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The dynamics and structure of periphyton communities in three Cascade Mountain streams[1]

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With 3 figures and 3 tables in the text

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Introduction

Streams in the Cascade Mountains, Oregon are influenced in varying degrees by the surrounding terrestrial vegetation of the watershed. The plants growing in these streams would seem to make up a community that would be sensitive to the shading influence of the forest through which they flow. Qualitative assessments of the relationship between periphyton growth and shading have been outlined (BLUM 1956; DOUGLAS 1958; HYNES 1970). Few quantitative studies have been concerned with the effects of shading by terrestrial vegetation. WARREN et al. (1960) found increased rates of primary production in sections of a stream from which the canopy had been removed. HANSMANN (1969) found greater rates of primary production of periphyton in coastal streams after logging.

To examine the influence of shading in three different streams in the same drainage, the community structure, seasonal growth pattern, standing crop, and rates of colonization of the periphyton communities were measured for more than a year. All three streams are in the drainage of the H. J. Andrews Experimental Forest with an environment and vegetation typical of much of western Oregon and Washington. Old-growth (450 years) Douglas-fir-western hemlock are dominant with mixed true fir-hemlock forests above 1,000 m. Topography is mature with elevations from 450 to 1,600 m. Bedrock is largely volcanic and soils are reddish brown lateritic or podsolic. A maritime climate with 240 cm precipitation characterizes the environment.

The smallest stream studied, Watershed 10 (WS-10), was the most heavily shaded stream (Tab. 1). This stream is a steep, terraced series of small pools formed by debris dams connected by short falls or riffles over bedrock. WS-10 had nitrate concentrations of approximately 0—50 μg/l and phosphate concentrations of 50—200 μg/l. Mack Creek was the intermediate sized stream (Tab. 1), which had both forested and clearcut sections. The forested section was almost completely covered except for the small opening in the canopy directly over the stream. The clearcut section was only 400 m in length, so that the major physical influence of the open canopy was greater light intensity on the stream. Stream morphology can be described as a series of intermediate pools connected with areas of fast water flowing around houlders. The pools in the forest section were generally formed by debris dams, as opposed to rock terraces in the clearcut section. Mack Creek had nitrate concentrations of approximately 50—105 μg/l and phosphate concentrations of 50—200 μg/l. Lookout Creek, the largest stream studied (Tab. 1), consisted of a series of large, deep pools and long, fast riffles. Nutrient concentrations were similar to those found in Mack Creek.

Tab. 1. Physical characteristics of four study sites in three streams of the Cascade Mountains, Oregon.

Stream	Approximate drainage area (ha)	Mean width of channel (m)	Stream discharge (l/sec) summer min.	winter max.	Approximate stream gradient (%)	Per cent shaded
WS-10	10	0.75	0.2	140	45	99
Mack Creek	650	5	100—140	1,500—1,800	20	Forested 80 Clearcut 15
Lookout	6,000	15	1,800	138,000	10	5

Community structure

Differences in the streams were reflected by different algal growth forms. Rather than using species composition, the predominant genera were selected to describe community structure. Distinct differences in this structure occurred both annually and with differences in the canopy (Tab. 2).

Tab. 2. Community characteristics and patterns of growth of the periphyton communities at four study sites in three streams of the Cascade Mountains, Oregon.

Community type	Characteristic plant	Location	Pattern of Growth J F M A M J J A S O N D
Pennate Diatom	*Achnanthes*	Upper Mack Creek Lower Mack Creek Lookout Creek Watershed 10	
Thallus Green Algae	*Prasiola*	Upper Mack Creek Lower Mack Creek	
Filamentous Green Algae	*Ulothrix* *Zygnema*	Lower Mack Creek Lookout Creek	
Centric Diatom	*Melosira*	Lookout Creek	

The pennate diatom community persisted throughout the year in all four locations. The green algae and centric diatom communities, however, exhibited seasonal patterns. We attribute these patterns to the increasing photoperiod and light intensity during the early spring with subsequent senescence and sloughing of the algae in late summer and fall. Patterns of community structure also corresponded to the degree of shading by streamside vegetation. WS-10 and upper Mack Creek exhibited very little change in algal growth forms. Lower Mack Creek and Lookout Creek were open due to clearcutting in the case of Mack Creek and due to the width of the stream bed in the case of

Lookout Creek. These two sites supported communities of filamentous green algae and the filamentous diatom, *Melosira*.

