Federal Water Pollution Control Administration
Division of Water Quality Research
Analytical Quality Control Laboratory
Cincinnati, Ohio

CLEAN WATER

USE OF A FLOATING PERIPHYTON SAMPLER FOR WATER POLLUTION SURVEILLANCE

Reprint
February 1970

U.S. DEPARTMENT OF THE INTERIOR

USE OF A FLOATING PERIPHYTON SAMPLER FOR WATER POLLUTION SURVEILLANCE

by

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and

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Reprint

February 1970

Preface

This report was first published on September, 1966 as Applications and Development Report No. 20 of the Water Pollution Surveillance System. The laboratory that operated the Water Pollution Surveillance System was subsequently transferred to the Office of Research and Development, and was renamed the Analytical Quality Control Laboratory.

At the time this report was written, Ronald Raschke was an aquatic biologist in the plankton laboratory. He later received his doctorate from Iowa State University, Ames, and is now on the staff of the Botany Department, Rutgers University, New Brunswick, New Jersey.

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Use of a Floating Periphyton Sampler for Water Pollution Surveillance

Abstract

A floating sampler was used to collect periphyton in the Ohio River at Cincinnati. The rate of colonization of glass slides by diatoms was determined, and the periphyton and plankton diatom communities were compared. The density of live diatom cells on the slides reached 15,000 per mm^2 in approximately 30 days. The periphyton diatoms were dominated by species of Nitzschia and Navicula, whereas the plankton diatoms consisted largely of species of Melosira and Cyclotella. Dry weights of scrapings from slides exposed 14 days ranged from 149.5 mg per slide (32.5 cm^2) in July 1965, to 2.7 mg per slide in December 1965. Ash-free weights averaged 16.2% of the dry weight.

Glass slides were exposed in the floating sampler above and below a group of polluted outfalls on the upper Klamath River, Oregon. Gomphonema parvulum and Nitzschia palea were the most abundant diatoms in samples taken in the vicinity of the pollution sources; whereas Cocconeis placentula was dominant above the outfalls, and in the oligosaprobic zone downstream.

Introduction

Exploratory periphyton studies were initiated by the Water Pollution Surveillance System of the U. S. Public Health Service in the Fall of 1964 to augment phytoplankton data collected from a nation-wide system of approximately 135 stations.

Many aquatic biologists (Fjerdinstad, 1964; Hynes, 1963; Nowak, 1940) have recognized that a satisfactory interpretation of phytoplankton data obtained for pollution studies from widely separated river stations is rarely achieved. Attempts to relate the quality and quantity of algae in grab water samples to known or suspected types of pollution are usually confounded by an ignorance of the origin and physiological condition of the organisms. In contrast, the presence of significant quantities of attached algae on natural or artificial substrates is strong evidence of the suitability of the water for the growth of the organisms collected at a station. Inferences regarding water quality can be formulated with greater confidence therefore, if they are based on the composition and density of the periphyton. Periphyton communities have long been used by European biologists to characterize pollution (Kolkwitz and Marsson, 1908; Butcher, 1946, 1947, 1949, 1955; Fjerdinstad, 1950, 1964; Sladeckova, 1962; Sladeckova and Sladecek, 1963). Interest in the periphyton developed later in this country (Blum, 1957; Hohn, 1959; Patrick, 1953, 1957). Except for the work of Neel (1953), the periphyton has received little attention in Federal pollution studies in the United States.

Methods and Equipment

The sampler consists of a styrofoam float approximately 12 X 12 X 2 in., supporting a central plexiglass cradle holding 1- X 3-in. glass microscope slides (Figure 1). The construction materials are commercially available and cost approximately $2.50. The slides are held with their long axes parallel to, and their short axes perpendicular to, the water surface.

Slides were removed from the sampler after exposures of 1, 4, 7, 15, and 32 days. The periphyton was scraped from the slides with a razor blade, and counts were made to determine number of cells per mm^2 of slide area (Weber, 1966). Live and dead diatom cells were identified to genus on millipore filter preparations examined at 1000X. Species determinations were made from permanent (Hyrax) mounts of incinerated diatom materials.

Samples used to determine dry and ash-free weights consisted of material from four replicate slides, each treated as a separate sub-sample. These slides were allowed to air dry in the field. The material was further dried at 50°C in the laboratory and stored in sealed containers until used. When processed, the slides were wetted with distilled water, scraped, and the scrapings dried 24 hours at 105°C and fired for 1 hour at 500°C.

