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MONITORING RIVER PERIPHYTON WITH ARTIFICIAL BENTHIC SUBSTRATES[1]

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Abstract

The objective of this research was to identify the materials and methods necessary to study the attached algal community on a river bottom in deep water. The study site was the Susquehanna River near Falls, Pennsylvania. Artificial substrates of smooth glass, frosted glass, Vermont slate, 'sandy slate' (flagstone) and acrylic plate were placed on the stream bottom in detritus free sample holders by scuba divers. Both monthly and long-term cumulative samples were collected from the plates employing scuba and a Bar-Clamp sampler. River stones (natural substrates) were collected for comparison. Samples were analyzed in a Palmer Cell under a Bausch and Lomb research microscope. Diatoms were the most important colonizers of river stones, with the genera *Nitzschia* and *Navicula* most abundant. Highest periphyton densities occurred on natural substrates in winter with a maximum of 2.2×10^4 units/mm^2. Artificial substrates with one month exposure periods accumulated maximum periphyton density from May through October with relatively low densities in winter. Cumulative artificial substrates were most like river stones in patterns of colonization. Frosted acrylic is recommended for future studies employing benthic artificial periphyton substrates.

Introduction

Phycoperiphyton, periphytic algae, has been employed extensively in lotic water quality research (Lowe & McCullough, 1974; Lowe, 1972; Butcher, 1947; Dam, 1974; VanLandingham, 1976; Patrick, 1968, 1973). In most instances, some sort of artificial substrate has been employed and the phycoperiphyton colonizing the substrate analyzed for community structure (Patrick *et al.*, 1954; Patrick & Hohn, 1956; Hohn & Hellerman, 1963; Lowe & McCullough, 1974). Most periphyton samplers have been modeled after the Catherwood Diatometer of Patrick & Hohn, 1956. This has become a popular and successful means of monitoring water quality (Patrick, 1973). The diatometer is normally placed in the stream channel and floats a few centimeters below the surface. The community of algae colonizing this substrate, although useful in monitoring the water quality, may be qualitatively and quantitatively different than the community colonizing the substrate on the stream bottom. This may be particularly true in deep, clear rivers with good light penetration. The effect of water quality on the periphyton communities as they exist in the stream may best be measured by observing communities collected directly from the stream bottom. The objective of this study was to identify a practical artificial substrate for studying phycoperiphyton on the bottom of a stream. Our criteria for the substrate required that it be inexpensive, readily available, easy to handle and support a community representative of the natural community.

Methods and materials

The site at which periphyton studies were conducted was the Susquehanna River near Falls, Pennsylvania. Water depth at the sampling site varied from 2.5 to 6 m during the investigation. Artificial substrates tested for peri-

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phyton colonization included (1) Vermont slate (roughened by sandblasting; (2) 'Sandy Slate' (flagstone); (3) smooth glass; (4) frosted glass and (5) frosted acrylic. All substrate plates were 14 x 14 cm and were fastened by brass pins to an acrylic holder (Fig. 1), which lacked projections that might catch drifting detritus. The plates faced upstream at 5° from horizontal so that they offered little resistance to current and accumulated little silt or detritus. The holder and plates were lowered to the river bottom at mid-channel by a scuba diver on a submersible raft (Gale & Thompson, 1974) and fastened into position with steel stakes driven into the substrate. The front of the holder and steel stakes were covered with small stones to prevent detritus from catching on them.

Sixteen plates of Vermont slate, with one-half of the upper surface of each covered by acrylic, were placed in the river late in 1973. Three plates were randomly selected for monthly sampling at each station. The three slots where plates were removed were filled with clean plates for the following monthly samples. The remaining 13 plates provided samples of cumulative periphyton and were exposed from two to thirteen months. In April, 1974, plates of smooth and frosted glass and sandy slate were placed in a second holder on the river bottom beside the first one.

For comparison, samples were also collected from river stones in water with a minimum depth of 1.5 m. Table 1 indicates the schedule followed for sampling artificial substrates and river stones.

