



No. 39

October 1990

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## TEMPERATURE REGIMES OF SMALL STREAMS ALONG THE MENDOCINO COAST

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Stream temperature measurements have been collected in the Caspar Creek drainage on Jackson Demonstration State Forest periodically over the past 25 years. Review of this data and other recently collected data from western Mendocino County illustrates much about the temperature regimes of small coastal drainages, and how they are impacted by timber harvesting. This article gives a synopsis of these studies and summarizes reasons for concern. Additionally, it presents a model currently in use by the U.S. Forest Service to predict changes in maximum summer temperatures resulting from canopy reductions.

### INTRODUCTION AND BASIC PRINCIPLES

Concern over elevated stream temperatures resulting from logging have generally centered around impacts on the fisheries resource. Field and laboratory studies done in many areas show that high water temperatures increase the metabolic rate of fish, increase their susceptibility to pathogens, and decrease the dissolved oxygen content of the water. Tempera-

ture changes that can result from logging may have indirect or sub-lethal effects on salmonid fish populations. Examples of these impacts include: decreases in the emergence time of fry from gravels; earlier, less favorable smolt migration to the sea; and lowered abundance and diversity of food organisms (Holtby 1988).

Various species of salmonids respond differently to elevated stream temperatures. Water temperatures for good survival and growth of juvenile coho salmon range from 50° to 59° F, with 55° appearing to be the optimum. Growth is slowed considerably at 64° and ceases at 68°. The upper lethal limit has been reported to be 78° from laboratory studies (Bell 1973). Young steelhead trout prefer temperatures between 45° and 68° F, with the optimum about 56°. The upper lethal limit is considered to be 82° (W. Jones, CDF&G, pers. comm.). Both species are stressed at temperatures over 68° F. Chinook salmon juveniles rarely over-summer in freshwater, so they are the least affected.

Researchers have documented that slight temperature increases in small headwater streams following harvesting sometimes increases fish biomass. This results from greater primary production, and subsequently higher production throughout the food chain for these fishes. The cumulative or additive effect resulting from harvesting many areas in a sizable watershed on mid-order (i.e., larger) streams usually has not been addressed. It is likely that moderate stream temperature increases are a significant problem for streams inland from the buffered coastal environment.

Stream temperatures increase after logging largely because of the increased exposure of the stream surface to solar radiation. Higher air temperatures resulting from harvesting are not the reason for higher water temperatures (Brown 1969). The key factors to consider are the surface area of the stream exposed to sunlight, and its discharge (i.e., amount of streamflow at a given time).

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Buffer strips have been required along all streams bearing fish since 1973 in California. One of the reasons for this requirement was to reduce the potential adverse impacts of increased stream temperatures due to logging. These protection zones vary in width based on the steepness of the ground, and require half of the initial shade-producing canopy to remain following harvest. Effective buffer strips for temperature control are those which leave the trees and shrubs that actually shade the stream during the critical summer months of the year. The size of a stream, its orientation (east-west vs north-south), surrounding topography, and type and density of vegetation need to be considered when designing a buffer strip. In addition, attention must be given to stability during windstorms and damage from logging and slash burning.

## TWO CASE STUDIES OF COASTAL STREAMS

### A. Caspar Creek

As part of the Caspar Creek Watershed Study, stream temperatures were measured in the North and South Forks from 1965 to 1969, and again from 1988 to the present. When the first data was collected, the second-growth redwood and Douglas-fir forest was 60 to 80 years old. The entire 5,000-acre basin extends inland only six miles and empties directly into the ocean. Periods of summer fog exist, but often burns off before mid-day beyond three miles inland. Both gauged tributaries are slightly more than 1,000 acres.

Most observed summer maximum stream temperatures (i.e., the highest temperature during a 24-hour period) in both forks before disturbance were slightly below 60° F. Absolute maximums of 62° F were recorded several times. Road building in the South Fork in 1967 left 3,000 feet of the channel with greatly decreased shading. Maximum water temperatures were frequently near 70° F, and most were above 60°. The highest single temperature observed after roading was 78° F. Two years after the road was built, temperature increases of 3° to 4° F were documented for water flowing from shaded to open areas. No data

was collected after selective harvesting was done in the South Fork.

