SPECIES COMPOSITION AND RELATIVE BIOMASS OF ALGAL COMMUNITIES ON LEAF DETRITUS IN A SPRING-FED STREAM

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Nine genera of Chlorophyta, 113 taxa of Chrysophyta (Bacillariophyceae), nine taxa of Cyanophyta, and two genera of Euglenophyta were found to grow on leaf detritus and on glass slides placed in Byrd's Mill Spring Stream (Pontotoc County, Oklahoma). The algal biomass consisted mostly of diatoms, although chlorococcalean algae were prominent in early January and early February 1972 samples. Seventy-six taxa of diatoms new to Oklahoma are reported.

Recent investigations in stream ecology have emphasized the importance that autumn-shed leaves may have in the energetics of the recipient stream community (1, 2). However, no previous studies have attempted to relate decomposition of leaf litter to growth of stream algae. The objectives of this study were (a) to identify the various algal taxa growing together on autumn-shed detritus in a spring-fed limestone stream, and (b) to determine the relative biomass proportions of the algal groups found on leaf detritus surfaces.

MATERIALS AND METHODS

A portion of Byrd's Mill Spring stream approximately 1.8 km below the spring source and 7.2 km west of Fittstown, Pontotoc County, Oklahoma, was selected for the study site. Byrd's Mill Spring is a water source for the city of Ada, and the excess water forms a headwater of a tributary of Mill Creek. The stream may be characterized as oligotrophic, high in carbonates, and free from pollution. Surrounding land is a densely wooded bottomland forest, fenced off from several surrounding pastures.

Three study sites were established within a 100-m radius. Sites 1 and 2 were in regions of fast current (0.25 m/sec) in a 2.5-m-wide raceway of approximately 30 cm depth. Site 3 was 100 m north of site 2 and at the bottom of a 0.6-m-deep pool which was formed by impoundment of the stream by an abandoned beaver dam. No current was observed at site 3.

Sample placement at sites 1 and 2 differed in that samples at site 1 were tied into roots of an ash tree (*Fraxinus americana* L.) extending into the stream so that these samples never touched the stream bottom, whereas site 2 samples were placed on the deepest part of the raceway bottom to reflect benthic raceway conditions. Benthic substrates at site 1 and site 2 were sand along the quieter stream edges, and small pebbles, gravel, and rocks up to 20 cm diameter in the deeper portions of the stream. The benthic substrate at site 3 consisted of silt and decomposed organic debris.

Leaf detritus of sycamore (*Platanus occidentalis* L.), pin oak, (*Quercus palustris* Muench.), winged elm (*Ulmus alata* Michx.), black willow (*Salix nigra* L.), and red mulberry (*Morus rubra* L.) were gathered within a 2-km radius of the study site. Leaves originated from single trees, except that the oak leaves were gathered from two adjacent trees near the spring source. These leaves were judged to have fallen during the week prior to collection, and all leaves were in good condition. Leaves were air-dried and stored in plastic bags until they were placed in the stream.

Plastic-covered aluminum screening with a 0.64-cm mesh was folded into approximately 25 x 30-cm bags and the plastic was removed with acetone. Five leaves, one of each of the selected species, together with a clean Corning-brand glass slide were placed into each bag; the slide and each leaf were isolated from each other by monofilament nylon line sewn around all margins. Edges of the bags were closed and reinforced by stainless steel wire. Eight bags were placed in each of the respective habitats on November 30, 1971. Rocks were

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used to weight the edges of the bags in the site 2 raceway, and monofilament line was used to tie bags to tree roots at site 1. The bags at site 2 were placed directly on the limestone bedrock, while the bags at site 1 were situated approximately 15 cm above the bedrock. Bags at site 3 were placed directly on the substrate; at this site current did not move them from their original position.

