Spawner survey sample frame development for monitoring adult salmonid populations in California.

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Introduction

We developed a procedure for constructing an unbiased reach-based sampling frame using a geographic information system (GIS) specifically for adult salmonid spawner ground surveys within Chinook and coho salmon and anadromous steelhead spawning distributions. This procedure provides a methodology for generating a sample frame of defined stream reaches in a systematic process that is readily reproducible for any salmonid population. For example, in order to assess salmonid species status and trends, each species needs to be assessed primarily at the population level (CDFG 2004, Boydstun and McDonald 2005, Williams et al. 2006, Williams et al. 2008). In order to meet recovery goals outlined in the federal Endangered Species Act, each species needs to be assessed across multiple populations throughout an Evolutionary Significant Unit (ESU) (Williams et al. 2008). These species assessment criteria require species monitoring information to be consistent between populations. Given the large geographic extents of most salmonid ESU's, this procedure allows separate salmonid population monitoring groups to develop comparable sampling frames.

Using a simple set of inclusion rules, we take full advantage documented salmonid distributions, expert knowledge and migration barrier data, while applying stream gradient and stream size thresholds to identify potential distribution for inclusion where salmonid distributions are unknown. Sampling frames were developed and validated specifically for the Humboldt Bay and Redwood Creek independent salmonid population units in the central and southern diversity strata as defined by NOAA fisheries (Williams et al. 2006). These two population units were identified by DFG and NOAA as critical monitoring units for tracking long-term salmonid population status and trend information (DFG 2004, Williams et al. 2008).

Development of an Unbiased Sampling Frame

We used five systematic steps in a GIS to develop unbiased salmonid spawning distributions for the Humboldt Bay and Redwood Creek population units (Fig. 1.). Data were derived from

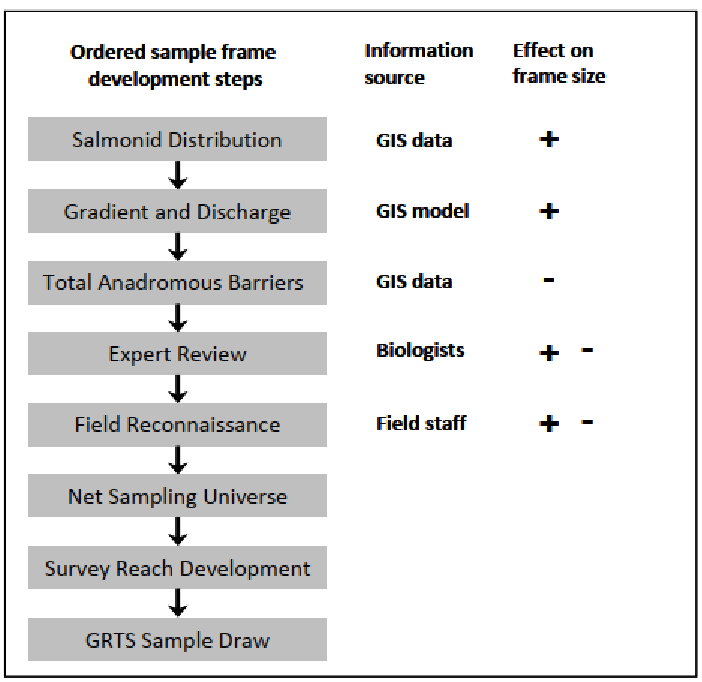

Figure 1. Ordered steps for developing an unbiased population-level sampling frame for salmonid spawning ground surveys.

sources defined in Appendix A. Each of the five development steps are outlined in detail below.

Known Salmonid Distributions

The first step in defining species distribution was to collect comprehensive regional distribution datasets for the three target species. We used a GIS data set of ordinal coordinates of presence of coho and Chinook salmon (Appendix A). Juvenile trout observations were not used to define distribution due to the occurrence of non-anadromous populations of fish found above barriers to anadromy and our inability to distinguish the life history of fish from these data. This GIS data included information available from historic reports and contemporary observations.

Criteria for Potential Salmonid Distribution

To determine values of stream gradient and stream size thresholds (Upper Extents) in streams lacking reliable salmonid distribution data, landscape stream attributes were used as an unbiased approach to estimate survey extents. Threshold values used in the two sample frames (Table 1) for both maximum gradient and Mean Annual Discharge (MAD) variables for Coho and Chinook were determined by plotting over 4000 spawning locations from surveys conducted by CDFG from 2001 to 2008 on Caspar Creek, Pudding Creek, and the Noyo River on the Mendocino coast and Freshwater Creek in Humboldt Bay (Fig. 2). These watersheds had surveys conducted throughout the entire extent of anadromy over a wide range of abundance and water years (S. Ricker and S. Gallagher unpublished data). Spawning locations were either plotted in a GIS by LLID 'To' distance from recorded meter marks (Freshwater Creek) or digitized off of field maps (Mendocino Coast) using the FRAP 1:24k hydrography (Appendix A). These location data were snapped to the CLAMS IP line-work and maximum gradient and MAD values were extracted. The maximum gradient and MAD values were plotted and threshold 'cutpoint' values were determined as the 95% of the observed data (Fig. 2).

Table 1. Threshold values for gradient and flow variables imposed on the CLAMS dataset to predict potential species distributions in stream sections lacking complete species distribution data.

Species	Humboldt Bay Maximum Stream Gradient[a]	Redwood Creek Maximum Stream Gradient[a]	Mean Annual Discharge (CMS)[a]
Coho Salmon	5%	5%	0.05
Chinook Salmon	4%	4%	0.15
Steelhead Trout	5%	8%[b]	0.05

[a]*Both gradient and discharge variables were combined in an ARCgis definition query on the IP Stream data using species specific criteria For Example: where "MAX_GRAD" <=0.05 And "MEANANNCMS" >=0.05 = Potential Adult Coho Spawning Habitat*

[b]*Value used for the upper portion of Redwood Creek where scant distribution data for anadromous steelhead exists.*

Gradient

Stream gradients were derived from 10m Digital Elevation Models (DEM), then aggregated into 50-200m reaches (Burnett et al. 2003, Agrawal et al. 2005, Burnett et al. 2007). The maximum value however was maintained within the reach aggregation and represents the steepest 10m to 10m DEM increase in elevation within the reach. Maximum gradients were used as an upstream threshold for anadromous salmonid distribution. All streams above gradient breaks were eliminated from the sample space.

