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EFFECTS OF LOGGING ON PERIPHYTON IN COASTAL STREAMS OF OREGON[1]

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Abstract. Changes in the stream algal flora were observed during a multi-disciplinary logging study of small watersheds in Oregon. Clearcut logging was applied to one watershed of 71 hectares, while a second watershed of 304 ha was patch-cut leaving a buffer-strip of vegetation along the stream channel. A third watershed of 203 ha was not logged but remained as a control. Pre-logging and post-logging oxygen levels, temperature, and sedimentation loads were analyzed. Access roads were built in 1963, and logging completed in 1966.

Analysis of the algal communities of the three watershed streams prior to the logging operation of 1966 indicated that the communities were predominantly a periphyton type composed mainly of diatoms. Immediately following the yarding operation of the clearcut watershed, large quantities of *Sphaerotilus natans* colonized all debris and mud in the stream, and a change in the algal flora appeared to take place. Large mats of green algae were observed colonizing all mud and slash. Results from glass substrates indicate that some changes may have taken place in the diatom community.

INTRODUCTION

The study of all factors affecting the quality of water is particularly important in Oregon. The production of salmonid fish, and therefore the sport and commercial fishing industry of Oregon depends on the water quality of the streams arising in the forested watersheds of the state. These watersheds also provide the logging industry with timber used for paper pulp, plywood and lumber. Logging is usually by clearcut operation for both biological and economic reasons. However, the effects of complete removal of the overstory on the aquatic environment of these watersheds are poorly understood.

The Alsea Watershed Study began in Oregon in 1957. The objective of the study was to compare the effects of two patterns of logging on water quality and biological resources of small coastal streams. The study is scheduled for 15 years, with the first 7 years devoted to a pre-logging study of the watersheds. Logging roads were constructed in 1965, and logging operations were started in 1966. Changes in the logged watersheds including the streams will be followed for 7 years after logging to analyze immediate and long term changes. This Alsea study is broadly interdisciplinary with many cooperators involved. Temperature, stream flow, suspended sediment, dissolved oxygen, and chemical nutrients have been analyzed in each stream. Biological studies have included the analysis of the algal flora of the streams, abundance of aquatic insects, and the productivity of fish populations, primarily coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*).

The objective of this segment of the study was to analyze the short term changes in the stream flora associated with the logging operation. Some data were available on the flora prior to the logging operation in 1966. Algal productivity appears to be extremely low in these heavily shaded streams. The observations of Chapman and Demory (1963) suggested that terrestrial material, insects and leaf litter, is more significant as a basic food source than are the primary producers in the stream. Lane (1965) worked on the same three streams prior to the logging of 1966, and from glass substrate collections, he found that diatoms were the dominant flora of the streams; there was very little filamentous algal growth. Periodic field observations, and samples taken with a No. 20 mesh plankton net from September, 1965, to the logging operations of 1966 corroborated Lane's results.

DESCRIPTION OF STUDY AREA

The 3 streams used in this study, Deer Creek, Needle Branch, and Flynn Creek are a part of the Drift Creek drainage in the Alsea Basin of the Oregon Coast Range, approximately 16 km from the Pacific Ocean at elevations of 140 to 490 meters. The watersheds are steep, with mean slopes between 34 and 40 percent. The climate is maritime with dry summers and heavy precipitation extending from October to March or April. Mean annual precipitation recorded from 1959 to 1965 was 244 cm, ranging from 208 to 292 cm. Snowfall is uncommon and the

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TABLE 1. Summary of the stream flow regimes in the three study streams before logging, 1959 through 1965. Data from U.S. Geological Survey expressed in liters per second

Stream	Daily means	Mean maximum summer flow	Peak winter flow
Deer Creek	183.0	8.5	5688
Flynn Creek	126.0	4.5	3877
Needle Branch	41.6	0.6	1415

TABLE 2. Summary of the temperature regimes (C) in the three study streams before logging, 1959 through 1965. Data from U.S. Geological Survey

Stream	Annual means	Range of monthly range	Minimum temp.	Maximum temp.	Diurnal temp. range
Deer Creek	9.6	6.7–12.8	1.1	16.1	0.5–2.2
Flynn Creek	9.7	7.2–12.8	2.2	16.6	0.5–2.2
Needle Branch	9.7	6.1–12.8	1.6	16.1	0.5–1.5

air temperatures are relatively mild (ranging from −7°C to 32°C.

