SUMMER WATER TEMPERATURE CONDITIONS IN THE EEL RIVER SYSTEM, WITH REFERENCE TO TROUT AND SALMON

by

Paul F. Kubicek

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

August, 1977

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IN THE EEL RIVER SYSTEM
WITH REFERENCE TO TROUT AND SALMON

Approved by the Master's Thesis Committee

John W. DeWitt, Chairman

Charles M. Rosse

Terry D. Roelofs

D W Kedrick

Approved by the Graduate Dean

Alba M. Gillespie

ACKNOWLEDGEMENTS

I extend my gratitude to the many persons who encouraged and helped me during this study. The study was suggested by Dr. John W. DeWitt. He, Dr. Terry D. Roelofs, and Charles M. Roscoe, the members of my thesis committee, gave me guidance and advice throughout the study and critically reviewed the manuscript. Personnel of the United States Geological Survey in Eureka and Santa Rosa and personnel of the California Department of Water Resources in Red Bluff provided me with access to their data files. N. Frank Kubicek, Phil Kubicek, Mary Loquvam, and Joel Loquvam assisted on backpack trips. Didi Dempster provided constant inspiration and assisted with typing. The San Francisco Tyee Club helped me finance this study with a scholarship award.

ABSTRACT

During the past few decades, it has become apparent that there is a summertime water temperature problem that may be limiting the well-being of salmonids in the Eel River system of California. It was the objective of this study to determine, from a water temperature standpoint, the locations and amounts of suitable habitat available to native anadromous and resident salmonids in the main stems of the Eel River system during the summer.

Water temperatures were measured with hand thermometers at 179 stations during the summer of 1973. Additionally, temperature data were collected from 30 thermographs. Temperatures measured with hand thermometers and the times at which they were measured were compared with records of nearby thermographs to estimate probable maximum water temperatures at all stations. The main stems of the system were divided and classified into stream sections having similar temperature conditions with respect to suitability of habitat for native salmonids.

Stream sections reaching a maximum temperature of 28.0 C or greater for at least 100 continuous minutes were classified as "lethal" (i.e., considered to cause total mortality

of exposed salmonids). Stream sections reaching a maximum temperature from 26.5 C up to, but not including, 28.0 C for at least 100 continuous minutes were classified as "marginal" (i.e., considered to cause the mortality of at least some of the exposed salmonids). Stream sections reaching a maximum temperature of less than 26.5 C were classified as "satisfactory" (i.e., not considered to directly cause the mortality of salmonids).

Of the total of 444.0 miles of stream surveyed, 196.25 miles (44.2 percent of the total) were classified as lethal; 96.25 miles (21.7 percent of the total) were classified as marginal; and 151.5 miles (34.1 percent of the total) were classified as satisfactory. Observations of the distribution and abundance of salmonids supported the temperature classification system.

The major factors influencing stream temperature and the effects of high water temperature on salmonids are discussed. However, it was not possible, nor was it the purpose of this study, to gather enough information on stream area conditions to be able to precisely explain the causes of the observed stream temperature conditions, section by section.

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INTRODUCTION

The Eel River system has long been considered a good producer of steelhead-rainbow trout, *Salmo gairdneri* Richardson, coho salmon, *Oncorhynchus kisutch* Walbaum, and chinook salmon, *Oncorhynchus tshawytscha* Walbaum. The records of past runs of these fish over the Benbow Dam and Cape Horn Dam fish ladders, as well as other evidence, support this view. During the 36-year period from 1938 to 1973, annual spawning escapements estimated for steelhead, coho salmon, and chinook salmon in the Eel River averaged 91,000, 24,000, and 60,000, respectively (Lee and Baker 1975). In California, the Eel River ranks second in steelhead and coho salmon production and third in chinook salmon production; its sport fishery is the second largest in northwestern California (California Department of Fish and Game 1965a and 1965b).

During the past decade, however, there apparently have been substantial declines in the sizes of the spawning runs of steelhead and salmon in the Eel River system. The apparent declines have been attributed to poor watershed management practices such as careless logging, extensive road building, and overgrazing by livestock (California Department of Fish and Game 1968). Natural occurrences, such as the extreme flooding that has occurred several times in the past three decades, may also have contributed to the problem.

Although no clear evidence has been developed to prove that there has been a change in the water temperature regimes of the Eel River system that might have accounted partly for any decline, it seems entirely possible that such a change has occurred. Stream temperatures adverse to native salmonids were reported as early as 1938 (Wales 1938) and were attributed to man-made causes (Shapovalov 1939 and 1941). In recent years, water temperatures above or near lethal levels for salmonids have been recorded during the summer months at several locations in the system (United States Geological Survey 1961-1963 and 1964a-1973a; Puckett and Van Woert 1972).

The thermal requirements of fish and the effects that temperature may have on fish have been reviewed by numerous researchers (Belding 1928; Fry 1947; Brett 1956, 1959, and 1970; Jones 1964; Mihursky and Kennedy 1967; Dunham 1968; Lantz 1971; Snyder and Blahm 1971; Sylvester 1972a; Brown 1974). High water temperature may act as a lethal factor and exert limiting effects on the distribution of fish in a stream. Sublethal effects of high temperature can also exert considerable control on the distribution and success of a species. Detrimental effects of high water temperature may include mortality, decreased metabolic scope for activity, decreased food utilization and growth rates, reduced resistance to disease and parasites, increased sensitivity to some toxic materials, interference with migration, reduced ability of a species to compete with a more temperature-resistant species, and increased vulnerability to predation.

A knowledge of the life histories of steelhead and salmon in the Eel River system is necessary to understand the potential effects of high summer stream temperatures on their well-being. Fall- and winter-run salmon and steelhead enter the river from late summer to late winter and move upstream to spawn in suitable areas from late fall to early spring. A small run of summer steelhead enters the river in the spring and spends the summer resting in upstream pools until spawning the following winter or spring. The eggs of steelhead and salmon incubate for a few weeks to several months, depending on several environmental factors, and they generally hatch in the spring. Juvenile chinook salmon migrate to the ocean by midsummer of their first year of life. Juvenile coho salmon, however, spend an entire year in freshwater, and juvenile steelhead spend one or more years in freshwater. The downstream migration by the young of all three species occurs primarily from spring to mid-summer.

At least one life stage of each native anadromous salmonid species can be found in the Eel River system during a portion of the summer months and, thus, may be exposed to high water temperatures. Juvenile steelhead, juvenile coho salmon, and adult summer steelhead (all of which spend at least one entire summer in the Eel River system) are the forms expected to be affected most by high stream temperatures. These forms need suitable thermal conditions in streams throughout the summer in order to complete their life cycles.

In addition to anadromous salmonids, small numbers of resident rainbow trout occur in headwater areas of the Eel River system. These trout complete their entire life cycle in freshwater, and thus, some of them may also be affected by high summer stream temperatures.

Due to the great ecological importance of water temperature and the indication that a summertime water temperature problem exists in the Eel River system, a study to examine summer thermal conditions with reference to trout and salmon was deemed desirable. The study was conducted during the summer of 1973. Thermal conditions were examined primarily in the main stems of the system. Streams were classified by section as to their general suitability for trout and salmon from a water temperature standpoint; the classifications employed were "lethal", "marginal", and "satisfactory."

It was not the purpose of this study to attempt to determine the exact causes of the observed water temperature conditions; a complete analysis of this would have to involve extensive data on stream shading, rates of insolation, air temperature, ground water accretion, tributary temperatures and flows, and data on hydrological and geological configurations that bear on the heating of water. However, factors that influence stream temperatures are discussed, and a thorough discussion of the possible significance and implications of summertime water temperature conditions in the Eel River system is presented. The detailed observations made on stream and stream area conditions and fish distribution and abundance in each stream section are provided in the appendix.

STUDY AREA

The Eel River system (Figure I) has been described by the California Department of Fish and Game (1965a), California Department of Water Resources (1966), and Brown and Ritter (1971).

The system is located in northwestern California in parts of Humboldt, Mendocino, Trinity, Lake, and Glenn counties. The drainage area of the system is approximately 3,700 square miles, and the elevation varies from sea level to 7,600 feet. The Eel River originates on the slopes of Bald Mountain and flows south through Lake Pillsbury, west to Van Arsdale Reservoir, and northwest approximately 100 miles to the Pacific Ocean at a point 15 miles south of Eureka. The major tributaries to the Eel River include the Middle, North, and South Forks of the Eel River and the Van Duzen River. Their respective drainages are 753, 283, 690, and 428 square miles.

The topography of the system is characterized by long, rugged, steep-sided canyons. The Eel River and its major tributaries are of steep gradient only in their extreme headwaters and are of moderate gradient throughout most of their lengths. Smaller tributaries are of steeper gradient,

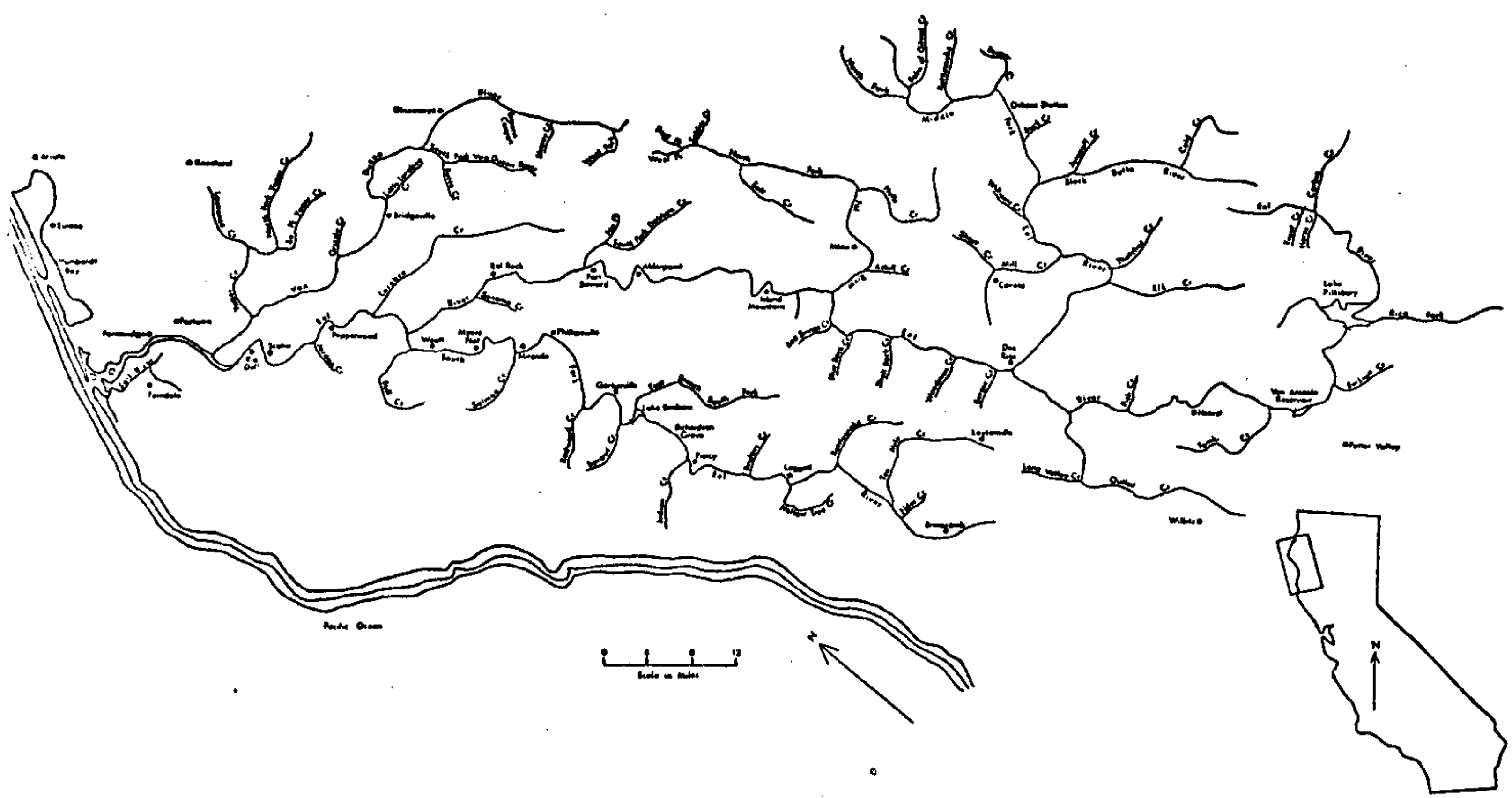

Figure I. Eel River system.

and many follow short, tortuous routes to the main streams. Flood plains begin to appear in the middle and lower portions of major tributaries of the system and progressively widen on the main stem to extensive gravel bars as the river approaches the coast.

Run-off from the Eel River system averages 6,300,000 acre-feet annually. Streamflow is highly responsive to rainfall, which is concentrated in the winter months. Average annual precipitation in the system is approximately 60 inches. Run-off is rapid, and there is a wide variation between winter and summer flows. Many streams which flow continuously through winter, often flooding, become dry or intermittent during the summer.

The climate of the Eel River system has been described as Mediterranean with subregional variations (California Department of Water Resources 1966). The watershed can be divided into three general climate zones. A Mediterranean cool summer with fog extends from the mouth of the Eel River in a band southward along the western edge of the watershed. This zone, known as the "fog belt", contains the lower portions of the Eel and Van Duzen Rivers and much of the South Fork Eel River. Winters are mild and wet. Summers are cool and foggy. Fogs reduce incoming solar radiation and increase precipitation efficiency.

A Mediterranean cool summer without fog is found directly east of the "fog belt" and covers most of the Eel River system. Due to the changing topography and increased distance from the coast, wider temperature ranges occur in this zone. Most of this area receives some snow, which accumulates only at the higher elevations in the eastern part of the watershed. Summers are usually hot and dry.

A Mediterranean warm summer occurs in an oval-shaped area encompassing the Eel River from Island Mountain to Fort Seward and in a circular area containing Covelo and the lower portion of the Middle Fork Eel River. This climate zone is similar to that found over most of the Sacramento and San Joaquin Valleys, but with a greater amount of winter precipitation. Summers are hot and dry.

The distribution of vegetative types in the Eel River system forms four roughly defined and discontinuous belts running in a northwest-southeast direction (California Department of Water Resources 1966). Along the western side of the watershed coinciding with the "fog belt" region, grow forests of coast redwoods, Sequoia sempervirens. The redwoods are concentrated in a large area surrounding the lower reaches of the Eel and Van Duzen Rivers and occupy most of the western drainage of the South Fork Eel River.

The forest belt directly east of the redwoods, extending from Kneeland south through Willits, is predominently Douglas fir, *Pseudotsuga taxifolia*, but includes grasslands and scattered stands of pines, *Pinus* spp.

The third belt of vegetation is generally a woodland-grassland vegetative group. It is less readily defined but includes a variety of hardwoods, mixed conifers, and chaparral in the central and southern parts of the watershed.

The fourth vegetative belt consists of pines and Douglas fir. This forest type covers the higher elevations of the eastern and southern parts of the watershed, extending over the headwaters of all the eastern drainage.

METHODS

Data Collection

Water temperatures were measured with pocket thermometers to the nearest 0.5 C at stations throughout the Eel River system during three separate watershed-wide sampling periods in the summer of 1973. The thermometers were checked against laboratory reference thermometers for accuracy before and after each sampling period and were found to be accurate to within 0.5 C. All temperatures were read while the bulb of the thermometer was being shaded and immersed in running water. Moore (1967) reported that temperatures measured in running water were closely representative of the mean temperature of the stream cross-section. Temperatures at the bottom of pools and other deep areas of the stream were measured while skin-diving.

The first watershed-wide sampling period was June 20 to June 25. During this period, locations of temperature sampling stations for subsequent sampling periods were established. The second and third sampling periods were July 20 to July 26 and August 17 to August 24, respectively. Water temperatures were generally measured at the established stations during these sampling periods; however, some additions and deletions of stations were necessary to better cover the entire watershed.

The locations of temperature sampling stations were primarily based on accessibility. Portions of the watershed that were not easily accessible were not feasible to sample from temporal and monetary standpoints. Temperature sampling stations were established every 1 to 3 miles along stretches of stream that were paralleled by public roads. In less accessible areas, stations were established whereever it was possible to reach the stream by car or short hike. Some less accessible stream sections were hiked for short distances during the watershed-wide sampling periods, and stations were established periodically.

The largest sampling effort was applied to the main stems of the Eel River system. Tributaries to the main stems were sampled where access and time permitted. Where possible, temperature sampling stations were located immediately above and below major tributaries on the main stems and in the tributaries themselves.

During the three watershed-wide sampling periods, a section of stream that could be covered easily by car in one day was surveyed. Two temperatures, usually one in the morning and one in the afternoon, were recorded for each station in that section. Temperatures were measured at successive stations in either an upstream or downstream direction in the morning and in the reverse direction in the afternoon. The time at which each temperature was measured was recorded. Several water temperature measurements were actually made at each station for any one time recorded. Temperatures were measured a few hundred feet upstream and downstream from the immediate sampling station to obtain a more representative measurement of temperatures in each stream section.

In addition to the areas sampled during the three watershed-wide sampling periods, two less accessible areas were surveyed while backpacking. The main stem of the Eel River from confluence with the Middle Fork at Dos Rios to Island Mountain was surveyed from July 31 to August 3. The Middle Fork from Osborn Station to Mill Creek was surveyed from August 28 to August 31. Temperatures were measured periodically with hand thermometers during both trips.

Figure II shows the locations of all stations sampled during the three watershed-wide sampling periods and two backpack sampling periods.

During the summer of 1973, personnel of the United States Geological Survey (USGS) monitored water temperatures in the Eel River system with ten thermographs. USGS

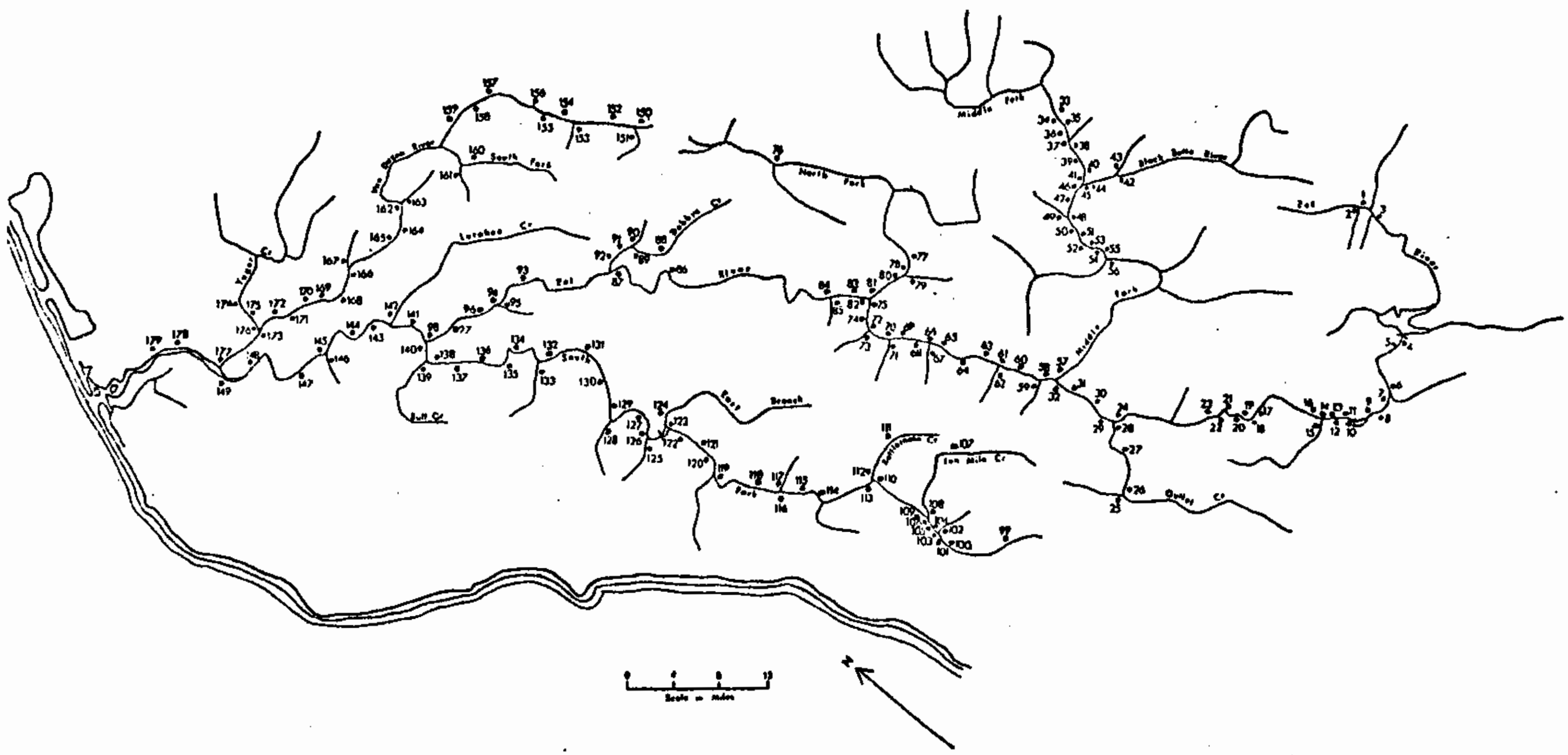

Figure II. Locations of water temperature stations in the Eel River system during the summer of 1973.

thermographs went unchecked for up to two months at a time; consequently, malfunctions could go unnoticed, resulting in a lack of temperature data for some thermograph sites during portions of the summer. To supplement USGS thermographs, personnel of the California Department of Water Resources (DWR) monitored temperatures with six thermographs during the summer of 1973. DWR thermographs were checked every 2 weeks, resulting in better temperature data with fewer gaps. From July 18 to August 10, personnel of the DWR set an additional 13 thermographs in the main stem of the Eel River from Van Arsdale Reservoir to Fish Creek to determine effects of variation in flow releases from Van Arsdale Reservoir. In addition to USGS and DWR thermographs, one personal thermograph was set at Island Mountain and was checked every 2 to 3 weeks. Figure III shows the locations of all thermographs in operation during at least a portion of the summer of 1973.

Environmental factors that influence stream temperature and that might be responsible for differences in temperature regimes in different sections of the watershed were noted and recorded at each temperature station. Environmental factors included: weather conditions, air temperature, shading from vegetation and land masses, water surface area exposed, stream depth, streamflow, stream velocity, stream

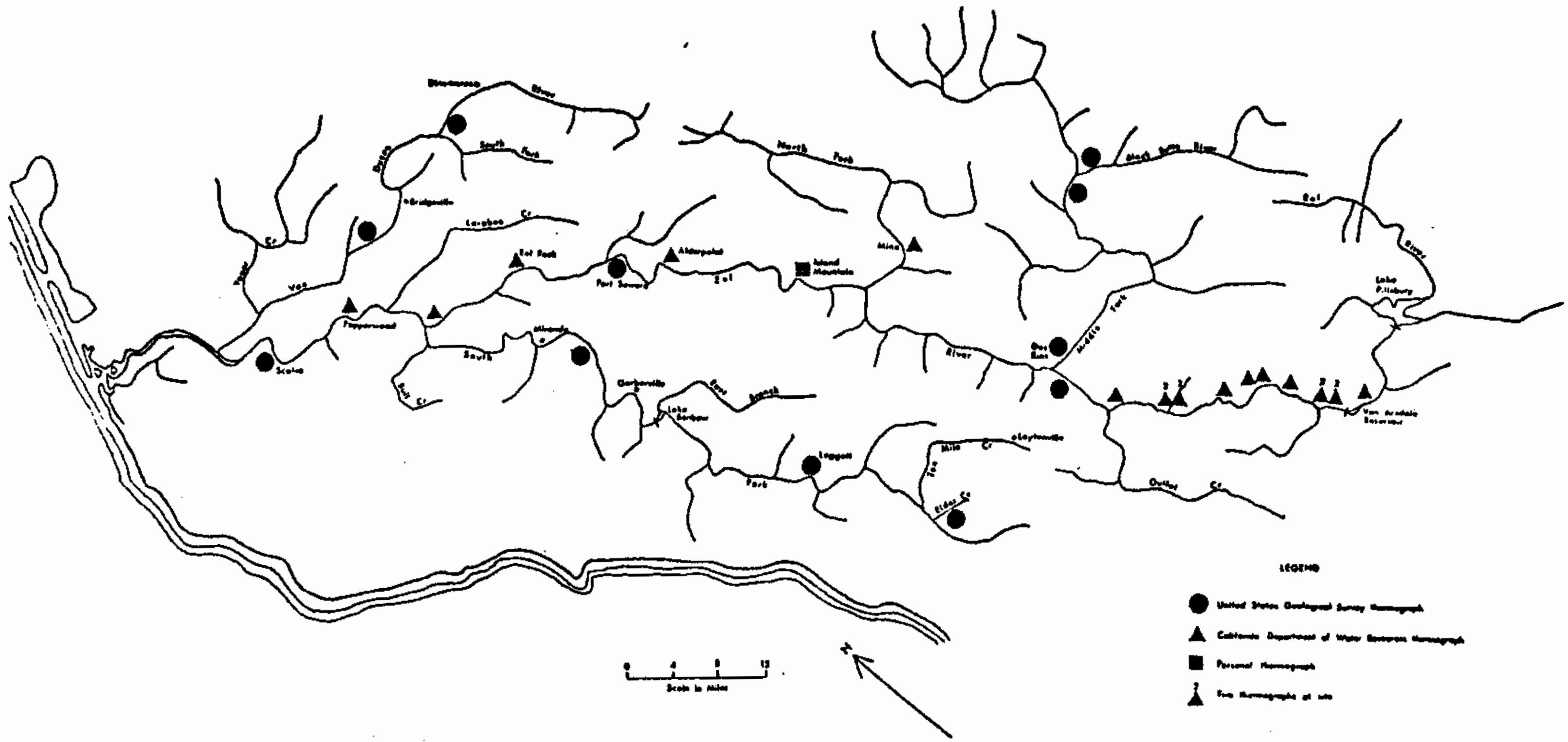

Figure III. Locations of thermographs in the Eel River system during the summer of 1973.

gradient, elevation; location, amount, and temperature of spring and tributary flows; and man-made influences. All of these observations were qualitative in nature except air temperature, which was measured prior to water temperature measurement at each station. Additionally, air temperature data collected by National Oceanic and Atmospheric Administration (1973) at various points in the watershed and streamflow data collected by USGS (1973b) at various gaging stations were utilized.

The distributions and relative abundances of fish species, particularly with respect to observed water temperature, were noted throughout the summer. All observations were made at streamside or while skin-diving.

Data Analysis

For each day that a water temperature was measured at a specific station, a daily maximum and a daily minimum water temperature were estimated for that station. This was accomplished for any single day in the following manner. Hand thermometer temperature measurements and times at which the temperatures were measured at a station on a single day were compared with the same day's data from the nearest thermographs. Through this comparison, the daily maximum and minimum temperatures at the station were interpolated.

Environmental factors that might influence stream temperature and be responsible for differences in the temperature regimes between stations and thermographs in different sections of the watershed were taken into consideration during the temperature estimation process.

Upon completion of the daily maximum and minimum temperature estimations, a maximum water temperature for the entire summer of 1973 was estimated for each station. This was accomplished in the following manner. Daily maximum temperatures estimated at each station on sampling days were compared with the daily maximums recorded at nearby thermographs during the entire summer. Through this comparison, the maximum summer temperature at each station was interpolated. Again, environmental factors that might cause differences in the temperature regimes of the stations and the thermographs were taken into consideration during the temperature estimation process. Similarly, a highest minimum temperature for the entire summer was estimated for each station.

