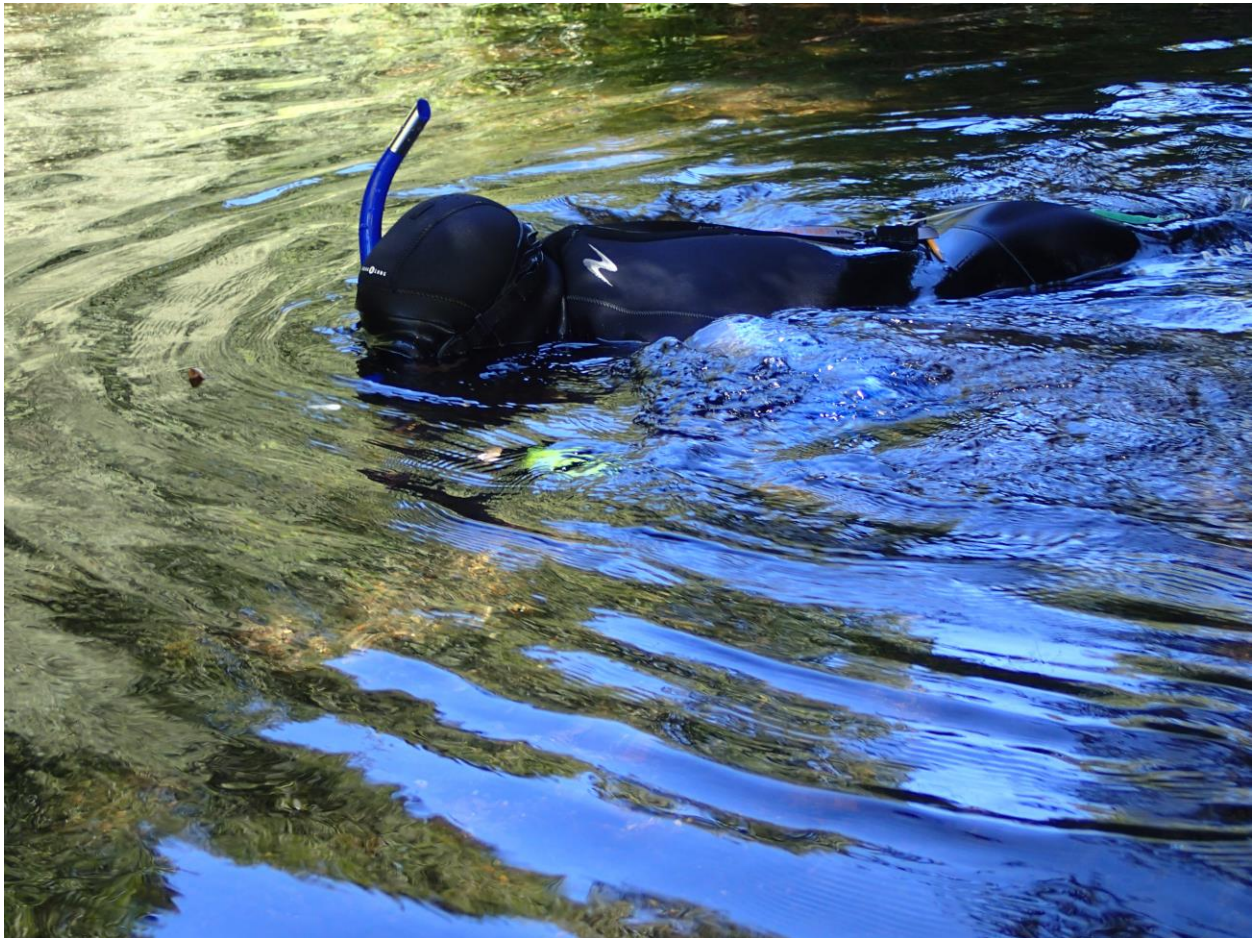




Fisheries and Aquatic Resources of Prairie Creek, Redwood National and State Parks

Natural Resource Report NPS/REDW/NRR—2017/1492





ON THIS PAGE

Godwood Creek
(NPS)

ON THE COVER

Student P. Drobny counting fish in Prairie Creek
(CCRU-USGS)

Fisheries and Aquatic Resources of Prairie Creek, Redwood National and State Parks

Natural Resource Report NPS/REDW/NRR—2017/1492

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National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Abstract

This report synthesizes information on the status of fisheries and aquatic resources in the Prairie Creek sub-basin of Redwood Creek in Humboldt County in northern California, founded on a bibliographic search we conducted of historic and current datasets, unpublished reports, theses, and publications. The compiled Prairie Creek Fisheries Bibliography is available at <https://irma.nps.gov/DataStore/>. This report describes life histories and population status of the salmonid fishes, and species occurrence of non-salmonid fishes, amphibians, macroinvertebrates, and common benthic algae in Prairie Creek. We assessed habitat conditions that may limit salmonid production in relation to recovery targets established by the National Marine Fisheries Service and the State of California. Although salmon abundance has decreased from historic levels, production of juvenile salmonids in Prairie Creek is relatively stable and robust in comparison with the rest of the Redwood Creek Basin. Carrying capacity likely differs between the undisturbed upper reaches of Prairie Creek and reaches in the lower creek, the latter of which are affected by legacy impacts from timber and agricultural activities. Increased sediment supply and lack of channel structure and floodplain connection in lower Prairie Creek appear to be the greatest stressors to salmonid production. Existing datasets on aquatic resources and environmental variables are listed, and subject areas where few data are available are identified

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List of Acronyms, Abbreviations, and Units

Some agency and other acronyms or abbreviations used throughout this manuscript include:

CCRU_USGS: California Cooperative Fish and Wildlife Research Unit, United States Geological Survey

CDFW: California Department of Fish and Wildlife; until 2013, known as CDFG: California Department of Fish and Game

HSU: Humboldt State University

NMFS: National Marine Fisheries Service

NWS: National Weather Service

PCFWWPA: Pacific Coast Fish, Wildlife, and Wetlands Restoration Association

PCRSP: Prairie Creek Redwoods State Park

REDW: Redwood National Park

RNP: Redwood National Park

RNSP: Redwood National and State Parks

RS�_USFS: Redwood Sciences Laboratory, United States Forest Service Pacific Southwest Research Station

USACOE: United States Army Corp of Engineers

USDA NRCS: United States Department of Agriculture Natural Resources Conservation Service

USFWS: United States Fish and Wildlife

USGS: United States Geological Survey

DPS: Distinct Population Segment

ESU: Evolutionarily Significant Unit

FNU: Formazin Nephelometric Units (used in measuring turbidity)

GIS: Geographic Information System

LWD: large, woody debris

Mg = mega grams = 1,000,000 grams = 1.1 tons

mg = 1/1000 of a gram

Note: Two creek names in Prairie Creek have changed from earlier literature. Streeflow Creek was formerly named Wolf Creek, and Boyes Creek was sometimes referred to as Elk Prairie Creek.

Introduction

The 103 km² Prairie Creek watershed is almost entirely situated within Redwood National and State Parks, which is a World Heritage Site and part of the California Coast Range Biosphere Reserve. Although the lower half of the watershed has been impacted by highway construction, timber harvest, and other land use, the creek in the upper watershed flows through undisturbed forest of late seral coast redwood and provides outstanding habitat for fisheries and aquatic resources. The upper watershed often serves as a reference site in studies evaluating land use impacts on aquatic resources. Prairie Creek and its tributaries support populations of listed Chinook Salmon, Coho Salmon, and Steelhead, as well as Coastal Cutthroat Trout and other valued fishes and aquatic vertebrates.

Many studies of watershed conditions, stream habitat and aquatic resources have been conducted in the Prairie Creek watershed over the last 50 or more years, by diverse groups including university researchers, federal and state agency scientists, and others. Unfortunately, much of the data from these studies remains buried in files and reports which are not publicly available. We identified and located existing datasets and reports and compiled an annotated bibliography, which is accessible at <https://irma.nps.gov/DataStore/>. References may be found by selecting the Reports tab, selecting the “Featured Content” tab under the Reports Dashboard, and selecting “Redwood National Park” from the drop down menu under “Select a Park, Office, Program or Region”. Under “Category of Featured Content”, select “Prairie Creek Fisheries Bibliography” from the drop down menu, select “View Report” button. The bibliography can be downloaded as a Word or Excel file by selecting the “Review Report” button, and selecting the “export” button.

In this report, we synthesize the available literature on fisheries and aquatic resources from the Prairie Creek watershed, focusing in particular on salmonid fishes that are commonly the targets of restoration efforts. The goal is to provide context and background for other researchers and managers to provide site-specific information to assist in planning and evaluating efforts to protect or restore freshwater habitat. Non-salmonid fishes, amphibians, macroinvertebrates, and common benthic algae which inhabit the creek are listed. Life histories and population status of the salmonid fishes within Prairie Creek are described, along with a description of habitat factors which may limit their production. Available datasets on the physical/chemical template and on aquatic biota of the sub-basin are summarized, and subject areas where few data are available are identified.

This report is not intended to represent a full watershed assessment (e.g. literature on forest vegetation or soils was not included), nor does it offer recommendations regarding management or restoration of aquatic resources. Detailed watershed assessments of the Prairie Creek sub-basin are described in The North Coast Assessment of the Redwood Creek Basin (Cannata et al. 2006) of the California Department of Fish and Wildlife, and in the Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (National Marine Fisheries Service 2014).

Background

Prairie Creek drains 103 km² of the northwestern portion of the 731 km² Redwood Creek basin, in coastal northern California (Figure 1). The largest and most pristine of the Redwood Creek tributaries, Prairie Creek enters Redwood Creek close to its mouth, at river km 5.6. Redwood Creek flows into the Pacific Ocean 2.7 km west of the town of Orick, California. The Prairie Creek sub-basin is composed of forested terrain from approximately 8 m to 692 m elevation (Appendix A), nearly all (98%) of which is in public ownership, and managed by Redwood National and State Parks. Drainage area, basin slope, floodplain area, and perennial stream length within each of its catchments are listed in Table 1.

Climate and Hydrology

The regional climate of coastal northern California is characterized by mild, wet winters and cool, dry summers. Air and water temperatures are moderated by the dense canopy cover of the redwood forest and by summer fog (Johnstone and Dawson 2010). From 1948-2006, annual air temperatures at the “Orick Prairie Creek Park” weather station ranged from 6-16 °C, with a summer mean of 14 °C and a winter mean of 7 °C (Western Regional Climate Center 2016). Snowfall in the Prairie Creek sub-basin is rare. Over a period of record from 1937-2004, annual rainfall in Prairie Creek averaged 171 cm (Figure 2), with most of the rainfall occurring between November and March.

Prairie Creek flows perennially, with a flow regime reflective of its winter rainfall hydrograph. Flow history of the creek can be characterized from a record of over 68 years of continuous streamflow recorded at the U.S. Geological Survey gaging station on Redwood Creek in Orick (station code 11482500). The gage is located immediately downstream of the confluence of Prairie Creek with Redwood Creek.

From the 1950s through the early 1970s the basin experienced several extremely large flood events (Figure 3). From the mid-1970's through water year 2015, peak discharge on Redwood Creek has exceeded the discharge of a 5-year recurrence interval (32,000 ft³s⁻¹ or 906 m³s⁻¹) only once, in 1997, when the recurrence interval was estimated at 11 years. Klein and Marquette (2010) summarized available annual discharge data within catchments of the Prairie Creek sub-basin, and provided flood frequency curves for Prairie Creek above May (station PRW) and Little Lost Man Creek. They estimated peak discharge of a 20-year recurrence interval for Prairie Creek above May Creek (drainage area = 32.6 km²) to be approximately 1650 cfs (47 m³s⁻¹). The highest discharge that has been measured over the period of record was 778 cfs (22 m³s⁻¹).

Geology

While most of the Redwood Creek drainage is underlain by metamorphic and sedimentary rocks of the Franciscan assemblage, a majority of the Prairie Creek watershed is underlain by weakly consolidated shallow marine and alluvial sediments known as the Prairie Creek Formation. Sediments are derived from ancestral Klamath River and estuary deposits (Cashman et al. 1995); the oldest of these contain fragments of Pliocene plant fossils (Hardin et al. 1981). The steeper Lost Man and Little Lost Man Creek catchments east of Highway 101 are underlain primarily by the Coherent Unit of Lacks Creek.

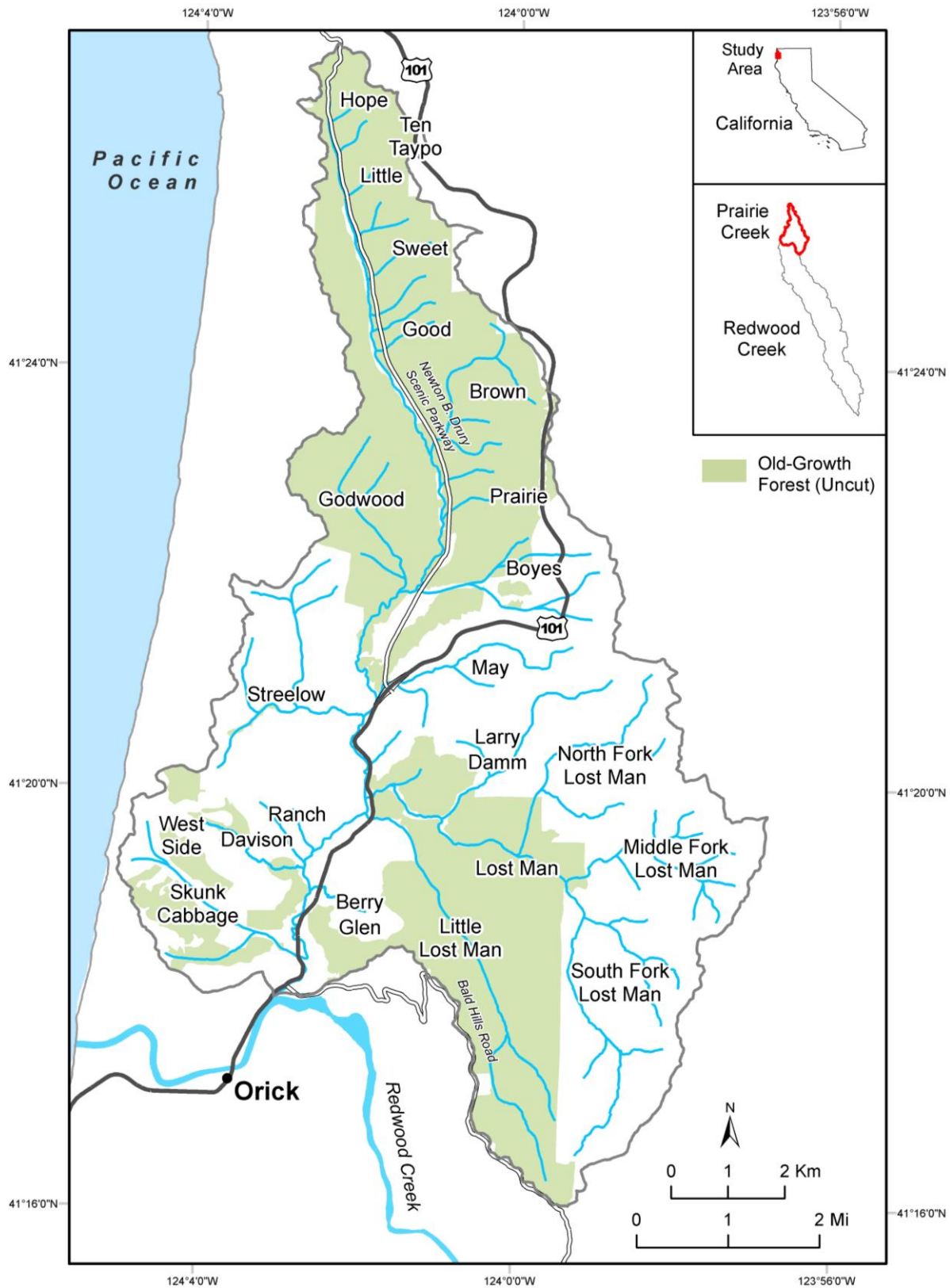


Figure 1. Major catchments within the Prairie Creek sub-basin of Redwood Creek, Humboldt County, California.

Table 1. Drainage area, average basin slope, floodplain area, and stream length of catchments within the Prairie Creek basin, listed north to south. Stream lengths were measured as blue-line equivalents from Lidar-created streams. Values were generated by RNP GIS on July 16, 2017.

Catchment	Drainage Area (km²)	Basin Slope (%)	Basin Slope (degrees)	Floodplain Area (km²)	Stream Length (km)
Hope Creek	0.26	47	25	—	0.89
Ten Taypo Creek	1.08	43	23	—	1.6
Little Creek	0.83	45	24	—	1.2
Sweet Creek	0.97	47	24	—	1.5
Good Creek	0.59	51	26	—	1.2
Brown Creek	4.71	46	24	—	7.0
Boyes Creek	4.72	40	21	0.11	8.3
Godwood Creek	4.63	42	22	0.62	7.1
May Creek	4.62	41	22	—	7.0
Streelaw Creek	7.36	38	20	0.41	11.5
Lost Man Creek (Total)	31.49	43	22	0.24	43.7
Lost Man Creek Mainstem	4.66	41	21	0.24	6.5
Larry Damm Creek	4.78	43	22	0	5.7
North Fork Lost Man Creek	5.73	44	23	0	8.3
Middle Fork Lost Man Creek	5.78	45	23	0	9.6
South Fork Lost Man Creek	10.55	43	22	0	13.6
Little Lost Man Creek	9.19	43	22	0.07	11.3
Ranch Creek	0.49	46	24	—	0.85
Davison Creek	1.04	40	21	—	1.2
West Side Creek	1.72	33	18	—	1.6
Berry Glen Creek	1.08	43	22	—	0.94
Skunk Cabbage Creek	5.80	37	20	0.64	7.8
Prairie Creek Floodplain	4.51	12	6.6	4.51	28.0
Other drainages to Prairie Creek: West Side	7.66	47	24	—	1.6
Other drainages to Prairie Creek: East Side	10.20	45	23	—	10.5
Prairie Creek Total	102.95	41	22	6.59	154.9

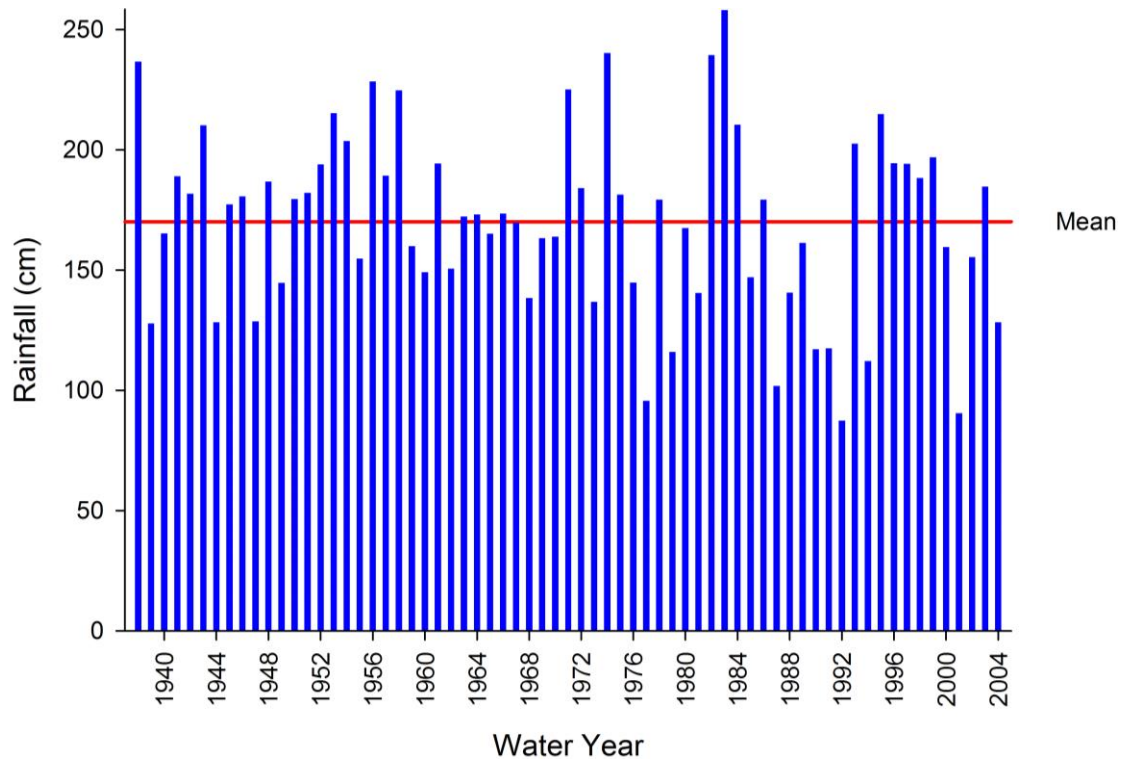


Figure 2. Annual rainfall at Prairie Creek Redwood State Park during water years 1938-2004. Mean rainfall over the period of record is denoted by red horizontal line. Data from RNP.

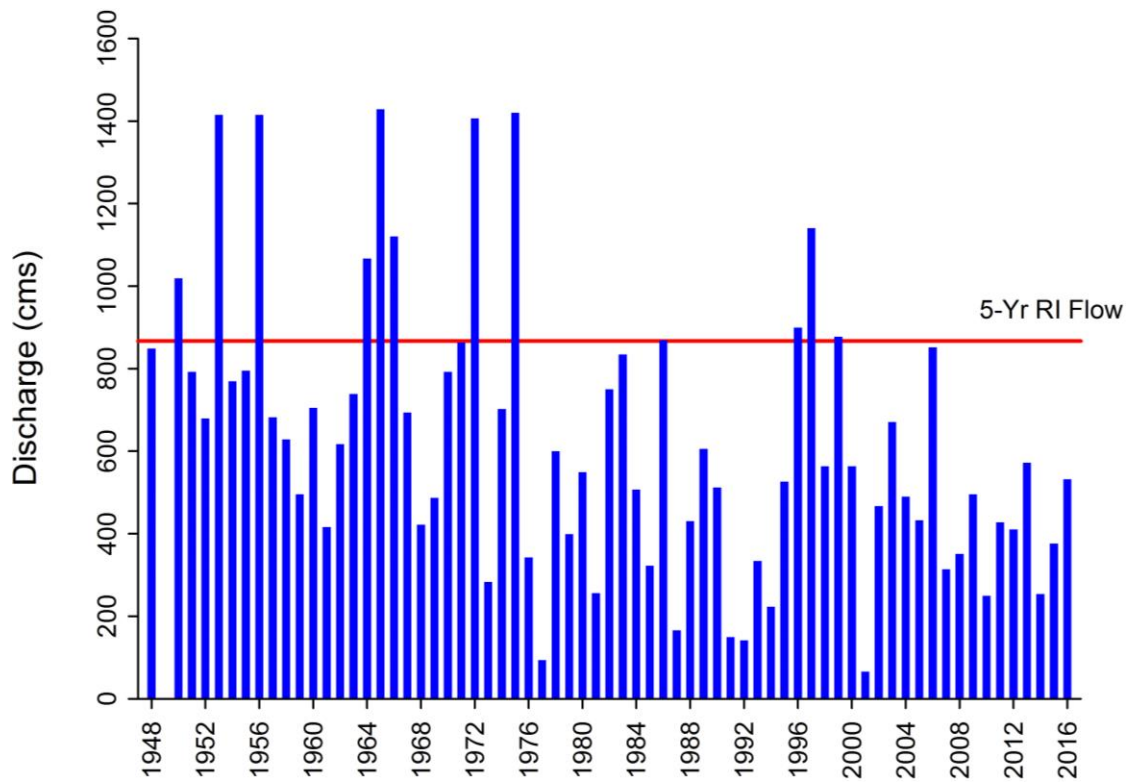


Figure 3. Peak flows recorded by the U.S. Geological Survey gage at Redwood Creek at Orick, California from 1948 through 2016. Discharge with a five-year recurrence interval (RI) is indicated with a red line.

Vegetation

The sub-basin of Prairie Creek is almost entirely (93%) vegetated in coniferous forest. Approximately 48% (47 of 98 km²) of the forest consists of late seral (unlogged old-growth) stands of coast redwood (*Sequoia sempervirens*), Sitka spruce (*Picea sitchensis*), and Douglas-fir (*Pseudotsuga menziesii*). Remaining forest (52%) is mid-seral, most of which regenerated from old-growth forests that were harvested in the 1950s and 1960s. Much of the second-growth is dominated by Douglas-fir (Teraoka 2010), some of which was aurally seeded by timber companies at high densities following logging when the lands were privately owned. In these areas of aerial seeding, stands are in need of thinning to enhance tree growth. The distribution of old-growth and second-growth forest is given in Table 2.

