THE ALSEA WATERSHED STUDY

by

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The current concern about the impact of logging on water and fish is not new, as many people wish to believe. Similar questions were raised by the people of Oregon and their legislators in 1958. At that time, the Governor's Committee on Natural Resources established the Alsea Watershed Study to consider the impact of logging on aquatic resources of the entire Alsea river basin. Later, this study was reduced in scope. Three small watersheds in the headwaters of Drift Creek, a tributary of the Alsea River, were selected for detailed study.

The study was undertaken as a cooperative research effort. Cooperators included Oregon State University, Oregon Game Commission, Georgia-Pacific Corporation, U.S. Forest Service, U.S. Geological Survey, Environmental Protection Agency, and Mr. Fred Williamson, a local land owner.

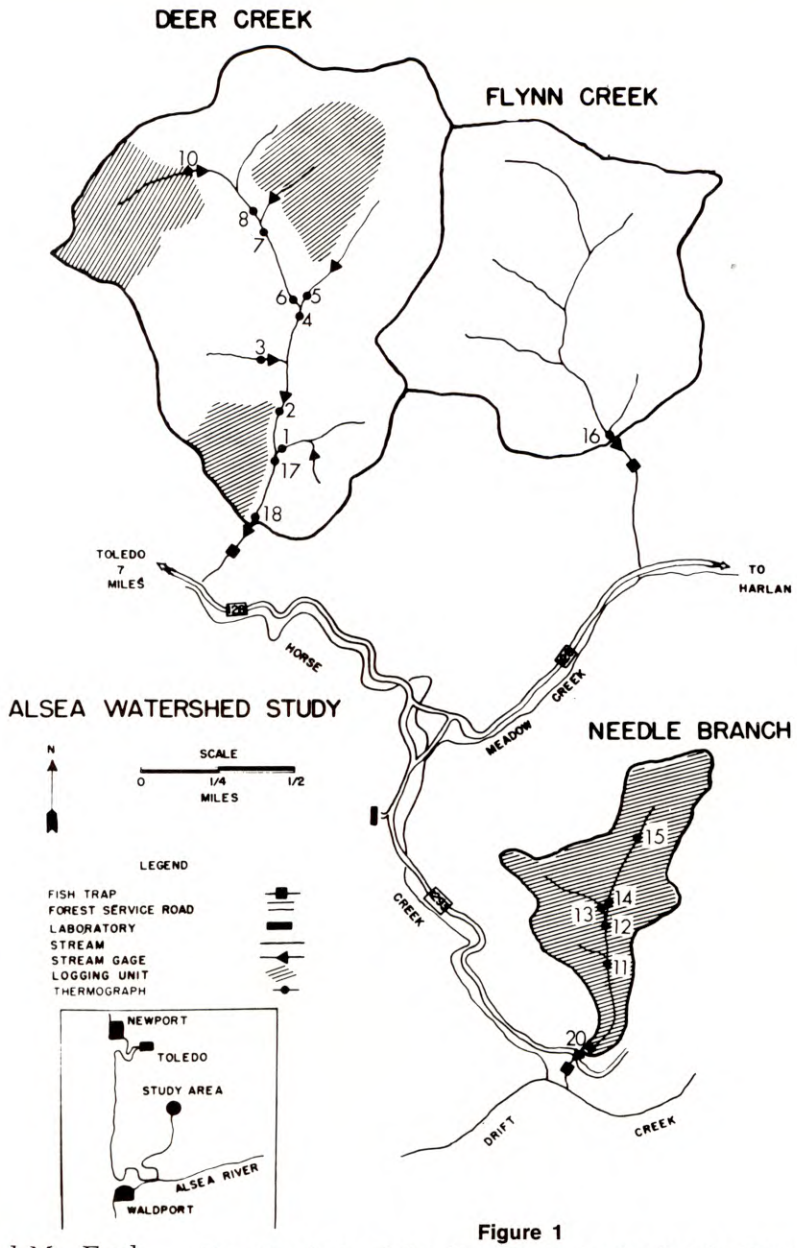

Figure 1
The watersheds of the Alsea Basin Logging-Aquatic Resources Study (after Brown and Krygier, 1970).

