2011-2016 Salmonid Redd Abundance and Juvenile Salmonid Spatial Structure in the Smith River Basin, California and Oregon

FEBRUARY 2017

FINAL PROGRESS REPORT TO THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
FISHERIES RESTORATION GRANTS PROGRAM
GRANTEE AGREEMENT: P1210524

ON BEHALF OF

THE SMITH RIVER ALLIANCE

AND

THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
ANADROMOUS FISHERIES RESOURCE AND MONITORING PROGRAM

2011-2016 Salmonid Redd Abundance and Juvenile Salmonid Spatial Structure in the Smith River Basin, California and Oregon

Final Report to the California Department of Fish and Wildlife
Fisheries Restoration Grants Program
Grantee agreement: P1210524

Prepared by: Jolyon Walkley[1] and Justin M. Garwood[2]
[1]Smith River Alliance, PO Box 2129 Crescent City, CA 95531, Jolyon.Walkley@gmail.com
[2]California Department of Fish and Wildlife, 5341 Ericson Way, Arcata, CA 95521, Justin.Garwood@wildlife.ca.gov

Abstract

We investigated two essential population viability metrics of salmonids over five consecutive years in the Smith River basin (Oregon and California), with ESA listed coho salmon as the focal species. First, we monitored adult salmonid escapement and distribution from 2011 to 2016 using live fish, carcass, and redd counts as defined in California's Coastal Salmonid Monitoring Plan. Second, we estimated the summer spatial structure of juvenile salmonids and adult coastal cutthroat trout annually from 2012-2016 using multiple-pass snorkel surveys in an occupancy modeling framework. We constructed separate sample frames for each monitoring component using a reproducible approach that relied on empirical and modeled stream habitat information. Each sample frame was divided into survey reaches resulting in 161.8 kilometers of stream habitat (68 reaches, 30 sub-reaches) for the adult sample frame and 298.1 kilometers (126 reaches, 40 sub-reaches) for the juvenile spatial structure sample frame. We estimate the adult sampling frame covered 78% of potential coho salmon spawning habitat and the juvenile sampling frame covered essentially all likely juvenile coho salmon juvenile rearing habitats. This report provides detailed results from the 2015-2016 survey effort not reported previously as well as five-year summaries spanning the length of this monitoring effort. This document is also supported by previously published reports offering greater detail on annual results (i.e. Garwood and Larson [2014], Garwood et al. [2014] and Walkley and Garwood [2015]).

We completed 1896 spawning ground surveys across 87 survey reaches over the five years representing a sum total of 3346 kilometers surveyed. We made 1380 live adult coho salmon observations over the five years with annual observations ranging from 125 in 2015-2016 to 494 in 2013-2014. All but nine live coho salmon observations occurred in Mill Creek; eight observations were recorded in Rowdy Creek over three winters and one observation occurred in Hurdygurdy Creek during the 2013-2014 season. We recovered 196 coho salmon carcasses over the five years ranging from 15 in 2011-2012 to 82 in 2014-2015. All but five coho salmon carcasses were observed in Mill Creek; one carcass was found in Morrison Creek during the 2012-2013 season and four were found in Rowdy Creek during the 2013-2014 season. We were able to verify 293 individual coho salmon redds over the five seasons. All verified redds were found in the upper Mill Creek subbasin. Since our coho salmon observations were almost exclusively clustered in the Mill Creek, we determined that our redd population estimates for the whole sample frame were biased high and unreliable based largely on large between-reach error estimates. However, Chinook salmon and steelhead estimates were determined for the sample frame since these species were more evenly distributed throughout the basin. We estimated total coho salmon redd abundance annually in the Mill Creek subbasin which ranged from 149 (95% CI: 139 - 159) redds in 2014-2015 to 482 (95% CI: 464 - 501) redds in 2011-2012. Chinook salmon were far more abundant, with estimated redd abundances ranging from 516 in 2013-2014 to 3819 in 2011-2012. Our sampling did not cover the entire steelhead spawning season. However, we estimated steelhead redd abundance during our sampling period to range from 356 in 2013-2014 to 1120 in 2015-2016. Last, hatchery origin Chinook salmon and steelhead were observed spawning throughout much of the sampling frame over the five years, especially in Rowdy Creek and Mill Creek. The mean hatchery proportion of Chinook salmon carcasses ranged from 8.8% in tributaries below the Smith River forks to 32.9% in Rowdy Creek. No carcasses were observed above the forks. The mean hatchery proportion of live steelhead ranged from 5.3% below the forks to 28.6% in Rowdy Creek. No live hatchery steelhead were observed above the Smith River forks.

We used multi-scaled occupancy models to estimate the probability of salmonid occupancy at the sample reach and at the sample unit (within reach) simultaneously while accounting for species detection probabilities. From 2012 to 2016 we completed a 323 reach surveys totaling 608 cumulative stream kilometers within the Smith River. We sampled 7254 pools over the five years with annual totals ranging from 1115 pools to 1837 pools. Only ten of the 167 reaches (6%) did not get surveyed at least once over the five-year period due a lack of access to a few private lands. We documented juvenile coho salmon occurring in 64 of the 157 (41%) individual reaches surveyed at least once over the five years. Annual reach-level occupancy estimates were numerically similar between years but declined annually from 0.42 in 2012 to 0.30 in 2016. Annual pool-level occupancy estimates ranged from 0.47 to 0.68. The annual estimated proportion of area occupied declined each year of the study from 0.29 in 2012 to 0.14 in 2016. The difference in PAO was most apparent between 2012 and 2016 with 2016 representing less than half of the estimated PAO in 2012. Coho salmon maintained patchy distributions relative to the sampling frame over the five years. Based on the summer distribution data collected throughout the basin, we describe five extant juvenile coho salmon patches. Four of the five patches are maintained by independent spawning sub-populations and we consider the lower mainstem Smith River and tributaries to be the only significant non-natal coho salmon rearing patch. Coho salmon juveniles used a variety of non-natal rearing habitats highlighting diversity in life-history and complementary resource needs. Last, in addition to coho salmon, we describe spatial structure estimates and detailed distributions of stream-type juvenile Chinook salmon, age zero and 1+ are trout, and adult coastal cutthroat trout.

Table of Contents

Table of Contents continued

List of Tables

List of Tables continued

List of Tables continued

List of Figures

List of Figures continued

List of Figures continued

List of Figures continued

Acknowledgements

This is the largest stream biological inventory ever conducted throughout the Smith River. This inventory could not have been possible without the long-term dedication of dozens of passionate biologists, multiple agencies, and several funding sources. We would like to thank Patty McCleary and Grant Werschkull of the Smith River Alliance for taking on this project with enthusiasm and attention to ensure the project was a success. The vision and collaboration of the Smith River Alliance provided a lasting motivation for all involved resulting in a highly organized effort. The California Department of Fish and Wildlife (CDFW) provided the initial project scope and monitoring design. The CDFW was also an essential resource and partner throughout the five-year study. Beatrijs deWaard of CDFW provided excellent and pragmatic grant support throughout the study. We thank Monty Larson for his dedication as the first crew leader of this project and setting the initial rigor of our sampling regime. Monty's dedication has had a lasting effect on the project's rigor. We thank Marisa Parish for providing logistical support and organization throughout the study. We also thank Marisa for assisting with the species distribution maps in this report. We thank all of the 22 highly skilled field biologists who collected data to the highest standards and consistency: Jeff Abrams, Gaytha Babcock, Diana Baetscher, Alessandro Broido, Sunny Bourdon, Stewart Capper, Tara Dettmar, Vimal Golding, Molly Gorman, John-Deibner-Hanson, John Hagan, Iris Koski, Monty Larson, Ken Lindke, Rachael McCain, Jesse Nolan, Matt Olson, Marisa Parish, Jonathan Pini, Melissa Reneski, Mieling Roddam, Zack Wenderott. We also thank AmeriCorps Watershed Stewards Project (WSP) volunteers: Diana Baetscher, Adam Cockrill, Sylvia Gwozdz, David Lam, Jen Olson, and Tim Sandborn who assisted us with great enthusiasm. We also thank Michael van Hattem, Scott Bauer, and Allan Renger of CDFW for allowing their WSP members to join our team during critical survey periods. The former Mill Creek Salmonid Monitoring Program assisted greatly with the spawning ground surveys in 2011-2012 so we could census the upper Mill Creek watershed. Field staff included Paul Albro, Thomas Dunklin, Zack Larson, Rod McLeod, and Bradford Norman. Many thanks to Jeff Bomke of State Parks for the opportunity of leasing park office and housing space. The 'river house' proved to be a vital element to our program and we hope it can be maintained into the future as a vital research facility. We thank Marisa Parish, Tony LaBanca, Philip Bairrington, Mary Kuehner, and Brenda Tuel for administrative assistance throughout the study. Seth Ricker and Ken Lindke provided early statistical assistance in estimating adult salmonid redd abundance. We thank Seth Ricker and Doug Burch for providing continuous database development and support throughout the study. We are in debt to Wade Sinnen, Michael Wallace, Sarah Borok, Frank Kemp, Charles Bartolotta, Mary Claire Kier, and Scott Bauer of CDFW for loaning vehicles during times of need. This work would not have progressed as quickly or smoothly without the early planning insight provided by Mike McCain, Jim Waldvogal, Zack Larson, Scott Bowman, Tom Weseloh, Dan Burgess, Andy Van Scoyk, Rod McLeod, Ian Reid, Pat Righter, Michelle Gilroy, and James Simino. Last, we would like to thank all the generous landowners who provided critical access to stream sections on their properties. Understanding salmonid distributions and abundance throughout both public and private lands remains essential to defining the status and trends of Smith River salmonid populations.

Introduction

Severe population declines of coho salmon (*Oncorhynchus kisutch*) in freshwater habitats in California have led to both federal and state listings under the federal (ESA) and California (CESA) Endangered Species Acts (Federal Register 1997, CDFW 2002). These listings have initiated the development of recovery plans which include delisting goals (CDFW 2004, NMFS 2014) for the Southern Oregon Northern California Coho (SONCC) Evolutionary Significant Unit (ESU). The 'population' has been defined as the scale used to assess population viability (Williams et al. 2006). For a coho salmon ESU population to meet or exceed a viable threshold, it must show a low risk of extinction over 100 years (McElhany et al. 2000). NOAA established four viable salmon population (VSP) parameters to determine a population's risk of extinction. These parameters include: abundance, productivity (population growth rate), spatial structure, and diversity (McElhany et al. 2000). Trend monitoring for these VSP parameters is the measure by which extinction risk and recovery status of an ESU is evaluated. To address critical data needs for the viability assessment, CDFW and NOAA (National Oceanic and Atmospheric Association) cooperatively developed the Coastal California Salmonid Monitoring Plan (CMP). The current major funding source in California for VSP trend monitoring of ESA and CESA listed salmonids is through the Federal and State supported Fisheries Restoration Grants Program (FRGP) where funding is allocated based on population and demographic specific monitoring goals relative to focal species defined by the grants program. Coho salmon are currently the only ESA listed salmonid in the Smith River basin and thus are the only focus species identified in the watershed by FRGP.

The Smith River has been ranked by the North American Salmon Stronghold Partnership Initiative as among the highest for salmonid conservation value. 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). Until recently, no basin-wide assessments of salmonid distributions or abundance have occurred within the Smith River. However, adult salmon and steelhead catch estimates have been generated utilizing creel censuses and steelhead and salmon report cards. The first basin-wide escapement estimates of adult Chinook salmon and steelhead have been obtained using sonar technology (Larson 2013a). This sonar project operated during the 2010-2011 and the 2011-2012 salmon and steelhead spawning seasons and during the 2012-2013 steelhead spawning seasons (Larson 2013a, Larson 2013b). While the project demonstrated sonar technology could effectively estimate adult Chinook salmon and steelhead populations, its main limitation was assigning sonar images to rare species, especially coho salmon. The Smith River anadromous adult salmonids generally have broad overlap in run-timing, with coho salmon spanning the ladder half of the Chinook salmon run and the early half of the steelhead run. In addition, sonar stations are at fixed locations greatly limiting inference into the spatial distributions of salmonid populations. Given these challenges, we developed a unique population monitoring program tailored to obtaining reliable estimates of coho salmon abundance and spatial distribution.

Prior to this five-year study, only two directed investigations focused on coho salmon within the Smith River basin. A study by Garwood (2012) incorporated a rigorous literature review of all previously known coho salmon observations coupled with a standardized field observation effort to compare historic and contemporary coho salmon distributions. Historic records documented coho salmon occurring in 36 streams within in the Smith River Basin. Contemporary field surveys from 2000 to 2002 described coho salmon occupying 18 of 23 surveyed streams that were known to have previous verified observations (Garwood 2012). The second coho salmon investigation was through a long-term salmonid population monitoring program in Mill Creek (McLeod and Howard 2010). This program was initially started in 1994 in upper Mill Creek by Relliam Timber Company as a requirement by Federal regulators while coho salmon were being considered for ESA listing. This study was focused on juvenile life stages through outmigrant trapping. Repeated adult spawner surveys only occurred in index sections of Mill Creek (McLeod and Howard 2010). After the property changed ownership to State Parks, the program continued through various grants through the year 2013. After 2013, the program was adapted to meet the needs of a life-cycle monitoring station as defined by the CDFW coastal salmonid monitoring program.

In the fall of 2011 the Smith River Alliance (SRA) and CDFW initiated an intensive coho salmon monitoring program to assess two of the four viable salmonid population parameters outlined in McElhany et al. (2000): abundance and spatial structure. For the last five years, this monitoring effort has produced critically important abundance and distribution data for coho salmon but also Chinook salmon, steelhead and coastal cutthroat trout. Due to a lack of funding necessary for long-term population monitoring, this study concluded after the summer of 2016. This report summarizes project operations and data collection for the 2015-2016 seasons and provides a comprehensive summary spanning the five-year monitoring program. Detailed annual findings can also be found in previous documents by Garwood and Larson (2014), Garwood et al. (2014) and Walkley and Garwood (2015).

Materials and Methods

Study Area

The Smith River watershed encompasses 1,862 square kilometers in the northwest corner of California (Del Norte County), and southwest corner of Oregon (Curry County) (Figure 1). The Smith is the largest undammed river in California, and thus retains a natural flow regime maintaining excellent water quality throughout most of the basin. Elevations range from sea level to 1,954 meters at Bear Mountain summit in the Siskiyou Mountains. Three major subbasins drain the majority of the eastern and northern portions of the basin including the South Fork, Middle Fork, and North Fork. These subbasins occur in the western most portion of the rugged Klamath-Siskiyou Mountains physiographic province and are dominated by steep slopes and complex topography. The geology of this area is largely ultramafic rock which over time has been altered into various serpentine rocks. These soils are stable, unproductive, poorly vegetated, and contain high quantities of metals including nickel, chromium, or copper (McCain et al. 1995). Landslides on steep canyon slopes are common features that deposit large amounts of fractured rock into stream channels. The western edge of the basin includes portions of the coast range and is dominated by redwood forests. Major subbasins include Mill Creek and Rowdy Creek. The Smith River Plain is within the coastal zone and is approximately 31 square kilometers in area. This broad flat emerged marine terrace has been characterized by river floods producing alluvial fans and river terraces which receive windblown sand deposits resulting in highly productive soils.

The high-elevation portions of the basin receive moderate winter snowpack; however, the primary precipitation falls as rain. Annual rainfall totals for the Smith River basin are among the highest in the United States, with the annual average totaling 92.33 inches at the Gasquet Ranger Station gauge (CDEC 2016). Precipitation is usually delivered during large winter storm events with 84% of annual average rainfall received from October to March (CDEC 2016). The sparsely vegetated and shallow rocky soils hold little precipitation and streams directly respond with highly variable flows. Stream flow measured by the USGS at the Jed Smith gauging station indicates mean annual discharge ranges from 975 (1977) to 7,027 (1974) cubic feet per second (cfs) (USGS). However monthly mean summer (August) flow is 336 cfs and monthly mean winter (January) flow is 8,320 cfs. The highest recorded flow on the Smith River was on December 22, 1964 at 228,000 cfs (USGS 2012). Average annual peak flow from 1932 to 2016 is 82,120 cfs.

The federal government is the dominate land manager within the basin. Six Rivers National Forest manages 1233 square kilometers (66.2%) and Siskiyou National Forest manages 235 square kilometers (12.6%). Six Rivers National Forest includes the Smith River National Recreation Area (NRA) and most of the streams throughout the watershed are classified as Wild and Scenic. Redwood National and State Parks

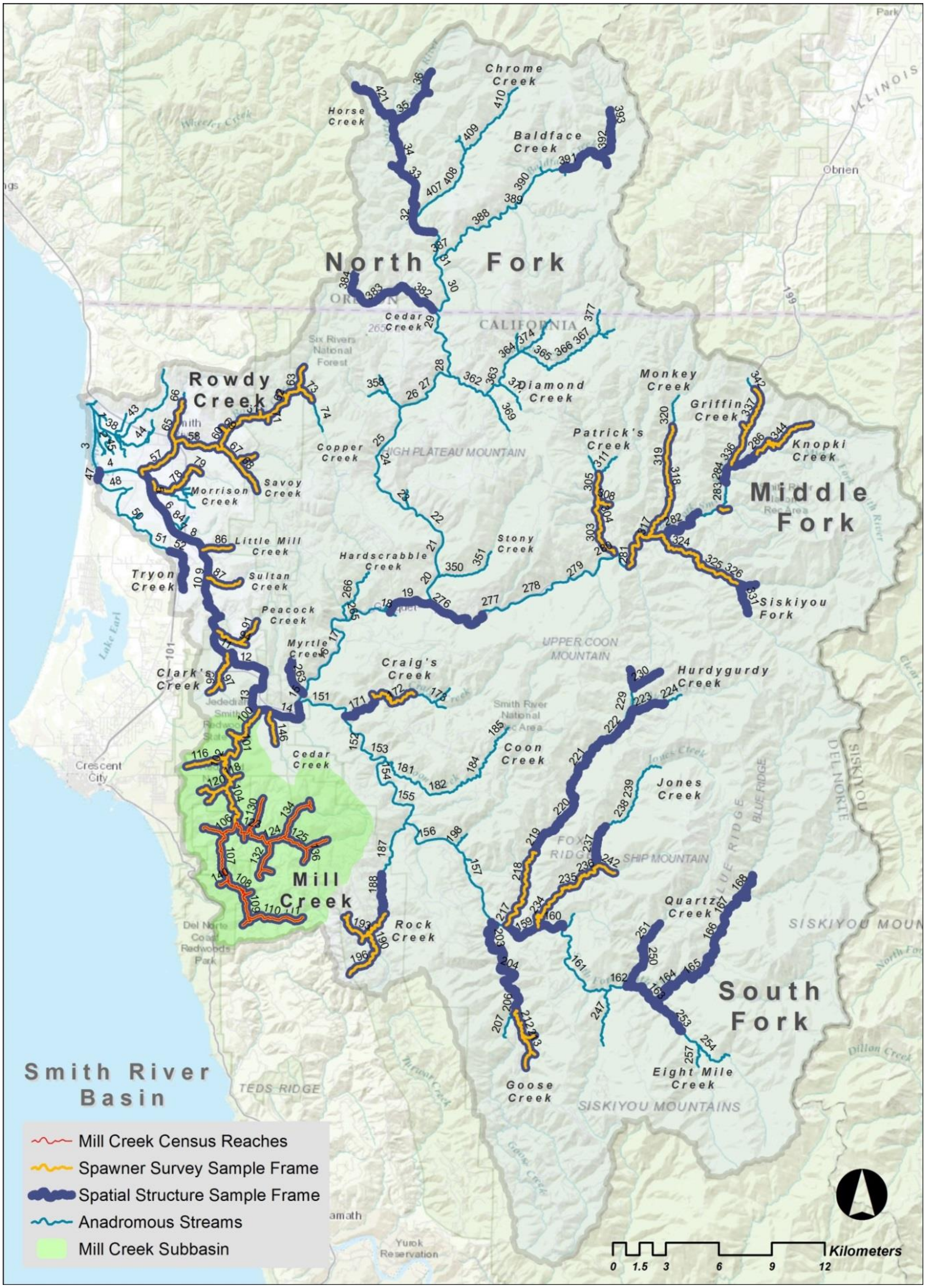

Figure 1. Map of the Smith River Basin, Del Norte County (California) and Curry County (Oregon). Stream lines indicate potential anadromous salmonid stream habitat based on this studies sample frame development process. Numbers represent 275 individual reach location codes used in generalized random tessellation sampling (GRTS).

manage 65 square kilometers, 3.5% of the basin. The remaining 17% is privately owned, most of which is located in the productive soils around the coastal plain. This area has been highly modified by anthropogenic activities including diking, tide gates, agriculture, resource extraction, and invasive vegetation (Voight and Waldvogel 2002, NMFS 2014). Primary land uses in the coastal plain include cattle ranching, hay production, lily bulb production, water diversions for irrigation, and aggregate mining.

Spawning Ground and Spatial Structure Sample Frames

Potential coho salmon spatial extents for adult spawning and juvenile rearing habitats in the Smith River basin can be found in Garwood and Larson (2014) who offer detailed explanations of methods used to develop two reach-based sampling frames used for the past five years. Although coho salmon were the focus of this work, Garwood and Larson (2014) also define spatial extents for Chinook salmon and steelhead so species distribution and abundance data could be assessed for each species relative to the sampled fraction of available habitats (*see* Garwood and Larson [2014] for estimated anadromous distribution by species).

Our sample frame construction resulted in 68 primary reaches and 30 sub-reaches totaling 161.8 km within the coho salmon spawning ground survey sampling frame (Figure 1). These reaches collectively represent 78% of the total estimated coho salmon spawning habitat in the Smith River basin. We eliminated the remaining 22% of potential habitat occurring in extreme remote areas within the Siskiyou Wilderness of the South Fork Smith River, the Oregon portion (Kalmiopsis Wilderness) of the North Fork Smith River, and the headwaters of the Siskiyou Fork. These areas are not accessible during the winter due to having locked US Forest Service gates preventing the spread of an invasive Port Orford cedar pathogen, persistent winter snowpack, or multiday remote treks requiring unsafe stream crossings and winter camping. Since these remote areas will never feasibly be sampled during the winter with the current protocol, we cannot consider the reaches when calculating adult coho salmon redd population estimates. This consideration eliminates any ill effects from non-response errors associated with failing to ever sample reaches having unique properties (e.g. high elevation, isolated) in the population. Notwithstanding, we included these remote reaches in the juvenile summer spatial structure sample frame. During implementation, we eliminated three spawning survey reaches based on field surveys including Goose Creek (205, 206) and Craig's Creek 171 and added West Branch Mill Creek (111, 141), and East Branch Mill Creek (133, 135) after the first survey year.

Field Methods

Spawning Ground Reach Survey Protocol

We used the protocols defined by Gallagher et al. (2007) and recommended by (Adams et al. 2011) to survey for salmonid redds, live fish, and carcasses throughout our annual reach sample draw. Each year the project was staffed to ensure each reach in the sample draw could be surveyed every 10 to 14 days. Surveys were completed by a team of two walking the reach in an upstream direction. However, a few larger reaches were surveyed with kayaks in a downstream direction when stream discharge had increased but survey conditions were acceptable. A stream discharge threshold was determined for each survey reach using Smith River discharge estimates from the USGS Jed Smith gauging station in Hiouchi, CA. Our minimum water visibility for surveys ranged from 40 to 50 cm depending on stream size, with larger streams exceeding this threshold once safe flow conditions permitted surveys. When our survey return interval was interrupted by storm events, we returned to reaches as soon as they became available to maximize survey effort in each reach for the season.

Our survey protocol is designed to maximize the detection of redds during a given survey by having a primary observer searching for all redds and a dependent secondary observer searching redds the primary observer may have overlooked. We suggest this method maximizes redd detection rates by forcing each observer to identify all redds in contrast to a two person crew dividing the search effort. Overall redd observation probabilities of the primary observer equaled 97% in 2011-2012 and 98% in 2012-2013 (Garwood and Larson 2014), 97% in 2013-2014, 98% in both 2014-2015 and 2015-2016. Given our secondary observer found only 2-3% more redds on average than the primary observer, this indicates a single observer was highly effective at finding most redds across all five years of this monitoring project. However, the field crew was exceptionally experienced over these five survey years and we would expect detection probabilities to decrease among crews having less survey experience. For these reasons, we plan to continue using this double-dependent approach to maximize overall redd detection rates.

We only identified redds to species when identified salmonid(s) were observed constructing or guarding the feature. Only redd features having distinct pot and tail spills were considered (i.e. test digs were not recorded). Redds observed without identified live fish were recorded as unknown species. All new redds were identified with flagging tied to available riparian vegetation. A unique redd record number, redd age, total redd length, distance, and compass bearing were transcribed on the flagging to identify the redd location and status on subsequent surveys. Spatial coordinates were collected for all individual redds using Garmin 60csx GPS with point averaging (minimum of 200 positions) employed to maximize location accuracy (Mean accuracy= 3.4 meters). Redd age categories included (1) new since last survey, (2) still visible and measurable, (3) still visible but not measurable, (4) no longer visible, (5) unknown due to poor visibility. During a survey, all newly observed redds were recorded as age=1 and all previously flagged redds were aged according to their current status (e.g. 2, 3, 4, or 5). When a redd was recorded as age four, the flag was tied into a knot and was no longer considered on subsequent surveys. Redd dimensions (size, depth, and substrate characteristics of redds) were measured during the first 3 years of this monitoring program following Gallagher et al. (2007) to investigate the utility of using redd measurements to predict redd species (i.e. Gallagher and Gallagher 2005, Gough 2010) in a basin where the models had not yet been tested. If a redd increased in size between survey periods, measurements were recorded again. Redd dimensions were not recorded after 2013 because we found a non-parametric K-nearest neighbor algorithm (kNN) (Cover and Hart 1967) outperformed redd measurements for redd classification in the Smith River basin (Ricker et al. 2014a, Garwood and Larson 2014).

Live salmonid information is important for identifying redd species, describing reach-level relative abundance, and identifying spatial distributions of species having cryptic spawning behaviors. We identified all observed live salmonids to species and gender whenever possible. We collected spatial coordinates for all salmonid locations using a Garmin 60csx GPS without point averaging. Fork lengths were estimated to the nearest five centimeters. Field staff would also inspect the body of each live fish for the presence or absence of clips that would indicate hatchery origin. Rowdy Creek Fish Hatchery has used an adipose fin clip for Chinook salmon and steelhead. However, a left-ventral fin clip was used by Rowdy Creek Fish Hatchery on Chinook salmon during the 2009 brood year (Garwood 2010). The observation of this clip was generally unreliable on live fish and was confounded by what side of the fish an observer was facing. Stray coho salmon could have an adipose (Oregon hatcheries) or a maxillary bone (Klamath/ Trinity hatcheries) clip with the maxillary also difficult to determine on live fish. Generally, we reserved the inspection of left-ventral and maxillary clips to salmonid carcasses. To minimize bias associated with clip inspections on live fish, we did not include observations in the hatchery vs. wild analysis if the immediate area around the adipose fin was obscured from view.

Carcasses are a source for biological samples including scales and genetic tissue and provide key information on demographic measurements including body size, sex ratios, age, and origin (hatchery or wild) (Crawford et al. 2007). All adult salmonid carcasses we encountered were identified to species and gender when possible. We collected spatial coordinates for each carcass location using a Garmin 60csx GPS without point averaging. Fork length was measured to the nearest centimeter and we examined the carcass for clip marks whenever possible. Potential clip observations included adipose fin (all species), left-ventral fin (Chinook salmon only), left or right maxillary (coho salmon only). We vouchered the heads of all Chinook salmon having adipose clips to retrieve the coded wire tag (CWT) for age and hatchery origin information. Starting in the fall of 2015, all coho salmon carcasses encountered on surveys were scanned with portable PIT tag wands to detect the presence of a PIT tag. All carcasses encountered that had a complete lower jaw were marked with a uniquely numbered metal tag attached to the left lower jaw. We aged all carcasses based on stages of decomposition: (1) carcass fresh clear eye, (2) carcass cloudy eye low fungus, (3) carcass cloudy eye or no eye heavy fungus, (4) carcass skin and bones with head, (5) carcass skin and bones no head, (6) loose tag no fish. Last, we collected biological samples from carcasses on the first encounter only. Scales were collected from the left side of the carcass posterior to the dorsal fin and above the lateral line unless scales were no longer present. We collected tissue samples from numerous locations on the body concentrating upon fleshy areas with the least amount of decomposition. All scale and tissue samples were preserved by dehydration and submitted to the DFW scale and tissue archive in Arcata, CA.

Mill Creek Spawning Ground Census Protocol

We designed a spawning survey census in the Mill Creek subbasin to incorporate coho salmon redd abundance into the Mill Creek Life Cycle Monitoring Station (LCS). By conducting a census of all available spawning habitat within a LCS we avoid excessive estimation error associated with between-reach redd abundance variation. The census area includes 14 primary reaches and seven sub-reaches totaling 33.5 stream kilometers within the West Branch Mill Creek and East Fork Mill Creek (Figure 1). Reaches in the LCS that were not selected during our annual GRTS draw were simply added to our survey effort.

Spatial Structure Field Survey Protocol

We designed this survey to incorporate both local (within reach) and landscape (between reach) scales. Our survey focused on stream pools as the sample unit since pools generally provide slow water habitats and are preferred for rearing by juvenile coho salmon (Bisson et al. 1988, Nickelson et al. 1992). For small and mid-sized streams, we used systematic sampling in every second pool throughout the entire length of each GRTS selected survey reach that met our maximum depth, size, temperature and visibility criteria (*see protocols:* Garwood and Ricker 2013, Garwood and Ricker 2016). We based our pool sampling frequency on optimal sampling rates in a field protocol proposed by Webster et al. (2005). Through simulations, these authors determined a fixed sampling fraction of every second unit surveyed by two independent snorkel dives was optimal in detecting coho salmon in a low abundance scenario. We conducted two independent surveys by separate divers for each selected sample unit during the first two years (2012-2013) of the project to calculate species detection probabilities (Garwood and Larson 2014). Based on these data, we found detection probabilities to be very high (p=0.94, 0.95) indicating not all sample units needed two independent passes. After sub-sampling the available data under various two-pass sample frequencies, we found changing the frequency of two-pass pools from every sampled pool to every fourth sampled pool had negligible influence (p=0.92, *see* Garwood et al. 2014) on detection probabilities. The primary advantage of reducing sampling effort was to allow for more surveys to be completed at less cost. In addition, we found the error around reach-level occupancy estimates was more sensitive to sample size than pool-level sampling rates which is likely a function of the patchy nature of annual coho salmon distributions and our ability to identify all patches given various sample sizes (Garwood et al. 2014)

Sampling in large mainstem Smith River reaches differed from smaller streams by restricting our sample units to slow water portions of edge, side channel, off-channel, and beaver characterized areas. Mainstem pools were effectively difficult to survey based on size and depth (i.e. >5 m deep) and we did not expect juvenile coho salmon to occur in open pelagic waters during daytime hours. Based on preliminary field work, we decided to census all available mainstem habitats in selected reaches because features were typically rare (i.e. usually less than 10 units per reach) and had unique qualities. Each sample unit was surveyed by two independent dive passes occurring on the same day. 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.

Prior to each survey season, we completed intensive underwater training on fish identification and quantitative dive counts in at least three streams of various sizes hosting different assemblages of fish species. Underwater tests on species identification were given to each crew member to ensure coho salmon and other salmonids were confidently identified. Underwater flashlights were used at all times so shadowed and complex habitats could be inspected thoroughly. All fishes and amphibians observed in each sample unit were identified and enumerated independently by each diver using dive slates. Species and age classes of fish were divided into categories based on size and physical appearance. (*see* Garwood and Ricker 2016). 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.

Spawning Ground Survey Statistical Methods

Redd Speciation

We used a non-parametric K-nearest neighbor algorithm (kNN) (Cover and Hart 1967) to classify all unidentified redds to a unique species. Spawning date and the XY spatial coordinates of known-species redds and live fish are equally scaled in dimensional space and are then used to predict the nearest unknown redds through the majority vote of the three known nearest neighbors in Euclidean distance (Ricker et al. 2014a). This approach takes advantage of the spatial and temporal clustering of salmonid spawning runs and only requires accurate GPS coordinates to be taken at individual redds and live fish. The primary reason for including live fish observations was to maximize the use of known species spatial and temporal distributions. We found that mean live fish dates were similar to mean known redd dates (*see* Garwood and Larson [2014] *and* Table 3 in results section), so the kNN date vectors are comparable between fish and redds. Most importantly, we discovered the proportion of known species redds ranged from 43% in the early season to only 9% in the late season (Garwood and Larson 2014). This range is likely due to differences in species-specific spawning behaviors between salmon and steelhead. Steelhead spawn later in the season and are observed on redds far less often than Chinook salmon or coho salmon, resulting in a lower percentage of known-species redds later in the season. By including live fish, we are able to incorporate more known-species observations at times when few fish were observed constructing redds but were observed nearby.

