THE ALSEA WATERSHED STUDY:
Effects of Logging on the Aquatic Resources of Three Headwater Streams of the Alsea River, Oregon
Part I - Biological Studies

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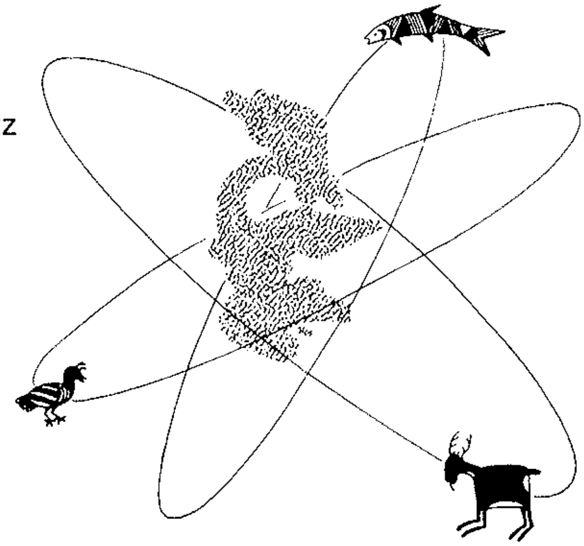

Fishery Research Report Number 9
Oregon Department of Fish and Wildlife
Corvallis, Oregon
October, 1975

Federal Aid to Fish Restoration
Project AFS-58
Final Report

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ABSTRACT

Three small tributaries of Drift Creek, tributary to the Alsea River, Oregon, were monitored during a 15-year logging study 1959-1973. One watershed (Needle Branch) was clearcut without buffer strips. A second (Deer Creek) was clearcut in patches with buffer strips and the third (Flynn Creek) was unlogged, and served as a control. This report covers the biological results of the study, and outlines those components that were altered as a result of logging activities (road construction, yarding, felling). Cutthroat trout populations were severely depressed after logging in Needle Branch, and remained low during the eight-year post-logging period. The timing of downstream migration of cutthroat juveniles in the stream was altered for two years after debris clearance and slash burning in Needle Branch. Coho salmon were less affected by logging, but average lengths and weights and condition factors were low in juveniles in Needle Branch the summer after logging. Those fish that were fry and fingerlings in Needle Branch at the time of logging had lower fecundities when they returned as adults. Coho biomass and net production rates increased in the streams of the two logged watersheds following logging. The two youngest year classes of reticulate sculpins were almost completely destroyed by logging in Needle Branch and there was a decline in numbers of adult western brook lampreys in Needle Branch in post-logging years. Additional biological data on fish populations are presented.

INTRODUCTION

The small coastal streams of western Oregon are important spawning and rearing areas for several species of salmon and trout. Of the two important salmon species in Oregon (chinook and coho), coho salmon are characteristically present in these smaller streams. They share the stream habitat with cutthroat trout, rainbow and rainbow steelhead trout, as well as some nonsalmonid fish species. These small headwater streams are often located in timbered areas suitable for logging and associated road construction. Because of their small size and isolated location, they are often overlooked during felling and yarding operations.

Logging practices can indirectly result in changes in the biological components of a stream, and can have direct and indirect effects on the physical environment in streams. Felling trees into streams, or yarding timber across streambeds do not in themselves directly kill or redistribute fishes. But, changes in environmental parameters can and do influence the biological segment of the stream ecosystem. The primary environmental changes of concern are the effects of siltation, logging debris, gravel scouring, destruction of developing embryos and alevins, blockage of streamflow, decrease in surface and intragravel dissolved oxygen, increase in maximum and diel water temperatures, changes in pool/riffle ratios and cover, redistribution of fishes, reduction in fish numbers, and reduction in total biomass. The relationship of logging activities to these undesirable changes in stream environments has been explored in numerous logging studies in the western continental United States, Alaska, British Columbia, and elsewhere.

In earlier years, logging studies were characteristically short-term and concerned with obvious stream damage related to logging activities. Although short-term studies continue to be undertaken, they are much more detailed and involved with pertinent problems. When sufficient funds are available, researchers are turning to long-term case history studies, where definitive results can be obtained.

The principal logging study in Montana was the long-term Pinkham Creek project in the Stillwater River Drainage. The studies involved, primarily, the yearly monitoring of trout and char population numbers (Stefanich 1957; Hanzel 1961). Several studies in Idaho have concentrated on the effects of logging on salmonid streams. Bachman (1958) measured physical and biological conditions in trout streams of three uncut watersheds and one logged Idaho watershed. Water temperatures apparently did not change following logging, but sedimentation from road construction did increase, especially during periods of heavy runoff. Edgington (1969) reviewed the findings of an 11-year study of two trout streams. The stream in one watershed (where 8 percent of the area was logged) exhibited no significant change in water quality or level of bottom invertebrates. On the other stream, however, 97 percent of the basin was cut, and several changes were noted. Siltation was evident in the early years as a result of road construction, and the abundance of four orders of insects declined for several years, then recovered by the end of the study. The U.S. Forest Service has studied sediment levels, gravel composition and salmon populations on the South Fork of the Salmon River (Platts 1974a, 1974b, 1974c). Sediment levels increased on the stream from 1952-1965 as a result of logging and road construction. Since 1966, the river system has been able to expell much of the excess sediment. Although the available spawning gravel appears to be increasing in known spawning grounds, it is doubtful the sediment loads in the river will ever return to the pre-logging conditions.

Washington logging studies have been limited. Wendler and Deschamps (1955) described the blockage of salmon runs by splash, roll and pond-type log dams. Cederholm and Lestelle (1974) and Fiksdal (1974) studied the effects of logging on Stequaleho Creek and the Clearwater River. Generally, the concern was several landslides into the river, resulting in siltation increases. Cederholm and Lestelle studied salmonid populations during 1971-72, along with gravel composition, suspended sediment, and benthic invertebrates. Levels of fines increased in the spawning bed gravel of the streams, but the hatching survival of cutthroat trout embryos was not significantly changed in these areas from hatching survival in unaffected sections. Coho salmon population densities were low, and the levels of benthic invertebrates were significantly lower than in unaffected areas of Stequaleho Creek.

The California Department of Fish and Game has been involved in logging damage surveys and localized surveys for many years (Cordone and Pennoyer 1960; Fisk et al. 1966), but this type of activity has given way to the long-term case history type of study. One of the enduring logging studies in the west has been the cooperative Caspar Creek study in northern California (Kabel and German 1967; Burns 1972). From its inception in 1960, researchers at Caspar Creek, and other northern California streams, continually monitored streamflow. Other factors measured for shorter periods have included biological aspects (Burns 1971), and environmental changes (Burns 1970; Kopperdahl et al. 1971; Krammes and Burns 1973). Researchers have found that sediment levels increased during and after road construction. During the first winter following road construction, sediment levels were over four times higher than pre-construction levels, but have decreased in subsequent years (Krammes and Burns). Water temperatures increased slightly following road construction (Krammes and Burns), but temperature increases were greater following logging (Kopperdahl et al.). Burns (1972) indicated salmonid populations were altered as a result of logging and road construction.

British Columbia logging research has been applied to several logging related problems. The Canada Department of Fisheries and other agencies (1966) analyzed the problem of log driving on salmonid populations and their environment in the Stellako River. Results indicated their log driving causes gravel scouring and disruption of spawning beds, erosion of river banks, a greatly reduced recreational fishery along the river, and increased levels of bark and debris in the stream and in the spawning gravel. Additional studies by Servizi et al. (1970) have shown that decaying bark may have a significant effect on developing sockeye salmon eggs. Short-term logging studies on Jump Creek and Wolf Creek, Vancouver Island, indicate some changes in fish populations in logged streams (Narver 1972), while the ongoing Carnation Creek study hopes to answer several questions with the case history approach (Narver 1971).

The harvest of timber in Alaska has increased significantly in the past 30 years. Initial logging research by the U.S. Forest Service began in 1949, and has continued at various levels to date in southeast Alaska (Sheridan and McNeil 1968; Meehan et al. 1969; Sheridan and Olson 1970). Beginning in 1956, the Fisheries Research Institute of the University of Washington has supplemented the federal research in several stages. The major emphasis in the 1950's and 1960's was on the pink and chum salmon streams of southeast Alaska (Salo 1967). More recent logging studies have concentrated on coho salmon and associated changes in environmental conditions (Tyler and Gibbons 1973), and the effects of log rafting on the marine benthos (Pease 1974). In the last several years, the National Marine Fisheries Service has conducted research into log rafting problems (Ellis 1973). The Alaska Department of Fish and Game has continued research into the effects of logging on Dolly Varden populations (Reed and Elliott 1972), and the toxicity of decaying bark on pink salmon fry and some crustaceans (Buchanan and Tate 1975). Out of the Dolly Varden study came a series of guidelines for logging operations and baseline biological measurements in important southeast Alaska sports fishing areas (Elliott and Reed 1973). Several logging studies have been undertaken in the Cascade Range of Oregon, including the Steamboat Creek drainage area (Brown et al. 1971), and the H.J. Andrews Experimental Forest (Wustenberg 1954; Brown and Krygier 1967; Levno and Rothacher 1967, 1969). Brazier and Brown (1973) studied applications of buffer strips in both the Cascade Range and the Oregon Coast Range, and Moring and Lantz (1974) reported the findings of a six-year study of 12 coastal streams of western Oregon. Cutthroat trout populations appeared to decrease on streams following logging, but the reactions of coho salmon populations were mixed. Maximum stream temperatures increased, and dissolved oxygen levels generally declined after logging. There were also changes in amounts and composition of spawning gravel, but those streams with intact buffer strips suffered less damage than those without buffer strips.

The limitations of short-term studies, however detailed, become apparent when the lack of background data on biological and physical cycles hinders the interpretation of results. Most long-term case histories of logged watersheds have only been undertaken in the last 25 years. The results of the largest such study, the Alsea Watershed Study, will be reported here. The 15-year study was the most extensive study of biological and environmental features of logged and unlogged watersheds ever undertaken in North America.

The Governor's Committee on Natural Resources established the Alsea Watershed Study in 1957. Funding from this source disappeared a year later, but federal and state agencies supported the work for the 15-year study period. The Alsea Watershed Study was a cooperative venture involving hundreds of individuals. Principal cooperators throughout the study were the Oregon State Game Commission (Oregon Department of Fish and Wildlife), Oregon State University (primarily the School of Forestry, and the Departments of Botany, Civil Engineering, Entomology, and Fisheries and Wildlife), the U.S. Forest Service, U.S. Geological Survey, Federal Water Pollution Control Administration, the Georgia-Pacific Corporation, and Mr. Fred Williamson, a private landowner. Other cooperators included the U.S. Public Health Service, Oregon Cooperative Wildlife Research Unit, Oregon State Board of Forestry, and the Department of Environmental Quality. In addition to the Georgia-Pacific Corporation, the logging companies were the Stokes Lumber Company and Timber Access Industries, both of Corvallis, Oregon.

Studies began in July 1959 on three small watersheds in Lincoln County, Oregon. The three creeks involved are headwater tributaries of the lower Alsea River. One watershed, Flynn Creek, was left unlogged, and served as a control. The Deer Creek watershed was patch cut with intact buffer strips along the stream. The Needle Branch watershed was clearcut without buffer strips.

Logging road construction took place during May to October 1965. The timber harvest on the Deer Creek and Needle Branch watersheds occurred the following year, again during May to October. Slash burning was completed on Needle Branch and on two sections of Deer Creek prior to November 1966. The remaining section was slash burned some months later. Post-logging studies continued until October 1973.

This sequence provided a 7-year pre-logging study period, 1959-1965, logging in 1966, and a 7-year post-logging study period 1967-1973. For comparative estimates, the period 1959-1965 constituted the pre-logging work and 1966-1973 constituted the post-logging work. Among the primary objectives of the work were:

1. To study in depth the population characteristics of salmonids and other fish species in Flynn Creek, Deer Creek and Needle Branch over a 15-year period, 1959-1973.
2. To study the direct and indirect effects of logging on fish.
3. To compare the effects of two common logging techniques on biological and physical properties of streams, using Needle Branch and Deer Creek as test streams, and Flynn Creek as a control stream.
4. To analyze the effects of environmental changes (natural and logging-related) on salmonid fish species, particularly coho salmon and cutthroat trout.
5. To derive some indication of the natural fluctuations in fish populations and physical and biological properties of the three Alsea Study streams.
6. To make recommendations, on the basis of accumulated data, as to desirable and undesirable logging practices (including road construction, buffer strips, and yarding and felling of trees).

In order to present the results of this extensive study in the most logical manner, three separate but related Alsea Watershed Study reports are being issued. Part I includes the results of the biological investigations of the study. Part II includes the results of the environmental measurements during the study. Part III includes the discussion, summary and recommendations. Numerous papers, theses and dissertations have been issued on various aspects of the study during the past 15 years. Pertinent results of these publications, as they pertain to the results and discussion of accumulated data, will be included.

STUDY AREAS

Three headwater tributaries of the Alsea River were selected for study. The Deer Creek, Flynn Creek and Needle Branch watersheds are located in a portion of Lincoln County, approximately 16 km (10 miles) south of Toledo, Oregon (Figure 1). All three streams eventually flow into Drift Creek, and ultimately into Alsea Bay. Deer Creek is a tributary of Horse Creek. Flynn Creek is the major tributary of Meadow Creek, which then flows into Horse Creek. Horse Creek joins Drift Creek approximately 60 meters from the junction of Needle Branch and Drift Creek (Figure 2). Drift Creek flows southward until entering Alsea Bay approximately 6.4 km (4 miles) east of Waldport.

The three streams have extremely variable flow rates, and are of different sizes. Needle Branch is the smallest stream,

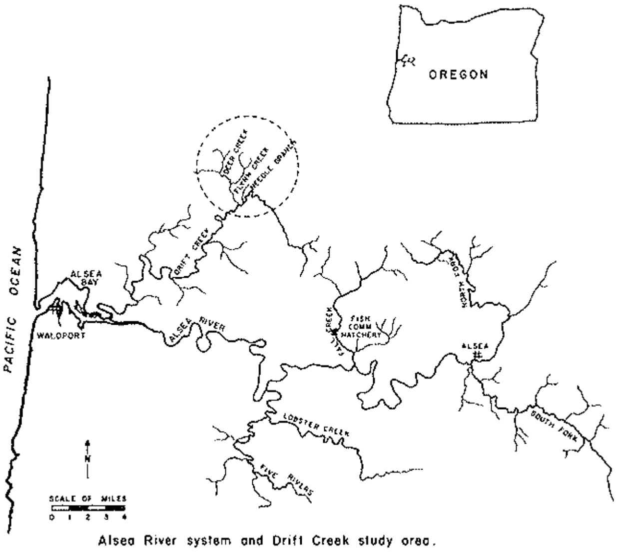

Figure 1. Location of Alsea Watershed Study in western Oregon.

followed by Flynn Creek, and then Deer Creek. The three creeks can be considered typical of small western Oregon headwater streams. The principal cause of the variable flow rates is the combined effect of the small sizes of the streams, and the effects of winter freshets, which generally occur from November to February.

The study area is located in the northern Oregon Coast range in a region of heavy rainfall. Mean annual precipitation was reported by Hall and Lantz (1969) as 244 cm (96.1 inches) during the 1959-1965 pre-logging period. Air temperatures ranged from approximately -7 to 32°C (19 to 90°F). Snowfall in the area is relatively light, occurring only two or three times per year, and never remaining on the ground for long periods.

The geology of the region is typical of the northern Oregon Coast range, with the principal underlying component the northern extension of the Tyee sandstone formation. Corliss and Dyrness (1965) have summarized the principal soil and vegetation components of the area, but particular vegetation characteristics of each watershed will be discussed in more detail in the descriptions of individual stream sites. Generally, 100-year-old Douglas fir (*Pseudotsuga menziesii*) was the principal commercial species harvested. The important hardwood in the area was red alder (*Alnus rubra*). Understory vegetation was primarily salmonberry (*Rubus spectabilis*), sword fern (*Polystichum munitum*), skunk cabbage (*Lysichitum americanum*) and vine maple (*Acer circinatum*).

Four salmonid species were present in one or more of the study streams: coastal cutthroat trout (*Salmo clarki clarki*), steelhead trout (*S. gairdneri gairdneri*), chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*). Steelhead trout and chinook salmon are uncommon and are usually only present in Deer Creek.

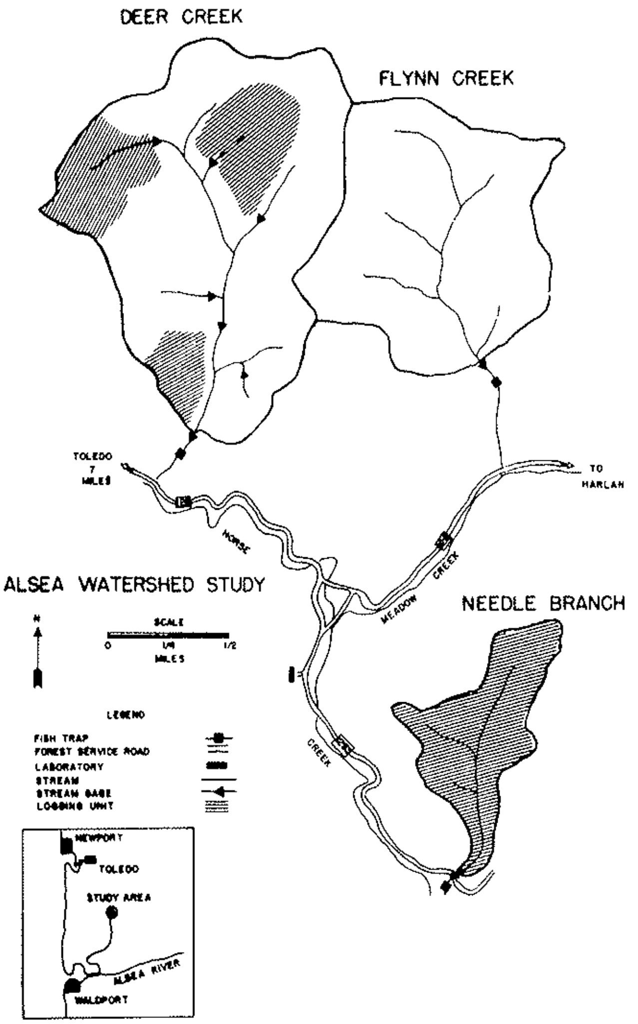

Figure 2. Map of the study watersheds. The approximate lengths of the streams accessible to anadromous salmonids are: Deer Creek – 2,324 m, Flynn Creek – 1,433 m, Needle Branch – 966 m.

Chapman (1961, 1962, 1965), Au (1972) and Lindsay (1975) have described the life history patterns of coho salmon in the three study streams. Generally, adult coho salmon enter the streams to spawn from November through February. The fry emerge February through May. After a year of residence in the creeks, most juvenile coho migrate to sea the following spring. Lowry (1964a, 1965,1966) has described the biology of cutthroat trout in the study streams. Sea-run adults follow similar migration timing as adult coho salmon, but juveniles may remain in the streams for several years prior to migration. There is probably a resident population of cutthroat trout in the streams, but the sea-run component dominates. Distinguishing which juveniles or adults in streams may be "residents" is difficult, because some sea-run individuals may remain in the stream for as much as five years before migrating (Richard Giger, personal communication). Others may move to the estuary and no further, thus confusing scale analysis.

Other fish species in the streams were the reticulate sculpin (*Cottus perplexus*), Pacific lamprey (*Entosphenus tridentatus*), and western brook lamprey (*Lampetra richardsoni*). No other fish species were noted during the 1959-1973 study period.

Principal laboratory and housing facilities for the project were located at the laboratory located along Horse Creek (Figure 2). Studies concerning gravel incubation, predation, and the effects of sedimentation, among others, were conducted at this station (see Methods sections in Parts I and II). The field location of the laboratory provided easy access to the biological and physical components of the study streams.

Flynn Creek

The Flynn Creek watershed (approximately 202 ha) was not logged, and served as a control for the study. Stream length is approximately 1,433 m, with mean summer width 1.74 m, and mean summer depth 13 cm (Chapman 1961). The stream gradient averages 0.025 meter per stream meter.

Stream distance was marked by stakes from the gauging station (0 meters, 0 feet). The fish collection trap was located 305 meters (1,000 feet) downstream from the stream gauge. Between marker 305 meters (1,000 feet) and 549 meters (1,800 feet) there is a steep canyon which restricts the available stream area. Historically, there was little spawning in this steep area of much exposed bedrock. Following scouring in the winter flooding of 1971-72, the remaining gravel largely disappeared, and spawning activity in the canyon effectively ceased. There are four small tributaries to Flynn Creek (Figure 2), evenly spaced along the stream length. The final study marker stake was at 1,006 meters (3,300 feet) upstream. The portion of the stream beyond that point was unstudied.

During the pre-logging period, mean summer streamflow was 4.5 liters per second (0.16 cfs), and peak winter flow reached 3,877 liters per second (137.0 cfs) (Hall and Lantz 1969). Annual mean water temperature was 9.7°C, ranging from a minimum of 2.2 to a maximum of 16.6°C, essentially the same as those recorded on other streams in the pre-logging period. Diurnal temperature range varied from 0.5 to 2.2°C (Hall and Lantz).

The Flynn Creek watershed is owned by the U.S. Forest Service, and the principal species of trees are Douglas fir and red alder. Douglas fir present were primarily 30 to 50 and 70 to 110-year-old stands. Alder stands were 30 to 70 years old. The understory species were salal (*Gaultheria shallon*), sword fern, vine maple and salmonberry. Isolated groups of bracken fern (*Pteridium aquilinum*) were also present.

Deer Creek

The Deer Creek watershed is the largest of the three study areas, covering approximately 304 ha. The stream length is approximately 2,324 m, with an average summer width of 1.80 m, and an average summer depth of 11 cm (Chapman 1961). Stream gradient averages 0.018 meter per stream meter.

The fish trap was located 152 meters (500 feet) below the gauge station (or a stream location of -152 meters). A steep canyon is present from the 152 meter stream marker to approximately the 427 meter (1,400 foot) location. From 427 meters to 1,219 meters (4,000 feet), the stream is quite slow moving and meandering. A beaver dam was generally present after 1967 at 792 meters (2,600 feet), reducing water velocity at that point. The major tributary of Deer Creek was East Fork, entering at the 1,433 meter (4,700-foot) marker. Two smaller tributaries entered the main stream below the East Fork junction, and two smaller tributaries entered above East Fork. The final study marker stake was at 2,195 meters (7,200 feet) upstream from the gauge station.

Mean summer minimum streamflow in the pre-logging period was 8.5 litters per second (0.30 cfs). Peak winter flow was 5,688 liters per second (201 cfs). Annual mean water temperature in the pre-logging period was 9.6°C, ranging from a minimum of 1.1 to a maximum of 16.1°C. The diurnal range was 0.5 to 2.2°C (Hall and Lantz 1969).

Most of the watershed is owned by the U.S. Forest Service, with a small section near the mouth owned by the Georgia-Pacific Corporation, and the principal logged species of timber was Douglas fir. Fir stands were primarily 50 to 70 and 70 to 110 years old. A few trees younger than 20 years were present in one small area. Red alder were primarily 40 to 60 years old. A few 20 to 40-year-old alder were present in the lower clearcut section. The understory was almost entirely salmonberry, vine maple and sword fern. Salal and bracken fern were present in a few isolated locations.

Locations of the three patches clearcut are shown in Figure 2. The lower section was along the west side of the stream at the effective lowest portion of the watershed. A buffer strip was left along the creek. The northern clearcut was on the hillside between the East Fork drainage and the main creek drainage. Buffer strips were left along all branches of the stream. The third area was at the extreme northwestern section of the watershed. Clearcutting occurred on both sides of the main branch in a section located immediately above the study area.

Needle Branch

The Needle Branch watershed is the smallest of the study areas, only 75 ha in size. The stream length studied is approximately 966 m. The stream gradient is 0.014 meter per stream meter. Mean summer width is 1.10 m, and mean summer depth is 7 cm (Chapman). The fish trap was located approximately 61 meters (200 feet) below the stream gauge. The two distinctive features along the stream are small waterfalls at approximately 808 meters (2,650 feet) and 869 meters (2,850 feet). Two small tributary streams enter Needle Branch above the second falls. Beyond approximately 1,067 meters (3,500 feet), flow is greatly reduced, and isolated pools are present to the headwaters. The 792 meter (2,600-foot) marker was the final study area stake, but population estimates and other surveys were conducted above this point after 1966.

Mean summer minimum streamflow was 0.6 liters per second (0.02 cfs). The peak winter flow was 1,415 liters per second (50.0 cfs). The annual mean water temperature of 9.7°C was similar to that on the other study streams. Water temperatures ranged from a minimum of 1.6 to a maximum of 16.1°C. The diurnal temperature range was 0.5 to 1.5°C prior to logging (Hall and Lantz 1969).

Part of the lower section of Needle Branch watershed was privately owned by Mr. Fred Williamson. The remainder was owned by Georgia-Pacific Corporation. Several timber species were present, including Douglas fir, western red cedar (*Thuja plicata*), and red alder. Douglas fir stands were all 70 to 110 years old, while cedar stands were 30 to 50 years old. A small stand of 30-50 year old Oregon white oak (*Quercus garryana*) was also present. The age of a small patch of alder was in excess of 100 years. The understory was primarily vine maple and sword fern, although salal, bracken fern, salmonberry, thimbleberry (*Rubus paraviflorus*) and dewberry (*R. vitifolius*) were also present. The vegetation of the lower and central portions of the watershed was similar to that on Deer and Flynn creeks, but the understory at the head of the stream consisted primarily of shrubs, herbs and various grasses.

The entire watershed was clearcut and later slash burned. No buffer strip was left along the streambed. No effort was made to protect the stream from logging activity, except to eventually clear debris from the channel.

METHODS

Biological components of the three selected streams were studied primarily at the upstream and downstream traps located at the lower sections of the streams. Techniques of studying upstream populations of resident and spawning fish, and other portions of the aquatic fauna are described below. Throughout the Methods and Results sections, the comparative terms "pre-logging" and "post-logging" are often used for all three streams, even though there was no actual logging on Flynn Creek. In the case of Flynn Creek, the terms refer to the periods of pre-logging and post-logging on the other streams, and are used with the Flynn Creek control parameters only as a means of comparison within these time frames.

Trap Operation

Large fish traps were constructed across all three streams. As indicated in Figure 2, the traps on Deer Creek and Needle Branch were located very near the mouths of the streams. However, the trap on Flynn Creek was located over two miles above the mouth of Meadow Creek, a tributary of Horse Creek. We do not believe that coho salmon spawning activity was significant between the mouth of Meadow Creek and the trap on Flynn Creek. Subsequent stream checks revealed only few coho salmon spawning in this area. The numbers of cutthroat trout in this area are unknown.

The original traps used for the 1959 sampling were all constructed of wood (Figure 3). Rotating screens prevented loss of small fish, but also accumulated debris, and needed to be cleaned several days each week.

After the 1964 flood, it was realized that the wooden traps were inadequate for a long-term project of this nature. There were also problems with the wooden trap on Needle Branch. For unexplained reasons, female coho salmon passed through the upstream trap would not stay upstream and spawn, but turned around and moved back downstream through the trap. The upstream trap was partially of concrete, with an inclined plane. Because of the difficulty in keeping female spawners upstream, the inclined plane was removed and fish were allowed to pass freely during the coho migration period, November to early February. As a result, only redd counts were made in the three seasons immediately prior to logging.

New concrete traps were installed in the following schedule:

STREAM	CONSTRUCTION BEGAN	CONSTRUCTION COMPLETED
Deer Creek	September 1965	November 1965
Needle Branch	August 1966	October 1966
Flynn Creek	August 1967	October 1967

These new traps were easier to maintain, and worked well during the remainder of the study (Figure 4 and 5). There were problems during winter freshets (Figure 6), but trap design was not the cause.

A covered work area was located next to each trap. Fish entering each trap could be examined, weighed, and measured at the site (Figure 7). Data books were kept at work stations, and detailed instructions were issued each year.

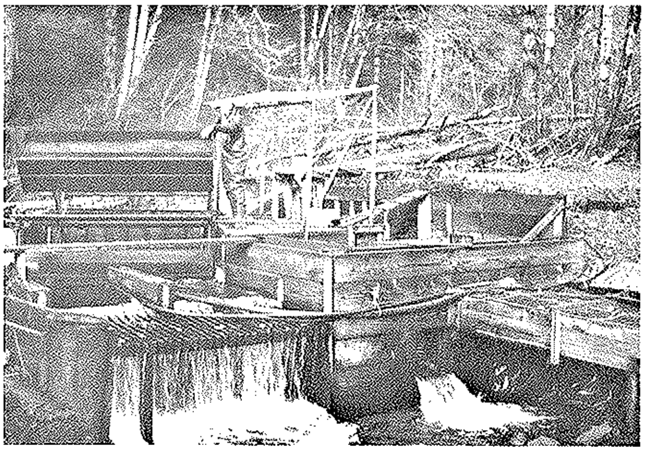

Figure 3. Original wooden fish trap on Deer Creek, fall 1960.

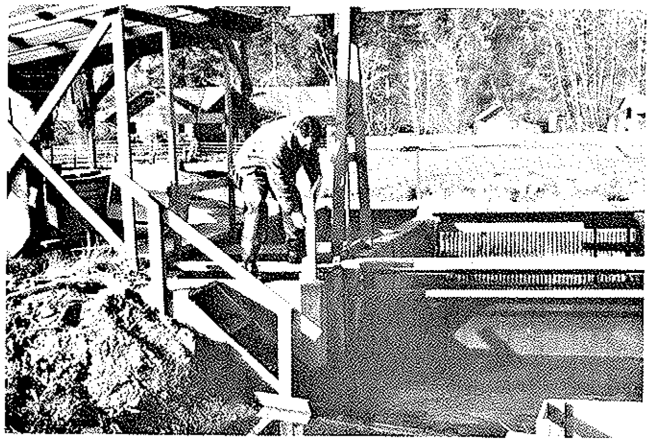

Figure 4. Concrete fish trap on Needle Branch, late winter 1970.

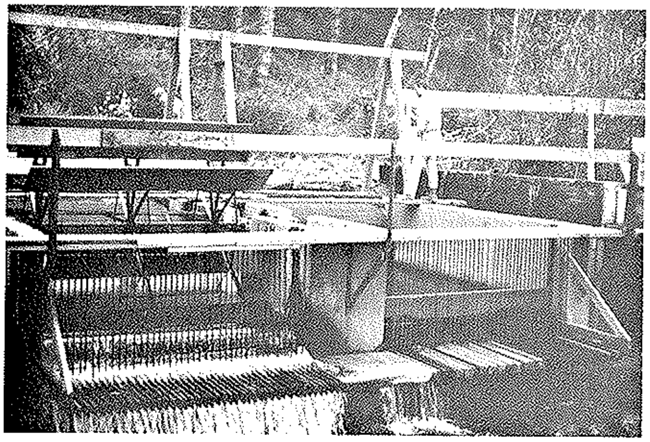

Figure 5. Concrete fish trap on Deer Creek.

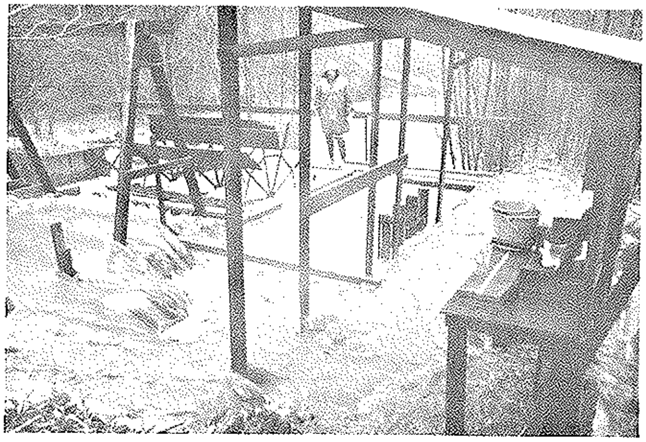

Figure 6. High water spills over the trap at Deer Creek during a freshet, January 11, 1972.

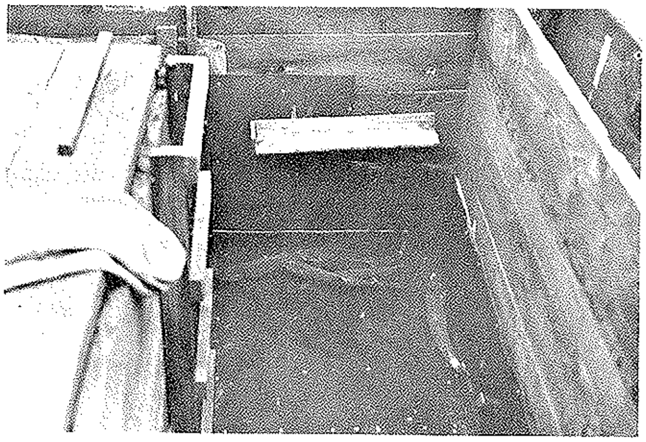

Figure 7. Adult coho salmon in one of the original wooden upstream traps.

Traps were taken out of commission at various times in the course of the study, usually for 1-3 day periods. The primary reasons for such closures were high water, debris clogging the openings, and general maintenance. Closures were generally short in duration and occasional in timing.

In addition to fish species, traps collected many reptiles, amphibians, mollusks, insects and small mammals. Among the animals collected by the traps were mice, wood rats, a beaver, frogs and tadpoles, aquatic and terrestrial snakes, crayfish, salamanders and newts, a muskrat, freshwater snails, various terrestrial and aquatic insects, and a kingfisher.

Length and Weight Sampling at the Traps

All adults passing through the upstream traps were examined. Fish were measured in millimeters and weighed in grams. Sex and condition (e.g. green, spent) were recorded. Most females were weighed and measured, whereas many males, especially in early years, were only measured.

All fish trapped and placed upstream were fin clipped: adipose on coho salmon, and the top portion of the caudal fin on cutthroat trout. A sample of scales was routinely collected from adult salmon and trout.

Adults passing through the downstream trap were handled in a similar manner, except no additional fin clip was applied. There was no concerted effort to weigh and measure adults moving downstream except in the last few years of the study. Females entering the downstream trap for the first time were marked and placed back upstream. This was because some fish are frightened, and may be stressed into moving downstream. After the second entry, females were passed downstream.

Information from carcasses collected at the downstream trap was included in trap records. The sex of these fish was identified, and egg retention in females was noted. In later years, all carcasses were also weighed and measured.

Juvenile salmonid fry passing through the downstream trap were too numerous to individually weigh and measure. During peak runs in most years, a daily sample of 50 juvenile coho salmon and cutthroat trout fry provided the length-weight information. All smolts were measured. All other fish were enumerated. In the last few years of the study, sample sizes were considerably higher. Small trout (steelhead and cutthroat trout < 75 mm) were enumerated only. As steelhead trout were only present in Deer Creek, the designation on other streams always referred to cutthroat.

Reticulate sculpins were generally measured (mm TL) from the upstream and downstream traps. All other fish species were enumerated only.

Tagging

After measuring length and weight, coho salmon females were routinely anesthetized with MS-222 (Tricaine Methanesulfonate). Coho salmon females were then tagged with dorsal or opercular spaghetti tags or color coded Petersen disc tags (Figure 8). After 1968, a radio tag was attached to the back of some of the females, just below the dorsal fin (Figure 9). Each radio tag was identified with a distinct number, and emitted a signal on a distinct radio frequency. This signal could be detected with a portable FM radio.

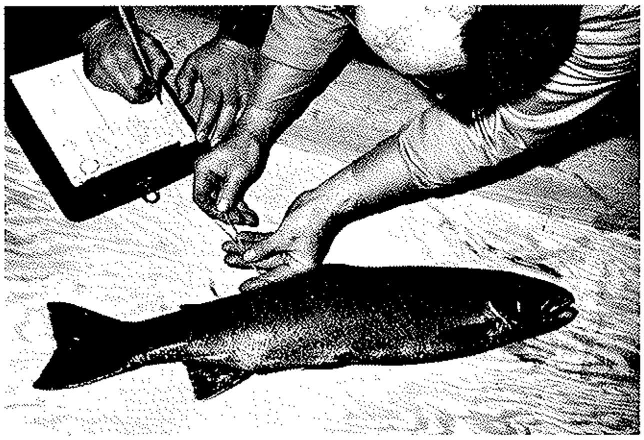

Figure 8. Attaching a spaghetti tag to the back of a female coho salmon.

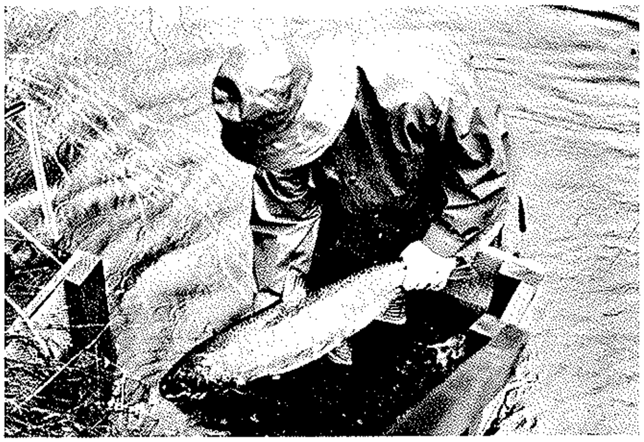

Figure 9. A female coho salmon with a radio tag and Petersen disc tag in place below the dorsal fin.

Only coho salmon females were tagged regularly (with color-coded Petersen disc tags) during the 15-year study period. Coho salmon males were only tagged in 1963-64 and again in 1972 and 1973. When males were tagged, each received Petersen disc tags or colored Floy anchor tags.

Large cutthroat trout were tagged in the last few years of the study only. These fish were tagged with colored Floy anchor tags. During Lowry's (1964) study of cutthroat trout, plastic subcutaneous tags (described by Butler 1957) were used to study stream movement. Similarly, adult steelhead trout were tagged with colored Floy anchor tags only in 1973.

Population Estimates

During the 15-year study, population estimates were conducted for cutthroat trout and coho salmon on the three streams. In some years, cutthroat trout and coho salmon population estimates were carried out only in Needle Branch.

Generally, a standard section of each stream was studied every year. On Deer Creek, this study section extended from the trap (at -152 meters) to 1,920 meters (6,300 feet) –– a distance of 2,073 meters (6,800 feet). During most years, a section of the East Fork of Deer Creek was also analyzed. This section extended anywhere from 0 to 229 meters (750 feet), to 0 to 274 meters (900 feet) in length. During early years, 244 meters (800 feet) were shocked. During the middle years usually 259 meters (850 feet) were shocked; and in later years, 274 meters (900 feet) were shocked. On Needle Branch, the study section extended from the trap (at -61 meters) to 808 meters (2,650 feet) – a total distance of 869 meters (2,850 feet). During 1968-71, an additional area above the first falls was also studied (an additional 488 meters, or 1,600 feet). The study area on Flynn Creek extended from the trap (-30 meters) to 1,006 meters (3,300 feet) – a total distance of 1,311 meters (3,400 feet). In 1962 and 1963 during the intensive cutthroat trout studies by Lowry (1964a), the study sector was extended to 1,113 meters (3,650 feet), making the total stream length equal to 1,417 meters (4,650 feet). However, all yearly comparative estimates have been adjusted to account for discrepancies in stream lengths surveyed.

Population estimates were typically undertaken in August and September. Occasionally population surveys extended into October, but an attempt was made to complete surveys before water levels increased and adversely affected sampling efficiency and reliability. During the intensive coho salmon studies by Chapman (1961) in the years 1958-1961, and cutthroat trout studies by Lowry (1964a) in 1962 and 1963, population estimates were conducted in all seasons of the year. For comparative purposes, however, the late summer estimates by Chapman and Lowry were used in most analyses of long-term trends.

Fish were primarily captured with the use of backpack electrofishing units (Figure 10). Different shockers were in use during the 15-year study, but the typical equipment was described by Lowry (1964b). Salmonids were anesthetized with MS-222 and marked with a particular fin clip which was different from marks applied at the traps (often a temporary caudal clip or adipose clip).

After fish were redistributed throughout the stream length, they were later recaptured (Figure 11). Petersen

Figure 10. Collecting juvenile coho salmon and cutthroat trout using a back-pack electrofishing unit.

Figure 11. Juvenile coho salmon and cutthroat trout collected with a back-pack electrofishing unit.

population estimates were computed in the manner described by Ricker (1958), using the modification of Bailey (1951):

$$\hat{N} = [M(C+1)]/(R+1)$$

Where:

N = estimated population size;
M = the number of fish originally marked;
C = size of sample during recapture; and
R = number of recaptured marks in sample.

The variations in stream length surveyed were adjusted for final, comparative estimates.

The fork lengths of coho salmon and cutthroat trout recaptured were recorded in millimeters. Occasional weights were recorded in grams on the Ohaus balance. During some later years special biomass estimate areas were established. Fish population estimates were correlated with weights of recaptured fish to estimate total biomass of coho salmon and cutthroat trout (see section on Biomass).

Population estimate methods used by Chapman (1961), Lowry (1964), and Au (1972) varied somewhat from those used by Wildlife Commission biologists. Some estimates were based on marking fish in streams, then recovering them at the traps. Reference should be made to those studies for specific methods.

Biomass and Pool-Riffle Population Estimates

Biomass measurements were taken from 1959 to 1969, and in 1972. Au (1972) has summarized the coho salmon biomass values of the years 1963-1968. Oregon State Game Commission personnel collected biomass data for both coho salmon and cutthroat trout in 1969 and for coho in 1971 and 1972. Chapman (1965) analysed the coho salmon biomass features of the three streams for 1959-1963 and Lowry (1964) studied cutthroat trout biomass during 1962 and 1963.

Methods varied with researcher, but, in general, a standard biomass area(s) was established, and comparative biomass measurements were taken only in the same area or areas. All fish of the desired species were measured in millimeters and weighed in grams. Using a Petersen population estimate (see Methods: Population Estimates), the total population within a study area was compared to the average weight for the population sampled. A total biomass weight was derived for the area. Generally, the biomass measurement was expressed as g/m^2 or pounds per acre.

During the Oregon State Game Commission surveys, specific biomass areas were established. On Deer Creek, there was generally a lower sampling area (-137 to -15 m), a middle area (15 to 46 m), and an upper area (792 to 1,250 m). On Needle Branch, biomass sampling occurred in a lower area (183 to 335 m) and an upper area (488 to 640 m). Flynn Creek biomass areas were the lower area (61 to 213 m) and the upper area (701 to 853 m). Studies on biomass areas were usually conducted in September, but occurred as early as July. Biomass studies by Au, Chapman and Lowry were often undertaken throughout the year, particularly in the case of coho salmon. The specific methods used in these more intensive studies were somewhat different from those described above, but the objectives were often the same.

Spawning Surveys

One to two days after a tagged coho salmon female was released upstream, biologists would locate the fish using the radio signal as a tracking tool. If the female was engaged in any spawning behavior, the redd location would be recorded. During a 10 to 20-minute observation period, the following types of activity were noted: digging behavior, number and position of attendant or "alpha" males, eggs or milt in the water, condition of spawning fish, other species in the redd area (e.g., cutthroat trout), etc.

The locations of dead spawners were noted and carcasses were returned to the respective trap areas for measurement of lengths, weights and egg retention. After spawning coho salmon left a redd, the location was flagged and a stake was inserted on each bank at the approximate mid-point of the redd. These stakes marked the redd for fry trap installation approximately 80 to 90 days later.

Fry Emergence

Emerging coho salmon fry were studied with the aid of a nylon fry trap previously described by Phillips and Koski (1969). The trap consisted of a cap of nylon placed over an individual redd in a stream (Figures 12 and 13). The trap edges were buried to a depth of 15 cm (Figure 14). The standard trap was 2.4 m by 6.4 m in size, constructed of 3.2 mm mesh nylon netting. A tapered collection bag was attached. Zippers were sewn to the collection bag and the main trap section. Most emerging fry were removed from the collection bag. The trap was large enough to provide a 15 to 30 cm border between the actual redd and the trap edge. This allowed for some lateral, intragravel movement of alevins.

Figure 12. Installing emergent fry trap over salmon redd.

Figure 13. The fry trap installed over a coho salmon redd.

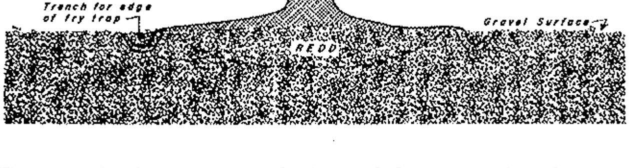

Figure 14. Cross-sectional view of fry trap placed over a salmon redd.

Traps were installed on coho salmon redds each season from 1964 to 1971 on each of the three streams. Daily inspection of an installed fry trap provided a record of emergent fry. Samples of emergent coho salmon were measured. Not all redds contain viable eggs, so this method gives some indication of deposition-to-emergence survival, emergence mortality, length of emergence period, as well as success of spawning. Multiple spawning does occur in redds, but can be detected by records of numbers of emerging fry, tag numbers of spawning females and species of emergent fry (for multi-species spawning in a single redd).

Determination of survival percentages is based on the fecundity of spawning females. The fecundity of coho salmon females was estimated on the basis of weight. A table of fecundity estimates for coho salmon was developed by Koski (1966) on the basis of egg counts from 92 adult females from Fall Creek Hatchery.

Age Determination

Thousands of coho salmon and cutthroat and steelhead trout scales were collected during the 15-year study. In most cases, scales collected from inidividual fish in the field were placed between two small pieces of plastic sheeting and stored in an identification envelope containing the following information: species, stream, date, length and weight of fish, sex, type of trap, collector, and an identifying scale number.

Scales from adults and precocious males were examined and three good scales were selected from those collected from each fish. After cleaning with water and a camel hair brush the scales were wet mounted on numbered, gummed cards. After the gummed cards were flattened, they were pressed into clear acetate. Pertinent information was added to each scale sheet.

The best scale of the three selected was used for age determination with a projector. A transparent millimeter rule was used to measure scale distances from the center of the nucleus. Measurements of freshwater and saltwater checks were made in this manner. A "plus growth" in freshwater indicates that portion of scale growth after the final freshwater or saltwater check.

Using the direct scale measurements and their proportional relationships, calculated lengths were derived. This back-calculation provides an indication of the fish's length at the various ages in freshwater and saltwater.

Scales of juvenile salmonids were often mounted on slides rather than directly on acetate. For these fish, several scales were placed on slides and a cover glass was taped securely by the edges. All slides were labeled and stored.

All scales collected by the Oregon Game Commission during the 15 years were analyzed by F.H. Sumner. Interpretation is often difficult when scales are obtained from an environmentally stressed location (Needle Branch and Deer Creek during and after logging). Certain physical factors, such as temperature, can provide false annuli.

Because of this, specific questions regarding interpretation should be directed to Mr. Sumner's scale analysis guidelines.[1] Not all scales collected were eventually read, but unread scales are labelled and stored.

Study Pool Observations

During the summers of 1969 and 1970 special study pools were established in Needle Branch and Flynn Creek. The objective was to study fish behavior (coho salmon and cutthroat trout) in a stream with elevated temperature (Needle Branch) and in the control stream, Flynn Creek. In 1969 one study pool was established at the 213 m marker on Flynn Creek and two at the 389 and 518 meter markers in Needle Branch. In 1970 one pool was used at 183 m in Flynn Creek and one at 358 m in Needle Branch.

A two-way trap was located at the upper and lower boundaries of each pool, to monitor fish movement. A known number of marked fish (weighed and measured) were introduced into the pools at densities comparable to other areas of the stream.

Each pool was divided into grids to facilitate accurate observations on the positioning and movements of fish and changes in surface areas. These grids were above the pools and were constructed of stretched strings from stakes along the edges. Two observation platforms were constructed beside the Needle Branch pool in 1970 and three were constructed by the Flynn Creek pool. Observers were effectively hidden behind the platform (Figure 15).

Observations of fish behavior were made two days per week from mid-June through September, usually in the morning and afternoon. Specific observation methods are described in detail by Lantz and Moring (1975 MS). Because an objective of the study was to compare behavior in two different thermal regimes, water temperatures were continually monitored with Partlow thermographs.

Growth data on fish populations were obtained from monthly electrofishing sampling. Fish were collected in this manner from May to September. Fork lengths were measured to half millimeters. Weights were recorded to the nearest gram on an Ohaus Balance.

Insect Sampling

Methods of insect sampling varied with researcher and specific problem. Often analysis of fish stomachs yielded information on insect groups (Demory 1961; Lowry 1964). Methods for actual *in situ* collection of insects were usually different.

Chapman (1961) and Demory (1961) collected insects in a fine cloth net of 1 mm mesh. Approximately one square foot of bottom was agitated, and the net was swept upstream along the bottom. Such samples were from randomly selected stations in the stream. In Chapman's study, 10 samples were collected in Needle Branch and 20 in Deer Creek on each sampling date. Most insects were placed in plastic vials and cooled in ice water. Some samples were preserved in ethanol. If stomachs were to be examined, they were checked within 6 hours of collection if unpreserved, and 72 hours if preserved. The food habits of insects in the Alsea Study streams have been reported by Chapman (1961) and Chapman and Demory (1963).

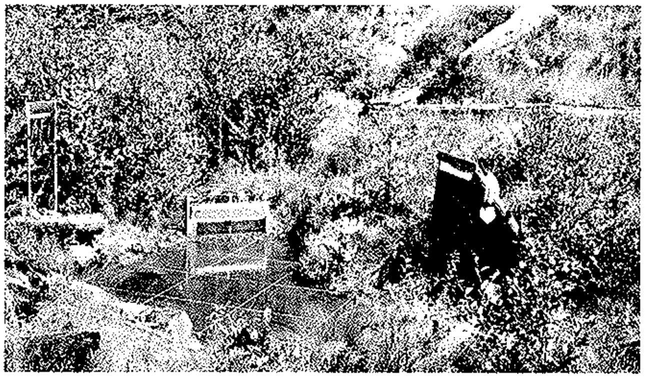

Figure 15. Needle Branch study pool used for coho salmon and cutthroat trout behavioral studies. Note the observation platforms, two-way traps at each end of the pool, and the visual grid pattern above the pool.

The methods employed by Lantz and Moring (1975 MS) were somewhat different. Invertebrate drift was sampled at the downstream end of a riffle near each study pool (used for behavioral studies). This drift sampler consisted of a plastic-coated metal rectangular frame 30 cm by 20 cm, with an attached net. This net was 57 cm long with a mesh size of 500 microns. A collecting jar was attached to the terminal end of the net. The entire apparatus was attached to two steel rods driven into the streambed. Benthic invertebrates were also collected in this series of study pool experiments. A gravel core sampler of the type described by McNeil and Ahnell (1960) was slightly modified for use as a benthic invertebrate sampler. This type of sampler could be inserted into the gravel trapping invertebrates. All material was then removed and later analyzed in the lab. Insects collected by the methods described by Lantz and Moring were separated from detritus and transferred to 2-ounce sample bottles. After identification in the laboratory, insects were placed in formalin solution. Later samples were dried to obtain dry weights.

The degree of insect identification varied with researcher. In some cases identification was to the family level; in most cases it was to the generic level.

Herbicide Studies

Two herbicides (1,4-D and 2,4,5-T) and Endrin were applied to the cut areas of Deer Creek and Needle Branch, respectively. The herbicides were sprayed on the cutting area of Deer Creek by helicopter. Herbicides were applied at a rate of one pound of each compound acid per acre.[2]

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[1] Sumner, F.H. 1973 MS. Methods of study –– coho scales. Oregon St. Game Comm., unpublished report, May 30, 1973. 10 p.

[2] L.A. Norris and J.D. Hall. Information presented to the 1970 Annual Watershed Study cooperators meeting, June 18, 1970.

Water and biological samples were collected prior to and after herbicide spraying. One pre-spraying water sample was collected along with samples every 10 minutes for the first hour following spraying and every 20 minutes for the second hour. Thereafter water samples were taken every 30 minutes the third hour, then at intervals of 3 hours, 24 hours, 45 hours and 7 days. Water samples were collected in one-quart glass jars with 15 g NaOH added. Plastic "Saran" wrap was placed over the top before capping. All samples were collected in the same location.

Biological samples were taken at three times: (1) a pre-spraying sample was collected March 17 –– 10 days prior; (2) 3 days after spraying; and (3) 7 days after spraying. All biological material was brought live to the Oregon State University campus on the day of collection for later analysis by University and federal personnel.

Endrin-coated Douglas fir seeds were seeded over the Needle Branch watershed at a rate of 0.6 percent endrin at 0.84 Kg per acre (Moore et al. 1974). During the endrin experiments water samples were taken at the stream gauge stations. Samples were collected in 4 liter metal containers, stored in ice and later placed in a cold room at 2°C. As described by Moore et al., water samples were taken at 15-minute intervals from 30 minutes prior to seeding, to two hours after. Samples were taken at 30-minute intervals for the next hour, followed by sampling at intervals of 1 hour, 2 hours, 3 hours and 4 hours. These were followed by samples every 12 hours for 36 hours, every 24 hours for the following 72 hours and a sample at the end of seven days post-seeding. Additional samples were collected at 2 weeks and 3 weeks after seeding and during winter freshets (Moore et al.).

Details of water sample analysis for endrin have been described for biological sampling (Marston et al. 1973, Moore et al. 1974). Eyed coho salmon eggs were planted in the gravel prior to seeding and later removed and frozen for analysis. Aquatic insects, reticulate sculpins, and fry and fingerling coho salmon were also collected following seeding and frozen for later analysis.

RESULTS

COHO SALMON

Adults

Magnitude of Runs

Runs of adult coho salmon were quite variable each year on all streams. All fish entering the upstream trap were classified as alive, alive but spent, or dead. The number of spawners was related to the size of the stream. The run on Deer Creek averaged 146 fish per year, or 51.6 percent of the total run for the three streams. The Flynn Creek run averaged 92 fish per year (32.5 percent of the study area run). The run on the smallest stream, Needle Branch, averaged only 45 fish per year, accounting for only 15.9 percent of the study area run. However, the yearly runs shown by Appendices 4, 5 and 6 show wide variations from year to year.

Average numbers of spawners were higher in post-logging years on all three streams. The change was only minor in Deer Creek and Flynn Creek, but statistically significant on Needle Branch. During the four seasons of pre-logging data, runs were quite low, averaging only 16.8 fish per year. No trap records are available for the three seasons immediately prior to logging on Needle Branch (see Methods: Trap Operation). For the seven years following logging, runs were heavier, averaging 61.1 fish per year. There is no indication that logging activities had any adverse effects on adult coho salmon returns to any stream in the study area.

In examining the length frequencies of precocious coho salmon on the study streams, Au (1971) found a distinct break below 470 mm FL. He considered fish smaller than 470 mm FL as jacks. Using this value, precocious males were determined for each year (Appendices 4, 5 and 6). The percentage of precocious males in the population varied yearly, but averaged 24.3 percent on Flynn Creek, 17.1 percent on Deer Creek and 40.5 percent on Needle Branch. In many cases precocious males arrived together in groups rather than individually. The post-logging percentages of precocious males increased on Flynn Creek and Deer Creek but declined on Needle Branch. However, the numbers of returning adults, regardless of marine age, were low during the pre-logging period. As a result, the effect of precocious males may have appeared greater in pre-logging years.

Age Characteristics

Biologists studying coho salmon have reported 11 different age combinations from stocks along the Pacific Coast of the United States and Canada. By far the most common combinations are 1/2 and 2/2. In more northern latitudes the 2/2 group dominates, while in British Columbia and more southern waters, fish of age class 1/2 constitute most of the run (Drucker 1972). This age designation expresses freshwater checks (annuli) to the left of the diagonal, and saltwater checks to the right of the diagonal. A fish of 1/2, for example, would indicate one freshwater check and two saltwater checks. A + indicates plus growth after the last freshwater check.

Of the coho salmon scales collected, a total of 2,351 were analyzed during the study period. Of these, 1,802 were from adults and 549 were from jacks. All scale data are stored on cards and magnetic tape at the Research Division Laboratory, Corvallis.

Four age combinations were present on the streams: 1/1, 1/2, 2/1 and 2/2 (Table 1). As with most coho stocks from British Columbia southward the 1/2 age group dominated

(Table 2). Two, three and four-year-old fish were present in the following proportions:

	2-year-old %	3-year-old %	4-year-old %
Needle Branch	29.6	66.0	4.4
Flynn Creek	24.7	73.3	2.0
Deer Creek	15.4	81.6	2.9
Average for all streams	21.2	75.9	2.8

All fish classified as jacks were of the age groups 1/1 and 2/1, spending only one summer in salt water. The 1/1 age group dominated, with 88.9 percent of the jacks on Deer Creek, 91.6 percent on Needle Branch and 92.1 percent on Flynn Creek. All fish classified as adults were of the age groups 1/2 and 2/2, spending two years at sea. Of the two, the 1/2 age group dominated; accounting for 93.5 percent of the adults on Needle Branch, 96.5 percent on Deer Creek and 97.3 percent on Flynn Creek.

Table 1. Life history patterns of 2351 adult wild coho salmon from the three study streams (taken at the upstream traps).

Years in Salt Water	Years in Freshwater 1	2
1	499	50
2	1735	67

Table 2. Percentages of age combinations in adult coho salmon in the three study streams, 1960-1973.

STREAM	AGE GROUP 1/1	1/2	2/1	2/2
Needle Branch	29.6	63.3	2.7	4.4
Flynn Creek	24.7	71.2	2.1	2.0
Deer Creek	15.4	79.7	1.9	2.9
Total Average	21.2	73.8	2.1	2.8

There was a direct correlation between the size of the run between streams and the percentages of various age groups. The proportion of fish of age 1/2 increased from Needle Branch to Flynn Creek, and from Flynn Creek to Deer Creek. Likewise, the percentages of jacks (1/1 and 2/1) decreased with increasing run size.

There was no discernible change in age groups due to logging. The percentage of jacks was higher in post-logging years on Needle Branch, but this same trend was present in Deer Creek and Flynn Creek as well. Fish of the age class 1/2 declined in proportion from pre-logging to post-logging on Needle Branch, but, again, this decline was present on all three streams.

The size of adults originating from smolts spending two years in freshwater was not significantly different from that of adults originating from smolts that spent only one year in freshwater. Likewise, the average lengths of jacks spending two years in freshwater before migrating to sea was no different than those that spent one year in freshwater

The growth rates of the two groups of jacks (1/1 and 2/1) were quite different (Figure 16). Growth in the first year of freshwater residence (based on scale samples) was greatest in fish that migrated as one-year-old fish. That group (1/1) experienced greater growth in one year of saltwater residence than the year of freshwater residence. Those fish remaining in freshwater two years (2/1), experienced less growth the first year and only moderate growth the second year in freshwater. However, the growth rate was considerably better the first year in saltwater than for the similar period in 1/1 fish. The net result is that after one year at sea both groups were essentially the same size when they ascended the streams as jacks.

Analysis of adult coho salmon growth rates reveals a pattern similar to that of jacks. The two age groups of adults (1/2 and 2/2) were essentially the same average length at the

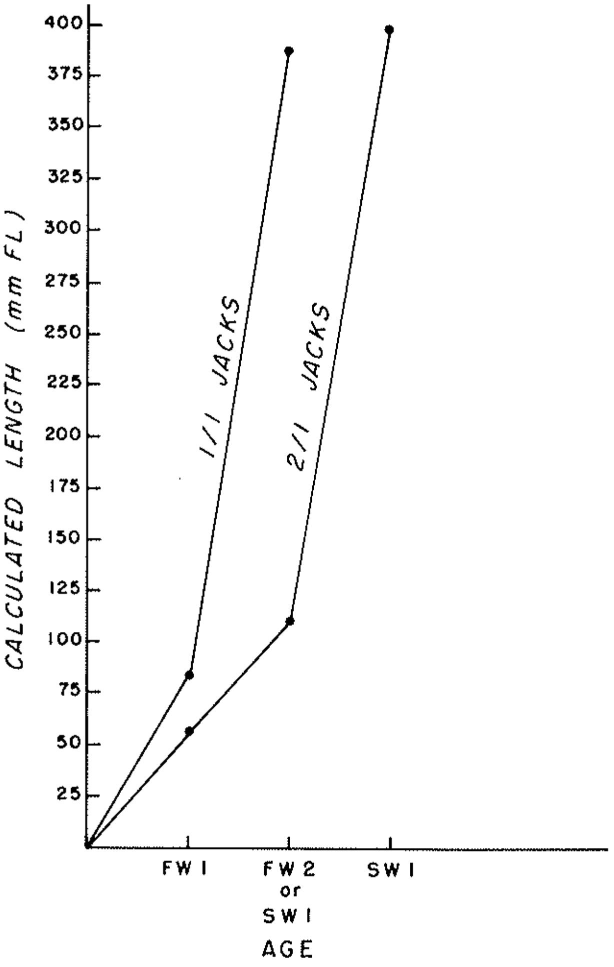

Figure 16. Growth of coho salmon jacks derived from calculated lengths from scale samples. Two groups of jacks were present – those spending one year in freshwater, and those spending two years.