Samples were collected employing a Bar-Clamp sampler and scuba (Gale, 1975). Periphyton was removed from the substrate in the laboratory by vibration with an ultrasonic dental cleaning probe. After settling five or more days, periphyton samples were concentrated to 50 ml by decanting and analyzed and enumerated in the laboratory employing a Palmer-Malony counting chamber and a Bausch and Lomb research microscope operating at a total magnification of 430 X. In most instances, 750 units (Gale & Lowe, 1971) were enumerated and identified to genus in each sample (about 250/each of 3 subsamples). Extremely low algal densities in some samples made it impractical to count 750 units. The most

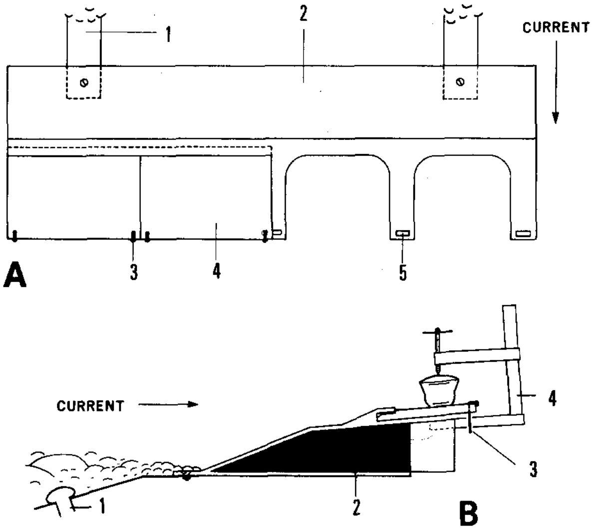

Fig. 1. Detritus-free apparatus for periphytic algae studies: A. Acrylic holder with two plates removed (top view): 1) metal retaining strap; 2) deflecting shield, acrylic; 3) brass pin; 4) acrylic plate; 5) pin retaining slot. B. Acrylic holder (end view) with sampler in place: 1) steel stake (buried); 2) concrete ballast; 3) brass pin; 4) bar-clamp sampler.

Table 1. Sampling schedule for periphyton on artificial substrates and river stones.

Substrates	Dates Sampled (months)												
	J	F	M	A	M	J	J	A	S	O	N	D	J
Vermont Slate	x	x	x	x	x	x	x	x	x	x	x	x	x
Sandy Slate						x	x	x	x	x	x		x
Frosted Acrylic	x	x	x	x	x	x	x	x	x	x	x	x	x
Smooth Glass					x	x	x	x	x	x	x	x	x
Frosted Glass					x	x	x	x	x	x	x	x	x
Cumulative Vermont Slate			x	x	x	x	x	x	x	x	x	x	x
Cumulative Frosted Acrylic					x		x		x		x	x	
River Stones (Shore)	x	x			x		x		x		x	x	
River Stones (Channel)												x	x

abundant taxa in each sample were identified to species. Species identification often necessitated a magnification of 1000 X with an oil immersion objective. Soft forms were identified in wet mounts and diatoms were identified from Hyrax mounts.

Results

A total of 38 genera of algae was identified in samples from natural river stones. Diatoms were the most important group of algae with the genera *Nitzschia* and *Navicula* most often dominating the community (Table 2). The stones supported 3.8 x 10^3 units of periphyton/mm^2 in January (Fig. 2). *Nitzschia dissipata* (Kütz.) Grun. was the most abundant species. In February the periphyton standing crop reached 2.2 x 10^4 units/mm^2 as *N. dissipata* continued to dominate the community. The May, July and September collections all yielded less than 2 x 10^3 units/mm^2. The population of *N. dissipata* had decreased both relatively and absolutely in these samples. Taxa becoming relatively more abundant during these months included *Cocconeis placentula* Ehr., *Navicula cryptocephala* Kütz., *N. cryptocephala* var. *veneta* (Kütz.) Rabh., *N. viridula,* Kütz. *N. tripunctata* (O. F. Müll.) Bory, *N. salinarum* var. *intermedia* (Grun.) Cl., *Cyclotella pseudostelligera* Hust., *Ankistrodesmus convolutus* Corda and *Scenedesmus quadracauda* (Terp.) Breb., the latter three probably representing plankton fallout. In November and December, standing crops were again around 4 x 10^3 units/mm^2 and increased to 7.3 x 10^4 units/mm^2 in January, 1975. Diatoms were responsible for much of the fall-winter increase, the most important species being *Cocconeis placentula, Cyclotella pseudostelligera, Navicula cryptocephala* var. *veneta, N. salinarum* var. *intermedia, N. tripunctata* and *Nitzschia dissipata.* The com-

Table 2. Changes in number of genera of algae colonizing monthly artificial substrates at Falls, 1974-5.