The objective of this detailed study was to compare the impact of two patterns of clearcutting on water yield, water quality, and fishery resources of the small watersheds. To accomplish this task, the three watersheds and their fish populations were studied for seven years in their natural condition. Throughout the study, Flynn Creek, a 500-acre watershed, remained untreated and served as a control (Figure 1). In the spring and summer of 1965, ridge-line roads were constructed into Deer Creek (750 acres) and Needle Branch (175 acres). The impact of these roads was studied the following winter. The next spring (1966) logging began in these two watersheds. Deer Creek was patch-cut with three small clearcuttings that covered about 25 percent of the area. Clearcutting boundaries were separated from streams by buffer strips of vegetation from 50 to 100 feet wide. Needle Branch was completely clearcut. In October, the lower unit on Deer Creek was lightly burned. About the same time, Needle Branch also was burned. The fire in this drainage, however, was very severe, exposing mineral soil throughout much of the watershed. The impact of logging on stream temperature and nutrient release was monitored through 1969. Streamflow, sediment, and fish populations will continue to be measured through July 1, 1973.

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RESEARCH FINDINGS

Many of the findings from the Alsea Watershed Study confirm the findings from similar studies across the country. This is particularly true for streamflow, sediment yield, stream temperature, and nutrient release. Much of the fisheries work has not been dupli-

cated elsewhere. Only a brief summary of the findings will be presented; details of each study can be found in the references provided.

STREAMFLOW. It has been known for many years that trees use large quantities of water in transpiration. Clearcutting has been shown to increase streamflow in every watershed study undertaken. The magnitude of the increase varies from site to site depending on soil, vegetative type, and climate. Some of the largest increases have been found in the Northwest. Rothacher (1970) reported increases in annual water yield of 35 to 40 percent after clearcutting in the Oregon Cascade Mountains.

Annual streamflow seems to have been increased from about 25 to 35 percent after clearcutting in the Alsea study. No increase in streamflow was observed after patchcutting. Flood runoff, or peak flow, was not significantly changed after clearcutting except from the fall or spring storms. Summer low flows have been increased as a result of clearcutting (Harr and Krygier, 1972). This result corresponds with Rothacher's (1970) findings in the Cascades.

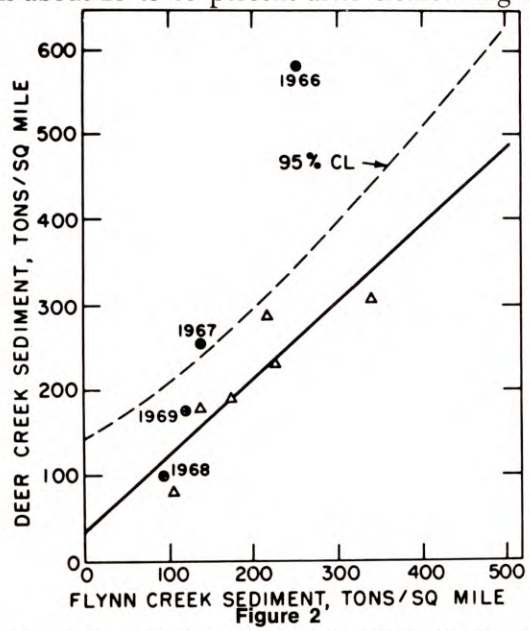

Figure 2

Comparison of annual sediment yield from Flynn Creek (unlogged) and Deer Creek (Patch-cut) for 7 years before treatment. Comparative yields after road building (1966) and logging (1967-1969) are shown in relation to the 95% confidence limit on the pretreatment regression (after Brown and Krygier, 1971).

SEDIMENT. The source of sediment for forest streams is soil erosion. This may occur either as surface or as mass soil movement from landslides or slumps. By far the greatest source of sediment in logged watersheds of the Pacific Northwest is mass soil movement. Fredriksen (1970) has described the increases observed after road construction across a watershed in the Cascades.