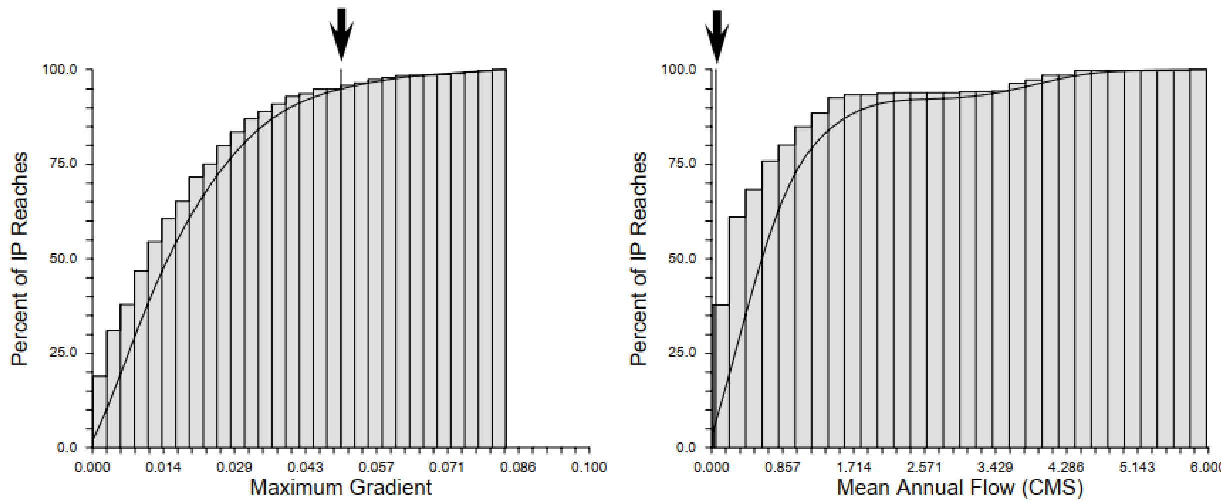

Figure 2. Percent accumulation curves for maximum gradient and stream discharge among 4, 669 known salmonid redd locations in one Humboldt and five Mendocino Streams. Arrows represent the values for 95%of the redd locations. Individual 95% species values are displayed in Table 1.

Stream Discharge (Mean Annual Flow)

Streams in general must be large enough to support habitat for anadromous salmonids. Stream Discharge will effect channel width, as well as control access to upstream reaches. Mean Annual Discharge (MAD) was calculated for each 50-200m IP reach using rainfall vs. discharge relationships(Burnett et al. 2003, Agrawal et al. 2005, Burnett et al. 2007). All streams falling below MAD valueswere eliminated from the sample space. These thresholds effectively remove the smaller most upstream portions of basins.

This definition query effectively defined the potential spawning space within maximum stream gradient and MAD values on the IP line-work. To determine if fish were ascending gradients larger than our definition, the subset IP line-work was inspected for maximum gradient values that were lagerthan our definition, but lower in the stream network than known spawning locations. Gradient data derived from 10m DEM's have some erroneous values due to road crossings, bridges etc. We inspected each occurrence of gradient values larger than our defined cut points to determine if the GIS gradient data might be in error. One meter resolution aerial imagery, National Agriculture Imagery Program (NAIP) imagery and road layers were used to identify possible IP gradient errors.
Questionable gradient cut points observed in the IP line-work that could not be validated with the NAIP imagery or road network layers were identified for field reconnaissance.

Salmonid Barrier Identification

All stream sections above known adult anadromous salmonid barriers were eliminated from the sample frames. However, if known distribution of coho or Chinook salmon occurred above a barrier, the obstruction was ignored. Barriers were determined through the best available knowledge from biologists, but were largely identified through the California Fish Passage Assessment Database (PAD). The PAD currently provides the most comprehensive framework for the analysis of fish passage for the state of California. The PAD has a total of eight categories defining the passage status of potential barriers. We limited passage status criteria to: "Total Barrier", defined as a complete barrier to all life stages of anadromous salmonid species at all times of the year (PAD 2009). The data quality in the PADcan vary widely depending on the source and date of recorded barrier information. We reassessed all identified permanent barrier locations for the sampling reaches using the PAD incidental reporting protocol (PAD 2009). Some barriers to adult salmonids can be intermittent in nature. For example, logjam barriers can operate differently under various flow conditions and the configuration of debris and sediment retention in these structures can change rapidly. We did not eliminate stream sections above possible barrier structures that were likely modified under stochastic conditions. However, barrier structures in small streams, at or near the top of possible anadromous fish distribution, were not considered to be as responsive to modification under stochastic conditions.

Expert Review of Salmonid Distributions

We generated large-scale paper maps depicting adult salmonid spawning distributions from the previous steps for Humboldt Bay tributaries and Redwood Creek basin. Local watershed experts werecalled upon in group meetings to augment, and verify salmonid spawning distributions to form the ‘known distribution’ (Appendix A). This step was especially useful in defining the downstream most extents for potential salmonid spawning habitat in streams draining directly into the Pacific Ocean, estuary, lagoon, bay, or a levee system. Additionally, information provided from local experts on unknown barriers and barriers that had been removed further defined current salmonid distributions.

Field Reconnaissance

After designing the sample frames in a GIS, field crew’s ground-truthed all upper and lower extents of each sample frame during the spawning season for potential use by adult salmonids. For lower spawning extents, field crews inspected the streambed for suitable spawning sites. Spawning areas must have contained pool-riffle sequences and gravel spawning substrate. For upper extents of terminal reaches, crews walked each reach to the uppermost coordinates identified by the GIS. If barriers were encountered that were not identified in the PAD or by expert review, they were photographed, measured for height and a PAD incidental reporting form was filled out to update the PAD (PAD 2009). All non-permanent ephemeral barriers (e.g. logjams) were not included as barriers toupstream migration even if they might be during some years or some flows. Once upstream extents were established, a Garmin 60cx GPS unit with point averaging was used to identify the location and the frame was updated with the new upstream extent. No attempt was made to quantify the quality of spawning habitat in upper extents. If adult anadromous salmonids had access, and the stream was within the appropriate gradient and size constrant’s, it was included regardless of the current state of the habitat.

Physical Access and Logistical Constraints

Land managers and experts in each area were queried about the possibility of winter access by field sampling crews to remote areas. If a remote area could not be accessed and surveyed by a team oftwo surveyors in a ten hour day, it was removed from the frame. Additionally, any stream section considered a safety hazard for walking or boating was removed from the sampling frames. For example, the lower canyon section of Redwood Creek was removed because it is too dangerous to survey by floating. These areas typically do not provide much spawning habitat due to whitewater conditions and large boulder fields.