Maximum temperatures that were recorded during the summer of 1973 and those that were estimated during the present study were compared with past temperature records of Puckett and Van Woert (1972) and USGS (1961-1963 and 1964a-1972a).

Such a comparison was made to determine if stream temperature conditions during the summer of 1973 were typical of conditions during past summers.

Major streams of the Eel River system were divided and classified into stream sections having similar temperature conditions with respect to suitability of habitat for salmonids. If temperatures determined at two successive stations in the watershed were the same or at least considered to have the same limiting effects on salmonids, temperatures between these stations were assumed to be not greatly different. The temperature classification system was based on a review of the literature concerning the effects of high temperatures on salmonids. Stream sections reaching a maximum summer temperature of 28.0 C or greater for at least 100 continuous minutes were classified as "lethal" (i.e., considered to cause total mortality of exposed salmonids). Stream sections reaching a maximum summer temperature from 26.5 C up to, but not including, 28.0 C for at least 100 continuous minutes were classified as "marginal" (i.e., considered to cause the mortality of at least some of the exposed salmonids). Stream sections reaching a maximum summer temperature less than 26.5 C were classified as "satisfactory" (i.e., not considered to directly cause the mortality of salmonids).

RESULTS

Of the total of 444.0 miles of stream surveyed, 196.25 miles (44.2 percent of the total) were classified as lethal; 96.25 miles (21.7 percent of the total) were classified as marginal; and 151.5 miles (34.1 percent of the total) were classified as satisfactory (Table 1). It should be pointed out that the values listed in Table 1 represent the main stems of the Eel River system and do not reflect the stream mileage of tributaries.

Stream sections classified as satisfactory were generally the headwater areas of all major streams and the downstream portions of the system contained in the "fog belt" (Figure IV). In headwater areas, excellent shading was provided by streamside vegetation, forests, narrow and steep-sided stream canyons, and adjacent land masses; many springs and tributaries supplied cool water; streambeds were narrow; and stream velocity was rapid. Satisfactory temperatures found in the "fog belt" area can be attributed to the influences of the cooler, foggy coastal climate.

Stream sections classified as lethal were generally the middle portions of the major streams in the system (Figure IV). Such stream sections received little shading due to

Table 1. Total number of stream miles estimated to fall within each temperature classification in each of the main streams of the Eel River system.

Stream	Lethal[a]	Marginal[b]	Satisfactory[c]	Total
Eel River	94.0	32.5	57.0	183.5
Middle Fork Eel River	30.25	2.25	30.0	62.5
North Fork Eel River	26.5	*	*	26.5
South Fork Eel River	36.0	41.5	20.5	98.0
Van Duzen River	9.5	20.0	44.0	73.5
Total	196.25	96.25	151.5	444.0
Percentage of total miles	44.2	21.7	34.1	100.0

[a] Maximum summer temperature estimated to be 28.0 C or greater.

[b] Maximum summer temperature estimated to be from 26.5 C up to, but not including, 28.0 C.

[c] Maximum summer temperature estimated to be less than 26.5 C.

* Upper portions of the North Fork were not examined.

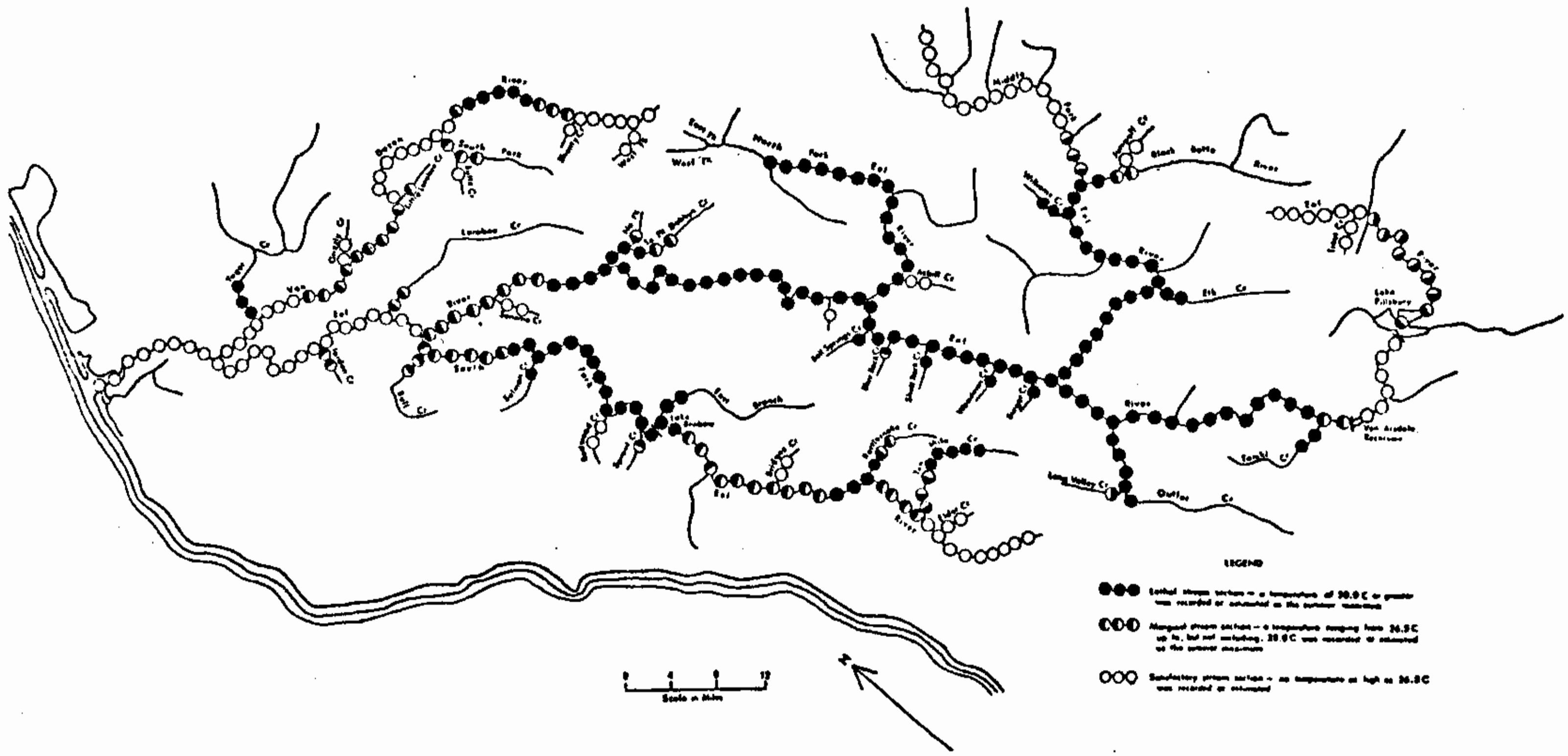

Figure IV. Classification of stream sections in the Eel River system based on the suitability of habitat for salmonids from a water temperature standpoint.

the wide nature of stream canyons, the sparseness of streamside and canyon slope vegetation, and the subdued nature of adjacent land masses; few cool springs or tributaries existed; streambeds were wide; and stream velocity was slow.

Stream sections classified as marginal were generally areas of increasing stream temperature found between satisfactory headwater sections and lethal sections, or areas of decreasing stream temperature found between lethal sections and downstream satisfactory sections in the "fog belt" (Figure IV).

Maximum stream temperatures estimated to have occurred in each stream section during the summer of 1973 and the classification of each section based on the suitability of habitat for salmonids, from a water temperature standpoint, are presented in Table 2. A map of the system illustrating the classification of all streams examined is presented in Figure IV.

Detailed stream temperature data collected during the summer of 1973 are presented in Appendices I, II, and III.

Stream temperatures measured with hand thermometers and the times at which they were measured are listed by station in Appendix I. Listed along with these data are the maximums and minimums estimated at each station for those days

Table 2. Estimated maximum stream temperatures and classification of stream sections in the Eel River system during the summer of 1973.

Stream Section (Station Numbers)	Estimated Maximum Temperature (C)	Classi-fication*
Eel River		
headwaters above Horse Creek (1)	25.0	S
Trout Creek		
at mouth (2)	21.0	S
Eel River		
between Horse Creek and Lake Pillsbury (3)	26.5	M
between Lake Pillsbury and Van Arsdale Reservoir (4-9)	19.0-22.0	S
between Van Arsdale Reservoir and Tomki Creek (10-14)	26.5-27.5	M
Tomki Creek		
at mouth (15)	28.0	L
Eel River		
between Tomki Creek and Outlet Creek (16-24)	27.5-30.5	L
Outlet Creek		
between Long Valley Creek and mouth (26-28)	30.0	L
Long Valley Creek		
at mouth (25)	26.5	M
Eel River		
between Outlet Creek and Middle Fork Eel River (29-32)	27.5-30.0	L
Middle Fork Eel River		
headwaters above Buck Creek (33-36)	24.0-25.5	S
between Buck Creek and 1.25 miles above Black Butte River (37-39)	26.5-27.5	M
between 1.25 miles above Black Butte River and mouth (40-41, 46-48, 50-57)	28.0-30.5	L
Black Butte River		
at Jumpoff Creek (42)	27.5	M
between 0.5 mile below Jumpoff Creek and mouth (44-45)	28.0-30.5	L

Table 2. (Continued)

Stream Section (Station Numbers)	Estimated Maximum Temperature (C)	Classification*
Jumpoff Creek at mouth (43)	23.5	S
Williams Creek at mouth (49)	30.5	L
Eel River between Middle Fork and North Fork Eel River (58, 60-61, 63-66, 68-70, 72, 74-75)	29.0-30.5	L
Burger Creek at mouth (59)	29.5	L
Woodman Creek at mouth (62)	28.0	L
Shell Rock Creek at mouth (67)	31.5	L
Blue Rock Creek at mouth (71)	27.0	M
Bell Springs Creek at mouth (73)	28.5	L
North Fork Eel River between Salt Creek and mouth (76-78, 80-81)	28.0-30.5	L
Asbill Creek at mouth (79)	25.5	S
Eel River between North Fork Eel River and Eel Rock (82-84, 86-87)	28.0-30.0	L
Unnamed stream 2.5 miles above Island Mountain - at mouth (85)	25.0	S
Dobbyn Creek between junction of North and South Forks Dobbyn Creek and mouth (91-92)	28.0-29.0	L

Table 2. (Continued)

Stream Section (Station Numbers)	Estimated Maximum Temperature (C)	Classification*
South Fork Dobbyn Creek		
between 2 miles above and 1 mile above mouth (88)	27.0-27.5	M
between 1 mile above mouth and mouth (89)	28.0-29.0	L
North Fork Dobbyn Creek at mouth (90)	27.0	M
Eel River		
between Eel Rock and South Fork Eel River (93-94, 96-98)	26.5-27.5	M
Sonoma Creek		
at mouth (95)	20.0	S
South Fork Eel River		
headwaters above Ten Mile Creek (99-101, 103-106)	24.5-26.0	S
Elder Creek		
at mouth (102)	19.5	S
Ten Mile Creek		
between Mill Creek and Grub Creek (107)	28.0-30.0	L
between Grub Creek and mouth (108)	26.5-27.5	M
South Fork Eel River		
between Ten Mile Creek and Rattlesnake Creek (109-110)	26.0-27.5	M
Rattlesnake Creek		
between Cummings Creek and 0.25 mile above mouth (111)	27.5	M
between 0.25 mile above mouth and mouth (112)	28.0-29.5	L
South Fork Eel River		
between Rattlesnake Creek and Hollow Tree Creek (113)	28.0-28.5	L
between Hollow Tree Creek and 1 mile above Lake Benbow (114-116, 118-121)	26.5-27.5	M
Bridges Creek		
at mouth (117)	26.0	S

Table 2. (Continued)

Stream Section (Station Numbers)	Estimated Maximum Temperature (C)	Classification*
South Fork Eel River between 1 mile above Lake Benbow and Myers Flat (122-123, 126-127, 129-132, 134)	28.0-29.5	L
East Branch South Fork Eel River 1 mile above mouth (124)	29.0	L
Sprowl Creek 0.25 mile above mouth (125)	26.5	M
Redwood Creek 0.5 mile above mouth (128)	25.0	S
Salmon Creek 0.5 mile above mouth (133)	29.0	L
South Fork Eel River between Myers Flat and mouth (135-138, 140)	27.0-27.5	M
Bull Creek at mouth (139)	26.5	M
Eel River between South Fork Eel River and mouth (141, 143-145, 147-149, 178-179)	24.0-26.0	S
Larabee Creek 0.25 mile above mouth (142)	26.5	M
Jordan Creek at mouth (146)	26.5	M
Van Duzen River headwaters above Shanty Creek (150-152)	24.0-25.5	S
Shanty Creek at mouth (153)	23.0	S
Van Duzen River between Shanty Creek and Browns Canyon (154-155)	26.5-27.0	M

Table 2. (Continued)

Stream Section (Station Numbers)	Estimated Maximum Temperature (C)	Classification*
Van Duzen River (Continued)		
between Browns Canyon and 1 mile below Dinsmores (156-158)	27.5-28.0	L
between 1 mile below Dinsmores and Little Larabee Creek (159)	26.0	S
South Fork Van Duzen River		
3 miles above mouth (160)	26.5	M
Butte Creek		
0.75 mile above mouth (161)	22.0	S
Little Larabee Creek		
at mouth (163)	27.0	M
Van Duzen River		
between Little Larabee Creek and Hely Creek (162, 164-166, 168-169)	26.0-27.0	M
Grizzly Creek		
at mouth (167)	25.0	S
Van Duzen River		
between Hely Creek and mouth (170-173, 177)	25.0-25.5	S
Yager Creek		
between 2 miles above mouth and mouth (174-175)	28.0	L
at mouth (176)	26.0	S

* L - lethal

M - marginal

S - satisfactory

on which temperatures were measured, and the maximum and highest minimum estimated at each station for the entire summer.

Daily maximum and minimum temperatures measured by the thermograph at Island Mountain are listed in Appendix II. Temperature data taken with all other thermographs in the Eel River system during the summer of 1973 can be obtained from USGS in Eureka and Santa Rosa, California (USGS 1973a) and from DWR in Red Bluff, California.

Temperature conditions in individual stream sections and observations of environmental factors that may be influencing stream temperatures are described by stream section in Appendix III.

The distributions and relative abundances of fish species corresponded closely with the classification of stream sections. Salmonids were most abundant in "satisfactory" sections. Salmonids were practically non-existent in "lethal" sections and were observed only in cool-water pockets created by spring inflow, tributary inflow, subterranean seepage, or thermal stratification. In "marginal" sections, the abundance of salmonids was intermediate between those in satisfactory and lethal sections. Nongame fish were relatively more abundant than salmonids in "lethal" stream sections and less abundant in "satisfactory" sections. General observations on the distributions and relative abundances of fish species are described by stream section in Appendix III.

DISCUSSION

Factors Affecting Stream Temperature

Factors that affect stream temperature include solar radiation, shading, weather conditions, air temperature, land mass temperature, water impurities, water surface area exposed, streamflow, stream depth, tributary and spring inflow, snowmelt, mixing of water masses, and the presence of impoundments (Sylvester 1963; Moore 1967).

The principal source of heat and the most important factor governing stream temperature is the amount of solar radiation received at the stream surface (Sylvester 1963; Moore 1967; Brown and Krygier 1970; Brown 1971). Solar radiation can account for 95 percent of the heat input to small, unshaded streams during midday in midsummer (Brown 1969). The most important factor regulating the amount of solar radiation received at the stream surface is shading (Brown 1971). Shading can be provided by vegetation, canyon slopes, land masses, clouds, and stream orientation (Moore 1967).

In the Eel River system, shading accounted for major differences in temperature conditions between stream sections. Those sections having the most extensive shading had the lowest temperatures. The headwater sections of the main streams and most small tributaries received extensive shading from streamside vegetation, vegetation on stream canyon slopes and ridge tops, steep stream canyon slopes, and land masses of adjacent ridges. As a result, such stream sections had satisfactory water temperatures.

Stream canyons in the drainage typically broadened in a downstream direction, and consequently, less shading was provided below headwater areas. Streamside vegetation was more scarce, particularly in those areas having extensive flood plains, and vegetation on the slopes of stream canyons provided less shading due to the generally sparser nature of the vegetation and the greater distance of vegetation from the stream. Additionally, canyon slopes were less steep, and adjacent ridges were subdued in downstream areas, providing less shading from land masses. In response to a reduction in shading, stream temperatures increased to marginal and lethal levels below headwater areas.

Although few stream sections below headwater areas received significant shading from vegetation and land masses, the lower portion of the drainage contained within the Mediterranean cool summer with fog or light fog climate zones received significant shading from clouds and fog. As a result, water temperatures decreased to satisfactory levels in this portion of the drainage.

Stream orientation can significantly affect shading of streams and, therefore, stream temperature (Moore 1967). The effect of stream orientation on the shading of a stream is closely related to the nature of the stream canyon and the angle of direct solar radiation. Because solar radiation strikes the Eel River system at an angle from the south, streams in canyons receive the most shading when oriented east-west.

Smith and Elwell (1961) reported that sections of the Middle Fork Eel River with a north-south orientation were subjected to more direct solar radiation and higher diurnal temperatures; sections with an east-west orientation reportedly received more shading in canyons during long summer days. Because most streams in the Eel River system flow through at least moderately narrow and moderately deep canyons, the observations of Smith and Elwell (1961) can be used to generalize for most of the system. It appears that the north-south orientation of most streams in the system reduces shading potential.

Stream temperatures in portions of the Eel River system may have been increased over the years by the removal of vegetation that at one time provided shading to streams. Streamside vegetation, as well as vegetation on stream canyon slopes and ridge tops, has been removed in portions of the system by extensive logging and road building. As early as 1941, high stream temperatures in the system were partially attributed to the increased exposure of streams to solar radiation caused by man (Shapovalov 1941). It is well documented that the removal of vegetation providing shading to a stream, may increase stream temperatures by allowing more solar radiation to reach the stream (Titcomb 1926; Greene 1950; Chapman 1962; Fisk et al. 1966; Levno and Rothacher 1967; Gray and Edington 1969; Hall and Lantz 1969; Meehan et al. 1969; Brown and Krygier 1970; Brown 1971; Kopperdahl et al. 1971).

Major floods in the system have also removed streamside vegetation and, consequently, may have increased stream temperatures. Levno and Rothacher (1967) reported that maximum water temperatures may increase as a result of dramatic exposure of a stream section following the scouring and removal of streamside vegetation by flood waters. Major floods have occurred in the Eel River system on the average of once every 3 to 4 years during the past 30 years (United States Army Corps of Engineers 1968). The two largest recorded floods occurred in 1955 and 1964. Local residents reported that streamside vegetation that once provided good shading in portions of the system was lost during the 1955 and 1964 floods and has not had the opportunity to re-establish itself due to the smaller recurring floods.

The type of vegetation growing on stream canyon slopes affects the amount of shading a stream section receives. In the Eel River system, the best shading was provided by Douglas fir and mixed conifer forests, which were generally located in headwater areas, and by redwood forests, which were located in the lower drainage and along much of the South Fork Eel River. The great height and dense stands of these trees provided extensive shading in narrow stream canyons and provided a significant amount of shading in portions of wider stream canyons. Extensive woodland-grass areas in the watershed provided little or no shading to streams due to the sparse nature and low height of the vegetation.

Although the most important process governing stream temperatures in the Eel River system was the amount of solar radiation striking the stream surface, the processes of convection, conduction, and evaporation played an important role in large sections of the system. These processes are mainly dependent upon the differences between water surface and air temperatures, wind velocity, and vapor pressure (Edington et al. 1968; Brown 1969). Under dense cover, changes in water temperature vary primarily with air temperature by convection (Levno and Rothacher 1967).

In headwater sections of the Eel River system, the amount of solar radiation striking the stream surface was limited by vegetation and land masses, and water temperature changed more greatly in response to air temperatures. In fog belt sections, incoming solar radiation was often limited by fog or clouds. Cooler air temperatures near the coast, cool afternoon winds, and increased water vapor in the air significantly cooled stream sections in the fog belt.

Close correlations were noted between maximum air temperatures measured by the National Oceanic and Atmospheric Administration (1973) at various points in the watershed and maximum water temperatures recorded by thermographs. Maximum summer stream temperatures were generally recorded during hot spells, when daytime and nighttime air temperatures were at or near their summer maximums on several successive days. This occurred even in exposed stream sections whose temperatures were governed primarily by the amount of solar radiation striking the stream surface. The close correlation found between air and water temperatures in such sections was largely due to the fact that solar radiation affects both air and water temperatures simultaneously (Moore 1967).

Stream surface area, depth, velocity, and flow were all important factors that contributed to temperature condition differences in the Eel River system. The amount of solar radiation absorbed by a stream (as well as the rate of heat transfer between the stream and the air above the stream surface) is a function of its exposed surface area (Sylvester 1963). The temperature change that occurs between two points on a stream is directly proportional to the surface area of the stream and the heat load applied between the two points (Brown 1970). Thus, a wide, shallow stream will heat up faster than a narrow, deeper stream with the same streamflow (Brown 1971).

The effect of streamflow on water temperature is related to the water surface area. As streamflow increases, it increases more rapidly than water surface area, and therefore, changes in water temperature resulting from varying conditions of solar radiation will be proportionally smaller for larger streamflows (Moore 1967; Brown 1971). When stream velocity is low, the water is exposed to solar radiation for a longer period of time; when low velocity is coupled with a smaller streamflow, the heating potential of solar radiation exerts a much greater effect, and water temperatures are higher (California Department of Fish and Game 1965a).

The headwater sections of main streams and most small tributaries in the Eel River system generally flowed rapidly over narrow streambeds with alternating riffles and deep pools. However, stream canyons broadened downstream, and stream gradients became considerably flatter. Streams tended to spread over a wider streambed and became shallower, and stream velocity was reduced. Thus, downstream sections had larger exposed surface areas, and stream waters were exposed to the sun for longer periods of time. Such stream sections tended to heat up faster and attained higher maximum temperatures, unless the increased exposed surface area and lower velocity were compensated for by shading or cooler climate. In general, moderate increases in streamflow below headwater areas did not significantly compensate for the larger surface areas and lower velocities.

Although streamflow decreased at all gaging stations continually during the summer, there was no clear correlation between increasing water temperature and decreasing streamflow as summer progressed. There was an indication, however, that maximum temperatures were magnified during hot spells by low streamflow late in summer. Thus, maximum summer stream temperatures may be expected to occur during a hot spell late in summer when streamflows are lower; higher maximum temperatures may be expected during low streamflow years.

It is possible that decreases in streamflow from historical levels in portions of the Eel River system may have increased stream temperatures. As early as 1941, high stream temperatures in the system were partially attributed to low streamflow caused by man (Shapovalov 1941). Numerous water diversions, the largest of which is located at Van Arsdale Reservoir, exist in the system. These diversions reduce streamflows and create the potential for higher stream temperatures.

The temperature, amount, and location of spring flow are major factors that can affect stream temperature. Streams that are largely spring-fed have little diurnal and annual fluctuations in temperature, and streamflow is better sustained in spring-fed streams (Moore 1967). Streamflow in the Eel River system during summer was primarily supplied by spring-fed headwaters and groundwater that became more limited as summer progressed. Snowmelt on the eastern boundary of the drainage was complete by summer and, therefore, did not contribute to summer streamflows.

Most streams in the system did not receive sufficient spring or groundwater inflow to either maintain cool temperatures below headwater areas or significantly cool large areas in lethal stream sections. Areas of greatest spring inflow were the satisfactory headwater areas of most of the main streams. Cool spring inflow in marginal and lethal stream sections formed scattered pockets of satisfactory water.

The subterranean seepage of stream water through gravel areas was found to cool lethal and marginal waters sufficiently to produce small pockets of satisfactory water temperature. Areas creating such cool water seepage included gravel areas between intermittent sections of streams, gravel bars forming sharp bends in streams, gravel bars separating two streams above their confluence, and gravel bars across the mouths of tributary streams.

Tributary streams can significantly affect the temperature of receiving streams. The influence of a tributary stream on the temperature of a receiving stream varies according to the relative temperatures and flows of the two streams (Brown 1971; Marlega 1971). In the Eel River system, tributaries had greatly varying degrees of influence on the temperatures of the main streams.

Tributary streams were most abundant in satisfactory headwater areas. During the summer, relatively few tributaries flowed into lethal and marginal stream sections. Tributaries to headwater stream sections and other satisfactory sections provided sources of cool water helping to maintain the satisfactory temperatures of these sections. Cool tributaries to lethal and marginal sections were not of sufficient size to reduce the temperatures of main streams to satisfactory levels, although they did form satisfactory plumes extending as much as two hundred feet downstream. Some tributaries to lethal and marginal stream sections were cooler than the main stream during the morning, but reached temperatures higher than those of the main stream in the afternoon; such tributaries helped maintain the temperature problem or worsen temperature conditions in the main stream.

Besides cool springs and tributaries, the thermal stratification of deep pools was found to produce limited areas of satisfactory water temperature within lethal and marginal stream sections. In thermally stratified pools, a strong temperature gradient exists between warm surface waters and cool bottom waters. In general, the warm surface water flows over cool stationary bottom water with little mixing. Thermal stratification can be partially created by the nature of the streambed at the head of the pool causing water to flow onto the surface of the pool offering little chance for mixing (Brown 1972). Pool depth is also an important factor that helps determine whether thermal stratification will occur. During the summer of

1973, thermal stratification was not personally observed in pools less than 8 feet in depth; Lee and Baker (1975) reported that stratification was not observed in pools less than 9 feet in depth.

California Departments of Fish and Game and Water Resources carried out a study in the summer of 1973 to determine the effects of streamflow on thermal stratification in pools of the Eel River below Van Arsdale Reservoir (Lee and Baker 1975; DWR 1976). Thermal stratification broke down, and the volume of satisfactory bottom water was reduced as the flows were sequentially increased from the normal summer flow of 5.6 cfs to 22, 40, and 83 cfs. At 83 cfs, stratification was completely eliminated in the deepest pool tested (16.5 feet). At normal summer flows, thermal stratification only occurred during the day. At night, as surface water temperatures decreased, temperatures were found to be uniform throughout the pools tested.

Water impoundments can significantly affect the temperature of streams. The four major factors that determine the effect of impoundments on downstream temperatures are the volume of water impounded, depth of impounded water, depth at which water is withdrawn, and the rate of withdrawal compared to the rate of natural flow (Moore 1967). In general, if an impoundment is deep and water is drawn off the bottom, there is a decrease in downstream temperatures; if an impoundment is shallow with a large surface area and/or water is drawn off the surface, there is an increase in downstream temperatures (Sylvester 1963; Moore 1967). A reduction in normal streamflow below an impoundment can cause marked temperature increases (Sylvester 1963).

Three major impoundments exist in the Eel River system: Lake Pillsbury, Van Arsdale Reservoir, and Lake Benbow. All of these impoundments were found to significantly affect the temperature of downstream waters.

Lake Pillsbury is a deep reservoir formed behind the 120-foot Scott Dam. Water is drawn off the bottom of the reservoir, and as a result, satisfactory temperatures were found in the Eel River for 11 miles downstream to Van Arsdale Reservoir.

Van Arsdale Reservoir is formed by the 67-foot Cape Horn Dam. A large portion of the streamflow of the Eel River is diverted to the Russian River at the dam, limiting flows in the Eel River below this point. Water that is allowed to pass down the Eel River is composed of the warmer surface waters of Van Arsdale Reservoir. This condition increased stream temperatures to marginal and lethal levels downstream of Cape Horn Dam.

Lake Benbow formed behind the 44-foot Benbow Dam has been completely filled by sediment. Therefore, an 11-foot superstructure is added to the dam for recreational purposes each summer. The shallow impounded water at Lake Benbow acts as a heat sink, not only increasing maximum temperatures but also minimum temperatures downstream.

