JUVENILE SALMONID HABITAT
OF THE REDWOOD CREEK BASIN
HUMBOLDT COUNTY, CALIFORNIA

by

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Approved by the Master's Thesis Committee

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ABSTRACT

During the summer-fall periods of August 4 to October 12, 1980 and August 13 to 21, 1981, the streams of the Redwood Creek basin, Humboldt County, California were surveyed to describe and characterize the salmonid rearing habitat and distribution of juvenile salmonids. Twelve streams throughout the basin, 10 east-west paired tributaries and Prairie and Redwood Creeks, were intensively sampled August 24 to October 5, 1981, to measure biotic and physical parameters. The basin was divided into east and west sides, the Prairie Creek basin, and the lower, middle, and upper basins for the purposes of comparison.

Salmonid fish occurred in 58 (52 percent) of the 111 tributaries sampled for fish. Juvenile steelhead were most common and widely distributed. Cutthroat trout and coho salmon primarily occurred in the Prairie Creek system. Most fish occurred in streams with flows greater than 3 l/s (0.1 cfs). The westside tributary 0+ steelhead mean lengths (mm) and weights (g) were significantly larger than those of the eastside tributaries. There were no east-west or north-south trends in fish population estimates, fish per m^2, or salmonid grams per m^2. The eastside streams, which generally had lower flows, had larger numbers of fish per unit flow.

Measured water parameters were flow (l/s), alkalinity (mg $CaCO_3$/l), pH, specific conductivity (µmhos @ 25 °C), dissolved oxygen (ppm), and temperature (°C). All eastside mainstem basin sections had lower mean flows than their adjacent westside sections. The Prairie Creek basin had the highest mean flow, the upper eastside basin the least. Mean alkalinity and pH of nine study sites sampled were 35 mg $CaCO_3$/l and 6.9, respectively. Specific conductivity values were higher in the upper basin and eastside basin sections. There was a south to north trend of decreasing values on both sides of the basin. Mean basin tributary specific conductivity was 133 µmhos (S.D. = 84). Tributary dissolved oxygen values were generally in the 9-10 ppm range, and between 7-9 ppm in the mainstem of Redwood Creek. Maximum measured water temperatures ranged from 10.5 °C to 23.0 °C for the tributaries and 14.0 °C to 26.0 °C for Redwood Creek. The surface water temperatures of mainstem Redwood Creek were generally hotter in the middle basin, and cooler in the headwaters and lower basin.

Twenty-four hour drift samples revealed the westside tributaries to generally have larger numbers of individual drift organisms, drift density (number of individuals/100 m^3), richness, number of taxa, and terrestrial invertebrate contribution to drift than the eastside tributaries. The eastside tributaries had significantly greater diversity (H') and evenness values than the westside tributaries.

The major insect orders contributing the greatest number of organisms to drift samples were Diptera, Ephemeroptera, Trichoptera, and Coleoptera. Drift organism composition showed decreasing ephemeropterans and increasing dipterans from north to south. Similarity indices of drift samples amongst the 12 streams ranged from 0.81 to 0.41. Comparisons of mean similarity indices between streams were usually nonsignificant, with the exception of the Redwood Creek site. Redwood Creek had the lowest mean similarity index, 0.52.

The study showed the character of each stream as a single entity, determined baseline rearing habitat conditions, and can serve as the basis for future evaluation of the rearing habitat and watershed rehabilitation efforts.

ACKNOWLEDGMENTS

I would like to thank the National Park Service, Redwood National Park, for funding this study and providing me with field equipment, vehicles, and computer facilities. I would also like to acknowledge Simpson Timber Company, Barnum Timber Company, and the Stover family for providing access to the Redwood Creek basin through their properties.

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Thanks to Vicki Ozaki, who provided assistance with the graphics; Tom Marquette who furnished the basin map for my use; and to Jill Albert, who helped me with the word processing software.

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INTRODUCTION

Historically, Redwood Creek was known as having substantial runs of large salmon (Feranna and Ricks 1981). However, in the past century north coast adult salmon and steelhead populations have declined below historical records (Citizens Advisory Committee on Salmon and Trout 1971). By 1960, Redwood Creek runs were estimated to be 5,000 chinook, 2,000 coho, and 10,000 steelhead (U.S. Department of the Interior 1960). These estimates were imprecise and based on extrapolation of data from other streams. Kondel and McIntyre (1987) report that, based on escapement trends for 1968-84, some anadromous salmonid populations of coastal Oregon and California are continuing to decline. Many variables both natural and man-induced can affect anadromous salmonid life cycles. Limiting or deleterious factors affecting a certain life-stage, (e.g. freshwater rearing), can influence population numbers in latter stages.

For Redwood Creek, little if any information was known about nursery habitat and limiting factors affecting juvenile salmonid distribution throughout the entire watershed. Past aquatic studies of the watershed focused on other aspects of the salmonid life cycle: spawning (Briggs 1953); stream damage surveys (Fisk et al. 1966); water chemistry (Bradford and Iwatsubo 1978); downstream migration of smolts (McKeon 1985); estuarine habitat (Larson 1987, Salamunovich 1987); and general aquatic inventories including benthic invertebrates and fish (Averett and Iwatsubo 1975, Iwatsubo et al. 1975, Iwatsubo et al. 1976, Iwatsubo and Averett 1981). The information available on rearing habitat (Burns 1971, Hawkins et al. 1983) covered a few individual tributaries within limited areas of the basin.

This study was initiated during the summers of 1980 and 1981 to measure the quantity and quality of salmonid nursery habitat of the entire Redwood Creek watershed. The survey, covering a two year period, had split objectives. During the summer-fall period of 1980, the objective was to survey the entire basin to determine the habitat conditions and distribution of juvenile salmonids. In the summer-fall period of 1981, the objective was to intensively study representative basin streams. Their selection was based upon conditions measured during the survey of 1980. The study measured juvenile salmonid distribution and abundance, nursery habitat, and other associated parameters such as water quality and invertebrate drift (fish food organisms). Assuming a constant spawning stock, these physical and biological parameters, together with the amount of nursery area available to fish, determine the production of juvenile fish in a basin. The specific objectives were to:

1. Obtain rearing habitat information and assess the present condition of the juvenile population;

2. Describe and characterize fish distribution, drift organisms, and water quality for streams and discrete areas of the basin, the east-west sides, and the upper, middle, lower, and Prairie Creek basin sections, as well as the entire Redwood Creek basin;
3. Compare conditions between tributary streams and between discrete areas of the basin.

In addition, the data were intended to serve as a baseline for comparisons in future years to measure the recovery of the fishery, the benefits of the extensive watershed rehabilitation programs at Redwood National Park, and in making fish resource management decisions.

STUDY AREA

Janda et al. (1975) have provided a detailed description of the Redwood Creek basin. Redwood Creek, and its tributaries, drain a 730 km^2 watershed in Humboldt County, California (Figure 1). The 108 km long basin is steep-sided, with average hillslope gradients ranging from 31 percent to 34 percent, and narrow, from 7.2 to 11.1 km wide. The drainage pattern is trellised, reflecting a large number of tributaries draining small areas. Total basin relief is 1,615 meters. Redwood Creek basin is underlain by two rock types of the Franciscan assemblage: unmetamorphosed sandstones and siltstones and quartz-mica schist on the east and west sides of the basin, respectively. The Grogan Fault, occupied by the Redwood Creek channel, juxtaposes the two rock types. A large portion of the Prairie Creek watershed is composed of coastal plain sediments. The Redwood Creek basin has unstable, eroding slopes.

The northern portion of the basin has a coastal Mediterranean climate, consisting of mild winters and warm dry summers with frequent fog. The southern portion of the basin, further from marine influences, has a interior Mediterranean climate; mild winters and hot dry summers with infrequent fog (Janda et al. 1975). Estimated average basin-wide precipitation is 203 cm a year. The amount of

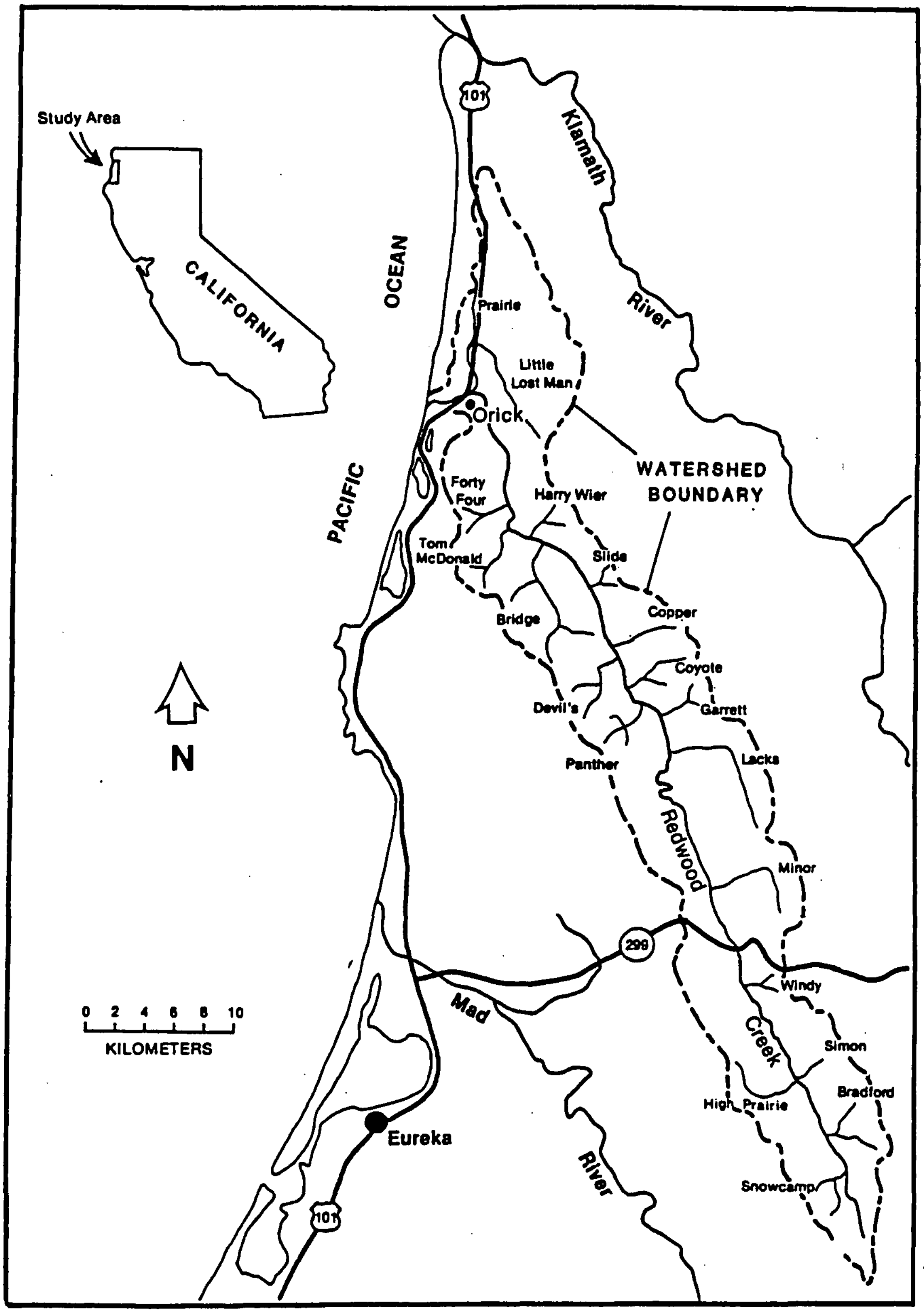


Figure 1. The Redwood Creek Watershed, Humboldt County, California.

precipitation varies within the basin. Annual precipitation is greater in the southern basin averaging 260 cm at Board Camp Mountain (nine years of record, 1964 to 1972). Precipitation in the northern basin at Orick averages 178 cm a year (36 years of record, 1938 to 1973).

Mainstem stream flow is lowest between August and October, and highest between November and April. Extreme minimum and maximum flows measured at Orick in the past 28 years were 0.26 $m^3 sec^{-1}$ (9.3 cfs) and 1,430 $m^3 sec^{-1}$ (50,500 cfs), respectively. Severe flood events occurred in 1953, 1955, 1964, 1972, and 1975. The December 1964 event caused the most habitat damage. During the 1980 and 1981 survey of the basin (August 4 to October 12, 1980 and August 13 to October 4, 1981), the mean daily flows measured at Orick were 0.84 $m^3 sec^{-1}$ (29.7 cfs) and 0.60 $m^3 sec^{-1}$ (21.3 cfs), respectively (U. S. Geological Survey 1981 and 1982, Markham et al. 1984).

Both anadromous and resident fish utilize the basin. Salmonid species occurring in the study area are steelhead trout (<u>Salmo gairdneri</u>), coastal cutthroat trout (<u>S. clarki</u>), coho salmon (<u>Oncorhynchus kisutch</u>), and chinook salmon (<u>O. tshawytscha</u>). Other fish found are Humboldt suckers (<u>Catostomus occidentalis humboldtianus</u>), sculpin (<u>Cottus</u> sp.), three spine stickleback (<u>Gasterosteus aculeatus</u>), and Pacific lamprey ammocoetes (<u>Lampetra tridentata</u>). Amphibians found include neotenic Pacific giant salamanders (Dicomptodon ensatus), red-legged frogs (Rana aurora), and yellow-legged frogs (R. boylei).

Potential predators to juvenile fish commonly found in the basin are the great blue heron (Ardea herodias), merganser (Mergus sp.), osprey (Pandion haliaetus), belted kingfisher (Megaceryle alcyon), garter snake (Thamnophis sp.), and otter (Lutra canadensis).

Some summer sport-fishing occurs in the more accessible locations, mainly the Redwood Creek estuary, where salmonid smolts are caught. In winter, heavy sportfishing pressure on returning adult steelhead occurs in Redwood Creek in the vicinity of Orick.

Vegetation in the basin consists of coast redwood (Sequoia sempervirens) and Douglas-fir (Pseudosuga menziesii) forests, their associated flora, and ridgetop prairies. The prairies and oak-woodlands (Quercus sp.) occur primarily on the inland southwest facing slopes and ridges. Inland, Douglas-fir is the dominant conifer. Redwood/Douglas-fir mosaics occur closer to the coast. Red alder (Alnus rubra) thickets are common in moist areas where soil has been disturbed. Alder are the dominant streamside vegetation in Redwood/Douglas-fir second growth areas.

Commercial timber harvest is one of the major land use practices in the basin. Prior to 1930, 82 percent of the basin was virgin Douglas-fir/Redwood forest, 9 percent oak-woodland, and 9 percent prairie grassland (Best 1984). By 1978, 66 percent of the basin drainage, comprising 81 percent of the original conifer forests had been logged. Logging no longer occurs in a large portion of the Prairie Creek basin as a result of the establishment of Prairie Creek Redwoods State Park in 1923. Logging no longer occurs in the lower one-third of the watershed, site of Redwood National Park. The National Park was established in 1968 and later expanded in 1978 to protect park resources. Cattle ranching on the prairies and upper watershed is the other major land-use activity.

METHODS

During the period of August 4 to October 12, 1980, a time of low summer flow and elevated water temperatures, a survey of Redwood Creek and most of its tributaries was conducted to determine the extent and quality of anadromous salmonid nursery habitat and to identify factors that might limit salmonid production (Figure 2). During the period of August 13 to 21, 1981, tributaries not surveyed the year before were surveyed. A 12 V DC battery backpack electroshocker was used to evaluate the presence and distribution of different fish species in each tributary and identify potential barriers to anadromous migration. In addition to the electroshocker, a small beach seine was used in Redwood Creek. Fork lengths of representative fish were measured to the nearest mm and scales were sampled. Water quality parameters were measured. Specific conductivity (µmhos at 25 °C) was measured with a YSI model no. 33 salinity-conductivity-temperature meter (Yellow Springs Instrument Co., Yellow Springs, Ohio). Water temperature (°C) was measured in the center of the stream with a hand held thermometer. Dissolved oxygen (ppm) was measured with a HACH kit using prepackaged chemicals (HACH, Ames, Iowa). Measurements made with the HACH kit were not precise, and resulted in a one part per million range.