The streams are composed of riffles and pools that are moderately shaded throughout the year by the overstory, but most extensively in the summer months, when the understory is also in leaf. Depth of the water in the riffles varies with the season, ranging from 2.5–15 cm in the summer to a winter depth of 15–30 cm. The substrate consist of rubble and gravel ranging from a few millimeters to 15 cm or more in diameter. The rock is soft and porous and derived from the Tyee sandstone of the Coast Range. The overstory on the watersheds consists of *Pseudotsuga menziesii* (Mirb.) Franco (Douglas Fir), *Alnus rubra* Bong. (Red Alder), and a few scattered specimens of *Tsuga heterophylla* (Raf.) Sarg. (Western Hemlock). The understory is of *Acer circinatum* Pursh. (Vine Maple), *Rubus spectabilis* Pursh. (Salmon Berry), *Polystichum munitum* (Kaulf.) Presl. (Western Sword-Fern), and *Pteridium aquilinum* (L.) Kuhn. (Bracken Fern).

Stream flow fluctuates with the season (Table 1), and freshets occur periodically during the rainy season which scour large amounts of organic matter from the rock, leaving a scant amount of algae on the rock substrate. Before logging, the temperature regimes of the streams were similar (Table 2).

In March 1966, Needle Branch (71 ha) was clear-cut, Deer Creek (304 ha) was subjected to a staggered pattern of logging (patch-cut) with a buffer strip of vegetation left standing along the stream channel. Flynn Creek watershed (203 ha) was not logged and will remain as a control for the remainder of the study (Fig. 1).

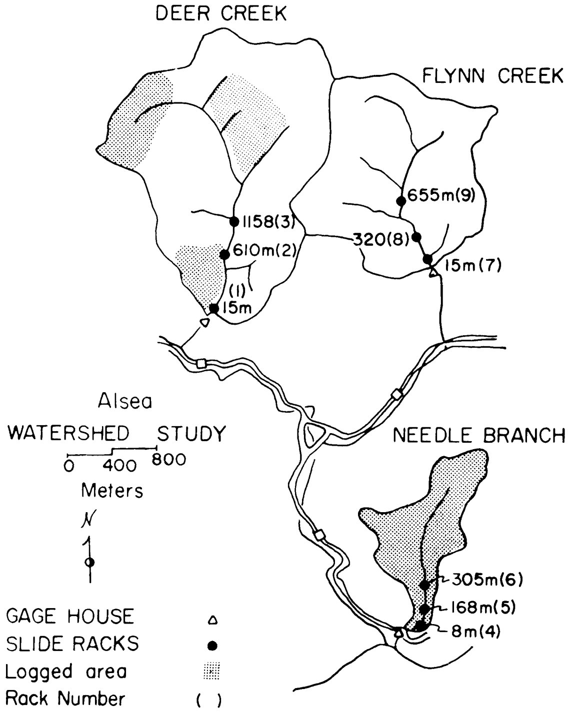

FIG. 1. Diagram of study area. Black dots indicate diatom study areas.

METHODS

At the beginning of sampling of the algal community, it was not known what changes would occur as logging progressed; thus, the major emphasis was placed on sampling the diatom community. Visual observations were made of other changes that took place in the algal community. Three riffle areas in each stream were selected for study of diatom community structure (Fig. 1). The soft porous rock of the riffles made it extremely difficult to sample the natural substrate and identify the individuals on the species level. Thus, glass microscope slides were used as growth substrates. The slides were vertically positioned, edge facing the current, for four-week periods. It was assumed that changes in the diatom community of the riffles would be reflected in changes in the community composition colonizing the glass substrates. This assumption may be questioned as indicated by the recent results of Tippett (1970). In Deer Creek, rack 1 was placed in position in May, racks 2 and 3 were placed in September. In Needle Branch, rack 4 was placed in position in May, racks 5 and 6 in July. Racks 7–9 were placed in Flynn Creek in June and July, 1966. One set (2 slides) was removed from the racks at the time of sampling and immediately replaced by a clean set.

In the laboratory, the organic matter was scraped from the glass slides and washed into a beaker. This mixture was oxidized with nitric acid leaving a residue of diatom frustules. The frustules were washed several times, and randomly distributed in distilled water. Aliquots of the suspensions were made into diatom slides with Hyrax mounting media.

The diatom community was characterized by determining the percent relative abundance of each species in the total number of individuals identified on a randomly selected strip across the 22 mm cover glass. An average of 484 individuals was observed per strip. Although the number of individuals observed was below that recommended by Hohn (1961) and Patrick (1963) for a detailed analysis of the community, the authors felt that the dominant species colonizing the slides were observed.