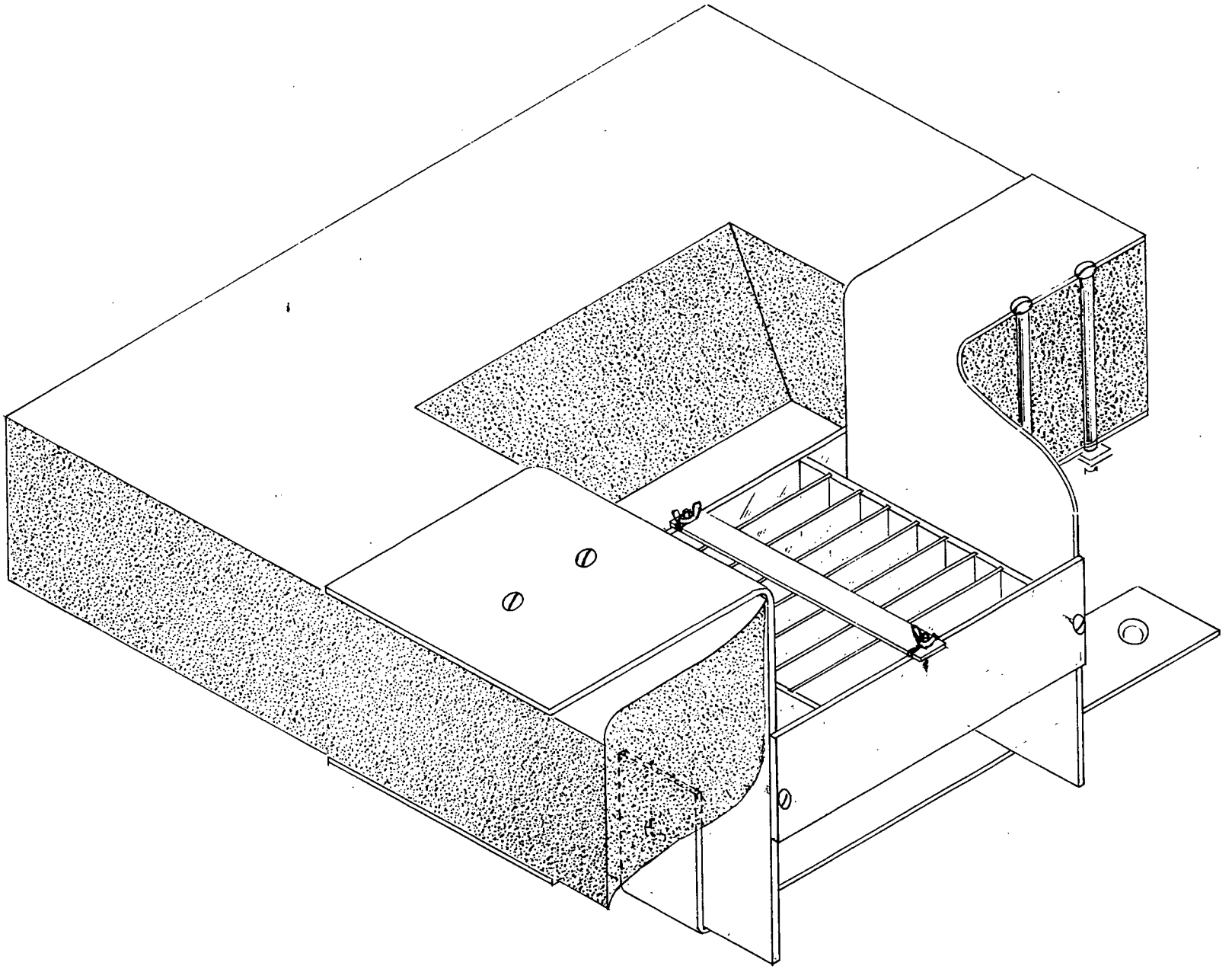

Figure 1. The periphyton sampler.

Rate of Colonization

Following a brief initial lag period, the density of live diatom cells on the slides increased exponentially, reaching approximately 15,000 per mm^2 in 32 days (Figure 2). This rapid rate of increase indicated that the colonization resulted primarily from the division of cells which had become attached to the slides during the first few days of exposure (during the lag period). Diatom counts in the plankton taken near the sampler remained relatively constant during the study period. Had the colonization of the slides resulted principally from the gradual deposition of drifting cells, a linear rise in density would have been observed.