Road construction increased sediment yield in both Deer Creek and Needle Branch (Brown and Krygier, 1971). The largest increase occurred in Deer Creek (Figure 2) after landslides in the upper part of the watershed. The data point for 1966 illustrates the magnitude of the change. Road runoff water probably was responsible for the slight increase in sediment yield observed in Needle Branch during 1966 (Figure 3).

Surface erosion in forested watersheds is uncommon in the Northwest, unless the soil has been disturbed severly or the litter layer, which protects the soil from rainfall, has been removed. Clearcutting using cable systems seldom produces significant surface erosion. Fredriksen (1970) found no increases in sediment yield after clearcutting using a Wyssen sky-line system.

Clearcutting using a standard hi-lead system caused no increase in sediment yield from any of the units in Deer Creek. The slightly higher-than-normal sediment yield for 1967 shown in Figure 2 is undoubtedly a carry-over from the landslides in 1966. Sediment yields were measured below each of the clearcut units and no increases were found (Brown and Krygier, 1971).

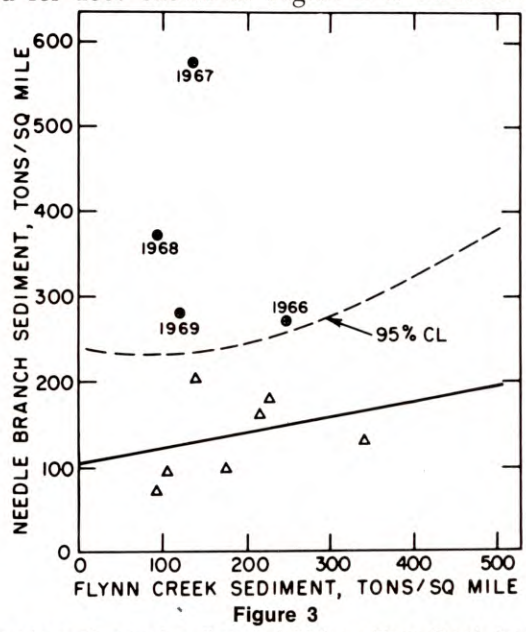

Figure 3

Comparison of annual sediment yield from Flynn Creek (unlogged) and Needle Branch (clearcut) for seven years before treatment. Comparative yields after road building (1966) and logging and burning (1967-1969) are shown in relation to the 95% confidence limit on the pretreatment regression (after Brown and Krygier, 1971).

Clearcutting, followed by severe burning, can significantly increase sediment yields. The increase in sediment yield shown in Figure 3 for 1967 is evidence of this impact. Such a change was not at all surprising; the combination of steep slopes, exposed mineral soil, and 100 inches of percipitation invariably cause erosion. A similar impact was reported by Fredriksen (1970) after the Wyssen-logged watershed described above was burned. The steady decline in sediment yield for 1968 and 1969 is the result of vegetation returning to cover the soil surface (Figures 4 and 5).

STREAM TEMPERATURE. The temperature of small forest streams is regulated by the amount of solar radiation they receive, and their streamflow volume. Given the same amount of radiation, small streams become warmer than large streams simply because there is less water to heat. Clearcutting, if it

Figure 4
Needle Branch immediately after clearcutting and burning in 1966.

Figure 5
Needle Branch four years later in 1970.

removes the shade from alongside small streams, can produce large changes in water temperature. The magnitude of the change, again, is determined by the amount of exposure and the size of the stream. As a result of work done as part of the Alsea study, temperature change expected after clearcutting now can be predicted without much difficulty (Brown, 1970).

Patch-cutting in Deer Creek, where clearcutting boundaries were separated from the stream by buffer strips, did not increase stream temperature. This result was to be expected; the amount of shade was unaltered by logging. Clearcutting on Needle Branch significantly increased mean monthly maximum temperatures and the magnitude of the annual high temperature, as shown in Figure 6 (Brown and Krygier, 1970). The temperature changes shown in this figure result from completely exposing a stream that has a summer flow of only 0.01 cubic feet per second, or about 4 gallons per minute. The highest temperature was recorded in 1967 after all of the logging debris and streamside vegetation were removed by the fire. Temperatures began to decline as streamside vegetation returned.