Periodically, live samples were analyzed from the slides to determine the relationship of diatoms to other algal forms. The percent relative abundance of the other algal forms was determined by the following method. Before the organic material was oxidized, the scrapings were suspended in water from which a wet slide mount was prepared. Proportional counts were made across the wet mount cover slip; all forms other than diatoms were identified to genus and cell counts were made. At the same time, a total count was made of the diatoms present. The proportion of diatoms to other algal forms observed on the wet mount was applied to the total number of diatoms observed on the hyrax slide. From the data obtained, the total observed number of cells (diatoms and other forms) was tabulated and percent relative abundance for each taxon was calculated. In this study, only the dominant taxa are presented. A taxon was considered to be a dominant part of the community if it numbered at least 10% of the individuals counted on the slide. After the logging operations, periodic wet mounts were also made from samples taken from the natural rock substrate to evaluate the physiological state of the diatom community as possibly affected by the change in the aquatic environment. Visual field observations were also made to supplement the observations from the glass substrates.

Results

Needle Branch watershed was clearcut in March 1966; all standing timber and most of the plants of the understory were removed. This operation had a pronounced effect on the aquatic habitat. Timber which fell across the stream formed dams and pools, and reduced the stream velocity. Yarding began in late April, and the dragging of logs across and from the stream added large quantities of soil to the stream bed, completely covering all riffle areas to a depth of several centimeters in many areas. In September, the large slash was removed and stream velocity increased. In October, the watershed was completely burned to remove the remaining debris and prepare the land for seeding, which occurred in the winter.

The patch logging of Deer Creek watershed caused little change in the stream habitat. An occasional log fell in the stream, but was soon removed during the yarding operation. Two landslides associated with road building may pose a threat to the stream in the future. The consequences of these landslides will be evaluated in the long term study.

Stream temperature, dissolved oxygen, and sedimentation loads

Brown and Krygier (1970) observed significant increases in average maximum monthly, and diurnal fluctuation in stream temperature associated with the clearcut logging. Average maximum monthly temperature was 7.8°C higher, while maximum diurnal fluctuation was approximately 14.4°C higher than recorded before logging in 1965. A significant increase in stream temperature was also observed in the upper canyon of the stream during slash burning in October 1966 (Hall and Lantz 1969). The maximum temperature observed in Needle Branch after clearcut logging was 29.4°C in 1967 as compared to 13.8°C previous to clearcut logging in 1965. No significant increase in stream temperature was observed in Deer Creek associated with patch-cut logging or slash burning.

Prior to logging, all stream were approximately saturated with oxygen (10–12 ppm) throughout the year. Hall and Lantz (1969) observed a rapid decline in the oxygen level when the slash was in the stream. The lowest level observed in Needle Branch (clearcut) was 0.6 ppm. The concentration returned to a level similar to that in Flynn Creek (control watershed) in October or November when the slash was removed, and fall rains flushed the stream. The patch-cut logging of Deer Creek produced no significant change in the dissolved oxygen level as compared to Flynn Creek. Increases in the suspended sediment loads have been observed in Needle Branch during the two winters following clearcut logging. Increases have also been observed in Deer Creek, but at a considerably lower concentration.

Biological Results

Visual results

The first visual change in the floral community of Needle Branch associated with clearcut logging was the abundant growth of *Sphaerotilus natans*. This species was the only organism observed, colonizing both the mud and silt and all slash in the stream.

With the decline of *Sphaerotilus natans* in July, a filamentous algae bloom, primarily Chlorophyta, formed a mat over most pool areas, slash, and mud. Samples taken from this mat included the following species:

Chlorophyta:

Chlamydomonas sp.
Draparnaldia glomerata (Vauch.) Ag.
Spirogyra gravilleana (Hass.) Kutz.
Tetraspora sp.

Cyanophyta:

Anabaena affinis Lemm.
Oscillatoria amphibia Gom.

With the removal of the large slash in September and increased stream velocity, the algae decreased in density until most of the living biomass was located in small riffle areas where the silt had been partially removed. That attached to the small debris or clinging to the mud in the pools was highly decomposed.

In October 1966, increased water flow due to periodic rain removed much of the algal mat, silt and mud, exposing large areas of the original riffle area. In November, a major freshet removed all remaining mud and organic material. Neither the filamentous mats nor the slash and mud accumulations were ever observed in Deer (patch-cut) or Flynn Creek (control) watersheds.