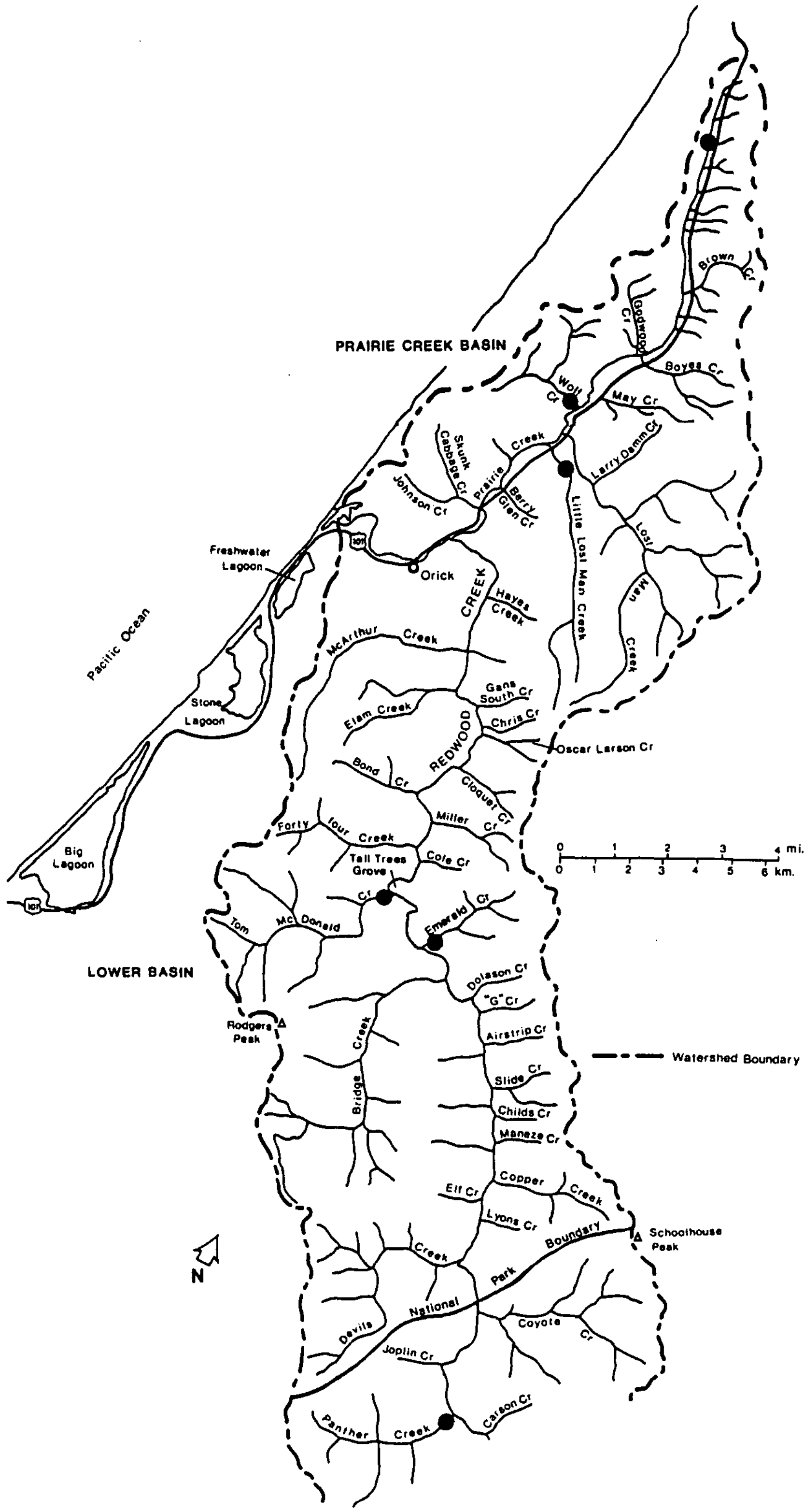
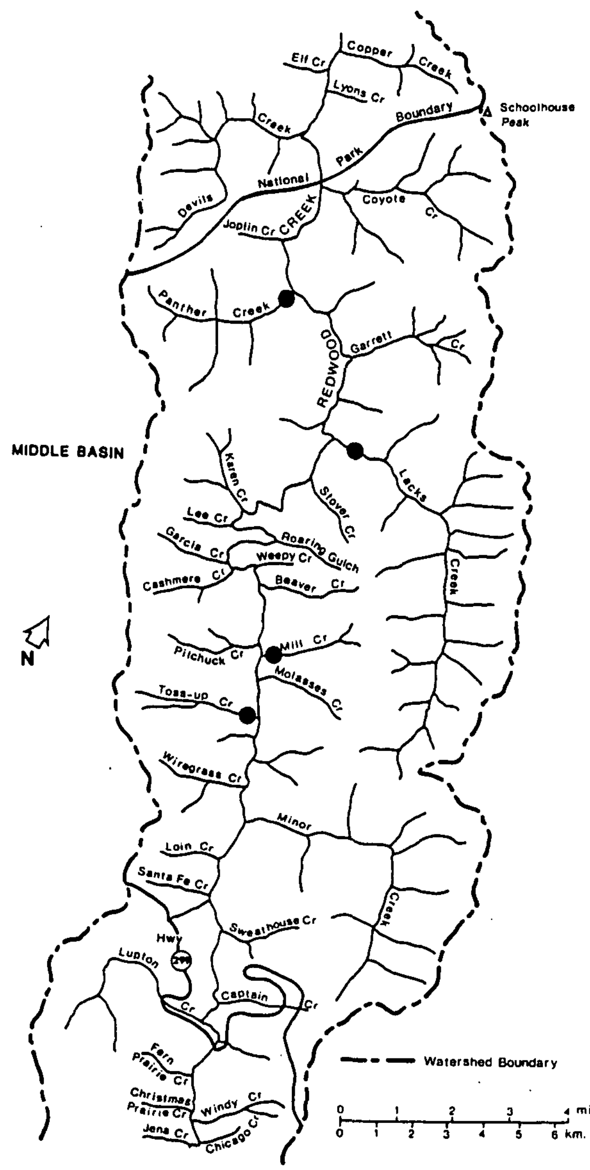


Figure 2. Tributaries of Redwood Creek, and Study Sites (●) of the Redwood Creek Basin, Humboldt County, California. The Basin is Divided into the Prairie Creek Basin, and the Lower, Middle, and Upper Basins, as Delineated by the Park Boundary and Highway 299.



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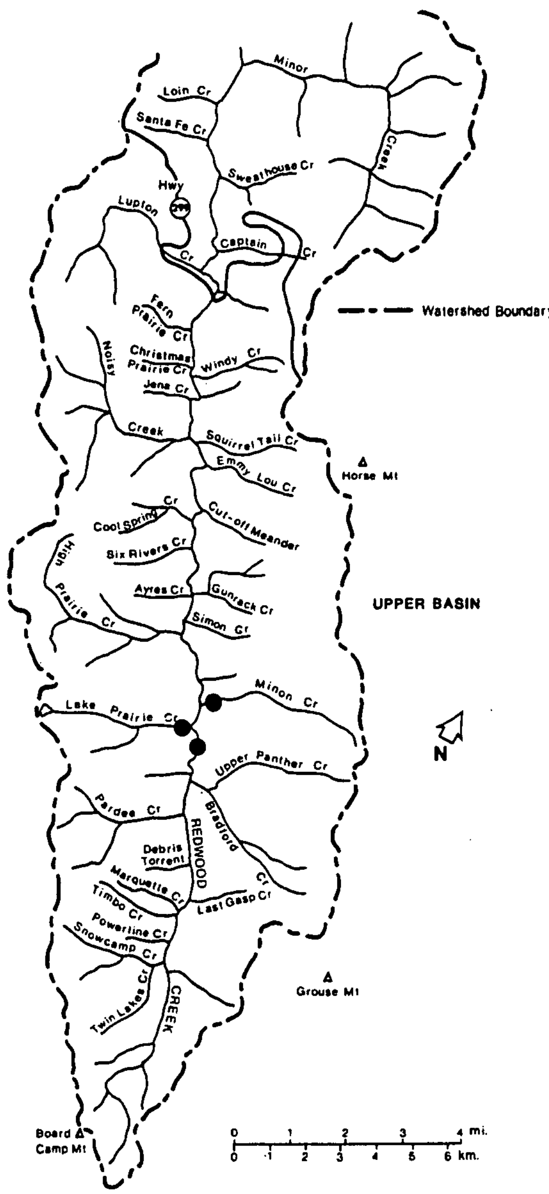

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Flow, liters/second (l/s), was estimated by timing a floating object, usually a stick, through a uniform section of stream of measured width, depth, and length.

In 1981, using observations from the previous year, the Redwood Creek watershed was subjectively divided on the basis of climate and vegetation into three areas; upper, middle, and lower basin (Figure 2). The demarcation boundaries of the divisions were the southern national park boundary and Highway 299. Best (1984) and Madej (1984) identified similar boundaries based on differences in climate, land use history, and vegetation.

Twelve streams representative of streams within the basin were sampled between August 24 and October 5, 1981 with regard to aquatic organisms and physical parameters. The streams selected were Prairie Creek, Wolf Creek (also known as Streelow Creek), Little Lost Man Creek, Tom McDonald Creek, Emerald Creek (also known as Harry Weir Creek), Panther Creek, Lacks Creek, Mill Creek, Tossup Creek, Minon Creek, Lake Prairie Creek, and Redwood Creek. The 12 sites consisted of 11 tributaries and the upper mainstem of Redwood Creek (Table 1, Figure 2). Ten of the tributaries were paired eastside-westside tributaries located along Redwood Creek and Prairie Creek, the major tributary. The eastside-westside tributary pairs were Little Lost Man and Wolf Creeks, Emerald and Tom McDonald Creeks, Lacks and Panther Creeks, Mill and Tossup Creeks,

TABLE 1. Physical Characteristics of Sample Site Streams of Redwood Creek Watershed in 1981. Values in Parentheses Are Stream Order at Site or Area above Site if Sample Site Was a Significant Distance from Stream Mouth.

Stream	Abbrev	Date Sampled	E or W/[a] River Km	Stream Order	Watershed Area (km^2)	Gradient[b] (m/m)	Study Flow (l/s & cfs)		Canopy[c]
1. Prairie	PC	10/3-6/81	E5.1	7 (4)	104.0 (8.5)	0.015	38	1.34	PTCL
2W. Wolf	---	9/28-30/81	W6.5 [d]	5	7.5	0.007	67	2.35	PTCL
2E. L. Lost Man	LLM	9/24,26-27/81 10/3-4/81	E4.5 [d]	4	10.2	0.020	5	0.18	CL
3W. Tom McDonald	TMD	9/11-13/81	W19.4	5	18.0	0.006	47	1.67	CL
3E. Emerald	EMD	9/21-22/81	E22.2	4	7.8	0.046	5	0.18	PTCL
4W. Panther	PAN	8/29-30/81 9/25/81	W39.2	5	15.4	0.056	59	2.08	PTCL
4E. Lacks	LACK	9/2-4/81	E45.3	5	44.0	0.024	15	0.55	OP
5W. Tossup	TOSS	9/4-6/81	W60.3	5	6.8	0.037	8	0.29	CL
5E. Mill	---	9/9-10/81	E58.9	3	3.5	0.054	12	0.41	CL
6W. Lake Prairie	LPR	8/24-26/81 9/18/81	W91.3	4	8.8	0.089	46	1.64	CL
6E. Minon	MIN	8/25-26/81 9/15-16,18/81	E90.5	5	11.1	0.044	8 3	0.28 0.10	PTOP
7. Redwood	REDWD	9/17-18/81	91.4	7 (6)	730.0 (66.0)	0.016	18	0.65	OP

a. Stream location on Redwood Creek, east or west side of basin and river kilometer.
b. Stream gradient from site to mouth or landmark.
c. Canopy: CL = closed, PTCL = partly closed, PTOP = partly open, OP = open.
d. Aspect and river km on Prairie Creek.

and Minon and Lake Prairie Creeks. All 12 sites were located in watersheds that had been logged to varying degrees.

Fish

A 50 m section in each of the 12 streams was arbitrarily selected to be reasonably representative with respect to pools, riffles, width, and canopy, of rearing habitat available to anadromous salmonids. Another criterion in selecting the section was its suitability to be effectively sampled by a two person crew with a backpack electroshocker. The section was blocked off at each end with 6.4 mm mesh nets and a multiple pass removal method (Seber and LeCren 1967, Zippen 1958) was used with an electroshocker to estimate fish numbers. The equal effort passes (timed), generally proceeded from upstream to downstream, but varied depending upon flow and sediment. Captured fish were anesthetized with MS-222 (tricaine methanesulfonate), identified to species, and fork length and volume measured to the nearest 1.0 mm and 0.5 ml respectively. Salmonid fish weights were calculated from measured volumes using a straight 1:1 relationship (1.0 ml = 1.0 g). Biomass of each section was determined from average fish weights multiplied by estimated fish numbers.

Drift Organisms

Drift organisms at each site were sampled for a 24 hour period with a drift net. The drift net, placed just upstream of the 50 m section, sampled from the substrate to the water surface in a cell of greatest flow. The net measured 30.5 cm high by 45.7 cm wide by 1.2 m long. Net mesh size was 0.5 mm. Before retrieval of the sample, flow (m^3sec^{-1}) through the mouth of the drift net was calculated by measuring water velocity entering the net with a pygmy meter (model no. 625, Teledyne Gurley, Troy, New York). The sample was emptied into a bucket, sieved through a no. 35 USA Standard Test Sieve (mesh opening 0.5 mm), the remainder transferred to jars, and preserved with 70 percent ethyl alcohol. Samples were cleaned of debris by hand under a 8X to 40X stereomicroscope, organisms identified to family, and enumerated. Keys used to identify the invertebrates were Merritt and Cummins (1978), Usinger (1956), Edmunds et al. (1976), Wiggins (1977), Borror et al. (1981), and Ward and Whipple (1959).

Water Quality

Water quality parameters of water temperature, specific conductivity, dissolved oxygen, alkalinity, and pH were measured. Water temperature and specific conductivity were measured using the same methods as before. Dissolved oxygen was measured with a YSI model no. 51B meter (Yellow Springs Instrument Co., Yellow Springs, Ohio). A 1000 ml unfiltered water sample was taken from the center of the stream in a opaque Nalgene bottle, packed in ice, and returned to the laboratory for analysis. There, total alkalinity ($mgCaCO_3/l$) was measured by titrating with standardized acid to an endpoint of pH 4.5 (Kopp and McKee 1979). The maximum time between sample collection and analysis was one day. An Orion pH meter (Orion, Cambridge, Massachusetts) was used to measure pH in the laboratory.

Physical Parameters

Stream velocity was measured with a pygmy meter to calculate discharge (l/s) (Platts et al. 1983). Stream gradient (m/m) and distance (m) from the study site to the mouth of the stream or other landmark were determined with a clinometer and measuring tape. Cross sections and surface areas of stream sections were determined from transects taken at 5 m intervals. Streamside riparian vegetation canopy closure was subjectively determined as closed, partly closed, partly open, and open.

Analyses

Drift

Drift samples were analyzed several ways. The percentage composition of each taxon was calculated by dividing the number of individuals in each taxon by the total number of individuals in each sample and multiplying by 100 (Greeson et al. 1977). Diversity was calculated using the Shannon-Weiner Diversity Index (H') (Wilhm and Doris 1968):

$$H' = -\sum_{i=1}^{s} n_i/N \ \log_2 \ n_i/N$$

where: ni = number of individuals in the ith taxon

N = total number of individuals of all taxa

s = number of taxa in sample.

The index of diversity was calculated primarily at the family taxonomic level (Hughes 1978, Kaesler, et al. 1978). An evenness index (e), a measure of allotment of individuals among the taxa was calculated (Krebs 1972):

$$e = \frac{H'}{\log_2 s}$$

where: H' = Shannon-Weiner Diversity Index

s = number of taxa in sample.

Evenness ranges from 0 to 1, where 1 would signify an equal number of individuals in each taxon, and 0 would indicate a disparate allotment among the taxa.

An index of similarity, S, (Odum 1971) between drift samples was determined for all the study sites:

$$S = \frac{2C}{A + B}$$

where: A = number of taxa in sample 1

B = number of taxa in sample 2

C = number of taxa common to both samples.

The value of the index can range from 0 to 1. Zero would indicate they have no taxa in common, and 1 would indicate the taxa sampled were common to both samples.

In order to standardize the drift samples for comparison between streams, the drift rate, number per 24 h period, was divided by the total 24 h flow, resulting in no./m^3. Richness, the number of taxa in each sample, was reported as well as abundance, the number of individuals in each sample.

Terrestrial and aquatic invertebrates were also distinguished and terrestrial percentage in each sample calculated. Terrestrial invertebrates were defined as those without an aquatic component to their life cycle requirements.

Statistical Analyses

Student's t-test was used to determine differences between groups of sites. In accordance with Rosner (1986), for multiple comparisons of means, a Bartlett's test for homogeneity of variances was run. If it was significant, pairs were compared using t-tests for independent samples with equal or unequal variances. The F-test was used to test for equality of variances between pairs. MINITAB, a statistical package was used to compute descriptive statistics and compare means with t-tests (Ryan, et al. 1981).

RESULTS

Fish

Salmonid Fish Distribution

Salmonid fish occurred in 58 (52 percent) of the 111 tributaries sampled during 1980 and 1981 (Table 2). Juvenile steelhead, the most common salmonid encountered, were distributed throughout the Redwood Creek basin. They were observed in 57 of the 111 tributaries surveyed for fish, in addition to mainstem Redwood Creek. Juvenile coho salmon were predominantly observed in Prairie Creek and its tributaries. Their only occurrences in Redwood Creek tributaries, other than Prairie Creek were in Tom McDonald, Coyote, and Karen Creeks, and an unnamed tributary adjacent to Hayes Creek. Cutthroat trout displayed a similar pattern: common in Prairie Creek and its tributaries, and less numerous below barriers on tributaries to lower Redwood Creek. Chinook salmon juveniles were not observed in any of the streams during the time of the survey. The distribution of non-salmonid fish and amphibians encountered in Redwood Creek tributaries is presented in Appendix A.