Table 2. Areal coverage of old-growth uncut and harvested forest within catchments of the Prairie Creek sub-basin, listed north to south. Values were generated by RNP GIS on November 7, 2016.

Catchment	Uncut Old-Growth Area (km ²)	Uncut Old-Growth (%)	Harvested Area (km ²)	Harvested (%)
Hope Creek	0.26	100	0.00	0
Ten Taypo Creek	1.01	94	0.04	4
Little Creek	0.77	93	0.06	7
Sweet Creek	0.86	88	0.12	12
Good Creek	0.59	100	0.00	0
Brown Creek	4.43	94	0.13	3
Boyes Creek	1.36	29	2.94	62
Godwood Creek	4.60	99	0.03	1
May Creek	0.04	1	4.28	93
Streelaw Creek	0.50	7	6.86	93
Lost Man Creek (Total)	7.56	24	23.77	75
Lost Man Creek mainstem	4.46	96	0.03	1
Larry Damm Creek	0.91	19	3.87	81
North Fork Lost Man Creek	0.59	10	5.14	90
Middle Fork Lost Man Creek	0.13	2	5.63	97
South Fork Lost Man Creek	1.48	14	9.07	86
Little Lost Man Creek	8.22	89	0.94	10
Ranch Creek	0.00	0	0.49	99
Davison Creek	0.00	0	1.04	100
West Side Creek	0.45	26	1.26	73

Table 2 (continued). Areal coverage of old-growth uncut and harvested forest within catchments of the Prairie Creek sub-basin, listed north to south. Values were generated by RNP GIS on November 7, 2016.

Catchment	Uncut Old-Growth Area (km ²)	Uncut Old-Growth (%)	Harvested Area (km ²)	Harvested (%)
Berry Glen Creek	0.14	13	0.86	80
Skunk Cabbage Creek	2.42	42	3.33	57
Prairie Creek Floodplain	1.88	42	0.19	4
Other Drainages to Prairie Creek: West Side	4.45	58	3.06	40
Other Drainages to Prairie Creek: East Side	7.63	75	1.95	19
Prairie Creek Total:	47.17	46	51.34	50

Vegetative composition of riparian forests, which connect upland forests with adjacent aquatic ecosystems, is particularly important to stream biota because it affects stream water temperature, bank stabilization, and supplies to the stream channel of large woody debris, nutrients, detrital material, and invertebrate prey for fish and other stream predators. Keyes and Teraoka (2014) reported differences in structure and composition of overstory and understory riparian stands between paired old-growth and second-growth stands in South Fork Lost Man and Little Lost Man creeks. Redwood was the dominant overstory tree in old-growth riparian areas, while second-growth was dominated by red alder (*Alnus rubra*), Douglas-fir, and redwood. Understory species were similar in both forests, but understory species differed in importance values (a measure of species dominance) between old-growth and second-growth stands. Redwood sorrel (*Oxalis oregano*) and western white trillium (*Trillium ovatum*) had higher importance values in old-growth, and red huckleberry (*Vaccinium parvifolium*), wood fern (*Dryopteris* spp.), and sedges *Carex* spp. had higher importance values in second-growth.

Emergent wetland vegetation and forested/shrub wetland vegetation in Prairie Creek were surveyed and classified as part of a U.S. Fish and Wildlife Service Floodplain and National Wetland Inventory conducted in 1987 of the Redwood Creek estuary, Prairie Creek, and surrounding wetlands area (Figure 4). Mapping data in lower Prairie Creek were updated with ground-truthing of aerial photos in 2015 by RNP soil scientist Seney (Figure 5). Emergent and forested/shrub wetland habitats are most extensive at Davison Ranch and Skunk Cabbage Creek. As expected, the floodplain broadens and increases in area as the creek increases in size from headwaters to mouth (Table 1, Figure 4). Several non-native plant species have become established in floodplain and wetland areas of lower Prairie Creek, including Himalayan blackberry (*Rubus armeniacus*), reed canary grass (*Phalaris arundinacea*), and mannagrass (*Glyceria* spp.).

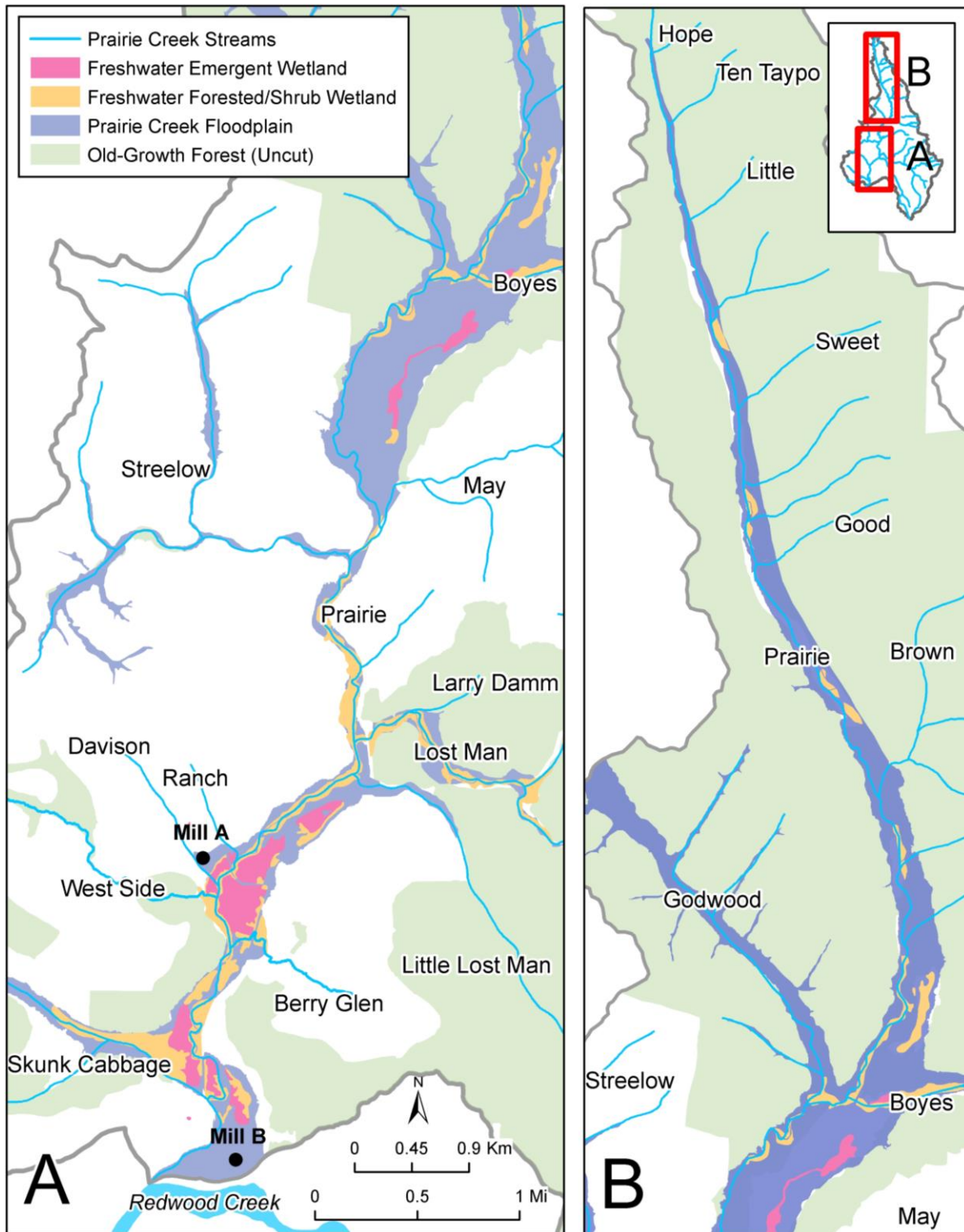


Figure 4. Distribution of wetland types and floodplain habitat in Prairie Creek based on data from the 1987 Floodplain and National Wetland Inventory of the U.S. Fish and Wildlife Service.

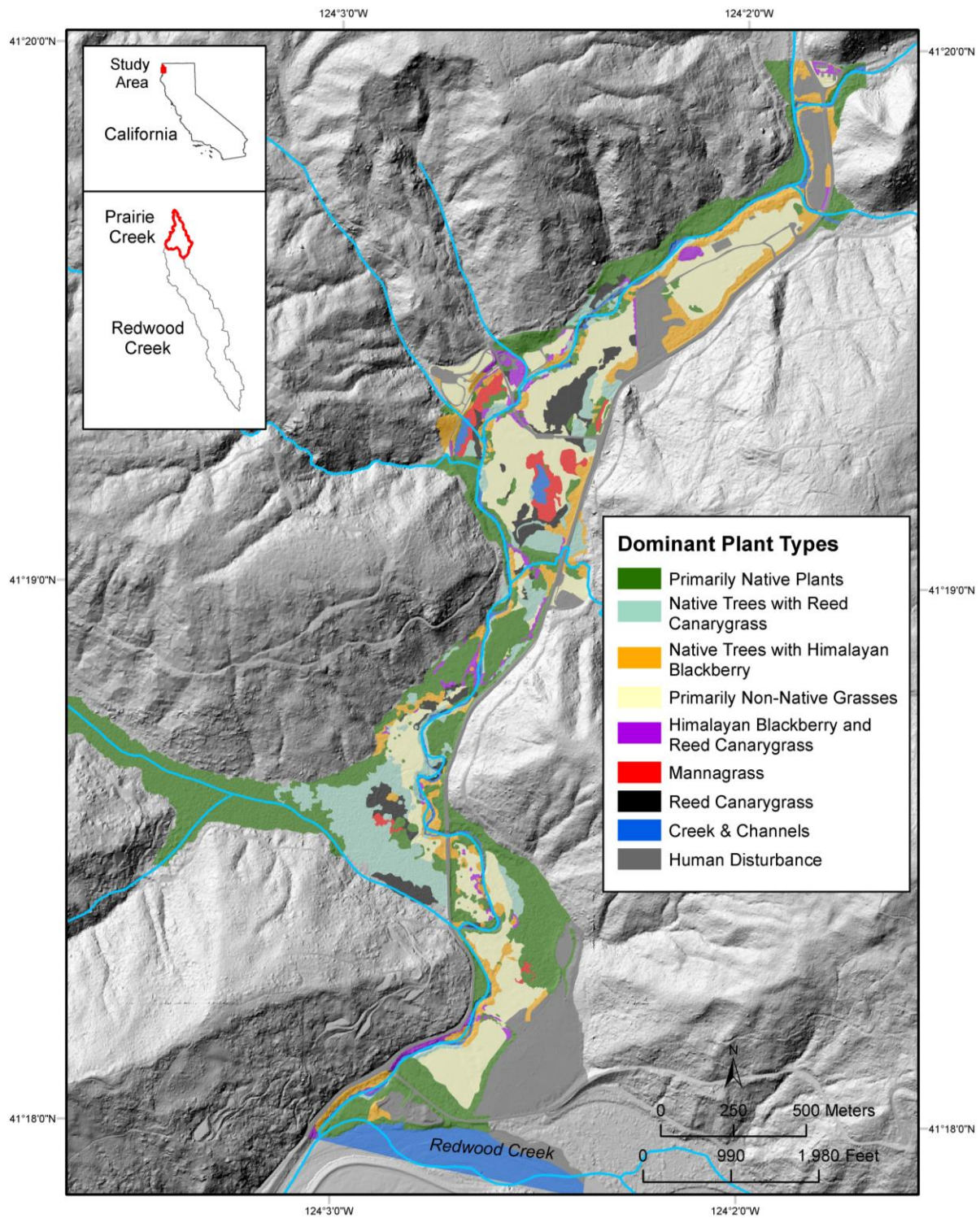


Figure 5. Distribution of dominant native and non-native plant types in the floodplain of lower Prairie Creek based on 2015 ground survey by RNP (NPS/JOSEPH SENEY).

Land Use History

Land Development, Timber harvest, and Park Management

Euro-American settlement of northwest California coast began with the discovery of gold at Gold Bluffs Beach in 1851, and resulted in the large-scale displacement of indigenous peoples who had inhabited the region for over 3,000 years. While gold mining operations were short-lived, commercial logging of old-growth redwoods to supply building needs of the settlers boomed. Between 1880 and the early 1900's, hundreds of hectares of virgin redwoods were cleared. Mounting concern over the loss of the ancient trees was reflected in the establishment in 1918 of the Save the Redwoods League, which aimed to preserve redwood forests through land purchase. The League and the State of California together purchased old-growth redwood stands adjoining Prairie Creek in the upper part of the watershed. Prairie Creek Redwoods State Park (PCRSP) was created in 1923 with an initial donation of 65 ha from a landowner to the League; through subsequent acquisitions, the PCRSP now encompasses 5,339 ha of virgin redwood forest, prairies, beaches, and streams.

While the lands within State Park boundaries have been protected from logging since the establishment of the park, logging and extensive road-building continued on private lands in lower Prairie Creek through the 1970s (Figures 6 and 7). The last timber harvest occurred in 1977 in the Skunk Cabbage drainage. Prior to implementation of the California Forest Practice Rules in 1973, road and landing construction were unregulated, and large areas of forest were clearcut by tractor yarding from the 1950s onward. Establishment by the U.S. Congress of Redwood National Park in 1968 secured 23,471 ha, including much of the few remaining stands of uncut redwoods in the Prairie Creek watershed outside of PCRSP. Logging practices in upland and riparian areas during the 1950s to 1970s exacerbated high natural rates of erosion. Further loss of riparian redwoods, along with widespread erosion and sedimentation in Redwood Creek, were experienced during large floods from the 1950s to mid-1970s. Redwood National Park boundaries were expanded by Congress in 1978, with the addition of 19,424 ha from largely logged-over portions of Redwood Creek and the lower Prairie Creek watershed. Since 1994, the National Park Service and the California Department of Parks and Recreation have jointly managed Redwood National and State Parks.

Since 1978, the Park has removed approximately 114 km of abandoned logging roads within the Prairie Creek sub-basin (Figure 7). In early years of the road rehabilitation program, some of the roads were mulched with straw and trees were planted on the recontoured road bench, but now the park relies on redwood re-sprouts and volunteer plants, such as alders growing from seeds of adjacent areas for revegetation. Not including skid roads, approximately 140 km of existing road (both paved and unpaved) remain. Catchment-specific road density averages 1.67 km/km². While 40% of the roads were sited in areas estimated as having high landslide potential (Cannata et al. 2006), historically active landslide features account for less than 1.5% of the Prairie Creek drainage area. Road removal and second-growth management efforts are ongoing.

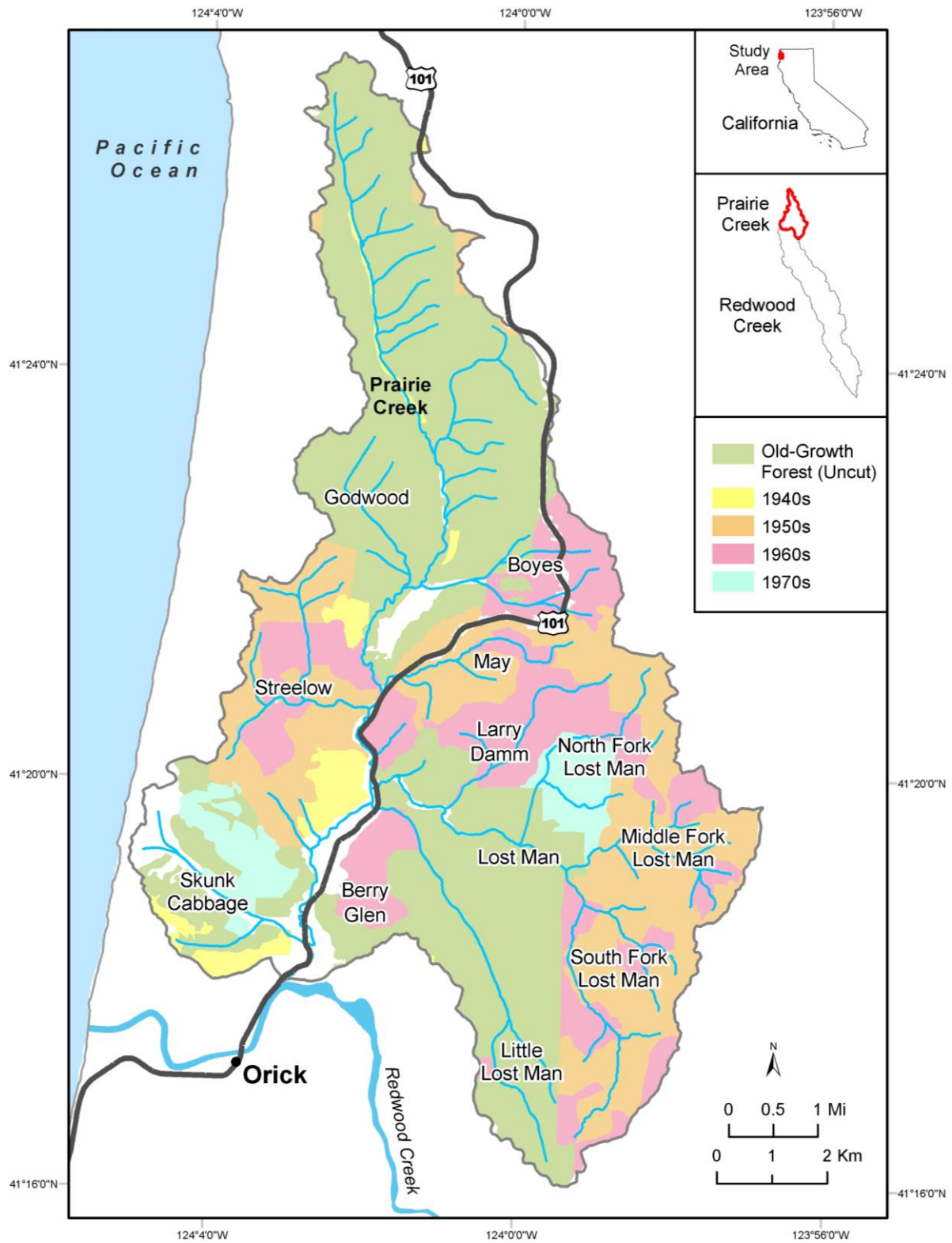


Figure 6. Timber harvest history within the Prairie Creek Basin. Data from RNP.

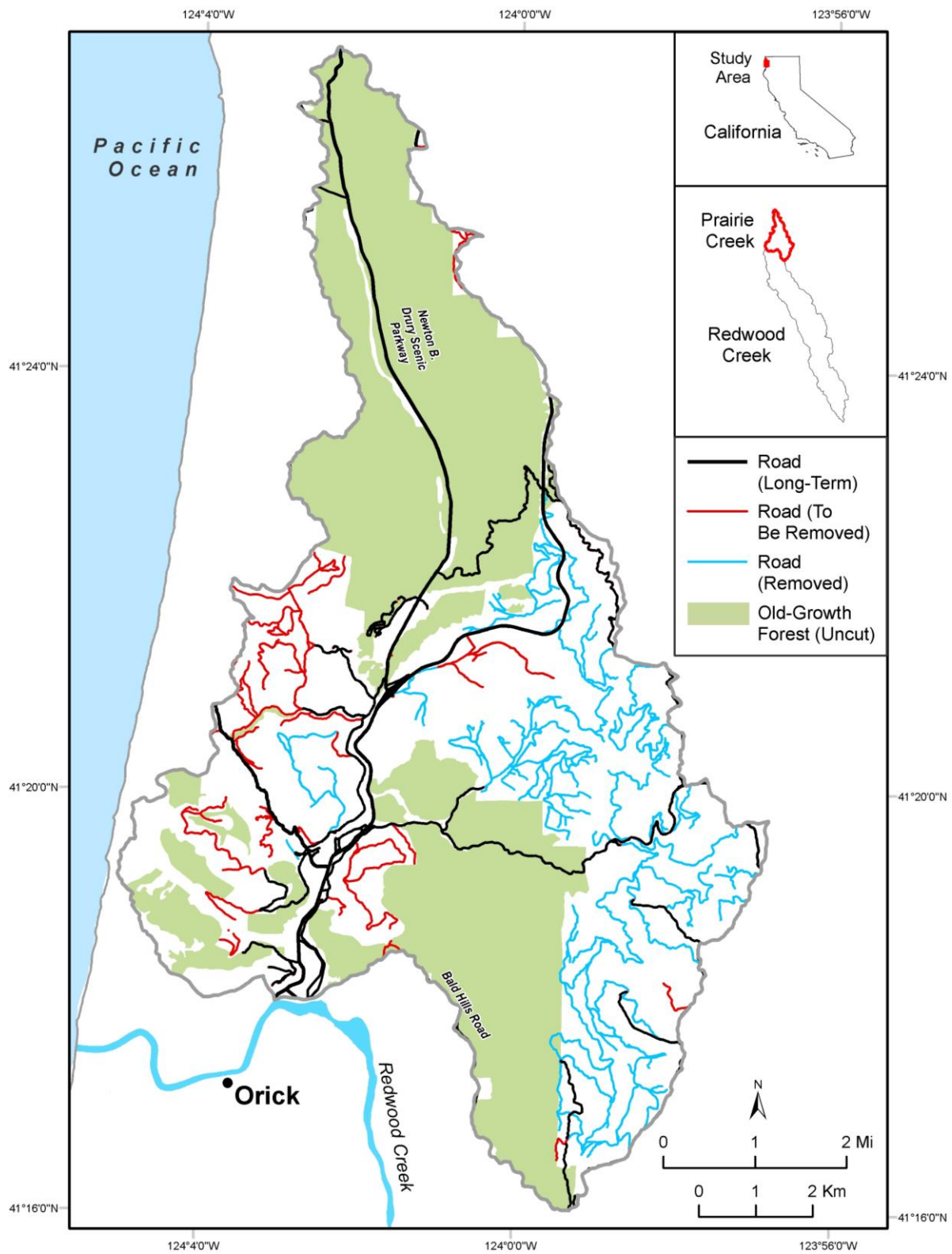


Figure 7. Existing and removed roads in the Prairie Creek Basin. Data from RNP.

Channel and Floodplain Alteration.

The floodplain, riparian vegetation and channel structure of lower Prairie Creek were substantially altered in association with dairy and ranching operations, timber harvest, and construction of Highway 101 and county roads, as well as with housing and business developments prior to acquisition of landholdings by RNSP (Ferrana and Ricks 1981, RNP 1996). The floodplain and wetlands were filled and pastured, riparian vegetation was cleared, the stream channel was diked, and log jams were removed from the creek to reduce flooding. In some instances, log jams were removed with dynamite. The 40-ha Davison Ranch, a former dairy ranch in operation for close to a century, was acquired by Redwood National Park, National Park Service in 1991. The A- and B- Mills were logging mills and log decks used in large-scale industrial forestry operations in the Prairie Creek valley. The former B- Mill, adjacent to the Davison Ranch, was also acquired by the park and in 1999 the paved log deck adjacent to Prairie Creek was removed and the area restored. The rest of the site was converted to a day use area with bathrooms, parking lot, and trails. Save the Redwoods League acquired the 51-ha A- Mill property in 2013, and has initiated a planning project to restore ecological functioning of the creek and wetland areas at the site, construct a visitor center, and develop trails. Approximately 187 ha of the lower Prairie Creek watershed remains in private ownership, and is used in part for livestock grazing.

In an early winter storm in October 1989, erosion of soils which were exposed during construction of the Highway 101 Prairie Creek Bypass delivered large amounts of fine sediments to Brown, Boyes, and May creeks. Sediments were subsequently transported into the mainstem of Prairie Creek. The storm transported 30 times the amount of suspended sediment than storms of a similar magnitude that occurred later that year (Klein 1999). Impacts on aquatic biota and on channel structure are detailed in the aquatic resources and habitat assessment sections (Sediment Supply and Hydrologic Function) of this paper. Roadway sanding during icy conditions in winter and other highway activities may continue to introduce sediments into stream channels. Channels have also been altered in association with operation of the Prairie Creek fish hatchery, as described below.

