0.5488	5
4)	ψ(minDO), γ(.), ε(.), p(.)	73.68	1.31	0.094	0.5194	5
5)	ψ(LWD), γ(.), ε(.), p(.)	73.90	1.53	0.0842	0.4653	5
6)	ψ(DEPTH), γ(.), ε(.), p(.)	74.09	1.72	0.0765	0.4232	5
7)	ψ(BEAVER COVER PRESENT), γ(.), ε(.), p(.)	74.28	1.91	0.0696	0.3848	5
8)	ψ(%cover), γ(.), ε(.), p(.)	74.37	2.00	0.0665	0.3679	5
9)	ψ(BEAVCOV), γ(.), ε(season), p(.)	74.66	2.29	0.0576	0.3182	7
10)	ψ(.), γ(.), ε(season), p(.)	74.73	2.36	0.0556	0.3073	6
11)	ψ(.), γ(season), ε(.), p(.)	76.05	3.68	0.0287	0.1588	6
12)	ψ, γ(.), ε(season + salinity), p(.)	76.38	4.01	0.0244	0.1347	7

Occupancy (ψ) was modeled to be constant (.) or to vary on covariates including area cover created by beaver (m^2, BEAVCOV), maximum salinity (ppt, maxSALINITY), minimum dissolved oxygen (mg/L, minDO), large woody debris count (LWD), maximum depth of a unit (cm, DEPTH), and percent cover area (%cover). Extinction (ε) is either constant, constant with regard to monthly MWMT, or to vary by season based on monthly MWMT. Colonization (γ) and detection (p), are held constant in all models. k: number of parameters in the model, AIC w: probability the current model is the best approximate model in the candidate set.

Table 17. Covariate estimates and standard errors individually modeled on occupancy of coho salmon at apex monitoring sites during the winter 2014 - 2015.

Covariate	Estimate	SE with $\sqrt{\hat{c}}=1.24$	95% Confidence Interval with $\sqrt{\hat{c}}=1.24$ lower limit	upper limit
Area Beaver Cover	1.669	1.6306	-1.526976	4.864976
Maximum Salinity	-4.294	8.80772	-21.557131	12.969131
Minimum Dissolved Oxygen	-0.904	1.51776	-3.8788096	2.0708096
Large Woody Debris	-0.303	0.54436	-1.3699456	0.7639456
Maximum Depth	0.429	0.83576	-1.2090896	2.0670896
Beaver activity present	0.568	1.9406	-3.235576	4.371576
Percent Cover Area	-0.027	0.67828	-1.3564288	1.3024288

Winter Residence Time and Emigration

We marked a total of 77 coho salmon with PIT tags at seven apex sites during the first three of four survey occasions. We recaptured nine tagged individuals over the study period, all at apex station eight (Figure 5) where they were originally captured. The average detected residence time at this habitat was 26.67 days (22 – 45 days) for the period we studied indicating some individual juvenile coho salmon maintained residence at this location throughout the winter. This site is a large alcove that was once a gravel harvest pit in an intermittent side channel and provides slow water refuge during flood events. Additionally, beavers have further characterized the site with bank lodges and have built a small dam on the downstream end likely controlling the water depth at the site.

Because we scanned all captures for PIT tags, we determined four recaptured coho salmon were tagged during another concurrent coho salmon tagging study occurring in Mill Creek. The Mill Creek study tagged a total of 1,500 juvenile coho salmon in the fall of 2014 from September 23rd to October 22nd as part of an ongoing effort to quantify annual stage-based survival and emigration rates (J. Garwood, unpublished data) from Mill Creek. Three of the four individuals derived from Mill Creek were recaptured at winter apex site eight (Figure 3, Table 18) during the first sampling occasion in January and were not captured again. A fourth individual coho salmon, tagged in Mill Creek on October 7, 2014, was captured in a small tributary of Morrison Creek on Feb 26, 2015 (Figure 3, Table 18). This individual travelled a minimum of 28 km down the Smith River basin and over two kilometers up Morrison Creek. The tributary consisted of a small channel confined to a ditch along Fred Height Drive that connects to Morrison Creek through a dairy pasture. A total of 25 other unmarked coho salmon were captured in this tributary along Fred Haight Drive on the same sampling occasion. Overall the four Mill Creek fish grew an average of 22 mm (17 - 27 mm) and traveled an average of 28 stream km (22 - 30 km) (Table 18) between capture occasions.

Table 18. Capture dates, locations, fork length (FL) and distance between capture events of four individual juvenile coho salmon first tagged in Mill Creek during the fall of 2014 and subsequently captured during the winter of 2015 in the Smith River coastal plain and estuary.

Tag Number	Marked Date	Location Code	Initial Fork Length (mm)	Recapture Date	Location Code of Recapture	Recapture Fork Length (mm)	Distance Between Captures (km)
986114100003425	9/22/14	125 (EF Mill Creek)	70	1/28/15	7 (Smith River)	90	30.1
986114100003991	9/26/14	124 (EF Mill Creek)	75	1/28/15	7 (Smith River)	92	27.8
986114100004455	10/7/14	104 (Mainstem Mill)	80	1/28/15	7 (Smith River)	105	22.8
986114100004507	10/7/14	105 (Mainstem Mill)	82	2/26/15	80 (Morrison Creek)	109	30.0

Summer and Winter Estuary Salinity Transects

A salinity transect conducted by Mizuno (1998) throughout the Smith River estuary during the summer of 1993 found the summer salt wedge to extend 6.75 km upstream of the mouth to the mouth of Rowdy Creek (Figure 14). To reevaluate the summer salinity influence within the same general area, we collected salinity readings at 92 locations from 4.5 km to 8.5 km from the mouth. We found the salt wedge extended 7.65 km upstream from the mouth with a salinity reading of 6.53ppt at a depth of 3.0 meters (Figure 14). Additionally we found the salt wedge extended into Rowdy Creek 0.37 km with a terminal reading of 1.1 ppt at a depth of 1.0 meters. These data indicate a much larger tidal influence is occurring in the estuary than previously known during the summer low river flow period at