Sample Frame Results

Figure three depicts the sequence of frame construction in a GIS for the Humboldt Bay watershed. Westarted with the base FRAP 1:24k hydrography (Fig. 3, frame A). Lower extents were then subtracted with points defined by expert opinion and field reconnaissance, and upper extents pruned with permanent barriers (Fig. 3, frame B). Known salmonid distribution was plotted and if this distribution

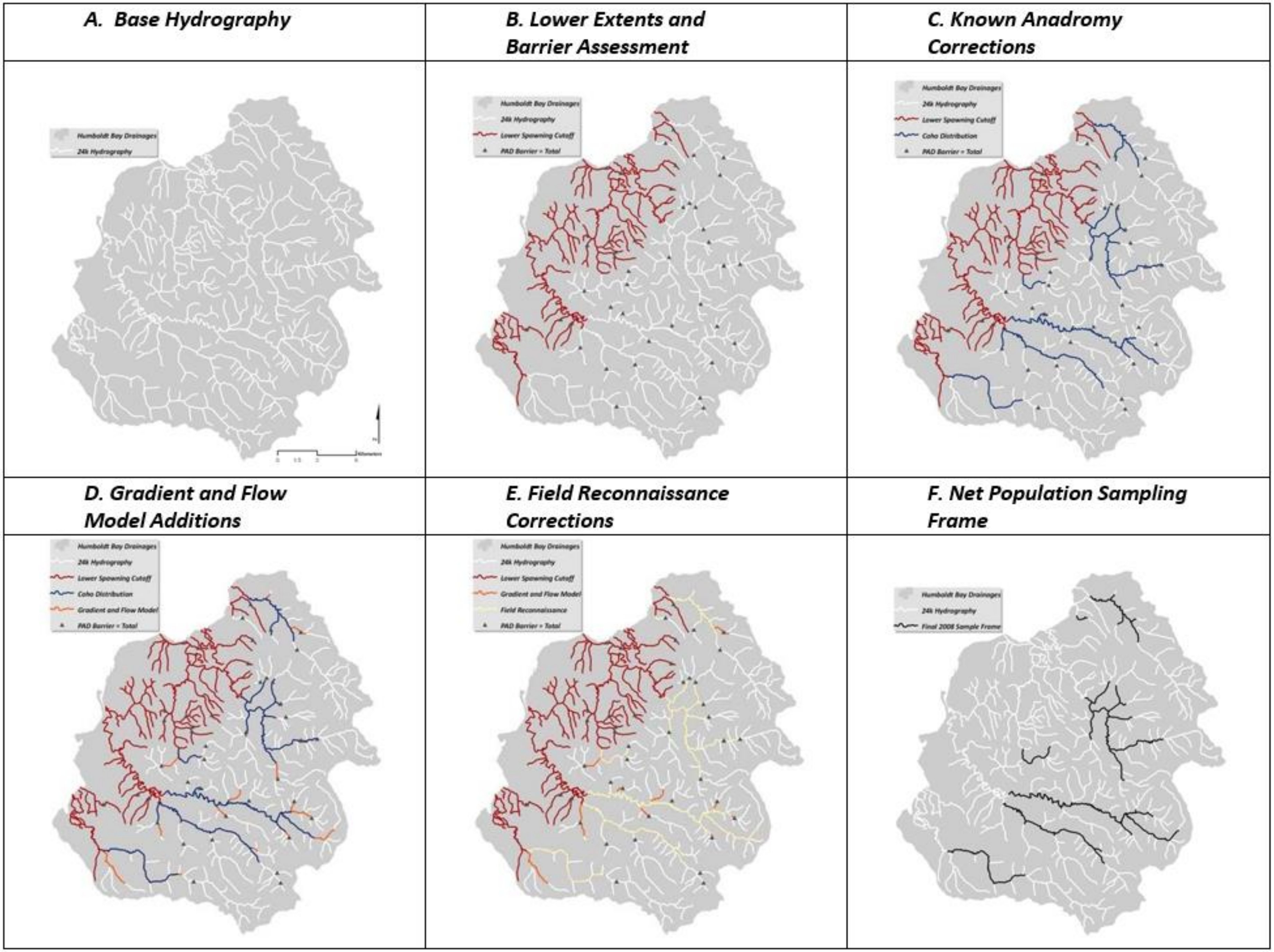

Figure 3. Humboldt Bay tributaries sample frame development procedures processed in a GIS.

extended past barriers from the PAD dataset, the barriers were ignored (Fig. 3, frame C). Next, the gradient and flow model was used to extend potential distribution to areas where there was no known distribution data (Fig. 3, frame D). Finally, field reconnaissance was used to truth both questionable gradient breaks above defined values, as well as all upper extents of anadromous salmonid distribution (Fig. 3, Frame E) resulting in the final trimmed sampling frame (Fig. 3, Frame F).

Performance of Sample Frame Development Criteria

Humboldt Bay

Based on our sample frame addition criteria, the Humboldt Bay tributaries net coho salmon and steelhead trout population sample frame equaled 83.1 km, or 17% of the total base hydrography (Table 2, Fig. 4). The net Chinook salmon sample frame equaled 38.4 km, or 8% of the total base hydrography and represented 46% of net coho/ steelhead sample frame (Table 2, Fig. 4). The CDFG coho salmon observations database explained 86.7% of the net three species sample frame followed by 10.3 % by the gradient/ discharge model and 3.0% by field reconnaissance. These results indicate our gradient and discharge model performed excellent in this region by explaining 97% of the net sampling frame. The largest sample frame reduction that occurred, after determining lower extents and the upper modeled extents, resulted from field reconnaissance (12.27km) then by total barriers (2.9 km).

Table 2. Summary table for salmonid sample frame development within Humboldt Bay Tributaries, California. Frame addition and reduction criteria are summarized by attribute and basin. See text for attribute definitions and frame development criteria.