One bag was removed from each site beginning on December 19, 1971 and at two-week intervals thereafter until the last sample was taken on March 28, 1973. Bags were removed horizontally from the water, placed in plastic bags for transportation to the laboratory, and sections of the leaves were preserved in formalin-acetic acid fixative. Five acid-cleaned glass beads, 3 mm in diameter, were added to each container and the containers were shaken for one minute. The resulting debris was pipetted into a centrifuge tube, rinsed in tap water, and centrifuged at 3500 rpm. The sample was subdivided; half was used for qualitative and quantitative determination of the diatom species present, and half was used to determine the relative biomass of the various algal divisions present.

One ml of the resultant 3-ml subsample was rinsed in distilled water by centrifugation and spread evenly onto a cleaned, No. 1 thickness, 22 x 40-mm coverslip. The coverslip was air-dried, and the diatomaceous material was cleaned by incineration in a muffle furnace at 550 C for eleven minutes, a modification of the method of Zoto et al. (3). The coverslip was then mounted in Hyrax (i.r. 1.65), or in Carmount (i.r. 1.62, Cargille Corporation, Cedar Grove, New Jersey.) Identification to species was made using a Leitz dialux microscope with an oil immersion lens, and a magnification of 1000x. Most diatom identifications were made according to Patrick and Reimer (4). Hustedt (5) was cited for species of *Cymbella* and *Amphora* and for the Epithemiaceae, Nitzschiaceae, and Surirellaceae. Identification of *Gomphonema* species was made according to Mayer (6). All diatom slides are on deposit in the diatom herbarium of Ohio State University.

A portion of the remaining leaf debris and glass slide scrapings was placed in soil-water culture and incubated at 29 C at 300 ft-c in a 12 hr light - 12 hr dark photoperiod. Cultures were examined periodically for genera of Chlorophyta, Cyanophyta, and Euglenophyta. All cultures were prepared by tyndallizing either Byrd's Mill Spring creek bank soil or University of Oklahoma greenhouse soil with water taken from Byrd's Mill Spring creek. Tyndallization procedures were carried out at 100 C for 1 hr on two successive days in an autoclave, after which no growth of algae or fungi was observed in uninoculated control tubes. Identification to genus followed Smith (7) and Prescott (8), except that the Oscillatoriaceae were identified according to Drouet (9).

TABLE 1. *Arbitrary biomass units assigned to representative algal groups, based upon estimated size of protoplast.*

Taxa	Biomass unit values
Chlorophyta	
Chlamydomonad-sized zoospores	1
Chlorococcum-like	5
Coelastrum-like	10
Filamentous algae	as necessary
Chrysophyta	
Achnanthes lanceolata, A. minutissima, Amphora ovalis var. *pediculus*	1
Navicula tripunctata, Nitzschia palea and like-sized organisms	5
Synedra ulna, Nitzschia sublinearis	10
Cymbella mexicana, Nitzschia sigmoidea, Nitzschia linearis	25
Cyanophyta and Euglenophyta	
Protoplasts estimated relative to appropriately sized Chrysophyta	

In order to indicate relative contributions the algal divisions might make to stream productivity, biomass ratios of Chlorophyta, Chrysophyta, Cyanophyta, and Euglenophyta were determined. Arbitrary biomass units based on the size of the protoplast were assigned for representative taxa (Table 1). Sweep counts of a wet mount of the 3-ml biomass samples were made until more than 500 live biomass units (units with protoplasts) had been counted. Relative biomass percentages of Chlorophyta, Chrysophyta, Cyanophyta and Euglenophyta were determined, and the relative proportions of living and dead Bacillariophyceae in the respective size classes were noted. A comparison of diatom biomass on glass slides with diatom biomass on leaf substrates was also made.

Measurements of stream velocity were made by averaging the time (in seconds)

for a floating marker to move 10 m downstream. Temperature was measured with a mercury thermometer, and pH, dissolved oxygen, total hardness, and other parameters were measured using a Hach DR-EL portable engineer's water laboratory (Hach Chemical Co., Ames, Iowa). Whenever possible, all measurements were taken during collection; however, pH and total hardness were occasionally determined, within 24 hr, at the laboratory.

RESULTS AND DISCUSSION

Current velocities at sites 1 and 2 increased and decreased with stream discharge during and after mid-January and mid-February rains, but did not decrease below a value of 0.2 m/sec. No current was detectable at site 3, although other physical and chemical conditions at site 3 were similar to those of sites 1 and 2.