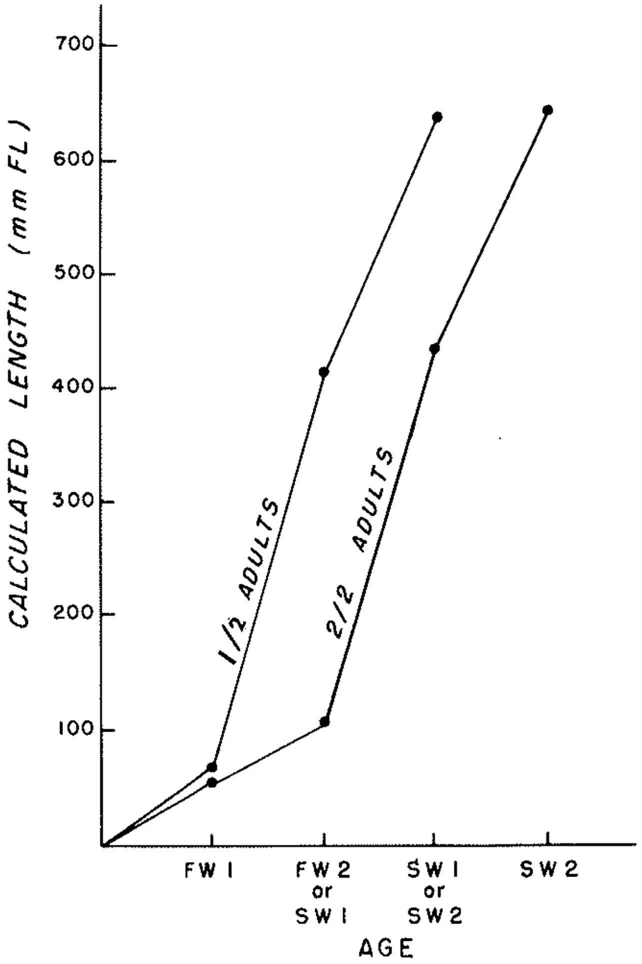

Figure 17. Growth of coho salmon adults derived from calculated lengths from scale samples. Two groups of adults were present – those spending one year in freshwater and those spending two years.

time of upstream migration. However, their previous growth patterns were divergent (Figure 17). Growth during the first year of freshwater residence was slightly less in the 2/2 group. Growth in the second year continued at approximately the same rate for this group. However, growth in the first saltwater year was rapid and apparently compensatory, as the two age groups were of the same approximate size at the end of the first saltwater year. The growth rate during the second saltwater year was virtually the same in both groups. In both jacks and adults, maximum growth rates (slopes) were obtained during the first year of saltwater residence.

Length and Weight

The average lengths of upstream migrating adults declined in post-logging years on all three streams (Table 3). This decline was virtually the same on Needle Branch (5.6 percent) and Flynn Creek (5.1 percent), and only slightly less on Deer Creek (2.6 percent). As a result no decline in average length of adult spawners can be attributed to logging activities. There was an increase in the numbers of males entering all three streams (see section on Coho Adults – Sex Ratio). There was also an increase in numbers of smaller, precocious males on Flynn Creek and Deer Creek, but a decline on Needle Branch (see section of Coho Adults – Magnitude of Runs).

The average weight of salmon increased on the Deer Creek run in post-logging years, but decreased on Flynn Creek. The change on Needle Branch run is unknown because no fish were weighed during pre-logging years. The overall average weights were virtually the same on all streams, with only 101 grams separating the average weights of fish on the three streams.

Length-weight regressions were derived from the entire 14-season study period. The correlation coefficients in all three regressions were quite good ($r = 0.94$). The non-linear regression lines were virtually the same, and this would be expected with three closely situated runs in the same river system.

The lengths of precocious males were taken from 521 scale samples of known jacks averaging 396.9 mm FL. This is slightly less than the value of 406 mm FL reported by Au (1972) for incomplete records of the Alsea test streams, or the value of 409 mm FL for Waddell Creek, California (Shapovalov and Taft 1954). The difference is greater, however, between the average size of jacks and that reported at the Big Creek Hatchery (Johnson 1970).

The size frequency distribution of precocious males is quite distinct (Figure 18). Au considered fish less than 470 mm to be jacks (for visual identification). Use of the lengths for scale samples indicates only 5.4 percent of all jacks exceeded a size of 469 mm FL, so this assumption is probably valid.

Table 3. Average lengths and weights of adult coho salmon on the three study streams, for pre-logging and post-logging years. The total sample (N) refers only to those fish weighed and measured, not to the total upstream count of adults.

		Length	Weight				
Stream	N	Pre-Logging	Post-Logging	Ave.	Pre-Logging	Post-Logging	Ave.
DEER CREEK	587	618.6 mm	602.6 mm	610.3 mm	2.50 kg	3.12 kg	3.05 kg
FLYNN CREEK	338	612.8	518.3	596.7	3.24	3.04	3.09
NEEDLE BRANCH	129	583.2	550.7	554.7	-	3.15	3.15

Table 4. Average lengths of adult and jack coho salmon on the Alsea test streams, 1959-1973.

Stream	N	Females *mm FL*	Males (exclusive of jacks) *mm FL*	Males (total) *mm FL*
Deer Creek	2059	699.2	607.2	589.8
Flynn Creek	1289	714.2	592.6	566.8
Needle Branch	503	693.9	587.5	518.9

Average lengths of females were significantly greater than males on all three streams (Table 4). This size difference was evident in pre-logging as well as post-logging years.

Average lengths of females declined slightly on all streams after logging. Average lengths of males declined by only 24 mm on Flynn Creek and 13 mm on Deer Creek. The average length of males increased by 28 mm in Needle Branch. However, this slight change was due to: (1) an increase in numbers of males in post-logging years; and (2) a small number of length measurements in four pre-logging years (35) compared to a larger number (365) in seven post-logging years.

The length frequencies of coho salmon in the three streams (Figure 18) show two peaks, one for precocious males and one for adults. The peaks for jacks in Flynn Creek and Deer Creek occurred in the length range, 400-424 mm FL, while in Needle Branch a peak occurred in the range, 375-399 mm FL. The peaks were quite different for males and females, but were similar for the three streams. There were no significant changes in the length frequency patterns between pre-logging and post-logging years in the logged watersheds.

Condition Factors

Average condition factors were essentially the same on all three streams. For the 120 live spawners weighed and measured on Needle Branch, the average condition factor was 1.12 (range: 0.84-1.68). The average condition factor on Deer Creek was also 1.12 (range: 0.85-3.51), for 587 live spawners. The 338 live spawners on Flynn Creek had an average condition factor of 1.11 (range: 0.66-1.76).

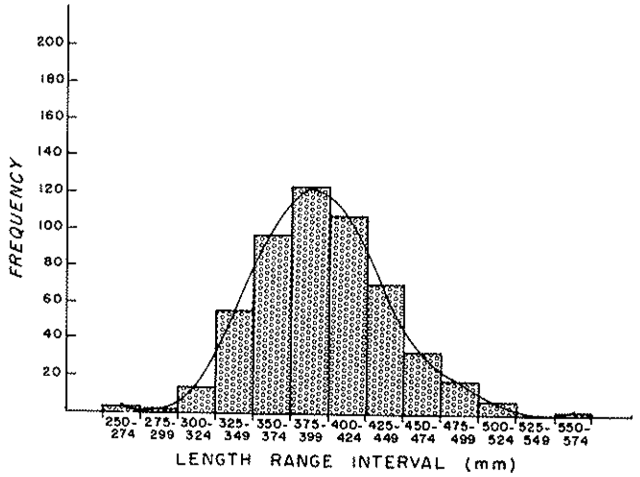

Figure 18. Length frequency of adults and precocious male coho salmon on the three study streams, 1959-1973.

There was no significant change in coho condition factors due to logging. The greatest change was from 1.09 to 1.12, occurring in the control stream, Flynn Creek. The value on Deer Creek changed only slightly from 1.11 during pre-logging years to 1.12 during post-logging years. No adult spawners were weighed in pre-logging period on Needle Branch, so condition factors are not available and the post-logging values reflect the average for that stream.

Sex Ratio

The sex ratio of upstream migrating adult salmon varied from year to year on all streams. For adults passing through the upstream traps, this ratio was most consistent on Deer Creek and most inconsistent on Needle Branch. Differences are primarily related to the sizes of streams and the sizes of coho salmon runs. The greater the run, the less variability associated with sex ratio (i.e., the presence of a single fish of a given sex has less effect on the sex ratio of a large run than a small run). The sizes of the coho runs corresponded directly with the stream size. The largest salmon run occurred on Deer Creek, where 2,041 live, unspent adults were processed upstream during the 14 seasons. The sex of only one fish was not determined. Of the remainder, 81.6 percent were males. This is a ratio of 4.4:1, males to females. The ratio changed only slightly between pre-logging and post-logging years. Individual yearly values varied from 2.8:1 (1962-63 and 1971-72) to 11.6:1 (1969-70). The ratio increased significantly for those live, unspent adults that returned downstream, through the downstream trap. Of this group, 97.8 percent were males, for a sex ratio of 45.5:1, males to females. The ratio was even higher for adults returning to the upstream trap for a second time after having been processed downstream. Of 52 such fish on Deer Creek, only one was a female, for a ratio of 51:1. Conversely, the sex ratio of spawning fish declined with the passage of adults back downstream, then rose slightly as some of them returned upstream.

On Flynn Creek, a total of 1,283 live, unspent adults were processed upstream. The sex of two was not determined. For the remainder, 80.2 percent were males, for a sex ratio of

4.0:1. The ratio rose slightly more than on Deer Creek for pre-logging to post-logging years: 3.4:1 to 4.9:1. Of the live, unspent adults processed through the downstream trap, 98.1 percent were males, for a ratio of 51.5:1. All of the 19 fish returning through the upstream trap a second time were males.

The smallest coho salmon run occurred on Needle Branch, where 495 live, unspent adults were processed upstream during 11 seasons of trap operation (see Part I: Methods - Trap Operation). The sex of only one of these fish was unknown. Of the remainder, 79.6 percent were males, for a sex ratio of 3.9:1. There was a distinct shift in sex ratio from pre-logging to post-logging years, from 1.5:1 to 4.7:1. Although the sex ratio on all three streams was higher in post-logging years, the ratios were almost the same in post-logging years. Because the run is quite small on Needle Branch, and only four years of pre-logging data are available, the pre-logging sex ratio may be only approximate. Of the live, unspent adults returning downstream, 97.0 percent were males, for a ratio of 31.9:1. All of the 11 fish returning upstream a second time were males.

On all three streams more male spawners were present in post-logging years than in pre-logging years (Table 5). The percent increase was almost exactly the same on all streams, indicating the shift was not related to logging activities, but to natural fluctuations in the run. While numbers of males were increasing, the total numbers of spawning females remained almost the same for pre-logging and post-logging periods on Deer Creek and Flynn Creek. However, the number of female spawners more than doubled between these periods on Needle Branch (the four years of pre-logging data were adjusted to correspond to the seven years of post-logging data). For the adults actually considered to be spawners on the streams, the average sex ratios were: Deer Creek 2.6:1; Flynn Creek 2.1:1; and Needle Branch 1.6:1.

Other workers have found slightly different sex ratios for adult returns. Including jacks, Shapovalov and Taft (1954) found a 1.3:1 ratio, males to females, for coho returning to Waddell Creek, California. Excluding jacks, the ratio drops to 0.9:1. Including jacks, the coho ratio on the South Fork Eel River, California, was 1.3:1, males to females. Without jacks, the ratio drops to 0.8:1 (Murphy 1952). For an artificial situation (freshwater rearing in a reservoir, Lake Merwin, Washington), the returning adults averaged a 2.9:1 ratio, males to females, for three years of study (Hamilton et al. 1970).

Fecundity

Fecundity estimates are based on the work of Koski (1966) who sampled 92 females returning to Fall Creek Hatchery, on a tributary of the Alsea River. He compared volumetric egg counts to length and weight. Regression relationships were derived for egg count on fork length ($Y=7.81X - 3,184$) and egg count on weight ($Y=479.3X + 559$), where X is in centimeters or kilograms, respectively. This relationship was determined for hatchery fish, because sufficient local wild stocks were not available.

Fecundity estimates based on weight of female spawners were virtually the same of all three streams for 10 years of weight records. Average fecundity of coho spawners on Flynn Creek was 2,587; that on Deer Creek was 2,499; and that on Needle Branch was 2,485. Drucker (1972) has shown a correlation between increasing latitude and increasing fecundity along the Pacific coast. The average numbers of eggs from the three study streams compare favorably with fecundity measurements for Washington, Oregon and California.

Comparison of pre-logging and post-logging fecundities is actually based on weights or lengths of adults, but reveals no significant changes. Average egg number estimates increased by only 115 between the two periods on Flynn Creek and

Table 5. Coho salmon runs, by percentage, during 14 seasons, based on calulated numbers of actual spawners.

	Deer Creek	Flynn Creek	Needle Branch
Pre-Logging:			
Percent Males	65.1	61.1	51.2
Percent Females	34.9	38.9	48.8
Sex Ratio (M:F)	1.9:1	1.6:1	1.1:1
Post-Logging:			
Percent Males	76.6	72.9	63.9
Percent Females	23.4	27.1	36.1
Sex Ratio (M:F)	3.3:1	2.7:1	1.8:1
Total:			
Percent Males	71.9	67.8	61.7
Percent Females	28.1	32.2	38.3
Sex Ratio (M:F)	2.6:1	2.1:1	1.6:1

decreased by only 27 eggs on Deer Creek. No weights are available for pre-logging years on Needle Branch, but utilization of the fecundity length regression formula of Koski (a less powerful regression) can provide four years of pre-logging fecundity estimates. With these figures, changes in average fecundities were insignificant.

An interesting trend was apparent during the first returns of coho adults that may have been affected by actual logging operations. Fecundities dropped in adult females returning in 1968-69 (juveniles in streams during logging) and 1969-70 (fry and Age 0 fingerlings during logging), but returned to near average levels the following year. These changes in fecundity reflect changes in average weight of adult spawners, as our estimates of fecundity are based on size of adults.

Timing of Spawning Migrations

Coho salmon spawning migrations had well defined limits, with a peak in December (Figure 19). Salmon never arrived before October 23 nor later than March 8. The typical run on all three streams was from mid-November to early February. Fish arriving in October and March accounted for only 0.7 percent of all arrivals.

Figure 19 indicates that spawning migration times, by month, were almost the same on all three streams. Logging considerations aside, this relationship would be expected in three small geographically similar streams. Total arrivals for peak months of November, December and January accounted for 96.4 percent of the run in Needle Branch, 94.2 percent in Flynn Creek and 93.8 percent in Deer Creek. The larger run in Deer Creek provided more variability in arrival times. Nineteen fish arrived in October in Deer Creek, while only three arrived in that month in Flynn Creek and only two in Needle Branch. Four March spawners arrived in Deer Creek, while no March arrivals were noted for Flynn Creek or Needle Branch (Appendices 1, 2 and 3).

There was no apparent change in arrival times of coho spawners due to logging activities. The only changes of note in monthly arrivals in Needle Branch were a reduction in February arrivals and an increase in December arrivals. However, these same changes occurred on the control stream, Flynn Creek, as well as Deer Creek.

Au (1972) has shown that timing of coho salmon upstream migrations is related to streamflow, particularly the periods of peak discharge. Similar behavior of coho has been recognized by Shapovalov and Taft (1954) and other workers. The relationship between salmon movement and streamflow levels will be explored in more detail in Parts II and III.

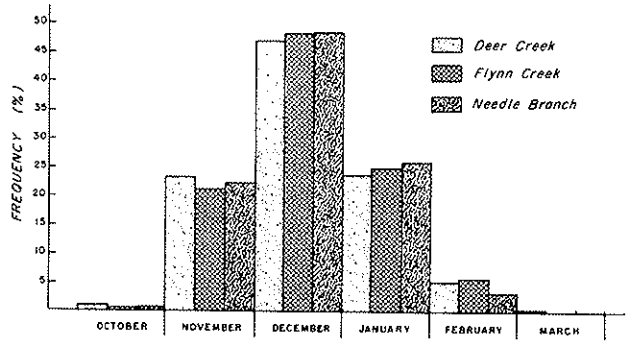

Figure 19. Arrival times of adult coho salmon on the three Alsea Watershed streams.

Movement of Adults

Of those fish entering the upstream trap, some were already spent and others were found dead. Part of this mortality was due to the traps themselves. Table 6 indicates that between 95.9 and 98.5 percent of the fish entering the upstream trap were live, unspent adults and jacks passed upstream. Many fish, but few precocious males, returned back downstream through the downstream trap. Records indicate 43.4 percent of the Flynn Creek fish returned back downstream as live, unspent fish. Another 1.9 percent were spent and 9.9 percent were recorded through dead. For Deer Creek 39.9 percent of the fish returned alive and unspent downstream. An additional 1.4 percent were spent and 12.9 percent were dead in the trap. On Needle Branch 54.5 percent of the upstream fish returned downstream unspent and alive. Another 4.2 percent were spent and 16.8 percent were dead in the trap.

Of those fish that returned downstream, a few returned to the upstream traps a second time and were passed upstream to spawn. Only 1.5 percent (19 fish) of the original Flynn Creek upstream migrants returned upstream a second time. The percentages on the other streams were slightly higher: 2.2 percent on Needle Branch (11 fish) and 2.5 percent on Deer Creek (52 fish).

As a result of downstream movement and some return upstream, the actual numbers of spawners in the streams were less than two-thirds of the original upstream run. The actual numbers of presumed coho spawners for the streams are indicated in Table 7. Only 47.1 percent of the original upstream run (adults and jacks) eventually spawned in Needle Branch and 57.2 percent of the upstream run spawned in Flynn Creek. On Deer Creek 61.1 percent of the run eventually spawned in the creek.

The numbers of actual spawners increased in post-logging years on all streams primarily because of an increase in males entering and spawning in the stream. Average numbers of spawners on Deer Creek increased from 74.1 fish per year in pre-logging years to 108.6 fish per year in post-logging years. Spawners in Flynn Creek increased from an average of 45.9 fish per year to 60.6 fish per year. Spawners on Needle Branch increased from 10.3 to 28.9 fish per year. It is evident that numbers of spawners on the streams were unaffected by logging activities. Numbers increased in post-logging years in response to natural fluctuations occurring in the control stream as well as in the experimental streams.

Spawning Surveys

The behavior of tagged coho salmon females was studied on and near redds, and the positions of known redds were flagged (marked) for later fry emergence studies. The

Table 6. Counts of adult coho salmon entering the upstream traps of Deer and Flynn Creeks and Needle Branch for the total study period, 1959-1973.

	Deer Creek	Flynn Creek	Needle Branch	Total
Number Counted in Trap	2094	1303	516 (657)*	3913 (4054)*
Number Dead	20	12	8 (10)*	40 (42)*
Number Spent	33	8	13 (17)*	54 (58)*
Total Unspent, Live Spawners Passed Upstream	2041	1283	495 (630)*	3819 (3954)*
Pre-Logging Yearly Ave.	143.1	87.0	16.8	
Post-Logging Yearly Ave.	148.4	96.3	61.1	
Total Average	145.8	91.6	45.0	
Yearly Range of Live Spawners	58-277	11-226	5-117	

*Actual numbers are based on only 11 years of trapping, so values in parentheses are weighted for comparison with actual numbers obtained on other streams during the 15 years of study.

Table 7. Numbers of coho salmon adults and jacks known to be spawning on the three study streams during fourteen seasons, 1959-1973.

	Deer Creek		Flynn Creek		Needle Branch	
Year	♂	♀	♂	♀	♂	♀
1959-1960	59	21	22	7	1	0*
1960-1961	49	19	60	26	5	1
1961-1962	44	28	80	51	7	15
1962-1963	18	18	0	0	8	4
1963-1964	68	27	11	20	not trapped	
1964-1965	70	44	3	10	not trapped	
1965-1966	30	24	20	11	not trapped**	
1966-1967	137	56	59	55	11	19
1967-1968	56	23	32	10	23	15
1968-1969	128	39	56	19	40	17
1969-1970	51	8	13	5	2	1
1970-1971	61	10	42	5	17	2
1971-1972	101	36	74	18	23	18
1972-1973	48	6	33	3	13	1
Total	920	359	505	240	150	93

*Approximately1500 fry were transplanted in Needle Branch.

**Field spawning survey notes indicate a maximum of 11 females and 19 males on the Needle Branch spawning ground during 1965-66.

purposes of the spawning surveys were: (1) to determine the specific attributes of coho spawning activity in the streams; and (2) to locate redds for later trapping of fry with equipment described by Phillips and Koski (1969).

Other than the locations of spawning redds, there could be no indication of changes due to logging because spawning surveys were only available for the years 1965-1971. In particular, detailed observations are available only for the 1968-69, 1969-70 and 1970-71 seasons. In earlier years only the locations of adults (and tag combinations) were noted.

Generally, these surveys indicated that each stream has certain favored spawning areas, but redds were scattered throughout much of the three streambeds. At some point in the experimental period, redds were established in almost all areas having appropriate amounts of spawning gravel. Au (1972) has compiled and graphed the locations of spawning redds during the first 11 years of study.

From the three years of detailed spawning observations, 96 tagged females were tracked in the stream: 50 in Deer Creek, 27 in Flynn Creek and 19 in Needle Branch. Other tagged fish moved back downstream, lost their radio tags, or were never located.

Only 22 of the 96 females were actually observed emitting eggs. However, other spawning activities were observed, such as digging and interacting with attendant males. These observations were generally daily and usually lasted ten to fifteen minutes. Active digging was observed in 35.7 percent of the observation periods on Deer Creek, 38.0 percent of the periods on Needle Branch and 43.8 percent on Flynn Creek. A total of 79.2 percent of all females were observed digging redds at some point during the surveys. The frequency of this digging varied between individual fish. Records indicate that during periods of active digging, rates varied from once every 15 minutes to 12 in 15 minutes. Individual digging lasted three to four seconds. Females turned on their right or left sides to dig, usually alternating the side. A female was observed digging from her left side for a 10-minute period, but most fish alternated sides.

The number of attendant males, including associated or "alpha" males, also varied between observation periods. On the average, one male was associated with each female, but the range was 0 to 8 males (adults and precocious males). During all observation periods the following numbers of attendant males were noted with each spawning female:

0 males – 47.9% of times checked
1 male – 29.6
2 males – 13.7
3 males – 4.2
4 males – 2.9
5 males – 1.1
6 males – 0.4
7 males – 0.0
8 males – 0.2

An interesting phenomenon was observed in Needle Branch in January 1971 when two males formed a "spawning pair". Although no milt was shed, the two reacted to each other as male and female. Each took a turn lying on the right side of the other, quivering two to four times. There was no active digging but both fish had frayed caudal fins. The caudal fin and caudal peduncle of one fish were quite deteriorated with injuries quite similar to those suffered by females digging. It was obvious this male had engaged in digging but apparently not at the "redd". The two fish also exhibited traits of territoriality with one chasing away jacks that ventured near the "redd" (B. G. Pohl, personal communication).

Fry and fingerlings

Fry Emergence

The survival rates of salmonids from egg deposition to emergence vary with species, but are characteristically low. McNeil (1966) found chum and pink salmon survival rates from egg deposition to emergence were generally less than 25 percent. Similarly, Merrell (1962) found pink salmon survival rates of 0.2 to 20.0 percent, averaging 2.4 percent, and Wickett (1962) reported pink salmon survival rates of 0.4 to 32.3 percent. Hunter (1959) found pink and chum salmon survival rates of 5.7 to 31.1 percent.

Foerster's (1968) review of considerable sockeye salmon data indicates survival rates ranged from 1.8 to 19.3 percent, while chinook salmon survival (to fry migration) was measured at 7 to 32 percent (Wales and Coots 1955). Survival percentages for coho salmon are quite variable, but were generally low. An 8-year average reported by Pritchard (1947) was 21.0 percent (ranging from 11.8 to 30.4 percent).

Several researchers have explored fry emergence problems on the three streams. Koski (1966) looked at physical and biological influences on coho salmon eggs, alevins and fry. Au (1972) reviewed emergence patterns and relationships for coho salmon. Koski utilized fry traps for capturing emergent fry (Phillips and Koski 1966: see Methods section). Phillips et al. (1975) further explored the relationship between sediment levels and emergence survival of coho salmon and steelhead trout. Au (1972) used some of the early trapping data in his analysis of fry emergence.

The Oregon State Game Commission trapped coho salmon redds on all three streams yearly from the 1963-64 season through the 1970-71 season. Koski based his analysis of fry emergence patterns on the 1964 year class, with eggs deposited in December 1963 and January 1964. Au based most of his analyses on the 1969 year class, with eggs deposited in November and December 1968, and January 1969. Lantz (1967) has provided a table of fry emergence survival rates for 1964-67. Other data from 1964-67, and information from the remaining years was not previously published.

Examination of the eight consecutive years of data reveals considerable variation in survival rates and other parameters between individual redds on the same stream, between individual streams, and between year classes. A total of 113 individual redds was trapped from 1964 to 1971. Of these, three were actually multiple redds by females. As a result, 110 trapped redds were utilized in the analysis of the data. Of these 110 redds, no fry emerged on 16 (14.5 percent). Koski (1966) mentioned the problem of zero emergence from redds in the 1963-64 season. He discounted the possibility of false redds because of the intensive observations on spawners and redds. Because most redds with zero emergence had no embryos or fry when uncovered, Koski feels the condition was due to gravel scouring.

The percentage of redds where no fry emergence occurred varied from zero (N = 5 total redds) to 23.8 percent (N = 21 total redds). Zero emergence redds were not confined to any one stream or year, as four were detected on Deer Creek (spread over the years), seven on Flynn Creek, and five on Needle Branch. Spawning redds were trapped between markers 130 m and 777 m on Needle Branch, between -114 m and 1,006 m on Flynn Creek, and -40 m and 1,923 m on Deer Creek.

Females spawning in redds subsequently trapped were very similar in average size (Table 8). Average fecundity was also similar. Emerging fry exhibited similar characteristics when data for each stream were averaged, but the survival rates from egg deposition to fry emergence were variable

Table 8. Synopsis of coho salmon fry emergence information from trapped redds, 1963-1971.

	Average for Years on Trapped Redds on Streams		
	Deer Creek	Flynn Creek	Needle Branch
Number of Emerging Single Redds Trapped	32	30	32
Survival Percentage (successful emergence only)	37.9%	25.7%	34.6%
Survival Percentage (including zero emergence)	33.5%	20.8%	29.8%
Average Length of Emergent Fry	38.7 mm	38.5 mm	38.5 mm
Average Length of Spawning Females	685 mm	706 mm	684 mm
Average Weight of Spawning Females	3.99 Kg	4.00 Kg	4.00 Kg
Average Fecundity of Spawners	2443	2519	2368

Table 9. Survival rates of trapped coho salmon redds from egg deposition to fry emergence. Zero emergence redds are not considered in this analysis.

Year	Needle Branch		Flynn Creek		Deer Creek	
	Ave. %	Range %	Ave. %	Range %	Ave. %	Range %
1963-1964	29.2	3.8-54.9	20.4	1.1-35.6	68.0	58.1-77.5
1964-1965	22.4	6.4-41.9	24.7	14.3-31.0	39.1	28.2-47.5
1965-1966	46.9	16.6-82.0	22.9	0.7-48.0	18.4	6.2-30.6
1966-1967	20.1	4.3-41.5	43.9	27.5-60.3	41.9	13.7-61.8
1967-1968	33.0	9.8-65.5	9.4	2.2-13.6	41.1	17.0-66.6
1968-1969	40.3	0.0-76.0	34.2	4.0-78.0	28.8	1.0-37.0
1969-1970	52.7	52.7	23.4	15.1-31.7	25.3	6.1-37.8
1970-1971	-	-	30.4	0.6-46.4	19.5	1.4-37.6
8-Year Average	34.6	0.0-82.0	25.7	0.6-78.0	37.9	1.0-77.5

Weighted Average Survival for all Streams =32.9%
Range of Individual Redd Survival Rates = 0.0 - 82.9%

from year to year, and highly variable from redd to redd. Table 9 indicates survival rates of individual redds varied from 0.0 to 82.0 percent from egg deposition to fry emergence. Average survival rate for successful redds was 32.9 percent, with 37.9 percent survival on Deer Creek, 34.6 percent survival on Needle Branch, and 25.7 percent survival on Flynn Creek. Including zero emergence redds, the survivals were 33.5, 29.8, and 20.8 on Deer Creek, Needle Branch, and Flynn Creek, respectively.

There was no significant shift in survival rates from pre-logging to post-logging years on Needle Branch or Deer Creek. It is apparent from the variability associated with individual redd survival data, that utilizing the records of a single year, as did Koski (1966) and Au (1972) can result in different values of emergence survival. Koski utilized data from the 1963-64 season, and his survival to emergence values are different than those indicated in Table 9. This discrepancy originates from his inclusion of zero emergence redds in the computations. As a result, Koski's fry survival values reflect the presence of redds which never produced viable fry because of gravel scouring, false spawning, incomplete fertilization, or other physical and biological factors. We feel that utilizing only the producing redds gives a better indication of fry survival to emergence. In this way we can indicate a value or values applicable to a species (coho salmon) rather than to a particular area (the Alsea test streams only). Physical and biological influences on fry emergence vary with geographical locale. Therefore, it seems logical to apply survival rates for coho salmon, then determine the percentage of zero emergence for the particular stream, rather than make survival values contingent upon a stream having the same set of environmental conditions. We have, however, computed the survival rates both ways, as a means of comparison.

Temperature is the principal regulator of incubation time of salmonid embryos, and the variation in incubation periods on the three study streams reflects changes in water temperature and certain other environmental factors. After hatching, alevin movement is regulated by gravel composition, intragravel dissolved oxygen, and certain other factors. Even though the hatching times of coho salmon embryos may be similar for several redds on a given stream, the time to emergence may vary due to gravel conditions. On the average, fry first emerged on Needle Branch in 105 days from egg deposition. Fry averaged 106 days to emergence on Deer Creek, and 112 days to emergence on Flynn Creek. The time to emergence was quite variable, as indicated in Table 10.

Despite an increase in temperature in Needle Branch (potentially reducing hatching and emerging time), time to emergence was not drastically altered. Average time to first emergence for three pre-logging years was 106 days, while that for four post-logging years was 101.5 days. Average time to last emergence was almost the same 140 and 141 days, respectively. During the time of embryo incubation (winter months), temperature alterations may have been minimal.

For the most successful redds (over 60 percent fry emergence survival), the time to first emergence was slightly less, but the relative times on the three streams remained similar: 100, 109 and 104 days for Needle Branch, Flynn Creek and Deer Creek, respectively. Likewise, for the least successful redds (less than 15 percent survival), the times to first emergence were also similar: 105, 116 and 107 days, respectively.

Fry emergence was typically from February to early June, although some fry continued to emerge as late as July. Koski (1966) and Au (1972) have indicated that peak emergence of coho fry occurs approximately eight to ten days after first emergence. Au has calculated that approximately 90 percent of the fry emerge within the first ten days. Despite the fact that Dill and Northcote (1970) found no change in coho fry survival or emergence timing due to gravel composition, Koski (1966) and Phillips et al. (1975) have demonstrated that such a relationship does occur. Our data support their conclusions (see Part II: Section on Gravel Composition).

Au (1972) has observed that most coho fry emergence occurs at night, principally in a few hours after darkness.

Table 10. Emergence times of coho salmon fry measured as time in days from egg deposition. Records of zero emergence redds are not included.

	Needle Branch	Flynn Creek	Deer Creek
Average Time to First Emergence (and Range)	105 (85-147)	112 (99-140)	106 (80-122)
Average Time to Last Emergence (and Range)	142 (110-174)	159 (119-230)	160 (126-204)
Average Period of Emergence (and Range)	37 (1-62)	47 3-115)	54 (24-102)

Apparently fry emerge to just below the surface in daylight hours. But, as they are photo-negative, peak emergence occurs just after darkness, at about 2000 to 2100 hours (mid-winter months). Similar behavior has been observed with sockeye salmon by Bams (1969), but Dill and Northcote (1970) believe coho salmon alevins are negatively phototactic during their intragravel existence, but become positively phototactic during the final upward emergence.

To test the efficiency of salmonid fry traps, two series of experiments were undertaken. The first was a study to determine the extent of lateral movement of emerging coho salmon fry. The second was a trapping of fry that may have emerged beyond the confines of the primary fry trap.

The objective of the lateral movement study was to determine the extent of fry emergence in the horizontal vector. In the laboratory, concentric rings of screening were placed at 6, 12 and 18-inch diameter distances from a centrally placed standpipe where alevins were introduced (Figure 20). Four such cells were constructed and fry emerging in each ring, as well as those emerging outside all rings, were counted. The results of tests run during early 1965 were mixed (Table 11). The results of this test were inconclusive because of the small diameters of retaining rings, the extreme variability of numbers of emerging fry in particular rings, and the significant numbers of fry emerging outside all rings.

A better approach to determining trap efficiency is that reported by Phillips and Koski (1966). A 1.8 m by 2.4 m fry trap was installed over a salmon redd as usual, but a larger trap, measuring 2.4 m by 3.7 m was installed over the smaller trap. During tests in 1966 and 1967, from 100 to 300 alevins were released into four standpipes in the gravel. In 12 tests, efficiency of the primary trap varied from 97 to 100 percent, averaging 99.6 percent efficiency. Biologists conducting the tests felt actual efficiency was higher because two of the three fry found in the larger trap probably entered through an open zipper rather than emerging from the gravel. These fry were larger in size than other emergents and the open zipper at the same time lead biologists to believe these fish were intruders from other natural redds.

Whatever the origin of the few questionable fry, the efficiency of the fry traps appears to be quite high. By installing the trap in the manner described by Phillips and Koski (1969), fry escaping the confines of the trap would have to move extensively in a lateral direction. Dill and Northcote (1970) have found that lateral movement of coho alevins is significantly reduced in small gravel of the size found in the three study streams. As a result, the number of fry emerging beyond the borders of the fry trap is undoubtedly insignificant.

Figure 20. Concentric rings of screening at 6, 12, and 18 inches diameter from a standpipe where alevins were introduced. Rings were used to determine lateral movement of emerging coho salmon fry in the laboratory.

Age and Growth

Coho salmon juveniles along the Pacific coast go to sea after one, two, three, or even four years in freshwater. For most coho salmon stocks south of Alaska, fish spend one year in freshwater. Smolts aged in most studies exhibit one freshwater check plus some additional growth prior to spring migration. Hence, one-year-old smolts are more accurately described as 1+/.

Of the scale samples collected from downstream migrants during the study, 359 were analyzed. Scale analysis was sporadic with scales read in the following years: Needle

Table 11. Numbers of emerging coho salmon fry in various concentric screen rings from a central alevin introduction point. Tests were conducted at the Alsea field laboratory during February, March, and April 1965.

	Fry Emerging From the Following Diameter Distances				
Cell	6 in.	12 in.	18 in.	Outside	Total
1	3	7	4	57	71
2	20	58	12	4	94
3	39	37	1	13	90
4	47	32	14	4	97

Branch (1972, 1973), Deer Creek (1959, 1960), Flynn Creek (1967, 1968, 1969, 1970, 1971).

Of these samples, 194 were collected in Flynn Creek, 70 in Deer Creek and 95 in Needle Branch. An average of 83.3 percent were from 1/ or 1/+ fish. The remainder were from 2/ or 2+/ fish. Au (1972) has estimated that approximately 90 percent of the outgoing smolts are of age class 1/ with the rest being 2/. Using the total scale samples for the study, we have found that percentage to be lower with the exception of Needle Branch (Table 12). On the basis of scale samples, the number of holdover juveniles average 16.7 percent of the outgoing smolts. Fish of age group 1/ constituted only 2.3 percent of all one-year-old fish, and fish of age group 2/ constituted only 1.7 percent of all two-year-old fish. Therefore, all 1/ and 1+/ fish will be termed 1/, and 2/ and 2+/ fish will be termed 2/ in this discussion.

There is no indication that age characteristics of coho smolts changed due to logging. Pre-logging scale data are limited, and numbers are not sufficient to pick up any changes due to logging.

Table 12. Age groups of coho salmon downstream migrants passing through the traps on the study streams. Expressed as percent occurrence.

Stream	Age Groups 1/	2/
Needle Branch	90.5%	9.5%
Deer Creek	81.4	18.6
Flynn Creek	80.4	19.6
Average	83.3	16.7

It should be noted that the percentages of age 2/ fish from smolt samples in Table 12 are higher than those found in returning adults in Table 3. Fish of age 2/ comprised only 7.1 percent of the returnees to Needle Branch, 4.1 percent to Flynn Creek, and 4.8 percent to Deer Creek, for an average of 4.9 percent. In contrast, 95.0 percent of the returning adults were 1/, and 83.3 percent were 1/ as outgoing smolts. It would appear that one of three things may be happening: (1) scale sampling was inadequate for coho juveniles; (2) age 2/ fish suffered a higher oceanic mortality than age 1/ fish; or (3) detection of juvenile 2/ fish was erroneous.

In regards to possibility (1), adult scale samples were over 6.5 times greater in number than juvenile samples, so this explanation may be valid. Regarding Option (2), Drucker (1972) believes the additional year of freshwater residence results in higher freshwater mortality rates, but lower oceanic mortality rates. If so, the age 2/ fish should return in higher proportions of returns. However, the opposite seems true. Recognizing the presence of age 2/ fish from juvenile scale samples can be difficult (Option 3). It is certainly conceivable that many of the fish that are aged as 2/ may, in reality, not have the second freshwater check, thus lowering the actual percentage of 2/ smolts.

Coho juveniles were separated by age group and fork length ranges (Table 13). From this information it is evident that one-year-old fish were of a size range, 51-120 mm FL, with a peak between 91 and 100 mm. Two-year-old fish ranged in size from 71 and 153 mm FL, with a peak between 101 and 110 mm.

Table 13. Age characteristics of juvenile coho salmon, grouped by fork length range, taken from scale samples of downstream-migrating juveniles at the downstream traps.

Fork Length	Age Group 1+/	2+/
51 - 60 mm	5	
61 - 70	38	
71 - 80	48	4
81 - 90	44	4
91 -100	91	11
101-110	73	24
111-120	11	13
121-130		3
131-140		1
141-150		
151-160		1

Length and Weight

Average lengths of coho fry and fingerlings were similar for pre- and post-logging periods (Table 14). Although overall records do not indicate a change in average lengths in Needle Branch in 1967 (the period of highest water temperatures), records for July, August, and September are not included. Au (1972) has found that average lengths declined in Needle Branch during this period.

Records of weights for coho juveniles are lacking until post-logging years, but Au (1972) found a decrease in average weight during summer 1967. Later records for juvenile weights, from 1969-1973, show average weights of smolts in April to 8.3, 8.5, 10.0, 9.8, and 8.2 g during 1969, 1970,

Table 14. Average lengths of juvenile coho salmon in Needle Branch and Flynn Creek during the pre- and post-logging periods, 1959-1973.

	Flynn Creek	Needle Branch
Fry		
Pre-Logging N	1651	1396
Post-Logging N	2459	3046
Pre-Logging Ave. Length (mm)	41.9	42.3
Post-Logging Ave. Length (mm)	40.0	45.6
Fingerlings		
Pre-Logging N	3521	1394
Post-Logging N	3595	1406
Pre-Logging Ave. Length (mm)	83.3	82.8
Post-Logging Ave. Length (mm)	84.9	90.6

1971, 1972, and 1973 in Deer Creek; 9.1, 11.9, 9.1, 9.5, and 6.7 g in Flynn Creek; and 8.7, 9.7, 11.6, 17.7, and 11.6 g in Needle Branch.

Condition Factors

Consistent condition factor data are available only for 1969-1973, when juvenile coho salmon were weighed and measured with regularity. During this period, average monthly condition factors varied from 0.98 to 1.05 on Deer Creek, 0.97 to 1.08 on Flynn Creek, and 0.98 to 1.13 on Needle Branch.

Au (1972) found a distinct change in condition factors in Needle Branch during the summer of 1967, the time of the highest temperatures. Mean condition factors dropped from 1.12 in 1966 to 1.02 in 1967, then rose to 1.07 in 1968. Condition factors declined for all length categories from 1966 to 1967.

Biomass

Biomass measurements for coho salmon have been relatively consistent between the streams surveyed by biologists along the Pacific coast (Table 15). Small unlogged

Table 15. Some biomass measurements of coho salmon in Pacific coastal streams. Data are from logged and unlogged watersheds.

Stream	Biomass (g/m^2)	Logging Activity[1]	Reference
Wolf Creek, British Col.	1.7 - 2.8	L	Narver (1972)
Wolf Creek, British Col.	1.7 - 2.7	U	Narver (1972)
Carnation Creek, B.C.	2.5	U	Narver (1972)
Stequaleho Creek, Wash.	0.3	Landslides	Cederholm and Lestelle (1974)
Briar Creek, Oregon	0.8	U	Moring and Lantz (1974)
Briar Creek, Oregon	1.3	L	Moring and Lantz (1974)
Coal Creek, Oregon	1.8	U	Moring and Lantz (1974)
Crane Creek, Oregon	2.3	U	Moring and Lantz (1974)
Crane Creek, Oregon	1.3	L	Moring and Lantz (1974)
Dick Creek, Oregon	0.3	L	Moring and Lantz (1974)
Fivemile Creek, Oregon	2.6	U	Moring and Lantz (1974)
Fivemile Creek, Oregon	3.9	L	Moring and Lantz (1974)
Panther Creek, Oregon	6.0	U	Moring and Lantz (1974)
Panther Creek, Oregon	5.9	L	Moring and Lantz (1974)
Park Creek, Oregon	2.2	U	Moring and Lantz (1974)
Park Creek, Oregon	0.4	L	Moring and Lantz (1974)
Sourgrass Creek, Oregon	2.6	U	Moring and Lantz (1974)
Sourgrass Creek, Oregon	2.8	L	Moring and Lantz (1974)
Whittaker Creek, Oregon	1.2	U	Moring and Lantz (1974)
Whittaker Creek, Oregon	2.4	L	Moring and Lantz (1974)
Williamson Creek, Oregon	1.5	U	Moring and Lantz (1974)
Williamson Creek, Oregon	1.5 - 1.6	L	Moring and Lantz (1974)
Little N. Fk. Noyo R., Calif.	2.1	U	Burns (1971)
Godwood Creek, California	1.1	U	Burns (1971)
Bummer Lake Creek, California	0.2	U	Burns (1971)
N. Fk. Caspar Creek, California	0.2	U	Burns (1971)
S. Fk. Caspar Creek, California	1.6	U	Burns (1971)

[1] Coding: U - unlogged; L - logged

headwater streams of western Oregon surveyed by Moring and Lantz (1974) had biomasses ranging from 0.8 to 6.0 g/m^2, averaging 2.3 g/m^2. Logged streams averaged 2.2 g/m^2, and ranged from 0.3 to 5.9 g/m^2.

Biomass measurements are available for 1959 through 1969, and for 1972. Most of the information has previously appeared in dissertations or other publications. Chapman (1965) provided data for the years 1959-1962, estimating the biomass on the three streams monthly. Au (1972) estimated total biomass for the years 1963-1968, but did not convert it to weight per unit area. The Oregon State Game Commission has unpublished records for coho salmon biomass in 1969 and 1972 and partial records in 1971.

To analyze the biomass data, Au's values have been converted to g/m^2 using the surface area records indicated by Lowry (1964) and Koski (1966). Comparative values from all biomass studies are shown in Table 16.

Table 16. Biomass estimates for coho salmon in the three study streams, 1959-1972. Values are expressed as g/m^2 during mid-September. Chapman's (1965) data for 1959-1962 is averaged between the 1 September and 1 October data. Au's (1972) data for 1963-1968 are converted to g/m^2.

Year	Deer Creek	Flynn Creek	Needle Branch
1959	3.0 g/m^2	3.0	2.1
1960	2.4	2.6	2.1
1961	3.3	2.4	1.8
1962	4.4	3.0	2.8
1963	3.1	2.5	2.7
1964	3.2	2.0	1.2
1965	3.4	1.7	3.3
1966	4.1	3.0	4.2
1967	6.8	2.1	6.8
1968	5.3	2.6	4.5
1969	2.6	0.4	2.4
1970	-	-	-
1971	-	-	0.9
1972	3.0	0.7	1.2
Pre-Logging Ave.	3.3	2.5	2.3
Post-Logging Ave.	4.4	1.8	3.3

Biomass values for coho increased on Deer Creek and Needle Branch, but declined in Flynn Creek from pre-logging to post-logging. It should be noted that biomass increased in the two streams whose watersheds were logged. However, other more subtle factors may be occurring. The interrelationships between fish species may be changing. Cutthroat populations decreased following logging in Needle Branch (see section on Cutthroat Trout Juveniles – Population Estimates), and the numbers of young steelhead trout declined in post-logging years in Deer Creek (see section on Steelhead Trout Juveniles – Movement through Traps). This decrease in biomass of other species may have been compensated by an increase in coho salmon biomass. In addition, there may be other population changes that could influence biomass. These interrelationships will be explored in Part III.

Population Estimates

Population estimates of coho salmon in logging situations have been limited. The concensus of opinion is that the coho salmon is a fairly resiliant species (Au 1972; Burns 1972). Tyler and Gibbons (1973) found no significant changes in coho populations between logged and unlogged sections in the Thorne River and Staney Creek, Alaska. Likewise, Narver (1972) found Wolf Creek, British Columbia, coho populations were evenly distributed between logged and unlogged sections. Populations in the smaller tributaries were 30 percent more abundant in unlogged sections.

Burns (1972) obtained mixed results for pre- and post-logging surveys of coho populations in three northern California streams. Coho numbers declined during logging on Bummer Lake Creek but soon returned to normal levels. Bummer Lake Creek was clearcut in blocks, and there was little streambed damage. Population numbers declined immediately after logging on the South Fork of Caspar Creek. The population reached 80 percent of the pre-logging size two years after logging, but declined again the following year. There was considerable yarding into the stream, debris in the channel, and streambed siltation from nearby road construction. On the Little North Fork of the Noyo River, coho populations declined after logging and remained depressed. The stream experienced bulldozer yarding and an opened canopy of vegetation along the stream.

Population levels on nine coastal headwater streams of Oregon were varied with respect to logging. Population estimates declined on four streams and increased on five. A follow-up survey on a stream where levels decreased indicated population numbers returned to within nine percent of the pre-logging value two years after logging (Moring and Lantz 1974).

Population estimates of coho salmon were sporadic during the 15-year study period. Several different techniques were used, and to present several years of estimates required the comparisons of at least two of these techniques. Unfortunately, such comparisons are difficult to analyze.

Information on juvenile coho salmon population numbers in the streams can be derived from four sources: (1) the early work by Chapman (1961) providing estimates for 1959-1962; (2) the work of Au (1972) in which estimates for 1963-1968 can be derived by analyzing the numbers of marked juveniles passing through the downstream traps; (3) population estimates from electro-fishing capture and recapture during 1970 (Needle Branch), 1971 (Needle Branch) and 1972 (all streams); and (4) population estimates taken from 1,000-foot study sections on all streams in 1969.

Both Chapman and Au utilized Petersen population estimates based on initial capture of fish by electrofishing units and seines. However, recaptures were only collected at the downstream traps. Later population estimates by the Oregon State Game Commission were by the classical technique of mark and recapture. As a result, population estimates may be somewhat different. In 1969, 1,000-foot study zones were analyzed for biomass studies. Population estimates were computed for those study sections only. Approximate values for the total sections of streams can be derived by expanding the population numbers for the limited study areas.

Table 17 summarizes the coho population estimates for the study period. The scattered information appears to indicate a slight decrease in coho salmon populations in all three streams. However, using Au's values only (three years of pre-logging and three years of post-logging data), there was an increase in population estimates during post-logging years.

Because of data appearing in Table 17 are derived from three methods of sampling, it is difficult to determine whether these changes are due to logging activities or simply to changes in sampling methods. We have no basis for attributing any adverse changes in juvenile coho population numbers to logging activities.

Production

Net production has been defined by Ricker (1958) as the net summation of all growth increments over a given time period. This is usually expressed over a monthly or yearly period. This type of measurement is useful in comparing productivity of one stream to another, or in determining the causes of changes in population characteristics.

Two researchers (Chapman 1965; Au 1972) studied the production aspects of coho salmon populations in the Alsea test streams. In summary, Chapman found differences in yearly net production rates, but similarities in the values of production per unit area during 1959-1962. This average production rate was 9 g/m^2 per year, and was similar on all three streams from fry emergence to smolt migration. Chapman found changes in production rates dependent upon seasonal and growth characteristics. Mean production was highest following emergence but dropped to a low point during winter. The production rate increased again by the time of smolt migration. The actual values are of dubious value to report here because they were partly based on faulty assumptions. One such assumption was an estimate of 65 percent survival to emergence. Koski (1966) and our data have shown the actual value to be approximately half that figure.

Au studied the production characteristics of the coho populations during 1963-1968. Unit area net production averaged 3.4, 5.3 and 6.2 g/m^2 per year in Flynn Creek, Needle Branch and Deer Creek, respectively. Chapman's

Table 17. Population estimates for juvenile coho salmon in streams. Data from 1959 are taken from Chapman (1961); data from 1960-1962 are taken from Chapman (1965); data from 1963-1968 are taken from Au (1972). Other data are from collections by the Oregon Wildlife Commission.

Year	Deer Creek	Flynn Creek	Needle Branch
1959	9100[1]	3556	1379
1960	5500[2]	4000[2]	1500[2]
1961	7000[2]	3000[2]	1000[2]
1962	10000[2]	4900[2]	2500[2]
1963	7600	1450	1600
1964	4500	1750	525
1965	9200	2000	2100
1966	6600	2850	1225
1967	10700	3600	4075
1968	7600	2325	1850
1969	3681[3]	258[4]	435[5]
1970	no estimates		205
1971	no estimates		159
1972	4827	834	1106
1973	no estimates		
Pre-Logging Average	7600	2189	1401
Post-Logging Average	6682	1975	1294

[1] Interpolated value to reflect population on 15 August.

[2] Interpolated from figures by Chapman (1965).

[3] Expanded from a study area estimate of 478 per 1000 ft. of stream.

[4] Expanded from a study area estimate of 60 per 1000 ft. of stream.

[5] Expanded from a study area estimate of 164 per 1000 ft. of stream.

average values per unit area for the June 1 to June 1 period were 5.0, 4.3 and 5.3 g/m^2 per year, respectively.

Although there was considerable variation in net production values between years (Deer Creek range: 20-38 kg/year; Flynn Creek: 7-20 kg/year; Needle Branch: 3-9 kg/year), comparisons of pre-logging and post-logging values reveal some interesting trends. Au has indicated that Chapman's values appearing in Table 22, although covering a slightly shorter period, include essentially the same amount of production time. Au also found post-logging production values increased on all three streams. However, Chapman's values were not included. When they are included, the trend changes. With these data we have seven years of pre-logging and three years of post-logging data. The net production in Flynn Creek was essentially unchanged from pre-logging to post-logging (10.6 to 10.7 kg/year). However, the net production on Needle Branch and Deer Creek increased. The actual production increase was higher in Deer Creek but the relative increase was higher in Needle Branch.

Fry Dispersion and the Behavior and Movement of Juveniles in Streams

Dispersion of coho salmon fry was extensively discussed by Chapman (1961), Au (1972) and Lindsay (1975). Detailed information can be found in these three sources. During 1969-1970, Au had the opportunity to observe the dispersion of fry in Needle Branch during the spring. Only one female spawned that season and the location of the redd was flagged. A fry trap was installed over the redd and a series of wire screen traps were spaced at standard distances downstream. The emerging fry were released at night from the fry traps and their progress downstream was monitored.

Au found that emergent fry began their downstream migration almost immediately and spread themselves between the redd and the first two downstream traps the first night. This movement increased during the night and peaked just prior to dawn. During each successive night fry dispersed farther downstream until some equilibrium distribution was established. Apparently the numbers of fry in each section and their further downstream movement was related to density of fry, population regulators, and the availability of food items.

Fry moving downstream in the Alsea study streams were termed "nomads" by Chapman (1961) to refer to their nomadic behavior. Lindsay (1975), however, believes the term "emigrants" is more correct, as this refers to migrating fish that eventually establish residence in the stream – but downstream from the original redd.

Some fry remained in the stream, establishing residence above the traps. The number of fry and their relative positions with respect to other members is related to a number of factors. Lindsay (1975) followed those emigrants below traps and found the highest proportion of fry were found immediately below the trap release sites. Numbers decreased in proportion from that point downstream. Survival was significant for these fish in downstream areas. Lindsay also noticed some straying of emigrants after being released from the downstream traps - taking up residence in other study streams.

Movement and Timing of Movement through Traps

Most juvenile coho salmon migrations occur during spring months along the Pacific coast of the United States and Canada, with the peak periods dependent upon individual stock characteristics. The Waddell Creek migration of coho in California peaks in April and May with stray migrants throughout the remainder of the year (Shapovalov and Taft 1954). In contrast, the Karluk River migration in Alaska begins in mid-May, peaks in June, and is generally over by early July (Drucker 1972). The migration from Lake Merwin, Washington begins in March, peaks in May and June, and is over by early July (Hamilton et al. 1970), but the Bear Creek, Alaska run does not begin until June and does not peak until late July (McHenry 1972). The factors which govern the timing and extent of individual migrations include flow, water temperature, size of smolts and latitude. Drucker (1972) has found that time of migration is later in higher latitudes.

On the three Alsea study streams, coho salmon juveniles migrated downstream at any time of the year, but there were distinct peaks of migration. Fry movements were concentrated during spring months. Fingerlings and smolts peaked in spring months but were also present during the winter period, October-January, when fry migration was minimal. Au (1972) has described the downstream movement of fry and fingerlings. The fry were primarily recent emergents which dispersed downstream from redd sites.

Most fry movement downstream occurred during March, April and May, while peak runs of smolts were in March and April (Tables 18, 19, 20). Overall, 86.1 percent of the fry and juveniles moved downstream during these months in Flynn Creek. During pre-logging years on Needle Branch, 86.9 percent of the migrants passed through the trap during this period. In post-logging years this percentage was almost the same, 86.2 percent. On Deer Creek, 86.6 percent of the juveniles migrated downstream during these months in pre-logging years, and 84.7 percent during post-logging years.

Mortalities in Streams

Au (1972) and Lindsay (1975) have reviewed the subject of mortalities of coho salmon in the streams. Their discussions are the most complete for the Alsea test streams and they will be summarized briefly here. During the study of 1963-1968 coho year classes, Au found relative mortality rates peaked in mid-summer, then declined to a level of less than two percent per week in fall months. Mortalities then increased during winter months to a secondary peak in late winter. Lindsay also reported a high over-winter mortality of resident coho. This mortality averaged 60 percent during the period late August to mid-March (206 days).

This same trend in mortalities was also noted by Chapman (1961) for the 1959 year class in Deer Creek. However, Chapman's values, and the shapes of his population curves,

Table 18. Timing of downstream migrations of coho salmon juveniles and fry on Flynn Creek, 1959-1973. Expressed as average number of fish per year.

Month	Pre-Logging Period	%	Post-Logging Period	%
January	15.9	0.1	5.1	0.1
February	127.1	1.2	56.7	0.9
March	729.6	7.0	1529.3	24.9
April	4709.8	45.2	1949.8	31.8
May	2833.3	27.2	2348.1	38.2
June	1871.2	18.0	196.4	3.2
July	54.5	0.5	24.3	0.4
August	23.5	0.2	2.0	<0.1
September	5.2	<0.1	0.5	<0.1
October	4.5	<0.1	1.7	<0.1
November	17.6	0.2	9.9	0.2
December	19.0	0.2	16.3	0.3

Table 19. Timing of downstream migrations of coho salmon juveniles and fry on Needle Branch, 1959-1973. Expressed as average number of fish per year.

Month	Pre-Logging Period	%	Post-Logging Period	%
January	1.7	<0.1	11.1	0.2
February	134.7	1.5	466.3	8.7
March	1850.9	20.7	982.6	18.3
April	3683.3	41.2	2027.6	37.7
May	2222.8	24.8	1578.0	29.4
June	997.5	11.2	204.1	3.8
July	27.5	0.3	20.8	0.4
August	6.0	0.1	2.8	0.1
September	1.2	<0.1	2.8	0.1
October	9.0	0.1	14.0	0.3
November	10.6	0.1	38.1	0.8
December	0.4	<0.1	24.1	0.4

Table 20. Timing of downstream migrations of coho salmon juveniles and fry on Deer Creek, 1959-1973. Expressed as average number of fish per year.

Month	Pre-Logging Period	%	Post-Logging Period	%
January	52.3	0.8	64.4	1.1
February	210.0	3.0	230.1	3.8
March	1486.3	21.4	1298.3	21.5
April	3063.7	44.1	2731.1	45.3
May	1466.0	21.1	1077.6	17.9
June	352.8	5.1	449.1	7.4
July	41.8	0.6	49.5	0.8
August	7.7	0.1	13.1	0.2
September	1.8	<0.1	5.8	0.1
October	18.3	0.3	4.3	0.1
November	127.0	1.8	48.1	0.8
December	115.9	1.7	58.6	1.0

are somewhat different from those of Au. This is due partly to the fact that Chapman assumed 60 percent survival to emergence for coho fry. This is almost twice the survival rate reported by Koski (1966), or shown herein (see section of Fry Emergence), or assumed by Au. In addition, inclusion of recruitment portions of the population (in spring) can bias the ultimate mortality and population curves. Au has accounted for this possible source of error.

In terms of actual mortality numbers, large numbers of mortalities occur in the streams during summer months, followed by low numbers of deaths in fall and early winter. During the smolt migration in late winter these absolute numbers increase and continue to do so until fall. These relationships are shown in Au's Figures 27a, 27b and 27c.

The ultimate effect of this changing mortality pattern is evident in its effect on the total population picture. Of each year class of coho salmon, Au estimated that approximately 80 percent will die by September. The major periods of mortality occur during the spring period of recruitment, and in summer months. It is estimated that coho populations in streams were decreased by an average of 56 percent during the period of summer residence. This apparently occurs at a rate of approximately 6 percent per week. Chapman and Au (1972) believe behavioral traits and fish densities are the prime aspects influencing the extent of this mortality.

Lindsay followed the fate of emigrant, or "nomad", coho through the downstream traps to Horse Creek and Meadow Creek. Of those downstream emigrants only seven percent survived from the time of emigration to September (120 days). Those "resident" fry (remaining in the study streams) had much higher survival rates ranging up to 78 percent during the high July to September mortality period in Flynn Creek.

Table 21. Smolt yield for Deer Creek, Flynn Creek, and Needle Branch for 1959-1973. Live and dead fish are included.

Year	Deer Creek	Flynn Creek	Needle Branch
1959*	1	0	0
1960	2969	1242	192
1961	1861	849	431
1962	1818	803	216
1963	2126	1393	421
1964	1785	523	282
1965	1852	702	153
1966	1078	731	259
1967	2098	845	238
1968	2327	663	177
1969	1701	403	132
1970	1317	188	136
1971	796	161	77
1972	1056	325	137
1973**	1864	393	344
Pre-Logging Average	2068.5	918.7	282.5
Post-Logging Average	1529.6	478.6	193.5

*Study began 1 October 1959

**Study terminated 30 September 1973

Smolt Yield

Despite the fact that numbers of spawners varied greatly during the years, numbers of outgoing smolts remained relatively steady from year to year (Table 21). Au (1972) believes this regularity in smolt yield may be due to some natural regulatory ability of the ecological system. There was a decrease in post-logging years in Needle Branch, but there was a similar decline in smolt yields in Flynn Creek and Deer Creek. As a result, no adverse effects of logging are readily apparent regarding smolt numbers. Dead and live smolts are included in this analysis, as it is probable that most mortalities recorded in the traps were due to the traps themselves. Dead smolts amounted to only 5.5 percent of all smolts passing through the Needle Branch trap, 4.0 percent of smolts passing through the Flynn Creek trap, and 2.4 percent of smolts passing through the Deer Creek trap.

CHINOOK SALMON

Chinook salmon were incidental fish in the three study streams during the 15-year period. Apparently all records of chinook salmon in the streams were cases of straying. The evidence for this assumption is: (1) there were no consistent runs of chinook salmon each year, and occurrence was scattered; (2) all chinook encountered at the upstream and downstream traps were males; (3) most chinook moving upstream moved back downstream shortly after the initial capture; and (4) no chinook fry or fingerling were ever observed in the streams.

