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State of California

Department of Fish and Wildlife

and

Humboldt Redwood Company

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Lower Eel River and Van Duzen River

Juvenile Coho Salmon (*Oncorhynchus kisutch*)

Spatial Structure Survey 2013-2016 Summary Report

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Abstract

Monitoring of coho salmon population spatial structure was conducted, as a component of the California Department of Fish and Wildlife's Coastal Salmonid Monitoring Program, in the lower Eel River and its tributaries, inclusive of the Van Duzen River, in 2013, 2014, 2015, and 2016. Potential coho salmon habitat within the lower Eel River and Van Duzen River study areas was segmented into a sample frame of 204 one-to-three kilometer stream survey reaches. Annually, a randomly selected subset of sample frame stream reaches was monitored by direct observation. Using mask and snorkel, surveyors conducted two independent pass dive observations to estimate fish species presence and numbers. A total of 211 surveys were conducted on 163 reaches, with 2,755 pools surveyed during the summers of 2013, 2014, 2015, and 2016. Coho salmon were observed in 13.5% of reaches and 7.5% of pools surveyed, and the percent of the study area occupied by coho salmon juveniles was estimated at 7% in 2013 and 2014, 3% in 2015, and 4% in 2016.

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Introduction

Coho salmon (*Oncorhynchus kisutch*) in the Southern Oregon/Northern California Coast (SONCC) Evolutionary Significant Unit (ESU) were listed as threatened under the federal Endangered Species Act in 1997 (62 FR 24588); and their listing was reaffirmed in 2005 (70 FR 37160). The SONCC coho salmon ESU was also listed as threatened under the California Endangered Species Act in 2002 (CDFG 2002). California Department of Fish and Wildlife (CDFW) and the National Marine Fisheries Service (NMFS) recovery plans for coho salmon outline recovery goals, prioritize recovery actions, and offer criteria that must be met in order to delist the species (CDFW 2004, NMFS 2014). Long-term population monitoring is an essential component of these recovery plans, as population metrics are needed to assess recovery actions and track the species' progress towards recovery. The CDFW and NMFS "*Fish Bulletin 180 California Coastal Salmonid Monitoring Plan*" (CMP) established the approach for monitoring ESA/CESA listed anadromous salmonid population(s) status and trend in California (Adams et al., 2011). In the CMP's Northern California area, monitoring of juvenile coho salmon is consistent with the salmonid population spatial structure data needs and protocols of the CDFW Coastal Monitoring Plan/Program.

The Eel River flows through portions of Humboldt, Mendocino, Lake, Trinity, and Glenn counties and, encompassing 3,684 square miles, is California's third largest watershed. The mainstem Eel River is approximately 197 miles in length from its headwaters in the Mendocino National Forest to its outlet to the Pacific Ocean near Ferndale, California. The predominant land uses throughout the basin are timber harvest, livestock grazing, and dispersed rural development. Historically, the Eel River was one of the state's most productive rivers for anadromous salmonids, supporting runs of coho salmon, Chinook salmon (*O. tshawytscha*), and steelhead/rainbow trout (*O. mykiss*). It is also the southernmost range of coastal cutthroat trout (*O. clarki clarki*) which are not as commonly found. However, Pacific salmon runs in the Eel River have markedly declined over the last 100 years and the distribution of coho salmon in the lower Eel River watershed is known to be limited (Garwood 2012) (National Marine Fisheries Service, 2014). In 2013, a partnership of CDFW, Pacific States Marine Fisheries Commission (PSMFC) and Humboldt Redwood Company (HRC) established a coho salmon population spatial structure CMP monitoring project on the lower Eel River and Van Duzen River, and results of that monitoring effort are the subject of this report.

Methods

We implemented survey protocol and data analysis methods as described by Garwood & Larson (2014) and Garwood and Ricker (2013, Revised 2016). The Project's coho salmon population study area is a CMP-modeled and team-defined survey sample frame of 204 lower Eel River and Van Duzen River sample reaches between 1 km and 3 km long and subreaches less than 1 km long. Sections of streams that were within tidally influenced areas and upstream of adult migration barriers were excluded from the sample frame (Figure 1). Generalized Random Tessellation Stratified (GRTS) was used to randomly order sample reaches for survey frame, and one third of the reaches are surveyed annually. Personnel were trained in underwater identification and counts of fish species that occurred in the lower Eel River and Van Duzen River. Counts of salmonids were identified to categories based on size and physical appearance. Salmonids born within the last year were classified as young-of-the-year (YOY). Juvenile trout over a year old were classified as 1+ trout. Juvenile trout were not identified to species since steelhead, rainbow trout, and coastal cutthroat trout juveniles have similar physical characteristics. Since the lower Eel and Van Duzen River is the southernmost extent of the coastal cutthroat trout range and are very rare in this study area, we can generally assume that most of the juvenile trout observed are steelhead or rainbow trout. Rainbow trout and coastal cutthroat trout were only identified when no parr marks were present. Monitoring is conducted by a two person snorkel/dive survey team. Pools are identified within a survey reach that meet specific habitat parameters which deem them suitable for direct observations. Pool habitat suitability is defined as having at least 1.25 m of underwater visibility, water temperatures less than 22° Celsius, and minimum criteria for pool depth, width, and surface area which are defined by mean annual flow. Visibility is determined using a Secchi disk. Water temperatures are noted at least once per reach and when water temperature changes occurred. Depth and width measurements are taken with a metric stadia rod or tape measure. An optimal percentage of the suitable pools are randomly selected for surveying. Coho salmon observations were documented using underwater photographs and/or videos.

Two surveyors conducted independent dive observations in each pool and analysis of the independent passes are used to estimate fish detection probability. Coho salmon were the target species of the survey, however, all observed fish were counted and identified, if possible, in each pool. In addition to the GRTS surveys, a few incidental reaches were surveyed that were not used in the data analysis. Based on detection probability, the number of reaches in which a salmonid species was observed, and the total number of reaches surveyed, multi-scaled occupancy models

(Nichols et al. 2008) were used to determine occupancy at the pool level, reach level, and the overall occupancy of each species and age class category. Analysis of data collected included individual species detection probability if present in a given sample pool (p), the occupancy in a sampled pool if the species is present in the reach being sampled (Θ or theta), the occupancy in a reach if the species is present in the reach (Ψ or psi), and the estimate of percent of area occupied (PAO), which is the product of Θ and Ψ .

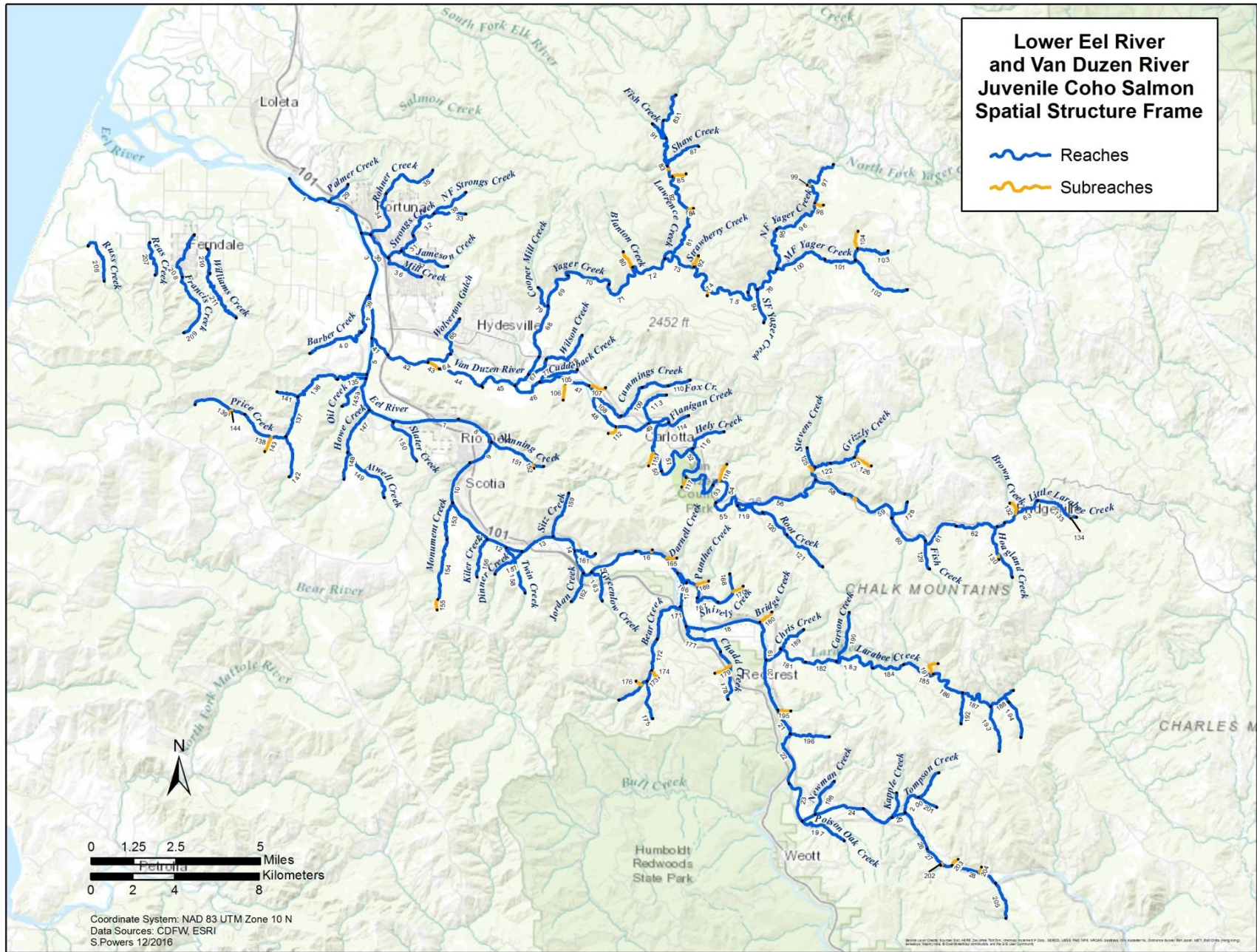


Figure 1. Lower Eel River and Van Duzen River survey frame of 204 reaches and subreaches, Humboldt County, CA.