Each summer, many small impoundments are built on streams in the Eel River system to provide recreation. Additionally, many small impoundments are formed behind temporary summer road crossings with small culverts. Sylvester (1963) reported that the surface areas of such "run of the river" impoundments are not markedly increased and that only small temperature increases will occur below the impoundments. However, it appears likely that the additive effect of such impoundments on streams in the Eel River system may significantly increase downstream temperature conditions.

The Effects of High Temperatures on Salmonids

General discussions of the effects of high temperatures on fish have been presented by Fry 1947, Brett 1956, 1959, and 1970, Jones 1964, Mihursky and Kennedy 1967, Dunham 1968, Lantz 1971, Snyder and Blahm 1971, Sylvester 1972a, and Brown 1974. Definitions of terms used in the forthcoming discussion can be found in these sources.

A review of the literature concerning the effects of high temperature on steelhead-rainbow trout, coho salmon, chinook salmon, and other closely related species of salmonids shows considerable variation between the results of different researchers working with identical species. This may be partially due to the differences under which laboratory studies were conducted. Lethal temperatures, as defined by Brett (1952), have been based upon temperature exposures varying from several hours to a week. Additionally, uncontrolled variables such as water chemistry, season, day length, acclimation level, physiological condition, size, age, sex, reproductive condition, nutritional state, and genetic history of test fish may influence the lethal temperature determined in the laboratory (Brown 1974).

Upper lethal temperatures and preferred temperatures of steelhead-rainbow trout reported in the literature are summarized in Table 3. Resistance times at several lethal temperatures are summarized in Table 4. It should be noted that rainbow trout have been observed surviving in temperatures as high as 29.5 C (Embody 1921; Soldwedel 1968); however, exposure times to high temperatures were not reported in these studies.

Table 3. Upper lethal and preferred temperatures of steelhead-rainbow trout, *Salmo gairdneri*.

Factor	Acclimation Temperature (°C)	Temperature (°C)	Length of Test (hrs.)	Reference
Upper lethal temperature	11.0	24.0	24	Black (1953)
	12.0	23.5	-	Threinen (1958)
	12.0	24.92	24	Charlon *et al.* (1970)
	14.0	25.22	24	Charlon *et al.* (1970)
	16.0	25.41	24	Charlon *et al.* (1970)
	18.0	25.31	24	Charlon *et al.* (1970)
	20.0	25.82	24	Charlon *et al.* (1970)
	24.0	26.35	24	Charlon *et al.* (1970)
	15.0	25.3	16.5	Alabaster (1962) cited by Charlon *et al.* (1970)
	20.0	26.6	16.5	Alabaster (1962) cited by Charlon *et al.* (1970)
	15.0	25.0-26.0	-	Bidgood and Berst (1969)
	-	23.5-26.5	-	Angelovic *et al.* (1961)
	-	24.0-29.0	-	McAfee (1966)
Preferred temperature	10.0	15.0-17.0		Javaid and Anderson (1967)
	15.0	17.0-19.0		Javaid and Anderson (1967)
	20.0	21.0-23.0		Javaid and Anderson (1967)
	10.0	15.0		Garside and Tait (1958)
	15.0	13.0		Garside and Tait (1958)
	20.0	11.0-12.0		Garside and Tait (1958)
	18.0	17.0-20.0		McCauley and Pond (1971)
	14.0-18.0	13.0-19.0		Mantelman (1958)
	-	<21.0		McAfee (1966)
	12.0	14.4		Cherry *et al.* (1975)
	15.0	16.9		Cherry *et al.* (1975)
	18.0	18.1		Cherry *et al.* (1975)
	21.0	20.1		Cherry *et al.* (1975)
	24.0	22.0		Cherry *et al.* (1975)

Table 4. Thermal resistance times in minutes for steelhead-rainbow trout, Salmo gairdneri.

Life Stage	Acclimation Temperature (°C)	Test Temperature (°C) 31.0	30.5	30.0	29.5	29.0	28.5	28.0	27.5	27.0	26.5	26.0	25.5	25.0	24.0	Reference
Juvenile	18.0	-	-	-	20	50	-	100	-	300	3000	-	-	-	-	Alabaster and Welcomme (1962)[a]
Juvenile	15.0	-	-	-	-	-	-	-	100		-	-	1000	-	-	Alabaster and Downing (1966)[a]
Juvenile	20.0	-	-	-	-	-	-	100	-	-	1000	-	-	-	-	Alabaster and Downing (1966)[a]
Juvenile	15.0	-	-	-	-	-	-	24	-	75	-	-	-	-	-	Ebel et al. (1971)[a]
Juvenile	15.0	6	16	-	32	50	-	75	108	158	333	-	-	-	-	Coutant and Dean (1972)[b]
Juvenile	15.0	-	-	5	-	15	-	30	-	100	-	250	-	-	-	Becker (1973)
Juvenile	15.0	-	-	<10	-	-	-	-	-	-	-	-	-	>5760	-	Bidgood and Berst (1969)
Yearling	20.0	-	-	-	-	54	-	104	-	423	-	-	-	-	-	Craigie (1963)[a,c]
Yearling	20.0	-	-	-	-	70	-	158	-	572	-	-	-	-	-	Craigie (1963)[a,d]
Yearling	20.0	-	-	-	-	42	-	83	-	363	-	-	-	-	-	Craigie (1963)[a,e]
Yearling	20.0	-	-	-	-	61	-	112	-	357	-	-	-	-	-	Craigie (1963)[a,f]
Adult	16.0-19.5	-	-	-	-	30	-	40	-	68	-	175	-	-	1500	Coutant (1970)[b]

[a] Median resistance times.

[b] Geometric mean resistance times.

[c] Fish reared in soft water, tested in soft water.

[d] Fish reared in soft water, tested in hard water.

[e] Fish reared in hard water, tested in soft water.

[f] Fish reared in hard water, tested in hard water.

The thermal tolerances of juvenile coho and chinook salmon have been reported to be similar to those of steelhead-rainbow trout (Ebel *et al.* 1971). The upper lethal temperatures of coho salmon and chinook salmon have been found to range from 22.9 to 25.0 C and from 21.5 to 25.1 C, respectively, for acclimation temperatures ranging from 5.0 to 24.0 C (Brett 1952). The preferred temperature of juvenile coho and chinook salmon has been found to be in the range, 10.0 to 14.0 C, for acclimation temperatures of 15.0 to 24.0 C (Brett 1952). Because juvenile coho and chinook salmon have nearly identical temperature tolerances to high temperatures (Brett 1952; Ebel *et al.* 1971), only coho salmon temperature tolerance data will be discussed in this report. Resistance times for coho salmon at various lethal temperatures are summarized in Table 5.

The heat death of salmonids follows a common pattern: loss of equilibrium, coma, and physiological death (Coutant and Dean 1972). Resistance times listed in Tables 4 and 5 refer to physiological death endpoints. Equilibrium loss can result at exposure times significantly less than those resulting in death (Coutant and Dean 1972; Coutant 1972a). Thus, exposure times less than those listed in Tables 4 and 5 may be expected to lead to the inability of salmonids to escape unfavorable thermal conditions and to result in death.

Table 5. Thermal resistance times in minutes for coho salmon, *Oncorhynchus kisutch*.

Life Stage	Acclimation Temperature (°C)	Test Temperature (C)										Reference
		30.0	29.0	28.0	27.5	27.0	26.5	26.0	25.5	25.0	24.5	
Juvenile	23.0	-	-	-	360	590	1100	2810	4760	9000	-	Brett (1952)[a]
Juvenile	20.0	-	-	-	90	230	420	2630	2100	8800	-	Brett (1952)[a]
Juvenile	15.0	-	-	-	-	122	170	360	415	2430	6000	Brett (1952)[a]
Juvenile	20.0	-	20	60	-	121.5	-	-	-	-	-	Ebel *et al.* (1971)[b]
Juvenile	15.0	-	-	13.5	-	62	-	-	-	-	-	Ebel et al. (1971)[b]
Juvenile	20.0	8	33	83	-	167	-	833	-	3333	-	Dean (1970)[c]
Juvenile	15.0	3	12	50	-	117	-	167	-	833	-	Dean (1970)[c]
Juvenile	16.0-19.5	4	15	57	-	120	-	220	-	-	-	Coutant (1970)[c]
Adult	16.0-19.5	12	15	24	-	40	-	42	-	-	-	Coutant (1970)[c]

[a] Median resistance times.

[b] Mean resistance times for half of sample to die.

[c] Geometric mean resistance times.

Lantz (1971) reported that there is difficulty in applying laboratory results to the actual effects of fluctuating temperatures on fish in streams. In light of this report, Edge and Vigg (1973 unpublished data) carried out a temperature tolerance study on juvenile steelhead-rainbow trout and coho salmon using fluctuating temperature regimes in laboratory aquaria to simulate Eel River temperature regimes. Groups of fish (usually 10 per group) were acclimated to various temperatures in test aquaria. The water temperature in each aquarium was then raised from the acclimation temperature to a predetermined maximum temperature over a 6- to 8-hour period. Maximum temperatures were generally maintained for less than 1 hour, and temperatures were then allowed to decrease at the same rate as they had been increased. Results of this study are summarized in Table 6.

Data presented in Tables 4, 5, and 6 were used to predict the lethal effects of maximum temperatures recorded and estimated in the Eel River system and to create the temperature classification system defined in the methods section. In order to use the tables for these purposes, it was necessary to determine not only the magnitude and duration of lethal temperatures recorded and estimated in the

Table 6. Temperature tolerance of juvenile coho salmon, *Oncorhynchus kisutch*, and steelhead-rainbow trout, *Salmo gairdneri* (Edge and Vigg 1973 unpublished data). See text for experimental details).

Acclimation Temperature (C)	Maximum Temperature (C)	Percent Mortality
Coho salmon:		
12.0	26.5	40
12.0	27.5	100
13.9	25.5	0
13.9	28.0	70
14.4	26.6	30
15.0	23.5	0
15.0	26.5	10
15.0	27.2	40
15.5	26.1	0
20.0-22.0	26.0	0
20.0-22.0	27.0	10
20.0-22.0	27.0	0
20.0-22.0	27.0	0
20.0-22.0	27.5	40
20.0-22.0	28.0	100
20.0-22.0	28.0	100
20.0-22.0	28.0	100
20.0-22.0	28.5	100
20.0-22.0	29.0	100
23.0	28.5	100
Steelhead:		
13.9	28.3	100
14.4	27.7	100
14.4	26.6	10
15.0	24.4	0
15.0	25.5	0
15.5	27.2	0
16.0-22.0	27.0	0
16.0-22.0	28.0	100
20.0-22.0	27.5	85.7

system, but also the temperature to which the fish were believed to be acclimated.

Alabaster and Downing (1966) reported that the resistance times of trout held at a constant 15.0 C for eight days prior to testing were nearly equivalent to the resistance times of trout held at temperatures fluctuating between 11.0 and 19.0 C on 24- and 48-hour cycles, when tested at 26.5 C. Therefore, it was assumed in the present study that steelhead and salmon at any one time were acclimated to a temperature at least as high as the minimum temperature being recorded, and probably near the daily mean temperature. As a general rule in the Eel River system during midsummer, acclimation temperatures could be assumed to be near 20.0 C.

Stream temperatures of 28.0 C or greater recorded or estimated to have occurred for at least 100 continuous minutes in the Eel River system (lethal classification) were expected to cause complete mortality of exposed salmonids. A stream classified as lethal was expected to be devoid or nearly devoid of salmonids during the summer, after a lethal temperature was attained. A limited number of salmonids may be able to survive in some lethal stream sections due to the existence of cool-water pockets created by spring inflow, tributary inflow, subterranean seepage, or thermal stratification.

Stream temperatures ranging from 26.5 C up to, but not including, 28.0 C recorded or estimated to have occurred for at least 100 continuous minutes in the Eel River system (marginal classification) were expected to cause the mortality of a portion of the exposed salmonids. Naturally, maximum temperatures at the upper end of this temperature range were expected to cause greater mortality than temperatures at the lower end of the range. Stream sections attaining marginal maximums infrequently were expected to have less mortality and larger numbers of salmonids than stream sections consistently attaining marginal maximums. Any stream section classified as marginal was expected to contain limited numbers of salmonids.

Stream temperatures less than 26.5 C (satisfactory classification) recorded or estimated in the Eel River system were not expected to directly cause the mortality of salmonids. Stream sections classified as satisfactory were expected to provide the most suitable habitat for salmonids and, therefore, contain larger numbers of salmonids than other stream sections.

Observations on the summer distribution and relative abundance of salmonids made during the present study and during past studies in the Eel River system (Wales 1938; Shapovalov 1941; Smith and Elwell 1961; Elwell 1965;

Rogers et al. 1968) agreed with the expectations of the temperature classification system. Salmonids were most abundant and nongame fish species were least abundant in satisfactory stream sections. The distribution of adult summer steelhead was confined to satisfactory stream sections in the Middle Fork Eel River (Shapovalov and Taft 1954; Smith and Elwell 1961), the Van Duzen River (Shapovalov and Taft 1954; Puckett et al. 1968; Horton and Rogers 1969), and possibly the South Fork Eel River.

Few salmonids were observed in lethal stream sections. When observed, salmonids were almost without exception in cool pockets of water formed by cool-water inflow or thermal stratification.

Numbers of salmonids observed in marginal stream sections were intermediate between satisfactory and lethal stream sections. Relatively fewer salmonids were observed in those marginal sections that attained higher marginal temperatures and/or attained marginal temperatures on a greater number of days.

Salmonids surviving within lethal and marginal stream sections remained in cool pockets of water during warm afternoons when stream temperatures were lethal or marginal, but utilized the remainder of the stream during cooler night and morning hours and during cool days when stream temperatures were satisfactory. However, salmonid numbers were limited within these stream sections by the quantity and temperature of cool-water pockets. During periods of lethal and marginal stream temperatures, salmonids were highly concentrated in cool-water pockets.

As stream temperatures increased to marginal and lethal levels in early summer, salmonids within some marginal and lethal stream sections moved to cooler stream sections. Smith and Elwell (1961) also reported observing fewer salmonids in the marginal and lethal portions of the Middle Fork Eel River in midsummer than in June and suspected that the fish had moved to cooler water.

Temperature related fish kills reported by Wales (1938), Shapovalov (1941), and Shapovalov and Taft (1954) and observed during the present study were comprised of large numbers of salmonids which remained in marginal and lethal stream sections during midsummer. The number of salmonids surviving lethal temperatures by remaining in cool-water pockets was limited further in late summer as some cool-water sources became dry.

Although stream temperatures less than 26.5 C were not assumed to directly cause the mortality of salmonids in the Eel River system, sublethal effects of temperatures greater than 20.0 C may have caused decreased production and indirect mortality. Snyder and Blahm (1971) interpreting the work of Brett (1959) stated that steelhead and Pacific salmon can survive at temperatures greater than 20.0 C, but only at the expense of feeding, growth, maturation, and migration.

Sublethal effects of high temperatures on salmonids include decreased metabolic scope for activity (Fry 1947 and 1957; Brett 1956, 1959, 1970, and 1971), decreased food utilization and growth rates (Donaldson and Foster 1941; Baldwin 1956; Brett 1970 and 1971; Lantz 1971; Warren 1971), reduced resistance to disease and parasites (Belding 1928; Wales 1938; Ordal and Pacha 1963; Lantz 1971; Snyder and Blahm 1971; Fryer and Pilcher 1974), increased sensitivity to some toxic materials (Belding 1928; Dunham 1968; Macek *et al*. 1969; Lantz 1971; MacLeod and Pessah 1973; Cairns *et al*. 1976), interference with migration (Smith and Elwell 1961; Dunham 1968; Lantz 1971; Snyder and Blahm 1971), reduced ability to compete with more temperature resistant species (Titcomb 1926; Macan 1961; Dunham 1968; Snyder and Blahm 1971), and increased vulnerability to predation (Sylvester 1972b; Coutant 1972a, 1972b, and 1973). Each of these effects will be discussed in reference to the Eel River system.

A review of the literature indicates that temperatures of 20.0 C and less are best suited for maximum metabolic scope for activity, food utilization, and growth of steelhead-rainbow trout and coho salmon. Dickson and Kramer (1971) reported that the scope for activity of hatchery and wild rainbow trout was maximum at 15.0 and 20.0 C, respectively, and slightly less at 25.0 C. However, Fry (1948, cited by Brett 1956) reported that the scope for activity increased throughout the 5.0 to 25.0 C range of temperatures tested. The reported increase at temperatures above 20.0 C may be part of an avoidance or escape mechanism from high temperatures, as suggested by Frank and Meyer (1971).

Food utilization and growth rates of rainbow trout are best at temperatures ranging from 12.0 to 20.0 C (Schaeperclaus 1933; Mantelman 1958; Aiken 1971). Temperatures between 20.0 and 24.0 C have been reported as being responsible for high maintenance requirements and low conversion efficiency of food into growth for juvenile steelhead (Coche 1967). Dickson and Kramer (1971) reported that rainbow trout held at 25.0 C refused to feed.

Burrows (1963) reported that the preferred temperature of Pacific salmon, 10.0 to 14.0 C (Brett 1952), coincides with the temperature of optimum production. Averett (1969, as cited by Lantz 1971 and Warren 1971) concluded that optimum growth of coho salmon in late summer occurred at temperatures ranging from 14.0 to 17.0 C with the levels of food availability that probably exist in nature. Maximum growth on excess rations occurred from 17.0 to 20.0 C, but maximum food conversion occurred from 14.0 to 17.0 C (Averett 1969, as cited by Griffiths and Alderdice 1972).

Brett et al. (1958) and Griffiths and Alderdice (1972) reported that the swimming performance of coho salmon was optimum near 20.0 C and decreased at higher temperatures. Griffiths and Alderdice (1972) suggested that 20.0 C may provide maximum metabolic scope, maximum food gathering capacity, and maximum growth for juvenile coho salmon as long as food availability is not limiting.

In the Eel River system during summer, however, it has been suggested that food is limiting. There is believed to be a loss of aquatic fish food organisms, resulting from high water temperatures and excessive siltation from logging operations, which has contributed to a lower level of salmonid productivity (Elwell 1965).

From this literature review, it appears that temperatures greater than 20.0 C are suboptimal for the success and production of salmonids in the Eel River system.

Because most lethal and marginal stream sections remained above 20.0 C for a majority of time on most summer days, production of salmonids surviving in these sections was expected to be limited. In satisfactory stream sections, where temperatures were generally less than 20.0 C for a majority of time on most summer days, production of salmonids was expected to be near optimum for the existing level of food availability.

The reduced resistance of salmonids to diseases and parasites and the increased virulence of disease and parasite organisms in high water temperatures have been reported as problems in the Eel River system (Wales 1938; Shapovalov 1941). The death of salmonids due to a disease and parasite infestation during a 1938 hot spell, when stream temperatures reached as high as 26.5 to 29.5 C, has been discussed by Wales (1938). He stated that the high temperatures combined with a decreased dissolved oxygen content of the water reduced the resistance of salmonids to diseases, and that the warm water increased the multiplication of disease organisms. He suggested that the diseases and parasites he identified were probably always present to a negligible extent in wild steelhead of the Eel River.

It may be assumed that some salmonids in the Eel River system die each summer due to disease and parasite infestation during periods of high water temperature. During the present study, several diseased salmonids, all of which had a white fungus, were observed in areas of lethal, marginal, and near-marginal temperatures. Pale, yellowish-colored salmonids were also observed in such areas. The paleness may have been caused by disease organisms and could have been an indicator of stream temperatures high enough to cause heat stress. Wales (1938) observed yellowish-colored salmonids during the 1938 hot spell and stated that these fish were parasitized individuals that had lost their black pigment and appeared pale yellow. He was unable to correlate this paleness with any disease or parasite, but stated that any one of the diseases or parasites he had identified might have stimulated the melanophore control mechanism.

Although the toxicity of chemicals generally increases with increased temperature and salmonids subjected to toxic materials are less tolerant of temperature extremes, the temperature related death of salmonids from toxicants is not a current problem in the Eel River system.
At present, Eel River water quality is good, and toxic materials are not released into the system. However, if a release of toxic materials did occur, high levels of salmonid

mortality would be expected due to the combined effect of the toxicant and existing high water temperatures.

It is evident that high stream temperatures during summer interfere with the downstream migration of juvenile salmonids in much of the Eel River system. Smith and Elwell (1961) reported that high temperatures in 1959 constituted a thermal block to downstream migrating juvenile salmonids in the Middle Fork Eel River. Their observations follow. The downstream migration of juvenile salmonids was continuous and of a large volume through spring to the middle of June. The migration declined sharply from the middle of June through the middle of July, coincident with a sharp rise in stream temperatures to marginal and lethal levels. Although a very few salmonids moved downstream at night, for all practical purposes the high temperatures from July through September appeared to constitute a thermal block to downstream migration. Following the first fall rains during the middle of September, the downstream movement of steelhead resumed, apparently as a result of lowered stream temperatures and/or increased streamflow.

The downstream migration of juvenile salmonids in other streams in the system also ceases by early or midsummer with the bulk of migration occurring during spring (Elwell 1965; Lee and Baker 1975). This cessation of downstream movement coincides with a sharp increase in stream temperatures to marginal and lethal levels through much of the system. As stream temperatures rise and the downstream migration of juvenile salmonids is blocked, many migrants may become trapped in lethal and marginal stream sections in early summer and succumb to the high temperatures. It appears possible that young salmonids in much of the Eel River system are forced to migrate as temperatures approach marginal levels and may migrate to the ocean at a younger age and smaller size than would be considered advantageous. Shapovalov and Taft (1954) found a positive correlation between age and/or size of downstream migrant steelhead and survival to first spawning.

Whether or not high summer stream temperatures block the upstream migration of adult salmonids in the Eel River system is a matter of speculation. Some adult chinook salmon and steelhead enter the Eel River as early as August and remain in pools near the mouth until fall rains increase the streamflow and allow salmonids to pass over shallow riffles (California Department of Fish and Game 1965a; Elwell 1965). It is possible that these early upstream migrants remain in the lower river due in part to warm stream temperatures and do not continue upstream until temperatures decrease in fall. It should be noted that the majority of adult salmonids enter the river after the fall rains begin and are, therefore, unaffected by low flows and high summer stream temperatures.

As water temperatures increase, the ability of salmonids to compete with more temperature resistant fish species in sections of the Eel River system is apparently reduced, and salmonids are replaced by nongame species. Smith and Elwell (1961) observed a rather sharp transition in fish population composition in the lower portion of the Middle Fork Eel River as stream temperatures increased during the early summer of 1959. Their observations follow. Until the end of June, salmonids were observed throughout the lower portion of the stream, and nongame fish appeared to be absent. As stream temperatures rose to lethal levels in July, salmonids disappeared, and nongame fish began appearing. Only nongame fish populations were present during the remainder of the summer. As temperatures decreased in September, salmonids were found to be distributed again throughout the lower portion of the Middle Fork, and nongame fish again became scarce.

Similar observations were made during the present study in lethal and most marginal stream sections throughout the system. Salmonids disappeared and nongame species predominated in lethal stream sections and, to a lesser extent, in marginal stream sections as temperatures increased to marginal and lethal levels in early summer. The salmonids either succumbed to high temperatures or migrated to the cooler waters of satisfactory stream sections, tributaries, and springs.

Laboratory experiments have shown that the vulnerability of salmonids to predation may increase with an increase in temperature. Sylvester (1972b) suggested that the increase in vulnerability may be due to a decrease in the swimming efficiency of prey, an increase in predator forage activity, or both. Heat stressed salmonids change their behavior patterns, reducing the ability of salmonids to escape unfavorable thermal conditions and providing important stimulatory cues to predators (Coutant and Dean 1972; Coutant 1973).

During the present study, several salmonids experiencing heat stress were observed in lethal and marginal stream sections of the Eel River system. Stressed fish demonstrated unnatural behavior and were, therefore, more noticeable than unstressed fish. Additionally, stressed fish showed a reduced ability to escape predation based upon their apparent inability to move to cover quickly when threatened. As temperatures increase to lethal and marginal levels in the system, some, and perhaps many salmonids which would otherwise survive the period of thermal stress are no doubt lost to predation by fish, snakes, birds, and mammals.

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APPENDIX I

HAND THERMOMETER WATER TEMPERATURE MEASUREMENTS IN THE EEL RIVER SYSTEM DURING THE SUMMER OF 1973

Water temperatures (°C) and the times at which they were measured, the maximum and minimum temperatures estimated at each station for those days on which temperatures were measured, and the maximum and highest minimum temperatures estimated at each station for the entire summer are listed below by station (see Figure 2). Stations are listed in a downstream direction along the main stream, and stations on tributaries are listed between stations on the main stream in the order in which those tributaries enter the main stream. Stations on tributaries to tributaries are listed in a similar manner. Station locations can be found on USGS topographic maps.