We used UTME, UTMN, and date as spatial and temporal dimensions to calculate Euclidean distance (d_{ij}) between redd x_i and redd or fish x_j as:

$$d_{ij} = \sum_{l=1}^{n} \sqrt{(x_{il} - x_{jl})^2}$$

Where:
l = redd and fish attributes (UTME, UTMN, JDate); and
n = 3 when UTMs and JDate are used, and n = 1 when JDate only is used

We only used live fish observations that were not associated with a known-species redd to avoid pseudo-replication of l neighbors. That is, known-species redds were only counted once, and the fish associated with those redds were not used in the kNN classification of unknown redds. kNN selects classes based on the shortest Euclidean distance in time (date) and space (UTMs). These attributes are on two distinctly different scales resulting in uneven weighting of attributes, so we standardized attribute data into z-scores:

$$z_i = \frac{x_i - \mu}{\sigma}$$

where the value of z represents the distance between the raw score and the population mean (μ) in units of standard deviation (σ). We classified each unidentified redd by the majority vote of the three nearest known individual fish or redd neighbors (l=3) in time and space as recommended in previous work by Ricker and Stewart (2011) and Ricker et al. (2014a), who found a l of 3 produced the highest accuracy of classification with the fewest ties. Cross validation was used to evaluate the performance of the kNN model (Ricker et al. 2014a). Cross validation is an iterative process in which a single observation is removed from the data set, the model is fit to the remaining data, and the removed observation is then predicted. Overall, model accuracy is assessed as the total percentage of correctly classified known-species redds. All analyses were performed using program R (R Core Team 2013) and associated packages defined in Ricker et al. (2014a).

Estimation of Within-Reach Redd Abundance

Schwarz et al. (1993) developed a theoretical foundation for the problem of estimating a total from repeatedly sampling, marking, and releasing salmon returning to the Chase River, British Columbia, Canada. The estimator developed by these authors extends the Jolly-Seber capture-mark-recapture model to allow for the estimation of the population total by making assumptions about the recruitment process, estimating survival of fish between sampling occasions via capture-mark-recapture, then using these parameters to adjust counts for animals that enter the population and die between survey occasions. We apply this general approach to periodic redd surveys, assuming that all newly deposited redds are recruited at the mid-point of each survey interval, and estimate redd survival between occasions by inspecting the number of individually tagged redds that remain visible between each subsequent survey occasion. The estimation of total redd construction within a survey reach can be described as an age-based open population mark-recapture experiment in which redds are either marked and/or recaptured on each survey occasion, and redds are individually identified and marked with unique redd IDs applied to flagging. The population of redds is considered open because new redds are recruited into the population when they are constructed, and 'die' when they become obscured from view. In the context of repeated spawning ground surveys we estimate total redd abundance within a sample stream reach as:

$$\hat{\tau}_J = B_0 + \frac{\sum_{i=2}^{k} B_i - 1}{\sqrt{\hat{S}_p}}$$

where $\hat{\tau}_J$ is the estimate of the total number of redds within a sample reach j; B_i is the number of new redds on the ith survey occasion; k is the total number of survey occasions; and B_0 is the number of redds observed on the first survey of the season. The numerator of the second term is then the sum of all new redds observed from the second occasion to the last occasion, divided by survival of flagged redds pooled across all survey occasions for which at least one new redd of the target species was observed following the advice and methods of Ricker et al. (2014):

$$\hat{S}_p = \frac{\sum_{i=1}^{k-1} R_{i+1}}{\sum_{i=1}^{k-1} M_i}$$

where $\hat{S}_p$ is the pooled survival rate of flagged redds when i denotes the survey occasion and k is the total number of survey occasions. The numerator is then the sum of recaptured redds from the second survey occasion to the last survey occasion, and the denominator is the sum of marked redds and recaptured redds that were still visible from the first occasion to the second to last occasion.

This age-based mark recapture model has the following assumptions based on Ricker et al. (2014b):

(1) Field surveyors correctly identify all redds as redds, and no redds are missed during each survey occasion.

(2) Redds do not become detectable again after they have been classified as obscured from view.

(3) All redd flags are seen, individually identifiable, and recorded properly.

(4) All flagged redds survive with the same probability, regardless of species (homogeneity of survival between redds), and in our pooled case all flagged redds survive with the same probability across all occasions (homogeneity of survival between occasions).

(5) Recruitment of new redds from occasion *i* to *i* +1 occurs at midpoint of the interval between survey occasions, starting with the second survey during which redds are observed.

(6) Redds are considered obscured in the interval between occasion *i* and *i* + 1 if the flag (and redd) are not observed after occasion *i*.

Estimation of Total Redd Abundance within the Sample Frame

Total redd abundance within the Smith River adult coho spawning ground survey frame is estimated using a Simple Random Sample estimator for total (Adams et al. 2011):

$$\hat{T} = N\left(\frac{\sum_{j=1}^{n} \hat{\tau}_j}{n}\right)$$

where *N* is the number of reaches within the Smith River spawning ground survey sample frame, *n* is the number of reaches surveyed, and $\hat{\tau}_j$ the estimate of the total number of redds present in sample reach *j*. The standard error of $\hat{T}$ was calculated using within-reach and between-reach variance derived from bootstrap resampling, and applying the finite population correction factor as in Adams et al. (2011):

$$se(\hat{T}) = N\sqrt{\left(1-\frac{n}{N}\right)\hat{\theta}_b + \frac{1}{N_n}\left(\sum_{i=1}^{n}\hat{\theta}_w\right)}$$

where $\hat{\theta}_b$ is the between-reach variance of bootstrapped replicates, and $\hat{\theta}_w$ is the within-reach variance of bootstrap replicates. The bootstrap resampling process is described in detail in Ricker et al. (2014b). *N* is the total number of reaches in the Smith River spawning ground survey sample frame, *n* is the number of sample reaches.

Live Fish and Carcass Information

After a review of the scientific literature regarding estimation of salmon population size we chose not to use two methods we had considered when we proposed this work. As an example, Gallagher et al. (2010) found that population estimates using Area Under the Curve (AUC) (English et al. 1992) were unreliable due to the sensitivity of the two primary parameters used in the estimator: residence time (rt) and observer efficiency (v). Review of residence time and observer efficiency in literature was highly variable within studies, between streams, and between years so we determined we could not use estimates of these parameters from outside of the Smith River. We determined that we could not calculate residence time or observer efficiency because both of these parameters would require the construction of a weir to capture adult fish as they migrate up stream into spawning reaches. Construction and maintenance of even a temporary weir was found to be cost prohibitive and logistically challenging. We also did not use the Jolly Seber carcass capture-recapture estimator for similar reasons as Gallagher et al. (2010) based on having few recoveries of marked fish and unequal capture probabilities.

Spatial Structure Statistical Methods

Occupancy Models

We applied multi-scaled occupancy models (Nichols et al. 2008) to estimate the probability of salmonid occupancy simultaneously at two spatial scales while accounting for detection probabilities. The larger scale corresponds to the probability of occupancy at the sample reach(ψ), whereas the smaller scale corresponds to the probability of occupancy at the sample pool(θ), given the species was present in the sample reach. Detection probability (p) is modeled at the smaller pool scale based on individual snorkel passes in each sampling unit. The advantage to modeling occupancy at two spatial scales is both landscape and local spatial distributions of a given species can be calculated while accounting for individual survey detection probabilities in a single framework. The primary assumption of this approach is the target animal's occupancy status cannot change over the course of the study season (MacKenzie et al. 2006, Nichols et al. 2008). We fixed our sampling season to the summer period after river flows stabilized and the coho salmon smolt migration period was largely complete.

Model parameter definitions:

p_t^s = Pr (detection at occasion t at pool s given the reach is occupied and the species is present in the immediate pool).
ψ = Pr (sample reach occupied);
θ_t = Pr (species present at the immediate sample pool given the reach is occupied)

We used using the single-season multi-method approach in program PRESENCE (USGS 2016) to calculate estimates of occupancy (ψ), estimates of conditional occupancy (θ), and detection probability (p) of each species and age class category. We assumed p was constant in pools between the two snorkel passes. The proportion of area occupied was determined by simply multiplying the two occupancy parameters ($\psi * \theta$).

Database and Data Storage

We collected spawning ground survey data using field computers (PDA's) operating the DFW Coastal Monitoring Program Aquatic Survey Program database (current version: 0.9.7.) (Burch et al. 2014). We collected the spatial structure data using paper entered into a Microsoft Access program due to the Aquatic Survey Program database lacking specific data elements at the time of surveys. We fixed data fields in all PDA forms within specific ranges to minimize data entry error. Standard QAQC queries were run each day after PDA's were downloaded to correct any data errors directly after surveys were completed. Databases were backed up once a week and uploaded to the regional central data server after the QAQC was complete.

2015-2016 Spawning Ground Survey Results

Spawning Ground Survey Conditions and Effort

We completed 353 surveys in 30 main reaches and 13 sub-reaches during the 2015-2016 survey period which extended from November 3, 2015 through March 9, 2016 (Table 1). GRTS sampling represented 29% of the total frame with 20 reaches and 7 sub-reaches. An additional 10 reaches and 6 sub-reaches were surveyed to complete a census of the Mill Creek LCS (Table 1). The precipitation regime for the first month of the 2015-2016 spawning survey period was comprised of multiple, frequently occurring lower magnitude storms while the remainder of the season was characterized by frequent high magnitude storms (Figure 2). Rainfall at the Gasquet Ranger Station totaled 135% of average during the survey period. Rainfall totals for December and January were 224 and 133% of average while totals for November and February were 66 and 62% of normal (CDEC 2016).

Multiple storm events elevated discharge and turbidity beyond our maximum survey threshold of 16,000 cubic feet per second at the USGS Jed Smith gaging station (Figure 2). On average, conditions were favorable for surveying reaches 73% (SD= 7%) of days within the spawning survey period. We surveyed 73 days out of a possible 114 available days resulting in an effort of 64%. On average, we surveyed each reach 8 times (range 3-14) with an overall reach return interval of 17 days (Table 1, Figure 2). Survey revisit intervals were consistent for most reaches during November despite multiple storms that maintained daily average mainstem flows above 1000 cfs at the USGS Jed Smith gauge site in Hiouchi (Figure 1). Significant storm events resulted in elevated streamflow and decreased water visibility in survey reaches through much of December, late January and during early February. These storm events, particularly those during mid-December, inhibited return visits to some reaches because either minimum visibility thresholds were not met – reaches 58, 100 and 106 for example – or conditions were unsafe for surveying – reaches 172 and 303.

2016 GRTS Spawning Ground Surveys

Live Fish Observations

We made 1,735 observations of live anadromous salmonids within the GRTS surveyed portion of the Smith River during the winter of 2015-2016 (Table 2, Figure 3). These live salmonid totals do not represent unique individual observations because live individuals could be observed over multiple survey periods. Live anadromous fish observations in GRTS reaches included 924 Chinook salmon, 34 coho salmon, 679 steelhead and 98 unidentified salmonids (Table 2, Figure 3). Live Chinook salmon dominated the first half of the survey season's observations (Table 3, Figure 3). Mean observation date for Chinook salmon was December 7 and ranged from November 3 to February 9. Most live Chinook were detected before mid-January; however, one female Chinook salmon was observed building a red in Rowdy Creek on February 9. As was the case in 2014, early storms in October and series of storms during November, December, and January enabled Chinook salmon to access most GRTS reaches and they were detected in 18 of 20 main reaches and one of 7 GRTS sub-reaches surveyed (Table 2, Figure 5). Chinook salmon were detected for the first time during this monitoring program in reach 69, a sub reach to Rowdy Creek and for the first time above a steep bedrock pinch in reach 120, a tributary to main stem Mill Creek. Live coho salmon were observed from December 2 through February 17 with a mean observation date of January 11 (Table 3, Figure 5). Live coho salmon were observed in GRTS reaches from December 16 through February 17. All of the 29 live coho salmon observed in GRTS reaches were detected in Mill Creek (Table 2, Figure 5). Two adult coho salmon (and 79 Chinook salmon) were observed upstream of the former site of an anadromous adult barrier on Hamilton Creek (reach 38) that was removed in the early fall of 2015. Steelhead dominated live salmonid observations throughout the latter half of the survey season (Figure 3). Steelhead observations occurred from December 12 through the end of spawning surveys on March 9, with a mean observation date of February 15 (Table 3). Thus, we only captured a portion of the steelhead spawning season during our survey. Steelhead were widely distributed across the geographic extent of the sampling frame and were observed in 19 of 20 main GRTS reaches but were not observed in any GRTS sub-reaches (Table 2). Most live steelhead recorded in GRTS reaches were observed in Rowdy Creek, Little Mill Creek and in Upper Middle fork and South Fork reaches.

Carcass Observations

We recovered 161 anadromous salmonid carcasses in the GRTS survey reaches during the winter of 2015-2016. Chinook salmon carcasses were the most abundant, with 148 individual carcasses recovered (Table 2, Figure 7). Next most abundant were unidentified salmonid carcasses, 7 individuals, and coho salmon, 3 individuals. All coho salmon carcasses were recovered in Mill Creek between December 16 and February 15 (Table 2, Table 3). As was the case in 2014-2015, sustained high flows likely flushed or dispersed carcasses and thus decreased our ability to detect them on subsequent surveys. No tagged coho salmon carcasses were recaptured in GRTS sampling reaches.

Hatchery Origin Salmonid Observations

Hatchery origin salmonids were observed below the confluence of the Middle Fork and South Fork of the Smith River during the winter of 2015-2016 (Table 4). The proportion of hatchery origin salmonids varied by species and watershed area (above the confluence of the Middle and South Forks, below the confluence of the Middle and South Forks excluding Rowdy Creek, and Rowdy Creek) (Table 4). Hatchery origin fish constituted 6.3% (range: 0% to 23.8%) of all live Chinook salmon observations where the presence or absence of an adipose fin could be determined, and 8.9% (range: 0% to 25.9%) of all Chinook salmon carcasses recovered. No Chinook salmon were identified as having a left ventral fin clip. The Rowdy Creek Fish Hatchery (RCH) used a left-ventral fin clip for the 2009 brood year and individuals with this clip have been detected in previous years. Hatchery origin steelhead constituted 6.5% (range: 0% to 75%) of all live observations where the presence or absence of an adipose fin could be determined (Table 4). Live steelhead with missing adipose fins were observed in Rowdy Creek and Little Mill Creek (Figure 8). It should be noted that detecting adipose fin clips on live steelhead was difficult, especially during higher flows and when turbidity was even moderately elevated. All steelhead carcasses recovered in Rowdy Creek (N=6) had adipose fin clips. No hatchery origin live coho salmon or coho salmon carcasses from other basins were encountered during the winter of 2015-2016. Coho salmon are not produced by Rowdy Creek Fish Hatchery.

Redd Observations

We identified 598 anadromous salmonid redds within the GRTS surveyed portion of the Smith River during the winter of 2015-2016 (Table 5, Figure 9). Live fish were observed constructing and/or guarding 223 of the 598 redds or 37percent of the observations. Of these occupied redds, 161 were identified as Chinook salmon redds, 9 as coho salmon redds and 53 as steelhead redds. A total of 375 redds were not occupied and thus remained unidentified. The average total reach-level redd density within the GRTS surveyed reaches equaled 11.4 redds per kilometer, with the highest observed densities occurring in the Rowdy, Little Mill Creek and Mill Creek watersheds (Table 5). Cumulatively, 37 percent of redds observed in the GRTS sampled reaches were identified to species, however, this proportion fluctuated across the season. During November and December – when Chinook salmon were abundant – roughly 50 percent of observed redds had fish occupying them. After January – when observations of coho salmon and steelhead in the river increased and observations of Chinook salmon decreased – the percentage of occupied redds ranged from 6 to 24 percent (Figure 9). All verified coho salmon redds were observed in the Mill Creek LCS above the confluence of the East Fork and West Branch (Table 5, Figure 5). In contrast, verified Chinook salmon and steelhead redds were distributed in the subbasins across the survey area (Table 5, Figure 4, Figure 6). The first verified coho salmon redd was observed on December 15 and the last was observed on February 2 (Table 3). Overall, mean observation dates of known species redds were consistently within a few days of mean live fish dates for all three species.

Redd Prediction Performance

The kNN classifier performed well in the 2015-2016 survey season, correctly predicting 337 of 345 (98%) redds verified to species from GRTS and Mill Creek census reaches (Table 6). Unlike 2013-2014, but as was the case during 2014-2015, known species redd abundance was more similar between steelhead and coho salmon. The kNN classifier correctly predicted 100% of steelhead redds, 98.8% of Chinook salmon redds and 83.3% of coho salmon redds. No unknown redds outside of the Mill Creek LCS were predicted to be coho salmon redds by the KNN classifier.

Total Redd Abundance

Total redd abundance estimates of Chinook salmon and steelhead for the Smith River GRTS sample frame in 2015-2016 were 1955 (1004 - 2905) and 1120 (329 – 1911), respectively (Table 7). We did not detect a verified coho salmon redd outside of the Mill Creek LCS, and thus, as in previous years, we did not calculate a coho salmon population estimate for the entire GRTS sample frame and only report the Mill Creek LCS coho salmon estimate.

Mill Creek Spawner Survey Census

Live Fish Observations

During the winter of 2015-2016 we had 1191 observations of live anadromous salmonids in Mill Creek LCS census reaches. These observations included 859 Chinook salmon, 125 coho salmon, 127 steelhead and 80 individuals of unknown species (Table 2). Chinook salmon were observed in most portions of the mainstem reaches of the East Fork and West Branch Mill Creek, but not in the upper extents of their tributaries (Figure 4). Relatively few observations of live coho salmon were made in the lower East Fork and West Branch of Mill Creek; however, coho salmon were present in the upper portions of many tributaries (Figure 5).

Carcass Observations

During the winter of 2015-2016 we observed 227 Chinook salmon, 18 coho salmon, 1 steelhead and 11 unknown anadromous salmonid carcasses in the Mill Creek LCS (Table 2). Seventy-nine Chinook salmon carcasses and no tagged coho salmon carcass were recaptured on subsequent surveys. One spawned out female chum salmon carcass was recovered in the West Branch of Mill Creek. This was the first confirmed chum salmon identified in Mill Creek during the five years of CMP monitoring. As was the case in the GRTS sample reaches, anadromous adult carcasses distribution and detectability was likely affected by high stream flow. Also, mammalian and avian scavengers quickly consume adult salmonid carcasses. In a pilot study CDFW deployed game cameras in several Mill Creek reaches during the 2015-2016 spawning season to photograph carcass scavengers.

Redd Observations and Abundance

Verified coho salmon redds were observed throughout most of the Mill Creek LCS (Figure 11). During the 2015-2016 spawning survey season we observed 138 Chinook salmon redds, 30 coho salmon redds, 17 steelhead redds, and 458 unknown species redds in the Mill Creek LCS (Table 5). The known species redds plus the kNN predicted species redds (i.e. total number of observed redds) resulted in 136 coho salmon, 338 Chinook salmon, and 169 steelhead redds. We estimated total redd abundance in the Mill Creek LCS subbasin for 2015-2016 as 184 coho salmon redds (171 - 197), 471 Chinook salmon redds (436 - 506), and 206 steelhead redds (197 - 216) (Table 8).

Coastal Cutthroat Trout and Pacific Lamprey

During the winter of 2015-2016 we made incidental observations of coastal cutthroat trout (*Oncorhynchus clarki clarki*) but did not observe Pacific lamprey (*Lampetra tridentata*) while conducting our anadromous salmonid spawning surveys. We observed 19 coastal cutthroat trout redds in six reaches and two sub-reaches within the Mill Creek LCS (Table 5). Coastal cutthroat trout redds were observed from December 31 to February 16, with a mean observation date of January 23. In comparison, during 2013-2014, 83 coastal cutthroat redds were observed in the Mill Creek LCM and their mean observation date was January 27 (Garwood et al. 2014). In 2014-2015, 20 coastal cutthroat redds were observed and their mean observation date was January 9.

Table 1. Summary statistics of spawning ground reach survey effort and reach survey availability based on flow conditions for the winter of 2015-2016, Smith River basin, Del Norte County, CA. Surveys occurred from November 3, 2015 to March 9, 2016. Location codes with shaded cells were not GRTS drawn for the annual survey but indicate they were surveyed to complete the annual upper Mill Creek census. Reach lengths were extracted from the USGS National Hydrological Dataset, 24K routed hydrography.

Subbasin	Location Code[a]	Reach Length (m)	# of surveys	Mean # of days between surveys	Std Dev.	Max	Proportion of season available to survey
Rowdy	58	1860	7	19	13	43	0.59
Rowdy	60	1901	6	22	9	36	0.62
Rowdy	61	2320	6	21	10	36	0.62
Rowdy	69	415	8	16	8	25	0.84
Rowdy	70	355	8	15	7	25	0.84
Rowdy	71	356	7	18	8	30	0.84
Morrison	77	1485	7	18	11	40	0.72
Little Mill	86	1737	9	14	6	26	0.73
Mill	100	1805	8	17	7	29	0.67
WB Mill	**106**	**2111**	**9**	**15**	**8**	**31**	**0.70**
WB Mill	**107**	**2674**	**10**	**14**	**8**	**34**	**0.73**
WB Mill	**108**	**2031**	**12**	**11**	**5**	**25**	**0.74**
WB Mill	**109**	**1801**	**13**	**10**	**4**	**15**	**0.75**
WB Mill	110	2382	12	11	3	14	0.77
WB Mill	**111**	**1358**	**3**	**42**	**13**	**55**	**0.76**
Mill	116	2990	10	13	4	20	0.75
Mill	120	1921	7	16	4	22	0.75
Mill	121	770	6	19	7	32	0.76
EF Mill	**123**	**2149**	**8**	**15**	**6**	**30**	**0.71**
EF Mill	124	2298	8	17	8	30	0.72
EF Mill	**125**	**1589**	**12**	**11**	**3**	**19**	**0.76**
EF Mill	**126**	**1452**	**9**	**14**	**6**	**27**	**0.76**
EF Mill	**129**	**436**	**5**	**21**	**8**	**30**	**0.74**
First Gulch	**130**	**2506**	**8**	**15**	**5**	**26**	**0.82**
Kelly	132	2482	12	11	4	19	0.83
Kelly	133	593	10	12	5	20	0.82
Bummer	**134**	**2997**	**8**	**15**	**4**	**22**	**0.84**
Bummer	**135**	**300**	**7**	**18**	**5**	**28**	**0.83**
Low Divide	**136**	**863**	**9**	**14**	**5**	**26**	**0.83**
WB Mill	138	1427	14	9	3	18	0.83
WB Mill	**140**	**741**	**14**	**10**	**4**	**20**	**0.84**
WB Mill	**141**	**442**	**12**	**10**	**5**	**21**	**0.84**
WB Mill	**143**	**835**	**10**	**15**	**5**	**23**	**0.75**
Craig's	172	3310	5	26	14	42	0.35
Rock	196	2455	6	21	9	36	0.68
Hurdygurdy	218	2696	6	21	12	40	0.61
Middle	286	1823	7	19	9	35	0.64
Patrick	303	2250	6	22	11	41	0.61
Patrick	305	1666	6	22	11	41	0.62
Siskiyou	325	2937	6	21	12	40	0.63
Idlewild	333	542	6	21	9	35	0.68
Griffin	336	2600	6	23	10	37	0.67
Griffin	339	357	5	29	7	37	0.74
	Total	-	353	17	-	-	0.73[b]

[a]*Bold indicates Mill Creek Census reach,* [b]*Mean value.*

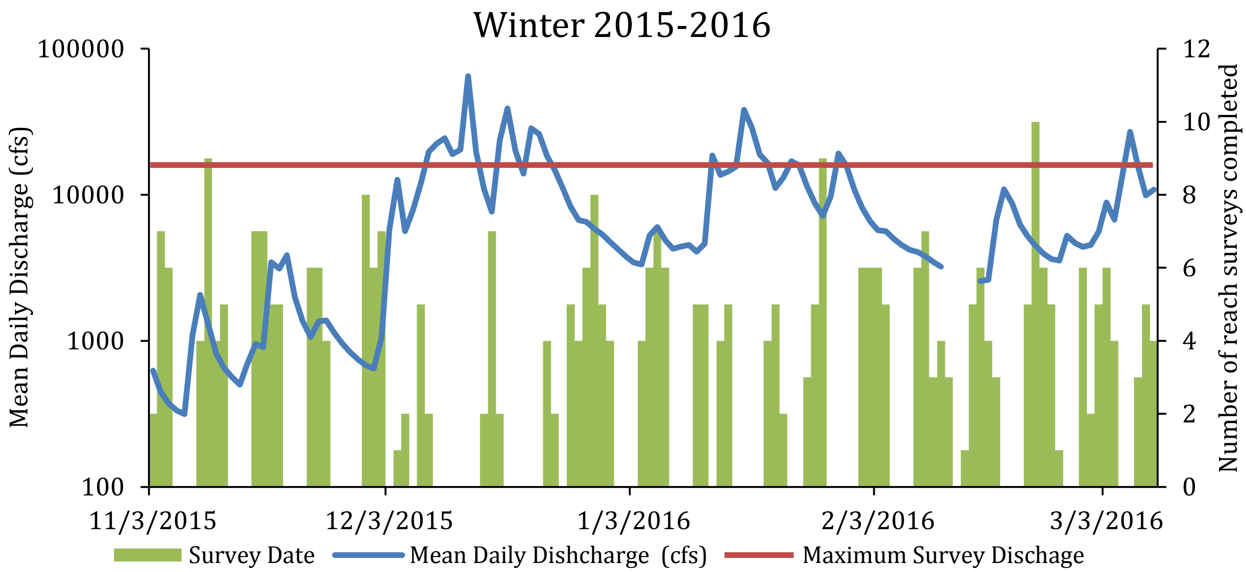

Figure 2. Spawning ground survey effort and timing during the 2015-2016 survey year in the Smith River basin (Del Norte County, CA) as it relates to mean daily river discharge. The dashed red line represents the maximum discharge (16,000 cubic feet per second) where spawner surveys could be safely completed in smaller streams without being impaired by decreased water clarity.

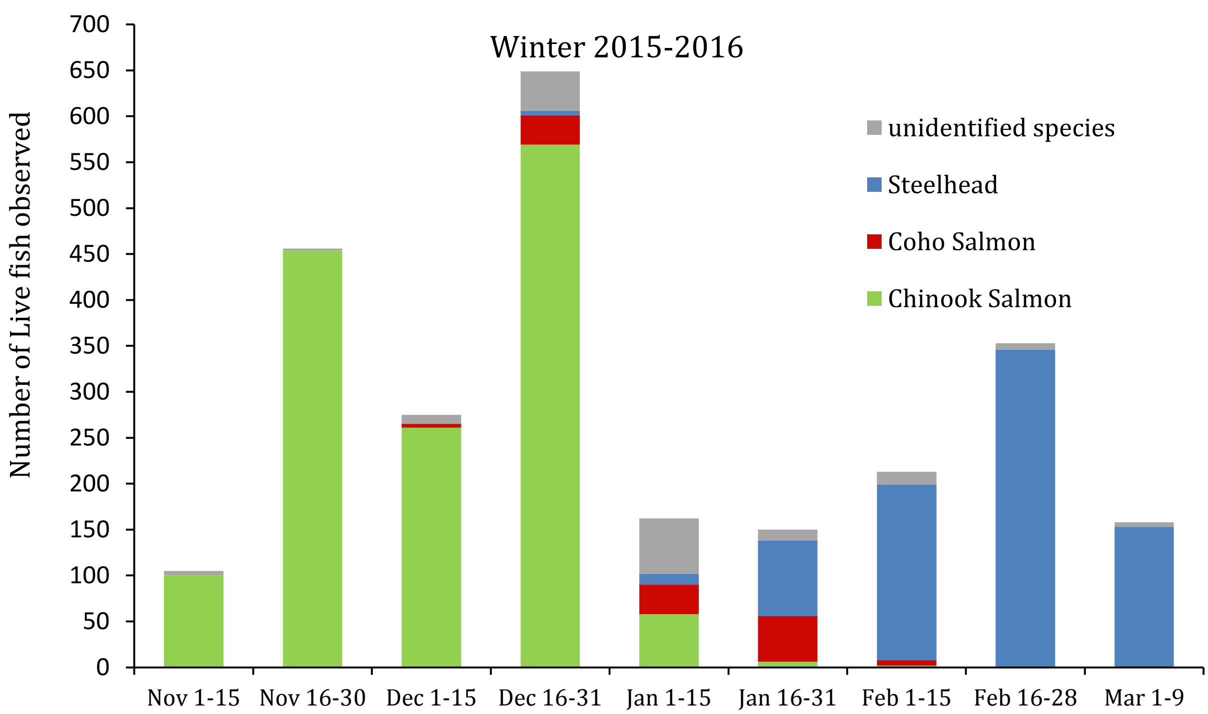

Figure 3. Number of identified live salmonids, by species and survey period, observed during spawner surveys occurring from November 3, 2015 to March 9, 2016 in the Smith River basin, Del Norte County, CA.

Table 2. Summary of live adult and salmonid carcasses observed by species and reach from November 3, 2015 to March 9, 2016, Smith River basin, Del Norte County, CA. Live salmonid totals do not represent individual fish observations since live individuals could be observed over multiple survey periods. All observed salmonid carcasses were uniquely tagged with numbered jaw tags so totals represent the number of tagged carcasses. Location codes with shaded cells were not GRTS drawn for the annual survey but indicate they were surveyed to complete the annual upper Mill Creek census.

		Live salmonids				Salmonid carcasses				
Subbasin	Location Code[a]	Chinook Salmon	Coho Salmon	Steelhead	Unknown species	Chinook Salmon	Coho Salmon	Steelhead	Chum Salmon	Unknown species
Rowdy	58	41	-	400	47	19	-	4	-	-
Rowdy	60	87	-	75	11	13	-	2	-	-
Rowdy	61	127	-	69	5	7	-	-	-	-
Rowdy	69	23	-	-	1	1	-	-	-	-
Rowdy	70	-	-	-	-	-	-	-	-	-
Rowdy	71	-	-	-	-	-	-	-	-	-
Morrison	77	1	-	-	-	-	-	-	-	-
Little Mill	86	160	-	18	3	16	-	-	-	1
Mill	100	34	-	7	3	16	2	-	-	-
WB Mill	**106**	77	1	12	5	18	1	-	-	3
WB Mill	**107**	112	10	32	12	43	2	-	-	3
WB Mill	**108**	53	10	8	4	25	1	1	1	3
WB Mill	**109**	73	10	15	19	40	3	-	-	1
WB Mill	110	112	5	6	7	9	-	-	-	-
WB Mill	**111**	-	-	-	-	-	-	-	-	-
Mill	116	-	-	1	1	3	-	-	-	-
Mill	120	13	-	1	-	2	-	-	-	-
Mill	121	0	-	-	-	0	-	-	-	-
EF Mill	**123**	30	-	12	-	8	1	-	-	-
EF Mill	124	51	1	7	3	9	-	-	-	-
EF Mill	**125**	81	7	16	6	7	3	-	-	-
EF Mill	**126**	7	-	-	-	3	-	-	-	-
EF Mill	**129**	-	-	-	-	-	-	-	-	-
First Gulch	**130**	8	12	1	2	10	2	-	-	-
Kelly	132	91	21	2	9	26	1	-	-	-
Kelly	133	-	5	-	1	-	-	-	-	1
Bummer	**134**	58	10	6	3	6	-	-	-	-
Bummer	**135**	1	-	2	-	-	-	-	-	-
Low Divide	**136**	6	7	-	1	1	-	-	-	-
WB Mill	138	79	2	3	-	15	-	-	-	-
WB Mill	**140**	7	14	-	2	2	2	-	-	-
WB Mill	**141**	6	6	4	4	-	2	-	-	-
WB Mill	**143**	7	4	1	2	4	-	-	-	-
Craig's	172	11	-	19	-	4	-	1	-	-
Rock	196	6	-	4	-	3	-	-	-	-
Hurdygurdy	218	11	-	32	2	-	-	-	-	-
Middle	286	5	-	12	-	-	-	-	-	-
Patrick	303	39	-	5	1	3	-	-	-	1
Patrick	305	8	-	9	-	1	-	-	-	-
Siskiyou	325	25	-	3	3	-	-	-	-	-
Idlewild	333	-	-	-	-	-	-	-	-	-
Griffin	336	-	-	6	1	-	-	-	-	-
Griffin	339	-	-	-	-	-	-	-	-	-
	Total	1450	125	788	158	314	20	8	1	13

[a] *Bold indicates Mill Creek Census reach*

Table 3. Descriptive statistics for observation date of live fish, observation date of known species redds, observation date of carcasses, and carcass fork lengths for the 2015-2016 spawning ground survey season in the Smith River basin, Del Norte County, CA. Totals include data from GRTS drawn reaches and the Mill Creek Lifecycle Monitoring Station census.