Glass slide observations

During the 17 months of sampling with glass substrates (May 1966, to October 1967), 79 species of diatoms were observed. These data are available upon request, and are comparable to that of McIntire (1968). Seven of the species formed the dominant part of the flora, each having a relative abundance of 10% or higher frequently during the study. These samples indicated that changes in the diatom community may have been associated with clearcut logging of Needle Branch (Fig. 2).

Flynn Creek (control watershed) had 3 dominant species in 1966. *Achnanthes lanceolata, Cocconeis placentula* and *Eunotia arcus*. Little monthly variation was observed in the relative abundance, with *A. lanceolata* the most abundant found. In 1967, the community varied slightly from that of 1966, *A. lanceolata* remaining the dominant, but its relative abundance was less than in similar months of 1966. This reduction was associated with an increase in *C. placentula* during the same period.

In 1966, Deer Creek had the same 3 dominants as Flynn Creek. However, they varied seasonally in a well developed periodicity. *A. lanceolata* being dominant in the winter and spring, and *C. placentula* in

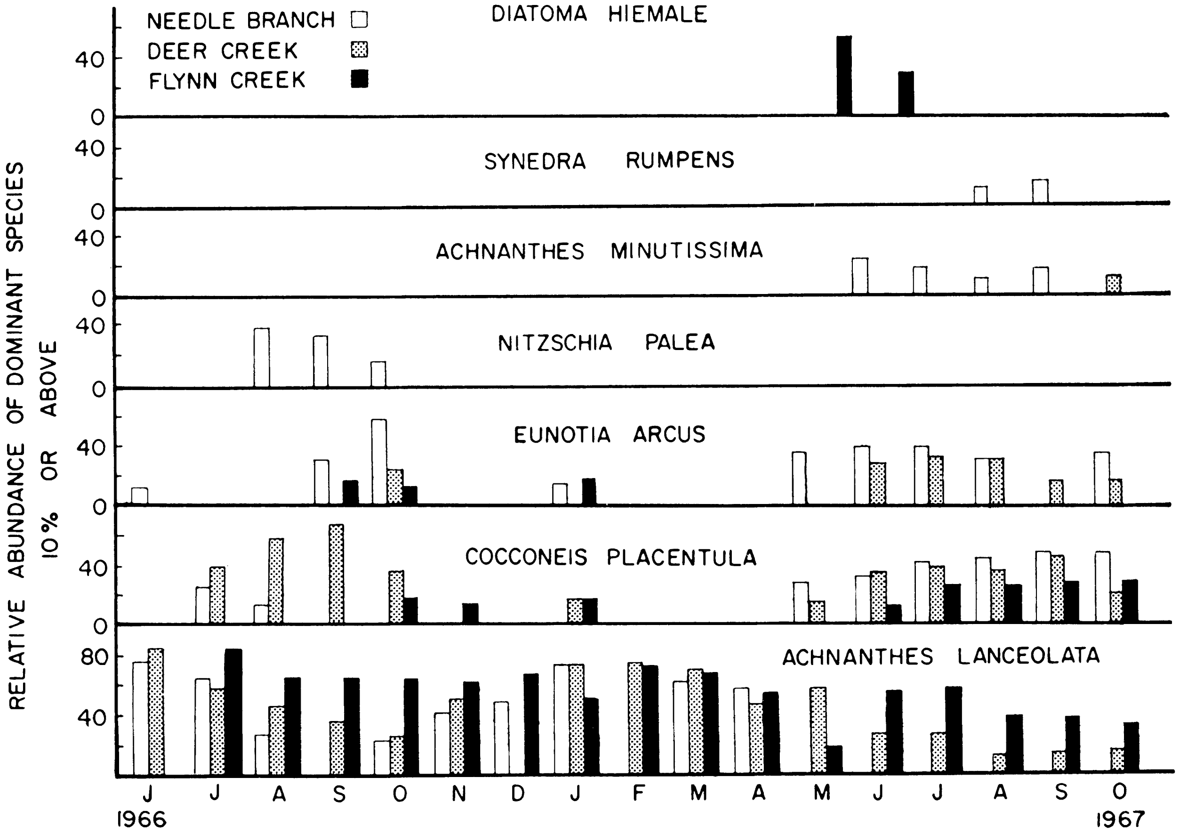

FIG. 2. Relative abundance of dominant species of diatoms observed on glass artificial substrates in Flynn Creek (control), Deer Creek (patch-logged), and Needle Branch (clearcut) watersheds during the logging (1966), and post-logging (1967) years.

the summer and fall months. In 1967, the community was generally similar, although some variation did occur. *A. lanceolata* and *C. placentula* were slightly less abundant than in similar months of 1966; however, the observations of 1966 were taken only from site 1, while those of 1967 are mean observations from site 1 through 3. *Eunotia arcus* was found more extensively in the summer of 1967 than in 1966.