Each of these community types was assigned a cover class of from 1 to 5, cover class 1 having a mean cover of 2 per cent and cover class 5 having a mean cover of 85 per cent (Oosting 1956). This was done visually with the aid of a m² grid. It is important to note that the pennate diatom community was always assigned a cover class of 5 because it covered virtually 100 per cent of the submerged rocks. However, the communities of green algae were patchy and were generally assigned cover class 1, infrequently cover class 2 or 3. Because the pennate diatom community was present throughout the year in all streams studied, the following experiments were conducted to determine the standing crop and colonization rates of this community type.

Standing crop

Because scraping was ineffective in removing the pennate diatom community from natural rock substrates, an alternative method of utilizing chlorophyll *a*

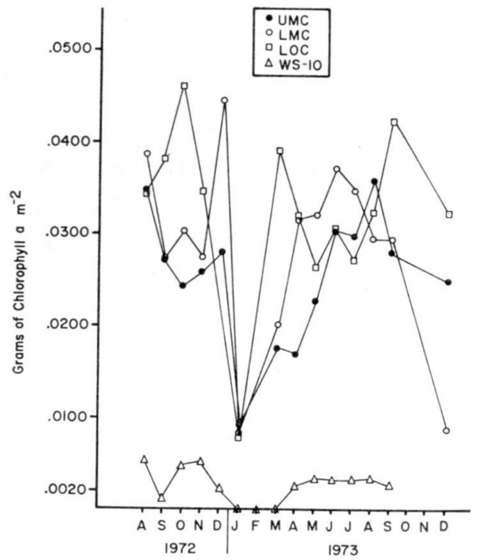

Fig. 1. Chlorophyll *a* per unit area at four study sites in three streams of the Cascade Mountains, Oregon.

as an indirect measurement of biomass was used. Three samples of resident stream rocks, each with a surface area of approximately 100 cm², were collected weekly at each site. The chlorophyll *a* was extracted directly from the rocks and measured using the methods described by Wetzel & Westlake (1969). Except for WS-10, the highly shaded stream, there was little distinction between the stream sites (Fig. 1), in spite of the fact that there were major differences in stream size and amount of shading. One of the major problems in using chlorophyll *a* as an indirect measurement of biomass is the uncertainty of the biomass/chlorophyll ratio for particular communities. Wetzel & Westlake (1969) describe approximate conversions to organic weight by multiplying the amount of chlorophyll *a* by a factor of 60 for high-chlorophyll populations (not limited by nutrients) or 120 for low-chlorophyll populations (nutrient limited). However,

they recognized that such estimates may be between one-third and three times the true value. With such estimates it is not possible to distinguish between particular streams with differing light intensities. Accordingly, we determined the biomass/chlorophyll *a* ratios for each of the streams.

Biomass/chlorophyll ratios

Forty clean cover glasses (Corning No. 1, 22 × 40 mm) were weighed and placed in plastic Petri dishes (50 × 12 mm) which had been perforated so that water could circulate freely within the dish. Ten such units were placed in each

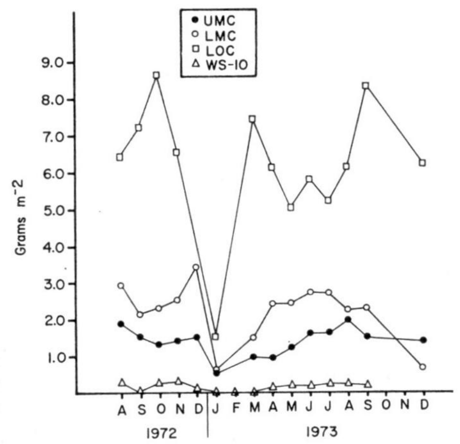

Fig. 2. Standing crop of periphyton (ash-free organic matter) at four study sites in three streams of the Cascade Mountains, Oregon.

stream studied. They were allowed to colonize for 6 weeks and then were collected, dried in a dessicator in the dark and under refrigeration for 20 hours and weighed. Chlorophyll was then extracted and micrograms of chlorophyll *a* were determined by the formula described by Wetzel & Westlake (1969). The biomass was converted to ash-free dry weight by assuming the diatom frustules to be approximately 60 per cent of the total weight. Colonization of the diatom community on the cover glasses in WS-10 was slight, so this estimate is probably not as accurate as that of the other three sites. Estimates of biomass/chlorophyll *a* ratios were 58 for WS-10, 54 for upper Mack Creek, 75 for lower Mack Creek, and 188 for Lookout Creek. When the chlorophyll *a* per unit area is multiplied by the factors above the relationship between standing crop and stream characteristics becomes more evident (Fig. 2). Not only is the largest stream differentiated from the others, but the standing crops of the forested and clearcut sections of the same stream were quite different.

