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AN INVESTIGATION OF THE PERIPHYTON IN A RIFFLE OF THE WEST GALLATIN RIVER, MONTANA[1]

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INTRODUCTION

Few quantitative investigations on the abundance and distribution of periphyton in streams and lakes have been made. Young (1945) completed a careful limnological study of periphyton in Douglas Lake, Michigan, and gave a comprehensive list of organisms found on three types of substrata. Butcher (1932) found seasonal variation in sessile algae growing on glass slides submerged for certain periods in the Rivers Lark and Tees. Neel (1953) listed the periphyton organisms scraped from stones and other submerged objects in the North Platte River in Wyoming and Nebraska during July, August and October.

The present investigation of periphyton was confined to a riffle area on the West Gallatin River, immediately upstream from Shedd's Bridge, Gallatin County, Montana. Thirty-four collections were made at intervals, from August 1952 through February 1954 (Table 1). A total of 491 samples was taken during this period. The objective was to determine kinds and seasonal abundance of periphyton organisms.

Variable definitions of periphyton occur in the literature. Young (1945) described periphyton as an "assemblage of organisms growing upon the free surfaces of submerged objects in water, and covering them with a slimy coating". He excludes benthos from the definition but does not separate benthic organisms from periphyton in his tabulations. Hunt (1952) defines this complex as an assemblage of algae and minute animals covering submerged objects with a slimy coating. He includes both free-living and sessile organisms. Neel (1953) describes periphyton

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as an assemblage of mainly microscopic organisms that form or live in coatings upon rocks and other submerged objects. His definition closely parallels Ruttner's (1953) "Aufwuchs". In the present study all organisms forming or living within the mat are considered part of the periphyton complex.

TABLE 1

Number of sampling visits and samples taken at Shedd's Bridge, West Gallatin River, Montana, 1952–1954.

	No. Visits			No. Samples			Total Samples
Month	1952	1953	1954	1952	1953	1954	1952–54
January		2	2		14	24	38
February		1	2		22	30	52
March		2			11		11
April		—			—		—
May		4			44		44
June		—			—		—
July		2			30		30
August	2	4		19	70		89
September	3	1		25	36		61
October	1	2		9	68		77
November	1	2		9	49		58
December	2	1		15	16		31
Total	9	21	4	77	360	54	491

DESCRIPTION OF STUDY AREA AND GENERAL METHODS

In 1954 the riffle gradient was 1.76 feet per 100 lineal feet as compared with the average of 0.64 feet per 100 lineal feet, for the valley portion of the West Gallatin River (Purkett, 1950). In 1952 the riffle was located at the convergence of two channels; one was about 30 feet and the other 45 feet in width. Floods in 1953 widened the larger channel to about 80 feet and reduced the smaller to approximately 10 feet. This placed the riffle upstream 6–8 feet from the 1952 position. The approximate average riffle depth for both years was 12 inches. In 1952 the riffle proper was about 12 feet long and 60 feet wide while in 1953 it was approximately 20 feet long and 100 feet wide. Maximum and minimum recorded discharge for 1952 was about 6,320 and 110 cubic second-feet respectively, and for 1953, approximately 4,405 and 50 cubic second-feet (Bureau of Reclamation).

Bottom materials in the riffle did not noticeably change in type or size during the study period. Most stones were stream worn and irregularly rounded. In 1954, 2.8 percent of the area in two one-yard quadrats was coarse gravel (1/8 to 1 inch diameter), 3.3 percent pebbles (1 to 2 inches diameter, 38.5 percent cobbles 2 to 10 inches diameter), and 55.4 percent boulders (10 inches or more in diameter). Some stones were solid colors while others were mottled or streaked. The colors recognized were white, cream, pink, red, red-brown, brown, light gray, blue-gray, and black. The texture of stone surfaces ranged from semi-polished to a roughness equal to about number four grit sandpaper.

Each sample consisted of one square centimeter. This was marked off by a brass ring and the material enclosed was scraped off with a scalpel and immediately preserved in four percent formalin. Velocities to the nearest 0.01 second-feet (Leupold & Stevens Midget Current Meter) and depths to the nearest 0.5 inch were measured for all stations on each sampling date. Turbidity was determined to the nearest 0.01 ppm with a Hellige Turbidimeter at irregular intervals, usually on collection dates. From August 1952 to July 1953 water temperatures were secured with a "checked" Taylor pocket thermometer and thereafter with a corrected maximum-minimum thermometer.

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The Periphyton Complex

Methods of Study

Selection of Stations and Sampling: Cobblestones for stations were secured from the river bank. These were scraped clean and an identification number and reference point for velocity and depth measurements were painted on the top center of each stone. Stones were treated with full strength formalin for a few minutes and then immediately rinsed. This latter procedure was followed so that the order in which organisms appeared could be determined.