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
1. Eel River at Trout Creek							
	6/25	1005	16.0	14.5	21.0		
	7/25	1400	24.0	17.5	24.5	19.0	25.0
	8/22	1030	16.5	14.5	21.5		
2. Trout Creek at mouth							
	7/25	1400	20.0	15.5	20.5	16.5	21.0
3. Eel River at Horse Creek							
	7/25	1040	21.0	18.0	26.0		
		1350	25.5			19.5	26.5
	8/22	0945	15.0	14.5	23.5		
		1100	18.5				
4. Eel River 100 yards below Scott Dam (Lake Pillsbury)							
	6/25	0910	14.0	13.5	15.0		
		1325	14.0				
	7/25	0920	14.5	14.0	15.5	19.0	19.0
		1445	15.0				
	8/22	0900	15.0	15.0	18.5		
		1230	17.0				
5. Eel River 1 mile below Scott Dam							
	6/25	0850	14.0	14.0	17.0		
		1405	16.0				
	7/25	0905	15.0	14.5	17.5	19.5	19.5

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
5. (Cont.)	7/25	1450	17.0				
	8/22	0845	15.5	15.0	18.5		
		1245	17.0				
6. Eel River 4.5 miles above Cape Horn Dam (Van Arsdale Reservoir)							
	7/25	0835	15.0	15.0	19.5		
		1520	19.0			19.5	20.5
	8/22	0825	15.5	15.5	18.5		
		1315	17.0				
7. Eel River 3.5 miles above Cape Horn Dam							
	7/25	0820	16.0	15.5	20		
		1535	19.5			19.5	21.0
	8/22	0810	15.5	15.5	19.5		
		1330	18.0				
8. Eel River 2 miles above Cape Horn Dam							
	6/25	0810	16.0	16.0	20.5		
		1450	20.0				
	7/25	0805	16.0	16.0	20.5	19.5	21.5
		1545	20.0				
	8/22	0800	15.5	15.5	20.0		
		1340	18.0				
9. Eel River 1 mile above Cape Horn Dam							
	6/25	0800	17.5	17.0	21.0		
		1500	20.5				
	7/25	0740	17.5	17.0	21.5	20.0	22.0
		1600	21.0				
	8/22	0750	16.5	16.0	20.5		
		1350	19.0				
		1615	20.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
10. Eel River 100 yards below Cape Horn Dam							
	6/25	0750	19.0	19.0	24.5		
		1510	24.0			23.5	26.5
	7/25	0735	20.0	20.0	23.5		
		1610	23.5				
11. Eel River 1.5 miles below Cape Horn Dam							
	6/25	0735	22.0	22.0	25.0		
		1520	24.5				
	7/25	0725	22.5	22.0	24.5	24.0	27.0
		1615	24.0				
	8/22	0735	20.0	20.0	23.5		
		1400	23.0				
		1600	23.0				
12. Eel River 0.25 mile above Whitney Creek							
	8/22	1415	23.5	20.0	24.0	24.5	27.0
		1545	24.0				
13. Eel River 0.75 mile above Tomki Creek							
	8/22	1440	23.0	20.0	23.5	24.5	27.0
		1525	23.0				
14. Eel River 0.1 mile above Tomki Creek							
	8/22	1445	24.5	20.0	25.0	24.5	27.5
		1520	25.0				
15. Tomki Creek at mouth							
	8/22	1455	24.5	20.0	25.0	24.5	28.0
16. Eel River 0.25 mile below Tomki Creek							
	8/22	1500	24.0	20	24.5	24.5	27.5
17. Eel River 0.25 mile above Hearst							
	6/24	1700	26.0	21.0	26.5		
	7/25	1745	28.0	21.0	28.0	25.0	30.0

APPENDIX I. (Continued)

Station Number		Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
17.	(Cont.)	8/22	1745	24.0	20.0	24.0		
		8/23	0850	20.0	19.0	24.0		
			1630	24.0				
18.	Eel River at Salt Creek							
		8/23	0900	20.5	19.0	23.0	24.5	29.0
			1620	23.0				
19.	Eel River 1 mile below Salt Creek							
		8/23	0925	20.0	18.5	24.0	24.5	30.0
			1545	24.0				
20.	Eel River 2.25 miles below Salt Creek							
		8/23	1015	20.0	18.5	23.5	24.5	29.5
			1500	22.5				
21.	Eel River 3 miles above Twin Bridges Creek							
		8/23	1050	20.0	18.5	24.0	24.5	30.0
			1430	23.0				
22.	Eel River 1 mile above Twin Bridges Creek							
		8/23	1140	20.5	18.5	24.5	24.5	30.0
			1340	23.0				
23.	Eel River at Twin Bridges Creek							
		8/23	1215	21.5	19.0	24.0	24.5	30.0
			1300	22.0				
24.	Eel River 50 yards above Outlet Creek							
		6/24	0725	21.0	20.5	27.5		
			1535	27.0				
		7/24	0740	19.5	19.5	27.0		
			1750	27.0			25.0	30.5
		8/21	0755	20.0	19.5	26.0		
			1650	25.5				
		8/23	1740	24.0	18.5	24.0		

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
25. Long Valley Creek 0.5 mile above mouth							
	8/21	0725	17.0	17.0	22.5	23.0	26.5
		1715	22.0				
26. Outlet Creek 0.5 mile below Long Valley Creek							
	6/24	0705	18.8	18.5	26.0		
		1600	25.5				
	7/24	0710	20.0	20.0	27.5	25.0	30.0
		1815	27.0				
	8/21	0730	18.5	18.5	25.0		
		1705	25.0				
27. Outlet Creek 3 miles above mouth							
	6/24	1550	26.0	18.5	26.5		
	7/24	0720	20.0	20.0	26.5	25.0	30.0
		1805	26.0				
28. Outlet Creek at mouth							
	6/24	0730	19.5	19.5	26.5		
		1535	26.0				
	7/24	0735	19.5	19.5	26.0		
		1750	26.0			25.0	30.0
	8/21	0750	19.0	18.5	25.5		
		1645	25.0				
	8/23	1735	23.5	18.5	23.5		
29. Eel River 0.5 mile below Outlet Creek							
	6/24	0745	20.0	20.0	27.5		
		1525	27.0				
	7/24	0745	19.0	18.5	26.0	25.0	30.0
		1740	26.0				
	8/21	0805	19.5	19.0	25.5		
		1640	25.0				

* 32. Eel River 25 yards above Middle Fork

6/24	0835	20.5	20.0	26.0		
	1500	25.5				
7/24	0810	19.5	19.0	25.5		
	1710	25.0			25.0	29.0
7/31	1500	28.0	23.0	28.5		
8/21	0840	20.0	19.5	24.5		
	1600	24.0				
8/31	1400	23.0	20.0	24.5		

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
30. Eel River 2.5 miles below Outlet Creek							
	6/24	0755	20.0	20.0	25.0		
		1520	24.5				
	7/24	0755	19.0	18.5	23.0	25.0	27.5
		1735	23.0				
	8/21	0815	19.5	19.0	23.0		
		1625	23.0				
31. Eel River 2 miles above Middle Fork Eel River							
	6/24	0805	20.5	20.0			
		1510	25.5				
	7/24	0800	19.0	18.5		25.0	28.5
		1725	24.0				
	8/21	0825	20.0	19.5			
		1615	25.0				
* 33. Middle Fork Eel River above Osborn Station							
	7/24	1330	20.0	17.5	22.0		
	8/28	1615	20.0	17.0	20.5	21.0	24.0
		1700	20.0				
34. Middle Fork 0.5 mile below Fly Creek							
	8/28	1830	20.0	17.0	21.0	21.0	24.5
	8/29	0700	17.0	17.0	20.5		
		0820	17.0				
35. Middle Fork at Hellhole Canyon							
	8/29	0915	17.0	17.0	21.0	21.0	25.0
36. Middle Fork 1 mile below Hellhole Canyon							
	8/29	1010	18.5	17.0	21.5	21.0	25.5
37. Middle Fork at Buck Creek							
	8/29	1200	20.5	18.0	22.5	22.0	26.5

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
38. Middle Fork at Bar Creek							
	8/29	1310	21.0	19.0	23.0	23.0	27.0
		1415	22.0				
39. Middle Fork 0.75 mile below Bar Creek							
	8/29	1500	22.5	19.5	23.0	24.0	27.5
40. Middle Fork 1.25 miles above Black Butte River							
	8/29	1630	23.5	19.5	23.5	24.0	28.0
41. Middle Fork 25 yards above Black Butte River							
	6/24	1040	19.0	18.0	23.5		
		1330	21.5				
	7/24	1140	23.0	21.5	25.5		
		1550	25.0			24.5	29.0
	8/21	1020	22.0	20.5	26.0		
		1420	25.0				
	8/29	1815	23.5	19.5	24.5		
42. Black Butte River at Jumpoff Creek							
	8/21	1145	20.0	17.5	23.5	22.5	27.5
		1230	20.0				
43. Jumpoff Creek 25 yards above mouth							
	8/21	1135	17.0	16.0	20.0	20.0	23.5
		1240	17.5				
44. Black Butte River 0.5 mile above mouth							
	6/24	1100	20.0	18.5	25.0		
		1320	23.0				
	7/24	1155	23.0	21.5	27.5	24.5	30.5
		1535	27.0				
	8/21	1040	21.0	20.0	26.5		
		1410	25.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
45.	Black Butte River at mouth						
	6/24	1045	19.5	18.0	24.5		
		1325	22.5				
	7/24	1145	23.0	21.5	27.5		
		1540	27.0			24.5	30.5
	8/21	1025	21.0	20.0	27.0		
		1425	26.0				
	8/29	1810	24.0	20.0	25.0		
46.	Middle Fork 0.25 mile below Black Butte River						
	6/24	1025	19.0	18.0	24.0		
		1345	22.5				
	7/24	1130	23.0	21.5	26.0		
		1555	25.5			24.5	29.5
	8/21	1010	21.0	20.0	26.0		
		1435	25.0				
	8/29	1830	23.5	19.0	24.5		
47.	Middle Fork 1.5 miles below Black Butte River						
	6/24	1350	23.0	19.0	24.5		
	7/24	1125	23.0	21.5	26.5		
		1605	26.0			25.0	29.5
	8/21	1000	21.0	20.0	25.5		
		1450	25.0				
	8/29	1000	20.0	19.5	25.5		
48.	Middle Fork at Williams Creek						
	6/24	1005	19.5	19.0	24.5		
		1405	23.0				
	7/24	1110	23.5	21.5	26.5		
		1620	26.0			24.5	29.5
	8/21	0940	22.0	21.0	26.5		
		1505	26.0				
	8/29	1045	22.0	19.5	25.5		

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
49. Williams Creek 0.25 mile above mouth							
	6/24	0955	18.4	18.0	26.0		
		1410	25.0				
	7/24	1100	20.0	18.0	27.5	23.5	30.5
		1610	27.0				
	8/21	0950	21.5	20.0	25.5		
		1510	25.0				
50. Middle Fork at Spenser Ranch							
	8/30	1130	22.0	20.0	25.5	24.5	29.5
51. Middle Fork 0.75 mile below Spenser Ranch							
	8/30	1200	22.5	20.0	25.5	24.5	29.5
52. Middle Fork at Etsel Flat							
	8/30	1230	23.5	21.0	26.0	25.0	30.0
		1330	24.0				
53. Middle Fork 2 miles below Etsel Flat							
	8/30	1430	25.0	21.0	26.5	25.0	30.5
54. Middle Fork 2 miles above Mill Creek							
	8/30	1530	25.0	21.0	26.0	25.0	30.0
55. Middle Fork 1 mile above Mill Creek							
	8/30	1630	25.5	21.0	26.0	25.0	30.0
56. Middle Fork at Mill Creek							
	8/30	1730	26.0	20.0	26.0	24.5	30.0
	8/31	1000	21.0	20.0			
57. Middle Fork 25 yards above mouth							
	6/24	0835	19.5	19.5	26.0		
		1500	25.5				
	7/24	0825	20.0	20.0	27.0		
		1705	27.0				
	7/31	1500	28.0	23.0	28.5	24.5	29.0

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
57. (Cont.)	8/21	0845	19.0	19.0	26.0		
		1600	25.5				
	8/31	1400	23.0	20.0	24.5		
58. Eel River near Burger Creek							
	6/24	0825	19.5	19.5	26.0		
		1500	25.5				
	7/24	0815	20.0	19.5	26.5	24.5	29.0
		1710	26.0				
	7/31	1615	28.5	23.0	28.5		
59. Burger Creek at mouth							
	7/31	1615	29.0	23.0	29.0	24.5	29.5
60. Eel River near Stoney Creek							
	7/31	1710	28.5	23.0	28.5	24.5	29.0
61. Eel River at Woodman Creek							
	7/31	1850	28.0	23.0	28.5	24.5	29.0
	8/1	0830	23.0	23.0	28.5		
62. Woodman Creek at mouth							
	7/31	1840	27.0	20.5	27.5	22.5	28.0
	8/1	0700	21.0	20.5			
63. Eel River 2 miles above Camp Rest							
	8/1	0915	23.0	22.0	29.0	24.0	30.0
64. Eel River at Camp Rest							
	8/1	1020	24.0	22.0	29.0	24.0	30.0
65. Eel River near River Garden							
	8/1	1210	26.5	22.0	29.0	24.0	30.0
66. Eel River at Shell Rock Creek							
	8/1	1330	28.5	23.0	30.0	25.0	30.5
		1600	30.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
67. Shell Rock Creek at mouth							
	8/1	1315	29.0	22.0	31.0	24.0	31.5
		1600	31.0				
68. Eel River at Spy Rock							
	8/1	1730	30.0	23.0	30.0	25.0	30.5
69. Eel River 2 miles above Blue Rock Creek							
	8/1	1815	28.5	23.0	29.0	25.0	30.0
70. Eel River at Blue Rock Creek							
	8/1	1900	27.5	23.0	28.5	25.5	29.5
	8/2	0700	25.0	24.5	28.5		
71. Blue Rock Creek at mouth							
	8/1	1900	25.0	21.0	26.0	22.0	27.0
	8/2	0700	21.0	21.0	26.5		
72. Eel River at Bell Springs Creek							
	8/2	1000	24.5	22.5	27.5	24.0	28.0
73. Bell Springs Creek at mouth							
	8/2	1000	25.0	22.5	28.0	24.0	28.5
74. Eel River 2 miles above North Fork Eel River							
	8/2	1100	26.0	23.0	28.5	25.0	29.5
75. Eel River 100 years above North Fork							
	8/2	1300	27.0	23.0	28.5	25.0	29.5
		1615	28.0				
76. North Fork Eel River at Salt Creek							
	8/24	1230	18.5	18.0	22.0	24.0	28.0
		1315	19.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
77. North Fork at Mina							
	7/26	1300	27.0	23.0	29.0		
		1515	28.5			25.0	30.5
	8/24	1530	23.0	19.0	23.5		
78. North Fork 0.1 mile above Asbill Creek							
	7/26	1430	28.5	23.0	29.5	25.0	30.5
		1510	29.0				
79. Asbill Creek at mouth							
	7/26	1430	24.0	19.0	24.5	22.0	25.5
		1500	24.0				
80. North Fork 0.1 mile below Asbill Creek							
	7/26	1430	26.0	21.0	26.5	24.0	28.0
		1500	26.0				
81. North Fork 0.25 mile above mouth							
	8/2	1300	27.0	23.0	29.5	25.0	30.0
		1615	29.0				
82. Eel River 0.1 mile below North Fork							
	8/2	1300	27.0	23.0	28.5	25.0	29.5
		1620	28.0				
83. Eel River 1 mile below North Fork							
	8/2	1735	28.0	23.0	28.0	25.0	29.0
84. Eel River 2.5 miles above Island Mountain							
	8/2	1930	28.0	23.5	28.0	25.0	29.0
	8/3	0730	23.5	23.5	28.0		
85. Unnamed stream 2.5 miles above Island Mountain							
	8/2	1930	23.0	18.0	23.5	20.0	25.0
	8/3	0730	18.0	18.0			

APPENDIX I.' (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
86. Eel River at Alderpoint							
	6/23	1050	22.0	21.0	27.0		
		1330	24.0				
	7/23	1100	21.0	19.5	26.0	24.0	30.0
		1400	24.0				
	8/20	1140	23.0	20.5	28.0		
		1330	26.0				
87. Eel River at Fort Seward							
	6/23	1005	22.7	21.0	26.5		
		1410	24.7				
	7/23	0955	22.0	20.5	25.5	24.0	29.0
		1445	24.0				
	8/20	1030	22.0	20.5	26.0		
		1435	24.0				
88. South Fork Dobbyn Creek 2 miles above North Fork Dobbyn Creek							
	6/23	1345	22.0	16.5	24.0		
	7/23	1045	19.5	17.5	25.0		
		1410	23.5			22.0	27.0
	8/20	1125	20.0	18.0	25.0		
		1345	23.0				
89. South Fork Dobbyn Creek 25 yards above North Fork							
	7/23	1035	19.5	17.5	27.0		
		1425	26.0			22.0	29.0
	8/20	1110	20.5	18.5	27.5		
		1405	26.0				
90. North Fork Dobbyn Creek 50 yards above South Fork							
	7/23	1030	18.0	16.0	24.5		
		1420	23.5				
	8/20	1105	19.5	17.5	25.5	21.0	27.0
		1405	24.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
91. Dobbyn Creek 50 yards below North and South Forks							
	7/23	1030	18.5	17.0	26.0		
		1420	25.0			22.0	28.0
	8/20	1105	20.0	18.0	26.5		
		1400	25.0				
92. Dobbyn Creek 1.25 miles above mouth							
	6/23	1025	18.5	17.0	25.0		
		1400	23.0				
	7/23	1010	19.0	17.5	26.5	22.0	29.0
		1435	25.0				
	8/20	1045	20.0	18.0	27.5		
		1415	26.0				
93. Eel River at Eel Rock							
	6/23	0855	21.6	21.5	24.5		
		1515	24.0				
	7/23	0900	20.0	20.0	24.5	24.0	27.5
		1535	24.0				
	8/20	0935	20.0	19.0	25.5		
		1525	25.0				
94. Eel River at Whitlow							
	7/23	0820	19.0	19.0	24.5		
		1615	24.5			24.5	27.5
	8/20	0855	20.0	20.0	25.0		
		1600	25.0				
95. Sonoma Creek 100 yards above mouth							
	7/23	0825	15.0	15.0	17.0		
		1620	16.5			17.0	20.0
	8/20	0900	14.0	14.0	16.0		
		1600	15.5				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
96. Eel River at McCann							
	6/23	0815	21.5	21.5	24.0		
		1615	23.5				
	7/23	0755	18.0	18.0	21.0	24.5	27.0
		1645	21.0				
	8/20	0825	19.5	19.5	22.5		
		1630	22.0				
97. Eel River at Camp Grant							
	6/23	0800	20.5	20.5	24.5		
		1630	24.0				
	7/23	0735	18.0	18.0	21.0	24.0	27.5
		1710	21.0				
	8/20	0810	18.0	18.0	22.0		
		1645	22.0				
98. Eel River 25 yards above South Fork Eel River							
	6/21	1020	22.0	21.0	25.0		
		1650	24.5				
	6/23	0720	21.5	21.5	23.0		
		1700	22.7				
	7/21	0920	19.0	18.5	22.0		
		1640	21.5			24.5	26.5
	7/23	0700	19.0	19.0	21.0		
	8/18	0900	18.5	18.0	21.5		
		1645	21.0				
	8/20	0730	18.0	18.0	21.0		
		1715	21.0				
99. South Fork Eel River 0.25 mile above Mud Springs Creek							
	7/22	1105	17.0	16.0	22.0		
		1415	20.0			19.5	24.5
	8/19	1100	15.0	14.5	21.0		
		1445	19.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
100. South Fork 2.5 miles below Branscomb							
	6/22	1415	20.5	17.5	22.0		
	7/22	1120	17.0	16.0	21.5		
		1405	19.5			19.5	24.5
	8/19	1115	15.5	15.0	21.0		
		1440	19.0				
101. South Fork 50 yards above Elder Creek							
	6/22	1340	21.5	18.0	23.0		
	7/22	1150	19.0	17.0	22.0		
		1345	20.0			20.0	25.5
	8/19	1145	19.0	17.0	22.0		
		1415	20.0				
102. Elder Creek at mouth							
	6/22	1335	16.5	13.5	17.0		
	7/22	1155	14.0	13.0	16.5		
		1345	16.0			17.0	19.5
	8/19	1150	15.0	13.5	16.0		
		1420	15.0				
103. South Fork 50 yards below Elder Creek							
	6/22	1335	20.5	18.0	22.5		
	7/22	1145	18.5	17.0	21.5		
		1340	19.5			20.0	25.0
	8/19	1150	17.0	16.0	21.5		
		1415	20.0				
104. South Fork at Wilderness Lodge							
	6/22	1250	20.5	18.0	22.5		
	7/22	1210	18.0	17.0	21.5		
		1330	19.0			20.0	25.0
	8/19	1210	20.0	18.5	22.5		
		1405	21.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
105.	South Fork at Eel River Lodge						
	8/19	1230	21.0	18.5	23.5	20.0	26.0
		1400	22.0				
106.	South Fork 50 yards above Ten Mile Creek						
	8/19	1300	21.0	18.5	23.5	20.0	26.0
		1330	21.5				
107.	Ten Mile Creek 8 miles above mouth						
	7/22	1030	19.0	18.0	27.0	20.5	30.0
		1450	26.0				
	8/19	1025	20.0	19.0	27.5		
		1515	27.0				
108.	Ten Mile Creek at mouth						
	8/19	1300	22.0	19.0	24.0	20.5	26.5
		1330	22.0				
109.	South Fork 100 yards below Ten Mile Creek						
	8/19	1305	21.0	18.5	23.5	20.0	26.0
		1330	21.5				
110.	South Fork 100 yards above Rattlesnake Creek						
	6/22	1035	21.0	19.0	25.5		
		1520	24.5				
	7/22	0945	19.0	18.0	25.0	21.0	27.5
		1520	24.5				
	8/19	0955	19.0	18.5	25.5		
		1545	25.0				
111.	Rattlesnake Creek 3.5 miles above mouth						
	6/22	1055	20.5	18.5	26.0		
	7/22	1010	18.5	17.5	25.5	20.5	27.5
		1500	24.5				
	8/19	1530	25.0	16.5	25.5		

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
112.	Rattlesnake Creek at mouth						
	6/22	1030	20.0	18.5	26.5		
		1520	25.5				
	7/22	0940	17.5	17.0	27.0	20.5	29.5
		1515	26.0				
	8/19	0950	17.0	16.5	27.5		
		1540	27.0				
113.	South Fork 100 yards below Rattlesnake Creek						
	6/22	1035	20.5	19.0	26.5		
		1520	25.5				
	7/22	0950	19.0	18.0	25.5	21.0	28.5
		1524	25.0				
	8/19	1000	19.0	18.5	26.0		
		1550	25.0				
114.	South Fork at Leggett						
	6/22	0945	19.5	18.5	24.0		
		1540	23.5				
	7/22	0920	19.0	18.0	24.0	20.5	27.0
		1545	23.5				
	8/19	0930	19.5	19.0	25.0		
		1610	24.5				
115.	South Fork at Standish-Hickey State Park						
	6/22	0935	20.0	19.0	23.5		
		1550	23.0				
	7/22	0910	19.5	19.0	24.0	21.0	26.5
		1600	23.5				
	8/19	0915	20.0	19.5	24.5		
		1625	24.0				
116.	South Fork at Bridges Creek						
	6/22	0920	20.0	19.5	24.0		
		1600	23.5				
	7/22	0850	19.0	18.5	24.0	21.5	27.0
		1610	23.5				
	8/19	0900	20.0	19.5	24.5		
		1635	24.5				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
117. Bridges Creek at mouth							
	6/22	0915	17.0	16.5	21.0		
		1600	20.5				
	7/22	0850	17.5	17.0	23.0	19.5	26.0
		1615	22.5				
	8/19	0905	18.0	17.5	22.0		
		1640	22.0				
118. South Fork 2 miles below Bridges Creek							
	6/22	0900	19.5	19.5	25.0		
		1620	24.5				
	7/22	0830	18.0	18.0	24.5	21.5	27.5
		1625	24.0				
	8/19	0845	19.0	18.5	24.5		
		1650	24.5				
119. South Fork at Piercy							
	6/22	0830	19.5	19.5	25.0		
		1655	25.0				
	7/22	0805	18.0	18.0	24.5	21.5	27.5
		1650	24.0				
	8/19	0815	18.0	18.0	24.5		
		1710	24.5				
120. South Fork at Cook's Valley							
	6/22	0805	19.5	19.0	25.0		
		1710	24.5				
	7/22	0750	17.5	17.5	23.5	21.0	27.5
		1705	23.0				
	8/19	0800	18.0	18.0	24.0		
		1720	24.0				
121. South Fork at Richardson Grove State Park							
	6/22	0755	19.5	19.5	24.5		
		1725	24.5				
	7/22	0740	18.0	18.0	23.0	21.5	27.0
		1715	23.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
121. (Cont.)	8/19	0755	18.0	18.0	24.5		
		1730	24.5				
122. South Fork 0.5 mile above Lake Benbow							
	6/22	0735	19.5	19.0	26.5		
		1740	26.5				
	7/22	0730	17.0	17.0	24.5	21.0	28.5
		1725	24.5				
	8/19	0740	18.0	18.0	24.5		
		1740	24.5				
123. South Fork at Lake Benbow							
	6/22	0725	21.8	21.5	24.0		
		1755	23.5				
	7/22	0710	20.0	20.0	23.0	23.0	28.5
		1735	22.5				
	8/19	1800	25.0	19.5	25.0		
124. East Branch of South Fork 1 mile above mouth							
	6/22	0730	19.0	18.5	26.0		
		1745	26.0				
	7/22	0700	18.0	18.0	26.0	21.5	29.0
		1730	26.0				
	8/19	0730	18.0	18.0	26.5		
		1750	26.5				
125. Sprowl Creek 0.25 mile above mouth							
	7/21	1240	20.0	18.0	23.0		
		1400	22.0			20.0	26.5
	7/18	1210	20.0	18.0	23.5		
		1345	22.0				
126. South Fork 0.5 mile below Sprowl Creek							
	6/21	1425	26.4	21.5	27.5	23.0	29.5
	7/21	1245	23.0	20.5	25.5		

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
127.	South Fork 2 miles below Sprowl Creek						
	6/21	1325	25.0	21.5	27.0		
		1435	26.0				
	6/22	0705	20.0	20.0	26.0		
		1830	26.1				
	7/21	1300	23.0	20.5	25.0		
		1410	24.0			23.0	29.0
	7/22	0655	18.5	18.5	26.0		
		1745	26.0				
	8/18	1200	22.0	19.5	25.5		
		1400	24.0				
	8/19	0710	20.0	19.5	25.0		
		1810	25.0				
128.	Redwood Creek 0.5 mile above mouth						
	7/21	1215	19.5	18.0	21.0		
		1435	20.0			20.0	25.0
	8/18	1145	18.5	17.5	20.5		
		1415	19.5				
129.	South Fork 0.5 mile above Dean Creek						
	6/21	1245	25.0	21.5	26.0		
		1455	25.1				
	7/21	1200	21.5	19.5	25.5	23.0	28.0
		1445	24.5				
	8/18	1130	21.0	19.0	25.5		
		1430	24.0				
130.	South Fork 1 mile above Hooker Creek						
	6/21	1230	24.5	21.5	27.0		
		1510	26.0				
	7/21	1145	20.5	19.0	23.5	23.0	28.5
		1500	22.5				
	8/18	1115	19.0	17.5	23.0		
		1450	22.0				