One precocious male chinook was captured in the Needle Branch upstream trap in December 1967. All other records were from Deer Creek (Appendix 7). Fourteen chinook were taken in the upstream trap on Deer Creek: four in 1960, one in 1963, one in 1966 and eight in 1967. Of these, the one fish in 1966 was passed downstream a day later. Seven of the eight fish in 1967 ultimately moved downstream from one to five days after their capture in the upstream trap.

For the 15 chinook in Deer Creek and Needle Branch, 14 were precocious and one was an adult male. The jacks averaged 475.9 mm FL, and ranged from 413 to 572 mm FL. One jack examined on Deer Creek (503 mm) weighed 1,247 g (2 pounds 12 ounces). The adult male measured 860 mm FL.

All fish encountered were fall chinook entering Deer Creek and Needle Branch between October 29 and December 7. Chinook encountered in these streams undoubtedly strayed from spawning stocks on Horse Creek and Drift Creek. Chinook salmon have long been known to utilize these two tributaries of the Alsea River (Oregon State Game Commission 1954). Recent spawning surveys by the Fish

Commission of Oregon show a small spawning population on Horse Creek between Meadow Creek and Drift Creek, and a considerable spawning population in Drift Creek (Delbert Skeesick, personal communication).

CUTTHROAT TROUT

Age characteristics and growth

Several researchers have studied the age composition of coastal cutthroat trout. Seldom do fish spend more than five years in freshwater. The majority spend two, three or four years. Giger (1972) reported in a study of the Alsea and two other coastal rivers that cutthroat may undertake as many as five spawning migrations. Giger found no fish over 7+ years of age, but Sumner (1962) and Jones (1974) have reported eight, nine and ten-year-old cutthroat trout.

Sea-Run Adults

Age of migrating adults was determined from scale samples taken at the upstream traps. Scale samples read from fish with ocean histories numbered 359. Only 12 scales were read from Needle Branch sea-run adults (one from pre-logging years and 11 from post-logging years), so age information is quite limited. For the other two streams 12 age combinations were evident (Table 22). The 3/1 group dominated in Flynn and Deer creeks. Fish of age group 4/1 were also important in the two streams, and those of age 2/2 were important in Deer Creek.

Table 22. Percentages of occurrence of age groups of upstream migrating, sea-run cutthroat adults from the Flynn Creek and Deer Creek traps, 1959-1973*.

Flynn Creek:

	Ocean Years		
Freshwater Years	1	2	3
1	1.0	0.5	
2	6.2	5.3	
3	35.9	9.6	1.9
4	27.3	8.6	1.4
5	1.0	1.4	

Deer Creek:

	Ocean Years		
Freshwater Years	1	2	3
1	2.9	0.7	
2	12.3	5.1	
3	42.8	15.9	1.4
4	13.0	2.9	
5	2.2		
6	0.7		

*Only 12 scale samples were read for Needle Branch upstream adults (with ocean history). Of these, 4 were 3/1, 3 were 4/1, 2 were 1/2, 2 were 4/2, and 1 was 2/1.

Four and five-year-olds made up over 75 percent of the runs in the two streams (Table 23). Fish spent up to six years in freshwater before migrating, but most migrated after three or four years. Ocean residence varied from one to three years with the bulk of the fish having spent only one year at sea.

Table 23. Percentages of ages of upstream migrating adult cutthroat (with ocean history) for Flynn and Deer Creeks, 1959-1973.

Age	Flynn Creek	Deer Creek
2 - year olds	1.0	2.9
3 - year olds	6.7	13.0
4 - year olds	41.2	47.9
5 - year olds	36.9	28.9
6 - year olds	11.5	6.5
7 - year olds	2.8	0.7
Number Sampled	209	138

Resident Adults

Adults tentatively classified as "residents" were those with no ocean history collected at the upstream traps on each stream. We felt that this source of data would provide the best records for fish with no ocean history, moving upstream to spawn. Fish that were obviously juveniles were not included in this analysis, but, because of the overlap in sizes between juveniles and adults, some large juveniles might have been included.

A total of 289 scales were read of these adults with no ocean history. Seven age groups were present in the resident adult population: 1/, 2/, 3/, 4/, 5/, 6/ and 8/. Between 67.1 percent and 80.3 percent of the upstream migrating resident portion of the population were three and four-year-old fish (Table 24). Although the four-year-old component dominated in Flynn Creek, three-year-olds were the significant age group in the two logged streams. There was no shift in age groups from pre-logging to post-logging years and the same trends were present during pre-logging years in both streams.

One eight-year-old fish was trapped in the Deer Creek upstream trap in January 1973. The female was 347 mm FL,

Table 24. Percentages of ages of upstream migrating adult cutthroat (with no ocean history) for Flynn and Deer Creeks and Needle Branch, 1959-1973.

Age	Flynn Creek	Deer Creek	Needle Branch
2 - year olds	4.5	16.2	23.7
3 - year olds	23.9	48.6	55.9
4 - year olds	43.2	31.7	15.3
5 - year olds	26.1	2.8	3.4
6 - year olds	2.3	-	1.7
7 - year olds	-	-	-
8 - year olds	-	0.7	-

and 7.1 percent of its total growth in length was during its eighth year of life (about half the rate during the previous year).

Juvenile Age Groups

Juveniles and resident adults were difficult to distinguish in the downstream traps. However, almost all juveniles passing downstream were of three age groups: 1/, 2/ and 3/. Few 1/ fish were actively moving downstream; juveniles of the other two ages dominated.

Growth Rates

From the calculated lengths taken from scale samples, growth rates were derived for cutthroat trout. Growth between sea-run and resident components were compared (Table 25). Patterns were similar, but this may be a function of the mixed population in the stream. Fish with no ocean history when the scale was collected might have migrated to sea at a later date. Fish can migrate to sea at virtually any time. A 7-year-old fish was trapped on Deer Creek in December 1972. It spent six years in freshwater before moving to sea. When trapped, it was on its first spawning migration, although it was seven years old. Similarly, several fish on each stream migrated to sea after only one year in freshwater. By the same token, the 8-year-old cutthroat from Deer Creek, previously mentioned, never migrated to sea.

Table 25. Calculated growth patterns of cutthroat trout derived from calculated lengths from scale samples (principally from Flynn Creek fish).

Age	Fish With an Ocean History *mm FL*	Fish With No Ocean History *mm FL*
1/	64.4	67.1
2/	118.2	123.7
3/	179.5	176.5
4/	227.7	223.7
5/	253.6	251.8
6/	280.0	291.3
7/	-	324.0
8/	-	347.0
/1	336.9	
/2	400.7	
/3	424.2	

Length and weight

It is difficult to separate the records of cutthroat trout by adults, smolt, or parr, or by the number of spawning years, except by scale analysis. Length grouping gives an approximate separation, as does migration timing (see sections on Movements, and Timing of Movements of Adult and Juvenile Fish). However, the records are only conveniently separated into upstream and downstream trap data. Fish entering the upstream traps are primarily adults, but some juveniles are included in counts. Fish entering the downstream traps include spent adults, new smolts, and parr moving to downstream areas.

Average lengths of upstream migrating cutthroat were variable (Table 26). There was a slight increase in average length from pre- to post-logging years in Flynn Creek, but there was also an increase in the numbers of adults in post-logging years (Appendix 8). The average length declined slightly in Deer Creek, but there was also a slight decrease in numbers of adults in post-logging years (Appendix 9). There was a large increase in average length of upstream migrating cutthroat in Needle Branch following logging. There was also an increase in numbers of adults in post-logging years (Appendix 10).

There was a pronounced decrease in average length of cutthroat trout in Needle Branch during the summer of 1967, the time of the highest water temperatures. For the years immediately prior to and after logging, the instream average lengths were as follows: 1965 - 114.8 mm FL (N = 122); 1966 - 121.3 mm FL (N = 63); 1967 - 89.3 mm FL (N = 64); 1968 - 117.6 mm FL (N = 83). The decline in average length appears to be related to the increased water temperature, but sizes of cutthroat returned to pre-logging levels by the following year.

Weights of cutthroat trout from the upstream traps ranged from 19 to 624 g in Deer Creek, 11 to 284 g in Needle Branch, and 28 to 765 g in Flynn Creek. The numbers of fish weighed were too few to make valid comparisons between average weights from pre- to post-logging years.

There was little change in average weights of downstream migrating cutthroat from pre-logging to post-logging (Table 27). There was a slight increase in size of fish in Needle Branch and Deer Creek, and a slight decrease in size in Flynn Creek, None of the changes exceeded 2.9 percent, and there was no indication logging affected length characteristics. There were increases in downstream migrating trout on all streams in post-logging years. The numbers of adults moving downstream increased in Flynn Creek and Needle Branch, but declined in Deer Creek.

Length-weight regressions were derived for 55 adults from the upstream trap on Flynn Creek, and 33 adults from the upstream trap on Deer Creek. Only a few adults in Needle Branch were weighed, so no regression was calculated. Correlation coefficients were high (r = 0.92 and 0.98).

A length range frequency profile for Flynn Creek shows a pronounced peak between 300 and 425 mm (Figure 21), indicating that the majority of upstream migrants are adults. Few adults larger than 425 mm were trapped, and most of the fish of smaller sizes were juveniles.

Condition factors

Little information on condition factors is available from pre-logging years because most cutthroat trout were not weighed until later years. No information is available for any pre-logging year in Needle Branch, so we cannot detect any changes in condition factors due to logging. Only one year of information is available from upstream and one year from downstream trap records for Deer and Flynn creeks.

Table 26. Average lengths of upstream-migrating cutthroat trout during pre-logging and post-logging years.

	STREAMS		
Period	Needle Branch	Flynn Creek	Deer Creek
Pre-Logging Average	123.3 mm FL	298.4 mm FL	280.9 mm FL
Pre-Logging Range	66-343 mm	80-458 mm	92-496 mm
Pre-Logging N	93	199	196
Post-Logging Average	201.4 mm FL	318.8 mm FL	260.1 mm FL
Post-Logging Range	83-517 mm	108-480 mm	94-505 mm
Post-Logging N	93	258	225
Total	162.4 mm	309.9	269.8

Table 27. Average lengths of downstream-migrating cutthroat trout during pre-logging and post-logging years.

Period	Needle Branch	Flynn Creek	Deer Creek
Pre-Logging Average	130.7 mm FL	131.4 mm FL	148.1 mm FL
Pre-Logging Range	26-395 mm	24-470 mm	55-465 mm
Pre-Logging N	1035	2862	3090
Post-Logging Average	134.5 mm FL	129.8 mm FL	151.9 mm FL
Post-Logging Range	45-510	26-490	53-434
Post-Logging N	1243	3766	2766
Total Average	132.8 mm FL	130.5 mm FL	149.9 mm FL

Table 28. Condition factors of cutthroat trout from the three study streams. Upstream trap records are for adults and juveniles, while downstream trout records are primarily juveniles.

	Deer Creek		Flynn Creek		Needle Branch	
Year	Up	Down	Up	Down	Up	Down
1959-60	-	-	-	-	-	-
1960-61	-	-	-	-	-	-
1961-62	-	-	-	-	-	-
1962-63	-	0.97	-	1.00	-	-
1963-64	1.13	-	1.01	*	-	-
1964-65	-	-	-	-	-	-
1965-66	-	-	-	-	-	-
1966-67	*	-	-	-	-	-
1967-68	-	-	-	-	-	-
1968-69	-	-	-	-	-	-
1969-70	-	0.91	-	0.94	-	0.89
1970-71	-	0.90	-	0.94	-	0.95
1971-72	1.03	0.94	1.12	0.98	*	1.02
1972-73	1.01	0.87	0.91	0.90	*	0.93
Pre-Logging Ave.	1.13	0.97	1.01	0.98	-	-
Post-Logging Ave.	1.04	0.92	1.06	0.96	*	0.94
Total Average	1.07	0.92	1.05	0.96	*	0.94

*Data not sufficient for comparison

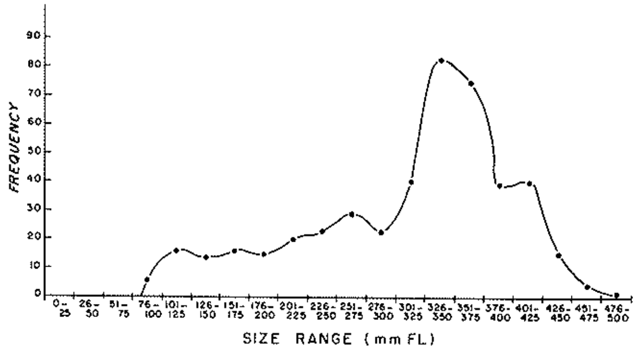

Figure 21. Length range frequency for all upstream migrating cutthroat trout in Flynn Creek, 1959-1973.

Generally, these values were slightly higher in pre-logging years than values in later years, but the difference is insignificant due to the insensitivity of the records (Table 28).

Upstream trap records are approximately evenly divided between juveniles (<275 mm) and adults (>275 mm). Downstream trap records are almost exclusively from juveniles. This explains why upstream trap values are higher than downstream trap values. Fewer, but generally larger fish, were moving through the upstream traps.

Sex ratio

There were generally greater numbers of males in the cutthroat trout populations than females, but the sex of most fish was not determined. Almost 98 percent of the fish in the downstream trap were not designated "male" or "females". Between 40.1 and 73.3 percent of the upstream trapped fish were not identified by sex. This is partially due to the fact that sex was often difficult to distinguish in most juveniles, while many adults (higher numbers in the upstream traps) could be so identified. Sex ratios from upstream traps were 1.8:1, males to females in Deer Creek, and 1.6:1 in Flynn Creek. There were very few cutthroat identified as to sex in Needle Branch, so the sex ratio was not determined. Pre-logging to post-logging ratios increased in Deer and Flynn creeks.

Downstream trap ratios were 1.2:1 in Deer Creek, and 1.8:1 in Flynn Creek. Again, the numbers of fish identified by sex in Needle Branch were quite low, but the sex ratios did increase in all three streams from pre-logging to post-logging years.

Population estimates

Changes in Population Numbers

There was a significant decline in cutthroat trout population numbers following logging in Needle Branch watershed (Figure 22). A t-test showed the difference between pre-logging and post-logging values to be significant at the 99 percent levels (t = 5.6). Population numbers showed no decline following logging in Deer Creek and Flynn Creek in post-logging years (Figure 23, 24; Appendix 11).

This depression of cutthroat trout is the most obvious biological change that is a direct result of logging. It should be noted that there was a significant increase in water temperature in Needle Branch after clearcutting and slash burning of riparian vegetation (see Part II – section on Stream Temperature). Because of the buffer strips along the clearcut areas of the Deer Creek Watershed, there was no such increase in temperatures in Deer Creek. Cutthroat trout

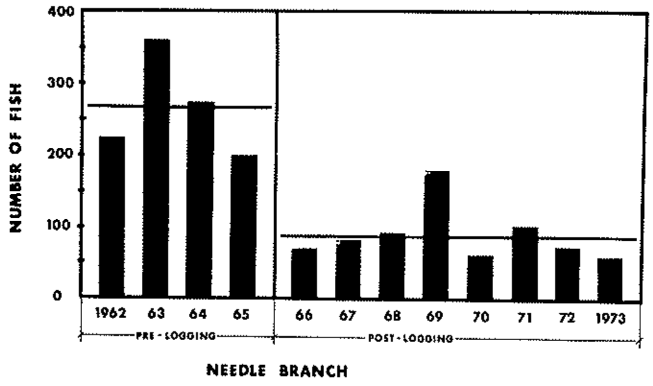

Figure 22. Estimated population numbers of cutthroat trout in Needle Branch, 1962-1973. Logging occurred in 1966.

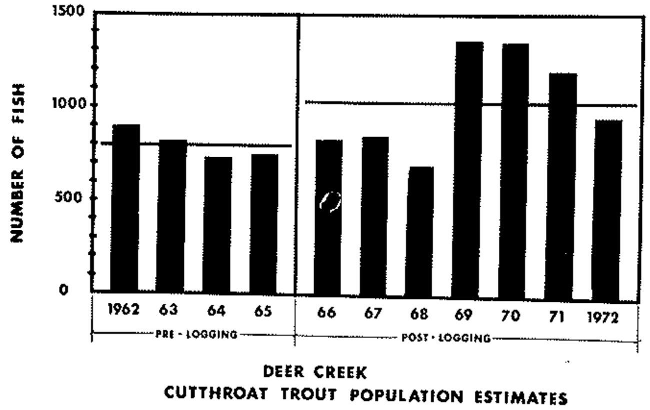

Figure 23. Estimated population numbers of cutthroat trout in Deer Creek, 1962-1972. Logging occurred in 1966.

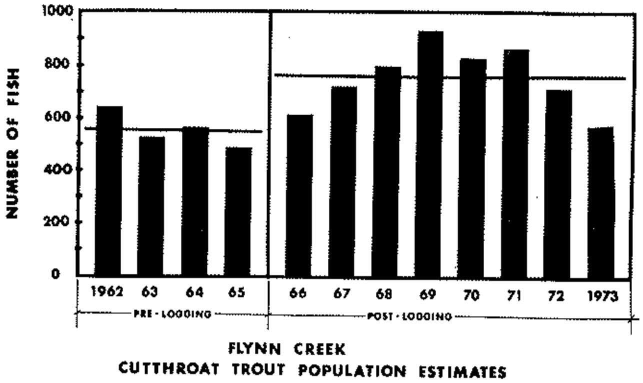

Figure 24. Estimated population numbers of cutthroat trout in Flynn Creek, 1962-1973. Logging occurred in 1966.

populations showed no decline in numbers in Deer Creek, but instead, followed the pattern of populations in Flynn Creek.

Post-logging population estimates were above pre-logging estimates in Deer and Flynn creeks, but individual post-logging yearly values fell within the pre-logging ranges of values. On Needle Branch, however, no post-logging yearly estimate ever approached the lowest estimate for pre-logging years. This population was depressed for the eight years following logging. The 1973 population was only 21.2 percent of the pre-logging average.

The extreme temperature increases following clearcutting, slash burning, and debris clearance slowly returned to pre-logging levels as the years passed, and riparian vegetation returned (see Part II – section on Stream Temperature). However, the population of cutthroat trout remained depressed. The change in water temperature may have contributed to the original population decline, but the population in later years has remained depressed. This population is now responding to other factors in the environment, exclusive of current water temperature patterns. The population may not have been able to compensate for the initial shock of increasing water temperatures.

It should be noted that the numbers of cutthroat juveniles passing through the downstream trap on Needle Branch were generally greater than the population estimates the previous fall. We believe the source of these additional fish is the upper, unstudied area above the falls on Needle Branch.

Comparisons with Other Studies

This type of decline in cutthroat trout populations has been noted in short-term logging studies, but the historical documentation for a given stream has been lacking until now. Burns (1972) found that steelhead and cutthroat trout (combined) populations declined immediately after logging in Bummer Lake Creek, California. Fourteen months after logging the age 0 populations had returned, but the yearling and adult populations remained depressed, presumably from the low numbers in the year class during logging. Water temperatures were higher in clearcut than noncut areas (4.4°C higher), but maximum temperatures were never as extreme as those found in Needle Branch (see Part II – section on Stream Temperature).

Similarily, Moring and Lantz (1974) found declines in cutthroat populations in four Oregon streams following logging. The reductions were greatest in the two streams with clearcut watersheds and no buffer strips: a 48.6 percent decline in the Dick Creek population, and a 44.1 percent decline in the Hidden Valley Creek population. Changes were minor in the stream with only road construction in the watershed (Hodges Creek: 4.4 percent decline) and the stream clearcut with a buffer strip (Fivemile Creek: 6.6 percent decline).

Biomass

Lowry (1964) measured cutthroat trout biomass during 1962 and 1963, and the Oregon State Game Commission derived cutthroat biomass values in 1,000-foot study sections during 1969. Lowry found that cutthroat trout averaged 46, 48 and 33 kg/ha for Deer Creek, Flynn Creek and Needle Branch, respectively. Deer and Flynn creeks had deep pools and more deeply undercut banks than Needle Branch. It is interesting to note that Lowry made the observation in 1964 that cutthroat trout were more dependent upon cover and pools than were coho salmon. Two years later, when riparian vegetation along Needle Branch was removed during logging, the cutthroat trout population decreased dramatically (see section on Cutthroat Trout – Population Estimates). From Lowry's research, the reduction in cutthroat biomass following logging may be due, at least in part, to removal of cover.

Lowry studied monthly biomass levels of cutthroat trout populations in the three test streams. He found total biomass was lowest near the first of May, and slowly increased with the addition of the new year class of fish. Peak biomass was generally reached by the first of October. Biomass at that time was almost twice the level of May 1. After the fall peak, growth rates declined with decreasing water temperatures, and biomass declined until May.

Values were higher in all streams in 1969 than during Lowry's pre-logging measurements in 1962 and 1963. However, measurements in 1969 were during September, the period of peak biomass for cutthroat. Converted cutthroat biomass was 50.6 kg/ha (5.1 g/m^2 or 45.1 pounds per acre) in Deer Creek, 56.3 kg/ha (5.6 g/m^2 or 50.2 pounds per acre) in Flynn Creek, and 29.1 kg/ha (2.9 g/m^2 or 26.0 pounds per acre) in Needle Branch. It is interesting to note that the biomass of cutthroat was higher than coho salmon in all streams during 1969 (see section on Coho Fry and Fingerling - Biomass). But, the population estimates indicate the population of cutthroat was depressed as a result of logging.

Adult fish

Timing and Magnitude of Upstream and Downstream Migrations

Upstream migrations of adult cutthroat along the Pacific coast begin in late June to July at the mouths of rivers (Giger 1972; Jones 1974), but the Eva Lake, Alaska, run begins as early as May (Armstrong 1971). The runs peak in late September to mid-October, and all movement into the large rivers is generally completed by November. Spent adults move downstream with downstream moving smolts and parr. Peak numbers generally precede the peak run of smolts (Giger 1972).

Upstream migrations of adult cutthroat (>275 mm FL) in the study streams are restricted to only six months of the year with the vast majority of fish migrating in November, December and January (Table 29). For the entire study period, 100 percent of the upstream migrating adults in Needle Branch moved in these three months. The percentages moving during these peak months were also high on the other streams: 91.2 percent in Deer Creek, and 96.3 percent in Flynn Creek. There was no significant change in upstream migration times due to logging. There was an increase in

Table 29. Percentage of occurrence, by month, of upstream migrating cutthroat trout.

	Month											
Stream	J	F	M	A	M	J	J	A	S	O	N	D
Deer Creek												
Pre-Logging	26.3	7.0	0.9	-	-	-	-	-	-	1.8	25.5	38.6
Post-Logging	21.8	4.0	-	-	-	-	-	-	-	4.0	20.8	49.5
Flynn Creek												
Pre-Logging	27.1	2.3	0.8	-	-	-	-	-	-	-	30.8	39.1
Post-Logging	16.8	2.2	-	-	-	-	-	-	-	2.2	24.9	54.1
Needle Branch												
Pre-Logging	80.0	-	-	-	-	-	-	-	-	-	20.0	-
Post-Logging	19.0	-	-	-	-	-	-	-	-	-	28.6	52.4

post-logging years in peak numbers in December. However, this occurred on all three streams.

Downstream migrations of adults generally occur within a narrow period of the year (Table 30). A few adults may begin to move downstream in November, but 85.8 percent of the trout passed back downstream during December to March. There are scattered adults moving downstream in May. As reported by Giger, the peak in adult numbers takes place earlier than downstream movements of juveniles. Peak months were January and February on all streams. With the exception of one fish in 14 years, no adults moved downstream from June through October.

Adult Movements in Streams

Lowry (1965) tagged cutthroat trout larger than 125 mm in the upstream areas of Deer Creek. Typically, there was little instream movement during summer months and considerable movement during higher water levels in winter and spring. During the period June to November, trout were usually recovered in the same pool in which they had been placed after tagging. But, during the winter months there was often an upstream migratory pattern for trout in Deer Creek. We have recognized this same pattern for juveniles and small adults on the other streams as well (see section on Cutthroat Juveniles – Movements of Juveniles in Streams).

Table 30. Monthly pattern of migration for adult cutthroat trout through the downstream trap, 1960-1973.

	Stream			
Month	Deer Cr.	Flynn Cr.	Needle Br.	Total
January	42	87	14	143
February	70	62	12	144
March	35	27	8	70
April	11	18	6	35
May	4	3	-	7
June	-	-	-	0
July	1	-	-	1
August	-	-	-	0
September	-	-	-	0
October	-	-	-	0
November	13	9	6	28
December	17	41	13	71

During this upstream migration in winter months, Lowry noted that larger trout would move to the upper sections of the creeks, or enter the tributaries for spawning. By summer most older fish return back downstream often to the same pools where they resided the previous summer.

Spawning

No cutthroat trout spawning surveys were undertaken with regularity during the study. Cramer (1939) discussed the spawning of cutthroat in the North Fork of the Alsea River. Most cutthroat spawn in December, January and February, with a few extending into March and April. Lowry (1964) tagged adults in the stream and found little upstream movement until fall. At that time spawning adults were in the tributaries or upper portions of the main streams. Lowry found some spawners later returned to pools where they were originally tagged. A primary reason for not conducting spawning surveys or trapping redds during the Alsea Watershed Study was the difficulty in locating spawning pairs and redds in the winter period of high streamflow.

Juvenile fish

Movements and Timing of Movements Through Traps

The timing of downstream movements of juvenile cutthroat trout is fairly consistent along the Pacific coast. Downstream movements may occur as early as March (Sumner 1962; Skeesick 1965), but generally begin in April (Hansen 1963; Armstrong 1971; Giger 1972; Royal 1972; Jones 1974). The peak of migration is usually from late April to mid-May.

Giger (1972) and Jones (1974) noticed a correlation between age and size in the downstream migration. The first group of juveniles to migrate downstream are the smolts destined for the sea. These are larger fish than subsequent migrants in the Alsea River. Giger has shown the smolt migration to be generally from April to early June. Smolts are generally followed by "parr", or young nonsmolting cutthroat destined for freshwater areas downstream. Their migration begins in late April, peaks in May, and continues with lesser numbers into late fall and winter months.

Lowry (1975) used the figure of 275 mm as being the length separating trout passing downstream for the first time and kelts (trout returning downstream). This figure was found to be statistically valid for separating adults and smolts by length. The only way to distinguish some smolts and downstream migrating parrs is by migration time, visual appearance, or scale analysis.

Downstream migration was primarily a seasonal occurrence, but migrants were recorded through the traps in all months of the year. In most years peak movement was in April, with lesser numbers in March and May. Over 80 percent of the downstream migrants (parr and smolts) passed through the traps in March, April and May. Over one-third of the migrants moved in April in all three streams.

The migration pattern was similar in all three streams. A few scattered migrants appeared in September and October, but in most years juveniles did not begin to migrate downstream until November. Numbers were generally low in November and December, but higher in January and February. The peak of the run was over by the end of May, but there were some migrants in June and a few scattered fish as late as July and August in some years.

Analysis of the migration pattern in Needle Branch illustrates characteristic timing (Figure 25), and also a change in downstream movement following logging (Table 31). Logging occurred in 1966, and the maximum stream temperatures (see Part II – section on Stream Temperatures) were reached in 1967, following slash burning and debris clearance. During the following two years, 1968 and 1969, there was a shift to earlier downstream migration times for juvenile cutthroat. From Giger's (1972) study of cutthroat we expect this initial group to be smolting fish heading for

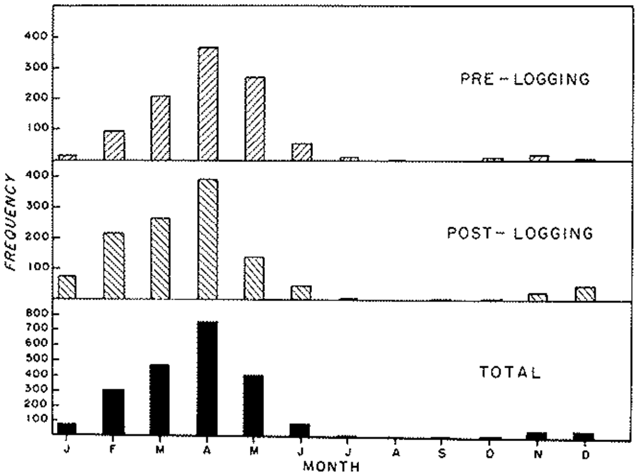

Figure 25. Downstream migrations of juvenile cutthroat trout in Needle Branch during pre-logging and post-logging years.

Table 31. Timing of downstream migrations of juvenile cutthroat trout in Needle Branch, 1960-1973.

Season	Month											
	S	O	N	D	J	F	M	A	M	J	J	A
1959-60		6	12	2		13	56	78	49	2	2	
1960-61		2			6	24	22	42	33	8		
1961-62		2	2				11	29	16	1	1	1
1962-63			3			1	31	71	40	13	5	
1963-64			2			18	53	18	63	15	2	
1964-65			2			16	9	124	55	7		1
1965-66			2	1		21	25	4	9	6	2	
1966-67			5	8	1	5	24	45	14			
1967-68		2	11	9	26	99	84	44	43	40	1	
1968-69	1	1	1	18	19	85	28	80	30	2	1	
1969-70	1	1	3	2	21	15	64	114	25		1	
1970-71		2	5	5	7	4	19	49	7	2	1	
1971-72				1		3	21	19	12	2		
1972-73					1		25	39	8			
Pre-Log. Total	0	10	21	2	6	93	207	366	265	52	12	2
Post-Log. Total	2	6	27	44	75	211	265	390	139	46	4	0
Total	2	16	48	46	81	304	472	756	404	98	16	2

sea. This is understandable since migrations in some salmonids are regulated by temperature patterns. As the temperature range was reached earlier in the year, there was a shift in migration timing. By 1970, the timing of migrations had shifted back to the pre-logging patterns. It should be noted that there were no significant shifts in numbers of downstream migrants following logging.

Movements of Juveniles in streams

Upstream movements of juveniles (<200 mm FL) were primarily seasonal in nature. Fish migrating during November, December and January accounted for 88.3 percent of the total numbers in Deer Creek, 71.2 percent of those in Flynn Creek and 47.7 percent of those in Needle Branch.

An interesting trend was noted on all three streams. Prior to the 1966 logging, juvenile cutthroat were taken in the Deer Creek upstream trap during March through September (17.9 percent of all pre-logging fish) and the Flynn Creek upstream trap (42.5 percent of all pre-logging fish). In Needle Branch the bulk of the pre-logging runs were during March-September (83.0 percent of all pre-logging fish). After logging, there was never again a fish trapped during these months. The fact that the absence of fish during this period occurred in all three streams confuses the issue. The presence of weirs may have influenced these returns. Also, in some post-logging years, upstream traps were not operated during summer.

Confusion with Steelhead Trout

Young cutthroat and steelhead trout were often difficult to accurately distinguish in the field. The most definitive characteristic is the presence of basibranchial teeth in cutthroat trout and the lack of same in steelhead trout. Above 75 mm FL, external characteristics can generally separate cutthroat and steelhead trout. Below that size, separate subsampling must determine the proportion of steelhead in the migrants at the time of their downstream migration.

Juvenile cutthroat and steelhead trout have certain characteristics (morphometric and coloration) which can be used in distinguishing the two species. These identifications were later verified by subsequent analysis of basibranchial teeth. Fortunately, most downstream steelhead migrants processed at the Deer Creek downstream trap were larger than 60 mm in length and could generally be separated from cutthroat trout by examination of maxillaries, coloration, spots on caudal fins and abdomen, black borders on adipose fins, and appearance of parr marks.

STEELHEAD TROUT

Adults

Sex ratio

Eighty-one adult steelhead passed through the Deer Creek upstream trap during the 14 winter seasons. The sex of one fish was not recorded, but of the remainder 55 were males and 25 were females, providing a ratio of 2.2:1. Sixty of these adults returned downstream after passing through the downstream trap. Of those, 46 were males and 14 were females, representing a downstream or "return" ratio of 3.3:1. The indication is that a higher proportion of males moved back downstream because of limited numbers of females and redds. Of those adults actually spawning in Deer Creek, the ratio was 1.6 males to 1 female.

Wallace (1961) has reported steelhead sex ratios of 0.16:1 to 1.25:1, males to females, for trap returns on the upper Alsea River. In British Columbia, Withler (1966) has reported female dominant ratios of 1:1.3 to 1:3.2, males to females. Shapovalov and Taft (1954) have reported sex ratios of 1:1.1 in California, and Pautzke and Meigs (1940) have noted ratios near 1:1 in Washington.

To determine whether early or late migration of adults was related to the sex of individual fish, two procedures were used. First, the numbers of males and females passing through the trap prior to and after the middle of February (the approximate mid-point of the run for all years) were counted. Results indicate male and female arrivals were evenly divided during the two periods: 28 males before February 12 and 27 after; 12 females before and 13 after. Next, the numbers of early arrivals (prior to February) were counted, as were the late arrivals (after February). Again, the males and females were evenly divided: 15 early males and six early females; 13 late males and six late females. The term "late" is a relative one and applies only to the Deer Creek population during the 14-year study period. It appears that neither early nor late arrivals were of any one sex or significantly different from the overall adult sex ratio.

Throughout the 15 years of study, only one precocious male (121 mm FL) was collected. It was passed through the downstream trap in February 1967.

Age Characteristics

Steelhead may spend as many as five years in freshwater (Narver 1969), but four years is generally the limit along the Pacific Coast. Adult steelhead spend no more than five to six years at sea, but most never reach that age. Most steelhead trout returning to streams along the Pacific coast have spent at least two years at sea. The maximum age of steelhead trout is generally considered to be seven years, but rare older individuals have been noted (Sumner 1948; Washington 1970). Scales of only 73 adults were analyzed during the 15-year study. At least one scale was read every year from 1960 to 1973, with the exception of 1970. The maximum number analyzed in any one year was 14 in 1967. Despite the limited amount of age information, the age classification pattern was similar to that found by Chapman (1958) for wild Alsea River steelhead. Eleven different age combinations were obtained (Table 32).

The most frequent combination was 2/2 (41.1 percent of all adults). The next most frequent groups were 1/2 (21.9 percent) and 3/2 (19.2 percent). For all adult samples 82.2 percent spent two years at sea.

The only differences in age group percentages in Deer Creek and those found by Chapman are because his samples

Table 32. Life history patterns of 73 adult wild steelhead trout taken at the upstream trap of Deer Creek.

Years in Salt Water	Years in Fresh Water 1	2	3
1	3	1	1
2	16	30	14
3	0	4	1
4	1	1	0
5	0	0	1

Table 33. Comparisons of percentages in different age groups for adult wild steelhead trout. Alsea River samples were obtained by Chapman (1958) during 1951-1955, while the Deer Creek samples were collected during 1960-1973.

Age Combination	Alsea River Steelhead	Deer Creek Steelhead
1/1	-	4.1%
1/2	0.2%	21.9
1/3	0.9	-
1/4	0.3	1.4
2/1	4.0	1.4
2/2	52.5	41.1
2/3	21.8	5.5
2/4	1.9	1.4
3/1	1.3	1.4
3/2	13.6	19.2
3/3	2.9	1.4
3/4	0.4	-
3/5	-	1.4
4/1	0.1	-
4/2	0.1	-

came from other sections of the Alsea River, not from the Drift Creek system. The principal areas of difference between Chapman's Alsea River data and patterns on Deer Creek are a significantly higher number of Deer Creek fish of age 1/2, and a significantly lower number of Alsea River fish of age 2/3 (Table 33). Although Deer Creek is part of the Alsea River system, the Drift Creek system is the first major tributary system encountered by fish moving from the estuary. It is logical to assume that age characteristics of this system would be slightly different than all other portions of the Alsea River summed.

A single 8-year-old steelhead returned to the upstream trap on Deer Creek in 1967. Such an old fish is rarely encountered. The fish was 800 mm FL and weighed 4.48 kg.

For the ten individual freshwater/saltwater age groups there was little change between pre-logging and post-logging years. It should be noted that the sample size is not sufficient to warrant additional comment concerning logging influences on steelhead adult age groups.

Life history patterns were compared with fork lengths of returning adults (Table 34). As might be expected, the larger fish were generally the older fish. Two-year-old fish (in their third year) comprised only 4.1 percent of the returnees, and these were all less than 475 mm FL. Except for one small fish (apparently a jack), three-year-olds were larger than 550 mm FL. Four-year-old fish were the largest component of the run (42.5 percent). Except for one small fish, all were between 526 and 700 mm FL. The average age components of the Deer Creek run for 1960-1973 are as follows:

2-year-old	4.1%
3-year-old	23.3%
4-year-old	42.5%
5-year-old	26.0%
6-year-old	2.7%
7-year-old	0.0%
8-year-old	1.4%

Growth rates were analyzed for adult steelhead on the basis of 73 scale samples (Figure 26). Freshwater growth was similar to that found from juvenile steelhead scale samples (see section on Juvenile Steelhead Age Characteristics).

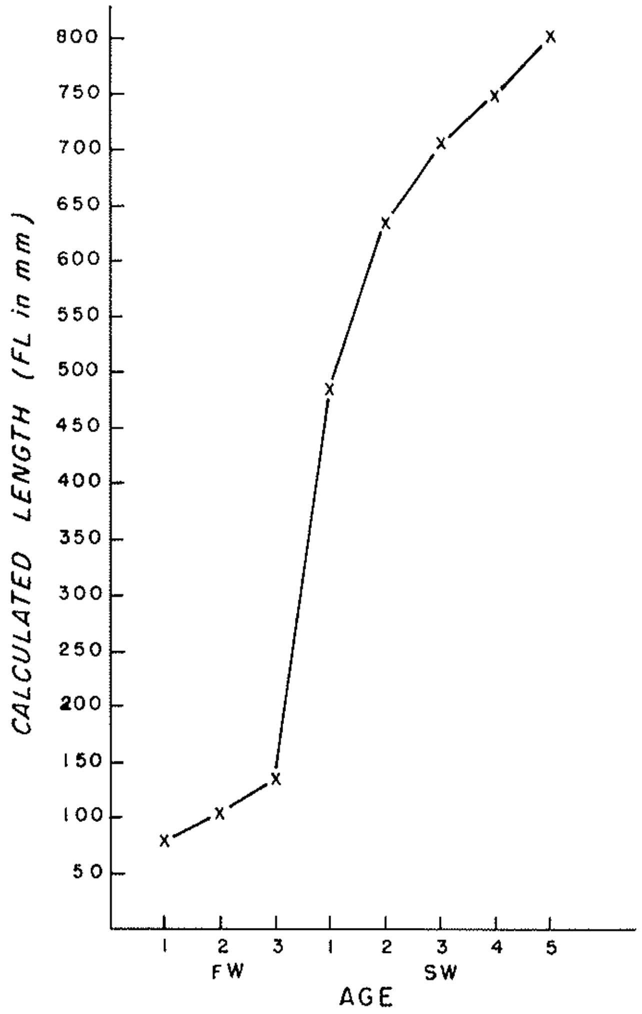

Figure 26. Growth of steelhead trout from Deer Creek. Lengths are back-calculated from adult scale samples.

Table 34. Life history patterns of returning adult steelhead trout on Deer Creek compared to fork lengths of adults.

Length Range	Age 1/1	1/2	1/4	2/1	2/2	2/3	2/4	3/1	3/2	3/3	3/5
400-425 mm											
426-450	1							1			
451-475	2			1							
476-500											
501-525											
526-550					1						
551-575		2			1				1		
576-600		3									
601-625		3			7				6		
626-650		1			10				3		
651-675		2			9				4		
676-700		1			2	1					
701-725						3	1				
726-750		3								1	
751-775		1	1								
776-800											1

Growth during the first year of freshwater residence was somewhat greater in adult samples, but this can be attributed to the fact that many of the adults could have remained in freshwater for a period after spawning and entry into traps. Scales of 20 adults that spent only one year in freshwater showed an average proportional length of 59 mm at the first freshwater check. The average for the remaining 1/ fish was 52 mm, which is virtually the same as the growth point in juvenile scales.

The greatest growth in steelhead trout was achieved from the time of the final freshwater winter check to the time of the first ocean check. For an average steelhead (2/2) the growth achieved during this transition period from freshwater to saltwater represents approximately 51.6 percent of the length achieved by the steelhead during its lifetime. For the one 8-year-old steelhead recovered, growth during the transition period was still 42 percent of its entire lifetime length increase. In the case of this fish, 38.8 percent of its lifetime length growth was achieved from the actual time of entry into saltwater and its first saltwater check. After the first year in saltwater, growth rates (in terms of length) decline for successive years.

Length and Weight

Average lengths and weights of upstream migrating adult steelhead are shown in Table 35. The limited number of fish makes interpretation difficult, especially for weight data. Fish ranged in size from 133 to 800 mm FL, but lack of sufficient data makes analysis a futile exercise.

Sheppard (1972) has expanded a table of Withler (1966) to compare the size characteristics of steelhead stocks from California to Alaska. There appears to be a direct relationship between larger sizes and higher latitudes. Hallock et al. (1961) have shown that steelhead returning to the Sacramento River average only three pounds in weight (1.4 kg). Smaller fish (one year at sea) average 15.5 inches (394 mm), while larger fish (two years at sea) average 20.5 inches (521 mm). The average size of adult steelhead from Deer Creek was similar to that found by Bulkley (1967) for females trapped on the North Fork of the Alsea River. Following the same trend, more northerly races of steelhead appear to be larger than those in Deer Creek (Withler 1966; Narver and Withler 1971).

Condition Factors

Only 16 adult steelhead were weighed and measured, so condition factor data are limited. Condition factors averaged 0.96 and ranged between 0.76 and 1.10. The average condition factor for eight female adults was 0.98 while the average condition factor for seven male adults was 0.96.

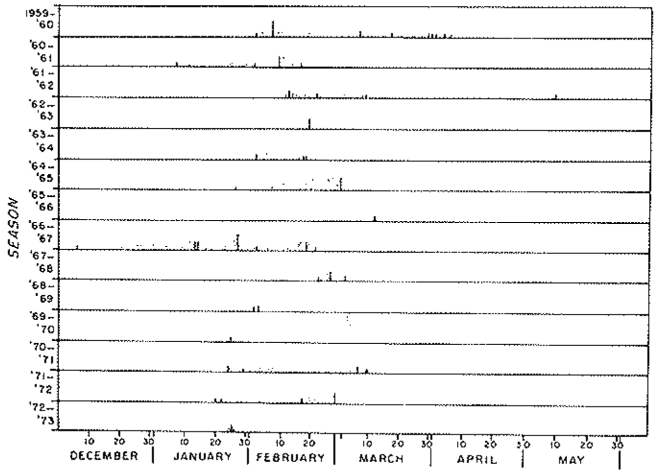

Figure 27. Timing of arrival of adult steelhead trout on Deer Creek.

Table 35. Average lengths and weights, with ranges, for upstream migrating adult steelhead trout on Deer Creek, 1959-1973.

Year	Number	Average Length (mm) and range in ( )	Average Weight (Kg) and range in ( )
1959-60	15	590.5 (260-711)	-
1960-61	6	484.5 (133-686)	-
1961-62	5	666.8 (616-743)	-
1962-63	3	643.3 (622-667)	-
1963-64	4	605.8 (459-705)	2.20 (851-3260)
1964-65	5	622.8 (442-710)	-
1965-66	1	595.0	-
1966-67	17	638.8 (461-800)	4.48 (4479.3)*
1967-68	6	628.0 (555-745)	-
1968-69	3	606.0 (604-609)	-
1969-70	1	738.0	4.39 (4394)
1970-71	6	638.3 (530-760)	2.25 (1956-2552)**
1971-72	6	636.0 (601-656)	2.44 (2098-2920)
1972-73	2	671.0 (650-692)	2.89 (2552-3232)
Pre-Logging Average		593.8	2.20
Post-Logging Average		638.3	2.82

*17 fish measured, but only one (the largest) weighed.

**6 fish measured, but only two weighed.

Timing and Extent of Spawning Runs

Upstream trap records indicate that February is the peak of the spawning run of winter steelhead on Deer Creek (Figure 27). Of all arrivals, 49.4 percent moved into Deer Creek in February. Another 25.9 percent arrived in January and 19.8 percent arrived in March. Only 4.9 percent (four fish) moved into the stream in other months. Of those four fish, one female arrived in December 1966, but remained in the stream for 73 days, spawning with later arrivals. Of the two April 1960 arrivals (both males), one left without spawning, while the other remained in the stream for 12 days and apparently spawned. The lone May arrival (a male in 1962) arrived long after other fish and apparently died in the stream without spawning.

Analysis of pre-logging and post-logging steelhead returns shows a mean shift in arrival time by almost three weeks. Mean arrival time in pre-logging years was February 23, while mean arrival time in post-logging years was February 4. During pre-logging years fish arrived as early as January 7 and as late as May 9. After logging, no fish ever arrived after March 10. With the exception of one fish in December, there were no spawning adults before Janaury 13 (Figure 28).

The distinct shift of arrival times of steelhead between pre-logging and post-logging years cannot be explained by logging-related activities. Adult steelhead returns to the North Fork Alsea Hatchery have shown a subtle shift in spawning arrivals over the past 30 years. Since the introduction of hatchery runs in the Alsea River, there has been a trend toward earlier arrival times of spawners (H. H. Wagner, personal communication). Historically, the peak of the Alsea River steelhead run was April with early arrivals in February and March and late arrivals in May and June. With the establishment of hatchery runs, the arrival times at the hatchery have been earlier. It has been thought that the heavy hatchery component of the run may have influenced the timing of migrations of wild stock. If so, this would apparently explain much of the shift in the Deer Creek population from pre-logging to post-logging years. The Deer Creek run is wild, although there is some straying into the stream (and out again) of wild stocks from Horse Creek and Drift Creek and of hatchery fish from the North Fork Hatchery.

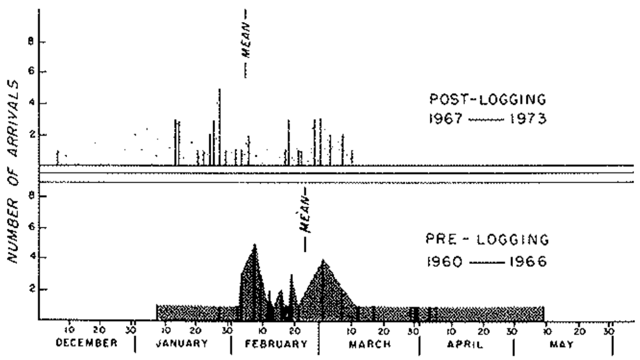

Figure 28. Timing of steelhead adults on Deer Creek for pre-logging and post-logging years.

This reasoning would also explain the presence of scattered wild arrivals in April and May during the early years of the study and their absence in the spawning runs since 1962. When the timing of the run is shifting to an earlier arrival, the late arrivals have fewer and fewer fish with which to spawn. Soon this component of the run ceases, and the April, May and June arrivals disappear.

Movement of Adults Through Traps

Eighty-one adults passed through the upstream trap during the 14 winter seasons. Sixty of these ultimately moved back downstream and were processed through the downstream trap. Some remained in the stream for extended periods, others died in the stream and an unknown number could have escaped, unprocessed, out of the downstream trap.

Table 36 summarizes the best indication of numbers of adult steelhead entering and leaving Deer Creek and the number and sex of presumed spawners each year. Of those fish processed and passed upstream, 74.1 percent ultimately moved back downstream. These fish moving downstream were from the following groups: (1) spent spawners from Deer Creek; (2) assumed strays from Horse Creek and Drift Creek exploring Deer Creek and then returning downstream to spawn; and (3) strays from hatchery releases. Some of the latter strays remained in Deer Creek to spawn. Others moved back downstream to either spawn in Horse Creek or Drift Creek or return to the main Alsea River.

Of the 81 adults returning to Deer Creek over the 14 years, ten had been previously marked by fin or maxillary clipping. An attempt was made to trace the origin and disposition of these fish. The best indication is that four of these fish actually spawned in Deer Creek. It is believed that three others also spawned, but their ultimate disposition is unknown. The remaining three fish left Deer Creek soon after entering without spawning. Information on these strays is summarized in Table 37.

The time spent by spawners and strays in Deer Creek varied greatly. Spawning fish that ultimately exited alive spent a minimum of six days in the stream and a maximum of 89 days. The average residence time was 34 days. Fish that died during or after spawning were generally carried downstream and recovered long after spawning. The longest duration between upstream migration and downstream carcass recovery was 144 days.

Assumed strays from other creeks (39.5 percent of all adults) spend little time in Deer Creek. Of all unspent adults, 44.4 percent spent one day or less in Deer Creek and 74.1 percent spent less than five days.

The trap complex apparently had no disconcerting effect on upstream migration of steelhead. Upstream migrants may have returned downstream, but none ever moved upstream again. Several species of *Oncorhynchus* tend to be easily "spooked" on their upstream migration and may move back downstream. These fish generally continue the upstream migration at a later date. Steelhead trout on Deer Creek exhibited no such behavior and we must assume that the unspent fish moving back downstream were strays from other streams.

Fry and fingerlings

Length and Weight

A total of 59 juvenile steelhead were weighed and measured. They weighed an average of 14.8 g, ranging from 3.2 to 40.6 grams. The size range was 67 to 166 mm, averaging 108.6 mm FL. An additional 840 juvenile steelhead were measured only. The total group of 899 averaged 105.0 mm FL, with a size range of 59 to 198 mm FL.

Figure 29 illustrates the length-weight relationship for these juvenile salmonids. The correlation coefficient was high (r = 0.98).

There was a slight decrease in average size of downstream migrating juveniles from pre-logging to post-logging years

Table 36. Numbers of adult steelhead moving through the upstream and downstream traps, and the presumed numbers of spawners each year on Deer Creek, 1960-1973.

Season	Number of Adults Moving Upstream	Number of Adults Moving Downstream	Presumed Number of Spawners M	F
1959-60	15	15	3	2
1960-61	6	5	2	1
1961-62	6	6	1	1
1962-63	3	2	1	1
1963-64	4	4	1	2
1964-65	5	1	3	1
1965-66	1	0	0	1
1966-67	17	11	9	3
1967-68	6	5	2	1
1968-69	3	3	1	1
1969-70	1	0	0	1
1970-71	6	5	2	1
1971-72	6	3	4	2
1972-73	2	0	1	1

Table 37. Records of adult steelhead entering Deer Creek with previous hatchery fin clips, 1961-1973.

Date of Entry	Sex	Length	Fin Clip	Date of Exit	Condition at Exit	Duration in Stream	Spawned in Creek?	Hatchery Release?
9 February 1961	♂	686 mm	Adipose	20 February	-	11 days	yes	1959
6 December 1966	♀	555 mm	Adipose, Right Vent.	17 February	-	73 days	yes	1965
18 February 1967	♂	461 mm	Left Vent.	22 February	-	4 days	no	1965
26 February 1968	♂	670 mm	Left Vent., Right Vent.	27 February	-	1 day	no	1966
7 March 1971	♂	600 mm	Adipose	9 March	spent at entry	2 days	no	1968
20 January 1972	♂	652 mm	Adipose, Right Vent.	2 March	dead	41 days	yes	possibly-1969
17 February 1972	♂	635 mm	Right Max.	11 May	dead	83 days	yes	1970
28 February 1972	♀	642 mm	Adipose	unknown	-	-	yes	1970
28 February 1972	♀	656 mm	Adipose	unknown	-	-	yes	1970
25 January 1973	♂	692 mm	Adipose	18 June	dead	144 days	yes	1971

(107.0 and 100.1 mm FL, respectively). This may be related to the significantly lower numbers of outgoing steelhead smolts in post-logging years (see section on Movements of Juveniles Through Traps). Andrews (1958) has reported the mean length and weight of migrating wild juveniles (regardless of age) to be 163 mm FL and 42.6 g, respectively on the Alsea River.

Condition Factors

Condition factors were determined for the 59 juvenile steelhead which were weighed and measured. The average condition factor was 0.99, ranging from 0.87 to 1.12. All measurements were for juveniles collected in post-logging years (1971-1973). The lengths of these juveniles ranged from 67 to 150 mm FL. The condition factors shown by these downstream migrating juveniles are comparable to values found by steelhead researchers on the Alsea River.

Age Characteristics

Scale samples of juvenile steelhead trout from Deer Creek were only analyzed periodically: in 1961, 1962, 1971, 1972 and 1973. A total of 176 scales were analyzed. Age 1+/ fish comprised the majority of these scales examined, followed by age 2+/, 2/ and 3+/ (Table 38). Overall, 56.2 percent of the fish migrated through the trap after one winter and most of these had some additional freshwater growth (prior to spring emigration). Of the remainder, 34.7 percent of the fish left after two freshwater winters and 9.1 percent stayed for three winters. No fish examined spent longer than three years in freshwater.

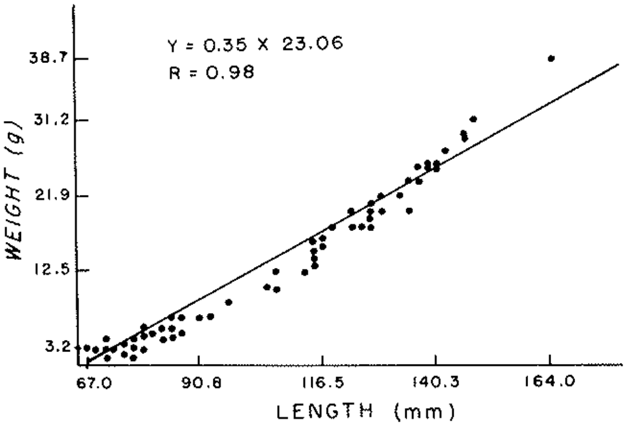

Figure 29. Length-weight regressions for juvenile steelhead trout on Deer Creek.

It is apparent that most of the downstream migrants passing through the trap were not destined immediately for sea. The fish were smaller than most smolts in the main Alsea River (see section on Juvenile Length and Weight), and the freshwater age characteristics of adult scale samples indicates over half the adults spent two years in freshwater. Only one-quarter of the returning adults actually left freshwater after 1/ or 1+/ years. We believe that a large number of these

Table 38. Age characteristics of juvenile steelhead trout from scale samples of downstream-migrating juveniles at the Deer Creek downstream trap.

Year	N	Fork Length Range	Age Class 1/	1+/	2/	2+/	3/	3+/
1961	2	109-133 mm			1		1	
1962	114	64-158		68	8	28	3	7
1971	14	78-148		12		1		1
1972	26	105-166		1	8	14		3
1973	20	67-135	1	17		1	1	
Total			1	98	17	44	5	11
Percentage			56.2%		34.7%		9.1%	

Table 39. Age characteristics of juvenile steelhead trout arranged by size (mm FL) from downstream trap scale sampling on Deer Creek.

Size Range	Freshwater Age 1/	1+/	2/	2+/	3/	3+/	Total
61 - 70		7					7
71 - 80	1	34					35
81 - 90		34	1	1			36
91 - 100		17	5	4			26
101 - 110		3	4	12	1	2	22
111 - 120		3	2	12	1	1	19
121 - 130			3	6	1	1	11
131 - 140			1	4	1	1	7
141 - 150			1	4		4	9
151 - 160				1	1	1	3
161 - 170						1	1
Total	1	98	17	44	5	11	176

downstream migrants are actually moving to larger branches of the Alsea River, Horse Creek and Drift Creek to complete their freshwater residence.

To study the correlation between juvenile fish size and freshwater age history, the age characteristics were projected against 10 mm FL size groups (Table 39). As might be expected, the older fish were also the largest and vice-versa. Most one-year-old fish were 71-90 mm FL, while most two-year-old fish were 101-120 mm FL. The lengths of the three-year-old fish were scattered between 101 and 166 mm FL. The length frequency information indicates a peak in the 71-90 mm FL area. Of the fish in that size range 97.2 percent were 1/ or 1+/.

As might be expected, growth was more rapid during the first year of freshwater than in subsequent freshwater years. Likewise, growth was more rapid the second year than the third. Three-year-old fish averaged 54 mm FL the first year, 93 mm after the second year, and 123 mm after the third year. This is an increase in size of 72.2 percent the second year, and a size increase of 32.2 percent the third year. Fish that eventually migrated as two-year-olds grew slightly better: 56 mm FL average after the first year and 107 mm FL after the second year. This is a size increase of 91.1 percent the second year for these fish. Fish that migrated as one-year-olds averaged 58 mm FL after the first year. All lengths are back-calculated from scales, using proportional measurements.

There was no significant difference between the age characteristics of juveniles during pre-logging years and those in post-logging years. During both periods, age group 1+/ dominated followed by 2+/ and 2/.

Movement Through Traps

Downstream migations of juvenile steelhead primarily occur in spring months, but may occur at any time. Hallock et al. (1961) found that peak migration in the Sacramento River was during spring, but a smaller peak occurred in fall. In both cases, mass movement was triggered by the first heavy runoff of the spring or fall. Shapovalov and Taft (1954) also found that peak downstream migration of juvenile steelhead to be spring in Waddell Creek, California. They also found a relationship between age classes and timing of runs. On the Green River, Washington, Pautzke and Meigs (1940) found peak migration was May, with migrants leaving as early as April and as late as June. Sheppard (1972) has also noted that the principal migration times in Oregon and Washington are April through June, with a peak in mid-April. On the Alsea River, Wagner et al. (1963) found the peak downstream migration of juveniles occurred from mid-April to mid-May. Juveniles in lesser numbers migrated out from early April to early June (traps closed other times). Andrews (1958) reported the peak migration during his 1957 studies as April 27 to May 7.

Downstream migrations of juvenile steelhead were seasonal on Deer Creek. With few exceptions all downstream migrations were during February through June. A few scattered migrants passed through the trap in January, July, October and December, but these fish accounted for only 1.2 percent of all migrants (Table 40). The peak of the migration occurs in early April with 45.8 percent of all migrants leaving in April and 27.0 percent in March. On the average 89 percent of the migrants leave during three months of the year (March, April and May) (Figure 30).

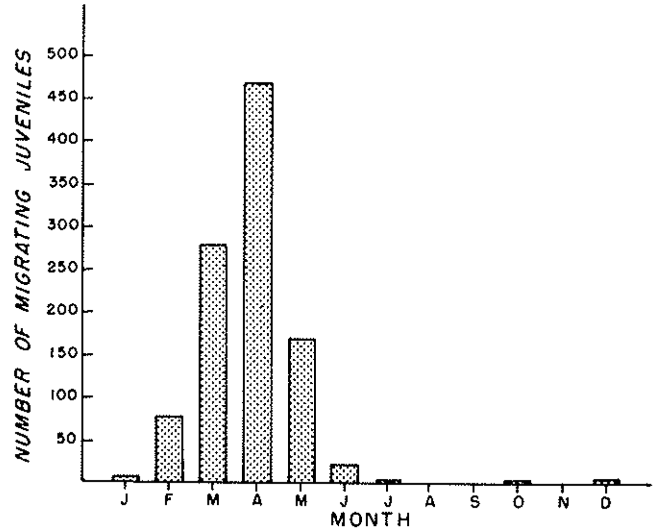

Figure 30. Monthly migratory patterns of juvenile steelhead trout on Deer Creek, with the years 1959-1973 summed.

By analyzing the monthly migratory patterns of juveniles, two points can be made. First, there is a change in the number of outgoing juveniles from pre-logging to post-logging years. Second, there is an apparent cyclic nature of migrations which is not related to numbers of adult spawners.

During the pre-logging years, outgoing steelhead smolt production averaged 108 juveniles, ranging from a low of 10 in 1964 to a high of 333 in 1960. The average length of these fish was 107.0 mm FL. After logging, the average migrant production dropped by 64.9 percent to 38 fish. The post-logging levels varied from a low of zero fish in 1969 to a high of 87 fish in 1971 and 1973 (Figure 31). Despite these differences between pre-logging and post-logging, the smolt numbers are not significantly different at the 95 percent level (t = 1.54).

To determine if variations in smolt production could be related to changes in potential fecundity (from variations in adult spawner numbers), a smolt quotient value was

Table 40. Numbers of measured and unmeasured juvenile steelhead trout passing through the downstream trap on Deer Creek (compiled by month of migration).