On August 9, 1952 ten treated stones were placed at five foot intervals along a transect across the riffle width. One was lost August 23, 1952, another between February 22 and March 9, 1953; six more disappeared between March 9 and 20, 1953 and by March 30 all had been lost. On May 2, 1953, ten more treated stones (stations) were arranged in five groups of twos along one-half the length of the 1952 transect. Stations in each of the five groups were placed 2–6 inches apart. These were sampled from May 9 to 23; shortly after the latter date all were washed from the area. On August 3, 1953, 16 treated stones were placed in groups of fours along a transect one-half the width of the riffle and six inches or less apart. The distance between groups was 12 feet. Between November 14 and 29, 1953, eight stones (two groups) were lost and four others (one group) was believed pushed from the area by floating ice on January 21, 1954.

Random stones were slected in the riffle proper as controls for the treated stones. These also supplemented the treated stones which were washed away. Three were selected on March 9, 1953, nine on July 11, six on July 18, three on August 6; four on February 7, 1954 and three on February 23. No important difference in numbers and kinds of organisms was found on treated and random stones, except where samples were taken earlier than one week after treatment. In a single instance random sample stones showed greater quantities of periphyton than the treated ones. One periphyton sample was taken from each station on each sampling visit from August 1952 to March 1953. After the stone (station) was removed from the water, the sampler was placed at random (without looking) on its surface and the enclosed periphyton scraped off and preserved. From March 1953 through February 1954, two samples were secured from each station. A transect was established along the midline of the exposed surface from the upstream to downstream end of each stone. Samples were secured at random from each half of the transect without sampling any area twice.

Periphyton Analysis: The volumetric method and large counting cell used by Young (1945) and the differential plankton count method described by Welch (1948) were adapted for sample analysis. Samples were diluted or reduced to five ml and centirifuged for one minute at 360 rpm. Centrifuged volumes less than 0.05 ml were recorded as trace; greater than 0.05 ml and less than 1.0 ml were estimated to the nearest 0.05 ml; greater than 1.0 ml were estimated to the nearest 0.5 ml. Volumes over 1.0 ml could not be estimated closer than 0.5 ml because of the nature of the graduations on the centrifuge tube. A sample was placed in a counting cell (10 ml capacity) under a magnification of 27 X and all large organisms were counted. The average for each collection was based on total counts of all samples. This sample was diluted again and placed in a Waring Blendor (10,000–12,000 rpm) for 30 seconds. All rotifers and nematodes in a one ml sub-sample were counted using the same magnification. Diatoms, filamentous algae, and protozoa were counted at 100X magnification using a Whipple ocular grid. Counts were made on fifteen 0.5618 cu mm "count units" obtained by random selection from each one ml sub-sample. Using dilution and sample area, estimated averages were based on numbers calculated per one ml sub-sample. Fragments of diatoms, those less than 0.021 mm long, or those of doubtful identification were not counted. Fragments of filamentous algae smaller than 0.106 mm in length were also disregarded. Organisms of the same species attached to each other were considered one; only those wholly within a unit were included.

Calculations were performed in an attempt to find the number of counts needed to give satisfactory precision in estimating the population mean numbers of various organisms per one ml sub-sample. Each of two one-square centimeter samples were diluted to five ml and centrifuged. One (No. 1) of these was diluted to 15 ml (centrifuged volume 0.2 ml) and periphyton clumps were teased apart with needles. The other (No. 2) was diluted to 60 ml (centrifuged volume 0.5 ml) and placed in a Waring Blendor for 30 seconds.

A one ml sub-sample was taken from each. Fifteen units of a sub-sample from No. 1 were counted and 20 units of a sub-sample from No. 2. The averages were computed for the numbers of each kind of organism in the first sub-sample for 5, 10, and 15 units and for 5, 10, 15, and 20 units in the second. Ninety-five percent confidence limits for the true mean numbers of organisms per 0.5618 cu mm were found using the data from the 5, 10, 15, and 20 counts. All results were then multiplied by 1779 to secure estimates for a one ml sub-sample. In sub-sample one, only the confidence band for *Cymbella* narrowed as the number of "count units" was increased. In sub-sample two, the confidence band narrowed for *Navicula*, *Synedra*, *Diatoma*, *Cocconeis*, *Cymbella*, Gomphonemataceae, and *Oscillatoria* as the number of count units was increased. A leveling off in the estimated mean values occurred when the number

TABLE 2

List of organisms.

