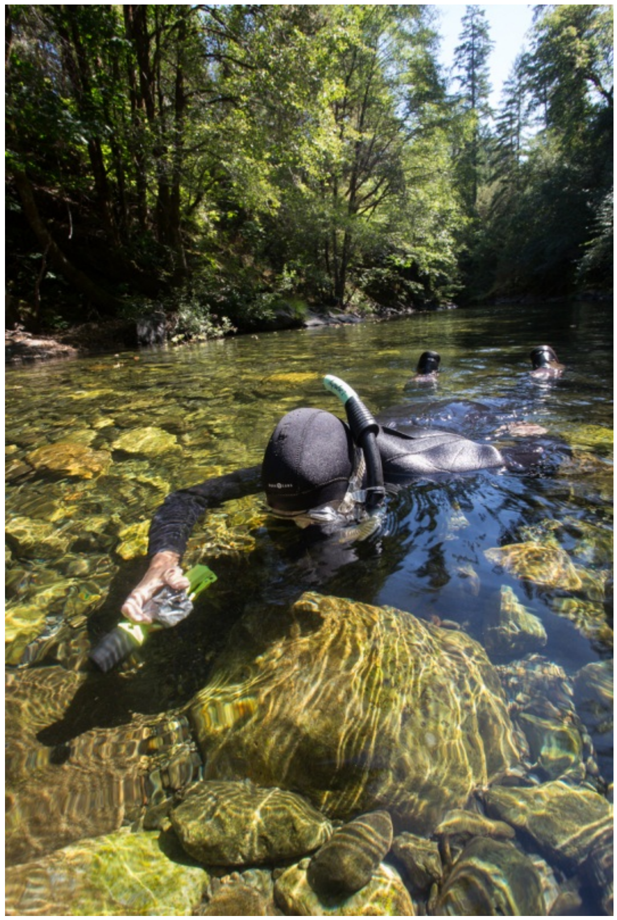
Reconnaissance of Salmonid Redd Abundance and Juvenile Salmonid Spatial Structure in the Smith River with Emphasis on Coho Salmon (*Oncorhynchus kisutch*)



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FINAL REPORT TO THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
FISHERIES RESTORATION GRANTS PROGRAM
GRANTEE AGREEMENT: P1010504

ON BEHALF OF

THE SMITH RIVER ALLIANCE

AND

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

Reconnaissance of salmonid redd abundance and juvenile salmonid spatial structure in the Smith River with emphasis on Coho Salmon (*Oncorhynchus kisutch*)

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Prepared by: Justin M. Garwood[1] and Monty D. Larson[2]

Abstract

We investigated two essential population viability metrics of salmonids 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 for two consecutive years (2011-2013) using live fish, carcass, and redd counts as defined in California's Coastal Salmonid Monitoring Plan. Second, we developed a new protocol for monitoring the summer spatial structure of juvenile salmonids and adult coastal cutthroat trout during the summers of 2012 and 2013 using multiple-pass snorkel surveys in an occupancy modeling framework. To implement these studies, we developed two unbiased sample frames tailored specifically to identify stage-based coho salmon habitats. We compiled empirical species distribution data and physical stream attributes into a geographic information system model that was later verified in the field. We divided each sample frame 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 completed 388 and 398 spawning ground surveys throughout the Smith River basin for the 2011-2012 and 2012-2013 seasons, respectively. We made 389 and 129 live adult coho salmon observations in 2011-2012 and 2012-2013, respectively. All live coho salmon observations occurred in Mill Creek except one individual was observed in the Rowdy Creek sub-basin during the 2011-2012 season. We recovered 82 and 24 coho salmon carcasses in 2011-2012 and 2012-2013, respectively. All coho salmon carcasses were observed in Mill Creek except one individual in Morrison Creek in 2012-2013. We were able to verify 90 and 25 individual coho salmon redds for the 2011-2012 and 2012-2013 seasons, respectively. All verified redds were found in the upper Mill Creek sub-basin. 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 in the Mill Creek sub-basin as 482 (95% CI: 464 - 501) and 227 (95% CI: 217 - 236) redds for 2011-2012 and 2012-2013 seasons, respectively. Hatchery origin salmonids were observed spawning throughout sampling frame with the mean hatchery proportion of Chinook salmon carcasses ranging from 7.5% to 22.7% and mean hatchery proportion of live steelhead ranging from 8.5% to 11.1%. Our results highlight the limitations of spawning ground surveys when your target species is rare and narrowly distributed while other species are common and widespread. 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. In 2012 we detected juvenile coho salmon in 17 out of 41 surveyed reaches in five portions of the watershed. Eleven (65%) of the reaches with coho salmon were non-natal rearing areas. Estimated large-scale occupancy of juvenile coho salmon equaled 0.42 (SE=0.08) while estimated small-scale occupancy equaled 0.68 (SE=0.01) resulting in a proportion of total area occupied (PAO) of 0.29. In 2013 we detected juvenile coho salmon in 23 out of 60 surveyed reaches in four portions of the watershed. Nine (39%) of the reaches with coho salmon were non-natal rearing areas. Estimated large-scale occupancy of juvenile coho salmon equaled 0.39 (SE=0.06) while estimated small-scale occupancy equaled 0.60 (SE=0.02) resulting in a PAO of 0.23. All other salmonid species had much wider spatial distributions with reach-level occupancy estimates ranging from 0.71 (SE=0.07) to 1.00 depending on species and age class. Based on our surveys, we found the Smith River coho salmon population had two remote inland sub-populations and a core coastal plain sub-population. Coho salmon juveniles used a variety of non-natal rearing habitats highlighting diversity in life-history and complementary resource needs.

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Acknowledgments

Without the generous help of numerous individuals, groups, and agencies, we would know much less about the biological resources of the Smith River basin than we do today. 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 throughout. The vision and collaboration of the Smith River Alliance provided a lasting motivation for all involved resulting in a highly organized effort. Beatrijs deWaard provided excellent grant support throughout the study. We thank all of the exceptional field biologists who assisted us in establishing the California Department of Fish and Wildlife's Coastal Salmonid Monitoring Program in the Smith River basin with rigorous data collection standards: Gaytha Babcock, Diana Baetscher, John-Deibner-Hanson, Tara Dettmar, John Hagan, Jesse Nolan, Marisa Parish, Melissa Reneski and Jolyon Walkley. We also thank AmeriCorps Watershed Stewards Project (WSP) volunteers: Diana Baetscher, Adam Cockrill, Jen Olson, and Tim Sandborn who helped ease busy days and inspire us with their budding enthusiasm for salmonids. We also thank Michael van Hattem and Scott Bauer of CDFW for allowing their WSP members to join our team during critical survey periods. Rachael McCain (National Park Service) provided field assistance at critical survey periods and helped us overcome logistical challenges with sampling on State and National Park lands. The 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 Frank Kemp and Charles Bartolotta of CDFW for providing last minute office space at Lake Earl Wildlife Area during our first season and to Jeff Bomke of State Parks and Rachael McCain of National Park Service for the opportunity of leasing park office and housing space. We thank Philip Bairrington, Mary Kuehner, Brenda Tuel, and Marisa Parish for administrative assistance throughout the study. Seth Ricker and Ken Lindke provided detailed solutions to estimating adult salmonid redd abundance and many conversations on analytical approaches to our data. We are in debt to Wade Sinnen, Michael Wallace, Sarah Borok, Frank Kemp, Charles Bartolotta, Mary Claire Kier, and Scott Bauer for loaning vehicles during times of need. This work would not have progressed as quickly or smoothly without 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.

Introduction

Observed 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, *draft* NOAA SONCC recovery document) for the Southern Oregon Northern California Coho (SONCC) Evolutionary Significant Unit (ESU). The Smith River basin has been identified as a functionally independent coho salmon population in the central diversity strata for the SONCC ESU by NOAA (McElhany et al. 2000, Williams et al. 2006, Williams et al. 2008) and is recognized as a recovery unit by California Department of Fish and Wildlife (CDFW 2004). The 'population' has been defined as the scale used to assess population viability (Williams et al. 2006). For a coho salmon population to meet or exceed a viable threshold, it must show a low risk of extinction over 100 years (McElhany et al. 2000). Therefore, to determine recovery for the SONCC ESU, numerous long-term population monitoring programs need to be established and maintained across the ESU.

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 data needs for the viability assessment, CDFW and NOAA (National Oceanic and Atmospheric Association) cooperatively developed the Coastal California Salmonid Monitoring Plan (CMP). Boydstun and McDonald (2005) and Adams et al. (2011) describe the strategy, general design, and general methods that are used in CMP monitoring. 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-specific monitoring goals and focus species which are 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). However, the status of the coho salmon population is among the least understood in California as assessments conducted previously were limited in scale, and almost exclusively restricted to a single sub-basin. This uncertainty around the status of Smith River coho salmon prevents managers from critically assessing ESA recovery goals and prioritizing an effective restoration strategy defined by NOAA and CDFG (Beechie et al. 2003, CDFG 2004). The work described in this report represents the first comprehensive effort for monitoring viable salmon population parameters in the Smith River basin as defined by California's Coastal Salmonid Monitoring Program. Monitoring VSP parameters of anadromous salmonids in basins having habitat resiliency and high salmonid conservation value will also benefit recovery priorities throughout the SONCC ESU by comparing data across a wide range of habitat conditions.

Monitoring Approach

We developed this coho salmon monitoring effort to assess two of the four viable salmonid population parameters: Abundance and Spatial Structure (McElhany et al. 2000). Each monitoring component requires well planned study designs, sampling protocols, analysis and reporting metrics, and data storage (Adams et al. 2011). Application of various monitoring components also needs to be standardized across multiple salmonid populations in order to assess population metrics at the ESU scale. Notwithstanding, the implementation of the CMP has only occurred in recent years for much of the monitoring area and methods are being refined as lessons from new monitoring programs and data sets are becoming available to program managers.

Population Abundance

Abundance is perhaps the most important population metric since it can generally be used to assess overall extinction risk without needing to understand all the species-specific factors influencing the population (McElhany et al. 2000). Spawning ground surveys are the primary monitoring method used for tracking salmonid population abundance trends in the northern monitoring area (Boydstun and McDonald 2005, Adams et al. 2011). Surveys are confined to an annual sample of stream reaches where redds, live fish, and carcasses are counted across multiple survey periods throughout a season (Gallagher et al. 2007). Total redd production is the primary abundance metric and is carried out using flag-based mark-recapture of individual redd features in a population model. The total number of redds are estimated for each survey reach and these totals are used to expand the estimate across the entire sample frame (Boydstun and McDonald 2005). Although this monitoring effort was designed for coho salmon, all salmonid species were incorporated into data collection and analysis based on the need to divide individual redds into separate species. Ultimately redds are converted to adult numbers based on adult to redd correction factors produced at local life cycle monitoring stations or from the scientific literature (Gallagher et al. 2010, Adams et al. 2011).

Spatial Structure

The spatial structure of a population refers both to the spatial distributions of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). Spatial structure is important for assessing viability because understanding extinction risk for population abundance trends occurs at longer timescales than measured changes in the spatial arrangement of the population. Understanding patch use, patch size, patch connectivity, and patch colonization and extinction processes of the population will help managers define source patches while also protecting isolated patches that are much more vulnerable to extinction (Adams et al. 2011). For coho salmon, juvenile life stages are the most widely distributed across the riverscape with habitats being spatially and temporally dynamic (Wigington et al. 2006, Henning et al. 2006, Anderson et al. 2008, Koski 2009, Flitcroft et al. 2013). Two distinctive periods representing a high likelihood of contrasting stream habitat availability include the winter and summer. We suggest both periods are critical to understanding spatial structure dynamics and sampling strategies should be developed for each. For example, estuaries have been shown to be important temporal rearing locations for coho salmon during the winter (Koski 2009, Wallace and Allen 2009). Methods for monitoring juvenile salmonid spatial structure have not been formally developed by the CMP. However, Adams et al. (2011) suggested juvenile salmonid surveys be conducted during the summer on an annual basis in a sampled fraction of reaches throughout a population.

We adapted a snorkel survey protocol by Webster et al. (2005) to sample for juvenile coho salmon throughout a randomly selected set of reaches with pools defined as the primary sampling unit. We based our design on an occupancy modeling framework that incorporates both reach-level and pool-level occupancy while accounting for imperfect detection rates (Nichols et al. 2008, MacKenzie et al. 2006). By tracking occupancy at both scales, we were able to determine the overall proportion of area occupied during the summer rearing period. Results from each year can be directly compared to assess the relative change in annual spatial structure. Our study is the first attempt at formalizing sampling methods and a statistical framework specifically for measuring juvenile salmonid spatial structure in California so this work should be considered a pilot effort. As such, our methods have not been reviewed or endorsed by the CMP. We hope results from this study will offer critical empirical data to further the development of an accepted state-wide spatial structure monitoring component. Methods in the occupancy modeling construct are currently rapidly evolving suggesting opportunities to use new tools and methods in the near future.

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 sub-basins drain the majority of the eastern and northern portions of the basin including the South Fork, Middle Fork, and North Fork. These sub-basins 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 portion of the basin includes portions of the coast range and is dominated by redwood forests. Major sub-basins 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 2013). Precipitation is usually delivered during large winter storm events with 84% of annual average rainfall received from October to March (CDEC 2013). The sparsely vegetated and shallow rocky soils 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 338 cfs and monthly mean winter (January) flow is 8,491 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 2013 is 82,363 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 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, NOAA 2012). Primary land uses in the coastal plain include cattle ranching, hay production, lily bulb production, water diversions for irrigation, and aggregate mining.

Smith River Salmonid Populations

Previous to this study, no thorough effort had been made to identify coho salmon distribution throughout all major portions of the Smith River basin. A literature review by Garwood (2012) verified coho salmon historically occurring in 36 Smith River tributaries within the California portion of the basin from as early as 1935. From 2001 to 2003, twenty-three of these tributaries were surveyed for coho salmon and 18 had confirmed presence (Garwood 2012a, 2012b). The Mill Creek watershed has been the focus of various salmonid population monitoring efforts since 1994 and contains the largest amount of information on coho salmon occurrence in the Smith River. A long-term spawning survey focused on Chinook salmon in a small

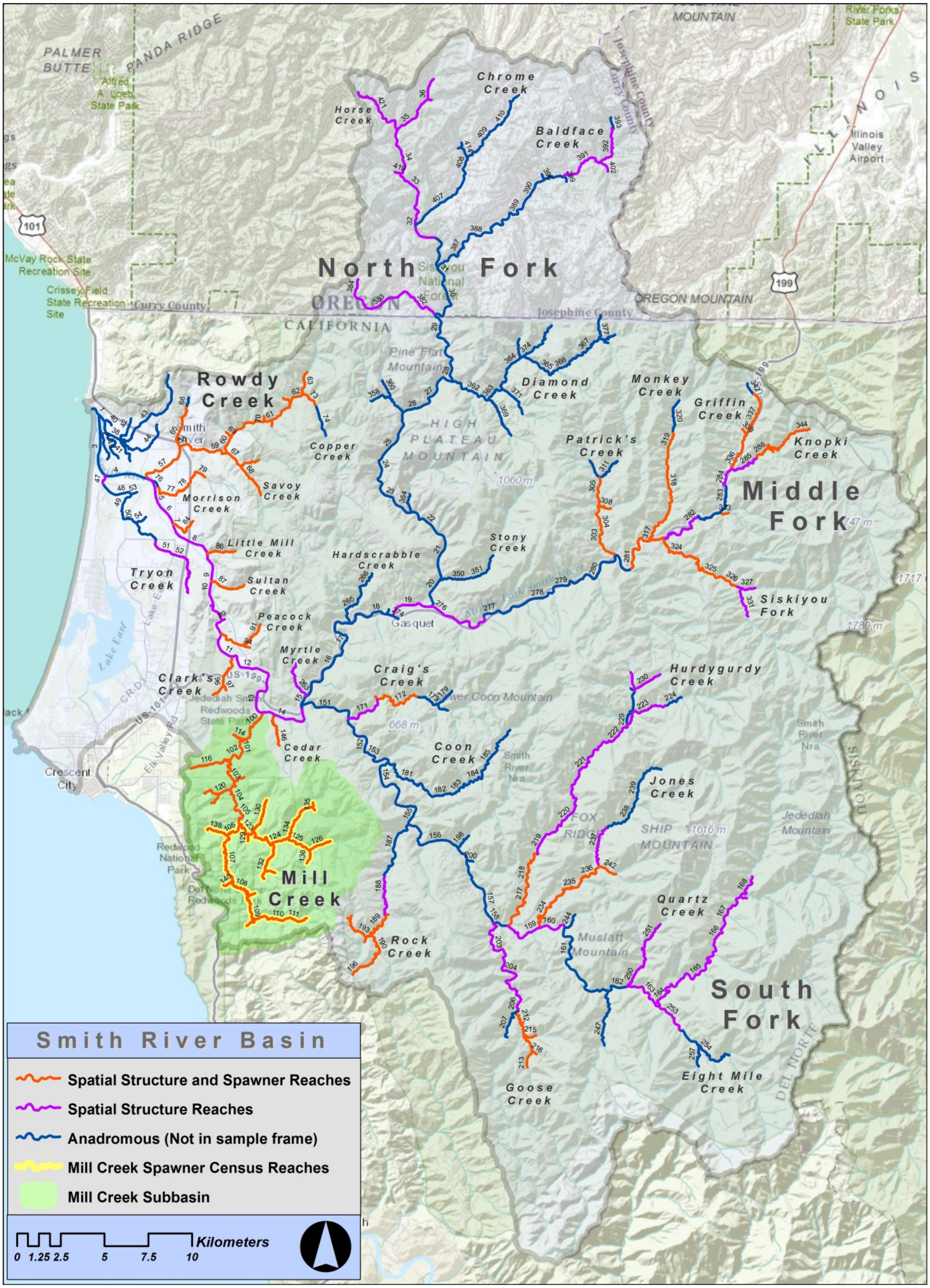


Figure 1. Map of the Smith River Basin, Del Norte County (California) and Curry County (Oregon). Stream lines indicate potential anadromous salmonid stream habitat based on this studies sample frame development process. Numbers represent 275 individual reach location codes used in generalized random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

Index section of Mill Creek documented spawning coho salmon each year from 1980 to 2002 (Waldvogal 2006). Additionally, the Mill Creek salmonid restoration monitoring program documented adult and juvenile coho salmon occurring in the watershed every year from 1994 to 2012 with spawning ground surveys and smolt outmigrant trapping (Howard and McLeod 2005, McLeod 2010, Larson 2013a). Adult coho salmon have also been recorded at the Rowdy Creek Fish Hatchery weir in 27 out of the last 30 years of operation (Andrew Van Scoyk, pers. Comm.), with most years counting less than 20 individuals. However, the hatchery produced coho salmon in seven of the 30 years, and these year cohorts represent some of the highest annual weir counts. The US Forest Service has conducted opportunistic spawning ground surveys on National Forest streams in the South and Middle forks since 1976. These surveys were focused on Chinook salmon and steelhead. However, spawning adult coho salmon were observed in the Siskiyou Fork in 2003 and the upper Middle Fork in 2010 (Mike McCain, pers. Comm.). Juvenile coho salmon have also been documented in the Oregon portion of the North Fork Smith River (USFS 2006, Ian Reid, pers. comm.). Last, prior to this study we knew very little regarding the spatial-temporal rearing distribution of juvenile coho salmon in the Smith River estuary. An initial survey conducted on public lands by Garwood and Reneski (2012) indicates juvenile coho salmon rear in specific habitats throughout the estuary during the winter. However, the majority of the estuary is under private ownership so further investigation is needed to determine the extent of juvenile distribution in this habitat.

Other salmonids, including fall run Chinook salmon (*O. tshawytscha*), winter run steelhead and resident forms (*O. mykiss*), and coastal cutthroat trout (*O. clarki, clarki*) are widespread throughout the basin. Few spring run Chinook salmon and summer steelhead are observed in the Smith River (McCain 2011). A report by Larson (2013b) used a sonar counting station located in the lower river coupled with weir counts at Rowdy Creek Fish Hatchery and a dive census to estimate basin-wide escapement of fall Chinook salmon and winter steelhead. The study estimated a minimum of 22,500 adult Chinook salmon and 16,000 adult steelhead returned to the Smith River during the winter of 2010-2011 (Larson 2013b). Summer coastal cutthroat dive counts from 1982 to 2011 indicate the species is common and widespread across a large gradient of habitats (McCain 2011). Last, chum salmon (*O. keta*) sporadically return to Mill Creek (Waldvogal 2006, McLeod and Howard 2010) and adult sockeye salmon (*O. nerka*) have been noted during the summer in the Middle and South Fork Smith River (this study).

Rowdy Creek Fish Hatchery

The Smith River has the only privately operated anadromous salmonid fish hatchery in California and has been in continuous operation since 1973 (Andrew Van Scoyk, pers. comm.). Rowdy Creek Fish Hatchery (RCH) is located in lower Rowdy Creek near the Smith River estuary and raises Chinook salmon and steelhead to enhance the river's adult population sport fishery. The current rearing permit issued by CDFW sets production goals at approximately 100,000 smolt's of each species annually. Fisheries managers also require that 100% of RCH raised salmonids have an external fin clip so hatchery fish can be identified by commercial and sport anglers and salmonid monitoring programs. In addition to an adipose fin clip, Chinook salmon are required to be coded wire tagged so adult recoveries can be aged and identified to their hatchery of origin. Hatchery produced salmonids are easily identified during spawning ground surveys and provide data on relative occurrence and stray rates throughout a survey area.