Prairie Creek Hatchery

The Prairie Creek Hatchery operated between 1927- 1992. Hatchery operations began with the establishment of a temporary tent facility on Prairie Creek (Van Kirk 1996). A permanent facility was erected in 1936 by the California Department of Fish and Game Hatchery on Lost Man Creek close to its confluence with Prairie Creek. The objective of the hatchery was to improve sport and commercial fishing in the area, particularly for Cutthroat Trout, as the Department believed that Prairie Creek had the greatest potential within the state to supply Cutthroat Trout eggs. Humboldt County assumed control of the hatchery in 1962 from the state, and operated it until operations ceased in 1992.

Channel modifications accompanied hatchery operations. During early years of the hatchery, log jams and other obstructions were removed from the creek when these were judged to be problematic for fish passage. The primary trapping site was a weir and fish ladder located at the hatchery, with a secondary weir and trap placed in Prairie Creek 200 upstream of the confluence with Lost Man Creek. A dam was built 0.5 km upstream in Lost Man Creek as a water source for the hatchery, and

abandoned in 1955 when it filled with sediment. The dam was replaced by another dam closer to the Hatchery, which is no longer operational. The channel subsequently migrated around the lower dam in the mid-1990s. The upper dam, which was a partial barrier to migrating salmon, particularly Chinook Salmon, was removed by Redwood National Park in August 1989. Removal of the dam increased salmonid spawning access and use of 2.9 km of upstream habitat in the creek (Ozaki and Anderson 1993). Relative percent of live adult salmonids, carcasses and redds nearly doubled upstream of the dam site following dam removal.

During its operation, the hatchery received eggs and broodstock from several locations outside of the Redwood Creek Basin and it stocked hatchery fish in locations outside the basin. Eggs and broodstock of Coho Salmon, for example, were received from the Trask, Klaskanine, and Sandy rivers in Oregon, the Skaggit and Soos rivers in Washington, and the Trinity and Noyo rivers in California. Cutthroat Trout broodstock were obtained from the Alsea River in Oregon. During 1990-91, plantings of hatchery fish in Prairie and Lost Man creeks included 52,000 Chinook Salmon, 109,835 Coho Salmon, 65,985 Steelhead, and 260 Cutthroat Trout (Yarbrough 1991). The genetic effects on wild stocks of salmon and steelhead through introgression with non-native strains and from domestication are unknown. Among the hatchery fish planted in Prairie Creek were 4,395 Atlantic Salmon (*Salmo salar*), which are native to the North Atlantic Ocean basin. The planting was apparently not successful.

Aquatic Resources

Prairie Creek supports self-sustaining populations of 4 species of salmonid fishes: Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), resident and anadromous Coastal Rainbow Trout (*O. mykiss irideus*), and resident and anadromous Coastal Cutthroat Trout (*O. clarki clarki*), all of which are native to western North America. Small numbers of Chum Salmon (*O. keta*) occasionally stray into Prairie Creek, but are not common. Pink Salmon (*O. gorbuscha*) have also been observed (Smedley 1952). Anadromous life history forms of Coastal Rainbow Trout are referred to as steelhead. Steelhead and Coastal Cutthroat Trout are known to hybridize within the creek (Neillands 1984). A brief synopsis of the life history and population status of each salmonid species follows below a listing of other aquatic taxa inhabiting the creek.

Non-Salmonid Fishes

Non-salmonid fishes present in the Prairie Creek watershed include: Threespine Stickleback (Gasterosteidae: *Gasterosteus aculeatus*), Sacramento Sucker (Catostomidae: *Catostomus occidentalis*), Prickly Sculpin (Cottidae: *Cottus asper*), Coast Range Sculpin (Cottidae: *C. aleuticus*), Pacific Lamprey (Petromyzontidae: *Lampetra tridentata*), and Pacific Brook Lamprey (Petromyzontidae: *L. richardsoni*). Non-salmonid fishes in Prairie Creek have rarely been the direct focus of research efforts; information on their presence and relative abundance have been obtained from by-catch of collection efforts targeting salmonid fishes (Table 3). Two Eulachon (*Thaleichthys pacificus*), a small anadromous smelt of the eastern Pacific Ocean, were captured in 2015 and one in 2016 in a rotary screw trap at the mouth of Prairie Creek for the first time in the trap's operation (Wilzbach et al. 2016, Wilzbach et al. 2017). Populations of this fish are considered by the U.S. Fish and Wildlife Service as likely extirpated in Redwood Creek, and individuals had not been observed since the 1970s. The last large runs of Eulachon occurred in 1967 (Van Kirk 1994) and 1973 (Rogers 1973). Eulachon in the Southern Distinct Population Segment (which includes Washington, Oregon, and California) are listed as threatened under the Endangered Species Act (ESA).

Table 3. Annual abundance of non-salmonid fishes captured in a rotary screw trap operated by CDFW and the CCRU-USGS above the confluence of Prairie Creek with Redwood Creek, averaged from 2011-2013. The trap was operated during the downstream salmonid migration period, approximately February through July. Data are from Sparkman et al. (2015).

Species Captured	3-year Average Catch
Prickly Sculpin	1,588
Coast Range Sculpin	2,252
Sacramento Sucker	239
Three-Spined Stickleback	1,658
Pacific Lamprey adults	27
Lamprey ammocoetes	625
Brook Lamprey	48

All of the fish species occurring in Prairie Creek are regionally native. The distribution of the anadromous Pacific Lamprey coincides with the North American distribution of Pacific salmon and steelhead. As is the case for salmon, lamprey runs in North Coast streams of California are much smaller than they were historically, based on living memories of tribal subsistence fishers. Population sizes of adult lamprey are poorly understood and are not formally monitored. Tribal fishers on the adjacent Klamath River have reported consistently low runs since the mid-1980s; declines in adult abundance of Pacific Lamprey in the Mad-Redwood Creek system are estimated to be in the range of 50-70% (Goodman and Reid 2012). The fish, however, is believed to currently occupy most historical anadromous habitat in the region downstream of impassable dams. Small numbers of adult Pacific Lamprey, and hundreds of lamprey ammocoetes have been routinely captured in downstream migrant traps annually operated in Prairie Creek. Pacific Lamprey co-occur with the non-parasitic Brook Lamprey in Prairie Creek.

Amphibians

Amphibians collected from Prairie Creek include 5 salamanders and 5 frogs (Table 4). With the exception of the American Bullfrog, all amphibian species are native to the region. The American Bullfrog is native to the eastern and Midwestern United States and southeast Canada, and has become established in California following its introduction in the 1920's by commercial frog farmers.

Table 4. Scientific and common names of amphibians collected from Prairie Creek. Records derive from Ashton et al. (2006), Welsh and Ollivier (1999), and unpublished reports of the USGS CCRU and CDFW.

Scientific Name	Common Name
Order Caudata	Salamanders
Ambystomatidae	Mole Salamanders
<i>Ambystoma gracile</i>	Northwestern Salamander
Dicamptodontidae	Giant Salamanders
<i>Dicamptodon tenebrosus</i>	Coastal Giant Salamander
Plethodontidae	Lungless Salamanders
<i>Ensatina eschscholtzii</i>	Ensatina
Rhyacotritonidae	Torrent Salamanders
<i>Rhyacotriton variegatus</i>	Southern Torrent Salamander
Salamandridae	Newts
<i>Taricha granulosa</i>	Rough-skinned Newt
Order Anura	Frogs
Bufonidae	True Toads
<i>Anaxyrus boreas</i>	Western Toad

Table 4 (continued). Scientific and common names of amphibians collected from Prairie Creek. Records derive from Ashton et al. (2006), Welsh and Ollivier (1999), and unpublished reports of the USGS CCRU and CDFW.

Scientific Name	Common Name
Leiopelmatidae	Tail-wagging Frogs
<i>Ascaphus truei</i>	Coastal Tailed Frog
Ranidae	Brown Frogs
<i>Rana aurora</i>	Northern Red-legged Frog
<i>Rana boylei</i>	Foothill Yellow-legged Frog
<i>Lithobates catesbeianus</i>	American Bull Frog

The Coastal Giant Salamander (formerly the Pacific Giant Salamander), Tailed Frog, and Southern Torrent Salamander are common throughout perennial streams in the watershed. Larval and pedomorphs (sexually mature animals with larval morphology) of the Coastal Giant Salamander are strictly aquatic and function as benthic predators. Often found under cobble-sized substrate, the Coastal Giant Salamander may account for as much as 99% of the predator biomass in small streams. Metamorphosed adults are found under rocks and logs in the vicinity of streams. Only the larval stage of the Tailed Frog is aquatic. Specialized folds that create suction, and a ventrally placed mouth, allow Tailed Frog tadpoles to cling to underwater rock surfaces, where they feed as scrapers on attached periphyton. Tailed Frogs are unique among temperate frogs in being specifically adapted to fast-flowing and cold water habitats. Adults of the small, secretive Southern Torrent Salamander occur both within small streams and streamside. Larvae are aquatic, and found on the streambed in coarse gravel. The Southern Torrent Salamander feeds on small insects and spiders, and is preyed upon by the Coastal Giant Salamander. The Southern Torrent Salamander has the lowest desiccation tolerance of all North American salamanders, and exhibits temperature stress at temperatures above 17 °C. Northwestern Salamanders and their egg masses are found in ponds and side channel alcoves.

The Coastal Giant Salamander, Tailed Frog, and Southern Torrent Salamander have all been found to be more abundant in streams bordered by late seral forest than in streams bordered by second-growth forest (Ashton et al. 2006). Welsh and Ollivier (1999) reported that their densities were lower in streams impacted by sediment delivery from the 1989 Bypass incident than in control streams, but that density differences had disappeared 6 years later. Madej et al. (2006 a) found that stream reaches in undisturbed redwood forests within the Redwood Creek basin had significantly higher biomass and density of tailed frogs than streams in logged watersheds with various degrees of road removal work.

None of the native amphibian taxa found in Prairie Creek are federally or state listed as threatened or endangered. The Southern Torrent Salamander, Red-legged Frog, and Foothill Yellow-legged Frog, however, are considered Species of Special Concern by the California Department of Fish and Wildlife.

Macroinvertebrates

Benthic and drifting macroinvertebrates (invertebrates > 0.5 mm at maturity) from Prairie Creek have been sampled and described in several reports and theses. These include Averett and Iwatsubo (1995), Meyer and Haux (1995), Madej et al. (2006 a), Dinger (2015), and Humboldt State University theses, e.g., Anderson (1988), Strange (1989), Beesley (2006), and Gonzales (2006), and senior projects (Kvam 1988). In addition, RNP sampled benthic macroinvertebrates in the Lost Man Creek drainage (North Fork, Lost Man above North Fork, Larry Damm Creek, Lost Man below North Fork, and Lost Man at Larry Damm Creek) in 2007 to monitor impacts associated with road removal. Voucher specimens from some of these projects, including the Madej et al. (2006 a) collection and collections made in association with Highway 101 Prairie Creek Bypass monitoring, can be found in the Redwood National Park museum collection.

Studies were conducted with differing objectives. Invertebrates sampled in the Redwood Creek drainage by the U.S. Geological Survey in 1973-1975 (e.g., Iwatsubo et al. (1976), Averett and Iwatsubo 1995) and collections by Anderson were intended as general descriptors of aquatic resources and habitats within Redwood National Park. Madej and co-authors (2006 a) compared abundance and diversity of benthic macroinvertebrates and other aquatic organisms between 2004-2005 and the 1970s to assess the impact on stream health of 30 years of extensive watershed restoration. Kvam (1988) developed keys for identification of genera of Chironomidae (Order Diptera, Insecta) from invertebrate samples previously collected as part of a program to monitor effects of construction of the Highway 101 Prairie Creek Bypass. Meyer and Haux (1995) also reported on invertebrate impacts from the Bypass construction. Beesley (2006) estimated annual production for one genus of mayfly in Prairie, Boyes, and Streelow creeks, and Gonzales (2006) reported on diet and invertebrate prey consumption of juvenile Coho Salmon. Invertebrates were sampled in Prairie Creek and other RNSP sites by Dinger (2015) to assess status of stream ecological condition as a component of the Klamath Inventory and Monitoring Network.

Invertebrate studies differed in the level of taxonomic resolution according to study objectives. A list of insect and non-insect invertebrate taxa that have been collected and identified from the above-referenced studies of Anderson, Kvam, Madej and co-authors, Strange, and RNSP is given in Appendices B and C, respectively. Invertebrate prey items found by Gonzales to be important in the diets of juvenile Coho Salmon included larval and adult Diptera, and the Oligochaeta. Amphipods contributed substantially to fish diets in Streelow Creek, but not in other streams where amphipods do not appear to be present or abundant. Differences in amphipod distribution among Prairie Creek tributaries potentially result from differences in water buffer variables (e.g., calcium concentration, alkalinity, and water hardness).

Efforts to relate assemblage structure of benthic macroinvertebrates to adverse effects from influx of sediments from road construction or removal, or to improved physical conditions following watershed restoration in Prairie Creek, have not been greatly successful. Using bioassessment metrics of an Index of Biological Integrity (IBI) that was developed for southern California, Madej et al. (2006 a) did not find clear trends in macroinvertebrate metrics between the 1970s and 2000s, and they reported high variability in macroinvertebrate composition between seasons and years, and

among sites. The most pristine sites did not have the highest IBI ratings. An IBI specific to northern coastal California, where timber harvest is a major stressor, has been developed subsequent to their analysis (available at www.waterboards.ca.gov/swamp), and may be more relevant. However, use of a multi-metric rapid assessment approach, based on coarse levels of taxonomic resolution and distinguishing only among a small number of categories of biological condition (very poor to very good), may reveal only large-scale changes in assemblage structure. Bioassessment protocols are developed from samples of riffle habitat only, and thus do not reflect assemblage structure within pools or in association with large woody debris. The ability to detect loss or addition of species sensitive to disturbances such as sedimentation likely require a different type of analysis. Sampling by RNP in the Lost Man Creek drainage also did not reveal substantial differences in IBI scores among sampling locations affected and unaffected by road removal. North Fork Lost Man Creek was ranked as very good (NorCal IBI score=88 out of 100), other sites except Lost Man Creek at Larry Damm were ranked as good (IBI scores ranged from 68-71), and Lost Man at Larry Damm received a ranking of fair (IBI score = 59). Prairie Creek sites sampled by the NPS Klamath Network Inventory and Monitoring Group were ranked as good or very good (Dinger 2015); based on macroinvertebrate assessment, they concluded that no sites within RNSP were impaired. Benthic invertebrates, monitored from 1985-1992, did not appear to be adversely affected from construction of the Highway 101 Prairie Creek Bypass construction (Meyer and Haux 1995).

Although differences in annual production of the mayfly genus studied by Beesley (2006) were slight and variability of the estimates was unknown, the pattern of production magnitude generally fit the pattern of perceived disturbance among the three streams she studied. Production was highest in Prairie Creek, considered the least disturbed of the sites, and lowest in Boyes Creek, where disturbance was most recent.

None of the aquatic invertebrate taxa sampled in Prairie Creek are known to be non-native. The highly invasive and exotic New Zealand mud snail has been detected in the Redwood Creek estuary, but a recent survey did not detect New Zealand mud snails in Prairie Creek. The mud snail, like other mollusks, depends on calcium availability, as CaCO_3 is necessary for shell deposition and growth. Low alkalinity and water hardness in Prairie Creek may discourage or limit colonization of the snail (Vazquez et al. 2016).

Algal Assemblages

Benthic algae, along with nonliving organic carbon from a variety of sources, constitute the primary energy source at the base of riverine food webs. Photosynthetic activity of benthic algae provides oxygen for aerobic organisms in the ecosystem, and the carbon fixed by algae through photosynthesis provides food resources for herbivorous invertebrates and fishes. Benthic algae remove nutrients from the water column, attenuate the current and stabilize sediments, and provide habitat for other organisms. Composition of benthic algae is often used in rapid bioassessment protocols as a water quality indicator in California's surface water ambient monitoring program (SWAMP). Madej et al. (2006 a) compared rates of periphyton accrual on artificial substrates between 1973-1975 and 2004-2005 in Little Lost Man and Lost Man creeks (and other sites in Redwood Creek) as a means of assessing changes in stream health following extensive watershed restoration. Periphyton growth

rates at sites throughout the Redwood Creek basin, including Prairie Creek, were lower in 2004 and 2005 in comparison with periphyton growth in the early 1970s, which was attributed to an increase in riparian canopy cover. Periphyton growth did not differ between years with level of watershed disturbance or extent of road removal.

Few taxonomic descriptions of benthic algae in Prairie Creek are available. Iwatsubo et al. (1976) described the summer periphyton composition in 1974 and 1975 close to the mouths of Little Lost Man and Lost Man creeks, and reported both a greater taxonomic richness and overall abundance in Little Lost Man than in Lost Man Creek. Both streams were dominated by diatoms (algal division Bacillariophyta), with *Achnanthes lanceolata* and *Achnanthes* spp., *Cocconeis placentula*, and *Synedra amphicephala* occurring in largest numbers. Occurrence of filamentous blue green algae (division Cyanobacteria) and green algae (division Chlorophyta) was low in both streams. In mid-summer of 1975, however, the unicellular green alga *Chlamydomonas* sp. was abundant.

Salmonid Fishes

Data on salmonid fishes in Prairie Creek come from many sources, including monitoring data and reports of RNSP, CDFW, and consultants, and theses, and class projects of the CCRU-USGS and Humboldt State University. The known distributions of Chinook Salmon, Coho Salmon, and steelhead within Prairie Creek are shown in Figures 8, 9, and 10, respectively, based on passage assessment data from the California Cooperative Anadromous Fish and Habitat Data Program (CalFish 2016). The Prairie Creek sub-basin supports most of the Coho Salmon and Cutthroat Trout in Redwood Creek (Sparkman et al. 2014). While steelhead are the most widely distributed salmonid in the Redwood Creek basin, Coho Salmon outnumber steelhead and commonly outnumber Chinook Salmon in the Prairie Creek watershed. For example, during the 2013-2014 spawning season, CDFW estimated a total of 538 Coho Salmon, 151 Chinook Salmon, and 57 steelhead redds within Prairie Creek (Ricker et al. 2014).

Chinook Salmon

The largest of the anadromous Pacific salmon, with mature fish reaching lengths of 1 m or more, Chinook Salmon typically spend 2-4 years or more at sea, and migrate as adults from the ocean into the freshwater rivers of their birth in order to mate. Like other Pacific salmon, the fish are semelparous, i.e., dying after spawning once. Adult Chinook Salmon returning to Prairie Creek to spawn are usually in their 3rd - 5th year and are fall-run. Upstream passage during late spring and summer months is prevented by low stream flows and sand bar closure of the Redwood Creek mouth. Precocious males, referred to as jacks, may return to the creek to spawn after only one summer in the ocean, at a weight of about 1.4-1.8 kg (Ridenhour and Hofstra 1994). Freshwater entry is typically coincident with the first heavy fall rains; most of the individuals comprising the first main run commonly enter Prairie Creek during the first two weeks in November. The run usually continues through the end of December or early January. Briggs (1953) noted that the distribution of spawning by Chinook Salmon within the mainstem and larger tributaries of Prairie Creek reflects its preference for areas of comparatively greater flow. Prairie Creek, he observed, is an unusually small stream to support spawning by Chinook Salmon.

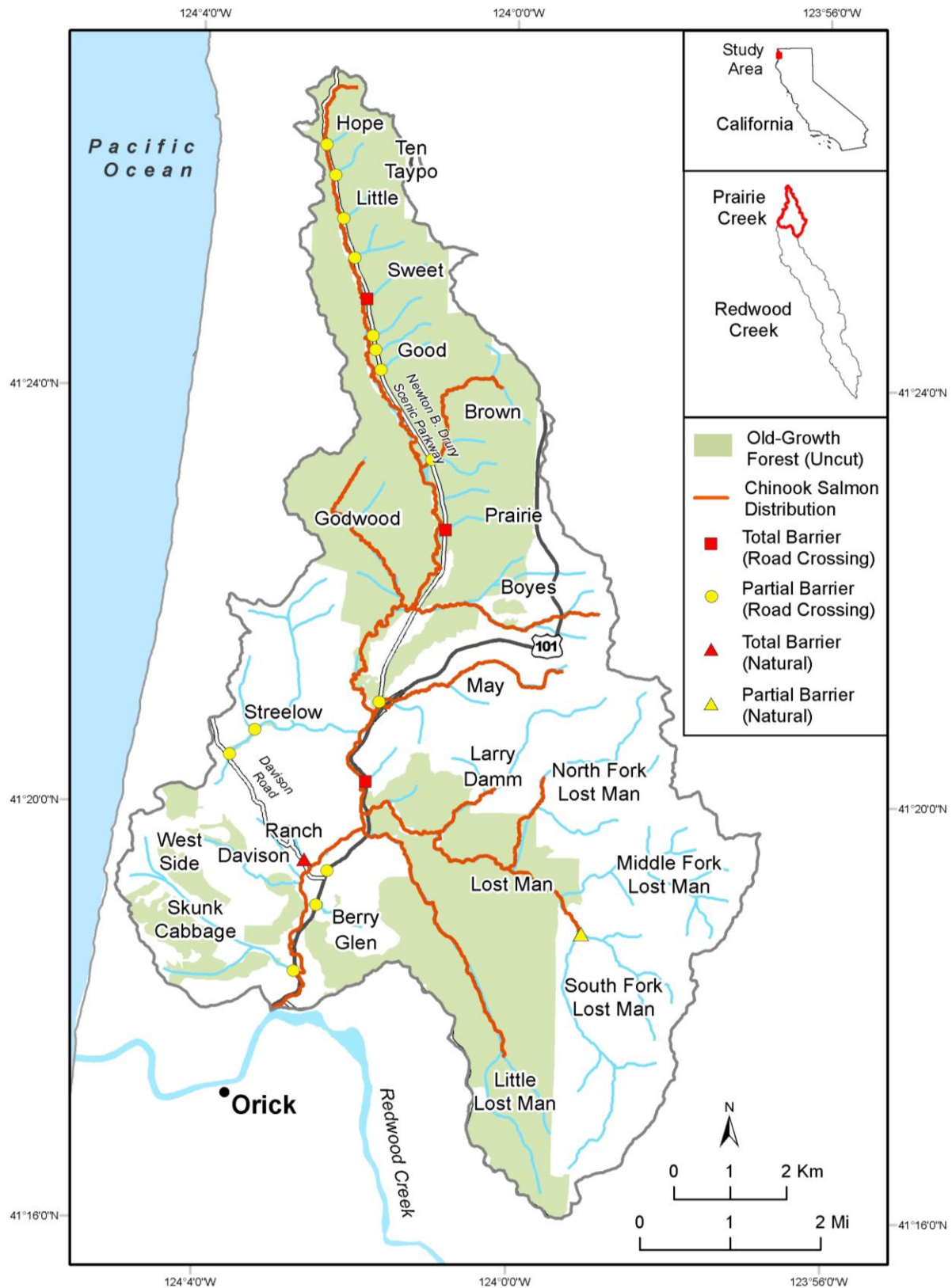


Figure 8. Distribution of Chinook Salmon within the Prairie Creek Basin, based on the 2016 Calfish database.