- CHLOROPHYTA
  - Tetrasporales
    - *Tetraspora* (?)
  - Cladophorales
    - *Cladophora* sp.
  - Chlorococcales
    - *Treubaria* (?)
  - Zygnematales
    - *Closterium* sp.
- CHRYSOPHYTA
  - Centrales
    - *Melosira varians*
  - Pennales
    - *Meridion* sp.
    - *Diatoma vulgare*
    - *Fragilaria* sp.
    - *Synedra ulna*
    - *S. ulna* var. *oxyrhynchus*
    - *S. ulna* var. *ramsei*
    - *Ceratoneis arcus*
    - *Rhoicosphenia curvata*
    - *Cocconeis placentula* var. *euglypta*
    - *Navicula cryptocephala*
    - *Navicula* sp.
    - *Pinnularia* sp.
    - *Gomphonema olivaceum*
    - *G. herculeanum* var. *robusta*
    - *Gomphoneis herculeana* var. *robusta*
    - *G. herculeana*
    - *Cymbella prostrata*
    - *C. turgidula*
    - *C. cistula*
    - *C. mexicana*
    - *C. affinis*
    - *C. sinuata*
    - *Epithemia sorex*
    - *E. zebra*
    - *Rhopalodia* sp.
    - *Nitzschia dissipata*
    - *Cymatopleura solea*
    - *Surirella ovata*
- CYANOPHYTA
  - Oscillatoriales
    - *Oscillatoria* spp.
    - *Lyngbya* sp.
    - *Nostoc* sp.
- PROTOZOA
  - Ciliata
    - *Vorticella* sp.
    - Unknown sp.
- ROTATORIA spp.
- NEMATODA spp.
- TARDIGRADA sp.
- ARTHROPODA
  - Hydracarina
    - *Sperchon glandulosus*
    - *Megapus* sp.
    - *Aturus* sp.
    - *Feltria* sp.
  - Plecoptera sp.
  - Ephemeroptera spp.
  - Trichoptera
    - Limnephilidae spp.
    - Rhyacophilidae
      - *Glossosoma* sp.
    - Brachycentridae
      - *Brachycentrus* sp.
  - Coleoptera sp.
  - Diptera
    - Deuterophlebiidae sp.
    - Blepharoceridae sp.
  - Simuliidae
    - *Simulium arcticum*
    - *S. vittatum*
  - Tendipedidae
    - Hydrobaeninae spp.
    - *Diamesa* spp.
    - *Syndiamesa* sp.
    - *Calopsectra* sp.
    - *Circotopus* sp.
  - Rhagionedae
    - *Atherix* sp.

of counts (count units) approached 15. These results suggest that no fewer than 15 counts should be made per one ml sub-sample of the specified dilution if satisfactory estimates are to be realized. Therefore 15 counts per one ml sub-sample were made for all estimates of square centimeter samples and all samples were treated with a Waring Blendor.

Qualitative Features

Organisms: Most of the organisms found in the periphyton complex were identified to genus and some to species (Table 2), however, it was not possible to determine certain ones beyond the larger categories. The algae included 34 species representing three divisions while the animals included 35 species representing five phyla.

The Chlorophyta was represented by four genera and species; *Tetraspora* was the most frequently occurring and *Cladophora* and an undetermined green algae were common. *Treubaria* and *Closterium* were observed rarely.

The Chrysophyta contained 18 genera and 26 species (all diatoms). Neel (1953) found 21 genera of diatoms in the periphyton from the North Platte River and Young (1945) reported nine genera in the periphyton on stones in Douglas Lake.

The genera of diatoms which appeared most frequently were *Navicula*, *Diatoma*, *Cymbella*, *Cocconeis*, *Synedra*, and *Ceratoneis*. Undetermined representatives of the family Gomphonemataceae also occurred frequently. *Rhoicosphenia*, *Surirella*, *Epithemia*, *Fragilaria*, *Melosira*, and *Pinnularia* appeared commonly and *Meridion*, *Rhopalodia*, and *Nitzschia* were rare.

The Cyanophyta had three genera and four species. The most frequently occurring genus was *Oscillatoria* while *Lyngbya* was common and *Nostoc* was rare.

Protozoa, Rotatoria, and Nematoda occurred infrequently. A single specimen of Tardigrada was found.

The Arthropoda was represented by two classes and six orders. Diptera occurred most frequently with five families and 17 species; 12 of these were in the family Tendipedidae, two in Simuliidae, and single species in each of Blepharoceridae, Deuterophlebiidae, and Rhagionidae. Ephemeroptera were common and Trichoptera and Plecoptera were rare. A single Coleoptera was found. Only three Hydracarina were observed.