Juvenile steelhead occurred along the length of Redwood Creek. In the lower and middle watershed, sculpin, suckers, stickleback, and lamprey ammocoetes were

TABLE 2. Distribution of Salmonid Fish in Tributaries (Listed North to South) of Redwood Creek, Humboldt County, California Observed during Summer-Fall Periods of 1980 and 1981. STEELHEAD = Steelhead Trout, CUTTHROAT = Cutthroat Trout, COHO = Coho Salmon. X Denotes Capture of at Least One Specimen.

CREEK	STEELHEAD	CUTTHROAT	COHO
1. Prairie	X	X	X
2. Godwood	X	X	
3. Wolf	X	X	X
4. Lost Man/Larry Damm	X	X	
5. Little Lost Man	X		X
6. Skunk Cabbage		NOT SAMPLED	
7. Unnamed 1			X
8. Hayes			
9. McArthur	X	X	
10. Elam	X		
11. Gans South			
12. Chris			
13. Larson			
14. Unnamed 2			
15. Cloquet			
16. Bond	X	X	
17. Miller	X		
18. Forty-four	X	X	
19. Cole			
20. Tom McDonald	X		X
21. Unnamed 3			
22. Emerald	X	X	
23. Bridge	X		
24. Unnamed 4			
25. Unnamed 5			
26. G	X		
27. Unnamed 6			
28. Unnamed 7			
29. Airstrip			
30. Unnamed 8			
31. Unnamed 9			
32. Unnamed 10			
33. Unnamed 11			
34. Slide	X		
35. Unnamed 12			
36. Unnamed 13	X		
37. Unnamed 14			
38. Unnamed 15			
39. Childs			
40. Unnamed 16			
41. Unnamed 17			

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CREEK	STEELHEAD	CUTTHROAT	COHO
42. Unnamed 18			
43. Maneze			
44. Unnamed 19	X		
45. Unnamed 20			
46. Copper	X		
47. Unnamed 21			
48. Elf			
49. Lyons			
50. Devils	X		
51. Coyote	X		X
52. Joplin			
53. Unnamed 22			
54. Panther	X		
55. Garrett	X		
56. Lacks	X		
57. Stover			
58. Karen	X		X
59. Lee	X		
60. Roaring Gulch	X		
61. Garcia	X		
62. Cashmere	X		
63. Weepy	X		
64. Unnamed 23			
65. Beaver	X		
66. Pilchuck	X		
67. Mill	X		
68. Molasses	X		
69. Tossup	X		
70. Wiregrass	X		
71. Minor	X		
72. Loin	X		
73. Santa Fe	X		
74. Sweathouse	X		
75. Captain	X		
76. Lupton	X		
77. Fern Prairie			
78. Unnamed 24			
79. Christmas Prairie			
80. Windy	X		
81. Jena	X		
82. Unnamed 25			

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CREEK	STEELHEAD	CUTTHROAT	COHO
83. Unnamed 26			
84. Unnamed 27			
85. Noisy	X		
86. Squirrel Tail	X		
87. Emmy Lou	X		
88. Unnamed 28			
89. Cutoff Meander	X		
90. Cool Springs			
91. Six Rivers	X		
92. Unnamed 29			
93. Gunrack	X	X	
94. Ayres			
95. Simon	X		
96. High Prairie	X	X	
97. Minon	X		
98. Lake Prairie	X		
98b. Redwood	X		
99. Upper Panther/ Bradford	X		
100. Pardee	X		
101. Unnamed 30			
102. Unnamed 31			
103. Debris Torrent			
104. Unnamed 32			
105. Unnamed 33			
106. Unnamed 34			
107. Last Gasp	X		
108. Marquette			
109. Timbo			
110. Powerline			
111. Snowcamp			
112. Twin Lakes	X		

encountered. Adult summer steelhead were seen on Redwood Creek at Garrett Creek and Tall Trees Grove.

The number of streams with and without juvenile salmonids were summarized according to the discharge categories of dry, intermittent flow, low flow, less than 3 l/s (0.1 cfs), greater than 3 l/s (0.1 cfs) but less than 28 l/s (1.0 cfs), and equal to or greater than to 28 l/s (1.0 cfs). Flows were not measured in seven streams and one creek, Skunk Cabbage, was not sampled for fish due to mechanical difficulties. Ninety four percent of the streams (46) without juvenile salmonids had flows equal or less than 3 l/s (0.1 cfs), while 62 percent of the streams (34) with flows greater than 3 l/s (0.1 cfs) contained salmonids (Table 3).

Fish Fork Lengths and Weights

Mean fork lengths (mm) and weights (g) were calculated for the captured electroshocked juvenile salmonids (Table 4). A fork length of 90 mm was used as the cutoff point between 0+ (young-of-year) and 1+ steelhead. The cutoff was determined from scale analyses and a fork length-frequency table of all captured steelhead (Appendix B). For 0+ steelhead, the mean lengths ranged from 46.9 mm (Minon Creek) to 81.0 mm (Wolf Creek). The mean weights ranged from 1.4 g to 6.9 g for the same two creeks, respectively. For 1+ steelhead, the mean lengths ranged from 98.0 mm (Wolf Creek) to 139.4 mm (Tossup Creek). The mean weights ranged from 11.5 g to 32.0 g for the same

TABLE 3. Frequency of Juvenile Salmonid Presence (With Fish) or Absence (Without Fish) According to Discharge in 104 Streams Sampled for Fish in Redwood Creek Basin during Summer-Fall of 1980 and 1981. (Flows Were Not Measured in 7 Streams.) DRY = No Flow, INT = Intermittent Flow, and LOW = Discharge Was too Low to Estimate.

NO. OF STREAMS	DISCHARGE					
	DRY	INT	LOW	<=3.0 l/s (0.1cfs)	>3.0 l/s (0.1cfs)	>=28.0 l/s (1.0 cfs)
WITHOUT FISH	16	4	18	8	2	1
WITH FISH	0	7	5	9	11	23

TABLE 4. Mean Fork Lengths (mm) and Weights (g) and Their Respective Standard Deviations (S.D.) of Salmonid Fish Electroshocked at the Twelve Study Sites in the Redwood Creek Basin, Humboldt County, California during Summer-Fall of 1981.

	CREEK	Species	Age	No.	Mean FRKL (mm)	S.D.	Mean WT (g)	S.D.
1.	Prairie	SHD	0+	2	64.0	25.5	2.3	1.1
		SHD	1+	1	110.0	---	14.5	---
2W.	Wolf	SHD	0+	6	81.0	5.2	6.9	1.3
		SHD	1+	3	98.0	8.5	11.5	2.8
2E.	Little Lost Man	SHD	0+	71	52.4	9.4	2.2	1.2
		SHD	1+	6	93.3	2.9	9.2	0.5
3W.	Tom McDonald	SHD	0+	19	76.5	7.6	5.7	1.5
		SHD	1+	2	111.0	22.6	17.8	8.8
3E.	Emerald	SHD	0+	20	67.3	6.5	4.1	1.1
		SHD	1+	3	111.0	20.1	16.3	8.4
4W.	Panther	SHD	0+	85	56.0	12.8	2.4	1.5
		SHD	1+	15	118.2	24.6	20.3	13.8
4E.	Lacks	SHD	0+	205	52.0	9.9	1.9	1.2
		SHD	1+	10	116.6	21.8	18.9	12.8
5W.	Tossup	SHD	0+	209	53.1	10.1	1.9	1.2
		SHD	1+	5	139.4	27.2	32.0	16.3
5E.	Mill	SHD	0+	79	53.2	12.5	2.1	1.4
		SHD	1+	3	102.3	5.0	11.8	0.6
6W.	Lake Prairie	SHD	0+	23	53.7	11.2	2.2	1.7
		SHD	1+	3	111.0	18.5	13.8	9.8
6E.	Minon	SHD	0+	90	46.9	8.6	1.4	0.8
		SHD	1+	4	110.0	17.4	15.0	7.0
7.	Redwood	SHD	0+	529	53.1	9.8	2.0	1.2
		SHD	1+	15	105.1	13.1	14.1	6.0

two creeks, respectively. Since so few cutthroat and coho were caught, they were not compared in this study. Their mean lengths and weights are reported in Appendix C. In order to test if steelhead fork lengths and weight differences between streams was a product of sampling over time, August 26 to October 4, 1981, a correlation was run between Julian calendar day, and mean length and mean weight. The correlation coefficients between mean length and Julian day, and between mean weight and Julian day were 0.466 and 0.413, respectively. They show a weak and nonsignificant correlation with time ($p > 0.05$).

In individual comparisons of east-west paired tributaries of Redwood Creek, with the exception of Tossup Creek mean fork lengths and weights, all the westside tributary mean fork lengths and weights of 0+ steelhead were greater than the eastside values. The same pattern was true for the two Prairie Creek paired tributaries. Where fish in the westside tributaries were larger, the differences were significant (Table 5). Overall, combined fork lengths and weights of 0+ steelhead in the westside mainstem tributaries were significantly greater than in the eastside tributaries, $p = 0.0001$ and $p = 0.0050$, respectively. The correlation coefficient between 0+ steelhead mean fork length and stream discharge (l/s) was 0.61 and significant ($p < 0.05$). For 1+ steelhead, the westside tributary mean fork lengths and weights were generally larger than their respective paired eastside tributaries. However, none of the differences was

Table 5. Results of Student's T-test on 0+ and 1+ Steelhead Fork Lengths and Weights for Paired Study Streams of the Redwood Creek Basin, Humboldt County, California, Summer-Fall 1981.

East - West Stream Pairs	Significant	p [a]	df.
<u>0+ FISH FORK LENGTH</u>			
2. Wolf and Little Lost Man	Yes	p < 0.0001	75
3. Tom McDonald and Emerald	Yes	P = 0.0002	37
4. Panther and Lacks	Yes	p = 0.0101	127
5. Tossup and Mill	No	p = 0.9443	118
6. Lake Prairie and Minon	Yes	p = 0.0018	111
<u>0+ FISH WEIGHT</u>			
2. Wolf and Little Lost Man	Yes	p < 0.0001	75
3. Tom McDonald and Emerald	Yes	p = 0.0006	37
4. Panther and Lacks	Yes	p = 0.0101	126
5. Tossup and Mill	No	p = 0.2442	286
6. Lake Prairie and Minon	Yes	p = 0.0379	24
<u>1+ FISH FORK LENGTH</u>			
2. Wolf and Little Lost Man	No	p = 0.4551	2
3. Tom McDonald and Emerald	No	p = 1.0000	3
4. Panther and Lacks	No	p = 0.8693	23
5. Tossup and Mill	No	p = 0.0639	6
6. Lake Prairie and Minon	No	p = 0.9444	5
<u>1+ FISH WEIGHT</u>			
2. Wolf and Little Lost Man	No	p = 0.2867	2
3. Tom McDonald and Emerald	No	p = 0.8678	3
4. Panther and Lacks	No	p = 0.7961	23
5. Tossup and Mill	No	p = 0.0507	4
6. Lake Prairie and Minon	No	p = 0.8598	5

a. p = probability of t value.

significant (Table 5). Small sample sizes may have contributed to the lack of significance. Overall, the differences between mainstem eastside and westside combined 1+ steelhead fork lengths and weights were not significant, $p = 0.2017$ and $p = 0.1877$, respectively. Length-weight relationships for all salmonids captured are presented in Appendix D.

Salmonid Fish Population

Fish population estimates, 95 percent confidence interval estimates of population size, estimated biomass, number of fish per m^2, and salmonid grams per m^2 were determined for the study sites (Table 6). There were no obvious east-west trends in the data. No apparent north-south patterns were evident either.

In the mainstem tributaries, the number of juvenile steelhead fish per 50 meter section ranged from 24 for Emerald to 301 for Lacks Creek. The largest number of fish per section for all study sites, 653, was Redwood Creek. In the Prairie Creek system, steelhead numbers were low for Prairie and Wolf Creeks, 3 and 10 fish respectively. However it is difficult to differentiate between juvenile cutthroat trout and steelhead. The combined steelhead/cutthroat numbers for Prairie and Wolf Creeks 50 meter sections were 34 and 19 fish respectively.

In the mainstem tributaries, numbers of salmonids/m^2 and salmonid grams/m^2 ranged from 0.14 to 2.17 salmonids/m^2,

TABLE 6. Salmonid Population Estimates, 95 Percent Confidence Interval Estimates of Population Size, Estimated Biomass (grams), Number of Fish per m^2, Salmonid grams per m^2, and Number of Fish per m^2 per $m^3 sec^{-1}$ of 50 meter Sections at Twelve Study Sites in Redwood Creek Basin, Humboldt County, California, Summer-Fall 1981.

STREAM	SPECIES	N	95% C.I.	BIOMASS (g)	FISH/m^2	G/m^2	FISH/m^2/m^3sec^{-1}
1. Prairie	SHD	3	3 - 6	21.3			
	COHO	36	32 - 45	182.2			
	CUT	31	30 - 34	237.6			
				444.1	0.35	2.2	9.23
2W. Wolf	SHD	10	9 - 16	91.6			
	COHO	7	7 - 10	66.4			
	CUT	9	8 - 15	213.3			
				371.3	0.14	1.9	0.21
2E. L. Lost Man	SHD	80	77 - 85	228.7	0.40	1.1	77.83
3W. Tom McDonald	SHD	28	21 - 47	214.0	0.15	1.2	3.17
3E. Emerald	SHD	24	23 - 26	156.4	0.14	0.9	26.91
4W. Panther	SHD	107	100 -116	634.4	0.61	3.6	10.36
4E. Lacks	SHD	301	231 -371	1089.1	1.14	4.1	73.71
5W. Tossup	SHD	267	225 -309	926.4	2.17	7.5	265.82
5E. Mill	SHD	93	82 -107	308.6	0.92	3.0	80.00
6W. Lake Prairie[a]	SHD	26	----	113.5	----	---	----
6E. Minon	SHD	104	94 -115	297.8	0.95	2.7	325.59
7. Redwood	SHD	653	598 -704	2140.7	2.57	8.4	138.96

a. An estimate at Lake Prairie was not possible, actual numbers and biomass presented.

and 0.9 to 7.5 g/m^2 for Emerald Creek and Tossup Creek, respectively. Values for Lake Prairie were not reported since a population estimate was not possible due to equipment failure. The largest values of $fish/m^2$ and g/m^2 measured were those of Redwood Creek, 2.57 $fish/m^2$ and 8.4 g/m^2. The smallest measured were those of Emerald Creek. When fish numbers were standardized to take into account area, (number of $fish/m^2$), and divided by stream discharge, (m^3sec^{-1}), ($fish/m^2/m^3sec^{-1}$), the eastside paired tributaries, with the exception of Mill Creek, had greater values than their paired westside tributaries. However, the overall difference between the eastside and westside $fish/m^2/m^3sec^{-1}$ was not significant at ($p > 0.05$). Minon Creek was excluded because of missing data for Lake Prairie Creek. When compared using $fish/m^2/m^3sec^{-1}$, the streams with low discharge had larger numbers of fish per discharge and thus higher fishery values, than streams of higher discharge (Table 6).

Flow

Measured minimum flow was measured for the tributaries surveyed and study sites (Tables 7 and 2). Amongst the 1981 study sites, westside tributaries, except for Tossup Creek had greater discharge than their paired eastside tributaries. Discharges, however, were not measured at the same times. A week generally separated the measurements between the pairs. Of the tributaries with

TABLE 7. Basin Aspect: Eastside or Westside, Values of Maximum Water Temperature (°C), Specific Conductivity (μmhos @ 25 °C), Minimum Dissolved Oxygen (D.O.) (ppm), and Minimum Flow (l/s and cfs) Measured during the Survey of Tributaries (Listed from North to South) of the Redwood Creek Basin in Summer-Fall 1980 and 1981.