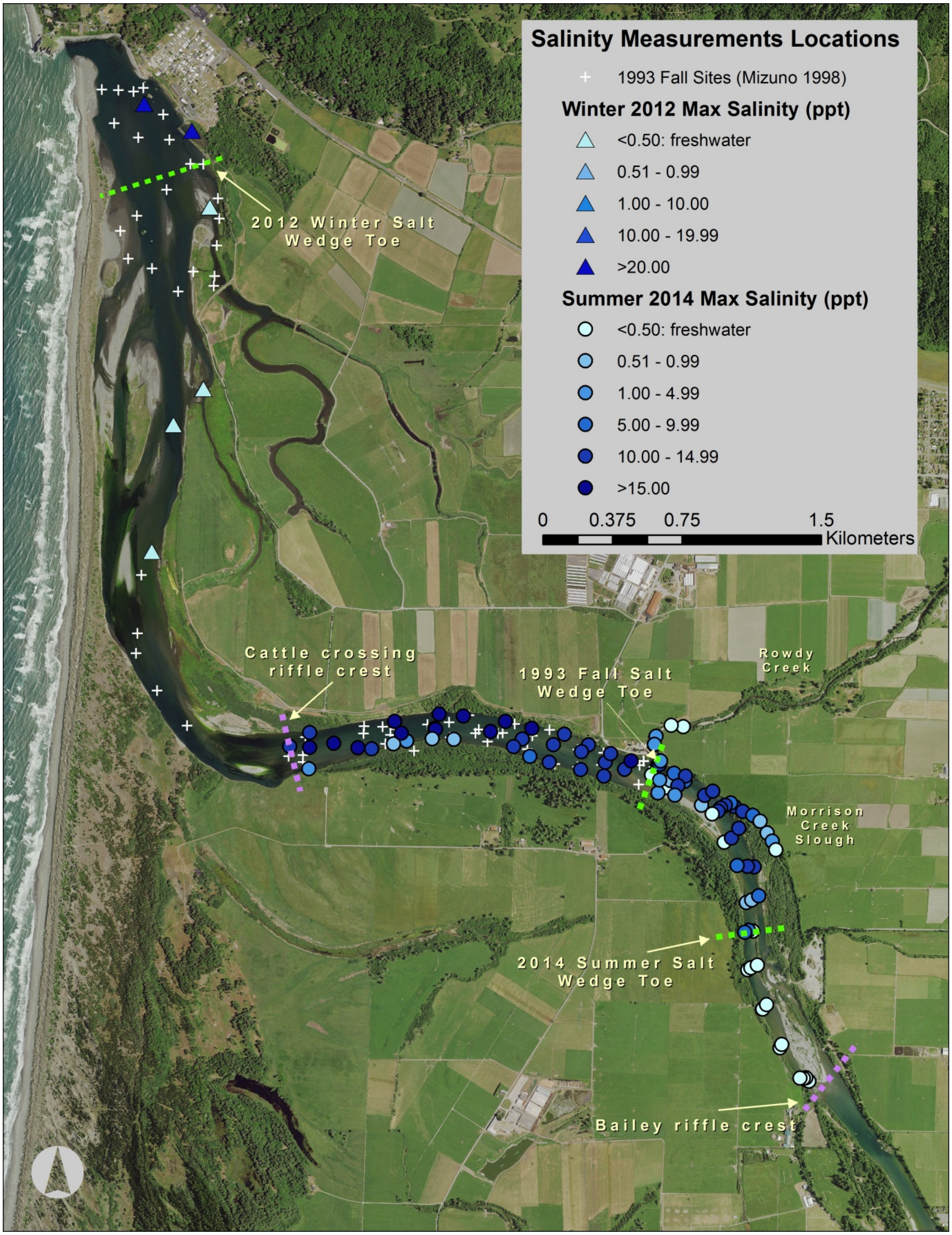

Figure 14. Maximum salinity concentration at each sample location in Rowdy Creek, Morrison slough, and the mainstem Smith River, Del Norte County, California, during sampling conducted during winter of 2012 and summer 2014. Approximate locations of the salt wedge toe are identified for the fall of 1993 (Mizuno 1998), the winter 2012, and the summer of 2014. The maximum observed freshwater tidal prism at high-tide extended up to the Bailey Riffle crest during the summer of 2015.

exceptionally high tides. Salinity isocline profiles for both 1993 and 2014 were created using readings collected from similar locations in the thalweg along the north bank of the channel (Figure 15). During both years of surveys a freshwater lens of <0.05 ppt was detected at surface readings throughout channel upstream from the cattle crossing (Figure 14, Figure 15). These findings suggest that water quality conditions remain within the tolerance threshold of juvenile coho salmon upstream of the cattle crossing throughout the summer even though the salt wedge extends another 2.03 km upstream from this location. In contrast to the summer, we found the general winter salt wedge location much lower in the estuary. Salinity dropped to zero throughout the water column at approximately 900 meters from the mouth of the Smith River (Figure 14).

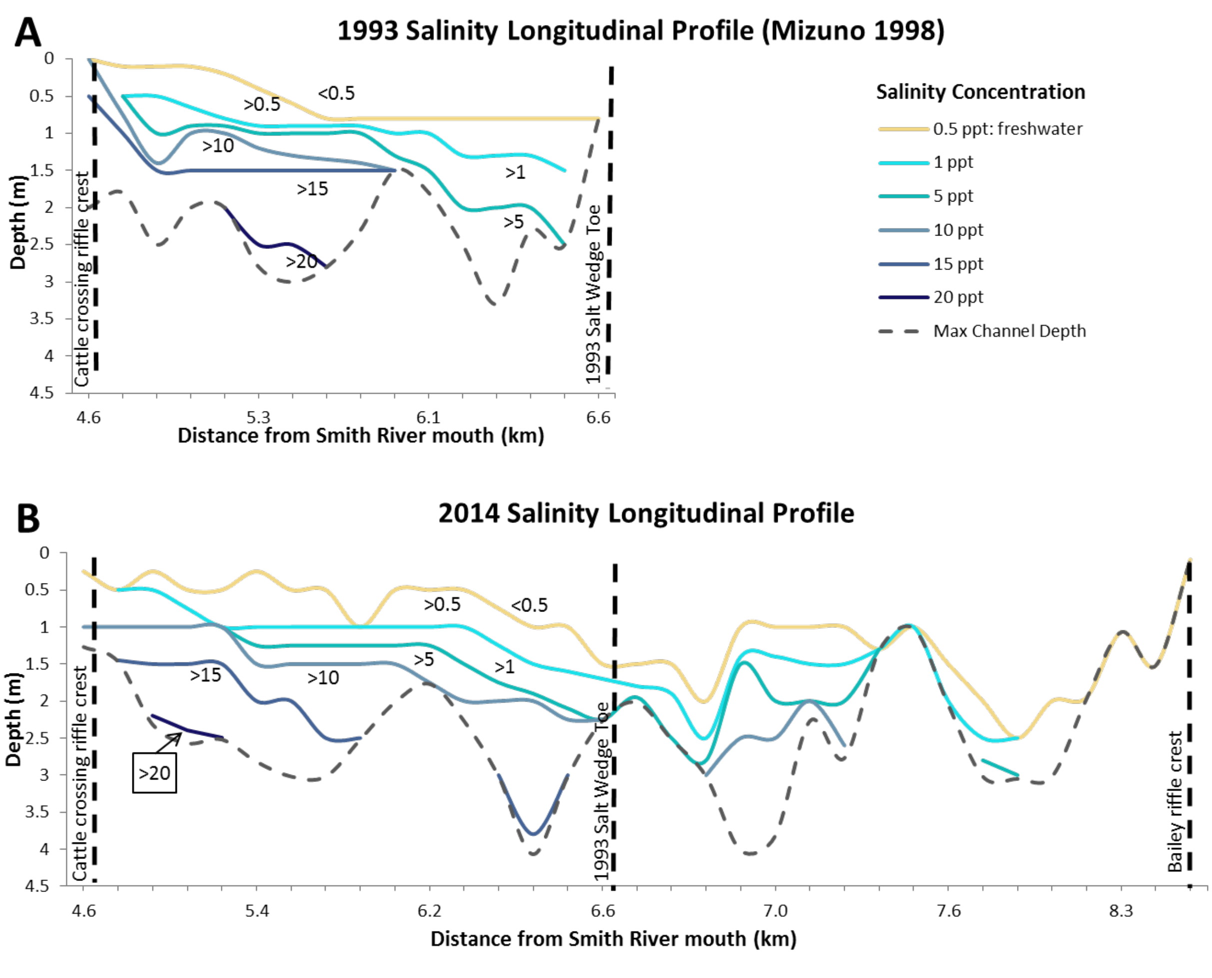

Figure 15. Longitudinal isocline profiles comparing salt concentration and the salt wedge toe from data collected in 1993 (A) (Mizuno 1998) and 2014 (B). Legend salinity color gradient applies to both graphs.