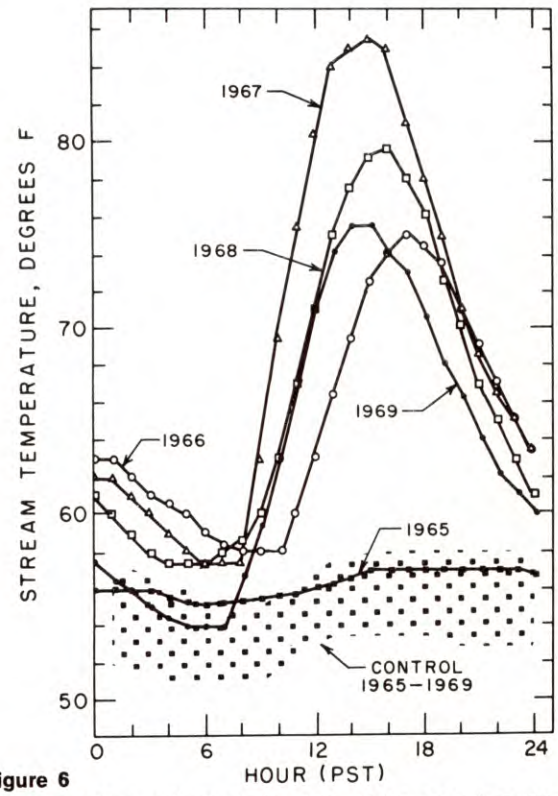

Figure 6
The temperature pattern on the days of the annual maximum recorded on the clear-cut and uncut control watersheds before (1965), during (1966), and after (1967-1969) logging (after Brown and Krygier, 1970).

NUTRIENT RELEASE. A forest stores and cycles large quantities of nutrients. Nutrient elements enter in precipitation, are made available from the slow decomposition of minerals in the soil, and are fixed by soil microorganisms. One of the principal pathways of nutrient loss is in water that leaches through the soil and into the stream. Trees and other plants form an integral part of the cycling process. They take up nutrients from the soil, participate in the fixation process, and return the element to the soil in their litter. The impact of tree removal on nutrient cycling has received considerable attention because of some research findings in New Hampshire (Likens *et al.*, 1970). In this study, clearcutting followed by continued herbicide application produced large increases in nutrient loss, with nitrate nitrogen concentrations in stream water far above the recommended level for domestic consumption.

Nitrate nitrogen, potassium, and phosphorous were monitored in the Alsea study streams before and after logging. No change in any of these elements was observed in stream water from Deer Creek, the patchcut watershed. A four-fold increase in nitrate nitrogen loss was observed in Needle Branch after logging and burning. Nitrate concentrations in the stream water were always less than 3 parts per million (ppm), far less than the limit of 40 ppm recommended for domestic use and well below any level deemed harmful to fish. This loss also represents no threat to forest soil productivity. Annual loss for the first two years after logging and burning was about 15 pounds per acre. The total nitrogen capital on these soils is about 10,000 pounds per acre. Additional nitrogen probably was lost on the sediment from Needle Branch, but

even doubling or tripling this loss to account for sedimentation still poses no threat to forest soils in Needle Branch. Similar results have been reported by Fredriksen (1971) after logging and burning in the Cascade Mountain. Potassium concentrations increased immediately after burning in Needle Branch, but quickly returned to prelogging levels. No increases were observed in phosphorous.

DISSOLVED OXYGEN. Fish and other aquatic organisms depend upon the oxygen that is dissolved in stream water for their life processes. The amount of oxygen that water can hold at saturation depends upon water temperature. The higher the temperature, the less oxygen water can hold. The amount of dissolved oxygen present in the stream at any one time depends upon its temperature, how much oxygen is being consumed by the aquatic community, and how fast it is being replaced.