Month	Substrate	No. Genera Present
1974		
Jan	Acrylic	11
	Vermont slate	0
Feb	Acrylic	–
	Vermont slate	4
Mar	Acrylic	16
	Vermont slate	5
Apr	Acrylic	18
	Vermont slate	4
May	Acrylic	12
	Vermont slate	9
	Smooth glass	18
	Frosted glass	17
	'Sandy' slate	–
Jun	Acrylic	27
	Vermont slate	19
	Smooth glass	22
	Frosted glass	19
	'Sandy' slate	24
Jul	Acrylic	30
	Vermont slate	25
	Smooth glass	21
	Frosted glass	28
	'Sandy' slate	21
Aug	Acrylic	27
	Vermont slate	24
	Smooth glass	30
	Frosted glass	30
	'Sandy' slate	23
Sep	Acrylic	20
	Vermont slate	18
	Smooth glass	23
	Frosted glass	23
	'Sandy' slate	25
Oct	Acrylic	21
	Vermont slate	20
	Smooth glass	18
	Frosted glass	17
	'Sandy' slate	19
Nov	Acrylic	11
	Vermont slate	6
	Smooth glass	8
	Frosted glass	16
	'Sandy' slate	13
Dec	Acrylic	8
	Vermont slate	3
	Smooth glass	–
	Frosted glass	6
	'Sandy' slate	–
1975		
Jan	Acrylic	5
	Vermont slate	7
	Smooth glass	9
	Frosted glass	7
	'Sandy' slate	7