		Chinook Salmon	Coho Salmon	Steelhead
Live fish observations:	N	1450	125	788
	Mean	7-Dec-15	11-Jan-2016	15-Feb-16
	SD	17.72	13.82	13.41
	Min	3-Nov-2015	2-Dec-2015	12-Dec-2015
	Max	9-Feb-2016	17-Feb-2016	9-Mar-2016
Live fish sex ratio:	F / M	1 / 0.88	1 / 1.40	1 / 1.47
Known species redd:	N	249	30	67
	Mean	10-Dec-2015	13-Jan-2016	19-Feb-2016
	SD	18	13	15.7
	Min	3-Nov-2015	15-Dec-2015	28-Dec-2015
	Max	9-Feb-2016	2-Feb-2016	8-Mar-2016
Carcass observations:	N	314	20	8
	Mean	29-Dec-2015	20-Jan-2016	14-Feb-2016
	SD	14.7	15.65	12.6
	Min	10-Nov-2015	16-Dec-2015	27-Feb-2016
	Max	27-Jan-2016	15-Feb-2016	02-Mar-2016
Carcass sex ratio:	F / M	1 / 0.74	1 / 0.73	1/ 3.0
Carcass fork length (cm)	N	261	19	7
	Mean	87	61	78
	SD	9	11.7	8.4
	Min	48	38	65
	Max	108	75	92

[a] *Live salmonid totals do not represent individual fish observations since live individuals could be observed over multiple survey periods.*

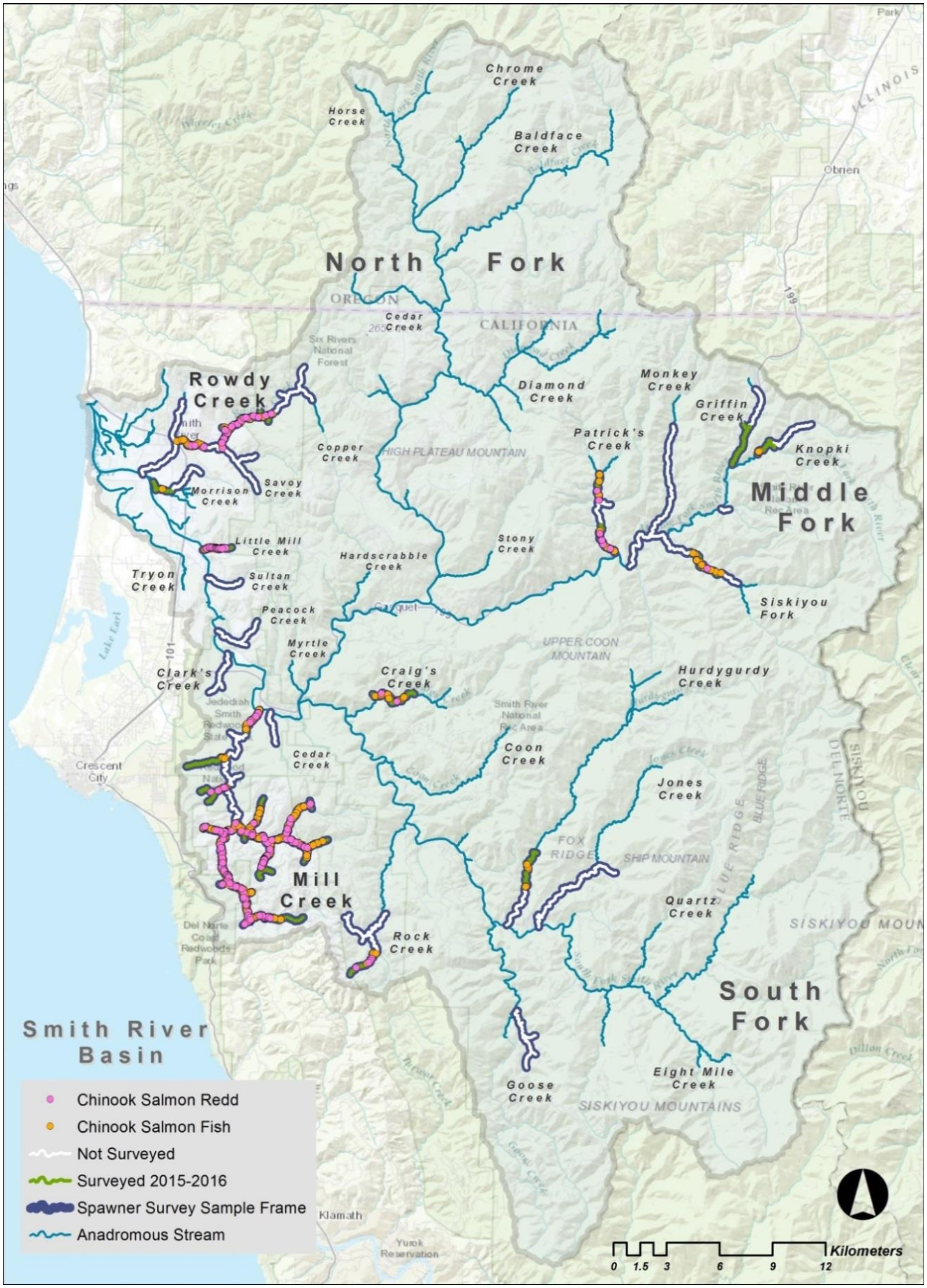

Figure 4. Map showing annual survey reaches, distribution of observed adult Chinook salmon, and verified Chinook salmon redds, Smith River Basin, Del Norte County, CA. Note: redd location symbols are displayed above fish observation symbols and may obscure fish observations in reaches with numerous verified Chinook salmon redds.

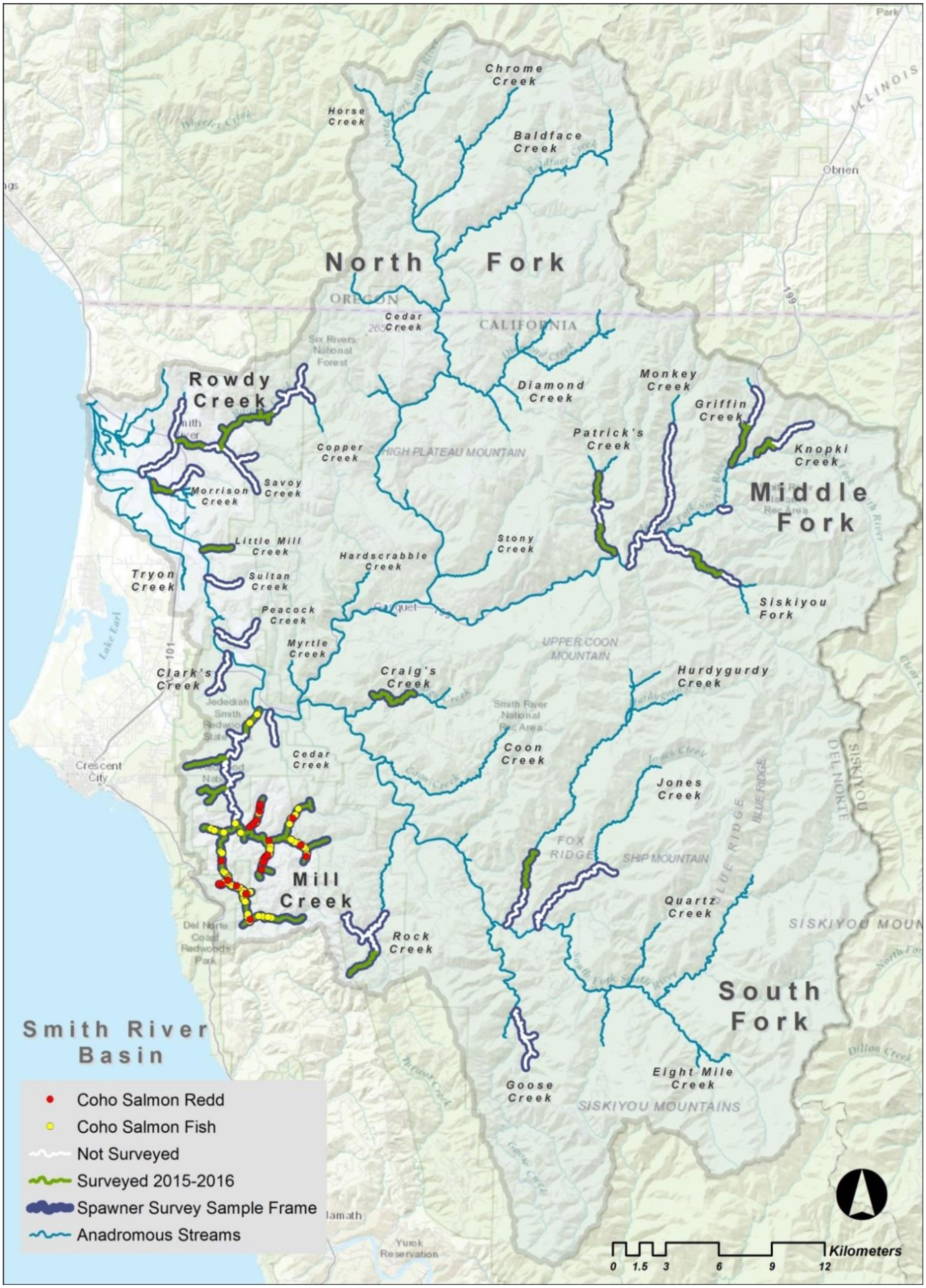

Figure 5. Map showing annual survey reaches, distribution of observed adult coho salmon, and verified coho salmon redds, Smith River Basin, Del Norte County, CA. Note: redd location symbols are displayed above fish observation symbols and may obscure fish observations in reaches containing high densities of verified coho salmon redds.

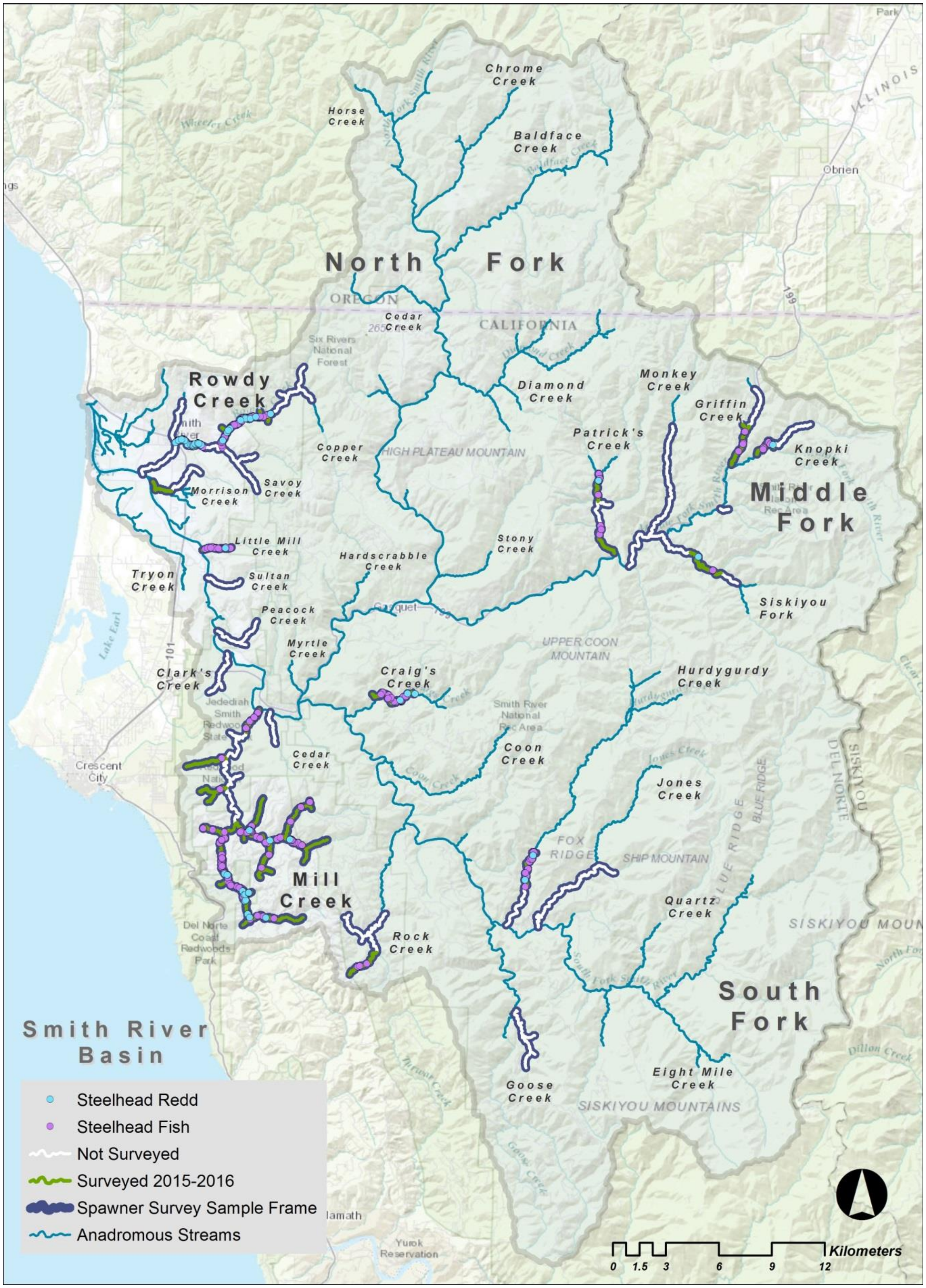

Figure 6. Map showing annual survey reaches, distribution of observed adult steelhead, and verified steelhead redds, Smith River Basin, Del Norte County, CA. Note: redd location symbols are displayed above fish observation symbols and may obscure fish observations in reaches containing high densities of verified steelhead redds.

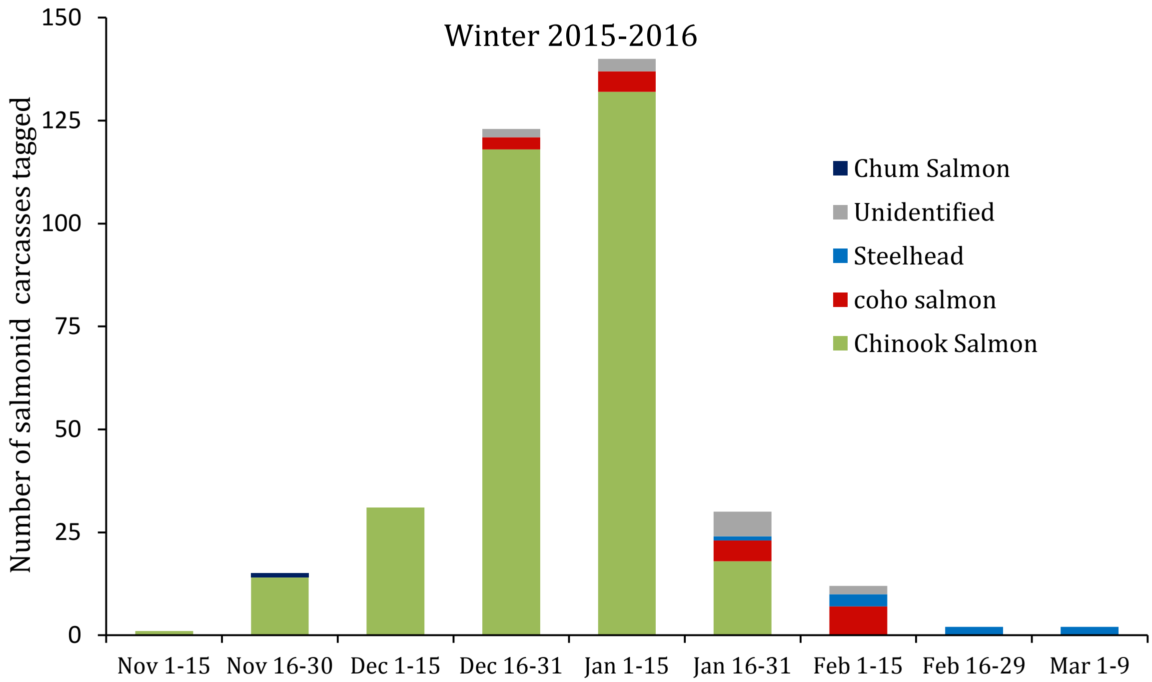

Figure 7. Number of uniquely tagged salmonid carcasses identified by species and survey period during the 2015-2016 spawner survey season, Smith River basin, Del Norte County, CA.

Table 4. Proportion of observed hatchery-origin salmonids summarized by species, observation type, and major subbasin, during the winter 2015-2016 spawning ground surveys conducted throughout the Smith River basin, Del Norte County, CA. Subbasins include Rowdy Creek (all reaches sampled in the subbasin with fish hatchery), Below forks (all reaches sampled in tributaries [excluding Rowdy Creek] below the confluence of the Middle and South forks of the Smith River), and Above forks (all sampled reaches occurring above the confluence of the Middle and South forks of the Smith River). Mill Census (all reaches sampled in the Mill Creek LCS and a component within the Below Forks subbasin) is also given for comparison, Note that live fish and carcass observation totals represent occasions only where an inspection of the individual fish allowed the observer to identify if a fin (adipose or left ventral) or maxillary bone (left or right) were present or absent. Many occasions did not allow for us to inspect the animal for marks based on visual obstructions, distance, water clarity, partial carcass scavenging or carcass decay. Data are from GRTS drawn reaches and the Mill Creek Life Cycle Monitoring Station census reaches.

Live fish observations 2015-2016									
	Coho Salmon			Chinook Salmon			Steelhead		
Subbasin	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	0	0	-	48	15	23.8	1	3	75
Below Forks	44	0	0	539	27	4.8	47	1	2.1
Above Forks	0	0	-	37	0	0	10	0	0
Total	**44**	**0**	**0**	**624**	**42**	**6.3**	**58**	**4**	**6.5**
Mill Census	44	0	0	438	22	4.8	43	0	0
Carcass observations 2015-2016									
	Coho Salmon			Chinook Salmon			Steelhead		
Subbasin	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	0	0	-	20	7	25.9	0	6	100
Below Forks	19	0	0	190	14	6.9	0	0	-
Above Forks	0	0	-	6	0	0	1	0	0
Total	**19**	**0**	**0**	**216**	**21**	**8.9**	**1**	**6**	**85.7**
Mill Census	17	17	0	162	14	8.0	0	0	-

Table 5. Summary of total observed redds separated by reach and species for the winter of 2015-2016, Smith River basin, Del Norte County, CA. Surveys occurred from November 3, 2015 to March 5, 2016. Location codes with shaded cells were not GRTS drawn for the annual survey but indicate they were surveyed to complete the annual upper Mill Creek Life Cycle Monitoring Station census. The number of observed redds per kilometer was calculated by dividing the total number of unique observed redds by the reach length obtained from the USGS National Hydrological Dataset, 24K routed hydrography.

		Number of observed redds by species						# of redds per KM[b]
Subbasin	Location Code[a]	Chinook Salmon	Coho Salmon	Steelhead	Unknown Species	Coastal Cutthroat Trout	Pacific Lamprey	
Rowdy	58	6	-	30	97	-	-	71.5
Rowdy	60	12	-	4	39	-	-	28.9
Rowdy	61	16	-	6	35	-	-	24.6
Rowdy	69	2	-	-	3	-	-	12.0
Rowdy	70	-	-	-	-	-	-	-
Rowdy	71	-	-	-	-	-	-	-
Morrison	77	-	-	-	-	-	-	-
Little Mill	86	40	-	1	19	-	-	34.5
Mill	100	11	-	-	18	-	-	16.1
WB Mill	**106**	15	-	-	60	-	-	35.5
WB Mill	**107**	25	1	3	77	-	-	39.6
WB Mill	**108**	8	1	2	48	-	-	29.0
WB Mill	**109**	7	2	5	54	-	-	36.6
WB Mill	110	13	3	2	29	-	-	18.5
WB Mill	**111**	-	-	-	2	1	-	1.5
Mill	116	-	-	-	3	-	-	1.0
Mill	120	6	-	-	4	2	-	5.2
Mill	121	-	-	-	-	-	-	-
EF Mill	**123**	5	-	1	17	-	-	10.7
EF Mill	124	5	1	1	26	-	-	14.4
EF Mill	**125**	13	1	1	35	-	-	31.5
EF Mill	**126**	1	-	-	7	-	-	5.5
EF Mill	**129**	-	-	-	-	2	-	-
First Gulch	**130**	1	7	-	11	1	-	7.6
Kelly	132	14	1	-	18	6	-	15.3
Kelly	133	-	2	-	2	3	-	6.7
Bummer	**134**	7	1	-	36	-	-	14.7
Bummer	**135**	1	-	-	-	-	-	3.3
Low Divide	**136**	-	1	-	12	-	-	15.1
WB Mill	138	18	-	-	5	2	-	16.1
WB Mill	**140**	2	5	-	9	-	-	21.6
WB Mill	**141**	-	3	2	4	-	-	20.4
WB Mill	**143**	3	1	-	6	-	-	12.0
Craig's	172	2	-	3	16	-	-	6.3
Rock	196	4	-	-	11	2	-	6.1
Hurdygurdy	218	-	-	3	6	-	-	3.3
Middle	286	-	-	1	8	-	-	4.9
Patrick	303	8	-	-	9	-	-	7.6
Patrick	305	3	-	1	6	-	-	6.0
Siskiyou	325	1	-	1	15	-	-	5.8
Idlewild	333	-	-	-	1	-	-	1.8
Griffin	336	-	-	-	5	-	-	1.9
Griffin	339	-	-	-	-	-	-	-
Total		249	30	67	753	19	0	13.8[c]

[a]Bold indicates Mill Creek Census reach, [b]Excludes Coastal Cutthroat Trout redds, [c]Mean value.

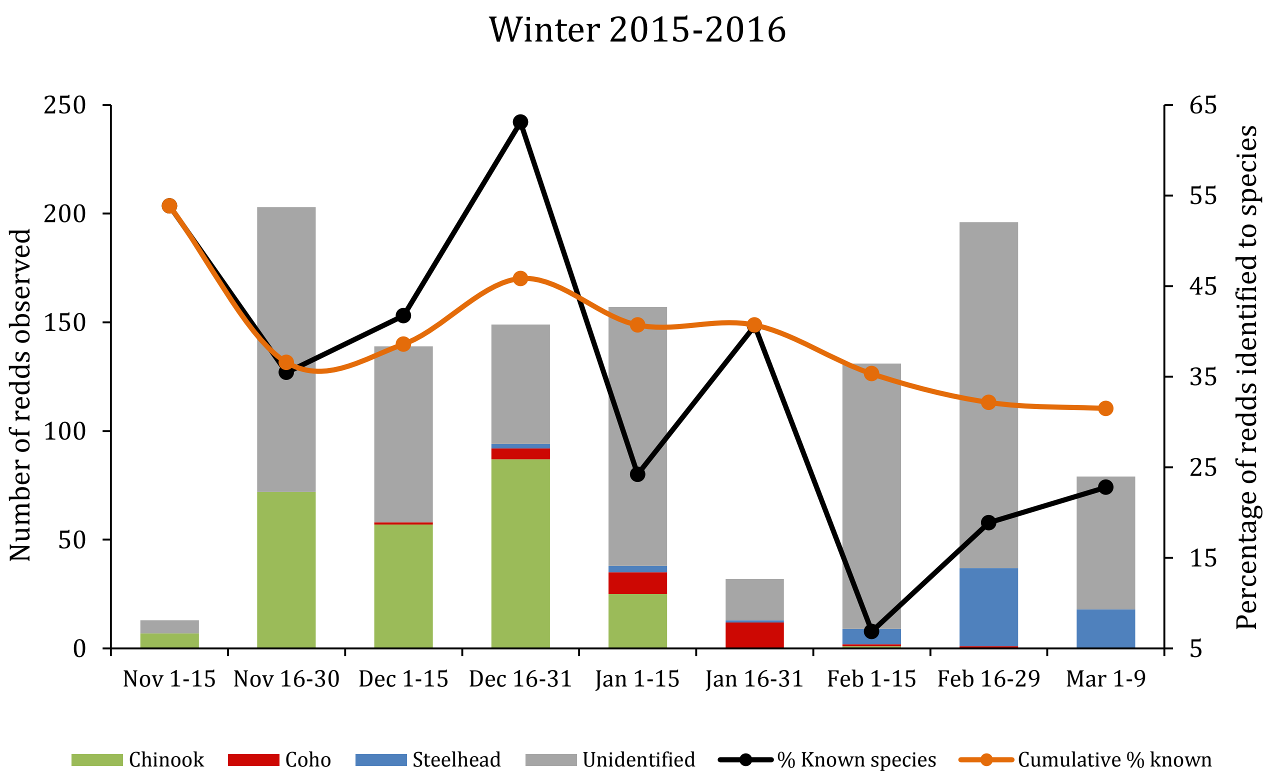

Figure 8. Number of individual salmonid redds observed by survey period during the 2015-2016 spawner survey season in the Smith River basin, Del Norte County, CA. Line plots represent percentages of redds identified to species by survey period through direct observations of live fish actively building or guarding individual redds.

Table 6. Confusion matrix, statistics, and number of redds by species for the 2015-2016 spawning ground survey seasons in the Smith River basin, Del Norte County, CA. Redds were predicted with the kNN algorithm using known species redds and live fish locations as a training dataset. Model performance was assessed using a leave one out cross validation. Data are from GRTS drawn reaches and the additional Mill Creek Life Cycle Monitoring Station census reaches. The number of correctly predicted redds, by species, are identified in bold text. Sensitivity indicates 1- the probability of type II error. Specificity indicates 1- probability of a type 1 error.

Winter 2015-2016		Reference		
		Coho Salmon	Chinook Salmon	Steelhead
Prediction	Coho Salmon	**25**	2	0
	Chinook Salmon	3	**246**	0
	Steelhead	2	1	**67**
	Sensitivity	0.833	0.988	1.00
	Specificity	0.994	0.969	0.989
	Accuracy (95% CI)		0.98 (0.95 - 0.99)	
Number of Redds	Known Species	30	249	67
	kNN Predicted	106	309	338
	Total	136	558	405

Table 7. Estimated total number of redds by species in the Smith River GRTS spawner survey sample frame for the winter of 2015-2016. Components of estimated variance are broken down to the estimation of the number of redds within the reach and estimation of redds by expanding the sample reaches to the entire frame (sample error).

GRTS reaches

	Coho Salmon[a]	Chinook Salmon	Steelhead
Redd estimate	NA	1955	1117
SE	NA	450.5	378
Total within reach variance	NA	1349.5	62.6
Total between reach variance	NA	1258.7	875
% Within reach variance	NA	52	7
% Between reach variance	NA	48	93
95% CI	NA	(1004, 2905)	(325, 1908)

[a]*No known or predicted coho salmon redds were observed outside of the Mill Creek life cycle monitoring station.*

Table 8. Estimated total number of redds by species within the Mill Creek Life Cycle Monitoring Station for the winter of 2015-2016. Components of estimated variance are broken down into the estimation of the number of redds within the reach. There is no between-reach variation since all reaches were surveyed.

Mill LCS

	Coho Salmon	Chinook Salmon	Steelhead
Redd estimate	186	470	206
SE	6.1	16	4.3
Total within reach variance	36.7	256.4	18.4
95% CI	(173,199)	(435,505)	(197,216)

2016 Spatial Structure Survey Results

Sampling Effort and Coho Salmon Occupancy

We surveyed a total of 65 reaches and 22 sub-reaches during the summer of 2016 representing 54.9 percent (162 stream km) of the total sampling frame (Table 9). Surveys extended from June 14th to September 1st with 45 work days and 181 person days. Each survey reach required an average of 1.2 crew days to complete. Juvenile coho salmon were detected in five general regions throughout the basin including the lower Smith River and proximal tributaries, Rowdy Creek, Mill Creek, upper South Fork Smith River, and the North Fork Smith River (Table 9, Figure 9). We documented coho salmon occurring in 26 out of 87 surveyed reaches and within 330 of 1861 sampled pools. The median number of coho salmon observed per pool equaled 9; range: 1 to 154 (Table 9). We determined seven out of the 26 reaches (27%) with coho salmon were non-natal rearing areas (Table 9). However, only one percent of the total fish counted were observed in non- natal reaches. Individual surveyors performed well at detecting juvenile coho salmon in pools. The overall detection probability (p) equaled 0.95 (SE= 0.02). Estimated large-scale probability of occupancy (ψ) equaled 0.30 (SE= 0.05), (Table 10). The estimate of conditional pool-level occupancy, given present in a reach ($\theta|\psi$), equaled 0.47 (SE 0.02) (Table 10). The overall proportion of area

Table 9. Summary statistics of coho salmon occupancy and relative abundance based on snorkel surveys occurring in 87 GRTS drawn reaches during the summer of 2016, Smith River Basin, California and Oregon.

Subbasin	Location code	Reach length (m)	Number of units surveyed	Number of units occupied	Mean pool count	Total number observed	Rearing type
Smith River	6	798	3	0		0	
Smith River	7	1639	2	0		0	
Smith River	11	2765	2	0		0	
Smith River	12	3335	8	3	8.0	24	Non-natal
North Fork Smith River	33	2491	34	8	1.4	11	Non-natal
North Fork Smith River	35	2090	27	1	2.0	2	Natal
North Fork Smith River	36	1902	57	10	1.2	12	Natal
Smith River	47	597	3	2	6.5	13	Non-natal
Tryon Creek	52	3505	27	1	NA	1	Non-natal
Rowdy Creek	57	3216	11	4	3.0	12	Natal
Rowdy Creek	62	2278	18	0		0	
Rowdy Creek	65	2727	28	0		0	
Rowdy Creek	67	2492	38	0		0	
Rowdy Creek	72	579	9	0		0	
Rowdy Creek	73	1098	16	0		0	
Coastal Plain	79	1407	13	0		0	
Coastal Plain	86	1737	35	1	NA	1	Non-natal
Coastal Plain	87	2273	32	0		0	
Mill Creek	101	1944	16	10	4.1	41	Natal
Mill Creek	105	1412	9	9	61.6	554	Natal
Mill Creek	106	2111	26	26	24.7	641	Natal
Mill Creek	109	1801	10	10	85.8	858	Natal
Mill Creek	110	2382	46	41	29.3	1201	Natal
Mill Creek	111	1358	8	2	5.5	11	Natal
Mill Creek	114	603	6	0		0	
Mill Creek	116	2990	51	0		0	
Mill Creek	120	1921	17	0		0	
Mill Creek	121	770	7	0		0	
Mill Creek	130	2506	51	45	12.0	538	Natal
Kelly Creek	132	2482	56	46	18.0	830	Natal
Kelly Creek	133	593	11	0		0	
Bummer Lake Creek	134	2997	82	33	14.6	482	Natal
Bummer Lake Creek	135	300	9	0		0	
Hamilton Creek	138	1427	30	19	5.9	113	Natal
Mill Creek	143	835	8	8	26.5	212	Natal
Smith River	146	2351	44	1	1.0	1	Non-natal
South Fork Smith River	159	2461	7	0		0	
South Fork Smith River	164	2852	15	0		0	
South Fork Smith River	166	3582	42	5	1.6	8	Non-natal
South Fork Smith River	167	2445	22	0		0	
Craigs Creek	171	2473	33	0		0	
Craigs Creek	172	3310	40	0		0	
Craigs Creek	175	230	7	0		0	
Rock Creek	189	2075	24	0		0	
Rock Creek	192	151	2	0		0	
Rock Creek	193	2280	29	0		0	
Rock Creek	194	296	4	0		0	
Rock Creek	195	171	3	0		0	
Goose Creek	204	2809	17	0		0	
Goose Creek	212	1746	23	0		0	
Goose Creek	213	2292	39	0		0	
Goose Creek	214	188	3	0		0	
Goose Creek	215	840	7	0		0	
Goose Creek	216	319	5	0		0	
Hurdygurdy Creek	218	2696	17	0		0	
Hurdygurdy Creek	219	2729	15	0		0	
Hurdygurdy Creek	220	3155	24	0		0	
Hurdygurdy Creek	223	2984	34	0		0	
Hurdygurdy Creek	230	1835	32	0		0	
Hurdygurdy Creek	232	1046	20	0		0	
Jones Creek	234	2445	18	3	1.0	3	Natal
Jones Creek	235	2210	12	2	1.0	2	Natal
Quartz Creek	250	2999	34	0		0	
Quartz Creek	251	1944	22	0		0	
Myrtle Creek	263	2347	44	0		0	
Middle Fork Smith River	276	3987	7	0		0	
Middle Fork Smith River	281	3888	10	0		0	
Middle Fork Smith River	286	1823	24	0		0	
Patricks Creek	303	2250	32	0		0	
Monkey Creek	319	2674	44	0		0	
Siskiyou Fork	324	2511	20	0		0	
Siskiyou Fork	326	1187	10	0		0	
Siskiyou Fork	331	1888	24	0		0	
Idlewild Creek	333	542	13	0		0	
Idlewild Creek trib.	334	67	3	0		0	
Griffin Creek	336	2600	24	0		0	
Griffin Creek	339	357	6	0		0	
Knopki Creek	344	3225	63	0		0	
Cedar Creek	382	2548	45	0		0	
Baldface Creek	391	2823	26	14	6.6	92	Natal
Baldface Creek	392	2473	34	23	9.0	208	Natal
Baldface Creek	393	731	11	3	1.0	3	Natal
Baldface Creek	400	144	5	0		0	
Baldface Creek	402	771	6	0		0	
Baldface Creek	403	78	3	0		0	
North Fork Smith River trib.	419	373	2	0		0	
North Fork Smith River trib.	422	249	5	0		0	
Totals			1861	330	17.8	5874	

occupied (θ ∗ ψ) equaled 0.14 or 14% of the total sample frame. Last, we incidentally detected juvenile coho salmon in one additional reach; Location code 96 (Clark's Creek) that was not part of the GRTS sample draw but was surveyed as a training reach before official surveys began (Figure 9).