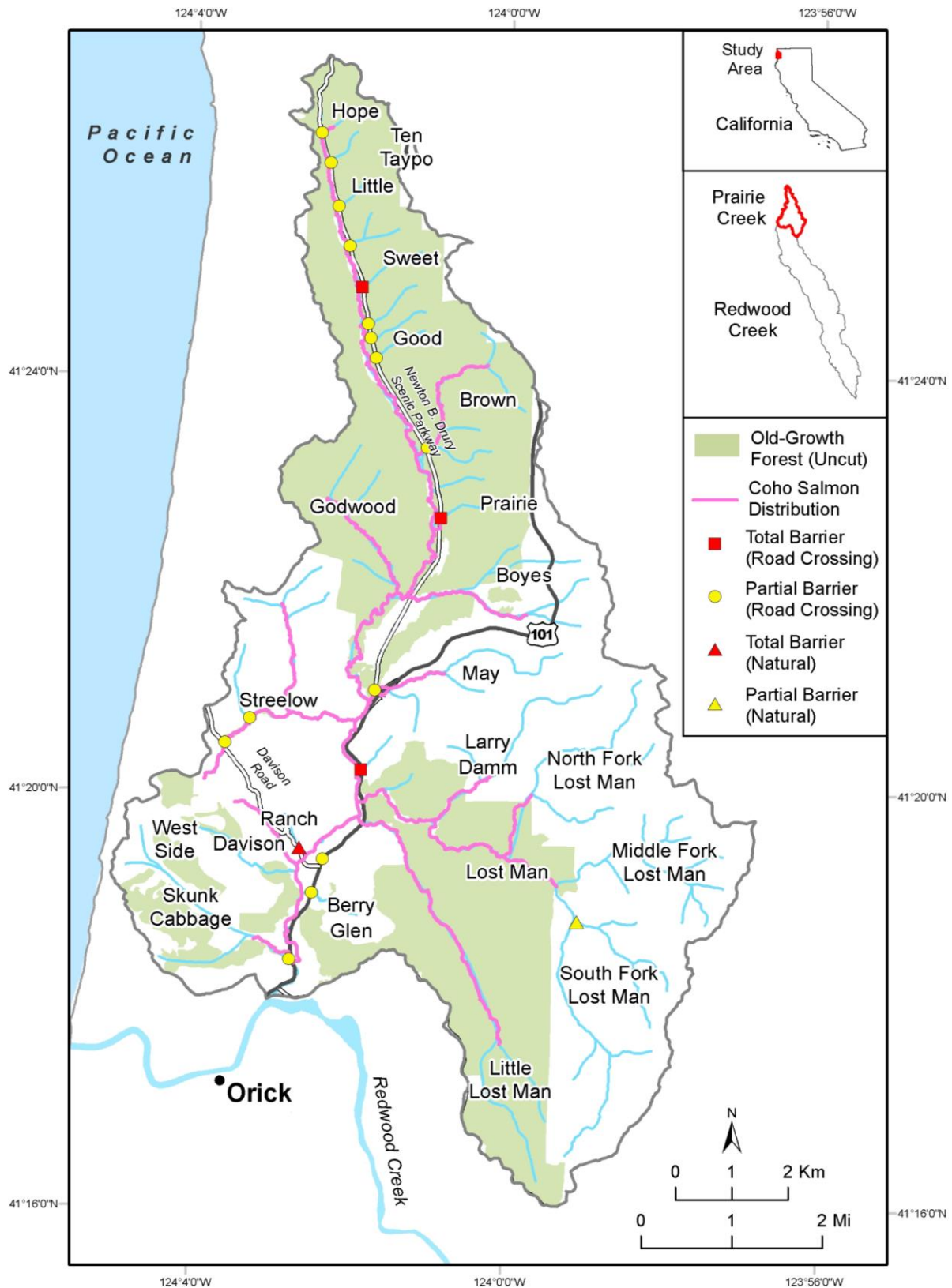


Figure 9. Distribution of Coho Salmon within the Prairie Creek Basin, based on the 2016 Calfish database.

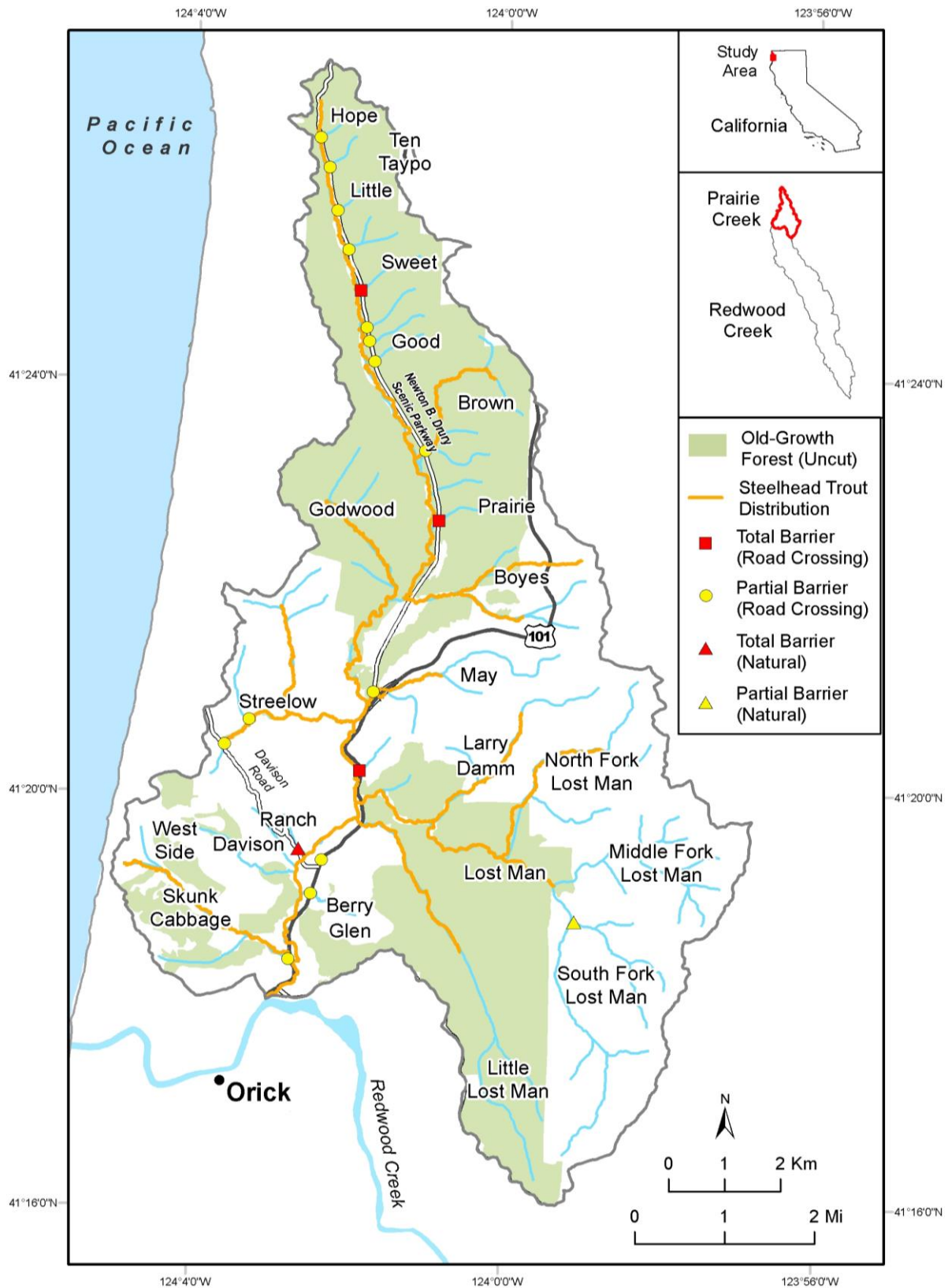


Figure 10. Distribution of steelhead within the Prairie Creek Basin, based on the 2016 Calfish database.

Juvenile Chinook Salmon in Prairie Creek are predominantly ocean-type rather than stream-type, with individuals migrating to the estuary as smolts within the first 3-6 months of life. Small numbers of juveniles, however, have been found to reside in Prairie Creek for 1-2 years before migrating. Peak smolt migration typically occurs in April and May. Chinook Salmon smolts from Prairie Creek have been found to enter the estuary earlier than do smolts from Redwood Creek upstream of Prairie Creek, and at a smaller size (Sparkman et al. 2015). This suggests a greater dependency of Prairie Creek Chinook Salmon to complete their rearing in lower Redwood Creek and estuary to reach a size that increases marine survival. Impairment of lower Redwood Creek and the estuary from sedimentation, channelization, sparse accumulations of LWD, and altered riparian and floodplain functioning may reduce the number of adult Chinook Salmon returning to spawn in Prairie Creek, because of reduced growth and survival of smolts.

Chinook Salmon in Prairie Creek are included in the California Coastal Chinook Salmon Evolutionary Significant Unit (ESU), which is federally listed as threatened under the Endangered Species Act. The listing reflects concern over greatly depressed population sizes relative to historical abundance. Early records of adult Chinook Salmon in Prairie Creek are sparse. Based on carcass and redd counts, McCormick (1954) estimated a spawning population of 400-555 fish in Prairie Creek above Lost Man Creek, and 30 fish in Lost Man Creek. In 1960, approximately 2,000 adults were estimated to return to Prairie Creek and lower Redwood Creek [(USFWS 1960), cited in Ridenhour and Hofstra (1994)], based on extrapolation from Eel River returns. Duffy (2011) compiled escapement estimates between 1999-2008 for Chinook Salmon derived from Area-Under-the-Curve (AUC) analysis of live fish observations, and reported a high value of 710 fish in 2002, and a low of 38 fish in 2008 (Figure 11). Estimates of redd and smolt abundances of Chinook Salmon from 2011-2014 are shown in Figure 12. Lack of complete correspondence in abundances among years between redds, and smolts may be attributable to the effect of spring storm events on survival of emergent fry. For both adults and smolts, abundances were exceptionally high in 2013. Based on records from the USGS gaging station on Redwood Creek at Orick extending from 1911-2014, spring flows during 2013 were less than 50 percent of the means of monthly discharge. During 2011, a year in which smolt abundance was low despite a high abundance of redds, flows were substantially higher than the long-term mean during March and April (e.g. mean March discharge = $1930 \text{ ft}^3\text{s}^{-1}$ ($55 \text{ m}^3\text{s}^{-1}$); March 2011 discharge = $3,931 \text{ ft}^3\text{s}^{-1}$ ($111 \text{ m}^3\text{s}^{-1}$).

Spawning of Chinook Salmon usually occurs in reaches with gradients of 0.2-1%, in water 0.3-0.9 m deep over substrate dominated by large pebble/small cobble (25-76 mm diameter) (Flosi et al. 2010). During years of higher flows, spawning can occur in upper basin tributaries 2-3 m wide. During years of low flow, spawning is restricted to the lower mainstem of Prairie Creek. After emergence, fry are found in quiet water, close to cover structures. Juveniles tend to feed in faster water than is used by Coho Salmon.

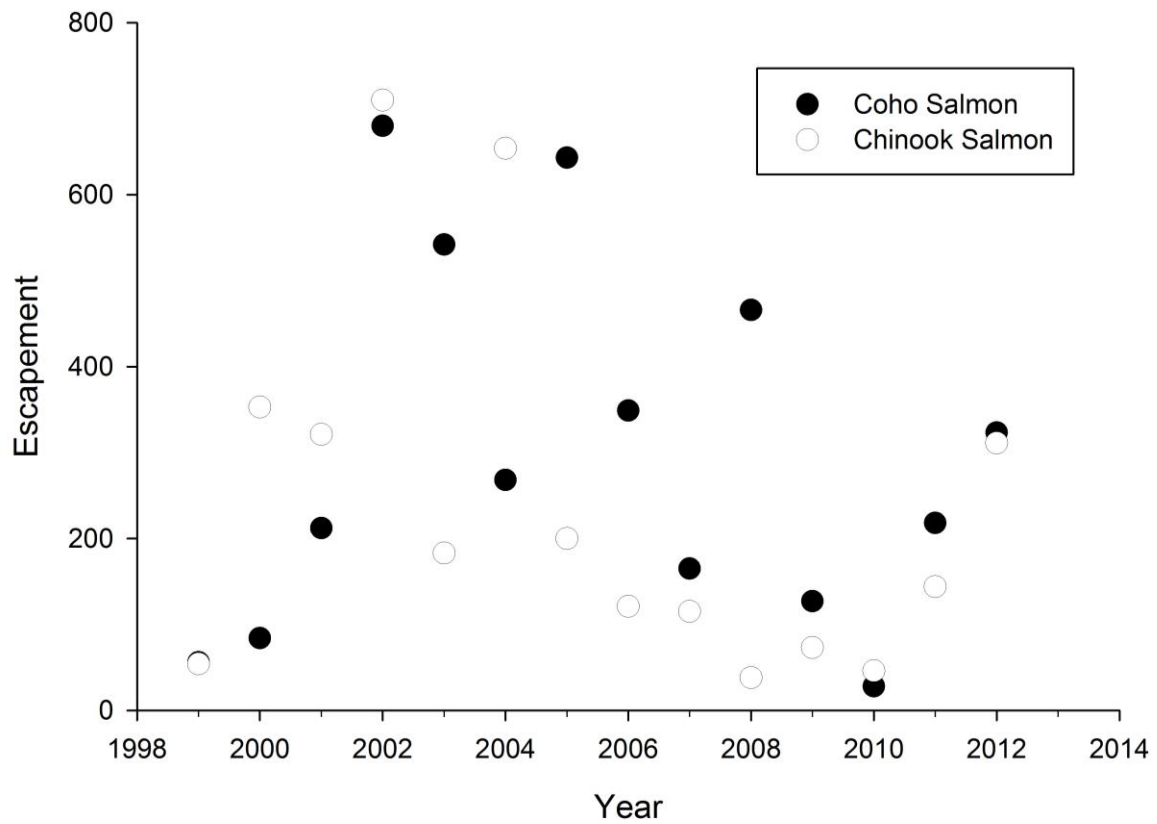


Figure 11. Estimated escapement of Coho Salmon and Chinook Salmon to Prairie Creek from spawning seasons 1998/1999 through 2011/2012. Data from Duffy (2011).

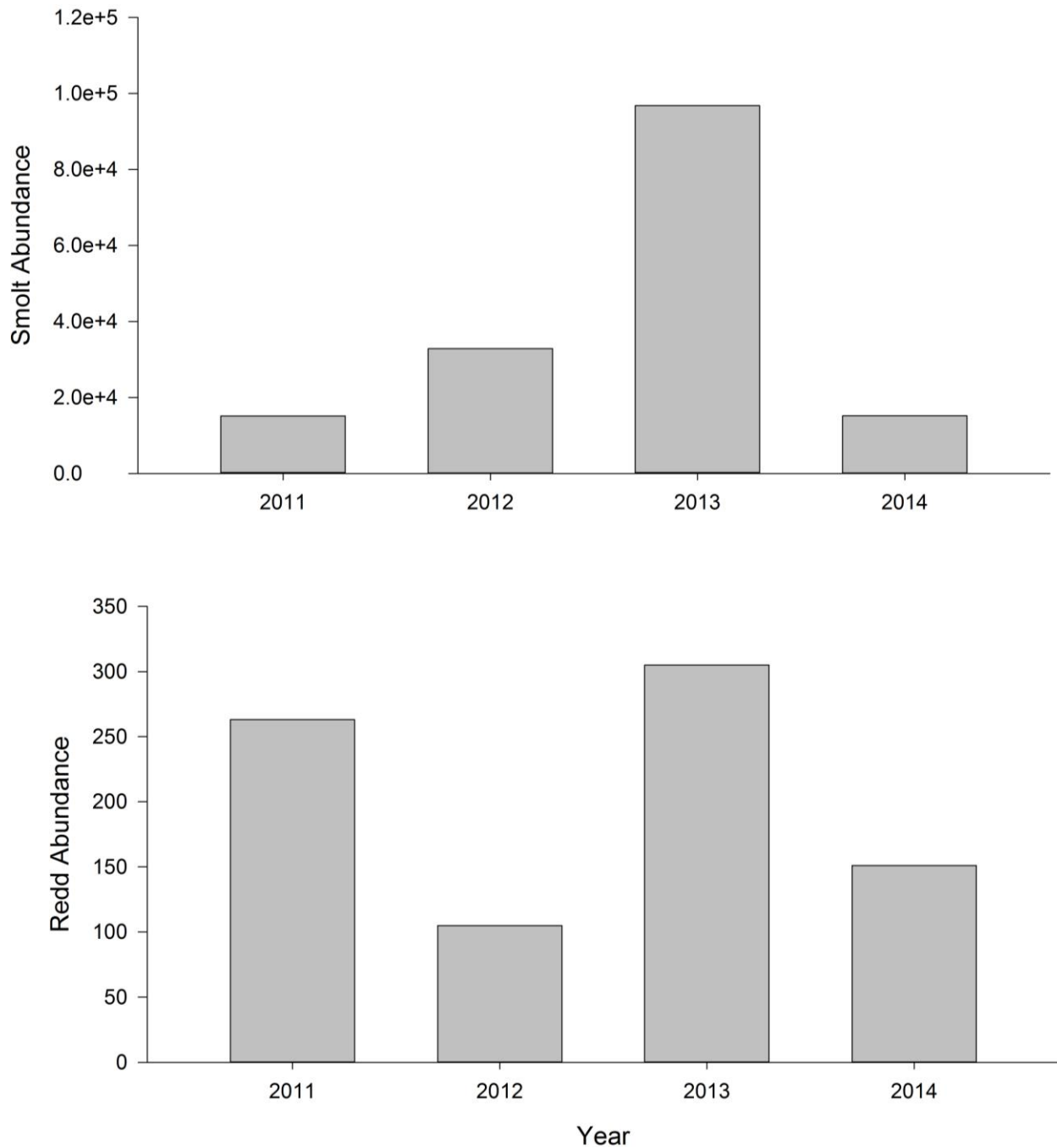


Figure 12. Estimates of smolt (upper) and total redd (lower) abundances of Chinook Salmon in Prairie Creek, 2011-2014. Data are from Sparkman et al. (2015) and Ricker et al. (2015 a,b,c,d).

Coho Salmon

Coho Salmon are anadromous and semelparous. Adults return to their stream of origin to spawn and die, usually at three years of age. Some precocious males, referred to as jacks, may return as 2-yr old spawners. In Prairie Creek, the run timing of adults (November – February) overlaps with that of Chinook Salmon. Spawning habitat for Coho Salmon is in water with an average velocity of 60 cm/s, with a minimum depth of 0.12-0.18 m, in gravel and small pebble substrate (e.g., Briggs 1953,

Regnart 1991, Mull and Wilzbach 2007) in streams with a gradient $\leq 3\%$ (Reeves et al. 1989). Juvenile Coho Salmon in California typically rear in freshwater for one year, before migrating to the ocean as smolts. A 2-yr freshwater life history has been documented in Prairie Creek and in other small streams in northern California (Bell and Duffy 2007, Ransom 2007, and Moore 2014). For the three Prairie Creek streams he studied (Prairie, Streelaw, and Boyes creeks), Ransom found that the incidence of a 2-yr freshwater life history ranged from 1.6 to 29.5 percent in 2000 through 2002. Peak winter streamflow best explained the amount of extended rearing among the variables he examined: the largest proportions of individuals with a 2-yr life history were observed during summer, following the winter with the mildest streamflow. Neither density nor average size of fish showed clear relationships with extended rearing. The peak in timing of smolt migration in Prairie Creek occurs in April and May.

Coho Salmon in Prairie Creek are within the Southern Oregon/Northern California Coasts ESU, which is federally listed as threatened under the Endangered Species Act. Populations within this ESU have experienced dramatic declines in abundance from historical levels, and for many populations the trend in abundance continues to be downward (National Marine Fisheries Service [NMFS] 2014). The Redwood Creek population is considered by NMFS to be at a high risk of extinction, with lack of floodplain and channel structure, and impaired estuarine/mainstem function regarded as the key stresses limiting the population. However, Prairie Creek is considered a stronghold for Coho Salmon, and produces most of the Coho Salmon (and Cutthroat Trout) within the basin (Brown 1988). This has been attributed to the lower gradient habitat and cooler water temperatures than are present elsewhere in basin, and greater availability of habitat in nearly pristine condition. Coho Salmon are distributed throughout the Prairie Creek watershed (Anderson 1988). Williams et al. (2006) rated all of the named and unnamed tributaries and mainstem reaches of the creek as having high intrinsic potential to support Coho Salmon.

Coho Salmon spawner surveys have been conducted in the Prairie Creek watershed since 1991, although differences in methodologies and monitoring locations have made trend analysis difficult. The first surveys were in response to concerns over the Highway 101 Prairie Creek Bypass (1990-1998) sediment episode. Surveys were continued by the CCRU_USGS from 1998-2008, and by CDFW from 2009-2016. Spawner data on Chinook Salmon and steelhead were included in CCRU_USGS and CDFW surveys, although surveys did not extend throughout the entire steelhead spawning season.

Estimates of smolt abundances were made by the CCRU_USGS from 1998-2011, generally from trapping in the mid to upper portions of the basin (above the confluence of Streelaw Creek), and these are summarized in Duffy (2012). Smolt abundance was monitored from 2011-2016 in the lowermost section of Prairie Creek, to provide an estimate at the sub-basin level, by CDFW in collaboration with the CCRU_USGS. Data are summarized in Sparkman et al. (2015), Wilzbach et al. (2016), and Wilzbach et al. (2017).

Spawner surveys of Coho Salmon in Prairie Creek were conducted by CDFW from 2009 - 2015 in randomly selected and index reaches to provide sub-basin scale estimates of escapement (Ricker et al. 2014 a, b, c, d and Ricker 2011). During the period between the winters of 1998/1999 through

2011/2012, spawning density of Coho Salmon averaged 19-20 fish/km. Relative abundances of adult Coho Salmon and Chinook Salmon, estimated from live fish observations using area-under-the-curve analysis, varied among years (Figure 12), with Coho Salmon tending to outnumber Chinook Salmon from 2005 onward. Coho Salmon apparently outnumbered Chinook Salmon earlier as well, as Briggs (1949) reported that Coho Salmon were six times as abundant as Chinook Salmon in Prairie Creek. During 2011-2014, the annual estimate of 1+ Coho Salmon emigrating past the downstream migrant trap in lower Prairie Creek averaged 17,804 individuals (SD=6,530), a majority (86%) of which were classified as smolts. With approximately 80 km of accessible habitat, this would result in an estimated smolt production of 223 1+ Coho Salmon smolts per kilometer.

The earliest record of juvenile abundance of Coho Salmon in Prairie Creek may come from Briggs (1949), who reported counts of 61-171 fish from an approximately 300 m reach of Prairie Creek. Hallock et al. (1952) seined 9,610 juvenile Coho Salmon from Boyes Creek and an unnamed tributary of Prairie Creek in 1951 as part of a fingerling marking program. Estimates of juvenile abundance of Coho Salmon in Prairie Creek over the period 1999-2011, based on a modified Hankin and Reeves (1988) sampling methodology in 2 - 6 km reaches of Boyes, Streelaw, and Upper Prairie (above Brown) creeks, ranged between 2,393 (2001) and 8,664 (2003) individuals (Duffy 2012). Summer density of juvenile Coho Salmon was greater in Boyes Creek (0.77 individuals/m²) than in Upper Prairie (0.33 fish/m²) or Streelaw (0.38/m²) creeks. Using a 2-pass snorkeling methodology in pools distributed throughout the Prairie Creek watershed, Drobny (2016) estimated a juvenile density of Coho Salmon in late summer 2014 to be 0.52 fish/m² (SD=0.38, SE = 0.03, n = 159). Briggs (1949) reported a density of juvenile Coho Salmon along a linear stretch in Prairie Creek of 0.19 - 0.52 fish/m.

Emergent fry of Coho Salmon are found along quiet water margins, in side channels, backwater, and dammed pools. During higher flows and cold water temperatures, juveniles move to slow, deep pools, beaver ponds, or to side channels and backwater pools off the main stream, and seek cover under rocks or in cover structures (Bell 2001). In summer, juveniles use primary pools or backwater eddies in association with tree roots or LWD or undercut banks (Flosi et al. 2010).

Steelhead

Steelhead are the anadromous form of the Rainbow Trout (*Oncorhynchus mykiss*), which may also occur in Prairie Creek in nonanadromous form, with individuals residing in freshwater for the duration of their lives. The percentage of non-anadromous residents, and amount of gene flow between resident and anadromous forms in Prairie Creek or the Redwood Creek basin have not been studied. Unlike other Pacific salmonids, steelhead exhibit iteroparous reproduction, i.e. they can spawn more than one time. Repeated spawning is more common in female than in male steelhead. In common with steelhead from many coastal streams of northern California and the Pacific Northwest, steelhead in Prairie Creek belong to the fall or winter run type. A diminishing number of summer-run steelhead are found in the mainstem of Redwood Creek. Adult steelhead enter Prairie Creek from the ocean with well-developed gonads in late fall and winter, and spawn shortly thereafter, usually between February and April. Juvenile steelhead normally smolt and enter the ocean at 1-2 years, with April and May the peak months for downstream migration of juveniles. Sparkman et al. (2015)

reported that during the years 2011-2014, most steelhead in Prairie Creek smolted at 1 year; 2+ fish averaged 23% of the steelhead smolt population each year. The majority of steelhead spend 2 years in the ocean before their first spawning. A small number of “half-pounder” steelhead have been captured at downstream migrant traps (Sparkman et al. 2014), but this life history is not prevalent in Prairie Creek, or Redwood Creek. Instances of repeat spawning have been observed in marked steelhead from Prairie Creek (Poxon 2012), but the frequency of repeat spawning has not been described from the basin.