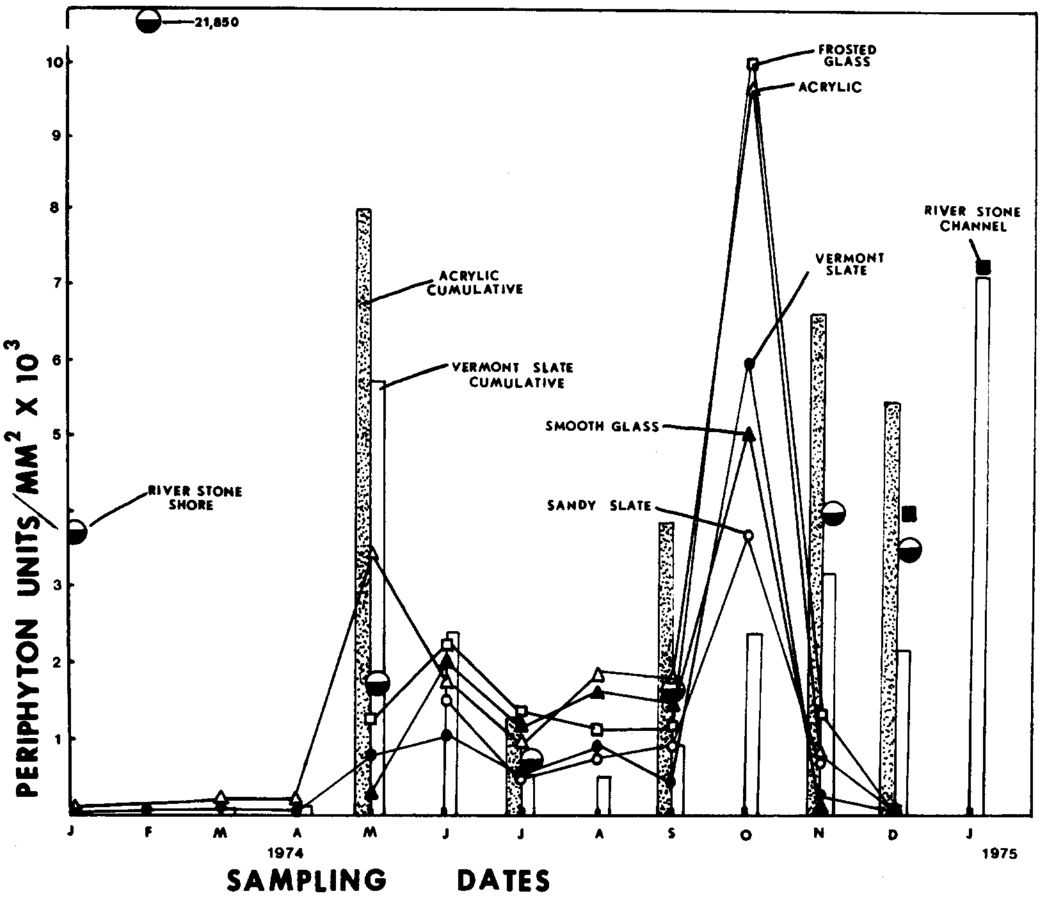

Fig. 2. Density of periphyton on various substrates submerged in the Susquehanna River from January, 1974 to January, 1975.

munity dynamics of phycoperiphyton on river stones can be summarized as follows: relatively large standing crops in January and February, decreasing to a minimum in mid-summer, then increasing to a winter maximum again.

All of the substrates which were allowed one month colonization periods (frosted acrylic, Vermont slate, sandy slate, frosted glass and smooth glass) displayed community dynamics similar to one another (Fig. 2). Colonization rates were very low from January through April on both Vermont slate and acrylic substrates. The largest standing crop observed during this period was 1.4 x 10^2 units/mm^2 on frosted acrylic in March. Most of the colonizers were diatoms of the genera *Navicula* and *Nitzschia* (Table 3). Frosted acrylic and Vermont slate were more heavily colonized in May with 3.4 x 10^3 and 7.7 x 10^2 units of phycoperiphyton/mm^2. Expanding populations of *Nitzschia dissipata, N. palea* (Kütz.) W. Sm., *Navicula cryptocephala, N. cryptocephala* var. *veneta, N. tripunctata, N. viridula* and *Cymbella minuta* Hilse *ex* Rabh. accounted for most of the increase in community density. Smooth and frosted glass substrates were collected for the first time in May and supported 2.4 x 10^2 and 1.2 x 10^3 units/mm^2 respectively. In June, sandy slate was collected for the first time. All five artificial substrates collected in June supported standing crops between 1.1 x 10^3 and 2.3 x 10^3 units/mm^2. All substrates displayed relatively stable colonization rates until October when colonization rates on all artificial substrates increased by at least 3 fold. Vermont slate displayed the greatest increase in algal density when the standing crop increased from 3.6 x 10^2 units/mm^2 in September to 5.9 x 10^3 units/mm^2 in October. Frosted glass supported the densest community of the October samples (1.0 x 10^4

Table 3. Most abundant three genera of algae on River stones and artificial substrates (M = monthly; C = cumulative) at Falls 1974-5. Genera with identical values are listed alphabetically if all can be included; otherwise, none are included.

