DISTRIBUTION AND RELATIVE ABUNDANCE OF JUVENILE COHO SALMON IN THE REDWOOD CREEK BASIN, HUMBOLDT COUNTY, CALIFORNIA

FINAL REPORT
TO THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
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1. INTRODUCTION

1.1 Background

Coho Salmon (*Oncorhynchus kisutch*) in the Redwood Creek basin are listed threatened under the Federal Endangered Species Act (ESA), and the California Endangered Species Act (CESA). Both the ESA and CESA require that recovery plans be developed for all listed species. To comply with the ESA, recovery plans must contain objective, measurable delisting criteria, and a description of site-specific actions necessary to return the species to a self-sustaining, viable condition that would justify delisting. The National Marine Fisheries Service (NMFS) defines a viable salmonid population (VSP) as "An independent population that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, or changes in genetic diversity over a 100-year time frame (McElhany 2000)." To predict the long-term persistence of salmonid populations, stock assessment scientists require scientifically defensible data pertaining to four key population parameters (VSP parameters): abundance, productivity (growth rate), diversity (genetic and phenotypic), and spatial structure (geographic distribution). These parameters must be monitored to evaluate progress towards specific recovery goals. In the Redwood Creek basin, monitoring requirements for three of the four VSP parameters (abundance, productivity and diversity) are largely addressed by existing projects. The objective of this project is evaluate the fourth parameter (spatial distribution) through occupancy modeling based on snorkel surveys conducted underwater census of a spatially balanced random selection of reaches during the summers of 2013 and 2014.

1.2 Study area

Redwood Creek drains a 730-km^2 watershed which empties into the Pacific Ocean in northwestern California (Figure 1). The basin is steep-sided and narrow, with few major tributaries. Elevations range from 1,616m at the headwaters, to sea level at the mouth. Basin geology is dominated by the Franciscan assemblage, which is highly susceptible to chemical decomposition and erosion (Janda and Nolan, 1979). Annual precipitation averages 200 cm, which falls largely as rainfall between November and April. Streamflow is not regulated, and exhibits an annual hydrograph characterized by low summer flows, and winter flows driven by storm events. During the period of study (July-Sept 2013 and June-Sept 2014), summer flows averaged 53 and 26 cfs, respectively. Average monthly discharge in water year 2014 was third lowest of record (USGS 2014).

The primary vegetation types within the Redwood Creek watershed include coniferous forest (82%), oak woodland (9%), and prairie (9%). Vegetative distribution depends on available soil moisture during the summer months and is influenced by proximity to the coast, soil types, land disturbance, and the occurrence of fire. The coast redwood (*Sequoia sempervirens*) is the dominant tree, and is generally found in mixed stands with other tree species including Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), big leaf maple (*Acer macrophyllum*), tanoak (*Lithocarpus densiflorus*) and red alder (*Alnus rubra*).

Redwood Creek supports self-sustaining populations of and Coho Salmon, steelhead (*Oncorhynchus mvkiss*), Chinook Salmon (*Oncorhynchus tschawytcha*), and both resident and anadromous forms of Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*). Overall, Redwood Creek and its tributaries provide approximately 151 km of accessible habitat for anadromous salmonids (NMFS 2014).

The lower portion of the basin (approximately 44%) is within Redwood National and State Parks (RNSP) and managed for protection, conservation, and restoration of natural and cultural resources. The upper 56 % is privately owned and managed primarily for timber production and grazing. Sediment aggradation and removal of riparian forests from legacy and continuing land uses have resulted in warm, shallow and wide channels that have severely impacted Coho Salmon (Cannata et al. 2006, NMFS 2014). Redwood Creek is listed as sediment and temperature-impaired under section 303(d) of the Clean Water Act (CWA 2002; SWRCB 2003; USEPA 2003)., and high summer water temperatures are believed to limit the distribution of juvenile Coho Salmon in the basin (Cannata et al. 2006; Sparkman 2006).

To simplify reporting and interpretation of survey results, this report distinguishes among five spatially delimited sections of Redwood Creek basin (Table 1, Figure 1), based on the "subbasins" defined in the Redwood Creek Basin Assessment (Cannata et al. 2006).

Table 1.The five subbasins of Redwood Creek defined in the Redwood Creek Basin Assessment.

SECTION	DESCRIPTION
ESTUARY	Includes Redwood Creek below the confluence with Prairie Creek, including Sand Cache Creek, Dorrance Creek, and the lower Strawberry Creek basin. We did not survey any streams in this section.
PRAIRIE CREEK	Includes the entire Prairie Creek sub-basin except for a small portion of Skunk Cabbage Creek. 98% of the Prairie Creek sub-basin is managed by Redwood National and State Parks (RNSP). Prairie Creek is Redwood Creek's largest tributary, and provides high quality spawning and rearing habitat for Coho Salmon.
LOWER REDWOOD	Includes Redwood Creek and all tributaries above the Prairie Creek confluence, upstream to the Devils Creek confluence, including Devils Creek. This section is located entirely within the boundaries of RNSP.
MIDDLE REDWOOD	Includes Redwood Creek and all tributaries above the Devil's Creek confluence to the Lupton Creek confluence, including Lupton Creek. This section is privately owned land primarily managed for timber production and grazing. Madej et al.(2006) described this section of Redwood Creek as the "hot zone," and noted that channel aggradation and widening, combined with the removal of large riparian conifers has increased summer water temperatures..
UPPER REDWOOD	Includes Redwood Creek and all tributaries above the Lupton Creek confluence. Privately owned and managed primarily for timber production, grazing, and marijuana cultivation. Access to private property is very limited in this section.

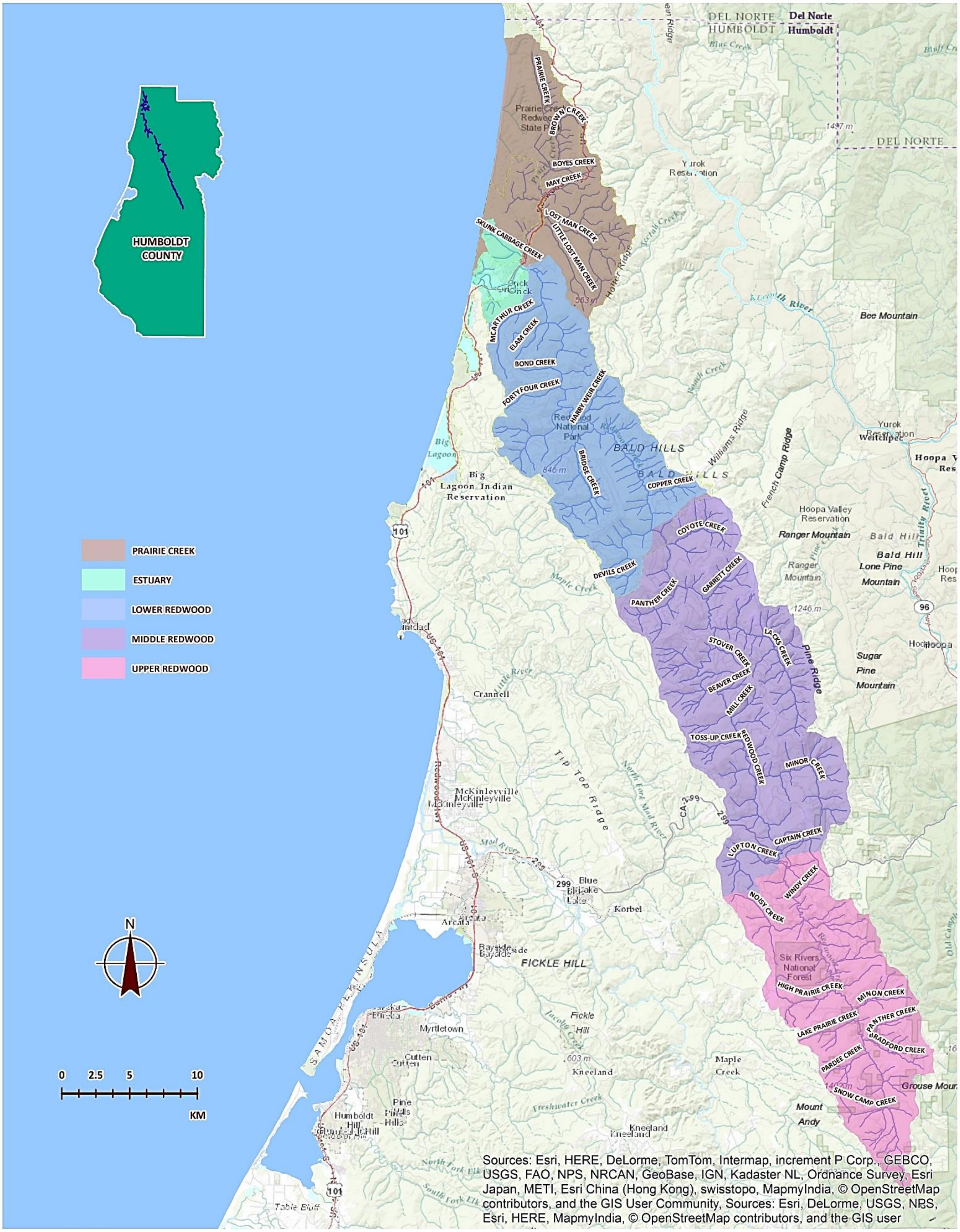

Figure 1. Map showing the Redwood Creek basin divided into five sections based on subbasins defined in the Redwood Creek Basin Assessment (Cannata et al. 2006).

2. METHODS

2.1 SAMPLE FRAME CONSTRUCTION

We surveyed a spatially balanced, random sample of stream segments (reaches) selected from a sample frame designed to include all potential spawning reaches accessible to anadromous salmonids in the Redwood Creek basin. To construct the sample frame, Garwood and Ricker (2011) used empirical data, expert opinion, and physical habitat attributes (stream gradient and discharge) modeled in a geographic information system (GIS) to define spawning distributions for Coho Salmon, steelhead, and Chinook salmon in the Redwood Creek basin. Streams within the sample frame were divided into 1-5 km sections; with start and end points established at geographic landmarks, and upstream extents defined by physical or model-derived limits to anadromy. To increase sampling efficiency while retaining ecologically important small tributaries within the sample frame, streams containing less than 1 km of accessible or suitable habitat were designated "sub-reaches," and surveyed along with the nearest primary reach. All reaches were assigned unique numeric identification codes based on geographic location within the watershed. The final sample frame resulting from this process includes 114.5 km of potential spawning habitat for Coho Salmon.

2.2 FIELD SURVEY PROTOCOL

We systematically sub-sampled each selected reach based on specific habitat criteria, as described in the protocol developed by Garwood and Ricker (2013; Appendix A). In small and mid-sized streams (estimated mean annual discharge parameter of ≤10 m3 s-1); we sampled every second pool meeting specific criteria for depth, area, visibility, and temperature with at least one independent dive pass. To account for diver and species specific detection rates, we sampled every fourth qualifying pool with two independent dive passes. In large main-stem reaches (estimated mean annual discharge parameter of ≤10 m3 s-1); we completed two independent passes through all backwaters, side channels, alcoves, and off-channel pools meeting specific criteria for cover area in addition to the parameters listed above.