Judging from the decline in the growth rate during the latter part of the exposure period, it was assumed that the population was largely established within 15 days, and had leveled off at approximately 15,000 per mm^2 (32 days). This is similar to the cell density that Butcher (1946) found on glass slides exposed 30 days in eutrophic (oligosaprobic) waters.

It was decided, on the basis of the cell density data, to tentatively adopt a two-week exposure period for the collection of periphyton samples at Water Pollution Surveillance System stations. This period would be long enough to permit the development of a populous periphyton community, yet brief enough to reflect short-term changes in the water quality.

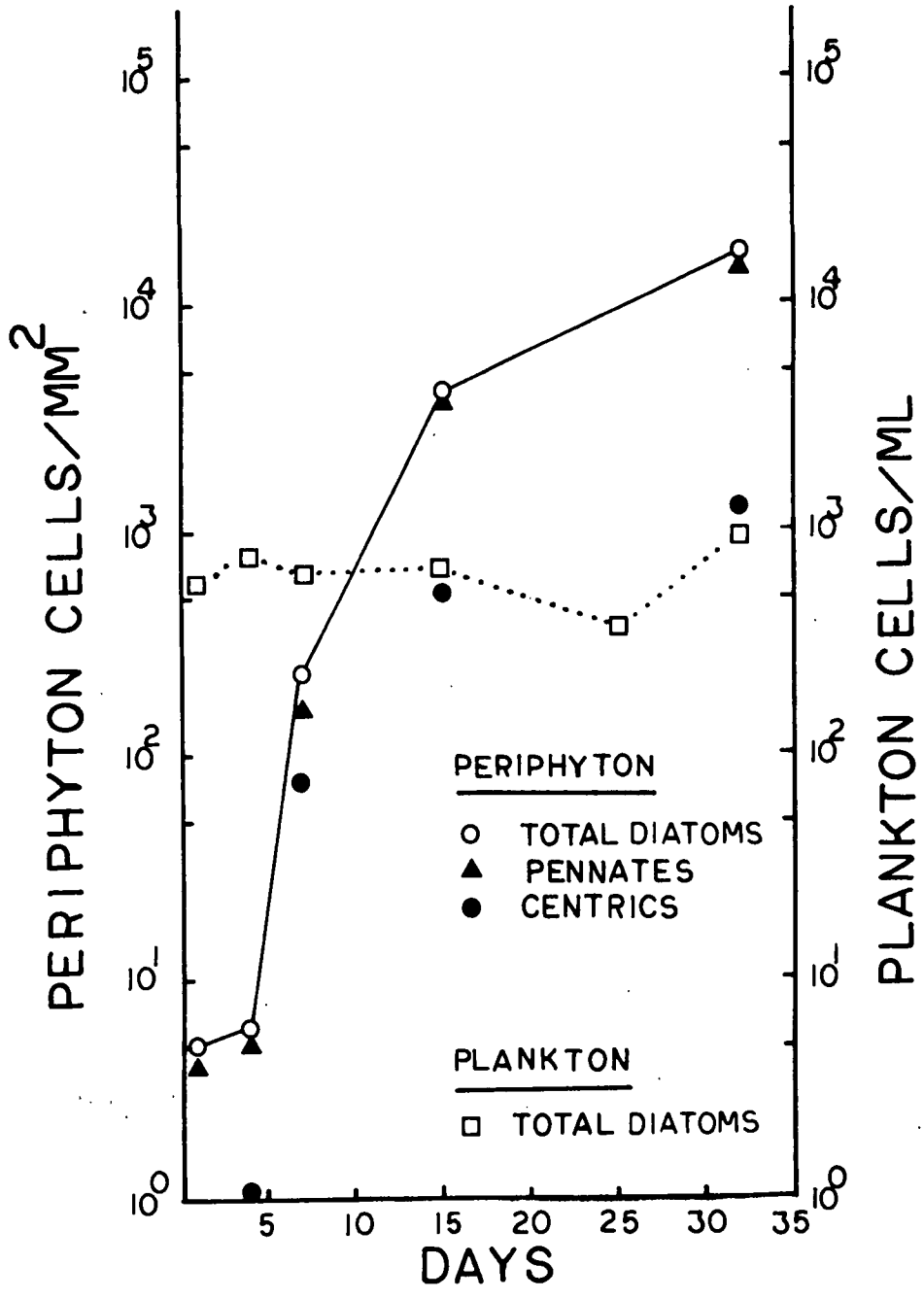

Figure 2. Density of live diatoms in periphyton and plankton samples from the Ohio River at Cincinnati, October 20 - November 21, 1964.

