Winter Distributions, Movements, and Habitat use by Juvenile Salmonids throughout 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: P1410545

ON BEHALF OF

SMITH RIVER ALLIANCE

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Summary

Properly functioning estuaries are complex systems where aquatic organisms benefit from a variety of spatial and temporal niches. This is especially evident for Pacific juvenile salmonids, where studies have shown estuarine habitats can be more productive and can lead to greater growth and survival compared to those derived from natal stream habitats occurring upstream. Habitats including low gradient streams, sloughs, backwaters, off channel ponds, and emergent tidal wetlands have been shown to be especially productive features for rearing juvenile salmon throughout California and the Pacific Northwest. Understanding the functional role of coastal streams and estuaries can aid management and restoration decisions in maximizing population resilience through protection of diverse life-history patterns expressed among various salmonid populations. To fully understand current and potential life-history variation in individual salmonid populations, intensive studies designed to describe the spatial and temporal distribution of salmonids, their respective habitats, and potential limiting factors are needed. This information can then be used towards the goal of recovering populations by maximizing life-history variation through various habitat restoration and conservation strategies.

Extensive background on the lower Smith River, including the physical description, reclamation history, current land use, and previous fisheries monitoring can be found in Parish and Garwood (2015). This study adds a second winter period to a two-year comprehensive fish and habitat inventory of the lower Smith River and its estuary. The first year (Parish and Garwood 2015) included both summer and winter periods and found salmonid distributions, especially coho salmon, were more widespread throughout the estuary and coastal plain during the winter when temporary streams and slough channels maintained water. Additional summer salmonid distribution monitoring has occurred since 2012 throughout the Smith River basin (Garwood and Larson 2014, Garwood et al. 2014, Walkley and Garwood 2015). This second winter sampling effort was initiated to fill in salmonid distribution gaps since only 45% of the total winter estuary sampling frame was surveyed in 2015 (Parish and Garwood 2015). We were also motivated to revisit productive salmonid rearing sites identified during the winter of 2015 to assess their use over a range of environmental conditions and across separate cohorts.

From January 7 to March 19, 2016 we surveyed a total of 200 habitats across 24 reaches representing 55% (35.9 km) of the total estimated winter salmonid rearing habitat using minnow traps, beach seines, and snorkel surveys. Estimated probability of occupancy for coho salmon equaled 0.24 (SE= 0.08). Winter occupancy probabilities for other salmonids were also low equaling 0.12 (SE= 0.03) for 1+ trout spp. However, our winter sampling methods were chosen to maximize coho salmon detections and may limit our ability to detect other species. 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 a sites cover quality rating. Additionally, site maximum depth was negatively associated with coho salmon occupancy. In addition to sampling various reaches we also monitored 27 select rearing habitats "apex monitoring stations" to better understand the temporal occupancy patterns of salmonids as they relate to habitat quality. Coho salmon were detected at 11 of the 27 sites during at least one of the three sampling periods with occupancy probabilities remarkably consistent throughout the sampling season ranging from 0.34 (SE= 0.09) in January to 0.35 (SE= 0.10) in March. Both extinction (0.09, SE=0.09) and colonization (0.06, SE=0.04) were estimated to be low indicating stations with coho salmon generally remained occupied throughout the winter. Detection probability was found to be 0.68 (SE = 0.08) using contained bait. This was an increase compared to uncontained bait used by Parish and Garwood (2015), and also resulted in decreased variation between the two sampling days and confidence interval of the estimates. Model selection ranking found water temperature in January modeled on occupancy to be the top ranked model carrying 96% of the AIC*w*, with warmer water temperatures having a positive influence on coho salmon occupancy.

We evaluated migration timing and residence in coastal streams by utilizing PIT tag antennas located in Morrison Creek and Tryon Creek. We detected 96 of the 821 (11.7%) coho salmon and 1 of the 10 (10%) juvenile trout, marked in Mill Creek

during the fall of 2015, rearing in the coastal plain. We detected the first Mill Creek individual on December 4, 2015 in Morrison Creek and on December 16, 2015 in Tryon Creek. We evaluated growth and residence by individually marking 198 juvenile coho salmon with PIT tags and capturing 13 individuals with PIT tags that had been applied during the fall of 2015 in Mill Creek. Captured individuals averaged 89 mm (52 - 129) and 8.4 g (1.9 – 25.6), with average size continually increasing throughout the winter. We determined mean daily growth rate for fish rearing in the coastal plain to be 0.20 mm/ day and 0.07 g/ day. For the years we had March size data (2013, 2015, 2016), yearling coho salmon rearing in the coastal plain near the end of winter (i.e. just prior to ocean migration) were significantly larger (mean FL=100 mm, SE=0.78 mm) than those rearing in Mill Creek (mean FL=92 mm, SE=0.86 mm) regardless of year. Based on individuals having an entry and exit date, Mill Creek tagged individuals resided in Morrison Creek upstream of the antenna for an average of 67 days (1 – 114) and in Tryon Creek for an average of 61 days (3 – 114). Based on day of initial capture and tagging in the coastal plain to the date of exit, winter tagged coho salmon resided upstream of an antenna for an average of 57 days (1 - 124) in Morrison Creek and an average of 51 days (20 – 73) in Tryon Creek. The last individual detected exiting Morrison Creek was on May 16, 2016 and the stream was no longer flowing at the antenna beginning on June 2, 2016. The last individual coho salmon detected in Tryon Creek at the antenna was on April 13, 2016 and the stream was no longer flowing at the antenna beginning on April 25th. Last, based on the antennas and minnow trapping, we detected individual coho salmon utilizing and multiple coastal streams (e.g. both Morrison Creek and Tryon Creek) during the winter months.

We measured the extent of the salt wedge occurring in the Smith River estuary during the winter months to refine the available habitat and salinity conditions during winter base flows. We found the salt wedge to extend 1765 meters upstream from the mouth with a salinity reading of 4.26 ppt at a depth of 2.4 m and freshwater present throughout the water column at the sample location 1785 meters upstream. We detected a freshwater lens of <0.5 ppt at surface readings and a layer of 10 – 17.5 ppt throughout the entire transect. Coho salmon can utilize these areas with increasing salinity to acclimate prior to and during the physiological changes required to mature to smolts, which allows for increased growth and survival. We continuously recorded dissolved oxygen in Tryon Creek and Yontocket Slough during the spring to evaluate the influence of DO on available rearing habitat. We found dissolved oxygen continuously decreased in a downstream fashion and fluctuated daily with peaks in the late afternoon and lows in the early morning hours. In early April all dissolved oxygen loggers in and downstream of Yontocket slough recorded DO below tolerance levels for juvenile salmonids were reached at some point during the day.

Based on our sampling, we found four drainages that were especially important winter coho salmon rearing locations: Morrison Creek, Tryon Creek, Stotenburg Creek, and an unnamed tributary downstream of Tillas Slough. This finding is similar to results from the previous winter indicating these tributaries are important winter rearing locations for coho salmon regardless of cohort or river flow regime. We found coho salmon occupancy to remain consistent from January through March at apex monitoring stations regardless of year (2015 apex site monthly occupancy range: 0.19 – 0.20; 2016 apex site monthly occupancy range: 0.34 – 0.35), highlighting the importance of the coastal plain as non-natal rearing habitat throughout the winter months. Furthermore, we found a minimum estimate of the Mill Creek coho salmon population rearing in the coastal plain during the winter (11.7%) emphasizing life history diversity is present and common in the Smith River basin. Past restoration efforts in the basin have focused on tributaries occurring above the estuary including fish passage, wood loading, road removal, and forest restoration. While these efforts are needed to protect spawning ground and areas of natal rearing, we present considerations for management and restoration efforts focused throughout the coastal plain where habitat has been simplified due to anthropogenic land alterations. In addition to these recommendations we suggest the need for a systematic planning effort to identify specific restoration projects that address fish barriers, habitat enhancement, sea-level rise scenarios, and water quality in the coastal plain. With such an effort, guided restoration projects can maximize the survival of estuarine rearing individuals and aid in the recovery and conservation salmonids in the Smith River basin.

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Acknowledgments

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Smith River estuary on 28 December, 2015 looking southeast below the 'cattle crossing' riffle. A snow covered Siskiyou crest is visible in the distance. The dark cut bank in the foreground is the edge of Tolowa Dunes State Park upstream of Yontocket Slough and contains the largest bank swallow (*Riparia riparia*) nesting colony in the Smith River. *Photo: J. Garwood*

Introduction

Understanding the functional role coastal streams and estuaries have on the expression of salmonid life-history diversity has gained broad attention (Simenstad et al. 1982, Emmett et al. 1991, Hughes et al. 2014, Flitcroft et al. 2016, Levings 2016). This has been motivated by the concept of maximizing population resilience through understanding and protecting diverse life-history patterns expressed among various salmonid populations (Hilborn et al. 2003, Bottom et al. 2009, Healy 2009). Estuaries are locally unique and have dynamic forces which can dramatically change habitats on hourly, seasonal, and decadal timescales. Given the transient nature of these habitats, properly functioning estuaries serve as a complex system where aquatic organisms such as Pacific salmonids benefit from a variety of spatial and temporal niches. This is especially evident for juvenile salmonids, where studies have shown estuarine habitats can be more productive and can lead to greater growth and survival compared to those derived from natal stream habitats occurring upstream (Simenstad et al. 1982, Beck et al. 2001, Bond et al. 2008, Levings 2016). Habitats including low gradient streams, sloughs, backwaters, off channel ponds, and emergent tidal wetlands have been shown to be especially productive features for rearing juvenile salmon throughout California and the Pacific Northwest (Wissmar and Simenstad 1998, Wigington et al. 2006, Hayes et al. 2008, Koski et al. 2009, Wallace et al. 2015). To fully understand current and potential life-history diversity in individual salmonid populations, intensive studies designed to describe the spatial and temporal distribution of salmonids, their respective habitats, and potential limiting factors are needed (Levings 2016). This information can then be used towards the goal of recovering populations by maximizing life-history diversity through various habitat restoration and conservation strategies.

The Smith River Basin

The Smith River is the largest river system in California that flows freely along its entire course and is considered one of the premier "Salmonid Strongholds" along the Pacific Coast. Furthermore, the Smith River is one of two watersheds in California described as "irreplaceable" with respect to salmonid population resiliency and biodiversity (Wild Salmon Center 2012). These endorsements are largely based on the river's undammed status, the majority of the upper watershed being within public ownership, and having an unrivaled sport fishery for fall Chinook salmon, winter Steelhead, and Coastal Cutthroat Trout. The Smith River watershed also receives more annual precipitation than any other drainage in California and maintains exceptional water quality and cool water temperatures throughout much of the basin. Lastly, the Smith River has been spared from the invasive predatory species (e.g. Brown Trout, Sacramento Pikeminnow) that have devastated aquatic biodiversity in other regional rivers. These attributes collectively highlight the exceptional conservation value of the Smith River watershed and its role as a current and future climate refuge for salmonids and other aquatic species.

While much of the upper Smith River basin is relatively unimpaired and is protected via various land management designations (National and State Park, Wilderness, Wild and Scenic River, etc.), most of the estuary is under private ownership and is a working landscape. Like most of the estuaries in the Pacific Northwest, the Smith River estuary has undergone extensive historic conversion into productive agricultural areas. This conversion resulted in loss of riparian vegetation, diking and draining of emergent wetlands through trenching, fill, levees, tidegates, and rip-rap. These conversions have caused a large reduction in the available suitable salmonid habitat in the estuary with some remaining habitats being severely degraded (Voight and Waldvogel 2002, NMFS 2014, Parish and Garwood 2015). However, based on recent data collection, some areas of the estuary and coastal plain appear to remain productive at key time periods for individual species. For example, Quinones and Mulligan (2005) and Zajanc (2003) found large numbers of juvenile Chinook salmon and trout *sp*. rearing throughout the freshwater portion of the estuary from the spring through late summer. Additionally, Garwood and Larson (2014) found young-of-the-year coho salmon rearing in the estuary during the summer (June-August) where they were almost exclusively found in the mainstem Smith River. Lastly, Parish and Garwood (2015) documented extensive use of sloughs and tributaries along the coastal plain and estuary by yearling coho salmon during the winter months (January-April). These documented life-history patterns indicate different species and age classes are taking advantage of a spectrum of habitats in the coastal plain and estuary. The objective of this study is to add to existing knowledge of space use and temporal migration behavior by surveying more potential habitats across the estuary during a second winter. Based on the funding source and methods, the design of this effort is largely focused on coho salmon so we acknowledge limitations on the inference dedicated to other salmonid species we report on.

Previous Work

Extensive background on the lower Smith River, including the physical description, reclamation history, current land use, and previous fisheries monitoring can be found in Parish and Garwood (2015). This study adds a second winter period to a two-year comprehensive fish and habitat inventory of the lower Smith River and its estuary. The first year (Parish and Garwood 2015) included both summer and winter periods. We found salmonid distributions, especially coho salmon, were more widespread throughout the estuary and coastal plain during the winter when temporary streams and slough channels maintained water. Additionally, summer salmonid distribution monitoring has occurred annually since 2012 throughout the Smith River basin (Garwood and Larson 2014, Garwood et al. 2014, Walkley and Garwood 2015) and these efforts overlap with the majority of available summer estuary and coastal plain habitat described extensively by Parish and Garwood (2015). This sampling effort was initiated to fill in salmonid distribution gaps not surveyed during the previously since only 45% of the total winter sampling frame was surveyed in 2015 (Parish and Garwood 2015). We were also motivated to revisit productive salmonid rearing sites identified during the winter of 2015 to assess their use across a range of environmental conditions and separate cohorts.

Materials and Methods

Study Area

The Smith River is the northern most coastal watershed in California entering the Pacific Ocean six km south of the Oregon border and drains 1167 km^2. The Smith River receives 235 cm of rainfall annually at the Gasquet Ranger Station (CDEC 2015). Precipitation is usually delivered during large winter storm events with 84% of annual average rainfall received from October to March (CDEC 2015). 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 2016 is 82,520 cubic feet per second (cfs) (USGS 2016) resulting in an estuary largely formed by river dominated hydrological processes, particularly during the winter months. The extent of tidal influence and salinity concentrations in the estuary fluctuate widely based on season, variation in river flows, and tidal cycles (Mizuno 1998, Parish and Garwood 2015). Based on the current and past studies a total of 39 fish species, 7 of which are salmonids, have been documented utilizing the Smith River estuary (Table 1).

The study area includes the entire mainstem Smith River downstream of Highway 199 near Hiouchi and various tributaries and sloughs that enter the mainstem river below Highway 101 (Figure 1). The

Table 1. Annotated list of 39 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
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, P	
Klamath smallscale sucker	*Catostomus rimiculus*	Catostomidae	C, P	
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, O, P	Yes
Prickly sculpin	*Cottus asper*	Cottidae	A, C, D, E, O, P	Yes
Buffalo sculpin	*Enophrys bison*	Cottidae	*This Study*	Yes
Staghorn sculpin	*Leptocottus armatus*	Cottidae	C, E, P	Yes
Cabazon	*Scorpaenichthys marmoratus*	Cottidae	C	
Redtail surfperch	*Amphistichus rhodoterus*	Embiotocidae	A	
Shiner surfperch	*Cymatogaster aggregata*	Embiotocidae	A, C, D, P	Yes
Striped surfperch	*Embiotoca lateralis*	Embiotocidae	C, E	Yes
Northern anchovy	*Engraulis mordax*	Engraulidae	A, C, E	
Threespine stickleback	*Gasterosteus aculeatus*	Gasterosteidae	A, C, E, P	Yes
Tidewater goby[2]	*Eucyclogobius newberryi*	Gobiidae	E, F, G, P	
Whitebait smelt	*Allosmerus elongatus*	Osmeridae	C	
Surf smelt	*Hypomesus prefiosus*	Osmeridae	A, C, D, E, P	Yes
Night smelt	*Spirinchus starksi*	Osmeridae	C	
Eulachon[2]	*Thaleichthys pacificus*	Osmeridae	A	
Pacific lamprey	*Lampetra tridentata*	Petromyzonidae	A, C, P	
Western brook lamprey	*Lampetra richardsonii*	Petromyzonidae	H	
Saddleback gunnel	*Pholis ornata*	Pholidae	A, C, D, E	Yes
English sole	*Parophrys vetulus*	Pleuronectidae	E	
Starry flounder	*Platichtys stellatus*	Pleuronectidae	A, C, D, E, P	Yes
Sand sole	*Psettichthys melanostictus*	Pleuronectidae	C	
Coastal cutthroat trout	*Oncorhynchus clarki clarki*	Salmonidae	A, C, D, P	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, P	Yes
Steelhead	*Oncorhynchus mykiss*	Salmonidae	A, C, D, E, M, P	Yes
Sockeye salmon	*Oncorhynchus nerka*	Salmonidae	N	
Chinook salmon	*Oncorhynchus tshawytscha*	Salmonidae	A, C, D, E, M, P	Yes
Black rockfish	*Sebastes melanops*	Scorpaenidae	A	
Bay pipefish	*Syngnathus leptorhynchus*	Sygnathidae	A, C, P	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);* ***O:*** *White, J. and B. Harvey (1999);* ***P****: Parish, M. and J. Garwood (2015).*

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

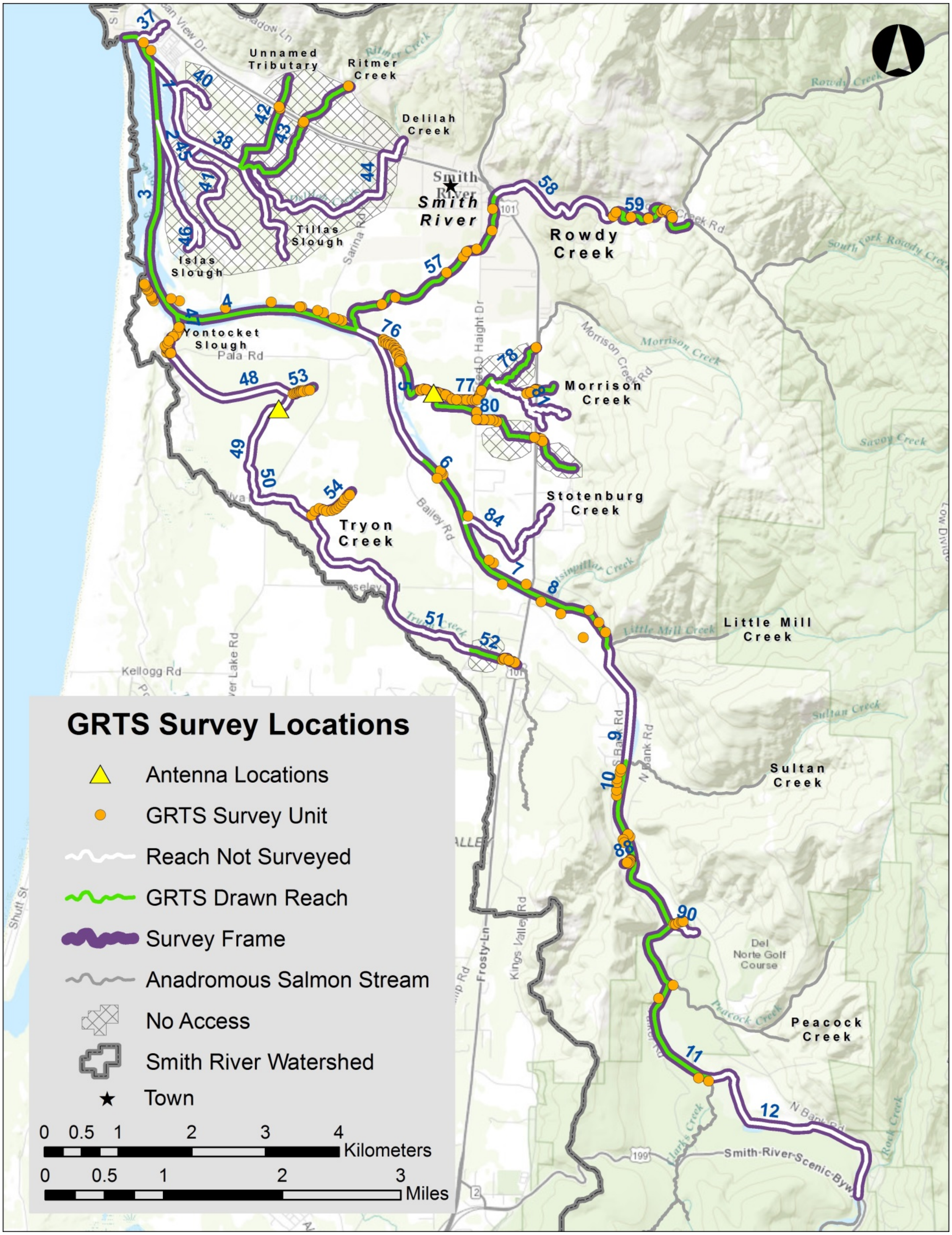


Figure 1. Survey locations of GRTS drawn reaches and Passive Integrated Transponder (PIT) tag antennas throughout the winter estuary survey frame in the Smith River coastal plain, Del Norte County, California. Reach location codes are labeled in dark blue.

combined channel length of the various stream and slough channels included in the study area equals 65.3 km (Table 2).