In 1988, electronic data loggers were installed to record water temperatures at two locations in the South Fork and five locations in the North Fork, prior to clearcut harvesting. Small, totally uncut tributary basins in the North Fork show summer maximum temperatures of about 56° F. Average daily highs are about 54° F. Diurnal fluctuations are slight, with daytime highs usually only about 1.3° F higher than nighttime lows. A temperature station on the mainstem below recent clearcut harvests with buffer strips on both sides of the channel shows summer maximums of 61° F (see Figure 1). Average daily highs are approximately 59° F. Diurnal fluctuations here are commonly 4° F (see Figure 2). Large masses of filamentous algae now grow in most of the open stretches, probably due to the increased light. Further down the

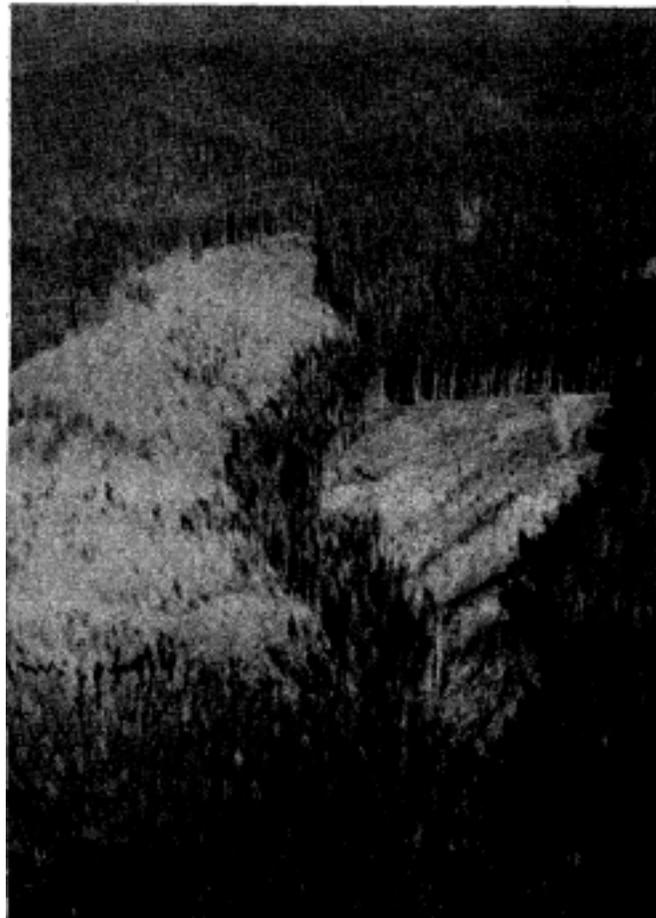


Figure 1. Aerial view of the North Fork of Caspar Creek.

mainstem, summer maximums are 60° F; this site is slightly diluted with cooler water from three uncut tributaries below the clearcuts. The highest stream temperatures in the North Fork are found just above the large weir pond. Shading is very poor and summer peaks reached 65° F.

Winter low temperatures on these streams have dropped down to 36° F, but usually are no lower than 37.5° F. High temperatures for winter days are around 46° F. During cloudy, rainy conditions, temperatures show little fluctuation and may be considerably warmer (e.g., 50° F).

### B. Railroad Gulch

Railroad Gulch is a 2000-acre tributary of the Albion River, located about seven miles south of Caspar Creek. This drainage is owned by Louisiana-Pacific Corporation and ex-