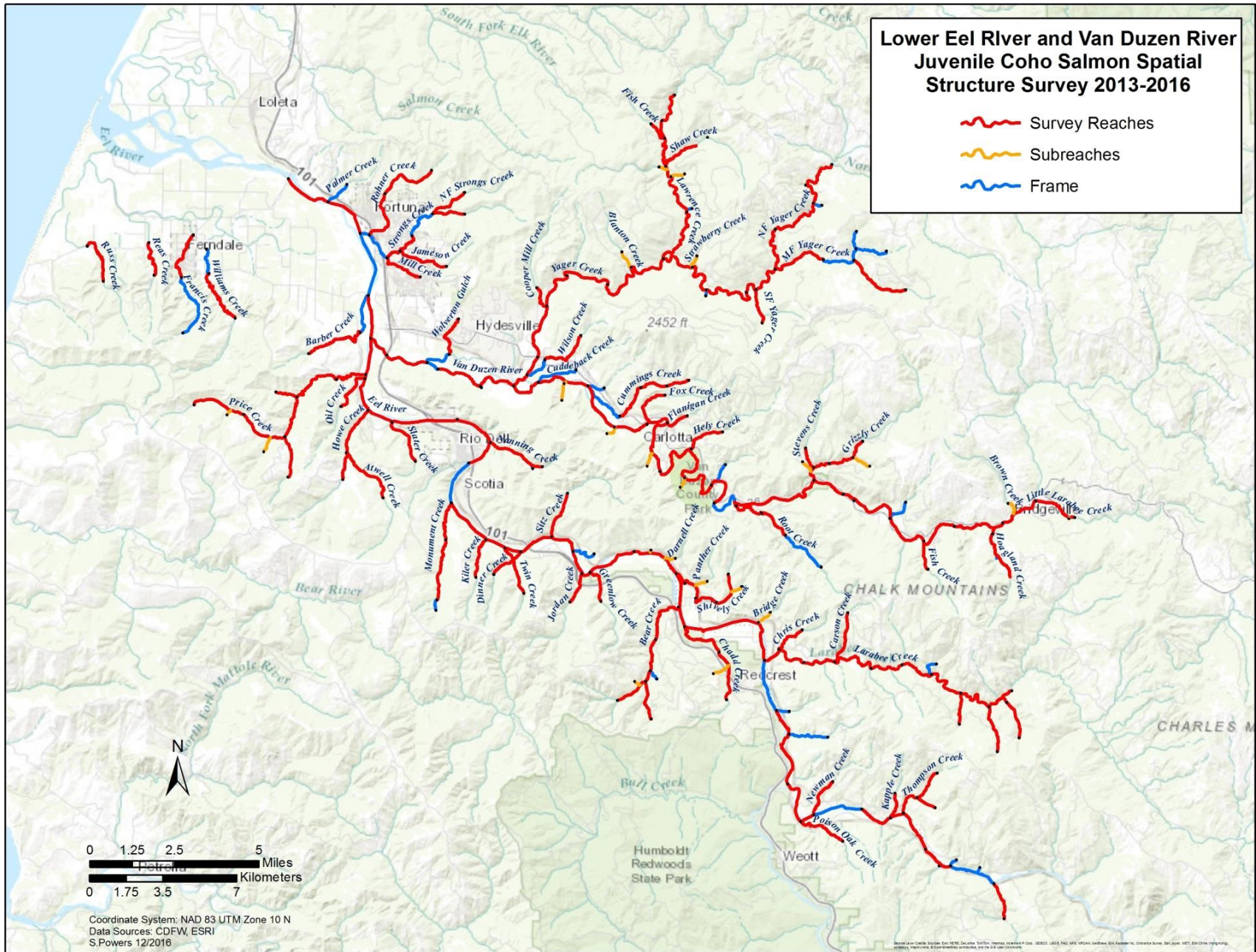


Figure 2. Lower Eel River and Van Duzen River surveys completed in the survey frame (2013-2016), Humboldt County, CA.

Results

A total of 163 unique reaches of the 204 available in the sample frame were surveyed at least once from 2013 to 2016. A total of 211 surveys were completed during the summer over the four years; 23 reaches were not surveyed due to lack of landowner access permission and 42 reaches had no pools which met the suitability protocol. Analysis was conducted on data obtained from the 211 reach surveys. Analysis of data collected included individual species detection probability if present in a given sample pool, the probability that a species is detected in a sampled pool if the species is present in the reach being sampled, and the estimate of percent of area occupied (Table 1) (Table 2). We found that coho salmon occupied 3% to 7% of the survey area and occurred in small patches within the frame through all years of the survey. Coho salmon and Chinook salmon were often observed in the same reaches and streams. We also found that coho salmon and invasive species largely do not overlap. Trout were found in nearly every stream surveyed except for the mainstem Eel River and a few small tributaries. Since the boundaries of this survey were partly defined by coho anadromy, some trout habitat was not surveyed. Sacramento pikeminnow and California roach, which are not native to the Eel River, were observed in all the mainstem Eel and Van Duzen survey reaches and larger tributary reaches with warm water temperatures ($>20^{\circ}\text{C}$). They were found in smaller cold water streams as well, but in smaller numbers. Sacramento pikeminnow and California roach often occupied habitat that was deemed unsuitable for coho salmon and was not surveyed. Thus the pikeminnow and roach numbers reported here are not comprehensive for these non-native fish species.

2013 Survey

In 2013, 54 randomly selected reaches were surveyed from June 26th to September 20th (Figure 3). Coho salmon were observed in 11 of the 54 reaches surveyed. The majority of coho salmon juveniles were observed in the Lawrence Creek watershed and in Shively Creek. Small numbers of coho were observed in Price Creek, Nanning Creek, Monument Creek, Bear Creek and an unnamed tributary to the Van Duzen River. Unidentified trout YOY were observed in 28 of the 54 reaches surveyed. Age 1+ steelhead trout were observed in 34 of the 54 reaches surveyed. YOY Chinook salmon were observed in 10 of the 54 reaches surveyed. Chinook salmon were found in 11 reaches, mainly in the Yager/Lawrence Creek watershed, but also in Grizzly Creek, Root Creek and the mainstem Van Duzen River. The Chinook salmon found in the mainstem Van Duzen River were likely downstream migrants. Sacramento pikeminnow (*Ptychocheilus grandis*) were observed in 34 of 54 reaches surveyed. California roach (*Lavinia symmetricus*) were observed in 35 of 54 reaches.

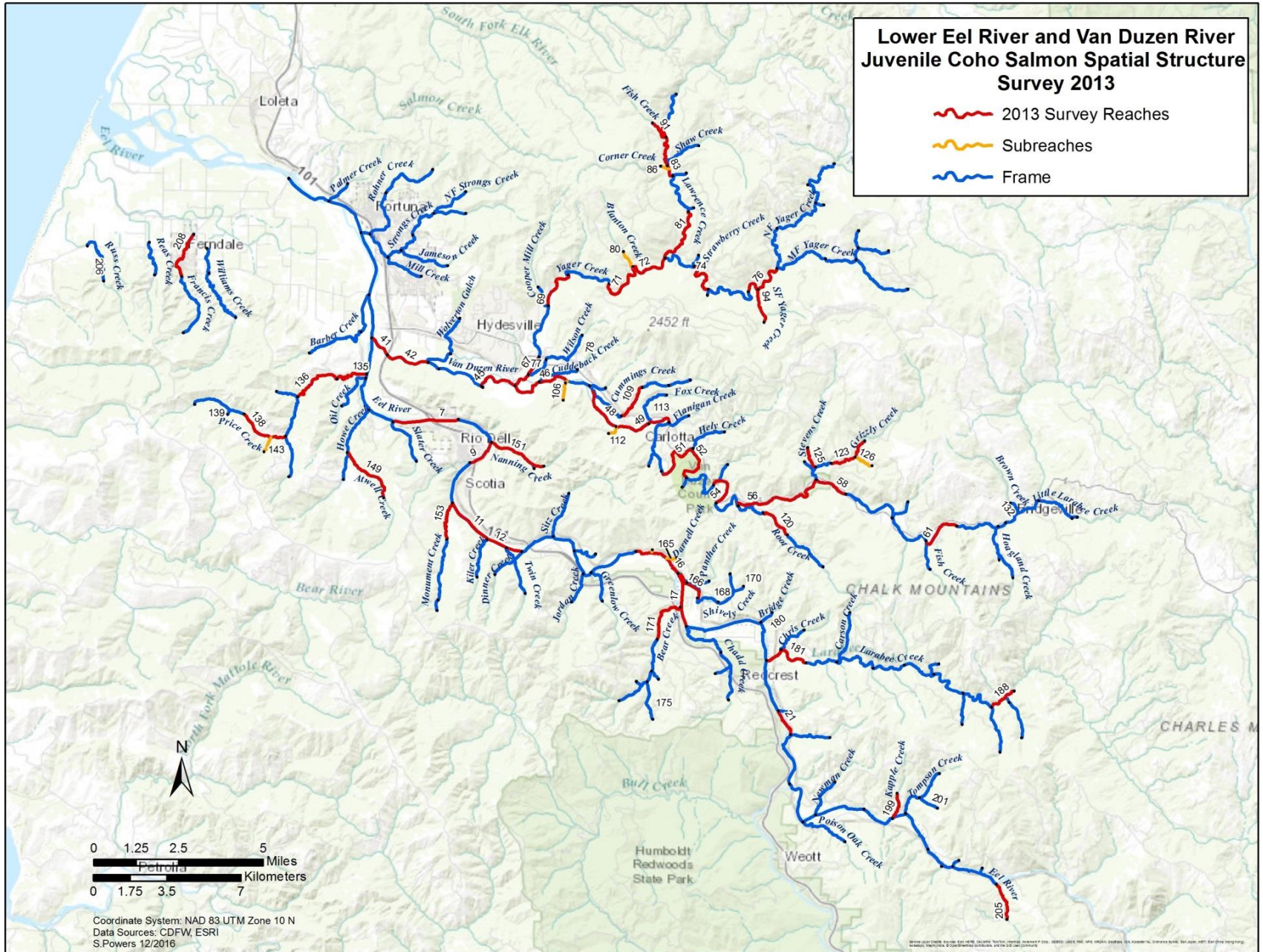


Figure 3. Lower Eel River and Van Duzen River reaches and subreaches surveyed in 2013, Humboldt County, CA.

2014 Survey

In 2014, 59 randomly selected reaches were surveyed from June 12th to September 4th (Figure 4). Coho salmon were observed in 8 of the 59 reaches surveyed, with the majority of coho salmon juveniles observed in Shaw Creek, Chadd Creek and Bear Creek. Small numbers of coho were observed in Lawrence Creek, Root Creek, Howe Creek and Shively Creek. Trout YOY were observed in 38 of the 59 reaches surveyed. Age 1+ steelhead trout were observed in 44 of the 59 reaches surveyed. Unidentified trout were found in every stream surveyed except for Chris Creek and two small unnamed tributaries. Chinook salmon were observed in 6 of the 59 reaches surveyed. Chinook were found in in the Yager/Lawrence Creek watershed, Oil Creek and Chadd Creek. Sacramento pikeminnow were observed in 25 of the 59 reaches. California roach were observed in 17 of the 59 reaches.

2015 Survey

In 2015, 39 randomly selected reaches were surveyed from June 24th to October 2nd (Figure 5). Coho salmon were observed in 3 of the 39 reaches surveyed. They were only found in Shively Creek and Lawrence Creek. The ongoing California drought may have played a role in the limited distribution of coho in 2015. Coho adults may have been excluded from their natal streams due to low flows, and streams that coho juveniles would normally occupy may have dried up. Trout YOY were observed in 31 of the 39 reaches surveyed. Age 1+ steelhead trout were observed in 28 of the 39 reaches surveyed and were found in nearly every stream surveyed except for the mainstem Eel River and a few small tributaries. Chinook were observed in 5 of the 39 reaches surveyed and within 4 stream systems; mainstem Eel River, mainstem Van Duzen River, Stitz Creek and Shively Creek. The Chinook salmon observed in the mainstem Eel River and Van Duzen River were likely downstream migrants. Juvenile Chinook salmon observed in Shively Creek and Stitz Creek would have over-summered as both creeks were dry at their mouths throughout the summer months. Adult cutthroat trout were observed in 5 of the 39 reaches surveyed. They were observed in Fox Creek, Stitz Creek, Russ Creek. Sacramento pikeminnow were observed in 7 of the 39 reaches. California roach were observed in 13 of the 39 reaches. Only four mainstem reaches were surveyed in 2015, thus Sacramento pikeminnow and California roach observations were fewer than previous years.