Month	Substrate	Genera	% Total
1974			
Jan	River stone (shore)	Nitzschia	51.3
		Navicula	24.8
		Cocconeis	7.0
	Acrylic (M)	Nitzschia	59.3
		Navicula	20.0
		Oscillatoria	7.4
	Vermont slate (M)		0
Feb	River stone (shore)	Nitzschia	73.4
		Navicula	11.1
		Synedra	7.5
	Acrylic (M)		--
	Vermont slate (M)	Nitzschia	57.0
Mar	Acrylic (M)	Nitzschia	59.3
		Navicula	18.5
	Acrylic (C)		--
	Vermont slate (M)	Navicula	32.9
		Nitzschia	24.2
		Asterionella	21.9
	Vermont slate (C)	Navicula	40.6
		Nitzschia	40.6
Apr	Acrylic (M)	Navicula	49.6
		Gomphonema	17.6
		Meridion	6.9
	Vermont slate (M)	Navicula	42.9
		Cymbella	28.6
	Vermont slate (C)	Fragilaria	33.3
		Navicula	20.8
		Nitzschia	12.5
May	River stone (shore)	Navicula	55.9
		Nitzschia	18.5
		Cocconeis	11.0
	Acrylic (M)	Navicula	47.8
		Nitzschia	36.9
		Cymbella	4.6
	Acrylic (C)	Nitzschia	50.8
		Navicula	33.5
		Gomphonema	7.5
	Vermont slate (M)	Navicula	41.6
		Nitzschia	38.9
		Cymbella	7.4
	Vermont slate (C)	Nitzschia	71.3
		Navicula	25.6
		Gomphonema	1.1
	Smooth glass	Navicula	33.6
		Nitzschia	19.3
		Cymbella	15.1
	Frosted glass	Navicula	52.6
		Nitzschia	24.0
		Cymbella	11.8
	'Sandy' slate		0
Jun	Acrylic (M)	Navicula	24.2
		Nitzschia	20.6
		Ankistrodesmus	14.0
	Vermont slate (M)	Navicula	43.4
		Nitzschia	13.8
		Ankistrodesmus	12.7
	Vermont slate (C)	Nitzschia	54.6
		Navicula	26.2
		Stephanodiscus	5.8
	Smooth glass	Cyclotella	21.8
		Navicula	19.8
		Nitzschia	12.5
	Frosted glass	Navicula	21.2
		Cyclotella	19.4
		Nitzschia	18.8
	'Sandy' slate	Navicula	37.4
		Nitzschia	18.9
		Stephanodiscus	9.7
Jul	River stone (shore)	Navicula	23.9
		Cocconeis	23.1
		Cyclotella	18.8
	Acrylic (M)	Cyclotella	27.6
		Ankistrodesmus	14.1
		Stephanodiscus	9.2
	Acrylic (C)	Ankistrodesmus	19.6
		Navicula	19.5
		Cyclotella	17.5
	Vermont slate (M)	Cyclotella	23.2
		Navicula	13.0
		Stephanodiscus	11.8

Table 3. Continued

Month	Substrate	Genera	% Total
	Vermont slate (C)	Cyclotella	20.7
		Ankistrodesmus	17.0
		Scenedesmus	11.4
	Smooth glass	Cyclotella	30.3
		Stephanodiscus	13.5
		Navicula	10.8
	Frosted glass	Cyclotella	24.3
		Stephanodiscus	11.6
		Navicula	9.5
	'Sandy' slate	Navicula	24.8
		Cyclotella	21.0
		Cocconeis	10.7
Aug	Acrylic (M)	Cyclotella	25.3
		Scenedesmus	19.4
		Stephanodiscus	12.8
	Vermont slate (M)	Cyclotella	24.3
		Scenedesmus	19.5
		Stephanodiscus	13.9
	Vermont slate (C)	Scenedesmus	26.4
		Cyclotella	17.4
		Dictyosphaerium	12.8
	Smooth glass	Scenedesmus	23.3
		Cyclotella	22.2
		Stephanodiscus	12.7
	Frosted glass	Cyclotella	23.4
		Scenedesmus	17.4
		Stephanodiscus	17.4
	'Sandy' slate	Cyclotella	25.9
		Scenedesmus	17.5
		Stephanodiscus	12.0
Sep	River stone (shore)	Cyclotella	34.8
		Navicula	29.3
		Cocconeis	7.7
	Acrylic (M)	Cyclotella	38.9
		Navicula	14.2
	Acrylic (C)	Cyclotella	29.6
		Stephanodiscus	23.6
		Navicula	17.0
	Vermont slate (M)	Cyclotella	41.4
		Navicula	24.2
		Stephanodiscus	9.9
	Vermont slate (C)	Cyclotella	34.0
		Navicula	25.8
		Stephanodiscus	9.8

Table 3.

Month	Substrate	Genera	% Total
	Smooth glass	Cyclotella	30.0
		Stephanodiscus	24.1
		Navicula	14.7
	Frosted glass	Cyclotella	42.3
		Stephanodiscus	12.2
		Navicula	12.0
	'Sandy' slate	Cyclotella	34.9
		Navicula	19.7
		Stephanodiscus	18.9
Oct	Acrylic (M)	Navicula	44.9
		Nitzschia	26.1
		Cyclotella	8.3
	Vermont slate (M)	Navicula	35.7
		Nitzschia	35.4
		Cyclotella	4.5
	Vermont slate (C)	Navicula	47.5
		Nitzschia	19.9
		Stephanodiscus	8.3
	Smooth glass	Navicula	36.7
		Melosira	17.6
		Nitzschia	14.4
	Frosted glass	Nitzschia	29.3
		Navicula	28.0
		Melosira	11.0
	'Sandy' slate	Navicula	29.2
		Cymbella	27.5
		Nitzschia	20.5
Nov	River stone (shore)	Navicula	56.1
		Nitzschia	28.9
		Cocconeis	2.9
	Acrylic (M)	Navicula	47.5
		Nitzschia	32.8
		Phormidium	8.2
	Acrylic (C)	Navicula	38.2
		Nitzschia	32.7
		Cocconeis	6.0
	Vermont slate (M)	Navicula	64.8
		Nitzschia	27.3
		Fragilaria	2.8
	Vermont slate (C)	Navicula	53.0
		Nitzschia	26.2
		Cocconeis	5.9