Noteworthy Observations of Native Flora and Fauna

During this study, we discovered native eelgrass (*Zostera marina*) growing in sheltered areas of the sublittoral zone within the Smith River estuary. To our knowledge this is the first description of this flowering plant occurring in the Smith River estuary, despite its role as a keystone species in marine and estuary ecosystems throughout California and the Pacific Northwest. We mapped the perimeter of all patches at a minus tide during the peak growing season on July 5th, 2015 using a kayak and GPS. Polygons were imported into a GIS and were checked for accuracy using satellite images and photo points (Appendix A). The total estimated area from all patches equaled 1.67 acres. One area was not accessible via boat due to depth (old inner boat dock) and was surveyed by walking around the perimeter and estimating the size of the eelgrass patches inside. We also observed individual plants had conspicuous fruits (seeds) throughout the patches at the time of the survey.

In addition to salmonids and other commonly observed fish species, we captured a bay pipefish (*Syngnathus leptorhynchus*) during the summer of 2014 above the Tillas Slough levee tide gates which is only the third observation for the species occurring in the Smith River estuary (Table 1, Figure 9). We also captured a single tidewater goby (*Eucyclogobius newberryi*) while beach seining during the winter in the pool below the levee tide gates on Tillas Slough (Figure 9). Tidewater gobies are listed as threatened under the Federal Endangered Species Act and very little information exists on the status of the Smith River population.

Invasive Species Observations

We systematically documented the presence of invasive flora and fauna during the summer of 2014 and winter of 2015 field seasons to assess the spatial overlap of these species with salmonid habitats. However, our list is not complete, especially for other potential invasive aquatic plants. Generally we report on the most obvious occurrences of commonly occurring invasive species in the region.

Flora– Reed canary grass (RCG) is a perennial, cool-season, rhizomatous plant native to Eurasia and was very common throughout the coastal plain below Highway 101. RCG was identified in the mainstem Smith River, Tillas Slough, Ritmer Creek, Delilah Creek, Islas Slough, Morrison Creek, Yontocket Slough, and Tryon Creek (Figure 16). However, of these locations we believe RCG is causing the most detriment to fish habitat in Morrison Slough, Morrison Creek, Yontocket Slough, and Tryon Creek. Many portions of these channels are completely filled with dense patches or floating mats of vegetation. These areas also typically lack riparian shading which is known to suppress of eliminate RCG productivity. We also found two small patches (~3m^2 each) of yellowflag iris (*Iris pseudacorus*) along the banks of Morrison Creek in reach 77 (Figure 16). Originating in Europe, yellowflag iris was introduced to North America as an ornamental plant. It is an herbaceous perennial up to 1.5m tall with bright yellow or cream-colored flowers and thick rhizomes.

Fauna– The New Zealand Mudsnail (*Potamopyrgus antipodarum*) (NZMS) was first detected in the western United States in 1987 (Bowler 1991) and is now present in lakes and rivers across the western United States (USGS 2015b). NZMS were first detected in the Smith River and Tillas Slough in September, 2008 (USGS). We detected NZMS at 14 sampling locations in the lower estuary, with the furthest upstream (easting) location occurring in Morrison Slough at 7.4 km upstream of the Smith River mouth (Figure 16). The majority of NZMS observations were in slough channels, with one observation occurring in the mainstem Smith River. We generally noticed NZMS relative abundance increased during the 2014 summer sampling season and was lowest during the 2015 winter sampling, a trend also observed in Polecat Creek, WY (Hall et al. 2006).

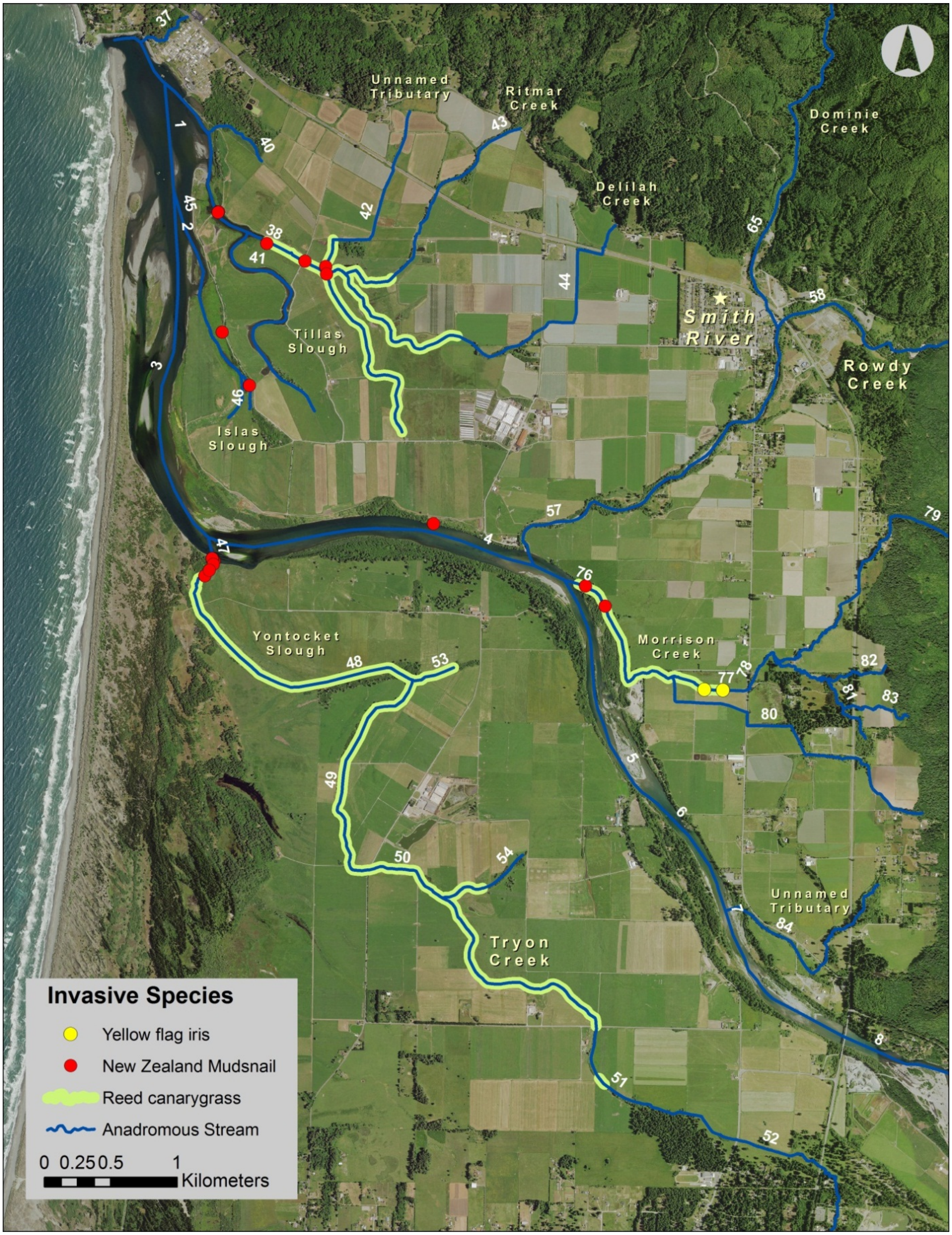

Figure 16. Distribution of invasive flora and fauna cataloged during salmonid distribution surveys occurring in the summer of 2014 and winter of 2015, Smith River Basin, Del Norte County, California. Note: mapped distributions are not complete but based on our sampling locations defined in Figures three and four. Reach location codes are labeled in white.