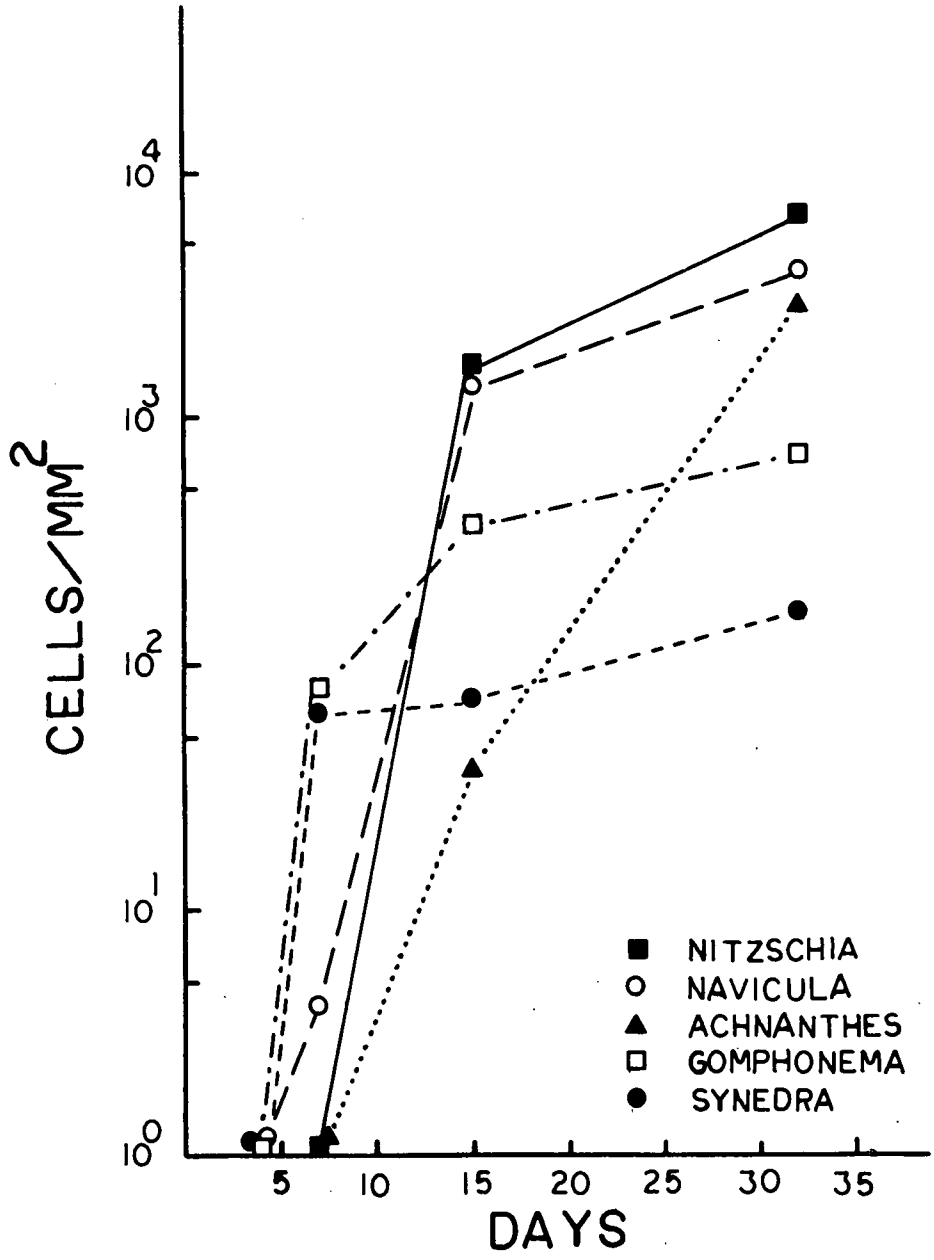

Figure 3. Rate of colonization of glass slides by pennate diatoms in the Ohio River at Cincinnati, October 20 - November 21, 1964.