Seasonal Variation

Gross Seasonal Changes: This complex varied in numbers of organisms at different seasons of the year. Floods at time of run-off (May–June) caused extreme scouring by movement of sand, gravel, cobblestones, and even boulders. It was only possible at that time to observe riffle bottom materials near the bank. Those materials examined were without organisms. No coating of organisms was visible in late June although stones felt slick probably due to the presence of diatoms and blue-green algae. A thin brown film of diatoms and small scattered filaments of green algae appeared on stone surfaces in late July and this began to accumulate sand grains. By mid-September a relatively thick layer of diatoms, with obvious strands of filamentous green algae, completely covered riffle bottom material. By late November this growth became patchy, lighter brown in color, and the filamentous algae appeared in clumps. Scouring action of ice from late November to early March caused variations in the quantity of periphyton present. By late March the filamentous algae was less obvious and the entire periphyton complex was predominantly dark brown in color. From April to the May–June flood period no obvious changes occurred. No crusty layer was found on stones in the riffle at Shedd's Bridge similar to that reported by Young (1945) for Douglas Lake or a calcareous growth as described by Percival and Whitehead (1930) in the River Wharfe.

Order of Appearance of Organisms: An attempt was made to determine the order of appearance of organisms on "cleaned" stones but samples were not taken soon enough after stones were placed to determine the earliest arrivals. Samples were taken August 16, 1952 and May 9, 1953, seven days after treated stones were placed in the riffle. On August 15, 1953, samples were taken on a third group of cleaned stones which were in the riffle nine days.

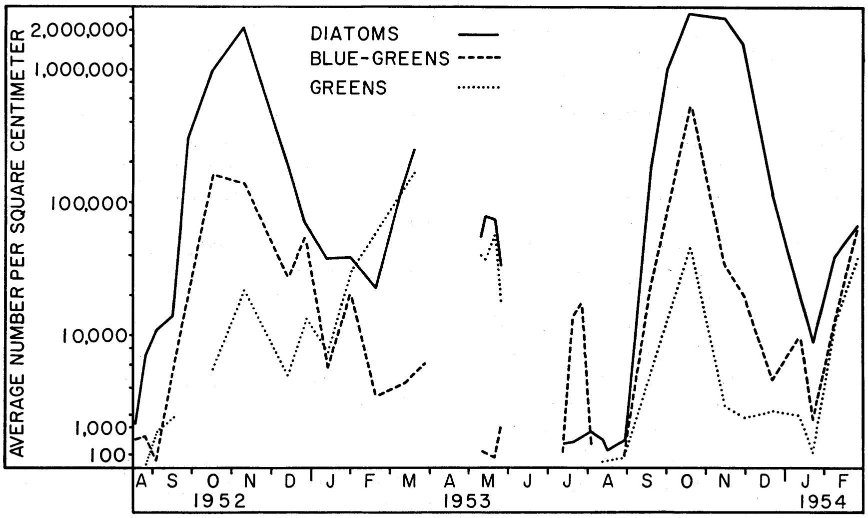

FIG. 1. Quantitative distribution of diatoms, blue-green, and green algae, West Gallatin River, Montana, 1952-54.

Diatoms occurred in all three collections; those present were *Diatoma*, *Synedra*, *Cocconeis*, *Navicula*, *Cymbella* and undetermined representatives of the Gomphonemataceae. Blue-green algae (*Lyngbya*) appeared in the August 16, 1952 collection and green algae (*Tetraspora*) was found in the May 9 and August 15, 1953 samples. Tendipedidae larvae were present in all three collections while *Simulium* larvae occurred August 16, 1952 and May 9, 1953 and Ephemoroptera on May 9, and August 15, 1953.

Quantitative Features

Distribution (Fig. 1): A marked numerical increase in diatoms, blue-green, and green algae occurred from August through September in both years (1952–53) (Table 3) which resulted in a major peak in early November. In the 1952 peak, the estimated average number of diatoms per square centimeter of stone surface was 2,175,000; blue-green, 144,000; and green algae, 23,000, while in 1953 the diatoms numbered 2,525,000; blue-green, 561,000; and green algae, 46,000. A decisive general decline occurred during December and January in both years

(1952–53 and 1953–54) and was followed by another increase of lesser proportions in March (1953). A sharp decline in diatoms and green algae appeared in May and this probably continued to July although lack of samples in June makes this somewhat obscure. The number of blue-green algae was low in May and remained about the same in early July. During July, diatoms were scarce (4,300–5,000). Blue-green algae made a decided increase (300–13,600), and green algae (60) appeared in only one collection.

The most abundant diatom which contributed to the August-September increase in both years was *Navicula*. *Oscillatoria* was the only blue-green and *Tetraspora* the only green algae which occurred in large numbers. Diatoms were by far the most abundant organisms during this period.

TABLE 3

The calculated total average numbers and total average volumes per square centimeter for all collections made at Shedd's Bridge, West Gallatin River, Montana, 1952–1954. (L) = Larvae. (P) = Pupae.