Discussion

Coho salmon have been shown to exhibit diverse life history strategies. The historic assumption was that early emigrates or "nomads" had low survival rates and did not substantially contribute to the adult escapement population (Crone and Bond 1976). However recent studies have shown that individuals exhibiting alternative life histories including early emigration and non-natal rearing contributed to approximately 30 percent of adult escapement (Bennett et al. 2014; Jones et al. 2014). As seen in other Pacific Northwest streams, we found coho salmon utilizing non-natal rearing habitat in the mainstem and estuary ecotone during the summer and winter months (Miller and Sadro 2003; Wallace 2006; Koski 2009; Jones et al. 2014) throughout the Smith River plain.

We found coho salmon occupancy in the coastal plain to be higher during the summer months than the winter months across both GRTS surveyed reaches and apex monitoring stations (Table 7, Table 9, Table 13) and was relatively stable throughout both seasons (Table 9). Furthermore, coho salmon had higher occupancy in the mainstem than the coastal tributaries during the summer but higher use of coastal tributaries during the winter than the summer. Seasonally utilizing varying habitats in the stream estuary ecotone has also been documented in the other Pacific Northwest basins (Jones et al. 2014; Wallace et al. *in review*). Additionally, these same seasonal movements were observed with the North American beaver most prevalent in the mainstem during the summer and use of smaller coastal tributaries (Tryon Creek, Morrison Creek, and an Unnamed Tributary (Reach 84)) increasing during the winter. Beavers are likely an important component in creating and maintaining habitat availability and complexity for rearing coho salmon in the Smith River plain.

We found backwater and alcove features to be important rearing habitats during both the summer and winter sampling seasons as has been documented in other coastal regions (Bustard and Narver 1975; Nickelson et al. 1992). Specifically during the winter months these habitat features were more commonly occupied than other coastal mainstem features (i.e. sloughs and edge waters). Historically these features were more common; however the construction of private levees has channelized the mainstem and estuary leading to a decreased availability of these important off-channel rearing habitats. Based on historic aerial imagery, the total active channel area in 1942 was 650 acres from the Pacific Ocean to the mouth of Rowdy Creek. Based on NAIP imagery in 2012 the total active channel area was 580 acres (Figure 2). To aid in the recovery of the Smith River coho salmon population, restoration should focus on adding complex off-channel habitats throughout the active channel of the coastal plain.

While stream temperature is likely a limiting factor to non-natal summer rearing habitat we found coho salmon to occupy sites reaching >23 °C (Table 4). All summer apex stations had either a cold water seep or dense overhanging cover and depths >1m. Fluctuations in temperature occurred daily and at various water depths. These fluctuations likely play a role in allowing for juvenile coho salmon to survive peak summer water temperatures. Restoration and habitat improvement projects should focus efforts in areas of cold water seeps, confluences with cold water tributaries, sites with water depths >1m throughout the summer, and/or encourage dense overhanging cover to provide shade and decreases in water temperature.

Our probability of detecting coho salmon with minnow traps was within the range of that reported in other studies which used minnow traps to detected juvenile coho salmon (Bryant 2000; Sethi 2013). However, we believe detection with minnow traps could be further improved within the Smith River coastal plain. No individual fish was captured during back to back days of trapping. This 'trap shy' behavior was likely a function of the bait availability. It is probable that captured fish were less likely to be captured on day 2 as a function of them being satiated without sufficient time to digest. Future trapping studies aimed at assessing occupancy should contain the bait to prevent a reduction in the trappable population on subsequent sampling days.

Adult escapement estimates for the spawning season preceding our study was low (J. Garwood. unpublished data). Additionally our study was conducted during the third consecutive year of drought. Variations in life history strategies likely buffers negative impacts of environmental and population stochasticity on coho salmon and adds resilience to the population as has been documented for other salmonid species (Hilborn et al. 2003; Greene et al. 2010). Coho salmon spatial and temporal use of non-natal rearing habitats in the Smith River basin was not previously well documented. Throughout our study and past incidental surveys we have documented non-natal rearing throughout the mainstem and coastal tributaries including Tryon Creek, Morrison Creek, and an unnamed tributary (Reach 84). Furthermore we captured individual coho salmon previously encountered in Mill Creek marked with PIT tags as part of an over winter survival study. Further understanding of coho salmon movement and survival in these tributaries is needed to identify source and sink populations and to prioritize where restoration should be focused.

Estuary

Overall the Smith River estuary lacks habitat complexity, cover and off-channel rearing habitats. A levee system flanking rowdy creek and the northern bank of the river (Figure 2, Appendix B) has reduced connectivity to the floodplain and decreased channel structure, both of which are identified as stresses limiting the recovery of coho salmon (NMFS 2014). The size of and access to coastal sloughs and tributaries has also been reduced due to construction of the levee and tide gates along the east/northeast bank (Figure 2). Overall the levee has caused the estuary and lower mainstem to become more channelized reducing the availability rearing habitat and particularly slow water refuge habitat during the winter storm events.

The furthest downstream detection of coho salmon was at the mouth of a small tributary (reach 40) on the east bank (Figure 5) near the mouth of the river. A tide gate is located directly at the mouth of this stream (Figure 6) and is likely limiting passage of juvenile salmonids into this coastal tributary. We also seined up two adult steelhead holding in the pool below this tide gate during the winter of 2013 (J. Garwood, unpublished data). Upstream from the tide gate the tributary is surrounded by vegetation and likely provides year round rearing habitat however, it remains unclear if the tributary provides spawning habitat. During the late summer months the extent of salinity influence limits the available rearing habitat. While we detected juvenile coho salmon downstream of the cattle crossing riffle in early June, this area reaches salinity levels above pre-smolt coho salmon thresholds later in the summer. After winter storms elevate river flows, the extent of salinity influence is pushed downstream near the mouth making the majority of the river within salinity levels that coho salmon can tolerance.