Dissolved oxygen levels in the water that percolates through the stream gravel also was affected by the logging. The level of oxygen in gravel water depends, for the most part, on circulation between the surface and gravel water. In Needle Branch, this circulation was restricted by sediment, which reduced the porosity of the stream gravel. Changes of the magnitude observed in Needle Branch were not observed in the dissolved oxygen concentrations in Deer Creek, the patch-cut watershed, where stream temperature changes and slash accumulation were minimized by buffer strips along the stream. Gravel compaction and intergravel dissolved oxygen also were not affected.

Clearcut logging can influence all three of these processes. We have seen how complete exposure of the stream can increase stream temperature; the high temperature also reduces the oxygen concentration. In Needle Branch, logging debris accumulated in the stream channel. The slash, which contains much simple sugars, was used as a food source by aquatic microorganisms. These organisms extracted a great deal of oxygen from the water in the process. Slash also ponded the stream, which slowed its velocity and reduced its turbulence. As a result, the stream was unable to reaerate or replenish the oxygen used by the microorganisms. As a result of these combined processes, dissolved oxygen levels were far below those observed in Flynn Creek, the control, where oxygen levels remained about 10 ppm throughout the summer. Oxygen levels in Needle Branch dropped to less than 1 ppm for a limited time in one short reach and were generally below 6 ppm for most of the summer. Dissolved oxygen levels in the surface water returned to saturation after stream clearing and the beginning of the winter rains (Hall and Lantz, 1969).

FISH POPULATIONS. Coho salmon and cutthroat trout inhabit the study watersheds. Some of the cutthroat are resident and remain in the streams throughout their life cycle. Others migrate to the ocean and return as "bluebacks." The migrant cutthroat may spend up to six years in the streams before moving to the ocean. The coho salmon spawn in these streams from November through February when stream flow is high. The young fry emerge from the gravel from February through May and spend at least one year in the stream before migrating to the ocean the following spring (Hall and Lantz, 1969). Both trout and salmon fry occupy the streams continuously, even during the summer months when flow is very low. In Needle Branch, for example, flows of four gallons per minute are common each summer.

Fish production from these watersheds is highly variable and depends on a wide range of biologic and hydrologic factors. The number of coho salmon yearlings produced before logging ranged from 1,809 to 3,175 in Deer Creek, 566 to 1,413 in Flynn Creek, and 166 to 630 in Needle Branch. Resident cutthroat trout numbers before logging ranged from 731 to 898 in Deer Creek, 493 to 640 in Flynn Creek, and 199 to 361 in Needle Branch (Hall and Lantz, 1969).

The number of yearling coho salmon and cutthroat trout produced from Deer Creek did not change after patch-cutting (Hall and Lantz, 1969). This is not surprising. It was, in fact, to be expected because there was little change in the aquatic environment after logging.

The number of yearling salmon produced in Needle Branch also was unchanged after clearcutting and burning. The number of fish produced was 327 in 1966 and 276 in 1967, well within the range of variation observed before logging and very close to the seven-year pre-logging mean of 334 (Hall and Lantz, 1969).

Cutthroat trout populations, however, dropped to about one-third of the pre-logging level. The resident trout population averaged 264 fish from 1962 to 1965 (Hall and Lantz). The population has averaged only 95 fish in the six years after logging (1966-1971), and has ranged from 59 to 179 during this period.[1]

INTERPRETING THE RESULTS

When looking at the results of a study like this, the first thing you have to keep in mind is that it is a case study. That means the results must be interpreted with respect to the specific conditions under which the study was conducted. These include soil, topography, climate, vegetation, fish species, logging method, and the particular application of the method to these watersheds. Studies such as this generally give us some insight about problems, but it is usually dangerous to directly extrapolate the results to conditions greatly different from those studied. It means that we must interpret the results in terms of the processes involved and not the absolute values observed. With that word of caution in mind, what did we learn from the study that would help you do a better job of managing and logging our forests in terms of the aquatic resources?