For each sampling unit, we attempted to identify and count all fish and amphibians observed. All salmonids were identified to species (if possible), and assigned to stage and age class categories based on size and physical appearance (Appendix A, Table 1). We did not attempt to identify Juvenile trout to species. To ensure thorough inspection of shaded areas and complex habitats, we used underwater flashlights at all times. Large complex units (>5 meters wide) were surveyed by two divers using lanes (O'Neal 2007). After the first pass, divers switched lanes and completed a second pass. To ensure independent counts and allow pools to equilibrate, divers maintained a distance of at least one pool apart. All observations of Coho Salmon in unexpected locations were documented with a digital photograph or video. In addition to biological data, we recorded the following physical habitat information for each pool sampled: pool type, total length (m), average width (m), maximum depth (cm), large woody debris count, cover area, a ranking from 1-5 of estimated cover quality , estimated rank from 1-5 of instream shelter, and standardized GPS coordinates (UTM: NAD83 Zone 10N).

2.4 DATA ANALYSIS

We (Garwood and Larson 2014) applied multi-scaled occupancy models (Nichols et al. 2008) to estimate the probability of occurrence for juvenile Coho Salmon and other salmonids in the Redwood Creek basin during the summers of 2013 and 2014. Occupancy models use detection/ non-detection data from repeated visits to sampling units to account for imperfect detection of the target species (Mackenzie et al. 2002). The pattern of detections at occupied sites provides information about species detectability that can be applied to sites without detections. A primary assumption underlying this model is the target animal's occupancy status (reach-level) cannot change during the survey period (Mackenzie et al. 2006, Nichols et al. 2008). To avoid violating this assumption, we performed surveys during the summer low-flow period, when the migration period for Coho Salmon smelts was largely complete.

Model parameter definitions:

p = the probability of detecting the target species in a single survey, using the field methods employed, provided the species was actually present at the sampling unit.

ψ= the probability that a given reach is occupied by the target species during the survey year.

θ= the probability that a given sample pool is occupied by the target species, provided the species was present in the sample reach during the survey year.

PAO= Proportion of area occupied for the sample frame for the survey year, estimated as **ψ*θ**. .

3. RESULTS AND DISCUSSION

3.1 2013 SURVEY EFFORT AND COHO SALMON OCCUPANCY

During the summer of 2013 (July 1- September 24), we surveyed 19 reaches (49.4 km), representing 43% of the sample frame in stream km. We documented juvenile Coho Salmon occurring in 10 out of 19 (53%) of reaches, and 257 out of 626 (41%) of pools surveyed. As we expected based on the distribution of Coho Salmon reds observed during the 2012-13 spawning season (Figure 2), the majority (99 %) of detections were recorded in Prairie Creek (Table 2). However, we also observed relatively low numbers of juvenile Coho Salmon in the lower section of Redwood Creek (Figure 2).

Occupancy estimates are reported in Table 3. The average estimated detection probability for all sample units (p) was 0.96 (SE 0.01); meaning that on average, we observed 96 ± 1% of juvenile Coho Salmon in pools where they were present. The estimated large scale (reach-level) probability of occurrence (Ψ) was 53± 12%. In reaches where Coho Salmon were present, the probability that juvenile Coho Salmon were available for detection in a given sample pool (θ) was 74 ± 2%, and the estimated overall percent area occupied (ψ* θ*)* for the population for the survey year was 39%.

Reach-specific habitat attributes of sampled pools in 2013 are shown in Table 4.

3.2 2014 SURVEY EFFORT AND COHO SALMON OCCUPANCY

During the summer of 2014, we surveyed 20 reaches (54.1 km), representing 38% of the sample frame in stream km. We detected juvenile Coho Salmon in in 16 out of 20 (80%) of reaches, and 316 out of 534 (59%) of pools surveyed (Figure 3, Table 5). As we expected based on the distribution of Coho Salmon redds observed during the 2013-2014 spawning season, the majority (77%) of detections were recorded in Prairie Creek, and the lower section of Redwood Creek (22%). The remaining 1% were observed in the middle section of Redwood Creek. All of the pools containing juvenile Coho Salmon in this section of Redwood Creek were located either within or immediately downstream of tributaries with cooler water than the mainstem. Juvenile Coho Salmon were detected in Toss-up Creek, which had no previous record of Coho Salmon, and in Minor Creek, more than 10 km upstream of any Coho Salmon redds documented during the 2013-14 spawning season (Figures 2, 3). Tributaries and other sources of cool water refugia are likely crucial for the survival of juvenile Coho Salmon in the middle section of Redwood Creek, which was described by Madej et al. (2006) as a "hot zone". Reach-specific habitat attributes of sampled pools are given in Table 6.

Occupancy estimates are reported in Table 3. The overall average detection probability (*p*) was 94 ± 2%. The estimated large scale (reach-level) probability of occurrence (Ψ) was 80± 9%. In reaches where Coho Salmon were present, the probability that juvenile Coho Salmon were available for detection in a given sample pool (θ) was 70 ± 2%, and the estimated overall percent area occupied ($\psi * \theta$) for the population for the survey year was 56%. Compared to 2013, the percent of area occupied, median pool count per occupied pool, and ψ were higher in 2014, while θ and p were slightly lower (Table 2). These results are consistent with our observations that juvenile Coho Salmon were more widely but less evenly distributed in 2014, and were generally more abundant in core areas.

Table 2. Proportion of pools occupied, average pool counts, and estimated rearing type (natal/non-natal) for juvenile Coho Salmon observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2013.

Section	Stream	Reach ID	Reach length (m)	# Pools surveyed	#Pools Coho present	% Pools occupied	Total # observed	Average count/ occupied pool	Suspected rearing type
Prairie Creek	Larry Dam Creek	88	2,661	123	31	25%	235	8	Natal
Prairie Creek	Lost Man Trib-U	91	2,209	94	26	28%	109	4	Natal
Prairie Creek	Godwood Creek	111	2,243	81	65	80%	300	5	Natal
Prairie Creek	Boyes Creek	114	1,731	44	43	98%	642	15	Natal
Prairie Creek	Boyes Sub-reach	115	617	9	6	67%	15	2	Natal
Lower Redwood	Redwood Creek	26	5,417	17	7	41%	20	3	Unknown
Lower Redwood	Redwood Creek	28	6,087	24	4	17%	9	2	Unknown
Lower Redwood	Redwood Creek	31	3,826	9	0	0	0	0	N/A
Lower Redwood	Redwood Creek	33	1200	3	0	0	0	0	N/A
Middle Redwood	Redwood Creek	37	4,481	20	0	0	0	0	N/A
Middle Redwood	Redwood Creek	47	5,009	20	0	0	0	0	N/A
Middle Redwood	Redwood Creek	49	2,922	13	0	0	0	0	N/A
Middle Redwood	Garrett Creek	206	360	4	0	0	0	0	N/A
Middle Redwood	Lacks Creek	210	2,075	29	0	0	0	0	N/A
Upper Redwood	Lupton Creek	262	305	7	0	0	0	0	N/A
Upper Redwood	Redwood Creek	50	2,263	10	0	0	0	0	N/A
			50,493	626	257	28%	4,291		

Table 3. Estimated proportion of area occupied (PAO) and relative abundance of salmonids in the Redwood Creek basin during the summers of 2013 and 2014.

Coho Salmon

Survey year	ψ	SE	95% CI	Φ	SE	95% CI	p	SE	95% CI	PAO	# of Reaches Coho present	Average count/ occupied pool*	Median count/ occupied pool
2013	0.53	0.12	0.31 - 0.73	0.74	0.02	0.69 - 0.78	0.96	0.01	0.93 - 0.97	0.39	10 of 19	26	9
2014	0.80	0.09	0.57 - 0.93	0.70	0.02	0.65 - 0.74	0.94	0.02	0.90 - 0.97	0.56	16 of 20	24	14

YOY Chinook Salmon

Survey year	ψ	SE	95% CI	Φ	SE	95% CI	p	SE	95% CI	PAO	# of Reaches present	Average count/ occupied pool	Median count/ occupied pool
2013	0.84	0.08	0.61 - 0.95	0.44	0.03	0.38- 0.49	0.72	0.03	0.65 - 0.78	0.37	16 of 19	7	3
2014	0.45	0.13	0.22 - 0.70	0.17	0.04	0.10 - 0.26	0.56	0.10	0.36 - 0.74	0.08	7 of 20	4	2

YOY trout spp.

Survey year	ψ	SE	95% CI	Φ	SE	95% CI	p	SE	95% CI	PAO	# of Reaches present	Average count/ occupied pool	Median count/ occupied pool
2013	1.00	–	–	0.96	0.01	0.93 - 0.97	0.90	0.01	0.88 - 0.92	0.96	19 of 19	17	7
2014	1.00	–	–	0.83	0.02	0.79 - 0.87	0.92	0.02	0.88 - 0.95	0.83	20 of 20	17	9

1+trout spp.

Survey year	ψ	SE	95% CI	Φ	SE	95% CI	p	SE	95% CI	PAO	# of Reaches present	Average count/ occupied pool	Median count/ occupied pool
2013	1.00	–	–	0.82	0.02	0.78 - 0.86	0.79	0.02	0.75 - 0.82	0.82	19 of 19	4	2
2014	1.00	–	–	0.84	0.03	0.78 - 0.89	0.84	0.02	0.79 - 0.88	0.84	20 of 20	3	2

Coastal Cutthroat Trout > 150 mm FL

Survey year	ψ	SE	95% CI	Φ	SE	95% CI	p	SE	95% CI	PAO	# of Reaches present	Average count/ occupied pool	Median count/ occupied pool
2013	0.92	0.07	0.63 - 0.99	0.46	0.03	0.40 - 0.52	0.62	0.03	0.55 - 0.69	0.42	17 of 19	2	1
2014	0.99	0.05	0.00- 1.00	0.65	0.05	0.54 - 0.75	0.59	0.04	0.50 - 0.68	0.58	19 of 20	2	1

p = the probability that the target species will be detected if present in a given sample pool.

ψ= the probability that a given reach is occupied by the target species during the survey year.

θ= the probability that the target species is present in a given sample pool, provided the species was present in the sample reach during the survey year.

PAO=product of ψ* θ. Proportion of area occupied for the entire sample frame for the survey year.

*High counts of salmonids in some exceptional reaches make the median more representative of central tendency of the population than the mean.

Table 4. Reach-specific habitat attributes, averaged over all sampled pools during summer 2013 in the Redwood Creek basin.