Tillas Slough

Tillas slough is comprised of two main forks, an east and west, and three tributaries, Delilah Creek, Ritmer Creek, and the unnamed tributary (Reach 42), contributing to the east leg (Figure 1). To access these three tributaries and the upper section of the east leg, spawning or non-natal rearing salmon must first pass through a functioning tide gate located 430m upstream from the levee (Figure 2). Low dissolved oxygen upstream of this tide gate further hinders upstream movement and rearing habitat availability for rearing coho salmon. Water quality readings during summer sampling were below coho salmon tolerance threshold with a minimum of 0.07 mg/L and a maximum of 2.47 mg/L. Passage in this section as well as the mouths of the three tributaries is further impaired by dense RCG within the channels. Furthermore, all three tributaries have been heavily impacted due to agriculture resulting in a lack of riparian vegetation and channel complexity.

Water quality readings between the two tide gates and throughout the east leg were above coho salmon tolerance thresholds. Thermal stratification was recorded at most sampling locations, and colder temperatures were always at the maximum depths where dissolved oxygen was lowest. Low dissolved oxygen and high water temperature is likely due to a lack of water flow and connectivity throughout Tillas slough. Furthermore, Parthree (2004) reported phosphate concentrations were greater than levels identified as causing eutrophication (EPA 1986) in Tillas slough downstream of the levee during the summer of 2000 and 2001. Throughout the Tillas slough sub-basin there is a lack of riparian vegetation and channel complexity. Restoration aimed at providing a vegetated riparian buffer could improve water quality by reducing phosphate, ammonia, and nitrate inputs from runoff of the surround pasture (Lowrance et al. 1983; Osborne and Kovacic, 1993).

Islas Slough

While we did not detect any coho salmon in Islas slough, they have been observed there in the past (Parthree 2004). Based on historic aerial imagery, Islas slough once functioned as a side channel during elevated winter flow events. Winter storms likely scoured this featured creating a variety of depths. With the construction of the private levees, the upstream connection to Islas slough has been blocked resulting in a decreased depth, area and habitat availability (Figure 2, Appendix B). When surveyed in July 2014 dissolved oxygen and salinity were within coho salmon tolerance thresholds though temperature ranged from 17.9-22.2°C. An increase in depth would likely help to reduce the stream temperature and improve rearing habitat. By reconfiguring the levee, a listed priority recovery action (NMFS 2014), habitat conditions would naturally improve due to winter flows flushing and re-scouring the slough.

Yontocket Slough/Tryon Creek

During summer sampling we found the majority of Tryon Creek to be dry (Figure 6). However, we do find patches of water in reach 50 (Figure 3), upstream from Lower Lake Rd but downstream from Moseley Rd, with water quality readings within coho salmon tolerance thresholds. While we did not detect any coho salmon we did capture a coastal cutthroat trout with a seine (Figure 9). During our winter sampling effort we detected coho salmon both above and below Pala Rd. However, no salmonids were detected within the pond of Yontocket Slough. Multiple barriers within the subbasin (Figure 6) likely hinder coho salmon use of this stream for non-natal rearing. Culvert replacement and evaluation is needed to improve passage and access to summer and winter rearing habitat.

Yontocket slough is a remnant stream channel with potential to benefit the Smith River salmonid populations (Love 2006). However RCG entirely fills the channels in sections throughout the Yontocket/Tryon Creek basin, hindering fish passage, reducing habitat availability, and decreasing dissolved oxygen. The rhizomes of RCG can form a thick sod layer, excluding beneficial riparian plants (Tu et al. 2004), leading to channel aggradation and increased flooding of the surround lands. Removal of RCG in main channel of Strawberry Creek, a tributary to Redwood Creek, CA, showed an immediate increase in dissolved oxygen. However within five years the RCG had regrown in the channel again reducing dissolved oxygen levels (RNP 2014). Research is needed to evaluate effective long term restoration techniques for RCG removal in the Smith River basin (Love 2006) and to improve habitat quality and availability in the Yontocket slough/Tryon Creek basin.

Rowdy Creek

After Mill Creek, Rowdy Creek is the largest coastal tributary that provides spawning and rearing habitats for coho salmon in the Smith River. Potential rearing habitats in the lower four kilometers of the basin have been substantially reduced due to the levees and rip-rap lined banks effectively preventing the channel from migrating and providing slow water refuge during high winter flows. We especially found no slow water refuge during the winter through the lower 1.5 km of stream.

Substantial barriers on Rowdy and Dominie Creeks (Figure 6) prevent the upstream migration of juvenile salmonids and limit adult migrations to specific flow criteria.

Morrison Creek and Slough

The mouth of Morrison Creek empties into a slough feature that becomes a side channel during high winter flows. The slough has two distinct sections divided by a shallow pinch approximately halfway upstream from the mouth. During the summer the mouth of the downstream section is tidally influenced with temperatures ranging from 17-21°C. This area is fairly open with submerged aquatic vegetation only along the margins. The upstream section has consistently cooler temperatures ranging from 13-18 °C with both native (yellow pond lily) and non-native (RCG) filling the majority of the slough. We detected coho salmon in the upper section of the slough during our winter apex surveys (Figure 11) but no coho salmon have been detected during incidental summer sampling conducted during this or past sampling efforts. Low levels of dissolved oxygen have been measured during summer sampling in the upper section of the slough which is likely caused by decomposing RCG.

Coho salmon were documented throughout Morrison Creek during both the summer and winter GRTS sampling efforts (Table 6, Table 12). Compared to other coastal tributaries outside of Mill Creek, Morrison Creek has been used most consistently by coho salmon (Garwood 2012, Garwood and Larson 2014, Garwood et al. 2014). Due to anthropogenic use of the surrounding lands rearing habitat has been decreased due to channelization, sedimentation, road crossings, and diversion/retention of cool water tributaries (Figure 6). Additionally, non-native vegetation including RCG and Yellow Flag Iris armors banks, encroaching on stream habitat, and competing with native riparian vegetation (Figure 16). We documented coho salmon in small tributaries which feed into reach 78 (Figure 5) resulting in the creation of three new reaches in our sample frame. These streams run through second growth forest on private property. Restoration should focus on removing non-native RCG, yellow flag iris (Figure 16) and problem culverts (Figure 6) as well as increasing slow water refuge, cattle exclusion fencing, and riparian buffers. Lastly, we captured an individual which was previously captured and PIT tagged in Mill Creek during the fall 2014 (Figure 5). Further research evaluating movement, growth, and survival of nomads occurring in Morrison Creek is needed.

Unnamed tributary (Reach 84)

The unnamed tributary (Reach 84) that parallels and crosses Fred Haight Drive (Figure 3) was found to be entirely dry during summer GRTS surveys (Table 6). However, during two days of incidental survey of this reach during February 2015, 37 individual coho salmon were captured (Figure 5). The mouth of reach 84 was disconnected from the mainstem during these surveys when the daily average flows of the Smith River were 1,910 cfs and 1860 cfs, respectively. During incidental surveys conducted in February of 2013, 111 coho salmon were detected in this reach (Garwood and Bauer 2013). Sections of this stream have dense willow large black cottonwood trees, though other sections are devoid of vegetation due to a lack of cattle exclusion fencing. Furthermore multiple culverts, two of which are cattle crossings, are temporal juvenile barriers (Figure 6). Reach 84 is likely used as winter non-natal rearing habitat every year. Furthermore, beavers move into this stream during the winter, creating channel spanning dams and increasing available rearing habitat (Figure 17). However, due to a lack of connection at the mouth, the stream currently has the potential to be a population sink for coho salmon accessing the stream during high flow events. Evaluation and replaced of culverts and prolonged connection at the mouth is needed to improve passage and access to rearing habitat.