STREAM	Date(s) Sampled	West/ East	Max. Temp. (°C)	Spec. Cond. (μmhos)	Min.[a] D.O (ppm)	Min.[b] Flow (l/s	cfs)
PRAIRIE CREEK BASIN							
<u>Prairie Creek Tributaries</u>							
1. Prairie	10/3-4/81	E	10.5	91	10.3	38	1.3
2. Godwood	10/09/80	W	12.0	117	9-10	55	1.9
3. Wolf	9/28/81	W	13.0	98	10.3	67	2.4
4. Lost Man /	10/11/80	E	11.0		9-10	234	8.3
Larry Damm		E	12.0	---	----	NE	
5. Little Lost Man	9/24-27/81	E	14.0	77-91	10.2	5	0.2
6. Skunk Cabbage	9/28/80	W	14.0	124	----	NE	
LOWER BASIN							
<u>Redwood Creek Tributaries</u>							
7. Unnamed 1	8/19/80	E	12.5	90-96	----	INT	
8. Hayes	8/19/80	E				DRY	
9. McArthur	8/04/80	W	13.0	60-63	9-10	170	6.0
10. Elam	8/04/80	W	18.8	55	8-9	76	2.7
11. Gans South	9/21/80	E	----	---	----	INT	
12. Chris	9/21/80	E	11.5	109	8-9	3	0.1
13. Larson	9/21/80	E	12.0	120	----	3	0.1
14. Unnamed 2	9/21/80	W	12.0	---	----	LOW	
15. Cloquet	9/21/80	E	12.0	78	----	3	0.1
16. Bond	8/08/80	W	13.0	57	10-11	37	1.3

TABLE 7. Basin Aspect: Eastside or Westside, Values of Maximum Water Temperature (°C), Specific Conductivity (µmhos @ 25 °C), Minimum Dissolved Oxygen (D.O.) (ppm), and Minimum Flow (l/s and cfs) Measured during the Survey of Tributaries (Listed from North to South) of the Redwood Creek Basin in Summer-Fall 1980 and 1981. (continued)

STREAM	Date(s) Sampled	West/ East	Max. Temp. (°C)	Spec. Cond. (µmhos)	Min.[a] D.O (ppm)	Min.[b] Flow (l/s	cfs)
17. Miller	8/09/80	E	12.5	73	10	7	0.3
18. Forty-four	8/09/80	W	13.0	51	10-11	71	2.5
19. Cole	8/09/80	E	13.5	54	----	3	0.1
20. Tom McDonald	8/06/80	W	15.5	60	9	189	6.7
21. Unnamed 3	8/30/80	W	12.0	---	----	LOW	
22. Emerald	9/06/80	E	13.0	114	8-9	7	0.3
23. Bridge	8/30/80	W	15.5	---	----	NE	
24. Unnamed 4	8/30/80	W	12.0	---	----	LOW	
25. Unnamed 5	8/30/80	W	12.0	---	----	NE	
26. G	8/30/80	E	12.0	150	9-10	LOW	
27. Unnamed 6	8/29/80	E				DRY	
28. Unnamed 7	8/29/80	W	13.0	---	----	LOW	
29. Airstrip	8/29/80	E	13.5	---	----	LOW	
30. Unnamed 8	8/29/80	W	12.0	---	----	LOW	
31. Unnamed 9	8/29/80	W	----	---	----	LOW	
32. Unnamed 10	8/29/80	W	12.0	94	----	LOW	
33. Unnamed 11	8/29/80	W	----	---	----	LOW	
34. Slide	8/29/80	E	14.5	135	9-10	3	0.1
35. Unnamed 12	8/29/80	W	13.0	50	----	1	0.03
36. Unnamed 13	8/29/80	W	12.0	---	----	LOW	

TABLE 7. Basin Aspect: Eastside or Westside, Values of Maximum Water Temperature (°C), Specific Conductivity (µmhos @ 25 °C), Minimum Dissolved Oxygen (D.O.) (ppm), and Minimum Flow (l/s and cfs) Measured during the Survey of Tributaries (Listed from North to South) of the Redwood Creek Basin in Summer-Fall 1980 and 1981. (continued)

STREAM	Date(s) Sampled	West/ East	Max. Temp. (°C)	Spec. Cond. (µmhos)	Min.[a] D.O (ppm)	Min.[b] Flow (l/s	cfs)
37. Unnamed 14	8/29/80	W	----	---	----	LOW	
38. Unnamed 15	8/29/80	W	13.0	51	9-10	3	0.1
39. Childs	8/29/80	E				DRY	
40. Unnamed 16	8/29/80	W	----	---	----	LOW	
41. Unnamed 17	8/29/80	W	----	---	----	LOW	
42. Unnamed 18	8/29/80	W	11.5	42	----	8	0.3
43. Maneze	8/28/80	E	16.0	---	----	LOW	
44. Unnamed 19	8/28/80	W	13.5	92	----	3	0.1
45. Unnamed 20	8/28/80	W	----	---	----	INT	
46. Copper	9/20/80	E	17.0	190-232	9-10	9	0.3
47. Unnamed 21	8/28/80	W	12.5	54	----	3	0.1
48. Elf	8/28/80	W	12.5	103	9-10	5	0.2
49. Lyons	8/28/80	E				DRY	
50. Devils	8/23-24/80	W	14.5	76	9-10	80	2.8
MIDDLE BASIN							
51. Coyote	9/03/80	E	22.0	180	8-9	42	1.5
52. Joplin	8/27/80	W	13.5	147	----	NE	
53. Unnamed 22	8/27/80	W	13.5	---	----	NE	
54. Panther	8/26/80	W	15.5	74	9-10	42	1.5
55. Garrett	9/04/80	E	17.5	207	8-9	14	0.5

TABLE 7. Basin Aspect: Eastside or Westside, Values of Maximum Water Temperature (°C), Specific Conductivity (µmhos @ 25 °C), Minimum Dissolved Oxygen (D.O.) (ppm), and Minimum Flow (l/s and cfs) Measured during the Survey of Tributaries (Listed from North to South) of the Redwood Creek Basin in Summer-Fall 1980 and 1981. (continued)

STREAM	Date(s) Sampled	West/ East	Max. Temp. (°C)	Spec. Cond. (µmhos)	Min.[a] D.O (ppm)	Min.[b] Flow (l/s	cfs)
56. Lacks	9/18/80	E	15.5	186	8-9	45	1.6
57. Stover	8/21/80	E	14.5	---	----	LOW	
58. Karen	8/21/80	W	14.0	48	9-10	34	1.2
59. Lee	8/21/80	W	14.0	59	9-10	14	0.5
60. Roaring Gulch	8/21/80	E	14.0	181	8-9	1	0.04
61. Garcia	8/15/80	W	14.5	36	9-10	142	5.0
62. Cashmere	8/12/80	W	14.0	48	9	37	1.3
63. Weepy	8/12/80	E	----	---	----	LOW	
64. Unnamed 23	8/12/80	W				DRY	
65. Beaver	8/12/80	E	13.5	112	9	1	0.03
66. Pilchuck	8/16/80	W	15.0	73	9	8	0.3
67. Mill	8/05/80	E	17.0	144	8-9	14	0.5
68. Molasses	8/16/80	E	14.0	167	9-10	10	0.4
69. Tossup	8/05/80	W	15.5	106	9.4[c]	35	1.3
70. Wiregrass	8/05/80	W	15.0	87	8	6	0.2
71. Minor	8/13/80	E	21.0	167-220	8-9	85	3.0
UPPER BASIN							
72. Loin	8/15/80	W	16.5	159	9.4	LOW	
73. Santa Fe	8/15/80	W	15.5	137	9.1	NE	
74. Sweathouse	9/24/80	E	14.5	196	8-9	0.2	0.01

TABLE 7. Basin Aspect: Eastside or Westside, Values of Maximum Water Temperature (°C), Specific Conductivity (μmhos @ 25 °C), Minimum Dissolved Oxygen (D.O.) (ppm), and Minimum Flow (l/s and cfs) Measured during the Survey of Tributaries (Listed from North to South) of the Redwood Creek Basin in Summer-Fall 1980 and 1981. (continued)

STREAM	Date(s) Sampled	West/ East	Max. Temp. (°C)	Spec. Cond. (μmhos)	Min.[a] D.O (ppm)	Min.[b] Flow (l/s	cfs)
75. Captain	9/24/80	E	14.0	273	8-9	1	0.03
76. Lupton	8/22/80	W	14.5	107	9-10	38	1.3
77. Fern Prairie	8/22/80	W	12.5	73	----	NE	
78. Unnamed 24	9/10/80	E	----	---	----	INT	
79. Christmas Prairie	9/10/80	W	14.0	112	9-10	1	0.04
80. Windy	9/10/80	E	15.0	296	4-5	INT	
81. Jena	9/10/80	W	10.0	---	----	INT	
82. Unnamed 25	9/10/80	E				DRY	
83. Unnamed 26	9/10/80	W				DRY	
84. Unnamed 27	9/10/80	E				DRY	
85. Noisy	9/09/80	W	13.0	50	9-10	99	3.5
86. Squirrel Tail	9/09/80	E	15.0	362	----	INT	
87. Emmy Lou	9/09/80	E	15.0	305	----	INT	
88. Unnamed 28	9/11/80	W				DRY	
89. Cutoff Meander	9/11/80	E	16.0	---	----	INT	
90. Cool Springs	9/11/80	W	13.5	85	9-10	38	1.3
91. Six Rivers	9/11/80	W	14.0	89	9-10	35	1.3
92. Unnamed 29	9/12/80	E				DRY	
93. Gunrack	9/12/80	E	15.0	188	6-7	INT	
94. Ayres	9/12/80	W				DRY	

TABLE 7. Basin Aspect: Eastside or Westside, Values of Maximum Water Temperature (°C), Specific Conductivity (µmhos @ 25 °C), Minimum Dissolved Oxygen (D.O.) (ppm), and Minimum Flow (l/s and cfs) Measured during the Survey of Tributaries (Listed from North to South) of the Redwood Creek Basin in Summer-Fall 1980 and 1981. (continued)

STREAM	Date(s) Sampled	West/ East	Max. Temp. (°C)	Spec. Cond. (µmhos)	Min.[a] D.O (ppm)	Min.[b] Flow (l/s	cfs)
95. Simon	9/12/80	E	15.5	299	4-5	1	0.04
96. High Prairie	8/19/80	W	13.5	82	10.0	NE	
97. Minon	9/15-16/81	E	17.0	245-252	8.8	3	0.1
98. Lake Prairie	8/21-25/81	W	14.0	65-71	9.8	30	1.0
98b Redwood	9/17-18/81		20.0	189-209	7.7	18	0.7
99. Upper Panther/ Bradford	8/20/81	E	16.5	169-210	9.6	4	0.2
100. Pardee	9/30/80	W	11.5	99	8-9	45	1.6
101. Unnamed 30	9/30/80	W				DRY	
102. Unnamed 31	9/26/80	W	---	---	----	LOW	
103. Debris Torrent	9/29/80	W				DRY	
104. Unnamed 32	9/29/80	E				DRY	
105. Unnamed 33	9/29/80	E				DRY	
106. Unnamed 34	9/29/80	W	13.0	70	----	LOW	
107. Last Gasp	9/26/80	E	14.0	242	9-10	LOW	
108. Marquette	9/26/80	W	13.0	---	----	LOW	
109. Timbo	9/26/80	W	12.0	351	----	LOW	
110. Powerline	9/26/80	W				DRY	

TABLE 7. Basin Aspect: Eastside or Westside, Values of Maximum Water Temperature (°C), Specific Conductivity (µmhos @ 25 °C), Minimum Dissolved Oxygen (D.O.) (ppm), and Minimum Flow (l/s and cfs) Measured during the Survey of Tributaries (Listed from North to South) of the Redwood Creek Basin in Summer-Fall 1980 and 1981. (continued)

STREAM	Date(s) Sampled	West/ East	Max. Temp. (°C)	Spec. Cond. (µmhos)	Min.[a] D.O (ppm)	Min.[b] Flow (l/s	cfs)
111. Snowcamp	9/25/80	W	15.0	339	8-9	INT	
112. Twin Lakes	9/25/80	W	15.0	321		2	0.06

a. The more precise D.O. readings measured with YSI meter.
b. DRY = No, Flow LOW = Flow too low to estimate, INT = Intermittant Flow, isolated pools and subgravel flow, NE = No Estimate of discharge
c. Measured 9/05/81

measurable flow, all the eastside basin sections, upper, middle, and lower, had less mean flow than their adjacent westside sections. The upper eastside basin section had the lowest mean flow, and the Prairie Creek basin, the highest mean flow.

Water Quality

Water quality data were collected during a critical period of juvenile salmonid rearing. While not gathered synoptically, they were gathered throughout the summer-fall period of low flows and elevated water temperatures, critical habitat conditions.

Alkalinity and pH

Alkalinity (mg $CaCO_3$/l) was measured for nine of the study sites (Table 8). Mean alkalinity was 35 mg $CaCO_3$/l (S.D. = 24.9). The pH values were near neutral, the mean pH of the nine sites sampled being 6.9 (S.D. = 0.2), with a range of 6.6 to 7.3 (Table 8).

Specific Conductivity

The specific conductivity (µmhos @ 25 °C) values in the Redwood Creek basin tributaries were measured at different times and dates (Table 7). They ranged from a low of 42 µmhos to a high of 362 µmhos. Specific conductivity ranges and some single readings were measured at the 12 study sites (Table 8). The higher values occurred in the upper section of the watershed. The values of eastside

TABLE 8. Ranges of Water Quality Parameters of Summer 1981 Sample Sites of Redwood Creek Watershed. Includes Temperature (°C), Dissolved Oxygen (ppm), Dissolved Oxygen Saturation (%), pH, Alkalinity, and Specific Conductivity (µmhos @ 25 °C).

Stream	Temp °C	D.O. (ppm)	D.O. Sat. (%)	pH	Alkalinity ($mgCaCO_3/l$)	Conductivity (µmhos @ 25 °C)
1. Prairie	10.5	10.3	94	6.7	24	91
2W. Wolf	11.0-13.0	10.3-10.6	94-101	6.8	16	98
2E. L. Lost Man	10.5-13.0	10.2-10.3	96--98	7.0	22	77--91
3W. Tom McDonald	12.0-15.5	9.8-10.2	95--97	6.8	16	64
3E. Emerald	12.5-13.0	10.2	98	7.0	41	114
4W. Panther	10.0-15.0	----	----	7.0	24	70--79
4E. Lacks	17.0-23.0	9.0--9.5	101-110	---	--	193
5W. Tossup	12.0-14.5	9.4-10.4	94-100	---	--	130
5E. Mill	13.0-15.5	9.1--9.8	94--98	---	--	165
6W. Lake Prairie	11.0-14.0	9.8-10.0	98-102	6.6	23	65--95
6E. Minon	13.0-17.0	7.4--9.0	76--98	7.3	89	221-252
7. Redwood	15.0-20.0	7.7--9.4	88-103	7.1	62	189-209

sections of the basin were always greater than their counterpart westside sections. The mean specific conductivity values of the basin were 103 µmhos for Prairie Creek basin, 114 µmhos for lower eastside basin, 65 µmhos for lower westside basin, 183 µmhos for middle eastside basin, 89 µmhos for middle westside basin, 266 µmhos for upper eastside basin, and 142 µmhos for upper westside basin. There was an obvious south to north trend in decreasing values on both sides of the basin. The mean basin tributary specific conductivity of the basin was 133 µmhos (S.D.= 84).

Dissolved Oxygen

The minimum values of dissolved oxygen (D.O.), in parts per million, measured for the tributaries of the Redwood Creek basin, were in the 9 to 10 ppm range, with a few in the 8 to 9 ppm range (Table 7). Ranges of 4-5 ppm, the lowest minimum values measured, occurred twice. These measurements were not synoptically derived, but were measured at different times and dates. If treated as synoptically derived, mean D.O. values of the upper eastside basin are the lowest, 7.2 ppm, but with a small number of samples, the 4-5 ppm data point heavily influences the mean. The lowest values recorded were in this area. For the other basin sections, mean D.O. ranged from 8.7 to 10.0 ppm. Ranges of D.O. were measured at the 12 study sites

(Table 8). Overall, study site D.O. ranged from 7.4 to 10.6 ppm, with dissolved oxygen saturation (percent) from 76 percent to 110 percent.

Redwood Creek dissolved oxygen measurements determined with the HACH kit ranged between 7 and 10 ppm. Most were in the 7-8 and 8-9 ppm ranges. At the sample site, using the YSI meter, D.O. ranged from 7.4 to 9.4 ppm.

Temperature

Maximum measured temperatures (°C) were determined for the tributaries surveyed (Table 7). The temperatures ranged from 10.5 °C in Prairie Creek to 22.0 °C in Coyote Creek. It is difficult to conclude much as they were measured at different dates and times of the day over two years, 1980 and 1981. The maximum measured temperatures may not necessarily be the seasonal maximum temperatures that have occurred. If the readings were treated as synoptically derived, the mean maximum temperatures measured for each watershed section would be 12.4 °C for Prairie Creek basin, 13.1 °C for lower westside basin, 13.3 °C for lower eastside basin, 14.7 °C for middle westside basin, 16.1 °C for middle eastside basin, 13.2 °C for upper westside basin, and 15.4 °C for upper eastside basin. The higher temperatures occurred in the larger eastside streams; Copper, 17.0 °C; Coyote, 22.0 °C; and Minon, 21.0 °C.

With a few exceptions, tributary water temperatures were cooler than the receiving waters of mainstem Redwood Creek. The largest temperature difference measured between a tributary and Redwood Creek was 11.5 °C at Santa Fe Creek. The average temperature difference between some selected tributaries and Redwood Creek was approximately 6 °C. The exceptions, the large eastside tributaries, Coyote and Lacks Creeks, were measured at 2 °C and 2.5 °C warmer respectively than Redwood Creek. Other eastside tributaries, such as Copper, Minor, and Garrett were the same, 1 °C less, and 0.5 °C less respectively than Redwood Creek.

The temperature ranges were determined for the 12 study sites (Table 8). For the twelve 1981 sample sites, the maximum measured temperatures ranged from 10.5 °C in Prairie Creek to 23.0 °C in Lacks Creek, a large eastside stream. The correlation coefficient between fish per m^2 and maximum measured study site water temperature was 0.55 and not significant ($p > 0.05$).