	Month											
Year	J	F	M	A	M	J	J	A	S	O	N	D
1959										1		
1960		21	89	127	78	17						1
1961	3	9	25	44	10							
1962	1	10	55	108	18	2						
1963		21	2	11								
1964	1			6	3							
1965			9	27	2							
1966	1	1	10	27	19							
1967		1	2	16	9							
1968			12	9	6	3						
1969												
1970				1	1							
1971			16	52	16		2					1
1972		14	10	2	3							
1973	1	1	46	38	1							
Totals	7	78	276	468	166	22	2	0	0	1	0	2

N = 1002

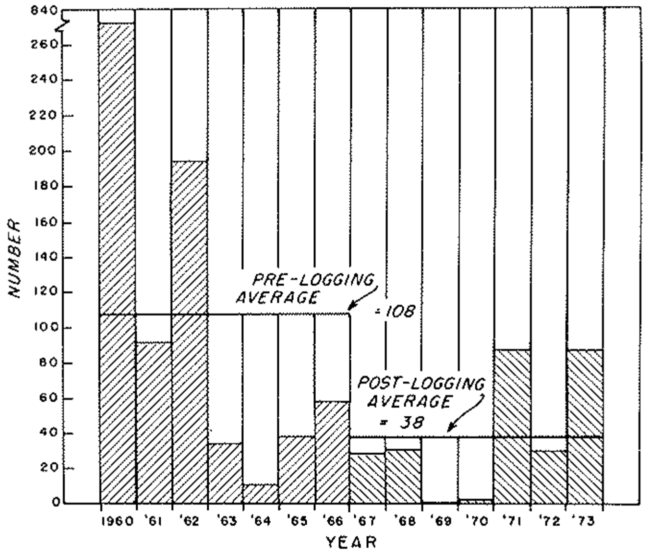

Figure 31. Numbers of downstream migrating juvenile steelhead trout on Deer Creek.

determined for each year. No attempt was made to predict the actual smolt production because of the variations in freshwater mortalities. These values were calculated to give only relative values which would indicate that there was a potential each year for production of steelhead fry.

During the analysis of the upstream and downstream trap records, the fate of all upstream-moving adults was charted. The total numbers of males and females actually spawning in Deer Creek were recorded. Next, an estimate of potential fecundity for each female spawner was determined using the formula of Bulkley (1967):

$$E = 130.53L - 5{,}054$$

where L refers to the fork length of the female in millimeters and E is the potential fecundity in thousands of eggs. The total potential fecundity (ΣE) was calculated for all spawners in a given year. The number of spawning females varied from one (10 of the 14 years) to three. Using the age-growth information from scale sampling of juveniles in Deer Creek the percentages of one, two and three-year-old fish ultimately produced from a given egg deposition season were derived. Using these percentages portions of the potential E for year X can be reflected in some lesser numbers of outgoing migrants in years X + 1, X + 2 and X + 3.

A plot of resultant smolt quotient values does not fit closely the plot of actual smolt numbers moving through the downstream traps, as freshwater mortalities undoubtedly varied over the entire study. In addition, a redd may have good survival-to-emergence one year, while a redd in a subsequent year may have poor survival-to-emergence. If, as was the case in most years, only one spawning female was present, the survival-to-emergence percentages can vary greatly from year to year. What the smolt quotient values did indicate is that at least one spawning pair of adults was present in Deer Creek each year and the total potential fecundity (ΣE) was sufficient each year to provide adequate numbers of fry to the stream.

There is an apparent cyclic nature to the yearly runs. This trend, if present, may be difficult to accurately analyze because of the limited numbers of spawners and outmigrants. During 1960, 1961 and 1962, there were distinct migrations with peaks in April, lesser numbers in March and May, and fewer numbers in February. During the following two years, the patterns of the runs were indistinct. The peak of the limited numbers in 1963 was February, while very few fish migrated in 1964. During the next three years, 1965, 1966 and 1967, the distinctive pattern was again present: peak in April, lesser numbers in March and May. The pattern was again indistinct with few out-migrants in 1968, 1969 and 1970, but was reestablished in 1971. Migration patterns of the next two years were again shifted to an early migration peak.

With the limited numbers of spawners, each with slightly different life history categories, variations in numbers and timing of migrants are to be expected. The limited age-growth information (see section on Age Characteristics) indicates the proportion of 1/, 2/ and 3/ fish in the samples is variable from year to year. As a result, it is reasonable to assume that a poor hatch of the mating between two 1/ adults might result in a lower number of potential 1/ juveniles migrating the following year. Of course, other factors contribute to this variation in numbers, including the amount of available food to obtain sufficient growth for smoltification to occur. Environmental changes can also influence juvenile mortalities, but there is no indication that logging activities on Deer Creek contributed to mortalities.

OTHER FISHES

Reticulate sculpins

The reticulate sculpin, *Cottus perplexus*, is widely distributed throughout the central and northern coastal streams of Oregon (Bond 1963, 1973). Patten (1971) has noted the species is generally found in waters of low velocity in pools near banks.

The reticulate sculpin is of interest to the work on the Alsea watershed for three reasons: (1) population numbers were generally higher than for all salmonid species; (2) total biomass of sculpins was quite significant and; (3) there is evidence that reticulate sculpins were predators on salmonid embryos and fry in the three study streams. Three studies have concentrated on the biology of the reticulate sculpin in Alsea River tributary streams. Phillips et al. (1966) made population and biomass estimates, Phillips and Claire (1966) discussed the predatory role of the reticulate sculpin, and Krohn (1967) analyzed the population characteristics and predatory capabilities.

Population Characteristics

Krohn (1967) studied the population characteristics of the reticulate sculpin on the three streams. His studies began in July 1965 during pre-logging conditions and continued into November 1966. This provided some comparison of pre-logging and post-logging conditions. As was the case with cutthroat trout, Krohn found reticulate sculpin populations on Needle Branch were adversely influenced by clearcut logging.

Dissolved oxygen levels were extremely low in certain areas after logging (see Part II, section on Dissolved Oxygen). Surface values were less than 2 ppm in these sections, below the minimum tolerance level for many cottids. As a result, sculpins were absent from these areas. After removal of logging debris in the streambed, the two youngest year classes (1965 and 1966) were almost nonexistent (Krohn). The combination of several environmental conditions following logging resulted in the almost complete destruction of the young of the year (year class 1966) in Needle Branch. Krohn observed eyed sculpin eggs in Needle Branch in April 1966. He surmised that they hatched during the period of unfavorable environmental conditions and most perished.

Population numbers on Deer Creek and Flynn Creek were apparently little changed during the experimental period 1959-1973. The buffer strips of vegetation and lack of significant change in environmental factors on Deer Creek appears to have promoted this condition. Krohn calculated the total density of sculpins per square meter in April 1966 as 3.00 on Deer Creek, 3.24 on Flynn Creek, and 2.10 on Needle Branch. Growth patterns of reticulate sculpins are somewhat opposite of those of many salmonids. The greatest growth rates are during late winter to early summer. Growth rates decline in late summer and early fall, and are minimal in late fall and early winter. The annual production of sculpins under natural (Flynn Creek) or protected (Deer Creek) conditions was approximately 2.8 g/m^2 (Krohn 1967).

Counts of sculpins moving through the three stream fish traps were quite low most years. Krohn found that what movement did occur was primarily during winter and spring months. Since Krohn's work, the average monthly number of cottids moving through the downstream traps were determined for the 1966-1973 post-logging period. It was found that the peak downstream movement occurred during the months of March, April and May (Table 41).

Summation of counts in the downstream, spillway, and upstream traps for the 15-year period, 559 sculpins were checked on Flynn Creek, 341 on Deer Creek, and 224 on Needle Branch (Appendix Tables 12, 13 and 14). Fish collected in traps ranged in length from 14 to 100 mm TL. There is some indication of a cyclic trend in the average lengths of sculpins over the 15-year period. The lack of sufficient data during certain years makes the validity of such a trend debatable.

Few sculpins were ever found dead in the traps. This is partly because relatively few fish were collected each year and partly because the Cottidae are generally hardy fishes. In Needle Branch, 1.8 percent of the sculpins were found dead in the traps and only 4.1 percent and 6.4 percent were dead in the Flynn Creek and Deer Creek traps, respectively.

Table 41. Average monthly counts of reticulate sculpins (*Cottus perplexus*) in the downstream trap of the study streams for the 1966-1973 post-logging period. Values were averaged for the complete years of 1966 to 1972 only, and serve to supplement pre-logging counts reported by Krohn (1967).

Month	Deer Creek	Flynn Creek	Needle Branch
January	1.1	2.9	0.3
February	2.6	1.4	0.4
March	3.0	4.3	1.7
April	3.6	5.6	1.4
May	2.9	3.4	0.1
June	2.7	2.0	0.4
July	3.0	1.9	0.4
August	2.3	0.7	0.0
September	3.0	0.1	0.0
October	1.0	1.6	0.1
November	1.9	2.1	0.0
December	1.4	1.4	0.6

In an attempt to determine if logging practices may have affected reticulate sculpin populations in the study streams, average lengths and average numbers per year of the pre-logging and post-logging periods were determined. Average lengths were vitually the same on Flynn Creek (52.1 mm pre-logging periods and 51.3 mm post-logging period) and Needle Branch (68.1 mm and 70.8 mm). Average lengths were slightly lower after logging on Deer Creek (59.2 mm and 47.7 mm). The average number of trapped sculpins per year declined from 24.0 to 5.0 fish following logging on Needle Branch and from 52.0 to 24.4 during the same period on Flynn Creek. The average number increased from 15.1 to 29.4 on Deer Creek following logging.

Biomass

Measurements by Phillips in Needle Branch in October 1964 (Phillips et al. 1966) indicated that reticulate sculpins constitute, perhaps, the most numerous fish species in the stream. In terms of biomass, Phillips felt the sculpins made up over one-third the total fish biomass in the stream (3.1 g/m^2). Using October 1966 biomass records of Krohn (1967), Deer Creek sculpin biomass was 3.7 g/m^2, and Flynn Creek was 3.1 g/m^2. The Needle Branch value (the first season after logging) had declined to 2.1 g/m^2. Krohn's figures indicate biomass levels were slightly under one-third of total fish biomass on streams following logging.

Predatory Behavior

Many members of the family Cottidae have been known to act as predators of salmonid embryos and fry. Previous studies have indicated that reticulate sculpin predation on trout embryos and fry may not be significant, but the results are mixed. There appears to be more agreement with the role of sculpin predation on Pacific salmon. Patten (1962, 1971) found predation of chinook and coho salmon fry by the coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*C. asper*), torrent sculpin (*C. rhotherus*), and reticulate sculpin. Generally, researchers have found that sculpins are feeders of opportunity and will prey upon young salmon along with other foods. Predation tendencies seem to be size and density dependent.

Phillips and Claire (1966) collected reticulate sculpins from the North Fork of the Alsea River and tested their predatory traits with steelhead trout embryos at the laboratory along Horse Creek. Tests indicate that the ability of reticulate sculpins to move into gravel varied directly with the size of the gravel and indirectly with the size of the fish (Table 42). There was no pre-hatching predation with this size of sculpin. Similar behavior was found with the coastrange sculpin by McLarney (1964). Sculpins less than 70 mm consumed only insignificant numbers of eggs.

Table 42. Maximum observed depth, in centimeters, of intragravel movement of the reticulate sculpin in four gravel sizes. Table from Phillips and Claire (1966).

Mean Diameter and Range of Gravel in Centimeters	Total Length of Sculpins in Centimeters 3.0 - 4.0	5.0 - 7.5
2.9 (2.5-3.2)	36	18
2.2 (1.9-2.5)	18	10
1.6 (1.3-1.9)	8	0
1.0 (0.6-1.3)	0	0

Phillips and Claire noted the reticulate sculpins readily attacked the recently hatched steelhead alevins. No estimates were made regarding the extent of mortality caused by sculpin predation, but Patten (1971) has estimated the loss to all sculpin species to range from 1.3 to 3.9 percent of fry released in the Elokomin River, Washington. Loss was negligible in the other stream studied, Herman Creek, Oregon.

Krohn (1967) believes there is little intragravel predation by the reticulate sculpin on coho salmon fry in the three study streams. Predation of coho fry was limited to sculpins larger than 69 mm and this portion of the population was quite small. Krohn also feels that predation may be density dependent. This agrees with the conclusions of Patten (1962). The only predation of fry observed by Krohn was on Needle Branch where the coho fry density was considerably higher than on Deer Creek. Patten surmises and Krohn agrees that predation by reticulate sculpins is related to the density of fry surpassing the available cover for young salmonids. With this theory, the coho fry consumed by large sculpins on Needle Branch represented some excess over the rearing or cover capacity of the stream.

Lampreys

The Pacific lamprey (*Entosphenus tridentatus*) was a comparatively rare fish species in the study streams. It was definitely identified only in Deer Creek. The western brook lamprey (*Lampetra richardsoni*) was present on all streams.

Pfeiffer and Pletcher (1964) have indicated adult and ammocoete lampreys are generally not eaten by coho salmon, cutthroat trout, rainbow trout, or prickly sculpins. Apparently, the granular cells of the skin of Pacific lampreys and western brook lampreys produce a distasteful secretion which accounts for their low mortality among salmonids and other fishes. Because no fish species in the streams were active predators of lampreys, it can be assumed that production was related to environmental factors and nonaquatic predation. Thomas (1961) determined that low streamflow and soft bottom characteristics are the important environmental qualities controlling ammocoete density.

If the production of ammocoete stages of the two lamprey species is any indication of population size, the importance of lampreys as members of the stream biota cannot be overlooked. It is known that other species of ammocoetes generally move downstream at about 1.5 miles per year (Thomas 1961), and that almost all ammocoete stream movement is downstream. This is supported by the data from the fish collection traps on the three study streams. Almost all counts of ammocoetes and adults were derived from fish collection in the main downstream and spillway traps. Only seven adults and one ammocoete (0.1 percent of all records) were ever taken in the upstream traps.

Appendices 15, 16 and 17 indicate a large fluctuation in lamprey numbers over the 15 years of data collection. Numbers of adult brook lamprey passing through the trap on Needle Branch decreased from a pre-logging average of 23.4 fish per year to a post-logging average of 7.8 fish per year. On Flynn Creek averages were essentially the same (11.7 fish per year and 10.8 fish per year, respectively). Average counts increased on Deer Creek from 10.3 fish per year to 37.3 fish per year. In the heaviest run during the experimental period, 219 adult western brook lampreys passed downstream in 1968.

Average counts of Pacific lampreys declined slightly following logging. It is probable that in many years Pacific lampreys were simply grouped with brook lampreys and, hence, the records may not be complete on Deer Creek.

Counts of ammocoetes fluctuated greatly from year to year, but this is a natural phenomenon experienced with sea lampreys (*Petromyzon marinus*) along the Great Lakes (Lamsa 1961). Ammocoete movement was greatest on Flynn Creek where 6,616 were counted over the 15-year period. The average count of 1,104 fish per year during 1959-1965 on other streams dropped to an average of 137 fish per year during 1966-1973. Numbers of ammocoetes were less on Deer Creek (3,667 fish), and the average 1959-65 count of 405 fish per year dropped to 155 fish per year for 1966-1973. The numbers of downstream ammocoetes were quite low on Needle Branch - only 504 during the 15-year period. The yearly average rose slightly from 36 fish per year to 41 fish per year. The largest yearly movement of ammocoetes occurred on Flynn Creek in 1962, when 1,934 of the immature fish passed through the downstream trap. The largest yearly number on Deer Creek also occurred in 1962 (879 fish), but the peak number on Needle Branch in 1965 was only 128 fish.

STUDY POOL OBSERVATIONS

The behavioral traits of coho salmon and cutthroat trout from the study pools in Flynn Creek and Needle Branch are discussed in detail by Lantz and Moring (1975 MS). The results will be summarized here. Competitive interactions between fishes (coho to coho, cutthroat to cutthroat, coho to cutthroat) were more numerous in Needle Branch (with an elevated temperature profile) than in Flynn Creek. Competitive interactions for space accounted for the great majority of all types of interaction.

Cutthroat to cutthroat interactions were minimal, while coho to coho interactions were most numerous in the two streams. Coho salmon spent less time resting and were more active than cutthroat in the streams.

Feeding behavior was similar in both streams, with almost all feeding by coho occurring at the water surface. There was little bottom feeding by this species. Cutthroat trout spent less time feeding, but utilized other segments of the stream than the water surface.

INSECT STUDIES AND SALMONID FOOD ITEMS

Insects available to or consumed by salmonids were studied by Demory (1961), Lowry (1964) and Lantz and Moring (1975 MS). The food available to insects was discussed by Chapman (1961, 1966) and Chapman and Demory (1963). There was no consistent sampling of insects throughout the 15-year study. Demory analyzed the food items consumed by coho salmon in streams, and Lowry studied the food habits of cutthroat trout. Lantz and Moring studied the benthos and drift available in the streams.

Annelids and six Orders of insects constituted the principal items in the diets, the drift and the benthos (Table 43). Coho juveniles fed primarily on Diptera with lesser amounts of other Orders. With the exception of annelids, noninsect items consumed were insignificant, but included some gastropods and fish eggs (Demory 1963).

Food habits of cutthroat trout were different than coho salmon because of the greater size range in cutthroat in streams. The most popular food items were not insects: frogs (*Rana* spp.) made up 16.6 percent of the diet of all cutthroat, annelids were 15.6 percent, salmonids 9.7 percent, cottids 7.5 percent, and other fish remains an additional 7.6 percent. Fish eggs also made up 4.0 percent of the total. Of the insects, Diptera was the most significant Order (Lowry 1964).

Items available in the drift were those consumed by coho salmon and cutthroat trout, but their percentage of occurrence was different. The principal food items from drift samples were insects of the Order Ephemeroptera (31.0 percent), followed by Plecoptera, Diptera, Trichoptera and Arachnida. Gastropods were the only noninsect group in the drift. There was a difference in the drift items in Needle Branch where there was an increase in water temperature due to logging. Sixty-eight percent of the drift items were of the Ephemeroptera, with dipterans the only other significant group (Lantz and Moring 1975 MS).

The principal Orders in the benthos were Plecoptera and Diptera, followed by Ephemeroptera, Trichoptera and Coleoptera. Annelids and aquatic snails were the principal noninsects present in the benthic samples. Essentially the same Orders were present in the Needle Branch benthos, but in different percentages: the Coleoptera and Diptera were most important followed by the Plecoptera and Emphemeroptera.

Chapman and Demory (1963) studied the food habits of insects in Deer Creek and Needle Branch from 1959 to 1961. Examination of stomach contents of insects revealed some insects were primarily detritus feeders, others were largely herbivores, and a few were carnivores. The type of feeding depends largely on the locations of insects in the stream environment (i.e., slow-moving water, living in mosses and liverworts). Several species demonstrated seasonal trends in utilization of algae and debris. Much of the diets of coho salmon is derived directly from terrestrial sources, or from aquatic insects deriving energy from terrestrial sources (Chapman 1966).

Table 43. Principal items in the diet of coho salmon and cutthroat trout in the drift, and in the benthos.

Invertebrate Group	Consumed by Coho Salmon (Demory, 1961)	Consumed by Cutthroat Trout (Lowry, 1964)	In Flynn Cr. Drift (Lantz and Moring, 1975MS)	In Flynn Cr. Benthos (Lantz and Moring, 1975MS)
Diptera	42.9 %	7.3 %	16.0 %	25.0 %
Ephemeroptera	14.0	0.5	31.0	13.0
Coleoptera	9.2	2.1	1.0	11.0
Trichoptera	7.9	6.6	15.0	13.0
Annelida	7.1	15.6	0.0	3.0
Arachnida	5.2	0.1	13.0	3.0
Plecoptera	4.0	2.3	16.0	30.0

HERBICIDE STUDIES

Two herbicides and one insecticide were sprayed or introduced to cutting units of Deer Creek and Needle Branch: endrin, 2,4-D, and 2,4,5-T. Endrin[1] is a chlorinated hydrocarbon insecticide, while 2,4-D[2] and 2,4,5-T[3] are phenoxy herbicides. The herbicides are used primarily to retard growth of fast-growing broad-leaved plants that sometimes invade cutover areas (Sears and Meehan 1971). Endrin is generally applied directly to Douglas fir seeds to protect them from rodents and insect feeding after aerial seeding (Moore et al. 1974). Analysis of 2,4-D and 2,4,5-T in streams was minimal, but some mention of endrin analyses can be made.

Endrin-coated Douglas fir seeds were aerially seeded on Needle Branch on three occasions. The first seeding, in early January 1967, was inadequate (Marston et al. 1969). An additional reseeding occurred in December 1967. Half of the seed was sown on December 16 and the other half on December 18.

Coho salmon fry and fingerlings and aquatic snails were sampled following the first seeding in January 1967. Endrin was present in most samples, but the data are probably unreliable because of the apparent contamination of pre-seeding and post-seeding samples. Likewise , Moore et al. (1974) have reported contamination of aquatic insects, fish and salmon eggs sampled following the December seeding. Moore and his associates did report, however, that endrin was present in all the biological material sampled. Despite contamination, endrin levels never reached known tolerance levels for salmonids. Additional samples of eggs, fish and aquatic insects were collected on all three Alsea study streams in December 1968 and June 1970. No endrin residues were found. Study of the small number of biological samples did suggest that endrin concentrations were highest within hours after seeding but declined soon afterwards (Moore et al. 1974).

In their analysis on Needle Branch water samples, Moore et al. (1974) found no endrin in the stream water until six hours after seeding. A peak concentration of 0.013 ppb was reached after 21 hours. Residues remained near that level for three days after seeding, then declined for the next five days. Measurable quantities of endrin were again detected three weeks after seeding. This was related to increased flow from a spring freshet.

In contrast to the results reported by Moore et al. (1974) on the December 1967 seeding, Marston et al. (1969) found endrin present in the stream water for only two hours following seeding, and again during a freshet six days later. The maximum concentration in the water was 0.1 ppb reached soon after seeding.

Using the streamflow values for Needle Branch (see Part II: Streamflow), Moore and his co-workers related the endrin in the water samples to the total streamflow, and then to the endrin applied to the total watershed. Approximately 0.06-0.14 percent of the endrin applied to the total watershed was ultimately recovered in the stream. Compared to the total area in the streambed only, the endrin recovered was only three percent. They surmised that the remainder was carried from the watershed by floating seed. The appearance of Endrin in the stream was related to streamflow (Marston et al., 1969).

Katz and Chadwick (1961) found coho salmon to be the most sensitive of three salmonids to endrin (the other salmonids: rainbow trout and chinook salmon). The 96-hour TLM (median tolerance limit) was 0.27 ppb at 20°C. But, Snow (1971) has outlined several objections to the use of 96-hour TLM values. Snow believes that any level above ten percent of the 96-hour TLM (or 0.03 ppb in this case) may have disastrous consequences for the aquatic life in streams. Concentrations less than the 96-hour TLM can be harmful if present for extended periods. Henderson et al. (1959) have rated endrin as the most toxic chlorinated hydrocarbon insecticide to fish of ten such insecticides tested. The toxicity of the compound is well known, but Morton (1967) and Moore et al. (1974) feel the danger to aquatic life is not serious in most streams under the conditons tested. On Needle Branch the maximum concentrations of endrin remaining in streams were well below the median tolerance levels and were diluted from the stream quickly.

SUMMARY

General

1. Three small headwater tributaries of the Alsea River, Oregon, were studied from 1959 to 1973. One watershed (Flynn Creek) remained unlogged as a control. Another watershed (Needle Branch) was completely clearcut in 1966. No buffer strips were left. The third watershed (Deer Creek) was patch clearcut in three blocks in 1966. Buffer strips were left along the stream.

2. Coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki clarki*) were the important salmonids in all three streams. Steelhead trout (*Salmo gairdneri gairdneri*) were present only in Deer Creek. Other fishes present in all streams were reticulate sculpin (*Cottus perplexus*) and western brook lamprey (*Lampetra richardsoni*). Incidental species were the Pacific lamprey (*Entosphenus tridentatus*) and chinook salmon (*Oncorhynchus tshawytscha*).

Effects of Logging

3. Adult coho salmon were of four age combinations: 1/1, 1/2, 2/1 and 2/2. Fish of age 1/2 dominated. Precocious males were principally of age group 1/1. There was no change

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[1] 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,endo-endo-5,8-dimethanonaphthalene

[2] 2,4-dichlorophenoxyacetic acid

[3] 2,4,5-trichlorophenoxyacetic acid

in age groups due to logging. There was an increase in numbers of precocious males in all streams.

4. There were no significant changes in adult coho length frequencies, condition factors, sex ratios, or timing of spawning migrations in streams with logged watersheds.

5. There was a decline in fecundity for returning coho adults that had been juveniles or fry in Needle Branch during clearcut logging in 1966.

6. Numbers of coho spawners were higher in post-logging years in all three streams, but the change was only significant in Needle Branch. However, because of the lack of data for the three years prior to logging on Needle Branch watershed, there is no indication that logging activities were responsible.

7. There was no change in coho fry survival rates from pre-logging to post-logging years.

8. There was a decline in average weight, average length, and condition factors in juvenile coho in Needle Branch during the summer of 1967, the time of the highest water temperatures.

9. Biomass values for coho increased in Deer Creek and Needle Branch and decreased in Flynn Creek from pre-logging and post-logging years.

10. There were no adverse changes in juvenile coho population numbers or smolt yield as a result of logging.

11. Net production for coho in Flynn Creek remained essentially unchanged from pre-logging to post-logging years (10.6 to 10.7 kg/year). However, net production in Needle Branch and Deer Creek increased during this period (4.1 to 7.3 kg/year, and 26.1 to 32 kg/ year, respectively).

12. There was no significant change in average weights of juvenile cutthroat as a result of logging.

13. Average lengths of cutthroat trout adults changed from pre-logging to post-logging years, but these shifts were related to increases and decreases in numbers of adults in streams. There was, however, a decrease in average length of fish in the stream during summer 1967, the time of highest water temperatures.

14. There was a significant decline in resident cutthroat trout population numbers following logging in the Needle Branch watershed. The 1973 population was only 21.2 percent of the pre-logging average. Population numbers in Flynn and Deer Creek experienced slight increases over this same period.

15. There were no significant changes in timing of cutthroat upstream migrations.

16. There was a shift to earlier migration time for downstream cutthroat migrants in Needle Branch following logging. Apparently correlated with increased water temperatures, this migration shift lasted for two years following slash burning and debris clearance.

17. There was a shift in mean arrival times of steelhead trout from pre-logging to post-logging years. This shift was to earlier migration by almost three weeks. However, this shift may be related to a subtle shift in migration time in the main Alsea River.

18. There was no change in steelhead age characteristics from pre-logging to post-logging years.

19. Average yearly numbers of steelhead migrants dropped after logging in the Deer Creek watershed, but the change was not significant. There were large numbers of migrants in three pre-logging years (1960, 1961, 1962) which affected the results. Other pre-logging runs were similar in magnitude to post-logging years.

20. The two youngest year classes of reticulate sculpins were almost entirely destroyed in Needle Branch as a result of logging.

21. Counts of adult western brook lampreys varied from year to year. There was a decrease in numbers of fish from pre-logging to post-logging years in Needle Branch. Counts on Deer Creek averaged higher and those on Flynn Creek were essentially the same during the two periods.

22. Average yearly counts of downstream migrating lamprey ammocoetes declined in the post-logging period in the Deer Creek and Flynn Creek drainages. Counts in Needle Branch were virtually the same before and after logging.

23. Competitive interactions between and among coho salmon and cutthroat trout were more numerous in Needle Branch (with elevated temperature) than in Flynn Creek (control). Coho salmon were more active than cutthroat in both streams.

Other Biological Results

24. The average length of coho adults declined slightly in post-logging years in all three streams – primarily because of the increased numbers of precocious males. Average lengths of females were significantly greater than males in all streams.

25. The peak in the coho spawning migration was in December, with over 90 percent of the run occurring in November, December and January.

26. Because of upstream and downstream movements of coho adults, the actual numbers of spawners in the streams were less than two-thirds of the original upstream run.

27. Sex ratios of upstream migrating coho were in favor of males by a factor of 4 to 1. The ratio of males to females was higher in those fish returning downstream and higher still for those fish returning upstream a second time.

28. Actual numbers of coho spawners increased in post-logging years on all three streams, primarily because of increases in numbers of precocious males.

29. A total of 110 coho redds were trapped from 1964 to 1971. No fry emerged in 16 (14.5 percent). Average survival to emergence was 37.9 percent in Deer Creek, 34.6 percent in Needle Branch, and 25.7 percent in Flynn Creek.

30. Fry emergence from spawning to time of last emergence ranged from 142 to 160 days for coho.

31. Twelve age combinations of cutthroat trout were found. The 3/1 group dominated but age groups 4/1 and 2/2 were also important. Four and five-year-olds made up over 75 percent of the runs. Sea-run fish spent up to six years in

freshwater before migrating, while resident fish spent up to eight years in freshwater without migration.

32. Sex ratios of adult cutthroat averaged 1.6:1 and 1.8:1, males to females, on Flynn Creek and Deer Creek, respectively. Out-migrant ratios were 1.8:1 and 1.2:1.

33. Over 90 percent of the upstream migrating cutthroat arrived during November, December and January.

34. Of all downstream migrating adult cutthroat, 85.8 percent moved from December to March.

35. Juvenile cutthroat downstream migrants passed through the traps during all months of the year. Peak movement was in April, with 80 percent of the out-migrants moving during March, April and May.

36. During pre-logging years juvenile cutthroat were recorded in the downstream traps from March to September. After logging, no fish ever moved during these months. However, this same trend was apparent on the control stream as well as the logged streams.

37. Eleven age combinations of steelhead trout were recorded. The most frequent combination was 2/2. For all adults 82.2 percent spent two years at sea. One eight-year-old steelhead was found.

38. The greatest growth in steelhead was obtained between the time of the final freshwater winter check and the time of the first ocean check.

39. The sex ratio of steelhead in Deer Creek was 2.2:1, males to females. Many males returned downstream and the ratio of those fish actually spawning was 1.6:1.

40. Arrival times of male and female steelhead were equally spread throughout the migration period.

41. Peak migration time for steelhead is February. A total of 95.1 percent of all arrivals was during January, February and March.

42. Of those steelhead moving into Deer Creek 74.1 percent ultimately moved back downstream. During ten years only one female actually spawned in Deer Creek. Two females spawned in each of three years and three females spawned in one year.

43. Ten steelhead marked at the Alsea Hatchery (North Fork Alsea River) strayed into Deer Creek. At least four of these spawned in the stream.

44. Examination of adult and juvenile scale samples reveals that many of the juveniles passing through the downstream trap were not immediately destined for sea, but were heading to Horse or Drift Creek for another year of residence.

45. Peak downstream migration of steelhead juveniles was in early April. Eighty-nine percent of the migrants leave during March, April and May.

46. There was an apparent cyclic pattern to yearly migrations of steelhead out-migrants. A pattern was evident of distinct and indistinct peaks in monthly emigration.

47. Peak downstream movements of reticulate sculpins occurred during March, April and May.

48. There is some indication of a cyclic trend in average lengths of sculpins over the 15-year period.

49. Reticulate sculpins apparently constitute the largest single segment of the total biomass in the streams.

50. The ability of sculpins to move in the gravel varied directly with the size of the gravel. Sculpins larger than 70 mm were found to prey on salmonid alevins and fry, but the extent of this predation is debatable.

51. Annelids and six Orders of insects (Ephemeroptera, Coleoptera, Trichoptera, Arachnida, Plecoptera, Diptera) constituted the principal items in the diets of coho salmon in the drift and in the benthos.

52. Because of the greater size range of cutthroat trout, food habits of this species were more varied. The most popular food items were frogs (*Rana* spp.) and fishes.

53. Two herbicides (2,4-D and 2,4,5-T) and one insecticide (endrin) were sprayed on Deer Creek and Needle Branch watersheds. Endrin levels were highest in biological samples immediately after seeding but declined soon after. Peak levels of endrin in water samples occurred after 21 hours and did not decline for almost four days after seedling. Another study found endrin in water samples for only two hours following seedling.

ACKNOWLEDGMENTS

During the 17 years of field work and data analysis, hundreds of individuals made contributions that led to the successful completion of the project. Most are too numerous to mention individually here, but several people and groups should be singled out for their support, assistance, and/or constructive criticism. Dr. Donald Chapman was the first coordinator of the Alsea Watershed Study. He was succeeded by Dr. James Hall. Dr. James Krygier served as acting coordinator during the transition period. The efforts of all three were essential for the direction and completion of numerous Alsea studies.

The actual day-to-day operations of the 15 years of field work were the responsibility of the Oregon State Game Commission's Research Division. Drs. H. J. Rayner and Harry Wagner, and Mr. Homer Campbell directed the operations of this agency, with Mr. Robert Phillips as the first project leader. Several Game Commission biologists were primarily responsible for the collection of biological data: Messrs. Errol Claire, Wayne Hug, Patrick Keeley, Bruce Pohl and Richard Severson. Thanks are also due numerous seasonal biologists during the course of the study. Much biological and environmental data were collected by graduate students, and most of the following were at least partially supported by the Oregon Game Commission: Dr. David Au, and Messrs. Robert Demory, Paul Iwanaga, K Koski, David Krohn, Robert Lindsay, Gerald Lowry and Neil Ringler.

We are indebted to several professional foresters for their assistance whenever needed: Drs. George Brown and Henry Froehlich of Oregon State University, and Messrs. S. T. Moore and Dale Robertson of Siuslaw National Forest, U.S. Forest Service. Thanks are also due Messrs. John Corliss of the U.S. Forest Service, David Harris of the U.S. Geological Survey, and Fred Williamson. We also wish to acknowledge the cooperation and interest of the Georgia-Pacific Corporation, particularly Messrs. Ray Ayers, Rae Johnson, Wayne Knauf, Ronald Nutting and John Thompson.

Mr. Bruce Pohl was responsible for the massive computer filing and storage system for the data. Mr. Pohl and Dr. Norbert Hartmann assisted in statistical analysis of the data. We also wish to thank the following individuals for reviewing drafts of the manuscript: Drs. James Hall and Harry Wagner, and Mr. Homer Campbell.

LITERATURE CITED

Andrews, R. E. 1958. Factors influencing the seaward migration of smolt steelhead trout, *Salmo gairdneri gairdneri* Richardson, in the Alsea River, Oregon. M.S. Thesis, Oregon St. Col., Corvallis, 90 p.

Anonymous. 1966. Effects of log driving on the salmon and trout populations in the Stellako River. Inter. Pac. Salmon Fish. Comm., Prog. Rept. 14. 88 p.

Armstrong, R. H. 1971. Age, food, and migration of sea-run cutthroat trout, *Salmo clarki*, at Eva Lake, southeastern Alaska. Trans. Amer. Fish. Soc. 100(2):302-306.

Au, D. W. K. 1972. Population dynamics of the coho salmon and its response to logging in three coastal streams. Ph.D. Dissertation, Oregon St. Univ., Corvallis. 245p.

Bachman, R. W. 1958. The ecology of four northern Idaho trout streams with reference to the influence of forest road construction. M.S. Thesis, Univ. of Idaho, Moscow. 97 p.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38:293-306.

Bond, C. E. 1963. Distribution and ecology of freshwater sculpins, Genus *Cottus* in Oregon. Ph.D. Dissertation, Univ. of Michigan, Ann Arbor. 186 p.

__________ 1973 Occurrence of the reticulate sculpin, *Cottus perplexus*, in California, with distributional notes on *Cottus gulosus* in Oregon and Washington. Calif. Fish and Game 59(1):93-94.

Brazier, J. R., and G. W. Brown. 1973. Buffer strips for stream temperature control. Forest Res. Lab., Oregon St. Univ., Res. Paper 15. 9 p.

Brown, G. W., and J. T. Krygier. 1967. Changing water temperatures in small mountain streams. J. Soil and Water Conserv. 22(6):242-244.

__________, G. W. Swank, and J. Rothacher. 1971. Water temperature in the Steamboat drainage. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-119. 17 p.

Buchanan, D. V., and P. S. Tate. 1975. Acute toxicity of spruce and hemlock bark to some estuarine organisms in southeastern Alaska. J. Fish. Res. Bd. Canada. 32:In Press.

Bulkley, R. V. 1967. Fecundity of steelhead trout, *Salmo gairdneri*, from Alsea River, Oregon. J. Fish. Res. Bd. Canada. 24(5):917-926.

Burns, J. W. 1970. Spawning bed sedimentation studies in northern California streams. Calif. Fish and Game. 56(4):253-270.

__________ 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish and Game. 57(1):44-57.

__________ 1972. Some effects of logging and associated road construction on northern California streams. Trans. Amer. Fish. Soc. 101(1):1-17.

Butler, R. L. 1957. The development of a vinyl plastic subcutaneous tag for trout. Calif. Fish and Game. 43(4):201-212.

Cederholm, C. J., and L. C. Lestelle. 1974. Observations on the effects of landslide siltation on salmon and trout resources of the Clearwater River, Jefferson County, Washington, 1972-73. Fish. Res. Inst., Univ. of Wash., Final Rept., Part 1, to Wash. St. Dept. Nat. Res. FRI-UW-7404. 133 p.

Chapman, D. W. 1958. Studies on the life history of Alsea River steelhead. J. Wildl. Management 22(2):123-124.

__________ 1961. Factors determining production of coho salmon, *Oncorhynchus kisutch*, in three Oregon streams. Ph.D. dissertation, Oregon St. Univ., Corvallis. 214 p.

———— 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Canada 19(6):1047-1080.

———— 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Amer. Fish. Soc. 94(1):40-52.

———— 1966. The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. In: K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman (ed.), Organism-substrate relationships in streams, Pymatuning Lab. of Ecol., Univ. of Pitt. Spec. Publ. No. 4:116-130.

———— and R. Demory. 1963. Seasonal changes in the food ingested by aquatic insect larvae and nymphs in two Oregon streams. Ecology 44(1):140-146.

Cordone, A. J., and S. Pennoyer. 1960. Notes on silt pollution in the Truckee River drainage, Nevada and Placer counties. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 60-14. 25 p.

Corliss, J. F., and C. T. Dyrness. 1965. A detailed soil-vegetation survey of the Alsea area in the Oregon Coast Range. In: C. T. Youngberg (ed.), Forest-soil relationships in North America. Oregon St. Univ. Press, Corvallis:457-483.

Cramer, F. K. 1940. Notes on the natural spawning of cutthroat trout (*Salmo clarkii clarkii*) in Oregon. Proc. 6th Pac. Sci. Congr., Berkeley, 3:335-339.

Demory, R. L. 1961. Foods of juvenile coho salmon and two insect groups important in the coho diet in three tributaries of the Alsea River, Oregon. M.S. Thesis, Oregon St. Coll., Corvallis. 68 p.

Dill, L. M. and T. G. Northcote. 1970. Effects of gravel size, egg depth, and egg density on intragravel movement and emergence of coho salmon (*Oncorhynchus kisutch*) alevins. J. Fish. Res. Bd. Canada 27:1191-1199.

Drucker, B. 1972. Some life history characteristics of coho salmon of the Karluk River system, Kodiak Island, Alaska. Nat. Mar. Fish. Serv. Fish. Bull. 70(1):79-94.

Edgington, J. R. 1969. The impact of logging on the ecology of two trout streams in north Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 73 p.

Elliott, S. T., and R. D. Reed. 1973. A study of land use activities and their relationship to the sport fish resources in Alaska. Job D-I-A: Establishment of guidelines for protection of the sport fish resources during logging operations. Alaska Dept. Fish and Game, Ann. Prog. Rept., Project F-9-5. 11 p.

Ellis, R. J. 1973. Preliminary biological survey of log-rafting and dumping areas in southeastern Alaska. Mar. Fish Rev. 35(5-6):19-22.

Fiksdal, A. J. 1974. A landslide survey of the Stequaleho Creek Watershed. Supplement to: Cederholm, C. J., and L. C. Lestelle. 1974. Observations on the effects of landslide siltation on salmon and trout resources of the Clearwater River, Jefferson County, Washington, 1972-73. Fish. Res. Inst., Univ. of Wash., Final Rept., Part I, to Wash. St. Dept. Nat. Res., FRI-UW-7404. 8 p.

Fisk, L., E. Gerstung, R. Hansen, and J. Thomas. 1966. Stream damage surveys – 1966. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 66-10. 9 p.

Foerster, R. E. 1968. The sockeye salmon, *Oncorhynchus nerka*. Fish Res. Bd. Canada Bull, 162; 422 p.

Giger, R. D. 1972. Ecology and management of coastal cutthroat trout in Oregon. Oregon St. Game Comm., Fish. Res. Rept. No. 6. 61 p.

Hall, J. D., and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. In: T. G. Northcote (ed.), Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, Univ. of British Columbia:355-275.

Hallock, R. J., W. F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (*Salmo gairdneri gairdneri*) in the Sacramento River system. Calif. Dept. Fish and Game, Fish. Bull. 114. 74 p.

Hamilton, J. A. R., L. O. Rothfus, M. W. Erho, and J. D. Remington. 1970. Use of a hydroelectric reservoir for the rearing of coho salmon (*Oncorhynchus kisutch*). Wash. St. Dept. Fish., Res. Bull. No. 9. 65 p.

Hansen, D. 1963. The influence of natural mortality and other life history factors on the yield to the angler of planted cutthroat trout in Munsel Lake, Oregon. M.S. Thesis, Oregon St. Univ., Corvallis. 67 p.

Hanzel, D. A. 1961. Inventory of the waters of the project area. Northwest Montana Fish. Stud., Montana Fish and Game, Fish. Div., Fed. Aid in Fish Restor. Job Completion Rept., Project F-7-R-10. 9 p.

Henderson, C., Q. H. Pickering, and C. M. Tarzwell. 1959. Relative toxicity of ten chlorinated hydrocarbon insecticides to four species of fish. Trans. Amer. Fish. Soc. 88(1):23-32.

Hunter, J. G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Bd. Canada 16(6):835-886.

Johnson, A. K. 1970. The effect of size at release on the contribution of 1964-Brood Big Creek Hatchery coho salmon to the Pacific coast sport and commerical fisheries. Res. Repts. Fish Comm. of Oregon. 2(1):64-76.

Jones, D. E. 1974. Life history of the sea-run cutthroat trout in southeast Alaska. Alaska Dept. Fish and Game, Anadromous Fish Studies, Study AFS-42, Ann. Prog. Rept.: 15-31.

Kabel, C. S., and E. R. German. 1967. Caspar Creek study completion report. Calif. Dept. Fish and Game, Mar. Res. Branch Admin. Rept. 67-4. 28 p.

Katz, M., and G. C. Chadwick. 1961. Toxicity of endrin to some Pacific Northwest fishes. Trans. Amer. Fish. Soc. 90(4):394-397.

Kopperdahl, F. R., J. W. Burns, and G. E. Smith. 1971. Water quality of some logged and unlogged California streams. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 71-12. 19 p.

Koski, K. V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis, Oregon State Univ., Corvallis, 84 p.

Krammes, J. S., and D. M. Burns. 1973. Road construction on Caspar Creek watersheds. USDA Forest Service, Pac. SW Forest and Range Exp. Sta., Res. Paper PSW-93. 10 p.

Krohn, D. C. 1967. Production of the reticulate sculpin (*Cottus perplexus*) and its predation on salmon fry in three Oregon Streams. M.S. Thesis, Oregon St. Univ., Corvallis. 78 p.

Lamsa, A. 1961. Fish and lamprey movements in Silver Creek, Ontario. Fish. Res. Bd. Canada, Prog. Rept. Biol. Sta. and the Tech. Unit. 2:21-24.

Lantz, R. L. 1967. An ecological study of the effects of logging on salmonids. Proc. 47th Ann. Conf. West. Assoc. St. Game and Fish Comm., Honolulu, Hawaii: 323-335.

__________ and J. R. Moring. 1975 MS. Influence of water temperature changes on the behavioral ecology of coho salmon and cutthroat trout in small coastal streams. Oregon Wildl. Comm. Unpubl. Manuscript.

Levno, A., and J. Rothacher. 1967. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Note PNW-65. 12 p.

__________ 1969. Increases in maximum stream temperatures after slash burning in a small experimental watershed. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Note PNW-110. 7 p.

Lindsay, R. B. 1975. Distribution and survival of coho salmon fry after emigration from natal streams. M.S. Thesis, Oregon St. Univ., Corvallis. 41 p.

Lowry, G. R. 1964a. Net production, movement, and food of cutthroat trout *(Salmo clarki clarki* Richardson) in three Oregon coastal streams. M.S. Thesis, Oregon St. Univ., Corvallis. 72 p.

__________ 1964b. Some ways of increasing the utility of a backpack fish shocker. Prog. Fish-Cult. 26(3):127-130.

__________ 1965. Movement of cutthroat trout, *Salmo clarki clarki* (Richardson) in three Oregon coastal streams. Trans. Amer. Fish. Soc. 94(4):334-338.

__________ 1966. Production and food of cutthroat trout in three Oregon coastal streams. J. Wildl. Mgmt. 30(4):754-767.

Marston, R. B., R. M. Tyo, and S. Middendorff. 1969. Endrin in water from treated Douglas-fir seed. Pesticides Monitor. J. 2(4):167-171.

McHenry, E. T. 1971. Silver salmon studies in the Resurrection Bay area. Alaska Dept. Fish and Game. Fed. Aid in Fish Restor. 13:Rept. No. G-11-A for 1971-1972. 20 p.

McLarney, W. O. 1964. The coastrange sculpin, *Cottus aleuticus*: structure of a population and predation on eggs of the pink salmon, *Oncorhynchus gorbuscha*. M.S. Thesis, Univ. of Michigan, Ann Arbor. 83 p.

McNeil, W. J. 1966. Effect of spawning bed environment on reproduction of pink and chum salmon. U.S. Fish and Wildl. Serv., Fish. Bull. 65(2):495-523.

__________ and W. H. Ahnell. 1960. Measurement of gravel composition of salmon streambeds. Fish. Res. Inst., Univ. of Wash., Circ. 120. 6 p.

Meehan, W. R., W. A. Farr, D. M. Bishop, and J. H. Patric. 1969. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. USDA Forest Service, Inst. Northern Forestry, Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-82. 45 p.

Merrell, T. R., Jr. 1962. Freshwater survival of pink salmon at Sashin Creek, Alaska. In: N. J. Wilimovsky (ed.), A symposium on pink salmon, H. R. MacMillan Lectures in Fisheries, Univ. of British Columbia:59-72.

Moore, D. G., J. D. Hall, and W. L. Hug. 1974. Endrin in forest streams after aerial seeding with endrin-coated Douglas-fir seed. USDA Forest Service, Pac. NW Forest and Range Expt. Sta., Res. Note PNW-219. 14 p.

Moring, J. R., and R. L. Lantz. 1974. Immediate effects of logging on the freshwater environment of salmonids. Oregon Wildl. Comm., Res. Div., Project AFS-58, Final Rept. 101 p.

Morton, W. M. 1967. Effects of aerial distribution of endrin-coated Douglas-fir seeds on the aquatic life of an Oregon coastal stream. U.S. Bur. Sport Fish & Wildl., Div. Fish. Serv., Portland, Oregon, Spec. Rept. Mimeo. 13 p.

Murphy, G. I. 1952. An analysis of silver salmon counts at Benbow Dam, South Fork of Eel River, California. Calif. Fish and Game. 38(1):105-112.

Narver, D. W. 1969. Age and size of steelhead trout in the Babine River, British Columbia. J. Fish. Res. Bd. Canada 26(10):2754-2760.

———— 1971. Carnation Creek Watershed Study. Fish. Res. Bd. Canada, Pac. Biol. Sta., Nanaimo, B.C. 7 p. (Mimeo).

———— 1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. Fish. Res. Bd. Canada Tech. Rept. 323. 55 p.

———— and F. C. Withler. 1971. Age and size of steelhead trout (*Salmo gairdneri*) in angler's catches from Vancouver Island, British Columbia streams. Fish. Res. Bd. Canada, Pac. Biol. Sta., Nanaimo, Circ. 91. 26 p.

Oregon State Game Commission. 1954. The fishery resource of the Alsea Basin. Mimeo. 28 p.

Patten, B. G. 1962. Cottid predation upon salmon fry in a Washington stream. Trans. Amer. Fish. Soc. 91(4):427-429.

———— 1971. Predation by sculpins on fall chinook salmon, *Oncorhynchus tshawytscha*, fry of hatchery origin. Natl. Mar. Fish. Serv., Spec. Sci. Rept.—Fish. No. 621, 14 p.

Pautzke, C. F., and R. C. Meigs. 1940. Studies on the life history of the Puget Sound steelhead trout (*Salmo gairdnerii*). Trans. Amer. Fish. Soc. 70:209-220.

Pease, B. C. 1974. Effects of log dumping and rafting on the marine environment of southeast Alaska. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Gen. Tech. Rept. PNW-22. 68 p.

Pfeiffer, W., and T. F. Pletcher. 1964. Club cells and granular cells in the skin of lamprey. J. Fish. Res. Bd. Canada 21(5):1083-1088.

Phillips, R. W., H. J. Campbell, W. L. Hug, and E. W. Claire. 1966. A study of the effect of logging on aquatic resources, a progress report 1960-66. Oregon St. Game Comm., Res. Div., Prog. Memorandum, Fish., No. 3. 28 p.

————, and E. W. Claire. 1966. Intragravel movement of the reticulate sculpin, *Cottus perplexus*, and its potential as a predator on salmonid embryos. Trans. Amer. Fish. Soc. 95(2):210-212.

———— and K V. Koski. 1969. A fry trap method for estimating salmonid survival from egg deposition to fry emergence. J. Fish. Res. Bd. Canada. 26(1):133-141.

————, R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. The effects of 1-3 mm sand on emergence of coho salmon and steelhead trout fry. Trans Amer. Fish. Soc. 104(3):in press.

Platts, W. S. 1974a. Chinook salmon runs, fish standing crop and species composition in South Fork Salmon River, Idaho. U.S. Forest Service, Intermountain Region, Prog. Rept. V. 48 p.

———— 1974 b. Geomorphic and aquatic conditions influencing salmonids and stream classification in the Salmon River drainage, Idaho, 1970-1972. Ph.D. Dissertation, Utah St. Univ. 200 p.

———— 1974c. Stream channel sediment conditions in the South Fork Salmon River, Idaho. U.S. Forest Service, Intermountain Region, Prog. Rept. IV. 38 p.

Prichard, A. L. 1947. Efficiency of natural propagation of Pacific salmon. Canadian Fish. Cult. 1(2):22-26.

Reed, R. D., and S. T. Elliott. 1972. Effects of logging on Dolly Varden, Alaska Dept. Fish and Game, Fed. Aid in Fish Restor., Ann. Prog. Rept., Project F-9-4, Job R-IV-B. 62 p.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada Bull. 119, 300 p.

Royal, L. 1972. An examination of the anadromous trout program of the Washington State Game Department. Vol. I. Wash. St. Dept. Game, Olympia. 112 p.

Salo, E. O. 1967. Study of the effects of logging on pink salmon in Alaska. Proc. Soc. Amer. Foresters. 1966:59-52.

Sears, H. S., and W. R. Meehan. 1971. Short-term effects of 2,4-D on aquatic organisms in the Nakwasina River watershed, Southeastern Alaska. Pesticides Monitor. J. 5(2):212-217.

Servizi, J. A., D. W. Martens, and R. W. Gordon. 1970. Effects of decaying bark on incubating salmon eggs. Inter. Pac. Salmon Fish. Comm., Prog. Rept. 24. 28 p.

Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dept. Fish and Game, Fish Bull. 98. 375 p.

Sheppard, D. 1972. The present status of the steelhead stocks along the Pacific coast. In: D. H. Rosenberg (ed.), A review of the oceanography and renewable resources of the Northern Gulf of Alaska. Inst. of Mar. Sci., Univ. of Alaska, IMS Rept. R72-73, Sea Grant Report 73-3:519-556.

Sheridan, W. L., and W. J. McNeil. 1968. Some effects of logging on two salmon streams in Alaska. J. Forestry 66:128-133.

________ and S. T. Olson. 1970. Timber harvest and the salmon and trout fisheries of southeast Alaska. Proc. 50th Ann. Conf. West. Assoc. State Game and Fish Comm., Victoria, B.C.:186-191.

Skeesick, D. G. 1965. Catch, migration, growth and survival of stocked coastal cutthroat trout in Munsel Lake, Oregon. Oregon St. Game Comm., Fish. Res. Rept. No. 2, 37 p.

Snow, S. H. 1971. Objections to insecticide research. In: Water and Oregon's ecology, Water Resources Res. Inst., Oregon St. Univ., Seminar WR 013.70:77-78.

Stefanich, F. 1967. The effects of logging on Pinkham Creek's fish population. Montana Fish and Game, Fed. Aid in Fish Restor., Job Completion Rept., Project F-7-R-6. 10 p.

Sumner, F. H. 1948. Age and growth of steelhead trout, *Salmo gairdnerii* Richardson, caught by sport and commercial fishermen in Tillamook County, Oregon. Trans. Amer. Fish. Soc. 77:77-83.

________ 1962. Migration and growth of coastal cutthroat trout in Tillamook County, Oregon. Trans. Amer. Fish. Soc. 91(1):77-83.

Thomas, M. L. H. 1961. Ammocoete biology. Fish. Res. Bd. Canada, Prog. Rept. Biol. Sta. and the Tech. Unit 2:14-17.

Tyler, R. W., and D. R. Gibbons. 1973. Observations of the effect of logging on salmon-producing tributaries of the Staney Creek Watershed and the Thorne River Watershed and of logging in the Sitka District. Fish. Res. Inst., Univ. of Wash., Final Rept., Part 1, to Alaska Loggers Assoc. FRI-UW-7307. 58 p.

Wagner, H. H., R. L. Wallace, and H. J. Campbell, 1963. The seaward migration and return of hatchery-reared steelhead trout, *Salmo gairdneri* Richardson, in the Alsea River, Oregon. Trans. Amer. Fish. Soc. 92(3):202-210.

Wales, J. H., and M. Coots. 1955. Efficiency of chinook salmon spawning in Fall Creek, California. Trans. Amer. Fish. Soc. 84:137-149.

Wallace, R. L. 1961. An analysis of adult steelhead trout returns to the Alsea River from hatchery releases in 1956 and 1957. M.S. Thesis, Oregon St. Univ., Corvallis. 79 p.

Washington, P. M. 1970. Occurrence on the high seas of a steelhead trout in its ninth year. Calif. Fish and Game 56(4):312-314.

Wendler, H. O., and G. Deschamps. 1955. Logging dams on coastal Washington streams. Wash. St. Dept. Fish., Fish. Res. Paper 1(3):27-38.

Wickett, W. P. 1962. Environmental variability and reproduction potentials of pink salmon in British Columbia. In: N. J. Wilimovsky (ed.), A symposium on pink salmon, H. R. MacMillan Lectures in Fisheries, Univ. of British Columbia:73-86.

Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. J. Fish. Res. Bd. Canada 23(3):365-393.

Wustenberg, D. W. 1954. A preliminary survey of the influences of controlled logging on a trout stream in the H. J. Andrews Experimental Forest, Oregon. M.S. Thesis, Oregon St. Col. (University), Corvallis. 51 p.

APPENDICES

Appendix 1. Arrival times, by month and number, for adult coho salmon on Deer Creek.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	March	Spawning Dates
1959-60	6	48	44	23	5	-	10/23- 2/7
1960-61	-	38	26	35	5	-	11/10- 2/4
1961-62	-	32	91	19	28	2	11/22- 3/5
1962-63	-	20	10	16	23	1	11/21- 3/8
1963-64	-	54	85	34	1	-	11/4 - 2/1
1964-65	-	67	93	37	7	-	11/12-2/16
1965-66	-	22	95	52	4	-	11/14-2/12
1966-67	-	25	158	93	4	-	11/12-2/21
1967-68	13	32	78	51	11	-	10/28-2/7
1968-69	-	73	91	33	5	-	11/8-2/8
1969-70	-	21	61	14	8	-	11/5-2/10
1970-71	-	14	55	28	1	1	11/12-3/1
1971-72	-	42	42	55	4	-	11/3-2/25
1972-73	-	-	53	5	-	-	12/18-1/20

Appendix 2. Arrival times, by month and number, for adult coho salmon on Flynn Creek.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Spawning Dates
1959-50		14	25	9	4	11/23-2/8
1960-61		24	45	39	2	11/13-2/6
1961-62	2	34	95	10	46	10/28-2/23
1962-63		5	3	3		11/20-1/8
1963-64		9	45	16		11/12-1/16
1964-65		1	15	19		11/24-1/26
1965-66		35	74	39	5	11/19-2/14
1966-67		37	87	101	1	11/14-2/1
1967-68	1	19	42	18	13	10/28-2/10
1968-69		33	56	16		11/8 -1/20
1969-70			33	2		12/12-1/21
1970-71		32	24	18		11/12-1/26
1971-72		32	58	14	2	11/9 -2/17
1972-73			26	20		12/19-1/18

Appendix 3. Arrival times, by month and number, for adult coho salmon on Needle Branch.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Spawning Dates
1959-60			1	4	1	12/12- 2/2
1960-61		8	11	8		11/15- 1/16
1961-62			10		15	12/2 - 2/12
1962-63		9		4		11/20- 1/5
1963-64			NOT TRAPPED			
1964-65			NOT TRAPPED			
1965-66			NOT TRAPPED			
1966-67		9	46	33	1	11/13- 2/4
1967-68	2	25	59	31		10/30- 2/4
1968-69		28	47	18		11/8 - 1/16
1969-70			5			12/13-12/21
1970-71		28	27	9		11/12- 1/12
1971-72		7	27	26		11/3 - 1/26
1972-73			16	1		12/18- 1/14

Appendix 4. Numbers of live, unspent, adult coho salmon passing through the upstream trap on Flynn Creek during spawning migrations, 1959-1973.

Year	Males	(Jacks)	Females	Sex Unknown	Total
1959-60	36	(3)	16	0	52
1960-61	84	(30)	26	0	110
1961-62	126	(11)	52	2	180
1962-63	9	(3)	2	0	11
1963-64	49	(2)	20	0	69
1964-65	24	(1)	10	0	34
1965-66	140	(53)	13	0	153
1966-67	171	(19)	55	0	226
1967-68	83	(41)	10	0	93
1968-69	80	(6)	19	0	99
1969-70	30	(11)	5	0	35
1970-71	66	(38)	5	0	71
1971-72	87	(8)	18	0	105
1972-73	42	(24)	3	0	45

Appendix 5. Numbers of live, unspent, adult and jack coho salmon passing through the upstream trap on Deer Creek during spawning migrations, 1959-1973.

Year	Males	(Jacks)	Females	Sex Unknown	Total
1959-60	98	(18)	25	1	124
1960-61	84	(30)	19	0	103
1961-62	132	(7)	32	0	164
1962-63	50	(10)	18	0	68
1963-64	145	(20)	28	0	173
1964-65	155	(7)	48	0	203
1965-66	140	(11)	27	0	167
1966-67	221	(9)	56	0	277
1967-68	162	(70)	23	0	185
1968-69	156	(16)	40	0	196
1969-70	93	(18)	8	0	101
1970-71	74	(30)	10	0	84
1971-72	102	(10)	36	0	138
1972-73	52	(29)	6	0	58

Appendix 6. Numbers of live, unspent, adult and jack coho salmon passing through the upstream trap on Needle Branch during spawning migrations, 1959-1973.

Year	Males	(Jacks)	Sex Females	Unknown	Total
1959-60	4	(2)	1	0	5
1960-61	19	(13)	6	0	25
1961-62	9	(1)	15	1	25
1962-63	8	(6)	4	0	12
1963-64		NO TRAPPING			
1964-65		NO TRAPPING			
1965-66		NO TRAPPING			
1966-67	70	(9)	19	0	89
1967-68	100	(57)	17	0	117
1968-69	73	(8)	17	0	90
1969-70	4	(3)	1	0	5
1970-71	58	(43)	2	0	60
1971-72	32	(4)	18	0	50
1972-73	16	(13)	1	0	17

Appendix 7. Records of chinook salmon straying in Deer Creek and Needle Branch during the 15-year period.

Deer Creek:

Date	Sex	Length	Remarks
Upstream Trap:			
17 November 1960	♂	451 mm FL	Jack
17 November 1960	♂	572	Jack
16 November 1963	♂	503	Jack, 2 lbs 12 oz.
14 November 1966	♂	521	Jack
29 October 1967	♂	420	Jack
29 October 1967	♂	455	Jack
6 December 1967	♂	465	Jack
6 December 1967	♂	470	Jack
6 December 1967	♂	513	Jack
6 December 1967	♂	860	Adult
7 December 1967	♂	436	Jack
7 December 1967	♂	522	Jack
Downstream Trap:			
15 November 1966	♂	515	Jack
30 October 1967	♂	419	Jack
30 October 1967	♂	458	Jack
7 December 1967	♂	464	Jack
7 December 1967	♂	517	Jack
7 December 1967	♂	851	Adult
11 December 1967	♂	460	Jack
12 December 1967	♂	520	Jack

Needle Branch:

Date	Sex	Length	Remarks
Upstream Trap:			
6 December 1967	♂	451	Jack

Appendix 8. Numbers of cutthroat trout passing through the upstream trap on Flynn Creek, 1959-1973.