Mainstem

Upstream of Highway 101 the mainstem is sinuous with hardened bedrock features stabilizing the channel form. Side channels developed during high flow events cause scour and create of backwater and alcove habitat features which occur into the summer. Cold water seeps are commonly associated

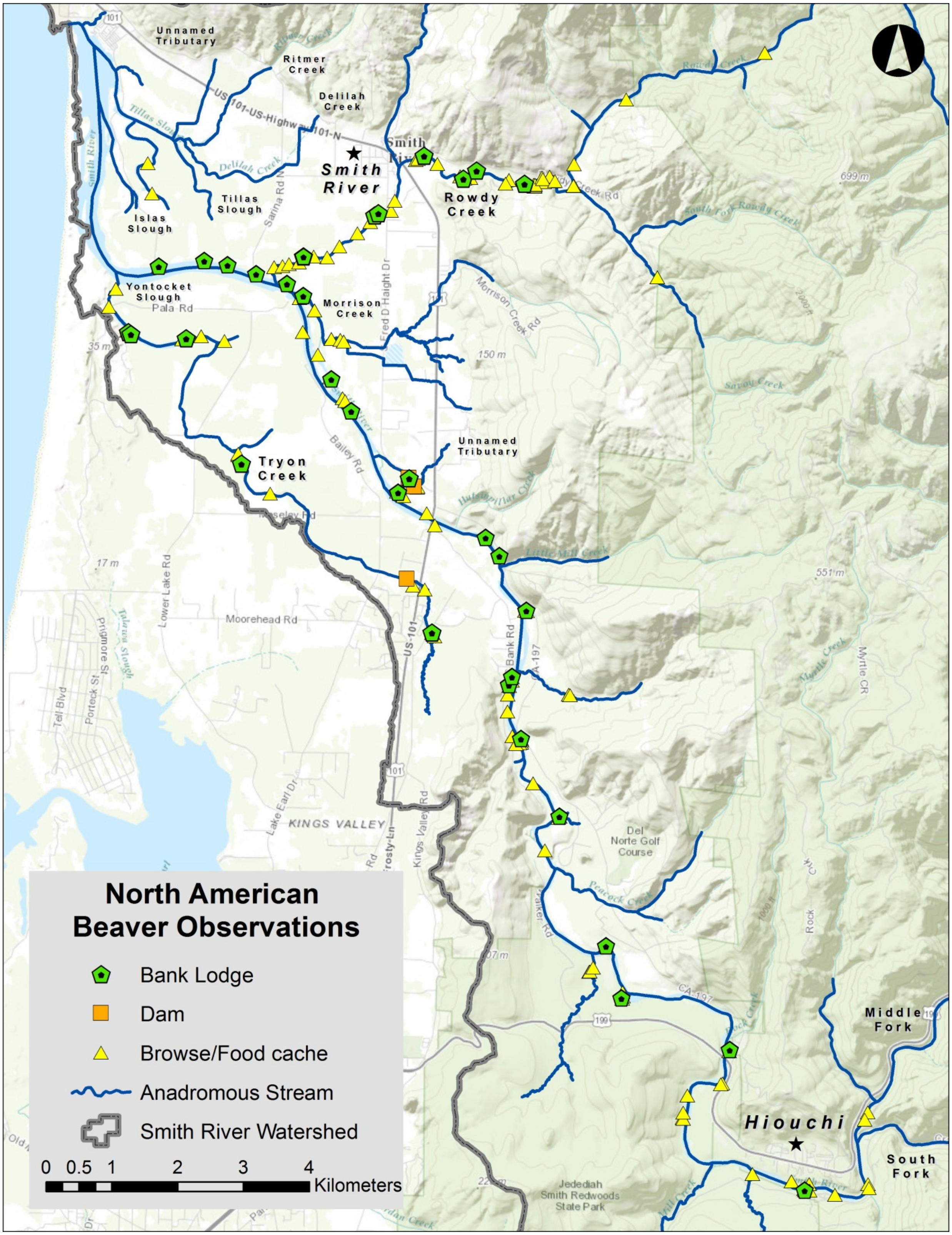

Figure 17. Distribution of American beaver (*Castor canadensis*) observations recorded during this study throughout the lower Smith River and coastal plain, Del Norte County, California.

with these features and provide rearing habitat throughout the hot summer months. Furthermore these features are commonly utilized by beavers whose activities maintain channel connectivity and habitat complexity has the water level lowers throughout the summer months. Downstream from highway 101 the channel bedrock features become less common allowing the river to move across its flood plain resulting in shallower habitats and less complexity.

Historic gravel harvesting created multiple backwater features (Reach 5) many of which we did not detect coho salmon utilizing during the summer or winter months. These features are largely devoid of cover or habitat complexity. These features would likely benefit from the addition of large woody debris and increased overhanging riparian vegetation. Downstream from Rowdy Creek the levee on the north bank has resulted in channelization and loss of slow water refuge. Removal, setting back or reconfiguring the levees would likely result in the creation of off-channel habitats, alcoves, backwater habitat, and old stream oxbows. Both of these restoration tasks are listed as priority recovery actions (NMFS 2014).

Mill Creek

The majority of coho salmon observations are in within the Mill Creek watershed making it the most important sub-basin for the species throughout the entire Smith River basin. While our study did not focus in this sub-basin, many of the coho salmon we observed in the study likely originated from Mill Creek highlighting the connection between Mill Creek and the coastal plain. Numerous restoration projects have occurred throughout the Mill Creek sub-basin however the coho salmon population has not yet recovered to historic numbers proposed by NMFS (2014). Improved habitat and adult escapement in Mill Creek will likely produce more early emigrants rearing in non-natal habitats throughout the lower river and estuary. Intact non-natal rearing areas throughout the mainstem-estuary ecotone and coastal tributaries are needed to increase survival of individuals emigrating from natal streams during both the summer and winter months. The increased survival of individuals exhibiting various life-histories adds resilience to the Smith River coho population and increases overall recovery of the species (Hilborn et al. 2003).

Recommendations

Salmonid Habitat Enhancement and Restoration

Through this study we have identified many opportunities for restoring or enhancing salmonid habits in the lower Smith River and its estuary. Given much of the lands surrounding the study area are largely in private ownership, strong partnerships with various landowners will be essential to planning and implementing various restoration efforts. Though some restoration actions identified in this investigation may be obvious, prioritization of restoration activities is beyond the scope of this project, and many important topics have yet to be investigated. However, this document can serve as a starting point for understanding the current state of these important salmonid habitats and the current data gaps that need to be addressed.