* 135. South Fork at Meyer's Flat

6/21	1115	22.5	21.0	24.5		
	1610	24.0				
7/21	1040	20.5	19.5	24.5	23.0	27.0
	1555	24.0				
8/18	1005	19.0	18.0	24.5		
	1550	24.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
131.	South Fork at Phillipsville						
	6/21	1210	24.0	21.5	26.5		
		1525	25.5				
	7/21	1130	21.5	19.5	24.0	23.0	28.5
		1510	23.0				
	8/18	1105	21.0	19.0	24.0		
		1505	23.0				
132.	South Fork at Miranda						
	6/21	1150	23.5	21.5	26.5		
		1545	25.5				
	7/21	1110	20.5	19.5	25.0	23.0	28.5
		1530	24.0				
	8/18	1050	23.0	19.0	24.0		
		1515	23.0				
133.	Salmon Creek 0.5 mile above mouth						
	6/30	0700	22.0	22.0	26.5		
		1600	26.0				
	7/21	1120	20.0	19.0	26.0	23.5	29.0
		1520	25.0				
	8/18	1040	20.0	19.0	26.0		
		1525	25.0				
134.	South Fork at Landsdale Bar						
	6/21	1130	22.5	21.0	27.0		
		1555	26.5				
	7/21	1050	21.0	19.5	24.5	23.0	28.5
		1545	23.5				
	8/18	1020	20.0	18.5	24.0		
		1540	23.5				
* 136.	South Fork at Garden Club of America Grove						
	6/21	1055	23.0	21.5	25.5		
		1620	25.0				
	7/21	1025	20.0	19.0	22.5	23.0	27.5
		1610	22.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
136. (Cont.)	8/18	0955	19.5	18.5	23.0		
		1600	22.5				
137. South Fork 0.5 mile above Weott							
	6/21	1040	21.5	20.5	26.0		
		1635	26.0				
	7/21	1010	19.0	18.5	24.0	22.5	27.5
		1615	23.5				
	8/18	0940	18.0	17.5	23.0		
		1610	22.5				
138. South Fork at Bull Creek							
	7/21	0955	18.0	17.5	23.5		
		1620	23.0			22.5	27.5
	8/18	0925	17.0	17.0	23.5		
		1625	23.0				
139. Bull Creek at mouth							
	7/21	0955	16.0	15.5	23.0		
		1630	22.5			18.5	26.5
	8/18	0920	15.0	14.5	21.5		
		1625	21.0				
140. South Fork at mouth							
	6/21	1020	21.5	20.5	25.5		
		1650	25.0				
	6/23	0720	21.0	21.0	23.5		
		1655	23.0				
	7/21	0920	19.5	19.0	23.0	23.0	27.0
		1635	22.5				
	7/23	0655	18.5	18.5	21.5		
	8/18	0900	19.0	18.5	22.0		
		1645	22.0				
	8/20	0730	19.0	19.0	22.0		
		1715	22.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
141.	Eel River 2 miles below South Fork						
	6/21	1005	22.0	20.5	24.5		
		1705	24.5			23.0	26.0
	7/21	0905	19.0	19.0	22.5		
		1645	22.0				
142.	Larabee Creek 0.25 mile above mouth						
	7/21	0850	17.5	17.5	23.0	21.5	26.5
		1700	23.0				
	8/18	0835	18.0	18.0	24.0		
		1705	24.0				
143.	Eel River at Holmes						
	6/21	0945	21.0	20.5	24.5		
		1715	24.0				
	7/21	0840	18.5	18.5	22.0	23.0	25.5
		1705	22.0				
	8/18	0830	18.0	18.0	22.5		
		1710	22.5				
144.	Eel River at Shively Road						
	6/21	0930	20.5	20.0	24.0		
		1720	23.5				
	7/21	0825	19.0	19.0	21.5	22.5	25.0
		1715	21.5				
	8/18	0820	19.0	18.5	22.0		
		1715	22.0				
145.	Eel River at Jordan Creek						
	6/21	0910	21.0	20.0	23.0		
		1730	23.0				
	7/21	0810	19.0	19.0	21.5	22.5	24.5
		1725	21.5				
	8/18	0800	19.0	19.0	21.0		
		1725	21.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
146. Jordan Creek at mouth							
	6/21	0910	15.0	14.5	25.0		
		1730	25.0				
	7/21	0805	15.0	15.0	23.0	18.0	26.5
		1720	23.0				
	8/18	0805	14.0	14.0	22.0		
		1725	22.0				
147. Eel River 0.25 mile above Twin Creek							
	6/21	0845	21.0	20.0	22.5		
		1740	22.5				
	7/21	0750	18.0	18.0	21.0	21.5	24.0
		1735	21.0				
	8/18	0745	18.5	18.5	21.0		
		1740	21.0				
148. Eel River at Rio Dell							
	6/21	0825	20.0	20.0	22.0		
		1750	22.0				
	7/21	0730	18.0	18.0	21.0	21.5	24.0
		1750	21.0				
	8/18	0730	18.0	18.0	21.0		
		1755	21.0				
149. Eel River 0.5 mile above Van Duzen River							
	6/21	0810	20.5	20.5	22.0		
		1800	21.5				
	7/21	0715	19.0	19.0	20.0	21.5	24.0
		1800	20.0				
	8/18	0715	18.0	18.0	21.0		
		1815	21.0				
150. Van Duzen River at Hettenshaw Valley							
	7/20	1220	22.0	17.5	24.5		
		1330	23.0			19.0	25.5
	8/17	1205	19.5	17.0	23.5		
		1330	21.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
151. West Fork Van Duzen River 0.5 mile above mouth							
	7/20	1240	20.0	16.0	22.0		
		1320	20.0			17.5	24.0
	8/17	1220	19.0	16.0	21.5		
		1320	19.5				
152. Van Duzen River 2.5 miles above Shanty Creek							
	6/20	1310	19.5	15.0	22.5		
	7/20	1200	21.0	17.0	23.5		
		1340	22.0			18.5	25.0
	8/17	1150	21.0	17.0	23.5		
		1345	22.0				
153. Shanty Creek at mouth							
	6/20	1325	18.0	14.5	20.0		
	7/20	1145	18.0				
		1355	21.0	15.5	22.0	16.0	23.0
	8/17	1140	16.0				
		1355	19.0	14.5	20.5		
154. Van Duzen River 0.5 mile below Shanty Creek							
	6/20	1255	20.5	15.5	24.0		
		1400	22.0				
	7/20	1140	21.5	17.5	25.5	19.0	26.5
		1400	24.0				
	8/17	1130	19.5	17.0	24.5		
		1400	23.0				
155. Van Duzen River 0.25 mile below Crooks Creek							
	7/20	1125	22.0	18.0	26.0		
		1415	24.5			19.5	27.0
	8/17	1115	19.0	17.0	25.5		
		1410	24.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
156.	Van Duzen River 0.25 mile below Browns Canyon						
	6/20	1235	22.0	16.5	26.0		
		1420	24.0				
	7/20	1110	22.0	18.5	27.5	20.0	28.0
		1425	25.5				
	8/17	1100	22.0	18.0	25.5		
		1430	24.0				
157.	Van Duzen River 3.25 miles above Dinsmores						
	6/20	1215	21.5	16.5	26.0		
		1440	24.0				
	7/20	1045	20.0	18.0	25.5	20.0	28.0
		1440	24.0				
	8/17	1035	21.0	18.0	27.0		
		1450	26.0				
158.	Van Duzen River 1 mile above Dinsmores						
	6/20	1205	20.5	16.5	26.0		
		1455	24.5				
	7/20	1035	19.0	18.0	25.5	20.0	27.5
		1455	24.0				
	8/17	1020	18.0	16.5	26.0		
		1500	25.0				
159.	Van Duzen River 1.5 miles below Dinsmores						
	6/20	1150	19.0	15.5	24.0		
		1510	22.5				
	7/20	1025	18.5	17.5	23.5	20.0	26.0
		1520	22.0				
	8/17	1010	18.0	16.5	23.0		
		1510	22.0				
160.	South Fork Van Duzen River 3 miles above mouth						
	6/20	1125	19.5	16.0	25.5		
		1535	24.5				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
160. (Cont.)	7/20	0945	18.0	16.5	25.5	19.5	26.5
		1540	25.0				
	8/17	0945	16.0	15.5	23.5		
		1550	23.0				
161. Butte Creek 0.75 mile above South Fork Van Duzen River							
	7/20	1550	20.0	14.0	20.5		
	8/17	0940	14.0	13.0	19.0	15.5	22.0
		1600	19.0				
162. Van Duzen River at Little Larabee Creek							
	6/20	1055	20.0	17.5	26.0		
		1600	25.0				
	7/20	0915	19.0	18.5	24.5	19.5	26.5
		1605	23.5				
	8/17	0915	19.0	18.0	24.5		
		1625	24.0				
163. Little Larabee Creek 25 yards above mouth							
	6/20	1100	20.0	17.5	27.0		
		1600	26.0				
	7/20	0920	17.0	16.5	25.5	18.5	27.0
		1605	25.0				
	8/17	0915	18.0	17.0	25.5		
		1625	25.0				
164. Van Duzen River 0.5 mile below Bridgeville							
	6/20	1045	18.5	17.0	26.0		
		1610	25.0				
	7/20	0905	19.0	18.5	22.0	19.0	26.0
		1615	21.5				
	8/17	0900	18.5	18.0	23.0		
		1630	22.5				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
165. Van Duzen River 3 miles above Grizzly Creek							
	6/20	1025	20.0	17.5	27.0		
		1625	26.5				
	7/20	0850	18.5	18.0	23.5	19.0	27.0
		1625	23.0				
	8/17	0845	18.0	17.5	24.5		
		1640	24.0				
166. Van Duzen River at Grizzly Creek							
	6/20	1010	18.5	17.0	26.0		
		1640	25.5				
	7/20	0840	19.0	18.5	21.5	19.0	26.0
		1635	21.0				
	8/17	0830	18.0	18.0	21.0		
		1650	21.0				
167. Grizzly Creek at mouth							
	6/20	1010	15.5	14.5	25.0		
		1640	25.0				
	7/20	0840	16.0	15.5	19.0	16.5	25.0
		1640	19.0				
	8/17	0835	15.0	15.0	20.0		
		1650	20.0				
168. Van Duzen River 2.5 miles below Grizzly Creek							
	6/20	1000	18.5	17.0	26.0		
		1700	25.5				
	7/20	0830	18.0	18.0	21.5	19.0	26.0
		1645	21.0				
	8/17	0820	18.0	17.5	22.5		
		1700	22.0				
169. Van Duzen River 3 miles above Hely Creek							
	6/20	0945	18.5	17.0	26.5		
		1705	26.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
169. (Cont.)	7/20	0820	18.0	18.0	22.5	19.0	26.5
		1655	22.0				
	8/17	0810	17.0	17.0	22.0		
		1705	22.0				
170. Van Duzen River at Pamplin Grove							
	6/20	0935	19.0	17.5	25.0		
		1715	25.0				
	7/20	0810	18.0	18.0	22.0	19.0	25.5
		1700	21.5				
	8/17	0800	18.0	17.5	22.0		
		1710	22.0				
171. Van Duzen River 0.5 mile below Flanigan Creek							
	6/20	0925	18.5	17.5	25.5		
		1730	25.0				
	7/20	0800	18.0	18.0	20.5	19.0	25.5
		1705	20.5				
	8/17	0755	18.0	17.5	21.5		
		1715	21.0				
172. Van Duzen River 3.5 miles above Yager Creek							
	6/20	0910	18.5	17.5	25.5		
		1740	25.0				
	7/20	0745	18.0	18.0	21.0	19.0	25.5
		1710	21.0				
	8/17	0745	18.0	17.5	21.0		
		1725	21.0				
173. Van Duzen River at Yager Creek							
	6/20	0810	17.0	17.0	25.5		
		1755	25.5				
	7/20	0710	16.5	16.5	19.0	18.0	25.5
		0730	19.0				
	8/17	0700	16.0	16.0	19.0		
		1750	19.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
174.	Yager Creek 2 miles above mouth						
	7/20	0725	16.0	16.0	21.5		
		1725	21.0			18.5	28.0
	8/17	0720	16.0	16.0	23.5		
		1740	23.5				
175.	Yager Creek 0.75 mile above mouth						
	6/20	0825	17.0	16.5	28.0		
		1745	27.5				
	7/20	0735	16.5	16.5	21.0	18.5	28.0
		1720	20.5				
	8/17	0730	16.0	16.0	23.0		
		1735	23.0				
176.	Yager Creek at mouth						
	7/20	0715	16.0	16.0	18.5		
		1735	18.0			18.0	26.0
	8/17	0705	15.0	15.0	19.0		
		1750	19.0				
177.	Van Duzen River 0.5 mile above mouth						
	6/20	0740	17.0	16.5	25.0		
		1815	24.0				
	6/21	0740	18.0	17.5	22.5		
		1825	21.5			18.0	25.0
	7/20	0625	16.5	16.5	19.0		
		1745	19.0				
	8/17	0645	16.0	16.0	19.0		
		1805	19.0				
178.	Eel River at Fortuna						
	6/21	0730	20.0	20.0	22.0		
		1835	21.5			21.0	24.0
	7/21	0650	18.0	18.0	20.0		
		1810	20.0				

APPENDIX I. (Continued)

Station Number	Date	Time	Temperature Recorded	Estimated Minimum for Date	Estimated Maximum for Date	Estimated Highest Summer Minimum	Estimated Summer Maximum
179. Eel River at Fernbridge							
	6/21	0705	20.1	20.0	22.0		
		1845	21.5				
	7/21	0635	17.0	17.0	20.0	21.0	24.0
		1825	20.0				
	8/18	0645	18.0	18.0	20.0		
		1830	20.0				

APPENDIX II. Daily maximum and minimum water temperatures (C) recorded by a thermograph in the Eel River at Island Mountain during the summer of 1973.

Day	June max.	June min.	July max.	July min.	August max.	August min.	September max.	September min.
1	-	-	23.5	18.0	27.0	21.0	23.0	19.5
2	-	-	24.0	18.5	27.0	21.5	22.5	19.5
3	-	-	24.5	18.5	27.0	22.0	23.0	20.0
4	-	-	25.0	21.0	26.0	24.0	24.0	18.5
5	-	-	24.5	21.0	26.5	23.5	24.0	20.5
6	-	-	-	-	26.0	23.0	23.5	21.0
7	-	-	-	-	26.0	23.0	23.5	21.0
8	-	-	-	-	25.5	23.0	22.5	20.0
9	-	-	-	-	24.5	22.0	23.5	19.0
10	-	-	-	-	24.5	22.0	22.5	18.5
11	-	-	-	-	24.5	19.5	22.5	20.5
12	-	-	24.5	21.0	24.5	21.0	23.0	20.0
13	-	-	26.5	20.5	24.5	18.5	23.0	18.5
14	-	-	26.5	-	25.5	19.0	-	-
15	-	-	26.5	20.0	26.0	-	-	-
16	-	-	-	-	24.0	20.5	-	-
17	-	-	-	-	24.0	18.0	-	-
18	-	-	26.0	20.0	24.0	21.0	-	-
19	22.5	-	25.0	20.0	23.5	20.0	-	-
20	25.0	18.0	23.5	18.5	23.0	19.0	-	-
21	25.0	19.5	23.5	19.0	22.5	-	-	-
22	25.0	19.5	23.0	18.0	22.5	19.5	-	-
23	23.5	19.5	23.0	19.0	22.5	-	-	-
24	24.5	19.5	23.5	19.0	21.0	-	-	-
25	26.0	19.5	24.5	20.5	21.5	19.0	-	-
26	27.5	21.0	26.0	21.5	22.0	19.5	-	-
27	27.5	21.5	26.5	24.5	22.5	20.0	-	-
28	25.5	20.0	27.0	22.0	22.5	20.0	-	-
29	24.0	19.0	27.5	22.0	24.0	18.5	-	-
30	23.5	19.0	28.0	23.0	23.5	21.0	-	-
31	-	-	27.0	21.5	23.5	19.5	-	-

APPENDIX III

Water temperature conditions, environmental factors that may be influencing water temperatures, and observations of fish in individual stream sections of the Eel River system.

Individual stream sections are described below in downstream order. Each stream section is classified as lethal, marginal, or satisfactory for salmonids based on water temperature conditions.

Eel River above Horse Creek

The 8-mile headwater section of the Eel River above Horse Creek is classified as satisfactory; the maximum water temperature estimated during the summer of 1973 was 25.0 C.

The Eel River flows southeast 10 miles from the slopes of Bald Mountain to Horse Creek, dropping from an elevation of approximately 6000 feet to 2700 feet; however, the upper 2 miles, above the 5700-foot elevation, are believed to become intermittent during summer. A local forester stated that other portions of this stream section may also flow intermittently in some years. Due to the steep stream gradient, the river flows rapidly through boulders, forming cascades and a series of riffles and pools. Shading is provided by the narrow, steep-sided stream canyon and streamside vegetation. The major vegetative type in this portion of the watershed is chaparral, although areas of mixed conifers exist, especially in the headwater areas of the tributaries to this stream section. Conifers supplement the shading provided by streamside vegetation and canyon slopes.

Several small tributaries enter this section and provide sources of cool water, helping maintain the satisfactory nature of the stream. Trout Creek, which enters the river from the west approximately 1 mile above Horse Creek, had an estimated maximum temperature of 21.0 C. Excellent shading is provided to this creek by streamside vegetation.

Many resident rainbow trout up to 7 inches in length were observed in this section, and a few fingerlings were observed in the lower 50 yards of Trout Creek. Resident rainbow trout are the only salmonids found in this stream section due to the blockage of anadromous salmonids at Scott Dam, which forms Lake Pillsbury, approximately 15 miles below Horse Creek.

Eel River between Horse Creek and Lake Pillsbury

This 13-mile stream section above Lake Pillsbury is classified as marginal; the maximum summer temperature estimated for this section was 26.5 C. Marginal temperature conditions were believed to occur rarely during the summer and to be of short duration. Although only one temperature station (at Horse Creek) existed in this section, temperatures below this station were assumed to be approximately the same.

The river generally flows south through this section and turns west just before entering the lake. The stream gradient is flatter than that of the prior section; the elevation drops from approximately 2700 feet to 1800 feet. The river flows rapidly (although not as rapidly as in the prior section) through boulders, forming a series of riffles and pools to 8 feet in depth in the Horse Creek area.

As in the prior section, shading is provided by narrow canyons and streamside vegetation. Mixed conifers predominate in the upper third of this stream section and provide additional shading; however, in the lower two-thirds of this section, the river flows through areas of chaparral which provide less shading. Several tributaries enter the river between Horse Creek and Lake Pillsbury. Such tributaries may supply cool water to the river, forming areas that are satisfactory for salmonids throughout the summer, and may be good salmonid habitat themselves.

Resident rainbow trout up to 9 inches in length were found to be abundant in the Horse Creek area.

Lake Pillsbury

Lake Pillsbury is a 2,280-acre storage reservoir with a maximum storage capacity of 93,724 acre-feet formed behind Scott Dam. Contents of the reservoir during the summer typically decrease from approximately 86,000 acre-feet on June 1 to 40,000 acre-feet by the end of September (USGS 1961-1963 and 1964b-1972b). The two main tributaries to the lake are the Eel River and Rice Fork Eel River, which drains chaparral-covered slopes in the southern tip of the watershed. The major vegetative type surrounding Lake Pillsbury is chaparral.

Scott Dam forms a complete blockage to migrating fish; therefore, anadromous salmonids are only found below the dam. Rainbow trout is the principal sport fish in the lake, and it maintains itself through natural reproduction in tributary streams, primarily the Eel and the Rice Fork (Evans 1957). Midsummer die-offs of trout have occurred in Lake Pillsbury. Evans (1957) reported that high temperatures during the summer resulted in some fish mortality, and California Department of Fish and Game (1968) stated that the temperature of Lake Pillsbury during late summer was borderline for trout. Fisk and Pelgen (1955) stated that a warm summer together with a rapid drawdown could create conditions intolerable to trout. They reported that trout sought the cooler waters of the thermocline when surface temperatures reached about 24.0 C; however, the optimum temperatures of the hypolimnion were unavailable due to a dearth of dissolved oxygen.

Kabel (1960) recorded maximum surface temperatures at several stations in the lake during the summer of 1957. He found temperatures as high as 27.0 C and consistently found temperatures between 25.0 and 27.0 C. Temperatures recorded by USGS for the years 1966 to 1968 are similar to the findings of Kabel (Puckett and Van Woert 1972). Thus, Lake Pillsbury is classified as marginal.

Eel River between Scott Dam and Cape Horn Dam at Van Arsdale Reservoir

This 11-mile stream section below Scott Dam is classified as satisfactory. Water is released at Scott Dam from the cool hypolimnion water of Lake Pillsbury, thus producing a satisfactory habitat for salmonids. The estimated maximum temperature of water released from Scott Dam from June through August was 19.0 C. Estimated maximum temperatures increased downstream through this section to a maximum of 22.0 C just above Van Arsdale Reservoir. The maximum temperature recorded here from July 20 to August 8, 1973, by a DWR thermograph was 21.0 C.

Records of past temperatures below Scott Dam show that maximum temperatures are usually not reached until mid-September, when the maximum may be 2.0 C higher than in August due to warmer water being drawn out of Lake Pillsbury (Puckett and Van Woert 1972); even with this increase, stream temperatures remain satisfactory. The highest temperature recorded 0.7 mile below Scott Dam from 1964 to 1971 was 23.0 C, although maximums in most years were 21.0 C or less. Incomplete records from the lower portion of this stream section in 1964, 1966, and 1968 show that the maximum temperature recorded was 23.5 C (Puckett and Van Woert 1972; USGS 1970a and 1971a).

The Eel River flows west 11 miles from Scott Dam to Cape Horn Dam, dropping in elevation from approximately 1700 feet to 1500 feet. Although streamflows below Scott Dam during the summer fluctuate yearly and in some years fluctuate greatly over the course of a summer, flows generally average greater than 200 cfs and always average greater than 100 cfs (USGS 1961-1963 and 1964b-1972b). Mean monthly flows measured during the summer of 1973 were 173 cfs in June, 171 cfs in July, 176 cfs in August, and 298 cfs in September (USGS 1973b). The river flows rapidly through this stream section, forming alternating riffles, runs, and pools.

Shading is provided, particularly in the upper two-thirds of this section, by the narrow, steep-sided stream canyon, streamside vegetation, and mixed conifer forests. The lower third also has much streamside growth; however, the stream canyon is not as narrow and steep-sided. The major vegetative types are mixed conifers in the upper two-thirds of the section and hardwood woodlands in the lower third.

Shapovalov (1945) stated that the Eel River between Scott Dam and Van Arsdale Reservoir was one of the most productive stream sections in California. He reported that this section was heavily populated by juvenile steelhead and resident rainbow trout of large size. A fish ladder exists at Cape Horn Dam, allowing anadromous species to utilize this stream section. Fish counts at Cape Horn Dam indicate that steelhead spawn in this area in all years, chinook salmon in some years, and coho salmon not at all. In fact, coho salmon are not known to utilize the Eel River above the Middle Fork (California Department of Fish and

Game 1965a). During the summer of 1973, several fishermen were observed catching juvenile steelhead and/or resident rainbow trout 6 to 8 inches in length in this section.

Eel River between Cape Horn Dam and Tomki Creek

This 4-mile section of stream below Cape Horn Dam is classified as marginal; estimated maximum summer temperatures ranged from 26.5 to 27.5 C. A DWR thermograph located just above Tomki Creek recorded marginal temperatures up to 27.5 C on 7 days from July 18 to August 8, 1973.

Almost the entire streamflow entering Van Arsdale Reservoir is diverted to Potter Valley and the Russian River system during summer; flows at Potter Valley parallel those at Scott Dam (USGS 1961-1963 and 1964b-1972b). Therefore, flows in the Eel River below Cape Horn Dam are limited. Mean monthly streamflows measured at Cape Horn Dam from 1961 to 1972 ranged from 2.28 to 95.5 cfs in June, 1.55 to 4.73 cfs in July, 1.26 to 7.39 cfs in August, and 1.37 to 8.67 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean monthly flows measured during the summer of 1973 were 4.56 cfs in June, 7.68 cfs in July, 13.9 cfs in August, and 2.49 cfs in September (USGS 1973b).

Warmer surface waters of Van Arsdale Reservoir are allowed to flow through the fish ladder at Cape Horn Dam and form the river below the dam. Maximum temperatures measured in the fish ladder in 1963 and 1964 were usually satisfactory. The maximum recorded in 1963 was only 25.0 C; however, the maximum recorded in 1964 was 29.0 C (Puckett and Van Woert 1972). Even if water temperatures in the fish ladder are satisfactory, temperatures quickly increase to marginal levels downstream during warm summer periods due to the low streamflow.

Although this stream section is classified as marginal, thermally stratified pools with satisfactory bottom temperatures do exist. DWR monitored surface and bottom temperatures in two 10-foot deep pools above Tomki Creek from July 18 to August 8, 1973. Although surface temperatures were marginal on 7 days, bottom temperatures indicated a satisfactory habitat (21.0-24.5 C) during normal summer flows. To determine the effects of streamflow on the vertical stratification of temperature, flows of 5.6 (normal summer flow), 22, 40, and 83 cfs were released from Cape Horn Dam during this period. As flows increased, thermal stratification broke down, and bottom temperatures increased. Bottom temperatures became the same as warm surface temperatures at 22 cfs in one pool and 40 cfs in the other. Under present conditions, normal low summer flows prevent the mixing of warm surface and cool bottom waters in deep pools during warm afternoons and, thus, are important in maintaining areas of satisfactory habitat for salmonids between Cape Horn Dam and Tomki Creek. A few springs were noted entering this stream section which may indicate that cool bottom water in some pools is supplied by spring flow.

The Eel River flows north 4 miles from Cape Horn Dam to Tomki Creek, dropping in elevation from approximately 1450 feet to 1400 feet. Due to the flat stream gradient, the river is characterized by long, slow-flowing pools several hundred feet long and up to 10 feet deep; these pools are connected by shallow, wide riffles with abundant algae. Not as much shading is provided in this stream section as in upstream areas. The stream canyon is wider, and its slopes are not as steep. The river flows through hardwood woodlands in the upper two-thirds of this section and chaparral in the lower third; both vegetative types provide little shading. A small amount of streamside vegetation exists, particularly in the upper two-thirds of this section, and provides some shading.

Although most tributaries in this area go dry at least in their lower portions during the summer, Tomki Creek had a flow of approximately 1 cfs at its mouth in August. However, the estimated maximum temperature in Tomki Creek was 28.0 C, making it lethal and worsening the temperature condition of the river. The lower portion of Tomki Creek is highly exposed to the sun, and conditions upstream do not appear to be any better; streamflows measured 5.8 miles above the mouth indicate that this portion of the creek goes dry by midsummer (USGS 1964b-1970b).

Juvenile steelhead up to 7 inches in length were abundant in the pool immediately below Cape Horn Dam during all three sampling periods; this pool was particularly well shaded and offered a suitable habitat. However, few steelhead were observed in the rest of this stream section. Local residents reported observing some juvenile steelhead in a few of the deeper pools. In the lower portion of this section, several Sacramento suckers, *Catostomus occidentalis*, and California roach, *Hesperoleucus symmetricus*, were observed.

Eel River between Tomki Creek and Outlet Creek

This 27-mile stream section below Tomki Creek is classified as lethal; estimated maximum temperatures were as high as 30.5 C. Due to low streamflow and limited shading, water temperatures quickly increase below Cape Horn Dam and reach lethal levels in this section. DWR monitored stream temperatures from July 18 to August 9, 1973, at six thermographs in this stream section. Thermographs were located at Thomas Creek, Emandal Resort (2), Ramsing Ranch, and Fish Creek (2); 4, 7, 10, and 19 miles below Tomki Creek, respectively. The number of days on which lethal temperatures were attained at each of these thermographs ranged from 7 to 19 during this 23-day period, and maximum temperatures ranged from 29.5 to 30.5 C. The DWR thermograph located above Outlet Creek recorded lethal temperatures on 30 days during the summer of 1973; the maximum recorded here was 30.0 C.

Water temperatures recorded by thermographs at Hearst in 1966 and 1967 indicated that maximum temperatures were marginal in 1966 and satisfactory in 1967 (Puckett and Van Woert 1972). Judging from nearby temperature records for the same years, it appears unlikely that those temperatures recorded at Hearst were representative of the section for that time period. Lethal temperatures as high as 30.5 C were recorded just above Outlet Creek in 1966 (Puckett and Van Woert 1972). It appears that the thermographs at Hearst may have been set in an area of cool spring flow.

As in the prior stream section, a few thermally stratified pools with satisfactory bottom temperatures exist in this section. DWR monitored surface and bottom temperatures in two pools at Fish Creek; the pools were 10.5 and 12.5 feet in depth. Bottom temperatures were found to be satisfactory during normal summer streamflows. Flows were increased from 5.6 cfs to 22, 40, and 83 cfs. As flows increased and more mixing occurred, bottom temperatures increased. Bottom temperatures were marginal at 22 cfs and lethal at 40 cfs in the shallower pool and were marginal at 40 cfs and lethal at 83 cfs in the deeper pool. As mentioned for the prior stream section, it appears that under present conditions, low summer flows help maintain areas of satisfactory habitat for salmonids in this stream section.

The Eel River flows generally northwest 27 miles from Tomki Creek to Outlet Creek, dropping from an elevation of approximately 1400 feet to 1000 feet. Mean monthly streamflow measured 1,100 feet above Outlet Creek from 1967 to 1972 ranged from 19.3 to 183 cfs in June, 7.88 to 22.5 cfs in July, 3.74 to 11.4 cfs in August, and 3.27 to 13.9 cfs in September (USGS 1967b-1972b). Mean monthly flows measured during the summer of 1973 were 19.9 cfs in June, 10.6 cfs in July, 17.9 cfs in August, and 6.57 cfs in September (USGS 1973b).

Due to the flat stream gradient and low streamflows in midsummer, the stream is characterized by slow-flowing, shallow water and abundant algae. Throughout most of this stream section, the stream canyon is open and exposed to the sun, and little streamside vegetation exists. The major vegetative types are woodland-grass and chaparral, which provide little shading; small areas of Douglas fir and mixed conifers do exist in the upper portion of this section.