Steelhead in Prairie Creek are within the Northern California Distinct Population Segment (DPS) which is federally listed as threatened under the Endangered Species Act. Few historical estimates (pre-1960s) of steelhead abundance are available. Relative to 1930s dam counts from the Eel and Mad rivers in Humboldt County, current population abundances within the ESU are low and continuing to trend downward. Steelhead numbers in Prairie Creek were enhanced by hatchery production beginning in the 1930's, when steelhead from the Sacramento River were introduced via the hatchery to supplement the sport fishery. Between 1972 and 1980, yearly hatchery production averaged 78,988 fish. The hatchery continued to produce steelhead until it closed in 1992. Trapping records for adult steelhead from 1972-1973 through 1982-1983 from the weir on Lost Man Creek, at the site of the hatchery, ranged from 5 fish (in 1974-1975) to 104 fish (1976-1977). Annual escapement of steelhead to Prairie Creek, estimated from redd observations, ranged from 0-67 from 1998/1999 through 2012/2013. Annual production of steelhead smolts from Prairie Creek averaged 7,059 during 2011-2014, representing approximately 16% of the total smolt population abundance in the Redwood Creek basin.

Although steelhead are the most widely distributed salmonid in the Redwood Creek Basin (Anderson 1988), they are outnumbered by Coho Salmon and Cutthroat Trout in the Prairie Creek watershed. Juvenile distribution within Prairie Creek has been documented throughout the mainstem and tributaries. Most spawning occurs in the mainstem of Prairie Creek or in Lost Man Creek. Spawning requirements of steelhead are similar to those for Coho Salmon, with preferred gravel size dominated by gravel and small pebbles. Young of year are found in shallow riffles, and the heads of pools and runs during summer, feeding in faster water than do juvenile Coho Salmon. During winter juveniles are found along stream margins or pools with cover, where they are likely to enter interstitial habitat within the substrate at temperatures below 4 °C. Yearling and older steelhead are found in riffles or runs with wood or boulder cover in summer or in cool water pools with extensive cover. In winter, they use backwater pools, secondary channel pools, and pocket water (Flosi et al. 2010).

Cutthroat Trout

The Coastal Cutthroat Trout includes anadromous and non-anadromous life history forms. Tussing (2006) found both life history forms in headwater and lower reaches of Prairie Creek. The nonmigratory form includes fish that reside in small streams and headwater tributaries through their lives, where they grow more slowly and are smaller at maturity than are the anadromous fish. In anadromous forms, juveniles migrate from freshwater natal areas in late winter and spring to feed in estuarine or nearshore marine environments during the summer. Freshwater rearing prior to their initial seaward migration is typically two to three years. Unlike other anadromous salmonids, the

Coastal Cutthroat Trout does not overwinter in the ocean. The fish return to freshwater in the winter to feed, seek refuge, or spawn, sometimes returning again to seawater in the spring. Cutthroat Trout typically spawn in small tributaries and headwater streams from December through June, with peak spawning in February. Peak emergence of fry occurs in mid-April. Rearing requirements of Cutthroat Trout are similar to those of steelhead, although the morphology of Cutthroat Trout is somewhat less specialized for fast water rearing (Hawkins and Quinn 1996). Peak months of downstream juvenile migration are in April and May.

A status review of Coastal Cutthroat Trout in Washington, Oregon, and California by the National Marine Fisheries Service in 1999 concluded that insufficient evidence exists to demonstrate that Coastal Cutthroat Trout are at a significant risk of extinction. At the same time, they concluded that “there is insufficient evidence to demonstrate that Coastal Cutthroat Trout are *not* at significant risk of extinction”. Anecdotal reports compiled by Van Kirk (1994) suggest that sea-run Coastal Cutthroat Trout were very abundant in the Prairie Creek watershed during the late 1800s and early 1900s, and that their numbers have since declined considerably. They were determined to be overfished by sport anglers by 1925 (Van Kirk 1994), and populations declined further in response to habitat degradation during the 1950s to 1960s (Gerstung 1997). DeWitt Jr. surveyed Cutthroat Trout in Prairie Creek in 1954. More recently, Duffy and Bjorkstedt (2008) reported that northern California Cutthroat Trout populations appear to be stable. The average population abundance of juvenile Coastal Cutthroat Trout moving past the trap in lower Prairie Creek from 2010 – 2015 was 5,782 (SD = 1595; SE = 713 (Sparkman et al. 2015). Approximately half of these were classified as smolts; few were parr.

The Prairie Creek sub-basin supports nearly all of the Cutthroat Trout production in the Redwood Creek Basin. The fish is found in nearly all Prairie Creek tributaries. Neillands (1984) found evidence of recent hybridization between steelhead and Cutthroat Trout based on gel electrophoresis; overall extent of hybridization using current genetic technologies has not established. Baumsteiger et al. (2005) cautioned that field crews commonly misidentify hybrids between these two species from visual field identification, particularly in juvenile fish.

Salmonid Habitat Condition and Potential Limits to Production

Freshwater habitat requirements of anadromous or resident salmonids in Prairie Creek and elsewhere include: 1) an adequate supply of cool, clean water; 2) a food supply sufficient to enable growth; 3) protective cover to escape predators and ambush prey, and to provide velocity refuges during high flows; 4) clean gravel suitable for successful spawning; and 5) free access to migrate up and down their natal streams as needed to complete life cycle needs.

Salmonid production will be limited if any of the above requirements are not met. Specific requirements vary among species and life history types, and needs may change seasonally, by life stage, and the presence of other biota. For example, spawning requirements in Prairie Creek may not be met when high winter stream flows wash away redds or when gravels are silted. Chinook Salmon and Coho Salmon, which spawn near the beginning of the winter storm season, are at greater risk of redd washout or sediment burial than are steelhead, which spawn later in winter. Juvenile steelhead typically feed in faster water than do Coho Salmon and are likely to rely to a greater extent on drifting than on benthic invertebrates as a food source; optimal pool-riffle ratios and needs for floodplain connectivity would not be the same for these two fishes. Distribution of Coho Salmon is limited by stream gradient (usually less than 3%, Reeves et al. 1989) as steeper streams lack the abundance of slower velocity habitats that the fish requires.

Salmonid stressors represent alterations in habitat conditions and associated ecological processes which affect their population viability. The Recovery Plan for Coho Salmon in the southern Oregon/northern California ESU (NMFS 2014) identified key stressors affecting various life-stages of Coho Salmon in the larger Redwood Creek population as lack of floodplain and channel structure, and impaired estuary/mainstem function. Additional stressors included in the assessment were impaired water quality including elevated water temperatures, degraded riparian forest, altered sediment supply, altered hydrologic function, barriers, adverse fishery and collecting-related effects, and adverse hatchery-related effects. Threats identified by NMFS that cause or contribute to the stresses in the Redwood Creek Basin included existing roads; diking of the lower river; grazing and agricultural practices in lower Prairie Creek; climate change; and invasive/non-native species. Findings for Coho Salmon are generally applicable to other anadromous Pacific salmon with an extended freshwater residence (i.e., steelhead and Coastal Cutthroat Trout).

The Prairie Creek sub-basin differs substantially in physical setting and in past and current land uses from the Redwood Creek drainage situated above the Prairie Creek confluence. Because of its lower gradient, broader floodplain, and coastal temperature regime, Prairie Creek offers a higher intrinsic potential (Burnett et al. 2007) to support production of Coho Salmon than do the middle and upper reaches of Redwood Creek. Impaired functioning of the estuary and lower Redwood Creek, and reduced floodplain and channel structure in lower Prairie Creek are certainly stressors affecting Coho Salmon in Prairie Creek as well as other sub-basins of Redwood Creek. However, stressors such as impaired water quality, degraded riparian conditions, and altered sediment supply and hydrological function in Redwood Creek are not operative in the upper part of the Prairie Creek watershed.

While literature suggests that oceanic conditions more strongly drive annual variability in population abundance of Coho Salmon and other anadromous Pacific salmon than does the freshwater environment (Gallagher et al. 2012), freshwater conditions are nonetheless critical in providing population resilience necessary to buffer against fluctuations in ocean survival. Within Prairie Creek, growth and survival of the Coho Salmon population has been shown to be density-dependent (e.g. Bjorkstedt et al. 2001, Drobny 2016), as has been found for populations in Pacific Northwest rivers. Limiting resources likely vary seasonally and with discharge. During summer, constraints on prey availability and habitat volume imposed by low flows may be a bottleneck to growth and survival; during winters with frequent or high-intensity storms, availability of slow-water refugia and opportunities for feeding may be in short supply. Curiously, while Drobny detected density-dependence in overwinter survival of juvenile Coho Salmon in pools, survival was not found to be affected by abundance of large, woody debris, cover, or pool depth. His study, however, was conducted in a water year in which the peak flow did not exceed bankfull discharge (i.e., recurrence interval of storm events was < 1.5 yr), and velocity refugia may not have been limiting.

Effects of seasonal limitations in resource supply interact. Resource shortages in one season should not be construed as more limiting or important to population growth than bottlenecks during another season. Several studies in Prairie Creek and elsewhere in the Pacific Northwest have documented that over-winter survival of anadromous salmonids is positively correlated with fish body size (e.g. Brakensiek and Hankin 2007, Moore 2014, Drobny 2016). The ability to reach a large body size is critically dependent on resource availability in early summer, when salmonid growth has been found to be most rapid (Gonzales 2006). In recent years, overwinter survival estimates of juvenile Coho Salmon have been higher in Prairie Creek (Moore 2014, Sparkman et al. 2015, Wilzbach et al. 2016) than in other streams within the region, such as Mill Creek in Del Norte County. In comparison with Freshwater Creek, fewer juvenile Coho Salmon exhibited an early (fall) migration from Prairie Creek in fall of 2013 or 2014 (e.g., 2% of tagged fish in 2013 v. 30% in nearby Freshwater Creek (Rebeneck et al. 2015)), perhaps reflecting more favorable habitat conditions.

General stability in the production of juvenile Coho Salmon in Prairie Creek over the last decade of monitoring (Duffy 2011, Sparkman et al. 2014) suggests that the population is likely to be at or close to the carrying capacity of the creek, that is, the maximum equilibrium population size that can be indefinitely supported in a given environment. However, carrying capacity likely differs between the pristine, old-growth upper reaches of Prairie Creek, and reaches in lower Prairie Creek, which are affected by legacy impacts and present impacts on riparian and floodplain functioning from grazing or other agricultural activities. Loss of the floodplain connectivity in lower reaches of Prairie and Redwood creeks, and the large reduction in volume and degradation of water quality in the estuary are particularly problematic for juvenile Chinook Salmon and steelhead, which have been found to leave Prairie Creek earlier and at a smaller size than elsewhere in Redwood Creek. These fishes need to achieve greater growth in the lower mainstem and estuary to improve probability of survival in the ocean. A more detailed review of the status of various components potentially affecting population status of salmonid fishes follows (e.g., floodplain and channel structure, water quality, sediment

supply and hydrological function, riparian vegetation, biological interactions and disease, passage barriers, fishery and scientific collections, and hatchery operations).

Floodplain and Channel Structure

The pristine, upper portion of the Prairie Creek and the Little Lost Man Creek catchment of the sub-basin offers some of the highest quality habitat for Coho Salmon and other salmonid fishes within California. Extensive road removal in the Lost Man Creek drainage by RNSP has removed future sediment sources from old logging roads and landings. Catchments still recovering from legacy impacts, such as Streelaw and May creeks, are expected to provide increasing habitat quality with time and/or appropriate management activities. Below the Highway 101 bridge to the Bald Hills bridge, the habitat quality of the mainstem is impaired by a deeply incised channel and eroding stream banks (personal communication, J. Anderson, Northern Hydrology & Engineering, McKinleyville CA 95519).

Indicators of the status of channel structure relative to its capacity to support salmonid populations and a diverse aquatic biota used by NMFS, CDFW and other agencies include the median substrate particle size (D50), spacing and depth of pools, large woody debris frequency, and development of alcoves, side-channel, and off-channel (floodplain) habitat. Each of these components is reviewed.

Substrate particle size

Particle sizes of streambed substrate in Prairie Creek reflect underlying bedrock and stream gradient. Hillslopes are predominantly underlain by unconsolidated to weakly consolidated silts, sands, and gravels, and much of the stream length in the Prairie Creek watershed has a relatively gentle gradient (approximately 40% of stream length $\leq 4\%$ gradient; 84% of stream length $\leq 25\%$ gradient) (Klein 1999). Streambed substrate consists largely of sands, fine gravel, and pebble (Janda et al. 1975). Lisle (1989) found that median particle size in Prairie Creek in the vicinity of the Wolf Creek Bridge was 22-26 mm, with a majority of its surface material falling within the preferred range of sizes used by spawning salmon (80% was between 10 and 100 mm). Madej et al. (2006 a) measured a range in median particle sizes from 18 mm (Godwood Creek) to 147 mm (Little Lost Man Creek at gage).

Klein (1999) reported results of 9 years of monitoring by RNSP and others of physical conditions in Prairie Creek associated with the Highway 101 Prairie Creek Bypass construction. Streambed surfaces in streams affected by the 1989 erosion event were extensively covered with silt, and fine sediments infiltrated into the substrate, potentially affecting egg survival and fry emergence in salmon redds. Most of the silt was flushed downstream during the first runoff season in water year 1990; some of the material may have infiltrated into coarse gravels farther downstream in Prairie Creek. Tracking of subsurface fines in Prairie Creek was discontinued in 1995.

Embeddedness, which describes the percent of cobbles or gravel at a pool tailout which are covered with fine sediments, can indicate altered sediment supply. High embeddedness reduces intra-gravel water flow, which may result in suffocation of salmon eggs or developing embryos, and it reduces substrate complexity for benthic organisms. NMFS (2014) established rankings of stream habitat suitability with respect to embeddedness as: Very Good (low embeddedness): $\leq 25\%$; Good: 25-30%; Fair: 30-45%; and Poor: $>45\%$. In a survey of 10 Prairie Creek locations, Cannata et al. (2006)

reported the least embeddedness in May, Godwood, and upper Prairie creeks (> 50% of pools rated as very good), and the greatest embeddedness in Brown and Boyes creeks (> 50% of pools in poor category).

Pool Spacing

Salmonid and other vertebrate consumers require a diversity of erosional (e.g. riffles, runs) and depositional (e.g. pools at low flows) habitat types at various life history stages, and species differ in optimal ratios of habitat types within life stage categories. Coho Salmon parr, for example, have a higher requirement for pools and slow velocity water than do steelhead parr, which rear in higher velocity waters. Pool spacing is often expressed as a ratio of the number of bankfull channel widths per pool. In undisturbed forested streams of the Pacific Northwest, the frequency of pools is controlled by channel slope, type, and width, and by loading of large, woody debris (LWD) (Montgomery et al. 1995). Pool spacing in steep, step-pool channels is independent of large woody debris. However, mean pool spacing in pool-riffle, plane-bed, and forced pool-riffle channel reaches decreases as the supply of large woody debris increases, from greater than 13 channel widths per pool to less than 1 channel width per pool. Values of 2-7 channel widths per pool are typical in streams of the northern California coast. In pool-riffle and plane bed reach types, pieces of large wood have been found to force the formation of approximately 40% of the pools. Reaches flowing through previously logged forests tend to have lower loading of large woody debris and consequently fewer pools than reaches in pristine forests.

Pools composing 40% or more of stream length is set by agencies including CDFW and NMFS as a desirable standard for anadromous fish habitat (Flosi et al. 1998, NMFS 2014). Several reaches in the Prairie Creek sub-basin fail to attain these standards. Cannata et al. (2006) reported a channel width: pool ratio of 5:1 in a sample of 10 reaches within the Prairie Creek sub-basin, with pools comprising an average of 27% of stream length. The lowest percentage of pools was found in Boyes Creek (19%), and the highest was found in a reach of Lost Man Creek (47%). Pool spacing was not notably different between pristine reaches (Godwood and Prairie above Brown Creek, with 26 and 20% pools by length, respectively) and more disturbed locations. Lack of correspondence of pool spacing with disturbance suggest that single numeric targets, without consideration of the suite of factors affecting pool formation (e.g. channel width, slope, type) may not be meaningful in Prairie Creek or elsewhere.

Pool Depth

Deep pools provide year round habitat for rearing juvenile salmonids such as Coho Salmon, and are important holding areas for adult salmonids during spawning migrations. Landscape disturbance can result in loss of deep pools and limit fisheries production. Low gradient reaches are particularly vulnerable to pool filling and accumulation of fines from an increased sediment supply. Residual pool depth (the difference in depth between a pool and the downstream riffle crest) is negatively correlated with stream gradient, and positively correlated with watershed area. Based on an Environmental Decision Management Support model, lack of deep pools was the habitat factor most often identified as limiting to salmonid production in Prairie Creek in the CDFW Assessment of the

Redwood Creek Basin (Cannata et al. 2006). This conclusion, however, is not fully consistent with fisheries data.

Target values used in the watershed assessment of pool condition of anadromous salmonid habitat in North Coast California streams were pools with maximum depth of from 0.61-0.76 m for 1st and 2nd order streams, 0.91 m for 3rd order streams, and >1.22 m deep for 4th order streams. Pools were often below target values for depth in Prairie Creek. Mean maximum depth for pools was 0.55 m for 1st and 2nd order tributary streams, and 0.82 m for the mainstem of Prairie Creek. Results of summer habitat surveys conducted in association with fish sampling in Prairie Creek above Brown Creek, Streelow, and Boyes creeks during 1998-2004 were summarized by Duffy (2012). Despite finding the shallowest pool depths and lowest pool volume in Boyes Creek, densities of Coho Salmon were also greatest there. Duffy attributed this to the concentrating effect of pools at low flow, but expression of fish abundance as density (numbers per unit area) already corrects for area.

Large Woody Debris

Large woody debris (LWD, often measured as in-channel logs, stems, limbs, and rootwads greater than 10 cm diameter and > 1 m in length) plays vital structural and functional roles in lotic ecosystems, positively affecting habitat formation, material retention, and stream productivity. LWD density and the way in which it accumulates in streams (as debris jams or single pieces) varies with forest types, landscape topography, and flow regime. In a comparison of published data on volumes and biomass of LWD in streams flowing through natural (unmanaged) temperate forest in North America, Harmon et al. (1986) reported a range in LWD volume of 10-4,500 m³/ha, with the extreme high value coming from Prairie Creek. The authors noted that abundance of LWD was higher in streams in the Pacific Coast Ecoregion than in other forested areas of North America. Within the Pacific Coast Ecoregion, LWD abundance decreased with an increase in latitude. The very high wood loading in Prairie Creek appears largely attributable to the effect of forest type, as most of the LWD in streams comes from redwood trees. In stream reaches draining < 1000 ha in northwestern California, Harmon and co-authors found that more than ten times the amount of LWD had been reported from stands of redwood forest than from stands of Douglas-fir. The residence time of large redwood debris in stream channels is in the range of centuries.

Notwithstanding the very high volume of large wood in Prairie Creek, past timber harvest degraded riparian forests in lower Prairie Creek, with a resultant decrease in the number of large conifers supplied to and available for recruitment into the channel. Early settlers cleared wood from streams to facilitate movement of logs and prevent formation of log jams. Hatchery records indicate that fishery managers also cleared wood from the creek to ensure fish passage (Van Kirk 1994). Keller et al. (1995) found that nearly all the pools they surveyed in the upper reaches of Prairie Creek were either directly formed by large, woody debris or they were influenced by it; in the lower reaches, approximately 50% of the pools were influenced by large organic debris.

However, the extent to which a decreased role of LWD in pool formation in lower Prairie Creek reflects a diminished supply of LWD as a result of human activity, or the natural decline in wood loading as channel width and drainage area increases is not clear. Debris loading within a basin decreases with stream size because 1) tree density is related to topography, with a greater areal

density on steeper slopes; 2) the area of active channel increases downstream; and 3) flow in upper reaches may not be sufficient to float large wood, whereas stream power further downstream is usually sufficient to move and sort debris into jams farther downstream (Harmon et al. 1986).

Several surveys have been made of counts and/or volume of large woody debris in Prairie Creek. These include unpublished surveys for RNSP by: 1) Klein and Kramer above Streelow Creek in the late 1990s, and Seney in 2015 extending from the mouth of Prairie Creek to its confluence with Lost Man Creek and from just south of the Prairie Creek Redwoods State Park Visitor Center to 1.5 miles north of the visitor center. The most spatially extensive survey was conducted by Deibner-Hanson (CCRU-USGS) in 2014 and 2015. As part of his thesis research, he measured and georeferenced LWD in 27.5 km of the active channel of the Prairie Creek mainstem, from the Elk Meadow trail bridge upstream to Little Creek. The survey was extended for RNP to also include the mainstem reach from the trail bridge below Davison Road downstream to the Redwood Creek confluence (approximately 2.5 km), as well as reaches of May, Godwood, and Streelow creeks, which were inventoried by species and size classes of LWD. Deibner-Hanson's data provides a conservative value for LWD volume in Prairie Creek, as his estimate of bankfull channel width was generally less than bankfull width estimated by a RNP crew.

Deibner-Hansen found that the number of pieces of LWD per kilometer of mainstem Prairie Creek was variable among reaches, and did not noticeably differ between lower, previously logged reaches and upper, more pristine reaches (Table 5, Figure 13). Number of LWD pieces per kilometer in all reaches greatly exceeded target values established by NMFS (2014) for ranking channel structure as very good (e.g., > 53 pieces/km for streams with a wetted width less than 6 m and > 40 pieces/km for streams with a wetted width between 6 and 9 m). Evidence of a legacy effect of prior logging in lower reaches of the stream, however, is suggested in the reduced volume of LWD/km relative to that observed in upper reaches (Figure 13), particularly in the largest size class (> 60 cm diameter) (Figure 14). The highest percentage of LWD pieces in lower reaches was observed in the smallest size category (10-15 cm diameter, 1-3 m length) (Figure 15). Legacy impacts of logging were also observed in the species composition of LWD. Although redwood comprised 80 and 90 percent of the total LWD volume in uncut Godwood Creek and heavily logged Streelow Creek, a greater relative percentage of alder pieces were found in Streelow Creek (Figure 16).

Table 5. Density and volume of large woody debris (LWD) per kilometer in CDFW spawning reaches of the Prairie Creek mainstem and in May, Godwood, and Strelow creeks, 2014-2015. Data were collected by Deibner-Hanson (CCRU_USGS) and RNP staff. Mainstem reaches are numbered using CDFW assignments, as follows: 68=mouth of Prairie Creek to trail bridge below Davison Road; 69=trail bridge below Davison Road to Little Lost Man Creek; 70=Little Lost Man Creek to Strelow Creek; 71=Strelow Creek to Boyes Creek; 72=Boyes Creek to Brown Creek; 73=Brown Creek to Zigzag Trail crossing; 74=Zigzag Trail crossing upstream to Little Creek.