Fish Passage

Replacement of complete and partial barriers is listed as a priority recovery action in the SONCC coho salmon recovery plan (NMFS 2014) and is an efficient method to increase seasonally available rearing habitat throughout the coastal plain. The Rowdy Creek Fish Hatchery weir is a complete barrier to juvenile salmonids and partial barrier to adult salmonids. A total of 18.4 kilometers of spawning and rearing habitat exists above the weir making it the highest priority in the Smith River, and it ranks among the largest passage problems throughout the SONCC ESU. Juvenile and adult coho salmon have been found above the barrier indicating only intermittent reproduction is occurring, despite the abundance of available coho salmon spawning and rearing habitats. With recent findings from other studies describing non-natal rearing and colonization of distant habitats by juvenile coho salmon, the alluvial valley portion of Rowdy Creek could also offer substantial low gradient non-natal rearing habitats for nomadic juvenile salmonids; habitats which have been largely lost in the lower Smith River estuary ecotone. Additionally, portions of Rowdy Creek above the weir have been the recent focus of wood loading projects adding complexity to Rowdy Creek fish habitats. Complete removal, or providing juvenile passage alterations to this structure, would substantially increase natural migratory behavior for all salmonid and lamprey species.

Throughout the study area, we have identified road crossings and cattle crossings with compete and partial barriers as well as those with unknown passage status (Figure 6). Evaluation of these culverts is needed to enable restoration practitioners to prioritize and replace problem culverts. Documented use by coho salmon highlights the need to prioritize efforts in Tryon Creek, Morrison Creek, and the unnamed tributary (Reach 84) along Fred Haight Drive. The documented seasonal movement upstream into the coastal tributaries, some of which dry during the summer months, highlights the need to ensure juvenile salmonid passage is possible even at very low flows. Furthermore passage assessment of the tide gates in Tillas slough and reach 40 is needed at various flows. Installation of fish friendly tide gates or studying the feasibility for complete removal would likely increase passage and reduce stranding for juvenile salmonids in the lower estuary ecotone.

Levees and Rip-Rap

A substantial portion of the northern estuary has been modified using levees and rip-rap to control for flooding and to provide bank stability. However, these modifications have severed many connections to slow water habitat and have simplified these areas into deep high-velocity channels during high flows. Recommendations on how to modify, set back, or remove portions of these features to benefit stream habitat is beyond the scope of this study. However, some locations with these features may be suitable for modification or removal if substantial benefits are recognized and landowners are willing to cooperate. For example, the historic mill site located along the banks of Rowdy Creek directly above Highway 101 that has sat vacant for decades. The mill used rip-rap in multiple locations to protect infrastructure and buildings from channel migration. Prior to these modifications, this portion of Rowdy Creek had a wide valley and a dynamic meandering channel that likely provided multiple off-channel and slow water habitats during high winter flows.

Hydroperiod

This study was conducted during an extended severe drought and we documented multiple dry channels in the coastal plain during the early summer of 2014. However, most of the places we documented dry channel have been recognized as ephemeral in normal water years. Based on our observed fish distribution, we suggest Morrison Creek, Tryon Creek, and an unnamed tributary (reach 84) likely pose the largest problem for annual fish kills through drying channels. For example, Morrison Creek, near Fred Haight drive has completely dried up over the past four summers. We have documented juvenile coho salmon, Chinook salmon, steelhead, and coastal cutthroat trout rearing throughout this portion of stream during the early summer in each of these years indicating hundreds to thousands of individuals likely get stranded and die annually as the stream channel dries up. Any effort to increase surface flows of these identified streams to maintain perennial status throughout the summer would greatly increase the survival of rearing salmonids in these streams.

Water Quality

The impacts of runoff from agricultural fields surrounding the Smith River estuary are not well documented. Levels of ammonia have not been assessed since the EPA water quality criteria for freshwater species, including threatened salmonid species, have been updated (USEPA 2013). Research is needed to identify current water quality conditions and to identify areas of concern that may be limiting coho salmon rearing habitat in the Smith River estuary. Currently the California Water Board is conducting water sampling to aid in understanding water quality conditions and to assist in the development of a permit process for agricultural discharges, particularly those associated with Easter lily bulb cultivation (CWB 2015).

Our salinity monitoring found salt water intrusion to reach 7.65 km upstream of the mouth during summer low flow conditions. Comparatively the salt water intrusion was minimal during the winter season indicating the majority of the lower Smith River estuary is freshwater during the winter months. The ability of coho salmon to adapt to salinity levels has been documented to seasonally vary, with a tolerance level increasing from 22-25 ppt during the summer, a slight decline through the fall, and tolerance again increasing in the winter from 30-35 ppt (Otto 1971). Furthermore the limiting effects of salinity on survival were reduced after exposure to dilute salinities (Otto 1971) highlighting the need for rearing habitat in areas with various salinity levels. The area of the Smith River where salinities remain under the summer salinity thresholds but provide brackish water, from the cattle crossing riffle to the bailey crossing riffle (Figure 14, Figure 15), is channelized and lacks off-channel habitat features. Improved channel complexity and creation of off-channel habitat throughout this area would provide rearing areas for coho salmon with high productivity potential.

Water Drafting

At least four agricultural water drafting locations were observed during the summer; three in the lower mainstem Smith River and one in lower Rowdy Creek. Screening on these large pipe diameter diversions, for the purpose of avoiding take on juvenile salmonids, appeared to vary and was likely not sufficient. Given juvenile coho salmon were found rearing throughout these areas when water pumping was active, proper screening designs should be considered.

Riparian Zone

Installation of vegetated riparian buffer strips along the waterways has been shown to reduce concentrations of nutrients from agricultural practice and thereby improving water quality (Lowrance et al. 1983; Osborne and Kovacic, 1993; Daniels and Gilliam 1996). Riparian buffers also aid in reducing sediment input (Daniels and Gilliam 1996) and water temperature (Poole and Berman 2001). To ensure long term production of installed riparian vegetation cattle exclusion fencing should be paired with project, particularly in the Tillas Slough sub-basin, the Yontocket slough/Tryon Creek sub-basin, reach 78 of Morrison Creek (between Fred Haight Drive and HWY 101), and the unnamed tributary (Reach 84). Additionally cattle exclusion fencing along sections of the mainstem would improve riparian vegetation and future wood recruitment to the channel. These efforts can also be paired with removal of non-native flora, particularly RCG and Yellowflag iris, which competes with and can displace native beneficial riparian vegetation. The small patches of Yellowflag iris could spread and displace desirable riparian vegetation. Due to the small patch and limited distribution the species is likely currently controllable. Research and restoration is needed to reduce the negative impacts of RCG throughout sections of the coastal plain, particularly in the Yontocket slough/Tryon Creek and Morrison Creek sub-basins (Figure 16).

New Zealand Mudsnails

NZMS can reproduce in salinities up to 15ppt and survive for shorter periods of time in salinities up to 35ppt. When found in high density NZMS can compete with native invertebrates and can consume high percentages (75%) of gross primary productivity (Hall et al. 2003). A proportion of NZMS, 20-50%, predated by fish are able to survive gut passage intact or alive, thereby providing little energetic benefit to fish predators (Brenneis et al. 2011). Currently the spatial extent of NZMS in the Smith River basin is minimal and restricted to the coastal plain. However due to the potential negative impacts of NZMS on native invertebrates and fish food, steps should be taken to prevent the spread of NZMS to new locations within the basin.