Table 3.

Month	Substrate	Genera	% Total
	Smooth glass	Navicula	55.6
		Nitzschia	27.0
		Cocconeis	6.4
	Frosted glass	Navicula	57.8
		Nitzschia	26.6
	'Sandy' slate	Navicula	60.5
		Nitzschia	29.5
		Cymbella	3.8
Dec	River stone (shore)	Nitzschia	49.3
		Navicula	35.6
		Cymbella	3.5
	River stone (channel)	Nitzschia	49.7
		Navicula	36.3
		Cymbella	2.0
	Acrylic (M)	Navicula	43.9
		Nitzschia	12.2
	Acrylic (C)	Nitzschia	39.7
		Navicula	35.0
		Cocconeis	6.6
	Vermont slate (M)	Navicula	75.0
		Gomphonema	12.5
		Nitzschia	12.5
	Vermont slate (C)	Navicula	46.0
		Nitzschia	44.8
		Cocconeis	3.6
	Smooth glass		--
	Frosted glass	Nitzschia	32.6
		Diatoma	21.7
		Navicula	21.7
	'Sandy' slate		--
1975 Jan	River stone (channel)	Navicula	50.9
		Nitzschia	42.8
		Cymbella	2.7
	Acrylic (M)	Navicula	47.8
		Cymbella	21.7
	Acrylic (C)	Nitzschia	58.7
		Navicula	24.3
		Amphora	9.6
	Vermont slate (M)	Melosira	32.0
		Nitzschia	32.0
	Vermont slate (C)	Navicula	50.7
		Nitzschia	43.8
		Cocconeis	2.2
	Smooth glass	Melosira	33.3
		Nitzschia	21.6
		Navicula	19.6
	Frosted glass	Melosira	32.1
		Navicula	32.1
		Nitzschia	14.3
	'Sandy' slate	Navicula	38.6
		Gomphonema	33.0
		Nitzschia	19.3

Table 3. Continued

units/mm^2). The increase in phycoperiphyton on all substrates in October was due primarily to expanding populations of *Cymbella prostrata* (Berk.) Cl., *Melosira varians* Ag., *Navicula cryptocephala* var. *veneta, N. symmetrica* Patr., *Nitzschia dissipata* and *N. palea.* Following the October standing crop maximum, all substrates supported relatively sparse communities in November with decreasing standing crops in December and January.

Cumulative diatom communities were collected from frosted acrylic and Vermont slate substrates that were exposed for longer periods than the monthly samples. It was felt that longer exposure periods might better simulate the community dynamics of phycoperiphyton on river stones. Frosted acrylic substrates were exposed from five to thirteen months with the 5 month sample collected in May, 1974 and the 13 month sample collected in January, 1975. The May collection from cumulative frosted acrylic yielded 1.0 x 10^4 units/mm^2 (Fig. 2). The substrate collected in July was exposed for 7 months and supported 1.3 x 10^3 units/mm^2. Following this minimum the phycoperiphyton increased in density in the September, November, December and January samples. The latter supporting 1.8 x 10^4 units/mm^2. Most of the increased density was due to increases in several species of *Navicula* and *Nitzschia.*

Cumulative Vermont slate substrates were exposed from three to thirteen months with the three month sample collected in March and the thirteen month sample collected in January. March and April collections each yielded less than 30 units of phycoperiphyton/mm^2

but in May 5.8 x 10^3 units/mm^2 were present (Fig. 2). *Navicula* and *Nitzschia* composed over 95% of the May community. The most abundant species were *Navicula cryptocephala, N. cryptocephala* var. *veneta, N. tripunctata, N. viridula, Nitzschia dissipata* and *N. palea*. The standing crop fell to 2.4 x 10^3 units/mm^2 in June and to less than 10^3 units/mm^2 in July, August and September. The most abundant genera in the summer months included *Cyclotella, Scenedesmus, Ankistrodesmus* and *Dictyosphaerium*. The standing crop increased to 2.3 x 10^3 units/mm^2 in October and by January had increased to 7.2 x 10^3 units/mm^2.

