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DIATOM COLONIZATION, COMMUNITY STRUCTURE, AND SUCCESSION ON ARTIFICIAL SUBSTRATES IN FRESH WATER

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DIATOM COLONIZATION, COMMUNITY STRUCTURE, AND SUCCESSION ON ARTIFICIAL SUBSTRATES IN FRESH WATER

by

Kyle D. Hoagland

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DIATOM COLONIZATION, COMMUNITY STRUCTURE, AND SUCCESSION ON ARTIFICIAL SUBSTRATES IN FRESH WATER

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TABLE OF CONTENTS

LIST OF TABLES

SECTION I

SECTION II

Table | Page

LIST OF FIGURES

SECTION II

SECTION I

COLONIZATION AND COMMUNITY STRUCTURE OF TWO PERIPHYTON ASSEMBLAGES, WITH MAJOR EMPHASIS ON THE DIATOMS

SECTION I

Introduction

In a provocative and timely essay, Allen (1977) drew attention to the microscopic algae as a most appropriate biological group for examining general ecological hypotheses, since they likely represent one of the smallest and simplest model systems available to ecologists. Recently, Connell (1978) noted that "with long-lived organisms such as trees or corals, gradual changes in climate over several hundred years represent the same scale as seasons do to a phytoplankton community." Indeed, Jassby and Goldman (1974) suggest that an appropriate time interval (between events) during a successional sequence would be 0.1-1 wk for plankton, versus 0.1-1 yr for forests. With algal systems, this temporal difference permits more rapid gathering of data and greater opportunity for experimental manipulation.

The present study focuses upon the diatoms, which often constitute the major taxonomic group of attached algae in fresh waters. In part, this approach is an outgrowth of the increasing interest in the structure-function relationships of diatom cell features as evidenced in the current phycological literature (Stephens and Gibson, 1979; Hasle, 1974; Fryxell and Miller, 1978). More important, however, is the general utility of periphyton communities for the study of ecological processes such as succession.

In contrast to studies of marine rocky intertidal macro-algal community structure and succession (Foster, 1975; Emerson and Zedler, 1978; Neill, 1979; Sousa, 1979), freshwater micro-algal attached communities are far less studied. Lengthy descriptive works by Cholnoky (1927), Fritsch (1929), Butcher (1932, 1949) and Godward (1937) established the basis for the later comprehensive studies by Castenholtz (1960), Sládečková (1960), and Hohn and Hellerman (1963). The investigations of McIntire and Phinney (1965), McIntire (1973a, 1978) and Sullivan (1975, 1977, 1978) analyzed attached diatoms from a community aspect. The methods for collecting and observing attached diatoms are, however, essentially unchanged since the first use of glass slides as an artificial substrate (Naumann, 1915). These techniques, scraping, remounting, and counting, offer no information concerning the three-dimensional periphyton community structure or the associated morphological characteristics (e.g., mucilage excretions, cell rosettes) of the organisms. With higher plant succession, this approach is analogous to cutting down a forest, laying it out at random, and attempting to analyze its structure and associations. Such methods afford little information beyond species compositions and abundances.

Recently, scanning electron microscopy (SEM) has revealed spatial relationships of periphytic diatoms (Allanson, 1973; Sieburth et al., 1974; Moss 1977; Perkins and Kaplan, 1978; Paul et al., 1977). Clearly, SEM offers promise in revealing the microcommunity structure both spatially and temporally, yet many SEM studies continue to use

detached material (e.g., scraped or centrifuged). The physical integrity of the microcommunity must be maintained if its structure and associations are to be revealed. Direct observation of critical-point dried or freeze-dried intact material, viewed at magnifications of 500-30,000X and with a variety of specimen tilt angles, is currently the method of choice. When applied to sequential seasonal samples, this treatment allows one to evaluate structural aspects of the micro-ecological community. Since different bodies of water show significant differences in periphyton colonization (Pieczynska and Spodniewska, 1963; Knudson, 1957), two reservoirs were included in this study.

Materials and Methods

Pawnee and Yankee Hill are small shallow eutrophic reservoirs, constructed in 1965 for flood control and recreational use. Located 15 km from Lincoln, Nebraska, and within 13 km of each other, these impoundments often exhibit massive blue-green algal blooms due to their continual mixing and their high nutrient loading received from surrounding agricultural land. Morphometric, physical, and chemical data have been published for these reservoirs (Roemer and Hoagland, 1979; Schwartzkopf and Hergenrader, 1978; Hergenrader, 1980b).