Sample Frame Development

We developed two reach-based salmonid sampling frames to define the potential spatial extents of adult spawning and summer juvenile rearing habitats in the Smith River basin. Prior to this project very little was known about coho salmon distribution outside of Mill Creek (Garwood 2012) making a modeling exercise especially useful to establish the initial sampling frame. The initial frame construction goal was to define all potential anadromous fish species distributions in the Smith River. Although this project's focus is monitoring coho salmon, we developed this multi-species frame so it could be adapted for use with multiple monitoring objectives in a single framework. We followed an unbiased and reproducible process developed by Garwood and Ricker (2011) to determine upper salmonid spatial extents by modeling physical stream attributes (i.e. maximum stream gradient and minimum stream discharge thresholds), while incorporating incomplete empirical information on salmonid migration barriers and known salmonid distributions in a Geographic Information System (GIS) (Figure 2, Appendix A). The primary empirical fish distribution and barrier datasets were obtained from verified historic coho salmon distributions (Garwood 2012), US Forest Service Level II survey reports, the California Fish Passage Database (PAD), and salmonid distribution layers obtained from the CDFW Biogeographical Information and Observation (BIOS) website (Appendix A). For the modeling component, we used gradient and stream discharge parameters derived from the Coastal Landscape Analysis and Modeling Dataset (CLAMS IP model) (Burnett et al. 2003) adapted for California by Agrawal et al. (2005).

Ordered Sample Frame Development Steps	Information Source	Effect on Frame Size
Salmonid Distribution	GIS Data	+
▼		
Gradient and Discharge	GIS Model	+
▼		
Total Anadromous Barriers	GIS Data	-
▼		
Expert Review	Biologists	+ -
▼		
Field Reconnaissance	Field Staff	+ -
▼		
Net Sampling Universe		
▼		
Survey Reach Development		
▼		
GRTS Sample Draw		

Figure 2. Ordered steps for developing an unbiased population-level sampling frame for salmonid spawning ground surveys; adapted from Garwood and Ricker (2011).

After constructing initial salmonid distributions, we consulted fisheries professionals having direct knowledge on salmonid distributions in the Smith River (Appendix A). Maps containing known species distributions, barriers, and our modeled distributions were provided to these experts for critique and adjustments were made to the initial sampling frame. Unique to the spatial structure frame, we incorporated water salinity data collected from the estuary (Mizuno 1998), summer water temperature data (Garwood et al. 2014), and estuary juvenile salmonid sampling data (Garwood and Reneski 2012) to define lower river extents having favorable conditions for summer rearing coho salmon. Last, high-gradient portions and bedrock gorges occurring within the Middle and South Forks were excluded from the spatial structure frame due to these areas lacking quality rearing habitats. Over the course of this study, the majority of reaches in both sample frames were ground-truthed by experienced field biologists and adjustments were made to frame extents where necessary resulting in a thorough inventory of potential coho salmon and other anadromous salmonid habitats (Table 1). During initial field visits, all terminal reach ends were marked with flagging and identified with GPS coordinates.

Table 1. Estimated stream kilometers available to anadromous salmonids by species and the total stream kilometers included in both the spawning survey and summer spatial structure sample frames in the Smith River basin, Del Norte County, California and Curry County, Oregon. Stream kilometers were calculated from the National Hydrological Dataset, 24K routed hydrography, and likely underestimate actual stream channel sinuosity.

	Chinook	Coho	Steelhead
Total spawning habitat in kilometers	358.0	207.4	470.1
Spawning frame size (% of total in frame)	142.6 (39.8)	161.8 (78.0)	161.8 (34.4)
Total summer rearing habitat in kilometers	392.7	328.4	527.0
Spatial structure frame size (% of total in frame)	262.1 (66.7)	298.1 (90.8)	293.6 (55.7)

Sample Unit Development

After we identified all potential anadromous fish distributions for the Smith River basin we divided the available stream area into 275 individual sample units, hereafter: ‘reaches’ (Figure 1). We designed reaches to start or end at tributary junctions or bridge crossings, with terminal reaches ending at permanent adult salmonid migration barriers. We then divided reaches into two categories depending on the length of channel. Primary reaches were designed to be between 1- 3.5 km in length to assure a spawner survey crew could finish a survey in a single day and a spatial structure survey could be completed within three days or less. Reaches less than one kilometer in length were defined as ‘sub-reaches’ and were connected to the nearest primary reach. Sub-reaches are surveyed by implication if the connected primary reach is selected in the sample draw. This strategy assures sub-reaches are sampled in an economical fashion by grouping survey effort rather than sending a crew out to a remote location to sample a short reach.

All reaches were numbered in a unique sequence to establish a spatial order to the sample frame. Beginning at the river mouth in the main stem, reaches were numbered in a progressive sequence to the top of the main stem. Next, the lowermost tributary was numbered up to its end. This sequence of ordering continued through the dendritic pattern of the sub-basins. In this way, the frame was recursively sorted, from watershed to main stem to tributaries. This effectively makes features such as a main stem and tributary occurring in close proximity actually spatially far away (Figure 1) (Boydstun and McDonald 2005). This ordering was chosen to increase the possibilities of obtaining a main stem segment, along with a nearby tributary segment, in the observed sample. In addition, when coupled with the sample draw mechanism (*see* Sample Draw Procedure below) this ordering ensured that selected sampled units were spatially balanced (Boydstun and McDonald 2005) and statistical inference can be made at multiple spatial scales (Stevens and Olson 2004, Adams et al. 2011).

Spawning Ground Survey Frame

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 (Table 1, 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 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.

Spatial Structure Survey Frame

We identified 126 primary reaches and 40 sub-reaches totaling 298.1 km within the coho salmon summer spatial structure sampling frame (Table 1, Figure 1). These reaches collectively represent 91% of the total estimated summer juvenile coho salmon rearing habitat in the Smith River basin. We eliminated the remaining 9% of potential habitat occurring in slough and stream channels in the lower Smith River estuary due to visual observation surveys likely suffering from poor underwater visibility. Other methods, such as minnow trapping or seining, could be employed to generate occupancy patterns in these unique habitats. Coho salmon use of the lower estuary likely represents a separate monitoring objective requiring different habitat and water quality metrics than stream-based snorkel surveys. We intentionally included the Oregon portion of available coho salmon rearing habitat in the final sample frame. The North Fork represents a unique and isolated portion of the Smith River coho salmon population. With the help of field biologists from the Oregon Department of Fish and Wildlife and the US Forest Service, we were able to implement our protocol in selected reaches occurring in Oregon.

Sample Draw Procedure

We used the generalized random tessellation stratified (GRTS) algorithm (Stevens and Olson 2004) to establish our annual adult spawning ground and juvenile spatial structure samples. We did not employ a rotational visitation scheme as suggested by Adams et al. (2011) since concurrent field efforts have been focused on refining sampling frames and collecting base-line data. However, an informed fixed rotating panel sampling strategy could be implemented in the near future once we determine optimal sampling rates for obtaining acceptable population estimate precision targets. Our GRTS sample draws included all available primary reaches so alternate reaches could replace any that could not be surveyed due to the inability to secure landowner permission. This ensured our anticipated survey effort could be maintained. A unique sample draw was performed for each year and each monitoring component.

Sampling Rate

Spawning Ground Surveys

The optimal sample rate for determining population abundance trends from redd counts has not been completely assessed across northern California and proposed rates from available studies vary substantially. Boydstun and McDonald (2005) recommended a reach sample rate of 10% but this was based on live fish and carcasses of coho salmon in Oregon (Jacobs 2002). Gallagher et al. (2010) assessed how sample rate affected coho salmon and steelhead redd abundance estimates and statistical power to detect population trends in coastal Mendocino County. Based on their results, a suggested sample size of 15% or 41 reaches (whichever results in fewer survey reaches) had adequate precision and statistical power for population trends. Last, a study by Ricker (2011) assessed how sample rate affected precision and determined sample size of roughly 50% was needed to achieve sufficient levels of estimated redd population size for coho salmon, Chinook salmon, and steelhead. Since this was the first implementation of the CMP methods in the Smith River, we sampled at a rate of 41% in the first year, and 35% in the second year based on the resources we had (i.e. staff, vehicles, funding). Additionally, the uncertainty around general coho salmon spawning distributions and abundance warranted increased effort. Last, our sampling levels allowed us to complete frame reconnaissance in just two years. We plan to assess sample rate as it relates to precision after collecting three consecutive years of data.

Spatial Structure Surveys

We set our initial within-reach sampling rate based on simulations performed by Webster et al. (2005) who used using repeated snorkel survey counts of coho salmon in California. 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. Furthermore, we wanted to ensure our surveys had a high pool sampling fraction anticipating annual differences in spatial structure are likely more sensitive within reaches rather than between reaches. Our reach sample rate was largely based on available resources with the goal of maximizing the number of survey reaches each year. To properly assess sample rate as it applies to within-reach and between-reach variance requires a meta-analysis across multiple populations. Differences in relative coho salmon abundance, spatial representation, and spatial autocorrelation, can be incorporated into simulation routines for estimating optimal and cost efficient sampling rates throughout northern California. This study design and protocol has been implemented in four basins for one year and we plan to work with others to determine optimal sampling rates.

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. 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. However, the field crew was exceptionally experienced over the two years of this study 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. Size, depth, and substrate characteristics of redds were measured based on 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 have not been tested. If a redd increased in size between survey periods measurements were recorded again.

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. 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 sub-basin 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 protocol:* Garwood and Ricker 2013). 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. Sampling in large main stem 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. Main stem 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 main stem 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 2013). 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

Two methods have been used to classify unidentified redds to species using field data. Gallagher and Gallagher (2005) and Gough (2011) classify redds using a two-step binomial logistic regression model where the first step partitions salmon and trout redds, and the second step partitions coho salmon from Chinook salmon. These models specifically take advantage of spawning timing and size measurements of individual redds to predict the species of all unclassified redds. This approach was developed using data from coastal Mendocino County, and in Prairie Creek, Humboldt County and is supported by Adams et al. (2011) as an accepted method of species partitioning in the CMP. The second approach used to classify redds is through a non-parametric K-nearest neighbor algorithm (kNN) (Cover and Hart 1967). Spawning date and the XY spatial coordinates of known-species redds 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. *in CMP Technical Team review*). 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.

Both redd prediction methods were assessed for performance from redd data collected throughout numerous watersheds in northern California (Ricker et al. 2014) using the CMP spawner survey protocol

(Gallagher et al. 2007, Adams et al. 2011). The kNN prediction approach outperformed the fully parameterized logistic regression models in the Smith River and throughout northern California by correctly predicting 95% of known species redds relative to 91% predicted correctly through logistic regression (Ricker et al. *in CMP Technical Team review*). Furthermore, kNN predicted 97% of known coho salmon redds relative to 91% through logistic regression. Based on the prediction performance meta-analysis by Ricker et al. (*in CMP Technical Team review*), we used the kNN algorithm to predict redd species in the Smith River. However, in addition to using all known-species redds, we adapted the approach to also incorporate all individual live fish observations for which a positive species ID could be obtained that were not observed directly on redds as part the known neighbor dataset. 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* Tables 4 and 11 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 (*see* Figure 10 in results section). 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. (*in CMP Technical Team review*), 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. *in CMP Technical Team review*). 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 analysis were performed using program R (R Core Team 2013) and associated packages defined in Ricker et al. (*in CMP Technical Team review*).

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 fagged 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 *i*th 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. (2014):

(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. (2014). 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 with few recoveries of marked fish.

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 2013) 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 ($\psi * \theta$). We collected habitat covariates but their effect on occupancy and detection were not explored in this analysis since a more thorough meta-analysis including multiple basins is forthcoming.

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: 0.9.1.) (Burch et al. 2014). We collected the spatial structure data using paper and PDA forms later 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.

Spawning Ground Survey Results

2011-2012 Spawning Ground Survey Conditions and Effort

We completed 388 surveys in 36 main reaches and 13 sub-reaches in the Smith River during the 2011-2012 survey period which extended from October 31, 2011 to February 28, 2012 (Table 2). GRTS sampling represented 41% of the total frame with 28 reaches and 10 sub-reaches. Three GRTS drawn reaches were replaced based on private landowners denying access to portions of the reaches. An additional six reaches and three sub-reaches were surveyed to complete a census in the Mill Creek LCS (Table 2). The precipitation regime for the 2011-2012 survey period was marked by extended dry conditions with rainfall amounts for the survey period equaling 76% of average at the Gasquet Ranger Station (DWR 2014). Most of the rain fell in January and the second half of the season produced only slightly higher stream base discharge than the first half (Figure 3A). Three storms increased river discharge enough to delay our reach survey return interval (Figure 3A). Overall, 90% of the days within the survey period had favorable conditions where the daily average river discharge was below our maximum survey threshold (16,000 cubic feet per second at the USGS Jed Smith gaging station). On average, the availability of reaches with

Table 2. Summary statistics of spawning ground reach survey effort and reach survey availability based on flow conditions for the winter of 2011-2012, Smith River basin, Del Norte County, CA. Surveys occurred from November 1, 2011 to February 28, 2012. 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	1858	9	13	6	26	0.79
Rowdy	59	1227	9	13	6	26	0.79
Rowdy	60	1901	9	12	5	21	0.80
Rowdy	62	2276	8	14	5	25	0.80
Dominie	65	2729	7	15	7	26	0.80
Savoy	68	2080	8	15	4	23	0.82
Rowdy	72	579	3	20	6	25	0.82
Peacock	91	3296	7	16	6	27	0.85
Peacock	94	402	7	16	6	27	0.85
Clark's	96	2277	8	12	2	15	0.90
Mill	101	1944	8	15	6	28	0.77
Mill	103	1314	8	15	4	23	0.78
Mill	104	1416	9	13	4	20	0.79
Mill	105	1412	8	15	5	23	0.79
WB Mill	**106**	2111	12	10	5	22	0.84
WB Mill	**107**	2675	12	9	3	16	0.85
WB Mill	**108**	2030	12	9	4	18	0.85
WB Mill	**109**	1802	11	10	5	22	0.86
WB Mill	**110**	2582	11	11	4	20	0.89
Mill	118	676	6	17	7	28	0.80
Mill	119	115	3	20	8	28	0.80
EF Mill	**123**	2149	11	11	4	16	0.81
EF Mill	**124**	2298	11	11	6	27	0.81
EF Mill	**125**	2308	10	12	3	17	0.87
EF Mill	**129**	436	9	13	7	28	0.81
First Gulch	**130**[b]	1100	11	10	3	14	0.88
Kelly	**132**	2481	8	14	5	23	0.89
Bummer	**134**	2296	10	9	4	18	0.87
Low Divide	**136**	863	10	12	4	17	0.86
WB Mill	**138**	125	10	11	6	25	0.89
WB Mill	**140**	741	6	9	3	14	0.89
WB Mill	**141**	442	10	9	4	14	0.89
WB Mill	**143**	834	12	9	3	15	0.89
Cedar	146	2351	6	20	9	36	0.86
Goose	205[c]	1703	6	18	6	28	0.75
Goose	212	1746	6	18	3	22	0.75
Goose	214	188	1	-	-	-	0.75
Hurdygurdy	217	2989	8	15	4	21	0.76
Hurdygurdy	218	2696	8	15	4	21	0.76
Jones	234	2445	7	15	3	21	0.76
MF Smith	286	1822	7	18	9	35	0.79
Patrick's	304	1519	8	15	5	27	0.77
Patrick's	305	1668	7	18	4	26	0.79
Shelly	308	875	4	27	12	43	0.79
Monkey	319	2677	8	14	5	25	0.82
Siskiyou Fork	324	2509	8	15	8	33	0.78
Siskiyou Fork	326	1187	5	18	5	27	0.78
Idlewild	333	542	6	20	9	29	0.79
	Total	-	388	14.2[d]	-	-	0.82[d]

[a]Bold indicates Mill Creek Census reach, [b]Incomplete effort; reach length was extended after the 2011-12 survey season, [c]Incidental non-GRTS Survey [d]Mean value.

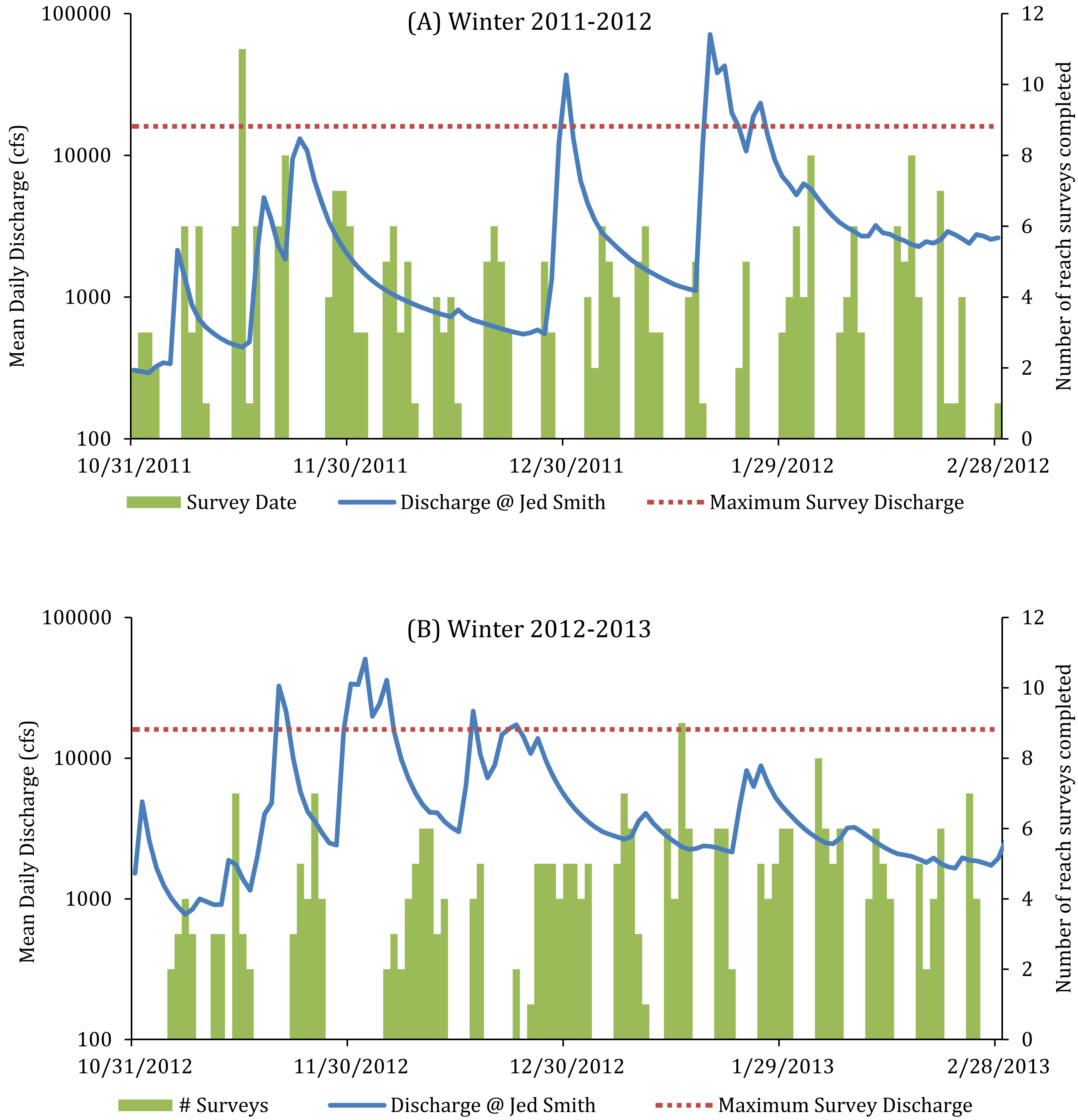


Figure 3. Spawning ground survey effort and timing in the Smith River basin (Del Norte County, CA) as it relates to mean daily river discharge. Panel A represents the 2011-2012 survey and panel B represents the 2012-2013 survey. The dashed red line represents the maximum discharge (16,000 cubic feet per second) where spawner surveys could be safely completed in smaller streams without being impaired by decreased water clarity.

favorable survey conditions equaled 82% (SD= 5%) of days within the survey period (Table 2). We surveyed on 71 of 109 available days resulting in an effort of 65%. On average, we surveyed each reach 8.1 times (range 1-12) with an overall average reach return interval equaling 14 days (Table 2, Figure 3A). However, we did not survey all reaches during extended dry periods since low stream flows prevented anadromous fish migration in some small tributaries.

2011-2012 GRTS Spawning Ground Surveys

Live Fish Observations

We made 2928 observations of live anadromous salmonids within the GRTS surveyed portion of the Smith River during the winter of 2011-2012 (Table 3, Figure 4A). Live salmonid totals do not represent individual fish observations since live individuals could be observed over multiple survey periods. Observations included 192 coho salmon, 2080 Chinook salmon, 331 steelhead, and 325 unidentified salmonids (Table 3, Figure 4A). As expected, the first half of the season was dominated by live Chinook salmon observations with the mean observation date equaling December 2 (Table 4, Figure 4A). Chinook salmon were widely distributed throughout the surveyed area (Figure 5) with detections in 27 of the 38 GRTS surveyed reaches. Live coho salmon observations ranged from November 25 through February 14 with a mean observation date of January 21 (Table 4, Figure 4A). Live coho salmon were narrowly distributed with 191 of the 192 observations occurring in nine GRTS reaches in Mill Creek (Table 3, Figure 6). We observed only one male coho salmon in Savoy Creek, tributary to Rowdy Creek (Figure 6). Live steelhead observations increased steadily during the ladder half of the survey period with a mean observation date of January 31 (Table 4, Figure 4A). Thus, our observations represent only a portion of the steelhead spawning season since our effort ended February 28. We found our steelhead observations were moderately distributed with detections in 25 of 38 GRTS surveyed reaches (Table 3, Figure 7).

Carcass Observations

We recovered 828 anadromous salmonid carcasses in GRTS survey reaches during the winter of 2011-2012. Carcass totals were dominated by Chinook salmon with 746 individuals followed by 43 coho salmon, 4 steelhead, and 35 unidentified salmonids (Table 3, Figure 8A). All coho salmon carcasses in the GRTS survey were recovered in Mill Creek (Table 3). We encountered the first coho salmon carcass on December 6 and the last on February 23. The mean coho salmon carcass date was February 2 (Table 4). Of the 43 tagged coho salmon carcasses in the GRTS survey, we recaptured 14 on subsequent surveys. One carcass was recaptured on two occasions.