Reach	Reach Length (km)	Drainage Area (km ²)	Pieces/km	Volume (m ³)/km	Volume/piece (m ³)	LWD >60 cm diameter, pieces/km	LWD >60 cm diameter, volume (m ³)/km
68	3.2	9.0	381	63	0.17	11.7	26.9
69	2.0	14.1	413	105	0.25	10.7	69.4
70	2.1	41.3	296	57	0.19	9.5	23.0
71	4.1	17.7	284	79	0.28	21.4	47.8
72	3.4	8.9	228	147	0.64	34.6	115.5
73	3.5	4.4	291	113	0.39	27.9	81.9
74	2.5	7.6	390	88	0.22	23.4	49.1
Strelow Creek	1.4	7.4	575	83	0.14	19.1	33.1
May Creek	0.5	4.6	458	99	0.22	37.8	50.2
Godwood Creek	1.4	4.6	302	102	0.34	42.4	72.7

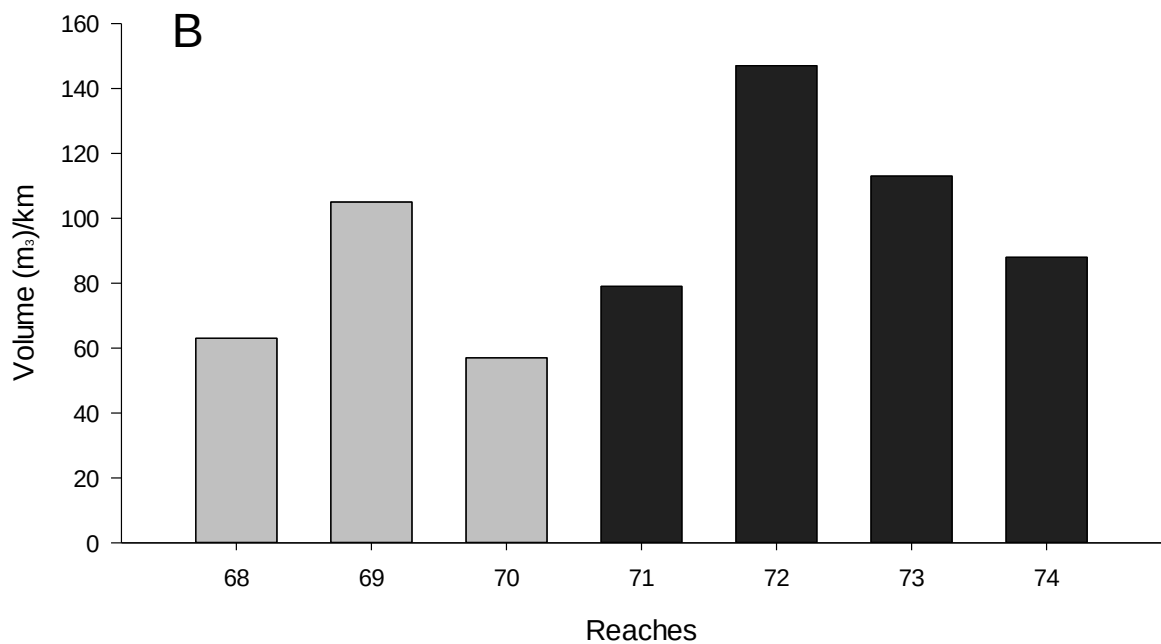
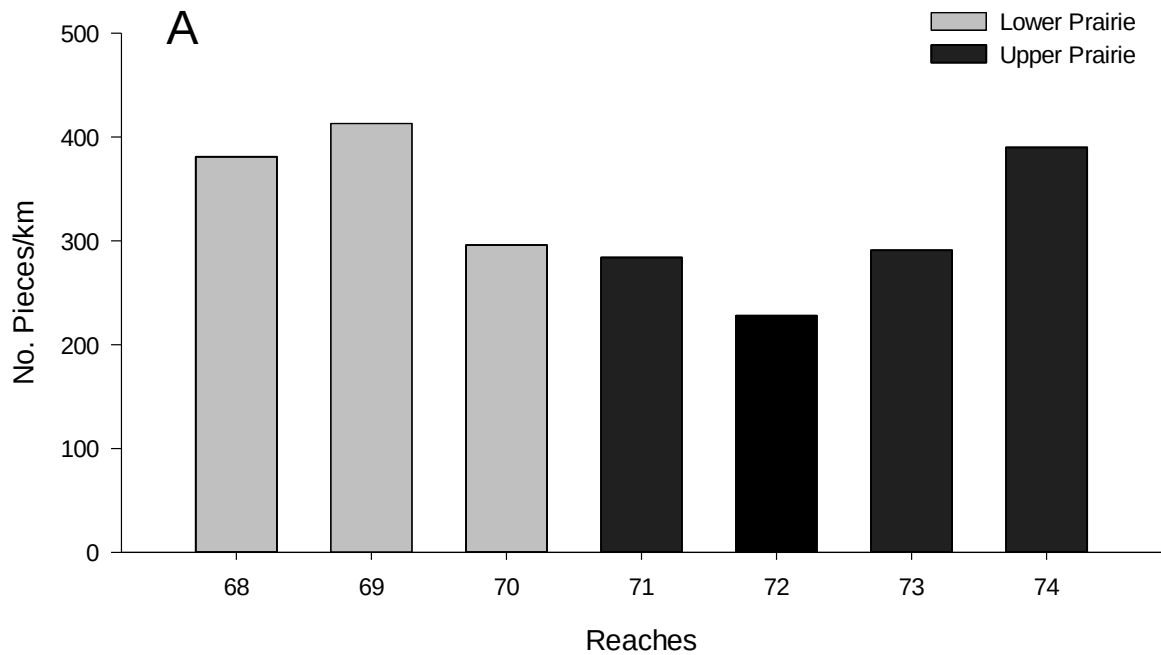


Figure 13. Reach-specific number of pieces (A) and volume (B) of large, woody debris per kilometer of stream in lower and upper Prairie Creek. Reach boundaries are numbered using CDFW conventions. Upper Prairie lacks commercial logging history, and includes the uppermost 13.7 km of creek. Lower Prairie Creek was managed for timber harvest until the late 1970s, and includes the lower 7.8 km of creek.

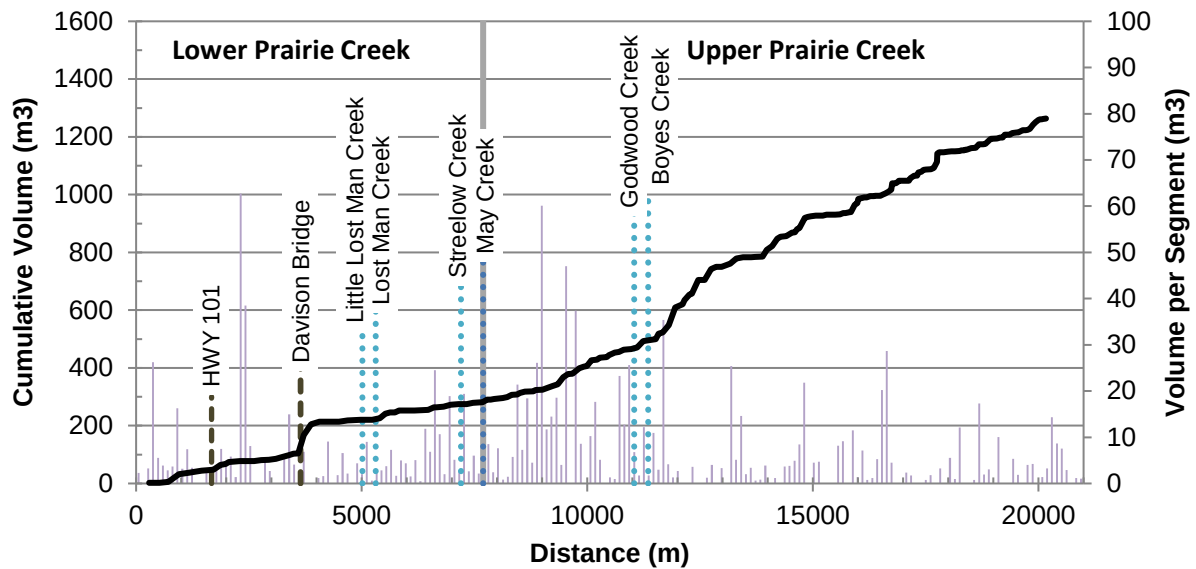


Figure 14. Cumulative volume of large wood (> 60 cm diameter) from the mouth of Prairie Creek to Little Creek.

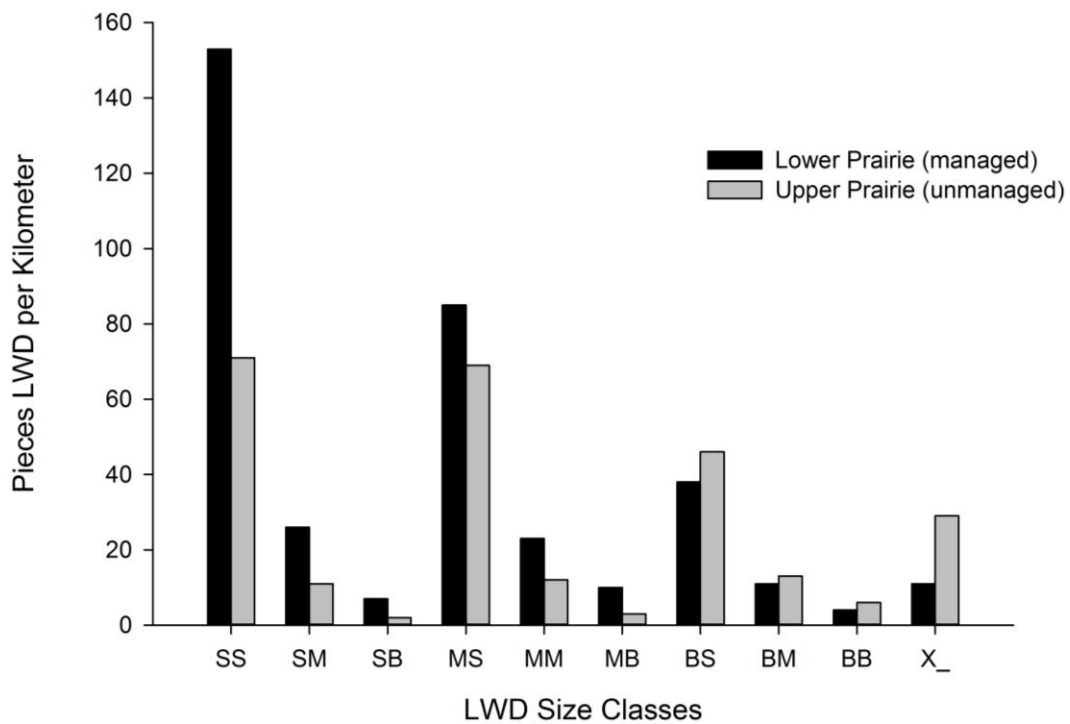


Figure 15. Distribution of the number of pieces of large woody debris by size class in upper and lower Prairie Creek. Lower Prairie Creek includes the lower 7.3 km of creek, which was managed for timber harvest until the late 1970s and grazing into the 1980s. Upper Prairie Creek represents about 7.3 km of fairly pristine channel. The first letter indicates the diameter size class and the second indicates length class. Diameter size classes: S=Small (10-15 cm), M = Medium (15-30 cm), B = Big (30-60 cm), X = Extra Large (>60 cm). Length size classes: S = Small (1-3 m), M = Medium (3-6 m), B = Big >6 m). Because Extra Large LWD pieces (> 60 cm in diameter) were measured for length individually rather than in bins, only diameter is shown for this category (i.e., as X_).

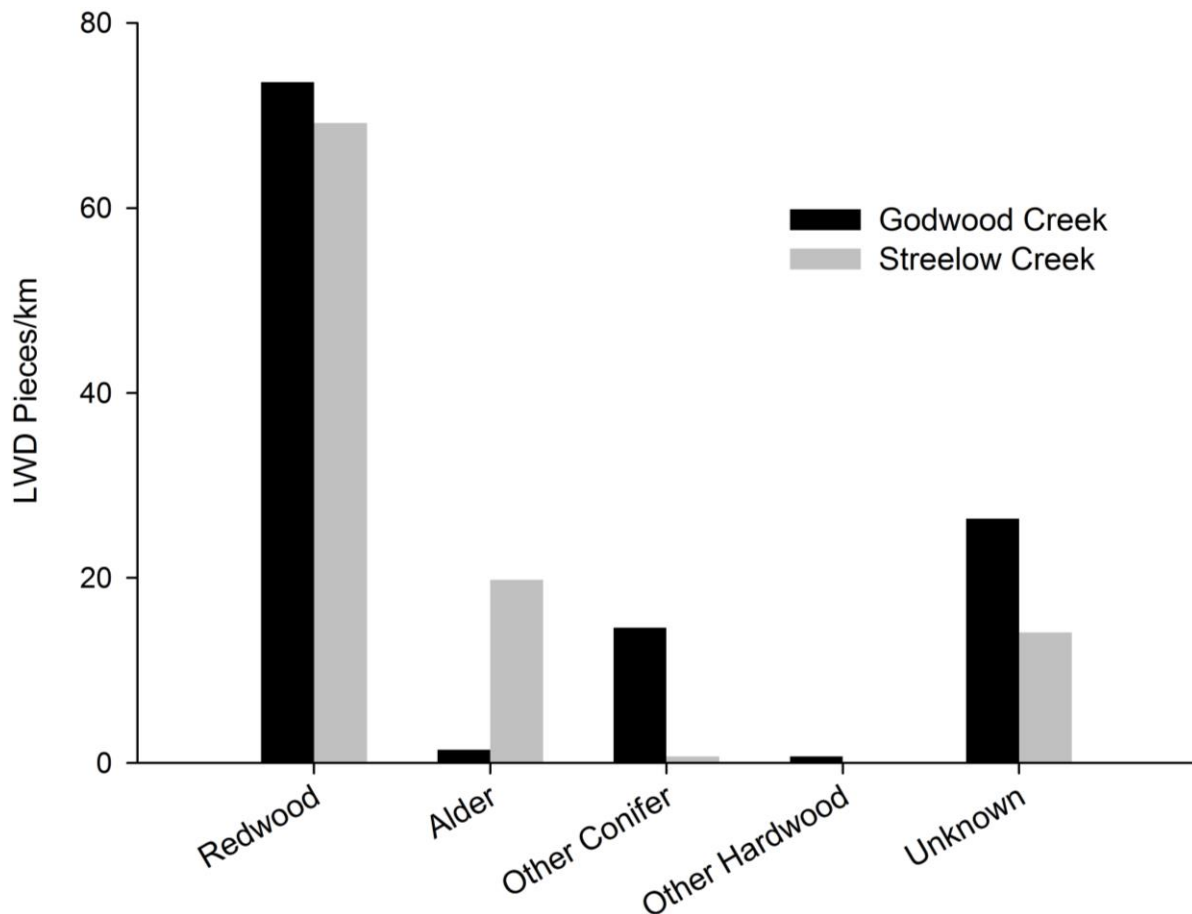


Figure 16. Distribution of the number of pieces of LWD per kilometer by tree species in Godwood (unharvested) and Streelow (previously harvested) creeks.

The choice of the attribute or metric used to characterize LWD in assessment of ecological functioning is of significance. A high density of small pieces of wood would play different roles in stream channel processes and pool formation than would a similar density of large pieces. Carbon cycling (wood processing) and salmonid production are likely better correlated with volume of LWD, inventoried by tree species, than with LWD density. One of the metrics used by NMFS (2014) in assessing adequacy of channel structure to support Coho Salmon is key pieces of LWD, where a key piece is greater than 10 m in length, with a diameter greater than or equal to 60 cm. Key pieces are valuable because they resist downstream transport and represent long-term wood retention capacity of a stream (Foster et al. 2001). Particularly in upper reaches of Prairie Creek, a single downed redwood tree may control channel morphology and affect material retention for a distance of numerous active channel widths (Keller et al. 1995). Curiously, only one of the mainstem reaches surveyed by Deibner-Hansen (reach 72, from Boyes Creek to Brown Creek), met the NMFS target value to be ranked as ‘very good’ on the basis of number of key pieces of LWD (> 3 key pieces per 100 m). Only reaches 71-74 (extending from Little Creek downstream to Streelow Creek) qualified to receive a ranking of good (2-3 key pieces per 100 m). Inasmuch as LWD loading in Prairie Creek is at the extreme high end of values documented from streams across North America, target values for the ‘key pieces’ metric warrants re-evaluation.

The relationship between large woody debris and salmonid production is incompletely understood (Lisle 2002). Solazzi et al. (2000) and others have shown that adding wood to historically cleared streams on the Oregon coast increased over-winter survival of juvenile Coho Salmon, but the precise quantities and spatial distribution of wood required for maximum salmonid production or to adequately fulfill ecologic and geomorphic functions are likely to be site-specific and to differ among salmonid species.

Floodplain Connectivity

Overwinter survival and rearing success of juvenile Coho Salmon is strongly dependent on complex, slow water habitats. Apart from main channel pools, slow water habitats can include alcoves, side-channels, backwaters, sloughs, and beaver ponds from unconstrained reaches in low-gradient streams such as Prairie Creek. Bell (2001) compared habitat fidelity and survival of juvenile Coho Salmon rearing in alcoves versus main channel pools and other habitats of the Prairie Creek headwaters, and found higher survival in alcoves during a winter of high flows. In lower Prairie Creek, riparian clearing, and ditching and diking of the channel in association with agricultural and timber harvest activities reduced hydrological connectivity between the channel and floodplain, and legacy effects remain. A longitudinal profile conducted for Save-the-Redwoods League in 2015 in the vicinity of the Mill A property evidenced a deeply incised channel, eroding stream banks, and disconnected tributaries, floodplains and wetlands (personal communication, J. Anderson, Northern Hydrology & Engineering, McKinleyville CA 95519).

Professional judgement rather than numeric indicators of floodplain connectivity was used by NMFS (2014) in assessing stresses to habitat suitability for recovering Coho Salmon in Redwood Creek. A separate assessment of Prairie Creek is not available. Differences among catchments in floodplain area within Prairie Creek (Table 1, Figure 4) suggest that the potential for complex side-or off-channel rearing available for overwintering juvenile salmon is variable. A 2015 assessment by RNP of wetland condition in Prairie Creek below the confluence of Lost Man Creek using the California Rapid Assessment Method listed major stressors as including legacy impacts from past land use, compaction and grading of portions of floodplain, levees and channel, engineered/altered stream channels and floodplain, and the presence of non-native, invasive vegetation (personal communication, J. Seney, RNP, Orick, California).

Water Quality

Parameters considered here include water temperature, dissolved oxygen concentration, and pH/alkalinity, in reference to water quality targets specified by the California North Coast Regional Water Quality Control Board for the Redwood Creek Hydrologic Unit. Nutrient concentrations were not included in water quality assessments by the Water Board, but may strongly affect aquatic productivity. In contrast to streams impacted by agricultural activity or urbanization, where nutrients may be present in excess, the nutrient-poor water in Prairie Creek may play a role in limiting aquatic primary production. This possibility has not been previously investigated.

Temperature

Temperature is a master environmental variable in stream ecosystems. Ecosystem processes, including decomposition, primary production, community respiration, and nutrient cycling, are all

temperature dependent. Most stream organisms are ectothermic; their metabolism, growth, life cycles and overall productivities of populations are all temperature dependent. Elevated water temperature stemming from human activities is among the most widespread and greatest stressor facing Coho Salmon throughout the Southern Oregon/Northern California ESU (NMFS 2014).

In a review of laboratory and field studies of temperature effects on salmonid fishes in the Pacific Northwest (Region 10), USEPA (1999) concluded that temperatures of approximately 22-24 °C limit salmonid distribution generally, and they designated 16 °C as the seven-day average of the daily maximum temperatures (7-DADM or MWMT) temperature that should not be exceeded in areas designated as core rearing locations (USEPA 2003). Carter (2005a) summarized temperature needs of differing life stages of steelhead, Coho Salmon, and Chinook Salmon.

Although Redwood Creek is listed as temperature impaired under section 303(d) of the Clean Water Act and high summer water temperature is believed to limit the distribution of juvenile Coho Salmon in the mainstem Redwood Creek (Madej et al. 2006 b), water temperature in Prairie Creek is at present fully suitable throughout the year to support production of salmonid and other cold water fishes (Figure 17). On some dates prior to 2007, sites in Prairie, Lost Man and Little Lost Man creeks exceeded an MWMT of 16 °C.

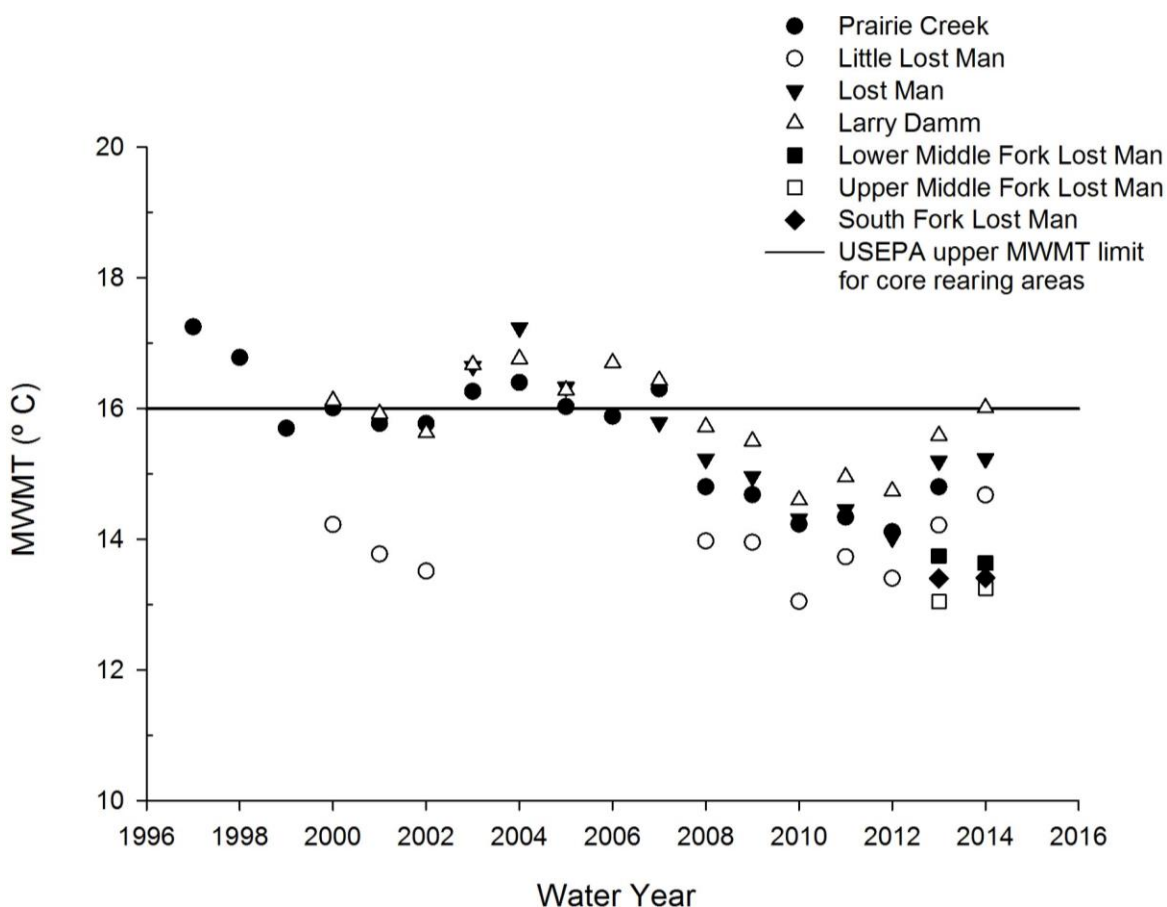


Figure 17. Maximum weekly maximum temperature in the Prairie Creek Basin, Jul 1 – Aug 31, 1997–2015. Data from RNP.

Stream temperature has been continuously monitored during summer months (Jun-Sept) by RNSP at a number of sites since 1997 (Table 6), and annual reports with temperature statistics from Jul 1- Aug 31, the period with the warmest temperatures, have been compiled for each station (data available on request from RNSP). Two of the monitored sites (Prairie at Wolf Creek Bridge and Little Lost Man) are in pristine locations; other monitoring sites are in watersheds impacted by past land use.

Table 6. Monitoring locations of summer water and air temperature in Prairie Creek by RNSP, and years of record.

Location	Years	Medium Monitored
Prairie Creek at Wolf Creek Bridge	1997-2016	Water, Air
Lost Man Creek at the Hatchery	2000-2016	Water
Larry Damm Creek	2000-2002, 2008-2016	Water
Lost Man Creek Lower Middle Fork	2013-2016	Water, Air
Lost Man Creek Upper Middle Fork	2013-2016	Water, Air
Lost Man Creek South Fork	2013-2016	Water, Air
Little Lost Man Creek at gaging station	2003-2016	Water, Air

Numerous other studies conducted in Prairie Creek since the 1970s have included temperature data, but temperature has not been routinely monitored throughout the year. Beesley (2006) reported an annual degree-day accumulation (i.e. the summation of daily mean temperatures above 0 °C) of 3473 degrees in Prairie Creek during the 1999 water year. Degree-day accumulation is ecologically relevant to stream biota as it affects life cycle timing in many organisms and voltinism (the number of generations per year) in invertebrates. Salmonid egg development and emergence from redds is related to accumulated water temperature, with fry emergence in Prairie Creek beginning at approximately 700 degree-days (Sparkman 2003). Among invertebrates, most mayflies require 2000+ degree-days to complete one generation from egg to adult. If the required number of generations are not provided within a year, two or more years will be required to complete a generation. Invertebrate taxa with more rapid turnover provide more continuously available prey for fish and amphibian predators.