Water temperature was lowest on December 19, 1971 (13 C) and increased gradually until a high of 18 C was noted on February 29, 1972. Because of the spring source, variations in water temperature were extremely gradual. The stream temperature was not greatly affected by runoff water and/or air temperature.

Dissolved oxygen and turbidity exhibited little change throughout the duration of the study. Dissolved oxygen decreased slightly from 8 to 6 ppm in March, but this change is not considered limiting for the algal communities. Turbidity was found to be essentially nil in all sites throughout the study.

A near neutral pH of 7.1 was recorded in December and early January for all sites; by the middle of January, pH had increased slightly to 8.4 and this level was maintained through the end of March. Total hardness decreased slightly in the December to March period, but always remained above 300 ppm (Table 2). Silica levels of 14 ppm in the fast-water sites and 16 ppm in the still water site were noted in December and early January. Since sand was present on the stream bottom, silica is not thought to be a factor limiting diatom growth. Because phosphate and nitrate were not measurable using Hach techniques on December 20, 1971, or on January 4, 1972, no further measurements of these nutrients were made thereafter.

Using culture methods, preserved material, and burn mounts, 9 genera of Chlorophyta, 113 taxa of Chrysophyta (Bacillariophyceae), 9 taxa of Cyanophyta, and 2 genera of Euglenophyta were found in association with the leaf detritus and glass slides at the various times (Table 3). Complete absence of one organism from a particular habitat was noted in only one or two instances. Seventy-six taxa of diatoms in addition to those reported by Maloney (10) and Leake (11) are reported; these are believed to be new for the state. Variations in composition of the diatom flora were noted, and comments on quantitative dynamics of that community will be published in a later paper.

The flora on all leaves and on the glass slides may be characterized as typical of a winter community in a limestone stream.

TABLE 2. *Physical and chemical parameters of study sites.*

FACTOR	SITE	DEC. 19	JAN. 4	JAN. 17	FEB. 1	FEB. 15	FEB. 29	MAR. 14	MAR. 28
pH	1	7.1	7.1	8.4	8.3	8.3	8.25	8.35	n.a.[a]
	2	7.1	7.1	8.4	8.3	8.3	8.25	8.35	n.a.
	3	7.1	n.a.[a]	8.3	8.2	8.2	8.4	8.3	n.a.
Total hardness (ppm)	1	340	340	330	320	320	310	325	n.a.
	2	340	340	330	320	320	310	325	n.a.
	3	340	340	340	330	330	330	340	n.a.
Water temp. (C)	1	13	17	17	16	17	18	n.a.	17
	2	13	17	16	16	17	18	n.a.	17
	3	13	17	16	16	17	18	n.a.	17
Dissolved oxygen (ppm)	1	8	8	6	8	n.a.	6	6	7
	2	8	8	8.5	8	n.a.	6	6	6
	3	7	7	8	7	n.a.	5.5	6	6

[a] n.a. = data not available

TABLE 3. *Algal species observed on leaf detritus and glass slides. Asterisk denotes new to Oklahoma.*

Chlorophyta
Chlorococcum-like
Closterium sp.
Coelastrum sp.
Dictyosphærium sp.
Gleocystis sp.
Microspora sp.
Oedogonium sp.
Scenedesmus sp.
Stigeoclonium sp.