Occupancy of Chinook Salmon and Trout Species

Reach-level occupancy (ψ) estimates and pool densities for individual salmonid species other than coho salmon (i.e. Chinook salmon, age 0 and 1+ juvenile trout spp., adult coastal cutthroat trout) are reported in Table 10. All groups were widely distributed throughout the basin during the summer of 2015 (Table 10, Figures 10, 11, 12) with ψ ranging from 0.69 (Chinook salmon) to 1.00 (1+ trout spp.) (Table 10). Adult coastal cutthroat trout were found in 60 reaches with ψ estimated at 0.86. The estimate of conditional pool-level occupancy (θ), given present in a reach (θ|ψ), varied more between species. Adult coastal cutthroat trout were estimated to occur in 25% of the pools. Chinook salmon had a slightly larger estimated pool-level occupancy at 35% of the pools. Last, both YOY and 1+ trout were widely distributed in pools with pool-level occupancies estimated at 0.98 and 0.81, respectively (Table 10).

Table 10. Occupancy estimates, proportion of area occupied, and relative count densities of salmonids observed during the summer of 2016, Smith River basin, California and Oregon.

Species	PSI	SE	95% CI	Theta	SE	95% CI	*p*	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count
Coho Salmon	0.30	0.05	0.21 - 0.41	0.47	0.02	0.43 - 0.51	0.95	0.02	0.90 - 0.97	0.14	25 of 87	17.8	9
Chinook Salmon	0.69	0.06	0.57 - 0.79	0.35	0.02	0.31 - 0.39	0.76	0.03	0.70 - 0.81	0.27	52 of 87	6.0	3
Trout (YOY)	0.97	0.02	0.90 - 0.99	0.98	<0.01	0.97 - 0.99	0.98	<0.01	0.97 - 0.99	0.95	82 of 87	21.3	14
Trout (1+)	1.00	–	–	0.81	0.01	0.78 - 0.84	0.86	0.01	0.83 - 0.88	0.81	79 of 87	4.3	3
Adult Cutthroat Trout	0.86	0.05	0.73 - 0.94	0.25	0.02	0.22 - 0.29	0.65	0.04	0.56 - 0.73	0.22	60 of 87	1.4	1

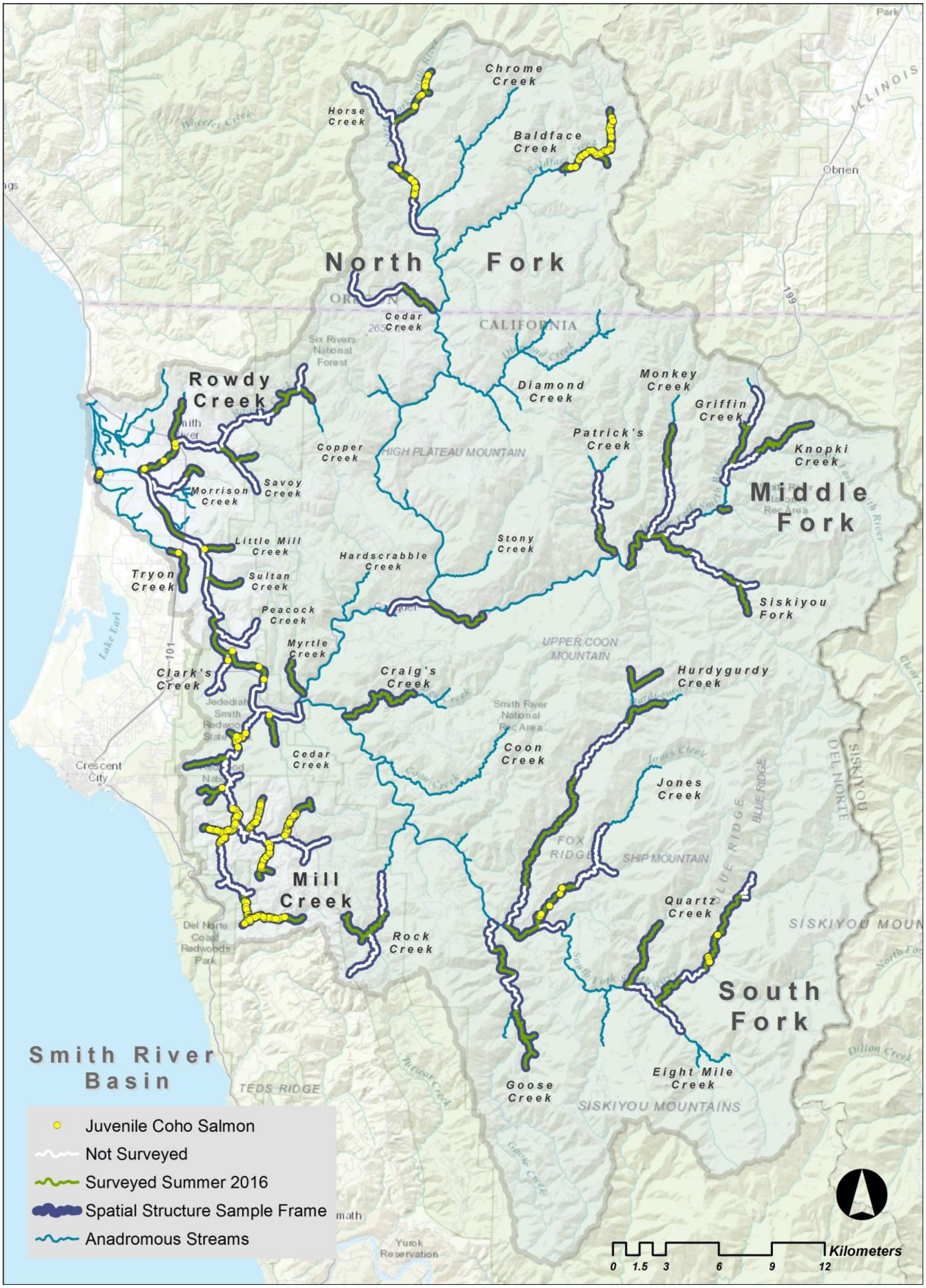

Figure 9. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing juvenile coho salmon from summer 2016, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

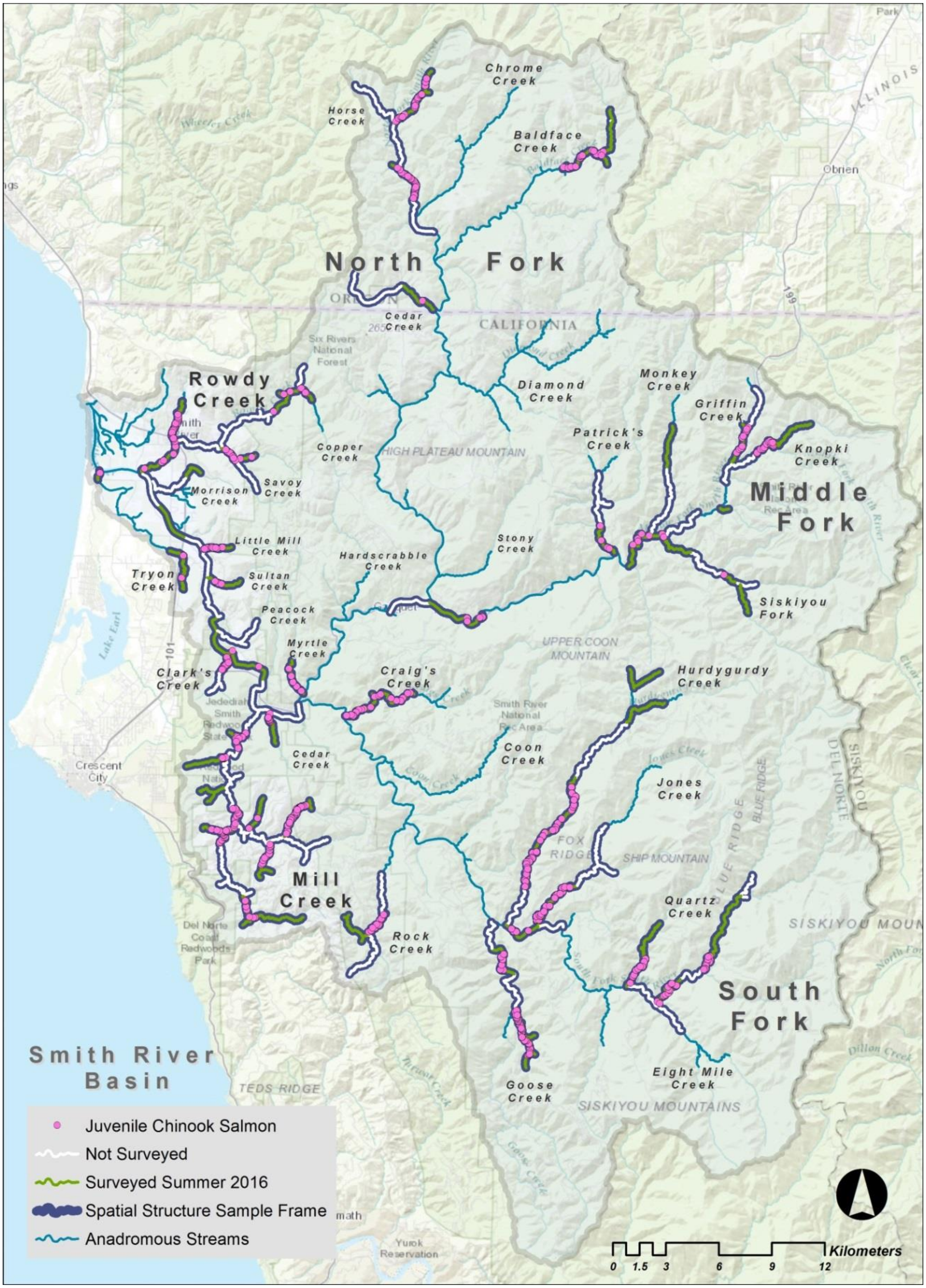

Figure 10. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing juvenile Chinook salmon from summer 2016, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

Figure 11. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing juvenile trout (spp.) from summer 2016, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

Figure 12. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing adult coastal cutthroat trout from summer 2015, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

2011 to 2016 Spawner Survey Results

Survey Conditions and Effort

Our adult coho salmon sample frame development process resulted in a sampling frame comprised of 68 primary reaches and 30 sub-reaches with a total stream length of approximately 161.8 km or 78 percent of the estimated total coho salmon spawning habitat in the Smith River basin. Spawning surveys were conducted on 63 of the 68 primary and 24 of the 30 sub-reaches during five survey seasons spanning October 31, 2011 through March 9, 2016. A total of 1,896 individual stream surveys were completed on GRTS and Mill Census reaches between the fall of 2011 and the spring of 2016 (Table 11). A total of 3,346 stream kilometers was surveyed during the five survey seasons. Annual overviews of survey conditions and expended effort during the first four years of the survey can be found in Garwood and Larson (2014), Garwood et al. (2014) and Walkley and Garwood (2015).

Chinook Salmon

We observed a total of 8,940 live Chinook salmon in 60 individual reaches and 11 sub-reaches during the five years of this sampling program (see Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015, Table2, and Figures in Subbasin section). Mean observation date of live Chinook salmon across all survey years was December 8 (Table 12, Figure 13). Minimum observation date was November 3 and maximum observation date was February 11. Chinook salmon were observed before November 7 during all five survey years, however, relatively few adult Chinook were observed in the early half of November during 2011-2012 and 2013-2014 (Figure 15). During 2013-2014, for example, only three live Chinook salmon were observed between November 6 and November 22. Numbers of observed live Chinook salmon remained elevated into early January during most survey years and then decreased. Chinook salmon were occasionally observed on surveys after mid-January. Numbers of observed live Chinook salmon during the 2013-2014 survey year, however, remained elevated into the end of January. The later run-timing during the 2013-2014 survey season was likely a result of the dry conditions that persisted into early January. The entire 2013-2014 survey season was marked by exceptionally dry conditions resulting in extremely low stream discharge. Rainfall at the Gasquet Ranger Station totaled 59% of average during the survey period however, rainfall from November through the end of January was just 24% of average (CDEC 2014). In other years, observations of live fish increased after episodic storm events. Due to the lack of these episodic storm events, adults did not have the important environmental cues triggering migration into the Smith River from the Pacific Ocean. Stream flows during this period may also have been low enough to prevent adult migration into and within tributaries or even within the Smith River mainstem.

A total of 2,116 Chinook carcasses were marked with unique tags during the five survey years in the adult sampling frame. Carcasses were encountered in 56 primary reaches (2102 carcasses) and 5 sub-reaches (14 carcasses) (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015). The majority of these carcasses were encountered in the Mill Creek (52%) and Rowdy Creek (37%) subbasins. Chinook salmon carcasses were encountered in Clarks Creek and Hurdygurdy Creek. Over the five survey years, the first Chinook salmon carcass was captured on November 4 and the last was encountered on February 23 (Table 12). Mean Chinook salmon carcass observation date was December 27.

We observed a total of 1,655 Chinook salmon redds in the adult sampling frame during both GRTS and Mill LCS census surveys across the five survey years. Chinook salmon were observed building or guarding redds in 55 primary reaches (1,627 redds) and 9 sub-reaches (28 redds) (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015). Chinook salmon redds were encountered from November 3 through February 9 with a mean observance day of December 6 (Table 12, Figures 14 and 16). Cumulative daily observations of redds for the five survey years show a primary Chinook salmon reproductive effort extending from early November into late December and a second, smaller reproductive effort during early January(Figure 14). This pattern can be seen during the 2011-2012 and the 2015-2016 seasons (Figure 16). Forty-six percent of all chinook redds were observed in Rowdy Creek and 31percent were observed in Mill Creek. Survey reaches within these two subbasins generally had the highest mean annual Chinook salmon redd counts across survey years (Figure 17).

Coho Salmon

A total of 1,380 live coho salmon were observed in 20 primary reaches (1,214 coho salmon) and six sub-reaches (166 coho salmon) in the sampling frame during the five survey seasons. Most live coho salmon were observed within the Mill LCS or in mainstem Mill Creek reaches (see subbasin section). Live individuals were also observed intermittently in Rowdy Creek and one live male coho salmon was observed in Hurdygurdy Creek in January of 2013. Mean observation date of coho salmon across all five survey years was January 23 and coho salmon were encountered from November 25 to March 7 (Table 12, Figure 13 and Figure 15). Observations of small numbers of live coho salmon adults were made during late November or early December during each survey year, with observed numbers of live individuals increasing by late December or early January in four out of the five survey years (Figure 15). Live coho salmon observations during the 2013-2014 survey did not increase until after mid-January. Water visibility and viewing conditions on surveys during December 2013 through mid-January 2014 were excellent due to a prolonged dry period and reach revisit rates were high. As was the case for Chinook salmon, the prolonged dry period and its associated low stream flows likely inhibited coho salmon movement into and within Mill Creek.

We encountered a total of 196 coho salmon carcasses in 19 reaches (181 individual coho salmon carcasses) and three sub-reaches (14 individual coho salmon carcasses) over the five survey seasons (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015, Table 2). One hundred and eighty coho salmon carcasses were encountered within the Mill LCS (92% of coho salmon carcasses) and 10 carcasses were encountered in the six main stem Mill Creek reaches. Four carcasses were encountered in Rowdy Creek and one coho salmon carcass was observed upstream of the Highway 101 culvert in Morrison Creek. Mean coho salmon carcass observation date across all five survey seasons was February 2 with coho salmon carcasses encountered from December 6 to March 4.

We identified 293 coho salmon redds during the five survey seasons. All identified coho salmon redds were observed within the Mill Creel LCS and no coho salmon were observed guarding or building redds during spawning surveys in other portions of the survey frame. Coho salmon redds were identified in 12 primary reaches (238 redds) and 6 sub-reaches (55 redds) (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015, Table 5). The mean survey date coho salmon were observed constructing redds across the five survey seasons was January 24, with the earliest redd observed on November 25 and the latest redd observed on February 27 (Table 12, Figure 14 and Figure 16).

Steelhead

We observed a total of 2,519 live steelhead in 59 primary reaches (2,489 steelhead) and 6 sub-reaches (30 steelhead) in the spawner sampling frame. Mean observation date of live steelhead across all five survey years was February 12 and live steelhead were encountered from November 17 to March 9 (Table 12, Figure 13, Figure 15). Numbers of steelhead observed increased during the latter part of each of the five seasonal survey efforts. Thus our observations only represent only a portion of the steelhead spawning season.

We encountered a total of 20 steelhead carcasses between fall 2011 and winter 2016 on spawning surveys in GRTS and Mill LCS census reaches. All steelhead carcasses were encountered in primary reaches. Twelve carcasses were observed in Rowdy Creek; four were observed in Mill

Creek and one carcass was recovered in Craig's Creek, Griffin Creek and Hurdygurdy Creek (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015 and Table 2). Mean observation date of steelhead carcasses was February 14 across the five survey years and carcasses were observed from January 22 to March 2.

We observed 180 steelhead redds during the five survey years in 40 primary reaches (171 redds) and 4 sub-reaches (9 redds) (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015 and Table 5). Mean annual proportion of observed steelhead redds was highest in Rowdy Creek (Figure 17). Forty-six percent of steelhead redds were observed in Rowdy Creek, 31% were observed in the Mill Creek subbasin, 26% were observed in South Fork Smith River subbasin reaches, 8 % were observed in Middle Fork subbasin reaches and 6% of steelhead redds were observed in coastal plain tributaries (see subbasin section maps). Mean observation date for steelhead redds across the five survey seasons was February 12 and steelhead redds were observed from December 28 to March 8 (Table 12).

Coastal Cutthroat Trout and Pacific Lamprey

A total 316 live coastal cutthroat trout were identified on spawning surveys from the fall of 2011 through the winter of 2016 in 23 primary reaches (306 individuals) and five sub-reaches (14 individuals) (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015 and Table 2). Mean observation date across all five survey seasons was December 28 and live individuals were first observed on November 2 and final observations occurred on February 20. Only seven coastal cutthroat trout carcasses were found during the five survey years. Six of these carcasses were found in the Mill LCS and one was recovered in the Upper Middle Fork.

We observed a total of 224 coastal cutthroat trout redds in GRTS and Mill LCS census reaches (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015 and Table 5). Because of their small size (often under 100 cm total length) – yet fully developed features compared to Chinook salmon, coho salmon and steelhead redds or test digs – trained surveyors were able to identify a redd as a cutthroat redd without observing live fish actively guarding and occupying it. Coastal cutthroat trout redds were observed in 22 primary reaches (194 redds) and 8 sub-reaches (30 redds). Across the five sampling seasons the first coastal cutthroat trout redd was observed on November 7 and the last was observed February 27. Mean observation date for coastal cutthroat redds was January 19.

All Pacific lamprey individuals and redds identified as Pacific lamprey redds during spawning surveys were observed within the Mill Creek LCS (Garwood and Larson 2014, Garwood et al 2014 and Walkley and Garwood 2015 and Tables 2 and 5). A total of six live Pacific lamprey adults were observed during spawning surveys over the five survey seasons. Mean observation date of live Pacific lamprey was February 12 and Pacific lamprey were observed between December 30 and February 25. Only two carcasses were detected. We observed a total of 14 Pacific lamprey redds during the five survey seasons, three of which were actively being constructed by live individuals. Pacific Lamprey redds were observed from February 18 to March 4, with a mean observation date of February 28 across all five survey seasons. We suspect Pacific lamprey spawn later in the spring based on other results from other studies in coastal streams (Gunckel et al. 2009, C. Anderson pers. comm.). Rowdy creek weir is a barrier to Pacific lamprey migration.

Hatchery Origin Salmonid Observations

The Smith River is unique given it has the only privately run salmon and steelhead fish hatchery in the State of California. Large salmonid hatcheries operate throughout California and were implemented as mitigation to habitat loss imposed by hydroelectric dams. The Rowdy Creek Fish Hatchery was constructed shortly after the 1964 flood based on local citizens concerns over a declining river fishery. The long-term objective of the facility has been to enhance the in-river catchable population of Smith River Chinook salmon and steelhead. This study identified hatchery salmonids throughout the Smith River by inspecting live fish and carcasses for clipped adipose fins during spawning ground surveys (Table 13, Figure 18). Based on our effort, the overall observed distribution of hatchery marked salmonids was concentrated in Rowdy Creek, Mill Creek, and a few coastal tributaries occurring below the Smith River forks (Figure 18). Overall, Rowdy Creek contained the highest percentage of hatchery Chinook salmon (24% live, 33% carcass) followed by tributaries occurring below the Smith River forks excluding Rowdy Creek (5.4% live, 8.8% carcasses) (Table 13, Figure 18). Upper Mill Creek had 5.3 percent live strays and 9.8 percent carcass strays on average over the five years. We observed three live hatchery Chinook salmon out of a total of 464 observations (0.6%) in tributaries above the Smith River forks including Jones Creek, Upper Middle Fork Smith River, and Siskiyou Fork (Table 13. Figure 18). Given steelhead carcasses are rarely encountered, the best information we collected on hatchery strays was based on live steelhead observations. Overall Rowdy Creek contained the highest percentage of hatchery steelhead (28%) followed by tributaries occurring below the man river forks excluding Rowdy Creek (5.3%) (Table 13). Upper Mill Creek had 3.3 percent strays on average over the five years. Although sample sizes were small, no marked hatchery steelhead were observed above the Smith River forks over the five years of this study. Last, Rowdy Creek Fish Hatchery does not raise coho salmon, however, we did find three stray individuals out of 466 coho salmon having hatchery maxillary bone clips derived from the Klamath and Trinity River hatcheries (Table 13) (Garwood and Larson 2014, Garwood et al. 2014).

Redd Abundance

The estimated number of Chinook salmon redds in the GRTS spawner sample frame for the 2015-2016 season was similar to estimates derived for the 2014-2015 (114%) and the 2012-2013 (109%) spawning seasons. Estimated Chinook salmon redd abundance for the 2015-2016 spawning season was much higher than the estimate for the 2013-2014 season (379%), however, it was only 51 percent of the 2011-2012 season estimate (Figure 19). The steelhead redd estimate for the 2015-2016 season was slightly higher than during the previous four seasons. As was the case with Chinook salmon, steelhead redd estimates were lowest for the 2013-2014 season. Estimated redd abundance for the 2015-2016 season equaled 123 percent of the 2014-2015, 315 percent of the 2013-2014 estimate, 161 percent of the 2012-2013 estimate and 107 percent of the 2011-2012 estimate (Figure 19).

Because we did not detect or predict any coho salmon redds outside of the Mill Creek LCS over the five survey years we report only redd abundance estimates of coho salmon for the Mill LCS subbasin (Figure 19 and Figure 20). The estimated number of coho salmon redds in Mill Creek in 2015-2016 equaled 125 percent of the 2014-2015 estimate, 72 percent of the 2013-2014 estimate, 82 percent of the 2012-2013 estimate, and 39 percent of the 2011-2012 estimate (Figure 20). Estimates of annual Chinook salmon redd abundance across the 5 years in the Mill LCS subbasin followed a similar pattern to estimates generated for the broader GRTS sampling frame. Annual estimates of steelhead redds were lowest during the 2013-2014 season and highest during the 2015-2016 season. The estimated number of steelhead redds in 2015-2016 was 157 percent of the 2014-2015 estimate, 327 percent of the 2013-2014 estimate, 178 percent of the 2012-2013 estimate and 186 percent of the 2011-2012 estimate.

Table 11. Spawning survey effort across five field seasons spanning Fall of 2011 through winter 2016 in the Smith River basin.

Year	# Reaches surveyed	# Sub reaches surveyed	# of surveys	Stream length surveyed (km)	% of total sample frame surveyed	Avg # days between revisit	Proportion of season available to survey
2011-2012	36	13	388	677.1	41	14.2	0.82
2012-2013	33	15	398	685.5	35	12.6	0.77
2013-2014	27	12	343	682.4	29	16.3	0.86
2014-2015	30	11	414	714.7	27	14	0.82
2015-2016	30	13	353	587.1	29	17	0.73
Totals:	156	64	1896	3346.8	32.2[a]	14.82[a]	0.80[a]

[a]=Mean value

Table 12. Descriptive statistics for observation date of live fish, observation date of known species redds, observation date of carcasses, and carcass fork lengths for five survey seasons from 2011-2012 through 2015-2016 in the Smith River basin, Del Norte County, CA. Survey day is standardized for the 130 day period beginning on November 1 of each survey season (Day 1) and extending to the end spawning surveys each survey year including February 29 on leap years (max 130). Totals include data from GRTS drawn reaches and the Mill Creek Lifecycle Monitoring Station census.

		Chinook Salmon	Coho Salmon	Steelhead
Live fish observations:	N	8,940	1,379	2,519
	Mean	8-Dec	23-Jan	12-Feb
	SD	99.3	21	43.8
	Min	3-Nov	25-Nov	17-Nov
	Max	11-Feb	7-Mar	9-Mar
Live fish sex ratio:	F / M	1 / 1.02	1 / 1.29	1 / 1.50
Known species redd:	N	1,655	293	180
	Mean	6-Dec	24-Jan	12-Feb
	SD	22.7	4.8	3.4
	Min	3-Nov	25-Nov	28-Dec
	Max	9-Feb	27-Feb	8-Mar
Carcass observations:	N	2,116	195	20
	Mean	27-Dec	2-Feb	14-Feb
	SD	16.8	19.5	10.96
	Min	4-Nov	6-Dec	22-Jan
	Max	23-Feb	4-Mar	2-Mar
Carcass sex ratio:	F / M	1 / 0.84	1 / 0.73	1 / 1.57
Carcass fork length (cm)	N	1,844	167	16
	Mean	85.4	66.6	77.4
	SD	13.8	9.8	7.1
	Min	42	38	65
	Max	120	84	92

[a]*Live salmonid totals do not represent individual fish observations since live individuals could be observed over multiple survey periods.*

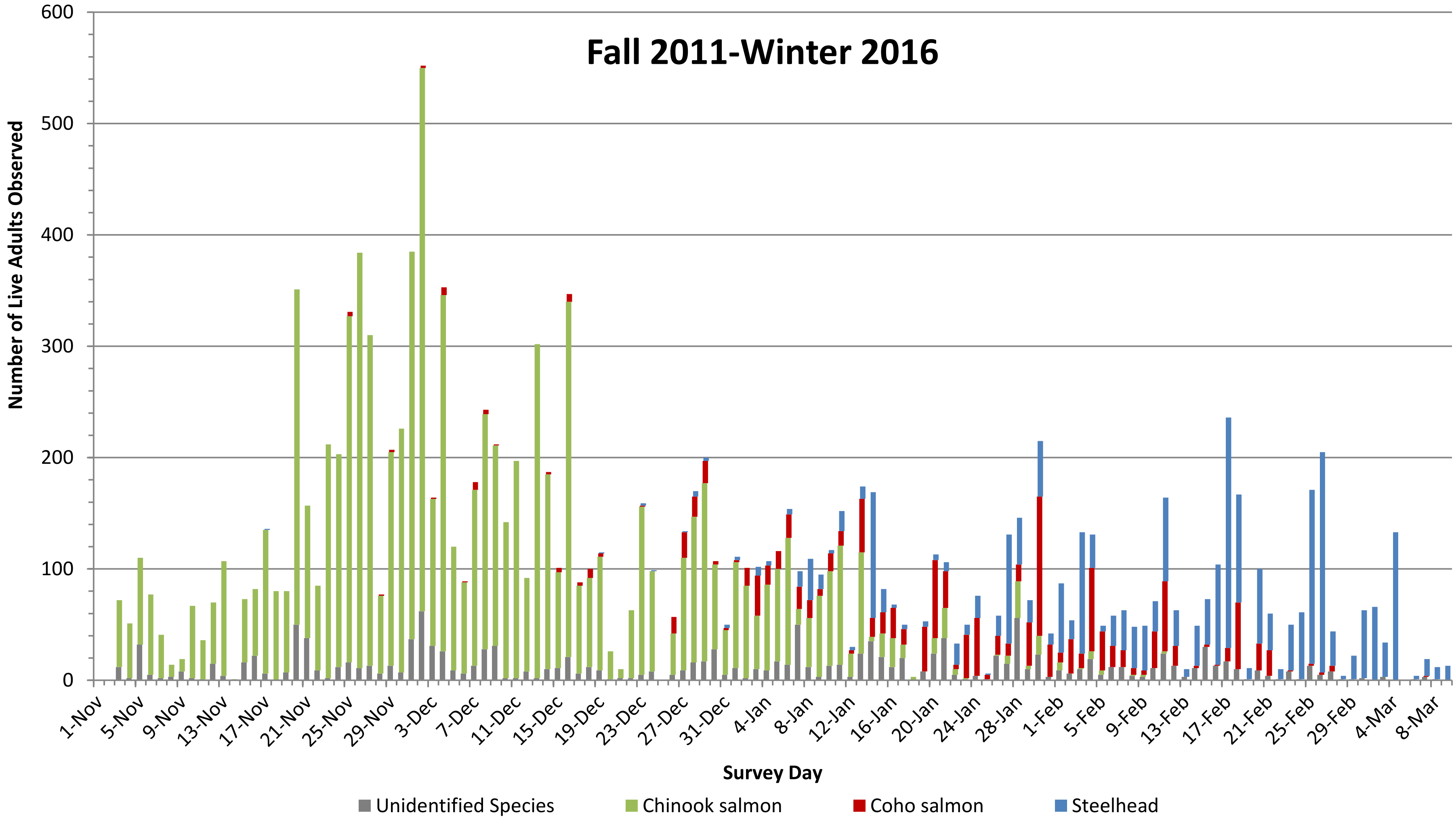

Figure 13. Number of live adult salmonids observed by survey day during 2011-2012 through 2015-2016 during GRTS and Mill Creek Census spawner surveys. Survey day is standardized for the 130 day period beginning on November 1 of each survey season (Day 1) and extending to the end spawning surveys each survey year including February 29 on leap years (max 130).

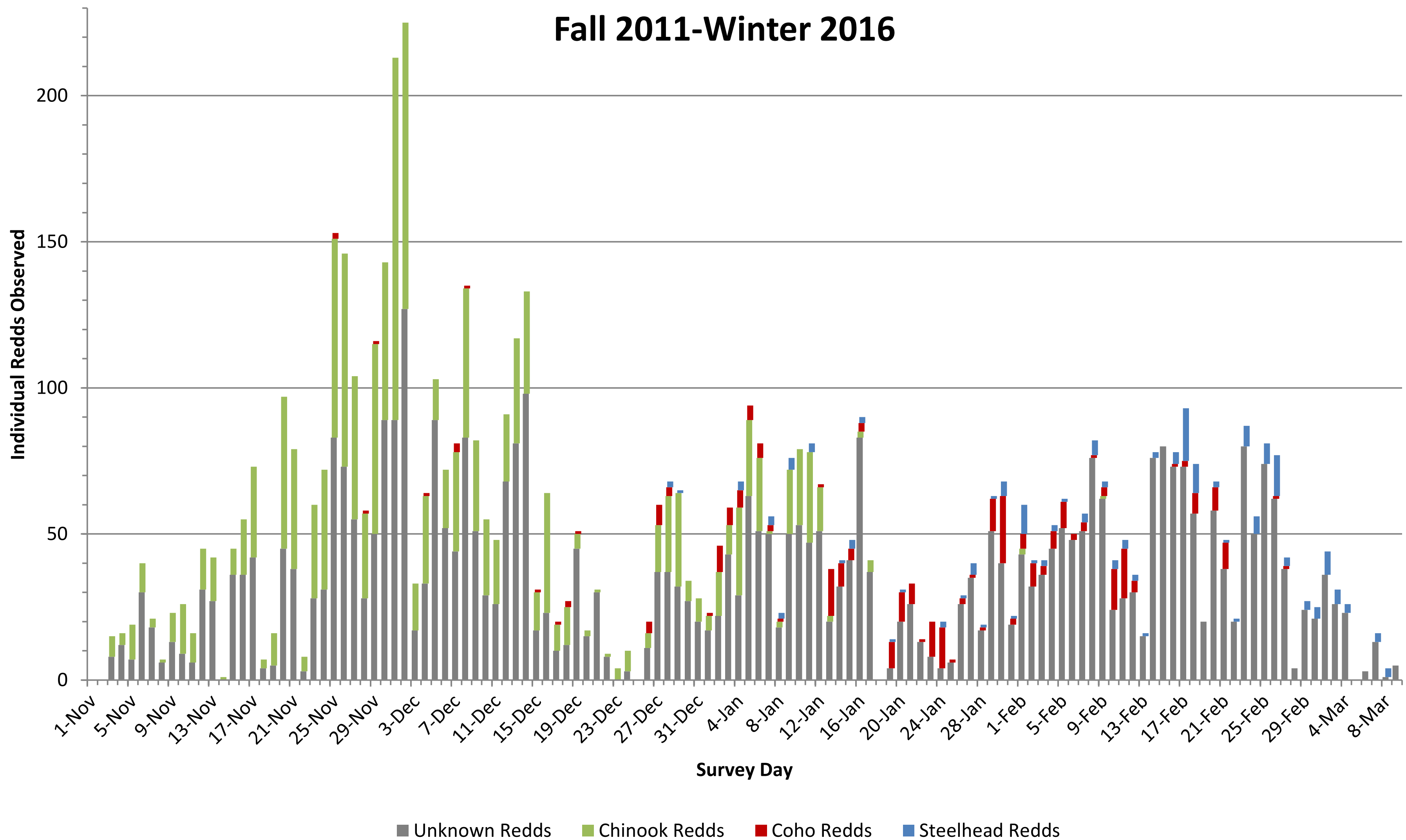

Figure 14. Sum of individual salmonid redds observed by survey day during 2011-2012 through 2015-2016. Data include redds observed during GRTS and Mill Creek Census spawner surveys. Survey day is standardized for the 130 day period beginning on November 1 of each survey season (Day 1) and extending to the end spawning surveys each survey year including February 29 on leap years (max 130). Redds were identified to species through direct observations of live fish actively building or guarding them.