Hatchery Origin Salmonid Observations

We identified Hatchery origin salmonids throughout the Smith River during the winter of 2011-2012 (Table 5, Figure 9). 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 5). Hatchery origin fish constituted 15.4% (range: 1% to 35%) of all live Chinook salmon observations where the presence or absence of an adipose fin could be determined, and 22.7% (range: 0% to 33.1%) of all Chinook salmon carcasses recovered. The difference in the percentages between live and dead Chinook salmon is likely due to Rowdy Creek Fish Hatchery (RCH) using a left-ventral fin clip for the 2009 brood year. Determining a left-ventral fin clip on a live fish is difficult so carcasses likely better represent the actual proportion of hatchery origin Chinook salmon. Hatchery origin steelhead constituted 8.5% (range: 0% to 14%) of all live observations where the presence or absence of an adipose fin could be determined (Table 5). The only steelhead carcass we recovered that had an observable adipose fin was of hatchery origin. No hatchery origin live coho salmon or carcasses were encountered during the winter of 2011-2012. Coho salmon are not produced by RCH but are produced in Oregon and in the Klamath River basin in California.

Table 3. Summary of live adult and salmonid carcasses observed by species and reach from November 1, 2011 to February 28, 2012, 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 individual carcass observations. 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	Unknown species
Rowdy	58	259	-	34	19	134	-	3	3
Rowdy	59	263	-	13	16	118	-	-	8
Rowdy	60	173	-	8	6	92	-	-	3
Rowdy	62	174	-	18	44	26	-	-	-
Dominie	65	192	-	74	74	88	-	-	-
Savoy	68	32	1	3	3	3	-	-	-
Rowdy	72	3	-	-	-	-	-	-	-
Peacock	91	-	-	16	2	-	-	-	-
Peacock	94	-	-	1	-	-	-	-	-
Clark's	96	27	-	1	-	15	-	-	-
Mill	101	80	-	9	14	41	1	-	7
Mill	103	63	-	-	14	17	1	-	4
Mill	104	73	4	5	21	43	1	-	1
Mill	105	91	1	30	10	36	1	-	3
WB Mill	**106**	238	11	7	9	93	4	-	-
WB Mill	**107**	230	38	38	25	88	12	-	3
WB Mill	**108**	161	45	12	8	39	12	-	-
WB Mill	**109**	65	25	3	-	39	6	1	-
WB Mill	**110**	28	86	3	8	-	7	-	-
Mill	118	-	-	-	-	-	-	-	-
Mill	119	-	-	-	-	-	-	-	-
EF Mill	**123**	85	2	2	11	26	4	1	2
EF Mill	**124**	94	21	12	13	7	5	-	-
EF Mill	**125**	68	40	7	18	7	9	-	1
EF Mill	**129**	-	-	-	-	-	-	-	-
First Gulch	**130**	4	9	-	3	3	3	-	-
Kelly	**132**	2	17	-	4	1	4	-	1
Bummer	**134**	12	16	1	5	-	3	-	-
Low Divide	**136**	-	1	2	2	-	-	-	-
WB Mill	**138**	3	-	-	-	2	-	-	1
WB Mill	**140**	-	19	-	2	-	7	-	-
WB Mill	**141**	-	20	4	-	-	1	-	-
WB Mill	**143**	2	33	1	8	-	1	-	-
Cedar	146	15	-	12	2	-	-	-	-
Goose	205	15	-	9	-	-	-	-	-
Goose	212	1	-	6	5	-	-	-	-
Goose	214	-	-	-	-	-	-	-	-
Hurdygurdy	217	50	-	8	5	1	-	-	-
Hurdygurdy	218	6	-	12	6	1	-	-	-
Jones	234	32	-	7	8	4	-	-	-
MF Smith	286	2	-	-	-	-	-	-	-
Patrick's	304	66	-	-	-	4	-	-	-
Patrick's	305	61	-	1	-	2	-	-	-
Shelly	308	1	-	-	-	-	-	-	-
Monkey	319	-	-	4	1	-	-	-	-
Siskiyou	324	5	-	17	9	-	-	-	-
Siskiyou	326	-	-	-	-	-	-	-	-
Idlewild	333	-	-	-	-	-	-	-	-
	Total	2676	389	380	375	930	82	5	37

[a] *Bold indicates Mill Creek Census reach*

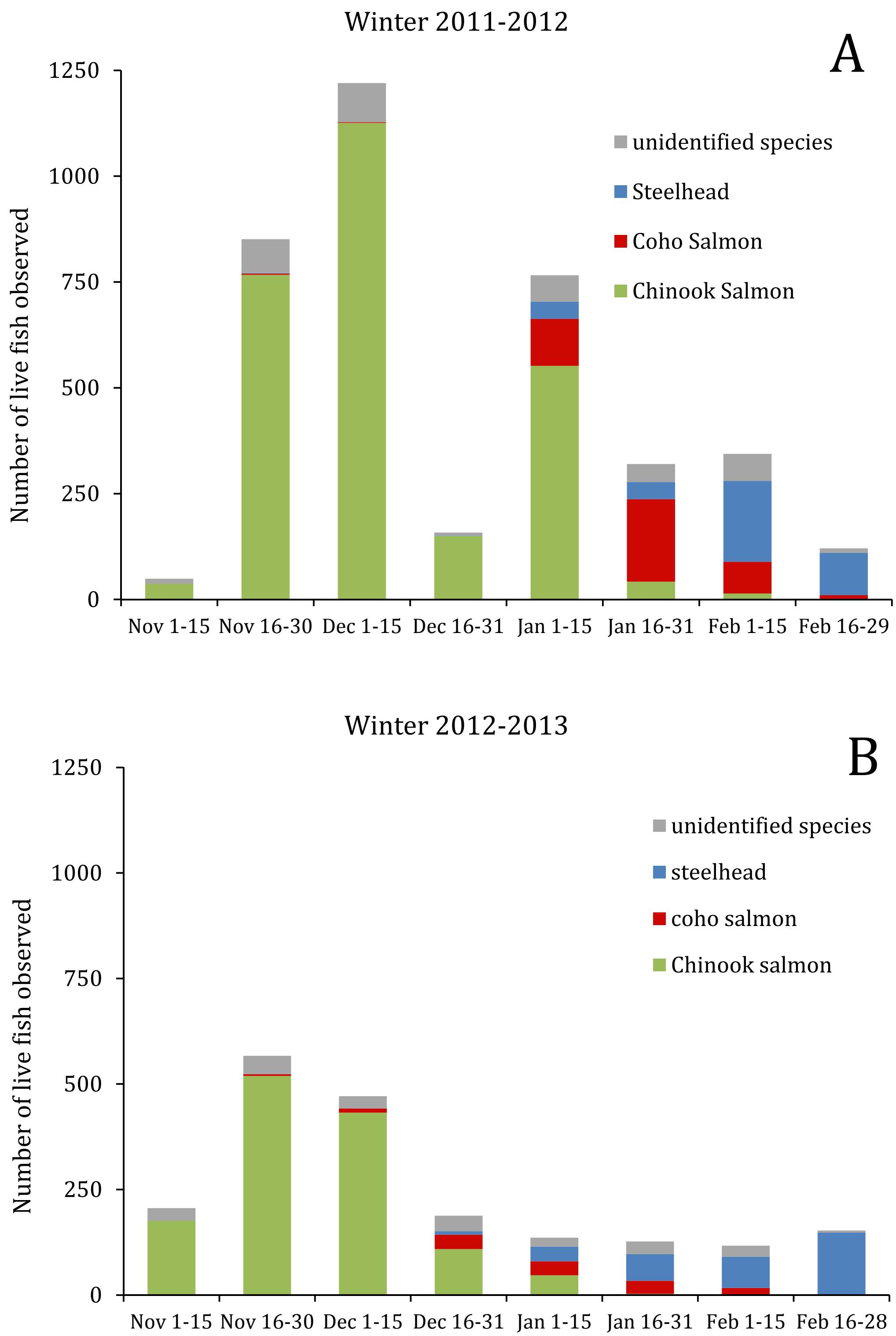


Figure 4. Number live salmonids, identified to species and survey period, observed during spawner surveys occurring over two winters in the Smith River basin, Del Norte County, CA. Panel A represents the 2011-2012 survey and panel B represents the 2012-2013 survey.

Table 4. Descriptive statistics for observation date of live fish, observation date of known species redds, observation date of carcasses, and carcass fork lengths for the 2011-2012 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 date:	N	1993	327	228
	Mean	13-Dec-2011	21-Jan-2012	31-Jan-2012
	SD	18.0	14.4	13.9
	Min	7-Nov-2011	28-Nov-2011	17-Nov-2011
	Max	8-Feb-2011	23-Feb-2012	28-Feb-2012
Live fish sex ratio:	F / M	1 / 0.70	1 / 1.14	1 / 1.31
Known species redd:	N	686	90	36
	Mean	10-Dec-2011	22-Jan-2012	28-Jan-2012
	SD	18.5	15.2	12.8
	Min	7-Nov-2011	28-Nov-2011	4-Jan-2012
	Max	1-Feb-2012	21-Feb-2012	20-Feb-2012
Carcass date:	N	899	82	5
	Mean	28-Dec-2011	2-Feb-2012	10-Feb-2012
	SD	17.0	17.7	4.7
	Min	27-Nov-2011	6-Dec-2011	6-Feb-2012
	Max	23-Feb-2012	23-Feb-2012	17-Feb-2012
Carcass sex ratio:	F / M	1 / 0.73	1 / 0.90	-
Carcass fork length (cm)	N	824	71	4
	Mean	88	67	76
	SD	13.0	9.8	7.5
	Min	42	38	65
	Max	114	84	86

Redd Observations

We identified 1798 anadromous salmonid redds within the GRTS surveyed portion of the Smith River during the winter of 2011-2012 including 49 coho salmon, 533 Chinook salmon, 32 steelhead, and 1184 unidentified species (Table 6, Figure 10A). The average total reach-level redd density equaled 30.8 redds per kilometer, with the highest observed densities occurring in Rowdy Creek and Mill Creek watersheds (Table 6). Thirty two percent of the overall observed redds were identified to species, though this proportion varied greatly over the spawning season. During the first half of the spawning season we identified 39% of the redds to species while in the second half we only identified 25% to species (Figure 10A). All verified coho salmon redds were observed in the Mill Creek LCS above the confluence of the East Fork and West Branch (Table 6, Figure 6). In contrast, verified Chinook salmon and steelhead redds were distributed throughout the surveyed area (Table 6, Figure 5, Figure 7). The first verified coho salmon redd was observed on November 28 and the last was observed on February 21 (Table 4). Overall, mean observation dates of known species redds were consistently within a few days of mean live fish dates for all species (Table 4).

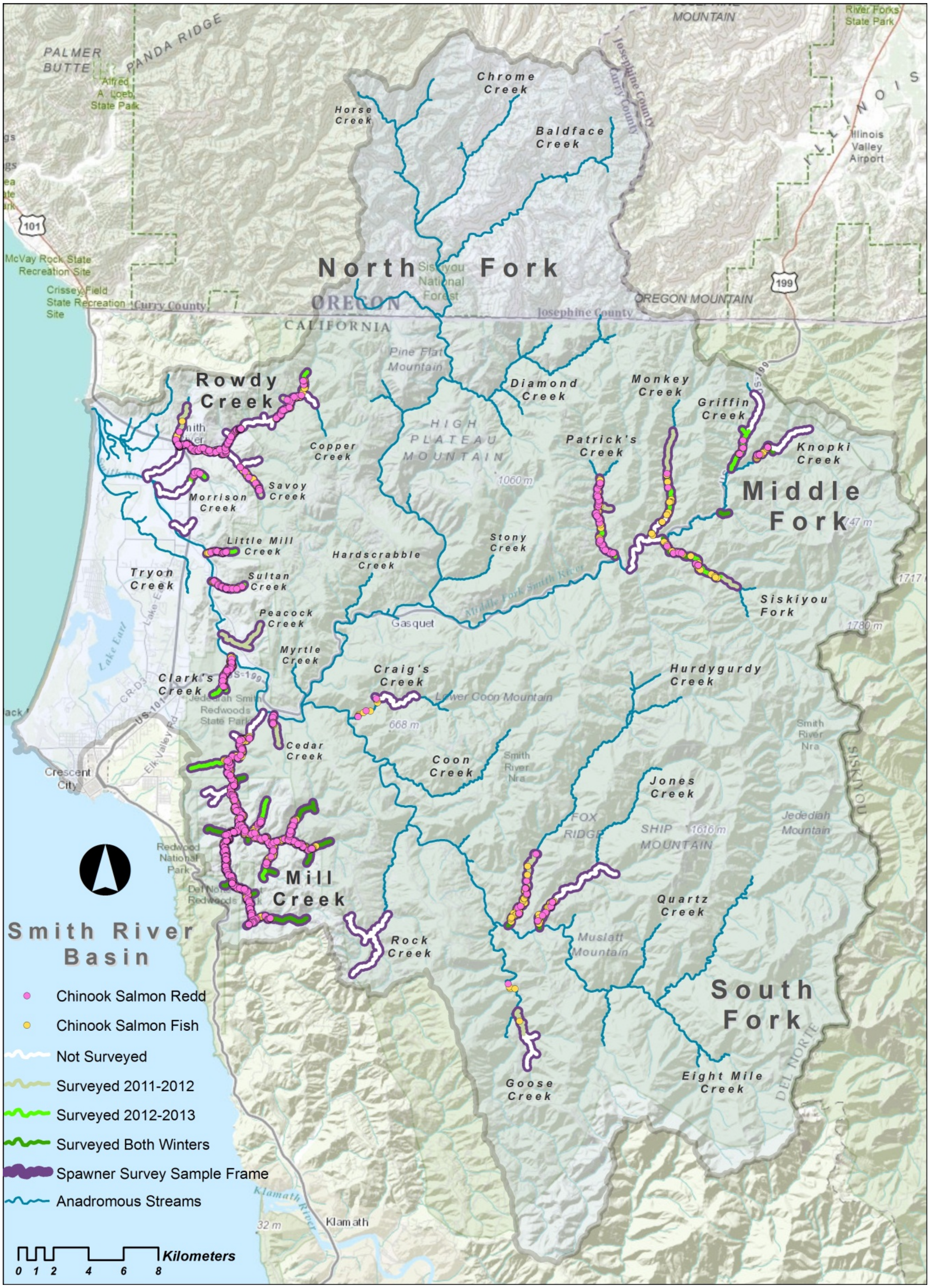


Figure 5. Map showing annual survey reaches, distribution of observed adult Chinook salmon, and verified Chinook salmon redds, Smith River Basin, Del Norte County, CA. Note: redd location symbols are displayed above fish observation symbols and may obscure fish observations in reaches with numerous verified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

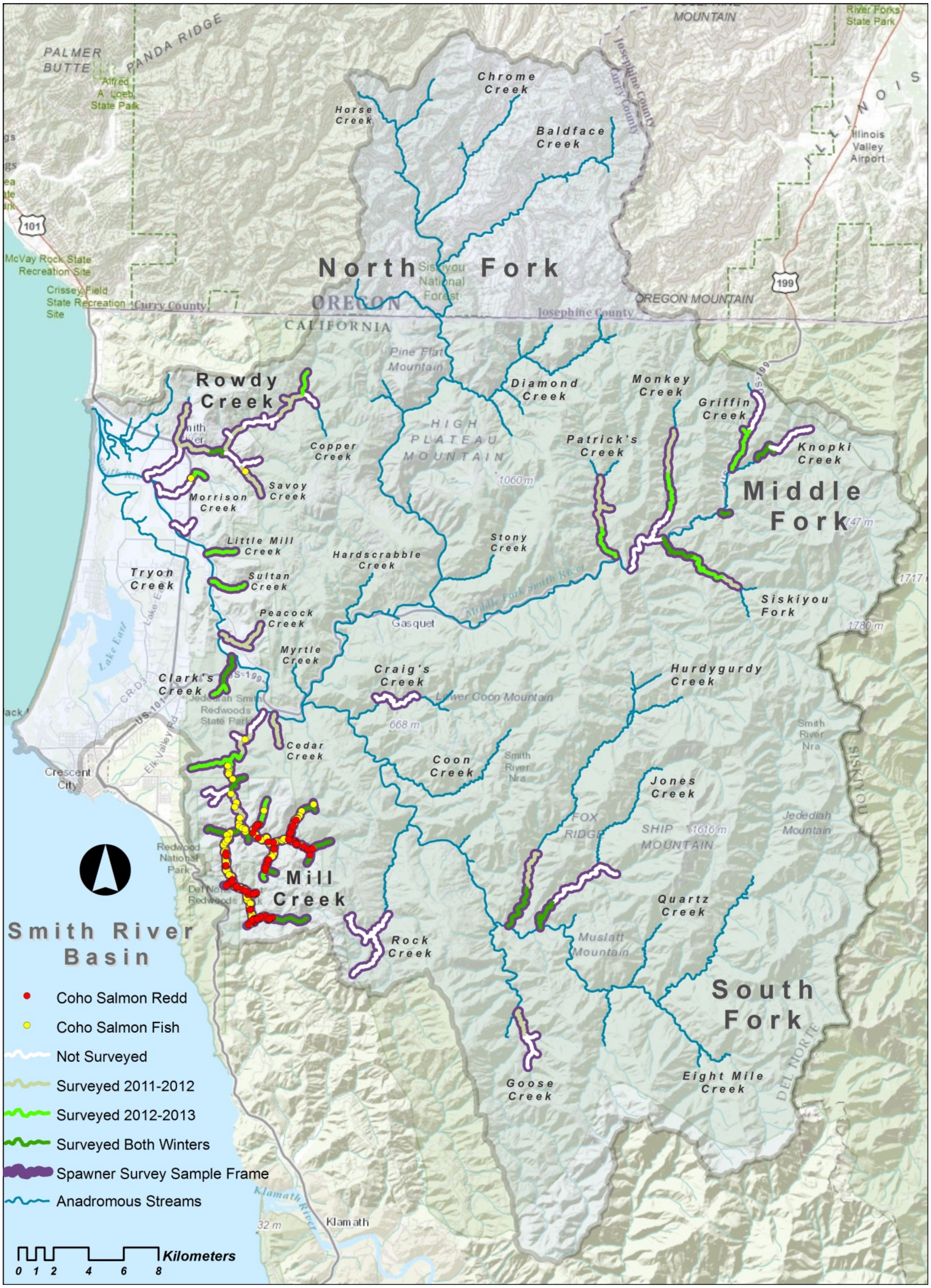


Figure 6. Map showing annual survey reaches, distribution of observed adult coho salmon, and verified coho salmon redds, Smith River Basin, Del Norte County, CA. Note: redd location symbols are displayed above fish observation symbols and may obscure fish observations in reaches containing high densities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

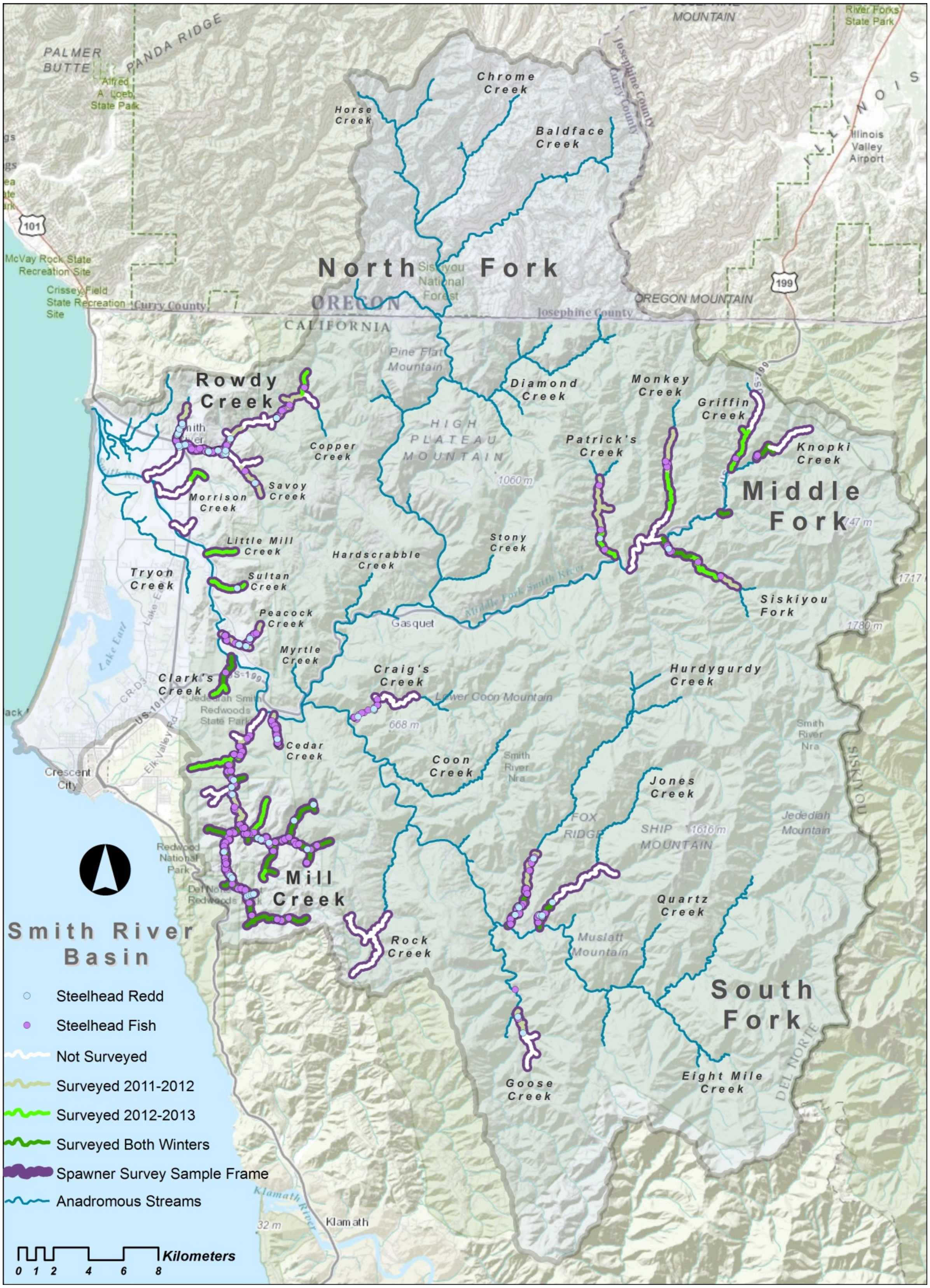
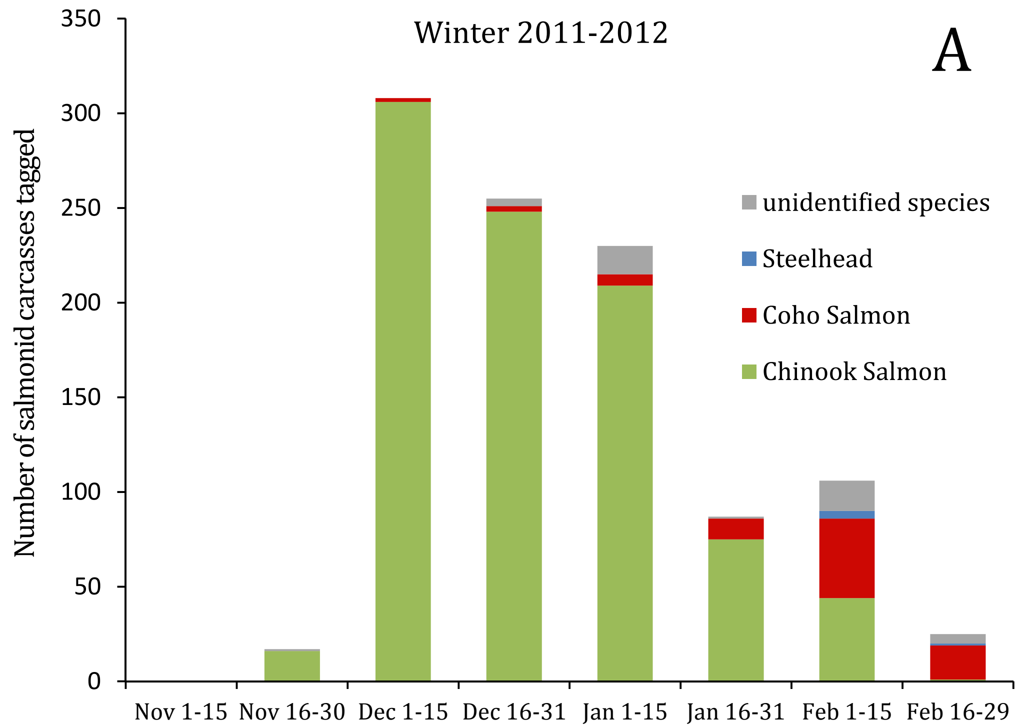


Figure 7. Map showing annual survey reaches, distribution of observed adult steelhead, and verified steelhead redds, Smith River Basin, Del Norte County, CA. Note: redd location symbols are displayed above fish observation symbols and may obscure fish observations in reaches containing high densities of verified steelhead redds.