One of the benefits from logging forested water-

[1] Unpublished data, Oregon Game Commission.

sheds is increased streamflow. Where precautions have been taken to preserve water quality, these increases in streamflow mean a better aquatic habitat for fish. More streamflow means more sites for occupancy, and in a small stream like Needle Branch, these sites are at a premium during the late summer. It is also quite obvious from these streamflow results that the old adage about logging drying up streams is not true. What about the question of logging and floods? We had no large floods in the period immediately after logging to compare with the flood of 1964. Our biggest increases in storm flow as compared with the control were for fall and spring storms, which were much smaller. A similar result was obtained by Rothacher (1970). He also concluded that during major floods, peak flows from logged watersheds were not significantly different from those observed on forested watersheds nearby. We could expect the same result on our Alsea watersheds.

Although no major floods occurred in the three years after logging, the highest flood flows on Deer Creek and Needle Branch each year were not different from those before logging.[1] Why should this be so? The answer lies in understanding the relations between logging, soil moisture, and streamflow. Compared to an unlogged watershed, a logged watershed has higher soil moisture in spring, summer, and fall because less water has been lost from transpiration. More runoff will occur from the logged watershed from storms during these seasons because the logged watershed's soil is wetter. That is why our results show higher runoff from spring and fall storms. During the winter, soils tend to be saturated on both logged and unlogged watersheds, particularly after such major storms as the one in 1964. Runoff from logged and unlogged watersheds is about the same under these conditions, which is why Rothacher (1970) reported no change in peak storm runoff from major floods after logging.

Erosion and the sediment it produces are caused not by felling and hi-lead yarding of trees, but by the road system and slash disposal methods used. This same conclusion has been reached in numerous studies across the country in a variety of forests logged in a variety of ways. The conclusions are fairly obvious. Road placement, design, and construction are critical in our steeply sloping, often unstable soils. Unfortunately, little information is available to make this task of road building less hazardous, but we need to avoid things we now know not to do, such as overloading steep slopes. Fire, as a slash disposal tool, is one that must be used with care. On soils like those in the Alsea study, very hot slash fires that expose mineral soil to 100 inches of precipitation will cause erosion. Fires that remove only the slash, but do not consume the duff and litter layers, probably will cause very little erosion. Timing and control of slash burning are therefore critical.

Stream temperature can be controlled by shade. Very simply, this means leaving vegetation alongside the stream. It is difficult to be more specific than that as the stream, its orientation, and the nature of the existing streamside vegetation dictate the configuration of this buffer strip. One thing is clear; vegetation left for shading the stream need not necessarily be commercially valuable trees. On many of our small coastal streams, Needle Branch for example, streamside brush, such as salmonberry or vine maple, or alder provide excellent shade. In research conducted after the Alsea study, Brazier (1973) found that the efficiency of buffer strips in controlling stream temperature was not related to either commercial volume in the strip or the width of the strip. Buffer strip efficiency was related only to canopy density, a value independent of species or size.

Logging slash, if allowed to accumulate in streams during summer months, can cause some serious problems. Part of this impact is because of the sugars contained in the fine material, such as needles and leaves, and part is caused by the ponding effect of slash, which slows stream velocities and inhibits natural reaeration. Keeping slash out of streams, either by buffer strips, special felling techniques, or rapid removal, should alleviate both problems. It is certain that the excellent job of clean-up given Needle Branch at the conclusion of logging hastened the recovery of the stream. Without such clean-up, there is little doubt that much of the spawning and rearing habitat in the small channel would have been lost.

Nutrient losses as a result of clearcutting are not a significant problem in soils such as those in this study, especially where slash burning is not practiced. These soils have high capacity for holding and storing nutrients. Quick revegetation further limits nutrient loss by rapidly reestablishing the cycling process. In short, the rapid sterilization of forest soils after timber harvest in Oregon hypothesized from studies in New Hampshire is highly unlikely.

How can we interpret the fisheries data? This is the crucial question of the entire study. In viewing the fisheries results, we must look only at the number of young fish produced, not the number of adults that returned. The reason for this is that once the young fish leave the nursery stream and migrate to the sea, many unknown factors not associated with logging influence their return. These factors include fishing pressure, streamflow conditions, and a tendency for these fish to wander. Fish from Needle Branch, for example, could wander into other nearby streams to spawn; likewise, fish from other streams could enter Needle Branch. Not all salmon return to exactly the same stream to spawn, contrary to popular belief.