Surface water temperatures recorded in mainstem Redwood Creek ranged from 14 °C to 26 °C. These temperatures are daytime and evening temperatures measured during August and September of the two different years the study was conducted. Since no recording thermographs were used during the survey periods, ranges were probably greater. Temperatures recorded to the nearest hour from 0700 h to 2000 h over the duration of the study exhibited an apparent warming trend peaking around 1500 h (Figure 3). Temperatures measured in late evening remain high, in the high teens and low twenties. Morning temperatures were

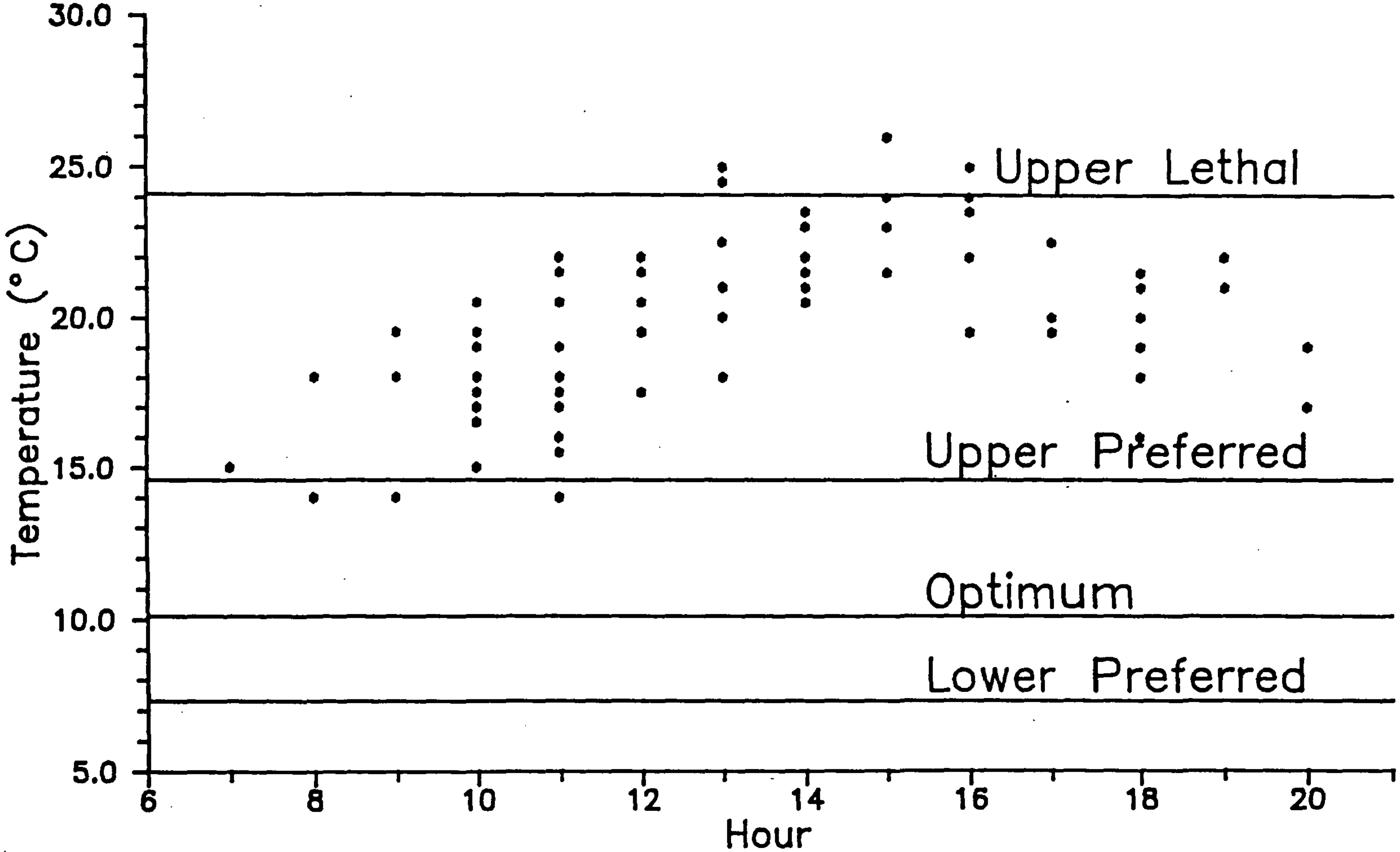

Figure 3. Ranges of Redwood Creek Surface Water Temperatures (°C) Versus Time, 0700 h to 2000 h. Temperatures are Graphed to the Nearest Hour and for the Period Summer-Fall 1980 and 1981. Redwood Creek is Located in Humboldt County, California. Upper and Lower Preferred and Optimum Refer to Temperatures Preferred By Juvenile Steelhead Trout. Upper Lethal is the Upper Lethal Temperature to Steelhead.

generally lower, as low as 14 °C. The same mainstem temperatures graphed at locations along the 108 km long Redwood Creek are illustrated in Figure 4. They show temperatures to be generally hotter in the middle of the watershed, and cooler in the headwaters and lower basin.

Drift Organisms

Twenty four hour drift samples from the twelve streams, were collected and analyzed (Table 9). Numbers of individuals collected during the 24 hour period ranged from 297 for Emerald Creek to 11,766 for Wolf Creek. In four of the five westside paired streams, Tossup Creek was the exception, the number of individuals collected was larger than that of its eastside paired stream. The number of individuals collected over 24 hours was positively correlated with stream discharge, $r = 0.790$, and significant ($p < 0.01$).

Drift Density

Drift density, the number of individuals per 100 m^3 of discharge, was calculated for the sampled streams (Table 10). Drift density ranged from 56/100 m^3 for Little Lost Man Creek, to 571/100 m^3 for Lake Prairie Creek, with the mean of all creeks, 185/100 m^3 (S.D. = 152). Three of the four westside Redwood Creek tributaries sampled had greater drift densities than their respective paired eastside tributaries. Tossup Creek was the exception. Overall, the combined difference between the eastside and

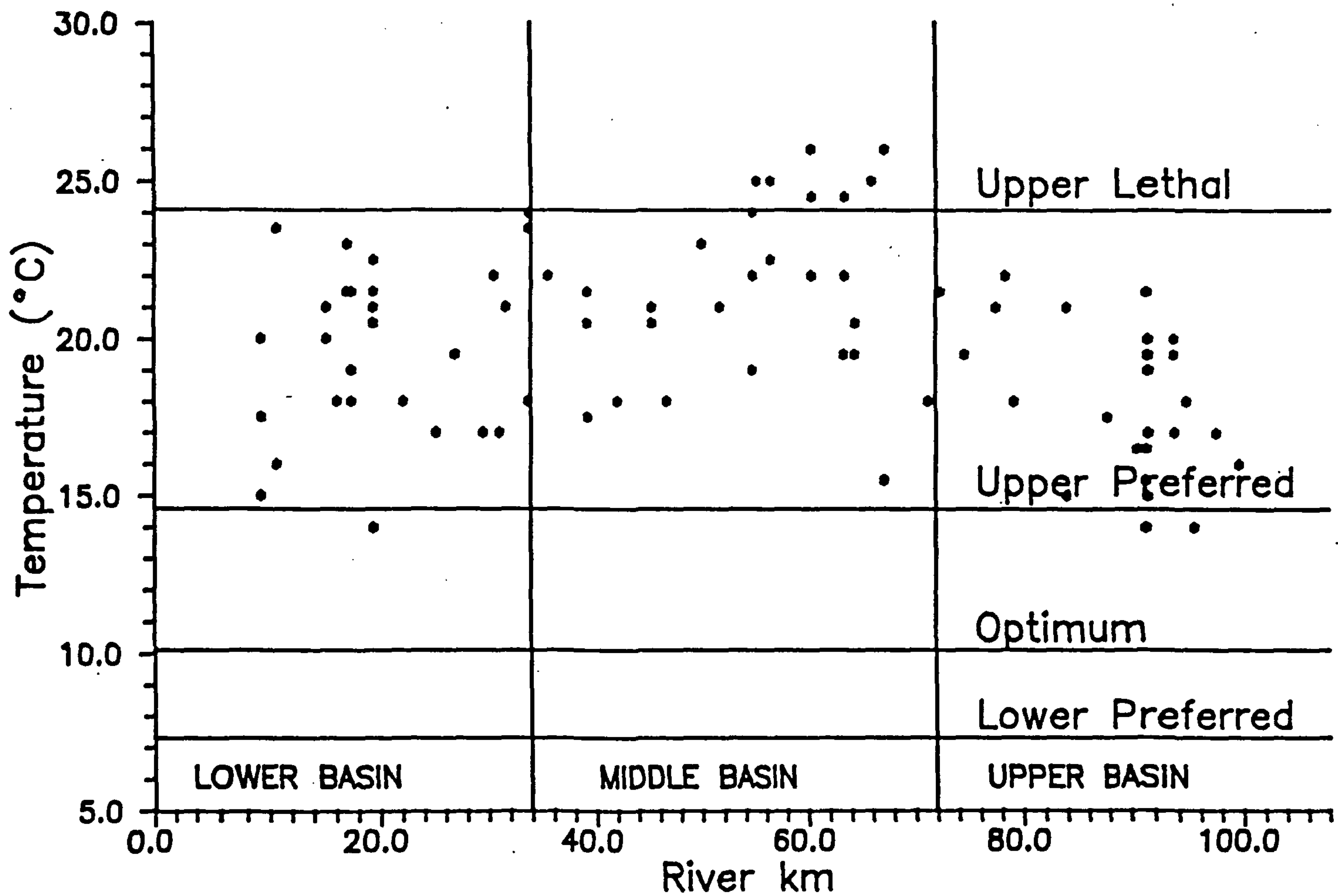

Figure 4. Ranges of Mainstem Surface Water Temperatures (°C) at Locations along the 108 km Redwood Creek, Humboldt County, California, for Summer-Fall 1980 and 1981. Temperatures Measured from 0700 h to 2000 h. Lower and Upper preferred and Optimum Refer to Temperatures Preferred by Juvenile Steelhead Trout. Upper Lethal is the Upper Lethal Temperature to Steelhead.

Table 9. Twenty-four Hour Drift Samples from 12 Streams, Prairie (PR), Wolf, Little Lost Man (LLM), Tom McDonald (TMD), Emerald (EMD), Panther (PAN), Lacks (LACK), Mill, Tossup (TOSS), Minon (MIN), Lake Prairie (LPR), and Redwood (REDWD) of the Redwood Creek Basin, Humboldt County, California. Streams Were Sampled during the Summer-Fall of 1981.

Taxonomic classification PHYLUM Class Order Family	STREAM											
	PR	WOLF	LLM	TMD	EMD	PAN	LACK	MILL	TOSS	MIN	LPR	REDWD
ANNELIDA												
Hirudinea				1	1		4					
Oligochaeta				2				7	2		3	
ARTHROPODA												
Arachnida												
Arcari	28	148	85	376	14	124	140	26	78	8	30	88
Araneida	27	58	20	84	3	27	5	6	7	6	18	1
Phalangida	2			3							1	
Pseudoscorpionida	1	2										
Chilopoda		1										
Crustacea												
Amphipoda												
Gammaridae	5	30	4									
Isopoda						6			1	1	3	
Diplopoda	3	38	1	9	2	24			1			
Insecta												
Unidentified									3			15
Coleoptera												
Amphizoidae		1					1	1	1		1	
Carabidae								2			1	
Chrysomelidae				5						1		
Coccinellidae				1					1		3	
Curculionidae	2	1		2								
Dryopidae						5				1	3	1
Dytiscidae	6	44	1	13		5	11	1	3	1		1
Elmidae	124	524	73	568	13	560	154	73	71	71	252	67
Gyrinidae			2									
Haliplidae			1									

Table 9. Twenty-four Hour Drift Samples from 12 Streams, Prairie (PR), Wolf, Little Lost Man (LLM), Tom McDonald (TMD), Emerald (EMD), Panther (PAN), Lacks (LACK), Mill, Tossup (TOSS), Minon (MIN), Lake Prairie (LPR), and Redwood (REDWD) of the Redwood Creek Basin, Humboldt County, California. Streams Were Sampled during the Summer-Fall of 1981. (continued)

Taxonomic classification PHYLUM Class Order Family	STREAM											
	PR	WOLF	LLM	TMD	EMD	PAN	LACK	MILL	TOSS	MIN	LPR	REDWD
Coleoptera (continued)												
Hydraenidae		3		3		23				2	4	
Hydrophilidae	1	3		3				1	1	1	17	
Psephenidae			1	1	1	3	9	1	5	16		2
Staphylinidae		14	1	18	1	5			1	2	10	1
Unidentified	2	44	1	45	1	15			3	1	16	1
Collembola	10	187	17	18	4	5	1	2	8	1	8	
Diptera												
Ceratopogonidae		2			4		4	1	13	1	3	
Chironomidae	49	1410	99	602	59	992	265	345	389	110	1241	1147
Dixidae	24	698	26	34	36	21	2	11	17	5	27	7
Empididae		1		3		4	5	5	1		2	
Ephydridae	1	3	2			1	6	1			2	2
Muscidae											1	
Pipunculidae				1								
Psychodidae	1		2	2			14	2	1		1	
Simuliidae	11	258	41	208	4	15	433	110	16	25	18	
Stratiomyidae							59			2		55
Tabanidae			1									
Tipulidae			3	2			6		3	2		3
Unidentified	19	459	43	167	36	41	73	32	23	11	114	52
Ephemeroptera												
Baetidae	465	2762	330	3406	66	868	133	73	56	70	165	10
Ephemerellidae	10		91	11		2	2		1		26	
Heptageniidae	127	353	144	92	8	60	45	8	32	41	47	14
Leptophlebiidae	27	99	9	8	3	2	6	10	5	10		
Siphlonuridae	4	91	1	32	1	4						
Tricorythidae							2					
Unidentified			3	1	1					1		
Hemiptera												
Gerridae		1	1	2		5	3	1	2	3		
Hydrometridae										1		

Table 9. Twenty-four Hour Drift Samples from 12 Streams, Prairie (PR), Wolf, Little Lost Man (LLM), Tom McDonald (TMD), Emerald (EMD), Panther (PAN), Lacks (LACK), Mill, Tossup (TOSS), Minon (MIN), Lake Prairie (LPR), and Redwood (REDWD) of the Redwood Creek Basin, Humboldt County, California. Streams Were Sampled during the Summer-Fall of 1981. (continued)

Taxonomic classification PHYLUM Class Order Family	STREAM											
	PR	WOLF	LLM	TMD	EMD	PAN	LACK	MILL	TOSS	MIN	LPR	REDWD
Hemiptera (continued)												
Largidae				4								
Lygaeidae						1						
Miridae				5								
Pentatomidae				1					2			
Tingidae		3		12		1	2			2	120	
Veliidae		2		6			10	32	18	8		1
Unidentified						3						
Homoptera												
Aphididae	4	2491	7	28			3		3		104	
Cercopidae	1	2		40		1					3	
Cicadellidae	4	22	2	25	1	3	1	1	4	2	5	
Membracidae				1								
Unidentified	2	7		5								
Hymenoptera												
Apoidea											2	
Formicidae	1	11		25		13		5	5	17	10	
Vespidae				2			1			1	1	
hymenoptera (adults)	17	99	8	45	1	48	12	5	9	7	11	1
hymenoptera (larvae)		1				2					3	
Isoptera												
Hodotermitidae								2				
Lepidoptera												
Pyralidae							4					
Unidentified	2	4	2	10			3			2	6	
Odonata												
Zygoptera-Coenagrionidae							5					
Anisoptera-Cordulegastridae									1			

Table 9. Twenty-four Hour Drift Samples from 12 Streams, Prairie (PR), Wolf, Little Lost Man (LLM), Tom McDonald (TMD), Emerald (EMD), Panther (PAN), Lacks (LACK), Mill, Tossup (TOSS), Minon (MIN), Lake Prairie (LPR), and Redwood (REDWD) of the Redwood Creek Basin, Humboldt County, California. Streams Were Sampled during the Summer-Fall of 1981. (continued)

Taxonomic classification PHYLUM Class Order Family	STREAM											
	PR	WOLF	LLM	TMD	EMD	PAN	LACK	MILL	TOSS	MIN	LPR	REDWD
Orthoptera												
Gryllacrididae											1	
Tettigoniidae				3								
Plecoptera												
Capnidae		2										
Chloroperlidae	33	80	43	3		3	2		1		3	
Leuctridae	1	1		14	2	2		3			5	
Nemouridae	104	184	41	57	16	50	5	53	22	40	79	
Peltoperlidae	20	2	1	1		1		1			2	
Perlidae	27	3	37	4	2	19	8	1	20		4	
Perlodidae	14	12	20							3	5	3
Pteronarcidae	2		1					1				
Unidentified	2											
Psocoptera	8	266	4	620	1	8		2	4	8	13	1
Thysanoptera			2	2							2	
Trichoptera												
Brachycentridae	20	7	14	5	1		3				5	
Calamoceratidae	2	2	3	4		1		1	7	2		
Glossosomatidae	16	7	10	18	4	11	23	5	7	2	3	2
Hydropsychidae	48	3	10	16	6	22	56	8	22	13	10	24
Hydroptilidae	2		1				19					14
Lepidostomatidae			23	45		10	2		3	6	6	1
Limnephilidae	586	1291	12	30	5	1		2	46	140	171	
Philopotamidae	83			9		17	37	2				
Polycentropodidae	4	1										
Rhyacophilidae	38	8	30	24		13	2	6	11		22	
Unidentified											61	
CHORDATA												
Agnatha												
Petromyzontidae	1	2		3			6					

Table 9. Twenty-four Hour Drift Samples from 12 Streams, Prairie (PR), Wolf, Little Lost Man (LLM), Tom McDonald (TMD), Emerald (EMD), Panther (PAN), Lacks (LACK), Mill, Tossup (TOSS), Minon (MIN), Lake Prairie (LPR), and Redwood (REDWD) of the Redwood Creek Basin, Humboldt County, California. Streams Were Sampled during the Summer-Fall of 1981. (continued)

Taxonomic classification PHYLUM Class Order Family	STREAM											
	PR	WOLF	LLM	TMD	EMD	PAN	LACK	MILL	TOSS	MIN	LPR	REDWD
MOLLUSCA												
Gastropoda												
Lymnaeidae											1	
Planorbidae	1	3		1								
Pleuroceridae	28	15	33			1	27	495	38	27	10	1
Unidentified								5				
NEMATOMORPHA												
Nematomorpha												
Gordiida	1		1	1			11	1			7	
PLATYHELMINTHES												
Turbellaria	3		2			11		4				
UNIDENTIFIED				1				2				
TOTAL NUMBER OF INDIVIDUALS	2024	11766	1310	6793	297	3059	1625	1356	968	674	2692	1515
TOTAL NUMBER OF TAXA	53	55	50	66	29	47	46	44	46	42	56	26

TABLE 10. Total Drift, Number per 24 Hours, of Drift Samples; Drift Density, the Number of Individuals per 100 m^3 of Water Discharge; and Terrestrial Contribution, Numbers and Percentages in the Twelve Sample Sites in the Redwood Creek Basin, Humboldt County, California, Summer-Fall 1981.