Dissolved Oxygen (DO)

An adequate concentration of dissolved oxygen in stream water is essential to the respiratory metabolism of most aquatic organisms. The water quality objective for dissolved oxygen is 6.0 mg/L. During critical salmon spawning and egg incubation periods, the objective is increased to 9.0 mg/L, to maintain adequate intra-gravel oxygen for developing embryos. Intra-gravel oxygen concentrations are typically around 3 mg/L lower than water column measurements (US EPA 1986); thus a water column DO reading of 9.0 mg/L would correspond to an intra-gravel oxygen concentration of 6.0 mg/L. Life-stage and species-specific requirements for dissolved oxygen for Chinook Salmon, Coho Salmon, and steelhead were provided by Carter (2005b).

Dissolved oxygen concentration has not been problematic in Prairie Creek. Mean summer concentrations in 2014 at 4 stations (Prairie above Wolf Creek bridge, and mouth of May, Streelow, and Skunk Cabbage creeks) measured by RNSP all exceeded the objective. Woods (1980) reported that the weekly mean of intra-gravel oxygen in Little Lost Man Creek from June-November 1974 averaged 9.6 mg/L. In a previously logged section of a tributary to Lost Man Creek during the same time period, the weekly mean concentration of intra-gravel oxygen was 6.6 mg/L. Intra-gravel oxygen concentration following input of sediments from the Highway 101 Prairie Creek Bypass project following a 1989 storm did not differ between stream reaches upstream of and below the sediment input (Roelofs and Sparkman 1999).

pH and Alkalinity

The solubility and biological availability of nutrients and heavy metals is affected by pH, which also affects many cellular processes of aquatic organisms. The water quality objective established in 2011 by the California North Coastal Regional Water Quality Board for pH ranges from 6.5-8.5. Alkalinity measures the capacity of water to absorb hydrogen ions, buffering changes in pH. Buffering capacity is primarily due to the presence of bicarbonate and carbonate ions, and is usually measured as mg/L of calcium carbonate. Alkalinity is frequently positively correlated with stream productivity and with taxonomic richness. Water with alkalinity less than 20 mg/L has little capacity to buffer acidic inputs and has been often found to support a greatly reduced diversity of aquatic organisms, particularly of mollusks and crustaceans. The fairly low alkalinity of Prairie Creek water may make it more resistant to invasion by the exotic New Zealand mudsnail.

During summer 2014, RNSP reported mean pH values at 4 sites in Prairie Creek (Prairie above Wolf Creek Bridge, and mouths of May, Streelow, and Skunk Cabbage creeks) of 7.2, 7.1, 6.8, and 5.9, respectively, from continuous water quality monitors recording hourly measurements. The pH of Skunk Cabbage Creek was below the criterion value, and may reflect the leaching of humic acids into the channel from wetland plants. Values from the other sites are in compliance and consistent with previous measurements of pH. Anderson (1988), for example, reported pH values of 6.7, 6.8, and 7.0 for Prairie, Wolf (Streelow), and Little Lost Man creeks, respectively. Bradford and Iwatsubo (1978) reported higher measurements of pH (7.5) in the dry than in the wet season (6.8) in Prairie Creek. Alkalinity has been measured in Prairie Creek infrequently. Anderson (1988) reported values ranging from 16-22 mg CaCO₃/L at the same sites mentioned above. Vazquez et al. (2016) measured calcium concentration of water sampled from Prairie Creek at less than 5 mg/L.

Sediment Supply and Hydrologic Function

Stream ecosystem function depends on a balance of instream structure such as large wood or boulders, transport capacity, and sediment supply (Yarnell et al. 2006). Diverse benthic communities and successful spawning of salmonid fishes cannot be supported without a sufficient influx of sediment particles to provide heterogeneous streambed substrate, or without the flushing downstream of sediments present in excess. Alteration in the quantity, composition, or timing of sediment supply from land use activities such as timber harvest or road construction may be manifest in the suspended load or in deposited sediments stored within the channel. An increase in the suspended load of fine sediments increases turbidity, reducing light penetration for photosynthesis of aquatic plants and the

foraging efficiency and growth of visually feeding fish and amphibians. Suspended sediments may also abrade gill or soft tissues of invertebrates, amphibians, and fishes, and scour benthic surfaces. Turbidity can also have positive effects on fish by reducing predation risk. Deposition of sediments which are not transported downstream in the suspended load disturbs stream communities by smothering benthic invertebrates and fish redds, and reducing the primary production that fuels the food web. Increases in deposited sediments can substantially affect channel morphology through filling of pools and channel widening, burying large woody debris, and severing the channel connection with riparian or floodplain areas. Adverse effects of increased sediment supply on channel form and aquatic biota may be particularly persistent in low-gradient streams, where streams lack sufficient power to transport sediments except during infrequent, high magnitude flows.

Indicators of altered sediment supply, and rankings established by NMFS (2014) for assessing the degree to which Coho Salmon in the southern Oregon/northern California ESA are stressed by altered sediment supply include, among other indicators, percent embeddedness and turbidity. For turbidity, expressed as numbers of hours per year exceeding 25 FNUs, rankings of stream habitat suitability are: Very Good: < 120; Good: 120-360; Fair: 361-720; and Poor: > 720. Inconsistencies exist in the literature with respect to the threshold of impacts to salmonids. Some recent work suggest that these target values may be too conservative (e.g., White and Harvey 2007, Harvey and Railsback 2009). Measurements of turbidity in Prairie Creek are presented here; substrate embeddedness data are discussed in the section on substrate particle size.

The Redwood Creek basin was listed on California's Clean Water Act Section 303(d) beginning in 1992 as sediment impaired. High sediment loads and the level of sedimentation in the basin was judged to exceed existing criteria for supporting its coldwater fishery, and a TMDL (total minimum daily load) which established instream numeric targets was completed in 1998 to address sediment supply problems. The TMDL for Redwood Creek acknowledged differences in the severity of sediment impairment between Prairie Creek and the rest of the Redwood Creek basin. The TMDL sediment load analysis demonstrated that most sediment inputs came from logging and road building; and Prairie Creek has had less human disturbance than the rest of Redwood Creek. For this reason, the TMDL used Little Lost Man Creek to establish reference conditions for sediment in an undisturbed setting.

RNSP began operating gaging stations in Prairie Creek in 1990 to assess the impacts and persistence of fine sediment transported into Prairie Creek from the Highway 101 Prairie Creek Bypass construction project, and later to assess impacts from road removal projects, especially in Lost Man Creek. Gaging stations provide continuous stage and turbidity data, monitor stream discharge and collect suspended sediments using automated pumping samplers controlled by turbidity threshold sampling. At present, RNP operates three long-term gaging stations at Little Lost Man Creek (pristine), Lost Man Creek at the Hatchery (logged and most roads recently removed) and Prairie above Boyes Creek (pristine).

Klein (1999) summarized results of 9-yr of physical monitoring of control and impacted stream reaches to assess impacts and their persistence associated with the Prairie Creek Bypass construction. Suspended sediment flux varied primarily as a function of the magnitude of winter stormflows.

Subsequent to a large spike in sediment transport during the October 1989 storm, suspended sediment discharge measured at gaging stations settled down to levels which varied more with peak flow than with degree of sedimentation from the construction, except in Boyes Creek. In Boyes Creek, unit suspended sediment flux was over ten times higher than at Prairie Creek below Brown Creek in 1996. That same year, total suspended sediment yield from Boyes Creek comprised 85% of that passing Prairie Creek above May Creek, while Boyes Creek comprises only about 13% of the contributing drainage area. This was attributed by Klein to historic timber harvest in Boyes Creek, but erosion, both from the October, 1989, storm and later erosion events, may also have contributed significantly to the high suspended sediment discharges continuing in Boyes Creek. Biological impacts from erosion associated with the Highway 101 Prairie Creek Bypass were summarized by Meyer and Haux (1995). Degraded gravel quality in subsurface spawning gravels in Prairie Creek, particularly downstream from Boyes Creek, may have had an adverse effect on salmon egg survival in water year 1990.

Findings from 2003–2011 monitoring of erosion and turbidity associated with road removal projects in Lost Man Creek were summarized by Klein (2012). In 2000, approximately 52 miles of old logging roads had been identified for removal in the Lost Man Creek watershed and by the end of the project in 2009, over 50 miles of road and associated stream crossings had been removed. Excavations of stream crossings contributed large amounts of sediment on occasion, but contributions decreased rapidly over time. Suspended sediment yields and peak storm turbidities varied directly and linearly with treatment intensity. The road work, which was completed in 2010, is expected to reduce suspended loads and turbidities over coming years. Legacy and natural erosion and delivery are likely to continue indefinitely on an episodic basis.

Klein et al. (2011) summarized chronic turbidity levels for at least 2003-2005 for 9 stations in the Prairie Creek basin. Using NMFS (2014) recovery criteria for this metric, as numbers of hours per year exceeding 25 FNU, Prairie Creek above Brown Creek, Godwood Creek, and Prairie Creek above Boyes Creek would be ranked as very good, with <120 hrs/yr > 25 FNU). Pristine Little Lost Man Creek would rank as good (120-360 hrs/yr > 25 FNU), and Lost Man Creek stations would rank as good to fair (361-720 hrs/yr > 25 NTU). More recent among-catchment data on chronic turbidity levels within Prairie Creek are not available.

Hydrological function in Prairie Creek is not impaired by dams or large diversions. The state park campground at Elk Prairie, NPS housing, outdoor education center, and a fire cache within the national park boundaries are supplied with small amounts of water from wells. The extent to which hydrologic function may have been altered or recovered from previous timber harvest or floodplain alteration is not known. Road density can be a useful indicator of altered hydrologic function, as road density affects speed of delivery, path by which water is routed to stream, and peak flows from storm events. Overall road density in Prairie Creek (1.67 km/km², or 1.04 mi/mi²) places it in a very good category (< 1.6 mi/mi²) using NMFS (2014) targets.

Riparian Vegetation

The riparian zone bordering a stream interacts with the channel and strongly affects structure and functioning of aquatic ecosystems. Riparian vegetation affects the amount of direct sunlight reaching

the stream, which in turn affects water temperature and aquatic productivity. It supplies inputs of litter and terrestrial invertebrates important in supporting aquatic food webs, and large woody debris important in creating habitat complexity. Riparian vegetation also protects streambank from erosion, intercepts sediments and nutrient runoff, and moderates discharge during storm events.

Among the attributes of riparian conditions included in watershed assessment protocols by CDFW (Flosi et al. 2010) and NMFS (2014) are the percentage of canopy shading provided to the stream, and the relative percentage of riparian trees that are composed of conifer and hardwood. A target of $\geq 80\%$ canopy shading in streams supporting anadromous salmonids was established by CDFW to reduce direct sunlight from warming water, although the temperature gain in northern coastal waters from canopy opening may not increase temperatures to levels stressful to fish (e.g. Wilzbach et al. 2005). The importance of sunlight in fueling the food web is overlooked in this assessment. Riparian composition affects the potential for LWD recruitment, as streams flowing through stands of mature conifer tend to have larger amounts of wood with larger average piece size than do streams with younger riparian stands dominated by smaller deciduous species. Riparian composition dominated by mature conifer is favored because larger wood plays a larger role in pool formation, is less likely to move downstream, and it decomposes more slowly. Deciduous species, however, provide a greater amount of allochthonous inputs and terrestrial invertebrates, which can contribute significantly to salmonid production. NMFS (2014) ranked streams with $>40\%$ open + hardwood riparian vegetation as poor, and streams with $< 20\%$ open + hardwood vegetation as very good.

From a survey of 10 sites in the Prairie Creek sub-basin, Cannata et al. (2006) concluded that riparian canopy density was suitable for shading stream reaches. Canopy density exceeded 80% in all but one previously harvested site on Lost Man Creek and two sites in Prairie Creek above Boyes Creek. Compared to Godwood Creek and an uncut reach of Brown creeks (70% coniferous), the percentage of riparian conifer was lower at sites in Lost Man, May, and Boyes creeks ($< 10\%$), all of which were harvested for timber in the 1950s-1960s. Madej et al. (2006 a) also presented data on riparian shading at several sites in Prairie Creek; they found that shading ranged from 89% (Little Lost Man Creek at bridge) to 100% (Godwood Creek). The effect of heavy shading on primary and secondary (e.g. salmonid) production in Prairie Creek has not been

Biological Interactions and Disease

Effects of biological interactions, such as competition or predation, in structuring aquatic communities in Prairie Creek have received little attention. Strong biological interactions and diseases can limit recovery of some at-risk populations; these situations have been most commonly observed in settings greatly impaired from human-induced environmental alteration in hydrology, water quality, or habitat, or from intentional or accidental introductions of exotic species. One example of a potential biological interaction in Prairie Creek that has been observed to affect salmon reproductive success concerns the activity of a fish-egg eating earthworm, *Haplotaxis ichthyophagous*. The worm has been present in Prairie Creek at least since the 1950s, when Briggs (1953) observed high redd losses in the presence of the worm. He noted that worm infestation and high egg mortality typically occurred in the spring subsequent to the emergence of Chinook Salmon and early spawning Coho Salmon fry; thus, only steelhead and later spawning Coho Salmon eggs

appeared to be vulnerable to this mortality. The worm is attracted to fine sediments (Coey 1998, Sparkman 2003), and its abundance was found to be associated with a decrease in egg survival during the Highway 101 Prairie Creek Bypass study. Meyer (2003) found that the worm itself, however, accounted for little of the variance in egg survival. A much stronger negative relationship was observed between the amount of fine sediment ($< 0.5\text{mm}$) in the lower egg pocket and egg survival to hatching. An unexamined hypothesis is that the worm is primarily attracted to sediments enriched with organic matter from moribund eggs, and may cause relatively little direct mortality.

Briggs (1949) posited that the chief limitations on survival of juvenile salmonids in Prairie Creek came from competition for food and predation by salmon of the same or other species. The consumption of salmonid fry by free-swimming fish predators in Prairie Creek was investigated through a survey of diet contents by Duffy et al. (2011). They found that Prickly Sculpin, steelhead, Cutthroat Trout, and Coho Salmon relied more heavily on insect prey than on salmonid fry. Among the four fish, only Cutthroat Trout were observed with salmonid fry in their stomachs. Consumption occurred with greater frequency when the Cutthroat Trout were confined in downstream migrant traps than in natural habitats. Drobny (2016) was unable to detect an effect of small or large size classes of trout on density of juvenile Coho Salmon in the creek.

Diseases, particularly from myxozoan parasites, have caused significant mortality in juvenile salmonids in the nearby Klamath River in the last decade, but fish disease has not been problematic to date in Prairie Creek.

Passage Barriers

Barriers that block fish migration have been identified as a stress that potentially limits salmonid recovery (NMFS 2014). Some barriers to migration are natural, such as waterfalls or debris jams. Others are man-made, such as dams and culverts. Barriers can be partial or complete, depending on flows and the species/life stage of fish attempting to pass the barrier. Several unpublished files from Prairie Creek stream surveys conducted by CDFG from the 1950's-1970's noted concern over debris accumulations formed from logging debris (e.g., see reference codes 2236993, 2236984, and 2236987 in the Prairie Creek Fisheries Bibliography, available at <https://irma.nps.gov/DataStore/>). Today, barriers are of less concern to the persistence of Prairie Creek salmonids, as most have been treated or recommended for non-action. In 2007, Ross Taylor Associates assessed stream crossings in the Prairie Creek watershed. The results of this survey, as well as locations and descriptions of barriers are available in the California Department of Fish and Wildlife Passage Assessment Database (PAD). The PAD is available online as an interactive map at <https://nrm.dfg.ca.gov/PAD/>. Prairie Creek barriers and known distributions of anadromous Chinook and Coho Salmon and steelhead from the PAD are shown in Figures 8-10. Some culverts on tributaries just off mainstem Prairie Creek, associated with the Newton Drury Parkway, failed to pass fish because of shallow depths, excessive velocities, and insufficiency of fish burst speed to pass individuals through the entire culvert length before fish exhaustion. On May Creek, a log stringer bridge with soil on top is failing but is not currently a barrier to anadromous fish. RNP electrofished upstream of the bridge in September 2016 and captured steelhead and Coho Salmon juveniles. An impassable log jam 2 km upstream of the bridge at the Lost Man Creek Picnic Area sets an upper limit to salmon spawning

and rearing in Lost Man Creek except in years of high flows. This log jam has been in place at least since 1980 (D. Anderson, personal communication), and is considered a natural log barrier by RNSP. Current Park policy leaves natural barriers in place, as their formation is a natural process.

Fishery and Collecting-related Effects

Fishing, mostly catch and release, is permitted within portions of RNSP. In the Prairie Creek sub-basin, fishing under CDFW sport fishing regulations occurs from the fourth Saturday in May through October 31. It is closed to the take of salmon, Cutthroat Trout, and wild steelhead. Only a two hatchery trout or hatchery steelhead daily bag is allowed. Scientific collection is permitted and heavily regulated by the state and federal government. As NMFS (2014) concluded for the Redwood Creek basin in its entirety, fishing and collection-related activities likely pose a low stress to juveniles, smolts, and adult Coho Salmon, based on population status relative to depensation and estimates of the fishing exploitation rate. Historic commercial and recreational overharvest of salmon is believed to have contributed to the declines now observed in salmon abundance throughout the Pacific Northwest.

Hatchery-related Effects

Continuing impacts to aquatic biota from the historic operation of the Prairie Creek Hatchery are unknown, but likely to be low. Detection of domestication selection in contemporary populations would be difficult as more than 20 years have passed (and 7 or so generations of fish) since hatchery operations ceased. Wild adaptation is believed to be attained relatively rapidly following return to a wild condition (with no hatchery) (personal communication, A. Kinziger, Fisheries Department, Humboldt State University, Arcata). While the impact of out-of-basin sources on genetic structure can be detected, the literature has shown that the stocking must have been very extensive before effects are realized. Most transplanted fish fail to become established.

Summary of Existing Data and Data Gaps

Information on distribution, abundance, and status of aquatic resources in Prairie Creek is more available for some taxa and subject areas than others. Available datasets on fisheries and aquatic resources and relevant environmental variables are listed in Table 7, along with information regarding geographic location and the timeframe of data collection, data ownership, and, if known, principal investigators or current contacts associated with data collection. Taxa and areas for which information are limited are described below, but this listing should not be construed as all-inclusive.

Salmonid and other Fishes

While a great deal of effort has been expended in monitoring and studying salmonid fish populations in Prairie Creek, holes still remain in scientific understanding of the linkages between salmonid production and the physical and chemical conditions of their environment. Linkages may become more clear through trend analysis if monitoring efforts continue, and by comparison of population status among regional streams differing in disturbance history. Increased use of experimental research and modelling approaches would also advance understanding of relationships between habitat elements and seasonal production of salmonids in Prairie Creek, and be useful in guiding restoration and recovery actions.

At least within the past decade, studies and monitoring efforts in Prairie Creek have been biased toward Coho Salmon, reflecting the focus of grant funds available to support monitoring efforts. Understanding of other listed salmon and trout species is more limited, with data collection often coincidental while sampling for Coho Salmon. Steelhead and Cutthroat Trout populations, because of their long freshwater residence, are also highly sensitive to freshwater conditions and are useful indicators of watershed recovery.

Population parameters such as density, growth, and survival have not been equally monitored. Estimation of juvenile salmonid abundance in summer, based on the Hankin-Reeves approach that combined both snorkeling and electrofishing, was popular in the 1990's and early 2000s, and later fell from favor as investigators became persuaded that population bottlenecks occurred primarily in winter. Although recent studies in Prairie Creek have not supported a view that population limitation is restricted to winter (e.g., Moore 2014, Drobny 2015), overwinter survival has been estimated more often than growth or fish survival at other times of year. Both growth and survival are vital population processes.

Limitations to production of salmonid fishes are often assumed by managers and fish biologists to derive from physical or chemical features of the environment (e.g. LWD, suspended sediment loads, etc.). The possibility that availability of food resources is limiting to growth, and the manner in which this interacts with habitat elements, has not been investigated. Salmonid production is a product of fish biomass (density) and growth, and is often more strongly influenced by high growth rates than by dense populations (Warren 1971). Even when physical habitat and water quality are favorable for growth, high growth rates require abundant food resources (Bisson and Bilby 1998).

Table 7. Existing datasets of physical/chemical and biological variables in the Prairie Creek sub-basin of Redwood Creek, California through 2016, years of data acquisition, and data ownership. Principal investigator (PI) associated with data collection or current contact person is given when known. NWS=National Weather Service; RNSP=Redwood National and State Park; USGS=U.S. Geological Survey; CDFW=California Department of Fish and Wildlife; CCRU_USGS=(USGS) California Cooperative Fish and Wildlife Research Unit; PCFWWA=Pacific Coast Fish, Wildlife, and Wetlands Restoration Association; HSU=Humboldt State University.

Variable	Location	Years	Data Ownership	PI or Contact
Air Temperature	Prairie Creek State Park	1938-2004	NWS	–
Precipitation	Prairie Creek State Park	1938-2004	NWS, RNSP	–
Streamflow, continuous	Prairie Creek above Boyes Creek	2004-2016	RNSP	R. Klein (retired, RSNP), V. Ozaki, RNSP
	Prairie Creek at Wolf Creek bridge	1991-2012	RNSP	R. Klein (retired, RSNP), V. Ozaki, RNSP
	Upper Prairie Creek	1990-2011	RNSP	R. Klein (retired, RSNP), V. Ozaki, RNSP
	Little Lost Man	1975-2016	USGS, RNSP	R. Klein (retired, RSNP), V. Ozaki, RNSP
	Lost Man Creek at Hatchery	2003-2016	RSNP	R. Klein (retired, RSNP), V. Ozaki, RNSP
	Redwood Creek at Orick	1912, 1913, 1948-2015	USGS	http://waterdata.usgs.gov/nwis/
Streamflow, instantaneous	Prairie Creek USGS stations	1973-1974	USGS	R. Iwatsubo (retired, USGS)
Turbidity, Suspended Sediments	Prairie Creek Gaging Stations	2003-2016	RNSP	R. Klein (retired, RSNP), V. Ozaki, RNSP
	Prairie Creek USGS stations	1973-1974	USGS	R. Iwatsubo (retired, USGS)
Water Temperature and Water Chemistry	Prairie Creek USGS stations	1873-1974	USGS	R. Iwatsubo (retired, USGS)
	mouth of Prairie Creek: trap operation	2011-2016	CDFW	M. Sparkman, CDFW
	Various, summer water temperature only; Some winter temperature data after 2012.	1997-2016	RNSP	V. Ozaki, RNSP
	Several Prairie and Redwood Creek sites	Every 3 years beginning 2012	NPS Klamath Inventory and Monitoring Network	E. Dinger, NPS

Table 7 (continued). Existing datasets of physical/chemical and biological variables in the Prairie Creek sub-basin of Redwood Creek, California through 2016, years of data acquisition, and data ownership. Principal investigator (PI) associated with data collection or current contact person is given when known. NWS=National Weather Service; RNSP=Redwood National and State Park; USGS=U.S. Geological Survey; CDFW=California Department of Fish and Wildlife; CCRU_USGS=(USGS) California Cooperative Fish and Wildlife Research Unit; PCFWWA=Pacific Coast Fish, Wildlife, and Wetlands Restoration Association; HSU=Humboldt State University.

Variable	Location	Years	Data Ownership	PI or Contact
Substrate size	Area impacted by Highway 101 Bypass	1990-1999, and sporadic	RNSP	R. Klein (retired, RNSP)
	Selected sites	2004, 2005	RNSP, USGS	M. Madej (retired, USGS)
Large Wood	Prairie Creek below Streelow	2015	RNSP, CCRU_USGS	J. Seney and V. Ozaki, RNSP; J. Deibner-Hansen, CCRU_USGS
	Prairie Creek above Streelow	1990s	RNSP,	R. Klein (retired, RNSP), RNSP and S. Kramer, H.T. Harvey & Associates; J. Diebner-Hansen, CCRU_USGS
		2014-2015	CCRU_USGS	
	800 m reaches at several Prairie Creek locations	2004-2005	RNSP, USGS	M. Madej (retired, USGS)
Habitat Typing	Boyes, Streelow, upper Prairie	1998-2011	CCRU_USGS	W. Duffy (retired, CCRU_USGS)
	Lost Man Creek	2005-2011	RNSP	V. Ozaki, RNSP
Barriers	barriers associated with the Newton Drury Parkway Highway 101 culverts	2007	Ross Taylor Associates	R. Taylor, Ross Taylor Associates
	Basin wide	2004	HSU	M. Lang, HSU
	Redwood Creek, selected Prairie Creek locations	1980-1981	HSU	—
Wetland Vegetation	USGS Orick Quadrangle	2010	USFWS	National Wetlands Inventory
		2015		J. Seney, RNSP: wetlands assessment using CRAM methodology

Table 7 (continued). Existing datasets of physical/chemical and biological variables in the Prairie Creek sub-basin of Redwood Creek, California through 2016, years of data acquisition, and data ownership. Principal investigator (PI) associated with data collection or current contact person is given when known. NWS=National Weather Service; RNSP=Redwood National and State Park; USGS=U.S. Geological Survey; CDFW=California Department of Fish and Wildlife; CCRU_USGS=(USGS) California Cooperative Fish and Wildlife Research Unit; PCFWWA=Pacific Coast Fish, Wildlife, and Wetlands Restoration Association; HSU=Humboldt State University.