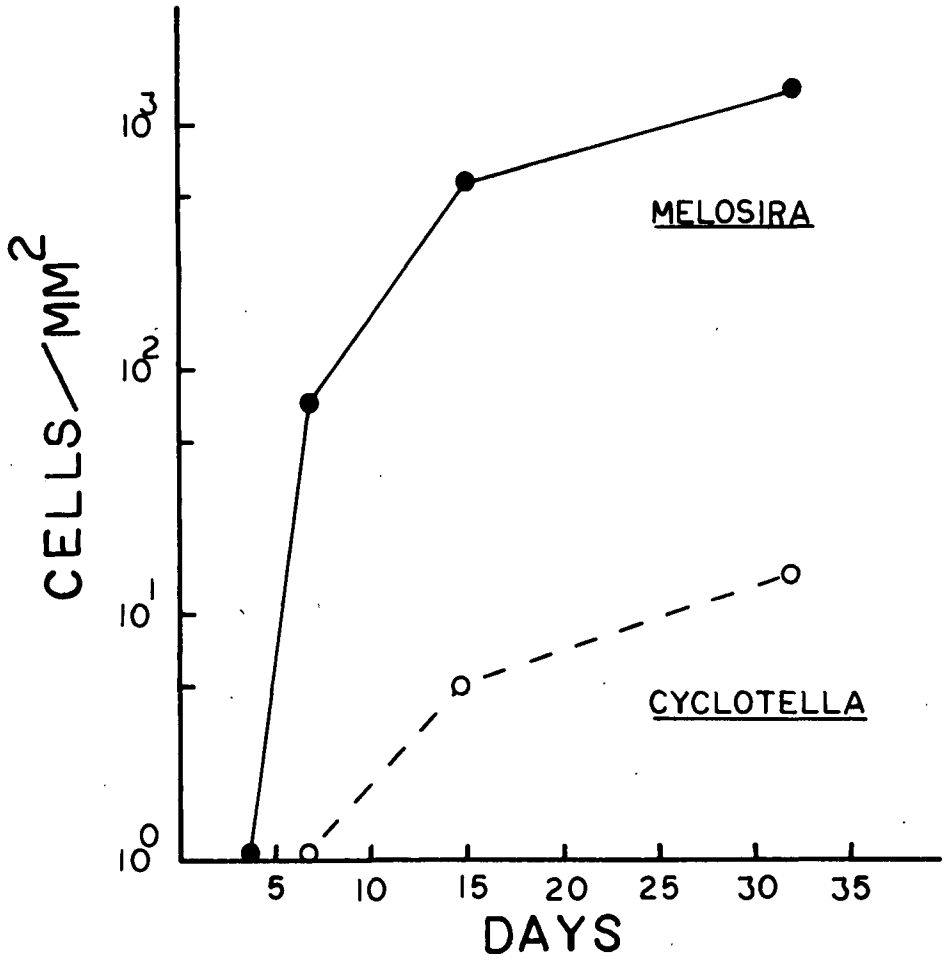

Figure 4. Rate of colonization of glass slides by centric diatoms in the Ohio River at Cincinnati, October 20 - November 21, 1964.

The periphyton diatom population was dominated by pennates during the entire period. They comprised 67% of the diatoms at 7 days, and approximately 85% at 15 and 32 days. Gomphonema and Synedra were the most abundant pennates at 7 days, but the density of both was later exceeded by Nitzschia, Navicula, and Achnanthes (Figure 3). The dominant species were Nitzschia paradoxa Gmel., Navicula cryptocephala Kutz., N. tripunctata (O. Mull.) Bory, Gomphonema parvulum (Kutz.) Grun., G. olivaceum (Lyng.) Kutz., Synedra ulna (Nitzsch) Ehr., and Achnanthes sp. The abundance curves of the centric diatoms are shown in Figure 4. The principal species were Melosira varians Ag., and Cyclotella meneghiniana Kutz.

Comparison of Plankton and Periphyton

Although colonization of the slides was unquestionably pioneered by "drifting" organisms, the composition of the periphyton and plankton diatom communities was very different throughout the entire exposure period (Table 1). In contrast to the periphyton, the plankton diatoms were principally centrics, consisting of Melosira ambigua (Grun.) O. Mull., M. distans (Ehr.) Kutz., and species of Stephanodiscus and Cyclotella. This was further evidenced by the ratios of live centric and pennate cells in the two types of samples shown in Table 2.