North American Beaver

Increasing beaver abundance is listed as a recovery strategy for coho salmon in the Smith River Basin (NMFS 2014). North American beaver (*Castor canadensis*) bank lodges and activity was prevalent throughout the sample area (Figure 17) and heavily overlapped with coho salmon distribution (Figure 5). These dynamic creatures create and maintain habitat complexity, especially in the summer. Some habitat features would have become isolated from the mainstem if not for beavers continued excavation activities. Furthermore we documented emigration of coho salmon from a beaver lodge when the lodge became abandoned by beavers. As summer flows decreased we observed a loss in habitat complexity due to loss of inundated overhanging vegetation, LWD, and undercut bank features. However, all locations with beaver activity had increasing habitat complexity and shade with the addition of small woody debris, through food caching and feeding activities, as well as by creation of new burrows. Coho salmon and other salmonids were commonly observed utilizing beaver created burrows and woody debris piles.

Increased growth and productivity of juvenile coho salmon has been documented in streams with off-channel rearing habitat created by beaver dams when compared to streams without dams (Pollock et al. 2003). Hood (2012) reported significantly higher densities and survival rates of juvenile Chinook salmon in tidal beaver ponds compared to other tidal channel habitats. Additionally, higher beaver lodge densities were found in the tidal channels of the Skagit Delta than have been recorded in non-tidal streams (Hood 2012) highlighting the possibility that beavers estuary use can increase fish habitat in an estuarine ecotone.

Restoration mimicking and encouraging beaver damming, such as beaver dam analogs (BDAs), have illustrated beaver dams can successfully restore incised streams in central Oregon through channel aggradation, raising the water table and increasing riparian vegetation (Pollock et al. 2007), thereby improving fish habitat. Areas to incorporate BDAs are limited in the Smith River coastal plain due to the hydrologic regime but could be used to recruit initial beaver activity in slow water channels suffering from ephemeral channels such as in Tryon Creek and reach in 84. Beaver created bank habitat ranked high in both our summer and winter occupancy analysis of coho salmon at apex monitoring stations. During both seasons models with beaver created habitat modeled on occupancy ranked higher than models with LWD, a commonly used restoration tool. Research investigating ecological effects of beaver bank lodges, not associated with dams, and impacts to fish habitat is lacking. However, these questions are currently being studied in the Smith River by Marisa Parish (coauthor of this report) as part of her graduate studies at Humboldt State University. Research focused on improving beaver habitat and increasing beaver abundance may provide additional restoration opportunities.

Future Biological Monitoring and Habitat Assessment

This study has provided much needed information on seasonal salmonid distributions and habitat availability throughout the Smith River coastal plain. However, this work only occurred over one year thereby limiting our inference on fish distributions and habitat quality. Understanding these dynamic populations requires multiple years of study across a range of environmental conditions and fish population abundances. During the winter of 2015-16 we will continue sampling for juvenile salmonids throughout this region to fill in multiple data gaps. Locations of particular interest include Tillas and Islas Sloughs, Morrison Creek, Tryon Creek, and multiple smaller unnamed tributaries throughout the estuary. In the future we would also like to install multiple PIT tag antennas in estuary tributaries to determine coho salmon migration timing and emigration rates. A thorough assessment of the barriers identified throughout the region would be valuable for prioritizing locations for passage improvement.

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Mainstem Smith River by Hiouchi during the Winter *Photo: Jon Parmentier*

Cover Photos: Top- *Airplane view of the mainstem Smith River near Peacock Bar looking west (Photo: Justin Garwood)*
Bottom- *View of the Smith River estuary from the foredune looking southeast (Photo: Justin Garwood)*

Appendix A. Distribution of native eelgrass (*Zostera marina*) occurring in the lower Smith River estuary during July of 2015, Del Norte County, California.

Appendix B. Aerial imagery of the lower Smith River and estuary published in Monroe (1975). The top image highlights the multiple channels connecting the mainstem, Islas and Tillas slough prior to completion of levee construction. The bottom image is looking downstream at the mouth of Rowdy Creek showing recent levee construction along Rowdy Creek and the north bank of the Smith River in 1973.

**Yellow star in both images identifies the same approximate location at Reservation Ranch bar.*

Appendix C. Various habitat and water quality metrics collected during the summer 2014 and winter 2015 GRTS survey and apex station monitoring sites, Smith River basin, Del Norte County, California.

Parameter	Units	Description	Survey	Season
Pool Type	Categorical	Physical description of habitat feature: main channel pool, scour pool, backwater pool, alcove, edge water. Derived from Flosi et al. (1998)	GRTS/ Apex	Summer/ Winter
Unit Length	Meters	Maximum length of the site to the nearest 0.1 meter, used to calculate site area.	GRTS/ Apex	Summer/ Winter
Unit Width	Meters	Average width representative of the site to the nearest 0.1 meter, used to calculate site area.	GRTS/ Apex	Summer/ Winter
Unit Depth	Centimeters	Depth of the deepest portion of the site measured to the nearest centimeter.	GRTS/ Apex	Summer/ Winter
Cover Rating	Category	Rank (1-5) of cover availability and complexity. See Garwood and Ricker (2014) for detailed definition and ranking criteria.	GRTS/ Apex	Summer/ Winter
Total Cover Area	$meter^2$	Overhead view estimate of available fish cover with a minimum of $0.25meters^2$ for any single habitat that is in the water column or within 1m of the water surface.	GRTS/ Apex	Summer/ Winter
Total Cover Volume	$Meter^3$	Quantity of underwater cover volume based on length, width, and average depth of cover features measured to the nearest 0.1m.	Apex	Summer
Beaver Cover Volume	$Meter^3$	Quantity of volume cover created or added to water due to beaver activity, (e.g. burrow and/or food caching).	Apex	Summer
Beaver Cover Area	$meter^2$	Quantity of area cover created or added to water due to beaver activity, (e.g. burrow and/or food caching).	GRTS/ Apex	Winter
Canopy Cover	Percentage	Average of three canopy cover readings (one reading facing the bank, facing upstream and facing downstream) measured 3m from the bank at the center of the site with a densiometer.	Apex	Summer/ Winter
LWD Count	Count	Count of all wood pieces which are greater than 30cm in diameter and 2meters in length which are in or suspended within 1 m of the water surface of the sample unit.	GRTS/ Apex	Summer/ Winter
Continuous Water Temperature	Degrees Celsius	Deployed HOBO V2 (Onset Corporation) thermographs in sampling reaches and at the 24 apex stations throughout the summer months. Logging interval was set at 0.5 hours.	GRTS/ Apex	Summer
Instantaneous Water Temperature	Degrees Celsius	Water temperature in degrees Celsius at time of survey. Recorded at all pools in Large River reaches and at least three pools throughout Small Stream reaches (i.e bottom, middle, top of reach).	GRTS/ Apex	Summer/ Winter
Dissolved Oxygen	Milligrams per liter	Instantaneous dissolved oxygen in water during surveys at all apex sites and winter GRTS sites.	Apex/ GRTS	Summer/ Winter
Salinity	Parts per thousand (ppt)	Instantaneous total salt concentration in water during surveys at all apex sites and at winter GRTS sites.	Apex/ GRTS	Summer/ Winter
Flow Turbulence	Percent of surface area with turbulence	Percent of total survey unit that exhibited a visibly elevated flow and lacked slow water refuge.	Apex/ GRTS	Winter