Date Av. Volume—ml	8/16/52 Tr.	8/23/52 Tr.	9/3/52 Tr.	9/15/52 Tr.	9/28/52 0.074
Tetraspora sp. (?)			839	1790	
Cladophora sp.		36			
Treubaria sp. (?)					
Closterium sp.					
Undet. Green sp.					
Melosira sp.					
Meridion sp.					
Diatoma sp.	569	1712	2826	1804	72868
Fragilaria sp.					
Synedra spp.	167	72	99	151	20879
Ceratoneis sp.	40		98		2334
Rhoicosphenia sp.		275	343		1263
Cocconeis sp.	79	772	2220	760	5600
Navicula spp.	1044	2800	3352	9043	167985
Pinnularia sp.					
Gomphonemataceae spp.	59	178	293	811	20145
Cymbella spp.	364	1564	1529	1650	17442
Epithemia spp.	40		296	381	
Rhopalodia sp.					
Nitzschia sp.					
Surirella sp.				151	398
Oscillatoria spp.		186		5347	28360
Lyngbya sp.	640	497	49		
Nostoc sp.					
Protozoa					
Rotatoria					
Nematoda					
Hydracarina					
Plecoptera		0.10			
Ephemeroptera			0.10	0.14	
Trichoptera					
Coleoptera sp.					
Deuterophlebiidae sp. (P)					
Blepharoceridae sp. (L)				0.14	
Simulium spp. (L)	4.33	5.40	5.10		0.33
Simulium sp. (P)		0.30			0.11
Tendipedidae spp. (L)	0.22	0.60	0.20	0.70	2.88
Tendipedidae spp. (P)					

TABLE 3 (Contiuued)

Date	10/15/52	11/8/52	12/13/52	12/27/52	1/13/53
Av. Volume—ml	0.139	0.201	0.117	0.098	0.222
Tetraspora sp. (?)	4800	17808	4937	13778	7869
Cladophora sp.	398	795			
Treubaria sp. (?)					
Closterium sp.					
Undet. Green sp.	398	4061			
Melosira sp.			244	693	
Meridion sp.					
Diatoma sp.	293670	1104759	90103	17481	4502
Fragilaria sp.	398	3578			
Synedra spp.	38430	52468	1672	1256	257
Ceratoneis sp.	4658	9458		907	824
Rhoicosphenia sp.	5126	4316	636	159	749
Cocconeis sp.	21143	48295		418	631
Navicula spp.	438799	591225	63236	42092	20149
Pinnularia sp.					
Gomphonemataceae spp.	101261	122990	10971	2969	4450
Cymbella spp.	101805	280426	15202	7520	6712
Epithemia spp.	2130	1590	286		
Rhopalodia sp.					
Nitzschia sp.					
Surirella sp.	795	5198	1601		
Oscillatoria spp.	163198	138988	27896	58897	4581
Lyngbya sp.	3323	4856			1129
Nostoc sp.					
Protozoa	398	9997			
Rotatoria					
Nematoda					
Hydracarina					
Plecoptera		2.11			0.20
Ephemeroptera	0.33				
Trichoptera					
Coleoptera sp.					
Deuterophlebiidae sp. (P)					
Blepharoceridae sp. (L)					
Simulium spp. (L)	0.11	0.66	3.66	1.75	2.40
Simulium sp. (P)	0.66	0.33			
Tendipedidae spp. (L)	3.55	12.55	1.66	2.37	3.20
Tendipedidae spp. (P)			0.16		

Date	1/30/53	2/21/53	3/9/53	3/20/53	5/9/53
Av. Volume—ml	0.860	0.370	0.588	1.000	0.250
Tetraspora sp. (?)	28067	51763	101357	168820	40916
Cladophora sp.			3391		
Treubaria sp. (?)					
Closterium sp.					
Udet. Green sp.					
Melosira sp.	353				
Meridion sp.		241	1540	12460	
Diatoma sp.	1893	2573	3895	6890	14135
Fragilaria sp.		217	707	3710	
Synedra spp.		525	129		1955
Ceratoneis sp.	353	457	7818	53550	15856
Rhoicosphenia sp.	1187	919	5498		355
Cocconeis sp.	2727	1575	13476	15015	933
Navicula spp.	26600	8882	41080	126470	13830
Pinnularia sp.					
Gomphonemataceae spp.	4448	5373	7132	3710	1373
Cymbella spp	1227	2408	31060	30560	6928
Epithemia spp.			707		
Rhopalodia sp.					