Reach ID	Stream	Pool length (m)	Pool width (m)	Pool depth (cm)	Cover rank (1-5)	Cover area (m)	LWD count/pool
28	Redwood Creek	30.9	3.5	190.9	4	76.6	7
35	Redwood Creek	15.3	6.7	189.3	4	63.9	4
37	Redwood Creek	24.9	4.1	268.1	3	43.8	2
41	Redwood Creek	20.7	3.2	182.8	4	36.3	1
45	Redwood Creek	23.9	4.2	92.7	3	18.2	0
54	Redwood Creek	21.6	5.2	340.5	3	23.8	0
71	Prairie Creek	38.4	5.7	92.7	3	18.7	3
72	Prairie Creek	21.6	4.3	70.8	3	14.6	3
74	Prairie Creek	12.0	3.3	56.3	3	6.5	1
85	Lost Man Creek	19.1	4.5	88.6	3	8.5	2
91	Lost Man- unnamed tributary	7.6	2.5	43.9	3	4.2	2
111	Godwood Creek	9.6	2.6	45.1	3	7.2	2
117	Jail Creek	5.7	3.1	62.8	3	2.5	3
147	Tom McDonald Creek	12.7	3.1	57.5	3	13.1	3
155	Emerald Creek	8.0	3.0	54.4	2	3.5	2
159	Bridge Creek	18.8	3.7	72.5	2	6.2	2
206	Garrett Creek	4.9	3.0	48.1	2	5.2	1

Reach ID	Stream	Pool length (m)	Pool width (m)	Pool depth (cm)	Cover rank (1-5)	Cover area (m)	LWD count/pool
28	Redwood Creek	30.9	3.5	190.9	4	76.6	7
35	Redwood Creek	15.3	6.7	189.3	4	63.9	4
37	Redwood Creek	24.9	4.1	268.1	3	43.8	2
229	Karen Creek	6.1	2.5	50.8	3	8.4	3
240	Tossup Creek	7.3	2.3	38.4	4	2.8	1
246	Minor Creek	12.8	3.7	66.6	2	1.8	0

Table 5. Proportion of pools occupied, average pool counts, and suspected rearing type for juvenile Coho Salmon observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2014.

Subbasin	Stream	Reach ID	Reach length (m)	#Pools surveyed	#Pools Coho present	% Pools occupied	Total # observed	Average count/ occupied pool	Suspected rearing type
Prairie	Prairie Creek	71	3,321	44	44	100%	2,211	50	Natal
Prairie	Prairie Creek	72	2,742	44	43	98%	1,412	33	Natal
Prairie	Prairie Creek	74	2,148	44	38	86%	302	8	Natal
Prairie	Lost Man Creek	85	2,916	31	28	90%	753	27	Natal
Prairie	Lost Man unnamed trib	91	2,209	66	16	24%	46	3	Natal
Prairie	Godwood Creek	111	2,243	79	67	85%	682	10	Natal
Prairie	Jail Creek	117	134	4	2	50%	35	18	Natal
Redwood	Redwood Creek	28	6,087	15	15	100%	597	40	Natal
Redwood	Redwood Creek	35	4,980	7	0	0%	0	0	N/A
Redwood	Redwood Creek	37	4,481	13	2	15%	1	1	Non-natal
Redwood	Redwood Creek	41	5,921	10	1	10%	2	2	Non-natal
Redwood	Redwood Creek	45	4,829	4	1	25%	2	2	Non-natal
Redwood	Redwood Creek	54	3,273	10	0	0%	0	0	N/A
Redwood	Tom McDonald	147	2,098	36	27	75%	673	25	Natal
Redwood	Emerald Creek	155	1,785	59	10	17%	140	14	Natal
Redwood	Bridge Creek	159	2,291	27	20	74%	216	11	Natal
Redwood	Garrett Creek	206	360	5	0	0%	0	0	N/A
Redwood	Karen Creek	229	608	11	0	0%	0	0	Non-natal
Redwood	Tossup Creek	240	417	3	1	33%	1	1	Non-natal
Redwood	Minor Creek	246	1,260	22	1	5%	5	5	Non-natal
			54, 103	534	316	59%	7,078		

Table 6. Reach-specific habitat attributes, averaged over all sampled pools during summer 2014 in the Redwood Creek basin.

Reach ID	Stream	Pool length (m)	Pool width (m)	Pool depth (cm)	Cover rank (1-5)	Cover area (m)	LWD count/pool
28	Redwood Creek	30.9	3.5	190.9	4	76.6	7
35	Redwood Creek	15.3	6.7	189.3	4	63.9	4
37	Redwood Creek	24.9	4.1	268.1	3	43.8	2
41	Redwood Creek	20.7	3.2	182.8	4	36.3	1
45	Redwood Creek	23.9	4.2	92.7	3	18.2	0
54	Redwood Creek	21.6	5.2	340.5	3	23.8	0
71	Prairie Creek	38.4	5.7	92.7	3	18.7	3
72	Prairie Creek	21.6	4.3	70.8	3	14.6	3
74	Prairie Creek	12.0	3.3	56.3	3	6.5	1
85	Lost Man Creek	19.1	4.5	88.6	3	8.5	2
91	Lost Man- unnamed tributary	7.6	2.5	43.9	3	4.2	2
111	Godwood Creek	9.6	2.6	45.1	3	7.2	2
117	Jail Creek	5.7	3.1	62.8	3	2.5	3
147	Tom McDonald Creek	12.7	3.1	57.5	3	13.1	3
155	Emerald Creek	8.0	3.0	54.4	2	3.5	2
159	Bridge Creek	18.8	3.7	72.5	2	6.2	2
206	Garrett Creek	4.9	3.0	48.1	2	5.2	1

Reach ID	Stream	Pool length (m)	Pool width (m)	Pool depth (cm)	Cover rank (1-5)	Cover area (m)	LWD count/pool
229	Karen Creek	6.1	2.5	50.8	3	8.4	3
240	Tossup Creek	7.3	2.3	38.4	4	2.8	1
246	Minor Creek	12.8	3.7	66.6	2	1.8	0

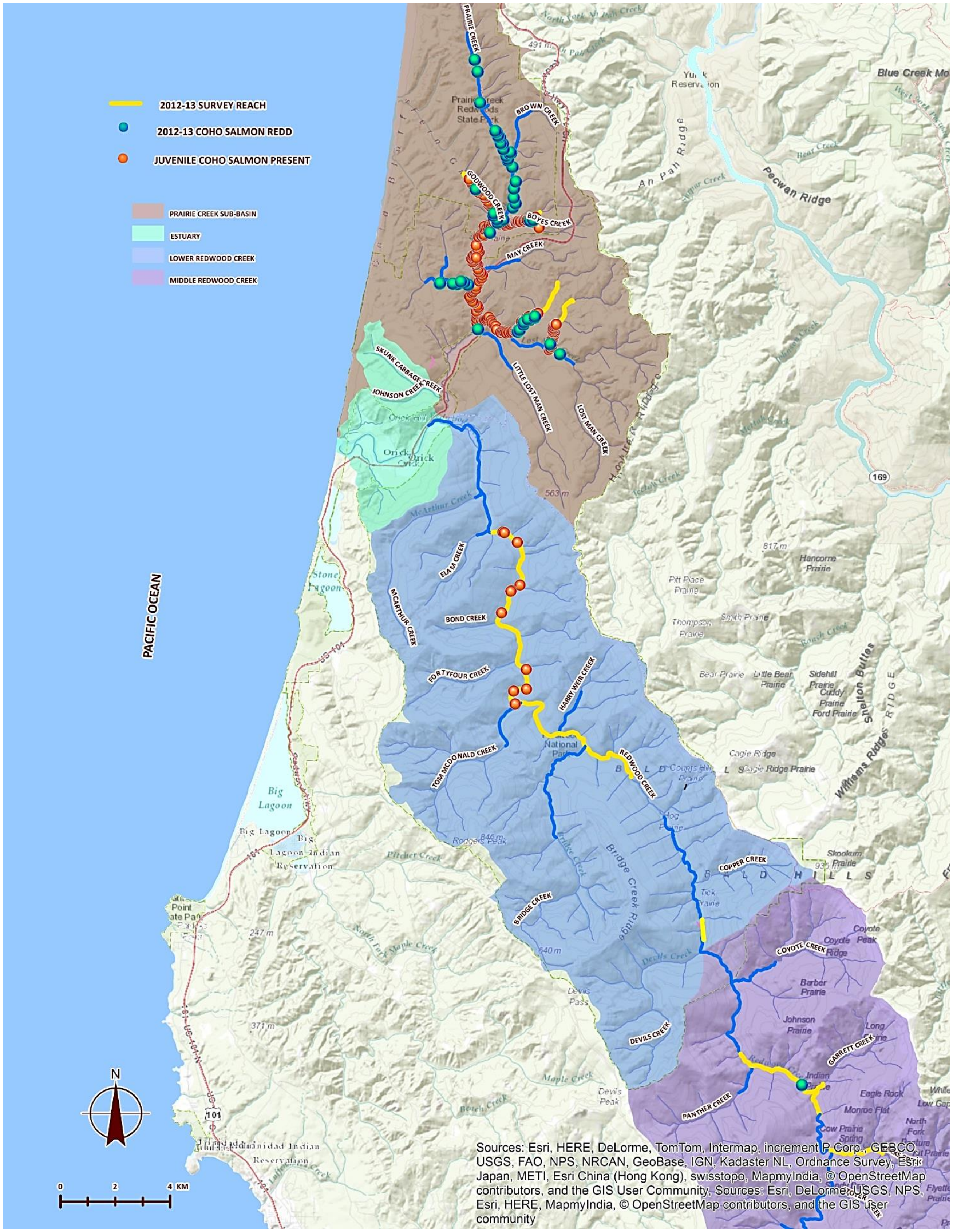

Figure 2. Spatial distribution of juvenile Coho Salmon observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2013, and Coho Salmon redds observed in the same reaches during the 2012-13 anadromous salmonid spawning season.