Chrysophyta (Bacillariophyceae)
**Achnanthes deflexa* Reim.
**Achnanthes exigua* Grun.
**Achnanthes lanceolata* Breb.
**Achnanthes linearis* (W. Smith) Grun.
**Achnanthes minutissima* Kutz.
**Achnanthes pinnata* Hust.
Achnanthes sp.
Amphipleura pellucida Kutz.
Amphora ovalis Kutz.
**Amphora ovalis* var *pediculus* Kutz.
**Anomoeoneis* sp.
**Caloneis bacillum* (Grun.) Cleve.
**Caloneis lewisii* (Schultze) Patr.
**Caloneis ventricosa* var. *truncatula* (Grun.) Meist.
**Camplyodiscus noricus* Ehr.
Cocconeis placentula Ehr.
Cyclotella meneghiniana Kutz.
**Cymatopleura elliptica* (Breb.) W. Smith
**Cymatopleura solea* (Breb.) W. Smith
Cymbella cistula var. *maculata* (Kutz.) V. Heurck
Cymbella mexicana Hust.
**Cymbella naviculiformis* Auerswald
**Cymbella prostrata* (Berk.) Cleve.
Cymbella ventricosa Kutz.
**Diatoma vulgare* Bory
Diploneis elliptica (Kutz.) Cleve.
**Diploneis marginistrata* Hust.
**Diploneis oblongella* (Naeg. *ex* Kutz.) Ross
Diploneis oculata (Breb.) Cleve.
Diploneis puella (Schum) Cleve.
Diploneis sp.
**Epithemia sorex* Kutz.
**Eunotia curvata* Kutz.
Eunotia sp.
**Fragilaria capucina* Desm.
**Fragilaria capucina* var *mesolepta* Rabh.
**Fragilaria leptostauron* (Ehr.) Hust.
Frustulia vulgaris (Thwaites) De T.
**Gomphonema acuminatum* var. *coronata* (Ehr.) W. Smith
**Gomphonema augustatum* Kutz.
Gomphonema constrictum Ehr.
**Gomphonema gracile* var. *lanceolata* (Kutz.) Cleve.
**Gomphonema intricatum* var. *pumila* Grun.
**Gomphonema longiceps* var. *subclavatum* Grun.
**Gomphonema montanum* var. *subclavatum* Grun.
**Gomphonema parvulum* var. *microcops* (Kutz.) Cleve.
Gomphonema sp.
Gyrosigma spencerii (Quek.) Griff. and Henfr.
Hantzschia amphioxys (Ehr.) Grun.
**Melosira varians* C. A. Ag.
**Meridion circulare* (Grev.) Ag.
**Navicula bicephala* Hust.
**Navicula capitata* Ehr.
Navicula cryptocephala Kutz.
Navicula cryptocephala var. *veneta* (Kutz.) Rabh.
**Navicula cuspidata* Kutz.
**Navicula decussis* Ostr.
**Navicula elginensis* (Greg.) Ralfs.
**Navicula exigua* Greg. *ex* Grun.
**Navicula festiva* Krasske
**Navicula lanceolata* (Ag.) Kutz.
**Navicula minima* Grun.
**Navicula mutica* Kutz.
**Navicula pelliculosa* (Breb. *ex.* Kutz) Hilse
**Navicula placentula* var. *placentula* fo. *rostratum* (Ehr.) Kutz.
**Navicula pupula* var. *capitata* Skv and Meyer
**Navicula pupula* var. *rectangularis* (Greg.) Grun.
**Navicula rhyncocephala* Kutz.
Navicula salinarum Grun.
Navicula salinarum var. *intermedia* (Grun.) Cleve.
**Navicula secreta* var. *apiculata* Patr.
**Navicula secura* Patr.
Navicula subfasciculata Patr.
**Navicula subtilissima* Cleve.
**Navicula texana* Patr.
**Navicula tripunctata* (O. F. Mull.) Bory
**Navicula viridula* Kutz.
Navicula spp.
**Neidium binode* (Ehr.) Hust.
Nitzschia acicularis W. Smith
**Nitzschia amphibia* Grun.
**Nitzschia apiculata* (Greg.) Grun.
Nitzschia dissipata (Kutz.) Grun.
**Nitzschia epiphytica* O. Mull.
**Nitzschia fonticola* Grun.
**Nitzschia frustulum* Kutz.
**Nitzschia gracilis* Hantz.
Nitzschia linearis W. Smith
**Nitzschia microcephala* Grun.
**Nitzschia palea* (Kutz.) W. Smith
**Nitzschia paleacea* Grun.
**Nitzschia parvula* Levis
Nitzschia sigmoidea (Ehr.) W. Smith
**Nitzschia sublinearis* Hust.
**Nitzschia tryblionella* var. *victoriae* Grun.
Nitzschia spp.
Pinnularia spp.
Rhoicosphenix curvata (Kutz.) Grun.
**Rhopalodia gibberula* (Ehr.) O. Mull.
**Stauroneis phoenicenteron* (Nitz.) Ehr.
Stauroneis smithii Grun.
Surirella angustata Kutz.
**Surirella linearis* W. Smith
Surirella ovalis Breb.
Surirella ovata Kutz.
**Synedra fasciculata* (Ag.) Kutz.
**Synedra parasitica* (W. Smith) Hust.
**Synedra parasitica* var. *subconstricta* (Grun.) Hust.
Synedra ulna (Nitz.) Ehr.
Synedra sp.