				Basin			
	Salmon Creek	*Elk River*	*Ryan Creek*	*Freshwater Creek*	*Rocky Gulch*	*Jacoby Creek*	*Humboldt Bay Totals*
				Stream Length (km)			
24K Base Hydrography:	57.68	191.77	60.39	138.60	4.32	45.14	497.90
Addition Criteria				*Frame Additions (km)*			
Coho Distribution:	8.67	31.75	2.94	21.33	0.00	7.36	72.05
Gradient/ Flow Model:	3.78	5.17	0.00	2.31	1.08	0.40	12.74
Field Reconnaissance:	0.00	0.06	0.95	0.63	0.00	0.88	2.52
Reduction Criteria				*Frame Reductions (km)*			
Terminal Cutoff:	8.71	59.94	39.23	92.40	1.04	1.76	203.08
Upper Model Cutoff:	30.20	86.38	15.59	21.11	2.20	34.61	190.09
Total Barrier:	0.00	2.90	0.00	0.00	0.00	0.00	2.90
Field Reconnaissance:	3.57	5.57	2.31	0.82	0.00	0.00	12.27
Remote/ Logistics:	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net by Species				*Net Sampling Frame (km)*			
Chinook:	2.59	16.18	1.50	11.57	0.00	6.57	38.41
Coho:	8.88	36.98	3.26	24.27	1.08	8.64	83.11
Steelhead:	8.88	36.98	3.26	24.27	1.08	8.64	83.11
Net Total:	**8.88**	**36.98**	**3.26**	**24.27**	**1.08**	**8.64**	**83.11**

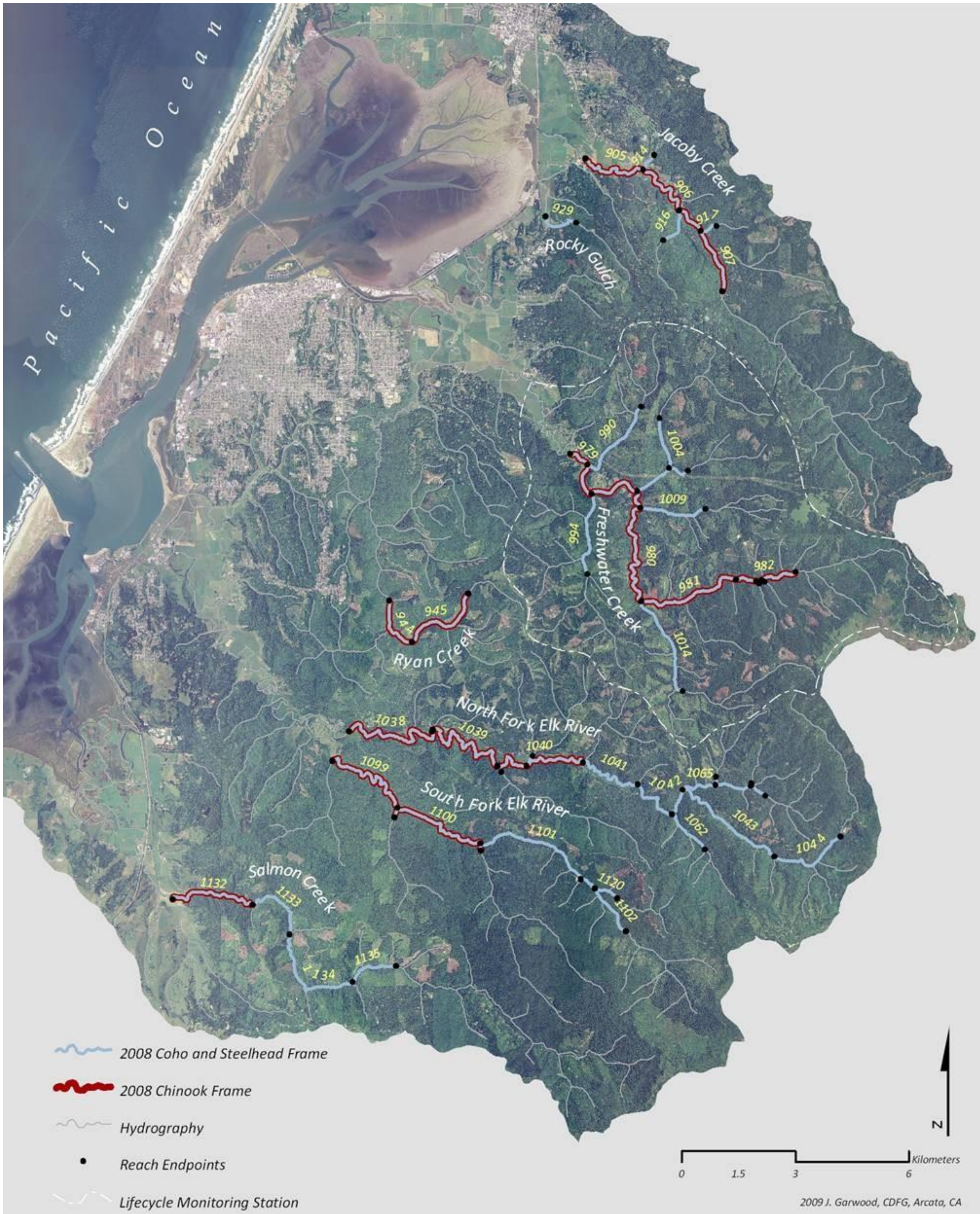

Figure 4. Map of the Humboldt Bay tributaries net salmonid spawner survey sample frame separated by species. Note potential species distributions overlap in many stream segments. Individual GRTS ordered survey reaches are labeled in yellow.

Redwood Creek

Based on our sample frame addition criteria, the Redwood Creek net steelhead population sample frame equaled 148.5 km (Table 3, Fig. 5), or 29.5% of the total base hydrography. The net coho salmon sample frame equaled 22.8% of the total base hydrography and 77.1% of the net steelhead sample frame. The net Chinook salmon sample frame equaled 90.31 km, or 17.9% of the total base hydrography and represented 60.8% of net steelhead and 78.9% of the net coho salmon sample frames (Table 3, Fig. 5). The CDFG coho salmon observations database explained 66.7% of the net three species sample frame followed by 36.4 % by the combined gradient/ discharge models. Field reconnaissance added only 0.26 km to the entire sample frame. These results indicate our gradient and discharge model performed excellent in this region by explaining approximately 99% of the total sample frame. The largest sample frame reduction that occurred, after determining lower extents and the upper modeled extents, resulted from barriers (5.7 km) and the removal of two remote areas based on logistical constraints (4.48 km). We anticipate further reach length adjustments to this sample frame since five reaches still need field reconnaissance.

Table 3. Summary table for salmonid sample frame development within Redwood Creek basin, California. Frame addition and reduction criteria are summarized by attribute and basin. See text for attribute definitions and frame development criteria.