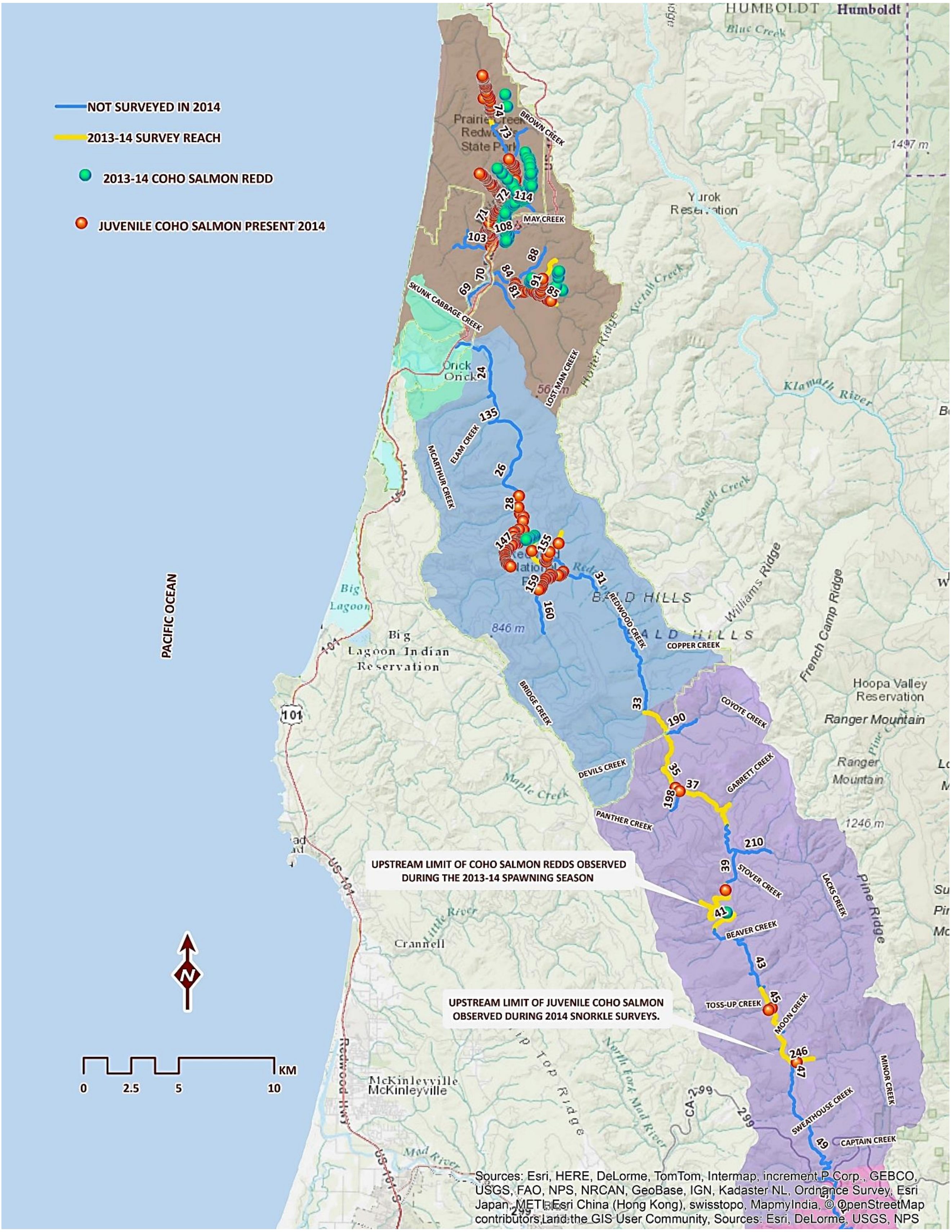

Figure 3. Spatial distribution of juvenile Coho Salmon observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2014, and Coho Salmon redds observed in the same reaches during the 2013-14 spawning anadromous salmonid spawning season.

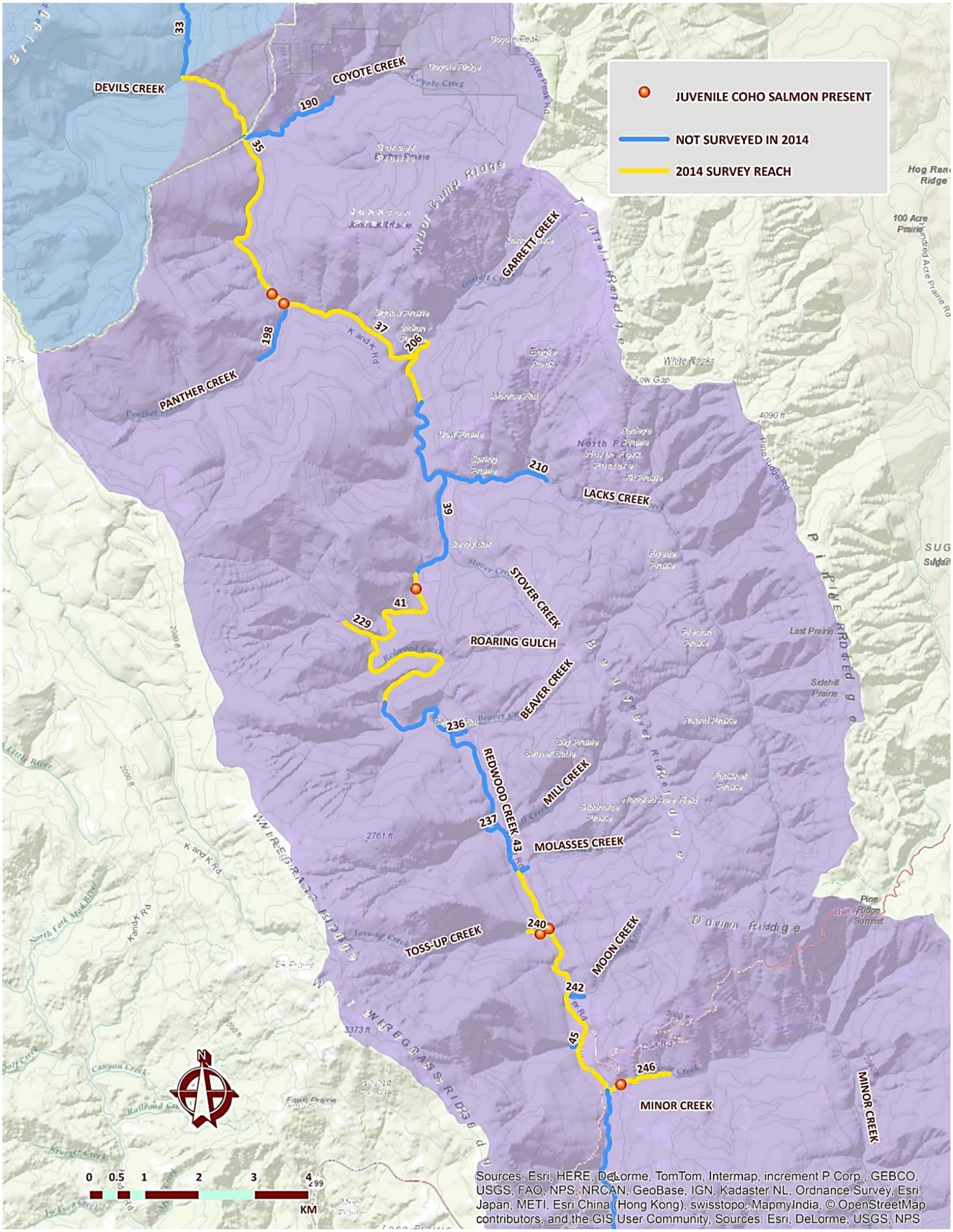

Figure 4. Spatial distribution of juvenile Coho Salmon observed in the middle section of Redwood Creek during snorkel surveys conducted in the Redwood Creek basin during the summer of 2014.

3.3 Occupancy of other salmonid species

The proportion of occupied pools and average pool count by reach for Chinook Salmon, age 0 and 1+ juvenile trout spp., and adult Coastal Cutthroat Trout are reported in Tables 5 and 6. Except for juvenile Chinook Salmon, all species and age-classes were widely distributed during the summers of 2013 and 2014 (Table 7, 8; Figures 5-10). Estimated parameters were similar for all except adult Coastal Cutthroat Trout [3] and juvenile Chinook Salmon. The distribution and abundance of Juvenile Chinook salmon decreased dramatically in 2014, as indicated by a 78% decrease in the estimated overall PAO. Escapement estimates for adult Chinook salmon were similar in 2012-13 and 2013-14 (Metheny and Sparkman 2014; Ricker et al. 2013; Ricker et al. 2014). However, Sparkman et al. (2015) reported that low stream flows likely prevented juvenile chinook from emigrating in 2013, and presented a barrier to upstream migration during the 2013-14 spawning season.

[3] Compared to 2013, θ increased by 30%, and PAO increased by 28% in 2014.

Table 7. Proportion of pools occupied and average pool counts for juvenile Chinook Salmon, Coastal Cutthroat Trout, and unidentified juvenile trout observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2013.

					Chinook salmon (YOY)			Coastal cutthroat trout			Unidentified trout (0+)			Unidentified trout (1+)		
Subbasin	Stream	Reach	Reach length (m)	# Pools surveyed	# pools Chinook present	% Pools occupied	Total # observed	# pools cutthroat present	% Pools occupied	Total # observed	# pools 0+ trout present	% Pools occupied	Total # observed	# pools 1+ trout present	% Pools occupied	Total # observed
Prairie	Prairie Creek	70	1,988	32	13	41%	15	15	47%	19	21	66%	473	21	66%	52
Prairie	Prairie Creek	71	3321	61	14	23%	10	29	48%	23	55	90%	682	51	84%	119
Prairie	Lost Man Creek	84	1778	26	7	27%	7	16	62%	21	20	77%	88	19	73%	78
Prairie	Larry Dam Creek	88	2661	123	0	0%	0	16	13%	32	64	52%	43	47	38%	207
Prairie	Lost Man Trib-U	91	2209	94	0	0%	0	16	17%	27	53	56%	607	41	44%	110
Prairie	Godwood Creek	111	2243	81	1	1%	2	26	32%	20	73	90%	705	60	74%	72
Prairie	Boyes Creek	114	1731	44	1	2%	1	6	14%	4	37	84%	417	32	73%	44
Prairie	Boyes Creek A	115	617	9	0	0%	0	0	0%	0	7	78%	335	3	33%	3
Redwood	Redwood Creek	26	5417	17	7	41%	19	8	47%	21	17	100%	259	16	94%	72
Redwood	Redwood Creek	28	6087	24	18	75%	80	18	75%	57	23	96%	986	21	88%	160
Redwood	Redwood Creek	31	3826	9	5	56%	19	10	100%	20	7	78%	348	8	89%	44
Redwood	Redwood Creek	33	5854	3	3	100%	14	2	67%	4	3	100%	362	3	100%	19
Redwood	Redwood Creek	37	4481	20	17	85%	261	14	70%	37	18	90%	292	16	80%	134
Redwood	Redwood Creek	47	5009	20	12	60%	38	6	30%	6	20	100%	171	17	85%	35
Redwood	Redwood Creek	49	2922	13	12	92%	118	2	15%	2	13	100%	63	12	92%	64
Redwood	Redwood Creek	50	2263	10	10	100%	95	5	50%	3	10	100%	5	9	90%	45
Redwood	Garrett Creek	206	360	4	2	50%	2	3	75%	3	4	100%	62	3	75%	14
Redwood	Lacks Creek	210	2075	29	20	69%	167	2	7%	3	24	83%	701	9	31%	16
Redwood	Lupton Creek	262	305	7	4	57%	12	0	0%	0	6	86%	214	4	57%	9
	Total		55,147	626	142		856	194		298	392		6,809	475		1,293

Table 8. Proportion of pools occupied and average pool counts for juvenile Chinook Salmon, Coastal Cutthroat Trout, and unidentified juvenile trout observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2014.