STREAM	TOTAL DRIFT	DRIFT DENSITY (#/100 m^3)	TERRESTRIALS Total	%
1. Prairie	2024	83	53	2.6 %
2W. Wolf	11766	398	2901	24.7
2E. L. Lost Man	1310	56	36	2.8
3W. Tom McDonald	6793	221	871	12.8
3E. Emerald	297	91	7	2.4
4W. Panther	3059	177	81	2.7
4E. Lacks	1625	113	12	0.7
5W. Tossup	968	140	27	2.8
5E. Mill	1356	174	18	1.3
6W. Lake Prairie	2692	571	285	10.6
6E. Minon	674	93	36	5.3
7. Redwood	1515	107	2	0.1

westside was not significant ($p = 0.21$). The pattern of westside greater than eastside was true for the pair of Prairie Creek east-west tributaries. The correlations between drift density and alkalinity, and drift density and maximum measured temperature were -0.41 and -0.18, respectively, and nonsignificant. The correlation coefficient of fish per m^2 and drift density was -0.27 and nonsignificant ($p > 0.05$). The correlation between salmonid grams per m^2 and drift density was -0.14 and nonsignificant ($p > 0.05$).

Terrestrial Contribution to Drift

Terrestrial invertebrate contribution to the drift ranged from 0.1 percent for Redwood Creek, to 24.7 percent for Wolf Creek (Table 10). Terrestrial insects providing major inputs were homopterans (aphids), hemipterans (leaf hoppers), and psocopterans (psocids) (Tables 9 and 11). Two streams with very little overhead canopy, Redwood and Lacks Creeks had the lowest terrestrial invertebrate percentages, 0.1 and 0.7 percent, respectively. Generally terrestrial invertebrate percentages were less than or equal to approximately five percent of the total drift. Lake Prairie, Tom McDonald, and Wolf Creeks with 10.6, 12.8, and 24.7 percent terrestrial invertebrate contributions, respectively, were the exceptions. In all cases, for both Redwood and Prairie Creek basins, the westside tributaries had at least twice the percentage of terrestrial drift as their paired eastside tributaries. However, the overall

TABLE 11. Percentage Taxonomic Composition of the Total Number of Drift Organisms Collected from Streams in the Redwood Creek Basin in 1981. Abbreviations of the Streams Are Prairie (PC), Wolf, Little Lost Man (LLM), Emerald (EMD), Tom McDonald (TMD), Panther (PAN), Lacks (LACK), Mill, Tossup (TOSS), Minon (MIN), Lake Prairie (LPR), and Redwood (REDWD).

Taxonomic Classification	Percentage Taxonomic Composition											
PHYLUM Class Order	STREAM											
	PC	WOLF	LLM	TMD	EMD	PAN	LACK	MILL	TOSS	MIN	LPR	REDWD
ANNELIDA				<0.1	0.3		0.3	0.5	0.2		0.1	
ARTHROPODA												
Arachnida	2.9	1.8	8.0	6.8	5.7	4.9	8.9	2.4	8.8	2.1	1.8	5.9
Chilopoda		<0.1										
Amphipoda	0.3	0.3	0.3									
Isopoda						0.2			0.1	0.2	0.1	
Diplopoda	0.2	0.3	<0.1	0.1	0.7	0.8			0.1			
Insecta												
Coleoptera	6.7	5.4	6.1	9.7	5.4	20.1	10.8	5.8	8.9	14.2	11.4	4.8
Collembola	0.5	1.6	1.3	0.3	1.4	0.2	<0.1	0.2	0.8	0.2	0.3	
Diptera	5.2	24.1	16.6	15.0	46.8	35.1	53.4	37.4	47.8	23.2	52.3	83.6
Ephemeroptera	31.3	28.1	44.1	52.3	26.6	30.6	11.6	6.7	9.7	18.1	8.8	1.6
Hemiptera		<0.1	<0.1	0.4		0.3	0.9	2.4	2.3	2.1	4.5	<0.1
Homoptera	0.5	21.4	0.7	1.5	0.3	0.1	0.3	<0.1	0.7	0.3	4.2	
Hymenoptera	0.9	0.9	0.6	1.1	0.3	2.1	0.8	0.7	1.5	3.7	1.0	<0.1
Isoptera								0.2				
Lepidoptera	0.1	<0.1	0.2	0.2			0.4			0.3	0.2	
Odonata							0.3		0.1			
Orthoptera				<0.1							<0.1	
Plecoptera	10.0	2.4	10.9	1.2	6.7	2.5	0.9	4.4	4.4	6.4	3.6	0.2
Pscoptera	0.4	2.3	0.3	9.1	0.3	0.3		0.2	0.4	1.2	0.5	<0.1
Thysanoptera			0.2	<0.1							<0.1	
Trichoptera	39.5	11.2	7.9	2.2	5.4	2.5	8.7	1.8	9.9	24.2	10.3	2.7
CHORDATA	<0.1	<0.1		<0.1			0.4					
MOLLUSCA	1.4	0.2	2.5	<0.1		<0.1	1.7	36.9	3.9	4.0	0.4	<0.1
NEMATOMORPHA	<0.1		<0.1	<0.1			0.7	<0.1			0.3	
PLATYHELMINTHES	0.2		0.2			0.4		0.3				
UNIDENTIFIED				<0.1				0.2	0.3			1.0

difference between the mainstem east and west tributaries was not significant ($p = 0.14$).

Percentage Taxonomic Composition

The major orders contributing the greatest percentage of individuals to the samples were Diptera, Ephemeroptera, Trichoptera, and Coleoptera (Table 11). In two streams the orders Mollusca and Homoptera accounted for a large percentage of the total individuals. In Mill Creek, Mollusca accounted for 36.9 percent of the drift, and in Wolf Creek, Homopterans accounted for 21.4 percent of the drift.

An apparent north-south change in invertebrate composition involved dipterans and ephemeropterans. The percentage of mayflies increased proceeding north and the percentage of dipterans increased proceeding south (Figures 5 and 6 and Table 11). Some aquatic invertebrates only occurred in certain streams. The crustacea, Gammaridae, was only observed in the Prairie Creek basin. Similarly, of all the streams surveyed, crayfish were found only in Gunrack Creek.

Similarity Index

Similarity indices, a measure of taxonomic similarity, were calculated amongst the drift samples from the twelve study streams (Table 12). The values ranged from 0.81, Prairie Creek versus Wolf Creek, to 0.41, Redwood Creek versus Tom McDonald Creek. Similarity indexes between

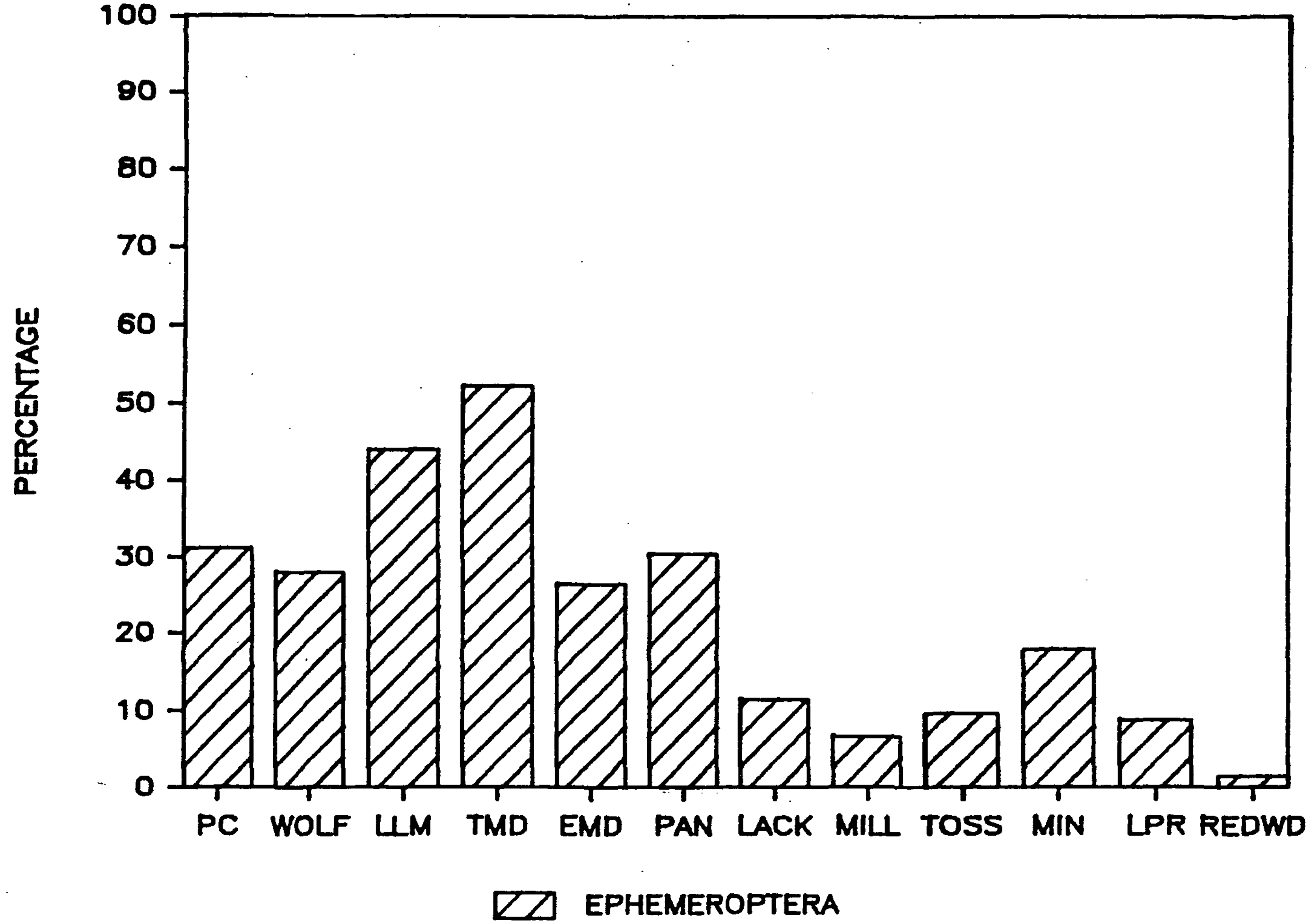

Figure 5. Ephemeropteran Percentage in Drift Samples from Twelve Study Streams, Listed North to South, of the Redwood Creek Basin, Humboldt County, California, Summer-Fall 1981.

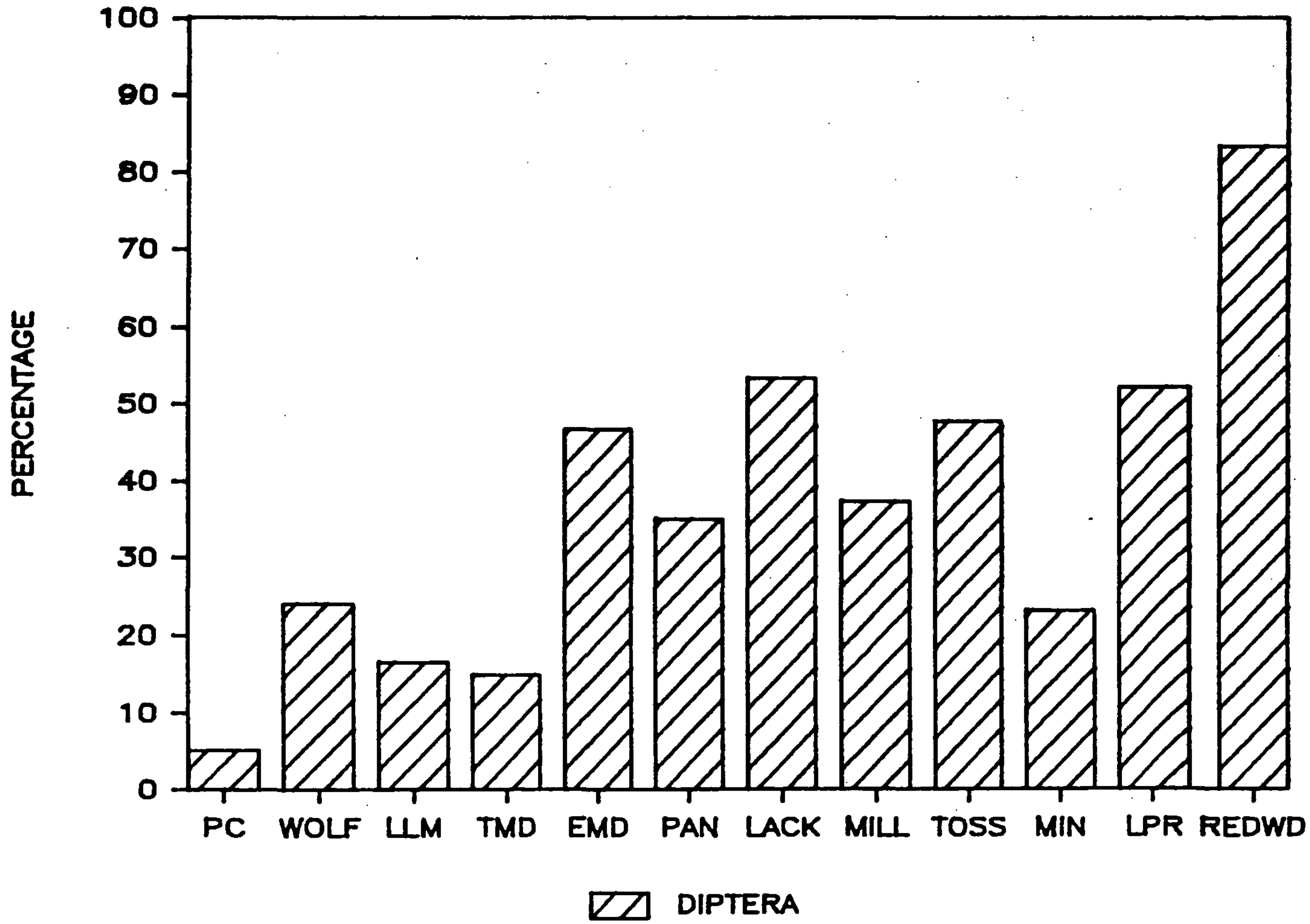

Figure 6. Dipteran Percentage in Drift Samples from Twelve Study Streams, Listed North to South, of the Redwood Creek Basin, Humboldt County, California, Summer-Fall 1981.

TABLE 12. Similarity Index, a Measure of Taxonomic Similarity of Drift Samples from 12 Streams in the Redwood Creek Basin, Humboldt County, California, Summer-Fall 1981. Values at Bottom Are Mean Similarity Indices.

	STREAM											
	PC	WOLF	LLM	TMD	EMD	PAN	LACK	MILL	TOSS	MIN	LPR	REDWD
PC	--	0.81	0.78	0.72	0.59	0.70	0.63	0.68	0.63	0.55	0.66	0.46
WOLF		--	0.69	0.73	0.62	0.75	0.63	0.67	0.69	0.66	0.70	0.44
LLM			--	0.69	0.66	0.72	0.69	0.66	0.71	0.65	0.64	0.58
TMD				--	0.59	0.69	0.66	0.64	0.71	0.65	0.69	0.41
EMD					--	0.66	0.56	0.60	0.64	0.65	0.54	0.55
PAN						--	0.62	0.70	0.73	0.70	0.70	0.55
LACK							--	0.67	0.70	0.64	0.62	0.56
MILL								--	0.73	0.63	0.64	0.49
TOSS									--	0.73	0.69	0.58
MIN										--	0.63	0.68
LPR											--	0.46
REDWD												--
$\bar{S}$	0.65	0.67	0.68	0.65	0.60	0.68	0.63	0.65	0.69	0.65	0.63	0.52

the five paired streams ranged from 0.59 to 0.73 with an mean of 0.65. The mean similarity index of all comparisons was 0.64. Among the individual streams, Tossup at 0.69 had the highest mean similarity index, the mean of all its comparisons. The lowest mean similarity index was that of Redwood Creek at 0.52. The other stream mean similarity indices ranged from 0.60 to 0.68. In three out of five tributary pairs, the westside tributary mean similarity index was larger than its paired eastside tributary. With the exception of Panther and Emerald Creeks, all east-west mean similarity differences between the paired tributaries were nonsignificant at $p > 0.05$ (Figure 7). For adjacent tributaries on each basin side, all were nonsignificant ($p > 0.05$). However, the comparisons between Redwood and Lake Prairie, and Redwood and Minon Creeks were significant ($p < 0.001$).