	Basin			
	Redwood Creek	*Other Redwood Creek Tributaries*	*Prairie Creek*	*Redwood Creek Basin Totals:*
	Stream Length (km)			
24K Base Hydrography:	108.17	286	108.74	503.33
Addition Criteria	***Frame Additions (km)***			
Coho Distribution	58.84	8.97	31.06	98.87
Gradient/ Flow Model[a]	11.29	2.77	5.14	19.20
Gradient/ Flow Model[b]	23.19	11.61	*NA*	34.80
Field Reconnaissance	0.00	0.02	0.24	0.26
Reduction Criteria	***Frame Reductions (km)***			
Terminal Cutoff	13.00	0.00	4.82	17.82
Upper Model Cutoff	5.89	261.35	63.24	330.48
Total Barrier	0.00	3.40	2.27	5.67
Field Reconnaissance	0.00	0.00	1.97	1.97
Remote/ Logistics	2.02	1.70	0.76	4.48
Net By Species	***Net Sample Frame (km)***			
Chinook:	66.35	5.04	18.92	90.31
Coho:	66.35	11.74	36.44	114.53
Steelhead:	91.30	20.74	36.44	148.48
Net Total:	**91.30**[a]	**20.74**[a]	**36.44**	**148.48**

[a]*Total sample frame lengths subject to minor changes based on future field visits to five reaches.*

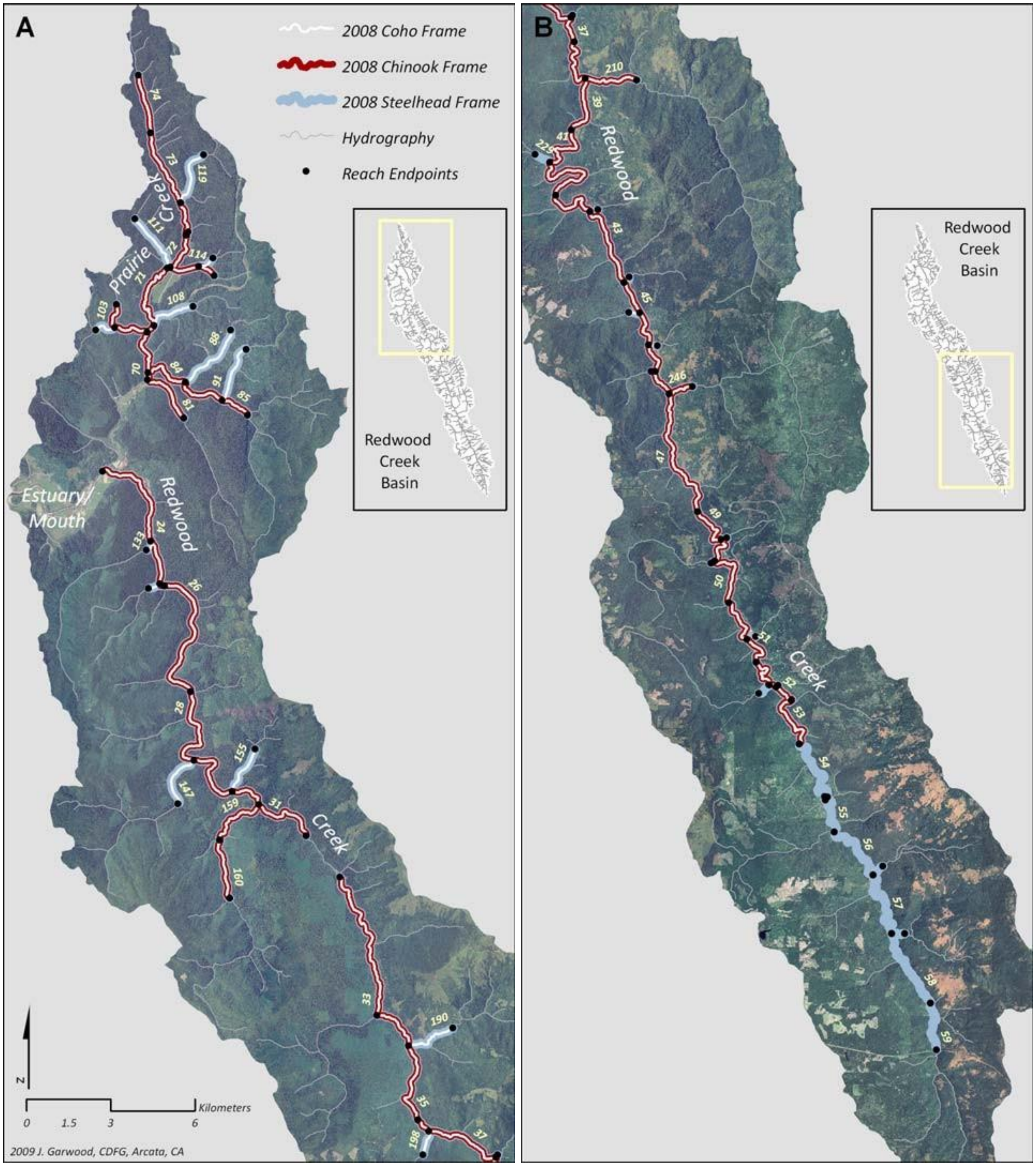

Figure 5. Map of the Redwood Creek basin net salmonid spawner survey sample frame separated by species. Panel A shows the lower Redwood Creek basin and the Prairie Creek sub-basin; panel B shows the upper Redwood Creek basin. Note potential species distributions overlap in many stream segments. Individual GRTS ordered survey reaches are labeled in yellow.

Spawner Survey Reach Development

Once spawning distribution was defined, survey reaches were developed for both Humboldt Bay tributaries and Redwood Creek basin to establish sampling units and create sample frames for probabilistic sampling. We used reaches defined in roughted hydrography by the Institute For River Ecosystems (McCanne and Brown 2005, McCanne 2008) trimmed to our defined distribution. The IRE reaches were developed using the following criteria:

- Upper and lower reach endpoints are defined by geographic landmarks (e. g. stream junctions, bridges) at start and endpoints.
- Full reaches must be between 1.5 and 3 km in length for walking surveys and 3 km to 5 km for floating surveys.

Some terminal reach endpoints were trimmed to an arbitrary endpoint without a geographic landmark. These endpoints were conspicuously marked with flagging and recorded GPS coordinates. Reaches less than 1 km in length were preserved in the sample frame but identified as a 'sub-reach'. Sub-reaches were not included in the probabilistic sample draw of reaches to be surveyed, but rather were surveyed if connected to a full reach that was sampled. The sub-reach was surveyed along with a sampled reach if it was connected to a full reach anywhere above the downstream starting point (Fig. 6). This criterion were implemented to ensure field crews had enough habitat to survey to reasonably expend the travel time to access the site while maintaining the potentially biologically important short reaches within the sample.