Several fingerling steelhead were observed at Hearst and several fingerlings and yearlings up to 5 inches in length were observed above Outlet Creek during the June sampling period; however, no steelhead were observed anywhere in this section later in the summer. The possibility does exist that steelhead may utilize the cool bottom waters of stratified pools. It has been reported that numerous salmonids have died below Cape Horn Dam due to high stream temperatures and low flows not sufficient enough to keep salmonids in good condition (Shapovalov 1941). Many suckers and roach were observed in areas surveyed, and several green sunfish, Lepomis cyanellus, were observed in isolated pools.

Outlet Creek

Outlet Creek is classified as lethal; the estimated maximum temperature in the lower 8 miles of the creek was 30.0 C. Temperatures measured 0.9 mile above the mouth during the summers of 1968 and 1969 indicated that lethal conditions existed in the lower portion of the creek in these years as well; the maximum recorded was 29.0 C (Puckett and Van Woert 1972). Although temperatures were only measured in the lower 8 miles of Outlet Creek, most of the upper 9.5 miles are believed to be at least marginal and probably lethal in many areas.

Many small streams unite to form Outlet Creek in Little Lake Valley near Willits. California Department of Fish and Game (1965a) stated that Outlet Creek is fed primarily by seepage from the valley and does not flow continuously during the summer due to heavy agricultural use. Due to the slight gradient in the valley, streams flow slowly and meander in dry grassland; some shading is provided by streamside vegetation.

Outlet Creek flows northwest 9.5 miles from Little Lake Valley to Long Valley Creek, dropping from an elevation of approximately 1350 feet to 1200 feet. The creek flows slowly through this stream section, forming shallow runs and pools. Shading is provided in some areas by steep-sided canyon slopes, streamside vegetation, and vegetation on canyon slopes. The main vegetative types are Douglas fir in the upper half of this section and woodland-grass in the lower half. Shading, particularly in the upper half, may keep temperatures lower than in downstream areas.

The estimated maximum temperature in Long Valley Creek near its mouth was marginal, 26.5 C. Long Valley Creek flows from the north into Outlet Creek with an estimated flow of less than 1 cfs by midsummer. It receives some good shading from streamside vegetation and canyon slopes.

Outlet Creek turns northeast and flows 8 miles from Long Valley Creek to the Eel River, dropping in elevation from approximately 1200 feet to 1000 feet. This section of stream is characterized by slow-flowing, shallow waters with abundant algae; riffles and pools to 4 feet in depth occur occasionally. Mean monthly streamflows measured in Outlet Creek, 0.9 mile above the mouth, from 1961 to 1972 ranged from 6.93 to 32.2 cfs in June, 1.29 to 7.40 cfs in July, 0.56 to 3.36 cfs in August, and 0.21 to 7.24 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean flows measured during the summer of 1973 were 7.31 cfs in June, 1.91 cfs in July, 0.76 cfs in August, and 1.78 cfs in September (USGS 1973b). This stream section receives little shading due to the openness of the stream canyon. Some streamside vegetation exists, but the wide nature of the streambed prevents significant shading. The major vegetative types are woodland-grass in the upper two-thirds of this section and Douglas fir in the lower third.

Several fingerling salmonids were observed in the lower portion of Outlet Creek during the June sampling period, but none were observed during subsequent sampling periods. During the August sampling period, several fingerlings were observed in the lower portion of Long Valley Creek. Many suckers and roach were observed in this creek system throughout the summer.

Eel River between Outlet Creek and the Middle Fork Eel River

The 6.5 miles of stream above the Middle Fork are classified as lethal; the estimated maximum temperature was 30.0 C. Portions of this stream section were actually found to be marginal during the summer of 1973. The maximum temperature estimated for the station 2.4 miles below Outlet Creek was 27.5 C, and the maximum recorded by the USGS thermograph 1.8 miles above the Middle Fork was 27.5 C.

Past temperature records at this thermograph site indicate that lethal temperatures are reached in most years, but that maximum temperatures are generally less than would be expected judging from nearby thermographs (Puckett and Van Woert 1972; USGS 1970a-1972a). It appears that portions of this stream section receive a significant amount of cool spring flow which may make certain areas marginal in some years.

The Eel River flows north 6.5 miles from Outlet Creek to the Middle Fork, dropping in elevation from approximately 1000 feet to 900 feet. Mean monthly streamflows measured 1.8 miles above the Middle Fork from 1961 to 1965 ranged from 34.0 to 101 cfs in June, 10.0 to 30.9 cfs in July, 2.22 to 10.6 cfs in August, and 2.08 to 8.13 cfs in September (USGS 1961-1963, 1964b, and 1965b). This stream section is characterized by shallow, slow-flowing water and abundant algae. Although the stream canyon is open, some shading is provided by canyon slopes and large boulders. The vegetation in this area is mainly woodland-grass and some hardwood woodland, both of which offer little shading. Little streamside vegetation exists.

Several fingerling and yearling salmonids up to 3 inches in length were observed in this stream section in June; a few were observed in July, and none were noted in August. Many suckers and roach were observed througout this stream section during the summer.

Middle Fork Eel River above Buck Creek

The Middle Fork above Buck Creek is classified as satisfactory. Approximately 30 miles of the Middle Fork exist above Buck Creek. Maximum temperatures estimated in the lower 5 miles of this stream section ranged from 24.0 to

25.5 C during the summer of 1973. Maximum temperatures in the upper portion of this section are believed to fall within this range or below it. The maximum temperature recorded by a thermograph at Rattlesnake Creek, 10.5 miles above Buck Creek, during portions of the summers of 1966 and 1967 was 24.0 C (Puckett and Van Woert 1972).

The Middle Fork Eel River flows southwest 13.5 miles from its headwaters to the North Fork of the Middle Fork, dropping in elevation from approximately 6000 feet to 3800 feet. Below confluence of the streams, the Middle Fork flows southeast 9.5 miles to Beaver Creek, dropping in elevation to approximately 2400 feet. The river then turns to the southwest and flows 7 miles to Buck Creek, at an elevation of 1700 feet. Smith and Elwell (1961) reported that flows in some sections of the upper river became intermittent during midsummer each year, particularly in the vicinity of Asa Bean Crossing, Wright's Valley, and portions of the North Fork. However, the river typically flows rapidly through boulders and bedrock forming small cascades and pools up to 15 feet in depth in this stream section.

Excellent shading is provided by the narrow, steep-sided stream canyon, overhanging rock ledges, large boulders in the streambed, and streamside vegetation. Most of this area is forested by mixed conifers which contribute to the shading. Several springs and small creeks, usually of steep gradient, enter the upper Middle Fork, providing sources of cool water and helping maintain the satisfactory nature of this stream section.

During the July sampling period, juvenile steelhead and/or resident rainbow trout up to 10 inches in length were abundant in the Osborn Station area. At the end of August, salmonids up to 10 inches were abundant from Osborn Station to Buck Creek. In addition, 24 adult summer steelhead were observed in the 2-mile stretch from Osborn Station to Hellhole Canyon. Smith and Elwell (1961) reported that summer steelhead and the greatest abundance of juvenile steelhead in the Middle Fork were concentrated above Osborn Station in 1959. Steelhead ascend at least the lower two-thirds of this stream section; chinook salmon ascend the Middle Fork up to a point near the lower boundary of this section; and coho salmon are not known to utilize the Middle Fork drainage (California Department of Fish and Game 1965a). A resident rainbow trout population is distributed throughout most of the Middle Fork, but the precise distribution and size of this population is unknown (Smith and Elwell 1961).

Smith and Elwell (1961) reported that from the end of July until the middle of September in 1959, nongame fish populations predominated below Osborn Station. However, few nongame fish (suckers and roach) were observed between Osborn Station and Buck Creek during the summer of 1973.

Middle Fork Eel River between Buck Creek and Black Butte River

The Middle Fork between Buck Creek and Black Butte River is a 3.5-mile stream section of generally marginal temperature conditions, rapidly changing to lethal in its downstream portion. During the summer of 1973, maximum temperatures estimated in the upper 2.25 miles of this section ranged from 26.5 to 27.5 C, while those in the lower 1.25 miles ranged from 28.0 to 29.0 C. Maximum temperatures measured 0.5 mile above Black Butte River during the last half of the summer of 1958 and the last third of the summer of 1959 indicated that at least marginal conditions existed in 1958 and lethal conditions in 1959; the maximum recorded was 28.0 C (Puckett and Van Woert 1972).

The Middle Fork flows 3.5 miles southwest from Buck Creek to Black Butte River, dropping in elevation from approximately 1700 feet to 1450 feet. Mean monthly streamflows measured 1.2 miles above Black Butte River from 1968 to 1970 ranged from 46.2 to 317 cfs in June, 16.8 to 46.1

cfs in July, 7.40 to 24.2 cfs in August, and 4.57 to 11.6 cfs in September (USGS 1968b-1970b).

Although the stream gradient is flatter than in the prior section, the river flows rapidly through bedrock and boulders and forms pools up to 10 feet in depth; however, there are several areas of shallow, slower-flowing water scattered through this section. The lower mile is characterized mainly by shallow riffles and runs and an increased abundance of algae. The streambed and stream canyon become wider in this section, and the canyon is not as steep-sided, leaving the river more exposed to the sun. Some shading is provided by canyon slopes, boulders, and vegetation. The upper half of this section is primarily forested by mixed conifers; the major vegetative type in the lower half is woodland-grass, which provides less shading.

Several juvenile steelhead and/or resident rainbow trout up to 7 inches in length, including one diseased individual, were observed between Buck Creek and Black Butte River at the end of August. The abundance of salmonids in this stream section was noticeably less than in the prior section, and the abundance decreased in a downstream direction through this section.

Suckers and roach were abundant, especially in the lower half of the section. Smith and Elwell (1961) found mixed populations of suckers and salmonids present in this section throughout most of the summer of 1959. They reported that when salmonids and suckers were observed in the lower portion of this section, they were almost always found in areas of cooler spring or subsurface upwelling.

During the August sampling period, approximately 100 juvenile steelhead and/or resident rainbow trout were observed in a pool of the Middle Fork just above confluence with Black Butte River. All fish were concentrated along the shoreline facing the gravel bar that separates the two streams. The temperatures of the Middle Fork above here and of Black Butte River were 25.0 and 26.0 C, respectively, in mid-afternoon; however, the temperature of the shoreline area where the fish were concentrated was only 23.0 C. It appears that some subterranean water of Black Butte River may seep under the gravel area of the lower river and flow into the Middle Fork, providing suitable areas for trout during hot afternoons.

Black Butte River

Only three temperature stations existed in Black Butte River (at the mouth, 0.5 mile above the mouth, and 3.5 miles above the mouth at Jumpoff Creek). The maximum temperature estimated at the lower two stations was lethal, 30.5 C. The maximum temperature estimated at Jumpoff Creek was marginal, 27.5 C. Temperatures measured 0.5 mile above the mouth from 1964 to 1972 show that lethal temperatures ranging from 28.0 to 31.5 C have consistently been recorded in every year except 1966; the maximum of 26.0 C recorded in 1966 is questionable (Puckett and Van Woert 1972; USGS 1970a-1972a). Temperature conditions in the rest of the river can only be surmised. It appears that temperature conditions may be very similar to those in the Middle Fork above Black Butte River.

Black Butte River flows 18.5 miles northwest from its headwaters to Jumpoff Creek, dropping in elevation from approximately 3500 feet to 1700 feet, and continues in the same direction for an additional 3.5 miles to the Middle Fork, dropping to 1450 feet. Mean monthly streamflows measured 0.5 mile above the mouth from 1961 to 1972 ranged from 20.7 to 101 cfs in June, 8.67 to 36.7 cfs in July, 2.51 to 11.3 cfs in August, and 1.87 to 10.9 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean flows measured during the summer of 1973 were 50.1 cfs in June, 16.7 cfs in July, 7.70 cfs in August, and 5.49 cfs in September (USGS 1973b).

The river flows rapidly, forming alternating riffles and pools to 8 feet in depth in at least the lower few miles of stream. The upper half of Black Butte River flows through hardwood woodlands in a narrow, steep-sided stream canyon, while the lower half flows primarily through woodland-grass areas in a wider canyon. It appears that shading is provided, particularly above Jumpoff Creek, by the stream canyon and vegetation.

Many small creeks and springs enter Black Butte River along its course and possibly provide a significant supply of cool water to the river. One creek in particular, Jumpoff Creek, was examined during the summer of 1973. The maximum temperature estimated for this stream was 23.5 C. Jumpoff Creek flows down a steep, narrow canyon, cascading through boulders and forming pools to 4 feet in depth. Excellent shading is provided by the narrow canyon and extensive streamside vegetation.

The physical characters of the lower 3.5 miles of Black Butte River (below Jumpoff Creek) and the 3.5 miles of the Middle Fork above Black Butte River are much the same; the elevation, stream gradient, canyon-type, and vegetative cover are all similar. This fact coupled with the water temperatures measured in the two stream sections indicate that temperature conditions are also similar.

However, lethal conditions, as found in the lower 1.25 miles of the Middle Fork stream section, probably extend farther upstream in Black Butte River due to lower streamflow.

The physical conditions of the upstream portions of the two streams differ. Black Butte River originates at a lower elevation and has a significantly flatter stream gradient. Shading is provided in both by narrow canyons and vegetation; however, the hardwood woodlands of the Black Butte probably provide less shading than the conifers of the Middle Fork. Streamflow in the Black Butte is considerably less than that in the Middle Fork. Due to these differences, the marginal stream section of Black Butte River can be expected to extend a greater distance upstream than found in the Middle Fork.

Thus it is surmised that lethal conditions exist in approximately the lower 3 miles of Black Butte River, marginal conditions in the middle 5 miles, and satisfactory conditions in the upper 14 miles.

Several juvenile steelhead and/or resident rainbow trout up to 7 inches in length were observed in Black Butte River, 0.5 mile above its mouth during the June and July sampling periods; however only roach and suckers were observed in August. Salmonids up to 10 inches in length were abundant in Jumpoff Creek. Smith and Elwell (1961) reported that the only steelhead nursery areas of any consequence were located in the upper portions of the river.

Middle Fork Eel River below Black Butte River

The lower 29 miles of the Middle Fork are classified as lethal; maximum temperatures estimated during the summer ranged from 29.0 to 30.5 C. The USGS thermograph located 0.2 mile downstream from Black Butte River recorded lethal temperatures on 9 days during the summer of 1973; the maximum recorded was 29.5 C. In 1961 and 1963-1970, no lethal temperatures were recorded at this site; however, temperatures were measured during only a small portion of the summer in most of these years (Puckett and Van Woert 1972; USGS 1970a). Lethal temperatures as high as 29.5 C were recorded in 1971 and 1972 (USGS 1971a and 1972a). Still, early records indicate the possibility that marginal temperature conditions could exist in a small area below Black Butte River in some years. It appears that cooler temperatures recorded here may be due to cool spring or subterranean inflow.

Past temperature records at sites farther downstream indicate highly lethal conditions. A thermograph located at Etsel Flat, 5.5 miles below Black Butte River, recorded lethal temperatures on more than half of the days during the summer of 1959; the maximum recorded was 33.0 C. Maximum temperatures measured 2 miles above the main Eel River during portions of the summers of 1958, 1959, and 1965-1972 indicate that lethal conditions exist here in most years; the maximum recorded was 32.0 C (Puckett and Van Woert 1972; USGS 1970a-1972a).

The Middle Fork flows south 15 miles from Black Butte River to Elk Creek, dropping from an elevation of approximately 1450 feet to 1150 feet; it then turns to the west and flows 14 miles to the Eel River, dropping to an elevation of 900 feet. Mean monthly streamflows measured 0.2 mile below Black Butte River from 1961 to 1967 ranged from 119 to 588 cfs in June, 31.5 to 97.7 cfs in July, 10.5 to 27.7 cfs in August, and 7.49 to 16.7 cfs in September. Mean flows measured 1.9 miles above the mouth from 1966 to 1972 ranged from 124 to 846 cfs in June, 39.4 to 119 cfs in July, 10.4 to 46.4 cfs in August, and 7.97 to 49.7 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean flows measured here during the summer of 1973 were 234 cfs in June, 39.3 cfs in July, 17.4 cfs in August, and 19.5 cfs in September (USGS 1973b).

Due to the flatter stream gradient and wider nature of the streambed, the river spreads out and becomes shallower in this stream section. The flow is generally rapid, although not as rapid as in the prior section, and algae are abundant. This stream section is characterized by shallow riffles, runs, and occasional pools typically less than 6 feet in depth.

Shading is provided in portions of this stream section by steep-sided canyon slopes, but the majority of the section is highly exposed to the sun in an open canyon. Little streamside vegetation occurs due to the existence of extensive flood plains. The river flows through areas of woodland-grass, pine, and chaparral in the upper half of this section and through woodland-grass in the lower half. Most of this section is contained within the Mediterranean warm summer climate zone; thus, hotter drier conditions are expected.

The lower portions of tributaries to this section of the Middle Fork typically become intermittent during summer and have lethal temperature conditions. Smith and Elwell (1961) reported that Short and Mill Creeks go dry throughout most of their lengths in late spring and remain that way up until winter rains occur. An aerial survey made on July 31, 1959, revealed that all tributaries to the

Middle Fork below Black Butte River were dry at their mouths; Smith and Elwell (1961) reported that this condition is apparently typical of conditions occurring during the summer months in the Middle Fork drainage. They stated that the only salmonid nursery areas of any consequence in the tributaries below Black Butte River are located in the upper sections of Williams and Thatcher Creeks, and in the extreme headwaters of Mill, Short, and Elk Creeks.

The lower mile of Williams Creek was examined during the summer of 1973, and temperature conditions were found to be lethal; the estimated maximum temperature was 30.5 C. The lower 100 yards of Williams Creek were dry during all observations, and by August many areas in the lower mile were dry. Mean monthly streamflows measured 1 mile above the mouth from 1962 to 1969 ranged from 6.32 to 22.0 cfs in June, 1.25 to 3.92 cfs in July, 0.23 to 2.15 cfs in August, and 0.10 to 1.29 cfs in September (USGS 1962, 1963 and 1964b-1969b).

Temperatures measured in the lower portion of Elk Creek from 1966 to 1968 indicate that lethal conditions are found during the summer months; the maximum temperature recorded was 34.5 C (USGS 1966a-1968a). Mean monthly streamflows measured in the lower portion of Elk Creek from 1965 to 1972 ranged from 12.0 to 78.2 cfs in June, 2.74 to 14.1 cfs in July, 1.20 to 4.55 cfs in August, and 0.90 to 5.04 cfs in September (USGS 1965b-1972b). Mean monthly flows measured during the summer of 1973 were 22.7 cfs in June, 2.97 cfs in July, 0.96 cfs in August, and 1.67 cfs in September (USGS 1973b).

Concentrations of juvenile steelhead and/or resident rainbow trout were observed in cool water pockets between Black Butte River and Williams Creek during the summer of 1973. In August, approximately 100 salmonids were concentrated at the edge of the river facing the gravel shore 300 yards below Black Butte River. The temperature in this pocket was 23.0 C, while that of the river was 25.0 C during mid-afternoon. The inflow of cool water was probably due to spring or subterranean seepage. Several salmonids were observed in a similar situation 1 mile above Williams Creek. A few juvenile steelhead were observed in a single pool in Williams Creek during all three sampling periods, although there were noticeably fewer fish in August. The pool was approximately 1 foot in depth and had bottom temperatures of 23.0 and 25.0 C when representative stream temperatures were 25.0 and 27.0 C, respectively. The cool water was evidently supplied by spring flow.

Between Etsel Flat and Mill Creek, a few salmonids were observed in isolated cool-water pockets. One such pocket was located against the downstream edge of a gravel bar that formed a bend in the river. Possibly, river water from above seeps through the gravel bar and is cooled. Other pockets were no doubt the result of spring flow. A few salmonids up to 7 inches in length were observed in the lower 100 yards of the Middle Fork in June and July. A few fingerlings, including one diseased individual, were observed here in August.

Roach and suckers were observed throughout this section of the Middle Fork during the summer and were abundant in most areas. These two species were also observed in the lower mile of Williams Creek.

Smith and Elwell (1961) reported that large numbers of salmonids were present throughout this stream section up until the end of June in 1959; however, during the remainder of the summer, there was almost a complete absence of salmonids, and from the end of July to the middle of September, nongame fish populations predominated. They found mixed populations of suckers and salmonids in areas of cool spring or subsurface upwelling above Williams Creek throughout the summer. They reported that only nongame fish populations were found from Etsel Flat to the mouth during the summer, and that there are indications that a kill of game and nongame fish occurs in the lower reaches of the Middle Fork each summer.

Eel River between the Middle Fork and the North Fork Eel Rivers

This 21-mile stream section of the Eel River below the Middle Fork is classified as lethal; maximum estimated temperatures for the summer of 1973 ranged from 28.0 to 30.5 C. Maximum temperatures measured during portions of the summer of 1966-1968 at Spy Rock, 7.5 miles above the North Fork, were 28.0, 29.5, and 26.5 C, respectively (Puckett and Van Woert 1972). The cooler temperatures recorded in 1968 are not believed to truly represent this stream section.

Local residents reported that a few thermally stratified pools exist in this stream section; the cooler bottom waters of such pools may be satisfactory for salmonids. Local residents also reported that a large amount of cool spring flow in the Bell Springs area cools portions of the river to temperatures which are satisfactory; the lowest estimated maximum temperature in this section (28.0 C) was in the Bell Springs area.

The Eel River flows northwest 21 miles from the Middle Fork to the North Fork dropping in elevation from approximately 900 feet to 600 feet. Mean monthly streamflows measured 2 miles below the Middle Fork from 1961 to 1966 ranged from 216 to 575 cfs in June, 51.2 to 150 cfs in July, 13.7 to 46.5 cfs in August, and 8.51 to 28.1 cfs in September (USGS 1961-1963 and 1964b-1966b).

This stream section is characterized by shallow, slow-flowing water with abundant algae. Riffles and pools which are generally less than 8 feet in depth, occur occasionally. Little shading is provided in this stream section. The stream canyon is wide and open, and some flood plain areas exist. Streamside vegetation is sparse, and the major vegetative type is woodland-grass, which offers little shading.

Temperatures of several small tributaries, all of which had an estimated flow of near 1 cfs or less at the beginning of August, were measured. The estimated maximum summer temperatures of these streams in downstream order were: Burger Creek, 29.5 C; Woodman Creek, 28.0 C; Shell Rock Creek, 31.5 C; Blue Rock Creek, 27.0 C; and Bell Springs Creek, 28.5 C. Several cool springs, most of which were centered in the Bell Springs area, were noted. These springs may provide cool pockets of water for a limited number of salmonids during the summer.

Observations of salmonids in this stream section were made during a hot spell when maximum summer temperatures were attained. Salmonids were non-existent through most of the section. When observed they were always found in areas of cool spring or subsurface upwelling and in or near cooler tributaries. Several dead salmonids were also observed; the heat-related death of salmonids has been reported in this stream section by Wales (1938). Observations made during the summer of 1973 were as follows: A few salmonids were found in Burger Creek; one was showing significant stress in the 28.5 C water. One salmonid was observed in a side pool of the river at Woodman Creek in 25.0 C water, while the temperature of the river was 26.0 C in the evening; this salmonid was no doubt able to survive the 28.5 C water earlier in the day by remaining in the apparent cool spring inflow. One dead salmonid was also noted near the mouth of Woodman Creek on the same day.

A pool near River Garden, 12 feet long, 5 feet wide, and 4 feet deep, situated at the edge of the stream canyon and not connected to the river, contained several salmonids. At midday, the pool was 25.0 C, while the river was 26.5 C. It is believed that this pool is spring-fed and probably receives little direct sun due to shading from the canyon slope and vegetation.

Two salmonids showing distress were observed in a shaded pool of Shell Rock Creek in 28.5 C water, while the temperature of the creek was 31.0 C in late afternoon; a small amount of spring flow was evident. Approximately 50 salmonids were observed along the edge of the river at the dried up mouth of Shell Rock Creek. These fish remained between and under rubble where there was a cool water upwelling; the temperature among the rubble was 25.0 C, while the temperature of the river was 30.0 C in late afternoon. The source of this water may have been from subterranean seepage from Shell Rock Creek.

Over 100 salmonids, including fingerlings, yearlings, and two-year olds to 8 inches in length, were observed in Blue Rock Creek, and at least 25 fingerlings were found dead in the creek and in the river at the mouth of the creek. Many of these fish, both alive and dead, were pale and yellowish in color; similar observations of fish becoming pale and yellow in warm waters of the Eel River have been reported by Wales (1938) and Shapovalov (1941).

In the evening, the temperature recorded in the creek was 25.0 C, but it is estimated that the temperature earlier in the day had been marginal (27.0 C).

Several fingerlings were observed in Bell Springs Creek in early afternoon when the stream temperature was 25.0 C. The estimated maximum later in the day was 28.0 C; however, some cool spring flow may have maintained cooler temperatures in portions of the creek. A local resident reported that he had observed several salmonids in the river during midsummer around Bell Springs, an area which apparently receives significant spring inflow.

Suckers and roach were abundant throughout this entire stream section. On two occasions, groups of as many as 200 suckers of a foot or more in length were observed in large pools.

North Fork Eel River

During the summer of 1973, temperature data were collected from the lower 6 miles of the North Fork. This area is classified as lethal; estimated summer maximums ranged from 28.0 to 30.5 C. The lowest maximum, 28.0 C, occurred just below Asbill Creek, which had an estimated maximum of 25.5 C. A DWR thermograph located approximately 6 miles above the mouth recorded lethal maximums on 19 days out of the 65 days it was in operation during the summer; the maximum recorded was 29.5 C. Temperatures measured here during a portion of the 1966 summer were found to be lethal on several days; the maximum recorded was 29.0 C (Puckett and Van Woert 1972). One other temperature observation was made in the North Fork during the summer of 1973; a maximum temperature of 28.0 C was estimated at Salt Creek, 26.5 miles above the mouth.

Rogers *et al*. (1968) made a limited survey of the North Fork. In the 5-mile stretch of stream from the mouth to Asbill Creek, they found shallow areas without cover and temperatures to 26.5 C; some juvenile steelhead were observed. Between Asbill Creek and Hulls Creek, a 9.5-mile stretch of stream, they found no suitable habitat and temperatures in excess of 26.5 C. In the 19-mile stretch above Hulls Creek, temperatures of 26.5 C were found in the lower portions, and temperatures of 21.0 C were found at higher elevations near Soldier Creek, 18 miles above Hulls Creek. No steelhead were observed in the 12-mile stretch from Hulls Creek to Salt Creek; however, some steelhead were observed between Salt Creek and Soldier Creek.

It can be surmised that lethal conditions exist in the 26.5-mile stream section from Salt Creek to the mouth; marginal conditions exist in the 6-mile stream section from

Soldier Creek to Salt Creek; and satisfactory conditions exist above Soldier Creek in about 11 stream miles, including 6.5 miles and 3.5 miles of the West and East Forks of the North Fork, respectively.

The West Fork flows southeast 7 miles to confluence with the East Fork, dropping in elevation from approximately 3600 feet to 2100 feet; however, the upper 0.5 mile above 3000 feet is believed to become dry during the summer. The East Fork originates at an elevation of 3000 feet and flows southeast 3.5 miles. From confluence of the two forks, the North Fork flows southeast 1 mile to Soldier Creek at an elevation of 2000 feet, generally south 6 miles to Salt Creek at 1800 feet, southeast 12 miles to Hulls Creek at 1250 feet, west and then southwest 8 miles to a point at 1050 feet, and finally northwest 6.5 miles to the mouth at 600 feet.

Mean monthly streamflows measured 6 miles above the mouth from 1961 to 1972 ranged from 20.3 to 71.3 cfs in June, 5.40 to 17.6 cfs in July, 1.58 to 9.41 cfs in August, and 0.65 to 7.18 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean monthly flows measured during the summer of 1973 were 26.4 cfs in June, 5.97 cfs in July, 0.57 cfs in August, and 9.77 cfs in September (USGS 1973b).