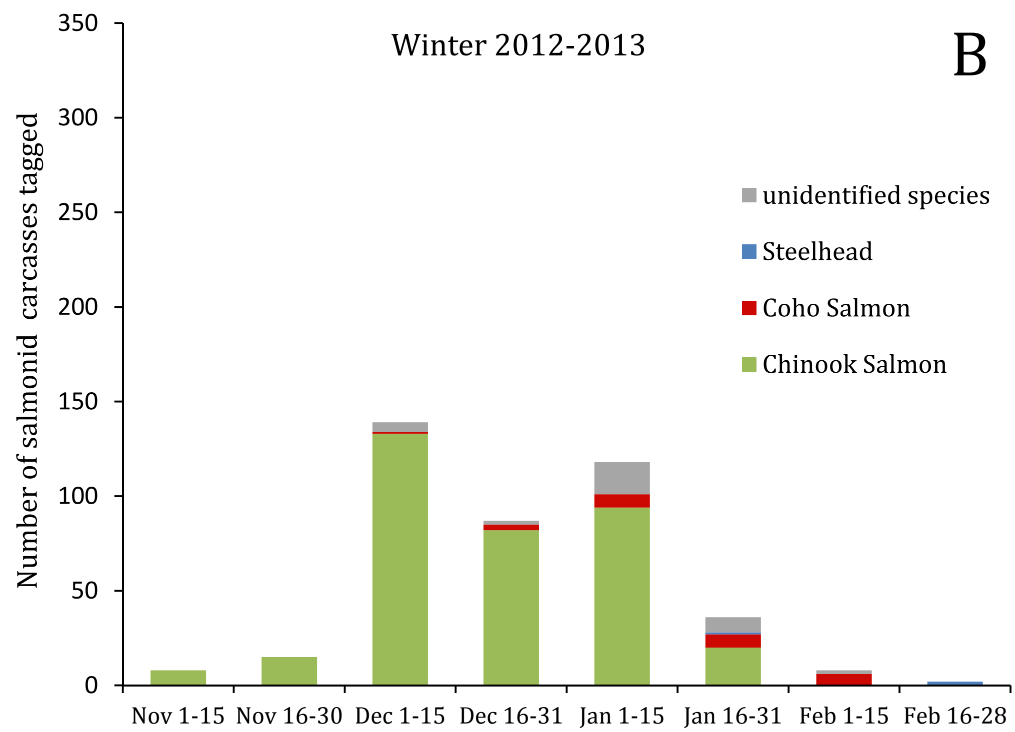


Figure 8. Number of uniquely tagged salmonid carcasses, identified by species and survey period, during spawner surveys occurring over two winters in the Smith River basin, Del Norte County, CA. Panel A represents the 2011-2012 survey and panel B represents the 2012-2013 survey.

Table 5. Proportion of observed hatchery-origin salmonids summarized by species, observation type, and major sub-basin, during the winter 2011-2012 spawning ground surveys conducted throughout the Smith River basin, Del Norte County, CA. Sub-basins include Rowdy Creek (all reaches sampled in the sub-basin 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). 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 2011-2012									
	Coho Salmon			Chinook Salmon			Steelhead		
Sub-basin	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	1	0	0	301	104	34.5	21	3	14.3
Below Forks	142	0	0	508	36	7.1	24	1	4.2
Above Forks	0	0	-	109	1	1	2	0	0
Carcass observations 2011-2012									
	Coho Salmon			Chinook Salmon			Steelhead		
Sub-basin	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	0	0	-	290	96	33.1	0	0	-
Below Forks	45	0	0	304	42	13.8	0	1	100
Above Forks	0	0	-	13	0	0	0	0	-

Redd Prediction Performance

The kNN classifier performed well in the 2011-2012 survey season, correctly predicting 769 of 810 (94.9%) redds verified to species from GRTS and Mill Creek census reaches (Table 7). Chinook salmon dominated the known species redds representing 84.4% of the total followed by coho salmon (11.1%) and steelhead (4.4%). The kNN classifier correctly predicted 97.2% of Chinook salmon redds followed by 84.4% of coho salmon redds and 77.8% of steelhead redds. Consistent with our live fish and carcass observations, no coho salmon redds were predicted by the kNN classifier outside of Mill Creek.

Total Redd Abundance

Total redd abundance estimates of coho salmon, Chinook salmon and Steelhead for the Smith River in 2011-2012, with 95% confidence intervals, are 609 (63 - 1154), 3819 (2777 - 4860), and 1050 (720 - 1380), respectively (Table 8). Because we did not detect or predict any coho salmon redds outside of the Mill Creek LCS we are not recommending the use of this coho salmon population estimate. We prefer using the LCS estimate for coho salmon and only report this estimate for comparative purposes.

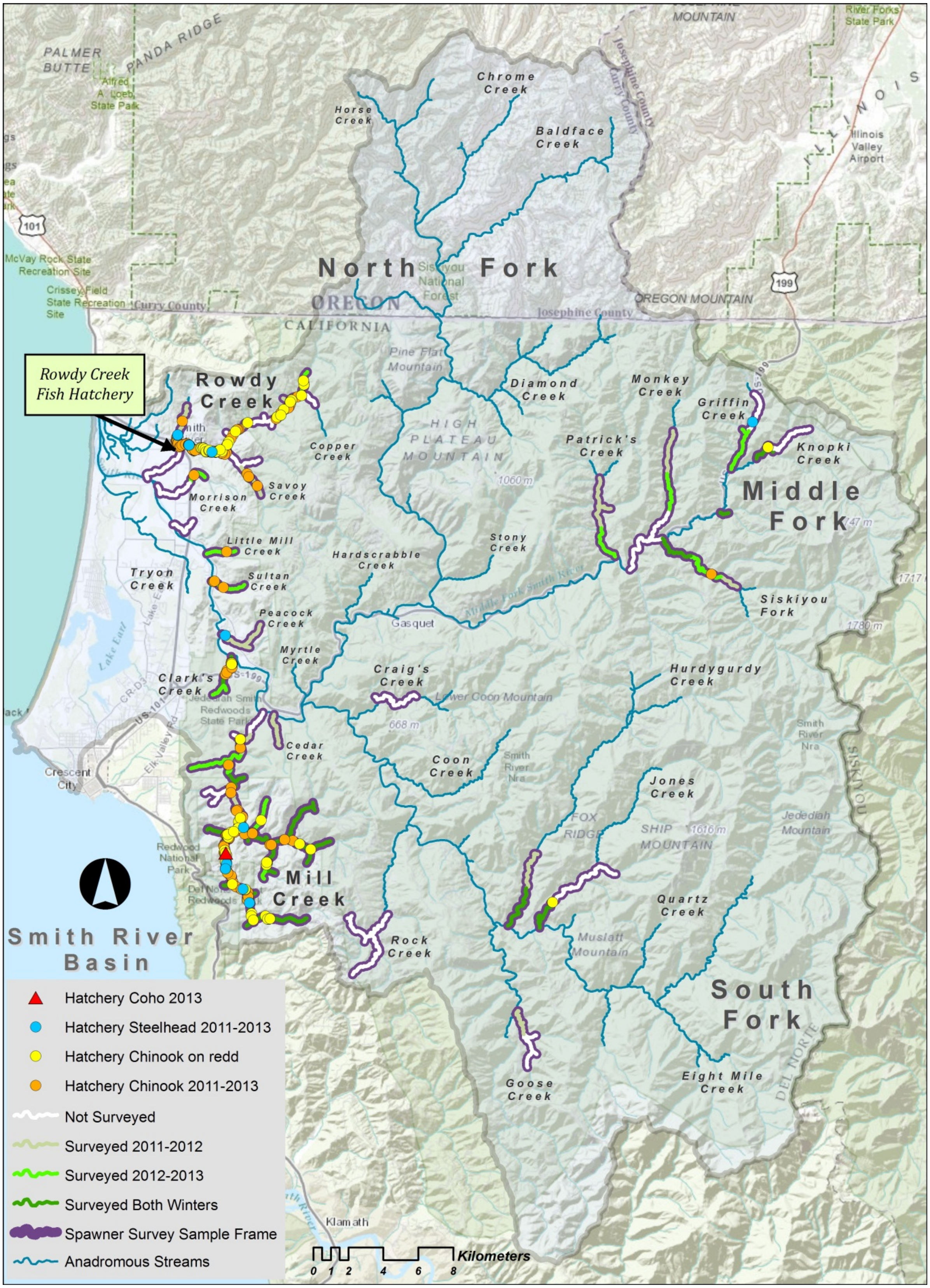


Figure 9. Map showing annual survey reaches and the distribution of observed adipose fin clipped adult hatchery Steelhead, adipose or left ventral fin clipped adult Chinook Salmon, hatchery Chinook salmon constructing redds, and a maxillary clipped coho salmon from the Klamath River; observed in the Smith River Basin, Del Norte County, CA.

Table 6. Summary of total observed redds separated by reach and species for the winter of 2011-2012, Smith River basin, Del Norte County, CA. Surveys occurred from November 1, 2011 to February 28, 2012. 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.

Subbasin	Location Code[a]	Number of observed redds by species					# of redds per Km[c]
		Chinook Salmon	Coho Salmon	Steelhead	Unknown	Cutthroat Trout	
Rowdy	58	48	-	2	90	-	75.2
Rowdy	59	41	-	1	54	-	78.2
Rowdy	60	59	-	2	62	-	64.7
Rowdy	62	44	-	2	57	-	45.2
Dominie	65	56	-	10	63	-	47.3
Savoy	68	14	-	1	53	1	32.7
Rowdy	72	2	-	-	-	1	3.4
Peacock	91	-	-	2	17	3	5.7
Peacock	94	-	-	1	3	-	10.0
Clark's	96	9	-	-	10	-	8.3
Mill	101	25	-	-	25	-	25.7
Mill	103	22	-	-	35	-	43.4
Mill	104	26	-	1	32	-	41.6
Mill	105	24	-	-	51	-	53.1
WB Mill	**106**	64	-	-	105	3	80.1
WB Mill	**107**	67	6	2	121	-	73.3
WB Mill	**108**	40	9	-	93	-	69.9
WB Mill	**109**	19	-	1	84	-	57.7
WB Mill	**110**	8	21	-	53	-	34.4
Mill	118	-	-	-	3	-	4.4
Mill	119	-	-	-	-	-	-
EF Mill	**123**	16	1	-	56	-	34.0
EF Mill	**124**	15	1	-	73	-	38.7
EF Mill	**125**	18	14	-	128	4	71.9
EF Mill	**129**	-	-	-	-	-	-
First Gulch	**130**[b]	4	3	-	23	1	NA
Kelly	**132**	1	7	-	38	1	18.5
Bummer	**134**	7	6	1	41	-	18.4
Low Divide	**136**	-	1	-	10	1	12.7
WB Mill	**138**	2	-	-	6	-	50.9
WB Mill	**140**	-	6	-	24	1	40.5
WB Mill	**141**	-	6	3	4	-	24.4
WB Mill	**143**	-	9	-	21	-	35.9
Cedar	146	5	-	1	23	1	12.3
Goose	205	1	-	-	19	1	11.7
Goose	212	-	-	2	27	12	16.6
Goose	214	-	-	-	-	-	-
Hurdygurdy	217	8	-	1	38	-	15.7
Hurdygurdy	218	2	-	1	9	-	4.5
Jones	234	5	-	2	51	-	23.7
MF Smith	286	1	-	-	5	-	3.3
Patrick's	304	16	-	-	18	-	22.4
Patrick's	305	16	-	-	29	-	27.0
Shelly	308	-	-	-	6	-	6.9
Monkey	319	-	-	-	17	-	6.4
Siskiyou	324	1	-	1	11	-	5.2
Siskiyou	326	-	-	-	2	-	0.9
Idlewild	333	-	-	-	1	-	1.8
		686	90	37	1691	31	30.8[d]

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

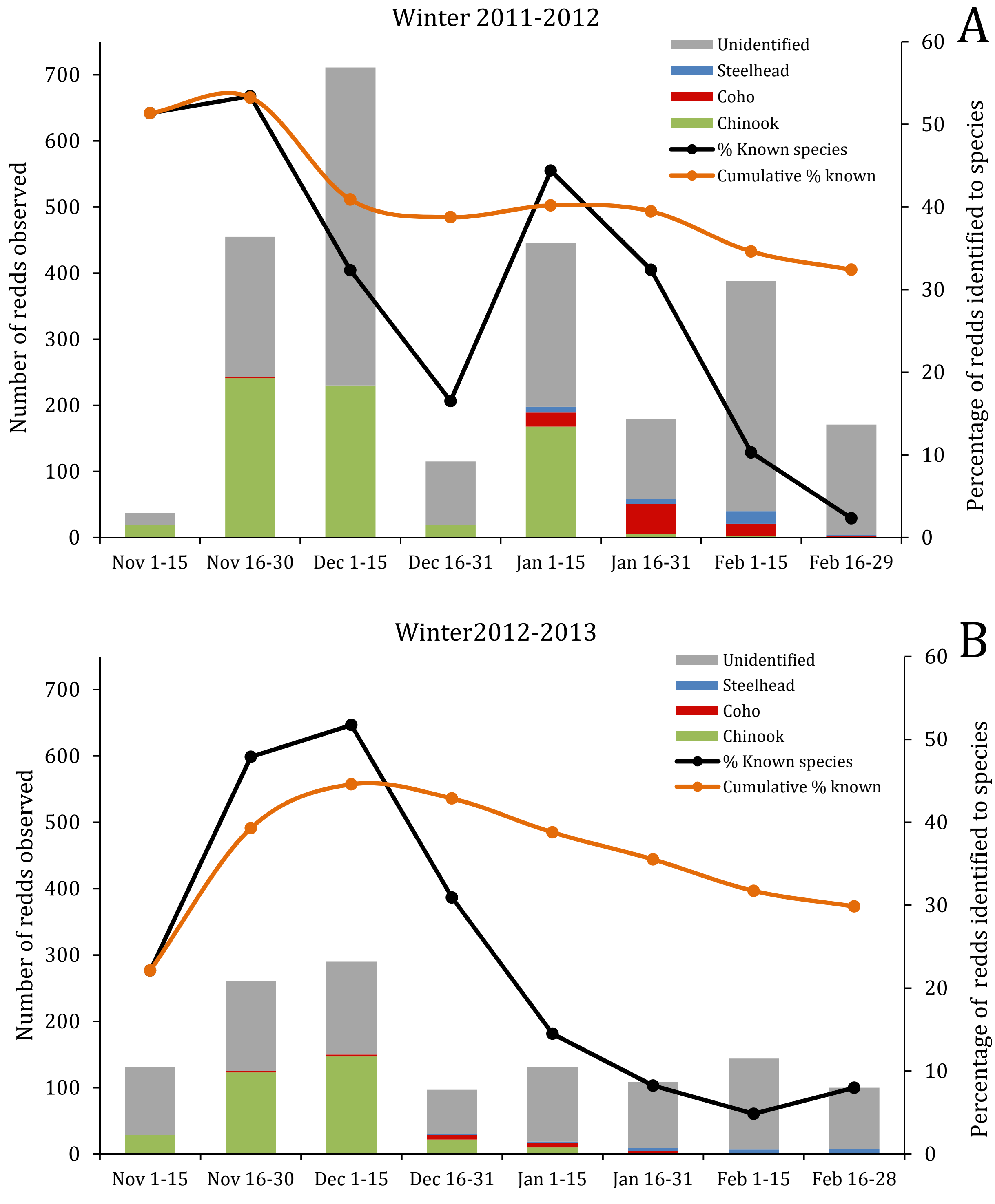


Figure 10. Number of individual salmonid redds observed by survey period during spawner surveys occurring over two winters in the Smith River basin, Del Norte County, CA. Panel A represents the 2011-2012 survey and panel B represents the 2012-2013 survey. Line plots represent percentages of redds identified to species by survey period through direct observations of live fish actively building or guarding individual redds.

Table 7. Confusion matrix, statistics, and number of redds by species for the 2011-2012 and 2012-2013 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 2011-2012		Reference		
		Coho Salmon	Chinook Salmon	Steelhead
Prediction	Coho Salmon	**76**	11	5
	Chinook Salmon	10	**665**	3
	Steelhead	4	8	**28**
	Sensitivity	0.844	0.972	0.778
	Specificity	0.978	0.897	0.985
	Accuracy (95% CI)		0.95 (0.93 - 0.96)	
Number of Redds	Known Species	90	684	36
	kNN Predicted	250	1055	384
	Total	340	1741	420

Winter 2012-2013		Reference		
		Coho Salmon	Chinook Salmon	Steelhead
Prediction	Coho Salmon	**17**	3	4
	Chinook Salmon	8	**324**	1
	Steelhead	0	4	**16**
	Sensitivity	0.680	0.979	0.762
	Specificity	0.980	0.804	0.989
	Accuracy (95% CI)		0.96 (0.92 - 0.97)	
Number of Redds	Known Species	25	331	21
	kNN Predicted	142	491	253
	Total	167	822	274

Table 8. Estimated total number of redds by species in the Smith River spawner survey sample frame for the winter of 2011-2012. 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).

	Coho Salmon[1]	Chinook Salmon	Steelhead
Redd estimate	609	3819	1050
SE	266.0	507.7	160.9
Total within reach variance	48.8	240.6	90.9
Total between reach variance	699.0	2994.3	244.2
% Within reach variance	6.5	7.4	27.1
% Between reach variance	93.5	92.6	72.9
95% CI	(63, 1154)	(2777, 4860)	(720, 1380)

[1]We recommend using the Mill Creek LCS census population estimate for coho salmon for reasons described in the discussion section.

2012-2013 Spawning Ground Survey Conditions and Effort

We completed 398 surveys in 33 main reaches and 15 sub-reaches the Smith River during the 2012-2013 survey period extending from November 6, 2012 to February 27, 2013 (Table 9). GRTS sampling represented 35% of the total frame with 24 reaches and 10 sub-reaches. One GRTS drawn reach was replaced based on a private landowner denying access to a portion of the reach. Similar to the previous year, the precipitation regime for the 2012-2013 was marked by extended dry conditions with rainfall amounts for the survey period equaling 89% of average at the Gasquet Ranger Station (DWR 2014). Most of the rain fell in November and December so unlike 2011-2012, the first half of the season produced higher stream base discharge than the second half (Figure 2B). Five storms increased river discharge with three storms causing delays in our reach survey return interval (Figure 2B). Overall, 85% of the days within the survey period had favorable conditions where the daily average river discharge was below our maximum survey threshold (16,000 cubic feet per second at the USGS Jed Smith gaging station). On average, the availability of reaches with favorable survey conditions equaled 77% (SD= 7%) of days within the survey period. We surveyed on 66 of the 96 available days resulting in an effort of 68.7% (Figure 2B). On Average, we surveyed each reach 8.5 times (range 4-14) with an overall average reach return interval equaling 13 days (Table 9, Figure 2B). However, we did not survey all reaches during extended dry periods since low stream flows prevented anadromous fish migration in some small tributaries.