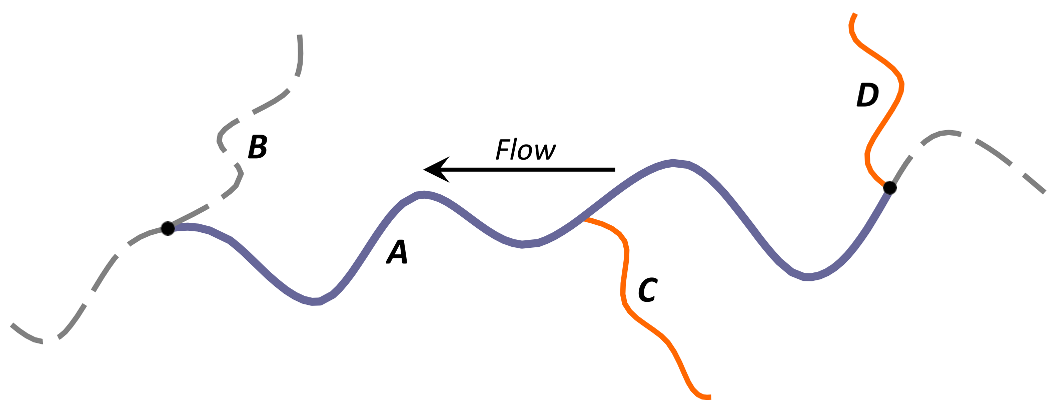

Figure 6. Drawing indicating sub-reach selection when connected to a selected GRTS sample reach. Stream section A: GRTS selected sample reach. Stream section B: Short reach (< 1KM) at bottom of selected reach A- not surveyed. Stream sections C and D: Short streams within, and at the top of section A, surveyed by implication. Note: if section A is the lowest potential reach in the stream, then section B would be surveyed as well.

All previously established spawner survey reaches developed for previous monitoring efforts were preserved and incorporated into the sample frame design for two reasons. First, future monitoring data in these reaches can be compared to previous spawner survey data. Second, planning and logistical information (for example: landowner agreements and access points) reduced overall reconnaissance efforts in previously established survey reaches.

Reach Development Results

The Humboldt Bay tributaries sampling frame resulted in thirty two reaches and 14 sub-reaches (Table 4, Fig. 4, Appendix A). The Redwood Creek basin sampling frame resulted in 46 reaches and 21 sub-reaches (Table 4, Fig. 4, Appendix B). The entire Humboldt Bay tributaries and 58% of Redwood Creek sampling frames were designed as walking reaches. The remaining 42% in the mainstem of Redwood Creek was designed for longer boating surveys. Average walking reach lengths approximated 2.4 km for both sampling frames; average boating reach lengths in mainstem Redwood Creek exceeded 5 km (Table 4). Sub-reaches represented less than six percent of both overall survey sample frames with reaches averaging less than 400 meters in length. Two reaches and four sub-reaches in Redwood Creek basin still lack field reconnaissance largely due to landowners having denied access.

Table 4. Summary statistics of resulting sample frame survey reaches in Humboldt Bay tributaries and Redwood Creek basin after field reconnaissance occurred for three survey years starting with the 2008-2009 field season. Walking reaches were summarized separately from boating reaches in Redwood Creek basin based on having different survey methodologies. Note: sections that were not surveyed based on access were not omitted from reach summary.

	Basin		
Summary Criteria	***Humboldt Bay Tributaries***	***Redwood Creek Walking***	***Redwood Creek Boating***
Reaches (≥ 1 km in length)			
Number of Reaches	32	34	12
Sum of reaches in stream km	78.53	79.09	61.67
(% of total frame)	(94.5)	(53.3)	(41.5)
Mean reach length in stream km	2.45	2.33	5.14
(± 1 SE)	(0.13)	(0.10)	(0.20)
# Reaches lacking field reconnaissance	0	2[a]	0
Sub-reaches (< 1 km in length)			
Number of sub-reaches	14	21	0
Sum of sub-reaches in stream km	4.57	7.71	0
(% of total frame)	(5.5)	(5.2)	(0.0)
Mean sub-reach length in stream km	0.33	0.37	0
(± 1 SE)	(0.06)	(0.04)	(0.00)
# Sub-reaches lacking field reconnaissance	0	4[a]	0

[a]Reach lengths are subject to change based on future field reconnaissance. Only reaches with terminal extents are represented; those reaches occurring downstream of another were assumed not to change in length.

Reach Labeling for GRTS Design

All reaches within the sample frame were assigned numeric reach ID's. The assignment of ID's progressed from north to south as streams entered the marine environment (e. g. Humboldt Bay). Beginning with the lower most reach in the main-stem, reach ordering progressed upstream to the top of the main-stem. The next reach in the ordering sequence was the lower most tributary to the main-stem. Ordering progressed up this tributary until it's end. This sequence of ordering continued through the dendridic pattern of the watershed (Figures 4 and 5). In this way, the frame was recursively sorted, from watershed to main stem to tributaries, and produced a unique ordering of the frame. It was possible under this scheme for a segment in a tributary near a confluence with a main stem to be "spatially" far away from a segment on the main stem that contains the confluence

(Boydston and McDonald 2005). However, 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) this ordering ensured that selected sampled units were spatially balanced (Boydston and McDonald 2005).

Acknowledgements

Many thanks to Tom Christy and Connie Shannon for providing GIS expertise and tailored DFG salmonid distribution information. We thank Sean Gallagher for providing advice and most of the salmonid redd distribution data used for developing our GIS model. We thank Dana McCanne for providing base data for our reach development procedures. We thank all the biologists, land managers, and landowners for providing detailed local knowledge on salmonid distributions. This work was supported in part by the Department of Fish and Game, Anadromous Fisheries Resource and Monitoring Program, and the Fisheries Restoration Grants Program.

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Williams et al. 2008. Framework For Assessing Viability Of Threatened Coho Salmon In The Southern Oregon/Northern California Coast Evolutionarily Significant Unit. NOAA-TM-NMFS-SWFSC-432.

Appendix A: Sample Frame Development Resources and Metadata

GIS Data:

Base Layers

- California Interagency Watershed Map of 1999 (Calwater 2.2, updated May 2004, "calw221"). Available at: http://frap.cdf.ca.gov/data/frapgisdata/select.asp
- 24k 1:24k Roughted Hydrography[1], Available at: http://frap.cdf.ca.gov/data/frapgisdata/select.asp
- 24k Reach Structured Roughted Hydrography[1], Modified data from Institute for River Ecosystems, Humboldt State University, CA. (McCanne and Brown 2005, McCanne 2008)
- 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).
- LIDAR Digital Elevation Model, Freshwater Creek Watershed and Elk River Watershed Tributaries of Humboldt Bay, California Environmental Protection Agency, North Coast Regional Water Quality Control Board, Santa Rosa, CA.
- 2005, 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
- 2008 Humboldt County GIS Parcel Data, Humboldt County Community Services District, Created on 04 April 2008, Eureka, CA

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

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

Coho Observations Dataset, CDFG Internal Aquatic Species Distribution Database, Redding , CA.