In Needle Branch, 4 species were dominant in 1966. *A. lanceolata* followed a similar, but more extreme pattern to that observed in Deer Creek, decreasing in the summer, and increasing in the fall and winter. In July, *C. placentula* began a pattern similar to that in Deer Creek, but rapidly fell below dominance in September, remaining there for the rest of the year. *Cocconeis* was replaced as a dominant by *Nitzschis palea* in August through October, and *Eunotia arcus* in September and October. *Nitzschia palea* was highly epiphytic on the filaments of the algal mat. In the spring of 1967, Needle Branch was again dominated by *A. lanceolata* as in the other streams. In May this species decreased, and was not a dominant during the remainder of the study, possibly the result of the higher temperatures in the stream during this period. *Cocconeis placentula*, an infrequent member in 1966, was very dominant in the summer of 1967. *Synedra rumpens* and *Achnanthes minutissima* became a dominant part of the flora in 1967. Previously, these two species were rare in all streams. *Nitzschia palea*, associated with the algal mat of the previous year, was uncommon in 1967.

During the summer of 1967, the community in Needle Branch appeared similar to that of the previous year. From visual observations, filamentous algae colonized many of the riffle areas. Data from live samples of glass substrates substantiated these observations, as filamentous algae appeared to constitute a major portion of the community found on the glass substrates (Fig. 3). No live samples were taken

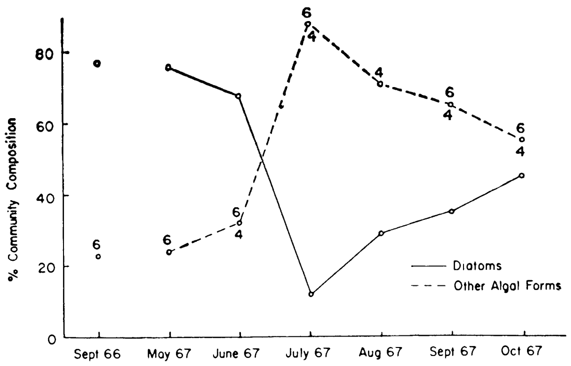

FIG. 3. Mean percent community composition found on glass artificial substrates in Needle Branch (clearcut) watershed. Numbers around points indicate sites sampled.

in the other two streams, although the filamentous algal growth was not present in Deer or Flynn Creeks.

Although more samples would have been desirable, the scrapings taken from the natural rock at six different locations during the early fall indicated that the environment was less optimum than prior to logging, as 34% of the diatoms were living, while 66% appeared to be empty frustules.

CONCLUSION

It is apparent that a close relationship exists between watershed practices and floral characteristics of the drainage stream. It is also apparent from the observations of Deer Creek (patch-cut) that stream characteristics, both biotic and abiotic, can maintain themselves if adequate protection is given to streamside vegetation; thus, the system is maintained and the high quality of water is preserved.

Of the various abiotic changes which took place in the clearcut watershed, several may be conductive to algal blooms and changes in floral characteristics of the aquatic habitat. If clearcut logging remains as a major means of harvesting forested watersheds, it becomes important to ask how the changes in the stream characteristics (biotic and abiotic) are going to affect the various trophic levels, pre-predator relationships, and productivity and economy of the system. This question can only be answered by a much longer and detailed analysis. In our study, the primary producers may play a much different role in the energy dynamics of the logged stream than that noted by Chapman and Demory (1963) for the unlogged stream. The primary productivity of the stream after clearcut logging appeared to be much higher than that of the prelogging period, as evidenced by the large amount of filamentous material present in 1966–67. Although the species composition was quite different, similar algal blooms of *Ulothrix zonata* were observed by Likens et al. (1970) after the removal of the vegetation on the Hubbard Brooks Watershed of the eastern hardwood forest. Their data and the observations made in this study suggest that filamentous algal blooms are common in streams influenced by the removal of the vegetation from the surrounding watershed.

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