Year	Adults	Juveniles	Unknown*	Total Live
1959-60	23	2	7	32
1960-61	23	4	4	31
1961-62	9	14	6	29
1962-63	17	11	0	28
1963-64	17	3	3	23
1964-65	11	2	2	15
1965-66	33	4	10	47
1966-67	46	0	3	49
1967-68	35	4	4	43
1968-69	24	3	4	31
1969-70	28	13	11	52
1970-71	25	3	7	35
1971-72	17	3	15	35
1972-73	10	0	3	13
Pre-Logging Yearly Average	19.0	5.7	4.6	29.3
Post-Logging Yearly Average	26.4	3.7	6.7	36.9

*Fish of a length which could be either adult or juvenile

Appendix 9. Numbers of cutthroat trout passing through the upstream trap on Deer Creek, 1959-1973.

Year	Adults	Juveniles	Unknown*	Total Live
1959-60	30	5	10	45
1960-61	16	7	3	26
1961-62	9	16	2	27
1962-63	7	8	0	15
1963-64	5	8	4	17
1964-65	33	5	5	43
1965-66	14	7	4	25
1966-67	25	6	4	35
1967-68	23	17	7	47
1968-69	20	25	4	49
1969-70	7	27	6	40
1970-71	7	11	4	22
1971-72	7	2	7	16
1972-73	12	1	3	16
Pre-Logging Yearly Average	16.3	8.0	4.0	28.3
Post-Logging Yearly Average	11.0	12.7	5.0	32.1

*Fish of a length which could be either adult or juvenile

Appendix 10. Numbers of cutthroat trout passing through the upstream trap on Needle Branch, 1959-1973.

Year	Adults	Juveniles	Unknown*	Total Live
1959-60	0	26	0	26
1960-61	4	40	2	46
1961-62	0	13	0	13
1962-63	0	15	0	15
1963-64	-	-	-	-
1964-65	-	-	-	-
1965-66	1	-	-	-
1966-67	2	6	3	11
1967-68	8	10	3	21
1968-69	6	21	1	28
1969-70	0	9	2	11
1970-71	0	7	1	8
1971-72	1	6	2	9
1972-73	3	2	0	5
Pre-Logging Yearly Average	1.0	23.5	0.5	25.0
Post-Logging Yearly Average	2.9	8.7	1.7	13.3

Appendix 11. Population estimates for cutthroat trout in Deer Creek, Flynn Creek, and Needle Branch during 1962-1773. Logging occurred during 1966.

Year	Deer Creek	Flynn Creek	Needle Branch
1962	898	640	225
1963	813	527	361
1964	731	568	272
1965	740	493	199
1966	834	612	65
1967	853	720	78
1968	694	801	89
1969	1366	934	179
1970	1350	835	59
1971	1205	868	102
1972	965	758	69
1973	-	577	56
Pre-Logging Average and (Range)	796 (731-898)	557 (493-640)	264 (199-361)
Post-Logging Average and (Range)	1038 (694-1366)	763 (577-934)	87 (56-179)

Appendix 12. Counts and lengths of reticulate sculpins, *Cottus perplexus*, from Deer Creek traps, 1959-1973.

Year	Total Number Measured	Number Length	Average Range	Length
1959	1	0	-	-
1960	19	3	55.7 mm	52-59 mm
1961	40	4	53.5	27-78
1962	17	16	59.0	26-89
1963	12	8	66.9	23-76
1964	7	7	50.1	27-86
1965	10	8	63.9	44-84
1966	9	9	54.9	28-83
1967	15	15	59.1	36-73
1968	44	34	43.1	23-76
1969	76	69	42.3	14-80
1970	53	48	47.1	18.5-91
1971	11	11	60.4	38-75
1972	12	10	62.1	42-72
1973	15	3	62.0	49-69
Total	341	240		14-91

Appendix 13. Counts and lengths of reticulate sculpins, *Cottus perplexus*, from Needle Branch traps, 1959-1973

Year	Total Number	Number Measured	Average Length	Length Range
1959	0	0	-	-
1960	7	7	67.0 mm	55-78 mm
1961	29	3	64.7	51-83
1962	16	14	72.3	62-86
1963	48	35	70.1	47-99
1964	37	35	72.7	48-100
1965	31	31	59.3	33-84
1966	14	10	67.7	63-75
1967	4	4	74.5	63-88
1968	2	2	83.0	78-88
1969	9	8	72.4	50-83.5
1970	3	2	71.0	60-82
1971	2	2	88.0	87-89
1972	5	3	61.7	41-79
1973	17	16	69.1	36-92.5
Total	224	168	-	33-100

Appendix 14. Counts and lengths of reticulate sculpins, *Cottus perplexus*, from Flynn Creek traps, 1959-1973.

Year	Total Number	Number Measured	Average Length	Length Range
1959	1	0	-	-
1960	22	2	62.0 mm	59-65 mm
1961	76	16	60.5	37-80
1962	58	36	57.9	29-80
1963	58	21	62.1	39-87
1964	42	41	57.8	21-91
1965	107	105	44.4	26-98
1966	7	5	69.0	61-79
1967	15	13	55.9	37-80
1968	26	24	61.4	24-89
1969	34	34	48.3	16-88
1970	51	49	42.2	18-95
1971	21	21	61.8	25-90
1972	34	34	46.8	21.5-71
1973	7	6	66.7	60-74
Total	559	398		16-98

Appendix 15. Counts of adult and ammocoete western brook lampreys (*Lampetra richardsoni*) from the downstream and spillway traps on Flynn Creek, 1959-1973.

Year	Adults	Ammocoetes
1959	11	*
1960	14	*
1961	12	425
1962	10	1934
1963	17	1265
1964	9	1144
1965	9	751
1966	2	380
1967	10	125
1968	50	149
1969	0	179
1970	5	127
1971	3	47
1972	13	52
1973	3	38
Total	168	6616

*No records available

Appendix 16. Counts of adult and ammocoete western brook lampreys (*Lampetra richardsoni*) from the downstream, upstream, and spillway traps on Needle Branch, 1959-1973.

Year	Adults	Ammocoetes
1959	0	*
1960	4	*
1961	2	5
1962	17	11
1963	37	11
1964	34	24
1965	70	128
1966	34	119
1967	8	16
1968	15	31
1969	0	40
1970	2	19
1971	1	53
1972	0	33
1973	2	14
Total	226	504

*No records available

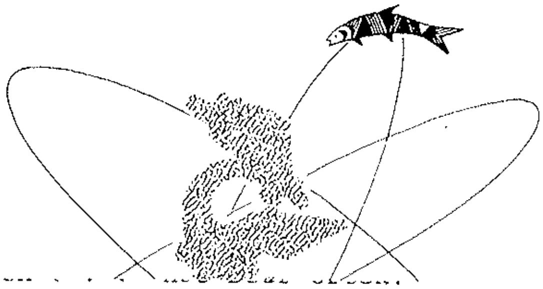
Appendix 17. Counts of adult western brook lampreys (*Lampetra richardsoni*), adult Pacific lampreys (*Entosphenus tridentatus*) and lamprey ammocoetes from downstream, spillway, and upstream traps on Deer Creek, 1959-1973.

Year	Pacific Lamprey	Brook Lamprey	Ammocoetes
1959	0	2	*
1960	1	24	2
1961	2	2	798
1962	0	4	879
1963	11	9	371
1964	10	7	208
1965	0	24	172
1966	0	19	105
1967	0	3	16
1968	0	219	225
1969	0	0	317
1970	4	2	115
1971	0	23	219
1972	0	30	133
1973	0	2	107
Totals	28	370	3667

*Records not available

THE ALSEA WATERSHED STUDY:
Effects of Logging on the Aquatic Resources of Three Headwater Streams of the Alsea River, Oregon
Part II - Changes in Environmental Conditions

Dr. John R. Moring



ERRATA
Alsea Watershed Study, Part II
Moring and Lantz
Fishery Research Report #9
Appendix 8, Page 38

Legend should read: "Mean daily discharge (cfs), by month, for Needle Branch . . ." not Deer Creek.

Fishery Research Report Number 9
Oregon Department of Fish and Wildlife
Corvallis, Oregon
December, 1975

Federal Aid to Fish Restoration
Project AFS-58
Final Report

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ABSTRACT

Three small tributaries of the Alsea River, Oregon, were monitored during a 15-year study, 1959-1973. One watershed (Needle Branch) was clearcut without buffer strips. The second (Deer Creek) was clearcut in patches with buffer strips. The third (Flynn Creek) was unlogged, and served as a control. This portion covers the environmental results of the study, and outlines those components that were altered as a result of logging activities (road construction, yarding, felling).

Water temperature maxima and ranges were significantly increased in Needle Branch by the removal of riparian, protective vegetation during clearcutting. Maximum temperatures reached 26.1°C near the mouth, and 29.5°C at a point upstream in summer 1967. Temperatures increased 12.7°C over the pre-logging average in June, and a 15.6°C maximum diurnal fluctuation was measured in 1967. Surface dissolved oxygen levels dropped to 2.5 mg/liter in the summer of logging, and intragravel levels decreased to a mean of 1.3 mg/liter the same summer. There was a pronounced decrease in intragravel dissolved oxygen during the first winter when salmonid eggs were developing in the gravel. Mean monthly streamflow increased by 26.9 percent in Needle Branch after logging. There was a 205.3 percent increase in suspended sediments in Needle Branch, and a 53.5 percent increase in Deer Creek following road construction. Permeability of the gravel in Needle Branch was depressed from logging, and remained so during the post-logging years.

INTRODUCTION

The small coastal streams of western Oregon are important spawning and rearing areas for several species of salmon and trout. Of the two important salmon species in Oregon (chinook and coho), coho salmon are characteristically present in these smaller streams. They share the stream habitat with cutthroat trout, rainbow and rainbow steelhead trout, as well as some nonsalmonid fish species. These small headwater streams are often located in timbered areas suitable for logging and associated road construction. Because of their small size and isolated location, they are often not given effective protection during felling and yarding operations.

Logging practices can indirectly result in changes in the biological components of a stream, and can have direct and indirect effects on the physical environment in streams. Felling trees into streams, or yarding timber across streambeds do not in themselves directly kill or redistribute fishes. But, changes in environmental parameters can and do influence the biological segment of the stream ecosystem. The primary environmental changes of concern are the effects of siltation, logging debris, gravel scouring, destruction of developing embryos and alevins, blockage of streamflow, decrease in surface and intragravel dissolved oxygen, increase in maximum and diel water temperatures, changes in pool/riffle ratios and cover, redistribution of fishes, reduction in fish numbers, and reduction in total biomass. The relationship of logging activities to these undesirable changes in stream environments has been explored in numerous logging studies in the western continental United States, Alaska, British Columbia, and elsewhere.

In earlier years, logging studies were characteristically short-term and concerned with obvious stream damage related to logging activities. Although short-term studies continue to be undertaken, they are much less detailed and involved with pertinent problems. When sufficient funds are available, researchers are turning to long-term case history studies, where definitive results can be obtained.

The principal logging study in Montana was the long-term Pinkham Creek project in the Stillwater River Drainage. The studies involved, primarily, the yearly monitoring of trout and char population numbers (Stefanich 1957; Hanzel 1961). Several studies in Idaho have concentrated on the effects of logging on salmonid streams. Bachman (1958) measured physical and biological conditions in trout streams of three uncut watersheds and one logged watershed in Idaho. Water temperatures apparently did not change following logging, but sedimentation from road construction did increase, especially during periods of heavy runoff. Edgington (1969) reviewed the findings of an 11-year study of two trout streams. The stream in one watershed (where 8 percent of the area was logged) exhibited no significant change in water quality or level of bottom invertebrates. On the other stream, however, 97 percent of the basin was cut, and several changes were noted. Siltation was evident in the early years as a result of road construction, and the abundance of four orders of insects declined for several years, then recovered by the end of the study. The U.S. Forest Service has studied sediment levels, gravel composition and salmon populations on the South Fork of the Salmon River (Platts 1974a, 1974b, 1974c). Sediment levels increased on the stream from 1952-1965 as a result of logging and road construction. Since 1966, the river system has been able to expell much of the excess sediment. Although the available spawning gravel appears to be increasing in known spawning grounds, it is doubtful the sediment loads in the river will ever return to the pre-logging conditions.

Washington logging studies have been limited. Wendler and Deschamps (1955) described the blockage of salmon runs by splash, roll and pond-type log dams. Deschamps (1971), Cederholm and Lestelle (1974) and Fiksdal (1974) studied the effects of logging on Stequaleho Creek and the Clearwater River. Generally, the concern was several landslides into the river, resulting in siltation increases. Cederholm and Lestelle studied salmonid populations during 1971-72, along with gravel composition, suspended sediment, and benthic invertebrates. Levels of fines increased in the spawning bed gravel of the streams, but the hatching survival of cutthroat trout embryos was not significantly changed in these areas from hatching survival in unaffected sections. Coho salmon population densities were low, and the levels of benthic invertebrates were significantly lower than in unaffected areas of Stequaleho Creek.

The California Department of Fish and Game has been involved in logging damage surveys and localized surveys for many years (Cordone and Pennoyer 1960; Fisk et al. 1966), but this type of activity has given way to the long-term case history type of study. One of the enduring logging studies in the west has been the cooperative Caspar Creek study in northern California (Kabel and German 1967; Burns 1972). From its inception in 1960, researchers at Caspar Creek, and other northern California streams, continually monitored streamflow. Other factors measured for shorter periods have included biological aspects (Burns 1971), and environmental changes (Burns 1970; Kopperdahl et al. 1971; Krammes and Burns 1973). Researchers have found that sediment levels increased during and after road construction. During the first winter following road construction, sediment levels were over four times higher than pre-construction levels, but have decreased in subsequent years (Krammes and Burns). Water temperatures increased slightly following road construction (Krammes and Burns), but temperature increases were greater following logging (Kopperdahl et al.). Burns (1972) indicated salmonid populations were altered as a result of logging and road construction.

British Columbia logging research has been applied to several logging related problems. The Canada Department of Fisheries and other agencies (Anonymous 1966) analyzed the problem of log driving on salmonid populations and their environment in the Stellako River. Results indicated log driving causes gravel scouring and disruption of spawning beds, erosion of river banks, a greatly reduced recreational fishery along the river, and increased levels of bark and debris in the stream and in the spawning gravel. Additional studies by Servizi et al. (1970) have shown that decaying bark may have a significant effect on developing sockeye salmon eggs. Short-term logging studies on Jump Creek and Wolf Creek, Vancouver Island, indicate some changes in fish populations in logged streams (Narver 1972), while the ongoing Carnation Creek study hopes to answer several questions with the case history approach (Narver 1971).

The harvest of timber in Alaska has increased significantly in the past 30 years. Initial logging research by the U.S. Forest Service began in 1949, and has continued at various levels to date in southeast Alaska (Sheridan and McNeil 1968; Meehan et al. 1969; Sheridan and Olson 1970). Beginning in 1956, the Fisheries Research Institute of the University of Washington has supplemented the federal research in several stages. The major emphasis in the 1950's and 1960's was on the pink and chum salmon streams of southeast Alaska (Salo 1967). More recent logging studies have concentrated on coho salmon and associated changes in environmental conditions (Tyler and Gibbons 1973), and the effects of log rafting on the marine benthos (Pease 1974). In the last several years, the National Marine Fisheries Service has conducted research into log rafting problems (Ellis 1973). The Alaska Department of Fish and Game has continued research into the effects of logging on Dolly Varden (Reed and Elliott 1972) and salmon (Kingsbury 1973), and the toxicity of decaying bark on pink salmon fry and some crustaceans (Buchanan et al. 1976). Out of the Dolly Varden study came a series of guidelines for logging operations and baseline biological measurements in important southeast Alaska sports fishing areas (Elliott and Reed 1973).

Several logging studies have been undertaken in the Cascade Range of Oregon, including the Steamboat Creek drainage area (Brown et al. 1971), and the H.J. Andrews Experimental Forest (Wustenberg 1954; Brown and Krygier 1967; Levno and Rothacher 1967, 1969). Brazier and Brown (1973) studied applications of buffer strips in both the Cascade Range and the Oregon Coast Range, and Moring and Lantz (1974) reported the findings of a six-year study of 12 coastal streams of western Oregon. Cutthroat trout populations appeared to decrease on streams following logging, but the reactions of coho salmon populations were mixed. Maximum stream temperatures increased, and dissolved oxygen levels generally declined after logging. There were also changes in amounts and composition of spawning gravel, but those streams with intact buffer strips suffered less damage than those without buffer strips.

The limitations of short-term studies, however detailed, become apparent when the lack of background data on biological and physical cycles hinders the interpretation of results. Most long-term case histories of logged watersheds have only been undertaken in the last 25 years. The results of the largest such study, the Alsea Watershed Study, will be reported here. The 15-year study was the most extensive study of biological and environmental features of logged and unlogged watersheds ever undertaken in North America.

The Governor's Committee on Natural Resources established the Alsea Watershed Study in 1957. Funding from this source disappeared a year later, but federal and state agencies supported the work for the 15-year study period. The Alsea Watershed Study was a cooperative venture involving hundreds of individuals. Principal cooperators throughout the study were the Oregon State Game Commission (Oregon Department of Fish and Wildlife), Oregon State University (primarily the School of Forestry, and the Departments of Botany, Civil Engineering, Entomology, and Fisheries and Wildlife), the U.S. Forest Service, U.S. Geological Survey, Federal Water Pollution Control Administration, the Georgia-Pacific Corporation, and Mr. Fred Williamson, a private landowner. Other cooperators included the U.S. Public Health Service, Oregon Cooperative Wildlife Research Unit, Oregon State Board of Forestry, and the Department of Environmental Quality. In addition to the Georgia-Pacific Corporation, the logging companies were the Stokes Lumber Company and Timber Access Industries, both of Corvallis, Oregon.

Studies began in July 1959 on three small watersheds in Lincoln County, Oregon. The three creeks involved are headwater tributaries of the lower Alsea River. One watershed, Flynn Creek, was left unlogged, and served as a control. The Deer Creek watershed was patch cut with intact buffer strips along the stream. The Needle Branch watershed was clearcut without buffer strips.

Logging road construction took place during May to October 1965. The timber harvest on the Deer Creek and Needle Branch watersheds occurred the following year, again during May to October. Slash burning was completed on Needle Branch and on two sections of Deer Creek prior to November 1966. The remaining section was slash burned some months later. Post-logging studies continued until October 1973.

This sequence provided a 7-year pre-logging study period, 1959-1965, logging in 1966, and a 7-year post-logging study period 1967-1973. For comparative estimates, the period 1959-1965 constituted the pre-logging work and 1966-1973 constituted the post-logging work. Among the primary objectives of the work were:

1. To study in depth the population characteristics of salmonids and other fish species in Flynn Creek, Deer Creek and Needle Branch over a 15-year period, 1959-1973.
2. To study the direct and indirect effects of logging on fish.
3. To compare the effects of two common logging techniques on biological and physical properties of streams, using Needle Branch and Deer Creek as test streams, and Flynn Creek as a control stream.
4. To analyze the effects of environmental changes (natural and logging-related) on salmonid fish species, particularly coho salmon and cutthroat trout.
5. To derive some indication of the natural fluctuations in fish populations and physical and biological properties of the three Alsea Study streams.
6. To make recommendations, on the basis of accumulated data, as to desirable and undesirable logging practices (including road construction, buffer strips, and yarding and felling of trees).

In order to present the results of this extensive study in the most logical manner, three separate but related Alsea Watershed Study reports are being issued. Part I includes the results of the biological investigations of the study. Part II includes the results of the environmental measurements during the study. Part III includes the discussion, summary and recommendations. Numberous papers, theses and dissertations have been issued on various aspects of the study during the past 15 years. Pertinent results of these publications, as they pertain to the results and discussion of accumulated data, will be included.

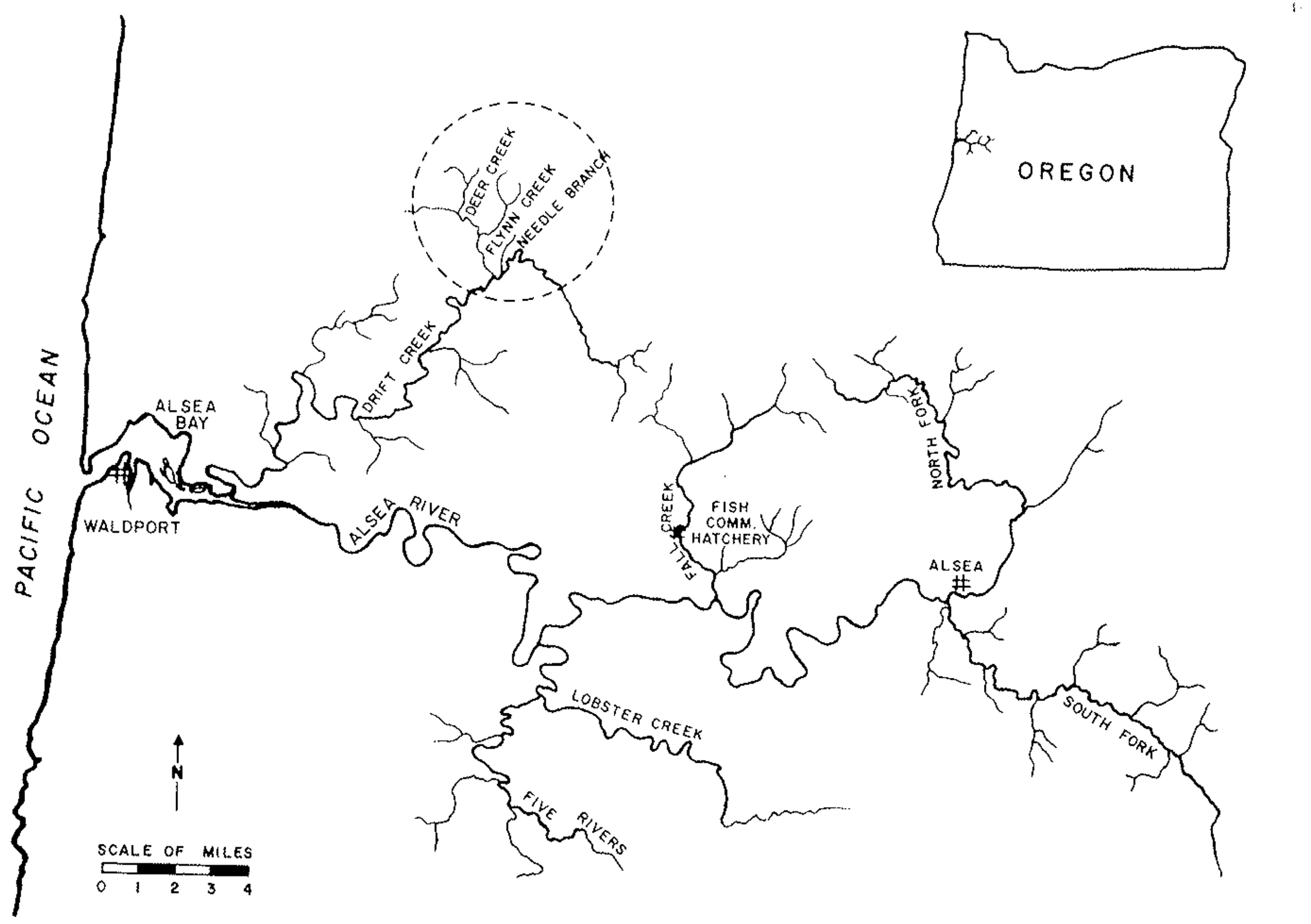
STUDY AREAS

Three headwater tributaries of the Alsea River were selected for study. The Deer Creek, Flynn Creek and Needle Branch watersheds are located in a portion of Lincoln County, approximately 16 km (10 miles) south of Toledo, Oregon (Figure 1). All three streams eventually flow into Drift Creek, and ultimately into Alsea Bay. Deer Creek is a tributary of Horse Creek. Flynn Creek is the major tributary of Meadow Creek, which then flows into Horse Creek. Horse Creek joins Drift Creek approximately 60 meters from the junction of Needle Branch and Drift Creek (Figure 2). Drift Creek flows southward until entering Alsea Bay approximately 6.4 km (4 miles) east of Waldport.

The three streams have extremely variable flow rates, and are of different sizes. Needle Branch is the smallest stream, followed by Flynn Creek, and then Deer Creek. The three creeks can be considered typical of small western Oregon headwater streams. The principal cause of the variable flow rates is the combined effect of the small sizes of the streams, and the effects of winter freshets, which generally occur from November to February.

The study area is located in the northern Oregon Coast range in a region of heavy rainfall. Mean annual precipitation was reported by Hall and Lantz (1969) as 244 cm (96.1 inches) during the 1959-1965 pre-logging period. Air temperatures ranged from approximately -7 to 32°C (19 to 90°F). Snowfall in the area is relatively light, occurring only two or three times per year, and never remaining on the ground for long periods.

The geology of the region is typical of the northern Oregon Coast range, with the principal underlying component the northern extension of the Tyee sandstone formation. Corliss and Dyrness (1965) have summarized the principal soil and vegetation components of the area, but particular vegetation characteristics of each watershed will be discussed in more detail in the descriptions of individual stream sites. Generally, 100-year-old Douglas-fir (*Pseudotsuga menziesii*) was the principal commercial species harvested. The important hardwood in the area was red alder (*Alnus rubra*). Understory vegetation was primarily salmonberry (*Rubus spectabilis*), sword fern (*Polystichum*



Alsea River system and Drift Creek study area.

Figure 1. Location of Alsea Watershed Study in Western Oregon.

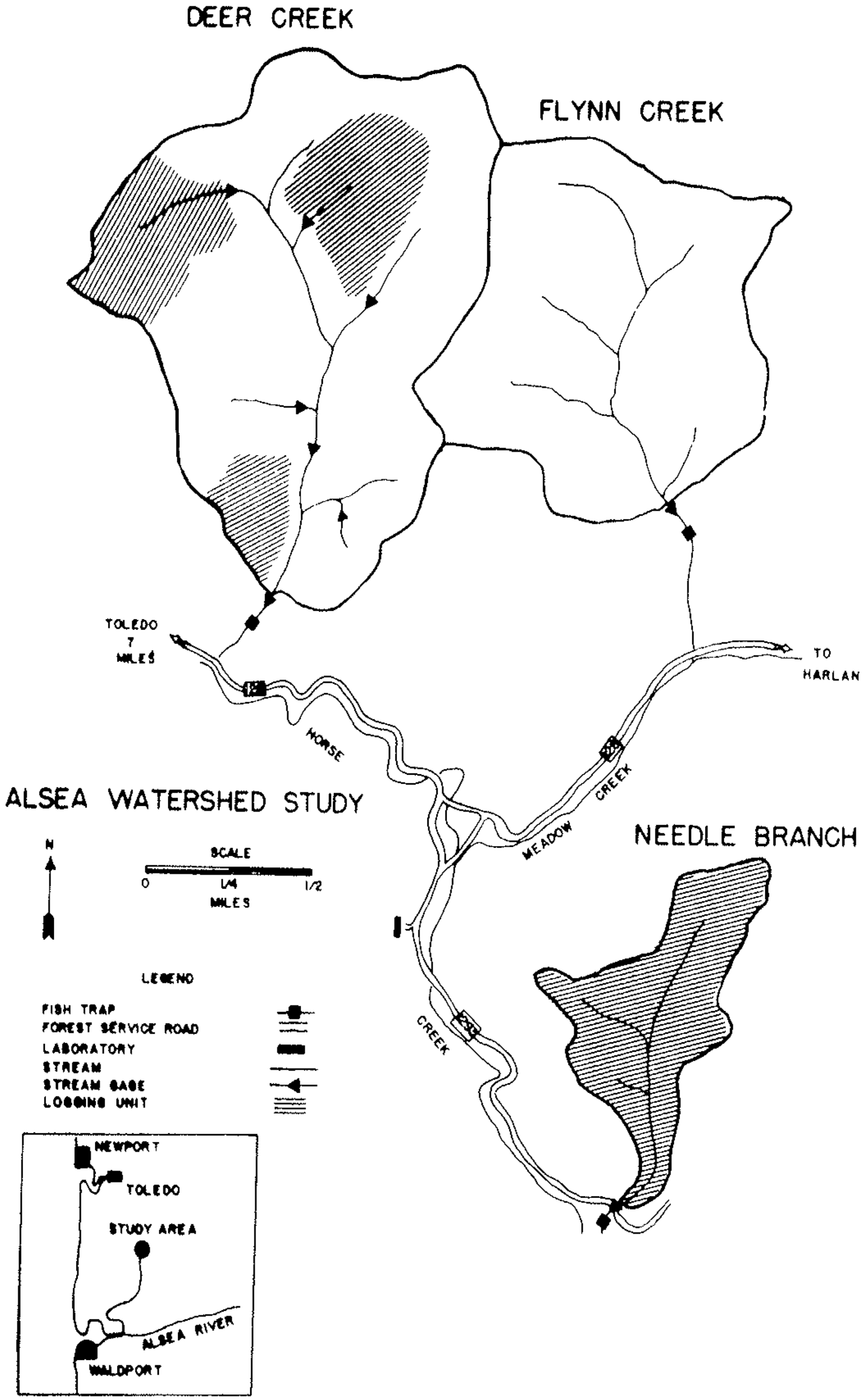


Figure 2. Map of the Study Watersheds. The approximate lengths of the streams accessible to anadromous salmonids are: Deer Creek –2324m, Flynn Creek–1433m, Needle Branch–966m.

munitum), skunk cabbage (*Lysichitum americanum*) and vine maple (*Acer circinatum*).

Four salmonid species were present in one or more of the study streams: coastal cutthroat trout (*Salmo clarki clarki*), steelhead trout (*S. gairdneri gairdneri*), chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*). Steelhead trout and chinook salmon are uncommon and are usually only present in Deer Creek.

Chapman (1961, 1962a, 1965), Au (1972) and Lindsay (1975) have described the life history patterns of coho salmon in the three study streams. Generally, adult coho salmon enter the streams to spawn from November through February and the fry emerge February through May. After a year of residence in the creeks, most juvenile coho migrate to sea the following spring. Lowry (1964, 1965, 1966) has described the biology of cutthroat trout in the study streams. Sea-run adults follow similar migration timing as adult coho salmon, but juveniles may remain in the streams for several years prior to downstream migration. There is probably a resident population of cutthroat trout in the streams, but the sea-run component dominates. Distinguishing which juveniles or adults in streams may be "residents" is difficult, because some sea-run individuals may remain in the stream for as much as five years before migrating (Richard Giger, personal communication). Others may move to the estuary and no further, thus confusing scale analysis.

Other fish species in the streams were the reticulate sculpin (*Cottus perplexus*), Pacific lamprey (*Entosphenus tridentatus*), and western brook lamprey (*Lampetra richardsoni*). No other fish species were noted during the 1959-1973 study period.

Principal laboratory and housing facilities for the project were at the laboratory located along Horse Creek (Figure 2). Studies concerning gravel incubation, predation, and the effects of sedimentation, among others, were conducted at this station (see Methods sections in Parts I and II). The field location of the laboratory provided easy access to the biological and physical components of the study streams.

FLYNN CREEK

The Flynn Creek watershed (approximately 202 ha) was not logged, and served as a control for the study. Stream length is approximately 1,433 m, with mean summer width 1.74 m, and mean summer depth 13 cm (Chapman 1961). The stream gradient averages 0.025 meter per stream meter.

Stream distance was marked by stakes from the gauging station (0 meters, 0 feet). The fish collection trap was located 305 meters (1,000 feet) downstream from the stream gauge. Between marker 305 meters (1,000 feet) and 549 meters (1,800 feet) there is a steep canyon which restricts the available stream area. Historically, there was little spawning in this steep area of much exposed bedrock. Following scouring in the winter flooding of 1971-72, the remaining gravel largely disappeared, and spawning activity in the canyon effectively ceased. There are four small tributaries to Flynn Creek (Figure 2), evenly spaced along the stream length. The final study marker stake was at 1006 meters (3,300 feet) upstream. The portion of the stream beyond that point was unstudied.

During the pre-logging period, mean summer streamflow was 4.5 liters per second (0.16 cfs), and peak winter flow reached 3,877 liters per second (137.0 cfs) (Hall and Lantz 1969). Annual mean water temperature was 9.7°C, ranging from a minimum of 2.2 to a maximum of 16.6°C, essentially the same as those recorded on other streams in the pre-logging period. Diurnal temperature range varied from 0.5 to 2.2°C (Hall and Lantz).

The Flynn Creek watershed is owned by the U.S. Forest Service, and the principal species of trees are Douglas-fir and red alder. Douglas-fir were primarily 30 to 50 and 70 to 110-year-old stands. Alder stands were 30 to 70 years old. The understory species were salal (*Gaultheria shallon*), sword fern, vine maple and salmonberry. Isolated groups of bracken fern (*Pteridium aquilinum*) were also present.

DEER CREEK

The Deer Creek watershed is the largest of the three study areas, covering approximately 304 ha. The stream length is approximately 2,324 m, with an average summer width of 1.80 m, and an average summer depth of 11 cm (Chapman 1961). Stream gradient averages 0.018 meter per stream meter.

The fish trap was located 152 meters (500 feet) below the gauge station (or a stream location of -152 meters). A steep canyon is present from the 152 meter stream marker to approximately the 427 meter (1,400-foot) location. From 427 meters to 1219 meters (4,000 feet), the stream is quite slow moving and meandering. The major tributary of Deer Creek was East Fork, entering at the 1433 meter (4,700-foot) marker. Two smaller tributaries entered the main stream below the East Fork junction, and two smaller tributaries entered above East Fork. The final study marker stake was at 2195 meters (7,200 feet) upstream from the gauge station.

Mean summer minimum streamflow in the pre-logging period was 8.5 liters per second (0.30 cfs). Peak winter flow was 5,688 liters per second (201 cfs). Annual mean water temperature in the pre-logging period was 9.6°C, ranging from a minimum of 1.1 to a maximum of 16.1°C. The diurnal range was 0.5 to 2.2°C (Hall and Lantz 1969).

Most of the watershed is owned by the U.S. Forest Service, with a small section near the mouth owned by the Georgia-Pacific Corporation, and the principal logged species of timber was Douglas-fir. Fir stands were primarily 50 to 70 and 70 to 110 years old. A few trees younger than 20 years were present in one small area. Red alder were primarily 40 to 60 years old. A few 20 to 40-year-old alder were present in the lower clearcut section. The understory was almost entirely salmonberry, vine maple and sword fern. Salal and bracken fern were present in a few isolated locations.

Locations of the three patches clearcut are shown in Figure 2. The lower section was along the west side of the stream at the effective lowest portion of the watershed. A buffer strip was left along the creek. The northern clearcut was on the hillside between the East Fork drainage and the main creek drainage. Buffer strips were left along all branches of the stream. The third area was at the extreme northwestern section of the watershed. Clearcutting occurred on both sides of the main branch in a section located immediately above the study area.

NEEDLE BRANCH

The Needle Branch watershed is the smallest of the study areas, only 75 ha in size. The stream length studied is approximately 966 m. The stream gradient is 0.014 meters per stream meter. Mean summer width is 1.10 m, and mean summer depth is 7 cm (Chapman). The fish trap was located approximately 61 meters (200 feet) below the stream gauge. The two distinctive features along the stream are small waterfalls at approximately 808 meters (2,650 feet) and 869 meters (2,850 feet). Two small tributary streams enter Needle Branch above the second falls. Beyond approximately 1067 meters (3,500 feet), flow is greatly reduced, and isolated pools are present to the headwaters. The 742 meter (2,600-foot) marker was the final study area stake, but population estimates and other surveys were conducted above this point after 1966.

Mean summer minimum streamflow was 0.6 liters per second (0.02 cfs). The peak winter flow was 1,415 liters per second (50.0 cfs). The annual mean water temperature of 9.7°C was similar to that on the other study streams. Water temperatures ranged from a minimum of 1.6 to a maximum of 16.1°C. The diurnal temperature range was 0.5 to 1.5°C prior to logging (Hall and Lantz 1969).

Part of the lower section of the Needle Branch watershed was privately owned by Mr. Fred Williamson. The remainder was owned by the Georgia-Pacific Corporation. Several timber species were present, including Douglas-fir, western red cedar (*Thuja plicata*), and red alder. Douglas-fir stands were all 70 to 110 years old, while cedar stands were 30 to 50 years old. A small stand of 30-50 year old Oregon white oak (*Quercus garryana*) was also present. The age of a small patch of alder was in excess of 100 years. The understory was primarily vine maple and sword fern, although salal, bracken fern, salmonberry, thimbleberry (*Rubus paraviflorus*) and dewberry (*R. vitifolius*) were also present. The vegetation of the lower and central portions of the watershed was similar to that on Deer and Flynn creeks,but the understory at the head of the stream consisted primarily of shrubs, herbs and various grasses.

The entire watershed was clearcut and later slash burned. No buffer strip was left along the streambed. No effort was made to protect the stream from logging activity, except to eventually clear debris from the stream channel.

METHODS

Throughout the Methods and Results sections, the comparative terms "pre-logging" and "post-logging" are often used for all three streams, even though there was no actual logging on Flynn Creek. In the case of Flynn Creek, the terms refer to the periods of pre-logging and post-logging on the other streams, and are used with the Flynn Creek control parameters only as a means of comparison within the two time frames.

Temperature

Continuous recordings of water temperatures were obtained with Partlow recording thermographs. At least one unit was established in each watershed throughout the study. In most years prior to 1969, 6 units were positioned along Needle Branch, 11 units were placed along Deer Creek, and 1 unit was located at the stream gauging station in Flynn Creek.

After 1969, the number of thermographs were reduced to 2 units on Deer Creek, a U.S.G.S. unit at the stream gauging station, and a Partlow gauge at marker 53 meters (175 ft.). Six units were used on Needle Branch after 1969, but one Partlow gauge (at 503 meters) was removed soon thereafter in 1969, another (at 192 meters) was removed in 1970, and a third (at 610 meters) was removed in 1971. Three units remained throughout the study, the U.S.G.S. unit at the gauge station, and Partlow gauges at 6 meters (20 ft.), and one at 305 meters (1000 ft.).

In addition to the above stations, additional Partlow units were operated during study pool observations in 1969 and 1970 (Lantz and Moring 1975 MS). Units were positioned at 389 meters (1275 ft.) and 518 meters (1700 ft.) in 1969, and at 358 meters (1175 ft.) in 1970 on Needle Branch. Units were also operated at 213 meters (700 ft.) in 1969, and 183 meters (600 ft.) in 1970 on Flynn Creek. These thermographs were used only during specific behavioral studies.

Partlow thermographs are accurate to within 0.3°C (0.5°F). Temperature records were recorded on circular 7-day charts. Temperatures were recorded in Fahrenheit, and later converted to degrees Celsius.

Specific, localized temperature measurements were made by graduate students conducting short-term (1-3 year) investigations. Thermograph probes were installed in salmon redds by Ringler (1970) to study the intragravel enviornment. Other studies also used portable thermometers to supplement thermograph readings.

Dissolved Oxygen

Dissolved oxygen levels were measured throughout the year at the surface and in the intragravel environment.

Intragravel measurements were obtained through perforated Mark VI standpipes (Figure 3). These standpipes were driven into gravel at several consistent station locations on each stream (Figure 4). Water samples were drawn from 10 inches below the streambed surface (Figure 5). This technique follows the method of Wickett (1954), with the improvements of Pollard (1955) and Terhune (1958).

Permanent standpipe locations were relatively consistent in number over the entire study period. Nine stations were established in Needle Branch and 11 in Flynn Creek. Twenty stations were used in 1963 and 1964 on Deer Creek, and 18 were used in 1973. In all other years, 19 were established. Standpipes were removed during actual logging, then replaced near their original locations.

Surface dissolved oxygen readings were made near the standpipe stations. During the 15-year study, dissolved oxygen levels for surface and intragravel were determined using the Winkler method, the Alsterburg modification of the Winkler method, and the portable Hach dissolved oxygen kits.

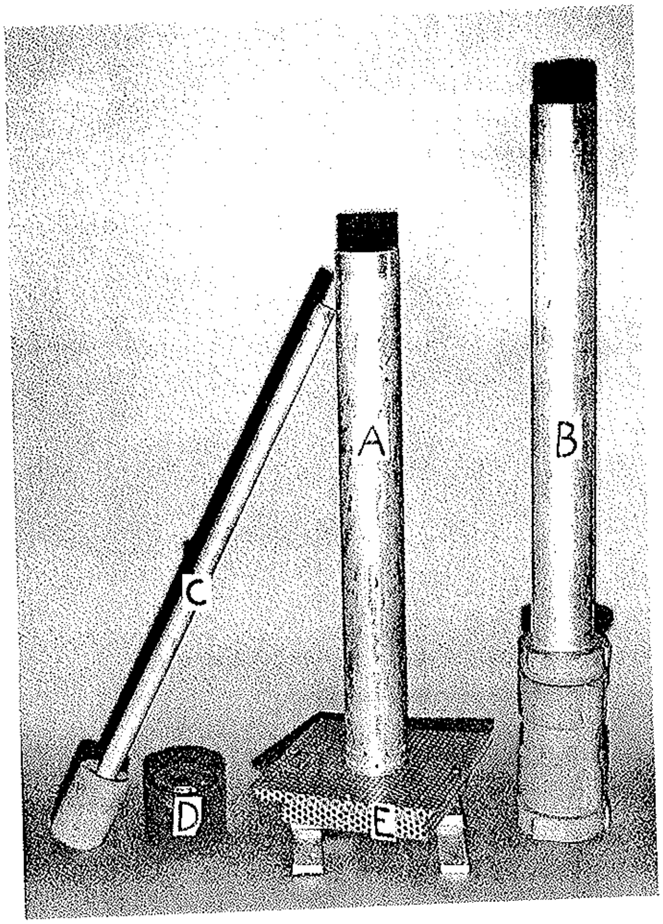


Figure 3. Components of Gravel Standpipe: (A) main body of standpipe that is inserted in the gravel, (B) extension tube, (C) sponge separator (prohibits surface/intragravel water exchange–dissolved oxygen sample is siphoned from this tubing, (D) cap, and (E) stainless steel box where fry or eggs can be placed for occasional emergence tests.

Figure 4. Permanent Standpipes inserted into locations along Flynn Creek.

Figure 5. Drawing Intragravel Dissolved Oxygen sample from 10 inches below streambed surface in standpipe inserted into gravel.

Precipitation

A standard U.S. Weather Bureau type, weighing rain gauge was positioned on each stream to record precipitation. The gauge registered cumulative rainfall over weekly periods.

Sunlight

Records of solar radiation were collected during all years in Needle Branch with a Belfort recording pyrheliograph. The radiation level activated a stylus, which recorded on a strip chart. Units were in gram calories/cm^2/minute.

Streamflow

Stream gauging stations were established near the outlets of the three watersheds in 1958 by the U.S. Geological Survey. Although records are available back to 1958, analysis in this discussion begins with the actual start of the study, October 1959. Each station housed a thermograph and a continuous streamflow recorder (Figure 6). Other equipment, such as suspended sediment sampling gear, was also housed in the locked unit. A V-notch, concrete streamflow recording weir (Figure 7) was constructed near the gauging station, and streamflow was monitored at this site.

Gauges were operated daily by Oregon State Game Commission personnel, with funding by Oregon State University, and serviced at intervals by the U.S. Geological Survey. Streamflow data were converted from gauge heights to discharge in cubic feet per second. During 1963-65, 6 additional gauges were established by the School of Forestry in Deer Creek to monitor streamflow upstream at two locations in Deer Creek proper, and on four principal tributaries.

Stream Erosion

Approximately 40 gravel erosion stations were established each year on the three streams from 1961 through 1972. Each station was the site of potentially good spawning gravel. A vertical column of 6 color coded, perforated ping-pong balls was placed in the gravel with a special driving pipe, in the manner described by McNeil (1962) and Pellet and McNeil (1964).

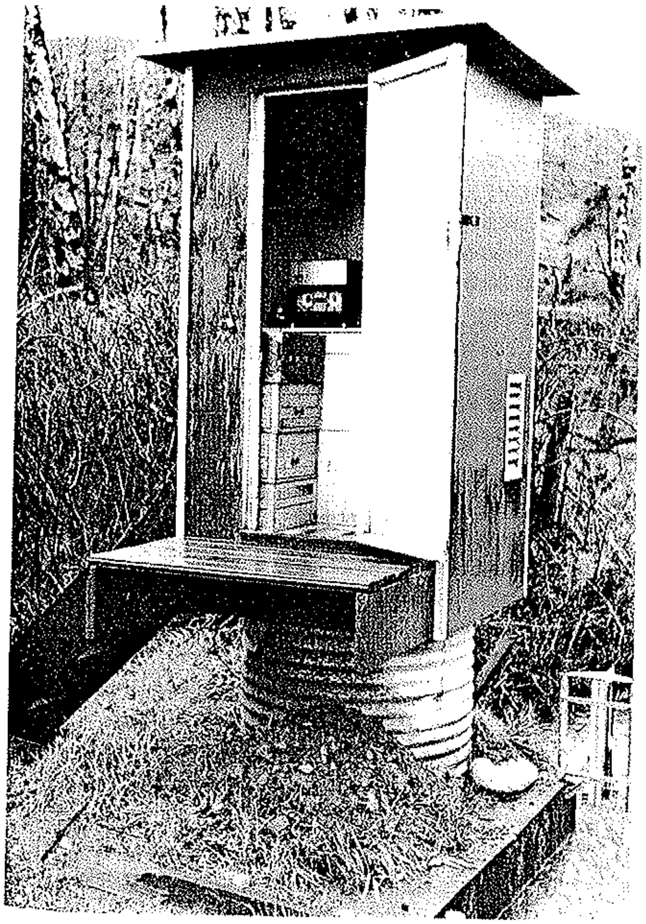


Figure 6. Gauge Station on Needle Branch. The unit houses a continuous streamflow recorder and a thermograph.

Figure 7. The Streamflow gauge weir on Deer Creek during low summer flows, August 7, 1967 (9.6 liters/sec, 0.34 cfs).

The 0.59 cm (1-½ inch) diameter balls were placed in the gravel in the fall, prior to spawning, and unearthed in the summer, after fry emergence. The color and/or letter marked on the remaining balls indicated the depth and extent of gravel erosion and scouring. Likewise, the amount of gravel on top of the balls indicated the extent of deposition. Data for 1961-66 were reported by Phillips et al. (1966), and cited by Koski (1966). Subsequent measurements have been unreported until now.

Gravel Composition

Composition of the gravel was determined with the method of McNeil and Ahnell (1960), using metal gravel samplers. The sampler was a round basin of stainless steel with a 4-inch diameter tube extending 10 inches from the bottom. The sampler tube was inserted into the gravel to a depth of approximately 10 inches (Figure 8). The bulk of the material from the tube was removed by hand and placed in the basin. Suspended fines were removed by inserting a plunger from a cistern pump into the tube. All gravel and fines were transported from the field sites in labelled, 3.79 liter (1 gallon) plastic jars.

All samples were analyzed volumetrically following the techniques of McNeil and Ahnell. Gravel samples were passed through a series of standard mesh Tyler Sieves: 50.8, 25.4, 12,7, 6.35, 3.327, 1.65, and 0.833 mm diameter (Figure 9). The material of each size class was compared to the total by determining the percent composition by volume. During 1967, some additional samples from Deer Creek were

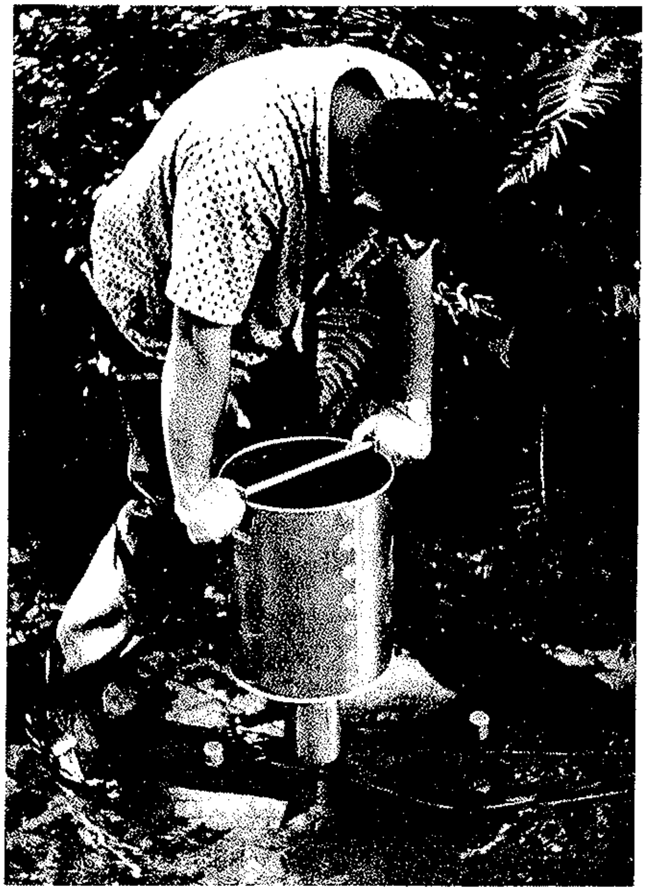


Figure 8. Inserting the Gravel Sampler into Spawning Gravel in Deer Creek.

compared by using gravimetric analysis. This analysis follows the methods used by the U.S. Forest Service.[1] In early 1968, samples were examined both volumetrically and gravimetrically.

Sediment

Sediment records are available throughout the study, as analyzed by the U.S. Geological Survey. All samples were collected with standard sediment samplers at the weirs.

Permeability

Measurements of gravel permeabilities were made with the aid of a permeability pump at permanent standpipe locations (Figure 10). The plastic cylinder pump apparatus (Figure 11) brought water from the subgravel environment, held under a one-inch head to determine permeability in units of ml/second pumped. These values were then converted to cm/hour following the methods of Terhune (1958).

Permeability measurements were recorded bi-weekly at standpipe locations, alternating with dissolved oxygen observations. Because of the problem of sand and sediment in

Figure 9. Sorting gravel samples by passing them through standard Tyler sieves.

Figure 10. Pumping water from a standpipe under 1-inch head to determine permeability of intragravel environment.

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[1] U.S. Forest Service. 1965. Analysis of streambed composition. Division of Resource Mgmt., Branch of Wildl. Mgmt. Mimeo. 3 p.

Mark VI standpipes, permeability measurements were not extremely accurate. However, data were used to denote relative permeabilities within gravel when the permeability of gravel is high or low compared to some point in time or another stream.

Stream Area Measurements

Stream area measurements were recorded on at least one stream in seven years during the study: 1959, 1960, 1961, 1962, 1968, 1971, and 1972. Measurements were recorded at 7.6m (25-foot) intervals during the months of July and August (the time of low flow). At each interval, the width was measured to the nearest ¼-inch (or tenth of inch) and the value was later converted to meters. Depth was measured at three equally spaced points across the stream, and the value converted to centimeters. An indication was made whether the measurement location was at a pool or riffle. The total lengths of pool areas and riffle areas, measured along the centerline of the streambed, were recorded. The amount of available spawning gravel was also determined during most surveys. Generally, the total amount of apparent spawning gravel was estimated as a percentage of the total stream area.

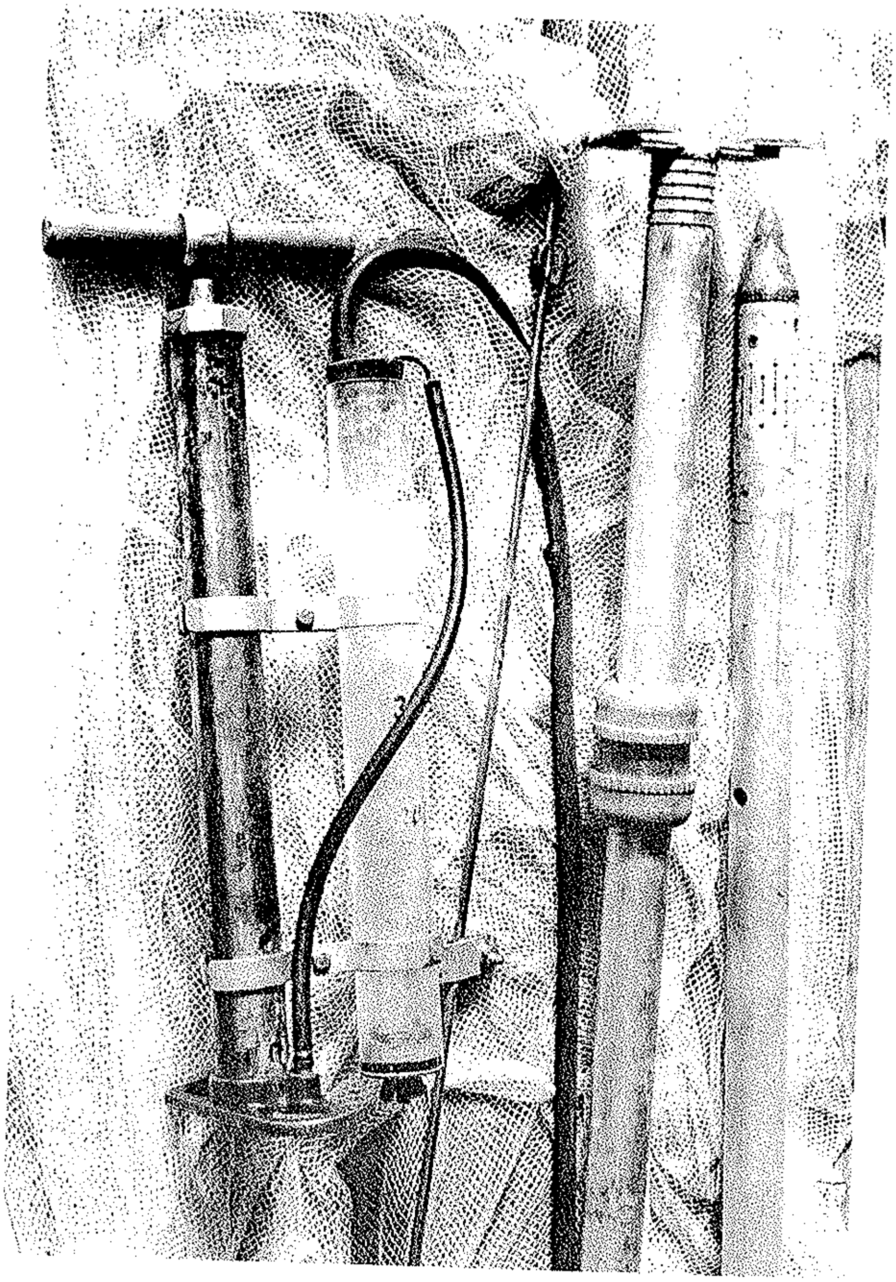

Figure 11. Stand pipe components and a permeability pump apparatus.

RESULTS

TEMPERATURE

The removal of streamside vegetation during clearcutting will increase solar radiation, which will ultimately increase water temperatures in small streams (Greene, 1950; Chapman, 1962b; Reinhart et al. 1963; Brown and Krygier 1967, 1970; Levno and Rothacher 1967; Gray and Edington 1969; Meehan et al. 1969; Meehan 1970; Brown et al. 1971; Narver 1972; Tyler and Gibbons 1973; Moring and Lantz 1974). The magnitude of temperature change depends upon the amount of cutting (Meehan et al. 1969; Brown and Krygier 1970). Often, maximum stream temperatures are found after debris clearance and slash burning (Levno and Rothacher 1969). Where buffer strips of vegetation are left along the streambanks, changes in water temperature are minimal (Brazier 1973; Brazier and Brown 1973).

The water temperature pattern evident in the control stream, Flynn Creek, is cyclic with very little range (Figure 12; Appendix 1). During 1965, the year prior to logging, annual temperature minimums ranged from 7.2°C to 12.2°C and maximums ranged from 7.8° to 14.4°C.

The pattern on Deer Creek was only slightly altered after logging (Figure 13). Temperature ranges were generally wider in Deer Creek than in Flynn Creek. But, this was evident before and after logging. The cyclic and range patterns remained similar in post-logging years, except for an unusually warm summer in 1972 (Appendix 2). The same condition was evident in Flynn Creek, but the peak was less extreme.

There was a significant change in the temperature pattern in Needle Branch following logging (Appendix 3). Figure 14 illustrates how the temperature patterns changed in 1966. At the stream gauge station (where temperatures did not reach the maximums found in upstream areas), pre-logging maximums ranged from 7.2° to 16.1°C. After logging and the removal of riparian vegetation, maximums ranged from 7.8° to 26.1°C. This reflects an increase in water temperature at the stream gauge of 12.7°C over the pre-logging average in June, 11.8°C over the pre-logging average in July, and 9.3°C over the pre-logging average in August.

Maximum water temperatures were reached in 1967, following debris clearance and slash burning (Figure 15). The yearly maximums and ranges have been decreasing each subsequent year (Figures 14, 15). Similar patterns were evident in the gauges at a higher station (Figure 16). The decline in maxima is due to the slow return of riparian vegetation, which reduced the amount of solar radiation reaching the stream.

A daily record of temperature minimums and maximums was plotted for the warmest year, 1967 (Figure 17), showing dramatic increases in stream range and maxima. Water temperatures rose sharply in mid-May, peaked at the end of June to early July, and declined slowly until January.

Brown and Krygier (1970) used 6 thermographs in Needle Branch, one in Flynn Creek, and 11 in Deer Creek. They detected a 15.6°C (28°F) maximum diurnal fluctuation in Needle Branch in 1967. The maximum temperature at an upstream gauge in 1967, 29.5°C (85°F), represented a 15.6°C (28°F) increase over the 1965 maximum. On the stream with a protective buffer strip, Deer Creek, the maximum water temperature only increased by 0.8°C (1.5°F) over the same period. The maximum diurnal fluctuation was only 5.6°C (10°F) both years.

Brown and Krygier also looked at the maximum fluctuations in Flynn and Deer creeks, and Needle Branch in 1965. These values were 3.3°C (6°F), 5.6°C (10°F) and 4.4°C (8°F), respectively. At no time during or after logging were these maximum fluctuations exceeded in Flynn or Deer creeks. On Needle Branch, however, the 4.4°C maximum

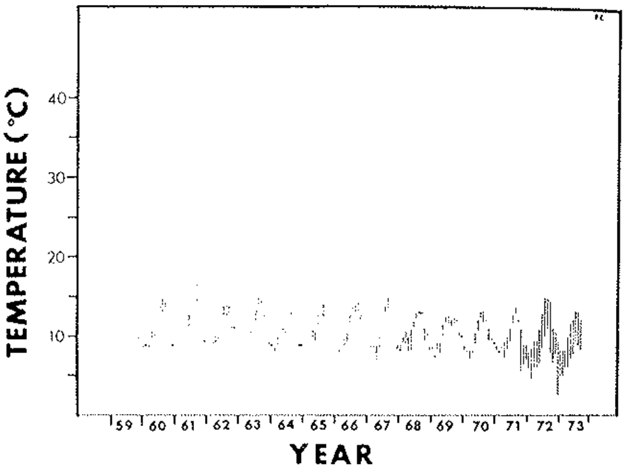

Figure 12, Monthly temperature minimums and maximums recorded at the 0 meter stream gauge on Flynn Creek. Data from the U.S. Geological Survey.

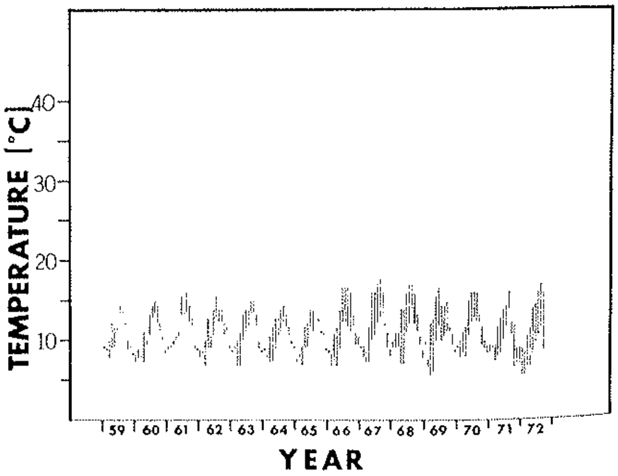

Figure 13. Monthly temperature minimums and maximums recorded at the 0 meter stream gauge on Deer Creek. Data from the U.S. Geological Survey.