					Chinook Salmon (YOY)			Coastal Cutthroat Trout			Unidentified Trout (0+)			Unidentified Trout (1+)		
Section	Stream	Reach	Reach Length (m)	# Pools Surveyed	# Pools Present	Total # Observed	Average Count/ Occupied Pool	# Pools Present	Total # Observed	Average Count/ Occupied Pool	# Pools Present	Total # Observed	Average Count/ Occupied Pool	# Pools Present	Total # Observed	Average Count/ Occupied Pool
Prairie	Prairie Creek	71	3,321	44	0	0	0	28	61	2	44	822	19	35	89	3
Prairie Creek	Prairie Creek	72	2,742	44	0	0	0	23	28	1	44	416	9	36	87	2
Prairie Creek	Prairie Creek	74	2,148	44	0	0	0	20	23	1	27	59	2	35	68	2
Prairie Creek	Lost Man Creek	85	2,916	31	0	0	0	19	33	2	31	599	19	28	112	4
Prairie Creek	Lost Man Trib-U	91	2,209	66	5	4	1	32	36	1	26	59	2	46	89	2
Prairie Creek	Godwood Creek	111	2,243	79	2	2	1	13	10	1	60	127	2	53	91	2
Prairie Creek	Jail Creek	117	134	4	0	0	0	1	1	1	4	20	5	1	1	1
Lower Redwood	Redwood Creek	28	6,087	15	5	17	3	10	40	4	15	608	41	14	134	10
Lower Redwood	Tom McDonald	147	2,098	36	0	0	0	15	17	1	33	299	9	29	74	3
Lower Redwood	Emerald Creek	155	1,785	59	2	2	1	14	12	1	27	143	5	29	80	3
Lower Redwood	Bridge Creek	159	2,291	27	0	0	0	7	8	1	27	1,269	47	20	31	2
Middle Redwood	Redwood Creek	35	4,980	7	2	3	1	5	13	3	7	183	26	7	31	4
Middle Redwood	Redwood Creek	37	4,481	13	10	26	3	10	18	2	13	388	30	13	58	4
Middle Redwood	Redwood Creek	41	5,921	10	2	22	11	9	17	2	10	453	45	10	64	6
Middle Redwood	Redwood Creek	45	4,829	4	0	0	0	0	0	0	4	250	63	4	11	3
Middle Redwood	Garrett Creek	206	360	5	0	0	0	1	3	3	5	34	7	1	10	10
Middle Redwood	Karen Creek	229	608	11	0	0	0	1	1	1	9	71	8	6	17	3
Middle Redwood	Toss-up Creek	240	417	3	0	0	0	2	2	1	3	35	12	2	7	4
Middle Redwood	Minor Creek	246	1,260	22	0	0	0	11	16	1	22	466	21	17	62	4
Upper Redwood	Redwood Creek	54	3,273	10	0	0	0	1	1	1	10	325	33	7	21	3
	Total		54,103	534	28	76	3	222	340	30	421	6,626	16	393	1,137	3

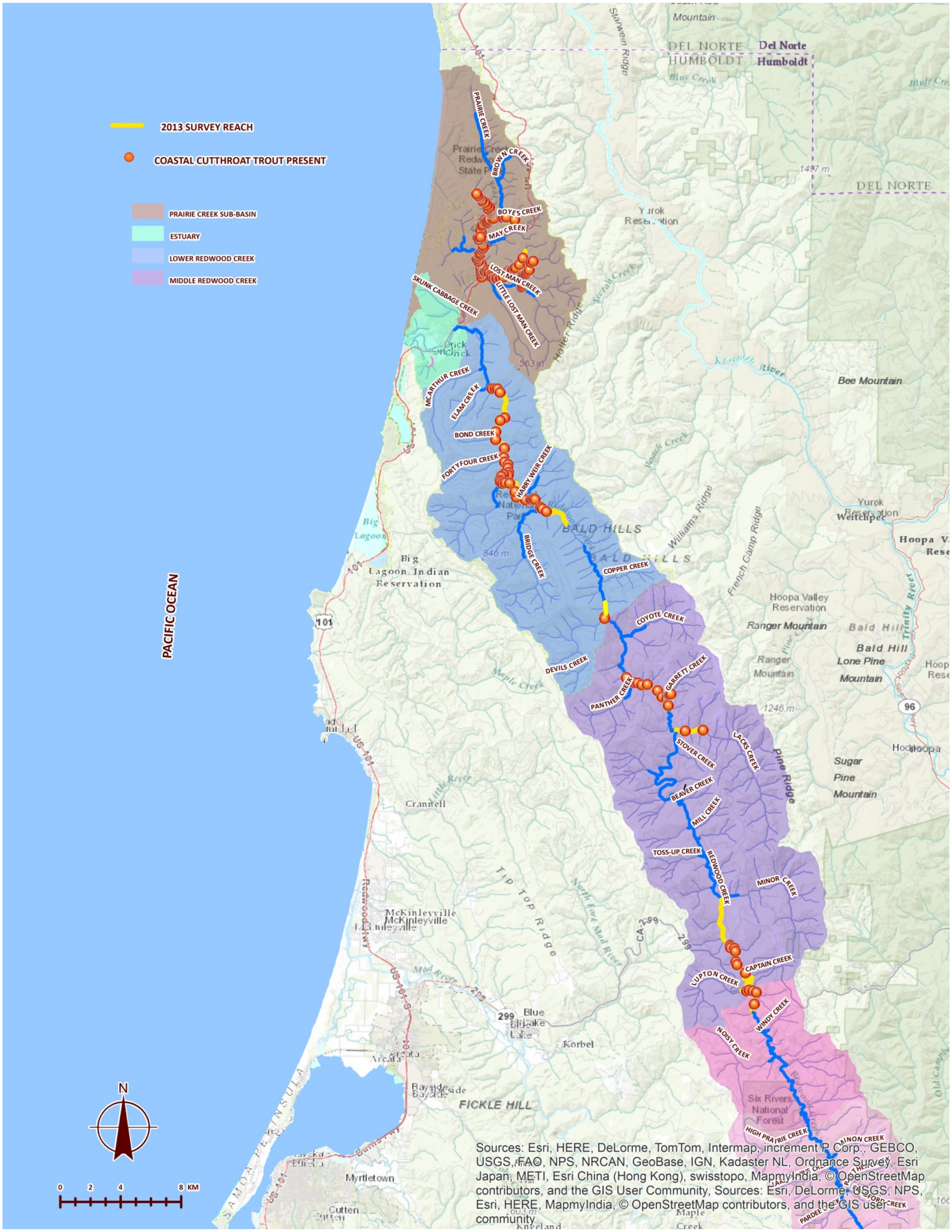

Figure 5. Spatial distribution of Coastal Cutthroat Trout observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2013.

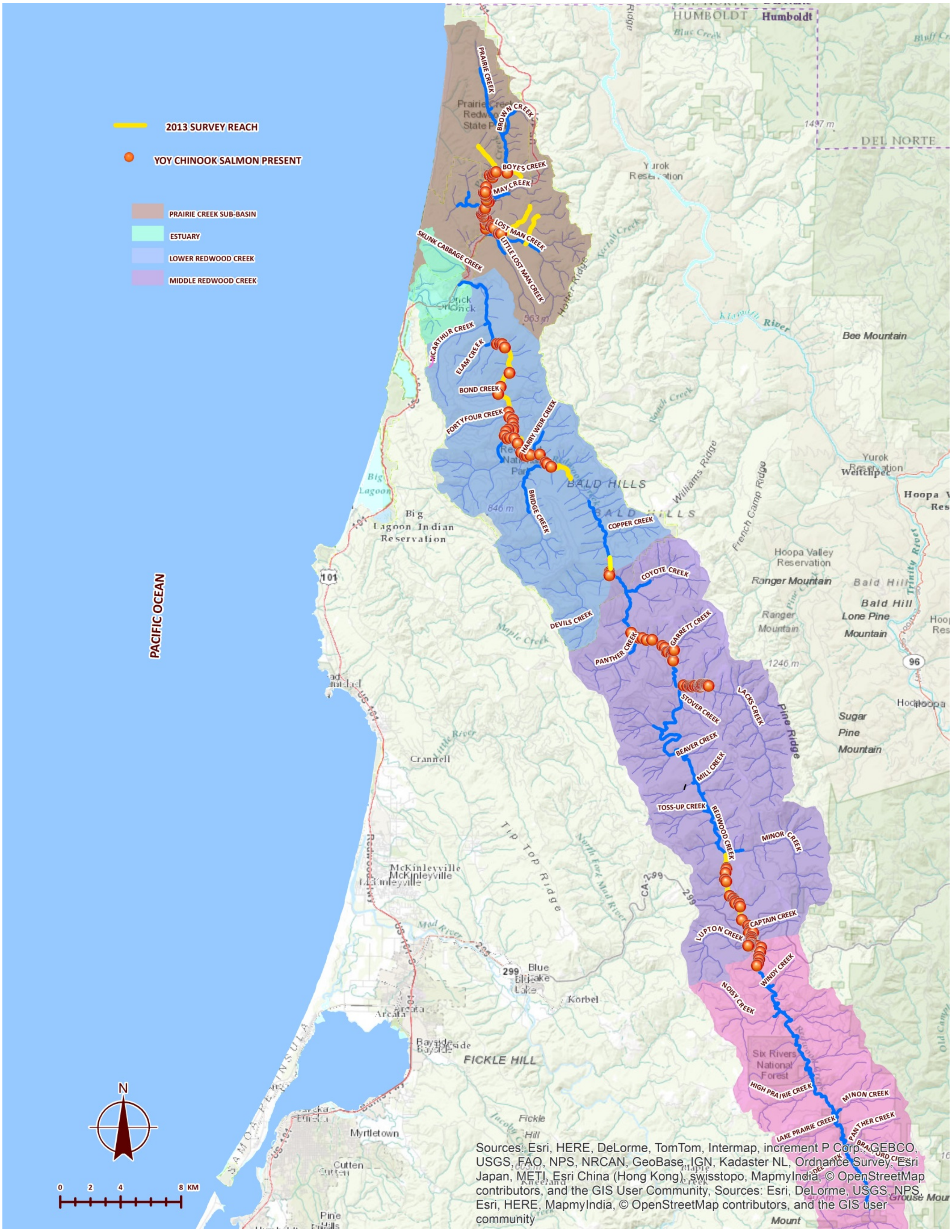

Figure 6. Spatial distribution of unidentified juvenile Chinook Salmon observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2013.