2012-2013 GRTS Spawning Ground Surveys

Live Fish Observations

We made 1245 observations of live anadromous salmonids within the GRTS surveyed portion of the Smith River during the winter of 2012-2013 (Table 9, Figure 4B). Live salmonid totals do not represent individual fish observations since live individuals could be observed over multiple survey periods. Observations included 59 coho salmon, 836 Chinook salmon, 218 steelhead, and 132 unidentified salmonids (Table 10, Figure 4B). As with the previous year, the first half of the season was dominated by live Chinook salmon observations with the mean observation date equaling December 2 (Table 11, Figure 4B). Chinook salmon were widely distributed throughout the surveyed area with detections in 27 of the 34 GRTS surveyed reaches (Table 10, Figure 5). Live coho salmon observations ranged from November 25 through February 14 with a mean observation date of January 8 (Table 11, Figure 4B). All live coho salmon were observed in Mill Creek and were narrowly distributed in 10 of the GRTS selected reaches (Table 10, Figure 6). Live steelhead observations increased steadily during the ladder half of the survey period with a

Table 9. Summary statistics of spawning ground reach survey effort and reach survey availability based on flow conditions for the winter of 2012-2013, Smith River basin, Del Norte County, CA. Surveys occurred from November 6, 2012 to February 27, 2013. 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	59	1227	8	14	3	18	0.71
Rowdy	63	1446	8	13	3	18	0.76
Morrison	79	1407	7	13	4	18	0.75
Little Mill	86	1734	10	10	5	21	0.76
Sultan	87	2270	8	12	3	19	0.80
Clark's	96	2277	9	11	3	14	0.86
Clark's	97	367	6	15	6	21	0.86
Clark's	98	968	6	15	6	21	0.86
Mill	102	2329	9	13	4	20	0.69
Mill	103	1314	9	14	4	20	0.69
WB Mill	**106**	2111	11	11	4	17	0.79
WB Mill	**107**	2675	11	10	4	20	0.79
WB Mill	**108**	2030	14	8	2	13	0.79
WB Mill	**109**	1802	11	10	3	16	0.83
WB Mill	**110**	2382	10	11	3	17	0.86
WB Mill	**111**	1356	5	13	3	17	0.86
Mill	**116**	2987	8	12	3	17	0.86
Mill	118	676	7	13	4	20	0.69
Mill	119	115	4	9	2	12	0.69
EF Mill	**123**	2149	11	11	3	17	0.73
EF Mill	**124**	2298	11	11	4	18	0.73
EF Mill	**125**	1589	13	9	3	15	0.83
EF Mill	**126**	1450	11	10	2	14	0.83
EF Mill	**129**	436	7	12	3	16	0.73
First Gulch	**130**	2506	10	9	3	13	0.84
Kelly	**132**	2481	11	9	3	16	0.84
Kelly	**133**	593	7	14	9	32	0.84
Bummer	**134**	2996	10	11	4	18	0.76
Bummer	**135**	300	7	11	3	18	0.76
Low Divide	**136**	863	11	9	3	15	0.83
WB Mill	**138**	125	10	12	5	22	0.79
WB Mill	**140**	741	11	8	2	12	0.80
WB Mill	**141**	442	9	10	4	17	0.80
WB Mill	**143**	834	11	10	3	16	0.84
Craig's	171[b]	2473	8	14	4	20	0.65
Craig's	175[b]	230	4	21	11	35	0.65
Hurdygurdy	217	2989	8	13	6	24	0.69
Hurdygurdy	232	1046	4	16	3	20	0.83
Jones Creek	234	2445	8	13	6	24	0.69
MF Smith	286	1822	7	17	7	28	0.71
Patrick's	303	2249	7	17	8	32	0.56
Monkey	318	2515	7	15	7	27	0.76
Siskiyou	324	2509	9	13	4	18	0.72
Siskiyou	325	2937	9	13	4	17	0.72
Idlewild	333	542	3	25	3	28	0.71
Griffin	336	2601	8	13	3	18	0.79
Griffin	339	357	5	18	10	34	0.79
	Total	-	398	12.6[c]	-	-	0.77

[a]Bold indicates Mill Creek Census reach, [b]Incidental non-GRTS Survey, [c]Mean value.

Table 10. Summary of live adult and salmonid carcasses observed by species and reach from November 6, 2012 to February 27, 2013, 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 individual carcass observations. 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.

Subbasin	Location Code[a]	Live salmonids				Salmonid carcasses			
		Chinook Salmon	Coho Salmon	Steelhead	Unknown species	Chinook Salmon	Coho Salmon	Steelhead	Unknown species
Rowdy	59	37	-	50	17	47	-	-	7
Rowdy	63	23	-	1	2	1	-	-	-
Morrison	79	14	-	-	-	8	1	-	1
Little Mill	86	78	-	-	-	21	-	-	-
Sultan	87	92	-	1	4	13	-	-	-
Clark's	96	128	-	-	4	47	-	-	1
Clark's	97	3	-	-	-	3	-	-	-
Clark's	98	1	-	-	-	-	-	-	-
Mill	102	39	1	17	8	22	1	-	2
Mill	103	28	1	23	2	20	-	-	2
WB Mill	**106**	130	1	7	8	27	-	-	4
WB Mill	**107**	111	19	18	11	38	3	1	2
WB Mill	**108**	109	22	6	24	33	5	-	3
WB Mill	**109**	41	11	3	3	4	3	-	1
WB Mill	**110**	22	9	-	1	1	2	-	-
WB Mill	**111**	-	-	-	-	-	-	-	-
Mill	**116**	4	-	-	1	9	-	-	-
Mill	118	-	-	-	-	-	-	-	-
Mill	119	-	-	-	-	-	-	-	-
EF Mill	**123**	38	2	28	19	9	1	-	3
EF Mill	**124**	56	9	22	26	7	2	-	-
EF Mill	**125**	32	4	2	5	3	3	-	-
EF Mill	**126**	22	2	1	2	1	-	-	-
EF Mill	**129**	-	-	-	-	-	-	-	-
First Gulch	**130**	19	7	-	4	2	1	-	-
Kelly	**132**	26	6	1	10	8	1	-	-
Kelly	**133**	-	3	-	-	-	-	-	-
Bummer	**134**	31	19	2	8	2	1	-	-
Bummer	**135**	-	-	2	-	-	-	-	-
Low Divide	**136**	-	-	-	-	-	-	-	-
WB Mill	**138**	1	-	-	-	-	-	-	-
WB Mill	**140**	-	7	-	4	-	-	-	-
WB Mill	**141**	-	2	-	-	-	-	-	-
WB Mill	**143**	22	4	-	2	1	-	-	-
Craig's	171	9	-	31	-	2	-	-	-
Craig's	175	1	-	-	-	-	-	-	-
Hurdygurdy	217	23	-	84	28	8	-	1	3
Hurdygurdy	232	-	-	-	-	-	-	-	-
Jones Creek	234	40	-	7	3	4	-	-	3
MF Smith	286	39	-	3	1	1	-	-	-
Patrick's	303	10	-	5	2	6	-	-	1
Monkey	318	5	-	-	2	1	-	-	-
Siskiyou	324	25	-	6	9	2	-	-	-
Siskiyou	325	19	-	11	8	1	-	-	-
Idlewild	333	-	-	-	-	-	-	-	-
Griffin	336	8	-	-	1	-	-	1	-
Griffin	339	-	-	-	-	-	-	-	-
	Total	1286	129	331	219	352	24	3	33

[a]*Bold indicates Mill Creek Census reach*

Table 11. Descriptive statistics for observation date of live fish, observation date of known species redds, observation date of carcasses, and carcass fork lengths for the 2012-2013 spawning ground survey season in the Smith River basin, Del Norte County, CA. Totals include data from GRTS drawn reaches and the Mill Creek Life Cycle Monitoring Station census.

		Chinook Salmon	Coho Salmon	Steelhead
Live fish date:	N	1232	129	168
	Mean	2-Dec-2012	8-Jan-2013	6-Feb-2013
	SD	14.2	19.9	19.1
	Min	6-Nov-2012	25-Nov-2012	19-Dec-2012
	Max	22-Jan-2013	14-Feb-2013	27-Feb-2013
Live fish sex ratio:	F / M	1 / 0.99	1 / 1.62	1 / 1.44
Known species	N	331	25	21
Redd:	Mean	3-Dec-2012	31-Dec-2012	5-Feb-2013
	SD	12.4	20.4	17.0
	Min	6-Nov-2012	25-Nov-2012	29-Dec-2012
	Max	8-Jan-2013	5-Feb-2013	26-Feb-2013
Carcass date:	N	352	24	3
	Mean	22-Dec-2012	17-Jan-2013	10-Feb-2013
	SD	15.8	19.5	13.5
	Min	9-Nov-2012	9-Jan-2013	22-Jan-2013
	Max	30-Jan-2013	13-Feb-2013	21-Feb-2013
Carcass sex ratio:	F / M	1 / 0.72	1 / 0.47	-
Carcass fork	N	298	20	2
Length (cm):	Mean	85	61.5	-
	SD	13.5	9.8	-
	Min	42	39	72
	Max	147	72	79

mean observation date of February 6 (Table 11, Figure 4B). Thus, our observations represent only a portion of the steelhead spawning season since our effort ended February 27. We found our steelhead observations were moderately distributed with detections in 16 of 34 GRTS surveyed reaches (Table 10, Figure 7). Overall, the mean run timing during the winter of 2012-2013 was earlier than the winter of 2011-2012 for coho salmon and Chinook salmon with the mean live observation dates 13 and 11 days earlier, respectively. The mean observation date of steelhead was 7 days later than 2011-2012 possibly due to low stream flows delaying migration.

Carcass Observations

We recovered 300 anadromous salmonid carcasses in GRTS survey reaches during the winter of 2012-2013. Carcass totals were dominated by Chinook salmon with 261 individuals followed by 14 coho salmon, 2 steelhead, and 24 unidentified salmonids (Table 10, Figure 8B). Thirteen of the 14 coho salmon carcasses in the GRTS survey were recovered in Mill Creek (Table 10). One coho salmon carcass was recovered in Morrison Creek, a tributary of the lower main stem Smith River (Figure 6). This was the only coho salmon (live or dead) observed outside of Mill Creek during the winter of 2012-2013 (Table 10, Figure 6). We encountered the first coho salmon carcass on January 9 and the last on February 13 with the mean date equaling February 2 (Table 11). Of the 14 tagged coho salmon carcasses in the GRTS survey, we recaptured four on subsequent surveys.

Hatchery Origin Salmonid Observations

We identified Hatchery origin salmonids throughout the Smith River during the winter of 2012-2013 (Table 12, Figure 9). 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 12). Hatchery origin fish constituted 5.9% (range: 2.5% to 18.5%) of all live Chinook salmon observations where the presence or absence of an adipose fin could be determined and 7.5% (range: 0% to 20.8%) of all Chinook salmon carcasses recovered. No live hatchery origin coho salmon were observed during the winter of 2012-2013. However, we did recover a hatchery origin coho salmon carcass in Mill Creek with a prominent left maxillary bone clip indicating origin at the Iron Gate Fish Hatchery on the Klamath River. Hatchery origin steelhead constituted 11.1% (range: 0% to 50%) of all live observations where the presence or absence of an adipose fin could be determined (Table 12). No steelhead carcasses we recovered (N=3) were of hatchery origin.

Redd Observations

We identified 814 anadromous salmonid redds within the GRTS surveyed portion of the Smith River during the winter of 2012-2013 including 13 coho salmon, 231 Chinook salmon, 13 steelhead, and 557 unidentified species (Table 13, Figure 10B). The average total reach-level redd density equaled 16.0 redds per kilometer, with the highest observed densities occurring in Rowdy Creek and Mill Creek watersheds (Table 13). Thirty percent of the overall observed redds were identified to species, though this proportion varied greatly over the spawning season. During the first half of the spawning season we identified 43% of the redds to species while in the second half we only identified 9% to species (Figure 10B). All verified coho salmon redds were observed in the Mill Creek LCS above the confluence of the East Fork and West Branch (Table 13, Figure 6). In contrast, verified Chinook salmon and steelhead redds were distributed throughout the surveyed area (Table 13, Figure 5, Figure 7). The first verified coho salmon redd was observed on November 25 and the last was observed on February 5 (Table 11). Overall, mean observation dates of known species redds were within a week of mean live fish dates for all species (Table 11).

Redd Prediction Performance

The kNN classifier performed well in the 2012-2013 survey season, correctly predicting 357 of 377 (94.7%) redds verified to species from GRTS and Mill Creek census reaches (Table 7). Chinook salmon dominated the known species redds representing 87.8% of the total followed by coho salmon (6.6%) and steelhead (5.6%). The kNN classifier correctly predicted 97.9% of Chinook salmon redds followed by 68.0% of coho salmon redds and 76.2% of steelhead redds. Consistent with our live fish and carcass observations, no coho salmon redds were predicted by the kNN classifier outside of Mill Creek.

Total Redd Abundance

Total redd abundance estimates of coho salmon, Chinook salmon and steelhead for the Smith River in 2012-2013, with 95% confidence intervals, are 306 (85 - 527), 1789 (1281 - 2297), and 694 (453 - 935), respectively (Table 14). Because we did not detect or predict any coho salmon redds outside of the Mill Creek LCS we are not recommending the use of this coho salmon population estimate. We prefer using the LCS estimate for coho salmon and only report this estimate for comparative purposes.

Mill Creek Spawner Survey Census

Live Fish Observations

Live coho salmon were observed throughout most of the Mill Creek LCS census area in both years (Figure 11). However, very few observations occurred in the two lowest reaches (106 and 123). During the winter of 2011-2012 we had 1583 observations of live anadromous salmonids in Mill Creek LCS census reaches. These observations included 383 coho salmon, 992 Chinook salmon, 92 steelhead, and 116 unknown

Table 12. Proportion of observed hatchery-origin salmonids summarized by species, observation type, and major sub-basin, during the winter 2012-2013 spawning ground surveys conducted throughout the Smith River basin, Del Norte County, CA. Sub-basins include Rowdy Creek (all reaches sampled in the sub-basin 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). 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 2012-13									
	Coho Salmon			Chinook Salmon			Steelhead		
Sub-basin	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	0	0	-	27	5	18.5	2	1	50.0
Below Forks	35	0	0	535	33	6.2	27	4	14.8
Above Forks	0	0	-	79	2	2.5	11	0	0
Carcass observations 2012-13									
	Coho Salmon			Chinook Salmon			Steelhead		
Sub-basin	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery	No Clip	Clip	% Hatchery
Rowdy Cr	0	0	-	24	5	20.8	0	0	-
Below Forks	18	1	5.6	196	14	7.1	1	0	0
Above Forks	0	0	-	14	0	0	2	0	0

species (Table 3). During the winter of 2012-2013 we had 879 observations of live anadromous salmonids including 127 coho salmon, 660 Chinook salmon, 92 steelhead, and 127 unknown species (Table 10).

Carcass Observations

During the winter of 2011-2012 we encountered 78 coho salmon, 305 Chinook salmon, two steelhead, and 8 unknown species carcasses in the Mill Creek LCS (Table 3). Of the 78 coho salmon carcasses we encountered we recaptured 35 on subsequent surveys. Two carcasses were encountered twice and three carcasses were encountered three times. During the winter of 2012-2013 we encountered 22 coho salmon, 136 Chinook salmon, one steelhead, and 13 unknown species carcasses in the Mill Creek LCS (Table 10). Of the 22 coho salmon carcasses we encountered we recaptured eight on subsequent surveys. One carcass was recaptured twice.

Redd Observations and Abundance

Verified coho salmon redds were observed throughout most of the Mill Creek LCS during both survey years (Figure 11). During the 2011-2012 spawning survey season we observed 90 coho salmon redds, 259 Chinook salmon redds, six steelhead redds, and 880 unknown species redds (Table 6). The known species redds plus the kNN predicted species redds (i.e. total number of observed redds) resulted in 338 coho salmon, 799 Chinook salmon, and 98 steelhead redds. We estimated total redd abundance in the Mill Creek LCS sub-basin for 2011-2012 as 482 coho salmon redds (464 - 501), 909 Chinook salmon redds (896 - 921), and 111 steelhead redds (105 - 117) (Table 15). During the 2012-2013 spawning survey season we observed 25 coho salmon redds, 154 Chinook salmon redds, six steelhead redds, and 487 unknown species redds (Table 13). The known species redds plus the kNN predicted redds resulted in 165 coho salmon redds, 422 Chinook salmon redds, and 85 steelhead redds. We estimated total redd abundance in the Mill Creek LCS sub-basin for 2012-2013 as 227 coho salmon redds (217 - 236), 534 Chinook salmon redds (513 - 554), and 116 steelhead redds (109 - 122) (Table 16).

Table 13. Summary of total observed redds separated by reach and species for the winter of 2012-2013, Smith River basin, Del Norte County, CA. Surveys occurred from November 6, 2012 to February 27, 2013. 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.

Subbasin	Location Code[a]	Number of observed redds by species: Chinook Salmon	Coho Salmon	Steelhead	Unknown species	Cutthroat Trout	# of redds per Km[b]
Rowdy	59	5	-	4	58	-	54.6
Rowdy	63	4	-	-	23	-	18.7
Morrison	79	5	-	-	2	-	5.0
Little Mill	86	24	-	-	16	1	23.0
Sultan	87	24	-	1	16	-	18.0
Clark's	96	37	-	-	20	-	25.0
Clark's	97	3	-	-	1	-	10.9
Clark's	98	1	-	-	2	-	1.0
Mill	102	20	-	-	28	-	20.9
Mill	103	6	-	2	24	-	24.4
WB Mill	**106**	33	-	-	75	-	51.2
WB Mill	**107**	23	3	1	79	-	39.6
WB Mill	**108**	21	2	-	63	-	42.3
WB Mill	**109**	9	3	-	25	-	20.5
WB Mill	**110**	4	2	-	19	4	10.5
WB Mill	**111**	-	-	-	3	11	2.2
Mill	**116**	1	-	-	14	2	5.0
Mill	118	-	-	-	-	-	-
Mill	119	-	-	-	-	-	-
EF Mill	**123**	3	1	1	32	-	17.2
EF Mill	**124**	8	1	2	38	-	21.3
EF Mill	**125**	9	1	1	38	3	30.8
EF Mill	**126**	5	-	-	22	1	18.6
EF Mill	**129**	-	-	-	-	-	-
First Gulch	**130**	8	2	-	17	11	10.8
Kelly	**132**	10	2	-	16	21	11.3
Kelly	**133**	-	2	-	1	1	5.1
Bummer	**134**	10	2	-	34	-	15.3
Bummer	**135**	-	-	1	-	-	3.3
Low Divide	**136**	-	-	-	4	1	4.6
WB Mill	**138**	1	-	-	1	-	12.7
WB Mill	**140**	-	3	-	4	3	9.4
WB Mill	**141**	-	1	-	3	6	9.0
WB Mill	**143**	10	-	-	13	-	27.5
Craig's	171	2	-	3	14	-	7.7
Craig's	175	1	-	-	-	-	4.3
Hurdygurdy	217	5	-	2	45	-	17.4
Hurdygurdy	232	-	-	-	1	5	1.0
Jones Creek	234	8	-	2	29	-	16.0
MF Smith	286	10	-	-	15	-	13.7
Patrick's	303	8	-	1	17	-	11.6
Monkey	318	2	-	-	16	-	7.2
Siskiyou	324	5	-	-	19	-	9.6
Siskiyou	325	3	-	-	31	-	11.6
Idlewild	333	-	-	-	-	-	-
Griffin	336	3	-	-	8	-	4.2
Griffin	339	-	-	-	-	-	-
Total		331	25	21	886	70	16.0[c]

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

Table 14. Estimated total number of redds by species in the Smith River sample frame for the winter of 2012-2013. Components of estimated variance are broken down into 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).

	Coho Salmon[1]	Chinook Salmon	Steelhead
Redd estimate	306	1789	694
SE	106.7	244.9	116.6
Total within reach variance	9.0	102.6	21.5
Total between reach variance	82.3	503.0	100.9
% Within reach variance	8.9	16.9	17.5
% Between reach variance	90.1	83.1	82.4
95% CI	(85, 527)	(1281, 2297)	(453, 935)

[1]We recommend using the Mill Creek LCS census population estimate for coho salmon for reasons described in the discussion section.

Two patterns that stood out both years in the Mill Creek LCS was the concentration of Chinook salmon spawning in the three lowest reaches of the West Branch (reaches 106, 107, and 108). These reaches represent 22% of the available anadromous spawning habitat in the LCS, however, 60% of known species Chinook salmon redds were found there (Tables 6 and 13). The other pattern was the importance of the West Branch sub-reach tributaries to coho salmon spawning (sub-reaches 140, 141, and 143). These three reaches represent 6% of the available spawning streams in the LCM but contained 22% of the known species coho salmon redds (Tables 6 and 13, Figure 11).

Coastal Cutthroat Trout and Pacific Lamprey

Coastal Cutthroat Trout Redds

During the winter of 2011-2012 we observed 31 coastal cutthroat trout (*Oncorhynchus clarki clarki*) redds in 12 GRTS drawn reaches (Table 6). The first cutthroat trout redd was observed November 7 and the last was observed on February 23 with a mean observation date of January 6. During the winter of 2012-2013 we observed 70 coastal cutthroat trout redds in nine main reaches and four sub-reaches (Table 13). The first coastal cutthroat trout redd was observed December 9 and the last was observed on February 27. The mean redd observation date was January 16. These observations are incidental and likely do not reflect actual redd abundance patterns. Coastal cutthroat trout exhibit diverse life-histories in the Smith River resulting in a prolonged spawning season (Moyle 2002) extending well beyond our survey period.

Pacific Lamprey Redds

We observed three Pacific lamprey (*Lampetra tridentata*) redds during the two winters of spawning surveys. All three redds were observed in reach #108 of West Branch of Mill Creek. We observed one redd February 22, 2012 and two redds February 26, 2013. 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.).