TABLE 3 (Continued)

Date Av. Volume—ml	1/30/53 0.860	2/21/53 0.370	3/9/53 0.588	3/20/53 1.000	5/9/53 0.250
Nitzschia sp.					
Surirella sp.			707		
Oscillatoria spp.	21227	2621	989	2180	
Lyngbya sp.		886	3391	2180	
Nostoc sp.					
Protozoa			707	2180	
Rotatoria					
Nematoda					
Hydracarina					
Plecoptera		0.01	0.11	0.50	
Ephemeroptera		0.14	0.66	2.00	1.25
Trichoptera					0.25
Coleoptera sp.					
Deuterophlebiidae sp. (P)					
Blepharoceridae sp. (L)					
Simulium spp.	7.80	2.68	6.30	3.00	0.25
Simulium sp. (P)					
Tendipedidae spp. (L)	16.30	3.95	4.88	45.00	5.00
Tendipedidae spp. (P)			0.11		

Date Av. Volume—ml	5/13/53 0.344	5/17/53 0.467	5/23/53 0.158	7/11/53 Tr.	7/18/53 0.004
Tetraspora sp. (?)	38102	58158	18633	59	
Cladophora sp.					
Treubaria sp. (?)					
Closterium sp.		88			
Undet. Green sp.					
Melosira sp.					
Meridion sp.			177		
Diatoma sp.	14134	20805	3694	477	
Fragilaria sp.	298	866	770	59	88
Synedra spp.	499	88	673	436	374
Ceratoneis sp.	24023	19098	8442	412	1670
Rhoicosphenia sp.	762	1341	265	176	
Cocconeis sp.	2389	3833	2325	370	555
Navicula spp.	17923	17398	10391	876	555
Pinnularia sp.					
Gomphonemataceae spp.	4643	1880	1259	59	177
Cymbella spp.	14706	10385	5999	945	1220
Epithemia spp.		750	91		
Rhopalodia sp.		442			
Nitzschia sp.					
Surirella sp.	160	1192		572	446
Oscillatoria spp.	66		972	303	13608
Lyngbya sp.	165	88	177		
Nostoc sp.					
Protozoa		750			
Rotatoria					
Nematoda	1.25	1.67			
Hydracarina			0.17	0.06	
Plecoptera					
Ephemeroptera		0.25	0.17		0.17
Trichoptera			0.08		
Coleoptera sp.					
Deuterophlebiidae sp. (P)					
Blheparoceridae sp. (L)					
Simulium spp. (L)					1.33
Simulium sp. (P)					
Tendipedidae spp. (L)	2.00	1.92	4.92	1.17	0.92
Tendipedidae spp. (P)			0.26	0.11	0.08

TABLE 3 (Continued)

Date Av. Volume—ml	8/6/53 Tr.	8/9/53 Tr.	8/15/53 Tr.	8/28/53 0.002	9/18/53 0.390
Tetraspora sp. (?)		66	71	103	843
Cladophora sp.					
Treubaria sp. (?)					
Closterium sp.					
Undet. Green sp.					1125
Melosira sp.				34	
Meridion sp.					
Diatoma sp.	710	1576	449	320	8657
Fragilaria sp.		66			66
Synedra spp.	591	1065	141	332	3257
Ceratoneis sp.	1524	409		34	277
Rhoicosphenia sp.		265	71	34	521
Cocconeis sp.	1669	331	366	607	8035
Navicula spp.	1023	909	295	2483	144752
Pinnularia sp.		133	141	34	199
Gomphonemataceae spp.			141	68	5954
Cymbella spp.	2201	1354	1502	1261	18123
Epithemia spp.			71		629
Rhopalodia sp.					
Nitzhscia sp.					
Surirella sp.	734		71	109	1361
Oscillatoria spp.	17338	199		177	24198
Lyngbya sp.	133				
Nostoc sp.					
Protozoa					
Rotatoria					
Nematoda					
Hydracarina					
Plecoptera					
Ephemeroptera	0.25	0.06	0.13	0.16	0.28
Trichoptera					
Coleoptera sp.					
Deuterophlebiidae sp. (P)			0.07		
Blepharoceridae sp. (L)					
Simulium spp. (L)	160	0.37		0.12	0.03
Simulium sp. (P)					
Tendipedidae spp. (L)	0.25	0.56	0.93	2.03	2.72
Tendipedidae spp. (P)				0.10	0.03

Date Av. Volume—ml	10/3/53 0.177	10/24/53 0.309	11/14/53 0.274	11/29/53 0.156	12/19/53 0.015
Tetraspora sp. (?)	5620	360	612	883	2349
Cladophora sp.	1248	2821	667		
Treubaria sp. (?)			906	989	66
Closterium sp.			427		
Undet. Green sp.	2663	889	359		
Melosira sp.	3127	2804	4913	2942	364
Meridion sp.			250		
Diatoma sp.	262236	1636041	1845831	962171	21748
Fragilaria sp.	359	530	1279	1684	133
Synedra spp.	13052	18733	17795	10276	343
Ceratoneis sp.	7180	1590	1932	1675	232
Rhoicosphenia sp.	3316	6862	11078	4678	575
Cocconeis sp.	45716	64349	59848	65022	3098
Navicula spp.	444706	495907	402951	465866	82078
Pinnularia sp.	102	940	975	495	
Gomphonemataceae spp.	127800	149648	72257	37351	3354
Cymbella spp.	95644	135491	67650	40018	3443
Epithemia spp.	1532	4524	11184	6326	575
Rhopalodia sp.					