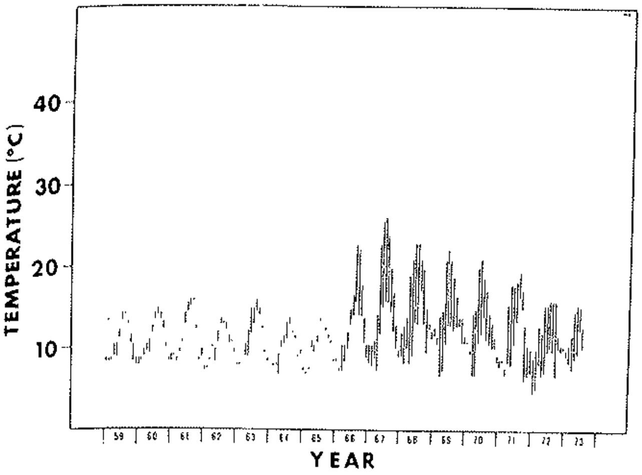

Figure 14. Monthly temperature minimums and maximums recorded at the 0 meter stream gauge on Needle Branch. Data from the U.S. Geological Survey.

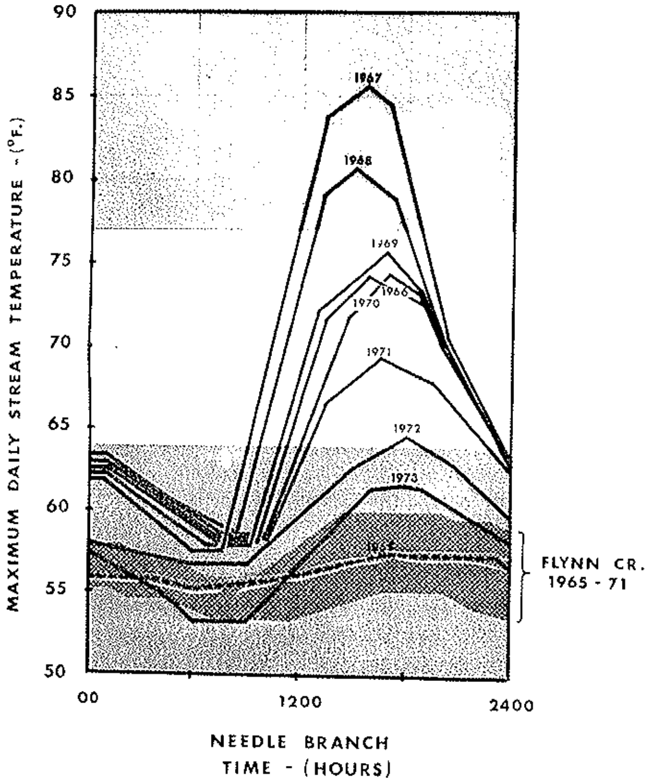

Figure 15. The temperature pattern on the days of the annual maximum recorded on Needle Branch and Flynn Creek before (1965), during (1966), and after (1967-1973) logging.

fluctuation was exceeded 28 percent of the time in 1966, and 82 percent of the time in 1967. The changes in ranges are quite evident in Figure 17. By 1968, the percentage dropped to 46 percent, and by 1969 it had dropped to 36 percent.

Levno and Rothacher (1969) have discussed the problem of increases in water temperature due to slash burning. During the time of burning, temperatures rose from 13°C to above 28°C in the upper canyon of Needle Branch (Hall and Lantz 1969). Juvenile coho salmon, cutthroat trout, and reticulate sculpin died during this period. The site of these mortalities was in the major rearing area for coho salmon. Because of the barrier aspect of the buffer strips on Deer Creek, there was no significant increase in water temperature due to slash burning.

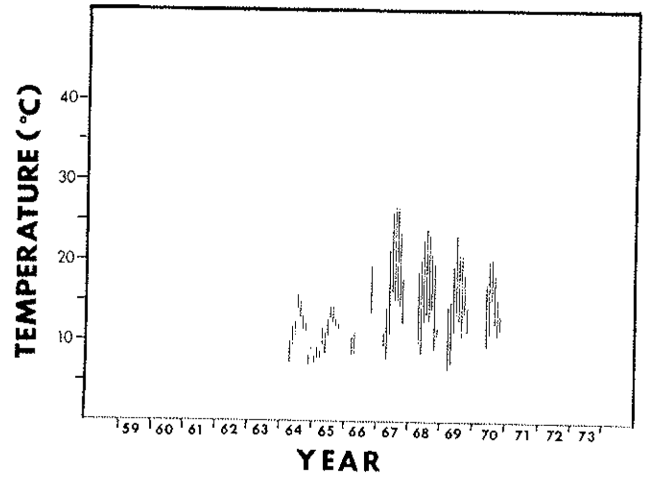

Figure 16. Monthly temperature minimums and maximums recorded at the 610 meter stream gauge on Needle Branch. Pre-1969 data courtesy of Dr. George W. Brown.

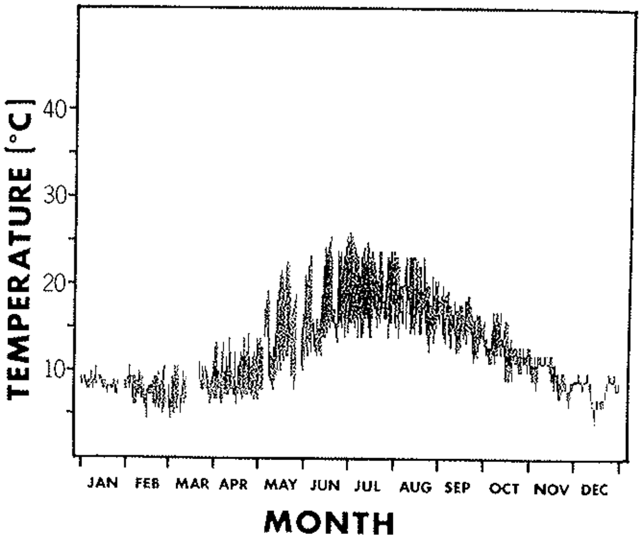

Figure 17. Daily temperature minimums and maximums at the 0 meter stream gauge on Needle Branch during 1967. Data from the U.S. Geological Survey.

Ringler and Hall (1975) studied the changes in water temperatures in the intragravel environment, and found considerable variation within gravel in Needle Branch. Intragravel maxima reached as high as 21°C in 1969 (the year of the study). The differences in intragravel temperature were significant, and Ringler and Hall believe they were due, at least partly, to increased levels of sediment in the system. There is also a relationship with surface water temperatures.

Large diel fluctuations were evident during sunny days, but smaller fluctuations were present on overcast days.

Clearcutting increased solar radiation to Needle Branch by removing riparian vegetation. This change was quite distinct and significant, and peaked during 1967, after water temperatures were further heated by slash burning. Changes occuring in surface waters were also reflected in intragravel waters, and remained significant during the 1969 study of Ringler (1970). No such changes were evident in Deer Creek because of the protective function of buffer strips.

DISSOLVED OXYGEN

Several researchers have shown that excess logging debris in streams can reduce stream velocity and intragravel and surface dissolved oxygen. Herrmann et al. (1962) found that juvenile coho salmon require at least 6.0 mg/liter for continued food conversion and growth. Moring and Lantz (1974) found minimum intragravel dissolved oxygen levels decreased in 7 of 12 coastal Oregon streams following logging.

Throughout the 15-year study, records were obtained for surface and intragravel dissolved oxygen during the time eggs were in the gravel, generally from November to June. Summer dissolved oxygen values were recorded occasionally in pre-logging years (to obtain natural summer values), and regularly during the critical summers of 1966 and 1967.

Surface dissolved oxygen

Fall-spring surface dissolved oxygen values were quite similar on all three streams over the 15-year study (Figure 18). Almost all winter values were well above that required for continued growth of coho salmon (6.0 mg/liter). Appendices 4, 5, and 6 indicate fall, winter, and spring surface values ranged from 7.9 to 13.0 mg/liter in Deer Creek, 5.4 to 13.7 mg/liter in Flynn Creek, and 6.0 to 13.4 mg/liter in Needle Branch.

Summer surface dissolved oxygen was monitored in 1966,1967, 1968, and 1969. As summarized by Hall and Lantz (1969), a reduction in surface dissolved oxygen occurred in Needle Branch in the summer of 1966 (Figure 19) when logging debris was in the stream. There was a gradual decline in surface dissolved oxygen from May to July, with a minimum value of 0.6 mg/liter registered on June 27, 1966. During this June-July period, all juvenile coho salmon placed in live boxes died in less than 40 minutes (some died in less than 8 minutes). Mortality was due directly to low dissolved oxygen. Dissolved oxygen levels in approximately one-third of the stream were too low for continued growth and survival of salmonids. Surface values were slightly higher in August, but improved considerably by September, after debris was hand cleared from the stream. Fall freshets removed much of the remaining debris, returning surface oxygen levels to pre-logging values.

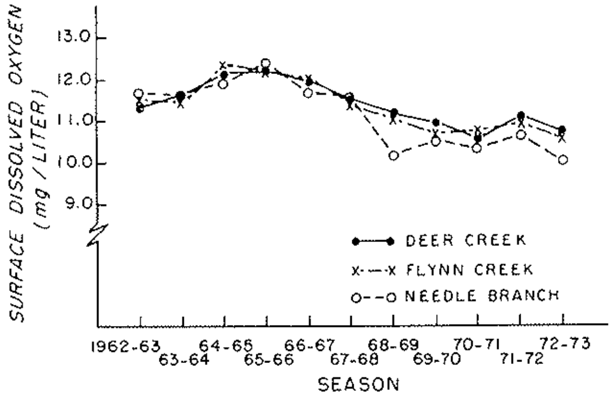

Figure 18. Surface dissolved oxygen means in Needle Branch, Deer Creek, and Flynn Creek, 1959-1973. Records are for winter and spring (November to June).

Measurements of surface dissolved oxygen were normal for the summers of 1967, 1968, and 1969. Mean values for these years were 9.6, 9.7, and 9.3 mg/liter, respectively. Flynn Creek surface dissolved oxygen values were always higher than those in Needle Branch during 1966, and remained so in subsequent years. The difference was partly due to the inverse relationship between oxygen retention in water and water temperature. Needle Branch had elevated water temperatures and lower dissolved oxygen, relative to Flynn Creek, from 1966-1975.

The significance of the reduction in surface dissolved oxygen in Needle Branch in 1966 is found in the fact that accumulation of logging debris does result in depression of dissolved oxygen levels below that required for continued survival and growth of trout and salmon.

Intragravel dissolved oxygen

Intragravel dissolved oxygen values were comparable in all three streams prior to logging. Intragravel dissolved oxygen measurements were made in a different manner in 1959-1963, so those values are not comparable with those of later years. Immediately after logging, there was a pronounced drop in fall-winter-spring dissolved oxygen in Needle Branch (Figure 20). Mean concentrations dropped by over 2 mg/liter (Figure 21).

Hall and Lantz (1969) and Lantz (1971) have reported in-progress accounts of the decline in Needle Branch intragravel dissolved oxygen for several years following logging. When all data for the 15 years are examined, a depression of Needle Branch dissolved oxygen in post-logging years is readily apparent, but there were also declines (not as pronounced) in Flynn Creek and Deer Creek as well (Figure 20). The declines in Needle Branch and Deer Creek were due, in part, to increased levels of sediment. The oxygen levels found on the three streams were comparable in pre-logging years, but were significantly lower in Needle Branch following logging. This fact has been supported by analyses of Ringler (1970) and Ringler and Hall (1975).

Part of the decline in Needle Branch dissolved oxygen may be related to the increased temperatures in the surface and intragravel waters following logging (see section on Tempera-

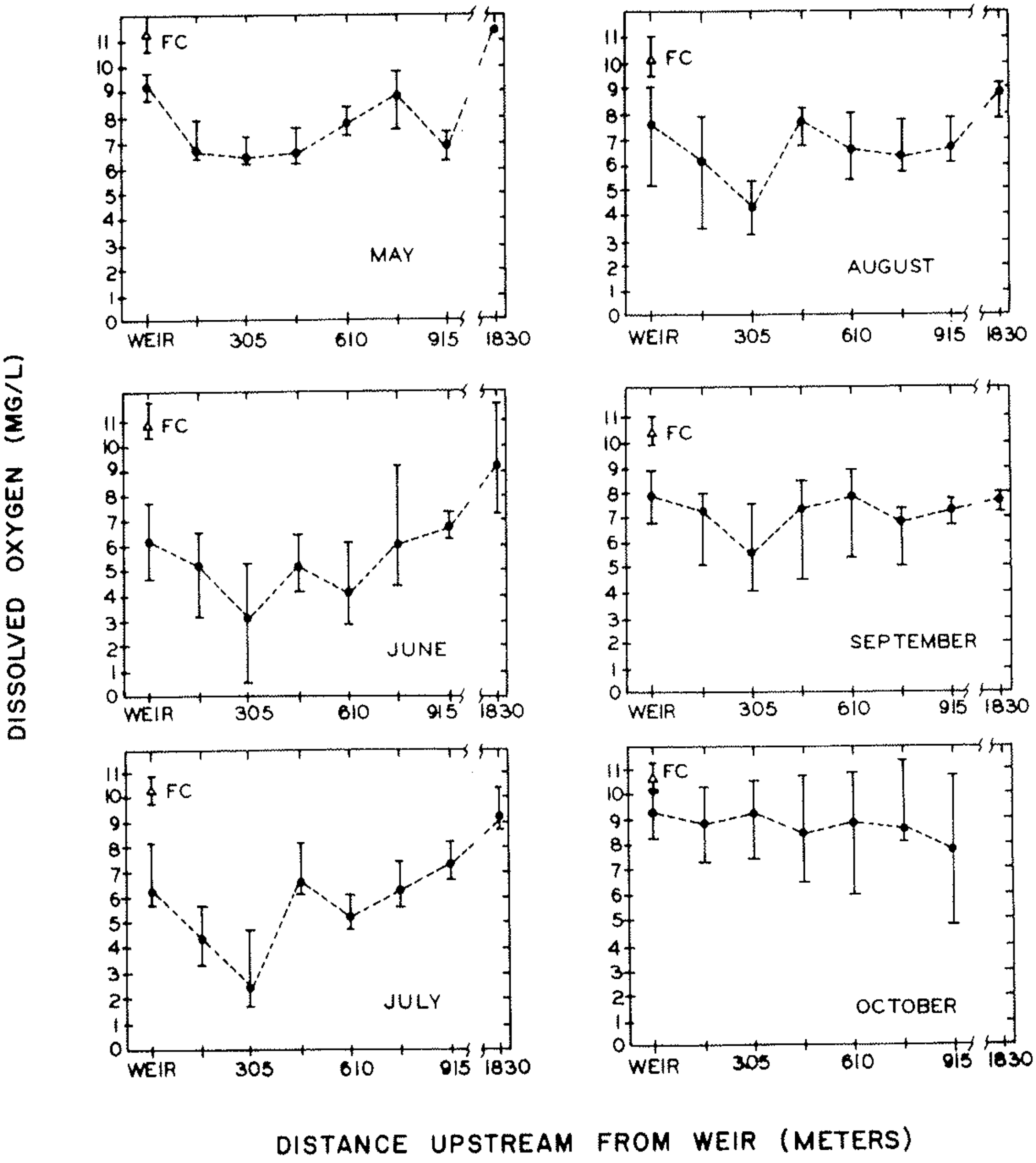

Figure 19. Surface dissolved oxygen levels (mean and range) taken twice weekly in Needle Branch and Flynn Creek during May-October 1966. Figure from Hall and Lantz (1969).

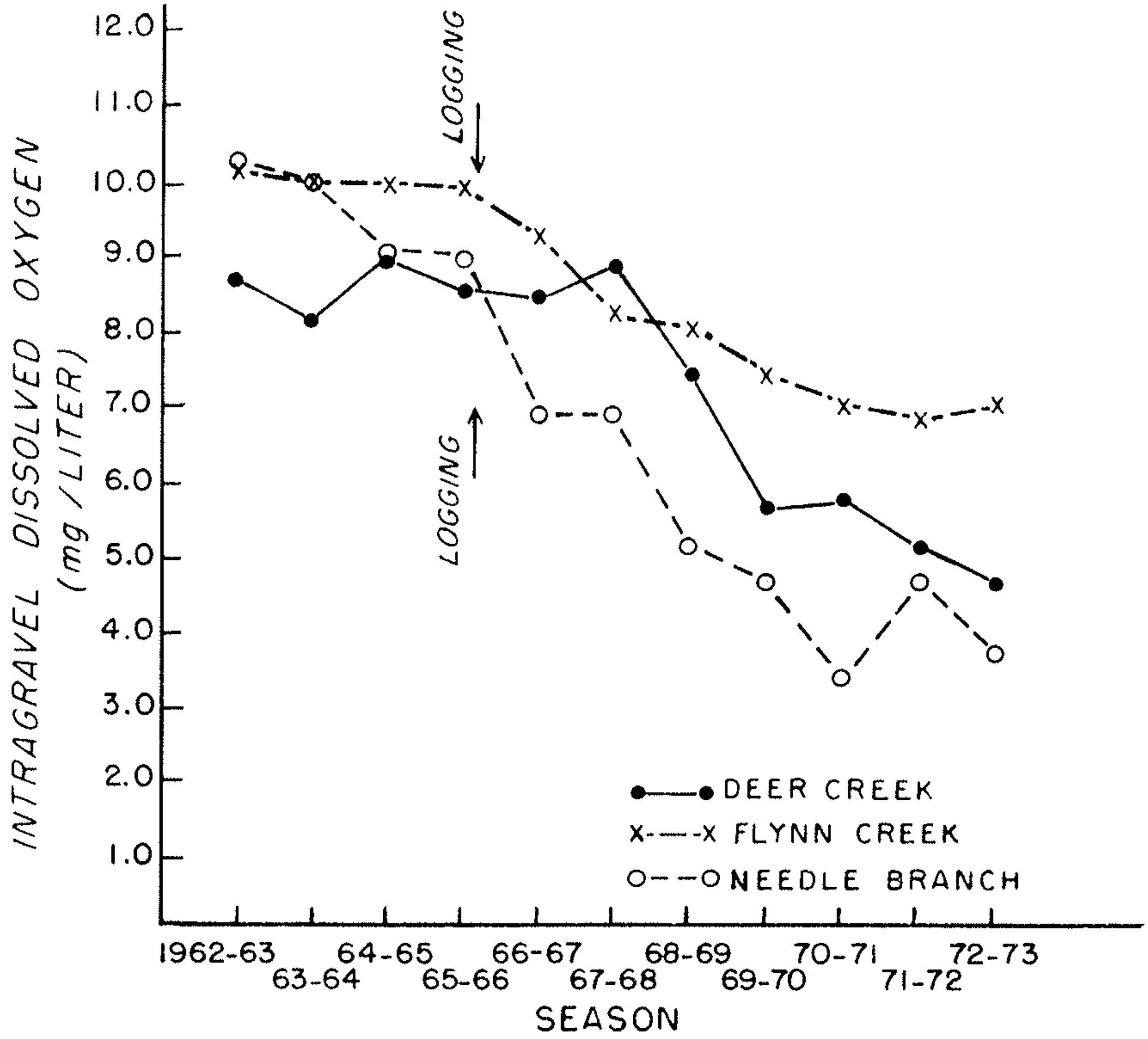

Figure 20. Intragravel dissolved oxygen means in Needle Branch, Deer Creek, and Flynn Creek, 1959 - 1973. Records are for winter and spring (November to June).

ture). As the solubility of oxygen is inversely proportional to the temperature of the water, some of the decline in intragravel dissolved oxygen can be attributed to the increase in water temperature. Ringler and Hall (1975) estimate this relationship may account for 25 percent of the difference in concentrations in the two streams, Needle Branch and Flynn Creek. This estimate is probably quite close, when one compares the solubility of oxygen with winter intragravel water temperatures (Gruesdale et al. 1955).

Ringler and Hall (1975) have further attributed the decrease in dissolved oxygen to increased levels of sediments in the stream. This assumption is based on measurements showing that replenishment of intragravel dissolved oxygen occurs primarily from exchange of surface and intragravel water (Sheridan 1962; Vaux 1962). Ringler and Hall also consider the slight decrease in intragravel dissolved oxygen in Deer Creek to be due to increased sediment from road slumps and landslides, which were well-documented (see section on Sediment). Our records indicate increases in sedimentation in Needle Branch and Deer Creek following logging, but the statistical comparison is weak because of the lack of sufficient pre-logging data. What our data indicate is that a significant decline in intragravel dissolved oxygen occurred in Needle Branch following logging. The indirect effects of logging were a decreased solubility of oxygen, and a natural decline in concentrations. There may have been added effects of sediment and other, unknown influences from logging.

Summer intragravel dissolved oxygen levels in Flynn Creek and Needle Branch were quite different (Table 1). As reported by Hall and Lantz (1969), the mean concentrations

Table 1. Summer intragravel dissolved oxygen measurements in Flynn Creek and Needle Branch, 1966-1969. Records are for the period after the start of logging in 1966 (April, May, June), and the summer period June to September in subsequent years. Data for 1966 appeared previously in Hall and Lantz (1969).

Year	Needle Branch		Flynn Creek	
	Mean	Range	Mean	Range
1966:				
April 19	10.7	7.0 - 12.0	10.2	7.7 - 11.8
May 30	4.2	2.4 - 7.3	9.0	6.8 - 10.8
June 30	1.3	0.5 - 2.2	7.2	4.0 - 9.1
1967	3.3	0 - 10.5	6.6	1.4 - 10.0
1968	3.6	0.1 - 10.4	6.6	1.2 - 10.9
1969	2.7	0 - 8.4	6.4	1.7 - 11.0

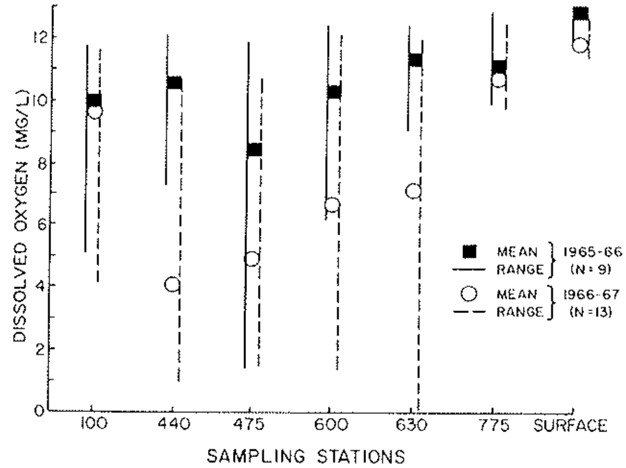

Figure 21. Intragravel dissolved oxygen levels in Needle Branch from December 1965 to May 1966 (pre-logging) and from November 1966 to May 1967 (post-logging). Figure from Hall and Lantz (1969).

and ranges during 1966 were similar in mid-April, but dropped drastically in Needle Branch by late May. Average intragravel concentrations in Needle Branch were only 1.3 mg/liter, and ranged from 0.5 to 2.2 mg/liter by the end of June. This disparity between the streams was apparent during summer measurements in 1967, 1968, and 1969 (Table 1). No summer measurements were recorded after 1969.

Intragravel dissolved oxygen and survival of salmonids

Coble (1961) and Phillips and Campbell (1961) conducted experiments in Deer and Flynn creeks on survival of coho salmon and steelhead trout at different dissolved oxygen concentrations. They found a positive correlation between survival of embryos and intragravel dissolved oxygen. For coho salmon, a minimum level of 8 mg/liter was required for survivals above 30 percent. For steelhead trout, survival was zero at mean concentrations below 7.3 mg/liter. Phillips and Campbell also found that larger coho and steelhead alevins were associated with higher intragravel dissolved oxygen concentrations. Although Coble could not separate the effects of intragravel water velocity on salmonid survival, Phillips and Campbell did find a correlation between higher survival and higher intragravel water velocity for steelhead trout. No such correlation could be made for coho salmon.

The relationship between survival of coho salmon and steelhead trout and intragravel dissolved oxygen, as reported by Coble (1961) and Phillips and Campbell (1961), is complicated by the relationship between gravel size and survival determined in later years by Koski (1966) and Phillips et al. (1975). Therefore, there is some uncertainty as to the magnitude of the effect of dissolved oxygen on embryo survival. Ringler and Hall (1975) believe the minimum intragravel dissolved oxygen levels occurred during the last 4-6 weeks of incubation, and any retardation effects would be minimal.

SUNLIGHT

Sunlight records are available for all years, but the charts have not been analyzed to date. These records are available at the Research Section Laboratory in Corvallis, if their use is needed for a related scientific investigation.

STREAM FLOW

It has been well documented that streamflow generally increases following clearcut logging and partial thinning (Rowe 1963; Rothacher 1965, 1970, 1971; Berndt and Swank 1970; Meehan et al. 1969). A significant portion of precipitation taken up by trees (and other vegetation) in transpiration no longer occurs and this storage component enters the streams as increased streamflow. The more extensive the clearcutting, the greater the increase in streamflow (Rothacher 1965). In addition, streams of low discharge are influenced by removal of riparian vegetation more than streams of larger size (Riggs 1965).

Stream discharge records from U.S. Geological Survey data indicate a significant increase in streamflow after clearcutting in the Needle Branch watershed. Mean streamflow (Appendices 7, 8, 9) increased by 26.9 percent in Needle Branch after logging. Changes in streamflow in the other streams during the same period were minor: 1.6 percent increase in Flynn Creek and 4.9 percent increase in Deer Creek. This increase in streamflow supports previous studies indicating a correlation between clearcut logging and streamflow. Streamflow is, of course, related to precipitation. However, the three test watersheds are in close proximity. The variations in precipitation were minor. By looking at a percentage increase in streamflow, we are comparing changes in streamflow in the experimental watersheds with that in the control watershed. There was an obvious increase in streamflow in Needle Branch in post-logging years.

Minimum streamflows occurred during August and September, and maximums were reached in December and January (Figures 22, 23, 24). In most streams, late summer streamflow is higher after clearcut logging (Hibbert 1967). In Needle Branch in June, July, September, and October, mean discharges averaged higher in post-logging years, but the average mean values for August were similar for pre- and post-logging years.

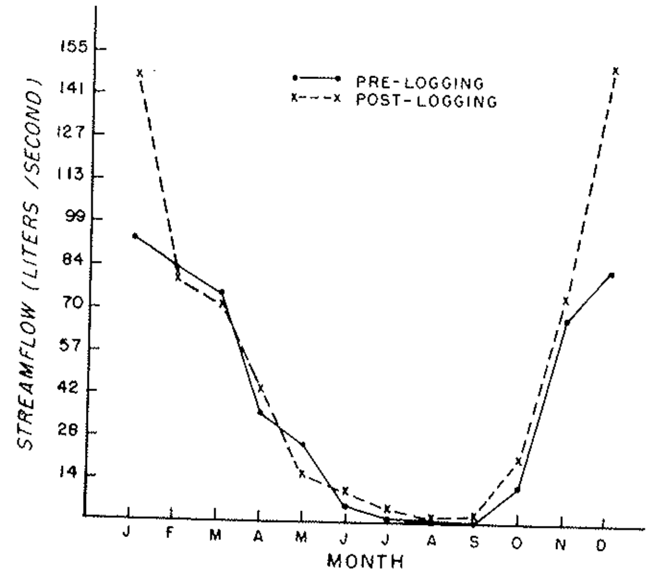

Figure 22. Pre-logging and Post-logging mean daily streamflow discharge by month (liters/sec) for Needle Branch, 1959-1973. Data from the U.S. Geological Survey.

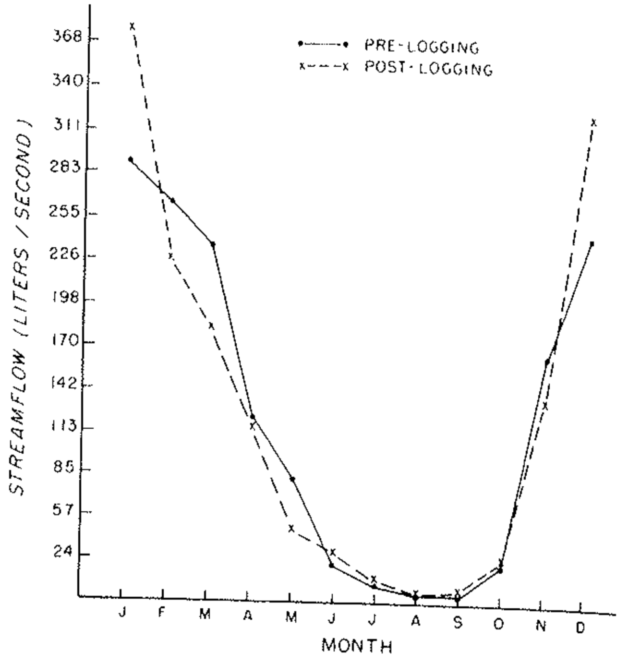

Figure 23. Pre-logging and Post-logging Mean Daily Streamflow discharge by month (cfs) for Flynn Creek, 1959-1973. Data from the U.S. Geological Survey.

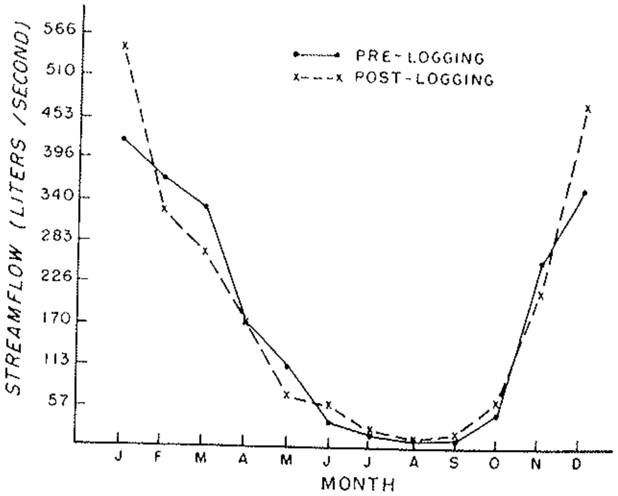

Figure 24. Pre-logging and Post-logging Mean Daily Streamflow discharge by month (cfs) for Deer Creek, 1959-1973. Data from the U.S. Geological Survey.

Harr and Krygier (1972) analyzed the relationship between clearcutting and low flow days in the Alsea study streams. They defined a low flow day as mean daily discharge less than 1 cfs per square mile, or 7.6 liters/sec (0.27 cfs) for Needle Branch, 22.1 liters/sec (0.78 cfs) for Flynn Creek, and

33.1 liters/sec (1.17 cfs) for Deer Creek. A decrease in number of low flow days would indicate an increase in minimum flow. Harr and Krygier found that the number of low flow days decreased significantly in all post-logging years in Needle Branch. Deer Creek showed a significant decrease in low flow days in only 2 of 5 post-logging years during peak months (December, January).

Gilleran (1968), Harper (1969), Hsieh (1970), and Harr et al. (1975) found that road construction had a pronounced influence on peak streamflows. When over 12 percent of the watershed was occupied by roads, peak flows were significantly increased. These flows increased further in the fall, when 72 percent of the drainage was logged. Although Rothacher (1971) and Harr et al. (1975) voice no concern over these changes as they affect streamflow, Harr and his associates feel that caution should be exercised in projecting the results of study on a small watershed like Needle Branch to larger drainages.

STREAM EROSION

Stream erosion and deposition at study sites varied yearly. There was no distinguishable pattern as to stream erosion or deposition (Figures 25, 26, 27). Stream deposition was generally more stable, with less year-to-year fluctuation. Mean deposition rates remained essentially the same from 1965-66 to 1970-71 in Flynn Creek, but deposition was significantly higher during 1964-65 and 1971-72. Deposition rates were similar throughout the study period in Deer Creek and Needle Branch.

In terms of net gain or loss of stream gravel/sediment, the data indicate the same sort of variability between seasons. Over the eight years of comparative data, there were net gains of gravel/sediment in 5 years in Deer Creek, 4 years in Flynn Creek, and 2 years in Needle Branch. There were net losses in 3 years in Deer Creek, 4 years in Flynn Creek, and 4 years in Needle Branch. Streambed levels were unchanged during one year in Deer Creek, and one year in Needle Branch. No measurements were available in Needle Branch during 1965-66 because of logging activity in and around the streambed. There was no evidence of changes in mean erosion or deposition due to logging in Deer Creek or Needle Branch.

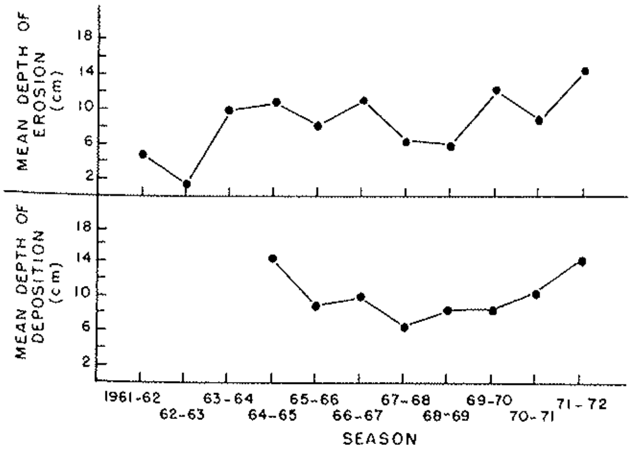

Figure 25. Mean Depths of Gravel Erosion and Deposition in Deer Creek, 1961-1972.

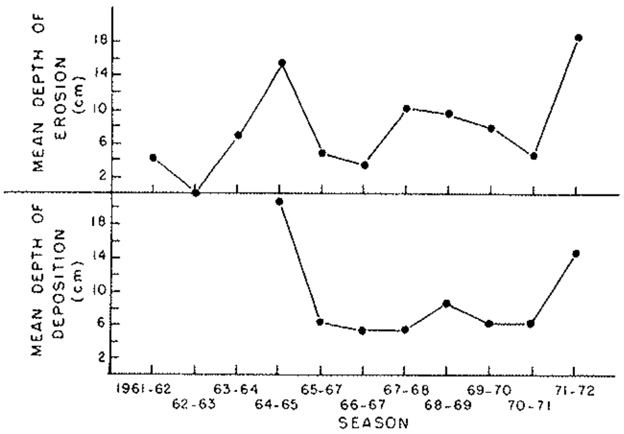

Figure 26. Mean Depths of Gravel Erosion and Deposition in Flynn Creek, 1961-1972.

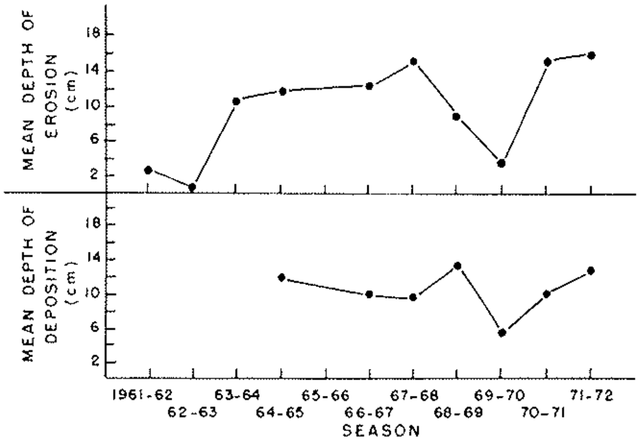

Figure 27. Mean Depths of Gravel Erosion and Deposition in Needle Branch, 1961-1972.

It is interesting to note that mean erosion and mean deposition were highest in Flynn Creek during the winters of the major floods (1964-65 and 1971-72). The pattern is less obvious in Deer Creek and Needle Branch. This may be related to the tendency for Flynn Creek to act as a sediment reservoir during these flood periods (Brown and Krygier, 1971).

GRAVEL COMPOSITION

A critical factor in the successful emergence of salmonids is the composition of gravel in spawning beds. Even moderate increases in sedimentation can be detrimental to survival and condition of embryos and emerging fry (Cooper 1965; Cordone and Kelley 1961). Studies by Wickett (1958), McNeil and Ahnell (1964), and Koski (1966) have indicated

Table 2. Gravel composition data from a logging study of 12 coastal Oregon streams. From Moring and Lantz (1974).

Stream	Treatment	Fines less than 3.327 mm diameter	
		Pre-Logging	Post-Logging
Coal Creek	Clearcut w/o buffer	27.0 %	41.4 %
Dick Creek	Clearcut w/o buffer	45.0	54.1
Hidden Valley Creek	Clearcut w/o buffer	45.5	39.9
Williamson Creek	Clearcut w/o buffer	52.7	72.3
Fivemile Creek	Clearcut w/buffer	42.1	41.2
Panther Creek	Clearcut w/buffer	37.2	32.8
Park Creek	Clearcut w/buffer	43.0	42.8
Whittaker Creek	Clearcut w/buffer	38.1	51.1
Briar Creek	Road Constr., thinning	54.9	58.6
Crane Creek	Road Constr., thinning	41.6	38.3
Hodges Creek	Road Constr., thinning	45.9	44.9
Sourgrass Creek	Road Constr., thinning	44.9	52.4

that survival of salmon alevins decreases as the permeability of the gravel decreases. As the percentage of fine sediments less than 3.327mm and 0.833mm in diameter increases, salmon survival to emergence decreases (Koski). Phillips et al. (1975) have since verified this relationship.

Moring and Lantz (1974) found that fines less than 3.327 mm increased in streams located in three of four clearcut watersheds in Oregon (streams without buffer strips) following logging (Table 2). Only one of the four streams clearcut with buffer strips exhibited an increase in fines following logging.

Clogging of spawning gravel will not only act as a barrier hindering alevin emergence but, will also reduce dissolved oxygen to the developing eggs, reduce intragravel water velocity, cause direct mortality to eggs and alevins, and delay the time of emergence. Coho salmon alevins alter their pattern of intragravel movement with such changes in gravel composition (Dill and Northcote 1970). Fry that do emerge under such conditions are small in size (Mason 1969).

Gravel analysis

Gravel from coho salmon redds was sampled for two pre-logging years (1964 and 1965), and 4-5 subsequent post-logging years. Gravel compositions for all sizes were derived, but the important components were the percentages of fines less than 3.327 mm in diameter and those less than 0.833 mm in diameter.

Because only two pre-logging years of data are available, the statistical power of comparison is weak. Although the levels of fines in the two logged watersheds increased following logging, a t-test indicates the differences are not significant at the 95 percent level (Table 3).

Fines increased on the two streams exposed to road construction and logging. For fines less than 3.327 mm in diameter, levels increased from 40.5 to 44.8 percent pre-logging to post-logging, in Needle Branch; and from 32.7 to 40.4 percent in Deer Creek. For fines less than 0.833 mm in diameter, levels increased from 26.5 to 32.3 percent in Needle Branch, and from 23.3 to 29.1 percent in Deer Creek. Because of the lack of pre-logging values, the statistical power of comparison is weak. A non-parametric test could not be made because of the limited pre-logging samples. As a result, differences in gravel composition were not significant (except for Deer Creek gravel <3.327 mm at the 95 percent level). The pre-logging and post-logging averages were almost identical in Flynn Creek: <0.833 mm gravel changed from 28.7 to 28.4 percent; <3.327 mm gravel changed from 42.9 to 42.5 percent.

Change in gravel fines is apparently related to road building and road slumps. Brown and Krygier (1971) found that annual sediment yield was signficantly higher in Deer Creek and Needle Branch after road building. The increase in suspended sediments (see section on Sediment) can be shown to occur in gravel fines as well; but the changes in levels of gravel fines were generally not as discernible.

Volumetric versus gravimetric analysis

Gravel samples from Deer Creek were analyzed volumetrically and gravimetrically in early 1968. The findings indicate no significant difference between results of the techniques at the 95 percent level (Table 4). We assume, from the comparison of these data, that our use of the volumetric technique is a valid method.

SEDIMENT

Sediment records are available from the U.S. Geological Survey, and these measure daily discharge in tons/year. Data have been converted to metric tons/year, and indicate increased sediment loads in Deer Creek and Needle Branch (Table 5). There was an increase in suspended sediments from

Table 3. Percentages of gravel less than 3.327 mm and less than 0.833 mm in diameter. Taken from gravel samples in coho salmon redds.

less than 3.327 mm dia.	Flynn Creek	Deer Creek	Needle Branch
1964	42.9	28.7	39.5
1965	42.9	36.7	41.5
logging			
1966	41.4	39.6	48.0
1967	42.0	37.4	43.8
1968	44.9	42.5	47.1
1969	39.7	39.9	50.4
1970	38.1	43.3	30.7
1971	48.9	40.2	-
less than 0.833 mm dia			
1964	28.8	23.1	26.1
1965	28.5	23.4	27.0
logging			
1966	25.5	27.5	32.9
1967	25.7	24.4	29.5
1968	30.6	30.4	34.5
1969	27.1	26.5	39.1
1970	27.4	34.7	25.6
1971	34.0	30.3	-

Table 4. Comparisons of levels of fines less than 0.833mm and less than 3.327mm in diameter determined volumetrically and gravimetrically. Samples are from Deer Creek in early 1968.

	less than 0.833 mm		less than 3.327 mm	
Sample Number	Vol. %	Grav. %	Vol. %	Grav. %
DCE480-1	17.4	18.8	33.5	33.0
DCE480-2	12.8	13.7	28.3	27.1
DCE480-3	10.6	11.1	21.6	21.2
DCE575-1	19.9	19.7	33.4	33.9
DCE575-2	17.5	17.0	33.8	32.0
DCE575-3	14.5	14.1	23.5	21.8
DC4770-1	15.4	15.8	31.3	30.4
DC4770-2	14.9	15.4	26.7	26.1
DC5260-1	16.7	16.7	26.9	25.9
DC5260-2	15.5	15.4	23.0	21.7
DC5290-1	15.2	14.9	24.5	23.9
DC5290-2	13.1	13.8	24.0	23.7
DC5310-1	15.7	15.8	28.4	27.3
DC5310-2	15.0	15.4	24.0	23.8
Average	15.3	15.5	27.4	26.6

293.8 to 451.0 metric tons (53.5 percent increase) in Deer Creek following road construction. There was also an increase from 39.5 to 120.6 metric tons (205.3 percent increase) in suspended sediments in Needle Branch. These changes were significant at the 95 percent confidence level. Sediment discharge increased by only 0.1 percent in Flynn Creek during this same period.

There were two years of heavy discharge (streamflow and sediment) related to precipitation. The floods of December 1964-January 1965 resulted in excessive sediment levels during water year 1965. Again, heavy flooding during winter 1971-72 resulted in high sediment discharge during water year 1972.

Brown and Krygier (1971) have shown that road slumps contributed greatly to the increased sediment load, particularly in Deer Creek. Slumps are the primary reason for high sediment levels in water year 1966. One road slump in Deer Creek in 1966 produced 316.6 metric tons (349 short tons) of sediment, on 40 percent of the weighted discharge for the year. The increase in sediment following road construction and logging was significant, but levels returned to pre-logging values within the following two years. There were fewer road slumps on Needle Branch following road construction, but sediment discharge increased dramatically after logging (water year 1967). Although sediment discharge decreased in subsequent years, levels were significantly higher than those during pre-logging years. Sediment discharge was unusually high in Flynn Creek in water year 1966, even though no road construction or logging occurred. This was explained by Brown and Krygier (1971) on the basis of previous observations by Williams (1964) and Anderson (1971). Apparently, the Flynn Creek watershed responded differently than the others during the 1964-65 flood. Pools in Flynn Creek held high levels of sediment from the storms. A sediment reservoir was created in Flynn Creek and this source supplied high levels of sediment during water year 1966, at a time when other streams were receiving sediment discharge primarily from road construction.

Table 5. Sediment discharge in metric tons/year from the three study streams. Data are from U.S. Geological Survey records, and are expressed over water years (October through September).

Water Year	Deer Creek	Flynn Creek	Needle Branch
1959	81.4	46.8	11.5
1960	81.7	35.1	9.6
1961	303.8	182.9	44.1
1962	105.4	63.7	33.5
1963	169.5	90.0	28.2
1964	211.0	147.6	45.8
1965	1104.1	875.4	103.6
1966	785.5	212.6	89.6
1967	226.2	96.4	221.4
1968	89.4	42.1	120.2
1969	172.2	98.0	126.3
1970	157.8	84.6	57.1
1971	225.7	132.0	102.0
1972	1500.3	777.8	127.9
Pre-Logging Yearly Average	355.3	206.8	45.7
Post-Logging Yearly Average	395.3	205.2	125.8
Pre-Road Construction Yearly Average	293.8	205.9	39.5
Post Road Construction Yearly Average	451.0	206.2	120.6

Sediment loads were variable from day to day, month to month, and year to year. On Deer Creek, 83.9 percent of the sediment yield occurred in December and January. On Flynn Creek, the value was 84.7 percent during these months and in Needle Branch, 58.7 percent of the sediments were in suspension at this time. The six month period, May to October, was the period of lowest sediment yield, with only 1.0 percent of the average annual discharge occurring on Deer Creek. Of the total sediment yield, only 2.4 percent occurred in Flynn Creek, and 3.5 percent in Needle Branch during these same months.

After road construction, there was a pronounced shift in stream discharge by month. Prior to road construction, most sediment yield occurred during December and January. After road construction, the percentage of this discharge occurring in February increased. The shift was apparent on Needle Branch and Deer Creek until 1971.

Sediment yield is closely correlated with streamflow, and the relationship was previously explored on these study streams by Brown and Krygier (1971). Using data for rising streamflow stages (because of higher correlation coefficients), they found this relationship to hold true during normal water years prior to logging. The only significant changes from this pattern occurred in 1966 on Deer Creek and Needle Branch (significant at the 90 percent level) and in Needle Branch in 1968 and 1969 (significant at the 95 percent level). Brown and Krygier concluded that daily sediment load is generally low (less than 10 ppm concentration) during low flow days (less than 5 ft^3/sec mile). These low flow days occurred during 60-70 percent of the year. The majority of the total sediment load is carried from the system during the few large storms each year.

The amount of sediment fines less than 3.327 mm (in the gravel) has been shown to correlate directly with the emergent survival of coho salmon and steelhead trout (Koski 1966; Phillips et al. 1975). This inverse relationship indicates high levels of sediment fines in the gravel can severely reduce the ultimate emergent survival (Figure 28). Levels of gravel fines increased in Needle Branch and Deer Creek (see section on Gravel Composition), but the differences were not statistically significant because of the lack of sufficent pre-logging data. Similarly, there was no apparent decrease in survival to emergence of coho salmon, but sufficient pre-logging data are lacking.

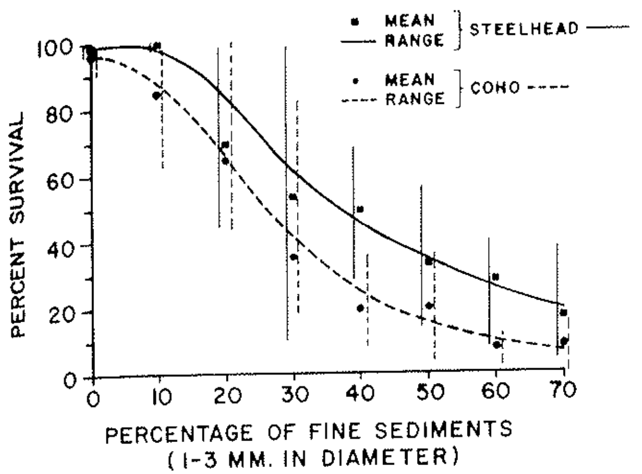

Figure 28. Relationship between the amount of sediment fines in an artificial gravel bed, and the emergent survival of coho salmon and steelhead trout placed in the gravel. Figure from Phillips et al. (1975).

PERMEABILITY

As a measure of the ease of movement of intragravel water through gravel, permeability is thought to be related to survival of salmonid embryos (Wickett 1958). Permeability measurements were taken in a slightly different manner in 1959-1961, than they were in subsequent years. As a result, only the values for 1962-1973 can be compared.

There was a distinct decrease in permeabilities in Needle Branch after logging (Figure 29). Permeabilities dropped to an average of only 1,139 cm/hour the winter following logging, and remained relatively constant, but depressed, for the following six years. Permeabilities in Flynn Creek and Deer Creek remained relatively stable throughout the study.

Individual permeability measurements were extremely variable between stations and between sampling dates in a season. The average permeabilities over a season (Appendix 10) can give a relative indication of change. Prior to logging, gravel was least permeable in Deer Creek, and most permeable in Needle Branch. After logging, Needle Branch gravel was least permeable of the three.

STREAM MEASUREMENTS

Seven stream measurement surveys were conducted during the 15 years of study. Pre-logging surveys are available for all streams in 1959, 1960, 1961, and 1962. Post-logging surveys are available for Needle Branch in 1968, 1971, and 1972, and for other streams in 1972 only. Pool/riffle ratios changed on all streams during all years surveyed (Tables 6, 7, 8). Stream area measurements were also collected on all streams in 1969; but only in the Biomass Study Areas (see Part I: Methods–Biomass). Since only 152 meter (500 foot) sections, or less, were measured, the 1969 measurements were not used as a comparison with other yearly surveys.

No parameters measured changed significantly on Flynn Creek between the pre-logging and post-logging periods. The

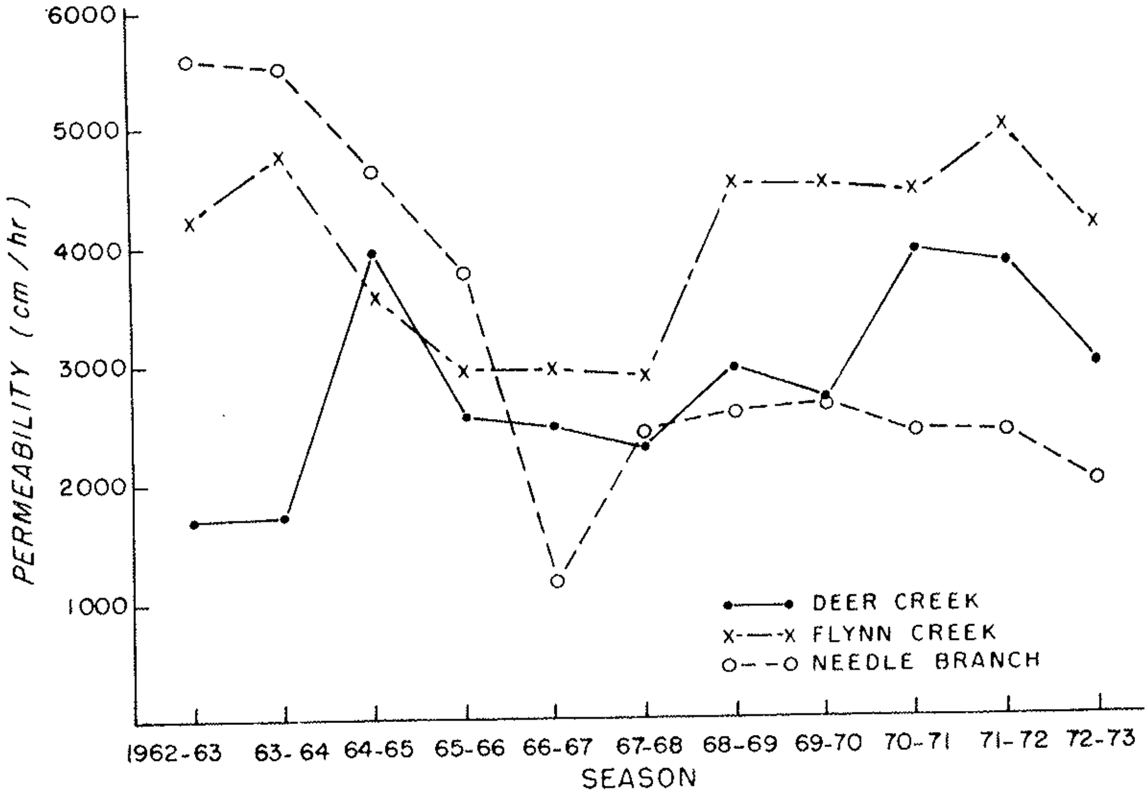

Figure 29. Average gravel permeability valves for the three study streams, 1962-1973.

Table 6. Stream area measurements for surveys in 1959, 1960, 1961, 1962, 1968, 1971, and 1972 on Needle Branch.

	Year						
	1959	1960	1961	1962	1968	1971	1972
Percent Pools	52.5	67.1	64.5	54.5	54.5	59.2	67.0
Percent Riffles	47.5	32.9	35.5	45.5	45.5	40.8	33.0
Gravel	41.6	35.2	37.0	-	30.9	-	35.0
Average Width	1.2 m	-	-	1.4 m	1.3 m	1.3 m	1.1 m
Average Depth	6.0 cm	7.0 cm	7.0 cm	7.3 cm	8.6 cm	8.6 cm	8.9 cm

PRE-LOGGING:	*POST-LOGGING:*
Percent Pool Average - 59.7	Percent Pool Average - 60.2
Percent Riffle Average - 40.3	Percent Riffle Average - 39.8
Percent Gravel Average - 37.9	Percent Gravel Average - 33.0
Average Width - 1.3 m	Average Width - 1.2 m
Average Depth - 6.8 cm	Average Depth - 8.7 cm

Table 7. Stream area measurements for surveys in 1959, 1960, 1961, 1962, and 1972 on Flynn Creek.

	Year				
	1959	1960	1961	1962	1972
Percent Pools	51.8	59.2	58.8	46.6	53.6
Percent Riffles	48.2	40.8	41.2	53.4	46.4
Percent Spawning Gravel	25.5	18.4	19.2	-	17.9
Average Width	-	-	-	1.9 m	2.0 m
Average Depth	10.0 cm	13.0 cm	13.0 cm	8.8 cm	9.7 cm

PRE-LOGGING:	*POST-LOGGING:*
Percent Pool Average - 56.6	Percent Pool Average - 53.6
Percent Riffle Average - 43.4	Percent Riffle Average - 46.4
Percent Gravel Average - 21.0	Percent Gravel Average - 17.9
Average Width - 1.9 m	Average Width - 2.0 m
Average Depth - 11.2 cm	Average Depth - 9.7 cm

Table 8. Stream area measurements for surveys in 1959, 1960, 1961, 1962, and 1972 on Deer Creek.

	Year				
	1959	1960	1961	1962	1972
Percent Pools	60.5	60.5	59.2	44.6	54.1
Percent Riffles	39.5	39.5	40.8	55.4	45.9
Percent Spawning Gravel	32.4	32.4	32.7	-	20.0
Average Width	-	-	-	2.6 m	2.3 m
Average Depth	10.0 cm	10.0 cm	10.0 cm	14.2 cm	13.7 cm

PRE-LOGGING:	*POST-LOGGING:*
Percent Pool Average - 60.1	Percent Pool Average - 54.1
Percent Riffle Average - 39.9	Percent Riffle Average - 45.9
Percent Gravel Average - 32.5	Percent Gravel Average - 20.0
Average Width - 2.6 m	Average Width - 2.3 m
Average Depth - 11.1 cm	Average Depth - 13.7 cm

yearly surveys during 1959-62 indicated, however, changes in pool areas of as much as 20.7 percent, and in riffle areas of as much as 29.6 percent between successive years. The largest change in spawning gravel between years was 27.8 percent between 1959 and 1960. When the 1959-1962 average is compared with the one set of measurements from the post-logging period, the changes are minor. The average width and depth remained essentially the same over the entire period.

There was more change in Deer Creek stream measurements. Pool areas and riffle areas were fairly constant during 1959, 1960, and 1961. But, pool areas decreased by 24.7 percent and riffle areas increased by 35.8 percent between 1961 and 1962. The only post-logging measurement available shows a decline of 10.0 percent from the pre-logging pool area average. No test of significance was made because of the lack of sufficient post-logging data. Spawning gravel values were virtually the same during 1959, 1960, and 1961, but were lower in 1972. The one pre-logging and one post-logging width measurement were comparable in value and the one post-logging depth measurement was slightly greater than the 4-year pre-logging average.

The only stream with several pre-logging and several post-logging measurements was Needle Branch. Four pre-logging values and three post-logging values can be averaged. The percentages of pools and riffles were almost exactly the same between the pre-logging and post-logging averages. The pool/riffle ratio changed only slightly from 1.48 to 1.51. The change was not significant at the 95 percent level. The average width remained virtually the same between pre- and post-logging, but the average depth increased. The percent of spawning gravel available varied only slightly between the two periods.

Unfortunately, no stream area measurements were recorded for the years immediately preceding or following logging on either Deer Creek or Needle Branch. Therefore, we have no knowledge of the immediate short-term changes in stream morphology due to logging activities. Surveys were completed on Needle Branch in 1962 (4 years before logging) and 1968 (2 years after logging). The pool/riffle ratios were identical for those two years. The average width and average depth were quite close. Despite the lack of survey information, we know that changes in pool/riffle ratios did occur as a result of logging and the subsequent slash burning and debris clearance.

The Deer Creek upstream trap was constructed during the fall of 1958, so stream characteristics at the lower portion of the stream were altered somewhat, prior to the 15-year study (Chapman, 1965). Table 8 indicates conditions were relatively stable during 1959-1961, so any changes in stream characteristics as a result of trap construction would have occurred prior to 1959.

The Flynn Creek traps were constructed in the fall of 1959, so changes in stream morphology would appear in 1960 records. There was an overall increase of 14.3 percent in pool areas of the stream between 1959 and 1960, and a corresponding decrease of 15.4 percent in riffle areas. Undoubtedly, the construction of trap facilities on Flynn Creek created additional pool areas immediately upstream from the trap, but detailed measurements in this area are not available for 1960.

The Needle Branch upstream trap was first constructed in the fall of 1958. As with Deer Creek, we have no comparative stream measurements of pre-constructon conditions in 1958 and post-construction conditions in 1959. It is noted that pool areas were 22.9 percent and 27.8 percent higher during the following two years, 1960 and 1961, respectively.

The permanent concrete traps were constructed on Deer Creek in the fall of 1965, on Needle Branch in late summer 1966, and on Flynn Creek in late summer 1967. No comparative stream measurements are available for years immediately prior to and after construction.

pH

Measurements of pH are available for only four seasons: 1959-60, 1962-63, 1963-64, and 1966-67. Values of pH varied, with the overall range 4.8 to 8.1. Table 9 summarizes the limited data.

Table 9. Synopsis of available pH data during the 15-year study.

	Deer Creek		Flynn Creek		Needle Branch	
Year	Ave.	Range	Ave.	Range	Ave.	Range
1959-60	6.9	-	6.9	-	6.5	-
1962-63	6.4	5.4-7.2	6.9	5.7-7.3	6.6	4.8-7.5
1963-64	7.6	7.3-8.0	7.9	7.7-8.1	7.2	6.7-7.8
1966-67	-	-	6.8	6.6-6.9	6.6	6.4-7.0

STREAM CHEMISTRY

Several nutrients were measured in the three Alsea study streams by the U.S. Environmental Protection Agency (Brown et al. 1973). Concentrations of nitrate nitrogen, potassium, and phosphorus were monitored for two years prior to logging and two years after logging. Other nutrients were also measured, but have not been analyzed, and the data are stored with the School of Forestry, Oregon State University.

Brown et al. (1973) found yield of nitrate nitrogen increased from 5.0 to 15.7 kg/ha the first year after clearcutting on the Needle Branch watershed, and did not return to pre-logging levels until six years after logging. Stream concentrations of potassium increased from 0.6 to 4.4 mg/liter after slash burning on Needle Branch, but returned to pre-logging levels within two months. There were no such changes in Deer Creek and Flynn Creek. There were no significant changes in levels of phosphorus on any stream.

PRECIPITATION

Precipitation levels were recorded on strip charts, and some of these charts have been analyzed and the results published (Harris 1973). Hall and Lantz (1969) reported the mean precipitation for the 1959-1965 pre-logging period to be 244 cm (96.1 inches) per year. There were slight differences in rainfall between the three watersheds, but, because of their close proximity, differences were minor over the entire study period. Original charts are stored with the Research Section of the Oregon Department of Fish and Wildlife and the Forest Research Laboratory, Oregon State University, both at Corvallis.

SUMMARY

1. Three small headwater tributaries of the Alsea River, Oregon, were studied from 1959 to 1973. One watershed (Flynn Creek) remained unlogged as a control. Another watershed (Needle Branch) was completely clearcut in 1966. No buffer strips were left. The third watershed (Deer Creek) was patch clearcut in three blocks in 1966. Buffer strips were left along the stream.

2. Water temperature ranges and maximums increased in Needle Branch following logging. Maximum temperatures occurred in 1967, after debris clearance and slash burning. Maximum temperature in summer 1967 was 26.1°C at the stream gauge and 29.5°C at a station 305 meters upstream.

3. Water temperatures in Needle Branch increased 12.7°C over the pre-logging average in June, 11.8°C over the pre-logging average in July, and 9.3°C over the pre-logging average in August. A 15.6°C maximum diurnal fluctuation was measured in 1967.

4. Water temperatures in Needle Branch exceeded the pre-logging maximum fluctuation (4.4°C) 28% of the days in 1966 and 82% of the days in 1967.