The proportions of live and dead diatom cells in the two types of samples were also of interest (Table 3). Since the organic matter must be removed from the diatom frustules before species identifications can be made, it is not possible to distinguish which cells in

Table 1. Dominant diatom species in periphyton and plankton samples from the Ohio River at Cincinnati, October 20 - November 21, 1964

Exposure Period				
1 Day	4 Days	7 Days	15 Days	32 Days
Periphyton				
Synedra ulna	Nitzschia paradoxa	Gomphonema parvulum	Gomphonema parvulum	Melosira varians
Melosira granulata	Melosira varians	Synedra ulna	Melosira varians	Nitzschia paradoxa
Nitzschia sp.	Synedra ulna	Melosira varians	Navicula cryptocephala	Navicula tripunctata
Navicula sp.	Gomphonema olivaceum	Nitzschia sp.	Nitzschia paradoxa	Navicula cryptocephala
Plankton				
Melosira ambigua	Stephanodiscus hantzschii	Melosira ambigua	Melosira distans	Melosira distans
Cyclotella meneghiniana	Melosira ambigua	Melosira distans	Melosira ambigua	Asterionella formosa
Unknown centric	Cyclotella meneghiniana	Fragilaria crotonensis	Melosira granulata	Melosira ambigua
Stephanodiscus invisitatus	Unknown centric	Cyclotella meneghiniana	Unknown centric	Unknown centric

Table 2. Live Centric to Live Pennate cell ratios in periphyton and plankton samples from the Ohio River at Cincinnati

Periphyton		Plankton	
Period Exposed	Live Centric:Live Pennate	Date	Live Centric:Live Pennate
10/20-21/64 (1 day)	1:2.4	10/20/64	3.7:1
10/20-24/64 (4 days)	1:4.2	10/24/64	5.2:1
10/20-27/64 (7 days)	1:2.0	10/27/64	28.5:1
10/20-11/4/64 (15 days)	1:6.4	11/4/64	2.0:1
10/20-11/21/64 (32 days)	1:10.7	11/21/64	0.7:1

Table 3. Percent dead diatom cells in periphyton and plankton samples from the Ohio River at Cincinnati

Periphyton		Plankton	
Period Exposed	% Dead	Date	% Dead
10/20-21/64 (1 day)	9	10/20/64	34
10/20-24/64 (4 days)	18	10/24/64	35
10/20-27/64 (7 days)	2	10/27/64	48
10/20-11/4/64 (15 days)	23	11/4/64	30
10/20-11/21/64 (32 days)	9	11/21/64	12
mean	12	mean	32

the permanent mounts were alive or dead when the samples were taken. We have observed that plankton samples usually contain a high percentage of dead diatom cells. The mean proportion of dead diatom cells in plankton samples taken twice monthly at this station during the 4 water years October 1, 1960 to September 30, 1964 was 29.6%, and the proportion of dead diatom cells in the plankton samples collected during this study averaged 32%. This is a serious weakness in the data, for although it is not likely that the majority of the cells of the dominant species in a sample would be dead, the possibility cannot be discounted. Therefore, a high degree of uncertainty is associated with any interpretation of plankton diatom species data.

The percentage of dead diatom cells in the periphyton was much lower, however, averaging only 12% during the 32-day period discussed above (Table 3), and 15.6% in 12 two-week samples taken in during the 1965 calendar year. The high percentage of live diatom cells in the periphyton confers a significantly greater reliability upon the inferences based on the diatom data from these samples.

Dry and Ash-Free Weights of Periphyton

Dry weights of scrapings from slides (area, 32.5 cm^2) exposed for two-week intervals from July 3 to December 10, 1965, decreased from 149.5 mg per slide to 2.8 mg per slide, and ash-free weights decreased from 21.8 mg per slide to 0.3 mg per slide (Figure 5). The proportion of organic matter in the samples, however, remained