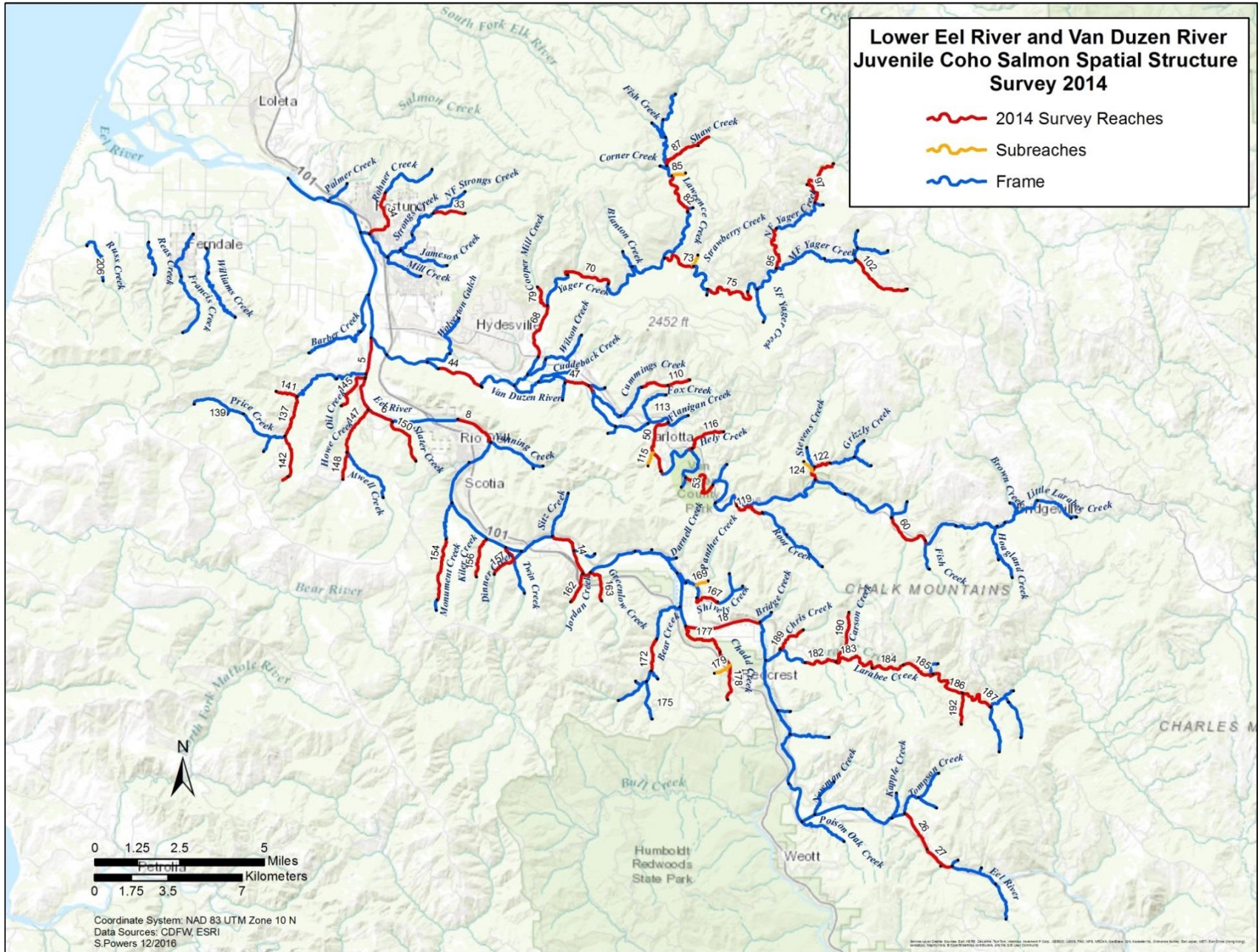


Figure 4. Lower Eel River and Van Duzen River reaches and subreaches surveyed in 2014, Humboldt County, CA.

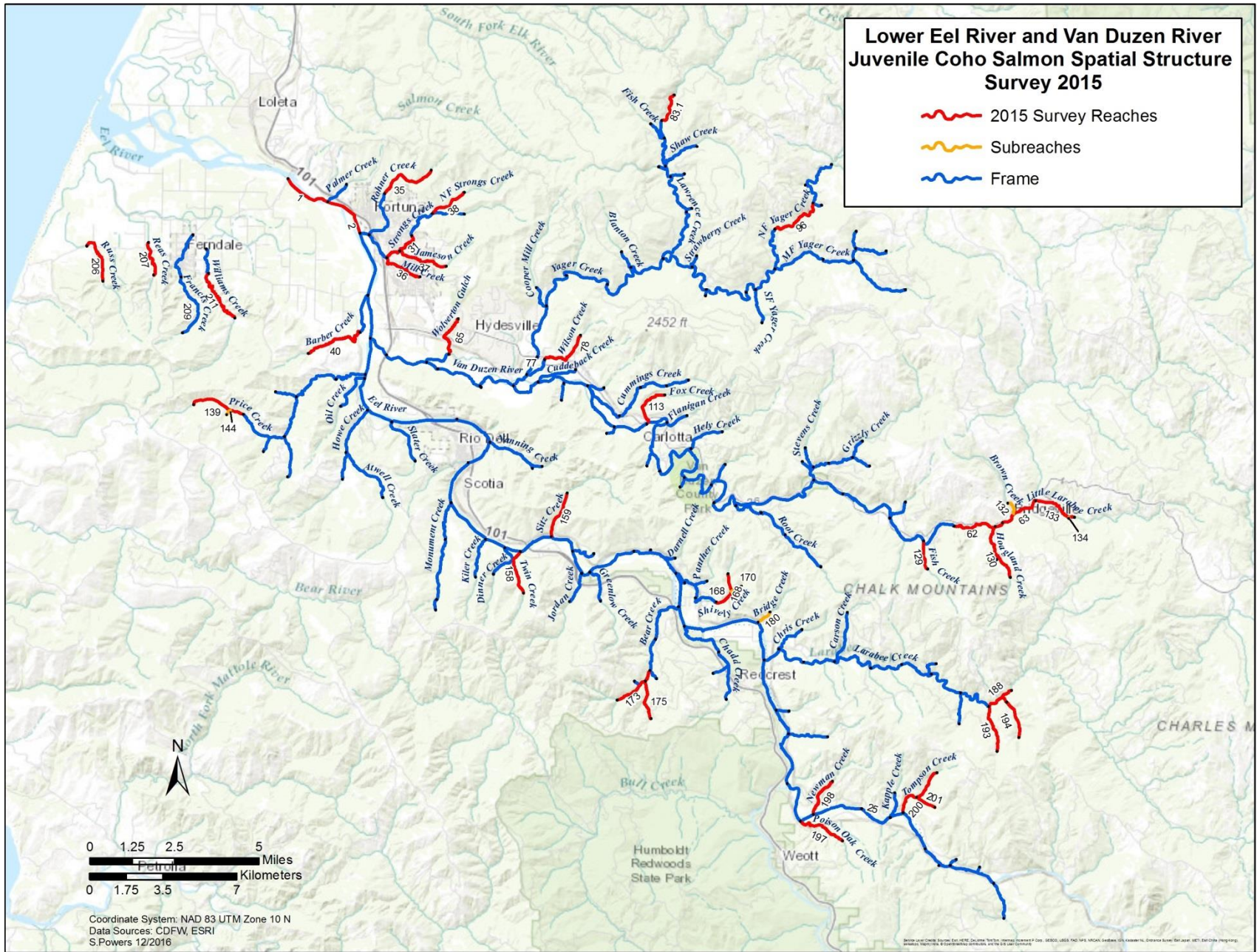


Figure 5. Lower Eel River and Van Duzen River reaches and subreaches in 2015, Humboldt County, CA.

2016 Survey

In 2016, 59 randomly selected reaches were surveyed from June 7th to August 30th (Figure 6). Coho salmon were observed in 5 of the 59 reaches surveyed. They were found in Lawrence Creek, Fish Creek, Monument Creek, and Shively Creek. We also conducted an incidental survey on Bridge Creek and found coho salmon in the most downstream portion of the reach near the Bridge Creek and Eel River confluence. Because juvenile coho were only observed in the most downstream section of Bridge Creek they may be the progeny of spawning that occurred in another Eel River tributary. Trout YOY were observed in 31 of the 59 reaches surveyed. Age 1+ steelhead trout were observed in 31 of the 59 reaches surveyed and were found in nearly every stream surveyed except for the mainstem Eel River and a few small tributaries. Chinook salmon were observed in 3 of the 59 reaches surveyed. They were found in South Fork Yager Creek, Stevens Creek, and Shively Creek. Adult cutthroat trout were observed in 1 of the 59 reaches surveyed and since they were rarely observed, we were not able to determine pool-level occupancy (θ) and the percent of area occupied (PAO). Sacramento pikeminnow were observed in 34 of the 59 reaches. California roach were observed in 32 of the 59 reaches. Sacramento pikeminnow and California roach were mainly found in the mainstem reaches and some of the smaller tributaries.

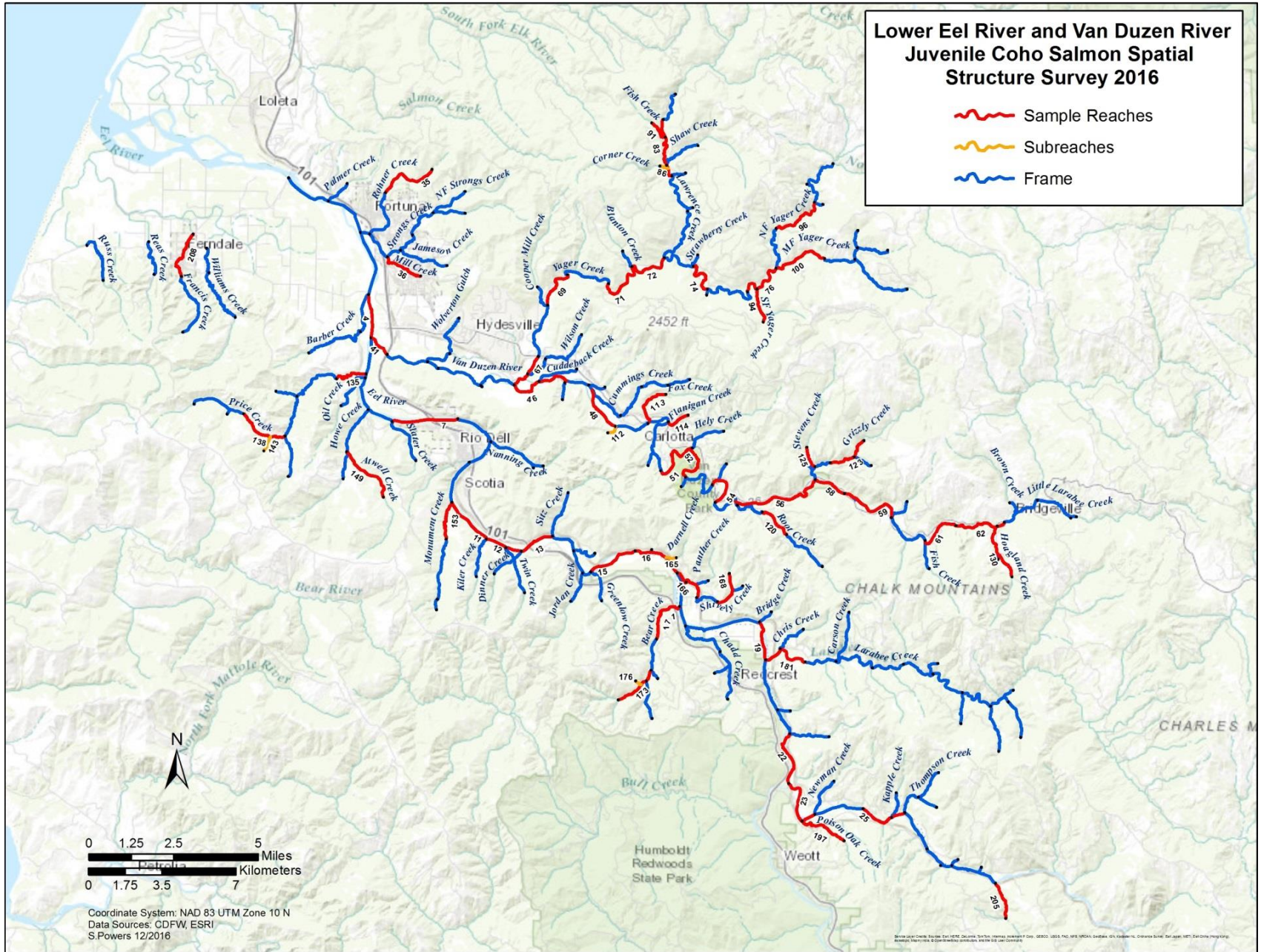


Figure 6. Lower Eel River and Van Duzen River reaches and subreaches in 2016, Humboldt County, CA.