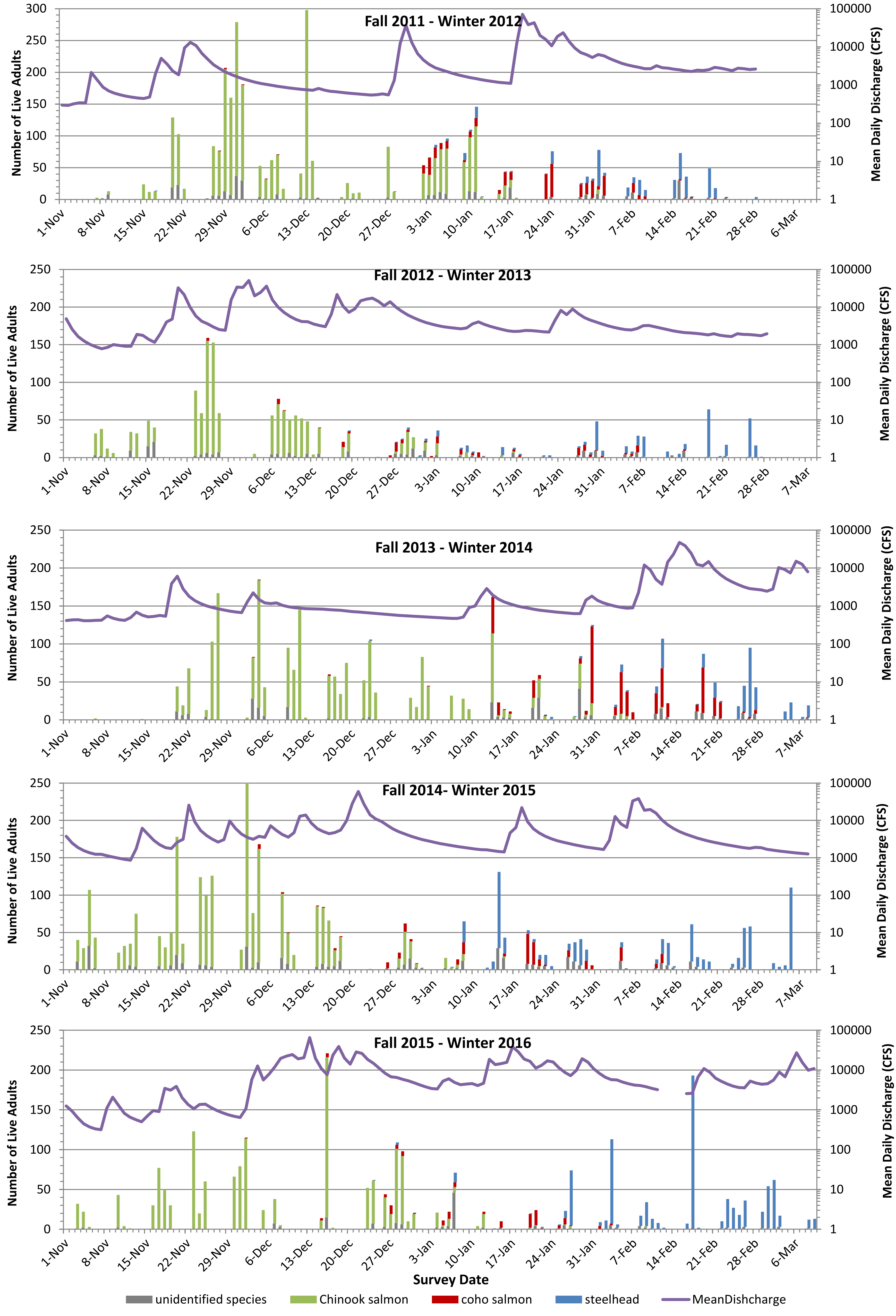

Figure 15. Number of identified live salmonids by species observed during spawning surveys on each day of the 5 survey seasons spanning Fall 2011 through Winter of 2016 in the Smith River basin, Del Norte County, CA. Mean daily flow (CFS) at the USGS Jed Smith gaging station for the survey period is also plotted. Totals include observations from both GRTS and Mill census surveys.

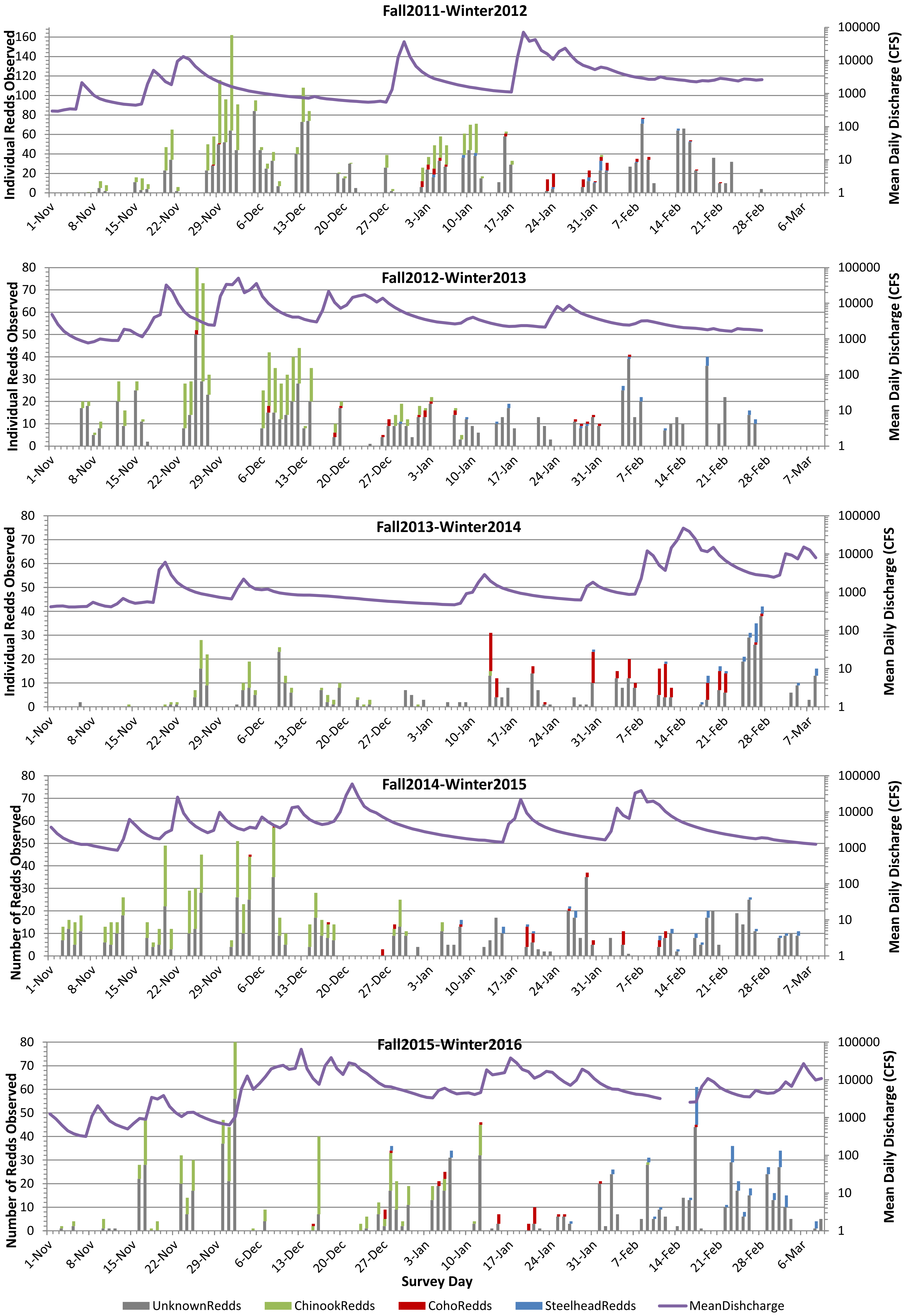

Figure 16. Number of unique individual salmonid redds observed during spawning surveys on each day of the 5 survey seasons spanning Fall 2011 through Winter of 2016 in the Smith River basin, Del Norte County, CA. Redd totals include observations from both GRTS and Mill census surveys.

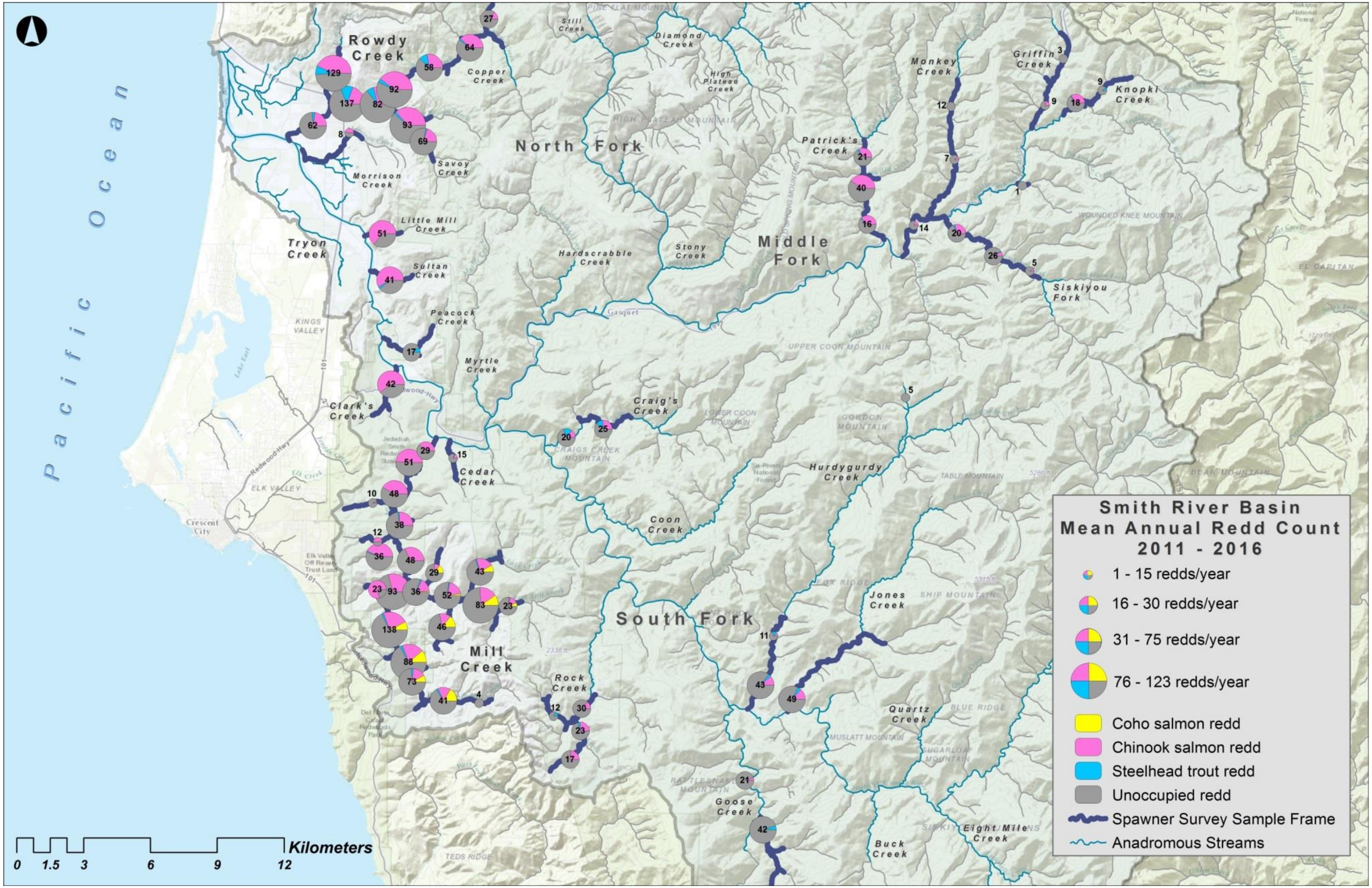

Figure 17. Map of pie charts showing the mean annual number of redds observed divided by species per reach, based on number of years each reach was surveyed during spawner surveys conducted from 2011 – 2016 throughout the Smith River basin, Del Norte County, CA. Pie charts are shown as a size gradient based on the total mean annual redds observed per reach. Labels on pie charts are the total mean number of redds per reach with charts centered on individual reaches.

Table 13. Proportion of observed hatchery-origin salmonids summarized by species, observation type, and major subbasin, from Fall 2011 through the Winter of 2016 during spawning ground surveys conducted throughout the Smith River basin, Del Norte County, CA. Subbasins include Rowdy Creek (all reaches sampled in the subbasin with fish hatchery), Below forks (all reaches sampled in tributaries [excluding Rowdy Creek] below the confluence of the Middle and South forks of the Smith River), and Above forks (all sampled reaches occurring above the confluence of the Middle and South forks of the Smith River). Mill Census (all reaches sampled in the Mill Creek LCS and a component within the Below Forks subbasin) is also given for comparison, Note that live fish and carcass observation totals represent occasions only where an inspection of the individual fish allowed the observer to identify if a fin (adipose or left ventral) or maxillary bone (left or right) were present or absent. Many occasions did not allow for us to inspect the animal for marks based on visual obstructions, distance, water clarity, partial carcass scavenging or carcass decay. Data are from GRTS drawn reaches and the Mill Creek Life Cycle Monitoring Station census reaches.

Live fish observations Fall 2011-Winter 2016									
Subbasin	Coho Salmon			Chinook Salmon			Steelhead		
	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	2	0	0.0%	546	174	24.2%	50	20	28.6%
Below Forks	321	0	0.0%	2276	130	5.4%	126	7	5.3%
Above Forks	1	0	0.0%	461	3	0.6%	57	0	0.0%
Total	**326**	**0**	**0.0%**	**3283**	**307**	**8.6%**	**233**	**27**	**10.4%**
Mill Census	311	0	0.0%	1760	98	5.3%	146	5	3.3%
Carcass observations Fall 2011-Winter 2016									
Subbasin	Coho Salmon			Chinook Salmon			Steelhead		
	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	2	2	50.0%	421	206	32.9%	0	12	100.0%
Below Forks	133	1	0.7%	864	83	8.8%	1	1	50.0%
Above Forks	0	0	-	73	0	0.0%	3	0	0.0%
Total	**137**	**3**	**2.1%**	**1358**	**289**	**17.5%**	**4**	**13**	**76.5%**
Mill Census	125	1	0.8%	578	63	9.8%	1	1	50.0%

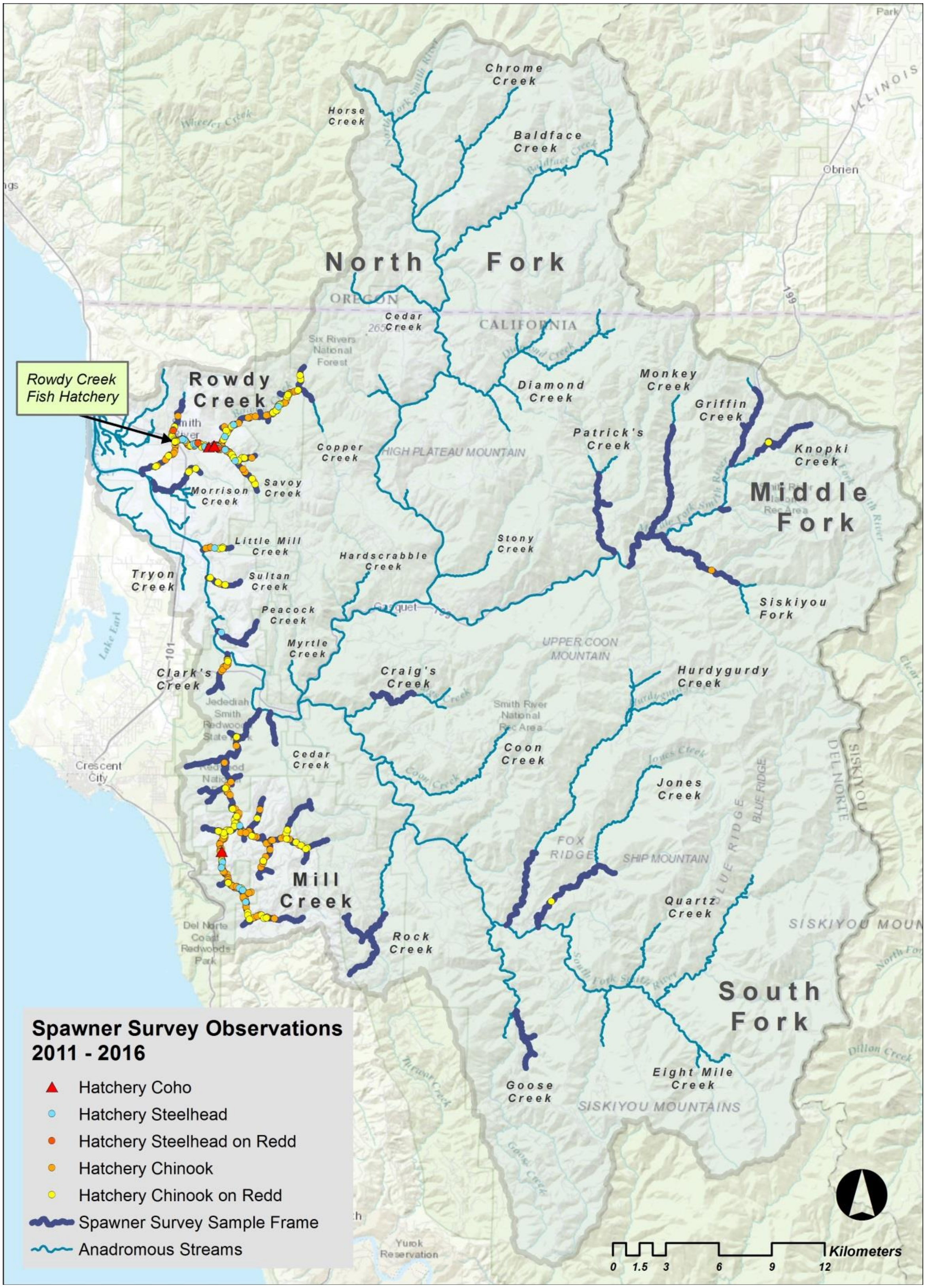

Figure 18. Map showing spawner survey reaches and the distribution of observed adipose fin clipped adult hatchery Steelhead, hatchery Steelhead constructing redds, adipose or left ventral fin clipped adult Chinook salmon, hatchery Chinook salmon constructing redds, and maxillary clipped coho salmon from the Klamath River; observed during five years of sampling effort from fall of 2011 – spring 2016, Smith River Basin, Del Norte County, CA.

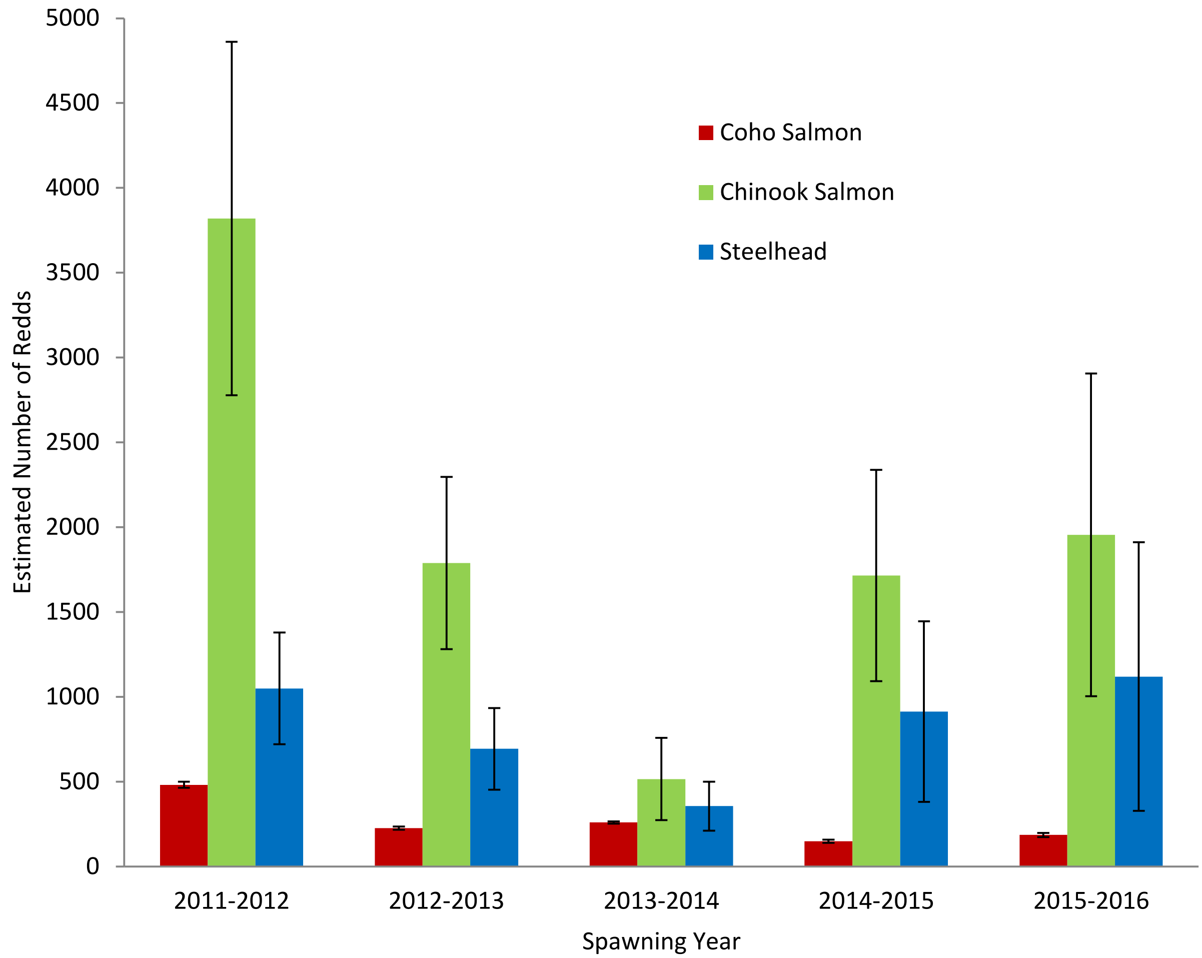

Figure 19. Estimated total number of redds produced in the Smith River GRTS spawner survey sample frame by species and spawning year, Smith River basin, Del Norte County, CA. Error bars represent 95% confidence intervals around point estimates. Coho salmon redd estimates are restricted to the Mill Creek spawner census area and thus have no between-reach variance as indicated by small 95% confidence intervals around estimates. Steelhead estimates do not represent the entire steelhead spawning season since surveys ended in March of each year.

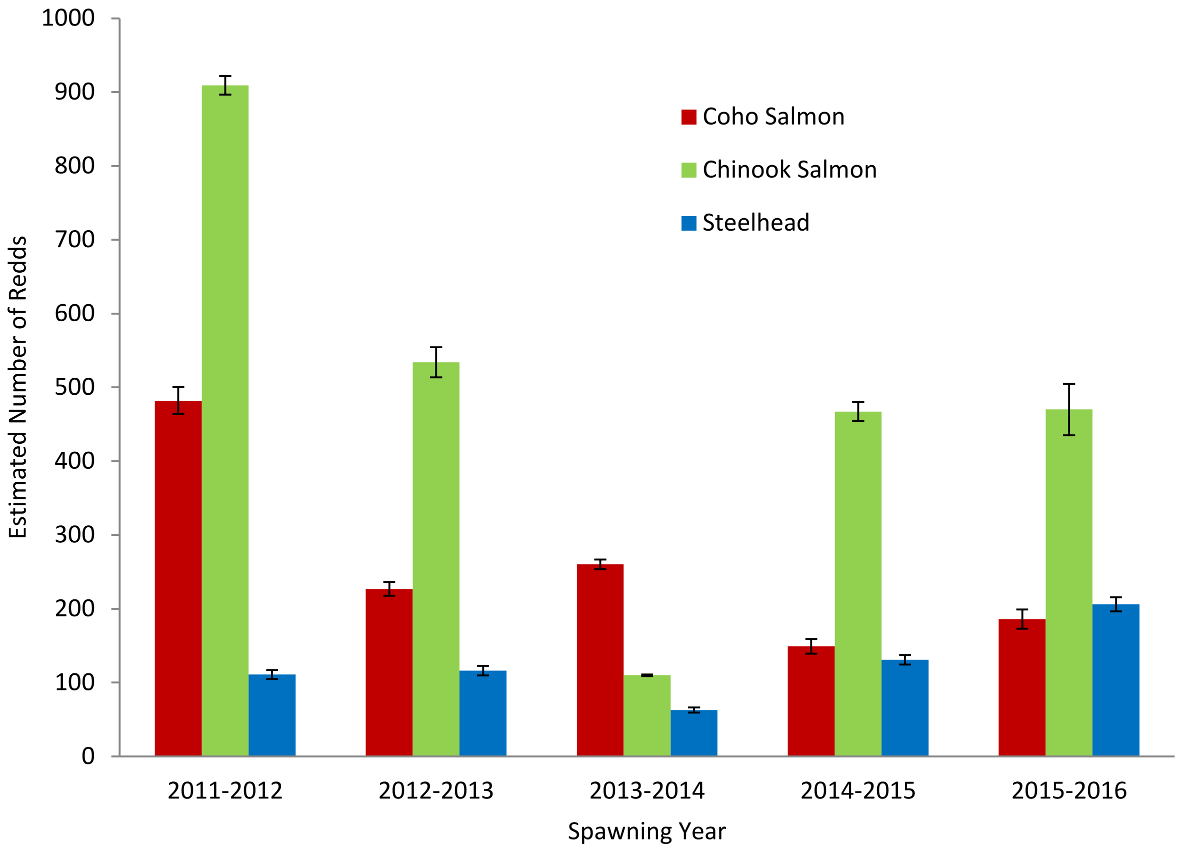

Figure 20. Estimated total number of redds produced in the Mill Creek LCS spawner survey sample frame by species and spawning year, Smith River basin, Del Norte County, CA. Error bars represent 95% confidence intervals around point estimates. Redd estimates are restricted to the Mill Creek spawner census area and thus have no between-reach variance as indicated by small 95% confidence intervals around estimates. Steelhead estimates do not represent the entire steelhead spawning season since surveys ended in March of each year.

2012 to 2016 Spatial Structure Results

2012-2016 Sampling Effort

Our current estimate of total anadromous fish waters in the Smith River basin equals 525 km. The distribution of resident populations of coastal cutthroat trout and rainbow trout, occurring above anadromous fish barriers, has not been systematically described. Based on our summer juvenile coho salmon sample frame development process, our coho salmon spatial structure sample frame resulted in sample 167 reaches totaling 296 stream kilometers, or 56 percent of available Smith River anadromous streams. From 2012 to 2016 we completed a 323 reach surveys totaling 608 cumulative stream kilometers within the Smith River (Table 14, Figure 21). We sampled 7254 pools over the five years with annual totals ranging from 1115 pools to 1837 pools (Table 14). Overall, number of pools sampled in a given reach survey averaged 22 but varied based on reach length and stream size. Our annual sampling fraction averaged 41 percent of the total sample frame in stream kilometers (Range: 29% [2012] to 55% [2016])(Table 14). Only ten of the 167 reaches (6%) did not get surveyed at least once over the five-year period due to either not being drawn (5 reaches), not being granted access to private lands (3 reaches), or due to severe drought conditions (2 reaches).

Table 14. Spatial structure survey effort across five summers (2012-2016), Smith River Basin, California and Oregon.

Year	# Reaches surveyed	# Sub-reaches surveyed	# pools surveyed	Stream length surveyed (km)	Percent of total sample frame surveyed
2012	37	4	1115	87.7	29
2013	49	11	1453	116.4	39
2014	49	18	1525	114.8	39
2015	53	15	1324	127.6	42
2016	65	22	1837	161.8	55
Totals:	253	70	7254	608.3	41[a]

[a]Mean value

Coho Salmon

We documented juvenile coho salmon occurring in 64 of the 157 (41%) individual reaches surveyed at least once over the five years. Annual estimated detection probabilities remained consistently high throughout the study (0.87 to 0.95) indicating our ability to detect coho salmon was consistent across a broad range of habitats among separate cohorts and dive teams. Annual reach-level occupancy estimates were numerically similar between years but declined annually from 0.42 in 2012 to 0.30 in 2016 (Table 15). Annual pool-level occupancy estimates, given coho salmon were detected in a reach, ranged from 0.47 to 0.68. (Table 15). The annual estimated proportion of area occupied (PAO) declined each year of the study from 0.29 in 2012 to 0.14 in 2016. The difference in PAO was most apparent between 2012 and 2016 with 2016 representing less than half of the estimated PAO in 2012. Mean annual pool counts were strongly related to annual estimated PAO (R^2=0.84) indicating a potential count density relationship between pool abundance and annual distributions. Coho salmon maintained a patchy distribution relative to the sampling frame over the five years. Based on the summer distribution data, we describe five extant juvenile coho salmon distribution patches the Smith River basin. We consider four of the five patches are maintained by independent spawning sub-populations based on patch isolation and a lack of suitable spawning or rearing habitats in waters occurring between patches (Figure 22). We consider the lower mainstem Smith River and tributaries, including Rowdy Creek up to the hatchery weir, to be the only significant non-natal rearing patch given fish were consistently found throughout this area each summer (Figure 22). Of the four spawning patches, three contained juvenile coho salmon each of the five years (i.e. five brood years). However, we only confirmed

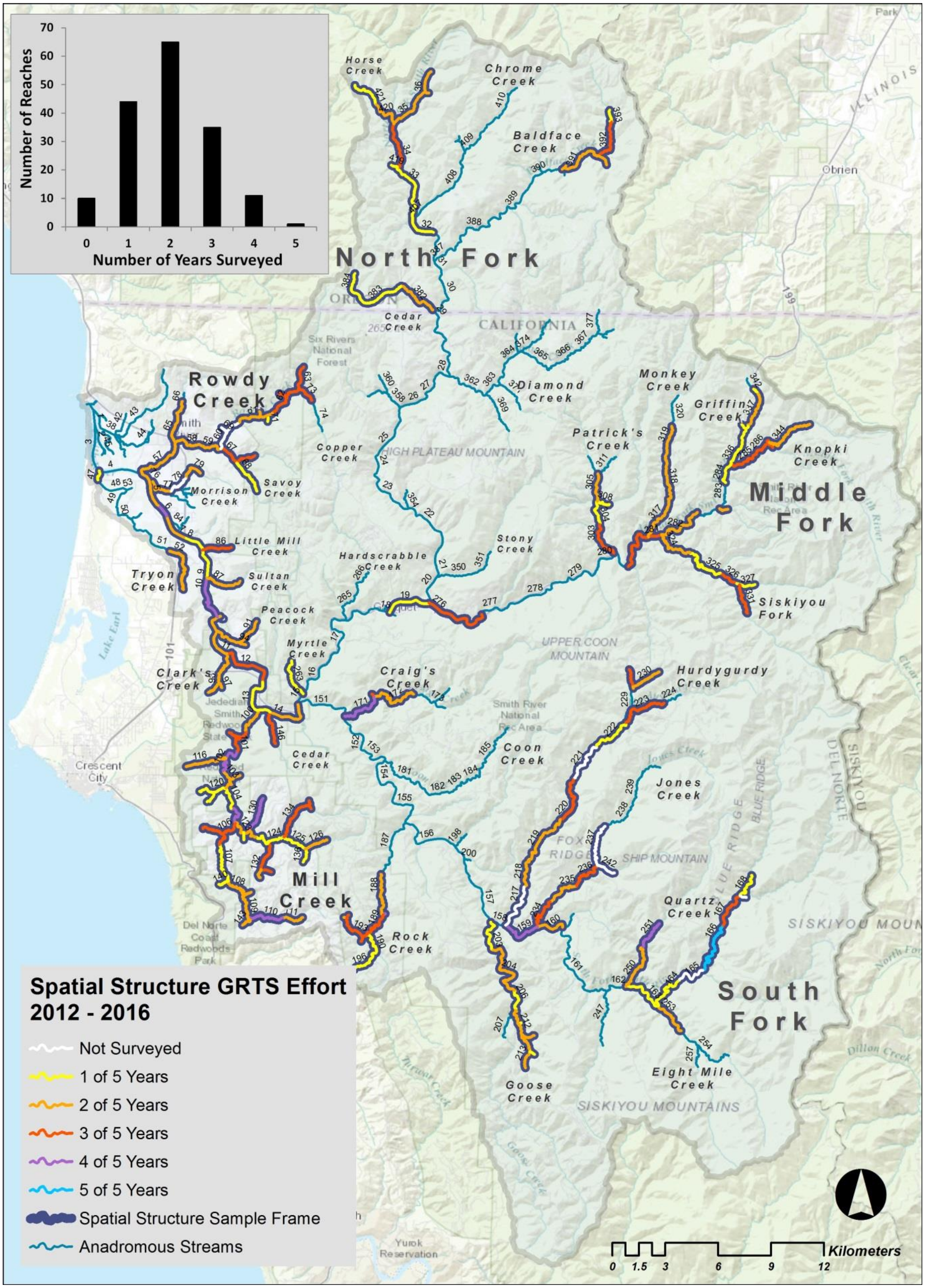

Figure 21. Map and bar graph showing the number of years every reach within the spatial structure sample frame has been surveyed during five years of snorkel surveys conducted during the summers from 2012 to 2016, Smith River Basin, Del Norte County, CA. Numbers represent 275 individual reach location codes used in generalized random tessellation sampling (GRTS).