5. Significant increases in intragravel water temperature were measured in Needle Branch after logging.

6. Surface dissolved oxygen levels dropped sharply during the summer of logging, when debris was in the Needle Branch streambed. Following debris clearance and winter freshets, surface levels returned to pre-logging concentrations.

7. There was a pronounced decrease in intragravel dissolved oxygen in winter following logging. Mean concentrations dropped by over 2 mg/liter.

8. Summer intragravel dissolved oxygen levels in Needle Branch dropped to a mean of 1.3 mg/liter by the end of June 1966.

9. Mean monthly streamflow in Needle Branch increased by 26.9% after logging. There was a 4.9% increase in streamflow in Deer Creek, and 1.6% increase in Flynn Creek during this same post-logging period.

10. Levels of fines (<0.833 mm and <3.327 mm in diameter) increased in Needle Branch and Deer Creek following logging, but the lack of sufficient pre-logging data makes the statistical comparison weak.

11. There was a 205.3% increase in suspended sediments in Needle Branch following road construction, and a 53.5% increase in Deer Creek. Sediment discharge increased by only 0.1% in Flynn Creek during this same period. Erosion and deposition patterns varied yearly.

12. Permeability of the gravel decreased in Needle Branch after logging, while the permeabilities in the other two streams remained essentially the same.

13. There was almost a 4-fold increase in loss of nitrate nitrogen in Needle Branch following clearcutting. This abnormal condition lasted six years. Concentrations of phosphorus increased for two months after slash burning on Needle Branch. These conditions were not evident in Deer Creek or Flynn Creek.

ACKNOWLEDGEMENTS

During the 17 years of field work and data analysis, many individuals made contributions that led to the successful completion of this project. Although too numerous to mention all individually here, several people and groups should be singled out for their support, assistance, and/or constructive criticism. Dr. Donald Chapman was the first coordinator of the Alsea Watershed Study. He was succeeded by Dr. James Hall. Dr. James Krygier served as acting coordinator during the transition period. The efforts of all three men were essential for the direction and completion of numerous Alsea studies.

The actual day-to-day operations of the 15 years of field work were the responsibility of the Oregon State Game (Oregon Department of Fish and Wildlife) Commission's Research Division. Drs. H. J. Rayner and Harry Wagner, and Mr. Homer Campbell directed the operations of this agency, with Mr. Robert Phillips as the first project leader, and Mr. Richard Lantz as second project leader. Several Game Commission biologists were primarily responsible for the collection of biological data: Messrs. Errol Claire, Wayne Hug, Patrick Keeley, Bruce Pohl and Richard Severson. I am particularly grateful to Messrs. Lantz and Pohl for their assistance in locating and compiling the extensive data. Thanks are also due numerous seasonal biologists during the course of the study. Much biological and environmental data were collected by graduate students.

We are indebted to several professional foresters for their assistance whenever needed: Drs. George Brown and Henry Froehlich of Oregon State University, and Messrs. S. T. Moore and Dale Robertson of the Siuslaw National Forest, U.S. Forest Service. Thanks are also due Messrs. John Corliss of the U.S. Forest Service, David Harris of the U.S. Geological Survey, and Fred Williamson. We also wish to acknowledge the cooperation and interest of the Georgia-Pacific Corporation, particularly Messrs. Ray Ayers, Rae Johnson, Wayne Knauf, Ronald Nutting, and John Thompson.

Mr. Bruce Pohl was responsible for the massive computer filing and storage system for the data. Mr. Pohl and Dr. Norbert Hartmann assisted in statistical analysis of the data. I also wish to thank the following individuals for reviewing drafts of the manuscript: Drs. James Hall and Harry Wagner, and Mr. Homer Campbell. Catherine Young provided several of the art illustrations.

LITERATURE CITED

Anderson, H. W. 1971. Relative contributions of sediment from source areas, and transport processes. In: J. T. Krygier and J. D. Hall (ed.), Forest land uses and stream environment, Cont. Ed. Publs., Oregon St. Univ., Corvallis:55-63.

Anonymous. 1966. Effects of log driving on the salmon and trout populations in the Stellako River. Inter. Pac. Salmon Fish. Comm., Prog. Rept. 14. 88 p.

Au, D. W. K. 1972. Population dynamics of the coho salmon and its response to logging in three coastal streams. Ph.D. Dissertation, Oregon St. Univ., Corvallis. 245 p.

Bachman, R. W. 1958. The ecology of four northern Idaho trout streams with reference to the influence of forest road construction. M.S. Thesis, Univ. of Idaho, Moscow. 97 p.

Berndt, H. W. and G. W. Swank. 1970. Forest land use and streamflow in Central Oregon. U.S. Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-93. 15 p.

Brazier, J. R. 1972. Controlling water temperatures with buffer strips. M.S. Thesis, Oregon St. Univ., Corvallis, 65 p.

———— and G. W. Brown. 1973. Buffer strips for stream temperature control. Forest Res. Lab., Oregon St. Univ., Res. Paper 15. 9 p.

Brown, G. W. and J. T. Krygier. 1967. Changing water temperatures in small mountain streams. J. Soil and Water Conserv. 22(6):242-244.

———— and ———— 1970. Effects of clearcutting on stream temperature. Water Resources Res. 6(4):1133-1139.

———— and ———— 1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resources Res. 7(5):1189-1198.

————, A. R. Gahler, and R. B. Marston. 1973. Nutrient losses after clear-cut logging and slash burning in the Oregon Coast Range. Water Resources Res. 9(5): 1450-1453.

————, G. W. Swank and J. Rothacher. 1971. Water temperature in the Steamboat drainage. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-119. 17 p.

Buchanan, D. V., P. S. Tate, and J. R. Moring. 1976. Acute toxicities of spruce and hemlock bark extracts to some estuarine organisms in southeastern Alaska. J. Fish Res. Bd. Canada. 33: In Press.

Burns, J. W. 1970. Spawning bed sedimentation studies in northern California streams. Calif. Fish and Game 56(4):253-270.

__________ 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish and Game 57(1):44-57.

__________ 1972. Some effects of logging and associated road construction on northern California streams. Trans. Amer. Fish. Soc. 101(1):1-17.

Cederholm, C. J. and L. C. Lestelle. 1974. Observations on the effects of landslide siltation on salmon and trout resources of the Clearwater River, Jefferson County, Washington, 1972-73. Fish Res. Inst., Univ. of Wash., Final Rept., Part I, to Wash. St. Dept. Nat. Res. FRI-UW-7404. 133 p.

Chapman, D. W. 1961. Factors determining production of coho salmon, *Oncorhynchus kisutch*, in three Oregon streams. Ph.D. Dissertation, Oregon St. Univ., Corvallis. 214 p.

__________ 1962a. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Canada 19(6):1047-1080.

__________ 1962b. Effects of logging upon fish resources of the west coast. J. Forestry 60(8):533-537.

__________ 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Amer. Fish. Soc. 94(1):40-52.

Coble, D. W. 1961. Influence of water exchange and dissolved oxygen in redds on survival of steelhead trout embryos. Trans. Amer. Fish. Soc. 90(4):469-474.

Cooper, A. C. 1965. The effect of transported stream sediments on the survival of sockeye and pink salmon eggs and alevins. Bull. Inter. Pac. Salmon Fish. Comm. 18. 17 p.

Cordone, A. J. and D. E. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish and Game. 47(2):189-228.

__________ and S. Pennoyer. 1960. Notes on silt pollution in the Truckee River drainage, Nevada and Placer counties. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 60-14. 25 p.

Corliss, J. F. and C. T. Dyrness. 1965. A detailed soil-vegetation survey of the Alsea area in the Oregon Coast Range. In: C. T. Youngberg (ed.), Forest-soil relationships in North America. Oregon St. Univ. Press, Corvallis:457-483.

Deschamps, G. 1971. A report on siltation in Stequaleho Creek. Wash. St. Dept. Fish., Management Res. Div. 7 p. (mimeo).

Dill, L. M. and T. G. Northcote. 1970. Effects of gravel size, egg depth, and egg density on intragravel movement and emergence of coho salmon (*Oncorhynchus kisutch*) alevins. J. Fish. Res. Bd. Canada. 27(7):1191-1199.

Edgington, J. R. 1969. The impact of logging on the ecology of two trout streams in north Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 73 p.

Elliott, S. T. and R. D. Reed. 1973. A study of land use activities and their relationship to the sport fish resources in Alaska. Job D-I-A: Establishment of guidelines for protection of the sport fish resources during logging operations. Alaska Dept. Fish and Game, Ann. Prog. Rept., Project F-9-5. 11 p.

Ellis, R. J. 1973. Preliminary biological survey of log-rafting and dumping areas in southeastern Alaska. Mar. Fish. Rev. 35(5-6):19-22.

Fiksdal, A. J. 1974. A landslide survey of the Stequaleho Creek watershed. Supplement to: Cederholm, C. J., and L. C. Lestelle. 1974. Observations on the effects of landslide siltation on salmon and trout resources of the Clearwater River, Jefferson County, Washington, 1972-73. Fish. Res. Inst., Univ. of Wash., Final Rept., Part I, to Wash. St. Dept. Nat. Res., FRI-UW-7404. 8 p.

Fisk, L., E. Gerstung, R. Hansen, and J. Thomas. 1966. Stream damage surveys – 1966. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 66-10. 9 p.

Gilleran, D. J. 1968. Rapid calibration of coastal streams to detect effects of road building. M.S. Thesis, Oregon St. Univ., Corvallis. 51 p.

Gray, J. R. A. and J. M. Edington. 1969. Effect of woodland clearance on stream temperature. J. Fish. Res. Bd. Canada 26:399-403.

Greene, G. E. 1950. Land use and trout streams. J. Soil and Water Conserv. 5(3):125-126.

Gruesdale, G. A., A. L. Downing and G. F. Lowden. 1955. The solubility of oxygen in pure water and sea water. J. Appl. Chem. 5:53-63.

Hall, J. D. and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. In: T. G. Northcote (ed.), Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, Univ. of British Columbia: 355-375.

Hanzel, D. A. 1961. Inventory of the waters of the project area. Northwest Montana Fish. Study., Montana Fish and Game, Fish. Div., Fed. Aid in Fish Restor. Job Completion Rept., Project F-7-R-10. 9 p.

Harper, W. C. 1969. Changes in storm hydrographs due to clearcut logging. M.S. Thesis, Oregon St. Univ., Corvallis. 116 p.

Harr, R. D., W. C. Harper, J. T. Krygier, and F. S. Hsieh. 1975. Changes in storm hydrographs after road building and clearcutting in the Oregon Coast Range. Water Resources Res. 11(3):436-444.

__________ and J. T. Krygier. 1972. Clearcut logging and low flows in Oregon coastal watersheds. Oregon St. Univ., Forest Res. Lab., Res. Note 54. 3 p.

Harris, D. D. 1973. Hydrologic changes after clear-cut logging in a small Oregon coastal watershed. J. Res. U. S. Geol. Survey 1(4):487-491.

Hibbert, A. R. 1967. Forest treatment effects on water yield. In: W. E. Sopper and H. W. Lull (ed.), International symposium on forest hydrology. Pergamon Press, New York:527-543.

Hermann, R. B., C. E. Warren, and P. Doudoroff. 1962. Influence of oxygen concentration on the growth of juvenile coho salmon. Trans. Amer. Fish. Soc. 91(2):155-167.

Hsieh, F. S-K. 1970. Storm runoff response from road building and logging on small watersheds in the Oregon Coast Range.M.S. Thesis, Oregon St. Univ., Corvallis. 149 p.

Kabel, C. S. and E. R. German. 1967. Caspar Creek study completion report. Calif. Dept. Fish and Game, Mar. Res. Branch Admin. Rept. 67-4. 28 p.

Kingsbury, A. P. 1973. Relationships between logging activities and salmon. Alaska Dept. Fish and Game, Com. Fish. Res. and Develop. Act. Completion Rep. 5-24-R. 54 p.

Kopperdahl, F. R., J. W. Burns and G. E. Smith. 1971. Water quality of some logged and unlogged California streams. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 71-12. 19 p.

Koski, K V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis, Oregon St. Univ., Corvallis. 84 p.

Krammes, J. S. and D. M. Burns. 1973. Road construction on Caspar Creek watersheds. USDA Forest Service, Pac. SW Forest and Range Exp. Sta., Res. Paper PSW-93. 10 p.

Krohn, D. C. 1967. Production of the reticulate sculpin (*Cottus perplexus*) and its predation on salmon fry in three Oregon streams. M.S. Thesis, Oregon St. Univ., Corvallis. 78 p.

Lantz, R. L. 1971. Guidelines for stream protection in logging operations. Oregon St. Game Comm. 29 p.

__________ and J. R. Moring. 1975 MS. Influence of water temperature changes on the behavior of coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) in small coastal Oregon streams. Oregon Wild. Comm., Unpubl. Manuscript.

Levno, A. and J. Rothacher. 1967. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. USDA Forest Service, Pac. NW Forest and Range Exp. St., Res. Note PNW-65. 12 p.

__________ and __________ 1969. Increases in maximum stream temperatures after slash burning in a small experimental watershed. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Note PNW-110. 7 p.

Lowry, G. R. 1964. Net production, movement, and food of cutthroat trout (*Salmo clarki clarki* Richardson) in three Oregon coastal streams. M.S. Thesis, Oregon St. Univ., Corvallis. 72 p.

__________ 1965. Movement of cutthroat trout, *Salmo clarki clarki* (Richardson) in three Oregon coastal streams. Trans. Amer. Fish Soc. 94(4):334-338.

__________ 1966. Production and food of cutthroat trout in three Oregon coastal streams. J. Wildl. Mgmt. 30(4):754-767.

Mason, J. C. 1969. Hypoxial stress prior to emergence and competition among coho salmon fry. J. Fish. Res. Bd. Canada 26:25-31.

McNeil, W. J. 1962. Mortality of pink and chum salmon eggs and larvae in southeast Alaska streams. Ph.D. Dissertation, Univ. of Wash., Seattle. 270 p.

__________ and W. H. Ahnell. 1960. Measurement of gravel composition of salmon streambeds. Fish. Res. Inst., Univ. of Wash., Circ. No. 120. 2 p.

——————and —————— 1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish and Wildl. Serv., Spec. Sci. Rept. – Fish. No. 469. 15 p.

Meehan, W. R. 1970. Some effects of shade cover on stream temperature in southeast Alaska. USDA Forest Service, Pac. NW Forest and Range Exper. Sta., Res. Note PNW-113. 9 p.

——————, W. A. Farr, D. M. Bishop, and J. H. Patric. 1969. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. USDA Forest Service, Inst. Northern Forestry, Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-82. 45 p.

Moring, J. R. and R. L. Lantz. 1974. Immediate effects of logging on the freshwater environment of salmonids. Oregon Wildl. Comm., Res. Div., Project AFS-58, Final Rept. 101 p.

Narver, D. W. 1971. Carnation Creek Watershed Study. Fish. Res. Bd. Canada, Pac. Biol. Sta., Nanaimo, B.C. 7 p. (mimeo).

—————— 1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. Fish. Res. Bd. Canada Tech. Rept. 323. 55 p.

Pease, B. C. 1974. Effects of log dumping and rafting on the marine environment of southeast Alaska. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Gen. Tech. Rept. PNW-22. 68 p.

Pellet, W. C. and W. J. McNeil. 1964. Measurement of gravel shift. In: T.S.Y. Koo (ed.)., F.R.I. Field Manual. Univ. of Wash., Fish. Res. Inst., Circ. 143 (rev. ed.):417.2(1-2).

Phillips. R. W. and H. J. Campbell. 1961. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions in gravel beds. 14th Ann. Rept., Pac. Mar. Fish. Comm.:60-73.

——————, R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout. Trans. Amer. Fish. Soc. 104(3):in press.

Platts, W. S. 1974a. Chinook salmon runs, fish standing crop and species composition in South Fork Salmon River, Idaho. U.S. Forest Service, Intermountain Region, Prog. Rept. V. 48 p.

—————— 1974b. Geomorphic and aquatic conditions influencing salmonids and stream classification in the Salmon River drainage, Idaho, 1970-1972. Ph.D. Dissertation, Utah St. Univ. 200 p.

—————— 1974c. Stream channel sediment conditions in the South Fork Salmon River, Idaho. U.S. Forest Service, Intermountain Region, Prog. Rept. IV. 38 p.

Pollard, R. A. 1955. Measuring seepage through salmon spawning gravel. J. Fish. Res. Bd. Canada 12(5):706-741.

Reed, R. D. and S. T. Elliott. 1972. Effects of logging on Dolly Varden. Alaska Dept. Fish and Game, Fed. Aid in Fish Restor., Ann. Prog. Rept., Project F-9-4, Job R-IV-B. 62 p.

Reinhart, K. G., A. R. Eschner and G. R. Trimble, Jr. 1963. Effect on streamflow of four forest practices in the mountains of West Virginia. USDA Forest Service, Northeast Forest Exper. Sta., Res. Paper NE-1. 79 p.

Riggs, H. C. 1965. Effect of land use on the low flow of streams in Rappahannock County, Virginia. U.S. Geol. Survey, Prof. Paper 526-C:C196-C198.

Ringler, N. H. 1970. Effects of logging on the spawning bed environment in two Oregon coastal streams. M.S. Thesis, Oregon St. Univ., Corvallis. 96 p.

——————and J. D. Hall. 1975. Effects of logging on water temperature and dissolved oxygen in spawning beds. Trans. Amer. Fish. Soc. 104(1):111-121.

Rothacher, J. 1965. Streamflow from small watersheds on the western slope of the Cascade range of Oregon. Water Resources Res. 1:125-134.

—————— 1970. Increases in water yield following clear-cut logging in the Pacific Northwest. Water Resources Res., 6(2):653-658.

—————— 1971. Regimes of streamflow and their modification by logging. In: J. T. Krygier and J. D. Hall (ed.), Forest land uses and stream environment. Cont. Ed. Publs., Oregon St. Univ., Corvallis:40-54.

Rowe, P. B. 1963. Streamflow increases after removing woodland-riparian vegetation from a southern California watershed. J. Forestry 61(5):365-370.

Salo, E. O. 1967. Study of the effects of logging on pink salmon in Alaska. Proc. Soc. Amer. Foresters 1966:59-62.

Servizi, J. A., D. W. Martens, and R. W. Gordon. 1970. Effects of decaying bark on incubating salmon eggs. Inter. Pac. Salmon Fish. Comm., Prog. Rept. 24. 28 p.

Sheridan, W. L. 1962. Waterflow through a salmon spawning riffle in southeastern Alaska. U.S. Fish and Wildl. Serv., Spec. Sci. Rept. – Fish. No. 407. 20 p.

__________ and W. J. McNeil. 1968. Some effects of logging on two salmon streams in Alaska. J. Forestry 66:128-133.

__________ and S. T. Olson. 1970. Timber harvest and the salmon and trout fisheries of southeast Alaska. Proc. 50th Ann. Conf. West. Assoc. State Game and Fish Comm., Victoria, B.C.:186-191.

Stefanich, F. 1967. The effects of logging on Pinkham Creek's fish population. Montana Fish and Game, Fed. Aid in Fish Restor., Job Completion Rept., Project F-7-R-6. 10 p.

Terhune, L. D. B. 1958. The Mark VI groundwater standpipe for measuring seepage through salmon spawning gravel. J. Fish. Res. Bd. Canada. 15(5):1027-1063.

Tyler, R. W. and D. R. Gibbons. 1973. Observations of the effect of logging on salmon-producing tributaries of the Staney Creek Watershed and the Thorne River Watershed and of logging in the Sitka District. Fish. Res. Inst., Univ. of Wash., Final Rept., Part 1, to Alaska Loggers Assoc. FRI-UW-7307. 58 p.

Vaux, W. G. 1962. Influence of stream and intragravel water in a salmon spawning riffle. U.S. Fish and Wildl. Serv., Spec. Sci. Rept. – Fish. No. 405. 11 p.

Wendler, H. O. and G. Deschamps. 1966. Logging dams on coastal Washington streams. Wash. St. Dept. Fish., Fish. Res. Paper 1(3):27-38.

Wickett, W. P. 1954. The oxygen supply to salmon eggs in spawning eggs. J. Fish. Res. Bd. Canada. 11(6):933-953.

__________ 1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Bd. Canada. 15(5):1103-1126.

Williams, R. C. 1954. Sedimentation in three small forested drainage basins in the Alsea River basin, Oregon. U.S. Geol. Survey Circ. 490.

Wustenberg, D. W. 1954. A preliminary survey of the influences of controlled logging on a trout stream in the H. J. Andrews Experimental Forest, Oregon. M.S. Thesis, Oregon St. Col. (University), Corvallis. 51 p.

Appendix 1. Records of monthly minimums and maximums for Flynn Creek, 1959-1963. Taken from U.S. Geological Survey records at 0 meter gauging station. Temperatures in degrees Celsius.

YEAR	JAN		FEB		MAR		APR		MAY		JUN	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1959	8.3	9.4	8.9	9.4	8.9	9.4	8.3	10.0	10.0	11.1	11.1	12.8
1960	8.3	8.9	8.9	8.9	8.3	10.0	9.4	10.6	9.4	10.6	10.6	12.2
1961	8.9	9.4	8.9	9.4	8.9	9.4	9.4	10.0	10.6	11.1	11.1	12.8
1962	7.8	8.3	8.3	8.9	8.9	9.4	8.9	10.6	9.4	10.0	11.1	12.8
1963	8.9	9.4	9.4	10.0	8.3	8.9	8.3	8.9	10.0	11.7	11.7	12.8
1964	8.9	8.9	7.8	8.9	8.3	10.0	7.8	10.0	10.0	11.1	10.0	11.1
1965	7.8	8.3	7.2	7.8	8.3	9.4	9.4	11.1	8.9	10.6	11.1	12.8
1966	8.3	8.9	7.8	8.3	8.3	10.0	8.3	10.0	8.9	10.6	11.1	12.8
1967	8.3	8.9	8.3	8.9	8.3	8.9	6.7	8.9	8.3	10.0	11.7	12.8
1968	8.0	9.0	9.0	10.0	9.0	11.0	8.0	10.0	8.0	11.0	11.0	12.0
1969	8.3	8.8	7.2	7.7	8.3	9.4	7.7	9.4	9.9	11.6	11.6	12.7
1970	8.3	8.9	7.8	8.3	7.2	8.3	7.8	8.3	8.9	10.6	10.6	12.2
1971	8.3	8.9	7.8	8.3	8.3	8.9	7.2	9.4	8.3	10.0	9.4	11.1
1972	5.0	8.0	4.5	8.5	6.0	9.5	6.0	9.5	6.5	11.0	8.5	13.0
1973	5.0	8.3	5.0	8.3	6.1	8.3	6.1	10.0	7.2	11.7	7.8	12.2

YEAR	JUL		AUG		SEP		OCT		NOV		DEC	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1959	12.8	14.4	12.8	14.4	11.1	12.2	10.6	11.1	9.4	10.0	9.4	10.0
1960	12.2	13.9	12.8	15.0	12.8	14.4	10.0	11.7	10.0	10.6	8.9	8.9
1961	12.8	15.0	13.9	16.7	13.9	16.7	11.7	13.3	8.3	9.4	9.4	9.4
1962	12.2	15.0	12.2	14.4	12.2	13.9	10.6	11.7	11.1	11.1	9.4	10.0
1963	11.7	13.3	13.3	15.0	13.3	15.6	11.7	12.8	9.4	10.0	8.3	9.4
1964	12.2	13.3	12.2	13.9	11.7	12.8	11.1	11.7	8.9	8.9	8.9	8.9
1965	12.2	13.9	12.2	14.4	11.7	13.9	11.7	12.8	10.6	11.1	8.9	9.4
1966	12.2	13.9	12.8	14.4	12.8	14.4	11.7	12.8	9.4	10.0	8.9	9.4
1967	12.8	13.9	13.3	15.0	13.3	13.9	11.0	12.0	9.0	10.0	8.0	9.0
1968	12.0	13.0	13.0	13.0	13.0	13.0	9.4	11.1	9.9	10.5	8.3	8.8
1969	11.6	12.7	11.1	12.2	11.6	12.7	11.7	12.2	10.0	10.6	10.0	10.0
1970	12.2	13.3	11.7	13.3	11.7	12.2	9.4	11.1	9.4	10.0	8.9	9.4
1971	11.7	12.3	12.8	13.9	11.7	12.2	5.5	11.0	6.5	9.0	7.0	9.0
1972	10.0	15.0	11.0	15.0	8.0	14.5	6.7	11.1	7.8	10.6	1.7	9.4
1973	9.4	13.3	8.9	13.3	8.3	12.2	0	0	0	0	0	0

Appendix 2. Records of monthly minimums and maximums for Deer Creek, 1959-1973.
Taken from U.S. Geological Survey records at 0 meter gauging station.
Temperatures in degrees Celsius.

YEAR	JAN		FEB		MAR		APR		MAY		JUN	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1959	8.9	9.4	8.9	8.9	7.8	10.0	8.9	12.2	8.9	11.7	11.1	11.7
1960	7.2	8.3	7.8	8.9	7.8	8.3	7.2	11.1	9.4	10.0	10.6	13.3
1961	8.9	9.4	8.9	9.4	9.4	10.0	10.0	10.6	10.0	11.1	12.8	15.6
1962	7.8	8.9	8.3	8.9	6.7	10.0	8.9	12.8	8.9	10.6	10.6	13.9
1963	8.3	8.9	8.9	9.4	6.7	10.0	6.7	11.1	10.0	13.3	11.1	13.9
1964	8.9	8.9	7.8	8.3	7.2	10.6	7.2	11.7	8.9	12.8	10.6	12.8
1965	7.2	7.8	7.8	8.3	6.7	9.4	8.9	11.7	8.9	12.2	11.7	13.9
1966	8.3	8.9	6.7	8.3	7.2	11.1	6.7	11.7	8.9	13.9	12.2	16.7
1967	8.9	9.4	7.8	9.4	7.2	9.4	7.2	11.7	10.0	16.1	10.6	16.1
1968	9.0	10.0	9.0	11.0	9.0	11.0	7.0	14.0	7.0	14.0	11.0	16.0
1969	9.4	9.9	6.6	7.7	5.5	12.2	6.1	12.7	9.9	15.5	11.6	16.6
1970	8.9	9.4	7.8	10.0	8.3	11.1	7.8	11.7	10.6	15.0	12.2	16.1
1971	8.3	9.4	8.9	9.4	7.2	9.4	7.8	11.7	8.3	12.8	10.0	13.9
1972	5.5	9.0	5.5	8.5	6.5	10.5	6.5	11.5	8.0	14.0	9.5	14.5
1973	0	0	0	0	0	0	0	0	0	0	0	0

YEAR	JUL		AUG		SEP		OCT		NOV		DEC	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1959	12.8	14.4	13.3	13.9	11.7	12.2	8.9	10.0	8.9	9.4	8.3	8.3
1960	12.8	14.4	13.3	15.0	12.2	14.4	11.1	12.2	10.0	10.6	8.3	8.9
1961	12.8	15.6	13.3	16.1	12.2	14.4	11.7	12.8	8.9	9.4	8.9	8.9
1962	12.8	15.6	12.2	13.9	12.2	13.9	10.6	12.2	11.1	11.7	8.9	9.4
1963	11.7	13.9	13.3	15.0	13.3	15.0	11.7	13.3	8.9	10.0	8.3	8.9
1964	11.1	13.9	12.2	14.4	11.7	13.3	10.6	11.7	9.4	10.0	8.9	9.4
1965	11.1	13.9	0	0	12.2	12.8	11.1	11.1	10.6	11.1	8.9	8.9
1966	12.2	16.7	11.7	16.7	11.1	16.1	11.7	13.3	9.4	11.1	9.4	10.6
1967	12.2	17.2	12.8	17.8	13.3	16.1	12.0	12.0	9.0	11.0	8.0	9.0
1968	12.0	17.0	14.0	17.0	12.0	16.0	11.1	13.3	9.4	10.5	7.7	8.8
1969	9.9	14.4	10.5	14.4	11.1	14.9	11.1	11,7	9.4	11.1	8.3	8.9
1970	12.8	16.1	12.2	16.1	12.2	13.3	9.4	11.7	8.9	10.0	8.3	9.4
1971	11.7	14.4	13.9	16.1	10.6	12.2	6.5	12.0	7.0	9.0	7.0	9.0
1972	10.5	16.0	11.5	17.0	8.5	16.0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3. Records of Monthly minimums and maximums for Needle Branch, 1959-73.
Taken from U.S. Geological Survey records at 0 meter gauging station.
Temperatures in degrees Celsius.

YEAR	JAN		FEB		MAR		APR		MAY		JUN	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1959	8.3	8.9	8.3	8.9	8.3	8.9	8.9	10.6	8.9	10.6	11.1	12.2
1960	7.8	8.9	8.3	8.9	8.9	10.0	9.4	10.6	9.4	11.1	11.7	12.8
1961	8.3	9.4	8.9	9.4	8.3	8.9	9.4	10.0	10.6	11.1	12.8	14.4
1962	7.2	7.8	7.2	7.8	8.3	8.9	10.0	10.6	8.3	10.0	10.6	12.2
1963	7.8	8.3	7.8	8.3	8.3	8.3	8.9	10.6	8.9	12.2	11.7	15.0
1964	8.9	8.9	7.8	8.3	7.8	8.3	6.7	9.4	10.0	11.1	10.6	11.7
1965	7.2	7.8	6.7	7.2	7.2	7.8	10.0	11.1	9.4	10.6	10.6	11.7
1966	8.3	8.9	7.2	7.8	7.2	10.6	8.3	10.6	10.0	12.2	12.8	15.0
1967	8.3	10.6	7.8	10.6	8.9	11.1	7.2	14.4	11.7	22.8	15.0	25.6
1968	9.0	12.0	8.0	13.0	10.0	14.0	8.0	19.0	9.0	21.0	13.0	23.0
1969	11.6	12.7	10.5	11.6	6.6	14.4	7.2	14.9	10.5	21.0	12.7	22.2
1970	10.6	11.1	9.4	10.0	6.7	14.4	6.7	15.0	10.6	20.0	11.7	21.1
1971	7.8	8.9	8.3	8.9	6.7	7.8	8.2	15.6	7.9	18.1	10.5	17.9
1972	4.5	9.0	5.0	10.0	8.0	13.0	6.5	12.0	7.0	15.5	9.5	15.5
1973	9.1	10.0	8.3	10.6	7.4	11.8	8.7	14.7	9.3	15.6	12.2	15.4

YEAR	JUL		AUG		SEP		OCT		NOV		DEC	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1959	13.3	14.4	13.9	14.4	12.8	13.3	10.6	11.7	8.3	10.6	7.8	8.9
1960	13.3	14.4	13.9	15.0	13.3	14.4	12.2	13.3	10.0	10.6	8.3	8.9
1961	14.4	15.6	15.0	16.1	15.6	16.1	12.2	12.8	8.3	8.9	8.9	10.0
1962	12.8	13.9	12.8	13.3	12.2	13.3	10.6	11.7	10.6	11.1	9.4	10.0
1963	12.8	15.0	14.4	16.1	13.9	15.0	12.2	12.8	9.4	10.0	8.3	8.9
1964	11.1	13.3	12.8	13.9	11.7	12.2	11.1	11.7	8.9	9.4	9.4	10.0
1965	13.3	13.9	13.9	13.9	12.2	12.8	11.1	11.7	10.6	11.1	8.3	8.9
1966	13.9	16.7	15.6	22.8	13.9	22.2	13.9	17.8	10.6	13.9	8.9	10.6
1967	15.6	26.1	15.6	23.9	14.4	20.0	12.0	17.0	10.0	13.0	9.0	10.0
1968	13.0	23.0	17.0	21.0	13.0	20.0	9.4	14.9	12.2	13.3	11.1	12.2
1969	12.7	21.0	12.2	18.8	12.7	16.6	12.8	13.9	10.6	13.9	10.6	11.7
1970	13.9	18.9	11.1	17.2	10.6	14.4	10.0	13.3	10.0	11.7	8.3	9.4
1971	13.2	18.4	16.3	19.5	14.8	17.5	6.0	13.0	6.5	10.5	7.0	10.0
1972	10.0	16.0	9.5	16.0	6.5	16.0	10.0	11.7	9.7	10.6	10.0	10.6
1973	10.0	12.8	0	0	0	0	0	0	0	0	0	0

Appendix 4. Mean intragravel and surface dissolved oxygen values from November-June sampling in Deer Creek in mg/liter.

	INTRAGRAVEL		SURFACE	
SEASON	MEAN	RANGE	MEAN	RANGE
1959-60	5.0	0-10.6	9.1	8.8- 9.5
1960-61	5.1	0-10.7	9.2	7.9-10.6
1961-62	4.9	0.1- 9.7	9.9	9.3-10.6
1962-63	8.6	0.3-12.2	11.3	9.6-12.6
1963-64	8.1	0.3-12.2	11.6	10.3-12.2
1964-65	8.9	0.2-12.2	12.1	11.4-12.5
1965-66	8.5	0.1-12.3	12.2	11.4-12.8
1966-67	8.4	0.5-12.7	11.9	11.0-12.4
1967-68	8.8	0.8-11.9	11.6	10.4-12.2
1968-69	7.4	0.1-12.9	11.1	9.5-13.0
1969-70	5.6	0-10.5	10.9	10.0-12.2
1970-71	5.7	0-10.9	10.6	9.9-11.0
1971-72	5.1	0-10.9	11.0	9.7-11.7
1972-73	4.6	0.4-11.5	10.7	9.6-11.7

Appendix 5. Mean intragravel and surface dissolved oxygen values from November-June sampling in Flynn Creek. Values in mg/liter.

	INTRAGRAVEL		SURFACE	
SEASON	MEAN	RANGE	MEAN	RANGE
1959-60	6.0	0-12.2	9.4	9.1- 9.8
1960-61	5.5	0-10.7	9.2	5.4-12.3
1961-62	6.1	0.1-14.1	10.2	9.5-10.8
1962-63	10.1	2.3-13.6	11.5	10.5-12.8
1963-64	9.9	1.7-13.8	11.5	7.7-13.2
1964-65	9.9	1.8-12.6	12.3	11.4-13.7
1965-66	9.8	1.6-12.2	12.2	11.3-13.4
1966-67	9.2	1.7-12.3	12.0	11.5-12.7
1967-68	8.2	1.0-12.0	11.4	10.1-12.6
1968-69	8.0	0.8-12.1	11.0	9.9-12.1
1969-70	7.4	1.3-11.4	10.7	9.6-12.2
1970-71	7.0	0.1-10.4	10.7	10.1-11.3
1971-72	6.8	0.3-11.0	10.9	8.8-12.1
1972-73	7.0	0.7-11.1	10.6	9.7-11.8

Appendix 6. Mean intragravel and surface dissolved oxygen values from November–June sampling in Needle Branch. Values in mg/liter.

	INTRAGRAVEL		SURFACE	
SEASON	MEAN	RANGE	MEAN	RANGE
1959-60	5.9	0-10.2	9.7	9.6- 9.8
1960-61	5.3	0-12.2	9.6	8.1-11.3
1961-62	5.7	0-11.3	11.1	9.9-11.9
1962-63	10.2	4.1-13.5	11.7	9.3-13.4
1963-64	9.9	1.1-12.8	11.6	11.1-12.5
1964-65	9.0	1.8-12.3	11.9	11.4-12.7
1965-66	8.9	1.1-12.7	12.3	9.6-12.9
1966-67	6.8	0.9-12.3	11.7	11.3-12.4
1967-68	6.8	0.7-12.1	11.6	10.5-12.9
1968-69	5.1	0-11.1	10.2	6.0-13.0
1969-70	4.6	0-10.4	10.5	9.6-11.9
1970-71	3.3	0- 9.7	10.3	8.9-10.7
1971-72	4.6	0-11.4	10.6	9.5-11.8
1972-73	3.7	0.3-10.9	10.0	9.1-11.7

Appendix 7. Mean daily discharge (cfs), by month,
for Deer Creek, October 1959 to September 1973 (1 cfs = 28.3 liters/sec).

	MONTH											
YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1959	—	—	—	—	—	—	—	—	—	5.10	4.18	6.93
1960	7.30	19.3	9.03	9.08	6.90	1.94	0.73	0.49	0.35	0.96	16.7	5.87
1961	10.7	27.6	20.8	4.83	4.08	1.33	0.63	0.45	0.44	1.51	6.08	14.4
1962	6.86	8.79	13.3	7.06	5.01	1.69	0.77	0.55	0.57	2.45	13.5	8.23
1963	4.47	11.4	6.93	11.2	6.35	1.34	0.81	0.41	0.47	1.36	13.0	7.69
1964	26.5	7.06	11.9	3.53	2.46	1.44	0.88	0.78	0.55	0.52	7.92	30.3
1965	28.1	9.82	3.45	3.35	2.40	1.12	0.53	0.39	0.27	0.43	5.39	12.6
1966	21.0	7.49	16.3	3.21	1.20	0.68	0.48	0.27	0.30	1.22	6.80	15.0
1967	19.4	10.8	10.7	7.40	2.16	0.95	0.49	0.29	0.26	4.01	4.08	12.7
1968	8.52	18.6	8.42	4.31	2.96	5.06	0.95	1.16	1.34	4.38	14.1	20.1
1969	18.1	14.6	4.08	2.74	2.19	2.68	1.94	0.63	0.68	1.49	4.37	11.0
1970	24.5	11.9	4.68	5.60	3.82	1.03	0.47	0.29	0.54	1.75	8.88	16.3
1971	26.0	8.23	14.2	10.3	2.35	2.14	1.19	0.52	1.52	2.23	12.0	23.4
1972	26.4	13.1	17.8	8.61	3.17	1.23	0.53	0.30	0.46	0.33	2.45	17.0
1973	12.3	2.91	7.10	3.19	1.52	1.59	0.84	0.36	0.57	—	—	—
Pre-Logging Average	14.99	13.07	11.67	6.04	4.06	1.36	0.69	0.48	0.42	1.69	9.20	12.63
Post-Logging Average	19.32	11.45	9.57	6.02	2.60	2.10	0.92	0.51	0.77	2.37	7.65	16.75

Appendix 8. Mean daily discharge (cfs), by month,
for ~~Deer Creek~~, October 1959 to September 1973 (1 cfs = 28.3 liters/sec).

	MONTH											
YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1959	—	—	—	—	—	—	—	—	—	1.55	1.16	1.77
1960	1.93	3.93	2.12	2.11	1.93	0.40	0.12	0.08	0.03	0.20	4.09	1.22
1961	2.37	6.17	4.54	0.89	0.85	0.24	0.10	0.09	0.05	0.45	1.75	3.33
1962	1.39	2.39	2.77	1.25	0.96	0.28	0.10	0.05	0.04	0.45	3.04	1.64
1963	0.82	2.73	1.99	2.62	1.35	0.24	0.12	0.09	0.08	0.29	3.38	1.66
1964	6.15	1.76	2.79	0.85	0.55	0.23	0.11	0.08	0.05	0.06	2.04	6.82
1965	6.06	1.84	0.70	0.75	0.57	0.21	0.08	0.04	0.02	0.08	1.43	3.15
1966	4.55	2.09	3.88	0.57	0.20	0.11	0.09	0.05	0.06	0.60	2.55	4.41
1967	5.19	2.31	3.21	1.71	0.41	0.19	0.08	0.04	0.04	1.86	1.48	4.09
1968	2.49	4.79	2.45	0.93	0.65	1.06	0.17	0.19	0.30	1.66	4.42	6.36
1969	5.31	4.06	1.44	0.69	0.52	0.49	0.42	0.12	0.11	0.34	1.58	3.75
1970	6.51	3.06	1.18	1.60	0.90	0.20	0.06	0.02	0.06	0.45	3.05	5.09
1971	6.74	2.31	3.81	2.72	0.48	0.36	0.22	0.07	0.18	0.39	4.63	7.75
1972	7.10	2.53	3.62	2.41	0.70	0.26	0.08	0.02	0.07	0.05	0.82	5.23
1973	3.17	0.65	2.02	0.83	0.33	0.18	0.07	0.04	0.08	—	—	—
Pre-Logging Average	3.32	2.99	2.68	1.29	0.92	0.24	0.10	0.07	0.05	0.46	2.43	3.00
Post-Logging Average	5.22	2.82	2.53	1.56	0.57	0.39	0.16	0.07	0.12	0.79	2.66	5.38

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17.0
–
12.63
16.75

D
1.77
1.22
3.33
1.64
1.66
6.82
3.15
4.41
4.09
6.36
3.75
5.09
7.75
5.23
–
3.00
5.38

Appendix 9. Mean daily discharge (cfs), by month, for Flynn Creek, October 1959 to September 1973 (1 cfs = 28.3 liters/sec).

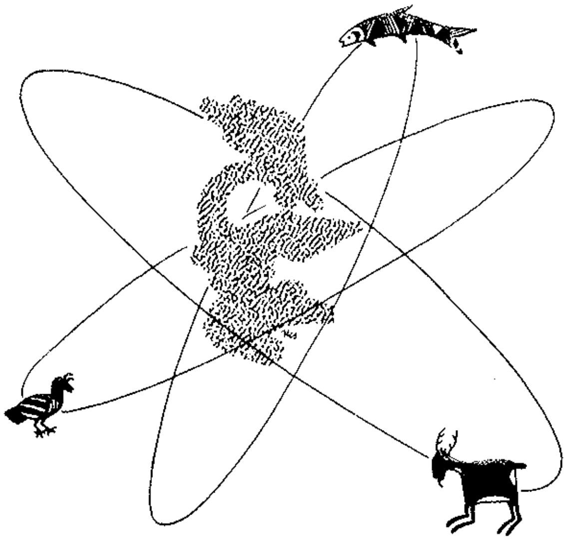
YEAR	MONTH											
	J	F	M	A	M	J	J	A	S	O	N	D
1959	–	–	–	–	–	–	–	–	–	3.18	2.88	4.88
1960	5.26	13.0	6.66	7.01	5.26	1.58	0.53	0.34	0.20	0.57	11.2	4.44
1961	7.47	19.2	14.5	3.52	2.82	0.93	0.40	0.22	0.25	0.93	3.89	9.61
1962	4.94	6.61	9.27	4.65	3.61	1.22	0.55	0.35	0.31	1.52	8.86	5.96
1963	3.18	8.58	5.42	8.25	4.39	0.93	0.55	0.31	0.27	0.64	8.70	4.93
1964	18.3	5.33	8.24	2.77	1.90	0.91	0.54	0.40	0.29	0.26	4.96	20.7
1965	18.4	7.39	2.65	2.23	1.80	0.78	0.35	0.20	0.14	0.25	3.05	8.15
1966	14.2	5.29	11.6	2.06	0.86	0.47	0.30	0.14	0.16	0.44	3.56	10.5
1967	13.8	8.15	7.84	5.18	1.54	0.64	0.31	0.15	0.14	1.64	2.30	9.04
1968	5.92	13.1	5.5	2.94	1.89	3.19	0.60	0.53	0.53	2.37	9.58	14.0
1969	13.4	11.2	3.05	1.83	1.53	1.35	1.16	0.34	0.31	0.55	2.31	6.99
1970	16.1	8.26	2.84	3.89	2.61	0.69	0.28	0.16	0.26	0.72	5.11	10.7
1971	17.2	5.39	9.55	6.75	1.52	1.11	0.73	0.30	0.68	0.96	8.64	17.2
1972	18.1	8.17	12.0	6.28	2.18	0.87	0.35	0.19	0.25	0.15	1.02	10.9
1973	8.55	1.96	4.42	2.29	1.05	0.77	0.47	0.22	0.31	–	–	–
Pre-Logging Average	10.25	9.34	8.33	4.36	2.95	0.97	0.46	0.28	0.23	0.97	5.89	8.65
Post-Logging Average	13.30	8.03	6.46	4.17	1.76	1.23	0.56	0.27	0.35	1.07	4.83	11.47

Appendix 10. Average seasonal permeability measurements for stations at the three streams. Values are expressed in cm/hour.

Season	Deer Creek	Flynn Creek	Needle Branch
1962-63	1708	4221	5640
1963-64	1712	4787	5500
1964-65	3925	3561	4643
1965-66	2502	2915	3740
1966-67	2490	2967	1139
1967-68	2267	2959	2372
1968-69	2981	4498	2560
1969-70	2636	4463	2600
1970-71	3920	4409	2366
1971-72	3836	4922	2369
1972-73	2911	4144	1992

THE ALSEA WATERSHED STUDY:
Effects of Logging on the Aquatic Resources of Three Headwater Streams of the Alsea River, Oregon
Part III - Discussion and Recommendations

Dr. John R. Moring



Fishery Research Report Number 9
Oregon Department of Fish and Wildlife
Corvallis, Oregon
December, 1975

Federal Aid to Fish Restoration
Project AFS-58
Final Report

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ABSTRACT

On the basis of the results of the Alsea Watershed Study, detailed in Parts I and II and outlined herein, recommendations are offered for logging operations in areas with small headwater streams. The use of buffer strips is supported, along with the careful design, construction, and maintenance of logging roads. Felling of timber should be away from the stream. No yarding of logs ought to take place in or across the stream. Logging debris must be removed from the stream as soon after cutting as possible, but some debris can remain in the stream. State fisheries agencies should have input into proposed cutting plans.

INTRODUCTION

The small coastal streams of western Oregon are important spawning and rearing areas for several species of salmon and trout. Of the two important salmon species in Oregon (chinook and coho), coho salmon are characteristically present in these smaller streams. They share the stream habitat with cutthroat trout, rainbow and rainbow steelhead trout, as well as some nonsalmonid fish species. These small headwater streams are often located in timbered areas suitable for logging and associated road construction. Because of their small size and isolated location, they are often not given effective protection during felling and yarding operations.

Logging practices can indirectly result in changes in the biological components of a stream, and can have direct and indirect effects on the physical environment in streams. Felling trees into streams, or yarding timber across streambeds do not in themselves directly kill or redistribute fishes. But, changes in environmental parameters can and do influence the biological segment of the stream ecosystem. The primary environmental changes of concern are the effects of siltation, logging debris, gravel scouring, destruction of developing embryos and alevins, blockage of streamflow, decrease in surface and intragravel dissolved oxygen, increase in maximum and diel water temperatures, changes in pool/riffle ratios and cover, redistribution of fishes, reduction in fish numbers, and reduction in total biomass. The relationship of logging activities to these undesirable changes in stream environments has been explored in numerous logging studies in the western continental United States, Alaska, British Columbia, and elsewhere.

In earlier years, logging studies were characteristically short-term and concerned with obvious stream damage related to logging activities. Although short-term studies continue to be undertaken, they are much more detailed and involved with pertinent problems. When sufficient funds are available, researchers are turning to long-term case history studies, where definitive results can be obtained.

The principal logging study in Montana was the long-term Pinkham Creek project in the Stillwater River Drainage. The studies involved, primarily, the yearly monitoring of trout and char population numbers (Stefanich 1957; Hanzel 1961). Several studies in Idaho have concentrated on the effects of logging on salmonid streams. Bachman (1958) measured physical and biological conditions in trout streams of three uncut watersheds and one logged watershed in Idaho. Water temperatures apparently did not change following logging, but sedimentation from road construction did increase, especially during periods of heavy runoff. Edgington (1969) reviewed the findings of an 11-year study of two trout streams. The stream in one watershed (where 8 percent of the area was logged) exhibited no significant change in water quality or level of bottom invertebrates. On the other stream, however, 97 percent of the basin was cut, and several changes were noted. Siltation was evident in the early years as a result of road construction, and the abundance of four orders of insects declined for several years, then recovered by the end of the study. The U.S. Forest Service has studied sediment levels, gravel composition and salmon populations on the South Fork of the Salmon River (Platts 1974a, 1974b, 1974c). Sediment levels increased on the stream from

1952-1965 as a result of logging and road construction. Since 1966, the river system has been able to expell much of the excess sediment. Although the available spawning gravel appears to be increasing in known spawning grounds, it is doubtful the sediment loads in the river will ever return to the pre-logging conditions.

Washington logging studies have been limited. Wendler and Deschamps (1955) described the blockage of salmon runs by splash, roll and pond-type log dams. Deschamps (1971), Cederholm and Lestelle (1974) and Fiksdal (1974) studied the effects of logging on Stequaleho Creek and the Clearwater River. Generally, the concern was several landslides into the river, resulting in siltation increases. Cederholm and Lestelle studied salmonid populations during 1971-72, along with gravel composition, suspended sediment, and benthic invertebrates. Levels of fines increased in the spawning bed gravel of the streams, but the hatching survival of cutthroat trout embryos was not significantly changed in these areas from hatching survival in unaffected sections. Coho salmon population densities were low, and the levels of benthic invertebrates were significantly lower than in unaffected areas of Stequaleho Creek.

The California Department of Fish and Game has been involved in logging damage surveys and localized surveys for many years (Cordone and Pennoyer 1960; Fisk et al. 1966), but this type of activity has given way to the long-term case history type of study. One of the enduring logging studies in the west has been the cooperative Caspar Creek study in northern California (Kabel and German 1967; Burns 1972). From its inception in 1960, researchers at Caspar Creek, and other northern California streams, continually monitored streamflow. Other factors measured for shorter periods have included biological aspects (Burns 1971), and environmental changes (Burns 1970; Kopperdahl et al. 1971; Krammes and Burns 1973). Researchers have found that sediment levels increased during and after road construction. During the first winter following road construction, sediment levels were over four times higher than pre-construction levels, but have decreased in subsequent years (Krammes and Burns). Water temperatures increased slightly following road construction (Krammes and Burns), but temperature increases were greater following logging (Kopperdahl et al.). Burns (1972) indicated salmonid populations were altered as a result of logging and road construction.

British Columbia logging research has been applied to several logging related problems. The Canada Department of Fisheries and other agencies (Anonymous 1966) analyzed the problem of log driving on salmonid populations and their environment in the Stellako River. Results indicated log driving causes gravel scouring and disruption of spawning beds, erosion of river banks, a greatly reduced recreational fishery along the river, and increased levels of bark and debris in the stream and in the spawning gravel. Additional studies by Servizi et al. (1970) have shown that decaying bark may have a significant effect on developing sockeye salmon eggs. Short-term logging studies on Jump Creek and Wolf Creek, Vancouver Island, indicate some changes in fish populations in logged streams (Narver 1972), while the ongoing Carnation Creek study hopes to answer several questions with the case history approach (Narver 1971).

The harvest of timber in Alaska has increased significantly in the past 30 years. Initial logging research by the U.S. Forest Service began in 1949, and has continued at various levels to date in southeast Alaska (Sheridan and McNeil 1968; Meehan et al. 1969; Sheridan and Olson 1970). Beginning in 1956, the Fisheries Research Institute of the University of Washington has supplemented the federal research in several stages. The major emphasis in the 1950's and 1960's was on the pink and chum salmon streams of southeast Alaska (Salo 1967). More recent logging studies have concentrated on coho salmon and associated changes in environmental conditions (Tyler and Gibbons 1973), and the effects of log rafting on the marine benthos (Pease 1974). In the last several years, the National Marine Fisheries Service has conducted research into log rafting problems (Ellis 1973). The Alaska Department of Fish and Game has continued research into the effects of logging on Dolly Varden (Reed and Elliott 1972) and salmon (Kingsbury 1973), and the toxicity of decaying bark on pink salmon fry and some crustaceans (Buchanan et al. 1975). Out of the Dolly Varden study came a series of guidelines for logging operations and baseline biological measurements in important southeast Alaska sports fishing areas (Elliott and Reed 1973).

Several logging studies have been undertaken in the Cascade Range of Oregon, including the Steamboat Creek drainage area (Brown et al. 1971), and the H.J. Andrews Experimental Forest (Wustenberg 1954; Brown and Krygier 1967; Levno and Rothacher 1967, 1969). Brazier and Brown (1973) studied applications of buffer strips in both the Cascade Range and the Oregon Coast Range, and Moring and Lantz (1974) reported the findings of a six-year study of 12 coastal streams of western Oregon. Cutthroat trout populations appeared to decrease on streams following logging, but the reactions of coho salmon populations were mixed. Maximum stream temperatures increased, and dissolved oxygen levels generally declined after logging. There were also changes in amounts and composition of spawning gravel, but those streams with intact buffer strips suffered less damage than those without buffer strips.

The limitations of short-term studies, however detailed, become apparent when the lack of background data on biological and physical cycles hinders the interpretation of results. Most long-term case histories of logged watersheds have only been undertaken in the last 25 years. The results of the largest such study, the Alsea Watershed Study, will be reported here. The 15-year study was the most extensive study of biological and environmental features of logged and unlogged watersheds ever undertaken in North America.

The Governor's Committee on Natural Resources established the Alsea Watershed Study in 1957. Funding from this source disappeared a year later, but federal and state agencies supported the work for the 15-year study period. The Alsea

Watershed Study was a cooperative venture involving numerous individuals and agencies. Principal cooperators throughout the study were the Oregon State Game Commission (Oregon Department of Fish and Wildlife), Oregon State University (primarily the School of Forestry, and the Departments of Botany, Civil Engineering, Entomology, and Fisheries and Wildlife), the U.S. Forest Service, U.S. Geological Survey, Federal Water Pollution Control Administration, the Georgia-Pacific Corporation, and Mr. Fred Williamson, a private landowner. Other cooperators included the U.S. Public Health Service, Oregon Cooperative Wildlife Research Unit, Oregon State Board of Forestry, and the Department of Environmental Quality. In addition to the Georgia-Pacific Corporation, the logging companies were the Stokes Lumber Company and Timber Access Industries, both of Corvallis, Oregon.

Studies began in July 1959 on three small watersheds in Lincoln County, Oregon. The three creeks involved are headwater tributaries of the lower Alsea River. One watershed, Flynn Creek, was left unlogged, and served as a control. The Deer Creek watershed was patch cut with intact buffer strips along the stream. The Needle Branch watershed was clearcut without buffer strips.

Logging road construction took place during May to October 1965. The timber harvest on the Deer Creek and Needle Branch watersheds occurred the following year, again during May to October. Slash burning was completed on Needle Branch and on two sections of Deer Creek prior to November 1966. The remaining section was slash burned some months later. Post-logging studies continued until October 1973.

This sequence provided a 7-year pre-logging study period, 1959-1965, logging in 1966, and a 7-year post-logging study period 1967-1973. For comparative estimates, the period 1959-1965 constituted the pre-logging work and 1966-1973 constituted the post-logging work. Among the primary objectives of the work were:

1. To study in depth the population characteristics of salmonids and other fish species in Flynn Creek, Deer Creek and Needle Branch over a 15-year period, 1959-1973.
2. To study the direct and indirect effects of logging on fish.
3. To compare the effects of two common logging techniques on biological and physical properties of streams, using Needle Branch and Deer Creek as test streams, and Flynn Creek as a control stream.
4. To analyze the effects of environmental changes (natural and logging-related) on salmonid fish species, particularly coho salmon and cutthroat trout.
5. To derive some indication of the natural fluctuations in fish populations and physical and biological properties of the three Alsea Study streams.
6. To make recommendations, on the basis of accumulated data, as to desirable and undesirable logging practices (including road construction, buffer strips, and yarding and felling of trees).

In order to present the results of this extensive study in the most logical manner, three separate but related Alsea Watershed Study reports are being issued. Part I includes the results of the biological investigations of the study. Part II includes the results of the environmental measurements during the study. Part III includes the discussion, summary and recommendations. Numerous papers, theses and dissertations have been issued on various aspects of the study during the past 15 years. Pertinent results of these publications, as they pertain to the results and discussion of accumulated data, will be included.

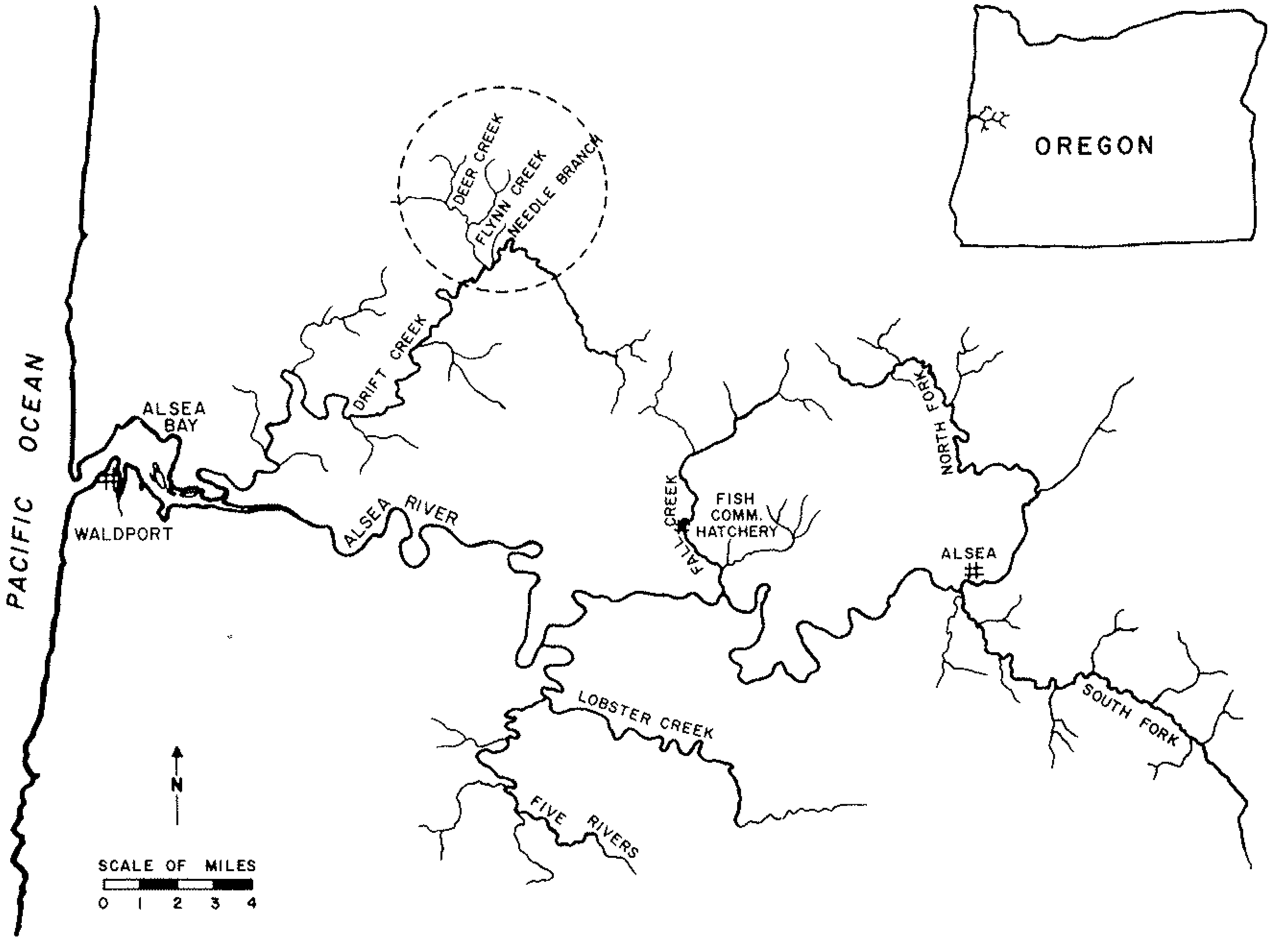
STUDY AREAS

Three headwater tributaries of the Alsea River were selected for study. The Deer Creek, Flynn Creek and Needle Branch watersheds are located in a portion of Lincoln County, approximately 16 km (10 miles) south of Toledo, Oregon (Figure 1). All three streams eventually flow into Drift Creek, and ultimately into Alsea Bay. Deer Creek is a tributary of Horse Creek. Flynn Creek is the major tributary of Meadow Creek, which then flows into Horse Creek. Horse Creek joins Drift Creek approximately 60 meters from the junction of Needle Branch and Drift Creek (Figure 2). Drift Creek flows southward until entering Alsea Bay approximately 6.4 km (4 miles) east of Waldport.

The three streams have extremely variable flow rates, and are of different sizes. Needle Branch is the smallest stream, followed by Flynn Creek, and then Deer Creek. The three creeks can be considered typical of small western Oregon headwater streams. The principal cause of the variable flow rates is the combined effect of the small sizes of the streams, and the effects of winter freshets, which generally occur from November to February.

The study area is located in the northern Oregon Coast range in a region of heavy rainfall. Mean annual precipitation was reported by Hall and Lantz (1969) as 244 cm (96.1 inches) during the 1959-1965 pre-logging period. Air temperatures ranged from approximately -7 to 32°C (19 to 90°F). Snowfall in the area is relatively light, occurring only two or three times per year, and never remaining on the ground for long periods.