Discussion

Of the 163 GRTS reaches surveyed from 2013 to 2016, coho salmon were present in 22 (13.5%), unidentified trout 116 (71.2%), Chinook salmon 22 (13.5%), Sacramento pikeminnow 79 (48.5%), and California roach 74 (45.4%). The 22 reaches where coho salmon were observed were located in 13 different streams (Figure 7). Out of the 2,755 pools which fell within the suitability parameters (Figure 8), coho salmon were observed in 206 pools (7.5%) (Figure 9), unidentified trout in 1,896 pools (68.8%) (Figure 10), and Chinook salmon in 89 pools (3.2%) (Figure 11) (Table 3). Non-native Sacramento pikeminnow were found in 449 pools (16.3%) (Figure 13), while California roach were found in 432 pools (15.7%) (Figure 14).

Observations from the 2013, 2014, 2015, and 2016 surveys confirm the distribution of coho in the lower Eel River watershed is limited to 3% to 7% of potential available habitat (Figure 9). Coho salmon juveniles were not observed in many of the suitable cold water streams, however, on-going drought conditions that occurred throughout the survey period may have played a role in the limited distribution of coho salmon within the study area. Coho salmon juveniles were observed in a few reach locations where they had not previously or recently been documented such as Price Creek, Monument Creek, and Bridge Creek. Coho salmon were observed in the majority of pools at reach locations in Lawrence Creek watershed, Shively Creek, upper Bear Creek, and Chadd Creek, and these streams are potential source populations for coho recovery in the lower Eel River and Van Duzen River watersheds.

This Project was designed specifically for detecting juvenile coho salmon observations and thus limited information can be gleaned from Chinook salmon observations. Chinook salmon juveniles predominately rear in the Eel River Estuary areas which are not surveyed in this project, yet they were observed in non-estuary tributary habitat sporadically during the four years of this study indicating alternative life-histories are being expressed. The Chinook salmon observed in mainstem channels were likely downstream migrants. Observation of tributary rearing Chinook may be associated with the drought conditions; such as Stevens and Shively creeks where late spring/early summer dry sections likely trapped juveniles prior to their outmigration. Conversely, Chinook salmon found in the Yager Creek/Lawrence Creek basin and in Grizzly Creek were not trapped by dry sections of streams and were found in relatively high numbers. Chinook salmon juveniles were often found in the same reaches and same pools as coho salmon. Habitat improvements geared towards coho salmon in these locations would likely benefit tributary rearing Chinook salmon juveniles as well.

Steelhead/rainbow trout consistently had the highest percent occupancy estimates during the study. Nearly all of the tributaries to the lower Eel River and Van Duzen River had trout present. Mainstem reaches of the lower Eel River and Van Duzen River were not highly occupied by trout, and lower population density is likely due to the higher water temperatures (>20°C) found in the mainstem reaches. The low numbers of trout in the mainstem reaches may also be due to their habitat preferences and space competition with Sacramento pikeminnow and California roach, as well as predation by adult Sacramento pikeminnow. The upstream extents of the sample frame for this study were defined by coho anadromy, thus trout habitat above coho migration barriers was excluded from the study. We also sporadically observed adult summer steelhead throughout these surveys. They were found in Van Duzen River, Yager Creek, Cummings Creek, Larabee Creek, and Eel River.

The non-native Sacramento pikeminnow and California roach were observed in all of the mainstem Eel River and Van Duzen River survey reaches as well as within the larger tributary reaches with the shared commonalities of water temperatures greater than 20°C and having wide stream channels. Juvenile pikeminnow were observed in large schools, numbering in the thousands in the mainstem reaches. Pikeminnow were found in some smaller cold water streams as well, but in much lower numbers. Adult pikeminnow, known to feed on juvenile salmonids and other native fish (Nakamoto 2003), were observed individually and in small schools in the larger mainstem reaches. Sacramento pikeminnow and California roach were by far the most numerous fish species observed during this study, but trout were found to be occupying more pools and more reaches than the non-native species. Project analysis found a wide range of PAO estimates for the non-native species over the four years of the study, and this may be due to the survey frame encompassing all possible coho habitat, with many tributaries that are too steep or cold for pikeminnow and roach. It is also dependent on the proportion of mainstem reaches to tributary reaches that are surveyed each year.

Additional species observed during the survey included the following: American Bullfrog (*Rana catesbeiana*), American Shad (*Alosa sapidissima*), coastal giant salamander (*Dicamptodon tenebrosus*), crayfish spp., foothill yellow-legged frog (*Rana boylei*) freshwater mussel spp., freshwater sponge spp., garter snake (*Thamnophis* spp.), northern red-legged frog (*Rana aurora*), Pacific lamprey (*Entosphenus tridentatus*), resident rainbow trout (*O. mykiss*), rough-skinned newt (*Taricha granulosa*), Sacramento sucker (*Catostomus occidentalis*), sculpin (*Cottus* spp.), sunfish (*Lepomis* spp.), three-spined stickleback (*Gasterosteus aculeatus*), western pond turtle (*Actinemys marmorata*), and western toad (*Anaxyrus boreas*).

Water temperatures were recorded in pools using a hand-held thermometer throughout the reach survey. Maximum water temperatures ranged from 11 to 24°C (Figure 15), with an average of 17.3°C and a median of 17°C. Maximum water temperatures in mainstem reaches (Eel River, Van Duzen River, Yager Creek and Larabee Creek) ranged from 17 to 24°C with an average of 20.2°C and a median of 20°C. Maximum water temperatures in all other streams ranged from 11 to 22.5°C, with an average of 15.5°C and a median of 15.5°C.

Tables and Figures

Table 1. Occupancy estimates, proportion of area occupied, and relative count densities of salmonids, for all years.

Summer 2013													
Species	PSI	SE	95% CI	Theta	SE	95% CI	<i>p</i>	SE	95% CI	PAO	# of Reaches present	Mean pool count	Median pool count
Coho Salmon	0.25	0.07	0.14 - 0.40	0.27	0.03	0.21 - 0.34	0.89	0.03	0.82 - 0.94	0.07	11 of 55	11.5	4
Chinook Salmon	0.19	0.06	0.10 - 0.34	0.33	0.04	0.26 - 0.42	0.68	0.06	0.56 - 0.79	0.06	10 of 55	2.4	2
YOY Trout spp.	0.52	0.07	0.39 - 0.66	0.82	0.02	0.78 - 0.85	0.95	0.01	0.94 - 0.97	0.43	28 of 55	18.6	14
1+ Trout spp.	0.66	0.07	0.52 - 0.78	0.70	0.02	0.66 - 0.74	0.79	0.02	0.76 - 0.83	0.46	34 of 55	4.7	3
Summer 2014													
Coho Salmon	0.15	0.05	0.08 - 0.27	0.49	0.05	0.40 - 0.57	0.88	0.05	0.74 - 0.95	0.07	8 of 59	9.0	4
Chinook Salmon	0.32	0.17	0.09 - 0.69	0.06	0.04	0.02 - 0.21	0.51	0.23	0.15 - 0.86	0.02	6 of 59	5.2	3
YOY Trout spp.	0.68	0.06	0.54 - 0.79	0.66	0.02	0.61 - 0.70	0.93	0.02	0.89 - 0.96	0.45	38 of 59	17.5	11
1+ Trout spp.	0.80	0.06	0.67 - 0.89	0.64	0.03	0.58 - 0.69	0.84	0.03	0.78 - 0.89	0.51	44 of 59	6.0	3
Summer 2015													
Coho Salmon	0.09	0.05	0.03 - 0.24	0.31	0.06	0.21 - 0.43	0.86	0.09	0.57 - 0.97	0.03	3 of 39	5.5	3
Chinook Salmon	0.15	0.06	0.06 - 0.32	0.34	0.11	0.16 - 0.58	0.53	0.16	0.25 - 0.80	0.05	5 of 39	1.8	1
YOY Trout spp.	0.82	0.06	0.66 - 0.92	0.65	0.02	0.60 - 0.69	0.92	0.02	0.87 - 0.95	0.53	31 of 39	19.2	6
1+ Trout spp.	0.76	0.07	0.59 - 0.87	0.65	0.03	0.59 - 0.70	0.83	0.03	0.77 - 0.88	0.49	28 of 39	5.3	2
Adult Cutthroat Trout	0.15	0.06	0.06 - 0.32	0.34	0.11	0.16 - 0.58	0.53	0.16	0.25 - 0.80	0.05	5 of 39	1.8	1
Summer 2016													
Coho Salmon	0.12	0.05	0.05 - 0.25	0.33	0.06	0.22 - 0.46	0.73	0.11	0.48 - 0.89	0.04	5 of 59	8.3	3
Chinook Salmon	0.13	0.06	0.03 - 0.31	0.08	0.04	0.03 - 0.20	0.57	Fixed ¹	Fixed ¹	0.01	3 of 59	1.7	2
YOY Trout spp.	0.56	0.07	0.43 - 0.69	0.84	0.02	0.80 - 0.87	0.95	0.01	0.92 - 0.97	0.47	31 of 59	17.4	13
1+ Trout spp.	0.60	0.08	0.45 - 0.74	0.67	0.03	0.60 - 0.74	0.77	0.03	0.69 - 0.83	0.46	31 of 59	2.3	2
Adult Cutthroat Trout	0.02	0.02	<0.01 - 0.13	NA	NA	NA	0.53	Fixed ¹	Fixed ¹	NA	1 of 59	1.4	1

PSI - The probability a species is detected in a given reach for the survey year.

Theta - The probability that 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 x Theta) Overall occupancy value; incorporates reach-level- and pool-level occupancy for the entire sample frame in a given year.

¹Due to observations being extremely rare in 2016, detection probabilities could not be estimated for these species. Detection was fixed to the mean estimated value from the previous 4 years of surveys.

Table 2. Occupancy estimates, proportion of area occupied, and relative count densities of invasive species, Sacramento pikeminnow, and California roach for all years.

Summer 2013													
Species	PSI	SE	95% CI	Theta	SE	95% CI	<i>p</i>	SE	95% CI	PAO	# of Reaches present	Mean pool count ¹	Median pool count ¹
Sacramento pikeminnow	0.67	0.07	0.54 - 0.79	0.49	0.03	0.44 - 0.54	0.95	0.01	0.92 - 0.97	0.33	35 of 55	9.3	6
California Roach	0.66	0.07	0.52 - 0.78	0.50	0.03	0.45 - 0.55	0.95	0.01	0.93 - 0.97	0.33	34 of 55	31.0	24
Summer 2014													
Sacramento pikeminnow	0.30	0.06	0.19 - 0.43	0.48	0.05	0.39 - 0.57	1.00	–	–	0.14	17 of 59	58.1	8
California Roach	0.43	0.07	0.31 - 0.56	0.66	0.04	0.59 - 0.73	0.99	0.01	0.91 - 1.00	0.28	24 of 59	342.2	50
Summer 2015													
Sacramento pikeminnow	0.38	0.08	0.23 - 0.55	0.28	0.03	0.22 - 0.35	0.89	0.05	0.76 - 0.96	0.11	12 of 39	146.0	44
California Roach	0.19	0.07	0.10 - 0.36	0.37	0.05	0.28 - 0.48	0.94	0.04	0.81 - 0.99	0.07	7 of 39	121.0	37
Summer 2016													
Sacramento pikeminnow	0.60	0.07	0.47 - 0.72	0.38	0.04	0.31 - 0.45	0.87	0.04	0.76 - 0.94	0.23	34 of 59	49.0	12.5
California Roach	0.58	0.07	0.44 - 0.70	0.58	0.04	0.50 - 0.66	0.88	0.04	0.78 - 0.93	0.34	32 of 59	78.5	40

PSI - The probability a species is detected in a given reach for the survey year.