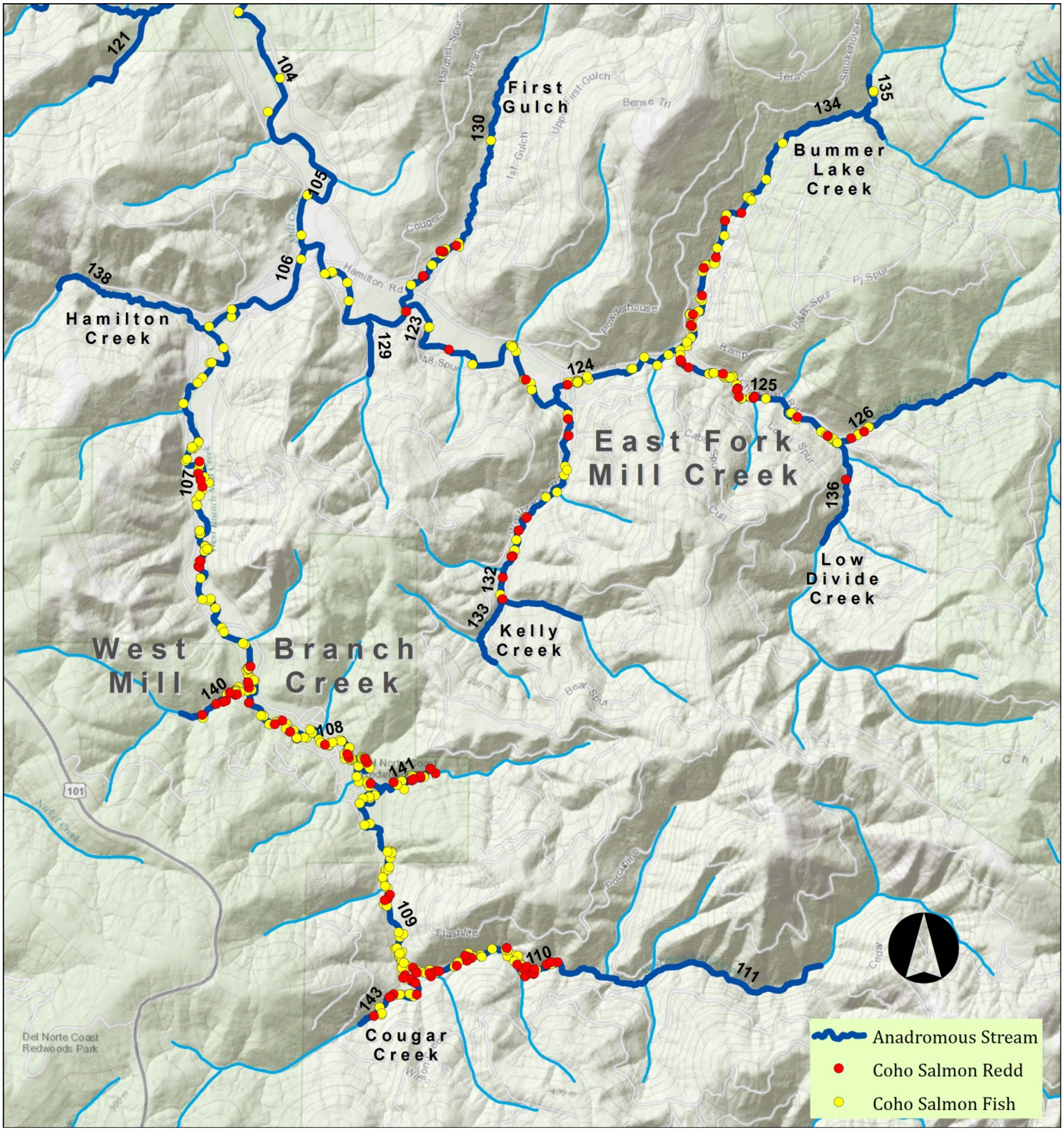


Figure 11. Map showing the distribution of observed adult coho salmon, and verified coho salmon redds in the Mill Creek spawning ground census (Life Cycle Monitoring Station) area during the winters of 2011-2012 and 2012-2013, Smith River Basin, Del Norte County, CA. Note: redd location symbols are displayed above fish observation symbols and may obscure fish observations in reaches containing high densities of verified redds. Although live coho salmon were observed holding in pools outside of the census region in the lower main stem Mill Creek, no coho salmon redds were confirmed below the confluence of the East Fork and West Branch.

Table 15. Estimated total number of redds by species within the Mill Creek Life Cycle Monitoring Station for the winter of 2011-2012. Components of estimated variance are broken down to the estimation of the number of redds within the reach. There is no between-reach variation since all reaches were surveyed.

	Coho Salmon	Chinook Salmon	Steelhead
Redd estimate	482	909	111
SE	9.4	6.5	3.1
Total within reach variance	87.8	41.7	9.7
Total between reach variance	-	-	-
% Within reach variance	100	100	100
% Between reach variance	-	-	-
95% CI	(464, 501)	(896, 921)	(105, 117)

Table 16. Estimated total number of redds by species within the Mill Creek Life Cycle Monitoring Station for the winter of 2012-2013. 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.

	Coho Salmon	Chinook Salmon	Steelhead
Redd estimate	227	534	116
SE	4.8	10.2	3.1
Total within reach variance	22.6	104.1	9.4
Total between reach variance	-	-	-
% Within reach variance	100	100	100
% Between reach variance	-	-	-
95% CI	(217, 236)	(513, 554)	(109, 122)

Spatial Structure Survey Results

2012 Sampling Effort and Coho Salmon Occupancy

We surveyed a total of 37 reaches and four sub-reaches during the summer of 2012 representing 29.4 percent of the total sampling frame in stream kilometers (Table 17). Surveys extended from June 5th to September 29th with 46 work days and 152 person days. Each survey reach required an average of 2.1 crew days to complete. Juvenile coho salmon were detected in five portions of the basin including the lower main stem Smith River and proximal tributaries, Rowdy Creek, Mill Creek, upper South Fork Smith River, and Baldface Creek (Table 18, Figure 12). We documented coho salmon occurring in 17 out of 41 surveyed reaches and within 289 of 1115 sampled pools. The median number of coho salmon observed per pool equaled 17; range: 1 to 168 (Table 19). We determined 11 out of the 17 reaches (65%) with coho salmon were non-natal rearing areas (Table 18). However, only 19% of the total fish counted were observed in

Table 17. Spatial structure survey effort during the summers of 2012 and 2013, Smith River Basin, California and Oregon.

Year	Reaches surveyed	Sub-reaches surveyed	# units surveyed	Mean # units per reach	Stream length surveyed (km)	Percent of total frame surveyed
2012	37	4	1115	27 (2-84)	87.7	29.4
2013	49	11	1453	24 (3-72)	116.4	39.0

non-natal reaches. Individual surveyors performed well at detecting juvenile coho salmon in pools. The overall detection probability (p) equaled 0.94 (SE= 0.02). Estimated large-scale probability of occupancy (ψ) equaled 0.42 (SE= 0.08), (Table 20). The estimate of conditional pool-level occupancy, given present in a reach($\theta|\psi$), equaled 0.68 (SE 0.01) (Table 20). Last, we estimated the overall proportion of area occupied ($\theta * \psi$) as 0.29.

2013 Sampling Effort and Coho Salmon Occupancy

We surveyed a total of 49 reaches and 11 sub-reaches during the summer of 2013 representing 39.0 percent of the total sampling frame in stream kilometers (Table 17). Surveys extended from June 17th to August 27th with 43 work days and 183 person days. Each survey reach required an average of 1.9 crew days to complete. Juvenile coho salmon were detected in four portions of the basin including the lower main stem Smith River and proximal tributaries, Rowdy Creek, Mill Creek, and the upper South Fork Smith River (Table 20, Figure 12). We documented coho salmon occurring in 23 out of 60 surveyed reaches and within 359 of 1453 sampled pools. The median number of coho salmon observed per pool equaled 12; range: 1 to 525 (Table 19). We determined nine out of the 23 reaches (39%) with coho salmon were non-natal rearing areas (Table 20). However, only 8% 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= <0.01). Estimated large-scale probability of occupancy (ψ) equaled 0.39 (SE= 0.06), (Table 19). The estimate of conditional pool-level occupancy, given present in a reach($\theta|\psi$), equaled 0.60 (SE 0.02) (Table 19). We estimated the overall proportion of area occupied ($\theta * \psi$) as 0.23. Last, we incidentally detected juvenile coho salmon in six additional reaches (Location codes: 4, 59, 60, 61, 96, 392) that were not part of the GRTS sample draw but were briefly inspected during field reconnaissance (Figure 12).

Table 18. Summary statistics of coho salmon occupancy and relative abundance based on snorkel surveys occurring in 41 GRTS drawn reaches during the summer of 2012, 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
Lower Smith River	6	797	5	4	10.0	40	Non-natal
Lower Smith River	10	2520	12	12	14.4	173	Non-natal
Lower Smith River	11	2765	3	1	NA	1	Non-natal
Lower Smith River	12	3335	4	1	NA	47	Non-natal
Lower Smith River	14	2617	8	0	-	0	-
Middle Fork Smith River	19	2632	10	0	-	0	-
North Fork Smith River	35	2697	26	0	-	0	-
Rowdy Creek	57	3216	23	11	3.5	39	Non-natal
Rowdy Creek	63	1446	46	0	-	0	-
Dominie Creek	65	2727	55	0	-	0	-
Savoy Creek	68	2080	59	0	-	0	-
Morrison Creek	77	1485	16	12	1.9	23	Natal
Sultan Creek	87	2270	67	1	NA	1	Non-natal
Unnamed Trib.	88	142	2	1	NA	1	Non-natal
Mill Creek	100	1805	12	5	3.2	16	Non-natal
Mill Creek	102	2329	23	21	27.0	566	Non-natal
Mill Creek	105	1412	12	12	55.6	667	Non-natal
West Branch Mill Creek	109	1802	41	41	77.8	3188	Natal
West Branch Mill Creek	111	1356	38	0	-	0	-
Mill Creek Trib.	116	2987	37	0	-	0	-
First Gulch	130	2506	84	77	20.0	1542	Natal
Kelly Creek	132	2481	63	52	28.8	1496	Natal
WB Mill Creek Trib.	143	834	20	19	26.9	511	Natal
South Fork Smith River	159	2461	8	0	-	0	-
South Fork Smith River	160	1766	9	0	-	0	-
South Fork Smith River	166	3582	21	5	1.2	6	Non-natal
Craig's Creek	171	2473	57	0	-	0	-
Goose Creek	212	1746	25	0	-	0	-
Goose Creek Trib.	215	840	6	0	-	0	-
Hurdygurdy Creek	220	3155	34	0	-	0	-
Hurdygurdy Creek	223	2984	50	0	-	0	-
Jones Creek	236	2232	16	0	-	0	-
Quartz Creek	250	2999	58	0	-	0	-
Quartz Creek	251	1944	21	0	-	0	-
Eightmile Creek	253	2178	16	0	-	0	-
Middle Fork	281	3888	15	0	-	0	-
Middle Fork	286	1822	30	0	-	0	-
Patrick's Creek	303	2249	47	0	-	0	-
Siskiyou Fork	326	1187	12	0	-	0	-
Baldface Creek	392	2473	21	14	6.0	84	Natal
Baldface Creek Trib.	403	78	3	0	-	0	-
Total			1115	289		8401	

Table 19. Occupancy estimates, proportion of area occupied, and relative count densities if salmonids for the summer spatial structure survey during 2012 and 2013, Smith River basin, Oregon and California.

Species	PSI	SE	95% CI	Theta	SE	95% CI	*p*	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count[1]
Summer 2012													
Coho Salmon	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
Chinook Salmon	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
Trout (YOY)	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
Trout (1+)	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
Adult Cutthroat Trout	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
Summer 2013													
Coho Salmon	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
Chinook Salmon	0.77	0.06	0.64 - 0.86	0.47	0.01	0.44 - 0.50	0.90	0.01	0.88 - 0.92	0.36	45 of 60	12.2	4
Trout (YOY)	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
Trout (1+)	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
Adult Cutthroat Trout	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

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 in a given year.
[1]High counts of coho salmon in Mill Creek reaches, relative to other portions of the basin, make the median more representative of central tendency.

Table 20. Summary statistics of coho salmon occupancy and relative abundance based on snorkel surveys occurring in 60 GRTS drawn reaches during the summer of 2013, 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
Lower Smith River	5	2044	5	0	-	0	-
Lower Smith River	7	1639	4	1	NA	1	Non-natal
Lower Smith River	9	1654	4	4	13.5	54	Non-natal
Lower Smith River	10	2520	12	5	7.4	37	Non-natal
Lower Smith River	13	2968	3	1	NA	2	Non-natal
North Fork Smith River	34	2845	31	0	-	0	-
Tryon Creek	52	3505	26	0	-	0	-
Rowdy Creek	58	1858	19	6	3.8	23	Natal
Rowdy Creek	62	2276	21	7	2.9	20	Natal
Rowdy Creek	63	1446	36	5	3.8	19	Natal
South Fork Rowdy Creek	67	2492	56	0	-	0	-
Rowdy Creek Trib.	72	579	9	0	-	0	-
Morrison Creek	77	1485	19	6	1.8	11	Natal
Morrison Creek	79	1407	18	0	-	0	-
Little Mill Creek	86	1734	29	0	-	0	-
Unnamed Tributary	89	184	3	0	-	0	-
Peacock Creek	91	3296	72	1	NA	1	Non-natal
Peacock Creek	94	402	8	0	-	0	-
Mill Creek	102	2329	18	17	17.2	293	Non-natal
Mill Creek	103	1314	10	9	29.1	262	Non-natal
Mill Creek	106	2111	27	26	34.2	888	Natal
West Branch Mill Creek	108	2030	40	40	62.7	2509	Natal
West Branch Mill Creek	110	2582	44	33	29.1	961	Natal
Mill Creek Trib.	118	676	3	0	-	0	-
East Fork Mill Creek	123	2149	18	17	93.5	1589	Natal
East Fork Mill Creek	126	1450	38	32	8.5	273	Natal
First Gulch	130	2506	70	54	20.5	1105	Natal
Kelly Creek	132	2481	60	49	14.1	692	Natal
Kelly Creek Trib.	133	593	17	11	1.9	21	Natal
Hamilton Creek	138	1427	33	0	-	0	-
WB Mill Creek Trib.	141	442	7	5	7.6	38	Natal
South Fork Smith River	159	2461	6	0	-	0	-
South Fork Smith River	163	2602	4	1	NA	3	Non-natal
South Fork Smith River	166	3582	39	19	2.5	47	Non-natal
South Fork Smith River	167	2445	25	10	3.2	32	Natal
Craig's Creek	171	2473	32	0	-	0	-
Craig's Creek Trib.	175	230	5	0	-	0	-
Rock Creek	188	2714	39	0	-	0	-
Rock Creek	190	1447	28	0	-	0	-
Rock Creek	192	151	3	0	-	0	-
Rock Creek	196	2455	41	0	-	0	-
Goose Creek	213	2292	36	0	-	0	-
Hurdygurdy Creek	222	2651	14	0	-	0	-
Hurdygurdy Creek	232	1046	23	0	-	0	-
Jones Creek	235	2210	16	0	-	0	-
Quartz Creek	251	1944	16	0	-	0	-
Middle Fork Smith River	281	3888	10	0	-	0	-
Middle Fork Smith River	282	3236	22	0	-	0	-
Middle Fork Smith River	285	1944	19	0	-	0	-
Patrick's Creek	304	1519	28	0	-	0	-
Shelly Creek	308	875	11	0	-	0	-
Monkey Creek	317	2229	25	0	-	0	-
Monkey Creek	319	2677	44	0	-	0	-
South Siskiyou Fork	331	1888	28	0	-	0	-
Griffin Creek	337	2336	49	0	-	0	-
Knopki Creek	344	3225	62	0	-	0	-
Baldface Creek	391	2823	19	0	-	0	-
Baldface Creek Trib.	400	144	6	0	-	0	-
Baldface Creek Trib.	402	771	10	0	-	0	-
Horse Creek	420	1956	33	0	-	0	-
Total			1453	359		8881	

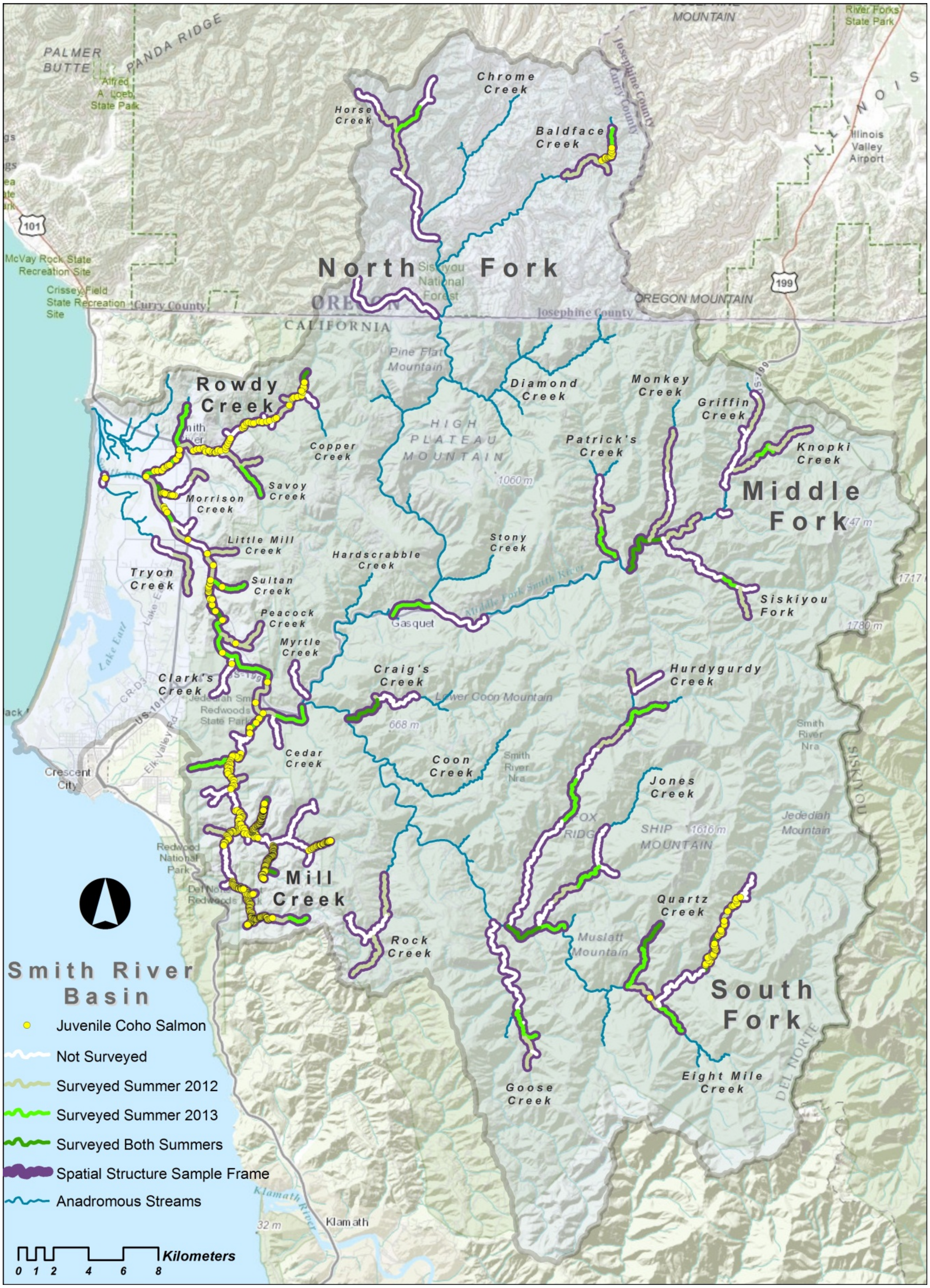


Figure 12. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing juvenile coho salmon from 2012 and 2013, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

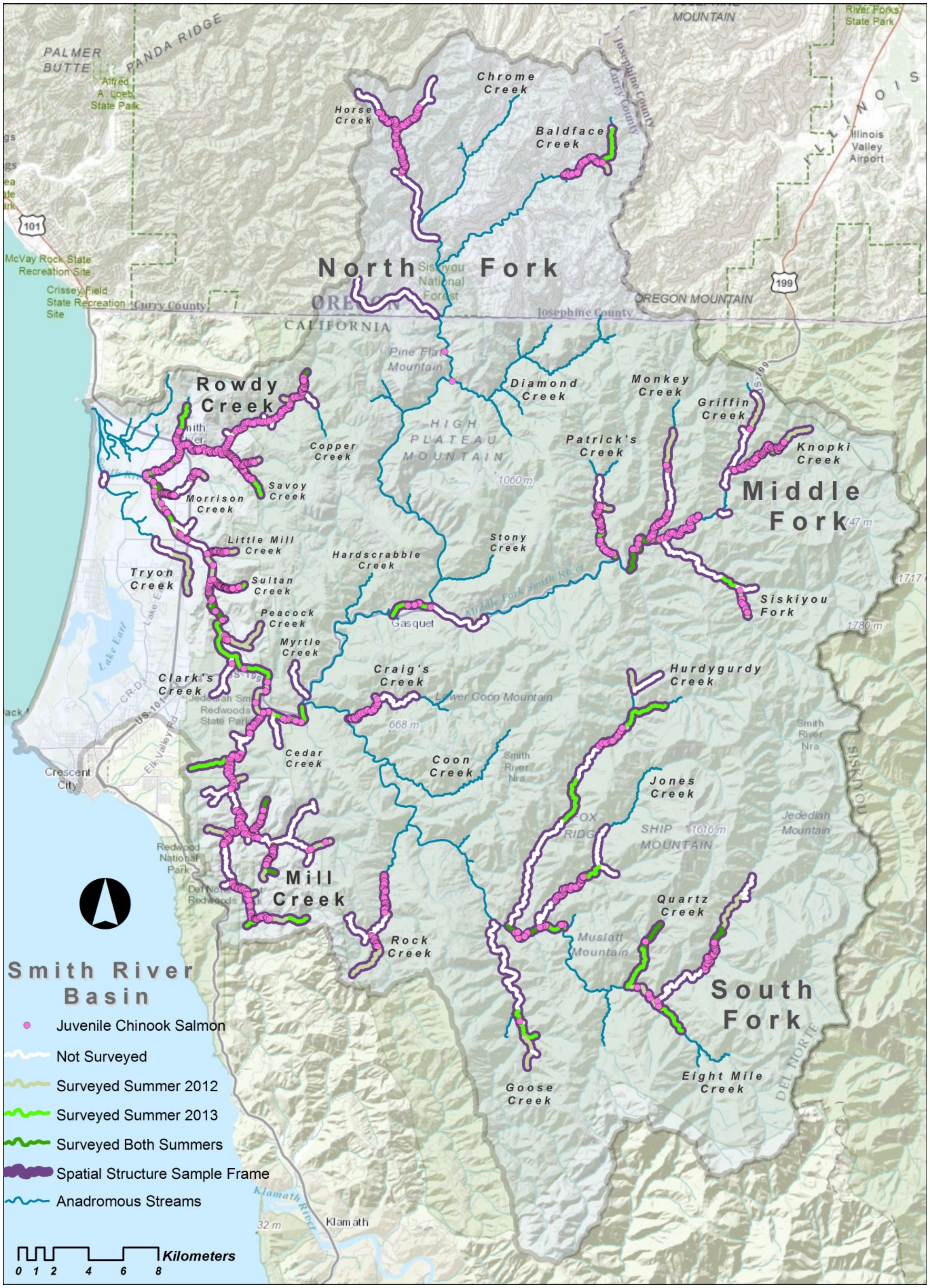


Figure 13. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing juvenile Chinook salmon from 2012 and 2013, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