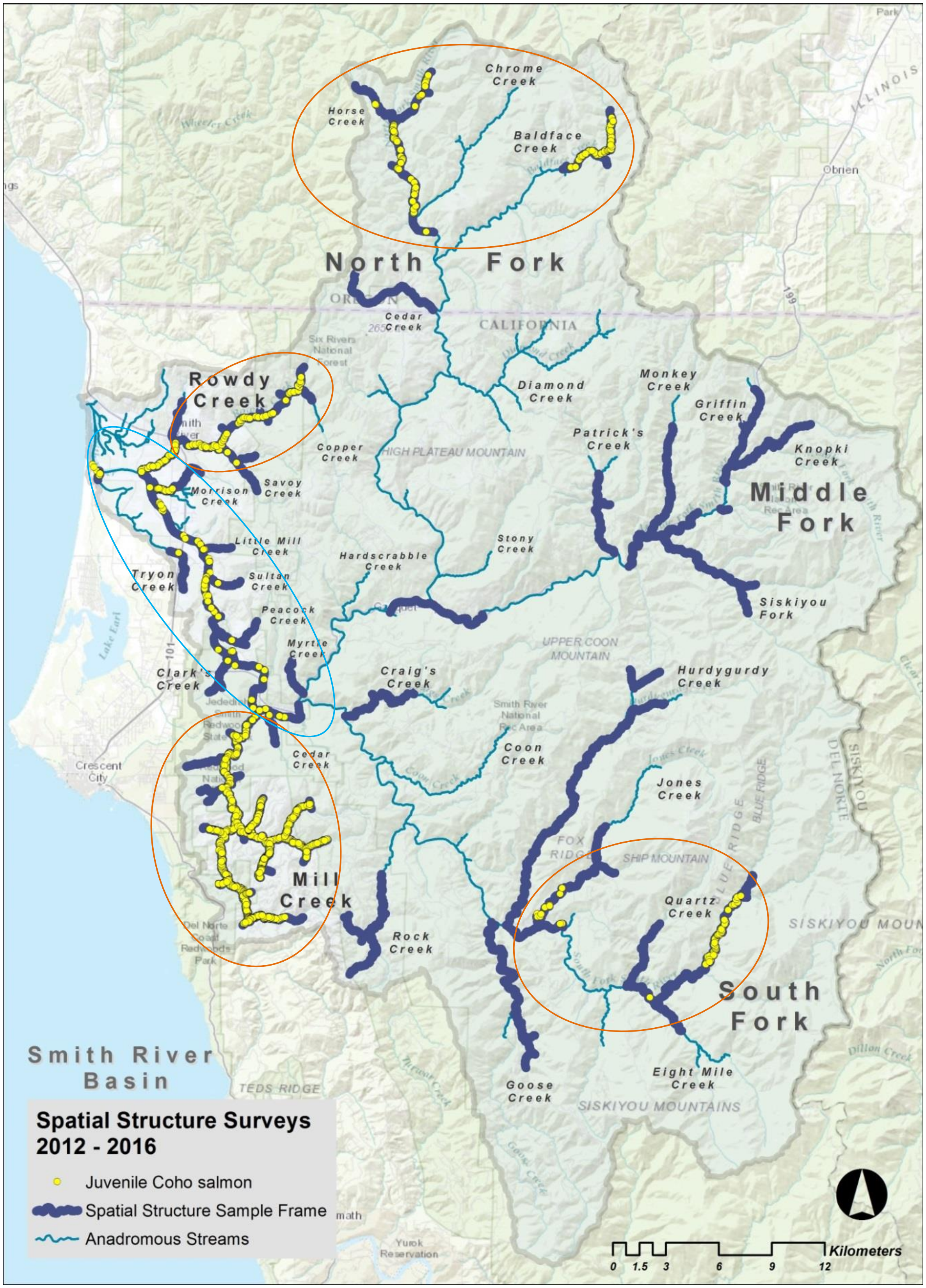

Figure 22. Map showing the spatial distribution of juvenile coho salmon observed during annual summer spatial structure surveys from 2012 to 2016, Smith River Basin, California and Oregon. Red polygons define independent spawning patches in sub-watersheds based on isolation. The blue polygon identifies a non-natal summer rearing patch largely throughout the lower mainstem Smith River and proximal tributaries.

Table 15. Occupancy estimates, proportion of area occupied, and relative count densities of juvenile coho salmon for the summer spatial structure survey, 2012 to 2016, Smith River basin, Oregon and California.

Year	PSI	SE	95% CI	Theta	SE	95% CI	*p*	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count
2012	0.42	0.08	0.28 - 0.57	0.68	0.02	0.63 - 0.72	0.94	0.01	0.92 - 0.96	0.29	17 of 41	27.2	17
2013	0.39	0.06	0.27 - 0.51	0.60	0.02	0.56 - 0.63	0.95	0.01	0.93 - 0.97	0.23	24 of 60	24.7	12
2014	0.35	0.06	0.24 - 0.47	0.67	0.02	0.62 - 0.71	0.92	0.02	0.87 - 0.95	0.23	23 of 67	20.8	12
2015	0.31	0.06	0.21 - 0.43	0.68	0.03	0.62 - 0.74	0.87	0.03	0.80 - 0.92	0.21	21 of 69	22.0	10
2016	0.30	0.05	0.21 - 0.41	0.47	0.02	0.43 - 0.51	0.95	0.02	0.90 - 0.97	0.14	26 of 87	17.8	9

PSI - The probability a species is detected in a given reach for the survey year.
Theta-The probability a species is detected in a given sample pool conditional to the species being present in the reach for the survey year.
p-Individual species detection probability if present in a given sample pool.
PAO-Proportion of area occupied. (PSI * Theta) Overall occupancy value; incorporates reach-level and pool-level occupancy for the entire sample frame.
SE= Standard error of the estimated value, **CI**=95% upper and lower confidence intervals around the estimated value

three brood years in the North Fork patch (2011, 2013, 2015) which could be an artifact of our sample rate coupled with the fires of 2015 preventing us from sampling Baldface Creek that year (Walkley and Garwood 2015).

Chinook Salmon

We documented Chinook salmon occurring in 110 of the 157 (70%) individual reaches surveyed at least once over the five years. Annual estimated detection probabilities ranged from 0.76 to 0.90 indicating our ability to detect Chinook salmon was moderately high across a broad range of habitats among separate cohorts and dive teams (Table 16). Given sub-yearling Chinook salmon typically migrate to sea in the spring and early summer, we did not assume the population was closed when estimating annual summer spatial structure. A study by Parish and Garwood (2015) found juvenile Chinook salmon occupancy rates steadily declined during the summer at fixed locations in the coastal plain. However, by September site occupancy was still at 0.44 indicating the Smith River has a strong stream-type life history. Our estimates should be considered an index of annual distribution patterns and general habitat use given the propensity for juveniles to smolt and migrate throughout the summer months and into early fall. Annual reach-level occupancy estimates ranged from 0.45 to 0.77 with 2014 being substantially less than the other four years (Table 16). Annual pool-level occupancy estimates, given Chinook salmon were detected in a reach, were relatively stable ranging from 0.33 to 0.47 (Table 16). The annual estimated PAO ranged from 0.15 to 0.36 with the 2014 estimate (0.15) being the only substantial outlier from the other four years which ranged only from 0.27 to 0.36 (Table 16). Mean annual pool counts were not strongly related to annual estimated PAO (R^2=0.22) indicating annual juvenile Chinook salmon densities had little influence on explaining their annual distribution.

We found juvenile Chinook salmon to be widespread occurring in every major anadromous tributary within our sampling frame. Adult Chinook salmon spawn throughout the watershed from large riverine reaches to small tributaries highlighting the extensive habitats available to this population when stream discharge does not limit population distribution. The 2014 Chinook distribution was likely truncated to larger stream reaches due to extended drought conditions that prevailed during the 2013-2014 adult spawning migration (Garwood et al. 2014). For example, we did not find any evidence of adult Chinook salmon spawning in the entire upper Middle Fork above the Little Jones Creek Canyon. We also did not detect any juveniles in this area the following summer which includes at least 44 kilometers of anadromous streams.

Table 16. Occupancy estimates, proportion of area occupied, and relative count densities of juvenile Chinook salmon for the summer spatial structure survey, 2012 to 2016, Smith River basin, Oregon and California.

Year	PSI	SE	95% CI	Theta	SE	95% CI	*p*	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count
2012	0.71	0.07	0.55 - 0.83	0.38	0.02	0.35 - 0.42	0.86	0.02	0.83 - 0.89	0.27	28 of 41	14.8	4
2013	0.77	0.06	0.64 - 0.86	0.47	0.02	0.44 - 0.50	0.9	0.01	0.88 - 0.92	0.36	45 of 60	12.2	4
2014	0.45	0.06	0.33 - 0.64	0.33	0.03	0.28 - 0.38	0.8	0.04	0.71 - 0.87	0.15	28 of 67	6.7	3
2015	0.75	0.06	0.62 - 0.84	0.46	0.02	0.41 - 0.48	0.87	0.02	0.83 - 0.91	0.35	48 of 68	10.0	4
2016	0.69	0.06	0.57 - 0.79	0.35	0.02	0.31 - 0.39	0.76	0.03	0.70 - 0.81	0.27	52 of 87	6.0	3

PSI - The probability a species is detected in a given reach for the survey year.
Theta-The probability a species is detected in a given sample pool conditional to the species being present in the reach for the survey year.
p-Individual species detection probability if present in a given sample pool.
PAO-Proportion of area occupied. (PSI * Theta) Overall occupancy value; incorporates reach-level and pool-level occupancy for the entire sample frame.
SE= Standard error of the estimated value, **CI**=95% upper and lower confidence intervals around the estimated value

Young-of-the-year Trout

Young-of-the-year (YOY) trout provide a good index of overall annual spawning distributions for steelhead and coastal cutthroat trout. Although our survey methods cannot effectively distinguish individuals to species, we suggest these data reflect organisms of the same genus and age occupying a similar niche. Both species are expected have spawning distributions throughout anadromous waters so their first-year young are expected to display similar distribution patterns. We documented young-of-the-year trout occurring in 154 of the 157 (98%) individual reaches surveyed at least once over the five years (Table 17). Annual estimated detection probabilities ranged from 0.96 to 1.00 indicating our ability to YOY trout was exceptionally high across a broad range of habitats among separate cohorts and dive teams (Table 17). Estimated reach-level distribution was consistently high, ranging from 0.97 in 2016 to 1.00 in 2014 and 2015 (Table 17) indicating spawning distributions remained stable throughout the study despite the region having an extended drought from 2014 to 2016. Annual pool-level occupancy estimates, given YOY trout were detected in a reach, were also high ranging from 0.93 to 0.99 (Table 17). The resulting overall PAO for the five years ranged from 0.91 to 0.96 indicating most of the available habitat in the survey frame was consistently occupied by YOY trout. The overall widespread distribution of this age class suggests spawning distributions are relatively stable throughout the sample frame despite contrasting temporal flow regimes and extended drought conditions.

Table 17. Occupancy estimates, proportion of area occupied, and relative count densities of young-of-the-year trout for the summer spatial structure survey, 2012 to 2016, Smith River basin, Oregon and California.

Year	PSI	SE	95% CI	Theta	SE	95% CI	*p*	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count
2012	0.98	0.02	0.85 - 1.00	0.93	0.01	0.91 - 0.94	0.96	0.01	0.95 - 0.96	0.91	40 of 41	23.0	14
2013	0.98	0.02	0.89 - 1.00	0.98	<0.01	0.97 - 0.99	1.00	–	–	0.96	59 of 60	34.5	18
2014	1.00	–	–	0.96	<0.01	0.94 - 0.97	0.96	<0.01	0.95 - 0.97	0.96	67 of 67	31.1	14
2015	1.00	–	–	0.96	<0.01	0.94 - 0.97	0.97	<0.01	0.95 - 0.98	0.96	68 of 68	33.3	19
2016	0.97	0.02	0.90 - 0.99	0.98	<0.01	0.97 - 0.99	0.98	<0.01	0.97 - 0.99	0.95	82 of 87	21.3	14

PSI - The probability a species is detected in a given reach for the survey year.
Theta-The probability a species is detected in a given sample pool conditional to the species being present in the reach for the survey year.
p-Individual species detection probability if present in a given sample pool.
PAO-Proportion of area occupied. (PSI * Theta) Overall occupancy value; incorporates reach-level and pool-level occupancy for the entire sample frame.
SE= Standard error of the estimated value, **CI**=95% upper and lower confidence intervals around the estimated value

Age One and Greater Juvenile Trout

Similar to YOY trout, both coastal cutthroat trout and steelhead parr (i. e. age one or greater having conspicuous parr marks) have sympatric distribution's in anadromous waters of the Smith River and cannot consistently be determined to species based on external visual characteristics alone. However, we suggest this age group provides insight into habitat resiliency given they have survived for at least one to two years. This could be especially evident in streams that are subject to periodic drying or suffer seasonally from excessively warm water temperatures. In addition, this age group is likely much more dependent on having quality food resources than YOY trout and their pool-level distributions and densities provide a potential index for local productivity. We documented age 1+ parr trout occurring in 151 of the 157 (96%) individual reaches surveyed over the five years. Annual estimated detection probabilities ranged from 0.81 to 0.87 indicating our ability to YOY trout was high across a broad range of habitats among separate cohorts and dive teams (Table 18). Parr trout were estimated to occur throughout all reaches of the Smith River each year with the exception of 2015 having 98% estimated reach-level occupancy (Table 18). Annual pool-level occupancy estimates, given age 1+ parr trout were detected in a reach, ranged from 0.81 to 0.96 (Table 18) with 2014 distinctly higher than the other four years. The resulting overall PAO was remarkably stable among four of the five years (PAO range: 0.81-0.82) with 2014 equaling 0.96.

Table 18. Occupancy estimates, proportion of area occupied, and relative count densities of age one or greater juvenile trout for the summer spatial structure survey, 2012 to 2016, Smith River basin, Oregon and California.

Year	PSI	SE	95% CI	Theta	SE	95% CI	*p*	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count
2012	1.00	–	–	0.82	0.01	0.80 - 0.85	0.81	0.01	0.79 - 0.83	0.82	40 of 41	3.3	2
2013	1.00	–	–	0.82	0.01	0.80 - 0.84	0.86	<0.01	0.84 - 0.87	0.82	60 of 60	4.4	3
2014	1.00	–	–	0.96	0.01	0.92 - 0.98	0.81	0.01	0.78 - 0.83	0.96	66 of 67	6.5	3
2015	0.98	0.02	0.90 - 1.00	0.83	0.02	0.80 - 0.86	0.87	0.01	0.84 - 0.90	0.81	66 of 68	6.2	3
2016	1.00	–	–	0.81	0.01	0.78 - 0.84	0.86	0.01	0.83 - 0.88	0.81	79 of 87	4.3	3

PSI - The probability a species is detected in a given reach for the survey year.
Theta-The probability a species is detected in a given sample pool conditional to the species being present in the reach for the survey year.
p-Individual species detection probability if present in a given sample pool.
PAO-Proportion of area occupied. (PSI * Theta) Overall occupancy value; incorporates reach-level and pool-level occupancy for the entire sample frame.
SE= Standard error of the estimated value, **CI**=95% upper and lower confidence intervals around the estimated value

Coastal Cutthroat Trout

The Smith River contains one of the most robust coastal cutthroat trout populations throughout their historic range and is the largest population in California. Both anadromous and resident forms occupy the vast majority of fish-bearing streams throughout the watershed. Given this study focused only on anadromous waters, our insights into purely resident forms are limited. We estimate their distribution is at least throughout 525 stream kilometers in anadromous waters and is expected to be far greater when considering resident waters above barriers. We documented adult coastal cutthroat trout occurring in 123 of the 157 (78%) individual reaches surveyed over the five years. Annual estimated detection probabilities remained moderate throughout the study (0.61 to 0.71) indicating our ability to detect adult coastal cutthroat trout was consistent across a broad range of habitats and years. Our protocol for counting coastal cutthroat trout changed after the 2012 season by restricting the focal age to adults based on the clear absence of parr marks. Juveniles could have inflated the 2012 count since our cutoff was size-based (>150mm) instead of determining the presence or absence of parr marks in surveys after 2012. We suggest the larger pool-level occupancy observed in 2012 (0.38) is reflective of the protocol difference and should not be compared to subsequent years. Annual reach-level occupancy estimates from 2013 to 2016 were stable between years ranging from 0.84 in 2015 to 0.91 in 2013 (Table 19). Annual pool-level occupancy estimates, given coastal cutthroat trout were detected in a reach, were also remarkably similar between years ranging from 0.20 to 0.22 (Table 19). Consequently, annual estimated proportion of area occupied (PAO) values were similar, ranging from 0.18 to 0.22. In addition, mean pool counts were also consistent between years ranging from 1.3 to 1.7 fish per pool highlighting the stability in spatial distribution and relative abundance observed during the duration of this study.

Table 19. Occupancy estimates, proportion of area occupied, and relative count densities of adult coastal cutthroat trout for the summer spatial structure survey, 2012 to 2016, Smith River basin, Oregon and California. Note: The 2012 estimate also includes juvenile individuals that we were able to identify as coastal cutthroat trout and thus cannot be compared to the 2013 to 2016 pool-level occupancy estimates or proportion of area occupied. The 2013 to 2016 estimates are restricted to adult coastal cutthroat trout individuals lacking parr marks.

Year	PSI	SE	95% CI	Theta	SE	95% CI	*p*	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count
2012	0.92	0.05	0.74 - 0.98	0.38	0.02	0.34 - 0.42	0.63	0.03	0.57 - 0.68	0.35	35 of 41	1.5	1
2013	0.91	0.05	0.75 - 0.97	0.22	0.01	0.20 - 0.25	0.61	0.03	0.55 - 0.66	0.20	46 of 60	1.3	1
2014	0.90	0.05	0.73 - 0.96	0.20	0.02	0.17 - 0.24	0.70	0.05	0.59 - 0.79	0.18	48 of 67	1.5	1
2015	0.84	0.06	0.70 - 0.92	0.26	0.02	0.22 - 0.30	0.71	0.04	0.61 - 0.78	0.22	49 of 68	1.7	1
2016	0.86	0.05	0.73 - 0.94	0.25	0.02	0.22 - 0.29	0.65	0.04	0.56 - 0.73	0.22	60 of 87	1.4	1

PSI - The probability a species is detected in a given reach for the survey year.
Theta-The probability a species is detected in a given sample pool conditional to the species being present in the reach for the survey year.
p-Individual species detection probability if present in a given sample pool.
PAO-Proportion of area occupied. (PSI * Theta) Overall occupancy value; incorporates reach-level and pool-level occupancy for the entire sample frame.
SE= Standard error of the estimated value, **CI**=95% upper and lower confidence intervals around the estimated value

Subbasin Summaries and Species Distribution Maps (2011-2016)

Lower Tributaries and Coastal Plain

Survey Effort (2011-2016)	Aquatic Species Detected
Spawner Surveys	Chinook Salmon
Number of spawner survey reaches: **26**	Coho Salmon
Total channel length in frame: **42.3 km**	Steelhead
Mean reach gradient: **4.0%**	Rainbow Trout (resident adult)
Sum of annual reach surveys: **43**	Coastal Cutthroat trout
Mean annual redd density: **23.6 redds/ km**	Three-spined Stickleback
Annual redd density range: **8.6 - 35.1 redds/ km**	Klamath Smallscale Sucker
Number of reaches with adult Coho Salmon: **4**	Coast Range Sculpin
	Prickly Sculpin
Snorkel Surveys	Lamprey *spp*.
Number of spatial structure reaches: **42**	Coastal Giant Salamander
Total channel length in frame: **68.4 km**	Northwestern Salamander
Mean reach gradient: **3.5%**	Rough-skinned Newt
Sum of annual reach surveys: **82**	Foothill Yellow-legged Frog
Number of reaches with juvenile Coho Salmon: **23**	Northern Red-legged Frog
Confirmed number of brood years: **5**	Coastal Tailed Frog
	Western Toad
	Western Pond Turtle
	Red Eared Slider (invasive)
	American Beaver
	Northern River Otter
	Northwestern Gartersnake
	Aquatic Gartersnake
	Western Pearlshell Mussel
	Crayfish *spp*.

Overall, this subbasin contains the richest assemblage of aquatic species in the Smith River do to its proximity to the estuary, and diversity of aquatic habitats. Chinook salmon and steelhead were the most abundant salmonids observed in Rowdy Creek and other coastal tributaries over the five years of this study (Figures 23 and 24). The mean annual redd density of 23.6 redds/ km was slightly greater than Mill Creek and the highest observed among the five subbasins (Figure 17). Given a Chinook salmon and steelhead enhancement hatchery exists on Rowdy Creek, the redd densities throughout the subbasin are likely inflated due to excess hatchery fish returning to their basin of origin. Rowdy Creek and Morrison Creek were the only tributaries in the coastal plain where we had evidence of adult coho salmon spawning though only adult fish or carcasses were observed. No actual coho salmon redds were confirmed. However, we did detect juvenile coho salmon above the Rowdy Creek Hatchery weir, a complete upstream migration barrier for juvenile salmonids, during the summers of 2013 and 2014 indicating successful coho salmon spawning does occur periodically in Rowdy Creek. Many tributaries in this subbasin are subject to having dry channels during periods with low water. For example, the terminus of Clark's Creek, Peacock Creek, Sultan Creek, and Rowdy Creek all have dry or intermittent channels by the late summer and remain so until winter storms arrive. Moreover, a large proportion of anadromous waters in Morrison Creek and Tryon Creek completely dry beginning in the early summer. These physical conditions impose migration barriers and likely influence juvenile salmonid survival and overall stream productivity.

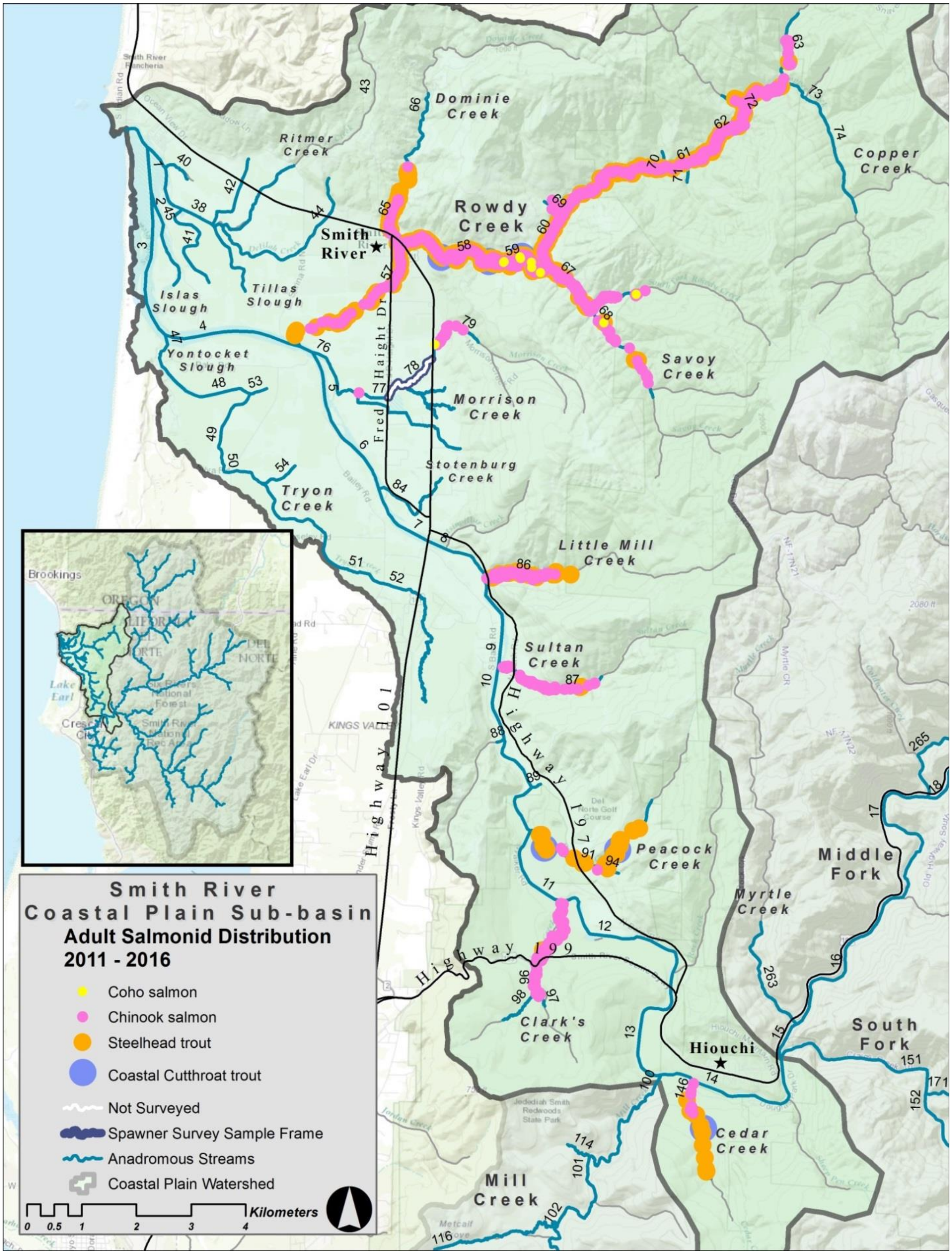

Figure 23. Map showing all salmonids observed during spawner surveys across five years of sampling (fall 2011 to spring 2016) in the Smith River Coastal Plain and Rowdy Creek, Del Norte County, CA.

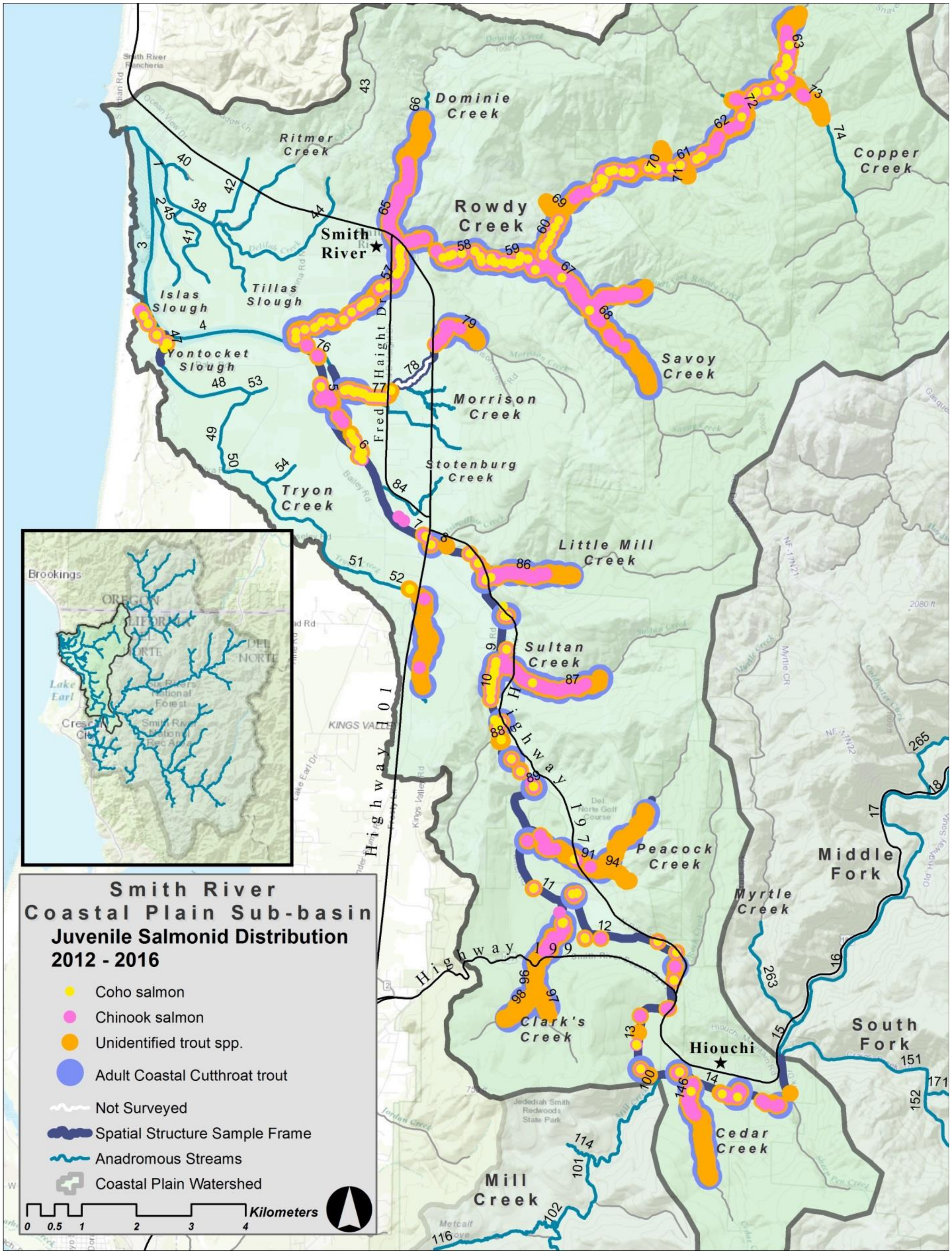

Figure 24. Map showing all salmonids observed during summer spatial structure surveys across five years of sampling (2012 – 2016) in the Smith River Coastal Plain and Rowdy Creek, Smith River Basin, Del Norte County, CA.

Mill Creek Watershed

Survey Effort (2011-2016)	Species Detected
Spawner Surveys	Chinook Salmon
Number of spawner survey reaches: **33**	Coho Salmon
Total channel length in frame: **50.8 km**	Chum Salmon
Mean reach gradient: **3.9%**	Steelhead
Sum of annual reach surveys: **59**	Coastal Rainbow Trout (resident)
Number of reaches with adult Coho Salmon: **24**	Coastal Cutthroat trout
Mean annual redd density: **21.8 redds/ km**	Three-spined Stickleback
Annual redd density range: **14.0 - 39.0 redds/ km**	Klamath Smallscale Sucker
	Coast Range Sculpin
Snorkel Surveys	Prickly Sculpin
Number of spatial structure reaches: **33**	Pacific Lamprey
Total channel length in frame: **50.8 km**	Western Brook Lamprey
Mean reach gradient: **3.9%**	Coastal Giant Salamander
Sum of annual reach surveys: **72**	Northwestern Salamander
Number of reaches with juvenile Coho Salmon: **28**	Foothill Yellow-legged Frog
Confirmed number of brood years: **5**	Northern Red-legged Frog
	Coastal Tailed Frog
	Western Toad
	American Beaver
	Northern River Otter
	Aquatic Gartersnake
	Western Pearlshell Mussel
	Crayfish *spp*.

Overall, Mill Creek was found to contain the second richest assemblage of aquatic species in the Smith River. Mill Creek has rich aquatic biodiversity due to its proximity to the lower Smith River and its low channel gradients providing hospitable colonization and migration opportunities. Mill Creek consistently contained among the highest concentration of spawning salmonids of the five subbasins investigated in this study. Mill Creek was the single-most important spawning tributary for coho salmon with only fourteen individual adults observed in other streams (Figure 25). Furthermore, no coho salmon redds were positively identified outside of Mill Creek despite extensive survey efforts in other streams. Mill Creek also contained the highest concentration of juvenile coho salmon which were distributed throughout all anadromous waters (Figure 26). Chinook salmon adults and juveniles were also widely distributed throughout Mill Creek with adults commonly observed spawning in small tributaries such as First Gulch and Kelly Creek (Figure 25). Spawning adult steelhead and coastal cutthroat trout were found using the upper-most portions of anadromous waters, though steelhead also constructed redds throughout the greater watershed (Figure 25). During the spatial structure surveys, we found juvenile trout and adult coastal cutthroat trout were widely distributed similar to coho and Chinook salmon (Figure 26).