TABLE 3 (Continued)

Date Av. Volume—nl	10/3/53 0.177	10/24/53 0.309	11/14/53 0.274	11/29/53 0.156	12/19/53 0.015
Nitzschia sp.			427		
Surirella sp.	11610	7372	3719	3711	232
Oscillatoria spp.	947631	54713	34427	17582	4671
Lyngbya sp.		1419	1343	1886	66
Nostoc sp.			239		
Protozoa	1626	1487	3211	883	
Rotatoria	2.50	36.50	39.20	1.87	
Nematoda	2.19	3.75	8.39	12.50	
Hydracarina					
Plecoptera		0.06		0.06	
Ephemeroptera	1.35	2.32	1.00	1.31	
Trichoptera	0.10	0.71	0.03		0.06
Coleoptera sp.			0.03		
Deuterophlebiidae sp. (P)					
Blepharoceridae sp. (L)					
Simulium spp. (L)	0.16	0.94	0.48	2.19	3.00
Simulium sp. (P)					
Tendipedidae spp. (L)	2.06	8.48	8.52	17.94	2.19
Tendipedidae spp. (P)	0.10	0.16			

Date Av. Volume—ml	1/11/54 0.023	1/21/54 0.015	2/7/54 0.049	2/23/54 0.332	
Tetraspora sp. (?)	1967	133	11229	38542	
Cladophora sp.			66		
Treubaria sp. (?)					
Closterium sp.					
Undet. Green sp.					
Melosira sp.	66				
Meridion sp.					
Diatoma sp.	5085	975	11575	14771	
Fragilaria sp.					
Synedra spp.	66		66	1022	
Ceratoneis sp.	66		885	3181	
Rhoicosphenia sp.	66		144	265	
Cocconeis sp.	2658	133	1249	1111	
Navicula spp.	14326	6557	19528	41912	
Pinnularia sp.					
Gomphonemataceae spp.	364		363	76	
Cymbella spp.	1381	1143	5198	5928	
Epithemia spp.	298				
Rhopalodia sp.					
Nitzschia sp.					
Surirella sp.					
Oscillatoria spp.	9968	1456	12678	67460	
Lyngbya sp.			298	454	
Nostoc sp.					
Protozoa					
Rotatoria					
Nematoda					
Hydracarina					
Plecoptera					
Ephemeroptera			0.06	1.00	
Trichoptera			0.06		
Coleoptera sp.					
Deuterophlebiidae sp. (P)					
Blepharoceridae sp. (L)					
Simulium spp. (L)	10.50	3.13	4.60	4.78	
Simulium sp. (P)					
Tendipedidae spp. (L)	0.50	0.13	1.70	5.14	
Tendipedidae spp. (P)					

During the early November peak (1952–53) *Diatoma* was the most numerous diatom and superseded *Navicula*. *Navicula* became predominant again in early December during the December-January decline (1952–53 and 1953–54) and remained in this position through March. *Ceratoneis* superseded *Navicula* as the most abundant diatom in May. In 1952 *Ceratoneis* probably peaked in early November but was relatively scarce in December. It reached maximum numbers in early October 1953 and declined sharply later that month. *Tetraspora* was the most abundant organism in late January 1953 and held this position through March and May, while in 1953–54 it was exceeded in numbers by *Navicula*, *Diatoma*, *Cymbella* and *Oscillatoria*.

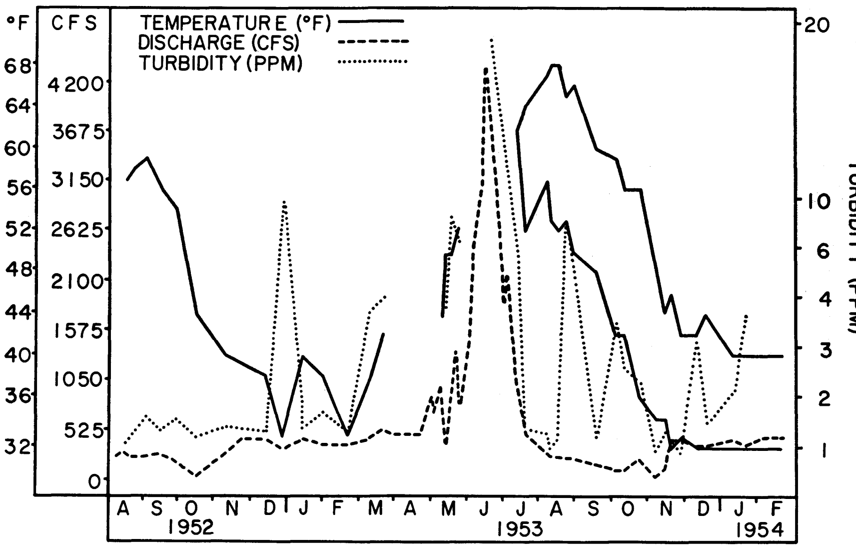

FIG. 2. Discharge, turbidity and temperature in the West Gallatin River, 1952-54.