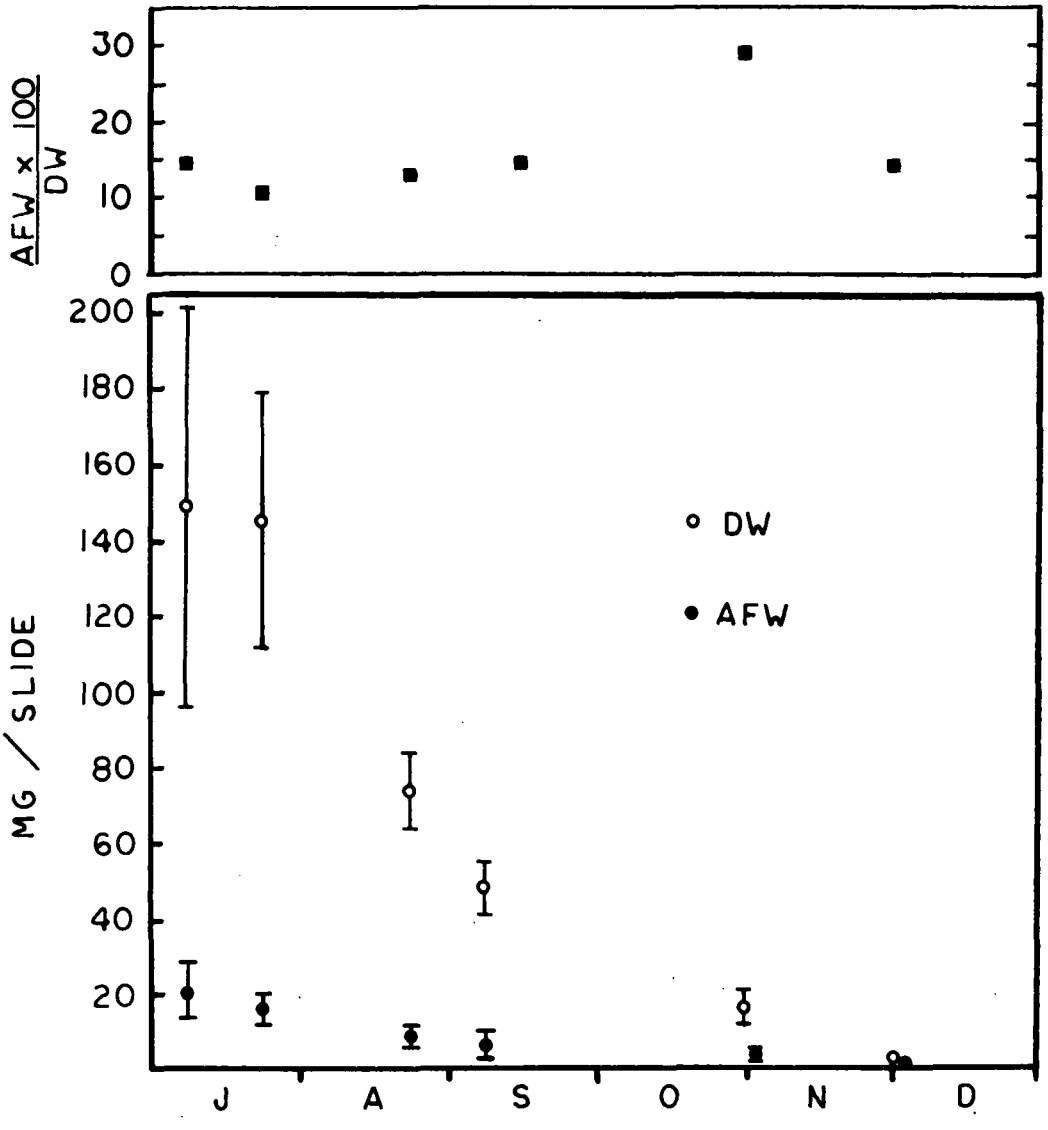

Figure 5. Dry and ash-free weights of scrapings from glass slides exposed 2 weeks in the Ohio River at Cincinnati, July 3 to December 10, 1965.

Table 4. Dry and ash-free weights of periphyton samples from the Ohio River at Cincinnati

Period Exposed	Dry Wt (mg)	C.V.* (%)	Ash-Free Wt (mg)	C.V. (%)	Ash-Free Wt / Dry Wt
7/3-7/17/65	149.5±53.4	37.5	21.8±6.4	29.4	.146
7/17-7/31/65	145.6±33.1	22.7	16.7±3.6	21.3	.115
8/14-8/30/65	73.8±14.8	20.0	9.5±1.8	18.9	.129
8/30-9/14/65	48.2±20.8	43.2	7.1±3.6	50.7	.147
10/30-11/14/65	16.5±9.6	56.4	4.8±2.7	56.2	.291
11/26-12/10/65	2.1±0.7	33.3	0.3±0.2	66.7	.143
				Mean	.162

*coefficient of variation.