The structure of communities on various combinations of substrates was evaluated by determining the coefficient of community for pairs of substrates of different types and by contrasting pairs of substrates of different types in percent similarity tests (Whittaker & Fairbanks, 1958). Coefficient of community indicates the percentage of genera that are shared by two samples and is determined by the formula $cc = \frac{c}{a+b-c}$, where a is the number of genera in sample 1, b is the number of genera in sample 2 and c is the number of genera in both samples. Percent similarity is determined by the formula $PSc = 100 - .5\ \Sigma|a-b|$, where a and b are, for a genus, the percentage of samples 1 and 2 which that genus represents. Percent similarity measures relative similarity of numerical composition and generally leads to grouping of communities by dominants (Whittaker & Fairbanks, 1958).

In table 4, communities colonizing the various substrates are compared. Replicate plates of Vermont slate usually displayed a relatively high percent similarity which exceeded 80% in five of eight months. When monthly Vermont slates (replicate 1) for the period from May through December are combined and compared to combined slates (replicate 2), an overall percent similarity of 85 was obtained. Rather similar values were obtained for other substrates combined for the same period (Table 4).

In July, the standing crops on artificial substrates and river stones were fairly similar numerically, and it was thought that the communities various substrates and on river stones might have a high percent similarity

Table 4. Comparison of algal communities on artificial substrates (M = monthly; C = cumulative) and River stones at Falls North Branch of the Susquehanna River as expressed by percent similarity and coefficient of community.

Month	Substrates Compared	% Similarity	Coefficient of Community
May	(M) Vermont slate (1) vs. (2)	88	62
Jun	" "	81	63
Jul	" "	69	54
Aug	" "	83	57
Sep	" "	57	26
Oct	" "	87	61
Nov	" "	87	40
Dec	" "	42	33
May-Dec	Acrylic vs. Vermont slate	90	70
"	Acrylis vs. Frosted glass	86	75
"	Smooth glass vs. Frosted glass	83	78
"	Frosted glass vs. Vermont slate	81	71
"	Acrylic vs. Smooth Glass	74	80
"	Smooth glass vs. Vermont slate	70	74
"	Vermont slate (1) vs. (2)	85	63
Jul	(M) Vermont slate vs. River stone	78	52
"	(M) 'Sandy' slate vs. River stone	78	68
"	(C) Acrylic vs. River stone	72	45
"	(M) Frosted glass vs. River stone	67	55
"	(M) Smooth glass vs. River stone	67	68
"	(C) Vermont slate vs. River stone	66	56
"	(M) Acrylic vs. River stone	60	55

during this time. There was not as high a similarity between monthly artificial substrates and river stones and values for all 7 comparisons were between 60% and 78%. Cumulative plates did not seem much, if any, more similar to river stones than did monthly plates.

The coefficient of community, percentage of total genera present on both substrates of pairs being compared, was from 26% to 63% when monthly Vermont slate replicates were compared (Table 4). The coefficient of community was much higher, 63% to 80%, when combined May through December data were compared for each of the substrates (Table 4). The July data for each of the artificial substrates compared with river stone communities yielded coefficients of community of 45 to 68 (Table 4).

Discussion

In most instances the three most abundant genera on various kinds of artificial substrates and on river stones were the same, although their relative position in the top three often varied. It seems that any of several artificial substrates could provide a reasonably good idea of the dominant algal genera and species present on river stones.

The number of genera on artificial substrates (sampled monthly) tended to be higher than the number on river stones. This phenomenon has also been reported to occur in other streams by Patrick *et al.* (1954).