Theta - The probability that 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 x Theta) Overall occupancy value; incorporates reach-level- and pool-level occupancy for the entire sample frame in a given year.

¹Mean and median pool counts for pikeminnow and roach in 2013 and 2014 are estimates since they were marked present instead of counted in some surveys.

Table 3. Reaches completed with year surveyed, total number of pools, and number of pools with juvenile coho, unidentified trout, and/or Chinook observed.

Stream Name	Reach Code	Year	Total No. of Pools Surveyed	No. of Pools with Coho	No. of Pools with Trout spp.	No. of Pools with Chinook
Eel River	1	2015	5	0	0	0
Eel River	2	2015	4	0	0	2
Eel River	4	2016	2	0	0	0
Eel River	5	2014	1	0	0	0
Eel River	6	2014	4	0	0	1
Eel River	7	2013	18	0	0	0
Eel River	7	2016	1	0	0	0
Eel River	8	2014	3	0	0	0
Eel River	9	2013	4	0	0	0
Eel River	11	2013	2	0	0	0
Eel River	11	2016	13	0	0	0
Eel River	12	2013	1	0	0	0
Eel River	12	2016	1	0	0	0
Eel River	13	2016	1	0	0	0
Eel River	14	2014	5	0	0	0
Eel River	15	2016	2	0	0	0
Eel River	16	2013	7	0	0	0
Eel River	16	2016	1	0	0	0
Eel River	17	2013	1	0	0	0
Eel River	18	2014	3	0	0	0
Eel River	19	2016	8	0	0	0
Eel River	21	2013	3	0	0	0
Eel River	22	2016	1	0	0	0
Eel River	23	2016	1	0	0	0
Eel River	25	2016	2	0	0	0
Eel River	26	2014	7	0	0	0
Eel River	27	2014	5	0	0	0
Strongs Creek	31	2015	12	0	1	0
Strongs Creek	33	2014	7	0	5	0
Rohner Creek	34	2014	2	0	0	0
Rohner Creek	35	2015	35	0	0	0
Rohner Creek	35	2016	10	0	0	0
Mill Creek	36	2015	25	0	22	0
Mill Creek	36	2016	26	0	24	0
Jameson Creek	37	2015	9	0	0	0
North Fork Strongs Creek	38	2015	31	0	5	0
Barber Creek	40	2015	4	0	0	0
Van Duzen River	41	2013	4	0	1	1
Van Duzen River	41	2016	1	0	0	0
Van Duzen River	42	2013	7	0	2	1

Stream Name	Reach Code	Year	Total No. of Pools Surveyed	No. of Pools with Coho	No. of Pools with Trout spp.	No. of Pools with Chinook
Van Duzen River	44	2014	5	0	1	0
Van Duzen River	45	2013	8	0	4	0
Van Duzen River	46	2013	7	0	4	0
Van Duzen River	46	2016	3	0	0	0
Van Duzen River	47	2014	4	0	1	0
Van Duzen River	48	2013	15	0	4	1
Van Duzen River	48	2016	4	0	0	0
Van Duzen River	49	2013	8	0	3	0
Van Duzen River	50	2014	1	0	0	0
Van Duzen River	51	2013	5	0	0	0
Van Duzen River	51	2016	3	0	0	0
Van Duzen River	52	2013	3	0	0	0
Van Duzen River	52	2016	2	0	0	0
Van Duzen River	53	2014	4	0	0	0
Van Duzen River	54	2013	7	0	0	0
Van Duzen River	54	2016	1	0	0	0
Van Duzen River	56	2013	6	0	1	0
Van Duzen River	56	2016	3	0	1	0
Van Duzen River	58	2013	8	0	0	0
Van Duzen River	58	2016	1	0	0	0
Van Duzen River	59	2016	2	0	0	0
Van Duzen River	60	2014	1	0	0	0
Van Duzen River	61	2013	1	0	0	0
Van Duzen River	61	2016	1	0	0	0
Van Duzen River	62	2015	13	0	6	0
Van Duzen River	62	2016	1	0	1	0
Van Duzen River	63	2015	10	0	6	2
Wolverton Gulch	65	2015	61	0	41	0
Yager Creek	67	2013	2	0	0	0
Yager Creek	67	2016	7	0	0	0
Yager Creek	68	2014	7	0	5	0
Yager Creek	69	2013	6	0	0	0
Yager Creek	69	2016	2	0	0	0
Yager Creek	70	2014	2	0	2	1
Yager Creek	71	2013	3	0	1	0
Yager Creek	71	2016	3	0	1	0
Yager Creek	72	2013	15	1	14	6
Yager Creek	72	2016	5	0	4	0
Yager Creek	73	2014	7	0	4	0
Yager Creek	74	2013	16	0	10	2
Yager Creek	74	2016	9	0	7	0
Yager Creek	75	2014	16	0	14	0
Yager Creek	76	2013	11	0	10	0
Yager Creek	76	2016	11	0	10	0

Stream Name	Reach Code	Year	Total No. of Pools Surveyed	No. of Pools with Coho	No. of Pools with Trout spp.	No. of Pools with Chinook
Wilson Creek	78	2015	36	0	27	0
Cooper Mill Creek	79	2014	19	0	17	0
Blanton Creek	80	2013	7	0	7	0
Lawrence Creek	81	2013	19	17	19	12
Lawrence Creek	82	2014	15	3	15	1
Lawrence Creek	83	2013	26	19	25	16
Lawrence Creek	83	2016	22	8	21	0
Lawrence Creek	83.1	2015	30	7	30	0
Tributary to Lawrence Creek	85	2014	5	0	0	0
Corner Creek	86	2013	7	0	4	0
Corner Creek	86	2016	8	0	5	0
Shaw Creek	87	2014	46	41	46	0
Fish Creek	91	2013	11	4	10	0
Fish Creek	91	2016	23	16	16	0
Strawberry Creek	92	2014	20	0	20	0
South Fork Yager Creek	94	2013	36	0	36	1
South Fork Yager Creek	94	2016	42	0	42	2
North Fork Yager Creek	95	2014	13	0	8	0
North Fork Yager Creek	96	2015	9	0	4	0
North Fork Yager Creek	96	2016	13	0	13	0
North Fork Yager Creek	97	2014	16	0	16	0
Middle Fork Yager Creek	100	2016	25	0	24	0
Middle Fork Yager Creek	102	2014	7	0	6	0
Tributary to Van Duzen River	106	2013	1	0	0	0
Cummings Creek	109	2013	35	0	34	0
Cummings Creek	110	2014	10	0	5	0
Tributary to Van Duzen River	112	2013	11	2	0	0
Tributary to Van Duzen River	112	2016	8	0	0	0
Fox Creek	113	2015	7	0	3	0
Fox Creek	113	2016	23	0	4	0
Flanigan Creek	114	2016	6	0	0	0
Tributary to Van Duzen River	115	2014	1	0	1	0
Hely Creek	116	2014	23	0	22	0
Tributary to Van Duzen River	117	2013	5	0	0	0
Root Creek	119	2014	13	4	10	0
Root Creek	120	2013	15	0	14	0
Root Creek	120	2016	37	0	34	0
Grizzly Creek	122	2014	12	0	12	0
Grizzly Creek	123	2013	27	0	27	13

Stream Name	Reach Code	Year	Total No. of Pools Surveyed	No. of Pools with Coho	No. of Pools with Trout spp.	No. of Pools with Chinook
Grizzly Creek	123	2016	30	0	30	0
Tributary to Grizzly Creek	124	2014	6	0	3	0
Stevens Creek	125	2013	17	0	17	0
Stevens Creek	125	2016	15	0	15	1
Tributary to Grizzly Creek	126	2013	6	0	0	0
Fish Creek	129	2015	25	0	24	0
Hoagland Creek	130	2015	9	0	7	0
Hoagland Creek	130	2016	11	0	11	0
Tributary to Van Duzen River	132	2015	5	0	3	0
Little Larabee Creek	133	2015	30	0	29	0
Tributary to Little Larabee Creek	134	2015	2	0	1	0
Price Creek	135	2013	15	1	15	0
Price Creek	135	2016	14	0	14	0
Price Creek	136	2013	18	1	18	0
Price Creek	137	2014	10	0	10	0
Price Creek	138	2013	32	0	32	0
Price Creek	138	2016	37	0	37	0
Price Creek	139	2015	43	0	41	0
Tributary to Price Creek	141	2014	10	0	6	0
Sweet Creek	142	2014	12	0	7	0
Unnamed Tributary to Price Creek	143	2013	5	0	5	0
Unnamed Tributary to Price Creek	143	2016	11	0	11	0
Tributary to Price Creek	144	2015	2	0	0	0
Oil Creek	145	2014	33	0	18	4
Howe Creek	147	2014	12	1	12	0
Howe Creek	148	2014	28	0	27	0
Atwell Creek	149	2013	16	0	16	0
Atwell Creek	149	2016	50	0	48	0
Slater Creek	150	2014	9	0	6	0
Nanning Creek	151	2013	31	1	23	0
Monument Creek	153	2013	26	4	26	0
Monument Creek	153	2016	25	4	18	0
Monument Creek	154	2014	32	0	20	0
Kiler Creek	156	2014	25	0	14	0
Dinner Creek	157	2014	4	0	2	0
Twin Creek	158	2015	25	0	24	0
Stitz Creek	159	2015	7	0	3	1
Jordan Creek	162	2014	9	0	9	0
Greenlow Creek	163	2014	7	0	3	0
Tributary to Eel River	164	2013	2	0	0	0
Darnell Creek	165	2013	6	0	0	0

Stream Name	Reach Code	Year	Total No. of Pools Surveyed	No. of Pools with Coho	No. of Pools with Trout spp.	No. of Pools with Chinook
Darnell Creek	165	2016	1	0	0	0
Shively Creek	166	2013	21	11	17	0
Shively Creek	166	2016	13	4	8	0
Shively Creek	167	2014	24	3	3	0
Shively Creek	168	2015	49	17	40	12
Shively Creek	168	2016	41	1	37	4
Panther Creek	169	2014	11	0	1	0
Tributary to Shively Creek	170	2015	14	2	7	1
Bear Creek	171	2013	30	1	29	0
Bear Creek	171	2016	31	0	31	0
Bear Creek	172	2014	24	21	24	0
Bear Creek	173	2015	6	0	6	0
Bear Creek	173	2016	18	0	18	0
Tributary to Bear Creek	175	2015	2	0	2	0
Tributary to Bear Creek	175	2016	4	0	4	0
Unnamed Tributary to Bear Creek	176	2016	6	0	5	0
Chadd Creek	177	2014	21	6	17	1
Chadd Creek	178	2014	49	6	30	1
Tributary to Chadd Creek	179	2014	9	0	1	0
Bridge Creek	180	2015	19	0	1	0
Larabee Creek	181	2013	14	0	6	0
Larabee Creek	181	2016	10	0	1	0
Larabee Creek	182	2014	4	0	3	0
Larabee Creek	183	2014	18	0	4	0
Larabee Creek	184	2014	9	0	1	0
Larabee Creek	185	2014	16	0	10	0
Larabee Creek	186	2014	9	0	9	0
Larabee Creek	187	2014	9	0	5	0
Larabee Creek	188	2015	11	0	10	0
Chris Creek	189	2014	9	0	0	0
Carson Creek	190	2014	19	0	9	0
Tributary to Larabee Creek	192	2014	3	0	0	0
Tributary to Larabee Creek	193	2015	10	0	6	0
Tributary to Larabee Creek	194	2015	5	0	3	0
Poison Oak Creek	197	2015	6	0	5	0
Poison Oak Creek	197	2016	8	0	0	0
Newman Creek	198	2015	27	0	24	0
Kapple Creek	199	2013	7	0	4	0
Thompson Creek	200	2015	30	0	25	0
Tributary to Thompson Creek	201	2015	7	0	2	0