relatively constant, averaging 16.2% (Table 4). This was considerably lower than the proportion of organic matter found in periphyton by Newcombe (1949, 1950) and Nielson (1953), and in the seston of Wisconsin lakes by Birge and Juday (1922, 1934). The proportion of organic matter in dried algal cells usually ranges between 50% and 90%. The value obtained for the periphyton in our study was similar to that reported by Nelson and Scott (1962) for the seston (12.9%) in the Oconee River. We have no data on the organic content of the seston in the Ohio River at Cincinnati. However, the organic content of the seston in 49 weekly samples from the nearby Little Miami River, taken during the 1964-65 water year, averaged 15.8%. It is likely, therefore, that the major portion of the organic matter which accumulated on the slides was derived from the seston (evan though the periphyton was shown to be very different from the plankton). It was concluded that dry and ash-free weights did not accurately measure the production of organic matter by periphyton growing on slides at this station.

Periphyton Diatoms as Pollution Indicators

The utility of periphyton in characterizing pollution is illustrated by the data obtained from three stations on the upper reaches of the Klamath River near Klamath Falls, Oregon. These samples were supplied by personnel from the Klamath Basin Project, as a part of a cooperative study.

Table 5. The most abundant diatom species in periphyton samples collected in August 1965 above and below a pollution source in the Klamath River, Oregon

Station 1 (7/23-8/6/65)			Station 2 (7/23-8/6/65)			Station 4 (7/9-8/6/65)		
Species	% Abundance	Cells Per mm^2	Species	% Abundance	Cells Per mm^2	Species	% Abundance	Cells Per mm^2
Cocconeis placentula	28	160	Gomphonema parvulum	44	2113	Cocconeis placentula	39	*-
Navicula Cryptocephala	22	125	Nitzschia (palea)	21	1008	Nitzschia oregona	9	-
Nitzschia oregona	13	74	Cocconeis placentula	18	864	Stephanodiscus invisitatus	6	-
Gomphoneis herculeana	9	51	Nitzschia oregona	5	240	Nitzschia amphibia	6	-
Others	28	502	Others	12	4686	Others	40	-

*A quantitative comparison of cell densities with this station was not possible because of the difference in length of the exposure period.

The general pattern of water quality at the stations can be established on the basis of the diatom populations alone, without other knowledge of environmental conditions (Table 5). The dominance of Cocconeis placentula (Ehr.) at Station 1, above Klamath Falls, indicates an abundance of inorganic nutrients and a low (or moderate) level of dissolved organics. At Station 2, just below the city, the dominance of Gomphonema parvulum (Kutz.) and Nitzschia palea (Kutz.) W. Sm. indicates high levels of dissolved organics (gross organic pollution). The reoccurrence of Cocconeis placentula as the dominant form at Station 4, 30 miles below the city, is indicative of a return to nearly oligosaprobic conditions, resulting from oxidation of the organics.

Station 1 is located at the mouth of the Link River, which drains Upper Klamath Lake, a eutrophic lake with a long history of nuisance algal blooms. The abundance of Cocconeis placentula at this station is in agreement with the distribution pattern of this organism found by Butcher (1947), who reported it as a dominant diatom in oligosaprobic (and eutrophic) waters. Fjerdinstad (1950) found it in alpha- and beta-mesosaprobic habitats also, which would explain its occurrence at Station 2, located less than two miles below sewage treatment plant, tallow works, and wood processing industry waste outfalls. The dominance of Gomphonema parvulum and Nitzschia palea at Station 2 is a direct result of the effects of

the organic pollution. Butcher (1947) found these two diatoms to be the most resistant to pollution, and Fjerdinstad (1964) refers to them as saprophilous, "Occurring most generally in polluted waters...".

Irrigation return water from the Lost River Basin is discharged into the Klamath River approximately 11 miles below Station 2. Another 7 miles downstream the river enters a narrow gorge and tumbles approximately 2 miles over a rocky bed, falling 300 feet. Station 4 is located 2 miles below this rapid. Here, Cocconeis placentula was again the most abundant diatom, accounting for 30% of the diatom population, whereas Nitzschia palea and Gomphonema parvulum each comprised only 3% (included under "others" in Table 5). The natural aeration caused by the rapids undoubtedly aided oxidation of dissolved organics and restoration of oligosaprobic conditions.

The usefulness of the periphyton in determining water quality is supported by an extensive literature concerning the ecology of the organisms, which has accumulated during many decades of work by European aquatic biologists. The examples cited above employed only the dominant diatom species. A more precise determination of conditions at these stations could have been made by describing the entire periphyton community.

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