The lower portion of the study area (downstream of Highway 101) is within agricultural lands used for dairy, cattle, and lily bulb production. This area is an emerged marine terrace and is characterized by low gradients and a wide valley. The low gradient of the mainstem channel 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. Major tributaries in this section include Rowdy Creek, Morrison Creek, Ritmer Creek, and Tryon Creek, all of which have adult salmonid spawning habitats. All of these streams, and additionally Stotenburg Creek, provide rearing habitats for juvenile salmonids during the winter months (Parish and Garwood 2015, *this study*). Three major sloughs occur in the lower portion of the estuary including Tillas Slough, Islas Slough, and Yontocket Slough (Figure 1, Table 2). Riparian vegetation in the lower river largely begins upstream of Yontocket slough and in tributaries. Woody vegetation is dominated by willows (*Salix* sp.), alders (*Alnus* sp.), and sitka spruce (*Picea sitchensis*).

The upper portion of the study area occurs from Highway 101 to the Hwy 199 bridge and is restricted to habitats along and adjacent to the Smith River channel. Here the channel actively meanders through alluvial point bars and bedrock creating side channels, backwaters and alcoves, and deep pools that collect finer sediments. Important salmonid spawning tributaries within this section include Little Mill Creek, Sultan Creek, Peacock Creek, and Clark's Creek (Garwood and Larson 2014). The riparian zone upstream of Rowdy Creek is dominated by willow, alder, black cottonwood (*Populus trichocarpa*), and coast redwood (*Sequoia sempervirens*).

Table 2. Total kilometers (km) of anadromous stream and number of reaches present in the sample frame for winter estuary sampling in the Smith River coastal plain, Del Norte County, California.

Stream	Km	Mi	# of reaches
Mainstem	23.58	14.65	15
Unnamed tributary (Reach 37)	0.46	0.29	1
Unnamed tributary (Reach 40)	0.57	0.35	1
Islas Slough	1.79	1.11	2
Tillas Slough and tributaries	11.96	7.43	5
Yontocket Slough	2.66	1.65	3
Tryon Creek	7.35	4.57	5
Rowdy Creek	6.79	4.22	3
Morrison Creek and tributaries	8.33	5.18	7
Unnamed tributary (Stotenburg Creek)	1.84	1.14	1
Totals:	65.33	40.59	43

Sampling Approach

We implemented two sampling approaches to assess juvenile salmonid spatial structure and habitat use in the lower Smith River and estuary during the winter rearing period. This period was selected as little is known about the winter rearing conditions and habitat use, especially for coho salmon. Additionally, it has been shown in other Pacific Northwest basins that winter rearing habitat have had larger declines compared to summer rearing habitat due to anthropogenic land alterations (Beechie et al. 1994).

Spatial Structure Sampling Design

We used the reach-based salmonid sampling frame developed by Parish and Garwood (2015) that represents the potential spatial extents of all winter juvenile coho salmon non-natal rearing habitats specific to the lower Smith River basin. Garwood and Larson (2014) defined 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). Through the use of field surveys, the accuracy of the distribution was ground-truthed during spawner surveys and summer spatial structure surveys (Garwood and Larson 2014). Additional winter field surveys conducted in the Smith River coastal plain and estuary by Parish and Garwood (2015) provided refined winter habitat availability and potential salmonid spatial extents.

After the potential spatial extents were defined, we divided the stream sections into reaches with the start or end located at tributary junctions or bridge crossings, for navigational purposes. Terminal reaches were designed to end at permanent juvenile salmonid migration barriers in non-natal rearing streams. Reaches that overlapped other concurrent monitoring projects in the basin (*see* Garwood and Larson 2014) were maintained, which allows uniform spatial extents for areas having multiple overlapping salmonid monitoring components. No single reach exceeded 3.5 km in length to assure a single survey effort could be completed in a single day. Our winter sample frame construction resulted in 43 primary reaches totaling 65.4 km within the lower Smith River and coastal plain (Figure 1, Table 2).

GRTS 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 winter spatial structure reach samples. Our GRTS sample draw included all available reaches. Oversampling ensured our anticipated survey effort could be maintained if landowner permissions could not be secured in individual reaches. Comprehensive fish distribution surveys within the study area have only been completed for one prior year, 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 Stations

We established 27 unique apex monitoring stations for the winter coho salmon rearing period based on pre-season surveys and previous data collected throughout study area by Garwood and Larson (2014), Garwood et al. (2014), and Parish and Garwood (2015) (Figure 2). Unlike the GRTS spatial structure study component, habitats were not selected at random within GRTS selected reaches, but were identified based on their unique properties and having a high likelihood of persisting throughout the winter rearing period. Based on findings of winter habitat use by Parish and Garwood (2015), monitoring stations were focused downstream of Highway 101 primarily in three tributaries:

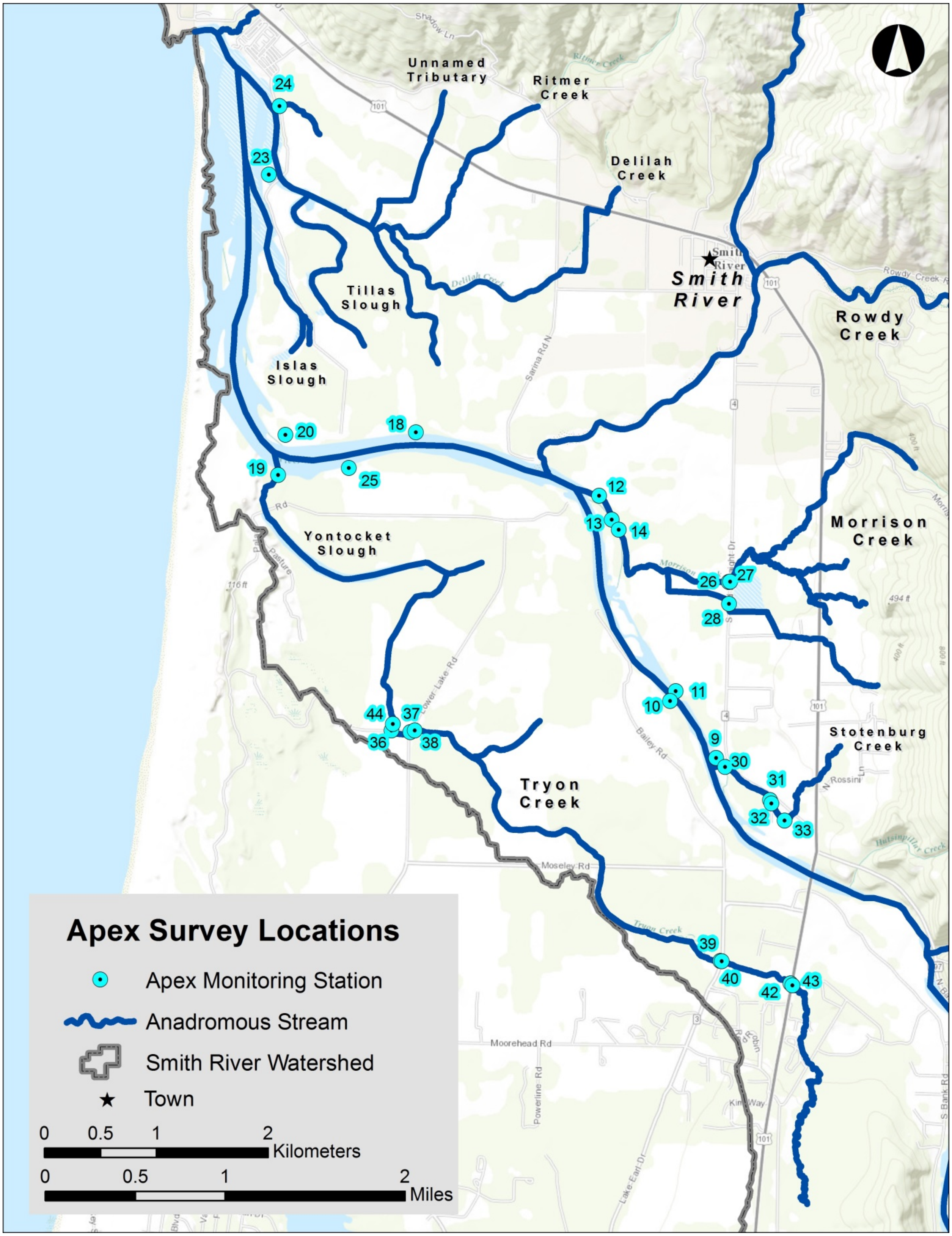


Figure 2. Winter survey locations at apex monitoring stations across the Smith River coastal plain, Del Norte County, California. Station numbers are haloed in bright blue.

Tryon Creek, Morrison Creek, and Stotenburg Creek (Figure 2). These tributaries represent a diverse range of potential salmonid rearing habitats including backwaters, edge waters, beaver lodges, and intermittent tributaries. In addition, nine of the apex sites were distributed throughout the lower mainstem and other smaller tributaries (Figure 2).

Field Methods

GRTS 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). Habitats are prone to large changes in environmental conditions during the winter months. Therefore, we used a combination of field methods (i.e. beach seines, minnow traps, snorkel surveys) to sample as much of the estuary as possible. Our survey focused on stream pools and areas with low water velocity as the sample unit since slow water habitats are preferred for rearing by juvenile coho salmon (Bisson et al. 1988, Nickelson et al. 1992). Sampling method was selected to best match the condition of the individual location. Individual methods are defined in detail in the Fish Sampling Procedures section below.

For small and mid-sized streams with lengths >1 km, we used a systematic sampling by placing a single minnow trap every 50 – 70 meters. We placed a single minnow trap every 25 – 50 meters in streams with reach lengths <1 km. Trap placement sites were required to have a minimum depth of 20 cm and an area of slow water to prevent fish from tiring while in the trap. 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). The sampling method used in the mainstem depended on individual site size, habitat complexity, and turbidity at the time of sampling. Most habitat measurements were collected based on Garwood and Ricker (2014) however additional measurements were collected to assess the influence of beavers and water velocity on coho salmon occupancy, *see* Table 3 for a detailed description.

Apex Station Monitoring Surveys

We establishing apex monitoring stations 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 throughout the winter 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, day one and two of trapping) but allows for colonization (γ) and extinction (emigration in this case) (ε) of a species between primary sampling occasions (i.e., between winter months). All 27 winter apex stations received three primary sampling occasions (once per month) in January, February, and March using baited minnow traps, which allowed for 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 procedures followed those outlined in the Winter Spatial Structure field survey section below. Most station habitat measurements were based on Garwood and Ricker (2014). However, additional station measurements specific to assessing beaver modifications, water quality parameters, and availability of low velocity rearing habitat were added to explore these influences on station characteristics; *see* Table 3 for detailed descriptions of these covariates. Although we planned for monthly sampling to occur at similar river discharges, we measured habitat covariates during each primary sampling occasion as varying water height and water quality may result in changing habitat conditions.

Table 3. Various habitat and water quality metrics collected during the winter 2016 GRTS survey and apex station monitoring sites, Smith River basin, Del Norte County, California.

Parameter	Units	Description	Survey
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
Unit Length	Meters	Maximum length of the site to the nearest 0.1 meter, used to calculate site area.	GRTS/ Apex
Unit Width	Meters	Average width representative of the site to the nearest 0.1 meter, used to calculate site area.	GRTS/ Apex
Unit Depth	Centimeters	Depth of the deepest portion of the site measured to the nearest centimeter.	GRTS/ Apex
Cover Rating	Category	Rank (1-5) of cover availability and complexity. See Garwood and Ricker (2014) for detailed definition and ranking criteria.	GRTS/ Apex
Total Cover Area	$meter^2$	Overhead view estimate of available fish cover with a minimum of 0.25 $meters^2$ for any single habitat that is in the water column or within 1m of the water surface.	GRTS/ Apex
Beaver Cover Area	$meter^2$	Overhead view estimate of available fish cover created or added to water due to beaver activity, (e.g. burrow and/or food caching).	GRTS/ Apex
LWD Count	Count	Count of all wood pieces which are greater than 30 centimeter in diameter and 2 meter in length which are in or suspended within 1 meter of the water surface of the sample unit.	GRTS/ Apex
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
Dissolved Oxygen	Milligrams per liter	Instantaneous dissolved oxygen in water during surveys at all apex sites and GRTS reaches. Measurements collected at the bottom, middle, and top of the water column.	Apex/ GRTS
Salinity	Parts per thousand (ppt)	Instantaneous total salt concentration in water during surveys at all apex sites and at GRTS reaches. Measurements collected at the bottom, middle, and top of the water column.	Apex/ GRTS
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

Fish Sampling Procedures

Minnow Traps— We used minnow traps to determine coho salmon occupancy throughout the small tributaries for the GRTS survey reaches and at all apex monitoring stations. Minnow traps could be deployed across wide ranges of flow and turbidity experienced during the winter months. 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, contained in clear film canisters with 10 – 12 3.2 mm holes drilled into the sides to prevent captured individuals from consuming the bait. 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 were sampled twice over two days using the same number of traps and same approximate trap soak times to account for detection rates. Prior to the survey season, we completed training on trapping protocol, trap placement, and habitat classification in streams of variable sizes.

Snorkel Surveys— We used snorkel surveys to determine coho salmon occupancy for the GRTS survey reaches throughout Rowdy Creek and the mainstem where water clarity permitted. Prior to the survey season, we completed intensive underwater training on fish identification and quantitative dive counts in streams 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 correctly 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.

Beach Seines— We used various sizes of beach seines in the mainstem and lower estuary GRTS reaches 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. Each survey location was seined with a single set on day one and then the location was 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.

Fish Processing and Marking Procedures

All salmonids captured during sampling with either a minnow trap or seine were identified to species (Chinook salmon, coho salmon, trout spp., coastal cutthroat trout), migrant stage (young-of-year, parr, smolt, adult), counted, measured, and weighted. All fork lengths of juvenile salmonids were measured to the nearest millimeter and weighed to the nearest hundredth of a gram. To assess growth rate, residence time, and movement we uniquely tagged a sample group of coho salmon and 1+ trout >70 mm with 11 mm FDX Passive Integrated Transponder (PIT) tags. Prior to tagging all coho salmon and 1+ age trout were first scanned for PIT tags to determine if any of the 831 individuals marked during the fall of 2015 (Garwood, unpublished data) in the Mill Creek sub-basin had emigrated to the lower basin and estuary prior to smolting. 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 2 mm 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. We marked salmonids <70 mm captured on the first trapping period with a batch fin clip to explore relative site abundances and possible trap effects on back-to-back capture rates (e.g. trap happy or shy). This clip was made with small sharp scissors removing approximately three square mm of the upper caudal fin. All other aquatic vertebrates observed during the various sampling events including fishes, amphibians, and mammals, were identified, aged, and counted. Additional observations of invasive vegetation and invasive species were also recorded.

Fall Tagging and Estuary Antennas

The core Smith River coho salmon population spawns and rears in the Mill Creek basin, the second largest mainstem tributary below the forks (Garwood and Larson 2014). While our study did not encompass this basin, salmonids spawned in Mill Creek and individually marked with PIT tags have been detected utilizing the mainstem and coastal tributaries during the winter months (Garwood and Larson 2014, Parish and Garwood 2015) highlighting the need to understand any benefits this alternative rearing strategy may have on the population. In October 2015, 821 juvenile coho salmon and 10 juvenile trout were individually marked with PIT tags in the West Branch and East Fork of Mill Creek. In collaboration with California Department of Fish and Wildlife and Alexandre EcoDairy, we installed two PIT tag antenna arrays in the coastal plain. One was placed on Morrison Creek 1220 m upstream from the confluence with mainstem Smith River and went online on November 21, 2015 (Figure 1). The other was placed in Tryon Creek 2640 m upstream from the confluence with mainstem Smith River and went online on November 20, 2015 (Figure 1). At each location we installed two independent antennas to record directional movement of PIT tagged fish swimming through the site. The primary objective of these antenna stations was to document entry, exit, and residence timing of juvenile salmonids rearing in these tributaries during the winter months. The antennas also allowed us to evaluate early emigration abundance and timing of Mill Creek PIT tagged individuals. We operated the antennas from the installation date in November until the channel was dry at the antenna in the spring or early summer. This timeframe spans the period when each stream can support migrating salmonids.

Water Quality Measurements

Fish Sampling Locations - Water quality readings were measured at a minimum of two sites per GRTS survey reach and at every apex monitoring station on the first day of each sampling period using a Yellow Springs Instrument Professional Plus multi-parameter meter. Frequency of readings was increased if any parameter was near the minnow trapping thresholds, if a confluence or seep entered the reach, or if the flow of the site varied from the main channel (e.g., backwater). 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. We deployed water temperature data loggers at both PIT tag antennas to determine when the channel went dry. 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 from early December until the channel was observed as dry with logging intervals set at every 30 minutes. To prevent solar radiation from influencing temperature readings a perforated PVC piping was used as a shield to prevent direct sunlight from altering the readings at any time while the loggers were deployed.