Stream Name	Reach Code	Year	Total No. of Pools Surveyed	No. of Pools with Coho	No. of Pools with Trout spp.	No. of Pools with Chinook
Sonoma Creek	205	2013	17	0	17	2
Sonoma Creek	205	2016	26	0	21	0
Russ Creek	206	2015	38	0	34	0
Reas Creek	207	2015	23	0	9	0
Francis Creek	208	2013	12	0	7	0
Francis Creek	208	2016	14	0	3	0
Williams Creek	211	2015	11	0	0	0
Totals:	211		2755	206	1896	89

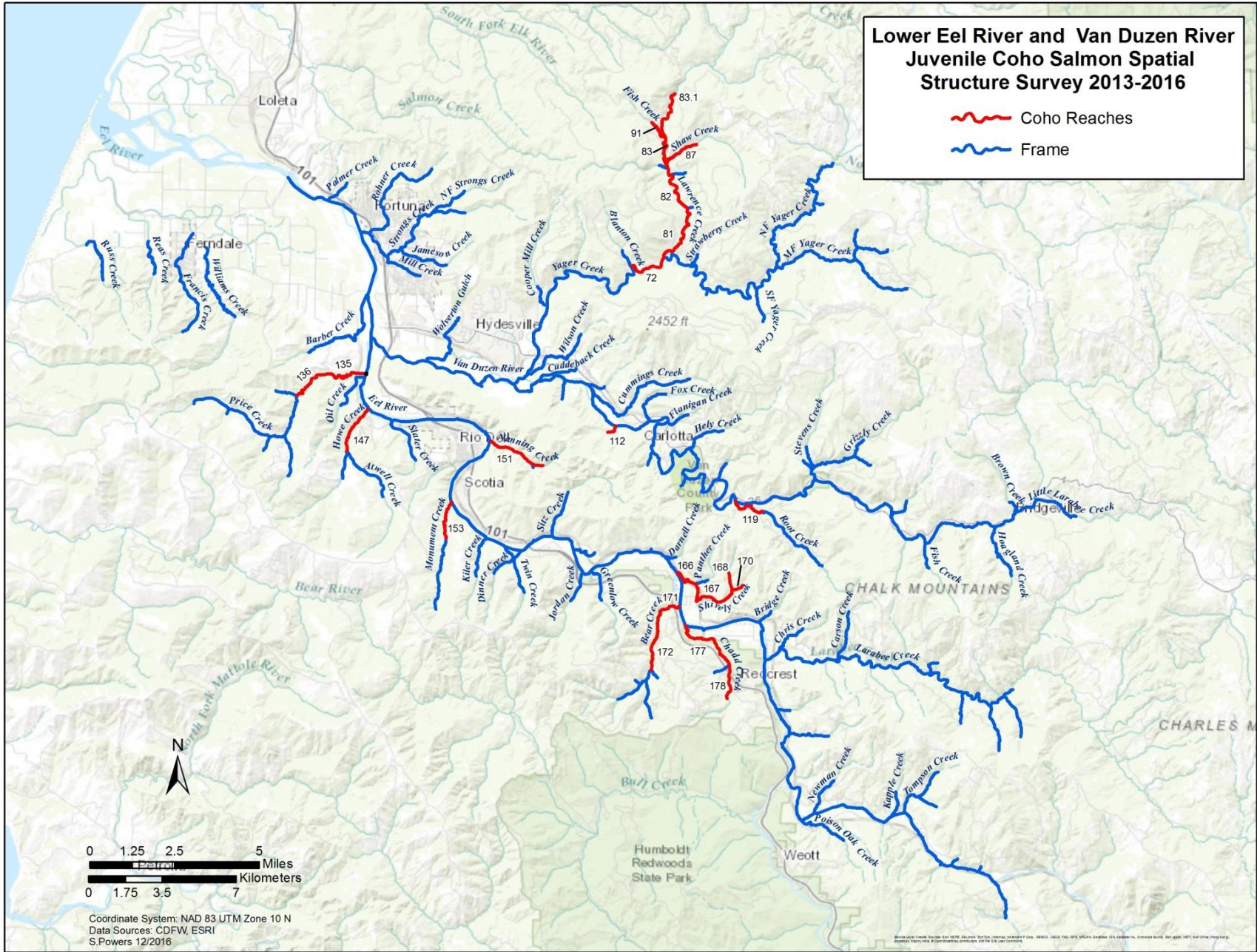


Figure 7. Lower Eel River and Van Duzen River reaches with coho salmon observations (2013-2016), Humboldt County, CA.

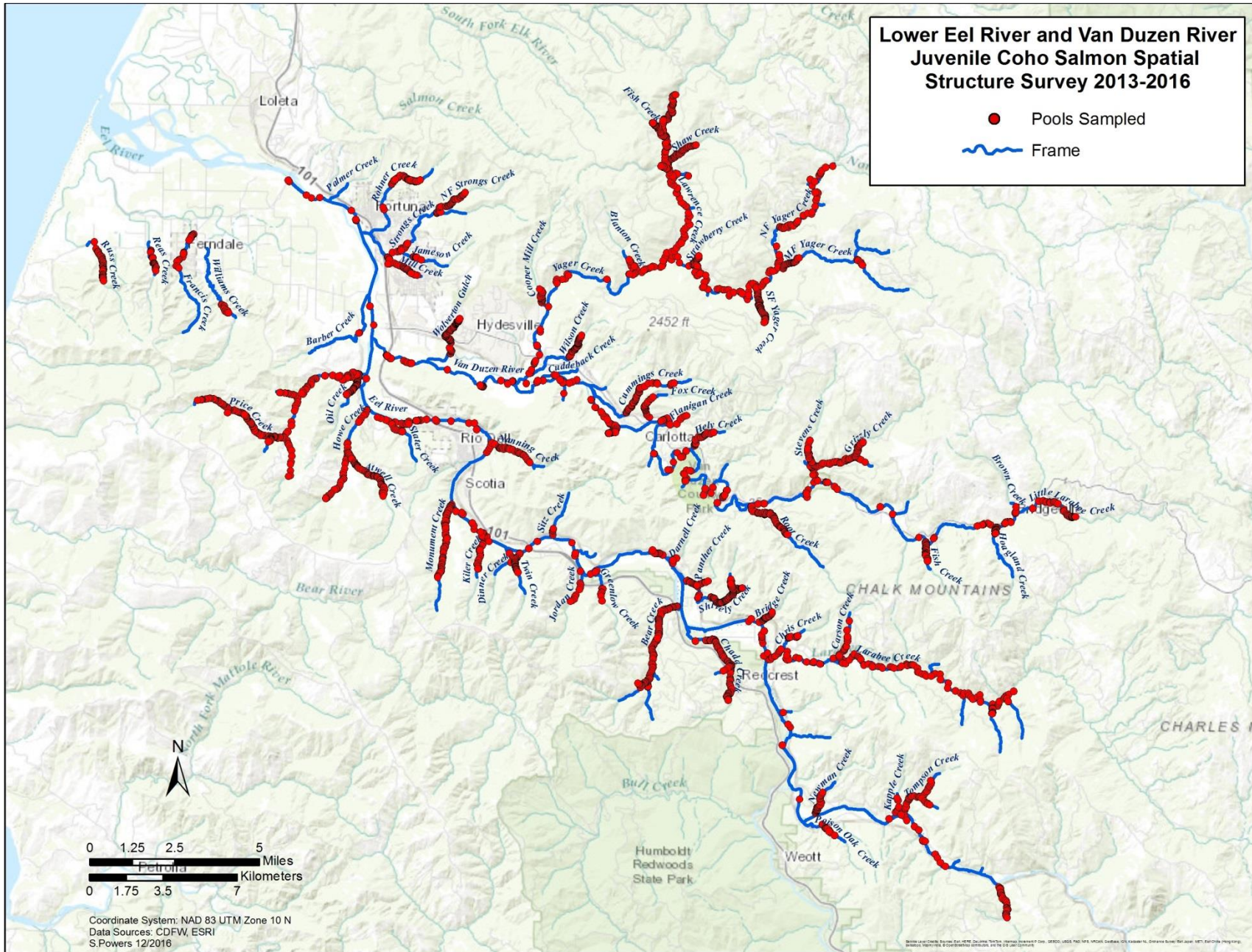


Figure 8. Locations of pools surveyed in the Lower Eel River and Van Duzen River (2013-2016), Humboldt County, CA.

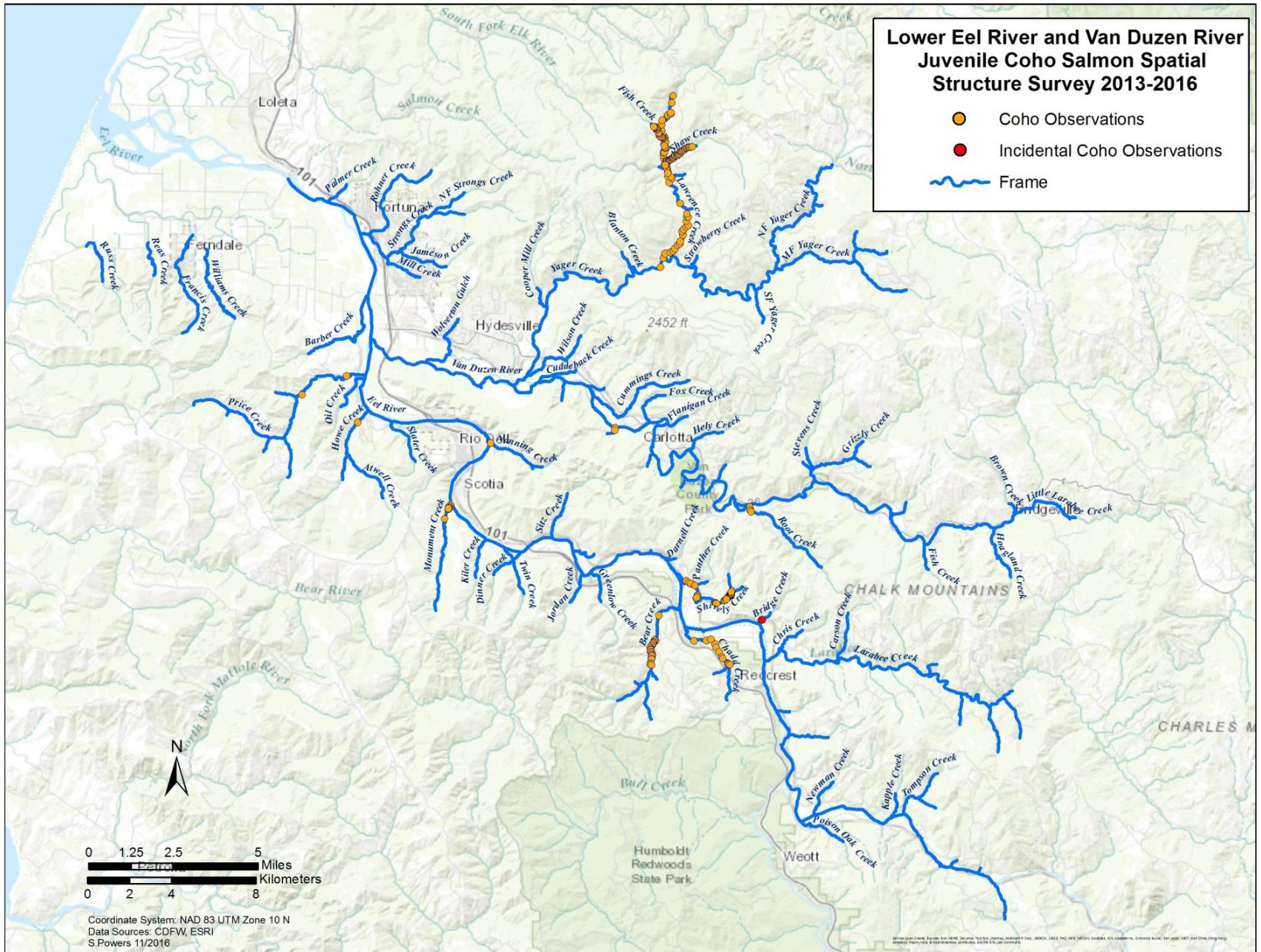


Figure 9. Pools with juvenile coho salmon observations in the Lower Eel River and Van Duzen River (2013-2016), Humboldt County, CA.