Richness

The total number of taxa represented in each creek ranged from 26 for Redwood Creek to 66 for Tom McDonald Creek, with a basin mean of 47 taxa (S.D. = 11) for the twelve sampled streams. In all cases, the number of taxa represented in westside drift samples were greater than in the paired eastside tributary. This difference was not significant ($p = 0.067$), between the east and west side mainstem Redwood Creek streams sampled.

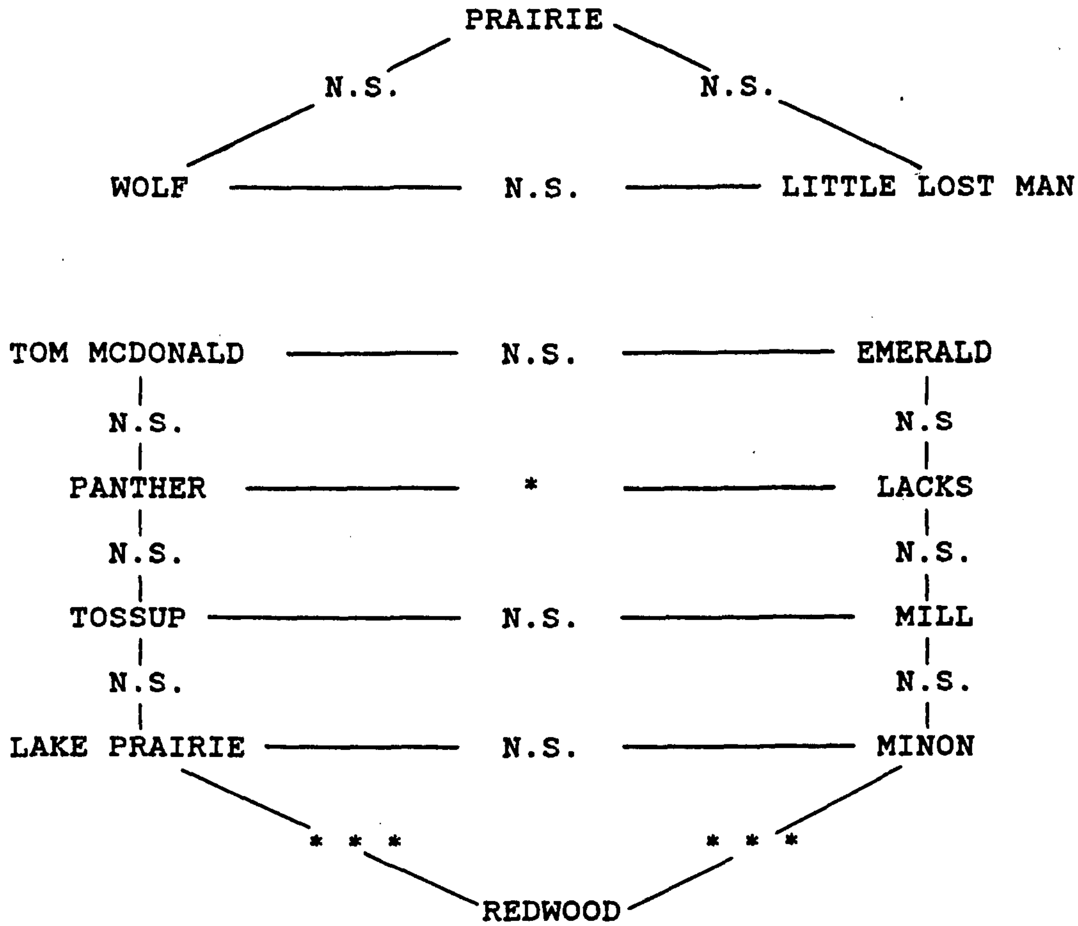

Figure 7. Results of Testing for Differences between Mean Similarity Indices of 24 Hour Drift Samples for Paired East-West Streams and Adjacent West-West and East-East Streams of the Redwood Creek Watershed, Humboldt County, California, Summer-Fall 1981. *** = $p < 0.001$, * = $p < 0.05$, and N.S. = Not Significant ($p > 0.05$). No Comparison Was Made between Wolf and Tom McDonald, and Little Lost Man and Emerald Creeks as They Are in Separate Systems (Redwood and Prairie Creeks), and Not Adjacent Tributaries.

Diversity

Diversity (H'), of the drift samples, including terrestrials, ranged from 1.594 to 4.097 for Redwood Creek and Little Lost Man, respectively (Table 13). The mean basin diversity was 3.314 (S.D. 0.67). Evenness (e), ranged from 0.339 to 0.733, Redwood Creek and Emerald Creek, respectively. In three of the four pairs of mainstem tributaries, for diversity and evenness with and without the terrestrial invertebrate contribution, the eastside tributaries were greater. The one exception, the westside tributary Tossup Creek, had a greater value than Mill Creek. All east-westside diversity differences between the paired tributaries were significant at $p < 0.001$ (Figure 8). For adjacent tributaries on each side, all were significant at $p < 0.001$, except for the nonsignificant differences between Tom McDonald and Panther Creeks, and Emerald and Lacks Creeks. Overall, t-tests of the number of taxa, diversity and evenness determined with and without terrestrial contribution between the westside and eastside basin of Redwood Creek were not significant ($p > 0.05$).

There was no statistically significant north-south difference in diversity, though the lowest and highest diversities calculated were from the southern extreme headwater Redwood Creek site and the northern Little Lost Man Creek site, respectively.

TABLE 13. Diversity (H'), Evenness (e), and Number of Taxa for 24 Hour Drift Samples from Twelve Streams in the Redwood Creek Basin With and Without Terrestrial Invertebrate Influence.

CREEK	WITH TERRESTRIALS			WITHOUT TERRESTRIALS		
	NO. OF TAXA	H'	e	NO. OF TAXA	H'	e
1. Prairie	53	3.664	0.640	43	3.519	0.648
2W. Wolf	55	3.474	0.601	44	3.269	0.599
2E. Little Lost Man	50	4.097	0.726	44	3.972	0.728
3W. Tom McDonald	66	2.922	0.483	47	2.461	0.443
3E. Emerald	29	3.560	0.733	25	3.437	0.740
4W. Panther	47	2.885	0.519	38	2.718	0.518
4E. Lacks	46	3.724	0.674	41	3.673	0.685
5W. Tossup	46	3.627	0.657	38	3.463	0.660
5E. Mill	44	3.037	0.556	38	2.943	0.561
6W. Lake Prairie	56	3.273	0.564	41	2.860	0.534
6E. Minon	42	3.905	0.724	36	3.693	0.714
7. Redwood	26	1.594	0.339	24	1.581	0.345

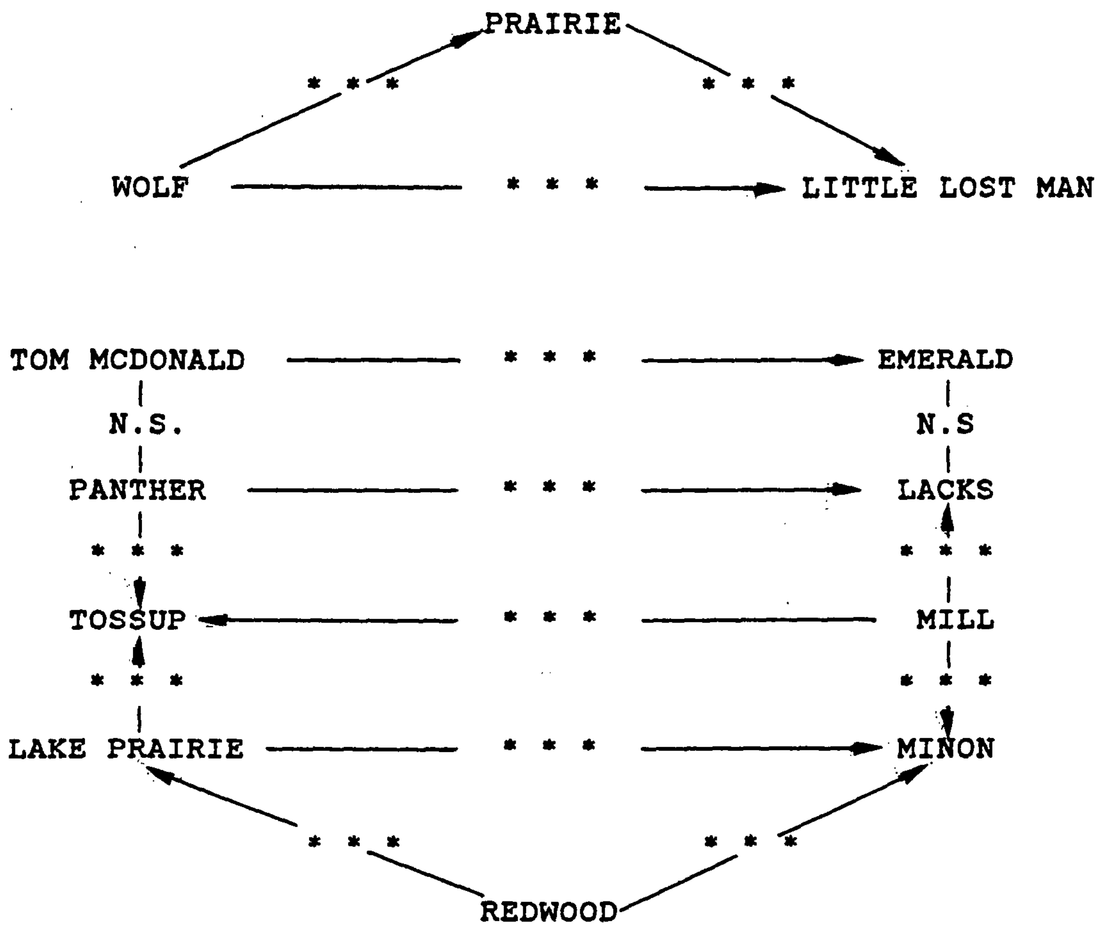

FIGURE 8. Results of Testing for Differences between Diversity Indices of 24 Hour Drift Samples for Paired East-West Streams and Adjacent West-West and East-East Streams of the Redwood Creek Watershed, Humboldt County, California, Summer-Fall 1981. *** = $p < 0.001$, N.S. = Not Significant ($p > 0.05$). Arrows Point to the Significantly Greater H' between Streams. No Comparison Was Made between Wolf and Tom McDonald, and Little Lost Man and Emerald Creeks as They Are in Separate Systems (Redwood and Prairie Creeks), and Not Adjacent Tributaries.

DISCUSSION

Physical and chemical conditions in streams will affect the aquatic organisms residing in them (Hynes 1970). Aquatic organisms, therefore, are reflective of conditions that occur in a watershed. The fish rearing environment has biological, physical, and chemical components. Each component, with its attributes will influence the quality of nursery habitat. These attributes include food, water quality, flow, space, cover, substrate, predation, and disease. A wide range of conditions will be present in each location. The effects on fish of each component, in synergistic combination with others are too complex to comprehend and distinguish. The scope of this survey was to report conditions present in 1980-81 in the basin in summer and fall, a period when summer rearing habitat is limiting in the natal stream.

Fish Distribution

Three salmonids, steelhead trout, cutthroat trout, and coho salmon were identified in the basin during the summer-fall survey period of 1980 and 1981. No chinook salmon were found in the tributaries or mainstem Redwood Creek. This is similar to the findings of Redwood Creek summer surveys of Averett and Iwatsubo (1975) of 1974 and

1975. However, they captured three chinook salmon, (0.3 percent of all fish captured), in Redwood Creek near Hayes Creek in late July. Larson (1987) reported that the peak immigration of juvenile chinook into the Redwood Creek estuary occurred in late May and early June of 1981. McKeon (1985) also reported that juvenile chinook salmon migrated downstream from late May through June. If chinook juveniles migrated downstream to the estuary for summer rearing prior to the beginning of our surveys in August, this would account for the absence of juvenile chinook salmon in the tributaries.

Coho salmon were present in relatively few of the mainstem Redwood Creek tributaries. Hartman (1965) reported that in spring and summer when fish densities are high, coho reside in pools and steelhead in riffles. This segregation is attributable to aggressive fish behavior. The lack of adequate pool habitat in the tributaries surveyed may be due in part to sediment filling in pools (Cordone and Kelly 1961, Everest et al. 1987). Pitlick (1982) reported in a study of some Redwood Creek tributaries, that 95 percent of the sediment stored in them occurred in their lower half. These were the areas surveyed in this study. Also, the lack of large organic structures that create scour pools could have limited the occurrence of coho salmon. The lack of large organic structures may be a result of past logging, streambed aggregation, and/or floods. Other factors, such as lack of winter habitat and low numbers of spawners may also have influenced the distribution and numbers of juvenile coho salmon.

Cutthroat trout were seldom found together with steelhead. It could be that steelhead outcompete them in disturbed areas. In areas where migrational barriers barred anadromous steelhead, cutthroat were found. In undisturbed areas, such as the Prairie Creek basin, cutthroat were common.

Steelhead were widely distributed. This is probably because of the number of spawners occurring in the Redwood Creek basin. Furthermore, based on survey results, most of the tributaries are suitable for steelhead spawning, as evidenced by the presence of juveniles. Adult steelhead have greater leaping and swimming abilities than those of chinook and coho salmon (Powers and Orsborn 1985), and therefore more spawning habitat would be accessible to them.

The presence or absence of juvenile salmonids in a stream was related to stream discharge (Table 3). The greater the flow, the greater the probability of fish occurrence. It stands to reason that at low flow conditions, habitat available to fish is severely limited, and at very low flow conditions the habitat would be absent. However, these low flow streams could provide spawning and early rearing habitat during the higher flow conditions prior to summer. Also, where fish are present, these low flow streams have high fishery values, as determined by fish/m^2/$m^3 sec^{-1}$ (Table 6).

Water Quality

Temperature

The effects of temperature on fish in the Pacific Northwest are reviewed by Lantz (1971) and Beschta et al. (1987). Fish metabolism, growth and development, survival, disease, scope of activity, and behavior are a few of the variables affected by temperature. The preferred ranges, optimum, and upper lethal temperatures reported by Reiser and Bjorn (1979) for rearing salmonids are presented in Table 14. In 70 percent of the tributaries, water temperature was within the preferred range for steelhead, and in 30 percent, between the upper preferred temperature and the upper lethal temperature (Table 15). No tributary temperatures were recorded at or above the upper lethal level. Individually, the basin sections, broken down by temperature ranges reflect temperature conditions of the basin (Table 15). In Prairie Creek and lower Redwood Creek basin, tributary temperatures were cooler and probably influenced by the coastal Mediterranean climate and frequent fog. Kubicek (1977) observed a similar pattern in the Eel River system. He attributed decreased temperatures in the lower Eel River basin to the influence of the coastal Mediterranean climate and its fog. No logging is occurring

TABLE 14. Water Temperature (°C) Preferences and Upper Lethal Temperatures of Rearing Juvenile Salmonids.

SPECIES	TEMPERATURE		
	PREFERRED (°C)	OPTIMUM (°C)	UPPER LETHAL (°C)
Steelhead Trout	7.8 - 14.6	10.1	24.1
Cutthroat Trout	9.5 - 12.9	---	23.0
Coho Salmon	11.8 - 14.6	---	25.8
Chinook Salmon	7.3 - 14.6	12.2	25.2

Source: Reiser and Bjorn 1979

TABLE 15. Percentage of Redwood Creek Tributaries within each Basin Occurring within the Different Temperature Ranges Affecting Juvenile Steelhead. Information Collected during the Summer-Fall of 1980 and 1981, Redwood Creek Basin, Humboldt County, California.

BASIN SECTION	NO. OF STREAMS	PREFERRED 7.3-14.6°C	ABOVE PREFERRED 14.7-24.0°C	UPPER LETHAL 24.1°C
Prairie Creek	7	100%	0%	0%
(Redwood Creek)				
Lower Westside	21	86	14	0
Lower Eastside	12	83	17	0
Middle Westside	13	54	46	0
Middle Eastside	11	55	45	0
Upper Westside	14	86	14	0
Upper Eastside	9	11	89	0
Redwood Creek Basin	87	70%	30%	0%

in these areas and stream canopy conditions provide shading on tributary streams. The middle basin with its interior Mediterranean climate and less frequent fog, had higher water temperatures. In the upper basin, the westside streams were appreciably cooler than the eastside and middle basin streams. A possible reason for this condition is that being on the westside of the basin and having an eastern aspect, the tributaries receive less insolation due to shading by the terrain. The increase of the percentage of eastside tributaries exhibiting temperatures above the preferred range from north to south is indicative of the summer climate pattern and the insolation received. When fog extended up the Redwood Creek basin, it normally did not burn off until later in the day, at which time the westside streams would receive less insolation from shading than those of the west facing streams and slopes of the eastside basin. In the mainstream Redwood Creek, most if not all temperatures measured along its length were between the upper preferred and upper lethal temperatures of juvenile steelhead (Figure 4). Some even exceeded the upper lethal temperature of 24.1 °C along river kilometer 60. These greater than preferred temperatures continued for most of the day and evening (Figure 3). Temperature data are lacking from 2100 h to 0600 h. However, the ranges of temperatures occurring in early morning generally were near to or above the upper preferred temperature, 14.6 °C, and were probably indicative that the temperatures remained above 14.6 °C throughout the night.