Salinity Transect - The Smith River salinity gradient varies by location, season, tide, and river discharge (Mizuno 1998). This natural process can greatly influence habitat availability for juvenile salmonids and all estuarine species that utilize the Smith River estuary. Before smolt transformation, juvenile coho salmon generally rear in habitats < 5 parts per thousand (Wallace and Allen 2009). However, by December pre-smolts upper incipient lethal salinity level ranges from 22 – 25 ppt (Otto 1971). Furthermore, exposure to and temporary rearing in saline environments allows for juvenile salmonids to acclimate to saline conditions and increases coho salmon survival and growth (Otto 1971, Wallace and Allen 2007, Levings 2016) highlighting the need to define salinity conditions during the winter months. We measured salinity concentrations during a high tide and low winter flow when salinity concentrations are expected to be highest. All measurements were collected from a boat with a Yellow Springs Instrument Professional Plus multi-parameter meter fitted with a 10 meter long probe. Readings were collected along the thalweg 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. Readings were collected on 23 February, 2016 from 11:26 – 12:22 at high tide (6.5 feet at 11:59 at Pyramid Point, Smith River) when the flow was 4,470 cfs, according to the Smith River USGS stream gauge (USGS 2016).

Dissolved Oxygen Transect– Low levels of dissolved oxygen (DO) can reduce the availability of rearing habitat for juvenile salmonids. Of particular concern is levels below 2.0 mg/l, which is considered lethal to juvenile salmonids (Water Quality Assessments 1996). Love (2006) found DO levels in Yontocket Slough to be at lethal levels to salmonids from August to January and surmised this was due to decaying reed canary grass (*Phalaris arundinacae*). We were interested in defining DO conditions during the spring when salmonids were migrating out of Tryon Creek and Yontocket Slough. We used four miniDO$_2$T© DO and temperature loggers (Precision Measurement Engineering, USA) to continuously read DO levels longitudinally in Yontocket Slough and Tryon Creek from April 1 to May 23 to evaluate DO levels as spring flows decreased. Loggers recorded DO every ten minutes with an accuracy of ±5% of the reading and were located 300, 450, 1950, and 2640 meters upstream from the confluence with the mainstem Smith River (*see* Figure 11 in results section). Loggers were placed on the substrate to collect measurements as long as water was flowing in the channel; however, the logger in Yontocket slough pond was suspended one meter above the thick layer of decaying organic matter to prevent biased low readings. The upstream-most logger, located at the Tryon Creek antenna, was out of the wetted channel from April 17 – 22. Last, we collected instantaneous dissolved oxygen readings downstream of Pala Rd to the mouth of Yontocket slough and perpendicular to flow along Pala Rd with a Yellow Springs Instrument Professional Plus multi-parameter meter on February 12, 2016. These measurements were recorded to evaluate DO levels during winter base flows when the Smith River flow averaged 3,100 cfs (USGS).

Statistical Methods

Spatial Structure Occupancy

We determined occupancy for individual salmonid species and age classes during the winter using the estimated probability of site occupancy as our derived spatial structure statistic. 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 (*see* Garwood and Larson 2014) so we suggest pool-level estimates better describe overall occupancy rates throughout this compact study area. We modeled occupancy (ψ_i) across all sites while accounting for sampling method specific detection probabilities (MacKenzie et al. 2002) using Program PRESENCE (USGS 2015).

We built multiple *a priori* candidate models based off the literature and results from the previous year of this study (Parish and Garwood 2015) to explore potential habitat relationships on predicting winter coho salmon occupancy. To better explore these relationships, we modeled both the 2015 (Parish and Garwood 2015) and 2016 datasets to increase our sample size across a range of habitats and environmental conditions. 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 2016) for all pairs of predictor variables. We only included uncorrelated variables (R^2 <0.6) in the same candidate models. 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. In general, very few coho salmon were detected in the mainstem of the Smith River across both winters, so initial models of the entire data set failed to converge. Given most coho salmon were found in tributaries, we then built models that excluded mainstem river sampling from the winters of 2015 and 2016. Models were ranked based on Akaike information criterion (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 assessed (Burnham and Anderson 2002) for the most complicated model under consideration.

Apex Station Occupancy

Winter surveys were conducted at 27 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 three primary sample occasions (t). To account for detection probability two secondary survey occasions were conducted with minnow traps deployed for 80-120 minutes on two back-to-back days.

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 2015). 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, depth, cover area, and beaver created cover were standardized. Models with a ΔAIC of < 2 were considered to have substantial empirical support (Burnham and Anderson 2002).

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).

Building on the systematic sampling conducted by Parish and Garwood (2015) a model set was built to examine multiple hypotheses about the relationship between coho salmon occupancy, habitat, water quality, and temporal movements. 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. However a secondary analysis was conducted to compare detection probability between sampling methods where the bait is either contained (2016 dataset) or uncontained (2015 dataset).

Growth, Residency, and Movement

We used days at liberty to calculate daily growth rate for both fork length (mm) and weight (g) of juvenile coho salmon having two or more captures. In addition, we explored if basin position (i.e. tributary vs coastal plain) and year influenced the size of yearling coho salmon smolts during the spring in natal vs non-natal habitats. We used analysis of variance (ANOVA) to investigate potential spatial and annual differences in the mean coho salmon fork length for years we had length data from both regions. The analysis was restricted to March since the only length data we collected in Mill Creek was from the spring out-migrant trap which is installed annually in early to mid- March. March approaches the end of the winter rearing period and likely captures the overall winter growth potential from each separate rearing location. Residual plots and length-frequency histograms were examined to detect outliers and to test for violations of ANOVA assumptions including normality and heteroscedasticity. Significance levels were set at *P*<0.05 and all post-hoc comparisons of groups were performed using Tukey-Kramer multiple comparisons (Zar 1999).

To calculate minimum residency time in the coastal plain, we used initial capture date of individuals marked with PIT tags in the coastal plain upstream of antennas in Morrison Creek and Tryon Creek and were later detected migrating downstream at the respective antenna. Additionally, we used Mill Creek PIT tagged individuals that were detected migrating both upstream and downstream at antennas in Morrison Creek and Tryon Creek. To evaluate migration timing, duration and relationship to the hydrograph we determined the first and last date, as well as movement direction, of all individuals detected at the coastal plain antennas.

Results

Spatial Structure

We sampled 55 percent of the total sample frame during the winter of 2016. Prior to this effort, we sampled 45 percent of the total frame during the winter of 2015 (Parish and Garwood 2015). Overall, we sampled 71 percent of the total winter sampling frame at least once with both efforts combined. Access permissions were not granted to all properties within the frame over the two winters (Figure 3) so reaches drawn in these locations were omitted.

Winter GRTS Reaches (2016)

We surveyed a total of 200 units across 23 of 24 GRTS drawn reaches (Table 4, Figure 3) during the winter period representing 55 percent (35.9 km) of the total winter sampling frame. Reach 2 was the only segment that did not have any units that met our sampling criteria. The survey period extended 61 days from January 7 to March 19, 2016. One percent of the sites were sampled with beach seines, 68 percent with minnow traps, and 31 percent with snorkel surveys. We documented juvenile coho salmon occurring in seven of the 23 GRTS surveyed reaches and in 25 of the 200 sampled units (Table 4, Figure 3). We detected coho salmon in only two of the 52 units (4 %) in the mainstem Smith River. We detected coho salmon in 23 of 148 units (16 %) in tributaries, all within the Tryon Creek and Morrison Creek watersheds (Figure 3). Estimated winter probability of occupancy (ψ) for coho salmon equaled 0.24 (SE= 0.08) (Table 5).

Estimated coho salmon detection rates varied dramatically by methodology and suffered from low detections for seining and snorkel surveys (Table 5). For example, detection equaled 0.04 (SE=0.04) for snorkel surveys (Table 5) in contrast to 0.40 (SE=0.22) during the previous winter (Parish and Garwood 2015). Furthermore, among the three sites sampled by beach seines, only one contained a coho salmon during one sampling event leading to extremely wide confidence intervals from small sample size (Table 5). Given the overall rarity of coho salmon detections from seining and snorkel surveys, one should view the estimated detection probabilities and their associated 95% confidence bounds as unreliable. Minnow trap detection rates were more robust than the other two methods and increased from 0.33 (SE=0.15) during the previous winter (Parish and Garwood 2015) to 0.40 (SE=0.14) during this study. As observed with minnow trap detection rates at apex monitoring stations, it appears that roe containment increased detection rates of coho salmon by eliminating trap shyness on the second occasion caused by fish feeding on roe on the first occasion.

We detected juvenile Chinook salmon in 14 units across four reaches (Table 4, Figure 4). Given their reproduction and development timing, the season closure assumption could not be met for winter occupancy modeling. However, we started observing small numbers of alevin stages

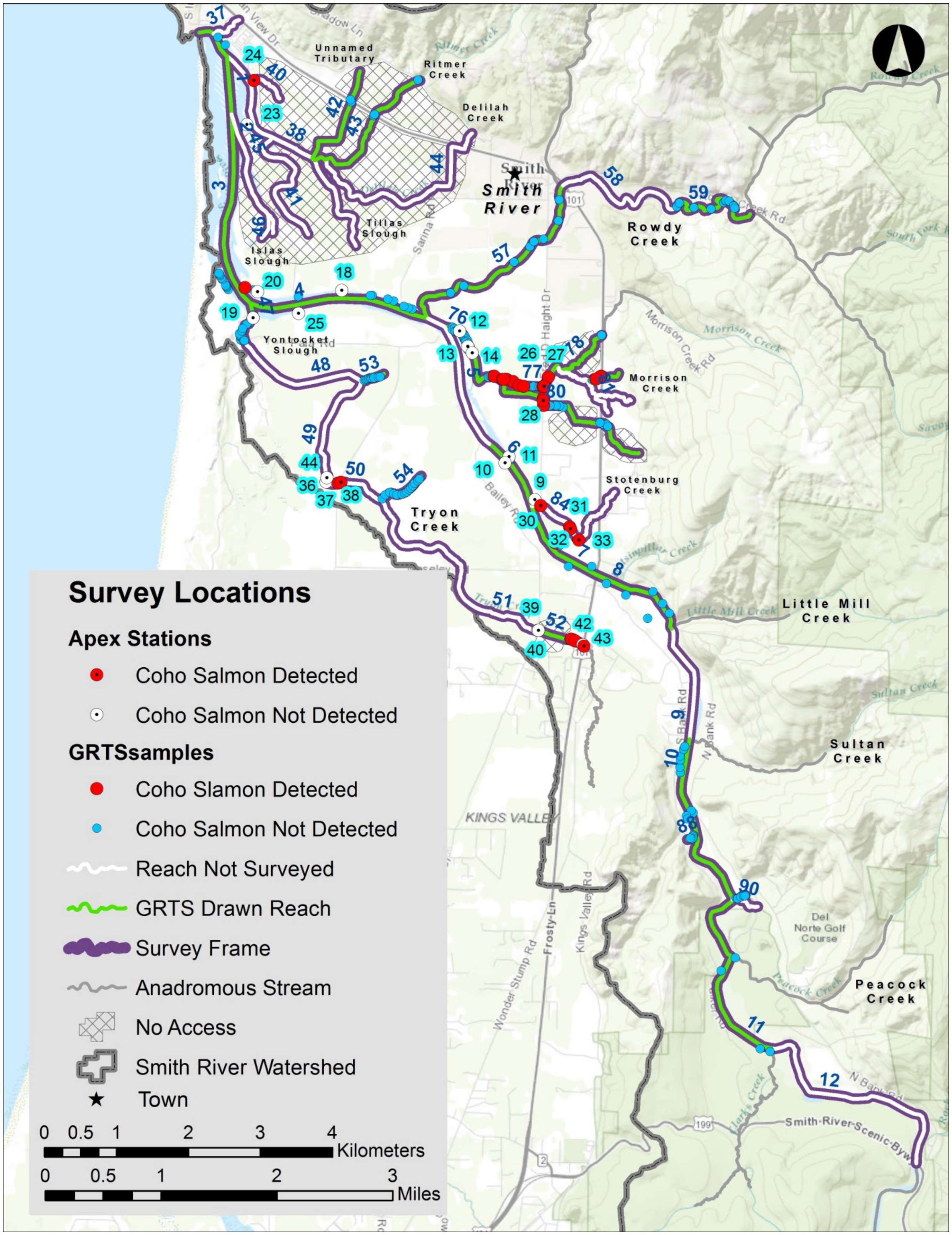


Figure 3. Coho salmon observations at GRTS survey locations and apex monitoring stations across the Smith River coastal plain, Del Norte County, California. Reach numbers are labeled in blue and apex station numbers are labeled and haloed in bright blue. Note: single locations may represent multiple observations between different days throughout the winter 2016 sampling season.

Table 4. Summary of sampling location characteristics and salmonid detections within 205 sample units across 24 GRTS drawn reaches surveyed during the winter of 2015-2016 in the Smith River Coastal plain, Del Norte County, California.

							Number of sample units with detections				
Stream Name	Location Code	Reach Length (m)	Number of Units Surveyed	Mean Unit Depth (cm)	Mean Unit Surface Area (m^2)	Survey Methods[1]	Coho Salmon	Chinook Salmon	0+ Trout spp.	1+ Trout spp.	Coastal Cutthroat Trout
Mainstem Smith River	1	1210	2	285 (260 – 310)	812 (703 – 920)	BS	0	1	0	0	0
Mainstem Smith River	2	956	0	NA	NA	-	-	-	-	-	-
Mainstem Smith River	3	1961	11	234 (180 – 303)	117 (24 – 933)	MT, BS	1	0	0	0	0
Mainstem Smith River	4	2541	9	238 (180 – 294)	59 (28 – 102)	SS	0	0	0	0	0
Mainstem Smith River	6	798	4	229 (28 – 400)	179 (69 – 380)	SS	0	0	0	0	0
Mainstem Smith River	7	1639	5	218 (90 – 450)	725 (46 – 1740)	SS	1	0	0	0	0
Mainstem Smith River	8	1419	6	174 (57 – 350)	379 (56 – 1292)	SS	0	0	0	1	0
Mainstem Smith River	10	2520	11	203 (93 – 320)	97 (11 – 226)	SS	0	2	0	0	0
Mainstem Smith River	11	2765	4	144 (113 – 180)	79 (45 – 162)	SS	0	0	0	0	0
Unnamed Tributary	42	1559	2	30 (29 – 31)	3 (3 – 3)	MT	0	0	0	0	0
Ritmer Creek	43	2202	3	58 (38 – 75)	17 (6 – 38)	MT	0	0	0	0	1
Yontocket Slough	47	597	15	139 (50 – 230)	30 (19 – 36)	MT	0	0	0	0	0
Tryon Creek	52	3505	7	61 (53 – 68)	32 (15 – 119)	MT	2	0	0	0	0
Tryon Creek Tributary	53	333	12	138 (69 – 166)	36 (30 – 36)	MT	0	0	0	0	0
Tryon Creek Tributary	54	736	15	71 (32 – 130)	32 (26 – 36)	MT	0	0	0	0	0
Rowdy Creek	57	3216	7	100 (60 – 130)	87 (27 – 166)	SS	0	1	0	0	0
Rowdy Creek	59	1228	11	104 (38 – 175)	140 (8 – 730)	SS	0	10	9	3	0
Morrison Creek	76	494	21	142 (45 – 195)	33 (18 – 36)	MT	0	0	0	0	0
Morrison Creek	77	1485	18	66 (35 – 100)	15 (7 – 26)	MT	8	0	0	8	0
Morrison Creek	78	1387	6	61 (36 – 90)	13 (8 – 18)	MT	3	0	0	2	0
Morrison Creek Tributary	80	2592	14	38 (18 – 75)	8 (0.5 – 15)	MT	7	0	0	1	1
Morrison Creek Tributary	82	530	6	53 (41 – 80)	8 (4 – 13)	MT	3	0	0	0	0
Unnamed Tributary	88	112	6	65 (45 – 140)	11 (2 – 25)	SS	0	0	0	5	0
Unnamed Tributary	89	130	5	86 (50 – 130)	17 (15 – 19)	MT	0	0	0	0	0
Totals:		35915	200	127 (18 – 450)	127 (0.5 – 1740)		25	14	9	20	2

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

(conspicuous yolk sacs) in the estuary as early as February 13, 2016. By late March, Chinook salmon were commonly captured throughout the estuary similar to the previous year (Parish and Garwood 2015). The mean size of Chinook salmon captured during the study period equaled 40 mm (Range: 38 – 46 mm). Young-of-the-year unidentified trout (steelhead or coastal cutthroat trout) were found in only nine sampled units (Figure 4) in reach 59 of Rowdy Creek (Table 4). 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 20 units across six reaches (Table 4, Figure 4) with an estimated winter occupancy rate of 0.12 (SE= 0.03) (Table 5). Detection rates varied by method ranging from 0.57 for minnow traps and 0.77 for snorkel surveys; no captures were made using seines. Last, we detected resident adult coastal cutthroat trout in only two units across two reaches (Table 4, Figure 4). The lack of adult coastal cutthroat observations likely results from size limitations of the minnow trap openings preventing larger adult individuals from entering the traps. Hence, actual winter distribution is not well understood based on our sampling limitations.

Last, two Red-eared sliders (*Trachemys scripta elegans*) were observed in reach 7, ~700 meters downstream from the Highway 101 bridge. To our knowledge, this is the first description of this invasive turtle species in the Smith River basin. Both individuals were in close proximity to one another (~130 meters) and utilizing a backwater and alcove where 70+ coho salmon were detected during the winter of 2015.

Table 5. Occupancy estimates and relative count densities of salmonids in the lower Smith River and estuary during the winter of 2016, Smith River basin, Del Norte County, California.

Species	ψ	SE	95% CI	*p*	SE	95% CI	# of units present
Coho Salmon	0.24	0.08	0.12 – 0.43	BS: 0.38	0.35	0.03 – 0.92	25 of 200
				MT: 0.40	0.14	0.17 – 0.68	
				SS: 0.04	0.04	0.004 – 0.24	
Chinook Salmon[1]	–	–	–	–	–	–	14 of 200
Trout spp. (YOY)[1]	–	–	–	–	–	–	9 of 200
Trout spp. (1 +)	0.12	0.03	0.08 – 0.20	BS: 0.00	–	–	20 of 200
				MT: 0.57	0.17	0.25 – 0.84	
				SS: 0.77	0.13	0.45 – 0.93	
Coastal Cutthroat Trout	–	–	–	–	–	–	2 of 200

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.