Plexiglas tabs (5 x 10 cm) and standard glass microscope slides were suspended vertically ca 0.8 m below the water surface in each reservoir, from a specially designed buoy system (Fig. 1). Each glass slide (suspended 0.5 m below the Plexiglas tabs) was held with

a plastic clothes pin and fastened to a styrofoam block with a golf tee. This simple design had several advantages: it positioned the slides away from the sampler to avoid uneven shading; rarely failed under turbulence; allowed rapid sample handling with minimal disruption; was very inexpensive and was believed to be non-toxic. The samplers were located in 3 m of water, 5-10 m from shore. The artificial substrates were allowed to incubate in situ from 5-7 wk concurrently in each reservoir from fall 1976-summer 1977. Samples were collected weekly during the fall (Oct. 17-Nov. 14), spring (Mar. 31-Apr. 28), and summer (Jul. 8-Aug.5) periods and biweekly during the winter (Feb. 10-Mar. 24). Samples were collected less frequently and over a longer period of time during the winter since periphyton development was slower in the colder waters. On each sampling date, a single Plexiglas tab and glass slide were removed. A quantitative sample was obtained by scraping a 33 mm^2 area from the Plexiglas tab and fixing in a merthiolate-iodine solution (Weber, 1968). The qualitative sample was collected by placing the slide into a plastic mailing container, while still submerged, and immediately fixing with 2% glutaraldehyde prepared with lake water.

The quantitative samples from Plexiglas tabs were treated with 28% hydrogen peroxide and potassium dichromate to remove organic matter (Van der Werff, 1955). After several dilutions and settlings of cells with distilled water, a measured portion of the concentrate was air dried onto a 22 mm square coverslip and permanently mounted with Hyrax. Diatom valve counts (500, except during periods of low

densities) were made at 1000X with a Zeiss microscope equipped with a planachromat phase objective.

Estimates of diatom cell densities were made from quantitative samples via the equation:

$$\text{cells mm}^{-2} \text{ on Plexiglas surface} = \frac{\text{number of diatom valves counted} \cdot (22\text{ mm})^2 \cdot \text{volume of concentrate}}{2 \cdot \text{area of coverslip counted} \cdot \text{subsample volume} \cdot (33\text{ mm})^2}$$

Quantitative comparisons of diatom communities were made by calculating a similarity index from the equation:

$$SIMI\ (a,b) = \frac{\sum_{i=1}^{s} P_{ai} P_{bi}}{\sqrt{\sum_{i=1}^{s} P_{ai}^2} \sqrt{\sum_{i=1}^{s} P_{bi}^2}}$$

where SIMI is the degree of similarity between communities a and b, in which P_{ai} and P_{bi} are the proportions of individuals represented by the i-th taxon in communities a and b, respectively, and s equals the total number of taxa in the two communities (McIntire and Moore, 1977). SIMI has a minimum value of 0 when the two communities being compared have no taxa in common, and a maximum value of 1 when their species composition and proportions are equal. SIMI indices were calculated by comparing communities from (1) the two reservoirs within each season, (2) the same week in different seasons, and (3) different weeks within each season.

Qualitative periphyton samples were prepared for SEM by cutting each glass slide into several 1 cm^2 pieces. Each piece was dehydrated in a 10% graded acetone series, critical-point dried (CPD) with a Denton DCP-1 apparatus, and coated with ca 30 nm of thermally evaporated gold/palladium using a Denton Vacuum Evaporator DV-515 (Rosowski and Glider, 1977). Recoating by diode sputtering (Technics Inc, Alexandria, Virginia) was often necessary. All samples were examined with a Cambridge S4-10 Stereoscan SEM operated at 20 kV. One glass piece from each sample was scanned before representative colonization and community features were recorded with Kodak commercial film 4127.

Results

Quantitative Analyses

The seasonal occurrences of each diatom in both reservoirs, the total number of taxa in each season, and the percentage of all samples in which a taxon occurred, are listed in Table 1. Ninety-three diatom taxa representing 23 genera were found in the 37 Plexiglas samples from Pawnee and Yankee Hill reservoirs. Of these taxa, 28 occurred only in Pawnee and 24 were restricted to Yankee Hill. Five occurred in every season in both reservoirs: Achnanthes minutissima, Gomphonema parvulum, Navicula salinarum var. intermedia, Nitzschia dissipata, and Stephanodiscus rotula var. minutula. Gomphonema parvulum was the most common, occurring in all but three samples from Pawnee and in every sample from Yankee Hill. The weekly (or biweekly