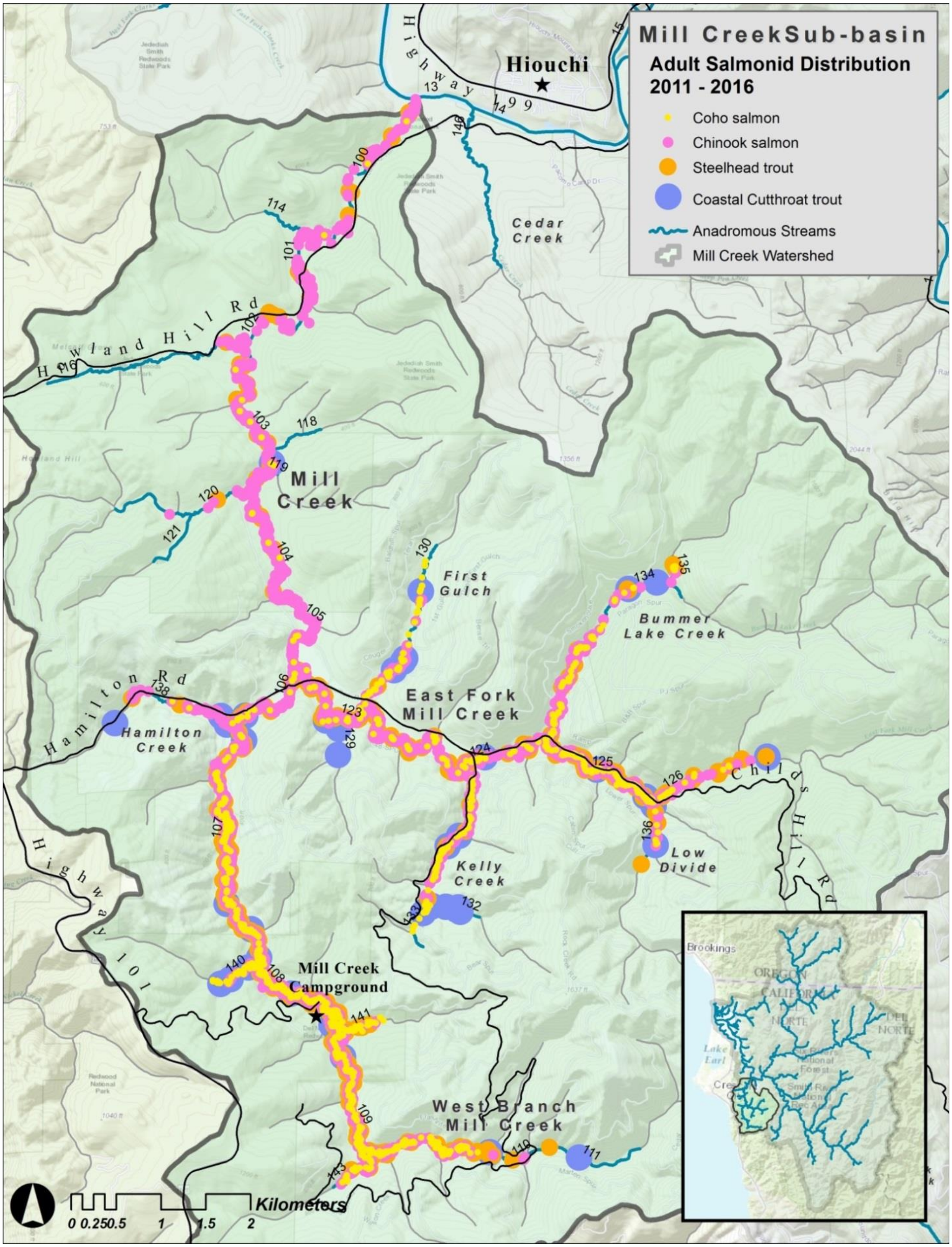

Figure 25. Map showing all salmonids observed during spawner surveys across five years of sampling (fall 2011 to spring 2016) in Mill Creek, Smith River Basin, Del Norte County, CA.

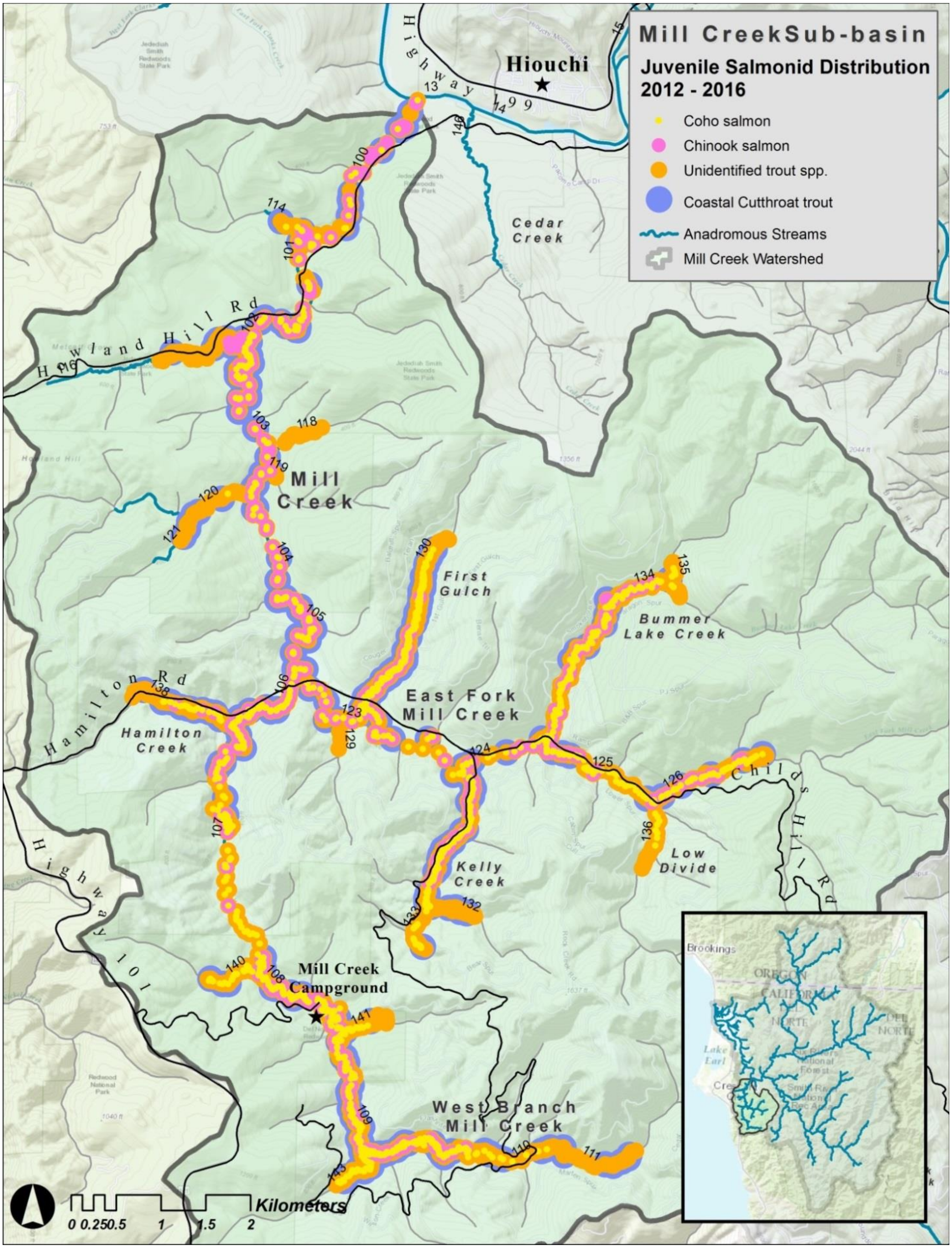

Figure 26. Map showing all salmonids observed during summer spatial structure surveys in Mill Creek across five years of sampling (2012 – 2016), Smith River Basin, Del Norte County, CA.

South Fork Smith River

Survey Effort (2011-2016)	Species Detected
Spawner Surveys	Chinook Salmon
Number of spawner survey reaches: **20**	Coho Salmon
Total channel length in frame: **31.5 km**	Sockeye Salmon
Mean reach gradient: **2.5%**	Steelhead
Sum of annual reach surveys: **20**	Coastal Rainbow Trout (resident adult)
Number of reaches with adult Coho Salmon: **1**	Coastal Cutthroat trout
Mean annual redd density: **10.9 redds/ km**	Klamath Smallscale Sucker
Annual redd density range: **5.4 - 15.3 redds/ km**	Coastal Giant Salamander
	Rough-skinned Newt
Snorkel Surveys	Foothill Yellow-legged Frog
Number of spatial structure reaches: **47**	Coastal Tailed Frog
Total channel length in frame: **91.4 km**	Western Toad
Mean reach gradient: **2.4%**	Aquatic Gartersnake
Sum of annual reach surveys: **93**	Northwestern Gartersnake
Number of reaches with juvenile Coho Salmon: **6**	Northern River Otter
Confirmed number of brood years: **5**	Crayfish *spp*.

The South Fork Smith River is the largest subbasin in the Smith River watershed and contained the most stream kilometers in our greater sampling frame. Of the four subbasins with spawning surveys, the South Fork averaged 10.9 redds per kilometer, almost twice the density of what was observed in the Middle Fork subbasin. However, redd densities were less than half of what was observed in Mill Creek or the coastal plain subbasin. Spawning distributions of Chinook salmon and steelhead were widespread throughout the adult spawning survey area with steelhead reaching the upper portions of anadromous waters (Figure 27). Typical with other subbasins, Chinook salmon were widespread but absent in the upper-most portions of all major tributaries (Figure 27, Figure 28). Over the five years, we only observed one adult male coho salmon in lower Hurdygurdy Creek during the winter of 2013-2014 (Figure 27). However, our juvenile spatial structure sampling documented juvenile coho salmon in the South Fork in each of the five years (Figure 28). Juvenile coho salmon observations were most consistent in the upper reaches of the South Fork between the mouth of Harrington Creek and the Mouth of the Prescott Fork (Figure 27). The upper and lower portions of this area are bisected by a sustained high-gradient reach characterized by cascades, long rapids, and extensive boulder fields. The section above this reach, and up to the mouth of the Prescott Fork, is lower gradient having large suitable spawning gravel patches. However, based on the low densities of coho salmon observed throughout this reach, we surmise that spawning adults could be migrating even further up the drainage and possibly into the lower portion of Prescott Fork. Future surveys are needed to identify if any additional spawning and rearing habitats are available in the upper South Fork. We also found juvenile coho salmon rearing at a few locations in the South Fork near Elkhorn Bar in 2013 and Indian Bar in 2014 (Figure 27). During the summers of 2015 and 2016 we documented coho salmon rearing in Jones Creek indicating the stream likely hosts spawning adults (Figure 27). We did not have access to upper reaches of Jones Creek but spawning habitats in the vicinity of Muzzleloader Creek appear significant based on aerial imagery. In addition, we were unable to survey Muzzleloader Creek due to access constraints but suggest it could provide spawning and rearing habitats for coho salmon. Last, we found adult coastal cutthroat trout were widespread in the South Fork highlighting the importance of this subbasin for resident salmonid populations (Figure 27).

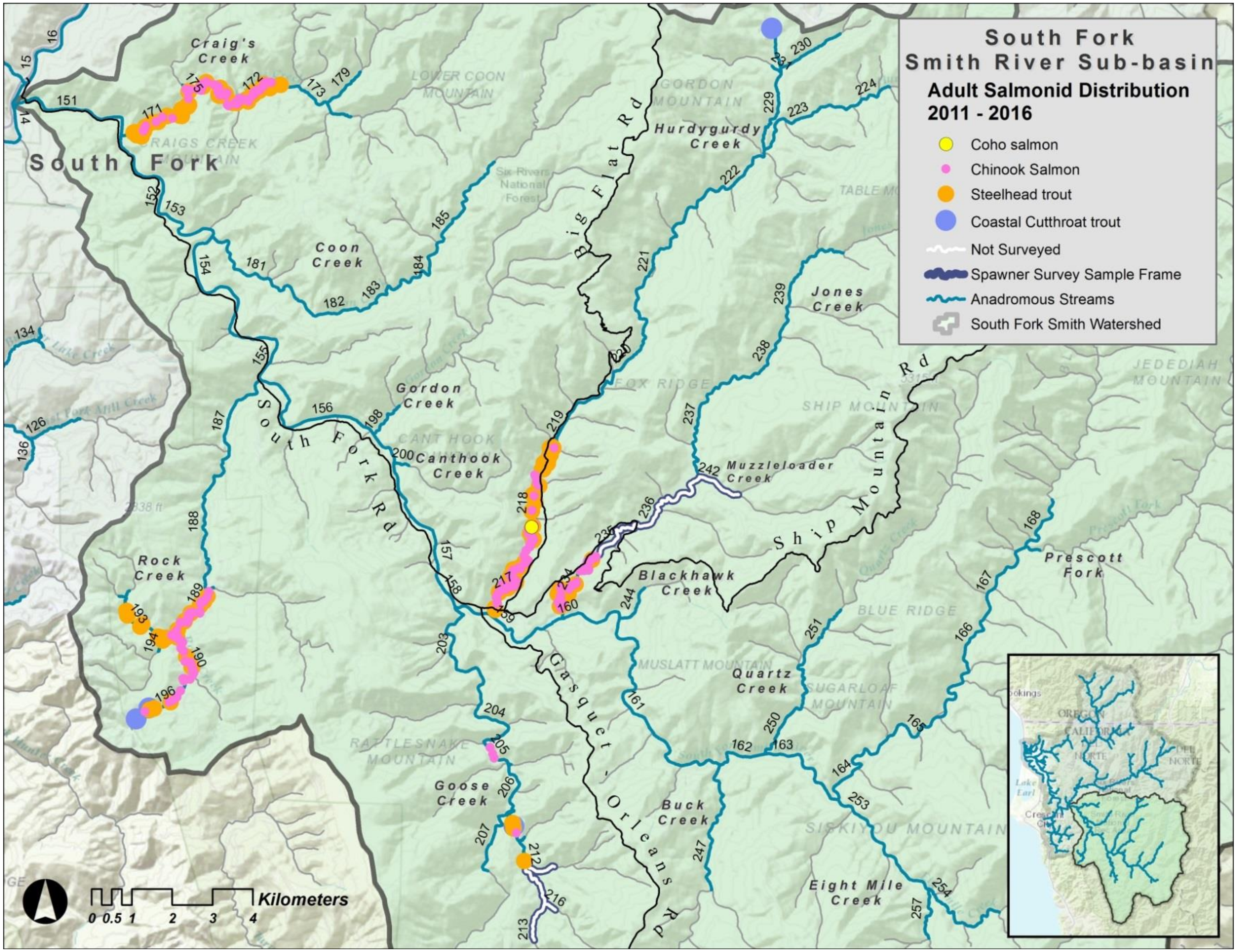

Figure 27. Map showing all salmonids observed during spawner survey across five years of sampling (fall 2011 to spring 2016) in the South Fork Smith River Basin, Del Norte County, CA.

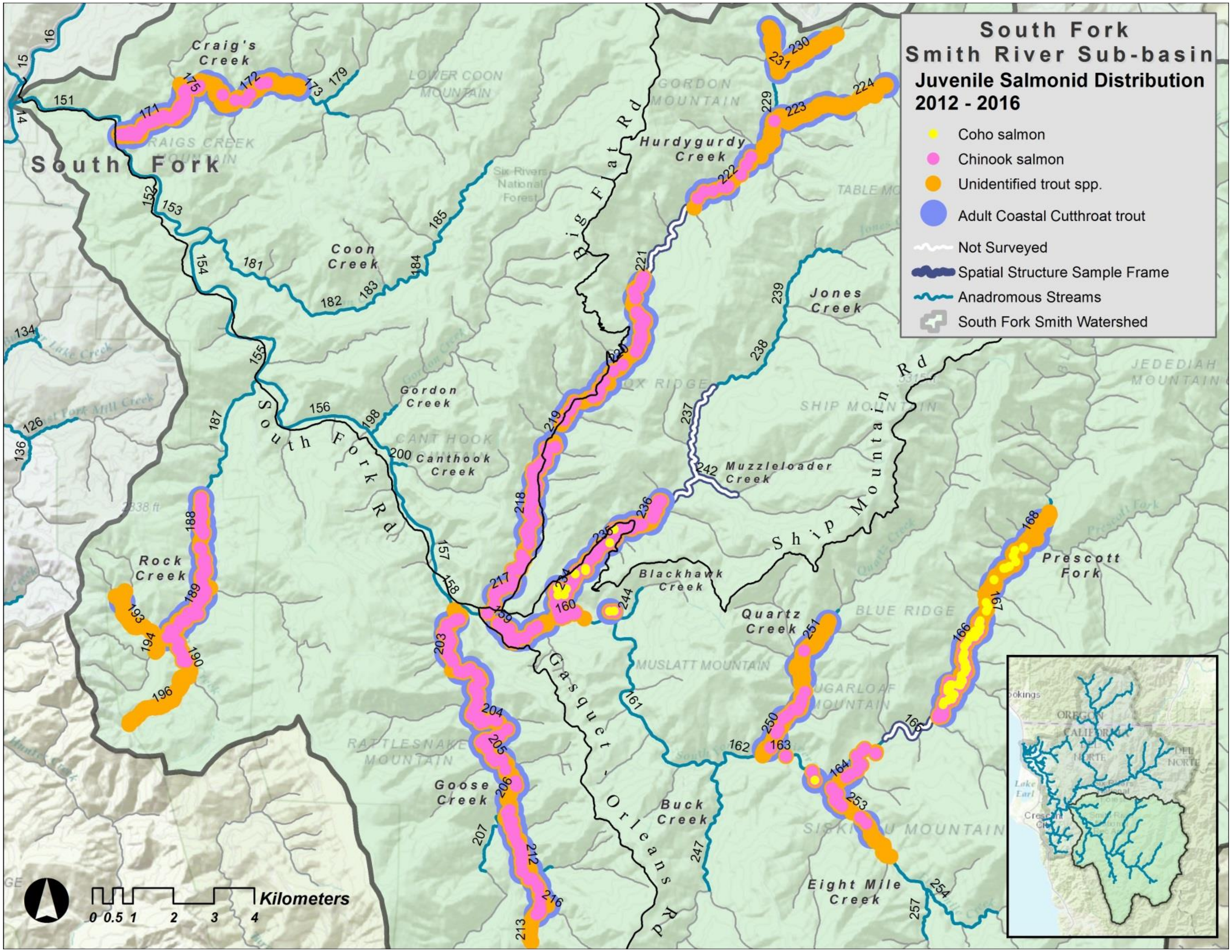

Figure 28. Map showing all salmonids observed during summer spatial structure surveys across five years of sampling (2012 –2016) in the South Fork Smith River Basin, Del Norte County, CA.

Middle Fork Smith River

Survey Effort (2011-2016)	Species Detected
Spawner Surveys	Chinook Salmon
Number of spawner survey reaches: **18**	Sockeye Salmon
Total channel length in frame: **35.4**	Steelhead
Mean reach gradient: **2.0%**	Coastal Rainbow Trout (resident adult)
Sum of annual reach surveys: **38**	Coastal Cutthroat trout
Number of reaches with adult Coho Salmon: **0**	Klamath Smallscale Sucker
Mean annual redd density: **6.5 redds/ km**	Pacific lamprey
Redd density range: **3.1 - 10.0 redds/ km**	Coastal Giant Salamander
	Rough-skinned Newt
Snorkel Surveys	Foothill Yellow-legged Frog
Number of spatial structure reaches: **26**	Coastal Tailed Frog
Total channel length in frame: **51.2 km**	Western Toad
Mean reach gradient: **1.8%**	Western Pond Turtle
Sum of annual reach surveys: **49**	Aquatic Gartersnake
Number of reaches with juvenile Coho Salmon: **0**	Northern River Otter
Confirmed number of brood years: **0**	Crayfish *spp*.

Mean annual redd densities in the Middle Fork were the lowest (6.5 redds/ km) among the four subbasins having redd surveys. Patrick's Creek and Siskiyou Fork had the most productive spawning activity with reaches averaging 16 to 40 redds per year (Figure 17). We did not detect coho salmon in the Middle Fork despite earlier survey efforts having verified observations (Figures 29 and 30). For example, surveys conducted during the summers of 2001 to 2003 described juvenile coho salmon present in Myrtle Creek, Patrick's Creek, Shelly Creek, Monkey Creek, Knopki Creek and Griffin Creek (Garwood 2012a) though most streams contained only one of three brood years surveyed (Garwood 2012b). Adult salmonid migrations to headwater reaches above the mouth of Patrick's Creek appear to be influenced by a minimum flow threshold at Little Jones Creek gorge. For example, the persistent drought observed during the winter of 2014-2015 prevented adult Chinook salmon from migrating through the gorge. Furthermore, no juvenile Chinook salmon were detected above the gorge during the following summer (Garwood et al. 2014). Run timing as it relates to discharge, is likely an important stochastic characteristic influencing the annual spatial distribution of salmonids in tributaries occurring above the gorge. The spawning bed in the Middle Fork Smith River below the mouth of Patrick's Creek contains one of the largest aggregations of spawning gravel in the entire Middle Fork Smith River making it an important habitat in years where migrations are inhibited.

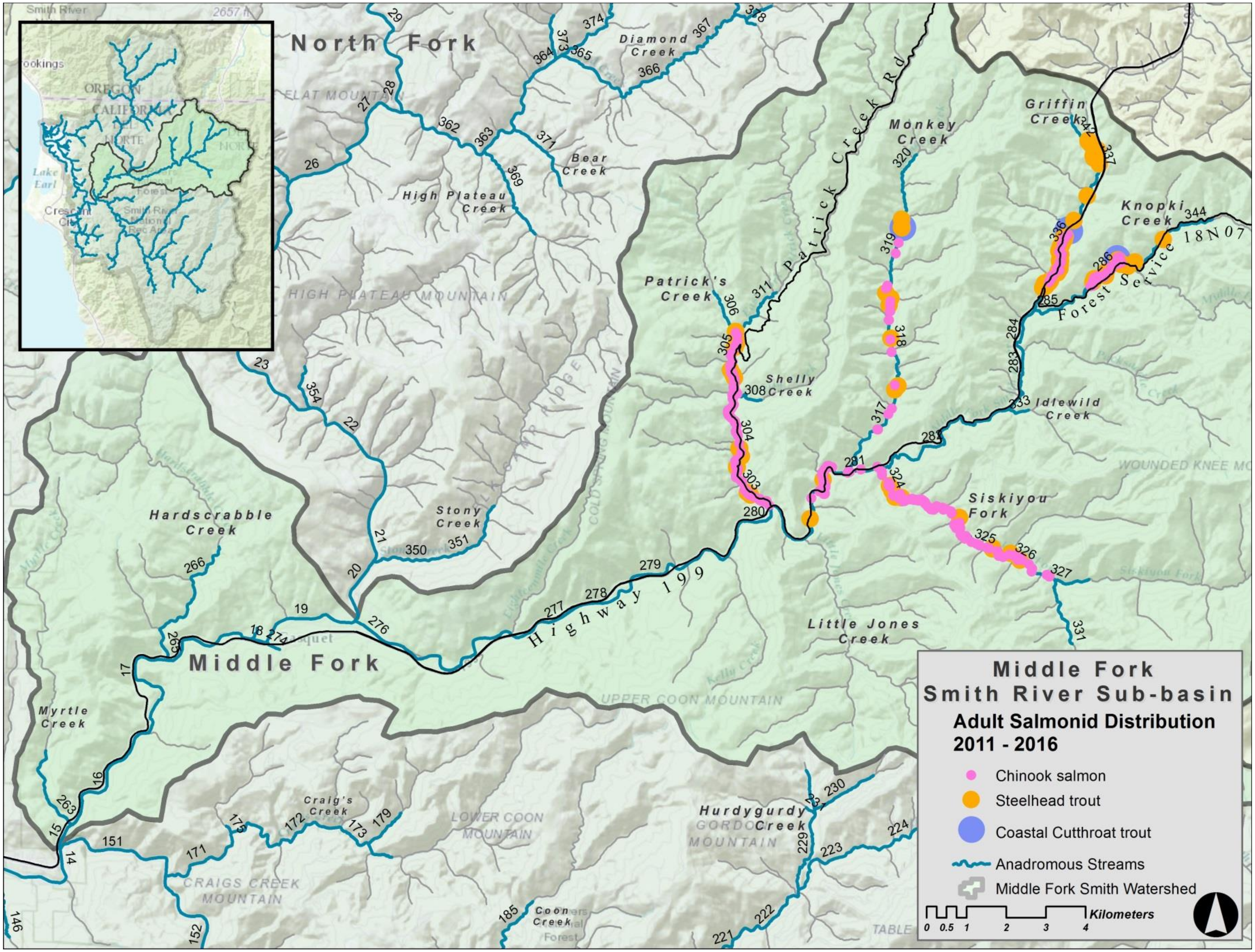

Figure 29. Map showing all salmonids observed during spawner surveys across five years (fall 2011 to spring 2016) in the Middle Fork Smith River Basin, Del Norte County, CA.

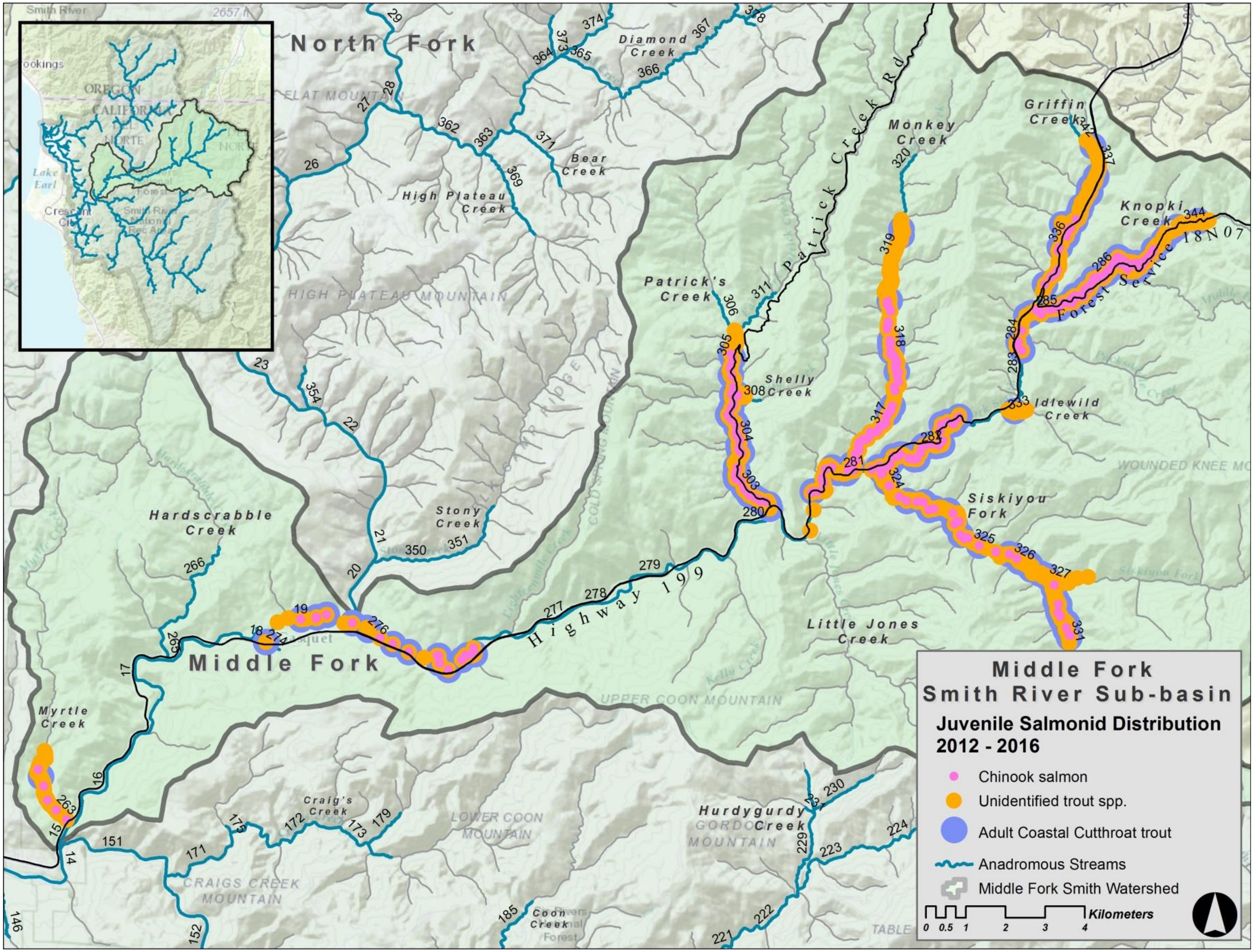

Figure 30. Map showing all salmonids observed during summer spatial structure surveys across five years of sampling (2012 –2016) in the Middle Fork Smith River Basin, Del Norte County, CA.

North Fork Smith River

Survey Effort (2012-2016)	Aquatic Species Detected
Spawner Surveys	Chinook Salmon
Number of Spawner Survey Reaches: **0**	Coho Salmon
	Chum Salmon
Snorkel Surveys	Steelhead
Number of spatial structure reaches: **20**	Rainbow Trout (resident adult)
Total channel length in frame: **30.9 km**	Coastal Cutthroat trout
Mean reach gradient: **3.9%**	Klamath Smallscale Sucker
Sum of annual reach surveys: **33**	Pacific Lamprey
Number of reaches with Coho Salmon: **9**	Coastal Giant Salamander
Confirmed number of brood years: **3**	Rough-skinned Newt
	Foothill Yellow-legged Frog
	Coastal Tailed Frog
	Pacific Chorus Frog
	Northern River Otter
	Mink
	Aquatic Gartersnake
	Crayfish *spp*.

The North Fork Smith River drainage is a rugged and isolated portion of the Siskiyou Range. The entire upper watershed is in public ownership. Additionally, much of the watershed drains the Kalmiopsis Wilderness and the Kalmiopsis Inventoried Roadless Area (Siskiyou Research Group 2006)(Figure 31). Given the watersheds isolation, very little information exists regarding salmonid distributions. However, detailed stream habitat inventories have been completed in numerous tributaries of the North Fork Smith River (Siskiyou Research Group 2002, 2003, 2005, 2006, 2014). Because coho salmon were our focal survey species, the majority of the sample frame was contained in headwater reaches having lower stream gradients than reaches occurring downstream. Generally, we observed the base geology was different in these upper headwater regions of the North Fork creating islands of low gradient forested streams having abundant quality spawning gravels and large wood materials distributed throughout the channels. For example, upper Baldface Creek flows through a relatively small emerged granite pluton forested with a dense forest stand dominated by Douglas fir. Reaches below are dominated by ultramafic soils and a sparse Jeffery pine forest creating a stark contrast in habitats. Chinook salmon, trout (juvenile steelhead or coastal cutthroat trout), and adult coastal cutthroat trout were all widely distributed throughout the North Fork Smith River survey area (Figure 31) and all were detected in each of the five survey years. The upper extents of Chinook salmon were typically lower than the trout species which extended to the end of anadromy. Coho salmon were found in two general areas including the upper North Fork/ Horse Creek drainage and in upper Baldface Creek (Figure 31). Coho salmon were previously detected in the headwaters of the North Fork Smith River during Forest Service Level II habitat surveys in 2006 (Siskiyou Research Group 2006). Available stream habitats in the upper North Fork Smith River are largely characterized by contrasting geologic features. Our observed species distribution and richness of aquatic species in this region highlight its unique attributes relative to other subbasins in the Smith River watershed.

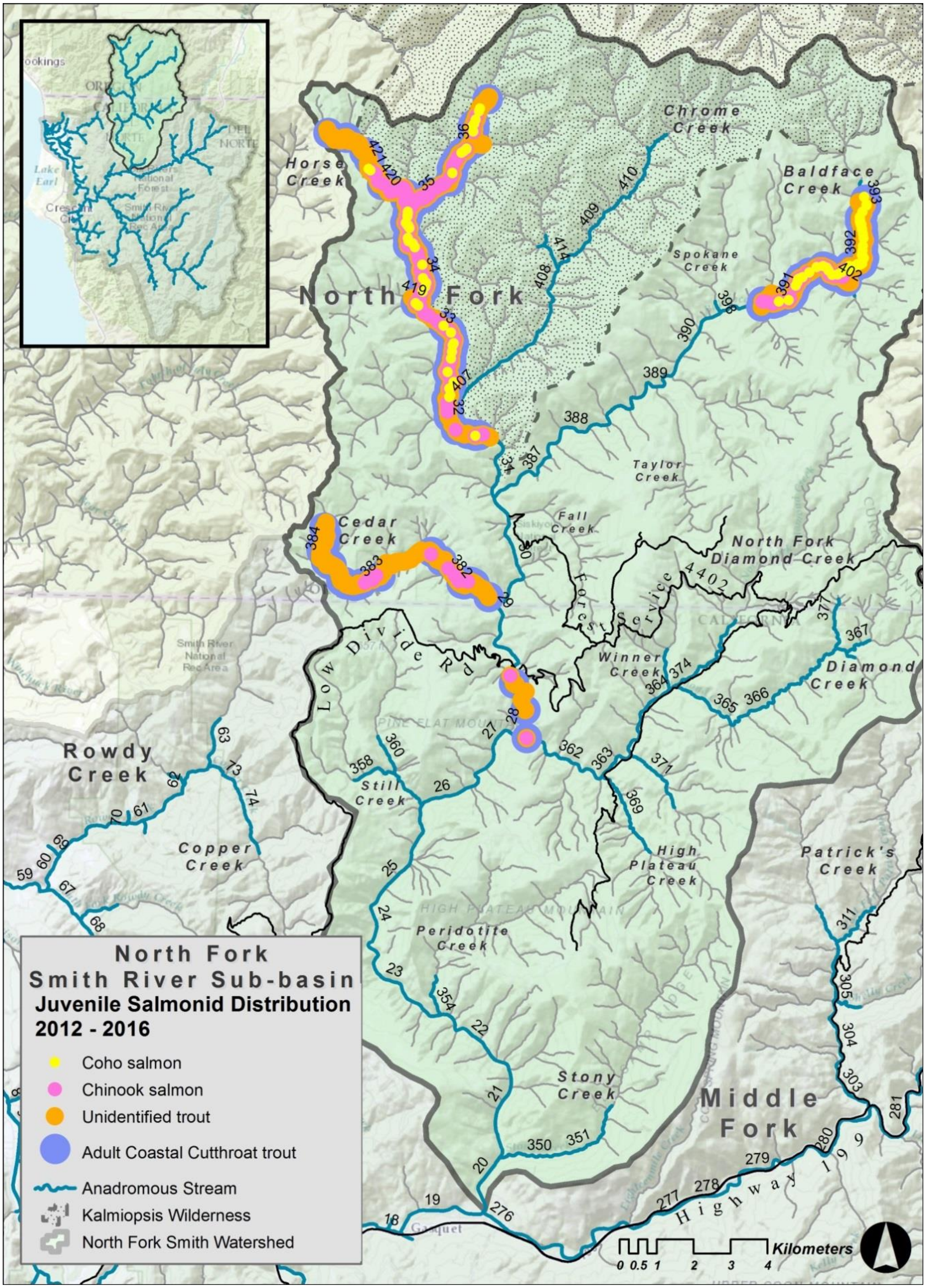

Figure 31. Map showing all salmonids observed during summer spatial structure surveys over five years (2012 –2016) in the North Fork Smith River Basin, Del Norte County, CA and Curry County, OR.