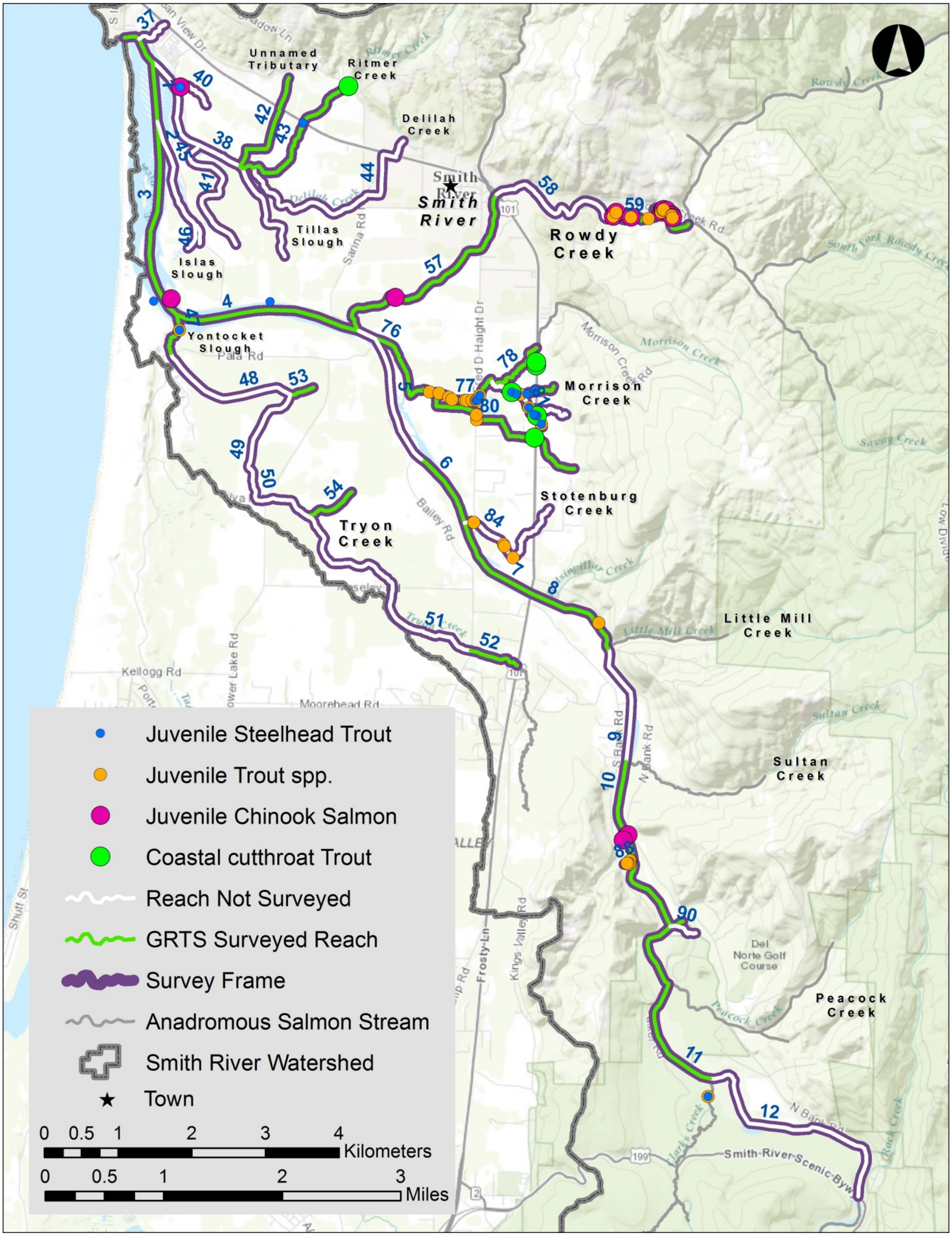


Figure 4. Distribution of various fish species captured during GRTS and apex surveys during the winter of 2016, Smith River coastal plain, Del Norte County, California. Reach location codes are labeled in blue.

Tributary Habitat Covariate Modeling (2015 and 2016)

To gain insight on how habitat correlates potentially influence winter coho salmon occupancy in tributaries, we modeled coho salmon distribution across two winters (2015 and 2016) as a separate and complementary analysis to the 2016 GRTS occupancy estimate presented in Table 5. We first explored if the year influenced overall occupancy in tributaries and found it to have little improvement to the simplest 'dot' model (Table 6, *see* model #10) so we merged both years into a single dataset. Testing of the global model (i.e. the most complex model) for describing winter coho salmon occupancy in tributaries did not indicate evidence of lack of fit using 10,000 bootstrap samples (X^2 = 0.39, P-value = 0.85, $\hat{c}$ = 0.00). Model selection statistics provided evidence that winter coho salmon occupancy probabilities were negatively influenced by the maximum depth and positively influenced by the amount of turbulent flow in the top ranked AIC model and effect plots (Table 6, Figure 6). Additionally, the model that contained maximum depth, the amount of turbulent flow, and the amount of cover area ranked second, with cover area adding very little to the model weight. Other covariates were not satisfactory in predicting coho salmon occupancy in tributaries during the winter.

Table 6. Summary of model selection procedure for juvenile coho salmon occupying tributary habitats in the lower Smith River coastal plain and estuary during the winters of 2015 and 2016.

Model		AIC	ΔAIC	AIC wt.	Model Likelihood	k
1)	ψ(TURBULENT + DEPTH), *p*(METHOD)	225.60	0	0.6025	1	6
2)	ψ(TURBULENT + DEPTH + COVAREA), *p*(METHOD)	227.59	1.99	0.2227	0.3697	7
3)	ψ(TURBULENT + DEPTH + COVAREA + COVRATE), *p*(METHOD)	228.35	2.75	0.1523	0.2528	8
4)	ψ(TURBULENT + COVAREA), *p*(METHOD)	234.15	8.55	0.0084	0.0139	6
5)	ψ(TURBULENT), *p*(METHOD)	235.19	9.59	0.0050	0.0083	5
6)	ψ(DEPTH), *p*(METHOD)	236.18	10.58	0.0030	0.0050	5
7)	ψ(COVAREA), *p*(METHOD)	236.28	10.68	0.0029	0.0048	5
8)	ψ(DEPTH = COVAREA + LWD), *p*(METHOD)	237.92	12.32	0.0013	0.0021	7
9)	ψ(COVAREA + COVRATE + BEAVER + LWD), *p*(METHOD)	239.30	13.7	0.0006	0.0011	8
10)	ψ(YEAR), *p*(METHOD)	239.92	14.32	0.0005	0.0008	5
11)	ψ(.), *p*(METHOD)	240.62	15.02	0.0003	0.0005	4
12)	ψ(LWD), *p*(METHOD)	241.46	15.86	0.0002	0.0004	5
13)	ψ(BEAVER), *p*(METHOD)	242.47	16.87	0.0001	0.0002	5
14)	ψ(COVRATE), *p*(METHOD)	242.62	17.02	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, 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), YEAR: the winter that given sampling occurred across two winters (Winter 2015 and Winter 2016).

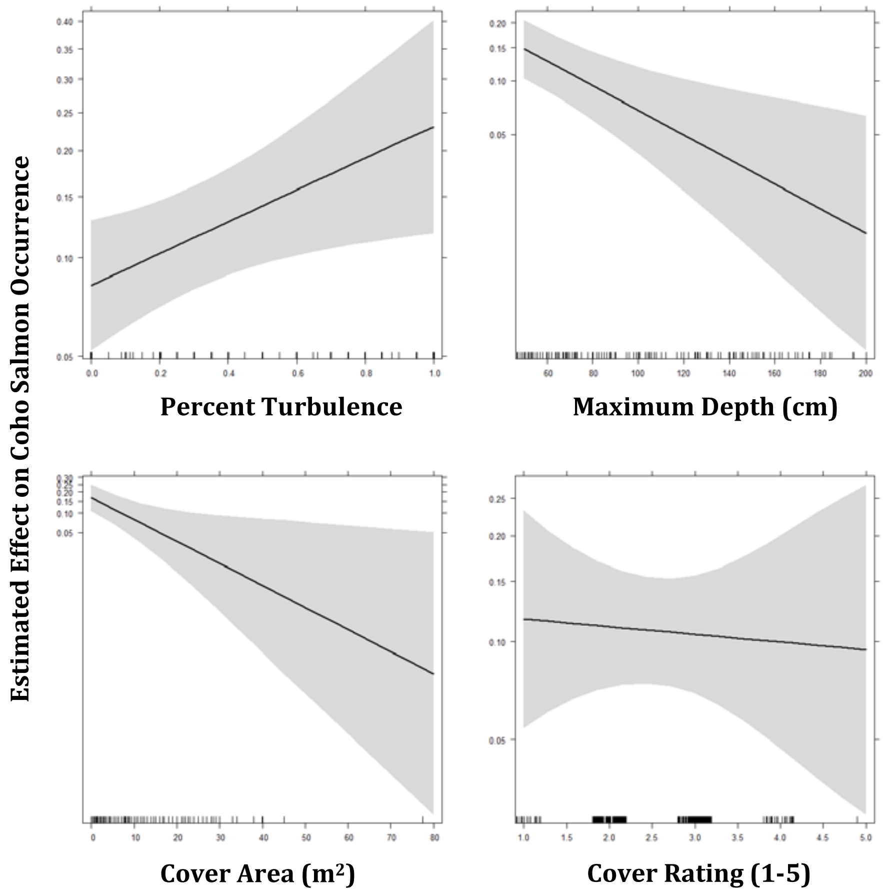


Figure 5. Effect plots showing the influence of individual habitat covariates on the probability of juvenile coho salmon presence at a given site from the winter 2016 spatial structure survey, Smith River, Del Norte County, California. 95% confidence intervals are displayed in grey shading. Plots are arranged in descending order based on AIC-based variable importance, with only the top four variables represented. Both cover area and cover rating did not contribute significantly to model performance but are displayed in order to compare to the previous winters results in Parish and Garwood (2015).

Apex Station Occupancy

All 27 apex monitoring stations were distributed across 21.6 km of stream beginning 0.97 km upstream from the mouth, with sites located throughout the mainstem and three coastal tributaries, Tryon Creek, Morrison Creek and Stotenburg Creek (Figure 2). The eight stations in Tryon Creek extended up 8.9 km upstream from the confluence with mainstem Smith River. The three stations in Morrison Creek extended up 1.9 km upstream from the confluence with mainstem Smith River and included a station on a Morrison Creek tributary. The three stations in Stotenburg Creek extended up 0.9 km upstream from the confluence with mainstem Smith River. We surveyed each station on three occasions in 2016 ranging from January 9 to March 18, with 20 - 38 days separating each primary sampling occasion and four days to survey all monitoring stations during each survey period. Smith River discharge ranged from 2,630 – 66,400 cfs during the sampling season with multiple winter storm events producing a rise in flows between each sampling occasion (Figure 7) and dictating the timing between sampling occasions. The peak flow was 114,000 cfs on December 13, 2015 (Figure 7).

Coho salmon were detected at 11 of the 27 apex sites and at the upstream-most station in all three tributaries at least once throughout the survey season (Table 7, Figure 3). Based on the model with no covariates (*hereafter* dot model), estimated coho salmon occupancy was 0.34 (SE = 0.09) and remained remarkably consistent (0.34 – 0.35) throughout the sampling season. Overall, estimated occupancy at apex locations was 43 percent higher in 2016 than observed in 2015 by Parish and Garwood (2015) (Table 8). Both extinction (0.09, SE=0.09) and colonization (0.06, SE=0.04) were estimated to be low (Table 8) indicating sites with coho salmon generally remained occupied throughout the winter. Detection probability was found to be 0.68 (SE = 0.08) using contained bait. We used uncontained bait in 2015 (Parish and Garwood 2015) and found detection was far less on the second sampling occasion (Table 9) indicating potential bias (i.e. trap shyness) on the second occasion from fish foraging less on the second day. Additionally containing bait reduced the variation between the two days of sampling and the confidence interval of the estimate (Table 9).

We used a reduced global model to assess model fit due to multicollinearity present between total cover area and percent of turbulent flow present (>0.6). We modeled depth, percent of turbulent flow, large woody debris, beaver created cover, minimum temperature, minimum dissolved oxygen, and maximum salinity on occupancy for each primary sampling season as single season occupancy model. The three primary occasion $\hat{c}$ values equaled 1.71, 0.51, and 1.05, respectfully, resulting in an average $\hat{c}$ of 1.09. Additionally the $\hat{c}$ was manually increased up to 2.0 to qualitatively assess the sensitivity of the model rankings (Cooch and White 2014). Because the overdispersion parameter was found to be near 1 (1.09), the need for a quasi-likelihood adjustment (QAIC) is negated (Burnham and Anderson 2002). Additionally, the model weight and AIC were not found to be highly sensitive to increases in $\hat{c}$ further supporting the use of AIC (Cooch and White 2014).

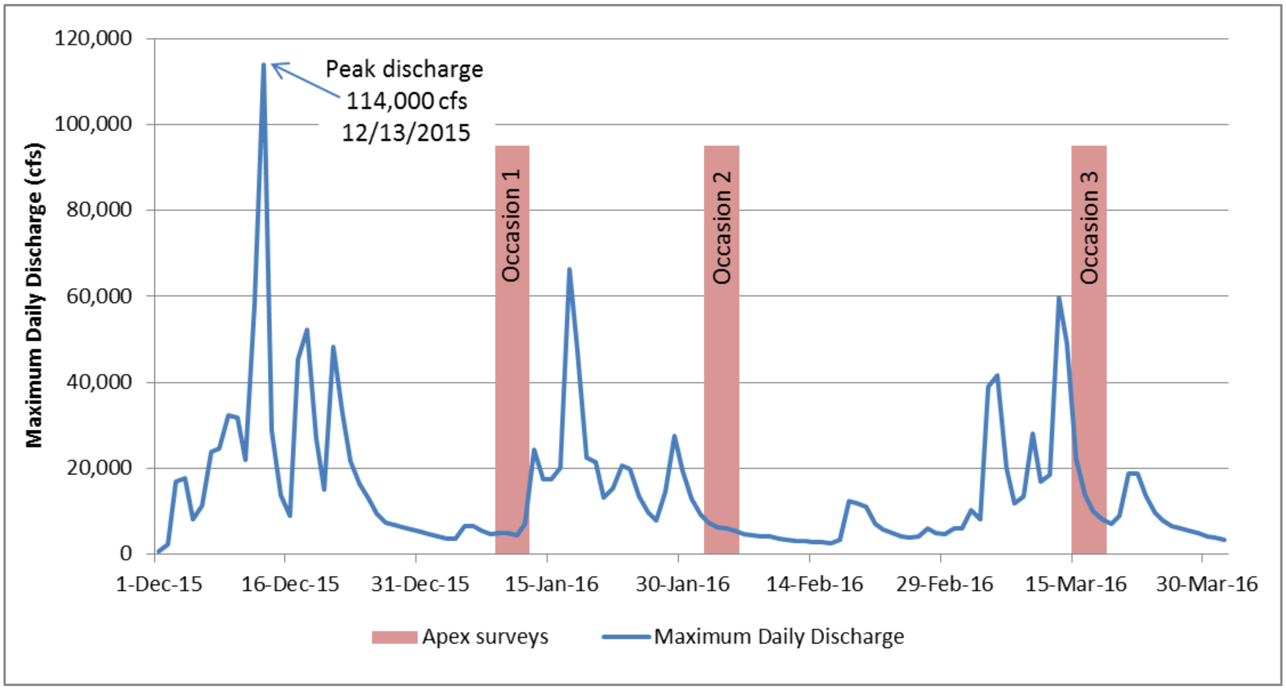


Figure 6. Daily peak winter discharge and timing of winter sample surveys conducted at winter apex sites. Flow measured and recorded by the USGS Jed Smith stream gauge (11532500) located on the Smith River 25.97km upstream from the mouth near Hiouchi, California.

Table 7. Combined two pass detection history of juvenile Coho salmon and combined water quality readings across three sampling periods at 27 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 three survey periods with a YSI professional plus. Temperature (temp) in degrees Celsius (°C). dissolved oxygen (DO) in milligrams/liter (mg/l), and salinity in parts per thousand (ppt).

			Occasion 1		Occasion 2		Occasion 3							
			1/9/16 - 1/12/16		2/2/16 - 2/5/16		3/15/16 - 3/18/16							
Location Code	Site	# of Traps/ Effort	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Mean Temp (°C)	Temp Range (°C)	Mean DO (mg/l)	DO Range (mg/l)	Mean Salinity (ppt)	Salinity Range (ppt)
7	9	4	0	0	0	0	0	0	11.03	(10.9 - 11.2)	10.66	(9.52 - 11.58)	0.04	(0.04 - 0.05)
6	10	2	0	0	0	0	0	0	9.38	(8.2 - 10.7)	11.81	(11.27 - 12.54)	0.04	(0.04 - 0.05)
6	11	2	0	0	0	0	0	0	9.37	(8.2 - 10.9)	10.87	(10.39 - 11.32)	0.04	(0.04 - 0.04)
76	12	3	0	0	0	0	0	0	11.28	(8.5 - 13.4)	9.68	(8.9 - 10.81)	0.04	(0.03 - 0.05)
76	13	2	0	0	0	0	0	0	9.62	(8.8 - 10.4)	10.46	(10.14 - 10.9)	0.05	(0.04 - 0.05)
77	14	2	0	0	0	0	0	0	11.00	(8.2 - 13.5)	10.20	(9.12 - 11.17)	0.04	(0.04 - 0.04)
4	18	2	0	0	0	0	0	0	9.89	(8.7 - 10.9)	11.71	(11.29 - 12.41)	0.04	(0.04 - 0.04)
47	19	5	0	0	0	0	0	0	10.39	(8.9 - 12.8)	4.12	(3.24 - 4.7)	0.13	(0.11 - 0.14)
3	20	5	0	0	0	0	0	0	9.46	(8.5 - 10.8)	10.53	(7.25 - 12.04)	0.12	(0.08 - 0.31)
38	23	6	0	0	0	0	0	0	9.22	(8.4 - 10.5)	10.56	(8.43 - 12.07)	0.18	(0.05 - 0.34)
40	24	5	0	1	1	0	1	0	8.81	(8.2 - 9.6)	9.76	(8.89 - 10.92)	0.27	(0.07 - 0.74)
4	25	3	0	–	0	0	0	.	9.23	(8.1 - 11.2)	3.78	(2.89 - 4.71)	0.23	(0.11 - 0.35)
77	26	2	3	5	0	0	1	0	10.80	(10.8 - 10.8)	10.63	(10.47 - 10.73)	0.03	(0.03 - 0.03)
78	27	2	8	4	0	0	0	0	10.65	(10.1 - 11.2)	10.92	(10.6 - 11.21)	0.03	(0.03 - 0.03)
80	28	6	15	38	1	6	3	2	12.38	(11.5 - 13)	10.41	(8.59 - 11.09)	0.04	(0.03 - 0.07)
84	30	2	0	1	0	1	0	0	11.95	(11.1 - 12.3)	10.34	(8.5 - 11.54)	0.03	(0.03 - 0.04)
84	31	2	16	17	1	0	2	4	11.50	(11 - 11.8)	11.59	(11.07 - 12.21)	0.03	(0.03 - 0.03)
84	32	3	2	5	2	8	1	2	11.65	(11 - 11.9)	11.03	(10.1 - 12.21)	0.03	(0.02 - 0.03)
84	33	5	16	25	12	24	9	8	11.40	(10.9 - 11.8)	10.43	(9.76 - 11.14)	0.02	(0.02 - 0.03)
50	36	3	0	0	0	0	0	0	10.20	(9.4 - 10.8)	5.83	(5.54 - 6.21)	0.11	(0.09 - 0.13)
50	37	2	0	1	0	0	1	0	10.39	(9.7 - 11.3)	7.31	(6.5 - 7.65)	0.12	(0.1 - 0.13)
50	38	2	0	0	0	0	2	0	10.73	(9.7 - 11.3)	7.21	(6.43 - 7.42)	0.11	(0.1 - 0.13)
51	39	2	0	0	0	0	0	0	9.43	(8.6 - 9.9)	10.16	(9.88 - 10.59)	0.04	(0.03 - 0.05)
52	40	2	0	0	0	0	0	0	8.95	(8.6 - 9.3)	10.29	(9.69 - 10.89)	0.05	(0.04 - 0.05)
52	42	4	0	0	0	0	0	0	8.58	(8.1 - 9.1)	10.12	(8.53 - 11.23)	0.04	(0.04 - 0.04)
52	43	2	0	0	0	0	0	1	8.97	(8.1 - 9.7)	10.53	(9.96 - 11.18)	0.04	(0.03 - 0.04)
50	44	2	0	0	0	0	0	0	10.61	(9.7 - 11.2)	6.86	(6.13 - 7.48)	0.11	(0.09 - 0.13)
	Overall:	82	60	97	17	39	20	17	10.23	(8.1 - 13.5)	9.55	(2.89 - 12.54)	0.08	(0.02 - 0.74)

Table 8. Estimates of multi-season occupancy parameters for all salmonids detected with minnow traps at apex monitoring stations during the winter of 2015 and 2016, based on the dot model. Station occupancy statistics include standard errors (SE) and 95% confidence intervals (CI) around the estimates.