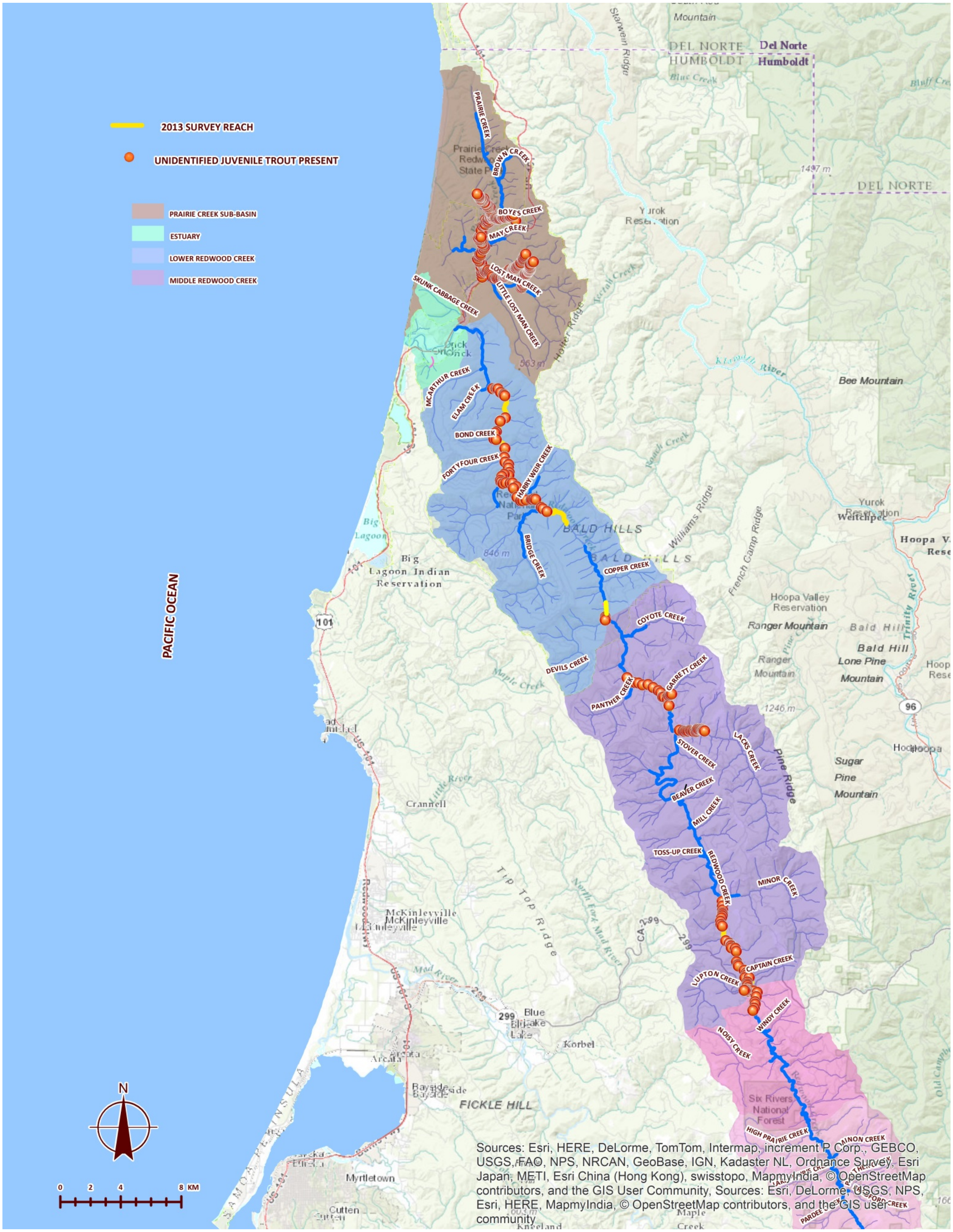

Figure 7. Spatial distribution of unidentified juvenile trout observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2013.

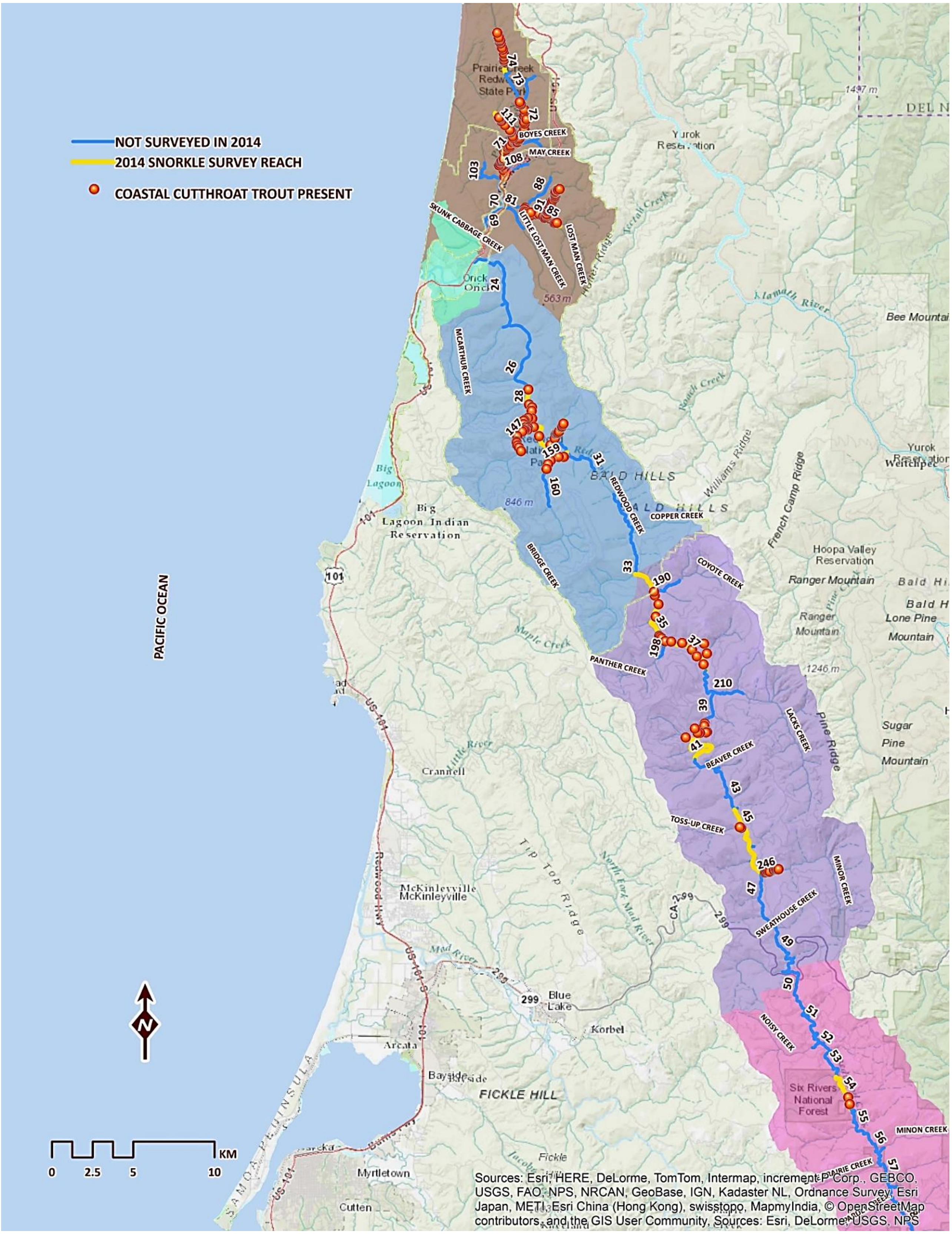

Figure 8. Spatial distribution of Coastal Cutthroat Trout observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2014.

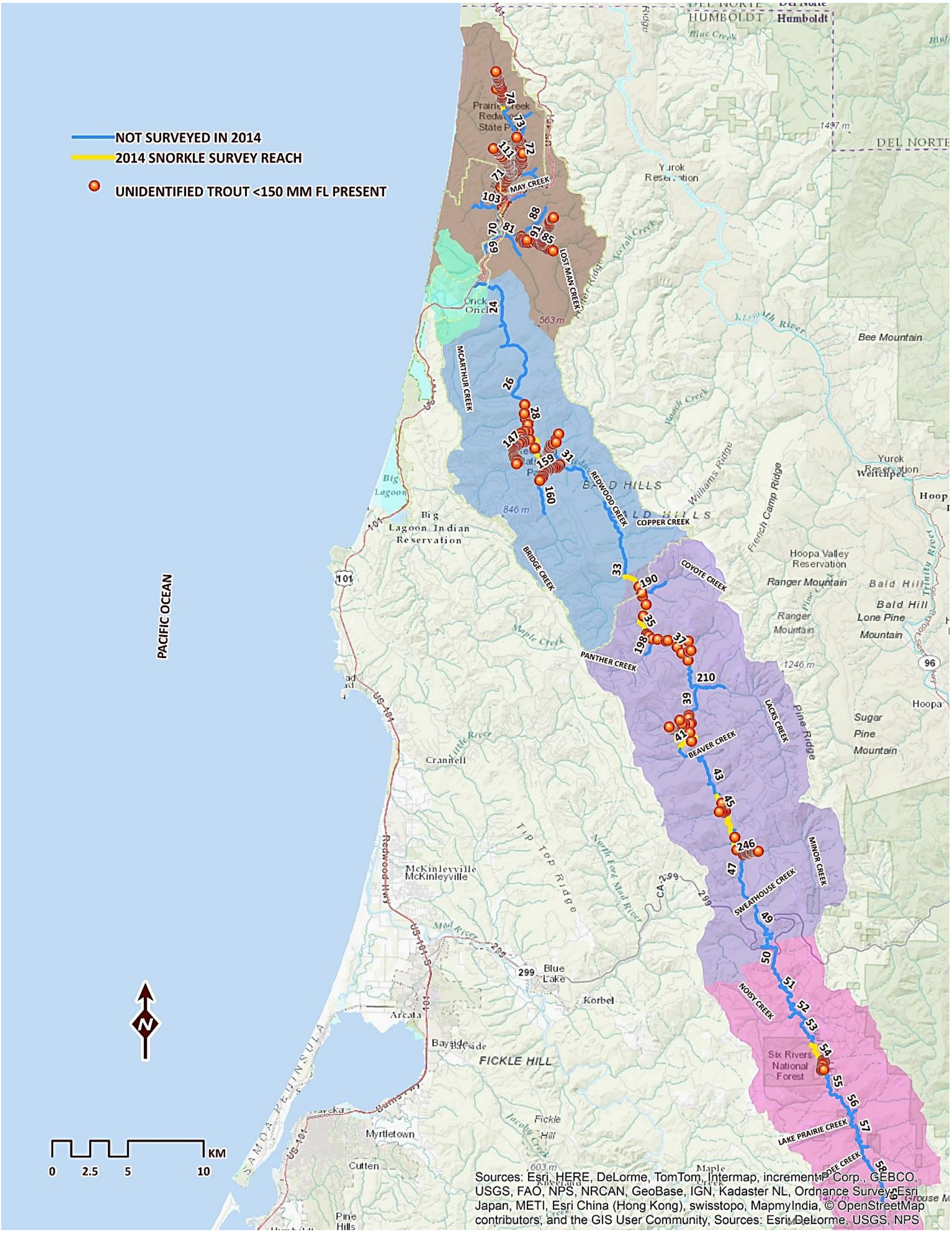

Figure 9. Spatial distribution of juvenile trout observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2014.