Of the seven streams with coho salmon, one was below the preferred temperature range, four were within the preferred temperature range and two were above the preferred temperature range. None was at or above the upper lethal temperature of 25.8 °C. Of the ten streams where cutthroat trout were observed, three were within the preferred range, and seven were above the preferred range. However, four of the maximum measured temperatures were at 13.0 °C, 0.1 °C higher than the upper range of the preferred range. None were at or above the upper lethal temperature of 23.0 °C. In general, coho salmon and cutthroat trout were restricted to streams exhibiting temperature regimes within or near their preferred temperature ranges.

It would appear that in the Redwood Creek basin, salmonid juveniles, particularly steelhead, were tolerant of greater than optimum temperatures. The presence of steelhead in mainstem Redwood Creek, where higher than optimum temperatures generally occur, attest to this. Beschta et. al (1987) in their review of reported temperature preferences stated that fish were tolerant of extremes and able to withstand periodic exposure to them. Two of the study sites with the highest temperatures measured, Lacks and Redwood Creeks, also contained the largest estimated fish populations (Tables 6 and 8).

Beschta et. al (1987) pointed out that the application to the natural system of preferred and lethal temperatures derived in the laboratory is not clear cut. Most laboratory values were derived with fish acclimating to stable temperatures values before being subjected to the temperature stress test. Under natural conditions, fish are subject to wide fluctuating temperatures that occur daily. The effect of higher temperatures must be viewed in the context of both temperature fluctuations and exposure time, information that was lacking in this study.

Fish do avoid higher temperatures and may use this behavior to cope with unfavorable conditions. Keller and Hofstra (1983) found in a August 1981 snorkel survey of Redwood Creek, the existence of 'cold pools', pools with ground water that are connected to the mainstem channel. The pool temperatures were cooler than adjacent mainstem pools and thalweg, and encompassed the preferred temperatures of steelhead. The pools provided summer rearing habitat for anadromous salmonids. The cold pools were observed to contain more fish than the adjacent areas. The same principal may be in effect at the confluence of tributaries to Redwood Creek. The colder effluent could provide some favorable salmonid habitat in Redwood Creek.

Dissolved Oxygen

Concentrations of dissolved oxygen measured in the Redwood Creek basin varied. Davis (1975) as cited by Reiser and Bjorn (1977) reported 7.75 mg/l (= ppm) as a concentration above which fish can function without impairment. Most tributaries were recorded in the 9-10 ppm range and 93 percent of the 54 tributaries where dissolved oxygen was measured were above 7.75 mg/l. In general, Redwood Creek dissolved oxygen was slightly lower. At most of the study sites, saturation values ranged up to near 100 percent. The aeration of the water through cascades and riffles most likely accounted for the high saturation level. Since no measurements were taken at night, decreases in dissolved oxygen resulting from algal respiration are unknown. Filamentous algae were common in the mainstem of Redwood Creek and some of the tributaries.

pH and Alkalinity

The neutral pH measured in the basin would not be harmful to aquatic organisms (Committee on Water Quality Criteria 1972). Alkalinity was low, indicative of a low buffering capacity. The low value means that the capacity of the system to resist change in pH is limited. Any major acid input would decrease the buffering capacity and result in eventual acidification of the waters, a condition deleterious to aquatic organisms (Haines 1981).

Craigie (1963) reported that rearing of rainbow trout in soft water, water defined as having a low alkalinity value, resulted in greater resistance to thermal stress. This may be a factor affecting the influence of higher than preferred temperatures on rearing Redwood Creek basin salmonids.

Specific Conductivity

Low values of specific conductance were measured in the basin. Averett and Iwatsubo (1975) reported that dissolved ion concentrations were low in all streams of the Redwood Creek basin. This would account for the specific conductivity values measured. The relatively larger values occurred in the upper section of the watershed. There was an increasing north to south trend in specific conductance for both sides of the basin. The values of the eastside basin sections were greater than their paired westside sections. Bradford and Iwatsubo (1978) suggested the higher specific conductivity values upstream were a result of greater weathering, logging activity, and the exposure of the soil to the elements. They attributed the east-west Redwood Creek basin differences in specific conductivity to the regoliths, the west side regolith of schistose being more resistant to weathering than the unmetamorphosed regolith of the east basin. The values measured were well below deleterious levels affecting aquatic organisms (U. S. Environmental Protection Agency 1976). Bradford and Iwatsubo (1978) reported a mean specific conductance of 80.2 µmhos at 25 °C for the Redwood Creek drainage basin from combined 1975 and 1976 data. This value is not comparable with the value determined from this study, 133 µmhos, as it includes Redwood Creek sample stations and year-round measurements. However, the maximum and minimum values they measured, 295 and 17 µmhos, respectively, are similar to the maximum and minimum values measured in this study, 362 and 42 µmhos, respectively.

Flow

Baseflow, a component of stream discharge, constitutes the major portion of discharge during the dry season (Bradford and Iwatsubo 1978). Baseflow is water that percolates into the ground and reemerges over a long period of time. The discharge patterns of the basin showed the westside basin greater than that of the eastside, and Prairie Creek basin the highest of all. Based on qualitative observations, Janda et al. (1975) inferred that the east-west difference of flows was due to the underlying geology. The tributaries of the westside, the schist terrain, sustained higher base flows than the east side, with its less metamorphosed sandstones and siltstones. There are undoubtedly other influences including climate, aspect, summer rainfall, vegetation, and land use activities.

Drift Organisms

The importance of invertebrate drift as food for fish is well established (Waters 1969, Griffith 1974, Gibson and Galbraith 1975, and Mancini et al. 1979). Elliot (1970) reported drift is heavily utilized by salmonid fry, and thus it is an important component of the nursery habitat. Stream drift is an indicator of water quality (Larimore 1974) and can also be used as a measure of invertebrate production. Waters (1961 and 1972) reported that invertebrate drift and standing crop appear higher in more productive streams. It should be noted that other factors such as light, life stage, temperature, and physical disturbances influence drift.

Drift Density

The east side streams of the basin were judged to have more solar insolation. Stream temperature is largely a function of insolation striking the water surface (Beschta, et al. 1987). Higher stream temperatures of eastside streams are an indication of this relationship. Hawkins, et al. (1982) reported that in Oregon Cascade streams during the summer-fall period, streams without shading had higher abundances of invertebrates. Murphy, et al. (1981) reported similar findings, with higher numbers of drift organisms in streams where the canopy had been removed. In the drift densities of the study streams, this was not the case. Three of the four westside Redwood Creek sampled tributaries and the westside Prairie Creek tributary had greater drift densities than their respective paired eastside tributary. Even the streams with the most open vegetation canopy, Redwood and Lacks Creeks, did not have greater drift densities than some of the streams with closed or partial canopies. Overall, the relationship between drift density and maximum measured temperature was very poor and almost nonexistent. Other factors must have been influencing drift density.

Alkalinity and productivity of a stream are related (Waters 1961 and Krueger and Waters 1983). Greater stream productivity generally corresponds with greater alkalinity. In this study, using drift density as a measure of productivity, the relationship was a weak negative one. The weakness of the relationship was probably caused by the low alkalinity values in the system and a small sample size. A wider range of alkalinity and drift density values were absent in the system and thus did not illustrate the association better.

Stream sediment also influences invertebrate abundance. Iwatsubo and Averett (1981) found that abundance appeared to decrease with the decrease of particle size. Cordone and Kelly (1961) established the fact that sediment is harmful to streams. The effect of sedimentation on the abundance of invertebrates was not documented in this study. No sediment sampling was done. Hawkins et al. (1982) did show that canopy type was more important than substrate composition in determining invertebrate abundance.

Terrestrial Contribution to Drift

The pattern of terrestrial contribution to the drift on the westside of the basin was evident. The percentage contribution to the drift was at least twice that in the eastside streams. This could be attributed to more overhead canopy on the westside of the basin. The eastside, particularly in the upper basin, was more open and prairies were major vegetation types. You could assume that if the canopy was a major source of terrestrial invertebrates, the greater the overhead canopy, the greater the terrestrial contribution, such as leafhoppers and aphids. However, no measurements of canopy density were taken, so this is conjecture.

Drift Composition

The change in drift organisms in terms of decreasing ephemeropterans and increasing dipterans from north to south is noteworthy. Two factors influencing the observed pattern of changes in drift composition may have been climate (Committee on Water Quality Criteria 1972) and canopy (Hawkins, et al. 1982). Both have been shown to influence the composition of aquatic communities. Similarly, these and other physical-chemical variables may influence the occurrence and distribution of certain taxa. Environmental tolerance quotients (Platts, et al. 1983) for Baetidae and Heptageniidae, and the order Ephemeroptera as a whole, were smaller than those of the dipterans Chironomidae, Dixidae, and Simuliidae, signifying a lesser tolerance to environmental conditions. Environmental tolerances could also explain why some taxa occurred only in certain areas.

Richness

When the terrestrial taxa were subtracted and the remaining fauna included only aquatic species, an east-west pattern was not as evident. In the Prairie Creek system, the pairs had equal numbers of taxa. Of the four mainstem pairs, one pair had an equal number of taxa, two pairs had the greater number of taxa on the westside, and one pair had the greater number of taxa on the eastside. However, when the aquatic and terrestrials were combined, all the westside streams had more taxa represented in the samples than their eastside pairs (Table 9). The number of taxa represented was an indicator of conditions present (Warren 1971). The higher the number of taxa present, the better and more stable the environment, and conversely the lower number of taxa present, the poorer the conditions. This relationship has been dramatically seen in point source disturbances, (ie. sewage outfalls), where upstream and downstream comparisons were possible. In areas where entire watersheds have been altered, as in the Redwood Creek basin, such comparisons are not possible. Richness may however suggest that in the Redwood Creek basin, the westside streams had better conditions.

Diversity Index

Diversity index values measured in the streams were only compared with the other study streams. No comparisons were made with any other regions or studies. Hughes (1978) stated that when comparing index values of other workers, the sampling method, time of year, and taxonomic level used in calculating the index are some of the factors that influence the values derived. For these reasons no other comparisons were made.

The value of the diversity index is greatest in unpolluted and nondisturbed rivers and lower in polluted and disturbed rivers (Wilhm and Doris 1968). Iwatsubo and Averett (1981) found in tributaries being logged in the Redwood Creek basin, diversity was significantly lower than the control streams, but not significantly different between controls and regenerating streams.

The connotation of better environmental conditions on the west side based on richness was not borne out by the diversity indexes of the drift samples. The eastside basin tributaries had significantly greater diversities, except Mill Creek, than the westside basin tributaries. This was true for the indices computed with and without the terrestrial components. Using this index, it could be said that in individual comparisons between east and west paired tributaries, eastside paired tributaries were in better condition. However, when taken as a whole, mean eastside diversity versus mean westside diversity, the difference was nonsignificant, and as such one can not say with certainty what is actually happening in the basin. Sampling more adjacent streams to obtain a larger sample size could illustrate basin trends better.

Comparisons of individual creeks with different environmental conditions, such as Little Lost Man and Redwood, however, do reveal diversity differences. The Redwood Creek site had the lowest values of number of taxa, diversity, and evenness. Little Lost Man Creek had the highest diversity and some of the higher taxa and evenness values.

Similarity Index

Another method to distinguish differences between the invertebrate samples was the similarity index measuring differences in composition. Generally the comparisons between streams were about the same, except for Redwood Creek. Redwood Creek was least similar in comparison to the others, having the lowest indices of similarity. The open canopy, and higher temperatures most likely affected these differences. When compared to the relatively undisturbed Prairie and Wolf Creeks, the differences were evident.

Fish

Fish distribution patterns in the basin indicated that the longer and heavier juveniles were in the westside tributaries. Rimmer (1985) in a study of underyearling rainbow trout and reduced discharge found that fish were smaller in channels with the least discharge. However, his results may have been affected by the differences in population densities in the channels. This study showed that 0+ steelhead fork length and discharge have a strong positive and significant correlation. This relationship would explain the differences in mean sizes and weights between the east and west basins.

The number of fish and salmonid grams per m2 were variable and no geographical patterns were evident. Burns (1971) in studies of northern California streams found that the natural variation of rearing populations can vary as much as 50 percent from year to year. Slaney and Northcote (1974) reported the relationship of prey abundance and fish density, with higher prey levels resulting in higher densities of 0+ rainbow trout. The relationship was a weak negative one in this study. The positive relationship between levels of drift and salmonid biomass described by Gibson and Galbraith (1975) was a weak and negative one for the data collected from the Redwood Creek basin. The amount of drift did not seem to be a large factor in determining the streams carrying capacity for fish.

Murphy et al. (1981) and Hawkins et al. (1983) both reported that salmonid density and biomass were greater in streams without riparian vegetation when compared with shaded streams. As no canopy measurements were taken, and since stream temperature is largely a function of insolation, it could be inferred that maximum water temperature is related to the degree of canopy openness present in the study sites. Thus, maximum water temperature could be used to relate fish density (fish numbers per m^2), and salmonid biomass (g/m^2) to canopy cover.

The relationships were positively correlated but not significant. Qualitatively, some of the more open streams such as Lacks and Redwood Creeks exhibited high values of fish density and biomass. However, some of the creeks with partially open canopies exhibited high values too.

Conclusions

This study has shown the character of each stream as a single entity, has determined baseline rearing habitat conditions, can serve as the basis for future evaluation of the rearing habitat and watershed rehabilitation efforts, and can help indicate the form of active management to improve production of fish.

The juvenile salmonid habitat of the Redwood Creek basin was highly variable, exhibited east-west patterns, and supported fish. The basin summer-fall rearing habitat is occupied primarily by 0+ steelhead, the larger fish observed on the west side of the basin. Stream discharge is generally lower on the eastside of the basin and in the upper basin. Water temperatures were generally warmer in eastside mainstem tributaries. No upper lethal temperatures were measured in the tributaries, but above preferred levels were present and common in some of the basin sections. Redwood Creek water temperatures were generally above preferred temperature levels with some upper lethal temperatures in the middle basin.

With so many variables in the natural system, it is difficult to partition out and explain everything satisfactorily, and still know what exactly is happening. When controlled laboratory experiments are done to eliminate or control variables, some of the complexity is removed, but the resulting conditions do not truly mirror the actual environment in nature. Further research on Redwood Creek basin rearing habitat would be to determine smolt production in conjunction with stream habitat measurements. This can be accomplished by trapping down-migrating fish in smolt traps. The more smolts captured from a stream would indicate the rearing habitat present provided the necessary requirements for juvenile fish to survive and grow to smolt size in the stream. Conversely, the number of juvenile fry migrating out of the stream would indicate rearing habitat is limiting and the stream carrying capacity had been attained. In addition to the variables measured in this study, habitat-typing the physical features of streams; pools, riffles, and flatwater areas, and relating them to the fish standing crop and smolt production would provide information on rearing habitat conditions that maximize smolt production. If in-stream rehabilitation is undertaken, those natural stream conditions determined from the relationships to enhance rearing habitat and smolt production can be duplicated in degraded streams.

In most of the comparisons made between the eastside and westside tributaries of mainstem Redwood Creek, Tossup and Mill Creeks did not exhibit the same patterns as the other four east-west paired tributaries. Mill Creek, an eastside tributary, had lesser values of drift individuals, diversity and evenness, and greater 0+ steelhead mean fork lengths and weights, and drift density than Tossup Creek, a westside tributary. What caused these differences is unknown. It could have been discharge, as the discharge of Tossup was less than that of Mill, 8 l/s (0.29 cfs) versus 12 l/s (0.41 cfs). All the other westside sample site discharges were greater than their paired eastside tributaries. Discharge may influence the variables. One other conjecture is human activity unbeknownst to us when conducting the study. The two streams, Mill and Tossup, located in the Redwood Valley are relatively accessible to people with vehicles. They are located next to the county road. The other streams studied including those in the Prairie Creek Redwoods State Park, Redwood National Park, and the private timber lands required some hiking, keys to gates, and/or permits to gain access.

In respect to the basin management, hasty decisions should not be made if conditions found such as high temperatures are deemed deleterious. Fish densities in the warmer streams may be the same if not greater than those of other streams thought to be at an ideal temperature. However, the long-term effects of less than optimal conditions in Redwood Creek basin are uncertain, and may affect the fish. The long-term exposure to these less than optimal conditions may be one of many causes contributing to the decline of the Redwood Creek fishery resources. Attempting to determine the impacts of an environmental perturbation, or as in the Redwood Creek basin, monitoring its recovery from information gathered from only one or two streams and applying these data to others may be invalid. A basinwide survey is appropriate to determine patterns within the basin and monitor its recovery over time.

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