Rates of colonization

From May through September 1973 an experiment was conducted to determine rates of colonization of the pennate diatom community at the four

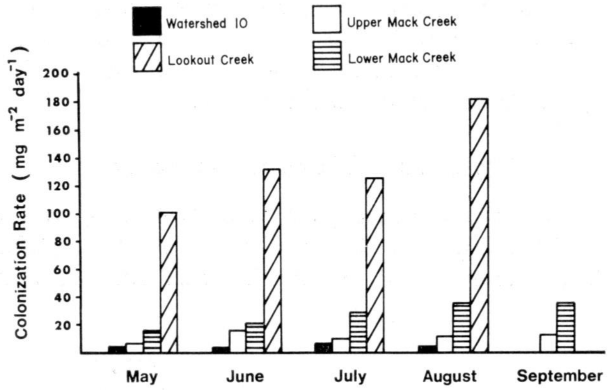

Fig. 3. Rates of colonization of periphyton at four study sites in three streams of the Cascade Mountains, Oregon.

study sites. At each site, cleaned, dry resident rocks were placed in 100 cm^2 wire baskets and allowed to incubate for two weeks. They were then collected and treated for chlorophyll *a* as described above, and replaced with another set of cleaned, dry, resident rocks. The biomass/chlorophyll factors described above were used to convert to ash-free organic weight. Rates of colonization were lowest in WS-10, the small, shaded stream (Fig. 3). In Mack Creek rates of colonization were greater in the clearcut section than the forested area. The highest rates of colonization were found in the largest stream, Lookout Creek.

Discussion

The examination of periphyton communities in three streams in the Cascade Mountains indicated that these communities were strongly influenced by the surrounding terrestrial vegetation. The seasonal change in algal growth forms, standing crop, colonization rates, and biomass to chlorophyll *a* ratios all increased as the streams received more light. The greater differences in light may favor a wider spectrum of algal types that are adapted to particular light intensities. The increase in biomass-chlorophyll *a* ratios with increasing light is consistent with laboratory studies of pigmentation of plants under various light levels. In one of the few studies of the biomass/chlorophyll relationship is periphyton, McIntire & Phinney (1968) found that in laboratory streams shade-adapted plants contained a lower biomass to chlorophyll *a* ratio than light-adapted plants. The increase in standing crop and rates of colonization of algae in the three streams as light increased was expected (Blum 1953). However, the increase in algal growth might be attributed to differences either in nutrient concentration of light intensity. However, the standing crop and rates of colonization were greater in the clearcut section of Mack Creek than in the forested area of the same stream. This indicates that light is the critical factor in determining the growth rates of algae in these streams.

During the time period described in this paper, other investigations were also being conducted at the Mack Creek sites. Studies by Grafius & Anderson (1973, pers. comm.) indicate that total insect emergence was four times greater in the clearcut section than the forested section of Mack Creek (Tab. 3). In addition, the standing crop and emergence of typical grazing insects, such as *Glossosoma*, were greater in the clearcut section, while the standing crop and emergence of typical detritivores, such as *Lepidostoma*, were greater in the forest section. Aho (1973 pers. comm.) found that trout biomass per unit area was greater in the clearcut section of the stream (Tab. 3). While not conclusive, these data suggest that total stream productivity is increased in response to increased light intensity.

Tab. 3. A comparison of biological characteristics of forested and clearcut sections of Mack Creek.

	Algal standing crop (g m^{-2})	Algal colonization rates (mg m^{-2} day^{-1})	Insect emergence (mg m^{-2} day^{-1})	Trout standing crop (g m^{-2})
Forest (UMC)	1.6	11.2	1.5	6
Clearcut (LMC)	2.3	25.8	6.0	12

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Discussion

Elwood: Did you observe any seasonal changes in water quality as a result of dilution-concentration mechanisms which could affect primary production rates?

LYFORD: The only significant change in water quality was the complete lack of nitrate in the summer in the smallest stream. Subsequent field experiments have shown that addition of nitrates at normal light intensities did not increase primary production. Increased light did, however, and nitrates stimulated primary production only after light was sufficient.

GOLDMAN: How did you handle the problem of measuring average light conditions in your study?

LYFORD: We used stationary recording pyroheliometers and made surveys using foot candle meters.