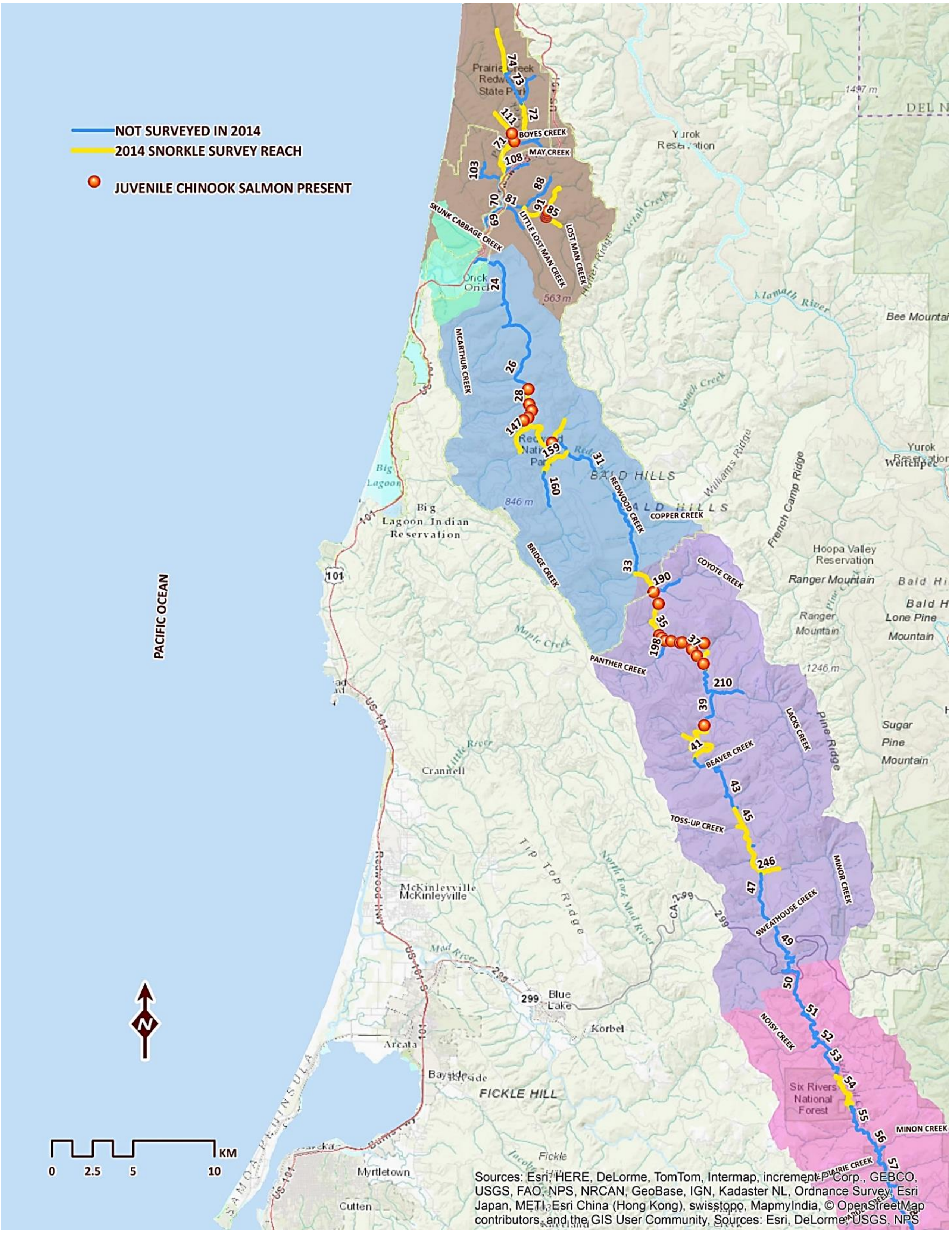

Figure 10. Spatial distribution of juvenile Chinook Salmon observed during snorkel surveys conducted in the Redwood Creek basin during the summer of 2014.

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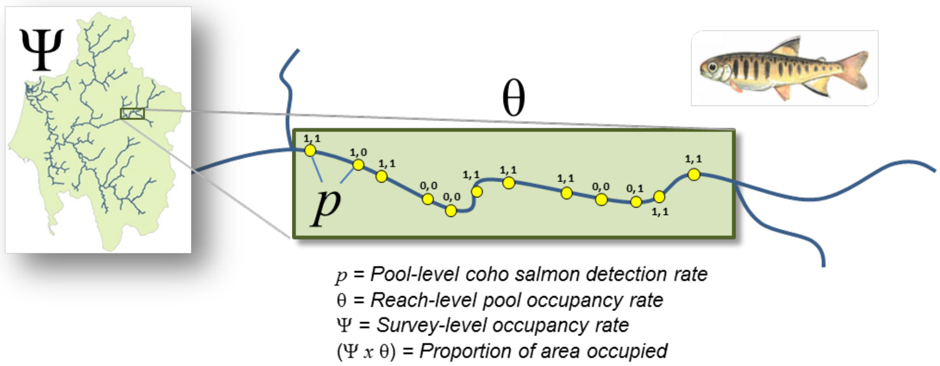
2014 Juvenile Coho Salmon Spatial Structure Monitoring Protocol:

Summer Survey Methods

California Department of Fish and Wildlife



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INTRODUCTION

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. NOAA's framework for assessing the viability of SONCC and CCC Coho Salmon includes several criteria. The first set of criteria dictates that all diversity strata within and ESU need to be represented by multiple viable populations. These criteria establish abundance targets for functionally independent populations within the ESU. The second set of criteria seek to ensure that populations, both viable and nonviable, are distributed in a manner that maintains connectivity among populations throughout an ESU. In particular, the criteria specify that both dependent and non-core independent populations exhibit occupancy patterns that indicate significant immigration is occurring from the 'core populations' (Williams et al. 2008, Spence et al. 2008). To address data needs for viability assessment, the California Department of Fish and Wildlife and the NOAA cooperatively developed the Coastal California Salmonid Monitoring Plan (CMP). Adams et al. (2011) describes the strategy, design, and methods that are used in CMP monitoring. This juvenile Coho Salmon spatial structure monitoring protocol uses the design based sampling of the CMP to measure occupancy patterns of juvenile salmonids during the summer juvenile rearing period.

SURVEY DESIGN

The juvenile monitoring protocol presented here is designed to allow estimation of Coho Salmon occupancy rates during the summer (June-September) based on detection-non-detection data collected from rapid visual encounter surveys. Models developed by Mackenzie et al. (2002) and modified by Nichols et al. (2008) allow occupancy to be estimated at two spatial scales: the sample reach (i.e., the proportion of habitat units---pools in this case---occupied by at least one fish in a sample reach) and the population (i.e., the proportion of reaches occupied within the sample frame) while accounting for imperfect detection at the both the sample reach and habitat unit. Both habitat unit (pool) and reach covariates (e.g. observer, habitat complexity, etc.) will be used assess their influence on local Coho Salmon detection rates and overall annual Coho Salmon occupancy patterns across the landscape. Ultimately, occupancy estimates obtained from this survey can be used to assess trends in Coho Salmon spatial structure for a given area as well as the habitat factors that best explain occupancy.

POOL UNIT SELECTION AND SAMPLING APPROACH

1) Pools are defined as typically having the following characteristics:

- Geomorphic depression in the channel (laterally concave)
- Impoundment or obstruction damming water
- Control structure, such as bedrock or log, forming a scour line
- Slow water velocities (except at the head of the pool)
- Lack of surface turbulence
- Wetted width typically greater than adjacent riffles or runs

Small Streams

2) Every second pool having specific minimum depth (see #3) and area (see #4) criteria will be sampled, along the entire length of each GRTS selected survey reach. To account for detection probabilities of individual divers and species, every 4th survey pool will be sampled with two independent passes (i.e. 2-1-1-1-2-1-1-1-2). The first pool will be selected at random by a coin toss and the survey will move from downstream to upstream. The first survey pool will be surveyed with two independent passes. Each 4th survey pool will be determined and flagged by the primary observer so the secondary observer will clearly identify the same individual habitat unit number and its specific boundaries. To minimize biases around species and count observations, all observations made by observers will remain confidential at the habitat unit level (i.e. counts of observer 2 are 'blind' to what observer 1 obtained until after both passes are completed and data is entered).

3) For a pool to be included as a potential sample unit, it must meet pool depth categories that are defined for each reach in advance using GIS and the NOAA IP model based on the size of a given stream:

< 0.1 CMS = 25 cm
0.1 – 1.0 CMS = 30 cm
1.0 – 1.5 CMS = 40 cm
> 1.5 CMS = 50 cm

These criteria are used to avoid excessive sampling in marginal quality habitats in larger streams.

4) For a pool to be included as a potential sample unit, it must have a minimum surface area of **3 m²** for streams with wetted channel width **<3 m** AND a width of **at least one-half** the wetted channel width. For streams with wetted widths > 3 m, a pool must have a minimum surface area of 6 m^2 AND a width of at least one-half the wetted channel width. Backwater pools **do not** need to equal at least one-half the channel width and must have a minimum surface area of at least 3 m^2.

5) Smaller side channels will be included in the survey sequentially after the primary channel has been completed up to where it rejoins the side channel. Units need a minimum depth of **30 cm** and surface areas of **3 m^2** and a width of **at least one-half** the wetted channel to be selected.

6) Pools having complex habitat features and exceeding five meters in average width will be surveyed by two divers using lanes. After the first pass, individual divers will switch sides for the second pass keeping observations confidential until data are recorded.

7) In general, pool boundaries should be defined based on hydrologic and geomorphic breaks or obstructions that would impede fish from passing from one unit to the next between dive passes. Attempt to break units based on shallow areas occurring between deeper habitats and/ or channel obstructions present. However, in some cases distinct breaks will not be present and breaking the unit becomes subjective. When clear breaks cannot be defined, attempt to keep fish from escaping the defined area with a careful primary dive approach.

8) Reaches that exhibit sustained water quality after the first dive pass (e.g. little/no siltation of the pool due to diver disturbance) will be sampled with two independent dive passes spaced five minutes apart or when conditions of the unit have returned to their normal state. Many coastal streams in California have excessive amounts of silt resulting in the first dive pass suspending sediments and compromising the ability to conduct a secondary pass in a reasonable timeframe. These streams should have secondary passes completed the following day. In this two day sampling, it is imperative that unit flagging tape include unit # and primary diver initials. Flagging needs to be secured such that it will be available the next day to identify the pool unit number.