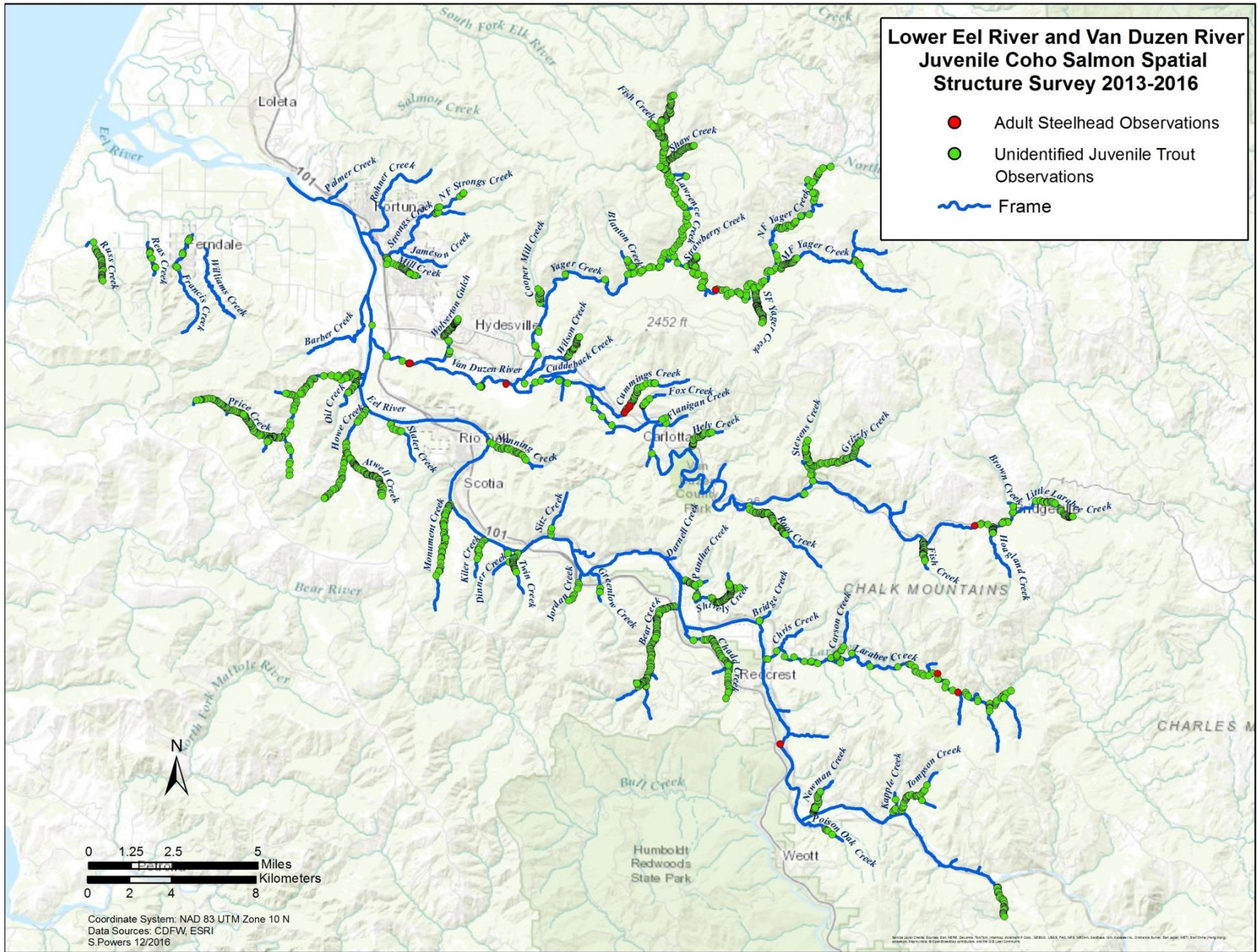


Figure 10. Pools with juvenile trout and adult steelhead observations in the Lower Eel River and Van Duzen River (2013-2016), Humboldt County, CA.

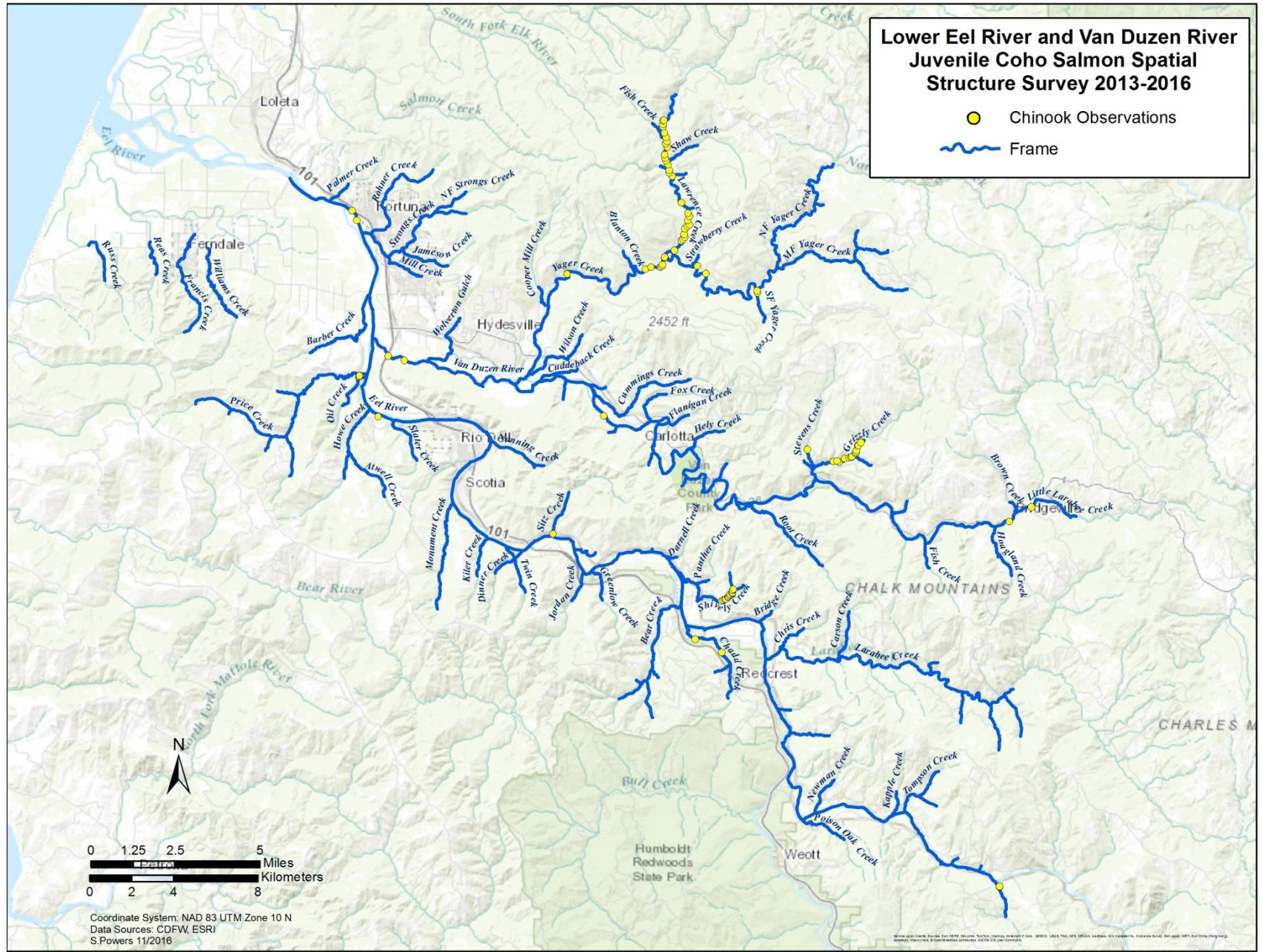


Figure 11. Pools with juvenile Chinook salmon observations in the Lower Eel River and Van Duzen River (2013-2016), Humboldt County, CA.

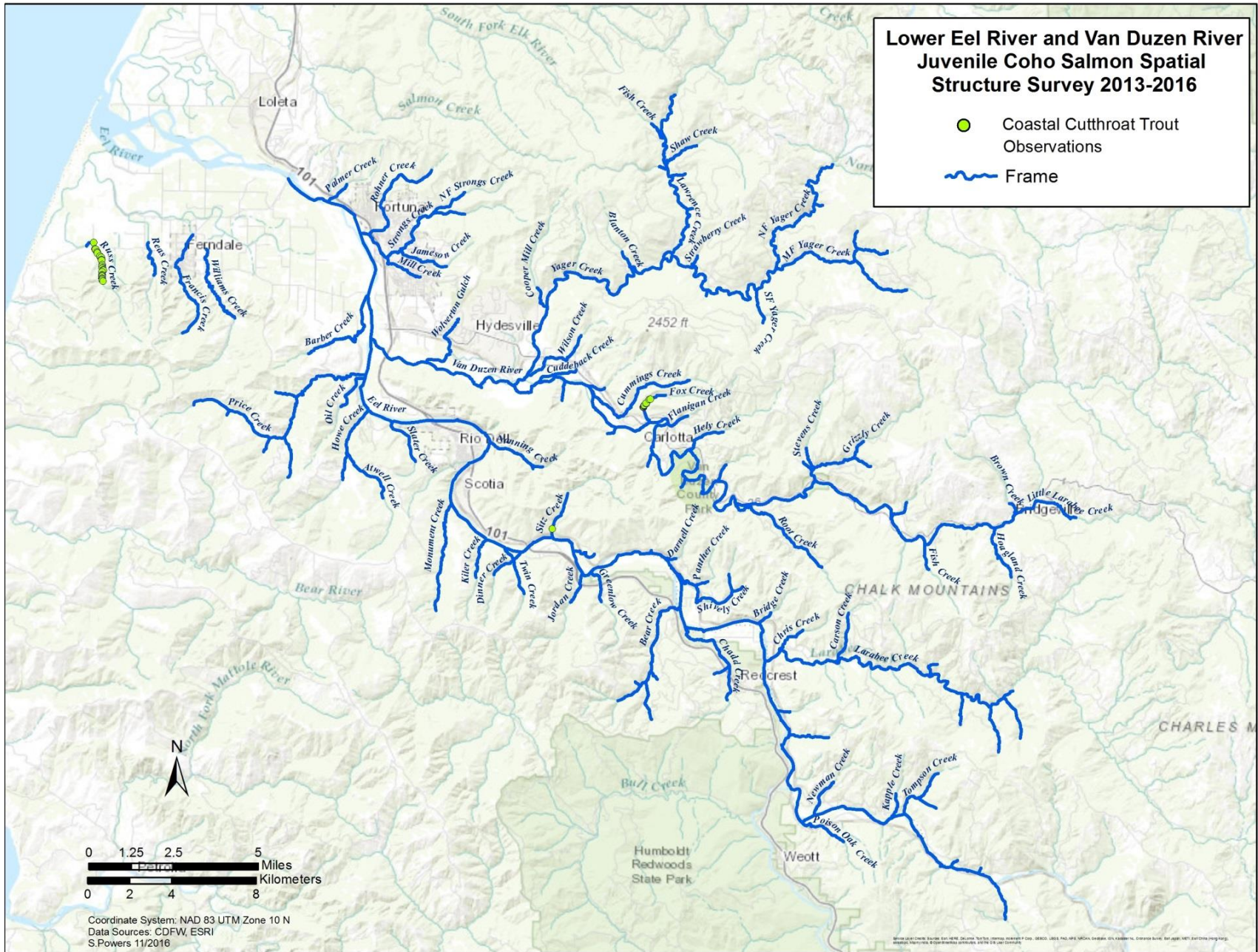


Figure 12. Pools with coastal cutthroat trout observations in the Lower Eel River and Van Duzen River (2013-2016), Humboldt County, CA.