		Apex Station Occupancy (ψ)			Colonization (γ)			Extinction (ε)			Detection (*p*)		
	species	January	February	March	estimate	SE	95% CI	estimate	SE	95% CI	estimate	SE	95% CI
2016	Coho Salmon	0.34 ± 0.09 (0.19 - 0.54)	0.35 ± 0.09 (0.18 – 0.52)	0.35 ± 0.10 (0.16 - 0.55)	0.06	0.04	0.01 - 0.23	0.09	0.09	0.01 - 0.46	0.68	0.08	0.52 - 0.80
	Unidentified Trout Spp.	0.29 ± 0.10 (0.14 - 0.50)	0.20 ± 0.07 (0.05 - 0.34)	0.14 ± 0.07 (0.00 - 0.29)	0.03	0.03	0.00 - 0.23	0.4	0.18	0.13 – 0.74	0.59	0.12	0.36 - 0.79
2015	Coho Salmon	0.19 ± 0.11 (0.05 - 0.50)	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
	Unidentified Trout Spp.	0.13[a]	0.08[a]	0.08[a]	-	-	-	-	-	-	-	-	-

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

Table 9. Comparison of detection probability between two back to back days of sampling using minnow traps where the bait is either contained (2016 sampling) or uncontained (2015 sampling).

		Day 1			Day 2		
Survey year	Bait method	*p*	SE	95% CI	*p*	SE	95% CI
2015	Uncontained	0.77	0.21	0.26 - 0.97	0.32	0.14	0.12 - 0.62
2016	Contained	0.69	0.10	0.48 - 0.85	0.66	0.10	0.45 - 0.82

Model selection ranking found minimum water temperature in January modeled on occupancy to be the top ranked model carrying 96% of the AIC*w*, given the candidate model set (Table 10), with minimum temperature having a positive influence on coho salmon occupancy (1.56, SE=0.50) (Table 11). Cover rating was not included in the candidate model set as all apex stations surveyed contained cover resulting in reduced variation and explanatory power of the variable. Models containing seasonally varying colonization were not stable (boundaries close to 0 or 1) resulting in spurious results so they were removed from the candidate model set. Correlation was found to exist between

Table 10. Multi-season occupancy models evaluating habitat and water quality covariates ability to explain coho salmon occupancy at apex monitoring stations during the winter 2016.

Model		AIC	ΔAIC	AIC wt.	Model Likelihood	k
1)	ψ(JanMinTemp), γ(.), ε(.), p(.)	116.44	0	0.96	1.00	5
2)	ψ(%TURBULENT), γ(.), ε(.), p(.)	124.31	7.87	0.02	0.02	5
3)	ψ(COVERln), γ(.), ε(.), p(.)	125.95	9.51	0.01	0.01	5
4)	ψ(Tributary), γ(.), ε(.), p(.)	126.13	9.69	0.01	0.01	5
5)	ψ(DEPTHln), γ(.), ε(.), p(.)	129.67	13.23	0.00	0.00	5
6)	ψ(COVER RATING), γ(.), ε(.), p(.)	129.88	13.44	0.00	0.00	5
7)	ψ(.), γ(.), ε(.), p(.)	129.91	13.47	0.00	0.00	4
8)	ψ(minDO), γ(.), ε(.), p(.)	131.06	14.62	0.00	0.00	5
9)	ψ(LWD), γ(.), ε(.), p(.)	131.38	14.94	0.00	0.00	5
10)	ψ,γ(.), ε(seasonal), p(.)	131.68	15.24	0.00	0.00	5
11)	ψ(BEAVCOV), γ(.), ε(.), p(.)	131.91	15.47	0.00	0.00	5

Table 11. Covariate estimates, standard errors (SE), and 95% confidence interval (CI) individually modeled on occupancy of coho salmon at apex monitoring stations during the winter of 2016.

Covariate	Untransformed Estimate	SE	Converted True Estimate	95% CI
January Minimum Temperature	1.56	0.50	4.76	1.79 - 12.68
% Turbulent	3.60	1.47	36.60	2.05 - 652.72
Cover Area[a]	-0.72	0.33	0.49	0.25 - 0.93
Hydrology	2.4	1.18	11.02	1.09 - 111.36
Maximum Depth[a]	-1.19	0.8	0.30	0.06 - 1.46
Minimum Dissolved Oxygen	0.19	0.21	1.21	0.8 - 1.83
Large Woody Debris	0.11	0.15	1.12	0.83 - 1.5
Beaver Created Cover[a]	0.02	0.35	1.02	0.51 - 2.03

[a]*Converted true estimate and CI on log scale*

four pairs of variables; total cover area and cover rating (R^2 = 0.66), cover rating and count of large woody debris (R^2 = 0.59), and between total cover and percent of turbulent flow at a station (R^2 = -0.62). Lastly correlation was present between hydrology (mainstem vs. tributary) and minimum temperature (R^2 = 0.63).

Unidentified trout were detected at eight of the apex stations and based on the dot model showed a declining occupancy from 0.29 (SE=0.10) in January to 0.14 (SE=0.07) in March (Table 8). Extinction was estimated to be 0.40 (SE=0.18) and colonization was much lower at 0.03 (SE=0.03) throughout the winter months. Both extinction (0.09, SE=0.09) and colonization (0.06, SE=0.04) were estimated to be low (Table 8). No Chinook salmon or coastal cutthroat trout were detected at apex stations.

Winter Size, Growth, Emigration Timing, and Residence Tenure

Fish Size and Growth

We captured 289 individual coho salmon throughout the Smith River coastal plain during our winter survey efforts. We individually marked 198 with PIT tags and 13 were detected with PIT tags that had been applied during the fall of 2015 in Mill Creek. Of the remaining 78 individuals, 17 were <70mm therefore were unavailable to be tagged and due to time restrictions we were unable to mark the remaining 61 individuals that were >70 mm. Captured individuals averaged 89 mm (52 - 129) and 8.4 g (1.9 – 25.6) with average size continually increasing throughout the winter months (Table 12). The pattern of increasing size is also observed in past incidental and directed studies in the Smith River coastal plain (Table 12) and in Humboldt Bay (Wallace et al. 2015).

Table 12. Mean month fork length (FL) and weight of juvenile coho salmon captured during incidental and directed survey efforts during the winters of 2012 – 2016 in the coastal plain of the Smith River, Del Norte County, CA. Data prior to 2016 is from Parish and Garwood (2015).

Survey Year	Month	Length (n)	Mean FL (mm)	FL Range (mm)	Weight (n)	Mean Weight (g)	Weight Range (g)
2012	January	32	88.88	73 - 104	32	7.9	3.8 - 13.5
	February	33	95.88	66 - 124	33	10.4	3.9 - 21.1
2013	January	31	91.61	66 - 112	31	9.5	3.6 - 17.0
	February	145	87.38	61 - 117	35	10.7	4.9 - 19.3
	March	18	97.89	80 - 121	8	11.2	6.4 - 16
	April	26	99.31	70 - 134	-	-	-
	May	4	107.75	102 - 111	-	-	-
2014	March	3	90.67	77 - 104	1	4.9	-
	April	1	105.00	-	-	-	-
2015	January	84	89.55	73 - 108	-	-	-
	February	119	99.03	73 - 134	-	-	-
	March	8	99.88	90 - 116	-	-	-
2016	January	291	86.71	52 - 120	257	7.5	1.9 - 24.1
	February	77	92.85	62 - 126	35	11.4	4.0 - 25.6
	March	44	100.11	80 - 129	44	12.6	5.6 - 24.0
	Overall Total	896	91.12	52 - 134	476	8.9	1.9 - 25.6

During GRTS and apex station surveys, we recaptured 32 PIT tagged coho salmon. Thirteen of these individuals had been marked in Mill Creek during the fall of 2015 and 19 were marked throughout the coastal plain during the winter of 2016. Based on days at liberty (DAL) and the difference between length and weight at time during initial tagging event and later at the recapture event, we determined mean daily growth rate to be 0.20 mm/ day and 0.07 g/ day (Table 13).

For the years we had March size data (2013, 2015, 2016), yearling coho salmon rearing in the coastal plain near the end of winter (i.e. just prior to ocean migration) were significantly larger (mean FL=100 mm, SE=0.78 mm) than those rearing in Mill Creek (mean FL=92 mm, SE=0.86 mm); ANOVA, $F_{1,355}$ =30.31, P<0.001 (Figure 7). Coho salmon from March of 2013 were significantly smaller than those from March of 2015 and 2016 (2013=89 mm, SE= 1.70 mm; 2015=98 mm, SE=0.79; 2016=96 mm, SE=0.98 mm); ANOVA, $F_{2,355}$ =10.09, P<0.001 (Figure 7). However, no interactions were detected between watershed position and year indicating mean fork lengths of coho salmon were consistently larger in the coastal plain when compared to Mill Creek regardless of year; ANOVA, $F_{2,355}$ =1.85, P=0.16 (Figure 7).

Mill Creek Early Emigration

During the fall of 2015 CDFW staff marked 821 coho salmon with PIT tags in the upper Mill Creek watershed (J.Garwood, *unpublished data*). This annual monitoring component is used to estimate early emigration and over-winter survival of coho salmon in conjunction with a spring outmigrant trap and antenna network maintained in Mill Creek. Based on PIT tag antennas located in Tryon Creek and Morrison Creek, as well as surveys with minnow traps and seines, a minimum of 94 (11.4%) coho salmon tagged in Mill Creek utilized streams in the coastal plain for winter non-natal rearing (Figure 8). A total of 37 individuals were detected in Morrison Creek and 56 individuals were detected in Tryon Creek. Additionally, two Mill Creek tagged coho salmon were detected in Stotenburg Creek with minnow traps. Three individuals were detected at both Morrison Creek and Tryon Creek antennas. One individual was originally tagged during the fall of 2015 in Mill Creek and two were tagged in Morrison Creek in January. Furthermore, a single individual that was tagged in Stotenburg Creek in January was detected 53 days later at the Tryon Creek antenna. Lastly, a single unidentified trout tagged in Mill Creek during the fall of 2015 was detected at the Morrison Creek antenna (Figure 8).

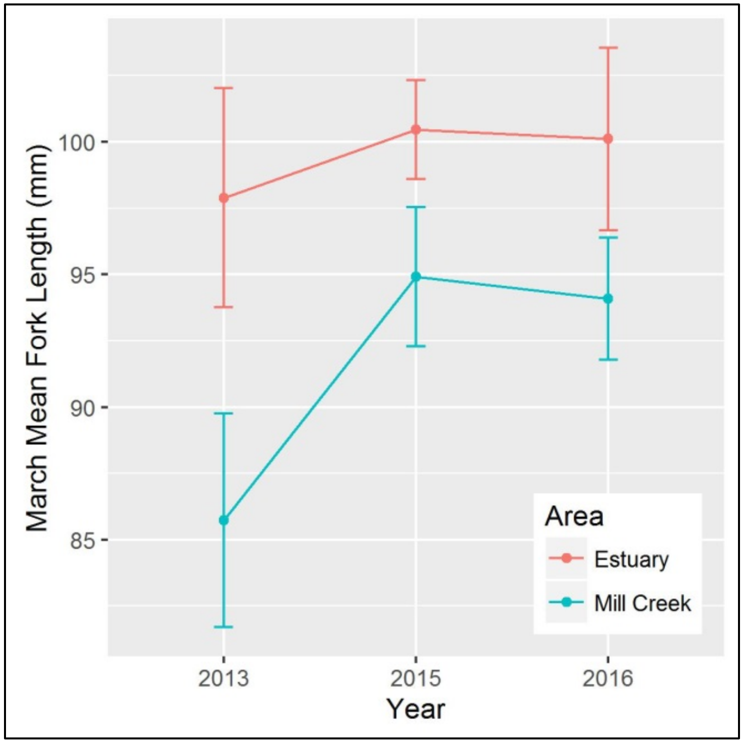
Residence and Migration Timing

Morrison Creek - The first Mill Creek tagged coho salmon detected migrating into (*hereafter* entering) Morrison Creek passed the antenna on December 4, 2015 (Table 14, Figure 9A). The antenna consistently detected new individuals every day until the peak winter storm event flooded solar power components on the morning of December 13, 2015 resulting in a system failure. We were unable to repair the antenna until the afternoon of January 2, 2016 and therefore the detection system was down for 20.5 days (Figure 9A). Before and after the equipment failure a total of 25 individuals were detected entering and 120 migrating out of (*hereafter* exiting) Morrison Creek. A total of 109 coho salmon were tagged in the Morrison Creek basin upstream of the antenna from January 7 – March 16, 2016, contributing to the larger sample size of exiting individuals (Table 14, Figure 9A). Based on individuals with both an entry and exit date, Mill Creek tagged individuals resided in Morrison Creek upstream of the antenna for an average of 67 days (1 – 114) (Table 14). Based on day of initial capture and tagging in Morrison Creek to date of exit, winter tagged coho salmon resided in Morrison Creek upstream of the antenna for an average of 57 days (1 - 124) (Table 14). A single trout *spp.* tagged in Mill Creek during the fall of 2015 was detected entering Morrison Creek on December 6, 2016 and was not encountered again. A total of 46 juvenile trout (unidentified steelhead or coastal cutthroat) were marked with PIT tags upstream of the Morrison Creek antenna. Based on the duration between tagging date and date of exit, winter tagged trout resided in Morrison

Table 13. Summary of length and weight of juvenile coho salmon individually marked with PIT tags during the fall 2015 in Mill Creek and during the winter 2016 in the estuary during their initial time at tagging. Summary of days at liberty (DAL), and length and weight growth rates (GR) in mm/day and g/day, respectively, from initial time at tagging to time at recapture during surveys in the Smith River coastal plain, Del Norte County, CA during the winter of 2016.

Group	Mean DAL	Range DAL	n (length)	Mean length at tagging (mm)	Range length at tagging (mm)	Mean GR (mm/day)	Range GR (mm/day)	n (weight)	Mean Weight at tagging (g)	Range Weight at tagging (g)	Mean GR (g/day)	Range GR (g/day)
Fall tagged	106	84 - 162	13	75.7	70 - 83	0.23	0.10 - 0.44	13	5.4	3.9 - 6.9	0.06	0.02 - 0.17
Winter tagged	30	21 - 64	19	88.4	72 - 105	0.17	0.04 - 0.41	9	7.8	4.1 - 12.3	0.08	0.02 - 0.18
Overall:	62	21 - 162	32	83.1	70 - 105	0.20	0.04 - 0.44	22	6.8	3.9 - 12.3	0.07	0.02 - 0.18

Figure 7. Comparison of annual mean fork lengths of age 1+ coho salmon during the month of March from the Smith River coastal plain (red lines) and Mill Creek (blue lines), Del Norte County, California. Bars represent upper and lower 95% confidence intervals. Coastal plain fish were captured using minnow traps and beach seines. Mill Creek fish were captured at outmigrant traps (2013: pipe trap, 2015-2016: rotary screw trap). Photo below shows a large (110 mm) pre-smolt coho salmon captured on February 2, 2016 in Morrison Creek. *Photo: M. Parish*



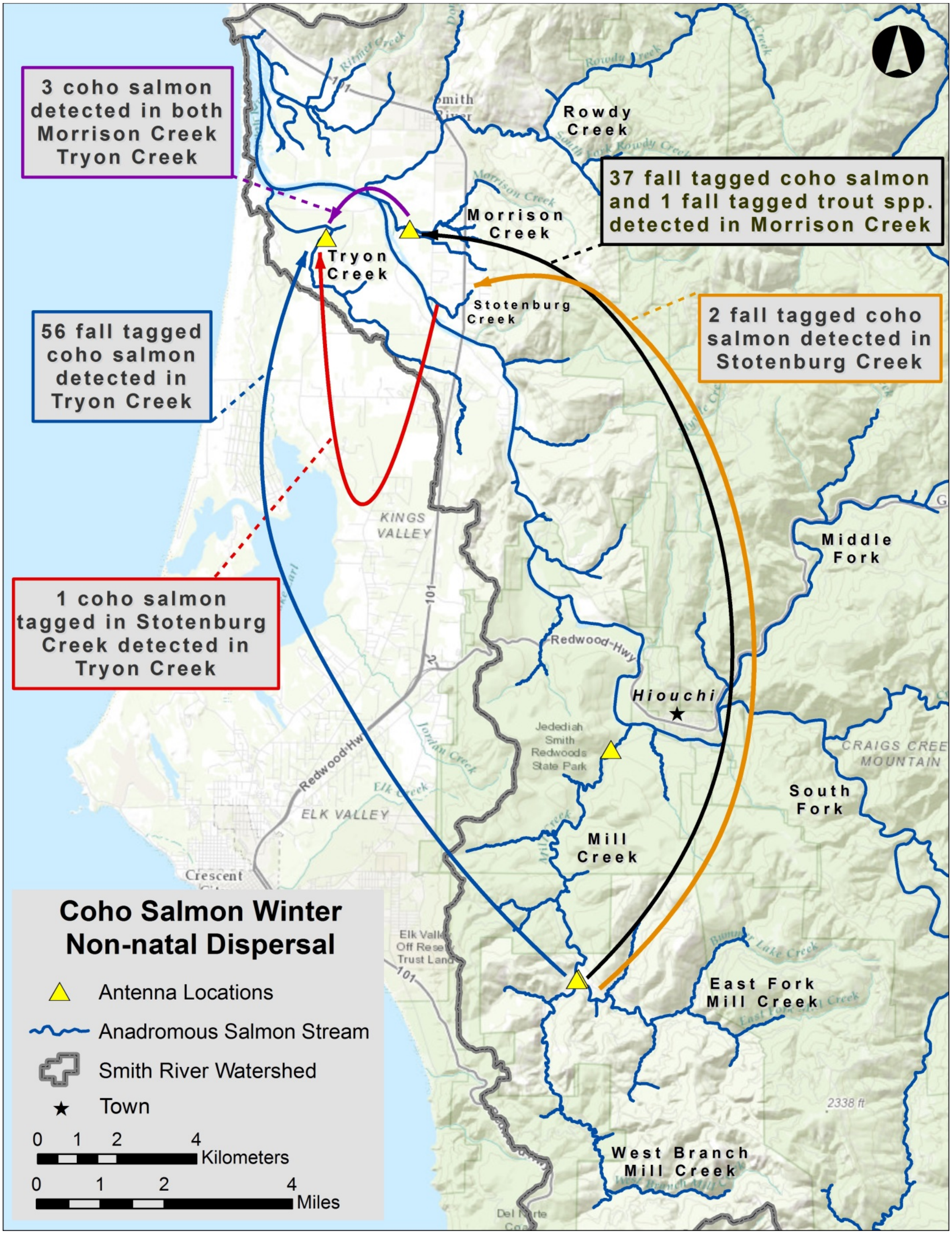


Figure 8. Locations of Passive Integrated Transponder (PIT) tag antennas throughout the Smith River coastal plain and Mill Creek. Raw counts of individual fish PIT tagged in Mill Creek during the October 2015 detected at antennas in Morrison Creek, Tryon Creek, and with minnow traps during the winter 2016.