Variable	Location	Years	Data Ownership	PI or Contact
Soils data	Redwood National and State Parks	2008	USDA NRCS	http://websoilsurvey.nrcs.usda.gov/ http://soils.usda.gov/survey/printed_surveys/
Aquatic Invertebrates	various locations	Sporadic	USGS, RNSP, CCRU_USGS, HSU	several authors; see text
Algal Assemblages	Prairie Creek near Lost Man Creek	1973-1974, 2004	USGS	R. Iwatsubo, M. Madej (both retired, USGS)
Amphibians	direct sampling	Sporadic	RSL_USFS	D. Ashton RSL_USFS; Welsh (retired, USFS); L. Ollivier (RSL_USFS)
Amphibians and non-salmonid fishes	bycatch of fish collections	Various	RNSP, CDFW, CCRU_USGS	D. Anderson, RNSP; M. Sparkman, CDFW; W. Duffy (retired, CCRU_USGS), M. Wilzbach, CCRU_USGS
Salmonid Fishes				
Outmigrant smolts	Prairie Creek near Streelow Creek	1992-1994	PCFWWA	M. Farro, PCFWWA
	Prairie Creek above Streelow Creek	1995-1998	PCFWWA, HSU	B. Klatte, USACOE, T. Roelofs (retired, HSU)
	Prairie Creek above Streelow Creek	1998-2008	CCRU_USGS	W. Duffy (retired, CCRU_USGS), HSU student theses
(Outmigrant smolts)	mouth of Prairie Creek	2011-2016	CDFW, CCRU_USGS	M. Sparkman, CDFW
Juvenile Abundance	Prairie, Boyes, Streelow Creeks	1998-2010	RNSP CCRU_USGS	D. Anderson, RNSP; Duffy (retired, CCRU_USGS), several HSU student theses
	Prairie Creek Basin	2014	CCRU_USGS	M. Wilzbach, CCRU_USGS, P. Drobny (HSU thesis)

Table 7 (continued). Existing datasets of physical/chemical and biological variables in the Prairie Creek sub-basin of Redwood Creek, California through 2016, years of data acquisition, and data ownership. Principal investigator (PI) associated with data collection or current contact person is given when known. NWS=National Weather Service; RNSP=Redwood National and State Park; USGS=U.S. Geological Survey; CDFW=California Department of Fish and Wildlife; CCRU_USGS=(USGS) California Cooperative Fish and Wildlife Research Unit; PCFWWA=Pacific Coast Fish, Wildlife, and Wetlands Restoration Association; HSU=Humboldt State University.

Variable	Location	Years	Data Ownership	PI or Contact
Adult Spawner Index	Lost Man Creek	1991-1998	RNSP	D. Anderson, RNSP; S. Haux, (former RNSP)
Adult Escapement	Prairie Creek above Streelow Creek	1995-1998	PCFWWA, HSU	B. Klatte (USACOE), Roelofs (retired, HSU)
	Prairie Creek above Streelow Creek	1998-2008	CCRU_USGS	W. Duffy (retired, CCRU_USGS)
	basin-wide sample	2008-2015	CDFW	S. Ricker, CDFW

Similarly, freshwater survival is often assumed to vary primarily with the availability of velocity refugia. The intensity of predation and its impact on survival, and the manner in which predation risk varies with habitat elements, has received little attention in Prairie Creek. Nor has the role of competitive interactions in structuring salmonid assemblages been studied.

Spatially, salmonids have been studied more frequently in the upper, more pristine reaches of Prairie Creek than in lower reaches of the creek. Understanding of the timing and extent to which juvenile salmonids rear or merely move through the lower river is limited, as is understanding of resource availability and limitations to production in the lower watershed.

Studies on non-salmonid fishes have been largely limited to enumerating the bycatch of trap or seining collections targeted at salmonid fishes.

Amphibians

Species such as the Coastal Giant Salamander, Tailed Frog, and Southern Torrent Salamander are valuable indicators of watershed integrity and recovery, as these are associated with late seral forests. Periodic monitoring of amphibian assemblage structure, which has been previously directly censused only sporadically, would allow trend analysis. Studies in Washington have shown promise in the use of *e*-DNA to detect presence/absence of amphibians without disruption to stream substrate; this approach could be considered in Prairie Creek.

Invertebrates

Use of invertebrates as indicators of habitat quality in Prairie Creek has not yielded great insight, perhaps because the rapid bioassessment protocols which have been used are able to detect only fairly coarse differences in community composition among sites differing in degree of disturbance. Taxonomic identity of species and genera occurring in Prairie Creek is well established. Data on the relative importance of different taxa or groupings in the diets of vertebrate consumers is more sparse. Should the New Zealand Mud Snail become established in Prairie Creek, its potential for rapidly disrupting invertebrate community structure and alter food web dynamics is high. Periodic monitoring of benthic invertebrates should be a high priority.

Ecosystem Dynamics

Most studies of aquatic resources in Prairie Creek have been directed at the level of individual populations for vertebrates, or assemblage structure for invertebrates and, to a lesser extent, amphibians. Very few data are available to assess structure and functioning of the stream ecosystem as a whole. Basal resources for stream food webs are provided through primary production and detrital decomposition – measurement of these rates would suggest the capability of the Prairie Creek ecosystem to support a diverse food web. Comparison of gross primary to community respiration would indicate the relative importance of autotrophic (produced within the channel) versus allochthonous (produced outside the channel) sources of energy. Measurement of nutrient spiraling (the downstream cycling of nutrients among stream biota and the water column) assesses the efficiency of a stream ecosystem in mineralizing inputs of organic carbon, which affects water quality locally and downstream. Secondary production of invertebrates and fishes are also important ecosystem-level functions for which data in Prairie Creek are limited.

The Physical/Chemical Template

Stream nutrient data are sparse in Prairie Creek, perhaps because of an understanding that Prairie Creek waters, like those in other forested streams in the Pacific Northwest, are infertile; excessive nutrient concentrations that may harm aquatic biota are not present. However, there is a possibility that a shortage of nutrients may limit algal production, with cascading effects through the trophic web. This possibility should be explored.

Although some data are available on the composition of riparian vegetation within the watershed, data on the amount and spatial patterning of incident light over stream channels appears to be absent. This information would be useful for establishing targets for riparian management to enhance aquatic productivity. Importance of light in affecting energy available to support stream biota has often been undervalued.

Data are not available on the distribution and supply of groundwater to Prairie Creek. The groundwater supply affects stream water temperature and local surface water chemistry. Many studies have documented the reliance of salmonid fishes on groundwater for key habitat needs, and in many cases where ambient temperatures are stressful, for their very survival.

Value of Long-Term Data Sets and Need for Continued Monitoring

Although data have been collected on aquatic resources in the Prairie Creek watershed at least since the 1950s, few long-term datasets, employing consistent or comparable methods and from the same locations, are available. As described by Lindenmayer et al. (2012), among the values of long-term monitoring are: 1) quantifying ecological responses to drivers of ecosystem change; 2) understanding complex ecosystem processes that occur over long period; 3) providing core ecological data for parameterizing and validating simulation models or developing theoretical models; and 4) providing data and understanding at scales relevant to management, thus critically supporting evidence-based policy, decision-making, and management of ecosystems. In contrast to short-term data, long-term ecological data are able to capture and recognize long-term events, changes in highly variable systems, time-lagged responses, cumulative effects of stressors, and biotic responses encompassing multiple generations (Dodds et al. 2012). Without long-term data, population evaluations of at-risk species may incorrectly indicate adverse impacts where none exist, or no impact where one is likely to occur (Lohner and Dixon 2013).

Long-term monitoring programs are difficult to maintain because they exceed the length of government administrations and funding cycles. Monitoring of discharge, suspended sediment, temperature and water quality in Prairie Creek has been supported with relatively stable funding from the National Park Service and the U.S. Geological Survey. Monitoring of fish populations and other aquatic resources has been more tenuous and vulnerable to disruption. For example, much of the monitoring of listed Coho Salmon over the last decade has been supported with state-administered funds from a competitive restoration grants program. As of this writing, monitoring of salmonid juveniles and smolts is poised to terminate at the end of 2016, and will continue only when new funding is procured. Interruptions in the data record make interpretation of trends in fish abundance problematic.

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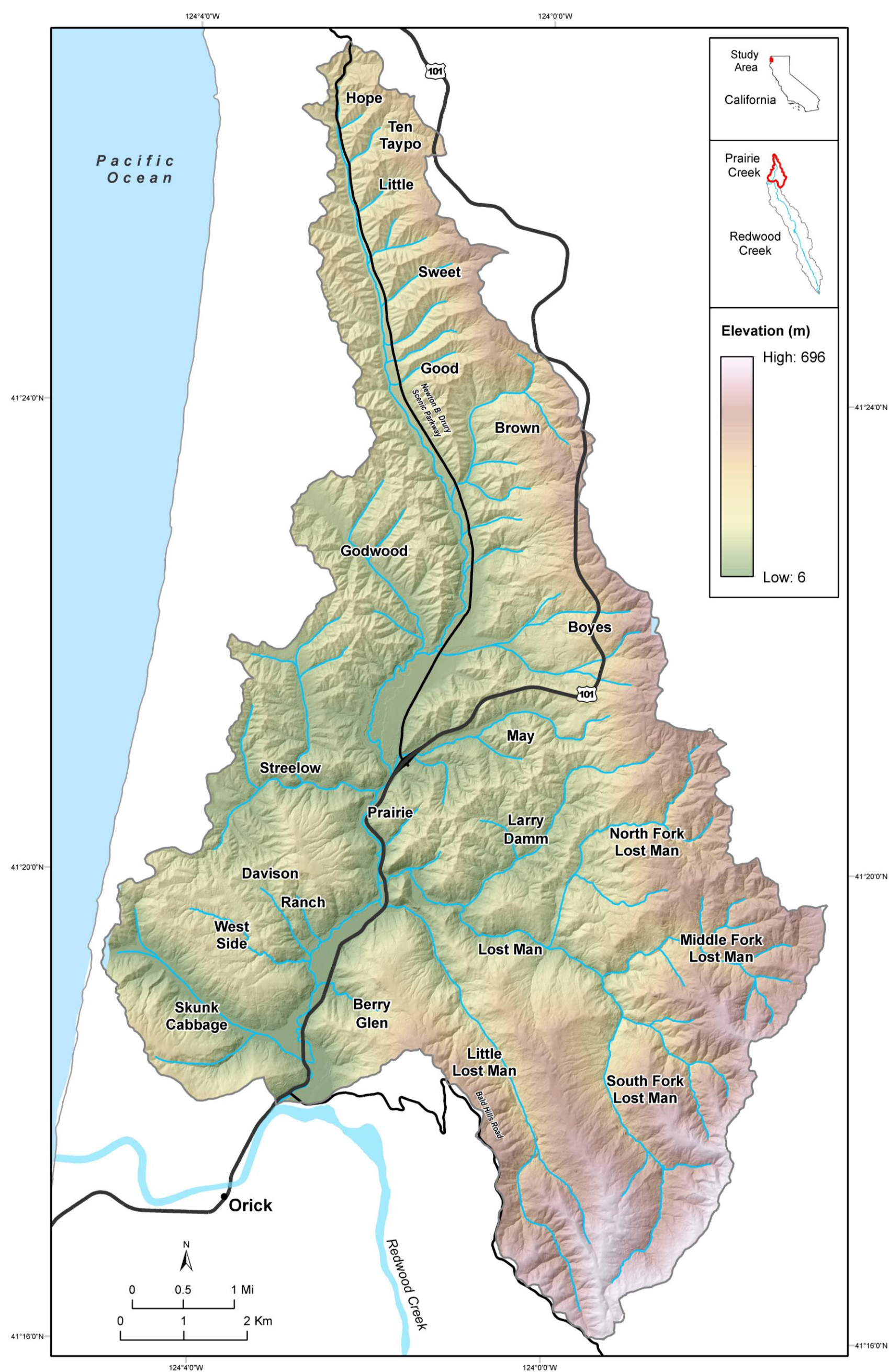
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Appendix A. Digital elevation map of the Prairie Creek sub-basin of Redwood Creek in northern California. (REDW GIS Project 148)



Appendix B. Aquatic insect taxa collected from the Prairie Creek Basin.

Aquatic insect taxa collected from Prairie Creek and its tributaries. An “x” indicates presence and a null field indicates absence. Only streams from which taxa were collected are listed. Data are compiled from Anderson (1988), Kvam (1988), Strange (1989), Madej et al. (2006 a), RNSP (2007), and Dinger (2010).

Taxon	Prairie	Brown	Boyes	Lost Man	Little Lost Man	Streelow
COLEOPTERA						
AMPHIZOIDAE						x
ANTHICIDAE				x		
CIRCULIONIDAE	x					x
DYTISCIDAE	x			x	x	x
<i>Oredytes sp.</i>	x			x	x	x
ELMIDAE	x			x	x	x
<i>Ampomixis dispar</i>	x			x		
<i>Heterlimnius koebelei</i>	x			x		
<i>Lara sp.</i>	x			x		
<i>Narpus concolor</i>	x			x		
<i>Optioservus sp.</i>	x			x		
<i>Ordobrevia nubifera</i>	x			x		
<i>Zaitzevia parvula</i>	x			x		
GYRINIDAE						x
HALIPLIDAE				x	x	
<i>Brychius sp.</i>				x		
<i>Haliplus sp.</i>				x		
HYDRAENIDAE	x			x		x
<i>Hydraena</i>				x		
<i>Ochthebius sp.</i>	x					
HYDROPHILIDAE	x					x
<i>Tropisternus sp.</i>				x		
PSPHENIDAE				x	x	
<i>Acneus</i>				x		
<i>Eubrianax edwardsi</i>	x			x		

Taxon	Prairie	Brown	Boyes	Lost Man	Little Lost Man	Streelaw
PTILLIDAE	x					
PTILODACTYLIDAE				x		
<i>Anchytarsus sp.</i>				x		
DIPTERA						
BLEPHARICERIDAE				x		
<i>Philorus californicus</i>				x		
CERATOPOGONIDAE	x			x		x
<i>Bezzia sp.</i>	x			x		
<i>Atrichopogon sp.</i>	x			x		
CHIRONOMIDAE	x			x	x	x
Subfamily Chironominae	x			x		
Tribe Chironomini	x			x		
<i>Polypedilum sp.</i>	x			x		
Tribe Tanytarsini	x			x		
<i>Rheotanytarsus sp.</i>	x			x		
<i>Stempellina sp.</i>	x			x		
<i>Stempellinella sp.</i>	x			x		
Subfamily Orthocladinae	x			x		
<i>Heterotanytarsus sp.</i>	x			x		
<i>Krenosmittia sp.</i>	x			x		
<i>Lopescladius sp.</i>				x		
Subfamily Podonominae						
Tribe Boreochlini				x		
<i>Boreochlus sp.</i>				x		
Subfamily Tanypodinae	x			x		
CULICIDAE						
<i>Anopheles sp.</i>	x					
DIXIDAE	x				x	x
<i>Dixa sp.</i>	x			x		
DOLICHOPODIDAE	x					
EMPIDIDAE	x			x		x

Taxon	Prairie	Brown	Boyes	Lost Man	Little	Streelow
					Lost Man	
<i>Chelifera sp.</i>	x			x		
<i>Neoplasta</i>				x		
EPHYDRIDAE	x				x	x
MUSCIDAE				x		
PETECORHYNCHIDAE	x					
<i>Glutops sp.</i>	x					
PSYCHODIDAE	x			x	x	
<i>Maruina lanceolata</i>	x			x		
<i>Pericoma sp.</i>	x			x		
PTYCHOPTERIDAE						
<i>Ptychoptera sp.</i>	x			x		
SIMULIIDAE	x			x	x	x
<i>Prosimulium sp.</i>				x		
<i>Simulium sp.</i>	x			x		
STRATIOMYIDAE						
<i>Allognosta sp.</i>	x			x		
<i>Myxosargus sp.</i>	x					
TABANIDAE				x		
<i>Tabanus sp.</i>	x					
TIPULIDAE	x			x		
<i>Antocha monticola</i>	x			x		
<i>Dicranota sp.</i>	x			x		
<i>Hexatoma sp.</i>	x					
<i>Limonia sp.</i>				x		
EPHEMEROPTERA						
AMELETIDAE	x			x		
<i>Ameletus sp.</i>	x	x			x	x
BAETIDAE	x			x		
<i>Baetis</i>	x	x		x	x	
<i>Diphetor hageni</i>				x		
EPHEMERELLIDAE				x		

Taxon	Prairie	Brown	Boyce	Lost Man	Little	
					Lost Man	Streelov
AMELETIDAE	x			x		
<i>Ameletus sp.</i>	x	x			x	x
BAETIDAE	x			x		
<i>Baetis</i>	x	x		x	x	
<i>Dipheter hageni</i>				x		
EPHEMERELLIDAE				x		
<i>Attenella margarita</i>				x		
<i>Caudatella heterocaudata</i>	x					
<i>Ephemerella inermis</i>	x			x		
<i>Ephemerella infrequens</i>	x					
<i>Drunella coloradensis</i>	x			x		
<i>Drunella doddsi</i>	x					
<i>Drunella grandis</i>	x					
<i>Drunella spinifera</i>				x		
<i>Serratella levis</i>	x			x		
<i>Serratella teresa</i>	x			x		
<i>Serratella tibialis</i>	x			x		
<i>Timpanoga hecuba</i>	x				x	x
HEPTAGENIIDAE	x			x		
<i>Cinygma</i>				x		
<i>Cingymula sp.</i>	x			x		
<i>Ecdyonurus</i>				x		
<i>Epeorus albertae</i>	x			x		
<i>Epeorus longimanus</i>	x			x		
<i>Heptagenia sp.</i>	x			x		
<i>Ironodes sp.</i>	x	x		x		
<i>Rithrogena sp.</i>	x				x	x
LEPTOPHLEBIIDAE	x		x	x		x
<i>Paraleptophlebia</i>	x	x			x	x
SIPHONURIDAE	x					
TRICORYTHIDAE						

Taxon	Prairie	Brown	Boyes	Lost Man	Little Lost Man	Streelow
<i>Tricorythodes sp.</i>	x					
HEMIPTERA						
CORIXIDAE	x					
<i>Sigara vandekeyi</i>						x
GERRIDAE				x		
<i>Gerris sp.</i>						x
VELIIDAE	x					x
MEGALOPTERA						
CORYDALIDAE	x			x		
<i>Orohermes crepusculus</i>	x			x		
SIALIDAE	x			x		
<i>Sialis sp.</i>	x					
ODONATA						
GOMPHIDAE	x			x		
<i>Gomphus sp.</i>						x
PLECOPTERA						
CAPNIIDAE	x			x		
<i>Capnia sp.</i>	x			x		
<i>Paracapnia angulata</i>	x				x	x
CHLOROPERLIDAE	x			x		
<i>Paraperla frontalis</i>	x			x		
<i>Suwalia sp.</i>	x					x
<i>Sweltsa</i>				x		
LEUCTRIDAE	x			x	x	x
<i>Despaxia augusta</i>				x		
NEMOURIDAE	x			x		
<i>Malenka</i>				x		
<i>Soyedina</i>				x		
<i>Zapada cinctipes</i>	x			x		
<i>Zapada oregonensis</i>	x				x	x
PELTOPLERIDAE	x			x		

Taxon	Prairie	Brown	Boyce	Lost Man	Little	Streelaw
					Lost Man	
<i>Soliperla</i>				X		
<i>Yoroperla brevis</i>	X				X	X
PERLIDAE	X			X		
<i>Calineuria californica</i>	X			X		
<i>Doroneuria baumanni</i>				X		
<i>Hesperoperla pacifica</i>	X			X		
PERLODIDAE	X			X		
<i>Cultus sp.</i>	X			X		
<i>Isoperla sp.</i>	X			X		
<i>Kogotus nonus</i>	X				X	
PTERONARYCIDAE	X			X		
<i>Pteronarcys californica</i>	X					
TRICOPTERA	X				X	X
APATANIIDAE				X		
<i>Apatania</i>				X		
BRACHYCENTRIDAE	X			X		
<i>Micrasema onisca</i>	X			X	X	X
CALAMOCERATIDAE	X			X		
<i>Heteroplectron californicum</i>	X			X	X	X
GLOSSOMATIDAE	X			X		
<i>Agapetus taho</i>	X			X		
<i>Glossosoma sp.</i>	X			X	X	X
HYDROPSYCHIDAE				X		
<i>Arctopsyche grandis</i>	X			X		
<i>Hydropsyche sp.</i>	X			X		
<i>Parapsyche sp.</i>	X			X	X	
HYDROPTILIDAE				X		
<i>Hydroptila sp.</i>	X			X		
<i>Ochrotrichia sp.</i>	X			X		
<i>Palaeagepetus nearcticus</i>					X	
LEPIDOSTOMATIDAE	X			X		

Taxon	Prairie	Brown	Boyes	Lost Man	Little	
					Lost Man	Streelow
<i>Lepidostoma sp.</i>	x			x	x	x
LIMNEPHILIDAE	x			x		
<i>Apatania sorex</i>	x			x		
<i>Cryptochia</i>				x		
<i>Dicosmoecus gilvipes</i>	x			x		
<i>Ecclisomyia conspersa</i>	x			x		
<i>Hydatophylax hesperus</i>	x			x		
<i>Neophylax rickeri</i>				x		
<i>Onocosmoecus sp.</i>	x					
PHILOPOTAMIDAE	x			x		
<i>Wormaldia sp.</i>	x					
PSYCHOMYIIDAE	x					
<i>Psychomyia lumina</i>	x					x
POLYCENTROPIDAE	x			x		
<i>Polycentropus sp.</i>	x				x	x
RHYACOPHILIDAE	x			x		
<i>Rhyacophila spp.</i>	x			x		
SERICOSOMATIDAE	x			x		
<i>Gumaga griseola</i>						
UENOIDAE	x			x		
<i>Farula sp.</i>	x			x		
<i>Neophylax</i>				x		

Appendix C. Non-insect aquatic invertebrates collected from the Prairie Creek Basin.

Non-insect aquatic invertebrates collected from Prairie Creek or its tributaries. An “x” indicates presence and a null field indicates absence. Only streams from which taxa were collected are listed. Data are compiled from Anderson (1988), Kvam (1988), RNSP (2007), Strange (1989), and Madej et al. (2006 a). C = Class; O = Order; S.O. = Suborder; F = Family.

Taxon	Prairie	Lost Man	Little Lost Man	Streelow
PHYLUM ANNELIDA				
C. HIRUDINEA	x			
C. OLIGOCHAETA	x	x		
C. ADENOPHOREA				
O. Rhabditida	x			
PHYLUM ARTHROPODA				
C. ARACHNIDA				
O. Acari	x		x	x
S.O. Hydracarina	x	x		
C. COLLEMBOLA	x		x	x
C. CRUSTACEA				
O. Amphipoda				
F. Gammaridae	x		x	x
<i>Anisogammarus confervicolus</i>	x	x		
O. ISOPODA	x		x	x
F. Asellidae				
<i>Asellus sp.</i>	x			
PHYLUM MOLLUSCA				
C. GASTROPODA				
F. Hydrobiidae				
<i>Amnicola sp.</i>	x			
F. Physidae				
<i>Physa sp.</i>	x	x		
F. Planorbidae				
<i>Gyraulus sp.</i>	x	x		
F. Pleuroceridae		x		

Taxon	Prairie	Lost Man	Little	
			Lost Man	Streelow
<i>Juga sp.</i>		x		
C. PELECYPODA				
F. Sphaeridae				
<i>Sphaerium corneum</i>	x	x		
PLATYHELMINTHES				
TURBELLARIA				
O. Tricladida				
F. Planariidae				
<i>Polycelis</i>		x		

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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