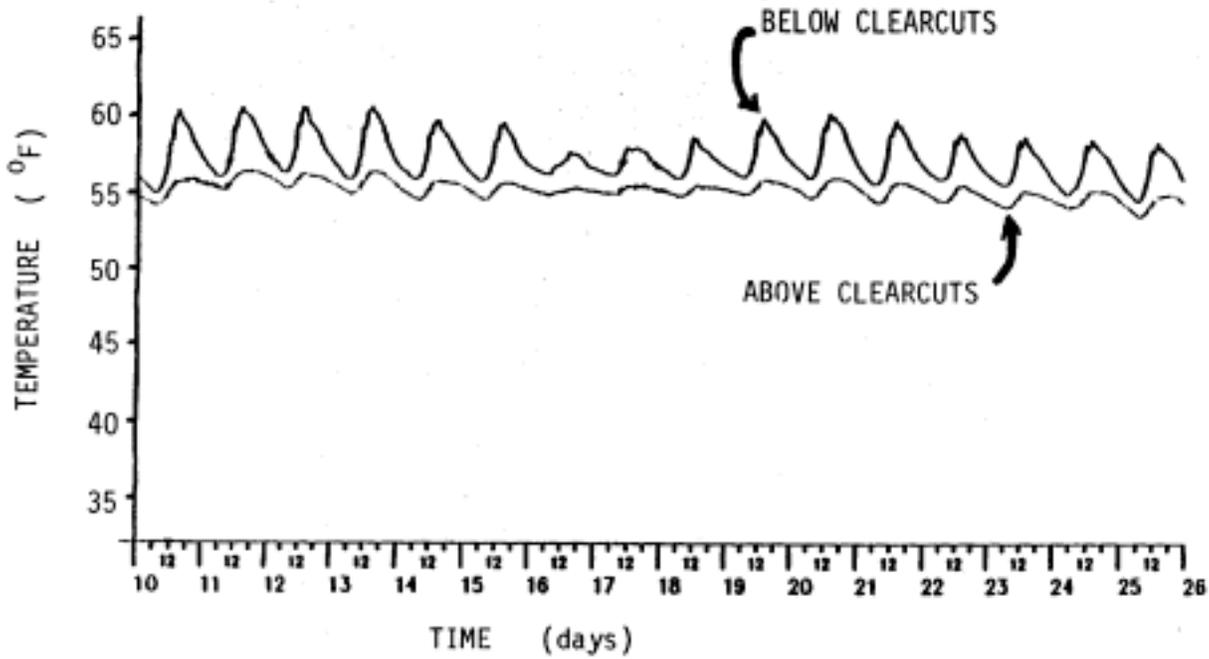


Figure 2. Plot of stream temperature, North Fork of Caspar Creek, July 10 - 25, 1990.

tends inland five miles from the ocean. Electronic data loggers were installed at two locations prior to harvesting. The first site is an uncut fork of the gulch (800 acres) with a measured shade canopy of 93 percent (see Figure 3). A device called a solar pathfinder was used to determine the canopy shading the water; it has proven to be an excellent tool for this job (see Figure 4). Maximum summer temperatures were found to be 58.5° F, with daily highs averaging 54.5° F. The lower site was used to document the impacts of clearcut harvesting a 40-acre block, with a buffer strip on both sides. A high water table through this reach had partially killed shade producing trees prior to harvest, and pre-logging maximums were 61.5° F. Daily highs averaged about 57° F. Following harvest, the effective shade for the stream was measured at 62 percent, and maximum water temperatures were 63° F. Average daily highs were 57.5° F.

### PREDICTING STREAM TEMPERATURE INCREASES

In order to predict stream temperature increases, several parameters must be measured or estimated. These include: discharge, stream length im-

pacted by logging, average stream width, travel time for the water to move through the harvested area, the effective shade before harvest, and estimated shade after harvest. Using an equation developed by Brown (1969) and modified by Amaranthus (1983), it is possible to calculate what the maximum increase in stream temperature will be.

The recent clearcuts in the North Fork of Caspar Creek were used to test this equation (see Figure 1). We

measured the parameters on July 17, 1990. The North Fork example is shown in Table 1.

The observed increase is about 4° F, based on measurements taken above and below the clearcut reach (see Figure 2). Incomplete information was available to test the equation for Railroad Gulch. No estimate of shade before logging was made, and no measurement of travel time through the logged reach was done.

Table 1. A method to predict maximum stream temperature increase.

discharge = 0.20 cfs  
length of flowing stream impacted by harvesting = 1800 feet  
average stream width = 3.4 feet  
travel time for the water through the unit = 6 hours  
heat input, based on latitude and travel time = 4.19 BTU/ft<sup>2</sup>-min  
(from published data)  
shade before logging = 93 percent  
shade after logging = 80 percent

The equation to predict temperature change ( $\Delta T$ ) is:

$$\Delta T = \frac{\text{Area} \times \text{Heat} \times \text{Percent Shade Lost}}{\text{Discharge}} \times \text{conversion factor}$$

$$\Delta T = \frac{1800 \text{ feet} \times 3.4 \text{ feet} \times 4.19 \text{ BTU/ft}^2\text{-min} \times 0.13}{0.20 \text{ cfs}} \times 0.000267$$

$$\Delta T = 4.5^\circ \text{ F}$$

## SUMMARY

Small coastal streams in Mendocino County provide valuable anadromous fish habitat. Prior to timber harvest operations in second-growth forests, maximum stream temperatures are generally below 60° F. Full exposure to solar radiation, as was permitted before modern Forest Practice Rules went into effect, sometimes allowed unacceptable temperature increases to occur. For the two case studies presented here, large temperature increases did not occur from clearcut harvesting with buffer strips. The predictive equation can be used to estimate what the maximum temperature increase will be from logging. The California Department of Forestry and Fire Protection (CDF) will soon provide foresters in California with a guidebook on watercourse temperature prediction.

## ACKNOWLEDGMENTS

The Caspar Creek data was collected as part of a joint watershed study being conducted by CDF and the USFS's Pacific Southwest Research Station. The Railroad Gulch data was supplied by Lee Susan of Louisiana-Pacific Corporation.

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Figure 3. Measuring canopy shade at Railroad Gulch. (Above)

Figure 4. Top view of a solar pathfinder. (Below)  
(Dark areas indicate shade, light areas are unshaded)