The use of artificial substrates in periphyton studies provides soms advantages to the investigator, but also includes several hazards. Two of these hazards merit a brief discussion here. It is clear that the length of time required to colonize a substrate varied a great deal with season. If the object of future studies is to allow the substrate to become colonized as heavily as the natural substrate or to establish a 'constant standing crop' as described by Elwood & Nelson (1972), then a 2-wk colonization period, like that recommended by Weber & Raschke (1970) and by others might suffice in summer. But, in winter even a month would be too little colonization time. Elwood & Nelson (1972) found that at least six weeks were required to attain a 'constant standing crop' on natural substrates in an artificial stream.

Colonization of subtrates placed near the river surface, like Weber & Raschke's (1970) might colonize faster than those near the bottom, where they were placed in this study. Placement of artificial substrates near the river bottom, in the same environment as the natural substrate, enhances the ecological value of the data collected on them (Brown & Austin, 1971).

This study also revealed that short term (monthly) colonization rates on clean plates are sometimes poor indicators of changes or trends in the development of the periphyton community on natural substrates. For example, in June, when colonization rates were high, algae on natural substrates became much less abundant. In November, when colonization rates declined on monthly plates, algal density on natural substrates increased markedly. In December, 1974 and January, 1975, when almost no colonization occurred, algal density on natural substrates and cumulative Vermont slate increased. Thus, it seems that if the objective of future studies is to detect moderate or large changes in the existing periphyton community that result from environmental modification, samples should be collected from river stones or from artificial substrates that have been submerged for several months. Obviously, it would be unrealistic to attempt to leave artificial substrates near the river surface for an extended period of time, for if they were not swept away by ice or floating debris, they would likely be destroyed by vandals. It would, however, be realistic to leave artificial substrates submerged on the river bottom if they were placed on 'detritus-free' holders like those described in Fig. 1. Plates placed in the Susquehanna River in January, 1975 have remained in place for over 29 months. The plates did not seem to have been affected by a major flood in September, 1974. If a single type of artificial substrate is to be used, frosted acrylic would be a good choice for it: (1) is readily available; (2) has a uniform surface texture; (3) is easily sawed, drilled and glued, and (4) colonizes well with algae that seem as representative of the algal community on river stones as the communities that developed on other artificial substrates. Although all of the artificial substrates in this study faced the current at about 5° from horizontal, plates could also be placed at other angles from the bottom.

It is not at all certain that the use of artificial substrates in this study was successful in reducing sample variability to an appreciable extent. There was usually substantial variability in numbers of algal units in replicated samples taken from Vermont slates, in spite of their homogenous surfaces. Sometimes there differences were as large or larger than differences found in samples from river stones.

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Summary

The Susquehanna River, Pennsylvania, U.S.A. was chosen as a site to study periphyton colonization on a river bottom. Artificial substrates of smooth glass, frosted glass, Vermont slate, sandy slate, and frosted acrylic were fastened to detritus free periphyton samplers and placed on the river bottom. Exposed substrates were collected monthly by scuba divers employing bar-clamp samplers. Some substrates were left on the river bottom for several months to collect cumulative periphyton samples. Natural river stones were also collected for comparison.

Diatoms were the most abundant algae on the substrates. The genera *Nitzschia, Navicula, Cocconeis, Synedra, Asterionella, Gomphonema, Meridion, Cymbella, Fragilaria, Stephanodiscus, Cyclotella, Diatoma,* and *Melosira* were all well respresented. Substrates with one month exposure times displayed very little periphyton colonization from December through April. From May through November, one month exposure periods resulted in periphyton communities with densities varying from less than 1,000 units/mm^2 to around 10,000 units/mm^2. October samples accumulated the densest communities.

Cumulative substrates generally maintained the densest periphyton communities in the winter months with density decreasing from June through October. Natural river stones yielded densities of periphyton most similar to cummulative substrates. The greatest periphyton density found was on a river stone in February (21,850 units/mm^2).

In most cases, the various substrates used had the same dominant genera and any of the substrates could provide a satisfactory estimate of dominant genera in the periphyton. In using benthic substrates one must be aware, however, that natural river stones are collecting cumulative algal samples and in most instances one month exposure periods of artificial substrates are not adequate. Frosted acrylic appears to be a good candidate for continued use as an artificial substrate because of it's ready availability, uniform surface and ease of manipulation.

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