Potential Spawning Distribution Parameter Threshold Data (Gradient and Flow Accumulation)

- California Department of Fish and Game, Freshwater Creek and Mendocino Streams salmonid redd location data 2002-2008.

Personal communications for salmonid distribution information:

Humboldt Bay

Larry Preston, CDFG, Arcata, CA
Mike Wallace, CDFG, Arcata, CA
Scott Downie, CDFG, Fortuna, CA
Darrold Perry, Green Diamond Resource Company, Korbel, CA
Darren Mierau, McBain and Trush, Arcata, CA
Mitch Farro, Pacific Coast Fish, Wildlife & Wetlands Restoration Association, Arcata, CA

Redwood Creek

Vicki Osaki, National Park Service, Orick, CA
David Anderson, National Park Service, Orick, CA
Baker Holden, National Park Service, Orick, CA
Michael Sparkman, CDFG, Arcata, CA
Tom Weseloh, California Trout, Mckinlyville, CA
Walter Duffy, USGS, California Cooperative Fish Research Unit, Arcata, CA
Dana McCanne, Institute for River Ecosystems, Humboldt State University, Arcata, CA

[1] We recommend future frame development projects use the USGS National Hydrography Dataset (NHD) 1: 24k hydrography to align with new California Department of Fish and Game hydrography standards.

Appendix B. Humboldt Bay tributaries reach attributes including: location, length, and salmonid species compositions.

SUBBASIN	STREAM	LLID[a]	REACH ID	FROM (KM)	TO (KM)	LENGTH (KM)	COHO	CHINOOK	STEELHEAD
Jacoby Creek	Jacoby Creek	1240814408436	905	1.761	3.802	2.041	Y	Y	Y
JacobyCreek	Jacoby Creek	1240814408436	906	3.802	6.551	2.749	Y	Y	Y
Jacoby Creek	Jacoby Creek	1240814408436	907	6.551	8.331	1.780	Y	Y	Y
Jacoby Creek	Golf Course Creek	1240477408342	914	0.000	0.520	0.520	Y	N	Y
Jacoby Creek	Morrison Gulch	1240364408247	916	0.000	1.049	1.049	Y	N	Y
Jacoby Creek	Unnamed	1240295408198	917	0.000	0.500	0.500	Y	N	Y
Rocky Gulch	Rocky Gulch	1240800408312	929	1.043	2.119	1.076	Y	N	Y
Ryan Creek	Ryan Creek	1241175407779	944	8.655	11.160	2.505	Y	Y	Y
Ryan Creek	Bear Gulch	1241286407455	956	0.000	0.754	0.754	Y	N	Y
Freshwater	Freshwater Creek	1240963407867	979	5.318	8.340	3.022	Y	Y	Y
Freshwater	Freshwater Creek	1240963407867	980	8.340	12.249	3.909	Y	Y	Y
Freshwater	Freshwater Creek	1240963407867	981	12.249	15.141	2.892	Y	Y	Y
Freshwater	Freshwater Creek	1240963407867	982	15.141	16.886	1.745	Y	Y	Y
Freshwater	McCready Gulch	1240640407638	990	0.000	2.439	2.439	Y	N	Y
Freshwater	Little Freshwater Creek	1240626407569	994	0.000	2.340	2.340	Y	N	Y
Freshwater	Cloney Gulch	1240483407577	1004	0.000	2.430	2.430	Y	N	Y
Freshwater	Falls Gulch	1240385407633	1006	0.000	0.591	0.591	Y	N	Y
Freshwater	Graham Gulch	1240474407538	1009	0.000	1.825	1.825	Y	N	Y
Freshwater	South Fork Freshwater Creek	1240467407315	1014	0.000	2.881	2.881	Y	N	Y
Freshwater	Lower Twin Tributary	1240109407366	1024	0.000	0.100	0.100	Y	N	Y
Freshwater	Upper Twin Tributary	1240092407369	1025	0.000	0.100	0.100	Y	N	Y
Elk River	North Fork Elk River	1241512407026	1038	2.023	5.408	3.385	Y	Y	Y
Elk River	North Fork Elk River	1241512407026	1039	5.408	8.934	3.526	Y	Y	Y
Elk River	North Fork Elk River	1241512407026	1040	8.934	11.935	3.001	Y	Y	Y
Elk River	North Fork Elk River	1241512407026	1041	11.935	14.136	2.201	Y	N	Y
Elk River	North Fork Elk River	1241512407026	1042	14.136	16.444	2.308	Y	N	Y
Elk River	North Fork Elk River	1241512407026	1043	16.444	19.789	3.345	Y	N	Y
Elk River	North Fork Elk River	1241512407026	1044	19.789	22.017	2.228	Y	N	Y
Elk River	Browns Gulch	1241116406999	1047	0.000	0.057	0.057	Y	N	Y
Elk River	Lake Creek	1240912406919	1049	0.000	0.201	0.201	Y	N	Y
Elk River	Bridge Creek	1240819406922	1053[3]	0.000	0.306	0.306	Y	N	Y
Elk River	South Branch North Fork Elk	1240364406810	1062	0.000	1.354	1.354	Y	N	Y
Elk River	North Branch North Fork Elk	1240331406868	1065	0.000	2.480	2.480	Y	N	Y
Elk River	Doe Creek	1240227406880	1068	0.000	0.219	0.219	Y	N	Y
Elk River	Little North Fork Elk River	1240119406879	1072	0.000	0.071	0.071	Y	N	Y
Elk River	South Fork Elk River	1241512407027	1099	2.569	5.644	3.075	Y	Y	Y
Elk River	South Fork Elk River	1241512407027	1100	5.644	8.376	2.732	Y	Y	Y
Elk River	South Fork Elk River	1241512407027	1101	8.376	11.741	3.365	Y	N	Y
Elk River	South Fork Elk River	1241512407027	1102	11.741	13.713	1.972	Y	N	Y
Elk River	McCloud Creek	1241221406816	1109	0.000	0.265	0.265	Y	Y	Y
Elk River	Little South Fork Elk River	1240961406734	1113	0.000	0.192	0.192	Y	Y	Y
Elk River	Unnamed	1240603406631	1120	0.000	0.692	0.692	Y	N	Y
Salmon Creek	Salmon Creek	1242196406870	1132	6.209	8.801	2.592	Y	Y	Y
Salmon Creek	Salmon Creek	1242196406870	1133	8.801	10.715	1.914	Y	N	Y
Salmon Creek	Salmon Creek	1242196406870	1134	10.715	13.728	3.013	Y	N	Y
Salmon Creek	Salmon Creek	1242196406870	1135	13.728	15.088	1.360	Y	N	Y

[a]*1:24,000 scale routed stream network, California Department of Forestry and Fire Protection*

Appendix C. Redwood Creek basin reach attributes including reach location, length, and salmonid species compositions.