9) In general, snorkel surveys should be **discontinued** if underwater visibility gets poor (Secchi Disk reading of **1.25 m or less**) prior to surveying a unit. However, if conditions improve after a few units, continue with the first unit in succession with reasonable visibility.

Large Rivers

Large river sections require different sampling unit selection criteria than small streams based on different stream channel morphology and most juvenile Coho Salmon rearing habitat being limited to features proximal to the main channel. **All identified habitat features** will be surveyed in large river reaches since available sampling units are expected to occur much less frequently per unit distance. Reaches within large river sections will be defined prior to field sampling so crews follow the correct unit selection criteria and sampling protocol. In the Smith River, we defined a large river using an estimated mean annual discharge parameter of >10 cms from the NOAA IP model in a GIS.

10) Sampling will be limited to areas containing off-channel pools, backwaters, side channels, alcoves, thermal refuge, and river bank edge features (e.g. dense riparian vegetation, beaver created structures, log jams). For bank edge features, each unit must have depth of at least

50 cm AND a minimum surface area of **6 m²** AND a water temperature **≤21° Celsius** at the time of inspection. For all off-channel and side-channel features, each unit must have a depth of **30 cm** and a surface area of **6m²**.

11) All identified off-channel and proximal channel habitats will be surveyed with two independent dive passes similar to those used in small streams. Many large stream units occurring on the edge of the main channel will have no defined boundaries in the pelagic region opposite of the bank. Prior to the survey, both observers need to define the area to be searched so equal effort is applied. The survey area is confined to existing cover features characterizing the defined unit.

12) If large river units need to be surveyed by two divers using lanes (see #6)

VARIABLE DEFINITIONS

These definitions define how each variable is collected within the three survey components: Survey Header, Habitat, and Observations. More specific variable definitions are also provided in

Survey Reach Header:

Date: Record the date of the survey (MM/DD/YYYY). Fill out a new header each day if a given reach takes multiple days to complete.

GeoArea: Record the geographic area of the given survey (e.g. Smith River, Mattole River).

LocationCode: Record the GRTS reach number you are surveying.

Survey: Record **GRTS** for GRTS selected survey reach or **INCIDENTAL** for an incidental reach survey.

Comments: Used to record any notes associated with the reach survey.

Pool Habitat Data:

To minimize disturbing fish and the unit's water clarity, pool measurements and cover estimates will be recorded by the secondary diver after they have completed their biological survey. However, these metrics will be recorded by both observers independently for every 10^{th} unit to explore variation in data collection.

UnitNumber: Record the pool unit number starting the reach with unit #1, then #2, etc. Record 999 if unit is not part of regular survey (i.e. exploratory survey in an unselected unit).

Water Temp: Record the water temperature in degrees Celsius. Record all pool temperatures in Large River reaches and at least three pool temperatures throughout Small Stream reaches (i.e. bottom, middle, top).

Secchi (m): Record the Secchi Disk distance to the nearest 0.1 meters in three units spread throughout a given reach (Beginning, middle, end). Be careful not to disturb sediment on the stream bottom when recording the Secchi distance. If the Secchi Disk distance is less than 1.2m terminate the survey (see #9 in previous section). If the distance exceeds the length of the unit record 999.

UTME: Record UTM Easting coordinates from GPS.

UTMN: Record UTM Northing coordinates from GPS.

GPS coordinates (UTM Datum: NAD83 Zone 10N) will be collected near the bottom of each pool through point averaging recorded during habitat measurements.

Pool Type: See BOX 1. Record the type that best represents the characteristics of a given pool: MCP (Main channel pool), SP (Scour pool), BP (Backwater pool), FL (Flatwater).

Max Pool Length: Record the maximum defined pool length to the nearest 0.1 meters.

Ave Pool Width: Record the pool width to the nearest 0.1 meters that best represents the average width that will be used to calculate the pool surface area.

Residual Pool Depth: Record the residual pool depth to the nearest centimeter by subtracting the maximum depth of the riffle crest exiting the pool from the maximum pool depth.

Cover Rating: See BOX 2. Record the overall rating of the pools available fish cover (1-5).

Cover Area: See BOX 2. Record the area of the pool unit occupied by fish cover in meters squared.

LWD Count: See BOX 2. Record the number of large logs occurring in or suspended above the wetted portion of a unit at the time of the survey.

Notes: Record any comments related to the pool unit.

Biological Observations:

Diver Initials: Record the diver's initials.

Dive Pass: Circle the number indicating if this is the first (1°) or second (2°) dive pass. If a single dive unit then circle both (1°and 2°) to indicate a single pass.

Common Name: Select the species of a given observation.

Count: Record the number of individuals observed.

Stage: Record the life stage of a given observation (See **Table 1** for specifics).

Age Class: Select the age category of organism (See **Table 1** for specifics).

Notes: Record any applicable notes.

BOX 1. Expanded Pool Habitat Type Definitions

Main Channel Pools: These pools encompass majority of wetted stream width (>60%).
Trench Pool: Canyon-like pool, generally U-shaped and often flanked by bedrock walls.
Mid-Channel Pool: Large pool formed by mid-channel scour with scour hole covering >60% wetted channel.
Confluence Pool: Large pool formed at or below the confluence of two or more channels.
Step Pool: A series of small pools separated by short cascades usually found in upper reaches with high gradients.

Scour Pools: These pools often contain scour holes less than 60% of wetted stream width.
Corner Pool: Lateral scour on bank forming pool at channel bend, usually found in lower reaches full of alluvium.
Log Scour Pool: Flow impinges on obstruction consisting of woody debris, usually <60% of wetted channel width.
Root Wad Scour Pool: Flow impinges on obstruction consisting of tree root mass, usually <60% of wetted channel.
Boulder Scour Pool: Flow impinges on obstruction consisting of one or more boulders, usually <60% channel.
Bedrock Scour Pool: Flow impinges against bedrock stream bank, usually <60% of wetted channel width.
Plunge Pool: Flow passes over complete channel obstruction such as a log and drops steeply creating scour pool.

Backwater Pools: These pools form apart or mostly apart from main channel.
Side Channel Pool: Pool formed outside the main channel, often dry or unconnected during summer.
Backwater Obstruction Pool: Pool formed in channel margin by eddies around boulder, log or root wad.
Dammed Pool: Formed upstream of a complete or nearly complete channel blockage (i.e. log jam, beaver dam, etc.)

Flatwater: Glides and Runs which fall into our unit selection parameters are recorded as flatwater.
Glide: Unit characterized by low flow and uniform channel bottom usually consisting of mud, sand or gravel.
Run: Unit generally faster flowing than glides, and has uniform channel bottom of gravel, cobble, and boulder.
Edgewater: We will encounter these usually on large (Mainstem Smith) channels in the stream margins. Diving the entire pool in these cases likely is not feasible. Water velocity is low and units mostly shallow, often associated with riffles.

BOX 2. Determining Habitat Unit Cover Quality

Cover Rating: is defined as an ocular three dimensional ranking of all cover available to salmonids in relation to the total pool volume at the time of survey. Cover includes any features within the pool (or suspended less than 1 meter above the pool) that are available refugia for juvenile salmonids including: undercut banks and boulders, woody debris, overhanging vegetation, bubble curtains, aquatic vegetation, etc. This rating is defined within five broad classes:

- **(1) None:** Unit is void of fish cover.
- **(2) Poor:** Unit is lacking significant fish cover and complexity. Unit contains at least one of the following features in limited availability: LWD, SWD, Boulders, root masses, undercut bank, submerged vegetation, overhanging vegetation, bubble curtain.
- **(3) Average:** Unit generally provides fish cover, but lacks complexity, containing at least two of the following features in moderate availability: LWD, SWD, Boulders, root masses, undercut bank, submerged vegetation, overhanging vegetation, bubble curtain.
- **(4) Good:** Unit provides extensive quality fish cover for up to 50% of the area from at least three of the following complex features: >1 LWD, > 2 SWD, deep undercut bank, large root mass, extensive aquatic vegetation/ submerged branches, >4 undercut boulders, dense submerged overhanging vegetation.
- **(5) Excellent:** Unit has excellent fish cover usually dominating >40% of the pool area with at least four complex cover features (each available in extensive amounts). Unit must include >2 LWD and numerous SWD. Unit is difficult to navigate and survey.

Cover Area: A measure of the area of the unit occupied by fish cover. The area is estimated from an overhead view and is recorded in meters squared. Cover includes both small and large woody debris, undercut banks, undercut boulders, roots and rood wads, overhanging vegetation, and aquatic vegetation. Features must be >0.25 m^2,

LWD Count: The number of logs greater than 30cm in diameter and greater than 2m in length occurring in (or suspended ≤ 1 meter directly above) the wetted area of the sampling unit.

Table 1. Age class and stage categories used for recording specific salmonid life stage observations.

Species	Age: 0+[1]	Stage	Age: 1+[1]	Stage	Age: Adult	Stage
Coho Salmon	Yes	Parr	Yes	Parr	No	NA
Chinook Salmon	Yes	Parr	Yes	Parr	No	NA
Trout spp.	Yes	Parr	Yes	Parr	No	NA
Cutthroat Trout	No	NA	No	NA	~ >150mm[2]	Adult
Rainbow Trout	No	NA	No	NA	~ >150mm[3]	Adult
Steelhead Trout	No	NA	No	NA	Yes, Sea run	Adult

[1]Size can vary by stream and/ or date of survey. Age classes need to be determined underwater by observers prior to a reach survey by defining specific size cutoffs of salmonids present in (or directly below) the reach.
[2]Individual has heavy black spotting especially below the lateral line and generally lacks parr marks, size may vary by stream.
[3]Resident: Individual lacks parr marks, usually darker in color overall compared to anadromous forms, white belly, may have reddish color along lateral line and cheeks, and usually occurs in headwater areas, size may vary by stream.

Core Sampling Equipment List

Personal Equipment
Dive duffle to hold all gear
Field backpack
Waterproof flashlight
Batteries (enough for entire season)
Neoprene dive gloves with kevlar® (seal stitch seams with aquaseal®)
Neoprene dive hood
Neoprene surf wetsuit 8-7mm with hood)
Neoprene bootees
Laced wading boots
Neoprene gravel guards for boots
Skateboarding knee pads with hard plastic knee cap protection
Dive mask, snorkel
Survey Equipment
Protocols/ species keys
Data sheets and/ or PDA
Tadum
GPS
waterproof camera
50 meter metric roll tape for large streams
15 meter metric roll tape for small streams
Secchi Disk for recording underwater visibility
Thermometer (should also consider thermographs over the season)
Stadia rod (with cm units)
Coin (flip for determining start pool)
Pencils
Flagging/ Sharpies (for defining individual survey units)
Handheld tally counters (Up to 2 per diver)
Dive slate with pencil (optional-good for large survey units)
Safety Equipment
SPOT® safety device
First aid kit
Emergency phone number contact sheet
Reach reconnaissance fact sheet with map and directions