Discussion

Spawning Ground Surveys

Coho Salmon Spawning Distribution and Abundance

We conducted five years of spawning ground surveys throughout the Smith River adult coho salmon sampling frame and determined adult coho salmon maintained a narrow spawning distribution within the adult sample frame. Very few adult coho salmon were observed outside of the Mill Creek basin and no coho salmon redds were detected outside of the Mill Creek lifecycle monitoring station (LCS) despite extensive survey efforts in these areas each year. Rare observations of either live or dead adult coho salmon occurred in just a few locations including the Rowdy Creek basin, Morrison Creek and Hurdygurdy Creek. By contrast, occupancy rates for live adult coho salmon in Mill Creek, and especially within the Mill Creek LCS, were significantly higher. In the Mill Creek LCS, adult coho salmon were observed in 19 of the 21 primary and subreaches sampled across the five survey years. Annually, live coho salmon were observed in between 15 (2011-2012) and 17 (2014-2015) of these reaches. Estimated redd abundance was lowest during the 2014-2015 season and highest during 2011-2012, however, coho salmon redds were identified in 13 reaches during both survey years. The stability in spawning distributions suggests lower abundance did not affect reach occupancy rates in Mill Creek. Our survey results highlight the significant role Mill Creek has with respect to coho salmon persistence in the Smith River basin.

Our overall detection probability of observing fish on redds averaged roughly 30 percent across the five seasons, with lower success during peak coho salmon and steelhead spawning. This detection rate is among the highest in California and is largely due to the basins exceptional water quality and lower turbidity relative to other regional streams. In an analysis of the first two years of this monitoring program, Garwood et al. (2014) suggested that having few returning adults in streams outside of Mill Creek, coupled with marginal numbers of fish on redds, prevented the confirmation of successful coho salmon reproduction outside of the core spawning area. After three additional years of surveying, we believe this to be the case. Limited numbers of coho salmon are spawning in a few locations outside of Mill Creek, but they are difficult to detect using spawning surveys alone. For example, during the summer of 2013 we detected juvenile coho salmon throughout the main stem of Rowdy Creek above the Rowdy Creek Fish Hatchery weir. The hatchery weir is a complete barrier to juvenile migrations so we consider juvenile fish rearing above the structure to be derived from Rowdy Creek basin. Based on the observed densities of juveniles, we suggest the production was small; likely from one to a few redds. Similar observations of juveniles occurred throughout much of the lower Jones Creek reach in the summer of 2016, which lacks a migration barrier (Figure 9). The densities and spatial distribution of these juvenile coho salmon, in relation to other observations within the South Fork Smith River, suggest this is a natal stream. These examples highlight the importance and benefits of surveying for multiple life history stages, especially when the adult stage of target animals are extremely rare and patchily distributed across the landscape.

Prior to our study, coho salmon were intensively studied in portions of Mill Creek. Because our sample frame was designed to include all anadromous waters, we substantially extended the known range of coho salmon. Both spawner and juvenile dive surveys identified several new streams consistently serving as important spawning and rearing habitats. These include First Gulch and a tributary to Kelly Creek. These data also supported the removal of the last identified major barrier in Mill Creek. A perched culvert in Hamilton Creek, 150m upstream of the mouth, blocked anadromous fish access to over 1000m of high-quality coho salmon spawning and rearing habitat. Adult and juvenile surveys conducted during the first four years of this study found anadromous fish adults and juveniles utilizing Hamilton Creek up to the culvert but only coastal cutthroat trout were observed upstream. This culvert was removed in the fall of 2015 and 2015-2016 spawning surveys documented Chinook salmon, coho salmon and steelhead spawning and rearing in the newly accessible habitat.

Redd Abundance

All abundance estimates in this report are strictly redd abundance and not those of spawning adult fish. There currently is no redd-to-fish correction available for the Smith River since the LCS does not have an adult trapping facility. We suggest the conversion of redds to fish numbers is largely a decision for managers since conversions from other regional life cycle monitoring stations or published studies are subject to vary widely. However, a recent transgenerational genetic mark-recapture study (Whitmore and Kinziger 2016, Hankin and Mohr 2016) was performed using our Mill Creek coho salmon carcass and smolt offspring DNA. This novel alternative to estimating adult coho salmon abundance used genotypes of individual fish in a mark-recapture framework to determine how many adults were explained by their smolt progeny. This study utilized two different statistical methods to generate preliminary spawning escapement estimates for coho salmon for the 2011-2012 and 2012-2013 spawning seasons. The first method was a binomial method and it estimated 576 and 131 coho salmon spawned in Mill Creek in 2011-2012 and 2012-2013 respectively (Whitmore and Kinziger 2016). The second method was a hypergeometric method and produced estimates of 444 and 193 coho salmon for these two years. The authors of the study stress that although the use of transgenerational mark-recapture holds great promise, they cannot recommend its immediate widespread adoption for estimating coho salmon spawning escapement because developing confidence intervals for the estimate is complex (Hankin and Mohr 2016) and further advances in genetic parentage analysis must be made (Whitmore and Kinziger 2016). Notwithstanding, simply multiplying our redd estimates by two fish per redd results in an estimated total adult abundance that is substantially larger (range: 41-71% depending on year and estimator used) than the genetic approach.

After the first two years of this study, Garwood et al. (2014) recommended using the coho salmon redd population estimate for the Mill Creek LCS over the GRTS survey for two reasons. First, no confirmed coho salmon redds were identified outside of Mill Creek, indicating coho salmon were narrowly distributed. Second, since all known coho salmon redds were observed in the LCS census, between-reach variance, the most substantial and sensitive source of error (Ricker et al. 2012), is effectively eliminated from the estimate. Our three additional years of spawning surveys and analysis continue to support this recommendation. Garwood et al (2014) also outlined potential sources of error in redd estimates that might lead to redd estimates that are biased high. These sources of error originate from unrealistic assumptions our data and analysis cannot support. Two primary assumptions are (1) redds, regardless of species, survive with the same probability and (2) all redds survive with the same probability across all sampling occasions. The stochastic influence of high stream discharge on redd survival has been simulated extensively by Jones (2012) who concluded redd counts may have substantial bias then estimating total redd construction. These assumptions are unlikely to occur within any stream system, especially one as stochastic as the Smith River Basin. For example during one 48 hour period in January of 2012 ten inches of rain fell in Gasquet, California. In response the river discharge increased nearly two orders of magnitude from 1,100 cfs to 96,000 cfs. Naïve redd survival from this flood event was eight percent (N = 589, range 0-52%) for all reaches combined (Garwood 2014). Events resembling this occurred multiple times over the five survey years (Figure 16). In contrast, redd survival approached 100% during extended dry periods, for example the approximately 5 week period in the 2013-2014 spawning season. Another source of error in our redd estimates was the prediction of redds to species. Each spawning season we were able to document salmonids occupying over 30% of redds we observed

(Garwood et al. 2014, Garwood and Larson, 2014, Walkley and Garwood 2015, and Figure 8). The proportion of identified redds changed across the duration of each season and this was likely influenced by species-specific spawning behaviors and a general increase in winter storm frequency as each survey season progressed (Garwood et al. 2014). In general the procession was a high percentage of Chinook salmon redds observed from November into January (up to 50% of total observed redds), then a shift toward coho salmon redds dominating redd observations in January followed by a smaller increase in steelhead redds in February. Surveyors noted that Chinook salmon were generally out spawning during the day, while coho salmon and steelhead tended to be more secretive. We observed significant temporal overlap in spawning between the three species, especially between steelhead and coho salmon (Figure 14). Due the differences in observation probability, we included the spatial locations all live fish observations into our kNN prediction analysis to maximize the use of known species spatial and temporal distributions. These additional data greatly improved the performance of our overall species prediction across the five years.

Chinook salmon distribution and redd abundance

Chinook salmon were the most widely distributed adult salmonid and the most numerous salmonid species observed in the spawning frame across the five spawning seasons. Reach occupancy was lowest during the 2013-2014 spawning season for both live adults and identified Chinook salmon redds. During the other four spawning seasons, live Chinook salmon were detected in between 27 and 34 primary reaches and in three to six subreaches while Chinook salmon redds were detected in between 24 and 32 primary reaches and one to four subreaches. By contrast, during 2013-2014, live adult Chinook salmon were detected in only 15 primary reaches while Chinook salmon redds were observed in 13 main reaches and zero subreaches. Chinook salmon distribution within tributary reaches also tended to be limited to their lower proximities (Garwood and Larson 2014). Garwood et al. 2014 suggest stream discharge during the fall migration period is likely influencing both adult and juvenile Chinook salmon spatial distribution. They noted that during the first two years of this study Chinook salmon were more narrowly distributed (but more abundant) during the fall of 2011, when storm activity was both delayed and infrequent, than during the wetter fall of 2012. To illustrate this pattern the authors cite observations from two upper Middle Fork reaches which were surveyed during both years: the upper Middle Fork (reach 286) and Siskiyou Fork (reach 324). Both reaches occur above a natural gorge (between Patrick's Creek and Monkey Creek) that likely limits anadromous fish access above it at low stream flows. In 2011-2012 seven live Chinook salmon and two Chinook salmon redds were observed in these two reaches. By contrast, 64 live Chinook salmon and 15 known Chinook salmon redds were observed during 2012-2013. Unfortunately these two reaches were not selected for spawning surveys during the 2013-2014 spawning effort, which was the driest of our five survey seasons (Figure 15). However, we did survey three spawning reaches above the natural gorge during 2013-2014 and, despite extensive effort, observed no adult Chinook salmon adults or redds (Garwood and Larson 2014). Chinook salmon have been observed in all of these reaches during wetter survey years (Figure 29). Surveys within the gorge – Middle Fork (reach 281) – did detect 49 live Chinook salmon and 3 Chinook salmon redds. This phenomenon in the upper Middle Fork has also been observed during spawning surveys performed by the US Forest Service (M. McCain Pers. Comm.) Furthermore the observed reduction in adult reach occupancy during the 2011-2012 and 2013-2014 spawning seasons was reflected in the 2012 and 2014 juvenile Chinook salmon spatial structure results (Table 15).

Steelhead distribution and redd abundance

Like Chinook salmon, adult steelhead were observed occupying much of the adult coho salmon spawning frame but were encountered in fewer GRTS reaches. Live adult steelhead were observed in between 22 and 29 reaches annually. Steelhead redds were observed in between 11 and 17 reaches each year. The lowest reach occupancy for adult steelhead and their redds occurred during 2012-2013. Low stream flows may have delayed spawning and limited access to streams in the late-winter of 2012-2013 (Garwood et al. 2014). Steelhead redds were observed in between 11 and 17 reaches each year. It is difficult to draw conclusions about run timing, changes in distribution or abundance for steelhead since we do not survey throughout the entire span of steelhead spawning. However, based upon sonar counts at the Smith River sonar counting station our survey period likely encompasses much of the steelhead upstream migration period (Larson 2013c).

Juvenile coho salmon spatial structure

Perhaps the most compelling information gained from this five-year study was defining annual salmonid species distributions across the entire Smith River basin. Through collecting data at this large scale, we have a much greater understanding of individual species patch sizes and annual fidelity to specific areas. For coho salmon, juvenile life stages are the most widely distributed across the riverscape, with patchy habitats being spatially and temporally dynamic. Understanding seasonal habitat patch size, utilization, connectivity and colonization, and also the extinction processes affecting a population, will help managers define source patches, while also identifying isolated patches that are much more vulnerable to extinction. This information is critical to defining restoration goals that are based on current population distributions. Effective management and restoration of areas currently being used by coho salmon, or areas in close proximity to population centers, will likely have a rapid positive effect on productivity.

Annual estimated detection probabilities of coho salmon juveniles remained consistently high across the study. Garwood et al. (2014) noted that during the first two years the survey protocol was extremely efficient at detecting salmonids throughout a given reach. Detection probabilities were especially high for our primary focal species, coho salmon (94-95% overall). During 2012 and 2013 the protocol specified that two independent dive passes be made in every selected unit. Based on these observations, the survey protocol was modified to include a combination of double and single dives passes beginning in 2013. This protocol change resulted in surveyors being able to complete reaches more quickly yet still ensured high detection probabilities for coho salmon (87-95% overall). The change also maintained high within reach sampling rates which in turn allow greater precision in estimating fine-scale changes in annual spatial structure. Reach-level occupancy (ψ) estimates were more stable across the five years than conditional pool-level occupancy (θ). This is to be expected because salmonids typically use the same general areas for spawning (Pess et al. 2002). Within these generalized areas variables such as predators, competition from congeners, temporal barriers and flow regimes act together to determine the distribution of an annual cohort of juvenile fish. Our protocol also allowed us to obtain counts of individual species and we are working towards using count models that incorporate spatial dependency to reduce reach-level occupancy variance and plan to include habitat covariates to test specific hypotheses explaining landscape distribution.

The spatial arrangement of resources across a landscape can have profound effects on species distributions (Dunning et al. 1992, Ricketts 2001). Resources are not randomly distributed, but reflect geological and geomorphic processes dictating physical and biological characteristics of fish habitat (Montgomery and Buffington 1998, Montgomery 2009). Salmonids have various life history needs depending on the age and time of year and move among complementary resources when resources become available or decline. We detected juvenile coho salmon (i.e. sub-yearling) in three general areas throughout the Smith River (Figure 22). The majority of observations were found throughout the coastal portion including Mill Creek, the lower main stem Smith River, Rowdy Creek, and various small terminal tributaries. We also detected them in the upper portions of the South Fork and North Fork watersheds.

We estimated that the coho salmon reproductive effort (number of redds) in 2014-2015 and 2015-2016 was less than half (31% and 39% respectively) of the 2011-2012 reproductive effort estimate despite adults using the same core area in upper Mill Creek for spawning. Overall median pool count densities of juvenile coho salmon were observed to decrease across the five survey years. Median pool counts in 2012 were 47 percent greater than those in 2016 suggesting higher production when adults were more abundant. Flitcroft et al. (2013) found juvenile coho salmon distributions expanded beyond core areas when adults were more abundant and contracted at lower adult abundances. We would thus expect juvenile coho salmon to occupy a greater proportion of habitat when adult abundance was high. We found this to be the case because the proportion of reaches occupied by juvenile coho salmon between the years decreased (0.42 in 2012 vs. 0.30 in 2016). Furthermore, the percentage of sampled pools occupied by juvenile coho salmon, independent of reach, decreased from 26 percent in 2012 to 18 percent in 2016. Garwood et al. suggested that the higher percentage of coho salmon observed using non-natal rearing areas in 2012 vs 2013 resulted from the larger adult population spawning in 2011. While we observed lower percentages of coho salmon rearing in non-natal reaches in subsequent survey years, the next highest percentage of coho salmon rearing in non-natal habitat occurred during 2015. Our redd estimates for the 2014 brood year are the lowest of the five survey years, suggesting that adult abundance alone may not explain juvenile use of non-natal rearing areas. Seasonal migration behaviors of juvenile coho salmon are common and well documented throughout their range (Chapman 1962, Koski 2009, Wallace and Allen 2009, Reeves et al. 2011, Bennett et al. 2011).

In contrast to our observed patchy distributions of coho salmon – with the exception of Chinook salmon in 2014 – juvenile Chinook salmon, juvenile trout (spp.) and adult coastal cutthroat trout were widely distributed in the sample frame. This indicates the community composition and species richness remains diverse across space and populations may be more resilient over time. Tracking the spatial distribution and richness of fish species communities through space and time allows managers to use a suite of biological metrics for assessing shifts in species compositions and habitat quality. Additionally, species compositions can be compared across populations having varying degrees of habitat resiliency.

Recommendations

Based upon data and analysis from this report, we have some recommendations we feel will further add to our understanding of the distribution of coho salmon, Chinook salmon, steelhead, coastal cutthroat trout and Pacific lamprey in the Smith River basin. We suggest spawner surveys and spatial structure surveys that provide vital information for managers and restoration groups and the Smith River monitoring program have long-term support. The Smith River also has substantial resiliency with respect to salmon and steelhead populations and serves as a vital unique comparison to other populations being monitored in northern California.

Future Biological Inventories:

Upper Jones Creek/ Muzzleloader Creek

We were unable to access upper portions of the Jones Creek watershed over the five years of the study, yet detected juvenile coho salmon utilizing Jones Creek on multiple survey years (Figure 28). The distribution and densities of individuals suggest that these coho salmon likely originated within upper Jones Creek/ Muzzleloader Creek.

Upper South Fork Smith River/ Prescott Fork

Because we detected juvenile coho salmon in the upper South Fork Smith River, salmonid inventories are needed in the South Fork from Prescott Fork up to the Island Lakes Trail to identify species distribution limits. An additional survey in the Prescott Fork is also needed to define habitat availability in this tributary. Habitats are likely limited in these reaches due to suspected barriers and a directed survey will refine the distribution potential of anadromous forms.

Diamond Creek

Based on our sample frame development, we did not survey any portions of Diamond Creek, tributary of the North Fork Smith River. Given we detected juvenile coho salmon in other North Fork tributaries, we suggest an inventory of Diamond Creek is now warranted. Much of the basin is likely inhospitable for summer rearing due to warm temperatures and spawning habitat is limited so this focus should be in smaller cooler tributaries having ample spawning gravel.

Non-anadromous waters

Level II habitat surveys conducted by the US Forest Service have thoroughly described resident salmonid (rainbow trout, coastal cutthroat trout) distribution extents in a number of Smith River tributaries. However, resident salmonid distributions are still poorly understood across the majority of the basin making it difficult to understand their population sizes and potential influence on anadromous waters occurring below migration barriers. Future systematic surveys in waters lacking salmonid inventories will benefit management in these poorly understood areas.

Spawning Gravel Distribution Census

Given the patchy spawning distributions we describe in this report, we suggest a course census of spawning gravel patch distribution beyond our sample frame and throughout the Smith River would be beneficial to understanding spawning patch sizes and the degree of patch isolation. For example, the lower Smith River contains an abundance of spawning habitats whereas the Middle Fork and North Fork have extended gorges lacking spawning gravels. We have identified some substantial isolated spawning patches in these streams that appear to be critical local habitat elements of anadromous salmonids. A thorough inventory of these patches throughout the basin would help define potential spawning carrying capacity while acknowledging the spatial construct of reproduction potential.

Rowdy Creek Fish Hatchery Weir Barrier Removal

The Rowdy Creek Fish Hatchery weir is a complete barrier to juvenile salmonids and partial barrier to adult salmonids. Given our survey results from multiple studies, we suggest this barrier is among the most immediate salmonid conservation issues in the Smith River and throughout northern California. A total of 18.4 kilometers of spawning and rearing habitat exists above the barrier. Juvenile and adult coho salmon have been found above the barrier indicating only intermittent reproduction is occurring, despite the abundance of available coho salmon spawning and rearing habitats. With recent findings from other studies describing non-natal rearing and colonization of distant habitats by juvenile coho salmon, the alluvial valley portion of Rowdy Creek could also offer substantial low gradient non-natal rearing habitats for nomadic juvenile salmonids; habitats which have been largely lost in the lower Smith River estuary ecotone. Additionally, portions of Rowdy Creek above the weir have been the recent focus of wood loading projects adding complexity to Rowdy Creek fish habitats. Complete removal, or providing juvenile passage alterations to this structure, would substantially increase natural migratory behavior and carrying capacity for all salmonid and lamprey species.

Wood Loading in Tributaries

We observed a low abundance of large wood in the wetted stream channel in many areas outside of the coastal plain subbasin. This was especially true in the Middle Fork Smith River and portions of the upper South Fork Smith River. Augmentation of wood in streams such as Craigs Creek, Rock Creek, Siskiyou Fork, Monkey Creek, Patrick's Creek and lower Shelly Creek may benefit both juvenile and adult salmonids by providing rearing habitats and hydrological complexity for recruiting and retaining spawning gravels.

Integrate Sonar Counting Station with Spawning Surveys

If managers want basin-wide Chinook salmon and steelhead spawning escapement estimates, then one or more fixed sonar counting stations coupled with spawning surveys may prove to be the best methodology. We observed broad overlap in run timing of adult salmonids while sonar counting stations have proven very effective at counting adult salmonids. Incorporating broader temporal and spatial observations into the fixed station counts may lead to better estimates provided that the spawning survey sample frame includes as much Chinook salmon and steelhead spawning habitat as possible.

Literature Cited

Adams, P., L. Boydstun, S. Gallagher, M. Lacy, T. McDonald and K. Shaffer. 2011. California coastal salmonid population monitoring: strategy, design, and methods. State of California, Fish Bulletin 180. 82p.

Bennett, T. R. Wissmar, and P. Roni. 2011. Fall and spring emigration timing of juvenile coho salmon from East Twin River, Washington. Northwest Science 85: 562-570.

Bisson, P., K. Sullivan, and J. Nielson. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead, and cutthroat trout in streams. Transactions of the American Fisheries Society 117: 262-273.

Burch, D. S. Gallagher, S. Ricker, and R. Bellmer. 2014. Database Management (DBM) Team Status: Report and Concept for Success. California Department of Fish and Wildlife, Redding, CA.

California Data Exchange Center (CDEC). 2016. 2016 Water Year Monthly Precipitation. California Department of Water Resources. http://cdec.water.ca.gov/cgi-rogs/profile?s=GAS&type=precip.

California Data Exchange Center (CDEC). 2014. 2014 Water Year Monthly Precipitation. California Department of Water Resources: http://cdec.water.ca.gov/cgi- progs/reports/PRECIPOUT.BSN.2014

CDFW 2004. Recovery Strategy for California Coho Salmon. 594p.

Chapman. D. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. Journal Fisheries Research Board of Canada 19: 1047-1080.

Cover T. and P. Hart. 1967. Nearest neighbor pattern classification, IEEE Transactions on Information Theory 13: 21–27.

Crawford, B., T. Mosey, and D. Johnson. 2007. Carcass counts. Pages 59-86. *In* D. Johnson, B. Shrier, J. O'Neal, J. Knutzen, X. Augerot, T. O'Neill, and T. Pearsons (editors), Salmonid Field Protocols Hand-book: Techniques for Assessing Status and Trends in Salmon and Trout Populations. American Fisheries Society, Bethesda, MD.

Dunning, J.B., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos, 65: 169-175.

Flitcroft, R. K. Burnett, J. Snyder, G. Reeves, and L. Ganio. 2013. Riverscape patterns among years of juvenile coho salmon in midcoastal Oregon: implications for conservation. Transactions of the American fisheries society 143:26-38.

Gallagher, S. and C. Gallagher. 2005. Discrimination of Chinook and coho salmon and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in Northern California. North American Journal of Fisheries Management. 25:284-300.

Gallagher, S., P. Hahn, and D. Johnson. 2007. Redd counts. Pages 197-234. *In* D. Johnson, B. Shrier, J. O'Neal, J. Knutzen, X. Augerot, T. O'Neill, and T. Pearsons (editors), Salmonid Field Protocols Hand-book: Techniques for Assessing Status and Trends in Salmon and Trout Populations. American Fisheries Society, Bethesda, MD.

Gallagher, S. P. Adams, D. Write, and B. Collins. 2010. Performance of spawner survey techniques at low abundance levels. North American Journal of Fisheries Management 30: 1086-1097.

Garwood, J. 2010. 2010 Rowdy Creek Hatchery Smith River salmonid marking program assessment with a review from years 2005 to 2010. California Department of Fish and Wildlife, Arcata, CA. 7p.

Garwood, J. 2012. Historic and Recent Occurrence of Coho Salmon (*Oncorhynchus kisutch*) in California Streams within the Southern Oregon/ Northern California Evolutionarily Significant Unit. California Department of Fish and Wildlife, Arcata CA. 77p.

Garwood, J. and M. Larson. 2014. Reconnaissance of salmonid redd abundance and juvenile spatial structure in the Smith River with emphasis on coho salmon. Final report to the California Department of Fish and Wildlife Fisheries Restoration Grants Program, Contract: P1010504. Smith River Alliance, Crescent City, CA. 63pp.

Garwood, J., M. Larson, and M. Reneski. 2014. 2013-2014 Salmonid Redd Abundance and Juvenile Salmonid Spatial Structure in the Smith River Basin, California and Oregon. Annual Progress Report to the California Department of Fish and Wildlife Fisheries Restoration Grants Program. Grantee agreement:P1210524. Smith River Alliance, Smith River Alliance Crescent City, CA. 39p.

Garwood J. and S. Ricker. 2013. 2013 juvenile coho salmon spatial structure protocol: summer survey methods. California Department of Fish and Wildlife, Arcata, CA. 10 p.

Garwood J. and S. Ricker. 2016. 2016 juvenile coho salmon spatial structure protocol: summer survey methods. California Department of Fish and Wildlife, Arcata, CA. 10 p.

Gough, S. 2010. A comparison of escapement estimates methods plus escapement-recruitment relationships for coho salmon and Chinook salmon in a coastal stream. MS Thesis. Humboldt State University, Arcata, CA.

Gunckel, S., K. Jones, and S. Jacobs. 2009. Spawning distribution and habitat use of Pacific and western brook lampreys in Smith River, Oregon. Pages 173–189 in L. R. Brown, S. D. Chase, M. G. Mesa, R. J. Beamish, and P. B. Moyle, editors. Biology, management, and conservation of lampreys in North America. American Fisheries Society, Symposium 72, Bethesda, Maryland.

Hankin, D.G. and M. Mohr. 2016. Status report: Assessment of statistical properties of transgenerational genetic-based mark-recapture estimators of abundance. Pages 1-23 in Genetic-Based Capture-Recapture Estimation of Coho Salmon. Completion report for California Department of Fish and Wildlife, Fisheries Restoration Grant Program: P1310322. Humboldt State University, Arcata CA.

Jones,E.C.2012. Environmental stochasticity and the reliability of redd count data: a simulation study of redd construction, redd loss, and survey frequency in a small coastal stream in northern California. Thesis, Humboldt State University, 85 p.

Koski, K. 2009. The fate of coho salmon nomads: the story of an estuarine-rearing strategy promoting resilience. Ecology and Society volume14, Issue 1, Article 4.

Larson, Z. 2013a. Mill Creek fisheries restoration monitoring program final report. 2010-2012. final report to the California Department of Fish and Wildlife. Mill Creek Fisheries Monitoring Program, Crescent City, CA. 72p.

Larson, Z. 2013b. Operation of dual frequency identification sonar (DIDSON) to monitor adult anadromous fish migrations in the Smith River, California: 2-year pilot study. Final report to the California Department of Fish and Wildlife. Contract: P0910315. 42p.

Larson, Z. 2013c. Use of dual frequency identification sonar to monitor steelhead escapement in the Smith River, California, 2012-2013. Final report to the California Department of Fish and Wildlife. Contract: P0910315. 27p.

MacKenzie, D. J. Nichols, A. Royle, K. Pollock, L. Bailey, and J. Hines. 2006. Occupancy estimation and modeling. Academic Press, Burlington, MA. 324p.

McCain, M., B. Devlin-Craig, and C. Black. 1995. Smith River ecosystem analysis: basin and subbasin analyses and late successional reserve assessment, version 1.0. United States Department of Agriculture (USDA), Forest Service, Six Rivers National Forest, Eureka, CA. 213pp.

McElhany et al. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42.

McLeod, R., and C. Howard. 2010. Mill Creek Fisheries Monitoring Program, Final Report, Del Norte County, California. 84p. 58

Montgomery, D., and J. Buffington .1998. Channel-reach morphology in mountain drainage basins. GSA Bulletin 109: 5, p. 596-61no1.

Montgomery, D., E. Beamer, G. Pess, and T. Quinn .2009. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Fisheries and Aquatic Sciences 56: 377-387.

National Marine Fisheries Service. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, CA.

Nichols. J. , L. Bailey, A. O'Connell, Jr., N. Talancey, E. Campbell Grant, A. Gilbert, E. Annand, T. Husband, and J. Hines. 2008. Multi-scale occupancy estimation and modeling using multiple detection methods. Journal of applied ecology 45: 1321-1329.

Nickelson, T., J. Rodgers, S. Johnson, and M. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49 (4): 783-789.

O'Neal. 2007. Snorkel Surveys. Pages 325-340. *In* D. Johnson, B. Shrier, J. O'Neal, J. Knutzen, X. Augerot, T. O'Neill, and T. Pearsons (editors), Salmonid Field Protocols Hand-book: Techniques for Assessing Status and Trends in Salmon and Trout Populations. American Fisheries Society, Bethesda, MD.

Pess, G., D. Montgomery, E. Steel, R. Bilby, B. Feist, and H. Greenberg. 2002. Landscape characteristics, land use, and coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 59: 613-623.

R Development Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Reeves, G., J. Sleeper, and D. Lang. 2011. Seasonal changes in habitat availability and the distribution and abundance of salmonids along a stream gradient from headwaters to mouth in coastal Oregon. Transactions of the American Fisheries Society 140: 537-548.

Ricker, S. and E. Stewart. 2011. Predicting redd species from spawning ground survey data. California Department of Fish and Game, Arcata, CA. 13p.

Ricker, S., J. Ferreira, S. Gallagher, D. McCanne, and S. Hayes. 2014a. Methods for Classifying Anadromous Salmonid Redds to Species. Coastal Salmonid Population Monitoring Technical Team Report. California Department of Fish and Wildlife, Arcata, California. 24p.

Ricker, S., K. Lindke, J. Garwood, and M. Larson. 2014b. Results of regional spawning ground surveys and estimates of total salmonid redd construction in the Smith River, Del Norte County, California, 2011. California Department of Fish and Wildlife, Arcata, CA. 33p.

Ricketts, T. 2001. The matrix matters: effective isolation in fragmented landscapes. The American Naturalist 158: 87- 99.

Schwarz, C., R. Bailey, J. Irvine, F. Dalziel. 1993. Estimating Salmon Spawning Escapement using Capture-Recapture Methods. Canadian Journal of Fisheries and Aquatic Sciences 50: 1811-1197.

USGS. 2012. Water-Data Report 2012, 11532500 Smith River near Crescent City, CA. U.S. Department of the Interior.3p. *Available at*: http://wdr.water.usgs.gov/wy2012/pdfs/11532500.2012.pdf

USGS 2016. (US Geological Survey, Patuxent Wildlife Research Center). (2012) PRESENCE 11.5 software. *Available at*: http://www.mbr-pwrc.usgs.gov/software/presence.html. (Accessed on October 5, 2016).

USGS. Accessed on 01/19/2017. USGS Surface-Water Annual Statistics for the Nation, 11532500 Smith River near Crescent City, CA. *Available at:* https://nwis.waterdata.usgs.gov/ca/nwis/annual/?referred_module=sw&site_no=11532500& por_11532500_12011=2210405,000

Voight, H and J. Waldvogel. 2002. Smith River Anadromous Fish Action Plan. Smith River Advisory Council. 78p.

Walkley, J., J. Garwood. 2015. 2014-2015 Salmonid Redd Abundance and Juvenile Salmonid Spatial Structure in the Smith River Basin, California and Oregon. Annual Progress Report to the California Department of Fish and Wildlife Fisheries Restoration Grants Program. Grantee agreement: P1410547 Smith River Alliance, Smith River Alliance, Crescent City, CA. 38pp

Wallace and Allen. 2009. Juvenile salmonid use of the tidal portions of selected tributaries to Humboldt Bay, California. Final report for contract P0610522. August 2009. 32p.

Webster, R. K. Pollock, and D. Hankin. 2005. A new protocol for detection of juvenile coho salmon in small coastal streams in northern California. 46p.

Whitmore, R. and A. Kinziger. 2016. Status report: Assessment of statistical properties of transgenerational genetic-based mark-recapture estimators of abundance. Pages 22-81 in Genetic-Based Capture-Recapture Estimation of Coho Salmon. Completion report for California Department of Fish and Wildlife, Fisheries Restoration Grant Program: P1310322. Humboldt State University, Arcata CA.

Wild Salmon Center. 2012. The California salmon stronghold initiative. Prepared for the California Department of Fish and Game. 21p. *Available at:* http://www.wildsalmoncenter.org/programs/north_america/california.php.

Williams et al. 2006. Historical population structure of coho salmon in the Southern Oregon / Northern California Coasts Evolutionarily Significant Unit. U. S. Department of Commerce, NOAA Technical Memorandum NMFSSWFSC-390.