Cyanophyta
Anabaena sp.
Aphanocapsa sp.
Cylindrocystis sp.

Merismopedia sp.
Nostoc sp.
Oscillatoria spp.
Schizothrix sp.
Schizothrix calcicola (Lemm.) Drouet
Spirulina sp.

Euglenophyta
Euglena sp.
Peranema sp.

Patrick and Reimer (4) suggest that *Diploneis puella, Navicula crytocephala* var *veneta, Navicula lanceolata, N. mutica, N. pelliculosa, N. secreta* var *apiculata,* and *N. texana* all prefer "waters of high mineral content." All these organisms, together with *Achnanthes minutissima,* a diatom usually associated with deposits of calcium carbonate (12), formed an important part of the flora at all study sites.

Diatoms formed a larger portion of the algal biomass as the winter progressed. As extreme variations in relative diatom biomass were noted among different substrates, an average relative diatom biomass was computed for all extant leaf detritus at each site, and compared with the biomass of diatoms epiphytic on the glass slides. Diatom biomass on the glass slides (as a percentage of the entire population) remained constant at sites 1 and 2 (Fig. 1 and 2), and increased with one sharp fluctuation at site 3 (Fig. 3).

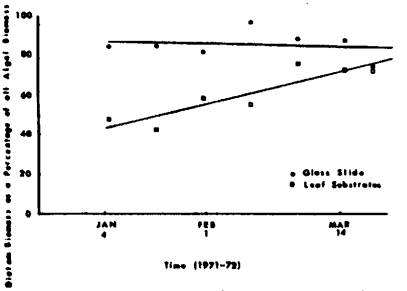

FIGURE 1. Relationship between sample time and diatom biomass as a percentage of all algal biomass at Site 1.

Initially high diatom biomass on leaf litter declined sharply in January and February, with a corresponding increase in the amount of green chlorococcalean algae present. The presence of the large amount of chlorococcalean algae was also observed in the field at sites 2 and 3 on January

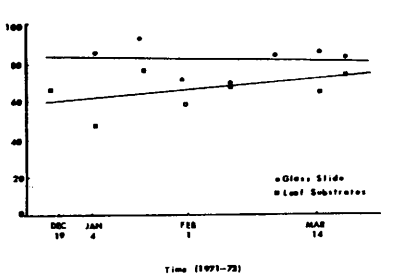

FIGURE 2. Relationship between sample time and diatom biomass as a percentage of all algal biomass at Site 2.

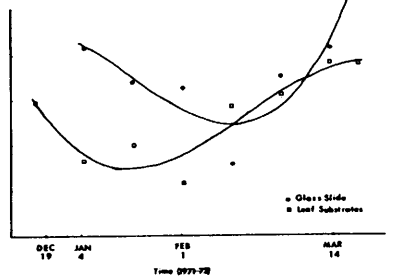

FIGURE 3. Relationship between sample time and diatom biomass as a percentage of all algal biomass at Site 3.

4 and February 1, 1972. Some difficulty was experienced in distinguishing between chlorococcalean algae and spores of a phycomycete fungus in site 3 material, and relatively high amounts of chlorococcalean algae (and correspondingly relatively low amounts of diatom) biomass might have been recorded. In most cases, biomass values for blue-green algae and Euglenophyta were insignificant.

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