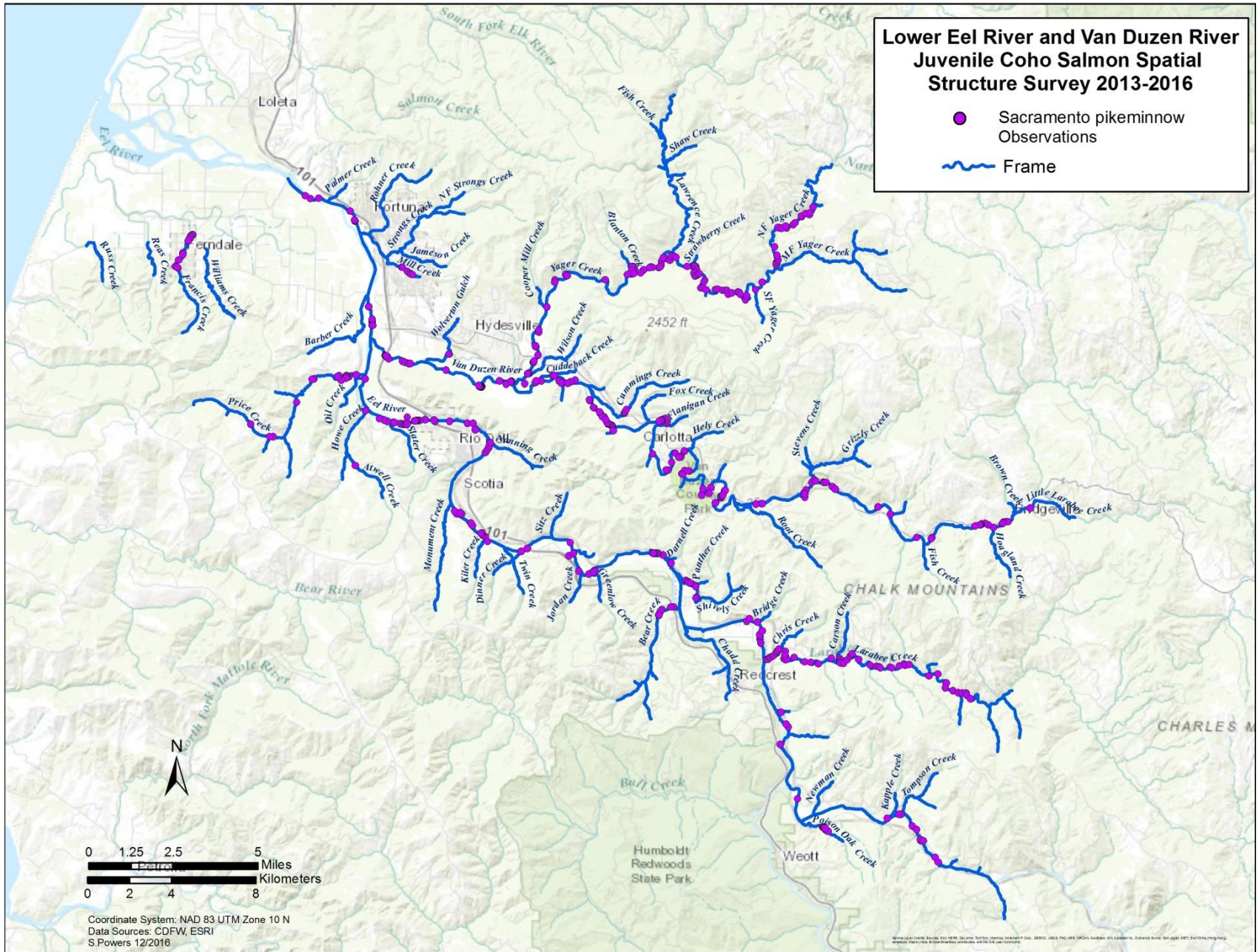


Figure 13. Pools with Sacramento pikeminnow observations in the Lower Eel River and Van Duzen River (2013-2016), Humboldt County, CA.

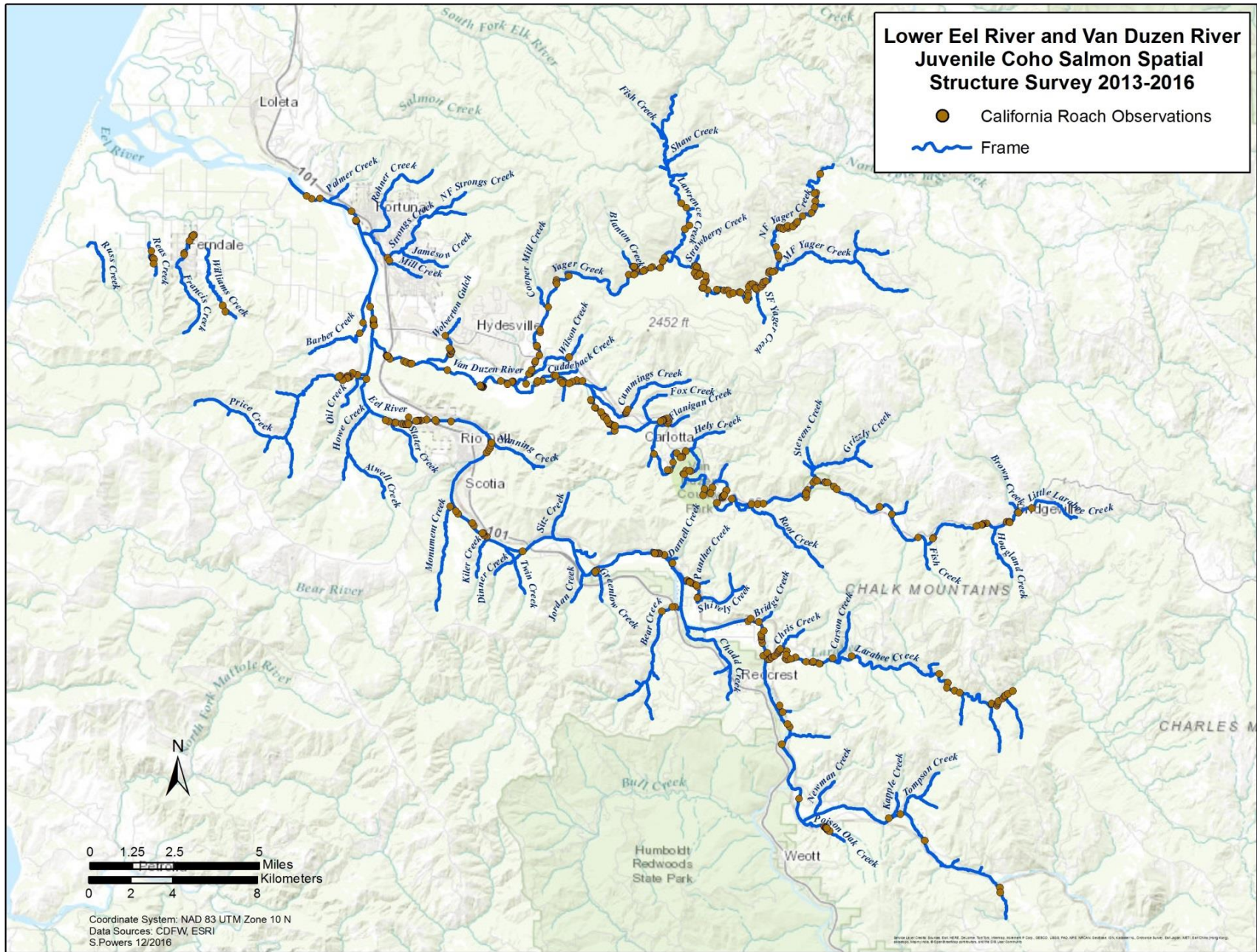


Figure 14. Pools with California roach observations in the Lower Eel River and Van Duzen River (2013-2016), Humboldt County, CA.

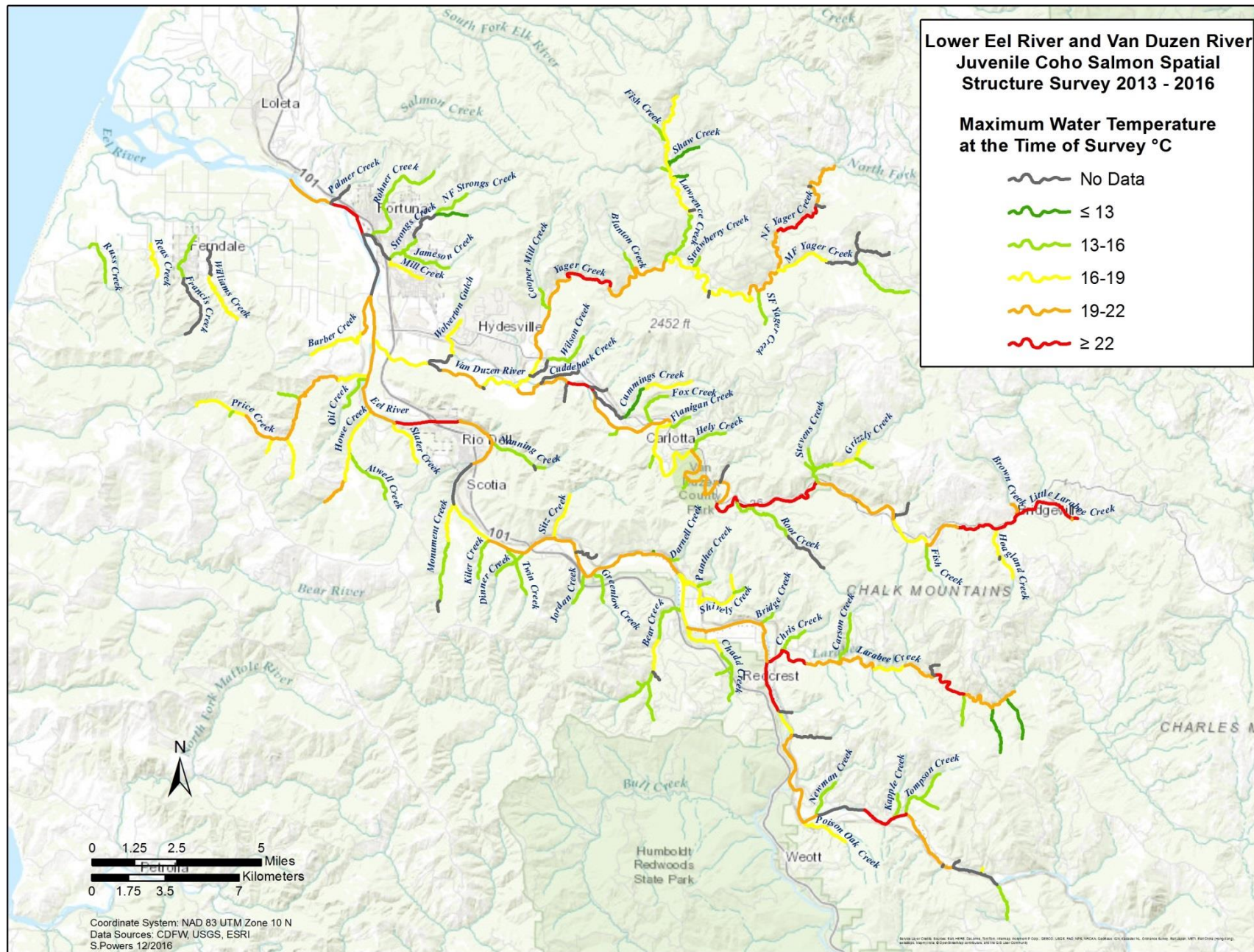


Figure 15. Maximum water temperatures in each reach recorded at time of snorkel survey (2013-2016), Humboldt County, CA.

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