SUBBASIN	STREAM	LLID[a]	REACH ID	FROM (KM)	TO (KM)	LENGTH (KM)	COHO	CHINOOK	STEELHEAD
Redwood Creek	Redwood Creek	1240905412925	24	6.040	11.717	5.677	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	26	11.717	17.134	5.417	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	28	17.134	23.221	6.087	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	31	23.221	27.047	3.826	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	33	29.066	34.920	5.854	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	35	34.920	39.900	4.980	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	37	39.900	44.381	4.481	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	39	44.381	48.724	4.343	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	41	48.724	54.645	5.921	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	43	54.645	59.890	5.245	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	45	59.890	64.719	4.829	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	47	64.719	69.728	5.009	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	49	69.728	72.650	2.922	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	50	72.650	74.913	2.263	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	51	74.913	78.062	3.149	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	52	78.062	80.704	2.642	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	53	80.704	83.121	2.417	Y	Y	Y
Redwood Creek	Redwood Creek	1240905412925	54	83.121	86.394	3.273	N	N	Y
Redwood Creek	Redwood Creek	1240905412925	55	86.394	88.039	1.645	N	N	Y
Redwood Creek	Redwood Creek	1240905412925	56	88.039	90.721	2.682	N	N	Y
Redwood Creek	Redwood Creek	1240905412925	57	90.721	94.063	3.342	N	N	Y
Redwood Creek	Redwood Creek	1240905412925	58	94.063	97.329	3.266	N	N	Y
Redwood Creek	Redwood Creek	1240905412925	59	97.329	99.348	2.019	N	N	Y
Prairie Creek	Prairie Creek	1240491412996	70	4.817	6.805	1.988	Y	Y	Y
Prairie Creek	Prairie Creek	1240491412996	71	6.805	10.126	3.321	Y	Y	Y
Prairie Creek	Prairie Creek	1240491412996	72	10.126	12.868	2.742	Y	Y	Y
Prairie Creek	Prairie Creek	1240491412996	73	12.868	15.723	2.855	Y	Y	Y
Prairie Creek	Prairie Creek	1240491412996	74	15.723	17.871	2.148	Y	Y	Y
Prairie Creek	Little Lost Man Creek	1240303413292	81	0.000	2.084	2.084	Y	Y	Y
Prairie Creek	Lost Man Creek	1240302413315	84	0.000	1.778	1.778	Y	Y	Y
Prairie Creek	Lost Man Creek	1240302413315	85	1.778	4.694	2.916	Y	Y	Y
Prairie Creek	Larry Dam Creek	1240142413285	88	0.000	2.661	2.661	Y	N	Y
Prairie Creek	Lost Man Trib-U	1239985413228	91	0.000	2.209	2.209	Y	N	Y
Prairie Creek	Streelow Creek	1240308413444	103	0.000	2.266	2.266	Y	Y	Y
Prairie Creek	Streelow Creek	1240447413458	104	0.000	0.815	0.815	Y	N	Y
Prairie Creek	May Creek	1240279413466	108	0.000	1.760	1.760	Y	N	Y
Prairie Creek	Godwood Creek	1240225413651	111	0.000	2.243	2.243	Y	N	Y
Prairie Creek	Boyes Creek	1240212413654	114	0.000	1.731	1.731	Y	Y	Y
Prairie Creek	Boyes Creek-A	1240092413658	115	0.000	0.617	0.617	Y	N	Y
Prairie Creek	Unnamed Trib	1240148413758	117	0.000	0.134	0.134	Y	N	Y
Prairie Creek	Brown Creek	1240173413862	119	0.000	2.171	2.171	Y	N	Y
Redwood Creek	McArthur Creek	1240282412775	133	0.000	0.415	0.415	Y	N	Y
Redwood Creek	Elam Creek	1240242412637	135	0.000	0.438	0.438	Y	N	Y
Redwood Creek	Tom McDonald Creek	1240088412073	147	0.000	2.098	2.098	Y	N	Y
Redwood Creek	Harry Weir Creek	1239924411974	155	0.000	1.785	1.785	Y	N	Y
Redwood Creek	Bridge Creek	1239810411933	159	0.000	2.291	2.291	Y	Y	Y
Redwood Creek	Bridge Creek	1239810411933	160	2.291	4.562	2.271	Y	Y	Y

Redwood Creek	Coyote Creek	1239164411165	190	0.000	1.947	1.947	Y	N	Y
Redwood Creek	Panther Creek	1239073410891	198	0.000	1.202	1.202	Y	N	Y
Redwood Creek	Garrett Creek	1238788410810	206	0.000	0.360	0.360	Y	Y	Y
Redwood Creek	Lacks Creek	1238725410615	210	0.000	2.075	2.075	Y	Y	Y
Redwood Creek	Karen Creek	1238871410345	229	0.000	0.608	0.608	N	N	Y
Redwood Creek	Beaver Creek	1238699410188	236	0.000	0.259	0.259	N	N	Y
Redwood Creek	Pilchuck Creek	1238598410038	237	0.000	0.227	0.227	N	N	Y
Redwood Creek	Molasses Creek	1238553409962	239	0.000	0.201	0.201	Y	N	Y
Redwood Creek	Toss-up Creek	1238485409865	240	0.000	0.417	0.417	Y	N	Y
Redwood Creek	Moon Creek	1238446409763	242	0.000	0.321	0.321	Y	N	Y
Redwood Creek	Wiregrass Creek	1238417409677	244	0.000	0.146	0.146	Y	N	Y
Redwood Creek	Minor Creek	1238356409605	246	0.000	0.929	0.929	Y	Y	Y
Redwood Creek	Captain Creek	1238132409139	261	0.000	0.234	0.234	Y	N	Y
Redwood Creek	Lupton Creek	1238158409070	262	0.000	0.305	0.305	Y	Y	Y
Redwood Creek	Windy Creek	1238019408820	268	0.000	0.470	0.470	N	N	Y
Redwood Creek	Noisy Creek	1237923408675	270	0.000	0.524	0.524	N	N	Y
Redwood Creek	Squirrel Tail Creek	1237895408668	272	0.000	0.100	0.100	N	N	Y
Redwood Creek	Gunrack Creek	1237685408317	276	0.000	0.109	0.109	N	N	Y
Redwood Creek	Minon Creek	1237478408068	286	0.000	0.490	0.490	N	N	Y
Redwood Creek	Bradford Creek	1237397407881	292	0.000	0.516	0.516	N	N	Y