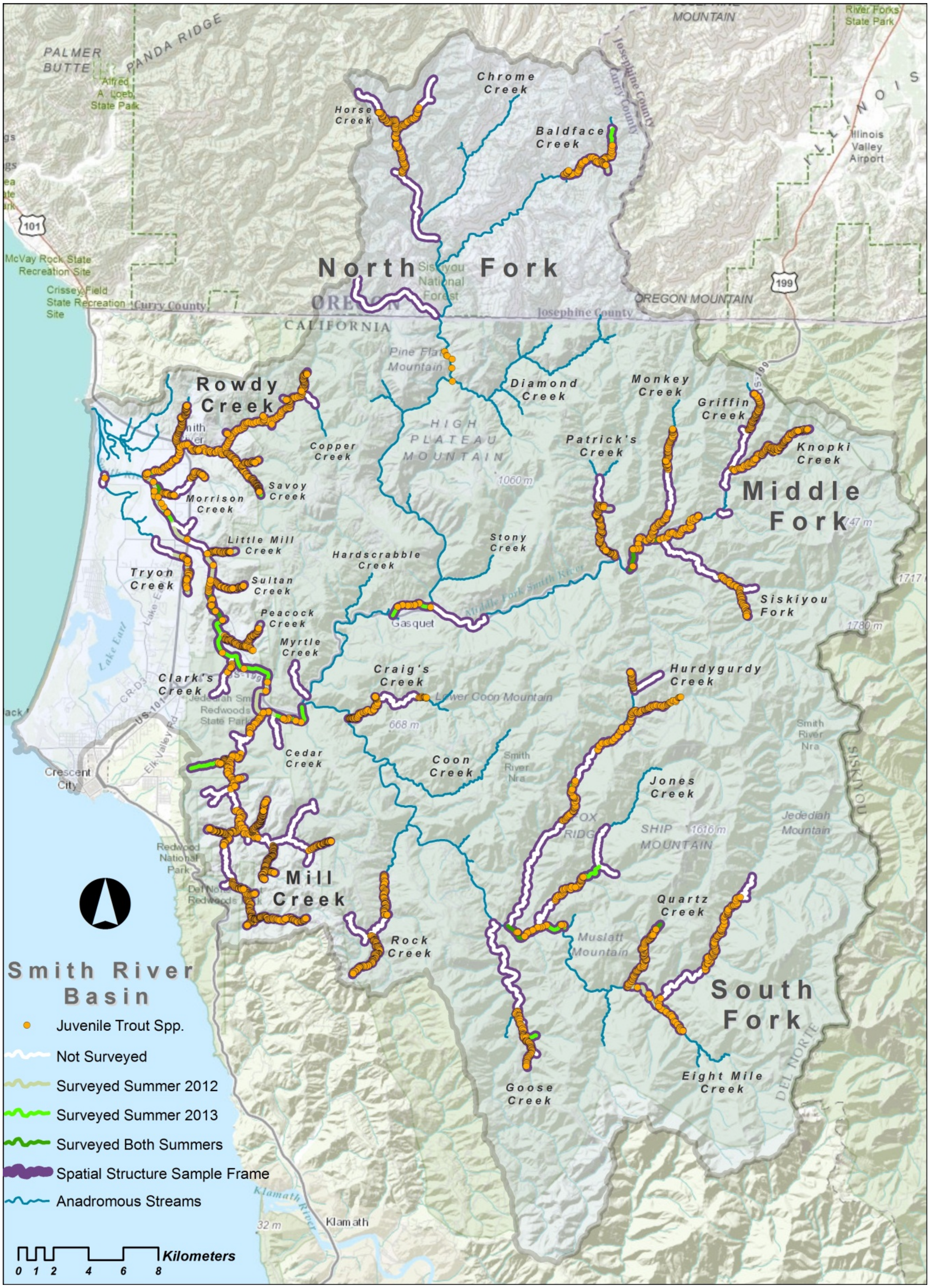


Figure 14. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing juvenile trout (spp.) from 2012 and 2013, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

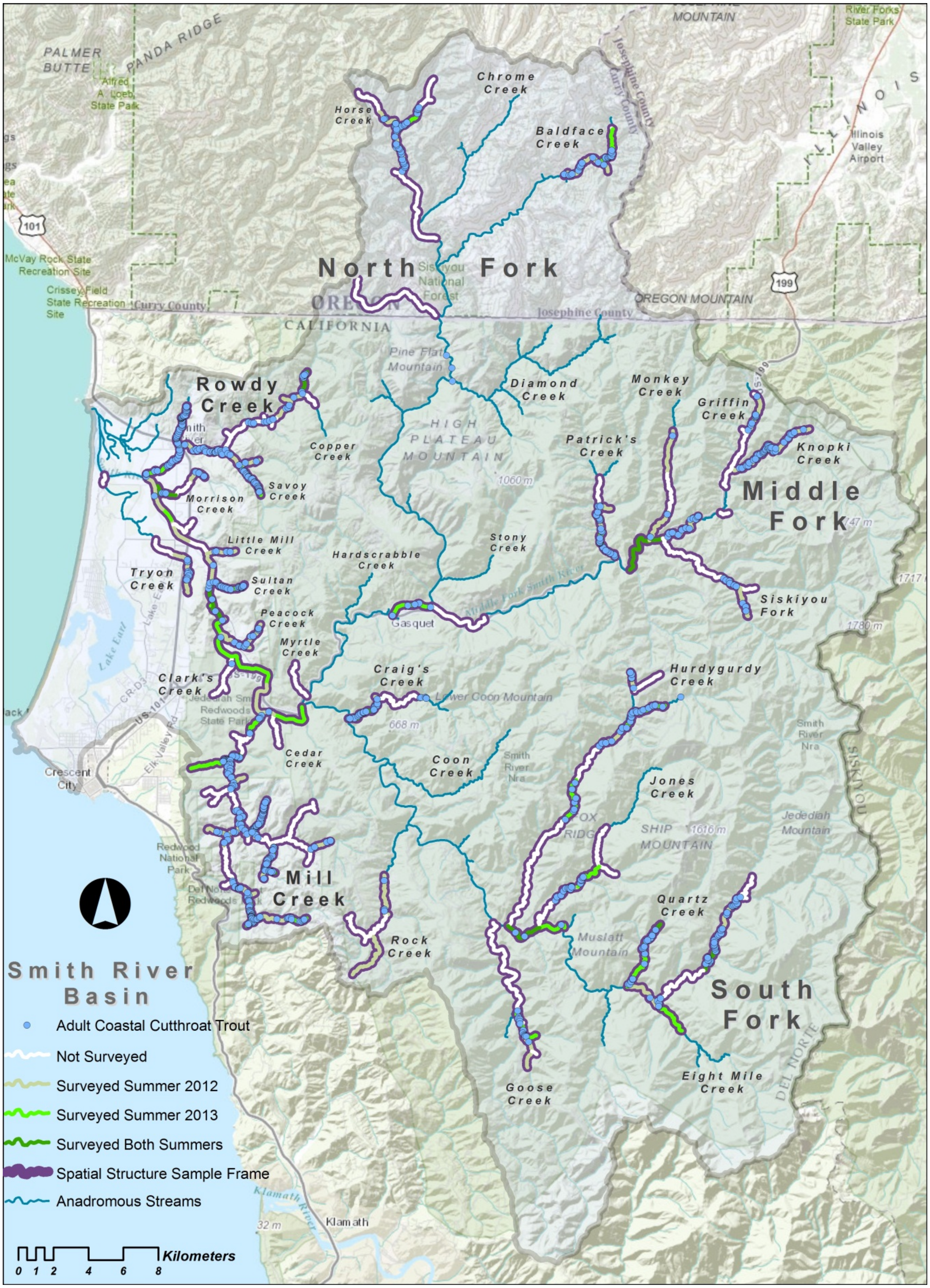


Figure 15. Map showing annual spatial structure survey reaches and the spatial distribution of pools containing adult cutthroat trout from 2012 and 2013, Smith River Basin, California and Oregon. Note: some minimal incidental observations are included on the map in areas outside of the GRTS sampled portion.

Occupancy of Other Salmonid 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 20, Appendix B, and Appendix C. All groups were widely distributed throughout the basin during both summers (Figures 13 [Chinook salmon], 14 [trout spp.], and 15 [adult coastal cutthroat trout]) with ψ ranging from 0.71 (Chinook salmon) to 1.00 (1+ trout spp.) (Table 19). Similar to coho salmon, overall reach-level occupancy estimates remained stable for all groups between the two years with the widest difference of only 6% for Chinook salmon (Table 19). The estimate of conditional pool-level occupancy (θ), given present in a reach(θ|ψ), varied for most groups between years except 1+ trout spp. (Table 19). Last, we observed adult sockeye salmon (*Oncorhynchus nerka*) on three occasions during snorkel surveys. In 2012 we observed on sockeye salmon near a fresh looking redd in the upper Middle Fork Smith River in reach #281 at the pool below the mouth of Monkey Creek. In the summer 2013 we observed a group of five adult salmon (two confirmed sockeye salmon) in the Middle Fork Smith River (Reach #280) in the pool directly above the mouth of Patrick's Creek. Last we observed one adult sockeye salmon during the summer of 2013 in the Siskiyou Wilderness portion of the South Fork Smith River in reach #163 below the mouth of Eightmile Creek.

Discussion

Spawning Ground Surveys

Coho Salmon Spawning Distribution and Abundance

We conducted two years of spawning ground surveys throughout the Smith River adult coho salmon sampling frame and determined adult coho salmon had a narrow spawning distribution relative to the sampling frame. No coho salmon redds were encountered outside of the Mill Creek lifecycle monitoring station despite having observed one adult coho salmon in Savoy Creek (tributary to Rowdy Creek) and one adult coho salmon carcass in Morrison Creek. Our results highlight the significant role the Mill Creek sub-basin has with respect to coho salmon persistence in the Smith River. The estimated redd abundance in 2012-2013 was 47% of 2011-2012 and this pattern was also apparent with the live fish and carcass counts. This lower abundance did not appear to affect reach occupancy rates of adult spawners since coho salmon redds were observed in 13 spawning reaches throughout upper Mill Creek each year.

Our overall detection probability of observing fish on redds averaged roughly 30 percent, with lower success during peak coho salmon and steelhead spawning. Having few returning adults in streams outside of Mill Creek, coupled with marginal numbers of fish on redds, prevented us from confirming successful reproduction outside of the core spawning area. 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 (Figure 12). 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. Coho salmon were observed spawning in all reaches and sub-reaches within the Mill Creek LCS except Hamilton Creek (reach 138), highlighting the extensive habitat availability throughout the upper watershed. Hamilton Creek, a tributary to the lower West Branch has 1,100 meters of high quality coho salmon spawning and rearing habitat. However, a perched culvert 150 meters upstream of the mouth is the last remaining significant barrier in the Mill Creek watershed. Providing anadromous fish access to this stream would instantly increase available spawning and rearing habitats to coho salmon currently using all available proximal habitats.

Redd Abundance Estimation

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 stations or published studies are subject to vary widely. However, a current genetic mark-recapture study being performed at Humboldt State University is using our Mill Creek coho salmon carcass and smolt offspring DNA to possibly determine adult abundance. Although we currently do not know the fate of this study, genetic mark-recapture could theoretically be used as an alternative to a weir-based adult coho salmon mark-recapture experiment since it shows utility in a recent Chinook salmon escapement study (Rawding et al. 2014).

We recommend using the coho salmon redd population estimate for the Mill Creek LCS over the GRTS survey for two reasons. First, we did not confirm any coho salmon redds 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 is eliminated from the estimate. However, we suggest our coho salmon redd abundance estimates for both the GRTS sample reaches and the Mill Creek LCS are biased high for both years based on unrealistic assumptions our data and analysis cannot satisfy. The most disconcerting 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. These assumptions are highly unlikely to ever occur given the nature of winter storm discharge in the Smith River. 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. In contrast, we observed extended periods lacking precipitation during both years where overall redd survival approached 100% across multiple survey visits. It is for these reasons and others that Jones (2012) suggested use of a time to event model as described in Gomez et al. (2009). This would allow redd survival to vary by storm intervals and include discharge as a dynamic and sometimes stochastic feature highly influencing redd survival. However, the challenge of fitting all of our survey effort into a matrix remains difficult when winter storms delay reach survey availability at different rates.

Another considerable source of error is the prediction of redds to species. We were able to document salmonids spawning on roughly 30% of redds we observed. The proportion of known species redds was not uniform over the duration of the spawning season. In November we observed primarily Chinook salmon spawning on 40-50% of redds. By February we observed primarily steelhead spawning on less than 10% of redds. We suggest spawning behaviors vary largely by species and detection varies based on the amount of time each species spends building and guarding redds. This factor has not been addressed in previous redd species prediction efforts (i.e. Gallagher and Gallagher 2005, Ricker et al. *in CMP Technical Team review*) and could have major influence on the error associated with redd species predictions. The only control over this factor we have is decreasing the time interval between survey occasions in attempt to observe more fish spawning. However, in 2012-2013 we were able to return to streams a full day sooner on average than we did in 2011-2012 but this shorter interval did not increase our proportion of known species redds. Alternatively, we chose to incorporate live fish observations into the kNN model in order to maximize the use of spatial and temporal data from known species. We found live fish locations had no effect on the accuracy of the known species redd prediction process. However, live fish additions did significantly change the predictions of unknown species redds. We believe redd species predictions that incorporate live fish reduces biases associated with individual species spawning behaviors (i.e. redd species verification). By incorporating live fish into the kNN algorithm, we predicted more steelhead and fewer coho salmon redds in both spawning seasons. This is largely based on data collected near the end of the season (late-January through early March) when steelhead are the most abundant species of salmonid present in the spawning reaches representing 75% and 93% of live fish observations (Figure 4). If we only relied on redds, then more coho salmon redds would be predicted based on seeing more individuals on redds than steelhead.

While the error in prediction of redds to species is unknown, a relative measure of the error can be seen in Table 7 as the difference between sensitivity and specificity for each species. Sensitivity is high for Chinook salmon while specificity is high for coho salmon and steelhead. An ideal predictor would have high sensitivity and specificity (~0.95) and these values would be similar. Overall the kNN model was 95% accurate in 2011-2012 and 96% accurate in 2012-2013, however, known species redds consisted of 84.4 and 87.8% Chinook salmon redds in 2011-2012 and 2012-2013 respectively. The overwhelming number of Chinook salmon redds mask the difficulty the kNN model had in correctly predicting coho salmon and steelhead redds. The model was 84.4% and 68% accurate at predicting coho salmon redds in 2011-2012 and 2012-2013 respectively. For steelhead redds the kNN model was consistent though not terribly accurate correctly identifying 77.8% and 76.2% in 2011-2012 and 2012-2013 respectively. While these results are not ideal they are superior to the logistic regression approach of Gallagher and Gallagher (2005) which correctly predicted 62% of coho salmon redds and 48% of steelhead redds.

Chinook Salmon Spawning Distribution and Redd Abundance

Chinook salmon were the most widely distributed anadromous salmonid in the GRTS sample reaches in both spawning seasons. Chinook salmon were observed in 84% of main reaches in 2011-2012 and 94% of main reaches in 2012-2013. Additionally, Chinook salmon were observed in 11% of sub-reaches in 2011-2012 and 16% of sub-reaches in 2012-2013. Similar to coho salmon, the estimated redd abundance in 2012-2013 was 47% of 2011-2012. However, we documented a greater reach occupancy rate by Chinook salmon in 2012-2013 despite a much lower abundance. The likely factor behind the broader distribution of Chinook salmon in 2012-2013 was from much higher stream discharge occurring at the beginning of the Chinook salmon spawning season in 2012 compared to dry conditions prevailing at this time in 2011. Two reaches that were surveyed in both seasons illustrate this pattern: upper Middle Fork (reach 286) and Siskiyou Fork (reach 324). Both reaches are in the upper Middle Fork and occur above a natural gorge (between Patrick's Creek and Monkey Creek) that likely limits anadromous fish access at low stream flows. In 2011-2012 we observed seven live Chinook salmon and two known Chinook salmon redds in these reaches. However, in 2012-2013 we observed 64 live Chinook salmon and 15 known Chinook salmon redds in the same reaches. This phenomenon in the upper Middle Fork has also been observed during spawning surveys performed by the US Forest Service (M. McCain Pers. Comm.). Last, our spatial structure sampling also reflected the broader spawning distribution in 2013 vs. 2012. Chinook salmon juveniles were observed in Baldface Creek, South Siskiyou Fork, upper Hurdygurdy Creek, and Quartz creek in the summer of 2013, but were not observed in adjacent reaches in 2012 (Figure 13).

Steelhead Spawning Distribution and Redd Abundance

Similar to Chinook salmon, steelhead had a broad distribution though were encountered in fewer GRTS samples reaches in both spawning seasons. Steelhead were observed in 76% of main reaches and 11% of sub-reaches in 2011-2012 and 69% of main reaches and 3% of sub-reaches in 2012-2013. Low stream flows may have delayed steelhead spawning and limited access to streams in the late-winter of 2012-2013. The estimated redd abundance in 2012-2013 was 66% of the 2011-2012 abundance. Similar to our observed difference in redd abundance, in 2012-2013 the Smith River sonar counting station recorded 71% of the upstream migration observations recorded 2011-2012 during the steelhead migration period (Larson 2013c). 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, sonar counts from the lower river indicate our survey period likely includes most of the steelhead migration period.

Hatchery Origin Salmonid Observations

Chinook salmon and steelhead have been propagated at the Rowdy Creek Fish Hatchery since 1973 to enhance the sport fisheries of these species. As such, hatchery salmonids are expected to stray from Rowdy Creek and be available to be caught throughout the river system. Prior to this study, reliable estimates of hatchery origin fish spawning with wild salmonids has never been thoroughly investigated in the Smith River basin. From our live fish encounters and carcass recoveries hatchery origin fish constituted greater than five percent of both Chinook salmon and steelhead spawning runs in both years. Additionally, hatchery origin fish of both species were found spawning in every major sub-basin. Good et al. (2005) suggested spawning by hatchery reared fish in wild populations must be less than five percent to avoid significant negative effects on the wild population. This determination is also stated in California's coastal salmonid monitoring plan cooperatively written be CDFW and NOAA (Adams et al. 2011). Prior to recent efforts using sonar (Larson 2013b, 2013c), the Smith River has had no reliable estimates of returning adult Chinook salmon and steelhead. This lack of information has made it difficult for managers determine the number of fish the hatchery should produce in order to minimize effects on wild produced salmonids, especially on ESA listed coho salmon. Up until 2011, Rowdy Creek primarily released smolts near the South and Middle forks in Hiouchi. Since 2011, all hatchery raised smolts are released into the main stem below highway 101 mainly to reduce predation (Naman and Sharp 2012) and competition (Weber and Fausch 2005) with the wild salmonids. Most fish we inspected were from cohorts released at the forks (prior to 2011) so any observed changes in stray rates would not be measured until 2014 and 2015. Additionally, we observed one hatchery produced coho salmon in Mill Creek from Iron Gate Fish Hatchery on the Klamath River indicating stray rates for coho salmon need to be assessed regionally.

Spatial Structure Surveys

Protocol Performance

We found our survey protocol was highly efficient at detecting salmonids throughout a given reach; perhaps too efficient. Detection probabilities were exceptionally high for coho salmon (94- 95% overall) suggesting our protocol could be modified to include a combination double and single dive passes rather than surveying every selected unit twice. This change could reduce the survey cost though scenarios would need to be optimized through statistical simulations addressing the number of passes as they relate to target species observed densities. Based on our occupancy models, reach-level occupancy (ψ) estimates were much more stable between the two years than conditional pool-level occupancy (θ) estimates. This resulted in pool-level occupancy estimates having the most influence on the overall calculated proportion of area occupied. We expected annual pool occupancy patterns within reaches to be much more variable than between reaches due to scale. Salmonids typically use the same general areas for spawning (Pess et al. 2002). However, local distributions are likely influenced by a combination of population density, annual stream flow regimes, temporal barriers, predators, and competition from congeners. These factors ultimately influence the initial distribution of each annual cohort of juvenile fish. We recommend continuing sampling a high fraction of units throughout each reach to maintain high precision in estimating fine-scale changes in annual spatial structure. Since we were able to obtain counts of individual species, we suggest incorporating relative abundance into future analysis to determine if counts offer a better assessment of spatial structure than occupancy alone. For example, counts could offer a better assessment of reach-level habitat quality. Last, having the Royle et al. (2008) occupancy models incorporate multiple years in the future would allow us to estimate colonization and extinction rates for predicting long-term trends in spatial structure patterns.