Due to the flat stream gradient and low streamflows during middle and late summer, the lower river is characterized by shallow riffles and slow-flowing runs with abundant algae. Occasional pools up to 8 feet in depth occur. Some shading is provided in portions of the stream by stream canyon slopes and vegetation; however, the shading does not appear extensive. Above Salt Creek, the river flows mainly through areas of hardwood woodlands and mixed conifers. Below Salt Creek the river flows predominantly through woodland-grass areas, which provide little shading.

Salmon are blocked near the mouth of the North Fork by a natural barrier (California Department of Fish and Game 1965a); therefore, steelhead and/or resident rainbow trout are the only salmonids found in all but the lower few miles of the North Fork. During the summer of 1973, trout were only observed in areas of cool spring upwelling or cool tributary inflow. Approximately 50 fingerlings, yearlings, and two-year olds up to 8 inches in length were observed on the bottom of an 8-foot deep thermally stratified pool below Mina. Water flowing into the pool and the surface water of the pool were 27.0 C in early afternoon; however, the bottom 2 feet of the pool measured 23.0 C, probably due to cool spring upwelling. A few fingerlings were also observed in the cool bottom waters of pools between here and Asbill Creek.

Several fingerlings and yearlings were observed in Asbill Creek and in a cool stretch below the creek. The North Fork above Asbill Creek was 29.0 C; Asbill Creek, 24.0 C; and the North Fork for at least 100 feet below Asbill Creek, 26.0 C in late afternoon during the July sampling period. Asbill Creek appeared to have a flow near 1 cfs in July and receives excellent shading from streamside vegetation.

Approximately 0.25 mile above the North Fork mouth a 10-foot deep thermally stratified pool was found, but it contained no fish. The inflow to the pool and the surface water was 29.0 C, while the bottom 3 feet measured 24.0 C in mid-afternoon. Nearby, a few fingerling steelhead were observed in a cool side pool where water of approximately 25.0 C upwelled through the rubble.

Many suckers and roach were observed in the lower 6 miles of stream below Mina. No fish were observed in the Salt Creek area during the August sampling period.

Eel River between the North Fork Eel River and Eel Rock

This 39.5-mile stream section below the North Fork is classified as lethal; maximum temperatures estimated during the summer of 1973 ranged from 28.0 to 30.0 C. Past temperature records and the thermograph records of the summer of 1973 indicate that portions of this stream section may be marginal in some years. The thermograph located at Island Mountain, 6.5 miles below the North Fork, recorded a lethal temperature of 28.0 C on only one day during the summer of 1973 (Appendix II). Incomplete records for 1966 show that no temperature greater than 27.0 C was recorded; however, in 1967, lethal temperatures were attained on 7 days, and the maximum temperature was 29.0 C (Puckett and Van Woert 1972).

The DWR thermograph at Alderpoint, 16.5 miles below Island Mountain, recorded lethal temperatures on 17 days out of the 55 days it was in operation during the summer of 1973; the maximum temperature recorded was 32.0 C. Past temperature records indicate somewhat milder lethal conditions and in some years even marginal conditions at Alderpoint (Puckett and Van Woert 1972). In 1961, lethal temperatures were recorded on 3 days; the maximum temperature was 28.0 C. In 1962 and 1963, the maximum recorded was only 27.0 C. However, in 1964, 5 lethal days were recorded, and the maximum temperature was 29.5 C.

The USGS thermograph at Fort Seward, 8.5 miles below Alderpoint, recorded no temperature greater than 27.0 C during the summer of 1973. Past thermograph records indicate much warmer temperature conditions at this site (Puckett and Van Woert 1972; USGS 1970a-1972a). In 1966, lethal temperatures up to 33.0 C were recorded on a majority of the summer days. Incomplete records for 1967 through 1972 show lethal conditions existing in each of these years, and in most years, lethal temperatures were measured on several days; maximum temperatures in these years ranged from 28.0 to 34.5 C. The great variation in recorded temperature conditions at thermograph sites in this stream section does not appear to reflect the true temperature conditions here.

The Eel River flows northwest 39.5 miles from the North Fork Eel River to Eel Rock, dropping from an elevation of approximately 600 feet to 200 feet. Mean monthly streamflows measured at Alderpoint from 1961 to 1965 ranged from 275 to 738 cfs in June, 70.7 to 126 cfs in July, 19.2 to 65.8 cfs in August, and 11.8 to 41.4 cfs in September. Mean monthly flows measured at Fort Seward from 1966 to 1972 ranged from 210 to 1318 cfs in June, 71.2 to 199 cfs in July, 27.6 to 100 cfs in August, and 22.2 to 99.8 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean flows measured during the summer of 1973 were 324 cfs in June, 79.4 cfs in July, 44.0 cfs in August, and 54.9 cfs in September (USGS 1973b).

Due to the flat stream gradient in this section, the river is characterized by large areas of shallow, slow-flowing water with abundant algae. Riffles and a few deep pools are scattered through the section. Little shading is provided by canyon slopes and vegetation. The stream canyon is open, and flood plain areas are more extensive than in the stream section immediately upstream. Little streamside vegetation exists, and the dominant vegetative type is woodland-grass, which provides little shading; areas of Douglas fir exist between Alderpoint and Fort Seward and in the lower portion of this stream section near Eel Rock. A Mediterranean warm summer climate is found from Island Mountain to Fort Seward; thus, hotter, drier conditions are expected.

Although this stream section is classified as lethal, marginal conditions may exist in a few limited areas due to cool tributary or spring inflow. The maximum summer temperature of an unnamed tributary, with a flow of less than 1 cfs in midsummer, located 2.5 miles above Island Mountain was estimated to be satisfactory (25.0 C). However, this tributary is not typical of most in this area.

The lower portion of Dobbyn Creek, a tributary entering the Eel River 0.5 mile below Fort Seward, was found to be lethal. Estimated maximum temperatures in the lower 3.5 miles of the creek below confluence of the North and South Forks of Dobbyn Creek ranged from 28.0 to 29.0 C. Just above confluence of the forks, the estimated maximum temperature of the North Fork was marginal, 27.0 C, and that of the South Fork was lethal, 29.0 C. The estimated maximum temperature of the South Fork 2.5 miles above the forks was 27.0 C.

Streamflow below the forks appeared to be greater than 1 cfs during the August sampling period. Those portions of creek surveyed were generally characterized by shallow waters flowing rapidly through boulders and rubble with occasional pools to 3 feet in depth. Some shading is provided in portions of the creek by canyon slopes and streamside vegetation, but in general, the creek is highly exposed to the sun. The dominant vegetative type is woodland-grass, which provides little shading.

In this section of the Eel River, salmonids were only observed during the June sampling period. A few fingerlings were observed in the Alderpoint area, and one dead fingerling was noted at Fort Seward. Suckers, roach, and threespine sticklebacks, *Gasterosteus aculeatus*, were abundant in most portions of this stream section during the entire summer. The heat-related death of large numbers of salmonids has been reported in this stream section by Wales (1938). He stated that the worst section of stream in the main Eel River that he observed was around Fort Seward.

A few salmonids were observed in Dobbyn Creek 1.5 miles above its mouth during the June sampling period, but only roach and stickleback were observed during the subsequent sampling periods. In July, approximately 30 fingerlings, yearling, and two-year-old salmonids up to 8 inches in length and 6 suckers up to 12 inches in length were observed in a 3-foot deep pool at the confluence of the North and South Forks of Dobbyn Creek. All fish were concentrated in the cooler current of the North Fork; in late afternoon, the temperature of the South Fork was 26.0 C, and that of the North Fork was 23.5 C. Similar observations were made here during the August sampling period. A few salmonids up to 6 inches in length and many roach were observed in the South Fork, 2.5 miles above the confluence of the forks, during all three sampling periods.

Eel River between Eel Rock and the South Fork Eel River

This 13.5-mile stream section above confluence with the South Fork Eel River is classified as marginal;

maximum summer temperatures estimated for this section ranged from 26.5 to 27.5 C. The DWR thermograph at Eel Rock recorded marginal temperatures on 6 days during the summer of 1973; the highest temperature recorded was 27.0 C. The DWR thermograph located above the South Fork recorded marginal temperatures on 3 days. A lethal temperature of 28.0 C was actually reached on one of these days; however, a temperature of this magnitude does not appear to truly represent this stream section.

In some years, the lower portion of this stream section may be satisfactory. In 1968, a thermograph at McCann, 6 miles above the South Fork, recorded no temperature greater than 25.5 C. In 1966, no temperature greater than 24.5 C was recorded during a small portion of the summer 1 mile above the South Fork (Puckett and Van Woert 1972).

The Eel River flows northwest 13.5 miles from Eel Rock to the South Fork, dropping in elevation from approximately 200 feet to 150 feet. The river basin becomes much wider in this stream section, and extensive flood plains exist. The river spreads out and generally flows slowly with few riffles through this low gradient stream section. Waters are generally deeper here than in the prior section, but some wide, shallow areas exist. Due to the wider nature of the stream canyon and extensive flood plains, shading from canyon slopes and vegetation is restricted.

All of this stream section except for a 2-mile stretch below Eel Rock is contained within the Mediterranean cool summer with light fog climate zone. This area was noticeably cooler on most days than upstream areas. The sun was often blocked by fog in the mornings and late afternoons, and cool winds blowing upstream were evident during some afternoons. The major vegetative types in this area coincide with the climatic types. Douglas fir are found in the 2-mile stretch below Eel Rock, and redwoods are found throughout the rest of this stream section.

Sonoma Creek, which is tributary to this stream section 8 miles above the South Fork at Whitlow, was examined during the summer. The estimated maximum temperature of this creek was only 20.0 C. Excellent shading is provided by dense streamside vegetation that forms a complete canopy over the lower portions of the creek. Streamflow at the end of July was less than 1 cfs near the mouth; during the August sampling period, streamflow was intermittent in the lower 300 feet of stream.

Several fingerling salmonids were observed at Eel Rock during the June sampling period, but none were observed during subsequent sampling periods. Fingerlings and a few yearlings up to 5 inches in length were observed in the lower portions of this stream section in June and July. A fisherman reported catching several salmonids up to 6 inches in length in a portion of the river just above the South Fork at the end of July. No salmonids were observed in this section during the August sampling period; however, visual conditions were poor at this time. Fingerling salmonids were abundant in Sonoma Creek during all sampling periods. Many roach, suckers, and sticklebacks were observed throughout this section of the Eel River. The heat-related death of salmonids has been reported in this stream section by Wales (1938). However, he stated that conditions in this section were much better than in upstream areas.

South Fork Eel River above Ten Mile Creek

The upper 20.5 miles of the South Fork Eel River are classified as satisfactory. Maximum estimated temperatures ranged from 24.5 C at the uppermost point surveyed, 8.5 miles below the headwaters, to 26.0 C at Ten Mile Creek.

Incomplete temperature records from a thermograph located 5 miles above Ten Mile Creek indicate that a portion of this stream section may be marginal and even lethal in some years (Puckett and Van Woert 1972; USGS 1970a). The maximum summer temperatures recorded in 1957, 1958, 1962-1964, and 1966-1969 were satisfactory and ranged from 23.5 to 26.0 C. However, in 1961, marginal temperatures were measured on 4 days, and a lethal temperature of 28.0 C was recorded one day. In 1965, 4 days of marginal temperatures as high as 27.0 C were recorded. In 1970, marginal temperatures were measured on 18 days, and lethal temperatures as high as 28.5 C were recorded on 6 days. Temperatures recorded by this thermograph in some years are not believed to be representative of this entire stream section, because the thermograph was located within a small logged section of stream with noticeably less shading than the rest of the section.

From its headwaters, the South Fork Eel River generally flows northwest 12.5 miles and then north an additional 8 miles to Ten Mile Creek, dropping from an elevation of approximately 2300 feet to 1200 feet. Mean monthly streamflows measured from 1961 to 1970 approximately 5 miles above Ten Mile Creek ranged from 10.3 to 31.9 cfs in June, 4.00 to 12.7 cfs in July, 1.79 to 7.42 cfs in August, and 1.20 to 5.29 cfs in September (USGS 1961-1963 and 1964b-1970b). Due to the moderately steep stream gradient, the river flows rapidly through bedrock and boulders, forming alternating riffles and pools. The pools are generally not deeper than 4 feet in the upper threequarters of this section but increase in size downstream to pools over 10 feet in depth.

The stream generally flows through a narrow, steep-sided canyon in the lower quarter of this stream section and in the extreme headwaters, providing good shading. The remainder of the stream flows through a small valley with less shading from land masses but receives excellent shading from dense streamside vegetation, which forms a complete canopy over portions of the stream. The major vegetative types are Douglas fir in the upper and lower quarters of this stream section and redwood in the center portion; both contribute to stream shading. The center portion is contained within the Mediterranean cool summer with light fog climate zone, while the upper and lower portions are contained within the Mediterranean cool summer climate zone. The cooling influence of fog was noted in this stream section during summer.

Several cool tributaries and springs enter the South Fork in this section. Elder Creek, which enters the river 4 miles above Ten Mile Creek, reached a maximum temperature of 19.5 C, as recorded by the USGS thermograph during the summer of 1973; the maximum temperature ever recorded here from 1968 to 1973 was 21.0 C (USGS 1968a-1972a). Mean monthly streamflows measured 0.2 mile above the mouth from 1968 to 1972 ranged from 2.75 to 5.36 cfs in June, 1.25 to 2.99 cfs in July, 0.81 to 1.62 cfs in August, and 0.59 to 1.34 cfs in September (USGS 1968b-1972b). During the summer of 1973, mean monthly flows were 3.66 cfs in June, 1.83 cfs in July, 0.97 cfs in August, and 1.54 cfs in September (USGS 1973b). Excellent shading is provided by dense streamside vegetation along this stream.

Fingerling and yearling salmonids up to 5 inches in length were abundant in this portion of the South Fork, and many fingerlings were observed in Elder Creek. Additionally, some larger salmonids were observed. A few 12-inch resident rainbow or steelhead trout were observed near Elder Creek, and six trout over 20 inches in length were observed in two pools, 2 miles below Elder Creek. The latter fish could possibly have been summer steelhead. In the lower mile of this stream section, fewer salmonids and many roach were observed. Elwell (1965) stated that some of the best nursery areas for juvenile salmonids in the South Fork are found in this stream section. He reported that young steelhead were far more abundant in this stream section (excluding approximately the lower 2 miles) than in any other portion of the South Fork which he surveyed.

Ten Mile Creek

Only two temperature stations existed in Ten Mile Creek during the summer of 1973. Temperature conditions in the rest of the watershed can only be surmised. The estimated maximum temperature at the mouth of Ten Mile Creek was marginal, 26.5 C, and it is possible that the lower 4 miles of the creek are marginal. The estimated maximum temperature 8 miles above the mouth was lethal, 30.0 C, and it is believed that lethal conditions extend from this point at least 4 miles downstream and 4 miles upstream. In 1966, a thermograph located 6.5 miles above the mouth recorded lethal temperatures on 15 days; the maximum temperature recorded was 31.0 C (Puckett and Van Woert 1972). Temperature conditions in the upper 8 miles of the stream are believed to be better; maximum temperatures may be marginal or even satisfactory in well-shaded areas.

Ten Mile Creek originates at an elevation of approximately 2500 feet and flows southwest 3.5 miles, dropping to 1700 feet; flows an additional 11.5 miles northwest, dropping to 1400 feet; and finally flows 5 miles southwest, dropping to 1250 feet at its mouth. Mean monthly streamflows measured 6.5 miles above the mouth from 1961 to 1972 ranged from 6.06 to 16.6 cfs in June, 1.01 to 4.49 cfs in July, 0.15 to 3.88 cfs in August, and 0.11 to 2.76 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean flows measured during the summer of 1973 were 6.12 cfs in June, 2.50 cfs in July, 1.48 cfs in August, and 3.57 cfs in September (USGS 1973b). Portions of the stream above this point, particularly the upper 2 miles, are believed to flow intermittently in most years.

Due to the flat stream gradient found throughout most of the stream and the low flows in late summer, the stream is characterized by shallow, slow-flowing runs with occasional shallow riffles and shallow pools. The upper two-thirds of the stream, excluding the upper 1.5 stream miles, flow through a flat open valley which is highly exposed to the sun. The remainder of the stream flows through a narrow river canyon and receives some shading from canyon slopes.

Streamside vegetation provides some shading, particularly along the upper third of the stream. Although temperatures were not measured in the upper third, excellent shading is believed to keep temperatures lower than in downstream areas, and temperatures here may be satisfactory for salmonids. The dominant vegetative types are Douglas fir and pine in the upper third of the stream, woodland-grass in the center third, and Douglas fir in the lower third.

Few salmonids were observed in the portions of Ten Mile Creek surveyed. The heat-related death of salmonids has been reported in the middle portion of this stream by Wales (1938). During the July and August sampling periods, a few fingerling salmonids were observed 8 miles above the mouth along with many roach and suckers. Possibly a limited number of salmonids are able to survive in this lethal area due to a cool spring inflow. During the August sampling period, a few fingerling salmonids were observed just above the mouth.

South Fork Eel River between Ten Mile Creek and Rattlesnake Creek

The 7.5-mile stream section below Ten Mile Creek is classified as marginal; stream temperatures increase through this section from satisfactory at Ten Mile Creek to lethal at Rattlesnake Creek. The maximum estimated temperature at Ten Mile Creek was 26.0 C, while the maximum estimated just above Rattlesnake Creek was 27.5 C.

The South Fork flows north 7.5 miles from Ten Mile Creek to Rattlesnake Creek, dropping in elevation from approximately 1200 feet to 850 feet. The river flows rapidly through boulders and bedrock, forming a series of riffles and pools to over 8 feet in depth. Shading is provided through this stream section by the narrow, moderately steep-sided stream canyon and streamside-vegetation. The dominant vegetative type is Douglas fir, which adds to the shading.

Salmonids were observed at both ends of this stream section. A few fingerling salmonids, including one diseased individual, and several roach were observed in the Ten Mile Creek area in August. During all three sampling periods, fingerling and yearling salmonids up to 5 inches in length were observed above Rattlesnake Creek. Although the area in between these points was not examined, salmonids are believed to inhabit this area, but not as abundantly as above Ten Mile Creek. A few fishermen reported that they observed several juveniles in the lower portion of this stream section.

Elwell (1965) reported that skin divers observed very few salmonids between Ten Mile Creek and the mouth of the South Fork; salmonids were only observed in small schools concentrated in the cooler depths of pools where there was an inflow from a spring or tributary. He also reported that several cool tributaries enter the South Fork between Ten Mile Creek and the mouth of the South Fork. He observed concentrations of salmonids in the lower portions of these tributaries, apparently escaping the warmer temperatures of the main stream.

South Fork Eel River between Rattlesnake Creek and Hollow Tree Creek

Maximum temperatures decrease through this 5.5-mile stream section from lethal conditions at Rattlesnake Creek to marginal conditions below Hollow Tree Creek. The maximum estimated temperature just below Rattlesnake Creek was 28.5 C. Lethal conditions below this point appear greatly influenced by Rattlesnake Creek; the maximum temperature estimated in the creek just above its mouth was 29.5 C. It is not certain if these lethal conditions extend as far downstream as Hollow Tree Creek, but it is known that marginal conditions exist below Hollow Tree Creek; the maximum estimated temperature 0.5 mile below the creek was 27.0 C. It is possible that lethal conditions exist only in a small area in the upper portion of this stream section.

The South Fork flows 5.5 miles northwest from Rattlesnake Creek to Hollow Tree Creek, dropping in elevation from approximately 850 feet to 750 feet. The river generally flows rapidly through boulders, rubble, and bedrock, forming scattered riffles which connect shallow pools and slow-flowing areas. Algae were more abundant in the Rattlesnake Creek area than in the remainder of this section. The area immediately surrounding the mouth of Rattlesnake Creek is open and exposed to the sun; however, the majority of this stream section is in a narrow, steep-sided canyon, which provides some shading. Shading is also provided by streamside and forest vegetation. Douglas fir predominate in the upper two-thirds of this section, and redwood predominate in the lower third.

The area immediately surrounding the mouth of Rattlesnake Creek is contained within the Mediterranean cool summer climate zone, while the rest of this stream section is contained in the Mediterranean cool summer with light fog zone. The cooling influence of fog was noticed in the morning and late afternoon at times in the lower portions of this section.

During the summer of 1973, the lower portions of Rattlesnake Creek were examined. As already mentioned, the estimated maximum temperature at the mouth was lethal, 29.5 C. The estimated maximum temperature 3.5 miles above the mouth was marginal, 27.5 C. Little shading exists in the lower 0.25 mile of stream; however, shading is provided above here by canyon slopes and streamside vegetation. The stream flows rapidly through boulders and had an estimated flow greater than 1 cfs near its mouth during the August sampling period. Rattlesnake Creek obviously adds to the temperature problem in this stream section during hot spells. Cool tributaries and springs below Rattlesnake Creek help cool this stream section.

A few fingerling salmonids and several roach were observed in the river just below Rattlesnake Creek during the July and August sampling periods. It should be noted that the salmonids were observed here only in the morning when the temperature of the inflowing creek water was cooler than that of the river; in the afternoon when the temperature of the creek became warmer than that of the river, only roach were observed. A few fingerling salmonids were observed in Rattlesnake Creek just above its mouth in June, but none were observed during subsequent sampling periods. A few fingerlings were also observed in the creek 3.5 miles above its mouth in July.

Shapovalov (1941) reported that the death of salmonids occurred in the South Fork, especially as far upstream as Rattlesnake Creek, during hot spells. Wales (1938) reported observing yellowish colored (heat-stressed) salmonids in this stream section at the mouth of Rattlesnake Creek.

South Fork Eel River between Hollow Tree Creek and 1 mile above Lake Benbow

This 24-mile stream section of the South Fork is classified as marginal; estimated maximum temperatures for the summer of 1973 ranged from 26.5 to 27.5 C. The USGS thermograph located 2.5 miles below Hollow Tree Creek, measured a marginal temperature of 26.5 C on only one day during the summer. Temperature records at this thermograph site from 1966 to 1972 indicate that temperature conditions were satisfactory in each of these years; the maximums recorded ranged from 24.0 to 26.0 C (Puckett and Van Woert 1972; USGS 1970a-1972a).

Temperatures measured in this stream section during the summer of 1973 indicate that the thermograph site is located in the coolest portion of the section. The lowest estimated maximum temperature, 26.5 C, was located just below the thermograph site; no other temperature station in this stream section had an estimated maximum below 27.0 C. However, it does appear that large portions of this stream section may be satisfactory in most years. It is also possible that the lower few miles of the section could be lethal in some years; the maximum temperature estimated 0.5 mile below this section was 28.5 C.

The South Fork Eel River meanders north 24 miles from Hollow Tree Creek to 1 mile above Lake Benbow, dropping in elevation from approximately 750 feet to just below 400 feet. Mean monthly streamflows measured 2.5 miles below Hollow Tree Creek from 1966 to 1972 ranged from 62.0 to 159 cfs in June, 28.3 to 70.2 cfs in July, 19.2 to 44.3 cfs in August, and 16.7 to 33.5 cfs in September (USGS 1966b-1972b). Mean flows measured in the summer of 1973 were 72.4 cfs in June, 36.6 cfs in July, 25.3 cfs in August, and 48.5 cfs in September (USGS 1973b).

The river generally flows rapidly through bedrock, boulders, and rubble, forming shallow riffles and pools. However, due to the flat stream gradient and somewhat wider nature of the streambed in portions of this section, some areas of shallow, slow-flowing water with abundant algae exist.

The stream canyon is generally narrow and steep-sided, providing some good shading; however, the lower 9 miles of the canyon in this section are wider and more open. Shading is provided in some areas by streamside vegetation. The dominant vegetative type in all but the upper few miles of this section is redwood; Douglas fir predominate in the upper portion. The combined effect of the narrow canyon and dense stands of redwood or Douglas fir provides good shading. The entire section is contained within the Mediterranean cool summer with light fog climate zone. The cooling influence of fog and cool winds was noted in portions of this section during mornings and late afternoons.

Cool springs and tributaries may provide sources of cool water helping to maintain satisfactory or marginal temperatures in portions of this section. Wales (1938) indicated that several cool tributaries and springs enter this section of the South Fork. One tributary was examined during the summer of 1973. Bridges Creek, 6.5 miles below Hollow Tree Creek, had an estimated maximum temperature of 25.5 C near its mouth. The flow of the creek was estimated to be less than 1 cfs during the August sampling period, and the lower 100 feet of stream were dry by this time.

During all three sampling periods, fingerling and yearling salmonids up to 5 inches in length were found only in small numbers scattered through this stream section, and during the July sampling period, a few yellowish-colored (heat stressed) fingerlings and yearlings were observed 0.5 mile below Hollow Tree Creek. The heat-related death of salmonids has been reported in this stream section by Wales (1938). Many fingerling salmonids were observed in the lower portion of Bridges Creek during all sampling periods, and a local resident reported observing salmonids in other cool tributaries to this section. Roach were abundant throughout the section, and a few suckers and sunfish were also observed.

South Fork Eel River between 1 mile above Lake Benbow and Myers Flat

This 30.5-mile stream section is classified as lethal; estimated maximum temperatures ranged from 28.0 to 29.5 C.

Approximately 2.25 miles below the upper boundary of this stream section is Benbow Dam, which forms Lake Benbow. Sediment has filled in the area behind the dam; therefore, to supplement the dam for recreational purposes during summer, an 11-foot board and beam superstructure is added, forming a 123-acre reservoir and backing up the river about 1 mile. The estimated maximum temperature of the stream flowing into the lake was lethal, 28.5 C, and the temperature of the water flowing out was believed to be higher. The maximum temperature estimated 2.5 miles below the dam was 29.5 C, the highest estimated in this stream section. It should also be noted that minimum temperatures were found to be typically 2.0 C warmer at the station below the dam than at the one above the dam.

A thermograph located 2 miles above Benbow Dam in 1959 recorded lethal temperatures on 6 days during its limited operation; the maximum recorded was 29.5 C. A thermograph located at Benbow Dam in 1958 recorded lethal temperatures on 27 days out of 54 that it was in operation; the maximum recorded was 31.0 C (Puckett and Van Woert 1972).

During the summer of 1973, the USGS thermograph 15 miles below Benbow Dam recorded lethal temperatures on 2 days; the maximum recorded was 28.5 C. Incomplete temperature records at this site indicate that temperature conditions are more severe in most years (Puckett and Van Woert 1972). There is a great variation in the records from year to year which may not truly reflect temperature conditions here. The maximum temperatures recorded for the years 1961, 1963, 1964, 1966-1968, 1971, and 1973 were 33.5, 32.0, 34.0, 26.5, 28.0, 28.0, 29.0, and 31.0 C, respectively, and the number of lethal days recorded were 28, 10, 29, 0, 5, 1, 3, and 15, respectively. Records were complete for each of these years except 1963 and 1971, which only had records for two out of the three summer months.

The South Fork Eel River flows generally northwest, although it changes direction several times within this stream section, 30.5 miles from 1 mile above Lake Benbow to Myers Flat, dropping from an elevation of approximately

400 feet to below 200 feet. Mean monthly streamflows measured 15 miles below Benbow Dam from 1961 to 1972 ranged from 121 to 353 cfs in June, 66.8 to 144 cfs in July, 39.7 to 85.4 cfs in August, and 33.7 to 90.5 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean monthly flows measured in the summer of 1973 were 148 cfs in June, 78.4 cfs in July, 48.6 cfs in August, and 94.7 cfs in September (USGS 1973b). Due to the flat stream gradient, the river flows slowly through this stream section with only occasional shallow riffles connecting long, slow-flowing stretches with abundant algae; this is particularly true in the lower half of this section.