The numerical abundance of Tendipedidae and *Simulium* for each month of the sampling period is found in Table 3. A gradual numerical increase in Tendipedidae larvae was observed from August through October resulting in a peak during November of each year (1952–53). The average number of larvae per square centimeter of stone surface was 12.55 during the first year and 17.94 the second year. A sharp decline occurred in December of both years. In late January (1953) there was a pronounced increase resulting in a peak (16.30). This was not found in 1954. A sharp decline occurred in February 1953, but an increase was found during the same month in 1954. The greatest number (45.00) was found in late march 1953.

Simulium larvae abundance was similar to that in Tendipedidae larvae. In December there was a definite increase in numbers which resulted in a peak during January in both years (1953–54). The greatest number (10.50) was reached in January 1954.

No rotifers or nematodes were included in the counts for 1952 because the methods used were inadequate to detect them. In 1953, the greatest abundance of rotifers, protozoans, nematodes and Ephemeroptera coincided with that of the diatoms, blue-green and green algae already described.

Rare organisms which occurred included Deuterophlebiidae, Blepharoceridae and Hydracarina.

Abundance of Organisms in Relation to Physical Characteristics (Fig. 2)

Diatoms, blue-green, and green algae increased in number during the period of high temperatures (late summer) in both years (1952–53) and peak periods were attained after temperatures began to decline (October-November). Minimum numbers were reached during the period of minimum temperatures in December-January. The first depression following maximum abundance occurred immediately after anchor ice and floating ice were observed. It is believed that this December-January decline in periphyton may have resulted from the effects of ice.

During the August-September increase in periphyton and through the peak periods in both years, recorded discharge and turbidity were low. A small increase in turbidity was observed on several occasions when floating ice was abundant. The decline in numbers of periphyton organisms in May was associated with a distinct increase in discharge and turbidity. The highest recorded discharge and turbidity were found in June and the minimum number of organisms was found in July. The low numbers very probably resulted from the molar action associated with high water and turbidity.

A preliminary effort was made to determine the effect of velocity on the distribution and abundance of organisms in the periphyton complex. Water velocities were measured in various places on the exposed surfaces of five stones at various depths (2–9 inches). These were found to increase from the upstream to downstream end of the stones. The average for the upstream half was 0.94 feet per second while the downstream half was 1.76.

The numbers of diatoms, blue-green, and green algae were about the same on both halves of the stone during August and September (1953). During November the number of diatoms, blue-green and green algae was higher on the downstream half. The numbers were as follows: diatoms: upstream 2,340,000; downstream 2,841,000; blue green: upstream 33,200; downstream 38,900; and green algae: upstream 2,400; downstream 3,400. In November and early December the numbers were similar on both parts of the stones. In January 1954, the numbers were as follows: diatoms: upstream 4,000; downstream 14,500; blue-green: upstream 890; downstream 2,000; and green algae: upstream 260; downstream none.

During the increase in August-September (1953) Tendepedidae and *Simulium* larvae were found in about the same numbers on both portions of the stones. In the November peak the numbers of Tendepedidae were somewhat higher on the downstream (9.73) than on the upstream side (6.94). There was little difference in the number of Tendepedidae on each half of the stones in December, January, and February (1952–53). More *Simulium* larvae were observed in early January on the downstream (18.88) than on the upstream (1.75) side of the stones while in December and February it was about equal on both sides.

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TUNDRA MOSQUITOES AT NAKNEK, ALASKA PENINSULA

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The author participated in the geographic resurvey of the Katmai National Monument of 1953–4 under National Park Service auspices, which enabled him to determine the common mosquitoes of the subarctic tundra along the Bering Sea near Naknek, Alaska. Hereabouts tundra from the northwest and forest from the northeast meet the eastward fringes of the Aleutian grasslands in a stalemated struggle for ecological dominance. The critical transition, where the trees characteristic of the upper Alaska Peninsula straggle and stop, drowned by tundra or choked by Calamagrostis grass, lies near Naknek. For relatively few miles farther out the Peninsula the watercourses are still delineated by wide margins of white spruce, alder, willow and birch before the landscape, apart from the volcanic mountains, becomes open tundra and/or Aleutian grasslands, altogether. The transitional, boggy, wooded valleys near Naknek exhibit a more varied biota than the open tundra. The grasslands, spotty and limited in the study area, were disregarded.