The first conclusion we must reach is that the patch cutting in Deer Creek did little to change the aquatic environment and, as a result, no statistically significant change was observed in the number of coho salmon or cutthroat trout yearlings produced. This finding is significant, as it tells us that fish production and log production can coexist on the same watershed. Log-

[1] Unpublished data, U.S. Geological Survey, Portland, Ore.

ging the remainder of the watershed in the same manner with buffer strips, ridge-line roads, and only light slash fires likewise should produce no change in fish production.

The fish population data for Needle Branch also lead to some very interesting conclusions. Coho salmon are able to withstand the severe environmental changes brought about by clearcutting and burning. The number of yearling fish produced in 1967 was not different from the average number produced before logging. The spawning technique of the female cleans the gravel and seems to overcome the impact of sediment concentrations of the levels observed in this study. Higher levels of sedimentation, which bury spawning gravels, obviously would be detrimental. These fish also are affected less by temperature than laboratory studies indicated. Brett (1952) listed the upper lethal limit for coho salmon as 77° F (25° C) in a laboratory study using constant temperatures. No mortality was apparent even though the temperature was above this level for as long as eight hours and reached a high of 85° F (Figure 5).

The response of the cutthroat trout population provides a contrast to the coho salmon results. Cutthroat seem less able to cope with large changes in their environment. Fisheries biologists tell us that cutthroat place their eggs at very shallow depths in the gravel. As a result, sediment may be more influential in regulating spawning success than with coho salmon. Cutthroat also may be more responsive to temperature changes. The truth of the matter is that we really don't know what caused the reduction in cutthroat numbers —sediment, temperature, or both. All we can conclude is that cutthroat seem to be more sensitive than coho salmon even though they live in the same environment and have evolved under the same conditions.

Where does this leave us? Does it mean that we really don't have to worry about water-quality changes brought about by logging? Certainly not. First, we now have a strong legal obligation to maintain the water quality of forest streams. Second, salmon streams are always trout streams, and if we're interested at all in the fishery resources of the Coast Range, then the water-quality requirements of these trout must be met. The large differences between the response of coho and cutthroat to change illustrate the highly varied species differences one can expect even though they occupy the same habitat. The situation becomes more complicated when steelhead, coho salmon, chinook salmon, and cutthroat trout may occupy the same habitat, though at different times. It has been suggested that cutthroat may be a good indicator species because of their sensitivity. Changes much beyond their tolerance level may affect other species as well.

We *can* conclude that very little change in normal logging procedures will insure high-quality water and no damage to fish populations. What are these changes? First, more attention needs to be paid to road location, construction, and maintenance. Road failures are one of our greatest sources of sediment as well as a source of disruption to an efficient logging operation. Second, regulation of slash disposal must be keyed to maintaining duff and litter layer protection for surface soil. Third, stream channels must be protected from the sun and from damage by logs and machinery. This can be accomplished by leaving shade along the stream and by keeping logging slash out of the channel. In short, no great change in procedure is required; the only requirement is that what is normally done should be done more carefully.

The Alsea Watershed Study has illustrated that the interaction between logging, water quality, and fisheries is not simple. How can a logger be expected to do a good job in this kind of situation? The answer is coordination between the logger, the fisheries biologist, and the soils or hydrology people. Only in this way can we expect to achieve the best combination of resource outputs for our forest watersheds. Although this appears to be further restriction of logging activity, specialist inputs into the management of forest lands may well increase, rather than decrease, log production. A good example is helping design streamside buffer strips that minimize both environmental impact and the loss of commercial timber. The same reasoning may apply to designation of stream sections for fishery production. Without expert advice, the tendency is to over-design rather than under-design so as to be "extra-safe". The Alsea Watershed Study was designed as a cooperative study because no one person or group of people had the expertise to evaluate all the impacts. As we move further toward integrating the production of our many forest resources, cooperative land management planning becomes a necessity in much the same way that cooperative research was a necessity in the Alsea Watershed Study. ■

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