The stream canyon in the upper half of this section is open and wider than in the prior section, and small flood plains are evident. In the lower half of this section, the river basin greatly widens and extensive flood plains exist, preventing shading from land masses. In the lower eighth of this section, the basin narrows but still contains some flood plain areas in an open canyon. Streamside vegetation provides some shading in this stream section, especially in the lower eighth and in portions of the upper half. Predominant vegetative types in this area are redwood, Douglas fir, and woodland-grass. Good shading is provided where the flood plains are minimal and redwoods exist.

Two different climate zones, Mediterranean cool summer with light fog and Mediterranean cool summer are found in this stream section. The cooling influence of fog and cool winds blowing upstream was noted in portions of this section in the morning and late afternoon.

Temperature conditions in four tributaries were examined during the summer of 1973. The East Branch of the South Fork, which enters Lake Benbow from the east 0.5 mile above the dam, had an estimated maximum temperature of 29.0 C, 1 mile above its mouth. In 1966, a thermograph located 1.9 miles above the mouth recorded lethal temperatures on 15 days out of the 75 days that it was in operation; the maximum temperature recorded was 30.0 C (Puckett and Van Woert 1972). Mean monthly streamflows measured from 1966 to 1972, 1.9 miles above the mouth, ranged from 14.4 to 32.8 cfs in June, 7.24 to 12.9 cfs in July, 4.57 to 7.09 cfs in August, and 3.29 to 7.12 cfs in September (USGS 1966b-1972b). The lower portion of the East Branch of the South Fork flows through an open woodland-grass canyon that is highly exposed to the sun. Some streamside vegetation exists and provides a little shading.

Sprowl Creek, which enters the South Fork from the west 2 miles below Benbow Dam, had an estimated maximum temperature of 26.5 C, 0.25 mile above its mouth. The flow at this point was approximately 1 cfs at the end of August. This stream is composed of a series of alternating riffles and pools and is well shaded by redwoods and streamside vegetation.

Redwood Creek enters the South Fork from the west 9 miles below Benbow Dam and had an estimated maximum temperature of 25.0 C, 0.5 mile above its mouth. A thermograph located in the same area in 1966 recorded a maximum temperature of 26.0 C during that summer (Puckett and Van Woert 1972). By the end of August, the flow was estimated to be less than 1 cfs. The creek in this area is composed of long pools to 2 feet in depth connected by shallow riffles. Excellent shading is provided by redwoods and streamside vegetation.

Salmon Creek, which enters the South Fork from the west 22 miles below Benbow Dam, had an estimated maximum temperature of 29.5 C, 0.5 mile above its mouth. The flow here was estimated to be less than 1 cfs by the end of August. This portion of the creek is composed of slow-flowing areas connected by shallow riffles with abundant algae. The lower portion of the creek is open and exposed to the sun, but some shading is provided by streamside vegetation.

Several fingerling salmonids and a few yearlings and two-year-olds up to 8 inches in length were observed scattered at various points through this stream section during each sampling period. It is possible that a limited number of salmonids survive in this lethal section due to cool spring or tributary inflow. Fite (1973) reported that by late summer in 1972 when stream temperatures reached as high as 29.0 C in this stream section, large concentrations of salmonids were found wherever there was cool subterranean or spring inflow. The heat-related death of salmonids has been reported throughout this stream section by Wales (1938). He reported that the worst section of the South Fork was around Garberville, 6 miles below Benbow Dam.

In the East Branch of the South Fork, salmonids were only observed in a cool-water pocket evidently formed by spring inflow. During the July sampling period, several fingerling salmonids were observed under a log in a cool sidearm of the East Branch; the temperature of the stream was 26.0 C in late afternoon, while the temperature under the log was 24.0 C. Several fingerling salmonids were observed in Sprowl Creek, and fingerlings and yearlings up to 6 inches in length were abundant in Redwood Creek.

A few fingerlings and yearlings up to 5 inches in length were observed in Salmon Creek.

Roach were abundant throughout this stream section and in Salmon Creek. Many suckers up to 12 inches in length were also observed in this section.

South Fork Eel River below Myers Flat

The lower 10 miles of the South Fork are classified as marginal; estimated maximum temperatures ranged from 27.0 to 27.5 C. The warmer waters from upstream are cooled as they flow through this stream section.

The South Fork flows northwest 10 miles from Myers Flat to the main Eel River, dropping in elevation from approximately 200 feet to 150 feet. Due to the flat stream gradient, this section is characterized by long, slow-flowing areas connected by short riffles with abundant algae. Flood plains exist, but they are not as extensive as in the prior stream section. The stream canyon is moderately open; however, dense stands of redwoods, as well as other vegetation, occur on the flats alongside the river, providing good shading. The entire stream section is contained within the Mediterranean cool summer with light fog climate zone. The cooling influence of fog and cool winds blowing upstream was observed in this section.

Several cool springs and tributaries may help cool this stream section. Bull Creek, a tributary to the South Fork 1.5 miles above the main Eel River, had an estimated maximum temperature of 26.5 C at its mouth. Mean monthly streamflows measured 4.6 miles above the mouth from 1961 to 1972 ranged from 7.13 to 25.4 cfs in June, 3.31 to 10.7 cfs in July, 1.49 to 6.61 cfs in August, and 1.30 to 3.67 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean monthly flows during the summer of 1973 were 9.58 cfs in June, 3.78 cfs in July, 2.16 cfs in August, and 3.31 cfs in September (USGS 1973b). The creek is composed of a series of alternating riffles and pools and flows through a moderately open canyon that receives good shading from redwoods and streamside vegetation in at least its lower 3 miles.

Many fingerling and yearling salmonids up to 5 inches in length were observed in this stream section during all three sampling periods. The heat-related death of salmonids has been reported in this section by Wales (1938). Several fingerling salmonids were observed in the lower 3 miles of Bull Creek, and a few yearlings and two-year-olds up to 7 inches in length, two of which were yellowish-colored (heat stressed), were observed in Bull Creek just above its mouth during the August sampling period. Many roach and a few suckers were observed in this section of the South Fork.

Eel River below the South Fork Eel River

The lower 38 miles of the Eel River below the South Fork are classified as satisfactory; estimated maximum temperatures decreased through this stream section from 26.0 C, 2 miles below the South Fork, to 24.0 C at Fernbridge, 6 miles above the mouth. The maximum temperature recorded at the DWR thermograph at Pepperwood, 9 miles below the South Fork, was 25.0 C. The maximum temperature recorded at the USGS thermograph at Scotia, 19 miles below the South Fork, was 22.5 C; however, this thermograph was not in operation when the warmest temperatures occurred in this stream section. The estimated maximum at Scotia was 24.0 C.

Past temperature records at Scotia show that no temperature greater than 25.0 C was recorded in the years 1958 and 1961-1972 (Puckett and Van Woert 1972; USGS 1970a-1972a). No temperature greater than 23.5 C was recorded at Fernbridge in 1958 and 1959 (Puckett and Van Woert 1972).

The Eel River flows northwest 38 miles from the South Fork to the Pacific Ocean, dropping from an elevation of approximately 150 feet to sea level. Mean monthly streamflows measured at Scotia from 1961 to 1972 ranged from 477 to 1,968 cfs in June, 192 to 504 cfs in July, 98.5 to 241 cfs in August, and 76.5 to 222 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean flows measured during the summer of 1973 were 618 cfs in June, 228 cfs in July, 132 cfs in August, and 304 cfs in September (USGS 1973b). The river widens and flows slowly through this stream section with only occasional riffles.

The Eel River below the South Fork flows through a wide, open canyon which progressively widens downstream into a flat coastal plain below the Van Duzen River, 12.5 miles above the mouth. Extensive flood plains are found along this entire stream section. Little streamside vegetation exists. The major vegetative type in the upper half of this section, above Scotia, is redwood; the majority of the lower half is in cultivated, urban, and industrial areas.

The upper two-thirds of this section are contained within the Mediterranean cool summer with light fog climate zone. The lower third is contained within the Mediterranean cool summer with fog climate zone. The cooling effect of fog and winds blowing upstream were obvious throughout this stream section during the summer.

Three tributaries to this stream section were examined during the summer of 1973. Larabee Creek, which joins the river from the east 4 miles below the South Fork, had an estimated maximum temperature of 26.5 C, 0.25 mile above its mouth. Mean monthly streamflows measured 2.8 miles above its mouth from 1961 to 1965 ranged from 25.7 to 54.0 cfs in June, 14.0 to 24.1 cfs in July, 9.15 to 20.0 cfs in August, and 6.91 to 11.3 cfs in September (USGS 1961-1963, 1964b, and 1965b). The creek, 0.25 mile above its mouth, is composed of a series of alternating riffles and pools to 4 feet in depth. Shading is provided by streamside vegetation and redwoods.

Jordan Creek, which enters the river from the southwest 12.5 miles below the South Fork, had an estimated maximum temperature of 26.5 C just above its mouth. The streamflow here was estimated to be less than 1 cfs in August, and the creek was composed of riffles and pools to only a few inches in depth. Shading is provided by streamside vegetation and redwoods.

Van Duzen River, which enters the Eel River from the east 12.5 miles above the mouth, was examined in detail, and the results are presented in following sections.

Several fingerling and yearling salmonids up to 5 inches in length were observed scattered throughout this stream section during each of the sampling periods. Fishermen at the mouth of Van Duzen River during the June and July sampling periods were observed catching several juvenile salmonids up to 7 inches in length. Several fingerlings and yearlings up to 5 inches in length were observed in Larabee Creek, and many fingerlings were observed in Jordan Creek. Roach, suckers, and sticklebacks were found throughout this stream section, and a few suckers up to 12 inches in length were observed in Larabee Creek.

Van Duzen River above Shanty Creek

The upper 14 miles of Van Duzen River, including 5 miles of the West Fork Van Duzen River, are classified as satisfactory. Estimated maximum temperatures ranged from 24.0 C in the West Fork, 0.5 mile above confluence with the main Van Duzen, to 25.5 C in the main Van Duzen 2 miles above the West Fork. After confluence of the two streams, temperatures are believed to increase downstream to the marginal level estimated 0.5 mile below Shanty Creek.

Van Duzen River flows northwest 2.25 miles from Hettenshaw Valley to the West Fork Van Duzen, dropping in elevation from approximately 3100 feet to 2900 feet. About 3.5 miles of streambed, originating at an elevation of 4000 feet, exist above here, but this portion of the stream is believed to be dry during summer. The West Fork flows southeast 4 miles, turns north, and flows an additional 1 mile to Van Duzen River, dropping from a 4600-foot elevation. After the confluence of the two streams, the Van Duzen River flows northwest 6.75 miles to Shanty Creek, dropping to an elevation of 2650 feet.

The streamflow of the Van Duzen 2 miles above the West Fork was estimated to be less than 1 cfs during the August sampling period. The river here is composed of shallow, slow-flowing pools and riffles. The upper 1 mile of stream flows through an open area as it leaves Hettenshaw Valley; however, some shading is provided by streamside vegetation. Between here and the West Fork, the river flows through a narrower canyon which, along with streamside vegetation, provides some shading. The major vegetative type in this area is hardwood woodland.

The West Fork Van Duzen River, 0.5 mile above the Van Duzen, was estimated to have a flow near 2 cfs in August. The river flows rapidly through boulders and bedrock, forming a series of riffles and pools to 4 feet in depth. Good shading is provided by canyon slopes and streamside vegetation. The major vegetative type is mixed conifers, which add to the shading.

Below the confluence of the two streams, Van Duzen River flows rapidly through boulders and bedrock, forming a series of riffles and pools to 6 feet in depth. Although there are some areas within this stretch that are open, good shading is provided in most areas by canyon slopes, streamside vegetation, and forests. The major vegetative type is mixed confers.

Several small tributaries enter this stream section and provide sources of cool water. Shanty Creek was examined during the summer of 1973 and had an estimated maximum temperature of 23.0 C. The estimated flow was less than 1 cfs in August. The creek cascades through boulders, forming pools to 4 feet in depth and is well shaded by streamside vegetation.

All salmonids observed in this stream section were resident rainbow trout; anadromous salmonids are unable to reach the upper drainage due to a natural barrier 1 mile above the South Fork Van Duzen River. Several fingerling trout and one 5-inch trout were observed in the Van Duzen above the West Fork; in the West Fork, many trout up to 5 inches in length were observed. In the stretch of river below the West Fork and in Shanty Creek, many trout up to 8 inches in length were observed.

Van Duzen River between Shanty Creek and Browns Canyon

The 3.5 mile section of stream below Shanty Creek is classified as marginal. Estimated maximum temperatures ranged from 26.5 to 27.0 C, and temperatures are believed to increase in a downstream direction through this section. It should be noted that marginal temperatures are expected to occur only occasionally and for short durations in this stream section.

The river flows northwest 3.5 miles from Shanty Creek to Browns Canyon, dropping in elevation from approximately 2650 feet to 2550 feet. The river flows rapidly throughout this section, forming a series of riffles and pools to 8 feet in depth. The stream canyon is somewhat wider in this stream section than in the prior section; therefore, it is more open and exposed to the sun. Shading is provided by canyon slopes, streamside vegetation, and forests. The major vegetative type is mixed conifers.

Many resident rainbow trout up to 9 inches in length were observed through this stream section, and two fishermen were observed catching a few 8-inch trout in the upper portion of this section.

Van Duzen River between Browns Canyon and 1 mile below Dinsmores

This 9.5-mile stream section below Browns Canyon is classified as lethal; the estimated maximum temperature at two stations in the upper portion of this section was 28.0 C. However, the estimated maximum 1.5 miles above Dinsmores was marginal, 27.5 C. It is believed that the lower temperature at this point is due to cool spring flow or the surfacing of cool subterranean flow. It is possible, although unlikely, that marginal conditions exist in the lower 2.5 miles of this stream section due to subterranean flow. It appears that several cool water pockets may exist in this stream section.

Van Duzen River flows northwest 9.5 miles from Browns Canyon to 1 mile below Dinsmores, dropping from an elevation of approximately 2550 feet to 2400 feet. The river in this entire stream section meanders through a wide, extensive flood plain. During the June and July sampling periods, the river branched and rejoined itself in several places in this section; the river was generally composed of alternating riffles and shallow pools. By the time of the August sampling period, many of the branches had become dry, and the river flowed only intermittently, forming isolated riffles and shallow pools with abundant algae.

Shading is limited and only occurs in small areas where the river flows close to the edge of the wide canyon or where streamside vegetation exists. The major vegetative type in this area is hardwood woodlands.

Resident rainbow trout were only observed in cool pockets in this stream section. During the August sampling period, several fingerlings and a few adults up to 10 inches in length were observed in a cool 2.5-foot deep pool, which was evidently spring-fed, near the upper boundary of this stream section. During the August sampling period, approximately 100 fingerlings and adult trout up to 8 inches in length were observed in a 6-foot deep pool 1.5 miles above Dinsmores. Many trout were also observed in this pool in June and July, but there were noticeably more in August when the stream became intermittent. This pool was believed to be fed by cool subterranean water.

Van Duzen River between 1 mile below Dinsmores and Little Larabee Creek

This 16-mile section of Van Duzen River above Little Larabee Creek is classified as satisfactory. Only two temperature stations existed in this stream section, one at either end. The station 1.5 miles below Dinsmores had an estimated maximum temperature of 26.0 C. The lethal conditions found in the prior stream section quickly change to satisfactory in this section upon loss of the flood plain and a sudden increase in stream gradient. It appears that water seeps through the flood plain and surfaces to form the cooler stream in this section.

At the Little Larabee Creek temperature station, the estimated maximum temperature was marginal, 26.5 C. It appears that marginal conditions may exist in the lower few miles of this stream section. In 1968, a thermograph located 2 miles above Little Larabee Creek recorded temperatures at the bottom of a pool for a portion of the summer; the maximum temperature it recorded was 25.5 C (Puckett and Van Woert 1972).

It should be noted that the estimated maximum temperature at Little Larabee Creek was partially based on the temperatures recorded during the summer of 1973 by the USGS thermograph 7 miles below here. Maximum temperatures recorded at this thermograph site have varied greatly through the years from satisfactory to lethal conditions (24.0-29.5 C); the maximum measured in the summer of 1973 was satisfactory, 26.0 C. Temperatures recorded at this thermograph will be discussed in more detail in the next stream section.

The USGS thermograph located 3 miles below Dinsmores was in operation for only a portion of the summer of 1973 and recorded a maximum temperature of 25.0 C. Incomplete records, which exist for this thermograph site from 1966 to 1972, show that the maximum temperature recorded here has been 25.5 C. Such satisfactory conditions are believed to extend downstream through much of this stream section. Rogers et al. (1968) reported that good conditions for juvenile salmonids existed through this stream section at least down to a point 1.5 miles above Little Larabee Creek.

Van Duzen River flows west 2.5 miles from 1 mile below Dinsmores to the South Fork Van Duzen River, dropping in elevation from approximately 2400 feet to 1950 feet; and then flows northwest 7 miles, dropping to 1100 feet; generally west 3 miles, dropping to 800 feet; and south 3.5 miles to Little Larabee Creek, dropping to 650 feet. Mean monthly streamflows measured 3 miles below Dinsmores from 1964 to 1972 ranged from 19.1 to 79.7 cfs in June, 5.05 to 19.6 cfs in July, 3.39 to 7.34 cfs in August, and 2.19 to 17.9 cfs in September (USGS 1964b-1972b). Mean flows measured during the summer of 1973 were 25.4 cfs in June, 6.57 cfs in July, 2.60 cfs in August, and 7.75 cfs in September (USGS 1973b).

Physical conditions of this stream section are greatly different than in the prior stream section. The river flows rapidly through bedrock and boulders, forming a series of alternating riffles and pools at each end of this stream section and is reported to be of a similar nature in the area between these points with pools up to 12 feet in depth (Puckett _et al_. 1968). The stream canyon is narrow and steep-sided. Good shading is provided by canyon slopes and streamside vegetation. This stream section flows through areas of hardwood woodlands, woodland-grass, Douglas fir, and grassland.

Several tributaries enter Van Duzen River in this stream section, and many may provide sources of cool water and additional salmonid habitat. The largest tributary is the South Fork Van Duzen River, which flows to the Van Duzen from the southeast 3.5 miles below Dinsmores. The estimated maximum temperature of the South Fork 3.25 miles above its mouth was 26.5 C. Past temperatures recorded at this point indicate that temperature conditions here are probably satisfactory in most years and that marginal temperature conditions are to be expected only occasionally and to be of a short duration. In 1961, 3 days of marginal temperatures up to 27.0 C were recorded; however, the maximum temperature recorded for the years 1962 to 1964 was 25.0 C (Puckett and Van Woert 1972).

Mean monthly streamflows measured in the South Fork 3 miles above its mouth from 1961 to 1967 ranged from 18.6

to 45.8 cfs in June, 8.25 to 13.2 cfs in July, 4.68 to 8.31 cfs in August, and 3.65 to 4.87 cfs in September (USGS 1961-1963 and 1964b-1967b). In this portion of the South Fork, the stream flows rapidly through bedrock and boulders, forming a series of riffles and pools to 8 feet in depth. Good shading is provided by streamside vegetation and canyon slopes.

Butte Creek, which enters the South Fork 3 miles above its mouth, was examined and found to have an estimated maximum temperature of 22.0 C, 0.75 mile above the South Fork. Butte Creek was estimated to have a flow of less than 1 cfs at the end of August and was composed of shallow riffles and long, slow-flowing pools. Excellent shading is provided by dense streamside vegetation, which forms a complete canopy over this portion of the creek.

Temperatures were measured in Little Larabee Creek, 25 yards above its mouth. The estimated maximum temperature was 27.0 C. The lower 50 yards of the stream are open and highly exposed to the sun; however, above here good shading from streamside vegetation exists, and temperatures are believed to be cooler. Rogers et al. (1968) reported that Little Larabee Creek provides excellent salmonid nursery habitat. The mouth of the creek was almost dry during the August sampling period; the flow above the open area was somewhat better, but less than 1 cfs.

Puckett et al. (1968) and Horton and Rogers (1969) reported that two natural rock barriers to salmonids exist in this stream section. A barrier to salmon exists approximately 9.5 miles below Dinsmores. This barrier is also a partial barrier to steelhead and in some years may be a complete barrier. A complete barrier to all salmonids exists approximately 3 miles below Dinsmores (0.5 mile above the South Fork). Above this point, the only salmonids are resident rainbow trout.

A few fingerling resident rainbow trout were observed 1.5 miles below Dinsmores, and several fingerling salmonids and a few suckers were observed at Little Larabee Creek during all three sampling periods. Several fingerling and yearling steelhead up to 6 inches in length were observed in the South Fork Van Duzen River, and some fingerlings were observed in Butte Creek. A few fingerlings were also observed in the lower portion of Little Larabee Creek during all three sampling periods.

Horton and Rogers (1969) reported that summer steelhead rest in deep pools during the summer between Bridgeville, 1 mile below Little Larabee Creek, and the confluence with the South Fork and may use the South Fork as well. Puckett et al. (1968) reported that, in 1967, summer steelhead were found in a 9-mile stretch above Bridgeville; most fish were in a series of pools below the lower barrier. They reported that progressively fewer fish were seen over a 6-week period. They suggested that warming water temperatures may have weakened the fish and indirectly caused mortality.

Van Duzen River between Little Larabee Creek and Hely Creek

This 16.5-mile stream section below Little Larabee Creek is classified as marginal; estimated maximum temperatures ranged from 26.0 to 27.0 C. There was no downstream warming or cooling trend through this section; estimated maximums were marginal, 26.5-27.0 C, in those portions of the section that were more exposed to the sun and satisfactory, 26.0 C, in those portions that were better shaded.

These estimated maximums were partially based on the 26.0 C maximum recorded at the USGS thermograph 7.5 miles below Little Larabee Creek during the summer of 1973. Temperatures measured at this thermograph site have varied greatly in past years. It should be noted that the thermograph was located 2 miles above its present location from 1961 to 1964. In 1962-1964 and 1966, the maximum temperature recorded each year was satisfactory; maximums ranged from 24.0 to 26.0 C. In 1961 and 1969, the maximum temperature recorded was marginal (26.5 C on 2 days in 1961 and 27.0 C on 1 day in 1969). In 1967-1968 and 1970-1972, lethal temperatures were recorded on at least 1 day and as many as 7 days, and marginal temperatures were recorded on from 5 to 29 days; the maximum temperature recorded each year ranged from 28.0 to 29.5 C (Puckett and Van Woert 1972; USGS 1970a-1972a).

It seems unlikely that temperatures could have varied so greatly in this stream section; it may be that such extremes are due to changes in placement of the probe or changes in conditions around the probe from year to year. Still, it appears that most of this stream section is marginal in most years.

Van Duzen River flows generally west 16.5 miles from Little Larabee Creek to Hely Creek, dropping in elevation from approximately 650 feet to 200 feet. Mean monthly streamflows measured 7.5 miles below Little Larabee Creek from 1961 to 1972 ranged from 49.2 to 158 cfs in June, 17.4 to 47.0 cfs in July, 10.1 to 33.0 cfs in August, and 7.73 to 32.0 cfs in September (USGS 1961-1963 and 1964b-1972b). Mean flows measured during the summer of 1973 were 54.7 cfs in June, 20.6 cfs in July, 10.1 cfs in August, and 29.3 cfs in September (USGS 1973b).

Physical stream conditions vary through this stream section. Portions of the stream canyon are narrow and boulder-strewn, and the river flows rapidly, forming a series of riffles and pools to 8 feet in depth. In some areas, particularly the lower third of this section, the stream canyon widens, and the river tends to meander through some small flood plain areas, forming scattered wide riffles and shallow pools with abundant algae.

Good shading is provided by canyon slopes, streamside vegetation, and forests where the stream canyon is narrow. The river in this section flows through three major vegetative types: grassland and Douglas fir in the upper third and redwoods in the lower two-thirds. Although the lower third of this section is in a wider stream canyon, redwoods provide shading in much of this area.

The climate zones in this section coincide with the vegetative types. The upper third of the section is contained within the Mediterranean cool summer climate zone; the lower two-thirds are contained within the Mediterranean cool summer with light fog climate zone. The cooling influence of fog and cool afternoon winds was evident here during the summer.

Several small tributaries enter this stream section and may provide sources of cool water and a small amount of salmonid habitat. Grizzly Creek, which enters the river 8.5 miles below Little Larabee Creek, had an estimated maximum temperature of 25.0 C just above its mouth. The streamflow was estimated to be less than 1 cfs during the August sampling period. The stream flows rapidly through rubble, forming 6-inch deep pools near its mouth. Excellent shading is provided above the mouth by streamside vegetation and redwoods.

Several fingerling and yearling salmonids up to 5 inches in length were observed scattered through this stream section during all three sampling periods. Several fingerlings were also observed in the lower portion of Grizzly Creek. One dead yearling was found during the June sampling period when the water temperature was 26.5 C. Whether this fish died due to the high temperatures is only a matter of speculation. Shapovalov (1941) stated that some losses of salmonids have been reported from Van Duzen River during hot spells; however, he did not report in what portions of the river the losses occurred. Many roach, sticklebacks, and suckers were observed in this stream section. Roach were also observed in Grizzly Creek.

Van Duzen River below Hely Creek

The lower 14 miles of Van Duzen River are classified as satisfactory; estimated maximum temperatures ranged from 25.0 to 25.5 C. Based on the variation in maximum temperatures recorded at the thermograph in the prior stream section, it appears that conditions may be marginal in this stream section in some years.

Van Duzen River flows generally northwest 14 miles from Hely Creek to the Eel River, dropping from an elevation of approximately 200 feet to 40 feet. The river meanders through extensive flood plains, forming scattered riffles and some slow-flowing areas. The stream canyon widens in this stream section, and little shading is provided by canyon slopes and streamside vegetation. The major vegetative type is redwood; the redwoods do provide some shading in the upper few miles of this stream section.

The majority of this stream section is contained within the Mediterranean cool summer with light fog climate zone. A small portion above the mouth is contained within the Mediterranean cool summer with fog climate zone. The cooling influence of fog and strong, cool winds blowing upstream was obvious during the summer.

The main tributary to this portion of the Van Duzen River is Yager Creek, which enters the river from the north

5 miles above the Eel River. The estimated maximum temperature recorded 0.75 mile and 2 miles above the mouth was lethal, 28.0 C; however, the estimated maximum at the mouth was 26.0 C. It appears that the water entering the Van Duzen is cooled either by significant spring flow or seepage of water from Van Duzen River through the gravel bar separating the two streams. The lower few miles of the creek flow through a wide open area, highly exposed to the sun. Upstream areas of the creek receive shading from canyon slopes, streamside vegetation, and forests; temperatures in upstream areas are believed to be significantly cooler. Burns (1972) reported that the maximum temperature typically attained in the South Fork of Yager Creek is 21.5 C. Mean monthly streamflows measured 3 miles above the mouth from 1966 to 1972 ranged from 21.3 to 44.7 cfs in June, 9.24 to 20.8 cfs in July, 5.81 to 11.1 cfs in August, and 3.51 to 11.9 cfs in September (USGS 1966b-1972b).

Several fingerling and a few yearling salmonids up to 5 inches in length were observed in this stream section, and many fingerlings and yearlings up to 6 inches in length were observed in Yager Creek during all three sampling periods. Approximately 50 salmonids were observed in a

6-foot deep pool of Yager Creek 0.75 mile above its mouth on a morning during the June sampling period; in late afternoon of the same day when the water temperature was 28.0 C, no salmonids were observed. During subsequent sampling periods, salmonids were always found in this pool. Apparently these fish were able to survive the lethal temperatures in June by seeking a cool spring inflow nearby. Several roach, sticklebacks, and suckers were observed in this stream section and in Yager Creek.