Table 14. Summary of coho salmon and juvenile trout migration timing and minimum winter residence in stream habitats occurring upstream of PIT tag antenna's in Morrison Creek and Tryon Creek, Del Norte County, CA.

			Entry Date			Exit Date			Minimum Residence		
			Average Entry	First Entry	Last Entry	Average Exit	First Exit	Last Exit	Average (days)	Min (days)	Max (days)
Coho salmon	Morrison Creek	Mill Creek Fall tagged (n = Entries: 25, Exits: 32)	12/28/2015	12/4/2015	2/22/2016	2/23/2016	12/12/2015	4/19/2016	67	1	114
		winter tagged (n = 88)	-	-	-	3/13/2016	1/9/2016	5/15/2016	57	1	124
	Tryon Creek	Mill Creek Fall tagged (n = Entries: 52, Exits: 29)	12/27/2015	12/16/2015	3/2/2016	3/1/2016	12/26/2015	4/13/2016	61	3	114
		winter tagged (n = 3)	-	-	-	3/12/2016	1/28/2016	4/4/2016	51	20	73
Trout spp.	Morrison Creek	mill fall tagged (n = 1)	12/6/2015	-	-	-	-	-	-	-	-
		winter tagged (n = 25)	-	-	-	3/19/2016	1/17/2016	5/16/2016	53	3	116

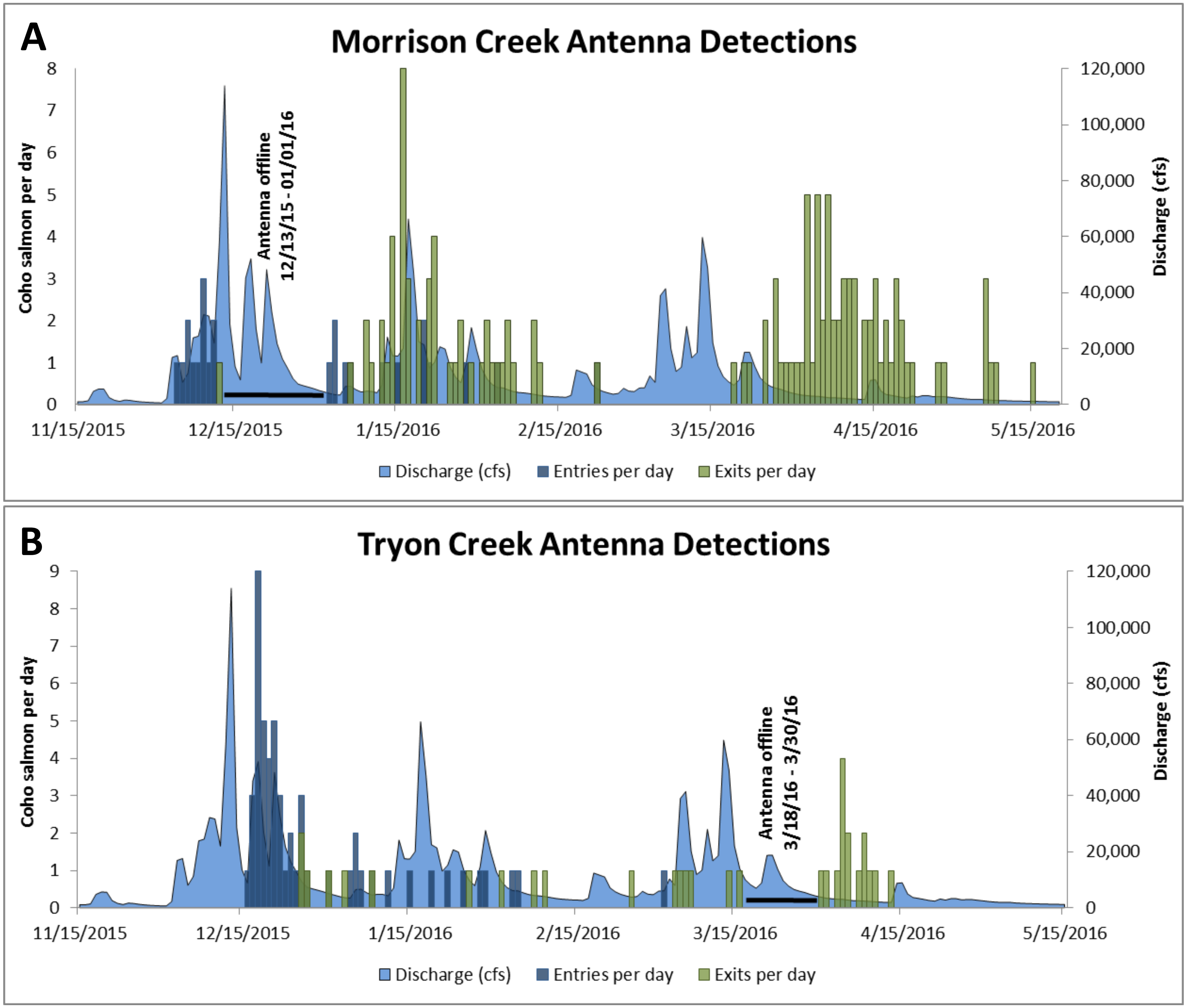


Figure 9. Count of individual coho salmon marked with Passive Integrated Transponder (PIT) tags entering and exiting Morrison Creek (A) and Tryon Creek (B) based on raw detections at an antenna located 1220 meters and 2640 meters upstream from the confluence with Smith River mainstem, respectively.

Creek upstream of the antenna for an average of 53 days (3 - 116) (Table 14). The last individual detected exiting Morrison Creek was on May 16, 2016 (Table 14). Based on temperature loggers placed in the channel at the antenna, Morrison Creek was no longer flowing at the antenna beginning on June 2, 2016.

Tryon Creek - The first Mill Creek tagged coho salmon detected entering Tryon Creek at the antenna was on December 16, 2015 (Table 14, Figure 9B). The peak upstream migration following shortly after on December 18, 2016 during elevated winter flows (Figure 9B). Wildlife caused a break in power supply at the Tyron Creek antenna on March 18, 2016. The damage was not detected and corrected until March 30, 2016 resulting in the station being down for 14 days. While individuals were detected migrating downstream before and after the shutdown occurred, the largest number of individuals exiting recorded was on April 4, similar to the peak observed on Morrison Creek from April 2 – 6, 2016 (Figure 9). Prior to and after the equipment shutdown a total of 54 individuals were detected entering and 32 exiting Tryon Creek. During winter surveys, 23 coho salmon were marked with PIT tags upstream of the Tryon Creek antenna. Based on individuals with both an entry and exit date, Mill Creek tagged individuals resided in Tryon Creek upstream of the antenna for an average of 61 days (3 – 114) (Table 14). Coho salmon initially captured and tagged above the antenna in Tryon Creek resided upstream of the antenna for an average of 51 days (20 – 73) (Table 14). No Mill Creek trout were detected at the antenna or in surveys upstream of the antenna in Tryon Creek. The last individual coho salmon detected in Tryon Creek at the antenna was on April 13, 2016. Based on temperature loggers placed in the channel at the antenna, Tryon Creek was no longer flowing at the antenna beginning on April 25th.

Water Quality

Winter Salinity Transect

To evaluate the winter salinity influence we collected salinity readings at 14 locations from 488 meters to 1785 meters from the mouth (Figure 10). We found the salt wedge to extend 1765 meters upstream from the mouth with a salinity reading of 4.26 ppt at a depth of 2.4 m (Figure 11). Freshwater was present throughout the water column at the sample location 1785 meters upstream from the mouth of the Smith River (Figure 11). The highest salt concentration recorded was 20.77 ppt, 488 meters from the mouth at a depth of 3.5 m. A freshwater lens of <0.5 ppt was detected at surface readings throughout the entire transect and a layer of 10 – 17.5 ppt throughout the transect.

Dissolved Oxygen

To evaluate the influence of DO on available rearing habitat in Yontocket slough we collected continuous readings of DO upstream, in, and downstream of the Yontocket slough pond (Figure 10). Diurnal shifts were recorded at all DO loggers. At the upstream most logger, peak DO was recorded in the afternoons around 13:30 and lows in the early morning hours around 06:00 and ranged from 2.07 – 10.99 mg/l. In the upper end of Yontocket Slough, peak DO was recorded in the mid to late afternoons, from 2:00 - 7:00 pm and ranged from 0.06 – 21.39 mg/l before the logger went dry on May 21, 2016. At Pala Rd, DO peaked in the late afternoons around 5:00 pm and ranged from 0.66 – 10.32 mg/l before the channel went dry on April 8, 2016. Downstream of Pala Rd, DO peaked in the afternoons around 5:00 and ranged from 0.10 – 6.13 mg/l before the channel went dry on April 13, 2016 (Figure 12). Readings collected on February 12, 2016 at the two middle culverts along Pala rd measured DO to range from 7.58 – 8.40 mg/l. DO was 1.04 mg/l in the shallow water flowing through the eastern most culvert. Downstream of Pala rd, where the water collects into a defined channel to the mouth of Yontocket slough, DO ranged from 4.61 – 5.34 mg/l. Finally, dissolved oxygen at apex station #19, located at the mouth of Yontocket slough, was lower during the winter 2016 (3.24 - 4.70 mg/l) than the winter of 2015 (3.79 – 10.75 mg/l).

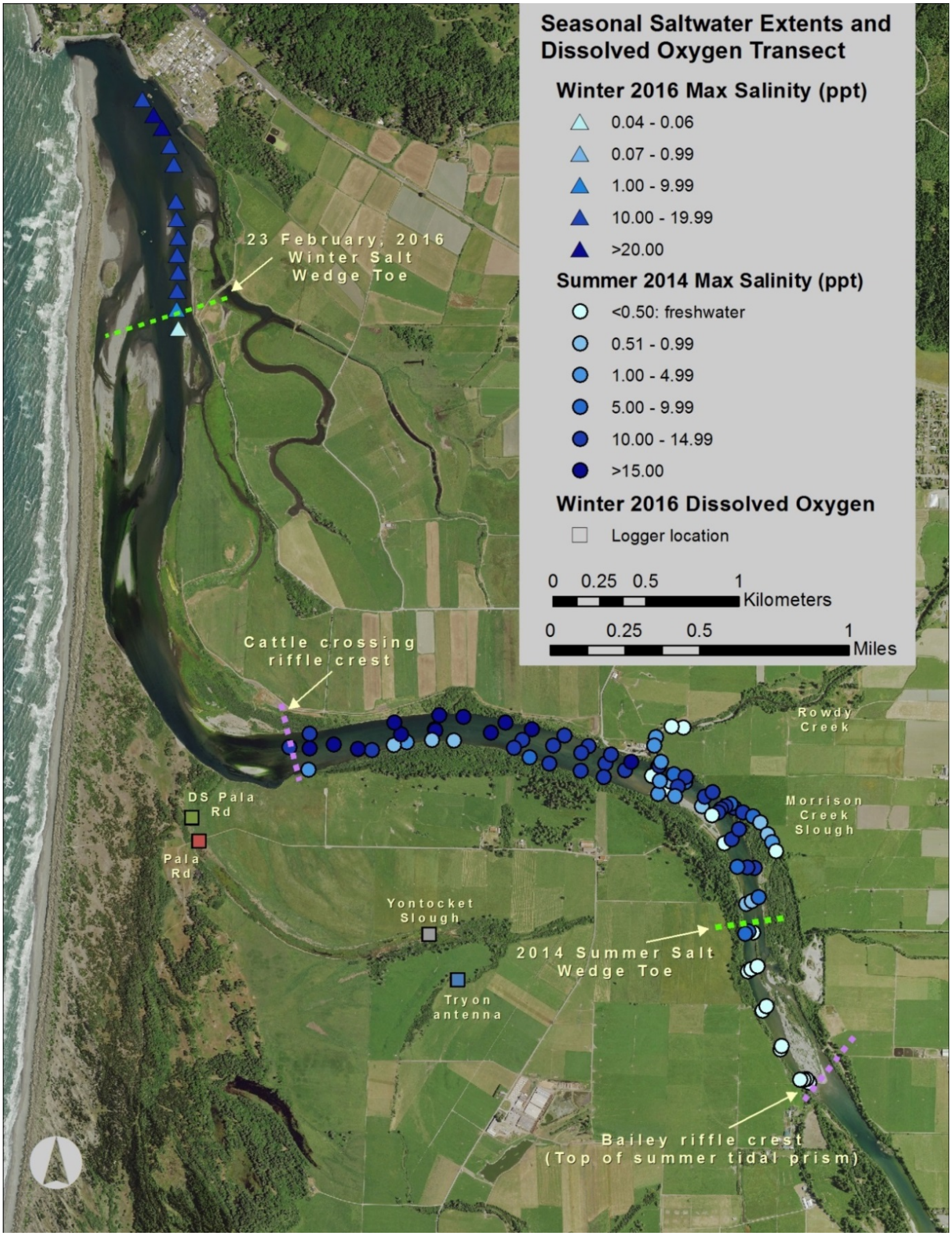


Figure 10. Maximum salinity concentration at each sample location in Rowdy Creek, Morrison slough, and the mainstem Smith River, Del Norte County, California. Sampling was conducted during the summer of 2014 and the winter of 2016. Approximate locations of the salt wedge toe at high tide are identified for the summer and winter seasons. The maximum observed freshwater tidal prism at high-tide extended up to the Bailey Riffle crest during summer of 2014. Dissolved oxygen probe locations in Yontocket Slough are also identified on the map.

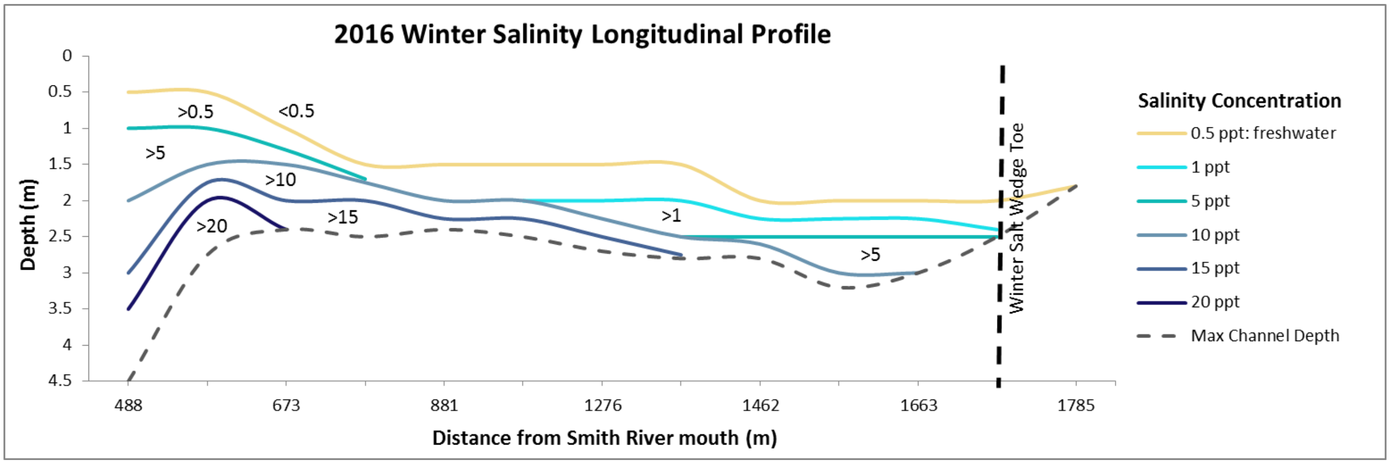


Figure 11. Longitudinal isocline profile of salt concentration and the salt wedge toe from data collected on 23 February, 2016, Del Norte County, CA. *See* Figure 10 for individual sampling locations.

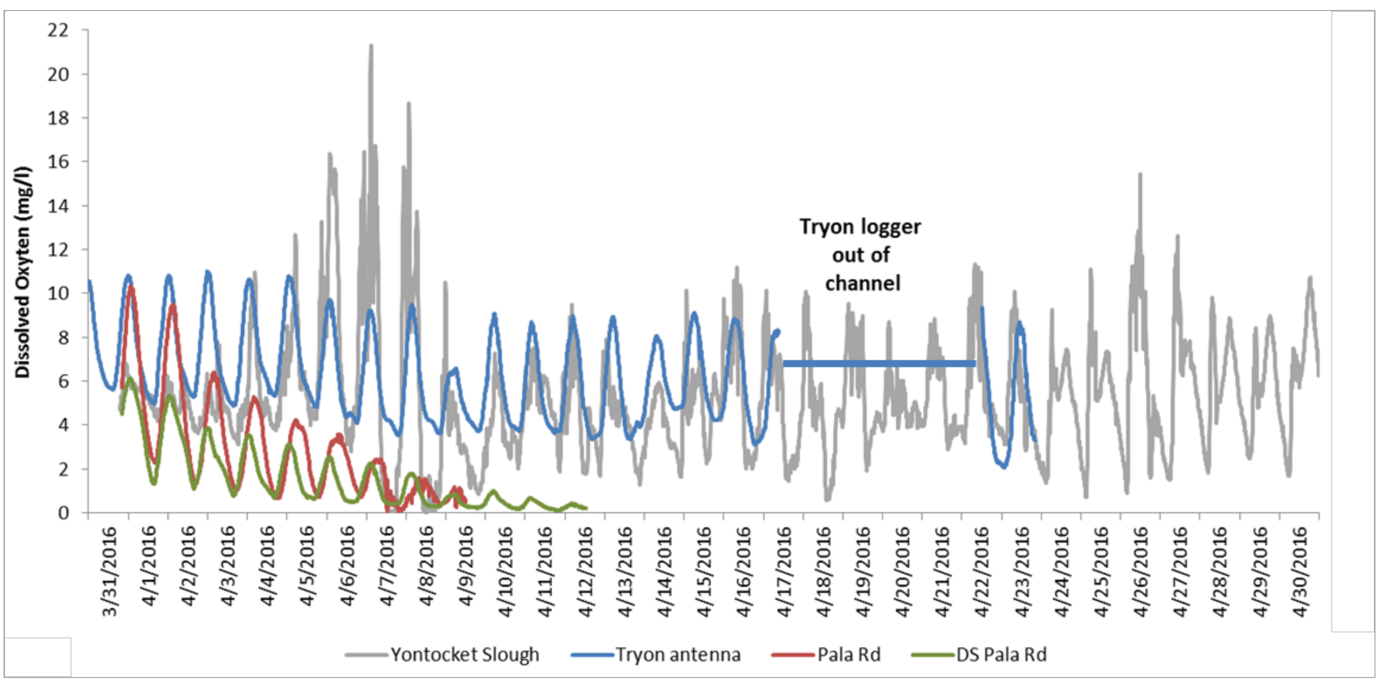


Figure 12. Dissolved oxygen measured every 10 minutes April 1, 2016 until the channel or logger went dry at four locations throughout Tryon Creek/Yontocket Slough, Del Norte County, CA. *See* Figure 10 for individual logger locations.