Coho Salmon 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. 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.

Our estimate of the adult coho salmon return in 2012-2013 was roughly half (47%) of the 2011-2012 despite adults using the same core area between both years in upper Mill Creek for spawning. Likewise, we found the overall median pool count densities of juvenile coho salmon progeny to be 29% greater in 2012 than observed in 2013 indicating higher production when adults were more abundant. Flitcroft et al. (2013) found juvenile coho salmon distributions expanded beyond core areas when adults were abundant and contracted at lower adult abundances. Therefore, we may expect juvenile coho salmon would occupy a greater portion of habitat when abundance is higher. We found this not to be the case because the proportion of reaches occupied by juvenile coho salmon between the years was similar (0.42 in 2012 vs. 0.39 in 2013). Furthermore, the percentage of sampled pools occupied by juvenile coho salmon, independent of reach, was nearly identical between the years (25% in 2012 vs. 26% in 2013). These observations suggest the fraction of occupied space was similar each year despite differences in abundance. However, when we incorporated the spatial distribution of these annual observations, we found the majority of reaches (65%) with coho salmon present were non-natal in 2012 where only 39% were non-natal in 2013. Additionally, the percentage of juvenile coho salmon found using non-natal rearing reaches in 2012 was over twice that observed in 2013 (19% in 2012 vs. 8% 2013). 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). We suspect more juvenile coho salmon were found in non-natal areas in 2012 due to having a larger adult population for that brood year; though longer-term information will be needed to determine if this prediction holds.

Based to the distribution of spawning adult coho salmon, we expected reaches in Mill Creek to have the highest densities of juvenile coho salmon in the watershed. We found juvenile coho salmon rearing in the main stem Smith River and in lower the sections of coastal plain tributaries from Hiouchi down to the mouth of Yontockot Slough. We did not expect to find juvenile coho salmon rearing throughout this region based on previous recorded water temperatures averaging >21 degrees Celsius (Garwood et al. 2014). However, incidental point temperatures recorded at sites with juvenile coho salmon ranged from 14 to 20 degrees suggesting areas in the lower river maintain thermal refugia. The majority of documented rearing habitats in this region were either created or majorly modified by beavers (*Castor candadensis*). Beavers are described as ecological engineers because their activities can have a major influence on the landscape, available resources for other species, and biodiversity (Jones et al. 1994, Wright and Jones 2002, Pollock et al. 2003). Beaver lodges comprised of wood and subterranean burrows were found to be common along the banks of the river throughout the coastal plain, and to a lesser extent in Mill and Rowdy Creeks (J. Garwood, unpublished data). Higher densities of salmonids, especially coho salmon, were consistently found at bank constructed beaver lodges relative to sampled habitats with similar water temperatures without beavers suggesting habitat selection. No studies we are aware of actually describe this salmonid niche in any detail or quantify this relationship since literature on the topic is largely focused on how beaver ponds and dams influence aquatic species. We are initiating a study during the summer of 2014 focused on quantifying habitat conditions at non-natal rearing habitats located in the main stem Smith River and estuary.

Perhaps the most surprising coho salmon distributions were found in the headwaters of Baldface Creek, tributary to the North Fork Smith River (85 km from the mouth), and the upper South Fork Smith River near Prescott Fork (78.2 km from the mouth) (Figure 16). Both of these locations are extremely remote and occur above sustained high-gradient stream reaches characterized by cascades, long rapids, and extensive boulder fields. We found coho salmon occurring in both areas for two consecutive years and suggest they represent portions of smaller inland sub-populations. The headwaters of Baldface Creek near Frantz

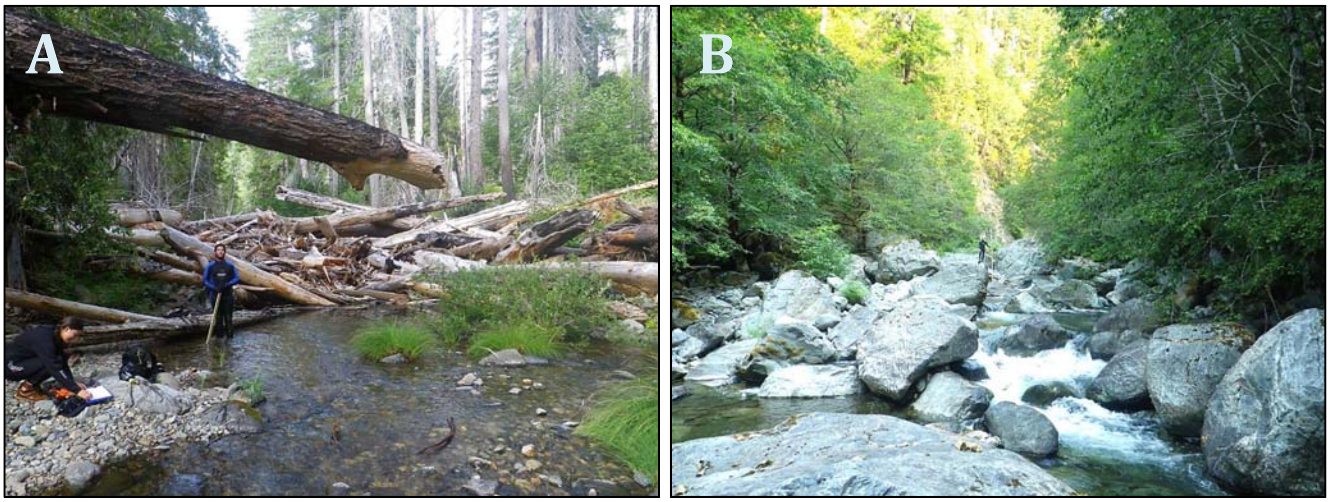


Figure 16. Stream sections in (A) Baldface Creek (North Fork Smith River), and (B) upper South Fork Smith River, where juvenile coho salmon were detected during both years of the study. Note large accumulations of LWD and small granite alluvium in Baldface Creek example (A). Note large high-gradient boulder field that extended for 1.4 km in the South Fork Smith River (surveyor in black wetsuit with stadia rod standing in back for scale). The calm pooled area in the left foreground of image B contained juvenile coho salmon and sporadic observations extended another 2.7 km up the drainage to the mouth of Prescott Fork where our survey reach ended.

meadow flows through a relatively small emerged granite pluton resulting in a strikingly different landform than the surrounding ultramafic geology. This portion of stream is low gradient, contains high-quality spawning gravel, and has an abundance of large wood debris recruited from the surrounding Douglas Fir dominated virgin forest. In contrast, we found coho salmon occurring in cascading pools in the upper South Fork Smith River that eventually lead up to lower gradient sections 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 further up the drainage. Because this study only represents two summers of information, our inference on coho salmon spatial and temporal dynamics is limited. This work is going to be conducted for at least three more summers and we will surely discover more vital information regarding coho salmon spatial structure and habitat preferences.

In contrast to our observed patchy distributions of coho salmon, other salmonids including juvenile Chinook salmon, juvenile trout (spp.), and adult coastal cutthroat trout were widely distributed in reaches we surveyed throughout the watershed. Because all of these salmonids were widespread, this indicates the community composition and species richness remains diverse throughout the watershed. 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.

Restoration Recommendations

Based on the data and analysis from this report, we have some restoration suggestions we feel will immediately increase the availability of coho salmon habitats and would directly support increased coho salmon abundance in the Smith River. There are many more current identified restoration opportunities at various stages of development, and more will be discovered as we refine the spatial and temporal distribution of coho salmon in the Smith River.

Rowdy Creek weir

The Rowdy Creek Fish Hatchery weir is a complete barrier to juvenile salmonids and partial barrier to adult salmonids. A total of 18.4 kilometers of spawning and rearing habitat exists above the 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 for all salmonid and lamprey species.

Hamilton Creek culvert at picnic road

The culvert barrier at picnic road 'Hamilton Creek' is the last significant manmade barrier to coho salmon in the Mill Creek watershed and prevents access to over one kilometer of excellent coho salmon spawning and rearing habitats. All of the nearby tributaries of similar size were used substantially by coho salmon during this investigation and we are certain coho salmon will immediately colonize this stream once the barrier is removed. Because upper Mill Creek represents the core sub-population for coho salmon in the Smith River, the impact of this barrier removal would be substantial towards increasing coho salmon production.

Maintain a healthy beaver population to benefit salmonid rearing habitats

We found a high overlap of juvenile coho salmon and beaver dens. In general, all species of salmonids were found concentrated around beaver dens. The den features we observed were complex 3-dimentional shaded underwater structures. Juvenile salmonids schooled in large numbers around these structures and they likely represent the most complex slow-water fish habitat occurring in the lower main stem Smith River. Managing for these specific habitat features, and for the recruitment of important beaver browse species (e.g. willow, alder, and cottonwood) along the riparian corridor, will likely benefit the current beaver population.

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Appendix A. Sample Frame Development Resources and Metadata

GIS data

Base Layers

- National Hydrography Dataset(NHD) High resolution NHD flowline adapted to CAstreams. DFG Northern Region Data Management and GIS Group, Contact: Tom Christy, tom.christy@wildlife.ca.gov.
- California Fish Passage Assessment Database (PAD), (Calfish). Available at: http://www.calfish.org
- Coastal Landscape Analysis and Modeling Dataset (CLAMS IP model) (Burnett et al. 2003) adapted for California by Agrawal et al. (2005).
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- 2010, one meter resolution aerial imagery, National Agriculture Imagery Program (NAIP), United States Department of Agriculture. Available at: http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=landing
- 2011 Del Norte County GIS Parcel Data, Land Vision Software. Available at: http://www.digmap.com/products/ParcelDataSolutions.html

Salmonid Distribution Layers, Available at: http://www.calfish.org

- Coastal California Chinook Salmon Distribution (Calfish)
- Coho salmon Distribution (Calfish)
- Winter Steelhead Distribution (Calfish)

Stream habitat survey reports

US Forest Service Level II Habitat and Snorkel Surveys

Completed for the US Forest Service Six Rivers, Rogue River, and Siskiyou National Forests by the Siskiyou Research Group from 2002 to 2008.

Available Reports: Coon Creek, Craig's Creek, Gordon Creek, Hurdygurdy Creek, North Fork Smith River, Stony Creek, Peridotite Creek, Diamond Creek, Baldface Creek, Biscuit Creek, Spokane Creek

Historical data

Garwood, J. 2012a. Historic and recent occurrence of Coho salmon (*Oncorhynchus kisutch*) in California streams within the Southern Oregon/ Northern California Evolutionary Significant Unit. California Department of Fish and Wildlife, Arcata CA. 77p.

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Personal communications on salmonid distributions

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Rod McLeod —Mill Creek Fisheries Monitoring Program
Ian Reid—US Forest Service-Rogue River/ Siskiyou National Forest
Pat Righter —Green Diamond Resource Company
James Simino—US Forest Service
Jim Waldvogal —Smith River Action Council
Tom Weseloh —Cal Trout

Appendix B. Number of pools occupied and density of Chinook Salmon, Unidentified juvenile trout (not identified to species), and adult Cutthroat Trout for all GRTS drawn reaches surveyed during spatial structure sampling in the Smith River, June - September 2012.

		Reach	Number of	Chinook Salmon		0+ Unidentified Trout		1+ Unidentified Trout		Coastal Cutthroat Trout	
Subbasin	Location Code	length (m)	units Surveyed	Pools occupied	Mean density	Pools occupied	Mean density	Pools occupied	Mean density	Pools occupied	Mean density
Lower Smith River	6	797	5	4	46.0	-	-	3	1.3	-	-
Lower Smith River	10	2520	12	10	66.6	4	1.8	6	3.7	5	2.0
Lower Smith River	11	2765	3	1	13.0	2	5.0	2	3.5	2	2.0
Lower Smith River	12	3335	4	2	1.5	2	7.0	2	2.0	-	-
Lower Smith River	14	2617	8	7	44.7	7	9.4	7	3.7	1	1.0
Middle Fork Smith River	19	2632	10	4	12.3	10	13.4	8	6.1	5	1.8
North Fork Smith River	35	2697	26	14	2.4	26	26.8	23	3.0	10	1.5
Rowdy Creek	57	3216	23	17	36.4	23	37.6	21	6.2	15	3.7
Rowdy Creek	63	1446	46	19	6.5	44	22.1	34	2.1	6	1.2
Dominie Creek	65	2727	55	13	5.0	55	35.8	41	2.5	17	1.7
Savoy Creek	68	2080	59	10	2.1	58	11.4	43	1.5	19	1.3
Morrison Creek	77	1485	16	14	6.7	5	1.2	2	1.5	3	1.0
Sultan Creek	87	2270	67	38	14.1	58	6.3	46	1.9	18	1.3
Unnamed Trib.	88	142	2	-	-	2	2.0	-	-	-	-
Mill Creek	100	1805	12	10	11.9	12	38.1	11	5.2	5	1.6
Mill Creek	102	2329	23	19	18.3	23	76.4	20	8.5	14	1.4
Mill Creek	105	1412	12	11	45.5	12	130.2	12	8.9	6	3.3
West Branch Mill Creek	109	1802	41	6	1.8	39	17.6	39	3.7	18	1.2
West Branch Mill Creek	111	1356	38	-	-	13	3.8	29	1.7	10	1.3
Mill Creek Trib.	116	2987	37	2	4.5	30	3.9	29	1.6	15	1.0
First Gulch	130	2506	84	11	1.1	79	5.4	77	2.5	29	1.2
Kelly Creek	132	2481	63	-	-	58	9.1	46	1.9	20	1.2
WB Mill Creek Trib.	143	834	20	-	-	20	4.2	11	1.6	8	1.1
South Fork Smith River	159	2461	8	5	28.0	8	34.9	5	2.8	1	1.0
South Fork Smith River	160	1766	9	7	3.1	9	31.0	5	3.0	1	1.0
South Fork Smith River	166	3582	21	8	5.3	21	42.1	21	12.7	5	1.2
Craig's Creek	171	2473	57	19	2.1	57	37.8	42	2.7	12	1.2
Goose Creek	212	1746	25	1	1.0	25	39.0	21	3.4	8	1.3
Goose Creek Trib.	215	840	6	-	-	6	9.7	5	1.6	4	1.3
Hurdygurdy Creek	220	3155	34	-	-	34	28.9	32	6.9	7	1.0
Hurdygurdy Creek	223	2984	50	-	-	50	17.5	39	2.5	12	1.3
Jones Creek	236	2232	16	10	10.4	16	45.9	16	5.7	7	1.6
Quartz Creek	250	2999	58	-	-	58	32.7	47	3.2	7	1.1
Quartz Creek	251	1944	21	-	-	22	11.5	18	2.6	8	1.1
Eightmile Creek	253	2178	16	-	-	16	28.8	14	3.7	-	-
Middle Fork	281	3888	15	1	1.0	15	20.0	9	2.4	-	-
Middle Fork	286	1822	30	16	11.8	30	43.1	28	3.4	18	2.6
Patrick's Creek	303	2249	47	9	11.4	47	38.3	44	4.6	15	1.5
Siskiyou Fork	326	1187	12	-	-	12	52.5	11	2.3	6	1.3
Baldface Creek	392	2473	21	-	-	21	39.7	17	6.4	10	1.2
Baldface Creek Trib.	403	78	3	-	-	3	6.7	1	1.0	-	-

Appendix C. Number of pools occupied and density of Chinook Salmon, Unidentified juvenile trout (not identified to species), and adult Cutthroat Trout for all GRTS drawn reaches surveyed during spatial structure sampling in the Smith River, June – August 2013.

Subbasin	Location Code	Reach length (m)	Number of units Surveyed	Chinook Salmon		0+ Unidentified Trout		1+ Unidentified Trout		Coastal Cutthroat Trout	
				Pools occupied	Mean density	Pools occupied	Mean density	Pools occupied	Mean density	Pools occupied	Mean density
Lower Smith River	5	2044	5	4	105.0	5	5.8	3	8.0	1	1.0
Lower Smith River	7	1639	4	4	20.3	-	-	1	2.0	-	-
Lower Smith River	9	1654	4	4	91.0	3	2.7	3	2.3	1	1.0
Lower Smith River	10	2520	12	9	51.3	8	3.6	6	2.3	1	1.0
Lower Smith River	13	2968	3	3	7.0	1	22.0	2	8.0	-	-
North Fork Smith River	34	2845	31	21	16.0	30	29.2	29	6.0	14	1.4
Tryon Creek	52	3505	26	-	-	24	3.0	20	3.0	9	1.3
Rowdy Creek	58	1858	19	18	64.4	19	275.2	17	16.7	8	2.0
Rowdy Creek	62	2276	21	15	9.4	21	136.4	19	5.6	4	1.8
Rowdy Creek	63	1446	36	15	6.5	35	24.1	30	2.8	2	1.0
South Fork Rowdy Creek	67	2492	56	39	10.4	55	46.1	45	3.5	5	1.0
Rowdy Creek Trib.	72	579	9	-	-	9	11.3	4	1.3	-	-
Morrison Creek	77	1485	19	17	3.5	13	2.6	4	1.8	-	-
Morrison Creek	79	1407	18	9	2.7	18	4.3	14	1.2	3	1.0
Little Mill Creek	86	1734	29	20	8.8	29	21.9	29	4.2	4	1.0
Unnamed Tributary	89	184	3	-	-	3	2.0	1	2.0	-	-
Peacock Creek	91	3296	72	4	2.8	72	15.0	54	2.8	10	1.1
Peacock Creek	94	402	8	-	-	8	3.5	5	1.0	-	-
Mill Creek	102	2329	18	15	40.0	18	103.1	15	8.1	10	1.5
Mill Creek	103	1314	10	9	42.1	10	160.0	9	12.2	7	1.6
Mill Creek	106	2111	27	19	5.7	27	72.9	23	7.2	5	1.2
West Branch Mill Creek	108	2030	40	19	2.3	40	65.7	31	4.6	8	1.0
West Branch Mill Creek	110	2582	44	10	3.5	44	36.0	37	4.4	5	1.0
Mill Creek Trib.	118	676	3	-	-	3	1.7	3	3.7	-	-
East Fork Mill Creek	123	2149	18	16	4.9	18	156.1	15	9.2	8	1.6
East Fork Mill Creek	126	1450	38	3	2.7	38	26.7	37	2.8	4	1.0
First Gulch	130	2506	70	18	2.7	69	11.9	55	2.7	6	1.0
Kelly Creek	132	2481	60	22	2.0	60	8.8	56	2.5	5	1.0
Kelly Creek Trib.	133	593	17	-	-	15	2.9	8	1.1	1	2.0
Hamilton Creek	138	1427	33	-	-	30	5.9	26	2.2	2	1.0
WB Mill Creek Trib.	141	442	7	-	-	7	7.3	4	1.3	-	-

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Appendix C continued. Number of pools occupied and density of Chinook Salmon, Unidentified juvenile trout (not identified to species), and adult Cutthroat Trout for all GRTS drawn reaches surveyed during spatial structure sampling in the Smith River, June – August 2013.

Subbasin	Location Code	Reach length (m)	Number of units Surveyed	Chinook Salmon		0+ Unidentified Trout		1+ Unidentified Trout		Coastal Cutthroat Trout	
				Pools occupied	Mean density	Pools occupied	Mean density	Pools occupied	Mean density	Pools occupied	Mean density
South Fork Smith River	159	2461	6	2	3.5	6	35.3	4	1.8	1	1.0
South Fork Smith River	163	2602	4	4	41.3	4	16.0	4	4.8	2	1.0
South Fork Smith River	166	3582	39	21	7.9	39	56.8	38	14.6	15	1.3
South Fork Smith River	167	2445	25	-	-	25	101.1	23	15.9	11	2.2
Craig's Creek	171	2473	32	18	5.3	32	63.3	28	4.3	10	1.4
Craig's Creek Trib.	175	230	5	-	-	5	19.2	3	1.3	-	-
Rock Creek	188	2714	39	18	6.7	39	60.8	28	3.9	3	1.0
Rock Creek	190	1447	28	10	3.3	28	23.6	10	1.8	-	-
Rock Creek	192	151	3	-	-	3	18.0	2	1.0	-	-
Rock Creek	196	2455	41	-	-	41	11.6	21	2.2	-	-
Goose Creek	213	2292	36	-	-	36	21.8	33	4.4	1	1.0
Hurdygurdy Creek	222	2651	14	9	10.0	14	71.9	13	9.1	7	2.0
Hurdygurdy Creek	232	1046	23	-	-	19	2.8	16	1.7	5	1.0
Jones Creek	235	2210	16	16	21.3	16	55.1	16	11.4	9	1.7
Quartz Creek	251	1944	16	1	2.0	16	12.1	16	4.9	2	1.0
Middle Fork Smith River	281	3888	10	5	2.6	10	28.9	3	1.7	-	-
Middle Fork Smith River	282	3236	22	21	16.6	22	97.8	17	7.7	12	1.4
Middle Fork Smith River	285	1944	19	18	23.1	19	69.6	18	5.4	7	1.0
Patrick's Creek	304	1519	28	18	3.8	28	34.4	26	3.7	7	1.1
Shelly Creek	308	875	11	4	10.5	11	18.9	10	1.8	2	1.0
Monkey Creek	317	2229	25	14	2.7	25	22.5	9	1.6	2	1.0
Monkey Creek	319	2677	44	5	2.8	44	15.3	36	2.1	1	1.0
South Siskiyou Fork	331	1888	28	7	1.3	28	41.3	27	4.8	3	1.0
Griffin Creek	337	2336	49	1	2.0	46	11.5	41	3.5	8	1.0
Knopki Creek	344	3225	62	20	6.9	62	39.4	58	3.9	10	1.0
Baldface Creek	391	2823	19	15	9.1	19	50.7	17	6.1	10	1.2
Baldface Creek Trib.	400	144	6	-	-	6	8.3	3	1.0	-	-
Baldface Creek Trib.	402	771	10	2	1.0	10	6.5	9	2.2	1	1.0
Horse Creek	420	1956	33	15	5.9	33	17.0	26	2.8	3	1.0