The geology of the region is typical of the northern Oregon Coast range, with the principal underlying component the northern extension of the Tyee sandstone formation. Corliss and Dyrness (1965) have summarized the principal soil and vegetation components of the area, but particular vegetation characteristics of each watershed will be discussed in more detail in the descriptions of individual stream sites. Generally 100-year-old Douglas-fir (*Pseudotsuga menziesii*) was the principal commercial species harvested. The important hardwood in the area was red alder (*Alnus rubra*). Understory vegetation was primarily salmonberry (*Rubus spectabilis*), sword fern *(Polystichum munitum),*



Alsea River system and Drift Creek study area.

FIGURE 1. Location of Alsea Watershed Study in western Oregon.

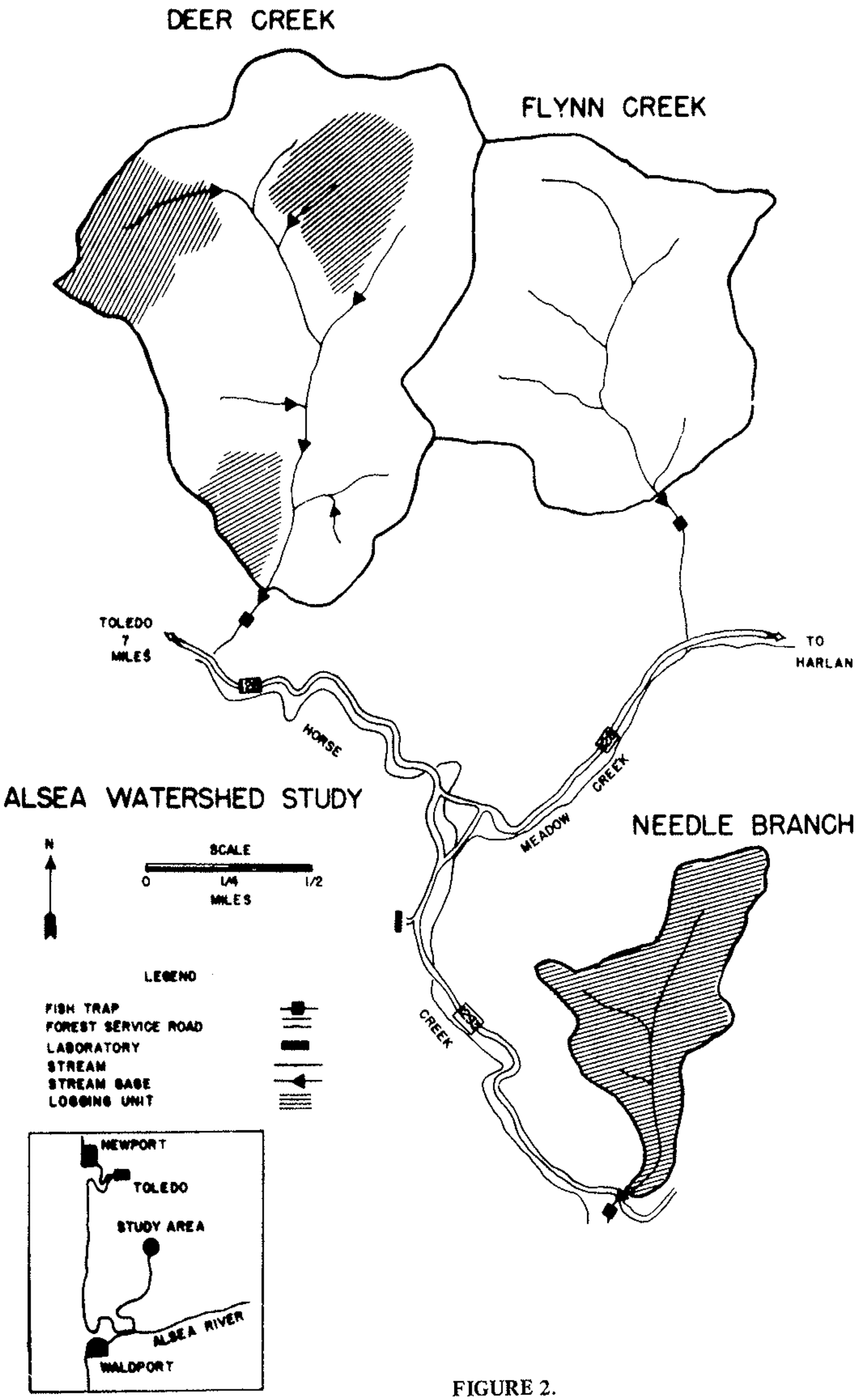


FIGURE 2.
Map of the study watersheds. The approximate lengths of the streams accessible to anadromous salmonids are: Deer Creek – 2324 m. Flynn Creek – 1433 m, Needle Branch – 966 m.

skunk cabbage (*Lysichitum americanum*) and vine maple (*Acer circinatum*).

Four salmonid species were present in one or more of the study streams: coastal cutthroat trout (*Salmo clarki clarki*), steelhead trout (*S. gairdneri gairdneri*), chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*). Steelhead trout and chinook salmon are uncommon and are usually only present in Deer Creek.

Chapman (1961, 1962, 1965), Au (1972) and Lindsay (1975) have described the life history patterns of coho salmon in the three study streams. Generally, adult coho salmon enter the streams to spawn from November through February and the fry emerge February through May. After a year of residence in the creeks, most juvenile coho migrate to sea the following spring. Lowry (1964, 1965,1966) has described the biology of cutthroat trout in the study streams. Sea-run adults follow similar migration timing as adult coho salmon, but juveniles may remain in the streams for several years prior to downstream migration. There is probably a resident population of cutthroat trout in the streams, but the sea-run component dominates. Distinguishing which juveniles or adults in streams may be "residents" is difficult, because some sea-run individuals may remain in the stream for as much as five years before migrating (Richard Giger, personal communication). Others may move to the estuary and no further, thus confusing scale analysis.

Other fish species in the streams were the reticulate sculpin (*Cottus perplexus*), Pacific lamprey (*Entosphenus tridentatus*), and western brook lamprey (*Lampetra richardsoni*). No other fish species were noted during the 1959-1973 study period.

Principal laboratory and housing facilities for the project were at the laboratory located along Horse Creek (Figure 2). Studies concerning gravel incubation, predation, and the effects of sedimentation, among others, were conducted at this station (see Methods sections in Parts I and II). The field location of the laboratory provided easy access to the biological and physical components of the study streams.

FLYNN CREEK

The Flynn Creek watershed (approximately 202 ha) was not logged, and served as a control for the study. Stream length is approximately 1,433 m, with mean summer width 1.74 m, and mean summer depth 13 cm (Chapman 1961). The stream gradient averages 0.025 m per stream meter.

Stream distance was marked by stakes from the gauging station (0 meters, 0 feet). The fish collection trap was located 305 meters (1,000 feet) downstream from the stream gauge. Between marker 305 meters (1,000 feet) and 549 meters (1,800 feet) there is a steep canyon which restricts the available stream area. Historically, there was little spawning in this steep area of much exposed bedrock. Following scouring in the winter flooding of 1971-72, the remaining gravel largely disappeared, and spawning activity in the canyon effectively ceased. There are four small tributaries to Flynn Creek (Figure 2), evenly spaced along the stream length. The final study marker stake was at 1,006 meters (3,300 feet) upstream. The portion of the stream beyond that point was unstudied.

During the pre-logging period, mean summer streamflow was 4.5 liters per second (0.16 cfs), and peak winter flow reached 3,877 liters per second (137.0 cfs) (Hall and Lantz 1969). Annual mean water temperature was 9.7°C, ranging from a minimum of 2.2 to a maximum of 16.6°C, essentially the same as those recorded on other streams in the pre-logging period. Diurnal temperature range varied from 0.5 to 2.2°C (Hall and Lantz).

The Flynn Creek watershed is owned by the U.S. Forest Service, and the principal species of trees are Douglas-fir and red alder. Douglas-fir were primarily 30 to 50 and 70 to 110-year-old stands. Alder stands were 30 to 70 years old. The understory species were salal (*Gaultheria shallon*), sword fern, vine maple and salmonberry. Isolated groups of bracken fern (*Pteridium aquilinum*) were also present.

DEER CREEK

The Deer Creek watershed is the largest of the three study areas, covering approximately 304 ha. The stream length is approximately 2,324 m, with an average summer width of 1.80 m, and an average summer depth of 11 cm (Chapman 1961). Stream gradient averages 0.018 meters per stream meter.

The fish trap was located 152 meters (500 feet) below the gauge station (or a stream location of -152 meters). A steep canyon is present from the 152 meter stream marker to approximately the 427 meter (1,400-foot) location. From 427 meters to 1,219 meters (4,000 feet), the stream is quite slow moving and meandering. The major tributary of Deer Creek was East Fork, entering at the 1,433 meter (4,700-foot) marker. Two smaller tributaries entered the main stream below the East Fork junction, and two smaller tributaries entered above East Fork. The final study marker stake was at 2,195 meters (7,200 feet) upstream from the gauge station.

Mean summer minimum streamflow in the pre-logging period was 8.5 liters per second (0.30 cfs). Peak winter flow was 5,688 liters per second (201 cfs). Annual mean water temperature in the pre-logging period was 9.6°C, ranging from a minimum of 1.1 to a maximum of 16.1°C. The diurnal range was 0.5 to 2.2°C (Hall and Lantz 1969).

Most of the watershed is owned by the U.S. Forest Service, with a small section near the mouth owned by the Georgia-Pacific Corporation, and the principal logged species of timber was Douglas -fir. Fir stands were primarily 50 to 70 and 70 to 110 years old. A few trees younger than 20 years were present in one small area. Red alder were primarily 40 to 60 years old. A few 20 to 40-year-old alder were present in the lower clearcut section. The understory was almost entirely salmonberry, vine maple and sword fern. Salal and bracken fern were present in a few isolated locations.

Locations of the three patches clearcut are shown in Figure 2. The lower section was along the west side of the stream at the effective lowest portion of the watershed. A buffer strip was left along the creek. The northern clearcut was on the hillside between the East Fork drainage and the main creek drainage. Buffer strips were left along all branches of the stream. The third area was at the extreme northwestern section of the watershed. Clearcutting occurred on both sides of the main branch in a section located immediately above the study area.

NEEDLE BRANCH

The Needle Branch watershed is the smallest of the study areas, only 75 ha in size. The stream length studied is approximately 966 m. The stream gradient is 0.014 meters per stream meter. Mean summer width is 1.10 m, and mean summer depth is 7 cm (Chapman). The fish trap was located approximately 61 meters (200 feet) below the stream gauge. The two distinctive features along the stream are small waterfalls at approximately 808 meters (2,650 feet) and 869 meters (2,850 feet). Two small tributary streams enter Needle Branch above the second falls. Beyond approximately 1,067 meters (3,500 feet), flow is greatly reduced, and isolated pools are present to the headwaters. The 792 meter (2,600-foot) marker was the final study area stake, but population estimates and other surveys were conducted above this point after 1966.

Mean summer minimum streamflow was 0.6 liters per second (0.02 cfs). The peak winter flow was 1,415 liters per second (50.0 cfs). The annual mean water temperature of 9.7°C before logging was similar to that on the other study streams. Water temperatures ranged from a minumum of 1.6 to a maximum of 16.1°C. The diurnal temperature range was 0.5 to 1.5°C prior to logging (Hall and Lantz 1969).

Part of the lower section of Needle Branch watershed was privately owned by Mr. Fred Williamson. The remainder was owned by Georgia-Pacific Corporation. Several timber species were present, including Douglas-fir, western red cedar (*Thuja plicata*), and red alder. Douglas-fir stands were all 70 to 110 years old, while cedar stands were 30 to 50 years old. A small stand of 30-50 year old Oregon white oak (*Quercus garryana*) was also present. The age of a small patch of alder was in excess of 100 years. The understory was primarily vine maple and sword fern, although salal, bracken fern, salmonberry, thimbleberry (*Rubus paraviflorus*) and dewberry (*R. vitifolius*) were also present. The vegetation of the lower and central portions of the watershed was similar to that on Deer and Flynn creeks, but the understory at the head of the stream consisted primarily of shrubs, herbs and various grasses.

The entire watershed was clearcut and later slash burned. No buffer strip was left along the streambed. No effort was made to protect the stream from logging activity, except to eventually clear debris from the channel.

DISCUSSION

THE WATERSHEDS DURING AND AFTER LOGGING

With the discussions in Parts I, II, and III of logging and its effects on aquatic life and habitat in the study streams, it is appropriate that the changes in Needle Branch and Deer Creek be shown pictorially. Road construction occurred in Deer Creek and Needle Branch from May to October 1965, but actual cutting did not begin until March 1966. The Georgia-Pacific Corporation, Stokes Lumber Company, and Timber Access Industries felled trees during late spring and early summer, 1966 (Figure 3, 4, 5, 6). Felling created considerable debris in Needle Branch (Figures 7, 8). Fish mortalities (coho salmon, cutthroat trout, reticulate sculpin) occurred in this period.

Debris was hand-cleared from Needle Branch in August 1966 (Figure 9), while the buffer strips left along Deer Creek protected the stream from most damage during the logging operation (Figure 10). The Needle Branch watershed and two units of the Deer Creek cutting were slash burned before November 1966 (Figure 11). The last Deer Creek unit was burned in the spring of 1967. Cutthroat trout and juvenile coho were killed during flash heating by slash fires in the canyon area (Figure 12).

In December and January 1967, there was a signficant increase in streamflow in Needle Branch over average flows for pre-logging years, and sedimentation increased during winter freshets (Figure 13). By the spring of 1967, Needle Branch was, visually, the most altered from pre-logging conditions (Figure 14, 15, 16).

In subsequent years, riparian vegetation (alder, salmonberry, vine maple) slowly returned to Needle Branch (Figure 17), helping to reduce the temperature extremes in summer months. Logging roads, however, continued to be a problem in post-logging years, particularly in Deer Creek (Figure 18). These road slumps and slides were a continuing source of sediment.

SYNOPSIS OF PRINCIPAL RESULTS

Changes in water temperatures

We have shown that water temperatures in Deer Creek were not significantly changed as a result of logging. The specific pre-logging temperature pattern was different in Flynn and Deer creeks, but the post-logging patterns were not altered from pre-logging conditions.

On Needle Branch, however, there was a pronounced change in water temperature maxima and ranges. Both aspects increased immediately after cutting, and increased further after debris clearance and slash burning, when solar radiation was maximized. Minimum temperatures remained essentially unchanged in post-logging years, but it took over 8 years after logging for temperature maxima and ranges to return to pre-logging values. The eventual return to normal values was due primarily to the return of noncommercial, riparian vegetation. This vegetative growth is more rapid in areas of the Coast Range than in the Oregon Cascades.

Water temperature increase was an important contributing feature in changes in other environmental and biological components of the stream. The increase in water temperature was partially responsible for the decrease in dissolved oxygen levels in the surface and intragravel environment. The rapid increase in water temperature during and after logging was probably the one factor most responsible for stressing and changing fish populations in Needle Branch. The fact that there was no such increase in temperature in the buffered Deer Creek system, and no such changes in dissolved oxygen and fish populations, lends credibility to this explanation that biological conditions were affected initially by changes in water temperature.

Lantz and Moring (1975 MS) have indicated a change in behavioral patterns of coho salmon and cutthroat trout in Needle Branch, as opposed to fish in a stream with nonelevated temperatures. Behavioral changes are a reflection of changes in environment and/or metabolism, and are important indicators of alterations in physical parameters. From a biological point of view, control of abnormal temperature changes would appear to be a principal concern in any regulations dealing with timber harvest in headwater areas.

Increases in streamflow

The 26.9 percent average annual increase in streamflow in Needle Branch following logging supports previous evidence that clearcut logging will generally result in increased streamflow (Reinhart et al. 1963; Rowe 1963; Rothacher 1965; Meehan et al. 1969; Berndt and Swank 1970). We have shown that this excess is generally expelled from the system during high winter flows. Principal months of excess streamflow in the study areas were December and January. Streamflow affects the timing of upstream migrations of adult salmonids, and we have shown the peak coho runs in this area also occur in December and January. One would anticipate that variations in streamflow at this time might affect the timing of runs of adult coho salmon. Au (1972) found this was the case, but the movement and numbers of fish depend more on the number of periods of streamflow increase than on the total volume in a given area. The timing of stream flow periods was unchanged, only the volume.

Logging and the gravel environment

The intragravel environment was significantly changed by logging activities. The entire zone was altered directly and indirectly by changes in physical components. Sediment in Deer Creek and Needle Branch increased significantly following road construction. Sediment entering the gravel (fines less than 3.327 mm) was slightly greater in post-logging years, but the lack of sufficient pre-logging samples reduces the power of comparison. There was, however, some indication of an increase in gravel fines in post-logging years because permeabilities in Needle Branch decreased after logging. Within the gravel itself, there was also a distinct drop in winter dissolved oxygen after logging on Needle Branch. As a result of intragravel changes, developing eggs in the gravel after logging were exposed to reductions in intragravel dissolved oxygen concentrations, decreases in intragravel water velocity, and, apparently, some alteration in the gravel composition.

Despite these changes, we cannot statistically detect differences (from field data) in pre- and post-logging emergent survival percentages for coho salmon, sizes of emergent fry, or timing of incubation and emergence. The only indication that changes might occur comes from field correlation studies by Koski (1966) and laboratory studies by Phillips et al. (1975). In both cases, results indicate that increases in gravel fines will generally result in lower coho salmon emergence survival. Our field results imply that any increases in gravel fines were not sufficient to decrease the overall emergent survival of coho salmon.

Changes in surface dissolved oxygen

We have shown that surface dissolved oxygen levels were significantly reduced in Needle Branch during summer 1966, the time of logging. The increased water temperature in Needle Branch, by itself, partly decreased the oxygen solubility of the water. The primary cause of this decrease in surface dissolved oxygen was the logging debris remaining in the stream during summer 1966.

There were natural mortalities in Needle Branch in these critical dissolved oxygen periods. This was further demonstrated by live-box experiments with juvenile coho salmon. Coho died in less than 40 minutes (Figure 19), due directly to lethal levels of dissolved oxygen in many areas of the stream. Hall and Lantz (1969) showed surface dissolved oxygen levels in Needle Branch subsequently increased due to debris clearance. Levels returned to normal after winter freshets cleared the stream of excess logging debris, and acted as instruments of oxygen exchange and replenishment. However, numbers of smolts were not significantly changed the following year. We cannot say how much mortality in fishes was due to dissolved oxygen, and how much was natural.

Changes in fish populations

All fish species in Needle Branch were affected in some manner. For coho salmon, the results were short-term. Those juveniles in the stream at the time of logging were apparently stressed by the rise in water temperatures and the decline in surface dissolved oxygen concentrations. They were smaller in size than juveniles in previous or subsequent years. When these fish returned as adults, they were still smaller in size, indicating this initial freshwater growth component was not compensated by saltwater growth. In addition, downstream migration patterns for juvenile coho were altered for several years after the 1967 season (the time of maximum water temperatures).

FIGURE 3.
Downed timber on the lower portion of Needle Branch watershed, July 1966. Photo at approximately stream marker 244 m (800 ft), looking downstream.

FIGURE 4.
Needle Branch watershed at approximately 610 m (2000 ft), showing cut timber on west side, July 1966.

FIGURE 5.
Cutting on lower end of Deer Creek watershed, July 1966. The fish trap is located in the center of the photo.

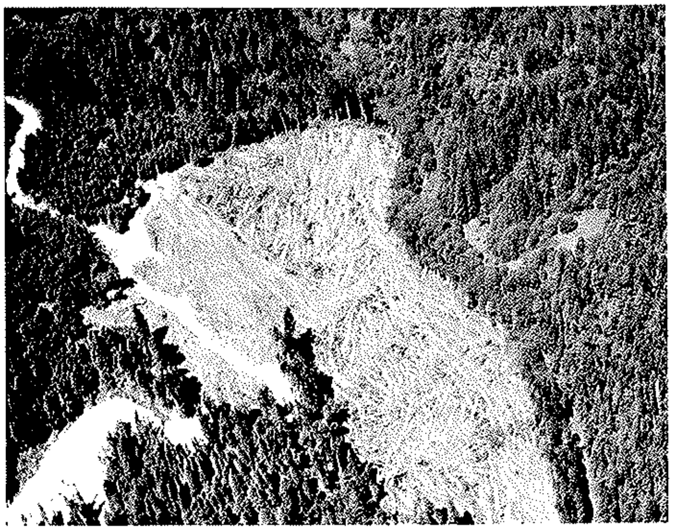


FIGURE 6.
A clearcut block on Deer Creek, with the buffer strip protecting the stream shown along the right side of the clearcut.

FIGURE 7.
Downed timber, slash, and debris in Needle Branch after felling.

FIGURE 8.
Logging debris in Needle Branch helped reduce flow and create critically low levels of dissolved oxygen.

FIGURE 9.
Debris was hand cleared from Needle Branch during August 1966.

FIGURE 10. Buffer Strip along Deer Creek.

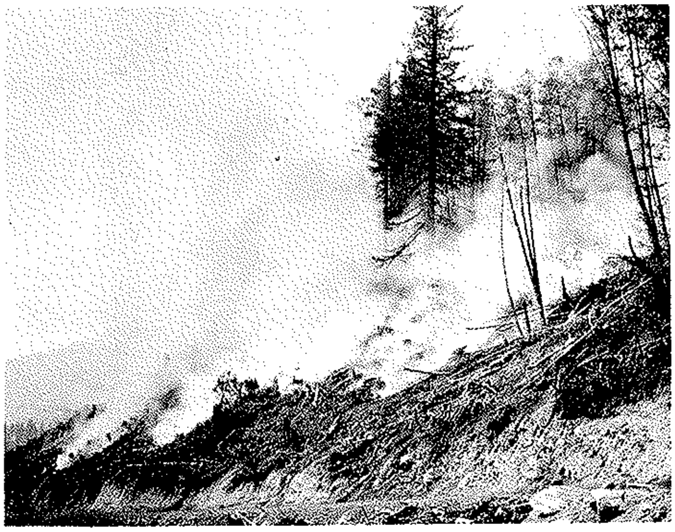


FIGURE 11. Slash burning in the Deer Creek watershed.

FIGURE 12.
Dead cutthroat trout and juvenile coho salmon in Needle Branch. These fish were killed during 1966 from flash heating by slash fires.

FIGURE 13. Erosion and siltation along one of the skid roads by lower Needle Branch, during a freshet in January 1967.

FIGURE 14.
The lower and central portion of Needle Branch watershed following clearcutting and slash burning.

FIGURE 15. The upper falls of Needle Branch following cutting and burning, February 1967.

FIGURE 16. Looking upstream from the 427 m (1400 ft) marker on Needle Branch, April 1967.

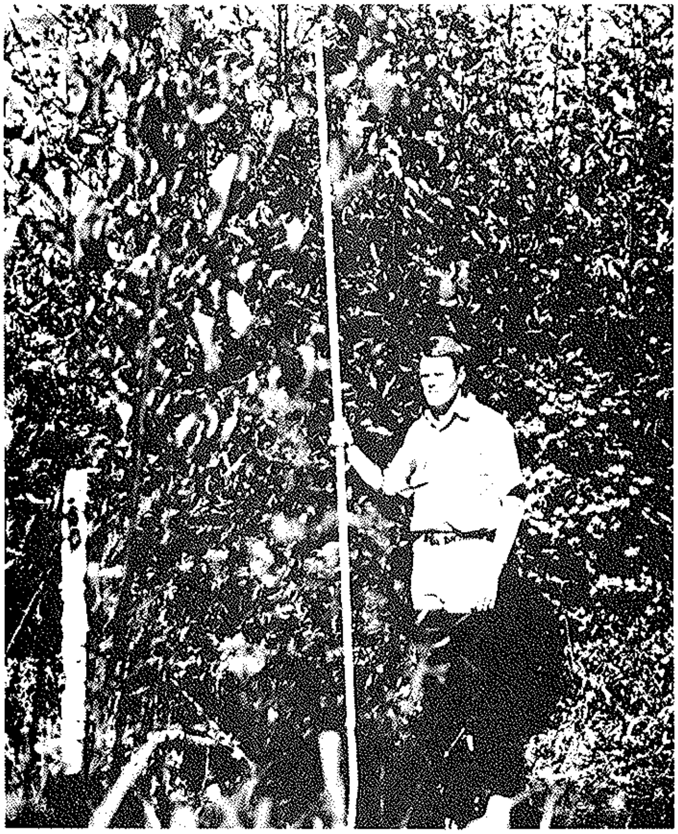
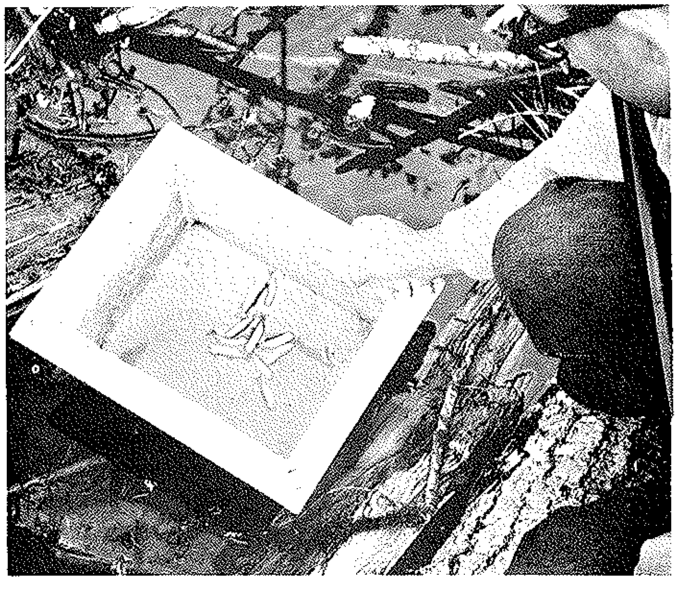


FIGURE 17.
Alder returned to the banks of Needle Branch, attaining a height of 4.6 m (15 ft) in some sections by 1969 (shown here). However, it was not until 1973 that riparian vegetation was sufficient to reduce water temperatures to near pre-logging levels.

FIGURE 18. Road slumps and slides from a logging road in the Deer Creek watershed.

FIGURE 19.
Juvenile coho salmon in a live box in Needle Branch, July 1966. Fish were killed by critically low surface dissolved oxygen levels in the stream during the summer of 1966.



Numbers of lampreys were reduced in post-logging years, but the biological or ecological significance of this change is unknown. The Needle Branch reticulate sculpin population, however, was definitely altered by logging. The population was directly affected by cutting, debris in streams, and slash burning. Krohn (1968) theorized eggs of reticulate sculpin hatched during periods of unfavorable environmental conditions. As a result, the two youngest year classes largely disappeared during the summer of logging, 1966. The population remained altered for an unknown number of years following logging. Unfortunately, Krohn ended his study shortly into the post-logging period. It is believed, on the basis of trap records, that sculpin numbers were returning to pre-logging levels by 1973.

The cutthroat trout population was significantly altered in Needle Branch, and the effects were long-term. We believe the initial decline in the population was due to environmental shock: a rapid increase in summer water temperatures, with critically high water temperatures during many days of the first few years, and critical levels of intragravel and surface dissolved oxygen. We know the cutthroat were responding to these thermal changes because downstream migrations of cutthroat (as well as coho) occurred earlier in the two years following temperature maxima; probably a reflection of migration triggered by water temperatures. These preferred water temperatures, or increases in water temperatures, occurred earlier during this period.

Water temperatures began to return to normal values over the post-logging years, and the low dissolved oxygen levels returned to normal, but the cutthroat trout population in Needle Branch remained depressed. Other factors held the population in check. One of two things may have occurred after logging: (1) a combination of changes in the biological and physical components of the stream may be working together to keep cutthroat trout populations depressed, or (2) habitat suitable for cutthroat trout may be more confined in post-logging years, and the carrying capacity of the stream for cutthroat may be lower. We have some inferences that both changes may have occurred, but we have no definitive evidence for either. After debris clearance in Needle Branch, cover for cutthroat trout and other fishes was reduced, but how much this affected cutthroat populations, even in later years when riparian vegetation returned, is unknown. We theorize that the sudden environmental changes coupled with a sudden reduction in suitable cover combined to alter cutthroat populations in the early post-logging years.

RECOMMENDATIONS

BUFFER STRIPS

The preservation of buffer strips is essential for the prevention of direct physical changes and indirect biological changes in the stream environment. We have shown in this study that buffer strips along Deer Creek prevented significant alterations of the physical and biological components that occurred in the stream without buffer strips, Needle Branch.

Buffer strips were shown in this study to be important in temperature control, reduction of excess gravel scouring, and disruption of stream habitat. The most significant feature of buffer strips is their function as "policemen" against logging near streambanks. Without their presence, it would be much easier for damage, intentional or otherwise, to occur. Buffer strips need not be a specified width, nor do they need to include commercial timber. This timber can be removed from the buffer strip zone if felling and yarding is away from the stream. Brazier and Brown (1973) found 90 percent of the maximum shading ability of buffer strips (including those along Deer Creek) was found within a buffer width of 55 feet (from each bank). From a biological point of view, the important criteria in the design of a buffer strip are the amounts of solar radiation reaching the stream and the maintenance of stream and streambank integrity.

ROAD DESIGN, CONSTRUCTION, AND MAINTENANCE

Roads should be designed and constructed so as to minimize their function as a source of excess sediment and mass transport of material in subsequent years. We have shown in this study that sedimentation increased in Deer Creek and Needle Branch, and that a principal source of this sediment increase (particularly in Deer Creek) was logging roads. Brown and Krygier (1971) documented the excess sediment loads from roads in the Deer Creek and Needle Branch watersheds.

Where possible, roads should be designed to utilize natural benches and saddles. Roads and sidecast material should be as far from the stream as possible, to minimize sedimentation. Whenever possible, unstable soil areas should be avoided. Roads constructed in these areas might continue to be a source of sedimentation in later years. At stream crossings, it is important to make sure the stream will not be blocked, either in construction or after the road is abandoned. Culverts at these crossings must take into account the fish species present, and their ability to move into and through culverts. Many states are now issuing guidelines for use of culverts, and these specifications should be followed.

We have shown in this study that maximum streamflow, before and after cutting, occurs in winter months, particularly during freshets. Avoid winter road building, as the chances of sediment entering streams are maximized at this time. Koski (1966) and Phillips et al. (1975) have shown that excess sediment fines in gravel will reduce emergent survival for coho salmon and steelhead trout. An increase in sediment from winter road building can only have detrimental effects on eggs which are developing in the gravel at that time.

FELLING

Whenever possible, no felling should occur into or across the stream itself, or on to the immediate bank. We have photographic evidence of Douglas-fir felled atop known coho salmon redds, with developing eggs in the gravel. Felling into streams results in excess slash and debris remaining in the stream, and the eventual yarding of downed timber from the stream. In addition, felling into streams has been shown in related studies (Moring and Lantz 1974) to partially destroy the protective functions of a buffer strip or any riparian vegetation.

YARDING

No logs should be yarded across or through streams. Such activity increases debris in streams, destroys riparian vegetation, scours gravel, breaks down stream integrity, disrupts or excavates developing salmonid eggs in the gravel and increases sedimentation to downstream areas. Whenever possible, downed logs should be yarded away from the stream by uphill high-lead yarding or use of ballons or helicopters. It is important to realize that any yarding in the proximity of a small stream can destroy vegetation, expose soil, and become a continuing source of sediment during winter freshets. The stream should never be used as a highway for yarding logs. From a biological viewpoint, the long-term damage can be extensive.

DEBRIS CLEARANCE AND THE VALUE OF COVER

Excess logging debris should be removed from a stream as soon as possible after felling; even if a buffer strip is present and debris is not extensive. We have documented in this study that debris remaining in Needle Branch after clearcutting created critically low surface and intragravel dissolved oxygen concentrations. Fish died because of lack of sufficient dissolved oxygen. It was shown quite dramatically that once the debris was cleared from Needle Branch, the surface dissolved oxygen levels returned to normal. Intragravel dissolved oxygen was much slower to respond to debris clearance and winter freshets, so debris should definitely not remain in the stream over winter, when salmonid eggs in the gravel rely on adequate levels of dissolved oxygen for growth and development.

Excess debris in the stream from logging operations creates an artificial situation. We have shown that this is detrimental. However, clearance of all debris creates another artificial situation, one where some natural cover is removed. Lewis (1969) found that cover and current velocity were the two most important factors influencing rainbow and brown trout populations in streams. Cederholm et al. (1975) have indicated that indiscriminate debris removal can result in changes in pool-riffle ratios and excessive stream erosion in winter freshets. Apparently, the presence of natural amounts of debris is useful in preserving stream stability. Therefore, during debris clearance, some material should be left in the stream for these cover and stream stability functions.

CONSULTATION WITH AGENCIES CONCERNED WITH FISH RESOURCES

It should become a matter of policy, when headwater streams may be affected in a potential cutting, to consult with the State fisheries agency and/or their district biologists. The potential damage to stream habitat and fish populations has been well documented in Parts I and II of the Alsea Watershed Study report. When these important spawning and rearing areas may be exposed to any type of logging operations, the State fisheries agency, with management responsibilities, should have input into logging plans.

ACKNOWLEDGEMENTS

Many individuals connected with the Alsea Watershed Study have already been identified in Parts I and II. I am particularly grateful to Messrs. Richard Lantz and Bruce Pohl for background assistance. Thanks are also due the following for reviewing the manuscript: Dr. Harry Wagner and Mr. Homer Campbell of the Oregon Department of Fish and Wildlife, Research Section, and Dr. James Hall of Oregon State University.

LITERATURE CITED

Anonymous. 1966 Effects of log driving on the salmon and trout populations in the Stellako River. Inter. Pac. Salmon Fish. Comm., Prog. Rept. 14. 88 p.

Au, D. W. K. 1972. Population dynamics of the coho salmon and its response to logging in three coastal streams. Ph.D. Dissertation, Oregon St. Univ., Corvallis. 245 p.

Bachman, R. W. 1958. The ecology of four northern Idaho trout streams with reference to the influence of forest road construction. M.S. Thesis, Univ. of Idaho, Moscow. 97 p.

Berndt, H. W. and G. W. Swank. 1970. Forest land use and streamflow in central Oregon. USDA Forest Serv., Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-93. 15p.

Brazier, J. R. and G. W. Brown. 1973. Buffer strips for stream temperature control. Forest Res. Lab., Oregon St. Univ., Res. Paper 15. 9 p.

Brown, G. W. and J. T. Krygier. 1967. Changing water temperatures in small mountain streams. J. Soil and Water Conserv. 22(6):242-244.

__________ and __________ 1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resources Res. 7(5):1189-1198.

__________, G. W. Swank and J. Rothacher. 1971. Water temperature in the Steamboat drainage. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-119. 17 p.

Buchanan, D. V., P. S. Tate and J. R. Moring. 1976. Acute toxicities of spruce and hemlock bark extracts to some estuarine organisms in southeastern Alaska. J. Fish. Res. Bd. Canada. 33:in press.

Burns, J. W. 1970. Spawning bed sedimentation studies in northern California streams. Calif. Fish and Game 56(4):253-270.

__________ 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish and Game 57(1):44-57.

__________ 1972. Some effects of logging and associated road construction on northern California streams. Trans. Amer. Fish. Soc. 101(1):1-17.

Cederholm, C. J. and L. C. Lestelle. 1974. Observations on the effects of landslide siltation on salmon and trout resources of the Clearwater River, Jefferson County, Washington, 1972-73. Fish. Res. Inst., Univ. of Wash., Final Rept., Part 1, to Wash. St. Dept. Nat. Res. FRI-UW-7404. 133 p.

__________, __________, B. G. Edie, D. J. Martin, J. V. Tagart and E. O. Salo. 1975. Effects of logging on the fishery resources of the Clearwater River System. In: D. D. Beall (ed.), 1974 Research in Fisheries, Univ. of Wash., Col. of Fisheries, Contrib. No. 415:26-28.

Chapman, D. W. 1961. Factors determining production of coho salmon, *Oncorhynchus kisutch*, in three Oregon streams. Ph.D. Dissertation, Oregon St. Univ., Corvallis. 214 p.

__________ 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Canada 19(6):1047-1080.

__________ 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Amer. Fish. Soc. 94(1):40-52.

Cordone, A. J. and S. Pennoyer. 1960. Notes on silt pollution in the Truckee River drainage, Nevada and Placer counties. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 60-14. 25 p.

Corliss, J. F. and C. T. Dyrness. 1965. A detailed soil-vegetation survey of the Alsea area in the Oregon Coast Range. In: C. T. Youngberg (ed.), Forest-soil relationships in North America. Oregon St. Univ. Press, Corvallis:457-483.

Edington, J. R. 1969. The impact of logging on the ecology of two trout streams in north Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 73 p.

Elliott, S. T. and R. D. Reed. 1973. A study of land use activities and their relationship to the sport fish resources in Alaska. Job D-I-A: Establishment of guidelines for protection of the sport fish resources during logging operations. Alaska Dept. Fish and Game, Ann. Prog. Rept., Project F-9-5. 11 p.

Ellis, R. J. 1973. Preliminary biological survey of log-rafting and dumping areas in southeastern Alaska. Mar. Fish. Rev. 35(5-6):19-22.

Fiksdal, A. J. 1974. A landslide survey of the Stequaleho Creek Watershed. Supplement to: Cederholm, C. J. and L. C. Lestelle. 1974. Observations on the effects of landslide siltation on salmon and trout resources of the Clearwater River, Jefferson County, Washington, 1972-73. Fish Res. Inst., Univ. of Wash., Final Rept., Part 1, to Wash. St. Dept. Nat. Res., FRI-UW-7404. 8 p.

Fisk, L., E. Gerstung, R. Hansen and J. Thomas. 1966. Stream damage surveys—1966. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 66-10. 9 p.

Hall, J. D. and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. In: T. G. Northcote (ed.), Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, Univ. of British Columbia:355-375.

Hanzel, D. A. 1961. Inventory of the waters of the project area. Northwest Montana Fish. Stud., Montana Fish and Game, Fish. Div., Fed. Aid in Fish Restor. Job Completion Rept., Project F-7-R-10. 9 p.

Kabel, C. S. and E. R. German. 1967. Caspar Creek study completion report. Calif. Dept. Fish and Game, Mar. Res. Branch Admin. Rept. 67-4. 28 p.

Kingsbury. A. P. 1973. Relationships between logging activities and salmon. Alaska Dept. Fish and Game, Com. Fish Res. and Develop. Act. Completion Rep. 5-24-R. 54 p.

Kopperdahl, F. R., J. W. Burns and G. E. Smith. 1971. Water quality of some logged and unlogged California streams. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. 71-12. 19 p.

Koski, K V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon streams. M.S. Thesis, Oregon St. Univ., Corvallis. 84 p.

Krammes, J. S. and D. M. Burns. 1973. Road construction on Caspar Creek watersheds. USDA Forest Service, Pac. SW Forest and Range Exp. Sta., Res. Paper PSW-93. 10 p.

Krohn D. C. 1968. Production of the reticulate sculpin (*Cottus perplexus*) and its predation on salmon fry in three Oregon streams. M.S. Thesis, Oregon St. Univ., Corvallis. 78 p.

Lantz, R. L. and J. R. Moring. 1975 MS. Influence of water temperature changes on the behavior of coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) in small coastal Oregon streams. Oregon Dept. Fish and Wildlife, Res. Section, Unpubl. Manuscript.

Levno, A. and J. Rothacher. 1967. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Note PNW-65. 12 p.

__________ and __________ 1969. Increases in maximum stream temperatures after slash burning in a small experimental watershed. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Res. Note PNW-110. 7 p.

Lewis. S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Amer. Fish. Soc. 98(1):14-19.

Lowry, G. R. 1964a. Net production, movement, and food of cutthroat trout (*Salmo clarki clarki* Richardson) in three Oregon coastal streams. M.S. Thesis, Oregon St. Univ., Corvallis. 72 p.

__________ 1965. Movement of cutthroat trout, *Salmo clarki clarki* (Richardson) in three Oregon coastal streams. Trans. Amer. Fish. Soc. 94(4):334-338.

__________ 1966. Production and food of cutthroat trout in three Oregon coastal streams. J. Wildl. Mgmt. 30(4):754-767.

Meehan, W. R., W. A. Farr, D. M. Bishop and J. H. Patric. 1969. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. USDA Forest Service, Inst. Northern Forestry, Pac. NW Forest and Range Exp. Sta., Res. Paper PNW-82. 45 p.

Moring, J. R. and R. L. Lantz. 1974. Immediate effects of logging on the freshwater environment of salmonids. Oregon Wildl. Comm., Res. Div., Project AFS-58, Final Rept. 101 p.

Narver, D. W. 1971. Carnation Creek Watershed Study. Fish. Res. Bd. Canada, Pac. Biol. Sta., Nanaimo, B.C. 7 p. (Mimeo).

__________ 1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. Fish. Res. Bd. Canada Tech. Rept. 323. 55 p.

Pease, B. C. 1974. Effects of log dumping and rafting on the marine environment of southeast Alaska. USDA Forest Service, Pac. NW Forest and Range Exp. Sta., Gen. Tech. Rept. PNW-22. 68 p.

Phillips, R. W., R. L. Lantz, E. W. Claire and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout. Trans. Amer. Fish. Soc. 104(3): in press.

Platts, W. S. 1974a. Chinook salmon runs, fish standing crop and species composition in South Fork Salmon River, Idaho. U.S. Forest Service, Intermountain Region, Prog. Rept. V. 48 p.

__________ 1974b Geomorphic and aquatic conditions influencing salmonids and stream classification in the Salmon River drainage, Idaho, 1970-1972. Ph.D. Dissertation, Utah St. Univ., Logan. 200 p.

__________ 1974c. Stream channel sediment conditions in the South Fork Salmon River, Idaho. U.S. Forest Service, Intermountain Region, Prog. Rept. IV. 38 p.

Reed, R. D. and S. T. Elliott. 1972. Effects of logging on Dolly Varden. Alaska Dept. Fish and Game, Fed. Aid in Fish Restor., Ann. Prog. Rept., Project F-9-4, Job R-IV-B. 62 p.

Reinhart, K. G., A. R. Eschner, and G. R. Trimble, Jr. 1963. Effect on streamflow of four forest practices in the mountains of West Virginia. USDA Forest Serv., NE For. Exp. Sta., Res. Paper NE-1. 79 p.

Rothacher, J. 1965. Streamflow from small watersheds on the western slope of the Cascade Range of Oregon. Water Resources Res. 1:125-134.

Rowe, P. B. 1963. Streamflow increases after removing woodland-riparian vegetation from a southern California watershed. J. Forestry 61:365-370.

Salo, E. O. 1967. Study of the effects of logging on pink salmon in Alaska. Proc. Soc. Amer. Foresters 1966:59-62.

Servizi, J. A., D. W. Martens and R. W. Gordon. 1970. Effects of decaying bark on incubating salmon eggs. Inter. Pac. Salmon Fish. Comm., Prog. Rept. 24. 28 p.

Sheridan, W. L. and W. J. McNeil. 1968. Some effects of logging on two salmon streams in Alaska. J. Forestry 66:128-133.

__________ and S. T. Olson. 1970. Timber harvest and the salmon and trout fisheries of southeast Alaska. Proc. 50th Ann. Conf. West. Assoc. State Game and Fish Comm., Victoria, B.C.:186-191.

Stefanich, F. 1967. The effects of logging on Pinkham Creek's fish population. Montana Fish and Game, Fed. Aid in Fish Restor., Job Completion Rept., Project F-7-R-6. 10 p.

Tyler, R. W. and D. R. Gibbons. 1973. Observations of the effect of logging on salmon-producing tributaries of the Staney Creek Watershed and the Thorne River Watershed and of logging in the Sitka District. Fish. Res. Inst., Univ. of Wash., Final Rept., Part 1, to Alaska Loggers Assoc. FRI-UW-7307. 58 p.

Wendler, H. O. and G. Deschamps. 1955. Logging dams on coastal Washington streams. Wash. St. Dept. Fish., Fish. Res. Paper 1(3):27-38.

Wustenberg, D. W. 1954. A preliminary survey of the influences of controlled logging on a trout stream in the H. J. Andrews Experimental Forest, Oregon. M.S. Thesis, Oregon St. Col. (University), Corvallis. 51 p.

PUBLICATIONS AND THESES FROM THE ALSEA WATERSHED STUDY

1960-1975

PUBLICATIONS

Brazier, J. R., and G. W. Brown. 1973. Buffer strips for stream temperature control. Research Paper 15. Forest Res. Laboratory, Oregon State Univ. 9 pp.

Brown, G. W. 1969. Predicting temperatures of small streams. Water Resources Res. 5(1):68-75.

Brown, G. W. 1970. Predicting the effect of clearcutting on stream temperature. J. Soil and Water Cons. 25(1):11-13.

Brown, G. W. 1971. Water temperature in small streams as influenced by environmental factors and logging. pp 175-181. In: J. T. Krygier and J. D. Hall (eds.), Forest land uses and stream environment. Oregon State Univ., Corvallis.

Brown, G. W. 1972. Effects of forest management on stream temperature. pp 93-105. In: Proceedings of a symposium on Interdisciplinary Aspects of Watershed Management. August 3-6, 1970. Montana State Univ. and Amer. Soc. Civil Eng.

Brown, G. W. 1972. Logging and water quality in the Pacific Northwest. pp 330-334. In: Proceedings of a symposium on Watersheds in Transition. Colorado State Univ. and Amer. Water Res. Assoc.

Brown, G. W. 1972. The Alsea Watershed Study. Loggers Handbook 32:13-15, 127-130.

Brown, G. W. 1973. The impact of timber harvest on soil and water resources. Ext. Bull. No. 827. Oregon State Univ. 17 pp.

Brown, G. W. 1974. Fish habitat. pp. E1-E15. In: Residues management in the Pacific Northwest. USDA For. Serv., Pac. NW For. and Range Exp. Sta.

Brown, G. W., and J. T. Krygier. 1967. Changing water temperatures in small mountain streams. J. Soil and Water Cons. 22(6):242-244.

Brown, G. W., and J. T. Krygier. 1970. Effects of clearcutting on stream temperature. Water Resources Res. 6(4):1133-1139.

Brown, G. W., and J. T. Krygier. 1971. Clearcut logging and sediment production in the Oregon Coast Range. Water Resources Res. 7(5):1189-1198.

Brown, G. W., A. R. Gahler, and R. B. Marston. 1973. Nutrient losses after clear-cut logging and slash burning in the Oregon Coast Range. Water Resources Res. 9(5):1450-1453.

Campbell, H. J. 1970. Alsea Watershed Study – a progress report. pp 172-181. In: Proc. 50th Ann. Conf., West Assn. State Game and Fish Comm.

Campbell, H. J. 1971. Economic and social significance of upstream aquatic resources on the West Coast. pp 11-19. In: J. T. Krygier and J. D. Hall (eds.), Forest land uses and stream environment. Oregon State Univ., Corvallis.

Chapman, D. W. 1962. Effects of logging upon fish resources of the West Coast. J. Forestry. 60(8):533-537.

Chapman, D. W. 1962. Agressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Canada 19:1047-1080.

Chapman, D. W. 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Amer. Fish. Soc. 94(1):40-52.

Chapman, D. W. 1966. The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. Pymatuning Laboratory Symposia in Ecology. Univ. of Pittsburgh. Spec. Publ. No. 4.: 116-130.

Chapman, D. W., J. F. Corliss, R. W. Phillips, and R. L. Demory. 1961. Alsea Watershed Study - Summary report. Oregon State Univ. Agric. Exp. Sta. Misc. Paper 110. 52 pp.

Chapman, D. W., and R. L. Demory. 1963. Seasonal changes in the food ingested by aquatic insect larvae and nymphs in two Oregon streams. Ecology 44(1):140-146.

Claire, E. W., and R. W. Phillips. 1968. The stonefly *Acroneuria pacifica* as a potential predator on salmonid embryos. Trans. Amer. Fish. Soc. 97:50-52.

Coble, D. W. 1961. Influence of water exchange and dissolved oxygen in redds on survival of steelhead trout embryos. Trans. Amer. Fish. Soc. 90(4):469-474.

Corliss, J. F., and C. T. Dyrness. 1964. Soil and vegetation survey, Alsea area, Oregon. USDA Soil Cons. Serv., in cooperation with Oregon St. Univ., USDI Bur. Land Management, and USDA For. Serv. 730 p.

Corliss, J. F., and C. T. Dyrness. 1965. A detailed soil-vegetation survey of the Alsea area in the Oregon Coast Range. pp 457-483. In: C. T. Youngberg (ed.) Forest-soil relationships in North America. Oregon State Univ. Press, Corvallis.

Hall, J. D. 1968. Effects of logging on fish resources. pp 24-27. In: The Loggers Handbook, Vol. 28. Proc. 58th Pac. Logging Congr.

Hall, J. D. 1970. Timber and fish: collision or coexistence? Oregon's Agr. Progr. 16(3):3, 12.

Hall, J. D., and J. T. Krygier. 1967. Progress Report: Studies on effects of watershed practices on streams. Report to Fed. Water Pol. Contr. Admin. on Res. Grant WP-423. Oregon State Univ., Corvallis. 95 pp.

Hall, J. D., and H. J. Campbell. 1968. The effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. pp 5-37. In: Logging and salmon, the proceedings of a forum. Sponsored by The Amer. Inst. of Fish. Res. Biol., Alaska Dist., Juneau, Alaska, February 8-9.

Hall, J. D., and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams, pp 355-375. In: T. G. Northcote (ed.). H. R. MacMillan Lecture Series, Symposium on salmon and trout in streams. Univ. of British Columbia, Vancouver.

Hall, J. D., and T. G. Scott. 1969. Recreational and esthetic values of wildlife in relation to forest management. pp 22-25. In: H. C. Black (ed.). Wildlife and reforestation in the Pacific Northwest. Oregon State Univ., School of Forestry.

Hansmann, E. W., C. B. Lane, and J. D. Hall. 1971. A direct method of measuring benthic primary production in streams. Limnol. Oceanog. 16:822-826.

Hansmann, E. W., and H. K. Phinney. 1973. Effects of logging on periphyton in coastal streams of Oregon. Ecology 54:194-199.

Harr, R. D., and J. T. Krygier. 1972. Clearcut logging and low flows in Oregon coastal watersheds. Research Note 54., School of Forestry, Oregon State Univ. 3 pp.

Harr, R. D., W. C. Harper, J. T. Krygier, and F. S. Hsieh. 1975. Changes in storm hydrographs after road building and clearcutting in the Oregon Coast Range. Water Resources Res. 11(3):436-444.

Harris, D. D., and R. C. Williams. 1971. Streamflow, sediment transport, and water temperature characteristics of three small watersheds in the Alsea River basin, Oregon. U.S. Geol. Survey Circular 642. 21 pp.

Harris, D. D. 1973. Hydrologic changes after clear-cut logging in a small Oregon coastal watershed. J. Research U. S. Geol. Survey 1(4):487-491.

Iwanaga, P. M., and J. D. Hall. 1973. Effects of logging on growth of juvenile coho salmon. Report EPA-R3-73-006 Ecol. Res. Ser. U.S. Environ. Prot. Agency. 35 pp.

Krygier, J. T., and J. D. Hall (eds.). 1971. Forest land uses and stream environment. Proceedings of a symposium, October 1970. Oregon State Univ. Continuing Education Publ. 252 pp.

Lantz, R. L. 1967. An ecological study of the effects of logging on salmonids. Proc. 47th Ann. Conf., Western Assn. of State Game and Fish Comm., Honolulu, Hawaii. pp 323-335.

Lantz, R. L. 1970. Effects of logging on aquatic resources. pp 13-16. In: H. J. Rayner, H. J. Campbell, and W. C. Lightfoot (eds.). Progress in Game and Sport Fishery Research ... 1964-69. Oregon St. Game Comm., Res. Div., Corvallis.

Lantz, R. L. 1971. Guidelines for stream protection in logging operations. Oregon St. Game Comm., Res. Div. 29 pp.

Lantz, R. L. 1971. Influence of water temperature on fish survival, growth, and behavior. pp 182-193. In: J. T. Krygier and J. D. Hall (eds.). Forest Land Uses and Stream Environment. Oregon State Univ., Corvallis.

Lowry, G. R. 1964. Some ways of increasing the utility of a back-pack fish shocker. Prog. Fish-Cult. 26:127-130.

Lowry, G. R. 1965. Movement of cutthroat trout, *Salmo clarki clarki* (Richardson), in three Oregon coastal streams. Trans. Amer. Fish. Soc. 94:334-338.

Lowry, G. R. 1966. Production and food of cutthroat trout in three Oregon coastal streams. J. Wildl. Manage. 30:754-767.

Marston, R. B., R. M. Tyo, and S. C. Middendorff. 1969. Endrin in water from treated Douglas-fir seed. Pesticides Monitor. J. 2(4):167-171.

Mason, J. C., and J. L. Fessler. 1966. A simple apparatus for the incubation of salmonid embryos at controlled levels of temperature, water flow and dissolved oxygen. Prog. Fish--Cult. 18:171-174.

Moore, D. G., J. D. Hall, and W. L. Hug. 1974. Endrin in forest streams after aerial seeding with endrin-coated Douglas-fir seed. USDA For. Serv. Res. Note PNW-219. Pac. Northwest For. and Range Exp. Stn., Portland, Oregon. 14 pp.

Moring, J. R. 1975. The Alsea Watershed Study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part II – changes in environmental conditions. Oregon Dept. Fish and Wildl., Fish. Res. Rept., No. 9 (part 2): in press.

Moring, J. R. 1975. The Alsea Watershed Study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part III – Discussion and recommendations. Oregon Dept. Fish and Wildl., Fish. Res. Rept. No. 9 (part 3): in press.

Moring, J. R., and R. L. Lantz. 1974. Immediate effects of logging on the freshwater environment of salmonids. Final Report AFS 58. Oregon Wildlife Comm., Portland. 101 pp.

Moring, J. R., and R. L. Lantz. 1975. The Alsea Watershed Study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part I: Biological studies. Oregon Dept. Fish and Wildl., Fish. Res. Rept. No. 9 (part 1): in press.

Oregon State Game Commission. 1963. Annual Report. Div. of Wildl. Res. Portland. pp 105-122.

Phillips, R. W. 1964. The influence of gravel size on survival to emergence of coho salmon and steelhead trout. Proc. of the Fifteenth Northwest Fish Cult. Conf., Oregon State Univ., Corvallis, Oregon.:90.

Phillips, R. W. 1965. Effect of fine materials on salmon and trout redds. pp 59-61. In: Proceedings of Meeting on Erosion and Sedimentation in the Northwest, 1964-65 Flood Season. U. S. Dept. of Agri., Soil Conserv. Service, Portland, Oregon.

Phillips, R. W. 1966. A trap for capturing salmonids emerging from spawning gravel. Prog. Fish-Cult. 28(2):107.

Phillips, R. W., and H. J. Campbell. 1962. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions in gravel beds. Fourteenth Ann. Rept. of the Pac. Mar. Fish. Comm. for the year 1961: pp 60-73.

Phillips, R. W., and E. W. Claire. 1966. Intragravel movement of the reticulate sculpin *(Cottus perplexus)* and its potential as a predator on salmonid eggs. Trans. Amer. Fish. Soc. 95(2):210-212.

Phillips, R. W., H. J. Campbell, W. L. Hug, and E. W. Claire. 1966. A study of the effects of logging on aquatic resources, a progress report, 1960-66. Prog. Memorandum, Fish. No. 3. Oregon St. Game Comm., Res. Div. 28 pp.

Phillips, R. W., and K V. Koski. 1969. A fry trap method for estimating salmonid survival from egg deposition to fry emergence. J. Fish. Res. Bd. Canada 26(1):133-141.

Phillips, R. W., R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout. Trans. Amer. Fish. Soc. 104(3): in press.

Ponce, S. L. 1974. The biochemical oxygen demand of finely divided logging debris in stream water. Water Resources Res. 10:983-988.

Ponce, S. L., and G. W. Brown. 1974. Demand for dissolved oxygen exerted by finely divided logging debris in streams. Forest Res. Lab., Oregon St. Univ., Corvallis. Res. Pap. 19. 10 p.

Ringler, N. H., and J. D. Hall. 1975. Effects of logging on water temperature and dissolved oxygen in spawning beds. Trans. Amer. Fish. Soc. 104:111-121.

Williams, R. C. 1964. Sedimentation in three small forested drainage basins in the Alsea River basin, Oregon. U. S. Geol. Survey. Circ. 490. 16 pp.

THESES

Au, D. W. K. 1972. Population dynamics of the coho salmon and its response to logging in three coastal streams. Ph.D. Thesis, Oregon State Univ. 245 pp (Dept. of Fisheries and Wildlife).

Berry, J. D. 1975. Modeling the impact of logging debris on the dissolved oxygen balance of small mountain streams. M.S. Thesis, Oregon State Univ. 163 pp. (Dept. of Forest Engineering).

Brazier, Jon R. 1973. Controlling water temperatures with buffer strips. M.S. Thesis. Oregon State Univ. 65 pp (Dept. of Forest Engineering).

Brown, George W. 1967. Temperature prediction using energy budget techniques on small mountain streams. Ph.D. Thesis, Oregon State Univ. 120 pp (Dept. of Forest Management).

Chapman, Donald W. 1961. Factors determining production of coho salmon, *Oncorhynchus kisutch*, in three Oregon streams. Ph.D. Thesis, Oregon State Univ. 214 pp (Dept. of Fisheries and Wildlife).

Coble, Daniel W. 1960. The influence of environmental conditions in redds on the survival of salmonid embryos. M.S. Thesis, Oregon State Univ. 37 pp (Dept. of Fisheries and Wildlife).

Demory, Robert L. 1961. Foods of juvenile coho salmon and two insect groups in the coho diet in three tributaries of the Alsea River, Oregon. M.S. Thesis, Oregon State Univ. 68 pp (Dept. of Fisheries and Wildlife).

Garvin, W. F. 1975. The intrusion of logging debris into artificial streambeds. M.S. Thesis, Oregon State Univ. 79 pp. (Dept. of Forest Engineering).

Gilleran, Dennis J. 1968. Rapid calibration of coastal streams to detect effects of road building. M.S. Thesis, Oregon State Univ. 51 pp (Dept. of Forest Management).

Hansmann, Eugene W. 1969. The effects of logging on periphyton communities of coastal streams. Ph.D. Thesis, Oregon State Univ. 120 pp (Dept. of Botany).

Harper, Warren C. 1969. Changes in storm hydrographs due to clearcut logging of coastal watersheds. M.S. Thesis, Oregon State Univ. 116 pp (Dept. of Forest Management).

Holtje, R. K. 1971. Reaeration in small mountain streams. Ph.D. Thesis. Oregon State Univ. (Dept. of Forest Engineering).

Hsieh, F. S. 1970. Storm runoff response from roadbuilding and logging on small watersheds in the Oregon Coast Range. M.S. Thesis, Oregon State Univ. 147 pp (Dept. of Civil Engineering).

Iwanaga, Paul M. 1971. Effects of logging on the growth of juvenile coho salmon. M.S. Thesis, Oregon State Univ. 44 pp (Dept. of Fisheries and Wildlife).

Kelly, Gerald D. 1968. A comparison of several methods for erosion measurement on cut and fill slopes of a logging road in the Oregon Coast Range. M.S. Thesis, Oregon State Univ. 114 pp (Dept. of Forest Management).

Koski, K Victor. 1966. The survival of coho salmon *(Oncorhynchus kisutch)* from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis, Oregon State Univ. 84 pp (Dept. of Fisheries and Wildlife).

Krohn, David C. 1968. Production of the reticulate sculpin *(Cottus perplexus)* and its predation on salmon fry in three Oregon streams. M.S. Thesis, Oregon State Univ. 78 pp (Dept. of Fisheries and Wildlife).

Lane, Charles B. 1965. Metabolism of periphyton communities in two small streams. M.S. Thesis, Oregon State Univ. 57 pp (Dept. of Fisheries and Wildlife).

Lindsay, Robert B. 1975. Distribution and survival of coho salmon fry after emigration from natal streams. M.S. Thesis, Oregon State Univ. 41 pp (Dept. of Fisheries and Wildlife).

Lowry, Gerald R. 1964. Net production, movement, and food of cutthroat trout *(Salmo clarki clarki,* Richardson) in three Oregon coastal streams. M.S. Thesis, Oregon State Univ. 72 pp (Dept. of Fisheries and Wildlife).

Ponce, S. L. 1974. The biochemical demand of Douglas-fir needles and twigs, western hemlock needles, and red alder leaves in stream water. M.S. Thesis, Oregon State Univ. 141 pp (Dept. of Forest Engineering).

Ringler, Neil H. 1970. Effects of logging on the spawning bed environment in two Oregon coastal streams. M.S. Thesis, Oregon State Univ. 96 pp (Dept. of Fisheries and Wildlife).