Discussion

This study was designed to define winter-spring habitat availability and use by salmonids in the Smith River coastal plain and estuary with an emphasis on juvenile coho salmon. Similar to our previous effort during the winter of 2014-2015 (Parish and Garwood 2015), we found juvenile coho salmon used tributaries and slough channels far more often during the winter than the mainstem channel (Figure 13). This pattern is opposite of the summer-fall period when coho salmon primarily rear in the mainstem river throughout the freshwater portions of the estuary (Garwood and Larson 2014, Parish and Garwood 2015) (Figure 13). Overall estimated winter occupancy equaled 0.24 representing a 33% increase from the previous winter's estimated occupancy of 0.16 (Parish and Garwood 2015). Based on our sampling, we found four drainages were especially important as winter coho salmon rearing locations: Morrison Creek, Tryon Creek, Stotenburg Creek, and an unnamed tributary downstream of Tillas Slough (Figure 13). This finding is similar to results from the previous winter indicating these tributaries are important rearing locations for coho salmon regardless of cohort or river flow regime. Most importantly, we consistently found coho salmon rearing in these streams throughout the winter. For example, occupancy remained consistent from January through March at apex monitoring stations (2015 apex site monthly occupancy range: 0.19 – 0.20; 2016 apex site monthly occupancy range: 0.34 – 0.35). Furthermore, residence times for individually tagged fish recorded entering and exiting PIT tag antennas on Morrison creek and Tryon Creek averaged 67 and 57 days, respectively. Although these two streams represent a fraction of the available winter habitat in the coastal plain, our results indicate a substantial portion of fish produced in Mill Creek disperse to the coastal plain for the winter.

Diverse life histories exhibited by coho salmon have been shown to substantially contribute to the adult escapement population (Bennett et al. 2014, Jones et al. 2014). Estuary rearing patterns have recently been well documented (Miller and Sadro 2003; Wallace 2006; Koski 2009; Jones et al. 2014, Wallace et al. 2015). We also found juvenile coho salmon that reared in the coastal plain during the winter were consistently larger than their upstream counterparts for three separate cohorts. This pattern is consistent with other studies in California, Oregon, and Washington who found larger coho salmon rearing in estuaries than in natal streams (Tschaplinski 1987, Miller and Sadro 2003, Craig 2010, Wallace et al. 2015). Water temperatures were slightly warmer in coastal tributaries than in the mainstem Smith River and had a positive relationship with occupancy at apex monitoring stations. Even slightly warmer water temperatures have been shown to accelerate salmonid growth rates (Murphy et al. 1989). Furthermore, larger outmigrating smolts have experienced increased marine survival rates over smaller individuals for juvenile coho salmon and steelhead (Holtby et al. 1992, Bond et al. 2008). The benefits associated with alternative rearing strategies highlights need to understand and manage the important linkages between isolated habitats at the basin scale.

Management and Restoration Considerations

Much of the recent stream restoration in the Smith River has focused on tributaries occurring above the estuary including fish passage at road crossings, wood loading in stream channels, logging road removal, and forest restoration. For example, three long-term salmonid stream barriers have been removed since 2015 including the culvert on Hamilton Creek (Mill Creek watershed) and two Highway 197 culverts (Sultan Creek and Little Mill Creek) have been replaced with bridges. The only significant manmade barrier remaining above the estuary is on Highway 199 at Clark's Creek and this is largely only impacting juvenile salmonid life stages. In addition, to improve channel complexity and fish rearing habitats, numerous wood loading projects have occurred since 2006 in tributaries of Mill Creek, Peacock Creek, and Rowdy Creek. Extensive road removal and forest restoration has occurred in Mill Creek since 2004. In contrast to this work, the Smith River coastal plain and estuary have not been assessed systematically for prioritized habitat restoration opportunities. Previous efforts

Figure 13. Coho salmon observations from GRTS, apex stations, incidental, spatial structure, spawner surveys, and literature from 2001 to 2016 throughout the lower Smith River and coastal plain, Del Norte County, California. Some privately owned stream sections lack surveys so the spatial extent of coho salmon is likely not fully represented. Observations are divided by summer and winter seasons. Reach numbers are labeled in blue. *Note:* single locations may represent multiple observations between different dates and years.

outline various topics associated with restoration in the Smith River coastal plain (Voight and Waldvogel 2002, 2014 NOAA Coho Salmon Recovery Plan) but lack specific detail. However, major factors identified as limiting survival and viability of coho salmon 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). Given the intensive focus on fisheries and habitat data collection in the estuary over the past five years, now a detailed planning effort outlining prioritized fish habitat restoration opportunities and management direction is needed. Potential restoration opportunities identified in Parish and Garwood (2015) and those further outlined below will assist planning. However, detailed assessments need to occur for topics lacking systematic information, for example, barrier assessment, sea-level rise scenarios, and potential water pollution associated with agriculture and chemical pesticide use.

Mainstem Estuary Channel and Floodplain

The function of the Smith River estuary has been simplified due to anthropogenic land use resulting in reduced off-channel habitat and channel complexity (Voight and Waldvogel 2002, 2014 NOAA Coho Salmon Recovery Plan, Parish and Garwood 2015). Habitat availability for rearing salmonids can vary dramatically depending on seasonal salinity gradients in a given estuary (Levings 2016). We conducted a winter salinity transect during a high-tide and the findings suggest the majority of the estuary below the cattle crossing riffle contains salinities that are within the tolerance threshold of pre-smolting salmonids. During the winter, freshwater occurs at least down to the mouth of Islas Slough at high tide, with a freshwater top layer (lens) extending further down to at least 600 meters above the Smith River mouth (Figure 10). We commonly captured juvenile Chinook salmon in the lower estuary below the mouth of Yontocket Slough as early as mid-February. We only captured one coho salmon in this section and suggest future sampling extend beyond the month of March to incorporate the parr-smolt transformation and seaward migration period from April to June. Understanding when smolts are using the lower estuary and if they are staging at specific habitats would contribute to our understanding for this important time period. However, during the summer months, the salt wedge extends much further upstream to the base of the Bailey Riffle (Figure 10)(Parish and Garwood 2015). This contrast in salinity concentrations is likely why the lower estuary lacks significant live woody vegetation along the riparian zone.

Course woody debris are an important habitat forming feature throughout the stream continuum, especially exceptionally large dead rot-resistant trees that can help shape ecological processes and persist for decades (Maser et al. 1988). Studies have shown woody debris (i.e. tree trunks and stumps) provide essential rearing habitat and cover in estuaries for Chinook salmon (Miller and Simenstad 1997), coho salmon (McMahon and Holtby 1992, Koski 2009), Steelhead (Wallace and Allen 2009), Pacific herring (Emmett et al. 1991), and Dungeness crab (Armstrong et al. 2003). Numerous whole sitka spruce trees have fallen into the Smith River along the western bank below the mouth of Yontocket Slough through sand dune erosion. These trees provide complex underwater cover and the potential to create and scour off-channel habitats in an area otherwise lacking riparian or aquatic vegetation (*see* photograph on page 49). Based on our surveys, the majority of the estuary is lacking course woody debris recruitment despite forests in the watershed containing some of the largest trees in the world. During the large flood on December 14, 2015 several port orford cedar logs and a ~9 ft diameter old growth coast redwood log washed up at several locations along the north bank of the main Smith River channel below Highway 101. These logs were cut and yarded away with heavy equipment from multiple locations in the active river channel by early January (J. Garwood, personal observation). Continuous removal of wood has resulted in this habitat forming feature being exceptionally rare in the lower Smith River and estuary. Retention of these logs, especially whole trees with attached root wads, should be a management priority given the limited vehicle access to the Smith River channel relative to that of other rivers suffering from chronic wood removal (e.g. Redwood Creek, Orick, CA).

The majority of the mainstem Smith River above the cattle crossing riffle is lined with a mosaic of riparian vegetation. However, cattle have direct access to the mainstem river where the bank has a lower slope and use the river as a water source through the opening of a fence. This was previously the site of a restoration project which offset the cattle fence away from the Smith River and planted native vegetation in an attempt to establish riparian vegetation to stabilize the river banks. Due to continuous cattle encroachment, there is a lack of riparian vegetation along this section and the banks are eroding into the river. Fence repair and the development of a nearby off-channel cattle watering location would allow for bank stabilization and riparian vegetation to re-establish along this section.

Last, two Red-eared sliders (*Trachemys scripta elegans*) were observed in reach 7, ~700 meters downstream from the Highway 101 bridge. To our knowledge, this is the first description of this invasive turtle species in the Smith River basin. Both individuals were in close proximity to one another (~130 meters) and utilizing a backwater and alcove where 70+ coho salmon were detected during the winter of 2015. The Smith River currently has a small population of native Western pond turtles (*Actinemys marmorata*) (J. Garwood, unpublished data), a California Species of Special Concern. Nonnative turtles can potentially introduce parasites or pathogens and compete for resources. To prevent the future introduction and spread of pet turtles, information should be distributed to local schools and pet stores helping to inform the public of alternatives to releasing non-native aquatic species in local waters.

Unnamed Tributary Below Tillas Slough (Reach 40)

A functional tidegate located ~45 meters above the stream mouth likely limits salmonid access to this stream. Above the tidegate, the channel generally splits into two tributaries within a forested block of land. Based on the NOAA coastal LiDAR dataset, one tributary flows south from the “ship” near the corner of Highway 101 and Chinook Street. The other tributary flows west from the forest with the channel configuration obscured by the forest. The land use near this tributary is mixed agriculture, residential and commercial. Coho salmon were detected during each primary sampling occasion at the mouth of reach 40, a small unnamed tributary (Table 7). In addition, past incidental winter surveys have consistently documented coho salmon utilizing the tidal portion of this stream (Parish and Garwood 2015) along with juvenile Chinook salmon, juvenile steelhead, and two adult steelhead in 2013 (J. Garwood, unpublished data). Given the consistent winter use of this stream by salmonids, it could provide substantial high-quality winter habitat. A fish passage assessment of the tidegate and an inventory of fish distribution and available habitat above the tidegate would benefit planning and restoration efforts.

Tillas Slough and Islas Slough

Tillas and Islas Sloughs drain the majority of the northwest estuary lowlands. The primary land use includes cattle grazing and lily bulb farming. The upper portion of Islas Slough historically connected to the Smith River and later closed off by the construction of earthen dikes resulting in reduced area of the slough. Currently the lower channel is connected to the Smith River mainstem and responds to varying river flows and tidal cycles. Tillas Slough includes at least four tributaries including Ritmer Creek and Delilah Creek. The lower portion of Tillas Slough is spanned by a levee containing two large culverts with tidegates installed in the 1970’s (Smith River Historic Atlas). The function of both tidegates has been compromised for many years, with one culvert missing a tidegate door and the other culvert sidewall completely rusted away. Given the condition of the tidegates, uninhibited fish passage is likely occurring and the structure only partially mutes floodwaters and tidal/ saltwater inundation. Another flow control structure occurs approximately 400 meters upstream in the main channel with unknown fish passage status, however, we captured a steelhead smolt occurring above this tidegate in upper Ritmer Creek at Highway 101 (*see* Figure 4 and details below).

While we did not sample the majority of these sloughs, we did regularly detect juvenile Chinook salmon rearing in navigable waters near their mouths as early as mid-February. A study by Parthree (2004) defined the fish community of Tillas Slough and Islas Slough monthly from the March-November for years 2000-2001. Chinook salmon used the sloughs extensively from March to August. However, the study did not conduct sampling from December through February when coho salmon are expected to be the most widely distributed throughout the estuary. While we did not survey the majority of Ritmer Creek, the largest tributary of Tillas Slough, we did detect a juvenile steelhead in advanced smolting condition at highway 101 and an adult coastal cutthroat trout further upstream at Ocean View Drive (Figure 4). We observed spawning gravels and riparian vegetation in Ritmer Creek at both of these locations indicating the stream likely supports all lifestages of salmonids. However, water diversions have been noted in Ritmer Creek during past stream assessments (McCloud and Preston 2000). Previous work conducted in these watersheds during the summer indicated some locations had dissolved oxygen and water temperature readings outside tolerance range for coho salmon and were likely caused by a lack of water flow, dense patches of reed canary grass, and eutrophication (Parthree 2004, Parish and Garwood 2015). However, during the winter months, water quality conditions of these streams is expected to be more hospitable to rearing salmonids due to lower water temperatures and increased stream discharge. This is evident in the Morrison Creek and Tryon Creek drainages. Salmonids use these streams extensively during the winter despite their lack of riparian vegetation and extensive dry channels during the summer months. Since these sloughs represent a significant portion of the estuary, future efforts defining winter fish distributions and winter water quality conditions are essential to fully understand how the greater Smith River estuary functions related to salmonid populations.

Yontocket Slough/Tryon Creek

Tryon Creek drains the majority of the southwest estuary lowlands and Smith River floodplain. The primary land use includes cattle grazing, pastured chickens, wildlife grazing (geese and elk) and residential. The stream above highway 101 is forested, perennial, and has gravel substrate. The east side is managed for timber and the west side is primarily bordered by dozens of residential properties. Below Highway 101, the stream flows through pasture fields where the channel is semi trapezoidal in shape with fine sediment as the primary substrate. Tryon Creek then drains into Yontocket Slough which remains ponded year-round above the Pala Road prism. Below Pala Road, the channel is temporary in a lowland swale adjacent to a hind dune and then becomes perennial in a deeply incised channel for the final 200 meters to the Smith River with tidal influence occurring during low flow summer months (Parish and Garwood 2015). Reed canary grass (RCG) (*Phalaris arundinacea*) is prevalent in the Yontocket Slough/Tryon Creek basin (Love 2006, Parish and Garwood 2015), a species shown to exclude beneficial riparian plants (Tu et al. 2004) and reduce levels of dissolved oxygen (RNP 2014). The growth and prevalence of RCG results in large quantities of decomposing plant material (Love 2006) and may cause a reduction in available winter rearing habitat for juvenile salmonids in the Yontocket Slough/Tryon Creek basin.

The consistent high flows experienced during the winter resulted in elevated inundation of decomposing RCG resulting in low levels of dissolved oxygen along the margins of the slough. Furthermore, even with regularly elevated winter flows, by April continuous dissolved oxygen readings found dissolved oxygen levels below lethal levels for coho salmon on a daily bases (Figure 12). While this does indicate extremely poor water quality and reduced available rearing habitat for juvenile salmonids, it is possible there are areas that remain tolerable while passage to the mainstem Smith River persists. The Tryon Creek antenna is located 2640 meters upstream from the confluence with the Smith River and ~ 250 meters upstream from the confluence with Yontocket Slough. Our counts of Mill Creek tagged coho salmon is likely an underestimate as others likely reared downstream of the antenna. Coho salmon were detected upstream of Pala Rd at the PIT tag antenna after water had stopped flowing at Pala Rd, thereby preventing out migration of these individuals. Dissolved oxygen has been shown to remain quite low throughout the summer months (Love 2006). If no areas with suitable water quality conditions remain within the tolerance levels for juvenile salmonids these individuals are likely unable to survive the summer in Yontocket Slough. Focused research is needed to identify ways to improve water quality, fish passage, and rearing conditions for juvenile salmonids.

Rowdy Creek

Second to Mill Creek, Rowdy Creek is the largest coastal tributary that provides both spawning and rearing habitat for coho salmon, Chinook salmon, steelhead and coastal cutthroat trout. Primary land use includes timber production, cattle grazing, and lily bulb farming. The upper watershed, upstream of Hwy 101, is heavily forested and managed for timber production. Directly above Highway 101 a historic mill site that has remained vacant for decades contains rip-rap in multiple locations that was used to protect infrastructure and buildings that no longer exist. Rowdy Creek Fish Hatchery (RCFH) is located directly downstream of Hwy 101 which contains a channel spanning weir with a concrete apron and hardened banks that protect hatchery infrastructure. Further bank stabilization is present downstream from the hatchery to the mouth protecting housing and pastures from flooding and channel migration.

The multiple channel alterations that have occurred over the years have resulted in reduced channel area, less off-channel low velocity rearing habitat, and less access to rearing habitats. Prior to channel modifications for mill infrastructure, this portion of Rowdy Creek had a wide valley and a dynamic meandering channel (GHD 2016) that likely provided multiple off-channel and slow water habitats during high winter flows. Levees and riprap along the lower four kilometers, which contain a number of dumped vehicles on the west bank of Rowdy Creek at its mouth, result in high velocity flows and a lack of off-channel habitat. Furthermore, the status of the submerged cars as a pollution problem has not been assessed. Lastly, complete barriers to juvenile upstream fish passage into Rowdy Creek and Dominie Creek during low flow years are present three kilometers upstream from the mouth at the RCFH (GHD 2016) further limiting available habitat to individuals exhibiting non-natal life history strategies in this basin.

Combined these alterations have resulted in reduced overall channel area, increased sediment transport capacity, and increased stream velocity (GHD 2016). These conditions are highlighted by the fact that fewer sampling units were available due to the high flows experienced during the winter of 2016 when compared to survey efforts conducted in 2015 (Parish and Garwood 2015). Restoration is needed to increase the quantity and quality to rearing habitat for juvenile salmonids throughout the Rowdy Creek basin. The RCFH weir is the largest remaining fish barrier in the Smith River and is among the largest in northern California. A total of 18.4 km of anadromous fish habitat occurs above the weir making this barrier one of the most substantial salmonid passage issues in California. Additionally, a series of barriers exist on Dominie Creek at the fish hatchery further complicating and limiting fish passage in the basin. Lastly, future research is needed to evaluate potential restoration opportunities where vacant mill lots have armored banks constricting the active channel of Rowdy Creek.

Morrison Creek

Morrison Creek has a dendritic drainage pattern with contributions from many small (previously unmapped) tributaries despite its small drainage area (Figure 14) and contains ~9 km of accessible anadromous fish habitat. Coho salmon were found to be widely distributed throughout Morrison Creek, including in tributaries up to Highway 101 (Figure 14). We documented coho salmon rearing in Morrison Creek from December 4, 2015 – May 16, 2016 with an average minimum residence time of 58 days (Table 14). Juvenile coho salmon and juvenile trout that originated in Mill Creek were detected utilizing Morrison Creek during our winter surveys highlighting the ecological connectivity this stream has with upper Smith River tributaries. Morrison Creek is also an important spawning tributary for Chinook salmon, with one report counting 84 spawning adults in a single survey above Highway 101 (Larson 2004).

Much of the surrounding parcels in the coastal plain are used for agriculture including cow pasture and lily bulb production. The primary land use within the watershed above Hwy 101 is commercial timber harvest. Historic land conversion in Morrison Creek has resulted in a loss of channel complexity, floodplain connectivity, and the amount of fish rearing habitat. For example, a large pond was constructed adjacent to Morrison Creek during the mid-20th century that likely alters the current stream flow patterns. Reed canary grass, Himalayan blackberry (*Rubus armeniacus*), and yellow flag iris (*Iris pseudacorus*), all nuisance riparian species, are present throughout the riparian zone, resulting in channel narrowing and bank stabilization. Yellow flag iris appears to be spreading, with small patches more numerous than reported by Parish and Garwood (2015).

The Morrison Creek drainage experiences annual flooding and excessive sediment deposition, especially in reaches occurring below Hwy 101. Causes of sediment deposition have been suggested including an increase in sediment supply from upstream and historical alterations to the channel course (Smelser 2013, Love 2014). The most severe flooding occurs at the Fred Haight Drive county road crossing. Here the Morrison Creek channel turns an abrupt ~60 degrees causing sediments to build up and plug three undersized culverts (Figure 15) on an annual basis (Smelser 2013). Prior to the 1970s the crossing was a bridge. An analysis by Smelser (2013) indicates the capacity of the three culverts at Fred Haight Drive only represent 17% of the cross-sectional area needed to pass a 100-year flood. The removal of a historic dam in upper Morrison Creek by CDFW between 2005 and 2006 has been debated as a cause to excessive flooding and sediment deposition near Fred Haight Drive. However, an analysis by Smelser (2013) indicates very little sediment was retained by the dam structure because it was severely broken apart prior to the removal. The analysis indicated that less than two-feet of accumulated sediment remained exposed to potential fluvial erosion following dam removal (*see* Smelser [2013] for detailed results and photographs). Some drainage ditches used by salmonids for winter rearing habitat also appear to be impacted from excessive sediment supplies. Much of the landscape surrounding these drainage ditches contains bare tilled topsoil (depending on crop rotation) on moderate slopes. These areas are exposed to erosion and runoff during the winter months. *See* the *Temporary Channels and Drainage Ditch* section below for more specifics associated with drainage ditches in the Morrison creek watershed.

The constructed pond is a unique feature in the watershed, and while it is currently not accessible to fish, it potentially has salmonid conservation value. For example, the pond is maintained by multiple springs. These springs originally fed into Morrison Creek prior to land conversion and possibly kept the channel perennial and cool throughout the summer months. Currently the pond is not accessible to salmonids. However, the pond outlet is routed through a drainage ditch (Reach 80, Figure 14) and we have captured juvenile coho salmon below the spillway regularly since 2014 (Parish and Garwood 2015, Figure 14). Given the consistent and widespread use by salmonids, Morrison Creek is an important watershed for various salmonids where they have a large overlap among various land uses and separate management regimes. The complexity of issues associated with land use, hydrology, and flooding highlight the necessity for a watershed-scale planning effort in this subbasin.

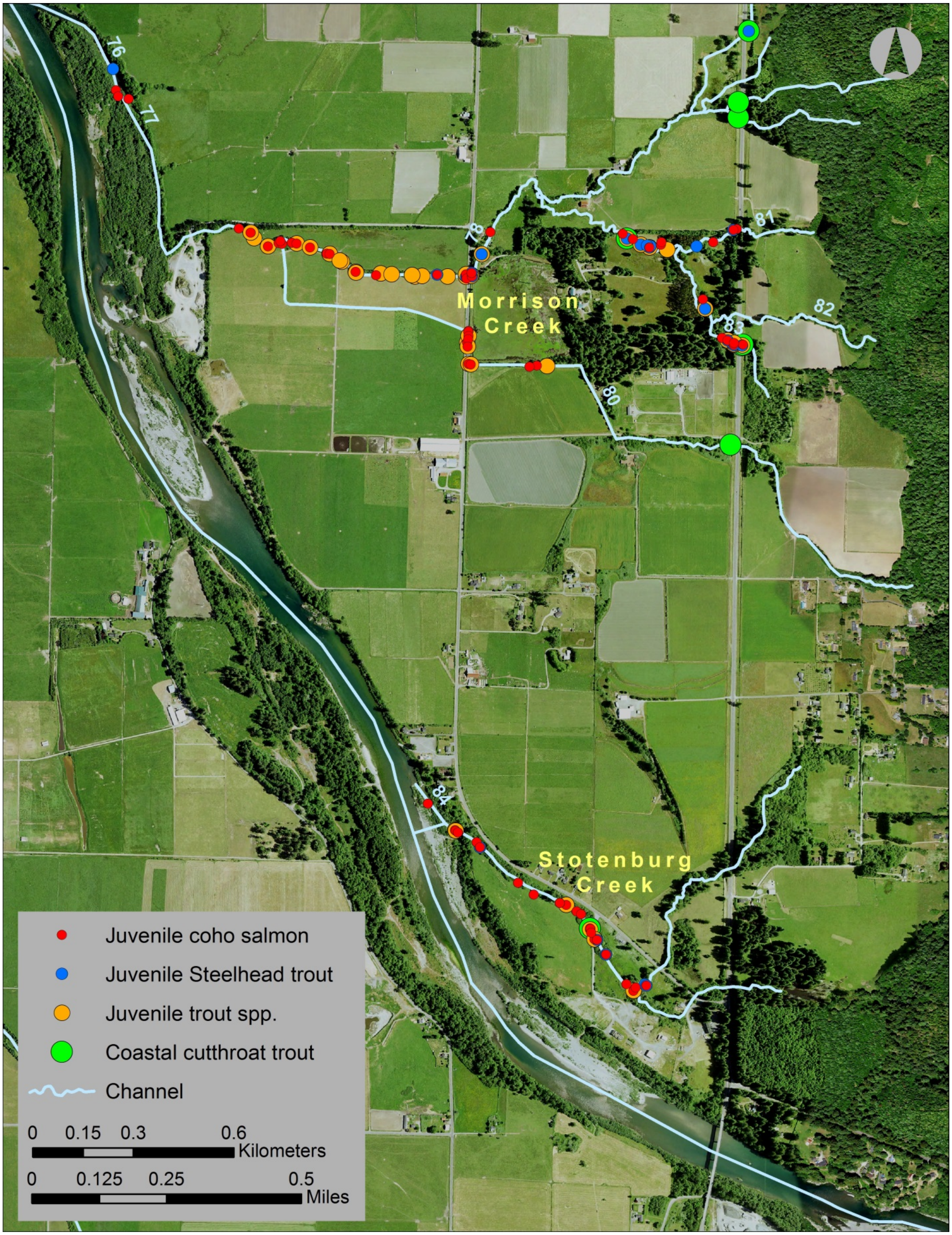


Figure 14. Distribution of winter salmonid observations in Morrison Creek and Stotenburg Creek from 2012 to 2016, Smith River, Del Norte County, CA. Streams continue beyond the extent of the blue line into forested areas and out of the coastal plain.

Figure 15. Fred Haight Drive crossing on Morrison Creek. Photo taken on July 17th, 2012. Note the three 48-inch diameter culverts are almost entirely filled with stream sediments. Flow separations associated with an abrupt bend in the channel upstream of the road, coupled with three separate water paths in the culverts, cause excessive sediment to collect at the crossing increasing localized flooding. *Photo: M. Larson*

Stotenburg Creek (Reach 84)

Stotenburg Creek is a small intermittent stream that originates from two streams surrounded by forest upstream of Hwy 101, one of which begins at a pond (Figure 14). These streams flow through used and unused pasture lands. The main channel is inundated and backwater by the mainstem Smith River during elevated flow events. Throughout the 2016 winter sampling season we detected 15 juvenile trout and 137 coho salmon, two of which were Mill Creek tagged individuals (Figure 8) rearing in Stotenburg Creek (Figure 14). These observations represent the third winter we have documented salmonids rearing utilizing Stotenburg Creek since 2012 (Garwood and Bauer 2013, Parish and Garwood 2015, *this study*) including juvenile steelhead, juvenile coho salmon, and coastal cutthroat trout. Spawning gravels are rare in the upper channel near Highway 101 and no adult spawning has been documented in the channel. Cattle grazing occurs throughout the lower section of the channel. While no cattle exclusion fencing is present, dense riparian vegetation is prevalent and prevents cattle from accessing the majority of the stream. Five culvert crossings are present throughout the channel (Garwood and Bauer 2013), some of which are undersized and limit fish passage to available rearing habitat. Additionally, multiple locations lack habitat complexity and remain shallow throughout the channel, even during elevated winter flows. Wood loading in key locations may benefit channel complexity. Beavers seasonally utilize this channel and have created various small channel-spanning dams (<0.25m) (Parish 2016). These features are rare across the

Smith River but increase water depth and rearing area, especially in intermittent streams. Lastly, little is known about the longitudinal profile of Stotenburg Creek and whether or not fish become stranded in the channel as the stream dries in the spring. Given the mouth of this stream becomes disconnected from the Smith River in the spring, potential modification of the channel at the confluence my increase connectivity during critical salmonid outmigration. Further research is needed to define salmonid exit timing to determine if the stream is serving as a population sink due to fish stranding.

Temporary Channels and Drainage Ditches

Some winter salmonid habitats included intermittent channels in agricultural and pasture lands that serve as seasonal drainage ditches. Based on our winter fish sampling throughout the Smith River coastal plain, we have captured hundreds of juvenile salmon using these drainage ditch channels, especially juvenile coho salmon. This pattern has similarly been documented in temporary drainages occurring in Humboldt Bay (Wallace et al. 2015) and Elk Creek in Crescent City (J. Garwood, unpublished data). Furthermore, other altered aquatic ecosystems, including rice fields in California's Central Valley floodplains, have shown to be beneficial to Chinook salmon growth and survival in the winter and spring relative to main river channels (Katz et al. 2013). Many of the coastal plain channels in the Smith River were historically straightened and in some cases moved to property boundaries or adjacent to roads to maximize land use and to advance runoff timing for the purpose of reducing localized flooding. The headwater portions of many of these water conveyance channels occur near the transition of coastal plain and forested lands. These channels in the upper watersheds are perennial, contain intact spawning gravels, and currently support salmonids; especially coastal cutthroat trout. Barriers in some of these channels currently block anadromous forms from accessing headwater spawning and rearing habitats, especially along Highway 101 and Fred Haight Drive.

Currently, a variety of management strategies are employed for maintaining the drainage function of these channels in working lands including mechanical and hand brush removal, livestock grazing, and periodic channel excavation. The need for channel excavation, especially in the lower gradient portions of these drainages is partially a result from excessive fine sediment transport from the surrounding landscape. Much of the landscape surrounding these drainage ditches contains bare tilled topsoil (depending on crop rotation) on moderate slopes that is exposed to erosion and runoff during the winter months. During our study in 2016 we observed one ditch completely fill in with sediment (Reach 80, Figure 14) resulting in the channel migrating into an adjacent lily bulb field. During the previous winter, the same section of ditch was sediment impaired, but was deep enough (~15 cm) to contain numerous juvenile coho salmon during the winter (Parish and Garwood 2015). Without maintenance of this channel, sediment delivered from upstream will continue to reduce fish passage and winter rearing habitat.

Because these channels are dry during the summer months, conventional strategies for stream management and regulation may not be the best approach for maintaining and enhancing functional winter fish habitats. For example, fish are likely foraging more on terrestrial food sources in these ditches due to their intermittent status and general lack of riparian vegetation. In addition, riparian shading in these channels, for the purpose of reducing stream temperatures, is likely not a significant factor for fishes during the winter months. Future physical, chemical, and biological monitoring of these channels will help managers understand the most beneficial strategy for maintaining their form and function while promoting high-quality overwintering habitats for fishes. Reducing sediment delivery into these channels through water runoff management practices would likely reduce the maintenance cost and frequency while increasing the availability of fish habitat.

Water Quality

Very little water quality monitoring has occurred throughout the Smith River watershed making it difficult to quantify potential water quality issues. The North Coast Regional Water Quality Control Board (Regional Water Board) established a water quality monitoring program with the Del Norte United Dairy Association in 2012 as part of the monitoring requirements for all dischargers enrolled under Conditional Waiver of Waste Discharge Requirements and General Waste Discharge Requirements for existing cow dairies. This program established a water quality sampling protocol for streams occurring on participating dairies and requires annual water quality reporting by the group to the Regional Water Board. Results from annual sampling are used to identify if stream temperatures, nitrates, or fecal coliforms are above established thresholds. The program works with the Regional Water Board and uses dairy best management practices (BMPs) to address potential nutrient problems in streams and groundwater to ensure water quality standards are meeting state regulatory standards.

The Regional Water Board has also been developing a permit with stakeholders for waste discharges from the cultivation of lily bulbs in the Smith River plain to meet the requirements of the California Water Code and the Nonpoint Source Policy (CWB 2015a). The regional Board has collected surface water, streambed sediment, and groundwater samples near lily bulb operations during 2013 and 2015 to better understand current water quality conditions and to inform the permit development process (CWB 2015b). Based on the two studies, some groundwater wells and surface waters had nitrates above USEPA thresholds for both 2013 and 2015 (CWB 2015a, CWB 2015c). Aquatic life toxicity in zooplankton was found in 3 of 12 surface water samples collected in 2013 (CWB 2015a) and toxicity results are still pending for the 2015 samples (CWB 2015b). Dissolved copper was found to be above USEPA standards in 3 of 12 surface water samples for the 2013 sampling effort (CWB 2015a). Last, ten out of 183 potential pesticides were detected in surface waters in 2013 but were at concentrations below USEPA standards (CWP 2015a). Future studies measuring potential bioaccumulation of metals and or pesticides in aquatic vertebrate tissues are necessary given fish taxa are expected to respond differently to potential pollutants.

In addition to the Regional Water Board water quality monitoring programs, local stakeholders are working on various natural resources issues related to surface waters occurring adjacent to working lands. The Del Norte Resource Conservation District (RCD) was formed in 2005 to provide local leadership for improving, conserving, and sustaining the natural resources and environment while maintaining the region's economic viability (RCD 2015). The jurisdictional boundary includes the majority of the Smith River plain and estuary and the lands surrounding Lake Earl. Of the five most recent identified priority natural resource issues, two are related to increasing water quality in streams within the region (RCD 2015). First, the district aims at reducing erosion and runoff on 50% of lily bulb fields and proposes the development of nutrient management plans for dairies as part of a non-point source pollution prevention program. Second, the district plans to complete 20 miles of stream bank and riparian enhancements. Prioritizing these efforts, as they relate to existing habitats, would provide the greatest benefit to salmonids. For example, sediment impaired channels in Morrison Creek (*see* Morrison Creek and Temporary Channels and Drainage Ditches sections) should be a high priority given their extensive use by salmonids.

Based on our study, most water quality readings were within the salmonid tolerance thresholds throughout our sampling sites. All water temperature readings were well below lethal limits of juvenile salmonids (<17°C) as expected during the winter months. However, we did document low levels of dissolved oxygen (<2mg/l) in Yontocket Slough. A study by Love (2006) also found dissolved oxygen levels below lethal limits in Yontocket Slough during the fall and winter of 2005 and 2006. Low dissolved oxygen levels have also been previously observed in Tillas Slough (CWB 2015a). Reed canary grass (RCG) has been documented in Tillas Slough, Morrison Creek, and Yontocket Slough/Tryon Creek basins (Love 2006, Parish and Garwood 2015). The growth and prevalence of RCG results in large quantities of decomposing plant material (Love 2006) and is likely a main contributor to low dissolved oxygen. Additionally, potential nutrients delivered from agricultural operations, particularly nitrogen and phosphorus, have been shown to contribute to eutrophication of surface waters (Schaafsma et al. 2000, Gottschall et al. 2006). Nitrate concentrations above USEPA thresholds have been identified in Tillas Slough, Delilah Creek, and Morrison Creek from sampling conducted in by the Regional Water Board in 2013 (CWB 2015a). RCG and other plant species used in constructed and natural wetlands have been shown to successfully reduce nutrients delivered from surrounding agricultural lands (Comin et al. 1997, Schaafsma et al. 2000, Edwards et al. 2006, Gottschall et al. 2007), though benefits of nutrient removal are typically highest during the early stages of plant growth and wetland construction (Gottschall et al. 2006). Efforts are needed to determine effective removal, control, and management of reed canary grass in order to reduce its negative impacts on fish passage, available habitat, and dissolved oxygen levels with particular focus on the lower Tryon Creek/Yontocket Slough basin. Recommended techniques include native planting, excavation, mowing, grazing, prescribed burning, shading, and tilling (Tu et al. 2004, Love 2006). Finally, focused research on the complex relationship between RCG, surrounding land practices, and water quality is needed to identify ways to improve water quality and rearing conditions for juvenile salmonids. Management decisions should also consider efforts to reduce seed dispersal as RCG has also been documented in the Mill Creek basin (Parish and Garwood 2015) which may have been introduced from park visitors.

North American Beaver

A population of North American beaver (*Castor canadensis*) is widely distributed throughout the Smith River mainstem and coastal tributaries (Parish 2016) with their distribution largely overlapping with coho salmon (Parish and Garwood 2015). While coho salmon occupancy appears to be influenced more by summer habitats maintained by beavers in mainstem river channels (Parish and Garwood 2015, Parish 2016), both species migrate into the intermittent tributaries during the winter months (Parish and Garwood 2015, Parish 2016, *this study*). Based on our observations, beavers typically build small (<0.5m tall) channel-spanning dams in these small streams that increase slow water rearing habitat for juvenile salmonids (Parish and Garwood 2015, Parish 2016). Furthermore, these water impoundments likely increase the stream hydroperiod into spring when smolt outmigration is most common. 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). Increasing beaver abundance is listed as a recovery strategy for coho salmon in the Smith River Basin (2014 NOAA Coho Salmon Recovery Plan). While beavers can create conflict with landowners, recent work has highlighted ways to maintain beavers on the landscape while minimizing the possible negative impacts of beaver's land alteration activities (Lundquist and Dolman 2016). Beaver habitat needs and possible benefits should be considered when making restoration and management decisions related to salmonid habitat enhancement.

Future Biological Monitoring and Habitat Assessment

A Smith River estuary salmonid habitat restoration planning effort in collaboration with stakeholders is forthcoming. Here are some future considerations for research and restoration assessments, some of which apply to planning.

- Collect continuous dissolved oxygen data on a transect in the Yontocket Slough/Tryon Creek drainage to identify sources and locations limiting fish passage and available rearing habitat.
- Identify successful techniques for managing reed canary grass to improve water quality in the Yontocket Slough/Tryon Creek basin. For example, identify if flash cattle grazing on reed canary grass benefits winter stream dissolved oxygen levels.
- Directed study on diet, growth, and survival of fishes rearing in the estuary with additional assessment of potential migration bottlenecks as channels dry in the spring.
- Obtain more refined fish distribution data in Tillas Slough and Islas Slough (reaches 38-46) and in sections of Morrison Creek (reaches 78 & 80) during the winter months.
- Assess salmonid habitat availability and use in the estuary, sloughs, and mainstem from April - July, with a focus on Chinook salmon and coho salmon.
- Assessment of year-round water quality and fish health in the mainstem Smith River.
- Evaluation of habitat creation and retention in the mainstem and estuary.
- Census and map woody debris in the river below HWY 101 and estuary. Provide recommendations for potential wood loading projects in key locations.
- Hydrologic and geologic assessment of Morrison Creek sub-basin to identify restoration and management opportunities.
- Conduct inundation mapping using LiDAR digital elevation models for various sea-level rise projections and map freshwater habitat loss.

Looking east from Tolowa Dunes State Park with the Yontocket Slough channel in the foreground and the Smith River channel in the upper left. *Photo: M. Parish*

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A Sitka Spruce (*Picea sitchensis*) with attached root wad in the Smith River estuary during the winter of 2015. One of a few wood debris structures scoring sediment and creating cover where habitat complexity is minimal. *Photo: J.Garwood*